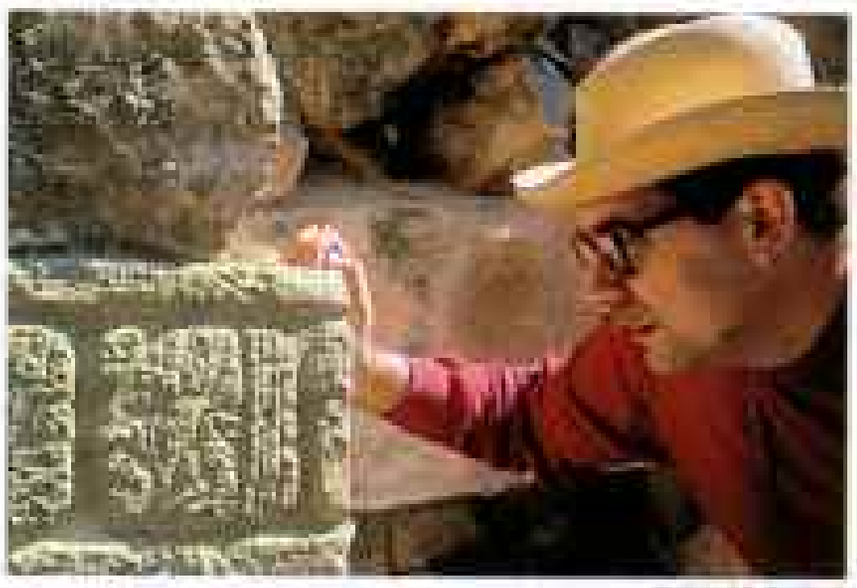
NATIONAL GEOGRAPHIC

From the Editor

IN 1958 A YOUNG ARCHAEOLOGY STUDENT labored under the hot Mexican sun, sketching finds and mapping the ancient Maya ruins of Dzibilchaltún on the Yucatán Peninsula.

It was a project funded in part by the National Geographic Society, and during a visit to the site President and Editor Melville Bell Grosvenor recognized the fellow's talent and promise. Two years later Dr. Grosvenor invited him to join the Society as a cartographic draftsman and illustrator.



I guess you could say it worked out. That young student became Dr. George E. Stuart, Senior Assistant Editor for Archaeology of NATIONAL GEOGRAPHIC magazine and Chairman of the Society's Committee for Research and Exploration. He is now retiring after 38 years of service.

His work has enhanced the Geographic's worldwide reputation for archaeological coverage. Throughout his 22 years on the committee—which has awarded nearly 6,400 grants for scientific research—George has shown an uncanny knack for asking the right questions and getting results.

George possesses a dry wit, a gentle Carolina charm, and an encyclopedic knowledge of Mesoamerican archaeology. His other passion is music. On occasion he would amble down the hallway at our headquarters building singing a song in Yucatec Maya. Some of my most pleasant evenings have been spent in George's office, surrounded by a lifetime of memorabilia, talking about archaeology and about life and listening to music from some Central American hillside—or from Pink Floyd.

George will be leaving us to establish a library and research center on regional geography and American archaeology in the shadow of the Blue Ridge mountains. But as we shape future coverage of significant archaeological discoveries, well, let's just say I've already got his new address and phone number in my Rolodex.

Bill Allen

The island nations of the tropical western Pacific cradle the richest coral life on our planet. These submarine archipelagoes are bathed in the warmest of waters, and the designs of life are fashioned like tapestries. Small creatures consort with great ones, as does this inch-long translucent goby that lives and feeds on the mantle of a giant clam.

GOBY, *FLEURIOBICYA MOSSAMBICA*; GIANT CLAM, *TRIDACNA GIGAS*

coral reef

Article and photographs by David Doubilet

under the hull of an outrigger canoe slipping across Goodenough Bay in Papua New Guinea.

ANTHIAS, PSEUDANTHIAS TUKA AND P. SQUAMIPINNIS; CORAL, TUBASTRAEA MICRANTHA

The living coral polyp: an animal that can be as small as an infant's fingernail, with a mouth and tentacles to sweep in plankton and organic matter floating in the sea. It secretes calcium carbonate to form a skeletal "house" as hard as concrete. When it dies, another generation grows on its skeleton. Uncounted trillions of polyps for uncounted millions of generations have built structures that surpass in scale the architecture of any other living beings, including humans.

Their cities, the reefs, grow in the warm, shallow oceans banding the Equator, but the distribution of corals is uneven. Some 67 species are found in the Caribbean Sea, compared with about 450 in the Pacific and Indian Oceans around Malaysia, Indonesia, the Philippines, Papua New Guinea, and Australia. That region, says marine biologist Eugenie Clark, represents the "evolutionary epicenter of coral life on our planet. The farther you journey from that center, the smaller the number of species."

This realm, this coral Eden, lies in a belt of intense geologic activity. Chains of volcanoes and huge, thrusting islands intertwine with deep-sea channels and basins. "The passing ice ages," says Richard Grigg, professor of oceanography at the University of Hawaii, "lowered sea levels, isolating small individual seas that went their own evolutionary ways and produced great diversification."

For the past 25 years I have been diving around the edges of coral Eden. Now I am in its heart, hanging and drifting at the edge of a reef near Sipadan Island off the northeastern corner of Borneo. I am waiting for a rendezvous with a school of enormous bumphead parrotfish, shy creatures normally but here somewhat acclimated to divers.

Long before I see them, I hear them. The noise comes through the sea like a riot in a dining hall, a smashing and grinding of crockery. The giants are feeding on the reef like undersea buffalo grazing on stony pastures. They bite and munch the corals, ingesting them for algae.

At close to 200 pounds and almost four feet long, the fish have bulbous, scarred heads, tiny eyes, and jutting

SHRIMPFISH, AEOLISCUS STRIGATUS; SEA MOTH, EURYPEGASUS DRACONIS

Thin as blades, shrimpfish in Papua New Guinea's Milne Bay (left) hunt minuscule mysid shrimps, inhaling them with mouths like soda straws. Hopping along with clawlike fins, a sea moth probes with its long nose for food in the soft bottom, levitating briefly to scout its territory.

teethlike beaks. Even as they crunch the corals, they excrete white plumes, pulverized coral sand that looks like locomotive steam. I watch as a large male breaks from the pack and bites a pizza-size slice out of a table coral. These fish are *eating* the reef, part of a long, natural cycle, not a destructive one.

They march and munch on by, leaving behind trails of smoky coral sand, and I am alone again, drifting in a peaceful, quiet moment.

Then I hear a *click* followed by a monstrous *boom!*, and a shock wave hits me. It presses on my internal organs, travels from my toes to my head and back again. Blast fishing! That's what they call it. The click is the trigger, and the boom, I know, comes from a lethal mixture of fertilizer and diesel oil—the explosive favored by terrorists.

Because Sipadan has a number of diving resorts, fishermen usually keep to the waters of surrounding islands—where the explosion came from. Even though blast fishing is illegal throughout the southwestern Pacific, laws cannot be enforced across a vast ocean.

There is a simple truth about coral reefs. They are oases of life in warm, nutrient-poor waters. They are richly diverse in species but not in sheer numbers. Unfortunately these days the fishermen catch the fish not to eat or trade locally but to sell. Besides blast fishing, cyanide is being spread across reefs to stun fish being collected for the aquarium industry.

In southeastern Indonesia, near the island of Alor, I find a beautiful scorpionfish nested in a sponge. I photograph it with care. It doesn't move. Then my diving partner, Gary Bell, gently pokes at it. Nothing: it is dead.

Later, in the fish market of the town of Kalabahi, Gary and I find tables of poisoned fish. Big-ticket species such as humphead wrasse (not to be confused with the parrotfish) and grouper are destined for the hungry cities of Southeast Asia: Manila, Singapore, Hong Kong, Jakarta, Kuala Lumpur.

Even the farthest reefs in this labyrinth of island

All appetite at nearly 200 pounds, a bumphead parrotfish commutes daily with its school. The fish pulverize corals with their beaks as they forage. They are no threat to the coral Eden that stretches from Malaysia to Papua New Guinea, but overfishing to satisfy Asian markets is.

countries are being rapidly depleted of big fish and major predators. Removing them may be removing keystone species from reef ecosystems. We realize that reefs are jewels, treasures, but only in the past 50 years, with the revolution in diving equipment, have scientists been able to study them closely—and now we're destroying them before we understand the consequences.

It is now night in a sea nearly the temperature of blood. The bumphead parrotfish are going to sleep under the coral ledges of Sipadan. Their skin color changes from blue-green to kelly green with faint stripes, as if they have put on pajamas.

I push out from the reef edge and look straight up. Through the calm surface I see the white disk of the moon. It is midnight, and this is still Eden, but time is growing ever shorter.

DAVID DOUBILET has been a regular contributor to the GEOGRAPHIC for 26 years. He took his first photographs of coral reefs at age 13.

SHRIMPS, PERICLIMENES COLEMANI; URCHIN, ASTHENOSOMA VARIUM

Taking up residence off eastern Bali, a striped hermit crab (below) emerges from a textile cone shell. The original occupant was a highly venomous mollusk. Marching along a sea star's arm, three commensal shrimps (bottom) graze in a rich pasture of dead skin cells, mucus, and other detritus.

CRAB, CILIOPAGURUS STRIGATUS; SHRIMPS, PERICLIMENES SOROR; SEA STAR, LINCKIA SP.

A pair of Coleman's shrimps (above, at center) have cleared a home for themselves in the forest of a fire urchin's poison-tipped spines. The shrimps gain protection from predators, but whether the urchin benefits from its tenants is not known.

Resplendent in art nouveau camouflage, a Merlet's scorpionfish yawns in late afternoon.

Its complex mouth inhales unsuspecting prey that swim haplessly by near Milne Bay.

JACKS, CARANX SEXFASCIATUS; GUNNARD, DACTYLOPTENA ORIENTALIS

While swimming off the coast of Bali at midday, I look down and see my shadow projected onto a school of jacks rotating in a perfect gyre. When night comes, the jacks will go their separate ways to hunt smaller fish, reforming their school for protection from barracudas when daylight returns.

Other fish travel solo in daytime, such as a flying gurnard (right), which unfurls its fins like wings and streaks in a glide path down a deep sandy slope.

In coral Eden development of reefs owes much to oceanic volcanoes such as Manado Tua (above right) near the northeastern tip of Sulawesi. The submerged slopes of volcanoes give corals a toehold

In partnership, volcanoes
and corals continuously alter the
architecture of the planet.

on which to grow. Gradually reefs may encircle the volcano. If extinct, the volcano will eventually sink into the sea, leaving behind a coral atoll. The waters around Manado Tua have been designated a national marine park.

At dusk along the edge of Milne Bay, whose sandy bottom is punctuated by coral heads, I find a yellow-margined moray eel being groomed by a cleaner shrimp (below). The shrimp's claws pick off bits of algae, loose flesh, and parasites, an act as much like doctoring as it is like grooming.

At 70 feet down I find a Haddon's sea anemone the size of an open umbrella (right). A family of saddleback anemonefish are in residence along with a group of three-spot dascyllus. Spread over the sand like a rug, the anemone feeds on plankton,

and as night falls the anemonefish burrow into the anemone, which curls into a clump. The fish are given protection and a place to lay their eggs. In return they keep their host free of parasites and drive away fish that prey on anemones.

EEL: GYMNOTHORAX FLAVIMARGINATUS; SHRIMP: LYSMATA AMBOINENSIS; ANEMONE: STICHODACTYLA HADDONI; ANEMONEFISH: AMPHIPRION POLYMNUS; DASCYLLUS: DASCYLLUS TRIMACULATUS

FROGFISH, ANTENNARIUS STRIATUS; COCKATOO WASPFISH, ABLABYS TAENIANOTUS; SEA WORM, EUNICE SP.

Dreamlike oddities haunt Milne Bay at night. To unwary prey a hairy striated frogfish (above) looks like an algae-covered rock planted solidly on the bottom.

A cockatoo waspfish (left) resembles a dead leaf, and it normally lies on the bottom, rolling back and forth in the gentle surge. Its large dorsal fin is supported by venomous spines for defense against predators.

Strangest of all, perhaps, is a segmented sea worm of the genus *Eunice* (above left). The size of a small carrot, it emerges from the sand and spreads jaws that look like miniature ice tongs, used for capturing small fish. It wiggles striped antennae, but when my flash illuminates its shiny skin, the little monster vanishes into the sand as if it never existed.

After these encounters, to see octopuses swim by as I head to the surface with dive lights dying seems as ordinary as watching squirrels in a city park.

In their only habitat, the waters around Banggai Island off the east coast of Sulawesi, rare

Banggai cardinalfish weave in and out of fields of protective sea urchin spines.

PTERAPOGON KALUDERMI

For green turtles the waters
of Sipadan Island are
an arena of love and death.

CHRIS NEWBERT

In October I follow a pair of mating green sea turtles paddling frantically and watch a second male join them (above). The turtles of Sipadan mate year-round, with peak nesting in August.

Winding caverns tunnel under the island, and one offers a rock ledge where turtles rest at night. But in trying to return to the surface the turtles sometimes become disoriented and drown.

I follow diver Ron Holland into the main cave and through a series of smaller passages and, finally, into a high-domed chamber—a tomb. The floor is cluttered with turtle skeletons and plates of shells that resemble discarded armor (right).

Holland and Randy Davis founded the first diving resort here and have made a cause of the turtles. With two other resorts they bought the rights to all turtle eggs from local residents, who once sold them as aphrodisiacs, and pay $20,000 yearly to continue that protection. Still, in the hatchlings' first moments at sea thousands fall prey to jacks and other predators.

Lying on dark, volcanic sand 70 feet down off the northeast coast of Bali, I watch a flag-tail goby and a Randall's goby shrimp play out their "odd couple" relationship (below). The shrimp is nearly blind; the goby acts as its "seeing eye" fish. The goby is messy; the shrimp is neat and cleans out the goby's burrow. The shrimp constantly touches the goby with its antennae, and the goby responds with wiggles that seem to say: Come out, go back, dig more. The shrimp responds by touching its claws to the goby's tail.

Nearby, a five-inch-long mantis shrimp (below right) attends to its housecleaning

by removing a rock from its burrow. Its darting bulbous eyes are thought to be the most complex in nature, and it strikes its prey with a crustacean karate chop that can break a pane of glass.

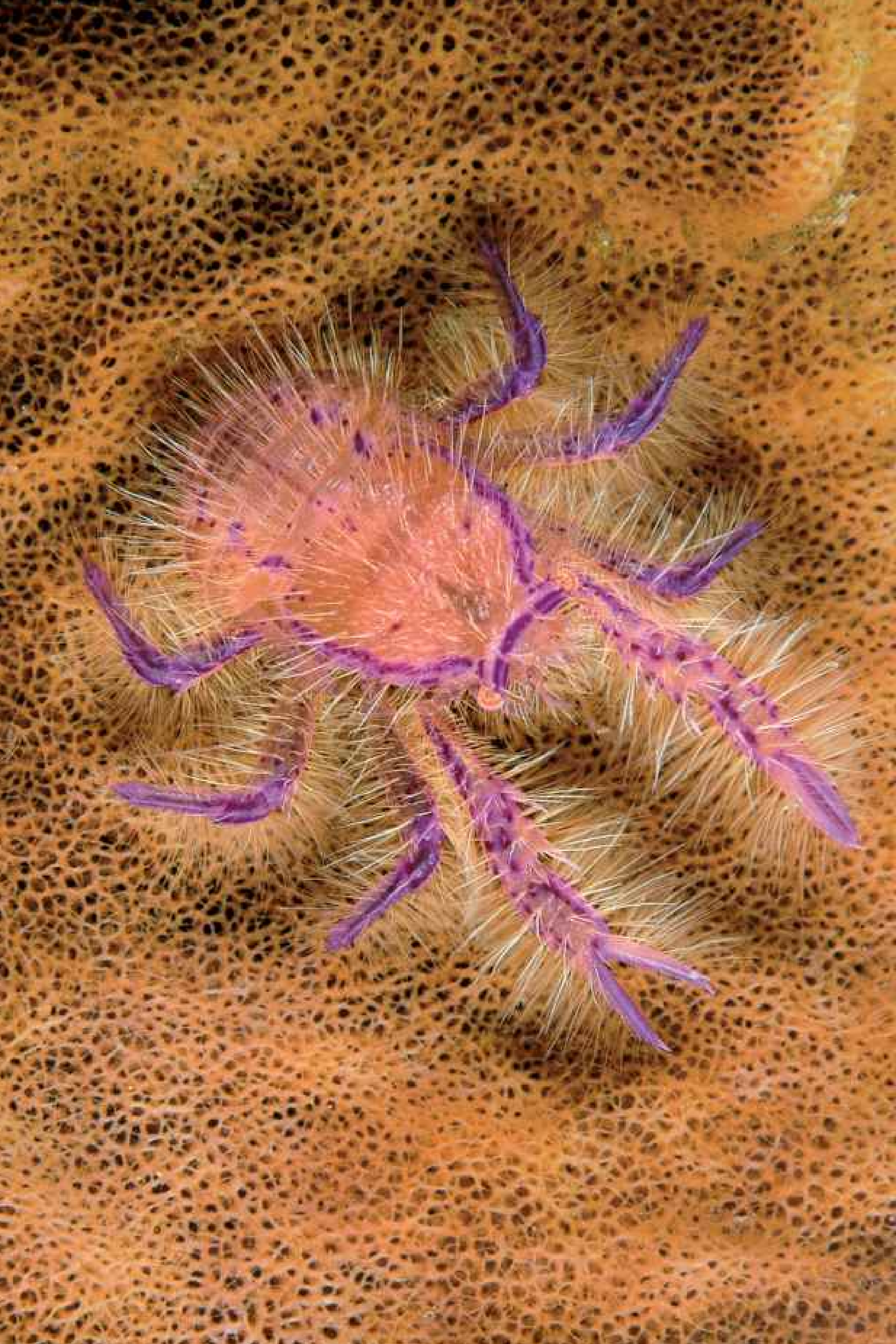
Gliding over filter-feeding strawberry ascidians and stinging hydroids, a green-spot nudibranch senses the sea with hornlike organs called rhinophores. Orange frills on its back are gills.

These shell-less snails eat sponges, hydroids, and ascidians that are poisonous to other creatures, incorporating the toxins. Nudibranchs advertise their nastiness with poster colors.

Where the flanks of Bali slope into the dark waters of Lombok Strait, I come across a colony of chest-high barrel sponges at 120 feet. I peer at the wrinkled exterior of the largest and, squinting, locate a pink fairy crab about the size of a penny, covered with white hairs (right). It skitters across its miniature moonscape, foraging on plankton that fall like dust onto the sponge's rough surface.

Down even deeper, an elephant ear sponge makes a home for a small goby (left), the sponge so porous that my light shines right through it from behind.

Then I am caught in a down current and pushed still deeper along the black slope, slipping against the sand and running out of air. Suddenly the current relents, and I begin to rise. Near the surface I meet a juvenile spotfin lionfish (above), a bright mote in a dark sea.



A spine-cheek anemonefish swims over a field of purple-tipped anemone

tentacles, adding its vibrant colors to the living spectrum of coral Eden. □

ANEMONEFISH: *PREMNAS BIACULEATUS*; ANEMONE: *ENTACMAEA QUADRICOLOR*

CORAL

Life returns to a reef in Papua New Guinea's Kimbe Bay (left), where a season of overheated waters in 1983 caused corals to die. As corals return, so do species such as the spine-cheek anemonefish (below). Rivaling rain forests in diversity of life, coral reefs are at risk from overfishing, pollution, and disease.

IN PERIL

By Douglas H. Chadwick Photographs by David Doubilet

UP ON THE SHOULDER of the Bighorn Mountains near the Wyoming-Montana line, the wind gets to whistling at a pretty good clip. It had all but drifted over the sagebrush with late winter snow, and we'd half-buried a pickup truck in the stuff. We dug for a while, got unstuck, wheeled on to Bighorn Cave in a plume of cold powder, unpacked climbing gear, and roped straight down 90 feet into blackness. Don Minchow, a local spelunker, led the way deeper while the beam from my headlamp set gardens of gypsum crystals ablaze. At the end of one long crawl I found him on his back pointing up at ribbed crescents embedded in the stone.

"Clams," Minchow said as I scrunched alongside. Then we began noticing sections of coral. Though close to a thousand miles from the nearest ocean and 5,000 feet higher, we had made our way to a warm-water reef. It just happened to be about 350 million years old.

Thrust upward from seas that covered North America's interior during the Mississippian epoch, this thick limestone layer, the Madison formation, is part of a geologic landscape that reaches from Idaho to the Dakotas and north into Canada. Travel Florida's Overseas Highway between Key Largo and Key West and you're atop coral reefs built 125,000 years ago during the Pleistocene. More fossil reefs of various ages emerge as outcrops from the Caribbean to the Northwest Territories. Throughout geologic history a variety of marine organisms have created reefs. But today the key element is

corals, the animals that helped make the world.

Coral reef limestone surrounds us in more ways than one. Cut into masonry, it houses families and institutions. Crushed, it becomes a major ingredient of cement. As marble, it further metamorphoses under sculptors' hands into pure art. Living coral reefs cover 360,000 square miles, an area slightly smaller than British Columbia, yet they host one of every four ocean species known. Along with tropical rain forests, these submarine animal forests are the most diverse ecosystems on the planet. We know rain forests are vanishing fast. How are the coral reefs doing? To find out, I lined up travels that would lead me to some of the answers.

In addition to sea anemones and most jellyfish, the group of tentacled creatures known as cnidarians includes soft corals, sea fans, and solitary corals, some of which thrive in cold, dark waters; hydrocorals and fire corals; black corals with horny skeletons; and the true reef-builders—hard, or stony, corals. Close to a thousand stony coral species currently exist, in distinctive shapes ranging from mushrooms to moose antlers, cabbages, tabletops, wire strands, fluted pillars, and wrinkled brains. These structures, referred to as coral heads, are actually colonies of individual polyps, each of which secretes a limestone cup around itself for protection.

Colonies grow slowly, seldom more than a half inch a year. Some atolls, accreting in stages for at least 50 million years, now stand almost a mile thick. It would seem safe to say that time is on the corals' side. But in just the past few decades, pollution, overfishing, dense coastal development, and other forces have destroyed a tenth of the Earth's coral reefs and seriously degraded almost a third. At this rate, scientists warn, nearly three-quarters could lie in ruins within 50 years.

Vacationers who swap snow shovels for snorkels are a vital source of income for many tropical countries. But the reasons for keeping coral communities healthy extend well beyond saving colorful undersea gardens for tourists or protecting wildlife for its own sake.

As John McManus, an ecologist with the International Center for Living Aquatic Resources Management, explained, "Reef fish make up perhaps 10 percent of the global fish catch. Together with mollusks, urchins, and other reef foods they support 30 to 40 million people. We're talking about the survival of families, villages, whole cultures—about whether kids have sufficient protein to properly nourish growing brains."

More than three billion people—the majority of humankind—occupy coastal regions. The figure is expected to double by 2050, with most of the increase coming in the tropics, where half the world's shorelines are found. A third of those coasts are associated with coral reefs. Because reefs often grow close enough to the surface to break up incoming waves, their value in buffering lands from storm surges and daily erosion reaches beyond calculation. At

Living coral reefs . . . host one of every four ocean species known.

Fish swim in but they can't swim out of this bamboo trap on a reef in Indonesia, where islanders, lured by big money, often overexploit the reef populations that feed them. Lips from a humphead wrasse (above), a Hong Kong delicacy, go for $225 a plate.

the same time, the relatively calm back-reef areas foster sea grass beds and mangrove forests, two enormously productive habitats that serve as nurseries for the juvenile stages of still more fish and shellfish.

Humanity's ties to the creatures living around coral reefs may multiply as medical research taps more of the organisms at home there. Some have already yielded compounds active against inflammations, asthma, heart disease, leukemia, tumors, bacterial and fungal infections, and viruses, including HIV. Studies found that chemicals used by sea slugs and certain sponges to repel fish also work on land as insecticides. Screening the venom of tropical cone snails for pharmaceutical properties turned up a possible nonaddictive substitute

STEPHEN FRINK, WATERHOUSE

for morphine. Sea whips, related to true corals, offer a potential painkiller as well, while coral skeletons themselves are being investigated as substrate for bone grafts. Finally, reefbuilding extracts roughly half the calcium entering the world's seas. Corals secrete calcium carbonate—limestone—on a scale massive enough to influence ocean chemistry and affect carbon dioxide levels in the atmosphere and, thus, the health of the planet as a whole.

How, then, did we come to be presiding over the collapse of one coral realm after another?

Together, the Indonesian and Philippine archipelagoes contain about 21,000 islands and nearly one-fifth of the Earth's coral reefs. There are none richer or more complex. A single bay in an Indo-Pacific sea may contain twice as many coral and fish species as grace the entire Caribbean—providing you can still find healthy reefs to compare. Fewer than 10 percent of Indonesia's remain in prime condition. In the Philippines the figure has fallen below 5 percent.

On the little Philippine island of Olango, I listened to Ramon Maloloyon describe fishing with cyanide for the aquarium trade. He used to squirt the chemical onto coral colonies, then pry them apart with a crowbar to capture stunned fish hiding in the crevices. Thousands of his countrymen did the same, starting in the 1960s, until they were putting 330,000 pounds of poison onto 33 million coral heads yearly. The aquarium industry annually sells 200 million dollars' worth of live-caught marine stock worldwide. Its biggest market is the United States. The business is perfectly legal, though the use of cyanide is not. More than half the fish die during capture and transport.

Larger live specimens from the reefs began going to places like Hong Kong so fashionable diners could pick them out of a restaurant tank

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Although he resides in landlocked Montana, wildlife biologist and author DOUGLAS H. CHADWICK has a special interest in the sea.

Global Threats

Coral reefs thrive in the clear, shallow coastal waters of tropical seas. The reefs of Southeast Asia—the world's richest—and those in the Caribbean have suffered the greatest degradation.

When climatic extremes such as El Niño increase water temperature, symbiotic algae flee the corals' tissue. Without the algae, corals lose their color and a source of energy. Bleached, they may eventually die.

If sediment from storms and coastal development blocks sunlight, corals weaken and become vulnerable to infections such as deadly black-band disease (near left). If sewage or agricultural runoff promotes an increase in plankton and a consequent population explosion of crown-of-thorns sea stars (far left), death comes by predation: Adult sea stars feed mainly on corals.

Estimated potential threat to coral reefs
(from coastal development, marine-based pollution, overexploitation of marine resources, and inland pollution and erosion)
- High
- Medium
- Low

SOURCES: *World Resources Institute, International Center for Living Aquatic Resources Management, and WCMC*

- **Metropolitan area greater than 200,000**
- **Natural stress occurrence 1986–1996**
(including hurricanes and typhoons, bleaching, and crown-of-thorns sea star infestations)

0 mi 500
0 km 500

NATIONAL GEOGRAPHIC MAPS

Masked for protection against stinging jellyfish, Philippine divers squirt illegal and deadly cyanide to stun and net fish, a practice that also kills coral—one more reason why time is running out for this ancient ecosystem.

to eat, paying hundreds of dollars for the privilege. Soon humphead wrasses, giant groupers, and other choice fish that can be filleted into multiple servings were selling for small fortunes. Providing such fare burgeoned into a billion-dollar-a-year industry. Commercial fleets that used to work offshore with nets took on diving crews and came to join in the plunder of the reefs.

When Maloloyon was diving for fish, he used homemade fins and breathed through a "hookah"—a thin plastic tube attached to a boat's air compressor. As fish got scarcer, he had to search deeper. No one told him how nitrogen bubbles can *sizzle* through your tissues if you come up too fast. He suffered the bends four times. Then a fifth.

"I went down 70 meters [230 feet] and worked for about two hours," he told me. "I came straight up. A minute after I got in the boat, I went into shock." His legs have been paralyzed ever since. About one in every ten cyanide divers ends up incapacitated or dead. Maloloyon had been after a flame goby, also known as the elegant firefish—a dazzling species that can bring nearly $50 retail. His share? "Ten pesos," around 50 cents at the time.

Some poison fishermen are being retrained by the International Marinelife Alliance, a Philippines-based conservation organization, to catch fish in hand-carried nets. After diving with them, I floated along for miles with one arm hooked around the bamboo outrigger of the alliance's boat. Through my mask all I saw was a white rubble of shattered coral heads.

When I lifted my head for a break, I saw what was causing the destruction—and what might have broken my eardrums had I been submerged. Boatmen chasing a school of fish nearby started lobbing bottles of homemade explosives into the sea. A marine official aboard our craft shot a pistol round over the

poachers' heads. They fled. I stroked down to inspect the bottom. Fusilier fish drifted past, some spinning aimlessly in convulsions, others already belly up, their electric blue stripes fading to gray. But I couldn't pick out the fresh blast sites among all the other recent craters.

The lethal combination of explosives and poisons—on top of overfishing with nets, traps, and spearguns—has become epidemic from remote South Pacific islands to the coast of East Africa and beyond. Meanwhile, living coral reefs are being mined for construction material, displaced by shoreline projects, and fragmented for sale as aquarium ornaments or jewelry. A far greater number of reefs are suffering from chemical runoff and increased silt loads caused by intensive farming and logging.

