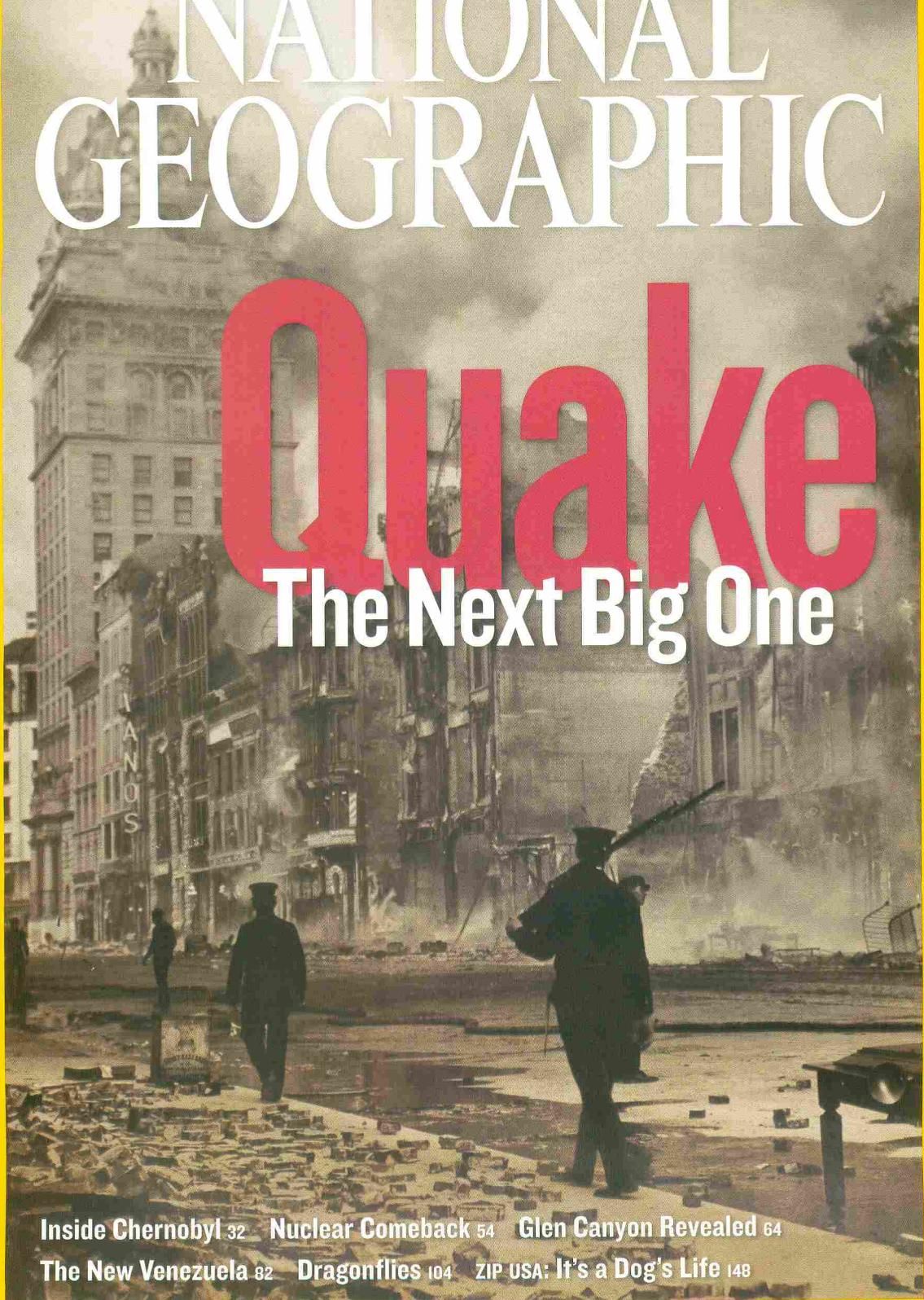


# NATIONAL GEOGRAPHIC

# Quake

## The Next Big One



Inside Chernobyl 32 Nuclear Comeback 54 Glen Canyon Revealed 64

The New Venezuela 82 Dragonflies 104 ZIP USA: It's a Dog's Life 148



AFTER WALKING TO THE  
**ENDS OF THE EARTH,**  
HE CLIMBED TO THE TOP OF IT.

Erling Kagge is a man of steely resolve. Carrying food, water, conviction and himself, he walked to the South Pole alone in 50 days. A feat made only the more unbelievable because before he trekked south, he laid claim to skiing to the North Pole. Both times, he travelled without dogs, motorised equipment or contact with the outside world. With the ends of the world behind him, he set out to climb to the top of it. He did so, easily taking Everest's peak. As the first person to take all three poles, he offers sage advice for those willing to follow his intrepid footsteps: "Think ahead, travel light and leave your fears behind."



OYSTER PERPETUAL EXPLORER II  
[WWW.ROLEX.COM](http://WWW.ROLEX.COM)

ROLEX



for a living planet®

© 1986 Panda symbol WWF. World Wide Fund for Nature (Formerly World Wildlife Fund) © "WWF" and "living planet" are WWF Registered Trademarks.

panda.org/powerswitch  
Climate Change at  
something about  
can do  
you



If you  
don't do  
something about  
Climate Change it  
will soon be too late

# NATIONAL GEOGRAPHIC

APRIL 2006 • VOL. 209 • NO. 4

## Venezuela's Democracy

A heroic mural of Venezuelan President Hugo Chávez—one of hundreds of such paintings around Caracas—smiles down upon residents of the city's poor El Horizonte neighborhood.



MEREDITH DAVENPORT

## Features

### Inside Chernobyl 32

Twenty years after a nuclear reactor exploded, blanketing thousands of square miles with radiation, the catastrophe isn't over.

BY RICHARD STONE PHOTOGRAPHS BY GERT LUDWIG

### Nuclear Power 54

It's controversial. It's expensive. And it just might save the Earth.

BY CHARLES PETIT

### Glen Canyon Revealed 64

A sustained drought has shriveled Lake Powell in the Southwest to expose a red-rock wonderland drowned decades ago.

BY DANIEL GLICK PHOTOGRAPHS BY MICHAEL MELFORD

### The New Venezuela 82

Hugo Chávez won the presidency of Venezuela by a landslide in 1998. Has he also won the hearts of his people?

BY ALMA GUILLERMOPRIETO PHOTOGRAPHS BY MEREDITH DAVENPORT

### Dragonfly Mating Game 104

Grab, shake, bite, puncture, punch—that's just the courtship ritual of these dazzling aerobats.

BY JENNIFER ACKERMAN PHOTOGRAPHS BY JÓZSEF L. SZENTPÉTERI

### The Next Big One 120

We understand earthquakes better than we did a century ago, when San Francisco was flattened. Now we'd like to predict them.

BY JOEL ACHEMBACH PHOTOGRAPHS BY PETER ESSICK

SPECIAL SUPPLEMENT: EARTHQUAKE RISK ZONES

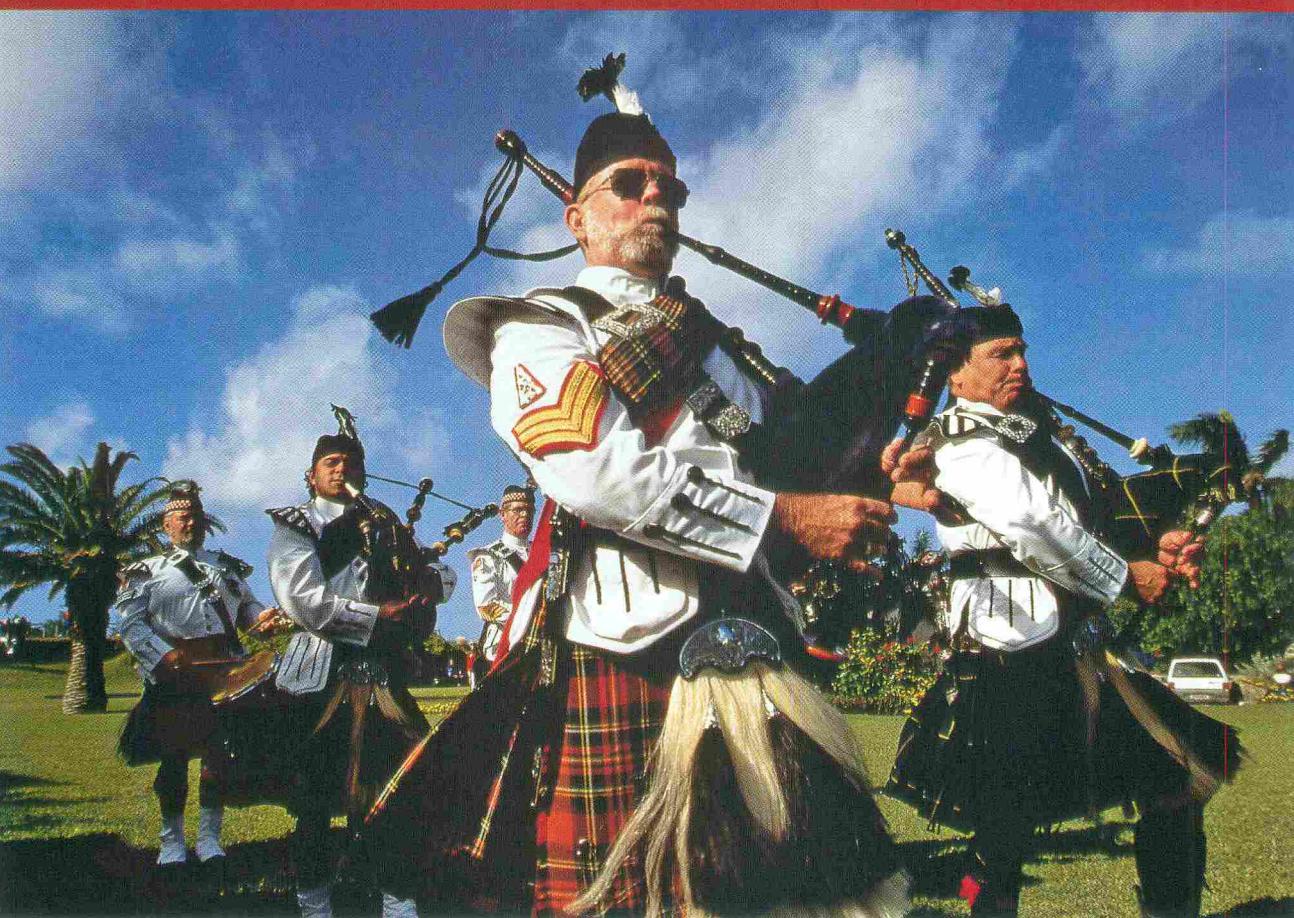
**COVER** U.S. soldiers patrol devastated Market Street in San Francisco after the 1906 earthquake. Deadliest in U.S. history, the quake ripped apart gas mains, enveloping the city in fire.

**THE BANCROFT LIBRARY, UNIVERSITY OF CALIFORNIA, BERKELEY**

© Cover printed on recycled-content paper

OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY

# Celebrations of the World



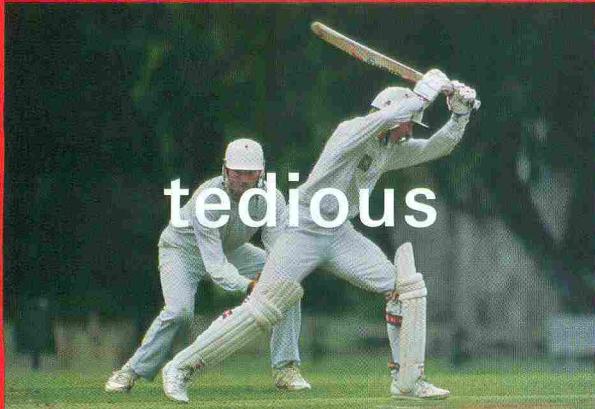
*The haunting echo of pipes and drums floats on a sea breeze as Bermuda's skirling ceremony unfolds. Kilted musicians and the high skirling wail of Scottish Highland bagpipes celebrate the island's rich British heritage—a curious blend of propriety, pink sand, and palm trees.*

**FORT HAMILTON, BERMUDA** "Bermuda is really a little mini Britain, and this weekly skirling ceremony captures the Old World feeling that permeates life here. Long before radios were invented, military orders were communicated musically. At the end of the day, the Regimental Sergeant Major would take buglers and drummers into town to sound the call that told soldiers it was time to march back to camp. Those days are gone, but the ceremony is a vivid reminder, like so many others on this tiny manicured island, of pride in the traditions, pomp, and pageantry of the past. As the bagpipes play tunes from centuries ago and drummers march in careful time, a passion for preservation is celebrated."

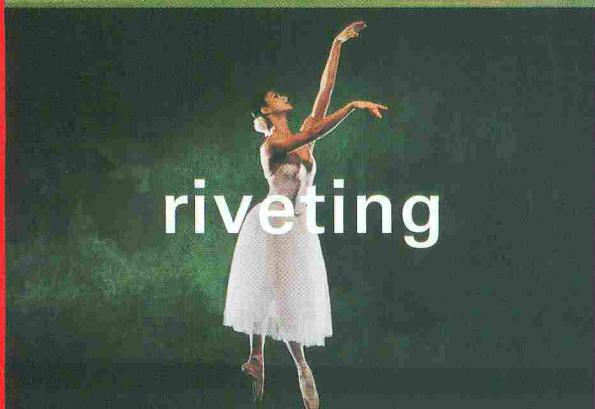


**Catherine Karnow, National Geographic Society Photojournalist**

NATIONAL  
GEOGRAPHIC  
Mission Programs



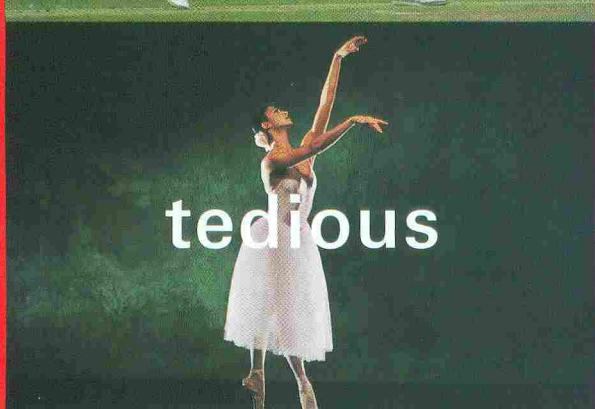
tedious



riveting



riveting



tedious

To the Bermudans, cricket is king – but that doesn't make it everyone's cup of tea.

And though many find that the ballet brings a tear to the eye – some people nod off to Sleeping Beauty.

We can all agree that we like to be entertained – but not on what entertains us.

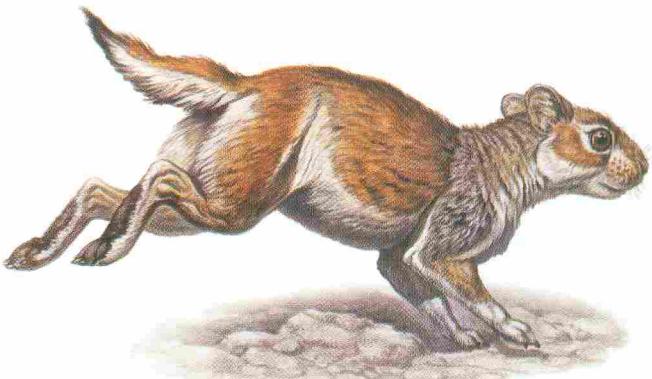
At HSBC we enjoy the company of over 100 million customers all over the world.

And it's always much more riveting than tedious.

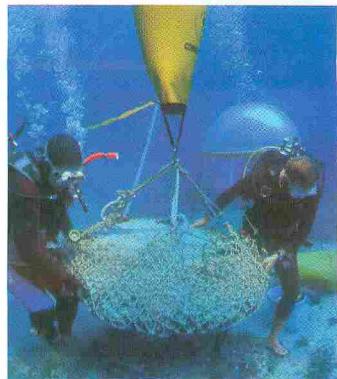
Because there's certainly no shortage of points of view.

[yourpointofview.com](http://yourpointofview.com)

**HSBC**   
The world's local bank



Paleo Bunny



Ancient Roman Shipwreck

## VISIONS OF EARTH

### FOSSILS

### SPACE

### COLOR OF MONEY

### ARCHAEOLOGY

### TECHNOLOGY

### SCIENCE

### ZIP USA

## Departments

Rio de Janeiro, Brazil  
Yakutsk, Russia  
Danco Island, Antarctica

### Paleo Bunny

### Saturn's Moon

### Iraqi Dinar

### Roman Shipwreck

### Moving a Giant Tree

### Saliva

BY JOEL ACHENBACH

### 94123 San Francisco, CA

BY MICHAEL MASON

PHOTOGRAPHS BY CATHERINE KARNOW

## Miscellany

### EDITOR'S NOTE

### LETTERS

### YOUR SHOT

### PHOTO JOURNAL

### INSIDE GEOGRAPHIC

### FLASHBACK

## ngm.com

### CRANE CAM

Watch via live webcam as half a million sandhill cranes descend on Nebraska's Platte River. Then enjoy video and photo highlights, interactive shows for kids, and a blog with crane experts at [ngm.com/cranecam](http://ngm.com/cranecam).

### SIGHTS & SOUNDS

Revisit Chernobyl and witness the physical and psychological effects the explosion left in its wake in a special multimedia show.

### PHOTO GALLERIES

Find more great photography online. Browse online-exclusive images with technical tips from photographers. Register for our Photo of the Month newsletter, and visit Fun Stuff for free wallpaper and postcards.

## Member Services

### Subscriptions

To order a subscription to NATIONAL GEOGRAPHIC magazine, give a gift membership, or change address, contact Customer Service online at [ngmservice.com](http://ngmservice.com), or call 1-800-NGS-LINE (647-5463). Outside the U.S. and Canada call +1-813-979-6845.

### Catalog

Order a free National Geographic catalog at [shopng.com](http://shopng.com) or call 1-888-225-5647.

### Customer Service Address

National Geographic  
PO Box 63001, Tampa, FL  
33663-3001

### Mailing List

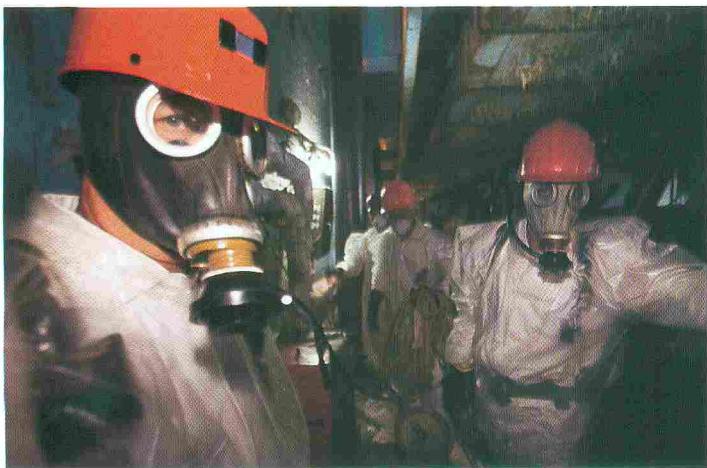
We occasionally make a mailing list available to carefully screened companies whose services may be of interest to National Geographic Society members. To remove your name from this list, email [ngslne@customersvc.com](mailto:ngslne@customersvc.com).

U.S. and Canadian customers call 1-800-NGS-LINE (647-5463).

International customers call +1-813-979-6845. Or write: National Geographic Society, PO Box 63005, Tampa, FL 33663-3005. Please include address label from the magazine wrapper.

**The unanticipated threat** is a photographer's greatest fear. During my years as a photographer for this magazine, I worried about being blindsided by anything from a cobra to a wild-eyed rebel with an AK-47, but it never occurred to me to worry about an invisible killer like radiation. Gerd Ludwig's coverage of Chernobyl's legacy made me think twice. The worst nuclear accident in history, the explosion of the Chernobyl reactor 20 years ago released 400 times more radioactivity than Hiroshima. Ludwig was prepared for the worst.

"I was concerned about my safety," he says, "particularly since I have a 17-year-old son who depends on me. But it was a calculated



Protective suits are standard for workers—and journalists—inside Chernobyl.

risk." He did meticulous research. He knew how much radiation he could tolerate safely. He bought Geiger counters, dosimeters, disposable coveralls, surgical gloves, face masks, and potassium iodide to protect his thyroid when he worked in the contaminated region. "As a photographer, you walk a thin line. You need to be safe, but you must push for the right shot."

Richard Stone, who wrote the article, has visited the Chernobyl reactor four times. "Standing outside it made my skin crawl," he says. "Yet I was compelled to see what was inside." Motivated by curiosity and a passion for truth, Ludwig and Stone put their health on the line to tell the story of "The Long Shadow of Chernobyl."

A handwritten signature in black ink, appearing to read "Chris Johns".

PHOTO: GERD LUDWIG

#### CHRIS JOHNS, *Editor in Chief*

Victoria Pope, *Managing Editor*  
Dennis R. Dimick, *Executive Editor*  
Bill Marr, *Executive Editor*  
Carolyn White, *Executive Editor*  
Robert L. Booth, *Associate Editor*

#### SENIOR EDITORS

Tim Appenzeller, *Science*  
Don Belt, *Geography & World Affairs*  
Bill Douthitt, *Story Development*  
John A. Echave, *Research Grants*  
Ken Geiger, *Technology*  
David Griffin, *Photography*  
Lisa Moore LaRoe, *Staff Writers*  
Valerie A. May, *New Media*  
Peter Miller, *Expeditions*  
Kathy Moran, *Natural History*  
Oliver Payne, *Manuscripts*  
Lesley B. Rogers, *Research*  
Christopher P. Sloan, *Graphics*  
David C. Whitmore, *Design & Typography*  
Margaret G. Zackowitz, *Departments*

#### TEXT

**Assistant Editors:** Alan Mairson, Peter L. Porteous, Jane Vessels. **Text Editors:** Lynn Addison, Karen M. Kostyal, Glenn Oeland, Barbara Paulsen, Jennifer Reek. **Senior Writers:** Joel K. Bourne, Jr., John L. Eliot, Jennifer S. Holland, Cathy Newman, Tom O'Neill, Cliff Tarpy, A. R. Williams. **Writers:** Chris Carroll, Peter Gwin, Carol Kaufmann, Michael Klesius, Karen E. Lange, Cate Lineberry, Neil Shea, Lynne Warren. **Departments:** Whitney Dangerfield, Siobhan Roth. **New Media:** Cassandra Franklin-Barbejosa, *Senior Writer*

#### PHOTOGRAPHY

Susan A. Smith, *Deputy Director*. **Photo Editors:** Bert L. Fox, Todd James, Elizabeth Krist, Sarah Leen, Kurt F. Mutchler, Sadie Quarrier, Susan Welchman. **Photographers:** William Albert Allard, Jodi Cobb, Michael Nichols, Mark Thiessen. **Photo Engineering:** Lawrence B. Maurer, Joseph S. Stancampiano

#### DESIGN AND GRAPHICS

**Design Editors:** Robert Gray, *Deputy Director*; Elaine H. Bradley, Beth L. Rakouskas. **Designers:** Betty Clayman-DeAtley, Joanna Foucheux, Oliver R. Uberit; Cinde Reichard. **Production Maps:** William E. McNulty, *Director*; Jeffrey L. Osborn, *Deputy Director*; Charles L. Floyd, Christopher A. Klein, Joshua Korenblat. **Infographics:** Brenna Malone, Juan Velasco. **Art Research:** Patricia B. Kellogg, *Director*; Ellie Boettiger, Ann R. Perry

#### RESEARCH

David Brindley, *Deputy Director*; Abigail A. Tipton, *Asst. Director*. **Research Editors:** Victoria C. Duchenaeau, Alice J. Dunn, Kathy B. Maher, Mary McPeak, Heidi Schultz, David W. Woodell, Barbara L. Wyckoff. **Senior Researchers:** Norel Gallagher, Mary Jennings, Marisa J. Larson, Elizabeth Snodgrass, Christy Ulrich. **Researchers:** Karen C. Courtwright, Emily Krieger, Nancie Majkowski, David A. O'Connor, Taryn Salinas, Brad Scriber, Shelley Sperry

#### EDITORIAL SERVICES

**Administration:** Marisa Dorneyko, *Staff*; Carol Dumont Kerby, *Scheduling*; Maria-Teresa Lawrence, *Business Manager*; Brian E. Strauss, *Electronic Publishing*; Karen Dufton Sligh, *Asst. to the Editor in Chief*; Sandra M. Dane, Ewart Ignacio, Caroline Wallinger. **Communications:** Mary Jeanne Jacobsen, *Vice President*; Barbara S. Moffet. **Correspondence:** Joseph M. Blanton, Jr., *Director*; Carol Stroud, Lisa Walker. **Image Collection:** Maura A. Mulvihill, *Vice President*; William D. Perry, *Sales*; Carolyn J. Harrison, John A. Rutter. **Libraries and Information Services:** Susan Fifre Canby, *Vice President*; Richard Braden, Ellen D. Briscoe, Barbara P. Ferry, Anne Marie Houppert, Ann E. Hubbs, Karen Huffman. **Travel:** Cristine E. Ghillani

#### PRODUCTION SERVICES

Hans H. Wegner, *Vice President*. **Digital Imaging:** Thomas J. Craig, *Director*; Clayton R. Burneston, Phillip E. Plude, Bernard G. Quarrick. **Distribution:** Michael Swart, *Director*. **Engraving:** George Bourelis, *Director*; William D. Reicherts. **Printing:** Joseph M. Anderson, Luz Garcia, Edward J. Holland. **Quality:** Ronald E. Williamson, *Director*

#### MAGAZINE PUBLISHING

**Advertising:** Stephen P. Giannetti, *Vice President and Group Publisher*; Sean P. Flanagan, *Vice President and Worldwide Publisher*; Claudio Malley, *Vice President and U.S. Publisher*. **International:** Declan Moore. **National Advertising Directors:** Jerry Brennan, *Western*; John Patten, *Eastern*. **Directors:** Ron Bottorff, *West Coast Sales*; Suzanne McKeon, *Marketing*; Margaret Robertson, *Business and Operations Managers*; Bob Amberg, *Southeast*; John Iavarone, *Detroit*. **Circulation:** Terry Day, *Vice President*. **Directors:** Elizabeth M. Safford, *North America*; John A. Seelye, *International*. **Member Services:** Christina C. Alberghini, *Director*

# LETTERS



**December 2005** Many readers responded to our global aid story, "Hope in Hell"; some wrote to see how they could help. On a lighter note, "North American Dialects" may have solved a family dispute. After learning his pronunciations reflect the region where he grew up, one reader joked that his wife "has to accept that I do not have a speech impediment!"

► Voice opinions about April stories at [ngm.com](http://ngm.com).

## Hope in Hell

Of all the stories featured, the one that spoke to me the most was that of the Ugandan night runners. While you have done your part in providing education about forgotten causes, I urge the rest of us to take action by writing our representatives to encourage U.S. support, by providing financial contributions to charities, and by sharing these accounts with others so that they remain top-of-mind. I ask each of us to tuck one vivid photograph into the forefront of our minds so that we resolve to remember the thousands of children like Dick O. in our prayers.

TERRY HEATH  
Loveland, Ohio

It struck me that your story described the monstrous Lord's Resistance Army as a group "fighting to overthrow the Ugandan government in

## Write, email, fax

### Write

National Geographic Magazine  
PO Box 98199  
Washington, DC 20090-8199  
**Email**  
[nsgforum@nationalgeographic.com](mailto:nsgforum@nationalgeographic.com)  
**Fax**  
202-828-5460  
Include name, address, and daytime telephone. Letters may be edited for clarity and length.

the name of strict Christian rule." Although the LRA may call itself Christian, most people would agree that its barbarism has nothing to do with Christianity.

MARK F. FISCHER  
Camarillo, California

I was moved by the children of Uganda. After seeing the picture of the children sleeping on the floor, I very much want to send my children's unused clothing to the Noah's Ark Centre in Gulu. Do you know how I could do this?

KATHLEEN LUNDSTEEN  
Elgin, Illinois

To find out how to donate to the Noah's Ark Centre, contact program coordinator Annet Kurui at the Noah's Ark Children's Ministry, Plot 4 Awach Road, Gulu, Uganda, or by email at [kururius@yahoo.com](mailto:kururius@yahoo.com).

I found quite interesting your juxtaposition of global aid, sea monsters, and "melting" polar bears. It made me wonder just exactly who or what are the real monsters on this planet. Thank goodness polar bears make me feel happy, and the prospects of Buddhism provide hope in this gloomy world.

MICHAEL RAY WILSON  
Denton, Texas

## Buddha Rising

If a picture is worth a thousand words, the one on pages 100-101 must be worth a million. This is a simple composition—a single person meditating outside the entrance to the Auschwitz-Birkenau camp—but it is the most emotive image I have seen in over 30 years of studying photography.

MICHAEL FODEN  
Southport, England

As a practitioner of Vipassana meditation, I know that it has contributed profoundly to my daily sense of peace and well-being. I have one comment on the author's understanding of the enlightenment he seeks but has not attained "yet." Enlightenment is not a permanent state to be achieved in the future. It happens in the present moment, breath by breath. The concept of a permanent state of enlightenment is the big romantic sham of Buddhism. I fell for it. It is a useful sham, though. Once the practice is started, it's difficult to quit.

TIM CARDOZA  
San Diego, California

King Ashoka (I was named after him) was instrumental in spreading Buddhism outside India. He was a great Mauryan emperor, who, sickened by the violence of war, vowed not to fight again. He then truly embraced Buddhist principles. His vast kingdom stretched from Afghanistan to the Indian states of West Bengal and Tamil Nadu. To honor his nobility, India adopted Ashoka's emblem, the "wheel of dharma," in the national flag.

ASHOK PATEL  
Holland, Michigan



"FOR THE INCREASE AND  
DIFFUSION OF GEOGRAPHIC  
KNOWLEDGE"

## Sea Monsters

It was exciting to see how these new reconstructions of prehistoric sea creatures had been inspired by illustrations by great paleoartists like Charles R. Knight. As always, some traditional imagery may be overdue for revision. Recently discovered fossil evidence suggests that some plesiosaurs may have been bottom-feeders. A more appropriate image of these beasts might show them feeding like moray eels suspended from their raft-like bodies.

JAMES M. BRYANT  
Curator of Natural History  
Riverside Municipal Museum  
Riverside, California

From our online forum  
[ngm.com/0512](http://ngm.com/0512)

## ZipUSA: Grand Central

I read with interest your article, particularly the reference and photo of the secret rail platform beneath the Waldorf-Astoria. My grandfather Lou Freedman owned Freem's, Ltd., the original men's shop at the Waldorf. My mother and her sisters stayed at the hotel periodically. During one visit in 1945, a hotel staff member invited my mother to the secret platform, where she was one of a handful of people who witnessed General Eisenhower's return to the U.S. following World War II.

ROBERT NEFSKY  
Lincoln, Nebraska

## North American Dialects

Thank you, thank you, thank you! Over the past 30 years my wife, from Philadelphia, has accused me, from Kansas, of either having a speech impediment or at least not paying attention in school. "Mary,"

"merry," and "marry" for me are all pronounced the same; as are "gulf" and "golf." I have many more "speech impediments." After your article, she has to accept that I do not have a speech impediment nor was I a delinquent!

LARRY WOELK  
London, England

I was pleased by the quality of the cartographic display, however, after reading the article, I was left disappointed. Grouping the dialects of Canada as a single monolith is unacceptable. Native English speakers from the Prairie Provinces often sound quite different from those born in Vancouver, Toronto, or Montreal. Although the accents of the Maritimes are different from the rest of Canada, the dialect doesn't just switch at the New Brunswick-Quebec provincial border. I thought this article had great potential, but if it's titled "North American Dialects," then please ensure that Canada is depicted appropriately as a diverse country full of variety.

JAY LANCASTER  
Vancouver, British Columbia

*Charles Boberg, a linguist at McGill University in Montreal and a co-author of The Atlas of North American English, responds: "While it's true that there are subtle phonetic differences in the English spoken in Canadian cities like Vancouver, Calgary, Toronto, Montreal, and Halifax, these are small compared to the more prominent differences among U.S. regions. Canada's regions, with the exception of Newfoundland, have much more in common linguistically than U.S. regions."*

The National Geographic Society is chartered in Washington, D.C., as a nonprofit scientific and educational organization. Since 1888 the Society has supported more than 8,000 explorations and research projects, adding to knowledge of earth, sea, and sky.

JOHN M. FAHEY, JR., President and CEO

### EXECUTIVE VICE PRESIDENTS

Terrence B. Adamson

Linda Berkeley, President, Enterprises

Terry D. Garcia, Mission Programs

John Q. Griffin, President, Magazine Group

Nina D. Hoffman, President, Books and School Publishing Group

Christopher A. Liedel, CFO

### BOARD OF TRUSTEES

Gilbert M. Grosvenor, Chairman

Reg Murphy, Vice Chairman

Joan Abrahamsen, Michael R. Bonsignore, Martha E. Church, Michael Collins, Roger A. Enrico, John M. Fahey, Jr., Daniel S. Goldin, John Jay Iselin, James C. Kautz, J. Willard Marriott, Jr., Floretta Dukes McKenzie, George Muñoz, Patrick F. Noonan, Nathaniel P. Reed, William K. Reilly, Rozanne L. Ridgway, James R. Sasser, B. Francis Saul II, Gerd Schulte-Hillel

### TRUSTEES EMERITUS

Joe L. Allbritton, William L. Allen, Thomas E. Bolger, Frank Borman, Lewis M. Branscomb, Robert L. Breeden, Lloyd H. Elliott, George M. Elsey, Mrs. Lyndon B. Johnson, Robert C. Seamans, Jr.

### COUNCIL OF ADVISORS

Roger A. Enrico, Chairman

Darlene T. Anderson, Michael R. Bonsignore, Howard G. Buffett, Craig D. Campbell, Jean N. Case, Juliet C. Folger, Robert B. Haas, Robert A. Heffner III, David H. Koch, Bruce L. Ludwig, Sally Engelhard Pingree, W. Russell Ramsey, Catherine B. Reynolds, Edward P. Roski, Jr., B. Francis Saul II, Michele Sofisti, Ted Waitt, Garry A. Weber, Tracy R. Wolfstencroft

### RESEARCH AND EXPLORATION COMMITTEE

Peter H. Raven, Chairman

John M. Francis, Vice Chairman

Martha E. Church, Steven M. Colman, Scott V. Edwards, Philip Gingerich, William L. Graf, Nancy Knowlton, Dan M. Martin, Scott E. Miller, Jan Nijman, Stuart L. Pimm, Elsa M. Redmond, David S. Smith, Patricia C. Wright, Melinda A. Zeder

### EXPLORERS-IN-RESIDENCE

Robert Ballard, Wade Davis, Sylvia Earle, Zahi Hawass, Louise Leakey, Meave Leakey, Johan Reinhard, Paul Sereno, Spencer Wells  
Conservation Fellow: J. Michael Fay

### MISSION PROGRAMS

Vice Presidents:

Barbara A. Chow, Education Foundation  
John M. Francis, Research, Conservation, and Exploration

Jacqueline M. Hollister, Development

Sarah Laskin, Public Programs

Exhibits: Susan S. Norton

Expeditions Council: Rebecca Martin

Geography Bee: Mary Lee Eiden

Lectures: P. Andrew van Duym, Gregory A. McGruder

Communications: Betty Hudson, Sr. Vice President  
Human Resources: Thomas A. Sabló, Sr. Vice President  
International: Robert W. Hernández, Sr. Vice President  
Treasurer: H. Gregory Platts, Sr. Vice President

### NATIONAL GEOGRAPHIC VENTURES

Dennis R. Patrick, Chairman

Timothy T. Kelly, President and CEO

Edward M. Prince, Jr., COO

National Geographic Channel: David Haslingden, President, International; Laureen Ong, President, U.S. Digital Media: Chris McAndrews, President

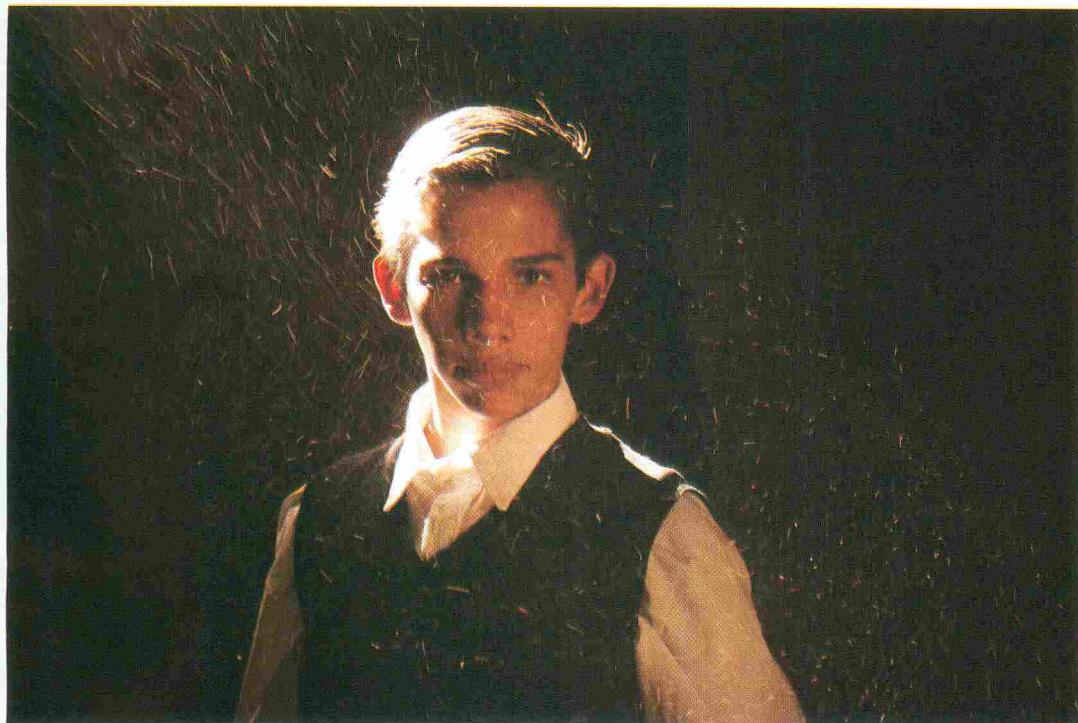
National Geographic Maps: Frances A. Marshall, President; Allen Carroll, Chief Cartographer

Television: Michael Rosenfeld, Executive Vice President

Contributions to the National Geographic Society are tax deductible under Section 501(c)(3) of the U.S. tax code.

Copyright © 2006 National Geographic Society. All rights reserved. National Geographic and Yellow Border: Registered Trademarks © Marcus Registradas. National Geographic assumes no responsibility for unsolicited materials. Printed in U.S.A.

**Be a National Geographic Photographer** Take your best shot—and send it to NATIONAL GEOGRAPHIC. Editors will select from the first 5,000 photographs submitted electronically each month. The theme for the July 2006 Your Shot page is "My Family." For guidelines, a submission form, and additional information, please go to [ngm.com/yourshot](http://ngm.com/yourshot).



### **Sunlight and Dust**

Sara Kranwinkle had her doubts. The Seattle mother of four had agreed to accompany her sister to a photo workshop in San Miguel de Allende, Mexico, but didn't think she fit the workshop's "amateur to professional" range of expertise. "I wasn't even an amateur," she admits. "I was a total beginner. I didn't know how my camera worked." Once in Mexico, though, Kranwinkle found she had an eye. In the dusty bull barn of a hacienda outside San Miguel, she shot this portrait of a young torero. "The sun was hitting him, the dust was dancing all around," she says. "I knew I'd gotten something good."



Firefighters outfitted in samurai-like headgear shout in unison during drills at a training facility in Kyoto, Japan.



Since 1979, when he was assigned to photograph Hokkaido in Japan, Yamashita has shot 23 features for NATIONAL GEOGRAPHIC.

**Fire Man** Most people flee from burning buildings, but at the sight of flames, I usually think one thing: It's time to get to work. Fires are exciting for me because they make good pictures. I've photographed blazes and the people who battle them in all kinds of places, from China to Italy. Many of my favorite images come practically from my own backyard in central New Jersey, but for these I pick up a hose before I pull out a camera.

For the past 18 years I have been a volunteer firefighter with Ralston Engine Company Number One in Mendham, New Jersey. Like most of the company, I joined because I wanted to get involved in my community. But there is also something to the cliché that firefighters are basically grown-up boys with big toys.

When I answer a call, my first obligation is to put out the fire. But once the fire is under control, I'm free to pick up my cameras and roam. Some of these photos end up being a featured event at our company's annual dinner, where I present a slide show of my fellow firefighters in action. It's great fun for me, but it also feels important. I always hope my photographs will inspire others to join their local fire departments. It's difficult to find volunteers these days, and, as I know, there are always, everywhere, fires to be fought.

---

↖ **Online Portfolio** View a presentation of Mike Yamashita's images from the story "Marco Polo Odyssey" at [ngm.com/0107](http://ngm.com/0107).

*Then*

*Now*

**hy•brid** \hi'brĭd\ *n.* A vehicle that runs on petrol and electricity.

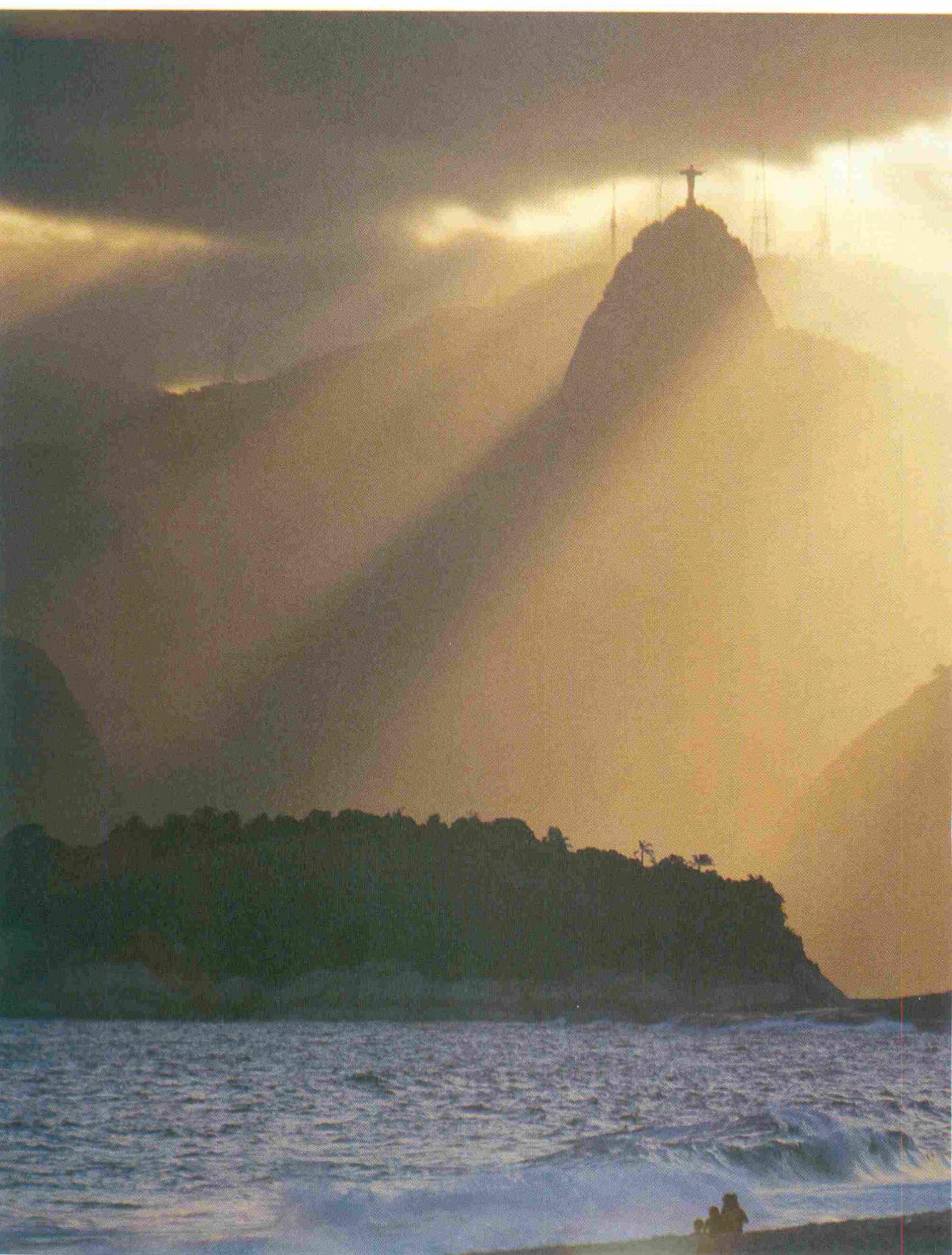
**hy•brid** \hi'brĭd\ *n.* A luxurious, stylish, innovative vehicle that appeals to the senses. A vehicle that allows the words "elegant" and "environmentally sound" to sit comfortably within the same sentence. A vehicle that outperforms most petrol-powered cars. (And by the way, it runs on petrol and electricity.)



*There are many definitions of what a hybrid is. But now, Lexus brings a whole new meaning to it.  
The Pursuit Continues. The World's First Luxury Hybrid.*

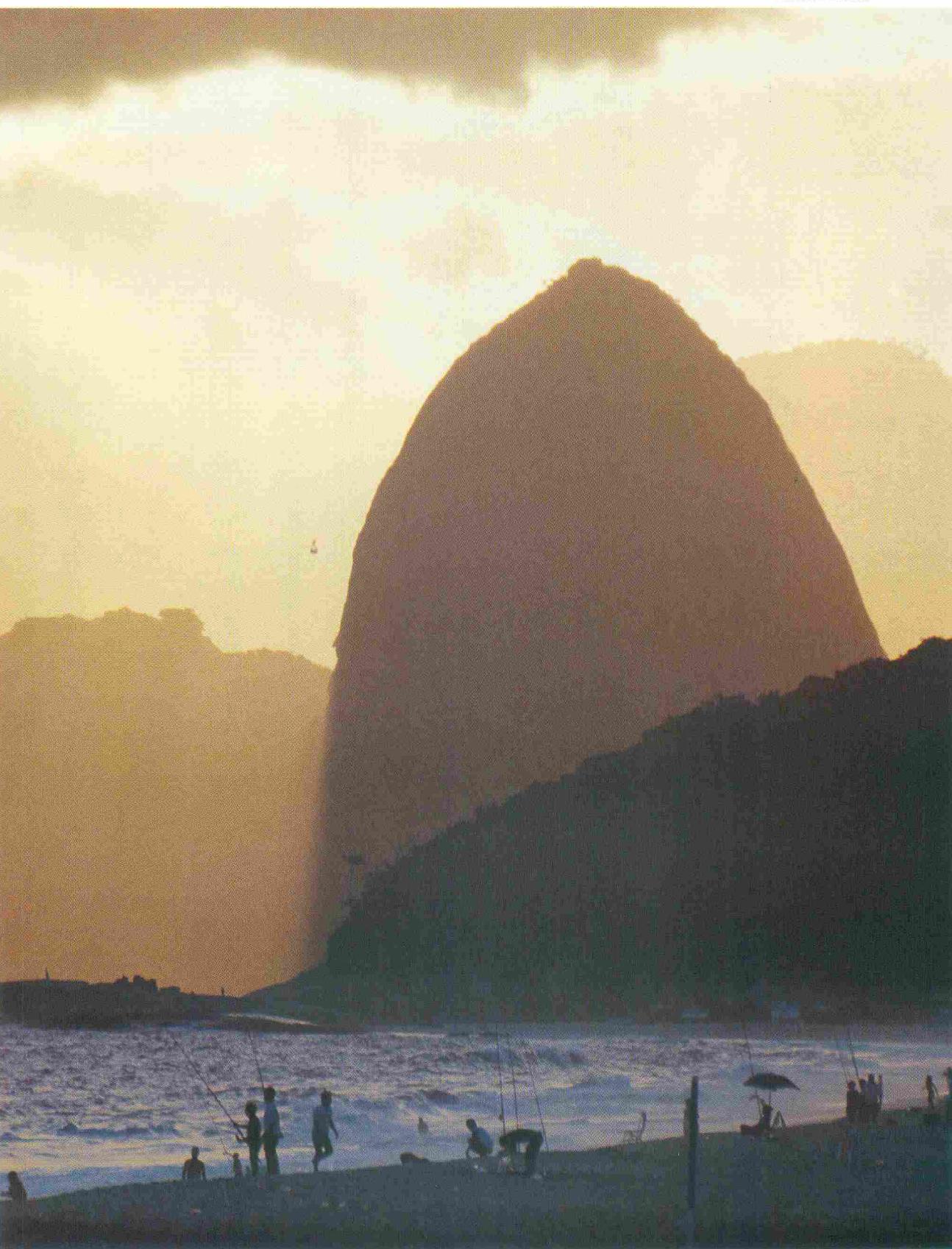
**LEXUS**  
THE RELENTLESS PURSUIT OF PERFECTION

**VISIONS OF EARTH**



**Rio de Janeiro, Brazil** Blankets of clouds soften a sunset over Guanabara Bay and suspend beachgoers and surrounding mountains in a moment of ethereal light.

