



NATIONAL GEOGRAPHIC



From the Editor

NATIONAL GEOGRAPHIC writers and photographers have always gone to extremes to capture the unusual, the beautiful, the important. In 1935 Capt. Albert W. Stevens and Capt. Orvil A. Anderson rode a balloon gondola 14 miles up to photograph the division between the troposphere and the stratosphere for the first time. Nearly 25 years later undersea adventurer Jacques Piccard wrote about his bathyscaph dive nearly seven miles to the bottom of the Mariana Trench.

This month we again take to the air and the water for discovery. Photographer George Steinmetz strapped a motor to his back and went soaring over the Sahara in what he calls a “flying lawn chair.” Half a world away Wes Skiles probed the unexplored labyrinth of caves and chambers whose waters feed the springs of north Florida—and joined other divers as they examined the sunken remains of a Civil War-era ship just beneath the surface.

In contrast to the earlier expeditions, George averaged just 300 feet above the ground, and Wes seldom ventured to depths of more than 200 feet. But the driving principle remains unchanged: It is only by finding new approaches to viewing the world that we can more fully understand it.

Bill Allen

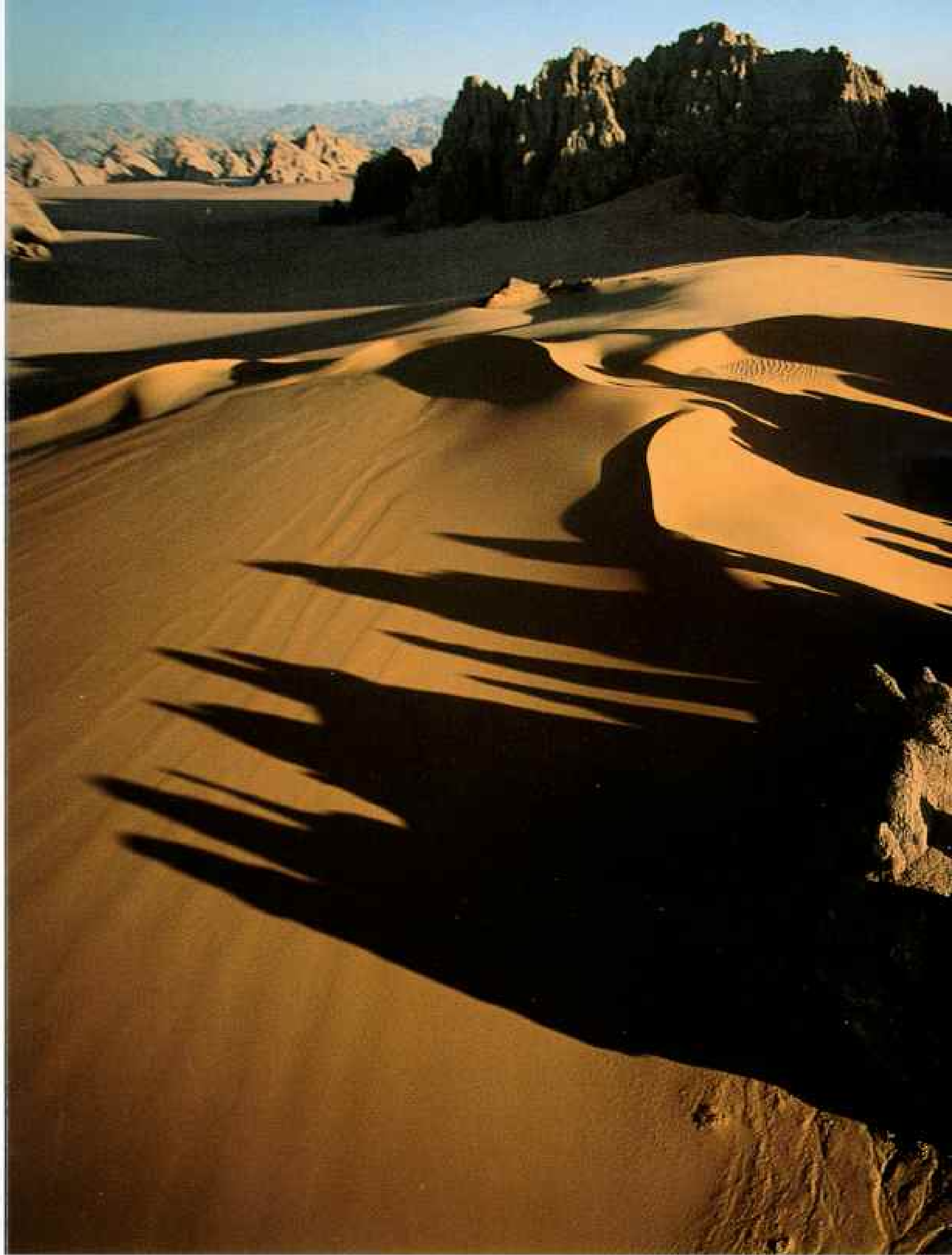


Boundless stretches of sand are the highways of Saharan Niger. Less than 500 miles of major paved roads serve a nation three times as large as California. Below the horizon a caravan heads for the town of Bilma to take on salt, a prized commodity. Another train laden with salt and other trade items heads toward markets at the desert's edge.

To fly high above the Sahara, to see it as the eagle does, is to behold startling patterns. Tracks of nomads disappear and reappear. Verdant rows of crops surround palm-dotted villages that suckle at the desert's stingy upwellings of fresh water. Craggy massifs rise from this *bahr belà mà*—"sea without water"—with its ripples of sand sheets, waves of dunes, and temperatures that can soar to 130°F and plunge to 20°. The Sahara's most remote reaches lie in Niger and Chad, countries twinned in their landlocked isolation. It is a world of hardscrabble living, knife-wielding men, shrouded women, and a beauty at once raw and serene.

JOURNEY TO THE HEART OF THE SAHARA

By DONOVAN WEBSTER Photographs by GEORGE STEINMETZ





Rocky skylines and dunes red with iron oxide make for a Martian landscape in northern Chad. Evidence of the Sahara's ancient seas and rivers, sandstone pinnacles were eroded by rainfall. The Sahara—the largest desert in the world—gets its name from the Arabic word sahra, or desert.





Back-bending labor produces salt at Teguidda-n-Tessoumt in Niger. Briny well water is mixed with salty earth in large depressions. The mud is then placed in smaller ponds for evaporation. Colors differ depending on the origin of the mud, the presence of algae, and the degree of salinity.

THE OLD MAN IS DYING. At the darkened end of his hut, away from the door where a parade of visitors peers inside, he lies on his back, his face black and wrinkled, his son seated close behind him.

His breaths come dry and weak. With each one the old man seems to choke on the air's perfumed sweetness, which has been freshened to cover the stench of impending death. His head lolls. He has been paralyzed by a series of strokes, which are slowly sapping his life. I step closer. His eyes are clouded by cataracts, a bitter by-product for many herdsmen who've spent their lives staring across the sun-scoured reaches of the Sahara.

"Before this he could see a little bit," his son says. "But now he is completely blind. I hope he can hear me. I hope he knows I am here. *Inshallah*." Allah willing.

We are in Diona, a loose settlement of stock pens and huts strung along a dry riverbed in Chad. Forty yards outside the old man's house, dark, sinewy women in bright scarves pull bucket after bucket from a well, splashing the contents into troughs for their sheep and goats.

Soon the old man will be dead, one of the women says. Still, acacia trees will line the dry river's banks. There will still be water in the wells. Diona will go on.

"It is sad," says another woman, "but he has had a long, good life. Still, may he go soon. *Inshallah*."

Three days later I run into the women at another well. "The old man is dead," one says, her children crowding the folds of her scarf as she talks. "He died the day after you were here. He is buried now—" she points toward some distant hills.

Then she goes back to work. Her life, like the old herdsman's, is a constant battle to convert water to survival in the Sahara, one of the harshest and most demanding environments on Earth.

Across the Sahara, where distance, dryness, and destiny render life treacherous, invocation of Allah's favor—*Inshallah*—has evolved into reflex. *Inshallah*, the camel caravan returns;

Family spat gets a wide-open airing in northern Chad. Gathered around firewood stacked to avoid drifting sands, elders of the village of Demi consider the plea of a woman named Zara, holding her newborn baby. She sought to leave her husband—who was not present—but refused to say why.

The session was witnessed only by men, who tried to talk her out of her decision. Such a divorce would cost dearly: A dowry of five camels, five goats, and blankets that went to each of the woman's adult relatives would have to be returned to the groom and his family.



Inshallah, the date harvest is good. *Inshallah*, the dunes don't roll in and swallow the town.

There's reason for this. The desert is large—larger than anything, the local saying goes—and to survive its caprices the people here have grown to rely upon a greater order. When confronted with the Sahara and its 3.5 million square miles—an area roughly the size of the United States—divine intervention is never a bad thing to have on call.

There are less populated deserts in the world, but perhaps none is less visited than the heart of the Sahara, where wars and political upheaval have kept outsiders away for decades. As that began to change, photographer George



Steinmetz and I set out in 1997 with a shifting cast of characters on a 4,000-mile expedition through this region: a largely roadless zone of desolate sand and rock defined by the collective borders of Niger, Chad, Libya, and Algeria. I could persuade only Niger and Chad to issue me a visa, forcing us to limit our journey to these two nations, skirting the borders of their northern neighbors.

In both countries we searched for fleeting glimpses of the old Sahara amid the rising tide of satellite dishes and Air Jordan knockoffs that has started to flow across their borders. We began in the sand dunes of Niger, now more accessible after a cease-fire between the Tuareg

and the country's government, which has slowly disenfranchised these desert warriors. Then we continued into rocky Chad, which is looking to rejoin the world after more than three decades of civil conflict and battles with Libya. Here the Touhou live a hard life in a nation long ravaged by poverty, drought, and sporadic bloodshed.

In this still untamed Sahara—among the

DONOVAN WEBSTER, author of *Aftermath: The Remnants of War*, a study of abandoned explosives, lives outside Charlottesville, Virginia. GEORGE STEINMETZ began his photographic career by taking pictures while hitchhiking through 19 African countries. Both are frequent contributors.

camel herdsman, young Koranic students, government officials, and merchants now anticipating a more peaceful and prosperous future—we were seeking rhythms of life unbroken since the time of Muhammad, 1,300 years ago.

THE FIRST DEAD CAMELS turn up on Day 2. They're mounds of pale, chalky bones, scattered atop dishes of desiccated, apricot-hued fur. Each is the size of a kiddie wading pool, and they rest balanced on low, wind-sculpted pillars of sand. In the natural autoclave of the Sahara, humidity sometimes hovers in the teens and daytime temperatures can reach 130 degrees Fahrenheit. Consequently the desert's sandy surface is sterile, and microorganisms can't survive there. Decay comes in the abrasive form of wind-blown grit.

Yesterday we left Agadez, Niger, driving east in a line of four-wheel-drive vehicles. Behind

us the minaret of the city's mosque rose seven stories above a grid of streets where low, mud-brick buildings hunkered in the sun. After a day's drive into scrublands east of town, we topped a rocky bluff, and beyond it began the Ténéré, a landscape of dune fields and sand plains larger than Germany with a name that means "nothing" in the language of the Tuareg.

Here strings of dunes stretch east to west, a hundred feet tall and several miles long, piled up by the wind. Devoid of water and completely unsettled, the Ténéré is lonely, hot, and breathtakingly gorgeous in rounded shades of beige.

Most every day we drive about 70 miles across the soft sand, often becoming bogged down and having to dig our way out with hands and shovels, placing perforated metal sheets called "sand ladders" beneath the tires for better purchase.

We pause at midday, when the sun heats the desert so thoroughly its sand grows impassably soft. Then we wait out the inferno for a few



Framed in the traditional indigo hue of the seminomadic Tuareg people, Tanelher Bailah makes up her face with powdered stone from Niger's Air mountains. Niger and neighboring Chad were the site of a three-month National Geographic exploration. The photographer-writer team encountered skin-scouring sandstorms, dehydration, venomous snakes, the threat of bandits, and black, crystalline nights brilliant with stars.



hours, hiding beneath a large canvas sheet draped across the roofs of the parked cars—creating the only shade for hundreds of miles.

In some of the valleys between dunes we've seen thousands of pancake-size footprints, apparently left by a camel caravan. And within another hour of driving, the caravan—a long, dark blotch on the horizon—creeps into view. We motor alongside, stop the car, and I step out to take up the dromedary's stately pace.

The caravan leader gives me a quick wave and hello. Then we move to the polite give-and-take of the desert's traditional greeting:

"How is the work?"

"Good. God willing. How is the work for you?"

"Good. God willing. How is the family?"

"Good. God willing. How is the family for you?"

"Good. God willing. How are the camels?"

After a few minutes of this the conversation becomes less formal, but the man remains

distant. He introduces himself as Aboubacar, 35, from the savanna south of Agadez, but offers up little else. "I do not want any distractions," he finally says. "We are behind in our travels, so I do not want to be slowed more."

But he gives in a bit as we walk awhile, and he begins to drop some details about his mission. The caravan is heading toward the oasis towns of Fachi and Bilma, Aboubacar says, where it will collect salt mined from watery basins and transport it some 400 miles back to towns on the desert's edge. In the Sahara high-quality salt sells at a premium. In ancient times salt is said to have been traded ounce-for-ounce with gold. Before external sources of salt became available, combined caravans totaled 30,000 camels.

Aboubacar leads a train of about 500 camels, and it stretches in loose lines of tethered animals for about a mile. He's made the 30-day circuit to Fachi and Bilma 19 times, he says. On this trip he's brought along his son,







Fashioned from salty mud, tall white vessels, foreground, stored food during sieges of Fachi by raiding tribes centuries ago. A station on a caravan route in Niger, the village supports a French-speaking school, though attendance waned after independence in 1960.

As sands soften under the blistering sun, drivers deflate tires to improve traction for their groaning trucks. Temporary workers returning from Libya to Chad sit on bags containing goods ranging from prayer rugs to VCRs. Some passengers show their displeasure at being photographed.



ten-year-old Bilal, for the boy's inaugural tour. As we walk, Bilal plays with the camels. He runs off, exploring behind neighboring dunes. He teases the men who continue walking slowly and purposefully east.

After a few hours I share some hard candies with the men, a mix of sub-Saharan Hausa and, like Aboubacar, North African Tuareg, also known as the "blue men" for the way the traditional indigo blue of their veils and turbans—called *tigelmusts*—stains their skin.

As the sun sets, the men stop and kneel facing east toward Mecca to make the fourth of five daily prayers to Allah. Then, resuming their trek, they share their dinner with me. A Tuareg man named Badou offers me a bowl filled with a raw-tasting mix of ground grains, goat cheese, and water from goatskins hung on the camels' cargo racks. Eat up, he says, we have a long way to go tonight.

Badou halts his line of 34 camels and has its lead animal kneel. I climb aboard, and the camel rises and carries on in a bowlegged, rolling gait. It's comfortable, and I quickly settle in.

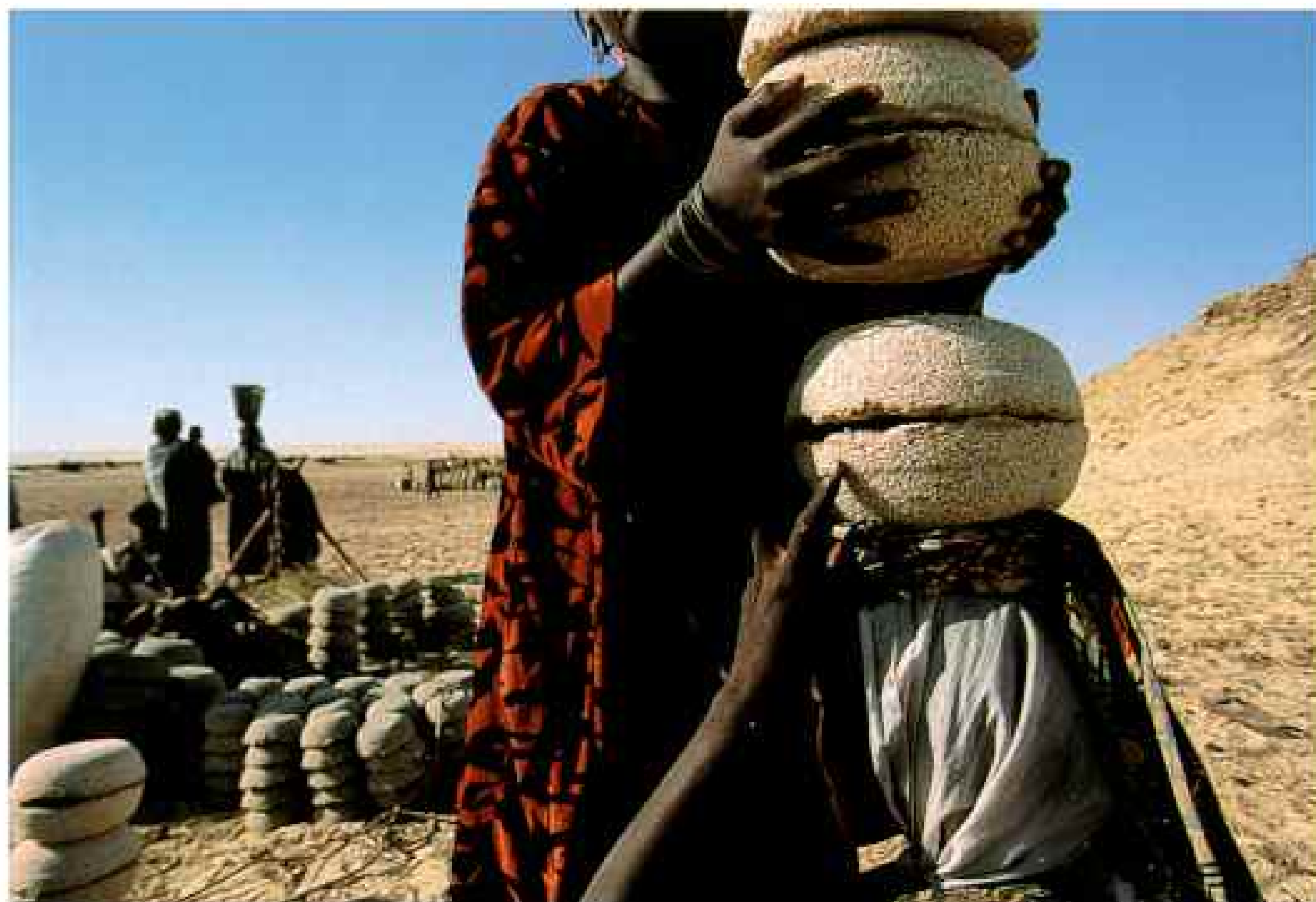
"Everything is fine?" Badou asks.

"Yes, yes," I reply.

Suddenly, after about five easy minutes, the load I'm seated on shifts abruptly—and I'm dumped unceremoniously ten feet off my steed's back onto the sand, barely missing a spinning ax as I fall. My tumble sets everyone laughing, and I take the fall as genially as I can; with their teasing I can tell I've been accepted. Without so much as a stern look, they stop the caravan and restore me and the scattered load back on the camel.

From the slow vantage of the camel's back, I have time to take a closer look at my surroundings. In the sand below, the desiccated body of a small bird—which obviously lost its bearings and died exhausted by the emptiness—passes beneath my camel's feet. In the northeast the Pleiades star cluster rises, showing the way. Around me the men walk on, filing knives and readjusting their camels' loads. Once in a while, to dent the boredom, a herdsman beats time to the camels' slow footfalls on a large brass bell, the sound rolling lonely across the desert night.

Fine-grained salt for human consumption—molded in bowls—is readied for a caravan leaving Bilma. Niger's lack of commercial salt mines or seawater for evaporation puts a high premium on a commodity taken for granted in other lands. "In this desert," says a Nigerien Tuareg, "salt is life."



Sometime after eleven o'clock the caravan stops, and the herdsman unload and hobble the camels with remarkable efficiency. After a night of dozing on mats near small fires, they rise in the predawn light and, with steel pokers turned red in the fires, cauterize wounds on the animals from the chafing of the cargo racks. Then they reload their camels with blankets, millet, and bales of hay.

From Badou's home south of Agadez, it's a six-day walk to the first town, Fachi. There he'll buy 50-pound pillars of animal-grade salt for 350 Central African francs (about 65 cents) each. Then, after resting the camels for a few days, it will be four more days to Bilma, where the caravan will buy purer salt. A few more days of rest and trading and the caravan—now heavy with salt—will retrace its steps out of the Sahara. Once home Badou can make a profit of about a thousand francs per pillar—or about two dollars. Each camel will net him up to \$16 for about eight salt pillars—a total of \$544 for 30 days of nearly nonstop walking.

In recent years faster and more efficient ways

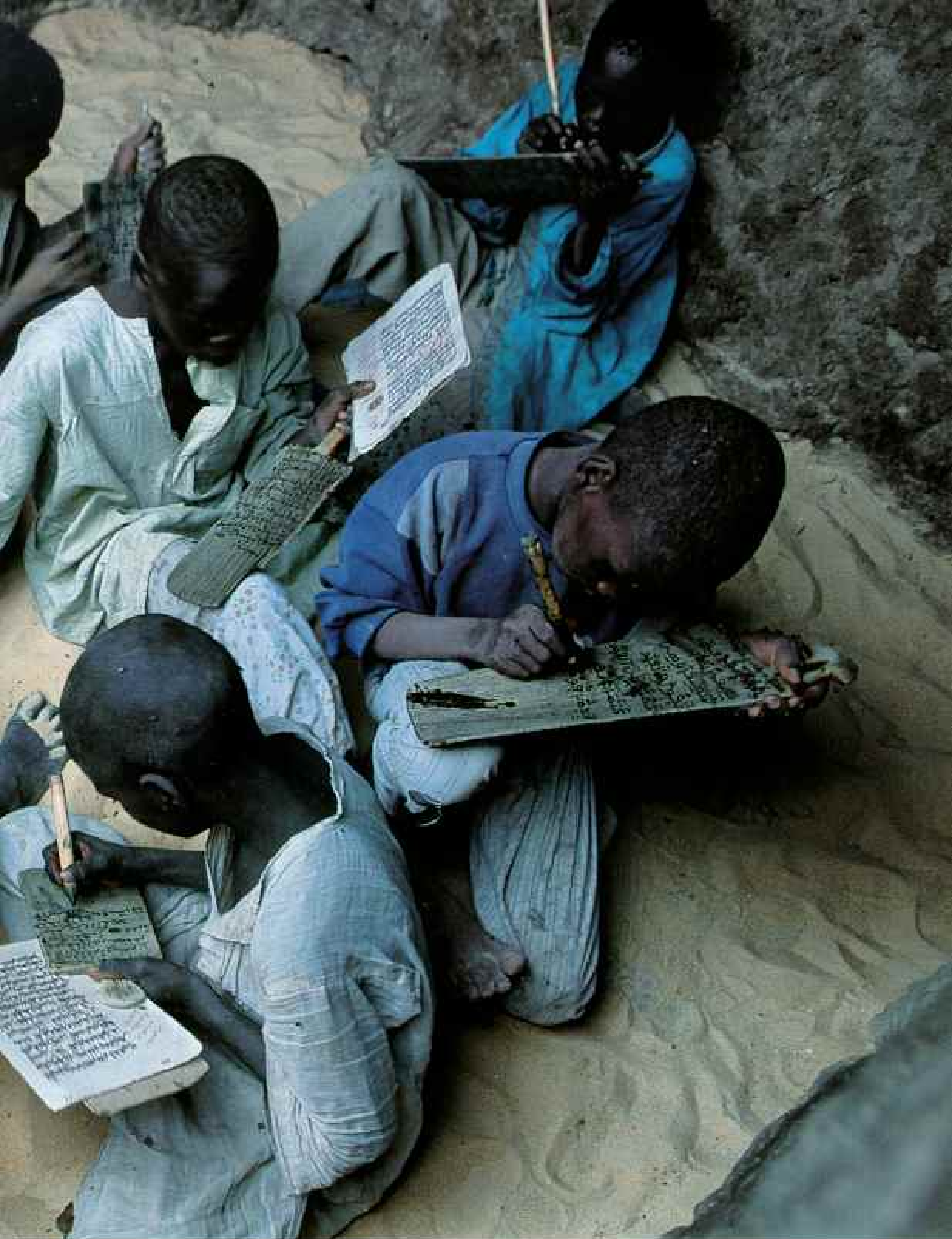
to transport salt have come to the desert. We've even seen a few tracks left by the lonely cargo diesels that move through every few weeks. "But the trucks are expensive to buy and maintain," Badou says, "while camels are inexpensive to keep and in winter can survive for more than 30 days on a little water and a little hay."

Badou smiles. "If you are not rich," he says, "there is only one answer: camels."

SALT CARAVANS aren't all that's kept intact by the Sahara's poverty and arid vastness. After three days with the caravan we arrive in Fachi, where a crumbling fort said to be at least 800 years old lies at the center of town. Dimly lit houses in the old part of town are surrounded by walled courtyards and streets too narrow to let two people walk abreast. The place exudes mystery. It takes two full days, in fact, to arrange an invitation here into the home of Marabout Kader, Fachi's oldest spiritual leader and keeper of the Koran.

Kader, a wrinkled old man, sits on a small





Allah speaks through nimble fingers in Fachi, where youngsters copy the Koran with ink made of water, charcoal, and gum arabic. Their task: Memorize all 114 chapters of Islam's sacred book. By reciting verses in a ceremony during adolescence, a boy becomes a man in the eyes of Muslim elders.

Standing fast in a changeable landscape, solid dunes are the work of the sun and morning dew. Over the ages the constant cycle of dampening and drying helped leach iron from the sand granules. The desert is only about 15 percent sand; the remainder is mostly gravel and rock.



rug in his house's large foyer. Behind him an interior courtyard opens beneath the hard light of a noon sky. At his side are stacks of flat wooden tablets, old and heavily grained, on which his students write their obligatory prayers. "You are here on a fortunate day," Kader says. "It is Friday. And each Friday afternoon I teach the Koran to the boys of town."

The point of the training, he says, is to memorize all the prayers of the Koran while also comprehending their messages. Then, once a year, some of the students recite a portion to the men of town as a rite of passage.

"To test what they've learned," Kader says, "I make them write what they've memorized. Like this."

He makes himself comfortable on his rug, lifts a wooden tablet, then sets to work writing in Arabic with a long quill. He grows lost in the effort, covering both sides of the plank, then reaching for a fresh one. The ink goes down dark, but as it dries the letters evaporate, leaving behind only faint shapes on the grayish grain of the tablet. Not that Kader cares. The

act of writing the prayers is what's important.

After completing a few panels, Kader stops to prepare for his students. His son makes him a glass of strong, sugary tea, and Kader drinks it down. He has a second, and a third. At two o'clock he turns toward Mecca and prays for the third time of the day, finishing as his students pour through his tiny wooden doorway.

Soon 11 teenage boys sit cross-legged in the ancient courtyard, with the marabout watching them write their lessons. After they're done, Kader asks them to recite what they've written from memory. It is a patience-testing drill, and the boys struggle. As they work, Kader smiles. He is slowly bringing these boys into religious adulthood, just as he was. "It is," he says later, "a life of satisfying work."

THE ABANDONED LAND CRUISER sits alone in an empty valley of the Ténéré, buried to its axles in sand, a vivid reminder of why the inhabitants of the Sahara so often call upon Providence. When we crest a sand dune and come upon it, our head

Mushroom cloud of stone erupts in the Ténéré desert, remnant of its watery past. This pedestal rock began as a mass of pebbly sandstone. Its sculptors were cycles of hot and cold, wet and dry, as well as blowing sand, which caused the sloughing off of shards scattered at the base.



guide, Mohamed Ixa, a Tuareg leader who is usually unflappable, is visibly surprised by the sight. He squints, rubs his chin, and brings our little caravan to a stop to investigate.

Sun and blowing sand have rendered the Land Cruiser's windows milky and portions of its body bald. Its tires have been baked to shiny hardness.

"There is history here," Ixa says. "This is the first time anyone has found this car." Three years ago, he explains, 35 people packed into three of these vehicles and left southern Algeria—which lies about 250 miles to our north—on a 500-mile trip to Agadez. They got lost and abandoned one vehicle after it began to fail. Three men were left with the car to guard it. They were eventually found—dead of thirst in the scant shade the car provided.

When the car we've discovered broke down, three other men got in the last vehicle and drove toward Agadez. They were eventually found dead too. They left behind a note giving directions to the survivors. "But they were never found," Ixa says. "So somewhere

around here, 29 people—mostly women and children—died."

Steinmetz walks to the driver's door, opens it, and is hit by a blast of hot gasoline-scented air. We find an empty hundred-liter water tank, a half dozen empty jerry cans for fuel, and a few poignant clues: a rubber and canvas sneaker . . . a cup for tea . . . a safety razor.

For the next hour we search the sand for remains. "They probably abandoned the car when thirst got bad," Ixa says. "Not a smart thing to do, but a desperate one. They probably walked west, toward Agadez, though they had no idea how far away they were. These people were very lost."

In the Sahara a person sweats about two gallons of water a day—four if walking. By the time one of these travelers lost roughly a gallon of water, without any liquids to replace it, he would have experienced dehydration: parched skin, dizziness, fatigue, loss of appetite, a low fever, and irritability.

By the time he lost a little more than two gallons of fluid, he could no longer stand upright;





On the cusp of springtime, a solar spotlight flares on Ounianga Kébir, an extremely salty lake in northern Chad. Springs of fresh water feed stands of palm trees on peninsulas formed by blowing sand being funneled through mountain passes.

swelling thickened his tongue and rendered swallowing difficult; locomotion—even on hands and knees—became impossible; his outer layers of skin began to tighten, darken, and split; and his kidneys and liver began to fail. As his body's core temperature rose, his central nervous system could no longer control his heart rate or breathing, leaving him to drift off into coma and death.

"Two years ago a friend of mine got lost out here for nine days," Ixa says. "By the time we found him, his face was black. We could not tell who he was. Not until we got some water into him and he regained consciousness a few days later could he speak his name. Then, we were all shocked."

In the central Sahara ask anyone about dying of thirst, and you'll get a story. There are the German honeymooners who became lost in their old Volvo and died up a canyon in search of shade and water. Or the local adventure-guide who carried two clients into the Ténéré in a single Range Rover. After the vehicle broke down, the guide died of thirst walking out to search for help. Or the truck driver who ran out of fuel and nearly perished of dehydration. As he was dying he had a vision: drain the oil from the crankcase, pour it into the diesel tank, and run the truck on oil. (It worked; he lived.)

Then there was the French couple and their six-month-old baby who were found dead in the middle of the desert, far from any established routes. From a journal found at the scene investigators learned the gruesome details of their ordeal.

As their thirst grew perilous, the young parents cut themselves, giving their baby their own blood to drink. The husband died first, his wife went a few days after him, leaving their infant alone in the vast desert. But as the woman lay slowly dying, she wrote in her journal describing the beatific silence and glorious swarms of stars of the desert night sky.

HAVING FACED DOWN the worst heat and distance of the Ténéré, we suddenly come upon the town of Bilma, an Eden in the furnace of sand. Here groves of date palms grow and pools of clear water burble from the ground thanks to a fortuitous break in the desert's deep substrate of rock. One morning, standing at the edge of a

pool, I notice an outflowing creek and follow it. Stepping through a wall of brush, I come across irrigation ditches running off the creek into dozens of gardens: corn, cassava, tea, groundnuts, milo, hot peppers, even some orange, lime, and grapefruit trees.

It's just after seven in the morning, and no one is around. I push on another hundred yards and find a huge pool—several acres across—mirroring the sky, surrounded by a carpet of short green grass and date palms. Donkeys and goats graze. Hand-size fish fin in the pool's depths.

An hour later, heading back to town, I come upon an outpost alone in the desert. Surrounded by cactuses and scrub, it's the local weather station, and the gray-suited man running it is Bilma's weather officer, Nouhou Agah. He may have the least demanding job for a thousand miles. Each day the sixtyish Agah rises, checks the rain gauge, anemometer, and barometer, then writes his findings in a ledger, which he sends off to the capital of Niamey once a year.

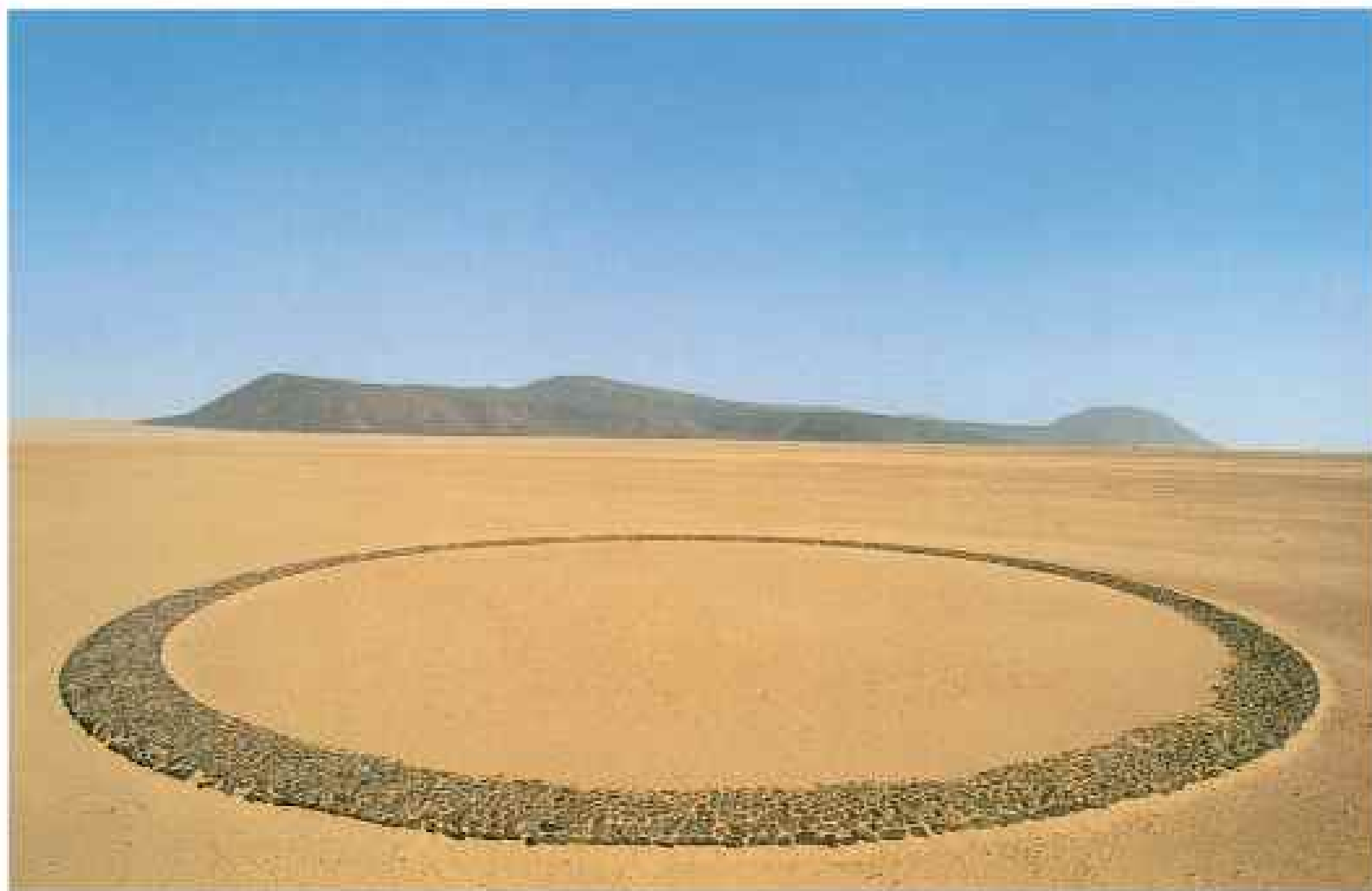
"It has not rained much here in 50 years," he says. "But this year, we got 30.4 millimeters in the months of June and July. That's the most rain in half a century. Next year, we should have a wonderful date crop. Inshallah."

He leads me into his shady office, filled with broken meteorological equipment. "This is it. This is my life," he says. Sitting at his desk, in no hurry, Agah leans back in his chair.

"I will tell you something about the Sahara," he finally says, pulling off his gold-rimmed glasses to wipe them clean. "This desert is very simple to survive in. You must only admit there is something on Earth larger than you . . . the wind . . . the dryness . . . the distance . . . the Sahara. You accept that, and everything is fine. The desert will provide. Inshallah. If you do not, the desert will break you. Admit your weakness to the Sahara's face, and all is fine."

This year, he says, Bilma has obviously resigned itself to the power of the desert, and it is being handsomely compensated. He shows me his precipitation ledger, running a finger down its grid of mostly zero rainfall totals. He points out April 29: 1.5 mm of rain. On May 6: Trace. On July 21: 1.1 mm. And—he gets excited—on August 4: 10.5 mm, less than half an inch. "A downpour like we have not seen in most people's lives," he says.

Stark circle of rock measuring about 60 feet in diameter lies in the Ténéré desert below the massif of Adrar Madet in Niger. Roughly a mile away in each of the four cardinal directions, similarly crafted arrows point away from the circle, whose origin, purpose, and age remain a puzzle.



He stands and goes to a steel cabinet in the office's corner. "Here," he says, returning to the desk with the 1996 rainfall ledger and flipping to its tally page. He drops his finger onto the annual rainfall total: 1.3 mm.

"That's less than a sixteenth of an inch," I say.

Agah smiles. "Yes," he says. "You understand, now? This was for all of 1996. That year the desert was larger than anything."

THE DESERTS of Niger and Chad differ, with the topography of each roughly mirroring the spirit of its people. Niger's Sahara is a world of smooth dunes and the friendly—almost courtly—Tuareg. Chad is a land of stony, eroded landscapes and the rock-hard Toubou, a seminomadic people whose men wear long daggers lashed to their biceps like advertisements of ferocity.

"The Toubou are quick to pull their knives," says our guide, a Milanese physician named Piero Ravà, whose tourism company, Spazi d'Avventura, is the first one inside Chad's Sahara. Ravà isn't kidding. A few weeks later I tour a hospital in the town of Faya-Largeau

and find that half the men admitted were there after being wounded in knife fights.

The Toubou inhabit a desert characterized by rocky spires, volcanic peaks, and screaming gales. So it's fitting that as Steinmetz and I cross into Chad's Sahara, a relentless wind from the northeast, called the harmattan, greets us. This wind whips the desert, turning its air to a gritty scrim so dense the sun behind is a pale disk you can stare at directly. It signals an end to the 60- or 80-degree cool of North African winter. When it leaves, the roasting 120- or 130-degree heat of the Saharan summer will arrive, bringing with it the relief of occasional rain.

The habitable edge of Chad's Sahara is the regional capital of Fada, a punishing 550-mile, three-day drive northeast from Chad's capital, N'Djamena. Remnants of the war with Libya—which broke out when Libya seized the northern half of Chad—are the trip's recurring theme. After seven years of conflict France helped its former colony drive the Libyans home. As they fled, the Libyan forces abandoned an estimated billion dollars' worth of military equipment.





Ghost town of Djado is steeped in moonlight and mystery. Once it was a station on a slave-trading route between Niger and Libya. Surrounded by malarial swamps, adobe dwellings are now occupied by scorpions and snakes. Itinerant date harvesters prefer their own palm-frond shelters.

Among the refuse was a rocket-launch truck twisted and scorched to a husk; Libyan military helmets, boots, and bones—mostly femurs and ribs—scattered across the desert; artillery shells, rifles, rocket-propelled grenades, and the roofs of buried personnel carriers poking from the sand; and those pale disks at the roadside—a few of the 70,000 antipersonnel land mines still buried here. As we crest one last rise—seeing Fada beyond—the turret of an exploded Russian T-72 tank, flipped and tossed away like a toy, stands between us and town.

Fada—held by Libya from 1980 to 1987—has returned to its former life as a Chadian trade and military outpost. Children play soccer in the large, dusty town square. They shoot at goals made from emptied 55-gallon fuel drums and dodge the donkeys, goats, and smoking diesel transports that regularly wander into their field of play.

At the southern end of the square is a market, where nuts, water, rice, soft drinks, tea, clothing, sandals, dried dates, meats, okra, and *pili-pili* (a ground hot pepper) are sold from tiny, dark shops. An enormous military garrison dominates the square's western side: thick, two-story walls of plastered mud-brick topped by razor wire and the blue-yellow-and-red Chadian tricolor. Sentries survey the square from watchtowers and a bulletproof kiosk at the fort's gate. The paranoia of enemies and spies remains so great that no one is allowed to photograph the place.

After a few minutes in town an offer arrives. Abdoullaye Djouho has invited us to tea in his garden, which—with its palm trees and yellow-flowering shrubs—is a welcome respite from the remains of war we had been seeing. Seated on a large mat of green wool in the midst of his garden, Djouho, a genial Toubou gentleman, is dressed in flowing white robes and a white skull-cap. A bright white bandage covers his right leg. "Welcome," he says, a smile creasing his gaunt cheeks. Around us Djouho's private oasis stretches placidly away, complete with a thicket of palms surrounding a small rocky pool.

As we all lift a hot glass of tea, Djouho says, "This is the most beautiful place in all the desert. It is peaceful and civilized, made more that way because it is surrounded by so much sand and rock."

As a young man, he tells us, in 1967, he went into the mountains of northern Chad to fight as

a revolutionary against the French Army and Chad's French-backed government, earning a place inside a new regime in 1979. Today he is subprefect of Chad's largest district, the nearly 200,000-square-mile area called BET, shorthand for the badlands of Borkou and the mountain ranges Ennedi and Tibesti. Taken together BET encompasses Chad's entire northern half. "After roughly 30 years of war," Djouho says, "what I see is the people being tired of war. They want peace. They want prosperity."

He holds up his thumb and index finger, pinches them almost together, and regards the slim space between. "We need just a little foreign investment—this much—and this part of Chad will prosper," he says. "There is great mineral wealth here. Natural gas. Uranium. Oil. We hope the French and Americans realize this. Both are here prospecting now. All we need is for people outside Chad to know the

Pungent, eye-catching foodstuffs—garlic, red peppers, okra—await shoppers in Faya-Largeau. Farming is highly concentrated in the Sahara. Except for the Nile Valley, this 3.5 million-square-mile desert has but 780 acres of oases, which require frequent irrigation.

Largest city in the Chadian Sahara, Faya-Largeau is a regional capital and the last important base abandoned by Libya in 1987 at the end of its war with Chad.



war is over, that life has again grown calm.”

Djouho then begins to unwrap the bandage on his foot. “Of course,” he says, “I understand that the war is only over in people’s souls. It remains very real out in the desert.”

He finishes unwrapping his foot, and what emerges is horrific: His toes are round and soft as overripe grapes, his ankle puffed with fluid; there is no heel, only flesh cantilevering out from the top of the bloated ankle and across the broken upper arch of Djouho’s foot.

“This happened the ninth of May 1996,” he says. “I had just been made subprefect here, and I was traveling around the district, meeting people. We were near the old airfield in Ounianga Kébir, and we went off the road and drove over a land mine. Four people in my car were gravely wounded.”

I have to ask: “I recognize what Chad has to give to the world now,” I say, “but because of

all the weapons still here, do you agree few outsiders will come and visit?”

Djouho chews on the question for a moment. “Yes,” he finally replies. “But after 30 years of seeing war and its ravages, I have to be an optimist. There is a better future ahead. There is no other choice.”

OUNIANGA KÉBIR, where Djouho was wounded, may be one of Chad’s best hopes for a better future. Despite the potentially dangerous remnants littering the region, the conflict seems forgotten here, and capitalism carries the day. All across town there’s the snappy energy that often accompanies commerce in the Sahara. It is ironic that most of what is bought and sold is trucked in to this broad, dun-colored plain from Chad’s former enemy and more affluent neighbor, Libya.







Knee-deep wading is bliss for camels in Chad's Archeï, a canyon whose trapped waters hold a zoological surprise. Fertilized by the beasts' droppings, algae are eaten by fish that are preyed upon by an isolated group of crocodiles.

The trucks—big green flatbed diesels—are loaded to preposterous heights. Boxy steel shipping containers provide the sturdy foundation for huge burlap sacks containing prayer mats, sandals, blankets, clothes, tinware, hay for animals, sheet metal, empty 50-liter water bottles, and woven plastic bags labeled “China Rice/Product of Libya.” Then—often 15 to 20 feet off the ground—rides an upper layer of passengers draped in robes and packed together as tight as the rice in the white sacks they sit upon.

The town of Ounianga Kébir is the first checkpoint inside Chad for trucks, which must stop for a customs inspection that can take a few days. In the shade of one of the lorries, seated on a large plastic mat and killing time with a game of hearts, I meet Mashala Kouri, the 28-year-old leader of a three-truck caravan headed south.

Kouri drives a 2,500-mile circuit from his home in the Libyan oasis of Kufra to the capital of N’Djamena and then on to Kutum in Sudan before returning home. “It’s three weeks, start to finish, eight days from Kufra to N’Djamena,” he says in broken English. “Each trip, for driving, I make \$3,000. Very good money.”

Kouri says his truck is carrying “everything, everything, everything,” but his biggest, most valuable cargo is tucked inside the shipping container. “In there is electronics equipment: TVs, VCRs, satellite dishes. They came into Libya from Dubai, loaded off ships from Singapore and Japan. They came on a truck to Kufra, where I buy the container and take it south.”

In Libya, Kouri says, almost every house is part of the television age. “We all have satellite dishes too,” he says. “Colonel Qaddafi watches CNN. I like to watch that too, but I also like NBC. *Friends* and *ER*. The best!”

While radios are fairly visible in Chad, televisions are still a rare commodity. But if Kouri and others like him are successful, that will soon change.

Kouri leads me up a ladder to the top of his truck, where—balancing on rice bags—we gaze across the brick, single-story shops and houses of Ounianga Kébir. He gives me a can of orange soda, sun-hot but good, a Libyan import rarely seen across Chad’s Sahara.

“See?” he says, taking a sip from his own can, “the view is good from here. It is high up. But in the desert when we travel, it is hot and windy. It is a very inexpensive way to go from Libya

Home fires burn at daybreak, boiling tea and quenching the late November chill at Tezirzek near Niger’s Air mountains. Dafi-leh Abegihay awaits the return of her husband, away on a two-month-long caravan. After breakfast she will mind the children, tend the livestock, and grind grain in a mortar. The rigors of desert life demand family teamwork and unrelenting toil—just to survive.



to Chad. I charge 15,000 Central African francs [about \$30] per person for the trip. It is slow, but the price is right.”