The once high fish yields of American Samoa's reefs have declined nearly 70 percent in recent years. The culprits: overfishing, pollution, and sediment runoff. Nine-tenths of the corals on Jamaica's northwest coast have been killed by hurricanes and diseases, but the reefs have no chance for recovery because they've been smothered by algae. The algae are nourished by pollution from coastal development and agricultural runoff, and overfishing has removed some species that kept the algae grazed down. Along Florida's Keys, I inspected reefs afflicted by a welter of rapidly spreading diseases. Aspergillosis, caused by a fungus that may have invaded from land; white plague type II, from a just discovered bacterium; and a number of other previously unknown coral ailments are also beginning to show up off other shores. "Something seems to be making colonies more and more susceptible to illness," said James Cervino, a marine biologist who has been tracking outbreaks in the Caribbean with Tom Goreau, director of an environmental group called the Global Coral Reef Alliance.

That *something* could be accumulated environmental stress. Corals deal with excess silt, pollutants, and similar irritants by secreting more of the mucous protein that coats their outer tissues. This costs the corals energy. Worse, viruses, bacteria, and fungi consider the slimy layer a fine place to breed. As corals continue to deplete their metabolic reserves and microbes prosper, the stage is set for infection.

All too many fishermen in all too many countries dump not only cyanide but bleach and other toxics directly onto coral reefs as a way of getting fish. But it was a different kind of bleaching that first caused public alarm. Huge tracts of coral reefs suddenly and inexplicably began to turn deathly white during the 1980s, even in relatively undisturbed areas.

Scientists soon realized the corals weren't done for; they had only expelled the single-celled, symbiotic organisms known as zooxanthellae, leaving limestone skeletons showing through transparent tissues. Corals bleach as a reaction to sharp changes in salinity and also in response to heavy ultraviolet radiation, despite possessing several kinds of natural sun-blocking compounds that are being studied for possible human use. However, most bleaching has been linked to abnormally high local ocean temperatures such as those spawned by El Niño.

The lethal combination of explosives and poisons . . . has become epidemic.

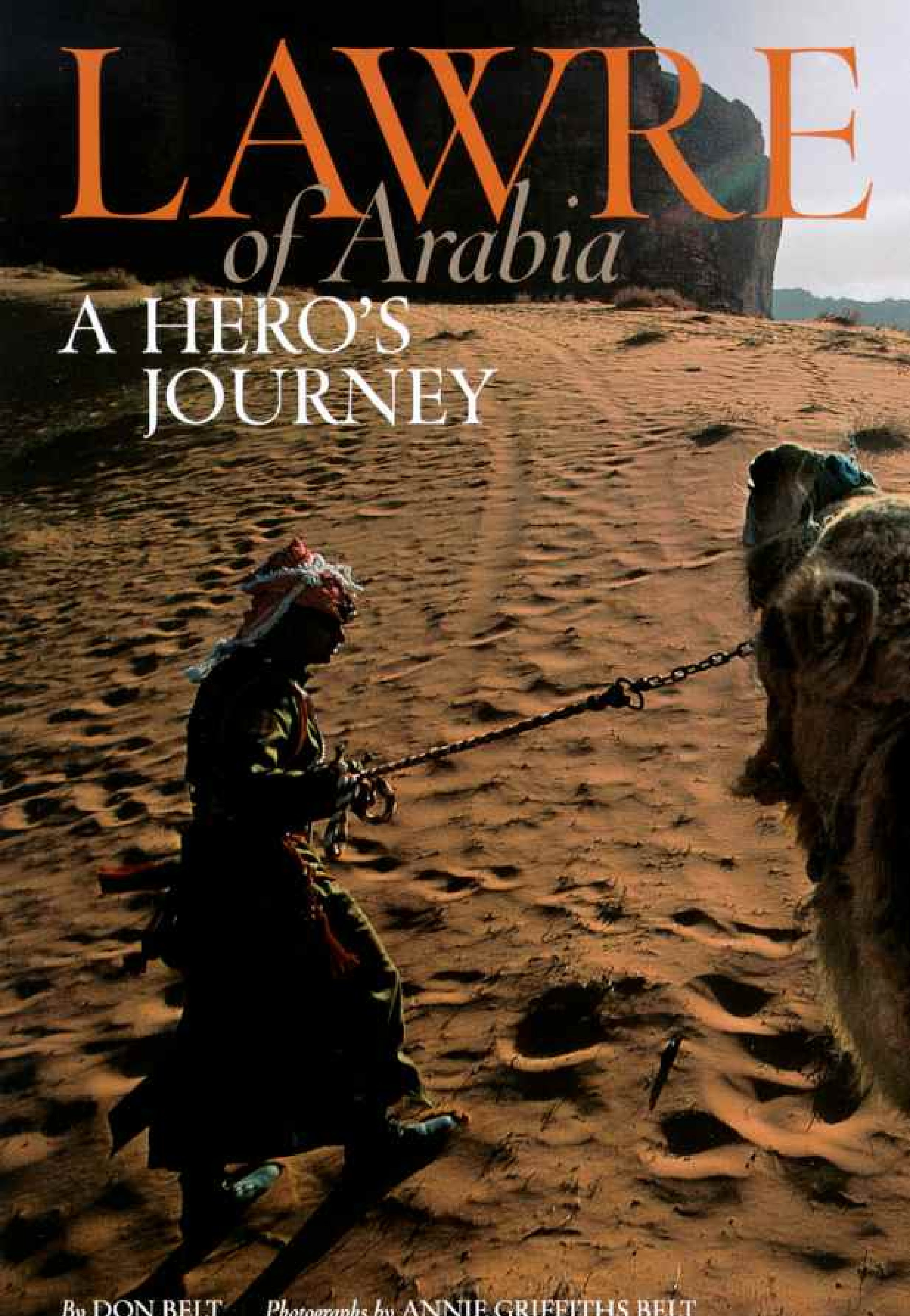
Corals are structurally fragile, easily damaged by a carelessly tossed boat anchor or snorkeler's fin, but biologically resilient. They have to be to have endured over time in the face of hurricanes, volcanoes, coastal landslides, and predators like the colony-devouring crown-of-thorns sea stars. Given time, bleached corals can regain their color and their potential for growth and reproduction. Then again, they may succumb if bleaching episodes are prolonged or recur too often, or if the colonies are trying in the meantime to cope with heavy metals, pesticide residues, or algae stimulated by nutrients flushed from coastal rivers and farms. Wherever corals are weakened by these factors, the possibility of disease looms larger.

Whether you prefer to believe that the underlying cause is natural or industrial, average global temperatures have been on the rise. Coral reefs may be warning us to pay closer attention, just as they can signal the pressures that modern populations are placing on tropical resources. Yet all along, the animals that helped build the world show us as plainly as any creatures can that environmental protection is not at odds with human needs. □

Discuss the plight of coral reefs in our online forum at *www.nationalgeographic.com/ngm/9901*.

LAWRENCE of Arabia

A HERO'S JOURNEY



By DON BELT
ASSISTANT EDITOR

Photographs by ANNIE GRIFFITHS BELT

NCE

Plunging into the world of sand and searing sun, a young British officer fought alongside Arab forces in World War I at places like Jordan's Wadi Rum. The Middle East, and T. E. Lawrence, would never be the same.

Scholar turned warrior, Lawrence dressed in Arab robes throughout the desert campaign—but his costume was no affectation. "If you can wear Arab kit when with the tribes you will acquire their trust and intimacy to a degree impossible in uniform," he advised fellow officers in 1917. He spoke from experience: For years he had worked in Syria, come to admire its people, like this youth at a racetrack in Tadmur (facing page), and dreamed of helping them win freedom. Their revolt against the Ottoman Empire also served Britain's strategy in its war against the Turks.

LAWRENCE WAS NOT CUT OUT for killing. That much became clear on one of his first forays of World War I, when the young British officer was leading a small party of Bedouin fighters through the mountains of western Arabia to join a larger force outside Medina. This was early in the Arab Revolt against the Ottoman Empire, a drive for Arab independence that Britain was supporting to advance its own war against the Turks. Lawrence at the time was a 28-year-old scholar with a history degree and a flair for schoolboy pranks and archaeology; his military experience consisted primarily of reading books on the subject at Oxford.

As his band passed through a rocky, tree-lined valley, Lawrence called a halt and collapsed on a blanket in the shade. He was stricken with dysentery and had already fainted twice that day from fever; he was also in excruciating pain with sores on his backside from weeks on a camel. As Lawrence rested, a fight broke out between two of his men. He heard a gunshot. Moments later he found himself confronted with a chilling test of his leadership.

A Moroccan under his command had shot and killed another guerrilla, a Bedouin of the Ageyl tribe. Relatives of the dead man howled for blood. As he stood before the killer, who was groveling for mercy, Lawrence's fever rose as he realized what he had to do.

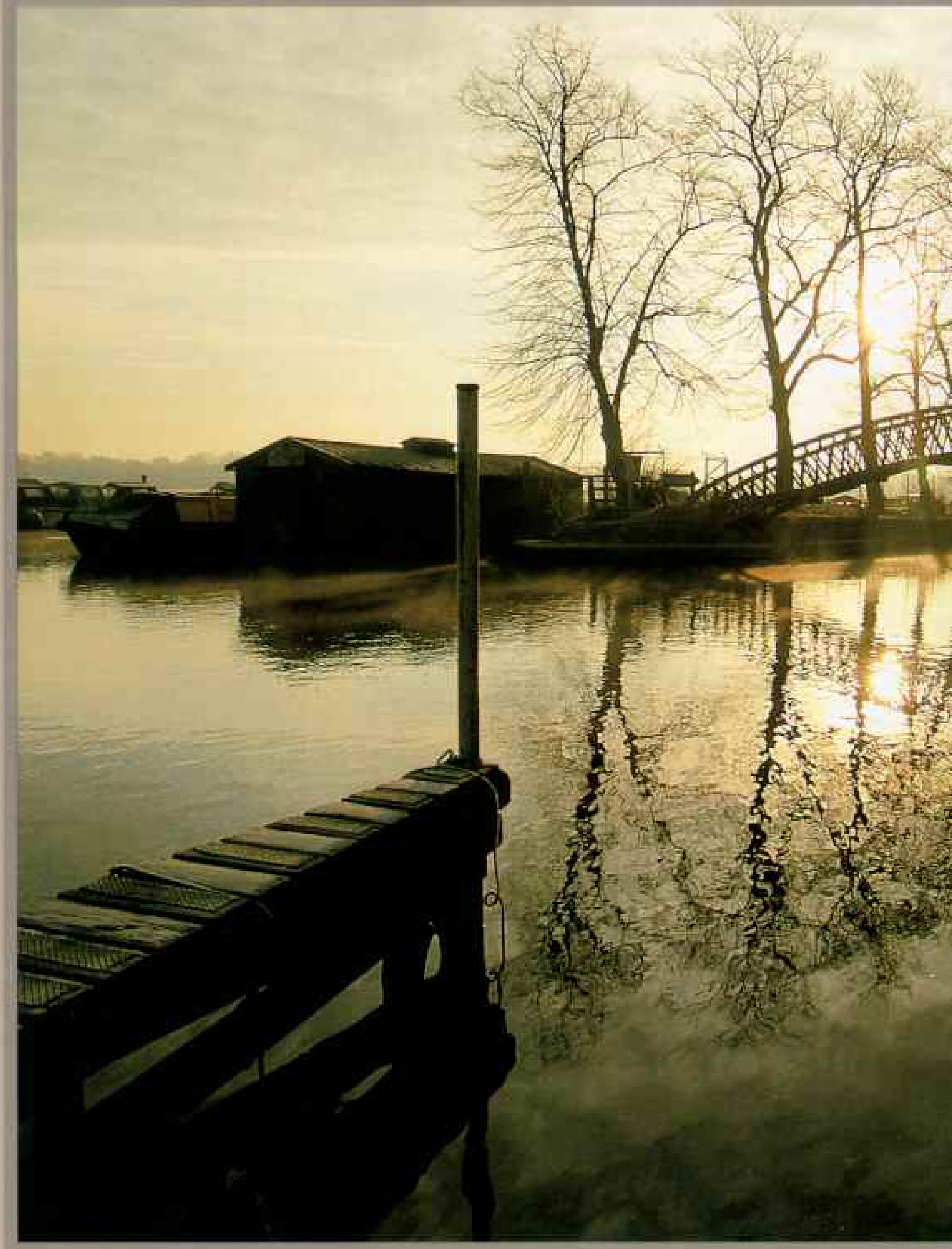
"There were other Moroccans in our army; and to let the Ageyl kill one in feud meant reprisals," he later wrote in *Seven Pillars of Wisdom*, his account of the war.* Likewise, if another of his men executed the Moroccan, there would be retribution. Lawrence had no choice: He had to kill the offender.

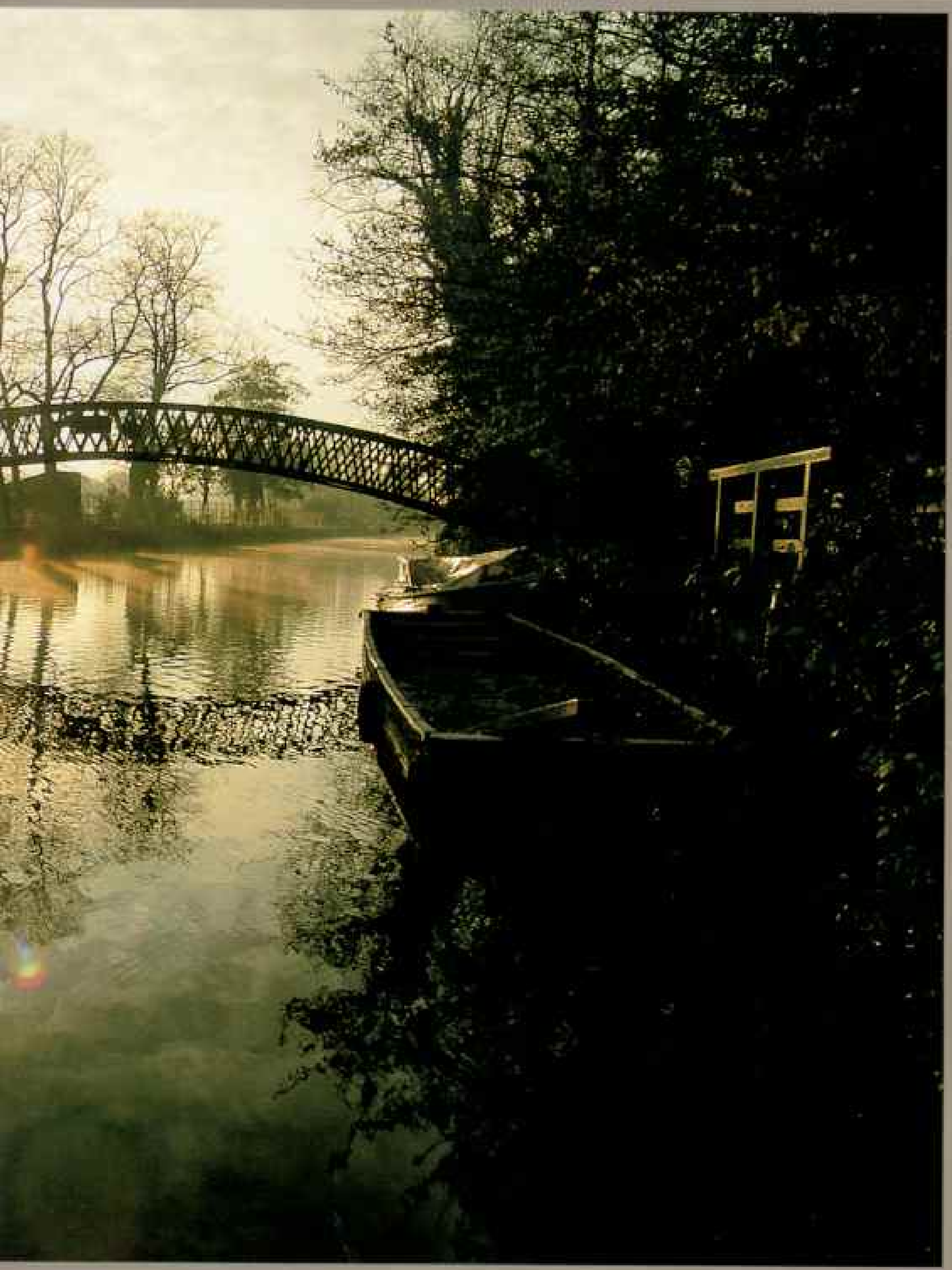
"I made him rise and shot him through the chest," wrote Lawrence, who had never killed a man. "He fell down on the weeds shrieking, with the blood coming out in spurts. . . . I fired again, but was shaking so that I only broke his wrist." Finally Lawrence leaned down and "shot him for the last time in the thick of his neck under the jaw." Afterward Lawrence was so ill that his men had to lift him into the saddle.

T. E. Lawrence would later be internationally acclaimed as Lawrence of Arabia. A many-sided genius, he would also make important contributions to the fields of literature, diplomacy, and the British military. No less a figure than Winston Churchill would call him "one of the greatest beings alive in our time." But because he was Lawrence—a hero fully conscious of his own failings—the things he did in that war would haunt him for the rest of his life.

"I once asked him whether he felt badly about such horrible exploits," George Bernard Shaw, a friend, wrote after Lawrence's death. "He said, of course he did, very badly indeed."

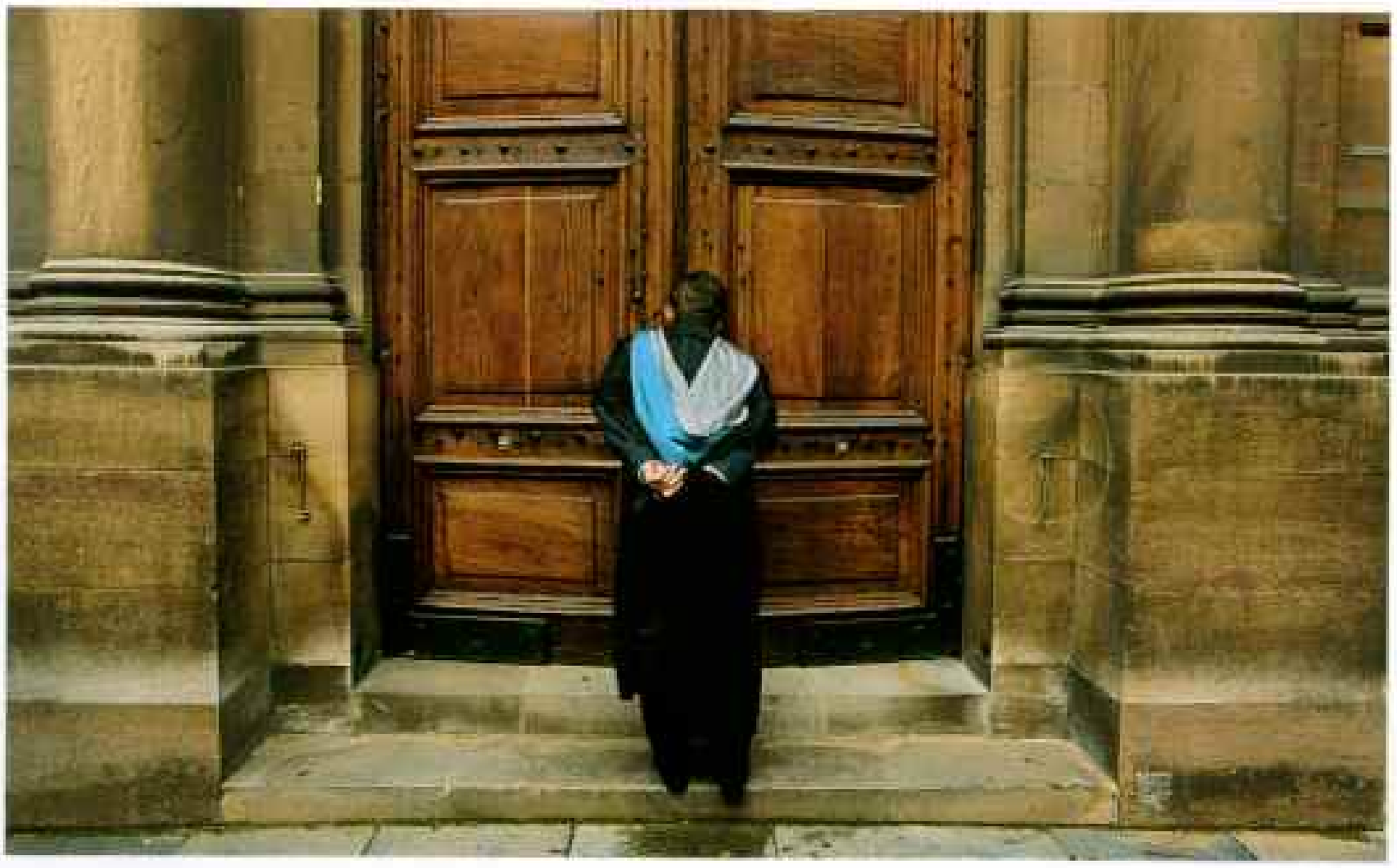
*Quoted with permission of Bantam Doubleday Dell Publishing Group, Inc., and Seven Pillars of Wisdom Trust.





Hooked on history as a boy, "Ned" roamed the fields and riverbanks behind his home in Oxford, England, on the lookout for artifacts from Britain's age of chivalry. At about age ten, he learned the unhappy truth about his own family: He and his four brothers were illegitimate, his parents unmarried, and the family name, Lawrence, fictitious.

Pursuing an honors degree from Oxford University (below), Lawrence in 1909 made a thousand-mile walking trip through Syria and Palestine to study castles built by the crusaders, a trek made easier by years of spartan self-denial. His senior thesis (left) bears marks of the perfectionist: corrections he made long after graduating.



THOMAS EDWARD LAWRENCE was a large man trapped in a small man's body. He stood five foot five, which annoyed him, but his facial expression—steady blue eyes, strong chin, handsome features—and his composure gave the impression of much greater size. When introduced to someone, he would instinctively clasp his hands behind his back and make a little bow: He loathed physical contact, even shaking hands. His voice was soft, with a touch of the upper class, and he rarely wasted words. Many people, including his mother, described him as inscrutable, even as a child growing up in Oxford, England.

By age eight or nine his hobby was history, especially the Middle Ages, and he would later spend long hours poking through excavations in Oxford for sherds of old pottery and glass or bicycling off to study some distant medieval castle. While his schoolmates were busy at sports and horseplay, Lawrence instead seemed to be hardening his body and spirit for some future ordeal. He slept little, ate little, and experimented with self-imposed tests of physical endurance. He papered his room with handmade portraits of knights and other luminaries to draw closer to the age of chivalry, which draped his rich imagination like some tapestry woven with codes of honor and heroic deeds—ideals by which Lawrence would ultimately judge his own life.

It was about this time that Lawrence pieced together the devastating truth about his family: He was illegitimate, and so were his four brothers. Lawrence's father, whose real name was Thomas Chapman, was an Anglo-Irish aristocrat who fled an unhappy marriage to live with his children's governess, Sarah Junner. The couple passed as "Mr. and Mrs. Lawrence" from then on and had five sons together, but they never married.

One can only guess how Lawrence, a rosy-cheeked acolyte intent on forming his own higher code of honor, felt about his parents and his unwitting part in their disgrace. Acknowledging his troubled identity in a letter in 1927, Lawrence wrote that his parents' shame had made him a "standing civil war" as an adult. "They should not have borne children."

As a student of medieval walls and turrets, Lawrence viewed the citadel of Aleppo as a natural stop on his 1909 journey. But when he returned in 1911 as an archaeologist, Lawrence preferred the streets and shops of the Syrian city, where he could "inhale Orient in lungloads."

Lawrence entered Oxford University in 1907 with a scholarship to Jesus College. Brigid Allen, a literary scholar who serves as the Jesus College archivist, helped provide me with a glimpse of his student days. From the trove of her office, she extracted the college register from 1907. There, in the bursar's compact scrawl, were listed terms of Lawrence's scholarship ("50 pounds per year"), his subject ("modern history"), and his father's occupation ("no occupation"). Also listed were the extra charges that students were billed for lunch foods—milk, cheese, beer, bread—delivered to their rooms. What did Lawrence eat for lunch? Bread and water, nearly every day.

"He probably felt that eating was a waste of time, or perhaps immoral," said Allen. "He was quite the oddball, you know. Back then everyone played on some team or other. Lawrence was having none of it. I can almost see him, sitting cross-legged on the floor smiling to himself while the other boys enthused about rugger or rowing. He must have been infuriating."

For his senior thesis Lawrence decided to trace the influence of the Crusades on European military architecture. He was already something of an expert on French and English castles; now he needed to learn about fortresses built by the crusaders in Syria and Palestine.

So in the summer of 1909, packing little more than a camera, a revolver, and an extra pair of socks, he boarded a ship for Beirut, and from there he set out alone, on foot, to visit as many crusader castles as he could before the fall term. He had planned his route carefully, studied Arabic, and politely ignored all warnings that an arduous solo trek through a neglected and dangerous corner of the Ottoman Empire might not be a good idea.

By September he had covered some 1,100 miles, walked his boots to shreds, and suffered four attacks of malaria. In northern Syria he'd traded gunshots with a passing horseman; elsewhere he was robbed, beaten, and left for dead. He even wore out his extra pair of socks. But he succeeded in visiting 36 crusader castles, making careful notes, drawings, and photographs of what he saw. These he included in his thesis, which earned him a first class at Oxford—graduation with highest honors.

The adventure also revealed Lawrence's gift for observing and assimilating new cultures. He embraced the ways of the Arabs, roamed their villages, and savored their hospitality. "Here I am Arab in habits and slip in talking from English to French and Arabic unnoticing," he wrote to his mother. "I will have such difficulty becoming English again." His brothers would later wonder if he ever truly did.

ANNIE GRIFFITHS BELT first took to the desert with husband Don Belt for a 1989 story on Baja California.

LAWRENCE'S YOUNGEST BROTHER, Arnold, was a guest on the Jack Paar television show one night in 1964, soon after the movie with Peter O'Toole, *Lawrence of Arabia,* had made his brother a household name in the United States. A professor of archaeology at Cambridge, Arnold was no blind guardian of his brother's memory—but still he detested the Oscar-winning film, which he labeled "pretentious and false." In portraying his brother, the filmmakers "used a psychological recipe," he told the *New York Times:* "take an ounce of narcissism, a pound of exhibitionism, a pint of sadism, a gallon of blood-lust and a sprinkle of other aberrations and stir well." The real Lawrence, he told Paar, "was one of the nicest, kindest, and most exhilarating people I've known. He often appeared cheerful when he was unhappy."

The happiest period of Lawrence's life, by most accounts, was the three years he spent digging at the ancient Hittite city of Carchemish in what is now southern Turkey. Then 22, Lawrence arrived there in March 1911, soon after graduation, to work as an archaeologist. By that time thousands of German engineers, builders, and military advisers were also in the Middle East, training Turkish troops and laying groundwork for what Britain and France feared might be a future military alliance.

Lawrence's duties *(Continued on page 52)*


TURKEY
3 1911-1914
Lawrence works as an archaeologist at the Hittite city of Carchemish.
Carchemish
Sanliurfa
Edessa
Jarabulus
Antakya
Antioch
Aleppo
MESOPOTAMIA
Latakia
2 July-September 1909
Covering more than a thousand miles on foot, Lawrence explores 36 castles, learns Arabic, and vows to return.
CYPRUS
1 July 7, 1909
Landing at Beirut, Lawrence sets out to research crusader castles for his Oxford thesis.
Tadmur
Palmyra
LEBANON
SYRIA
Beirut
Sidon
Damascus
12 October 3, 1918
After routing Turkish forces south of the city, Feisal, preceded by Lawrence, leads his army into Damascus.
Mediterranean Sea
Haifa
Dara
Deraa
IRAQ
4 December 1914-October 1916
Lawrence works as an intelligence specialist in the British War Office in Cairo.
11 1917-1918
Feisal's army moves north as Lawrence continues guerrilla attacks on the railway.
ISRAEL
Amman
Jerusalem
Beersheba
Wadi as Sirhan
Al Karak
Kerak
Bair
Maan
JORDAN
Cairo
SINAI
Petra
Al Jafr
9 May-June 1917
Joining forces with tribal chieftain Auda Abu Tayi, Lawrence and his Bedouin raiders disappear into the desert of Wadi as Sirhan.
Suez
Wadi Rum
Al Aqabah
Akaba
10 July 6, 1917
Catching the Turkish garrison by surprise, Lawrence and Auda capture Akaba.
Bir Fajr
Fajr
HEJAZ RAILWAY
NAFUD DESERT
EGYPT
Dirsa
8 May 9, 1917
Leaving Feisal at Wejh, Lawrence and a band of fighters head north.
Lawrence's routes 1909
Lawrence's attack route to Akaba 1917
Lawrence's other routes 1916-18
Major raid
Archaeological site
Historic place and regional names in brown
Present-day boundaries shown
Al Wajh
Wejh
7 March 1917
Lawrence launches attacks on the Hejaz Railway to immobilize Turkish forces.
Umm Lajj
Yanbu al Bahr
Yenbo
Red Sea
SAUDI ARABIA
Kheif
Medina
Al Hamra
Wadi as Safra
6 October 23, 1916
Lawrence meets Sharif Hussein's son Feisal, one of four brothers leading the Arab rebels.
Rabigh
5 October 16, 1916
Lawrence arrives in Arabia as part of a top secret British mission to the Arab Revolt.
SUDAN
Jeddah
Mecca

LAWRENCE'S WAR *and the* Making of the Modern Middle East

"An Arab war waged and led by Arabs for an Arab aim in Arabia." That was T. E. Lawrence's description of the Arab Revolt (left), a two-year guerrilla campaign in which he served as liaison between British and Arab forces attacking the Ottoman Empire, an ally of Germany. Launched from Mecca by Grand Sharif Hussein and led by his four sons (Feisal, Abdullah, Ali, and Zeid), the revolt aimed to win independence for the Arabs after four centuries of Turkish rule.