PHOTO: IZAN PETTERLE



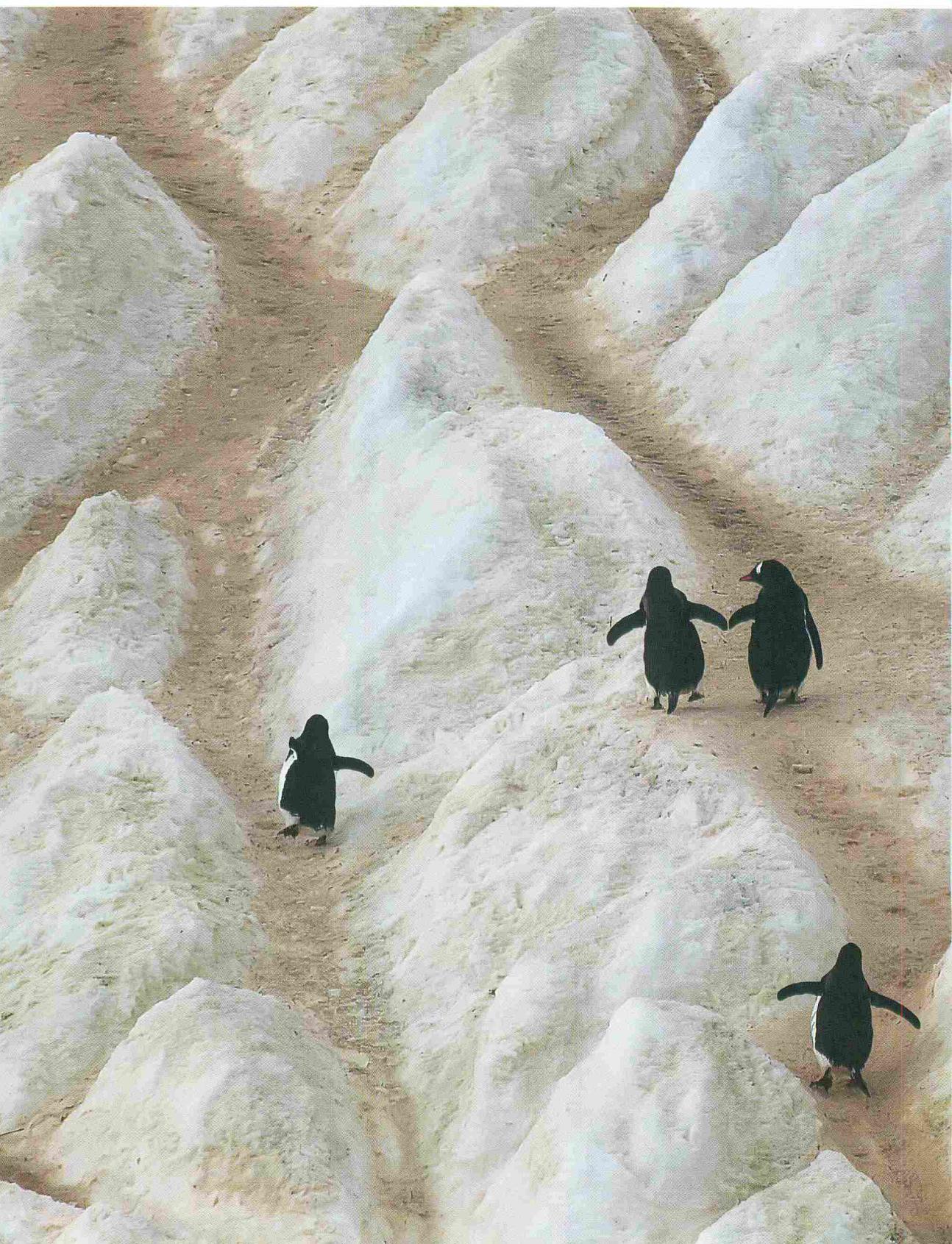
**Yakutsk, Russia** Swaddled in furs against the minus 43°F cold, three women glow in headlights that beam through morning fog in Sakha, an autonomous republic in eastern Siberia.



PHOTO: GERD LUDWIG

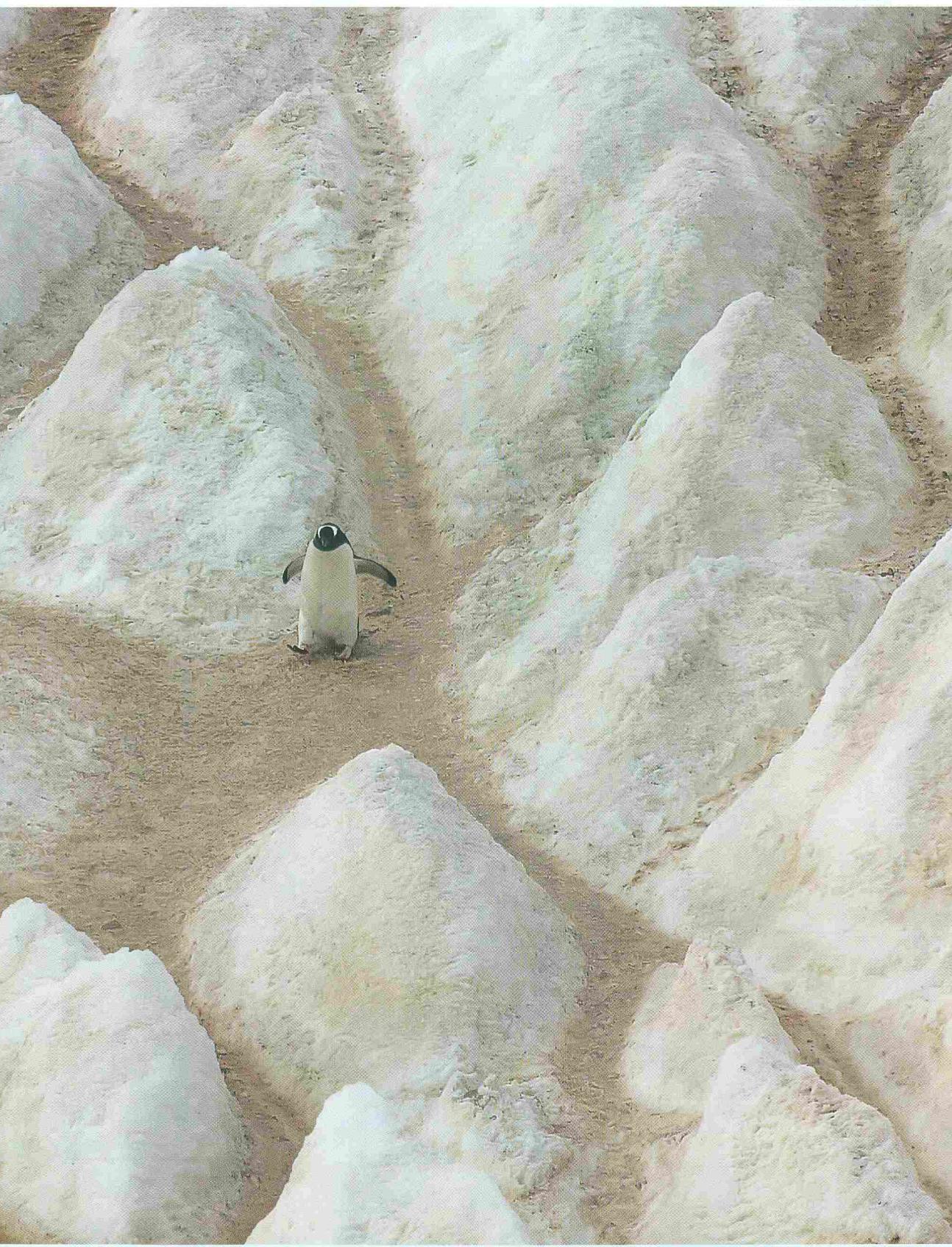


**Danco Island, Antarctica** Gentoo penguins waddle through a web of icy paths on the slope between their hilltop rookery and the open water where they feed.



Decorate Your Desktop with this and other images in Fun Stuff at [ngm.com/0604](http://ngm.com/0604).

PHOTO: MICHAEL POLIZA





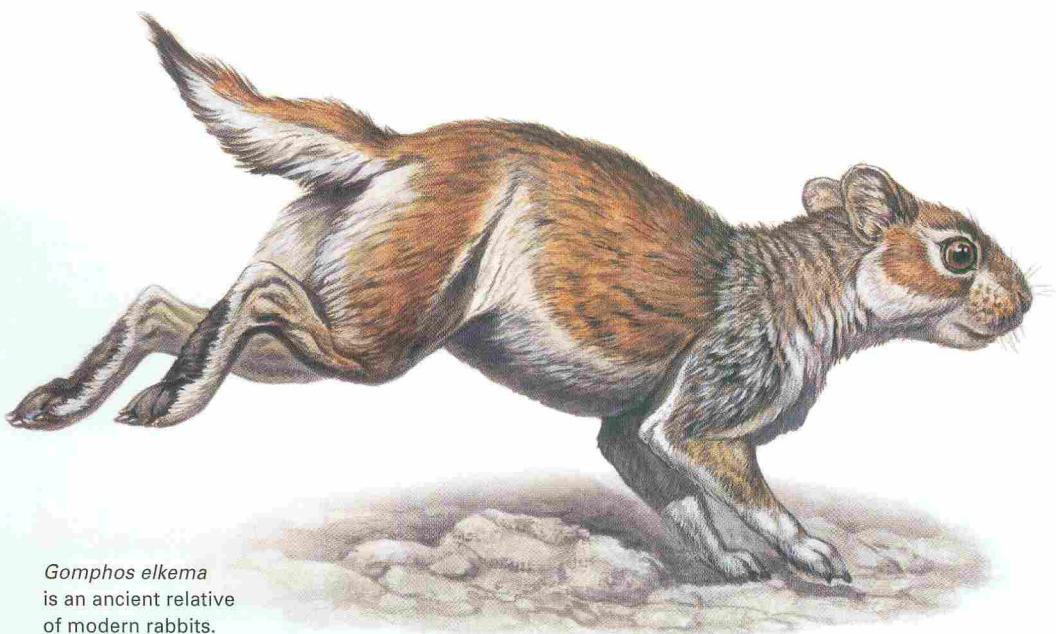


"Environmentally friendly" meets "fun to drive" in the Toyota Prius, the world's best-selling hybrid vehicle. The Prius is just one example of how Toyota brings "opposites" into harmony for a sustainable future.

 **TOYOTA**

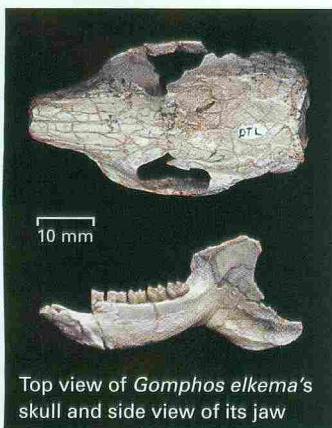
What can we harmonize today?

# FOSSILS



*Gomphos elkema*  
is an ancient relative  
of modern rabbits.

**Early Hopper** What jumped like a rabbit but chewed like a squirrel? *Gomphos elkema*, a 55-million-year-old relative of the rabbit, a fossil of which was found in the Nemegt basin, Mongolia. The discovery supports the long-held theory that rodents and lagomorphs—the group that includes rabbits, pikas, and hares—shared a common ancestor that lived around the time dinosaurs became extinct.



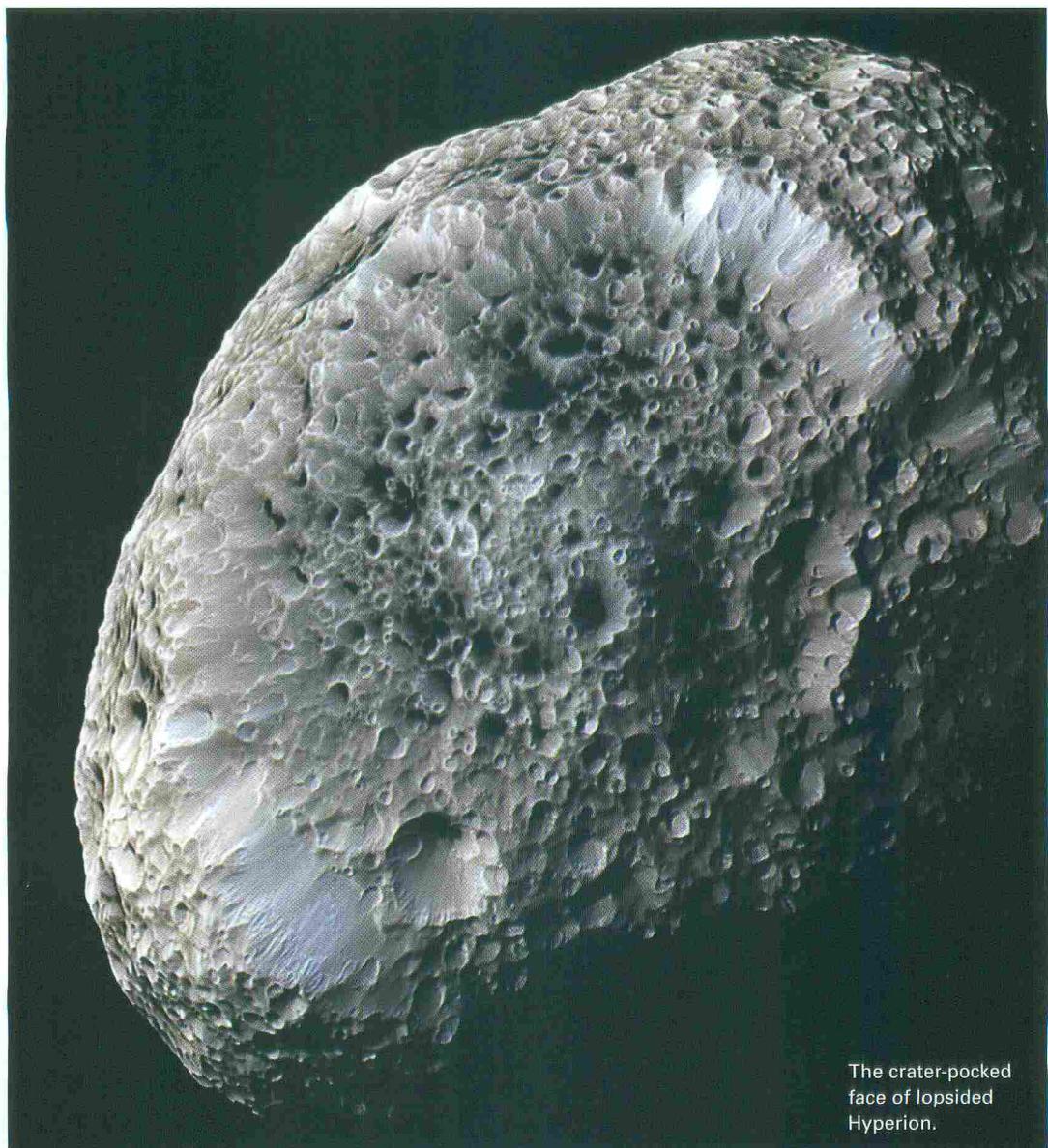
Top view of *Gomphos elkema*'s skull and side view of its jaw

Berlin Museum of Natural History. "They had cusps and roots like molars in a human or a squirrel." Its relatively large tail was also more like a squirrel's than a rabbit's. Another difference between *Gomphos elkema* and its modern kin: The fossil's skull suggests that the animal had a bony ear structure similar to that of rodents. —Angela Botzer

## Fresh Dirt

**Woolly mammoths stuck by their mothers.** By examining calves' tusks, which contain chemical information about what the extinct mammals ate, researchers have determined that woolly mammoths nursed for at least five years.

**It wasn't just the extinction of the dinosaurs** that helped boost mammals to dominance on Earth; it was also oxygen. About 200 million years ago the amount of oxygen in Earth's atmosphere hovered at 10 to 13 percent. Deep-sea core samples show the oxygen level rose to 18 percent 50 million years ago and climbed to 23 percent over the next 10 million years. This corresponds with a rise in huge mammals, culminating in *Indricotherium*, eight times bigger than its modern relative, the rhinoceros.



The crater-pocked face of lopsided Hyperion.

**Saturn's Strangest Moon** The Cassini spacecraft swooped in just 310 miles above the surface to get this closest ever view of Saturn's moon Hyperion. About 178 miles in diameter, the irregularly shaped satellite circles Saturn in a tumbling rotation. It's been theorized that Hyperion's odd shape was caused long ago by collisions with other objects in space. Hyperion's cratered surface, however, is a revelation; none of Saturn's other 46 moons looks similar. Scientists are now studying the new images to help clear up questions about Hyperion's origins. —Margaret G. Zackowitz

◀ **Interactive Quiz** Test your space knowledge at [ngm.com/space](http://ngm.com/space).

## COLOR OF MONEY

### Iraqi Dinar

The old dinar remained in Iraqi pockets long after Saddam Hussein was ousted. In fact, to keep the economy running, the U.S.-led Coalition Provisional Authority approved a reprint of bills bearing his portrait in June 2003.



Dinars lacked many security features after printing moved from Britain to Iraq following the gulf war.

**The Monument to the Unknown Soldier**, built during the Iran-Iraq War, honored fallen heroes.

The monument included a minaret and this disk representing a dying warrior's shield.

Saddam Hussein's image appeared on the dinar in the mid-1980s. It remained there until 2003.

The new Iraqi dinar was launched in October 2003 at an exchange rate of 1,500 dinars to one U.S. dollar. As its worth fluctuates, investors flock to place bets on the currency, which they hope will stabilize and climb in value.



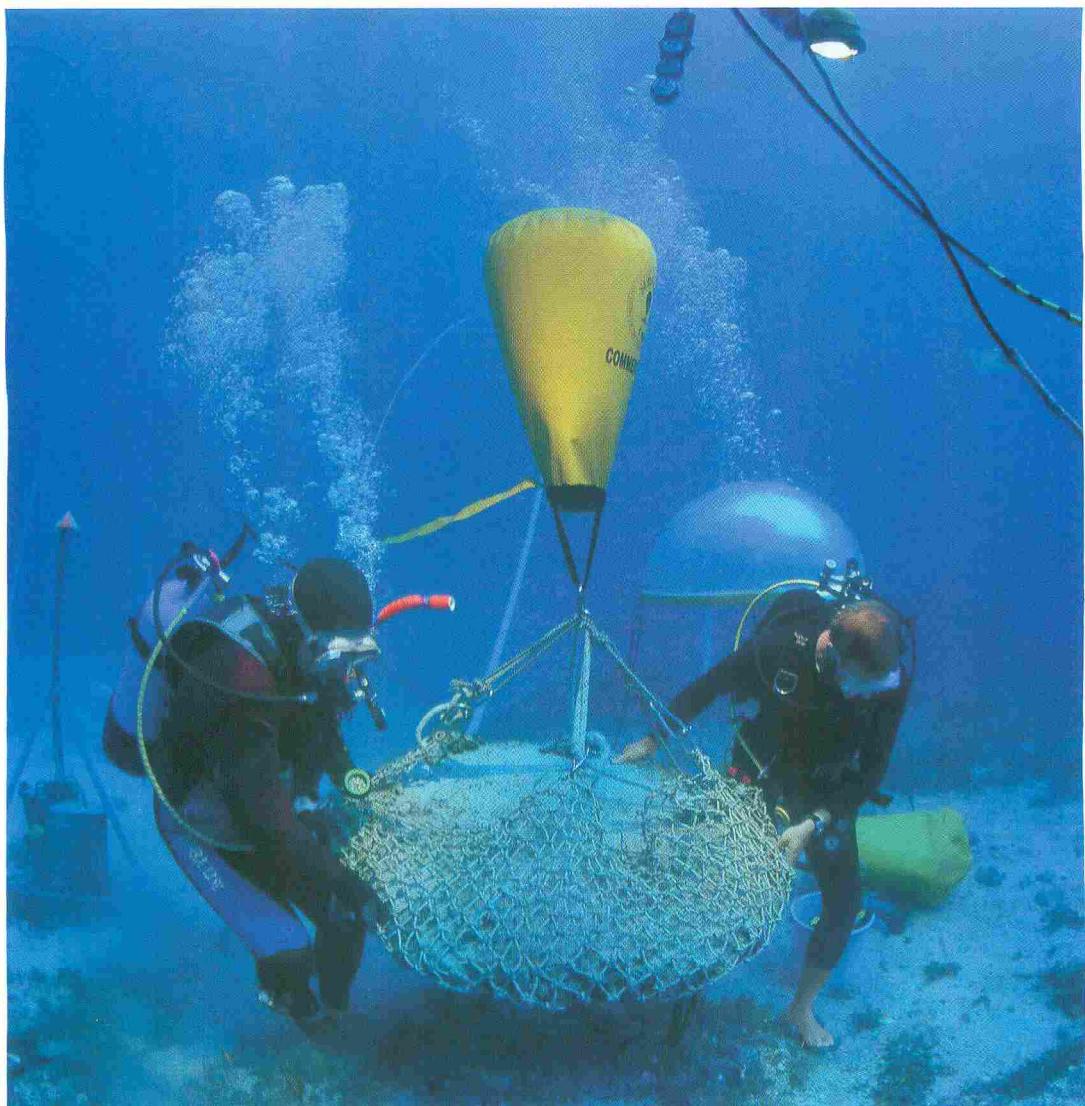
British printing firm De La Rue instituted anti-counterfeit measures, including this watermark.

**Writing** marks the year of this bill's issue: "Christian year 2004, Muslim year 1425."

**Patterns** rely heavily on traditional Iraqi designs originally featured on pre-Saddam bills.

**Scholar** Abu Ali al-Hasan ibn al-Haytham appears on this 10,000-dinar bill worth about seven dollars.

## ARCHAEOLOGY



Archaeologists hoist a stone washbasin, cargo of a ship that sank off Turkey's coast in the first century B.C.

**Sunken Cargo** Sometime between 100 and 50 B.C. a ship laden with more than 60 tons of freshly quarried marble—a column in eight pieces, a massive Doric capital, and other examples of Greek design—sank into the Aegean's ship-swallowing depths. Researchers are now excavating the wreck, discovered off Kizilburun, Turkey, home to at least four other ancient wrecks. This year they hope to move the column sections, under which portions of the ship's wooden hull may be preserved. Other hidden artifacts might provide clues about the vessel's passengers or destination, says Deborah Carlson, archaeological director of the undersea dig. Around the time the ship went down, inhabitants of Asia Minor rebelled against Rome, slaughtering 80,000 Romans, but the marble shipments continued. The bloodshed didn't seem to dampen Romans' appetite for goods from the area. —Chris Carroll

## TECHNOLOGY



The relocated oak stands five stories tall and weighs nearly as much as a Boeing 747.

**Tree Transplant** When a big chain store wanted to build on a certain lot in Auburndale, Florida, a 120-year-old oak stood in the way. Rather than cutting it down, the retailer paid more than \$100,000 to have the tree transplanted—a practice that's become more common as municipalities require developers to preserve tree canopy, says Dan Joy of the Davey Tree Expert Company, the firm that moved the oak. Saving trees creates positive publicity and attracts crowds who come to watch the process. "It's like the circus coming to town," says Joy. The Auburndale oak's move took six weeks of preparation. After uncovering and trimming its 42-foot-wide root-ball, the movers slid steel rods underneath (above), and the 353-ton tree was lifted onto a trailer for transport to its new home—just 500 yards away, in a wetland preservation area. So far the old tree is doing just fine. —Peter Gwin

### What's New?

**Imagine flexible robot "skin"** that can detect contact, or sensors for prosthetic limbs that can be integrated into human tissue. Stretchable silicon chips developed at the University of Illinois at Urbana-Champaign may make such things possible. The malleable, wavy silicon ribbons resemble accordion bellows

and are a thousandth the width of a human hair.

**Wasps can detect explosives** and drugs. Scientists have trained tiny parasitic wasps from the species *Microplitis croceipes* to associate certain smells with food rewards. To earn their rewards, the wasps are put into a cartridge

inside what the scientists call the "wasp hound," a length of PVC pipe equipped with a tiny camera and alarm. When the wasps detect a target odor, they move toward its source, triggering the alarm. Training the insects takes only five minutes, but there's high turnover: The wasps live only 12 to 22 days.

## Saliva's Saving Graces

Spit. Drool. Slobber. As body fluids go, writes Irwin Mandel of Columbia University, "Saliva is not one of the popular bodily fluids. It lacks the drama of blood, the sincerity of sweat, and the emotional appeal of tears."

But stand back and watch saliva enter its golden era. Scientists now argue that saliva is an elaborate substance that defends us against many hostile organisms. As a diagnostic tool, it appears to have breathtaking potential.

Mandel started his pioneering research on saliva in the late 1950s. Back then, most of what people knew about saliva was that it moistens food and contains enzymes that begin to digest it. Now scientists have charted many more components of saliva. Some proteins inhibit the transmission of the AIDS virus; others are critical in allowing friendly bacteria to adhere to teeth and gums, preventing severe infections.

The National Institutes of Health, meanwhile, is exploring the many ways saliva can be searched for warning signs of disease. The basic idea is, why draw blood when a patient can simply spit in a cup? Scientists can study saliva for stress-causing hormones and indicators associated with heart disease, HIV/AIDS, and osteoporosis. And since saliva contains DNA from cheek cells that are constantly being shed, analysts can potentially solve whodunits by examining saliva remnants on licked envelopes or stamps.

Next up, says Lawrence Tabak, head of the National Institute of Dental and Craniofacial Research is "a miniature laboratory on a chip small enough to be inserted in the mouth." Maybe it'll be mounted on a tooth. It'll monitor your saliva and transmit a radio signal about your health. (You can just imagine what else: "She hasn't been flossing.")

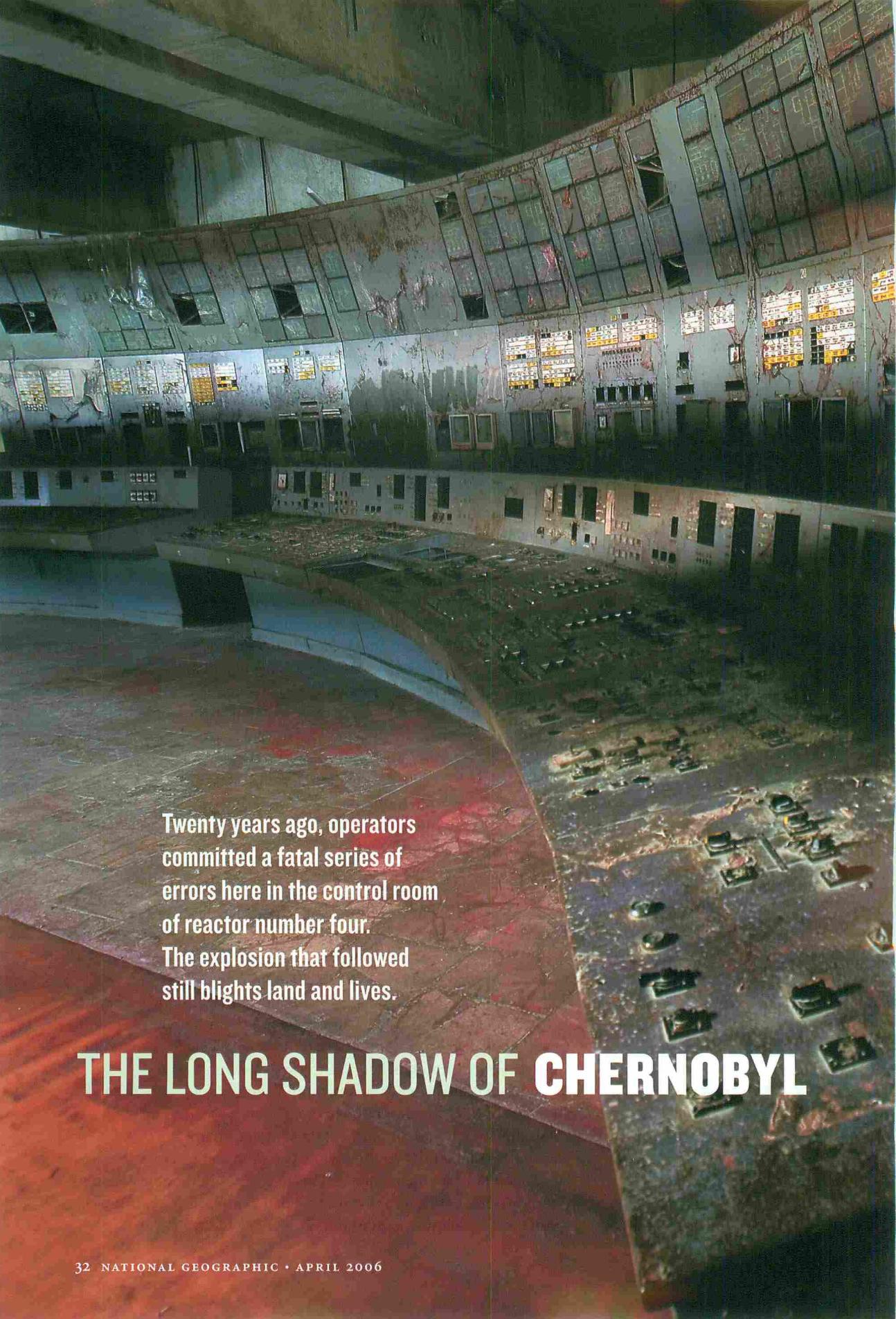
Saliva does a lot of work for other animals too. In some species of bats, saliva can neutralize poisons on the skins of frogs. Ticks, leeches, vampire bats, mosquitoes—and any of the other bloodsuckers known to science as hematophages—use saliva as an anticoagulant as they feed on blood. Experiments show that when certain salivary glands are removed from mice, their wounds don't heal as quickly after they lick them. This is apparently because a key component of their saliva is nerve growth factor, which stimulates nerves to close a wound.

And, of course, saliva is a communication tool. We're not talking about the human tendency to connote contempt through flamboyant spitting. In pigs, saliva contains chemicals that signal sexual availability. If you're swine, drooling can be sexy.

Saliva does all these interesting things even though it's 99 percent water. There's no reason to think it's gross. For gosh sakes, you swallow almost a quart a day.



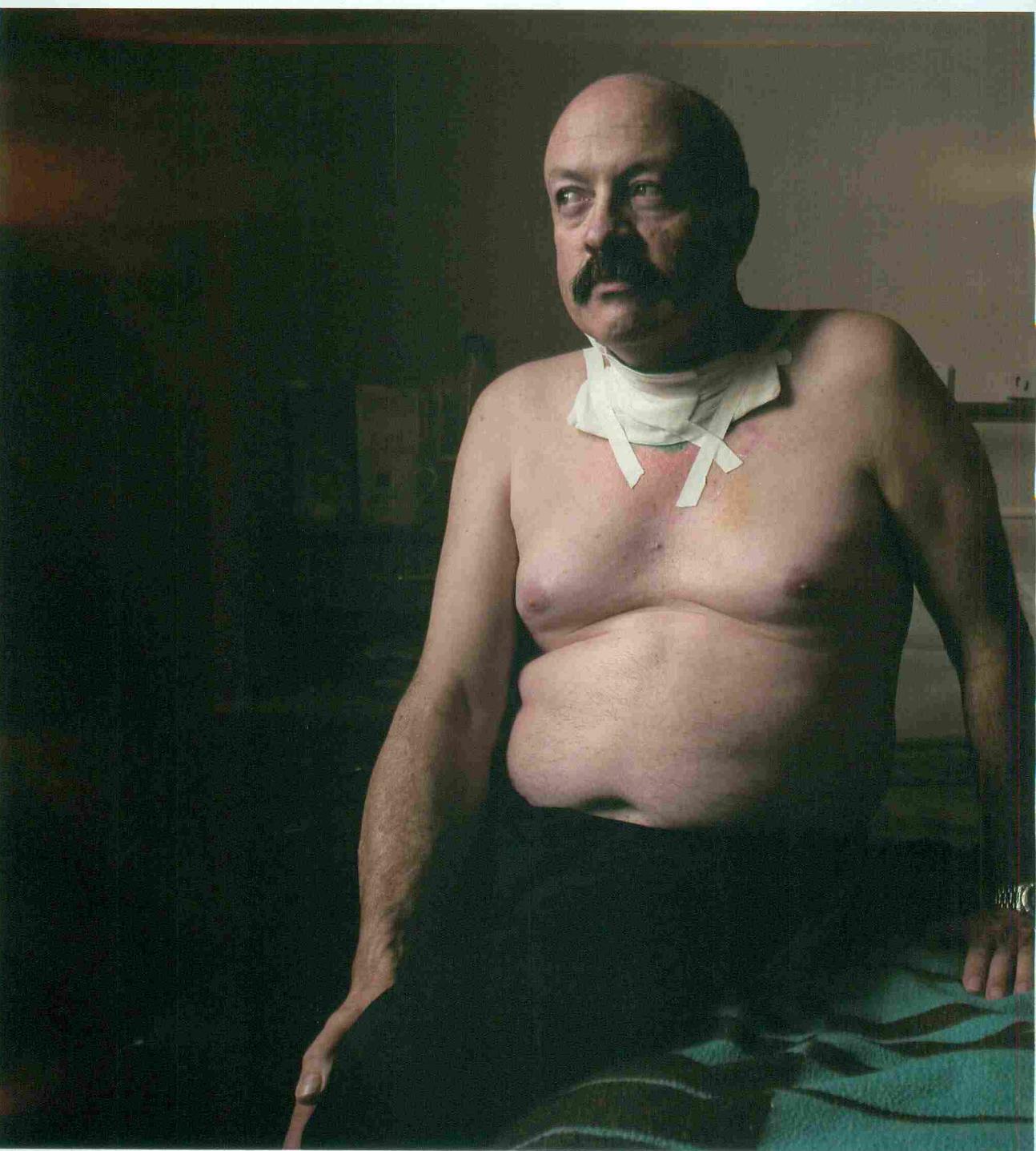
Joel Achenbach is a staff writer for the *Washington Post*.



Twenty years ago, operators committed a fatal series of errors here in the control room of reactor number four. The explosion that followed still blights land and lives.

## THE LONG SHADOW OF CHERNOBYL







**SICKNESS AND DOUBT** Suffering from thyroid cancer, Oleg Shapiro, 54, and Dima Bogdanovich, 13, receive care at a thyroid center in Belarus. As a "liquidator," Shapiro risked his health by razing contaminated houses near the destroyed reactor. It's unlikely that Dima, born long after the explosion, developed cancer because of it. While the radioactivity that causes thyroid cancer decayed soon after the accident, people throughout the region continue to blame a wide variety of ills on Chernobyl.

BY RICHARD STONE  
PHOTOGRAPHS BY GERD LUDWIG

In the wan light of a snowy spring morning, belongings scattered on the floor of an abandoned kindergarten speak of a time before the children of Pripyat lost their innocence. Musty sandals and ballet slippers for tiny feet. Cardboard pictures of Lenin as a young boy and as a youthful leader—the Soviet equivalent of baseball cards. In the next room, dolls in various states of dress and dismemberment, lolling on metal cots where the children once napped. Finally, on the gymnasium wall, photos of the children themselves—doing calisthenics, climbing monkey bars, balancing on boards.

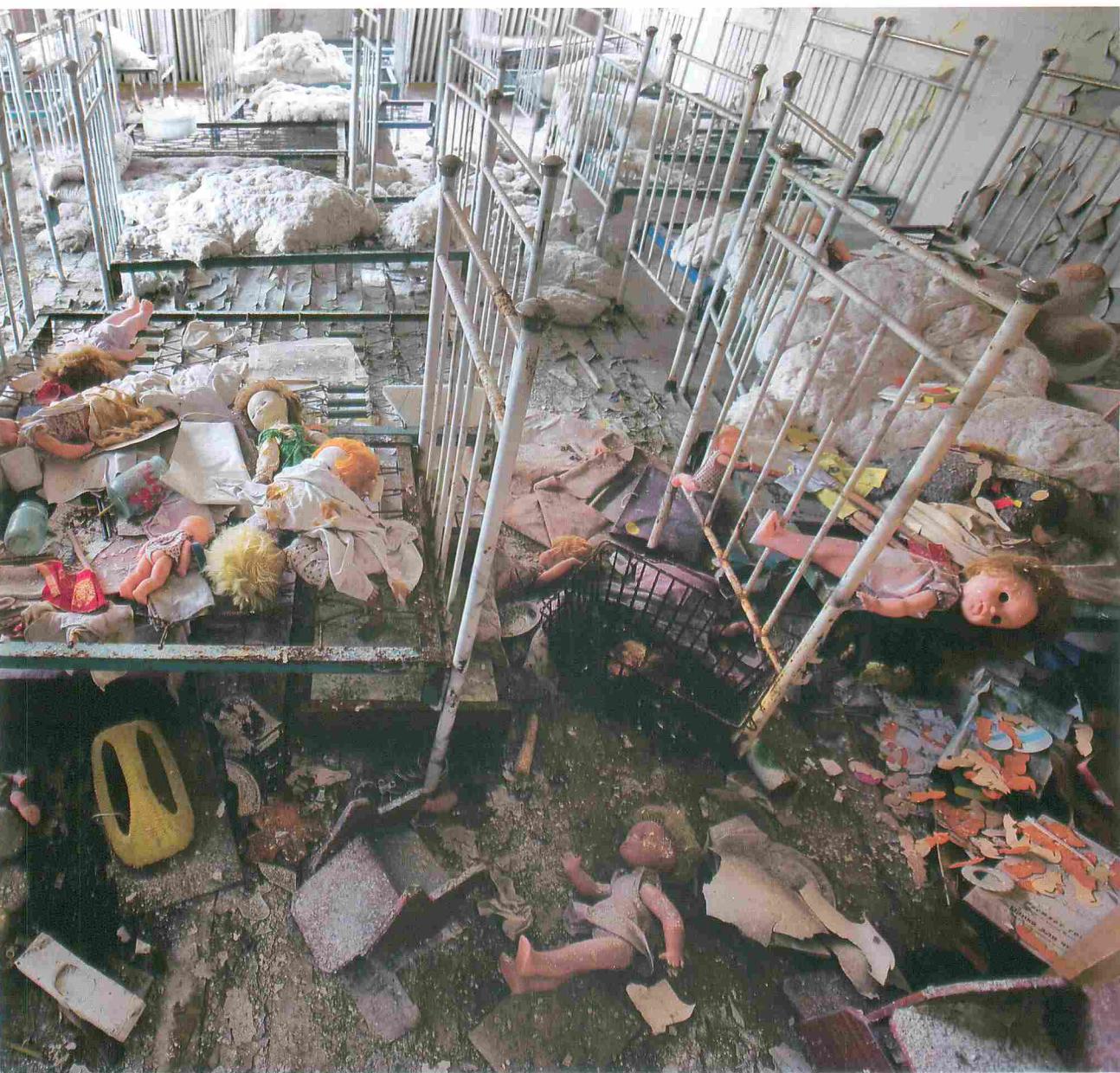
Twenty years ago this month, life in Pripyat came to a shuddering end. Before dawn on April 26, 1986, less than two miles south of what was then a city of 50,000, the Chernobyl Nuclear Power Plant's number four reactor exploded. Thirty people died in the blast and fire or were exposed to lethal radiation. The destroyed hulk burned for ten days, contaminating tens of thousands of square miles in northern Ukraine, southern Belarus, and Russia's Bryansk region. It was the worst nuclear accident the world has ever seen.

The fallout, 400 times more radioactivity than was released at Hiroshima, drove a third of a million people from their homes and triggered an epidemic of thyroid cancer in children. Over the years, the economic losses—health and cleanup costs, compensation, lost productivity—have mounted into the hundreds of billions of dollars. As evidence of government bungling and secrecy emerged in its wake, Chernobyl (or Chornobyl, as it is now known in



independent Ukraine) even sped the breakup of the Soviet Union.

Today the fiercely radioactive remnants of reactor four continue to smolder beneath the so-called sarcophagus, a decaying concrete-and-steel crypt, hastily built after the accident, that now threatens to collapse. Work is about to get under way on a replacement: an arched structure, the size of a stadium, that will slide over the sarcophagus and seal it off. With its completion the destroyed reactor will be out of sight. But for the



**SILENT NURSERY** On the day of the disaster, children oblivious to the nuclear accident played in this kindergarten in Pripyat, the reactor's company town. They were evacuated the next day.

region's people it will never be out of mind, as a slow-motion catastrophe continues to unfold.

Early estimates that tens or hundreds of thousands of people would die from Chernobyl have been discredited. But genetic damage done 20 years ago is slowly taking a toll. No one can

be sure of the ultimate impact, but an authoritative report estimated last year that the cancer fuse lit by Chernobyl will claim 4,000 lives. Alexei Okeanov of the International Sakharov Environmental University in Minsk, Belarus, who studies the health effects of the accident, calls it "a fire that can't be put out in our lifetimes."

Yet Chernobyl's most insidious legacy may be the psychological wounds borne by those who fled blighted homes, and by the several million who continue to live on contaminated land. "The

psychological effects have been devastating," says Mikhail Malko, a physicist in Minsk. "Many women feel they will give birth to unhealthy babies or babies with no future. Many people feel they will die from Chernobyl."

Olesya Shovkoshitnaya doesn't know whether to blame Chernobyl for her terrible headaches and the fact that, she says, "sometimes I forget everything." But she has fond memories of growing up in Pripyat, built in the 1970s for the Chernobyl plant's personnel. "It was fantastic. It was a warm town, lots of trees, roses," she says over a bowl of the cherry dumplings called *vareniki* in Kyiv, about 70 miles south of Chernobyl, where she now lives. "We had sport classes. I played handball, swam, played checkers. We had music. I was in choir. I enjoyed my childhood."

That life ended when Olesya was ten. At 1:23 a.m. that April morning, technicians botched

a routine safety test on reactor four. The graphite-core reactor, a Soviet design, had an inherent instability, and in seconds the nuclear chain reaction raced out of control. The reactor's cooling water flashed into steam, blasting apart the fuel rods. Western reactors are sealed inside heavy steel and concrete shells, but this one had little to contain the explosion. It blew off the roof, scattered the guts of the reactor around the building, and ignited a raging fire in what was left of the graphite core.

Olesya's mother, a technician at the plant, reported to work as usual that morning, several hours after the accident. Olesya went off to school. "It was hot that day, real summer," she recalls. At school, "people were gossiping. We were shut indoors. I couldn't understand why." After their lessons the children were told to go straight home and not to linger outside playing.

Olesya's mother returned in the afternoon and

## CHERNOBYL'S DEADLY FOOTPRINT

Windblown fallout like the plume shown below fell thick near the reactor, forcing the evacuation of more than a thousand square miles straddling the Ukraine-Belarus border (right). High-altitude winds swept radioactive smoke and ash across a wider area (map, lower right), which scientists traced from soil levels of cesium 137, a long-lived isotope.

### RADIATION RELEASE

After the initial explosion of the reactor, emergency workers tried to smother the fire with materials like sand and lead. But the next day, the material was ejected in a smaller blast that sent a plume of radioactive particles toward the town of Pripyat (below).

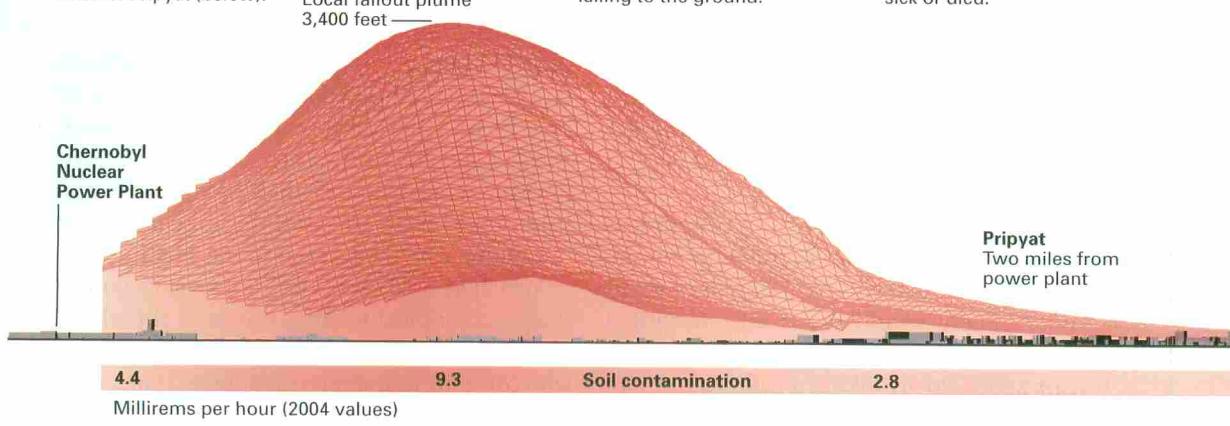
Local fallout plume  
3,400 feet —

### THREATENING CLOUD

Scientists combined recent measurements of soil contamination with wind data from the time of the accident to create a computer model of the local radiation plume. The red shows how the particles rose and spread before falling to the ground.

### NEAR MISS

Favorable winds kept this concentrated cloud of radioactive particles away from Pripyat, a city of 50,000 plant workers and their families, who had not yet been evacuated. If the city had suffered a direct hit, thousands could have fallen sick or died.





### GRIM LABORATORY

The abandoned city of Pripyat today is used to study urban fallout patterns. Why? Chernobyl resembled a giant dirty bomb, which spreads radiation with a conventional explosion.



PLUME DATA: RONALD CHESSER, TEXAS TECH UNIVERSITY, AND BRENDA RODGERS, WEST TEXAS A&M UNIVERSITY; ART BY DON FOLEY. LANDSAT IMAGE: UKRAINIAN LAND AND RESOURCE MANAGEMENT CENTER; CESIUM 137 DATA: INTERNATIONAL ATOMIC ENERGY AGENCY; NGM MAPS



**FIFTEEN MINUTES OF HELL** Workers wearing plastic suits and respirators for protection drill holes for support rods inside the shaky concrete sarcophagus, a structure hastily built after the explosion to isolate the radioactive rubble of reactor four. Their job is to keep the deteriorating enclosure standing until a planned replacement can be built. It's hazardous work: Radiation inside is so high that workers constantly monitor their personal exposure meters—and can risk shifts no longer than 15 minutes.



closed the windows. A city worker came by with iodine tablets, a prophylactic against radioactive iodine 131. Mom also gave Olesya a shot of vodka, widely believed in Soviet lands to protect against radiation. Her father, an engineer, returned that day from Moscow, where he had passed a doctoral exam. His thesis, ironically, was on the odds of a catastrophe at a nuclear power station. On his way home, he told Olesya later, he saw children splashing in puddles where the road had been hosed down. He pleaded with them to get indoors. They were drenching themselves with radiation.

