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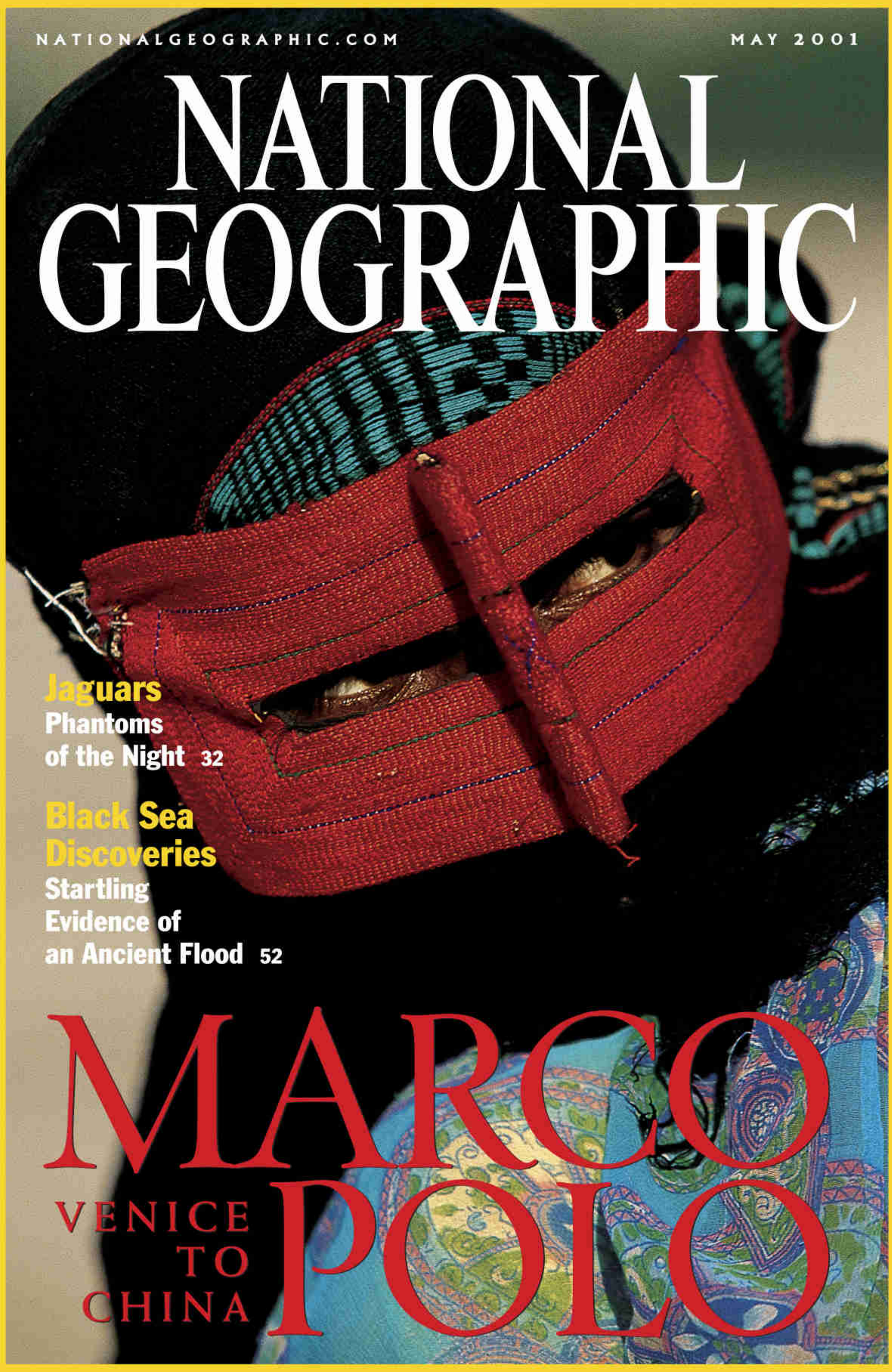

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MARCO POLO
VENICE TO CHINA

BEN AFFLECK

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MAY 25

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THE COVER
An 18-year-old Muslim woman wears a traditional mask in Minab, Iran, a place Marco Polo knew as Hormuz.
PHOTOGRAPH BY MICHAEL YAMASHITA

MORE INFORMATION

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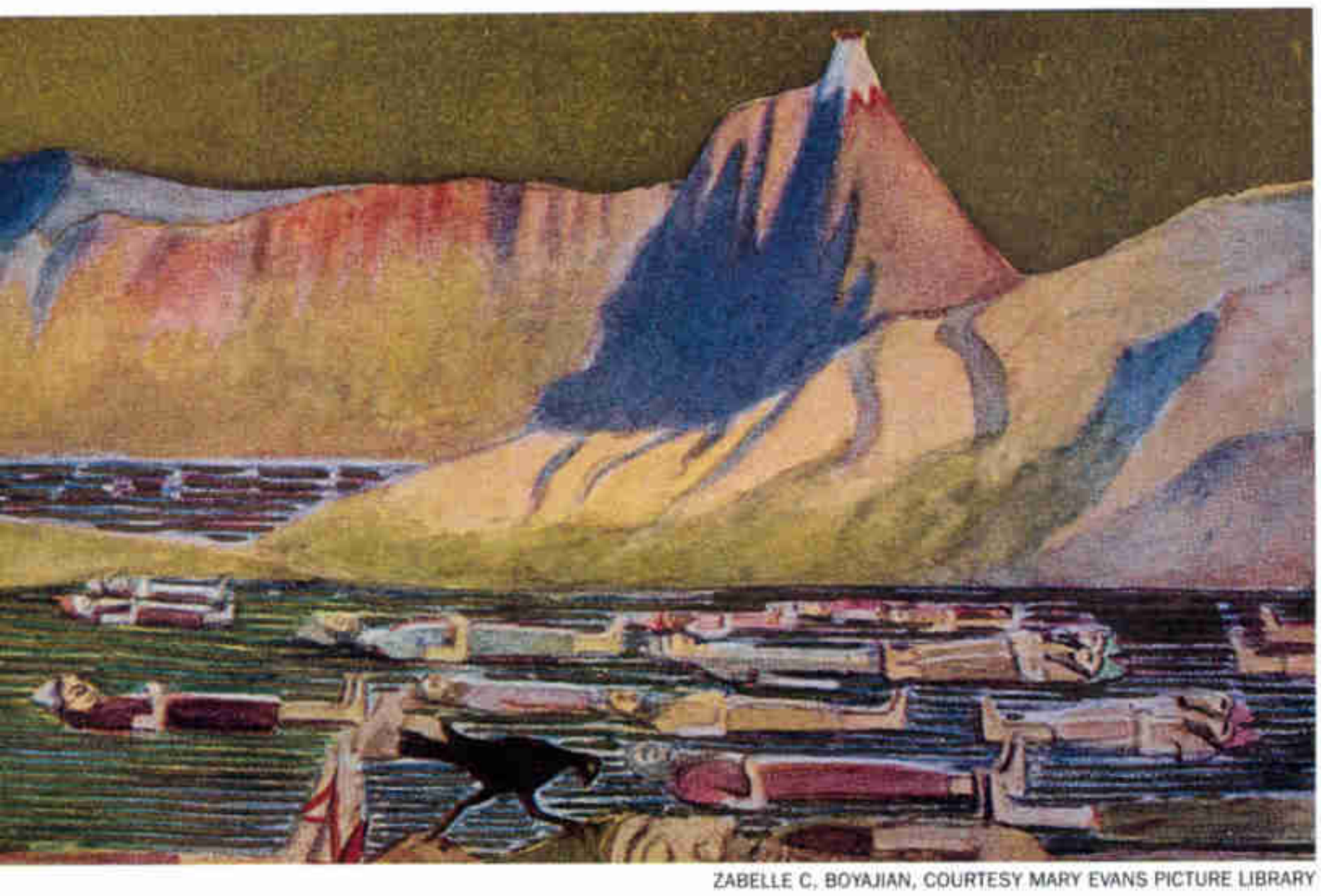
From the Editor



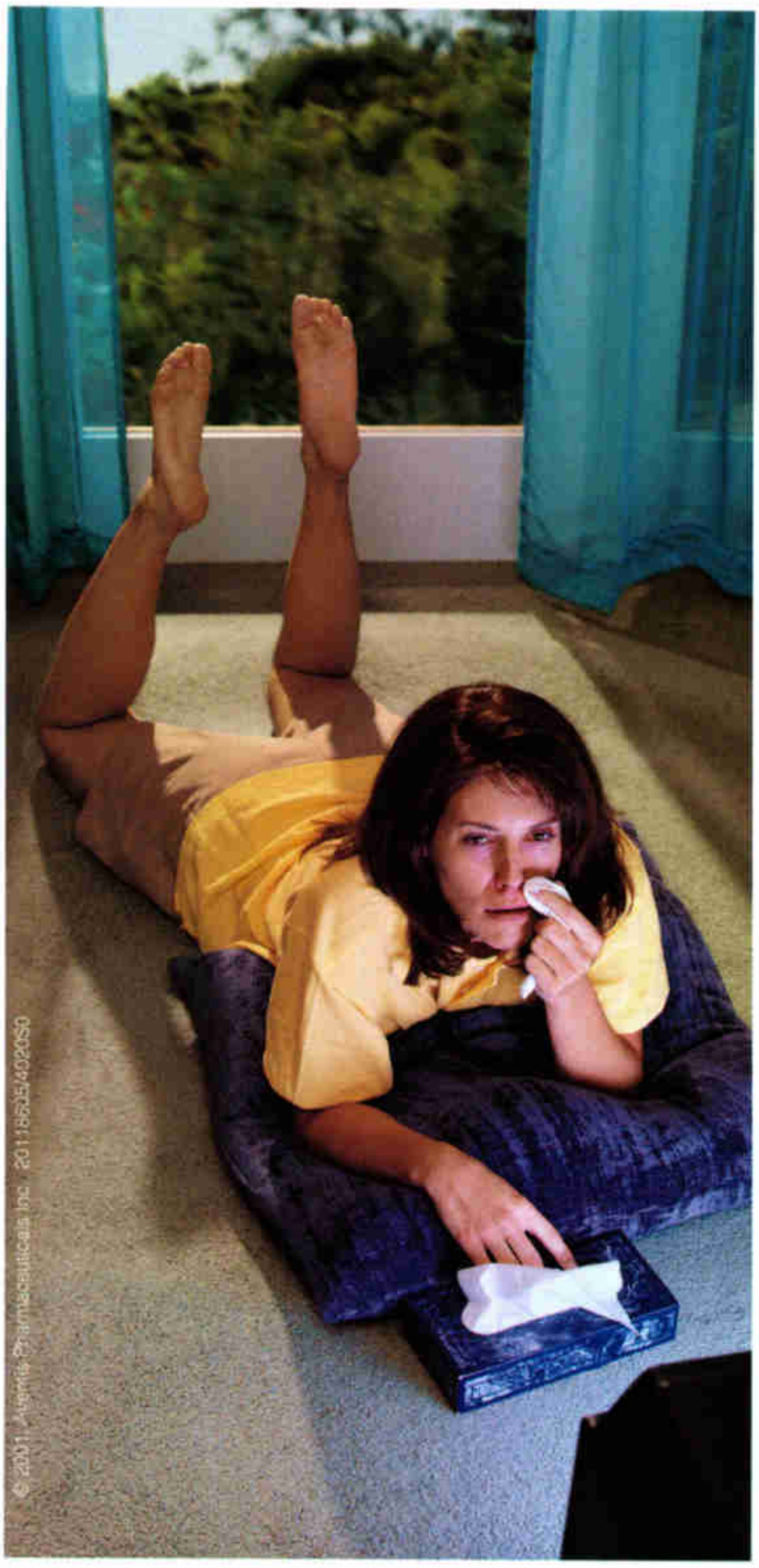
ZABELLE C. BOYAJIAN, COURTESY MARY EVANS PICTURE LIBRARY

In the beginning—or shortly thereafter—man created myths. In every culture throughout recorded history, human beings have woven powerful tales to help explain the inexplicable. Creation itself is perhaps the most universal theme of this common heritage, but second place likely goes to accounts of devastating floods. From Aztecs to Zoroastrians, in desert tents and Arctic ice houses, peoples the world over have told and retold stories of inundation.

In our article this month on the Black Sea, Explorer-in-Residence Robert Ballard discovers an ancient shoreline on the sea bottom that holds evidence of human habitation from a time before the Mediterranean breached the Bosporus around 7,500 years ago—rushing in, some geologists believe, with the force of 200 Niagara Falls. Could the account of that cataclysm have been passed down for 4,000 years to inspire the Sumerian epic of Gilgamesh and the oldest known flood myth (painting, above)? That tale in turn may have given rise to the Old Testament story of Noah and the Great Flood, though the majestic words of Genesis were penned no earlier than 1000 B.C.

Scientists and historians debate such connections. There is no debate, however, that mythic images are among our most enduring. In the seemingly endless torrent of suffering and catastrophe around the globe, we long at last to glimpse the dove of hope, returning with an olive branch.

Bill Allen



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Brief Summary of Prescribing Information as of February 2000

ALLEGRA®
(fexofenadine hydrochloride)
Capsules and Tablets

INDICATIONS AND USAGE

Seasonal Allergic Rhinitis

ALLEGRA is indicated for the relief of symptoms associated with seasonal allergic rhinitis in adults and children 6 years of age and older. Symptoms treated effectively were sneezing, rhinorrhea, itchy nose/palate/throat, itchy/watery/red eyes.

Chronic Idiopathic Urticaria

ALLEGRA is indicated for treatment of uncomplicated skin manifestations of chronic idiopathic urticaria in adults and children 6 years of age and older. It significantly reduces pruritus and the number of wheals.

CONTRAINDICATIONS

ALLEGRA is contraindicated in patients with known hypersensitivity to any of its ingredients.

PRECAUTIONS

Drug Interaction with Erythromycin and Ketoconazole

Fexofenadine hydrochloride has been shown to exhibit minimal (ca. 5%) metabolism. However, co-administration of fexofenadine hydrochloride with ketoconazole and erythromycin led to increased plasma levels of fexofenadine hydrochloride. Fexofenadine hydrochloride had no effect on the pharmacokinetics of erythromycin and ketoconazole. In two separate studies, fexofenadine hydrochloride 120 mg twice daily (two times the recommended twice daily dose) was co-administered with erythromycin 500 mg every 8 hours or ketoconazole 400 mg once daily under steady-state conditions to normal, healthy volunteers (n=24, each study). No differences in adverse events or QT_C interval were observed when patients were administered fexofenadine hydrochloride alone or in combination with erythromycin or ketoconazole. The findings of these studies are summarized in the following table:

Effects on steady-state fexofenadine hydrochloride pharmacokinetics after 7 days of co-administration with fexofenadine hydrochloride 120 mg every 12 hours (two times the recommended twice daily dose) in normal volunteers (n=24)

Concomitant Drug	*C_{maxSS} (Peak plasma concentration)*	*$AUC_{ss(0\text{-}12h)}$ (Extent of systemic exposure)*
Erythromycin (500 mg every 8 hrs)	+82%	+109%
Ketoconazole (400 mg once daily)	+135%	+164%

The changes in plasma levels were within the range of plasma levels achieved in adequate and well-controlled clinical trials.

The mechanism of these interactions has been evaluated in *in vitro*, *in situ*, and *in vivo* animal models. These studies indicate that ketoconazole or erythromycin co-administration enhances fexofenadine gastrointestinal absorption. *In vivo* animal studies also suggest that in addition to increasing absorption, ketoconazole decreases fexofenadine hydrochloride gastrointestinal secretion, while erythromycin may also decrease biliary excretion.

Drug Interactions with Antacids

Administration of 120 mg of fexofenadine hydrochloride (2 x 60 mg capsule) within 15 minutes of an aluminum and magnesium containing antacid (Maalox®) decreased fexofenadine AUC by 41% and C_{max} by 43%. ALLEGRA should not be taken closely in time with aluminum and magnesium containing antacids.

Carcinogenesis, Mutagenesis, Impairment of Fertility

The carcinogenic potential and reproductive toxicity of fexofenadine hydrochloride were assessed using terfenadine studies with adequate fexofenadine hydrochloride exposure (based on plasma area-under-the-concentration vs. time [AUC] values). No evidence of carcinogenicity was observed in an 18-month study in mice and in a 24-month study in rats at oral doses up to 150 mg/kg of terfenadine (which led to fexofenadine exposures that were respectively approximately 3 and 5 times the exposure from the maximum recommended daily oral dose of fexofenadine hydrochloride in adults and children).

In *in vitro* (Bacterial Reverse Mutation, CHO/HGPRT Forward Mutation, and Rat Lymphocyte Chromosomal Aberration assays) and *in vivo* (Mouse Bone Marrow Micronucleus assay) tests, fexofenadine hydrochloride revealed no evidence of mutagenicity.

In rat fertility studies, dose-related reductions in implants and increases in postimplantation losses were observed at an oral dose of 150 mg/kg of terfenadine (which led to fexofenadine hydrochloride exposures that were approximately 3 times the exposure of the maximum recommended daily oral dose of fexofenadine hydrochloride in adults).

Pregnancy

Teratogenic Effects: Category C. There was no evidence of teratogenicity in rats or rabbits at oral doses of terfenadine up to 300 mg/kg (which led to fexofenadine exposures that were approximately 4 and 31 times, respectively, the exposure from the maximum recommended daily oral dose of fexofenadine in adults).

There are no adequate and well controlled studies in pregnant women. Fexofenadine should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

Nonteratogenic Effects. Dose-related decreases in pup weight gain and survival were observed in rats exposed to an oral dose of 150 mg/kg of terfenadine (approximately 3 times the maximum recommended daily oral dose of fexofenadine hydrochloride in adults based on comparison of fexofenadine hydrochloride AUCs).

Nursing Mothers

There are no adequate and well-controlled studies in women during lactation. Because many drugs are excreted in human milk, caution should be exercised when fexofenadine hydrochloride is administered to a nursing woman.

Pediatric Use

The recommended dose in patients 6 to 11 years of age is based on cross-study comparison of the pharmacokinetics of ALLEGRA in adults and pediatric patients and on the safety profile of fexofenadine hydrochloride in both adult and pediatric patients at doses equal to or higher than the recommended doses.

The safety of ALLEGRA tablets at a dose of 30 mg twice daily has been demonstrated in 438 pediatric patients 6 to 11 years of age in two placebo-controlled 2-week seasonal allergic rhinitis trials. The safety of ALLEGRA for the treatment of chronic idiopathic urticaria in patients 6 to 11 years of age is based on cross-study comparison of the pharmacokinetics of ALLEGRA in adult and pediatric patients and on the safety profile of fexofenadine in both adult and pediatric patients at doses equal to or higher than the recommended dose.

The effectiveness of ALLEGRA for the treatment of seasonal allergic rhinitis in patients 6 to 11 years of age was demonstrated in one trial (n=411) in which ALLEGRA tablets 30 mg twice daily significantly reduced total symptom scores compared to placebo, along with extrapolation of demonstrated efficacy in patients ages 12 years and above, and the pharmacokinetic comparisons in adults and children. The effectiveness of ALLEGRA for the treatment of chronic idiopathic urticaria in patients 6 to 11 years of age is based on an extrapolation of the demonstrated efficacy of ALLEGRA in adults with this condition and the likelihood that the disease course, pathophysiology and the drug's effect are substantially similar in children to that of adult patients.

The safety and effectiveness of ALLEGRA in pediatric patients under 6 years of age have not been established.

Geriatric Use

Clinical studies of ALLEGRA tablets and capsules did not include sufficient numbers of subjects aged 65 years and over to determine whether this population responds differently from younger patients. Other reported clinical experience has not identified differences in responses between the geriatric and younger patients. This drug is known to be substantially excreted by the kidney, and the risk of toxic reactions to this drug may be greater in patients with impaired renal function. Because elderly patients are more likely to have decreased renal function, care should be taken in dose selection, and may be useful to monitor renal function. (See CLINICAL PHARMACOLOGY).

ADVERSE REACTIONS

Seasonal Allergic Rhinitis

Adults. In placebo-controlled seasonal allergic rhinitis clinical trials in patients 12 years of age and older, which included 2461 patients receiving fexofenadine hydrochloride capsules at doses of 20 mg to 240 mg twice daily, adverse events were similar in fexofenadine hydrochloride and placebo-treated patients. All adverse events that were reported by greater than 1% of patients who received the recommended daily dose of fexofenadine hydrochloride (60 mg capsules twice daily), and that were more common with fexofenadine hydrochloride than placebo, are listed in Table 1.

In a placebo-controlled clinical study in the United States, which included 570 patients aged 12 years and older receiving fexofenadine hydrochloride tablets at doses of 120 or 180 mg once daily, adverse events were similar in fexofenadine hydrochloride and placebo-treated patients. Table 1 also lists adverse experiences that were reported by greater than 2% of patients treated with fexofenadine hydrochloride tablets at doses of 180 mg once daily and that were more common with fexofenadine hydrochloride than placebo.

The incidence of adverse events, including drowsiness, was not dose-related and was similar across subgroups defined by age, gender, and race.

Table 1

Adverse experiences in patients ages 12 years and older reported in placebo-controlled seasonal allergic rhinitis clinical trials in the United States

Twice daily dosing with fexofenadine capsules at rates of greater than 1%

Adverse experience	*Fexofenadine 60 mg Twice Daily (n=679)*	*Placebo Twice Daily (n=671)*
Viral Infection (cold, flu)	2.5%	1.5%
Nausea	1.6%	1.5%
Dysmenorrhea	1.5%	0.3%
Drowsiness	1.3%	0.9%
Dyspepsia	1.3%	0.6%
Fatigue	1.3%	0.9%

Once daily dosing with fexofenadine hydrochloride tablets at rates of greater than 2%

Adverse experience	*Fexofenadine 180 mg once daily (n=283)*	*Placebo (n=293)*
Headache	10.6%	7.5%
Upper Respiratory Tract Infection	3.2%	3.1%
Back Pain	2.8%	1.4%

The frequency and magnitude of laboratory abnormalities were similar in fexofenadine hydrochloride and placebo-treated patients.

Pediatric. Table 2 lists adverse experiences in patients aged 6 to 11 years of age which were reported by greater than 2% of patients treated with fexofenadine hydrochloride tablets at a dose of 30 mg twice daily in placebo-controlled seasonal allergic rhinitis studies in the United States and Canada that were more common with fexofenadine hydrochloride than placebo.

Table 2

Adverse experiences reported in placebo-controlled seasonal allergic rhinitis studies in pediatric patients ages 6 to 11 in the United States and Canada at rates of greater than 2%

Adverse experience	*Fexofenadine 30 mg twice daily (n=209)*	*Placebo (n=229)*
Headache	7.2%	6.6%
Accidental Injury	2.9%	1.3%
Coughing	3.8%	1.3%
Fever	2.4%	0.9%
Pain	2.4%	0.4%
Otitis Media	2.4%	0.0%
Upper Respiratory Tract Infection	4.3%	1.7%

Chronic Idiopathic Urticaria

Adverse events reported by patients 12 years of age and older in placebo-controlled chronic idiopathic urticaria studies were similar to those reported in placebo-controlled seasonal allergic rhinitis studies. In placebo-controlled chronic idiopathic urticaria clinical trials, which included 726 patients 12 years of age and older receiving fexofenadine hydrochloride tablets at doses of 20 to 240 mg twice daily, adverse events were similar in fexofenadine hydrochloride and placebo-treated patients. Table 3 lists adverse experiences in patients aged 12 years and older which were reported by greater than 2% of patients treated with fexofenadine hydrochloride 60 mg tablets twice daily in controlled clinical studies in the United States and Canada and that were more common with fexofenadine hydrochloride than placebo. The safety of fexofenadine hydrochloride in the treatment of chronic idiopathic urticaria in pediatric patients 6 to 11 years of age is based on the safety profile of fexofenadine hydrochloride in adults and adolescent patients at doses equal to or higher than the recommended dose (see Pediatric Use).

Table 3

Adverse experiences reported in patients 12 years and older in placebo-controlled chronic idiopathic urticaria studies in the United States and Canada at rates of greater than 2%

Adverse experience	*Fexofenadine 60 mg twice daily (n=186)*	*Placebo (n=178)*
Back Pain	2.2%	1.1%
Sinusitis	2.2%	1.1%
Dizziness	2.2%	0.6%
Drowsiness	2.2%	0.0%

OVERDOSAGE

Reports of fexofenadine hydrochloride overdose have been infrequent and contain limited information. However, dizziness, drowsiness, and dry mouth have been reported. Single doses of fexofenadine hydrochloride up to 800 mg (six normal volunteers at this dose level), and doses up to 690 mg twice daily for 1 month (three normal volunteers at this dose level) or 240 mg once daily for 1 year (234 normal volunteers at this dose level) were administered without the development of clinically significant adverse events as compared to placebo.

In the event of overdose, consider standard measures to remove any unabsorbed drug. Symptomatic and supportive treatment is recommended.

Hemodialysis did not effectively remove fexofenadine hydrochloride from blood (1.7% removed) following terfenadine administration.

No deaths occurred at oral doses of fexofenadine hydrochloride up to 5000 mg/kg in mice (110 times the maximum recommended daily oral dose in adults and 200 times the maximum recommended daily oral dose in children based on mg/m^2) and up to 5000 mg/kg in rats (230 times the maximum recommended daily oral dose in adults and 400 times the maximum recommended daily oral dose in children based on mg/m^2). Additionally, no clinical signs of toxicity or gross pathological findings were observed. In dogs, no evidence of toxicity was observed at oral doses up to 2000 mg/kg (300 times the maximum recommended daily oral dose in adults and 530 times the maximum recommended daily oral dose in children based on mg/m^2).

Prescribing Information as of February 2000

Aventis Pharmaceuticals Inc.
(formerly Hoechst Marion Roussel, Inc.)
Kansas City, MO 64137 USA

US Patents 4,254,129; 5,375,693; 5,578,610

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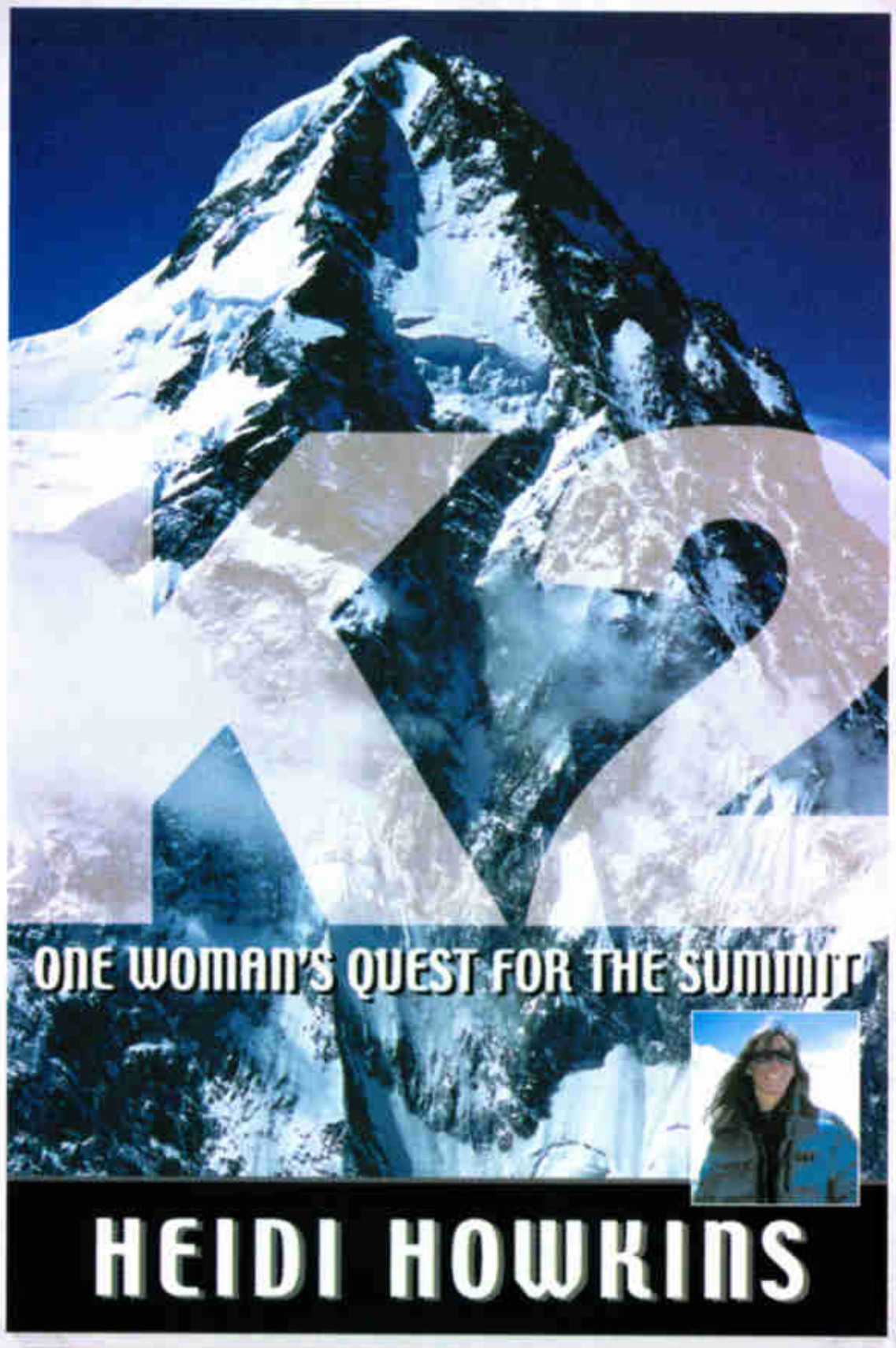

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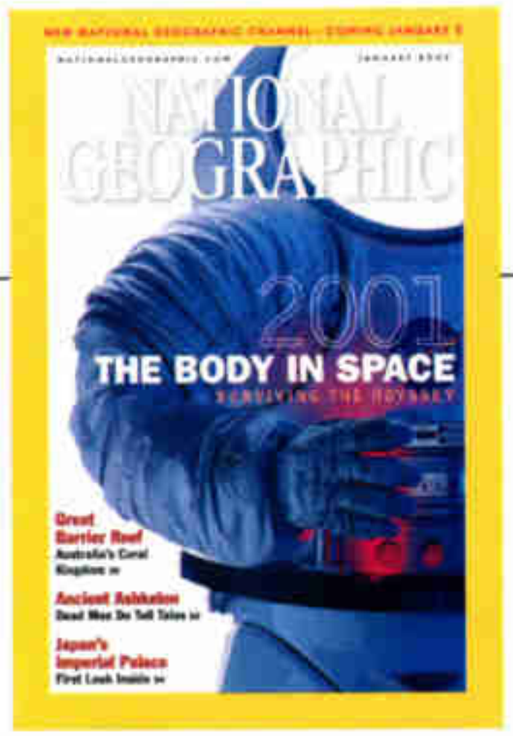

January 2001

The prospect of blasting off to Mars stirred the imagination of readers of the January issue, but they placed varying value on a manned mission to the unexplored planet. One described our article as "glorifying man's egotistical and expensive quest . . . when so much is still wrong in our own backyards." Another stated that "we can and must grasp the frontier. We must stop studying and start doing."

Ancient Ashkelon

I was a student volunteer with the Leon Levy Expedition during the summer of 1986, the second year of the dig, in the area where the now famous dog cemetery was discovered. I was able to excavate 42 of the dog skeletons myself and became known to the Israeli workers as the "dog doctor." I have very much enjoyed following the story of my "patients." I also worked in grid 50, shown on page 79. Being the smallest of the party, I was sent down into the well, which was very cramped and dusty. I much preferred dog duty.

JILL BRICKEY WILSON
Chesterton, Indiana

I'm compelled to point out a minor inaccuracy in your excellent article on Ashkelon: "excavations at Ashkelon and other Philistine sites have turned up evidence that they were . . . distillers of fine wine." Certainly it is nitpicking to point out that wine is merely fermented grape juice. When wine is distilled, it yields brandy—a trade item the Philistines might have appreciated.

JIM WALTER
Healdsburg, California

Rick Gore states that Ashkelon is a forgotten name outside Israel. But the following passage is familiar to readers of the Old Testament: "How are the mighty fallen! Tell it not in Gath, publish it not in the streets of Askelon; lest the daughters of the Philistines rejoice, lest the daughters of the uncircumcised triumph" (II Samuel 1:19-20). This is part of David's lamentation over the deaths of King Saul and his son Jonathan. Let me hasten to add that the above quote contained my entire knowledge of Ashkelon before reading Mr. Gore's fascinating article.

WALTER DUNN TUCKER
Richmond, Virginia

Beyond Gravity

I disagree with the author's opinion that it is an egocentric view to believe that "*H. sapiens* is the single intelligent life-form the cosmos has produced in billions of years on trillions of worlds." Our current knowledge indicates that it is highly unlikely that life, let alone intelligent life, exists on any other planet in the cosmos and that Earth is a remarkable exception. Future encounters with nonterrestrial life might show us other remarkable exceptions in the universe. But in 2001, believing that humans are the only intelligent

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WEDNESDAY: *Presentation*

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Japan's Imperial Palace

On a recent trip to Tokyo I took in the view from the 45th floor of the TMA building. Later, walking the grounds of the Imperial Palace, I could imagine the clash of swords and the footsteps of samurai on the gravel pathways. In one day I had seen an entire history unfold before my eyes.

MICHAEL A. FAMIANO
Columbus, Ohio

SAM ABELL, NGS

In the fall of 1987 Crown Prince Akihito and Princess Michiko visited the old North Bridge in Concord, Massachusetts, site of the first organized resistance to Great Britain. At the time I was captain of the Concord Minutemen. We marched, performed our manual of arms, and fired our reproduction muskets, most of which were made in Japan. The royal couple were very pleased.

ROBERT O. BOWEN
Concord, Massachusetts

Kudos on the excellent article on Japan, but I did note one error. Technically, Imperial Household Law specifies a successor to Crown Prince Naruhito in default of a direct heir. In this event the succession passes to Prince Akishino, the Emperor's younger son; Prince Hitachi, the Emperor's brother; Prince Mikasa, the Emperor's uncle; and then Prince Mikasa's three sons, Princes Tomohito, Katsura, and Takamado.

JEFFREY W. TALIAFERRO
Boston, Massachusetts

While there are indeed successors to Crown Prince Naruhito, the Japanese prefer a direct heir rather than a brother or cousin. So there is still concern that Naruhito have a son.

beings is the most reasonable stand for a scientific mind.

DOMINIQUE GRELET
Bedford, Maine

Sir Arthur Clarke dreams about manned voyages to another planet, but the 21st century will bring to Earth enormous problems. Overpopulation, pollution, and overuse of natural resources may bring the civilization that we knew in the 20th century to the edge of collapse. Manned voyages to planets like Mars or the moons of Saturn and Jupiter will stay a dream.

JANEZ MIHOVEC
Medvode, Slovenia

Surviving in Space

It was good to see an article on space; however, I must take issue with the nay-saying tone of it. Yes, human space travel holds biological and physiological challenges that should not be taken lightly, but to assert on the Editor's page that "we are fragile spacefarers at best" and that we have a slim chance of colonizing other worlds anytime soon is a disservice to the imperative of space exploration. What if the Portuguese had refused to send parties around Africa until it was guaranteed the risks were nil? If we wait to conquer space until every last issue is fully addressed, we will never make the trip and we will stagnate as a species, just as countless societies have throughout history as they turned themselves inward.

ERICH M. FISCHER
Cincinnati, Ohio

I'm truly impressed with the articles on space. However, I can't help but think what could be done in this world we live in if a fraction (or all) of the money being spent on this effort was used to alleviate hunger and homelessness, let alone poor education and disease.

SAMUEL N. McCAIN
Peaks Island, Maine

As a former space shuttle astronaut I would like to comment on a mission to Mars. Human sexuality and the myriad emotions connected with it will be very significant in any long-duration mission. I don't know anybody who can check their libido at the launch pad for a nearly three-year flight. So do you send married couples? They almost certainly will have to be childless. Would singles be better? For certain, reversible sterilization will be required for all crew members. There can be no chance of pregnancy. I suspect

WRITE TO FORUM

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wisdom teeth and appendixes will also be prophylactically removed from all crew members. In the end it won't be the spacecrafts operating at their limits on the trip. It will be their human occupants.

COL. R. MIKE MULLANE
U.S. Air Force, Retired
Albuquerque, New Mexico

Not only do humans belong in space, but it is our ultimate destiny to live among the stars if we are to survive indefinitely as a species. Eons from now our nourishing star, the sun, will begin to die as it exhausts its nuclear fuel. It will swell to a red giant, leaving everything in its path burned to a crisp, including our planet Earth. I would hope that long before this catastrophe happens, mankind will discover the technologies that will allow us to colonize other planets among the stars. Our ultimate survival depends upon one day leaving the solar system that bore us and nurtured us for millennia.

GLENN A. COOPERMAN
Atascadero, California

On page 10 you wrote about a platform used with animals to increase their bone density. If this could be used with astronauts, it could certainly be used with patients suffering from osteoporosis. Is there anything similar somewhere that is used for osteoporosis treatment experiments?

DIANE LIZOTTE
Dieppe, New Brunswick

Use of the platform to treat bone loss in humans is still several years—and a full clinical study—away, says Clinton Rubin of the State University of New York at Stony Brook, but early results are promising. For information on current treatments contact the National Osteoporosis Foundation (www.nof.org).

On page 15 you presented a graph on bone loss. Why is bone density presented in units of grams per square centimeter instead of grams per cubic centimeter?

DICK NOEL
Murrieta, California

Scanners measuring g/cm^2 are the most widely used for clinical purposes. They are smaller, easier to operate, and expose patients to less radiation than those using g/cm^3.

NATIONAL GEOGRAPHIC

earthpulse

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ZipUSA: Quartzsite, AZ

I was appalled at Irma Ruth's protests in this article about being charged $100 to have an RV on Bureau of Land Management property for seven months. That comes out to less than 50 cents a day. BLM management should be charging the going rate for RV's, which is $10 to $15 a day. I don't want my tax dollars going to subsidize this abuse of our public land.

DEBBIE ORTMAN
Hermantown, Minnesota

EarthPulse

As a longtime fisherman, I appreciated the focus of your January EarthPulse column, "Conserving the Sea." I was, however, surprised at two omissions. The first is that in 1998 the Canadian government ended the harvest of coho salmon by all fishermen on our country's west coast. The second is that our government had ended the huge and historic cod fishery in Atlantic Canada several years earlier. In both cases the cause was a combination of excessive harvest levels in the past and plummeting marine survival caused by natural phenomena like El Niño. Unprecedented socioeconomic consequences have been borne by coastal communities in an attempt to reverse these declines.

JEREMY MAYNARD
Campbell River, British Columbia

You hit the spot with EarthPulse. Let's take care of our small planet so when we do go to the stars, we will have enough wisdom not to continue the devastation elsewhere.

GERARDO MARTINEZ CASAS
San Miguel de Cozumel, Mexico

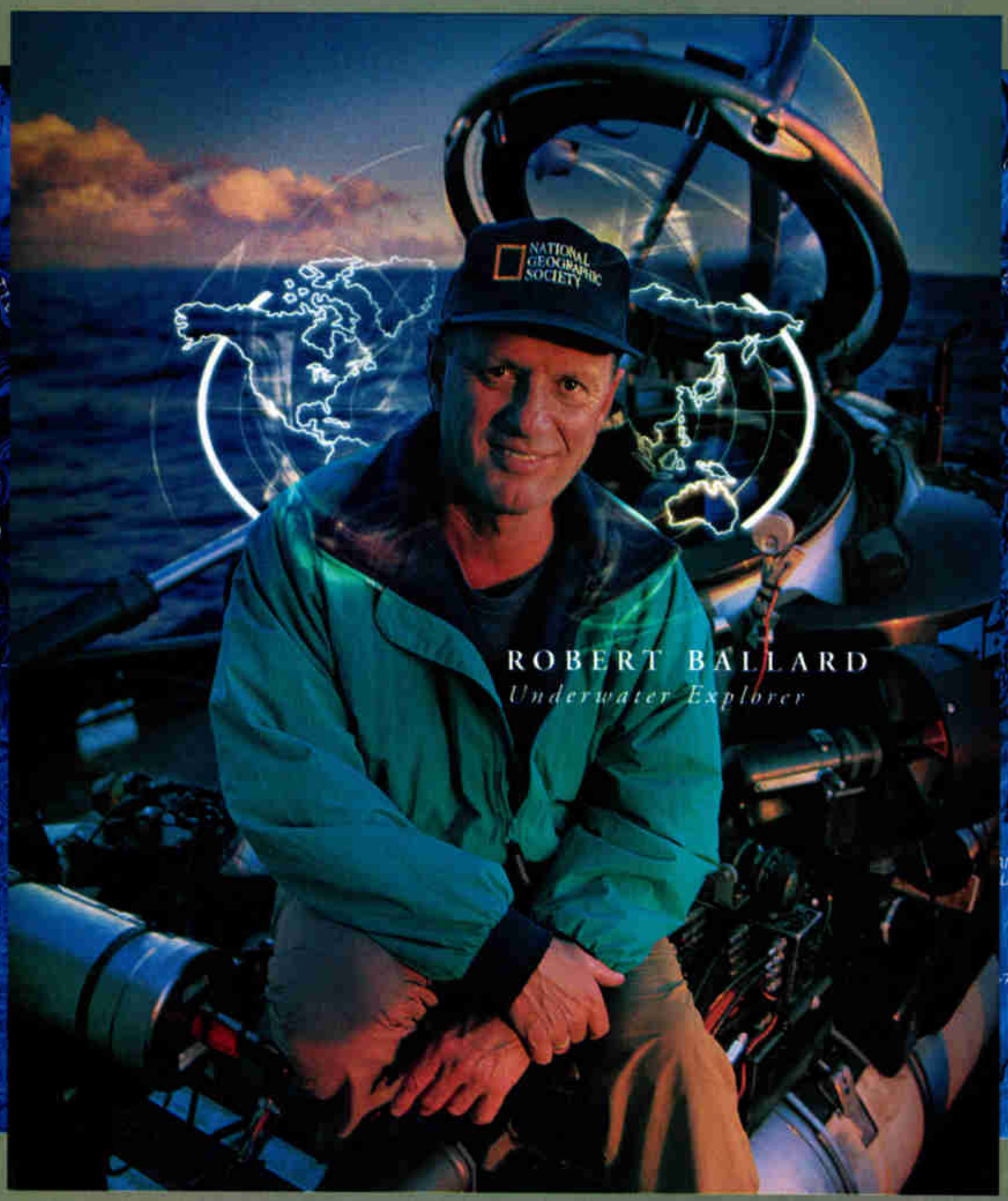
Geographica

I was moved beyond words when I saw the picture of the baby elephant. I showed the picture to my students, and it led to a lively discussion of what we in the United States can do to help conservation in Kenya. My class wanted to know if there was some way we could contribute to the David Sheldrick Wildlife nursery.

CHERYL POTTBERG
Perth Amboy, New Jersey

Mailing checks to Kenya can be risky. The organization's website (www.sheldrickwildlife trust.org) *suggests more secure methods.*

DID HE COME FROM ATLANTIS?



When he was young, the local pier was his playground. And it sparked a lifelong fascination with the sea. His name is Robert Ballard. He's coaxed secrets from the ocean. Spent 30 years at Woods Hole Oceanographic Institution. Founded the Institute for Exploration and the JASON Project. Discovered ancient shipwrecks. And uncovered the Titanic. Today, he's seeking evidence of a flood of biblical proportions in the Black Sea. Dr. Robert Ballard, underwater explorer, and National Geographic explorer-in-residence, is one of Ford Motor Company's Heroes for the Planet. A program that's part of ongoing Ford Motor Company initiatives to underwrite and support efforts that make the world a better place. To learn more about Dr. Ballard and other Heroes for the Planet, just visit our website. You'll find fascinating information, including links to his favorite web sites. Around the globe, there are amazing individuals who've dedicated their lives to our planet. You'll find them at www.ford.com/heroes. Stop by. The world is waiting.

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EarthPulse

SUSTAINABILITY

Cleaner Living and Driving

Technologies for a Greener 21st Century

How will we live and what will we drive in the next hundred years and beyond? Economics and environmental concerns are bringing alternative technologies to the fore. The 1992 Earth Summit of the United Nations emphasized, worldwide, "the need for a development process that does not jeopardize future generations." In other words, sustainability.

In housing and transportation, the glittering demonstration models are easy to spot. Last year energy-efficient windows and solar roof panels, developed by such environmentally minded organizations as Colorado's Rocky Mountain Institute, adorned housing for the Olympic Games in Sydney, Australia. Electric cars have begun to whiz along U.S. and European highways. But will infrastructure to support these innovations follow? Will super-efficient subdivisions succeed showcases? About 80 million residential and commercial buildings use two-thirds of all U.S. electricity. Within ten years another 18 million structures will go up. How will they be built?

Electric cars won't travel for long without an affordable and readily available system to plug them into. Hybrids use both electric motors and gasoline engines. A new generation of zero-emission vehicles is already in the works. Fuel-cell vehicles will run on electricity produced in an onboard system from hydrogen and oxygen.

The Future Is Near

"The Arizona desert is no place for the hard box walls of the . . . Middle West and East." More than 50 years after Frank Lloyd Wright foresaw the need for a new approach, his dream has risen in Phoenix. A potpourri of sustainable innovations, the Environmental Showcase Home uses 60 percent less electricity and 55 percent less water than the average Phoenix home, and it's built from 90 percent recycled materials. Sponsored by the Arizona Public Service utility, the house features shades called sun sponges that reflect light back into the house. Solar panels generate power and heat water, and some of the insulation is recycled from newspapers. The carpeting is made from plastic bottles.

Some 2,300 electric vehicles now travel California roads. Soon to join them will be Ford's Think City two-seaters, like the one below. Produced in Norway, the cars have a top speed of 56 mph and can go 53 miles before recharging.

Get Involved

How can you make a difference? Find a listing of resources and a forum at *nationalgeographic.com/ngm/0105/earthpulse*.

Rocky Mountain Institute
www.rmi.org

Office of Transportation Technologies
www.ott.doe.gov

BOTH BY JAMES A. SUGAR

Promising Initiatives

1 Aiming to make 50 fuel-cell-powered vehicles by 2003, the California Fuel Cell Partnership includes Ford, General Motors, and DaimlerChrysler.

2 Iceland may lead the way in hydrogen power. With its abundant, clean hydroelectric power, engineers plan to extract hydrogen from water by electrolysis, then use the fuel to power buses, trucks, cars, and eventually even fishing trawlers.

3 With one of the world's highest vehicle emissions per capita, Australia has pledged to reduce pollution, increase fuel efficiency, and promote alternative fuels as part of its National Greenhouse Strategy.

The idea took shape during the energy crisis of '73. The result is an innovative, pollution-free, battery-powered city car. As part of an ongoing commitment to affordable alternative transportation for our consumers, we'll introduce the TH!NK city to the United States and Canada in 2002. The name itself asks you to consider what getting from here to there is all about every time you see one on the street.

TH!NK Marketing Whiz Kristi Hegna Eggen woos customers who share a distinctive point of view about how people ought to get where they're going.

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UNITED STATES

Alternative transportation

doesn't always have to mean a boring vernment study about commuter trains.

SPACE TRAVEL

Racing for Space With the X Prize

Teams compete for millions—and more

ALL BY X PRIZE FOUNDATION

In the early days of aviation, cash prizes spurred pilots like Charles Lindbergh to take on challenges never before attempted, blazing trails for the commercial development of a new industry. Now the X Prize Foundation of St. Louis, Missouri, hopes to seed the commercial space industry by offering ten million dollars to the first privately funded and built spacecraft to fly two manned missions within 14 days to an altitude of 62 miles.

"We want to demonstrate that private interests can send people into space safely and efficiently," says Canadian contestant *Brian Feeney, whose* da Vinci Project is one of 21 entries to date. "We're in the dream-selling business."

APHICA

CREATURES OF OUR UNIVERSE

TGV ROCKETS

Named for the support team for this spacecraft (left), "two guys and a van," the Maryland-based group emphasized simplicity and low cost in developing the silo-shaped modular vehicle, shown here deploying its drag skirt in landing profile.

DA VINCI PROJECT

This Canadian entry will launch from the end of a thousand-foot tether attached to a 25-story balloon (right) floating at 40,000 feet. The spacecraft will ascend first at an angle, then vertically. A helium-filled, high-drag heat shield deploys during reentry (inset).

COSMOPOLIS XXI

Piggybacked aboard a carrier aircraft (left), the Russian *Cosmopolis XXI* module will separate from its launcher and fly vertically. During descent, small aerodynamic surfaces on the sides of the capsule will unfold to help the pilot steer.

BRISTOL SPACEPLANES

Ascender, a British entry, will take off and land at an ordinary airfield. *Ascender* (left) makes use of both jet and rocket engines to carry four people to the mandatory 62-mile altitude, ultimately traveling nearly three times the speed of sound.

STEVE WINTER

CONSERVATION

Black Cat With a Message

Wild jaguars at risk

The kids crowd around and their eyes get big. That's why the Belize Zoo has Ellen, the mysterious "black tiger"—she gets their attention. Ellen is an uncommon, melanistic form of jaguar; when the sun glints off her midnight coat, the jaguar's familiar spots and rosettes can be seen. She was named for her birthplace, the Ellen Trout Zoo in Texas. Zoo officials gave her to Belize as a symbol to dramatize the need to protect jaguars from poachers and habitat loss throughout the cats' range from northern Argentina to northern Mexico (see article, page 32).

ANTHROPOLOGY

Bringing Ishi Home

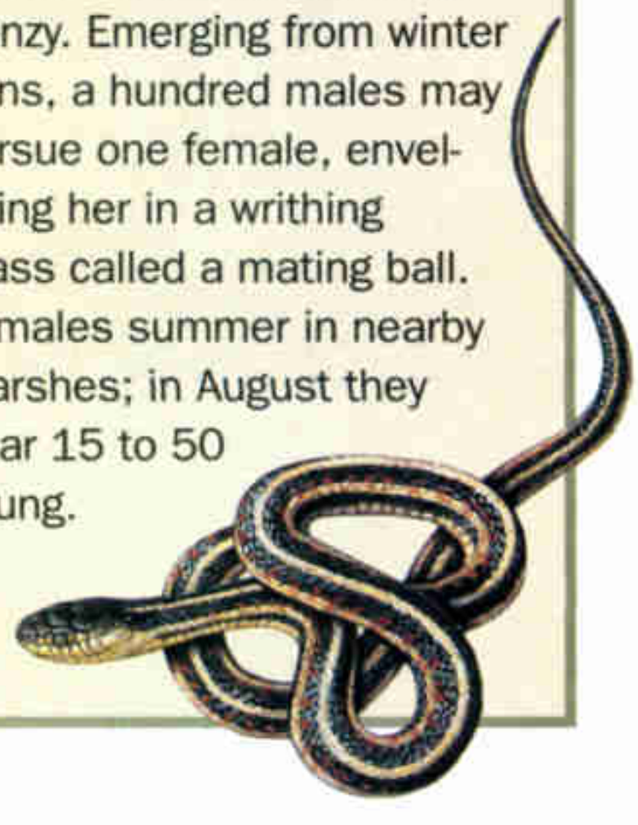
Ishi was one of the last Yahi Indians. Abandoning the northern California wilderness in 1911, he spent the end of his life living at the University of California's anthropology museum (right), where he demonstrated Yahi traditions for visitors. When Ishi died of tuberculosis in 1916, he was cremated, but first his brain was removed. Eventually it was sent to the Smithsonian Institution's Museum of Natural History, where it was placed in a storage facility. Last summer a group of California Native Americans reclaimed Ishi's brain, reuniting it with his ashes for a traditional burial in a secret location.