Calling the caravan’s trip slow is an understatement. Overheated engines and punctures in the truck’s bald tires stop Kouri’s convoy a dozen times a day. At each delay the truck’s passengers climb down from their seats, find spots to rest in the truck’s shade, and wait. Sometimes, if the repair is extensive enough, they make little fires and brew pots of tea.

If a tire is flat, rather than jacking up the truck and its impossibly heavy load, the team of drivers does the opposite. They insert stout wooden blocks between the sand and the truck’s frame, then dig into the sand beneath the afflicted tire until it hangs free in the air for change or repair.

Like us, Kouri and his passengers don’t travel at midday, but unlike us they drive



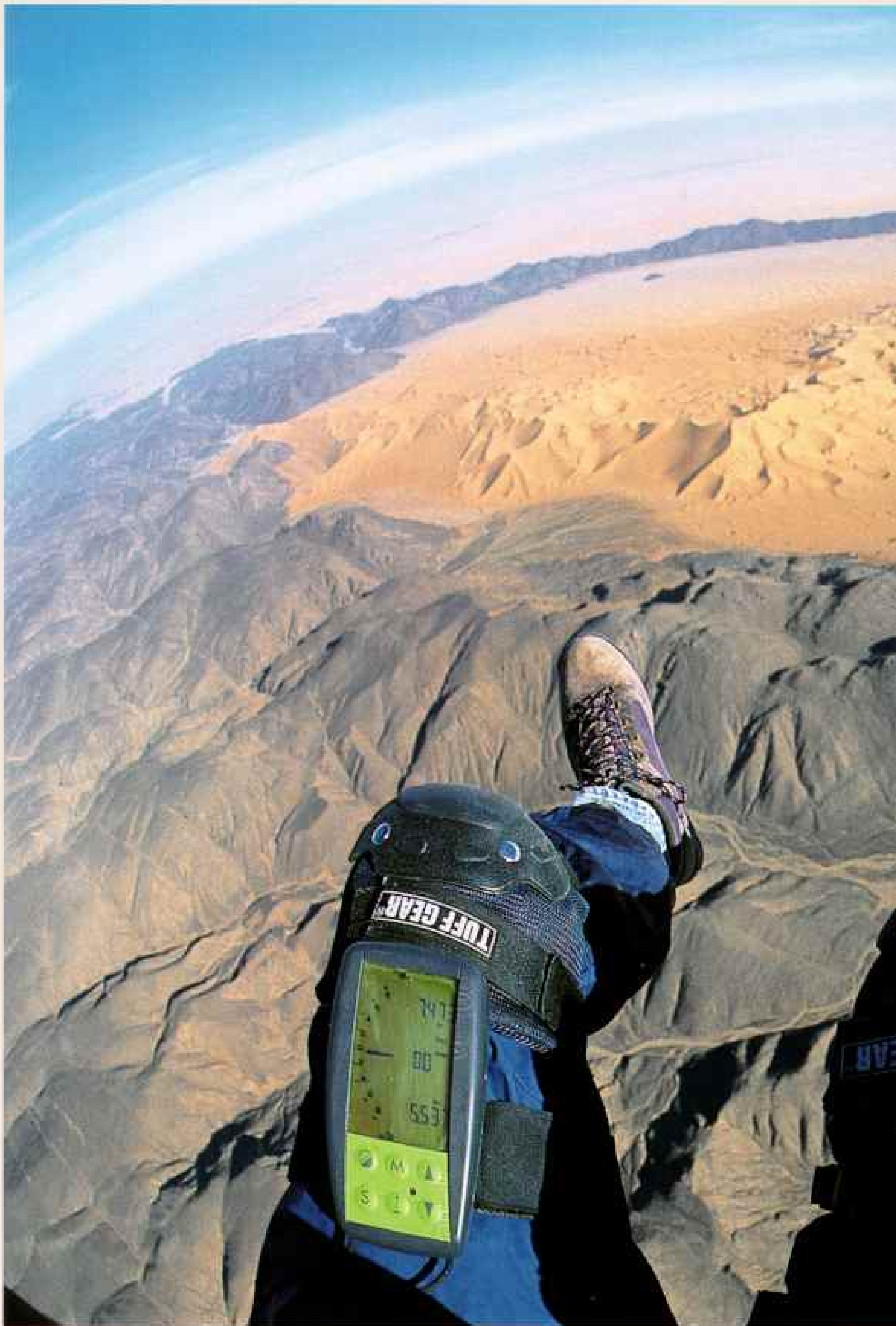
through the night, their massed humanity keeping bandits away. Still, in our fast four-wheel-drive vehicles we gobble up so many miles that for the next week we play hopscotch with Kouri's caravan, meeting and passing it daily before it again overtakes us in the night. Each time we see one another we stop, shake hands, and trade food for water, quickly falling into the ancient rhythm of two groups of nomads, cooperating to survive.

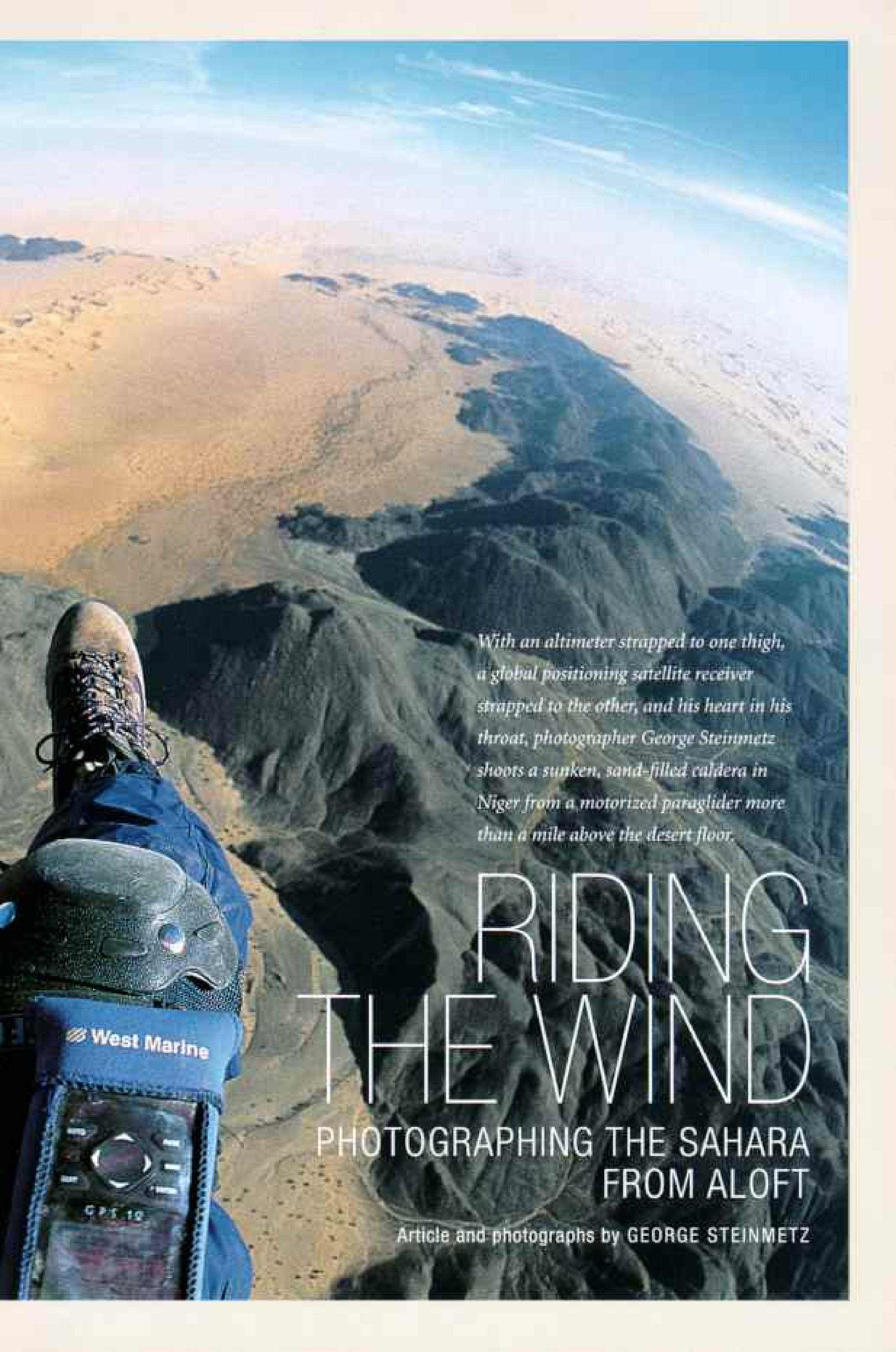
INSHALLAH. The desert is larger than anything, and now it is time to begin crossing it for home. Shortly after we leave Ounianga Kébir, Steinmetz and I part company. He'll head north, to photograph the people along the Libyan border. I'm beginning a long, four-day car trek back to N'Djamena.

Along the way I'll join a group of Italian tourists, down from the late winter Mediterranean

for some exotic landscape and heat. We'll talk of fresh vegetables and cool showers in real hotels; witness a camel caravan complete with a black-draped princess of the desert, who rides mostly hidden inside a padded box on her camel's back; and be battered nonstop by the worst blows of the harmattan all spring.

On my last night in Chad, under a dark, harmattan-fouled sky, I remember the women at the well in Diona. I smile and shake my head at their resigned assessment of the old man's impending death, their view of life hard-bitten because so little insulates them from its pains. I'm also forced to agree with them. Across the Sahara—or anywhere else—they're right. People die, life goes on, and sometimes it's good to be reminded that all any of us should hope to expect is some water and a little shade. Beyond that, everything is up to larger forces. Inshallah. □





With an altimeter strapped to one thigh, a global positioning satellite receiver strapped to the other, and his heart in his throat, photographer George Steinmetz shoots a sunken, sand-filled caldera in Niger from a motorized paraglider more than a mile above the desert floor.

RIDING THE WIND

PHOTOGRAPHING THE SAHARA
FROM ALOFT

Article and photographs by GEORGE STEINMETZ

My life hangs by the threads of Kevlar parachute lines. My hands fumble while changing lenses on the camera dangling from my neck. I'm afraid of dropping a lens and having it

fall into the propeller whirling at my back. At 7,500 feet, I'm higher than I'd planned to go, but it's the only way to gain the perspective I want on the immense volcanic crater below. Concentrating on my viewfinder helps control the fear.

I'm soaring above the central Sahara in a powered paraglider, a single-seat aircraft that looks like a flying lawn chair. Developed in France, it combines an inflated, parachute-like wing with a 50-pound motorized backpack. With three gallons of gas I can stay up for about two hours. But a sudden gust can cause its air-filled wing to collapse catastrophically. And there is always the danger of being blown so far off course that I would die of thirst or exposure before my companions found me. Deciding to use the motorized paraglider was difficult, but I had little choice. In country that counts few airplanes and no helicopters, I needed a portable craft that I could haul around the roadless desert.

For safety's sake I enlisted the help of two expert French pilots: François Lagarde, a physician and powered-paragliding enthusiast, and Alain Arnoux, the sport's reigning world champion. Both men joined me in the Sahara. I spent six weeks learning how to operate the contraption, which gives me unrestricted 180-degree views for photographing this little-known world. Arnoux's instruction gave me the confidence to concentrate on taking pictures while doing tricky maneuvers.

And now the risk is rewarded. As my partners and I drift high and slow, the desert is stranger and more beautiful than I imagined. It seems as if planet Earth has had its living skin peeled away, revealing something more akin to Mars. From on high we find things to explore later on foot: dry river channels that once watered dinosaurs, ceremonial sites of prehistoric peoples, and traces of camel caravan routes not noticeable from the ground.



Flying actually brings us closer to the desert: With no fuselage, we are fully exposed to the sun and wind that shape this land. We become students of those winds, reading their imprints on the dunes like kayakers scouting rapids.

Even my expert companions considered the flight conditions capricious and challenging. We sometimes found ourselves flying backward in sandstorms. Yet during three months in the Sahara, we flew more than 200 hours without accident. It's a dangerous place to trust new technology, and I was relieved to leave the desert. Occasionally I find its austere beauty pulling me back, and then I recall the remark of an old barefoot nomad who had watched us fly: "They want to die," he said, "but God has not chosen their time."



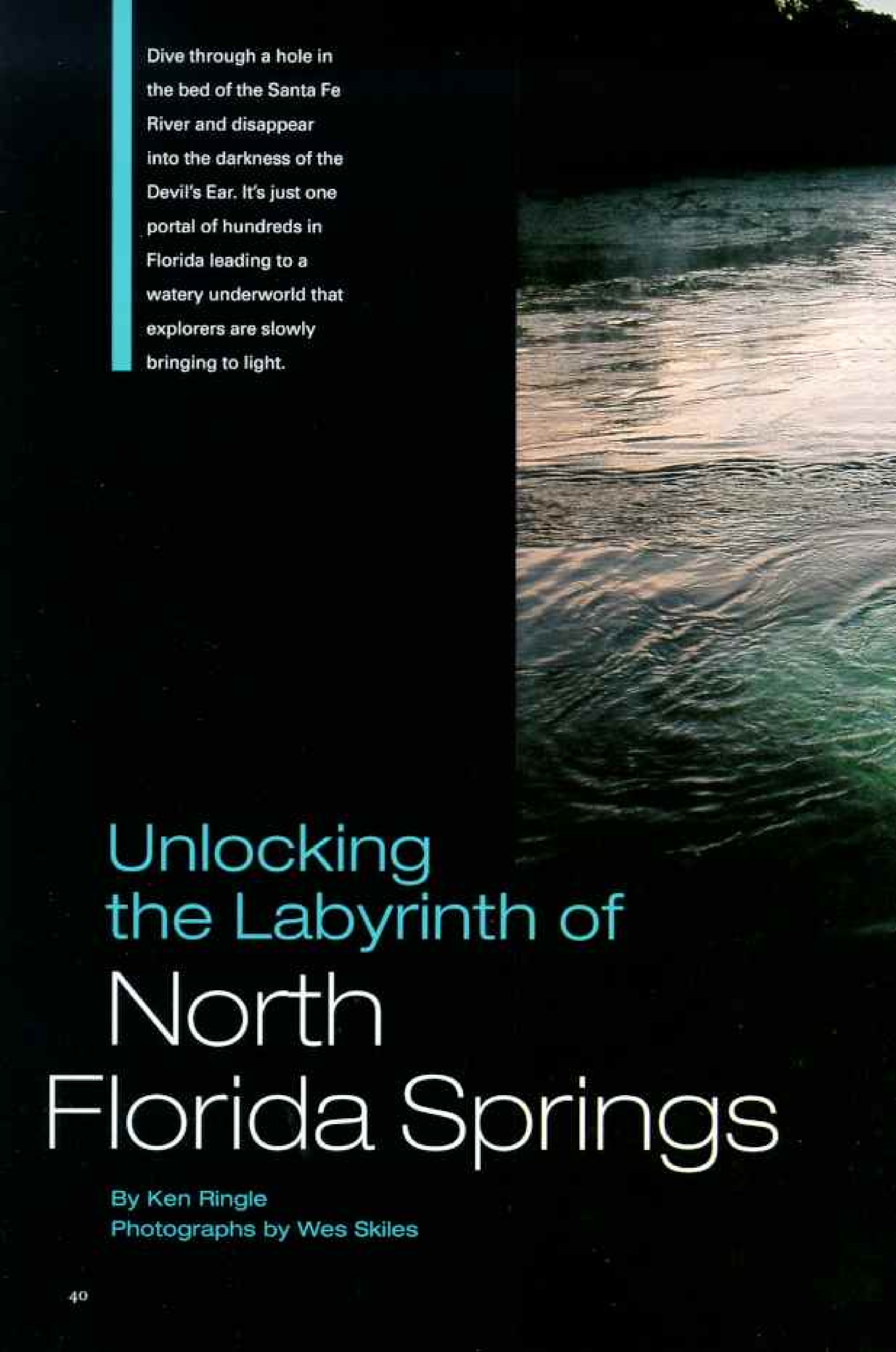
DONOUAN WEISZTER

All eyes turn to François Lagarde as he swoops over the village of Timia in Niger (above). In Fachi he helps Steinmetz take off in dangerously strong winds (left). Lagarde accompanied the photojournalist as flying coach and medical doctor ready to treat injuries in case of accident. Mercifully, none occurred.

*in grand solitude Logarde adds his shadow
to the Ténéré dunes. "Falling from 300
feet or 3,000—you're just as dead," says
Steinmetz. "But there's safety in altitude.
If there's a problem, you've got more time
to figure it out. It can be unsettling up
there. And very lovely in its isolation." □*





A photograph of a river with a hole in the bed, showing water flowing through a dark opening. The water is dark and turbulent, with white foam visible as it flows through the hole. The surrounding water is a deep blue-green color. The background is dark, suggesting a cave or a deep crevice.

Dive through a hole in
the bed of the Santa Fe
River and disappear
into the darkness of the
Devil's Ear. It's just one
portal of hundreds in
Florida leading to a
watery underworld that
explorers are slowly
bringing to light.

Unlocking the Labyrinth of North Florida Springs

By Ken Ringle
Photographs by Wes Skiles







TIGHT PASSAGES squeezed new ideas about equipment design out of cave divers, including air tanks that can pivot or be repositioned. Such on-the-fly flexibility has doubled the number of sites that divers can wiggle their way into.

THE COLD, MURKY WATER of the Santa Fe River didn't seem unhealthy or unnatural. Just creepy. Normally crystal clear, it was now almost opaque with tannin-stained runoff from the rain-swollen cypress swamps upstream. Even with my diving light I could see less than a foot ahead, but I could sense a faint warming—water gushing up from the Floridan aquifer here at Ginnie Spring. As I swam down toward the source, I stuck out my arm and felt rock, then the edge of an opening in the river bottom—a cave entrance called the Devil's Ear.

Clutching the rim, I pulled myself down against an upwelling current much stronger than that of the river. My fins struck stone, and my tanks scraped wall. The passage wasn't tight, but it was narrow enough for me.

Down, down. Not so much swimming as rock climbing upside down. In darkness. My diving light showed nothing but its own lens.

in a cavern 20 feet across and 8 to 15 feet high. It sloped down into a wider room from which other bulbous chambers bellied out into a half dozen tunnels and passageways, each branching and branching again, down and away into the darkness.

And from each, like the life force of the Earth itself, poured the aquifer's enormous flow. I could feel its current against my skin and wet-suited chest. Had I let go of my rocky handhold, I would have shot back up the chimney. The tunnels down which I shone my light were empty of anything but water, yet the power of the current surging from them gave the eerie, pulsing sense of geologic life. It was like crouching in the aorta of the world.

I removed my regulator mouthpiece and gulped the water, mesmerized by the occasional grains of sand speeding by. Where had they come from? And where were they bound?

I was two weeks into an exploration of Florida's freshwater springs. This bountiful aquatic network, which honeycombs the northern

half of the state, has mystified everyone from the Spanish explorer Ponce de León to the rubber-suited conquistadores of contemporary hydrology.

So abundant are the 320 springs that the 97 largest alone—most of them far from the state's urban centers—discharge some 7.7 billion drinkable gallons a day, 200 million more than Floridians consume daily from all their wells and watersheds put together.

So beautiful are the springs that they nourish a prosperous recreation industry, from families tubing beneath

waving Spanish moss at Cypress Spring to glass-bottom boaters at Silver Springs to the famously kitschy mermaids of Weeki Wachee.

"Most people think of Florida just in terms of Disney and beaches," says photographer Wes Skiles, who grew up in High Springs, just a few miles from the Devil's Ear. "But here in north Florida a whole culture has grown up around these springs. Families come and camp for weeks to swim and dive in them and float the rivers. The water is so clean and clear that canoes look like they're floating on air."



SPRING-FED FUN makes a snorkeler smile at Rock Bluff Spring, a popular swimming hole. Crystal clear water lures cave divers to Little River Springs (opposite), where a palette of freshwater blues gives way to the murky Suwannee River.

Then, about 30 feet down, the water gradually cleared. I was in a twisting rocky chimney about five feet across. Below me the cave elbowed off 90 degrees to my right above a white sand bottom.

I swam through the elbow and found myself

KEN RINGLER, who writes on everything from opera to politics for the *Washington Post*, has dived on reefs and wrecks from New England to Brazil. WES SKILES photographed one of the world's deepest cave systems for the September 1995 issue. He has also explored one of Earth's longest underground rivers, in Puerto Rico.



YET THE SPRINGS REMAIN profoundly mysterious. The rivers they feed arise for no obvious reason in one spot and vanish just as curiously in another, whirlpooling underground with a force that can suck whole trees out of sight. Entire spring-fed lakes, fresh and abundant most of the year, disappear almost overnight in dry seasons, siphoned suddenly underground as if God pulled the plug in a bathtub.

Scientists know that many of the springs are interconnected, draining an aquifer that reaches at least as far north as South Carolina. But they've never known exactly how. Only in the past decade or so have they begun to appreciate the complexity of the watery network lacing the limestone and dolomite geology of north Florida—and the dangers to the springs posed by the region's growth in population, agriculture, and industry.

For years many people assumed that the springs were outlets of huge underground rivers, geologic curiosities draining far distant uplands north of the state. Most Florida rainfall, it was thought, ran off as surface water before ever reaching the springs.

But in recent decades, partly through the efforts of a handful of dedicated cave divers,

that explanation has proved too simple. Probing miles into the clefts and crevices from which the springs' water pours, the divers have discovered that a watery interstate highway system does indeed flow beneath north Florida's moss-hung live oaks and sandy soil. But it's not just a one-way system flowing downhill from Georgia. While a small part of the flow from any given spring comes from far away, most originates as rainfall closer to home. Water is entering and leaving the Floridan aquifer all the time, sometimes bound for distant destinations, sometimes for the hydrologic equivalent of a trip to the nearest mall.

Much Florida rainfall drains directly into the state's rivers and creeks as surface runoff, as the Santa Fe's tannin-stained flow was proving darkly before my diving mask. But vast amounts also percolate through the subsoil to nourish the riverine network that underlies the state and feeds the springs. And that rainwater carries with it pollutants unfiltered by the grass and soil above, making Florida's historically pristine springs a potential chemical mirror of the surrounding environment. As the number of people and farm animals living above them continues to grow, the future of the springs has begun to darken.



BUBBLING FORTH

under deep cover, Bosel Spring flows to feed the Chipola River. “Exploring this system is a delightful game,” says photographer Wes Skiles, a cave-diving veteran. “The trick is to figure out where all this water is coming from.”

Although he and his family used to vacation occasionally in the Florida Keys, Wes Skiles’s earliest obsession was freshwater wonders like Ginnie Spring, a scuba-oriented campground on the shores of the Santa Fe, about 20 miles northwest of Gainesville. He was diving the springs at 12, probing their caverns at 16, and by 20 had helped devise many safety procedures that now regulate the potentially deadly sport of cave diving.

Unlike open-water diving, where the major hazards are associated with depth and uncontrolled ascent, the great peril in cave diving is disorientation. Cave divers always carry at least three lights, and they try to swim head down and fins up to avoid stirring up blinding storms of silt. But accidents still happen.

“It’s so easy to get lured into a cave entrance by curiosity,” Skiles says. “You swim in against the current to explore one of several tunnels and think you can just follow the current back out. Then you discover that all the currents don’t go back out, and your sense of direction gets confused by the silt you stirred up on the way in. And if you haven’t laid a guideline back to the entrance, you run out of air following clear passages you’re absolutely certain must be



the way out—passages that are really leading you farther underground.”

Two dozen divers perished at Ginnie Spring before the present owners barred off the major tunnel in 1976. It was just too hypnotic.

“I suppose I’m lucky I wasn’t killed in those early days,” Skiles says, “but I learned to be very careful. I had to retrieve a number of bodies of divers who weren’t.”

So total was his fascination with Florida’s springs that he toured the state exploring them on weekends and bypassed college for a hands-on self-education in geology. He now owns his own firm dedicated to underwater film work and subsurface hydrogeologic studies.

“There are very few places nowadays where the average person without a lot of money can



still extend human knowledge as an explorer," Skiles explains. "But deep in the cave systems of the Florida springs, that's what you are."

Brian Katz agrees. Katz, a groundwater geochemist with the U.S. Geological Survey in Tallahassee, points out that an elite group of Florida's cave divers "have greatly expanded our knowledge and understanding of how these springs work. And probably just in time."

Although the Geological Survey has been monitoring the springs since 1907, Katz notes that "all of us were slow to realize how vulnerable these systems are. Their water flow has been so huge and so pure for so long that there's been a tendency to think it's inevitable."

It isn't. Though most of the springs remain pure, in recent years chemists have begun to detect alarming traces of nitrates in a number of springs, especially in counties containing more chickens and dairy cows than people.

In addition to transporting groundwater over great distances, each spring swallows enough runoff from its own watershed to reflect local conditions above ground. And while the new golf courses and old cow pastures of the sparsely settled rural counties in north Florida look bucolic enough, hydrologists have discovered that grass and sandy soil are surprisingly limited in their ability to filter out contaminants.



"IT GETS REAL COLD by the end of a 30-minute show," says mermaid Beth Thomas, who dips, flips, and lip-synchs through "The Little Mermaid" at Weeki Wachee Spring. The temperature of these freshwater founts, typically near 72°F, proves balmy to manatees—said to be the "mermaids" of sailors' imaginations. Hundreds migrate from coastal waters to Florida's springs each winter.

Increasingly, local officials find themselves refereeing citizen arguments over how many people, chickens, dairy cows, fertilized fields, or septic tanks each watershed can handle. "All we seem to hear these days are people telling us we can't do this or that without contaminating the groundwater," says Jerry Wright, a zoning board member in Gilchrist County. "And they've always got experts with Ph.D.'s on both sides of every question. How are we supposed to know who to believe?"

It's a good question. There's so much water tunneling its way under north Florida that it's hard to know with absolute certainty where any one drop comes from. Yet the chemists and

cave divers are learning. They can even tell how long rainwater has been in the aquifer by measuring the relative concentration of chlorofluorocarbons, or CFCs, compounds released into the atmosphere during the past 40 years as aerosol propellants and refrigerants. The average time spent underground by a liter of springwater: 20 years.

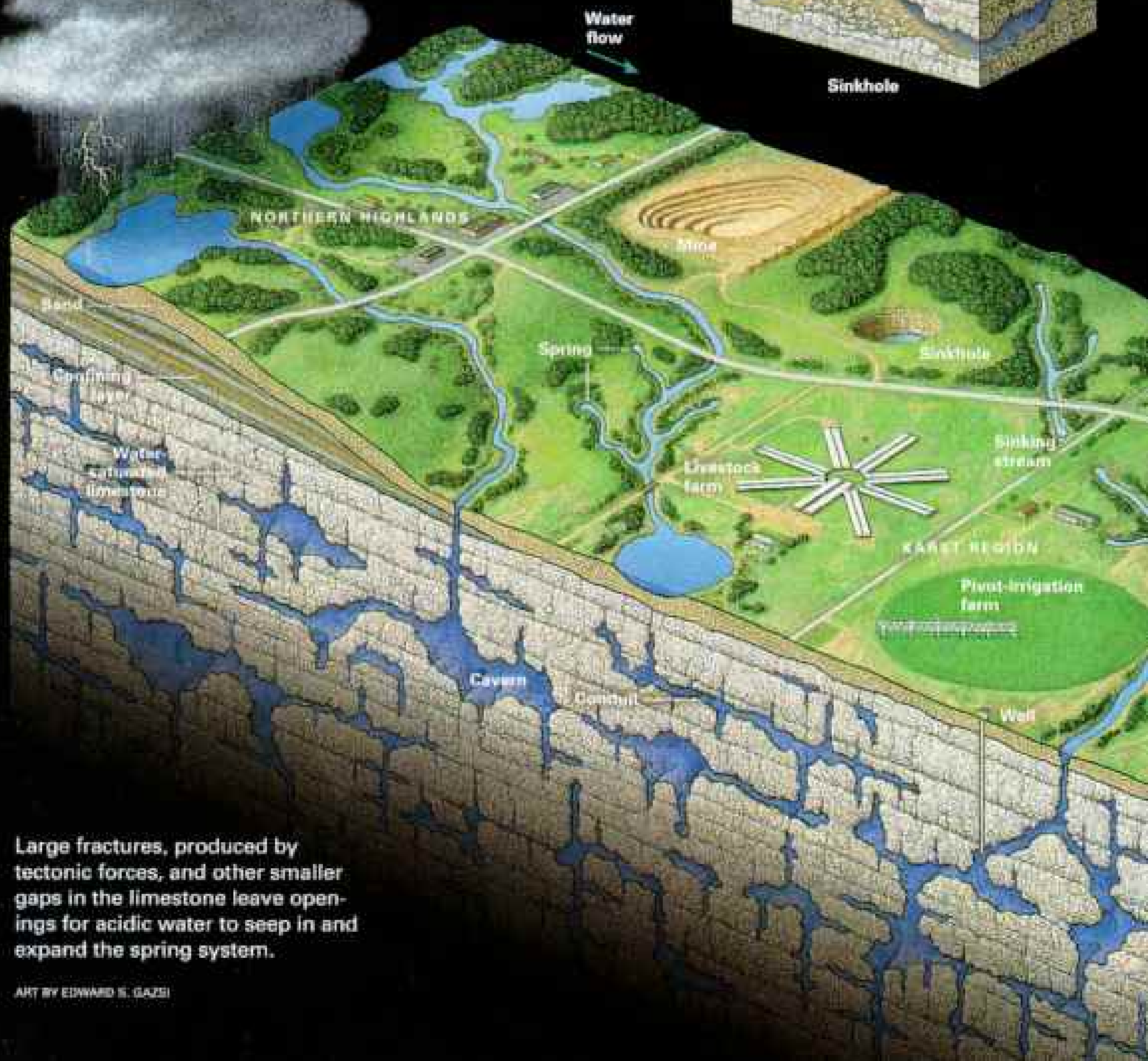
But tremendous amounts are far younger. Jim Stevenson, a lean, dignified ecosystems manager with Florida's Department of Environmental Protection (DEP), points to Ichetucknee Springs State Park as a textbook case of the learning process. Located just north of Fort White, Ichetucknee's crystalline springs

Shaping a spring

Stretching beneath north Florida is a huge bed of limestone easily dissolved by waterborne acids. Such chemical erosion creates an underground web of conduits and caverns, as well as sinkholes at the surface. Under the state's Northern Highlands (below, at left), a "confining layer" of impermeable clay covers the limestone, causing water to

collect on the surface. But across much of the state the confining layer is thin or absent. Here water drains directly into the aquifer—carrying with it pollutants from the surface. By decrypting the system's structure, hydrologists help explain how pollutants in one area can contaminate water that seems to circulate in a separate cycle.

As water dissolves limestone undergirding the surface, the ground and its stone substrate can cave in, leaving a debris pile at the bottom of a new sinkhole.



Large fractures, produced by tectonic forces, and other smaller gaps in the limestone leave openings for acidic water to seep in and expand the spring system.

feed a network of forest-ringed pools once frequented by Native Americans. In the 1600s the Spanish built a Franciscan mission there. Today Ichetucknee ranks as one of the crown jewels of Florida's park system and a cultural touchstone of communities for miles around.

The springs give birth to the Ichetucknee River, a feeder stream of the Suwannee, which

drains much of Florida's north-central Gulf Coast. But Stevenson, Skiles, and others suspected that the springs themselves were being fed by runoff from Lake City, a community of 10,000 fifteen miles to the north. How could they be certain?

At first glance Lake City looked like a distinctly separate environment. Oil and agricultural chemicals from the roads and fields around Lake City showed up in creeks south of town, which wind ten miles through scraggly woods to Rose Sink, a seemingly unremarkable pond skimmed with duckweed. There they appeared to stop.

One day after a generous rain, however, I stood on the pond bank while Skiles pointed out beer cans, pop bottles, and other flotsam rotating slowly in the mat of duckweed, drawn gradually to the center. "This is just like the drain in a bathtub," he says. "It all goes down to the aquifer. Chemicals and all. And it comes out at Ichetucknee."

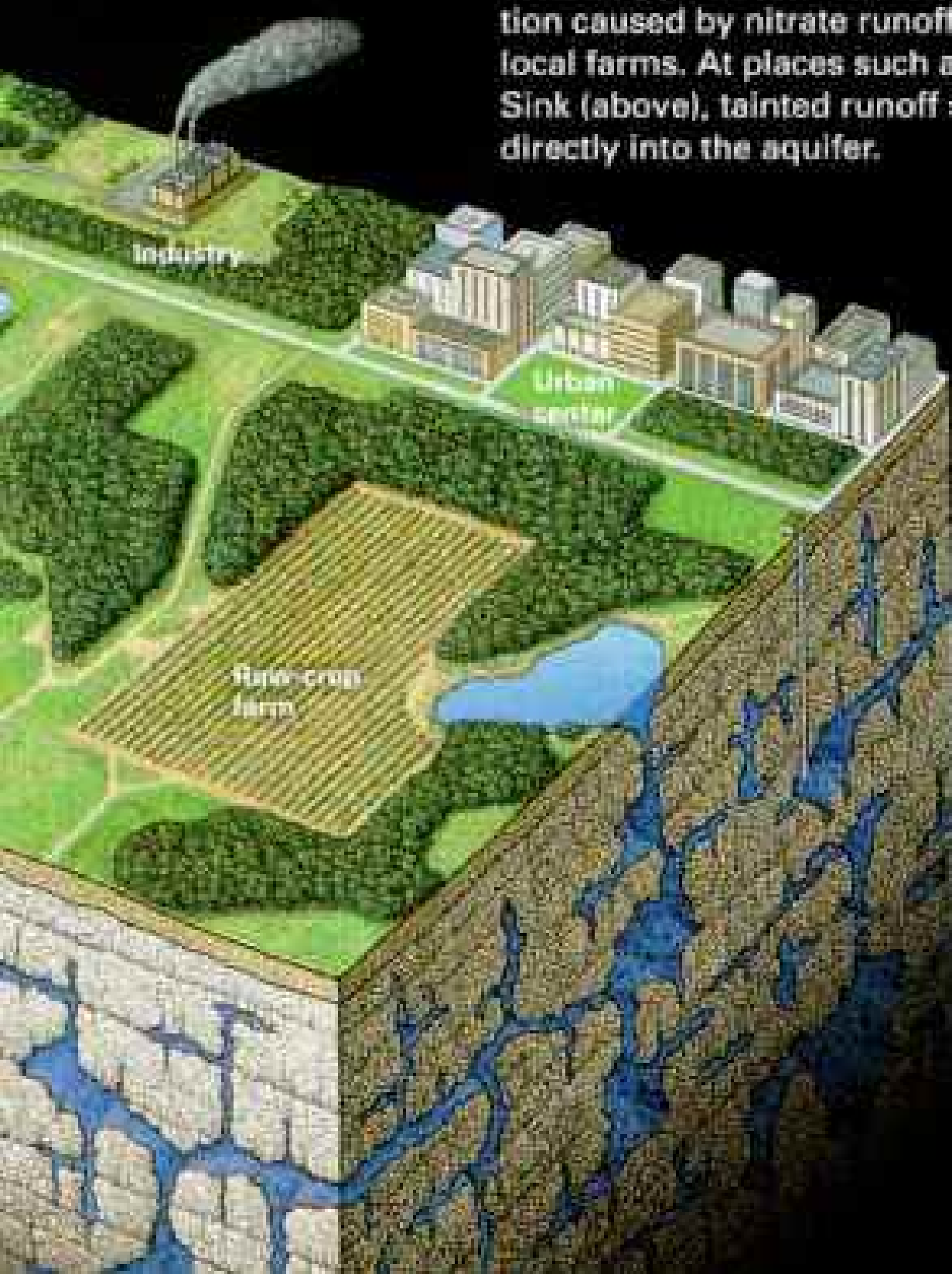
That seemed impossible. Only hours before I had dived the downstream receiving end of this pond—a jug-shaped Ichetucknee spring known as Blue Hole. Pierced by rays of sunlight beaming through its small ceiling entrance, the cave chamber and its diamond-clear water seemed to glow with purity—an azure cathedral lit from above.

I found it hard to connect that beautiful cave with the filth revolving before my eyes here at Rose Sink. Yet Skiles assured me he had dived into the bowels of Rose Sink and seen trash sticking to its rocky walls. Dye released here has shown up days later eight miles away at Ichetucknee.

"But only in the tiniest trace amounts," he says, in



Cities and suburbs (below) use huge amounts of water, but 50-plus inches of annual rainfall provides ample recharge for this aquifer. A much bigger concern is water pollution caused by nitrate runoff from local farms. At places such as Rose Sink (above), tainted runoff swirls directly into the aquifer.



NO SUNLIGHT

reaches the bowels of Diepolder Cave, leaving this large chamber—250 feet deep—devoid of life. Florida's caves have been tough on divers too: Since 1960 some 300 have died underground.







SIFTING THE SAND in Troy Spring, archaeologist Richard Haiduven examines the remains of a Civil War-era ship that local lore says was sunk to keep it out of enemy hands. But much like a canoe on the windowpane waters of Cypress Spring (right), the legend seems to have little supporting it.

wonder. "The amount of dilution is simply incredible. Our team had to put in more than 20 pounds of dye just to get it to register."

But for DEP's Stevenson, that was enough.

"People around here are incredibly protective of Ichetucknee Springs," he says. "They learned to swim there as kids. They were baptized there by their churches. They know what the springs mean to the area economy as a tourist attraction, but their real attachment is very personal and emotional. All you have to do is explain to them how the dirty oil they drain from their cars could end up in the springs, and they'll take all sorts of steps to see that doesn't happen. It's a matter of awareness."

While he acknowledges that the state's regulatory muscle "is always there offstage if we need it," his most important mission is "not confrontation but education. The more we learn about how the springs work and get that word out, the more people will voluntarily help us protect them. It's a constant process."

AQUIFER MAPPING has taken on far broader dimensions in the Woodville Karst Plain Project, a decade-old effort to map the entire hydrologic profile of the 450 square miles of northwest Florida that lie south of Tallahassee.

Begun by a diver named Parker Turner—later killed in an underwater cave-in—the project is now run by George Irvine, a muscular bond salesman from Fort Lauderdale. Irvine, 47,

quarterbacks nearly a hundred divers on weekend forays two miles or more underground.

It's not a casual activity. It rather resembles an assault on Mount Everest.

"We'll use as many as 18 divers breathing specialized mixes of nitrogen, oxygen, and helium to get set up for a single dive," Irvine says. Teams with electric underwater scooters "lay down as many as 33 emergency tanks twelve hundred feet apart in groups of three. Then we'll launch three divers on scooters" to discover what's around the next bend.

The final-assault divers use mechanical rebreathers. These complicated devices scrub suffocating carbon dioxide from a diver's exhausted air, permitting breath recycling and longer time in the cave without the limiting bulk and capacity of scuba tanks.

The emergency equipment stashed along most of their route provides the divers with "tremendous bailout capability should anything go wrong," Irvine says. "But the best tool is the human body. My divers have to be in top physical condition. I run at least five miles every morning and swim 4,000 meters every night. I have a resting heart rate of 38 to 42, so I can swim long distances without putting any effort into it. Most of my divers do the same. And that reduces your chance of decompression sickness and increases your stamina, awareness, and ability to react should anything go wrong."

It also improves how far a diver can go on a



given amount of gas. Even so, these marathon dives can involve as much as 14 hours of decompression time underwater to avoid the buildup of nitrogen bubbles in the blood—a potentially fatal condition known as the bends.

Over the years, Irvine says, the equipment and procedures have been “refined to a high degree of efficiency. When Parker Turner set up the project, perhaps 25,000 feet of the cave system in the area had been explored. We now have mapped more than 300,000 feet, including the Leon Sinks cave system, which runs uninterrupted for more than 17 miles.” At depths of more than 200 feet, Leon Sinks is the longest known underwater cave in the U.S. and the third longest in the world.

Seeing geology from the inside out is to cave divers what seeing the colors of a Caribbean reef is to sea divers, Irvine says. “Limestone itself can be quite beautiful. And the vastness of some of the structures is simply beyond belief.”

The attachment of Floridians to their springs may be as primal as it is personal. In these waters archaeologists have discovered Paleo-Indian spearpoints dating back more than 10,000 years, not to mention the bones of mastodons and other Ice Age mammals. And charcoal found inside a massive underwater cave at Wakulla Springs, south of Tallahassee, has caused some people to speculate that Florida’s early inhabitants may have used the cavern for shelter during a time when a lower sea level kept the area dry.

“In Wakulla Springs the immensity of the caves is stunning,” Irvine says. “Some of the tunnels are up to 200 feet wide and 80 feet high”—so large that divers entering them often have no idea where a given room will end.

“We keep one person on the line being reeled off to mark the way out and send two others out along each wall. That way we can backlight the walls with several lights and get some idea of the size.” When that doesn’t work, his divers just swim toward the darkest spot ahead, tracking their route by compass.

There’s a half-mile-long side tunnel 3,900 feet into Wakulla Springs, Irvine says, “that looks like the inside of Westminster Abbey . . . 40 feet wide, 80 feet high . . . cathedral shape . . . absolutely beautiful. When you see something like that, the image fixes itself in your mind. And it stays there until you can get back to discover what’s around the next corner.”



IF THE HEART of Florida’s springs lies below ground, their soul reclines on the surface, among the sparkling pools and moss-dripping oaks that surround them. No fewer than four springs around the state link themselves by name or folklore with Ponce de León’s search for the mythical fountain of youth—a search that historians now say probably never happened. The conquistador came here seeking gold and glory, not rejuvenating waters.

For today’s corporate soldiers of fortune, Florida’s springs have proved lucrative tourist magnets where nature is only the beginning. At Silver Springs near Ocala, where the glass-bottom boat was invented in 1878, the lush, heron-populated headwaters of the Silver River have been wrapped in a mini-mall; a country-and-western concert stage; safaris and jungle cruises featuring such transplanted attractions as zebras, giraffes, and Kodiak bears; a reptile “encounter”; and an auto museum honoring Don Garlits, the “father of drag racing.”



A SAND BOIL ROILS in Marion County, the result of sustained hydrologic pressure. In the more placid waters of Sims Sink, Joel Tower zooms in on *Procambarus erythrops*, an albino crayfish known to live in only three other sinkholes, all of them in Florida. While most types of crayfish live roughly three years, these slowly metabolizing cave dwellers live as long as 20.

Scenes for 24 movies have been shot at Silver Springs, starting with *The Seven Swans* in 1916 and including six Tarzan films, three James Bond movies, *Smokey & The Bandit III*, and that watery 1954 horror classic *The Creature From the Black Lagoon*.

As I wandered among the movie posters in the auto museum, I bumped into Delee Perry, who lives in Ocala, and whose father, Newton Perry, was part of all that moviemaking.

"As a boy, Dad used to walk six miles to Silver Springs to swim," she tells me. Grantland Rice, the celebrated sportswriter and sometime movie producer, was so impressed by Perry's diving and underwater ability that he used him as the subject for a short feature film entitled "The Human Fish." Other moviemakers took note of Perry's prowess as a swimmer and hired him to double for Johnny Weissmuller in nine of the early Tarzan movies.

"In those days underwater filming technique at Silver Springs was so primitive that they had

to shoot through a glass-bottom bucket," his daughter says, "so Dad helped develop a submersible chamber for the camera."

During World War II Perry again teamed up with Grantland Rice, this time at Wakulla Springs. There Rice made a stirring film about amphibious warfare that won a 1943 Academy Award in the short-subject category.

In 1946 Perry bought and developed what has become one of Florida's best known, and certainly its wackiest, freshwater tourist attractions—Weeki Wachee Spring, north of Tampa. Last year Weeki Wachee celebrated the 50th anniversary of its famous mermaid show, where young women in fishtailed costumes frolic underwater in skits and musical numbers with only occasional breaths from a bubbling air hose. Star of the golden anniversary show was Mary Darlington Fletcher, who'd been one of Perry's very first mermaids. Still trim at 66, she slipped back into a fishtail for the occasion.

"You can't imagine what Weeki Wachee

meant to me as a girl," Fletcher tells me when I look her up at her home in Gainesville. "After chores on weekends Dad would hitch our 1939 Chevrolet panel truck to the farm trailer and load both with kids and fried chicken. We'd spend the whole day at Weeki Wachee, swimming and diving from a rope swing tied to a tree. When I heard that Newton Perry had bought it and closed it to swimming, I thought it was the end of my life."

But then she learned that Perry planned an underwater show at Weeki Wachee and would be signing up mermaids the next Saturday. "That," says Fletcher, "was the longest week of my life."

The plucky 15-year-old passed the test of swimming a hundred feet across the spring and back and took like a trout to underwater acting classes and such tricks as drinking a soda and eating below the surface. She and her brother Ed were both in the show, where they not only performed but also excelled at flagging tourists off lightly traveled U.S. 19 to be their audience.

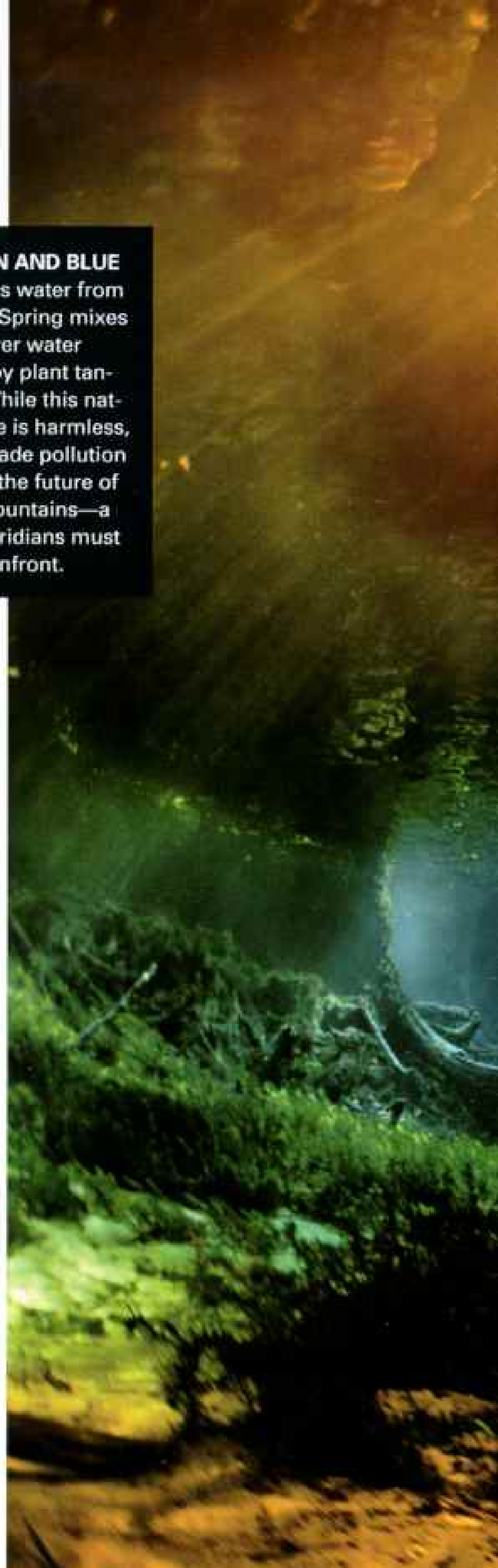
"If six or eight cars stopped, that was a big day in the beginning," she says. "But we got on the map pretty rapidly."

