

VOL. 142, NO. 5

NOVEMBER 1972

NATIONAL GEOGRAPHIC

*Surf batters
the Monterey coast*

**VENICE FIGHTS
FOR LIFE** 591
JOSEPH JUDGE
ALBERT MOLDAVAY
VICTOR R. BOSWELL, JR.

**GOLIATHS OF THE
GALAPAGOS** 632
CRAIG MACFARLAND
JAN MACFARLAND

**THE SEARCH FOR
TOMORROW'S
POWER** 650
KENNETH F. WEAVER
EMORY KRISTOF

**A LAND APART—THE
MONTEREY PENINSULA**
MIKE W. EDWARDS 682

**DROUGHT BEDEVILS
BRAZIL'S SERTÃO**
JOHN WILSON 704
GORDON W. GAHAN

**THE RED SEA'S
GARDENS OF EELS**
EUGENIE CLARK 724
JAMES L. STANFIELD
DAVID DOUBILET

FLARE!



Photos shot simultaneously in restricted space, under a difficult lighting situation. Compare Spotmatic results at left with the next three best known fine 35mm SLR cameras in the U.S. Spotmatic's secret: seven super-thin layers of lens coating.



Many 35mm cameras look a lot like Honeywell Pentax

But their results don't

Results are what fine photography is all about. Under ideal conditions, any fine camera will give you good pictures. But when lighting conditions are difficult—when you'd hesitate to even try with other cameras—the flare-taming Pentax Spotmatic II with its exclusive Super-Multi-Coated Takumar lens comes through with flying colors. Truer, more vibrant colors, with richness enhanced by greater contrast in both high-light and shadow areas. Ghosts and flare are dramatically reduced, even shooting into the sun. While other 35mm cameras look similar, ours sees better. See for yourself, at a Honeywell photo dealer. Or mail this coupon today for literature and names of some nearby dealers.



Honeywell

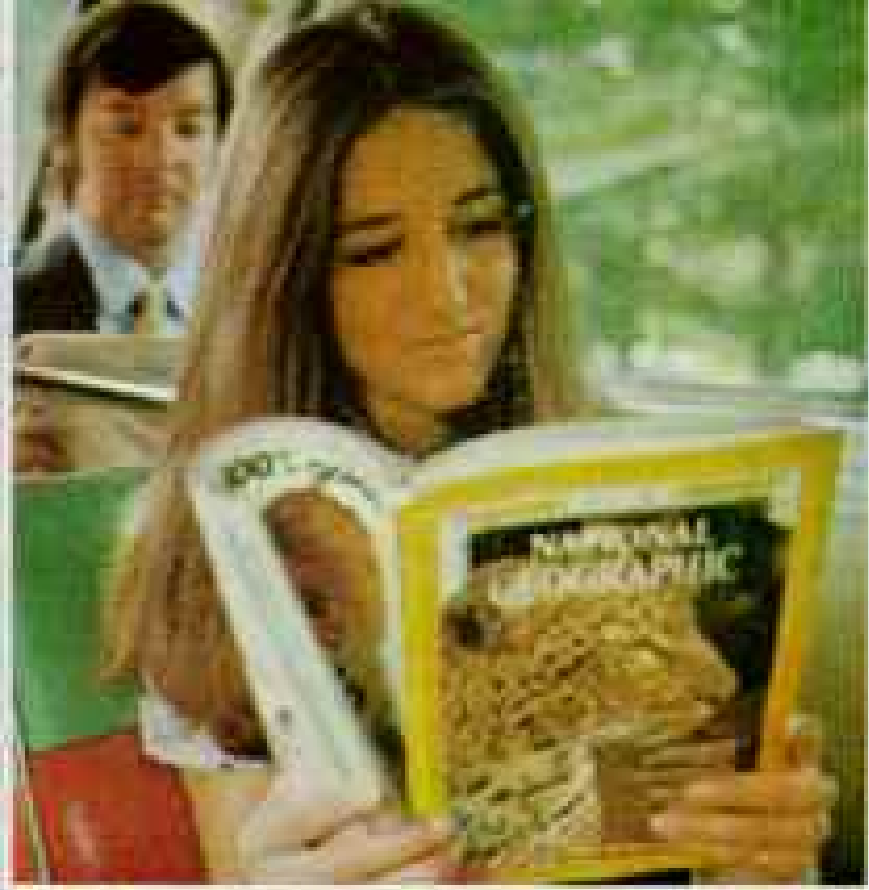
Honeywell Photographic, P.O. Box 22083, Denver, Colorado 80222
FREE information on Honeywell Pentax® cameras and Super-Multi-Coated Takumar lenses. Please send to: 101-384

Name _____

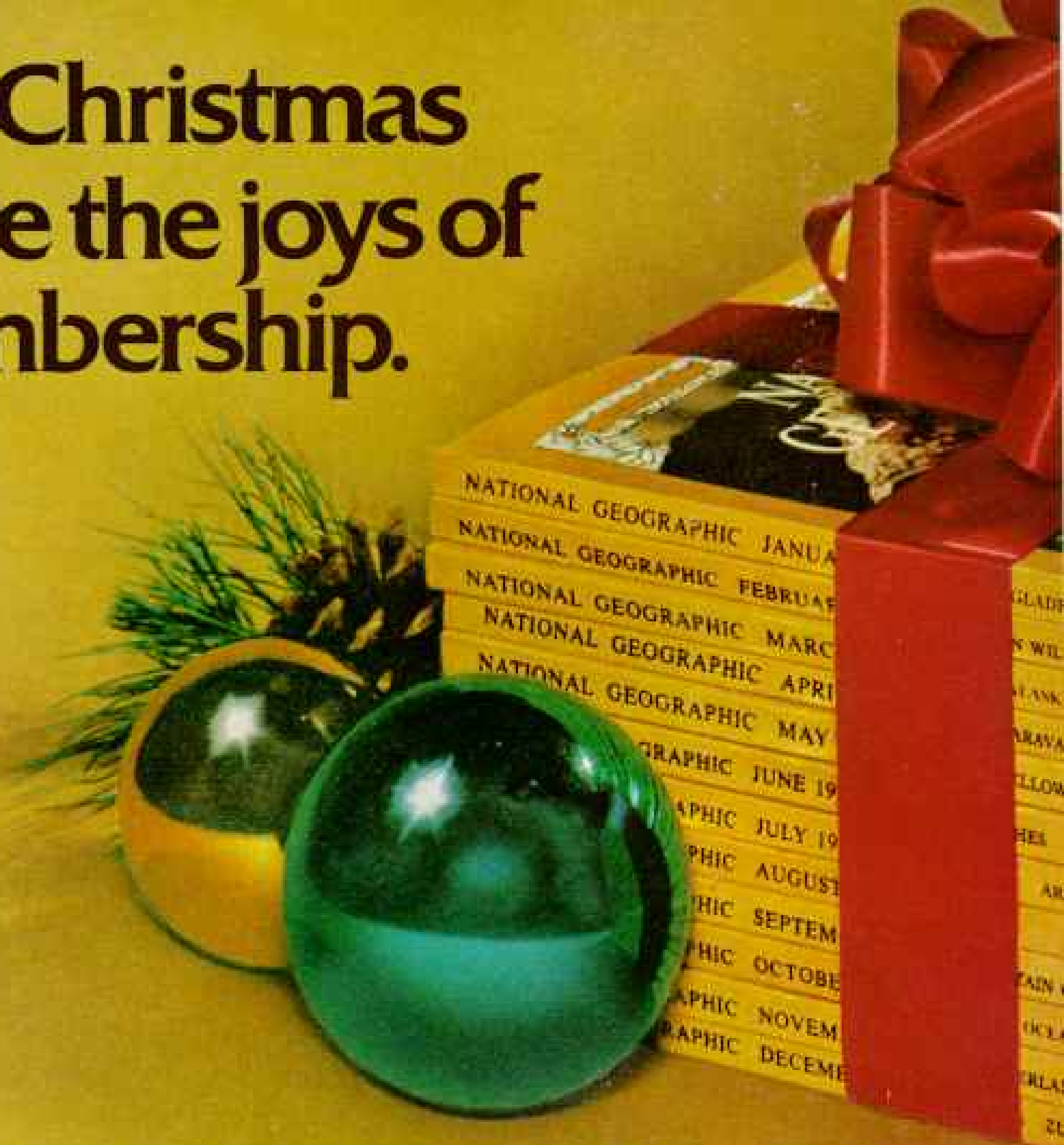
Address _____

City/State _____ Zip _____

*Honeywell Pentax in the U.S. and Mexico; Asahi Pentax elsewhere. In Canada: McQueen Sales Company, 1760 West 3rd, Vancouver, a Honeywell subsidiary.



This Christmas share the joys of membership.



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1972 MEMBERSHIP DUES in the United States and throughout the world are \$7.50 U.S. funds or equivalent. To compensate for additional postage and handling for mailing magazine abroad, please remit, for Canada, \$8.50 Canadian or U.S. funds; for all other countries, \$9.50 by U.S. bank draft or international money order. 80% of dues is designated for subscription to the magazine.

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WASHINGTON, D. C. 20036

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4113

Total remittance enclosed \$

Why this scre



en is blank.

You've seen ads and commercials for color television.

The pictures they show on the sets are very impressive. Rainbow-colored parrots. Dazzling drum majorettes. Bronzed giants on water skis.

You've also seen the disclaimers. The small legal type that says "Simulated TV Picture" or "Closed Circuit Transmission."

Meaning that what you see cannot quite be the real thing.

Because in the case of an actual picture on a set in a commercial, that picture can only be as good as the set you're watching it on. (Of course, if you're watching on black and white, you can't judge color anyway.)

And in the case of a magazine ad, it's obviously impossible to get a faithful reproduction of an actual television picture on a printed page.

At GTE Sylvania we're particularly concerned about this.

Possibly because GTE Sylvania has now come up with Chromatrix™—its newest, most advanced picture tube.

By its fine balance of brightness and contrast, the Chromatrix tube produces a picture that's about as close to real life as you can get.

But you can't see how close this really is by looking at an "idealized" picture in an ad.

Or by what you may see in a television commercial. Then, how do you judge?

The truth—and this goes for any color set—is that the only way to judge picture quality sensibly is to see the *actual* picture on the *actual* set (or sets) you're interested in.

We suggest you go to a dealer and see the same picture on 3 or 4 different sets, including Sylvania. Compare color, detail, ease of tuning.

Any other way is at best a waste of time. And at worst, a terrible way to buy a color television set.

GTE SYLVANIA
A part of General Telephone & Electronics

Andersen Windows. The energy savers.

To realize the most comfort from your heating and air conditioning, *and* to conserve energy and use it most efficiently, a home needs the quality construction and weathertightness of Andersen Windows. In the average home, about 50% of heat loss and gain occurs through and around windows and doors. But with top quality Andersen Windows you can reduce heat loss or gain by as much as 15%. Andersen Windows are a beautiful way to cut heating and cooling costs.

It's draft-free.

Traditional Andersen weathertightness reduces heat losses by infiltration by as much as 60% as compared with commercial standards. All-around vinyl weather-stripping keeps its shape. And chemically-treated wood is dimensionally stable.

Wood's a natural insulator.

Perma-Shield's core of warm, stable wood makes for both comfort and beauty.

No need for storm windows.

Xi[®] double-pane, welded insulating glass provides comfort and saves fuel. Andersen saves you the trouble and expense of changing storm windows.

Will not warp or stick.

Closes tight to seal out drafts, yet opens easily. Won't bind, because of the perfect combination of stable wood and the vinyl protective sheath.

I'd like to know more about Andersen Windows and Gliding Doors. Please send free booklets showing the 5 basic styles and hundreds of sizes.

NAME _____

ADDRESS _____

CITY _____ COUNTY _____

STATE _____ ZIP _____



Andersen Windowalls
A DIVISION OF ANDERSEN WINDOW AND DOOR COMPANY
ANDERSEN WINDOW AND DOOR COMPANY, ANDERSON, MINNESOTA 55003

NO-112

Q: It's said that America's known supplies of oil and gas won't last the century. Can UOP solve that dilemma?

A: No company in the world has a broader capability than UOP to provide the technology needed.

Q: What are the facts?

A: Take the energy-gap. In the last 30 years, our company was the leader in doubling the mechanical energy from a barrel of crude. But the nation's most assured long term energy source is coal. UOP is exploring processes to make crude oil from coal...at an affordable price. We can also make substitute "natural gas" from coal. And we can even make high-sulfur soft coal a respectable fuel. We're working on that with Commonwealth Edison in the Midwest right now. Coal offers a tremendous energy potential!

Q: Cleaning up the environment is a buzz-word, too.

A: Understandably. The nation is creating more pollution than energy. UOP has a converter for cars that removes most exhaust pollutants. And the converter will remove pollutants for the life of the auto if used with lead-free high-octane gas. Our company has the broadest line of air-pollution control devices in the world. For ridding cement plants of that pall of dust. For removing bad odors from chemical plants. For eliminating nitric acid fumes.

UOP has the know-how and hardware to both create new energy-sources and assure waste-free use of them. Right now. We intend to do good—and make money. I find that exciting!



Write to Office of The President for details on:

UOP's stake in the Energy and Environment Crisis

UOP's total Capabilities

UOP, Universal Oil

Products Company

Ten UOP Plaza

Des Plaines, Illinois 60016

UOP

The Answer Company

1973 bumpers
are tougher.

So here are the
bumper discounts
Allstate promised you.
The better the bumper,
the better the discount.



Tougher bumpers could mean great savings to American car owners. So in 1970, we made you a promise. We said we'd give you a break on auto insurance when bumpers got tougher.

Now we're keeping our promise. Allstate is giving every 1973 car sold in this country a 10%, 15% or 20% discount on collision insurance.

The better the bumper, the better the discount.

So if you're considering a 1973 car, come on in and see us about your 1973 bumper discount. (While you're at it, ask about our other discounts on auto insurance. We have a batch of them.)

We're trying to make driving a good thing again, and better bumpers are a good start.

With us, a promise is a promise.

Special rates and discounts available in most states.

Allstate
You're in good hands.



Travel light.

Do it right with a new Kodak pocket Instamatic 60 camera. The one that won't weigh you down, yet gives you all the features you could ask for.

Like the built-in automatic exposure control for taking pictures indoors and out. Plus a superb $f/2.7$ Ektar lens. Even a coupled rangefinder for extra-precise focusing. And it uses self-powered magicubes for flash.

The Pocket 60 takes the new little drop-in film cartridge. You get big, sharp $3\frac{1}{2} \times 4\frac{1}{2}$ -inch

color prints. Or color slides.

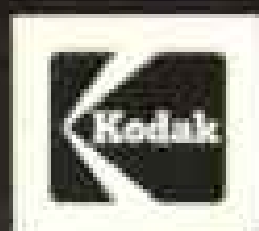
To show these new small slides, there are new Kodak pocket Carousel projectors. (You can also get adapters to show them on any 2×2 projector.) These new Pocket projectors, in stylish black with wood-grain panels, are only a little over 8 inches square. And yet, they take a full 120-slide tray.

See the Pocket 60 at your photo dealer's. It's less than \$128.

Kodak makes your pictures COUNT. Price subject to change without notice.



New Kodak pocket Instamatic® 60 camera.



Amid all the talk about luxury cars, one simple fact stands out. Cadillac commands the greatest owner loyalty of any American-built car. Figures continuously show that the percentage of repeat Cadillac owners is among the highest in the automobile industry.

*The most loyal car owner
in the land.*

The real question is: Why?

Why do the overwhelming majority of Cadillac owners return to Cadillac when they are ready to buy another car?

Cadillac owners themselves give many reasons. Riding comfort. Resale value (traditionally the highest of any car built in the land). Dependability. Handling ease. Quality of workmanship. Performance. Durability. Styling.

But it all seems to add up to one thing—owner satisfaction. In the car. And in the men who sell and service the car.

If you don't feel this kind of loyalty toward the car you are presently driving, maybe it's time you visited your authorized Cadillac dealer. Maybe it's time for you to drive a Cadillac.

Cadillac 



**SOMETHING ELSE
THE FIGURES SHOW.**

One out of every two
highway fatalities
involves the drinking
driver. One out of every

two. Please, if you drink,
don't drive. Thank you.
Cadillac Motor Car Division.





How often has it happened? You're scanning through this magazine, just looking at the pictures and captions the first time through. Suddenly you stop turning pages. Your attention is diverted, arrested, captured. Finally you do go on, almost reluctantly. Then you come back again.


That's the kind of impact a great photograph can have. If you're a regular reader of this magazine, if you appreciate the fine photographs on these pages, there just might be the makings of a photographer in you. Because you've already begun to develop a photographer's eye. And recognizing a good photograph is the first step in being able to create your own.

The second step is, of course, the right camera. One that can respond to your creative inputs without complicating your life unduly.

We have such a camera. The Nikkormat FTN.

Despite its professional reputation and abilities, it is surprisingly, disarmingly simple to use. People have graduated from instant-loaders to Nikkormat without missing a click.

Yet, with equal regularity, Nikkormat owners have crossed the line between amateur and professional photographer without changing cameras. Because the Nikkormat is part of the Nikon System, the most complete in 35mm photography. As fast and as far as you want to grow in photography, the Nikkormat grows with you.

Is the talent, the creative spark within you? There are two ways to find out: See your Nikon dealer, or write for details. And ask, too, about The Nikon School of Photography. Nikon Inc., Garden City, N.Y. 11530. Subsidiary of Ehrenreich Photo-Optical Industries, Inc. Dept. NG.  (In Canada: Anglophoto Ltd., P.O.)

**That quality which
lets you appreciate
great photographs
can make you a
fine photographer.**



Nikkormat. The beginning of your involvement.



The real

The lifeblood of our technological civilization is energy from fossil fuels. But easily accessible domestic reserves continue to diminish as demand steadily increases.

Man must perfect techniques to extract from nature's abundance greater quantities of supplemental energy. Perhaps giant satellite solar cells; perhaps proven safe atomic fission. Or perhaps he will be encouraged to seek greater yield from known natural reserves and synthetics without disturbing either the ecology or the economy.

The ideal

A practical way to harness the pure, clean force of the sun, source of every energy form man has ever known.

Whatever the answers, they must be found while we still have the energy to find them.

AtlanticRichfieldCompany 

artist: Ippolito: The Metropolitan Museum of Art



Kids, sugar and psychology.

Do you have that little impulse to say "no no" whenever you see your little one enjoying something with sugar in it?

Lots of mothers have this prejudice. But, in fact, sugar can often do kids quite a bit of good.

Sugar puts in the energy kids need in a form kids like. It not only helps youngsters stoke up

fast, but the good natural sweetness gives them a sense of satisfaction and well-being.

Nutritionists say that sugar, as an important carbohydrate, has a place in a balanced diet. A diet that includes the right kinds and right amounts of protein, vitamins, minerals and fats, as well as carbohydrates.

Sugar. It isn't just good flavor, it's good food.



How to tell if your child is overeating. Just going and growing, kids burn up a lot more body fuel than adults. If you're worried about overeating, take a look at your child. If he's not fat, he's not overeating.

For more facts about good nutrition, and sugar's role in it, write:

Sugar Information, General P.O. Box 94,
New York, New York 10001.



A-T-O. We help all kinds of people get their plans off the ground.

Construction is another primary area where A-T-O products and services play leadership roles. Big jobs, small jobs, we're there.

An example is the steel scaffolding shown here, scene of an impromptu lunch concert. Our Safway division, originator of tubular steel scaffolding, is also a major supplier of heavy-duty shoring for concrete structures.

Road graders, rollers and concrete mixers from our Huber, Essick and T. L. Smith divisions smooth and pave everything from interplant roadways to interstate highways. A fast, efficient way to move material around construction sites is with a Scott Midland truck crane.

Topside, our Essick division is the pacesetter producer of evaporative air coolers, make-up air systems and the leading maker of pumps that apply mortar, plaster, sealants and fireproofing materials.

Kersey is the world's leading manufacturer of battery powered mining equipment.

"You've Got to be Kidding!"
by Norman Rockwell

Construction is an ideal time for installing an "Automatic" Sprinkler fire protection system. And, if the above site was protected by Advance Industrial Security, the barefoot vocalist would have had to do his thing elsewhere.

Construction . . . it just wouldn't be the same without us!



For a 25" x 30" print of this Norman Rockwell painting, "You've Got to be Kidding!", suitable for framing, fill out and mail this coupon, along with a check or money order, to:

A-T-O Inc., P.O. Box 120N, Willoughby, Ohio 44094

Quantity _____ print(s) @ \$2.00 each.

Name _____

please print

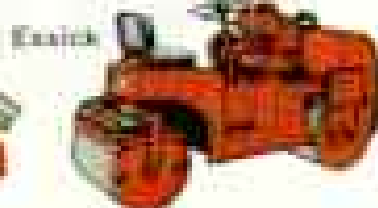
Address _____

City, State, Zip _____

Offer void where prohibited



© A-T-O Inc. 1972





**BUY A YORK CENTRAL HOME
AIR CONDITIONER NOW.
YOU DON'T START PAYING
UNTIL NEXT SPRING.**

If the heat this summer convinced you that you ought to have central air conditioning to help you get through *next* summer, your York Dealer® could have a proposition for you. It's a basic exchange of favors. Do him a favor by letting him install York Central Home Air Conditioning now, and he'll do you a favor by seeing to it that you don't have to pay a dime on it before May 15, 1973, assuming, of course, that you have a good credit rating.

What's more, some York dealers may

charge less for your unit now than they will next year.

So why wait? And take a chance on waiting even longer after the heat hits, and our men are working twelve-hour shifts just to keep up. Call your participating York Dealer today. He'll show you how you can be cool from the first hot day next summer – without putting any heat on your wallet this winter.

YORK MEMBER OF BORG-WARNER CORPORATION
BORG-WARNER
York, Pennsylvania 17405

*Participating dealers only

Winnebago '73.

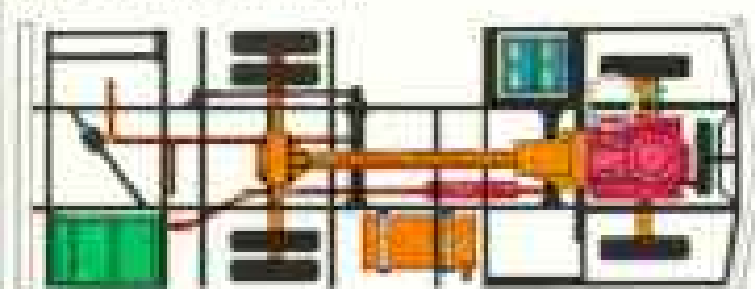
What it means to have the Flying W on your side.



Winnebago gives you more. A lot of features and built-in values that you just can't get in any other brand.

Most experienced manufacturer.

Winnebago is the world's largest producer of motor homes. We have almost 2,000,000 square feet of factory space, and manufacture most of the components that go into your motor home. There have been more Winnebago motor homes built, and owner-tested, than any other brand.



You get a big, tough chassis.

Load-carrying capability of all motor homes is measured by an official GVW (gross vehicle weight) rating system. No matter which Winnebago you choose, from the smallest to the largest, you'll get a chassis, steering, suspension and brakes that have been carefully mated to the size of the motor home.

You get more standard equipment.

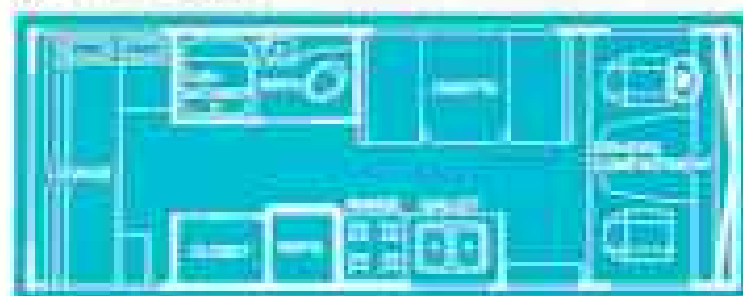
Even the smallest Winnebagos are completely self-contained. Forced-air furnaces. Complete kitchens with ranges, ovens and gas/electric refrigerators. Bathrooms with marine toilets and showers or tub/shower combinations. Twin gas bottles. Choice of new Herculon®* stainproof and flame retardant

fabrics. Dual rear wheels. Dozens of standard equipment features that are often "optional at extra cost" on other motor homes.



You get more space and more visibility.

We've added 3" right down the middle of every new Winnebago. Put in an escape window. Added 15% more space to all Indian and Chieftain side and rear windows. And we've made the windshields 20% larger in all of our motor homes to give you a better view of the road.



For '73, Winnebago gives you a choice of 13 motor home models—five Chieftains, three Indians, three Braves and two Minnie Winnies® (our new mini motor homes).

Winnebago gives you a complete Warranty and coast to coast service.

Winnebago construction, parts and accessories, with normal use and proper servicing—if found to be defective

in either materials or workmanship—will be replaced or repaired without charge to the original owner as follows:



Thermo-Panel® construction is warranted by Winnebago against defects in lamination for the lifetime of the vehicle.

Air compressors, air conditioners, antennas, auxiliary batteries, converters, speed controls, demand pumps, furnaces, LP gas bottles, power range hoods, pre-finished paneling, ranges, radios, refrigerators, sinks, stereos, vacuum cleaners, gauges, water conditioners, toilets and water heaters are warranted by Winnebago for one year.

Carpets, cushion foam, compartment doors, drainage hoses, driver and passenger seats, 12 volt and 115 volt wiring, cushion fabrics, fire extinguishers, refrigerator interior boxes, faucets, light fixtures, plumbing systems, switches, shower doors, shower heads, vinyl, jacks, sealants, LP gas valves and windows are warranted by Winnebago for 90 days.

If you ever need service, just see a Winnebago dealer. There are more than 300 of them from coast to coast. They can all provide factory-authorized warranty work.

Send the coupon. Even if you're not ready to buy, you can rent-a-way from it all for a weekend. You'll have fun and at the same time discover how Winnebago gives you more.

WINNEBAGO INDUSTRIES, INC. N
P.O. BOX 152
FOREST CITY, IOWA 50436

Hey, Winnebago!

Send me the name of my nearest dealer and complete information on all four lines and 13 motor home models for '73.

I'm interested in buying renting.

NAME _____

ADDRESS _____

CITY _____

STATE _____

ZIP _____

WINNEBAGO

We give you more.

The model D-27CL pictured above is priced at \$15,635. Other Winnebago motor homes priced from \$6,900. Both prices are F.O.B. Forest City, Iowa, excluding state and local taxes, dealer preparation, transportation and optional equipment, if applicable. Prices and specifications subject to change without notice. *Herculon® is a registered trademark of Hercules, Inc. for its Olefin fiber.



Every day Qantas flies to Australia. Qantas also flies the

On the Monterey Peninsula

A DISTINGUISHED RESORT. In a land of great beauty, a resort of distinction. Old world elegance plus latter day amenities. Golf on three famous courses (Pebble Beach, Spyglass Hill, Old Del Monte). Beach and Tennis Club privileges. Sports attire daytime and casually elegant dress in the evening. That's Del Monte Lodge, a resort for all seasons.

Del Monte Lodge Pebble Beach, Ca. 93953

A PLACE FOR LIVING. In this favored land, a realty service of reliability. Magnificent homes and homesites, ten thousand dollars to one half million. Condominiums. Rentals. That's Del Monte Realty, exclusive agents for new properties in the five thousand acre parkland of Del Monte Forest. There's a place for you here, whatever your interests and means.

Del Monte Realty Company

498 Calle Principal, Monterey, Ca. 93940





Looks more like four cops,
three meter maids, a desk clerk,
and an 11-piece band.

most 747B's. And to serve you, all these people fly along.

The easy-to-use fine camera. For weddings, graduations, vacations



or just plain horsing around.

A Minolta SR-T 101 makes it easy to capture all kinds of memories. Even silly ones.

To set shutter speed and lens opening, simply align two indicators in the viewfinder. You never have to look away. A Minolta SR-T 101 lets you frame, focus, and adjust exposure without losing sight of your subject.

For details, write to Minolta Corp., 200 Park Avenue South, New York, N.Y. 10003. In Canada: Anglophoto Ltd., P.Q.

Minolta



When identified by a factory-sealed "M" tag, Minolta 35mm reflex cameras are warranted by Minolta Corporation against defects in workmanship and materials for two years from date of purchase, excluding user-inflicted damage. The camera will be serviced at no charge provided it is returned within the warranty period, postpaid, securely packaged and including \$3.00 for mailing, handling and insurance.

You're holding at 10,000 feet. And suddenly the city disappears.



It happened to 18 planes in the crowded skies over New York City. It could happen again. To your city.

For most of us, a power failure is hardly more than the inconvenience of no lights or air conditioning. For others, it is a serious threat. To life. And property.

It's hard to understand why every hospital operating and emergency room isn't protected by a standby power system. Or all airport runway lights and control towers. Or crowded public places, industrial complexes involving volatile processes, water and sewage plants.

Check your police and fire departments. The hospital that cares for you. Your local airport. The place where you work. Your children's school.

Find out which facilities are protected with standby power. And which aren't. And why not.

Your life might depend on it.

For a free copy of "The Night The Lights Went Out," the New York Times account of the 1965 Northeast power failure, write to: Caterpillar Tractor Co., Dept. 627G, Peoria, Illinois 61602.



We can make the world a safer place to live in. Caterpillar Engines and Electric Sets will help.



CATERPILLAR

Caterpillar, Cat and  are Trademarks of Caterpillar Tractor Co.

HAVE YOU CAUGHT YOUR WATCH MAKING ADVANCES?