PHOEBE APPERSON, HEARST MUSEUM OF ANTHROPOLOGY (ABOVE); ART BY PETER GAEDE

ALMANAC

May

The town of Narcisse, Manitoba, is a-slither with 65,000 red-sided garter snakes in a spring mating frenzy. Emerging from winter dens, a hundred males may pursue one female, enveloping her in a writhing mass called a mating ball. Females summer in nearby marshes; in August they bear 15 to 50 young.



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DELAWARE ART MUSEUM

ADVENTURE

A Pirate's Tale Updated

Captain Kidd's ship found off Madagascar?

Underwater adventurer Barry Clifford discovered the *Whydah*—the first pirate ship ever found in North America (May 1999). Now he may have located another brigand's craft, the remains of Captain Kidd's *Adventure Galley,* scuttled off Madagascar in 1698. The wreck, patrolled by poisonous stonefish, lies among other sunken pirate ships.

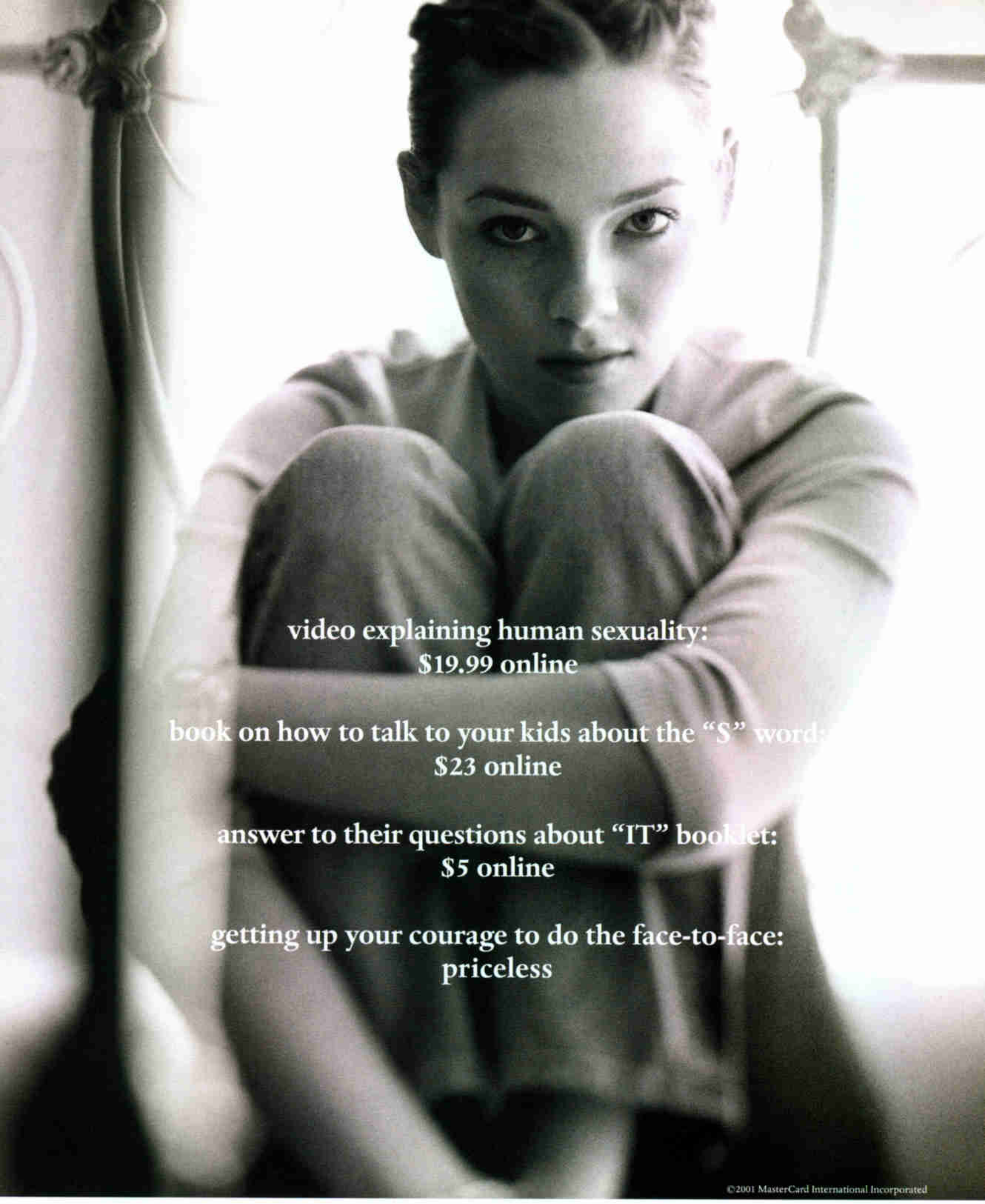
A wealthy New York businessman, William Kidd was 50 years old when England's King William III hired him in 1695 to battle pirates threatening trade routes in the Red Sea. But Kidd soon turned pirate himself, as portrayed in this 1902 illustration by Howard Pyle (left). Kidd was arrested, tried, and—still claiming innocence—executed in 1701. His tarred body hung in a metal cage over the London docks for many years as a warning to other potential pirates.

THE HUMAN BODY

Finding Their Way

Driving taxis can make your brain bigger, say researchers at University College London. Brain scans of the city's cabdrivers show that the part of the hippocampus associated with navigational skills is larger than in the average Londoner. Why? Cabbies must master London's maze of streets, and their calculation of routes may stimulate brain changes.

ANNIE GRIFFITHS BELT



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NATURE

Winged Gems of Ecuador

Biodiversity paradise

In 250 acres of Ecuador's lowland rain forest, some 1,700 species of butterflies may be found flying together, say Jason Hall of the Smithsonian Institution and Keith Willmott of the University of Florida. Together they have studied nearly all of them. A fast-flying male *Anteros kupris* (top left), which maintains a territory in the canopy to locate mates, seeks sodium by feeding on carrion and salty foods. A male *Anteros renaldus* (above) sports spectacularly tasseled leggings.

Many butterflies, though not poisonous themselves, mimic species that are toxic. One mimic, *Stalachtis phaedusa* (top right), always lands upside down on a leaf with wings open and thus betrays its identity. The poisonous model it resembles alights upright with wings closed.

One of the clearwing butterflies, a male *Oleria quadrata* (left) feeds on an aster. Its alkaloids make him distasteful. He passes the alkaloids' protection to females when they mate.

ALL BY KEITH WILLMOTT AND JASON HALL

Photographed by Nick Garbutt

WILDLIFE AS CANON SEES IT

In the relative cool of early morning, a terrestrial long-tailed ground-roller probes among leaf litter and around thorny thickets, hunting for insects and their larvae. The shy bird stands quietly for extended periods surveying an area, slowly lifting and lowering its long tail. Then, with a few quick hops, it disappears into the scrub. The usually solitary ground-roller stays with its mate while nesting, close to the nest cavity they have tunneled one meter into the sand. Confined to a small strip of unprotected coastal forest, the long-tailed ground-roller is threatened by loss and degradation of 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.

Long-tailed Ground-roller
(Uratelornis chimaera)
Size: Length, 47 cm
Weight: Approx. 70 g
Habitat: Dry, spiny forest and semi-desert scrub in southwest Madagascar
Surviving number: 10,000-20,000; population declining

The Nature Conservancy®
Saving the Last Great Places

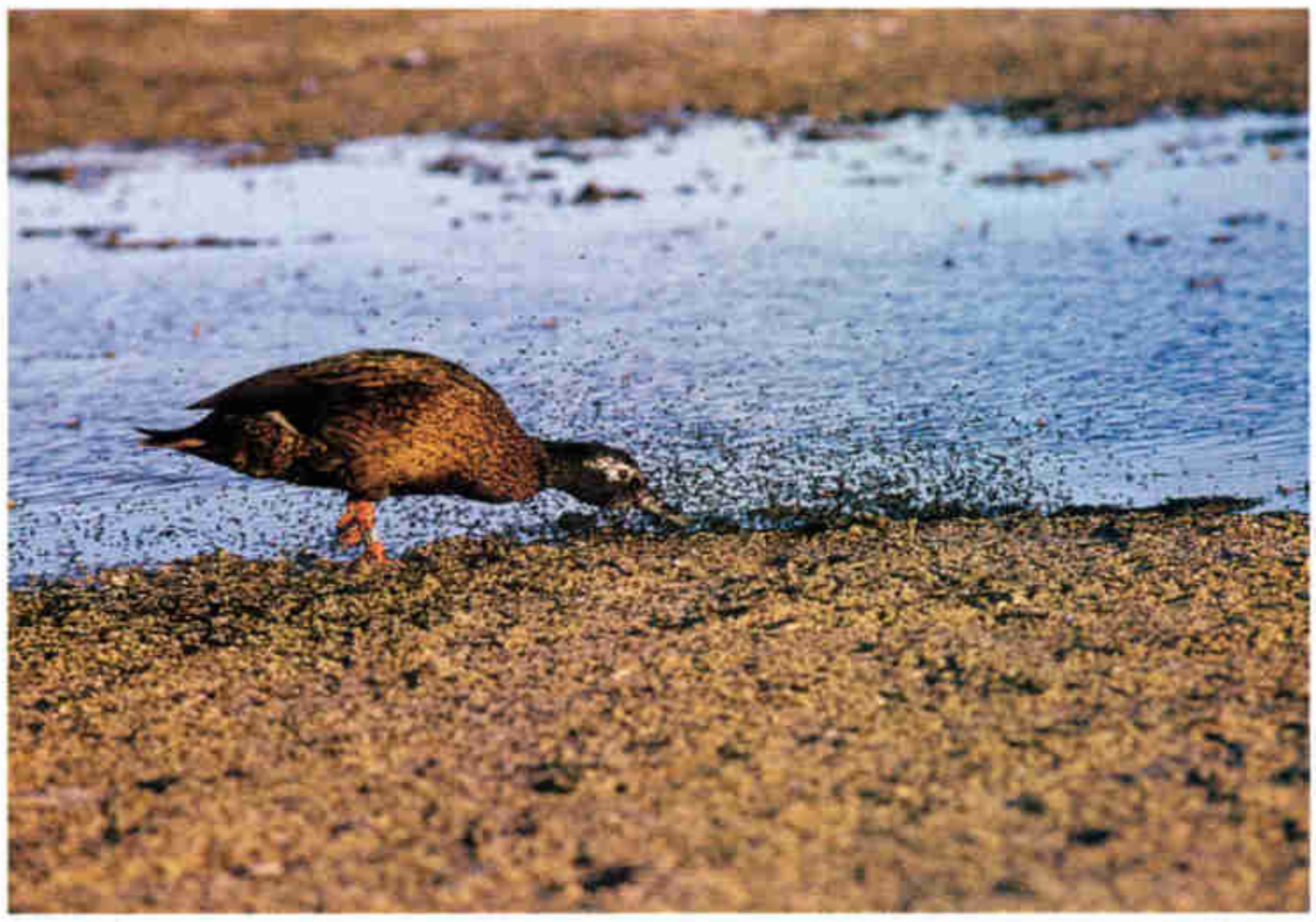
Canon makes possible The Nature Conservancy's "Wings of the Americas" program which protects birds and their habitats throughout the Americas.

Canon

NGS RESEARCH GRANT

Rare Ducks: A Homecoming?

Isolated species once lived on Hawaii's main islands



About 350 avian survivalists called Laysan ducks subsist on a 914-acre coral atoll, eating brine shrimp and brine flies (right) from a saline lagoon. They drink fresh water from tiny seeps. Laysan, in the far northwestern Hawaiian Islands, is the species' only haven.

Now researchers have found Laysan duck bones on the main islands—Maui, Hawaii, Molokai, Oahu, and Kauai. Biologist Michelle Reynolds (right, at left), attaching a transmitter, and the U.S. Fish and Wildlife Service wonder if the species could be reintroduced to its old haunts. "They were probably exterminated on the main islands after humans arrived some 1,600 years ago," she says. "But they must be more adaptable than we thought."

MICHELLE REYNOLDS (TOP); DORI DICK, NATIONAL MARINE FISHERIES SERVICE

NATIONAL GEOGRAPHIC PHOTOGRAPHER MICHAEL NICHOLS

CONSERVATION

Apes in a War Zone

Intelligent, social, and led by females, chimpanzee cousins called bonobos live only in the Democratic Republic of the Congo. With civil war raging there, no one knows how many survive, perhaps as few as 10,000. More bonobos are being hunted, both for sustenance and for sale in the bush-meat trade. Conservation groups have mobilized to save the apes. "We sent a Congolese team into Salonga National Park to set up an antipoaching patrol," says Gay Reinartz, a bonobo expert at the Zoological Society of Milwaukee County.

NEITHER RAIN, NOR SLEET, NOR BIRD...

Introducing patio sets by Coleman. You'll find each table and chair thoughtfully designed and stylishly crafted. And, in keeping with our 100 years of legendary Coleman quality, these sets are durable, easy to clean, fade resistant and rustproof. In short, it's furniture that really holds up against the elements. For more on our complete Coleman® BackHome™ collection or for a retailer near you, visit www.coleman.com. **Coleman. Inspired by Nature™**

FURNITURE GRILLS HEATERS LIGHTS SUNSHADES

MATT AYRES, DARTMOUTH COLLEGE (ABOVE); JAMES L. STANFIELD

Virginia (left). The beetles are nearly impervious to pesticide assaults. Forest managers have little recourse but to haul away infested trees. Some researchers think drought makes pines vulnerable, but others disagree.

"There appears to be no relationship," says John D. Reeve of Southern Illinois University. He points instead to a natural enemy, clerid beetles, which feed voraciously on southern pine beetles. Clerids' cycles fluctuate, and when they are scarce, pine beetle populations may explode.

ENVIRONMENT

Assassin of the Pine Forests

Do predators affect pine beetles' vicious cycles?

The most destructive insect plaguing pine forests in the southern U.S., the southern pine beetle caused an estimated 900 million dollars in damage from 1960 to 1990. Females bore into trees and lay their eggs within winding tunnels (above right). They emit a pheromone that attracts not only males but also more females, resulting in a mass infestation. The beetles quickly spread, killing the forest, as on Assateague Island in

CHEMISTRY

Disappearing Prints

At crime scenes, dust for children's fingerprints immediately. That's the message chemists at the Oak Ridge National Laboratory in Tennessee have for police investigators. They found that children's fingerprints contain more evaporative substances than adults' oilier prints and can disappear entirely within 24 hours, especially in high temperatures.

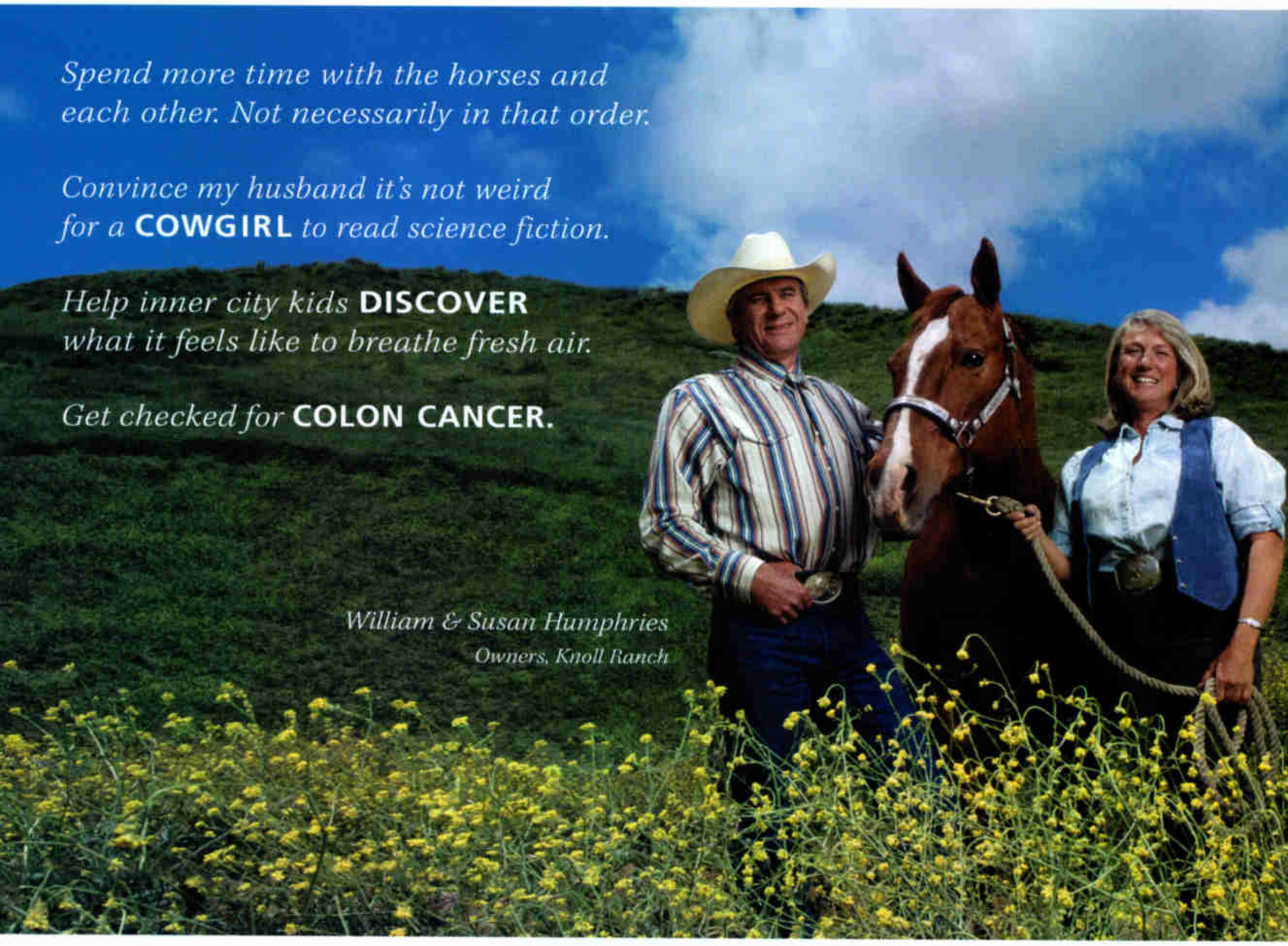
ANNIE GRIFFITHS BELT (ABOVE); ART BY DOUG STERN

THE HUMAN BODY

Speaking of Laughter

Why is it that babies can laugh long before they can talk? The laughing mechanism, says researcher Robert R. Provine of the University of Maryland, Baltimore County, might actually be a remnant of the earliest primate communication and not related to speech at all. "Laughter is a tool to study vocal evolution," he says, pointing out that chimpanzees laugh too—though in a manner much different from the universal human "ha." Chimps' mostly four-legged locomotion, he says, prevents the breath control that is necessary for human-sounding laughter and for vocal speech.

Things to do now that we're 50.



American Cancer Society®

Colon cancer is the second leading cancer killer in the U.S. And it affects women just as often as it affects men. But if it is caught in its early stages, colon cancer patients have a 90% survival rate. Make it a personal goal to get checked when you turn 50. That way, you'll have plenty of time to get to everything else on your list. Call your American Cancer Society any time, day or night, for free information on colon cancer.

Hope. Progress. Answers. / 800·ACS·2345 / cancer.org

PHARMACIA

NATURE

Desert Giraffes

Making do in a dry land

About 150 giraffes survive in the Namib Desert—seemingly with no water. Researchers have seen them drink only after rare rains. Instead, the giraffes eat leaves moist with fog that condenses at night. Lions once stalked them, but most of the cats have been killed by tribesmen.

CARY WOLINSKY

TECHNOLOGY

What's Niue?

The tiny Polynesian island of Niue has big ideas for the future. Its nonprofit Internet Users Society is marketing the island's URL suffix ".nu" to English-speaking business owners who want their online addresses to sound "new." But so far the largest customer base is in Sweden, where "nu" means "now." Part of the proceeds from the lease of the domain name will go to provide free Internet access for the island's 1,750 residents.

ART BY TIM LEWIS

SCIENCE

Venom: How Deadly?

Tens of thousands of people die worldwide from snakebites each year (with fewer than 15 in the U.S.). Now Bryan Fry, an Australian researcher, is creating the International Venom and Toxin Database to rank reptiles, insects, and other animals with the strongest venom. Australia's inland taipan (right) tops the list of toxic snakes, though no fatalities have been attributed to this placid and rare species.

JOHN WEIGEL

Before
nasal allergies
change your life

Make an easier Change

Nasal allergies can be so frustrating, you feel like moving to a place without pollen, trees, or a single blade of grass.

Of course, you would never go to these extremes. But before you change your life, maybe you should make an easier change. Ask your doctor about FLONASE.

Using multi-symptom FLONASE Nasal Spray once a day can relieve all these nasal allergy symptoms — congestion, sneezing, and itchy, runny nose — all day and night. Results may vary.

If side effects occur, they are generally mild and may include headache, nosebleed, or sore throat. For best results, use daily. Maximum relief may take several days. Available by prescription only.

Ask your doctor about multi-symptom FLONASE, or call 1-800-FLONASE, or visit www.flonase.com.

When you get it all, all it takes is Flonase® (fluticasone propionate) Nasal Spray, 50 mcg

gsk
GlaxoSmithKline

Please see important information on the following page.

FLONASE®
(fluticasone propionate) Nasal Spray, 50 mcg

BRIEF SUMMARY

SHAKE GENTLY BEFORE USE.

For Intranasal Use Only.

The following is a brief summary only; see full prescribing information for complete product information.

CONTRAINDICATIONS: FLONASE Nasal Spray is contraindicated in patients with a hypersensitivity to any of its ingredients.

WARNINGS: The replacement of a systemic corticosteroid with a topical corticosteroid can be accompanied by signs of adrenal insufficiency, and in addition some patients may experience symptoms of withdrawal, e.g., joint and/or muscular pain, lassitude, and depression. Patients previously treated for prolonged periods with systemic corticosteroids and transferred to topical corticosteroids should be carefully monitored for acute adrenal insufficiency in response to stress. In those patients who have asthma or other clinical conditions requiring long-term systemic corticosteroid treatment, too rapid a decrease in systemic corticosteroids may cause a severe exacerbation of their symptoms.

The concomitant use of intranasal corticosteroids with other inhaled corticosteroids could increase the risk of signs or symptoms of hypercorticism and/or suppression of the HPA axis.

Patients who are on immunosuppressant drugs are more susceptible to infections than healthy individuals. Chickenpox and measles, for example, can have a more serious or even fatal course in patients on immunosuppressant doses of corticosteroids. In such patients who have not had these diseases, particular care should be taken to avoid exposure. How the dose, route, and duration of corticosteroid administration affects the risk of developing a disseminated infection is not known. The contribution of the underlying disease and/or prior corticosteroid treatment to the risk is also not known. If exposed to chickenpox, prophylaxis with varicella zoster immune globulin (VZIG) may be indicated. If exposed to measles, prophylaxis with pooled intramuscular immunoglobulin (IG) may be indicated. (See the respective package inserts for complete VZIG and IG prescribing information.) If chickenpox develops, treatment with antiviral agents may be considered.

PRECAUTIONS:

General: Rarely, immediate hypersensitivity reactions or contact dermatitis may occur after the administration of FLONASE Nasal Spray. Rare instances of wheezing, nasal septum perforation, cataracts, glaucoma, and increased intraocular pressure have been reported following the intranasal application of corticosteroids, including fluticasone propionate.

Use of excessive doses of corticosteroids may lead to signs or symptoms of hypercorticism, suppression of HPA function, and/or reduction of growth velocity in children or teenagers. Physicians should closely follow the growth of children and adolescents taking corticosteroids, by any route, and weigh the benefits of corticosteroid therapy against the possibility of growth suppression if growth appears slowed.

Although systemic effects have been minimal with recommended doses of FLONASE Nasal Spray, potential risk increases with larger doses. Therefore, larger than recommended doses of FLONASE Nasal Spray should be avoided.

When used at higher than recommended doses, or in rare individuals at recommended doses, systemic corticosteroid effects such as hypercorticism and adrenal suppression may appear. If such changes occur, the dosage of FLONASE Nasal Spray should be discontinued slowly consistent with accepted procedures for discontinuing oral corticosteroid therapy.

In clinical studies with fluticasone propionate administered intranasally, the development of localized infections of the nose and pharynx with *Candida albicans* has occurred only rarely. When such an infection develops, it may require treatment with appropriate local therapy and discontinuation of treatment with FLONASE Nasal Spray. Patients using FLONASE Nasal Spray over several months or longer should be examined periodically for evidence of *Candida* infection or other signs of adverse effects on the nasal mucosa.

FLONASE Nasal Spray should be used with caution, if at all, in patients with active or quiescent tuberculous infection; untreated local or systemic fungal or bacterial, or systemic viral infections or parasitic infection; or ocular herpes simplex.

Because of the inhibitory effect of corticosteroids on wound healing, patients who have experienced recent nasal septal ulcers, nasal surgery, or nasal trauma should not use a nasal corticosteroid until healing has occurred.

Information for Patients: Patients being treated with FLONASE Nasal Spray should receive the following information and instructions. This information is intended to aid them in the safe and effective use of this medication. It is not a disclosure of all possible adverse or intended effects.

Patients should be warned to avoid exposure to chickenpox or measles and, if exposed, to consult their physician without delay.

Patients should use FLONASE Nasal Spray at regular intervals as directed since its effectiveness depends on its regular use. A decrease in nasal symptoms may occur as soon as 12 hours after starting therapy with FLONASE Nasal Spray. Results in several clinical trials indicate statistically significant improvement within the first day or two of treatment; however, the full benefit of FLONASE Nasal Spray may not be achieved until treatment has been administered for several days. The patient should not increase the prescribed dosage but should contact the physician if symptoms do not improve or if the condition worsens. For the proper use of the nasal spray and to attain maximum improvement, the patient should read and follow carefully the accompanying patient's instructions.

Drug Interactions: In a placebo-controlled, crossover study in eight healthy volunteers, coadministration of a single dose of orally inhaled fluticasone propionate (1000 mcg, 5 times the maximum daily intranasal dose) with multiple doses of ketoconazole (200 mg) to steady state resulted in increased mean fluticasone propionate concentrations, a reduction in plasma cortisol AUC, and no effect on urinary excretion of cortisol. This interaction may be due to an inhibition of the cytochrome P450 3A4 isoenzyme system by ketoconazole, which is also the route of metabolism of fluticasone propionate. No drug interaction studies have been conducted with FLONASE Nasal Spray; however, care should be exercised when fluticasone propionate is coadministered with long-term ketoconazole and other known cytochrome P450 3A4 inhibitors.

Carcinogenesis, Mutagenesis, Impairment of Fertility: Fluticasone propionate demonstrated no tumorigenic potential in mice at oral doses up to 1000 mcg/kg (approximately 20 times the maximum recommended daily intranasal dose in adults and approximately 10 times the maximum recommended daily intranasal dose in children on a mcg/m^2 basis) for 78 weeks or in rats at inhalation doses up to 57 mcg/kg (approximately 2 times the maximum recommended daily intranasal dose in adults and approximately equivalent to the maximum recommended daily intranasal dose in children on a mcg/m^2 basis) for 104 weeks.

Fluticasone propionate did not induce gene mutation in prokaryotic or eukaryotic cells in vitro. No significant clastogenic effect was seen in cultured human peripheral lymphocytes in vitro or in the mouse micronucleus test when administered at high doses by the oral or subcutaneous routes. Furthermore, the compound did not delay erythroblast division in bone marrow.

No evidence of impairment of fertility was observed in reproductive studies conducted in male and female rats at subcutaneous doses up to 50 mcg/kg (approximately 2 times the maximum recommended daily intranasal dose in adults on a mcg/m^2 basis). Prostate weight was significantly reduced at a subcutaneous dose of 50 mcg/kg.

Pregnancy: ***Teratogenic Effects:*** Pregnancy Category C. Subcutaneous studies in the mouse and rat at 45 and 100 mcg/kg, respectively (approximately equivalent to and 4 times the maximum recommended daily intranasal dose in adults on a mcg/m^2 basis, respectively) revealed fetal toxicity characteristic of potent corticosteroid compounds, including embryonic growth retardation, omphalocele, cleft palate, and retarded cranial ossification.

In the rabbit, fetal weight reduction and cleft palate were observed at a subcutaneous dose of 4 mcg/kg (less than the maximum recommended daily intranasal dose in adults on a mcg/m^2 basis).

However, no teratogenic effects were reported at oral doses up to 300 mcg/kg (approximately 25 times the maximum recommended daily intranasal dose in adults on a mcg/m^2 basis) of fluticasone propionate to the rabbit. No fluticasone propionate was detected in the plasma in this study, consistent with the established low bioavailability following oral administration (see CLINICAL PHARMACOLOGY section of the full prescribing information).

Fluticasone propionate crossed the placenta following oral administration of 100 mcg/kg to rats or 300 mcg/kg to rabbits (approximately 4 and 25 times, respectively, the maximum recommended daily intranasal dose in adults on a mcg/m^2 basis).

There are no adequate and well-controlled studies in pregnant women. Fluticasone propionate should be used during pregnancy only if the potential benefit justifies the potential risk to the fetus.

Experience with oral corticosteroids since their introduction in pharmacologic, as opposed to physiologic, doses suggests that rodents are more prone to teratogenic effects from corticosteroids than humans. In addition, because there is a natural increase in corticosteroid production during pregnancy, most women will require a lower exogenous corticosteroid dose and many will not need corticosteroid treatment during pregnancy.

Nursing Mothers: It is not known whether fluticasone propionate is excreted in human breast milk. When tritiated fluticasone propionate was administered to rats at a subcutaneous dose of 10 mcg/kg (less than the maximum recommended daily intranasal dose in adults on a mcg/m^2 basis), radioactivity was excreted in the milk. Because other corticosteroids are excreted in human milk, caution should be exercised when FLONASE Nasal Spray is administered to a nursing woman.

Pediatric Use: Five hundred (500) patients aged 4 to 11 years of age and 440 patients aged 12 to 17 years were studied in US clinical trials with fluticasone propionate nasal spray. The safety and effectiveness of FLONASE Nasal Spray in children below 4 years of age have not been established.

Oral and, to a less clear extent, inhaled and intranasal corticosteroids have been shown to have the potential to cause a reduction in growth velocity in children and adolescents with extended use. If a child or adolescent on any corticosteroid appears to have growth suppression, the possibility that they are particularly sensitive to this effect of corticosteroids should be considered (see PRECAUTIONS).

Geriatric Use: A limited number of patients above 60 years of age (n =275) have been treated with FLONASE Nasal Spray in US and non-US clinical trials. While the number of patients is too small to permit separate analysis of efficacy and safety, the adverse reactions reported in this population were similar to those reported by younger patients.

ADVERSE REACTIONS: In controlled US studies, more than 3300 patients with seasonal allergic, perennial allergic, or perennial nonallergic rhinitis received treatment with intranasal fluticasone propionate. In general, adverse reactions in clinical studies have been primarily associated with irritation of the nasal mucous membranes, and the adverse reactions were reported with approximately the same frequency by patients treated with the vehicle itself. The complaints did not usually interfere with treatment. Less than 2% of patients in clinical trials discontinued because of adverse events; this rate was similar for vehicle placebo and active comparators.

Systemic corticosteroid side effects were not reported during controlled clinical studies up to 6 months' duration with FLONASE Nasal Spray. If recommended doses are exceeded, however, or if individuals are particularly sensitive, or taking FLONASE Nasal Spray in conjunction with administration of other corticosteroids, symptoms of hypercorticism, e.g., Cushing's syndrome, could occur.

The following incidence of common adverse reactions (>3%, where incidence in fluticasone propionate-treated subjects exceeded placebo) is based upon seven controlled clinical trials in which 536 patients (57 girls and 108 boys aged 4 to 11 years, 137 female and 234 male adolescents and adults) were treated with FLONASE Nasal Spray 200 mcg once daily over 2 to 4 weeks and two controlled clinical trials in which 246 patients (119 female and 127 male adolescents and adults) were treated with FLONASE Nasal Spray 200 mcg once daily over 6 months. Also included in the table are adverse events from two studies in which 167 children (45 girls and 122 boys aged 4 to 11 years) were treated with FLONASE Nasal Spray 100 mcg once daily for 2 to 4 weeks.

Overall Adverse Experiences With >3% Incidence on Fluticasone Propionate in Controlled Clinical Trials With FLONASE Nasal Spray in Patients ≥4 Years With Seasonal or Perennial Allergic Rhinitis

	Vehicle Placebo (n=758) %	FLONASE 100 mcg Once Daily (n=167) %	FLONASE 200 mcg Once Daily (n=782) %
Headache	14.6	6.6	16.1
Pharyngitis	7.2	6.0	7.8
Epistaxis	5.4	6.0	6.9
Nasal burning/ Nasal irritation	2.6	2.4	3.2
Nausea/vomiting	2.0	4.8	2.6
Asthma symptoms	2.9	7.2	3.3
Cough	2.8	3.6	3.8

Other adverse events that occurred in ≤3% but ≥1% of patients and that were more common with fluticasone propionate (with uncertain relationship to treatment) included: blood in nasal mucus, runny nose, abdominal pain, diarrhea, fever, flu-like symptoms, aches and pains, dizziness, bronchitis.

Observed During Clinical Practice: In addition to adverse events reported from clinical trials, the following events have been identified during postapproval use of fluticasone propionate in clinical practice. Because they are reported voluntarily from a population of unknown size, estimates of frequency cannot be made. These events have been chosen for inclusion due to either their seriousness, frequency of reporting, causal connection to fluticasone propionate, occurrence during clinical trials, or a combination of these factors.

General: Hypersensitivity reactions, including angioedema, skin rash, edema of the face and tongue, pruritus, urticaria, bronchospasm, wheezing, dyspnea, and anaphylaxis/anaphylactoid reactions, which in rare instances were severe.

Ear, Nose, and Throat: Alteration or loss of sense of taste and/or smell and, rarely, nasal septal perforation, nasal ulcer, sore throat, throat irritation and dryness, cough, hoarseness, and voice changes.

Eye: Dryness and irritation, conjunctivitis, blurred vision, glaucoma, increased intraocular pressure, and cataracts.

OVERDOSAGE: Chronic overdosage with FLONASE Nasal Spray may result in signs/symptoms of hypercorticism (see PRECAUTIONS). Intranasal administration of 2 mg (10 times the recommended dose) of fluticasone propionate twice daily for 7 days to healthy human volunteers was well tolerated. Single oral doses up to 16 mg have been studied in human volunteers with no acute toxic effects reported. Repeat oral doses up to 80 mg daily for 10 days in volunteers and repeat oral doses up to 10 mg daily for 14 days in patients were well tolerated. Adverse reactions were of mild or moderate severity, and incidences were similar in active and placebo treatment groups. Acute overdosage with this dosage form is unlikely since one bottle of FLONASE Nasal Spray contains approximately 8 mg of fluticasone propionate.

The oral and subcutaneous median lethal doses in mice and rats were >1000 mg/kg (>20000 and >41000 times, respectively, the maximum recommended daily intranasal dose in adults and >10000 and >20000 times, respectively, the maximum recommended daily intranasal dose in children on a mg/m^2 basis).

GlaxoWellcome

Glaxo Wellcome Inc.
Research Triangle Park, NC 27709

U.S. Patent 4,335,121
INSEAL™ is covered by the following Inprint Systems patent applications: European 94916311.7, Canada 2140025, USA 08/373,213.

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Printed in USA. FL2292R0 May 2001

The eagle, the elk and the warrior

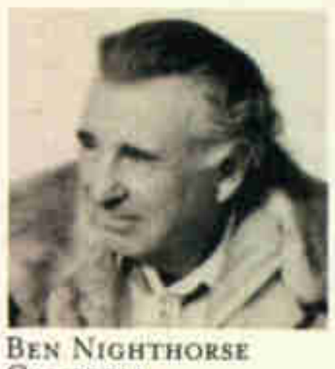
One day, a Cheyenne warrior was hunting alone, on foot. He came upon an elk lying dead by the side of a stream. Trapped in the antlers of the fallen elk was a large spotted eagle. The eagle spoke to the hunter.

"Free me from here," the eagle said, "and I will give you a gift."

The warrior did as the eagle requested. He lifted the elk's antlers and the eagle was free. As the great bird flew away, it said to the warrior, "Go over that next hill and you will see your gift." Then the bird was gone.

The warrior climbed the hill and when he reached the top he looked into a wide valley. There at the foot of the hill was a horse, its coat the same black and white as the eagle's feathers. This horse was the eagle's gift.

The Cheyenne Eagle Blanket is an interpretation of this legend as told by Ben Nighthorse Campbell. It employs traditional Cheyenne graphics and parfleche design elements to retell the story. This limited-edition saddle blanket, measuring 66" x 40", is the third in the Spirit Series of Native American Blankets. It is woven of pure wool by the Pendleton Woolen Mills for the American Indian College Fund.



Ben Nighthorse Campbell

Thanks to the generous donation of materials and time, 70% of the proceeds from the sale of this blanket go to fund our colleges and our scholarship programs. To learn more, call 1-800-880-5887 or visit our Web site at www.collegefund.org.

The eagle's gift was great because, at that time, a horse could mean the difference between a prosperous life and the struggle for simple survival. Today an education can make that same difference. The generous gift of your support helps our colleges thrive and our people grow.

Photograph by Raymond Meeks

American Indian College Fund

Educating the mind and spirit

Behind the SCENES

AT THE NATIONAL GEOGRAPHIC SOCIETY

MICHAEL FORSBERG (ABOVE); MARK THIESSEN, NGS

New Home on the Range

A photographer dreams of bringing back wildlife

The thought came to Joel Sartore (above) as he shot articles about federal land use and endangered species: Can we renew the glory of the Great Plains? Can we bring wildlife back in a big way? Joel, a resident of Lincoln, Nebraska, sat down with Lincoln attorney Tyler Sutton and devised a plan to create a nature reserve—"a million acres, two million acres"—in the area where Nebraska, Wyoming, and South Dakota meet (map; more at Online Extra, *nationalgeographic.com/ngm/0105*). Much of the land is already federally owned and would require only a land-use designation change by Congress, says Joel. His nonprofit Conservation Alliance of the Great Plains would "bring back what we've lost since European settlement: herds of free-roaming bison, elk, and all the other animals and plants that come with them." Through private land trusts and tourism revenue, he says, "local people would benefit as well."

EXPLORER-IN-RESIDENCE

Guided by an unerring sense of direction, historian Stephen E. Ambrose has written more than two dozen books on U.S. history, including best-sellers about Lewis and Clark and World War II. "In the 20th century our best minds went to work on how to conquer nature," says Ambrose, who is also the founder of the National D-Day Museum, which opened last June in New Orleans. "In the 21st century our best minds are going to work on how to restore nature."

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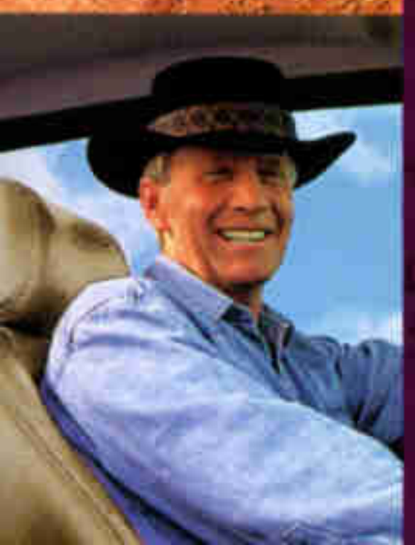

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Model Gift

Passing on family pride

When Clarence McNair, a Philadelphia tool-and-die maker, and his brother-in-law, Raymond Putz, saw a 1939 GEOGRAPHIC article on Henry Hudson (top right), they decided to craft 25-inch-high models of Hudson's ship *Half Moon.* The models—with wooden hulls and oilcloth sails soaked in coffee to make them look older—became family treasures. Last year McNair's widow gave this one to her grandson Steve McNair. "It's a unique link to my grandfather," he says.

WILLIAM H. CLARKE

For people with type 2 diabetes

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"I manage my type 2 diabetes through diet, exercise and medication."

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"They are the reasons I'm eating right and exercising more. When that wasn't enough, my doctor added *Avandia* to help me manage my type 2 diabetes. *Avandia* works differently than some diabetes medications. It helps my body use its own natural insulin more effectively.

"Since I started taking *Avandia* about a year ago, my blood sugar level has come down and stayed down. Your results may vary."

I will always take care of my diabetes

Avandia, along with diet and exercise, helps improve blood sugar control. It may be prescribed alone, with Glucophage® (metformin HCl tablets) or with sulfonylureas. When taking *Avandia* with a sulfonylurea, you may be at risk for low blood sugar. Ask your doctor whether you need to lower your sulfonylurea dosage.

In studies, the most common side effects included cold-like symptoms and headache. Less common, but important, side effects included tiredness, weight gain or swelling.

You should not take *Avandia* if you are in the later stages of heart failure. If you have a history of congestive heart failure or swelling, or if you experience an unusually rapid increase in weight, swelling or shortness of breath while taking *Avandia*, talk to your doctor immediately.

Also, blood tests to check your liver should be conducted before and during *Avandia* therapy because of serious liver problems caused by a similar drug. Tell your doctor if you have liver disease, or if you experience unexplained tiredness, stomach problems, dark urine or yellowing of the skin while taking *Avandia*. See important patient information on the following page.

If you are nursing, pregnant or thinking about becoming pregnant, or if you are a premenopausal woman who is not ovulating, talk to your doctor before taking *Avandia*.

Talk to your doctor, or for more information call 1-800-AVANDIA (1-800-282-6342).

www.avandia.com

Please see important patient information on the following page.

GlaxoSmithKline

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Avandia®
rosiglitazone maleate

You can be stronger than diabetes

Patient Information About AVANDIA® (rosiglitazone maleate) Tablets 2 mg, 4 mg, and 8 mg

What is *Avandia*?
Avandia is one product in a new class of prescription drugs called thiazolidinediones (thigh-a-zoe-lid-een-die-owns). It is used to treat type 2 diabetes by helping the body use the insulin that it is already making. Avandia comes as pills that can be taken either once a day or twice a day to help improve blood sugar levels.

How does *Avandia* treat type 2 diabetes?
If you have type 2 diabetes, your body still produces insulin but it is not able to fully use the insulin. Insulin is needed to allow sugar to be carried from the bloodstream into many cells of the body for energy. If insulin is not being used correctly, sugar does not enter the cells very well and builds up in the blood. If not controlled, the high blood sugar level can lead to serious medical problems, including kidney damage, blindness and amputation.

Avandia helps your body use insulin by making the cells more sensitive to insulin so that the sugar can enter the cell.

How quickly will *Avandia* begin to work?
Avandia begins to reduce blood sugar levels within 2 weeks. However, since Avandia works to address an important underlying cause of type 2 diabetes, insulin resistance, it may take 8 to 12 weeks to see the full effect. If you do not respond adequately to your starting dose of Avandia, your physician may increase your daily dose to improve your blood sugar control.

How should I take *Avandia*?
Your doctor may tell you to take Avandia once a day in the morning or twice a day in the morning and evening. It can be taken with or without meals. Food does not affect how Avandia works. To help you remember to take Avandia, you may want to take it at the same time every day.

What if I miss a dose?
If your doctor has prescribed Avandia for use once a day:

- *As soon as you remember your missed dose, take one tablet anytime during the day.*
- *If you forget and go a whole day without taking a dose, don't try to make it up by adding another dose on the following day. Forget about the missed dose and simply follow your normal schedule.*

If your doctor has prescribed Avandia for use twice a day:

- *As soon as you remember the missed dose, take one tablet.*
- *Take the next dose at the normal time on the same day.*
- *Don't try to make up a missed dose from the day before.*
- *You should never take three doses on any single day in order to make up for a missed dose the day before.*

Do I need to test my blood for sugar while using *Avandia*?
Yes, you should follow your doctor's instructions about your at-home testing schedule.

Does *Avandia* cure type 2 diabetes?
Currently there is no cure for diabetes. The only way to avoid the effects of the disease is to maintain good blood sugar control by following your doctor's advice for diet, exercise, weight control, and medication. Avandia, alone or in combination with other antidiabetic drugs (i.e., sulfonylureas or metformin), may improve these other efforts by helping your body make better use of the insulin it already produces.

Can I take *Avandia* with other medications?
Avandia has been taken safely by people using other medications, including other antidiabetic medications, birth control pills, warfarin (a blood thinner), Zantac® (ranitidine, an antiulcer product from GlaxoSmithKline), certain heart medications, and some cholesterol-lowering products. You should discuss with your doctor the most appropriate plan for you. If you are taking prescription or over-the-counter products for your diabetes or for conditions other than diabetes, be sure to tell your doctor. Sometimes a patient who is taking two antidiabetic medications each day can become irritable, lightheaded or excessively tired. Tell your doctor if this occurs; your blood sugar levels may be dropping too low, and the dose of your medication may need to be reduced.

What should I discuss with my doctor before taking *Avandia*?
You should talk to your doctor if you have a history of congestive heart failure or edema (swelling), if you have liver problems, or if you are nursing, pregnant or thinking of becoming pregnant. If you are a premenopausal woman who is not ovulating, you should know that Avandia therapy may result in the resumption of ovulation, which may increase your chances of becoming pregnant. Therefore, you may need to consider birth control options.

What are the possible side effects of *Avandia*?
Avandia was generally well tolerated in clinical trials. The most common side effects reported by people taking Avandia were upper respiratory infection and headache. As with most other diabetes medications, you may experience an increase in weight. You may also experience edema (swelling) and/or anemia. If you experience any swelling of your extremities (e.g., legs, ankles) or tiredness, notify your doctor. Talk to your doctor immediately if you experience edema, shortness of breath, an unusually rapid increase in weight, or other symptoms of heart failure.

Who should not use *Avandia*?
You should not take Avandia if you are in the later stages of heart failure. The following people should also not take Avandia: People with type 1 diabetes, people who experienced yellowing of the skin with Rezulin® (troglitazone, Parke-Davis), people who are allergic to Avandia or any of its components and people with diabetic ketoacidosis.

Why are laboratory tests recommended?
Your doctor may conduct blood tests to measure your blood sugar control. In addition, your doctor should conduct liver enzyme tests. Avandia did not show signs of liver problems in clinical studies. However, because a similar drug (Rezulin) was associated with serious liver problems, your doctor should recommend a blood test to monitor your liver before you start taking Avandia, every 2 months during the first year and periodically thereafter.

It is important that you call your doctor immediately if you experience unexplained symptoms of nausea, vomiting, stomach pain, tiredness, anorexia, dark urine, or yellowing of the skin.

How should I store *Avandia*?
Avandia should be stored at room temperature in a child-proof container out of the reach of children. Store Avandia in its original container.

DATE OF ISSUANCE FEB. 2001

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KENNETH GARRETT

A Fine Fellow

Professor goes to "school"

Leaving a village festival in Peru, Mark Dolan (above, at left) made some new friends—as the Syracuse University journalism professor did throughout his stay last summer as the magazine's photographic faculty fellow. "I had a chance to go to Peru and watch photographer Ken Garrett work on an archaeology article," Mark says. "I was impressed with the way he interacted with the scientists there and how they respected him because they knew how thoroughly he researches his subjects."

While with us at headquarters Mark photographed and recorded sessions involving photographers, illustrations editors, designers, and editors to capture how an article takes shape. "The end goal is to use the sound, my images, the photographers' images, and the layouts in a multimedia presentation to walk people through how a story comes together at National Geographic," he says. He'll share the result with other professors but especially with his photography, picture-editing, and graphic design students in Syracuse's S. I. Newhouse School of Public Communications.