Though Fletcher is proud of her enduring place in Florida culture—she turned out to meet me in a glittery mermaid T-shirt and matching earrings—it's the spring at Weeki Wachee rather than the show that most holds her heart. "When we did the show back in the 1940s," she says, "there were so many more fish and plants than there are now, and everything was so clean. Now part of what you see from the theater is black with algae."

But Weeki Wachee is still a magical place. The mermaid show is fun in a campy sort of way, and just downstream from the funnel-shaped cave that pumps 170 million gallons a day from the Floridan aquifer, the Weeki Wachee River sparkles with sunlight and purity. Egrets and herons flap lazily down the winding, jungly river, and otters play in the shallows near the occasional dozing manatee. It looks as though God just made it.


Far below the riverbed, where cave divers explore from time to time, the Floridan aquifer makes it all possible. □

BROWN AND BLUE blend as water from Ginnie Spring mixes with river water tinted by plant tannins. While this natural dye is harmless, man-made pollution clouds the future of these fountains—a fact Floridians must now confront.





The Russian Realm of STELLER'S



*Telltale white shoulders
bright as new snow,
a Steller's sea-eagle lifts
itself into the air with
a few quiet wing strokes.*

Article and photographs by KLAUS NIGGE

SEA-EAGLES



© Klaus Nigge 2013





The Steller's sea-eagles of Kamchatka's Kurilskoye Lake spend most winter days perched in trees (left), waiting for fish to wash up or digesting a meal. Their size doesn't register until an adult flies from its perch and banks gracefully to face me. A mature bird measures up to nine feet from wing tip to wing tip and at up to 20 pounds far outweighs the North American bald eagle. Steller's sea-eagles winter as far south as Japan and South Korea. They nest only in eastern Russia, in places like the island of Bolshoy Shantar (above).

Named after Georg Steller, the German naturalist who explored Kamchatka in the 1740s, Steller's sea-eagles gather in the hundreds at Kurilskoye Lake for the winter sockeye salmon run, Asia's richest. No roads lead here—I arrive by helicopter. I spend nights in a cabin and days in snow blinds near a sandbank where eagles scavenge fish.



German nature photographer and biologist KLAUS NIGGE has made seven expeditions to the wilderness of Russia's Far East.



FOOD FIGHTS

Steller's sea-eagles eat like sibling rivals—they seldom dine alone, and few scraps of food are won without a squabble.

Eagles begin each day by watching for magpies (upper left) and crows. Although equipped for hunting, eagles prefer to let other keen-eyed birds lead them to beached salmon. The scouts get food in return. An eagle's massive



beak can tear open a fresh salmon's tough skin, allowing smaller birds to steal a meal.

Minutes after the first eagle approaches food, others arrive and the frenzy begins. The owner of a fish, for the moment, lowers its wings to shield its prize (lower left). While off-camera competitors distract it from the left, another sneaks in from the right. Attempted larceny

can have a price. The marauder above recoils from a young eagle hungry enough to defend its breakfast with the strike of a beak.

Why steal when there's enough to share? Russian biologist Alexander Ladygin believes that salmon skin is so hard to breach that robbing a fellow eagle is easier than opening a fish. I think they fight because they like to.





*Head cocked back in curiosity,
an adult gives my snow blind
a puzzled stare. Feathers are
fluffed for better insulation.
For many of Kamchatka's eagles,
winter means scarce food—
even starvation—but those that
spend the season at the lake gain
weight. Some gorge themselves
till they're too full to fly. Ladygin
has caught overeaters by hand.*



EXPANSIVE AERIES

*Hair-trigger shy, *Haliaeetus pelagicus* breeds in some of Earth's least populated corners. Their nests have seldom been photographed. After weeks of searching, I found an eagle pair that allowed me to erect a tent blind near their nesting tree on Bolshoy Shantar, a Maui-size island in the Sea of Okhotsk 700 miles west of Kamchatka.*



Each spring eagles return to the same nest with the same partner. Favorite branches in lookout trees—ones with the best views of their nest and fishing cove—are rubbed bare by sentry duty.

Branches, dried grass, and moss form a ten-foot-wide platform (above), more than big enough for a king-size bed. Days are silent but for the chick's begging cries and its parents' harsh

warning calls (upper left) to eagles that fly too close. Before the salmon run begins, the adults wade into tide pools for small fish to carry to the nest. I saw only the mother feed the eaglet. She tears food into pieces and gently holds them in front of her chick (lower left). It will fledge in 90 days, but six to eight years will pass before it fully develops white shoulders, tail, legs, and forehead.



The helicopter will pick me up tomorrow. For days I've watched these colossal birds swoop and brawl. But this morning, my last on Kamchatka, I'm drawn to a quiet moment when the fights for food are over and a lone eagle lingers on a bank, the falling snow blurring the silhouettes of the trees. I'll be back. □



Its arms lashing Mexico's west coast, Hurricane Linda, spawned during an El Niño, churns northeastward in September 1997. Linda's 185-mile-an-hour winds made it one of the strongest eastern Pacific storms ever recorded.



*Drought and flood,
famine and pesti-
lence: Name your
calamity and at least
some cases can be
blamed on the
periodic warming
of Pacific Ocean
waters known as
El Niño and its*

NATURE'S VICIOUS CYCLE

*cooler sister, the
stormy, little under-
stood La Niña.*

By CURT SUPLEE

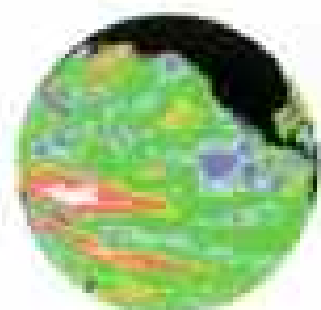
IT ROSE OUT OF THE TROPICAL PACIFIC in late 1997, bearing more energy than a million Hiroshima bombs. By the time it had run its course eight months later, the giant El Niño of 1997-98 had deranged weather patterns around the world, killed an estimated 2,100 people, and caused at least 33 billion dollars in property damage.

Isaias Ipanaqueé Silva knew none of that. All he and the other peasant farmers in the Peruvian hamlet of Chato Chico could see was that after weeks of incessant rain the adjacent Piura River had not stopped rising. The rainfall itself was no surprise. Every three to seven years, for as long as anyone could remember, the same rainfall had arrived after a pool of hot seawater the size of

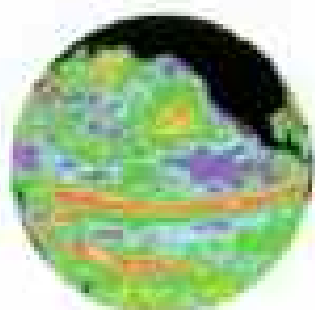
IMAGE PROCESSING BY MARIE JANHOFF-NILSEN AND ERIC HANSEN,
GODDARD SPACE FLIGHT CENTER, NASA, DATA FROM NOAA



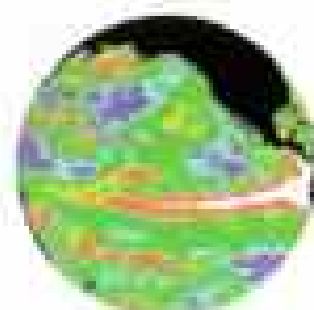
From early stages to El Niño's peak, warm water, shown in white, moved east across the Pacific Ocean.



Mar. '97



Apr. '97



May '97



Sep. '97



Dec. '97



CALIFORNIA

PHOTO: TURNER ABOVE; JET PROPULSION LABORATORY/ASA

SKIN AND BONES Its food sources driven away by abnormally warm water off San Miguel Island, California, this six-month-old California sea lion pup being readied for a necropsy was among hundreds that starved to death. Nursing females usually find plentiful squid and small fish near the surface, but the prey swam deep in search of cooler waters, out of sea lion diving range. In non-El Niño years the pup mortality rate runs about 25 percent. In 1997 it hit 70.



INDONESIA

BOTH BY MICHAEL YAMAGUCHI

WORLDWIDE IMPACT As brush fires raged in drought-stricken Sumatra, motorists were shrouded in smoke, and clinics were filled with patients (above). Flames charred trees and utility poles in Bunnell, Florida (below left), which endured severe drought last summer. Too much winter rain near Chino, California (below right), sent rescuers in front loaders to save cattle neck deep in mud.



UNITED STATES

TONY HANZE, AGENCY FRANCE PRESSE (ABOVE LEFT); CON KEVEL, LOS ANGELES TIMES

Canada appeared off the west coast of the Americas. The ocean would heat up right around Christmastime, so fishermen called the phenomenon El Niño, for the Christ Child. Then that titanic storm source would pour vast amounts of precipitation onto Peru's normally arid northwestern coast.

But few had ever seen this much rain—five or six inches a day in some places.

Finally, on February 15, 1998, the river broke its banks. The sodden ground could hold no more, and water swept into the riverside homes

of Chato Chico. The swirling torrent was first knee-deep and soon chest high. "Suddenly we were surrounded from all directions," Ipanaqué Silva says. "It took all the little animals. Then my house just fell down completely."

Hundreds of families splashed frantically through the muddy flood to save what they could. In most cases, says another villager, Rosa Jovera Charo, "we just grabbed clothes for the children." Everything else—chickens and goats, pots and pans, religious icons and personal treasures—washed away. Compared with



BRAZIL

JOHN MAIER, JR., THE IMAGE WORKS/STILL PICTURES (ABOVE LEFT); DOUGLAS EMILL, ASSOCIATED PRESS

Brazil's rain forest (above), and demonstrating farmers, demanding government aid, looted grocery stores (above right). El Niño usually brings drought to East Africa, but this time it brought crop-killing rains and famine to Sudan, where orphans ate soup supplied by relief organizations (below right). "We have always thought of rain as a blessing," said Ali Dulo in his flooded Kenyan village (below). "Now when we hear thunder it makes us feel very bad."



AFRICA

B. GIFFITHS, CHRISTIAN ANGELO PICTURES (ABOVE LEFT); ALESSANDRO ARBONNI, AGENCE FRANCE PRESSE; CONSULTANTS: MICHAEL H. GLANTZ, NCAR, AND BILL PATZERT, JET PROPULSION LABORATORY, NASA

other places in Peru and around the world, the residents of Chato Chico were fairly lucky. Some were evacuated on barges, a few in helicopters, to a barren but dry refugee camp in the desert. Nearly all survived.

That was not the case some 60 miles to the south, in a three-acre pocket of one-room houses called Motse outside the city of Chiclayo. "We thought that the water couldn't come here," says Flora Ramirez, "but we lost practically everything." Ramirez's neighborhood was overrun in a matter of minutes.

"They strung ropes from one house to another to rescue people," recalls Manuel Guevara Sanchez. "Some spent three days on the roof. Those who knew how to swim brought them food." When the flood finally receded, they could begin to count the dead: ten out of a village of just 150.

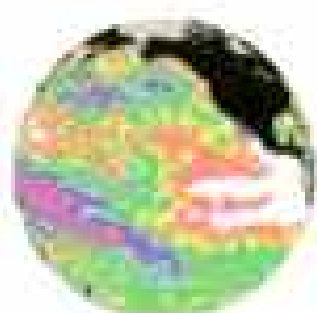
The runoff from the floods poured into the coastal Sechura Desert. Where there had been nothing but arid hardscrabble waste for 15 years, suddenly—amazingly—lay the second largest lake in Peru: 90 miles long, 20 miles



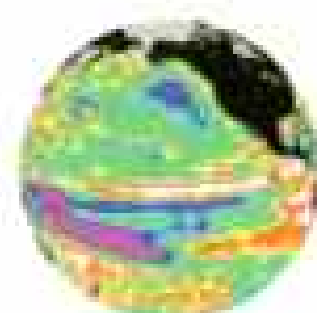
As El Niño's warm water receded, cooler water, shown in purple, replaced it, setting the stage for La Niña.



Jan. '98



Feb. '98



May '98



Jun. '98



Oct. '98



PERU

JOSUE BARRA, LA INDUSTRIA DE CARROTE LABOVEL, SET PROFULSION LABOVALDIF, NASA

RESCUED—JUST Heroes on shore saved a family overtaken by a wall of muddy water as they tried to wade across the usually shallow Huarmey River in northern Peru early last March. Such flash floods, along with dramatically high river levels along the Peruvian coast, were frequent during El Niño. Pacific clouds encountering the Andes dumped especially heavy rains on the steep western slopes.

wide, and ten feet deep, with occasional parched domes of sand and clay poking up eerily from the surface (page 92).

In other areas the water simply pooled. The mosquitoes that thrived in these places caused rampant malaria—some 30,000 cases in the Piura region alone, three times the average for its 1.5 million residents.

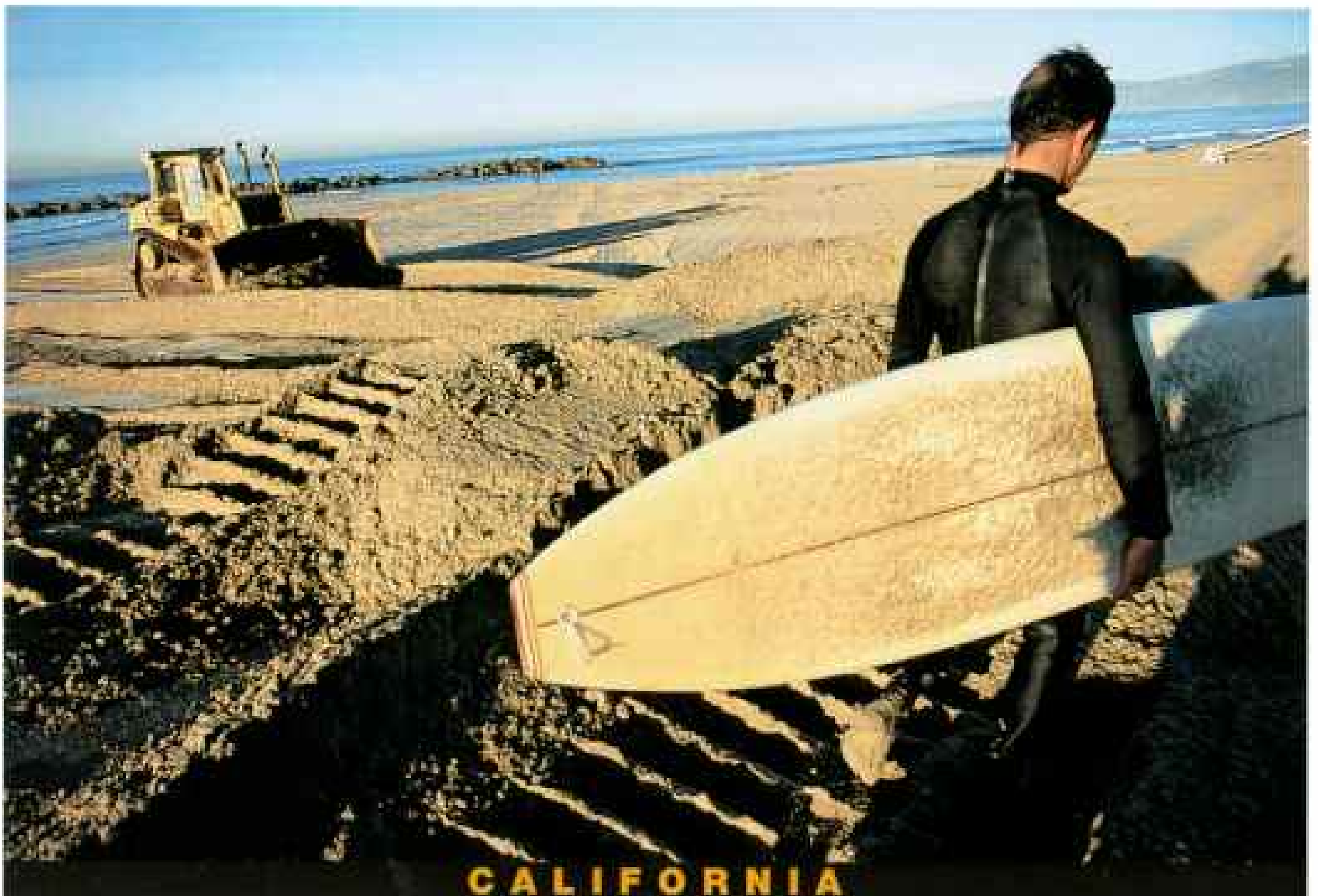
Peru was where it all began, but El Niño's abnormal effects on the main components of climate—sunshine, temperature, atmospheric pressure, wind, humidity, precipitation, cloud formation, and ocean currents—changed weather patterns across the equatorial Pacific and in turn around the globe. Indonesia and surrounding regions suffered months of drought. Forest fires burned furiously in Sumatra, Borneo, and Malaysia, forcing drivers to use their headlights at noon. The haze traveled thousands of miles to the west into the ordinarily sparkling air of the Maldivé Islands, limiting visibility to half a mile at times.

Temperatures reached 108°F in Mongolia; Kenya's rainfall was 40 inches above normal;

central Europe suffered record flooding that killed 55 in Poland and 60 in the Czech Republic; and Madagascar was battered with monsoons and cyclones. In the U.S. mudslides and flash floods flattened communities from California to Mississippi, storms pounded the Gulf Coast, and tornadoes ripped Florida.

By the time the debris settled and the collective misery was tallied, the devastation had in some respects exceeded even that of the El Niño of 1982-83, which killed 2,000 worldwide and caused about 13 billion dollars in damage.

And that's not the end of it. It is not uncommon for an El Niño winter to be followed by a La Niña one—where climate patterns and worldwide effects are, for the most part, the opposite of those produced by El Niño. Where there was flooding there is drought, where winter weather was abnormally mild, it turns abnormally harsh. La Niñas have followed El Niños three times in the past 15 years—after the 1982-83 event and after those of 1986-87 and 1995. Signs of another La Niña began to show up by June 1998.



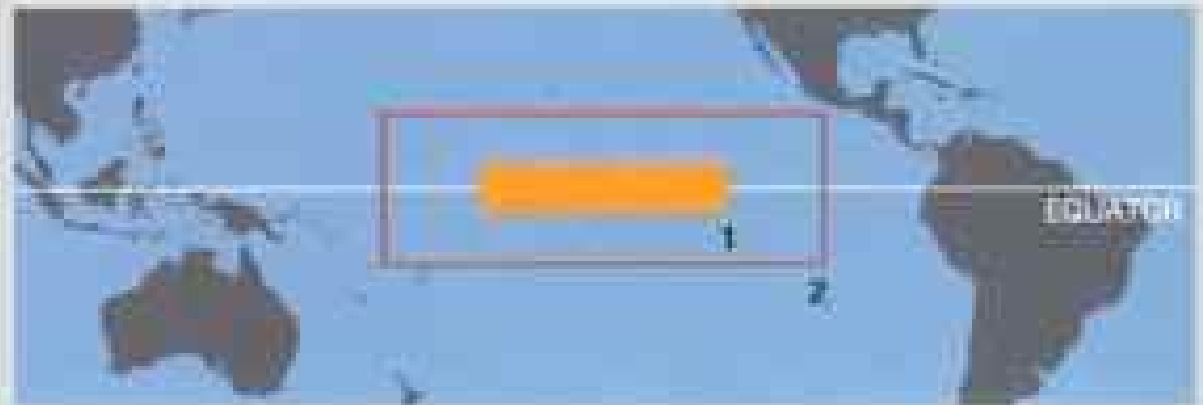
TYRONNE TURNER, BLACK STAR

GOOD NEWS . . . BAD NEWS Surfers were excited by prospects of monster El Niño waves, but California authorities feared beach erosion and built sand berms from Redondo Beach to Santa Barbara. By last March surf had washed the berms away, but the beach was intact.

Running Hot and Cold



Like a giant saucer with liquid sloshing back and forth across it, the Pacific Ocean contains huge masses of contrasting cool and warm water. During the past 50 years their slow cycle has created El Niño conditions 31 percent of the time and La Niña conditions 23 percent of the time.

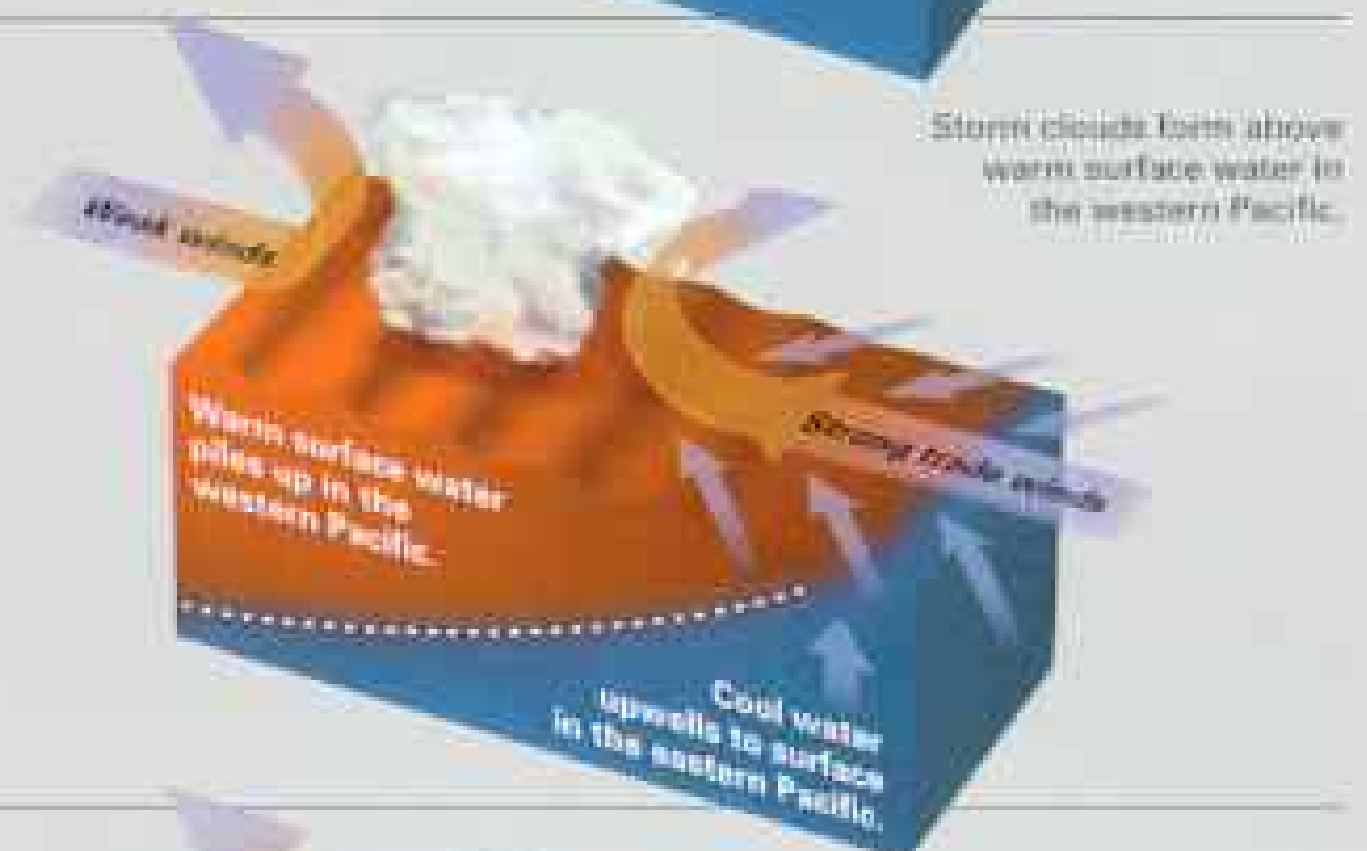


1. Information shown in the graph above is based on data from an area west of Peru. 2. Rectangle defines area depicted in cross-sections below.

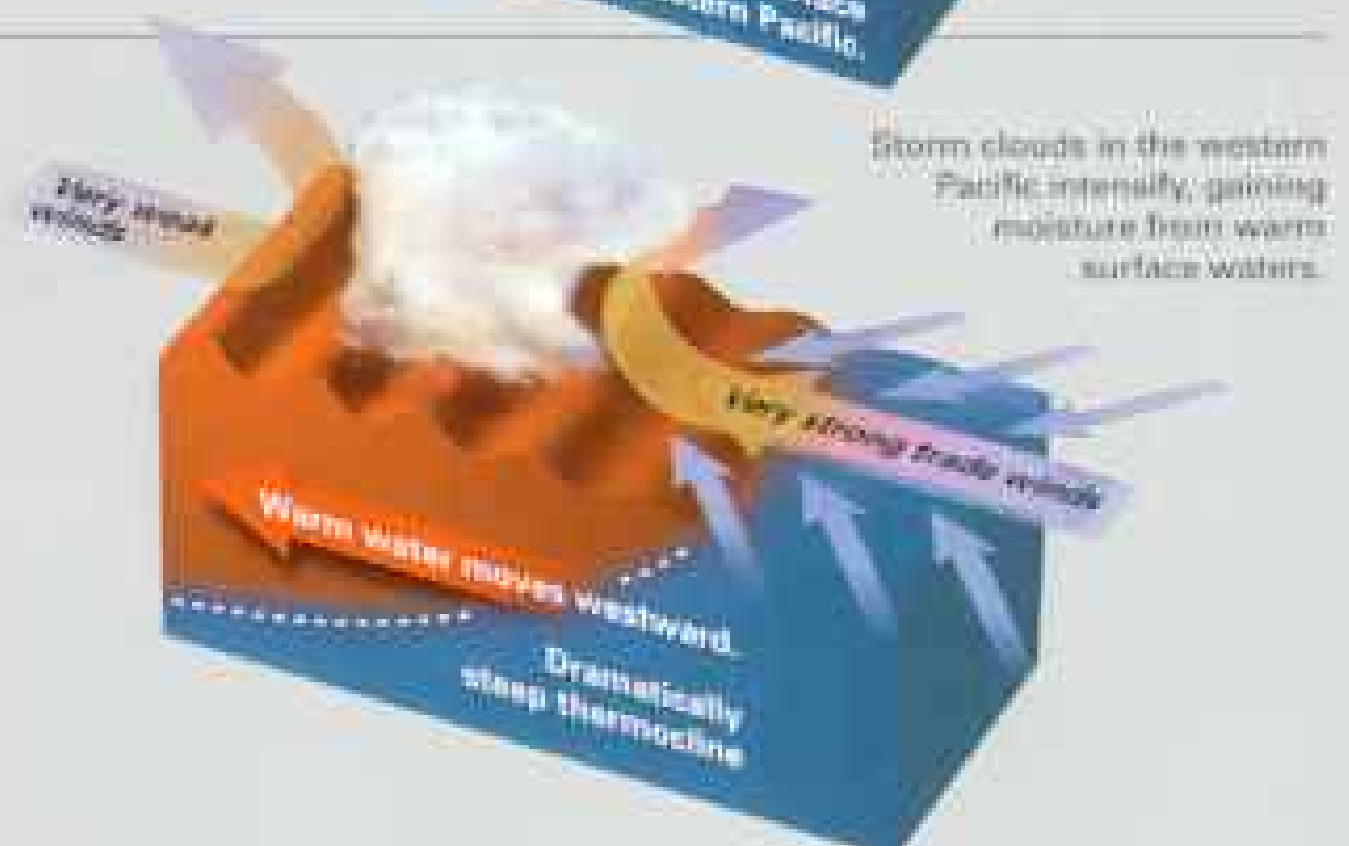
EL NIÑO / WARMING As easterly trade winds decrease, warm water in the western Pacific flows eastward. This layer, typically 500 feet deep, flows over cooler, nutrient-rich water and blocks its normal upwelling along North and South America. Sea life there can suffer from lack of food.

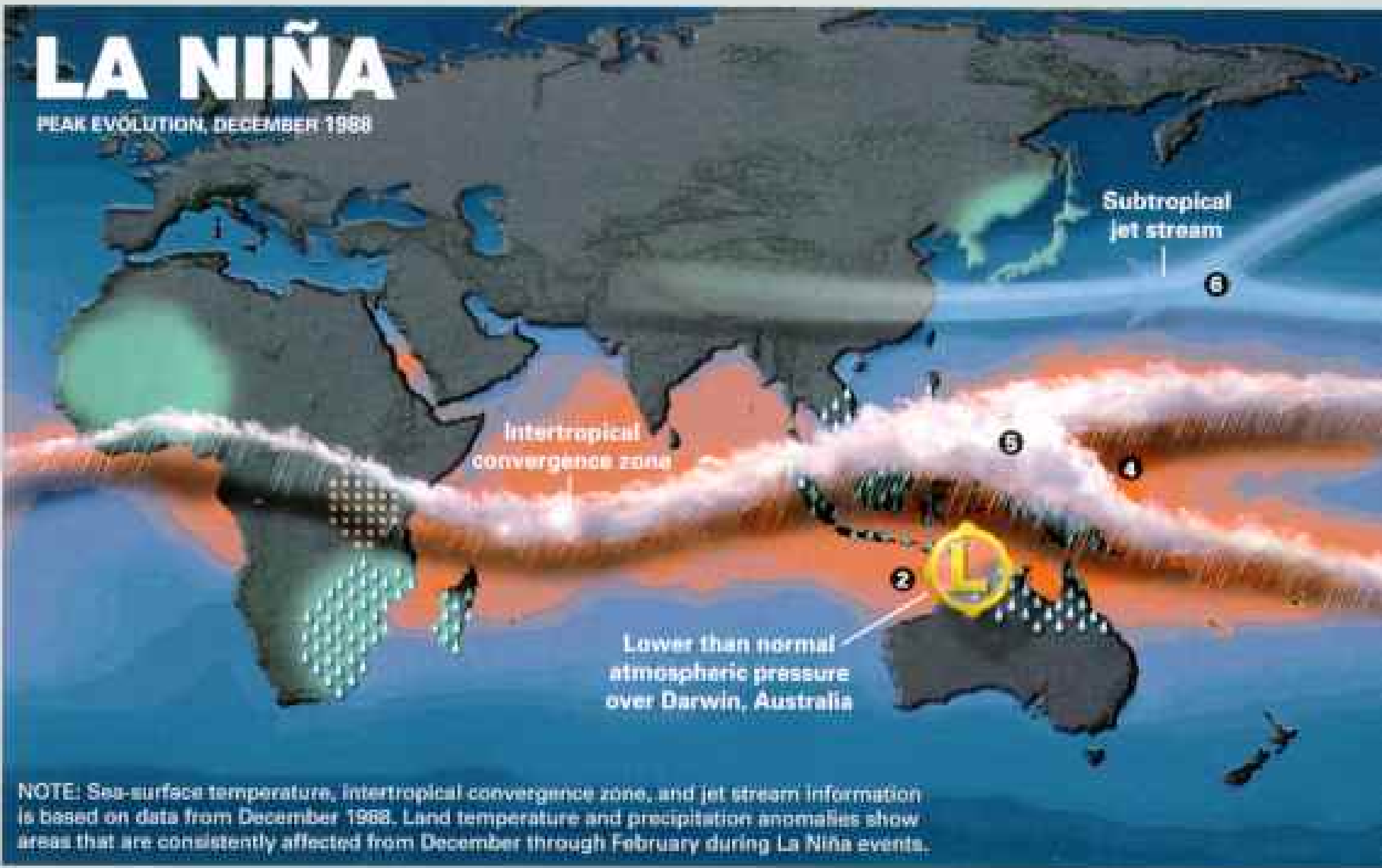
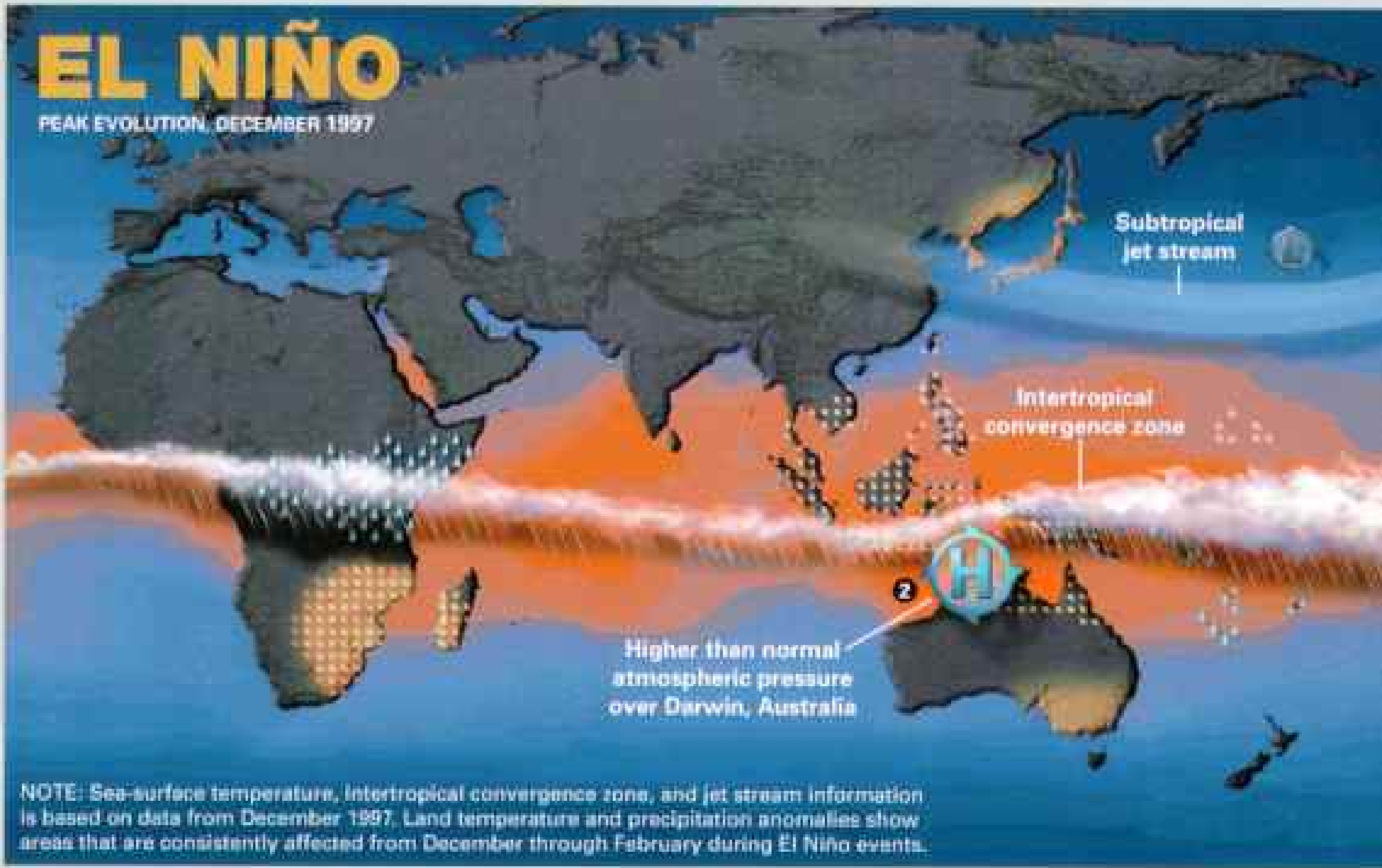


NORMAL Trade winds generally maintain a balance between warm western Pacific water and cool water in the eastern Pacific. The sun heats water in the east, but the thermocline, the boundary between warm water and the cold, nutrient-rich water, lies 130 feet below the surface.

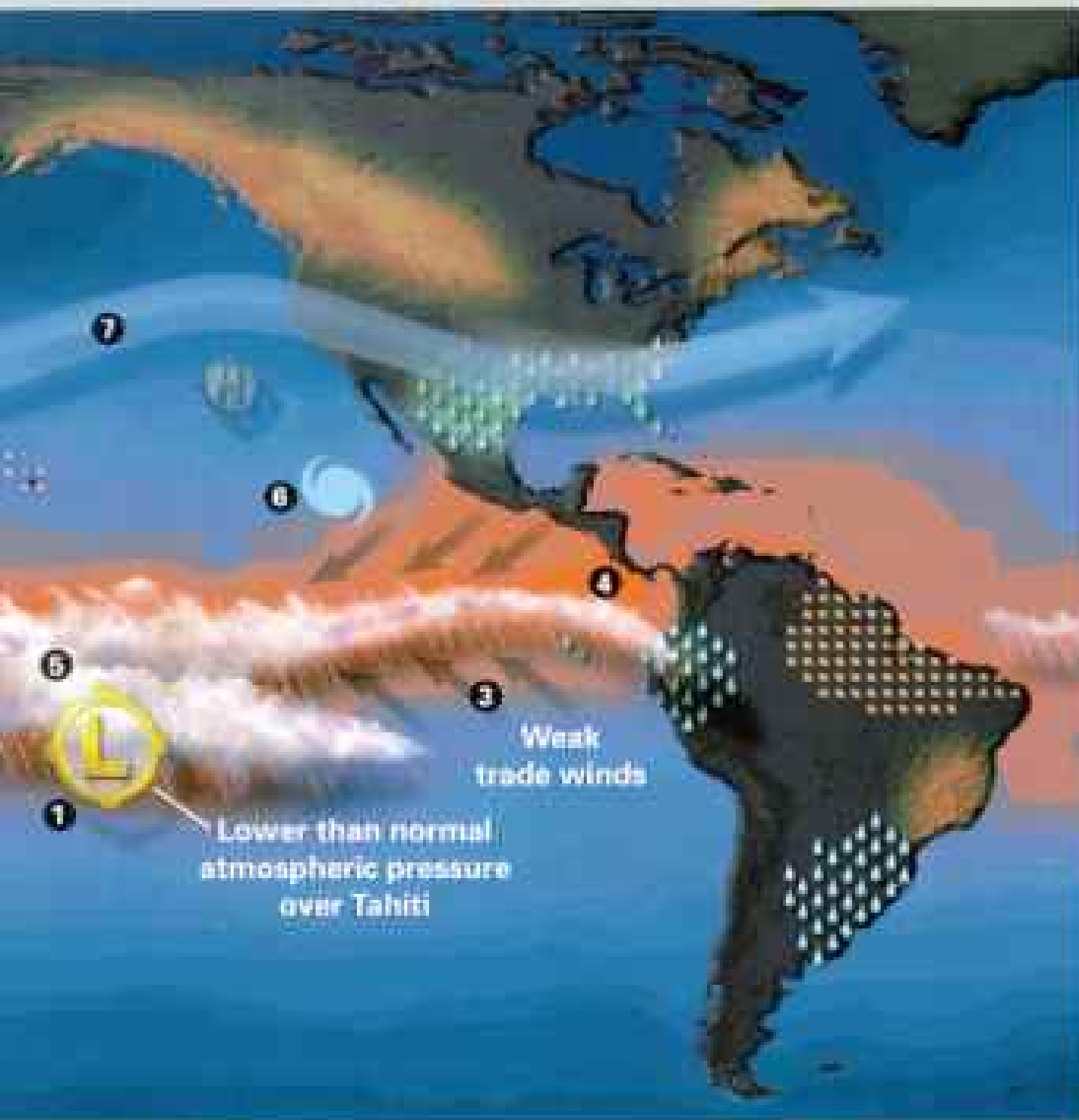


LA NIÑA / COOLING Pushed westward by strong trade winds, warm surface water flows toward Asia. Colder deep-sea water upwells to the surface along the Americas. Nutrients become more plentiful, and evaporation decreases, reducing storm cloud formation and rain in the region.





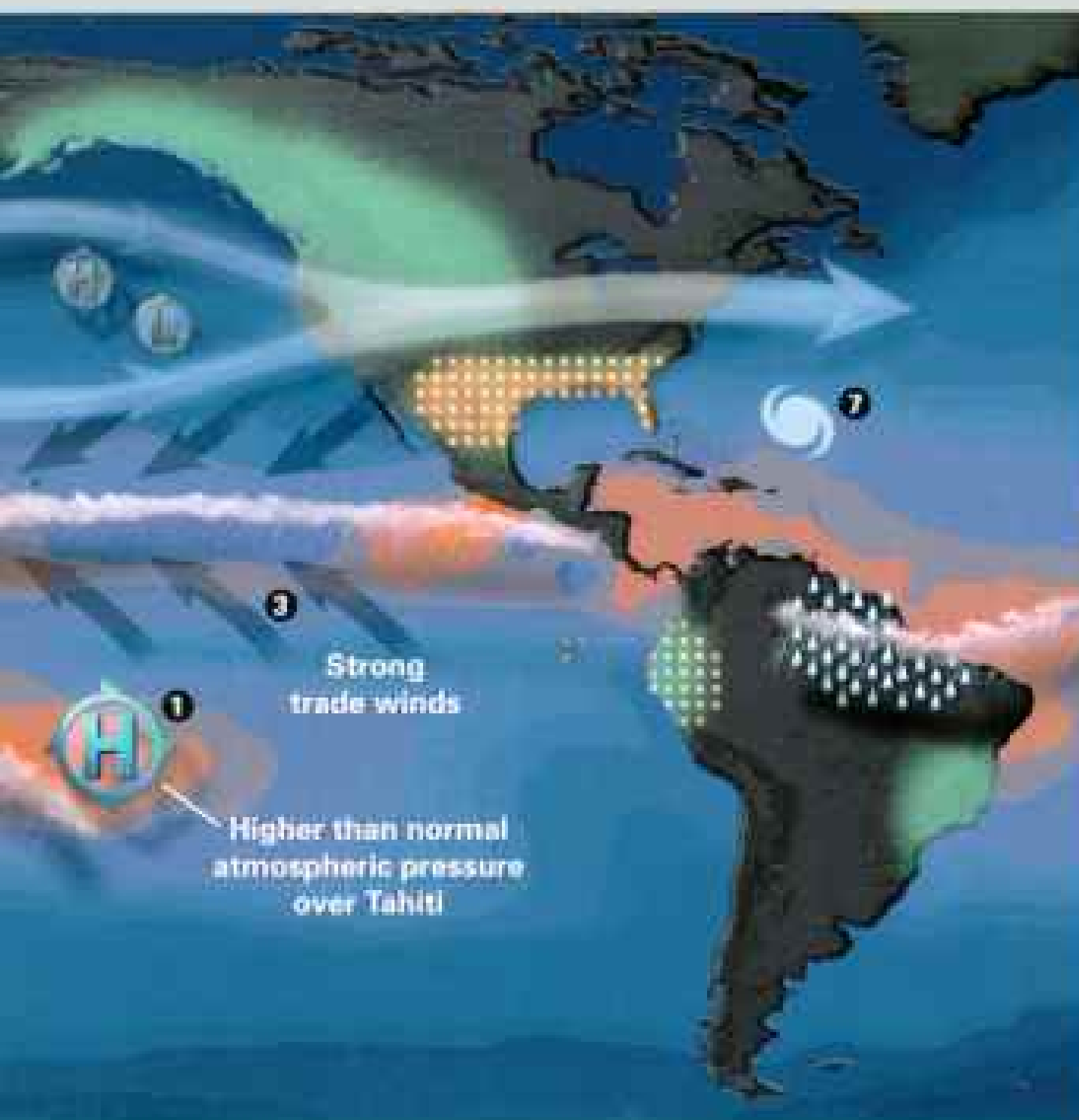
AT THE EXTREMES Influenced by countless variables, including variations in Earth's orbit, the strength of ocean currents, and possible human influences on the environment, no two El Niño or La Niña events are identical. Even within a single event, local conditions can change drastically over just a few days. Illustrated above are the most recent El Niño and La Niña events that have been fully



Highs and Lows of a Global Cycle

EL NIÑO

For reasons still not entirely understood, atmospheric pressure periodically becomes abnormally low near Tahiti (1) and unusually high over northern Australia (2). With the presence of the high-pressure system, Pacific trade winds that normally flow to the west become weak (3), allowing sun-warmed Pacific surface water to spread eastward. This creates a warm band of water that spans the equatorial Pacific (4). Along the Equator, where cloud formation is already heavy due to the convergence of northern and southern trade winds, more clouds than usual develop (5). Drawn south by the lower atmospheric pressure, the subtropical jet stream carries Pacific clouds eastward and increases the frequency of storms in that region (6). Continuing across southern North America, the jet stream (7) shears off the tops of westbound Atlantic storms, decreasing the development of Atlantic hurricanes.



LA NIÑA

In a reverse of the mechanism that triggers El Niño, atmospheric pressure is abnormally high over Tahiti (1) and low over Australia (2). Westbound trade winds are intense (3), pushing warm surface water farther west than usual (4). The equatorial cloud formation splits (5), separated by the Tahiti high. Similarly split, the subtropical jet stream is weakened (6), allowing Atlantic hurricanes to move westward and gather strength (7).

studied, depicting the most extreme conditions of each over a given month. All the conditions shown did not happen simultaneously.

While conditions during the past few events appear to have been more extreme than in earlier events, the evidence is not conclusive. Worldwide collection of detailed El Niño and La Niña data dates back only 13 years.

SOURCE: CHESTER ROFFENBERG, INTERNATIONAL RESEARCH INSTITUTE, KEVIN TRENBERTH, ANTI LEITMANN AND VERN RIGDON, CLIMATE PREDICTION CENTER, ALL PASTORY DATA FROM NOAA, ART BY HEIDI BERSCHER



AUSTRALIA

GARY BELL

BLEACHED CORAL As water approached 88°F, coral polyps living in Australia's Great Barrier Reef expelled their algae, leaving the coral white. Some areas, like this stretch at Heron Island, recovered. Along an 18-mile length in Western Australia, the polyps eventually died.

OVER THE YEARS, the appearance of La Niña has been less predictable than that of El Niño, and fewer of its effects have been recorded. But both patterns are now far better understood than ever before. That is because the most recent El Niño will be the first to be remembered for more than just a litany of disasters. The 1997-98 El Niño marked the first time in human history that climate scientists were able to predict abnormal flooding and droughts months in advance, allowing time for threatened populations to prepare. The U.S. National Oceanic and Atmospheric Administration (NOAA) first announced a possible El Niño as early as April 1997; Australia and Japan followed a month later. By summer detailed predictions were available for many regions.

CURT SUPLEE, a *Washington Post* science writer and editor, recently finished work on his book *Physics in the 20th Century*, to be published soon by Harry N. Abrams, Inc. He wrote "Unlocking the Climate Puzzle," in the May 1998 NATIONAL GEOGRAPHIC.