You become attached to your watch, you look after it, give it a home and what do you ask in return?

A little faithfulness.

But some watches are so ungrateful they'll pull a fast one. They'll lie and cheat until a man is forced to turn elsewhere.

Hopefully, to an Accutron® watch.

It has no balance wheel to get unbalanced

and cause it to take liberties with its hands.

It has no mainspring to get unsprung and make it run out on you, altogether.

Instead, every Accutron watch has a tuning fork movement that's guaranteed to keep it faithful to within a minute a month.*

Month after month.

Even when nobody's looking.



ACCUTRON® BY BULOVA

Accutron Date/Day "BD". All stainless steel. Blue dial, silver and white markers. Date resets instantly. Protected against common watch hazards. \$185. Other styles from \$110. *Timekeeping will be adjusted to this tolerance, if necessary, if returned to Accutron dealer from whom purchased within one year from date of purchase.

RCA XL-100 takes out a major cause of tv repairs.

And adds the strongest color tv guarantee in RCA history.



The XL-100s. 100% Solid State.

XL-100 model GF-502, "Raytheon" (22" diagonal). Simulated by reception.

Chassis tubes are a major cause of TV repairs. So RCA presents more than 50 models without a single chassis tube.

Tubes get hot and weaken with age. RCA XL-100s don't have chassis tube problems because they don't have chassis tubes. XL-100s are 100% solid state. Most set functions are controlled by RCA's 12 plug-in AccuCircuits. They're solid state—designed to keep cool, last longer, and be easy to service. Solid state color is the most advanced you can get. And RCA builds more, sells more, offers more than anyone in America. All backed with...

A stronger guarantee because...

1. You get a full year on parts (picture tube—2 years) and labor. Most other color TV models are not 100% solid state—and give you only 90 days on labor.

2. You choose any serviceman you

want. Most other warranties limit you to an authorized list.

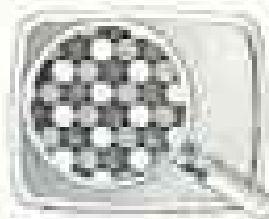
3. RCA encourages your serviceman to do his best work by paying him at his going rate. Most others set a maximum payment.

100% brighter picture.

XL-100s are 100% brighter than our comparable sets of 3 years ago. Every console and table model has RCA's black matrix picture tube. You get the kind of sharp, vivid color you'd expect from the people who pioneered color TV.

Simple automatic tuning.

RCA XL-100s have fiddle-free tuning—with a flexibility feature most other sets don't have. RCA's AccuMatic color monitor makes it simple to tune color to your individual preference... and keep it that way.



RCA black matrix picture tube

Your XL-100 guarantee.

Here are the basic provisions. If anything goes wrong with your new XL-100 within a year from the day you buy it—and it's our fault—we'll pay to have it fixed. This includes regular labor charges plus parts (new or, at our option, rebuilt). Use any service shop in which you have confidence—no need to pick from an authorized list. If your set is a portable, you take it in for service. For larger sets, a serviceman will come to your home. Present the warranty registration your dealer provided when you bought your set, and RCA will pay the repair bill. If the picture tube becomes defective during the first two years, we will exchange it for a rebuilt tube. (We pay for installation during the first year—you pay for it in the second year.) RCA's "Purchaser Satisfaction" warranty covers every set defect. It doesn't cover installation, foreign use, antenna systems or adjustment of customer controls.

Color you can count on.

RCA **XL-100**
100% SOLID STATE

Venice Fights for Life



GONDOLAS SLUMBER AT THEIR POSTS ON THE SAN MARCO CANAL.

THROUGH the long November afternoon, rain pours down in the Campo Santa Maria Zobenigo, waxing the paving stones. A man crosses the square, wrapped in a black topcoat, pushing a cart and crying in a melancholy voice, "*Ombrello! Ombrello!*" On the facade of the church, pigeons huddle under the damp wings of a marble angel who seems to be weeping. Rain teems now, in puddles, in pools, and makes a skein of circles on the surface of the Grand Canal, where a black gondola pitches its way toward Dorsoduro.

"*Acqua alta*, the high water. . . ." The word passes quietly. Heads nod, eyes scan the level of the lagoon, but without fear or excitement, for floods

have become a dismal way of life for Venice. The people of the Cannaregio district quietly move their things upstairs—if they have an upstairs.

In the gathering gloom an ill wind—the *sirocco*—piles heavy tides toward the city's foundations. You stand over a storm drain near the basilica of San Marco; a dark pool, glistening with oil, wells up over your boots. Swiftly it spreads into a pond; the pond widens to a wind-rippled lake. It seems that the huge Piazza San Marco is slowly submerging under the stony weight of its thousand-year-old history, going down like an enormous stricken ship.

The tide crests over the pavement of the piazza, streams under the

By **JOSEPH JUDGE**

SENIOR EDITORIAL STAFF

Photographs by **ALBERT MOLDVAY**





In its battles with the sea, Venice has triumphed—so far. But now floods arrive with increasing frequency, eroding the defenses of this canal-laced treasure-house of art and architecture. Pollution sullies the city's shining face. The sea rises, the land sinks. When a November storm strikes, water smothers the Piazza San Marco, heart and soul of Venice, and invades the basilica (left) and adjoining Doges' Palace. At a sidewalk café, students take the calamity in stride. But around the world concern grows, triggering a multinational effort to rescue this beloved jewel of Italy—and of people everywhere.



arches of the Doges' Palace, races past the arcades of the Sansovino Library, spills through the doors of the basilica in a gushing fall, and swallows the gay yellow and orange chairs of the Quadri café. With a handful of the curious, you wade toward higher ground. Most of Venice, which has memorized the different degrees of disaster, has gone to bed.

Thus it may happen on any day in autumn or winter. Engulfing tides, rare in the past, now surge over Venice regularly—30 times since 1960. That recurring whiplash of wind and water is, however, only the most visible of many afflictions besetting the still-lovely Queen of the Adriatic.

She is sinking, slowly but very surely. Pollution eats away at her marble sculpture, darkens the vast canvases of her great masters. She creaks and cracks and falls apart from plain old age. More and more young people desert the city, driven out by damp and dreary ground-floor housing, drawn by the lure of dry, inexpensive modern apartments on the mainland.

Rivals Vie for Venice's Future

Politically, they remain Venetians. For the governing unit, the commune of Venice, embraces two places—the old city, curled like a crenellated creature of the sea in its lagoon, and the brawny growing town of Mestre near the northwestern shore, with large industrial zones at Marghera, figured by oil refineries, factories, belching chimneys, and rusting scrap. Both beauty and the beast have laid a claim to the future of the commune, and those claims seem mutually exclusive. This confrontation between reverence for the past and industrial progress has more than once paralyzed the city's will.

So runs the litany of related ills, all too familiar to the modern world, but one with a particular poignancy in the city that scholar Bernard Berenson called "man's most beautiful artifact." Is she really doomed? Will the haunting splendor that is hers alone return to the waters from which it rose?

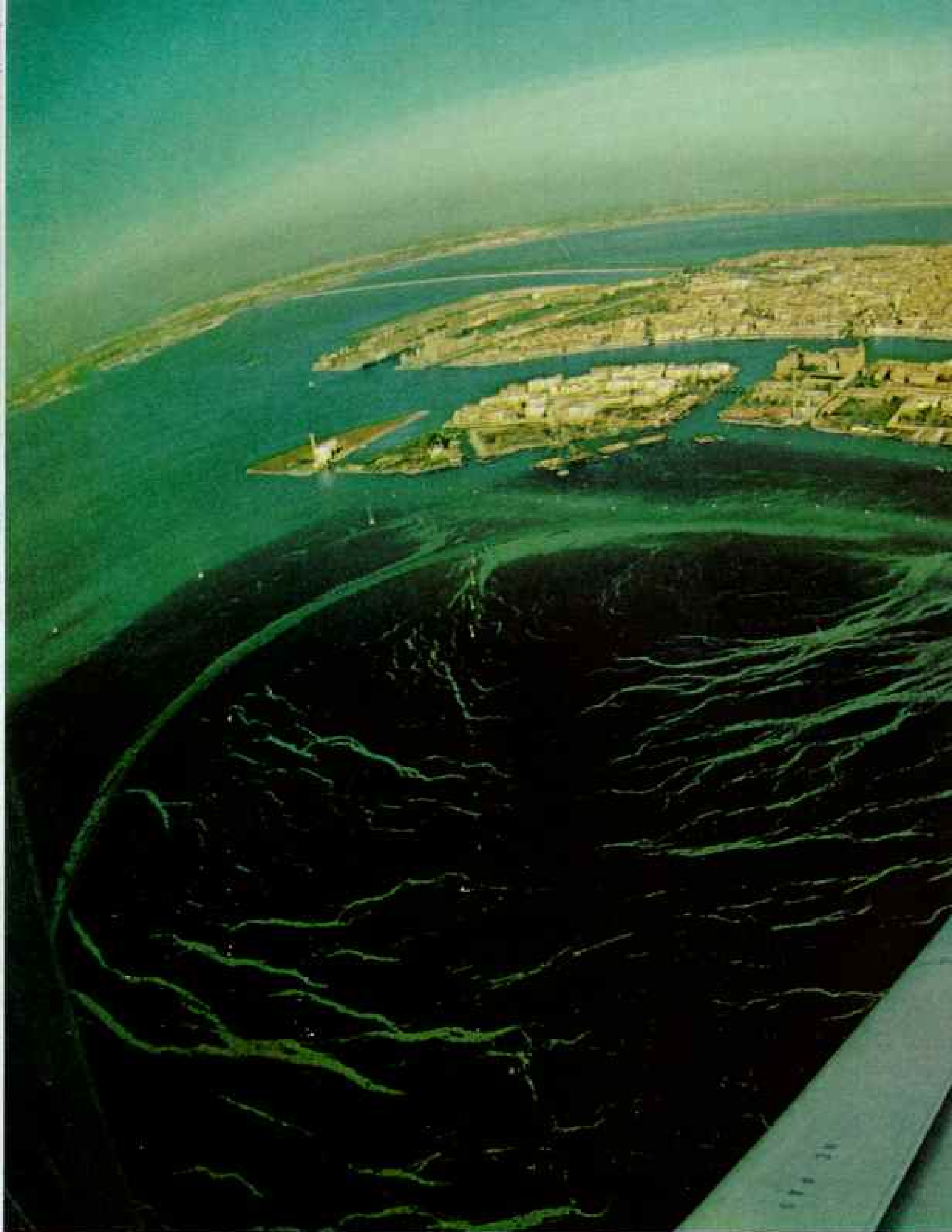
There is no denying the possibility that, without man's intervention, the sea will indeed claim Venice within a century. Yet, after several years of watching, I believe the old Serenissima Repubblica, the Most Serene Republic, is going to outwit her fate.

She will, at the least, make a fight of it. A spirited international effort has already restored 30 buildings, including half a dozen

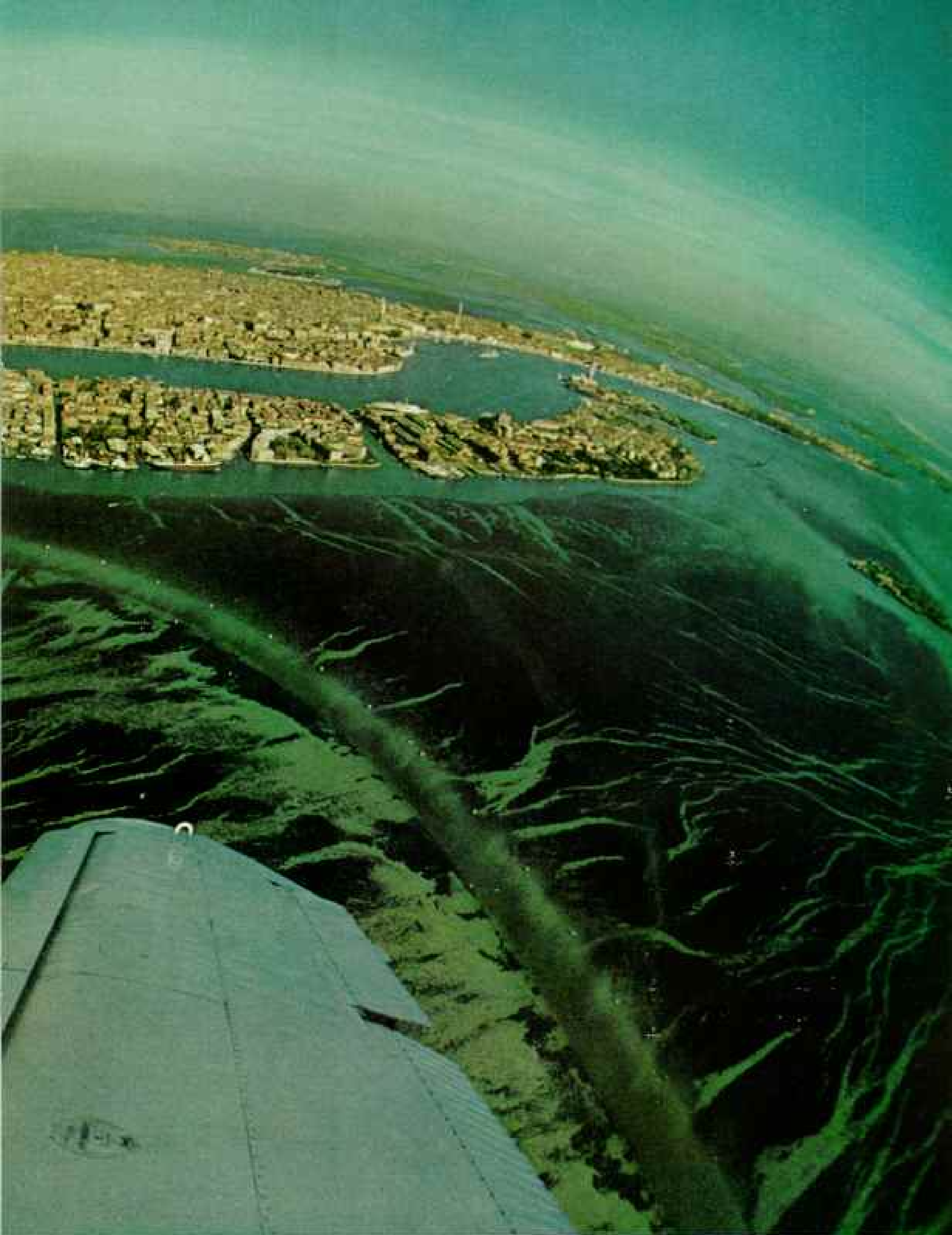


As if cringing from the flood, the "four princes"—probably fourth-century Syrian warriors—witness a rising tide from their corner of San Marco. Early merchants and soldiers brought home a wealth of such souvenirs to glorify the basilica—and Venice.

Caught with his boots off, a Venetian gets a piggyback ride through a November flood.



"Here you live like sea-birds. . . scattered over a watery expanse," wrote the sixth-century Roman Cassiodorus. On sand-and-clay islands in the shallow lagoon, early Venetians found refuge from invading hordes and began the unending task of filling, bridging, and buttressing their 118 islands. Today sailors follow the buoy-marked channel



in the foreground, dredged through the shallows to the near islands of La Giudecca, once the city's vegetable garden. Beyond lies old Venice, Queen of the Adriatic. The long span at left carries traffic to the mainland and the smoggy industrial complex of Marghera and Mestre, the more prosperous part of the Venetian municipality.



sagging churches, cleaned and restored about 4,000 square yards of murals and 1,500 paintings by masters like Tintoretto and Titian. Here and there a superbly restored palace stands proudly once again.

And last autumn it looked as though salvation was certifiably at hand when the Italian Government supplemented these private efforts with a major commitment of 400 million dollars. The legislation specifically allocated funds for such vast capital projects as rehabilitation of housing, a sewer system, and construction of movable gates at *porti*—inlets—of the lagoon to hold the raging sea at bay. With the administration's fall last winter, this hope was delayed. But it is now expected that the law will be passed by the end of the year.

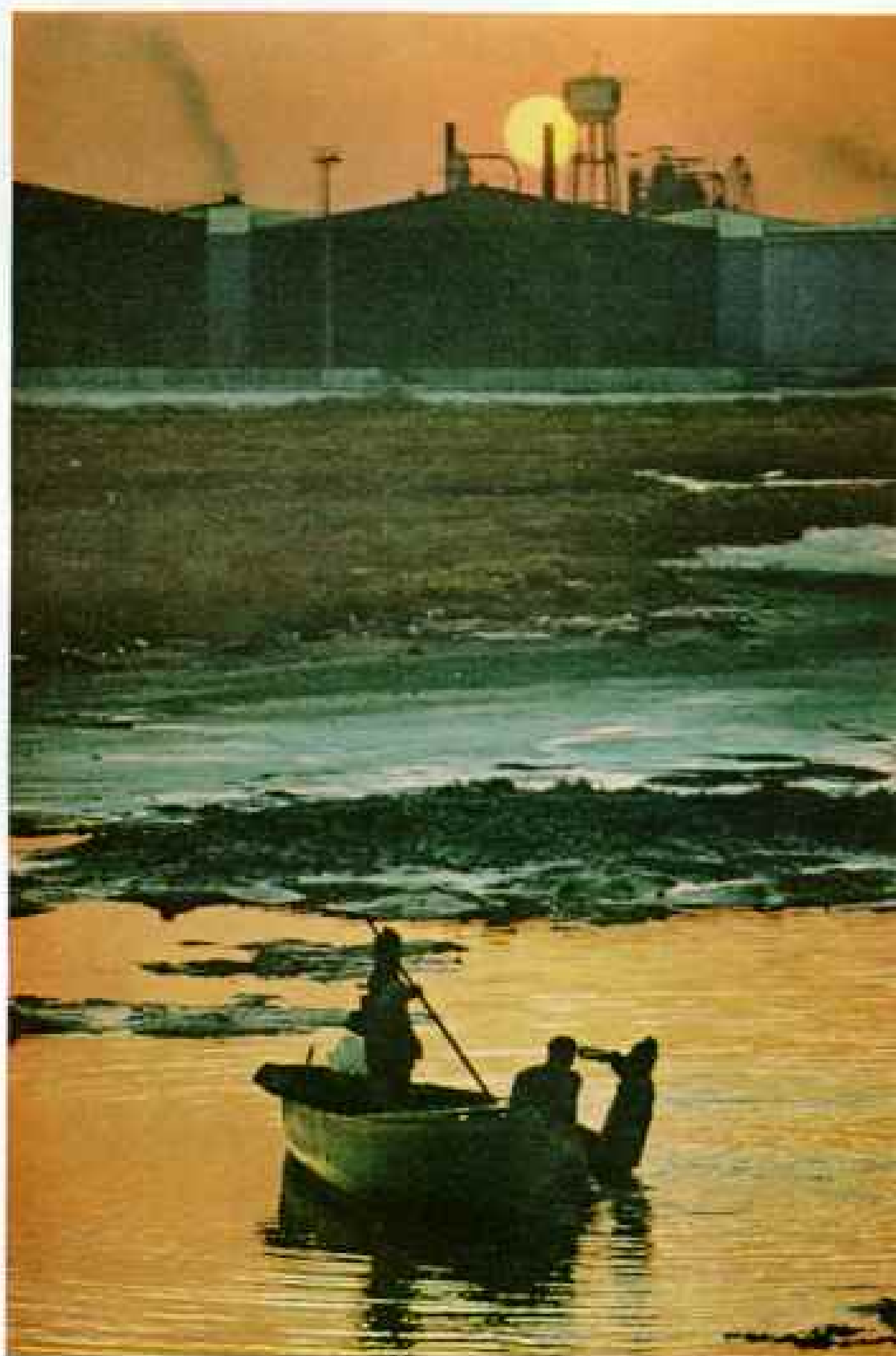
I think that Venice will live, too, because she holds a precious secret of life. Even if it is often underwater, the great space of the piazza, with its blizzard of pigeons blowing and banking to the strains of café orchestras, is still Europe's finest drawing room. And there is no sight of greater tranquillity and repose than the white dome of the basilica of Santa Maria della Salute, steadfast as a star in the rose of evening.

Nothing is more magical than a moonlit ride in a gondola across a lagoon brushed with mist. On such an evening I mentioned to a friend that the scene had not changed since the fifth century, when landsmen fled to the lagoon seeking safety from the Huns. And he said, "Time here is always present."

You realize it when a man like Conte

Men of the wharves—mainstay of the Venetian work force—express their discontent; the sign at center accuses the government of favoring the *padrone*, or boss. The jobs of the waterfront workers depend on modern port facilities. Only a plan to save Venice that assures continued industrial growth will win the approval of the working majority.

Enjoying the beauty, ignoring the blight, Venetian fishermen take a wine break in the sunset-gilded lagoon. Here the mud flats of Marghera are fouled with industrial wastes, sewage, and agricultural runoff. In contrast, the doges of the republic strictly enforced regulations against any impurities that offended the eye or nose. "Sometimes you can die of progress," laments a modern Venetian.



Lorenzo Donà dalle Rose extends a gracious hand and welcomes you to the palace his family has occupied for 350 years. "One of the few palaces in Venice still lived in by the family that built it," says the ebullient count.

Insidious Moisture Makes Endless Work

As we spoke, workmen maneuvered around piles of brick and bags of cement. None of the clutter disguised the grandeur of the great lower hall, with its gates open to the lilt of sunlight on the canal a step below.

The men were meticulously taking bricks out of the wall, and inserting lead sheets.

"To keep the moisture from rising," explained the count. "It goes brick by brick, *cuci-scuci*, as we say. The walls of the whole city are decaying. The waters come and go.

The sun shines and the tourists come back and everything seems wonderful again. But the salt and moisture stay inside the walls, and rise brick by brick, until one day, ker-ploop, into the canal, and so ends 350 years of living. Come upstairs for tea."

The way to the staircase led past a ship's lantern six feet high. "From the *Cristo di Venezia*, one of the fleet at the Battle of Lepanto in 1571. My ancestor, Bartolomeo Donato, commanded the ship. It belonged to the family. They helped save Europe and Christendom from the Turks, and a lot of thanks Venice got for it."

Upstairs, the count led me through a suite of splendid rooms and paused before a portrait of the family's most illustrious member, Leonardo Donato, posing with Philip II

Venice's lagoon: battered by nature,



burdened by man



SHELTERED in her fragile, island-guarded lagoon, Venice draws vitality from the tides. Their gentle cleansing flow pulses past the Lido, a famous resort, and sweeps up sewage and refuse, carrying much of it out to sea. Three-fourths of the 210-square-mile basin lie permanently under a thin sheet of water; mud flats and islands cover the rest. Increasingly, man-made obstructions—fish ponds and landfill (shown in red)—choke the lagoon. Deep-dredged ship channels speed the flow of the tides, causing erosion.

But natural forces, not man's handiwork, threaten eventual oblivion. The northern Adriatic region has subsided 70 to 120 inches since Roman times. Simultaneously the world's oceans rise as the ice masses melt. Victim of this double play, Venice, in effect, sinks an inch every five years.

When fierce gales, called siroccos, sweep up the Adriatic (inset A, arrows), they can push the water to three-foot heights in the city's piazza. One solution envisions submerged caissons (B, shown in cross section) at lagoon entrances. With the approach of high water, they would be raised, barring both sirocco-driven waves and ships for an estimated 200 hours a year.

of Spain. "By Titian. He lived around the corner here, a few hundred yards that way. Titian, that is. If he came in here right now, he'd know just where to sit."

Only one of several glass showcases in the place was empty, a large one near a window.

"There," said the count, pointing, "was the most marvelous collection of porcelain. I had to move it. Look here." We went to the window and gazed at the looming wall of the church of Santa Maria Assunta dei Gesuiti, cracked and threatening just across the canal.

"You walk in that church, it goes boom, boom, boom. The waters have eaten a great hole under it. That wall, if it ever fell, would have smashed all my lovely porcelain."

One has the feeling that neglected Venice herself might crack in the clumsy hands of change. The city was built just out of the reach of the highest tides, one to four feet above mean sea level. She survived because her aristocratic rulers understood and respected their unusual environment.

The long S-curve of the Grand Canal is in fact an ancient channel between islands; most of the canals are deepened passages between the 118 islands on which the city took root. As long as the lagoon remained the same and the movement of the tides was predictable, Venice's margin of safety was small but amazingly durable.

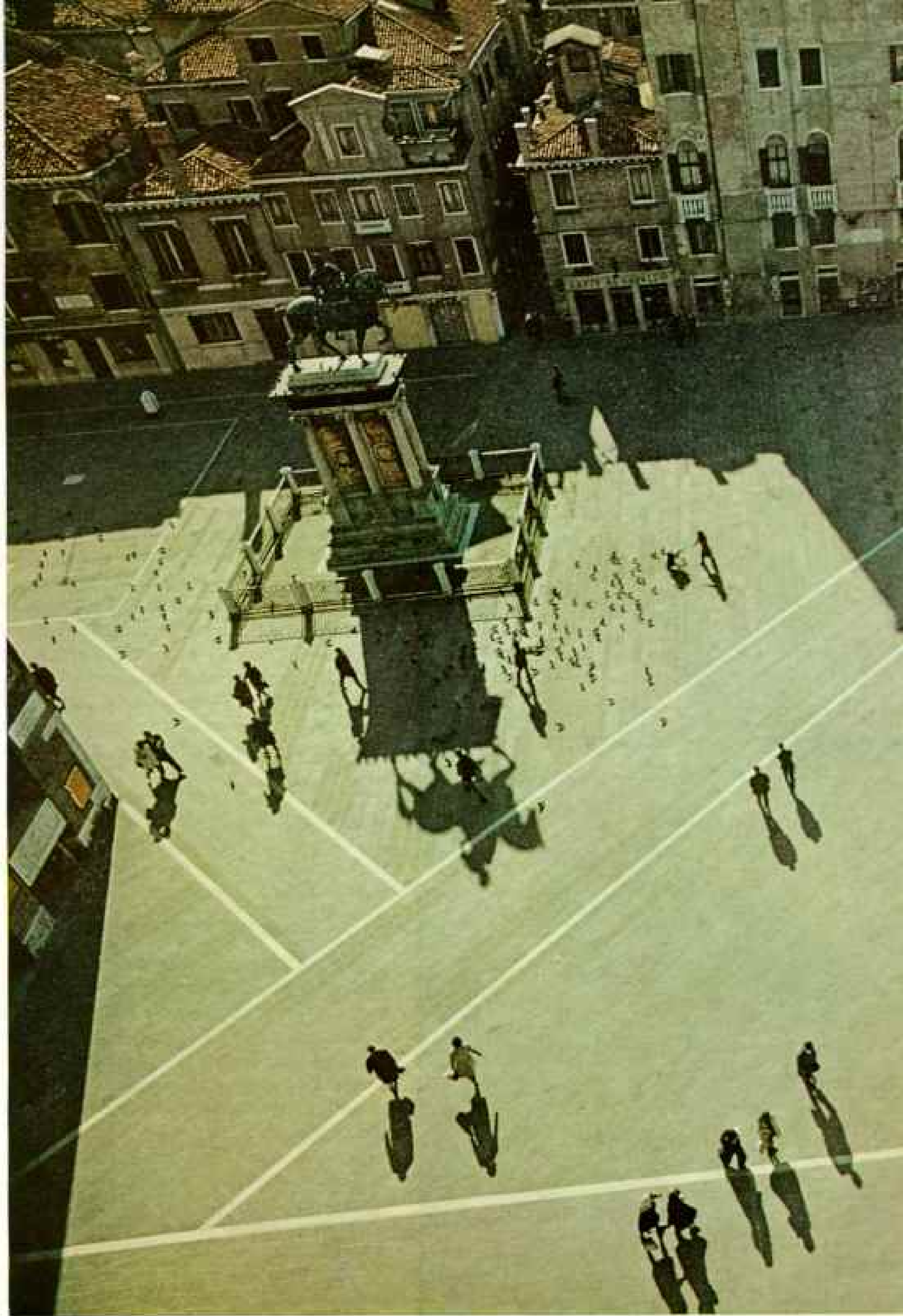
No more. Each year the margin narrows by another fraction. In the past 30 years Venice has slipped two inches closer to oblivion every decade, a process that would destroy her within the lifetime of living men.

Many Forces War on Venice

Yet the entire question of what is wrong, and what must be done to correct it, is surrounded with controversy and speculation. Thousands of jobs and millions of dollars are at stake, for the future of the port and of the industrial complex at Marghera will depend upon the steps taken in the lagoon to combat the sinking and the sea.

When I asked Dr. Giovanni Maraffi, head of public works for Venice, about the subsidence, he smiled wanly and said, "The lagoon is treated like a military secret, but I can tell you what is known.