100 YEARS AGO

May 1901

"A unique submarine boat is now being built at Wilhelmshaven, Germany, designed not for war, but for the search for the North Pole. . . . The boat will be capable of descending to a depth of 160 feet . . . and can remain fifteen hours under water."
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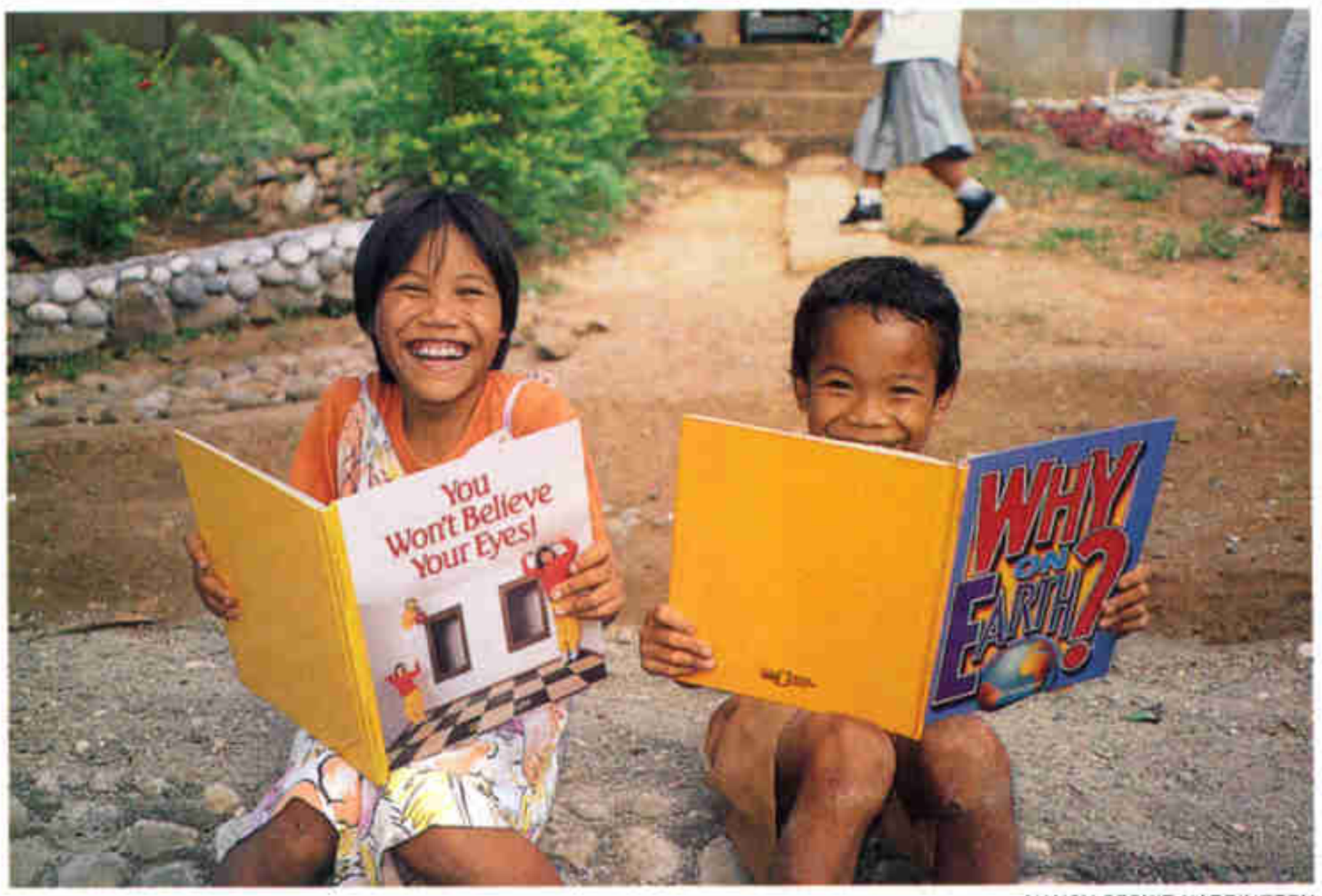

NANCY STOWE HARRINGTON

Giving the Gift of Education

California group ships reading materials to the needy

Excitement lights the faces of children in a remote village in the Philippines as they read National Geographic books provided by a California-based nonprofit group, Books for the Barrios. Unsold Geographic books and discarded magazines made up about 10 percent of the more than four million pieces of educational materials the group has shipped to isolated schools in the Philippines in the past decade. "No question, Geographic publications are the most valuable," says Dan Harrington, who founded Books for the Barrios with his wife, Nancy, after seeing poor children "on every street corner in the Philippines." Information on donating materials can be found at *www.booksforthebarrios.com.*

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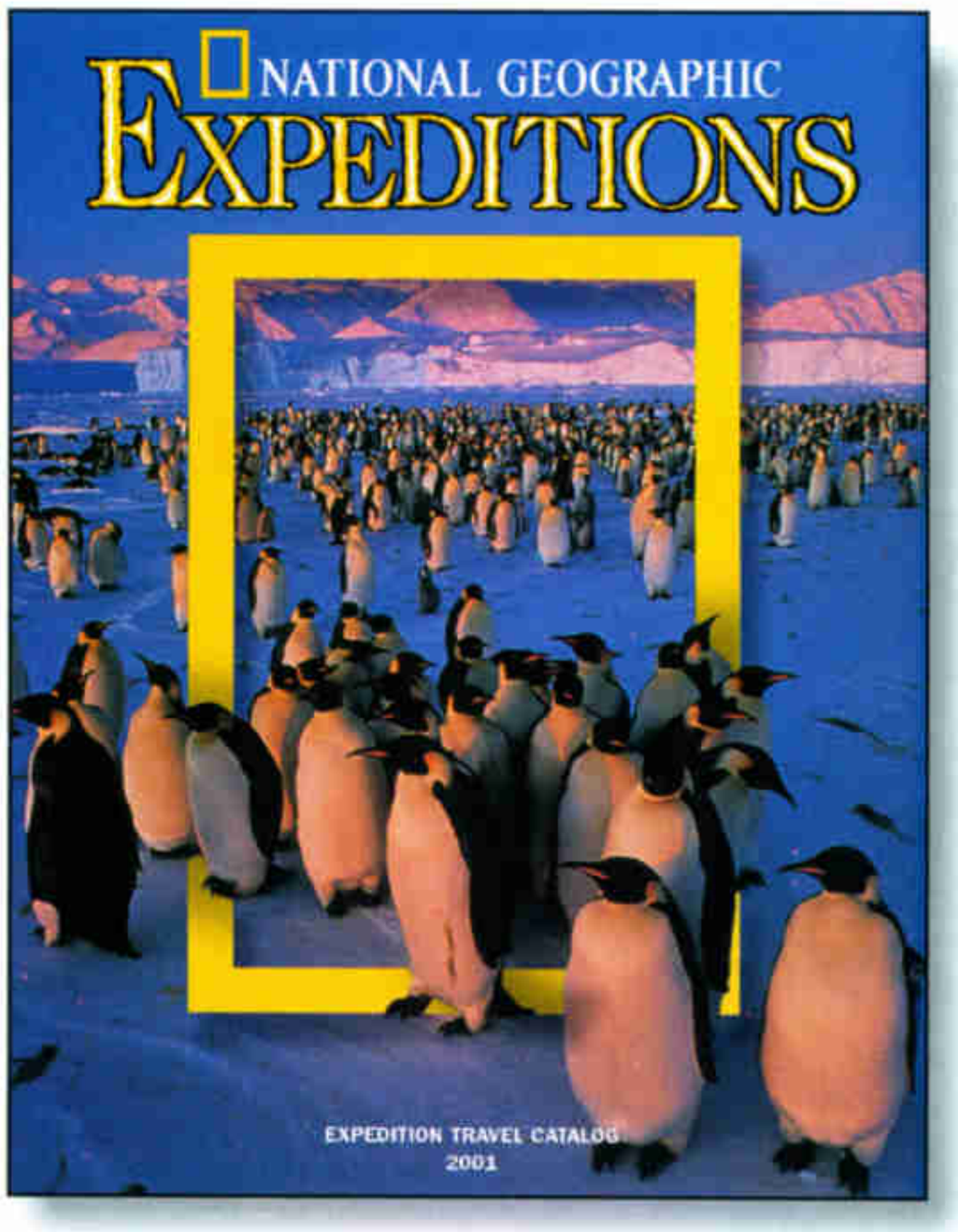

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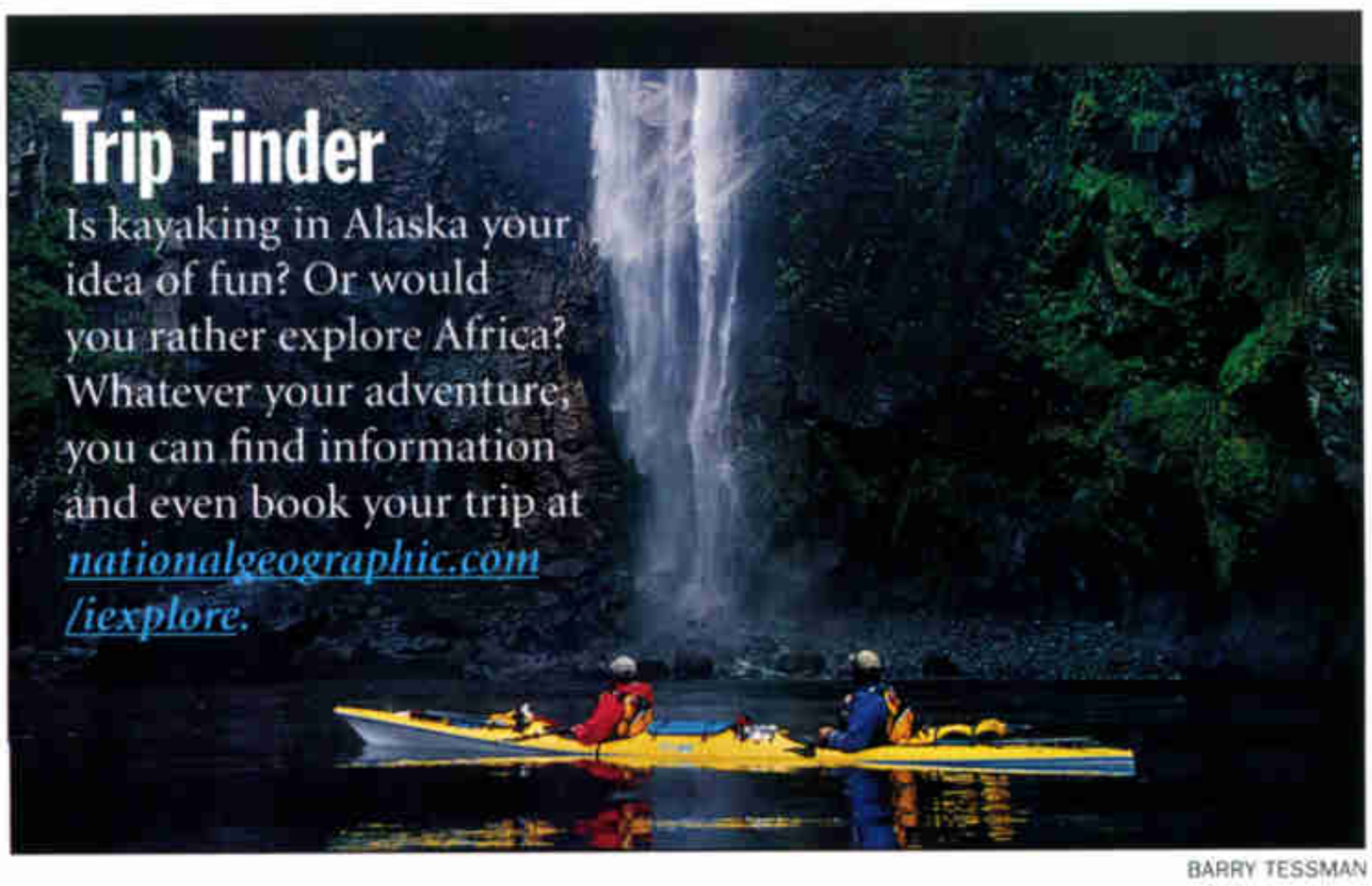

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Hidden China

Passing a cairn draped in Tibetan prayer flags, pilgrims circle snowy peaks in a remote corner of China's Sichuan Province revealed 70 years ago by National Geographic explorer Joseph Rock. A team of climbers retraces Rock's adventurous steps in *High Road to Shangri-La*, an EXPLORER premiere.

NATIONAL ARCHIVES (TOP); ROBERT MacKINLAY

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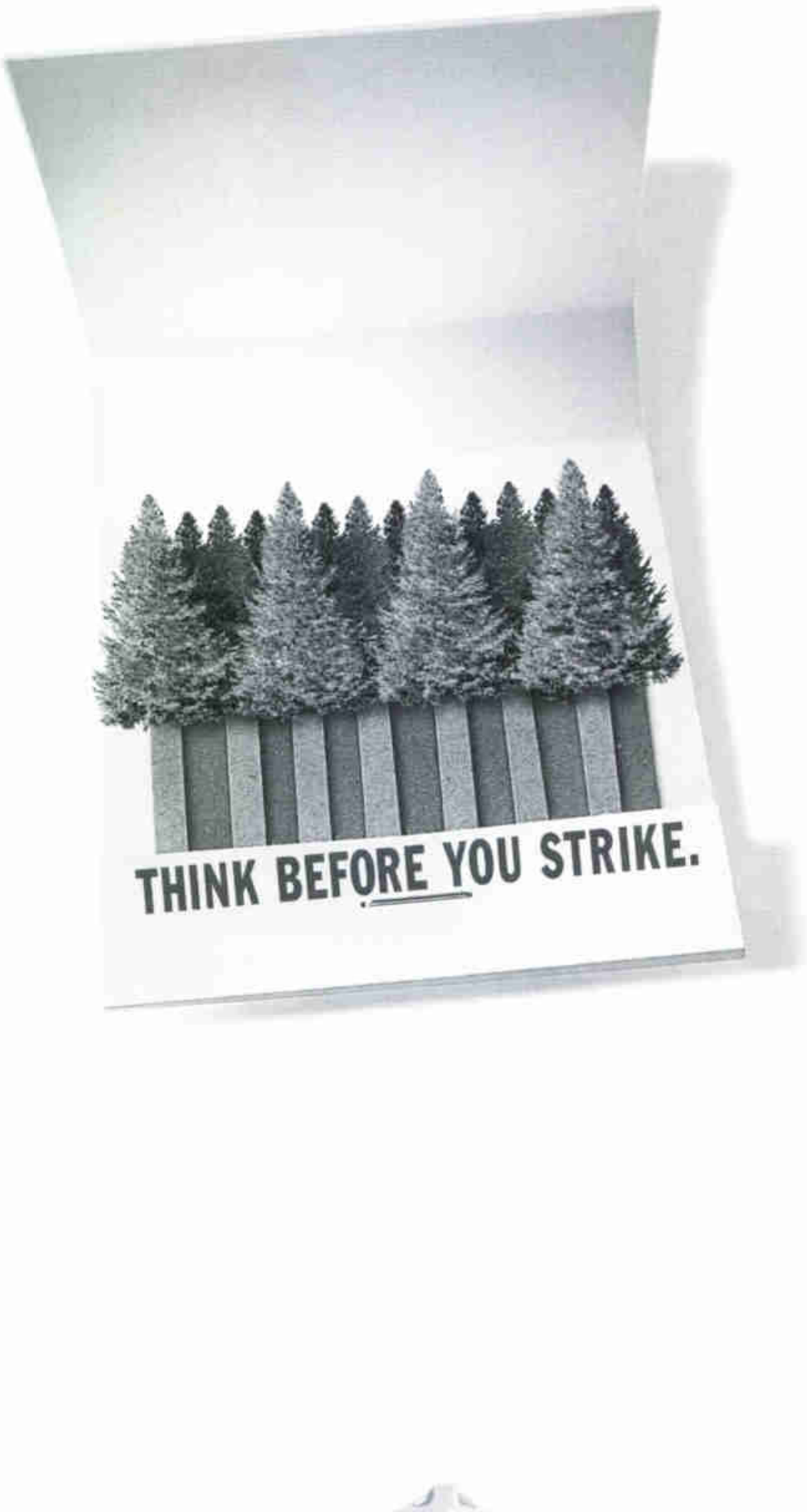

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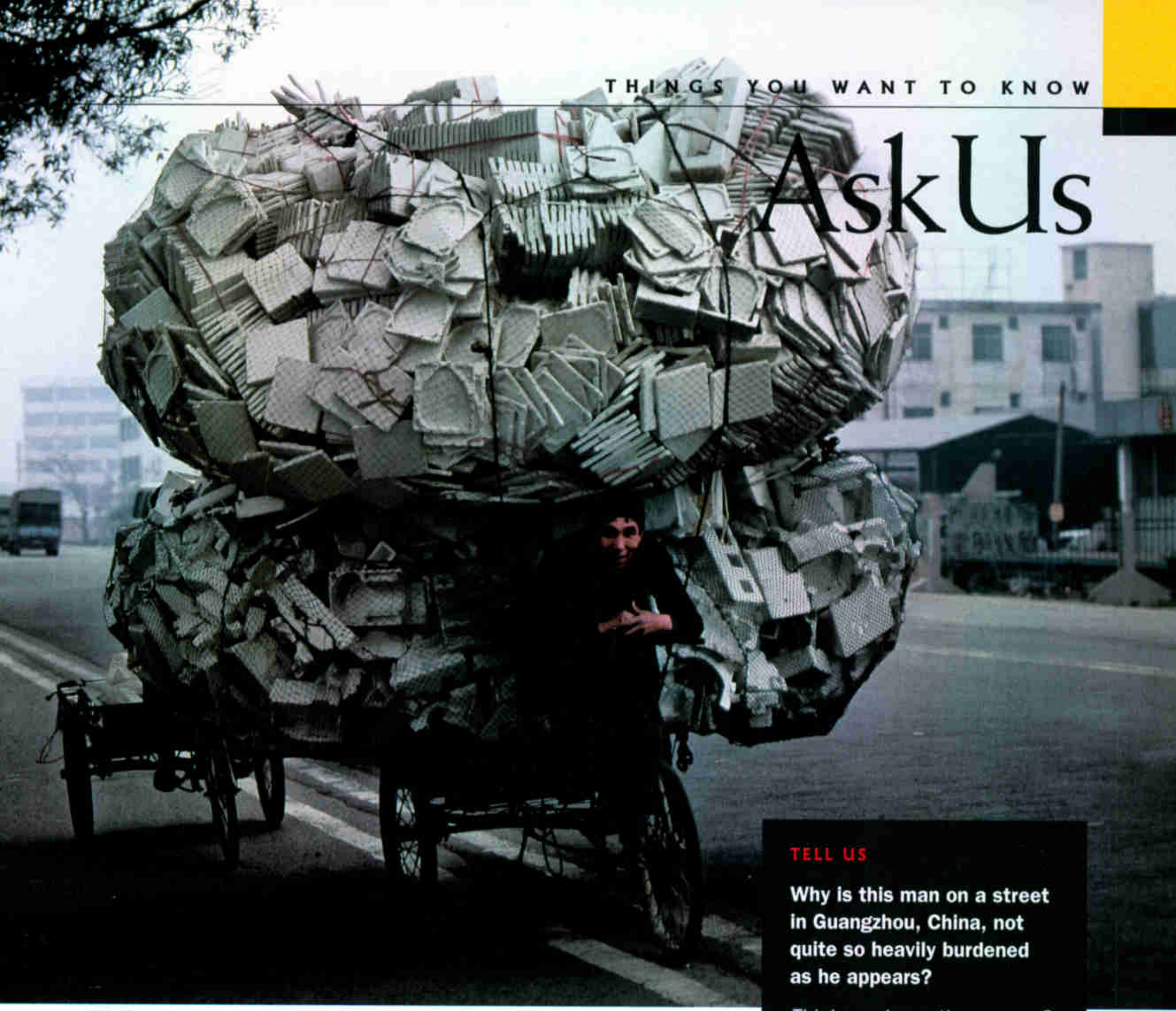


MICHAEL YAMASHITA

TELL US

Why is this man on a street in Guangzhou, China, not quite so heavily burdened as he appears?

Think you know the answer? Go online to national geographic.com/ngm/tellus/0105 and test yourself, or read it here in next month's issue.

April Answer The eggs of a nudibranch, or sea slug, are extruded in the form of wide, brightly colored ribbons often found attached to rocks or pieces of coral on the seafloor. This specimen was photographed off the coast of Sabah in Malaysia.

THE ANSWER PLACE

Our Research Correspondence staff responds to questions from curious readers.

Q What is the origin of the name of the town Saint-Louis-du-Ha! Ha! in Quebec, Canada?

A Canoeing on Lac Témiscouata, early French explorers dead-ended in a small bay, which they called a *haha,* an old French word for barrier. The name stuck to a number of locations nearby, including Saint-Louis-du-Ha! Ha!, named to honor founder Louis Marquis. Later cartographers, who may have taken the word for a proclamation of surprise, added the exclamation marks.

Q How many people have actually walked on the moon?

A Twelve. All were members of the U.S. Apollo Program and all walked on the moon's surface between 1969 and 1972.

Q Are there fish that can walk on land?

A Yes. Several species of fish can "walk" by digging their pectoral fins into the turf, like soldiers on an obstacle course. One of the most prevalent is *Clarias batrachus,* the "walking catfish," which was imported into Florida from Thailand in the 1960s as part of the tropical fish trade. Some of the fish walked away from their holding ponds and kept going. They now number in the millions.

MORE INFORMATION

Send questions to **Ask Us, National Geographic Magazine, PO Box 96095, Washington, DC 20090-6095** or via the Internet to **ngsaskus@nationalgeographic.com**. Include name, address, and daytime phone number.

THE ADVENTURES OF

MARCO POLO

PART I

In the year 1271 Marco Polo, age 17, set out from Venice with his father and uncle on a journey across Asia. Marco's account of his 24-year odyssey would reveal a world never before described. Traveling by caravan, as sculpted on a Venetian wall, left, the Polos followed ancient trade routes through lands that still evoke Marco's amazing finds.

By MIKE EDWARDS
ASSISTANT EDITOR

Photographs by
MICHAEL YAMASHITA

In Xanadu did Kubla Khan
A stately pleasure-dome decree . . .

—SAMUEL TAYLOR COLERIDGE, "KUBLA KHAN"

He revealed little of himself in his widely translated book, The Description of the World, *yet Marco is idealized as a learned explorer on a mosaic in Genoa, Italy. The book influenced Fra Mauro's world map from the 1450s (above), kept at Venice's Marciana Library.*

THE OLD PEOPLE CLAIM that sometimes the palaces and temples reappear, shimmering magically in the morning sun. "I have not seen this myself," said a shepherd named Wei Chang. "But that is what the elders told me." Wei Chang was grazing his flock on mounds that hold the bones of Shangdu, the summer capital that Kublai Khan decreed in the grassland of Inner Mongolia, 200 miles northwest of Beijing. He decreed lavishly, as attested by Shangdu's Mongol name, City of 108 Temples. The Chinese speak of Kublai's "crystal" palace, meaning that it shone brightly.

It was at Shangdu, probably in 1275, that Marco Polo first genuflected before the great Kublai; grandson of the conqueror Genghis Khan, he claimed to be suzerain over an empire that stretched from China to Iraq and Russia.

I entered the ruins as Marco may have entered the shining city, through a gateway in the western wall; defying erosion, the wall's packed earth still rises 12 feet. Within, Marco recorded, was "a vast palace of marble." Indeed, near where Wei Chang's flock grazed, I glimpsed big blocks of white marble, perhaps remains of the crystal palace.

Marco was about 21 years old when he reached Shangdu, accompanying his father, Niccolò, and uncle, Maffeo, merchants of Venice. They had traveled more than 7,500 miles, which took, Marco wrote, "quite three years and a half." Very few Europeans are known to have penetrated deep into Asia before them. And none came close to racking up such a long or far-reaching adventure as the Polos, whose odyssey spanned 24 years and concluded in a homeward sea journey via Sumatra and India.

The only Polo much remembered for this huge accomplishment is, of

Time-weathered waterfront on Venice's busy Grand Canal retains the aura of the Middle Ages when the Polo family, successful traders, set sail toward China for a meeting with

Kublai Khan. Kublai and other descendants of Genghis Khan, founder of the Mongol Empire, controlled much of Asia and made passage safe for intrepid merchants.

course, Marco, who chronicled it in his boldly titled *Description of the World.* The book overflowed with the wealth of Asia—silk, spices, jewels, porcelain—and with place-names unknown in medieval Europe, not only those of China but also Java, Cipangu (Japan), and many more. In time it became one of the great spurs goading Europeans, including another Italian, Columbus, to seek Earth's far corners.

Or did Marco fake the whole thing? A whiff of suspicion has lingered about him ever since he wrote his book, about 1298. After all, he chronicled things that even Venetians, worldly-wise traders, had never seen, such as paper money and a black rock that burned. Even now it is argued that Marco ventured no farther than Constantinople or the Black Sea and cribbed tales from more venturesome Arabs and Persians.

Most scholars who have dissected Marco's work, however, regard him as truthful. Well, mostly truthful. Some of his whoppers may have been invented by the writer who helped Marco set down his story, one Rustichello, an author of tales about chivalrous knights. Marco's work was further distorted by the monks and other scribes who copied and translated it in the 14th century and by printers whose editions began to appear in the 15th. They often amended and deleted as they saw fit, and misspelled and mistranslated to boot, so that today about 150 versions of the text are known. The version thought to be closest to Marco's original now belongs to the Bibliothèque Nationale in Paris.

That's the main one I use. I'm a Marco fan, a solid believer. I've lived with him off and on for four years now, following 6,000 miles of his travels, usually in the company of photographer Mike Yamashita. Like some of the scholars who've studied Marco, I can't believe he gathered so much information and got most of it down in guidebook order while sitting on a curb in Constantinople. He told me where in Iran to look for a hot spring whose

Outward bound, the Polos sailed down the balmy Dalmatian coast, a part of the Venetian trading empire. The hillside town of Korčula (right), on an island off Croatia, claims to be Marco's birthplace, though scholars believe that Venice is more likely.

"Here you will find all the greatest marvels and the great

waters could cure "the itch." In Afghanistan he guided me along an old Silk Road route that threaded formidable mountain ranges. In China I followed his lead across deserts and to great coastal cities. Finally, I traced his long journey home, touching Sumatra, Sri Lanka, and India.

Much that Marco recorded hasn't changed in seven centuries. In southern China I found—as he did—people with tattooed skin and teeth sheathed in gold. "They eat all coarse things," Marco wrote of the Chinese, having seen markets like today's, where dinner writhes, wiggles, croaks, clucks, and barks.

Marco probably would not have made his great journey had it not been for his father and uncle, Niccolò and Maffeo, who already had dared travel deep into the Mongol Empire, perhaps to Shangdu. In 1260, when Marco was six, the elder Polos set out from a merchants' colony in the Crimea to sell jewels on the lower Volga. Six adventurous years later they arrived at Kublai's court.

Marco says the Mongol emperor, much interested in Christianity, asked the brothers to carry a letter to the Pope requesting "as many as a hundred wise men" to spread the Gospel among his subjects. He also wanted oil from the lamp at Jesus' sepulchre in Jerusalem, considered a balm for body and soul, and the brothers promised to return with it.

When at last the Polos got home to Venice in 1269, Niccolò's wife, Marco's mother, was dead. The boy was being raised by a relative. We don't know what education he got, probably some practical merchant's arithmetic plus a lot else on the canals and streets, full of sailors, traders, and prostitutes.

In 1271 Niccolò and Maffeo set out again

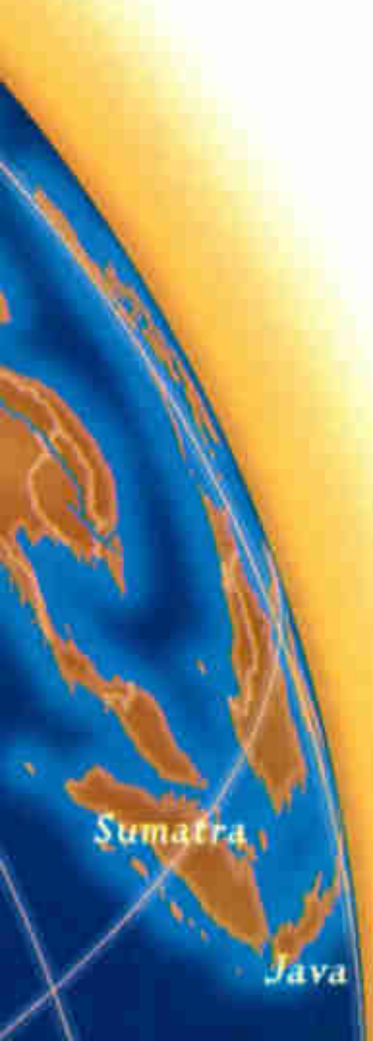
diversities . . . of Persie, and of the Tartars and Indie."

for the East, this time taking Marco, 17. Attempting to fulfill Kublai's requests for wise men and holy oil, they sailed first to Acre in the Holy Land. The oil was obtained easily enough, but they departed for Turkey accompanied by just two friars, all the church would spare. And these soon turned back. In Marco's account this seems not to matter much, suggesting that the Polos were more interested in profit and adventure than in propagating the faith.

No one knows if Marco kept a journal. But his first descriptions sound as if they came from one. Nomads in Turkey were an "ignorant people and have a barbarous language," he wrote scornfully. But in the bazaars were fine carpets and "cloth of crimson silk and other colors very beautiful and rich." Farther east, toward the Caspian Sea, was "a fountain which sends up oil in great abundance," he wrote, becoming the first European to pinpoint a source of petroleum. "It is good to burn, and to anoint the camels for the itch."

I BEGAN FOLLOWING MARCO toward the "sunrising," as he called the east, at Tabriz in the northwestern corner of Iran. We can't be sure what route the Polos took there, for Marco's chapter on that city is sandwiched between chapters on Baghdad, capital of Iraq. He may have visited Baghdad, but more likely he merely heard about it and other parts of Iraq from other travelers; he often reported hearsay.

Tabriz, however, was well-known to contemporary Italian merchants, who coveted the "goods that come there from strange lands," including "precious



Blizzard of shaving cream falls on a Kurdish wedding party in northern Iraq. Marco found the Kurds inhospitable, describing them as a people who "rob the merchants gladly."

Before reaching the Kurds' homeland, the Polos passed near the Caspian Sea, where Marco noted a "fountain which sends up oil," the first European description of a petroleum field.

"It is true that the men of Tauris live by trade and by crafts,

stones . . . found there in great abundance," probably imported from India and Sri Lanka.

Today it is mostly a city of concrete buildings two or three stories high. Earthquakes have knocked down nearly everything old. An exception is the enormous bazaar, with massive brick walls reaching high to clasp in elegant arches. Iran's busiest carpet mart thrives within those walls, attracting European connoisseurs and oil-kingdom sheikhs. "*Yaallah, yaallah!*—With Allah's help!" cry porters in warning as they bore through the crowds. From their pushcarts, rolls of carpet protrude like huge cannon barrels. Spread out, they splash the worn brick floors with lustrous flowers and tendrils. Not far away rows of jewelers' windows suffuse bazaar passageways in a golden glow. All in all, this is a bazaar full of delights and temptations, as it must have been for the Polos.

The travelers would have lodged in the Christian quarter, a neighborhood still known as the Qaleh, or fortress, because until a few decades ago it was separated from the Muslim community by a wall. Wherever he went, Marco reported on religion—whether the people were Saracens (Muslims), idolaters (Buddhists, Taoists), or Christians. In Tabriz the Christians were Armenians, Georgians, and followers of two predominantly Asian sects, the Nestorians and Jacobites. Most have vanished now; the Christian minority has long been in decline. The number leaving accelerated after Iran officially became an Islamic state in 1979.

Still, in the Qaleh I found a small building topped by a cross: the Armenian Church of St. Mary. Inside were a simple altar and portraits of saints painted on the walls. Nothing fancy. A layman told me, "There is a legend that Marco Polo worshiped here"—rather, in an older St. Mary's that fell in an earthquake.

From Tabriz I headed southeast on a highway through rocky peaks. Only

Strong tea fortifies members of the al-Imara clan in one of the last traditional reed buildings in Iraq, a region Marco described but probably did not visit. He seemed to prefer drinks more potent than tea, citing the pleasures of date wine. Marco liked fine muslin too, still a cloth of choice (above right) in Baghdad.

for there are made there many cloths with gold and of silk."

an occasional clutch of poplars relieved the country's thirsty look. Finally the road leveled out on a desert plateau. The Polos also came this way. But instead of striking east, they likely continued south, bound for the Persian Gulf, thinking they might find ships and arrange to sail to China.

Soon they reached the small city of Saveh, where Marco must have practiced his Persian. He says he had conversations about the three Magi, the wise men, Balthazar, Gaspar, and Melchior, who went to Bethlehem to worship the infant Jesus. They repose in Saveh "in three sepulchres very great and beautiful," he wrote, and the bodies, as if mummified, "are still all whole and have hair and beards." True? In Persia it wasn't customary to mummify the dead. And in Marco's time Europeans believed the wise men were interred in Cologne, Germany, placed there in 1164 by Frederick I, ruler of the Holy Roman Empire. Perhaps Marco's collaborator, Rustichello, added the intact bodies in Saveh to make the text more vivid.

Half of Saveh consists of concrete boxes and half of loaf-domed buildings made of soft brick, such as Marco must have seen. I went looking for someone familiar with local history and soon was drinking tea with Professor Ahmad Nemati, who believes Marco's account is at least partly correct. "We are sure the Magi are buried in Saveh," he said. "But the tombs were ruined and nobody knows where they were. The Magi were probably Zoroastrians, who revered fire. That was the principal religion before Islam came from Arabia in the 600s."

In Marco's account, the wise men journey to Bethlehem with gifts—gold, incense, myrrh—and the baby Jesus gives them a stone. It signifies that their faith should be strong, but they misunderstand and toss it into a well. Then "a burning fire came down from heaven and comes quite straight to the well." The Magi realize the fire is holy and take it home, to be kept eternally. And that, Marco concludes, is how fire came to be venerated in Persia.

"Good . . . for the itch," wrote Marco, likely grubby and saddlesore when he reached a hot spring in southern Iran. It could have been Cheshmeh Genu, where some 700 years later

locals still wash and soak in mineral-tinted water. Marco surprised European contemporaries by reporting that the three Magi of Christian fame were buried in the Iranian town of Saveh.

FOR PROTECTION FROM ROBBERS the Polos probably joined a caravan as they started for Yazd, 310 miles to the southeast. In Persia were "many cruel people and murderers," Marco wrote. Europeans who transited this region on horseback in the 19th century said they traveled about 25 miles a day, and this probably was the Polos' average. So the journey from Saveh to Yazd meant about 13 days in the saddle. Even if his body had become accustomed to riding days on end, Marco must have found this stretch of country wearying. There were few towns, little water, and the landscape probably was as monotonous then as it is now—just high desert prickly with thornbush.

No doubt the Polos were glad to see Yazd rising ahead. It was an oasis, thanks to *qanats,* tunnels that brought water from mountains miles away. Wells supply the city now, but dwellings in the old quarter still have openings to qanats. It is a living museum, this old quarter, a maze of mud-walled buildings and zigzagging lanes.

I knocked on a wooden door, old and heavy, and entered the workshop of Ramazan Rezaie. A small man in traditional loose *paejama,* he sat at his ancient loom, sending the shuttle flying across the warp with a resounding *thwack!* A bedcover was slowly materializing from silk threads of green, red, and yellow.

"Many cloths of silk which are called Iasdi are made, which the merchants carry them to many parts to make their profit," Marco wrote. When I told Rezaie that, he stopped weaving and offered tea. "I made

"The towns . . . have great abundance of all things good and fine.

yazdi 45 years ago," he said. "It was a heavy cloth. Sometimes it was decorated with birds or other designs."

Now 70, Rezaie tells me he is Yazd's last hand weaver. "No young people come to ask me to teach them," he said. "They say the work is boring." But not to him. "I keep doing this because I love it." He finished his tea and went back to the loom. "And my work is still improving," he added proudly. The shuttle's *thwack* reverberated again as I went out.

Like the Polos I continued to Kerman. It was night, and the city spread across the desert like an incandescent lake. Morning revealed rows of new buildings, for Kerman, a regional center, was booming. New streets sliced through ancient walls, cleaving domed roofs.

But in Rayen, an hour's drive to the south, Marco's era reemerged. Forges blazed in small workshops, and walls echoed the strike of metal on metal. Smiths showed me their wares: knives, cleavers, tongs, scissors, all fashioned by hand. Sometimes a master smith produces a sword.

Perhaps Marco was thinking of Rayen, a metalworking center for uncounted centuries, when he wrote that around Kerman men made swords and armor. The province had "veins of steel," he declared, as if steel came from its own ore, not from iron's. The mines in Rayen's vicinity no longer produce. "But if Allah creates you," said a master blademaker, "he will provide for you." What is provided today is steel from junked cars.

The road south from Kerman climbed into mountains, then plunged 5,000

feet to a hot plain. I went down, twisting and turning, on a smooth highway. Marco's descent took two days against my two hours.

Then I followed a trickle of a river, the Halil, until I found a stretch of rumpled earth flecked with bits of pottery and brick. I believe this was once Qamadin, a trading town where the route bringing pepper and other spices from India joined the highway coming up from the gulf. Invaders had "ruined it several times," Marco wrote.

Finally the Polos were in the port of Hormuz. Marco breathlessly cataloged the goods there: "spiceries and precious stones and pearls and cloth of silk and of gold and elephant tusks and many other wares." Alas, the Hormuz of the 13th century no longer exists. Its harbor long ago silted up, and the place is now known as Minab, or "blue water," as if in memory of its seafaring era.

Markets, workshops, mines, and rest stops, like a bathhouse (left) in Kerman, Iran, all caught the attention of Marco, whose book reads in part like a merchant's travel guide. Marco also had an eye for sporting pursuits, extolling in Persia (modern Iran) the spirited "chase of animals."

The Polos probably decided to go to China by sea after meeting Persian traders who had made the trip. The route was well established: to India, then to Zaiton or Quinsai in China. Perhaps they thought it would be easier or quicker than the overland journey. But would it be safer? "Their ships are very bad, and many of them are lost because they are not nailed with iron pins," Marco wrote. Though steel could be had in Kerman, boatbuilders chose not to use it; maybe it cost too much. Rather, hull planks were sewn in place with "thread which is made of the husks of nuts of Indie."

Ship planking sewn with coconut fiber? Could there have been such a thing? "Ten or twenty years ago I saw small fishing boats with tied planks," answered a fisherman in Bandar-e Abbas, Iran's chief port. Several other men also remembered such craft.

"It is great danger to sail in those ships," Marco concluded. And so the Polos backtracked toward Kerman to continue eastward by land. Traveling south to Hormuz had added at least 800 miles and perhaps 35 days of riding to their journey.

People all worship Mahomet . . . women there are beautiful."

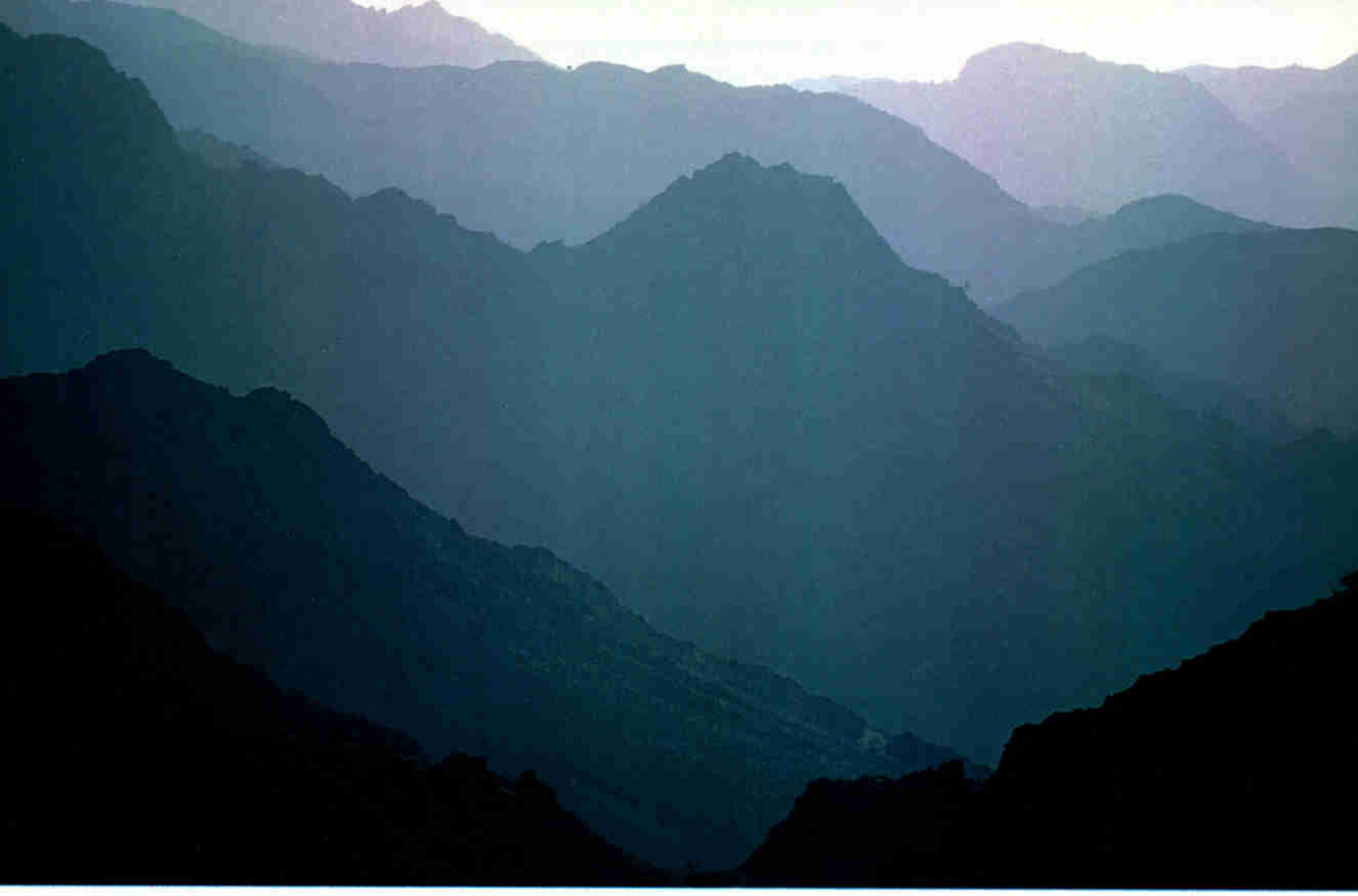
Before departing the coast, I took a bath. Whole families come to Cheshmeh Genu, a big hot spring. Men go to one walled-in pool, women to another, for Muslim Iran requires separate bathing. The smell of rotten eggs was powerful as I slipped into the water, which was vividly green, telegraphing the presence of copper in addition to sulfur. The water was a comforting 85°F. Marco said such baths were "good for many diseases and for the itch." Of the latter, after months in the saddle, he probably had considerable.

IN KERMAN THE POLOS probably joined another caravan and traded their horses for camels, better suited for the arduous journey that lay ahead, across the Dasht-e Lut, the Desert of Emptiness. They would have to carry food for at least eight days, so I imagine them loading pack animals with bread, dried fruit, salted meat, and hard cheese. Plus many goatskins filled with water, for the few desert springs were toxic.

Ali Amiri, a professor of geology, offered to be my guide toward that wasteland. "First," he counseled, "we should go to the police." Smugglers bringing drugs from Afghanistan and Pakistan use the roads in eastern Iran, he reminded me. They had taken several European travelers hostage while demanding the release of their own men captured by the police.

At the desert's edge I checked in at a police post. And for the rest of the day my SUV was escorted by a truck carrying five armed men.

Ahead, the terrain grew more hostile. The desert was almost bare of plants



Climate extremes assaulted Marco as he neared the Persian Gulf in Iran. Crossing 8,000-foot passes (above) exposed him to cold "one hardly escapes by wearing many clothes." He descended to a "great heat," taking notice of black-skinned Muslims, like a masked woman in Minab.

and finally dissolved, far off, in a gray haze. On one side rose cliffs rimmed with red rock. Banks of sand were plastered against the cliffs. "From the windstorms," Amiri said. People in this part of Iran speak of the "hundred days' wind" that blows as winter ends. "If you are in it, you can't see at all," Amiri added. "It picks up very fine sand. The roads disappear for days."

Marco wrote of being enveloped in such a darkness on the way to Hormuz, though Iranian scholars say it must have been in the Dasht-e Lut. Marco thought the darkness was not the consequence of suspended sand but something magically conjured by robbers. "They make the whole day become dark by their enchantments," he wrote. Then they attack—"they kill all the old, and the young they take and sell them for serfs and for slaves."

In a third-person account possibly supplied by Rustichello, the text declares, "Master Marc himself was as good as taken by that people." It must have been the scariest episode of his life, if it happened. The Polos, adds the book, escaped to the safety of a village, but others in the caravan "were taken and were sold, and some were killed."

I was mindful of these words as I regarded my rifle-toting escort. Relations between my country and Iran had been sour for years. Would they really protect an American? A burly sergeant named Reza assured me: "If the smugglers try to kidnap you, they'll have to kill us first." I decided I believed him.

PASSING INTO what is now Afghanistan in about 1273, Marco came upon the rubble of Balkh, which had once been numbered among the world's greatest cities—until Genghis Khan slaughtered the inhabitants during his Central Asian rampage in the 1220s. Marco chronicled the sight of "palaces and many beautiful houses of marble . . . destroyed and ruined."

"Ruined" describes much of Afghanistan today, after more than 20 years of war. Afghan *mujahidin,* holy warriors, valiantly resisted the invading forces

"Ramparts of earth high and thick" safeguarded towns on Marco's route through the bandit-infested southern highlands of Iran. Nowadays the sturdy clay walls encircling

the medieval citadel of Bam serve mainly to repel harsh rays of sunlight. Marco reported that robbers attacked his caravan in Iran, capturing or killing most of his party.

of the Soviet Union in 1979 and forced them to withdraw ten years later. But then the Afghans began fighting among themselves for control. Today most of Afghanistan is in the hands of the Taliban, or "religious students," dominated by ultraconservative leaders who effectively forbid education for women and sanction death by stoning for adulterers—while allowing their territory to become the world's biggest supplier of opium.

I had hoped to follow Marco's route to Balkh's ruins, but the Taliban refused me a visa. However, I was welcomed by their enemy, a more temperate regime whose military, called the Northern Alliance, clings to the northeastern part of Afghanistan. As a government the regime barely breathes; it can't repair the horrible roads, and its unit of money, the afghani, trades at a ridiculous 85,000 to a dollar. It is mostly an agglomeration of warriors who, though outnumbered, have survived Taliban onslaughts year after year.

Fishermen rise with the sun to launch a boat from the Iranian port of Bandar-e Abbas. Marco, apparently hoping to sail to China from nearby Hormuz, was appalled at boats held together with coconut fiber and wood pegs. Stoically he turned back and went overland across Persia.

An autumn morning found photographer Mike Yamashita and me at an airport in the former Soviet republic of Tajikistan, Afghanistan's northern neighbor, through which the Northern Alliance receives supplies from governments, such as Russia's, that fear the spread of Taliban fundamentalism. We were going to hitch a ride on a battered old helicopter that was being loaded with uniforms and radio batteries. These were destined for fighters in the Panjshir Valley, the most important bastion of the alliance, on the southern flank of the Hindu Kush range. The Panjshir Valley is far south of Marco's route, but at least the chopper would get us into Afghanistan.

The pilot, Wali, said we'd fly low. "The Taliban have radar near our route," he explained. "If we stay in the valleys, maybe they won't spot us and send a fighter plane." Taking off, we rumbled over the silvery braids of the Amu Darya, or Oxus, then burrowed into the Hindu Kush, threading between 12,000-foot peaks. After an hour we dropped to a pasture beside the Panjshir's tumbling green water. The rusted hulks of Soviet tanks littered the riverbank, testifying to intense fighting in the 1980s as the Soviets tried to win control of the valley.

Now the valley overflowed with refugees; in the town of Bazarak they filled the school and the mosque and camped in a copse of mulberry trees. Most had fled from fighting in the Shamali Plain, 50 miles away. "Is food coming?" people asked, mistaking me for an official of the United Nations food agency.

"For one person we get one piece of bread a day—nothing more," said a father of ten. His wife drew her *chadri* over her face when I approached their

blanket-walled hut. Babies wailed. "The Taliban burned our houses," said the man, Nazar Mohammad. "They cut down the fruit trees; they destroyed the irrigation canals."

Both sides tell of cruelties inflicted by the other. Everyone agrees that the Afghans are weary of war—how could they not be? But Afghanistan's long nightmare continues seemingly without end.

A FEW DAYS LATER Mike and I hitched another valley-hugging helicopter ride, landing in a pasture near the city of Taloqan, precisely on Marco's route.

"Taican," as Marco spelled it, lay "in a very beautiful country." Maybe Marco saw what I saw: a valley where rice fields spread a golden patina and stately poplars limned long irrigation canals. There may not be a lovelier scene in all Afghanistan.

But in Taloqan itself, bombs were falling. Almost every day a Taliban jet swept over the city. Thousands of people had fled, and so did we, hiring a battered pickup truck to resume our journey toward the sunrise.

The mountains along this link in the ancient network of Silk Roads were "all salt," Marco wrote—an exaggeration, though the deposits are large even today. As we lurched along, skirting tank carcasses, we met donkey teams taking blocks of salt to distant villages. "We sell it for money or for wheat," said a teamster. "On the scale we put salt on one side and wheat on the other—they are equal in value." A *ser* of either, about 15 pounds, fetched 60 cents.

Late at night we reached Feyzabad, the main city of Badakhshan Province. It was silent and dark; Feyzabad's decrepit generating plant supplied electricity for only an hour or so a day, if at all. We knocked on the door of an office of Doctors Without Borders, the international medical aid organization, and soon were spreading our sleeping bags in the office parlor. On other nights Northern Alliance commanders or UN workers put us up.

In the Feyzabad bazaar the Polos might have stayed at Khalid Mohammad's caravansary, an aged timber building. The charge today: animals, 12 cents; humans, nothing. "If the roads were good and there was no war, there would be trucks here, not animals," the owner said. "And I would build a nice hotel." A few days before, a 40-animal caravan had arrived after a 12-day trek from the far north. The caravan brought dried fruit and sheepskins and left with shoes and cloth that other caravans had brought up from Pakistan.

Niccolò and Maffeo must have passed many hours in Badakhshan's bazaars, for here were lapis lazuli, "the finest azure . . . in the world," Marco

Lush pasture in the foothills of the Pamir mountains in northern Afghanistan served as a campsite for generations of travelers on the trade route to China. Marco passed this way in the

Badakhshan region, where he may have spent a year recovering from an illness, possibly malaria. The wait gave him time to admire gem mines, horses, and women in trousers.

"One finds no dwelling because the people are all fled to the

wrote, and ruby-like spinels "of great value." These had been mined for centuries and were highly prized.

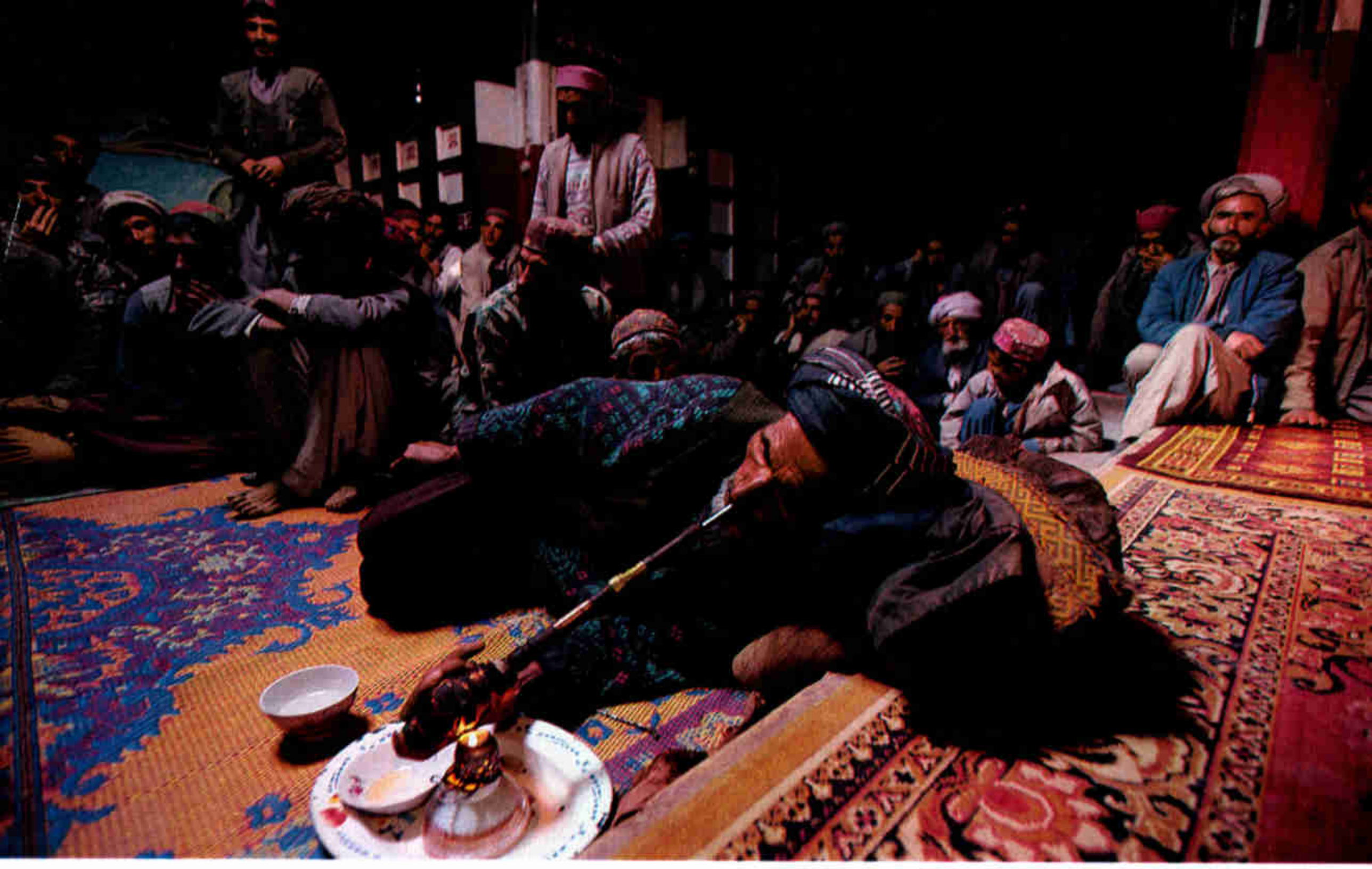
I found no spinels in Feyzabad; the mines that probably produced them are no longer worked. "But lapis I have," said a shopkeeper named Hafizullah. He had piles of it. "The best quality," he said, proffering a baseball-size piece. It was deep blue and flecked with goldlike pyrite. "Only $30," he said. That's a fraction of what it cost before Northern Alliance commanders began digging out tons of lapis every year to raise money for the war.

BY NOW, I ESTIMATE, the Polos had traveled at least 5,000 miles. Marco speaks of delays on account of rain, snow, and swollen rivers, explaining in part why it took three and a half years to reach China. They may also have lost time because Marco was ill. One version of his book says that in Badakhshan Marco "remained sick for about a year." What might his illness have been? Malaria is a good guess. If that's what it was, it finally ran its course, for once more the Polos were on their way, following a road that went "upwards by a river."