In northern Peru warnings allowed many farmers and fishermen to make the best of El Niño's effects. Grass grew on land that is usually barren, and farmers raised cattle. Rice and beans could be planted in areas normally too dry to support them; fishermen were able to plan for shrimp harvests in coastal waters, generally too cold for the shellfish.

"The potential uses of advance information are almost limitless," says Michael H. Glantz of the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, pointing out how governments and industries around the world can make planning for El Niño and La Niña pay off. For example, Kenyan coffee growers find their product in greater demand when droughts affect coffee harvests in Brazil and Indonesia. Palm oil production in the Philippines typically declines during El Niño, as does the squid catch off the California coast. Countries that anticipate these developments can fill the gaps and prosper.

At the very least, preparation can save

lives. Even in poverty-ridden Peru constructing storm drains and stockpiling emergency supplies saved hundreds of lives during 1997 and '98. Forewarnings brought timely international aid to such places as Papua New Guinea, where highland populations were threatened with starvation after frost and drought combined to destroy subsistence crops. Many affected areas could prepare for floods and fires, population migration, and the spread of disease.

THERE ARE WRITTEN records of El Niño's effects in Peru at least as far back as 1525, and researchers have found geologic evidence of El Niños in Peruvian coastal communities from at least 13,000 years ago. "We know the Inca knew about them," says Adm. Giampietri Rojas of Peru's Institute of the Sea. "They built their cities on the tops of hills, and the population kept stores of food in the mountains. If they built on the coast, it was not near rivers. That's why so many of their dwellings are standing today." But it was not until about 25 years ago that the rest of the world began to pay attention to El Niño. And after the surprise devastation of 1982-83, climate experts intensified efforts to understand how the process works globally. Governments invested in equipment to monitor the particular conditions in the Pacific that trigger El Niño.

Perhaps the most important effort was the development of the TAO (tropical atmosphere/ocean) array of 70 moored buoys to span the equatorial Pacific. Completed in 1994, the TAO buoys are now the world's premier early-warning system for change in the tropical ocean. They monitor water temperature from the surface down to 1,600 feet, as well as winds, air temperature, and relative humidity.

The data collected by the buoys are transmitted to polar-orbiting satellites and then to NOAA's Pacific Marine Environmental Laboratory in Seattle. Supplemented with temperature measurements taken by research ships, the data help create a comprehensive portrait of the upper ocean and lower atmosphere.

Meanwhile the TOPEX/Poseidon satellite, a U.S.-French mission begun in 1992, orbits Earth at a height of 830 miles, measuring sea-surface elevation and relaying information about ocean circulation, including the

enormous rhythmic sloshings called Kelvin and Rossby waves that travel back and forth across the entire Pacific.

Thanks to the TAO buoys, the TOPEX/Poseidon satellite, and a variety of other tools, climate scientists now have information of unprecedented range and accuracy, which has enabled them to confirm and expand their theories about what occurs both during normal weather patterns and during sea changes that herald the periodic—and inevitable—arrivals of El Niño and La Niña.

Weather is so variable that it's hard to call any situation normal. But in most years climate in the equatorial Pacific is governed by one generally dependable pattern. Sunlight heats the uppermost layer of seawater in the western ocean around Australia and Indonesia, causing huge volumes of hot, moist air to rise thousands of feet and creating a low-pressure system at the ocean's surface. As the air mass rises and cools, it sheds its water content as rain, contributing to monsoons in the area.

Now much drier and far aloft, the air heads east, guided by winds in the upper atmosphere, cooling even more and increasing in density as it travels. By the time it reaches the west coast of the Americas, it is cold and heavy enough that it starts to sink, creating a high-pressure system near the water's surface. The air currents then flow as trade winds back toward Australia and Indonesia. This giant circulatory loop, moving from west to east in the upper air and from east to west at low altitudes, is called the Walker circulation, for Sir Gilbert Walker, the British scientist who studied the process in the 1920s.

As the trade winds blow westward over the Pacific, they push the warm top layer of the ocean with them, causing the hottest water to pile up around Indonesia, where, because of both wind action and thermal expansion, the sea level is usually about 18 inches higher than it is off the west coast of Mexico. All along the eastern Pacific, and especially off Ecuador and Peru, colder subsurface water wells up to replace the sheared-off top layer, bringing up a bevy of nutrients from the deep ocean. That chemical bounty sustains an enormous food web and makes the coastal waters off Peru one of the world's most prolific fisheries.

El Niño changes all that. For reasons that scientists still do not comprehend, every few

years the trade winds subside or even disappear. The usual air-pressure pattern reverses itself in a phenomenon called the southern oscillation, making barometer readings higher in Australia than they are in the central Pacific. The resulting pattern—known as ENSO, for El Niño/Southern Oscillation—involves only one-fifth of the circumference of the planet. But it transforms weather around the globe.

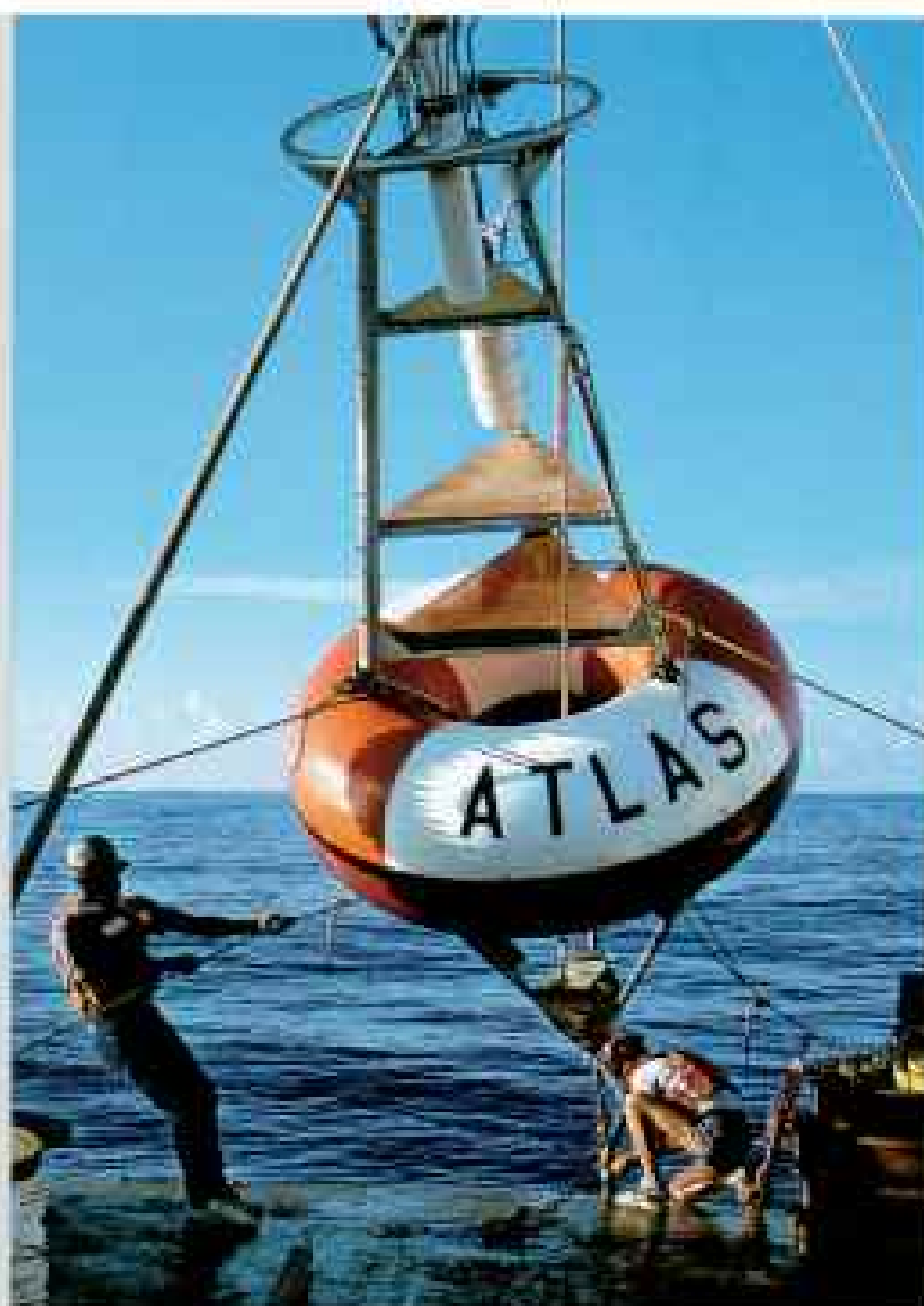
Without the trade winds the top layer of the eastern Pacific does not move west. It stays in place, getting hotter and hotter, swelling as it warms. Eventually it hits the threshold for what meteorologists call deep convection—the point at which the steamy surface air blasts into the upper atmosphere. (In some places during

1997-98, sea levels off South America were ten inches above normal and surface temperatures reached almost 86°F.) When that happens, water in the upper atmosphere condenses and falls as torrential rain on the west coast of the Americas.

This, in turn, reduces the salinity of the coastal seas, where deepwater upwelling has already declined or stopped. Marine life that customarily thrives off Ecuador and Peru, including economically essential anchovy populations, heads south in search of cooler, richer waters—to the great benefit of fishermen in Chile. Off North America exotic warmwater species suddenly appear farther north. In 1997, apparently for the first time, a fisherman

Tracking El Niño

The El Niño of 1982-83 took the scientific world by surprise: The enormous El Niño was at its peak before telltale changes in sea temperature were detected. To measure and predict future El Niños, the National Oceanic and Atmospheric Administration (NOAA) launched the tropical atmosphere/ocean array, 70 anchored buoys (right) spanning the equatorial Pacific. The buoys measure air and wind conditions at the surface and sea temperatures to a depth of 1,600 feet. Ground and satellite data were used to create the image at far right, showing deviations in El Niño temperature and wind direction in May 1997. East-to-west winds have reversed themselves, at left, and a counter-clockwise pattern near the top sends warm, moist air toward California.



GENIE SWENEY, NOAA

WARMING UP EL NIÑO'S RAIN MACHINE

Both El Niño and La Niña are driven by water temperature and atmospheric conditions, as seen in a series of cutaway views showing ocean and atmospheric measurements. In February 1997 the upper-atmosphere water-vapor levels and sea-surface temperatures were normal. In June, as the sea warmed both in the depths and at

the surface, evaporation increased the amount of water vapor in the air, and storm production increased. Water temperatures and water-vapor content continued to rise. Even as El Niño peaked in December, a tongue of cool water formed in the depths and began to return the region to normal conditions and perhaps to a La Niña.



caught a marlin in the ordinarily chilly seas off Washington State. Californians started pulling in bonito and albacore tuna, species normally found only far offshore. Other tuna were netted in the Gulf of Alaska.

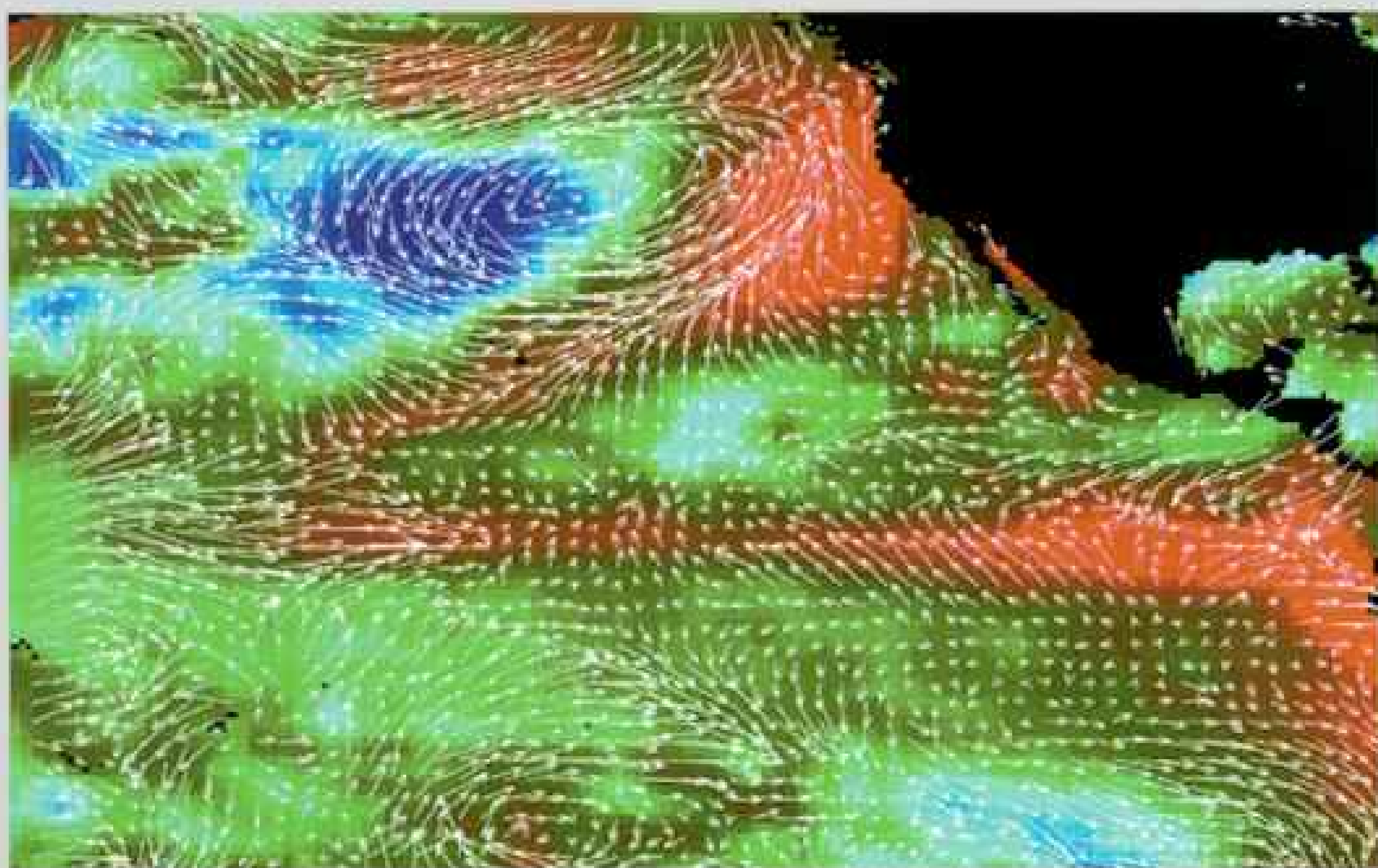
Because El Niño moves the rains that would normally soak the western Pacific toward the Americas, such places as Australia, Indonesia, and India may experience severe drought. According to historical records, 600,000 people died in just one region of India from the epic droughts of the 1789-1793 El Niño.

In Africa the altered wind, heat, and moisture patterns of El Niño portend drought—generally in the east and extreme south. In particular, cooling of the southwestern

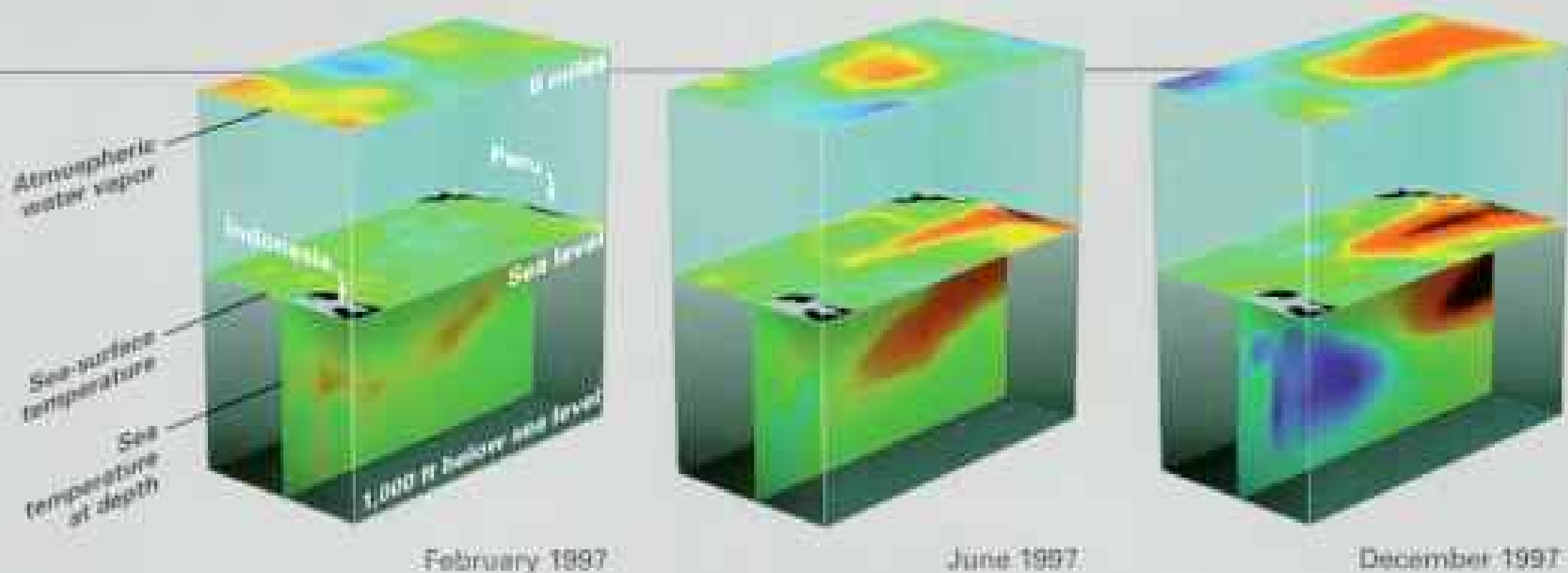
Indian Ocean customarily strengthens a high-pressure area that keeps rainfall from reaching the south.

Meanwhile, back in North America, the jet streams that travel five to eight miles above Earth's surface shift dramatically. The polar jet stream tends to stay farther north over Canada than usual; as a result, less cold air moves into the upper United States. In fact, northern-tier states saved an estimated five billion dollars in heating costs during the 1997-98 El Niño.

At the same time upper-level tropical winds reverse themselves, blowing the tops off cyclones forming in the mid-Atlantic and usually reducing the number of hurricanes that strike land in (Continued on page 93)



BY TIMOTHY LILL, JET PROPULSION LABORATORY, NASA (ARTIST: DIAGRAM BY DAVID FERSTER); SOURCES: JET PROPULSION LABORATORY AND GODDARD SPACE FLIGHT CENTER, NASA





SWEPT AWAY Mudslides tore Beatriz Baca de Chavez's home from its foundation in January 1998; now she cries not only for her loss but also for the entire town of Santa Teresa, Peru.

The slides, fed by the second worst El Niño rains in Peruvian history—and

aggravated by clear-cut logging that left the distant hills without trees—destroyed the village and killed 22. Flooding in Peru cut thousands of people off from their livelihood as some 300 bridges were washed out. To cross the San Francisco River between the towns of Tambo

Grande and Malingas, many commuted by inner tube pulled by ferrymen (above right). Even the dead were displaced by El Niño. Flooding from a ruptured earthen dam destroyed a cemetery (right), floating caskets and skeletons through the streets of Mampuesto.



EDUARDO ESTRADA/AGENCE FRANCE PRESSE (AMBIENT); JOHANNA B. PIVOT



ON HIGHER GROUND Before El Niño, Segundo Yovera and his wife, María, had a house with solid walls and a real roof—amid fields of rice, corn, and cotton—near the Piura River in northern Peru. Then came the rains of February 1998. The river rose, the mud flowed, and their



JOHANN B. FINKEL

town of Chato Chico was wiped off the map. The townspeople relocated to the desert and erected temporary homes. Despite flood records dating back to the Inca, people still settle in fertile but vulnerable river valleys. In Peru the 1997-98 El Niño destroyed 30,000 homes.



WITH BY JUANNA S. PERMO

LAKE OF THE DUNES

Like a 90-mile-long mirage, an El Niño-fed lake ten feet deep spread across the floor of Peru's Sechura Desert, usually one of the driest places on Earth. Over the

centuries native people have given the periodic lake temporary names. This time Lake La Niña prevailed. No humans were displaced by the flooding.

President Alberto Fujimori

(above), declaring that some good should come of El Niño, helped stock the lake with fish. They will be harvested until the lake, which drains to the Pacific Ocean, dries up in about two years.

(Continued from page 87) the U.S. by half—from an average of two a year to one or none, according to studies at Colorado State University and Florida State University. One study indicates that El Niño also generally reduces tornadoes in the southern Plains states.

AN UNEXPECTED CROP of sardines off the coast of Chile? Tuna in the Gulf of Alaska? Lower heating bills in the U.S.? Fewer hurricanes in the Atlantic?

Enter La Niña. During a La Niña event, an abnormal cooling in the eastern Pacific produces conditions more or less the opposite of those created by El Niño—nature's way, perhaps, of rectifying the heat imbalance that El Niño represents. As with El Niño, the effects of La Niña are most pronounced from December to March.

In La Niña years the easterly winds from the Americas are stronger than usual. That drives more than the normal amount of warm sea-surface water westward, in turn causing larger than normal volumes of deep, chilly water to rise to the surface and producing a "cold tongue" that extends 3,000 miles along the Equator from Ecuador to Samoa.

With so much warm water flowing toward Asia, the Pacific's mighty heat engine remains firmly anchored in the west, causing heavier monsoon rains in India, higher than average precipitation in Australia, and wetter than normal conditions as far west as southern Africa. The huge air masses and cloud banks associated with the hot zone also change the path of the jet streams, which move high-altitude air from west to east across the ocean.

The polar jet stream, which in an El Niño year stays high in Canada, moves farther south, driving frigid air down into the U.S. Winters are colder, especially in the northwestern and upper midwestern states. The subtropical jet stream that blows across Mexico and the Gulf during El Niño events weakens during La Niña; consequently, far less rain falls in the Gulf and southeastern states. Drought is common in the desert Southwest. Hurricanes in the tropical Atlantic encounter no westerly wind resistance and therefore are twice as likely to strike the U.S. The 1998 La Niña hurricane season was the deadliest in the past two centuries.

As experts use increasingly reliable data to comprehend the forces and patterns of these

periodic weather cycles, they are making better predictions of at least the broad contours of the cycle. There are two major ways of forecasting large-scale weather events such as El Niño, and climate scientists use both.

One method is statistical. Analysts pore over past weather records to determine what kind of conditions have the highest probability of occurring simultaneously. For example, lower barometric pressure and higher sea-surface temperatures in, say, Tahiti usually mean more rain for Ecuador and less for northern Brazil. This technique yields results even if the analyst has no idea how the two coexisting conditions are related, and traditionally forecasters have preferred its reassuring mathematical solidity.

But statistical procedures provide very little information about what cause-and-effect relationships may be producing various climate conditions. Moreover, statistical analysis can only determine the likelihood that past conditions will recur—and no two El Niños or La Niñas are the same.

With the advent of supercomputers, scientists have taken advantage of an alternative method of prediction called climate modeling. In this method, software incorporates the fundamental laws of oceanic and atmospheric physics into a simulated world where weather changes over time. Researchers then feed tens of thousands of specific pieces of information about the real world into the model and see how accurately the computer-generated results resemble what actually happens.

In theory, models can reveal the unique or idiosyncratic conditions that will result from a given climate pattern and then fast-forward to see how events related to that pattern will unfold. In practice, most of the results have proved too broad or uncertain to predict weather on even a large regional scale, much less in a local range of 100 to 200 miles.

So, historically, statistical predictions have been somewhat more accurate than computer-generated models—until now. The 1997-98 El Niño "was one in which the full climate models were more successful than statistical predictions for the first time," according to NCAR climate analyst Kevin Trenberth. "The tropical Pacific," says Trenberth, "appears to be predictable for a year or so in advance."

In fact, "to a certain extent we underplayed

what the models were telling us," says Aris Leetmaa, director of NOAA's Climate Prediction Center. He believes that if scientists had relied on the models more and the statistical evidence less, their 1997-98 predictions would have been even more accurate.

As encouraging as the model results have been, there is still room for improvement. For example, most of the best models created in advance of the 1997-98 El Niño predicted much smaller monsoons in India than actually occurred and far less rain than actually fell in southeastern Africa and Australia. Kenya and Somalia had heavy and prolonged rains that provoked an epidemic of waterborne Rift Valley fever and dengue fever, among other maladies. "The big question is why," says Leetmaa. "That's the challenge for the future."

It would be far easier to tune the climate models if scientists were able to look through centuries of records. But "we just don't have hundreds of years of data," Leetmaa explains. And even if they were available, "data sets aren't going to give us the full answer. But analyzing the data in combination with computer-simulated experiments is where we're going to make progress."

Greater distribution of monitoring equipment would also increase the accuracy of climate-pattern prediction. No observation networks have been established yet for the equatorial Atlantic and Indian Oceans. Since part of the variability among El Niños and their regional impacts can be attributed to activity in these ocean basins, the need for improved data reporting in these areas seems clear. Especially, experts note, if El Niños are becoming more ferocious.

THERE IS A CONSENSUS among climate scientists that El Niños have become more frequent and progressively warmer over the past century. Beyond that there is little agreement, particularly about whether human activity might be exacerbating their effects.

In the past 98 years there have been 23 El Niños and 15 La Niñas. (That's according to NOAA's definitions. Other organizations get a slightly different count.) Of the century's ten most powerful El Niños, four—the four strongest—have occurred since 1980. But no one knows whether this indicates a trend



or is simply a meaningless random clustering.

And no one *can* know at this point. Even a hundred years of precise rainfall and temperature observations in the Pacific might not be sufficient to confirm a major tendency one way or the other. Moreover, many experts now suspect that El Niños—and indeed many oceanic weather patterns—may alternate in form and severity on a timescale of decades or even centuries. "By and large," says NOAA's Leetmaa, "the El Niño patterns look a lot like the overall changes in U.S. rainfall and temperature patterns from decade to decade." But no matter what's happening, "the bottom line is the past 20 years are different from the previous 30."

It is difficult to imagine how the global warming observed over the past hundred years, which amounts to about one-tenth of a degree Fahrenheit a decade, could have much effect on the stupefying volume of water in the equatorial Pacific. But it is plausible, some scientists believe.

"El Niño moves heat," says Tom Karl, one of



RUSSELL BROWN/REUTERS (CLOCKWISE NEWS)

SLIM PICKINGS His son and a friend have water aplenty, but Cliff Etheredge's cotton crop was ruined by a West Texas drought. Farmers were encouraged by early spring rains, but "El Niño tricked us," he says. "After March the rain quit." La Niña threatens more of the same.

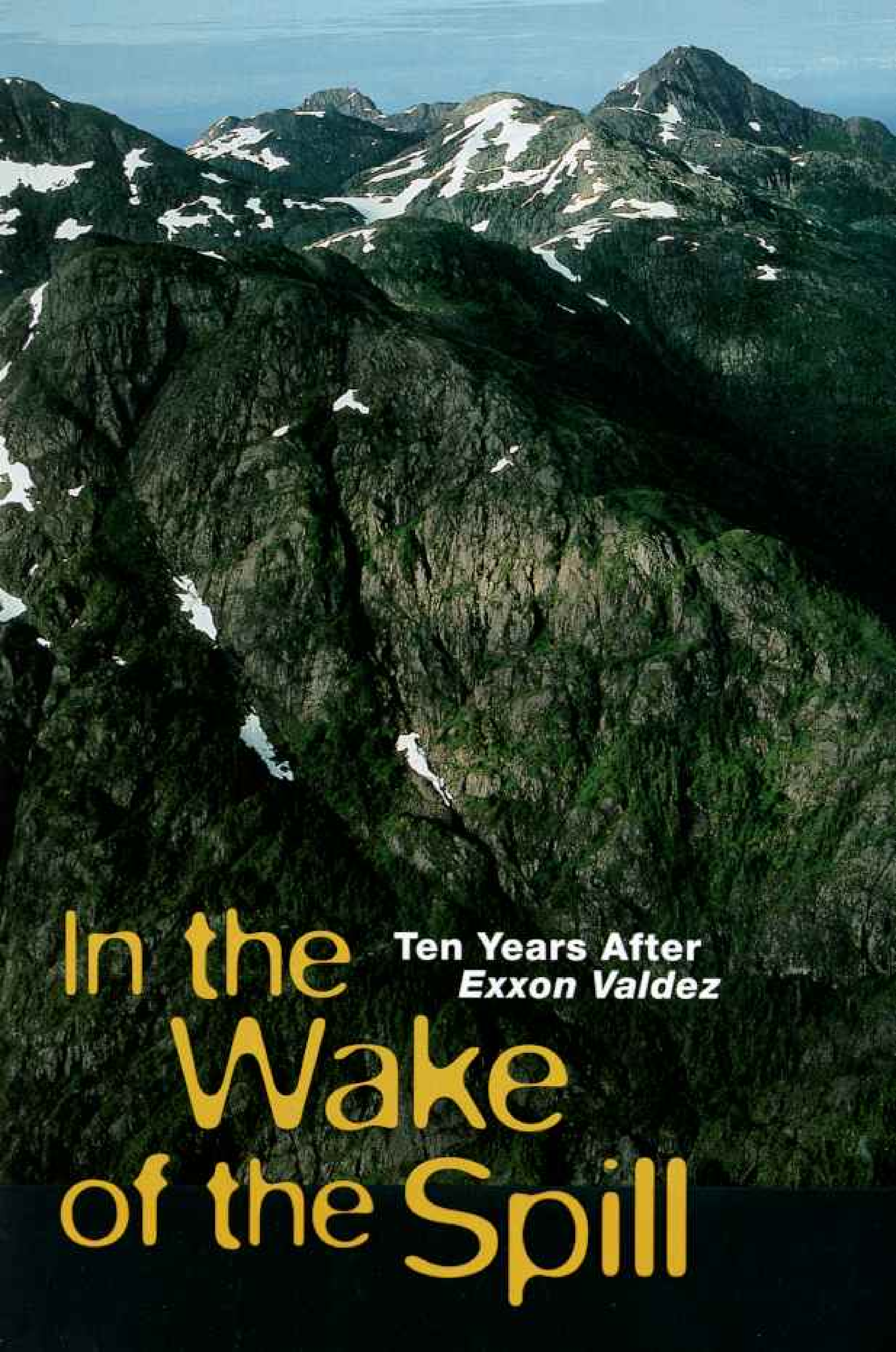
NOAA's veteran climate experts, "both in terms of water temperature and in atmospheric convection. This heat is transported out of the oceans and the tropics during the peak of El Niño as global temperatures increase. As the heat is released, the whole El Niño cycle begins again, with less cloudiness in the tropics and with the oceans absorbing more heat. With global warming there is more heat available. So the cycle may be shortened because the recharge time is shorter or because the release of heat is less efficient."

Whatever the future may bring, the world need never again be taken completely off guard by El Niño or La Niña. Due to the unprecedented foresight that climate science has made possible, the ocean's thermal moods may not seem so unpredictable and diabolical, but rather an ordinary part of life on the planet.

"We have to realize that it's something natural that's going to happen again and again," says Capt. Hector Soldi Soldi, a hydrographics expert with the Peruvian Navy. "And we have to be ready for that."

Even Isaias Ipanaque Silva—now living in one of the spare refugee camps in northern Peru, where homes are no more than four woven-straw walls with a plastic tarp for a roof—knows it. He and his neighbors walk three miles each way, every day, to farm the riverside fields that lay right next to their homes before El Niño swept their hamlet away. "We can't go back," he says, sad but resigned. "It will happen again. If God wants to save us next time too, we say thanks. But right now, this is where we will stay." □

Be on the lookout for the next El Niño or La Niña at www.nationalgeographic.com/elniño.



In the **Ten Years After**
Exxon Valdez
Wake
of the Spill



After the *Exxon Valdez* oiled 1,300 miles of Alaska shoreline in 1989, we asked, "Can the Wilderness Heal?" A decade later the answer seems to be yes—with scarring. Prince William Sound's shores don't readily betray signs of the spill. Yet a footstep on a lonely marsh draws an oily sheen.

Rebounding from a slick that killed perhaps 40 percent of their population, common murrelets are again making the Gulf of Alaska's Barren Islands a little less barren. Other species are also recovering, but a number still struggle.

By JOHN G. MITCHELL

SENIOR ASSISTANT EDITOR

Photographs by KAREN KASMAUSKI

FROM THE VILLAGE of Tatitlek, the way to Bligh Reef runs northwest to the cusp of Busby Island, then bounces into the bright blue chop of Prince William Sound. There is a red buoy far ahead to starboard. Closer and dead-on, a tall steel pylon rises from the water, festooned with navigational aids to speed the mariner on a safe voyage. The Alutiiq people of Tatitlek have a name for the pylon. They call it Hazelwood's Stick, in grudging memory of Joseph Hazelwood, the *Exxon Valdez* skipper who, just after midnight on March 24, 1989, found his fully loaded tanker fetched up hard on the jagged shoals of Bligh Reef. The pylon marks the spot where oil began to flow from the tanker's ruptured hull, poisoning birds, marine mammals, and pristine Alaska beaches for hundreds of miles and casting across the region's human community a psychic stain that lingers still, ten years later.

"It's not something that people can easily forget," says Gary Kompkoff, a commercial fisherman and president of the Tatitlek Village Council. We are four miles out from the village pier, approaching the reef in a motor skiff. "To some extent," he says, "the resources are recovering. But the people still hurt."

On such a clear and bracing morning as this, the healing of Prince William Sound from one of North America's most devastating offshore oil spills seems far more palpable than the residual hurt. Here are sparkling waters, seabird skies, high green headlands, the icy ramparts of the Kenai Peninsula gleaming across the sound. Even Hazelwood's Stick supports the



illusion that Prince William Sound is fully alive and well again. A soft brown lump reclines above the waterline on one of the pylon's ice guards—a movable lump that, as we draw near, turns out to be a Steller sea lion sunning itself.

"We see them here from time to time," says Kompkoff. "A good sign, but who knows?"

Apparently no one knows. The Steller sea lion, largest of all the eared seals and an endangered species, has been in serious decline in the northern Gulf of Alaska for 20 years. Scientists can only guess what effect, if any, the spill may have had on the decline of this graceful pinniped.

But there are some questions science *can* answer a decade after 11 million gallons of North Slope crude sullied this ecosystem and compelled the Exxon Corporation to pay the

Photographer KAREN KASMAUSKI collaborated with JOHN MITCHELL on "Oil on Ice" in the April 1997 issue. This is her 17th NATIONAL GEOGRAPHIC assignment.



state and federal governments more than a billion dollars in criminal and civil damages. Government at both levels has invested many of those dollars in research and monitoring, not only to assess the spill's damage and the prospects for achieving recovery but also to forge for the long term a better understanding of how all the pieces of the ecosystem fit together—prey and predators, plants and habitats, tides and currents.

It is understood, for example, that the natural flushing action of waves and storms was far more efficient in healing the sound than all the mops and sponges and power hoses of the cleanup crews. For despite its best intentions, the human response swept some of the oil out of sight—but not out of the sound. Globules of petroleum mousse still lurk here and there

under a littoral carpet of gravel and rocks.

Similarly, the initial effort to rescue and bathe oil-smearing otters and seabirds, however emotionally gratifying, may have had scant effect on the recovery of specific populations. In fact, many of the rehabilitated otters, and there were hundreds, died soon after they were released to the wild, in some cases possibly as a result of human handling.

So now the prevailing wisdom holds habitat protection to be a better cure than hand towels and tender care. "If you want to have marbled murrelets," a restoration scientist said to me in Anchorage as I was heading for Tatitlek, "you have to have old-growth trees for them to nest in. You want salmon, you need to protect the streams salmon spawn in. You can't just draw a line at the ocean's edge."



Looking landward from a skiff on Prince William Sound, one can only imagine the real metes and bounds that have been drawn in recent years with oil-spill settlement dollars—back from the ocean's edge to protect by purchase or easement more than half a million acres of private land, all prime habitat that otherwise might well have been logged or commercially developed at some time in the future.

Kompkoff points to Bligh Island, off our port side. It is owned by the village corporation of Tatitlek, but the corporation has placed these 8,267 acres under a conservation easement guaranteeing the government that the timber, much of it old-growth, will never be cut. And this is only one part of a larger conservation package that will preserve habitat along 61 trout and salmon spawning streams,

transfer 32,000 acres of corporation land to the Alaska state park system and Chugach National Forest, and enrich Tatitlek's 97 Alutiiq residents and other corporation members with the benefits of a trust fund worth 35 million dollars. Kompkoff declares it a good deal "all the way around."

In the Alutiiq tongue Tatitlek means Windy Place, though it wasn't very windy the night that the *Exxon Valdez* went aground on Bligh Reef. Prevailing currents began to carry the oiled waters out across the sound to the southwest, away from Tatitlek. When the people awoke the next morning and heard the first sketchy accounts of what had happened just five miles away but saw no oil on their beach, they could hardly believe it. Then the sharp, ambient stink of petroleum began to seep



How toxic is ten-year-old oil? Very, according to recent studies. Slow-degrading compounds in oil can damage salmon fry—as they have the one in the left vial below—at concentrations just one-tenth Alaska’s allowable limit. With pockets of oil still seeping into some intertidal spawning streams (left), the threat to salmon lingers.



through the thin frame walls of the houses of Windy Place.

“The smell made some people sick,” Kompkoff remembers. “The herring season was about to open, our first harvest after winter. The government had to shut it down. Shut down our salmon too. We lost it all.”

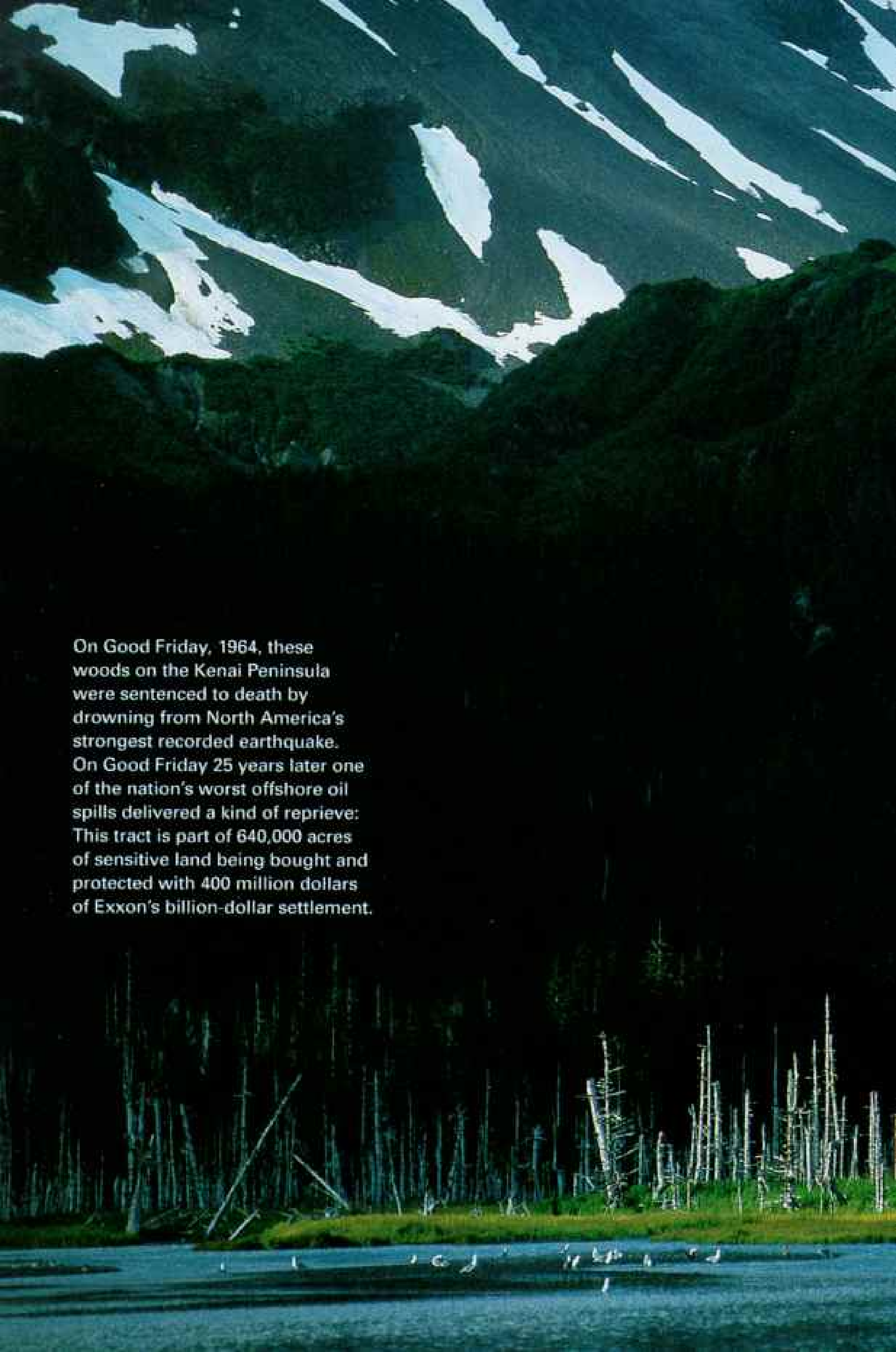
IF ANYONE HAS A SENSE of the resources that were lost here ten years ago and a good idea as to which of them might be bouncing back, it’s likely a dynamic woman named Molly McCammon, who presides in Anchorage as executive director of the *Exxon Valdez* Oil Spill Trustee Council. The council was established by Alaska and the federal government in 1991 to oversee the restoration effort and to expend some 900 million dollars of Exxon’s

out-of-court settlement on habitat protection, scientific research, and resource monitoring.

Before setting out on a tour of the spill area, I called on McCammon and Stan Senner, the council’s science coordinator, to see what their balance sheets showed of the gains and losses in Prince William Sound. Were things looking brighter?

“Yes,” said McCammon. “The injured ecosystem is on its way to recovery. But we cannot say that it has recovered because there are still signs of trouble among sea otters and other species on the western, most heavily oiled side of the sound.”

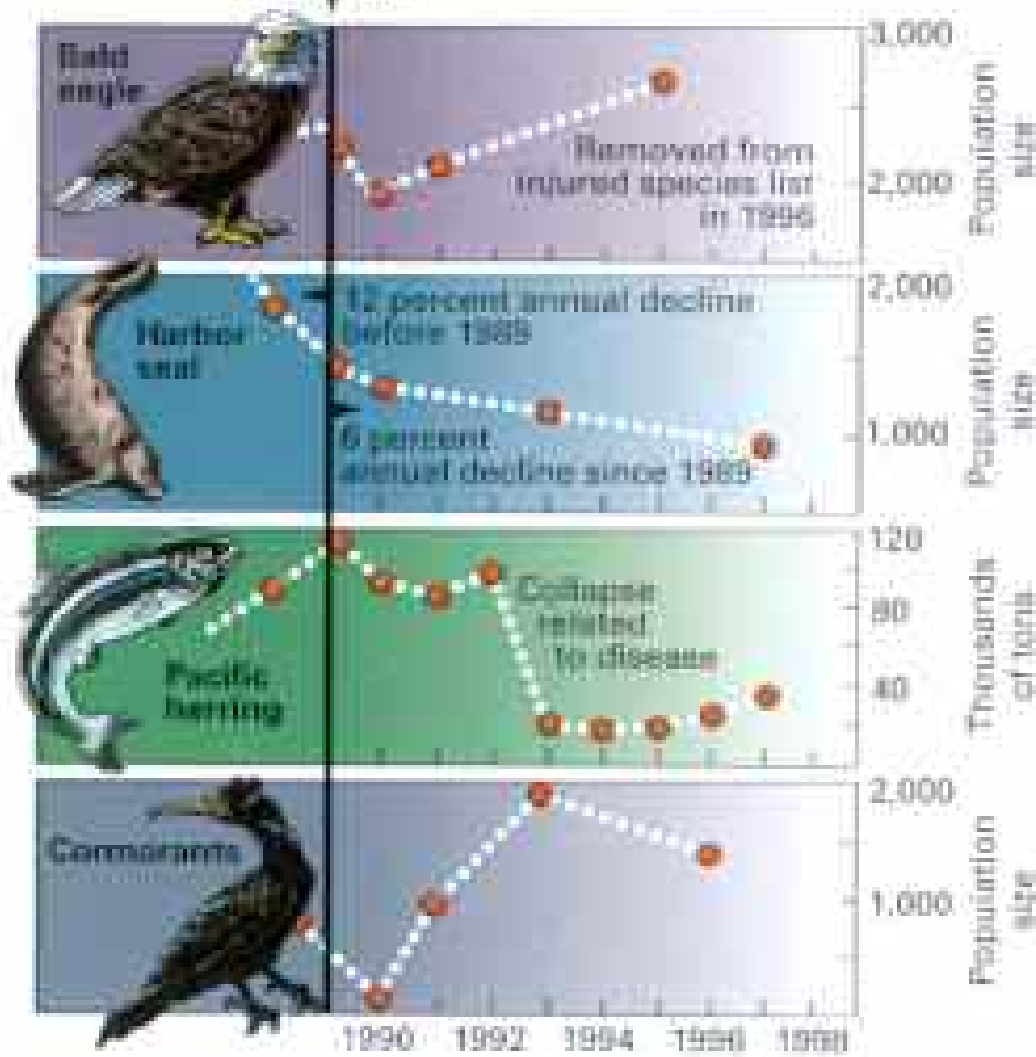
And Senner added: “The ecosystem that is there today is not the ecosystem that was there before the spill, and that is due both to the effects of the spill. (Continued on page 106)

A landscape photograph showing a mountain valley. The upper portion of the image features a dark, forested mountain slope with several irregular patches of snow or light-colored rock. Below the mountain, a dense forest of tall, thin, dead trees (snags) stands in a field. In the foreground, a body of water, possibly a lake or a wide river, is visible, with some small, dark objects floating on its surface. The overall scene is somber and evocative, reflecting the text's narrative of environmental impact.

On Good Friday, 1964, these woods on the Kenai Peninsula were sentenced to death by drowning from North America's strongest recorded earthquake. On Good Friday 25 years later one of the nation's worst offshore oil spills delivered a kind of reprieve: This tract is part of 640,000 acres of sensitive land being bought and protected with 400 million dollars of Exxon's billion-dollar settlement.