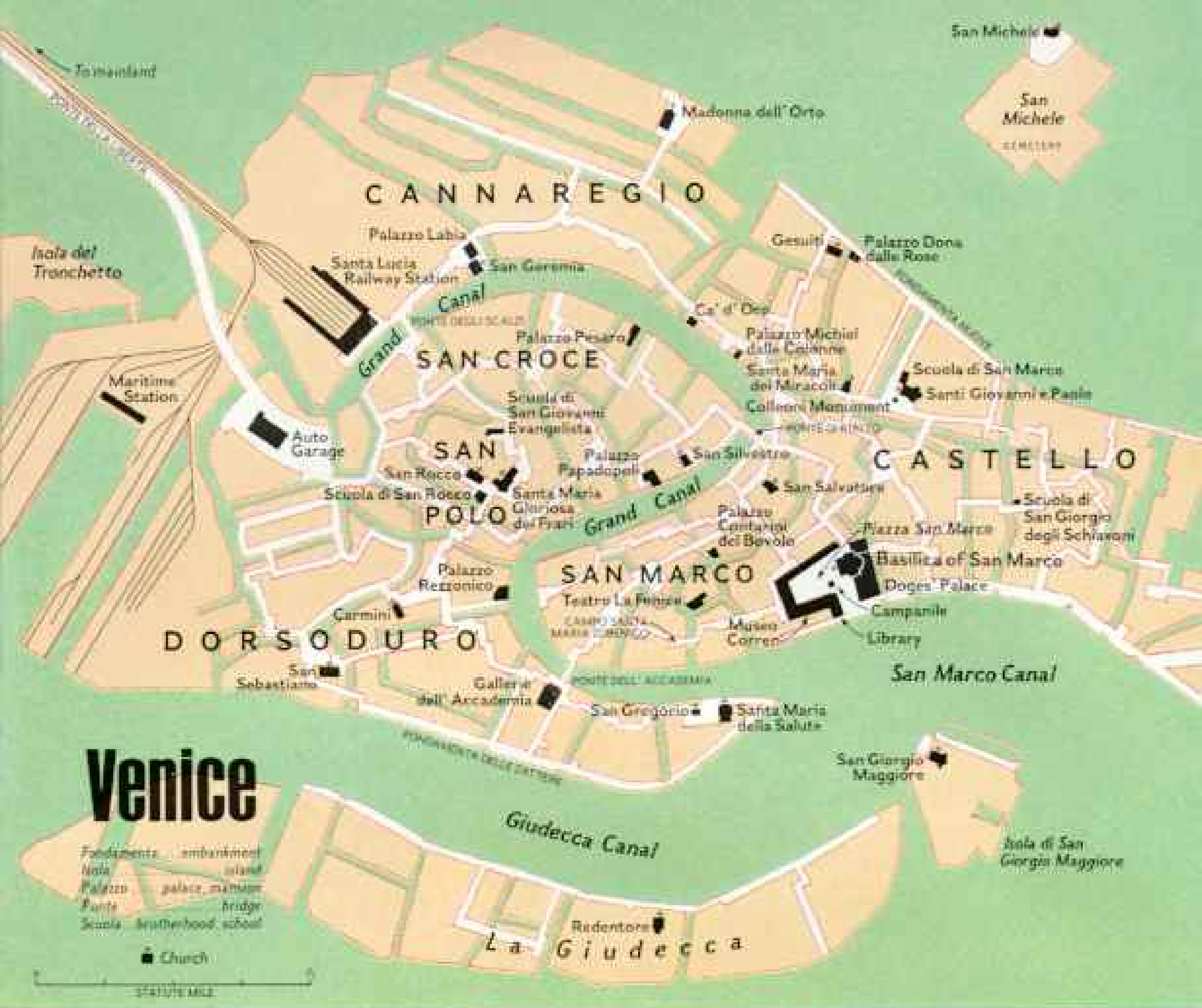
"The Venice region has been sinking for a very, very long time. The sea level is also rising all over the planet, due to the melting of the polar caps. These two events account for only half the measured shrinking of our



When the sun smiles, Venice becomes one of the world's most beguiling spots. This square, dominated by the equestrian statue of Bartolommeo Colleoni, offers breathing space at the heart of a bustling neighborhood.



An adjacent canal moves freight and passengers to the very doors of tile-roofed homes. Cars, motorcycles, and even bicycles are banned, but around housefronts tethered boats tug at mooring lines like so many restless horses.



DRAWN BY LEO ZEBARTH; COMPILLED BY ANN HUNTER

safety margin. Other forces are also at work."

One solid suspicion shared by most observers, and supported by cores drilled in the lagoon bed, is that much of the sinking is due to the mammoth thirst of industry for fresh water. Some 70 wells at Marghera alone bring up billions of gallons every year.

"Huge pumps are buried in the ground," a conservationist told me, "and they have been drawing the water table down at a fantastic rate, between thirty and fifty feet since industrialization began. The substrata of sediment under Venice has bowed and the ground subsided, and it is impossible to push it up again by pumping water back in. We have to stop pumping now and live with the damage that has been done."

Meanwhile, in an effort to reduce use of the wells in the Marghera area, private industry has begun construction of its own 12-mile-long aqueduct from the Sile River. One of the proposed items in the pending legislation

would provide a contribution to this scheme.

Will Venice stop sinking once the pumping stops? To answer a host of such difficult questions, the independent but government-supported National Research Council (NRC) has turned to modern man's best friend, the computer. This particular computer lives in high style, in a palace on the Grand Canal no less, attended like a modern doge by earnest young men in white jackets.

Tides Hold Key to City's Survival

Amid the baroque splendor of a large room in the Palazzo Papadopoli, I talked with Dr. Roberto Frassetto, the appropriately dynamic scientist who heads the NRC's Laboratory for the Study of the Dynamics of Large Masses.

"The physical problems here are all related," he said. "The subsidence is the critical factor, certainly, but another danger is a change in the hydrology of the lagoon in recent years. The sea is coming in faster now."

Labyrinth of canals laces the center of Venice. The city's main boulevard, the Grand Canal, snakes past dozens of palaces and churches.

To keep out the sea, centuries-old homes of Venice employ ingenious stratagems. When the water level was 39 inches lower than it is today, a layer of stone kept moisture from rising into the porous brick walls. Now owners must raise first floors to make them habitable. Some insert lead sheeting to stop the seepage of water into the brick. Here plaster has been crumbled by the wakes of motorboats, which far outnumber Venice's 400 remaining gondolas.



STAFF ARTIST WILLIAM H. BERRY

Dr. Frassetto's laboratory has carefully analyzed the three basic factors, each of massive power, that combine to produce Venetian tidal levels. The computer reviewed data on Adriatic tides and discovered a free oscillation in that sea—something like water rocking in a bath. This movement is superimposed on the regular tidal flow resulting from the pull of the moon's and sun's gravitational fields. And there is the sirocco, buffeting the shallow sea and driving it to surging levels. When a combination of these forces is pulling in the same direction, they create an overwhelmingly powerful force, as on the unforgettable fourth of November 1966.

"On that day," Dr. Frassetto said, "there was a terrific storm raging over most of northern Italy, the same one that deluged Florence. It filled the rivers and pumped water through them into the sea around Venice. The engine for the disaster, though, was the wind, blowing steadily for days until

it mounted to a furious 60 miles per hour. That violent wind out of the southeast created a surge of water six feet above normal tide levels, locked it against the city, and held it there for 12 hours. Thank God, though, the tides at that time of November were in a low phase. Had the tides been in a high phase, we would have had not six feet of water above normal but as much as nine. Venice might have died that day."

Electronic Seer Foretells the Future

The knowledge that it could happen again is the nightmare Venice lives with. One of the NRC lab's priority items was the construction, with the cooperation of IBM experts, of an early-warning system.

"What we can do now," said one of the experts, "is to tell the computer what is going on in the Adriatic at any given moment, and then ask it what will be going on inside the lagoon at Venice six hours from then."



VICTOR H. BOWELL, JR.



Mirror of pageantry, the Procession of the Cross in 1444 parades across the Piazza San Marco, center of public life in Venice then and now. In her golden days, the Republic of Venice ruled much of northern Italy and commanded the eastern Mediterranean. Exotic curiosities poured in from the Orient, and trade clothed her nobles in silks and lined her canals with palaces.

Today's solemn procession mounts a makeshift walkway thrown up along the waterfront. The church of San Giorgio Maggiore rises across the San Marco Canal. High water passes in a few hours, but Venice—already an aged lady—suffers painful after-effects: dampness creeps higher up the soft brick, walls crack, mold spreads across paintings, and oily waters leave ugly smears.



The NRC is also building a mathematical model of the lagoon, based on 145 recent sonar-drawn charts of the bottom. The aim is to determine the effects of changes in the hydrology of the lagoon, such as canal excavations, the closing of certain fishing areas, and the destruction of *barene*—mud flats. The model will help men predict Venice's chances of survival.

"The lagoon is alive," said an IBM man. "No, I don't mean only moving and three dimensional. I mean alive, with certain discernible moods that defy mere number."

I found this true when I went one sunlit afternoon into the southern half of the lagoon, a phantasmagoria of haunted islands rising into view, dwindling from sight, seeming to float suspended between water and sky as my boat churned an endless wake across an endless sea. Here in centuries past were bastions guarding the intersections between channels, but now many are deserted. Lazzaretto Vecchio and Santo Spirito crumble away in weeds and broken bricks. Some islands that are not abandoned have been given over to uses that add to the melancholy of the region. Poveglia is now a home for aged people. San Servolo looks across toward San Clemente, both mental hospitals. It is as though the once-wicked Venice of Casanova, putting away her masks and costumes, has turned like a penitent to works of mercy.

Tide Runs Out Like a Racing Stream

Beyond the Malamocco inlet I stopped at the town of San Pietro in Volta, and wandered past comfortable houses painted in pastel shades, to the large shed of a *squero*, a Venetian boatyard. Inside, in a drift of sawdust, an elderly man was cutting boards from a thick log and another was smoothing the flowing lines of a wooden boat with a chisel. Benedetto Schiavon introduced himself:

"It is a *topo*," he said, running a great, brown hand down the smooth gunwale of the flat-bottomed, half-decked fishing boat. "A very old Venetian design."

We walked through the dark shed into the pink light of late afternoon and looked out across the water, but it was no longer still; it flowed with the speed of a mountain stream. I expressed astonishment.

"The tide running out through Malamocco," he said. "Now always faster than before."

In thirty minutes a drastic change had
(Continued on page 620)

Photographs by
VICTOR R. BOSWELL, JR.
NATIONAL GEOGRAPHIC PHOTOGRAPHER





CLOUDS SCUDGING PAST THE MOON PRELUDE THE MORN OF THE STORMS THAT TORRENT THE CITY OF ST. MARK. YET THE PERSON STILL STANDS atop HIS BASILICA, BRIGHTEST JEWEL OF THE VENETIAN HERITAGE. PHOTOGRAPH BY ALBERT MULLOYAT

GREAT NATIONS leave autobiographies in their arts, said 19th-century critic John Ruskin. Nowhere is this more true than in Venice, a community created by merchants and seafarers.

At first, the republic looked east to the Christian capital of Constantinople, its guiding star in all things beautiful. Following that light, Venetians clothed their own Byzantine basilica of San Marco in garments of shining mosaic. In one of its 13th-century cupolas (left), the story of the creation unrolls in 24 episodes; they appear counterclockwise, beginning in the top panel of the inner ring. Tiny squares of gold leaf under glass form the glistening background.

Unless drastic steps are taken, half the city's 10,000 works of art will be damaged or destroyed in 30 years by pollution, humidity, and decay. The dolorous warning comes from UNESCO, the United Nations cultural organization. Accepting the challenge, private groups in Europe and America have already aided the Italians in saving 30 palaces, churches, and fraternal halls, and restoring more than 1,500 paintings and murals at a cost of 2½ million dollars.

Venice's Golden Legacy



BEAUTY WAS A BYWORD to Venetians, who sought the foremost artists of their day to embellish homes and public buildings. This spiral stair, known as the "snail," adjoins Palazzo Contarini del Bovolo, the residence of a noble family in the early 1500's. Today, like many restored palaces, it is divided into apartments and offices—served by an elevator.

On the ceiling of the Collegio, a hall in the Doges' Palace, Mars and Neptune flank a lion, the symbol of Venice. Thus Paolo Veronese represented Venetian power on land and sea in the 1570's—visible proof of the republic's greatness and permanence.



THE DOGE might bow before St. Mark, as in this 18th-century gold coin (left), but he expected homage from other men (below). Here in the Collegio he receives ambassadors, petitioners, and travelers in the mid-1600's, in a



SHIP OF ST. MARK sails on in an exquisite jeweled enamel (below), a detail from the Pala d'Oro, the gold altar screen of San Marco. In A.D. 828, Venetian legend has it, enterprising merchants stole St. Mark's body from Alexandria and brought it to Venice. Proud citizens raised the basilica to enshrine the evangelist's tomb.



painting by Giuseppe Heintz.

Venice was soon to become a resort of pleasure, famous for its courtesans, gambling casinos, and a carnival season that lasted for six months.

Masks, as seen on a couple at right, preserved the anonymity of revelers.

But Venetian power was already on the wane—her trade dominance lost after the Portuguese rounding of the Cape of Good Hope. In 1797 the last doge quietly surrendered to the might of Napoleon, ending the 1,100-year-old Venetian Republic.





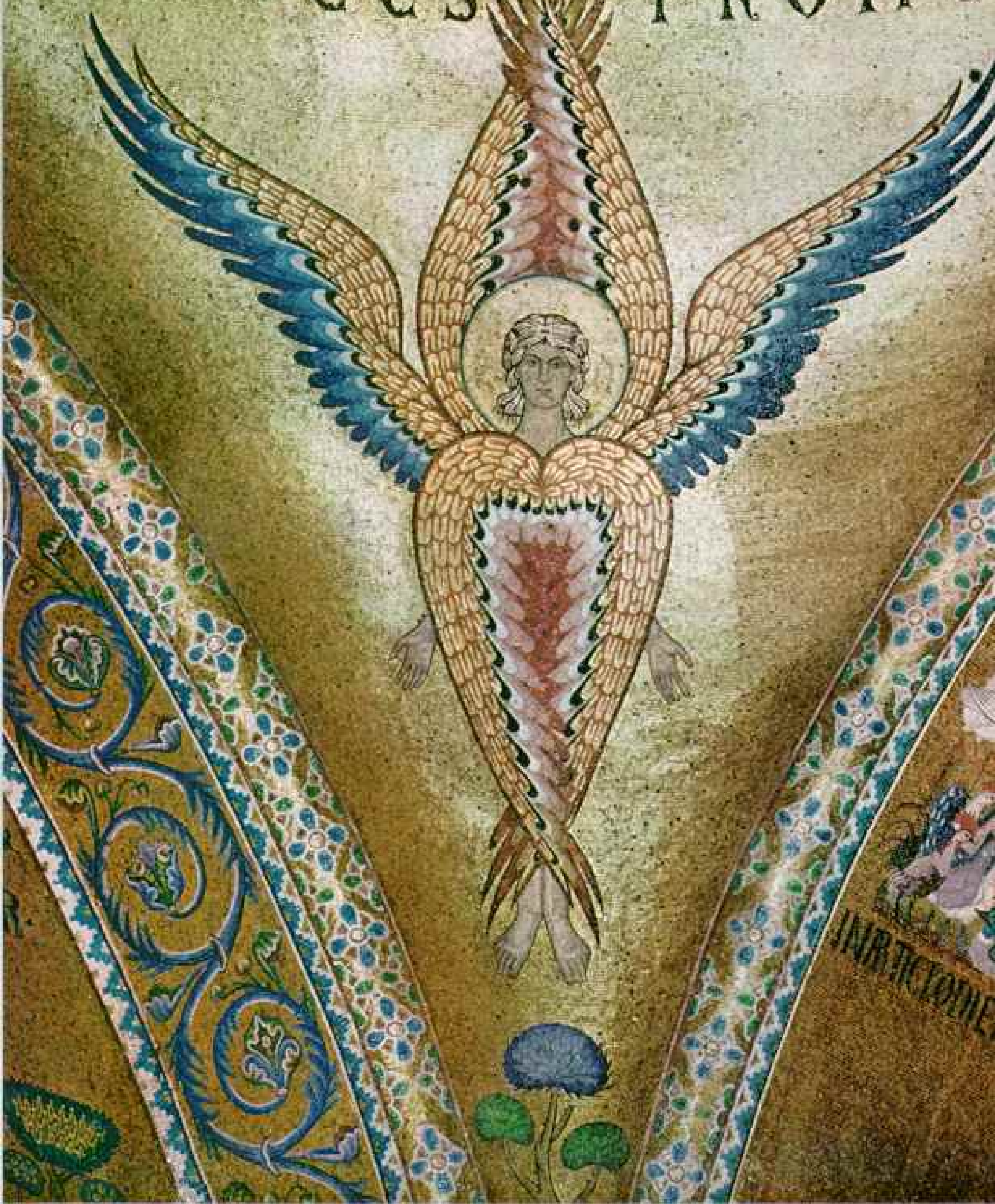
SKILLFUL SOLDIERS, *canny diplomacy, and wily intrigue kept Venice free for more than a millennium. In the 15th century the republic, like other Italian states, fought its land battles with the help of mercenaries. One of them, Bartolommeo Colleoni (left), purchased immortality by leaving his fortune to Venice on condition that the city erect a statue in his honor. Andrea del Verrocchio, a teacher of Leonardo da Vinci, portrayed the horseman, a bronze work acclaimed as the world's finest equestrian statue (page 602).*

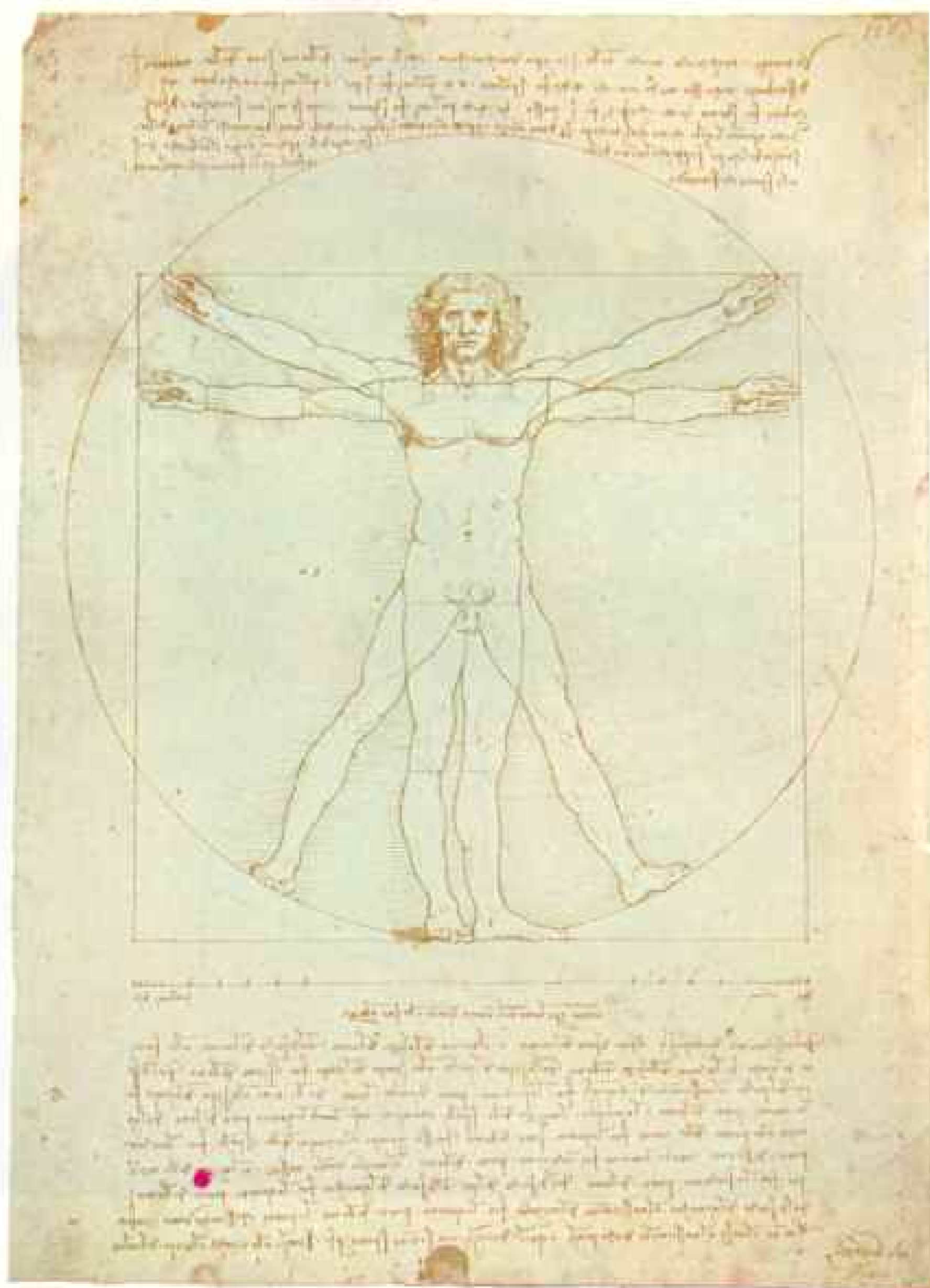
Ready for trouble even during Mass, Doge Francesco Morosini concealed a pistol in his prayer book (right); the knoblike "bookmark" triggered the weapon.

Fierce monster decorates this 16th-century cannon. A work of art more than a gun, it was probably never fired; no army ever took the republic by force.



DAT VOCES PROME





ACADEMIA

ABODE OF ANGELS AND OF MEN, Venice holds treasures that lay bare the medieval soul and the Renaissance mind. Fashioned in mosaic, a six-winged angel on a San Marco vault reflects the spiritual yearning of the 13th century. The revived focus on man in the 15th century is illustrated in Leonardo da Vinci's drawing of human proportions—a design used today as a symbol of the unity of man and the universe.



SHINING WITH ITS OWN LIGHT, "Enthroned Madonna and Child" brightens the basilica of Santa Maria Gloriosa dei Frari, for which it was painted in 1488. Giovanni Bellini caught the play of light on rich fabrics, on flesh, and on golden mosaics—luminous effects made possible by the use of oil paints and colored varnishes. Painted columns echo those carved on the gilded wood frame; slivers of landscape appear at the sides, adding to the realism. St. Benedict's direct stare draws the viewer into the altarpiece. Active for more than fifty years, Bellini taught the next generation of masters, including Titian, greatest of Venetian painters.

ENIGMATIC as the "Mona Lisa," Giorgione's mystifying landscape "The Tempest," illuminated by a flash of lightning, portrays no known historical or Biblical story. Recent X rays reveal that the artist first painted a nude bather where the soldier now stands. The small oil, created about 1505 for a private home, captured the beauty of nature and pointed future painters toward the goal of pleasing ordinary people.



(Continued from page 607)

occurred in the lagoon. Dozens of barene had appeared, their wet mud glistening like the humps of whales; fishing weirs that had been submerged stood out stark and wet; boats had come to rest on the mud; men walked, with hoes and buckets, to harvest clams.

"The barene here used to be covered with grass," the old man said, "but in the last fifteen or twenty years it has all changed. Now, nothing but mud, and fish that reek and taste so bad you spit them out of your mouth. It is the same with the boatyard. When I was young, my father had fifty or sixty men at work here. Now look, you came in a plastic boat through a dying lagoon."

Rivers Diverted for Defense

Centuries ago the Venetians of the republic regarded the lagoon as their fortress. Fearful lest it fill with silt and expose them to mainland enemies, they diverted the Brenta and other rivers that once flowed into it, leaving only a trickle in the old channels. It was a tremendous engineering feat. But I learned from a city engineer responsible for the Venetian water-and-sewer system that the old, dead rivers now create a serious pollution problem.

"One thing that is poisoning the lagoon," he told me, "is agriculture, in the form of fertilizers and pesticides washed down the old river channels during heavy rains. Likewise, small streams flowing into the lagoon contribute to this problem. One of these is the Marzenego, which now brings not only domestic waste from Mestre, but also a great quantity of agricultural chemicals."

Don't the Venetians themselves, with their lack of sewers, dirty their own bathtub?

"The canals are far more polluted now than they were 400 years ago," the engineer explained. "With a smaller population, the tides working like brooms, the water clear and pure, there was never a problem in old Venice. The first piped water system was installed in 1884, and five years later we had our first pollution problems. Even though about 60 percent of Venetian houses now have septic

systems, they still empty directly into the canals—and these days they empty detergents along with everything else."

Building gates at the lagoon's three inlets would interfere with the city's natural sewer system. Thus one solution leads to another problem, a round robin that introduces what a friend called "a particular humility" among Venice experts. How did it all start?

The Venetians of the republic understood perfectly that the lagoon was their very atmosphere. They established a commission, the Magistracy of Waters, with almost divine authority. If it failed, the remedy was quick. "Here is a Magistrate of Waters," said the doge as he introduced a new commissioner to the position. "Weigh him, pay him, and if he makes a mistake, hang him."

At one time there was a prison sentence for putting so much as a pole in the lagoon without permission. Debris might gather around it and start a swamp, the Venetians said. It was even forbidden to talk about the lagoon, a rule probably based on military security, but under which, one cynic remarked to me, the whole of Venice would now be in jail. Behind the talk, though, emerges a tale that began near the end of World War I, when the ancient city was at her lowest ebb.

Troubles Expand With Industry

The 18th century had been idled away with the buffoonery of carnivals, when all Europe came to play in the licentious atmosphere that provided both a living and a way of life for the once-noble city. During the next century her French, Austrian, and Italian masters did little to give her economic life, other than inserting a few ugly factories.

In 1917 three wealthy and influential Venetians came forward to lead a renaissance. Conte Giuseppe Volpi, Conte Vittorio Cini, and Senator Achille Gaggia believed that the salvation of Venice lay in building factories accessible by ship. They looked to the mainland and two small towns, Mestre and Marghera, where no more than 20,000 people then lived. At Marghera they filled in the lagoon and located Industrial Zone 1, to

Glorious visions of a genius, recently restored paintings by Jacopo Tintoretto enrich the great hall of the Scuola di San Rocco. "The Resurrection of Christ" hangs on the wall; a mirror reflects Old Testament scenes on the ceiling. The artist, with broad brush strokes and "*furioso entusiasmo*," finished 25 huge canvases here in six years. One art historian accused him of painting with a broom.

ALBERT WILSON



provide jobs for Venetians. With economic success came Industrial Zone 2, a second huge bite from the lagoon, and more deep wells (map, page 600).

By 1961, with all northern Italy booming, plans had been laid for a third industrial zone, twice as large as the old city of Venice herself, and for a deepwater channel from the inlet at Malamocco to Marghera to accommodate large tankers and freighters. When a new highway bridge across the lagoon to the Lido was proposed, the battle was joined. The Venice section of Italia Nostra, a national organization for defense of Italy's cultural heritage, went into combat to stop the indiscriminate expansion of industry. It was headed, ironically, by Contessa Anna Maria Cicogna Volpi, the daughter of the prime mover of Venetian industry.

Countess Strives to Save Tradition

"During his lifetime," Contessa Cicogna Volpi told me, "my father did what he thought was right, to save Venice. I am doing the same. The survival of Venice becomes, more clearly as time goes by, the emblematic fight between two irreconcilable points of view. On the one side lie culture, tradition, history, a deep feeling that our past should be preserved, at least in its highest manifestations. On the other side we have vested interests, a blind belief in a certain form of so-called progress. No doubt, culture will be defeated unless the civilized world steps in."

In 1969, after 3,200 acres of the planned 10,000 at Zone 3 had been filled and the deep channel had been cut almost to completion,

the Ministry of Public Works in Rome, under heavy international pressure, suddenly halted both projects. Proponents point out that the great storm of 1966 occurred when the new channel had just been started. On the other hand, the deepwater channels are workers of monstrous changes in the lagoon, say opponents of industrialization.

One such man is Giuseppe Rosa Salva, an architect who knew and loved the lagoon as a boy, and resents its destruction. His evidence is both circumstantial and compelling.

On a morning of mist and driving rain he picked me up at a landing on the Grand Canal, and we bounced and bumped our way toward Industrial Zone 1, running along the straight and deep channel opened in 1926 between the city and the mainland.

"Fifty years ago," said Signor Rosa Salva, "a tide flowing in the Porto di Lido at noon would arrive at Marghera two and a half hours later. But since deep channels were dug and barene were filled, that tidal flow takes only an hour and 40 minutes. A strong shove from the wind, and we have disaster."

The old industrial zone presented a bleak prospect. From the chimneys of a coke plant a cloud of smoke billowed southward under a gray sky. We idled along a channel between an aging aluminum plant and mounds of black coke and coal, framed by the weathered brick of a forlorn factory blinded by broken windows.

We turned to the south, along the new and controversial channel, past the red-and-white striped towers of a power plant in Zone 2. The Venice garbage dump, an island of



smoking refuse, wrinkled the air with its fires, and through the distortion I saw old Venice, her distant campaniles floating like a dream of beauty at the rim of vision.

"The lagoon has been humiliated and wounded by man," Signor Rosa Salva said. "In the days of the republic, everything was marshland, shallow, circuitous, from the Brenta to the Sile. The tide filtered in and was softened by the twists and turns and sponged up by the barene. Now many of the mudflats have been filled for industry, great areas have been diked for fish ponds, deep channels have been cut. We have invited the sea to our doorstep. I don't need a computer to tell me the result."

Migration Creates Another Dilemma

The managers of Venetian industry, wounded by sharp blows in the press and hounded by conservation groups, feel badly put upon. Giangiacomo Pancino, the president of Zone 3, an expansive and voluble man, poured a brandy and pronounced, "So many countries want to save Venice because they have ruined their own."

He went to the window of his office. San Marco's campanile was rose and gold in the twilight behind him. "You are looking, sir, at a despised man, but am I less a Venetian than the rest of them? To many, Venice is this, what you see. But Venice does not finish here, in the historic center. The city continues on to the mainland. Other countries have the luxury of thinking of Venice only in a romantic way. They want to save her, and I agree it would be a crime to destroy

any of Venice's beauty or her great treasures.

"But Venice has to live. She has to work. If people have left beautiful Venice for ugly Mestre, it is because of need, and desire for cars, comfort, and freedom. But they are still Venetians. A lot of other people take their place, people from outside who can afford to enjoy the beauty. But if everyone who goes is Venetian, and everyone who comes is not, what happens to Venice?"