That would be the Warduj, boiling through rapids below the track we followed. We were in another battered pickup truck, driven by a fellow named Agha. What I most remember about Agha is the smile perpetually creasing his beard, even as he forced his precious truck over rocks as if it were invincible. Every half hour or so he stopped to refill the radiator.

At about 9,000 feet the Warduj became a gentle stream braided across a wide valley of lush grass. Over the centuries thousands of caravans have camped in that idyllic place, and I have no doubt that the Polos stayed a couple of days to rest their animals. Then they rode across a low rise to the Pyandzh, as the upper Amu Darya is known, and followed that river into the valley that Marco called Vocan.

The "valiant" fighting spirit Marco noted in Afghanistan lives on. Ahmad Shah Massoud of the Northern Alliance leads officers in worship (above) and in war against Taliban forces. In the Wakhan Valley, an elder surrenders to opium (above right), now officially banned.



mountains in strongholds for fear . . . of the armies."

We too entered the Wakhan, the long finger of Afghanistan that reaches across to China, on a road tracking that rushing stream. The valley floor, 9,000 feet high, was a few miles wide at most. All around rose mountains crowned by glaciers.

At one stop to let Agha water his truck, an elderly man strode toward us in sheepskin boots. Any vehicle is a novelty to the Wakhi. "We might not see one for three or four months," Jamil Khan said. He remembered caravans passing through the valley. "Some of them came from western Afghanistan and some from Kabul," he said. "They took dried fruits to China or animal skins. The caravans from China carried silk cloth and dishes."

But after the communists took over China in 1949, they closed the Wakhan route. Though it had not been traveled as heavily as the northern Silk Road via Bukhara and Samarqand, the Wakhan route had served for perhaps 2,000 years as a highway of trade and cultural exchange, facilitating the spread of Buddhism, Islam, and maybe even Christianity.

We plowed on. The road vanished under fans of avalanched talus. Agha gripped the wheel with both hands, twisting to avoid the biggest rocks. In late afternoon we glimpsed ahead a pale fringe of poplars and willows, and then the scattered houses of Qaleh-ye Panjeh.

Beside the village a crowd appeared, but not to welcome us. The people clustered about a slender man of benign countenance, kissing his hand. Sayed Mohammad Ismail, the Wakhi's religious leader, was just returning after a two-week horseback trip to mountain villages. The Wakhi addressed him as Shah Sahib—king. "But I am not a political person," he told me later. "There is a commander in the Wakhan for that. I try to take care of the spiritual life." His flock, numbingly isolated, is without electricity, telephone, or even a bazaar. "But what can we do about this?" he asked—a question that today in Afghanistan has no answer.

Flash of green signals an oasis of cropland in arid highlands near Taloqan, Afghanistan. A mud-walled village clings to the hillside. Such villages were welcome sights for the Polos,

places for replenishing water and food. Marco rarely shows fear or anxiety in his book, even when remembering the Afghan wilderness with its "wild beasts"—lions and wolves.

In my mind's eye I see the Polos haggling with the Wakhi for pack animals—yaks, perhaps, because they are good climbers and tolerant of cold—and loading them with supplies. The most arduous part of their journey lay ahead in the towering mountains north of Shah Sahib's village.

The straight-line distance across these mountains to the city of Kashgar, in what is now China, is about 250 miles. By Marco's account the trip took nearly two months. If that's true, the Polos must have had to wait out blizzards or make long detours to avoid avalanches or crevassed snowfields. It's possible they traveled in winter, for Marco says that in the mountains "flying birds there are none."

They passed into a mountainous realm that "they say . . . is the highest place in the world," Marco recorded, and spent 12 days crossing a plateau "called Pamier"—the first mention by a European of the great Central Asian mountain range, indeed known today as "the roof of the world." Their trail topped 15,000 feet. "Fire is not so bright" there, Marco wrote, and "things are not well cooked." He attributed the weak flames to the cold; the oxygen-thin air was the reason, of course.

In the mountains were "great multitudes of wild sheep which are very large, for they have the horns quite six palms." Lucky is the man who today can spot even one *Ovis ammon polii*, the Marco Polo sheep. Their numbers shrank over the centuries as more herders invaded their pastures and as hunters began to shoot them with long-distance rifles. "I am 43 years old, and I have never seen one," Shah Sahib told me.

We said good-bye to Shah Sahib and began to backtrack out of the Wakhan. An hour later I heard a *bang* as Agha tried to avoid a big rock. He spun the wheel, but we just wobbled forward. "No steering," he said, smiling as always. Underneath, we found that a connecting arm had broken loose from the steering rod. "I can fix it," Agha said gamely, fetching rope. He tied the pieces together and we started again. But after a mile the rope stretched and the truck began to wander. Wire wouldn't hold either. A farmer gave us a rope of braided horsehair, which was tough stuff—for a few miles.

As afternoon wore on, the emptiness of the Wakhan made me uneasy. No village was in sight and, of course, no car or truck. We were 50 miles from Eshkashem, the first town outside the valley. It would be a long hike.

"Let me work on this," Mike Yamashita said when the steering failed once more. He cut the nylon straps from his backpack—about three feet put together—and tightly bound the two parts in a fat bandage. It actually held tight for a few miles. When it slipped, we rebandaged.

Limping along like this, we came after dark to a few houses. Though the villagers had seen our headlights, we must have seemed like invaders from Mars. Yet they made a place for us to sleep and even brought tea. Late the next day we wobbled into Eshkashem, where Agha could get repairs.

That unhappy episode compelled me to acknowledge that in some ways Marco was a more efficient traveler than I. If his horse went lame, he surely had a spare mount. A crippled horse would have furnished Marco's dinner, whereas we could not eat our truck.

As Marco ascended the Pamirs, he must have been on the roof of the world not only physically but also in spirit. Neither swollen rivers nor bandits, perhaps not even illness, had thwarted his journey. Beyond the Pamirs lay a desert, and beyond that awaited China—and 17 years of adventure. □

Civil war appears to have swept the Afghan town of Feyzabad back to Marco Polo's time. People travel on foot, women cover their faces, and hostels are dark and cold. The Polos, now in the third year of their journey, left this region to cross the lofty Central Asian mountains. Next stop: China.

MORE ON OUR WEBSITE

Check out more of photographer Mike Yamashita's images—and get some photo tips—at **nationalgeographic.com/ngm/0105**.

Locking eyes with a jaguar just 20 feet away, photographer Steve Winter found no comfort in the Guarani Indians' description of the cat as a beast that kills with one leap.

Phantom of the Night

The largest cat in the Western Hemisphere is also the least studied of the great cats. Scientists are gaining ground on the elusive jaguar, but it remains a moving target.

By Douglas H. Chadwick
Photographs by Steve Winter

A single gas lantern hissed above the camp table, orbited by beetles and moths. Shadows cast by their wings danced across the face of the hunter, Tony Rivera. "The local people believe every mountain has its jaguar," he said over the night sounds of Mexico's Yucatán Peninsula. "There is an old song that goes: 'I would like to be the jaguar of your mountains / And take you to my dark cave. / Open your chest there / And see if you have a heart.'"

Once when Maya called jaguars from the trees, the aim was to kill them. Now scientists tap the skills of those hunters to track the shy cats. Findings have helped prompt an increase in protected habitat. In Belize, site of the world's first jaguar preserve, a camera trap catches a male patrolling his territory.

Early the next morning as the darkness unraveled, Rivera joined a half dozen hounds, their handlers, and a couple of trackers to scout for fresh jaguar sign. They found paw prints leading away from the torn carcass of one of the goats they kept tethered in the hills to lure the big cats. The dogs were loosed on the scent, and the fastest men sprinted off after them. I came behind with a second party at a pace between a forced march and a jog, snagging on thorny vines and hoping none of the half-seen root shapes were snakes.

On all sides stretched the Calakmul Biosphere Reserve, its 1.8 million remote acres connected to more backcountry in the Yucatán, neighboring Belize, and Guatemala's Maya Biosphere Reserve. These areas are part of the largest swath of tropical forest left in the Americas north of the Amazon-Orinoco region. They also take in much of the former territory of the Maya civilization, whose golden age lasted from the third to tenth centuries A.D. and was marked by the building of grand pyramids and ceremonies of human sacrifice.

Weathered stones from Maya ruins appeared along our route as the light and birdsong grew stronger. Underfoot, legions of leafcutter ants freighted goods along their well-kept highways to underground nests—an enduring insect version of empire. We passed husks of nine-banded armadillos. The tracker beside me said jaguars had eaten them. He pointed out signs of white-tailed deer, brocket deer, collared peccaries, and tapirs, all jaguar food as well.

Finally the shouts and barking grew fixed in one place. Wiping away sweat, spiderwebs, and ticks, I struggled around a palm thicket and gazed up to find a 130-pound male jaguar high in the branches of a tree. Where the sun reached through the leaves, the animal's coat glowed like gold ore and its eyes were green fire. A Kayapó Indian near the headwaters of Brazil's Xingu River once told me that jaguars are shamans, but the creature above seemed more like a seriously pumped-up leopard.

Third largest in the feline family after tigers and lions, jaguars, *Panthera onca*, are found only in the New World and are its biggest cats. Their range runs from northern Argentina into northern Mexico. What was a broad, continuous range is getting thinner and beginning to tear like a rug trod by too many people. Today jaguars are considered threatened, although

local enclaves appear to be holding up rather well. Scientists and governments are working to shore up the species now, while it still has a good chance to survive.

"The jaguar is a powerful animal in its own right," said Alan Rabinowitz, who carried out key research on the cats in Belize and helped formulate an international strategy for their protection through the U.S.-based Wildlife Conservation Society. "Because it is the kind of symbol that can generate interest and funding, the jaguar has the power to conserve enormous landscapes filled with biological diversity."

For me, intent on learning about the jaguar's natural history and future survival, the expedition to Calakmul was a chance to see my first

Dead Ends

Arrayed on the roots of a fallen tree, a year's take of alleged cattle-killing jaguars from Brazilian ranches testifies to the cat's biggest challenge: sharing the land with humans. Many ranchers shoot on sight, preferring to break unenforced local laws rather than risk losing livestock. A mid-1970s international agreement ended the legal trading of jaguar pelts (left).

Dwindling Habitat

Though jaguars have lost two-thirds of their original range in Mexico and Central America and one-third in South America, they are less threatened than most big cats. They still have strongholds in the Amazon Basin and the Pantanal (below)—a vast wetland shared by Brazil, Bolivia, and Paraguay. Protected areas exist throughout the jaguar's range, but many of these nature reserves are small and isolated. A key goal: creating greenbelts to link scattered refuges.

one in the wild. For Rivera it was another day at the office. He had killed at least a hundred jaguars, both for sport and to control livestock raiders.

In 1987 Mexico finally joined other countries that had put a stop to the taking of jaguars. A decade later Rivera was hired for an ecology study conducted by the National Autonomous University of Mexico, a private group known as United for Conservation, and other partners, and guided sportsmen willing to pay $5,000 each to shoot jaguars with drug-laden darts. Once downed, the animals were fitted with radio collars.

But at the moment, instead of catch-and-release safari hunters, Rivera was with several researchers who wanted to observe him put another jaguar on the airwaves. A dart zinged into the male's rump. The sting spurred the cat to climb down. It reached the ground and bounded away, hounds in full cry at its heels. With an immobilizing chemical coursing through its bloodstream, we should have found this animal sprawled out within minutes. Instead, we encountered only trampled plants where it had spun to swipe at the pursuing pack. The drug dose may have been too light. Tracks led on to the mouth of a deep limestone cavern.

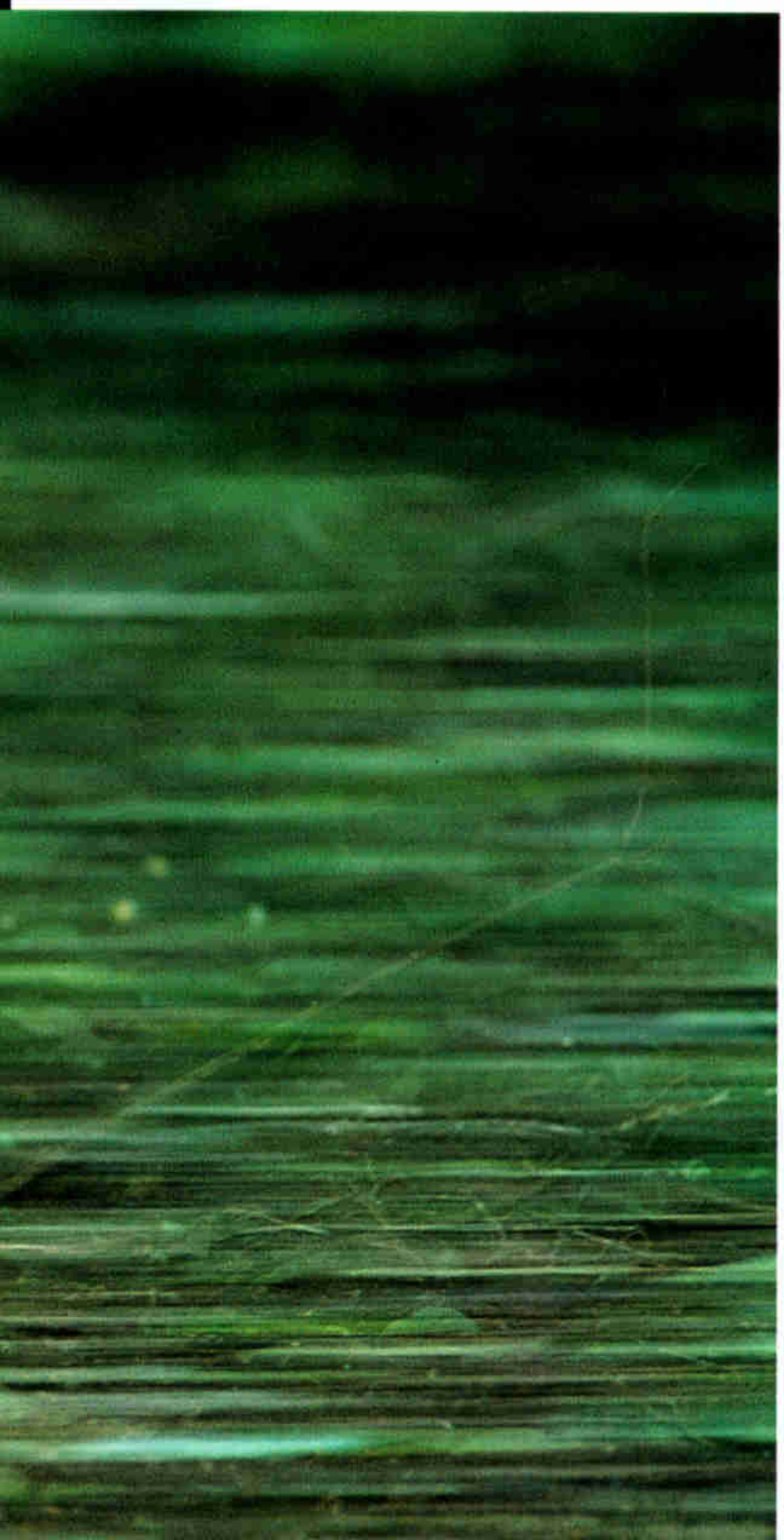
Enter my secret cave, where I wait stung and angry. Come, you men with your modern devices, and let me see if you have a heart. . . .

On the Run

A tree makes a safe haven for a jaguar in Mexico's Calakmul Biosphere Reserve. Outside the reserve trees fall as slash-and-burn agriculture advances. In protected areas jaguars still subsist on relatively large prey like peccaries (below), but in many places the cats must compete for such prizes with people. Underfed jaguars are more likely to attack livestock.

Rivera and Javier Díaz, a lead tracker, probed the echoing darkness a short way and turned back shaking their heads. "*Se lo tragó la tierra,*" Díaz said, "the earth swallowed him."

Jaguars have been intertwined with human fears and yearnings for a long time. The art of the Olmec culture, which rose to prominence in Mesoamerica around 1200 B.C., was suffused with human-jaguar figures sometimes interpreted as were-jaguars, akin to werewolves. After the Maya took over, images of the jaguar, *balam,* believed to be the embodiment of the night sun under the earth, kept watch from tombs, temples, and thrones. Nobles dressed in the big cats' yellow pelts, and rulers such as Smoke Jaguar assumed the jungle lord's name.



The neighboring Aztec had jaguar societies, a warrior elite called the Jaguar Knights, and, carrying on the tradition of human sacrifice, jaguar-headed altars to receive the still-beating hearts of victims.

The word "jaguar" is from Amazonia, where Guaraní Indians spoke of a beast that kills with one leap, *yaguara.* It often takes prey that way, delivering a bite through the skull or neck rather than strangling with a throat hold like most large cats do. *El tigre,* as Spanish speakers call the jaguar, is Latin America's most powerful predator, and it gets bigger going south; some males stretch eight feet from nose to tail tip and weigh more than 300 pounds. Corner or wound one, or harass a mother with cubs, and it might perform quick surgery on your sorry hide. Otherwise, despite all the legends and symbolic art, jaguar attacks on humans are rare.

Not only do jaguars shy from people, they are largely solitary, roam mainly between sunset and sunrise, and prefer thick habitats like lowland forests, riverside brush, and swamps. As a result, our understanding of their day-to-day activities remains awfully sketchy for such charismatic cats. They are an animal version of superstars with jealously guarded private lives, a source of endless gossip but few facts.

Meaningful counts being scarce as ice water in steaming frontiers, no one has a clue as to how many jaguars there really are—maybe hundreds, perhaps thousands. A small proportion of jaguars are melanistic, brownish to pure black. In Venezuela you hear of *tigres mariposos,* or butterfly tigers, whose rosettes of black spots are delicate ellipses in the shape of paired wings, making these jaguars appear lighter than usual. What sighting records of every kind make clear is that jaguars' habitats are rapidly shrinking; the species' range has decreased by more than a third in South America and at least two-thirds in Mexico and Central America.

The colonists came with new livestock and firepower and assigned jaguars the role of foes to be cleansed from the ever expanding forefront of settlement. Plenty existed apart until the mid-1900s, when demand for coats of dappled cat fur surged. Prices kept rising as men across Latin America headed into the wilderness to seek their fortune in jaguars and three smaller tropical felines: ocelots, margays, and oncillas. Between 1946 and 1966 Iquitos, Peru,

shipped out 12,700 jaguar pelts. Brazil was selling more than 6,000 a year through the latter part of the 1960s. Between 1968 and 1970, the U.S. alone imported 31,104. Jaguar populations plummeted until an international agreement to stop trade in most cat pelts took effect in the mid-1970s.

Today, the jaguar is officially protected in all but a few countries but faces widespread illegal killing linked to habitat loss and conflicts with livestock. It's a familiar story for most large cats, from tigers to clouded leopards to Iberian lynx, and for major carnivores in general.

There is room for optimism wherever wildlands persist. The opulent green mansions of Amazonia are the species' ultimate stronghold. However, jaguars grow heftier, thrive at higher densities, and are more visible in a basin that extends through the Brazilian states of Mato Grosso and Mato Grosso do Sul on into portions of Bolivia and Paraguay. This is the Pantanal. During the dry months it is a sea of lush grass with gallery forests outlining tributaries of the Paraguay River. Then summer rains blow in, streams overflow, and the place becomes a 55,000-square-mile marsh soaking amid wayward channels and shallow lakes.

Piranhas love the setting. In parts of the Pantanal, some say one in five jaguars has had its tail bobbed by these fish. "Something about the movement must draw them," said my guide, Sérgio Almeida. "I've seen piranhas go for dogs' tails." We had waded after a jaguar the day before and come upon a grassy bower where it had eaten a calf snatched from a cattle herd. Now we were riding with the local *pantaneiro* cowboys, whose horses are used to eruptions of crocodile-like caimans from the mud. I liked being able to see over the grass stalks. I liked it better after passing two bulls lying dead, unmarked except by snake fangs. What I didn't care for was how often the horse had to swim, dipping my tail in piranha territory.

Almeida, photographer Steve Winter, and I had flown from the northern Pantanal town of Cuiabá to Fazenda (Ranch Estate) São João, a 168,000-acre spread, where Teddy Roosevelt and his son Kermit once hunted jaguars. As Kermit later wrote, "there was a better opportunity of coming across them in the open as one does Lion in Africa."

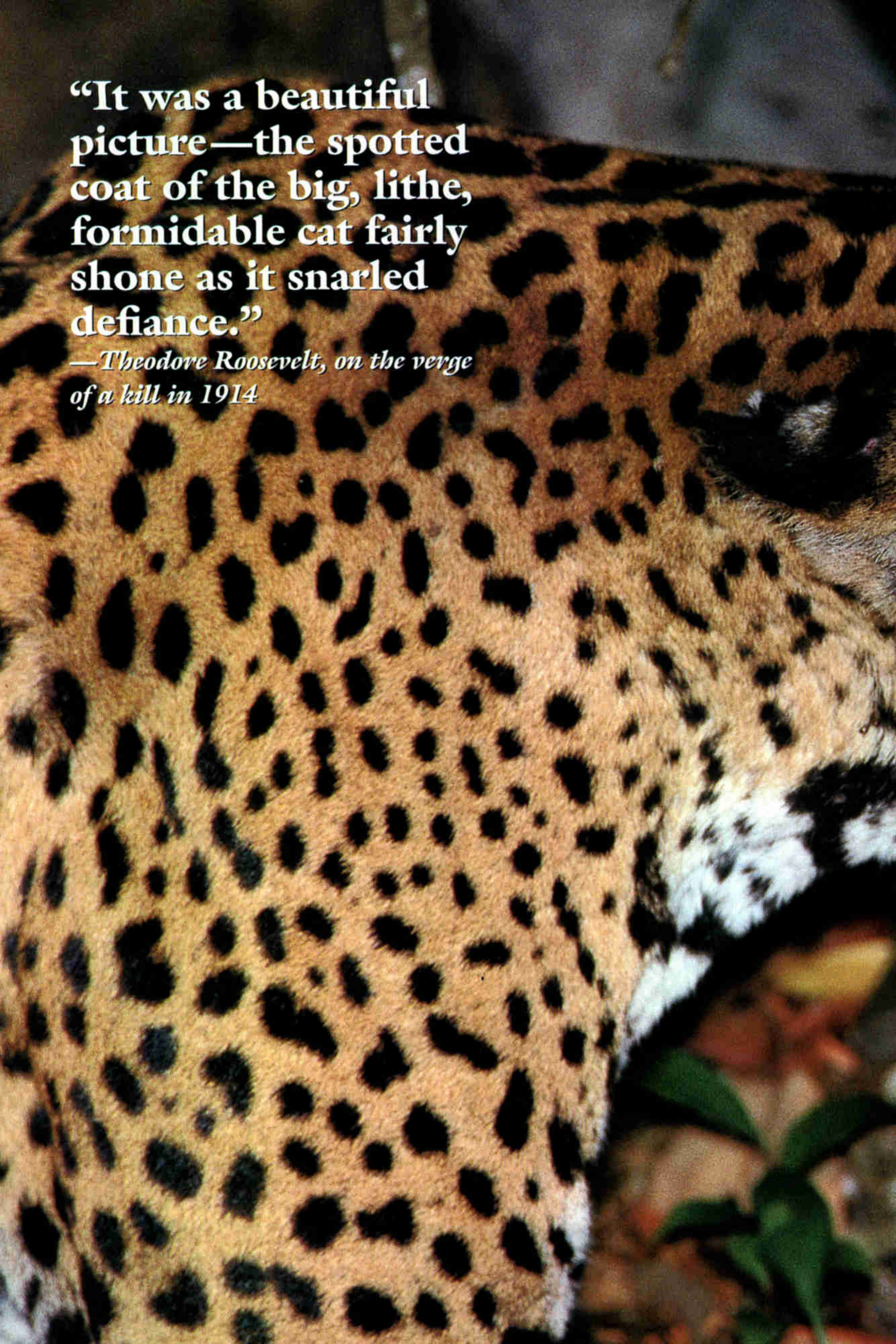
Secretive and powerful, jaguars have been revered by the peoples that have lived with them—perhaps none more than the Maya. In a traditional Maya dance still performed yearly, the trickster jaguar antagonizes the hapless men who hunt it.

Although commercial hunters went on to strip jaguars, other furbearers, and caimans from much of the region, jaguars have rebounded since the hide markets shut down. The Pantanal has proved too soggy for development other than ranching, and only large-scale operations like São João tend to last. People therefore remain thinly scattered and wildlife exactly the opposite.

Multiply the area of Florida's Everglades by about 14; saturate it with ibis and egrets and roseate spoonbills, jabiru storks tall as deer, the scavenger hawks called caracaras, toco toucans, monk parakeets, and a few hundred other bird species, and you can envision the extravagance of wings overhead as we searched along ranch roads for fresh paw prints. Owned by a leading Brazilian construction company, Fazenda São João has unusually good raised roadways, and the cats readily take to them for travel.

To improve our chances of meeting one, Fião—Oélio Falcão de Arruda, the local warden for a federal wildlife agency—stuck his head in a bucket from time to time and roared, and the sound carried over the reeds and wild cotton blossoms and caranda palms. Imitating the male jaguar's voice is an old hunter's trick, though the noise is traditionally made by rubbing the fingers along a clapper inside a hollow gourd or drum.

Along with claw scratchings on trees and urine-scented scrapes on the ground, the jaguar's calls are assumed to be about territory. Depending on the terrain and food supply, a male's claim will cover 10 to 60 square miles and overlap several smaller territories used by females and their cubs, which typically come in pairs and stay with their mother for one and a half to two years. Within its territory the jaguar tends to hunt a particular neighborhood for several days before moving on to the next.



"It was a beautiful picture—the spotted coat of the big, lithe, formidable cat fairly shone as it snarled defiance."

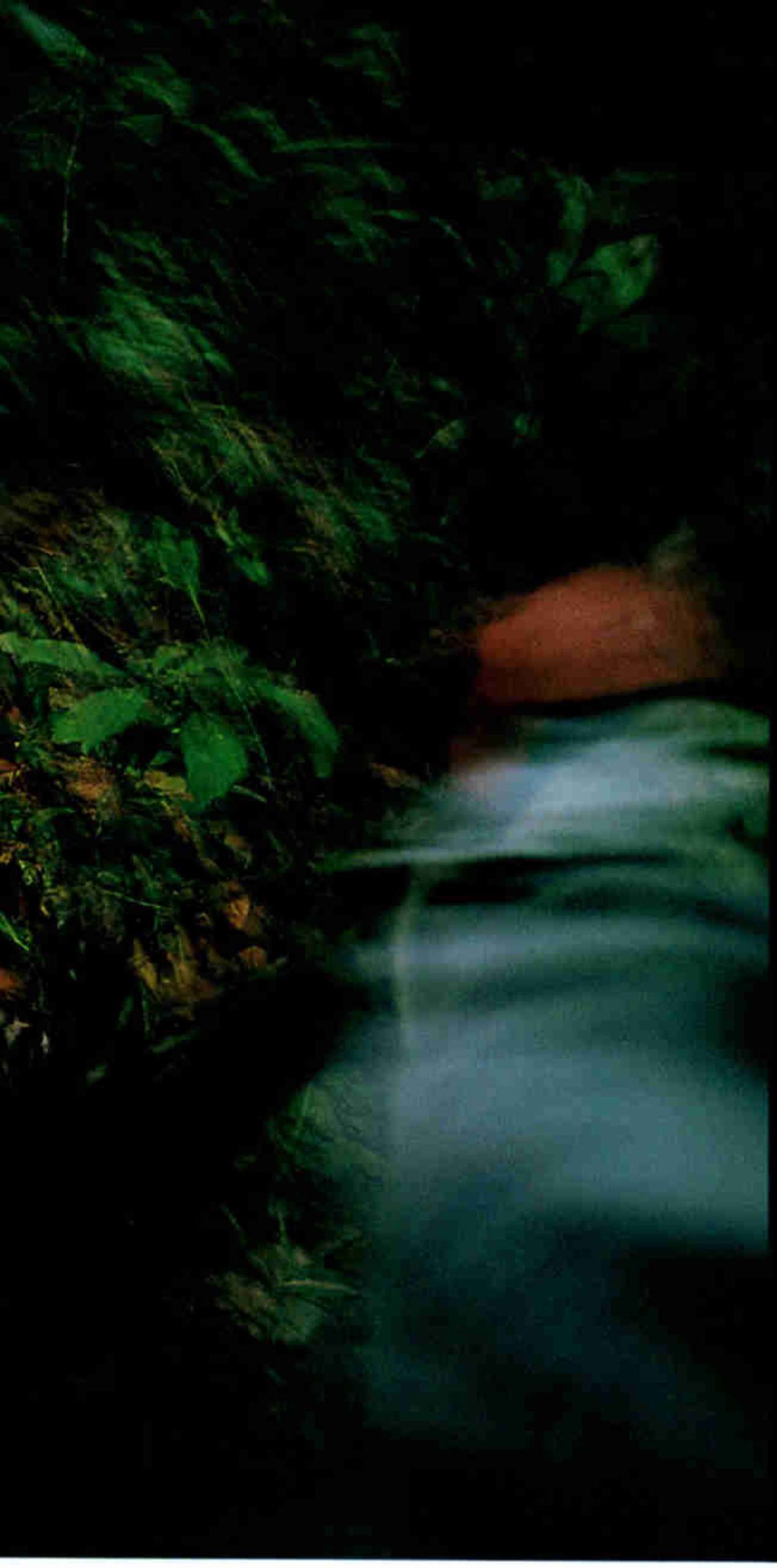
—Theodore Roosevelt, on the verge of a kill in 1914

Big-game hunters may not have seen the spirit world behind the jaguar's eyes, but they were enthralled nonetheless. Modern-day Teddy Roosevelts pay handsomely to hunt the cats with tranquilizer guns.

Poking along the road one day, we intercepted a giant anteater and several crab-eating foxes. Giant river otters barked when they spied us from the Cuiabá River. Howler monkeys reacted to Fião's calls with roars of their own. But a mother jaguar and cub crossing far ahead of the ranch truck provided only the briefest glimpse of our quarry. Darkness was flooding out the last of an orchid sky when Fião pointed far down the road and whispered "*Onça*"—jaguar, in Portuguese. Steve Winter checked his cameras, then the cat, and announced, "It's Bob."

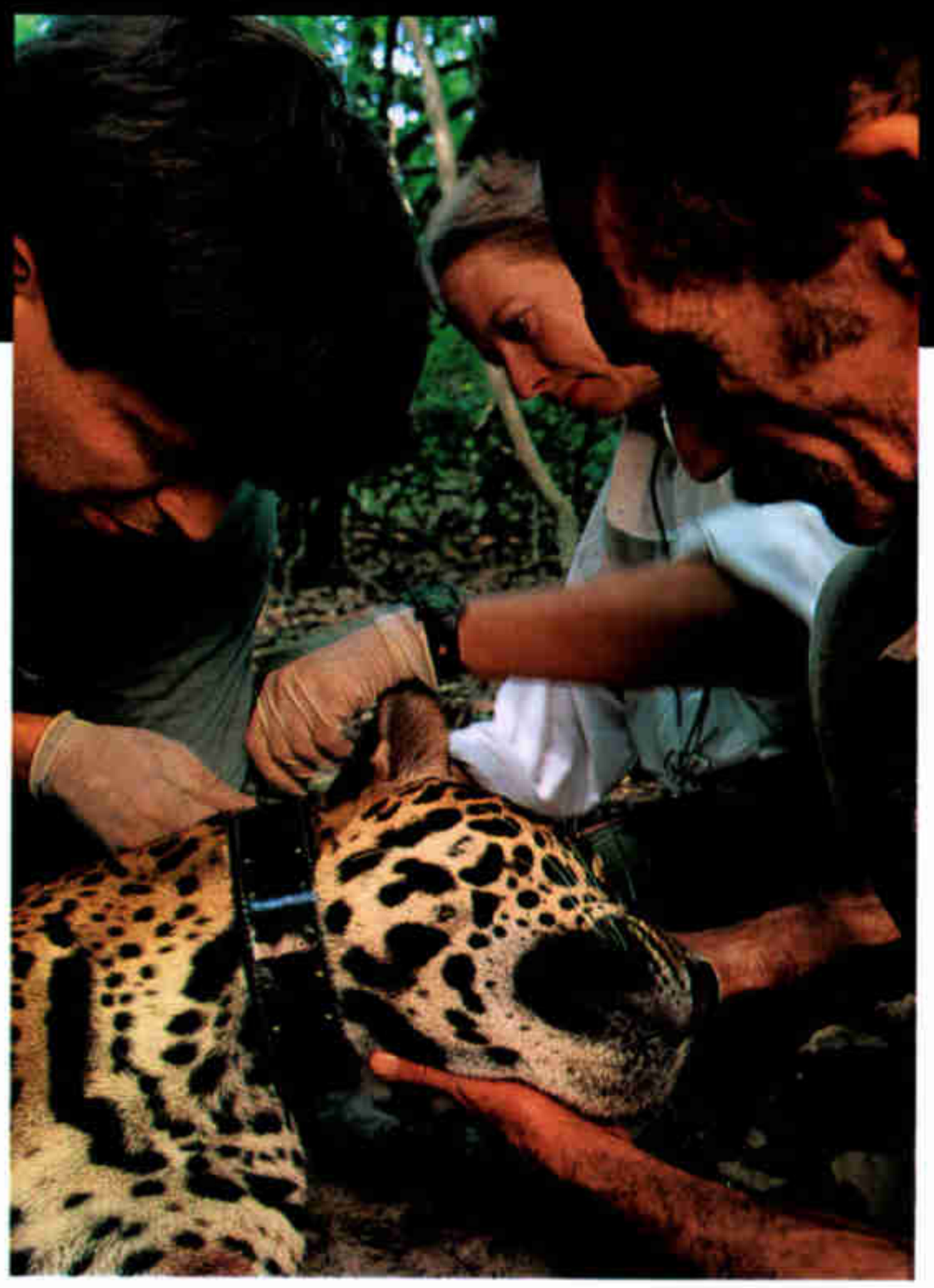
We had met the same jaguar lounging on the road the evening before, and it reminded someone in our crew of a burly, big-headed, rather unmotivated relative named Roberto. Now Almeida, Winter, and I crouched at the road's edge behind overhanging brush while onça Bob padded on, unaware or unconcerned that he was less than 100 yards from us, 80 yards, 50 yards. Pairs of tree-perching waterbirds known as southern screamers noisily marked the jaguar's progress, a habit that has earned them the alternate title of Pantanal guards. We kept as motionless as sunbathing caimans, though it occurred to me that in parts of the Pantanal those slender crocodiles are jaguars' principal prey. Don't bother with me, Bob, I thought, glancing at the mosquitoes coating every inch of my skin, you won't find any blood left.

At a distance of around 20 yards he paused



New Breed of Hunt

Sport piggybacks *science in Calakmul, Mex*ico (left), where hunters dart jaguars that will be fitted with radio collars. On a ranch in Brazil's Pantanal (below) researcher Sandra Cavalcanti measures the teeth of a pregnant female and fits her with a collar. Supported in part by the Wildlife Conservation Society, Cavalcanti hopes to learn if mothers with cubs are more likely to kill livestock than lone cats and if those habits are passed on to young.



to stare. All at once, this was no longer Bob or anything else except a massive, intelligent feline met deep in its homeland and taking our full measure. Winter began snapping pictures, flash attachment firing apace. The animal's only reaction was to slowly turn and amble across the roadway. It eased off the shoulder and into flooded woods, and we could hear footfalls in the water as the cat continued around us and on into the night. Ten minutes later Almeida was playing a flashlight beam over the brush out of curiosity and caught the twin sparks of jaguar eyes, still measuring. Then there were only fireflies casting their phosphor light among the tangles.

I had been entranced by the sway of the

beast's heavy belly as it approached. This cat was dining well; maybe that was why it seemed so patient with us. Whereas other big cats eat primarily hoofed prey, jaguars also take fish, iguanas, anacondas, turtles, unwary birds, and small mammals from monkeys to rodents. It would almost be easier to list what onça doesn't eat. Introducing livestock to its range is guaranteed to broaden its diet even further.

That evening at the house, while bats harried insects near the ceiling, Joaquim Proença, the ranch manager, told me that jaguars have killed as much as 8 percent of the ranch's cows in one year at São João. Fião said he and his brother lost almost 10 percent of the cattle on their small ranch to the cats. Like São João's owners they tolerated the kills as the price of Pantanal ranching, but most stockmen respond with dogs and guns. "We are paid to take good care of the herds," a cowboy elsewhere told me. "We spend a lot of time fixing calves with maggots or disease. Then one night the calf or its mother is gone. It is a hard thing to accept. Jaguars are very beautiful. If it wasn't for the cattle killing, I wouldn't hunt them." As things stood, he had killed about 70.

Researcher Sandra Cavalcanti from Utah State University studies jaguar activity in relation to ranching practices. At Fazenda Sete, one of three related family estates that jointly encompass 308,000 acres in the southern Pantanal, hyacinth macaws commented loudly

"God almighty—that's a jaguar!" Arizona rancher Warner Glenn said when he saw what his dogs had cornered on this outcrop in 1996. He took a photo, behind him, of the cat, which likely came from Mexico; U.S. jaguars vanished decades ago.

from an *ipê* tree while she tied her horse in its shade. Sniffing the air, she led me through the undergrowth to the flyblown remains of a cow. The animal had been reported as a jaguar kill by the cowboy who found it and noticed fresh cat tracks at the thicket's edge. His horse was unnerved by the shadows and scents, so he did not linger. Cavalcanti, who generally rides the countryside alone armed with a water bottle and a notebook, did. The cow had died giving birth. Like the cowboy, the passing jaguar had never even gone over for a close inspection.

"A rancher once told me he lost 70 head of cattle to jaguars," she said. "I checked and was able to document 19 jaguar kills; 24 other head turned out to have died from snakebite." Even when she finds a cat kill, Cavalcanti still has to determine which cat species. During our foray we passed a fair number of jaguar prints but also many of pumas, whose range overlaps that of their bigger cousin.

Peter Crawshaw, one of Cavalcanti's colleagues, carried out groundbreaking studies of jaguar ecology and now heads the National Predator Center, a government agency in Brazil. During a boat trip to explore side channels of the Pantanal's Aquídauana River for jaguar sign, he told me that many ranches lose less than 2 percent of their stock to jaguars.

"Basic changes in management can keep problems under control," he said. "Don't leave cattle in pastures next to wooded areas, where jaguars like to hunt. Bring the mother cows in close during calving. Oh, and supply your ranch hands with meat. Otherwise they will rely on wild game and take away the jaguars' supply. Ranch dogs do the same, and need to be controlled. What really worries me is that I hear more and more reports of people putting out poisons. This is why I am desperate to show ranchers alternatives and find ways to compensate them for their losses."

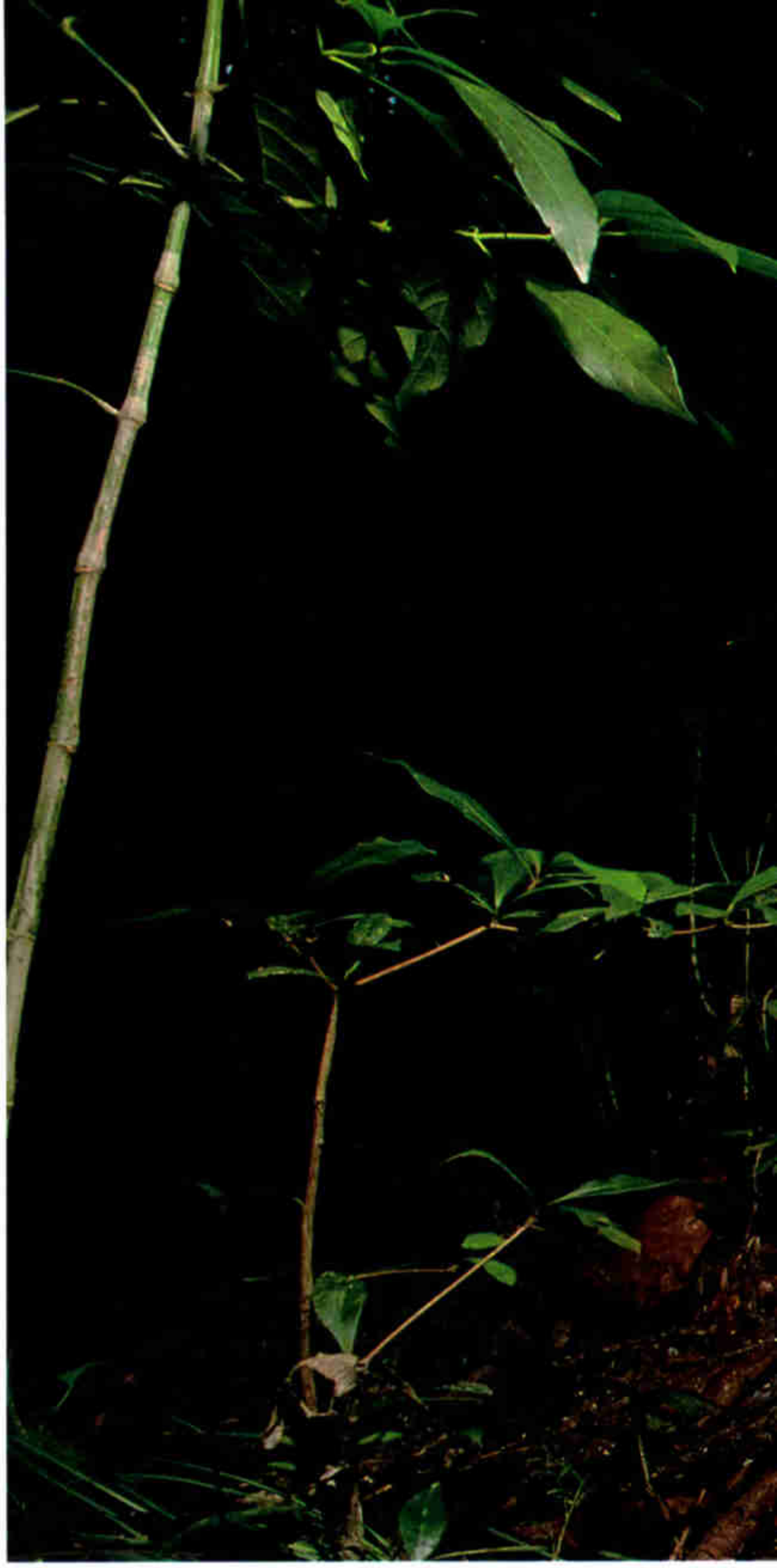
Israel Klabin, the Brazilian industrialist who owns Fazenda Sete, was pitching in by underwriting a research center at the ranch to promote long-term studies. At an adjoining ranch the emphasis had shifted from running cattle to shepherding bird-watchers and other tourists on natural history outings.

I originally met Crawshaw in Mexico City in 1999, when the Wildlife Conservation Society arranged for jaguar experts from throughout the Americas to gather for an unprecedented meeting. After the fur frenzy was halted and hunting phased out, jaguar numbers appear to have curved upward in the Pantanal, though no one knows for sure. But overall the trend looks to be downward and closely reflects the decline of remote acreage within the cats' original range. With that in mind the assembled scientists got busy pooling their knowledge to map out jaguar subpopulations, trying to see

where protection efforts would go the furthest.

An obvious choke point in the animal's range is Central America, where the land connection is narrow and deforestation rampant. From 1970 to 1990 countries there established 200 official nature reserves. Nearly all are too small, isolated, and vulnerable to outside influences to maintain wild ecosystems over time. But they might if natural corridors tied them together. Biologists had long envisioned a sort of Pan-American greenway to be called Paseo Pantera, the Panther's Path. Now, with better data and computer mapping techniques, they hope to make this a reality before the last bridges of intact habitat are gone.

The idea is not just to keep jaguars and pumas from dwindling but also to draw upon popular concern for these flagship species in order to benefit a whole range of more obscure creatures. The fate of the endangered Morelet's crocodile may not galvanize politicians, but the government of Belize set aside 184 square miles as the Cockscomb Basin Wildlife Sanctuary specifically to safeguard neighboring jaguars. And while a push to safeguard the living quarters of the black-tailed hairy dwarf porcupine might not gather too much momentum, the Wildlife Conservation Society was recently given a million dollars to help a fellow resident by the car company that borrowed its name and prestige: Jaguar.



A young male now roams the territory of the older cat pictured on page 35, which was illegally shot and killed two months after being photographed. Experts say there is still time to address the threats jaguars face, but maybe not much to spare.

Where New Mexico and Arizona come together just north of Mexico, the Malpai Borderlands Group of ranchers was working in the early 1990s to restore rangelands that support imperiled life-forms such as the Chiricahua leopard frog, Yaqui topminnow, and Cochise pincushion cactus. Then Warner Glenn's puma-hunting dogs put a jaguar at bay up on the side of the Peloncillo Mountains in 1996. The lanky, lifelong Arizona cowboy's photos of the encounter were widely published, and interest in the wildlife of this desert outback immediately jumped to new levels.

People had almost forgotten jaguars were a part of U.S. fauna before the 20th century. The cats were noted north of Los Angeles in 1855. General Sam Houston reported them to be "abundant" along tributaries of the Rio Grande in 1850, and Texas still had at least one in the 1940s. In Arizona the last jaguar was killed in 1986. Not long after Glenn ran into el tigre, hunting hounds bayed a jaguar in Arizona's Baboquivari Mountains, more than a hundred miles west of the Peloncillos.

As we wandered up Hog Canyon past cottonwoods and blackjack oaks, Glenn, a founder of the Malpai group, said, "We call this a working wilderness. We're trying to make a living off cattle but in a way that takes care of the grass

cover and the streams and springs wildlife depends on. There are rare snakes, bats, Aplomado falcons, and such to keep in mind, and then we have to provide for bigger animals like peccaries and mule deer and Coues' deer."

The closest known breeding population of jaguars was about 140 miles south of us, hanging on in riverside woodlands and thorn scrub where the Yaqui and Aros Rivers meet in the Mexican state of Sonora. Will they be there a decade from now? A century? Could enough follow the route of the jaguar Glenn saw to reclaim a piece of their U.S. range? The Malpai group contributes to jaguar research on the Mexican side of the international line. On the U.S. side, they maintain cameras furnished by the state game department to record the passage of large animals along likely travel routes. They are ready for jaguars.

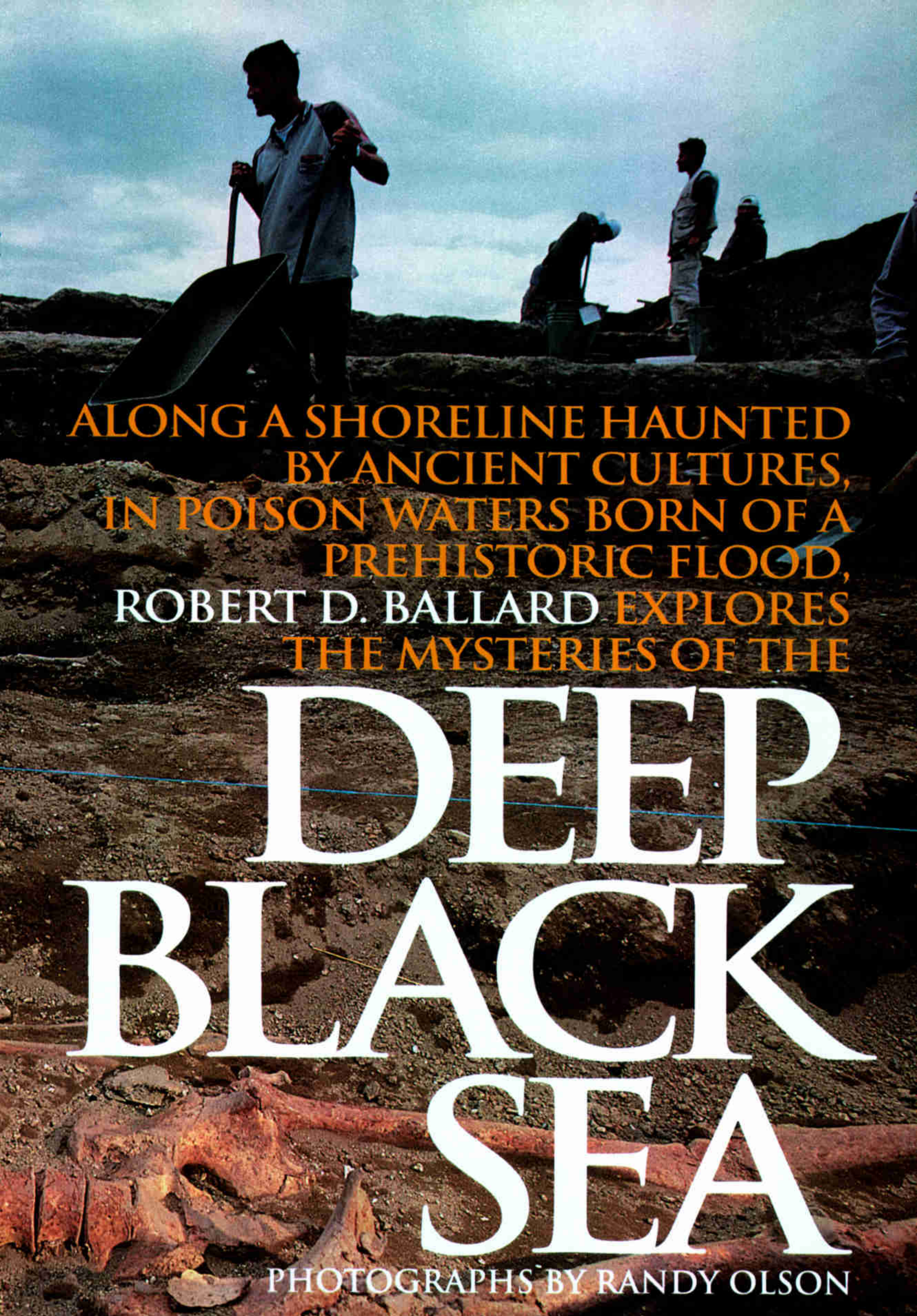
Glenn nodded at the Peloncillos marching on toward Mexico in a rumpled purple column and said, "Oh, it's wild and high and rugged and goes a helluva long way without a town or logging or much of anything. Animals can still move pretty freely around here. That's the secret. You've got to keep your wildlife corridors open." Only it's not a secret any longer. □

MORE ON OUR WEBSITE

Hear the awesome sound of a jaguar's strange roar and find out how photographer Steve Winter tracked these elusive cats at **nationalgeographic.com/ngm/0105.**

ON LAND

Bronze Age bones at least 4,000 years old rise again at İkiztepe, Turkey, on the Black Sea coast. Ballard's findings bolster the theory that people inhabiting these shores 7,500 years ago fled a deluge of biblical proportions.



ALONG A SHORELINE HAUNTED BY ANCIENT CULTURES, IN POISON WATERS BORN OF A PREHISTORIC FLOOD, ROBERT D. BALLARD EXPLORES THE MYSTERIES OF THE

DEEP BLACK SEA

PHOTOGRAPHS BY RANDY OLSON

UNDER WATER

Linked to its mother ship by fiber-optic cable, the unmanned vehicle Little Hercules helped Ballard—here making a point to the vehicle's pilot, Craig Elder (below right)—discover the Black Sea's submerged shoreline and four ancient shipwrecks.

THE FISH HAD GONE TO HELL, WE ALL AGREED. When we winched it back on deck, it had turned coal black and reeked of hydrogen sulfide, like rotten eggs. Demons might as well have been clinging to it.