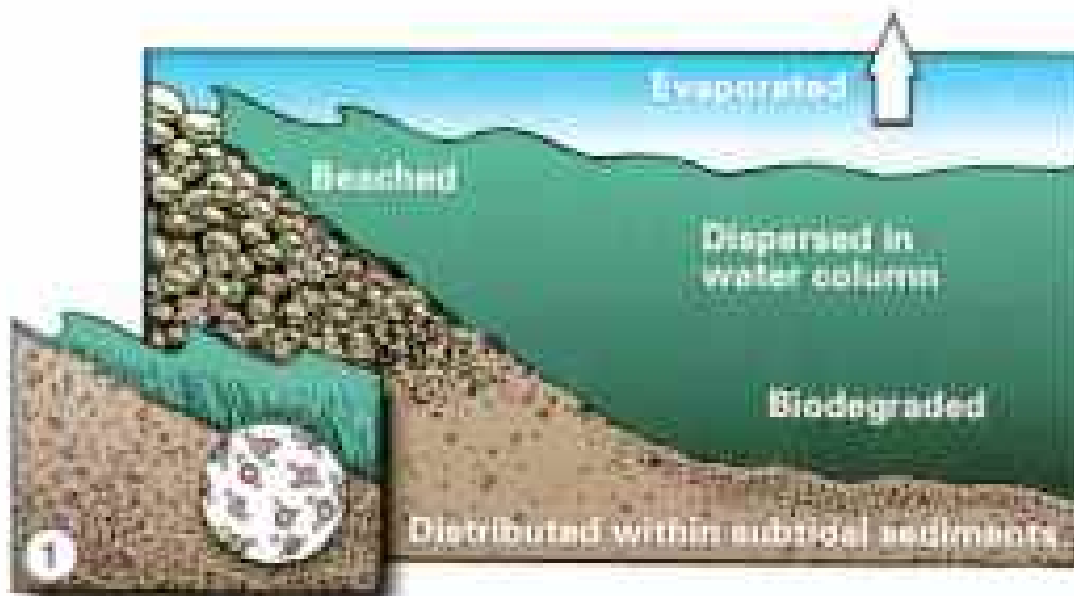
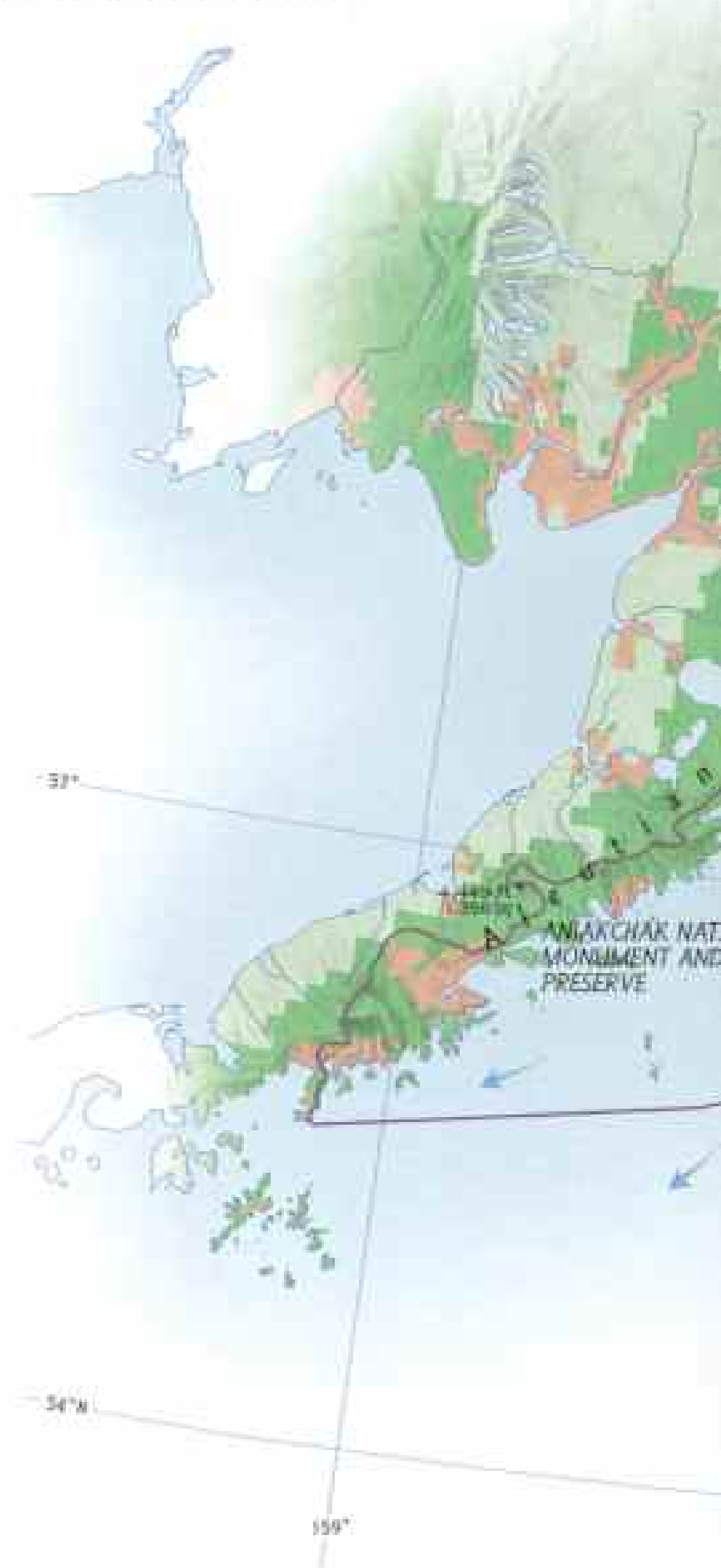


Exxon Valdez oil spill
March 1989



PRICE WILLIAM SOUND DATA COMPILED BY DEBORAH VALDEZ OF SPIG TRUSTEE COUNCIL; ART BY RICHARD L. JONES

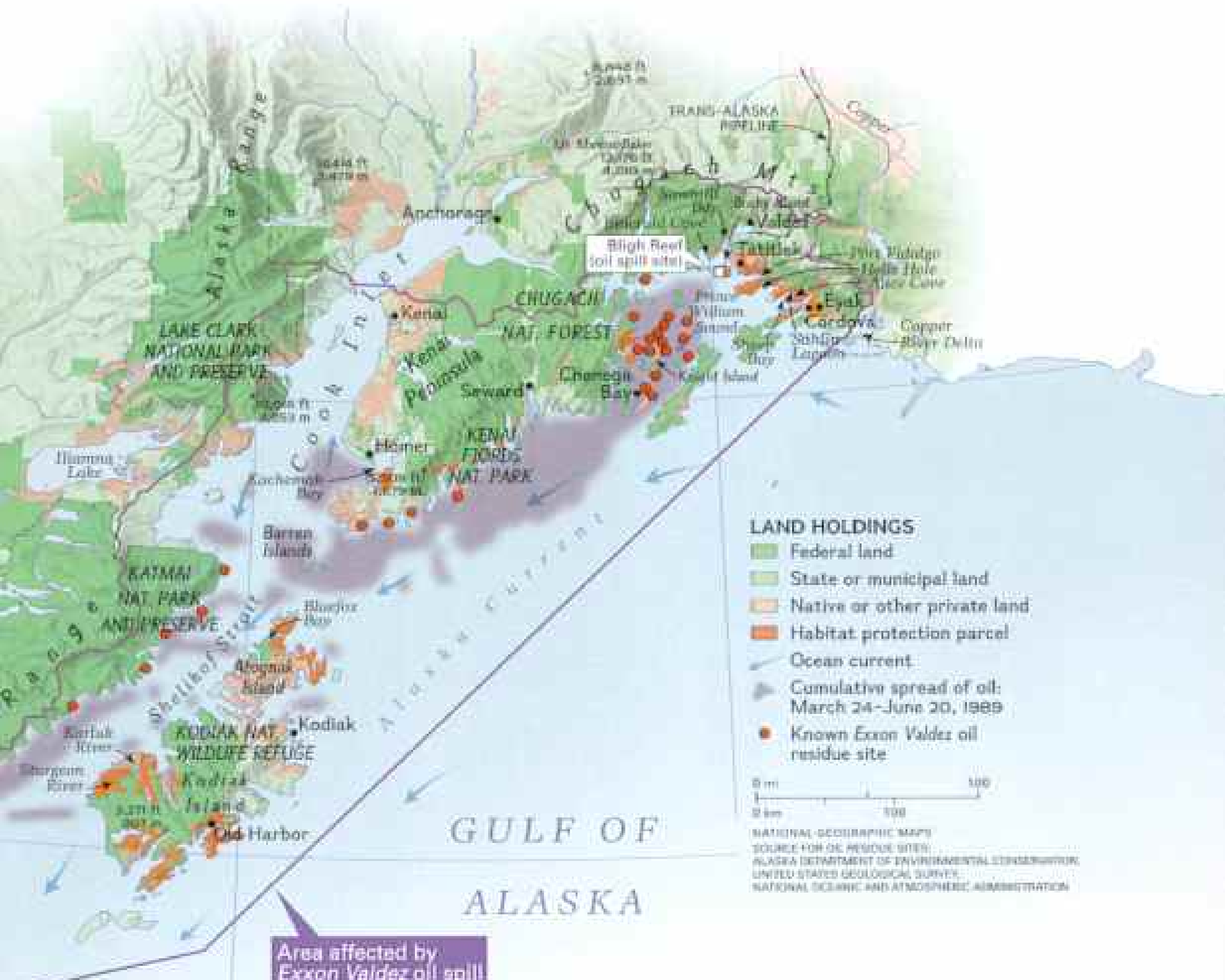
It was easy to count oily carcasses after the spill. It has been harder to assess long-term effects. Harbor seals were already in decline, and oil may or may not have contributed to a disease-induced herring crash in 1993. Bald eagles have returned to pre-spill numbers, while cormorants have again dropped.



Less than 15 percent of the spill was recovered. Most of the oil evaporated or biodegraded, but what remains is tenacious. While waves easily wash sandy beaches clean (1), on rocky shores oil can remain beneath and between rocks, sheltered from surf (2). Marshes and mudflats hold oil even tighter (3). Their fine sediments keep oxygen out—and with it the microorganisms that break oil into nontoxic elements.



A decade after disaster: still plenty of oil on this Knight Island cove. "It surprised me," says David Sale, ecotour leader and former damage assessment scientist, holding rocks he pulled from a crevice. "Most beaches haven't changed since I saw them in '91 and '92." But cleaning is expensive, environmentally disruptive, and controversial. The 11-million-gallon spill (right) spanned nearly 500 miles, hitting three national parks and eight other protected areas.



Ten years ago the port of Valdez (right) showed the world how *not* to contain oil spills. Now it's an industry showcase. In a monthly drill, workers on one of the port's escort response vessels (below) unfurl a containment boom. Spills are commonplace in the industry; worldwide, about 50 spills the size of *Exxon Valdez* or larger have happened since 1970. After the Alaska spill Congress passed laws designed to reduce the risk of such disasters.



and to natural change, which is happening all the time."

Among the known effects of the spill was a huge loss of wildlife—perhaps as many as 5,000 sea otters, 300 harbor seals, 22 killer whales, more than 150 bald eagles, and an estimated 250,000 waterfowl and other birds, including murrelets, cormorants, guillemots, oystercatchers, loons, and ducks. "I don't think anyone will ever know how many birds were lost," a U.S. Fish and Wildlife Service official had already told me. "There were windrows of feathers two feet high on some of the beaches."

But now, according to the council's monitoring reports, some of the species on the casualty list are looking healthier. The sound's bald eagle population, for example, was found to be fully recovered in 1996 and is holding strong. The common murre appears to be recovering after sustaining what some scientists believe was a 40 percent reduction in numbers. Pink

salmon, one of the region's top commercial species, have been rebounding after several years of high egg mortality in the intertidal stretches of their spawning streams.

That's the good news. The bad news is that harbor seals, herring, harlequin ducks, marbled murrelets, and pigeon guillemots do not seem to be recovering. The verdict is still out on the loon and the black oystercatcher.

I asked McCammon and Senner about the poor response of the harbor seal, a species of great importance in the subsistence diet of native villagers but one that, like the Steller sea lion, was in a downward spiral in this region long before the spill. Senner said: "In addition to the effects of the spill, there isn't the abundant prey that seals used to find in these waters. Over a couple of decades we've seen the system resetting itself to support fewer seals. But we don't know why. We're still looking into it."

And the herring? The herring had crashed.



While the catches were good until 1992, the following year herring returned for their spawning cycle infected with lesions. Researchers are busy sorting the possible causes—not all necessarily related to oil—from a viral infection to winter starvation. “Herring are the key to this ecosystem,” a fisheries oceanographer in Seward told me. Almost everything eats herring—including herring.

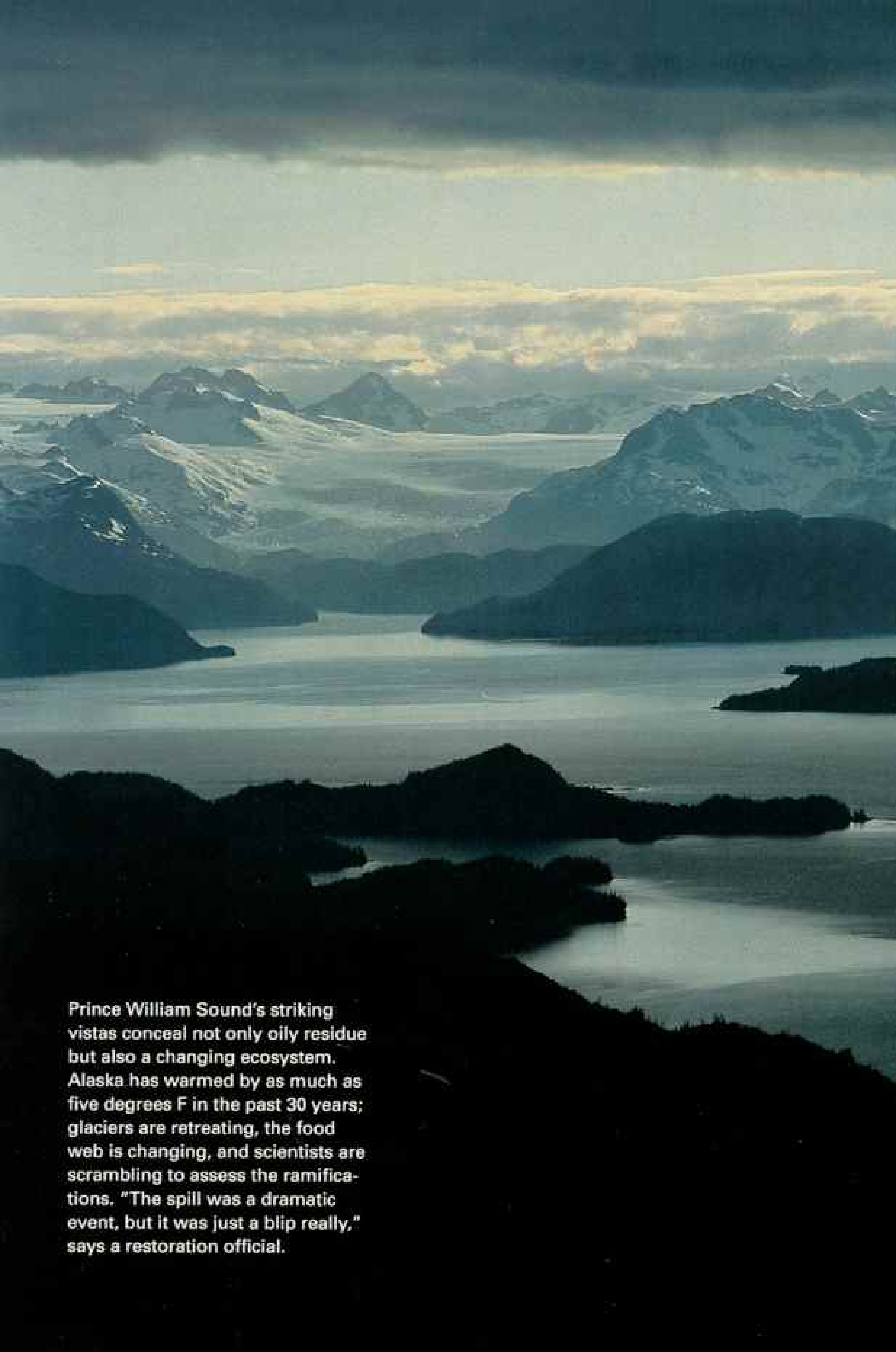
Including people. And how were *they* holding up, those 10,000 or so fishermen, cannery workers, charter-boat operators, and village chiefs sprinkled across the region from Cordova to Kodiak? Molly McCammon shook her head. She knows a thing or two about the Alaska psyche from her years as a journalist, a homesteader in the Brooks Range, a fisheries and subsistence specialist in the governor’s office and the statehouse.

“That’s the sad part,” she said. “The government settled with Exxon early on, in 1991. But

the private individuals who were affected by the spill—their claims are still under appeal, and who knows when they will be settled. There’s not been healing. This has become a metaphor for everything bad that has happened in the region in the past ten years.”

CORDOVA, ALASKA, is a town of some 2,600 people, snug in its harbor on the far southeastern edge of Prince William Sound, under the great green brow of the Chugach Mountains. “Take a New England fishing village and put it down in the Swiss Alps,” says Margy Johnson, a former mayor and the proprietor of the Reluctant Fisherman Inn on the waterfront, “and that’s Cordova.” Where bad things do happen nonetheless.

Over the years Cordovans have confronted, overcome, and moved beyond a number of wrenching events—a fire that razed much of the downtown business district in 1963, the



Prince William Sound's striking vistas conceal not only oily residue but also a changing ecosystem. Alaska has warmed by as much as five degrees F in the past 30 years; glaciers are retreating, the food web is changing, and scientists are scrambling to assess the ramifications. "The spill was a dramatic event, but it was just a blip really," says a restoration official.





great Alaska earthquake a year later that wreaked havoc with the harbor. But it was the aftershock of the spill of the *Exxon Valdez* that many Cordovans could not—and cannot yet—put behind them, even though no oil came within 60 miles of their community. “Look,” says Margy Johnson, “I’m sorry that some people can’t get on with their lives, because they should. But imagine how hard it must be if you’re in the middle of a class-action lawsuit and it just goes on and on and on. . . .”

In 1994, after a four-and-a-half-month trial in U.S. District Court in Anchorage, a jury awarded the commercial fishermen of Cordova and other affected communities five billion dollars in punitive damages for the economic losses they had incurred as a result of the spill. Exxon appealed. Today, five years later, the judgment is still unpaid, and many of the plaintiffs are bitter and frustrated.

“Before the spill we had a good thing going here,” said Stephen Riedel aboard his 42-foot purse seiner, *Lucky Lady*, in Cordova harbor. “We had confidence. Now we don’t know what

to expect. Exxon and the government just left us out in the cold.” In the late spring Riedel goes east to the Copper River Delta for sock-eye and king salmon, then, come July, seines in the sound for pinks. “Prince William Sound isn’t the same,” he said. “But we still have the Copper. It’s the lifeblood of this town.”

Torie Baker also fishes the Copper commercially, and with good results, for it is one of the most productive salmon rivers in the world. One evening she dropped by the Reluctant Fisherman, and we talked about the big river and its delta while the sun, going down, cast a rosy glow across the harbor. “You know,” she said, “some people who depend on the Copper River are beginning to worry that the next big spill will be a break in the pipeline.”

“I didn’t know the trans-Alaska pipeline crosses the Copper.”

“It doesn’t,” she said. “It runs beside it and crosses dozens of Copper tributaries. The pipeline was built to last 20 years. We’re past that now. Just stop to think what a break in it could do to that river.”

THE WAY Jerome Selby views it, the wound has healed, but "there's still a lot of shrapnel under the scar." At the time of my visit, Selby was mayor of Kodiak Island Borough, which embraces the namesake city and an archipelago of emerald isles that rise from the Gulf of Alaska to challenge the fogs and furies of the northern seas. The town itself, the oldest in Alaska with European roots, shelters some 7,500 residents, most of whom, directly or indirectly, are economically dependent on the bottom fish, crabs, and salmon the Kodiak fishing fleet hoists from the water. In March 1989 a Kodiak fisherman could feel only pity for the people of Tatitlek and Cordova, and at the same time much relief that Bligh Reef and Exxon's ruptured tanker were 300 miles away. Five weeks later, Exxon's slick came to Kodiak Island, and some borough residents have been pitying themselves ever since.

"I'd rather focus on the triumphs that came from this tragedy," Selby was saying in his office one day. "The science, the research, the critical lands acquired with settlement money. But let's face it. The disruption of human lives has had no compensation. Families fell apart that summer. When a judge brings the gavel down on a divorce, that's it. You can't restore a busted marriage."

I had heard about that, had poked into some of the reports documenting the social and cultural fallout, had spoken with one of the casualties. She had been married to a Kodiak fisherman. With the big commercial seasons shut down and his boat grounded, the husband shut *himself* down and, she said, spent the summer and fall staring out a window, speaking hardly a word. No change in the winter. Down came the gavel.

Possibly the most painful dislocations occurred in the native villages. First there was the temporary loss of the subsistence resources villagers claim, not just for sustenance but as the crux of their cultural heritage. Even today there is uncertainty among some villagers as to the safety of eating traditional foods harvested from the sea—"clean" by laboratory standards but nevertheless suspicious because of the continuing presence of oil residue. And then there was the stress generated by the cleanup itself; the sudden influx of strangers in hard hats with barrels of cash—\$16 an hour for grunt labor—was enough to tip more

Quality time with a puffin chick doesn't come easily on this island cliff, but at least it comes. Before 1989, data on regional wildlife were sketchy at best, making it difficult to gauge the spill's effects. But settlement money has helped turn the region into one of the world's most studied ecosystems. Biologist Kathy Frost tracks harbor seals with glued-on satellite tags (below). "The past ten years of biology has been tremendous," she says.



than a few impressionable young village men toward the alcohol and drugs that, in some cases, led to domestic violence. There was trouble like this even on Kodiak.

But Mayor Selby wanted to focus on triumphs, and among his favorites is the Alutiiq Museum, not far from his office. A real success story, he called it; built in 1995 with 1.5 million dollars from the oil spill trustee council as a repository for Alutiiq cultural artifacts, some of which were uncovered by cleanup crews at ancient seaside encampments. "It's already a big draw for tourists," Selby said. "There'll be ten cruise ships in here by the end of the summer. We never had that before."

To my way of thinking, the most outstanding triumph achieved so far in the wake of the *Exxon Valdez* disaster has been the effort to protect coastal and upland habitat the old-fashioned way—by owning it and letting it be. The program, into which the trustee council has pumped some 400 million dollars, has widespread support among Alaskans and environmentalists in the lower 48, but there are

His boat's called *Lucky Lady*, but salmon fisherman Steve Riedel (right) is quick to note that it was already named when he bought it a year after the spill. The sound's herring fishermen saw catches plummet in the 1990s; the cause is unclear. Alaska natives have faced fluctuations in their subsistence harvest, and some fear their food is not as safe as experts say. But life goes on. Of his son Loren (below), Old Harbor native Jeff Peterson says, "At least he'll be able to live off the land."



dissenters too, as I would presently discover.

To understand the conflicting perspectives here, it may be useful to examine the intent of the Alaska Native Claims Settlement Act of 1971. The act established among the state's Indian, Eskimo, and Aleut people a number of regional and village corporations, endowed them with cash to invest in profitable ventures, and allowed them to select from existing federal lands millions of acres to help sustain not only the old ways of hunting and gathering but also the corporate way of putting black ink on the bottom line. In the Gulf of Alaska region the villagers, being coastal people, selected much of their land from Chugach National Forest, Kodiak National Wildlife Refuge, and a string of de facto parklands on the Kenai Peninsula and the coast of Katmai.

Fast forward to 1994 and the *Exxon Valdez* Oil Spill Trustee Council's decision to enhance restoration through habitat protection. But

what habitats would the council protect? Why, none other than many of the lands now owned by the regional and village corporations, which in some cases had been busy pursuing their statutory mandate the new-fashioned way—by clear-cutting timber.

Before touching down at a couple of villages, I chartered out of Cordova in a small plane and flew over some of the lands recently or about to be acquired from the Tatitlek and Eyak Corporations on the eastern side of Prince William Sound. Sawmill Bay and Emerald Cove and Port Fidalgo and Hells Hole. Sheep Bay and Sahlin Lagoon and Alice Cove. Here and there in scattered patches the scalped slopes of clear-cuts passed in review. But here too were clean gray beaches and silver streams twisting through old-growth spruce, and tan meadows and turquoise ponds and brooding peaks with swatches of lingering snow in their shaded couloirs. And having seen the country, I was



better prepared to understand some of the passionate feelings people would express in discussing the pros and cons of selling it back to the government.

In Chenega Bay, home base of one of the first native corporations to strike a deal with the trustee council (59,520 acres for 34 million dollars), there is concern that too much cash in hand could entice some families to move away, further fragmenting a small community already stressed by the oil spill and, 25 years before that, a tsunami that carried off most of the original town and killed 23 people. The Chenegans later rebuilt their village in this new location. "I just hope," said Gail Evanoff, the village council president, "that what the corporation did two years ago, selling the land, doesn't come back at us in ten and bite us all in the leg."


Eyak people also have strong views about selling off their land. In Cordova, where many

of them reside, I stopped by the village council office and spoke with Glenn Ujioka, the council vice president. Ujioka said, "We lose our identity when we lose our land. We'd rather own the land with stumps on it than sell it off. Guess what—trees grow back."

But at his home across town, Jim McDaniel, a member of the Eyak Corporation board, told me: "Hey, there's no good market for timber now. The corporation has tried to strike the most lucrative deal we could in the spirit of protecting the land and our people."

Among the most coveted corporation lands in the entire spill area are several large parcels on Afognak, after Kodiak the largest island in the archipelago. These lands are endowed with dense stands of old-growth Sitka spruce, salmon spawning streams, and excellent breeding, feeding, or nesting habitat for many of the species most seriously affected by the spill.

After buzzing around the sky up north, it



Fog streaks these hills of eastern Prince William Sound—but clear-cuts never will. In the years after the spill Alaska native corporations, under pressure to return profits to shareholders, began logging coastal forests, a move widely seen as a second blow to a beleaguered ecosystem. Now, land sales are preserving dividends and wildlife habitat alike.





was good to get my feet on the ground at Bluefox Bay, at the north end of Afognak, where Jerry Sparrow and his partner, Colleen Rankin, run a low-profile, no-frills wilderness lodge and, semiofficially, keep an eye on things roundabout for their neighbor, Uncle Sam. At the time of my visit, Uncle was about to acquire from native corporations one of those cherished parcels abutting the Red Peak unit of Kodiak National Wildlife Refuge, right across the bay from Sparrow's place.

It is a lonely, faraway kind of country, the north side of Afognak. Sparrow and Rankin and I toured a bit of it in Sparrow's launch, saw hideaway coves and ancient forests, saw puffins and auklets and sea otters and seals in sufficient numbers to make one wonder if anything deadly could ever have happened here, which of course it did. We beached for a bit on the backside of a small island poised between Afognak and the full windblown fury of the Shelikof Strait, and Rankin sat down beside me on the bleached skeleton of a driftwood spruce and said, "You know

what it's all about? The most important thing?"

I said I could only guess.

"It's the land," she said. "I'm an Alaskan, and for Alaskans nothing's more important than the land."

SINCE 1994 the oil spill trustee council has been feeding 12 million dollars a year into an endowment called the Restoration Reserve. It is designed to keep good things happening after the final installment of Exxon's civil settlement comes due in 2001. By the following year the reserve is expected to be worth 140 million dollars. Already the potential beneficiaries are scrambling to stake out a slice of the pie.

Not surprisingly, many interests want the money invested in more research and monitoring. Commercial fishermen, who tend to be skeptical of biologists, seek assurance that the science will have some practical applications to their industry and to fisheries management. And some conservationists call for more habitat protection, preferably in the treeless

Spill-containment vessels are a familiar sight to Prince William Sound's sea otters these days. The *Exxon Valdez* they wouldn't recognize. Congress barred the ship from these waters in 1990—not as a precaution but as a symbol. In many Alaskans' eyes the *Valdez* fouled Eden; the wilderness may recover, but it will never again be pristine.

heath-and-shrub river valleys of Kodiak Island, in the salmon-rich commissaries of the Kodiak bear.

Protecting bear habitat ranks high on the agenda of those who would have the trustee council invest much of its budget—and the Restoration Reserve—in land acquisition. The most desirable lands still to be acquired are some 50,000 acres, formerly part of Kodiak National Wildlife Refuge but now owned by the Koniag regional corporation, embracing the Karluk and Sturgeon River watersheds. The Karluk is said to support runs of three million fish a year—all five species of Pacific salmon plus steelhead and arctic char.

With Jay Bellinger, the Kodiak refuge manager, I flew over the Karluk and the Sturgeon, and bears aplenty were there to be seen. The bears, he explained, den in the high country but store up protein when salmon run thick in the rivers below. "Koniag picked up the best of it," Bellinger said. "We kept the bedrooms, but they got the kitchens."

Though purchase negotiations between the trustee council and the corporation have not been concluded, a conservation easement prevents development on the Karluk and Sturgeon until 2002, the year the Restoration Reserve comes of age.

There is another, somewhat diffuse constituency, however, that would like to see more money invested in the prevention of any future oil spill and in the capability to respond effectively, should it ever come to that. Not that prevention and response have been ignored over the past ten years. On the contrary, the government, the Alyeska consortium that manages the pipeline terminal at Valdez, and the oil companies that own the tankers plying Prince William Sound have all made substantial investments in new equipment and procedures designed to cut the risk factor closer to zero.

To ensure safer tanker operations, for example, new escort procedures are in place, coastal

pilots stay on outbound ships longer, radar coverage has been extended, and reduced speed limits are in effect. On the response side, three large vessels equipped to assist a stricken tanker are on constant standby in the sound, containment and cleanup supplies are stockpiled at a number of communities, and airborne chemical dispersants are ready to fly out of Anchorage on a moment's notice.

If there is any significant worry about a weak spot in the defenses, by most accounts it is a fear that the industry might win postponement of a federal mandate that all tankers in U.S. waters have double hulls by 2015. According to a U.S. Coast Guard study, if the *Exxon Valdez* had been equipped with a double hull, as much as 60 percent less oil would have entered the water. As it is, only three of some 28 tankers operating out of Valdez now sail through Prince William Sound on the safety cushion of a second hull.

Yet Al Maki of Houston, Texas, an Exxon environmental adviser who has spent much of the past decade in Alaska, told me that the safeguards now in place leave him with a "comforting feeling." Did he feel sufficiently comfortable to predict that a major oil spill—from a tanker—would never again occur in Prince William Sound or the Gulf of Alaska?

"No one can provide a 100 percent guarantee that it won't happen again," Maki said. "But if it ever did, you can be sure there would have to be a highly unusual event of great magnitude, like an earthquake or a tidal wave, to make it happen."

It was good to hear these assurances. Yet now, as I sit in my electrified work space, sated with all the comforts of oil, I have to weigh the technological confidence of Houston, Texas, against the commonsense hunch of a man in a skiff from Tatitlek, Alaska, riding the chop of Prince William Sound. For as we turned away from Bligh Reef that morning only a memory ago, I had asked Gary Kompkoff the same question. I asked him if he thought there could ever be another spill like the last one.

"It won't happen right here," he said.

"But will it *happen*?"

His answer was a long time coming, his voice so soft and low I could barely hear it. He said, "Plan on it." □

Share your thoughts about the *Exxon Valdez* spill at www.nationalgeographic.com/ngm/9903.

Covert operator, an adult snapper lurks in the weeds of a Florida spring, its powerful jaws primed to snap. Feared for their bite and size—the carapace of one species can reach 31 inches in length—snapping turtles much prefer a worm or fish to a swimmer's big toe.



SWAMP

By RICHARD CONNIFF

Photographs by
GEORGE GRALL

Unmasking the
Snapping Turtle

THING

IT WAS A FINE, GONE-FISHING SORT of morning in May, and we were out on a lake in northern Louisiana peeling leeches off snapping turtles. The tupelo gums and bald cypresses grew close together, and the water around the trunks mirrored each tree perfectly, so our boat seemed to be suspended in middle space, a forest underfoot as well as overhead. The sun slanted down into the shadows.

J. Brent Harrel was trying to reason with a snapping turtle caught in his hoop trap: "I need those leeches, big girl, but you're not going to give 'em to me, are you?" The turtle hissed back. Harrel reached in to extricate her from the net, and she lashed out with her hooked jaws, her pink mouth gaping and her forefeet lurching clear off the bottom of the boat. The jaws clapped shut like a bear trap in midair.

Harrel, a wildlife biologist, deftly flipped the turtle onto her back. He planted the fingers of one hand in the soft yellow flesh under the chin to hold her down while he harvested a glistening bouquet of leeches at her throat. The leeches were a favor for a research colleague, to keep things from getting dull. But Harrel's real passion was for snapping turtles.

Harrel held the turtle up for inspection. Her mossy brown shell was about a foot long and deeply serrated on the back edge. Her wattled skin thickened into a saw-toothed ridge on the tail and leather plating on the legs. She was built like a tank, with a rocket-propelled neck in place of a cannon. She watched for an unwary limb to drift into range. Her sharp, curved claws reached back to scrabble at Harrel's wrists. "You want to pay attention to what she's doing all the time," he advised, "'cause if you forget, she'll remind you."

Big Girl was actually the smaller of the two snapping turtle species prowling around at that moment in the forest beneath our boat. She was a common snapper, *Chelydra serpentina*, which means "snakelike swamp thing." Though you may never see them, even when you swim with them, common snappers are everywhere in streams, lakes, and little ornamental ponds from Colorado eastward and from Ecuador to Nova Scotia. (Some scientists argue that the geographically isolated Central and South America common snappers are a separate species.) The adults typically weigh ten pounds or more. But they can live for decades, and the largest wild one on record weighed more than 76 pounds.

The other, larger species for which we had set our traps was *Macrocllemys temminckii*, which means "Temminck's big turtle." It's better known as the alligator snapper, or loggerhead, and large males can weigh more than 200 pounds. It was once so popular as an ingredient for soup and turtle sauce picante that it is now imperiled throughout its range, which extends from Texas to Florida and up into Illinois.

Snappers are a breed of loners. In their own world they live quiet as rocks, eating everything in reach, from crayfish to skunk cabbage. Alligator snappers actually lure their prey, wriggling a wormy pink appendage in the floor of their gaping mouths as a come-on to visitors. Common snappers appear to rely mainly on their natural camouflage to bring unsuspecting prey within range.

I peered, not too closely, into Big Girl's

RICHARD CONNIEFF often writes about unappreciated and unloved animals. His most recent GEOGRAPHIC article, "Body Beasts," appeared in the December 1998 issue. GEORGE GRALL is staff photographer at the National Aquarium in Baltimore, Maryland.



hostile little eyes, and the word "atrabilious" came to mind. It means gloomy and ill-natured. Just then Harrel noticed that trap number two was rocking violently in the tea-black water, and we put Big Girl in a burlap bag and paddled on.

I'D LEARNED the word atrabilious only a few days earlier up in New Hampshire from a friend named John Rogers (page 128), who travels the Northeast every summer catching common snappers for a living and listening to poetry tapes for self-improvement. It sounded to me like a good word for these malevolent-looking creatures, but I was making the usual mistake with snapping turtles: People



A bottom plodder by nature, a startled common snapper coaxes grace from its heavy, muscled body as it swims across a Florida pond. A saw-toothed tail and large head distinguish reclusive *Chelydra serpentina*, or “snakelike swamp thing.”

are sometimes atrabilious, Rogers said, but gloominess and malevolence aren't snapping turtle traits. Snapping turtles are merely quarrelsome. They are—he hit on the right word—fractious. You would be, too, if someone had just plucked you out of your natural world.

Rogers, who is sometimes known as the king of the snappers, could speak with a certain authority on the fine points of snapping turtle character. By his own estimate he has caught more than 100,000 common snapping turtles over the past 34 years to supply the meat and

soup trade. He has also reseeded his hunting grounds over the years by releasing 250,000 small ones into the wild. He has the scars of eight snapper bites on his right hand alone.

A tall man, “59 years old going on 25,” with a grizzled beard and a greasy pith helmet, Rogers is one of those convoluted people who deeply love the animals they hunt, to the point that predator and prey begin to resemble one another. It was early May, the start of mating season. “You’ll see turtles moving all day long now,” Rogers said, as he studied a pond with



Rough and ready, an alligator snapper feeds in the wild, as here in an aquarium, by wiggling a pink appendage in its mouth (right) to lure fish. The largest freshwater turtle in North America, the alligator snapper keeps to southern U.S. waters; while the smaller, more aggressive common snapper prowls lakes and streams from South America to Canada.





on me” spirit in a society that thinks nature ought to be approachable. Snapping turtles are throwbacks not merely to the dinosaurian epoch during which they evolved but also to our own past as a nation. They are hardheaded American originals.

Negative ideas about snapping turtles nonetheless abound. Teddy Roosevelt once called them “fearsome brutes of the slime,” and a large snapper was “the demon of the deep” in one popular children’s story early in this century. Even people who consider themselves environmentalists sometimes kill them because they think snappers are taking all the game fish or because they have seen a line of adorable ducklings get dragged down one by one in a tumult of downy feathers. But like any predator, turtles mainly pick off the weak, helping to strengthen the population of survivors. They also scavenge carrion. “If you were a vegan and you wanted to bribe me,” Rogers offered, “I could take you to places where the snappers are all vegetarians.”

Other places, of course, they eat almost nothing but flesh, and this may be the real source of human hostility toward them: When people see a big snapping turtle come clambering up out of their favorite swimming hole, they suffer a wildly misguided fear for human life and limb. Not long ago the residents of a wealthy neighborhood in my hometown showed up at a town meeting determined to

binoculars: “What they are is horny males, full of testosterone, looking for a female or a fight.” He grinned, “Just like guys hitting bars on Friday night.”

For Rogers and other admirers (many of whom are in prison, to judge from the letters I received the last time I wrote on this topic), the likable thing about snapping turtles is that they are, in a word, trouble. You would not put one in a petting zoo unless maybe you wanted the children to learn to count without using their fingers. On the other hand (a phrase one uses advisedly), they are interesting trouble—tough, reclusive, and fiercely independent, unhuggable in a culture determined to make all animals cute, paragons of the “Don’t tread



Nest of Possibilities

Unmoved by traffic, a female snapping turtle chooses a nest site beside a road in Mason Neck National Wildlife Refuge in Virginia. Before this June day ends, she will have dug a hole with her hind legs and deposited golf-ball-size eggs (above left). The average clutch is 30 to 50 eggs, although a few clutches have topped a hundred. With luck—three out of four nests are destroyed by predators—hatchlings (above right) will emerge 75 to 90 days later. The young promptly melt into the brush to begin the search for water.

shut down a public river access; they said visitors were liable to be attacked by monster snapping turtles lurking in the shallows.

But when they are in their own element, snapping turtles almost never bite people. They stick to whirligig beetles and other mouth-size prey. After Woodstock, the 1969 music festival, Rogers visited the pond where all those free spirits went skinny-dipping and collected dozens of snapping turtles, averaging 20 pounds apiece. Analysis of the stomach contents produced no human body parts. Snappers bite because they cannot retreat entirely within their shells. But even on land they bite only in self-defense and only when someone is dumb enough to fool with them.

Being dumb enough myself, I tested the old lore that a snapping turtle can bite through an oar. My experimental subject, a large alligator snapper, merely scarred the wood. Common snapping turtles typically cannot even bite through a pencil. The hooked jaws of either species will, of course, cut through flesh like tub margarine but generally stop when they hit bone.

When the subject of snapping turtles comes up, the conversation nonetheless turns inevitably, almost ritually, to tales of maiming and dismemberment. "My neighbor had a dog, about a 90-pound Labrador," a Louisiana ostrich farmer told me, "and one day we found him down by the water with a big chunk out of his backside, and it was the exact shape of a loggerhead turtle's jaw. We figured he was dead. But they took him to the vet and got him patched up, and he walked around after that with half a rump." He still ventured into the water, the farmer said. But if so much as a tupelo gum fruit hit the surface, that dog lit out for high country.

In turn, I told the farmer about a Connecticut man who cut off a snapper's head and buried it in a field. A day or two later the man's dog dug up the head, and it bit him on the nose.

Either story might be true: A researcher recently identified the bones of a full-grown raccoon in the scat of a 102-pound alligator snapper. And snappers can indeed still bite after they have been killed. In Louisiana I watched a fish-market counterman take the head off a snapping turtle with a band saw. Then he tapped the turtle's snout with his knife, and the decapitated head clamped

Sensitive intruder, zoologist Roy Nagle inserts temperature probes into a nest on the E. S. George Reserve in Michigan. Incubation temperature determines a hatchling's sex. In a deep cavity the warmest eggs on top often produce females, while from the cooler bottom eggs males emerge. Researchers have also noted that some nesting females will return to the same site year after year, "literally within inches," says Nagle.



shut reflexively on the blade. He held it up for display and said, "This thing'll bite tomorrow."

THE TRUTH is that people bite snapping turtles far more often than snapping turtles bite people. The tradition of eating snapper meat is strongest in Cajun areas of Louisiana. The fish-market man told me that he sells snappers mainly on Wednesdays and Fridays because of an old custom among Catholics that snapper was an acceptable substitute for meat on days of abstinence. "It don't taste like chicken," another turtle dealer told me, "and it doesn't taste like pork. It's that little thing in between." Otherwise the market for snapper meat is quirky and small, extending up the Mississippi into Illinois and Ohio, out to the snapper soupmakers of Philadelphia, and among Asians in New York City and



Scrambled turtle eggs make a meal for a nosy raccoon, drawn by the smell left by the nesting female. If eggs survive coons, skunks, and moles, hatchlings must still run a gantlet of crows, bullfrogs, and snakes. Adult snappers are hunted by humans for their meat.

California, who regard turtles as an edible symbol of long life.

Supplying these markets is a small-scale, backwoods sort of business. "The trappers sometimes remind me of the Clampetts," a woman named Sheila Millard Perry told me, the Clampetts being television hillbillies. Perry presides over Millard's Turtle Farm of Birmingham, Iowa, the largest snapping turtle dealer in the nation. Then she added: "My family sometimes reminds me of the Clampetts." The business operates out of a ramshackle assortment of sheds, trailers, and rough-dug ponds in the rolling Iowa hills, and Perry, who used to be a nurse, was wearing denim short shorts rolled up, a torn T-shirt, and white rubber galoshes. The family skinned 137,158 pounds of snapping turtles in 1997, she said. She buys live turtles at 60 cents a pound and sells at \$3.50 on the bone, \$5.75 boneless. It did not appear to be a get-rich-quick sort of business.

Perry took me on a tour of the property to show me some of the turtle by-products. Big shells were drying in the sun on a shed roof, to be sold to arts and crafts types who make them into clocks, saddlebags, breast shields, and Indian dream catchers. The smaller ones become rattles and drinking flasks. The belly plates get turned into knife sheaths. The liver becomes catfish bait. Paws get sewn into pouches. Claws become necklace parts, and a couple of throat bones get glued onto muskrat skulls to sell as Texas longhorn car-mirror ornaments at three dollars apiece.

"My father says the only thing out of the snapping turtle that he hasn't figured out how to sell," said Perry, "is the snap."

Researchers have argued that snapping turtles cannot sustain a commercial trade because they are slow to reach reproductive age, and when they do, they lose most of their nests to predators. The females usually bury their eggs in a dirt bank in May or June, and raccoons, skunks, and foxes promptly dig them up. A raccoon will sometimes treat a snapping turtle on the nest like a vending machine, sitting behind her and palming the eggs up into its mouth as they come out. Even if they survive to emerge in August, the hatchlings, which are the size of soda-bottle caps, may get eaten by birds, bass, and other predators.

Even so, common snapping turtles appear to

be thriving in most of their range. This may be because the market for snappers is small, and there is no incentive to overharvest. Rogers says he typically leaves a pond idle for five or six years between harvests to allow for recovery. But he argues that the turtles also do well on their own. Over more than 30 years, Rogers told me, he has taken 36,000 pounds of common snappers out of a single 200-acre waterfowl refuge in Massachusetts. A week after we talked, he went back to the refuge and found another thousand pounds of turtle ready for harvest.

DOWN IN LOUISIANA, where the alligator snappers are not thriving, Brent Harrel was making a careful study of trap number two. "This is going to be an ordeal," he said, indicating the large male alligator snapper inside. "These boys are tough to fool with. When we pull him up, he's going to be real aggravated."

It took both of us hauling on the hoop net to bring him to the surface, because of his weight and because he was lurching and tearing at the net. We drew him up a little more, and he suddenly clamped his jaw on the gunwale as if to shred the aluminum. We hesitated, regarding each other with raised eyebrows, then hauled the net over the side into the bottom of the boat. The tattered remains of the baitfish swung into range, and the turtle lunged again. His mouth closed on the skull of a buffalofish. The hollow sound of bone caving in echoed around the boat.

"This is real stressful for him," Harrel said, which, under the circumstances, was either wonderfully magnanimous or pure projection. Harrel reached in and grabbed hold of a hind leg. Drawing the turtle back out through the narrow throat of the trap was like trying to wrestle an angry fat woman out of an under-sized girdle. But he succeeded after a while.

The turtle's shell was two feet long, and he weighed 95 pounds. He had a smooth, wizened snout and a head like a rottweiler, 23 inches around. We flipped him onto his back, and his wrinkly, tubercled underflesh was stained rust colored. The plastron was smooth as an old stairway with long use. He made a low, irritated hissing sound, like a scuba diver exhaling.

"Can you just imagine how stressful this is for him?" Harrel said again. "You realize that

At least 50 years old, a record-breaking wild common snapping turtle weighs in hissing at 76.5 pounds. Snapper hunter John Rogers, in pith helmet, gaffed the giant male in Lake Rohunta, near Orange, Massachusetts. He sold it to the Toronto Zoo, where it later died from an infection from an old bullet wound. "Loads of people hate snappers," says Rogers, "but they don't see the turtle underwater, where it is one beautiful, majestic animal."



turtle's probably never been out of the water in a century?" Alligator snappers are thought to live at least that long, and we speculated about whether McKinley or Roosevelt might have been President when this turtle hatched. "The thing I hate when somebody kills one to eat is how old it is," he said. "To harvest a hundred-year-old animal for 40 pounds of meat doesn't make sense."

The rest of the traps yielded two platter-size softshell turtles, five more alligator snappers, and a mess of red-eared sliders. "Just think what a trapper could do here," he said. Louisiana's turtle-trapping regulations are lenient, and the alligator snappers mostly exceeded the minimum 15-inch shell length. "It'd be a pretty

good piece of change for an ol' boy who may not have a high school education. When they find 'em like that, they don't let up, they just keep catching 'em till they exhaust the supply."