In a radio broadcast the next morning, officials announced that there had been an accident and the town would be evacuated. That day 1,100 buses from across Ukraine lined up in Pripyat. By 5 p.m. the city was empty.

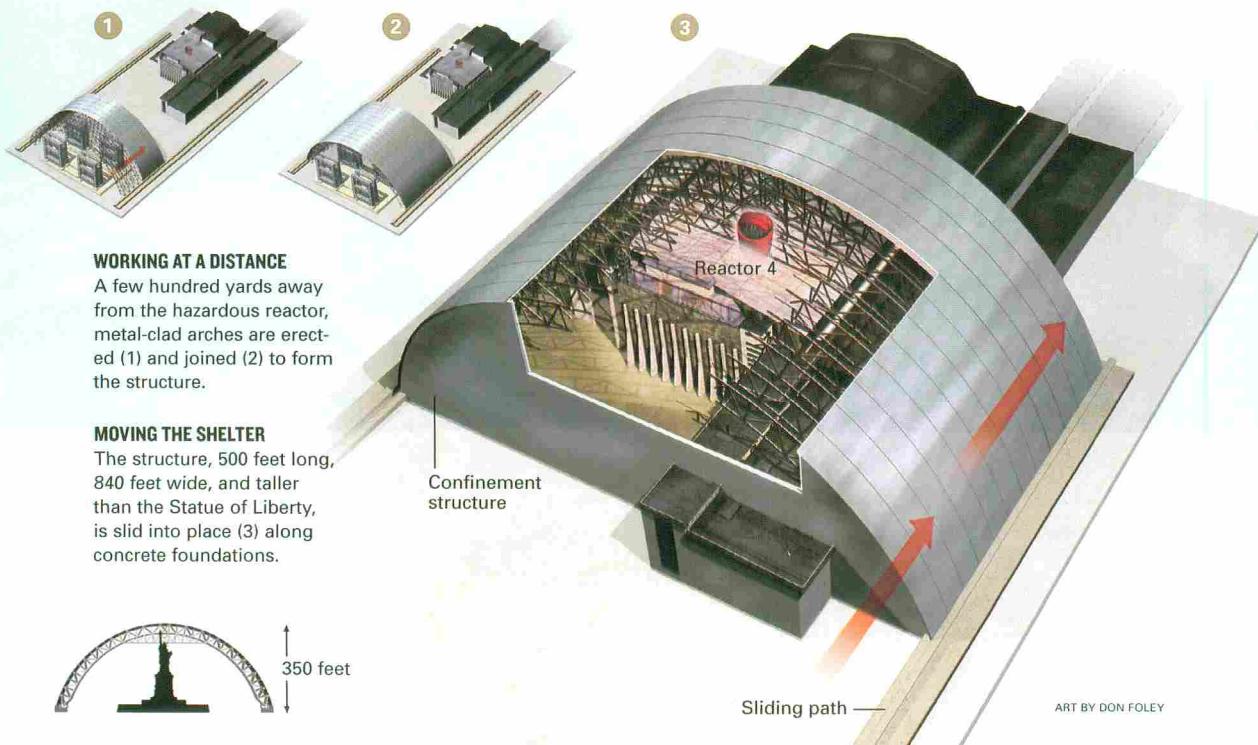
**Nineteen years later**, in 2005, a shivering crowd attends a midnight vigil in Slavutych, a city built

in the late 1980s as a replacement for Pripyat. Thirty miles away, it housed workers who tended the remaining three Chernobyl reactors until they were shut down, the last of them in 2000. Etched in black marble in the central square are the names and faces of the disaster's first victims. Two plant workers, Valery Khodemchuk and Vladimir Shishenok, died from the blast and fire. The others, 22 plant workers and six firefighters, were exposed to colossal radiation doses and succumbed within months. As an Orthodox priest chants and a choir hymns *Gospodi, Gospodi, Gospodi*—my God, my God, my God—family members solemnly set wreaths and candles under the engravings of their loved ones.

During the days after the explosion thousands of other workers, called liquidators, were rushed to Chernobyl to tame the radioactive inferno. Coal miners dug underneath the seething core

## ENTOMBING THE REACTOR

A new Chernobyl disaster could result if the fragile old sarcophagus collapses. Already it leaks rain and melted snow, which further weaken the structure. But starting as early as this year, engineers will begin work on a movable hangar-like structure, expected to cost 800 million dollars, that will safely isolate the ruin until a permanent solution can be found.





to allow liquid nitrogen to be pumped in and cool the nuclear fuel. Helicopter pilots dumped 5,000 tons of lead, sand, clay, and other material in an effort to douse the flames. Soldiers made timed dashes onto the roof to shovel smoking graphite blocks blown out of the reactor back into the core. Referred to, sardonically, as "biro-bots," many of the 3,400 surreally brave men who took part in this operation absorbed a lifetime radiation dose in seconds.

On May 6 the fires in the mangled reactor were finally extinguished, and an army of liquidators went to work building the sarcophagus and consolidating radioactive waste at several hundred dumps near Chernobyl. In those early days doctors monitoring the liquidators watched white blood cell counts drop and feared for their health. Most recovered.

But now a new wave of ailments may be striking the 240,000 men and women who worked on the front lines of the disaster. Cataracts, a

**LOOMING THREAT** Beneath the buttressed western wall of the sarcophagus—one of the shakiest parts of the reactor enclosure—a worker ducks into a lead-lined booth during a moment of downtime to minimize radiation exposure.

hallmark affliction of atom-bomb survivors in Japan, are on the rise. More worrisome, a study of Russian liquidators blamed the accident for 230 "excess" deaths in the 1990s—from heart disease as well as leukemia and other cancers.

The connection between Chernobyl and heart disease is controversial. Blasts of radiation can damage blood vessels, but some scientists believe the elevated rate of heart disease among the liquidators is more likely the result of heavy drinking and smoking, stress, and a poor diet. The cancer spike among the liquidators, however, was long expected, and the smattering of cases so far could be just the beginning. Jacob Kenigsberg, the chairman of the National Commission of

# **"The shelter was and is risky. It's a threat to people working here, to the residents, and to the environment."**

Radiation Protection of Belarus, notes that it took 20 to 25 years for some radiation-induced cancers to appear in the atom-bomb survivors. "We can say that we're on the beginning of the road."

**The millions of ordinary people** who had the bad luck to live downwind of Chernobyl are also at risk. The initial explosion rained radioactive material to the west of the reactor, sparing Pripyat a direct hit while killing a swath of pines that became known as the Red Forest for the eerie red needles of the dead trees. "The winds were very, very fortunate," says Ronald Chesser, an ecologist at Texas Tech University who is studying the plume as a model of what might happen if a radioactive dirty bomb exploded in an American city.

Then, as the reactor burned out of control, winds swept the cloud north. Seventy percent of the radioactivity drifted into Belarus, contaminating nearly a quarter of the country. Yet the Soviet government left people there in the dark. While children in Pripyat were taking iodine pills hours after the explosion, authorities in Belarus did not begin distributing pills for a week or more. All that time children were drinking milk laced with radioactive iodine 131 from cows that had grazed on contaminated grass. The short-lived, powerful isotope made its way to the thyroid gland, which has an affinity for iodine.

Starting in 1990, Alexei Okeanov and others observed the consequences: a sharp rise in childhood thyroid cancer. "It was absolutely obvious it was due to Chernobyl, but it was very hard to prove," Okeanov says. Before Chernobyl, Belarus had two or three cases a year in children under the age of 15. In 1995 there were 90 cases. To date about 4,000 children and teenagers in Belarus, Russia, and Ukraine have been diagnosed with the cancer, the largest fraction of them from Homyel, a heavily contaminated region of Belarus just north of Chernobyl. Although thyroid cancer has one of the highest cure rates of any

malignancy, at least nine children died when their tumors spread, and survivors must spend a lifetime on medication.

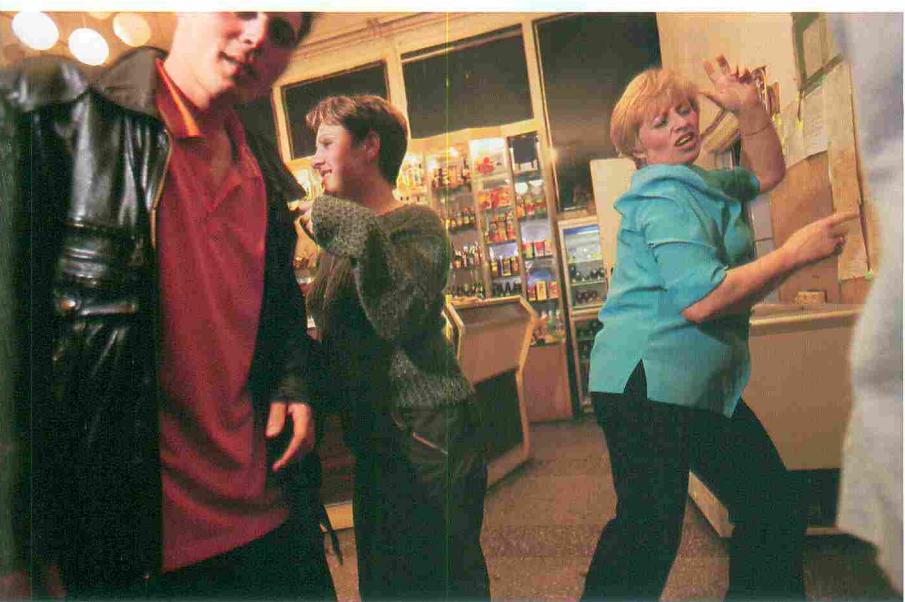
Now that a generation has passed since the accident, thyroid cancer is once again rare in children. But in adults the incidence may be rising. Okeanov says Belarus's national cancer registry also shows a rise in colon and bladder cancer in Homyel, although some experts think better surveillance after the accident may explain at least some of the cancer increases.

A report last year from the Chernobyl Forum, a group of experts convened by the International Atomic Energy Agency, the World Health Organization, and other United Nations agencies estimated that among the millions exposed to Chernobyl's radioactive cloud, nearly 4,000 will ultimately die from leukemia and other radiation-induced cancers. It's a measure of the health fears immediately after the accident that this number comes as a relief.

The impact of Chernobyl does not end with cancer deaths. In the early days "we never anticipated the psychological toll on the survivors," says Mikhail Balonov, the Chernobyl Forum's scientific secretary. Believing they are doomed, some live in fear, while others pursue a devil-may-care lifestyle: eating mushrooms and berries from contaminated soil, abusing alcohol, or engaging in unprotected promiscuous sex.

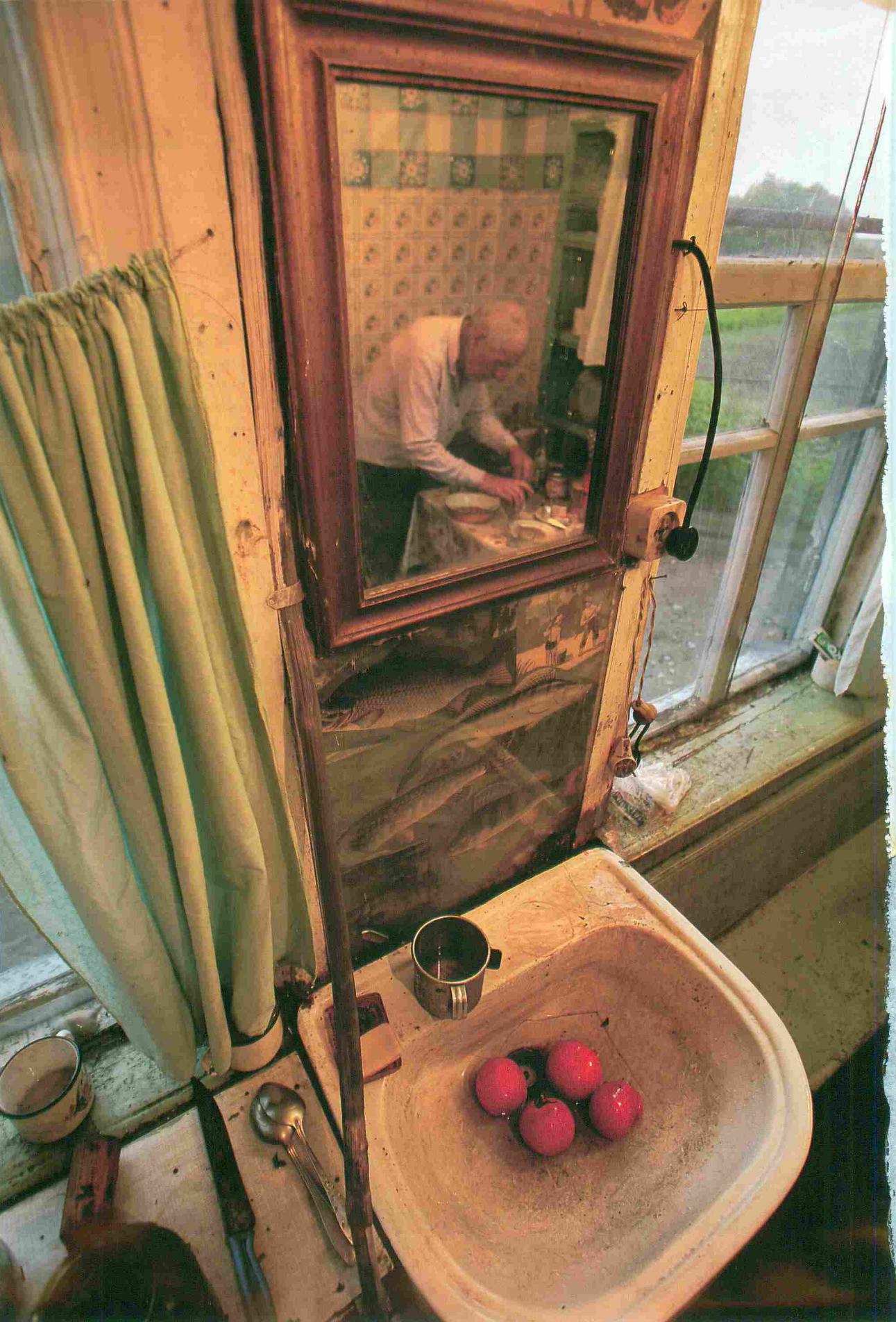
Adding to the suffering is the displacement of hundreds of thousands of people, who were either evacuated from the most heavily contaminated regions or fled on their own. Olesya Shovkoshitnaya, evacuated from Pripyat at ten, says life as a "Chernobyl child" hasn't been easy. "I was so depressed afterward," she says. Her family stayed with relatives in eastern Russia for three months before being allotted a spacious apartment in Kyiv and enough cash to buy furniture.

Not surprisingly, their new neighbors resented the torrent of evacuees and the preferential treatment they received as official Chernobyl



**LOST WORLD** Life continues, uneasily, in the evacuation zone, flaring into a dance at a bar in the village of Chernobyl, where cleanup workers, scientists, and others on official business try to forget radiation for a night. But for an exiled resident of Pripyat (below), the stillness of a city boulevard stirs memories of her former life. In her hand is an old photo of the same street years earlier.





victims. "Some people really hated us," says Olesya. "They said, we are living in a contaminated zone as well. But they got no compensation." Even today Ukraine and Belarus spend some 5 percent of their national budgets on Chernobyl, mostly on cash, holiday trips, and other benefits for the millions of registered victims.

Those who stayed behind still inhabit a contaminated landscape. The two most pervasive radionuclides from Chernobyl, cesium 137 and strontium 90, will remain in the environment for decades. Schools and other public buildings in southern Belarus are regularly washed down. Fields are fertilized with potassium to limit the uptake of cesium into crops and lime to block strontium. Lengthy regulations spell out what should be grown in which soils (only potatoes in peat but a wider range of crops in clayey soils, which lock up radionuclides). The most contaminated land—several hundred thousand acres—still lies fallow, though the government of Belarus is taking steps to reclaim it.

**At a gate and guardhouse** 18 miles from the reactor, cultivation stops entirely. Fields give way to forest, dark, fragrant, and still unsettling on my fourth visit in ten years to the exclusion zone, a tightly controlled area almost twice the size of Luxembourg. The first time, in 1995, a dog pranced up as I waited for guards to inspect my papers. I felt a stab of pity: A huge tumor had deformed its jaw. As the dog got closer, though, I realized that my

anxiety about radioactivity had played a trick on me. The tumor was really a chunk of asphalt the dog was carrying in its mouth.

At the center of this accidental wilderness stands the sarcophagus, naval gray and malignant, and rustier than I remember. Built in six months, it was planned to last at most 20 years. One beam supporting the corrugated steel roof rests precariously on a severely damaged wall of the reactor hall, while the western side of the structure has bulged several inches. None of the joints were welded: Workers couldn't get close enough. Any of a number of freak scenarios—an earthquake, a tornado, a heavy snow—could bring it crashing down. Or the sarcophagus, also known as the shelter, could simply collapse on its own.

This fragile shelter holds an estimated 200 tons of nuclear fuel, some of it in the reactor core and some in an unearthly radioactive "lava"—fuel rods, concrete, and metal that melted together in the inferno and oozed into the warren of rooms beneath the reactor. There's enough enriched uranium and plutonium in the hulk for dozens of atomic bombs.

But the immediate threat is water. A few years ago workers measured more than a thousand square yards of cracks and holes in the sarcophagus, which were allowing rain and melted snow to pool in its bowels. The water further weakens the structure, and it seeps out into the environment, carrying radioactive contaminants. Water can also act as a nuclear moderator: a substance

**SWEET HOME** Ivan Martynenko (left) and his wife have come home to their village near Chernobyl. Roughly 350,000 people were forced to evacuate after the explosion. Now, disaster be damned, some 400 elderly people have returned. At first Ukrainian officials discouraged them. But when it became clear they meant to die at home, medical care (right) and other services were provided.





**CANDLES FOR THE DEAD** In a midnight gathering at the Monument to the Firemen, shift workers in Chernobyl honor those killed by the explosion. Two plant workers died in the blast; another 28 workers and firemen soon succumbed to radiation poisoning. Some 4,000 more people may eventually die of cancer. That number is lower than originally feared, but the social upheaval caused by mass relocation and fear of disease has created its own deadly health risks—depression and alcoholism among them.



# **"The psychological effects have been devastating. Many women feel they will give birth to unhealthy babies or babies with no future."**

that aids a chain reaction. Though the risk is deemed minute, a renewed chain reaction could trigger another steam explosion, blowing open the sarcophagus, scattering chunks of fuel, and releasing tons of fine radioactive dust.

On the night of June 26, 1990, after two weeks of heavy rain, detectors in one lava-filled room registered a sharp rise in neutrons, a sign of an impending chain reaction. Four days later, a physicist from a technical center in the old town of Chernobyl, ten miles away, dashed in to pour neutron-quenching gadolinium nitrate on the lava. The neutrons subsided.

Similar selflessness over the years has taken a heavy toll. The technical center, run by the Ukrainian Academy of Sciences, is the home of the "stalkers," scientists who work in the sarcophagus, exposing themselves to high levels of radiation as they monitor the state of the reactor fuel. Near the entrance is a list of several dozen who have died, many in their 40s and 50s, many from cancer or heart disease. I recognize one, Edward Denisenko, whom I'd met a decade ago, and recall him musing about who in their right mind would want to work at Chernobyl. "If people from the West and Russia don't want to come here," he had asked, "who will? God? The devil?"

In the past two years 90 percent of the gaps have been plugged, and a new sprinkler system dispenses gadolinium in the central hall. Most rainwater is pumped out, though some is allowed to linger to suppress dust. But Yuliya Marusych, who works in the nuclear plant's information department, says flatly, "The shelter was and is risky. It's a threat to people working here, to the residents, and to the environment."

Marusych, a chain-smoker whose brown hair is dyed ginger red, takes me inside for a look. Radiation dosimeters in our pockets, masks on our faces, we pass through a series of corridors to a checkpoint where a plant engineer shows me a diagram marked with radioactivity levels. The hottest recorded spot in the sarcophagus,

at 3,400 roentgens an hour, would deliver a lethal dose in a few minutes.

The deepest that Marusych can take me is the control room of reactor four (pages 32-3). It was here 20 years ago that night-shift operators watched in horror as the chain reaction spiraled out of control. Though the ceiling tiles are gone, exposing pipes and a mass of wires and cables, the instrument boards are intact. Five years ago, the room was doused with a pink decontamination solution. Where the residue clings to the walls it looks disturbingly like blood.

This haunting monument will ultimately be dismantled. After ten years of complicated negotiations, work is expected to start later this year on a new sarcophagus, developed by the Battelle Memorial Institute, Bechtel Group, Électricité de France, and the Chernobyl Nuclear Power Plant. Longer than a football field, taller than the Statue of Liberty, costing perhaps 800 million dollars, the so-called New Safe Confinement (NSC) is designed as a giant steel arch. For safety, it will be built at a distance from the sarcophagus and then slid into place. It will be the largest moveable structure ever built.

Construction is expected to take four to five years, and it won't be easy. After the accident, reactor fuel and radioactive waste were buried haphazardly around the sarcophagus, where workers will have to excavate to build the NSC's foundation. "Who knows what we'll find down there," says project engineer Fabien Sauvadet.

Once the NSC is in place, remotely operated cranes will allow engineers to painstakingly dismantle the old sarcophagus. But the shattered reactor and its tons of nuclear fuel, far too radioactive to handle even from a distance, will stay where it is for now.

**Away from ground zero**, wildlife has reclaimed the hundreds of square miles of abandoned land in the exclusion zone. More than a hundred wolves prowl the forest, endangered black storks and



### SICK WITH FEAR

Mentally disabled children (left) live in an institution in Belarus. Children born in the region are said to have a higher rate of birth defects and retardation because of Chernobyl, a belief not supported by a recent UN study. The study did find that the accident left a damaging legacy of fear among new mothers like Yelena Banchuk, 32 (below), exposed to fallout as a girl in Belarus.



**LIFE ENDURES** A tree grows in a Pripyat school abandoned two decades ago. Nature is slowly dismantling the city even as the Chernobyl evacuation zone thrives with plant and animal life. It's a stark but perhaps hopeful contrast to the fear-plagued lives of the people who survived the world's worst nuclear accident.

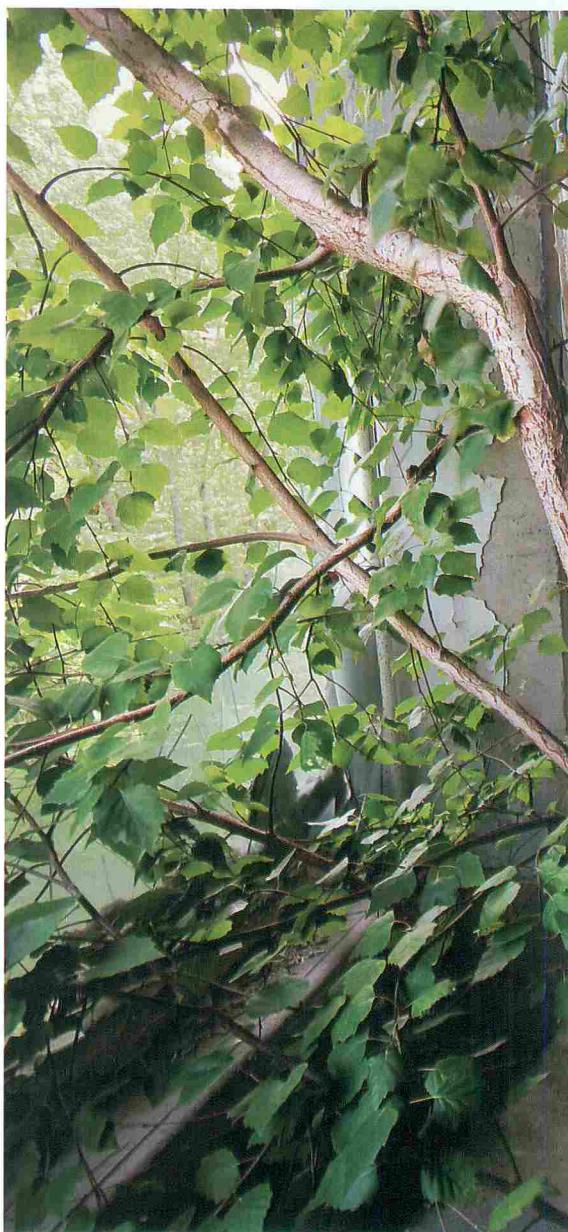
white-tailed eagles nest in the marshes, and several dozen Przewalski's horses, a rare breed that went extinct in the wild decades ago, are thriving after being released here in 1998. Pines are even reclaiming the Red Forest, though patches of lingering radioactivity have left them stunted and deformed, with unnaturally short or long needles and clusters of buds where normally there would be just one. This radiation-warped forest is an anomaly. On the whole, ecologists marvel at how resilient nature has proved to be in the face of radiological adversity.

So have people. The exclusion zone was vacated after the Chernobyl explosion. But within months some residents were drifting back, in defiance of Ukrainian authorities. Today 400 mostly elderly people live in the decaying wooden villages that dot the zone, and the government has mellowed enough to provide electricity and bus service to nearby towns for shopping.

In the village of Opachichi, population 19, a rooster and hens strut next to the weathered cottage of Anna and Vasily Yevtushenko. She has just turned 70; he's 66. Vasily, dressed in gray trousers and a plaid lumberjack-style shirt, does most of the talking. We stand in a corner under a painted wooden icon of the Virgin Mary and glance through a photo album. "This is our daughter," Vasily says, and then, pointing to the opposite leaf, "this is our cow."

A week after the accident, Anna and Vasily were evacuated to a village a hundred miles away. "We didn't enjoy the place; the climate was wrong," Vasily says. Two years later they reclaimed their cottage in Opachichi. "We have everything we need," Vasily says, including home-brewed vodka.

Vasily shows me the results of blood tests he and Anna took in 2004. Everything looks normal. "If there was something, we would have already died," he says. Anna chimes in. "People ask me why I am not afraid," she says, smiling a mouthful of gold fillings. "I say this is my own house. I get up in the morning, I have chores to do. That's all."



If Opachichi is a living relic of a nuclear nightmare, Pripyat is more like the clock found in the rubble of Hiroshima, its lifeless hands forever stuck at the moment of detonation. After passing through a checkpoint with a red-and-white-striped gate to deter looters and the merely curious, I meander through what was once a tidy town. Rows of white and pastel apartment blocks stand vacant, their windows dark and their lower stories overgrown. Near a kindergarten and a sports complex with a swimming pool, now



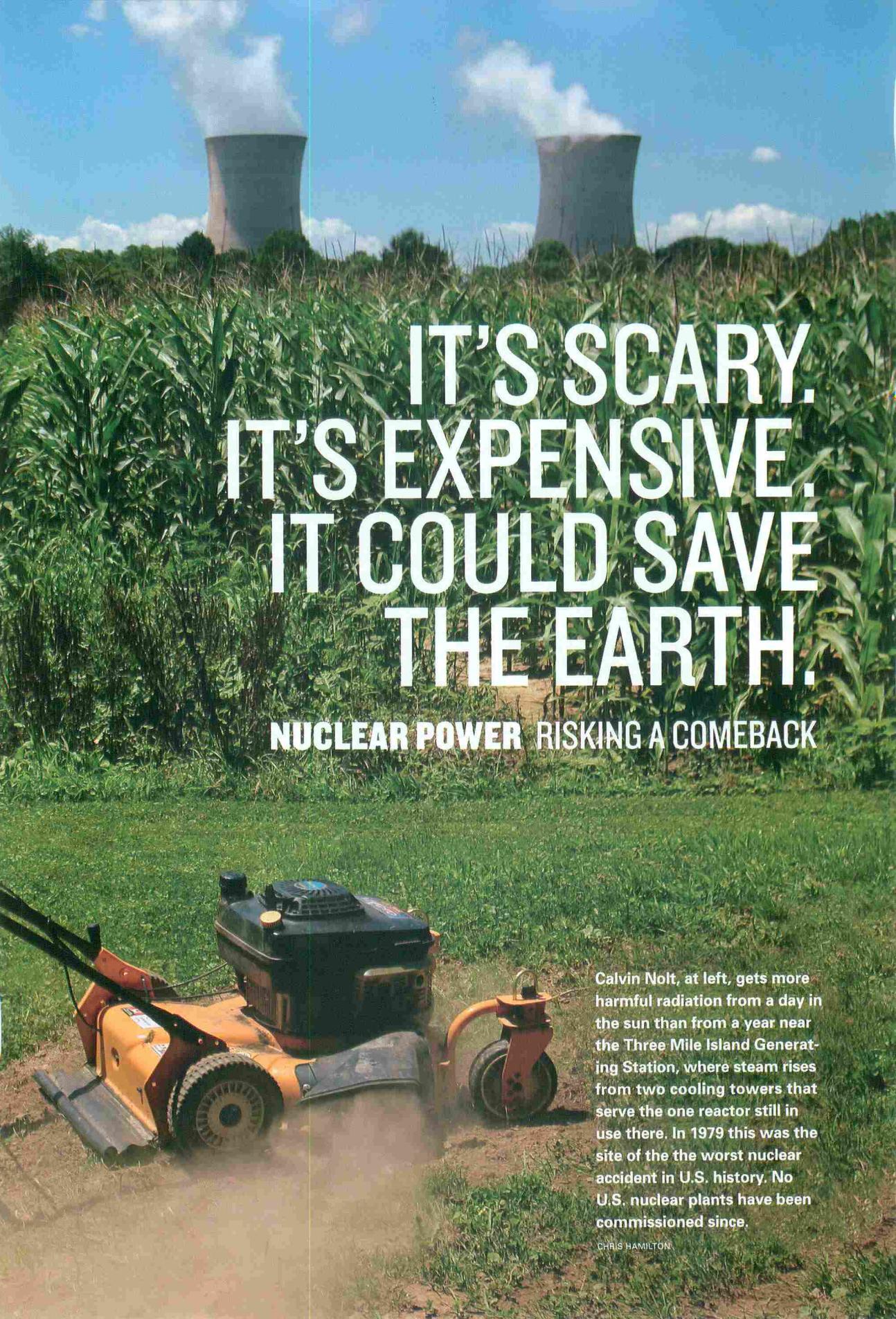
empty and debris-strewn, that Olesya recalled from her childhood stands a rusted Ferris wheel, its yellow cars groaning in the wind. It had been built just in time for May Day 1986.

The Energetik cultural palace, a grand hall where dances and concerts were held, presides over a desolate square. Poplars are pushing up through the pavement. Moss in the cracks sets a Geiger counter chattering. Although rains have cleansed some surfaces, a skein of hot spots will keep this soulless shell radioactive for a lifetime.

"What's so spooky about standing in the heart of Pripyat is not the destruction to the concrete and steel," says Ron Chesser. "It's the lack of people, the silence." Over time, the radionuclides will run through their half-lives, the survivors' fears will fade. But this loneliness knows no cure. □

► **After the explosion** Revisit Chernobyl with photographer Gerd Ludwig in a multimedia show and share your thoughts on whether we are prepared for another nuclear disaster at [ngm.com/0604](http://ngm.com/0604).





IT'S SCARY.  
IT'S EXPENSIVE.  
IT COULD SAVE  
THE EARTH.

**NUCLEAR POWER RISKING A COMEBACK**



Calvin Nolt, at left, gets more harmful radiation from a day in the sun than from a year near the Three Mile Island Generating Station, where steam rises from two cooling towers that serve the one reactor still in use there. In 1979 this was the site of the worst nuclear accident in U.S. history. No U.S. nuclear plants have been commissioned since.

CHRIS HAMILTON

# N

ukes again? Maybe. The United States operates 103 nuclear power reactors—that's a quarter of the world's total—even if the most famous U.S. nuke isn't even real. That would be the Springfield plant, where doofus TV cartoon hero Homer Simpson is a safety

inspector. "They're cash cows," says James Tulenko, a nuclear fuel specialist, University of Florida professor, and immediate past president of the American Nuclear Society. With hefty construction bills paid off at many plants, "you just deal with the operating costs. All those plants run flat out day and night," he says. And they deliver electricity more cheaply than gas or coal plants.

That's not the whole story, of course. The hopes of a burgeoning nuclear industry imploded 27 years ago after the partial meltdown at one of the Three Mile Island reactors in Pennsylvania, followed by the horror of Chernobyl seven years after that. Plus, decisions made by utility regulators in the 1970s and '80s left companies barely able to pay off billion-dollar nuclear construction bills. Now the U.S. produces half its electricity with cheaper coal-burning plants. The trouble with that is the two billion tons of climate-warming carbon dioxide spewing skyward every year. Industrializing nations, such as India and China, hungry for every megawatt of power they can produce, are also building new coal plants at a rapid clip.

**Still, for nearly a decade,** with no new plants, nukes' 20 percent share of U.S. electricity production has held steady, keeping pace as overall electricity output has risen 15 percent. In the 1970s and 80s unscheduled shutdowns for repairs or other problems limited U.S. plants to less than 65 percent of their potential output. Today, with experience and improved operating practices, output exceeds 90 percent.

So is it time to embrace the atom again?

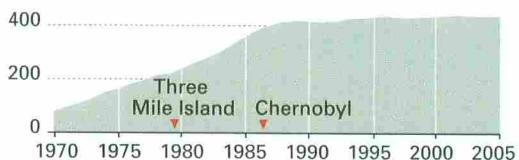
There's a "nuclear renaissance" buzz emitting from engineers who design and operate reactors, think-tank academics who worry about long-range energy and environmental strategies, utility company executives, top members of the Bush Administration, and members of Congress. Proponents say atomic energy is a proven technology for a 21st-century civilization desperate to swear off fossil fuels and not to go broke doing it. Nuclear fission emits none of the greenhouse gases that are warming the climate. The Nuclear Energy Institute estimates that without nuclear power playing its current role in the generation of electricity, the U.S. would spew 29 percent—190 million metric tons—more carbon than it does now.

Scratch a nuclear engineer these days, and you'll likely find, under the buttoned-down exterior, a raving green activist. Even among the ranks of environmentalists who a decade ago

## MISSILES TO MEGAWATTS

Technicians inspect a nuclear fuel assembly made of rods holding uranium pellets. In the U.S. half the uranium used in such assemblies comes from decommissioned Soviet weapons. The cost of new plants and memories of accidents have curbed demand for new reactors.

### Nuclear power reactors worldwide





could barely tolerate the mention of nukes, the possibility is getting an occasional thumbs-up. Climate change, for many, trumps any fear of nuclear energy. Its overwhelming advantage is that it's atmospherically clean, writes Stewart Brand, founder of the 1970s *Whole Earth Catalog*.

Yet, Brand points out: "Nuclear certainly has problems—accidents, waste storage, high construction costs, and the possible use of nuclear fuel for weapons." Most experts agree that such problems are no small drawback to forging ahead with new nukes. So despite shifting attitudes, atomic allergy has eased only slightly if at all among the bulk of prominent environmental leaders. Analysts also point to other problems, such as unresolved waste questions and limited public input on the whole issue of nuclear power. The current strategy, predicts Gus Speth, co-founder of the Natural Resources Defense Council and Dean of Forestry and Environmental Studies at Yale University, will just replay the battles of the 1970s.

**Other nations** are watching the U.S., but not waiting. France gets 78 percent of its electricity from nuclear power and is considering replacing its older plants with new ones. And the industry is expected to burgeon in Asia in the next quarter century. China, on top of its headlong rush to build coal-burning plants, also has ambitious plans for new reactors: It can get 6,600 megawatts of power now from nine reactors. It's aiming for 40,000 megawatts.

India, a nation of 1.1 billion people—and one beset both by crushing poverty and a tumultuously expanding economy—has 15 nuclear power reactors already at work. Eight more are under construction, more than in any other nation. The Department of Atomic Energy lauds the greenhouse benefits of nukes, but the main impetus is sheer gigawatt lust. "Our energy policy is simple," says Baldev Raj, director of the Indira Gandhi Centre for Atomic Research near the Bay of Bengal city of Chennai. "If you have a way to make electricity, then we say, make as much as you can."

That would include building reactors such as those at Kaiga Generating Station in a clearing in the jungled Western Ghats mountains about 20 miles inland from southwest India's seacoast. Coming upon the two 220-megawatt, pressurized heavy-water reactors is like stumbling into a

thumping big factory in the middle of Yellowstone National Park. The region gets more than 15 feet of rain yearly, and its forest is home to increasingly threatened species. "Tigers? Yes, they are near. Panthers and king cobra too," says Anwar Siddiqui, senior manager for the Nuclear Power Corporation of India.

A country with reactors in such places must really like them. Amid a jumble of construction cranes and heavy concrete walls, two similar reactors are rising next to the first two, and another pair, more than twice as powerful, will likely join them in coming years.

Back near the Indira Gandhi center a 500-megawatt breeder reactor is under construction and set to start up in 2010. Four more are to follow by 2020. They are very efficient at manufacturing plutonium fuel from their original uranium fuel load, which greatly increases the amount of energy they produce. But critics worry that the plutonium could possibly get in the wrong hands.

In part because of proliferation concerns, the U.S. has sworn off such breeder reactors for the time being. But outside powers have little leverage over India's nukes. With few exceptions they are entirely homegrown. India gave itself little choice about going it alone. In 1974, it set off an underground nuclear explosion using plutonium surreptitiously diverted from a test reactor that Canada helped it build in the 1950s.

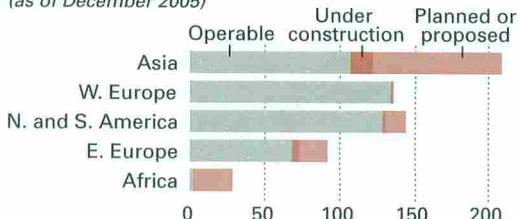
India became a nuclear pariah. Other countries suspended technical assistance, and Canadian engineers walked off a job in Rajasthan.

## POWER HUNGRY

The reactor under construction will make electricity for three million people in Chennai, India. Asia's expanding populations and industries are leading nations to seek energy from nuclear power along with coal and natural gas.

### Nuclear power reactors by region

(as of December 2005)



The Indians finished the plant themselves.

They are now enthusiastic masters of all things nuclear. The uranium fuel in Kaiga's reactors comes from mines west of Calcutta; workshops in the south provide the plant with gleaming, 65-foot-high, 110-ton steam generators that drive electric dynamos. Control systems, zircaloy fuel tubes, and 22-ton reactor components arrive from Hyderabad.

"We can't go back, we can only go forward," said Swapnesh Malhotra, a spokesman for India's atomic energy department. "Life depends on energy, and I ask, where do we get it? We will get it somewhere."

**Meanwhile**, the U.S. tiptoes ahead. In the nation that gave it birth, nuclear power may get its second wind in a mowed field outside the quiet town of Port Gibson, Mississippi. The field, close by a reactor that has been operating since 1985, is part of the Grand Gulf Nuclear Station, owned by a subsidiary of Entergy Corporation, the fourth largest electricity producer in the U.S.

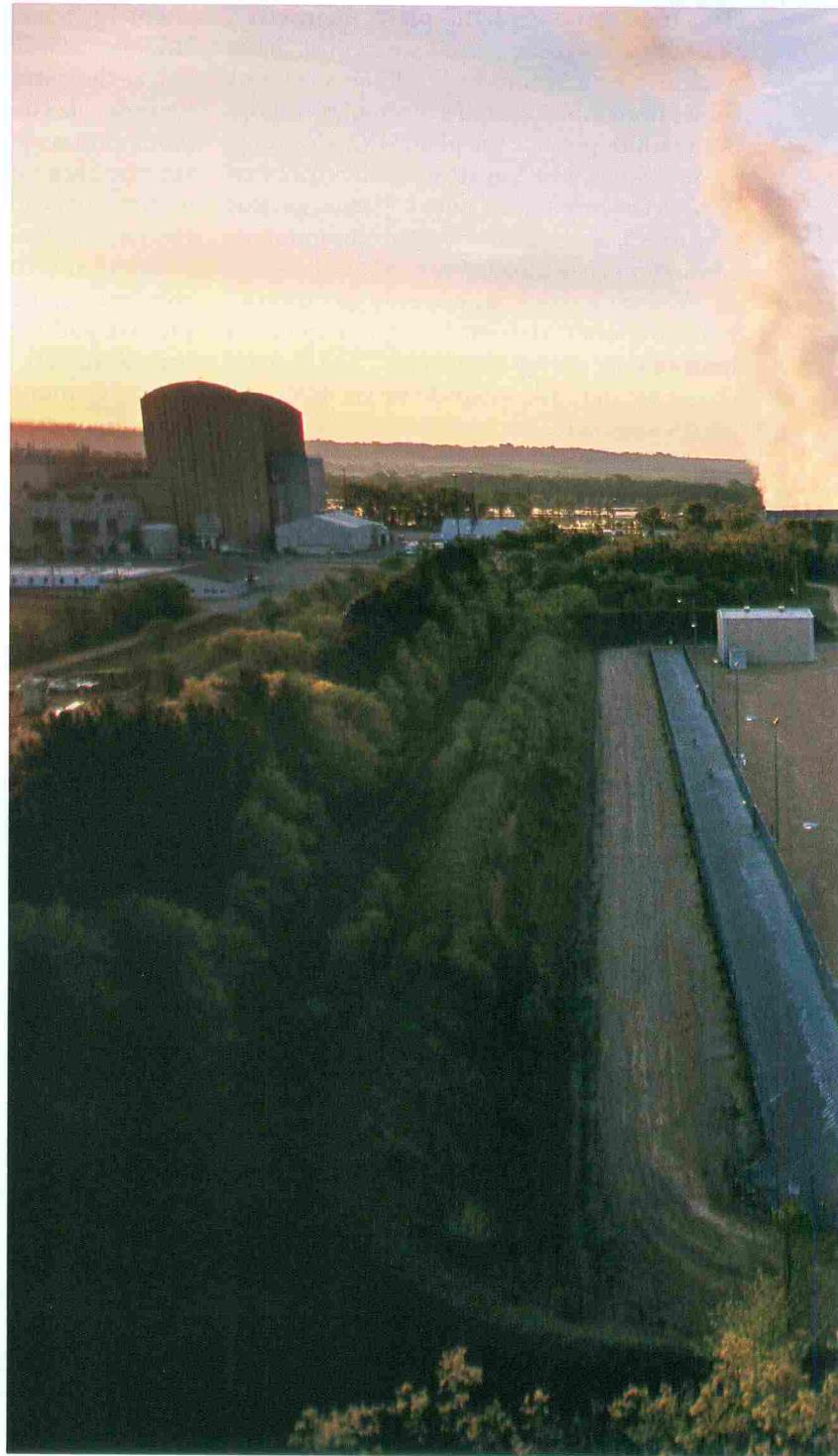
Entergy hopes to fire up a new nuke here by 2015. First, General Electric (GE) and Westinghouse, the nation's only reactor makers, must finish detailed designs for machines they've been promoting as more foolproof and easier to operate than those they built decades ago. Formal license applications could be filed by 2008. Federal regulators might chew on them until 2010.

To expedite the process, Entergy organized a consortium in 2004 of nine utility companies plus GE and Westinghouse. The consortium, named NuStart, hopes to test new Nuclear Regulatory Commission procedures that will grant a combined construction and operating license to avoid the interminable hearings of the 1960s and '70s.

Only then, if GE, Westinghouse, or both, get approval, will Entergy and other NuStart members decide on actual orders. Construction would take four to five years.

That's if there's money. Congress last year passed an energy bill that guarantees loans made by investors and includes a subsidy of up to six





## WHAT ABOUT THE WASTE?

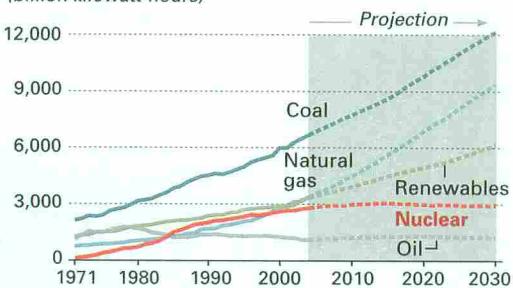
White steel casks hold spent fuel from Minnesota's Prairie Island nuclear reactors. Each of the nation's 103 power-generating reactors annually produces tons of radioactive debris that must be stored—and secured from terrorists. Future reactors may recycle spent fuel and reduce waste.



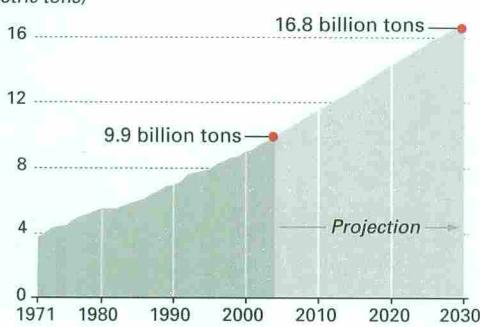
## MAKING THE CASE

Earth's electricity consumption is expected to double in the next 25 years. Natural gas and coal, the biggest CO<sub>2</sub> producer, will meet most of the demand. For nuclear power to replace them, nations would have to build thousands of expensive reactors. Even industry advocates like Adrian Heymer of the Nuclear Energy Institute concede that won't happen: "Meeting future energy needs will require many types of fuels. Nuclear needs to be part of the mix."

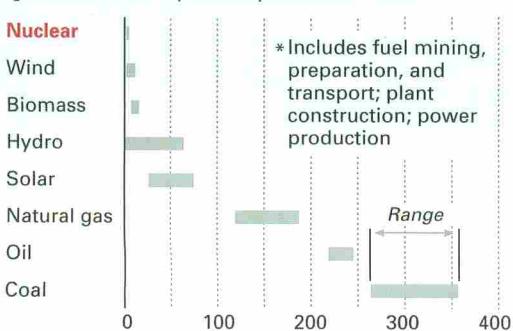
Electricity generation by fuel worldwide  
(billion kilowatt-hours)



CO<sub>2</sub> emissions from electricity production worldwide  
(metric tons)



Greenhouse gas emissions by fuel type\*  
(grams of carbon equivalent per kilowatt-hour)



billion dollars for running the first new plants. But the industry insists that it can't get private financing for construction of the plants without government loan guarantees. Environmentalists like Speth consider the nuclear industry mature enough to sink or swim without federal assistance—and with vigilant regulation.

Everyone in the business knows financial woes helped torpedo the first wave of atomic ambition four decades ago. Next to the vacant, waiting Grand Gulf field is an unfinished concrete silo that stares at the sky like an empty eye socket. It was to be the containment structure for a twin to the reactor there today. But just before Christmas 1979, staggered by construction costs, Entergy (then called Middle South Utilities) pulled the plug on the second silo.

Even so, the one reactor that was completed drained the company coffers. In 1984 it feared it wouldn't be able to make payroll. "We had the bankruptcy lawyers all lined up," says Randy Hutchinson, an Entergy senior vice president. American banks turned their backs. Only a high-interest loan from a consortium of European banks kept the company afloat.

In the long run, even nuclear advocates agree that the best hope for the future lies in new designs for reactors. In two or three decades the industry could see generation IV machines that run more efficiently at much higher temperatures, thus getting far more energy from their starting load of uranium. The intense nuclear reactions at such temperatures would leave waste that, compared to today's, is less toxic and lasts for a shorter period of time. Advanced reactors would have simpler safety features and require less sophisticated backup systems. They could cool themselves down in the event of an accident with little human intervention, making them less tempting targets for terrorists.