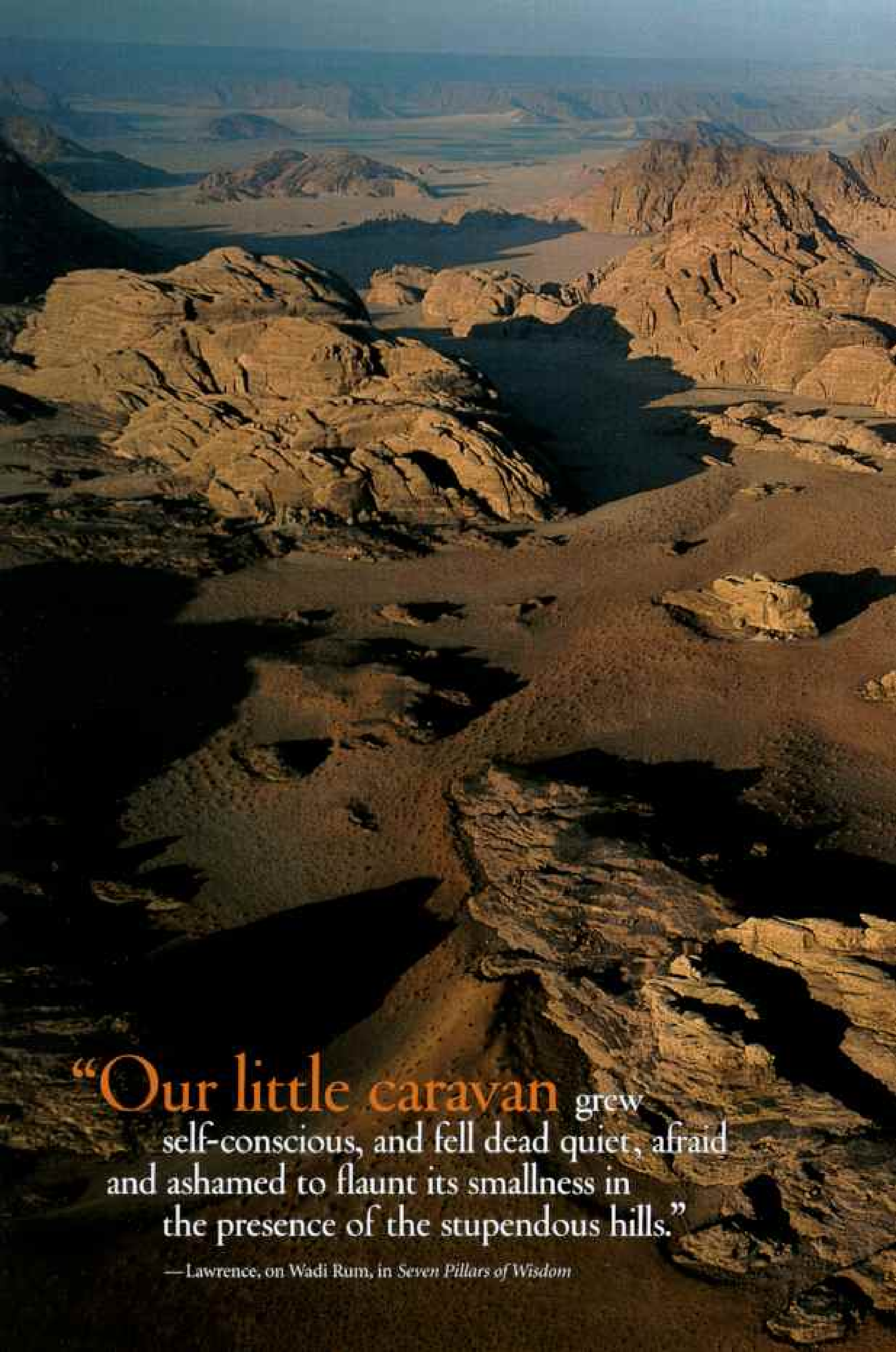
Yet even as Britain was endorsing Arab nationalist dreams, it was making secret alliances with France and Russia to divide Ottoman lands among themselves. Moreover, Britain in 1917 committed itself to creating a homeland for the Jews in Palestine. These actions produced a powder keg of competing territorial claims.

Against long odds the Arab Revolt succeeded under the leadership of Feisal and of Lawrence, who personally led raids against Turkish troops and supplies along the Hejaz Railway on the road to triumph in Damascus.

At the Paris Peace Conference of 1919, Feisal, with Lawrence at his side, argued for Arab independence—in vain. Over the next two years France was given control over Syria and Lebanon, and Britain received mandates for Palestine and the newly created nation of Iraq. Britain installed Feisal as King of Iraq and positioned his brother Abdullah to become king of another new nation parceled from the desert, Jordan.

British diplomats, including Lawrence, pressured Sharif Hussein to accept the peace agreement. When he refused, Britain abandoned him to the desert warlord Ibn Saud. In 1924-25 the Saudi army routed Hussein's people, the Hashemites, and seized Islam's holy cities.

The rise of nationalism forced out the British and French in the 1940s, while the founding of Israel flooded neighboring Arab countries with Palestinian refugees and polarized the region. Many Arabs today blame Britain, and her envoy Lawrence, for sowing the seeds of turmoil. "I admire Lawrence as a man," notes Suleiman Mousa, an Arab historian. "What I don't admire is the 'peace' he and his country imposed on us."


"Our little caravan grew
self-conscious, and fell dead quiet, afraid
and ashamed to flaunt its smallness in
the presence of the stupendous hills."
—Lawrence, on Wadi Rum, in *Seven Pillars of Wisdom*

(Continued from page 47) at Carchemish included supervising the site's Arab labor force, which he greatly enjoyed. The men respected him and relished his novel approach, which was to make the digging fun by turning it into a game. It was Lawrence who began the tradition of saluting archaeological discoveries with shots from a revolver, basing the number of blasts on the relative importance of the find.

In the evenings Lawrence often joined his crew around the fire for conversation ranging from local gossip to the intricacies of tribal politics. He struck up lasting friendships with several of the men, including his Arab foreman, Sheikh Hamoudi, and the site's 14-year-old water boy, Dahoum, who latched onto him like a big brother. Returning his devotion, Lawrence tutored Dahoum in mathematics, history, and geography. He taught him to read and write. And as he later suggested in *Seven Pillars of Wisdom*, Lawrence's dream—winning political freedom for the Arabs—was meant as a gift to lay at Dahoum's feet.

The intensity of their friendship raised eyebrows at Carchemish, especially after Lawrence, who loved to shock, refused to dispel rumors of a physical relationship. Many at Carchemish, including Lawrence's colleague Leonard Woolley, later dismissed these stories as nonsense. Like every other known relationship in Lawrence's life, this bond with Dahoum was almost certainly platonic.

In the British camp's occasional run-ins with the Turks and Germans, Lawrence also showed himself fully capable of using force or intimidation. "He had," Woolley wrote, "a cool indomitable courage . . . disguised by an impudent enjoyment of the humor of the situation; he did not mind the risk, and the bluff appealed to him immensely."

When he heard that a German engineer had horsewhipped one of his men during off-hours, Lawrence, furious, ran to confront him. By threatening to flog the German in front of the whole village, Lawrence extracted a public apology from him. "In 1914 I was a pocket Hercules," he later wrote, "as muscularly strong as people twice my size."

These petty quarrels with the Germans were symptomatic of larger tensions. Lawrence left Carchemish in the spring of 1914; by August Germany and Austria had declared war on their enemies in Europe. When Britain sided with France and Russia, Lawrence and three of his four brothers joined the war effort (the youngest, Arnold, was then 14). His older brother, Robert, became a medic, while his younger brothers Will and Frank were sent to the front lines in Europe. Both were killed within a few months of each other in 1915. Lawrence was devastated.

Because he spoke Arabic and had firsthand knowledge of the Ottoman Empire, which sprawled from southern Arabia to the Black Sea, Lawrence was assigned to army intelligence and posted to Cairo. For two years he drafted reports on the political situation inside the empire, which had allied with Germany in November 1914. Despite his lack of military experience, Lawrence advanced Britain's war strategy while gaining a reputation as something of a loose cannon. Sloppy in uniform and too cheeky for his own good, Lawrence conducted himself with a detached air of authority that made some of his superiors bristle.

Others, including Ronald Storrs, the powerful Oriental Secretary at the British Agency in Cairo, respected his judgment and thought his irreverence refreshing. In the autumn of 1916 Lawrence was assigned to accompany Storrs on a sensitive diplomatic mission to Arabia—a journey that would change his life.

In the southern provinces of the Ottoman Empire, an Arab Revolt against Constantinople had been launched in June. It was led by Grand Sharif Hussein, descendant of the Prophet Muhammad and ruler of the mountain province called the Hejaz, which included Mecca, Islam's holiest city. For several years British diplomats had been communicating secretly with Hussein, giving assurances that the crown shared his dream of an independent Arab nation with its capital in Damascus. Unknown to Hussein (and to Lawrence at first), Britain at the same time was making a secret pact with France, known as the Sykes-Picot Agreement. If the Allies won the war, they would divide the lands of the Ottoman Empire among themselves.

Hussein's army, largely made up of Bedouin tribesmen and commanded by his four grown sons, had won some early victories. But the ultimate goal, Damascus, was still 850 miles to the north. And by October, when Ronald Storrs visited to discuss Britain's role in the

IMPERIAL WAR MUSEUM

"We lived many lives in those whirling campaigns," Lawrence wrote of the guerrilla raids he and Feisal's army launched against the Turks. Surprising the enemy at Akaba (above, in a picture by Lawrence), the Arabs seized this vital Red Sea port. In Jordan, Khalaf Abu Tayi shares memories of his father, Zaal, whose portrait he sits beside, with his son and grandchildren. Zaal was one of Lawrence's fiercest commanders.

All that remains of the Hejaz Railway in south Jordan is scraps of rusty iron; here Lawrence dynamited Turkish trains and tracks, catching the world's attention. In turn, war shattered Lawrence and his illusions. He was captured by the Turks, beaten, and raped. And when the revolt succeeded, his country betrayed his Arab comrades.

Disheartened, Lawrence returned to England and furiously set to work finishing Seven Pillars of Wisdom, *an account of the war that he planned to publish for a small circle of friends. When Lawrence lost his only copy of the manuscript while traveling by train from Camberley to Oxford, he rewrote it from memory in less than three months.*

campaign, Hussein's forces were already running short of supplies, money, and manpower. Storrs promised to continue supplying the Arab Revolt with funds and materiel from Cairo; he would also have Lieutenant Lawrence stay behind to assess the situation.

Though he admired the Arabs and believed in their drive for independence, Lawrence understood the Bedouin well enough to know that they would not be moved to heroism by some abstract Western ideal like nationhood. What they needed, he and his superiors believed, was an Arab military leader of unquestioned stature and charisma. And of Hussein's four sons only Feisal seemed to him cut out for such a role.

In *Seven Pillars of Wisdom* Lawrence describes their first meeting in Feisal's tent:

"I felt at first glance that this was the man I had come to Arabia to seek—the leader who would bring the Arab Revolt to full glory. Feisal looked very tall and pillar-like, very slender, in his long white silk robes and his brown headcloth. . . . His eyelids were dropped; and his black beard and colourless face were like a mask against the strange, still watchfulness of his body. His hands were crossed in front of him on his dagger."

He and Feisal took measure of one another. How do you like our place here in Wadi Safra? Feisal asked, watching him intently.

"Well," Lawrence replied. Then, without missing a beat, he tweaked his host's pride: "But it is far from Damascus."

Feisal's advisers stiffened. No one dared to speak to a prince of Mecca so bluntly. But Feisal was amused by this brash newcomer and impressed by his reply. Thus began a partnership that propelled the Arabs northward; two years later they would march the Damascus streets in triumph, joining forces with the British under Gen. Edmund Allenby.

During this period, 1916-18, Lawrence served the Arabs as Feisal's adviser and Britain as General Allenby's liaison in the Arab camp. Besides managing the flow of British military and financial aid to the Arabs, Lawrence also led a campaign of guerrilla-style attacks on the Hejaz Railway, using dynamite to cripple the enemy and immobilize Turkish troops and equipment—no small feat, given that his own "troops" were often unruly tribesmen.

Lawrence studied his men relentlessly and never let a challenge pass unanswered. He also led by example, charging in with the others in his Arab robes, dodging the same bullets and blades; in camp, like them, he nursed his wounds—though he never let down his guard.

In Al Jafr, a desert village in Jordan, I met 67-year-old Khalaf Abu Tayi, whose father, Zaal, had been one of Lawrence's chief lieutenants on these raids. "My father always said that Lawrence was very clever, very tough, and expert with explosives," he told me. "He also had a bad, bad temper."

In Feisal's camp Lawrence usually kept a lower profile. Yet because he belonged to no tribe and was thus seen as impartial, he was sometimes called in to settle petty disputes. In one six-day raid, "there came to a head, and were settled, twelve cases of assault with weapons, four camel-liftings, one marriage, two thefts, a divorce, fourteen feuds, two evil eyes, and a bewitchment," he reports in *Seven Pillars*.

At first Lawrence relished his role at the center of history in the making. This was the kind of epic crusade he'd been fantasizing about, and perfecting himself for, since he was nine years old. But as the fighting wore on, the realities of war hacked away at his illusions. Friends perished before his eyes; innocent civilians suffered savagery beyond his imagining. He killed people. On reconnaissance south of Damascus, he was captured by the Turks, flogged, and raped. Though he escaped, Lawrence—who recoiled from a simple handshake and abhorred the thought of sex—was shattered by the experience. "The citadel of my integrity," he wrote, "had been irrevocably lost."

His noble cause—Arab independence—took another blow in October 1918, when the terms of the Sykes-Picot Agreement were revealed. By then Lawrence and many British officials considered Sykes-Picot obsolete, or at least negotiable. The unexpected success of the Arab Revolt, Lawrence hoped and led Feisal to believe, would surely nullify the agreement.

They were wrong. General Allenby informed them in Damascus. Allenby's orders were to enforce the agreement, in effect turning Syria over to France. Feisal was furious. Lawrence felt betrayed by his own government—and ashamed for having misled his friend and his many thousands of followers.

Lawrence was exhausted, depressed, and suffering from dozens of bullet and shrapnel wounds. He hadn't had a day's rest in more than two years. And then there was this news from Carchemish: His friend Dahoum, whose freedom he had dreamed of winning with this war, had died of typhus the previous winter.

"I wrought for him freedom to lighten his sad eyes: but he had died waiting for me," Lawrence later wrote on the flyleaf of a book. "So I threw my gift away and now not anywhere will I find rest and peace."

BY THE TIME Lawrence returned to England in 1918, tales of his exploits had spread by word of mouth from the War Office to the cabinet to Parliament, and beyond. Soon the public knew his story too.

Earlier that year Lowell Thomas, an American correspondent, had spent eight days with Lawrence and the Arab forces gathering material for a war travelogue. Based on raids he heard about, Thomas after the war prepared an illustrated lecture series and wrote several rather breathless accounts for magazines. These stories focused on the romanticized figure of Lawrence, whom Thomas dubbed the "uncrowned King of Arabia"—and provided welcome relief for a public steeped in blood-stained reports from the trenches of Europe. Thomas's travelogue thrilled packed houses in America, Britain, and around the world.

So at a time when Lawrence was grieving for his lost illusions—and loathing himself for complicity in Britain's deception—he was also being hoisted onto the world's shoulders and given a ticker-tape parade. Lawrence was an honorable man caught in dishonorable circumstances, and when he discovered, to his dismay, that a small corner of him actually relished the limelight, he was characteristically honest: "There was a craving to be famous; and a horror of being known to like being known,"

Lionized by the press and public as "Lawrence of Arabia," the reluctant hero dropped out of sight in 1922, reentering the British military under an assumed name. Though 34, he endured basic training in the Royal Air Force (above), even more grueling then than now. In the ranks "T. E. Shaw" (below) quietly added to his stature as a man of letters, while using his influence to make military life better for his mates.

NATIONAL PORTRAIT GALLERY, LONDON

he confessed in 1922 in *Seven Pillars*. "Contempt for my passion for distinction made me refuse every offered honour."

Lawrence did see a way, though, to use his growing influence to fight one last round for Arab independence. He mustered the will to lobby cabinet ministers, testify before high committees, write letters to the *Times*, and represent Britain—and the Arabs—at the Paris Peace Conference in 1919. In a ceremony at Buckingham Palace he even went so far as to decline the military decorations about to be pinned on him by King George V, citing Britain's shabby treatment of its friends in Arabia. The public was scandalized—and mesmerized—by this enigmatic war hero who seemed to be playing by a different set of rules.

AT THIS POINT Lawrence could have run for office and won by a landslide. If he'd turned to diplomacy, as Churchill urged him to do, he could have represented the British government at a very high level. With his background in history and antiquities, he could have found work as a teacher, writer, or archaeologist. Instead he chose to vanish. In August 1922, with help from well-placed friends, he enlisted in the Royal Air Force under an assumed name, "John Hume Ross," and began the strange final chapter of his life.

Bearing the rank of aircraftsman, lowest in the service—and the burdens of a body that had survived two years of combat and still bore the bright scars of flogging—Ross entered basic training and sought to pass into oblivion. Predictably the press, which had been clamoring after him since 1919, soon got wind of his disappearance. Within weeks John Hume Ross had been found out by a reporter, exposed as Lawrence, and discharged from the RAF.

Two months later Lawrence was back in the military—the Tank Corps of the army—and again he used an alias, "T. E. Shaw." This time the ruse worked. Blending into the ranks, Shaw served in the Tank Corps for two years, until his standing request for transfer back to the RAF was granted in 1925.

Despite his best efforts to live the rest of his life as an ordinary airman, Lawrence's genius shone through. He kept up one of the most intriguing correspondences of the modern age, writing long, impeccably honest letters to a legion of friends as varied as his background—from George Bernard Shaw and Churchill to his former mates in the service. He had "one of the most intensely real minds in my experience," noted Siegfried Sassoon, the poet, who especially admired "the way he hacks his way down to reality, never sparing himself."

Supplementing his meager income, Lawrence translated *The Odyssey* for an American publisher and wrote *The Mint*, a critically acclaimed book about his experiences in the RAF. All this was done quietly, in his spare time, and then folded neatly away into the world of barrack rooms and mess halls.

"He wasn't a bit toffee-nosed," remembered Alfred "Tony" Headon, who bunked 18 inches away from Aircraftsman Shaw for three and a half years at a base near Plymouth. "He was regular, just like one of the fellows. We all knew he was Lawrence, but we figured that was his business and kept our noses out of it."

A retired aviator pushing 90, Headon is a gentle, bright-eyed soul who lives in Bedfordshire, England, with his wife of 59 years, Katie. Like Lawrence, Tony was a war hero who makes a point of never talking about it. He usually doesn't talk about Lawrence either. But that afternoon I got lucky, and as Katie hovered nearby to fill our cups with steaming tea, Headon sat in his sky-blue Spitfire Society sweater and remembered his soft-spoken friend in Hut Number 6.

Shaw was the hut's early riser, and every morning just before reveille he'd give Tony's bunk a little wake-up kick as he returned from the bathhouse. "He was thoughtful that way, though he didn't have a lot to say. I was shy too, and I think that's why we hit it off."

Though Shaw went out of his way to avoid command and refused all promotions, Headon and the others did get one unforgettable glimpse of the leader in their midst. One day a military seaplane crash-landed just beyond the RAF breakwater, and the base mounted an emergency rescue. Headon and Shaw, among the first on the scene, found the situation dire—the plane was sinking fast under the waves. Any survivors would soon perish.

Amid the panic, Shaw quietly assumed control of the operation from his commanding officer, who was wise enough to let him. "Not only did Lawrence take charge," said Headon, "but he peeled off his shirt and dived down to

the wreck." Six of the airmen survived, and from that day on Shaw devoted himself to developing faster rescue boats for the RAF, which he often tested himself.

"He was mad about speed, you know," said Headon. "He was always racing about on his motorbike. I used to go to the airstrip and watch him race it against planes taking off."

Motorcycles were one of the few indulgences Lawrence ever permitted himself. Years before, he had become friends with George Brough, who manufactured the fastest motorcycles in the U.K. Whenever Brough came out with a faster model, Lawrence would scrape together the money to buy it, trading in his old one. He owned seven Broughs in the last 12 years of his life, each one better than the last.

I asked Tony if he ever went for a ride with him. "Hoooo, no!" he exclaimed. "It would have been like riding with the devil himself."

The day Lawrence dreaded arrived February 25, 1935, when he took mandatory retirement from the RAF at age 46. He knew where he would live: Years before he had bought a little cottage in the Dorset countryside named Clouds Hill, where he lived on weekends. What he didn't know was what he would do there.

To his disgust, the press was hounding him again. In mid-March he opened the door to a group of photographers who'd managed to find Clouds Hill. When they refused to leave, Lawrence punched one and fled on his bicycle.

Retired from the RAF at age 46, Lawrence settled into a cottage in Dorset (right), but the peace he'd felt in the military slipped away. While riding his motorcycle a few months later, Lawrence crested a hill and met two boys on bicycles, including Frank Fletcher (above), then 14 years old. Swerving to miss them, he crashed, fractured his skull, and died. Lawrence was, Winston Churchill assured a grieving Britain, "one of the greatest beings alive in our time."

A few weeks later he described himself in a letter, "sitting in my cottage rather puzzled to find out what has happened to me . . . I imagine leaves must feel like this after they have fallen from their tree and until they die."

On the morning of May 13, Lawrence rode his motorcycle to the post office to send a telegram. On his way back, doing about 40 miles an hour, he crested a hill and came upon two boys on bicycles. He swerved to avoid them, lost control, slammed into the ground, and massively fractured his skull. He never regained consciousness and died six days later. Because of his reaction, both boys survived.

In Dorset, an hour or so from St. Nicholas' Church in Moreton where Lawrence is buried, I met the man who owns what is thought to be one of Lawrence's fastest Broughs, and after a while he let me ride it. On this machine Lawrence would often hook his thumb over the throttle to hold it wide open—until he hit the bike's top speed, 108 miles an hour, which others considered crazy.

But blasting down the narrow roads of Dorset that day, I did get a taste of what Lawrence found on this bike at the end. It was a kind of surrender, I think—a speed-induced state of bliss in which things go empty and white, as they sometimes do in the desert, and where a hero's struggle might be briefly forgotten, or somehow resolved, and penance no longer seems necessary. □

TRACKING THE ANACONDA

By JESÚS RIVAS Photographs by ROBERT CAPUTO

ON DA

Wading barefoot through a snaky, flooded savanna in Venezuela, my wife, Renée Owens, and I haul a 16-foot-long anaconda to our research station. Our study—the first ever conducted of this reptile in the wild—is shedding light on the habits of the world's largest snake.

Giant man-eating snakes: That's just one myth about anacondas that's been embellished by folktales and Hollywood movies. For hard scientific facts I returned to the great plains, or *llanos*, of my native Venezuela to focus on *Eunectes murinus*—the green anaconda.

RESEARCH PROJECT

Supported in part by your Society

Prior to our investigation little was known about wild anacondas. For instance, how do they reproduce? We've studied scores of "breeding balls" (top right), slow-motion wrestling matches that can last for several weeks in which we've seen as many as 13 males writhe and wriggle, trying to muscle in and mate with a single female. We still don't know if a clutch, which can have more than 70 newborns, has one father or many. Perhaps half the young perish in the first year, eaten by predators such as ocelots (below) or caimans (below right). When anacondas mature, though, they attack animals as large as full-grown deer, killing their victims with a lethal squeeze that halts breathing and blood flow.

ALL BY ED GEORGE

Easy glider, an anaconda can cruise like a submarine and, with its eyes and nostrils strategically positioned atop its small, flat head, peer above water like a periscope. Anacondas tend to ambush their prey, not chase it, which might explain why these birds appear so unflappable.

JOHN THORBJARNARSON

WILLIAM HOLMSTROM (ABOVE AND RIGHT)

Getting a firm scientific grip on our subject calls for a bit of snake wrangling, but first we have to find the anacondas. Sloshing along at water's edge, we poke the mud with poles and with our bare feet, the better to feel snakeskin. This time we got lucky and turned up a tangle of snakes in a breeding ball (left).

To date we've examined nearly 800 adult anacondas and taken hundreds of blood samples. Each snake's DNA will help us determine how many males in a breeding ball sire the newborns (bottom middle). We also measured the snakes, the heaviest of which was 215 pounds. One surprising discovery: Adult females are almost five times bulkier than males, a sexual dimorphism much greater than any other terrestrial vertebrate.

Before we release the snakes, we sometimes implant a radio transmitter (bottom right) to track their whereabouts. On a local road we came across a dead female anaconda, and dissecting it we found unfertilized ova inside (bottom left).

We hope our work—a joint effort by the Wildlife Conservation Society and Venezuela's wildlife agency, with support from National Geographic—will help keep this snake, threatened by the degradation of its habitat, from losing more ground. □

Biologist Jesús Rivas is a doctoral candidate at the University of Tennessee, Knoxville. Robert Caruto, a regular contributor to the Geographic, is based in Washington, D.C.

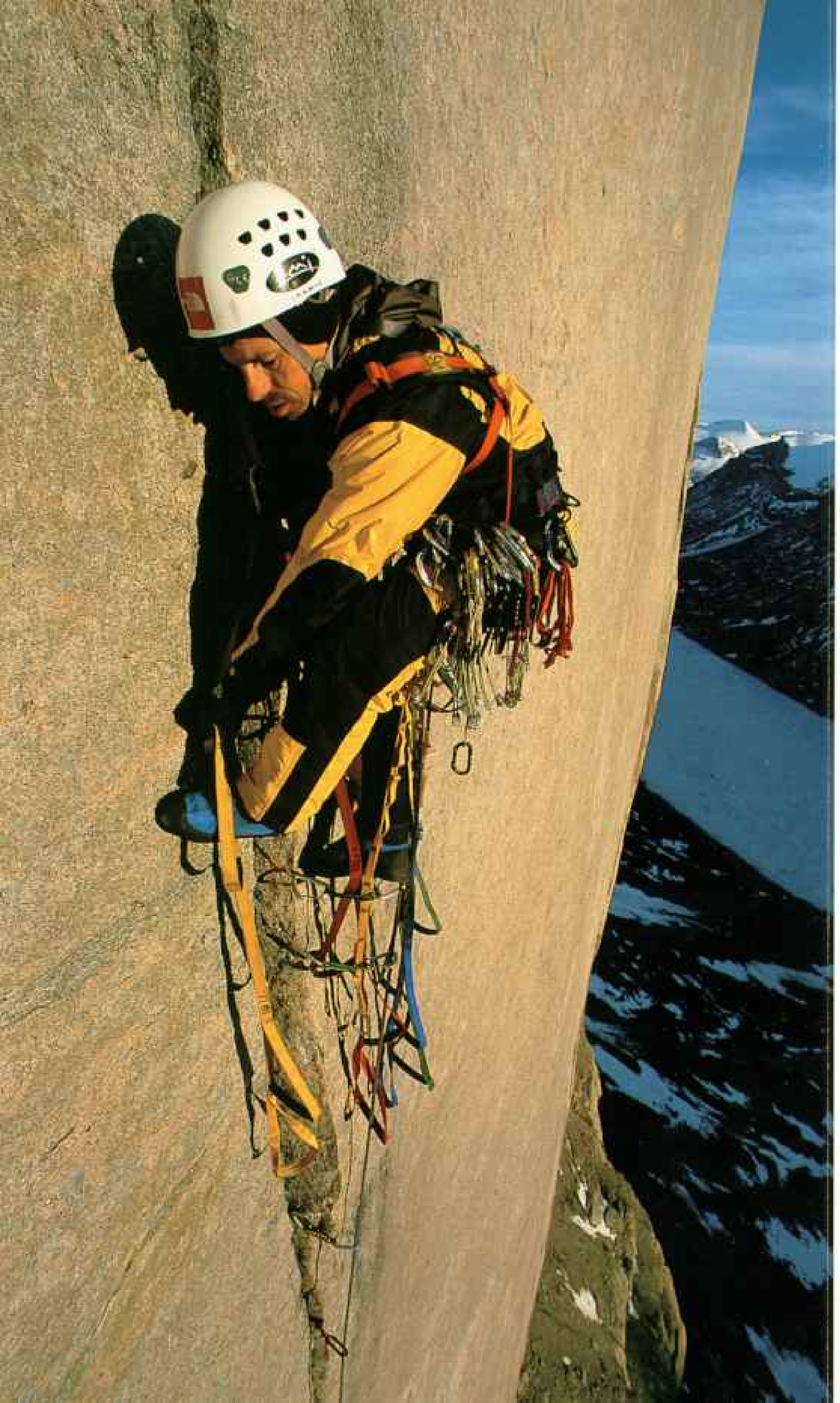
Hitting the Wall

First Ascent of a

BAFFIN ISLAND PEAK

Alone in a Canadian wilderness of ice-cut mountains, creeping glaciers, and frozen fjords, a team of climbers confronts the ultimate in technical climbing: scaling the sheer, blank wall of Great Sail Peak, elevation 5,300 feet.