We piled most of the catch into a pickup truck to be hauled into town, weighed, measured, and tagged, then returned to the lake later in the evening. But we didn't take the big alligator snapper. Harrel thought the biology department at Northeast Louisiana University, where he earned his degree, might want to keep him to observe in one of its holding tanks. He was also a little afraid that he might want to keep the turtle himself, just to study for a day or two. He wrestled with his Louisiana heritage: "My mama probably wouldn't let me



back in the house if she knew I had'm and let'm go," he said. He debated at least tagging the turtle for future recapture. But there was an element of desecration in this idea: "He's great the way he is."

So we took the turtle into the boat and paddled out among the gum trees. We eased him over the gunwale, and the moss began to float up again on his head. Harrel held onto the rear edge of the shell and the turtle kicked water back on us, then calmed down. "All right, this is it, big boy," he said. A thread of reluctance in his voice, he added: "He'll be gone forever."

Then he let go. The turtle headed straight for the bottom and vanished. A moment later he reappeared, walking across a high spot, a huge,

improbable creature, yellow-brown under the tea-colored water, the sun shining on his head. I thought of something John Rogers had told me: "They're beautiful when they're moving in the water. Graceful. Powerful. Majestic. Walking along the bottom, not afraid of anything. They're the king of everything down there. They've been there forever. They were watching dinosaur droppings fall in the water and fertilize the world."

The turtle vanished again into the depths, and we followed his progress for a while by the air bubbles and prickly gum balls his footsteps sent up from the bottom. He passed between two trees, then out into the lake, leaving behind only a long trail of effervescence. □



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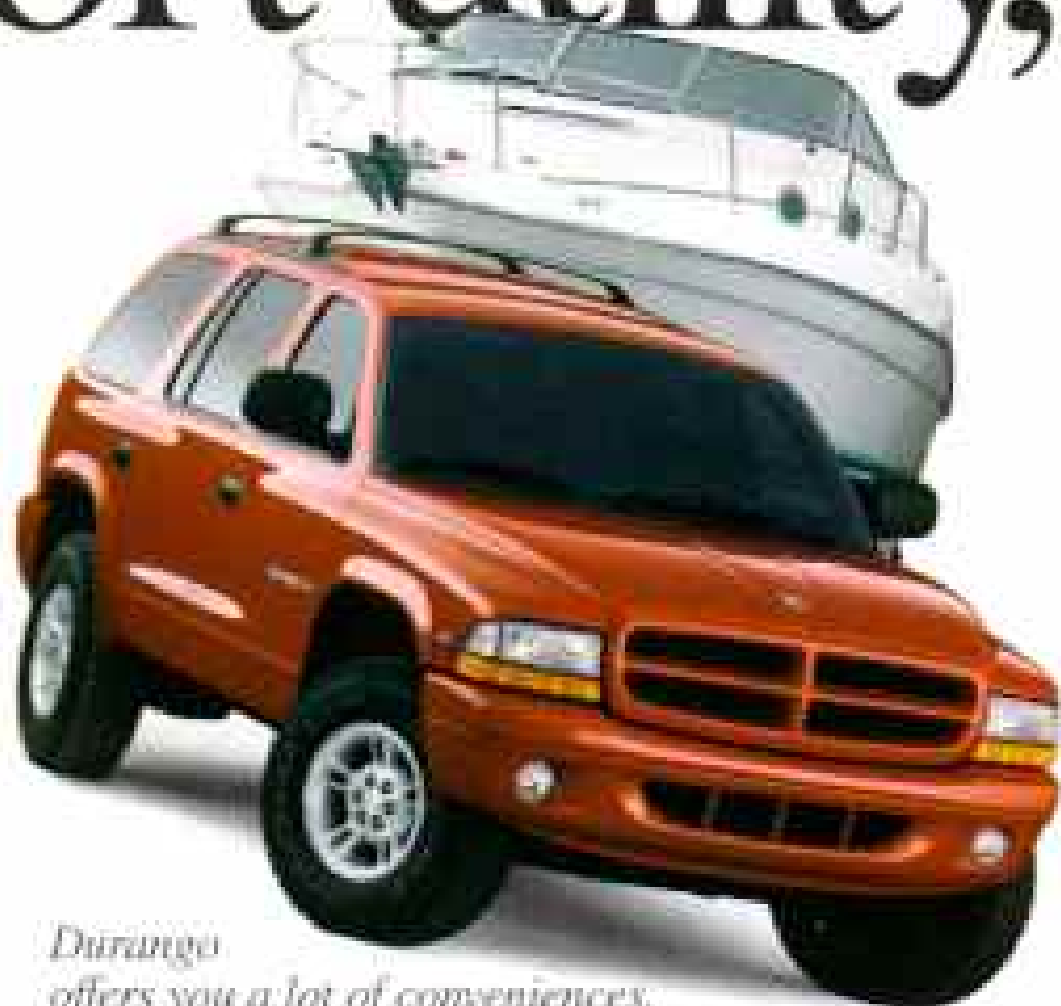


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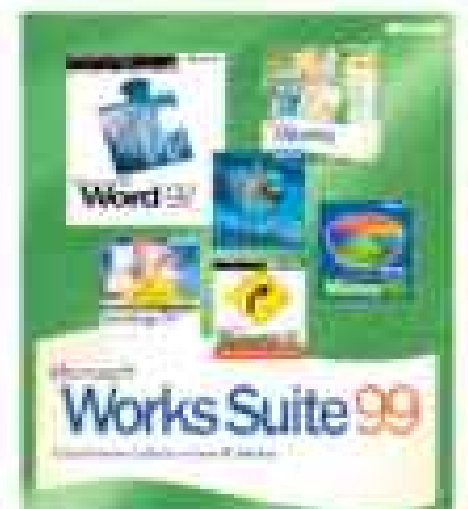
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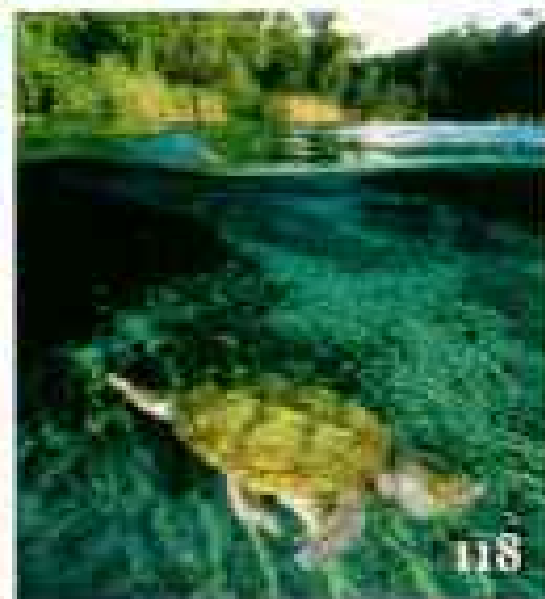
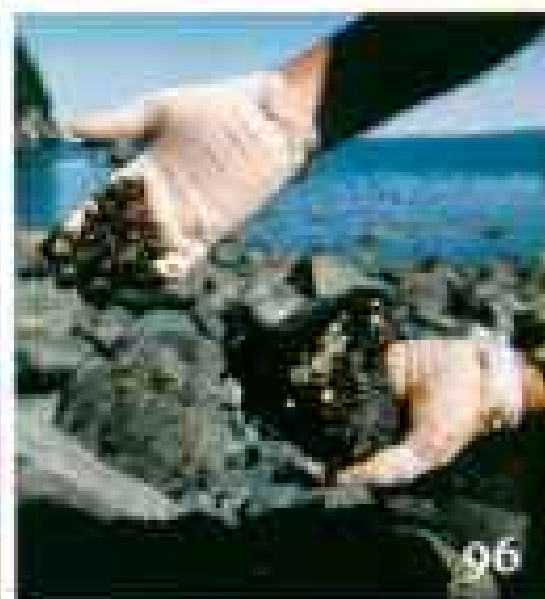
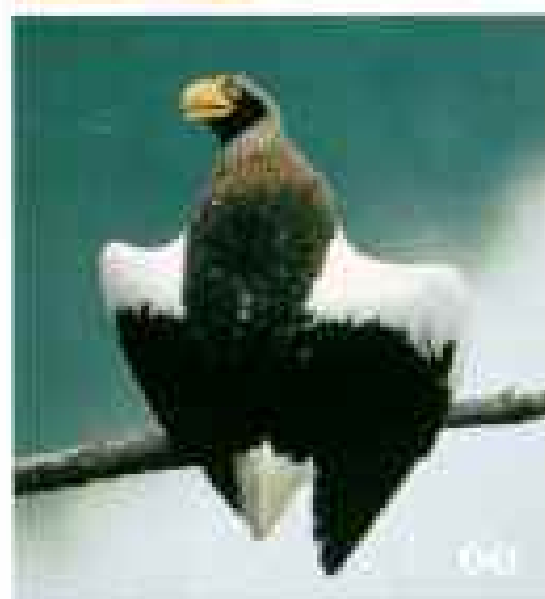
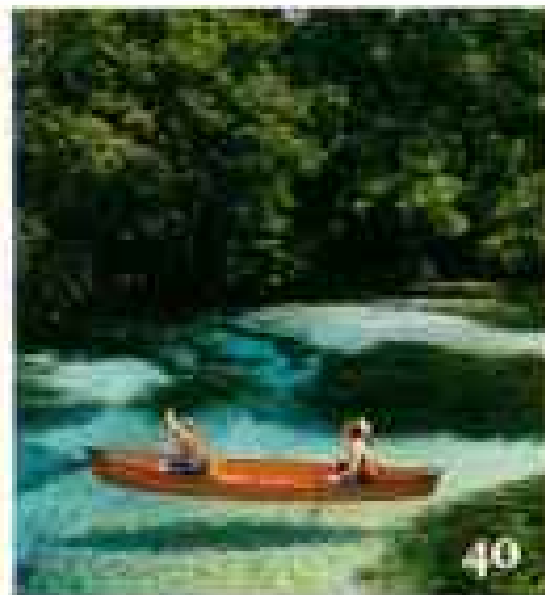
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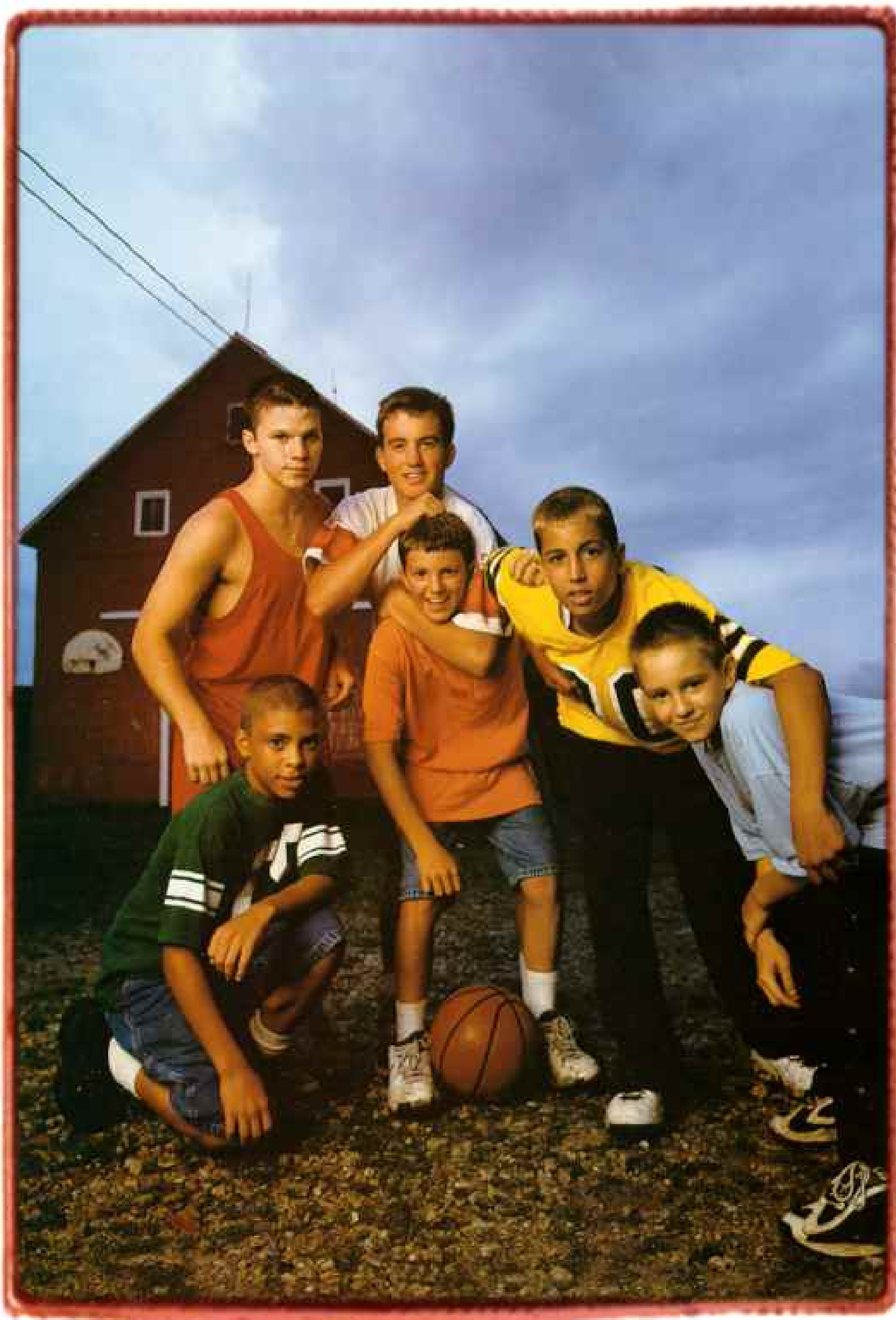
The Cover

In the El Niño of 1997-98, Hurricane Linda, one of the strongest storms ever recorded in the eastern Pacific, batters western Mexico. Image processed by NASA Goddard Laboratory for Atmospheres, with data from NOAA.

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Indiana has been home to some of America's greatest sports teams for more than a century. Maybe it's because Hoosiers are naturally competitive. Or maybe it's because the local fans are so supportive. Whatever the reason, teamwork is one of the



qualities that has made their state great. And it's definitely one of the reasons Indiana was chosen as the site of Toyota's major new U.S. vehicle manufacturing plant.

By the time it's fully operational, Toyota Motor Manufacturing, Indiana will have the capacity to produce 150,000 vehicles per year. The 2,300 new jobs created here will raise Toyota's direct U.S. employment to more than 25,000. Now that's what we call an expansion team.

As a company doing business in the global marketplace, Toyota recognizes the need to invest in local design, research and manufacturing, to ensure that the products we sell answer the special needs and standards of all of our drivers. That's why, in 25 countries around the world, Toyota vehicles are being manufactured by the same people who drive them - local people.

Sure, it makes good business sense for Toyota. But it also builds growth and competitiveness in the communities where we do business. That's what team spirit means to Toyota. It's how we play the game.

TOYOTA People Drive Us

These students can't picture the world without Dr. Noll.

Armed with a digital camera, Dr. Noll and his Special Education students venture into their community two or three times each week taking pictures of everyday destinations like the bank, store, or post office. When they return to the classroom, they download these images into their computers.

Students learn best in real-world settings. By "Digitizing the Community," they are able to bring the community back to the classroom where they can integrate their experiences and images into current classwork. Positive experiences gained from Dr. Noll's curriculum provide a much-needed boost to students' self-esteem while greatly expanding their life options.

For his innovative approach to improving his students' image of the world—and themselves—State Farm is proud to present Dr. Steven Noll with our Good Neighbor Award and to donate \$5,000 to the Sidney Lanier School in Gainesville, Florida.

Thanks to Dr. Noll, his students now have a clearer picture of just how much they can achieve.



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Behind the Scenes



Frequent Flier Smiles

Presiding over our international editions has kept Senior Assistant Editor Bernard Ohanian flying. Since the 1995 debut of the Japanese-language *GEÓGRAPHIC*, Bernard has put in a lot of time on the road—and in the air. Last year he spent his birthday, “all 37 hours of it, since we crossed the International Date Line,” flying home to Washington, D.C., from Tokyo. Bernard tries to visit each foreign office at least a couple of times a year, but they are

lightning trips. With editions now based in Japan, Spain, Mexico, Italy, Israel, and Greece—and more in the planning stages—he says, “I tend to visit seven cities in seven days.”

Given such a schedule Bernard sometimes has to think twice about exactly what country he’s in. And cultural conflicts have occurred. He still sighs over an after-hours basketball game put on by our Tokyo partners between the editorial staff and the printers. Unbeknownst to him, the game was predetermined to end in a tie, so that neither team would lose face.

“That was hard,” admits Bernard, who grew up playing on the courts of suburban Los Angeles.

European travel is more familiar territory, but some things still take getting used to. While touring Athens with our Greek partners, his host’s cellular phone rang. “There I was, admiring the beauty of the Acropolis but grumbling about how attached Europeans are to their cell phones,” Bernard says, “and it turned out the call was for me.”



NATIONAL GEOGRAPHIC PHOTOGRAPHER MARK THESSEN (TOP); O. LOUIS MAZZAFERTA

Schools Map It Out

We kicked off our massive map giveaway—113,000 world maps sent free to every school in the United States—with a visit to Harriet Tubman Elementary in Washington, D.C. Students there checked out the new map (left), as our neighbors to the north will soon be doing. The Society, with the Royal Canadian Geographical Society, is giving away 15,000 more copies, one to every school in Canada.

Office Space Then and Now

When you're one of the first staff members of the National Geographic Society, you get plenty of room to work with. John Oliver La Gorce, who during 54 years at the Society held the jobs of Editor and President from 1954 to 1957, was hired in 1905 as our third employee. La Gorce decorated his dark, pine-paneled digs with N. C. Wyeth paintings and a considerable collection of ancient weapons. "In this room," says the caption of a similar picture published in the January 1936 *GEOGRAPHIC*, "John Oliver La Gorce has labored with love and ceaseless energy." And with skulls, antlers, and a hollow elephant's foot.

Now that the Society employs some 1,300 people, space can be at a premium. But even an eight-by-eight-foot cubicle can't cramp Jelili Salako's style. The NG Interactive programmer (right) works in a dim room brightened only by computer screens and quiet jazz. Does he mind not having much room? "This isn't so bad," he says. "It's actually a bigger office than I had when I started!"



JACOB GAYEN



MANS THREDDEN



STUART FRANKLIN

Miguel's Dream

He grew up in the Peruvian rain forest—and last year attended Oxford University on scholarship. Since Miguel Hilario-Manenima first glimpsed the outside world at age 12 in a missionary's *GEOGRAPHIC*, he knew "I had to see those places myself." The 28-year-old Shipibo-Conibo Indian is now continuing his studies at California's Sonoma State University, "to help me help Peru's indigenous people. It is my life's work."

"I got Lyme disease last spring
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Protect yourself and your family with **LYMERix**, the world's first vaccine to prevent Lyme disease. Call your doctor *now*.

If you live or plan to travel where Lyme disease is a problem, there are important facts you should know. For example, you can get bitten by the tick that carries the disease while out gardening, walking, barbecuing, even playing with your dog. And, if you don't have any early symptoms, you might not know you have Lyme disease. You could be one of the few people who develop serious health problems. Left untreated, Lyme disease can lead to potentially serious joint and neurological conditions. Why put yourself or your family at risk?

Now, there's a vaccine that has been shown to be safe and effective in preventing Lyme disease. It's called **LYMERix**. New **LYMERix** is for people 15 to 70. As with any vaccine, **LYMERix** may not protect 100% of individuals. **LYMERix** may be associated with local injection-site reactions including redness and swelling, flu-like symptoms, arthralgias and myalgias.

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Lyme Disease Vaccine (Recombinant OspA)

Brief Summary. Please see complete prescribing information in SmithKline Beecham Pharmaceuticals literature.

INDICATION AND USAGE: LYMERIX is indicated for active immunization against Lyme disease in individuals 15 to 70 years of age. Individuals most at risk may be those who live or work in *Borrelia burgdorferi*-infested tick-infested grassy or wooded areas (e.g., landscaping, brush clearing, forestry, and wildlife and parks management), as well as those who plan travel to or pursue recreational activities (e.g., hiking, camping, fishing and hunting) in such areas. Most cases of Lyme disease in the United States are thought to be acquired in the peri-residential environment, through routine activities of property maintenance, recreation, and/or exercise of pets.

Previous infection with *B. burgdorferi* may not confer protective immunity. Therefore people with a prior history of Lyme disease may benefit from vaccination with LYMERIX. Safety and efficacy for this vaccine are based on administration of the second and third doses several weeks prior to the onset of the *Borrelia* transmission season in the local geographic area (see DOSAGE AND ADMINISTRATION in complete prescribing information). LYMERIX is not a treatment for Lyme disease. As with any vaccine, LYMERIX may not protect 100% of individuals. Do not administer LYMERIX to persons outside of the indicated age range.

CONTRAINDICATIONS: Contraindicated in people with known hypersensitivity to any component of LYMERIX.

PRECAUTIONS: General: LYMERIX will not prevent disease in those who have unrecognized infection at the time of vaccination. LYMERIX will not provide protection against other tick-borne diseases such as babesiosis or ehrlichiosis. Treatment-resistant Lyme arthritis (antibiotic refractory), a rare complication of *B. burgdorferi* infection, has been associated with immune reactivity to OspA of *B. burgdorferi*. Since the underlying etiology is not clearly understood, it is recommended that LYMERIX not be administered to such patients. As with other vaccines, although a moderate or severe febrile illness is sufficient reason to postpone vaccination, minor illnesses such as mild upper respiratory infections with or without low-grade fever are not contraindications. Before the injection of any biological, the physician should take all reasonable precautions to prevent allergic or other adverse reactions, including understanding the use of the product concerned, and the nature of the side effects and adverse reactions that may follow its use. Prior to immunization with any vaccine, the physician should review the patient's immunization history for possible vaccine sensitivity, previous vaccination-related adverse reactions and occurrence of any adverse-event-related symptoms and/or signs, in order to determine the existence of any contraindication to immunization and to allow an assessment of benefits and risks. Epinephrine injection (1:1000) and other appropriate agents used for the control of immediate allergic reactions must be immediately available should an acute anaphylactic reaction occur.

Packaging for the LYMERIX Tip-Loc™ syringe contains dry natural rubber, which may cause allergic reactions; packaging for the vial does not contain natural rubber.

Use a separate sterile syringe and needle or a sterile disposable unit for each patient to prevent transmission of infectious agents from person to person. Dispose of needles properly and do not recap. As with any vaccine administered to immunosuppressed persons or persons receiving immunosuppressive therapy, the expected immune response may not be obtained. For individuals receiving immunosuppressive therapy, consider deferring vaccination for 3 months after therapy.

Laboratory Test Interactions: LYMERIX immunization results in the generation of anti-OspA antibodies, which can be detected by an enzyme-linked immunosorbent assay (ELISA) for *B. burgdorferi*. The incidence of positive IgG ELISA tests depends on the sensitivity and specificity of the ELISA assay and the titer of anti-OspA antibody. In general, there is an association between anti-OspA titer and IgG ELISA index or Optical Density (OD) ratio; the higher the titer of anti-OspA achieved, the higher the IgG ELISA index or OD ratio. Therefore, because vaccination may result in a positive IgG ELISA in the absence of infection, it is important to perform Western blot testing if the ELISA test is positive or equivocal in vaccinated individuals who are being evaluated for suspected Lyme disease. Following vaccination, the appearance of a 31kD OspA band, possibly accompanied by other lower molecular weight bands on an immunoblot (Western blot), should not interfere with the determination of positivity when assessed by CDC-ASTPHLD criteria.

Drug Interactions: No data are available on the immune response to LYMERIX when administered concurrently with other vaccines. As with other intramuscular injections, do not give LYMERIX to individuals on anticoagulant therapy, unless potential benefit clearly outweighs risk of administration.

Carcinogenesis, Mutagenesis, Impairment of Fertility: LYMERIX has not been evaluated for carcinogenic or mutagenic potential, or for impairment of fertility.

Pregnancy, Teratogenic Effects, Pregnancy Category C. Animal reproductive studies have not been conducted with LYMERIX. It is not known whether LYMERIX can cause fetal harm when administered to a pregnant woman or can affect reproductive capacity. Give LYMERIX to a pregnant woman only if clearly needed. Health care providers are encouraged to register pregnant women who receive LYMERIX (Lyme Disease Vaccine (Recombinant OspA)) in the SmithKline Beecham Pharmaceuticals vaccination pregnancy registry by calling 1-800-368-8900, ext. 5231.

Nursing Mothers: It is not known whether LYMERIX is excreted in human milk. Because many drugs are excreted in human milk, use caution when LYMERIX is administered to a nursing woman.

Pediatric Use: Safety and efficacy in pediatric subjects younger than 15 years of age have not been evaluated. Therefore, the vaccine is not indicated for the age group at this time.

ADVERSE REACTIONS: During clinical trials involving 6,479 individuals receiving a total of 16,047 doses, LYMERIX has been generally well tolerated. Subjects with the following conditions: chronic joint or neurologic illness related to Lyme disease; diseases associated with joint swelling (including rheumatoid arthritis) or diffuse musculoskeletal pain; second- or third-degree atrioventricular block or a pacemaker were excluded from the efficacy trial because such conditions could interfere with the assessment of Lyme disease in the trial. Therefore, data are limited regarding the safety of the vaccine in subjects with these conditions (see below).

Unsolicted Adverse Events: The most frequently reported (≥1%) unsolicted adverse events within 30 days of vaccination for all subjects receiving at least one dose (n=10,936) in the double-blind, placebo-controlled efficacy trial are shown in Table 1.

Table 1. Incidence (≥1%) of Unsolicited Adverse Events Occurring Within 30 Days Following Each Dose* and Overall (after Doses 1, 2 or 3)

| Event | Dose | | | | | | Overall | |
|--|------------------|------------------|------------------|------------------|------------------|------------------|----------|----------|
| | 1 | | 2 | | 3 | | Vaccine | Placebo |
| | Vaccine (N=5462) | Placebo (N=5467) | Vaccine (N=5257) | Placebo (N=5417) | Vaccine (N=5207) | Placebo (N=5212) | (N=5462) | (N=5467) |
| Local | | | | | | | | |
| Injection site pain | 11.26 | 4.30 | 4.19 | 2.8 | | | 21.87 | 2.91 |
| Swelling at injection site | | | | | | | 1.57 | 0.91 |
| Systemic | | | | | | | | |
| Body as a Whole | | | | | | | | |
| Headache | 1.57 | 1.05 | 1.22 | 0.60 | | | 1.79 | 1.25 |
| Cold/flu-like symptoms | | | | | | | 2.09 | 0.72 |
| Fatigue | 2.02 | 1.08 | 1.22 | 1.0 | | | 2.85 | 2.42 |
| Fever | 1.20 | 0.91 | | | | | 1.28 | 1.81 |
| Mild-to-moderate influenza-like symptoms | 1.86 | 1.36 | | | | | 2.03 | 2.46 |
| Nausea | | 0.93 | | | | | 1.54 | 1.86 |
| | | | | | | | 1.02 | 1.34 |
| Musculoskeletal System | | | | | | | | |
| Arthralgia | 3.22 | 2.07 | 2.11 | 2.82 | 1.24 | 1.18 | 6.79 | 6.25 |
| Back pain | | | | | | | 1.90 | 1.52 |
| Myalgia | 2.89 | 1.72 | 1.52 | 0.98 | | | 4.89 | 3.28 |
| Stiffness | | | | | | | 0.25 | 1.21 |
| Nervous System | | | | | | | | |
| Dizziness | | | | | | | 1.01 | 1.08 |
| Headache | 3.12 | 2.08 | 2.28 | 2.22 | | | 5.01 | 5.02 |
| Respiratory System | | | | | | | | |
| Sore throat | | | | | | | 1.10 | 1.28 |
| Coughing | | | | | | | 1.50 | 1.48 |
| Pharyngitis | 1.28 | 1.12 | 1.15 | 1.05 | | | 2.32 | 2.45 |
| Sneezing | 1.35 | 1.40 | | | | | 2.41 | 3.61 |
| Tonsillitis | 1.14 | 1.17 | 1.25 | 1.27 | | | 2.16 | 2.93 |
| Upper respiratory tract infection | 2.02 | 2.22 | 1.65 | 1.75 | | | 4.35 | 4.98 |
| Ear/Nose/Throat | | | | | | | | |
| Rhinitis | | | | | | | 1.31 | 1.08 |

* Includes events observed through spontaneous reports following each dose and events reported 1 month after doses 1 and 2 (when all subjects were queried regarding the occurrence of any adverse event since the previous vaccination).

† p-value <0.05; ‡ p-value <0.01; § p-value <0.001.

The most frequently reported (≥1%) unsolicited adverse events occurring more than 30 days later after vaccination for all subjects (n=10,936) were similar in nature to those listed in Table 1, and most occurred at a frequency of <5%, in both the vaccine or placebo groups. The only late adverse events occurring with an incidence of >5% in vaccine or placebo recipients were arthralgia (13.64% vs. 13.55%, respectively) and headache (5.06% vs. 4.72%, respectively). No significant differences in late adverse events were noted between treatment groups after any dose and overall.

Separate post hoc analyses were conducted to assess two subsets of musculoskeletal events which occurred either early (<30 days) or late (>30 days) post-vaccination. There were no significant differences, either early or late, between the vaccine and placebo recipients with regard to experiencing arthritis, aggravated arthritis, arthropathy or arthrosis. However, vaccine recipients were significantly more likely than placebo recipients to experience early events of arthralgia or myalgia after each dose (for dose 1: odds ratio (OR), 95% CI = 1.35 (1.13, 1.61); dose 2: OR = 1.28 (1.05, 1.56); dose 3: OR = 1.59 (1.18, 2.16)). With regard to late events of arthralgia or myalgia, there were no significant differences between vaccine and placebo recipients.

There was no significant difference in the rates of cardiac adverse events between vaccine and placebo recipients. Neurologic adverse events which occurred at a rate <1% in the vaccine group and were noted to occur with a similar frequency in placebo recipients included: carpal tunnel syndrome, migraine, paresthesia, tremor, coma, dysphonia, ataxia, multiple sclerosis, myasthenia gravis, meningitis, trigeminal neuralgia, nystagmus, neuritis, neuralgia, nerve root lesion, neuropathy, hyperesthesia, hyperkinesia, and intracranial hypertension.

Overall, approximately 18% of subjects enrolled in the study had a prior history of some musculoskeletal condition (18% vaccinees, 18% placebo recipients). In a post hoc subgroup analysis, there was no significant difference between vaccine and placebo recipients with regard to development of musculoskeletal events (defined as arthritis, arthropathy, arthrosis, synovitis, tendinitis, polymyalgia rheumatica, bursitis or rheumatoid arthritis) and lasting more than 30 days in those with a prior history of musculoskeletal conditions. However, both vaccine and placebo recipients with a prior history of musculoskeletal conditions were more likely to experience musculoskeletal events than subjects without such prior history.

Solicited Adverse Events: The frequency of solicited local and systemic adverse events was evaluated in a subset of subjects (n=938) who comprised the total enrollment at one study center in the efficacy trial. Of these 938 subjects, 800 completed a 4-day diary card following each of three doses, and were evaluable according to protocol. Table 2 shows the percentage of subjects reporting a solicited symptom following any one of the three doses and overall. The majority of the solicited events were mild to moderate in severity and limited in duration.

Table 2. The Incidence of Local and General Solicited Adverse Events (Including Severe Events) Reported After Each Dose and Overall

| Event | Dose 1 | | Dose 2 | | Dose 3 | | Overall | |
|-------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| | Vaccine (N = 402) % | Placebo (N = 398) % | Vaccine (N = 402) % | Placebo (N = 398) % | Vaccine (N = 402) % | Placebo (N = 398) % | Vaccine (N = 402) % | Placebo (N = 398) % |
| Local Symptoms | | | | | | | | |
| Painness, any | 21.54 ^a | 8.24 | 18.37 ^a | 7.54 | 25.12 ^a | 11.81 | 41.79 ^a | 23.25 |
| Painness, severe* | 2.7 ^b | 0.0 | 1.0 | 0.0 | 2.9 ^b | 0.0 | 4.7 ^b | 0.0 |
| Swelling, any | 91.59 ^c | 39.95 | 75.37 ^c | 30.90 | 87.59 ^c | 52.26 | 92.53 ^c | 69.24 |
| Swelling, severe* | 1.2 | 0.0 | 1.0 | 0.3 | 1.0 ^b | 0.3 | 5.0 ^b | 0.0 |
| Swelling, any† | 14.42 ^a | 8.27 | 11.44 ^a | 3.27 | 19.15 ^a | 6.79 | 24.20 ^a | 11.31 |
| Swelling, severe† | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| General Symptoms | | | | | | | | |
| Arthralgia, any | 11.34 ^a | 4.52 | 16.70 ^a | 8.29 | 13.42 ^a | 7.54 | 24.52 ^a | 16.13 |
| Arthralgia, severe† | 0.7 | 0.0 | 0.7 | 0.3 | 0.0 | 0.3 | 1.0 | 0.0 |
| Fatigue, any | 20.90 | 16.30 | 20.15 ^b | 11.81 | 21.89 ^b | 16.30 | 40.80 ^b | 27.70 |
| Fatigue, severe† | 0.5 | 0.05 | 1.5 | 1.3 | 1.0 | 1.0 | 3.0 | 2.3 |
| Headache, any | 20.85 | 19.11 | 14.43 | 12.31 | 19.90 | 16.34 | 38.56 | 37.18 |
| Headache, severe† | 0.5 | 0.05 | 1.2 | 0.5 | 1.2 | 1.8 | 3.0 | 2.8 |
| Rash, any | 4.23 ^a | 1.51 | 4.99 ^a | 2.01 | 5.47 ^a | 1.79 | 11.60 ^a | 5.29 |
| Rash, severe* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Fever ≥38.5°F | 1.49 | 0.75 | 1.00 | 0.60 | 1.00 | 1.01 | 3.48 | 2.25 |
| Fever ≥102.2°F | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

* Severe = increasing >0.5 cm and persisting longer than 24 hours

† Severe = preventing everyday normal activity

a, p-value <0.05; b, p-value <0.01; c, p-value <0.001

Subjects with Previous Lyme Disease: Subjects with previous Lyme disease were assessed using two definitions: subjects whose baseline sera were evaluated for Western blot (WB) positivity and subjects who at study entry self-reported a previous history of Lyme disease.

Study participants did not routinely have baseline sera tested by WB for Lyme disease. WB at baseline was performed for subjects who were noted to have a positive or equivocal WB during a visit for suspected Lyme disease or when tested at months 12 or 20. Baseline serology was thus found to be positive in 250 subjects out of 628 tested. The nature and incidence of adverse events (either early or late) did not differ between vaccinees determined to have been WB-positive at baseline (n=124) compared to vaccinees determined to have been WB-negative at baseline (n=151).

There were 1,206 subjects enrolled in the study who self-reported a previous history of Lyme disease (610 vaccinees; 596 placebo recipients). For adverse events occurring within the first 30 days, there was an increased incidence of musculoskeletal symptoms in vaccinees with a history of Lyme disease compared to vaccinees with no history of Lyme disease (20% vs. 13%, p<0.001). No such difference was observed in the placebo group (13% vs. 11%, p=0.24). Subjects with a previous history of Lyme disease had an increased incidence of late (>30 days post-vaccination) musculoskeletal symptoms compared to subjects without a history of Lyme disease in both the vaccine and placebo groups. There was no significant difference in late musculoskeletal adverse events between vaccine and placebo recipients with a history of Lyme disease (30% vs. 35%, p=0.61).

Subjects with a self-reported prior history of Lyme disease had a greater incidence of psychiatric disorders (early and late), central, peripheral and autonomic nervous system disorders (late), and gastrointestinal disorders (late) than subjects with no prior history of Lyme disease. However, there was no significant difference in the incidence of any of these disorders between vaccine and placebo recipients with a prior history of Lyme disease.

Among the 10,936 subjects enrolled in the efficacy trial and followed for 20 months, a total of 15 deaths occurred (10 vaccine, 5 placebo). None of these deaths were judged to be treatment-related by investigators. In the vaccine group, causes of death included: cancer (5), myocardial infarction (3), sudden death (1), cardiac arrest (1). In the placebo group, causes of death included: cancer (1), sudden cardiac death (1), cardiac arrest (1), septic shock (1), homicide (1).

As with all pharmaceuticals, it is possible that expanded commercial use of the vaccine could reveal rare adverse events not observed in clinical studies.

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JIM BULLARD/NGS

A Traveler's Turkish Delight

"I'm not really a tour person," says Rebecca Klemm, of Washington, D.C., "but Geographic tours are different." They must be—she's taken two so far. "The spontaneity is the best part," she says. While driving through a village in central Turkey, the guide for her group spotted men playing antique musical instruments, so he stopped the bus to ask why. It turned out the village was preparing for a wedding. Soon the whole group was invited, including Rebecca (above, with camera), who mingled with the groom's family. The Society's Jim Bullard, head of National Geographic Expeditions, was leading the tour and has his own memories of that day. "I kept noticing our travelers disappearing from the party," he says. "They were easy to find though. The townspeople had taken them into their homes. All I had to do was look for American shoes on the doorsteps."

Friends and Family in Prince William Sound



KAREN KASMAUSKI

It may be the biggest state, but Alaska proved a small world for photographer Karen Kasmauski while she was working on the update of the *Exxon Valdez* oil spill for this issue. "There aren't that many people in the whole state," she says. "It makes sense you'd keep running into each other." While shooting on a research vessel in Prince William Sound, Karen (above, at left) met up with photographer Natalie Fobes, whose coverage of the accident appeared in the August 1989 and January 1990 issues. Karen's coincidences weren't over yet, however. Before she helicoptered over the *Valdez's* sister ship, the *Long Beach*, to take pictures, the crew was alerted that a GEOGRAPHIC photographer would soon be hovering. Karen later learned that that ship's first mate is a cousin of Senior Assistant Editor Bill Douthitt—her husband.

TEXT BY MAGGIE ZACKOWITZ



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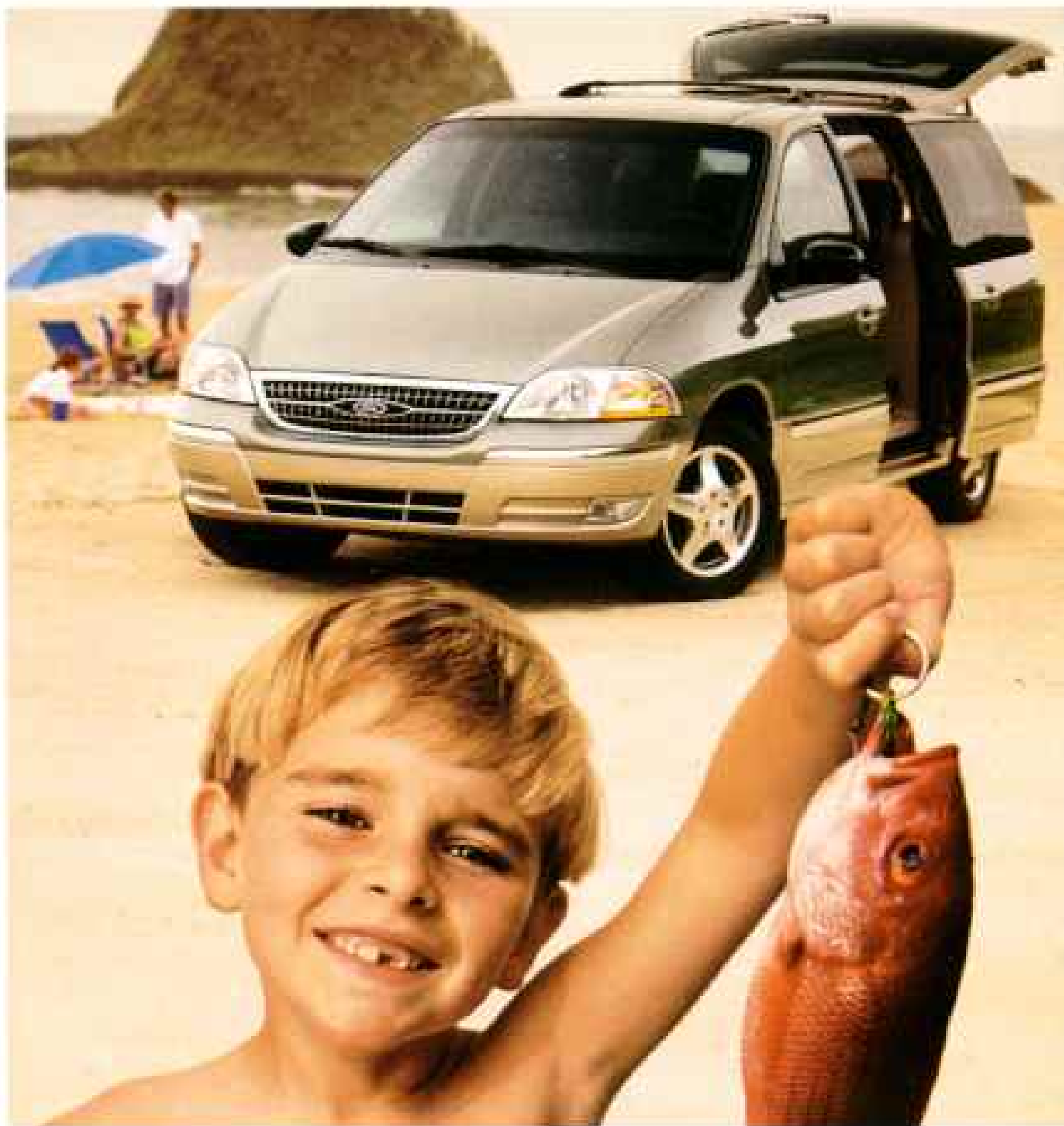
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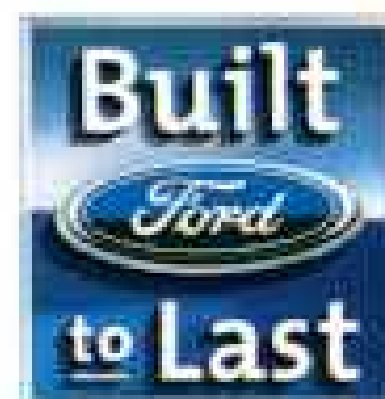
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Forum

In the November issue "A Comeback for the Cossacks" aroused passionate feelings from several readers who cited family stories of atrocities that "left a deep scar on every surviving Jewish family from the Pale." A reader from Chicago, Illinois, wrote: "Let us hope that if the Cossacks do succeed in reviving the ways of their past, they leave out those brutal aspects of it that are vividly remembered by us even to this day."

America's Wilderness

The opening statement referring to "swatches" of remaining wildlands and Luther Standing Bear's quote called to mind a quote by another great American author, Black Elk, also of the Oglala. In 1930 he said, "Once we were happy in our own country and we were seldom hungry, for then the two-leggeds and the four-leggeds lived together like relatives, and there was plenty for them and for us. But the Wasichus [whites] came, and they have made little islands for us and other little islands for the four-leggeds, and always these islands are becoming smaller, for around them surges the gnawing flood of the Wasichu."

Unfortunately his words are as true in our day as they were in his, with the "flood" surging ever higher.

DONALD CLARK
North Zulch, Texas

The article was refreshingly honest in its portrayal of legislated wilderness ("These lands haven't necessarily escaped the hands of man. . ."). However, overzealous wilderness advocates, both within federal agencies and among the American populace, continue to adamantly oppose the use of modern technology to rehabilitate areas designated as wilderness. Restrictions on such rehabilitation are especially problematic for conservationists attempting to maintain viable populations of large mammals within small wilderness areas previously affected by human activities.

VERNON C. BLEICH
Senior Wildlife Biologist
California Department of Fish and Game
Bishop, California

The lottery/permit system to restrict access is the best thing that has happened to American wilderness areas. In 1967 I hiked for the first time to the top of Mount Whitney. It was incredible. About every ten feet was a hiker. One line going up, another coming down. In 1979 I was lucky to get a permit to hike up again. What a pleasure, and what a difference. I could enjoy the wilderness and the

solitude. But unfortunately there are drawbacks. I would like to go one more time with my daughters and grandchildren, but for the past three years I have been unsuccessful in getting permits. But we'll keep on trying.

GÜNTER TSCHIEDEL
San Dimas, California

Having wilderness just for the sake of wilderness makes no sense to me. Is the fact of simply knowing that there is a wilderness out there enough to stir one's soul? I think not. The civilized landscape of England is a delight to a huge number of travelers. That kind of land use makes eminently more sense than setting aside land as a wilderness, especially if it can be used only by the selfish few who want to have these huge areas for their own private use.

JIM LACEY
Garnon, Mississippi

The one thing your beautiful photos couldn't give a sense of was the need for those of us who seek the wilderness to close out all sounds of civilization. I feel fortunate to live in a state where the legislature is addressing the problem of low-flying sight-seeing aircraft over our wilderness areas. The sounds as well as the sights of the wilderness are important. It should be treated with the sanctity of our most beloved cathedrals. After all, who was responsible for its creation?

LINDA L. KEIM
Parachute, Colorado

A Comeback for the Cossacks

As a descendant of the Cossacks (my grandparents were Hochli), I was delighted by your article. You made a major contribution to the understanding of Cossack lore by attributing much of it to "memory, or more correctly, *imagined memory*. . ." Oh well, as the toast goes, "*Posley nas, ni hoodet nas*—After us, there'll be no more of us."

JOHN M. BURLAKE
Crescent City, California

My grandpa remembers the Cossacks. When he was a boy, they rode into his village between Ukraine and what is now Belarus. He remembers his grandma standing outside her front door and having her head lopped off. During another encounter he remembers the Cossacks calling for his other grandma to come out of her house, where in mortal fear she hid. They then threw some sort of grenade-like bomb into her small home, killing everyone within. This article has left me in tears. Maybe you need to see an old man crying to understand.

KIRSTEN KOZA
Sutton, Ontario


Men who train as warriors sooner or later will be driven to make war. One likely target will be the Jews, whom the Cossacks have murdered out of some warped sense of nationalism for centuries. In a country as confused as Russia is today, scape-goating minorities is an easy way to divert attention



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from the general feeling of communal failure. If the Cossacks continue to grow in strength and numbers, how can the proud belligerence of these self-proclaimed superpatriots be contained?

STUART COHEN
Marblehead, Massachusetts

On pages 41 and 55 the article characterizes the limited role of Cossack women as "passive." There is nothing passive about cooking, keeping house, raising strong children, and simultaneously managing and working a farm. These activities require energy, strength, and resolve. The women may not be picking up whips and riding off beside their husbands, but without their active, supportive role at home, the husbands would not be riding off to battle either.