"They say that filling in the barene for Zone 3 has disturbed the equilibrium of the lagoon, but who really knows? If it is true, that's the end of Zone 3, as far as I'm concerned, but not until someone knows for sure.

"I'll tell you something," he continued. "Without industry, we are all dead here. Everyone will leave but the tourists. Do we want to leave Venice as a place that is only a weekend haunt for the rich people of the world, or as a place that is truly alive?"

On the Feast of All Souls, the people of Venice gather chrysanthemums from flower stalls along the wide walk called Fondamenta Nuove and board a free boat for the short passage to San Michele, the isle of the dead. All day the boats pass back and forth between the city and the walled island, its many graves shaded by magnificent stands of tall green cypresses. The famed composer Igor Stravinsky lies on San Michele, and I thought I would take some flowers to his grave.

On the boat, I chatted with an old woman, heavy set, ruddy, and sad of visage. Her golden flowers, wilted and tinged with brown, hung straight down from her lap.

"I'm a Venetian," she said. "If Venice sinks,

Audience and actors in their own drama (left), Venetians hear a discussion of national legislation to aid their city. A proposed bill would assure 400 million dollars to help finance a sewer system, mobile dikes at lagoon entrances, and residential restoration. Venetians also seek improved transportation—a subway or monorail.

"For love alone—that's why the canals were conceived," gondoliers proclaim. Lacking the privacy of a gondola, this couple find their own world in a *vaporetto*, or water-bus.





Angel with a dirty face shows the price of air pollution. Mainland factories and Venetian heaters and motorboats spew sulphur-laden fumes that, mixed with moisture, form sulphuric acid. The toxic brew, salted by the sea air, eats away the stone. Italy recently banned high-sulphur fuel for home use, and Venice hopes for total conversion to gas or low-sulphur furnaces soon.



Dulled by time, Tintoretto's 400-year-old masterpiece "The Ascension" revives under the restorer's touch. Professor Antonio Lazzarin has replaced the backing and cleaned the oil-painted surface. Now he retouches areas of missing paint on the figure of Christ.

Grimed by "progress," a 15th-century marble lunette gets a beauty treatment. Protected by masks, Kenneth Hempel and an assistant clean the Virgin and Child at the basilica of the Frari. A specialist from London's Victoria and Albert Museum, he aims a high-speed stream of dust-fine glass beads to blast away the dark encrustations.



I sink with her. You've seen the statues, how the marble rubs off on your fingers? Venice rubs off on you and you can't wash her off."

She gazed across the lagoon, toward the distant trees and towers riding on the haze.

"I married a man from Burano," she went on, "and had three daughters and two sons. One of my daughters moved away, over there." She pointed to the mainland. "She pays 50,000 lire a month for a decent place." At 580 to the dollar, that comes to roughly \$85. "In Venice, a decent place costs 70,000 to 80,000 lire. How can Venetians live? I don't know. But how can they leave?"

That afternoon I wandered the sunlit cemetery, through a marble surf of names entirely, unequivocally Venetian (page 628). It is a part of the Venetian character to be fastened to their city, to the memory of the Serenissima, to their lagoon, to every stone and every bridge and every cat that prowls at midnight. Yet, in sad fact, almost 70,000 have left in the past 20 years—including 71 percent of all those under 45.

"It is the first problem of Venice," Mayor Giorgio Longo had told me. "Not the high tide, but the exodus of young people. There are now only 122,000 souls left in the old city. People leave because there are no comfortable homes to be had at a reasonable price. Restored homes in good condition sell at astronomical prices. Even with wet feet, everybody wants to live in Venice! But not in damp misery."

Wartime Refugees Flocked to Venice

One architect, disturbed by the paradox that it is impossible to find a place to live in a city that has lost a full third of its population, turned up persuasive evidence that those who go are fleeing badly overcrowded housing or ground-floor apartments subject to the curse of floodwaters.

"They all came here during the war," he said. "They knew that not even a madman would bomb Venice. The city was overcrowded."

The architect said that the great palaces are also underpopulated several months of the year—"a few old people rattling around.

Some of the palaces have never been on the market, never, in a couple of centuries."

I asked a friend who lives in a comfortable apartment near Campo Santa Maria Zobenigo about the outside of her building, which was literally falling off.

"There are three owners inside," she said, "so we would all have to agree, and then get the necessary permissions from the city government, and then spend a fortune, and then our taxes would go straight up. Let it fall."

Talented Briton Comes to the Rescue

The illustrious basilica of Santa Maria Gloriosa dei Frari, named for the Lesser Friars of the Franciscan Order, holds in a vast interior the revered monuments of Jacopo Marcello, killed while leading a fleet against the Turks, of the sculptor Canova, of the immortal Titian, and of many other heroes of arms and culture in the Venetian pantheon. Among its artistic treasures is a marble lunette over the exterior door of the Corner Chapel, a Virgin and Child flanked by angels, a work of art so exquisite that it was once rumored to have been made by an artist from Tuscany (preceding pages).

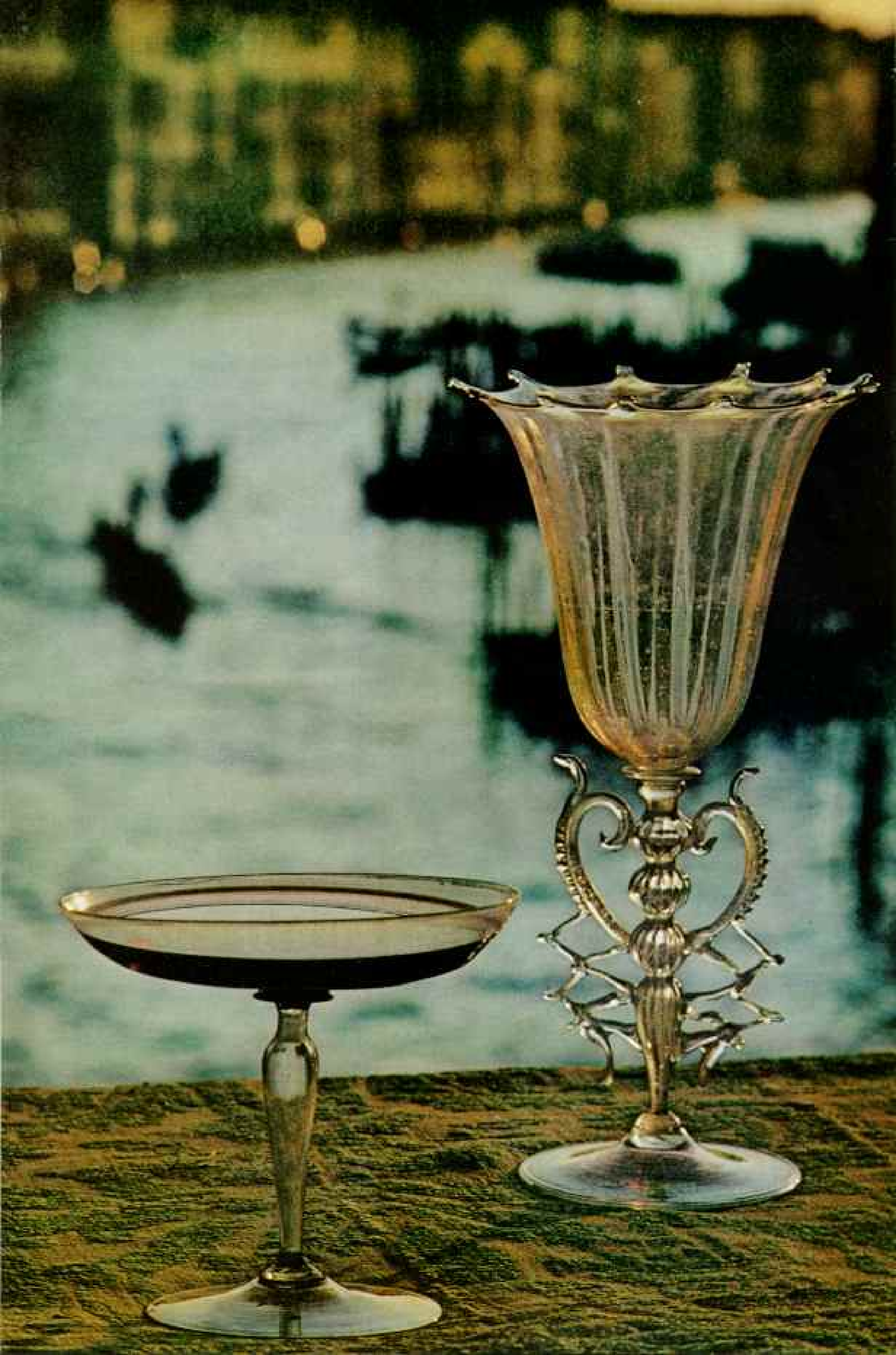
I found the doorway covered with a polyethylene skirt. Inside, ladders led upward through a scaffolding to a platform where a white-jacketed man and two women seemed to be preparing for an operation. The man introduced himself as Kenneth Hempel, an expert in art restoration from London's Victoria and Albert Museum. Before us the Virgin and Child made a forlorn appearance; ash-black hands gnarled by corrosion and faces blackened by pollution suggested an unknown tale of some terrible leprosy.

Mr. Hempel patted the head of the Madonna. "I'm afraid she's an old-age pensioner as well," he said. "After all, she was here before Columbus discovered America."

He adjusted his face mask and turned on a machine that whirred like a mixer. Then he held a pencil-thin tool that resembled a dentist's drill, manipulating it as carefully as a surgeon across the cheek of the Virgin. As the grime and black disappeared, the lustrous marble emerged.

Fragile mementos of bygone splendor, Renaissance goblets such as these graced the banquet halls of English lords and India's Great Mogul. As the glory of Venice faded, craftsmanship declined. Now glassblowers on the island of Murano create souvenirs for tourists, who come in ever-growing numbers during Venice's glorious summer season.

WILLIAM BLAIR ALLEN





Pampered pigeons of San Marco charm visitors old and young—but not the guardians of Venetian art. Droppings of the city's 100,000 birds are a major cause of stone decay.

Memories linger for a Venetian tending a grave on the cemetery island of San Michele. Crosses of Roman Catholics bear photographs, an Italian custom. In the Greek Orthodox section the gravestone of Russian ballet impresario Sergei Diaghilev voices the sentiment of countless artists, "Venice, ever our inspiration and fulfillment."



"It's an ingenious machine, something like a sandblaster," Mr. Hempel said. "It shoots out minute glass beads that bounce off the marble rather than cut."

No church facade or outdoor statue in Venice has escaped the terrible stone cancer that afflicts the marble. It sometimes seems as though heaven itself had collapsed and sent tumbling to earth a legion of cracked angels, faceless saints, and crumbling martyrs. Though there are some promising developments, no completely reliable cure has yet been found.

"The Venetians employed Istrian, Carrara, and Veronese marbles," Mr. Hempel said. "They are all basically made of the same stuff, calcium carbonate. What happens is that sulphur oxides dispersed into the air by the burning of coke, coal, oil, and petroleum mix with moisture and form an acid that comes into contact with the marble. Any soot in the air becomes involved in the whole thing and encapsulated. A chemical reaction takes place—finally a small piece of marble blows off, and we've got stone cancer."

Can Factories be Blamed?

Most Venetians are quick to point accusing fingers at the smokestacks of the petrochemical and coke factories of Marghera. UNESCO estimated that each year the industrial zones release more than 15,000 tons of sulphur oxide into the air, and it falls on the islands of the lagoon, like the quality of mercy, unstrained. Or does it? Other experts explain that the prevailing winds are from the sea, not from the land, and if anyone is getting those acid-laden clouds, it is probably the Paduans.

The once lucid air of Venice is, in any event, a heady chemical brew of salt-laden humidity and various sulphurous pollutants arising from a variety of sources—industry, motorboat engines, and, above all, heating units in hotels and homes that, until prohibited from doing so two years ago, burned the reeking crude oil that gives much of urban Italy its distinctive odor.

"It all started," Mr. Hempel said, "when the old Venetians cooked their food and warmed themselves at their fireplaces."

And it continued until Venice, before the disaster of 1966, was like a noble lady dying a lingering but a genteel death, something like Camille's. But on that single November day, she aged a century.

"In a way, though, the great storm was a blessing in disguise," said Professor Francesco Valcanover, the Superintendent of Works of Art for the region. "We were at last able to do some things."

One of the first things he did was open a large art-restoration laboratory in the abandoned church of San Gregorio. In the years since, many famous patients—wrinkled and cracked Titians, stained Tintoretos, grimy and splotted Tiepolos—have passed through the hands of the experts who work there.

Tintoretto Made Haste—Magnificently

In at least one case, the art healers have had to make a five-year-long "house call," to the Scuola di San Rocco, where Tintoretto performed one of those feats of human endeavor that stagger the modern mind.

Contessa Querina Querini, a charming woman who works at the special laboratory set up in the Scuola, told me the story.

"This was one of the six Scuole Grande of old Venice. They were religious and charitable fraternities, often quite rich, and good patrons of the arts. When the great hall upstairs was finished, Tintoretto started paintings for the ceiling. Two years later he offered to complete the series and decorate the walls in exchange for 100 ducats per year for the rest of his life. The deal was made, and he painted like a fury for the next four years. Have you seen what he did?"

Viewing the Sistine Chapel offers the only comparable experience to mounting the immense marble stairs of San Rocco, catching the first glimpse of a distant glory of paint and gold, and stepping finally under the huge ceiling on which masterpieces march, row on row, separated by gilded and intricately carved molding (page 621). How could one man do it at all, much less in six years?

"He was in a hurry," the contessa said.

In the laboratory a number of the paintings were being backed by new canvas, cleaned, and retouched. That close, I could see the furious brush strokes, the blurring of line, the repainting that had resulted from such prodigious labor. A hand with six fingers. Let it be. A long sword in an angel's hand, but at the wrong angle. Painted, not out, but simply over. Two feet on one angel's leg. He flies, not walks! The work of a man in an ecstasy of creation. Little wonder the contessa calls him "terrible Tintoretto."

Venice, the old sorceress, has other magic

still about her, magic made powerful by its very frailty—the sad figures of cardboard royalty from long-vanished dominions visiting from season to season at the homes of friends; elderly ladies taking the sun and thin tea along the Zattere, speaking French to small poodles wearing knit blankets. Once, near the Salute, I passed the aged poet Ezra Pound, peering with incandescent eyes toward a future beyond either politics or poetry. Or was it toward the past?

Marriage Falls on Evil Days

Each year, long ago, on Ascension Day, the doge of Venice took to wife the Adriatic Sea. He proceeded from the city in a marvelous golden barge, the Bucintoro. The boats and barges of the city followed in a splendid procession, sun-struck, framed in gold-and-red banners, the height of power and pomp.

At the Lido the fleet gathered round while the doge stood in the stern of his canopied barge and delivered a consecrated gold ring to the waters, intoning so all could hear: "We wed thee, O sea, in token of our true and perpetual dominion..." Divers went in shortly afterward to retrieve the ring. The man fortunate enough to find it could keep it. The doge returned to his palace, his city secure from the waters that were her fortress, her life, and her treasure.

Now the waters themselves, the betrothed, swarm upon the city. The dominion has ended.

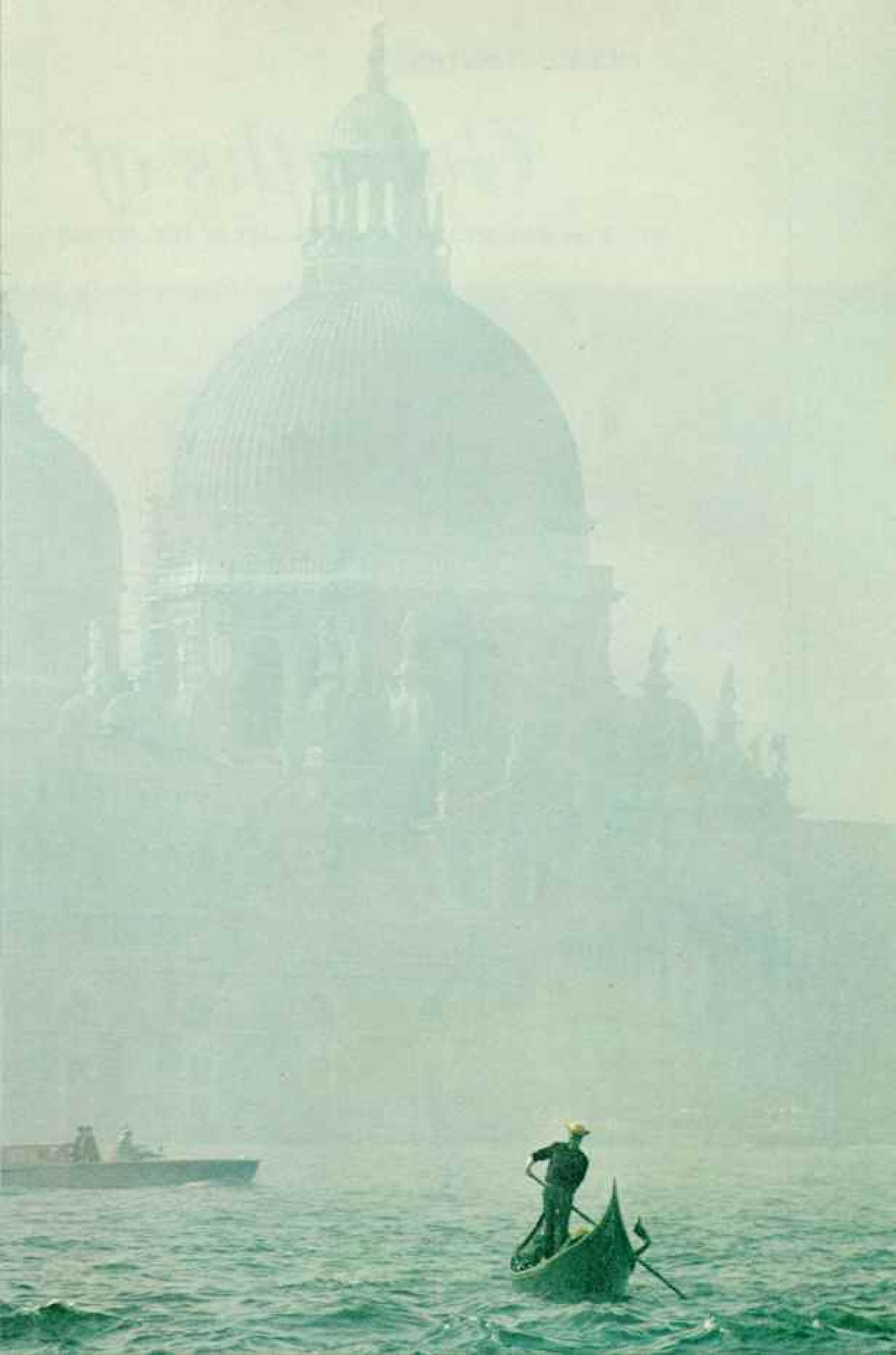
Amedeo Memo, my gondolier friend, picked me up one day, and we set off across the lagoon toward the Armenian monastery on San Lazzaro, which Byron loved so well. As we drifted in silence through the still afternoon, I thought of other cities strangling in cars, suffering tidal waves of commuter traffic, with poverty-stricken and decaying hearts.

The truth struck me that with all the flood and decay, Venice still lives one of the last privileged lives on earth.

The truth also is that Venice must somehow survive because the world cannot afford to let her die. As Memo said, "If man cannot save Venice, what can he save?" □

Gift of thanksgiving to the Virgin, Santa Maria della Salute—here mantled in morning mist—was raised by Venetians who survived the plague of 1630. If those who fight to save the city succeed, Venice herself will be a living tribute to their concern.





GIANT TORTOISES

Goliaths of

BY CRAIG MACFARLAND PHOTOGRAPHS BY THE AUTHOR



the Galapagos

AND JAN MACFARLAND



JAN TOUCHED MY ARM. We stopped in our tracks.

"Listen!" she said. "I hear them."

I dropped the machete to my side, and caught what had come to my wife's ears—a deep, guttural, rhythmic groaning. The voice of the tortoise, barely audible above the roar of a nearby geyser, floated up from the wide cloud-filled caldera of Alcedo Volcano on Isabela, one of the 13 major islands in the Galapagos archipelago.

We kept hacking our way through dense vegetation down the caldera's inner wall. At the bottom, where scattered fumaroles belch hot gases, we found the source of those sad and haunting sounds. They boomed from the throat of a male giant tortoise in the throes of a mating attempt.

Through the mist we picked out dozens of the dark, domed reptilians. Like walking boulders, they moved ponderously through the sparse grass and black volcanic rocks of the caldera's floor. Some were mating while others lumbered toward muddy pools where they would spend the night partially immersed in the ooze.

Isolation has long protected the unique wildlife of the Galapagos. Ancestors of these tortoises probably have shuffled across this scene for hundreds of thousands of years. Now, no longer shielded by their remoteness, these giants that may live more than 150 years are confronted with an uncertain future.

We had come to the Galapagos to study the ecology and behavior of the little-known beasts, the heavyweights among the world's cold-blooded land animals. Because of their

(Continued on page 639)

Sticking out her neck and legs, a Galapagos tortoise exposes wrinkle-dwelling ticks to two small ground finches. The author discovered this example of mutually beneficial behavior during a 28-month study of the reptiles, an imperiled species that man now hopes to save.

Galapagos Islands

(EQUADOR)



Rugged domain, Ecuador's Galapagos Islands lie 600 miles west of South America. Ancestors of the archipelago's tortoises may have drifted there on clumps of vegetation disorged from rivers of the continent. Eleven of 14 subspecies survive. Black symbols indicate extinct populations; red, habitats of the more endangered tortoises; green, the homes of less threatened groups. On Fernandina, free of introduced predators, tortoise sign has been found but no recent sightings have been reported.





ROBERT W. HEDGECOCK ABOVE AND BELOW

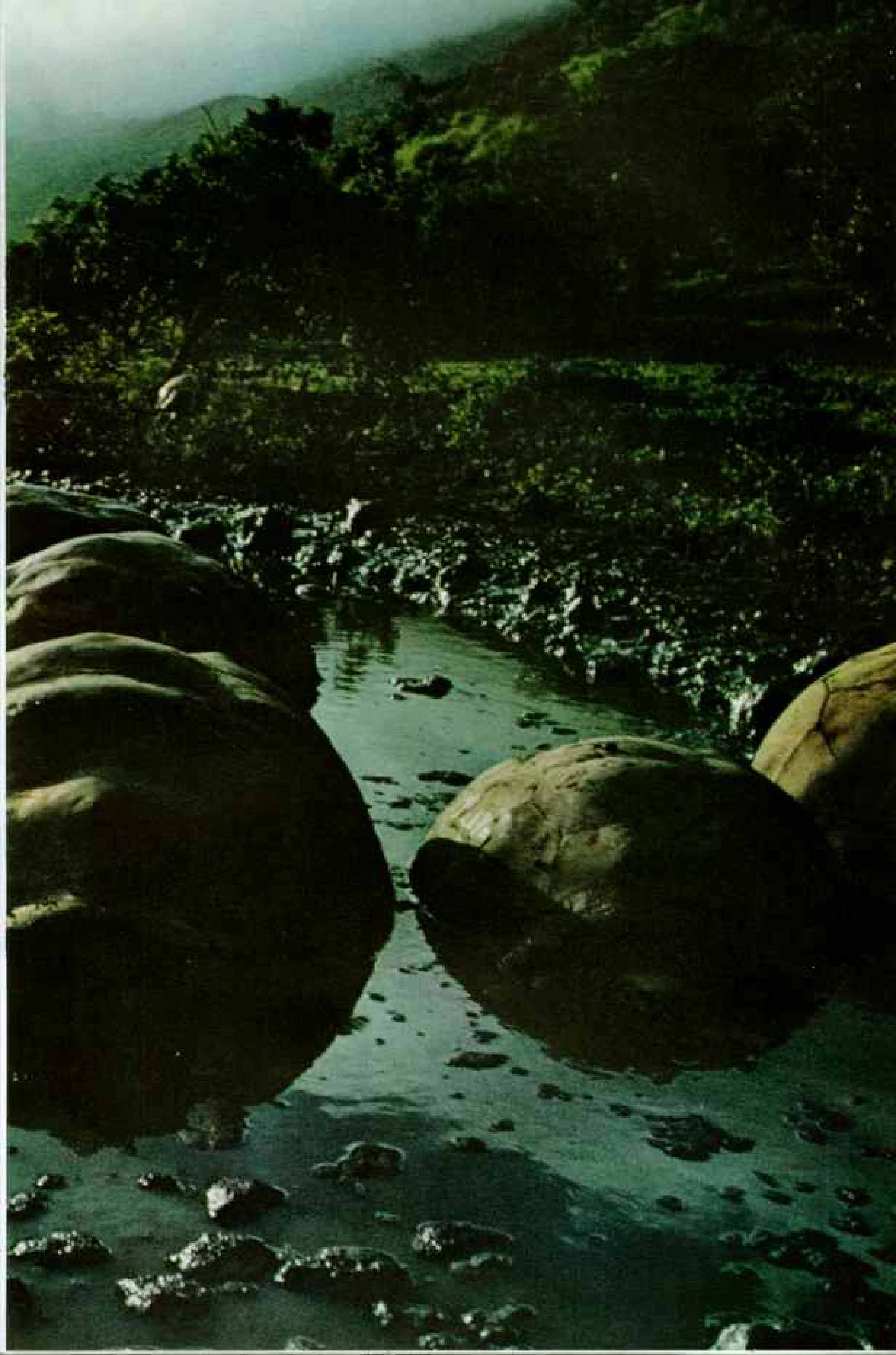
Her baby in a backpack, Jan MacFarland devoted many months to trekking with her husband, author Craig MacFarland, over the Galapagos Islands, helping him record the habits of the archipelago's 9,000 to 10,000 surviving tortoises (left). During the first year of the study, she took time off for the birth of daughter Bennett, who then became a regular member of the MacFarland field team. Craig adds to his statistics on tortoise size (below), after measuring a pair of dozing giants.



"The sun drops like a bullet over Santa Cruz," recalls the author, who with his family made camp many times in the island's tortoise reserve (left). After a meal of goat stew, Jan MacFarland feeds prunes to Bennett, now ten months old.

LIKE BOULDERS in a mountain stream, tortoises bead shallow pools in the caldera of Alcedo Volcano on Isabela Island.







Fitting form to function, nature gives saddle-shaped shells and long necks and legs (above) to tortoises of arid Española Island. The flared carapace enables them to stretch higher for food than their dome-shelled cousins on more densely vegetated islands.

A curious visitor on Santa Cruz pays a social call on wary Bennett (facing page). These foraging vegetarians, the MacFarlands soon learned, would eagerly devour socks, underwear, and even diapers.

Delicious, gaping yawn symbolizes the tortoises' indolent pace. Sleeping consumes about 16 hours of each day, and during the remainder the creatures usually travel only a few hundred yards in search of a meal. Caked dirt from occasional mud baths probably deters ticks and mosquitoes.





endangered status, the tortoises need protection and help in multiplying. Our research has already begun to provide a basis for strengthening conservation measures.

When young Charles Darwin visited the islands in 1835, he noted structural variations in animals and plants that gave impetus to his later theory of evolution by natural selection.* Darwin's journals contain many acute observations about *Geochelone elephantopus*, the reptilian Methuselah whose descendants we found congregated in Alcedo Volcano's muddy pools. Since Darwin's time, man has stilled their voices on two islands, and the surviving populations face great perils.

Now the Galapagos belong to Ecuador. In August 1969 we flew westward from Guayaquil, the nation's major seaport, to the airport on Baltra Island (map, page 634). With us came Dr. William Reeder, my advisor from the Zoology Department of the University of Wisconsin. During both summers of our two-year study, supported by the National Science Foundation and the National

Geographic Society, Dr. Reeder would work with us. The research results would constitute my doctoral dissertation.

Based at the Charles Darwin Research Station at Academy Bay on Santa Cruz Island, we commuted by boat among the islands and tramped hundreds of miles over Galapagos volcanoes, observing the various life phases of nine of the eleven known surviving tortoise populations, or races, a term sometimes used interchangeably with subspecies.

Soon after arrival, we made the long hike into the 64-square-mile Tortoise Reserve on the southwestern flank of Santa Cruz. Here lives one of the largest remaining tortoise populations, 2,000 to 3,000 individuals.

From the field camp we had set up, we made two- and three-day hikes over most of the Tortoise Reserve. The Santa Cruz tortoises grow as big as any in the archipelago. We were soon giving names and numbers to huge old males, some almost four feet long

*Alan Villiers told of Darwin's world-girdling quest in the NATIONAL GEOGRAPHIC, October 1969.

and weighing 500 to 600 pounds, and to females that seldom weigh half as much.

The living was superb. Days were sunny. Showers fell mostly at night. The screened sides of our 8-by-12-foot tropical tent provided daytime air conditioning. We ate wild burro steak, wild pig shish kebab, and immense quantities of broiled goat.

Our first year was complicated—delightfully!—by the arrival of our daughter Bennett. From her earliest months, Bennett cheerfully accepted being backpacked over rough trails (page 635). We changed her diapers in dinghies, on the backs of tortoises, and on large rocks and water cans.

Tortoises Dote On Easy Living

We found that the giant tortoise leads a generally peaceful, lazy life. He wakes between seven and eight in the morning and basks in the sun for an hour or so as his bulky body slowly warms. The rest of the day he spends grazing and browsing.