Jared Ogden follows a painstakingly laid "rope highway" toward the summit. Below stretches the ice lake of Stewart Valley, ringed by a fortress of largely unnamed, never climbed peaks. Says photographer Gordon Wiltsie, "It was like discovering an Arctic Yosemite Valley."



Gleaming in pale northern light, the mist-wreathed upper reaches of Great Sail Peak (right) offer Greg Child only the narrowest seam in which to insert pitons and hang rope ladders. His helmet protected him from rock and ice chunks during hours of tense climbing. "You have to be real delicate up here," he says.

By GREG CHILD

Photographs by
GORDON WILTSIE

JUSHUA ILLAUQ slid his hunting rifle onto the sled and yanked the starter cord of his battered black snowmobile. The aging machine sputtered in the frigid air, then roared to life. Soon all five of our snowmobiles were revving, and Jushua's sled dogs were howling from their nearby pens, pleading, it seemed to me, to join our journey across the ice toward the fjords of Baffin Island's east coast.

Jushua, like other Inuit in Clyde River, a hardscrabble village in Canada's far north, is a masterful hunter. He has lived for more than four decades on this rugged coastline. Yet this time he was traveling into less familiar country, hauling our team of climbers to the hidden Stewart Valley on a spur of land the maps ominously label Remote Peninsula.

For the Inuit the Stewart Valley is mostly a rocky wasteland, barren of game such as seal and caribou and blocked at both ends by boulder-strewn glaciers. But for climbers, who stalk a different quarry, the hunting is excellent. On a flight to find new climbing targets a month earlier, members of our team had peered down at cliffs as sheer and tall as anything in California's Yosemite Valley. Only a handful of places have such giant walls: the Karakoram Range in Pakistan, Argentina's Patagonia, southern Greenland, Queen Maud Land in Antarctica, and Baffin Island, where ages ago glaciers gouged canyons through some of the hardest bedrock on the planet.

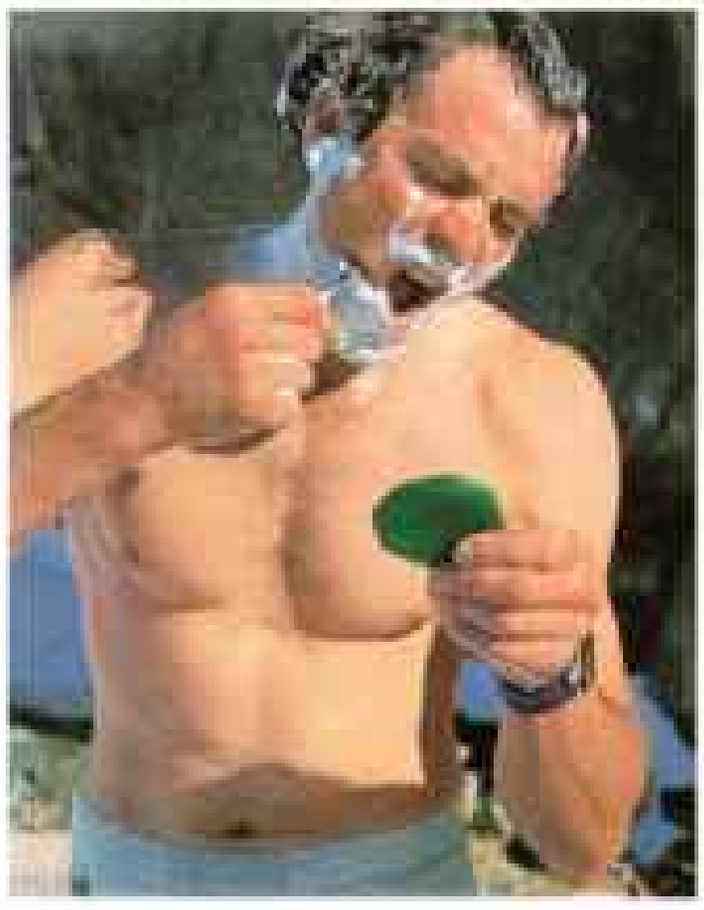
Now it was late May in Clyde River. Storms had delayed our departure for days. When the skies finally cleared, we saw icebergs and boats frozen into the harbor.

"OK, we go now," Jushua announced to our team of seven—four climbers plus photographer Gordon Wiltsie, videographer John Catto, and film producer David Hamlin. With guides Jayko Apak and Iqaqrialu, Jushua's young son Ben, and Ben's friend Romeo Palluq, we finished packing our 26-foot-long sleds with climbing gear, tents, caribou skins, bags of seal meat, and jug after jug of gasoline. Then we nestled into the baggage, braced against the coming windchill, and set off into the white.

WE WEREN'T GONE ten minutes before one snowmobile engine ground to a halt. "Oh, you'll have breakdowns," Jushua's wife, Beverly, had warned us. "Ski-Doos are buried in snow all along the coast." I just hadn't expected it to happen so soon.

Jushua opened the snowmobile's hood. In minutes he had engine parts scattered on a caribou hide and was levering on the clutch flywheel with a steel harpoon. After an hour or so of

Icebergs rise out of the midnight gloom on Baffin Bay as climbers and guides pause for tea on the way to Great Sail Peak. Snowmobile-pulled sleds heaped with 1,300 pounds of gear could not outrace a snowstorm. Whiteout conditions trapped the party for five days in an isolated and pungent cabin (left), ample time for sealskin *kamiks* to dry alongside modern down gloves.



Climbers cleansed body and mind at base camp. Though an ice well dug by guide Jayko Apak (top) fetched water laden with silt and minerals, a heat wave melted enough snow for Alex Lowe to groom (above). For luck, the team strung prayer flags (right), a custom from Himalayan climbs.

tinkering, he got the engine running. We were off once more.

Baffin's flesh-freezing winds can whip up at any time. Four hours and 16 miles after that first breakdown blinding snow halted our snowmobile convoy at the mouth of the Kogalu River, where we took shelter in an empty cabin. A polar bear had apparently broken in days before.

"Look up there," said Romeo, pointing at deep claw marks in the plywood ceiling. "A bear saw that lightbulb dangling there and took a swing at it."

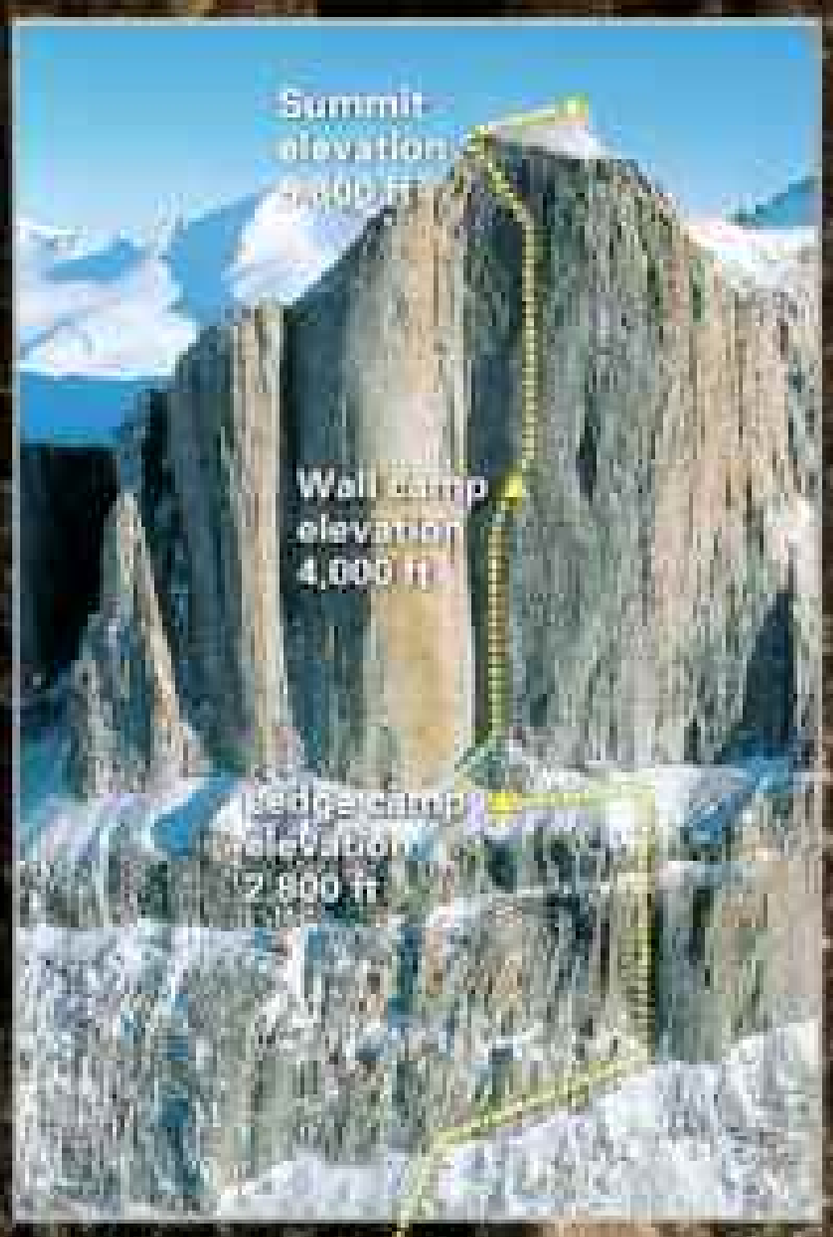
For Joshua and his men, raised in this land, weather delays were no surprise, but our team felt the clock ticking. The sooner we reached Stewart Valley, the sooner we could begin our ascent of the tallest cliff we'd seen on our reconnaissance flights, a previously unnamed mass of daunting stone we decided to call Great Sail Peak. We figured it could take us a month.

We waited out the blizzard, snacking on slices of raw seal and caribou and considering other climbers' close calls. In 1995 Paul Gagner and Rick Lovelace had been stranded on a beach in nearby Sam Ford Fiord with nothing to eat but a few goose eggs and one scrawny fish they had hooked on a line. By the time a caribou hunter in a boat slipped through the ice and found them, they could barely walk.

Wind rattled the cabin, and I munched on a piece of seal. But the uncooked contents of a caribou belly, smelling like moldy lawn clippings, were too much for me. I gagged.

Mountaineer GREG CHILD's most recent book is *Postcards from the Ledge*. Photographer GORDON WILTSIE ventured to the bottom of the world to shoot our February 1998 Queen Maud Land climbing story.

To survive three weeks on the granite wall, the team hoisted more than a half ton of gear, including water, to a ledge suitable for camping. One climber, his form etched in shadow, accompanies a convoy of 80-pound bags. Above him, Mark Synnott (opposite) shows the strain of lifting the load foot by foot via a pulley. Jared Ogden hangs on below as a counterweight.



Empire State Building
1,454 ft tall

ART BY BRYAN CHRISTIE

I surveyed a peak as intimidating as anything I'd ever climbed.

Joshua laughed at me. "You should eat it," he said. "It will make your body warm."

ON MAY 29, seven days after leaving Clyde River, we entered Stewart Valley, sledding across a glassy frozen lake and past a Stonehenge of nameless pinnacles. We arrived at the base of Great Sail Peak, wind screaming, clouds boiling, cold biting. Bending my head back, I surveyed a peak as intimidating as anything I'd ever climbed.

"Dude, this is radical!" shouted Jared Ogden, using the slang of younger climbers. At 26, Jared lives a nomadic existence in Colorado, moving his camper van from ski town to climbing area, according to season. He was excited because soon he would be a speck on that sweep of rock. Alex Lowe and I, at 39 and 41, were the elders of the climbing team. Between us we had a half century of mountaineering in the Himalaya and Alaska. We invited Jared and 27-year-old New Hampshire native Mark Synnott to join us because, despite their youth, they are two of the best big-wall climbers around. In 1997 Mark and Jared spent 25 days pioneering a bold route on 19,700-foot Shipton Spire in Pakistan, establishing their climbing credentials.

We planned to climb Great Sail Peak in three stages. First, we'd haul our gear up a 1,400-foot cliff to set up ledge camp on a broad terrace, pulling our ropes up behind us. From there we'd climb the glassy plinth to a height of 3,750 feet above the frozen lake, and under a jutting lip of rock we called the Visor we'd set up wall camp, a shantytown of porta-ledges. Finally we'd climb the upper wall to the summit. On our scouting flight, we'd spotted a possible route up the blank northwest face.

Can anyone out there hear us?

Lowe and Synnott wonder as they try to radio the village of Clyde River. Their message: We're leaving the ledge for the upper wall. A lingering look reminds them of the splendor that surrounds them.

Just then the polar sun burst through the clouds. . . . I knew . . . that I belonged to steep places like this one.

"There are barely enough features on that wall to call it a climb," Alex said—exactly the kind of challenge the lanky, Montana-bred athlete had been hoping for.

Jushua, David Hamlin, and the other guides returned to Clyde River the next day. Before leaving, Jayko Apak took off his sealskin mitt to shake my hand.

"Good hunting," he grinned, gesturing at Great Sail Peak.

None of us fully realized how much backbreaking work hauling our gear up Great Sail Peak would require. "I'm so sick of schlepping these pigs," Mark groaned, dumping an 80-pound haul bag onto a mound of loads at ledge camp. It was midnight on the fourth day of the climb, and we'd been on the move for 25 hours without sleep. The summer sun would not set again until August.

The lower cliff turned out to be an obstacle course of teetering rocks stacked as delicately as plates in a china cabinet.

"Whoa, that was close!" muttered Jared, after a chunk of granite whizzed by our heads and pounded the slope below.

The wall above ledge camp was a 2,400-foot sheet of granite and gneiss—among the hardest, smoothest rocks found in nature. Free climbing it would be impossible, since there were too few natural edges to grip with our fingers and toes. Instead we used a technique called aid climbing, a tedious process in which a climber places a piece of hardware in a crack, then suspends a foot sling from the hardware to stand on to fix another sling. Given the steepness and cold, it could take 12 hours to climb a single pitch, typically a 200-foot rope length.

After eight days of climbing we reached the Visor, where Alex drilled bolts to hang wall camp. We hoped the Visor would protect us from falling ice and stones. Before the climb we drew straws to decide who would lead each pitch.

Displaying the agility of Spiderman and the speed of a caterpillar, Alex Lowe sets the lead rope on the peak's upper wall (opposite). With the surface nearly bone smooth, lacking edges and cracks for free climbing, Lowe inserts a hook to hoist himself. Every few feet he checks his rack of gadgets—pitons and skyhooks—for the right device to aid his ascent.

Here, just above wall camp, I tackled the toughest pitch of my career. For nine exhausting hours in driving sleet I inched up a crack no wider than a strand of yarn. Teetering on my ladder-like slings, I tapped piton after piton into the fissure above my head. Each piton, a small blade of metal no thicker than the tip of a key, would not support an ounce more than my weight. Soon I lost sight of my companions, who hunkered a hundred feet below me in their porta-ledges. When I peered up the cliff, fusillades of snow pellets stung my eyes. Hugging cold rock, with nothing but a half mile of air beneath my feet, I took stock of the sublime craziness of my position.

If the piton I hung from ripped out, I would fall, and the flimsy bits of gear I'd rigged below it would rip from the crack like the teeth of a broken zipper. I'd survived risky moments on Everest, K2, and other climbs, but here I wondered if I was pushing my luck.

Just then the polar sun burst through the clouds. Dissolving fog unveiled acres of rocks dripping icicles. Warmth seeped into my numb, gloved fingers, and I was suddenly calm. My pulse slowed, and I knew, if I'd ever doubted it, that I belonged to steep places like this one.

I stretched up, slotted another piton into a crack, and tapped it in. Tinkering like a mechanic, I lost myself again in the ritual of climbing.

THE FINAL PUSH to the summit began without much promise on June 24. We had been waiting out a freezing rain squall at wall camp. Alex was nursing a knee he had twisted a week before carrying a heavy bag. Drips falling from the lip of the Visor had thumped a maddening drumbeat on our tents. We had finished reading our books, solved our crossword puzzles, exhausted our jokes. An edgy mood infected us.

"What's it like out?" I grumbled to Mark, who was peering out the flap of our tent through a spiderweb of string-tethered stoves, spoons, smelly boots, and ditty bags.

"More high cirrus clouds blowing in from the coast," he said. "Looks like the weather could spank us again, but right now we can climb."

Mark and Jared took the lead, ascending our swaying highway of ropes to explore the way ahead. Twenty hours later Jared was sprinting up a gaping fissure, pounding his gloved fists into the crack like a boxer.

"The weather is clearing!" Mark radioed down to the rest of us. "Jared has reached a big ledge we can all fit on, and the summit is close! Get up here!"

Alex, Gordon, John, and I raced up the ropes Mark and Jared

Home Steep Home: Far from solid ground the climbers pitched a hanging camp for a final bivouac, bolting tents and gear to the wall. An overhang shielded them from falling debris. All swore they slept soundly.

Wall Eye

The acrobatic art of mountain photography

On high alert for photo possibilities, Gordon Wiltsie looks skyward from a cramped belay station and gear depot (below). When he needed close-ups of the ascent, the climbers rigged a rope for him to climb alongside them. To create extra framing space, Wiltsie tied himself to a kind of sideways tripod (left) to capture an image of the wall camp (preceding pages). Most times he pushed off from the wall, hung in midair from a rope, and snapped.

Videographer John Catto also got vertical as he chronicled the expedition, which was sponsored by the Society and outdoor equipment manufacturer The North Face. His work premieres January 20, 1999, on TBS in a National Geographic EXPLORER feature, "Hitting the Wall."

JOHN CATTO (ABOVE); MARK SYNNOTT (BELOW)

Denied toeholds, Greg Child climbs out of fog with an ascender, a clamp enabling him to pull himself up a rope. He prefers gray cool weather, when rocks and ice stay put. "The nicer the day, the more dangerous the climb."

"Are we in the middle of nowhere, or what?" Alex grinned broadly.

had set in place, and at 10 a.m. on June 25 we surmounted the last shadowy cliff onto the gently sloping summit plateau. Having spent so long on the vertical, we wobbled as we walked to the apex of Great Sail Peak.

We shook hands, stared across the Arctic vista, then kicked off our boots and shed our shirts to bask in the sun. Flopping onto the lichen-covered granite, I felt the toll of our 23-day climb settle into my body. My muscles ached. Bloodied from constant scraping against rock, my hands stung. My unwashed body reeked. Living shoulder to shoulder in our porta-ledges and always connected by climbing ropes, my teammates and I were, frankly, fed up with each other and ready to head home.

"Are we in the middle of nowhere, or what?" Alex grinned broadly.

Emerging from my fatigue I looked east, where iceberg-speckled waters shimmered like a mirage. To the west lay the wasteland of the Barnes Ice Cap. The granite walls of Sam Ford Fiord rose to the south, and a barrier of dark, sinister cliffs stood to our north.

"Gibbs Fiord," Mark said, pointing to those mysterious walls. "No one has climbed there yet."

My eyes locked onto those unexplored ramparts, and I knew that once we were safely home and the aches and pains faded, we'd feel that familiar itch to return to the harsh, beautiful world of Baffin Island. □

Glorying in the moment, climbers stand tall on Great Sail Peak's summit. Success was touch and go. At wall camp, Alex Lowe frowned (below left) when the lead climbers reported flaking rock and dark clouds, but at news that the top was within reach he cried, "Yes!"

FRONTIERS OF

Scientific field data are the basis for important news about the state of the planet. Resulting reports may describe recently discovered plants or animals, identify habitats in peril, or reveal traces of ancient human settlements. The scientists profiled here, among the more than 250 who were awarded research grants by the Society last year, personify the global research that forms the bedrock of our mission.

—GEORGE E. STUART, *Chairman*

Follow the committee's work online at *www.nationalgeographic.com/research*.

DAVID COULSON (ABOVE); JOAN ROOT

ART IN THE SANDS
A satellite phone keeps grantee David Coulson of the Trust for African Rock Art in touch from the Sahara. He studies engravings like this 8,000-year-old, four-foot-six-inch specimen he found in Libya (left), which depicts a mythical beast. Hippos and crocodiles populate other engravings, evidence of the desert's once wetter climate.

COMMITTEE FOR RESEARCH AND EXPLORATION

KNOWLEDGE

"I do this work because rock bees are much more fascinating and

DROPPING IN

Skylifted to a Mexican mountaintop, S. Jeffrey K. Wilkerson wades through grass to study remains of an ancient fortress near the 2,000-year-old ruins of El Pital. "We inspect sites after rains," says Wilkerson, director of the Institute for Cultural Ecology of the Tropics. "Vegetation color helps us locate hidden features." Wilkerson, who has worked in Veracruz for 35 years, identified El Pital, one of the largest pre-Columbian cities on Mexico's Gulf Coast.

DRESSED FOR THE DANCE

Protected by a veil and thick clothing, Puja Batra peers into a rock bee colony to study the insects' unique dance language. Assisting her is Kethe Gowda, a honey collector from the Biligiri Rangan Hills of southern India. "I do get stung sometimes," says Batra, of the Michigan State University zoology department, "but it is worth it to learn more about rock bees. They are thought to be the major tree pollinators of Asia's forests."

important than they are dangerous." —PUJA BATRA, *Research Grantee*

DAVID HOGG

PUJA BATRA

BURIED TREASURE

Digging near a causeway at El Baúl, Guatemala, Oswaldo Chinchilla, curator of the Popol Vuh Museum in Guatemala City, discovered this sculpted image with the head of a jaguar and the body of an iguana. "It is a major example of the ancient Cotzumalhuapa style," he says. "The creature guarded the entrance to the ceremonial precincts of El Baúl." The site, dated by Chinchilla between A.D. 600 and 1000, is threatened by development.

ENRIQUE ORTIZ

"Development of wildlife management plans can't begin until we know

BOTH BY DIETMAR NILL

FROZEN BATS . . .

The pitch black of a Panamanian night is pierced by an array of flashes as Elisabeth Kalko studies foraging bats on Barro Colorado Island. High-speed images (top) by her team matched to taped ultrasound recordings show how bats use echolocation for various tasks, such as detecting prey and measuring distances. "We have also identified species by their calls," Kalko says, "including high-flying bats that would otherwise go undetected."

. . . AND REALLY BIG RATS

A rodent phobic's nightmare is a dream for Jim Patton, surrounded by rats, bats, and other small mammals he brought back from northern Vietnam. An evolutionary biologist at the University of California, Berkeley, Patton's numerous Society grants have helped him study small mammals around the world. "On a Geographic-sponsored expedition to western Brazil in 1991," he says, "20 percent of the small mammals we found were new to science."

what's living there in the first place." —JIM PATTON, *Research Grantee*

MARK W. MOFFETT

NET PROFIT FOR SCIENCE

From a freezing lake near the Bering Strait, Russian researcher Pavel Gudkov hauls in a char, the salmon-like fish that is the subject of his three-year study involving both Russian and American scientists. "We are learning much about the frequency of char migration between Asia and America," he says. "Normally each river has a distinct population, but sometimes nonspawning char migrate to neighboring rivers and even across the strait."

ALFRED BACKOS

"We are very grateful for the Society's support. Without it, we wouldn't

BROOKS WALKER

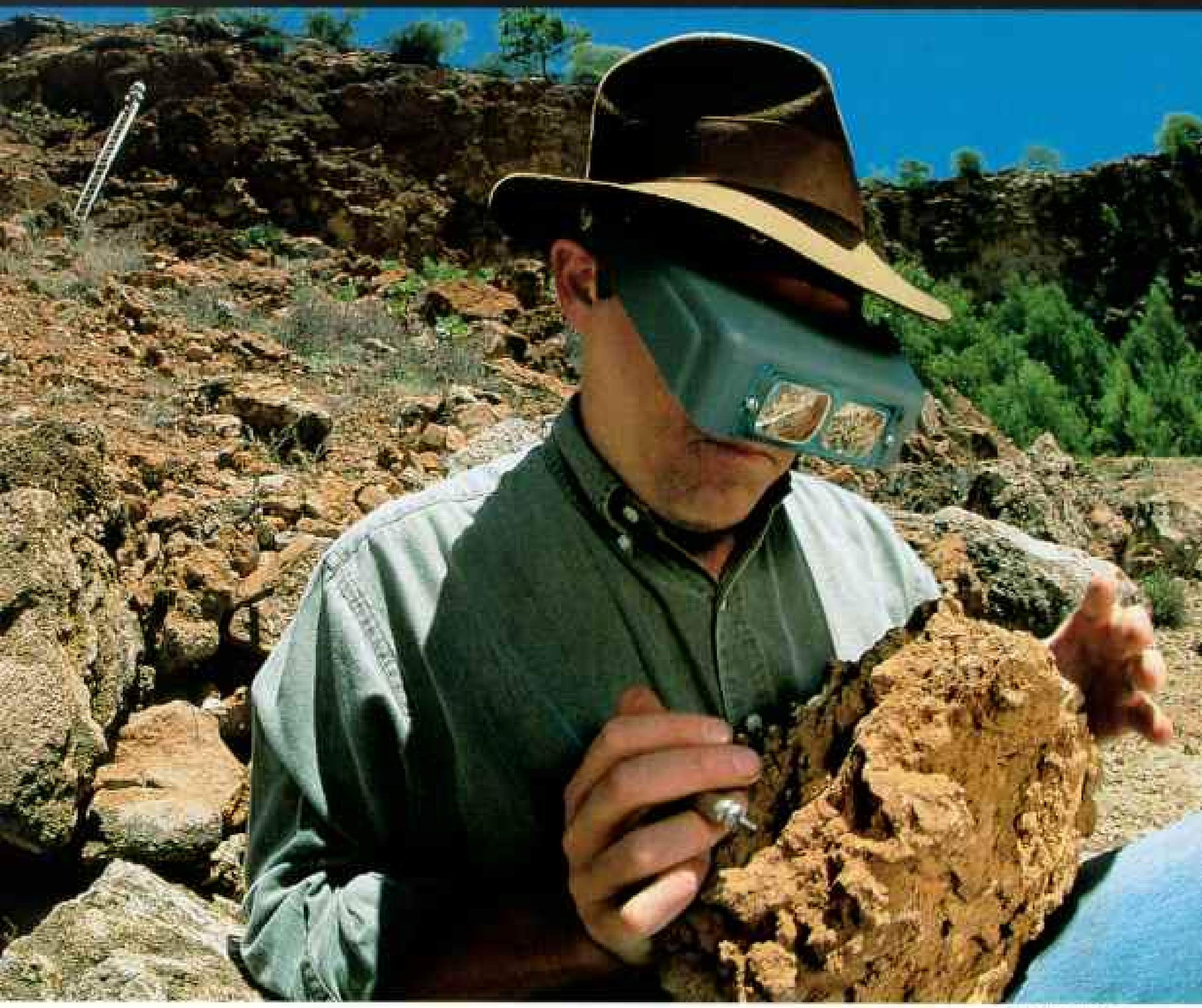
TWO GOOD EGGS

"This is something nobody had ever seen before," says Luis Chiappe (above, at right), who with expedition co-leader Lowell Dingus found fossilized sauropod dinosaur embryos in Patagonia complete with patches of skin. In the rotunda of their home base, the American Museum of Natural History in New York City, they hold two egg-and-embryo fossils beneath the mounted skeleton of a full-grown female sauropod.

A CLOSER LOOK

Rocks like this one containing a fossilized hominid tooth, found in a South African quarry, loom large in Lee Berger's view of human origins. His finds at sites near Johannesburg may someday lead to a redrawing of humankind's family tree. Winner of the 1997 National Geographic Research and Exploration Prize, the University of the Witwatersrand scholar has also helped record and preserve 117,000-year-old human footprints.