This "fish" was actually a 2,000-pound iron weight that stabilized a sonar sled towed behind our 250-foot oceanographic research vessel, *Northern Horizon*. The sled had been scanning the sea bottom for solid targets that stood out from the bottom muck. After only 24 hours the weight was thoroughly corroded. Wise guys on the team promptly christened it Tetanus, Greek god of rust.

The Black Sea had a nasty reputation, even with the ancient Greeks. They once called it Axenos, "inhospitable," for the ferocity of its storms and the hostility of the tribes that lived around it. We were steaming off the

CLUES FROM A CORE SAMPLE

A core sample from deep in the Black Sea shows an abrupt change from light-colored sediments deposited when the basin was a freshwater lake to darker, organic-rich sediments laid down after the inflow of salt water—evidence of a sudden transition from lake to sea.

CASE FOR A LONG-AGO FLOOD

In 1998 Walter Pitman and William Ryan, American geologists and co-authors of the book *Noah's Flood,* postulated that stories of a great deluge recorded in the Bible and other ancient literature may have grown out of a cataclysmic event: a violent flood that made refugees of those who lived along the shore of the Black Sea and transformed the basin from freshwater lake to saltwater sea. Using core samples of sediments and the dating of seashells, they concluded that the flood occurred about 7,500 years ago and that the shoreline of the ancient lake should now lie 500 feet below the surface. In 1999, sailing east from Sinop, Turkey, Bob Ballard set out to test their theory. He found the shoreline with sonar, exactly where predicted. And the shells he gathered from the submerged beach perfectly matched Pitman and Ryan's findings.

SUBMERGED SHORELINE

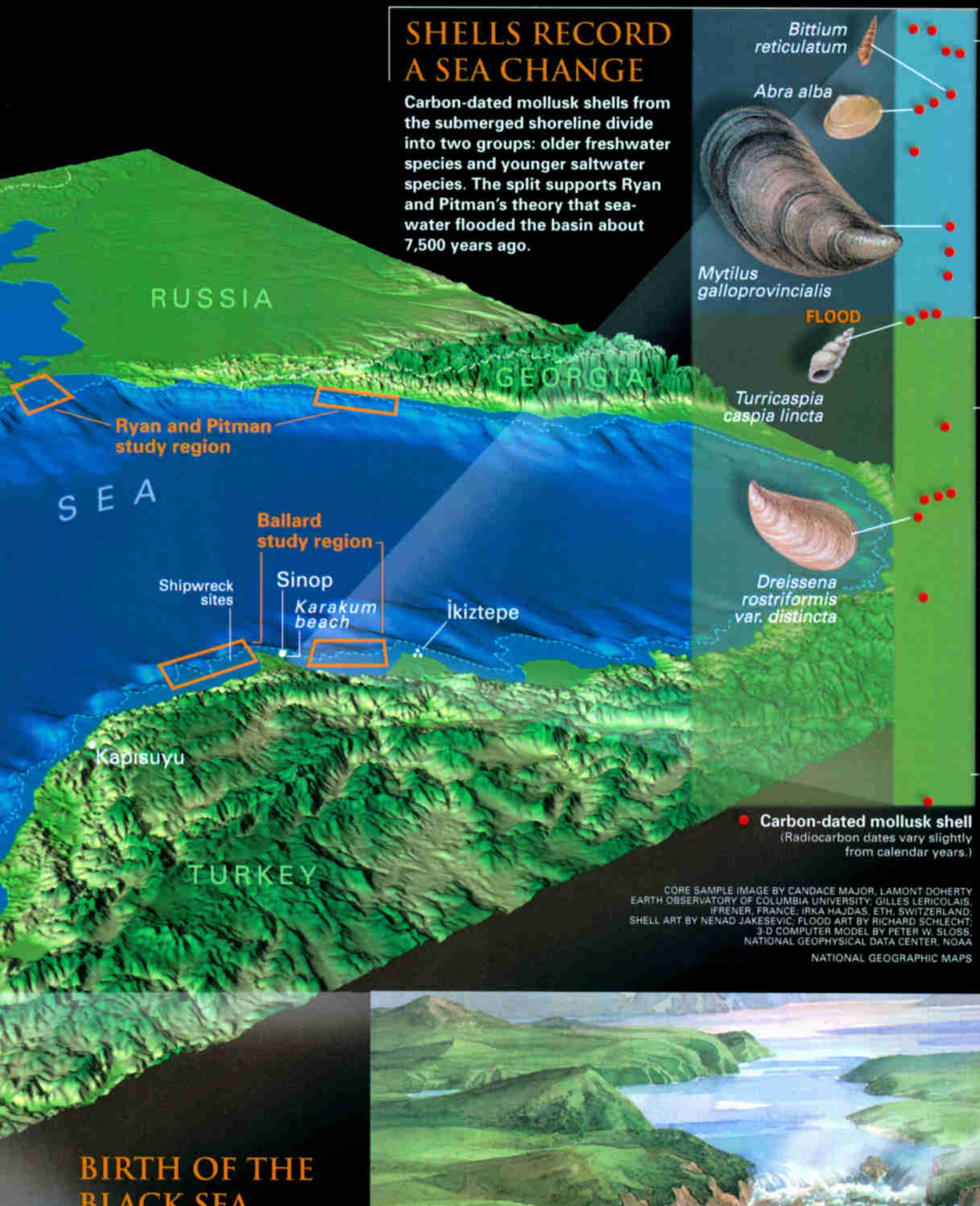
Using sophisticated sonar and a simple dredge, Ballard discovered the beach of the ancient freshwater lake 500 feet below the surface and miles from the modern shore.

MORE ON OUR WEBSITE

See another 3-D computer model of the Black Sea, drawn from a different perspective, at nationalgeographic.com/ngm/0105.

SHELLS RECORD A SEA CHANGE

Carbon-dated mollusk shells from the submerged shoreline divide into two groups: older freshwater species and younger saltwater species. The split supports Ryan and Pitman's theory that seawater flooded the basin about 7,500 years ago.



CORE SAMPLE IMAGE BY CANDACE MAJOR, LAMONT-DOHERTY EARTH OBSERVATORY OF COLUMBIA UNIVERSITY; GILLES LERICOLAIS, IFREMER, FRANCE; IRKA HAJDAS, ETH, SWITZERLAND; SHELL ART BY NENAD JAKESEVIC; FLOOD ART BY RICHARD SCHLECHT; 3-D COMPUTER MODEL BY PETER W. SLOSS, NATIONAL GEOPHYSICAL DATA CENTER, NOAA

NATIONAL GEOGRAPHIC MAPS

BIRTH OF THE BLACK SEA

When the last ice age waned some 12,000 years ago, world oceans rose as glaciers melted. In the scenario suggested by Ryan and Pitman, the swollen Sea of Marmara breached the Bosporus Valley (right), and salt water poured into the Black Sea Basin, then a freshwater lake. The new sea settled into two layers: a brackish upper layer and a deeper, salty layer bereft of oxygen and life.

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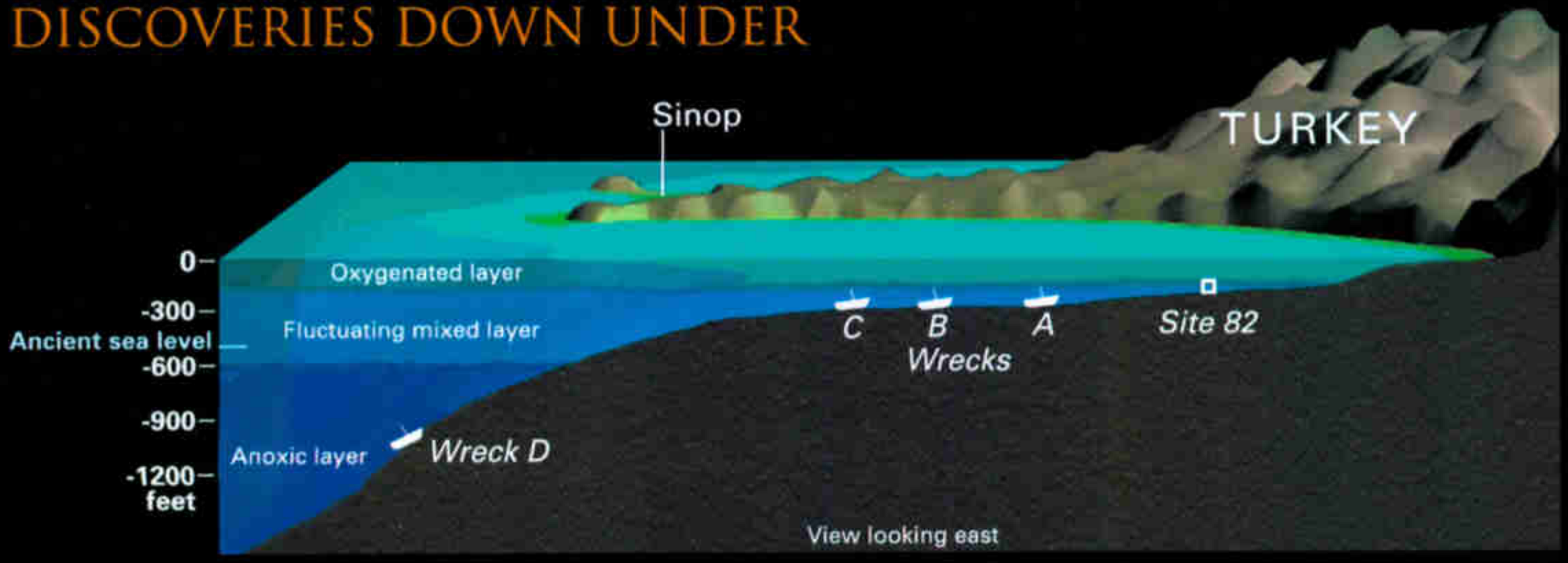
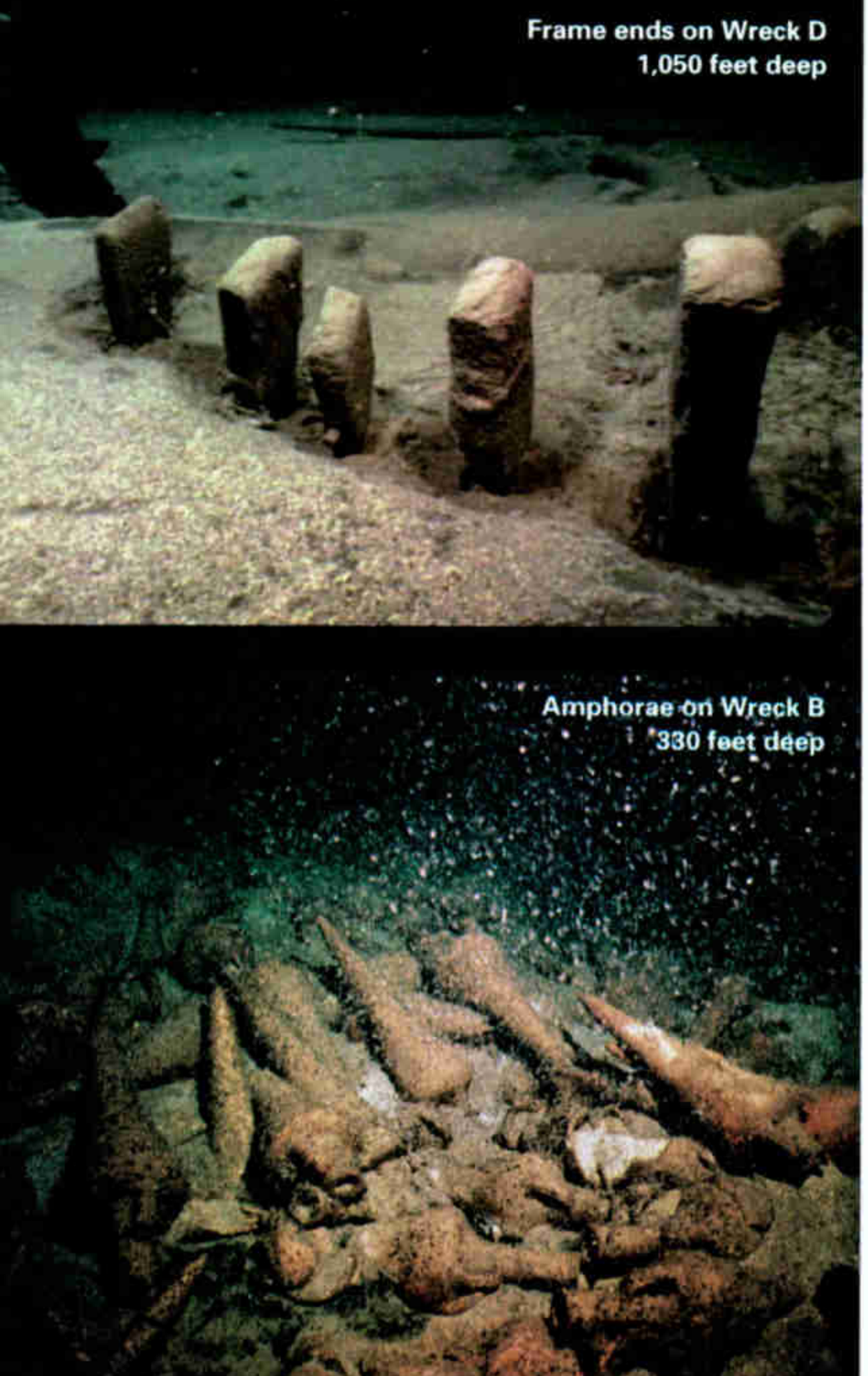
DISCOVERIES DOWN UNDER



PHOTOGRAPHS BY MARTIN BOWEN, WOODS HOLE OCEANOGRAPHIC INSTITUTION AND INSTITUTE FOR EXPLORATION; NG MAPS (ABOVE)

PRESERVED IN POISON

In the netherworld 1,050 feet deep, the Argus vehicle lights the remains of a 1,500-year-old wooden ship, the first intact classical shipwreck ever found. Its end post (1), rudder post (2), frame ends (3), stanchions (4), and spars (5) prove that organic material survives where deadly hydrogen sulfide has replaced oxygen. Labeled Wreck D, the 45-foot ship was the deepest of four found (cutaway, below left). Wrecks A, B, and C, also classical era, lie in shallower water, where sporadic waves of toxic water have destroyed wood-boring worms. Sinop's unique carrot-shaped amphorae on Wreck B (bottom) may have held such cargo as salted fish or olive oil.



Frame ends on Wreck D
1,050 feet deep

Amphorae on Wreck B
330 feet deep

SOCIETY GRANT

This Expeditions Council project is supported by your Society membership.

north Turkish coast near the ancient seaport of Sinop, in the fifth year of research into the substance of the Black Sea, a great kidney-shaped pool about 700 miles long and 250 miles wide, a sort of little brother to the Mediterranean. Aboard was a skilled interdisciplinary team: robotics experts from Woods Hole Oceanographic Institution and my own Institute for Exploration; scientists from the University of Pennsylvania and the Institute of Nautical Archaeology at Texas A&M; and students from MIT and Columbia University. Journalists and a television team from the National Geographic Society, which has partly funded the project, competed for bunk space with other financial supporters and Turkish officials.

Tetanus's corroded condition notwithstanding, the sea surface glittered benignly in the early September sunlight, and porpoises cavorted at our bow. The markets of Istanbul had been silver with tubs of bonito, mackerel, and *hamsi*, the Black Sea anchovy. Clearly life inhabited the upper reaches of the Black Sea. What then made the water 600 feet below, where Tetanus had suffered, as hostile as the storms of Saturn?

We knew that the Black Sea, millennia ago, was a freshwater lake about two-thirds its present size and unconnected with the Mediterranean. It must have been an oasis in a dry region in the time we now call Neolithic, the late Stone Age. We also knew that melting glaciers had raised sea levels as the last ice age waned some 12,000 years ago and that the Mediterranean breached the Bosporus Valley to flow into the Black Sea Basin. The denser salt water filled the bottom of the basin, leaving a layer of lighter, brackish water on top. Since the Black Sea lacks the temperature differences that drive circulation in the world's oceans, oxygen from the atmosphere couldn't reach the sea bottom. Deadly hydrogen sulfide formed there, and life suffocated.

Toxicity was precisely why I wanted to explore those murky depths. Twenty-five years ago the late Willard Bascom, a pioneer of deep-sea exploration, postulated that the bottom of the Black Sea was rich in preserved shipwrecks because the anoxicity (lack of oxygen) meant an absence of wood borers such as teredo

worms—mollusks that eat organic matter—and other marine life. Thus wood, canvas, cargoes such as grain and hides, and even human remains would theoretically be preserved.

Nobody had followed up on Bascom's theory until now. Leading nautical archaeologists, such as George Bass, were using scuba in shallow waters, maintaining that ancient trade routes followed coastlines, staying within sight of land. But surely there were captains bold enough to strike off across the unknown. They were businessmen after all, with a keen interest in saving time and money.

Were there preserved shipwrecks in the deep Black Sea? This seemed an opportune time to find out. The cold war was over, and the tracks of Soviet submarines that patrolled the sea bottom off the Turkish coast were no longer fresh. The Black Sea nations were huddling in an effort to combat pollution and enhance trade and commerce. Once again the sea could become a community that linked cultures rather than separated them.

And now we had some amazing new tools. Strapped to the aft deck were the DSL-120 sonar sled, towed behind Tetanus, and two remotely operated vehicles: Argus, a stainless-steel stabilizing platform the size of an MG roadster, and its partner, Little Hercules, a smaller, fine-tuned sea scooter. Li'l Herc attached to Argus with a tether, but we could maneuver either independently and use them to take still photographs and video.

Here's how the system would work: We'd drag Tetanus, with the sonar sled trailing behind, over broad swaths of sea bottom. Then we'd home in on each target and send down the ROVs. We'd lower Argus with a steel cable to depth, and Li'l Herc would run from it like a dog on a leash, sniffing and scrambling.

To narrow the search area, we would need to identify trade routes that quickened Black Sea

Hand-carved ribs of a Black Sea fishing vessel called a *çektirme* emerge in Kapısuyu village, a hundred miles west of Sinop, one of the few places such ships are still built. The firm, Tok Kardesler, is heir to a 2,500-year-old shipbuilding tradition. Wreck D may have resembled this fifth-century lateen-rigged fishing boat (below).

life. So I had recruited Fredrik Hiebert, a buoyant young archaeologist from the University of Pennsylvania Museum of Archaeology and an expert on ancient commerce. We looked for a focal point and decided on Sinop, which lies on the northern tip of the Turkish coast, 175 miles across the Black Sea from the Crimea, in today's Ukraine.

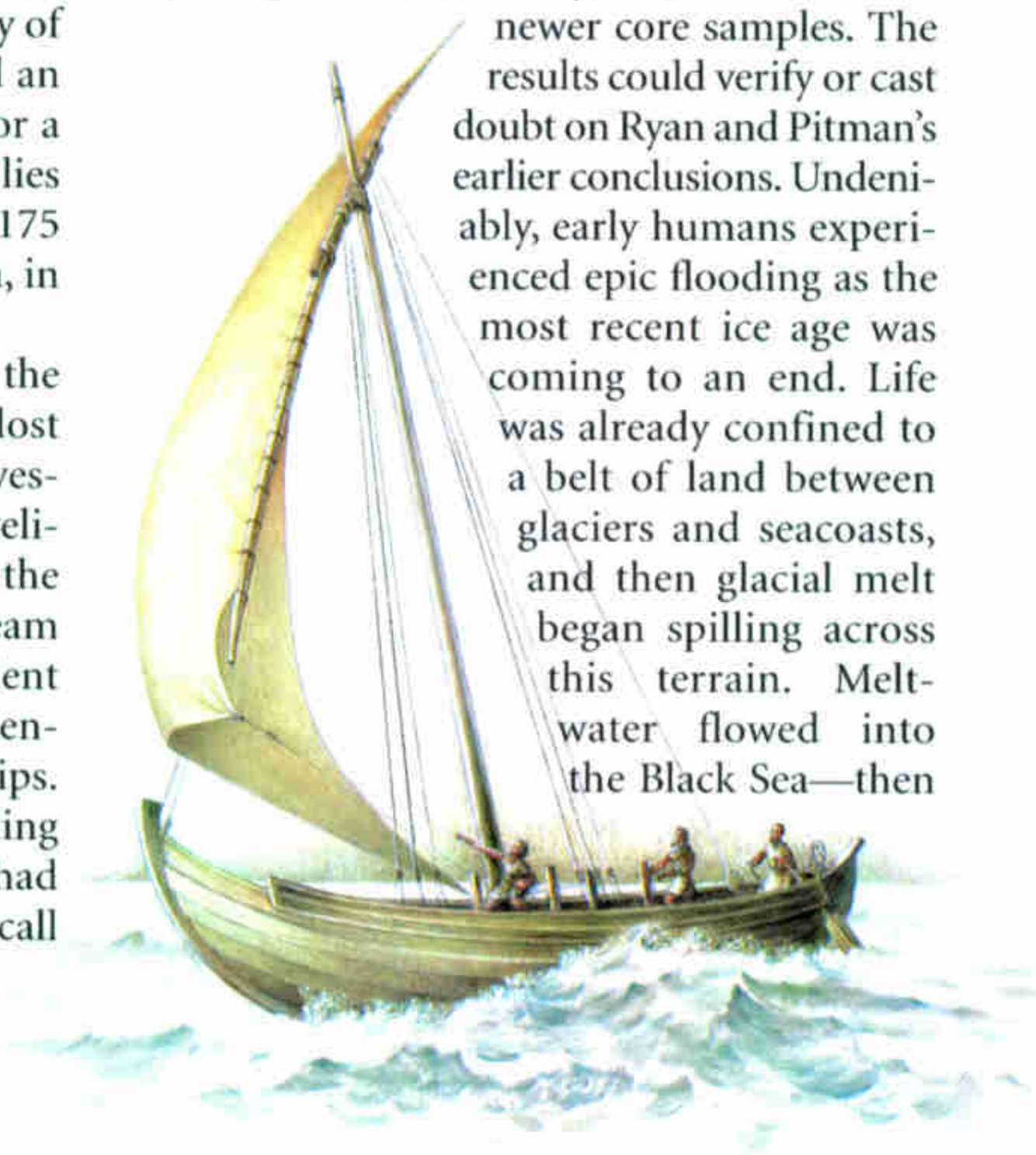
"The passageway between Sinop and the Crimea should be a treasure-house of lost ships," Fred told me right away. "Trading vessels carried cargoes important for the livelihoods of people living around the rim of the sea: beeswax, wheat, olive oil." Fred's team would work on shore, examining the ancient port and its surroundings; we would concentrate on searching the sea bottom for ships. And then we would link the two, melding land and deep-sea research in a way that had never before been attempted. We would call our endeavor the Black Sea Project.

But our plan was jolted by the 1998 publication of *Noah's Flood*, a book by William Ryan and Walter Pitman, geologists at Columbia University. Using bathymetry, core samples of sediments, and the dating of seashells, they concluded that the water transfer from the Mediterranean into the Black Sea was no gradual affair, but a sudden breakthrough over an earthen barrier at what today is the Bosporus.

WATER THUNDERED OVER THE BREACH WITH THE FORCE OF 200 NIAGARA FALLS, Pitman said in a lecture at Harvard University in 1998. Salt water poured into the low-lying lake until the two seas were at equilibrium. "At first it was a trickle," he said, "then the water flowed faster as it cut in toward the bedrock. It was a wild cascade in a matter of months."

Pitman and Ryan based their scenario on core samples collected in 1993. Those cores, and the seashells they contained, recorded a shift from fresh water to salt water about 7,500 years ago. The changeover is even clearer in later cores in which the boundary between the two sediment types is less than a millimeter thick, indicating a sudden transition—in short, a flood.

Recently, Bill Ryan and his colleague Candace Major began chemical analysis of shells from the newer core samples. The results could verify or cast doubt on Ryan and Pitman's earlier conclusions. Undeniably, early humans experienced epic flooding as the most recent ice age was coming to an end. Life was already confined to a belt of land between glaciers and seacoasts, and then glacial melt began spilling across this terrain. Meltwater flowed into the Black Sea—then



CHRISTOPHER A. KLEIN, NGS ARTIST

a freshwater lake—until about 10,000 years ago, when depressions made by the weight of the retreating Eurasian ice sheet trapped the water and diverted it westward. For a time the lake shrank, even as world sea levels rose, until finally it lay some 500 feet below the Mediterranean, separated only by a thin isthmus.

If a cataclysmic breach of that barrier did in fact take place, the Black Sea would have risen six inches a day, Pitman calculated. Any people living along the north shore, which borders the flat Eurasian steppes, would have been forced back as much as a mile a day; those along the Turkish coast could have found refuge in the nearby mountains. But the speed of the flooding would have left little time to dismantle homes and organize evacuation; the trappings of those lives must have remained intact beneath the sea—time capsules much like those buried beneath volcanic ash.

Could we put Ryan and Pitman's theory to the test? The coastal waters around Sinop, largely free of siltation, offered a perfect place to search for evidence of an ancient freshwater beach. I couldn't resist: We would include flood research in the Black Sea Project. We would attempt to find the beach as well as sunken ships. We would extend the Black Sea story from its Neolithic genesis to modern times.

The Black Sea Project actually began back in the summer of 1996. Our team of scholars, students, Turkish colleagues, and visitors often hovered close to 30, many of them bunched in dormitory conditions in Sinop's Hotel 57. The hotel, a block from the harbor in the shadow of a medieval stone tower, was in a cramped warren of shops and restaurants savory with lamb kebab, grilled mackerel, and morning bread from wood-burning ovens. Close by was a steamy, double-domed *hamam,* or Turkish bathhouse, that had been in constant use for some 500 years.

During the first two summers the land team made systematic walking surveys of the Sinop Peninsula, identifying hundreds of archaeological sites from Neolithic to Byzantine. In 1998 came the water team under David Mindell, a professor from MIT, whose mission was to find sonar targets in the surrounding seas.

This was innovative and holistic archaeology, with both land and water teams using similar transect methods to plot artifacts. We would have the record of Sinop and its seas plotted from mountaintop to ocean bottom.

"This is a living archaeological site," Fred Hiebert told me when I met with him and Owen Doonan, leader of the land team, in the summer of 1999. The team had been walking three-foot strips across the landscape, in the process picking up more than 4,000 sherds of pottery from Greek, Roman, Byzantine, and Ottoman villages. "We've found evidence of 3,000 to 4,000 years of settlement and vibrant trade," Hiebert said.

But my first task that summer was to find the ancient beach, which Ryan and Pitman said would be 500 feet below the surface of the sea. We had leased and outfitted local fishing boats for a series of day trips—boats that would be lost to us come September and the running of

The ancient port of Sinop (left) was colonized by Greeks from Miletus, which lay on today's Turkish Mediterranean coast. In turn, the colonists ventured out to establish trading posts around the Black Sea. Turkish tourists sun at Sinop's Karakum beach (right), whose black volcanic sand was mixed with clay to make amphorae.

the bonito. On July 11 we headed to a spot about 20 miles east of Sinop for a series of exploratory sonar runs.

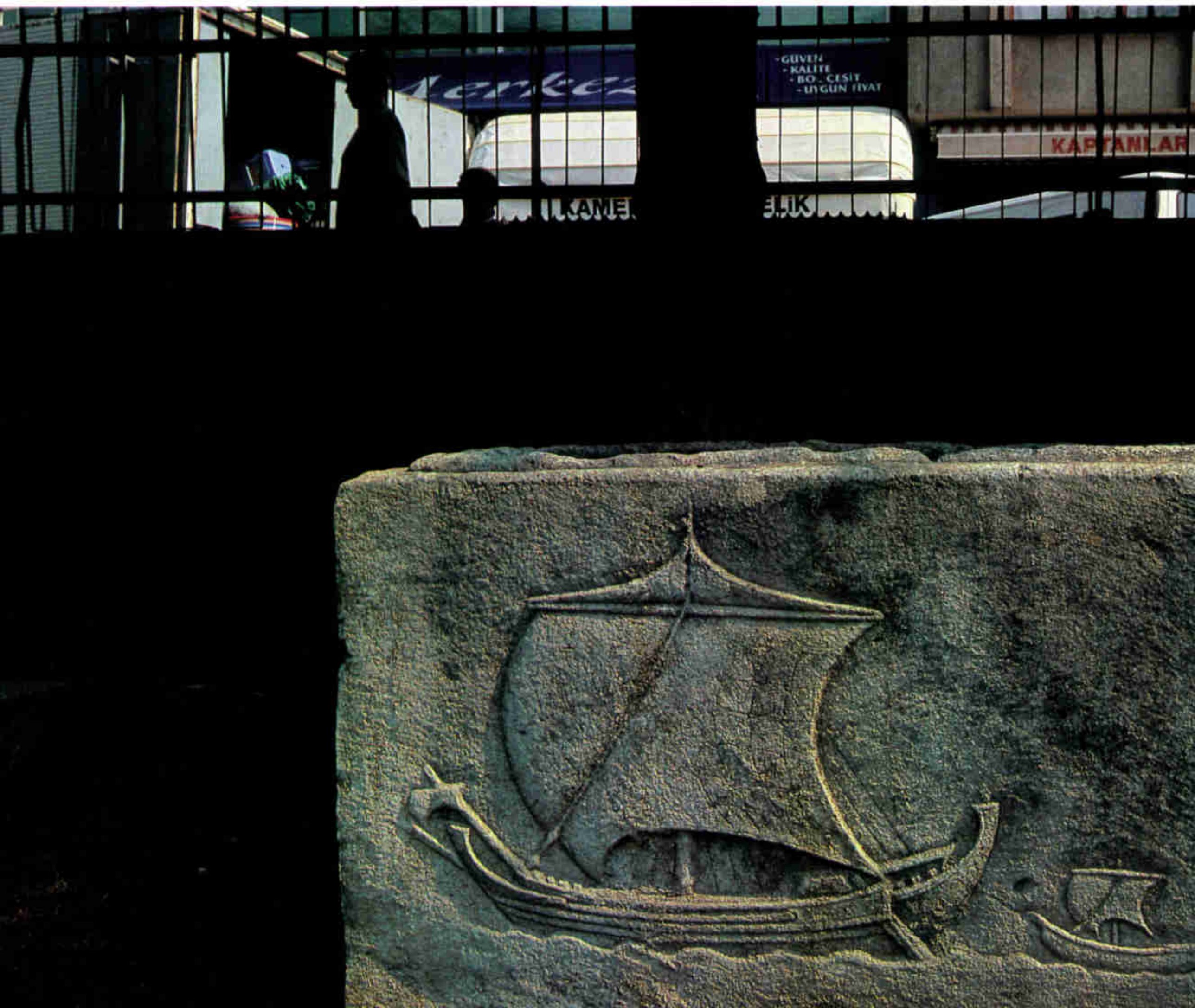
That afternoon Dwight Coleman, my assistant, called me to the sonar monitor. We were grazing over a giant jigsaw puzzle of a landscape, unlike any I had ever seen underwater. It ended on what looked like a sandbar followed by a classic berm, a ledge created by wave motion along a beach. This was it!

WE HAD FOUND THE ANCIENT BEACH. NOW WE HAD TO DOCUMENT IT, but the weather soured. I woke to the sound of branches whipping against my window. For two days whitecaps roiled the bay, and the fishing fleet chafed against the tire bumpers along the concrete quay.

In one of life's little ironies George Bass, a man widely regarded as the dean of nautical archaeologists, arrived in Sinop, and the weather broke. "I'm going to find something," I told him. "I'm going to bring up stones and shells from that ancient shoreline."

"We're not competitors," he said congenially as we sailed off. "You like to find things, I like to excavate them." But by early afternoon a sea had built up, and the sonar equipment was bobbing dangerously. Putting down an ROV for a photograph would be disastrous, so I decided to drop the dredge. If I had any advantage on George Bass, it was technology. But our secret tool that day was a simple dredge, an antique implement.

Everyone was on deck when it came back up. I reached into the gray glob of goo, pulled out some rocks and shells, and tossed a pebble to George. His face lit up. It was round! A beach stone. This was the beach of the ancient freshwater lake, no doubt about it. These rocks



had been banging together for centuries.

"Incredible!" said Bass. And then he looked at me with the pungent skepticism I'd come to expect from him: "Now we need to get lucky."

He meant that to find evidence of human habitation to match the beach would be hit-or-miss. Expectations had ballooned, and Noah was on everyone's tongue, but all I had was a pocketful of round stones and a cup of shells.

At least the science was solid. Between seasons the shells we dredged were carbon-dated. They ranged between 2,800 and 15,000 years old, and the boundary between the old freshwater shells and the younger saltwater shells was roughly 7,500 years—the same date Ryan and Pitman had come up with for the transition.

One thing raised questions: Among the dredge debris was a piece of wood dated 3,500 years old. Could that be right? It was in shallow water, clear of the anoxic abyss. What was it doing there, and how could it have endured so long?

In September 2000 we arrived off Sinop on the *Northern Horizon* and began to drag our sonar sled from east to west, just to the south of the ancient beachline, looking for habitation sites. We worked up a list of targets, and one looked especially promising: site 82, a square-shaped mishmash of signals.

On September 9 we sent Li'l Herc down. As always the descent was a piece of magic. Its spotlight beamed on a diaphanous swirl of jellyfish, shrimp, and plankton. Where the ROV bounced on the bottom and kicked up a divot, the underlying sediment of hydrogen sulfide oozed black.

By 10:30 a.m. our cameras were on the bottom, and we were sulking. No wood, no target yet. At eleven o'clock Li'l Herc was running at 300 to 330 feet deep, about 12 miles off the coast, when it motored into what looked like a construction site, with wooden poles and squared stones half buried in silt.

All eyes were riveted on the monitor screen. Fred Hiebert gasped, "Holy cow! It looks like wattle and daub! A collapsed building! Look—there are the sticks and lumps of mud. It's like looking at an x-ray of an archaeological site."

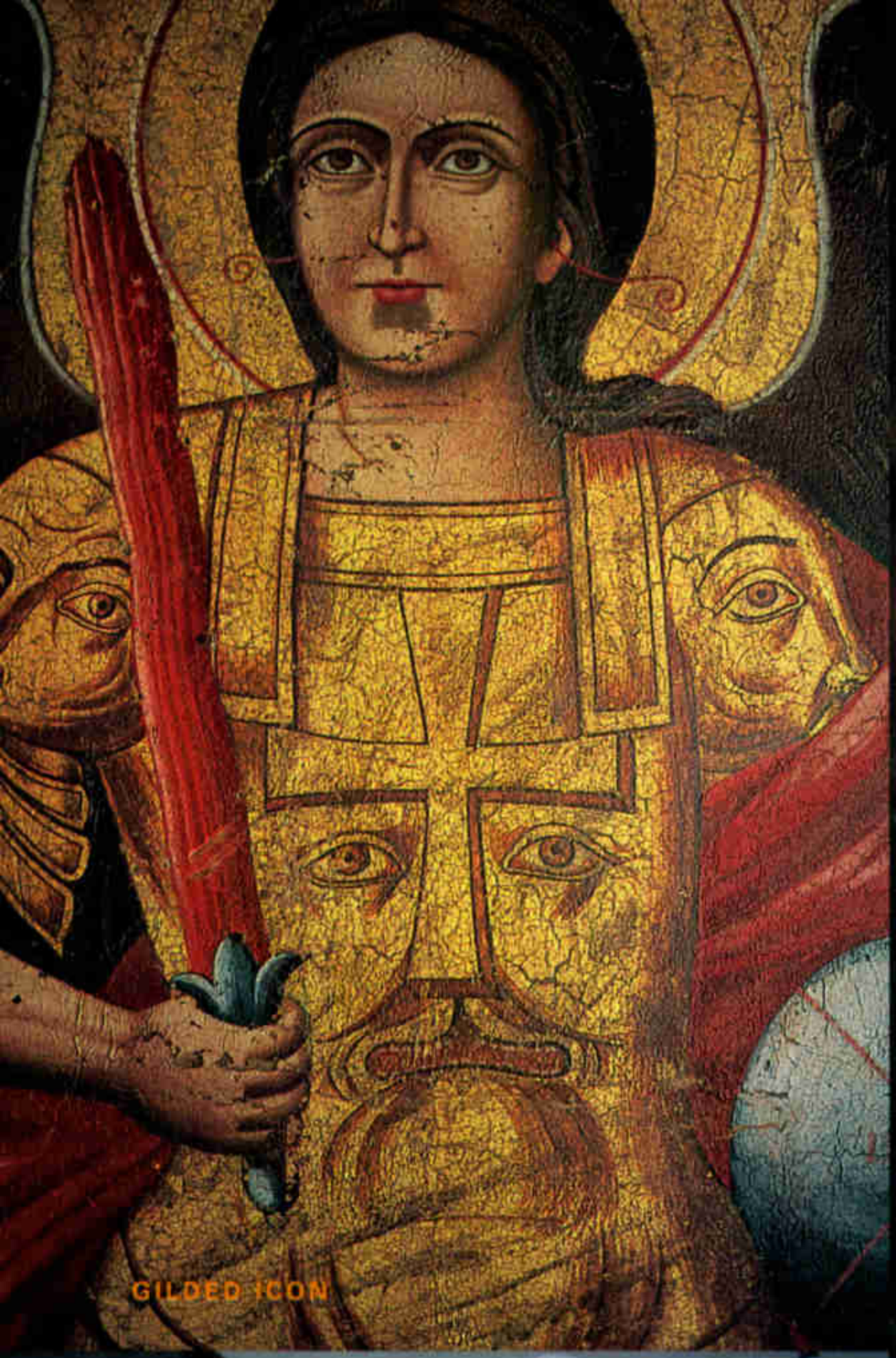
Li'l Herc circled the site. Wood? I had been hoping for some sort of organized stone, the side of a wall perhaps—anything linear. But here was wood at exactly the place where we expected to find evidence of human life, a hundred yards uphill from the ancient shoreline.

The discovery set off a flurry of e-mails, phone calls, press briefings, moments of both exhilaration and biting doubt. We were out there on the front page. Either we had evidence of an entire new civilization along the shores of the Black Sea—or we had a pile of trash.

It turned out to be both: Carbon dating a month later showed the wood was young, deposited within the past 200 years. But the stone blocks remain a valid question and concern. "Treat it like a land site," Fred coached. "That's what it really is. We have to excavate it."

Cheryl Ward of the Institute of Nautical Archaeology in Texas and John Broadwater

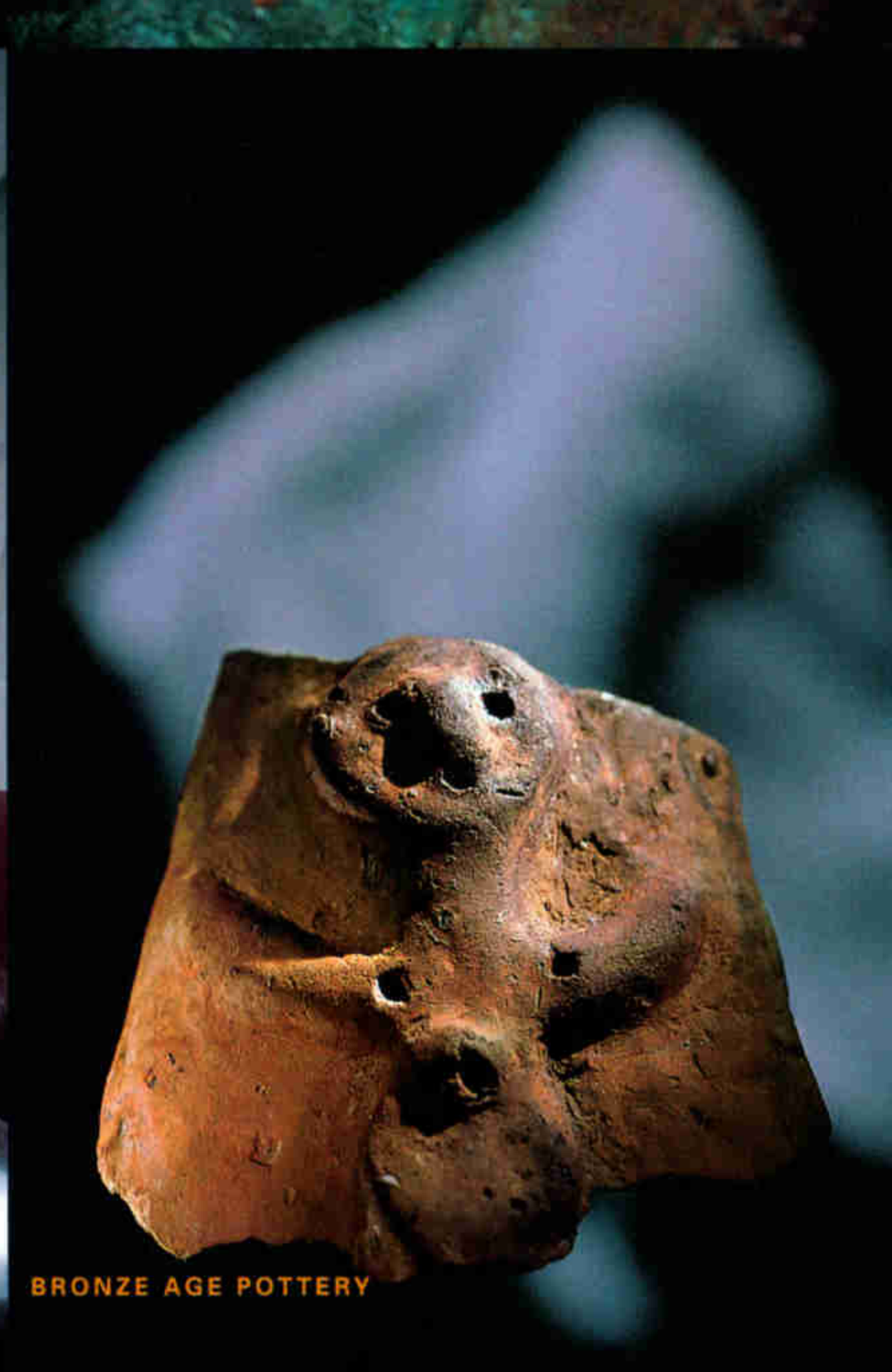
A man of the sea, Kornelios Arrianos once lay in this Roman-era stone sarcophagus, now in the Sinop Museum. A merchant ship and a harbor boat decorate its side. A fourth-century B.C. Sinop coin (above) depicts an eagle clutching a dolphin, a symbol of this port where mountains meet the sea.



GILDED ICON

ROMAN LAMP

TURKISH BATHHOUSE



BRONZE AGE POTTERY

from the National Oceanic and Atmospheric Administration arrived on board two days after the find. We all pored over film, argued and cajoled, and finally every archaeologist and Ph.D. with us reached the same conclusion: Even without the wood, we had found evidence of material worked by human hands beside the ancient shoreline—material that must have existed there before the flood.

For days the ship was stormy with theories and countertheories. I knew that the wood must be viewed with great suspicion, but had we not found a piece of wood the previous summer that was 3,500 years old and not in the preserving anoxic zone? But why?

The puzzle now became more complex. Late in the night of September 11, Li'l Herc floated into a majestic scene: an ancient shipwreck teeming with terra-cotta amphorae, small jars, an iron anchor, and wooden beams. A late fourth-century Byzantine trading vessel, Cheryl Ward calculated. The carrot-shaped amphorae, speckled with black, were straight from Sinop, fired along the coast near the port. Fred Hiebert and Owen Doonan already knew about the ancient kiln sites. The black came from Karakum beach, a volcanic beach near Sinop whose sands were mixed with clay in the amphorae's formula.

THERE WAS OUR LINK BETWEEN SEA AND SHORE. Some of the amphorae may even have intact stoppers of clay or wood, so the residue of cargo—sardines, olive oil, and wine—could still be inside. "Sinop amphorae are found all over the Black Sea coastline," Fred said. "The Sinop town symbol—an eagle holding a dolphin in its talons—was also known across the sea in Ukraine. But until now we've never actually seen these amphorae en route."

We were on a roll. That night we found a second shipwreck with another load of amphorae and much more wood—what looked like parts of the hull. We saw no fastenings and found no evidence of scarf joints that would have attached planks to each other.

And yet, we were seeing the wood of Roman-Byzantine ships at depths that should not have been anoxic. What did it mean? Fishermen at Sinop had spoken of fluctuating "poison waters." Could there be a zone where the anoxicity comes and goes?

At a quayside café in Sinop I had met a 75-year-old fisherman named Şukru Gumuş. "Fish understand the poison water," he said. "They go elsewhere. These poison waters, before, were at 300 feet. Now they sometimes come in to 165 feet or even 65 feet. On some days you drop bottom nets down and get fish; on other days the fish are dead and the nets are blackened. We are afraid that the Black Sea will be dead in 15 years."

Made sense. If the poison layer fluctuated, the free-swimming fish that live in the open sea could escape it. But benthic creatures—ocean-bottom dwellers such as shellfish and mollusks, the teredo worm among them—simply died. So exposed wood could survive in waters that were not fully anoxic.

But what caused the fluctuation? From my bookshelves on the *Northern Horizon* I pulled down some Russian oceanographic texts that were published before the political thaw. In them I found the logical mechanism. The border between the poison water and the upper layers is not a level plane; it bulges in the middle. Such a bulge is unstable by nature, and when bad weather buffets the sea surface, the energy is transferred to the edges of the bulge, generating internal waves. It is these waves, moving toward shore and then out again beneath the surface, that create a zone in the Black Sea at between 260 and 600 feet deep where wood survives in depths shallower than we had expected.

On Tuesday, September 19, the night watch found a third wreck, a fourth- to sixth-century ship about 345 feet away from the first wreck. This one had three piles of silt-covered amphorae but little wood showing.

One goal remained: We still needed to get to

The Black Sea's gallery of cultures includes a Bronze Age mother-goddess figurine (left) from İkiztepe. An oil lamp in the shape of an African head comes from Roman times, perhaps second century A.D. A gilded icon of the Archangel Michael, painted in the 19th century, once hung in an Eastern Orthodox church in Sinop. The town's traditional *hamam,* or public bath, was built in early Ottoman times and still thrives after 500 years.

ICON AND LAMP FROM SINOP MUSEUM

Layers of habitation support chief archaeologist Fred Hiebert, on a ladder (left) at the "bus station" dig, a bluff near one of Sinop's city gates. Owen Doonan and Jennifer Smith work the lowest, Bronze Age layer. Sinop's walls (right), first built by ancient Greeks and restored by 13th-century Seljuk Turks and others, guard a living history.

the murky bottom of the sea beyond 600 feet. But the continental shelf drops off precipitously around 700 feet, and the slopes are covered with debris from landslides. Northern Turkey lies on the Anatolian Fault, where earthquakes have been reshaping the land for millions of years.* The very center of the sea, more than 7,000 feet deep, would be clear of landslides, but it would take so long to get there and to get in and out with the machines that it might not be worth the chase.

Nevertheless, we steamed off to "Anoxia," the sterile heart of darkness, where the plankton that had pranced in the spotlight at shallower depths were limp and simply falling. And here, in rough seas just two days before the expedition ended, our patience rewarded us. Li'l Herc, bumping in the underworld over a thousand feet below, sailed into what at first seemed like a mirage—a fourth wreck, standing tall and gloriously upright, its mast towering 35 feet.

We maneuvered the vehicle closer and saw no metal fittings or fasteners, no rigging, no canvas sails. Either from a very poor culture or from a very old one. It was about 45 feet long, hand-hewn, dusted with silt, and so well preserved in the anoxic water that marine archaeologists are still reeling.

A late Roman or early Byzantine vessel from about A.D. 410-520—a 1,500-year-old ship with wood that looked as if it had been hewed yesterday. No one had ever seen a wooden ship from the classical world in this state of preservation. The cargo it carried would be intact too—and filled with answers to the conjectures of a generation of historians and nautical archaeologists.

"The find is extraordinary!" said Cheryl Ward. "There's no decay. I can see hand-carved stanchions and a rudder post. The ship looks as if it just left the dock."

Willard Bascom had been right. The bottom of the Black Sea, anathema to life, is a balm for wooden ships. And think: Before the tumult of the flood the lake was fresh and thus without wood-boring mollusks. The fuller picture then is wonderfully bizarre: the possibility that every ship that sailed and perished on the Black Sea, from humankind's earliest wanderings to our own time—perhaps 50,000 separate wrecks—lies preserved. In poison.

Can we excavate them? Learn from them? What good is making furtive pictures of a hull that remains a mystery? That's why I'm building Hercules, the world's first robotic deep-water archaeological excavation vehicle, due in 2002. It will be not only my eyes but also my pick and brush, my hands. The sea off Bulgaria, near the Danube Delta, will be our next target. We will find, and we will excavate. We will visit hell again. □

MORE ON OUR WEBSITE

Bob Ballard tells of the trials and triumphs of exploring the Black Sea—and previews the future of the project—in an online interview at **nationalgeographic.com/ngm/0105.**

*See "A History Forged by Disaster," by Rick Gore, NATIONAL GEOGRAPHIC, July 2000.

"Follow the white stream," villagers told explorers searching for caves in southern Mexico more than a decade ago. Scientists now beat a path to the waterway, made opaque by suspended sulfur, and the cave from which the water exits. The sulfur nourishes weird microorganisms in Cueva de Villa Luz, or Cave of the Lighted House, one of several names. Its unique ecosystem thrives amid toxic gases—an atmosphere where visitors must tread with care.

MEXICO'S POI

BY JOHN L. ELIOT
NATIONAL GEOGRAPHIC SENIOR WRITER

PHOTOGRAPHS BY
STEPHEN ALVAREZ

DEADLY HAVEN

SONOUS CAVE

SULFUR SPRINGS—BUT NOT A SPA

More than 20 underground springs, some rich in hydrogen sulfide, feed Villa Luz. Small fish, *Poecilia mexicana,* blush with high levels of hemoglobin needed to maximize capture of scarce oxygen from the water. Poisonous to humans, hydrogen sulfide sustains bizarre microbial life-forms that oxidize it and create sulfuric acid, which in turn dissolves rock and enlarges the cave. Living largely in the dark, cave fish have smaller eyes than their surface relatives, and some scientists believe that the farther the cave fish are from the light, the smaller their eyes.

We could smell the cave long before we saw it. Along the mile-and-a-half trail from the Almandro River a natural paradise unfolded. Oropendolas, hummingbirds, motmots, and other tropical birds perched in ceiba and quebracho trees. Leafcutter ants paraded across our path in this lush rain forest in southern Mexico's Tabasco state. But as the rotten-egg stench increased, paradise was about to be lost. At the entrance of the cave my scientific companions—all accomplished cavers—and I donned respirators for protection against the vapors within.

SOCIETY GRANT

This Research Committee project was supported by your Society membership.