The Galapagos tortoise consumes a great variety of foods, some of them seemingly unappetizing. He eats stinging nettles with gusto, and gorges himself on the crab-apple-like fruits of the manzanillo tree, the same manzanillo whose sap causes severe skin burns and occasionally even death to humans who unwisely sample the fruit. He relishes, too, the fallen fruits and the spiny pads of the prickly pear, avoiding only the heavily barbed young plants.

The tortoise usually retires at the genteel hour of four or five in the afternoon, spending the cool night half-submerged in mud or water (pages 636-7), or burrowed into dense brush. This keeps the animal warm for as long as possible through the Galapagos night, when temperatures may drop as low as 50° F., and the conserved body heat probably aids digestion. As with other reptiles, the body temperature of the Galapagos giants is largely determined by their surroundings. Their metabolic rate rises as the environment becomes warmer, and falls as conditions cool.

Curious creatures, tortoises are inclined to investigate anything new in their environment. We were returning to camp from a hike once, and Jan had gone ahead. "Hey, come here!" she called. "The whole place has been mangled, and I can't move this monster."

Together we managed to push a 450-pound tortoise we knew as Number 31 out the tent door. He had chewed and ripped open the

tent. Droppings and crunched plastic water bottles littered the floor. The big fellow had demonstrated his brute strength: A five-gallon steel can lay smashed flat.

Not much happens, however, to interrupt the tortoise's normally lackadaisical life-style. One disruption is the mating season, a period that varies from race to race but usually occurs between January and August. Then the rutting male tortoise stalks about looking for mates and sniffing the air for their scent. Spotting a female, he chases her down and usually begins courtship with intimidation, ramming her with the front of his shell and nipping at her exposed legs until she draws them in, immobilizing her.

Different races of tortoises start nesting at different times, but generally between June and December. The female treks to dry sunny lowlands—and usually to the same area year after year—where the eggs receive adequate warmth for incubation. The tortoises on Santa Cruz nested twice a year, laying from two to seventeen eggs—an average of ten—in each nest.

Mother Feathers Her Nest With Mud

We followed one female for ten days during her nest-digging attempts. She kept striking rocks, and would stop soon after nightfall.

One day I tired of waiting and went nest hunting. Returning, I heard Jan calling softly from the tent.

"Come around wide and stay low," she said. "I think she's going to make it this time."

I crept slowly to the side of the tent and whispered, "Where is she?"

"About thirty feet in front of me."

For hours we marveled at the tortoise's tremendous strength and agility as she excavated, using only her hind legs—probing, shaping, measuring. Her forelegs held the front half of her 150-pound body raised above the ground in an unchanging position. Her urine softened the hard soil so she could shape and mold the resulting mud to make a firm-walled cavity.

After five hours the female stopped digging; the tempo of her labored breathing abruptly increased. The animal swayed the rear of her body to center it over the nest cavity. She began to wriggle and wave her stubby tail.

Suddenly out popped a spherical white egg about the size of a billiard ball. It dropped ten inches to the bottom of the nest and landed unscathed. The thick, gelatinous fluid encasing

it acted as a tether to the female's tail, slowing the descent of the egg and cushioning it upon impact.

The tortoise laid nine eggs in 15 minutes. After the last one had dropped, she slowly and gently inserted a thick hind leg into the nest cavity. Down went the heavy foot—but it stopped instantly when the tip of one rough, horny toenail touched the top egg in the pyramidal heap.

With cautious, dexterous sweeps she maneuvered the stacked-up eggs into a single layer across the bottom. Finally, she packed mud over them in a covering six inches thick, enough to moderate the heat from

Mounted for the hunt, a vermilion flycatcher (below) lets its gargantuan steed act as beater. The tortoise's lumbering passage through underbrush scatters insects, which the bird seizes for its dinner.

Lichens, normally found on trees and stones, sometimes mottle the shells of the giant tortoises (bottom).



the sun-drenched surface and keep the embryos from cooking on hot days. Drying to the hardness of clay brick, the mud cap probably shields the nest cavity from the loss of moisture, without which the embryos would shrivel and die.

The eggs generally hatch between mid-January and late March. We found that incubation time for various clutches ranged from three to eight months, the longer periods having a relation to cooler weather.

The tortoise finished her work at 5:30 in the morning. I think we were more exhausted than she as we stumbled to the tent for an hour of sleep before Bennett woke to demand her breakfast.





Armored admirers of a nearby female clash in Alcedo Volcano (above). Nipping at each other rarely draws blood, and the half-minute wars inevitably end in victory for the animal whose head towers highest.

Slick trick by an unwilling female foils a huge male's attempt to mate (facing page). Fleeing, as do most female tortoises, she had reached the mud wallow before he overtook her. The male, though equipped with a concave underside (right) that facilitates mating, could not maintain his footing on her slippery carapace. Just behind them looms the shell of a second giant male.







However remarkable the tortoises' nesting habits may be, even more surprising, perhaps, are the creatures' relationships with other animals. Yellow warblers, vermilion flycatchers, and lava lizards feast on the flies and other insects that continually buzz around the eyes and other moist parts of tortoises. But a more astonishing symbiotic association awaited our discovery.

One misty dawn on the rim of Pinzón Island's caldera, Jan and I were still rubbing the sleep from our eyes when we saw a female tortoise clunking along in a rocky field. Suddenly several small ground finches flew out of nearby bushes and landed about two feet in front of the tortoise. Another alighted on top of her shell. The finches hopped up and down and chirped.

The tortoise stopped, craned her neck, and looked at the little visitors. Then she rose until her legs were completely outstretched, and extended her neck straight upward. She

stood motionless. The finches hopped onto her forelegs and began inspecting her skin, occasionally pecking at something. Others darted in and began examining the tortoise's hind legs, neck, and head.

Moving closer, we saw that the finches were removing ticks from the reptile's tough hide. The tortoise didn't even blink when the finches pulled ticks from the corners of her eyes and from her nostrils. Throughout the 5½-minute cleaning session, the animal stayed stock still. After the birds had all flown away, she drew in her neck and slowly settled to the ground.

We later saw the same behavior in other races of tortoises (pages 632-3). This cooperative behavior, advantageous to birds and beast alike, has never before been reported.

For most of the past million years, huge tortoises related to the Galapagos species roamed the prairies and forest parklands of Europe, Asia, North and South America, and

Burying precious treasure, a female gently scoops urine-dampened earth into a nest she took four-and-a-half hours to dig (**left**). Laying the six eggs required only 15 minutes, but refilling the pit and meticulously fashioning a low mound over it took another seven hours. Working only with her hind feet, the mother never sees the eggs, yet seldom does she break one.



A few days later the author shaves away part of the nest to insert humidity- and temperature-sensing devices (**below left**) before repacking the soil. Tortoises lay as many as seventeen eggs at a time.

Hatchlings emerging three to eight months later (**below**) face mortal danger from marauding rats, dogs, pigs, and cats introduced by man.



Africa. But eventually all the gigantic species disappeared from the main bodies of the continents. What caused their extinction? Perhaps winters became progressively colder, killing off the bigger animals. Or perhaps new predators evolved. One theory suggests that they were eliminated by prehistoric human hunting bands. Their disappearance remains a mystery.

Galapagos Stocked Sailors' Larders

By the 16th century, giant tortoises survived in only two places—the Galapagos, and on islands in the western Indian Ocean. Now only one of the Indian Ocean species lives in the wild—on Aldabra, an atoll 400 miles off the coast of Tanzania.

Men began exploiting the Galapagos tortoises in the 17th century. Buccaneers stacked the unfortunate animals in the holds of their vessels. Even without food or water, they could survive as long as 18 months, and were

still fat and succulent when finally made into a stew called “sea pie.”

The worst slaughter occurred at the hands of American and British whalers in the 19th century. The buccaneers, whalers, merchantmen, and fur sealers probably destroyed at least two to three hundred thousand giant tortoises in just two centuries.

Destruction continued almost up to the present day. “In the 1930’s,” recalled Anders Rambech, tortoise keeper at the research station, “oil hunters killed hundreds, maybe thousands, of tortoises on Santa Cruz. They invaded the interior with burro trains, each burro carrying two five-gallon wooden casks. After the shells were hacked open, the fat was stripped from the animals—some still alive—boiled down, and the rendered oil brought to the coast. It went to the mainland in 50-gallon drums—a huge business.”

Fortunately, man himself is no longer a serious enemy of the tortoises, but he has

exposed them to new threats by inadvertently bringing black rats to the islands, and by introducing domestic mammals whose descendants now run wild. In a nesting area on Santa Cruz we noticed the ground pockmarked with cone-shaped pits. Fragments of eggshells were scattered about.

"Pigs dug up these nests," explained Oswaldo Chappy, the Galapagos National Park warden who showed us the place. "One pig can destroy dozens of nests in a night and never miss an egg. Now we know when to expect the females to lay, and we can protect the nests with lava corrals."

Pigs also attack the young, and can chew up tortoises as large as twenty pounds. Dogs kill even larger ones. Rats and cats devour the hatchlings. Also, feral goats, burros, and cattle compete with the tortoises for food.

Animals Find an Ally in Man

Now the archipelago has suddenly blossomed as a tourist mecca, posing a new problem not only for the tortoises but for the entire unique Galapagos environment. In 1969 no more than 200 tourists visited the islands. Next year 5,000 to 6,000 are expected. Clearly, touring groups will have to be limited in numbers and supervised by well-trained guides.

Yet today there is hope for the preservation of the giant tortoises. In 1959 Ecuador set aside all uninhabited areas of the Galapagos as a national park. Hunting or capturing of native animals, including the tortoises, is specifically prohibited. Also, a 1970 law makes illegal the exportation of endangered species from Ecuador except for scientific research or governmental interchange. And the United States forbids importation of unlawfully exported species.

In 1959, too, the Charles Darwin Foundation for the Galapagos Isles was created under the auspices of UNESCO and the Ecuadorian Government to promote conservation and research. To carry out these aims, the foundation established the Charles Darwin Research Station on Santa Cruz. We spent much of our time working with Ecuador's National Park Service and the staff at the station to develop plans for conserving the tortoises.

Poaching by island settlers, a perennial problem, has been greatly reduced by regular patrols. A control program holds down the numbers of wild goats and pigs.

Fourteen tortoise races are known to have



Tortoise on the half shell pauses during a one- to five-day struggle to break out of its ivory-white first home (above). Free at last, it charges forth like a three-ounce





bulldozer (below). A yolk sac on the belly (below left) provides food for as long as seven months' survival underground after hatching, but the agile babies usually claw

their way to the outside world within a few weeks. Males of the larger Galapagos races may eventually weigh 600 pounds, females rarely as much as 300 pounds.



Return of the natives: Twenty-two youngsters raised at Santa Cruz's Charles Darwin Research Station are released by Ecuadorian Park Service wardens on Pinzón; the eggs were found here four years earlier. Weighing three to seven pounds each, the tortoises no longer



existed in the Galapagos; 11 definitely survive. Of the Española race, only two adult males and ten females have been located over the past decade. Apparently unable to find each other, they never mated. Wardens have brought 11 of the animals to a breeding enclosure at the Darwin Station. In 1970 they made several nests. The park service staff transferred the eggs to sun-heated incubators. Early in 1971 came the reward—19 healthy hatchlings. In four or five years, at a weight of three to ten pounds, they'll be returned to their native island.

Eggs from endangered races of other

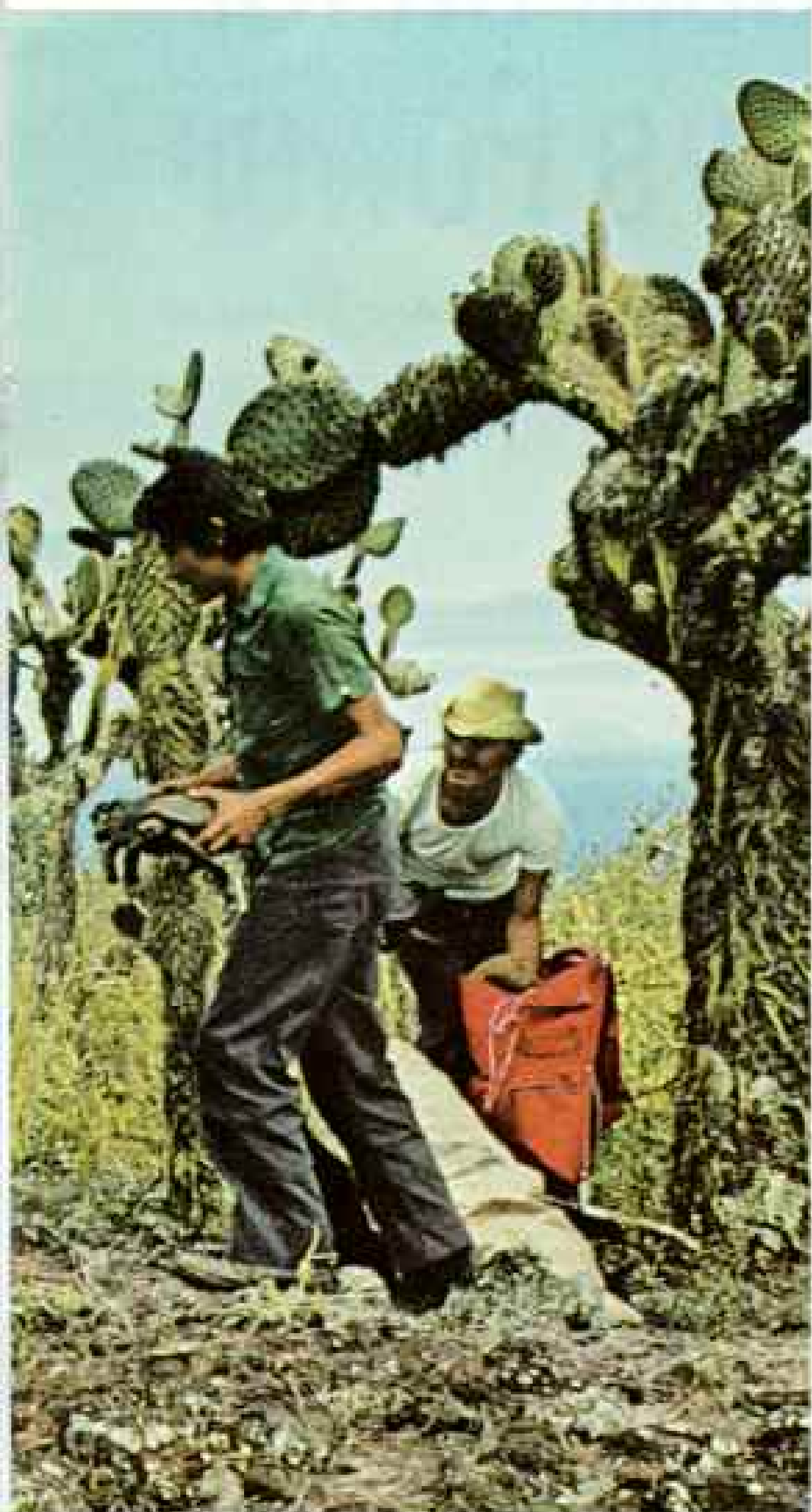
islands are also being incubated at the station. More than 240 young tortoises of six races are growing up there.

Until recently, the only survivors on the small island of Pinzón were 150 old and weather-beaten adults. Black rats were devouring all the hatchlings before they were big enough to defend themselves.

The first Pinzón eggs were taken to Santa Cruz in 1965. In each succeeding year, the station has raised another group.

In November 1971 Dr. Reeder and I sailed to Pinzón with Dr. Peter Kramer, station director, and several conservation officers

face death from black rats, the only introduced predators on this particular island. Ecuadorian law bans poaching throughout the archipelago.



Hanging in the balance: Survival of Galapagos tortoises, like the one being weighed, requires man's continuing research and concern.



ROBERT W. WARRLEN

and wardens. Our vessel bore a precious cargo—51 four- to six-year-old tortoises. At three to twelve pounds, they were large enough to discourage attacks by rats, which the park service staff hopes to eliminate.

Just after sunrise we lugged 22 of the four-year-olds up the east slope of the island to a grove of prickly pear trees below the volcano's rim. The men released the tortoises (above), and within minutes the creatures had scattered over the area. They squared off in mock battles, munched on green plants, and seemed fully at ease in their ancestral home.

Next day the rest were set free in two other

areas. Then Dr. Reeder and I visited the cactus grove where ten months before I had helped release the first 20 five-year-old tortoises in the repopulation program.

We found the sturdy youngsters spread out over a 12-acre area. They were sleeping, basking, grazing, and enjoying the good life. Amazingly, we accounted for every single tortoise.

We weighed, measured, and inspected each one. Their weights had doubled. None bore evidence of rat attack. Finished with our work, we sat down and watched the robust young tortoises clunk about.

They were home. □

The Search for Tomorrow's Power

650

Light pours from New York City in an extraordinary view made at 8 o'clock on a



*A world ever hungrier for
energy, yet wary of pollution's
peril, reaches for new,
clean ways to fuel the future*

Article by
KENNETH F. WEAVER
ASSISTANT EDITOR

Photographs by
EMORY KRISTOF
NATIONAL GEOGRAPHIC PHOTOGRAPHER

winter evening. Motion of the photographer's helicopter creates the shimmering effect.





MINUTES AGO the lights flickered, went out briefly, snapped on again. It was a warning. The electricity would last only a few moments longer, and then we would be plunged into three hours of darkness.

Now I am writing by the light of candles that my London hotel has thoughtfully provided. Outside, no streetlights glow, no storefronts blaze, no traffic signals wink. Only the occasional flash of automobile headlights relieves the six o'clock gloom of this February evening.

I am not the only one beset by darkness. Probably a million Londoners in scattered districts of this sprawling city share my inconvenience. For the third time today, by official edict, we are taking our turn without electricity. A miners' strike has reduced coal stocks almost to the vanishing point, and most of Britain's electricity comes from coal.

In the past three days I have covered miles of London streets, seeing what happens when modern man loses the electricity which he so

takes for granted, and on which his material civilization is based.

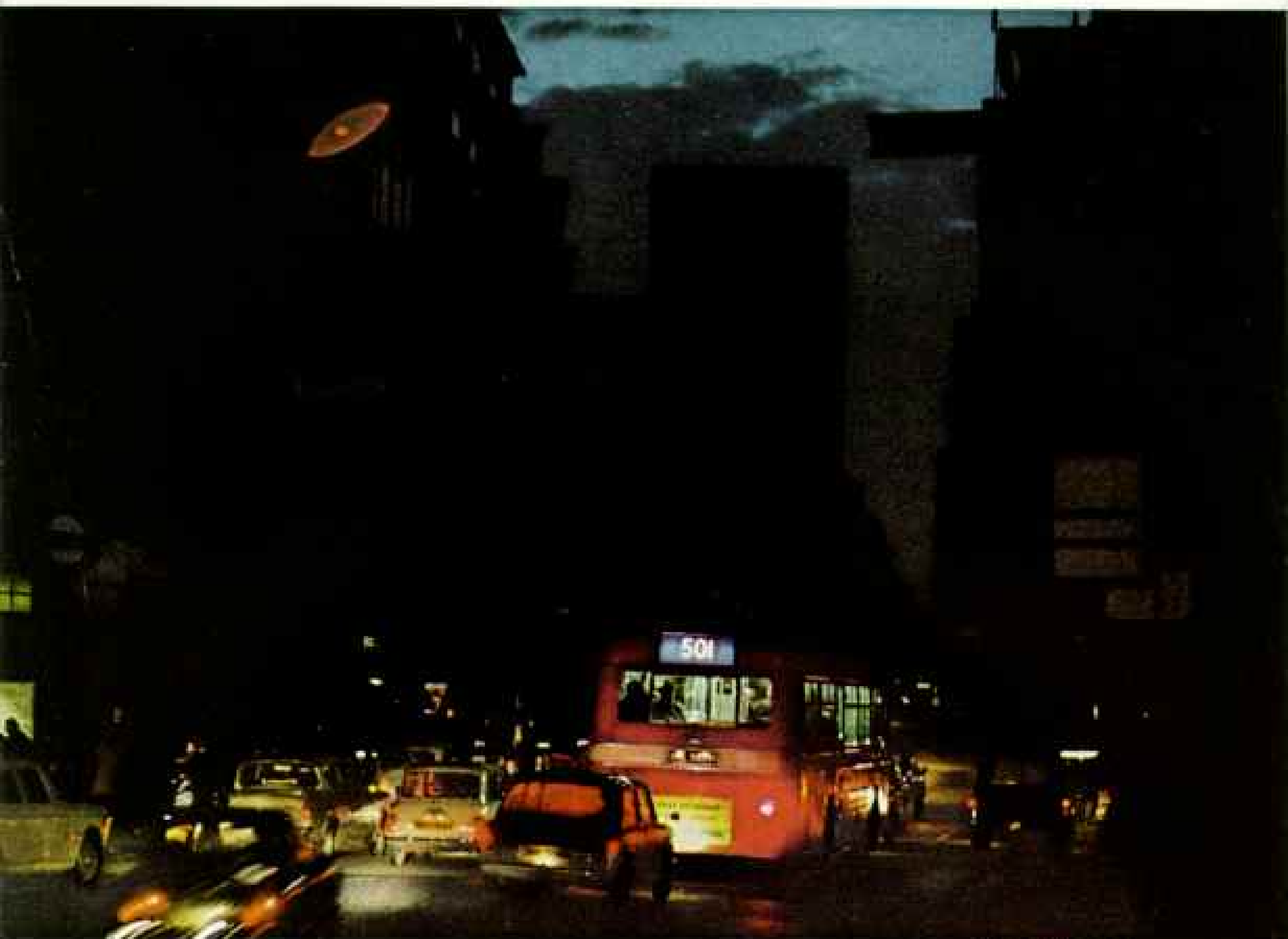
At Battersea Power Station I found furnaces still roaring and generators humming on a reduced schedule, but, outside, front-end loaders were scraping up the last remnants of coal from a pile normally covering an area half as large as a city block.

Blackout Boosts the Price of Candles

Along busy Oxford Street, shops and restaurants had turned off all their display lights for the duration. Inside, candles and pressure lanterns filled in during the blackouts. Impromptu corner vendors offered hard-to-get candles at inflated prices.

Piccadilly Circus, usually a dazzling glitter of advertising signs, lay in murk except for lights over subway entrances. Theaters managed with diesel-powered mobile generators.

"It's not so bad," an engineer at Battersea told me, with characteristic British fortitude. "We make a game of it. It's rather fun dining by candlelight, you know."



BOTH BY ADAM WOOLFIT

But as the three-hour blackout periods shifted from area to area and back again, people across the land fretted about whether frozen foods would spoil; dairies adjusted to hours when power would be available for milking machines; factories went on part-time schedules.

Now, over my battery-powered radio, I hear a newscaster announcing the end of the strike. But for three tense weeks Britain has faced an inescapable truth: Electricity has become the very bloodstream of modern life. . . .

My encounter with London's blackouts was sobering. Britain's experience was a preview of things that could happen elsewhere. Many industrial nations today are threatened with power shortages, and the United States, where 6 percent of the world's population uses 35 percent of the world's energy, is particularly vulnerable.

Americans find all this hard to believe, because for so long they have enjoyed abundant energy at low cost. As Hoyt C. Hottel and Jack B. Howard of the Massachusetts

When London's lights went out: Modern man's dependence on electricity became starkly evident last winter when a power shortage crippled Great Britain. Houses chilled, refrigerators warmed, elevators halted, and factories slowed, idling more than a million workers. Candles flickered in restaurants and pubs, and traffic crawled along night-blackened streets. As available power was rationed, some areas endured blackouts for nine hours a day. Dragging on for weeks, the ordeal dramatically alerted the United States and other industrial nations to problems they, too, will face before new sources of power can be tapped.

Institute of Technology have pointed out, "Total U. S. energy consumption . . . in 1970 [was] the equivalent of 80 slaves working for each one of us to maintain our modern, affluent way of life."

But the simple fact is that demand is outstripping supply. In the past hundred years, overall demand for energy of all kinds in the United States has increased twentyfold. The rate of increase is sharply accelerating, especially for electricity.

Says Shearon Harris, chairman of the Edison Electric Institute: "The utility industry expects consumption of electricity to double between 1970 and 1980, and almost to quadruple by 1990." Such rapid growth will pose enormous problems, for it now takes as much as eight years to get the necessary licenses, build a new power plant, and bring it on line.

More Power Brings More Pollution

The energy shortage is complicated by the problem of pollution, a problem inevitably associated with power plants—corrosive gases, waste heat dumped into waterways, and stack emissions fouling the atmosphere.*

S. David Freeman, formerly chief of the Energy Policy Staff at the White House, expresses it succinctly: "Americans as a nation no longer feel that we can produce and use energy with total disregard for its effect on the environment."

The pollution can be controlled, of course—at a price. For example, at the 950,000-kilowatt Bull Run Steam Plant near Oak Ridge, Tennessee, I saw very little ash escaping from the stacks, although each minute the furnaces were gobbling up five tons of coal as finely pulverized as face powder. A giant bank of precipitators trapped most of the fly ash, 950 tons of it a day, to be used for landfill instead of being spewed from the stacks.

But in Chicago, to my dismay, I watched a power plant pouring out thick plumes of fly ash, casting a dirty pall over the sky and coating everything downwind with dust.

Public resentment at such fouling of our air and water took legislative form in the National Environmental Policy Act of 1969, which requires that the impact on the environment by nuclear (and some fossil fuel) power plants must be weighed before licenses are granted. The new rules, added to serious

industry miscalculations of how fast nuclear power plants would come on line, have meant a slower growth of generating capacity than has been needed.

Of far greater importance, however, in the much publicized energy crisis, is the undeniable fact that we are beginning to see the bottom of the barrel for some fuels.

Many millions of years ago, the earth laid down thick deposits of organic materials that, under heat and pressure, became coal, oil, and gas. In effect, they were stored energy from the sun. These fossil fuel deposits once seemed endless; today, sadly, we know they are far from infinite. Yet we are depleting them at fantastically increasing rates. In the United States we depend on them for 80 percent of all our electricity. Only 16 percent comes from waterpower (a source that is not likely to be expanded much in this country), and 2 to 3 percent from nuclear reactors.

Look at the fossil-fuel picture:

- **NATURAL GAS:** Cheapest, most convenient, and cleanest of the fossil fuels, gas provides a third of the Nation's total energy and a quarter of its electricity. But we are using up our domestic reserves faster than we are discovering new ones. Most predictions see natural gas steadily declining in importance over the next 30 years. Already the gas company in the Washington, D. C., area has announced that it will accept no new customers.

A frantic scramble is under way for new sources of gas. Huge ultra-refrigerated tankers are beginning to arrive in Boston Harbor, bringing natural gas from Algerian ports. Kept liquid by temperatures of minus 260° F., the gas occupies only one six-hundredth of its volume under atmospheric pressure.

Also, a number of private and public organizations are developing plans to gasify coal, producing the same methane that is the basis of natural gas. The first large-scale plant is scheduled for operation in 1976.

But all such substitutes cost several times as much as domestically produced natural gas, and the price for newly discovered domestic gas itself has jumped markedly. Clearly the day of cheap gas is fading.

- **OIL:** This fuel, on which the United States' 116 million motor vehicles depend almost totally, is only slightly better off than gas. Forecasts of supply and demand indicate that present world oil reserves will last for maybe

*These problems were explored in "Pollution, Threat to Man's Only Home," by Gordon Young, *GEOGRAPHIC*, December 1970.

a hundred years. And domestic reserves may be exhausted sooner than that.

This year wells in the U. S. (except for discovery wells in Alaska) are for the first time in history pumping oil at capacity, and even at capacity they cannot meet demand. Already a fourth of our petroleum comes from abroad; by the early '80's it will be half, according to estimates of the National Petroleum Council.

Those responsible for United States security worry about such heavy reliance on foreign sources, especially the oil-rich but politically volatile Middle East. What if the Arab states should cut off oil shipments?

Even if we turn to supplies from other oil fields, economists question our ability to pay the huge annual bill for foreign oil—estimated to run as high as 25 billion dollars additional by 1980. Our balance of trade is already showing a heavy deficit.

Undeveloped resources that may prove highly significant in time are the vast deposits of oil shale in the West, especially on federal lands in Colorado. At the Lawrence Livermore Laboratory in Livermore, California, Dr. Barney Rubin showed me a chunk of oil shale. It was hard and heavy, and its dark surface held a high polish.

He put a match to one corner, and the rock burned with a heavy, smoky flame.

"There's 40 gallons of oil to the ton in that rock," Dr. Rubin said. "The oil is the plastic that holds the rock together."

We don't know yet how to extract oil from shale economically, and the process could

involve destructive strip-mining and leave horrendous piles of debris. But when someone learns how to do it without ruining thousands of square miles of western landscape, we will have tapped a resource many times larger than our present proven oil reserves.

▪ **COAL:** Of all the fossil fuels, coal is by far the most abundant. U. S. reserves amount to an estimated 1.5 trillion tons, 3,000 times the 500 million tons we burned last year.

On the face of it, this substantial reserve should last for hundreds of years. But coal offers special problems. It is the worst offender for producing sulphur compounds. These, when mixed with moisture in the atmosphere, turn to acid that slowly eats steel, marble, and—more frightening—even human lungs.

Moreover, getting coal out of the ground without major damage to the environment has become a serious problem, notably with the advent of ruthless strip-mining. On a recent visit to the Cumberland Mountains in Morgan County, Tennessee, I came to realize just how ugly strip-mining really is.