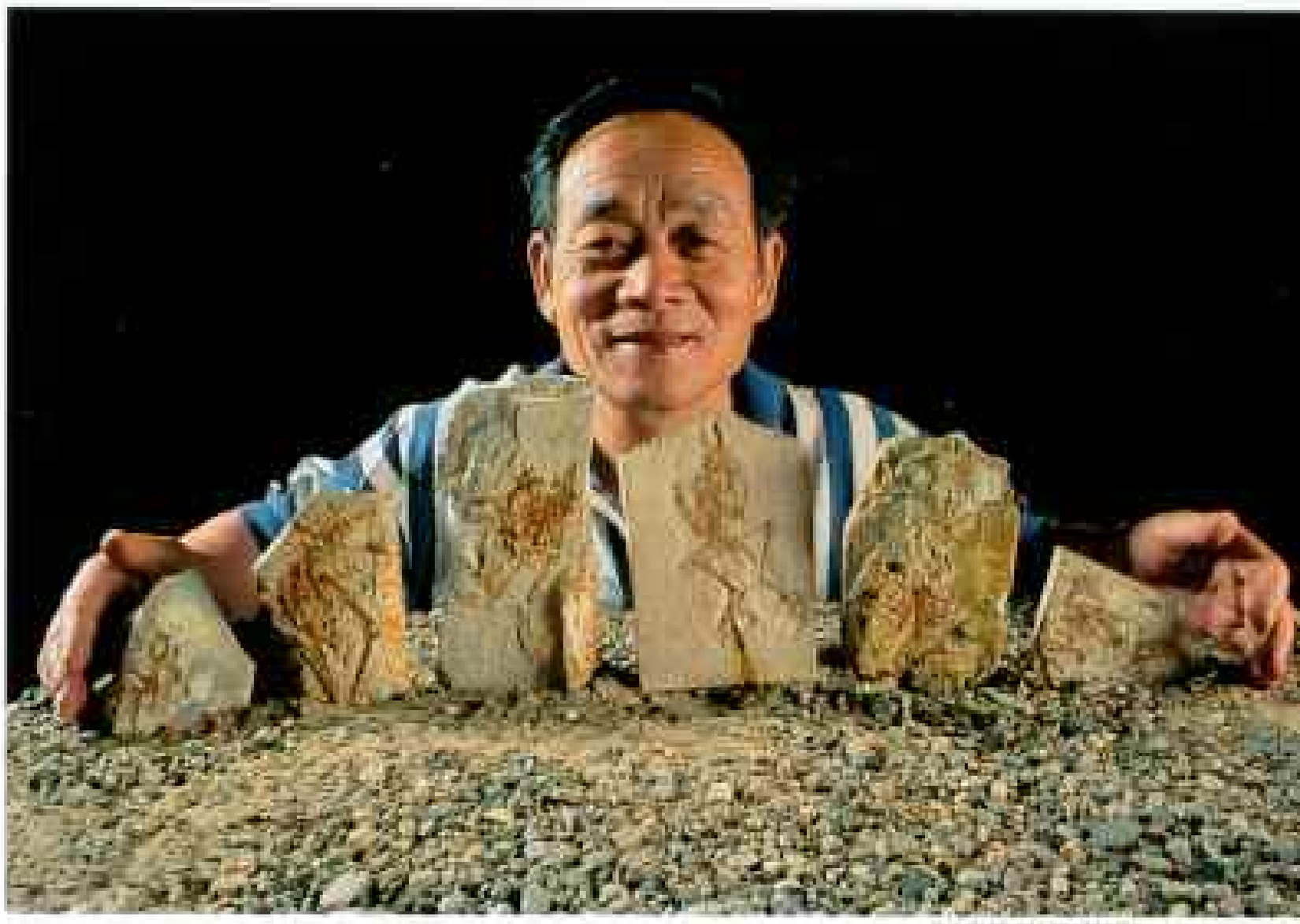
be sitting here with these old birds." —ZHOU ZHONGHE, *Research Grantee*



KENNETH GARRETT

FEATHERED FRIENDS

They've all got feathers, and they're all more than 120 million years old, but these creatures unearthed in a dry lake bed in China by Hou Lianhai (right) and colleague Zhou Zhonghe are not all ancestors of modern birds. Only the second and fifth from the left, which have distinctive skeletal differences from the others, have modern descendants. "In the study of bird evolution, this is already one of the world's most productive sites," says Zhou. □

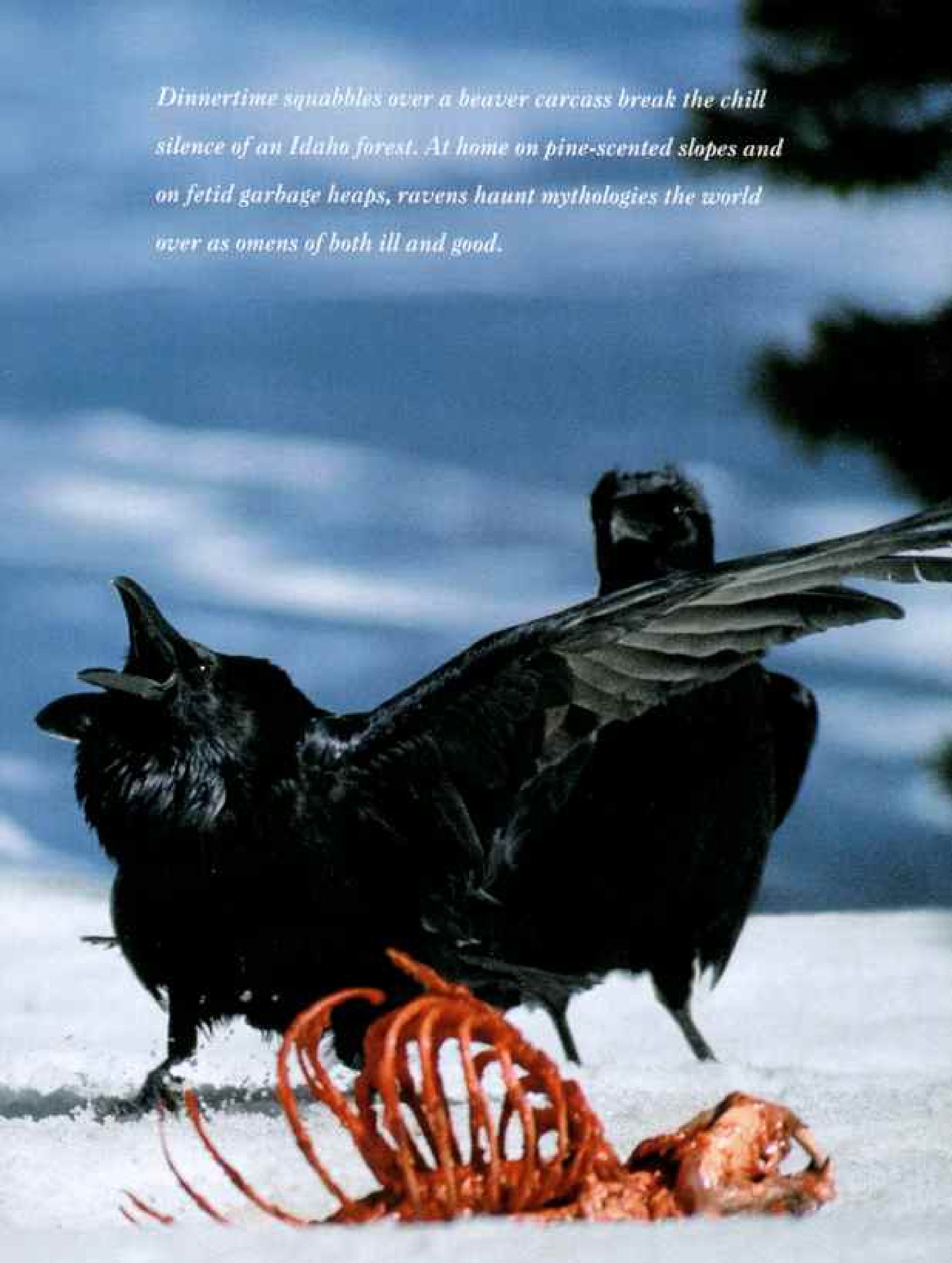


D. LOUIS MAZZATENTA

RAVENS

By DOUGLAS H. CHADWICK Photographs by MICHAEL S. QUINTON

Dinnertime squabbles over a beaver carcass break the chill silence of an Idaho forest. At home on pine-scented slopes and on fetid garbage heaps, ravens haunt mythologies the world over as omens of both ill and good.



Legendary Bird Brains

Bighorn sheep clung to the canyon walls above the river, and bison trailed across the floodplain. Fresh grizzly tracks punctured the mud at a melting snowbank's edge. But the creature that held my attention here in Yellowstone National Park was the one that seemed to be talking to itself. Hunched among the pine branches, it gabbled, growled, and mewled without pause. At times the voice resembled liquid gurgling through a pipe. Then it became a drum and, soon after, a rattle. I felt as if I'd happened upon a shaman in the midst of his prayers.

Two more flew above me a mile down the trail. As their kind will, they cried out in passing. I answered. They wheeled and called back, curious, demanding: *Quork. Quork. Tok!* Flying on, the pair began to spiral upward on a thermal. Before long, they were using the whole sky, streaking through a froth of spring clouds, polishing the winds.

They would hurtle earthward for hundreds of feet, then unfold their wings and let the speed begin to carry them upward, higher and steeper, until they nosed over into the next plunge, fashioning a giant roller-coaster ride for themselves. They made half rolls, full barrel rolls, corkscrew dives, and backward loops. They carried out maneuvers in perfect tandem, wing tips often touching, like a single bird and its reflection. Finally they flew straight ahead for a while, but did so upside down.

Aerial antagonists clash as one raven defends its
Yellowstone turf by pulling another's wing feather.
Once slaughtered as pests, ravens are on the rebound.

A twig becomes a toy in the waning days of a long Minnesota winter. Passing it could be play or the onset of courtship. Ravens mate for life and stake out territories that they vigorously patrol and defend.

With a four-foot wingspan, Corvus corax *is the world's largest perching bird—and North America's largest songbird. In Edgar Allan Poe's poem "The Raven," the dark visitor utters only "Nevermore." In reality this garrulous bird commands a broad, quirky vocabulary of* cr-r-ruks, prruks, *and* toks.

Every so often one would give forth a deep call that sounded like a sharply struck bell. And each time something inside me seemed to ring in response.

I don't mean to make this sound too mysterious. The birds were only common ravens. The first was probably a juvenile experimenting with raven vocalizations, a repertoire whose range, some say, is exceeded only by human speech. The others were engaged in unison soaring, one of many behaviors expressing the bond that keeps raven pairs together for life. Their aerobatics contained elements of play, which ravens display in more different forms than perhaps any other bird.

Awakening many mornings to the sight of ravens in the woods by my Montana home, I learned to tell when a romp was about to begin. Their movements grow kind of loose and flaphappy until, all at once, birds are toppling off perches backward to swing upside down by one leg. Or they start a long, noisy game of aerial tag or midair catch with sticks. They swoop through spray from irrigation sprinklers and slide down snowbanks on their backs like kids in slick winter jackets.

Ravens seem to notice, consider, and comment on everything in the world around them, and when one abruptly appears with an urgent squawk, people sometimes get the feeling that the bird is bearing a message for them. Years ago as I was driving up a mountain road, the sudden passage of a shouting raven left me unsettled enough that I slowed and pulled toward the shoulder a bit. A moment later a logging truck came roaring into view on the wrong side of the curve ahead. Had I not already moved aside, the hurtling truck would probably have killed me. Though I realize this only proves that big, obsidian black, talkative birds naturally compel our attention, I still owe a raven my life.

I've had a special interest in raven lore ever since. From the Old Testament I learned that Noah loosed a dove from the ark only after the raven he sent forth to search for dry land—a common practice among ancient mariners—failed to return. Rereading Edgar Allan Poe's poem "The Raven," I heard lost love cry out in despair as the raven perhaps best known to the English-speaking world croaked

Author Douglas Chadwick and photographer Michael Quinton have covered many wild creatures for the Geographic. This is their first collaboration.

BOTH BY JIM BRANDENBURG

"Nevermore"—pitiless as fate. In Norse legend two ravens, Hugin (Thought) and Munin (Memory), winged through Odin's realm each day, returning to perch on his shoulders and whisper the news in his ears.

The natural history of common ravens is no less evocative. Looking more closely into the subject, I discovered songbirds with a hawk's raw strength and mastery of gusty distances. Ravens live for decades and exhibit intelligence that has scientists reevaluating the meaning of the word "birdbrain."

SPANNING FOUR FEET on outstretched wings, weighing three to four pounds, and wielding a powerful three-inch-long beak, the common raven, *Corvus corax*, has made a home across much of the Northern Hemisphere. In the New World it nests from Nicaragua all the way to the tundra barrens of the high Arctic, where it is one of the few birds able to endure the long, bitter winters, aided by a metabolic furnace cranked a notch or two higher than most birds'.

A slightly smaller cousin, the Chihuahuan raven, inhabits parts of Mexico and the southwestern United States. Seven other kinds of raven dwell elsewhere in the world and, like the common raven, appear to be flourishing. They are part of the widespread and successful corvid family, which includes magpies, jays, rooks, and crows. Inquisitive and quick to learn, corvids have some of the most highly developed brains known among birds, and the raven's is the largest in the family.

To expand their omnivorous diet, ravens become serious scholars. They eat worms, insects, grains, and berries; soar hawklike over meadows hunting rodents; pirate food from other hunters; and scavenge carcasses. Some grasp nuts in their beaks and hammer the shells open against rocks. Others flush gull-like kittiwakes from their nests by dropping clods of turf on them to get at their eggs. Ravens have even killed newborn sheep, caribou, and seals, usually by stabbing out their eyes.

Ravenous. Ravening. I was beginning to understand these words better all the time. In South Africa I awakened from a nap alongside a hiking trail just in time to see a white-necked raven that had unzipped my backpack making off with my supply of cheese. A biologist at Yellowstone National Park informed me that ravens there have mastered the art of Velcro, undoing the fasteners on snowmobile storage compartments to snitch lunches and snacks.

To find out more about how raven intelligence works, Bernd Heinrich, a University of Vermont biologist, tried an experiment in the aviary attached to his house. He tied bits of meat to strings hanging from a perch. Crows grasped the strings with their beaks and lifted them as high as they could but never figured out how to bring the meat within reach.

Absolutely ravenous, chicks clamor for food 50 feet up a quaking aspen in Idaho. Running an endless shuttle, their parents stuffed the week-old chicks with carcass meat, insects, rodents, worms, and eggs of other birds. But the nest is no sure haven. On the nestlings' 26th day of life, two vanished and three perished on the ground (below), perhaps pecked to death and tossed out by aggressive young ravens seeking to usurp the resident pair's territory.

In another nest (above) an interloper mates with the female. Cuckoldry can occur even while a male is out proclaiming his territory with his calls. Egg clutches of three to seven eggs are sometimes fertilized by two or more males, yet the bonded pair remains together.

Snow flurries erupt as a raven refreshes itself after feeding on a deer carcass. Another bird's landing pattern leaves an angelic print. Snowbathing birds also fluff around in fresh powder just for fun or slide down snowbanks on their backs like giddy children.

The midnight-colored raven bodes misfortune in some legends. Yet for other cultures it is a guide, piercing the dark with keen eyes; sacred to Apollo in ancient Greece; creator of life for the Tlingit, Haida, and Tsimshian peoples of the Pacific Northwest.

Next, Bernd replaced the crows with ravens. "They looked over the situation, then pulled up a length of string, stood on it, pulled up another length, stood on that, and so on until they reached the prize," Bernd recalled as his birds stared at me and chatted among themselves as if sizing me up. "Since most succeeded the first time without trial and error or any previous learning, this simple experiment suggests that the ravens were using insight to solve the problem. That raises tremendous questions—and resistance in the scientific community."

Bernd's study of mental awareness in ravens was rejected by four academic publications before it finally appeared in *The Auk*, the journal of the American Ornithologists' Union. Science seems to be having enough trouble interpreting recent evidence suggesting that our closest relatives, chimpanzees and other great apes, possess reasoning abilities. The possibility that some raucous featherhead might have them too threatens to upend centuries of grand assumptions about humanity.

I decided that Bernd enjoys walking through New England's woods in the company of young ravens he is rearing in part because the boundless curiosity exhibited by these birds matches his own. "It's as if their mission in life is to investigate every new object in their environment," Bernd said. "A little while ago I brought out a length of pipe and let them see me put a frog or snake in one end. First the ravens peered into the end where the animal went, then they ran around to wait at the other end. I've done this with a handful of ravens so far. While I can't say for sure what mental processes are involved here, it just does not seem logical to keep insisting that humans are the only species that can think."

Ravens have complex relationships with other species and with their own kind. Easing my canoe onto the shore of a river island near Glacier National Park, Montana, I crawled through budding willow brush to get a closer view of a bald eagle feeding on a deer carcass. Four ravens circled down to join the feast. After a flurry of wary hops and screeches, the ravens appeared resigned to waiting their turn, giving their attention instead to the negotiations over status that take place almost continuously whenever ravens are together.

The dominant animals fluffed out feathers on their necks and their heads, which appeared

to sprout horns. Their legs transformed into pantaloons. Subordinates did the opposite, compressing their feathers to yield a sleeker, less threatening version of themselves. A few minutes into this posturing, one raven ambled up and tugged on one of the eagle's tail feathers. As soon as the larger bird turned to give chase, other ravens dashed in, alternately grabbing quick bites and distracting the eagle.

Ravens tweak the tails of coyotes and even wolves. The birds will follow wolf tracks or howls to locate a pack in hopes of sharing the spoils of a hunt. When they find a carcass on their own that's too tough to open, their loud calls may attract wolves that do the job. Like wolves, ravens cache extra bounty, digging holes with their stout beaks, dropping in a morsel, then covering over the spot to hide it.

While the raven's creative approach to obtaining nourishment is a key to its success, it led to a rapid decline during America's frontier days. As in the Old World, where a flock of ravens was called an "unkindness," people were quick to revile the birds as thieves of barnyard eggs and chicks, lamb killers, lovers of carrion—night-colored pests with an ominous croak. Settlers shot them on sight. Bounties encouraged the practice. Traps and poisons aimed at predators and rodents killed ravens as well. Before long, they were becoming scarce outside the backcountry.

Once lethal baits and persecution of wildlife were more strictly controlled, common ravens started to become common again. They are still missing from most of the Great Plains, where they vanished along with the bison. In the East they remain limited to scattered pairs along the high Appalachians and a modest population in New England's forests. But by taking advantage of both wilderness strongholds and rural settings with more human food sources than ever to exploit, ravens may enjoy higher numbers in some parts of the West and North today than they did during Indian times. One of the rewards of my raven-watching has simply been getting to know a species that is growing stronger, an all-too-rare trend in this age of vanishing wildlife.

Maybe it's not so surprising that ravens have found a way to flourish. After all, according to some native cultures of the Pacific Northwest and Siberia, Raven made the Earth, the heavens, and all living things. Great Inventor, they call him. Or Giant, Greedy One, Real Chief, He-With-the-Sun-in-His-Mouth.

"Raven is everything," Tony Hunt, a chief of the Kwagulth tribe, told me in Victoria on Canada's Vancouver Island. "For me Raven is a crest in my family lineage, which means he is an ancestor; he is a transformer who can turn himself into a hemlock needle; he is a trickster; or he is a human. We still relate to his power through our dances and songs."

Majestic elk becomes a cold buffet for a Yellowstone coyote and companions. Ravens will follow predators' tracks to a fresh kill. And carnivores can follow raven calls to a fallen animal, where the birds cautiously watch as a bite proves the creature truly dead and breaks its tough hide to ease feeding.

Street-smart in the wilderness, a hungry opportunist opens a snowmobile's storage compartment, making quick work of its Velcro-fastened flap. It extracted a crumpled map in its hunt for such favored items as cookies and potato chips. "Ravens adapt quickly to changing technology," says Yellowstone bird biologist Terry McEneaney. They can untie knots and unzip zippers, making off with car keys and other shiny objects. McEneaney's advice: Secure food and valuables with straps and strong buckles.

In part, tales of animals behaving as people and shifting forms with them recognize how much living things have in common, like varied faces emerging from the same totem pole. Perhaps research such as Bernd Heinrich's is a scientific way of seeing the human in the raven and the raven in the human.

When spring arrives, transmuting warmed dirt into bright petals, the mutual preening and bill touching that raven couples perform year-round grow more intense. Soon there are courtship displays on the wing. Both male and female bring in twigs and pass them to each other, working as a team to construct a stout nest. Where I watched, it was the female that wove the sticks into a final bowl shape and lined the result with grass, shredded bark, and tufts of animal fur.

Nests are generally in a tall tree or on a sheltered cliff ledge, though I've found a few in windmill towers and on the undersides of bridges, and one in the trunk of an abandoned car. They are often built atop nests from previous years, including those of raptors such as eagles, owls, and falcons. Raptors also use old raven nests, and there is sharp competition among these species for territories.

After laying a clutch of three to seven eggs, the female raven incubates them for three weeks while her partner ferries in nourishment. Six to seven weeks pass before the chicks can fly, and another several months pass before they separate from their parents. Young ravens succumb to accidents and to predators such as owls, foxes, raccoons—and other ravens. But their main enemy during this long rearing process is starvation, and the amount of food their parents have been able to cache during easier times may make the difference between survival and death.

At his house on the outskirts of Boise, Idaho, John Marzluff, then director of the Sustainable Ecosystems Institute, introduced me to a captive raven. The big male greeted me with a full dominance display. Ruffing his neck feathers and raising his horns, he bowed while showing the white membranes of his eyes and gave out a deep *kow* sound, followed by a snap of the heavy beak. I imitated this ceremony as best I could, then handed him some grass through the wire mesh as a kind of token offering. He merely set it aside. A moment later, though, he began wandering about the cage floor until he found a small

bone. Lifting it in his beak, he pushed his own gift out through the mesh to me. He did the same with a stone and a piece of bark.

When I asked John what the raven was up to, he replied, "I don't know. I've never seen one do that before." You hear those phrases a lot around raven experts. It is a good measure of how complex these birds are.

During our travels through the countryside near the Snake River Birds of Prey National Conservation Area, John pointed out pairs of ravens he recognized, explaining that they maintain their territories year-round. Ravens don't begin breeding until at least their second year. Immature birds often join wide-ranging flocks, together with adults that have not yet established territories. I followed one group to its nighttime roost on a transmission tower high above the sagebrush-scented plains. Other flocks kept arriving and wheeling round the tower like shards of the gathering night. Such roosts become centers for exchanging information on the whereabouts of food, since new members attracted to the throng can follow others to feeding areas in the morning. Strength in numbers gives them a better chance to get at food within territories already defended by adult pairs.

"Besides foraging in their natural habitat, they have the option of going to grainfields, livestock feedlots, and rendering plants," John explained. "These artificial food sources have boosted survival of the younger birds well above natural levels, and the population has grown fairly dense." He drew my attention to ravens flying directly along highways with their heads down, scanning the asphalt. The birds have learned that such surveys pay off in squashed jackrabbits and other unlucky wild pedestrians.

John's studies of raven feeding patterns, growth rates, and juvenile survival have proved crucial to efforts to salvage a close relative, the endangered Hawaiian crow. Would taking eggs from nests to hatch in the safety of captivity prompt parents to lay more? What is the best diet for hand-fed babies? With fewer than 35 Hawaiian crows left in the world, better to experiment with abundant Idaho ravens first.

Ravens are also thriving farther south in the Mojave Desert, and they too have a tie to an imperiled species, though the connection is of a very different kind. "Half a century ago ornithologists could scarcely find a raven here," Bill Boarman, a U.S. Geological Survey biologist, informed me as we traveled the drylands between towns spreading eastward from the Los Angeles–San Diego megalopolis. "The environment was too harsh to support more than a few, and there weren't many nesting sites in the low-growing desert scrub. Now the ravens have telephone poles and transmission towers all over to choose from. We're supplying them with water in sewage-treatment lagoons.

Who's afraid of the big bald eagle? Not this raven, nipping at a cutthroat trout snatched from an Idaho stream. Though repeatedly driven back, the smaller bird eventually made off with a sizable snack. One raven's squawk and flutter is sometimes distraction enough for another to steal the whole meal. Such is the raven, an uncannily bright bird that survives with wits and wiles as sharp as its beak.

Plus food from landfills and Dumpsters. And from almost everyplace our own messy species hangs out," he added, nodding toward a raven gleaning french fries from the parking lot of a fast-food restaurant.

Over the past quarter century ravens in the Mojave have increased at least tenfold. Meanwhile disease and human disturbances have pushed desert tortoises onto the threatened list. Walking beneath raven haunts, Bill and I examined pellets that ravens regurgitate after eating. Some held lizard bones, beetle wing covers, or scorpion remains. A couple contained candy wrappers. Others were full of small tortoise bones. Shells lay scattered nearby. Vulnerably soft for the first five to seven years of the tortoise's life, each shell had been pierced by a beak, then pried apart. These were raven kills, one more factor in the reptiles' decline.

Wildlife officials wanted to try killing large numbers of ravens to take some of the pressure off tortoises. Ironically, in light of the fact that people routinely obliterated the birds as vermin not long ago, a lawsuit was brought to stop the control program. Bill and his colleagues started casting about for a different solution. But first they needed a better picture of the birds' movements between human settings and more remote habitats.

Boom! The sound came not from a gun but from cannon firing a net over ravens at a sanitary landfill on Edwards Air Force Base in the western Mojave, where experimental aircraft test their wings. We caught 49 birds and spent the morning fitting them with yellow wing markers. Eighteen got miniature radio transmitters as well, but not before most of us had our hands purpled by pinches and bloodied by stabs from captives who fixed us steadily with their bright, unyielding gazes. Since several hundred ravens had been using the landfill regularly, we readied the cannon nets to trap more the next day. Few showed up. Not one went near our bait. The ravens, it seemed, had put out an alert.

Like us, ravens are too clever and adaptable for anyone to predict exactly what they're going to do next. I'm thinking of the one I saw in the desert town of Barstow, eating groceries from a brown paper sack in the back of a moving pickup truck. And I'm remembering a visit to a deep-space research facility in the Mojave where scientists once aimed radio telescopes out among the stars, searching for signs of intelligent life. When I went by, intelligent life in the form of loquacious, jet-black birds was nesting all over the dish-dotted site.

NATIVE AMERICANS have many stories about people talking to ravens in the forest. Such tales serve as reminders that the wonderfully varied calls of ravens in the wild convey information a hunter or even a casual hiker might do well to notice. After I learned to listen more carefully, ravens would tell me where elk were moving; the far-carrying *quorks* the birds make when something catches their interest tracked the herd long enough for me to catch up. And once the high-pitched yells of ravens approaching food they hoped to enjoy warned me of a grizzly guarding a carcass not far away.

Several people have told me of being startled when a raven alighted nearby and spoke to them in human phrases. Hmmm. All right: Ravens, like parrots, will learn to mimic our speech, much as they mimic other birds, music boxes, train whistles, and the jingle of ice-cream trucks. In all probability these folks encountered ravens that were raised as pets—they especially like to watch television, owners told me—scavenged some words from the household, and subsequently got loose.

As Mark Pavelka, who studied ravens for the U.S. Fish and Wildlife Service, said, "With other animals you can usually throw out 90 percent of the stories you hear about them as exaggerations. With ravens it's the opposite. No matter how strange or amazing the story, the chances are pretty good that at least some raven somewhere actually did that." □

Carefree for the moment, children in Santa Catalina Cuilotepec may have to flee for their lives someday along with tens of thousands of others in a 660-square-mile area. The nearby volcano, stirring after more than half a century of quiet, could soon erupt on a scale not seen for a thousand years in the fertile heart of Mexico.

Popocatépetl

Mexico's smoking mountain

A SERIOUS THREAT

One of the world's tallest active volcanoes at 17,802 feet, El Popo is also among the most dangerous. It now expels occasional clouds of hot gases, rocks, and ash, but is capable of much larger eruptions whose suffocating fallout can mix with rain and glacial meltwater to form lethal mudflows.

By A. R. WILLIAMS
NATIONAL GEOGRAPHIC SENIOR STAFF

Photographs by SARAH LEEN

EVEN THE ARMY WAS LOST. Perched in the open back of a transport truck, four helmeted soldiers from the Sixth Armored Reconnaissance Regiment of the Mexican Army were peering at a map. With them were three officials from the little town of Santa Catalina Cuilotepec in the state of Puebla. The empty gravel road that forked in front of them had no sign, and there was no one in sight to ask for directions. Hot, tired, and thirsty after an hour of jouncing along at almost a pedestrian's pace in the midday sun, the men shrugged in frustration.

"This worries me," said Sósimo Parada Guarneros, the mayor of Cuilotepec, who was following the lost men with me in a van. "I've never been here before, so I don't know where we are. We need an arrow to show us the way." Don Sósimo, a man of few words and infinite patience, concentrated on the details of the landscape. "I'm going to have to go over this route several times so I remember it well." The truck ahead started up again and turned to the right, where the road looked slightly better. We were close behind.

The mayor was worried for good reason. This was a reconnaissance trip, but someday he might have to lead his 400 townspeople to safety in a desperate hurry: Cuilotepec, a community of subsistence farmers who cultivate the age-old crops of corn, beans, and chilies, is just seven miles from the crater of steaming, quaking Popocatépetl—at 17,802 feet one of the tallest active volcanoes in the world.

In 1993, after almost 70 years of calm, Popocatépetl began to stir, emitting gases, shaking the earth, and reaffirming its Aztec name, "smoking mountain." At Christmastime in 1994 small explosions in the crater prompted a chaotic temporary evacuation of 25,000 people from the most vulnerable villages. Since then El Popo, as Mexicans affectionately call the mountain, has intermittently thrown clouds of ash thousands of feet into the air and incandescent rocks onto the steep upper slopes of its bare cone.

No one knows if the activity will escalate, but a cataclysmic eruption is possible. Every thousand years or so Popocatépetl lets go with a tremendous blast of hot ash and rock whose fallout blankets its slopes as well as those of Iztaccihuatl, a dormant volcano ten miles to the north. Rain and meltwater from two sizable glaciers on El Popo's north side form mudflows, called lahars, that race down ravines, churning up everything in their path. The last great eruption of Popocatépetl—determined through radiocarbon dating of charred trees—occurred about A.D. 820. Farmers already lived here then, drawn by the rich soil, the crop-ripening sunshine, the reliable rains.