Last year's energy bill authorized 1.25 billion dollars for the Department of Energy's Idaho National Laboratory to build an experimental, high-temperature, helium-gas-cooled reactor specifically to learn how efficiently such a thing can produce both electricity and—no small

► **Future Power** Do the benefits of nuclear energy outweigh the risks? Vote in our poll. Then find out how energy efficient your house is in an interactive game at [ngm.com/0604](http://ngm.com/0604).

extra—hydrogen gas, which could be used as vehicle fuel.

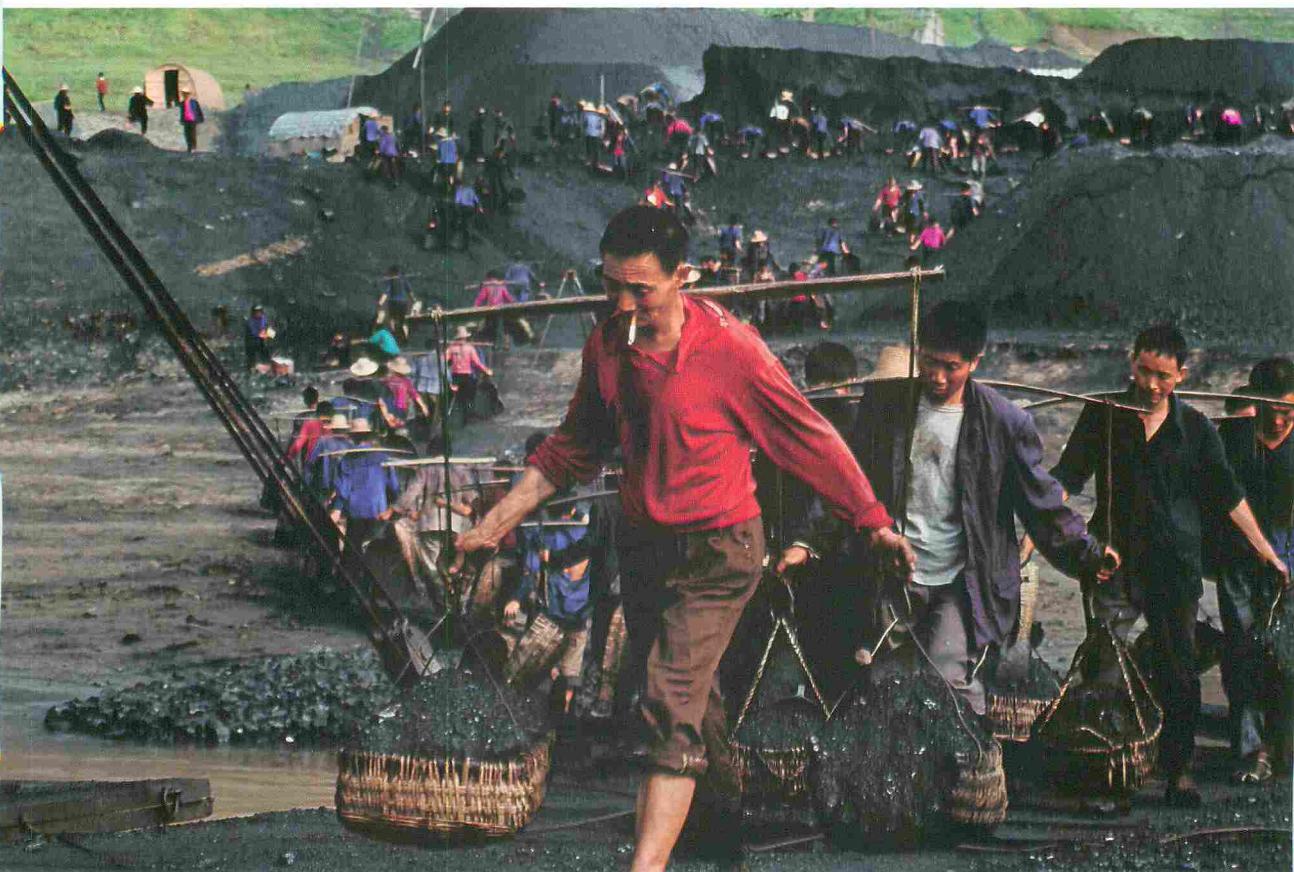
For now, however, the most ardent pro-nuke advocates can't argue with a worst-case scenario. A major release of radiation such as from Chernobyl in 1986; a terrorist attack that somehow penetrated elaborate security and steel-reinforced walls to purloin fuel or release a cloud of radiation; diversion of weapons-grade uranium or plutonium to rogue nations or criminal groups—all have visceral impact far beyond the pollution, coal-mine accidents, and climate-altering emissions of fossil fuel plants. In a speech at Grand Gulf, Gary Taylor, head of Entergy's nuclear division, stressed the hazard to both the public and the industry if a reactor should go seriously wrong. "We have 40 years

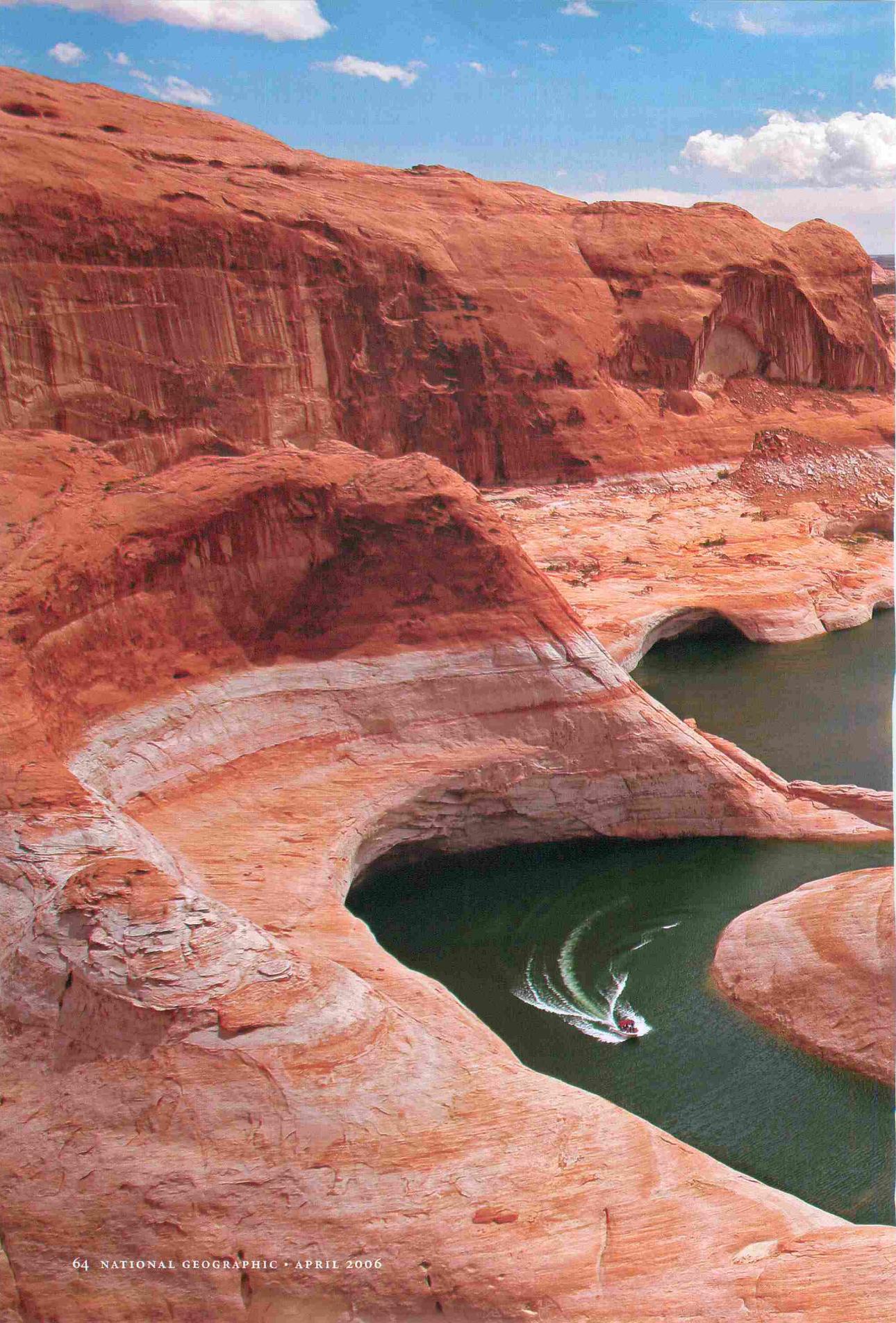
**Laborers carry the fuel that keeps China's economy booming: Coal provides 80 percent of China's electricity. Even with plans for dozens of new nuclear reactors, China, like much of the world, will rely on CO<sub>2</sub>-generating coal well into the future.**

in an industry that has proved itself to be safe—and I mean safe. Nukes haven't made news lately, but with just one major accident . . ." he snapped his fingers. "Everything we have worked for could die, just like that."

In the meantime, fields like the one at Grand Gulf lie untouched. Can a new nuclear era even get started? Nearby residents are eager to see action. National polls show a rising acceptance of nuclear energy, with some showing as high as 59 percent in favor. Port Gibson's mayor and board of aldermen endorse a new reactor for the boost its taxes would give local schools and other institutions.

Does anyone in town consider Grand Gulf's lone operating nuke a menace? Michael Herrin, pastor of Port Gibson's First Presbyterian Church, its tall spire topped by a golden hand pointing skyward, answers: "People from the plant speak at local meetings. We know the cloud of steam that comes from the cooling tower isn't radioactive. In this town, the dragon is unemployment. Entergy is the hero." □





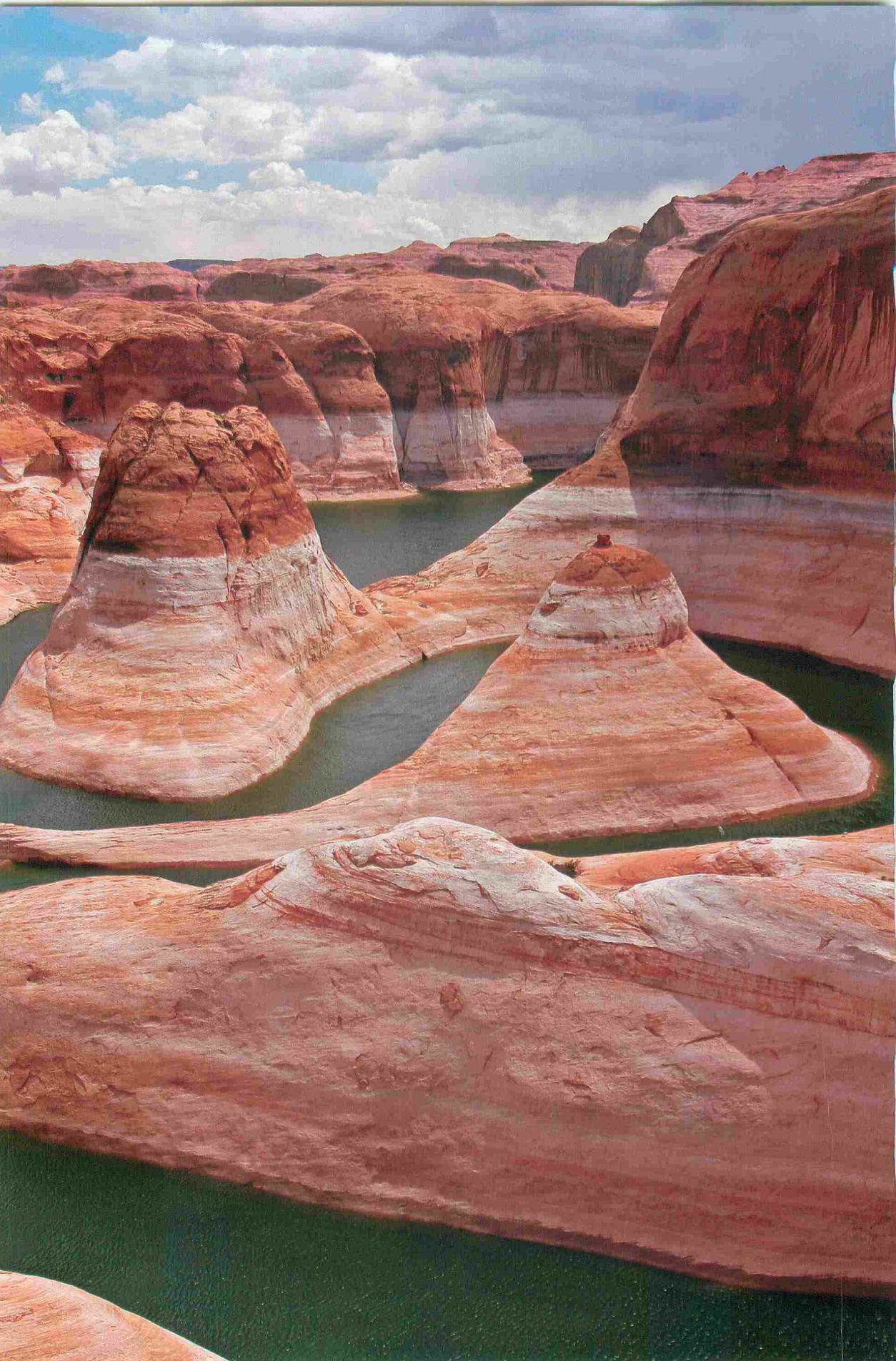


# A Dry Red Season

Drought drains Lake Powell—  
uncovering the glory  
of Glen Canyon.



*A speedboat traces the old curves of Utah's Reflection Canyon, a branch of Glen Canyon. Both were flooded by Lake Powell after the Colorado River was dammed in 1963. In recent years scant snowfall has caused the lake to drop more than 100 feet, exposing a white ring left by high water.*





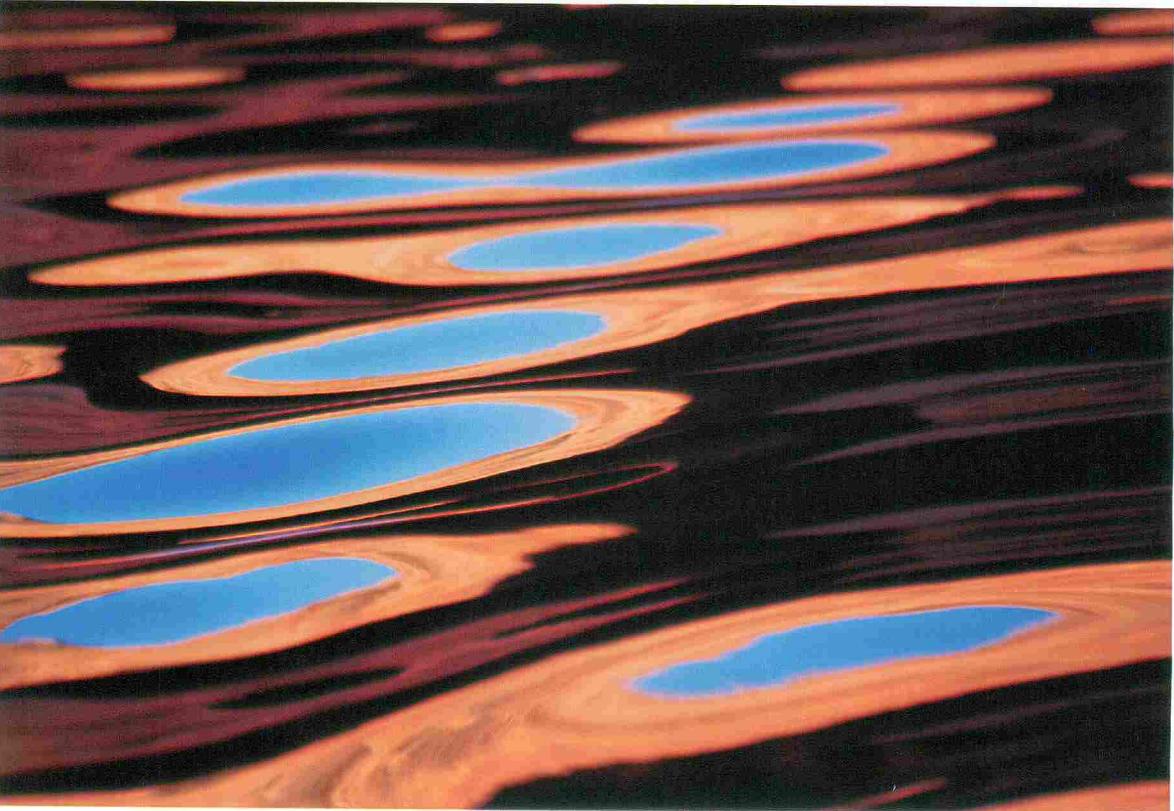
*The ghostly arms of cottonwoods emerge from Halls Creek Bay (left), and water again spills through*

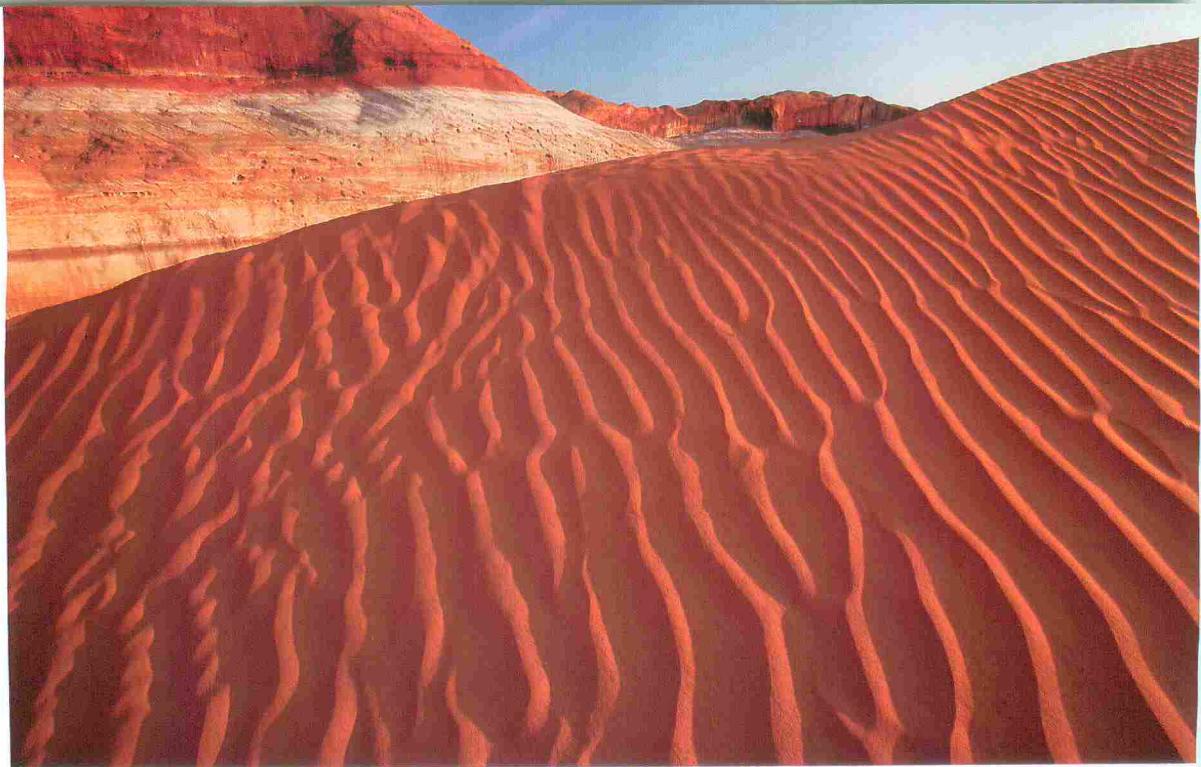


*Cathedral in the Desert, uncovered as Lake Powell hit its lowest point since 1969.*

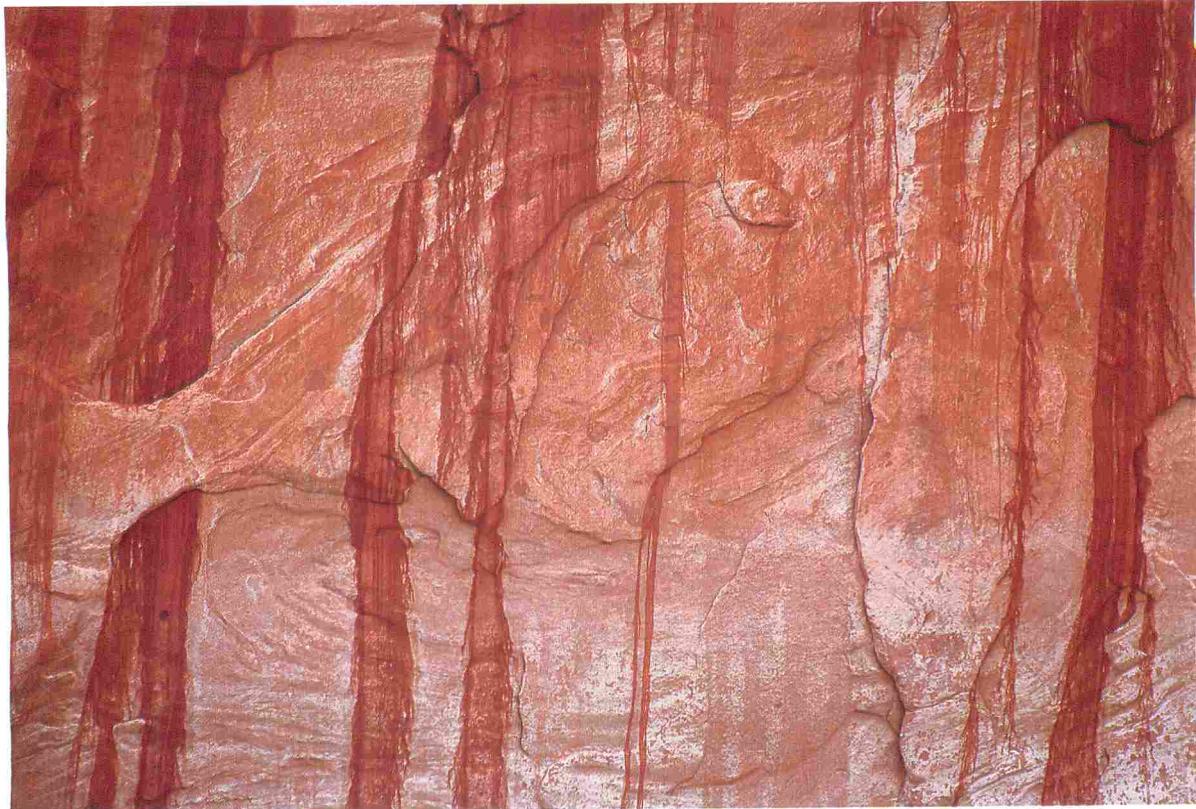


Desert varnishes streaked the sheer walls  
and soon began painting over the lake-  
bleached bathtub ring left by high water.





*The elements texture formations along the shrinking lake (clockwise from above): Receding water left a rippled sand dune near Clear Creek off the Escalante River. On Tapestry Wall at Warm Springs Canyon, iron and manganese from windblown dust created a patina called desert varnish. Reflections of red rock and azure sky pattern the flow in Willow Creek. And a triangular flake of weathered rock as wide as a billboard makes its mark on a canyon wall along Fiftymile Creek.*



BY DANIEL GLICK

PHOTOGRAPHS BY MICHAEL MELFORD

A year ago Lake Powell reached its lowest level since Jimi Hendrix played Woodstock and Neil Armstrong made his giant leap onto the moon. A sustained drought had sucked out two-thirds of its water, exposing 140 vertical feet of once drowned cliffs. The dry spell temporarily turned the great reservoir back into a red-rock

maze called Glen Canyon, stirring hopes that terrain whose grandeur rivals any on Earth may one day be revealed for good.

It also resurrected Tom McCourt's childhood.

McCourt holds forth on a newly exposed rock outcrop near the shrunken lake and reminisces about what was here 40 years ago: two small settlements flanking a vast floodplain cleaved by the Colorado River's milk-chocolate waters and guarded by fortress cliffs. His grandparents lived on this east side, in the town of White Canyon, before it was slowly inundated by the reservoir.

As a kid, he'd come regularly to visit, and he recalls the country as harsh and bountiful. "My grandfather told me it got so hot down here that the ravens left contrails because their feathers were smoking," McCourt says, a storyteller's glint in his eye. "The soil was so rich we couldn't grow watermelons, because the vines would grow so fast they'd drag the melons across the garden and wear them out before they could ripen."

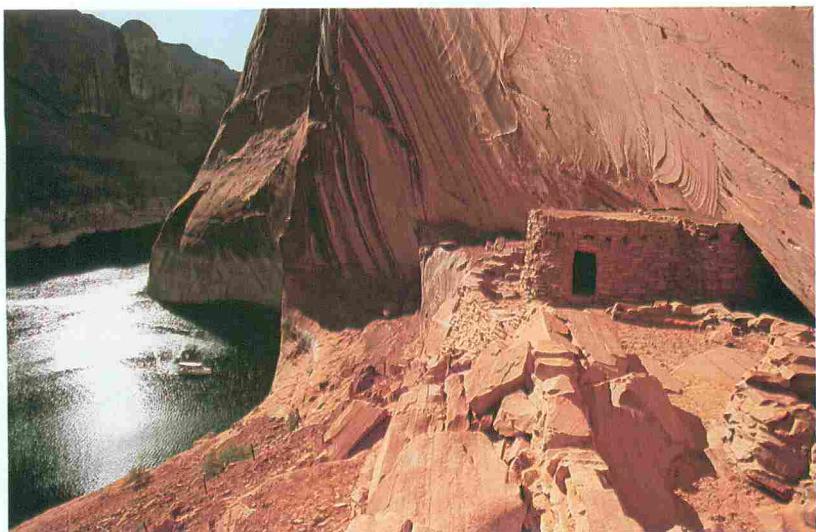
On this early spring day, visitors representing

three generations of two families with ties to White Canyon gather and bear witness to its unveiling. The water hasn't dropped enough to reveal the old landing strip or the site of McCourt's grandparents' house, but it's fallen more than enough to stir personal and collective memories.

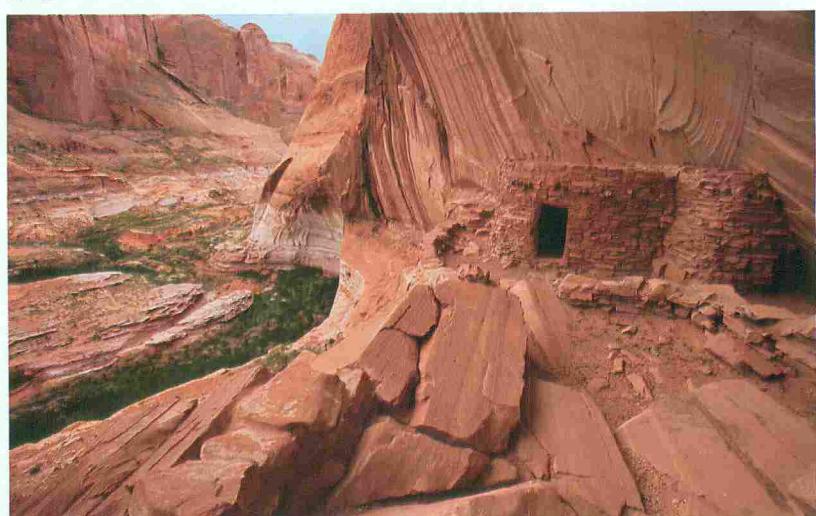
McCourt's entourage includes his cousin Janis York, who lived here with her parents until she was five. York shyly approaches, moved to tears by swirling childhood memories. She used to sit on a hill behind her grandparents' house and pretend she was queen of the land. "There were rocks that sparkled," she recalls—bits of glittering fool's gold. "I used to call them my little jewels." After her family left and the waters rose, she says, "I was brokenhearted."

York gazes out over the canyon and the years. "This is the heart of the whole world," she says. "I remember telling my jewels I'd be back some day."

After Glen Canyon Dam closed its gates on the Colorado River near Page, Arizona, in 1963, the river's cargo of snowmelt and spring rain,



1994



2005

*Ruins as benchmark: In 1994 winter snowmelt kept Lake Powell at the doorstep of Defiance House, a 13th-century shelter built by the Anasazi people. They eventually abandoned the area, perhaps during a long dry spell. Drought has once again left the same shore high and dry.*

gathered from much of the mountain West, hit the dam's concrete stopper and began to back up. The rising waters slowly transformed the lower reaches of the intricate, thousand-hued Glen Canyon into a monolithic blue-green reservoir, the country's second largest after Lake Mead, farther down the Colorado.

Aided by Lake Powell's aqueous bounty, Little League fields sprouted in Las Vegas, subdivisions multiplied in Los Angeles, golf courses carpeted Phoenix. As the reservoir waters rose, Glen Canyon drowned. This remote heart of the Colorado

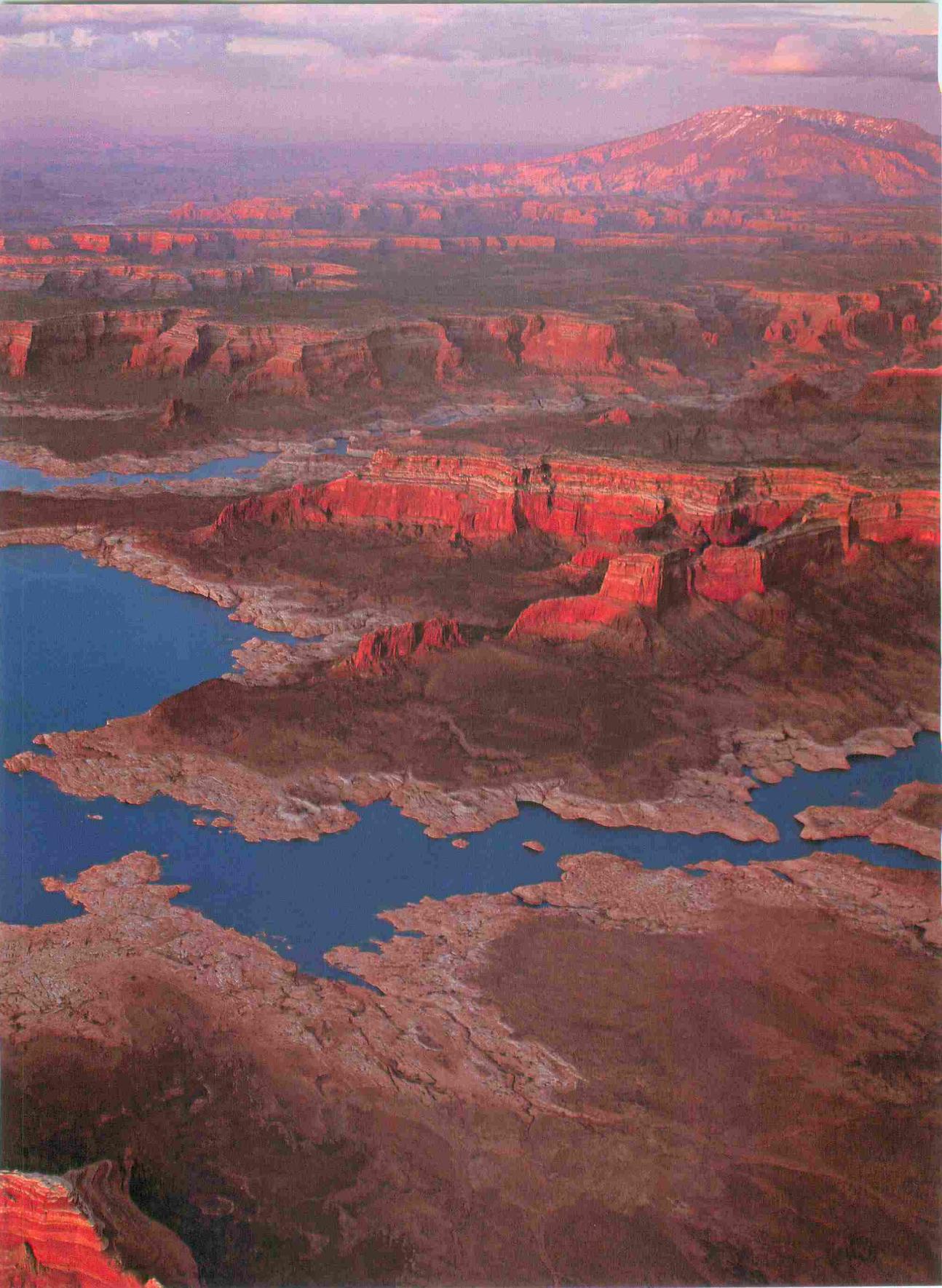
Plateau, dubbed "the place no one knew" in photographer Eliot Porter's ode to this lost landscape, gurgled underwater.

In unknown Glen Canyon's stead emerged the enormously popular Glen Canyon National Recreation Area—which quickly became a mecca for millions of houseboaters, water-skiers, and striped bass fishermen taking advantage of this watery miracle in the desert.

Then came the sustained drought that ushered in the 21st century, one of the region's periodic dry spells. For five years clouds yielded little



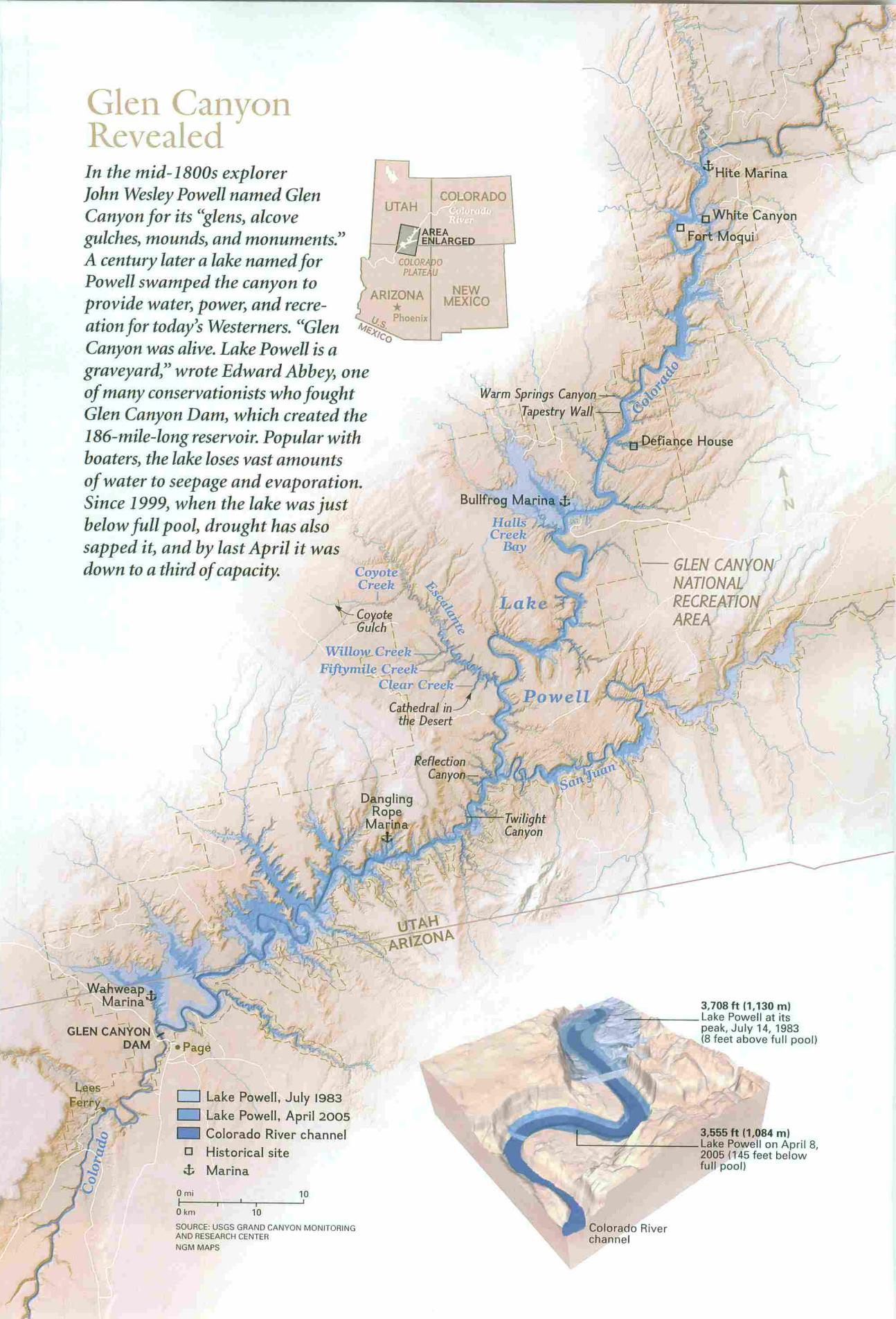
*Half full or half empty? Some conservationists want Lake Powell to be completely drained, allowing*



*plants and wildlife to thrive throughout a restored Glen Canyon.*

# Glen Canyon Revealed

In the mid-1800s explorer John Wesley Powell named Glen Canyon for its "glen[s], alcove gulches, mounds, and monuments." A century later a lake named for Powell swamped the canyon to provide water, power, and recreation for today's Westerners. "Glen Canyon was alive. Lake Powell is a graveyard," wrote Edward Abbey, one of many conservationists who fought Glen Canyon Dam, which created the 186-mile-long reservoir. Popular with boaters, the lake loses vast amounts of water to seepage and evaporation. Since 1999, when the lake was just below full pool, drought has also sapped it, and by last April it was down to a third of capacity.



SOURCE: USGS GRAND CANYON MONITORING  
AND RESEARCH CENTER  
NGM MAPS



moisture, even as the West continued to drink greedily. The Colorado River, lifeblood for seven states, dwindled. Lake Mead and Lake Powell, the river's massive catch basins, shriveled. No amount of hydro-engineering, cloud seeding, flow regulating, or other manipulation could change a simple fact: Not enough water was falling from the sky to keep the West's reservoirs full. Not with the increasing number of straws sucking upstream water to irrigate alfalfa fields, fill swimming pools, and sprinkle suburban bluegrass expanses.

Lake Powell's loss was and is Glen Canyon's unmistakable gain. People who were lucky enough to get a glimpse of Glen Canyon when they were young flocked to see it again, as if offered the chance to visit, after 40 years, a first love who had abruptly moved away. People who had only known the canyon through photos and descriptions—by John Wesley Powell, Wallace Stegner, Katie Lee, Eliot Porter, David Brower, and Edward Abbey—hurried for a first look.

The ancient Navajo sandstone itself shook off the water as easily as a dog emerging from a swimming pool. At an average rate of an inch a day, a lost sculpture garden of rock resurfaced, miraculously intact.

The uncovered slickrock sandstone told its astounding life story: of Sahara-size sand dunes marching across the landscape 190 million years ago; of three-toed dinosaurs that left tracks in

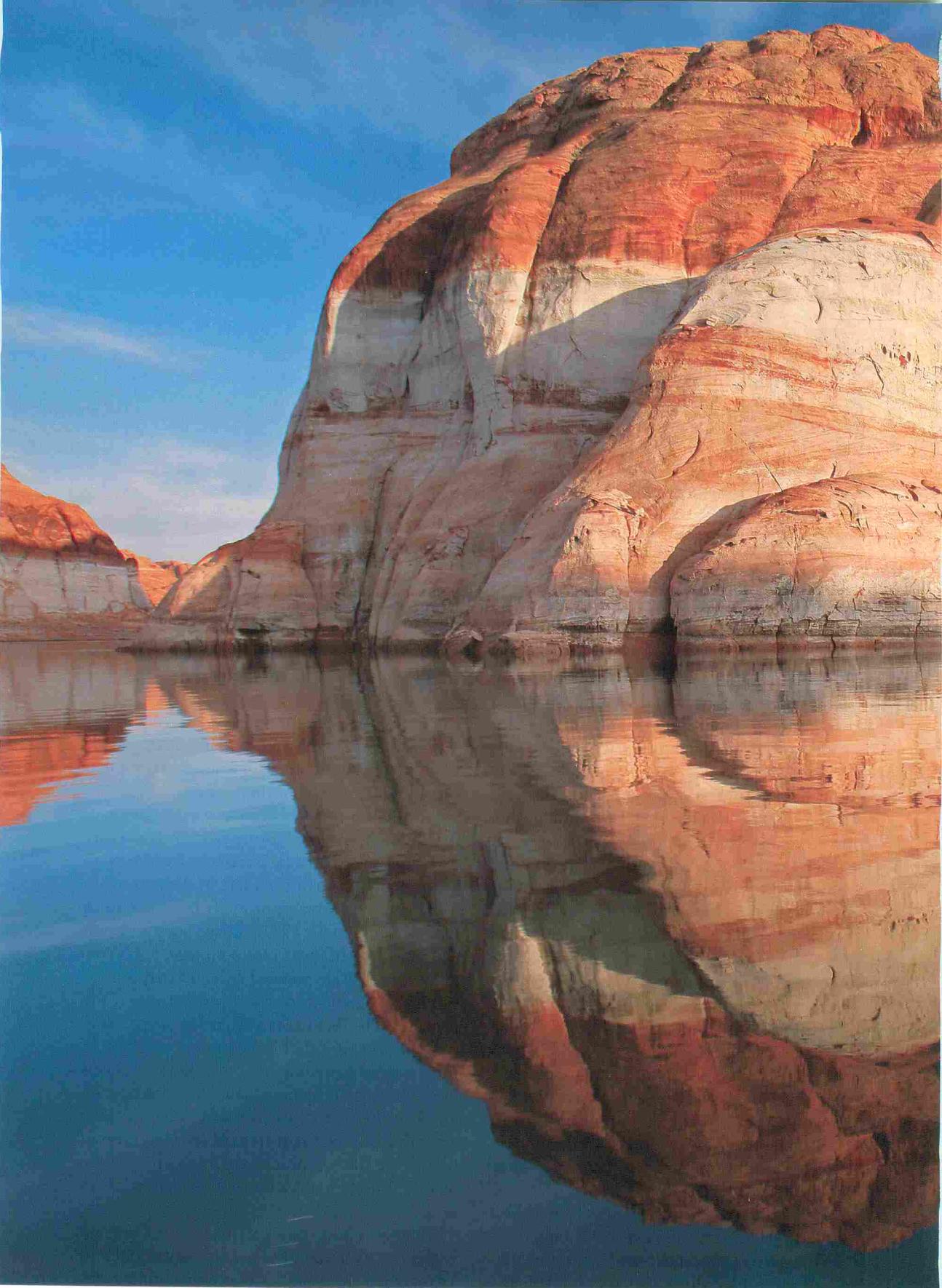
*Exposed in March 2005, Fort Moqui, a 12th-century Anasazi ruin, was soon submerged again by the highest spring runoff in five years. If this year is dry, the ruin may reappear.*

damp spots between the dunes; of deep burial that slowly squeezed sand and mud into rock; of epic uplifts and tectonic shifts; of water and wind that carved slot canyons hundreds of feet deep.

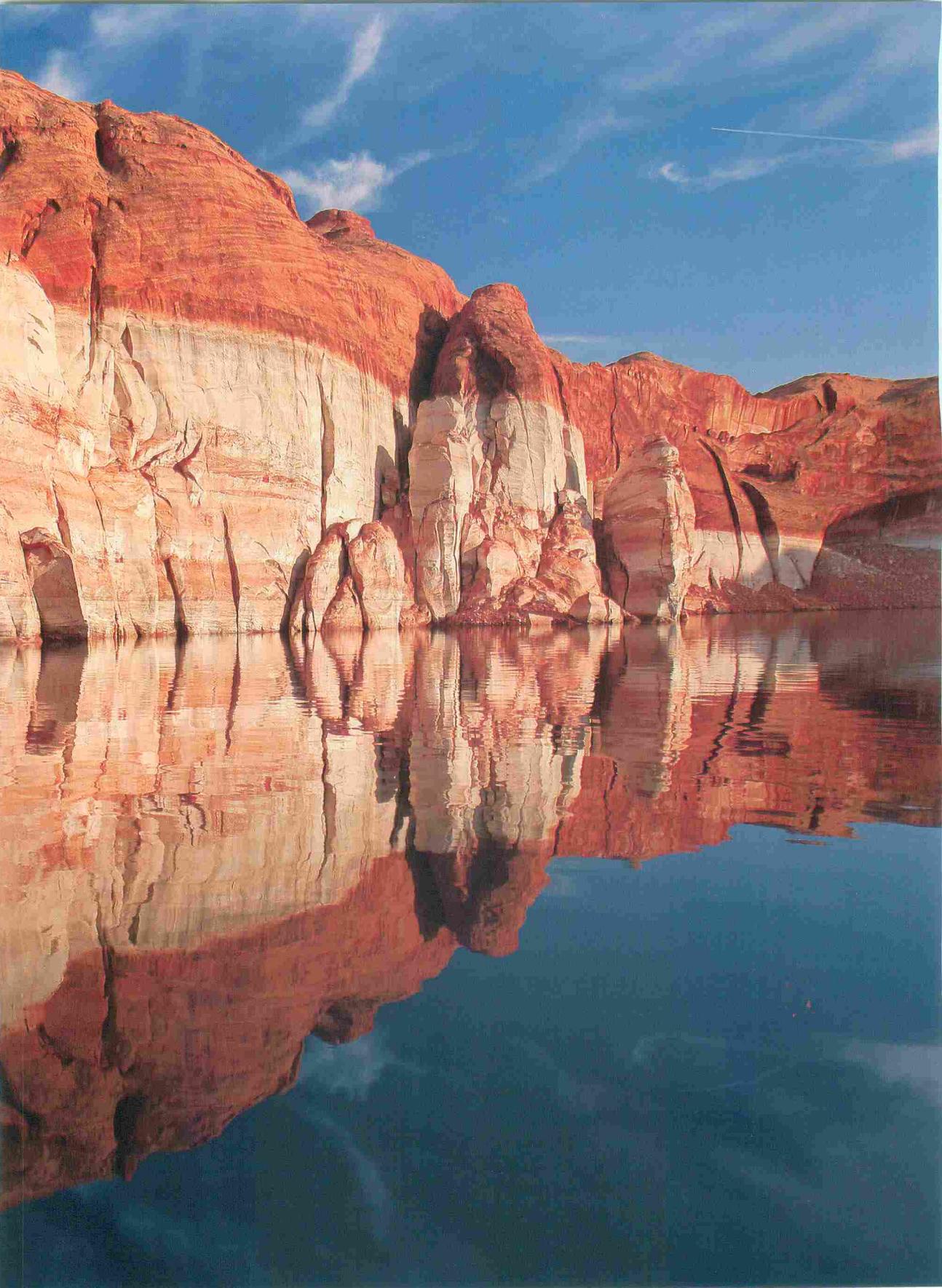
Layers of human history saw the light again too: thousand-year-old petroglyph panels and cave dwellings of the Anasazi; artifacts from Navajo settlements; inscriptions left by 19th-century Mormon pioneers; equipment from uranium miners' camps of the 1950s; sunken boats and even a lost airplane of more recent vintage.

Desert varnishes, mineral-rich dust transformed by microbes and moisture, soon streaked the canyon walls. Vermilion, rust, beige, taupe, slate, maroon, cocoa, coffee, pale orange, and peach, they began painting over the lake-bleached bathtub ring left by high water. Streams rippled anew in the side canyons that branch out like arteries from the main stem of the Colorado to distribute life—maidenhair ferns and coyote willow, soft-stem bulrushes and golden sedges—in this arid land.