Along once-lovely ridges, bulldozers have chewed away at graceful curves, creating jagged angles on the skyline. They have diminished noble hills into bulbous knobs; choked valleys with overburden; left massive treeless gashes. On one grand sweep I counted seven parallel scars, each a barren face thirty to fifty feet high.

No effort has been made here to restore the magnificent scenery, one of America's prime

Return to people power: Suddenly faced with the failure of things they had taken for granted, Britons improvised. Here a bicycle replaces an electric motor to drive a petrol pump.

Experts foresee such scenes in other nations, as many double their consumption of electricity each decade, and generating capacity falls behind peak demands.



ALAN WOODLITT





King coal: Most abundant of the fossil fuels, coal would last for centuries at the Nation's anticipated rate of use—if it could be efficiently mined and then cleansed of air-polluting sulphur. This rail-borne river of low-sulphur coal (left), deep-mined in Virginia, West Virginia, and eastern Kentucky, flows to Japan and Europe from a ship-loading yard in Norfolk, Virginia. Used in making steel, it commands such high prices that most domestic power-generating plants cannot afford to burn it.

Flayed in the quest for fuel, farmland in western Kentucky succumbs to strip-mining (above). It yields high-sulphur coal that will go to a Tennessee Valley Authority power plant. Landowners often watch helplessly as strip-mining ravages their property, because mineral rights were signed away by their forebears for pennies an acre. Today, an aroused citizenry demands an end to mining methods that scar America's face.



treasures. Landslides and washes have added their own disfigurement. Flooding streams, unchecked by vegetation, run foul with mud and silt. Stagnant yellow pools, poisoned by leaching acids, fill hollows that once bloomed with laurel and rhododendron.

It may well be, as many people contend, that no strip-mining should be permitted in mountainous areas that are difficult to restore; indeed, some states are beginning to regulate strip-mining, and federal laws are under consideration. But on flatlands there are new methods of stripping that do not necessarily despoil the land.

Crops Flourish on Strip-mined Land

One such technique, now used in Germany, involves a mobile machine called a "bucket-wheel excavator." This monstrous device, 23 stories tall and longer than two football fields, weighs 7,600 tons. In one day its buckets can scoop up enough dirt to cover ten city blocks to a depth of three feet.

Shortly after the excavator lays the overburden to one side and takes out the coal, another giant machine brings the soil back. On land thus restored, crops have been harvested only two years later.

These are today's problems. What about

tomorrow? Does the magic of technology hold bright new solutions for our power shortages? Or will the energy crisis grow worse?

The answer is mixed. Most observers agree that, during the next ten years or so, cities will see increasing brownouts, voltage reductions that cause electric motors to labor and burn out, TV pictures to shrink, and lights to dim.

On hot summer days, as demand for air conditioning and refrigeration push generating capacity to the limit, interruptions of service and rationing of power may become common. And when utilities can no longer maintain reserve capacity, and a major generator—such as the million-kilowatt "Big Allis" in New York City—unexpectedly breaks down, large areas may suffer loss of all electricity for hours at a time.

Dr. Herman Kahn, director of the Hudson Institute, sums it up bleakly, "We can confidently predict a crisis five to ten years from now. There is already a serious power shortage in the Northeast."

Observers also agree that large-scale solutions will not come quickly. In fact, John F. O'Leary, former director of the Bureau of Mines and now head of the Licensing Directorate of the Atomic Energy Commission,

Watts? Yes. New plants? Maybe.

ALMOST EVERYONE wants more electricity, but no one wants a power plant in his backyard. When concern for the environment mounted in the 1960's, New York's Consolidated Edison and other companies faced that classic dilemma.

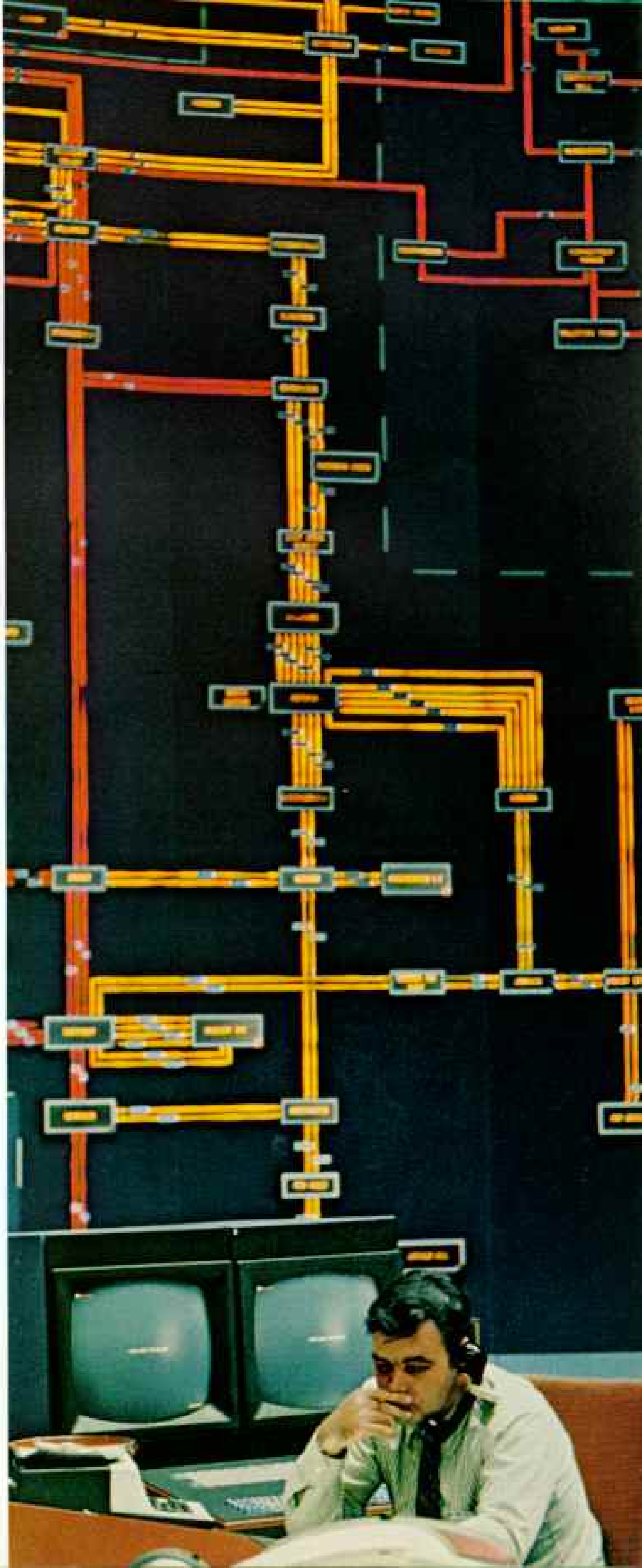
As a stopgap measure, Con Ed installed gas-turbine generators at existing power stations and even floated some on barges. Here four boxy units moor at a Brooklyn pier. Designed to meet peak-load demands, such generators now provide a quarter of New York City's 8,000,000 kilowatts—at twice the cost of power from conventional generators.

Con Ed also dropped advertisements of all-electric living and shifted to posters and pamphlets (below) teaching frugal use of appliances.

A power failure that briefly paralyzed the Northeast and part of Canada in 1965 spurred creation of the New York Power Pool, with a control center near Albany (right). Whenever a plant or line falters, lights flash on the wall. At once the dispatcher chooses substitute lines and power sources to keep the electricity flowing.



The Search for Tomorrow's Power



predicts that the year 2000 will see 75 percent of our total energy and half of our electricity still coming from whatever fossil fuels we have not yet exhausted.

But there are new promises that the energy problem—at least for electricity—eventually will be licked. I have seen much evidence of these promises in recent travels around this country and abroad. New and more effective nuclear reactors are being developed. I have found scientists enthusiastically seeking to extract energy from the sun, from the tides, from the wind, from the furnace deep inside the earth, even from seawater.

Some—perhaps all—of these schemes will work in time. Our own government is spending 620 million dollars this year on overall energy research.

Nuclear Power Brings New Problems

The most immediate solution, of course, is the nuclear reactor, which taps the mighty energy released when uranium atoms fission, or split. Twenty-eight commercial nuclear power plants are already operating in the United States, including the pioneering plant at Shippingport, Pennsylvania, that went on line 15 years ago. Forty-nine additional plants are under construction, and another 67 are on order. When all the new ones are completed, they will add more than 30 percent to the Nation's 370-million-kilowatt total capacity.

Nuclear power plants bring their own problems. Even more than conventional generating plants fired by fossil fuels, they produce large amounts of waste heat. Safeguards must be provided against leakage of radiation from the reactor itself, and also from the radioactive wastes that the process produces.

Finally, there is a scarcity of inexpensive

uranium. According to the Atomic Energy Commission, relatively low-cost nuclear fuel will probably be exhausted by the end of the century if we continue to build only the types of nuclear power plants operating today.

Fortunately there is a major development in nuclear reactors that may meet some of these problems. It is the liquid-metal fast-breeder reactor. To understand how it works, you need to know something about the conventional water-cooled reactor now in use.

Fast Breeder Makes Its Own Fuel

If you could examine the core of a conventional reactor, you would find it made up of thousands of zirconium-alloy tubes, called pins. About twice the thickness of a lead pencil and usually 12 feet long, they are inserted into the reactor in bundles. Constantly bathed with water, these pins hold a mixture of ordinary uranium 238, which does not fission, and a small amount of the scarcer uranium 235, which is the actual fuel. Heat given off when uranium atoms split is carried away by the circulating water and used to produce steam for a turbine generator, just as in a coal- or oil-fired plant.

One pound of uranium, about the size of a golf ball, stores as much energy as 15 carloads of coal. But in the water-cooled reactor barely one percent of that energy can be tapped.

That's where the breeder reactor comes in. The alchemist of old, who sought to turn base metals into gold, would have been entranced by the breeder, for it transmutes elements, producing more fuel than it consumes.

Pins holding uranium 238 are placed in a blanket around the core. As atoms split in the core, they give off heavy nuclear particles called neutrons, which bombard the uranium



Commuter car built in Illinois can scoot quietly along on battery power. Designed for smog-beset cities, it can go 100 miles at 30 mph. Electric cars, recharging at night when power plants have surplus capacity, would shift a major pollution source from exhaust pipes to power-station smokestacks, which can be more easily controlled. Transportation now burns more than half the oil consumed in the U. S.

in the core and in the blanket. Some of these atoms absorb neutrons and are converted to plutonium 239, which will fission.

The mixture of uranium and plutonium can be used as a nuclear fuel. After its energy is depleted, it can be reprocessed and returned to the breeder, and still more fissionable fuel will be produced. This process can be repeated until up to 40 times as much energy has been extracted from the raw material as can be produced in a conventional reactor. Thus with the breeder there is no longer a shortage of nuclear fuel.

The breeder offers other advantages. It is more efficient than the conventional reactor: It converts more of the nuclear heat to electricity. Thus it produces less heat loss and less radioactive waste, which is difficult and dangerous to dispose of. Also, the breeder operates at much lower pressure, so there is less chance of leakage of radioactive gases.

For these reasons, the Atomic Energy Commission and the power industry are moving rapidly to develop the breeder for commercial use. President Nixon, in his energy message last year, called the breeder "our best hope today for meeting the Nation's growing demand for economical clean energy." He called for a commitment to complete a successful demonstration breeder by 1980.

Commonwealth Edison of Chicago, the Tennessee Valley Authority, and a major contractor, yet unnamed, will build this \$500,000,000 plant near Oak Ridge, Tennessee. If it is successful, we may see the first commercial power from breeders by 1985.

Oddly enough, the breeder is not really new. On December 20, 1951, in a lonely laboratory on a windswept lava plain near Arco, Idaho, electricity from a fast reactor with a

core not much larger than a two-pound coffee can lighted four 200-watt bulbs.

It was the world's first nuclear reactor to generate electric power—some 200 kilowatts. More than that, it was the first breeder. Within two years it had proved that it could produce more fuel than it consumed.

The program moved ahead, and today that laboratory is empty. But within the steel fence and the locked doors, a huge pile of concrete blocks still shields the tiny core. On the wall a chalked sign notes that the age of atomic-generated power began on that December day nearly twenty-one years ago. And another sign proclaims that Experimental Breeder Reactor No. 1 is a registered national historic landmark. Some 25 miles away, on another part of that same National Reactor Testing Station, a plume of vapor rises from the water-cooling tower of another breeder, EBR-2, that tests fuels and materials for the larger breeders to come.

Reactor Resembles a Movie Set

Not only in the U.S., but also in Russia, Britain, France, West Germany, and Japan, the breeder is being vigorously developed.

On the bleak, treeless coast of Scotland's northern tip, where mists and sheep seem more at home than instruments of the Atomic Age, I visited Britain's breeder experiments. Hard by the sea, not far from the isolated town of Thurso, a white dome shields a small breeder used for testing materials. At the time of my visit, a much larger demonstration breeder, capable of producing 250,000 kilowatts of electricity, was under construction.

I learned about some of the problems of breeders at the Centre d'Études Nucléaires de Cadarache, in the foothills of the French

Answer to an eyesore? An underground electrical conduit being developed by Dr. Robert W. Meyerhoff of Union Carbide Corporation may help prune the Nation's growing tangle of overhead transmission lines. Cooled by liquid helium to -452° F., the three large pipes become superconductors, able to carry currents that would hopelessly overheat today's underground lines. The small pipe recirculates the helium.



Alps near Aix en Provence. In a parklike setting, I found a dozen research reactors, including a breeder with the whimsical name Rapsodie. M. Guy Denielou, head of the fast-neutron reactor department at Cadarache, took me inside Rapsodie's reactor chamber.

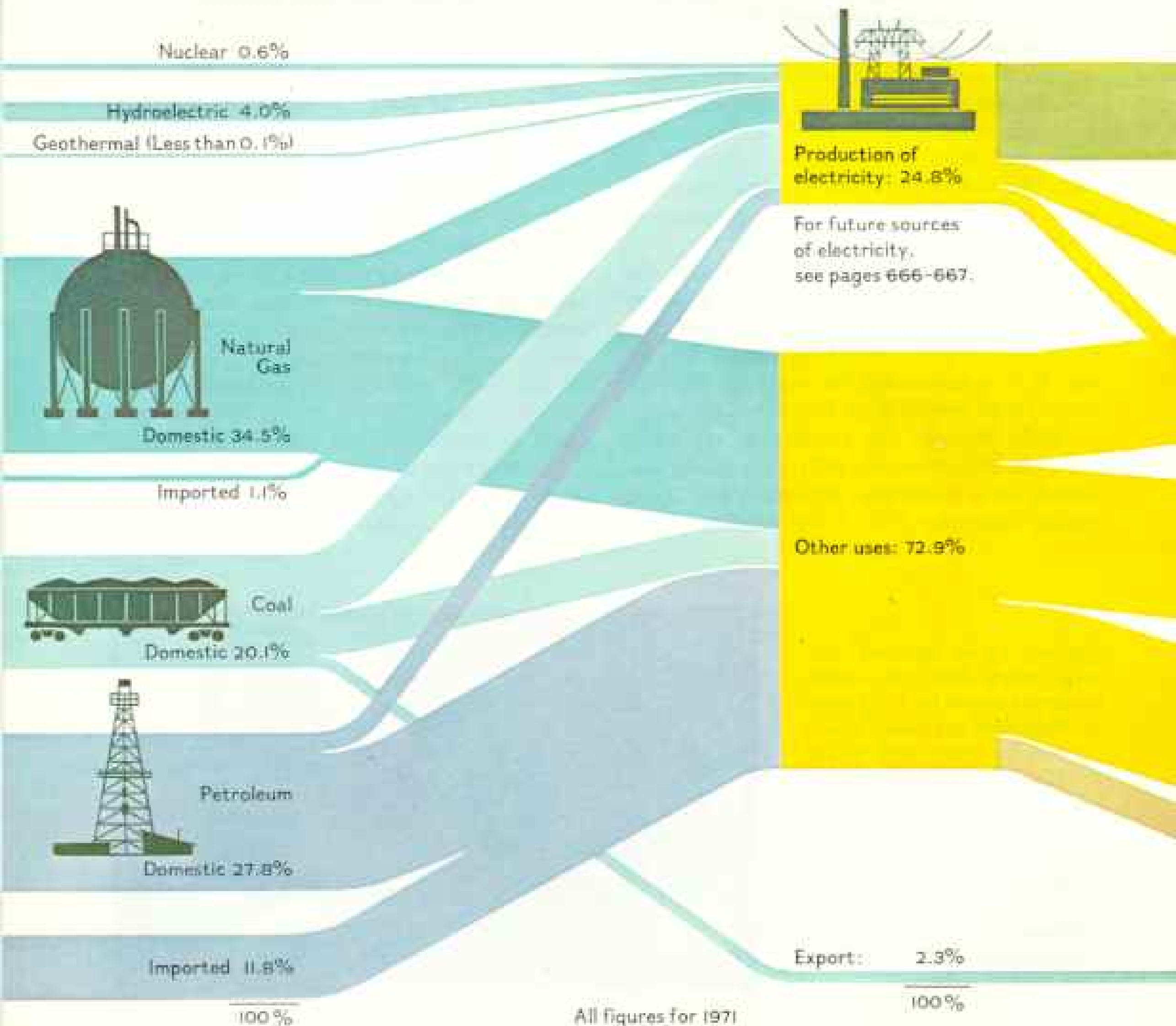
Garbed in white gowns and overshoes that we would shed before departure, along with any possible radioactive contamination, we entered by an airlock, passing through thick steel doors like those of a bank vault. Change of air pressure popped our eardrums, accompanied by a loud hissing as the doors swung ponderously open.

Inside the circular chamber we stood at ground level, with a high dome overhead.

The heart of the reactor, invisible, lay far below us, shielded by concrete and by a thick steel plate in the floor. The big white room was sparsely furnished: a few cabinets along the walls, an overhead dolly, and a pair of cranes for lifting fuel elements from the core. The control room with its many panels of gauges was elsewhere. Beneath our feet titanic primal forces were being unleashed. Yet nothing revealed them to our senses. No humming, no roar, no flashing lights.

Then, suddenly, I heard a loud chime, and a call for a scientist boomed from a loud-speaker; the sound echoed and re-echoed in the great chamber. I felt as though I were in a scene in a James Bond movie.

662



Outside again, Geiger counters checked our hands and feet for possible radioactivity. A loud and rapid ticking would have been a telltale signal, but the gentle background buzzing of the instrument never varied; we were uncontaminated.

Molten Metal Cools Atomic Fire

For cooling the core, and for transporting the heat to the turbine generator, the breeder uses liquid sodium, a soft silvery metal that melts at 208° F., below the boiling point of water. It is cheap and makes an excellent medium for transferring heat.

But, as M. Denielou pointed out, sodium does pose problems.

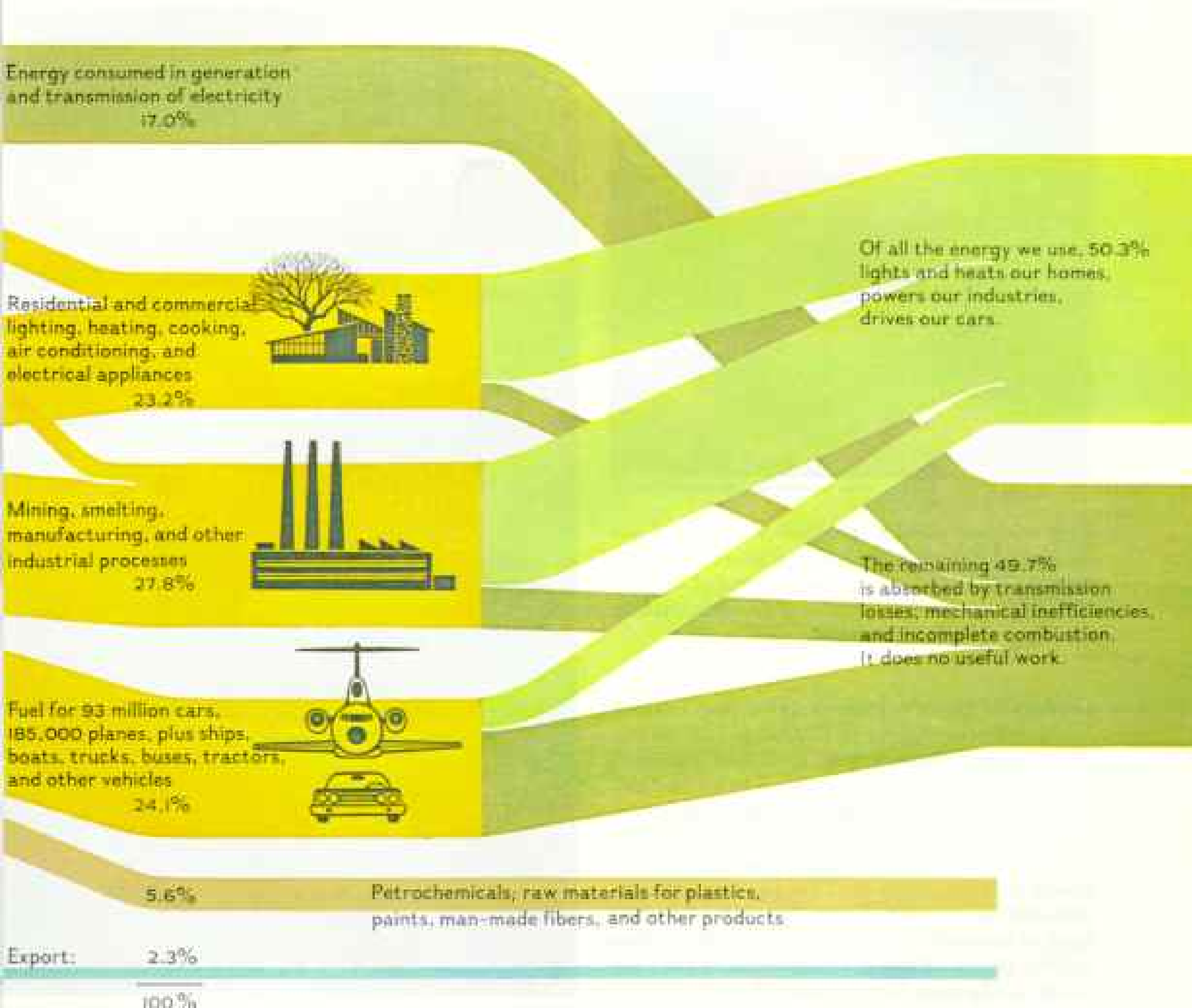
"Sodium expands much more than water when heated," he explained, "and in breeders it reaches temperatures as high as 550° centigrade [1,022° F.]. So we take precautions to avoid sudden expansion and breaks in the plumbing. Wherever possible, we keep the pipes thin and flexible, and we heat them before putting the sodium in."

France's largest and most advanced breeder, Phénix, a 250,000-kilowatt demonstration reactor, goes into operation next year at Marcoule, in the Rhône Valley near Avignon. Before 1,400 tons of molten sodium are added, all the metal in the reactor must be flushed for a month with hot nitrogen.

Another problem with breeders is that

663

U.S. energy: where we get it and where it goes



metals become weak under bombardment by the fast neutrons necessary for the process. Steel swells and becomes brittle. Learning to cope with such unusual conditions is the reason for prolonged experimentation with ever-larger demonstration breeders before their commercial production is attempted.

Beyond the breeder is a far more fantastic device—the fusion reactor—which would tame the power of the hydrogen bomb for peaceful use. While today's fission reactors split heavy atoms such as uranium or plutonium, the fusion reactor would combine heavy-hydrogen atoms to make helium atoms, releasing nuclear energy at the same time. This is the process by which energy is produced in the sun and the other stars.

It is an idea wondrously simple in its concept, yet so seemingly impossible in execution as to discourage any layman.

To make controlled fusion work, one must heat a very tenuous ionized, or electrified, gas (called a plasma) to temperatures on the order of a hundred *million* degrees, hotter than the interior of the sun; contain the gas so that it cannot touch the walls of the vessel; and hold it in this condition long enough for a fusion reaction to take place—a few tenths or even hundredths of a second.

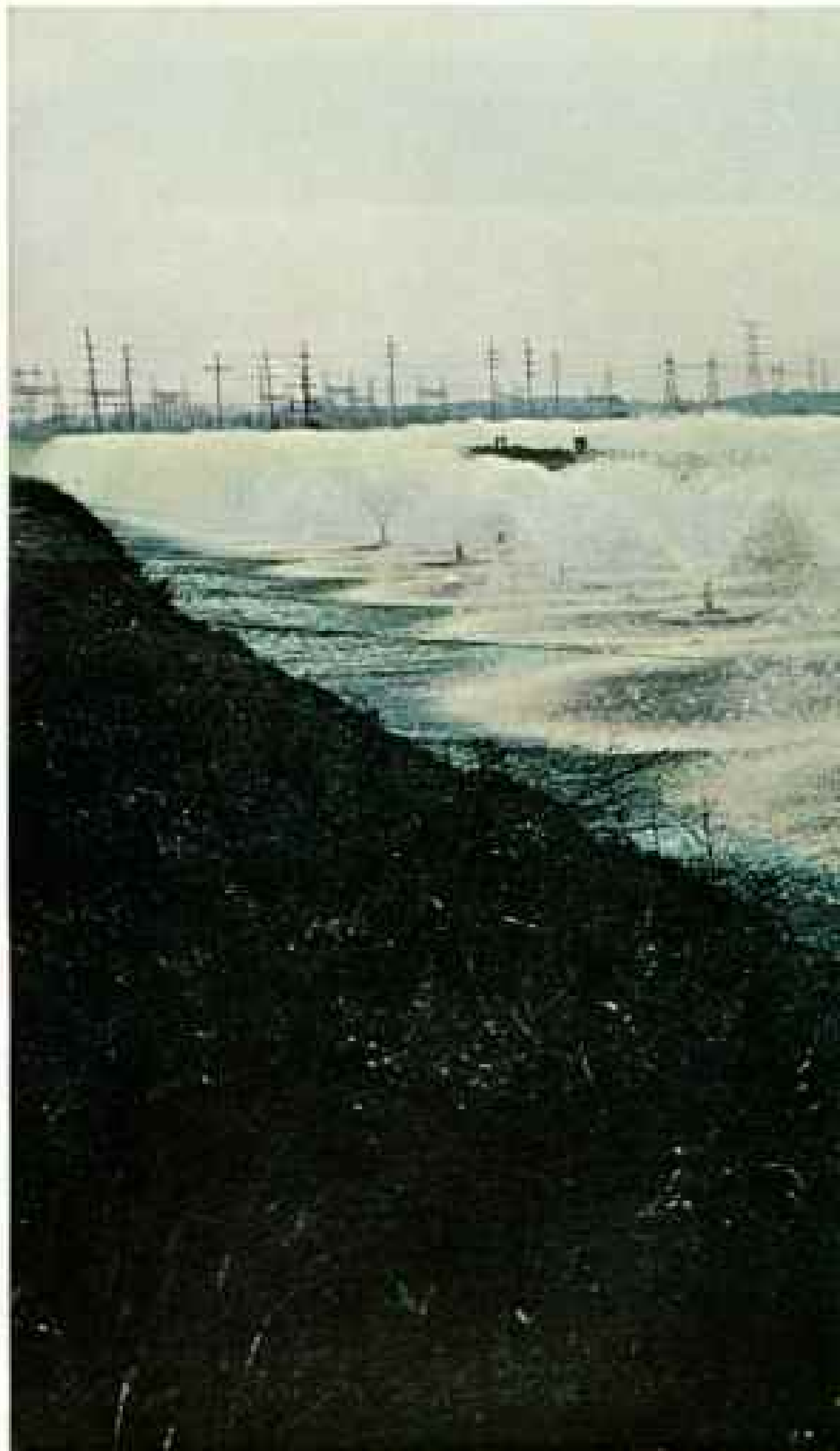
No one has yet made controlled fusion produce more energy than it consumes, although scientists have been trying for years, using powerful magnets, lasers, electron beams, and other tools. The latest survey lists nearly 200 controlled thermonuclear experiments in 14 countries. Researchers in the Soviet Union, Western Europe, Japan, and the U. S. have steadily inched closer to the goal, and some of them look for a breakthrough in the next five years. Even if it comes, the engineering



ESSO RESEARCH AND ENGINEERING COMPANY

Fire without smoke jets from a grapefruit-size furnace at Esso Research and Engineering Company in New Jersey. Turbulent mixing of air with oil yields more than 99 percent combustion, reducing fuel waste and pollution.

Garden of geysers cools water at the Dresden Nuclear Power Station in Illinois, one of the Nation's largest. Pumps pull a million gallons a minute from the Des Plaines River to bathe Dresden's condensers. Even these fountains and a two-square-mile lake cannot always cool the water enough to meet environmental standards for discharge back into the river. Thus Dresden next year will shift to a closed system that will recirculate most of the water. Other utilities consider putting nuclear plants offshore, where water of the open ocean can be used to cool them.



problems are so enormous that fusion can hardly make an impact on our energy supply before the turn of the century.

Scientists of wide experience have told me that man has never tackled a harder engineering problem than that of developing a fusion reactor.

Fusion Will Take Energy From Water

If and when fusion succeeds, fuel shortages for electric power generation become a thing of the past. A fusion reactor can use for fuel the heavy forms of hydrogen called deuterium and tritium. The tritium can be "bred" in the reactor by neutrons produced in the fusion process. The deuterium comes from water. A gallon contains 1/230th of an ounce, which costs only 4 cents to extract. Its fusion energy equals the combustion energy of 300 gallons of gasoline. There is enough deuterium in the

oceans to provide all the energy man is ever likely to need.