An eruption today would affect many more lives than those shattered by that blast. About 20 million people live within 50 miles

Plowed up near the farming village of San Gregorio Zacapechpan, the clay head of a figurine likely used in domestic pagan rituals was swept along by a mudflow after the last large eruption about A.D. 820. Matching the newly threatening mood of the volcano, a painted figure recalling the time of the Spanish Inquisition rattles his chain during the Catholic pageant of Carnival in San Nicolás de los Ranchos.

of Popocatépetl, and many of those—including the residents of Mexico City—have already been showered with ash. Hundreds of thousands in the city of Puebla, 28 miles east of the volcano, and in nearby towns could face devastating mudflows such as the one that surged down Colombia's Nevado del Ruiz volcano in 1985, killing 23,000. The most vulnerable, though, are the roughly 100,000 people in villages, like Cuilotepec, at the very foot of the volcano. They are likely targets of mudflows as well as showers of rocks as big as footballs and roiling clouds of hot gases and ash.

With any luck people will have enough warning to escape. The National Disaster Prevention Center, or CENAPRED, a branch of the federal government, monitors Popocatépetl constantly. "Every volcano works in a different way," explains Carlos Valdés González, a seismologist at the National University in Mexico City and adviser to CENAPRED. "What we're trying to learn here are the symptoms signaling that El Popo will erupt." These include earthquakes, changes in gas emissions, and any bulging of the mountain's surface. Even with that knowledge, the experts could be surprised: Volcanoes are unpredictable.

SARAH LEEN's photographs appear regularly in the magazine. Her most recent assignment was "Amelia Earhart" in the January 1998 issue.

In the tradition of Mexican murals, a simple map shows the official evacuation route for San Nicolás de los Ranchos. Villagers periodically rehearse assembling here at the town square. If the alarm ever sounds, private trucks and cars and public buses will pick them up to take them to safety.

THE MAYOR AND OFFICIALS of Cuilotepec have come to understand the importance of readiness. They have counted up the vehicles owned by town residents—25 farm trucks and a dozen cars—and assigned a list of passengers to each. "That's enough to get everyone out of town," figures Don Sósimo. The townspeople have also practiced the first stage of an evacuation: getting themselves and their vehicles to the town square at the sound of an alarm over the loudspeakers at city hall. That takes half an hour. In 15 more minutes the vehicles could be loaded and on their way.

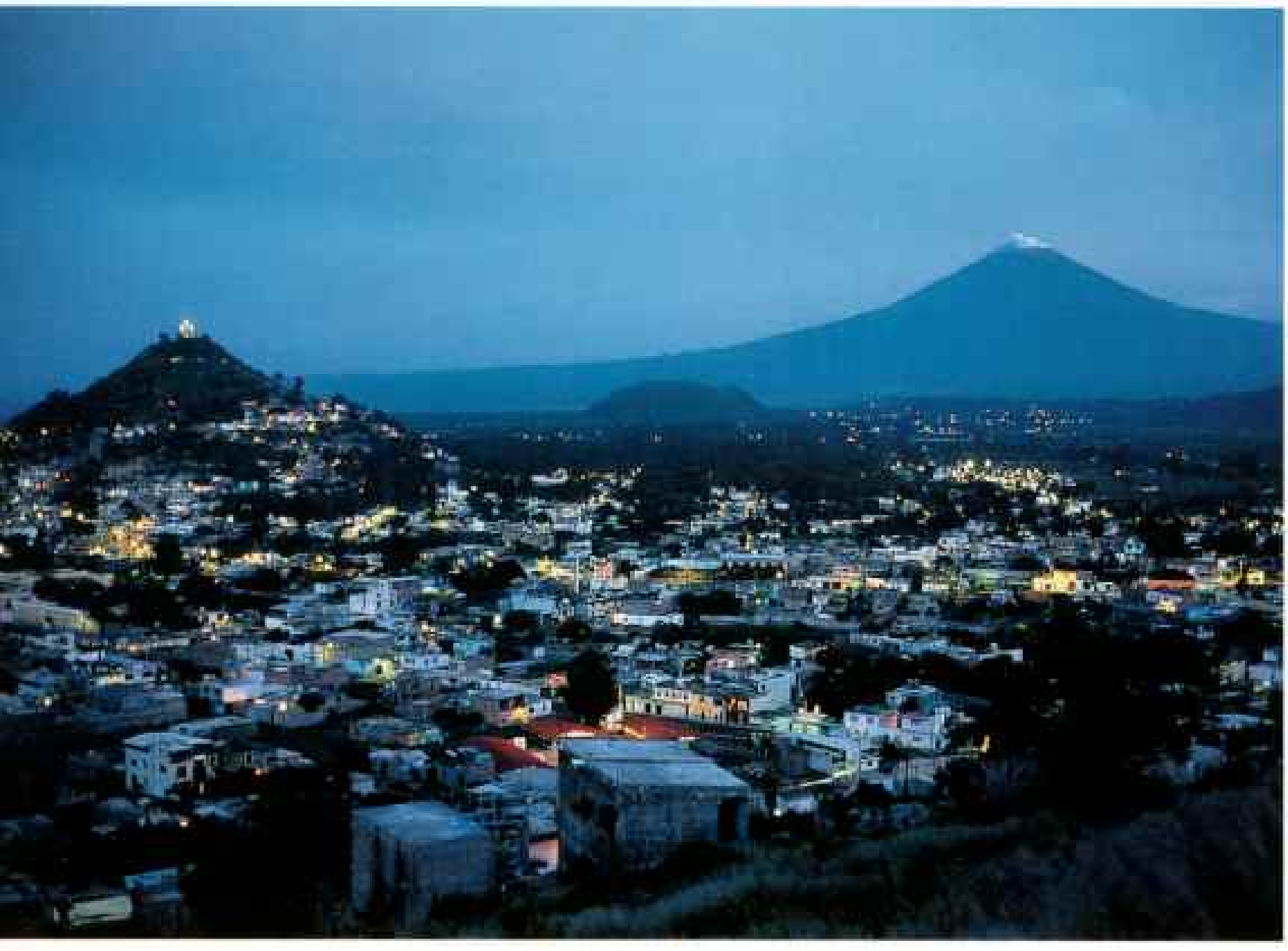
But as our experimental drive with the soldiers showed, confusion about directions could take precious minutes during a real evacuation. The decision to take the right fork was a mistake—we came to a bridge that was under construction and had no choice but to double back. Only after three hours on a tangle of spine-jolting trails did we reach Izúcar de Matamoros 30 miles to the southeast—Cuilotepec's designated haven in the event of a moderate eruption. I wondered what it would be like making a frenzied getaway with no guarantee of backup transport from the army, whose soldiers and trucks would be spread thin.

"By the time we got here we'd just about be dead of fright," said Vicente Ávila Graciano, head of Cuilotepec's farming commission and one of the three officials in the truck. "Besides, we can't afford to keep our vehicles in top shape. What if one breaks down? That would hold everyone up. And I didn't see a gas station along the way either."

"We're far from having everything in terrific shape," admits Alejandro Rivera Dominguez, one of the founders of the Center for the Prevention of Regional Disasters, or CUPREDER, at the University of Puebla. "In a few years you can't expect to fix everything that's been sitting here for centuries."

Along with logistics, teaching villagers rudimentary geology is a priority for Ramón Peña Melche, who as head of the state of Puebla's evacuation planning works with CUPREDER. "People have to know what the volcano can do to them," he said. "We've gone from village to village showing videos of eruptions. Now we're asking them to get organized and make a serious effort to save their own lives."

To that end Belinca González Fernández, a 20-year-old physics student, volunteered to work in Magdalena Yancuitlalpan, a community of a few thousand souls eight miles from the crater. She started with the basics: taking a census of residents and their vehicles. On the day I accompanied her, construction workers were laying bricks for a new school wing and setting



the foundation for a stone gate in front of the church—signs people were planning to stay.

"It's been difficult to convince them of the danger," Belinca said. "And hardly any of them want to take responsibility for doing things to help themselves."

The mayor, Máximo Aspiro Alonso, at least was willing to try. He and Belinca faced each other across his wooden desk and discussed the census results. His straw hat hung on a nail in the wall next to a government poster asking parents to protect their children by participating in evacuation plans.

"We have 131 vehicles," he began.

"Do they all have drivers?"

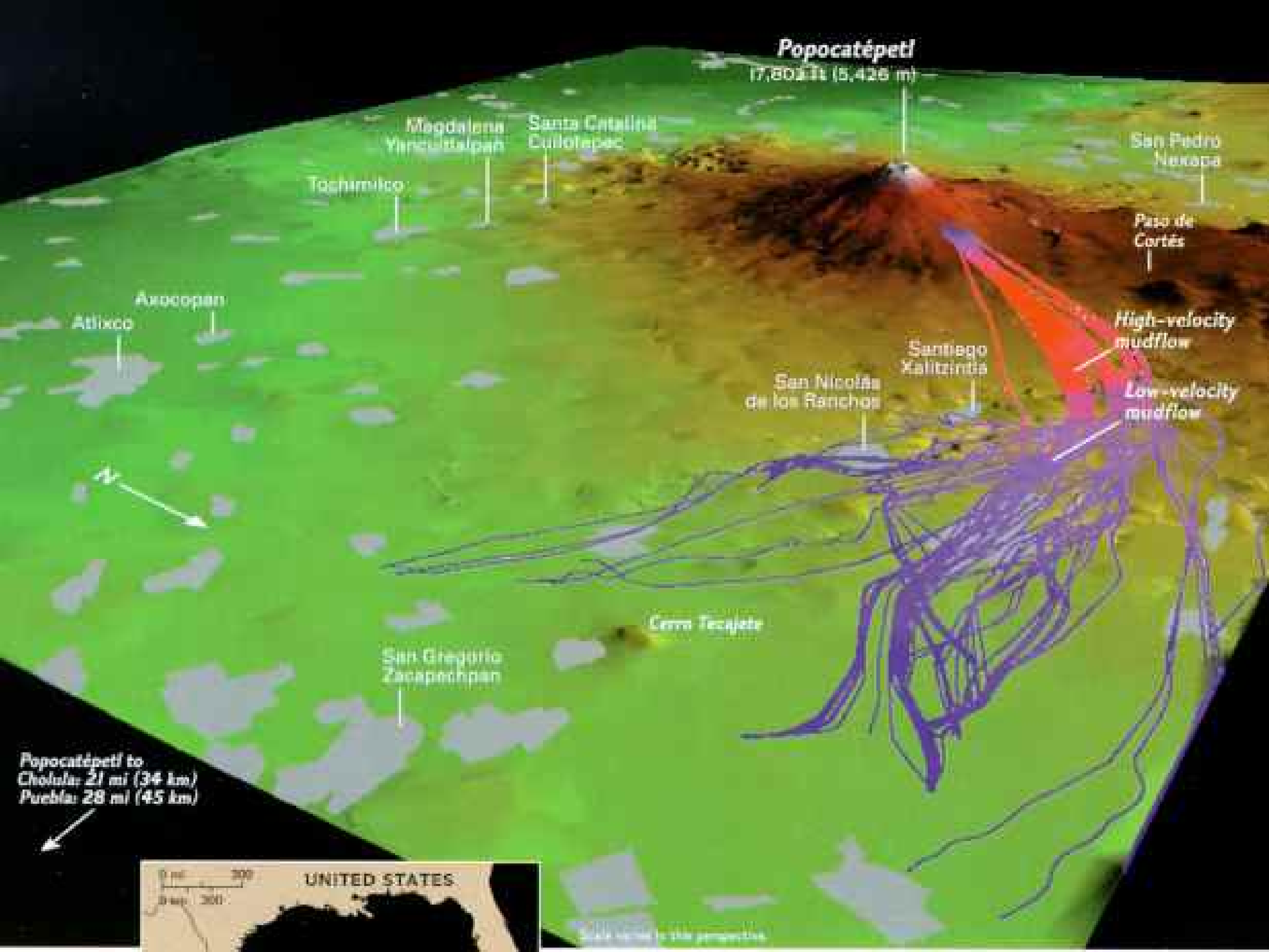
"No, some owners have more than one truck."

"Well, we have to find drivers for the extra trucks," said Belinca, pressing the point. But the mayor hadn't had to grapple with this kind of problem before. He just changed the subject, talking instead about whether the one-lane bridge at the town's entrance would support a convoy of heavily loaded trucks. Belinca promised to report his concerns to CUPREDER officials, and we left.

"It's another culture, a whole different way of looking at life," she said afterward, as we walked past houses of adobe and brick on a dirt lane that smelled of cattle and wood fires and tortillas cooking on the griddle. "You have to have a lot of patience."

MAKING THE PHYSICAL arrangements to get people out of threatened villages is one thing, but convincing people with little formal education, whose lives unfold with the cycles of nature, that they have some control over their destiny is quite another.

"Because we have fewer resources, there's a limitation in the way people approach things here," says Alejandra López García of CUPREDER, who directs workshops on risk management. "Four weeks after a hurricane, Florida is on its feet, and Yucatán isn't even close. We have to get people to understand that they can do things to lessen the impact of a disaster, that the volcano isn't some kind of



NATIONAL GEOGRAPHIC MAPS; DIGITAL TERRAIN MODEL BY MICHAEL SHERIDAN, STATE UNIVERSITY OF NEW YORK AT BUFFALO

Risk Assessment

"People will always be willing to take a chance and live on the volcano, but they should know what the possibilities are," says volcanologist Michael Sheridan, head of a State University of New York at Buffalo team that created a computer program for mapping the paths of future mudflows (top). Even a small eruption that melted El Popo's glaciers would have a catastrophic impact in and around Santiago Xalitzintla. Rains after a heavy ashfall could put the city of Atlixco (facing page) in jeopardy.

biblical penance they have to suffer through."

In the conservative Mexican countryside, beliefs are guided by the local Catholic priest. Towns take easily to evacuation planning if the priest supports it, but often the church is dead set against the whole idea.

"I'm not convinced of the risk, so how can I convince people of the need to evacuate?" asks José María Parra Aguirre, the priest in Yancuitlalpan. "Whatever happens comes from God, and I have faith everything will work out."

That exasperates Peña Melche, the disaster official. "I always tell people, 'God helps those who help themselves,'" he says. "But they don't always want to take my advice."

After talking with the townspeople of Yancuitlalpan, I began to understand why: Faith and fatalism are rooted in the realities of surviving on the land. One afternoon I spent some time with a group of women who had assembled at city hall for a public health meeting. They were strong campesinas with long black braids wrapped around their heads, frilly blouses, full skirts, and dusty huaraches.

DOWN TO EARTH

A nasty spill is no big deal at a rodeo in Magdalena Yancuitlalpan. The rigors of rural life have fostered a culture of toughing out adversity—even eruptions. Says one local farmer: "We won't leave unless it gets really bad. What's a little ash?"

Cobbled with volcanic stones in the 16th century, the streets of Tochimilco are exceptions to the rough village roads that would slow traffic in an evacuation. Hoping for enough warning to let people escape, engineers from CENAPRED, the National Disaster Prevention Center, watch for ominous changes in El Popo's shape. They anchor equipment high on the north slope (below), facing the sleeping volcano Iztaccihuatl.

Babies slept in the shawls slung over their shoulders, and toddlers crowded around them.

"Once we were weeding our cornfield, a two-hour walk from here," one of the women said. "We saw a huge ash cloud, and hot rocks rolled down the side of the volcano. But what could we do? How would we get out of there on foot with all our children? We crossed ourselves and prayed as we worked and left our fate in God's hands." High above Yancuitlalpan, they were a couple of miles from the crater—out of immediate danger but still close enough to be terrified.

During the 1994 evacuation, some people in Yancuitlalpan refused to leave. Pedro Morelos Molina, grizzled and sun-beaten at 69, was one. "I told the person in charge, 'Thanks just the same, but I think I'll stay.' I had to take care of my horses and pigs and chickens. Here I can support my family, but what would we do far away in a shelter? It takes money to go off navigating like that, and I don't have a hundred pesos in my pocket."

DON PEDRO WAS HEADING up the volcano to check on his crops, and I went with him. Faint strains of ranchera music from a radio followed us as we hiked along a rocky, switchbacking path. We talked of farming, his family, and the risk he ran by staying put when the authorities told him to go. "We all have to die," he said. "Here or there, no matter where we are. So why leave?"

We turned to cut across fields of golden, furrowed soil ready for planting. Bordering them were avocado, peach, and apple trees, and prickly pear cactuses with their flat green pads. "The treasures of the volcano are the crops it gives us," Don Pedro said. Anyone who farms near a volcano would agree, for the world's richest soils are volcanic. They produce bananas and coffee in Central America, sugar in the Caribbean, pineapples in Hawaii, rice in Indonesia. People have always been willing to risk an eruption for such bounty.

Stepping carefully between neat rows of spinach-like seedlings, I asked Don Pedro what they were. "That's amaranth," he said. The answer stopped me in my tracks. Amaranth, which bears a sorghum-like seed head when mature, was sacred to the Aztec and intimately connected to their worship of the volcanoes around them. Mountains such as Popocatépetl and Iztaccihuatl, by catching clouds heavy with water, were gods that brought rain. Every year people made offerings to the peaks to ensure adequate rainfall, and at the end of each ceremony they ate figurines that symbolized gods: miniature volcanoes made of amaranth and corn flour, with squash seeds for teeth and dried beans for eyes.

The Spanish tried to eradicate amaranth, along with other symbols of pagan culture. But amaranth survived, and today many who live

near Popocatépetl and Iztaccíhuatl continue to think of the peaks in ways that echo their pre-Hispanic heritage.

"El Popo is the second god," Don Pedro's wife, Gerónima, told me when we were watering her kitchen garden during a dry spell. "He decides when it will rain and when it won't."

According to the old beliefs, a volcano can be a god, a mountain, and a human all at the same time. People often speak of El Popo as being angry when he erupts. They call him Don Gregorio, using the male title of respectful familiarity, and pair him with Iztaccíhuatl, his female counterpart, known as Doña Rosita. Together they are seen as a fertile couple that give the gift of life.

"The volcano is a living being," explained Miguel Tapia Contreras, a retired farmer in a town not far from Yancuitlalpan. "He has to breathe, so he's unclogging himself right now. He's been good to us. He gives us food and something to drink. How am I to believe after all these years that he could explode?"

THE LANGUAGE of the Aztec, Nahuatl, provides proof of Popocatépetl's capacity to explode. An early name, Xaliquéhuac, or "sandy mound," was changed to Popocatépetl, "smoking mountain."

"If you know Nahuatl, the present-day map is a clue to the geologic history," said Claus Siebe, a geologist at the National University. "The name Xalitzintla translates as 'at the foot of the sand-like ash.' Nexapa is 'ash flow.' Those names mean that people experienced those things."

Siebe has been developing a chronology of Popocatépetl's large eruptions. "The better you understand what the volcano has done, the better you can extrapolate what might happen in the future," he said, as we started on a trip to examine some of the clues he has uncovered.

On the Paso de Cortés, the pine-shaded road cut into the valley between La Izta and El Popo, Siebe showed me the successive layers of pumice and ash that fell to the ground after the last three big blowouts: 5,000 years ago, 2,150 years ago, and nearly 1,200 years ago. "Pompeii was buried under deposits like these," he said, pointing to a layer of pinkish pumice a foot thick. It was the fallout from a column of hot gases and debris that must have risen tens of thousands of feet into the air and then collapsed in a dense, searing shower. "This is the death zone. Nothing would have survived."

Twenty miles to the northeast, near the ruins of Xochitécatl, we climbed the stone stairs to the top of a pyramid at least a thousand years old and looked out over an expanse of tilled fields toward Popocatépetl and Iztaccíhuatl. "This entire plain is meters thick with lahar deposits. On top of them Puebla is built, Cholula is built, Atlixco is built," Siebe said, naming the area's big urban centers. "And that's not even talking about the smaller towns."

He explained that lahars from the last great blast swept dwellings from their foundations and enveloped everything in them. When we stopped at places where the deposits had been cut—for roads, fields, the Puebla airport—we invariably found artifacts. Obsidian blades and pieces of ceramics were almost as plentiful as pebbles in concrete. In one place we found an arm and part of the torso of a clay figurine; in another adobe bricks were tumbled end over end at odd angles.

"There is not a single reason to believe that something like that will not happen again," Siebe said. "The question is when. We're well into the margin between eruptions, and the more time that goes by, the more probability there is that it will occur."

Most likely, judging from the volcano's behavior in the 1920s, El Popo will continue to throw out ash and rocks occasionally for several years and then become quiet again. But the possibility of disaster occurring on a grand scale in our lifetime cannot be discounted.

It's hard to imagine what that might mean for the city of Puebla. Each morning as I walked from my hotel along the cobbled streets in the colonial heart of the city, I tried to think of this handsome, comfortable place as impermanent. I knew that, in the very worst case, its gold-crowned stone churches, its stuccoed town houses trimmed with Spanish-style tiles and iron grillwork, its shaded parks with flagstones worn shiny by centuries of footsteps

As good as gold, corn grown near Axocopan means prosperity to the family of Rosa Elena Pérez Victor and her brother Alan Leonardo. Bounty from the rich volcanic soil has kept countless generations of farmers here, even in the face of danger.

INSPIRING SITES

"We call the volcano Zencapopoca now. That's 'always smoking' in Nahuatl," says a man in Cholula, using the Aztec language still spoken locally. The town's pre-Hispanic pyramid, crowned today by a church, may have been built in reverence to El Popo; its ancient name, Tlachihualtépetl, means "man-made mountain."

could fall to Popocatépetl. But everything around me seemed so solid.

Perhaps that's part of what keeps people from leaving places when evacuation orders come. The magnitude of nature's capacity for destruction may be beyond our ability to accept it. "We're told the stones won't reach here," said Maricarmen García Sánchez, who was knitting a yellow sweater for a grandchild as she minded her family's music store on a crowded pedestrian street. Puebla has gotten showered with ash often enough that keeping it off CDs and tapes is part of doing business. "We're not totally convinced though. If ash can reach Mexico City, what could happen here?"

Officials have not even begun to think about the possibility of having to prepare hundreds of thousands of people in and around Puebla to move to safety if and when lahars threaten the city. Mexico and the state of Puebla just don't have the resources to carry out detailed, on-the-ground disaster planning for that many people. "With the fall of the price of oil, the federal government has less to pass around, and so we get less," explains Aurelio Fernández Fuentes, director of CUPREDER. In the struggling Mexican economy, available resources are stretched to the limit by the task of getting the most vulnerable villages ready in case El Popo turns bad.

ONE OF THOSE VILLAGES is Santiago Xalitzintla, a farming community of several thousand about seven miles from the volcano's crater, where people still barter goods rather than buy what they need. Xalitzintla stretches along a barranca partially choked with mud and rocks that have been washing down from the slopes of El Popo.

If the volcano's activity intensifies, a large lahar could destroy the town in 20 minutes. Officials keep watch day and night for any sudden change, and the townspeople keep listening for the church bell that will signal an

From time out of mind people have worshiped El Popo as a god who catches clouds and sends down the rain vital to their crops. The cycle of ceremonies begins in March before the season of planting. Carrying food and gifts for the volcano, supplicants hike to a rocky outcrop—the Ombligo, or "belly button"—near the crater. There the rainmaker, Antonio Analco Sevilla (below, at far left), leads a Catholic prayer at an altar laden with offerings.

evacuation. Meanwhile the debris in the barranca edges ever closer.

As I picked my way between boulders stuck in the mire, I saw one abandoned house with mud halfway up its walls. A woman with long gray braids, who was bent under a load of grass for her livestock, paused to talk. Her house, a rough structure of adobe and stones, stood just beyond a ragged patch of corn. "A flood brought all these stones and took away my garden," she said, gesturing toward the surviving plants. "I heard the stones crashing together. They made a terrible noise. I'm sick with worry," she said, before shuffling on.

Although Antonio Analco Sevilla lives just a few blocks from the barranca, he isn't worried. "When our Father, God, tells Don Gregorio what's going to happen, Don Gregorio will let me know," he explained. "I'm in direct contact with him."

Don Antonio is a *tiempero*, a rainmaker, who is believed to have a mystical relationship with El Popo. Ever since he was a boy, he has seen the volcano in human form in his dreams at night and as an apparition during the day. He speaks to it and listens to its replies. "I won't tell you how we communicate," he said. "If I keep his secrets, he'll keep mine."

Keeping agricultural traditions that go back as far as anyone can remember, Don Antonio and his followers perform a cycle of ceremonies every year, in which they ask the volcano and God to look after the land: March 12 on El Popo they prepare for planting; May 2 on El Popo and May 3 on La Izta they ask for rain for the seedlings; June 13 they bring newly blessed crosses to each volcano; August 30 on La Izta they petition for a good harvest.

"We do these ceremonies without fail," said Don Antonio's wife, Inés. "If we didn't, we wouldn't get enough water for our crops."

Anyone interested is welcome to join in, and so last March 12, when farmers were starting to till their fields with horse and plow, I climbed

Popocatépetl to a sacred place within a mile of the crater. We were a group of about 50, mostly lay officers of Xalitzintla's church, their wives, and other villagers. Officials from CUPREDER, the doctor from the government clinic, a few scientists, and local journalists came too. They know that if they want the villagers to accept their ideas about things like evacuation planning and inoculations, they've got to be willing to accept some of the villagers' ideas as well. There's a mystical dimension too: Many of these people speak of the spiritual power they've felt at the ceremonies almost as if describing an electrical current.

Early in the morning trucks and vans took us up a logging road to a dense, enveloping pine forest where, at about 10,000 feet, we began our ascent. At that altitude hiking over knife-edged ridges covered in slippery needles had me gasping. The day was sunny, and I began to sweat under the layers of clothing I'd been advised to wear for the colder temperatures near the top.

The climb got worse when we came to a stretch of loose black sand, which gave way at every step—the StairMaster from hell. Clumps of dun-colored grass and dried prickly flowers called *rosas de las nieves*, or roses of the snows, were soon followed by an even steeper slope of shifting sand. This led to our destination: a

huge rounded rock outcrop called the Ombligo, or "belly button," protruding from the smooth sandy side of Don Gregorio.

Even fully loaded with ceremonial gear, the villagers made the mile or so trek in an hour. In that thin air it took me three, and I had to be hoisted the last few yards by my elbows. I joined the others, who were sitting around a fire drinking coffee and tequila.

Don Antonio's assistants, the church officers, attended to preparations in a cave-like hollow in the Ombligo, tying flowers onto wooden crosses and spreading a flowered cloth in front as an altar. A small band struck up several rounds of the Mexican birthday song, *Las Mañanitas* (Early Mornings), on a guitar, a trumpet, and a harmonica, and everyone sang along. Above us wisps of cloud skittered over the top of El Popo—silent that day.

Soon after the last climber had arrived, everyone gathered by the makeshift altar. As the Aztec did long ago, Don Antonio knelt and lit the sacred resin called copal, whose sweet smoke purified the air. He offered up traditional foods to nourish the volcano—a baked turkey, fresh fruit, a bowl of rice, a basket of blue-corn tortillas, and a bottle of brandy. He presented a white shirt and a necklace to adorn the volcano. Finally he began whispering incantations that only he and Don Gregorio could hear and understand.

Firecrackers set off by several young boys signaled the start of a picnic lunch. A cold wind whipped in, turning everyone's breath to vapor. As Don Antonio played his harmonica, first-time participants in the ceremony began a skipping dance in which they braided long colored ribbons around the maypole that his father, also a tiempero, had used in past ceremonies. Don Antonio's assistants shook bottles of beer and sprayed the liquid, a symbol of fertility, over the laughing crowd. At 4:30 a solemn recitation of the Lord's Prayer by all brought the ceremony to a close.

As I turned to leave, I saw people scooping sand into bottles and remembered what Julio Glockner Rossainz, an anthropologist at the University of Puebla who has spent years studying the tiemperos, had told me that morning when we set off: "Be sure to take some of the sand with you to sprinkle on your garden. Don Antonio says it's very powerful and makes plants grow like crazy."