There was little soul-searching when Congress voted to euthanize this hidden world back in 1956, when Ike was President, the country was



*Two-toned cliffs near Clear Creek canyon along the Escalante River—a major tributary of Lake Powell—*



*display pale calcite deposits left by water that once lapped the rock.*

# Layers of human history saw the light again too: thousand-year-old petroglyph panels and cave dwellings of the Anasazi, and artifacts from Navajo settlements.

poised to pave interstates coast-to-coast, and Sputnik was but a year away. Today, the fall of the lake has driven a rising debate about its future. Many scientists think Western droughts will intensify as the Earth's climate warms. Water will become even more precious—and reservoirs, which lose vast amounts through evaporation, will seem intolerably wasteful. Better, say many environmentalists, to exploit new technologies for storing water underground, decommission the dam, and let Lake Powell once again be Glen Canyon.

There's little chance of that for now. Lake Powell, however diminished, plays too important a role in the West's water supply, and its removal would mean rewriting complex water laws at a time of massive population growth. But even though slightly above-average runoff in the spring of 2005 raised the lake 53 feet from that year's historic lows, managers expect it to drop again, to perhaps 108 feet below full pool by this month. Another sustained dry spell would push the lake to new lows. And in the very long run, nature will defeat the dam. Over the centuries, Lake Powell will ultimately fill up with silt.

**L**et me get a little less disoriented here," says Bill Wolverton as he scrambles up a slickrock tower to gaze into Twilight Canyon. Wolverton, 57, has roamed this Glen Canyon backcountry for a quarter century, first as a furloughed railroad worker with time on his hands and a love of the desert, and for the past 18 years as a seasonal backcountry ranger and an ardent advocate for the canyon. On his days off he walks me up and down a half dozen remote canyons, observing what the reservoir wrought and the drought incrementally reversed.

In the lower reaches of each canyon, by the lake, we sink into giant pillows of sediment, deposited over the decades since high water flooded the canyon and stripped the banks of life. Wolverton calls this vegetation-free carpet of stinking mud the "death zone." At one point I am in it up to my

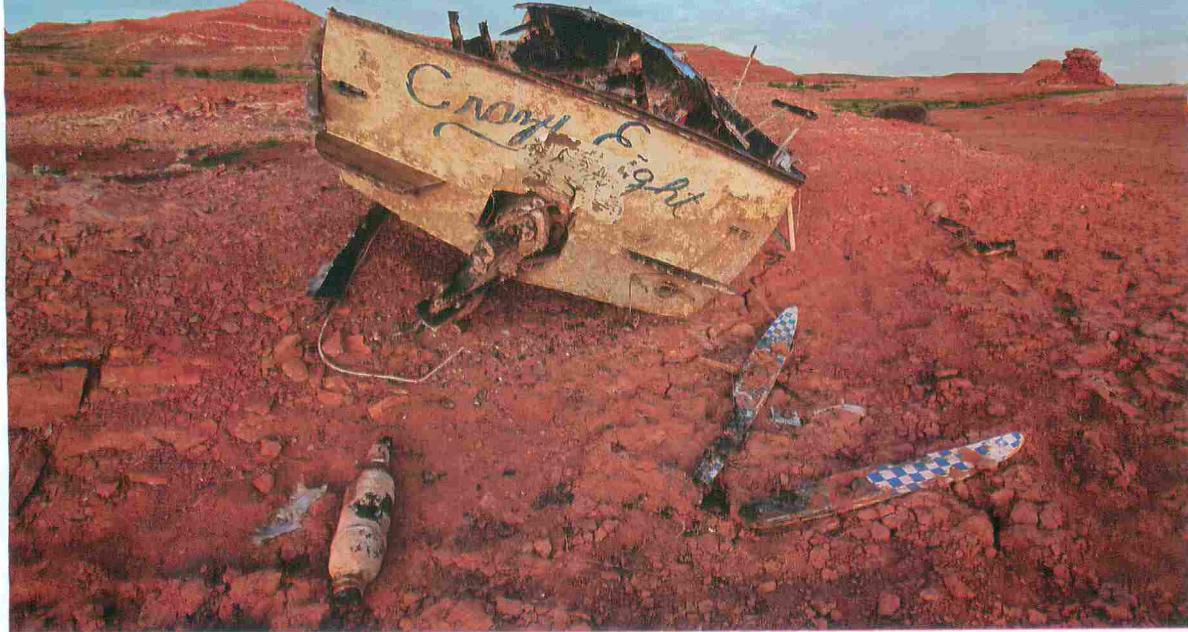
knees and elbows when solid-looking ground turns out to be quicksand.

Here gnarled gray hundred-year-old cottonwood branches beckon like skeletal hands from the mud. Detritus from boating trips—an anchor, the handle from a water-ski towrope, a swim fin—rests forlorn in the sandbars. Fishing line trails from broken rods tangled in driftwood.

The reservoir's drop of 140 feet, stretched over the gentle gradient of a side canyon, can mean that two or three miles of terrain have been slowly unveiled over the past six years. By last spring more than 100 square miles of canyons had seen air for the first time in decades. We slither up one of Twilight Canyon's tributaries, a magnificent narrow slot that requires gymnastic moves to explore. Seeing it for the first time delights Wolverton, and he doesn't hide his desire that the waters keep receding. "It's knowing that places this special are underwater that makes me want the reservoir gone," he says.

The farther we hike from Lake Powell, the more signs of life reappear. Less than half a mile from the water, frontier willow colonies and tiny reeds clothe the banks, along with a host of invasive species. Tamarisk, tumbleweeds, and cheatgrass, all aliens, have seized an unnatural advantage, battling with the natives for the new territory. Farther upstream, spring floods since the lake receded have blasted a channel into the sediment, uncovering the bedrock and exposing swirling patterns on the sandstone canvas.

A mile or so up from the reservoir's edge, the canyon feels like it is breathing again. The descending plaintive warble of canyon wrens, which Wolverton describes as the "call you can hardly forget," echoes off salmon-hued walls. Six-foot cottonwood saplings with fresh, electric green leaves sprout in the shadow of drowned, hulking snags. Cattails, horsetails, and black willows are revegetating the stream banks. On benches above the streambed, yellow and pink blooms of prickly pear cactus herald the spring. Gardens of monkey flower and cave primrose



take tenuous hold in aired-out alcoves wet from seeps. Gambel oaks and box elders cluster above the high-water mark. We are struck by wafts of desert flower perfume, of sage aroma awakened by the sun, of moist sand and earthy oak and fleshy cottonwood bark.

"This dam won't work forever," Wolverton says, and he shows me why. We hike to the confluence of Coyote Creek and the Escalante River, a tributary of the Colorado. Where the clear water washing down Coyote Gulch meets the pea green water of the Escalante, we stare at a steady underwater parade of pebbles, sand, and silt moving downstream. "Building a dam across sediment-laden rivers is like driving your car without ever changing the oil filter," he says. Sooner or later the marching sediment will have its day. "There's the answer right there," he says, pointing to the gravel on the march. "It's inexorable. This is the land of erosion."

Perhaps it all comes down to this place: a waterfall in a most unlikely location, a hidden cavern of mystical proportions aptly called Cathedral in the Desert. I arrive here alone by boat, following a sinewy side canyon, new desert varnish on its steep walls and the chalky white bathtub ring nearly gone. The water is green, deep, still. The walls close in, the canyon narrows. Rounding one last turn, I eye

*Near Bullfrog Marina, a runabout that may have caught fire and sank lies marooned on the dry lake bed. Nearly two million annual visitors, mostly boaters, still flock to the shrunken lake.*

a beach, cut the motor, and glide silently to shore.

Ahead, the canyon walls curve, rising hundreds of feet above me, overhanging to form a giant cavern, once drowned by Lake Powell. The waterfall drops 50 feet, bounding, bouncing, pulsing. It has left a splash of dark green on the wall. Water was at work here long before the dam and the reservoir, wearing a notch in the rock that now guides the stream the way a halved section of bamboo pipe funnels water in a Japanese garden. The cascade sounds eerily like the low murmur of a room full of people. Three hundred feet above, an opening frames a boomerang-shaped sliver of sky.

As I write this, the waters have risen again and put the waterfall at least temporarily back in the bottle. Somewhere, though, a canyon wren still warbles its haunting song. The warm desert wind rushes over the slickrock. Pebbles march toward the sea. And Glen Canyon abides. □

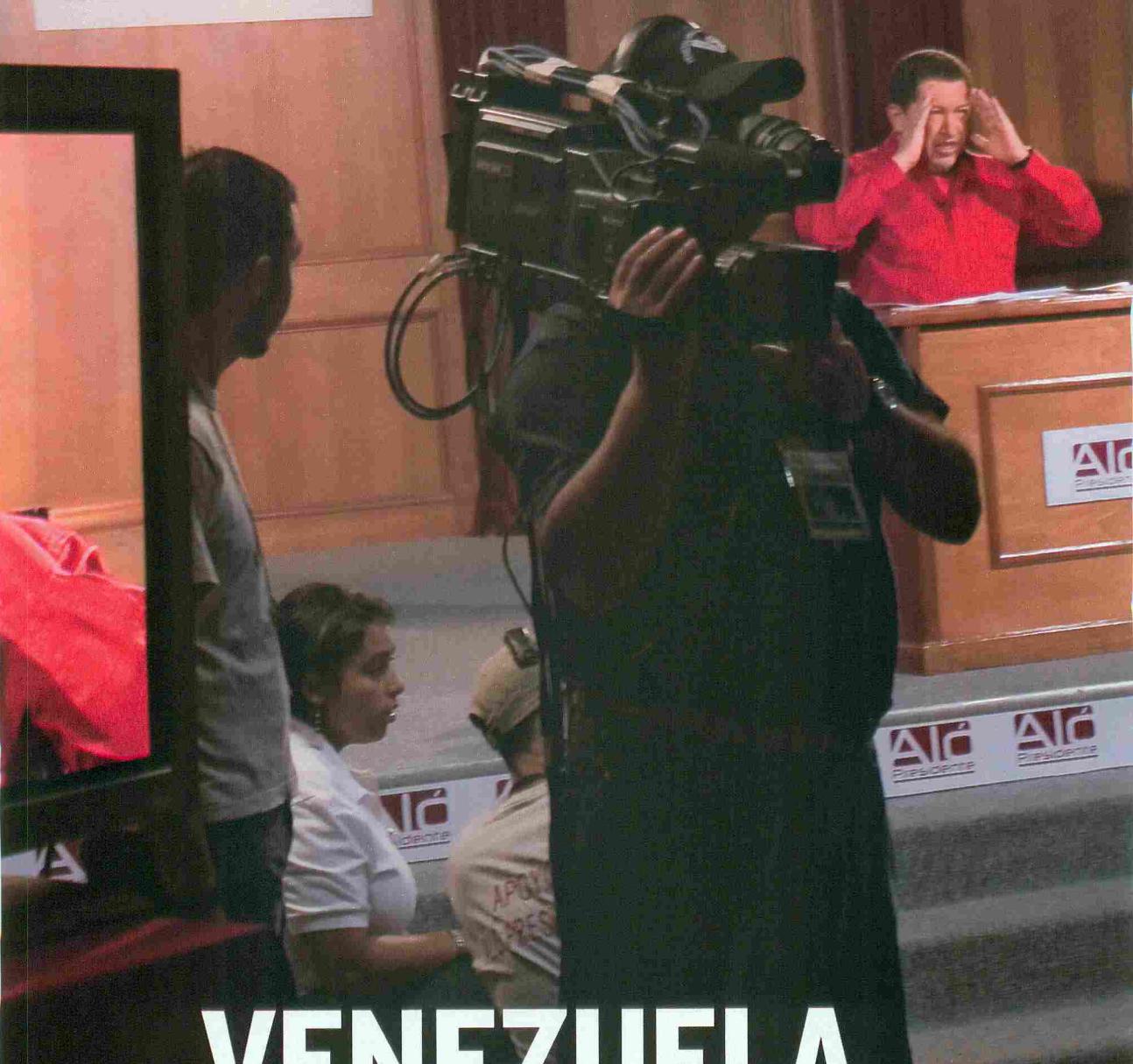
► **Red Rock Country** Download the glories of Glen Canyon to your desktop, view a photo gallery with pointers from photographer Michael Melford, and get travel tips at [ngm.com/0604](http://ngm.com/0604).



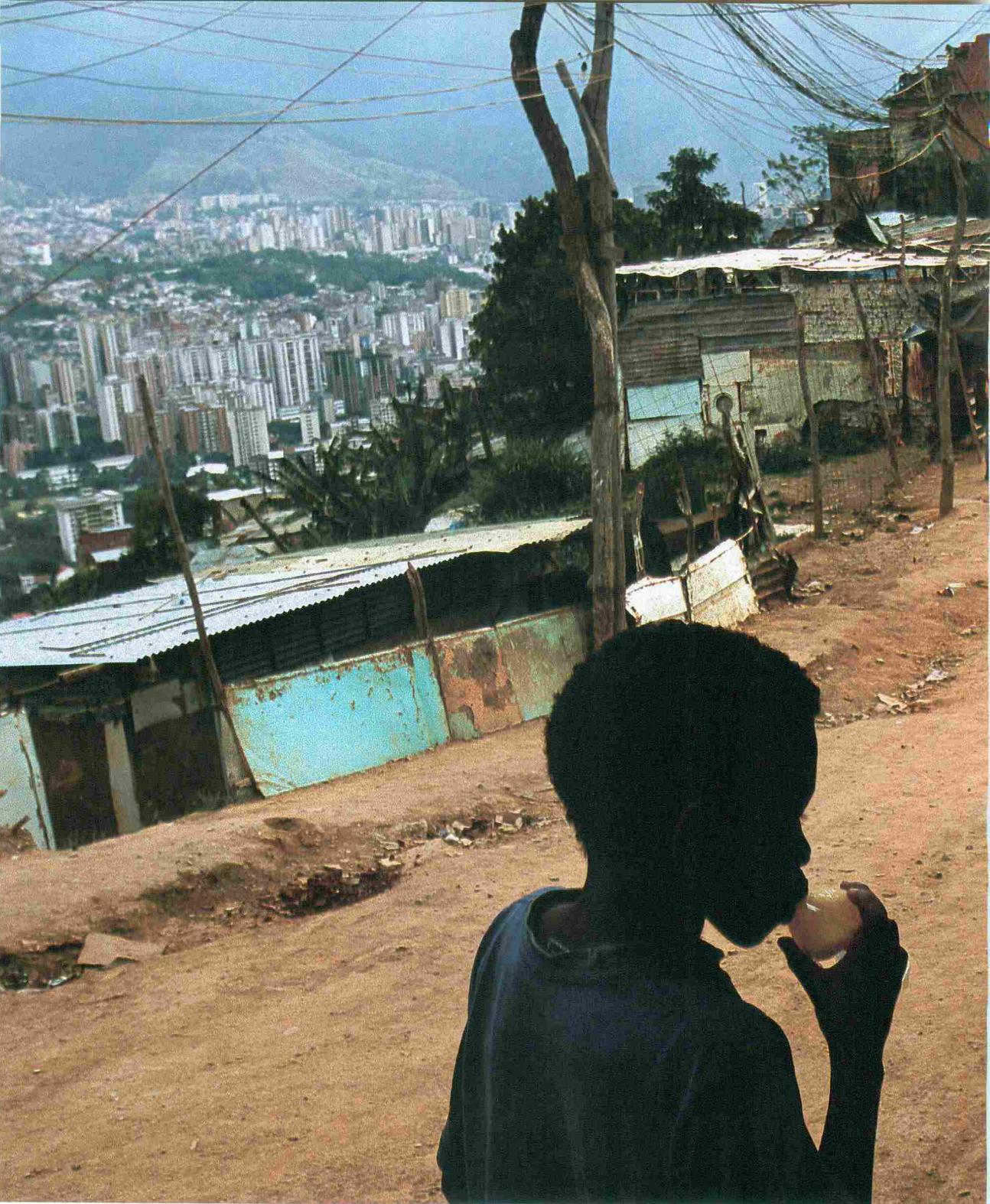
**Venezuela looks more and more like a one-man show, conceived and narrated by President Hugo Chávez. After seven years in office, his measures to lift the poor have achieved only limited success, and his opponents seem paralyzed.**

**Aló**  
Presidente

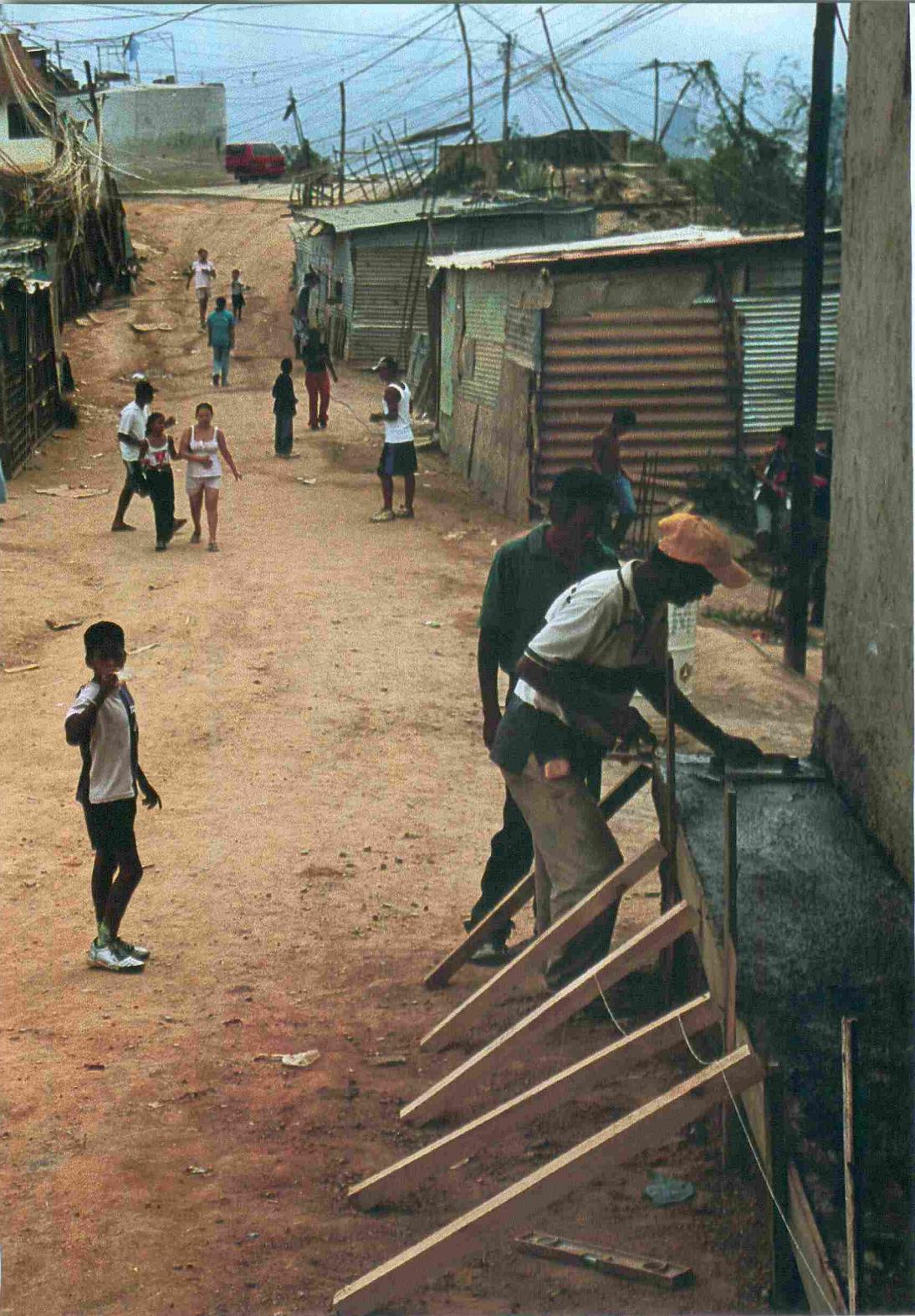
Every Sunday Hugo Chávez hosts *Aló Presidente*, a television talk show—often hours long—extolling his socialist revolution.



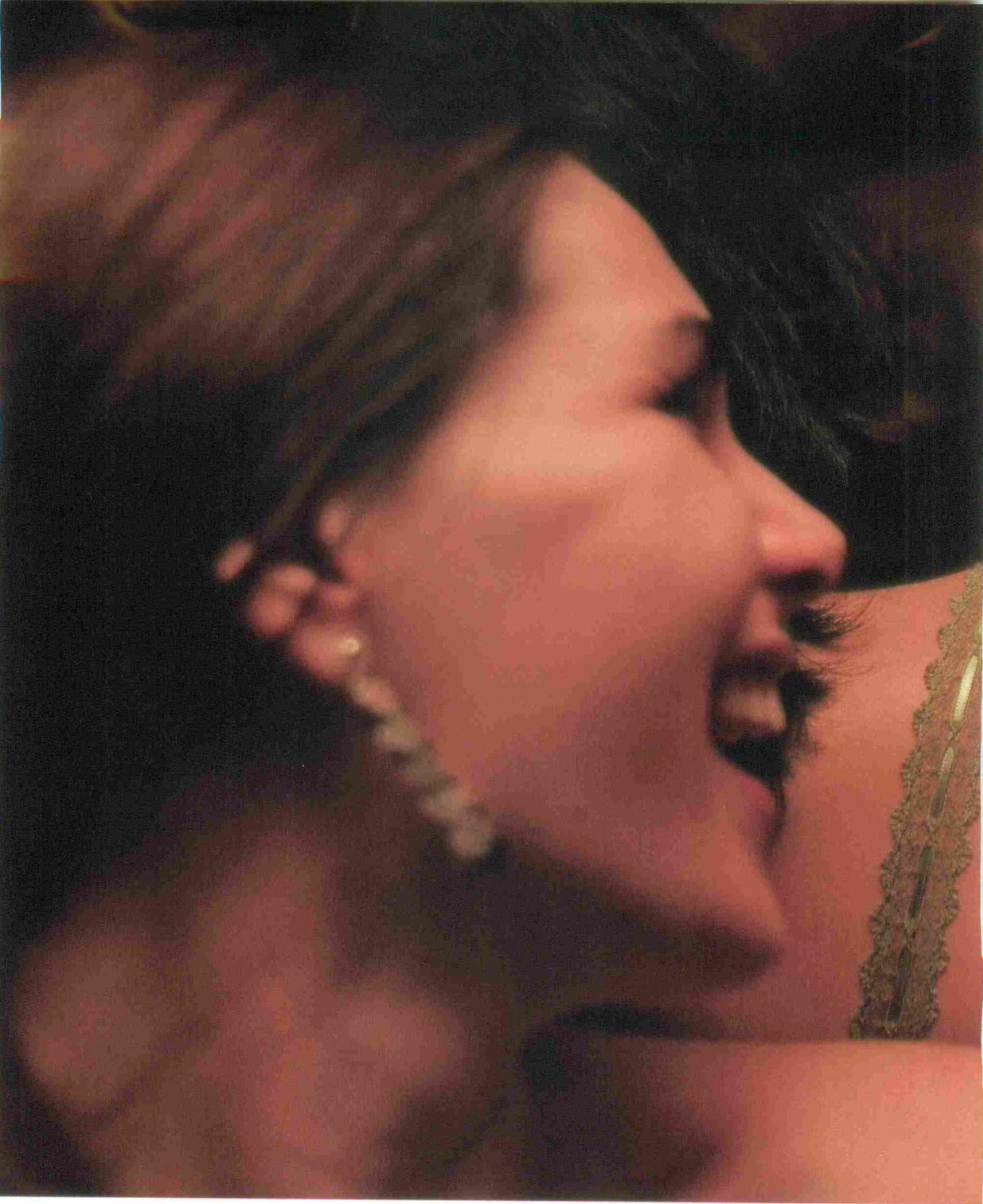
# VENEZUELA ACCORDING TO **CHAVEZ**



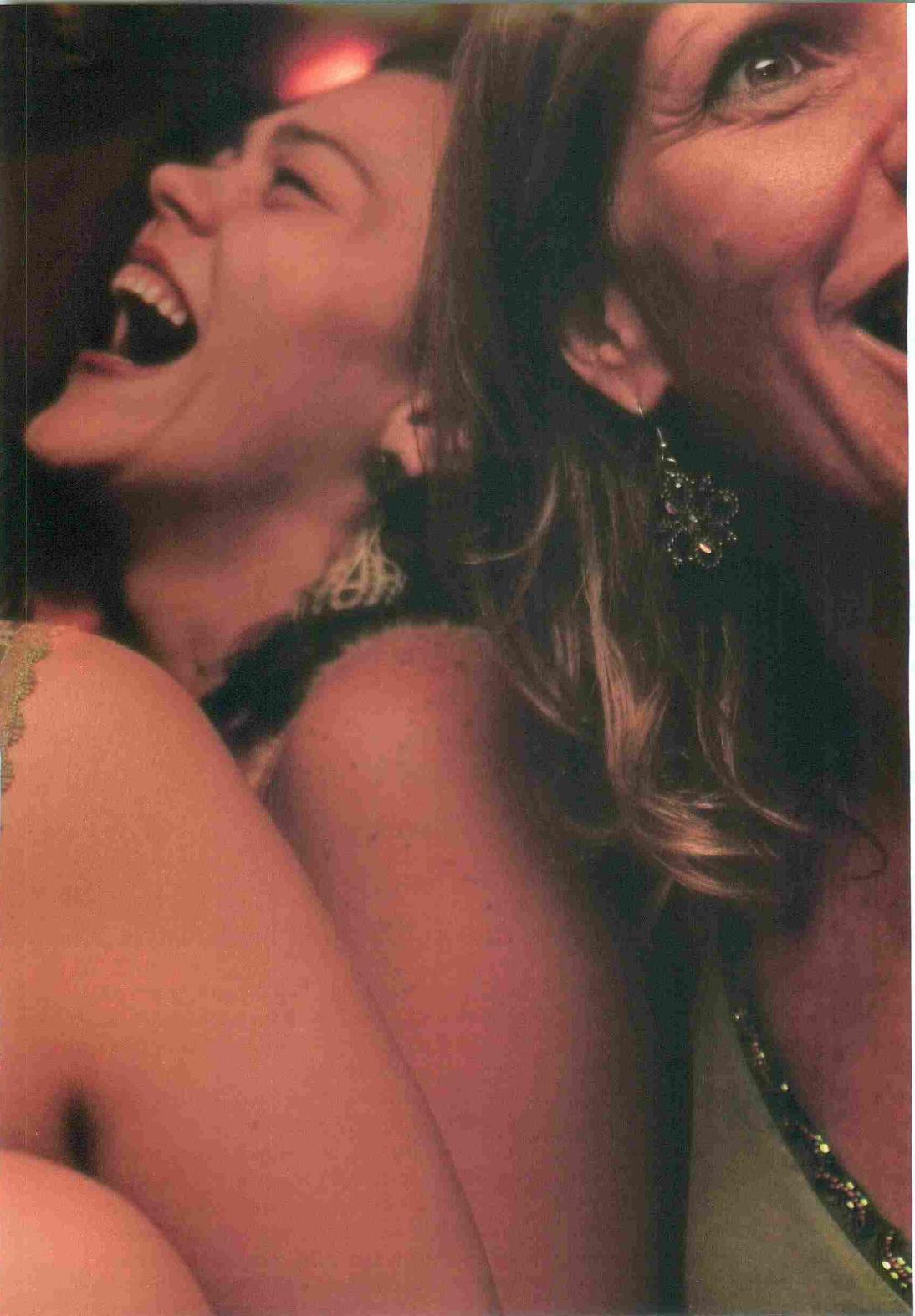
**TARGET AUDIENCE**



Slums like Barrio Esperanza ring the high-rise prosperity of the capital, Caracas. More than half of Venezuelans live in poverty, and the number of poor has grown since Chávez took office in 1999. But free health care and food from government-subsidized stores are easing some of their burdens—and propping up Chávez's popularity ratings.



**PARTY OF PRIVILEGE**



Club-hoppers in Caracas's elegant Las Mercedes section rub shoulders with elites like TV personality Amara Barroeta, at left. Latin America observer Barry Lynn has called the concentration of Venezuelan power and wealth in the hands of a few "one of the longest running fiestas of the 20th century." Chávez vows to break their grip.

BY ALMA GUILLERMOPRIETO  
PHOTOGRAPHS BY MEREDITH DAVENPORT

The best way to understand the spell the president of Venezuela casts over his fellow citizens is to do as they do every Sunday morning at eleven and settle down in front of the television in a favorite chair, with a good provision of drinks and sandwich ingredients, for a broadcast of *Aló Presidente*, Hugo Chávez's weekly televised communion with his country.

I watched *Aló Presidente* on the Sunday after the government took over a lush, well-managed cattle ranch in Chávez's home state of Barinas. Tongues wagged when it became known that in

a long-ago interview Chávez had said that his grandfather had lived on this 20,000-acre ranch, La Marqueseña, and had tried for years to get the legal deed. But the Agriculture Ministry explained that La Marqueseña was being taken over only because too much of its land lay idle, and because the owner, whose father had bought the property in 1949, could provide land titles from the colonial period but not for 1821—the year Simón Bolívar freed Venezuela from Spain.

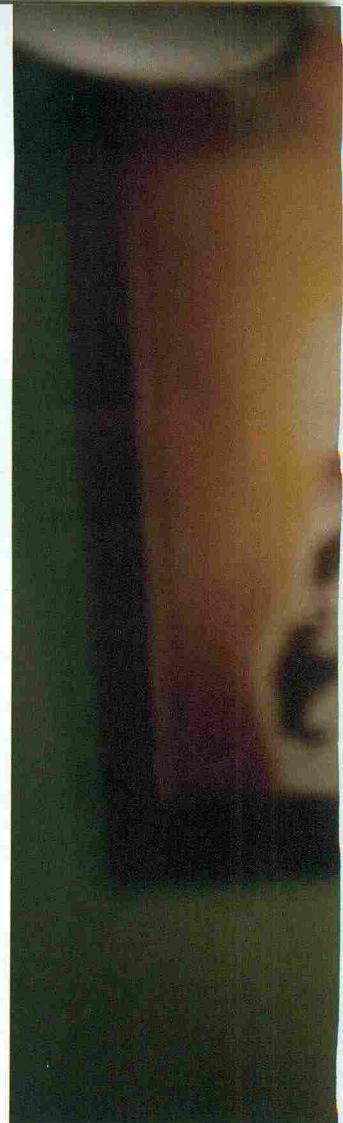
As it happened, I'd visited La Marqueseña on the day of the government takeover. In the shade of samán and ceiba trees, workers who had been locked out since the day before put on a soup kettle and, eyeing the troops guarding the grounds, wondered if they would be allowed back in. They told me they considered the owner, Carlos Azpúrua, to be an excellent land manager. "It's false that we're exploited

here," one of them said. "It's the only cattle concern around these parts where the owner lets you do your work without breathing down your neck all the time."

Another chimed in: "On payday they never say, 'We can't pay you because we're broke.'" On the whole, Azpúrua was considered a fair man.

On the day of this particular *Aló Presidente* broadcast, the owner, having fought a long and unsuccessful legal battle against the takeover, was refusing to vacate the premises, but Chávez moved in nevertheless, with camera crews and musicians and admirers from around the world, to announce from this spot the beginning of a reinforced land reform campaign.

The weather was calm, the view of the green land was exquisite, and the president was in a happy mood. "What a pretty woods this is! What fertile land, what good land! What a beautiful





**ROLE MODELS** Flanked by portraits of his heroes—leftist icon Che Guevara and Hugo Chávez—activist Humberto “Che” López helps guide families through the maze of new government welfare programs, and has led other partisans in attacks on Chávez’s opponents.

landscape that dawned this morning here in the savanna!” he said, greeting television viewers and also a local audience of perhaps a hundred people that included his father, who is the governor of Barinas. Possibly intoning a poem of his own, he continued, “This is where the immense Andean mountains embrace and kiss the infinite Venezuelan plain!”

Dressed in a dark green shirt that looked military, at ease in the steaming heat, Chávez addressed the camera without interruption for the next six hours. First-time viewers of *Aló Presidente* might think that he rambles, even tends toward the delirious, but in fact he never loses sight of the central message. His warm-up on this

occasion was typical: “What we must say, repeating Don Quixote’s maxim, is, ‘If the dogs are barking at us, it is because we are galloping.’ . . . And let us gallop, as Christ said. I think I am more Christian every day . . . and now I’ve got Fidel on the right path. Fidel is a Christian when it comes to social concerns.” Fidel Castro, who is his mentor and best friend.

The monologue segued to history lessons—Chávez has admirable command of the military exploits of Simón Bolívar, the “liberator of the Americas,” who is his greatest hero—plus a bit of audience participation, and a couple of short videos. There was also a brief account of the progress being made in the oil sector by the

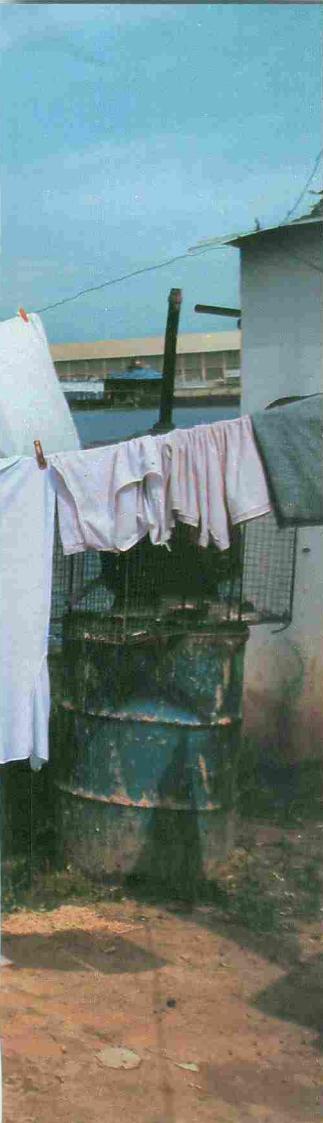


state-owned corporation Petróleos de Venezuela (PDVSA). He used figures previous PDVSA managers would no doubt dispute.

But between meanderings, Chávez returned, time and again, to the same point: Large landholders should reconcile themselves to the fact that much of their land will be taken over—because there will be no turning back. “I appeal to those people who say they are owners of great expanses of land to accept a reality and not to let somebody . . . fill their hearts with hatred, or the hearts of their relatives, their children, their families, their friends. Because the usual suspects, the lackeys of imperialism who own television stations here, who own newspapers, who have radio stations . . . are trying to use this moment to try to take us again to a situation of open conflict . . . so that they can ask again, as they have before, for the intervention of peacemakers from

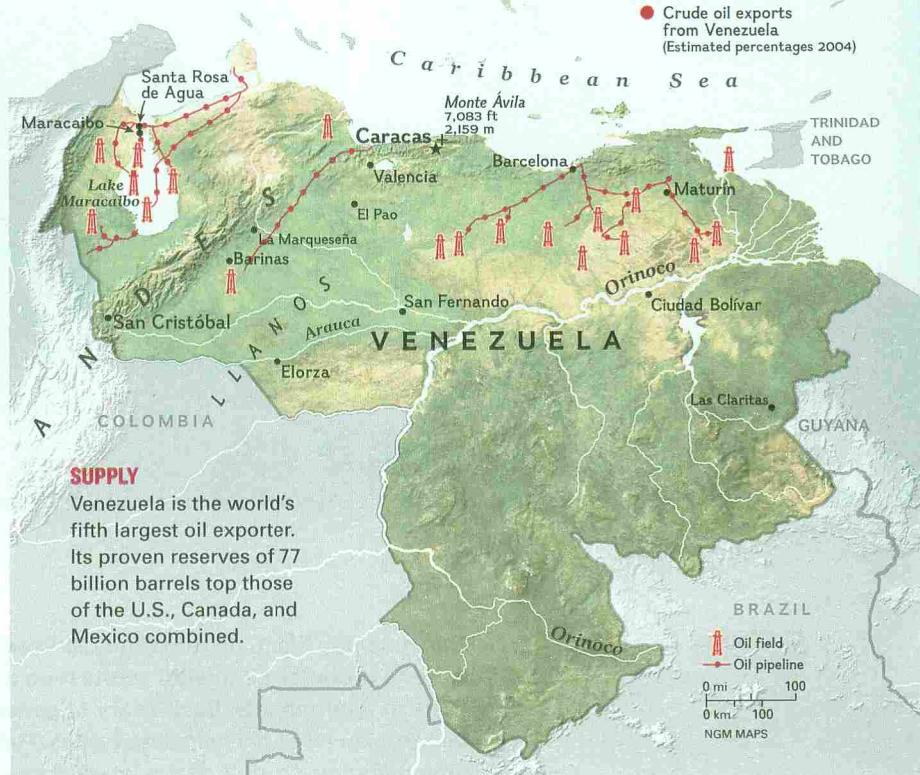
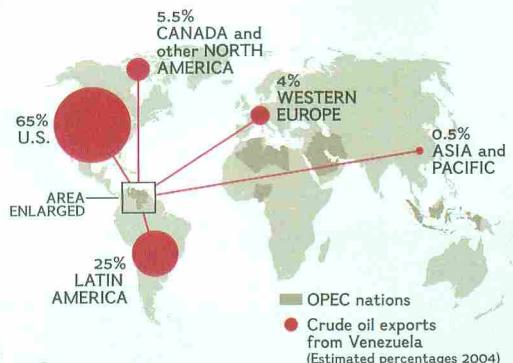
North America. And now that the United Nations talks about the right to protect and the right to reconstruct **countries**—well, that fits their purpose like a glove.”

There was more talk about Bolívar and about Chávez’s beloved grandmother Rosa Inés and the stories she had told him of his grandfather at La Marqueseña, and his own memories of the ranch when he was a young army officer stationed nearby. Chávez made a friendly appeal to its owner, Azpúrua (“a decent man”), to stay calm. There were any number of plans and programs announced for the ranch and other ranches to be confiscated soon: a training center for cattle breeding, agribusiness and model villages for the campesinos, coffee and cacao plantations in a forest on the premises (part of the ranch is a government wildlife preserve). There was even an acknowledgment that, given the



#### DEMAND

Despite frosty political relations, the U.S. remains Chávez's major customer, with more than 10 percent of its annual oil imports coming from Venezuela.



**FUELING THE REVOLUTION** Thousands of oil wells dot Lake Maracaibo (left), and the bulk of Venezuela's petroleum exports pass through its channel to the sea. Production of roughly three million barrels of oil a day nationwide generates about half the government's annual revenue—the primary source of funding for the Chávez social agenda.

turmoil of the wars of independence and the internece civil wars of the 19th century, few people in the countryside were actually in possession of proper title to their land.

Then there was a definitive, explicit statement: "If someone doesn't want [to reach an agreement with us], he can go to the courts, but we're going to ask you for all the [documents] from 1821, and if [the property] wasn't registered in 1821...." Here Chávez made the sound of a piece of paper being torn in half. But what Chávez demands doesn't exist: The fledgling government didn't get around to issuing titles until decades later.

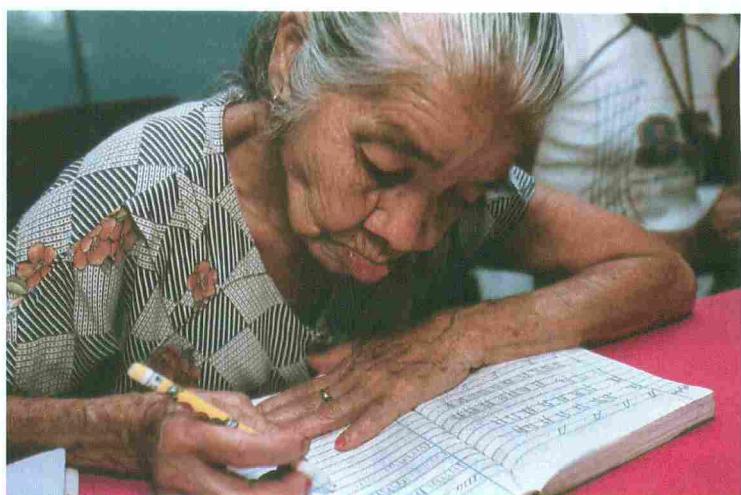
Six hours after he joyfully greeted the Venezuelan people, an obviously happy Chávez called *Aló Presidente* a wrap. As the cameras pulled away to show the fertile grasslands of La Marqueseña, he strolled over to where a quartet of local musicians was waiting to perform the lyrical, lilting music of the Venezuelan savanna and joined them in song.

Last September I spent a day in the company of a young woman, Trinidad Ramírez, from a poor barrio in Caracas, talking about her neighborhood, her life, and the president of her nation. Her barrio, La Vega, is one



## MISSIONS TO THE POOR

Painstakingly filling her notebook, 69-year-old Candida Rumbo (below) is one of 1.2 million adults who have learned to read and write at new schools. Beneficiary of generous shipments of Venezuelan oil at below-market rates, Fidel Castro has sent Cuban doctors to staff clinics (above) serving communities that had no access to health care. Chávez's opponents decry Castro's doctors as communist propagandists, yet the government reported that in two years the Cubans saved more than 2,500 lives.



of the hundreds of poor areas that occupy the steep hillsides ringing the Caracas valley. Across it, the prominence of Monte Ávila can be seen from some angles, and, in its shade, some of the pricier real estate in the prosperous capital of Venezuela. Due north, hidden from view by the Ávila, lie the clear waters of the Caribbean. Below are the shimmering office buildings of the business district. Once, these hillsides were lush, but that was decades before millions of dirt-poor campesinos from inland areas began their long migration to the capital, looking for modernity and the prosperous life. The greater part of Caracas's estimated 3.2 million people live on these now stripped inclines, and only a few twisting, potholed roads, linked to an intricate web of steep footpaths, connect the precipitous alleyways where bare-brick older dwellings and newer cardboard and tin shacks are pitched against each other at an impossible angle to the hills.

Instead of public transportation in the upper reaches of Caracas there are quite a number of privately owned rattletrap buses, and many more astoundingly decrepit jeeps, which for a few pennies will allow a dozen unfortunate passengers to wedge themselves onto low wooden benches nailed to the floor behind the driver's seat and hold on for dear life. I sat in one of these vehicles with Ramírez, hitting my head against the roof at every bounce, and tried to concentrate on what she was saying about Hugo Chávez, the army man who in 1992 attempted to stage a coup against the elected president of his country, and then went on to win the presidency himself, by a landslide, in 1998.

Seven years later, Chávez, 51, is more in control than ever—and Ramírez was experiencing moral conflict. She had been brought up in the fold of a progressive Catholic church, which has had an ongoing, and effective, educational mission in La Vega for many years, and she has been involved in community work since adolescence, tutoring children from the poorest homes in the barrio who have such trouble behaving that they cannot stay in school. The words "community" and "solidarity" have been deeply meaningful to her since long before Chávez came on the scene, but now, she said, here was Chávez, making his enormous presence felt in La Vega with his Bolivarian Revolution and his own solidarity programs and his big budgets and his community

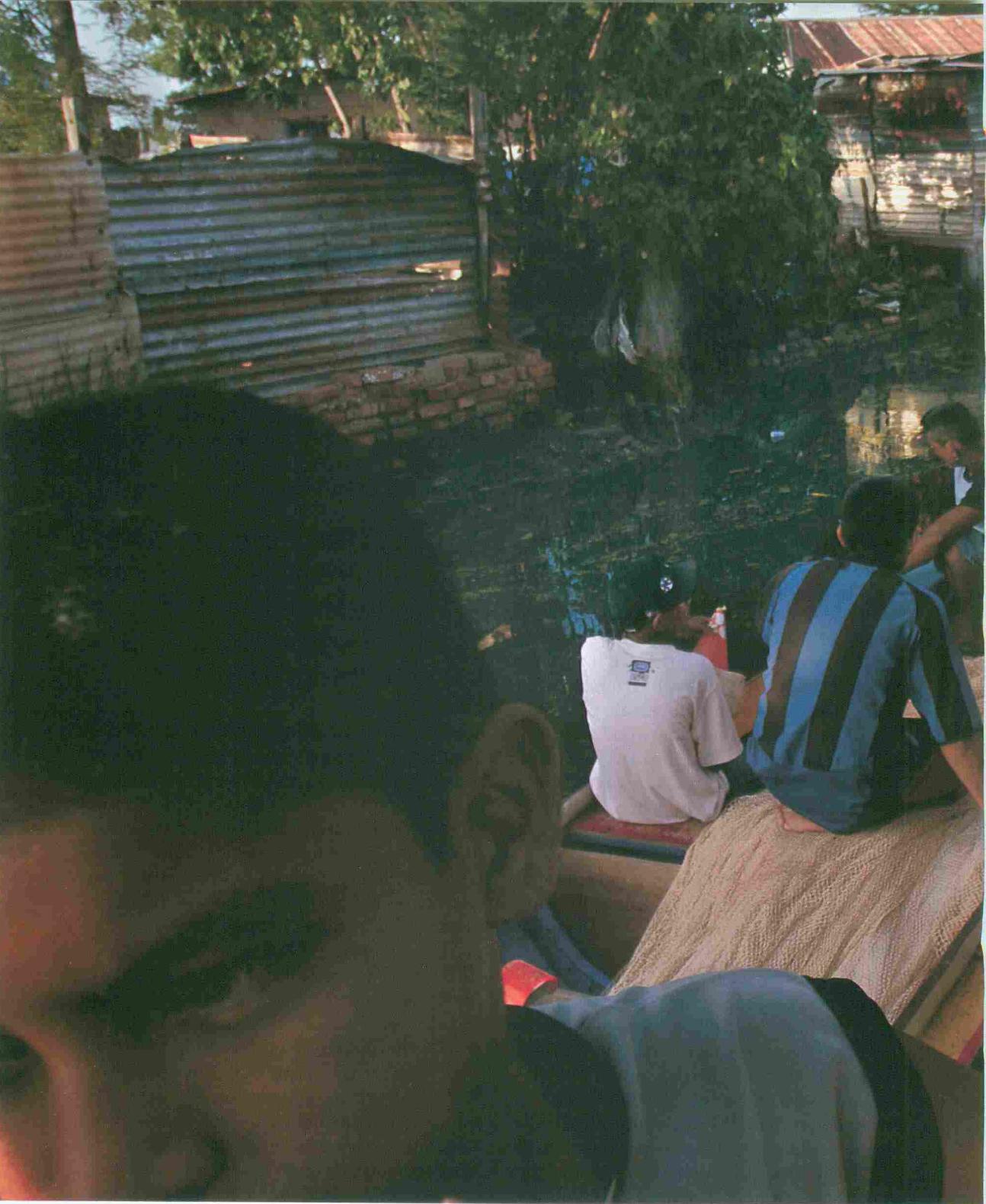
projects (known also as *misiones*), seemingly for every need: medical *misiones* staffed round the clock with Cuban doctors, sports *misiones* for the kids, supermarket *misiones* for all the poor, where they can buy food at cost.