ROSALYN G. PHILLIPS
San Luis Obispo, California

Maui Surf

I never knew it was possible for waves with up to 70-foot faces to be surfed by humans—and for them to live! Patrick McFeeley's eye-popping photography was a visual feast.

JAMES ALAN TREADWELL
Oxford, England

"Jaws" was awesome! Finally I can use that word with some relevance to reality. I know 14 pages seems like a lot when you're doing the layout, but it could have had more.

PETER BROCK
Anaheim Hills, California

Shackleton Expedition

Your excellent article on Ernest Shackleton and his intrepid crew brought to mind a quote attributed to Sir Edmund Hillary on Antarctic explorers: "For scientific discovery, give me Scott. For speed and efficiency of travel, give me Amundsen. But when disaster strikes and all hope is gone, get down on your knees and pray for Shackleton."

AL LATHAM
Chinacum, Washington

Author Caroline Alexander informs us that this often published quote is apocryphal.

Although polar firsts eluded him, Shackleton's leadership and ability to surmount continual adversity is even more inspiring than reaching 90 degrees south. I have little doubt that his decision in 1906 to turn back on his quest for the Pole, while only a few days' march away, saved more lives as well. He may not have been first, but he was arguably the best.

ROBERT NICHOLS
Altus Viejo, California

I have a burning question about the Shackleton Expedition. What happened to Mrs. Chippy, the ship's cat?

ILANA WEIN
Savoy, Illinois

Mrs. Chippy and three puppies born on the ship were put down on October 29, two days after the Endurance was lost. Years later the crew members still reminisced fondly about the cat.

Nebraska

Contrary to your article, most Nebraskans are not gap-toothed cowboys or telemarketing, stock-car-racing football fans or overweight men dancing shirtless while women watch adoringly. I was raised on a farm near Platte Center and know there really are educated, modern, diverse people living in the Cornhusker State!

NANCY BERKELAND
Los Angeles, California

The trouble with most writings about Nebraska is that they end up perpetuating the stereotypes they set out to correct: that the entire state is one long, flat cornfield, that cattle auctions are the only entertainment around, and that "folks" must trek to Chicago or Denver for tractor parts. Roff Smith's wonderful piece didn't fall into that trap, however. He deftly portrayed the urban and the rural and fairly showed that while Nebraska is a great place to live, it has its problems as well (and he didn't use the phrase "sleepy village" even once). You've made this native son mighty proud.

ROBERT D. GARRISON
Anelope, California

I know firsthand the passion Nebraskans have for the University of Nebraska football team. In 1974 my wife and I attended the Nebraska-Iowa State game in Ames, Iowa. Prior to the game we had lunch and shared our table with a couple from Nebraska. They told us that they had bought Iowa State season tickets just to guarantee they would have seats for the Nebraska game.

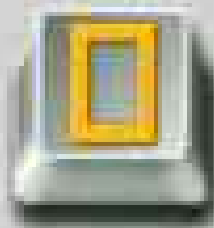
BILL BOWEN
Klamath Falls, Oregon

On page 139 Nebraska fans boasted to the author that coach Osborne was "the winningest active coach in college football history." Tom Osborne may have had the best winning percentage among active Division I-A coaches (83.6% at season's end), but most Penn State fans would point out that Joe Paterno has the most victories; he would have had over 295 at the November 1997 Oklahoma-Nebraska game mentioned in the article.

RON MATTIS
Kane, Pennsylvania

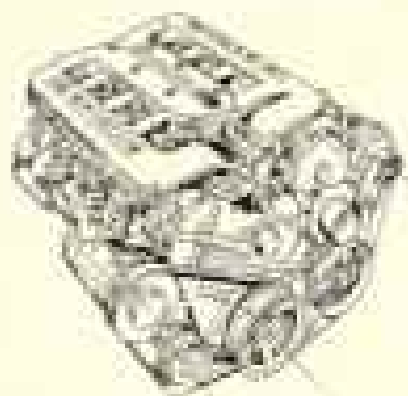
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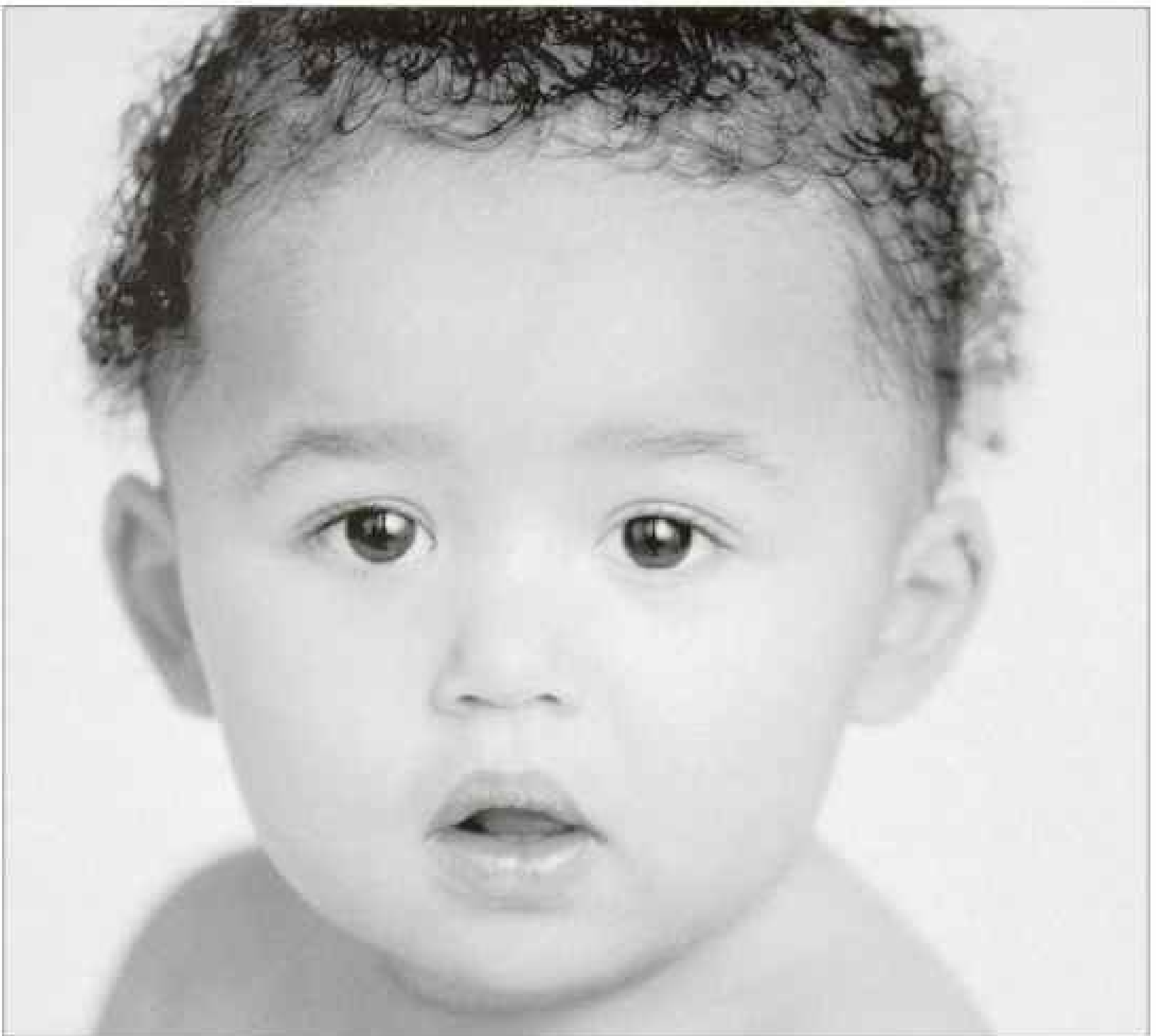
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Jefferson's Retreat Comes Back to Life

"The excellent dwelling house I have built there has been associated by me with delight," Thomas Jefferson wrote in 1813 about Poplar Forest, his occasional home.

Jefferson began to design that house, near Lynchburg, Virginia, while President, as a refuge from his busy, better known estate, Monticello. He journeyed to his country hideaway as often as four times a year from 1809 to 1823, constantly refining in his own hand the blueprint for the

small octagonal structure, its service wing, and the landscaping.

His grandson sold the house in 1828; an 1845 fire and repairs radically changed its look. Later alterations further distorted Jefferson's design. Finally, in 1984, encroaching development led to the creation of a nonprofit entity that bought the property and set about restoring it to its 1826 appearance, using original building methods.

The exterior restoration now is complete (above). Work continues inside in the skylit heart of Poplar Forest, a cube-shaped room that served as dining room and a place for the former President to receive visitors.

"Jefferson knew what he wanted; he designed it to satisfy himself," says Travis McDonald, head of the restoration. "Now it makes sense again as a kind of autobiography of its architect."





Puaiohi, or Small Kauai Thrush (*Myadestes palmeri*) Size: Length, 17 cm Weight: 35-42 g Habitat: Rain forest in the Alakai Wilderness Area on the Hawaiian Island of Kauai, USA Surviving number: Estimated at fewer than 200 Photographed by Jim Denny



WILDLIFE AS CANON SEES IT

The secretive Puaiohi haunts shady streambeds and dense understory along gorges carved into Kauai's central highlands. Pale-pink legs mark this smallest of Hawaii's rare thrushes. The solitary songster eats berries and insects, and builds its nest in a cavity on a streamside cliff. Surrounded by an overhang of matted ferns and mosses, the woven cup conceals the nestlings from

predators and shelters them from the driving rain and wind that persist in the clouded forest. A captive propagation effort is one part of a long-term program to assist Puaiohi recovery in its native habitat. 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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Twin Disasters, Ringed by Drought

The idea, to establish English colonies in the New World, made sense. But a study of rings of bald cypress trees—“silent witnesses to history,” in the words of University of Arkansas dendrochronologist David Stahle—suggests the timing was abysmal.

The 117 members of what became known as the “Lost Colony” in North Carolina vanished after 1587, leaving behind only the cryptic one-word carving “Croatoan” (right, top). Tree rings show that 1587 was the region’s driest year in 800 years.

Twenty years later the English established a new colony in Virginia called Jamestown. It survived but at a terrible cost: Only 38 of the original 104 colonists lived beyond the first year. They had the “colossal misfortune” of arriving during a drought that lasted from 1606 to 1612, another 800-year record. “We aren’t claiming that drought was the root cause of the problems, but we think it was a contributing factor,” Stahle says.



COURTESY: STEVE HAWKS



SHUTTERSTOCK: ALAN HARVEY

Rain, Rain, Go Away, Come Again on Saturday

These soggy folks waiting out showers at a weekend stock car race in Virginia may suspect what a statistical study proves: It rains more on weekends than during the week. And we may all be to blame. Precipitation figures from 1979 to 1995 recorded off North America’s Atlantic coast show that 22 percent more rain falls on Saturdays than on Mondays. Monday’s figures are the week’s lowest, and then the amount increases daily through the workweek, says Randy Cerveny, an Arizona State University geographer. He suspects that a pollution buildup caused by weekday driving helps bring weekend rain.



Linda begged Steve to log off the Internet for a day.

"How about we see the world in person this afternoon?" she challenged.

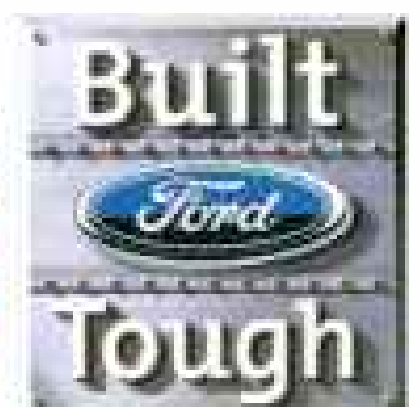
And before you could say "download," their Ford Expedition

took them to places so unreal and so far out there, Steve thought,

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■ NGS EXPEDITIONS GRANT New Inca Sacrifices Found in Peru's Andes

High atop the 19,100-foot volcano called Misti, which overlooks the southern Peruvian city of Arequipa, archaeologist Johan Reinhard and his companions became intrigued by rows of stones set up at the lip of the crater. Digging into the ash (right), they uncovered remains of Inca human sacrifices, the greatest number ever found at a single site. The pattern had never been seen before: three males, including a child, in one location; three females, including a child, in a second nearby.

Because the bodies—each in the fetal position—had been buried near still active fumaroles, the heat prevented freezing and allowed them to decompose, leaving only bones and not the well-preserved and wrapped mummies Reinhard found on earlier forays (GEOGRAPHIC, June 1996 and July 1998, and on our website at www.nationalgeographic.com/andes). But shawl

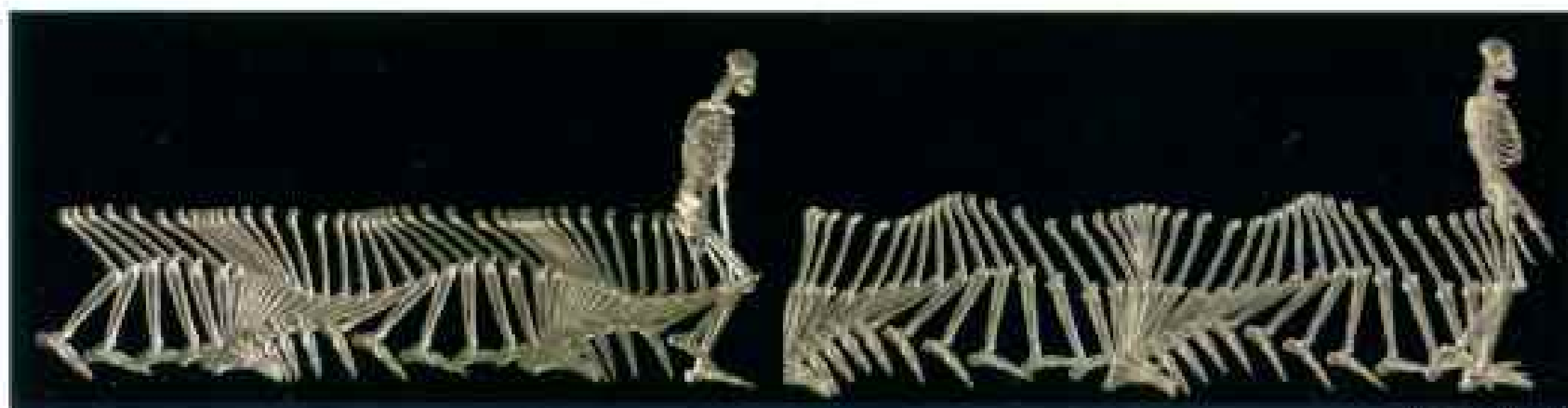


pins found with the female victims suggest that these too had been wrapped in textiles. The team also found eight silver and gold human figurines like the one at right, more than 20 miniature llamas, and pottery clearly of Inca origin, Reinhard says.

The Inca first arrived in the area about 1450. Local legend recalls an eruption shortly thereafter that was so severe it drew a visit by the emperor, who made offerings on the volcano.



BOTH BY JOHAN REINHARD



ELISS SAVAGE

Lucy Probably Walked Much Like Modern Humans

Scientists agree that *Australopithecus afarensis*, the little hominid whose best known fossil representative is nicknamed Lucy, got around Africa on two legs, among the first human ancestors known to do that. But how?

Robin Crompton of England's University of Liverpool set out to test the two competing theories of Lucy's gait: an erect, straight-knee humanlike posture versus a bent-knee, bent-hip walk closer to that of chimpanzees. Crompton's team entered Lucy's limb proportions into a

computer, then ran simulations, like those used in robot design, to determine the efficiency of each walk. They concluded that the biomechanical and metabolic costs of a bent-knee, bent-hip posture (above, at left) were too great and that Lucy probably walked upright, at right.

"Lucy was a successful animal in her own right, not merely a transitional creature," Crompton says. "And she was well on the road to humanlike walking."

TEXT BY BORIS WEINTRAUB



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Not for children or those with glaucoma, difficulty in urinating, or an allergy to scopolamine or other belladonna alkaloids. In clinical studies, some side effects were noted, including blurred vision, dryness of the mouth (in two-thirds of users) and drowsiness (reported incidence less than 1 in 6). While using this product, you should not drive, operate dangerous machinery or do other things that require alertness. Avoid using alcohol. If you are elderly, your physician should exercise special care in prescribing this product. See adjoining page for additional information on potential adverse reactions or side effects.

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Brief Summary

(For full prescribing information, see package insert.)

INDICATIONS AND USAGE: Transderm Scop is indicated for prevention of nausea and vomiting associated with motion sickness in adults. The patch should be applied only to skin in the postauricular area.

CONTRAINDICATIONS: Transderm Scop is specifically contraindicated in persons who are hypersensitive to the drug (scopolamine) or to other belladonna alkaloids, or to any ingredient or component in the formulation or delivery system, or in patients with angle-closure (narrow angle) glaucoma.

WARNINGS: Transderm Scop should not be used in children and should be used with special caution in the elderly. See PRECAUTIONS.

Since drowsiness, disorientation and confusion may occur with the use of scopolamine, patients should be warned of the possibility and cautioned against engaging in activities that require mental alertness, such as driving a motor vehicle or operating dangerous machinery.

Potentially alarming idiosyncratic reactions may occur with ordinary therapeutic doses of scopolamine.

PRECAUTIONS

General: Scopolamine should be used with caution in patients with pyloric obstruction, or urinary bladder neck obstruction. Caution should be exercised when administering an anticholinergic or antimuscarinic drug to patients suspected of having intestinal obstruction.

Transderm Scop should be used with special caution in the elderly or in individuals with impaired metabolic, liver, or kidney functions, because of the increased likelihood of CNS effects.

Caution should be exercised in patients with a history of seizure or psychosis, since scopolamine can potentially aggravate both disorders.

Information for Patients: Since scopolamine can cause temporary dilation of the pupils and blurred vision if it comes in contact with the eyes, patients should be strongly advised to wash their hands thoroughly with soap and water immediately after handling the patch. In addition, it is important that used patches be disposed of properly to avoid contact with children or pets.

Patients should be advised to remove the patch immediately and contact a physician in the unlikely event that they experience symptoms of acute narrow-angle glaucoma (pain in and redness of the eyes accompanied by dilated pupils). Patients should also be instructed to remove the patch if they develop any difficulties in urinating.

Patients should be warned against driving a motor vehicle or operating dangerous machinery while wearing the patch. Patients who engage in these activities should also be aware of the possibility of withdrawal symptoms when the patch is removed. Patients who expect to participate in underwater sports should be cautioned regarding the potentially disorienting effects of scopolamine. A patient brochure is available.

Drug Interactions: Scopolamine should be used with care in patients taking drugs, including alcohol, capable of causing CNS effects. Special attention should be given to drugs having anticholinergic properties, e.g., belladonna alkaloids, anticholinergics including meclizine, and anti-depressants.

Carcinogenesis, Mutagenesis, Impairment of Fertility: No long-term studies in animals have been performed to evaluate carcinogenic potential. Fertility studies were performed in female rats and revealed no evidence of impaired fertility or harm to the fetus due to scopolamine hydrobromide administered by daily subcutaneous injection. In the highest-dose group (plasma level approximately 100 times the level achieved in humans using a transdermal system), reduced maternal body weights were observed.

Pregnancy Category C: Teratogenic studies were performed in pregnant rats and rabbits with scopolamine hydrobromide administered by daily intravenous injection. No adverse effects were recorded in the rats. In the rabbits, the highest dose (plasma level approximately 110 times the level achieved in humans using a transdermal system) of drug administered had a marginal embryotoxic effect. Transderm Scop should be used during pregnancy only if the anticipated benefit justifies the potential risk to the fetus.

Nursing Mothers: It is not known whether scopolamine is secreted in human milk. Because many drugs are excreted in human milk, caution should be exercised when Transderm Scop is administered to a nursing woman.

Pediatric Use: Children are particularly susceptible to the side effects of belladonna alkaloids. Transderm Scop should not be used in children because it is not known whether this system will release an amount of scopolamine that could produce serious adverse effects in children.

ADVERSE REACTIONS: The most frequent adverse reaction to Transderm Scop is dryness of the mouth. This occurs in about two thirds of the people. A less frequent adverse reaction is drowsiness, which occurs in less than one sixth of the people. Transient impairment of eye accommodation, including blurred vision and dilation of the pupils, is also observed.

The following adverse reactions have also been reported on infrequent occasions during the use of Transderm Scop: disorientation; memory disturbances; dizziness; restlessness; hallucinations; confusion; difficulty urinating; rashes and erythema; acute narrow-angle glaucoma; and dry lips or red eyes.

Drug Withdrawal: Symptoms including dizziness, nausea, vomiting, headache, and disturbances of equilibrium have been reported in a few patients following discontinuation of the use of the Transderm Scop system. These symptoms have occurred most often in patients who have used the system for more than three days.

OVERDOSAGE: Overdosage with scopolamine may cause disorientation, memory disturbances, dizziness, restlessness, hallucinations, confusion, psychosis, convulsions, bronchospasm and respiratory depression, and muscular weakness. Should these symptoms occur, the Transderm Scop patch should be removed immediately, adequate hydration should be maintained, and appropriate symptomatic treatment initiated.

CAUTION: Federal law prohibits dispensing without prescription.

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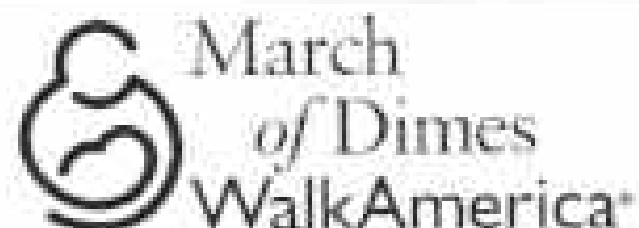
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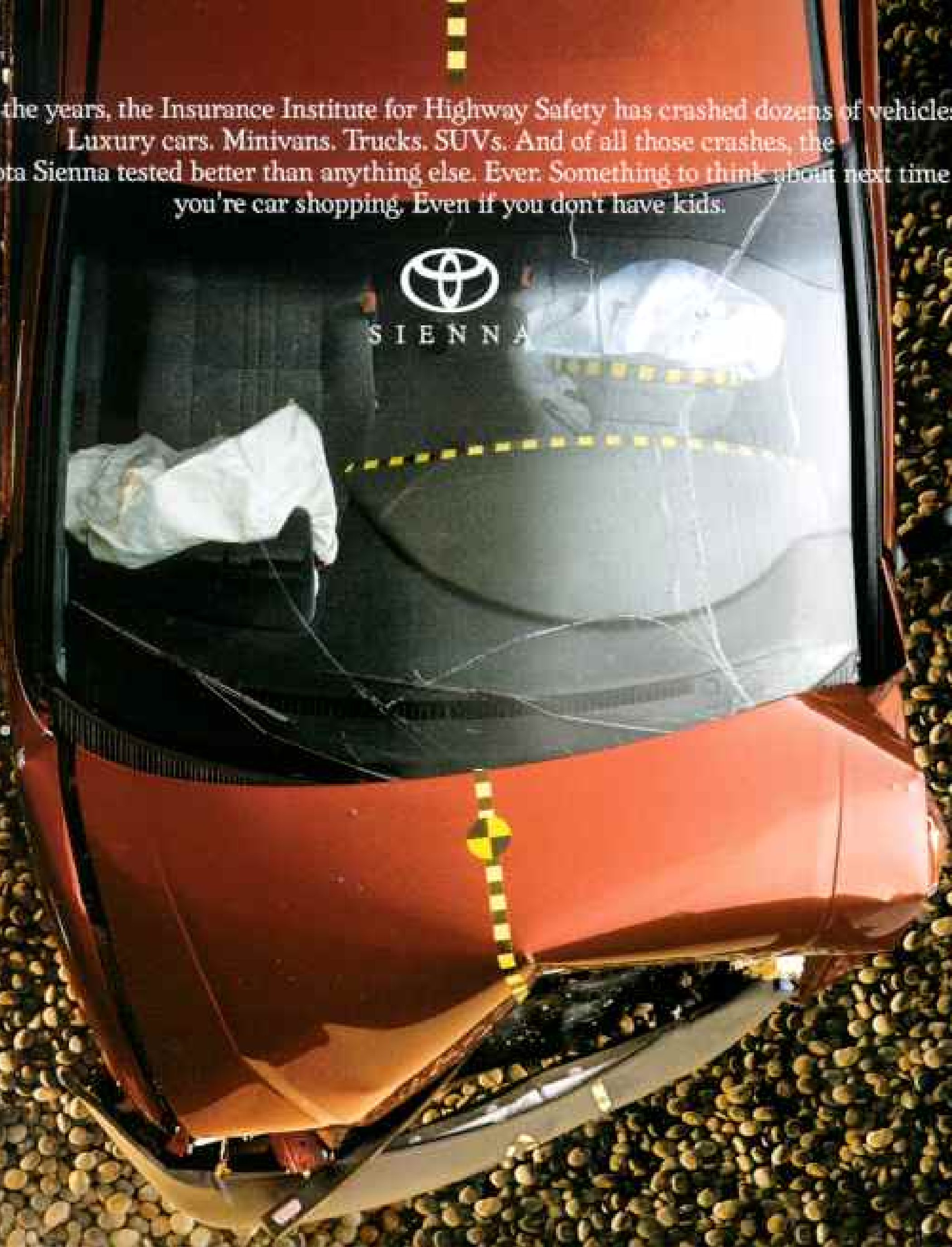
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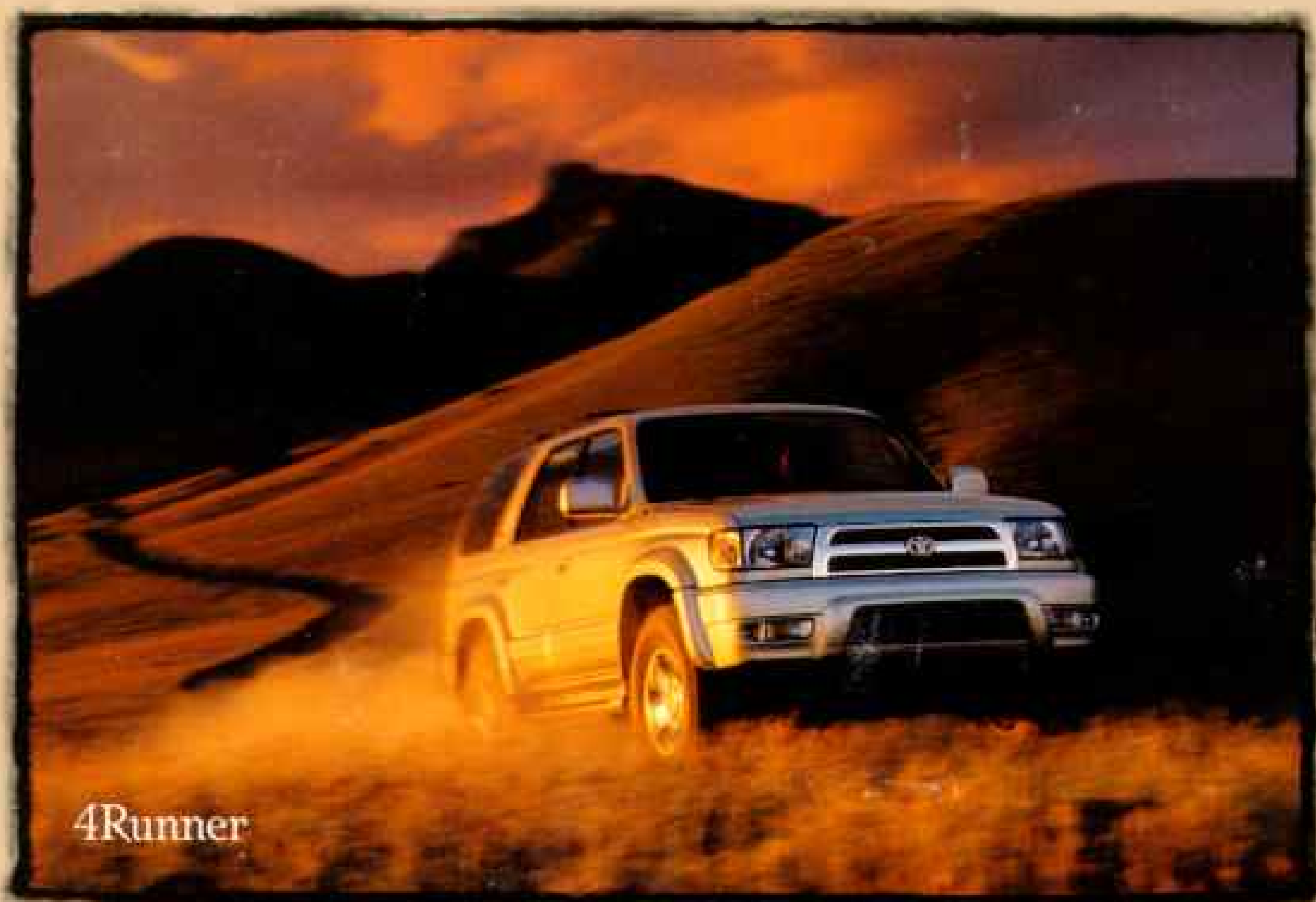
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NATIONAL GEOGRAPHIC

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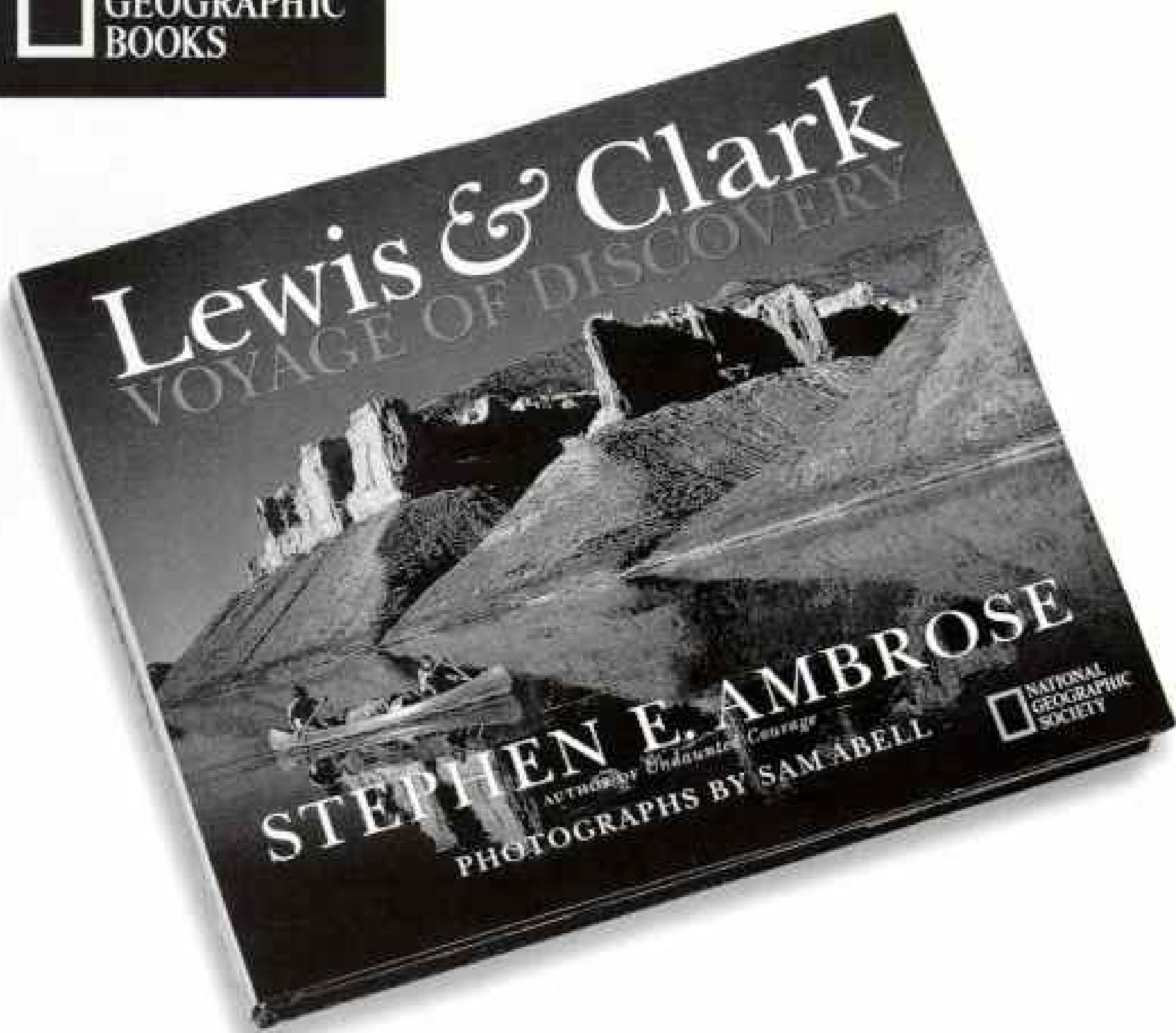
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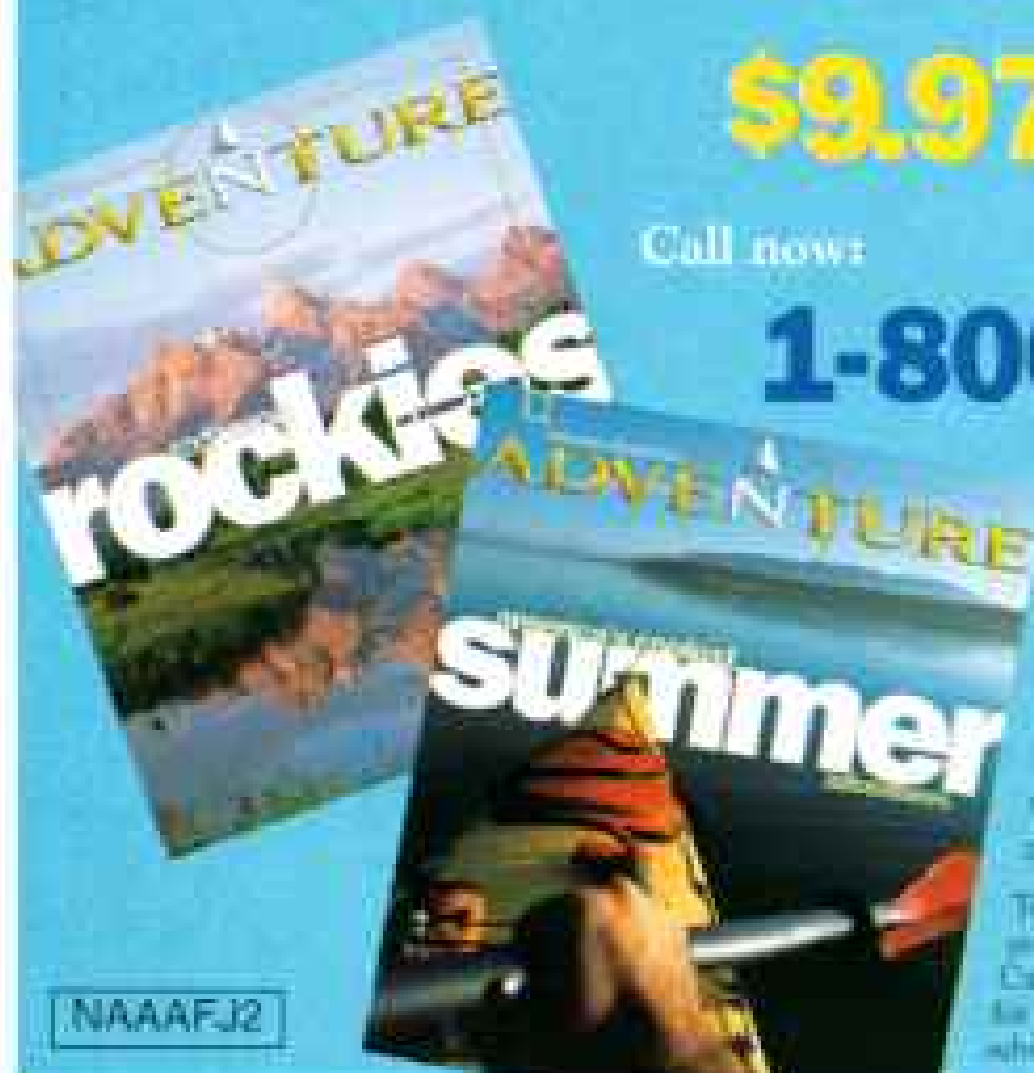
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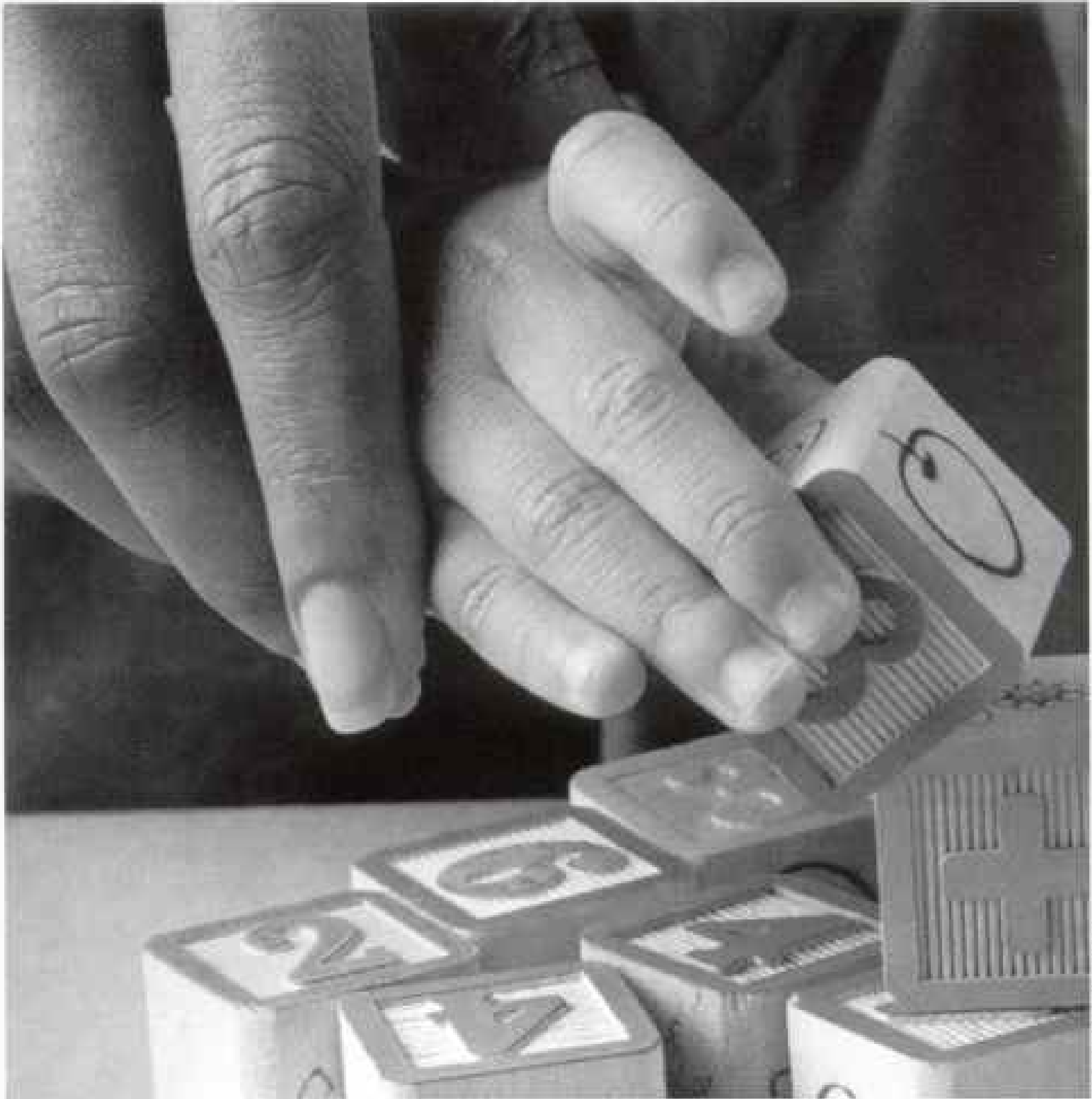
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CITROËN CENTRAL AFRICAN EXPEDITION

■ FROM THE GEOGRAPHIC ARCHIVES

Skeleton Crew

"How long ago did these victims of thirst fall by the wayside?" wrote Georges-Marie Haardt, leader of the Citroën Central African Expedition of 1924. Haardt's group—the first to cross the African continent by automobile—found the parched remains of three travelers in the Sahara's Tanezrouft region, 50 miles from the closest well. The book Haardt wrote with his second-in-command, M. Louis Audouin-Dubreuil, describes the scene: "Their clothes, mere frayed-out tatters, still remain; from an open bag grains of corn lie spilled, and on this cursed soil are unable to take root. We pass on in silence." Haardt needed no reminder of the dangers of the Sahara. During the desert leg of the 15,000-mile trip the expedition's eight trucks traveled for more than 330 miles without finding a drop of water. "Any breeze there is becomes a torment," the team reported. "We are suffocated, saturated with dust; we could almost believe ourselves to be like men turned into red brick." This photo was published in the June 1926 article "Through the Deserts and Jungles of Africa by Motor."



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■ A STORY OF SURVIVAL

Aloft on Desert Winds

Straining against the wind, a woman in an oasis village in the desert of Chad (above) carries home marsh grasses to feed her goats. Riding with the wind, photographer George Steinmetz maneuvered a powered paraglider—a craft with a parachute-like wing attached to a motorized backpack—to see the central Sahara as few have viewed it before.

In *Survive the Sahara* EXPLORER joins Steinmetz and writer Donovan Webster, whose article appears in this issue, on a caravan that traveled 4,000 miles and dared death both on the desert floor and in the air.

In his fragile flying machine Steinmetz found himself at the mercy of the elements that sculpt the desert and its people, from massive mounds of shifting sand to the deeply etched face of a Chadian woman (above right). Risking dangerous uplifts and downdrafts, Steinmetz soared as high as 8,000 feet for dazzling bird's-eye views.

The assignment fulfilled a long-time goal. "Twenty years ago, I dropped out of college for a year and hitchhiked and photographed



BOOTH BY GEORGE STEINMETZ

my way through Africa," says Steinmetz. "I'd always dreamed about going back deep into the desert and bringing out pictures that capture this little-known landscape."

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Joan Lunden

Talk to your doctor about a trial of nondrowsy, 24-hour CLARITIN®. One tablet daily gives you 24-hour, nondrowsy relief from seasonal allergy symptoms. Studies show that the incidence of drowsiness was similar to that with placebo (sugar pill) at the recommended dose. Drowsiness may occur if you take more than the recommended dose.

Experience CLARITIN® - safe and effective relief for ages 6 and older. CLARITIN® is well tolerated. It has a low occurrence of side effects, which occurred about as often as they did with placebo (sugar pill). Most common were headache, occurring with 12% of people; drowsiness, 8%; fatigue, 4%; and dry mouth, 3%.

Nondrowsy antihistamines, such as CLARITIN®, are available by prescription only.

Call toll free 1-888-833-0003. Notify your doctor of other medication(s) you are currently taking. Consult your doctor for important information concerning this product.

Please see additional important information on next page.

Talk to your doctor about a trial of

Once-a-day

Claritin®
10 mg
TABLETS (loratadine)

Schering/MSD

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www.claritin.com

CLARITIN[®] brand of loratadine TABLETS, SYRUP, and RAPIDLY-DISINTEGRATING TABLETS

BRIEF SUMMARY (For full Prescribing Information, see package insert.)

INDICATIONS AND USAGE: CLARITIN is indicated for the relief of nasal and non-nasal symptoms of seasonal allergic rhinitis and for the treatment of chronic idiopathic urticaria in patients 6 years of age or older.

CONTRAINDICATIONS: CLARITIN is contraindicated in patients who are hypersensitive to this medication or to any of its ingredients.

PRECAUTIONS: General: Patients with liver impairment or renal insufficiency (GFR < 30 mL/min) should be given a lower initial dose (10 mg every other day). (See **CLINICAL PHARMACOLOGY: Special Populations.**)

Drug Interactions: Loratadine (10 mg once daily) has been coadministered with therapeutic doses of erythromycin, cimetidine, and ketoconazole in controlled clinical pharmacology studies in adult volunteers. Although increased plasma concentrations (AUC 0-24 hrs) of loratadine and/or descarboethoxylopratadine were observed following coadministration of loratadine with each of these drugs in normal volunteers (n = 24 in each study), there were no clinically relevant changes in the safety profile of loratadine, as assessed by electrocardiographic parameters, clinical laboratory tests, vital signs, and adverse events. There were no significant effects on QT intervals, and no reports of sedation or syncope. No effects on plasma concentrations of cimetidine or ketoconazole were observed. Plasma concentrations (AUC 0-24 hrs) of erythromycin decreased 15% with coadministration of loratadine relative to that observed with erythromycin alone. The clinical relevance of this difference is unknown. These above findings are summarized in the following table:

Effects on Plasma Concentrations (AUC 0-24 hrs) of Loratadine and Descarboethoxylopratadine After 10 Days of Coadministration (Loratadine 10 mg in Normal Volunteers)

| | Loratadine | Descarboethoxylopratadine |
|----------------------------|------------|---------------------------|
| Erythromycin (500 mg Q8h) | +40% | +45% |
| Cimetidine (300 mg QID) | +103% | +6% |
| Ketoconazole (200 mg Q12h) | +307% | +73% |

There does not appear to be an increase in adverse events in subjects who received oral contraceptives and loratadine.

Carcinogenesis, Mutagenesis, and Impairment of Fertility: In an 18-month carcinogenicity study in mice and a 2-year study in rats, loratadine was administered in the diet at doses up to 40 mg/kg (mice) and 25 mg/kg (rats). In the carcinogenicity studies, pharmacokinetic assessments were carried out to determine animal exposure to the drug. AUC data demonstrated that the exposure of mice given 40 mg/kg of loratadine was 3.6 (loratadine) and 19 (descarboethoxylopratadine) times higher than in humans given the maximum recommended daily oral dose. Exposure of rats given 25 mg/kg of loratadine was 28 (loratadine) and 67 (descarboethoxylopratadine) times higher than in humans given the maximum recommended daily oral dose. Male mice given 40 mg/kg had a significantly higher incidence of hepatocellular tumors (combined adenomas and carcinomas) than concurrent controls. In rats, a significantly higher incidence of hepatocellular tumors (combined adenomas and carcinomas) was observed in males given 10 mg/kg and males and females given 25 mg/kg. The clinical significance of these findings during long-term use of CLARITIN is not known.