Moreover, fusion would reduce the problems of pollution and radioactive wastes far below the levels of even the breeder reactor.

Fusion experiments bear names as exotic as the technologies behind them—Tokamak, Stellarator, Heliotron. One of the most intriguing, at the Los Alamos Scientific Laboratory in New Mexico, is Scyllac, among the world's largest plasma experiments. Scyllac got its name in a curious way, as I learned from Dr. Fred L. Ribe, who heads the program.

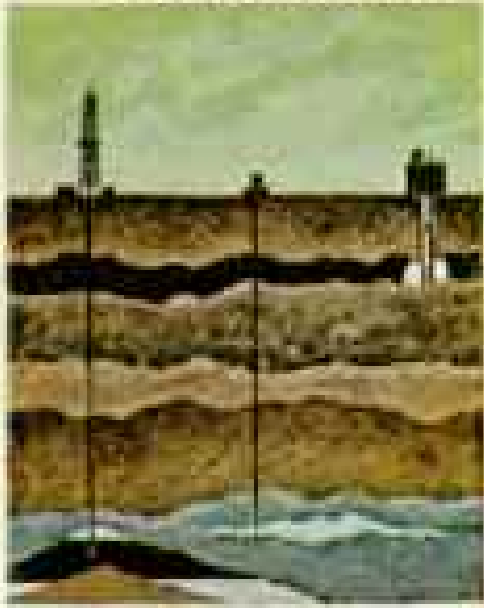
"Mariners in legend feared the Strait of Messina because of two hazards—a dangerous rock on which lived the sea monster Scylla, and a whirlpool called Charybdis.

"We thought of calling our device Charybdis because it creates a kind of magnetic whirlpool. But the name seemed too difficult. So,



NATURE'S ENERGY SOURCES

MAN'S CONVERSION METHODS



FOSSIL FUELS



URANIUM



SEAWATER



TIDAL ENERGY



RESERVOIR



WIND ENERGY



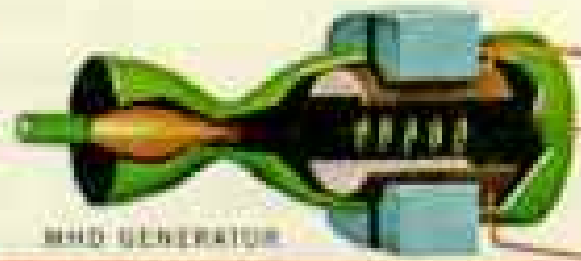
SOLAR ENERGY



GEOTHERMAL ENERGY



FOSSIL-FUELED POWER PLANT



MHD GENERATOR



NUCLEAR-FISSION REACTOR



NUCLEAR-FUSION REACTOR



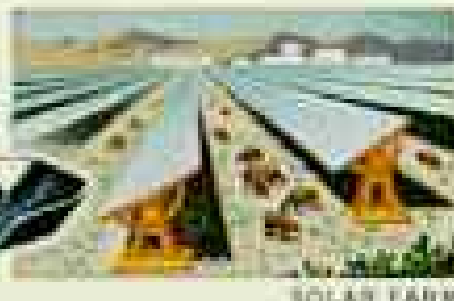
TIDE-POWERED TURBINE



HYDROELECTRIC POWER PLANT



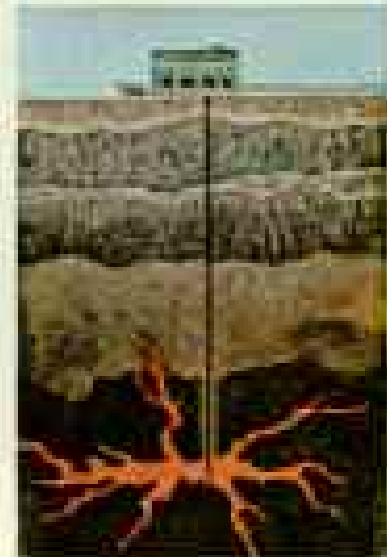
WINDMILL



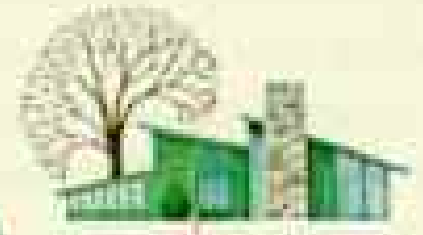
SOLAR FARM



ORBITING SOLAR-ENERGY COLLECTOR



GEOTHERMAL WELL

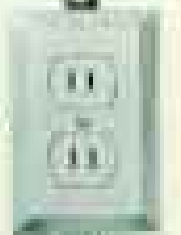


FUEL CELL



CONVENTIONAL STEAM-TURBINE GENERATOR

ELECTRICITY



RECEIVING ANTENNA

The struggle to convert natural energy to electrical energy

AS THE NATION HUNGERS for more and more electricity, scientists grapple with a wide variety of power sources (column at far left) and ways to harness them. Many techniques still rely on the turbine generator powered by steam (blue lines), while others convert natural forces directly to electricity (red lines).

- **FOSSIL FUELS:** Lifeblood of the power industry, oil, gas, and coal will retain their pre-eminence for years, perhaps decades. Burned today in steam power plants, they may someday fuel more efficient systems, such as magnetohydrodynamics (page 673) or a remarkable but still experimental home unit, the fuel cell. Involving no moving parts and creating little pollution, this device will use hydrogen from natural gas to generate electricity chemically.

- **NUCLEAR FISSION:** Despite a slow start, nuclear plants are taking hold. Next will come the amazing breeder reactor (page 672), which produces more fuel than it consumes.

- **NUCLEAR FUSION:** Man's ultimate power source may lie in harnessing the energy process of the stars. If and when the dream becomes reality, fuel for fusion will be extracted inexpensively from seawater.

- **TIDAL POWER:** The tides' restless energy already spins turbines in France's Rance River estuary. Engineers look longingly at Passamaquoddy Bay, between Maine and Canada, but few sites in the United States lend themselves to capture of tidal power.

- **HYDROELECTRIC ENERGY:** With prime sites already harnessed, the United States nears full utilization of this clean resource.

- **WIND:** Free and abundant, energy from the wind involves a serious flaw—unreliability. Man cannot yet store massive amounts of electricity for use during calms.

- **SOLAR POWER:** The sun's stupendous energy could drive civilization forever, if only man could harness it. The "solar farm" (pages 676-7) offers a possible approach, as does the orbiting solar collector.

- **GEOTHERMAL ENERGY:** Intriguing new techniques for tapping the heat in earth's crust (pages 674-5) make this one of the most appealing of potential power sources.

by a strange twist of logic, we switched to Scylla. Later, as the experiment evolved, we added the 'c' to signify 'Scylla closed.'"

Scyllac looks almost as monstrous as its name suggests. Its heart is an aluminum-and-quartz doughnut called a torus, which will eventually be 50 feet around. At the moment it operates with only a third of the circle.

This tube is all but hidden by a tangled web of thick electrical cables, some 70 miles in all, flowing from a three-story bank of capacitors where enormous electrical charges are stored (pages 670-671). When released, the charges flow into heavy magnets surrounding the torus. As the current charges the magnets, an intense magnetic field (60,000 times that of earth's) squeezes the plasma to the center of the tube, away from the containing wall. At the same time it heats the gas to the enormous temperatures required for fusion.

Strange as it seems, there is no problem of melting the walls of the tube, even if the magnetic field releases the plasma. True, the individual particles in the gas are at high temperatures because they are moving at extreme velocities. But because the gas is so very thin, the heat in the plasma in this experiment would seem less than that in a cup of hot coffee. If you could stick your finger in it, it would put the fire out immediately. Thus the plasma must be kept away from the tube walls so as not to cool it down!

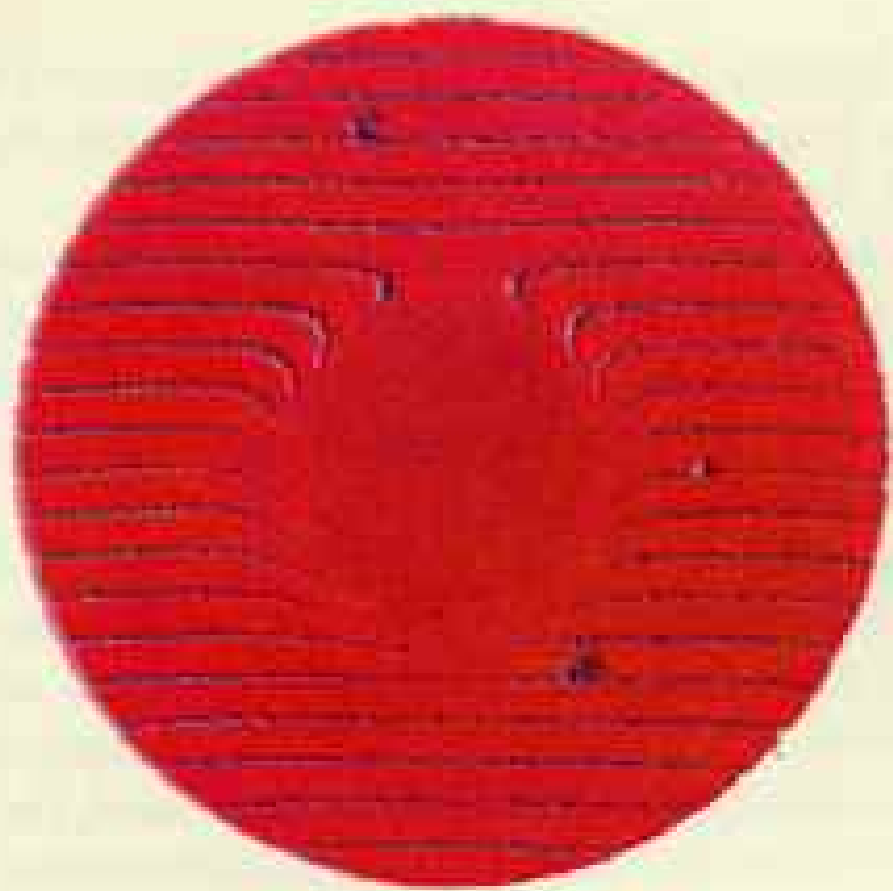
Scyllac Fires With a Bang

High up in a glassed-in observation room, I watched Scyllac go through its paces.

Dr. Warren Quinn directed the experiment from a control panel behind me, speaking by walkie-talkie to technicians below. First a charge of deuterium gas was fed into the evacuated tube. The correct amount of deuterium represented about 1/10,000th the density of the air we breathe. Then I saw a bright pink glow as an electrical charge was released into this gas, tearing electrons from the deuterium atoms and thus ionizing them.

Now Dr. Quinn watched his gauges closely. Five red needles showed the buildup of kilovolts in the capacitors. As the needles moved slowly, the scientist called out "Twenty . . . thirty . . . forty . . ." All the lights on the board turned yellow. A bell rang, signifying that the charge was ready to be triggered. A second later a loud bang echoed through the building, and a bright blue glow suffused the room.

(Continued on page 673)

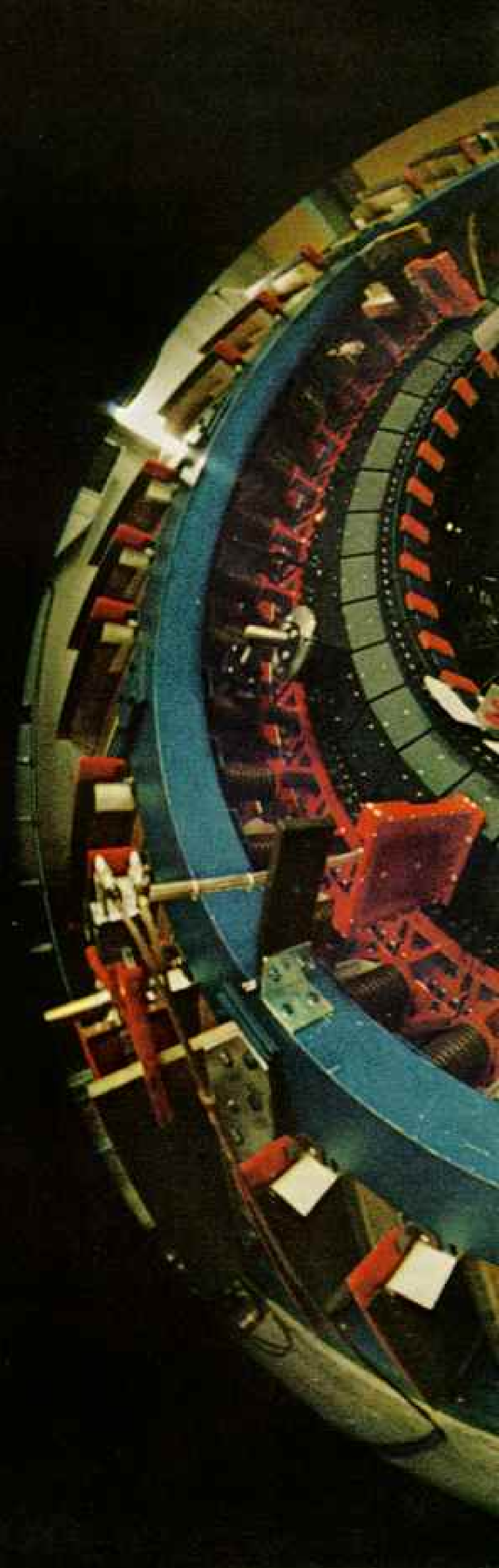


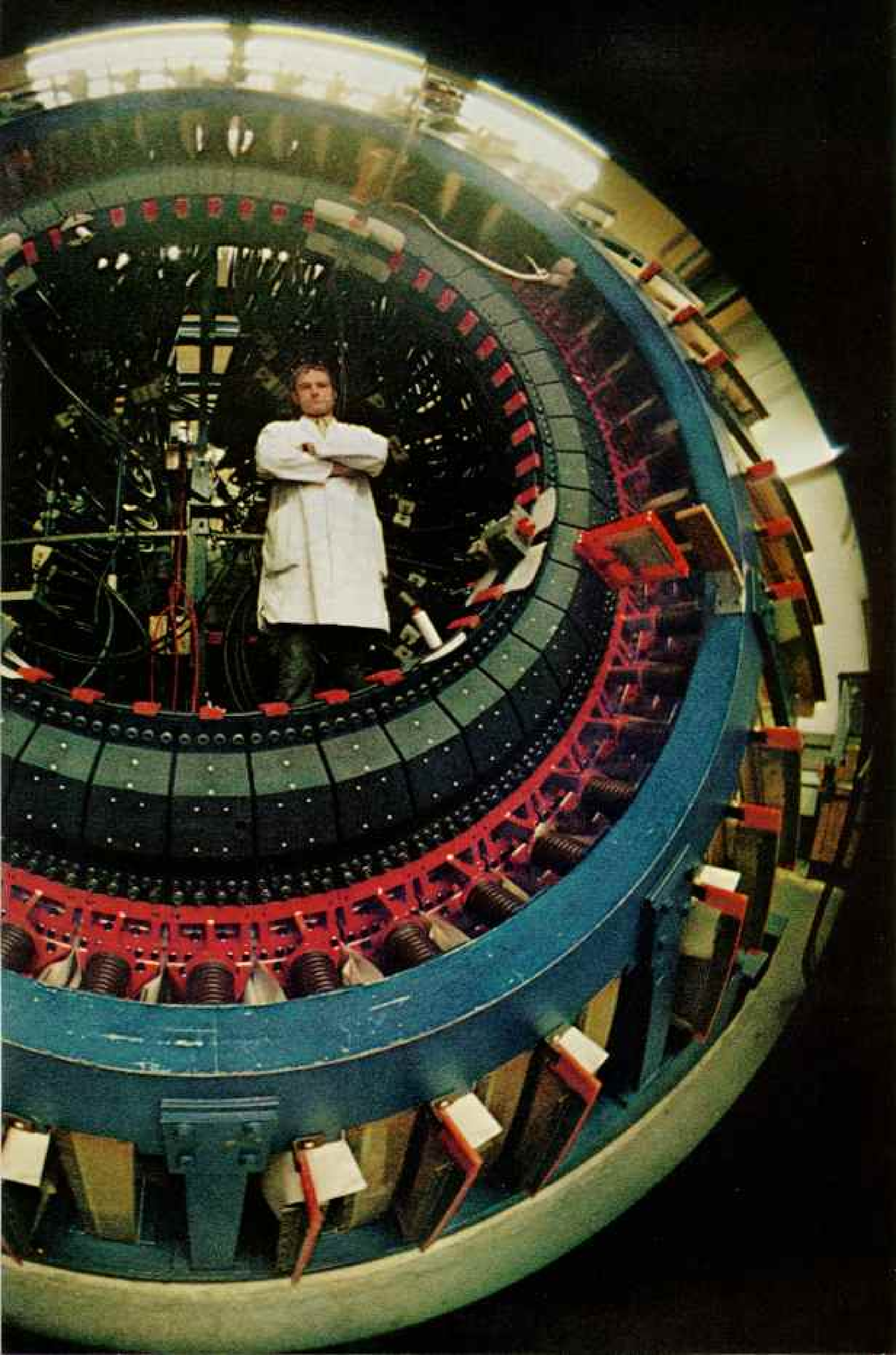
Nuclear fusion

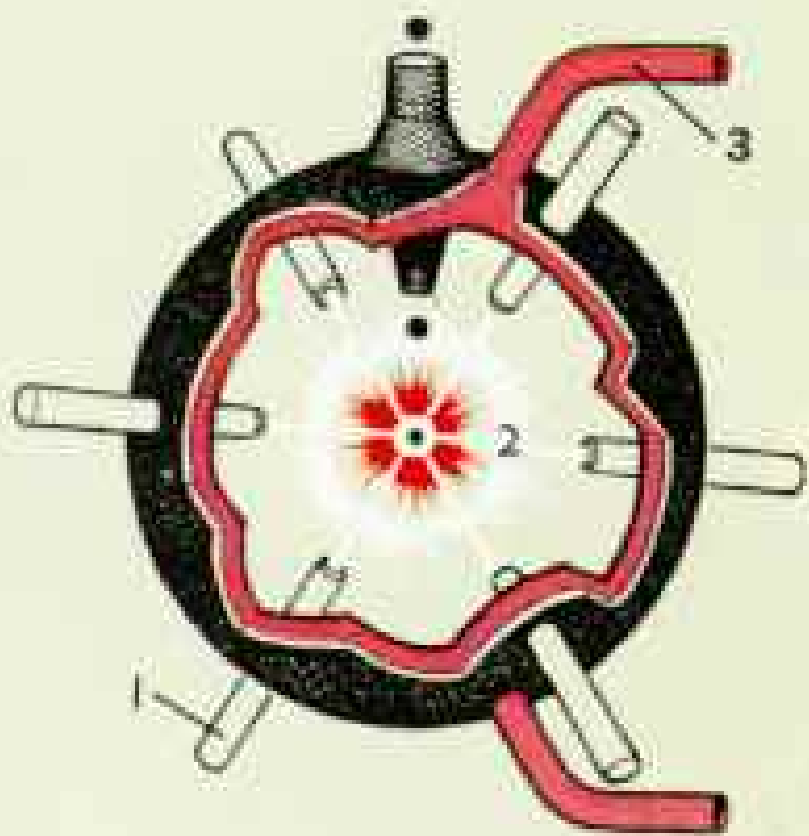
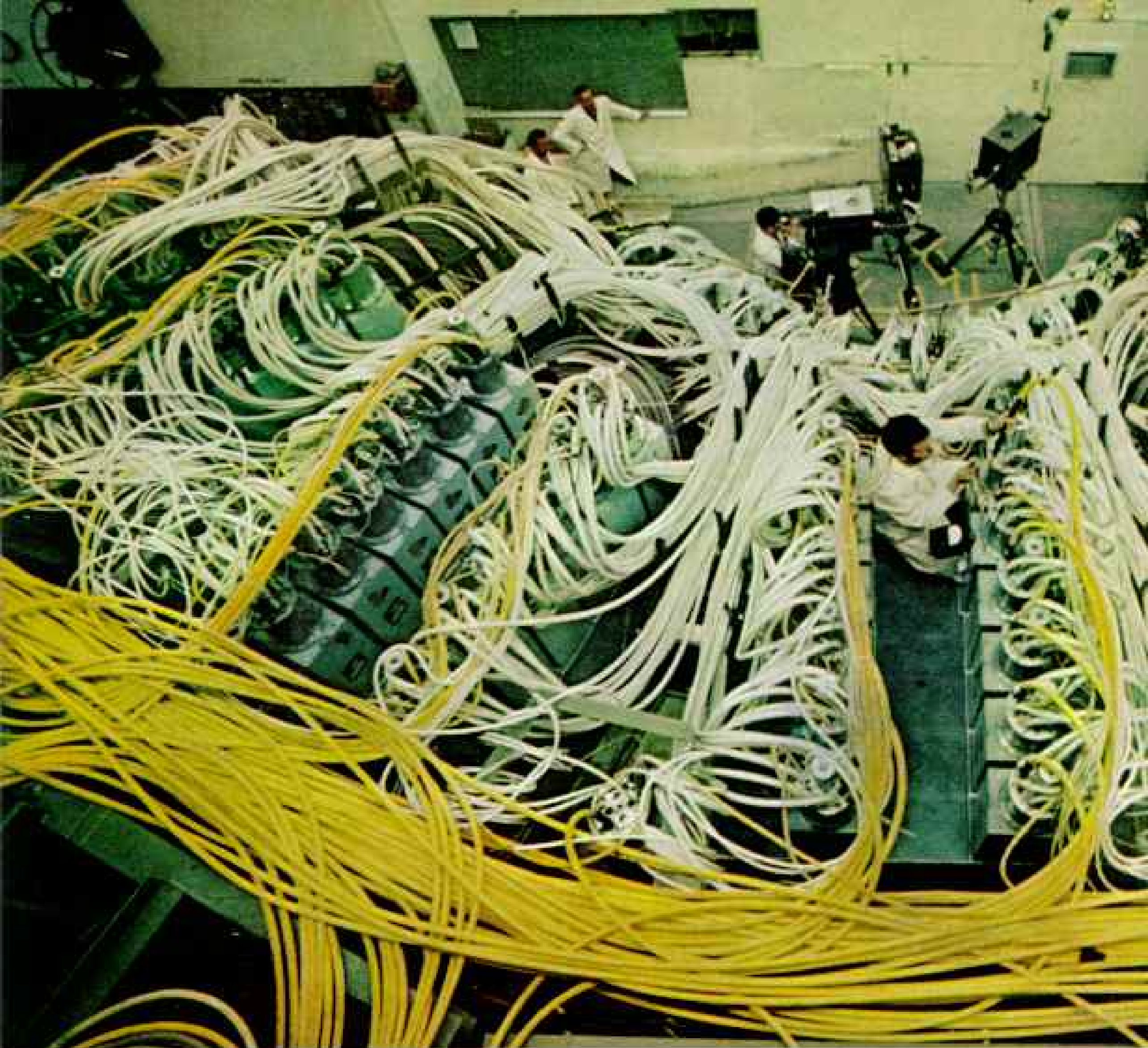
ATOMS FUSE under tremendous heat and pressure, releasing energy. If man can tame this reaction, already achieved in the hydrogen bomb, he will have virtually unlimited power at his command.

Can man kindle and control fusion's temperatures of 100 million degrees? Experimenting with a mammoth electromagnet known as Isar (right), scientists at West Germany's Max Planck Institute for Plasma Physics, near Munich, imprison the fusion process in a magnetic field. Within Isar's central circular magnet, a quartz doughnut holds heavy hydrogen. A massive electrical discharge heats the gas into an ionized state known as plasma. Simultaneously a magnetic field violently compresses the plasma into the center of the tube. Squeezed close together, the atoms collide with such impact that they fuse.

Pictures taken at Los Alamos Scientific Laboratory show the process in cross section by laser photography (above), and with compressed xenon gas (below).







Laser bombardment

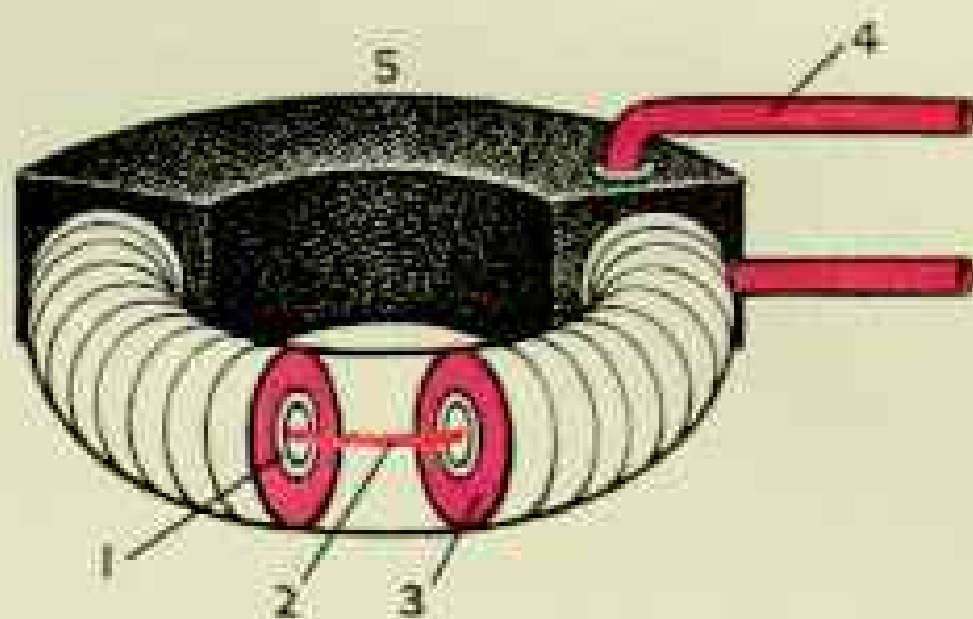
THE VERSATILE LASER holds promise of producing useful fusion. Eyes shielded, a scientist (right) at the University of Rochester in New York records the staggering power that drives the light beam.

To achieve fusion in a future laser reactor (diagram at left), scientists will train an array of beams (1) at a common point, then rhythmically drop pellets of frozen heavy hydrogen through the synchronized cross fire (2). The beams' fierce energy turns the pellets to plasma at solar temperatures and densities, causing fusion. The released heat transfers to a jacket of molten lithium, which is carried off (3) to produce steam for generating electricity.