As if she were still struggling with the issue, she said that she could not approve of the *Chavistas'* radicalized view of society, in which the rich are evil, the poor are sainted, and those who disagree with the president are enemies. Nor was she sure that Hugo Chávez could be called a democrat. For these reasons, many of her friends in La Vega were less than wild about him. "But I'm a Chavista," she said at last, and it was easy to see why. She had so many more opportunities now. All her life she had practiced folkloric dance and had longed for a formal education, and now

**"*Con Chávez tengo mi lugar—With Chávez I have a place where I belong. Before, we, the poor, were nothing. Now we are recognized.*"**

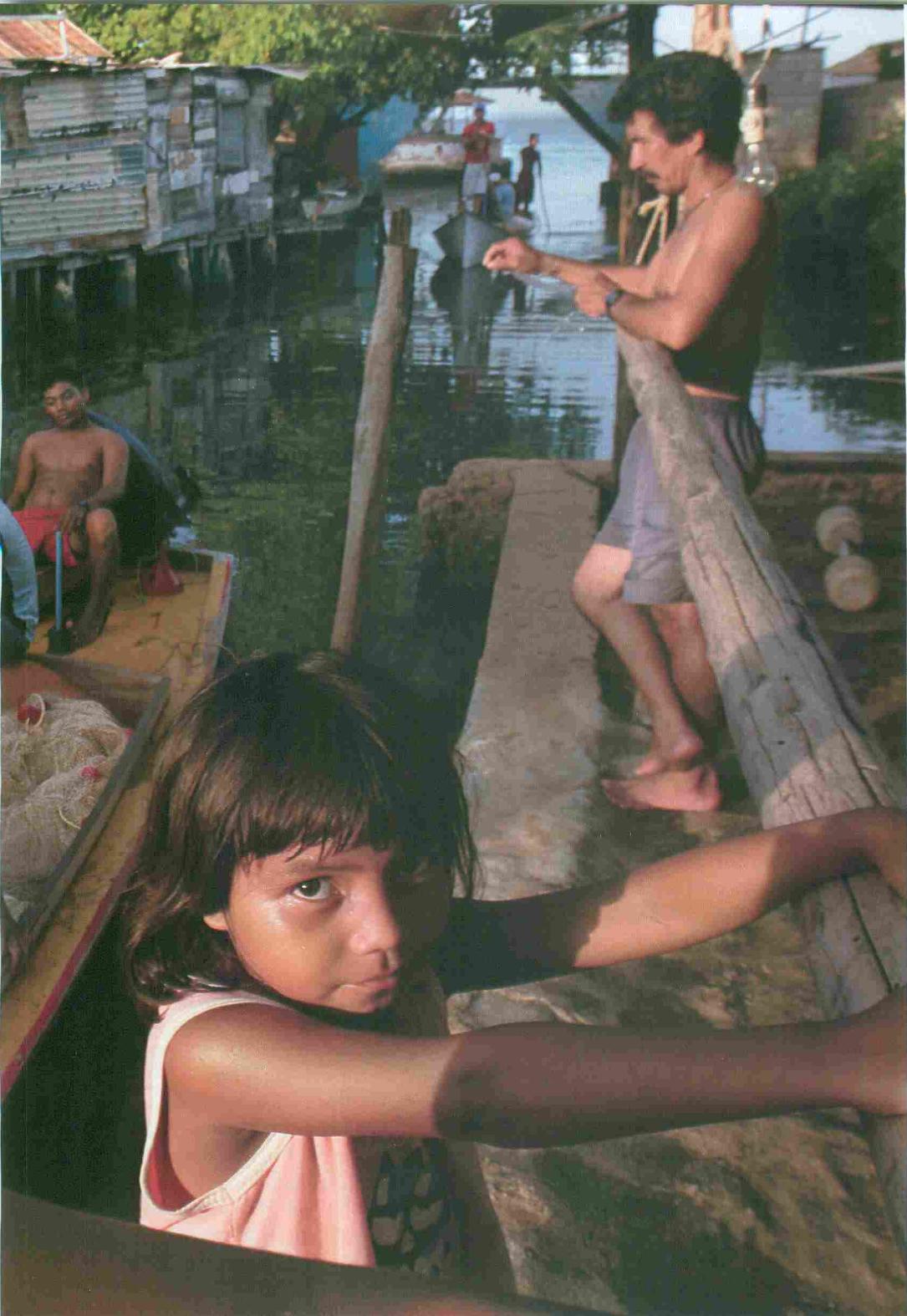
here she was coordinating a *misión cultura*, which encouraged young people in La Vega to form community folk dance and music groups. Thanks to another *misión*, she was working toward a college equivalency degree and receiving a monthly stipend in addition to the training. More important than that—much more important—she said, "*Con Chávez tengo mi lugar*—With Chávez I have a place where I belong. Before, we, the poor, were nothing. Now we are recognized." How could she deny the excitement and loyalty that made her feel?

**S**o the conquest of the poor by Hugo Chávez has progressed year after year, although his opposition at home and abroad would no doubt like to tell Ramírez that the changes in her own life are the result of profigate squandering of oil money on short-term fixes for deep-rooted problems, that the president will be respectful and considerate of her needs and opinions only as long as those opinions favor him, and that Venezuela's leader is playing a dangerous game of brinkmanship with the world at large. These are only dire predictions for a distant future, whereas Chávez's offer



## STRANGLED WATERWAYS

By Mark Miller  
Photographs by Steve McCurry



Families in Santa Rosa de Agua harvest shrimp from Lake Maracaibo—when they can. Rapid growth of an invasive plant (*Lemna obscura*) in waters made nutrient-rich by raw sewage, farm fertilizer, and petrochemical pollutants has fouled boat engines, clogged nets, and choked off livelihoods.

of help for people in urgent need is for right now.

With the support of millions of Venezuelans like Trinidad Ramírez, Chávez, the hallucinatory speaker, has gone from freak to phenomenon—an overwhelming figure who will cast a long shadow over Latin American politics for many years to come. How did that happen?

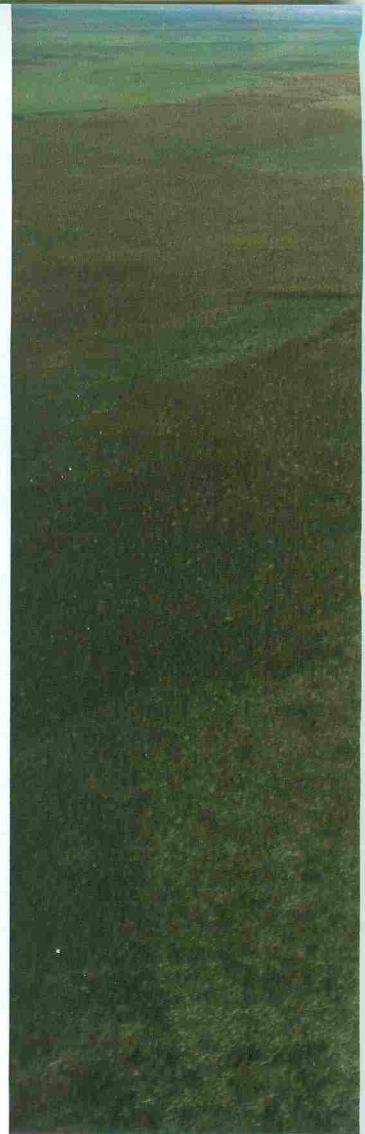
Certainly, the skinny backwoods kid who joined the military, he has often said, as a way to get to Caracas to play baseball in the big leagues did not look promising when he first took a handful of confused leftish political notions and knotted them into a plot to stage a coup, but he was helped immensely by his country's history. Following a long series of military dictatorships that had poisoned its political life since declaring independence from the Spanish crown in 1811, Venezuela had evolved into Latin America's most stable democracy, as it liked to boast to the world. (Although some might have pointed out that Costa Rica, say, had gone considerably farther along that road, and without the benefit of the oil gusher that fueled Venezuela's roaring economy.)

Starting with the overthrow of Gen. Marcos Pérez Jiménez, last of the military dictators, in 1958, Venezuela undertook the construction of something like a welfare state; some give credit to Pérez Jiménez himself for starting the process. Although tremendous problems of social inequality were not addressed, and racial prejudice continued to take its toll on social mobility (Chávez, who has a typical mixture of Spanish, African, and Amerindian blood, is still regularly described as "that half-breed" among the upper classes), in that time Venezuela was transformed from a country with an impoverished, mostly rural, population of seven million to one of the healthiest nations in Latin America, with a life expectancy of 74 and an outstanding literacy rate among a people nevertheless condemned to live largely in the barrios.

But when world oil prices sank, as they do periodically, and the rate of growth of the population outstripped the government's investment in health, education, and public works, Venezuelans lost their trust in a government that belonged largely to the elites. Carlos Andrés Pérez, a president who ruled lavishly during the 1970s oil boom—and, it would seem, to his own lavish profit as well—was reelected in 1988, in the midst of a severe economic crisis, on the strength of

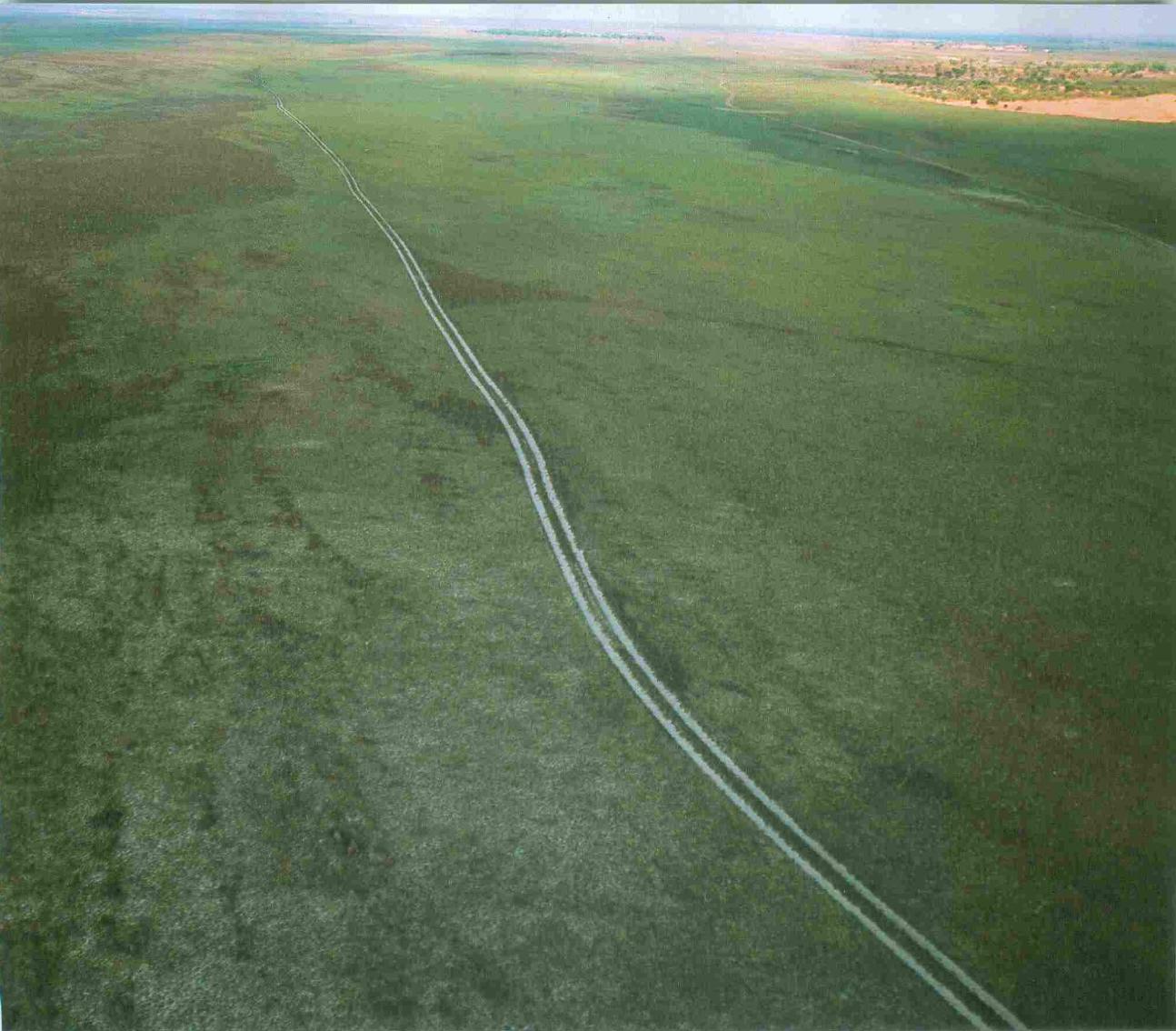
## GREAT PLAINS

Off-road 4x4 tracks cut across the western state of Apure, part of a 70-million-acre mix of forest and savanna known as the *llanos*. Conservationists call for this vital ecosystem to be protected, but Chávez supports land redistribution and agriculture in such areas, in part to achieve food independence for Venezuela, which now imports nearly three-fourths of its food.



people's faith that he could bring the good times back. What he did instead, in February 1989, was announce a package of stern economic measures that included an immediate increase in public transport fares. The first riots in Venezuela's modern history followed. Hundreds were killed when the president ordered out troops to fire on the people, something that had not occurred since the days of dictatorship, and Venezuelans felt they no longer recognized their own country.

Three years later, Hugo Chávez, by then a loquacious and single-minded lieutenant colonel with a significant following in the officer corps, tried to topple Carlos Andrés Pérez in a coup. The coup failed, but history was made. Chávez was thin and well behaved then, in a way that brought out many women's mothering instincts, and possessed of an emotional intensity that coursed like lightning through the exhausted

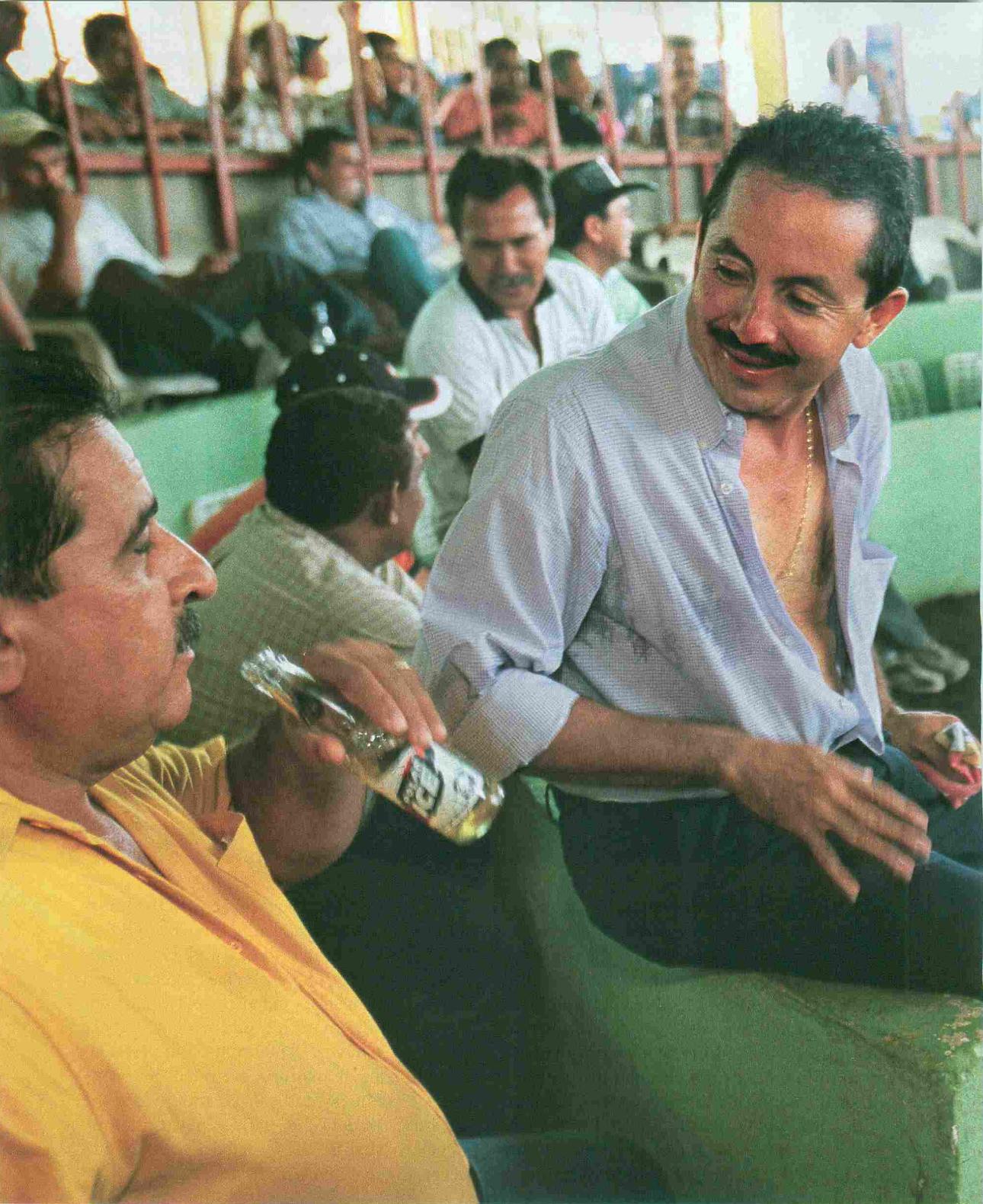


political scene. He did two years' prison time and left the army on his release, well-known to just about anyone who had turned on the television during the hours of his uprising. At election time in 1998, voters would remember not the hothead who had sought to destroy an elected government through force but the fiery upstart with proud military bearing who had promised to overturn a corrupt and tired system. With no political base of his own and a brand-new party, Chávez beat his opponent by a margin of more than 15 percent. Not even his supporters understood then what they had set in motion.

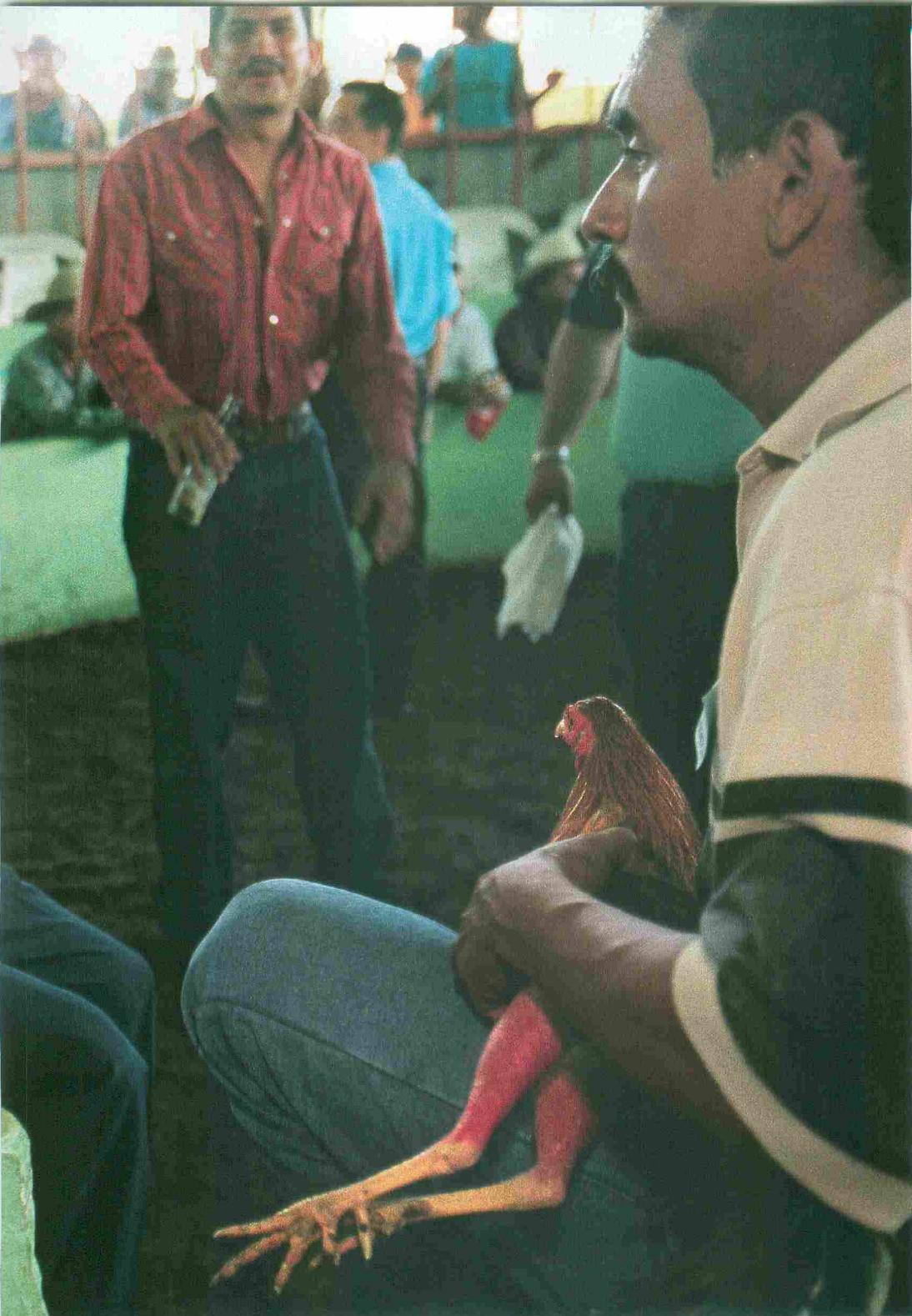
In the intervening years, Chávez has actively involved himself with every aspect of his nation's life. He decides where to place an agricultural cooperative on the overtaken cattle ranch and what produce will be grown there, how to allocate foreign currency reserves, and what

construction projects get priority in the housing ministry. He announces these changes on the weekly television program and then improvises a few more. Voters who have already given him three strong electoral victories feel passionately about the man they address face-to-face simply as "Chávez." The opposition's feelings about him are, if anything, even stronger. Many analysts say he has radicalized and divided the citizenry. On the other hand, Chávez's followers believe that he has revealed, and refused to accept, the real divisions in Venezuela.

**M**any of the most dramatic changes in the country since Hugo Chávez came to power were signed into law in the Capitolio, a grand 19th-century compound in the center of Caracas where the National Assembly—the legislative branch—holds session. A couple of



**SHOW OF PRIDE**



Cockfights and beer keep the crowd happy at the yearly patron saint's day celebration in Elorza, a small town on the Arauca River near the Colombian border. Elorza's mayor proudly tells visitors that Chávez—a Venezuelan military academy graduate who served part of his 17-year army career here—often returns for the festival.



## HOMEGROWN CULTURE

*El Camino a la Fama*, or *Path to Fame*, Venezuela's version of the British hit *Pop Idol* shares the Televen network's Saturday lineup with *Baywatch*, *Fresh Prince of Bel Air*, and *CSI: Miami*. New regulations mandate a share of airtime for locally produced content. A quarter of songs on radio must be folk music, like that played by harpist Edgar Vásquez (below). Increased exposure has spurred demand for concerts and recordings featuring the flutes, maracas, and guitars of Venezuelan tradition.



blocks away is the house where Simón Bolívar was born in 1783. Bolívar, who dreamed of a great Pan-American republic, is not just Chávez's hero; he appears regularly on altars and shrines in Venezuelan homes. Yet in his final years he lived in poverty, rejected by the politicians he had helped bring to power, who were emerging as satraps and petty warlords. Bolívar lamented that he had "plowed the seas." Still, the Capitolio, with its classic proportions and its French republican architecture, remains a symbol of the great Andean nation the hero envisioned.

At his inauguration in 1999, Chávez swore to overturn the "moribund" 1961 constitution. Six months later, in elections for delegates to his Constituent Assembly, members of his party or those allied with it won 125 of the 131 seats. The assembly's task was to create a constitution that would facilitate Chávez's concept of *democracia participativa*. But Carlos Correa, a lawyer who is the general coordinator of the respected human rights organization Provea, is among those who are not persuaded by the results. "There is a great deal of talk about democracy now, but in practice all decisions are concentrated in the president's hands, down to his own party's lists of candidates," Correa said. Even the armed forces now answer more directly to Chávez. "In the past all high-ranking promotions were reviewed by the Senate Armed Services Commission. Now, by law, they're reviewed directly by the president."

The assembly also made it nearly impossible for opposition parties to participate in elections on equal terms with the sitting candidates, because the new constitution removed all provisions for government funding of electoral campaigns. In one of the articles of the constitution that appears to have been designed expressly for Chávez, delegates passed legislation that allows presidents to stand for immediate reelection and extended the term of office from five to six years. (Chávez is the all-but-certain winner of elections scheduled for December 2006.) The new constitution also reduced the space for dissent by replacing the old bicameral Congress with a unicameral National Assembly. Their work finished, the delegates called presidential, municipal, and state elections (in which Hugo Chávez was reelected), and elections to the new National Assembly, in which Chavistas again won a majority.

But as Correa points out, the institutional alterations did not end with the Constituent Assembly. He is particularly concerned about modifications voted by the Chavista legislators that allow new members of the Supreme Court to be confirmed by a simple majority. The high court is now Chavista, and since the National Assembly also appoints all judges, the justice system in Venezuela has become almost entirely pro-Chávez. All in all, the result of the new constitution, Correa said, "has been the greatest institutionalized concentration of power in a single man in Venezuela's history." But there is more to come: In elections last December, in which nearly all the major opposition parties refused to participate, the Chavista parties won all the assembly seats, and they are expected to approve

**The middle classes appear to be almost unanimous in their hatred of him. Doctors have marched in the street against him.**

Chávez's call for a new constitutional assembly, whose main task will be to allow a president to be reelected an indefinite number of times, along with another change dear to Chávez's heart: the redesign of the national seal to show Simón Bolívar's horse charging leftward.

**D**uring an assembly session last September, a roiling, deafening tumult was in progress, but Iris Varela was one of the few *asambleistas* who was not yelling, arguing, and otherwise ignoring the assembly president's repeated pleas for silence and respect. Varela, one of Chávez's key operators on the assembly floor, was instead taking notes, and listening, and talking into the chairman's ear. She is known as Comandante Matchhead for her red hair and inflammable temper, and after less than a minute of conversation I understood the nickname but found her hard to dislike—she was so young and dead earnest and lively. In a common room where we could hear each other, I asked in what way she thought that *chavismo*, with its overwhelming majority in the assembly, and its weight in the court system and in the media—in which the largest circulation by far belongs to

a pro-Chávez newspaper, and the president can monopolize the airwaves for hours on end—in what way, I asked, did chavismo think it could best guarantee the rights of the opposition?

Varela's eyes flashed. "If there were a patriotic opposition," she began, "they would play a leading role. But they are only interested in getting the United States to intervene here," and in plotting coups. (A partially successful coup removed Chávez from power for three days in 2002.) "They don't have sensible proposals to make. They do not make the cause of the people their own!"

I suggested that a member of the opposition might legitimately have different sympathies and political opinions from a Chavista. "But they don't denounce the right things!" Varela exclaimed. "Like corruption—they could take up the flag of that noble cause. They never go beyond denouncing a scandal, and when that scandal is extinguished, they bring on another scandal. That's why we reformed the penal code, so that they won't be defaming us with impunity," she said triumphantly. Indeed, the new reform mandates up to five years in jail for crimes by the media that range from disrespecting the president to inciting panic—offenses that could at whim include unflattering photographs, nasty political cartoons, and vaudeville sketches, as far as I could tell.

Varela speaks faster as her indignation mounts, and at last I had to ask if she could slow down and, pretending for a moment that the opposition didn't exist, simply address the question of human rights. Varela smiled and made an effort, but within seconds she was at full gallop again, denouncing the noted human rights lawyer Carlos Ayala, who, on the basis of pitifully slight evidence, was being charged with conspiring to overthrow the Chávez regime during the 2002 coup. Varela stated fiercely that, if he had been charged, the proof against him must exist. (Charges against Ayala have since been dropped, but the investigation is still open.)

Finally I asked what her constituents expected from her back in Táchira, a state that borders Colombia and has many, and complicated, problems, including an incipient drug trade, use of its territory by guerrillas, and high immigration rates. Varela thought for a moment and answered, in her fiery way, "Loyalty!" Anything else? "Unconditional loyalty, and hard work," she said.

As Varela headed back to her assembly

session, a photographer I'd met earlier caught up with me. "You missed it," he said with a grin, and then he and his colleagues showed me pictures they'd taken minutes earlier, which showed Congressman X, a Chavista, beaming Congressman Y, an oppositionist.

**T**his too was a novelty of the Chávez era. The two parties—one liberal, one conservative—that ceremoniously rotated power between themselves during the entire second half of the 20th century made an entrenched vice of cronyism and the distribution of privilege, but congressional fistfights and politics as the art of denouncing enemies were not the custom before.

The president of Venezuela has many enemies—partly, at least, because he so clearly relishes the fight. In late 2002 the anti-Chavista workers and managers of Petróleos de Venezuela joined forces to stage a two-month strike, crippling the Venezuelan economy. The president sought to take control of the company by firing nearly half its workforce, but there is no way to tell whether those who got to keep their jobs are any more loyal to him now than they were before the strike. The middle classes appear to be almost unanimous in their hatred of him. Doctors have marched in the street against him, demanding better wages. An unknown number of military personnel—including several army officers I interviewed—dislike Chávez and his leftist politics intensely, if not openly (many others joined forces to lead the coup against him in 2002 and have since been discharged). For the moment, however, the aggregate numbers of his enemies don't add up to an opposition, and they have lost every battle so far.

In fact, his opponents told me repeatedly, Chávez has so many enemies that if it weren't for oil, he would no longer be in power. Oil is by far the largest source of foreign income: From 1928 to 1970, Venezuela was the largest oil exporter in the world. The country ranks fifth now, but there is more oil money than ever. The war in Iraq and gradually shrinking oil reserves worldwide have combined to push the price of oil from just over nine dollars a barrel the year Chávez took power to a recent high of more than sixty. The misiónes programs could hardly exist without this extravagant income.

Is oil really the key to Chávez's success? His



**WORKING THE LAND** José Artiaga, at right, and nephew Osman Marcelino Rojas grow vegetables on a cooperative farm near El Pao. In five years the government has distributed some five million acres of state land to more than 130,000 such groups. Venezuelans are still waiting for these new farms—and Chávez's new social order—to fulfill their promise.

supporters say that previous regimes used the rivers of oil wealth that streamed through the economy for their exclusive profit, but no one else seriously claims that the new elites—with their gleaming Mercedes-Benzes, flashy watches, hunger for pricey real estate, and, above all, their direct access to the budget—lead austere lives. It is also said that only oil has allowed Chávez to get away with his anti-U.S. policies and his cheeky foreign-policy rhetoric: Venezuela's head of state publicly called President Bush a *pendejo*—in Venezuela, a moron, a jerk—but sales of oil to the U.S. have continued at their same smooth pace during the years that Chávez has been insulting Bush.

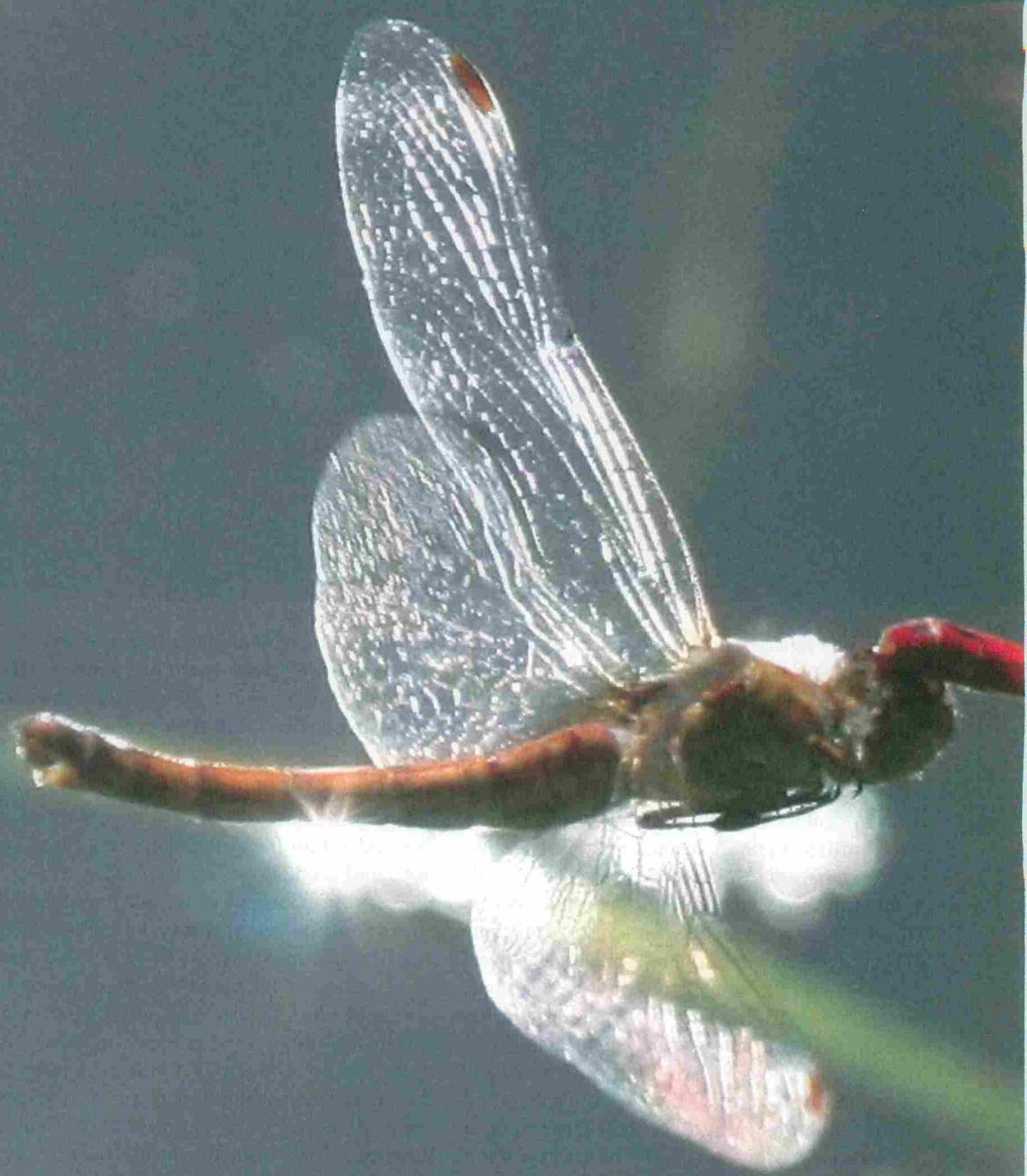
Oil money and heavy public spending help explain what is happening in Venezuela, of course, but in the end only Chávez can account for Chávez. The sheer force of his personality, the astonishing and overwhelming strength of his self-satisfaction, his utter lack of inhibitions, his inflamed nationalism, his obsessive need to cast

himself as a hero of the people, forever vanquishing the “demonios” (demons) that conspire against him and against the Venezuelan nation, are a hypnotic and unique combination.

Every time Hugo Chávez throws his weight around on the world scene, the admiration of poor people everywhere will likely increase. Venezuela's leader may be unpredictable and unreliable, but he is an outstanding politician, and he has understood an essential lesson that lesser, or more cautious, politicians ignore at their risk: The world has many times more poor people like the young barrio activist Trinidad Ramírez, so desperate for a future, than rich people like the cattle rancher Carlos Azpúrua, so anxious to conserve the past. □

---

► **Looking ahead** Share your opinion about Hugo Chávez's prospects in our forum. Browse a gallery of Web-exclusive images, view video of a street festival, and meet photographer Meredith Davenport at [ngm.com/0604](http://ngm.com/0604).



dragonflies



Airborne after mating,  
a male vagrant darter  
keeps the female  
in tow to prevent  
competing males  
from inseminating  
her. Dragonfly sex  
is often rough, even  
fatal. Now science  
is learning why.

*SYMPETRUM VULGATUM*  
PHOTOGRAPH BY GEORG RÜPPELL

# strange love



**Using claspers at the end of their abdomens to grip their mates, male white-legged damselflies guard against rivals as females lay eggs on the Danube River. Both damselflies and dragonflies belong to the Odonata order, 6,000 species strong.**

*PLATYCNEMIS PENNIPES*

A predator is born: Wriggling from its larval skin, this clubtail dragonfly faces a race for mates—and food. Its adulthood may last only two months—60 days of terror for other insects. Huge compound eyes give dragonflies acute vision for hunting, earning them the nickname “mosquito hawk.”



GOMPHUS FLAVIPES

By Jennifer Ackerman  
Photographs by József L. Szentpéteri

## You may have seen their antics

on a languid summer day: Somewhere on the reedy fringes of a pond, a male dasher dragonfly pursuing a female, like two hyphens of lightning. Or a tiger-striped spiketail diving, twirling, flashing its gossamer wings, then in a blink, meeting a mate to ascend together into the ether. Or a linked pair of brilliant green darners hovering as one over the dark water, the male towing the female, darting forward, then back, then straight up with the kind of aerial agility of which we masters of the helicopter can only dream.

From a distance, dragonfly rituals of courtship and sex look harmless, even romantic. But a close look at their mating game reveals a harsher tale of sexual harassment and conflict. Take the jewelwing *Calopteryx splendens*. Some males dispense with courtship altogether and just snatch unwary females while they're warming in the sun—even immature ones, shimmer-fresh after emergence from their larval youth. Others, called “stealers,” attack and split mating pairs by ramming, pulling, and biting them; still others, “water lurkers,” grab a female in the midst of egg laying so they can have their way with her, even if she drowns in the process. Females, for their part, attempt to escape this boorish behavior by flipping, zigzagging, spiraling upward or downward, submerging in water, fleeing at high speed, or fighting back, sometimes murderously.

Why such a war between the sexes? Scientists seeking clues to the answer are finding in dragonflies a bizarre mix of cooperation and conflict, instinct and experience, which may explain not just their odd reproductive habits but also their dazzling diversity of colors and species.

When my grandmother was growing up, dragonflies were known as devil’s darning needles and horse stingers, considered an annoyance by

some, a danger by others. In many places the insects are still under suspicion, dubbed finger cutter, horse killer, ear stick, and eye pisser. They are poisonous. They will sew together your lips. They will crawl into your ear and penetrate your brain. They will sting you. They will bite you. They will bring you rotten luck, or worse.

“Not so,” says Philip Corbet, a biologist from Cornwall in England. “Dragonflies are neither nuisance nor danger—that is, unless you’re a mosquito.” Or another dragonfly.

Corbet is fixed on a pair of elegant blue-tailed damselflies on the sunny bank of a small lake in Spain—one azure, one ocher, “both from the species *Ischnura graellsii*, renowned for having females of more than one color,” he says, and also, for the male’s distinctly “ungallant” behavior. “To secure a copulation, a male will seize a flying female and sometimes even bite her wings at the base.”

This pair, however, is locked in an embrace that can only be described as an ersatz heart.

Anyone who has watched dragonflies mating in the bright air has seen a wonder of evolution, Corbet says. Odonates, as they’re called, or “toothed ones,” have been around for more than 300 million years, which has given them time to figure all the angles on sex. Judged by their longevity and diversity (6,000 species) and the scope of their distribution (every continent except Antarctica), they’re *(Continued on page 114)*



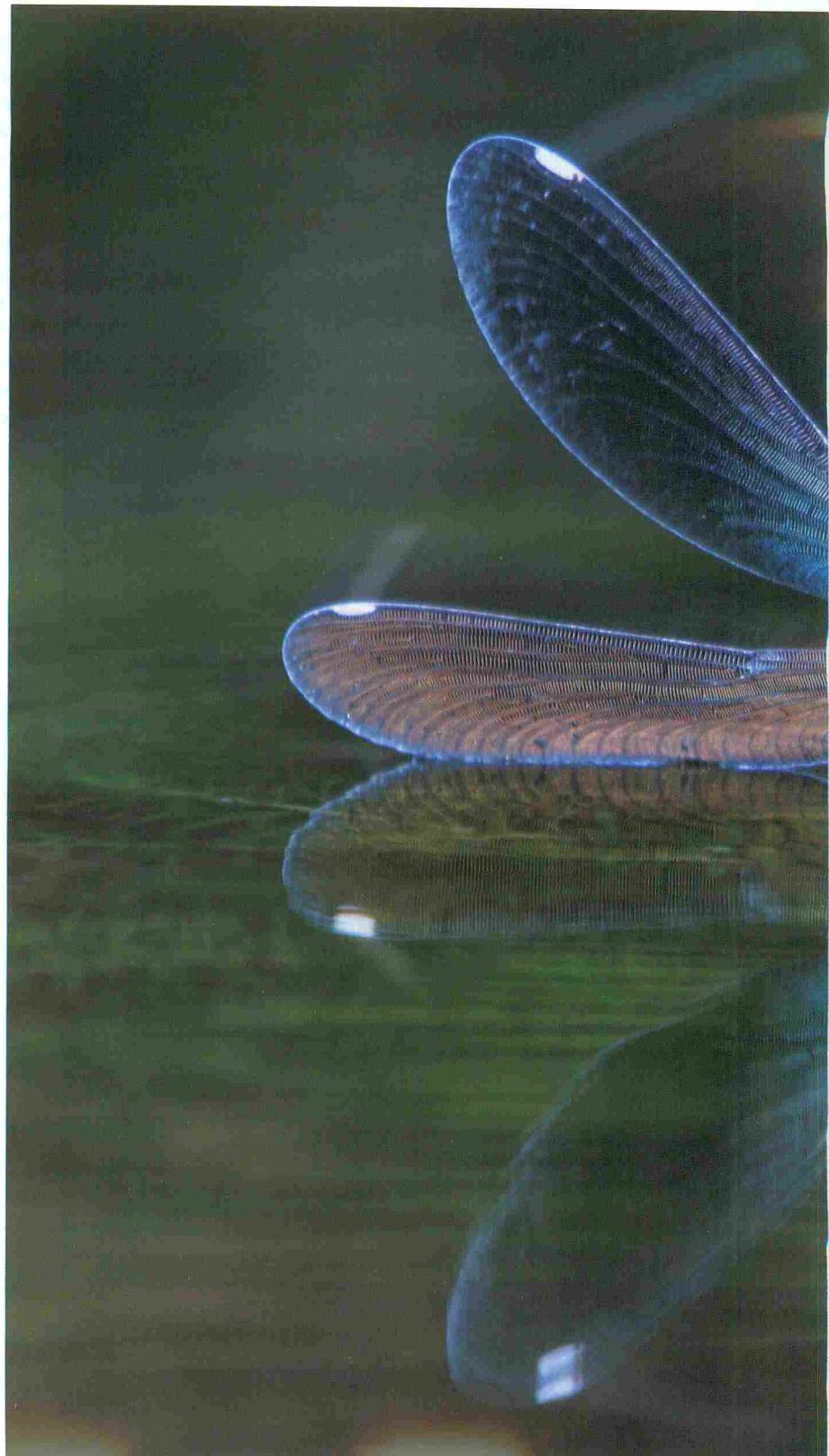


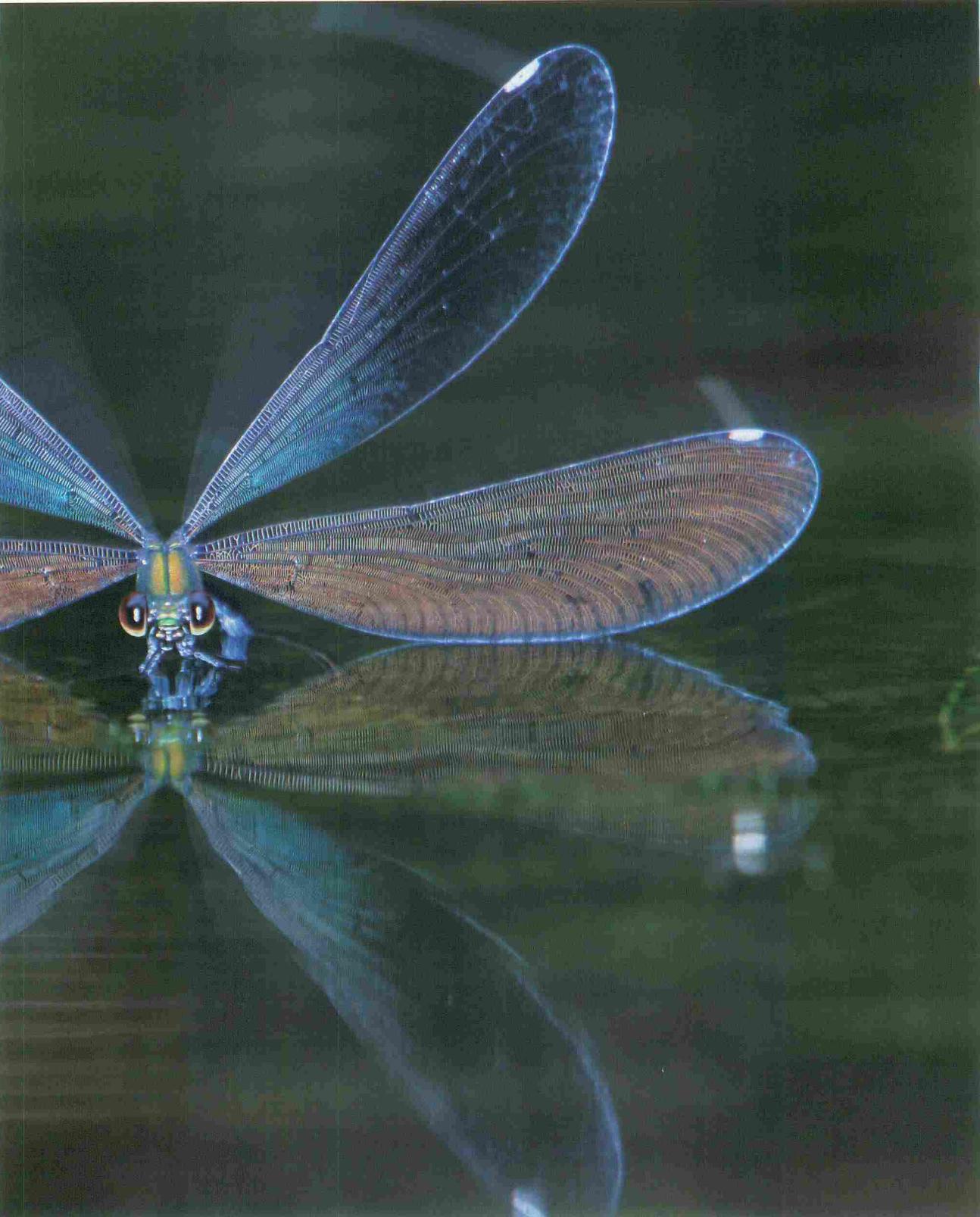
**Not even an hour after their final molt, soft-bodied clubtail dragonflies are vulnerable to birds and other predators. In a few days their bodies will harden, and they'll soon be ready to mate. It's a violent act in some clubtail species: The male's viselike mating claspers often pierce the female's head.**

*GOMPHUS FLAVIPES*

**After mating, a female Formosan jewelwing beats her white-tipped wings as she deposits fertilized eggs into plants just below the surface of a stream in Taiwan. After eggs hatch, the larvae sink to the bottom for six months before emerging.**

MATRONA CYANOPTERA





# Dragonflies are neither nuisance nor danger—that is, unless you're a mosquito. Or another dragonfly.



TRIACANTHAGYNA DENTATA (DRAGONFLY LARVA);  
MEGALOPREPUS CAERULATUS (DAMSELFLY LARVA)

one of nature's great reproductive success stories.

Corbet brings his net close to the coupled pair. He keeps the net's shadow low, then whips the net over with a quick flick of the wrist. Such skillful fliers are dragonflies and damselflies that they often make a mockery of such efforts at capture. (The difference between a damsel and dragon, in a nutshell, is that the damsel is small and slender and holds its wings over its back when at rest; the more robust dragonfly holds its wings outspread.) But Corbet is a master. As a child of six, he fell helplessly in love with the insects. Now in his 70s, with two wings of snow-white hair and a full white beard, he is the doyen of dragonflies and author of the "bible" on the subject.

He pulls the male out of the net and turns him upside down to look at his genital organs.

At the tip of the male's abdomen are its testes; at its base, behind its legs, is a penis and a small swollen pouch for storing sperm. Male dragonflies sport two sets of sex organs, the prerequisite equipment for a mating system that is unique in the insect world. Before he copulates, a male dragonfly must in essence self-inseminate, moving his sperm from the testes to the storage pouch

and into the penis. Here comes the tricky part. He must grip a female by the head or thorax and hold her in the tandem position, with claspers at the tip of his abdomen that fit neatly, like a lock and key, with a special plate on her thorax or behind her eyes.