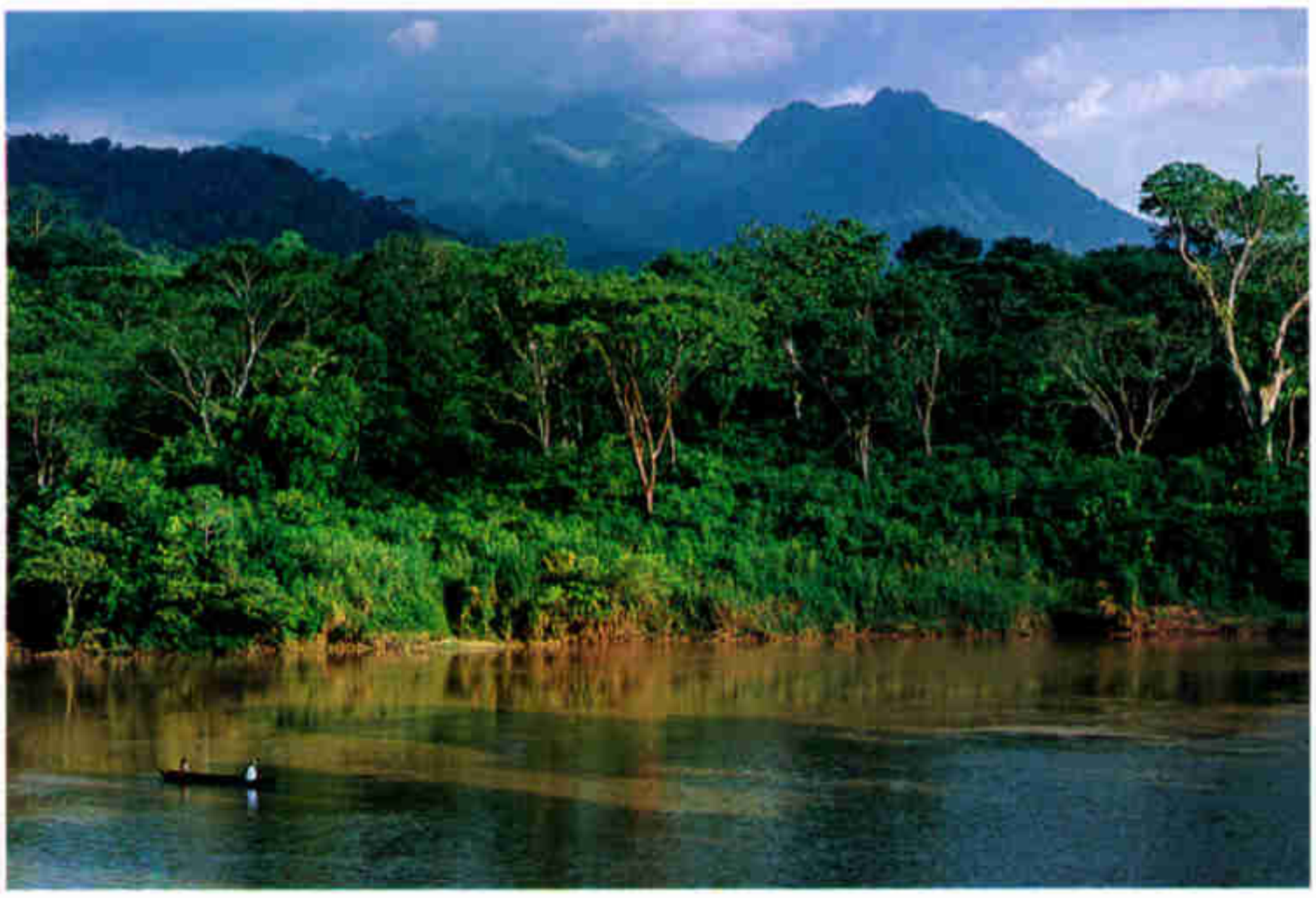
Then we descended. Louise Hose, a geologist at California's Chapman University, led me to a rock wall festooned with long white mucus-like colonies of sulfur-eating bacteria (right). "We joke that this cave has a cold, and we call these 'snottites,'" Hose said. The bacteria oxidize sulfur compounds in subterranean springs that feed into the cave—sulfur is the basis for nearly all its life. Besides the incredibly acidic snottites, the researchers term other forms of bacterial slime "phlegm balls." Some forms of bacteria are new to science, and some are even beautiful, like those christened "biovermiculations" by Hose. On some walls they grow in an intricate lavender texture, like a rich tapestry.

CHECKING FOR LIFE

Engineer Dave Lester, at left, and microbiologist Lynn Kleina collect gas samples to analyze the chemical composition of Flema Spring. Researchers wear respirators to filter out hydrogen sulfide and other dangerous gases.

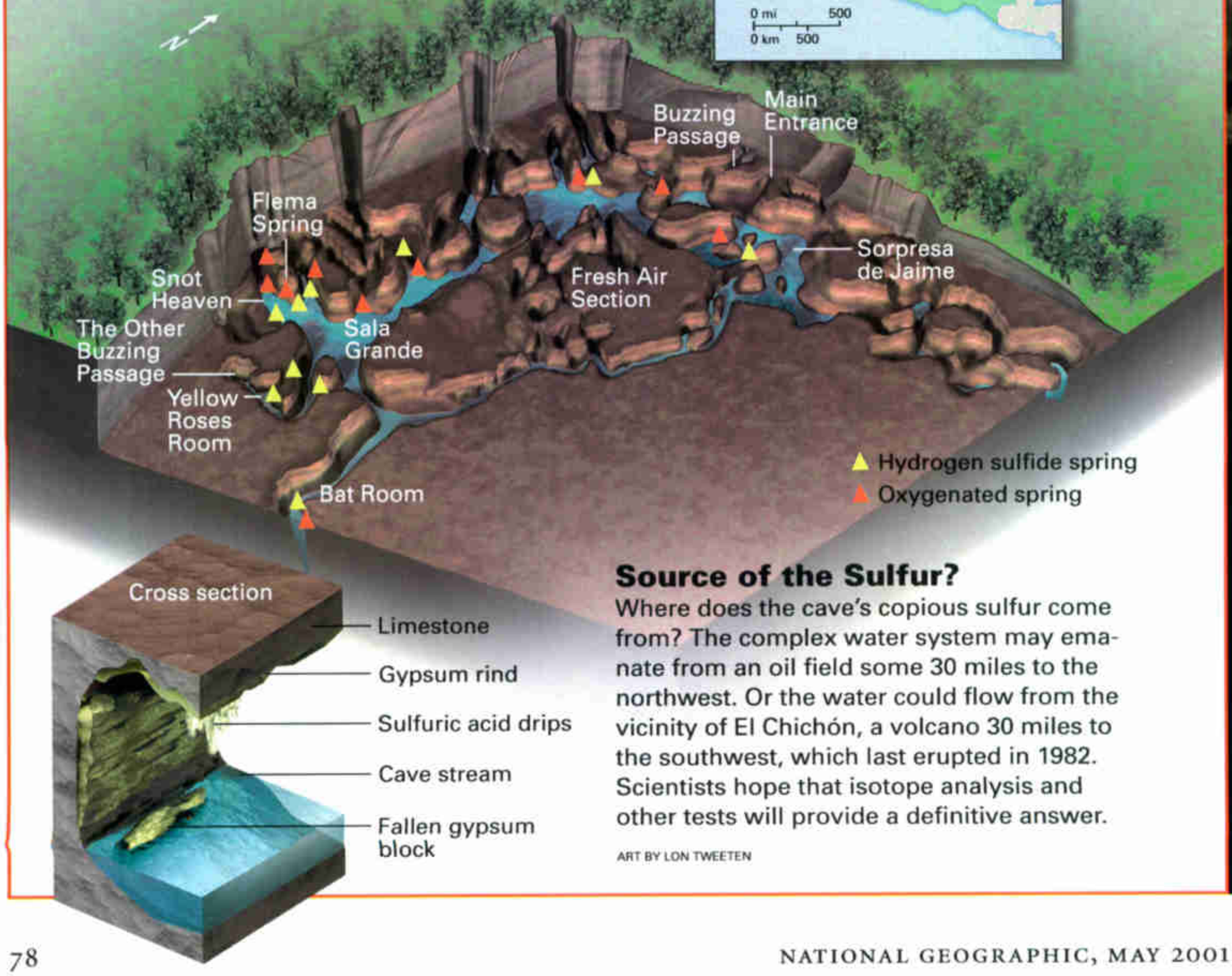
VITAL PORTALS

Light streams through one of about 25 skylights. Sulfuric vapor eats away at the roof, and sections collapse. Skylights, which give the cave its name, allow fresh air to enter and poisonous gases to escape. Without these vents, life in the cave would be even more tenuous. As it is, reptiles and small mammals fall in—and wish they hadn't.



Cave Anatomy

Probably only a few thousand years old, Villa Luz is far younger than most caves. Some of its underground springs are oxygen rich. Others bear hydrogen sulfide, oxidized by microbes into sulfuric acid that reacts with limestone, converting it to gypsum. Soft chunks fall into the cave stream and are washed away, rapidly enlarging the cave.



Source of the Sulfur?

Where does the cave's copious sulfur come from? The complex water system may emanate from an oil field some 30 miles to the northwest. Or the water could flow from the vicinity of El Chichón, a volcano 30 miles to the southwest, which last erupted in 1982. Scientists hope that isotope analysis and other tests will provide a definitive answer.

ART BY LON TWEETEN

EXPLORE WITH CAUTION

Entering a skylight, Dave Lester will descend to a section called Fresh Air, a reliable refuge from dangerous gas levels elsewhere. During five expeditions to Villa Luz since 1997, no serious accidents have occurred, in part because all three dozen team members have used electronic monitors to measure gas levels. Their alarms often shriek warnings, depending on the area and day-to-day conditions. In places, hydrogen sulfide levels have reached at least 200 parts per million (ppm)—the highest level that the researchers' monitors measure. Levels between 250 and 500 ppm can cause pulmonary edema, which can be fatal. The cave also exudes dangerous levels of carbon monoxide, carbon dioxide, and sulfur dioxide. In some passages cavers have found oxygen levels as low as 9.6 percent, compared with a normal 21 percent.

For centuries people from nearby Tapijulapa and its vicinity have trekked to the cave's sulfur springs. Today they often ride a boat on the Almandro River (left and far left) to a trail that leads to Villa Luz. The cave's gas levels vary widely. People enter even when the odor is strong, but they don't venture in too far or stay too long.

MYSTERIES OF THE MIDGES

Millions of tiny midges swarm through the cave, but at least they don't bite. Microbial ecologist Kathy Lavoie of Plattsburgh State University of New York found as many as 70 per square inch. Larvae (left) graze on microbes in the water and a white biofilm found on rocks; adults (below) probably don't eat at all. About half the adults are red, the others green—why? And are midges the source of the loud, persistent hum in two passages that are nearly inaccessible? Where midges can be seen, they don't hum.

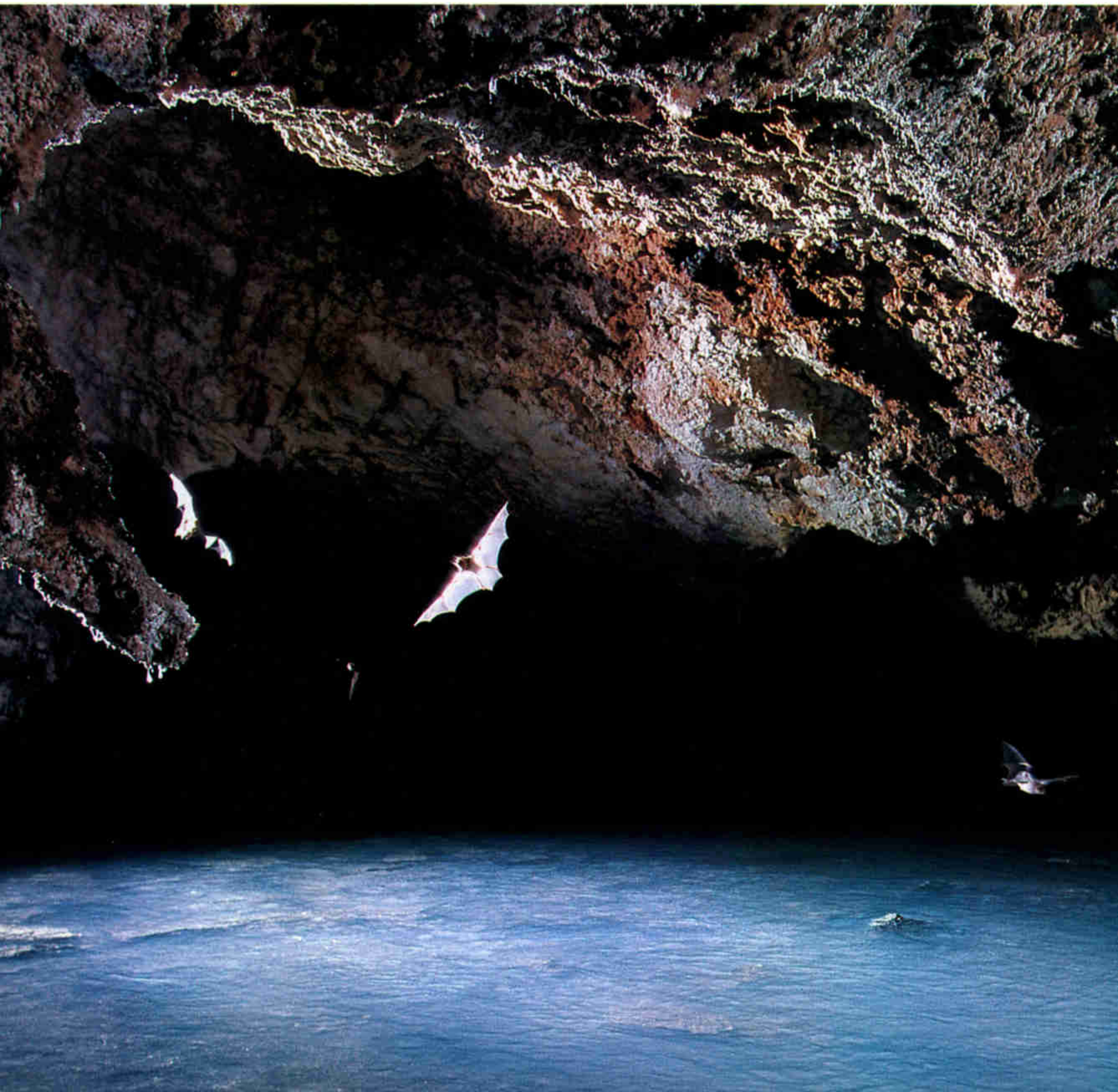
A RICH, TENACIOUS ECOSYSTEM

Sulfur-loving organisms find haven in the cave. For others it's a matter of supreme tolerance of an atmosphere that would fell unprotected humans. How cave vertebrates and invertebrates have adjusted to the gases could occupy researchers for years. With no light to provide photosynthesis in the most densely inhabited parts of the cave, the ecosystem depends on chemical sources of energy and so is termed chemoautotrophic.

Perhaps five varieties of bats have been observed (below): three leaf-nosed species, vampire bats, and Mexican free-tailed bats. Because toxic gases are usually heavier than air and stay near the floor, bats probably fly and roost above the danger level. In most caves bats are known to survive potent ammonia levels created by their own guano.

Insect life thrives, as do spiders—and fearsome spiderlike creatures known as amblypygids. Mites and water bugs like these (far right, top) also flourish. Female water bugs glue their eggs onto the backs of males, which carry the cache until it hatches. Adults are strong enough to kill and eat cave fish (far right, bottom).

Elemental sulfur adorns



rock where geologist Louise Hose takes a water sample from a spring (left). For her and her colleagues, micro is macro, and the smaller the better. Microbiologist Penny Boston, whose specialty is astrobiology, or extraterrestrial life, wonders if the more extreme forms of the Villa Luz microbes "could be an analog to life we might someday find deep beneath the surface of Mars."

MORE ON OUR WEBSITE

Watch an interview with photographer Stephen Alvarez and find out what life's like on assignment in an acid-filled cave at **nationalgeographic.com/ngm/0105.**

GIFT OF THE CAVE

During Holy Week hundreds of people make a fishing pilgrimage called La Pesca to the cave. Some are Zoque, descendants of the ancient Olmec. Villagers collect cave fish (above), using candlelight to illuminate their surroundings (right). Men sprinkle a paste of lime and the root of the toxic barbasco vine into a cave pool (top), making the fish stuporous and easy to collect. Eaten dried, the fish have no sulfur taste, say the locals. A longtime boon to them, the cave now presents a challenge to scientists seeking a whiff of its secrets. □

■ THE RISE OF LIFE ON EARTH

PTERO

Science and modelmakers' imagination—and wires—
return a *Pteranodon longiceps* to the skies over western
Kansas fossil beds 65 million years after the last of its
kind became extinct. The original vertebrate masters of
active flight, pterosaurs ruled the Mesozoic airways
for 150 million years, flapping and soaring long before
the first bird ruffled a single feather.

Lords of the Ancient Skies

PTEROSAURS

Fragile Flier

Hollow, ultralight bones aided pterosaur takeoff but made fossilization extremely rare. German paleontologist Peter Wellnhofer calls this *Pterodactylus kochi* "one of the most complete and best preserved in existence."

BAVARIAN STATE COLLECTION OF PALEONTOLOGY AND HISTORICAL GEOLOGY, MUNICH

By RICHARD MONASTERSKY
Photographs by JONATHAN BLAIR
Art by JOHN SIBBICK

THREE FLYING REPTILES from Earth's distant past glide above the gray Pacific, far beyond the rollers breaking on the shore of Point Reyes, California. They flap their wings slowly for a few beats, gain some altitude, then turn toward the beach. One peels out of formation and dives into the water with a splash, sinking just as far as its shoulders to snatch a fish with its long snout. Then, with a few powerful wing strokes, the beast takes off, using its webbed feet to hop off the waves until it clears the water. As it draws near, the primeval pterosaur transforms into an ordinary brown pelican.

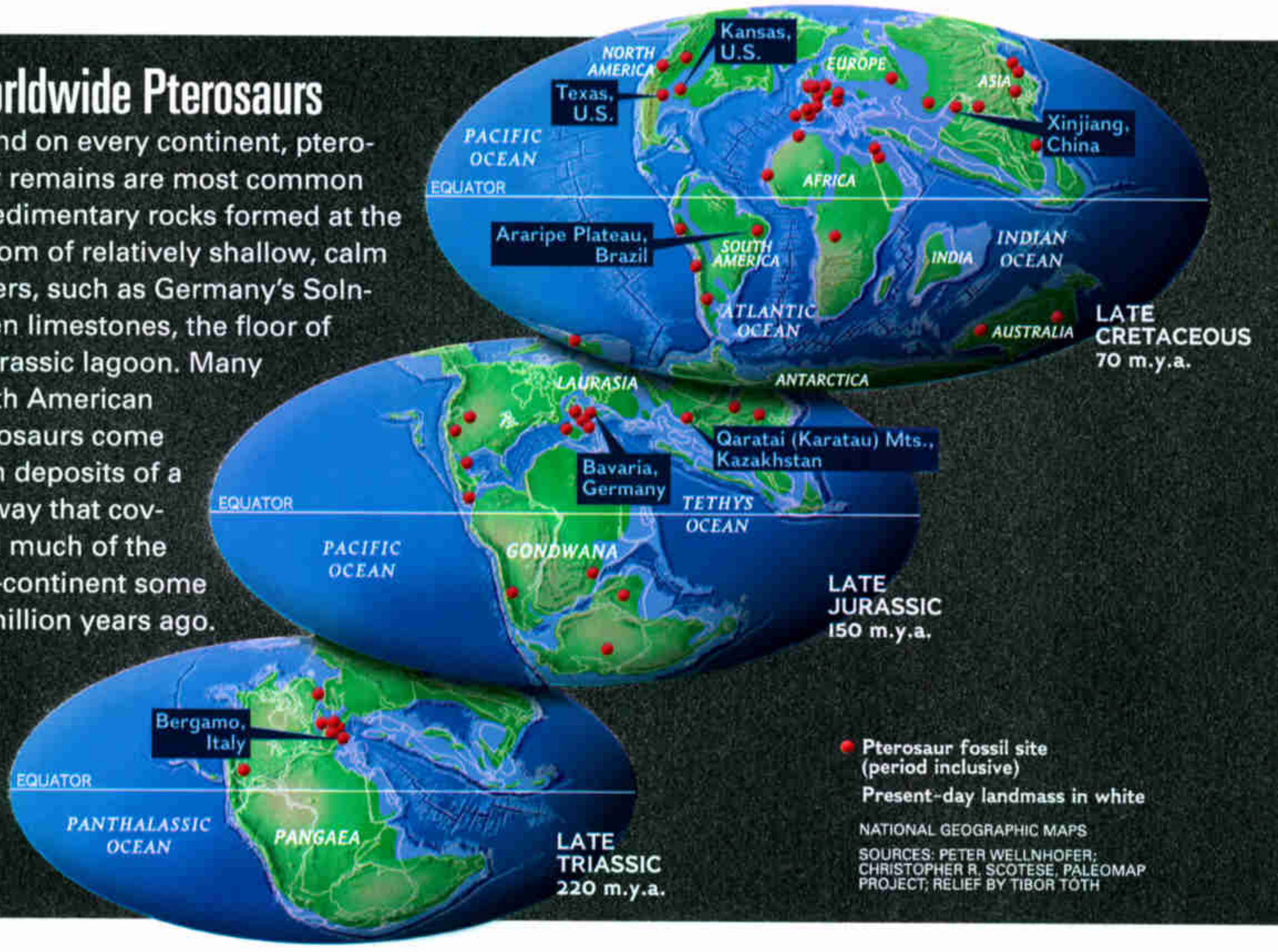
Kevin Padian, a paleontologist at the University of California, Berkeley, stands on the beach, gazing at the birds through binoculars. Watching coastal birds helps Padian envision the time when pterosaurs occupied the same ecological niche, plunging for fish like pelicans, soaring like gulls, and pecking at the sand like sandpipers.

"Pterosaurs were just the coolest things that were ever in the air," says Padian. "They were the first vertebrates to fly. They did it long before birds and bats. And in terms of size, they pushed the envelope as far as it could go for a flying animal."

Like their cousins the dinosaurs, pterosaurs stand out as one of evolution's great success stories. They first appeared during the Triassic period, 215 million years ago, and thrived for 150 million years before going extinct at the end of the Cretaceous period. Their endurance record is almost inconceivable compared with the span of humans, whose ancestors started walking upright less than four million years ago. Uncontested in the air, pterosaurs colonized all continents and evolved a vast array of

Worldwide Pterosaurs

Found on every continent, pterosaur remains are most common in sedimentary rocks formed at the bottom of relatively shallow, calm waters, such as Germany's Solnhofen limestones, the floor of a Jurassic lagoon. Many North American pterosaurs come from deposits of a seaway that covered much of the mid-continent some 85 million years ago.



shapes and sizes. Of more than 120 named species, the smallest pterosaur measured no bigger than a sparrow; the largest reached a wingspan of nearly 40 feet, wider than an F-16 fighter.

Until recently most paleontologists would not have put pterosaurs in the same league as birds in terms of flying ability. Because pterosaurs were reptiles, generations of scientists imagined that these creatures must have been cold-blooded, like modern snakes and lizards, making them awkward aerialists at best.

In the past three decades, however, a surge of fossil discoveries around the globe has prompted researchers to reexamine their views. The emerging picture of pterosaurs reveals that they were unlike any modern reptile. From a fossil discovered in Kazakhstan, paleontologists suspect that pterosaurs had a hairlike covering, perhaps akin to fur. If so, this detail provides evidence of a high-revving, warm-blooded physiology that could sustain the kind of exertion needed to stay in the air. Judging from the skulls of other fossils, scientists reason that many pterosaurs were gifted airborne predators, built to feed on the wing. They darted after insects, dive-bombed for fish, and soared hundreds of miles over open ocean on extended hunting expeditions.

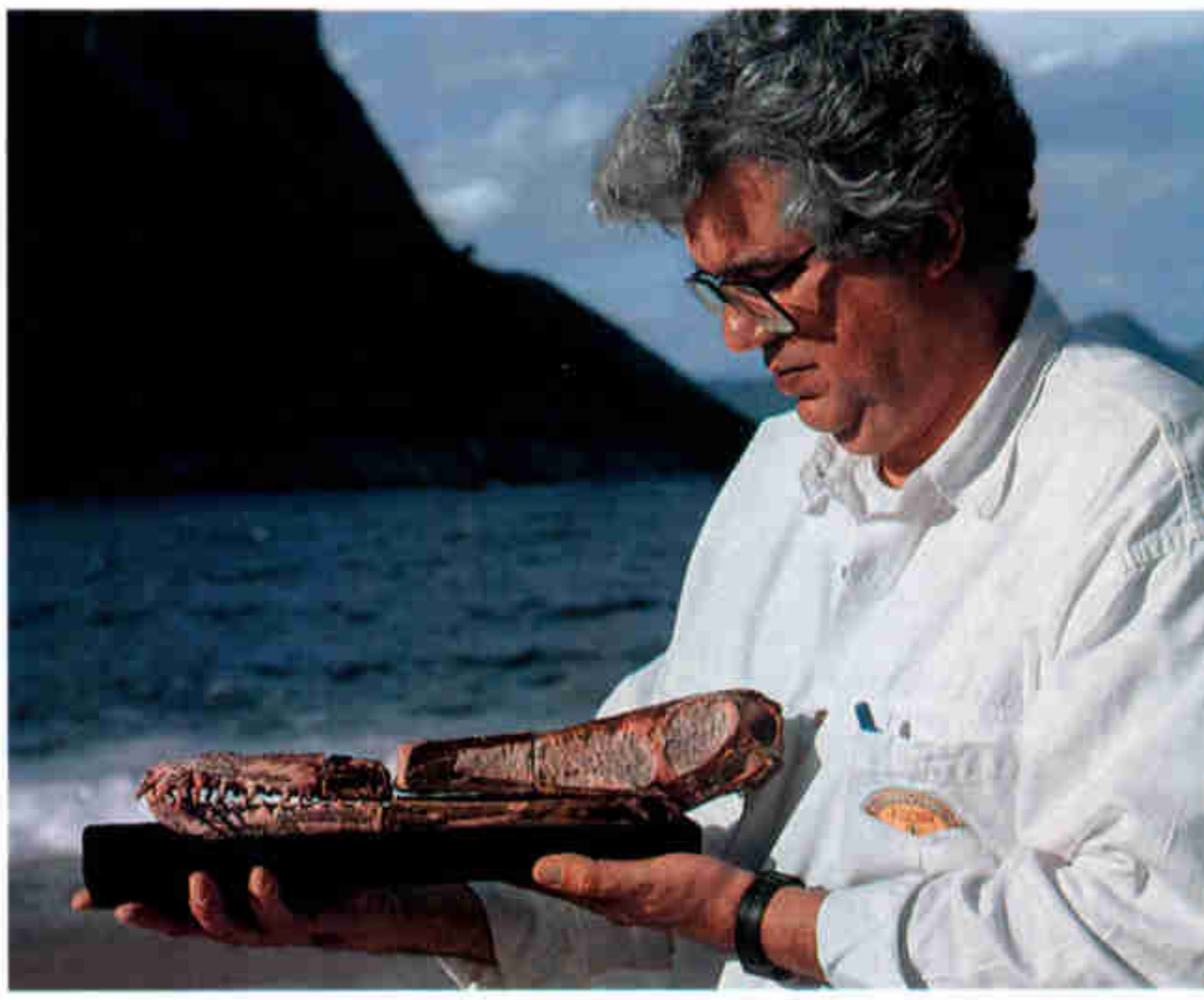
"For about 150 years pterosaurs were regarded as typical slow-moving, cold-blooded reptiles. People had the idea that pterosaurs could glide, but they couldn't really flap their wings," explains Alexander Kellner, a Brazilian paleontologist. "We thought they couldn't take off from the ground."

Pterosaurs first grabbed Kellner's attention when he was a child in Rio de Janeiro, where he became hooked on a television cartoon featuring one. His early fascination might have foundered, but when Kellner was a student, Brazilian scientists started to uncover a mother lode of pterosaur fossils in the northeastern part of the country, on the slopes of the Araripe Plateau. In the past 30 years Araripe has yielded remains of 19 new species, an unrivaled pace of discovery.

These pterosaurs soared over South America during the middle of the Cretaceous period, more than a hundred million years ago. At that time a large saltwater lagoon covered the Araripe area, and the African continent lay just over the horizon, separated by a young sliver of ocean that would later grow into the Atlantic.

Among the Araripe discoveries some of the strangest have been identified by Kellner and his mentor Diogenes Campos of the Brazilian Department of Mineral Production. At his office in Rio de Janeiro, Campos pulled out one of his favorite characters, a 110-million-year-old Araripe pterosaur that he and Kellner christened *Anhanguera,* or "old devil." It's an apt name—the fossilized skull could easily have flown out of a gothic ghost story.

Still partly entombed in rock, the glossy fossil looked leaden and cold. But as I ran my fingers over the 20-inch-long jawbone, tracing its curves and pits, I could imagine the Araripe pterosaurs sailing over the ancient lagoon. A solitary *Anhanguera* takes flight, its 13-foot wingspan silhouetted against the sky. The pterosaur sweeps its large keen eyes over the water, pulls its wings inward to pick up speed, and swoops low. Dropping its mouth into the water, the hunter uses its beak to slice through the waves like a black skimmer bird. In a flash



Brazil's Buried Treasures

Shaped to slice through the water, the skull of *Anhanguera* includes a jaw full of teeth likely used to snatch fish. Paleontologist Diogenes Campos (above) and colleague Alexander Kellner (facing page, at rear) unearthed the "old devil," along with a flock of other new pterosaur species, from the Santana formation in northeastern Brazil. In a town near the fossil beds Kellner and local museum founder Placido Cidade Nuvens show children a specimen found on their doorstep and prompt smiles with a group wing stretch.

the pterosaur jerks its head up and veers skyward, gripping a wriggling fish in its teeth.

Along the shore diminutive pterosaurs called *Tapejara wellnhoferi* pluck nuts and fruit from scrubby trees with their toucan-like beaks. Above the whole tableau soars the most impressive Araripe species, a giant called *Tupuxuara*, with a 20-foot wingspan. This toothless pterosaur had a rounded four-foot-long crest protruding from its skull like an exaggerated Mohawk haircut.

Paleontologists can paint this vivid portrait of Araripe pterosaurs because their bones were exquisitely fossilized, intact and uncrushed, within the quiet sediments at the bottom of the lagoon. By comparison, the flattened pterosaurs from most other sites around the world look like prehistoric roadkill. The Araripe fossils have enabled researchers to get a better fix on what pterosaurs actually looked like and how their bones fit together. They can see, for example, how the upper arm bone, or humerus, produced the flapping motion that kept pterosaurs in the air. The bone looks something like a hatchet: a stout shaft topped by a flared-out blade where it joined the shoulder. The wide head must have provided a broad anchoring point for the powerful chest muscles pterosaurs needed to flap their wings.

The weight of these large muscles was offset by lightweight, eggshell-thin bones filled with air. Larger species had slender struts inside hollow wing bones, adding strength without many additional pounds. So even with wings almost as wide as a house *Tupuxuara* may have weighed no more than a child. "They were so light," Campos said, "it's possible that they only had to open their giant wings and the wind would pick them up."

HOLLOW BONES gave pterosaurs an advantage during life but were a hindrance to their immortality. Pterosaur skeletons were so delicate that they survived as fossils only when their corpses came to rest in a protected environment. For that reason most pterosaur remains come from species that lived near the ocean—the soft seafloor ooze entombed their bodies for eternity.

Even with the new discoveries, the rarity of fossils leaves major gaps in knowledge about pterosaurs. No one knows how they evolved flight, why they vanished, or exactly what they looked like. Debate swirls around these reptiles like the air currents they once rode.

Controversy has surrounded pterosaurs since the first *(Continued on page 96)*

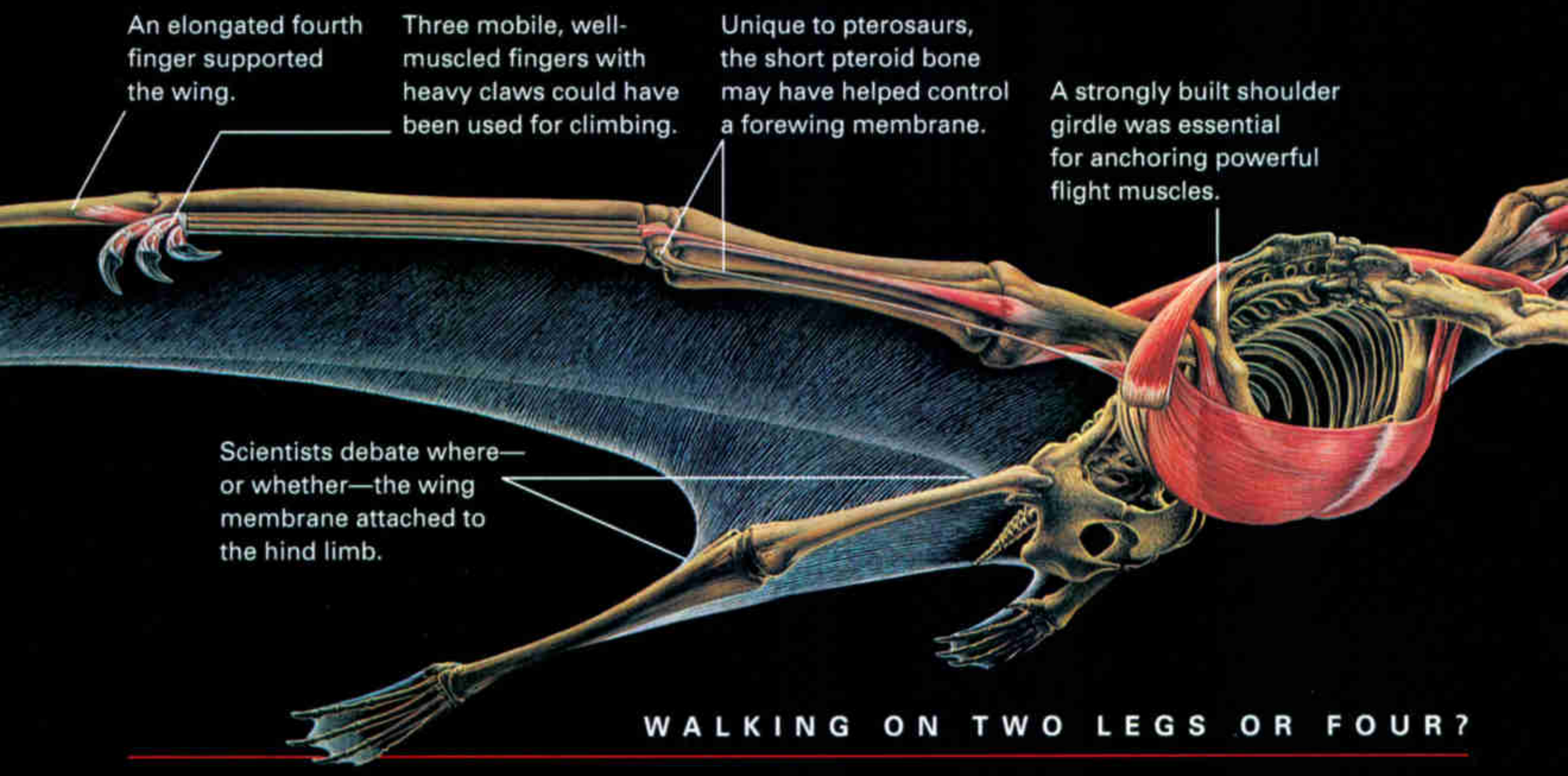
First Fossil

Naturalist Cosimo Collini described this fossil in 1784 but could not assign it to any animal group. In 1801 anatomist Georges Cuvier declared the oddity a flying reptile, later naming it *Pterodactylus*—wing finger—after the elongated digit he correctly surmised supported each wing.

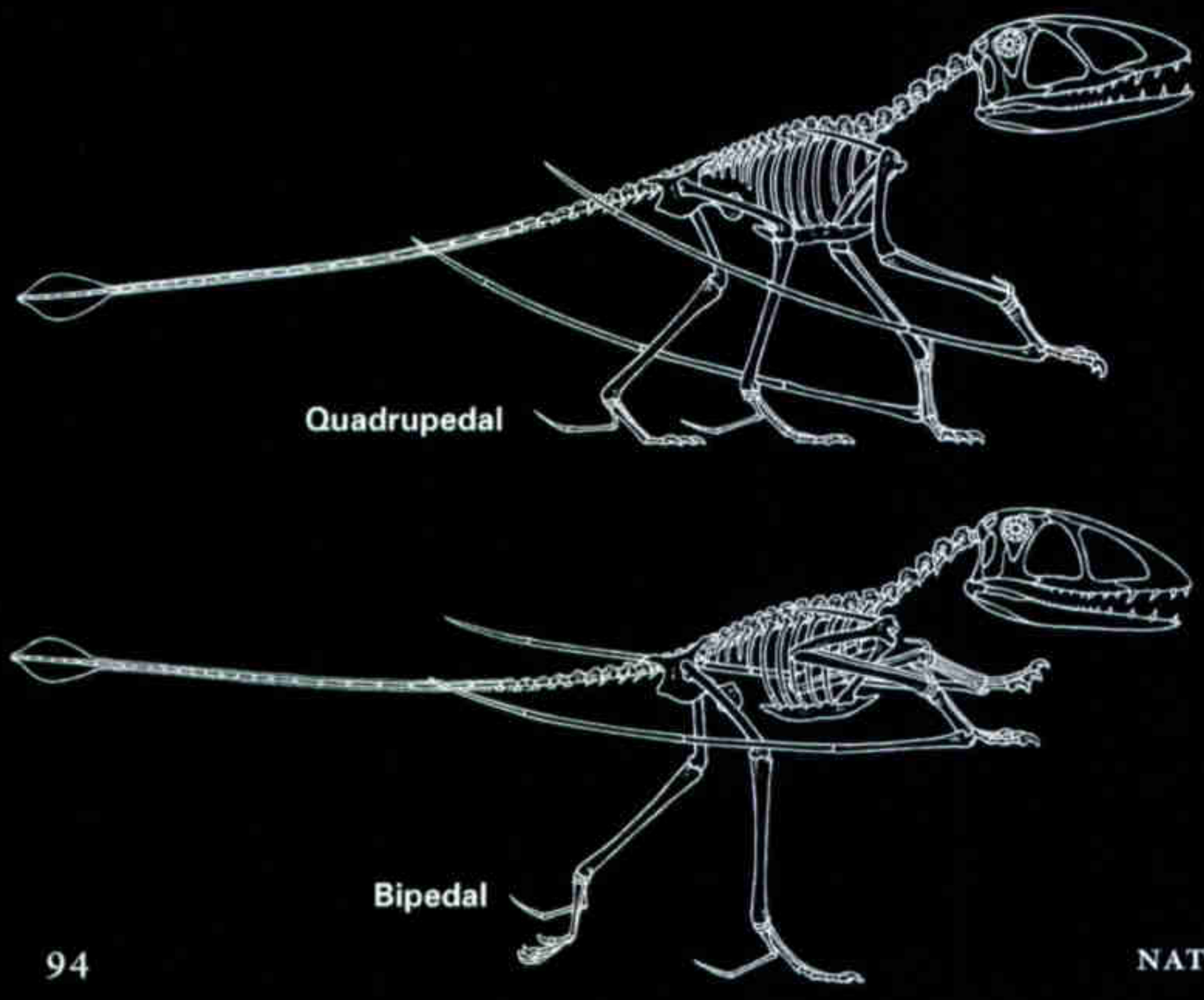
BAVARIAN STATE COLLECTION OF PALEONTOLOGY

Pterosaurs—Inside and Out

Scientists generally agree that pterosaurs were thoroughly flight-adapted and probably exploited as wide a range of ecological niches as do modern birds. Almost any other assertion provokes spirited discussion. Details of their aerodynamics, movement on the ground, and evolutionary relationships are still being debated after more than 200 years of study. Soft tissues—muscles, tendons, membranes—that could help resolve such disputes rarely fossilize. Even when found, such remains can defy analysis. Paleontologist Kevin Padian of the University of California, Berkeley, acknowledges that it's often difficult to distinguish between impressions that might be ordinary skin, or accessory flight membranes, or "simply the soft parts of a flattened and decayed Mesozoic roadkill."

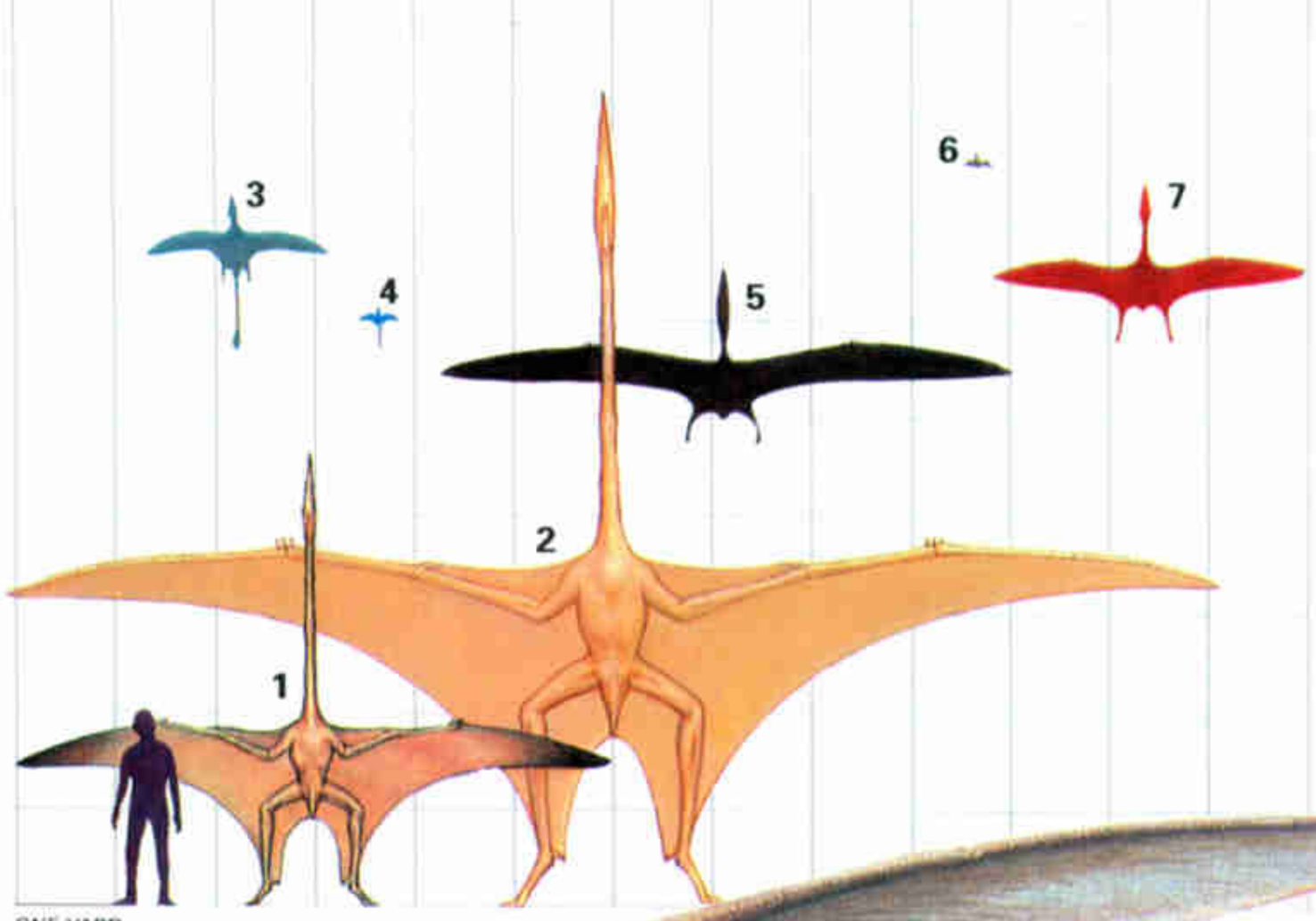


WALKING ON TWO LEGS OR FOUR?



Dimorphodon

Pterosaurs were agile in the air, and some scientists conclude that they were equally nimble on land, with an upright bipedal posture similar to birds and many dinosaurs. But most experts think that pterosaurs relied on a quadrupedal gait, with all four limbs bracing the body. *Dimorphodon,* an early long-tailed form, is used here to illustrate both postures.



From Sparrows to Sailplanes

1. *Quetzalcoatlus* sp.
2. *Quetzalcoatlus northropi*
3. *Rhamphorhynchus longiceps*
4. *Preondactylus buffarinii*
5. *Cearadactylus atrox*
6. *Pterodactylus elegans*
7. *Dsungaripterus weii*

Giant *Quetzalcoatlus*

Known from the Big Bend region of Texas, *Quetzalcoatlus* used its big wings to ride thermals—columns of air rising from heated ground. The largest, *Q. northropi,* had a wingspan of at least 36 feet, dwarfing the 18-foot wingspan of this smaller *Quetzalcoatlus* species.

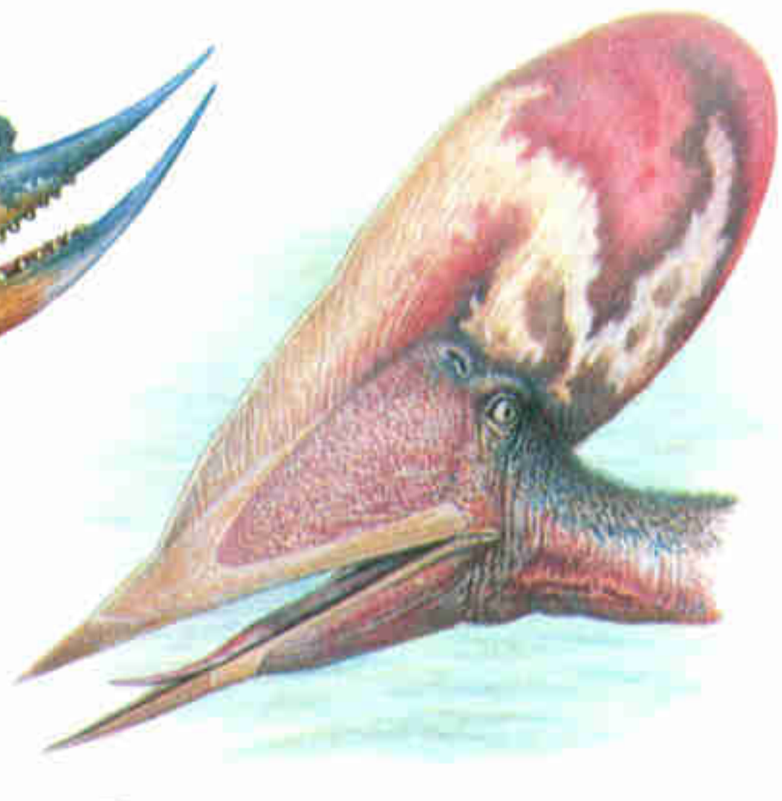
Tiny *P. elegans*

Perhaps the smallest pterosaur, *Pterodactylus elegans* had a skull just over an inch long, wings just ten inches from tip to tip. Shown to scale with *Quetzalcoatlus,* left, this sparrow-size flier relied on high-energy flapping to stay aloft.

JAWS TO SUIT THE BILL OF FARE

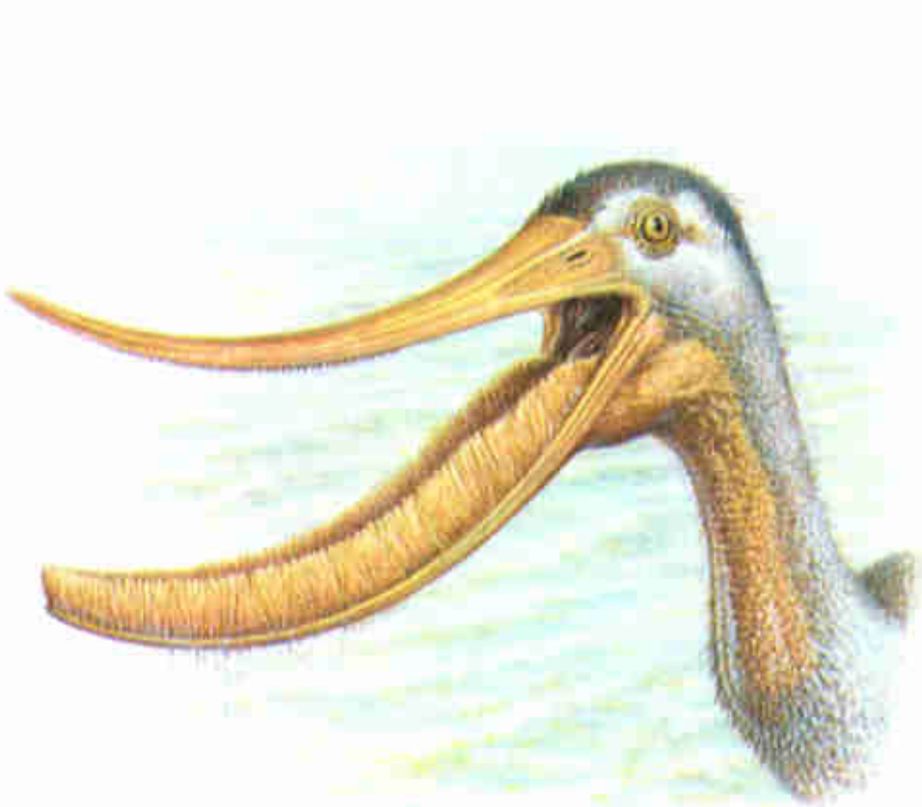
Dsungaripterus

First pterosaur known from China, *Dsungaripterus* may have used the curved, pointed ends of its jaws to probe shoreline rocks and burrows for shellfish. Flattened knobs lining the backs of its jaws could have been used to break open its catch.



Tupuxuara

Using tweezer-like jaws to pluck fish from Cretaceous seas covering what is now northeastern Brazil, toothless *Tupuxuara* likely gulped its meals whole. A 20-foot wingspan helped it stay aloft, scanning the water for near-surface prey.



Pterodaustro

Argentina's *Pterodaustro* is thought to have sieved tiny organisms from shallow waters using the thousand-odd bristle-like teeth in its lower jaw. Short, blunt teeth in the upper jaw probably ground up the contents of its "filter basket."

discovery of one at the end of the 18th century. At the Bavarian State Collection of Paleontology and Historical Geology in Munich, paleontologist Peter Wellnhofer pulled out a large drawer filled with fossils and pointed out a fragile skeleton, which was no bigger than my hand. "Here is the famous *Pterodactylus antiquus*," he said. Embedded in a slab of limestone 150 million years old, the creature lay with its mouth agape in a pose of prehistoric horror. It has a long toothy snout, a giraffe-like neck, and lanky legs, but its most unusual feature is its forelimbs. Next to three small fingers is a fourth that extends ten times the length of the other digits.

Cosimo Alessandro Collini, the first natural historian to study the fossil, was stumped when he described it in 1784. Seventeen years later the great French anatomist Georges Cuvier deduced that the animal was a flying reptile, whose fourth finger supported a wing. Although the wing surface had not fossilized, Cuvier surmised that a membrane of skin had attached to the forelimb in life.

He later named the fossil *Pterodactylus*, combining the Greek words for wing and finger. A few decades later the term pterosaur, or winged reptile, was coined to describe the growing list of similar fossils.

In 1873 a remarkable pterosaur specimen came to light that confirmed Cuvier's deduction. Unlike earlier fossils, this new find near the Bavarian town of Solnhofen contained delicate wing impressions, clear proof that the extinct reptiles could fly.

Even with more than a thousand pterosaur specimens known today, such wing impressions remain rare. Normally only bones survive the fossilization process. Material as ephemeral as skin or hair disintegrates long before an animal turns to stone. But time was kind to the pterosaurs that died near Solnhofen because many were preserved in the sediments of a Jurassic lagoon.

Wellnhofer slid open another drawer and gingerly removed a gull-size pterosaur named *Rhamphorhynchus*, with a wing so beautifully preserved that I could see impressions left by delicate folds of its skin. Under the microscope the surface of the wing looked corrugated, almost like corduroy. This texture comes from fine fibers only two-thousandths of an inch thick that were inside the membrane. Paleontologists don't know what the fibers were made of, but they suspect that they added strength to the wing, in much the same way the thin metal frame of an umbrella supports the fabric.

"This is a unique characteristic of pterosaurs," Wellnhofer said. "The fibers may have helped stiffen the wing membrane. They could also have kept the wing bent, cambering its surface."