I had nothing to put sand in and hadn't the energy to carry it anyway, so I started down without it. But as I took great sliding steps, my shoes filled with sand. Back in Puebla I tipped the sand into a plastic bag and saved it for my spring planting—just in case. □

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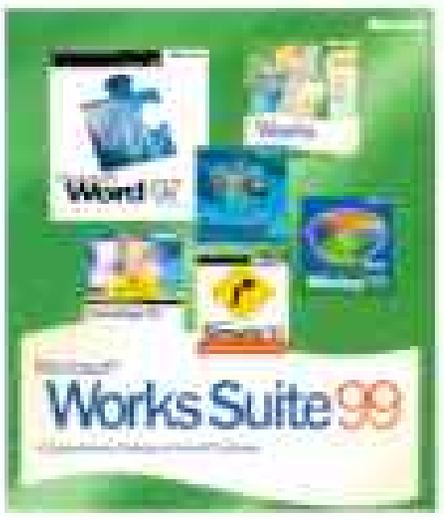

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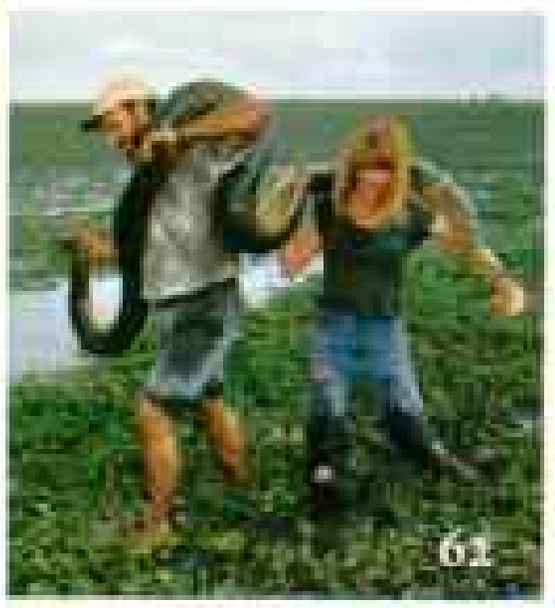

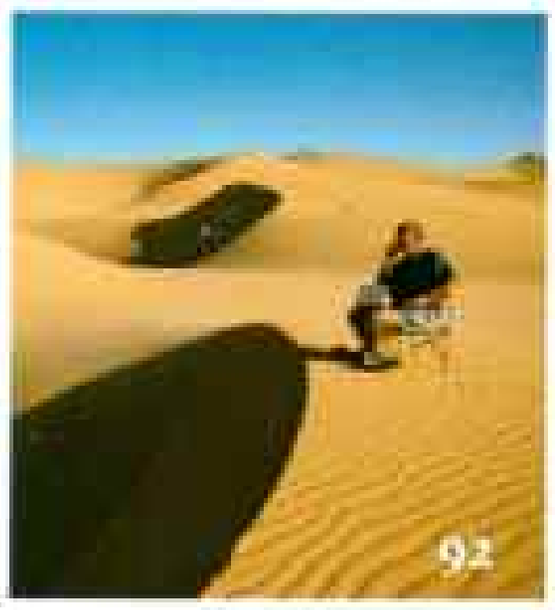

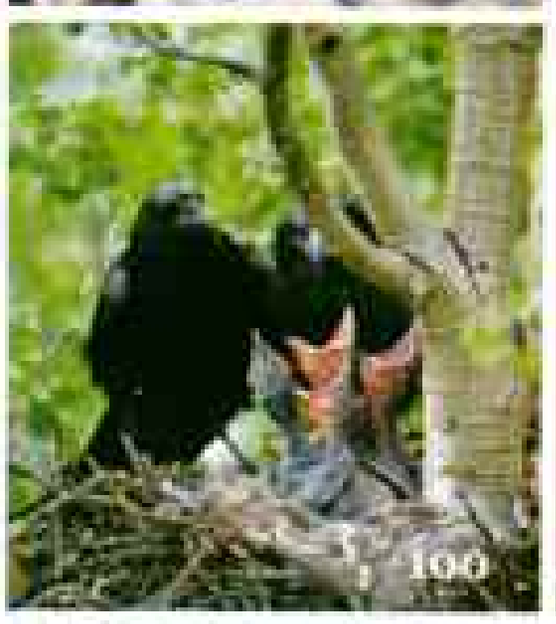

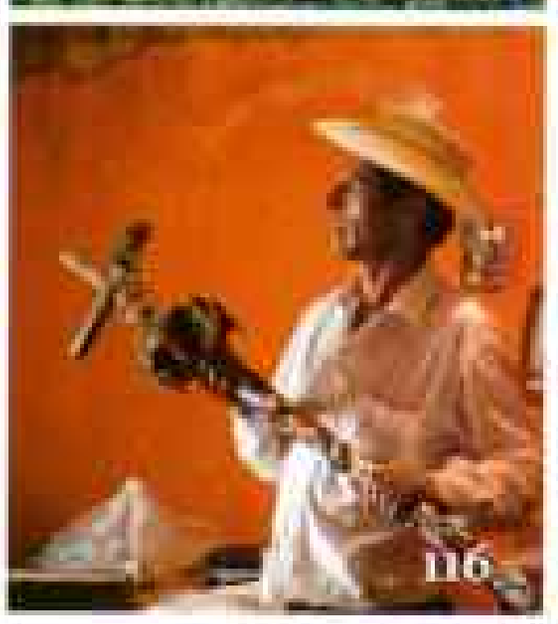

The Cover

On a coral reef near Papua New Guinea's Milne Bay a goby finds food and shelter on the mantle of a giant clam. Photograph by David Doubilet

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Breaking News

■ NGS RESEARCH GRANT

Earliest Evidence of Modern Behavior

As a boy Christopher Henshilwood explored his family's farm on the southern coast of South Africa. Now, in the farm's Blombos Cave (above), the University of Cape Town archaeologist and his colleague Judith Sealy have found evidence that humans living there 80,000 to 95,000 years ago behaved in ways that experts term modern—more than 40,000 years earlier than at any known site in Europe.

Anatomically modern humans had already left their mark in South Africa, in 117,000-year-old footprints found on the west coast (GEOGRAPHIC, September 1997). But the people of Blombos Cave made a variety of standardized bone tools (right, at left) as well as sophisticated pressure-flaked points, at top, from stone brought from more than 25 miles away. They drilled ocher—two pieces appear at bottom right—an earthy pigment possibly used ritualistically to decorate faces or bodies. The cave also held perhaps the world's earliest evidence of catching large fish: their vertebrae flank the bone point at center. Henshilwood thinks that fish were lured with bait and then speared with points tied to wood shafts.

TEXT BY BORIS WEINTRAUB

BOTH BY KENNETH GARRETT

In Ms. Williger's Class, It's Not Just The Seeds That Have Grown.

Like all teachers, Karen Williger plants the seeds of knowledge and understanding in the minds of the young. Except that in this case, it's actually her students who are planting seeds and who are beginning to bloom because of it.

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For helping her students find new ways to achieve personal growth, State Farm is proud to present Karen Williger of the John Ehret High School, in Gretna, Louisiana with our Good Neighbor Award and to donate $5,000 to the school's horticulture program.

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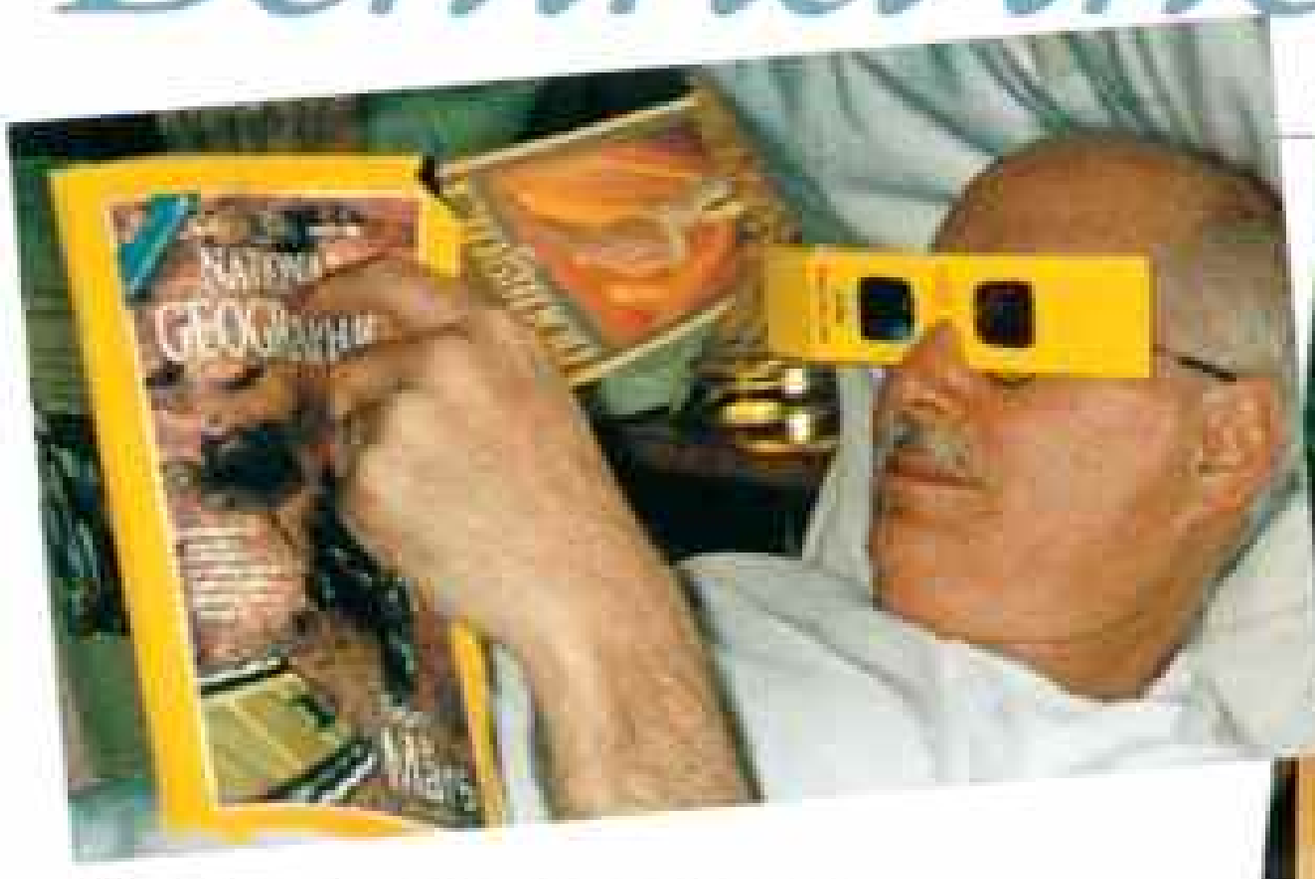
Behind the Scenes



Our Spectacles Spectacular

The Society's board (below) had fun with the GEOGRAPHIC's August 1998 issue, which paired 3-D coverage of the Mars probe and *Titanic* with special glasses to make the pictures leap to life. Our mail shows that the specs also enlivened our members: "We amazed and impressed our friends, awed our neighbors, and entertained and educated ourselves," wrote Jessica Franz of Oregon, who enclosed a shot of her sisters Madeleine and Emma (right). Una Ames (top right), 91, of Maine was similarly entertained, but Marylander Jonathan Austrian sent a complaint along with a photo (top) of his father, Mark: "Thanks for turning my dad into a dork!"

CLOCKWISE FROM TOP LEFT: JONATHAN AUSTRIAN; SHANA DRESSLER; JESSICA M. FRANZ; NATIONAL GEOGRAPHIC PHOTOGRAPHER MARK THISSEN

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Boning Up on Birds

The 120-million-year-old Chinese "dinosaur-bird" fossils identified by Society grantee Philip Currie (July 1998 GEOGRAPHIC) were such a hot topic that we took the wraps off them during a recent Explorers Hall exhibit. Dozens of scientists, including John Ostrom, Yale professor emeritus (left), examined the newly discovered fossils. Says Dr. Ostrom, who in the 1970s had revived a 19th-century theory of a link between dinosaurs and birds, "These specimens are the most exciting evidence yet about the reality of the evolutionary process." The exhibit is now touring the U. S. and Canada.

High Hopes

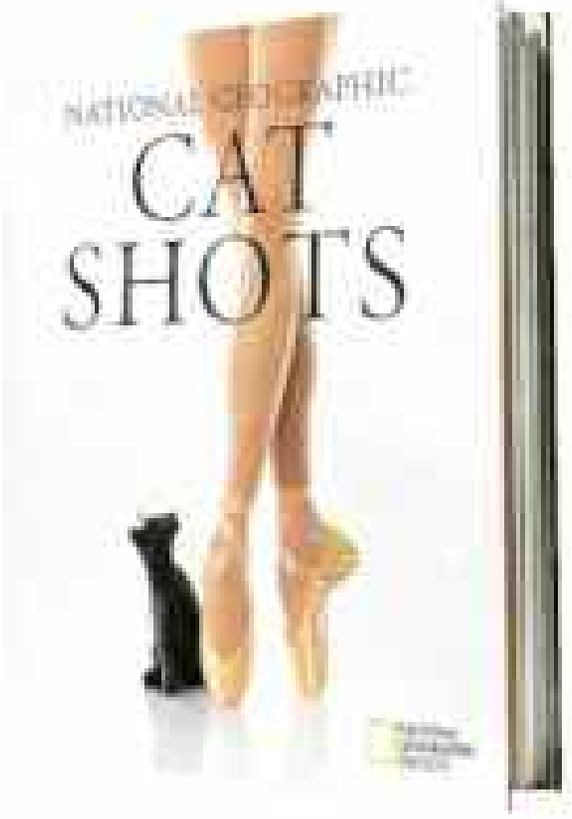
He's tinkered with electronics since he was a kid, and he's still at it, as an NGS systems engineer. But away from the office Barrett Foster's skills have landed him and his colleagues in the record books. Their model club's plane (right) set a 700-mile flight record last year. This fall they plan to set another: a satellite-navigated flight from Newfoundland to Ireland, with a tracking system Barrett designed.

MICHAEL LUTZKY

All the Mews Fit to Print

While working on the GEOGRAPHIC's June 1997 cat story, Illustrations Editor Kathy Moran and Rob Henry, marketing manager of the Image Collection, noticed that a lot of felines had padded their way into the magazine over the years—from all corners of the globe. Kathy and Rob liked what they found so much, they helped make a book of it: *Cat Shots*, now available in stores.

TEXT BY MAGGIE ZACKOWITZ



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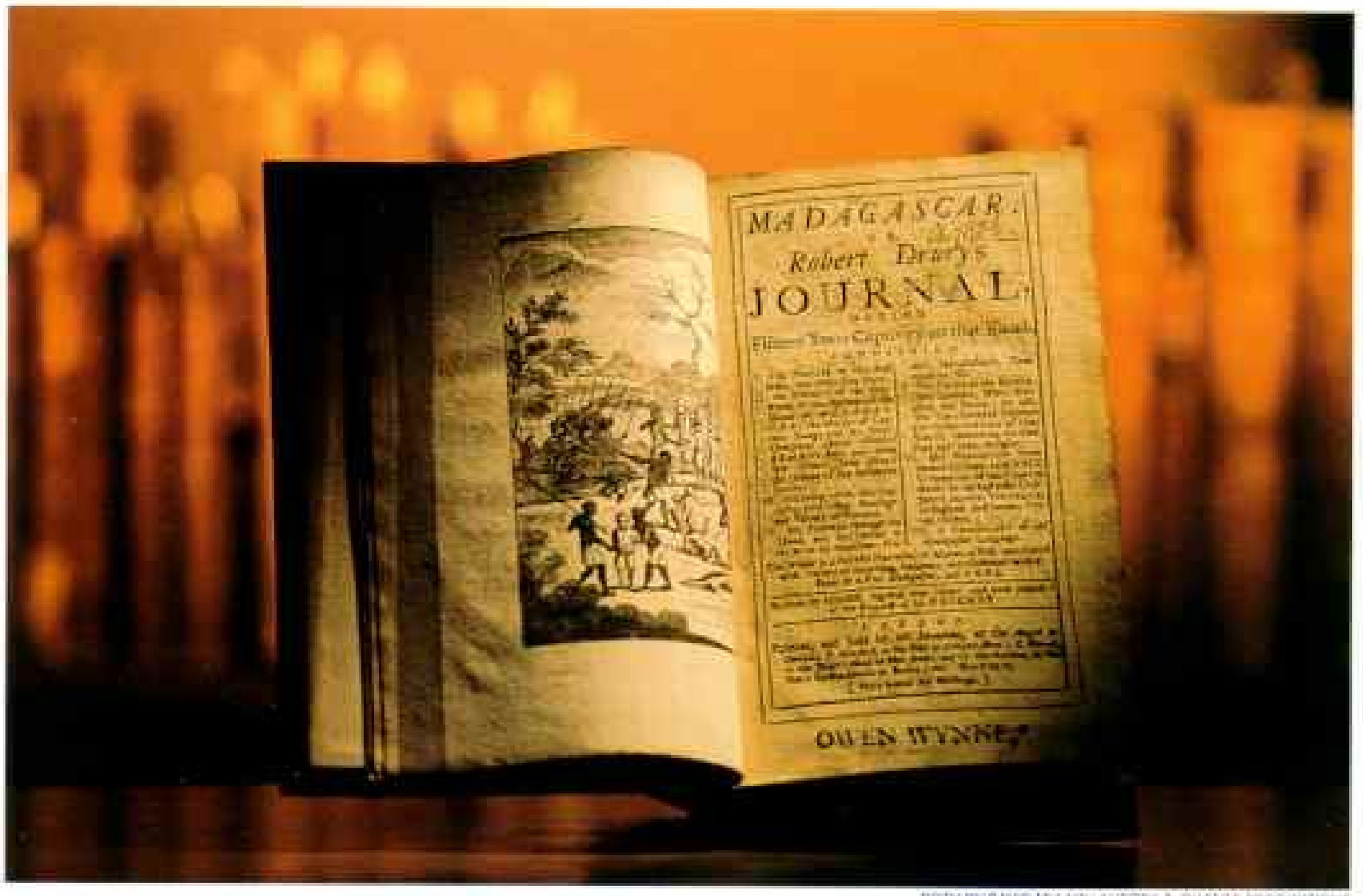

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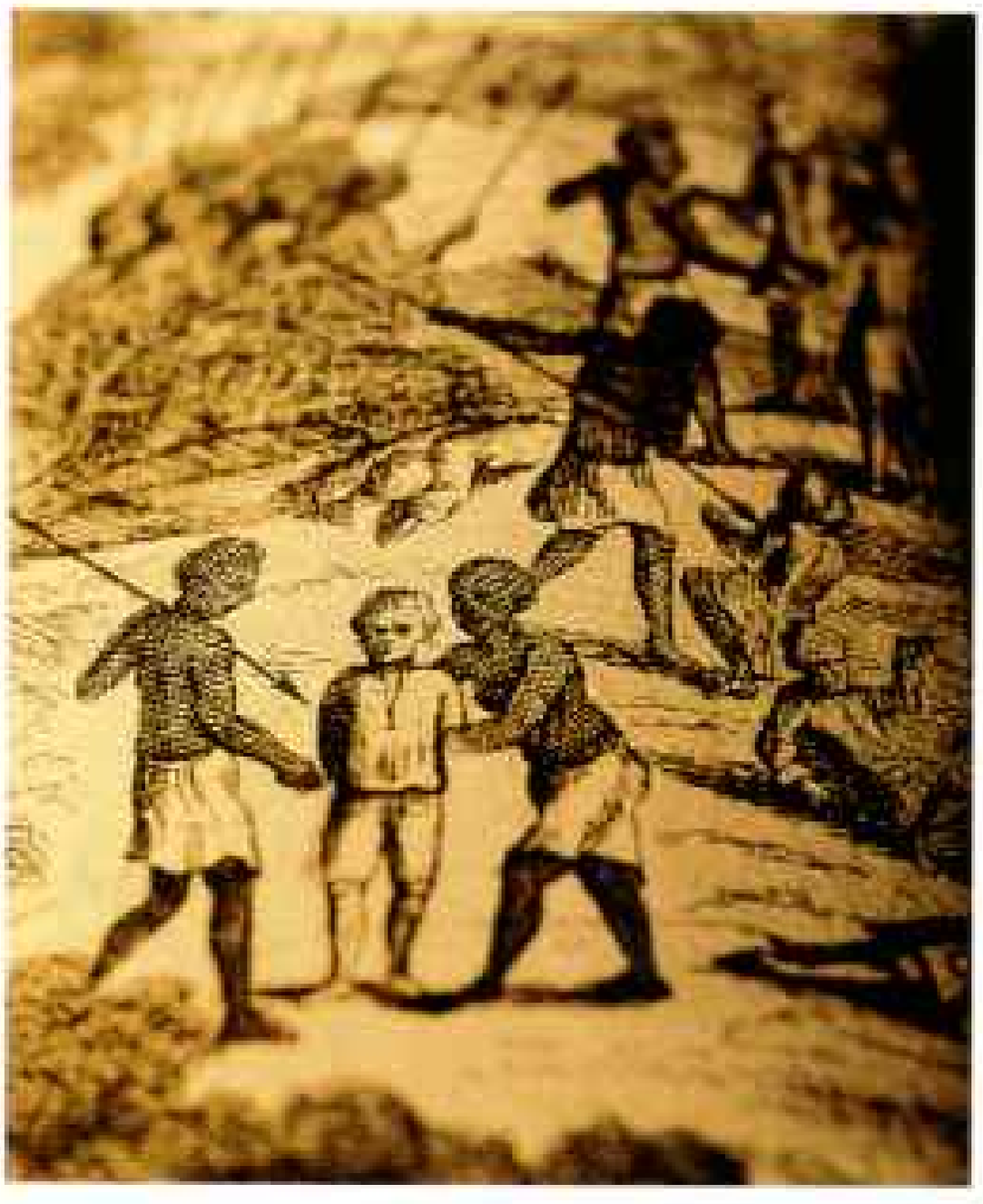

■ NGS RESEARCH GRANT

A True Survivor's Story?

It's a terrific tale: A 1703 shipwreck off the coast of Madagascar, a massacre, the enslavement (left) of a 15-year-old seaman, and his escape and return home to England 14 years later. But ever since *Robert Drury's Journal* was published in 1729, debate has raged about whether it is fact or fiction. Some experts think it is the work of novelist Daniel Defoe, author of *Robinson Crusoe*, or perhaps was edited by him. For the past seven years archaeologist Mike Parker Pearson of the University of Sheffield has led an Anglo-Malagasy team to southern Madagascar to test the accuracy of Drury's account. His conclusion: It's for real. "We've been to places he described—the rivers, the mountains—and corroborated traditional practices he described that are still in place today," he says. The team has found two cannon, and others have found parts of a bell, all from a wrecked English ship built between 1660 and 1750. Parker Pearson thinks they're from Drury's ill-fated vessel, the *Degrave*.

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ALL BY C. ANDREW BOYD

These Shoes Were Made for Walking—and Designed to Last

Sandals and slip-ons: Basic shoe styles never go out of fashion. And they apparently took shape earlier than expected, based on 35 shoes found in a Missouri cave since 1955. Using a new dating method that requires only a small piece of fiber from each shoe, researchers have found that Native Americans created the earliest one about 8,000 years ago. Almost all were made from rattlesnake master, a tough, spiny-edged, yucca-like plant.

"I knew they were old, but I didn't think they were *that* old," says Michael O'Brien, a University of Missouri archaeologist who found some of the shoes while excavating the cave. O'Brien calls the prehistoric cobblers "skilled craftsmen who knew what they were doing," but he was amazed that so many relied on the same raw material for at least 7,000 years. Small groups of people lived in the cave sporadically until the coming of Europeans, he says.

It's a Bird, It's a Plane, It's a . . . Flashy Satellite

They might have been UFOs, the startlingly bright flashes of light that began appearing in the sky (vertical streak, below) in 1997. But sky-watchers traced the flares to a constellation of low-Earth-orbit satellites launched by Iridium, a telecommunications company. Sunlight striking the silver-plated Teflon coating of the satellites' main antennas (above) causes reflections visible to the naked eye, "like a distant plane with its landing lights on," said one observer. Experts monitoring the 485-mile-high orbits of Iridium's satellites—now numbering more than 80—devised computer programs to predict where flares would occur. They posted the programs on the Internet, to the joy of satellite buffs everywhere.

TEXT BY BORIS WEINTRAUB

ART BY DAVID FIERSTEIN (TOP); DENNIS DI CICCO

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—Hector Elizondo

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Forum

Our September 1998 cover story on the Valley of the Kings was popular with our readers, several of whom expressed regret for not pursuing their childhood dream of becoming an Egyptologist.

Valley of the Kings

After reading the article about Egypt and the new discoveries, I find that no matter what time we live in, we will always celebrate life, love, and death, just as the ancient Egyptians did.

LUCIAN NICHOLSON
Evansville, Indiana

While the never ending archaeological findings in the Valley of the Kings continue to amaze and fascinate many, the removal of human remains from their ancient resting-places is very troubling to me. Why not leave the ancient royals alone and allow them to rest in peace forever? How would people react if I started digging at Arlington National Cemetery and Westminster Abbey and other sacred resting-places that we in the West hold so dear?

ED BROWNE
Bellingham, Washington

I am puzzled by the table of the New Kingdom pharaohs that appears on page 17. It would seem that Thutmosis III (1479-26 B.C.) and Hatshepsut (1479-58 B.C.) shared the throne of Egypt during all of Hatshepsut's reign.

CHARLES VAILLANCOURT
Quebec City, Quebec

Hatshepsut was clearly very powerful, as her magnificent temple outside the Valley of the Kings indicates, but the historic record shows that women weren't usually accepted as pharaohs. She probably ruled as a co-regent with Thutmosis III, her nephew and stepson, until her death or until he was old enough to assume full control or wrest it away from her.

A New Day for Romania

The caption on page 49 of your excellent article says, "Though communist authorities did not ban religion, they restricted worship, sometimes persecuting believers." In actuality, churches were closed and only priests and pastors who parroted the communist theology were allowed to minister. Those who declined or spoke of a heavenly ruler were cruelly imprisoned. The authorities did their utmost to eliminate any competing system of ethics.

JOHN M. HAUBNER
Carlton, Minnesota

Hungarians have inhabited Transylvania for over a thousand years, and many of its towns were built at the behest of the Hungarian kings. When Transylvania became part of Romania after World War I, none of the towns of any significance had a Romanian majority. This explains why the Hungarian character is so indelibly stamped on Transylvania.

CSABA K. ZOLTANI
Lutherville, Maryland

Street children are a reality in Romania, but so are the Romanian students who consistently win gold medals in international contests in math, computer science, physics, and chemistry. Their achievements are remarkable for such a small country.

LAWRENCE DAFINESCU
Toronto, Ontario

I was saddened to read about the drab apartment blocks and coal shafts of my Transylvanian hometown, Petroşani. It was not always like that. When I left 50 years ago, there was a pleasant main street, and three mountain peaks stood as sentinels above the landscape. The miners' "colony" occupied the lower town, with middle-class housing tucked among the town's half dozen churches. Apparently Ceauşescu had most of it razed, making a town of 30,000 people virtually unrecognizable.

ANDREW HOFFMANN
Westmount, Quebec

Greenland Sharks

From 1976 through 1978 and also in 1985 I was stationed at the Black Angel Mine (now closed) in Greenland, near the village of Umanaq. During one of these stays I heard a story that may classify the Greenland shark as man-eating.

A couple of Greenlanders set off in a small boat, and a storm blew up. They were never seen again. Some time afterward a Greenland shark was caught, and in its stomach was found clothing identified as belonging to one of the lost men. Considering the frigid water, it appears likely that the man drowned prior to being eaten.

MATS A. HEIMERSSON
Surrey, British Columbia

The Greenland shark, like all others of its kin, was shaped by the ages for survival and efficiency. I believe the semilunate tail and caudal keel evolved for speed. This is further supported by the stomach contents of captured Greenlands: seals, squid, and salmon. It is possible that in all instances these were carrion items, but unlikely.

SCOTT RILEY
Kennesaw, Georgia

Vermont: Suite of Seasons

Edward Hoagland fashioned a "poetry of words" I was unable to put down until I had read it over and over again. Thank you Edward Hoagland, and, of course, Michael Yamashita for exquisite photographs of the Northeast Kingdom.

FRANK WM. WARNER
Toronto, Ontario

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I was very disappointed in the article about Vermont and hope that this is not a style of writing you are introducing for future articles.

GEORGE WACHSMANN
Salt Spring Island, British Columbia

The statement on page 85 that after Labor Day "the guy living in a double-wide trailer . . . may come out and make the place his own . . . run some bear hounds through and sell the bear's gallbladder to Korean medicine men" provides readers with a dark image of our local inhabitants. It is legal to sell a harvested bear's gallbladder provided one has a bear license. But a recent survey of hunters found that 91 percent of those who harvest bears eat the meat and just 7 percent sell the parts.

RICHARD M. TETREAULT
Newport Center, Vermont

Catherine the Great

I have been researching my family history for over 30 years and acquired enough information on ancestors from Dumfries, Scotland, to publish a site on the Internet. Recently an antiques dealer in Mount Vernon, Texas, called me because he had found an old strongbox full of records on several families from Dumfries. Inside we found an 18th-century diary kept by a Dr. Rogerson. It seems he was Catherine the Great's court physician. He told of her favorite pet, a dog, that died. Catherine asked Dr. Rogerson to stuff it, and he laughed at the thought of studying in medical school just to stuff a dog. On page 104 of your article it says that Catherine "drank wine only if her Scottish doctor prescribed it." Do you know the name of the doctor? Was it Dr. Rogerson of Dumfries, Scotland?

CHARLES E. LOWE, JR.
Austin, Texas

Professor John Alexander of the University of Kansas, our main consultant for the article, confirms that Catherine's doctor was indeed John Rogerson.

When Catherine the Great invited Germans to settle Ukraine, she made an agreement with them that their sons would never have to serve in the Russian Army. However, in the latter part of the 19th century, the army did begin conscripting them, at which time many German-Russian families left Russia. My great-grandparents were among those who settled in North Dakota. My great-grandfather arranged for my grandfather to be smuggled out of the country in a barrel. Fear of being caught as a deserter caused him to have nightmares all his life.

BLANCHE KRAMER WOOLFORD
Mechanicsburg, Pennsylvania

On page 96 it states, "Since the fall of communism ordinary people endure much the same grinding struggle to survive, political uncertainty, and sense of lack of control over their own lives as did the serfs of Catherine's day." Doesn't anyone know it was like that *before* the fall of communism?