"If it seems that dragonfly biologists are inordinately preoccupied with sex, they may be excused," Corbet says. Sexual behavior is key to understanding how dragonfly species got to be the way they are. And sexual organs are key to their identity. "Slight differences in this clasper-plate system are what define some species that are otherwise nearly impossible to distinguish."

Once the pair is in tandem, and the female is receptive to the overtures of her suitor, she will curl the tip of her abdomen around to bring her vagina in touch with his penis, working the pair into that heartlike copulatory position.

"It's a jolly difficult business," says Corbet, "and there's much speculation about how it evolved." Some experts believe that the male originally placed his sperm package on the ground. This was risky, given what Corbet calls the "predatory proclivity" of some female dragonflies to



CROCOTHEMIS ERYTHRAEA (SCARLET DARTER); ERYTHRÖMMA VIRIDULUM

**Eating on the fly, a scarlet darter (above) consumes a damselfly over the Danube. All Odonata species are carnivorous. In Panama a darner dragonfly larva (opposite), photographed in a tank outside the water-filled tree hole where it hatched, feeds on the larva of a helicopter damselfly.**

banquet off their partners. Males may have adopted the tandem position to protect themselves from becoming their lovers' prey. Over the ages they evolved ways of keeping their sperm packages safely tucked under their abdomens and, eventually, a complex genital "sperm bank" for storing it there.

So, too, they evolved strategies for effectively guarding their mates and fending off rivals. After sex, many pairs do not disengage but fly about in tandem, the male guarding the female by continuing to grasp her while she lays her eggs. This may serve the female, protecting her from clamoring suitors so she can oviposit in peace.

But there's nothing chivalrous about male sexual behavior. Some males embrace females with spiny claspers in a viselike grip that causes damage. Look closely at the eyes of a female darner, and you may well see dark puncture marks. This sort of abuse appears widespread among some dragonflies. In one study of 12 species of clubtails by Sidney Dunkle, a biologist then at the University of Florida, 88 to 100 percent of all females had holes in their heads, caused by a male's iron hold. The aptly named dragonhunter

(*Hagenius brevistylus*) earned the dubious distinction of inflicting more severe damage than any other dragonfly: The spines of his appendages gouged the female's eyes, punctured and split her exoskeleton, and pierced her head, so that a "maximally damaged" female had as many as six holes of varying sizes punched in her head.

Grab, shake, bite, gouge, puncture, split, punch: It's enough to put anyone off sex.

In a brilliant experiment some years ago, Jonathan Waage of Brown University discovered the Rosetta stone to this strange mating behavior. Waage studied the jewelwing damselfly *Calopteryx maculata*. First he examined the sperm-storage organ of females after a couple of matings to determine whether sperm from a second mating was added to sperm from the first. He was surprised to find that the amount of sperm hadn't changed. Then he dissected pairs in the midst of copulation and studied their sex organs under an electron microscope. The experiment revealed that a male dragonfly uses his penis not just to transfer sperm to the female, but also to remove sperm left in her storage organ from previous matings. When he curls



**Adorned in camoufage markings that may deter predators, a newly emerged black-tailed skimmer hides in tall grass for extra protection against birds and wasps.**

*ORTHETRUM CANCELLATUM*



into that wheel position and begins his energetic **genital thrusting**, he's actually using his rigid, spoonlike, and sometimes spiky, penis to scrape out rival sperm before he deposits his own.

Such a ploy is necessary, Corbet says, because of female choice and sperm competition. A female nearly always mates with more than one male; it's in her interest to "upgrade" her fertilizations if she can, thereby exercising choice over the paternity of her offspring. Males want their sperm alone to prevail, so they have evolved strategies for purging other sperm and for discouraging mates from copulating with rivals. In this game of sexual chess, the last sperm into the female's storage organ wins by fertilizing her eggs.

Waage's discovery helps explain all sorts of cunning and perfidious dragonfly habits: why males harass females (to spread their sperm around); why they assume that weird heartlike copulatory position (the wheel facilitates the removal of rival sperm); why they guard females, and encourage them to lay eggs directly after mating.

This warring may have a surprisingly "creative" effect, says Ola Fincke, an evolutionary biologist at the University of Oklahoma. "It may be a novel mechanism for generating the different colors found among some females," she says, "and even entirely new species." In Fincke's view, the brilliant diversity of dragonflies may arise not only from adaptation to ecological niches,

**Named for its wing markings, a rubyspot damselfly rests on a leaf in Panama.**

**To repel competitors and stake out territories, males patrol stream sections favored by females for egg laying. Dragonfly larvae must have clean water to live. Pollution and loss of habitat are why hundreds of species worldwide are endangered or threatened.**



as with the famous Galápagos finches, but also as a response to sexual conflict.

Fincke studies *Enallagma* damselflies, known in North America as bluets. Mature female bluets come in two colors, the more common green type and also blue, the usual color of males. Why would females of different colors be maintained in a population? Fincke suspects that sexual harassment offers an answer. To measure harassment in bluets, she uses the “damsel-on-a-stick” technique: She glues live females to a perch and places them at the edge of a small pond, where males congregate. “Females may be harassed as often as five times a minute,” she says, “and not just by their own species, but by

males of closely related species.” Blue females suffer significantly less.

Studies show that females constantly hounded by suitors have lower fecundity. So, in the game of evolutionary one-upmanship, females may have evolved different color forms as a response to harassment. According to one hypothesis, a blue female would be hassled less because she looks like a male. Fincke has another explanation, with some startling implications.

“It may be that a female of rarer color doesn’t get harassed as much,” she posits, “not because she looks like a male but because she’s a less familiar form of female and doesn’t fit the male’s ‘search image’ for a mate.” In recent experiments, Fincke has shown that young males discover what a female looks like by exposure. If they’re reared with green females, they choose to mate with green females; if they’re reared with blue ones, they’ll go for blue. This suggests a revolutionary idea. Male dragonflies learn; their sexual behavior is not hardwired but more flexible, more “intelligent” than anyone ever imagined.

Like most scientists, Fincke follows questions, one leading to another. In her view, sexual conflict may explain another perplexing mystery: the relatively swift evolution of bluet species—18 new species in the past 250,000 years. Speciation is still poorly understood, and the explosion of new species in this genus in particular is a conundrum. “How do you explain the rapid evolution of dozens of different species of blue-and-black damselflies, all of them occupying essentially the same ecological niche?” she asks. Fincke suspects that females with slightly different thoracic plates are favored in evolutionary terms, because male claspers of some species won’t fit with them, so not as many males can harass them by taking them in tandem. In short, sexual harassment sparks the evolution of female plates that differ from the usual, which in turn triggers shifts in the shape of male claspers, in an evolutionary tango that gives rise to whole new species and unexpected variety.

The next time a pair of elegant jewelwing damselflies or feisty scarlet darters cavort in the flecked morning sun, consider it: evolution on the wing, in motion, right before your eyes. □

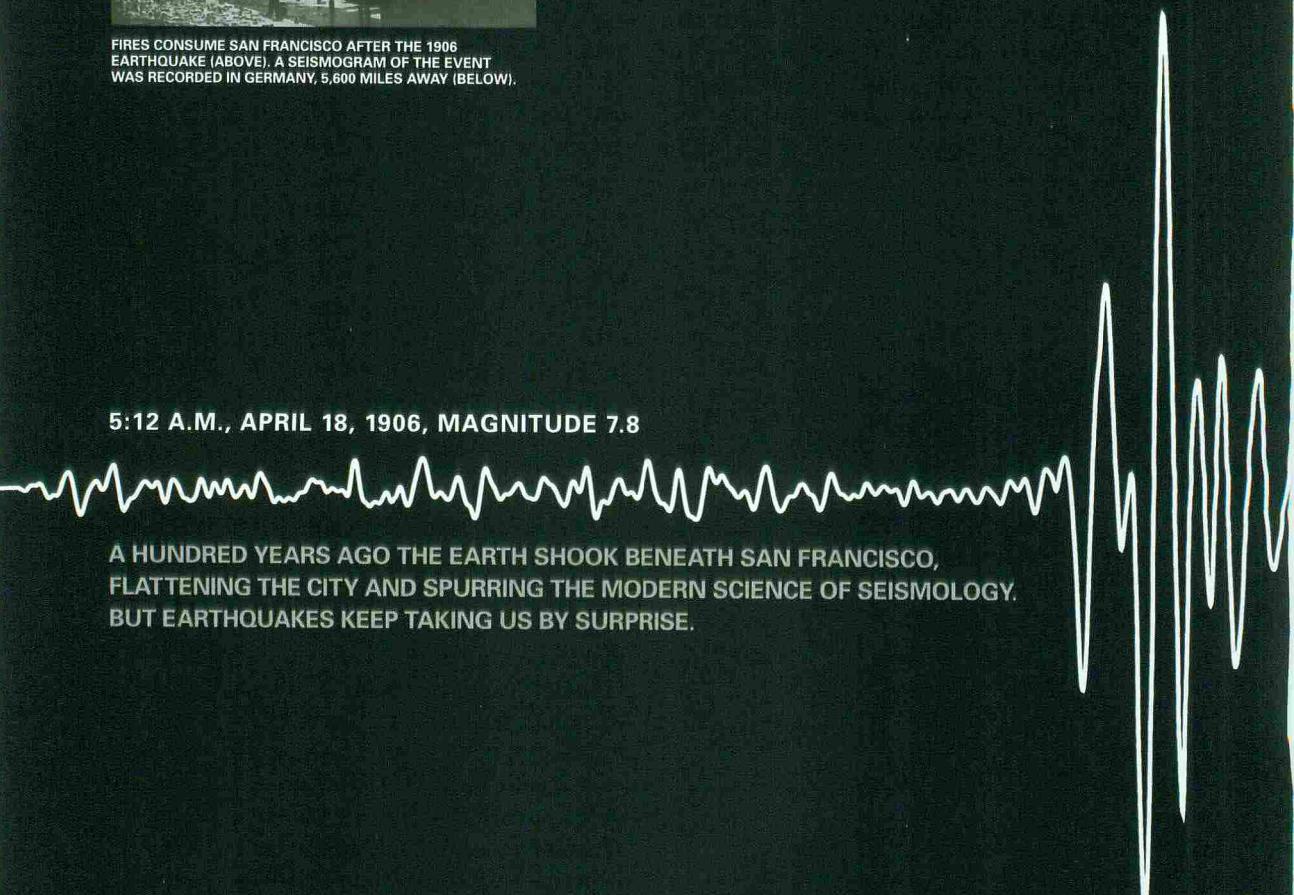
► **Sex on the Fly** View more photographs of dragonfly behavior and then download them to your desktop as wallpaper at [ngm.com/0604](http://ngm.com/0604).





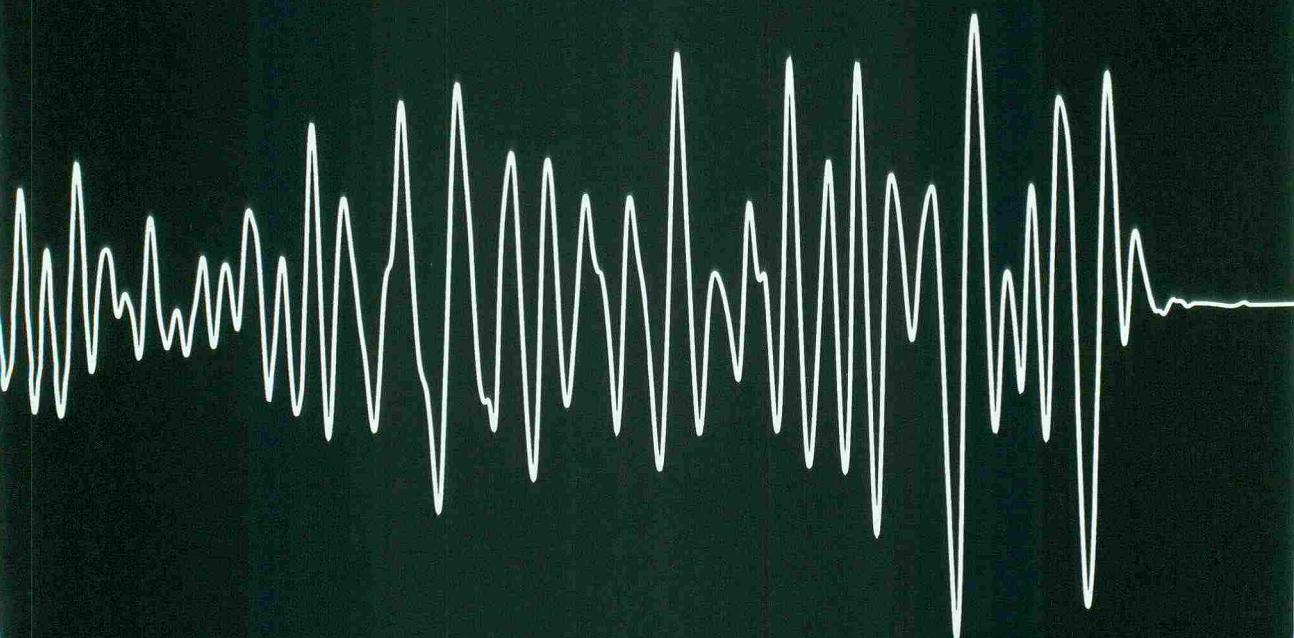
FIRE CONSUME SAN FRANCISCO AFTER THE 1906 EARTHQUAKE (ABOVE). A SEISMOGRAM OF THE EVENT WAS RECORDED IN GERMANY, 5,600 MILES AWAY (BELOW).

5:12 A.M., APRIL 18, 1906, MAGNITUDE 7.8



A HUNDRED YEARS AGO THE EARTH SHOOK BENEATH SAN FRANCISCO, FLATTENING THE CITY AND SPURRING THE MODERN SCIENCE OF SEISMOLOGY. BUT EARTHQUAKES KEEP TAKING US BY SURPRISE.

# The Next



# Big One

WHERE ON EARTH WILL IT STRIKE?



Will quakes ever be predictable?

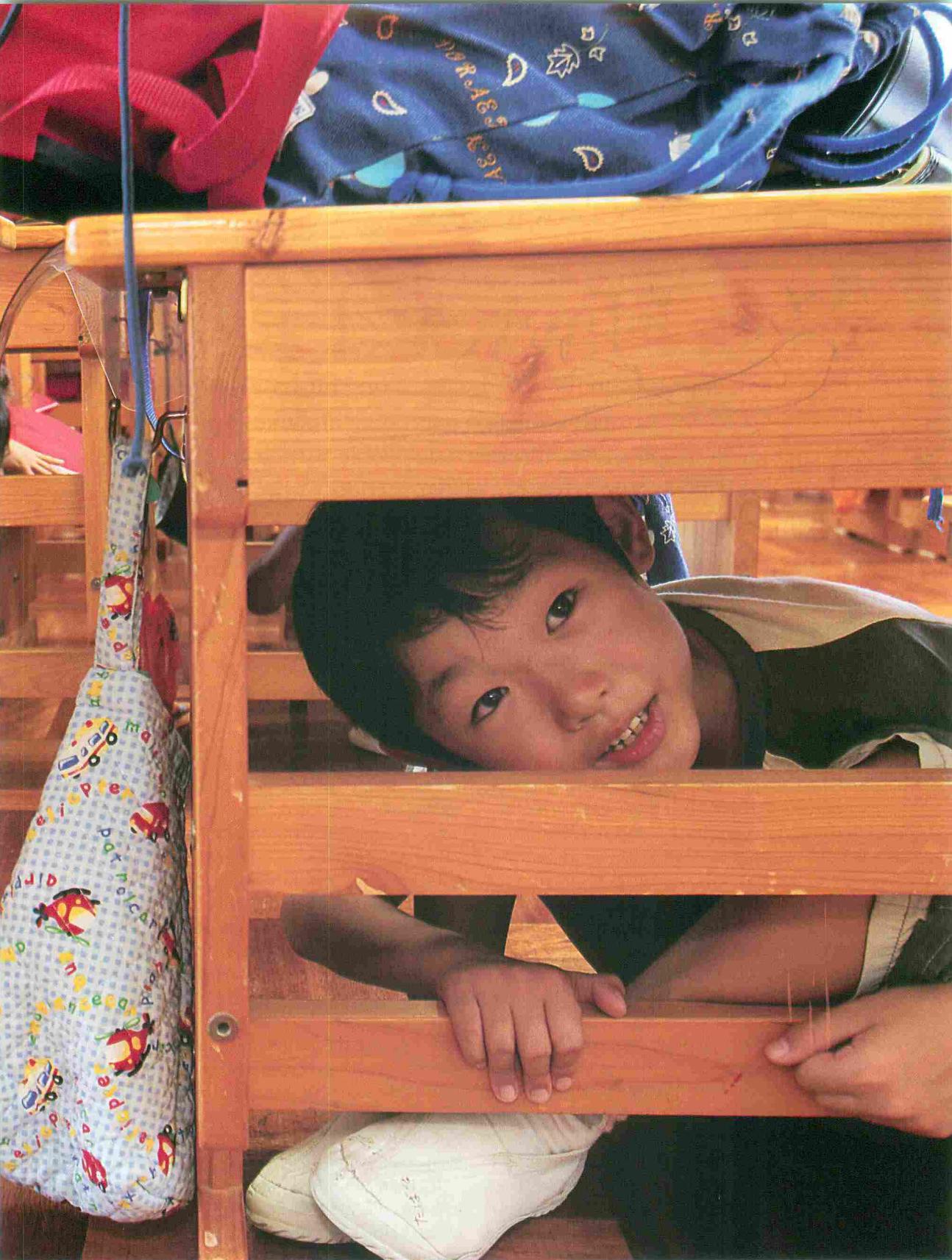


**Japan suffered its worst earthquake in a decade in October 2004, when a magnitude 6.6 rattled Niigata Prefecture, killing dozens and displacing 100,000 people. Scientists often can say where such extreme shaking is likely to hit—but still can't tell when.**

KIMIMASA MAYAMA, REUTERS



What precautions save lives?



Ducking under their desks, first graders in Shizuoka, Japan, learn how to shield themselves from falling objects. Schools hold drills like this every September to commemorate Tokyo's last big quake, in 1923, which killed more than 100,000.

BY JOEL ACHENBACH

PHOTOGRAPHS BY PETER ESSICK

# The Hayward Fault,

a long and lethal crack in the Earth, slices along the base of the Berkeley Hills and directly through the University of California. It passes under a theater and a couple of dormitories—no problem, they're just freshman dorms—and kinks the concrete steps outside California Memorial Stadium. You can straddle the fault, one leg up the steps, one leg down.

Then the fault runs underneath the stadium. One map shows it splitting the goal posts in the north end zone. It races downfield, barrels through the south end zone, and keeps going, careening down the street toward Oakland.

Back in the 1920s, when architects drew up plans for a grand football stadium at California's flagship university, they refused to let a geologic imperfection stand in their way. Earthquake science was still young, but the architects apparently realized that the Hayward is a fault, where two pieces of crust move past each other. So the architects gamely built the stadium in two halves, shaped sort of like a coffee bean, with a line, the fault, essentially splitting the structure. Each half of the stadium could move independently, riding the shifting crust without breaking a sweat.

Scientists now know that the Hayward creeps—it inches along steadily, although millimeters along would be more accurate. At the rim of the stadium, a Berkeley professor named Richard Allen shows me the result of 80 years of creep: a four-inch jog in the concrete, inelegantly bandaged with a rusty metal plate. We're both a little amused. What hubris to build a stadium on a fault!

But Allen points out the central problem: Faults don't just creep. They also "break." They "rupture." The creep happens in plain sight, but the breaking, the rupturing, the lurching—the earthquaking—will hit you blindsight.

Allen teaches Berkeley's oldest course on earthquakes. He calls it *Earthquakes in Your Backyard*.

The name couldn't be more appropriate, because the Hayward is a particularly dangerous fault. It hasn't spawned a major earthquake since 1868. Sometime soon, it could go.

Much of the stadium is built on soft ground, the kind that amplifies seismic waves. "In an earthquake," says Allen, "the entire field may liquefy." The players wouldn't sink into a jiggling vat of goo. They'd just get knocked off their pins —tackled by a temblor.

But of course no one on that field is worried about an earthquake. It's a hot summer day a few weeks before the start of the season. The players are worried about making the team. They're worried about beating Stanford.

YOU SEE RIGHT THERE a fundamental problem with earthquakes: They refuse to operate on human standard time. They're on their own peculiar schedule. Earthquake faults have a nasty way of combining patience with impulsiveness. Wait, wait, wait—lurch.

It's been a hundred years since the last big one in California, the 1906 San Francisco earthquake, which helped give birth to modern earthquake science. A century later, we have a highly successful theory, called plate tectonics, that explains why 1906-type earthquakes happen—along

with why continents drift, mountains rise, and volcanoes line the Pacific Rim. Plate tectonics may be one of the signature triumphs of the human mind, geology's answer to biology's theory of evolution. And yet scientists still can't say when an earthquake will happen. They can't even come close.

Some of the simplest questions about earthquakes remain hard to answer. Why do they start? What makes them stop? Does a fault tend to slip a little—telegraphing its malign intent—before it breaks catastrophically? Why do some small quakes grow into bigger quakes, while others stay small?

And there's the broader question: Are there clear patterns, rules, and regularities in earthquakes, or are they inherently random and chaotic? Maybe, as Berkeley seismologist Robert Nadeau says, "A lot of the randomness is just lack of knowledge." But any look at a seismic map shows that faults don't follow neat and orderly lines across the landscape. There are places, such as southern California, where they look like a shattered windshield. All that cracked, unstable crust seethes with stress. When one fault lurches, it can dump stress on other faults. UCLA seismologist David Jackson, a leader of the chaos camp, says the field of earthquake science is "waking up to complexity."

This regular versus chaotic debate isn't some esoteric academic squabble. Earthquakes kill people. They level cities. The tsunami of December 26, 2004, spawned by a giant earthquake, annihilated more than 220,000 lives. The magnitude 7.6 quake centered in Kashmir last October killed at least 73,000 people. Perhaps as many as a million would be dead or injured if a major quake felled the unreinforced high-rise structures of Tehran, Kabul, or Istanbul. One of the world's largest economies, Japan, rests nervously atop a seismically rambunctious intersection of

tectonic plates. A major earthquake on one of the faults hidden underneath Los Angeles could kill ten thousand people. A tsunami could smash the Pacific Northwest. Even New York City could be rocked by a tremor.

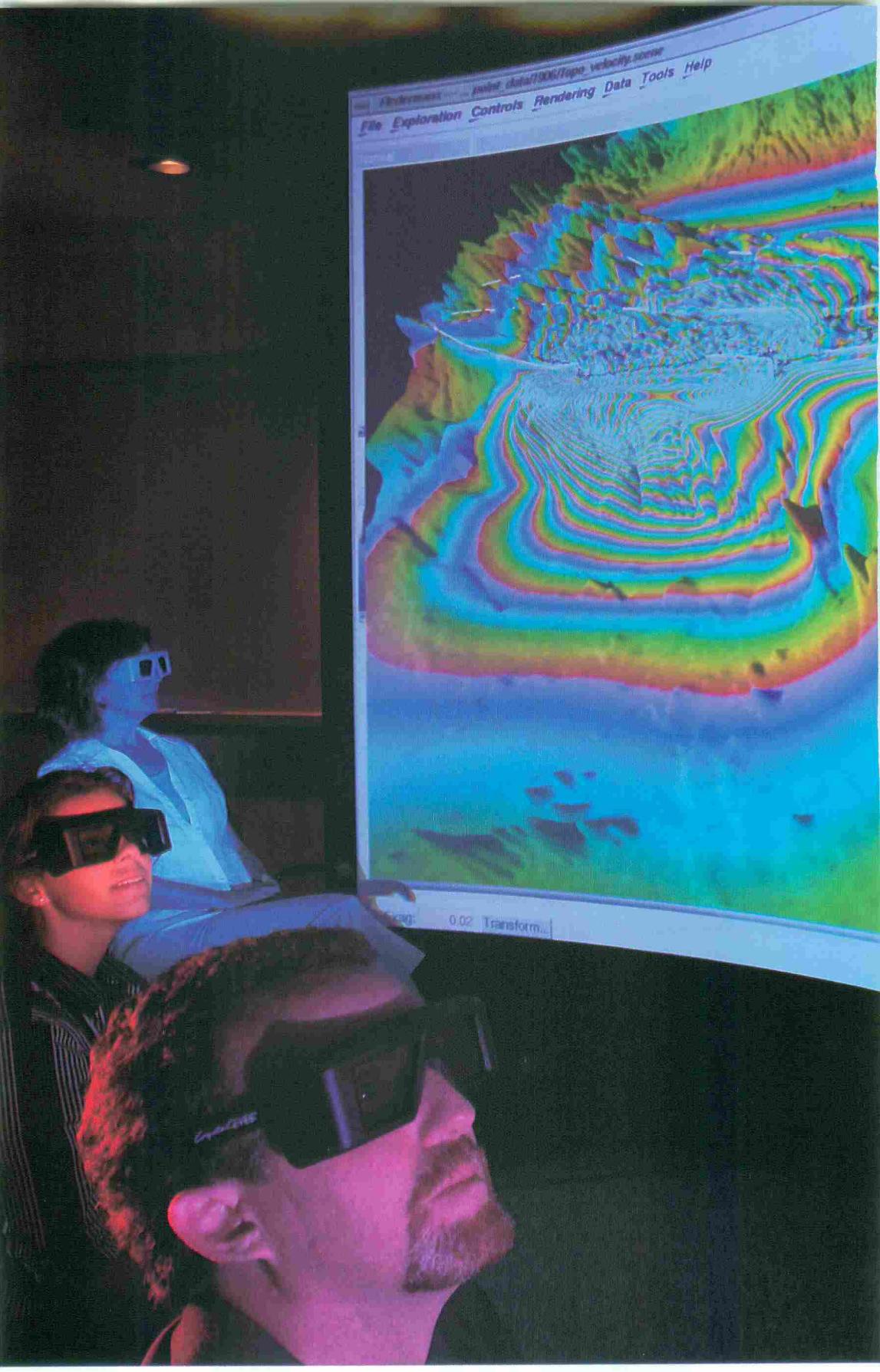
Yet at the moment, earthquake prediction remains a matter of myth, of fabulations in which birds and snakes and fish and bunny rabbits somehow sniff out the coming calamity. What scientists can do right now is make good maps of fault zones and figure out which ones are probably due for a rupture. And they can make forecasts. A forecast might say that, over a certain number of years, there's a certain likelihood of a certain magnitude earthquake in a given spot. And that you should bolt your house to its foundation and lash the water heater to the wall.

Turning forecasts into predictions—"a magnitude 7 earthquake is expected here three days from now"—may be impossible, but scientists are doing everything they can to solve the mysteries of earthquakes. They break rocks in laboratories, studying how stone behaves under stress. They hike through ghost forests where dead trees tell of long-ago tsunamis. They make maps of precarious, balanced rocks to see where the ground has shaken in the past, and how hard. They dig trenches across faults, searching for the active trace. They have wired up fault zones with so many sensors it's as though the Earth is a patient in intensive care.

Surely, we tell ourselves—trying hard to be persuasive—there must be some way to impose order and decorum on all that slippery ground.

WE'VE BEEN TRYING ever since the Earth humbled San Francisco. In April 1906 the city was the commercial and financial powerhouse of the West, a crucible of great fortunes, a place utterly decadent by reputation, gorgeous by any definition, with some 400,000 (Continued on page 133)





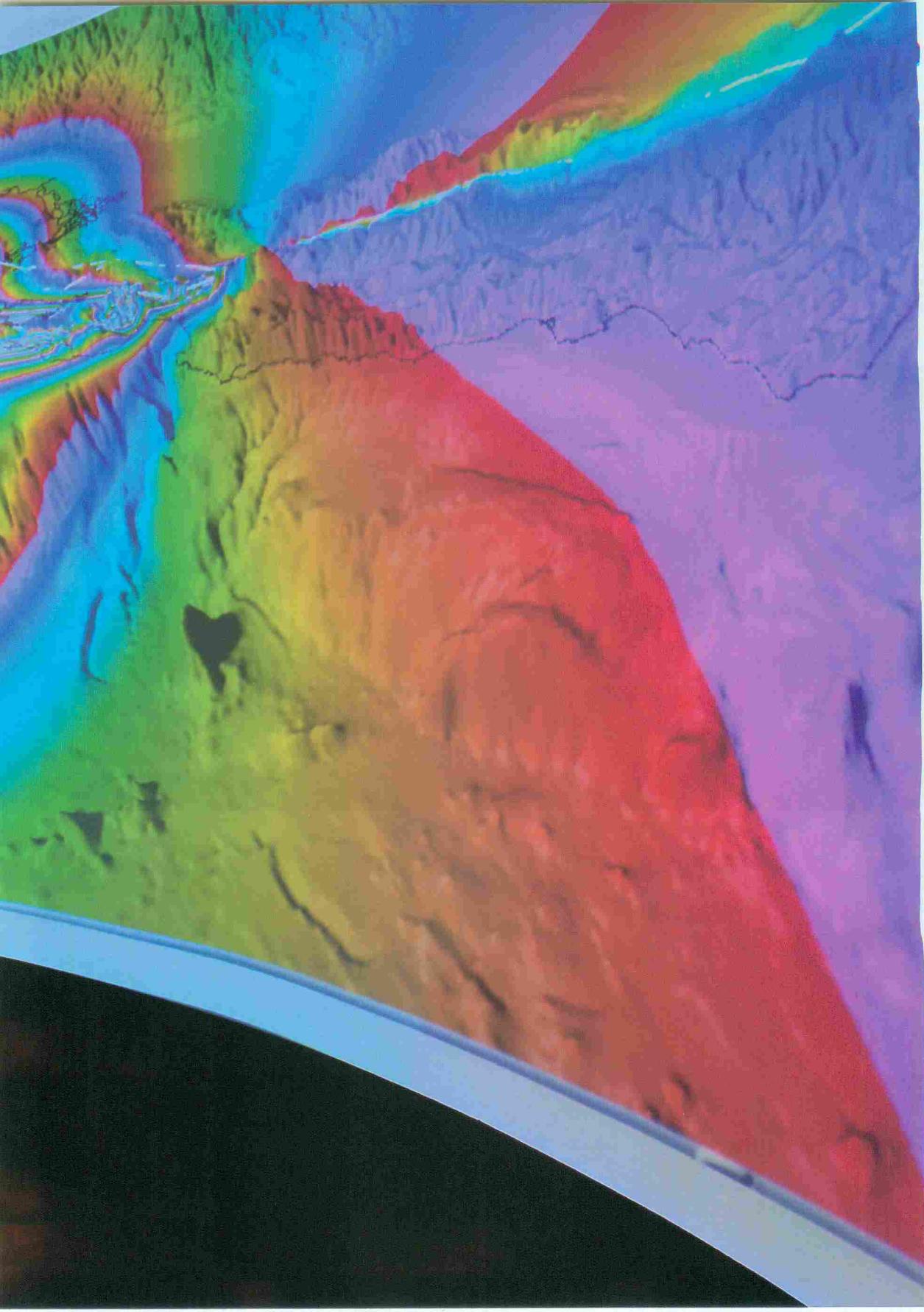


### SAN FRANCISCO 1906–2006

The shaking lasted less than a minute when the big quake hit a century ago. As stoves tipped over and gas lines ripped apart, fires broke out all over the city. With water mains ruptured and useless, soldiers dynamited buildings in a vain effort to contain the blazes. By the time the last embers died three days later, the Paris of the West was gutted. George R. Lawrence, a pioneer in aerial photography, sent a panoramic camera aloft with kites to record the damage (above). Some 500 blocks had been leveled and 225,000 people made homeless. Death-toll estimates run to 3,000 or more, making this the deadliest quake in U.S. history.

Today more than six million people live in the city (left) and its surroundings, which sprawl along the San Andreas Fault, a 700-mile slice through California that marks the boundary between the North American and Pacific plates. Minor quakes occur often. But a big one is coming—and could strike at any time.







**NO PLACE IS SAFE** on the San Andreas Fault. On the Carrizo Plain in south-central California, thousands of years of earthquakes have left a zippered scar (above). At Scripps Institution of Oceanography, a 3-D model of San Francisco after the 1906 quake (left) shows slippage—or land movement—along the fault; each rainbow of color represents about 1.5 inches.

(Continued from page 127) citizens and perhaps nearly as many bars. The famed Enrico Caruso performed at the opera the night of April 17.

All that changed at 5:12 the next morning, when the bars had finally emptied. Something happened deep under the seafloor just off the Golden Gate, out near the shipping channel. Along an ancient crack in the Earth, two slabs of rock began moving in opposite directions.

An earthquake will unzipper a fault at two miles per second. This one broke north and south. In some places the slip was just 6 or 7 feet, but elsewhere the ground lurched fully 16 feet in a snap. The fault broke for 270 miles, from Shelter Cove, way up in the redwood country of northern California, all the way south to the old mission town of San Juan Bautista.

It wasn't the worst earthquake in history by a long shot, but it was sensational. Not only did it heave the ground and topple buildings, it ruptured the water mains, leaving San Franciscans helpless as their Victorian homes and bustling

shopping districts and warehouses and opera burned to the ground. No one knows how many people died, but about 3,000 is the consensus.

It inspired a kind of war on earthquakes, using the weapons of science. Until the San Francisco earthquake, geologists weren't sure how earthquakes and faults were connected. Many believed that faults were the by-products of earthquakes, not their source. The great Berkeley geologist Andrew Lawson had discovered the San Andreas Fault more than a decade earlier, naming it after the San Andreas Valley—and possibly himself (Andreas equals Andrew). But he thought it was just a little sniffle of an earth crack, a trivial thing not much more than a dozen miles in length, responsible for the narrow valley that holds San Andreas Lake and Crystal Springs Reservoir on the San Francisco Peninsula.

But earthquakes are teachable moments. When the fires died down and San Francisco started to rebuild, Lawson and a team of colleagues set out to solve the mystery of the Great

Earthquake. They literally walked the "mole tracks" where the fault rupture had churned across barnyards and meadows. Then they continued south for 600 miles, reading the landscape, discovering the unbroken sections of the fault. This fault just kept going and going, all the way down past Los Angeles. In 1908 the team published the fabled Lawson report, which showed this rip in the Earth in vivid photographic detail.

In the course of the investigation, a scientist named Harry Fielding Reid figured out why earthquakes happen. Reid studied all the reports of ground motion, of roads and fence lines offset by the fault, and came up with the key concept of "elastic rebound." The surface of the Earth isn't perfectly stiff. It bends. Land at some distance from a locked fault will slowly stretch in opposite directions, but the fault itself will remain locked, under increasing strain. Finally the fault breaks, and the land springs back violently, releasing accumulated strain. An earthquake, says Bill Ellsworth of the U.S. Geological Survey in Menlo Park, California, is "a relaxation process"—from the standpoint of the planet at least.

Lawson, Reid, and their colleagues had no way of understanding the ultimate source of the forces behind earthquakes. But by the late 1960s,

scientists had come to realize that the Earth is divided into about 15 plates of crust, constantly shifting as new rock forms at mid-ocean ridges and old crust dives into the Earth's interior at subduction zones in the deep sea. Suddenly the Himalaya were revealed as a crash site, with India slamming into Asia. And the San Andreas was not just a long strike-slip fault: It was a plate boundary, where the North American and Pacific plates grind slowly past each other at a rate—precisely measured by GPS—of two inches a year.

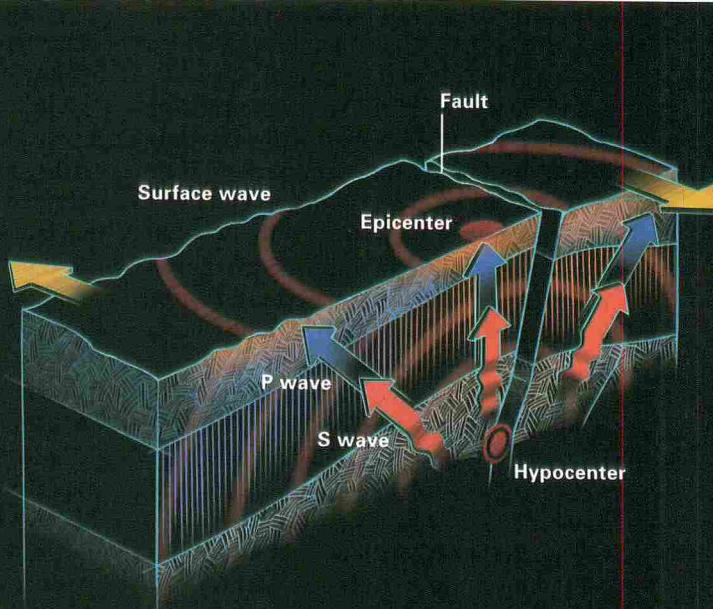
But except for a section called the "creeping zone" in central California, the San Andreas is locked. Around San Francisco, the fault hasn't budged since 1906. North of Los Angeles, a long stretch of the fault has been stuck since 1857. Near Palm Springs, there's been no action on the fault since about 1680.

At some point the San Andreas will have another relaxation event. When that happens, despite all the forecasts, all the measurements, all the scientific conferences, nearly everyone will be caught by surprise.

ALTHOUGH IT IS PROBABLY the most famous fault on the planet, the San Andreas is often strangely hard to find. It slices an enigmatic path through wildly varied topography. Sometimes

## INSIDE A QUAKE

When a fault like the San Andreas ruptures, adjacent plates in the Earth's crust suddenly lurch past each other. Two kinds of vibrations radiate from the hypocenter, the spot deep in the Earth where the rupture originates: P waves, which compress and stretch the rock as they go, and S waves, which shake the rock from side to side. Seismic stations around the world record these vibrations, allowing geologists to locate the hypocenter and the surface location directly above it, the epicenter. At the Earth's surface, P and S waves produce the heaving and rolling surface waves of an earthquake, which are usually most severe along the rupturing fault.



ART BY CHARLES FLOYD, NGM ART



**A MINI TSUNAMI** simulates an earthquake-generated wall of water crashing into a populated coast. At the O. H. Hinsdale Wave Research Laboratory in Oregon, a model based on a vulnerable area in Puget Sound shows the possible impact on buildings and the movement of debris. Scientists hope to use this information to reduce the damage that the monster waves inflict.

it's obvious—viewed from above on the Carrizo Plain in south-central California, for example, where it looks like a zipper, or at Thousand Palms in the Mojave Desert, where fan palms line up neatly to drink water percolating upward through the fault. But usually the San Andreas lurks in the landscape, a shadowy presence. When you search for the fault you spend a lot of time thinking: Is this it? Or is that it? Is this the boundary between two enormous tectonic plates, one stretching to Japan and the other to the middle of the Atlantic Ocean? Or am I standing in a random ditch?

A century after Lawson et al. rambled across California, researchers are still pinpointing the fault's active trace. I tagged along with Carol Prentice, a geologist with the U.S. Geological Survey in Menlo Park, who has been stomping through the dense redwood forests of northern California. She is aided by a new technology called LIDAR, which uses aircraft-borne lasers to trace the contours of the land. Photos and

maps in hand, she hikes through the woods, noting every feature that might reveal the exact location of the fault: sag ponds, offset streams, displaced fences. She has even found what appears to be a redwood stump literally ripped apart by the great quake. Prentice takes you into brush so thick and tangled you have to crawl. What we couldn't see on foot, we saw on knee.

I asked her what would happen if the fault broke right under us, out here in the boondocks. "That'd be so cool, if we were right here," she said. "Oh! I would love it. You wouldn't be able to stand up. It'd knock you on your butt. Presumably you'd see the 'rending and heaving of the sod.'" She was quoting from the Lawson report.

Scientists like Prentice would love to know when, exactly, the San Andreas had a major quake prior to 1906. You sometimes read that the San Andreas breaks every 150 years or 200 years or 250 years, but that is not hard data. That's an informed guess.

On the Point Reyes Peninsula, a knuckle of

land north of San Francisco, Tina Niemi is digging for an answer. In the compacted sediment and peat of a trench dug across the fault trace, the University of Missouri geologist can discern a faint fracture, a line that slants across the trench wall from upper left to lower right. The line isn't perfectly straight; it jogs and splays. Along with other clues, these kinks suggest that something has jolted the soil here as many as 12 times over the past 3,000 years. Niemi doesn't see any simple pattern to the quakes—not in time, not in magnitude. "Our data support more of a model for irregular occurrence," she says.

Nearby faults add another level of uncertainty. High in the Santa Cruz Mountains near Palo Alto you can stand on the San Andreas not far from the epicenter of the 1989 magnitude 6.9 Loma Prieta earthquake. That quake was strong enough to destroy freeways and bridges and kill scores of people, but it never ruptured the surface. To this day, no one is sure how much of the quake to blame on the San Andreas and how much on other, unknown faults.

"WITH FAULTS, you don't have the luxury of tinkering under the hood to see what's what," writes USGS seismologist Susan Hough in her book *Earthshaking Science*. But some scientists want to sneak a look. Their idea: Drill the San Andreas. Find the biggest oil drilling rig in California and ram huge steel pipes into the depths of the fault and send a bunch of gadgets down there to sample the rock and record its twitching. The project is under way near Parkfield, a village in a dusty central California valley.

Parkfield's claim to fame is earthquakes. At the Parkfield Cafe there's a sign that says, "If you feel a shake or a quake get under your table and eat your steak." The quakes aren't actually very strong here. They tend to be magnitude 6. There has been a string of them. After the M6 in 1966, scientists realized that these quakes had occurred fairly regularly, roughly every 22 years, and so in the early 1980s the notion arose that there ought to be another Parkfield quake around 1988.

Scientists wired the fault every which way, hoping to detect signs of building strain, moving water, or some other quake precursor. But year after year, the quake refused to show. It became something of an embarrassment for everyone who argued that earthquakes follow patterns. Finally, on September 28, 2004, an M6

struck near Parkfield, although its epicenter was miles farther south than expected. A camera had been set up to catch the fault rupturing from north to south, but it broke from south to north.

"We missed Parkfield by over ten years—and that was an earthquake in a barrel," said UCLA's David Jackson, he of the chaos camp.

Most disappointing to scientists was the lack of any precursors. They pored over the data and could find no evidence of anything unusual on the fault prior to the September 28 rupture. Maybe there was a very tiny change in crustal strain a day before the quake—but even that wasn't certain. The unsettling notion arose that the jig was up, that these things are just flat-out unpredictable, random, weird.

But science marches on—and digs deeper. At Parkfield there are still seismometers and GPS stations everywhere, and now there's even that 185-foot oil-drilling rig, a monument to what you might call testosterone science. By late summer 2005 it had punctured the fault and reached its terminal depth of two miles.

"In a sense we're testing the predictability of earthquakes," says Mark Zoback of Stanford University, part of the drilling team. Of the chaotic versus linear debate, he says, "we're the guys who are trying to find out which side is right. Not to be sanctimonious, but I think a lot of those positions are held more on belief than on data." His rig is the next best thing to sending a person down into the fault directly, although even the rig can't get instruments down to the six-mile depths where many large earthquakes start.

IN JAPAN, government scientists say they have settled the question. Earthquakes are not random. They follow a pattern. They have detectable precursors. The government knows where Japan's big one will most likely strike. This is a country where the trains run on time, and earthquakes are supposed to do the same. "We believe that earthquake prediction is possible," says Koshun Yamaoka, a scientist at the Earthquake

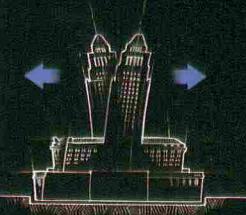
**SHIFTING GROUND: Along the San Andreas Fault near Point Reyes, California, sections of a fence show the dramatic displacement of land that occurred in the 1906 quake. This fence was built in the 1970s along the track of an old fence wrenched apart by the quake.**



## SEISMIC DESIGN IN L.A.

A beloved landmark since 1928, the Los Angeles City Hall suffered severe damage during the 1994 Northridge earthquake as cracks opened throughout the building and exterior tiles crashed to the ground.

A three-year restoration and safety upgrade included reinforcing walls in the tower with steel bars and connecting the north and south wings to the main structure with steel bracing. The most dramatic changes were made at the base: Engineers dug a moat around the building to separate it from heaving ground and installed a suspension system on the foundation to reduce the shaking in future quakes.



### Balancing Act

Rising 452 feet above street level, the tower must be rigid enough to keep from whipping back and forth catastrophically in a quake (above) but flexible enough to sway as the building moves beneath it.

Steel and concrete reinforcement

Bracing

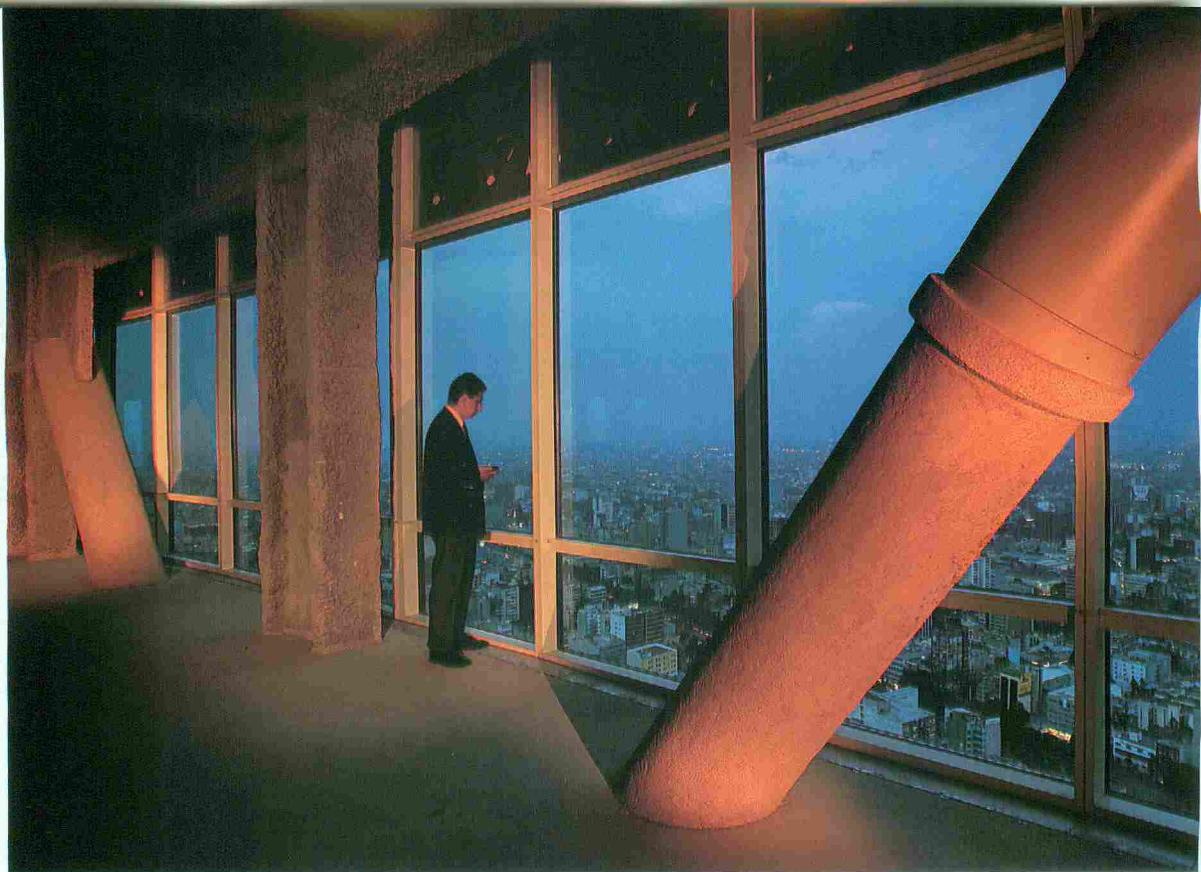
Moat

Isolator

Damper

### Suspension System

Seismic dampers at the base of support columns will act as shock absorbers during an earthquake, while steel-and-rubber isolators will allow the building to move independently from the ground.