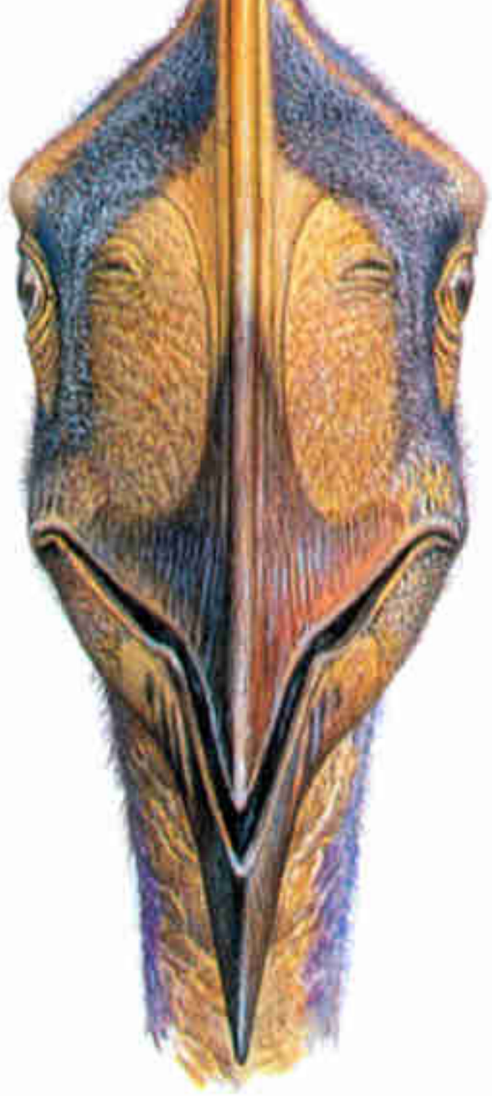
Some 150 million years after *Rhamphorhynchus* flew, aeronautical engineers would use the same cambered-wing principle when building planes.

Rhamphorhynchus would have displayed

Built for Work or Show?

Tapejara

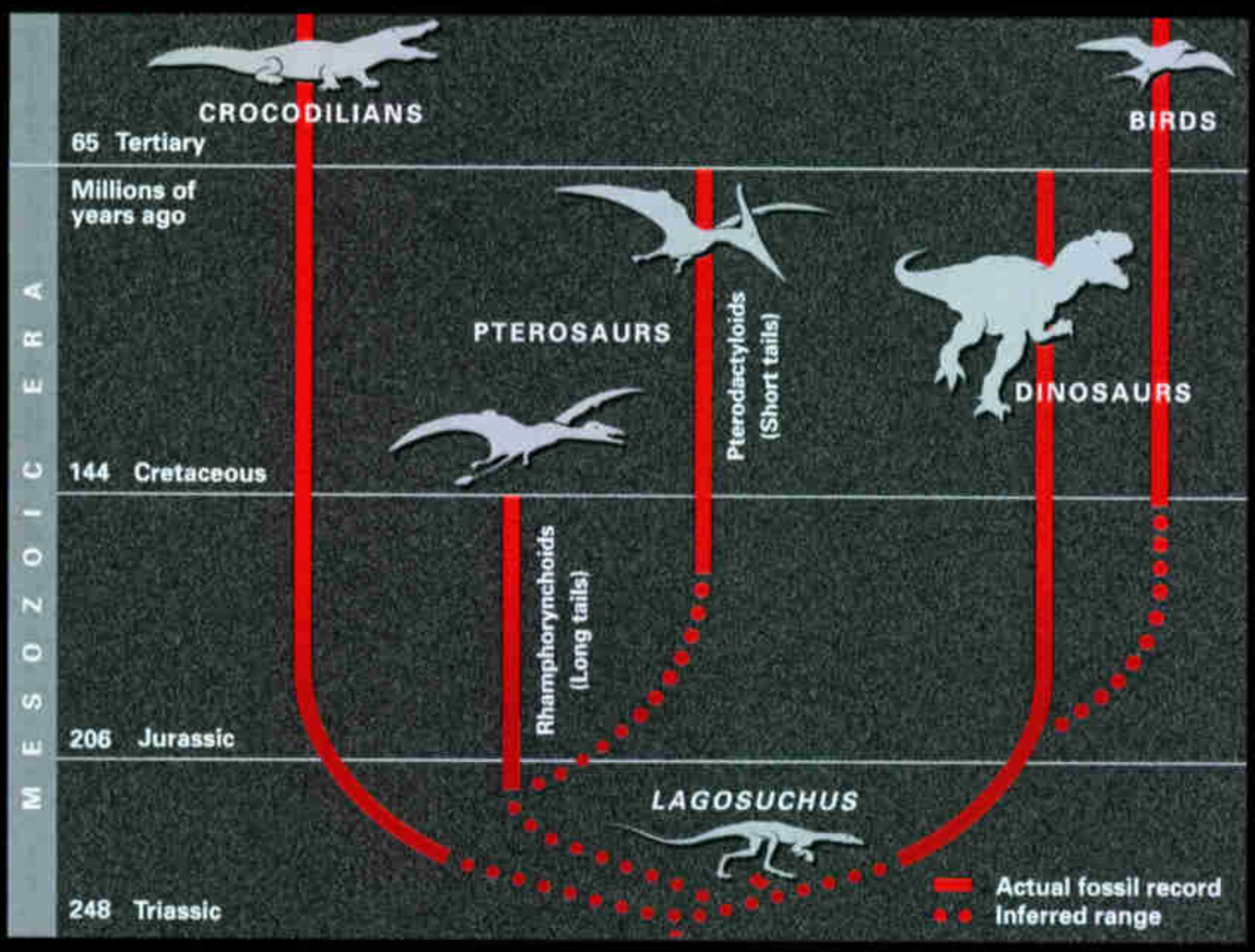
Flashy as a Carnival mask, Brazilian pterosaur *Tapejara imperator* sports a bony crest of exuberant proportions: three feet tall from the base of the skull. Some researchers see cranial crests as rudder-like steering aids. But paleontologist Chris Bennett notes that large crests correlate with large body size and narrow pelvic width, suggesting that the showiest pterosaurs were males whose cranial flourishes attracted potential mates.



Fleshing Out the Bones

Watching seabirds—like pelicans (above) and albatrosses—fly and fish helps paleontologist Kevin Padian (left, with beach buddies Marty and Maggie) develop ideas about how some pterosaur species may have behaved. "Airplanes make good models for the big soaring guys, like *Quetzalcoatlus* and *Pteranodon,*" he says, "but for smaller flappers, birds are the best living analog to study."

PTEROSAURS ARE NOT DINOSAURS



Sharing the Mesozoic with dino superstars like *T. rex,* pterosaurs are sometimes popularly called "flying dinosaurs," but they are a distinct lineage. Their common ancestor may have resembled the small reptile *Lagosuchus* (left, at bottom).

Pterosaurs appear to have reached maturity quickly, and some fossils preserve impressions of what may be hair. Rapid growth and an insulating coat are typical traits of modern warm-blooded animals and distinguish pterosaurs from crocodilians and other cold-blooded kin.

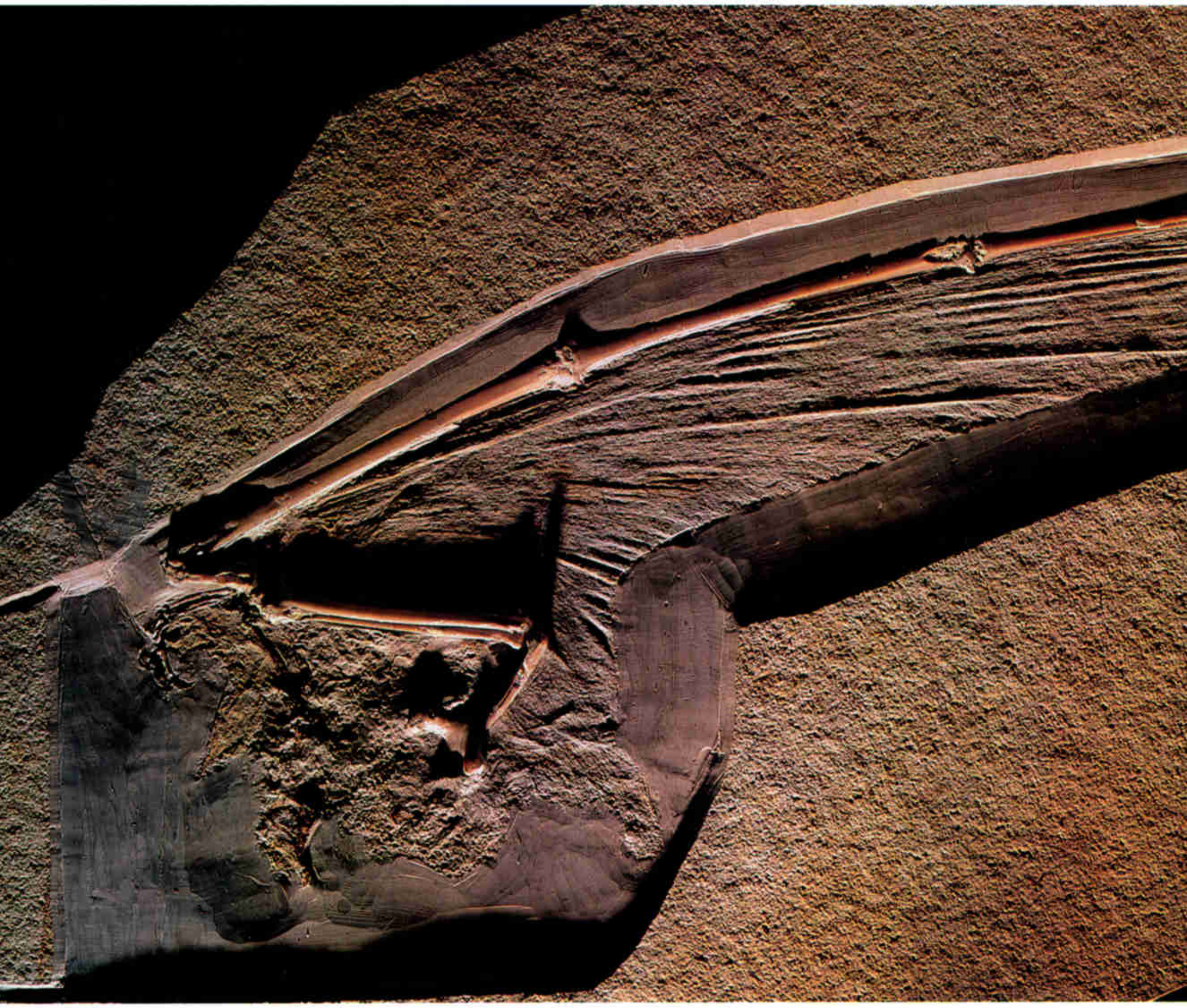
its piloting skills while fishing for food over the Jurassic lagoons, Wellnhofer said, pointing out the spearlike snout on one specimen. "Look at the end of the lower jaw. It is very long and pointed. They skimmed above the water, with just the tip of the lower jaw plowing through the water. And if they met a fish, they could catch it with their long slender teeth like so," he said, clamping his hands together.

Pterosaurs could carry out these precise actions because they had a highly specialized brain. Their enlarged cerebellum, a characteristic more like the brain of birds than reptiles, provided the enhanced muscular coordination required for maneuvering on the wing. Such adaptations of brain and body must have taken untold millennia to transform a four-legged reptile into a full-fledged flier.

But the evolutionary path to the air remains in dispute. Most researchers conclude that pterosaurs descended from a small arboreal reptile that spent its life jumping between branches. Like the modern flying squirrel, this creature would have spread its limbs, using flaps of skin attached to its limbs and body to brake its fall. Over many generations the fourth finger on each forelimb grew longer, enlarging the skin surface and enabling the animal to glide farther.

The competing theory holds that pterosaurs evolved from bipedal reptiles that ran along the ground, perhaps spreading their arms for balance. Through gradual growth, the forelimbs would have evolved into wings.

All paleontologists admit, however, that the question of origins remains open, awaiting



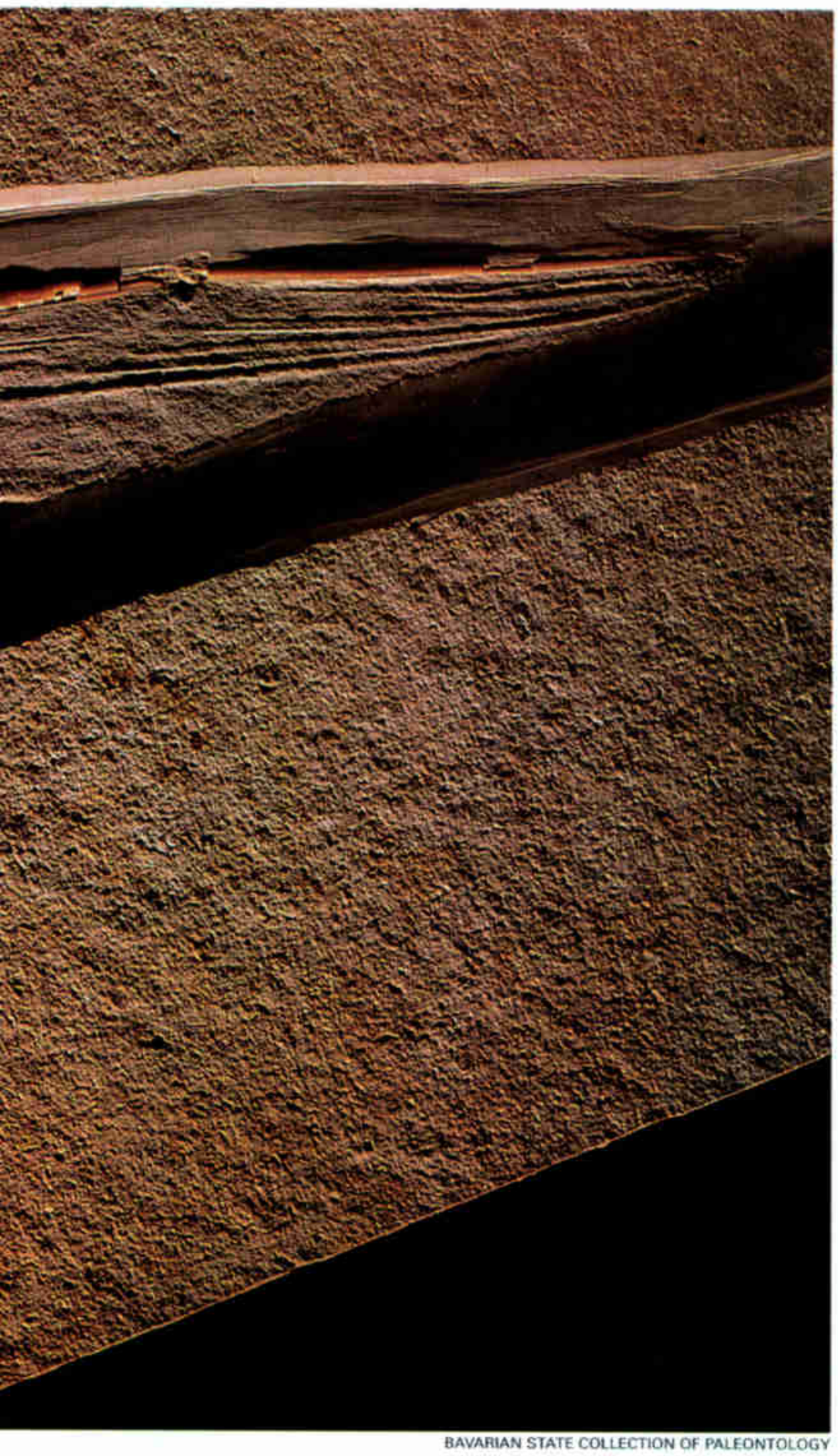
new fossil discoveries of early forms of pterosaurs. "It's very difficult to say how they evolved because the first pterosaurs we have are true, complete pterosaurs," said Fabio Dalla Vecchia, a researcher at the Paleontology Museum in Monfalcone, Italy. "Their fourth finger has already transformed into a wing."

The earliest known pterosaurs come from the mountains of northern Italy, where Dalla Vecchia has spent years prospecting for flying reptiles. These species have shorter wings than later forms, but there is evidence that they were adept fliers, capable of hunting for fish over open water. I found proof of this prowess while examining the fossil of a *Eudimorphodon*, a 215-million-year-old pterosaur unearthed near Bergamo, Italy, in 1973. Under a microscope in the Civic Museum of Natural Science in Bergamo, several fish scales glistened in the abdominal region of the specimen—the remnants of this pterosaur's last meal.

Rupert Wild, a German paleontologist who discovered the scales, suggests that the pterosaur caught its prey much like brown pelicans do, dive-bombing under the water to grab its victims. "*Eudimorphodon* had a wrist that could bend 180 degrees backward," Wild said. "So they could fold their wings very tight to the body and then plunge into the water."

Until the discovery of *Eudimorphodon*, paleontologists thought that pterosaurs originated 200 million years ago, near the beginning of the Jurassic period. The find pushed the record back 15 million years, to the Triassic period.

When *Eudimorphodon* first took to the skies, it gazed down on a landscape completely alien



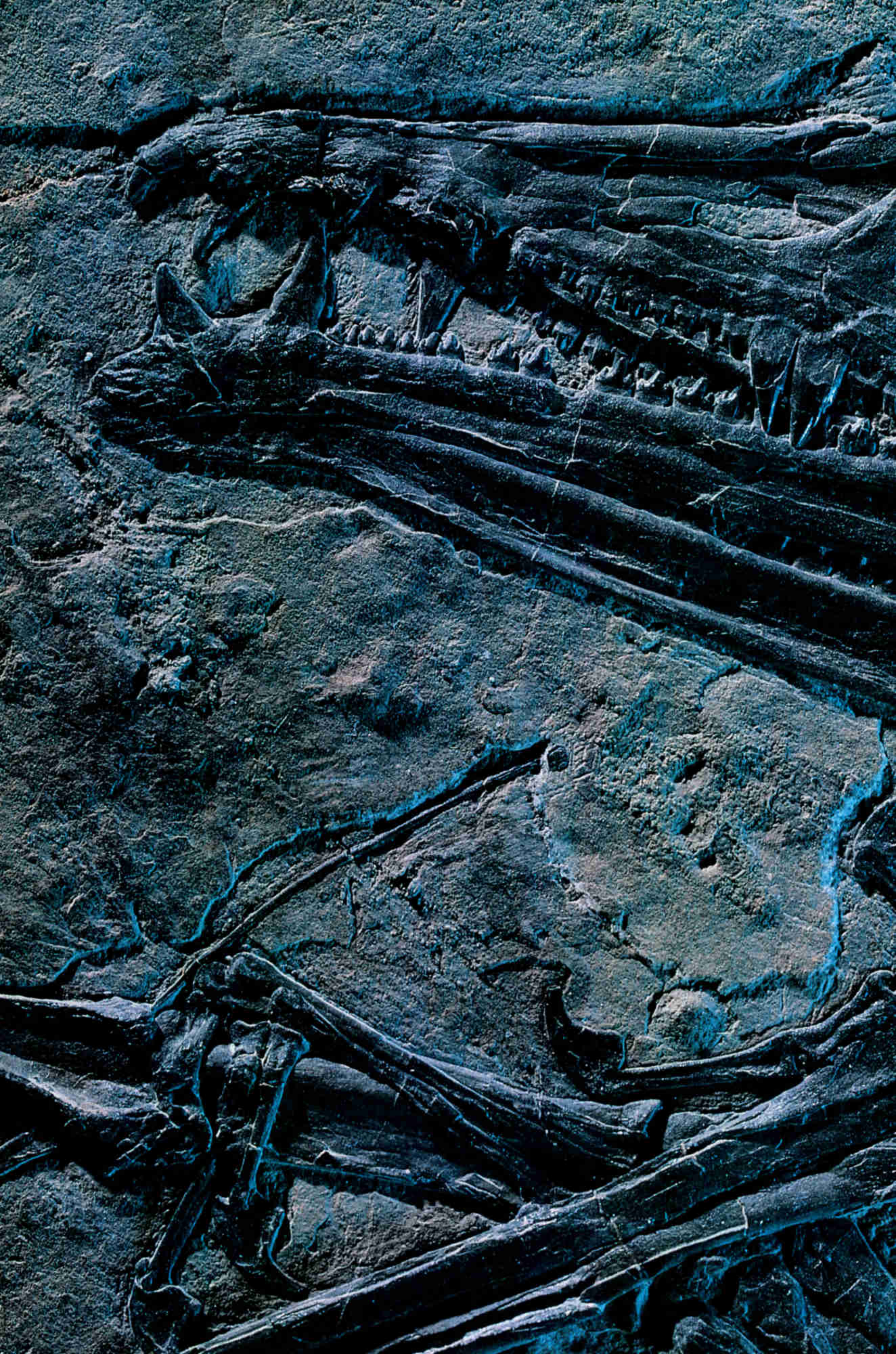
BAVARIAN STATE COLLECTION OF PALEONTOLOGY

Set in Stone

Grain so fine that it preserves minute details makes Germany's Solnhofen limestones (quarried slabs, above) a Jurassic mother lode for paleontologists. Parallel fibers that stiffened the wing membrane—each just two-thousandths of an inch thick—are visible in a Solnhofen *Rhamphorhynchus* fossil (left).

to modern eyes. The continents were gathered together into one landmass called Pangaea that stretched nearly from Pole to Pole. Crocodile-like reptiles reigned as top carnivores, while dinosaurs were increasing in number.

The balance of power shifted as the Triassic closed. Extinctions dethroned the prevailing reptiles, and fleet, meat-eating dinosaurs took over. During this period pterosaurs went through their own transformations, diversifying into



Tribal Elder

In 1973 an Italian fossil discovery pushed the pterosaur story back into the Triassic. Some 215 million years old, *Eudimorphodon ranzii* had a wingspan of about 39 inches and packed 114 teeth into jaws with a combined length of three inches.

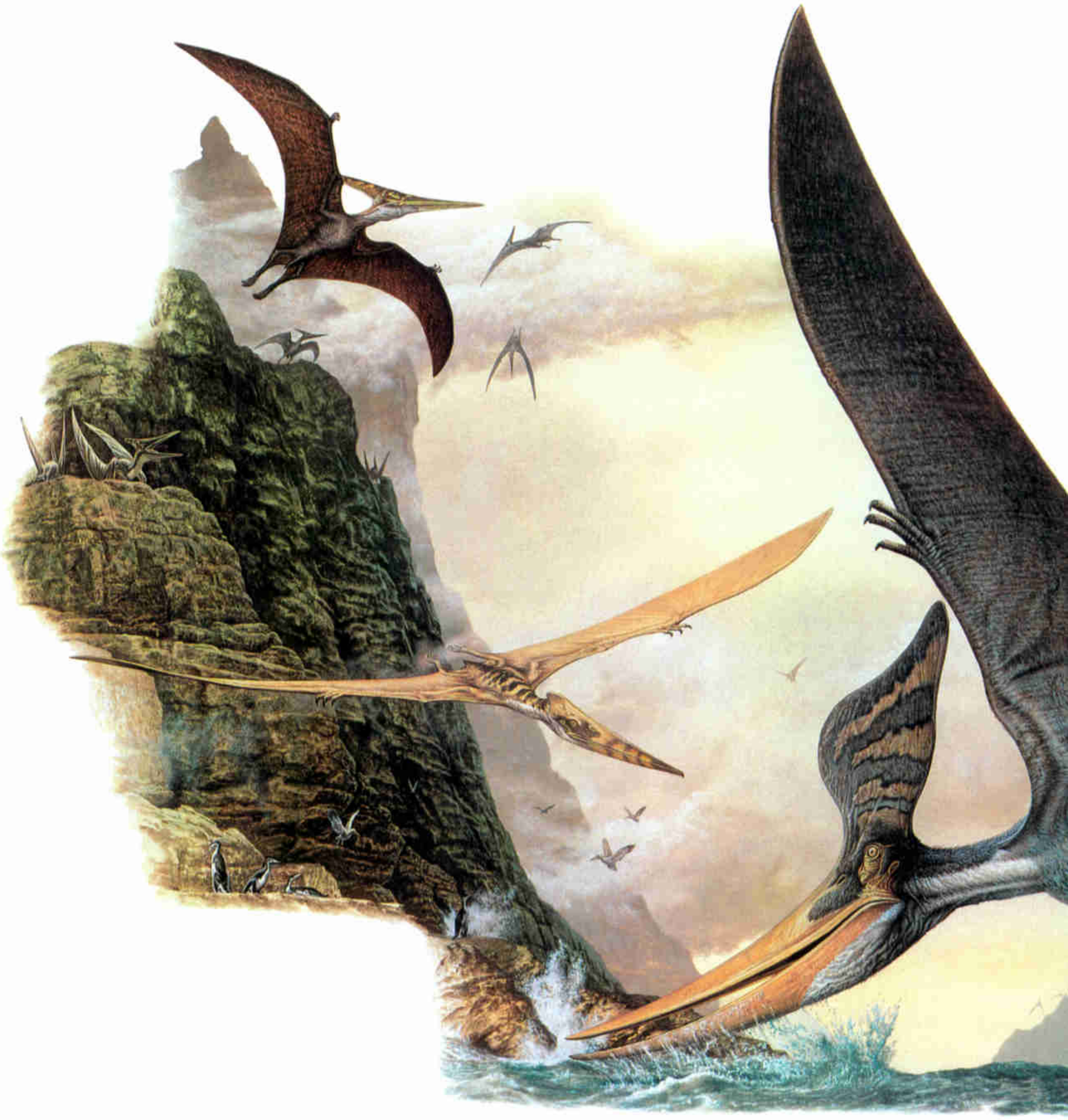
CIVIC MUSEUM OF NATURAL SCIENCE, BERGAMO, ITALY

dozens of species that ruled the winds. A clue to their evolutionary success came from the Qaratai (Karatau) Mountains of Kazakhstan in the 1960s when zoologist A. G. Sharov discovered fossils of an unknown species with well-preserved hairlike fibers. He named the new pterosaur *Sordes pilosus*, or "hairy devil."

Sordes clearly set pterosaurs apart from the reptiles known today. Crocodiles and lizards don't need an insulating layer over their bodies because they are cold-blooded: Their body heat and activity rise and fall with the ambient temperature. But the fibers on *Sordes* suggest that pterosaurs needed to keep their body temperature elevated. It's one clue that they may have evolved an advanced, warm-blooded physiology similar to birds and mammals.

This discovery of a "hairy" coat meshes perfectly with the animals' image as active fliers, said David Unwin, a paleontologist at Humboldt University's Museum of Natural History in Berlin. Warm-bloodedness would have given pterosaurs the endurance to power their muscles for long periods of time.

"There is no way that pterosaurs could have managed sustained flapping flight unless they



Living on the Wing: *Pteranodon sternbergi*

With a lower jaw nearly four feet long, tall cranial crest, and 24-foot wingspan, *P. sternbergi* (above and below, at right) soared far out over open ocean. Its remains are found in deposits 125 miles from the nearest Cretaceous shore.

STERNBERG MUSEUM OF NATURAL HISTORY, HAYS, KANSAS

had an elevated metabolic rate, unless they could get oxygen into their cells and carbon dioxide out rapidly," he said. "They couldn't have flapped for more than a few minutes if they had been cold-blooded. They would have crashed to the ground."

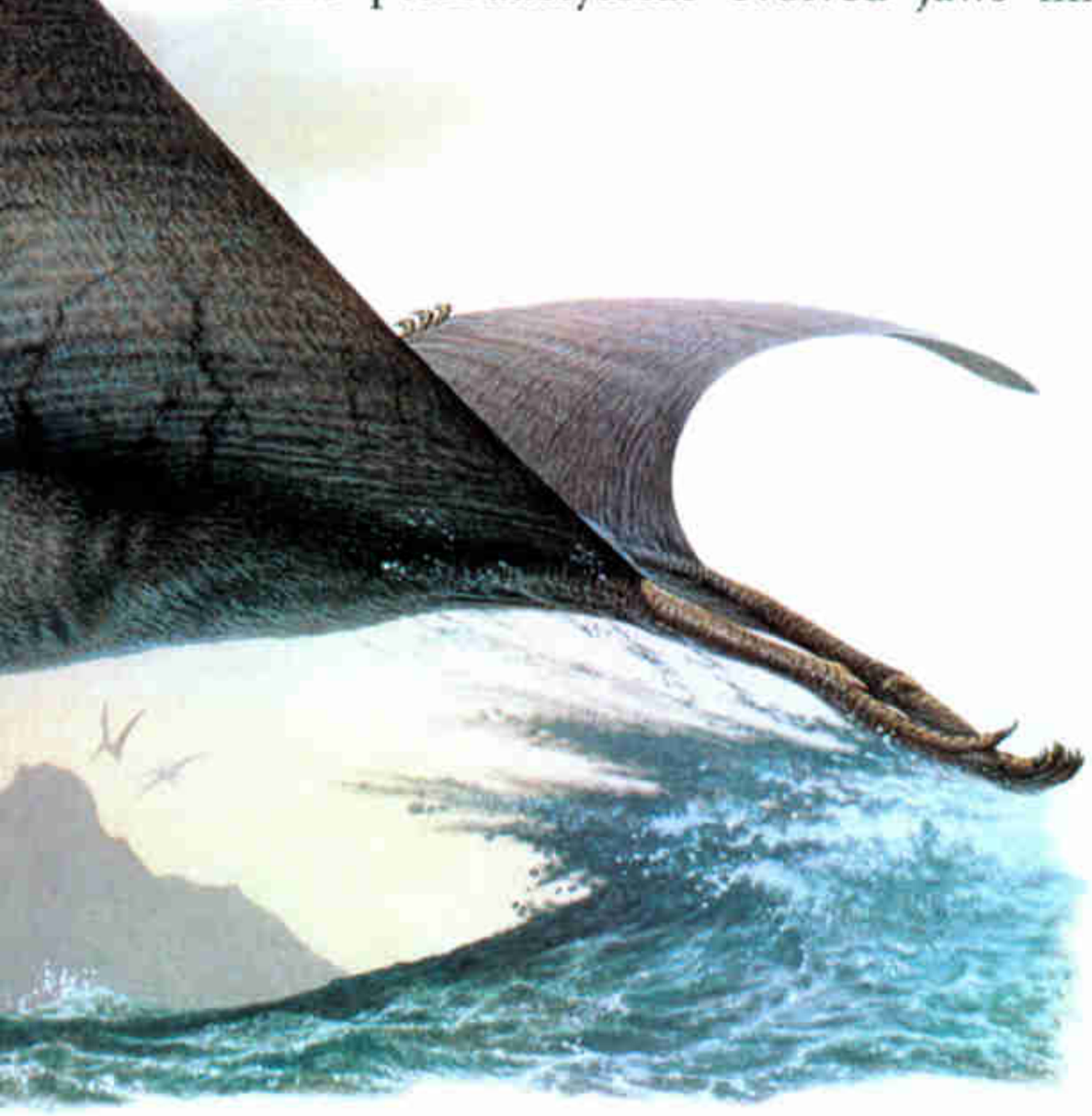
Like all early pterosaurs, *Sordes* had a long reptilian tail. By the time of *Sordes*' last hurrah at the end of the Jurassic, 144 million years ago, short-tailed pterosaurs called pterodactyloids had arrived. Over the next 80 million years these new forms would flourish, diversifying into an arkful of different species with unusual specializations for feeding and flight.

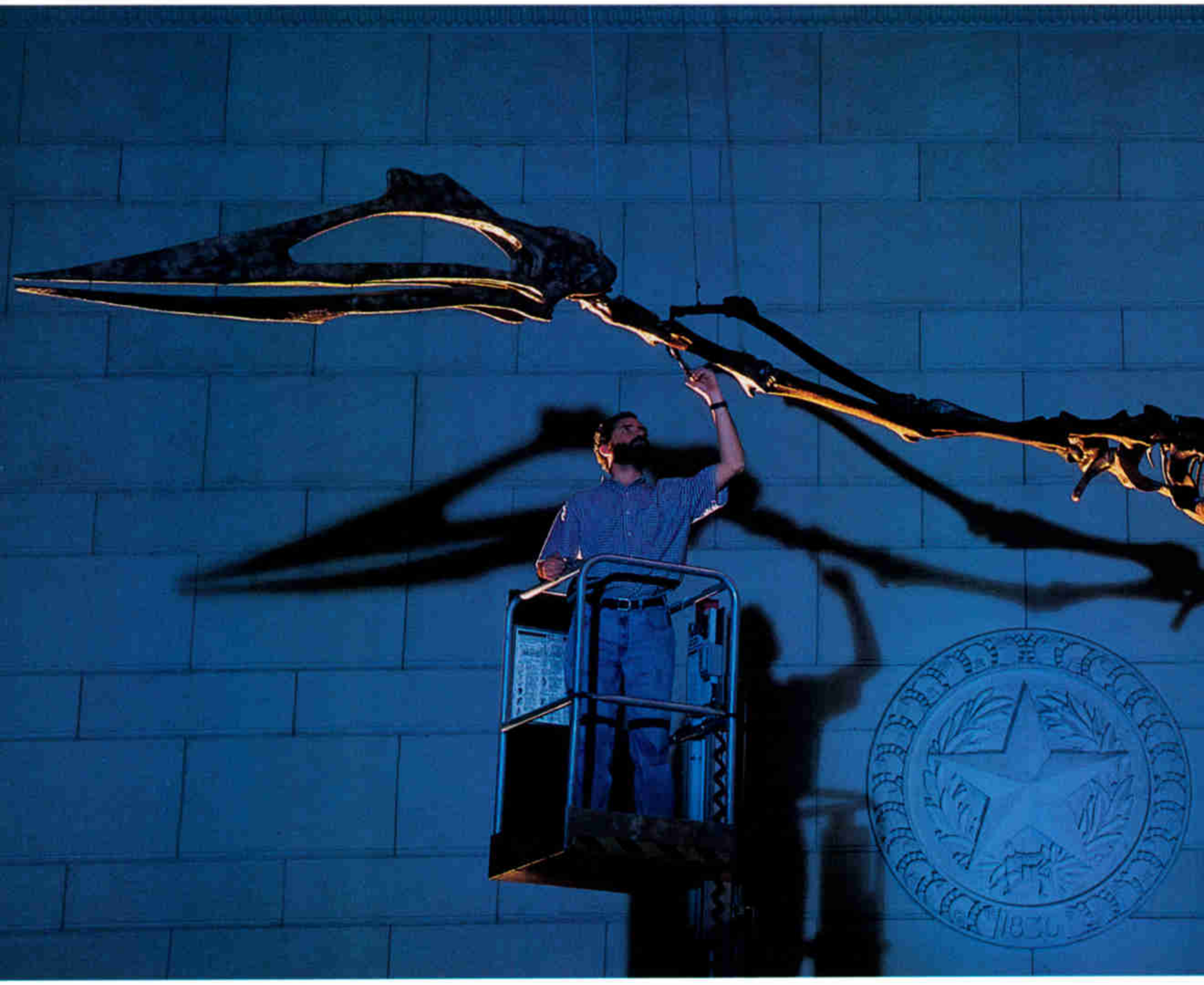
Some pterodactyloids evolved jaws lined with hundreds of needle-thin teeth, perfect tools for filtering tiny plants and animals from shallow lakes. Others such as the North American *Pteranodon* had no teeth. Its smooth jaws probably had a covering of hornlike material, similar to the beak of a bird.

What *Pteranodon* lacked in teeth, it more than compensated for with its imposing skull. One species had a head nearly six feet long, balanced on its neck like the top bar of the letter "T." The rear half of the skull consisted of a bony crest that grew straight backward. *Pteranodon* and its crest have perplexed researchers since the 1870s, when its bones turned up in the chalk layers of western Kansas. Some viewed the crest as a forward rudder, enabling the almost tailless pterosaur to steer while flying. Other scientists proposed that *Pteranodon*'s crest served as an air brake: To slow down for landing, the animal would simply turn its head broadside to the wind.

Chris Bennett, a paleontologist, dismissed both theories while showing me a *Pteranodon* fossil in the museum basement at the University of Kansas. The animal looked comically out of proportion, with a stretched-out skull that dwarfed its torso and hind limbs. To explain its huge head, Bennett invoked the same reason that teenage boys swagger: To establish rank among the guys and to impress the girls.

While studying *Pteranodon* fossils, Bennett concluded that the adult specimens fell into two categories. One group had big crests and





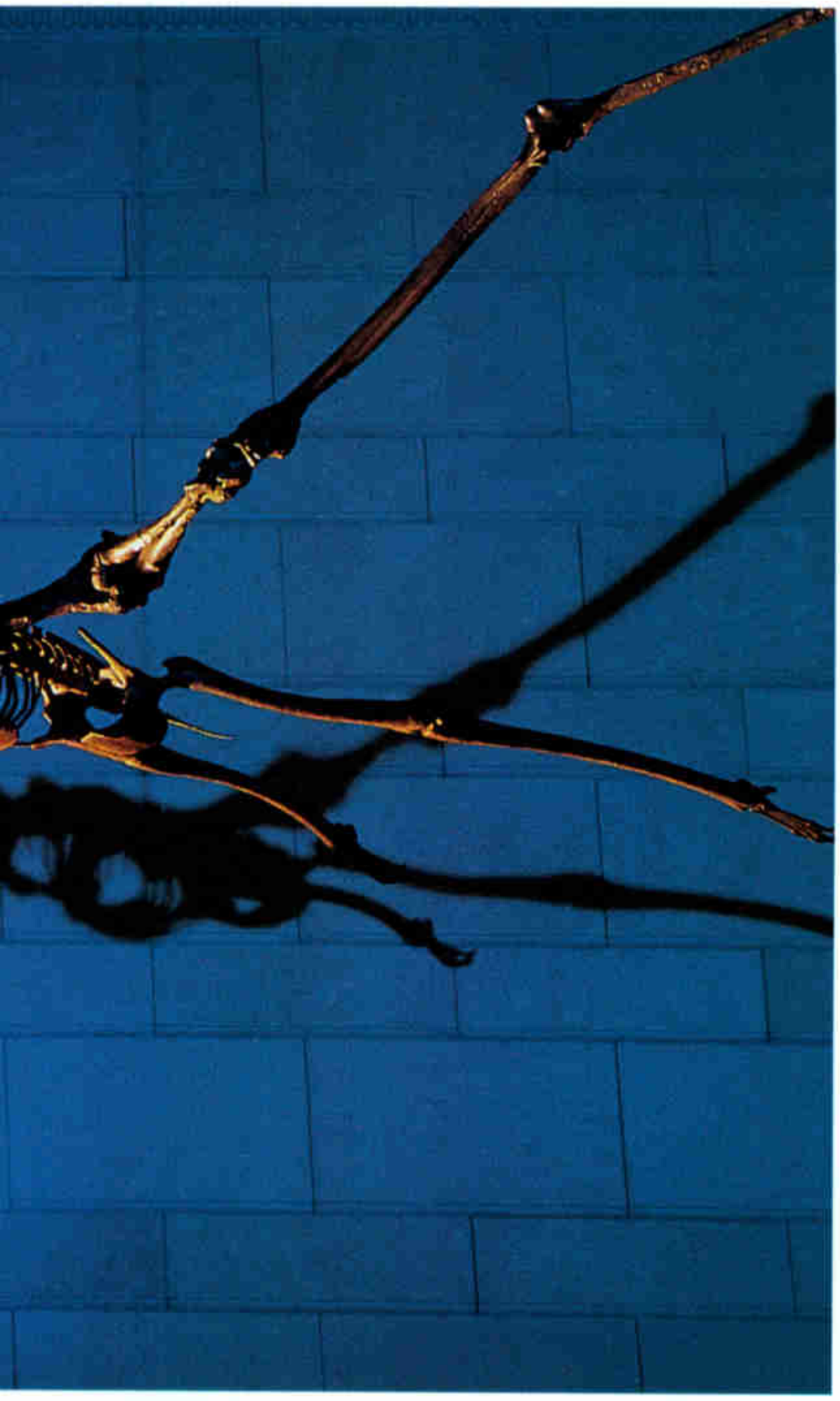
The Big Finish

Last—and perhaps largest—of its kind, *Quetzalcoatlus northropi* casts a long shadow in Texas Memorial Museum's Great Hall. Surviving to the end of the Cretaceous, this giant's soaring days were cut short by the mass extinction that both wiped out the dinosaurs and ended pterosaur domination of the skies.

small pelvises. The other had small crests and big pelvises. The latter were females, Bennett reasoned, because the large pelvises helped in laying eggs. The big crests belonged to the males. "My explanation for this is that the crest was a display device like the horns and antlers of mammals or the fancy feathers of birds," Bennett said. "I believe that *Pteranodon* was polygynous, that one male would mate with many females and only the dominant males would be mating with the females."

Although the mating rituals of *Pteranodon* remain speculative, one aspect of its behavior is clear from the fossil record. The remains of *Pteranodon* are found in rocks that lay more than a hundred miles out to sea in the Cretaceous period. This fish catcher, which had a wingspan of up to 24 feet, must have regularly soared vast distances over the waves, its wings outspread to catch the steady ocean winds.

AERONAUTICAL ENGINEERS once imagined that *Pteranodon* pushed the boundaries of animal flight. They calculated that a creature any larger would have been too heavy to lift itself into the air. The beast that broke those rules glares down at visitors milling about the Museum of Flying in Santa Monica, California. It is a life-size model of *Quetzalcoatlus northropi,* with a yellow beak the size of



a man and a wingspan wider than many of the planes exhibited nearby. Paleontologists estimate that this pterosaur and a related form had wingspans of at least 36 feet, making them the largest flying animals known. Birds don't come close. The wingspan of the largest living bird, the wandering albatross, measures only 11 feet.

Quetzalcoatlus represents the pinnacle of pterosaur design, capping a trend toward larger sizes that had started at the beginning of the Cretaceous, 144 million years ago. Unlike smaller pterosaurs, they could exploit natural up currents to stay aloft without having to flap continuously, said Paul MacCready, an aeronautical engineer. "Most animals don't get anything free from nature," he added, "but as some pterosaurs and birds got larger, they stumbled upon evolutionary benefits from soaring, making use of a free energy source. With their hollow bones, these pterosaurs had a super lightweight construction ideal for soaring."

As we circled underneath the *Quetzalcoatlus* in Santa Monica, MacCready pointed out its similarity to sailplanes, the most efficient of airplanes. Both have long slender wings designed to fly with minimum power. During flight, sailplane pilots routinely search for places where heat radiates from sunbaked earth, creating rising air currents called thermals. Undoubtedly *Quetzalcoatlus* would have exploited thermals as well, lazily circling over the river deltas that once covered the Big Bend region of Texas.

The triumphant reign of pterosaurs ended with this giant flier. At the end of the Cretaceous period 65 million years ago, a meteorite or comet slammed into Earth. That calamity —and other events—wiped out roughly three-quarters of all animal species, including all remaining pterosaurs and dinosaurs. But the number of pterosaur species appears to have dwindled for millions of years before the cataclysm, suggesting that something else contributed to their fate.

It could be that the evolutionary achievements of pterosaurs ultimately led to their downfall. *Quetzalcoatlus* and other late pterosaurs had evolved gigantic wings ideal for soaring, but the specialization came at a price. Longer wings make an animal less maneuverable and don't work as well in the strong winds that may have been typical late in the Cretaceous, said Wann Langston, Jr., a paleontologist at the University of Texas and an expert on *Quetzalcoatlus*.

"Pterosaurs were very delicate creatures. They were as light as butterflies, and if there were turbulent winds in the area, they would have had to remain on the ground," he said. "This may have been a factor in their extinction because world climate was deteriorating. And if climate deteriorates, the bigger the pterosaur, the bigger the disadvantage."

Whatever the cause of their demise, pterosaurs enjoyed unparalleled success. They trailblazed a path into sun-drenched skies before any other vertebrate. For 150 million years they sailed the winds on the strength of a fragile finger. What a glorious ride they had. □

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See more pterosaur photographs and read about life on assignment in the Mesozoic at **nationalgeographic.com/ngm/0105.**

The fragile world of FROG

Life and strife begin together as a tiny froglet hatches fully formed, bypassing the tadpole stage. Miraculously diverse—and in serious decline—frogs signal that something's amiss in the natural world.

FROGS

Oreophryne sp.

By Virginia Morell Photographs by George Grall

IT was a night for frogs and frog lovers: dark, wet, and warm. Raindrops the size of dimes pelted down, slapping on the broad-leaved trees of this Papua New Guinea forest, bouncing against my rain slicker, and sliding into the frothy creek at my feet. A few steps away a steep waterfall spilled over a pile of rocks. As rain, stream, and waterfall mixed, the night seemed to sound only of water. And as if in celebration of this liquid world, from every direction came the chirping, whirring, creaking calls of frogs.

"Beauty!" said Stephen Richards, an Australian herpetologist, using his countrymen's word of full approval as he took in the scene. Richards, a slim man in his 30s with a trim beard framing his face, has spent a good deal of his life traversing the woods of Papua New Guinea (PNG) and Queensland, Australia, searching out frogs—and has dozens of new species to show for his efforts. He also has the pallor of a man who works the graveyard shift. "You don't get much of a tan in this business," he explained. "If you want to catch frogs, you're going to be out at night."

But not just any night. Rain is generally a necessity too. To a frog the steady spatter of raindrops is like the seductive beat of a Ricky Martin song—a signal that it's time to find a mate. Male frogs gather near streams and ponds to call to the females, letting potential mates know where they are and why they—rather than some other male—should be chosen. The males' songs have another, coincidental use: They help scientists like Richards find them. Many frog species live quiet, secretive lives, and as Richards said, "If they're not calling, they can be very difficult to find."

Finding frogs has always been a basic herpetological skill. But in the past two decades, as frog numbers have declined alarmingly worldwide, that skill has taken on added importance. Increasingly it has become a key tool for monitoring the health of frog populations and species and for helping to identify the causes of some species' precipitous decline. Here, in the remote Star Mountains of western PNG, the frogs seem healthy, their populations stable. "But what do we really know about their populations?" asked Richards. "We're just now beginning to identify the species that live here. That's the situation in many places. We could be losing frogs that we've never seen."

Froggers, like skilled birders, can identify a species by its song, and Richards rattled off a list of what he was now about to catch.

"We've got three species here: a *Litoria,* a *Nyctimystes,* and a *Rana.* That translates to a tree frog, a torrent-stream frog, and a large bullfrog." Then, like a man on a mission, Richards waded into the stream, clambered up the waterfall, and disappeared into the woods. Only moments later he reappeared near the top of the fall. "Look at this!" he shouted over the rushing water. "It's a pair of *Nyctimystes,* and they're in amplexus."

In some situations a grown man standing in the rain at night on a steep mountainside while shouting in Greek and Latin might be enough to recommend him for long-term counseling. But I'd been traveling with Richards for two weeks and had picked up enough of his scientific lingo to know that this was a momentous occasion. Frog behaviors aren't often easy to witness in the wild, but Richards had found a prime example—a pair of lace-lid tree frogs, as this species is popularly known because of the delicate markings around their eyes, locked together in the mating position. Richards pushed through the tree ferns and bushes to set his prize in my hand.

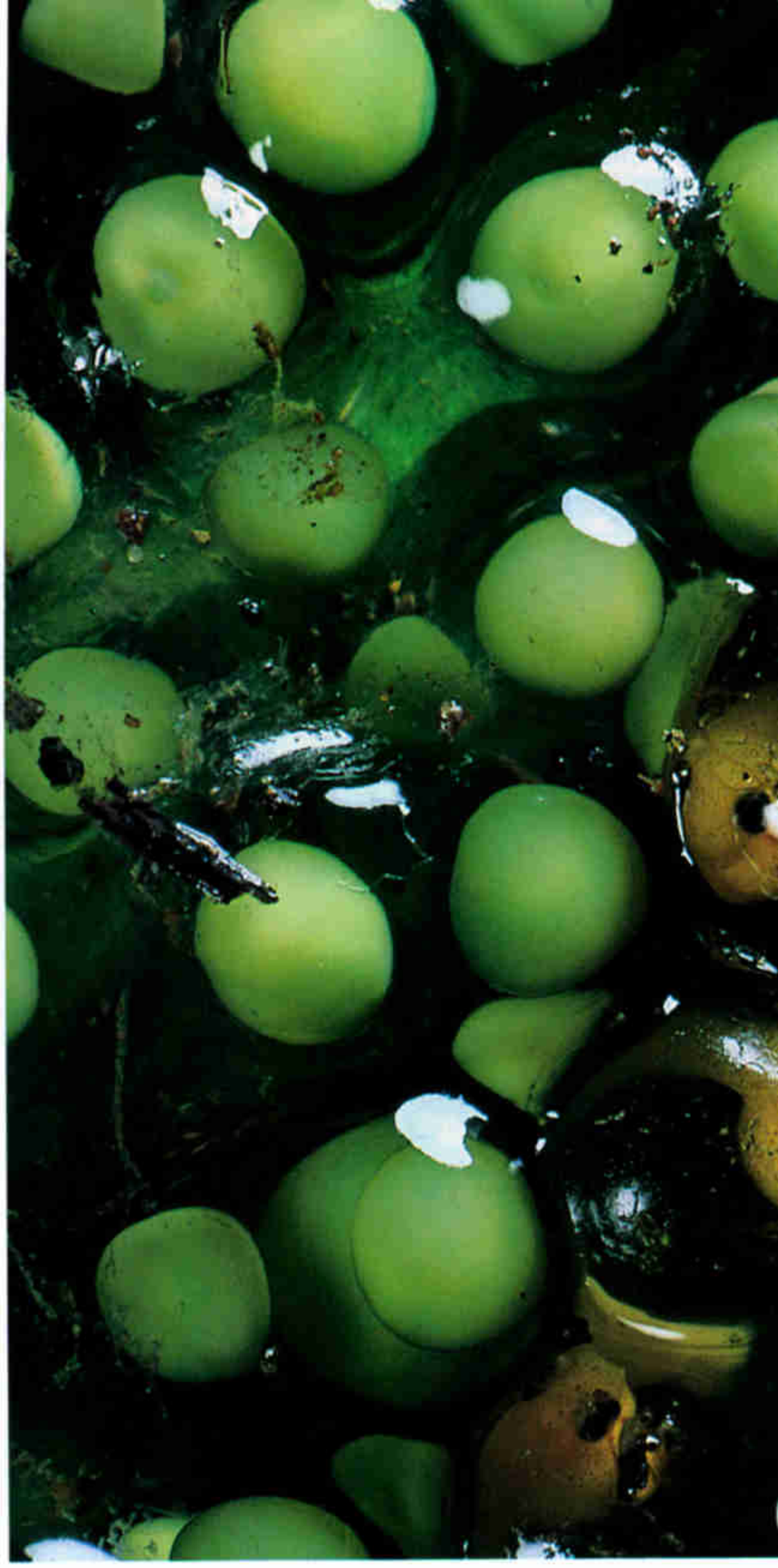
In this and many other frog species the female is substantially larger than the male. A rich, mottled jade green, she covered nearly the length of my hand, while the male was barely half as long. He grasped her with his nuptial

Nature takes its course

South American horned frogs engage in amplexus, the mating embrace. Drawn to pools born of seasonal rains, males fertilize females' eggs as they float to the surface. Within a day the eggs will hatch into tadpoles. Facing a gantlet of dangers, most won't survive.