RISEHART POTTS
Glassboro, New Jersey

While the empress flattered her own ego by pretending to be a child of the Enlightenment, she did little to bring real reform to her impoverished nation. When a young intellectual named A. N. Radishchev published the book *Journey from St. Petersburg to Moscow*, in which he vividly described the poverty of the countryside and the corruption of the regime, Catherine responded by condemning the author to death, although the sentence was commuted to ten years in exile in Siberia.

TOM PIERCE
Berwyn, Illinois

Borneo's White Mountain

I commend author Donovan Webster for expressing the dangers and fears that he had while on the assignment. Too often people think spelunking is an easy task.

PAMELA JO LEIGHTON
Houston, Texas

The article consistently dwelled on the hardships and dangers of spelunking, while only briefly mentioning a "broad, multidisciplinary survey of life." The expedition, even if resulting in protected status for Gunung Buda, will probably do little for the mountain, given that the economic crisis in the region necessitates using all sources of revenue, even if this jeopardizes national parks.

MILES COLMAN
Concord, Massachusetts

Geographica

I am quite familiar with "Elmhurst 11373, the most ethnically diverse zip code in the United States," having taught in one of the community's schools for the past 24 years. Not too many years ago the heart of Elmhurst, where my school is located, consisted of stately homes and broad vistas. Today's Elmhurst consists mainly of tall apartment blocks. The one characteristic I have noticed unchanged is how harmoniously the flavors of such a diverse community blend. It would be difficult to imagine a more congenial urban community anywhere.

THOMAS STRACZYNSKI
Elmhurst, New York

Letters for Forum should be sent to National Geographic Magazine, Box 98198, Washington, D.C. 20090-8198, or by fax to 202-828-5460, or via the Internet to ngsforum@nationalgeographic.com. Include name, address, and daytime telephone. Letters may be edited for clarity and space.

NATIONAL GEOGRAPHIC

From the President

DAVE HARMAN

JOHN FAHEY, AT LEFT, KENNY FAHEY, AND NATIONAL GEOGRAPHIC PHOTOGRAPHER CHRIS JOHNS

LONG BEFORE I BECAME PRESIDENT of the National Geographic Society, I counted myself among the millions of readers who are consistently moved by the artist's eye and technical genius of the Society's photographers. Recently my son Kenny and I had the pleasure of accompanying photojournalist Chris Johns on assignment in Botswana for two articles you'll see later this year, and I came away more impressed than ever.

Through his painstaking work, Chris is magnificently documenting the delicate balance between preserving one of the world's last great wild places and meeting the needs of the people who live off that land.

From time to time I will report the Society's activities to you, our members. For more than a hundred years the mission of the Society has been "the increase and diffusion of geographic knowledge," and in the past 12 months we have taken some giant steps in ensuring that the work of leading photographers, writers, and research grantees will reach more people than ever before.

As of the end of 1998 we had launched local-language editions of NATIONAL GEOGRAPHIC magazine in Japan, Spain, Latin America, Italy, Israel, and Greece. Our National Geographic cable channel is beamed by satellite to almost 30 million homes overseas. The Society's new Expeditions Council is sponsoring exploration projects ranging from the heights of the Andes to the depths of the oceans. And not a day goes by that I don't receive a letter from a teacher or principal thanking us for our recent giveaway of 128,000 world maps to elementary, middle, and high schools across the United States and Canada.

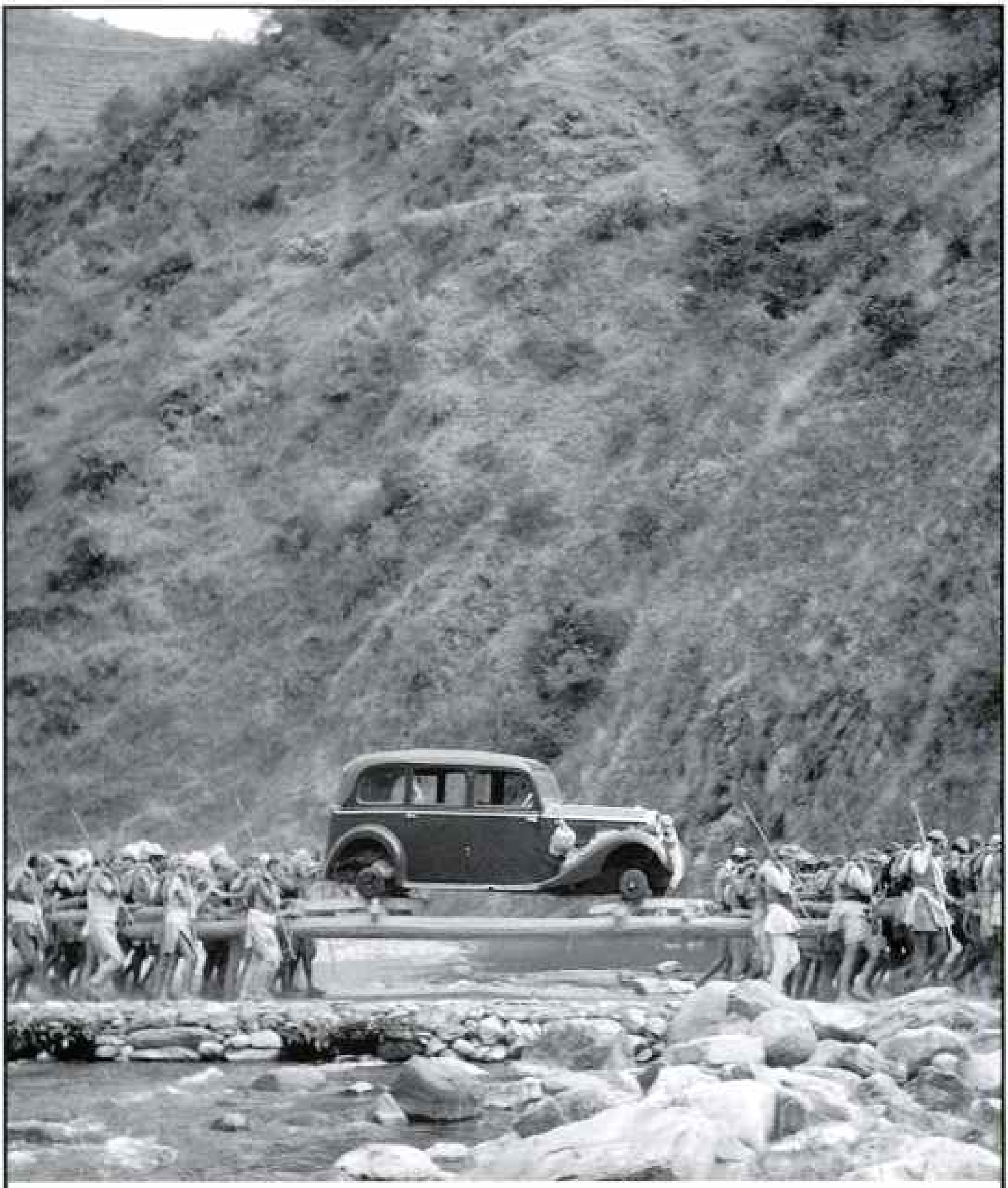
There's more to come, of course. This spring we will publish a major new magazine, *National Geographic Adventure*. We expect to launch another local-language edition of NATIONAL GEOGRAPHIC about the same time and several others in the near future. It is also my hope that we will soon be able to bring the National Geographic Channel to audiences throughout North and South America.

Because of our members' support, we are learning more about our world, our universe, and ourselves. Your Society is committed to bringing you that information as no one else can.

Black-faced Spoonbill (*Platalea minor*) **Size:** Height, 60 - 83 cm **Weight:** Approx. 1.5 kg **Habitat:** Estuaries, salt marshes, tidal flats and coastal areas in North and South Korea, Taiwan, China, Macau, Japan and Vietnam
Surviving number: Estimated at 613
Photographed by Lin Ben Chu

WILDLIFE AS CANON SEES IT

Black-faced spoonbills forage in Taiwan's Tseng-wen Estuary, using rhythmic side-to-side sweeps of their broad open bills to snatch small fish and crustaceans. Over half the world's population of these waterbirds gathers at this single location in winter. The only known breeding colonies are off the coast of North Korea, where just 35 pairs nest on the sheer cliffs of a few small rocky islands. Scientists are tracking the birds by satellite to locate other nesting sites and identify migration stopovers. Protection of wetlands is critical to saving the black-faced spoonbill from extinction. As a global corporation committed to social and environmental concerns, we join in worldwide efforts to promote greater awareness of endangered species for the benefit of future generations.



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NATIONAL GEOGRAPHIC

coral reef

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

Dr. Ballard, during an expedition in the Pacific, atop the ATV (Advanced Tethered Vehicle)

TO UNLOCK THE SECRETS OF THE OCEAN, DR. ROBERT BALLARD USES THE MOST SOPHISTICATED UNDERWATER EQUIPMENT.

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Using a remote controlled vehicle and the world's smallest nuclear submarine, the NR-1, a team of scientists led by Dr. Robert Ballard of the Institute for Exploration in Mystic, Conn. has uncovered a trove of ancient shipwrecks in the Mediterranean, some of which are more than 2,000 years old. "You come in with your robot, this most advanced technology on the planet, and you're hovering over a picture of antiquity two millennia old," says Dr. Ballard. "It's a breathtaking, unbelievable sight." Ballard's choice of equipment is no less astute when it comes to his timepiece: a Rolex Submariner. Equipped with a Triplock winding crown, modeled on the operation of a submarine hatch, the Submariner would seem the natural choice to accompany Dr. Ballard on all his explorations of the world's oceans and seas.

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Why are there no monuments to practicality?

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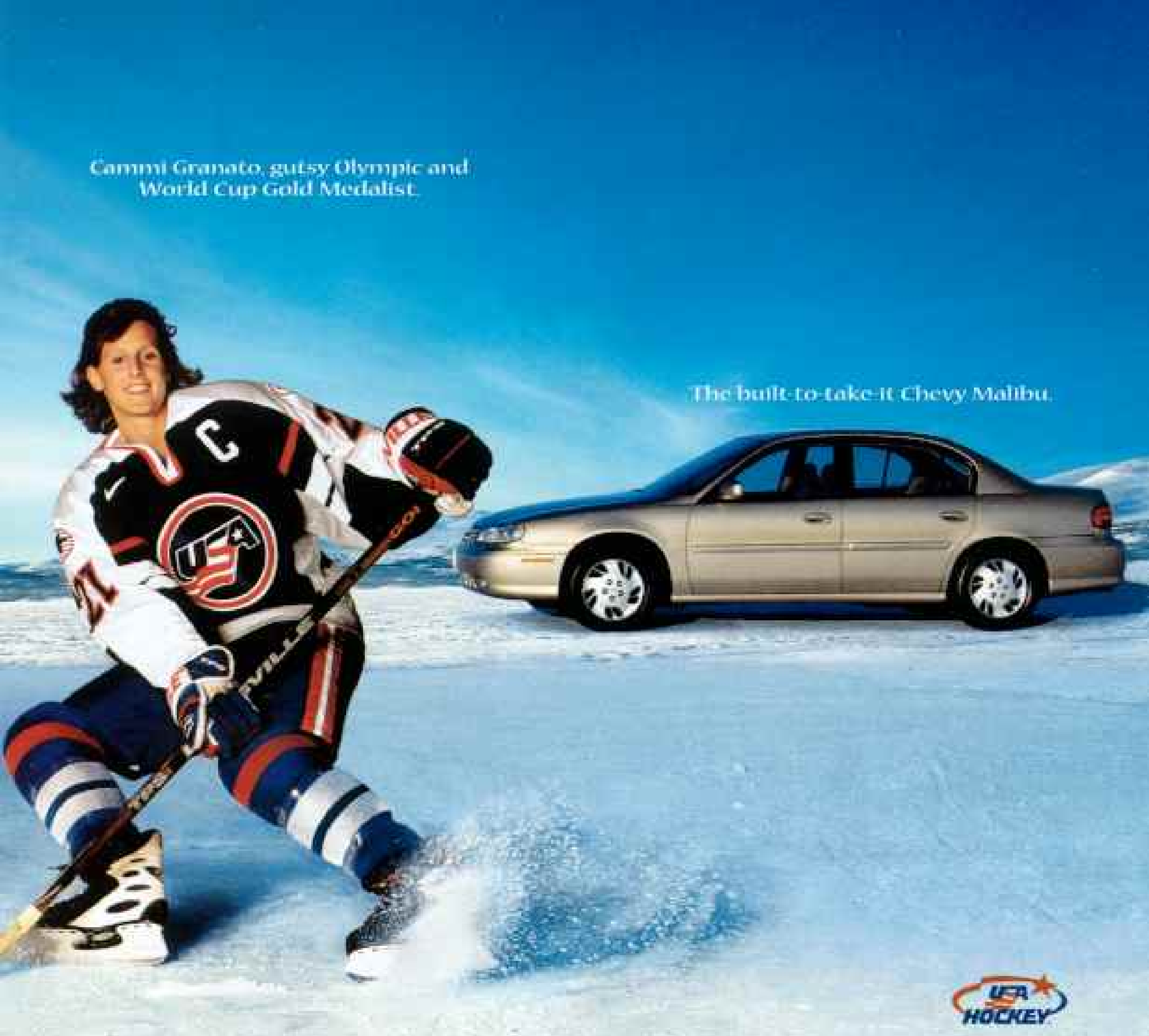

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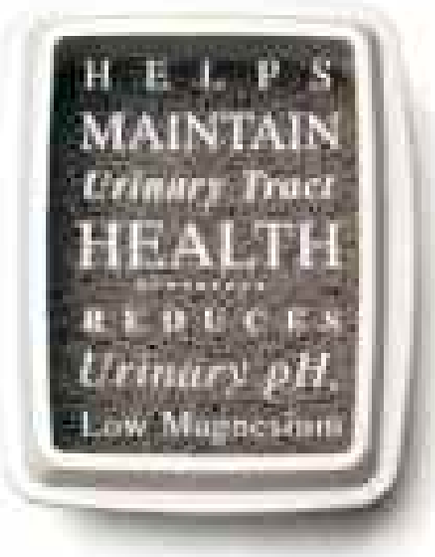

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■ FROM THE GEOGRAPHIC ARCHIVES

Diving Belle

A "modern mermaid," according to our records, actress Lula McGrath cavorted among corals with helmeted J. Ernest Williamson in this still from the 1922 silent movie *Wonders of the Sea*. Williamson and his brother, George, ran a "floating and under-sea" film studio in the Bahamas, specializing in photography from the porthole of their patented submarine chamber. In 1916 they shot the underwater scenes for the first Hollywood version of Jules Verne's *Twenty Thousand Leagues Under the Sea*. Society archives contain several of the Williamson brothers' photographs—including one image of a diver confronting a sleepy-looking "deadly" eel—but none were ever published in the magazine.

Cammi Granato, gutsy Olympic and World Cup Gold Medalist.

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PETER WEIMANN, ANIMALS ANIMALS

■ EXPLORER, SUNDAY, JANUARY 3

A Light in the Forest: Soon to Be Extinguished?

Will golden lion tamarins find refuge only in zoos, as this one has? Due to encroaching human populations, the monkey's native habitat—Brazil's Atlantic coast rain forest—has shrunk to less than 5 percent of its original extent. EXPLORER's *Golden Lions of the Rain Forest*, produced by Pauline and Jack Bellamy, makes the case for saving these primates. The film follows one tamarin family as it roams a reserve northeast of Rio de Janeiro, raising two infants. Filming was hard going. "The swampy land these tamarins favor was full of mosquitoes," says Pauline Bellamy. "And a flash flood tore through our camp." The payoff? Capturing incredible footage of these playful and nurturing animals to share their plight with the world.

■ PROGRAM GUIDE

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BOTH BY MARGARET MARCHIATIONNI

Midshipman Fish: Noisy Suitors and Lurking Loners

Like tiny golden goblins, two- to three-week-old embryos of midshipman fish rest atop their yolk sacs. How they were conceived is a strange tale.

Named for scattered body markings that resemble uniform buttons, midshipman fish skulk about the Pacific bottom off North America. In late spring and summer some males build rocky nests and at night emit a loud, relentless hum—audible even on the surface—that attracts females. "It's like the chanting of monks," says Andrew Bass, a Cornell University professor studying how the male's brain signals its body to hum and how the female's brain receives and interprets these messages.

But there are two separate classes of midshipman males. Some are large nestbuilders that hum, like this one (above right, at center right) next to

PHOTOGRAPHED AT BODEGA MARINE LABORATORY, CALIFORNIA

his mate. Flanking the couple are two members of the second class—smaller fish called sneaker males. These loners do not hum and build no nests but furtively invade those of the larger males, adding their own sperm to the nest and thus passing on their genes—even though they never get a date.

JACK JEFFREY

Tough Little Birds

Hawaii's honeycreepers once numbered more than 55 species but have been reduced to 23, in part by avian malaria (see "Hawaii's Vanishing Species," September 1995). But one group of honeycreepers called *'amakihi* has shown remarkable resistance to the disease. Researchers are testing the 'amakihi species to see if they carry a protective gene that may offer hope for other honeycreepers.

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Polar Bear Cubs Deformed by Toxics?

Researcher Andrew Derocher didn't like what he saw on this female polar bear's cub last spring in Norway's Svalbard archipelago. The little one bore female sex organs and a partial penis—a form of hermaphroditism.

Such aberrations can occur naturally but are very rare. "Toxic chemicals such as PCBs and DDT are a possible cause," says Derocher (right). With colleague Øystein Wiig he found seven such cases among 450 female polar bears in Svalbard. In the Canadian Arctic he has examined some 1,500 females and found only one case.

Norway's polar bears get three times the PCB exposure of Canada's and six times as much as Alaska's. The pollutants travel by sea and air from Europe, North America, and Asia. Sponsored by the Norwegian government, a team from the Norwegian Polar Institute, including Derocher and Wiig, is testing the immune systems of 35 Svalbard bears.

ØYSTEIN WIIG

Buzz Off, Beehive Burners

"Anywhere there was a sawmill 50 years ago, there was usually a burner like this," says Bob Beaty of British Columbia's Air Resources Branch. Nicknamed "beehive burners," the towering steel structures incinerate waste wood. They also produce airborne particulates hazardous to people with respiratory and heart diseases, according to a British Columbia medical report. Most of the province's 110 burners located near populated areas were closed by the end of 1998. About 50 remain in rural areas. Most burners in the western U.S. were phased out in the 1970s. Waste wood there is now pulped for paper, turned into fiberboard, or burned in power plants.

TEXT BY JOHN L. ELIOT

BARBARA YOUDS

NATIONAL GEOGRAPHIC

*Inter*active

■ ONLINE

Our Guest List Is Growing

Muhammad Ali, Jane Goodall, Walter Cronkite—what do they have in common? Each is a guest at our virtual millennium salon. The legendary boxer shares his optimism about the next thousand years. The chimp expert rues the environmental ills that have afflicted Africa, yet she draws hope from the "indomitable human spirit" that surfaces in the midst of adversity. The iconic TV newsman takes a hard look at his craft and finds it wanting. And other faces—chef Julia Child, astronaut Edwin E. "Buzz" Aldrin, Jr., and more—keep joining the conversation. Message boards let you chime in too, so pull up a chair at *www.nationalgeographic.com/faces*.

■ Coral is stunning, alluring—and threatened. Read "Coral in Peril" in this issue and discuss the problems facing this underwater wonder at . . . */ngm/9901*.

CLOCKWISE FROM TOP LEFT BY HOWARD BINGHAM, KENNETH LOVE, STEVE FRIEDMAN

■ CD-ROM

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"When we see land as a community to which we belong, we may begin to use it with love and respect."

—*Aldo Leopold*

NATIONAL GEOGRAPHIC

On Assignment

BOB CAPUTO

■ ANACONDAS

It's a Looooong Story

"Sure, I'm scared of snakes," admits photographer Bob Caputo, who has good reason to be. He's made a GEOGRAPHIC career of shooting stories in Africa, where wildlife isn't always friendly. "The bad thing about snakes is you never see one until you're next to it," he says. That's true even of anacondas, like the 14-footer (above) he tangled with—for fun—after researchers pulled it from its murky wetland lair on a ranch in Venezuela. "If something is that big," says Bob, "it's almost not a snake anymore."

Bob slithered onto the subject of the big snakes while covering the Orinoco River for the April 1998 issue. "There's a nice anaconda in that one too," he says.

■ RAVENS

For the Birds

Photographing ravens can get you into trouble, Michael Quinton learned. Not only did he get his snowmobile stuck trying to find the birds (right), but he also got blamed for their mischief. One winged bandit, caught on film raiding a snowmobile's storage bin (pages 112-13), flew off when the owner returned. "And there I was, trash all over, looking suspicious," says Michael.

CINDY QUINTON

NATIONAL GEOGRAPHIC (ISSN 0027-9358) IS PUBLISHED MONTHLY BY THE NATIONAL GEOGRAPHIC SOCIETY, 1145 17TH ST. N.W., WASHINGTON, D.C. 20036-4688. $27.95 A YEAR; $3.95 A COPY. PERIODICALS POSTAGE PAID AT WASHINGTON, D.C., AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: SEND ADDRESS CHANGES TO NATIONAL GEOGRAPHIC, P.O. BOX 63002, TAMPA, FLORIDA 33663-3002.

NATIONAL GEOGRAPHIC
Geoguide

Preparing for Popocatépetl to Blow Its Top

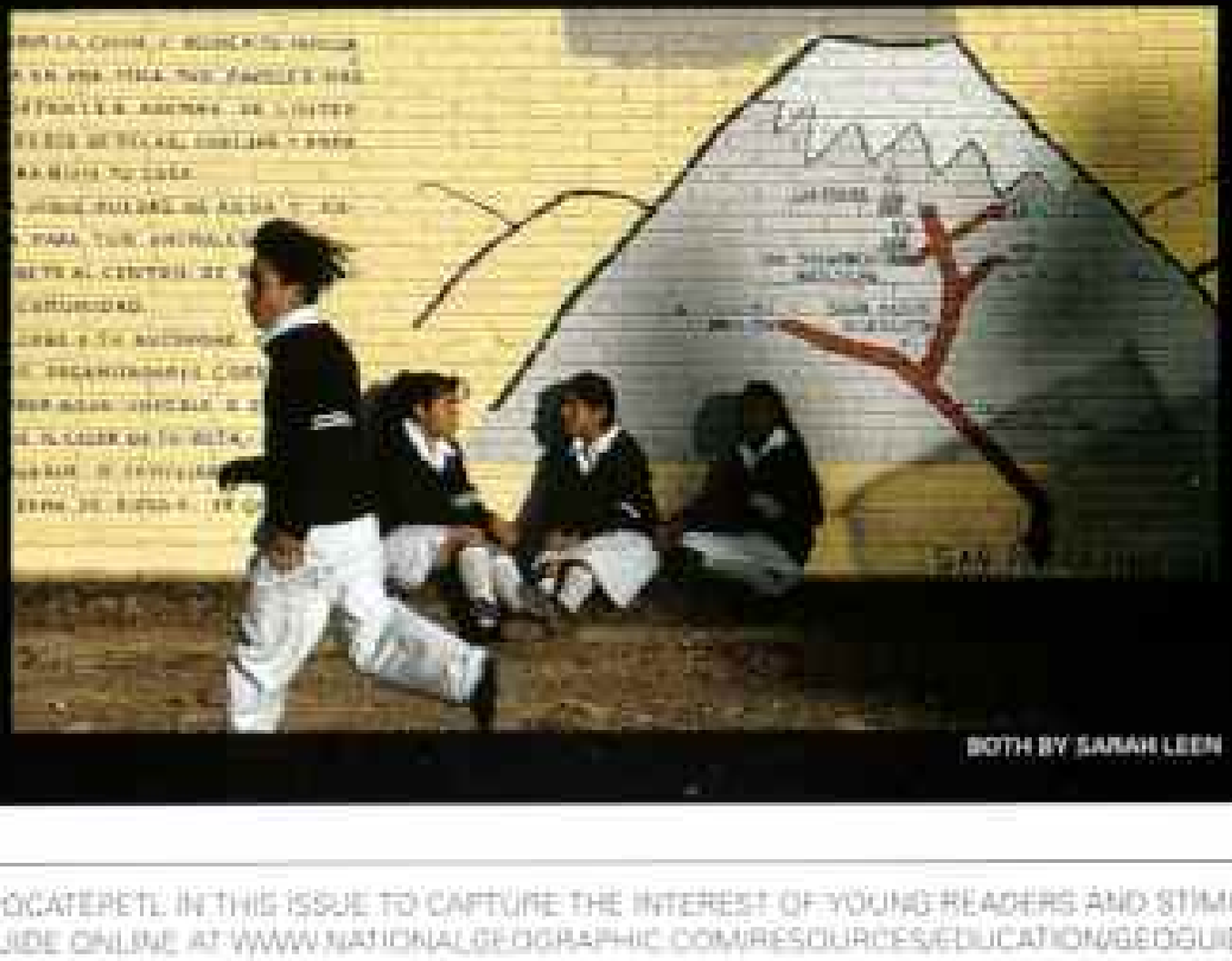
■ Many thousands of people in Mexico live in the danger zone around the active volcano Popocatépetl. When it erupts, falling ash and rocks, as well as mudflows, could pose lethal hazards. But the mountain offers people reasons to stay. What are they?

■ In the landscape model on page 125, mudflows are pouring down in which general compass direction? (Note where north is.)

■ When Popocatépetl erupts, the heat it generates could melt snow and ice on the mountaintop. How can there be snow and ice on a mountain at a tropical latitude?

■ Being prepared means practicing for evacuation. Airlines always alert passengers to the locations of exits from airplanes. Do you know all the exits from your home and school?

A Mexican soldier (above) eyes Popocatépetl, which is also monitored with scientific instruments. In a nearby village, a school wall shows evacuation routes.



BOTH BY SARAH LEEN

There are many

more volcanoes

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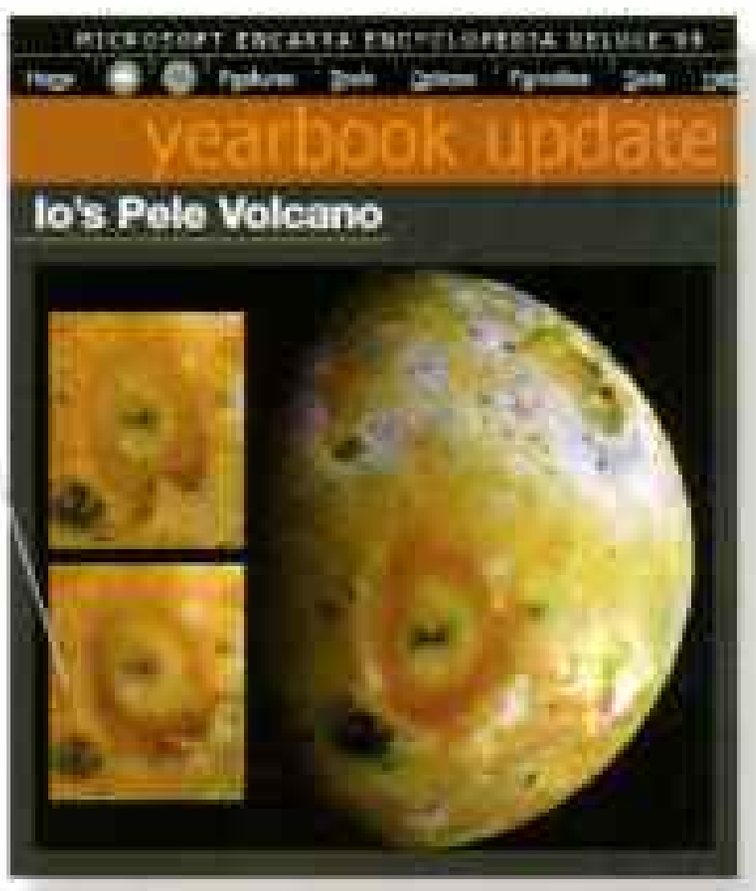

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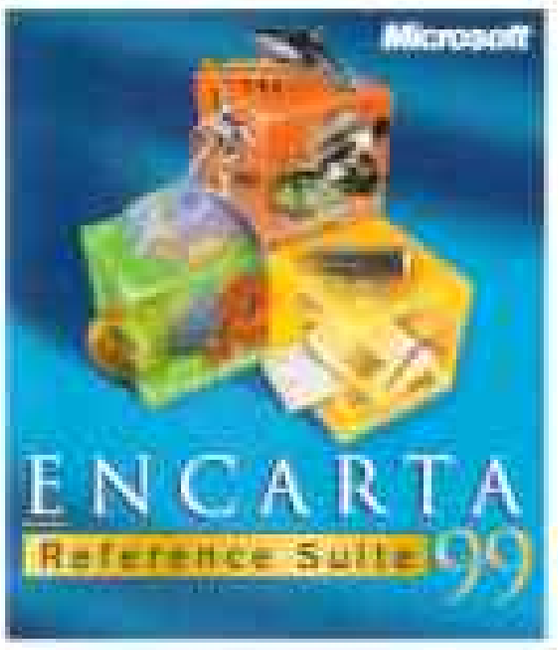

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