**MEXICO CITY'S TALLEST BUILDING** stands firm—so far—thanks to diagonal shock absorbers that should allow it to withstand a magnitude 8.4 earthquake. Months after it opened in 2003, the 55-story Torre Mayor rode out the shaking from a magnitude 7.4 quake 300 miles away. Tenants heard some creaking but felt little movement, and the building was undamaged.

Research Institute of the University of Tokyo.

In fact, Japan has already named its next great earthquake: the Tokai earthquake. The government has identified and delineated by law the precise affected area—a region along the Pacific coast about a hundred miles southwest of Tokyo. After a series of small quakes in the Tokai area in the 1970s, scientists predicted that a major quake might be imminent there. The Japanese government passed a law in 1978 mandating that preparations begin for the Tokai earthquake.

Scientists have estimated a death toll of between 7,900 and 9,200 for a quake striking without warning in the wee hours. Estimated property damage: up to 310 billion dollars. At the Tokai earthquake preparedness center in Shizuoka, a map pinpoints 6,449 landslide locations. Another map shows where 58,402 houses could burn in quake-related fires. It's all remarkably enumerated. The only thing left is for the earthquake to happen.

There is, indeed, a plate boundary, called the

Nankai Trough, that runs off the coast of the island of Honshu, where the Philippine plate is subducting beneath Japan. The boundary has generated massive earthquakes every 100 to 150 years. Two sections of it, side by side, broke in 1944 and 1946. But the section along Tokai hasn't generated a major quake since 1854, right about the time Commodore Perry sailed his warships into Tokyo Bay. The theory is that it's time for this part of the subduction zone to relieve its accumulated stress.

At the Earthquake Research Institute, Keiji Doi, who is in charge of public outreach, lays out the entire scenario. The land near Shizuoka is sinking toward the underwater trough at about five millimeters a year, indicating that strain is building up. "The earthquake occurrence is imminent, we believe," Doi says.

Up to this point, the Tokai tale is more a forecast than a prediction. But a precise prediction of time and place would be far more valuable for emergency planners. Thus has arisen the idea



What can governments do?



Deep under Tokyo's streets a construction crew prepares a quake-resistant duct for the city's water, electricity, telephone, and sewage lines. By minimizing damage to the main utility lines, the tunnel should allow services to be restored quickly after an earthquake.

of "pre-slip," a notion that skeptics say is part science and part wishful thinking.

Naoyuki Kato, another scientist at the Earthquake Research Institute, says his laboratory experiments show that before a rock fracture gives way, it inevitably slips a little. He believes that what happens in a lab at small scale will also happen on a fault hundreds of miles long and running deep into the crust, just before the next big one.

The government has an action plan built around pre-slip. Strain meters are embedded in the ground all over the Tokai area. If one or two meters show anomalies, scientists will confer and schoolkids will go home. Three anomalies will put the country on high alert. Police, soldiers, and firefighters will race to the border of the vulnerable area. The prime minister will make a speech and say that an earthquake is imminent.

Posters outlining this plan show a cartoon prime minister sitting at a desk with hands folded, looking very worried, but very much in charge.

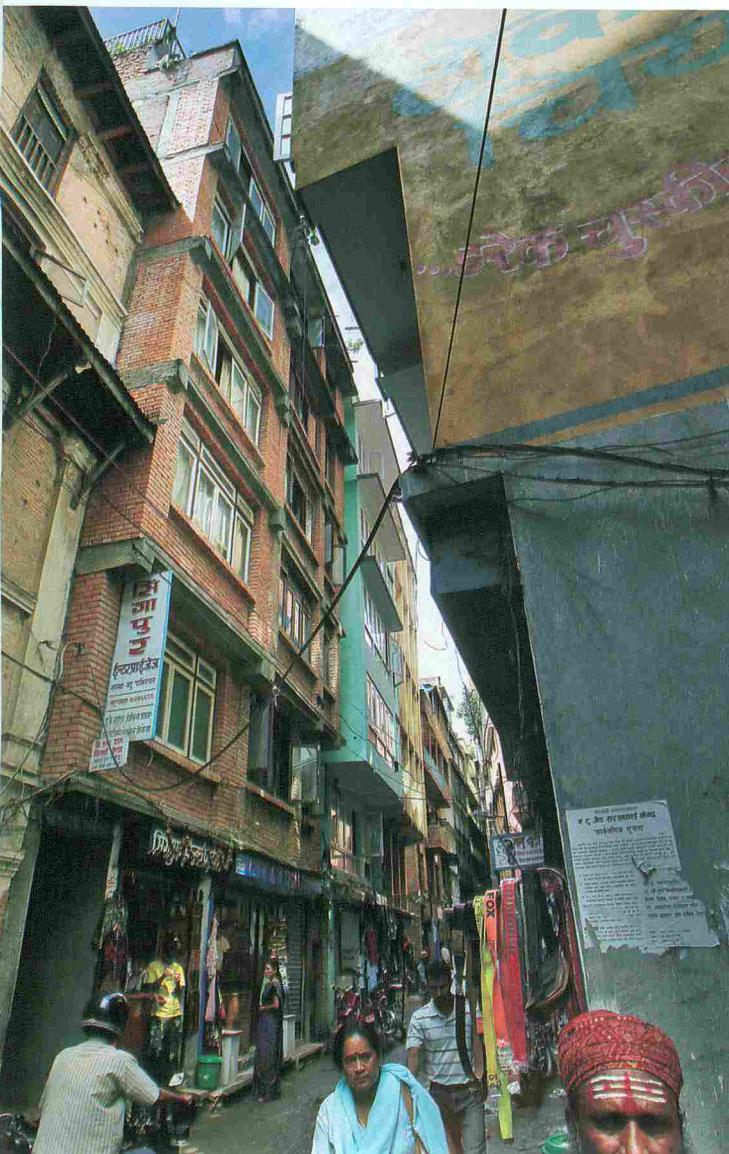
Yet none of the experts on the Tokai earthquake describe this scenario with much conviction. Press them, and they will admit their uncertainty. Yamaoka and Kato, for example, are both bullish on pre-slip, yet they also say it may be too small to be detected.

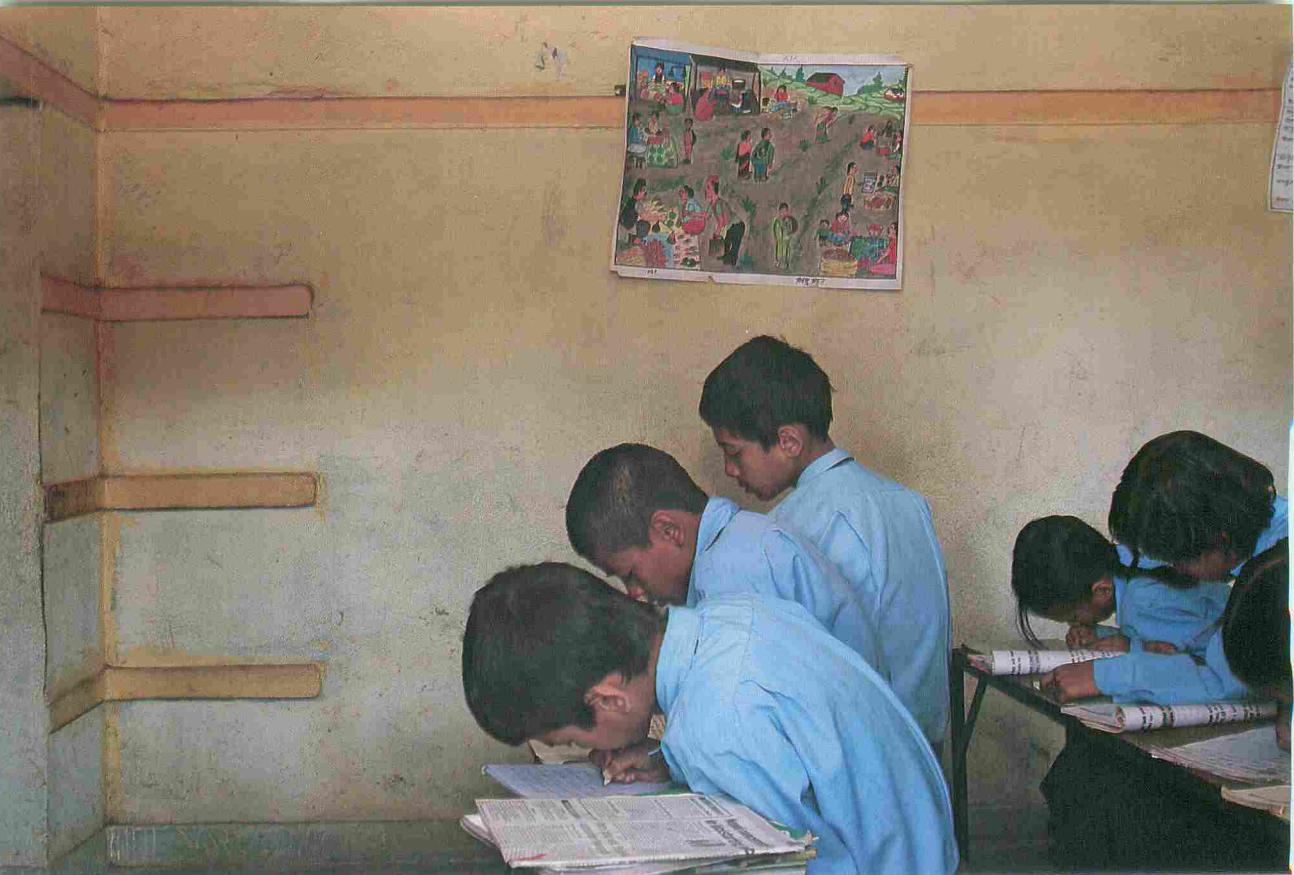
Robert Geller, an American geophysicist who works half a mile away at the University of Tokyo's school of science, is less circumspect. Geller has been in Japan for decades and has made "bashing earthquake prediction," as he puts it, a passionate hobby. He calls the prediction program "faith-based science." Pre-slip, he adds, "has never been verified to exist for actual earthquakes."

Geller's skepticism is not just a case of American outspokenness. Hideki Shimamura, an earthquake scientist at Musashino Gakuin University near Tokyo, is almost as blunt. "There may be pre-slip, but I rather doubt it," he says, adding that few researchers are willing to question the focus on Tokai lest they lose funding. The situation has potentially lethal consequences, he says: Prior to the Kobe earthquake in 1995, which killed 6,400 people, few people or public officials in Kobe had any inkling that they were vulnerable. Earthquakes were mainly someone else's problem—far to the east, in Tokai. "They didn't prepare," Shimamura says.

Since the Kobe quake, Japan has vowed to improve its readiness for a big jolt. Many of the bullet trains now brake at the first seismic tremor. Construction plans are supposed to get closer scrutiny, particularly in Tokyo, which sits on or near several dangerous faults. But the country has been shaken in recent months by a scandal: As officials looked the other way, crooked builders put up scores of structures that were far too fragile to withstand earthquakes. Their occupants were lucky that the scandal broke before the inevitable next earthquake.

Near Tokyo's sumo stadium is the Tokyo Restoration Memorial Hall, commemorating disasters that have struck





**IN QUAKE-PRONE NEPAL** the corners of a schoolroom have been retrofitted with steel-and-concrete braces. The feature echoes traditional Nepalese building design, in which walls are pegged together to keep them from collapsing individually. Buildings in Kathmandu (left) often lack such reinforcement, posing a grave danger to occupants and passersby.

the city. A dapper gentleman named Nobuo Yanai, 82 years old, visits every year to honor nine family members lost in the great Kanto earthquake of 1923. They died not in the quake itself but in a fire that raced through a field that had become a temporary home for 40,000 people—a huge throng suddenly immolated.

"They went up. Rose up in the sky. You may see the paintings over there"—and there, indeed, were paintings that showed the firestorm lifting people to the heavens. "My great-grandmother went up in the sky and disappeared."

PEOPLE STILL DIE in stunning numbers when the ground beneath their feet begins to shake. Almost always it's not the earthquake that kills them, but rather their collapsing homes, offices, stores, and schools. An earthquake that might kill dozens or hundreds in California or Japan can kill tens of thousands in Latin America and Central and South Asia, where many buildings are little more than unreinforced masonry piles.

There's a seismic gap between rich and poor.

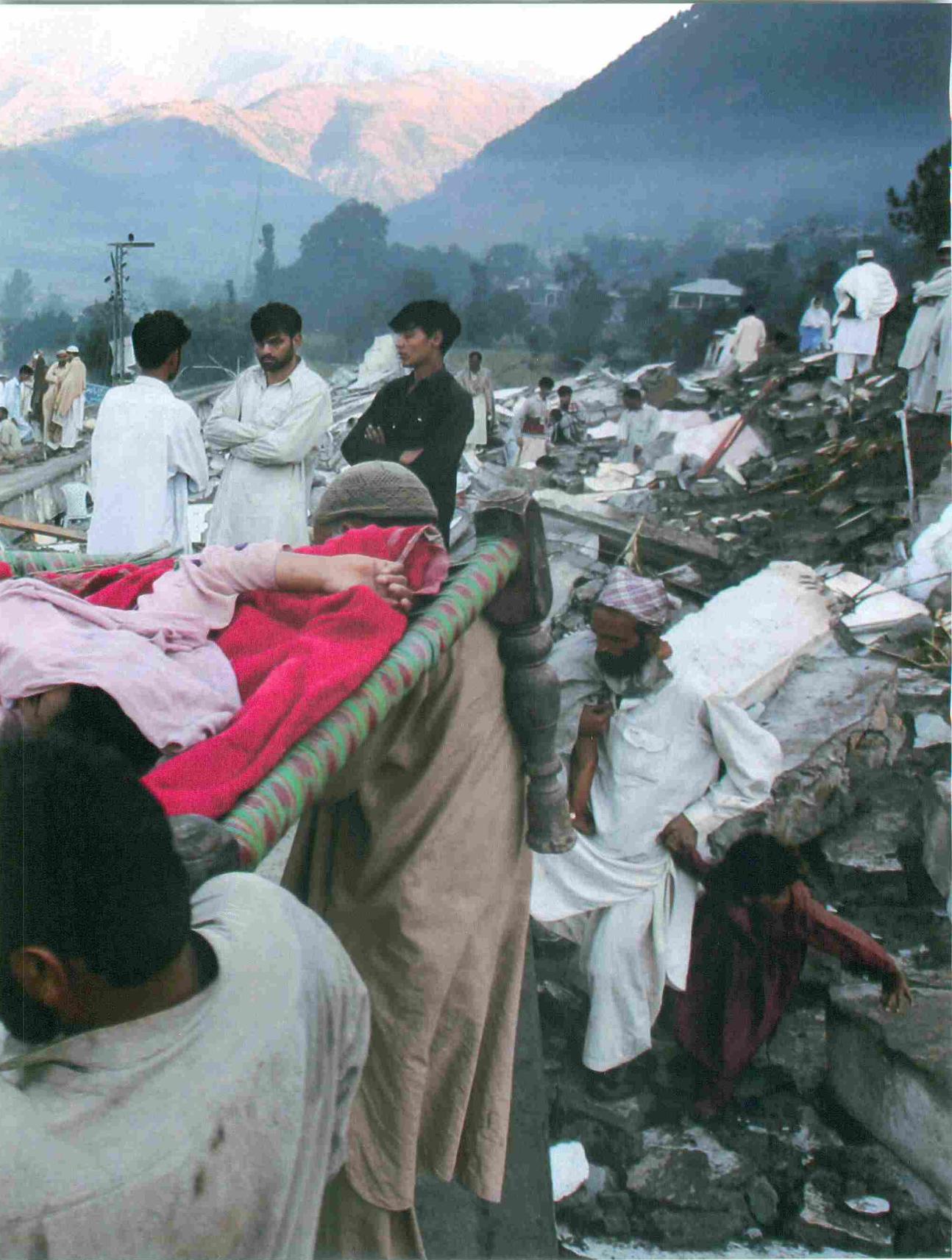
Last October a magnitude 7.6 earthquake rocked northern Pakistan and Kashmir, the mountainous region claimed by both Pakistan and India. Within minutes, tens of thousands of people were dead, and countless others died later of injuries and exposure. Many were crushed when apartment buildings that had little or no steel in the concrete pillars simply pancaked. Had the quake been centered in nearby Rawalpindi, a city of 1.8 million, the casualties could have been in the hundreds of thousands.

Geophysicist Brian Tucker, head of a nonprofit organization called GeoHazards International, has been traveling the planet to lobby local officials to build sturdier housing projects, schools, and highways. He's seen cities where impoverished citizens expand their dwellings vertically, piling one brick floor on top of another, waiting for gravity to pull it all down.

In Kathmandu, a city crammed with brick-pile high-rises, an official once told Tucker, "We



What about the survivors?



Stunned survivors rescue an injured neighbor in Balakot, Pakistan, after last October's magnitude 7.6 earthquake, which killed at least 73,000. Landslides blocked many roads, leaving millions of people without food or shelter as winter closed in.

B. K. BANGASH, AP

don't have earthquakes anymore." Surrounding the city are the Himalaya, pushed toward the stratosphere by tectonic forces. Tucker told the official, "Look out the window. That's Mount Everest. As long as you can see that, you're going to have earthquakes."

Mexico City is another catastrophe in waiting. Much of the city is built on soft mud, the remnants of a lake drained by the Spanish. In 1985 more than 9,500 people died when a subduction zone off the western coast of Mexico ruptured, sending seismic waves rolling hundreds of miles into the capital. Building codes have improved since then but only apply to new construction. And the population has boomed. Nearly 20 million people now live in a metropolis ringed by active volcanoes, testimony like the Himalaya to the tectonic forces that can level cities.

Calamity has been part of the city's cultural fabric for centuries. Underneath a church in the center of town, Cinna Lomnitz, an earthquake specialist from the University of Mexico, led me down a hidden stairwell to the remains of an Aztec pyramid, sagging on the soft lake bed. An ancient relief carved into the stone shows four suns surrounding a central sun. According to Aztec legend, each sun represents a period of earthly existence, and each is eventually destroyed.

"The fifth sun is the last one," Lomnitz said. "And it will end in earthquake."

KERRY SIEH BELIEVES science can help break the cycle of calamity. Sieh, a Caltech earthquake geologist, is convinced there's a way to read the messages in the rocks, to heed the warnings encoded in their trembling. He knows firsthand how much could be gained if we could pinpoint the most dangerous faults and know when they are due to rupture.

At 6:16 p.m. on Christmas 2004, Sieh was at his computer at home when he received an emailed bulletin about a seismic event at 3.3 degrees north latitude and 95.8 degrees east longitude, near Sumatra. For Sieh, earthquake bulletins are routine—quakes happen every day, all over the world. But a number jumped out at him: 8.5. That was the initial estimated

magnitude of the quake, which had happened just over an hour earlier. An 8.5 is enormous.

Soon came the aftershocks, scores of them in the next few hours. Gradually the data began to harden around the obvious fact: This was a great quake, upwards of magnitude 9. News reports said a tsunami had killed perhaps several thousand people in Sri Lanka. And then those numbers began to climb too.

The Sumatran earthquake was not a total geologic surprise. Two weeks earlier Sieh had given a talk about his research on the great undersea fault paralleling the coast of Sumatra, where one plate is subducting beneath another. He had warned that the section of the fault he was studying, well south of the part that actually ruptured, could break at any time and trigger tsunamis.

It had happened before, in the late 1300s, around 1600, and in 1797 and 1833—dates Sieh had determined by studying old coral heads along the islands off the west coast of Sumatra. When the Earth shifted in major quakes, the coral heads were lifted out of the water, leaving a gap in their growth layers. But the last really large earthquake had happened long before anyone now alive in Sumatra had been born.

Sieh and his team had distributed posters in some villages of southern Sumatra, warning of catastrophic tsunamis. But Sieh's colleague Catharine Stebbins found that the novelty of the posters and the American scientific expedition seemed to outshine the posters' message. "It was like a circus came to town." And no one thought the northern part of the fault would go first.

Late Christmas Day, as the news about the disastrous tsunami came over the wire, Sieh feared for his friends in Sumatra, and he had an ominous thought: There would be another huge quake. By releasing stress on one segment of the fault, this earthquake had increased stress on the next segment to the south.

Three months later, on March 28, 2005, that segment broke in a magnitude 8.7 quake—smaller than the first but still one of the ten biggest on record. Another tsunami followed, but this time collapsing buildings and falling debris were the big killers, taking more than 1,000 lives.

In his Caltech office, Sieh showed me a map of the Sumatran plate boundary, detailing the GPS stations he had placed along the fault before the March quake. They had all moved, yanked to and fro and up and down. One directly over the

◀ Prepping for the big one Visit an online photo gallery to view techniques that scientists use in their efforts to predict quakes. Then browse a list of related links and resources at [ngm.com/0604](http://ngm.com/0604).



**A MONUMENT TO FLEXIBILITY**, the Yasaka Pagoda in Kyoto, Japan, has survived more than five centuries of earthquakes. After a jolt, the building sways sinuously as each story rocks independently around a central, anchoring pillar. With a new appreciation of this ancient design, engineers are now adapting it for modern use.

March rupture had jumped 10 feet up and 14 feet to the southwest. The pattern of movements indicates that strain is still building. "If another great earthquake happens in the next year," he said, "my guess is that there'll be another couple hundred thousand dead."

He has heard the refrain that earthquakes are chaotic and unpredictable. That's not what he sees on the map of the plate boundary. He sees a

fault breaking incrementally from north to south. "Obviously this is not chaos. This is linear."

Sieh pointed to the area that he thinks is next in line. That's where he and his colleagues will spend the coming years, listening to the fault, tracking the Earth's movements, taking the measure of shaky ground.

"I would like to predict this earthquake," he said. □

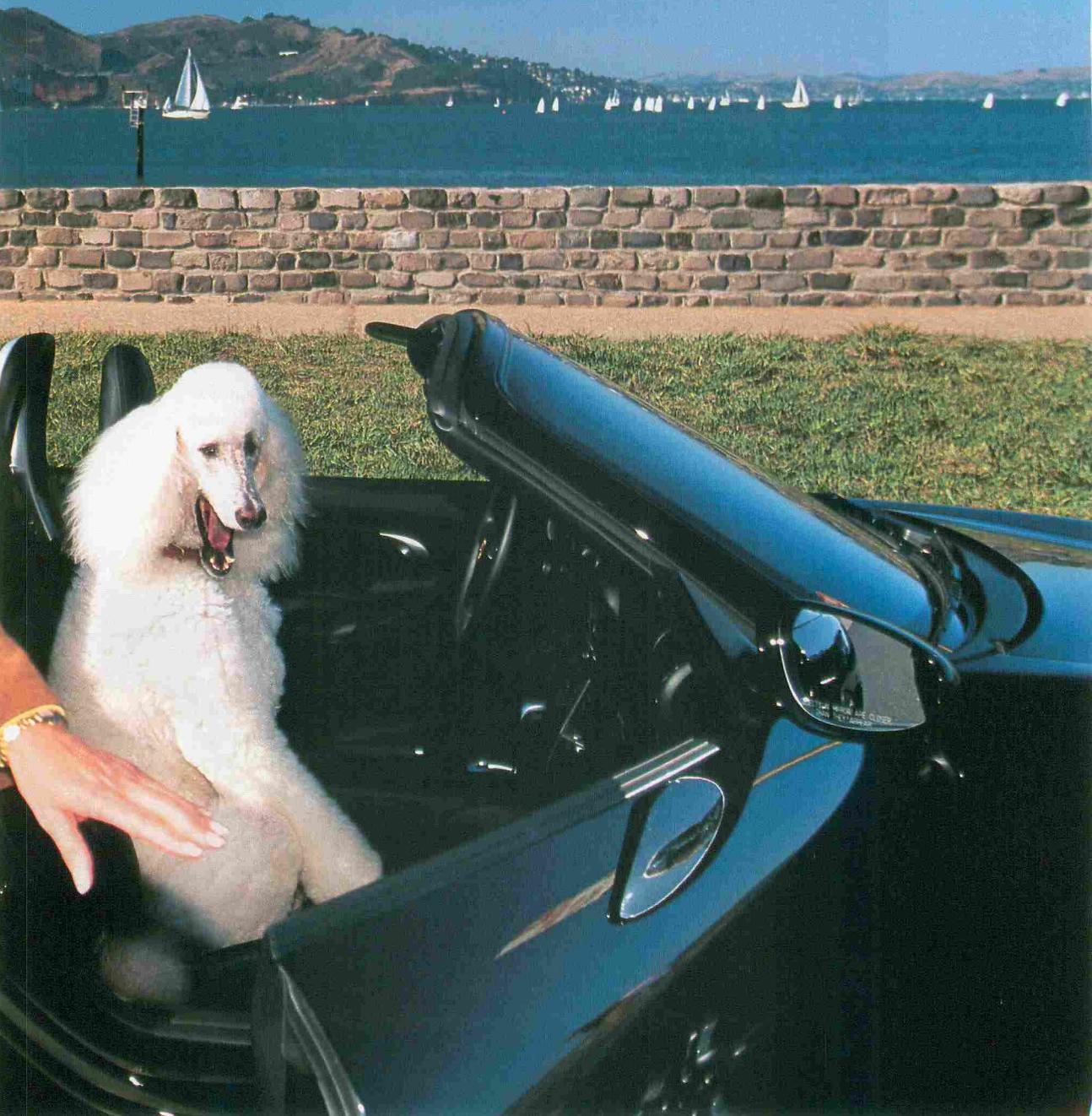


Slick the poodle is a fixture on the Marina canine scene.

ZIP USA | SAN FRANCISCO, CA 94123

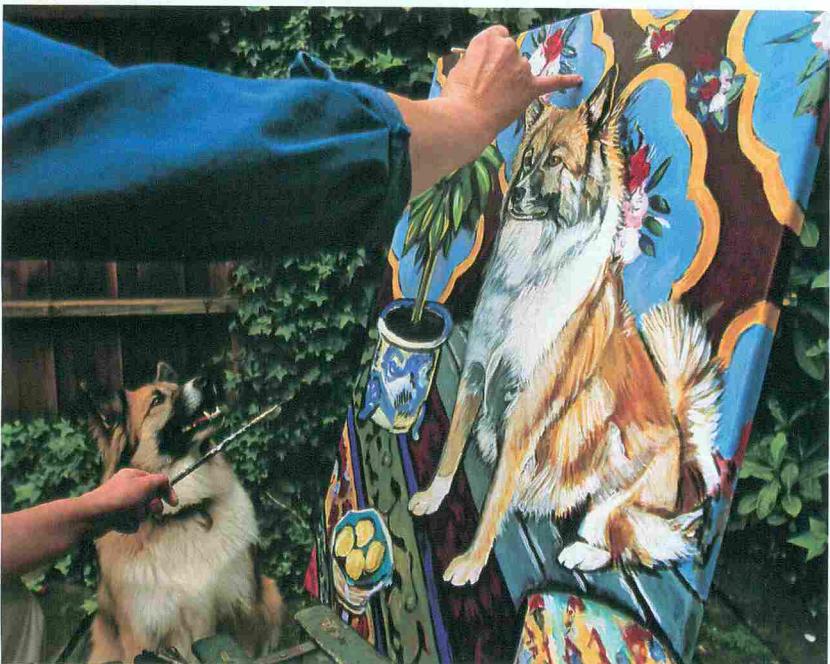
# Where Dogs Have Their Day

Black Porsche, bay view, doting owner. Life is a royal ride for dogs in San Francisco's Marina district, where canines outnumber kids.



BY MICHAEL MASON

PHOTOGRAPHS BY CATHERINE KARNOW



Leo poses for local artist Patti Miller, whose Matisse-inspired portraits go for about \$1,500. Upscale shops welcome dog walker Julia Frink and clients; owners demand the shih tzus return home with immaculate paws.

**O**n any given afternoon in San Francisco's Marina district, dogs fill the streets and parks, the outdoor cafés and shops. They keep appointments with their masseurs and acupuncturists; they sit for portraits and for readings with their astrologers. Over the objections of no less than the federal government, they romp unleashed through the delicate habitats of nearby Crissy Field. The Marina is dog country—no, dog Cannes—and no one here sees anything the least odd about it. San Francisco is home to 745,000 people and an estimated 110,000 dogs, packed into an insular fiefdom just seven miles long and seven wide. Not coincidentally, it also has the lowest ratio of children to adults of any major U.S. city: There is little doubt that dogs are helping fill a parental void—especially in the affluent Marina. "Those dogs are babied," says retired postal carrier Spence Burton, 58, who delivered mail in the Marina for 25 years. "Even tiny apartments have, like, two rottweilers. But they're not exactly guard dogs."

Not exactly. On a recent afternoon, Billy Franchey, 34, chauffeurs Gigi, a keeshond mix, and her "best friend" Ruby, an Australian dingo, to the neighborhood park in an electric cart for a bit of exercise. Afterward, in matching cowboy hats and sweaters, Gigi and Ruby may go to "yappy hour" at a Union Street boutique. "The Marina has a lot of young people who aren't





married so, you know, you get a dog," says Franchey's girlfriend, Lisa Mobini, 29, a former NFL cheerleader. Her cell phone is loaded with pictures of Gigi dressed as a princess for Halloween and as an angel for Christmas. "Honestly, she has a better wardrobe than I do."

A few blocks away, astrologer Billie O'Neill pores over the star charts of Franklin, a fat Welsh corgi unwilling to share toys with his buddies in the park. "He was a warrior in all of his past lives," she says thoughtfully. "But this life is about learning partnership and cooperation." Perhaps it's too much to expect him to share, really: With an ascendant water sign, Franklin's chart indicates he is focused on "material security."

A black Porsche glides down Chestnut Street with Slick, a seven-year-old standard poodle, regally upright in the passenger seat. Owner Sandra Ingrish takes him along on errands—to the grocery store, the bookshop, the bank—and so Slick, elegant and entitled, is a neighborhood fixture beloved by camera-toting tourists. "There are so many dogs, it's really kind of amazing for a city this size. Dogs in New York never really looked that happy," says Ingrish, who moved to San Francisco from Manhattan. Says Ted Rheingold, founder of *dogster.com*: "Folks here do not feel it's abnormal to be in love with their dogs."

But beyond canine couture and doggie day care, something unusual is happening in San Francisco. Residents are taking seriously the notion that dogs are family members, and pets are acquiring something that begins to resemble rights. The San Francisco Society for the Prevention of Cruelty to Animals established the nation's first no-kill shelter and built an adoption center with "condos" furnished with televisions and aquariums. Activists like Vanessa Getty—of San Francisco's famed oil dynasty—run a sort of underground railroad, rescuing unwanted dogs about to be euthanized in less enlightened cities.

"San Francisco is in the vanguard," says James Serpell, a professor of animal welfare at the University of Pennsylvania Veterinary School, "but

it's not just in San Francisco. People increasingly regard their pets as quasi persons, or honorary persons, and the laws in most places just haven't caught up with this moral sea change."

Leave it to the federal government to get caught in the crosscurrents. A few years ago, the National Park Service tried to enforce its requirement that dogs be kept on leashes in Crissy Field, adjacent to the Marina. There were howls of outrage, and not from the dogs. At a public meeting, some 1,500 people showed up, most angry owners. Eventually three challenged their tickets, and so far have prevailed in the courts.

"Whoa, those people can mobilize," says Jean Donaldson, director of the SPCA's school for dog trainers. "It's amazing the political power dog owners have here."

Some residents find it galling that so much attention is lavished on pets. After all, San



"It's all about extending dogs' lives," says masseuse Tanya Emes (with client), who makes house calls for \$75 an hour. Her own dog, massaged daily, "is 15 and doing great."



"Our dogs are our babies; we never leave them home," says Lisa Mobini, at right, with Gigi. It's a concept not lost on local businesses, which cater to the young, single "doggie" crowd. Specialty biscuits (below) "are like doggie crack," says maker Linda Gordon. "We sell jillions."

Francisco is a city beset by urban woes. Homeless people wander the streets, housing is unaffordable, and public schools are struggling. One group increasingly critical of people who relate to their dogs as if they were children: parents of *real* children. "We're treating dogs better than our kids or the homeless," says city supervisor Michela Alioto-Pier. In recent years the city has seen two highly publicized dog maulings, the latest involving a boy who was fatally attacked after his mother left him alone with two pit bulls.

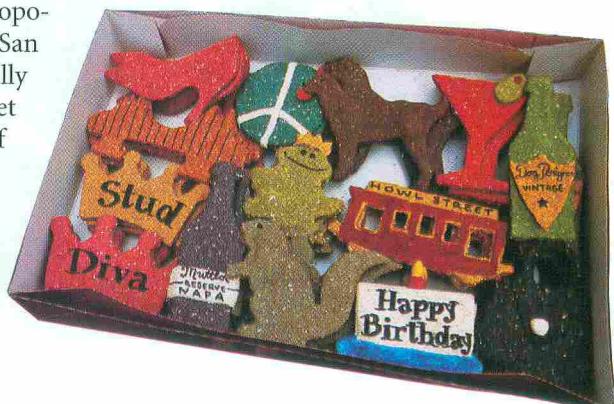
But animal welfare is not an either-or proposition, argues Sally Stephens, chair of the San Francisco Dog Owners Group. If dogs really are family members, then it's time they get the protections they deserve. "For a lot of people, especially singles, their family is close friends and pets," says Stephens. "For what they give, dogs deserve better."

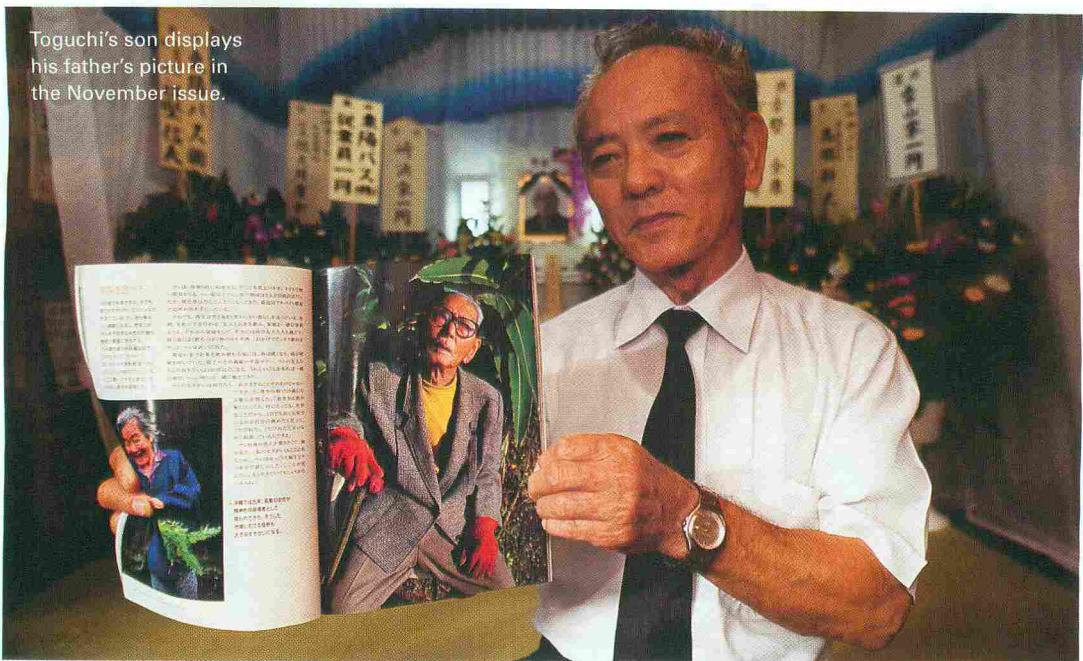
So many trends that begin in California seem silly at first, dissonant notes in the national chorus. But then

they wash over the rest of the country, and what seemed laughable becomes inescapable. "We are on the cusp of a major change," says Serpell. On a sunny afternoon in the Marina, as they lounge at cafés, scarf treats, and fetch Frisbees, dogs may finally be getting as good as they give. □

---

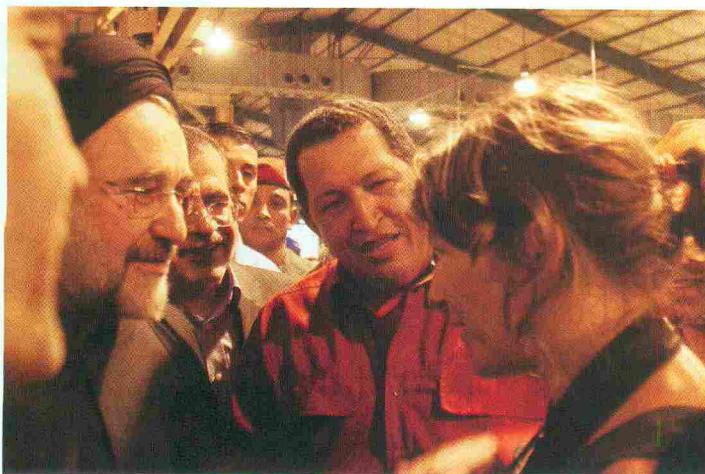
► **Welcome to Dogville** View more images of San Francisco's dog-friendly Marina district, then browse canine-lovers' websites at [ngm.com/0604](http://ngm.com/0604).





**UPDATE United in Death** His friends and family on Okinawa knew Seiryu Toguchi as a gardener and musician. The **GEOGRAPHIC** knew him as an inspiration, one of the centenarians in last November's longevity article. Though Toguchi died days before the magazine arrived, his son made sure the story stayed with his father; he had the issue cremated with him. The funeral culminated in the intermingling of Toguchi's remains with those of his late wife. Says writer Dan Buettner, who attended the service, "These two people, separated in life by one death, were reunited by another."

► **Website Exclusive** Watch footage of Toguchi's funeral, in Multimedia, at [ngm.com/0604](http://ngm.com/0604).

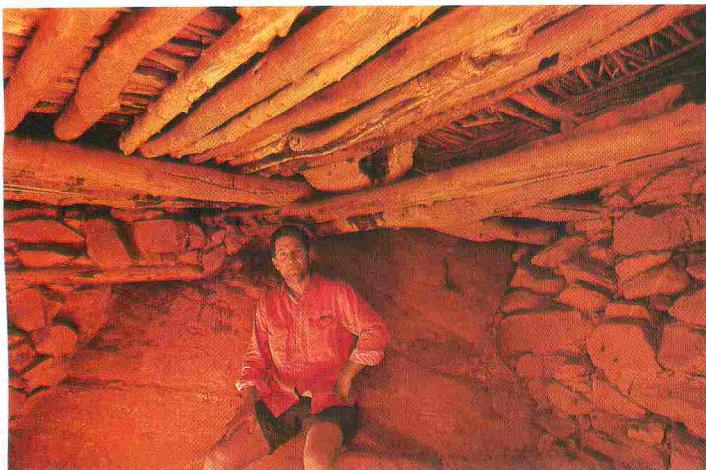


Venezuelan President Hugo Chávez, center, introduces photographer Meredith Davenport to then President of Iran Mohammad Khatami.

#### ON ASSIGNMENT

#### The Chávez Charm

While showing Iranian leader Mohammad Khatami through a Venezuelan tractor factory, Hugo Chávez spotted Meredith Davenport in a throng of photographers and called her over for a chat. She spoke to Khatami in English and Chávez in Spanish. "Both were charming," Davenport says, "but Chávez makes you feel like you're the most important person in the world—and he can do that for thousands of people at once. It's amazing, really."



Writer Dan Glick explores Three Roof Ruin, a 13th-century Anasazi cliff dwelling in Glen Canyon. "It was a scramble to get up here," he says.

## ON ASSIGNMENT

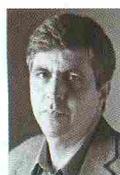
### Wanderlust

"Much of this assignment just let me roam, so I could see how much of Glen Canyon had been underwater," says writer Dan Glick. Drained by drought, Lake Powell has receded dramatically, uncovering much of the canyon and its offshoots. By boat and on foot, Glick discovered the canyon's unveiled natural and historic riches. He camped overnight at one of the most revered spots, a waterfall called Cathedral in the Desert. "It's a legendary place, beautiful and silent," he says.

## Contributors

### Charles Petit

It's tough to keep a low profile when doing a story for NATIONAL GEOGRAPHIC, as writer Charlie Petit learned while reporting on nuclear power. At the Kaiga facility southeast of Goa, India, workers draped Petit with flower garlands and planted a tree in his honor. Such "embarrassingly courteous" welcomes were routine in India, whose "nuclear mavens are eager for outside recognition."



### Peter Essick

Last October a devastating earthquake hit Kashmir, leaving at least 73,000 people dead. It struck just as photographer Peter Essick was wrapping up this month's story on earthquake technology—his 31st feature for the magazine. Essick had documented the damage such quakes can cause, and what's being done to minimize their destruction. "Scientists are learning a lot about big quakes," he says. "I hope one day they'll get a better handle on predicting them."

### Jennifer Ackerman

A "big fan of insects," science writer Jennifer Ackerman went on the prowl for dragonflies in the mountains of central Portugal. It was a scorching day during a dry summer, so water and dragonflies were scarce. Finally she found a remote water hole "alive with courting dragonflies." She plunged in to cool off—and saw an amazing display. "They were buzzing all around me," says Ackerman. "It was wonderful." She was particularly enthralled by a large golden-ringed male patrolling just above the surface. Suddenly a female swooped in to join him, and the two shot into the air to mate. "I've never seen such aerial acrobatics," says Ackerman.



### Gerd Ludwig

In 1994 photographer Gerd Ludwig did a story for NATIONAL GEOGRAPHIC on the catastrophic nuclear explosion at Chernobyl. This month he shows how Chernobyl fares today. During his coverage,

he suited up in protective gear and entered the still dangerously radioactive nuclear power plant where the accident occurred. As an added precaution, some scientists at the site urged Ludwig to drink up. "They say vodka protects against radiation," he says. Local folk seem to believe that, but do the scientists actually believe it too? "Hard to say," says Ludwig. "Chernobyl is an eerie place. You want to protect yourself any way you can."



### Catherine Karnow

"It's no exaggeration to say I'm obsessed with dogs," says Karnow, who photographed this month's dog-crazy zip code story. Despite the article's lighthearted tone, some of what Karnow encountered in the field was "remarkably moving," she says. "I met a female heroin addict who had fallen in love with a stray, but realized that she'd have to get clean to care for it properly. While she saved the dog, it also rescued her."

# INSIDE GEOGRAPHIC

A San Francisco street cleaved by the 1906 earthquake.



## The Great Quake

**Sunday, April 16 at 8 p.m. ET/ 9 p.m. PT** Shortly before sunrise on April 18, 1906, the ground beneath San Francisco, California, began to

shake. Within seconds the largest city in the American West started to topple. Collapsed buildings and an ensuing firestorm killed some 3,000 people and turned Golden Gate Park into a camp for the homeless. *The Great Quake* reveals the catastrophe as it unfolded and brings to life the harrowing stories of its survivors.

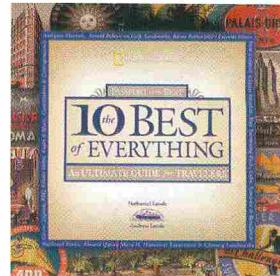
## The Real Spartacus

**Monday, April 10 at 9 p.m. ET/PT** How could a slave build an army of outcasts and lead a revolt against the might of Rome? Learn the true story of Spartacus, the gladiator who in the first century B.C. sought freedom for the tens of thousands of slaves who joined his insurgency. Witness his stunning battlefield victories and his final defeat at the hands of one of Rome's richest men.

## NG Books

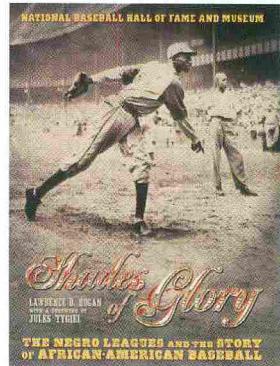
### The 10 Best of Everything

With help from experts including Prince Charles, Arnold Palmer, and Luciano Pavarotti, this "ultimate guide for travelers" ranks the top ten of everything from pubs to cameras to mountain climbs. The guide also includes itineraries for 20 trips to the world's greatest destinations. (\$19.95)



### Shades of Glory

Before Jackie Robinson broke baseball's color barrier by signing with the Brooklyn Dodgers, black players starred in the Negro leagues. The photo-filled *Shades of Glory* celebrates this chapter in the game's history. The book is available this month to coincide with National Baseball Hall of Fame events honoring Negro league players. (\$26)



## FLASHBACK



**Aftermath** "As these words are written, three days only have passed since San Francisco was shaken by the most destructive earthquake in her history, and the subsequent unparalleled ruin wrought by fire is not yet ended," wrote geologist Frederick Ransome in the May 1906 *GEOGRAPHIC*, published weeks after the April 18, 1906, disaster. His quickly assembled article, "The Probable Cause of the San Francisco Earthquake," was illustrated with maps of fault lines and the ominous scribbles of a seismograph. Readers had to wait for June's issue to see images similar to this one of the tumbled courthouse in Santa Rosa, California. Photo after photo revealed San Francisco's buckled streets, forlorn chimneys, and the ragged tent towns of the survivors. —Margaret G. Zackowitz

◀ **Flashback Archive** All the photos plus e-greetings, in Fun Stuff at [ngm.com/0604](http://ngm.com/0604).

PHOTO: LeBARON COLLECTION

NATIONAL GEOGRAPHIC (ISSN 0027-9358) IS PUBLISHED MONTHLY BY THE NATIONAL GEOGRAPHIC SOCIETY, 1145 17TH ST. NW, WASHINGTON, DC 20036-4688. \$34.00 A YEAR FOR U.S. DELIVERY, \$6.00 PER SINGLE COPY (INCLUDES POSTAGE AND HANDLING). IN CANADA, AGREEMENT NUMBER 40063649, RETURN UNDELIVERABLE CANADIAN ADDRESSES TO NATIONAL GEOGRAPHIC, PO BOX 4412 STN. A, TORONTO, ONTARIO M5W 3W2. UNITED KINGDOM NEWSSTAND COVER PRICE £3.75. PERIODICALS POSTAGE PAID AT WASHINGTON, DC, AND AT ADDITIONAL MAILING OFFICES. POSTMASTER: SEND ADDRESS CHANGES TO NATIONAL GEOGRAPHIC, PO BOX 63002, TAMPA, FL 33663-3002. MEMBERS: IF THE POSTAL SERVICE ALERTS US THAT YOUR MAGAZINE IS UNDELIVERABLE, WE HAVE NO FURTHER OBLIGATION UNLESS WE RECEIVE A CORRECTED ADDRESS WITHIN TWO YEARS.



**European Ground Squirrel** (*Spermophilus citellus*)

**Size:** Head and body length, 11 - 33 cm; tail, 3.5 - 7.5 cm   **Weight:** 200 - 500 g

**Habitat:** Dry grasslands throughout central and southeastern Europe

**Surviving number:** Unknown; populations declining



Photographed by Klaus Nigge

# WILDLIFE AS CANON SEES IT

Thin is definitely not in. A dedicated forager, the European ground squirrel works hard to pack on all the weight it can handle. After all, it has to live off its stored body fat for six to eight months as it hibernates through the cold weather in an underground den. Mature males emerge first, in February or March, followed by females and immature males. Adults waste no time in starting a family since the young—born naked—need to grow and fatten up before

their first winter rolls around. This cycle of life is under threat as agricultural development, building activity and afforestation lay claim to the squirrel's natural grassland habitat.

As an active, committed global corporation, we join worldwide efforts to promote awareness of endangered species. Just one way we are working to make the world a better place—today and tomorrow. Visit [ngm.com/canonwildlife](http://ngm.com/canonwildlife) to find out more.