Ceratophrys cornuta

Agalychnis callidryas



Improving the odds

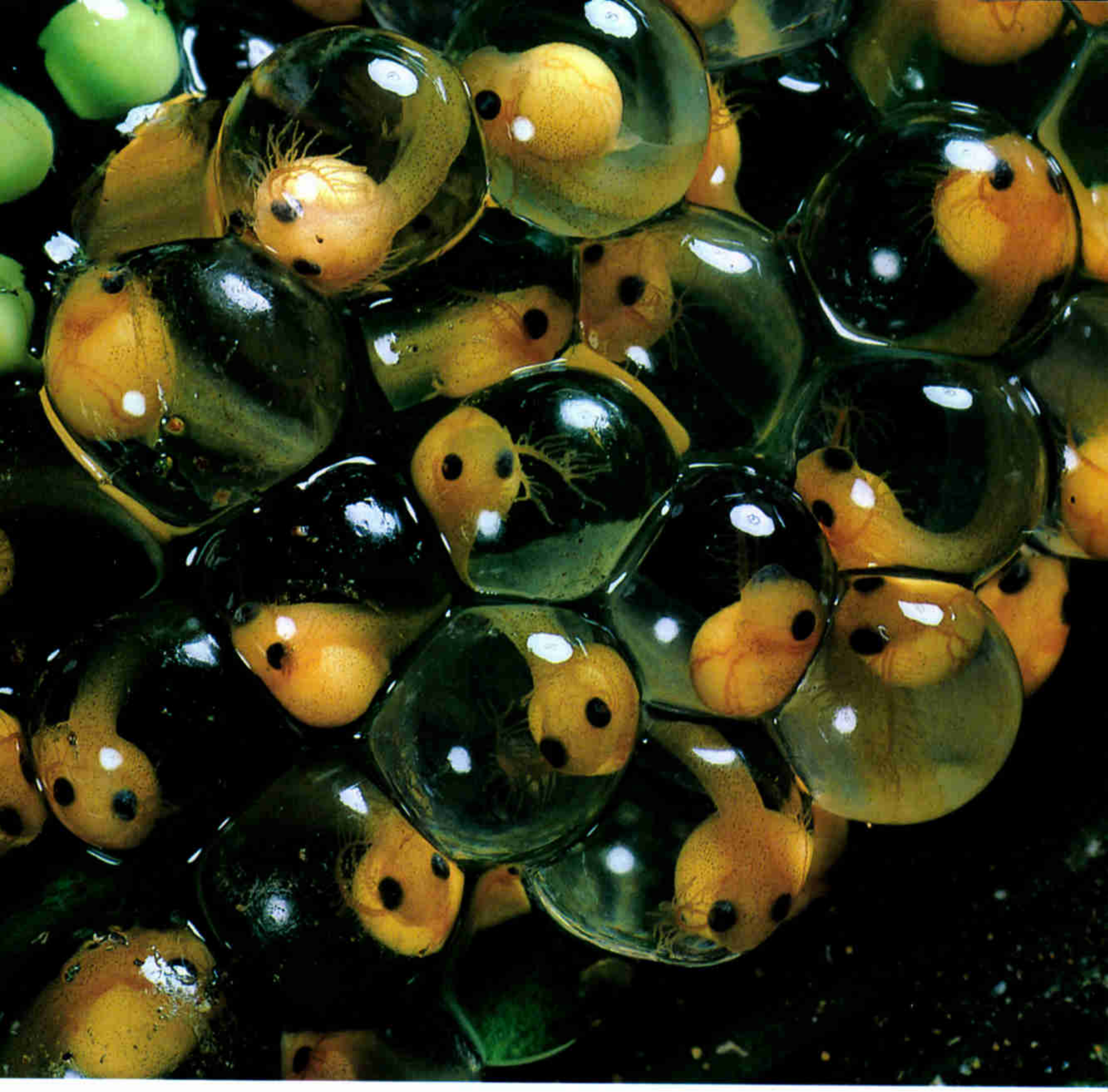
A slender frond overhanging a pond is nursery enough for red-eyed tree frogs mating in Panama. Newly laid green eggs adjoin a clutch whose embryos will soon hatch (right). *If attacked* by snakes or wasps, the tadpoles can pop out early, escaping to water below.

pads—small spiny structures on the inner surface of each thumb—just above her forelimbs and rode astride her back, jockey style. Nothing could make him budge—not the glare from our headlamps, not our long, inquisitive stares. "I think she must have just chosen him," Richards said, explaining that in many species the females listen to the male choruses around them, then approach the male they prefer. "She may have tapped him to let him know she had selected him, and then he climbed on board."

Richards had spotted the eyeshine of the happy pair in a tree not far from the water's edge. "She'd started her journey to the stream, where she'll lay her eggs," he said. Her chosen male will fertilize the eggs as they emerge from her cloaca. "But look where she plans to put her eggs—here, right on the underside of these rocks in this rushing current. It seems the most inhospitable place for a frog to lay eggs or for tadpoles to live—all this gushing water, the chance of floods and being bashed by the rocks. You'd think they'd want a quieter place."

It did seem surprising. Yet the torrent-stream frog's tadpoles thrive in this tumultuous environment because they have evolved enlarged mouths with suction lips that enable them to stick to the surface of a rock while grazing on the algae growing there. The next day we caught handfuls of these suctorial tadpoles, as they're called, and let them latch on to our fingers like amphibious pit bulls.

You had to give these frogs credit, I thought, while a suctorial tadpole minced its way along my forefinger. They'd found a way to live where the going was tough for an animal like a frog,



yet they'd been extremely successful, so much so that there were numerous torrent-stream species here, all with tadpoles adapted to living in the midst of riotous white water. But that, I was learning, was one of the joys of frog-watching: discovering the many variations they have evolved for the basic activities of life. Frogs were always turning up in places—dry deserts, cold mountains, plunging waterfalls—where they shouldn't be. They also had dozens of different ways to mate, lay their eggs, rear their young, and catch their prey. Yet even as scientists like Richards uncover the ways of the frog, frogs are vanishing, their numbers dwindling—and scientists have yet to figure out why or how to stop the declines.

FROGS HAVE BEEN on Earth at least 190 million years, and their ancestors, the first amphibians, arose some 350 million years ago. Amphibians were the first animals with backbones to walk on land. Some were large, crocodile-size creatures, but over time they evolved into the three orders of smaller animals known today: the Anura (frogs and toads), Caudata (salamanders and newts), and Gymnophiona (caecilians, wormlike creatures that live in leaf litter or streams).

Anurans, the frogs and toads, are the most successful living amphibians, with some 4,500 species now known, a count that's been steadily growing because in the past few years scientists have ferreted out more than 50 new species

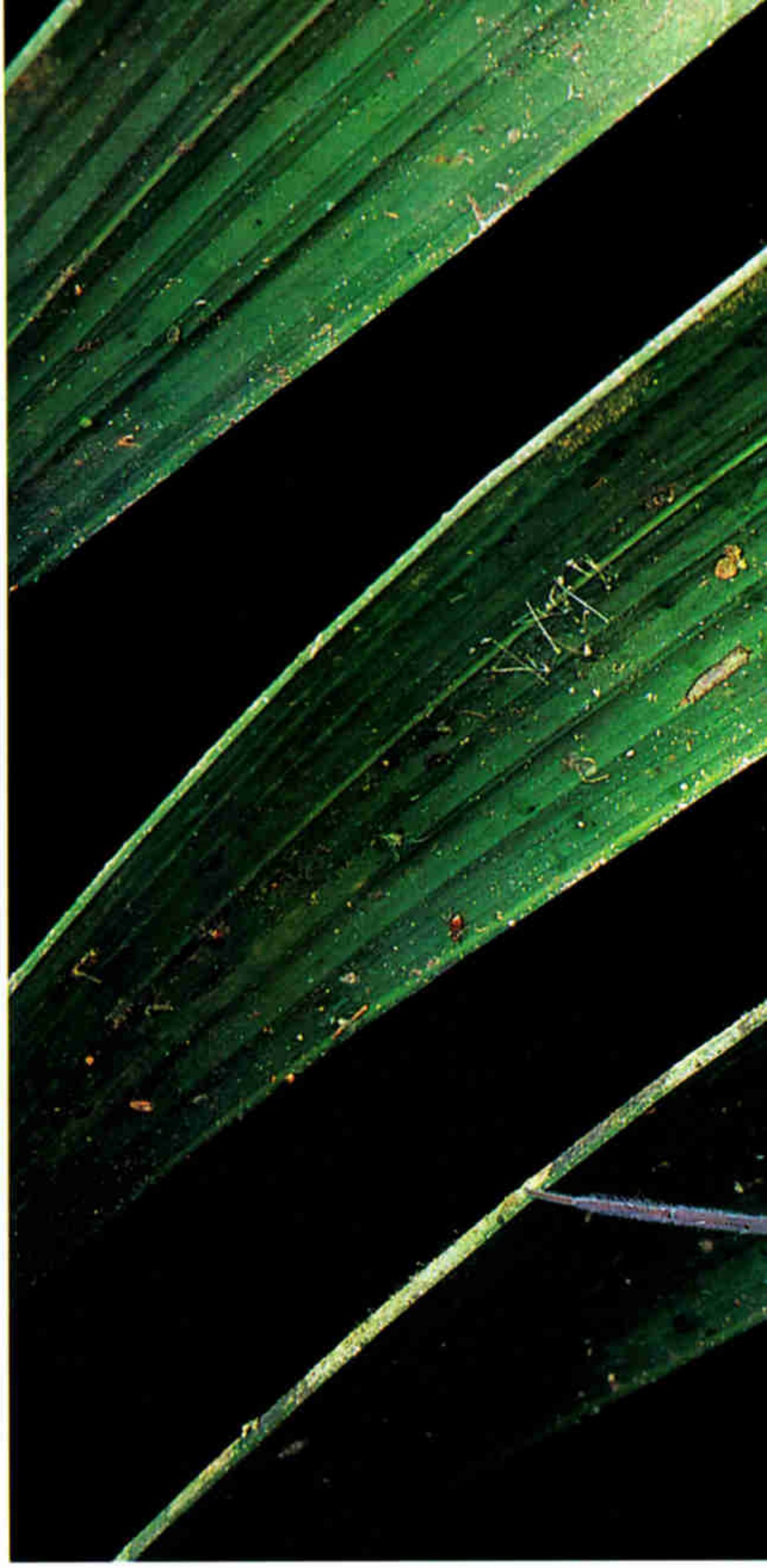
annually. Like most amphibians, frogs spend at least part of their lives in water. It might seem that that would limit where they can live, but frogs are found in almost every terrestrial environment, from Arctic tundra to the driest of deserts and from sea-level mangrove swamps to the 18,000-foot-high Tibetan Plateau.

To survive in such extreme environments, frogs have evolved an impressive range of adaptations. The North American wood frog *(Rana sylvatica)*, for instance, can survive freezing temperatures for as long as seven months, relying on a natural antifreeze in its blood to protect its organs. Some species in the dry forests of South America secrete a waxy coating to protect themselves from drying out, while the water-holding frogs of Australia actually store water in their bladder and under their skin for use during droughts. Another Australian frog, shaped like a fat turtle, spends most of its life burrowed beneath termite mounds in arid deserts, where it feeds on nothing but termites.

Equally intriguing are frogs' reproductive behaviors. Many frogs and toads have a multistage life, that passage from tadpole to adult called metamorphosis. There are at least a dozen ways frogs can make that journey. The standard method begins with fertilized eggs in a pond; the tadpoles hatch, feed on algae, and change into frogs. That route, however, is fraught with uncertainty since many predators lurk in water. Instead, many species have evolved methods that bypass the pond.

In Queensland's Paluma Range National Park, Adam Felton, a colleague of Richards's at James Cook University, heads down a slope in a vine-tied rain forest. For the past several months Felton has been watching a number of ornate nursery frog *(Cophixalus ornatus)* males, and despite the dark night he leads us right to their mossy nests. "*Cophixalus* is a microhylid," Felton explains, using the more inclusive family name, "and all Australian microhylids have what we call direct development." In other words the microhylid froglets develop inside the egg.

Felton, a lanky, blond young man, stops beside a decaying log and shines his headlamp on a patch of earth that he has marked with a surveyor's red flag. "See this little hollow? That's the male's nest, and those little clear balls are the eggs he's guarding—or should be, if he



was here." Dad has apparently stepped out, Felton thinks, and with no male in view he bends his own body into a froggy shape to demonstrate what dad should be doing—hunkering down on top of those eggs. "That protects them, keeps them moist, and may even prevent fungi and bacteria from growing on them."

In many frog species the males protect the eggs. Some males, such as those of the PNG species *Sphenophryne schlaginhaufeni*, go one step further: Their froglets climb aboard dad's back and ride with him for a few days. In South America male Darwin's frogs slurp up the fertilized eggs and hold them in their vocal sacs until the froglets emerge.

In other species females provide the parental

Agalychnis callidryas

It's a jungle out there

Deadly drama unfolds as a spider stalks a young red-eyed tree frog newly emerged from a pond. As a tadpole this frog survived dragonflies, water beetles, fish, and shrimps. As an adult it must evade bats, birds, snakes —and humanity's hunger for land.

care. The female poison dart frog *(Dendrobates pumilio)* not only attends her eggs but also transports the hatched tadpoles to pools in tree holes or within the inner leaves of bromeliads. She visits her offspring to lay unfertilized eggs for them to eat. The female Surinam toad *(Pipa pipa)*, an aquatic species, converts her entire back to a nursery. She and the male swim end over end in their mating dance, transferring the fertilized eggs to pouches in her back. Her skin grows over the eggs, sealing them in until the froglets hatch.

Even tadpoles left on their own sometimes have protective devices. In Panama, Stan Rand, a herpetologist with the Smithsonian Tropical Research Institute, guides me to a pond where the tree frog *Agalychnis callidryas* has laid masses of gelatinous eggs on palm fronds. Another researcher had discovered that these are a favorite food of an arboreal snake, but when the snake bumps the eggs, the tadpoles hatch prematurely. "It's a 50-50 chance for them," says Rand, nudging the eggs in imitation of the snake. "They'll still face predators in

Slipping Away

From tundra to tropics frogs have thrived for nearly 200 million years. Now they are vanishing—rapidly and perhaps irretrievably. Why? Habitat loss is only the most obvious villain. Additional causes remain unclear, particularly in Asia, Africa, and other regions where research has been minimal. Scientists warn that climate change, pollution, and other factors may be acting together to deform and kill frogs, regarded as "sentinel species" in ecosystems because of their intimate contact with air, water, and earth. "We share the planet," says Mike Lannoo of the Declining Amphibian Populations Task Force. "If something out there is affecting frogs, there's a chance it's affecting us too."

DEFORMITIES
Gruesome deformities have been grabbing headlines, particularly in Canada and the northern U.S. Natural causes such as trematode parasites account for some deformities, but pesticides and their by-products are increasingly suspected.

ULTRAVIOLET RADIATION
As Earth's ozone layer thins, ultraviolet radiation intensifies. Ultraviolet light can alter DNA in cells and suppress immune responses. Biologists believe UV radiation contributed to massive die-offs of frogs' eggs in Oregon.

INTERSPECIES COMPETITION
Non-native fish and voracious bullfrogs stocked for food and sport devour native frogs and their prey. Notably, trout plunked into Sierra Nevada rivers in California have nearly wiped out the mountain yellow-legged frog.

CLIMATE CHANGE
Populations of the golden toad, once found only in Costa Rica's cloud forests, collapsed when dry weather pushed moisture-giving clouds beyond its range. Biologists blame global warming for this and other declines.

NORTH AMERICA

SOUTH AMERICA

Rancho Grande harlequin frog
Atelopus cruciger
Venezuela
Last seen in 1982

Golden coqui
Eleutherodactylus jasperi
Puerto Rico
Last seen in 1981

Golden toad
Bufo periglenes
Costa Rica
Last seen in 1989

ART BY RACHEL IVANYI

Vegas Valley leopard frog
Rana fisheri
United States
Last seen in 1942

POLLUTION

The highly permeable eggs and skin of frogs easily admit toxic substances. Acid rain has caused frog declines in Britain, Canada, Scandinavia, and Eastern Europe. Heavy metals, fertilizer compounds, and agricultural chemicals also take a toll.

Israel painted frog
Discoglossus nigriventer
Israel
Last seen in 1955

OVERHARVESTING

Tens of millions of frogs die each year to supply restaurants with frog legs. Most come from Indonesia. India and Bangladesh banned exports after frog declines led to a rise in mosquitoes, malaria, and pesticide use.

EUROPE

ASIA

AFRICA

AUSTRALIA

DISEASE

Saprolegnia, chytrid, iridovirus—such diseases are afflicting frogs worldwide. Chytrid, in particular, has devastated frog populations in Australia and Central America. These fungi are common in nature, but this is the first time one is known to have attacked vertebrates.

HABITAT DESTRUCTION

As humans cut trees, drain marshes, pave meadows, and dam rivers, frogs die. The world over, habitat loss and alteration is by far the greatest cause of death for frogs—creatures of limited range that can't easily relocate. In Madagascar, for example, deforestation threatens the brilliant red tomato frog.

Mountain mist frog
Litoria nyakalensis
Australia
Last seen in 1990

Gastric-brooding frog
Rheobatrachus silus
Australia
Last seen in 1981

Fastest tongue in the West

Tempting a toad with a fat wax worm, researchers at Northern Arizona University study tongue protraction. These toads can unfurl their long sticky tongues (right) in a mere fraction of a second—too fast for most prey to escape the fate of being swallowed whole.

Bufo woodhousii (both)

the pond, but if they don't hatch, they'll be eaten by the snake." Rand's prods and bumps fool the tadpoles, and suddenly several eggs burst open. The tadpoles, barely a quarter of an inch long, flip out like Mexican jumping beans and hit the water—and their fate—below.

As wonderful as all these adaptations are, none is—or was—as remarkable as that of Australia's gastric-brooding frogs, *Rheobatrachus*. Researchers invariably mention the two species in this genus as the most astonishing example of what frogs can do. The females of this two-inch-long stream dweller swallowed their fertilized eggs or tadpoles, shut down their digestive systems, and hatched their young in their stomachs. About a month later the mother opened her mouth and regurgitated her tiny froglets.

"It was almost unbelievable," says Keith McDonald, the chief ranger with the Queensland Parks and Wildlife Service. "You could see the little buggers pushing their tiny hands and feet inside their mum's swollen belly."

Stocky and pink-faced, with a twinkle in his blue eyes, McDonald had helped monitor the two known populations of gastric brooders shortly after they were first discovered about 25 years ago. "Then bang! They disappeared in the blink of an eye. Ahhh, how can I describe my feelings?" he says, his voice cracking and his eyes misting up. "I'd been watching this population; I went back three months later, and

that's when it hit me in the guts." McDonald recalls walking frantically up and down the stream, turning over rocks, searching for frogs. None were to be found. No one has seen a gastric brooder in the wild since the 1980s, and none are in captivity; they are apparently extinct.

But the gastric brooders aren't the only species of frogs to have vanished or fallen on hard times. Since the 1970s more than a dozen Queensland frog species, especially the stream-dwelling types, have experienced sudden, massive die-offs. At the same time many frog populations in protected areas of Central and South America and the western United States also plummeted. In some cases, such as in these remote Queensland mountains, certain frog populations vanished in a few short months.

Other frog species in the U.S. West and Midwest began turning up with deformities, particularly misshapen or extra hind limbs, in disturbing numbers. Though no evidence suggested a link between the outbreak of deformities and the die-offs, this much was clear: Something in the environment was adversely affecting frogs, but no one was certain what it was or how many factors were to blame.

Now, after a decade of intensive study and monitoring programs, researchers have some strong clues. Some of the best leads for the mass deaths have come from the Queensland rain forests. Richards and others realized something was wrong with the Queensland frogs shortly after he started a study project in Paluma Range National Park in 1989. That year four species of frogs lived in the clear waters of Birthday Creek, a purling stream that courses through a parklike glade. Less than two years later two of the frog species—a lace-lid tree frog and a torrent frog similar to those in PNG—had vanished.

Elsewhere in Queensland, McDonald had noticed that the population of another species, a day frog, which had lived alongside the gastric brooders, was beginning to dwindle.

"We'd never paid much attention to the day frogs because we were all fascinated by the gastric brooders," says McDonald. "And the day frogs were about as common as fleas on a dog's back. But I liked watching them; they hopped around like little Charlie Chaplins. Then *phhht!* They were gone too."

In 1993 McDonald and other researchers happened to find some of the day frogs as they

Declines, deformities, and the search for CLUES

MARTIN OUELLET (BELOW)

On a stool of stone herpetologist Karen Lips measures a poisonous—and endangered—Panamanian golden frog. Since the 1980s its numbers have tumbled, even in remote protected areas. "I'd never say anything is pristine anymore," says Lips, who cites disease, habitat fragmentation, climate change, and the illegal pet trade as potential culprits in the decline. Lips rarely sees deformities in the tropics. Yet bizarre abnormalities like misplaced eyes (right) and missing or extra limbs are alarmingly common in some agricultural regions where pesticide use is heavy. Studies by herpetologist Martin Ouellet in Quebec's St. Lawrence River Valley show deformity rates in juvenile frogs as high as 70 percent in some farm ponds.

"It's rare to find deformed adults," says Ouellet. Hampered in their pursuit of food and unable to escape predators, few afflicted frogs make it to adulthood.

Atelopus zeteki (top); *Rana clamitans*

Siren song

With a lusty hum a male *túngara* frog sends out vibes that he's ready to mate. To amplify their repertoire of trills, grunts, and peeps, male frogs force air into a vocal sac. One frog may call hundreds of times a night. "It's the most energetically expensive thing a male frog ever does," says herpetologist Stan Rand.

Physalaemus pustulosus

Eleutherodactylus skydmainos

Turf wars

With stamina that belies their three-quarter-inch size, male eleutherodactylid frogs battle for mating territory in Peru. One leaps onto the other (above) and eventually gets him in a choke hold (right) to smash his vocal sac. After hours of struggle, the loser limps away.

were dying, one of the first times that frogs had been spotted in the throes of a massive die-off. They collected some of the animals and sent their remains to Rick Speare, an infectious disease specialist at James Cook University.

While the Australian frogs were disappearing, frogs in the rain forests of Costa Rica's mountains also began to dwindle. Most alarmingly the splendid Costa Rican golden toad *(Bufo periglenes),* whose red-gold skin made it look more like a jewel than a living creature, vanished. Not one has been seen in the wild since 1989. Other frog species disappeared in that habitat too, but not until 1996 did a scientist chance upon a dying population. That year

Karen Lips, a herpetologist at Southern Illinois University, found dead and dying frogs in the high rain forests of Panama, and like McDonald she dispatched them to a disease expert. These specimens, together with those from Australia and others from the National Zoo in Washington, D.C., led to the discovery of a previously unknown frog killer: a waterborne organism called a chytrid (KIH-trid) fungus.

Most chytrids are simply decomposers of plant materials. Some are known to live as parasites on plants and invertebrates, but this species is the first discovered to infect—and kill—vertebrates. Scientists still do not know how the chytrid kills frogs. Speare suspects that the fungus may release a toxin as it eats the keratin (a protein) in the frog's skin.

"We're looking at a newly introduced disease, an emerging pathogen," Speare said, which would make the chytrid a kind of hot-zone disease for frogs comparable to the Ebola virus in humans. Speare believes the disease came to Australia on an infected foreign frog.

The fungus has been found on 44 Australian frog species and appears to have caused the extinction of four, including the gastric brooders. Frogs that are most susceptible seem to live in water at higher, cooler altitudes.

That same pattern is found in several U.S. frog species that are now known to have died from the disease. The chytrid is suspected as the main cause of the sudden declines in frog populations in mountainous regions of Central and South America. But researchers still do not know where the chytrid originated or how it arrived in the Americas or Australia or how they can stop its spread in the wild.

THE CHYTRID FUNGUS, of course, is not the only frog killer around. High levels of fertilizers, ultraviolet light, viruses, climate change, and invasive species such as bullfrogs and trout have also been implicated in frogs' health troubles. Indeed the biggest problem facing frogs these days is habitat loss. Scientists actually know very little about how much territory any frog species requires, but they do know that the environments that harbor frogs—from Brazil's rain forests to the marshy wetlands once found throughout the United States—are being

destroyed or polluted at an unprecedented rate. That very fact makes the discovery of the lethal chytrid all the more troubling because many of the frogs at highest risk of succumbing to the disease live in places that people have set aside for their protection.

In the dense rain forest of Panama's Omar Torrijos National Park, Karen Lips hikes up a narrow, rocky stream, counting frogs and toads with her graduate assistant, Jeanne Robertson. Lips, a petite woman with a ready smile, is eager to find Panamanian golden frogs *(Atelopus zeteki)*, a species similar to the toads that had disappeared north of here, in Costa Rica. Lips thinks the chytrid killed Costa Rica's toads and other montane frogs. She found frogs dying from the disease at another Panamanian site and worries that it may have reached this national park.

Our first day of surveying, however, dispels her fear. Only a few minutes down the trail, Robertson calls out "Frog!" and leaps onto a rock, simultaneously bending down to grab her prize. She stands up and opens her hand, revealing a three-inch-long golden frog the color of a prizewinning Sunkist orange. There's nothing subtle about this hue, and Lips explains that it serves as a warning to potential predators: The frog's skin is laden with lethal poisons. Because it is so well protected, the golden frog doesn't hide, as many other frogs do, but sits out boldly in the daytime on the blocky boulders at the stream's edge. Males don't do much singing either, relying instead on their fancy dress to attract females.

Phyllomedusa vaillanti

We hike a short distance along the stream and find numerous frogs, including several tiny golden frog babies. There are also many small brown frogs called *Colostethus.* Lips and Robertson catch, weigh, and measure these, then gently scissor off one back toe to test for the chytrid. "Sorry, bubba," Lips says to each, explaining that this does not cripple the frog.

"Hear how musical this stream is with all these frogs singing?" she asks. "Well, imagine finding a stream like this one year, then coming back the next and finding it silent. That's what happened to me at two of my best sites. So while I don't like taking these toe clips, I make myself do it; they may help us understand more about this disease." In particular, researchers hope to discover why some species are susceptible to it and others are not. Lips's survey will also begin fleshing out the baseline list of frogs found in this park. "That's the thing about frogs," she said. "There's still so much basic work that needs to be done. Dozens of new species are found every year, and we know so little about any of them."

Take the small, dark brown *Asterophrys* frog that Stephen Richards plucked from beneath a mass of leaves next to a motel one night in Papua New Guinea. Bristling with bumps and spines, the rotund frog, all of two inches in length, opened its mouth, revealing a startling baby blue interior, then firmly bit Richards on the thumb. "Ouch!" he said, pulling away and laughing. "Now there's a frog with attitude," he added after placing the frog on the ground and watching in amusement as it leaped up at us with its blue mouth gaping.

At night these *Asterophrys* frogs fill the air with songs almost as melodic as a bird's trill. Yet until a decade ago few specimens of this frog had ever been seen. "We don't know what they eat or how often they mate," said Richards. "And we have no idea why they're so feisty."

IN ARIZONA scientists know all this and more about the Chiricahua leopard frog *(Rana chiricahuensis)*, including that it is in serious trouble; it is imperiled in much of its original range. Once common throughout the Southwest, it has nearly vanished from several desert canyons—but has found protection on a rancher's land. "The leopard frogs were

Physalaemus nattereri

about to blink out in Arizona's San Bernardino Valley," says Cecil Schwalbe, a herpetologist with the U.S. Geological Survey in Tucson, "when Matt Magoffin discovered a healthy population of them here." "Here" seems an unlikely spot: a large cattle tank, basically an earthen reservoir, on Magoffin's property. For two years during a bad drought Magoffin trucked a thousand gallons of water every week to the tank to keep the frogs going. Now conservationists such as Schwalbe are using the Magoffin frogs to restock other areas.

"It's people's actions that have led to the leopard frogs' low number," says Schwalbe, noting that everything from bullfrogs to the chytrid fungus have taken their toll on the species. "But people's actions are now the only thing protecting them."

After the drought Magoffin built a small concrete pond for the frogs, and we step through a fence and shine our lamps on this grassy haven. Schwalbe's light falls on a leopard frog about the size of a two-fisted hamburger. "See that egg mass there," he says. "She must be the one that's pumping them out. She's just beautiful." The leopard frog, a light green with

Striking a pose for posterity

A frog in Brazil bloats its rump in hopes that false eyes will frighten predators. In Peru a tree frog (facing page) contorts its body and plays dead to deter attackers. Such clever defenses, however, can't outwit the myriad threats posed by a burgeoning human race.

large, dark spots, sits with her nose half out of the water at the edge of the pond.

She's one of the lucky ones: a frog that has found a human defender.

In the distance we hear a male leopard frog call, its chuffing carrying across the desert night air to us and—we hope—to this beautiful female. "Keep it up, keep it up," Schwalbe says, bending down for one last look. She suddenly senses our presence and drops below the water's surface. The male calls again, and we step out of the enclosure and back into the desert, giving the frogs their privacy and letting the pair do what nature intended them to. □

MORE ON OUR WEBSITE

Meet a desert toad that dines on tarantulas and learn about the challenges of photographing frogs at **nationalgeographic.com/ngm/0105.**

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DOWN HOME AT THE TRUCK STOP

BY MICHAEL E. LONG

PHOTOGRAPHS BY

CARY WOLINSKY

Truckers pull off Interstate 40 to refuel, relax, shower, shave, sleep, eat, and even worship.

Long before sunup in western New Mexico, Irene Charley rolls pastry dough in the bakery of a truck stop off Interstate 40. Charley's white chef's hat has toppled backward over her shoulders, loosing sprinkles of Navajo-black hair onto her forehead. Her pies have heft, particularly the banana cream and chocolate cream, whose whipped centers peak at around five inches. Racks of other pastries —rich cakes, rolls thick with pecans, humongous frosted buns, turnovers in phyllo crust—all argue that while Jamestown's Giant Travel Center 17 miles east of Gallup may not be the mother of all truck stops, it could be the sweetest.

In the parking lot perhaps 200 trucks point Triassic snouts that hide engines thrumming to feed air conditioners—cooling perishables as well as drivers sleeping inside despite the din. Britt Jones, general manager of the center, explains that around 2,500 truckers pause here every day, and about as many tourists. There are 20 diesel fuel pumps, a truck wash that swallows 18-wheelers, 26 showers, 10 washing machines and 12 dryers plus a drop-off laundry, one hair salon, a 30-seat movie theater, a TV nook, a 290-seat restaurant with phones at many tables, three fast-food stalls, two convenience stores, video games, and one United States post office, zip code 87347. The 38,000 square feet of floor space is tended by 20 janitors. "Absolutely clean," declares Jones.

"Everything working," he adds. What about this out-of-order sign on a soft drink machine? Jones curiously tugs at a handle and provokes a hemorrhage of ice chips. "Put the sign on the ice part," he orders, "so truckers can still get their drinks."

Out back the competition—big Burlington Northern and Santa Fe locomotives—rackets over rails, dragging more than a hundred containers, coming in second behind the 3.1 million truckers who move two-thirds of the country's freight, some eight billion tons in 1999.

Not all drivers are American. Vanus Eelvee discloses that he is a Finn

WORKFORCE: 245, including 90 Navajo, 3 Acoma, and 2 Zuni Indians

CUSTOMERS: About 5,000 visitors arrive daily, half of them truckers.

HAZARDS: Electric power was shorted out twice, once by a crow and once by a rattlesnake.

CONNECTIONS: Each of 300 truck parking spaces has linkups to the Internet, cable TV, and telephone.

TRUCKING FACTS: Each year 4,900 truck stops in the U.S. serve 3.1 million drivers and pump 30 billion gallons of diesel fuel.

Mr. Kessenich teaches the most innovative math class under the sun.

They've been around for centuries. But only Jeremy Kessenich had the vision to see that designing and building sundials could teach essential math principles in a way that students would actually enjoy.

This spring, his high school class will paint a sundial face on the playground at the local elementary school. By standing at its center, grade schoolers become the rod that casts the time-telling shadow—and a new generation will experience the power, and fun, of mathematics.

For his bright ideas, State Farm is pleased to present Mr. Kessenich with our Good Neighbor Teacher Award™ and to donate $10,000 to his school, Mt. Horeb High in Mt. Horeb, Wisconsin.

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who likes driving American trucks. Eelvee is hauling 42,000 pounds of Coors beer, cooled to 40°F, to Los Angeles. He's on the road five weeks at a time, hustling to make a monthly lease payment of $3,000.

Chuck Gully of Denver has stopped to have a satellite TV dish installed on his rig. He's transporting bedsprings, 36,000 pounds' worth. Ed Brown from Suwanee, Georgia, has 46,000 pounds of steel shelving. Gary Warner packs 37,000 pounds of vegetable oil. Warner explains that he gets his mail in Irving, Texas, but his residence is his truck, which he shares with a high-stepping Chihuahua-terrier mix named Yogi.

How hard is it to handle a big rig? Pat Yoder, a slim grandmother from Pennsylvania, takes me east a few miles. It seems we're moving slowly. "We're doing 65," says Darwin Yoder, co-driver and husband, "but a big truck makes it seem slower." He prefers less-than-top speed to conserve fuel, tires, and engine, from which he expects a million miles of humming. Tons of rebuilt humvee engines for marines at Camp Pendleton are lashed to a flatbed behind Pat, but her grip on the 21-inch-wide steering wheel, which has the same power steering as a car, is relaxed.

Darwin shows off an interior taut and sparkling as an Amish kitchen —refrigerator, microwave, dining table, pantry with hard Pennsylvania pretzels, closets, drawers, shower, toilet, and built-in vacuum. In slumber drill he folds the dining table into the wall, then folds down the wall, which reveals a mattress. He smooths the quilt. All in 27 seconds.

In the 1800s stagecoaches rattled in the vicinity. Now we pass armies of junipers camped on soft hills near sagebrush scratching out a living in olive and brown grass. From distant sandstone cliffs, erosion has calved rock bergs that look bigger than the Pentagon, flaming red in the low sun.

It is Sunday morning, and the movie theater has become a chapel.

A 30-seat movie theater becomes a chapel on Sunday. Sausages, part of a 2,000-pound weekly meat budget, are hoisted to the oven. Ten varieties of pies fill stomachs ready to roll.

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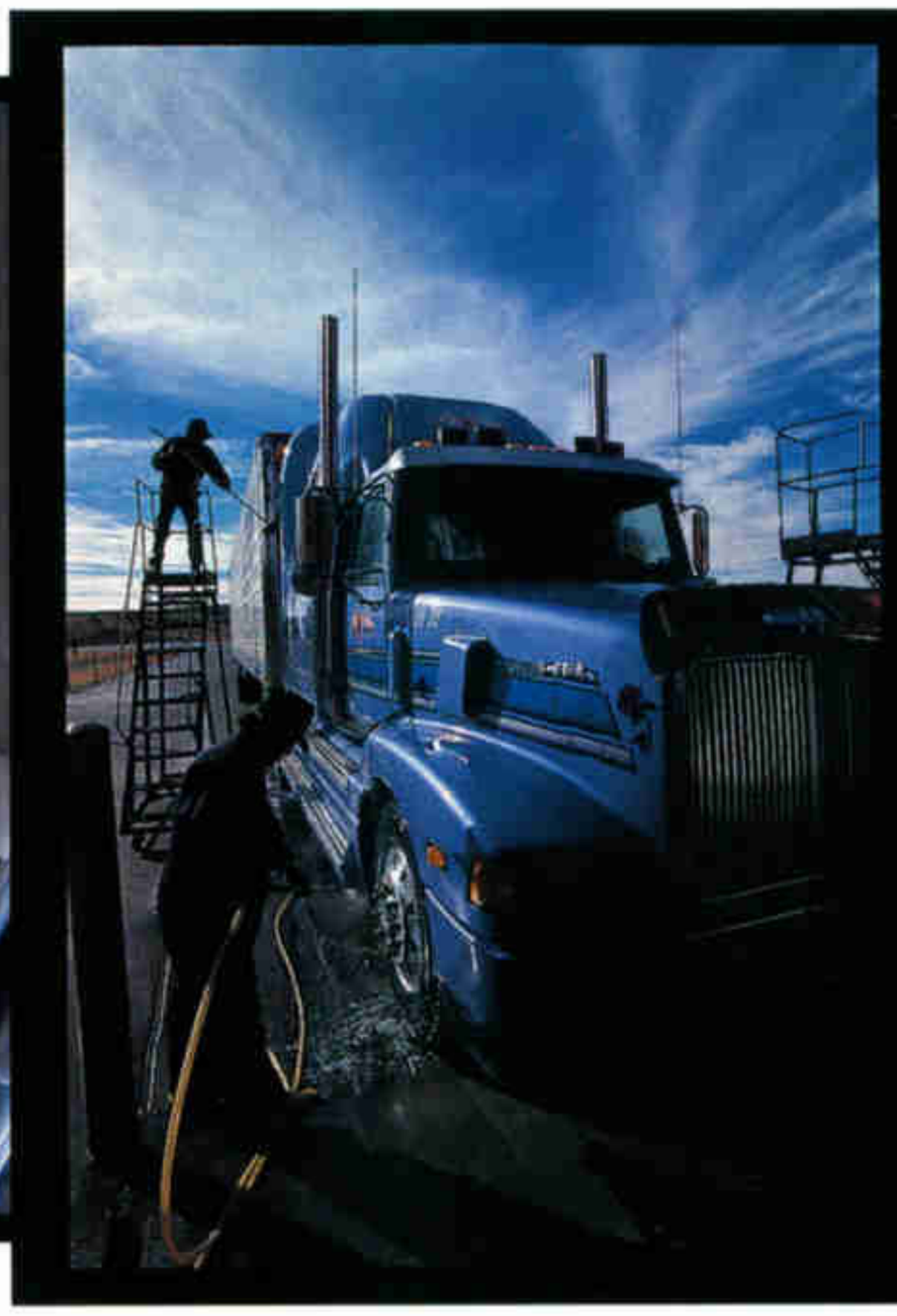
Chip Maurer urges the faithful to make a "joyful noise to the Lord." Six voices sing out: "Search me, O God, and know my heart today." Maurer, a counselor in a Gallup school, preaches part-time. His subject for today is hell. "Hell is hot," he says. "Hell is dark. Hell is where you call out 'Father,' and there is no answer."

Maurer asks for testimonials. Paul Pearson of Jamestown, New York, thanks the Lord for being with him when he drives. "Sometimes I ask the Lord to save a parking space for me at the truck stop," he testifies.

Someone observes that the Lord can relax at this truck stop, which can fit more than 400 trucks. Pat Azua, security supervisor, says the Lord is also not bothered here by "lot lizards," truckerspeak for prostitutes, who sometimes trail the big rigs like exhaust fumes. We keep the lizards out, says Azua, who wears a black uniform with badge and whistle, towers six feet nine, and is about as big around as a tire



Beneath the bunk Scott Vance plays a computer game in his truck's cab, outfitted with a closet, refrigerator, microwave, and stereo. Come washday, an 18-wheeler presents nearly 20 times the surface area of a car.

iron. On Sunday afternoons, Azua relates, truckers have nearly come to blows disagreeing over what to watch on TV—NFL football or NASCAR racing. Azua orders up a show of hands. "Sometimes it's like baby-sitting big children," he says.

At the fueling station I ask Carma McDaugale, assistant manager, how much diesel fuel the center pumps in a day. Eyebrows lift. "Can I see some identification? Maybe you are really from Petro" (a competitor). I produce my business card. "Don't see NATIONAL GEOGRAPHIC on this," she says. Well, how about this official National Geographic Society expense account book? "Where's your name?" she persists. I retreat, never to know how much diesel is pumped. But then neither will Petro.

It's time to hit the road. I'm remembering the heavy whiff of fuel, the elephantine wheezes of air brakes, Yogi prancing, a neat trucker's flashlight I bought that has a rubber casing, and rest-room washbowls deep enough to swallow your arm—"so truckers can wash off all the grease," Jones said. I purchase one of Irene Charley's blueberry pies, a pecan bun, a giant frosted bun, and various turnovers. To sweeten the miles. □

MORE INFORMATION

ON OUR WEBSITE There's more on 87347 at **nationalgeographic.com/ngm/0105**. Tell us why we should cover **YOUR FAVORITE ZIP CODE** at **nationalgeographic.com/ngm/zipcode**, or mail your suggestion to PO Box 96095, Washington, DC 20090-6095. E-mail: **zip@nationalgeographic.com**

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GEORGE GRALL

FRAGILE WORLD OF FROGS

Paternal Instincts

Doing his fatherly duty, a male *Oreophryne* frog in Papua New Guinea guards his clutch and two newly hatched froglets that rest atop the egg mass. Like many in the Microhylidae family, these frogs bypass the tadpole stage, developing fully within the egg. Each night the male *Oreophryne* embraces his clutch, possibly to keep the eggs moist or to protect them from small predators like insects. It's a rarely seen behavior that photographer George Grall was determined to capture. After more than a week in remote rain forest, he got his chance. But this frog was on the underside of a leaf high in the air. So Grall slowly pulled down the branch and taped it to another branch to get a close-up. "I did it very carefully so I wouldn't disturb him," says Grall. "He just held on."

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ON THE ROAD, IN THE FIELD,

IRVINE, CALIFORNIA

Where's Jonathan?

He's in among the big guys, and it's unnerving

Surrounded by several close friends, photographer **Jonathan Blair**—in the pith helmet—warns visitors to the Dinamation International Corporation warehouse: Please don't stir up the dinosaurs. "When you get in with critters that large, you feel pretty small," Jonathan says. "I felt like I didn't want them to know I was there." Dinamation makes full-size, movable dinosaur models for films and displays. It created the pterosaur model with a 24-foot wingspan that Jonathan photographed in Kansas (pages 86-7), where the first pterosaur fossils in North America were found.

Jonathan has photographed several articles about early life-forms for the magazine. "Learning about life on Earth is an endless fascination," he says. "You want to see what these animals that used to be here looked like."

KARL ALEXANDER AND JONATHAN BLAIR

GNMENT

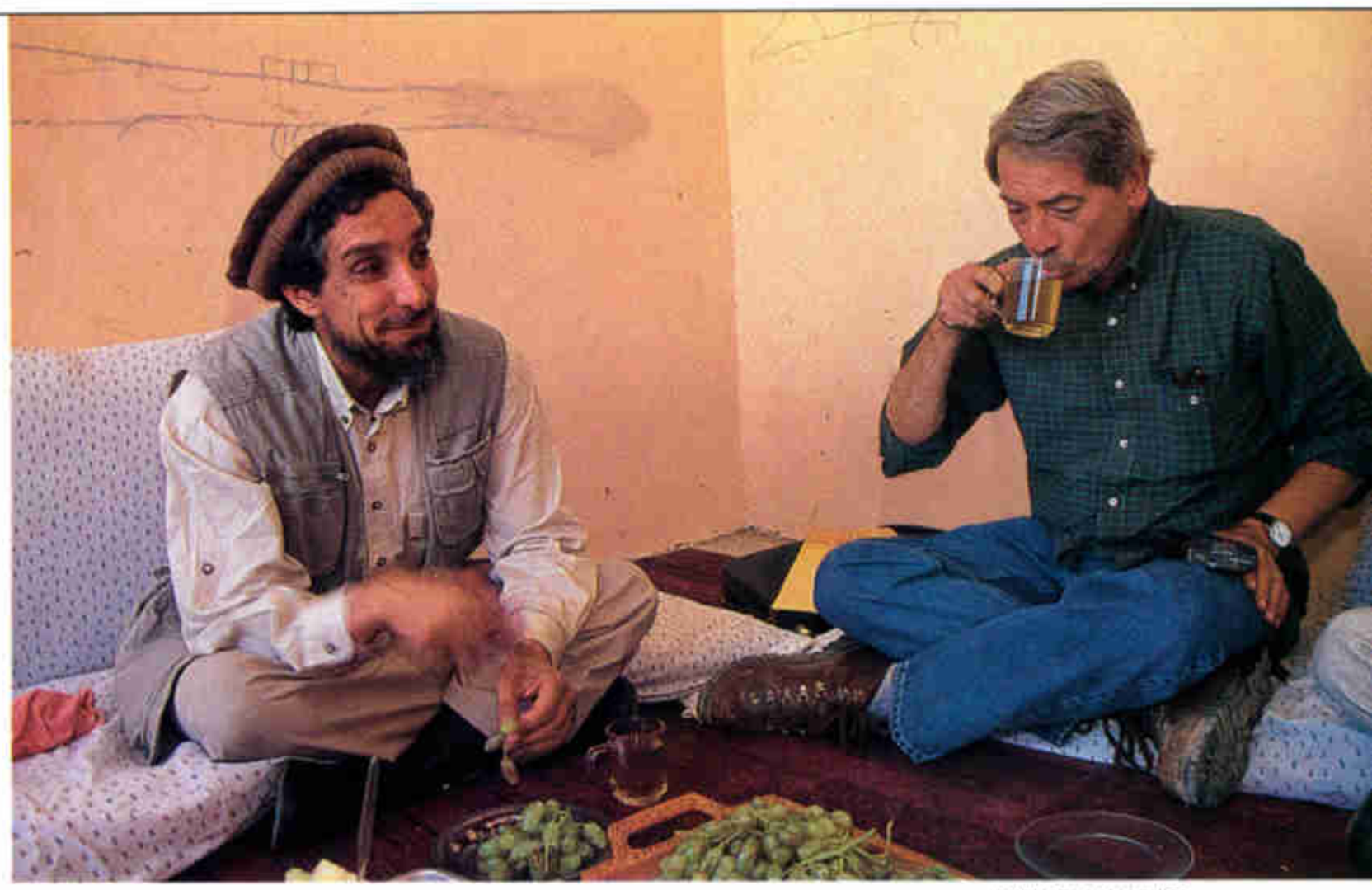
COVERING THE WORLD

AFGHANISTAN

Taking Tea With An Afghan Leader

Anti-Taliban commander smooths the way

To trace Marco Polo's trail, writer **Mike Edwards** had to go through Afghanistan. But the ruling Taliban militia would not permit him to enter, so he turned to Ahmad Shah Massoud, commander of the Northern Alliance, the anti-Taliban force controlling northeastern Afghanistan. Mike and photographer **Michael Yamashita** flew in on an old Soviet-era helicopter from Tajikistan, and Mike took tea with Massoud (above). The alliance leader gave them a safe-conduct pass for their two-week stay in his territory. "With it, we could get an armed escort, food, and a place to stay," Mike says. "It could have been a scary place, but nothing bad happened."



MICHAEL YAMASHITA

WORLDWIDE

After months of tracking jaguars through Latin America, **Steve Winter** got a close look at his quarry: a 190-pound pregnant jaguar that had been tranquilized and radio collared by biologists in Brazil's Pantanal (below). Most of the time Steve couldn't see the elusive cats. "It was the most frustrating, difficult story I've ever worked on," he says. A less relaxed meeting came when a cat that Steve had lost sight of suddenly appeared 20 feet from him: "I could hardly keep my camera steady. I shot seven frames and then slowly backed away."

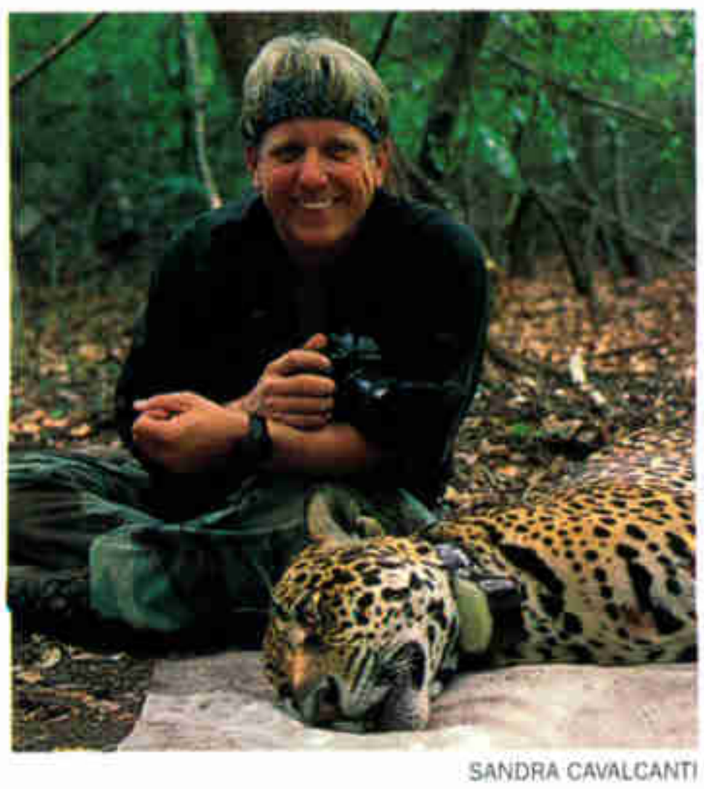
Stephen Alvarez calls himself "a photographer first, a caver maybe fifth or sixth." The veteran adventure photographer found the toxic gases in Mexico's Cueva de Villa Luz a constant menace. "If you designed a horror show, it would look like this cave," he says. The cave's unique lifeforms made it all worthwhile. "They're incredible," Steve says.

JESÚS LOPEZ

Staff writer **John Eliot** also had his troubles in the cave. "The worst part of the gas is wearing a respirator," he says. "It's like having a toilet plunger stuck to your face for five hours." John, an avid birder, took solace in the rain forest outside the cave: "The birds are fabulous."

No, photographer **George Grall** (above right) isn't doing push-ups, he's patiently waiting for schooling tadpoles to appear in a pond near Ubatuba in Brazil's São Paulo state. "It's kind of a funky position to be in," George says. "If you haven't done your exercises, you feel it quickly. You have to stay there a long time."

"Frogging" in Papua New Guinea with herpetologist Stephen Richards, writer **Virginia Morell** caught a frog that may be unknown to science. If that turns out to be true, the species could bear the name "morelli."



SANDRA CAVALCANTI

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I Nyoman Subrata

Master Carver, Bali

National Geographic and NOVICA.com Announce Alliance

National Geographic and Novica.com, a leading e-commerce site specializing in handcrafted works of fine art and home décor, have established an alliance that will build on the strength of the 113-year-old Society and enhance the thriving international website.

"National Geographic's participation in Novica marks a pivotal milestone in our initiative to preserve cultures and empower artists worldwide," explains Armenia Nercessian de Oliveira, Novica's co-founder and former United Nations human rights officer.

Novica.com unites the site's visitors with more than 1,700 extraordinary artisans. Read about the artists' lives, explore their cultures, and select from more than 8,500 handcrafted works, including Balinese sculptures, Andean tapestries, West African paintings and Thai celadon ceramics.

Novica's "Golden Rule" rests at the heart of its operating principles: Artisans make more; customers pay less.

Novica works directly with artisans through its offices in Brazil, El Salvador, Mexico, Peru, Venezuela, Ghana, Morocco, Zimbabwe, India, Indonesia and Thailand.

Art (top to bottom): cushion covers from Zimbabwe (starting at $30); mango wood vases from Thailand (starting at $30); masks from Bali (starting at $30); ceramics from Zimbabwe (starting at $50); rattan art from Bali (starting at $50).

Leoncio Tinoco, master weaver

Huancayo, Peru

"For me, as a member of the Novica family of artists, this alliance with National Geographic reaches beyond any dreams or expectations I could have imagined. One year ago, I struggled to sell my tapestries – even tapestries that had won significant awards here at home. Now, with Novica, I can earn my living as an artist and, with honor, represent my Inca heritage to the world."

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Flashback

P. O. CRAWFORD

■ MARCO POLO

Barred, for Life

Although Marco Polo apparently avoided bandits on Afghanistan's mountain trails, other travelers then and later were plagued by thieves. But our January 1921 article "Every-Day Life in Afghanistan," which included this photograph, reported that "owing to the aggressive pursuit and harsh punishment meted out by the Amir's troops, the once famous robbers of the Afghan hills have almost disappeared." One such punishment was the "man-cage," like this one at Lateh Band Pass. A thief was "put in this iron cage, raised to the top of the pole, so that his friends could not pass food or poison to him, and here he was left to die."

MORE ON OUR WEBSITE

You can send this month's Flashback as an electronic greeting card and access the Flashback photo archives at **nationalgeographic.com/ngm/flashback/0105.**

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