In mutagenicity studies, there was no evidence of mutagenic potential in reverse (Ames) or forward point mutation (CHO-HGPRT) assays, or in the assay for DNA damage (rat primary hepatocyte unscheduled DNA assay) or in two assays for chromosomal alterations (human peripheral blood lymphocyte clastogenesis assay and the mouse bone marrow erythrocyte micronucleus assay). In the mouse lymphoma assay, a positive finding occurred in the nonactivated but not the activated phase of the study.

Decreased fertility in male rats, shown by lower female conception rates, occurred at an oral dose of 64 mg/kg (approximately 50 times the maximum recommended human daily oral dose on a mg/m² basis) and was reversible with cessation of dosing. Loratadine had no effect on male or female fertility or reproduction in the rat at an oral dose of approximately 24 mg/kg (approximately 20 times the maximum recommended human daily oral dose on a mg/m² basis).

Pregnancy Category B: There was no evidence of animal teratogenicity in studies performed in rats and rabbits at oral doses up to 90 mg/kg (approximately 75 times and 150 times, respectively, the maximum recommended human daily oral dose on a mg/m² basis). There are, however, no adequate and well-controlled studies in pregnant women. Because animal reproduction studies are not always predictive of human response, CLARITIN should be used during pregnancy only if clearly needed.

Nursing Mothers: Loratadine and its metabolite, desca/boethoxylopratadine, pass easily into breast milk and achieve concentrations that are equivalent to plasma levels with an AUC₀₋₂₄/AUC₀₋₂₄ ratio of 1.17 and 0.85 for loratadine and descarboethoxylopratadine, respectively. Following a single oral dose of 40 mg, a small amount of loratadine and descarboethoxylopratadine was excreted into the breast milk (approximately 0.03% of 40 mg over 48 hours). A decision should be made whether to discontinue nursing or to discontinue the drug, taking into account the importance of the drug to the mother. Caution should be exercised when CLARITIN is administered to a nursing woman.

Pediatric Use: The safety of CLARITIN Syrup at a daily dose of 10 mg has been demonstrated in 188 pediatric patients 6-12 years of age in placebo-controlled 2-week trials. The effectiveness of CLARITIN for the treatment of seasonal allergic rhinitis and chronic idiopathic urticaria in this pediatric age group is based on an extrapolation of the demonstrated efficacy of CLARITIN in adults in these conditions and the likelihood that the disease course, pathophysiology, and the drug's effect are substantially similar to that of the adults. The recommended dose for the pediatric population is based on cross-study comparison of the pharmacokinetics of CLARITIN in adults and pediatric subjects and on the safety profile of loratadine in both adults and pediatric patients at doses equal to or higher than the recommended doses. The safety and effectiveness of CLARITIN in pediatric patients under 6 years of age have not been established.

ADVERSE REACTIONS: CLARITIN Tablets: Approximately 90,000 patients, aged 12 and older, received CLARITIN Tablets 10 mg once daily in controlled and uncontrolled studies. Placebo-controlled clinical trials at the recommended dose of 10 mg once a day varied from 2 weeks to 6 months' duration. The rate of premature withdrawal from these trials was approximately 8% in both the treated and placebo groups.

REPORTED ADVERSE EVENTS WITH AN INCIDENCE OF MORE THAN 2% IN PLACEBO-CONTROLLED ALLERGIC RHINITIS CLINICAL TRIALS IN PATIENTS 12 YEARS OF AGE AND OLDER

| | PERCENT OF PATIENTS REPORTING | | | |
|------------|------------------------------------|---------------------|-----------------------------------|-------------------------------------|
| | LORATADINE 10 mg QD n = 1326 | PLACEBO n = 2545 | CLEMASTINE 1 mg BID n = 536 | TERFENADINE 60 mg BID n = 684 |
| Headache | 12 | 11 | 8 | 8 |
| Somnolence | 8 | 6 | 22 | 8 |
| Fatigue | 4 | 3 | 10 | 2 |
| Dry Mouth | 3 | 2 | 4 | 3 |

Adverse events reported in placebo-controlled chronic idiopathic urticaria trials were similar to those reported in allergic rhinitis studies.

Adverse event rates do not appear to differ significantly based on age, sex, or race, although the number of nonwhite subjects was relatively small.

CLARITIN REDITABS (loratadine rapidly-disintegrating tablets): Approximately 500 patients received CLARITIN REDITABS (loratadine rapidly-disintegrating tablets) in controlled clinical trials of 2 weeks' duration. In these studies, adverse events were similar in type and frequency to those seen with CLARITIN Tablets and placebo.

Administration of CLARITIN REDITABS (loratadine rapidly-disintegrating tablets) did not result in an increased reporting frequency of mouth or tongue irritation.

CLARITIN Syrup: Approximately 300 pediatric patients 6 to 12 years of age received 10 mg loratadine once daily in controlled clinical trials for a period of 8-15 days. Among these, 188 children were treated with 10 mg loratadine syrup once daily in placebo-controlled trials. Adverse events in these pediatric patients were observed to occur with type and frequency similar to those seen in the adult population. The rate of premature discontinuance due to adverse events among pediatric patients receiving loratadine 10 mg daily was less than 1%.

ADVERSE EVENTS OCCURRING WITH A FREQUENCY OF ≥ 2% IN LORATADINE SYRUP-TREATED PATIENTS (6-12 YEARS OLD) IN PLACEBO-CONTROLLED TRIALS AND MORE FREQUENTLY THAN IN THE PLACEBO GROUP

| | PERCENT OF PATIENTS REPORTING | | |
|-----------------------------------|-----------------------------------|--------------------|---|
| | LORATADINE 10 mg QD n = 188 | PLACEBO n = 262 | CHLORPHENIRAMINE 2-4 mg BID/TID n = 170 |
| Nervousness | 4 | 2 | 2 |
| Wheezing | 4 | 2 | 2 |
| Fatigue | 4 | 2 | 2 |
| Hyperkinesia | 4 | 1 | 1 |
| Abdominal Pain | 4 | 0 | 0 |
| Conjunctivitis | 4 | +1 | +1 |
| Dysphonia | 4 | +1 | 0 |
| Melancholy | 4 | 0 | 1 |
| Upper Respiratory Tract Infection | 2 | +1 | 0 |

In addition to those adverse events reported above (≥ 2%), the following adverse events have been reported in at least one patient in CLARITIN clinical trials in adult and pediatric patients:

Autonomic Nervous System: Altered lacrimation, altered salivation, flushing, hypoaesthesia, impotence, increased sweating, thirst.

Body As A Whole: Angioneurotic edema, asthma, back pain, blurred vision, chest pain, epistaxis, eye pain, fever, leg cramps, malaise, rigors, tinnitus, viral infection, weight gain.

Cardiovascular System: Hypertension, hypotension, palpitations, supraventricular tachyarrhythmias, syncope, tachycardia.

Central and Peripheral Nervous System: Diploplopasm, dizziness, dysphonia, hypertonia, migraine, paresthesia, tremor, vertigo.

Gastrointestinal System: Altered taste, anorexia, constipation, diarrhea, dyspepsia, flatulence, gastritis, hiccup, increased appetite, nausea, stomatitis, toothache, vomiting.

Musculoskeletal System: Arthralgia, myalgia.

Psychiatric: Agitation, amnesia, anxiety, confusion, decreased libido, depression, impaired concentration, insomnia, irritability, paranoia.

Reproductive System: Breast pain, dysmenorrhea, menorrhagia, vaginitis.

Respiratory System: Bronchitis, bronchospasm, coughing, dyspnea, epistaxis, hemoptysis, laryngitis, nasal dryness, pharyngitis, sinusitis, sneezing.

Skin and Appendages: Dermatitis, dry hair, dry skin, photosensitivity reaction, pruritus, purpura, rash, urticaria.

Urinary System: Altered micturition, urinary discoloration, urinary incontinence, urinary retention.

In addition, the following spontaneous adverse events have been reported rarely during the marketing of loratadine: abnormal hepatic function, including jaundice, hepatitis, and hepatic necrosis; alopecia; atrophy; breast enlargement; erythema multiforme; peripheral edema; and seizures.

OVERDOSAGE: In adults, somnolence, tachycardia, and headache have been reported with overdoses greater than 10 mg with the Tablet formulation (40 to 180 mg). Extrapyramidal signs and palpitations have been reported in children with overdose of greater than 10 mg of CLARITIN Syrup. In the event of overdose, general symptomatic and supportive measures should be instituted promptly and maintained for as long as necessary.

Treatment of overdose would reasonably consist of emesis (ipecac syrup), except in patients with impaired consciousness, followed by the administration of activated charcoal to absorb any remaining drug. If vomiting is unsuccessful, or contraindicated, gastric lavage should be performed with normal saline. Saline cathartics may also be of value for rapid dilution of bowel contents. Loratadine is not eliminated by hemodialysis. It is not known if loratadine is eliminated by peritoneal dialysis.

No deaths occurred at oral doses up to 5000 mg/kg in rats and mice (greater than 2400 and 1200 times, respectively, the maximum recommended human daily oral dose on a mg/m² basis). Single oral doses of loratadine showed no effects in rats, mice, and monkeys at doses as high as 10 times the maximum recommended human daily oral dose on a mg/m² basis.

Schering Corporation
Kenilworth, NJ 07033 USA

Rev. 3/98

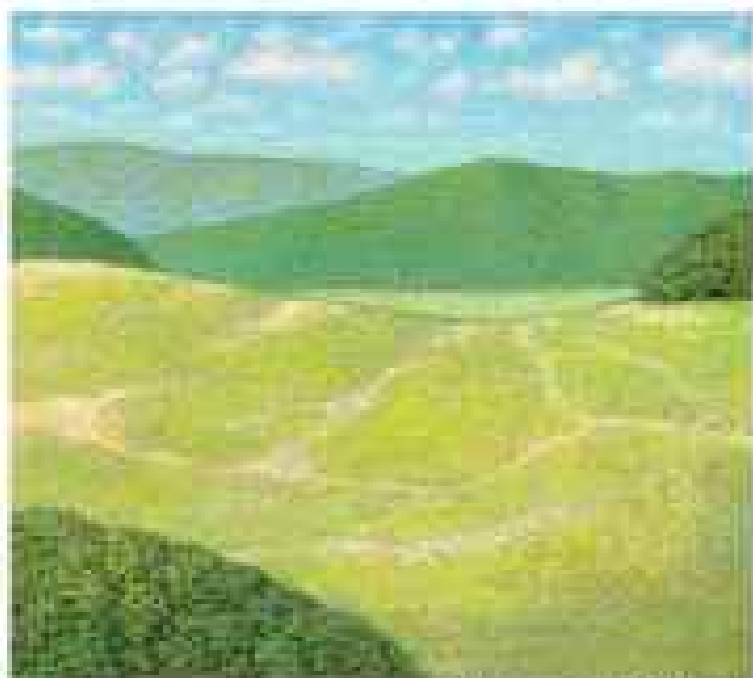
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CLARITIN REDITABS (loratadine rapidly-disintegrating tablets) are manufactured for Schering Corporation by Scherer DOS, England.

U.S. Patent Nos. 4,282,233 and 4,371,516.

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Earth Almanac



ART BY EDWARD S. GAZD



FRANK JOHNSTON, WASHINGTON POST

Mountain-mining Controversy Peaking

Coal near Earth's surface has long been dug by conventional strip mining. But since 1967 a method called mountaintop removal has been used in West Virginia and adjacent states. On a peak flanked by valleys (top left), forests are stripped by heavy equipment. Explosives loosen rock above a coal seam; then a dragline (above) removes the overburden and lowers the mountain (middle). After the coal is removed, debris fills the valleys, which by law must be replanted (bottom).

But people in surrounding communities complain that blasting damages their homes and worry that changes to the land increase flood threats and water pollution. Five religious denominations in West Virginia have passed resolutions calling for mountaintop removal to be halted pending further study. David Todd of Arch Coal, Inc., the nation's second largest coal company, responds: "Is the Earth being protected? Absolutely."

Caterpillar's Hair-raising Defense

When spinning a cocoon, a Peruvian caterpillar is vulnerable to predators such as ants. To block them, the caterpillar crafts whorls of its long, stiff hairs (right) and places them like barbed wire around its twig. And the whorls may be coated with toxic chemicals, says John E. Rawlins of the Carnegie Museum of Natural History. When caterpillar becomes moth, it mimics ferocious wasps—hence its name, *Ctenuchini*, or "wasp moth."



MARK W. WILFETT



STEVE NORTHUP

New Mexico Ranch May Go Public

Like a miniature Yellowstone, 95,000-acre Baca Ranch in northern New Mexico boasts more than 6,000 elk, plus hot springs and wildflower meadows. Filmmakers have used the ranch as a classic Old West setting. Privately owned since 1860, the

land may soon be sold to the U.S. Forest Service and become part of the surrounding Santa Fe National Forest. Last October Congress set aside 40 million dollars as seed money for the purchase, but the final cost could be more than twice that. "Hiking, fishing, and other public uses will definitely be allowed," says the Forest Service's Denise McCaig.

Fat Fish Eats Its Way to Freedom

Heaviest of all bony fish, a mola, or ocean sunfish, has eaten its way out of house, home, and the Monterey Bay Aquarium. It weighed 38 pounds in August 1997 when staffers captured it in the bay. As the aquarium's guest it was hand-fed squid, shrimp, pureed fish, and nutrient-enriched gelatin. Within

15 months the bottomless pit had ballooned to 880 pounds. "If it got any bigger, we worried that it might be injured if we tried to move it," says the aquarium's Ken Peterson. Last November senior collector John O'Sullivan positioned the mola in a sling before a helicopter flew it home to the bay.



BANDY WILDER, MONTEREY BAY AQUARIUM

Lemurs Go Home to Madagascar

Hunted for their meat, Madagascar's endangered black-and-white ruffed lemurs are also losing habitat to deforestation. To help restore their numbers, the Duke University Primate Center is raising the animals in a natural habitat enclosure. This lemur was among five reintroduced to the island in October 1997; one was killed by a predator, and another died from a fall. Last autumn four more lemurs raised in captivity made the trip home.



DAVID HARRIS, DUKE UNIVERSITY PRIMATE CENTER

TEXT BY JOHN L. ELIOT

**NO.
NOT NOW.**

**ANY OTHER TIME IS FINE.
BUT NOT NOW.
I MEAN IT.**

**OKAY,
I CAN WATCH
THE PLAYOFFS
NEXT YEAR.**

*What do you feed the
head of the household?
Only the best.*



Optional chrome wheels shown. *Driver and front passenger crash test. Government data only useful in comparing models within 5,000 lbs.



Mercury Sable. Imagine yourself in a Mercury



Sable LS Premium features include: 5-star government crash test rating* • 200-HP V-6 engine
• leather seating surfaces • automatic temperature control • 800 446-8888 • www.mercuryvehicles.com

Interactive

■ ONLINE

Underground Railroad

Freedom. For slaves in the Old South it was a dream, a prayer—and, perhaps, the end of a long trudge north (right). Tens of thousands of African Americans fled slavery by using the Underground Railroad, a clandestine web of helpers (both black and white) and hiding places. Learn the hard choices each runaway faced, and witness the brave ingenuity of both “passengers” and “conductors.” Trek to freedom at www.nationalgeographic.com/railroad.

■ Ten years have passed since the *Exxon Valdez* bled oil into Alaska’s Prince William Sound. Read the update in this issue and offer your opinions at . . . [/ngm/9903](http://ngm/9903).



ART BY JOHN RUSSELL



■ ONLINE

Peer Into Our Camera Bag

For more than a century the Society has been a leader in the realm of photography. Point your lens at www.nationalgeographic.com/photography to tap our expertise online. The site offers useful tips, answers to frequently asked questions, and portfolios from veteran Geographic photographers such as James L. Stanfield and William Albert Allard, as well as up-and-coming artists.

■ FOR INFORMATION

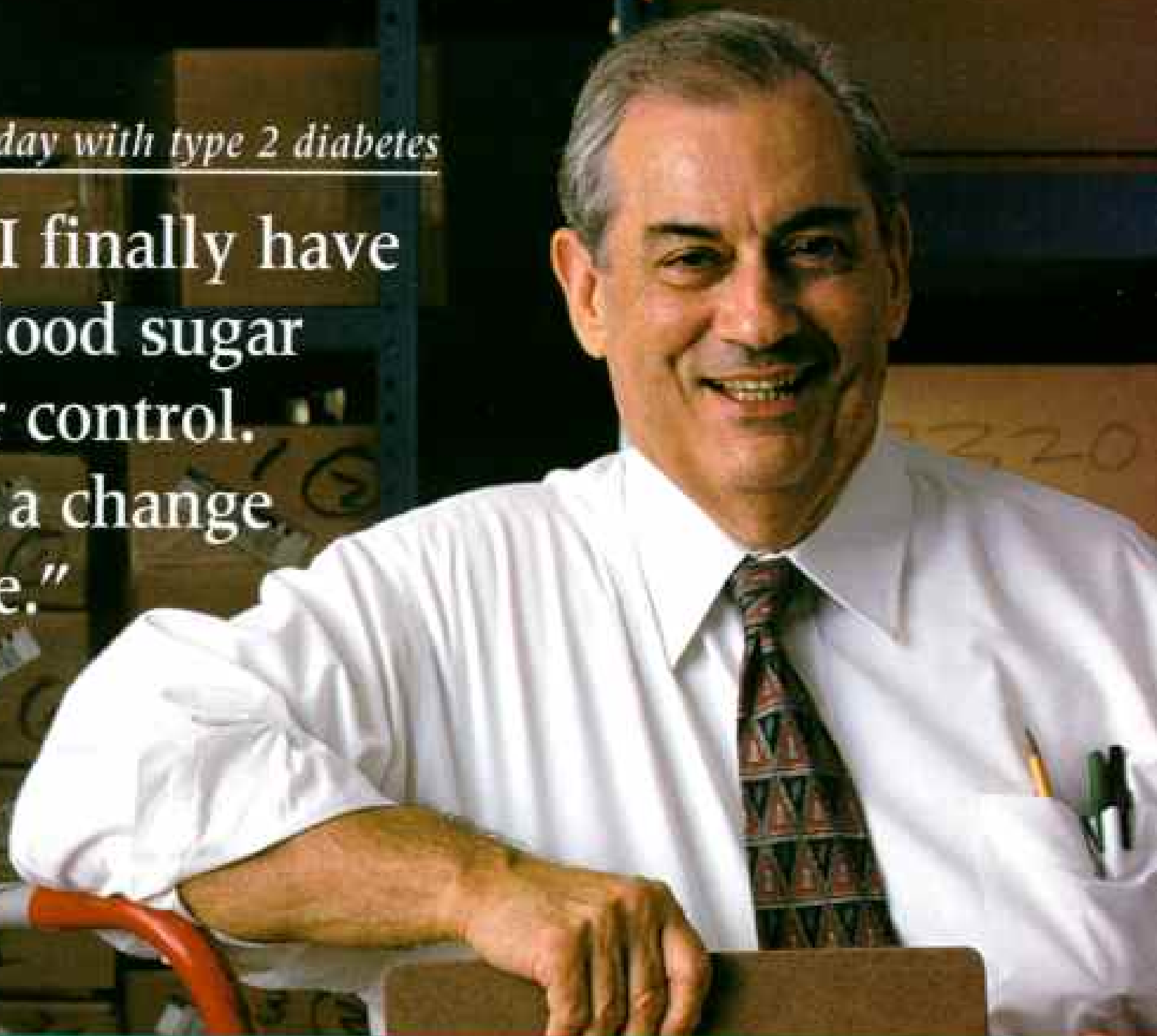
E-mail for Interactive: ngi@ngs.org

E-mail for Member Services: ngsline1@customersvc.com

CD-ROMs: In the U.S. and Canada call 1-800-881-9919; elsewhere call 1-916-939-1004.

Living today with type 2 diabetes

“Now I finally have my blood sugar under control. What a change for me.”

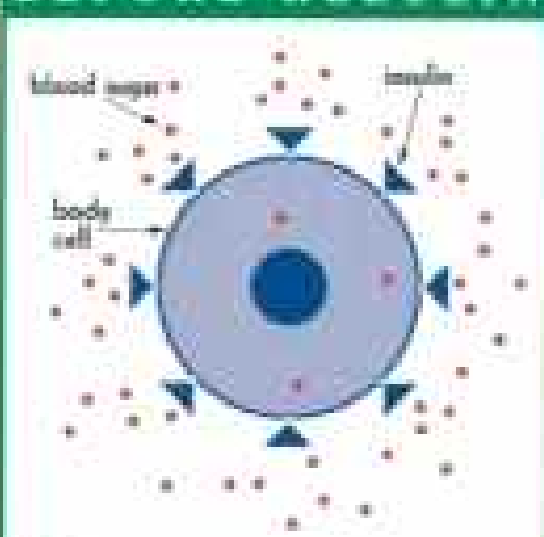


A ONCE-A-DAY PILL THAT CAN SIGNIFICANTLY IMPROVE BLOOD SUGAR CONTROL. Rezulin® (troglitazone) is the once-a-day pill for type 2 diabetes that helps your body to use its own insulin more efficiently by opening up diabetic body cells and letting blood sugar in. Rezulin can mean improved blood sugar control for many people with type 2 diabetes not well controlled with diet and exercise alone, oral pills known as sulfonylureas, or insulin.

REZULIN MAY HELP REDUCE AND PERHAPS ELIMINATE YOUR NEED FOR INSULIN INJECTIONS. With Rezulin, you may be able to decrease the amount of insulin or the number of injections you're taking. You may even be able to eliminate injections altogether.

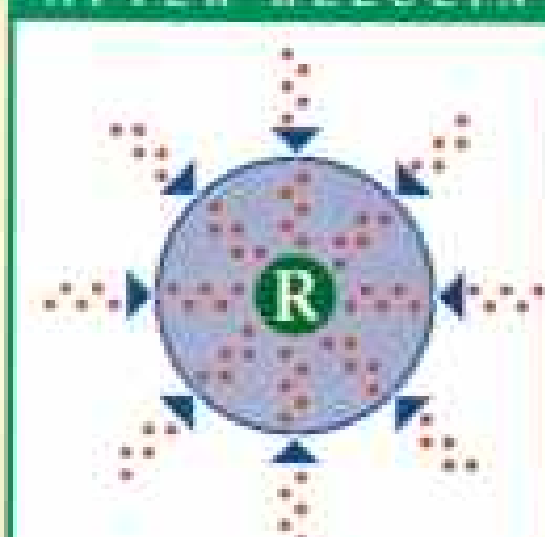
REZULIN INCREASES THE EFFECTIVENESS OF MANY ORAL MEDICATIONS. If your doctor finds that your blood sugar remains high with diabetes pills known as sulfonylureas such as Amaryl® Glucotrol XL® Glynase® PresTab® glipizide, or glyburide, Rezulin may

BEFORE REZULIN



DIABETIC BODY CELLS DON'T RESPOND EFFICIENTLY TO INSULIN AND BLEED OUT BLOOD SUGAR.

AFTER REZULIN



REZULIN WORKS WITHIN THE CELL TO HELP INSULIN LET BLOOD SUGAR IN.

improve blood sugar control when added to such diabetes pills.

ASK YOUR DOCTOR IF REZULIN IS RIGHT FOR YOU. Rezulin can provide a useful treatment option for millions of people with type 2 diabetes. Please be aware that Rezulin should not be used by patients with type 1 diabetes.

ASK YOUR DOCTOR ABOUT

ASK YOUR DOCTOR FOR MORE
NEWS ABOUT A SIGNIFICANTLY DIFFERENT
TREATMENT FOR TYPE 2 DIABETES.

ONCE-DAILY
REZULIN[®]
TROGLITAZONE



A once-a-day pill for diabetes
that helps your body use its own insulin.

Rezulin, like all the diabetes medications currently available to treat type 2 diabetes, has been associated with side effects. Although they are not usually serious, you should discuss these possibilities with your doctor. In rare cases, Rezulin has been associated with serious liver problems, which are generally reversible, but in very rare instances, these have resulted in liver failure and fatality. Your doctor can advise you about the new recommendations for regular liver monitoring with Rezulin, which will require routine blood tests. The most common side effects reported in medical studies were similar to placebo (a tablet with no medicine); they include infection (22% placebo vs. 18% Rezulin), headache (11% placebo vs. 11% Rezulin), and pain (14% placebo vs. 10% Rezulin). Talk to your doctor immediately if you have nausea, vomiting, stomach pain, fatigue, lack of appetite, dark urine, or yellowing of the skin (jaundice), as these may be signs or symptoms of a liver problem. Adhere to any dietary, exercise, or weight-loss recommendations made by your doctor, and test your blood sugar regularly. As with any

drug, tell your doctor or healthcare professional about any other medications you may be taking. If your therapy includes Rezulin and pills known as sulfonylureas, there is a chance you may incur a manageable weight gain. If you are a premenopausal woman who is not ovulating, you should know Rezulin therapy may result in resumption of ovulation, thus putting you at risk for pregnancy. You should not take Rezulin if you are pregnant unless your doctor says it is right for you.

MORE THAN 1,000,000 PEOPLE HAVE BEGUN USING REZULIN TO HELP MANAGE DIABETES.

And the number keeps growing. Your doctor or healthcare professional is the best source for finding out if Rezulin is right for you. To know more, see the important information on the adjacent page, and call:

**TOLL FREE 1-888-900-TYPE 2
FOR YOUR FREE INFORMATION KIT.**

*Amaryl is a registered trademark of Hoechst Marion Biotech; Glucotrol XL is a registered trademark of Pfizer, Inc.; Glyset and Pascale are registered trademarks of Pharmacia & Upjohn.

Please see important additional information on adjacent page.

FD-158-RJ-2301-0401/01

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THE REZULIN[®] DIFFERENCE.

ONCE-DAILY
REZULIN[®]
 TROGLITAZONE
 TABLETS

WARNINGS

Hepatic:
 Rare cases of severe idiosyncratic hepatocellular injury have been reported during marketed use (see **ADVERSE REACTIONS**). The hepatic injury is usually reversible, but very rare cases of hepatic failure, leading to death or liver transplant, have been reported. Injury has occurred after both short- and long-term troglitazone treatment. During all clinical studies in North America, a total of 49 of 2510 (1.9%) Rezulin-treated patients and 2 of 425 (0.5%) placebo-treated patients had ALT levels greater than 3 times the upper limit of normal. Twenty of the Rezulin-treated and one of the placebo-treated patients were withdrawn from treatment. Two of the 20 Rezulin-treated patients developed reversible jaundice; one of these patients had a liver biopsy which was consistent with an idiosyncratic drug reaction. An additional Rezulin-treated patient had a liver biopsy which was also consistent with an idiosyncratic drug reaction. (See **ADVERSE REACTIONS**, Laboratory Abnormalities.)
 Serum transaminase levels should be checked at the start of therapy, monthly for the first eight months of therapy, every two months for the remainder of the first year of Rezulin therapy, and periodically thereafter. Rezulin therapy should not be initiated if the patient exhibits clinical evidence of active liver disease or increased serum transaminase levels (ALT > 3 times the upper limit of normal). Liver function tests also should be obtained for patients at the first symptoms suggestive of hepatic dysfunction, eg, nausea, vomiting, abdominal pain, fatigue, anorexia, dark urine. If serum transaminase levels are moderately increased (ALT 1.5 to 2 times the upper limit of normal), liver function tests should be repeated within a week but that weekly until the levels return to normal. If at any time a patient has jaundice or ALT more than 3 times the upper limit of normal, Rezulin should be discontinued.

BRIEF SUMMARY

Consult Package Insert for full Prescribing Information.

INDICATIONS AND USAGE

Rezulin may be used concomitantly with a sulfonylurea or insulin to improve glycemic control. Rezulin, as monotherapy, is indicated as an adjunct to diet and exercise to lower blood glucose in patients with type II diabetes (see **DOSE AND ADMINISTRATION** in Package Insert for full Prescribing Information). Rezulin should not be used as monotherapy in patients previously well-controlled on sulfonylurea therapy. In patients inadequately controlled with a sulfonylurea alone, Rezulin should be added to, not substituted for, the sulfonylurea.

Management of type II diabetes should include diet control. Patient education, weight loss, and exercise are essential for the proper treatment of the diabetic patient. This is important not only in the primary treatment of type II diabetes, but in increasing the efficacy of drug therapy. Prior to initiation of Rezulin therapy, secondary causes of poor glycemic control, eg, infection or poor injection technique, should be investigated and treated.

CONTRAINDICATIONS

Rezulin is contraindicated in patients with known hypersensitivity or allergy to Rezulin or any of its components.

WARNINGS

(SEE BRIEF SUMMARY)

PRECAUTIONS

General

Exacerbation of pre-existing asthma. Rezulin is active only in the presence of insulin. Therefore, Rezulin should not be used in type I diabetes or for the treatment of diabetic keto-acidosis.

Hypoglycemia: Patients receiving Rezulin in combination with insulin or oral hypoglycemic agents may be at risk for hypoglycemia and a reduction in the dose of the concomitant agent may be necessary. Hypoglycemia has not been observed during the clinical trials of Rezulin as monotherapy and would not be expected based on the mechanism of action.

Insulin: In premenopausal amenorrheic patients with insulin resistance, Rezulin treatment may result in resumption of menses. These patients may be at risk for pregnancy.

Neutropenia: Across all clinical studies, hemoglobin declined by 2 to 4% in troglitazone-treated patients compared with 1 to 2% in those treated with placebo. While blood cell counts also declined slightly in troglitazone-treated patients compared to those treated with placebo, these changes occurred within the first four to eight weeks of therapy. Levels remained low and remained unchanged for up to two years of continuing therapy. These changes may be due to the diastolic effects of increased plasma volume and have not been associated with any significant hematologic clinical effects (see **ADVERSE REACTIONS**, Laboratory Abnormalities).

Use in Patients With Heart Failure

Heart enlargement without microscopic changes has been observed in rodents at exposures of parent compound and active metabolite exceeding 7 times the AUC of the 400 mg human dose (see **PRECAUTIONS**, Carcinogenesis, Mutagenesis, Impairment of Fertility, and Animal Toxicology). Serial echocardiographic evaluations in monkeys treated chronically at exposures of 4-8 times the human exposure to parent compound and active metabolite at the 400 mg dose did not reveal changes of heart size or function. In a 2-year active subchronic study of daily dosing 800 to 800 mg/day in dogs in patients with type II diabetes, no increase in left ventricular mass or decrease in cardiac output was observed. The methodology employed was able to detect a change of about 10% or more in left ventricular mass.

In animal studies, troglitazone treatment was associated with increases of 5% to 7% in plasma volume. In a study of 24 human volunteers, an increase in plasma volume of 5% to 6% compared to placebo was observed following 4 weeks of troglitazone treatment.

No increased incidence of adverse events potentially related to volume expansion (eg, congestive heart failure) have been observed during controlled clinical trials. However, patients with New York Heart Association (NYHA) Class III and IV cardiac status were not studied during clinical trials. Therefore, Rezulin is not indicated unless the expected benefit is believed to outweigh the potential risk to patients with NYHA Class III or IV cardiac status.

Information for Patients

Rezulin should be taken with meals. If the dose is missed at the usual meal, it may be taken at the next meal. If the dose is missed on one day, the dose should not be doubled the following day.

It is important to adhere to dietary instructions and to regularly have blood glucose and glycosylated hemoglobin tested. During periods of stress such as fever, trauma, infection, or surgery, insulin requirements may change and patients should seek the advice of their physician.

Patients who develop nausea, vomiting, abdominal pain, fatigue, anorexia, dark urine or other symptoms suggestive of hepatic dysfunction or jaundice should immediately report these signs or symptoms to their physician. Patients should be warned that blood will be drawn to check liver function at the start of therapy, monthly for the first eight months of therapy, every two months for the remainder of the first year of Rezulin therapy, and periodically thereafter.

When using combination therapy with insulin or oral hypoglycemic agents, the risk of hypoglycemia, its symptoms and treatment, and conditions that predispose to its development should be explained to patients and their family members. Use of Rezulin can cause resumption of ovulation in women taking oral contraceptives and in patients with polycystic ovary disease. Therefore, a higher dose of in vitro contraceptives or an alternative method of contraception should be considered.

Rezulin may affect other medicines used in diabetic patients. Patients started on Rezulin should ask their physician to review their other medicines to make sure that they are not affected by Rezulin.

Drug Interactions

Oral Contraceptives: Administration of Rezulin with an oral contraceptive containing ethinyl estradiol and norethindrone reduced the plasma concentrations of both by approximately 20%, which could result in loss of contraception. Therefore, a higher dose of oral contraceptive or an alternative method of contraception should be considered.

Tofenodine: Coadministration of Rezulin with tofenodine decreases the plasma concentration of both tofenodine and its active metabolite by 50-70% and may result in decreased efficacy of tofenodine.

Cholestyramine: Concomitant administration of cholestyramine with Rezulin reduces the absorption of troglitazone by 70%. Thus, coadministration of cholestyramine and Rezulin is not recommended.

Cyflamide: Coadministration of Rezulin and cyflamide does not appear to alter troglitazone or glyburide pharmacokinetics.

Digoxin: Coadministration of Rezulin with digoxin does not alter the steady-state pharmacokinetics of digoxin.

Warfarin: Rezulin has no clinically significant effect on prothrombin time when administered to patients receiving chronic warfarin therapy.

Acetaminophen: Simultaneous administration of acetaminophen and Rezulin does not alter the pharmacokinetics of either drug.

Metformin: No interaction is available on the use of Rezulin with metformin.

Alcohol: A single administration of a moderate amount of alcohol did not increase the risk of acute hypoglycemia in Rezulin-treated patients with type II diabetes mellitus.

The above interactions with tofenodine and oral contraceptives suggest that troglitazone may induce drug metabolism by CYP3A4. Studies have not been performed with other drugs metabolized by this enzyme such as astemizole, calcium channel blockers, cimetidine, carbamazepine, cyclosporine, HMG-CoA reductase inhibitors, tacrolimus, thiazolid, and trimethoprim.

The possibility of altered safety and efficacy should be considered when Rezulin is used concomitantly with these drugs. Patients stable on one or more of these agents when Rezulin is started should be closely monitored and their therapy adjusted as necessary.

Carcinogenesis, Mutagenesis, Impairment of Fertility

Troglitazone was administered daily for 104 weeks to male rats at 100, 400, or 800 mg/kg and to female rats at 25, 50, or 200 mg/kg. No tumors of any type were increased at the low and mid doses. Plasma drug exposure based on AUC of parent compound and total metabolites at the low and mid doses was up to 20-fold higher than human exposure at 400 mg daily. The highest dose in each sex exceeded the maximum tolerated dose. In a 104-week study in mice given 50, 400, or 800 mg/kg, incidence of hepatocellular carcinoma was increased in females at 400 mg/kg and in both sexes at 800 mg/kg; incidence of hepatocellular carcinoma was increased in females at 800 mg/kg. The lowest dose associated with increased tumor incidence (400 mg/kg) was associated with AUC values of parent compound and total metabolites that were at least 3-fold higher than the human exposure at 400 mg daily. No tumors of any type were increased in mice at 10 mg/kg or exposures up to 40% of that in humans at 400 mg daily based on AUC of parent compound and total metabolites.

Troglitazone was neither mutagenic in bacteria nor clastogenic in bone marrow of mice. Equimolar increases in chromosome aberrations were observed in an in vitro Chinese hamster lung cell assay. In mouse lymphoma cell gene mutation assays, results were equivocal when conducted with a microtiter technique and negative with an agar plate technique. A liver unscheduled DNA synthesis assay in rats was negative.

No adverse effects on fertility or reproduction were observed in male or female rats given 40, 200, or 1000 mg/kg daily prior to and throughout mating and gestation. AUC of parent compound at these doses was estimated to be 3- to 9-fold higher than the human exposure.

Animal Toxicology

Increased heart weights without microscopic changes were observed in mice and rats treated for up to 1 year at exposures (AUC of parent and active metabolite) exceeding 7 times the human AUC at 400 mg/kg. These heart weight increases were reversible in 2- and 13-week studies, were prevented by coadministration of an ACE inhibitor, and 14 days of troglitazone administration to rats did not affect left ventricular performance. In the thymus carcinogenecity studies, histologic changes were noted in the hearts of rats but not in mice. In control and treated rats, microscopic changes included myocardial inflammation and fibrosis and hypertrophy of atrial myocytes. The incidence of these changes in drug-treated rats was increased compared to controls at twice the AUC of the 400 mg human dose.

Pregnancy

Pregnancy Category B. Troglitazone was not teratogenic in rats given up to 2000 mg/kg or rabbits given up to 1000 mg/kg during organogenesis. Compared to human exposure of 400 mg daily, estimated exposures in rats (parent compound) and rabbits (parent compound and active metabolite) based on AUC at these doses were up to 9-fold and 2-fold higher, respectively. Early weights of fetuses and offspring of rats given 2000 mg/kg during gestation were decreased. Delayed neonatal development, attributed to decreased body weight, was observed in offspring of rats given 40, 200, or 1000 mg/kg during late gestation and lactation periods, no effects were observed in offspring of rats given 10 or 20 mg/kg. There are no adequate and well-controlled studies in pregnant women. Rezulin should not be used during pregnancy unless the potential benefit justifies the potential risk to the fetus.

Because current information strongly suggests that abnormal blood glucose levels during pregnancy are associated with a higher incidence of congenital anomalies as well as increased neonatal morbidity and mortality, most experts recommend that insulin be used during pregnancy to maintain blood glucose levels as close to normal as possible.

Nursing Mothers

It is not known whether troglitazone is secreted in human milk. Troglitazone is secreted in the milk of lactating rats. Because many drugs are secreted in human milk, Rezulin should not be administered to a breast-feeding woman.

Pediatric Use

Safety and effectiveness in pediatric patients have not been established.

Geriatric Use

Twenty-two percent of patients in clinical trials of Rezulin were 65 and over. No differences in effectiveness and safety were observed between these patients and younger patients.

ADVERSE REACTIONS

Two patients in two clinical studies developed reversible jaundice; one of these patients had a liver biopsy which was consistent with an idiosyncratic drug reaction. An additional patient had a liver biopsy which was also consistent with an idiosyncratic drug reaction. Symptoms that are associated with hepatic dysfunction or hepatitis have been reported, including nausea, vomiting, abdominal pain, fatigue, anorexia, dark urine, abnormal liver function tests (including increased ALT, AST, LDH, alkaline phosphatase). (See also **WARNINGS**.)

The overall incidence and types of adverse reactions reported in placebo-controlled clinical trials for Rezulin-treated patients and placebo-treated patients are shown in Table 1. In patients treated with Rezulin in glyburide-controlled studies (N=590) or uncontrolled studies (N=510), the safety profile of Rezulin appeared similar to that displayed in Table 1. The incidence of withdrawal during clinical trials was similar for patients treated with placebo or Rezulin (N%).

TABLE 1. North American Placebo-Controlled Clinical Studies: Adverse Events Reported at a Frequency ≥ 1% of Rezulin-Treated Patients

| | % of Patients | | | |
|-------------------|--------------------|---------------------|--------------------|---------------------|
| | Placebo N = 492 | Rezulin N = 1452 | Placebo N = 492 | Rezulin N = 1452 |
| Infection | 27 | 19 | 8 | 6 |
| Headache | 11 | 11 | 7 | 6 |
| Fatigue | 14 | 10 | 6 | 6 |
| Accidental injury | 6 | 6 | 6 | 6 |
| Arthralgia | 1 | 6 | 6 | 6 |
| Dizziness | 1 | 6 | 6 | 6 |
| Dark Urine | 1 | 6 | 6 | 6 |

Types of adverse events seen when Rezulin was used concomitantly with insulin (N=402) were similar to those during Rezulin monotherapy (N=1721), although hypoglycemia occurred on insulin combination therapy (see **PRECAUTIONS**).

Laboratory Abnormalities

Neutropenia: Small decreases in hemoglobin, hematocrit, and neutrophil counts (within the normal range) were more common in Rezulin-treated than placebo-treated patients and may be related to increased plasma volume observed with Rezulin treatment. Hemoglobin decreases to below the normal range occurred in 6% of Rezulin-treated and 4% of placebo-treated patients.

Lipids: Small changes in serum lipids have been observed (see **CLINICAL PHARMACOLOGY: Pharmacokinetics and Clinical Effects** in Package Insert for full Prescribing Information).

Serum Transaminase Levels: During all clinical studies in North America, a total of 49 of 2510 (1.9%) Rezulin-treated patients and 2 of 425 (0.5%) placebo-treated patients had ALT levels greater than 3 times the upper limit of normal. During controlled clinical trials, 3.2% of Rezulin-treated patients had reversible jaundice or ALT or AST greater than 3 times the upper limit of normal, compared with 0.8% of patients receiving placebo. Hypertrochloremia (>1.25 upper limit of normal) was found in 1.7% of Rezulin-treated patients compared with 1.7% of patients receiving placebo. If the population of patients treated with Rezulin, mean and median values for bilirubin, AST, ALT, alkaline phosphatase, and GGT were decreased at the final visit compared with baseline, while values for LDH were increased slightly (see **WARNINGS**).

Postmarketing Reports

Adverse events associated with Rezulin that have been reported since market introduction, that are not listed above, and for which causal relationship to drug has not been established include the following: congestive heart failure, weight gain, edema, liver, abnormal lab tests including increased CPK and creatinine, hyperphosphatemia, syncope, anemia, malaise.

As only

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July 1996

Manufactured by
Parke-Davis Pharmaceuticals, Ltd.
 Kings Road, PC 08094
 Distributed by
PARKE-DAVIS
 Division of Warner-Lambert Co.
 Morris Plains, NJ 07956 USA

Marketed by
PARKE-DAVIS
 Division of Warner-Lambert Co. and
SANKYO PARKE-DAVIS
 Parsippany, NJ 07654 USA

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On Assignment



GEORGE STEINMETZ

■ HEART OF THE SAHARA Caravan Man

Crossing the Sahara is dangerous business. "People die all the time," says writer Donovan Webster (above, with Tuareg tribesmen in Niger). "That's why you go with someone you trust."

Don figured a little technology wouldn't hurt though. "When I mentioned to my guide that I had a GPS [global positioning system] receiver to help us navigate, he said he didn't need it," says Don. "'I've got TPS,' he told me—Tuareg positioning system. And he did! He could find his way anywhere just by seeing ripples in the sand."

"They were as interested in my world as I was in theirs," Don recalls. "When I showed them a photo of my kids at Niagara Falls, they wanted to keep it. They thought the kids were cute—but they couldn't imagine that much water in the world."

■ SNAPPING TURTLES Caught Snapping

"I was an underwater cowboy!" says photographic assistant Jesús López (below), whose turtle herding for shooter George Grall went swimmingly. Jesús, a photographer himself, is an old

hand at helping our staff. A former government social worker in Mexico, Jesús got a job assisting photographer David Alan Harvey with a GEOGRAPHIC story in 1988. "I found out I love photography," he says. "I've worked on stories for the magazine every year since then."



GEORGE GRALL

NATIONAL GEOGRAPHIC

Geoguide



Camel Caravan Across the Sahara

■ Author Donovan Webster and photographer George Steinmetz found a landscape of splendid simplicity in Niger: limitless stretches of sand extending to the horizon. That arid environment is as treacherous to humans as any on Earth. What are the many challenges to safety faced by those who live or travel in this region? If you were going on a desert trek, what would be the most important thing to take with you? What advantages do camel drivers have over those who cross the Sahara in trucks?

■ Which compass direction was George Steinmetz facing when he photographed the camel caravans on pages 2-4? You can find clues in the caption, the article, and the map on pages 12-13.

■ In 1996 less than a sixteenth of an inch of rain fell in Bilma,

Niger. How does that compare with rainfall in a city near you? Check the Web or an almanac for local statistics.

■ Many towns and villages in Chad have no radios or televisions. When they are introduced, in what ways will they affect people's lives?

At dawn a young Tuareg boy holds the leader of a 500-camel caravan before another day's trek across the Sahara. Along with freight the camels must carry all their own food. A Tuareg woman (below) vies with a suckling kid for goat's milk, used to make cheese.



BOTH BY GEORGE STEINMETZ

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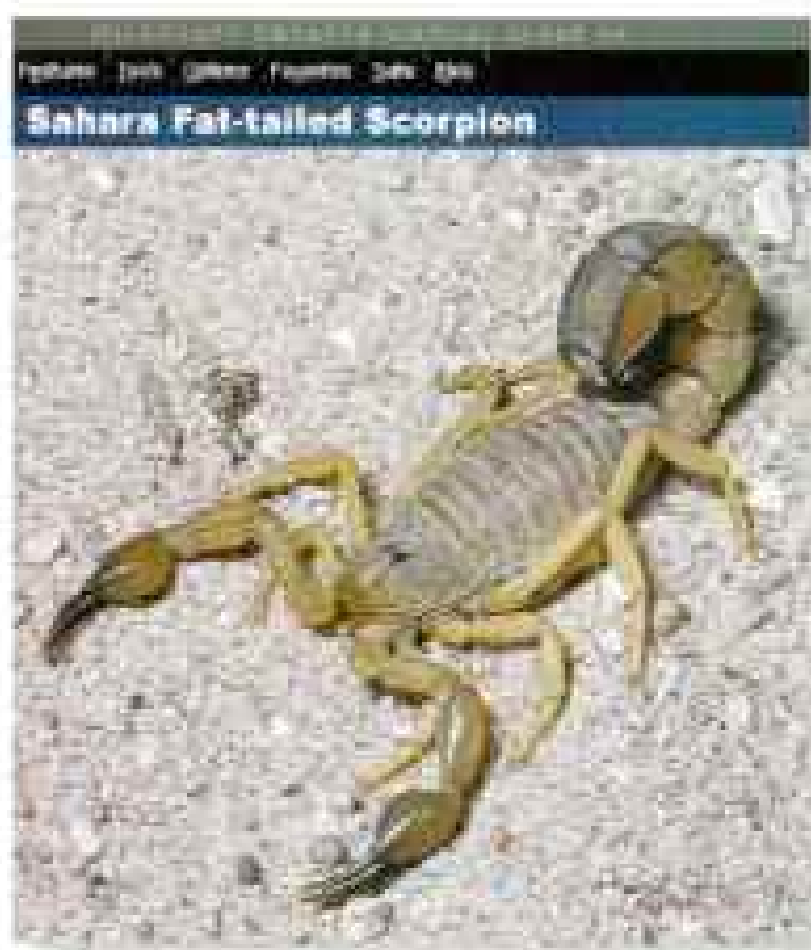
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- Sahara Occidental (disputed)
- Sahara El Gharbiya [Libyan I.
- Sahara el Sharqiya [Arabian
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