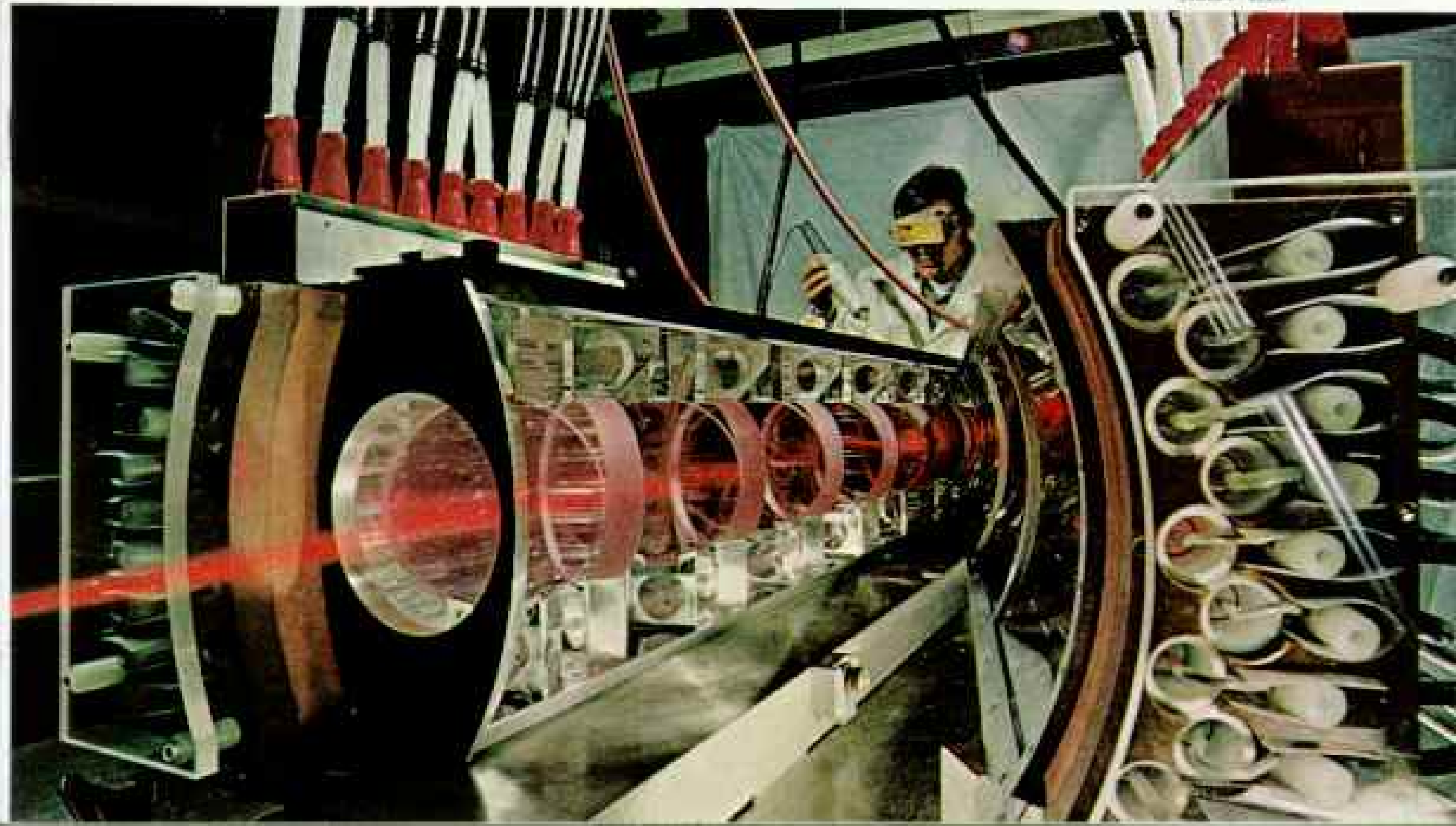


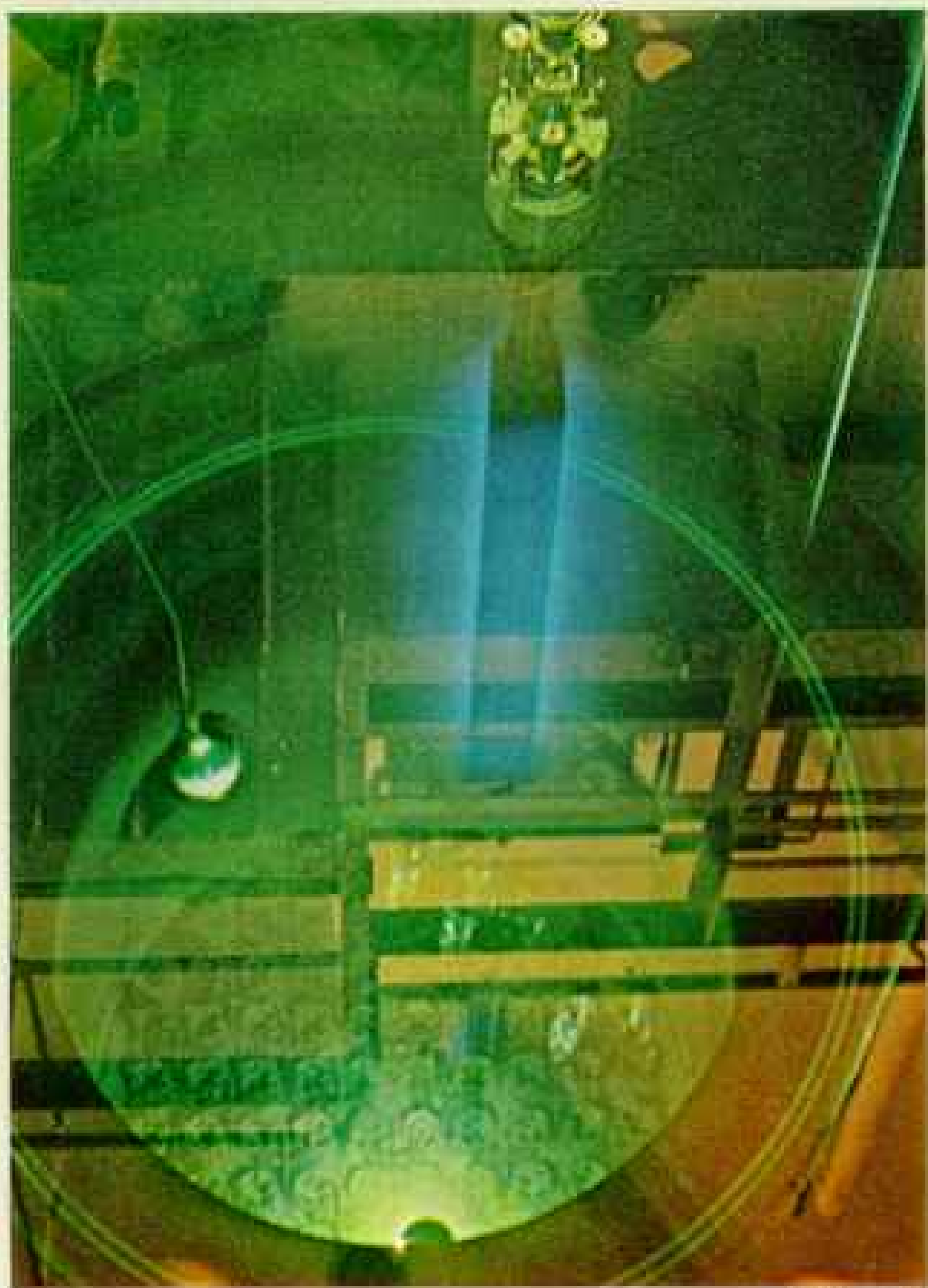
Magnetic squeeze

ELECTRICAL SPAGHETTI enmeshes technicians working on Scyllac (left), a fusion device at the Los Alamos Scientific Laboratory in New Mexico. The maze carries discharges of 60,000 volts from capacitors in the foreground to a quartz plasma tube. The eventual working reactor will form a complete circle, as in the simplified sketch below. Within the electromagnet (1), electrical pulses heat and magnetically compress the plasma (2), so that nuclei collide and fuse, releasing tremendous heat. Liquid lithium (3) absorbs the heat, then transfers it (4) to a steam generator. A concrete shield (5) encases the doughnut-shaped reactor.



PHILIP BLAKE





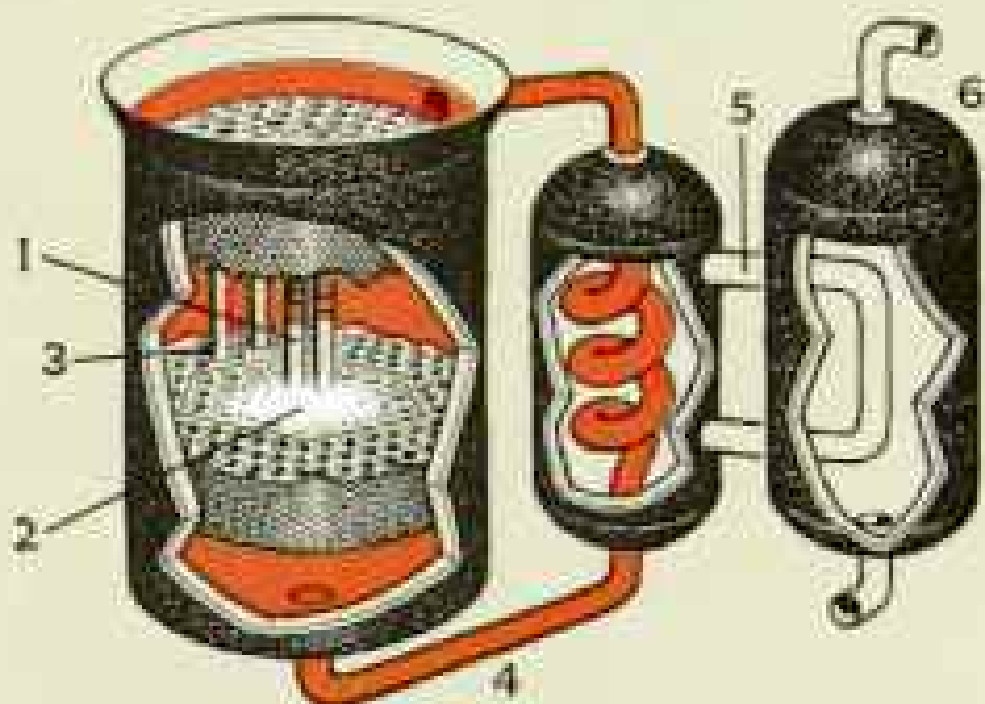
JAMES F. BLAKE

Nuclear fission

CONVENTIONAL NUCLEAR REACTORS "burn" cores of fissionable material, whose unstable atoms split, or fission, and release heat. At left, fuel rods withdrawn from a core during refueling glow with radiation at the Yankee Atomic Electric station in Rowe, Massachusetts. Unfortunately, supplies of fissionable uranium are limited. But *non*-fissionable uranium abounds; thus the beauty of the breeder (diagram).

The fast breeder, a miracle machine that creates more fuel than it consumes, suggests the alchemists' dream because it changes one element to another. Beneficiary of an intensive program of federal research, the breeder looms as a likely bridge between fossil fuels and the distant advent of fusion power.

Fuel rods (1) produce the radioactive fires in the core (2) and release large numbers of neutrons. Some of these atomic particles are trapped by nonfissionable uranium both in the core and in the surrounding blanket of rods (3), transforming part of the uranium into fissionable plutonium 239. The reactor creates five pounds of radioactive fuel for every four it consumes—enough to sustain itself and help supply another plant. Liquid sodium (4), circulating through the reactor, transfers the heat to a secondary loop (5), which in turn heats a steam generator (6).



How well had they done? Dr. Quinn checked the data recorded in the computer.

"We got up to 10 million degrees Kelvin [about 18 million degrees F.]," he reported. "We need 100 million. The density of the plasma was about 3×10^{16} [30 quadrillion particles per cubic centimeter], which is OK. We kept the plasma contained for 5 micro-seconds [5 millionths of a second], and what we need is two hundredths of a second."

No one seemed dismayed that the figures had not reached the necessary levels. This was just a routine experiment, one of thousands that will be run before a sustained fusion reaction can finally be achieved.

As Dr. Roy W. Gould, director of AEC's Division of Controlled Thermonuclear Research, says, "It's not whether, but when!"

While we wait and hope for the breeder and fusion to solve our fuel problems, thoughtful men are urging that we explore many other options for clean energy. Here are some of the more interesting proposals:

- **BURNING TRASH:** At the Brookhaven National Laboratory, Dr. Meyer Steinberg notes that India burns about 100 million tons of cow dung a year for cooking and heat, and suggests that we turn our waste into fuel.

"Each day the U. S. produces five pounds of garbage per person," he told me. "In addition there are 60 pounds per person per day of agricultural wastes—manure and vegetation. This grand total of nearly $2\frac{1}{2}$ billion tons of waste a year, if burned in power plants, would produce more than half the electricity we are now generating."

As if in support of Dr. Steinberg's idea, St. Louis last May began burning shredded trash with pulverized coal to make electricity. A fifth of the city's refuse is being converted each day into 300 tons of odorless, clean-burning fuel that resembles confetti. Every ton of trash saves half a ton of coal. A number of European cities are also now turning their trash into electricity.

- **FUEL CELLS:** When the Apollo astronauts go to the moon, their spacecraft uses fuel cells to convert hydrogen and oxygen into electricity. Someday you may get all your power from a similar box in your basement no larger than two low file cabinets, into which you would pipe gas.

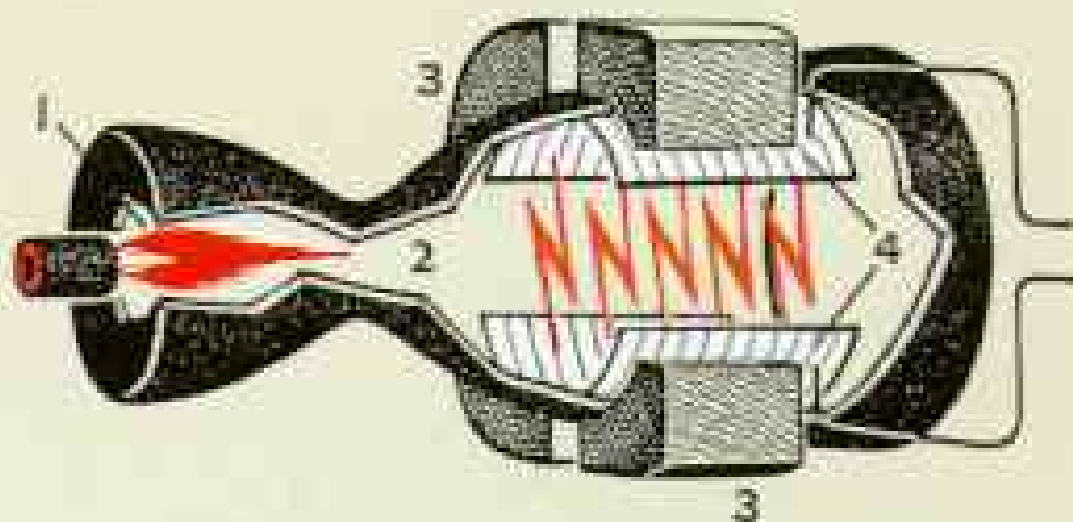
In one research project I saw, metal electrodes and plates made of carbonates took

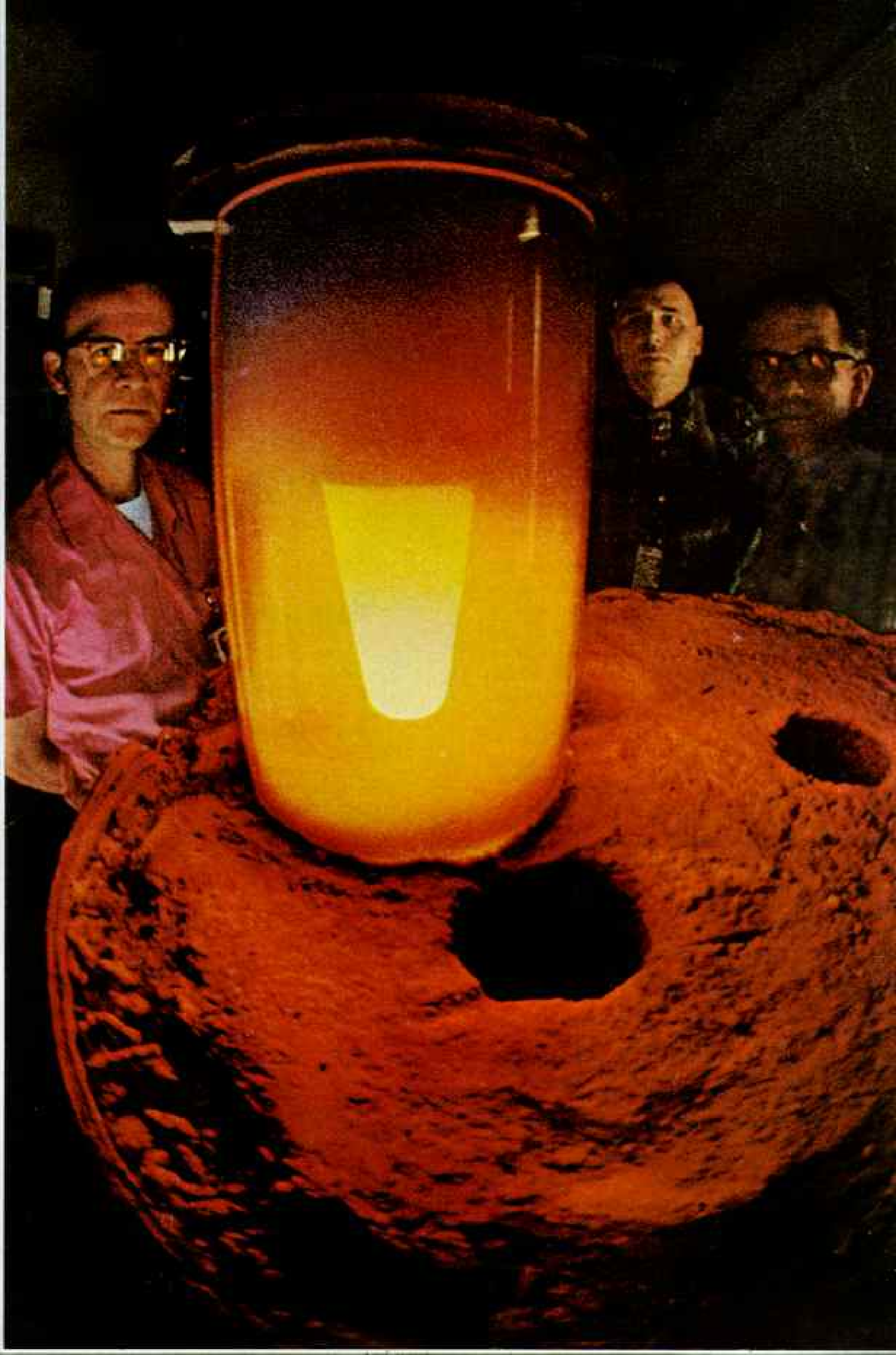


Magnetohydrodynamics

SIMPLE IN CONCEPT though long in name, a phenomenon known as MHD holds tantalizing promise of clean, efficient power. Demonstrating a process he has done much to advance, Dr. Arthur Kantrowitz, right, director of the Avco Everett Research Laboratory in Massachusetts, directs a flame between curved electromagnets. Using potassium salt, he "seeds" the gas flame to increase its conductivity. Suddenly, electrodes and wires leading from the flame begin to carry a current to a meter. The ionized gas and magnets have become a generator.

In an actual MHD generator, sketched below, powdered coal burns fiercely in a chamber (1). Squirting through a nozzle (2) at supersonic speed, combustion gases stream between magnets (3), yielding an electric current taken off by electrodes (4).





Geothermal energy

ROCK MELTS LIKE ICE at the touch of Subterrene (left), a molybdenum marvel glowing beside holes bored at the Los Alamos Scientific Laboratory. Sheathed here in a protective Pyrex case, electrically heated Subterrene will literally melt its way into the earth, lining its hole with a casing formed from the molten rock. Scientists envision drilling 10,000 to 20,000 feet to reach the almost limitless heat of earth's interior. After boring two shafts, they would pump water down one, where it would superheat and be forced up the second.

Suggesting Dante's inferno, a steam-field plant near Larderello, Italy (right), has a generating capacity of nearly 400,000 kilowatts. Giant cooling towers dissipate exhaust steam.



hydrogen (which can be extracted from natural gas) and combined it with oxygen from the air to make water and electricity.

A power-generating system based on this experiment would produce little pollution, little noise, and no overhead power lines, and gas would be used more effectively than in a central power station.

- **MHD:** Those initials stand for magneto-hydrodynamics, a jawbreaking name for a way of making electricity by substituting a hot, flowing ionized gas for the rotating copper coils in an electrical generator.

Dr. Arthur Kantrowitz, director of the Avco Everett Research Laboratory, and Dr. Richard Rosa built a small MHD device 14 years ago and have been vigorously promoting the idea ever since. Dr. Kantrowitz likes to demonstrate the technique by directing a blowtorch's flame (lightly salted so that it will easily conduct electricity) through the poles of a magnet (page 673). Electrodes extending into the flame pick up the current and carry it to a meter, whose needle clearly shows that the idea works.

But will it work on a large scale? Dr. Kantrowitz smiled ruefully.

"The Russians saw one of our early models in 1964," he said. "They went home and poured money and effort into MHD work,

while our own research languished for lack of funds. Last year they began shakedown operation of a large MHD generator called 'U-25,' designed to deliver 25,000 kilowatts of electricity into the Moscow grid."

Dr. Kantrowitz points out that any kind of fossil fuel can produce the hot gas for an MHD generator. He calculates that efficiency may reach as high as 60 percent—1½ times that of a conventional fossil-fueled power plant, because after part of the energy is converted directly to electricity, the hot gases are used to fire a regular boiler-and-turbine generator.

- **TIDES:** Anyone who has ever watched the excursions of the ocean tides has wondered if that rhythmic energy could be harnessed. For example, Canada and the U. S. have studied the possibilities of power plants in various parts of the Bay of Fundy, where surging tides may reach more than 50 feet.

Meanwhile the world's first large-scale tidal power plant operates successfully, although at high cost, on the Rance River estuary in Brittany. There I saw Frenchmen in berets riding their motorbikes across the low dam between St. Malo and Dinard, while, below, submarinelike turbine generators with reversible propellers churned out power at a quite respectable 240,000 kilowatts.



• **WIND:** The windmill, once so common for pumping water on the western plains, has all but died out, replaced by the electric pump. But the windmill as a useful power source, now that fuels are becoming so scarce and costly, has a champion in William E. Heronemus, a professor of civil engineering at the University of Massachusetts.

"Did you know that Denmark back in 1915 had 3,000 windmills producing electricity?" he asked me. "Or that on Grandpa Knob near Rutland, Vermont, a big windmill generated 1,250 kilowatts during World War II?"

Professor Heronemus seriously proposes that large windmill generators with rotors of glass-reinforced plastic be floated on the open Atlantic or the Great Lakes. Twenty miles out, he says, they would catch the strong prevailing winds, yet be invisible from land.

• **GEOTHERMAL POWER:** Using heat from the earth is an old story in countries like New Zealand, Iceland, and Italy. In the Italian province of Tuscany, southwest of Florence, the natural steam field of Larderello has been generating electricity since 1913 (page 675).

In the United States, I found that geothermal power is being produced in only one place—The Geysers, north of San Francisco, where the Pacific Gas and Electric Company expects to have generating capacity of half a million kilowatts by 1975.

As I drove through Sonoma County's green hills, awash with orchards, vineyards,

and moss-draped live oaks, I spotted across a ridge what appeared to be a jetliner's contrail. Oddly, it did not dissipate. When I topped the ridge, I found that my "contrail" was a towering column of steam roaring from the earth itself. It was Whistling Annie, largest of a series of such vents that filled the valley with white plumes and my ears with noise. Steam even oozed from the steel gateposts near the power plant.

At the University of California at Riverside, Dr. Robert W. Rex, the Nation's foremost exponent of geothermal power, assured me that "the largest practical new energy source available to society today is heat from the interior of the earth."

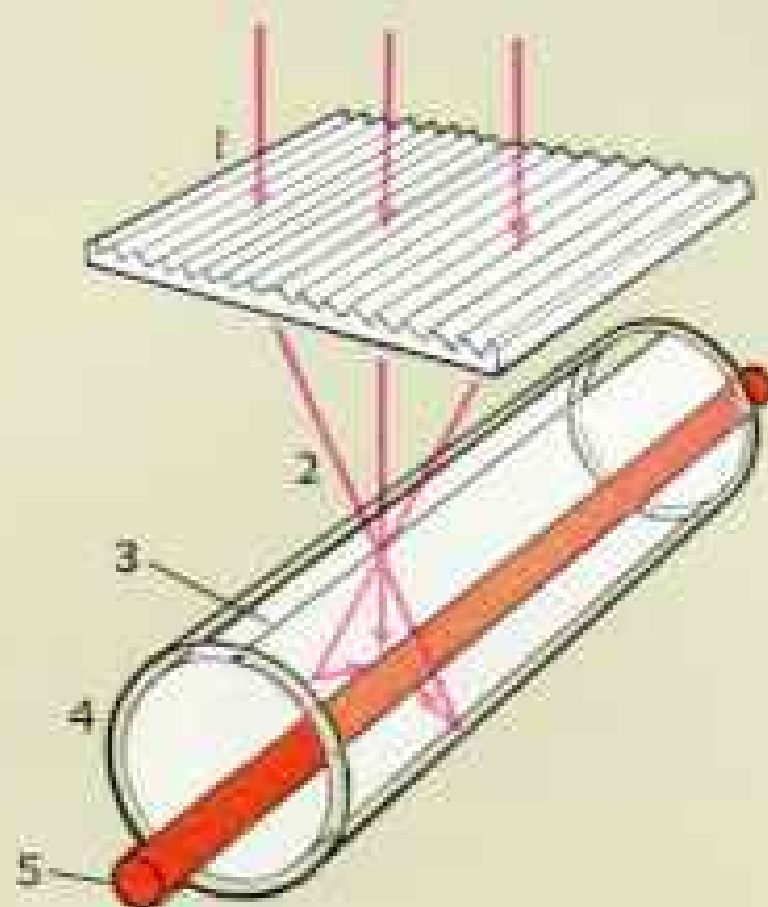
Natural steam such as I saw at The Geysers is limited in this country, he admitted. But there are many places, like California's Imperial Valley, where hot water can be tapped and used to evaporate freon to drive turbines. With geothermal power alone, Dr. Rex believes, California could meet all its present needs for electricity.

An even more exciting proposal involves intensely hot rock at one to five miles beneath the surface in many parts of the world. This heat could be harnessed by sinking a well, then forcing cold water down to fracture the rock. Hydrofracturing is a well-established technique used by drillers to open up passageways for oil.

Water heated by the rock to 350° F. would rise to the surface by convection through a

Solar heat

TO REAP the sun's enormous energy, Professor Aden B. Meinel and his wife, Marjorie, would cover areas of the Southwest with louverlike solar collectors. The land beneath them could still be used for grazing cattle or farming. In the diagram at right, ridged lenses (1), tilted toward the sun, train rays (2) down through a slot (3) into a glass pipe (4). Its mirrored inside surface reflects the heat onto a coated inner steel tube (5) that circulates gaseous nitrogen. Reaching temperatures of 1,000° F., the gas flows to tanks of molten salts capable of storing the heat for nighttime use. Steam heated by the salts drives turbines. The Meinels estimate a square mile of solar farm could supply power for a city of 60,000.



second shaft drilled nearby. Its energy would be used to drive turbines, then the water would go back into the earth to be reheated.

Dr. Rex argues that geothermal power is cheap, clean, and almost pollution free. He believes it can be developed at less cost and sooner than the new nuclear sources.

• **SOLAR POWER:** The greatest energy source of all, of course, is the sun itself, which pours onto the earth 100,000 times as much energy as the world's present electric-power capacity. I gained respect for this fantastic power at the world's largest solar furnace, near Odello in the French Pyrenees.

In a pastoral setting of chalets, flocks of sheep, and snow peaks, I first glimpsed the furnace as a great shimmering object of astonishing beauty—a parabolic mirror 148 feet high, which turned the landscape topsy-turvy and flung it back at me (next page).

The mirror captures large amounts of sunlight and focuses it into a small area of intense heat—much as a magnifying lens focuses sunlight on a piece of paper and sets it afire. The difference is one of degree. The concentrated fury of the sun's energy in the furnace reaches more than 6,000° F., enough to melt almost any substance on earth. In only one minute it can burn a 12-inch hole through three-eighths-inch steel, melting it into dribblets like so much taffy.

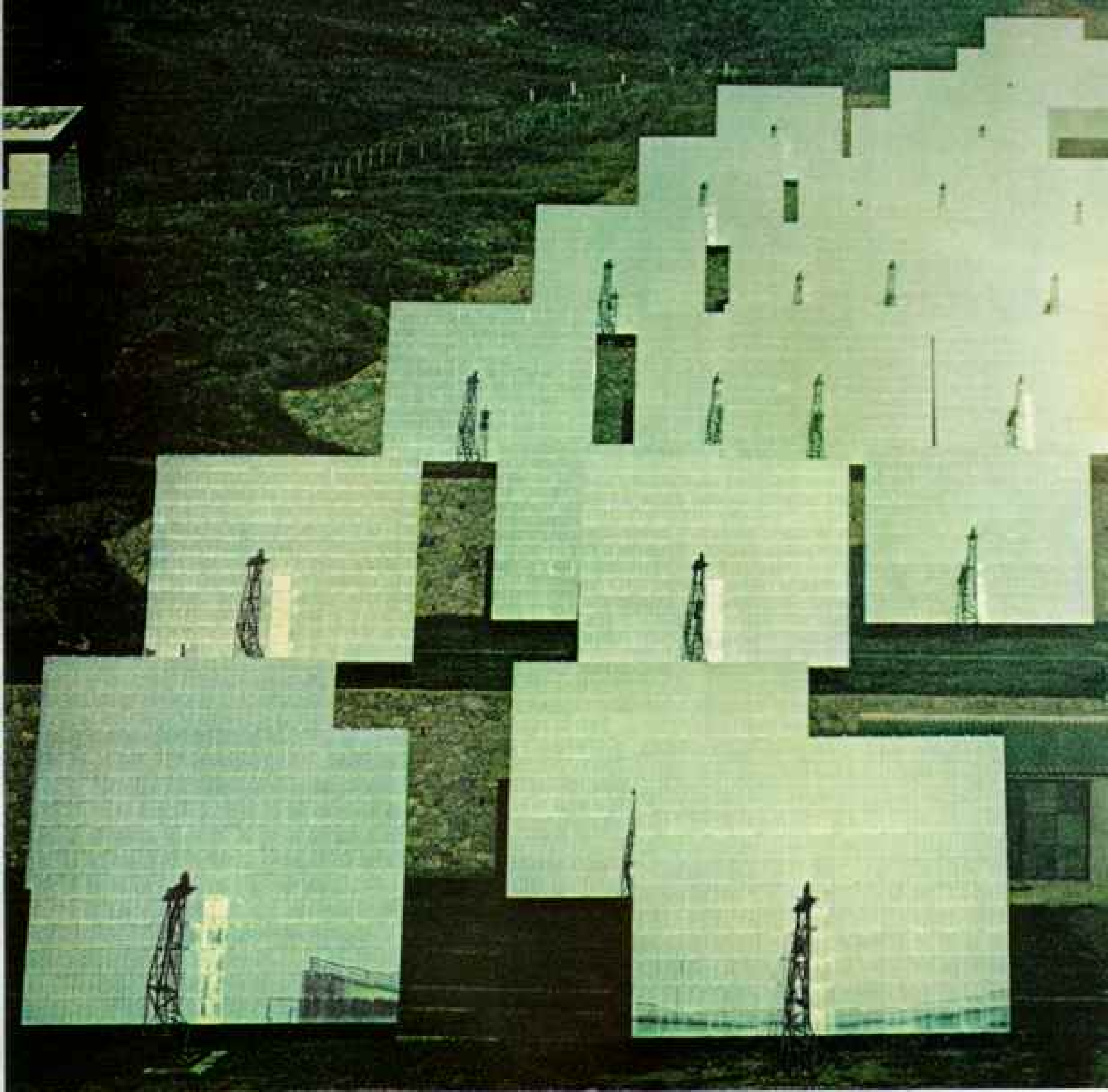
While I was in the furnace room examining the crucible used for high-temperature tests,

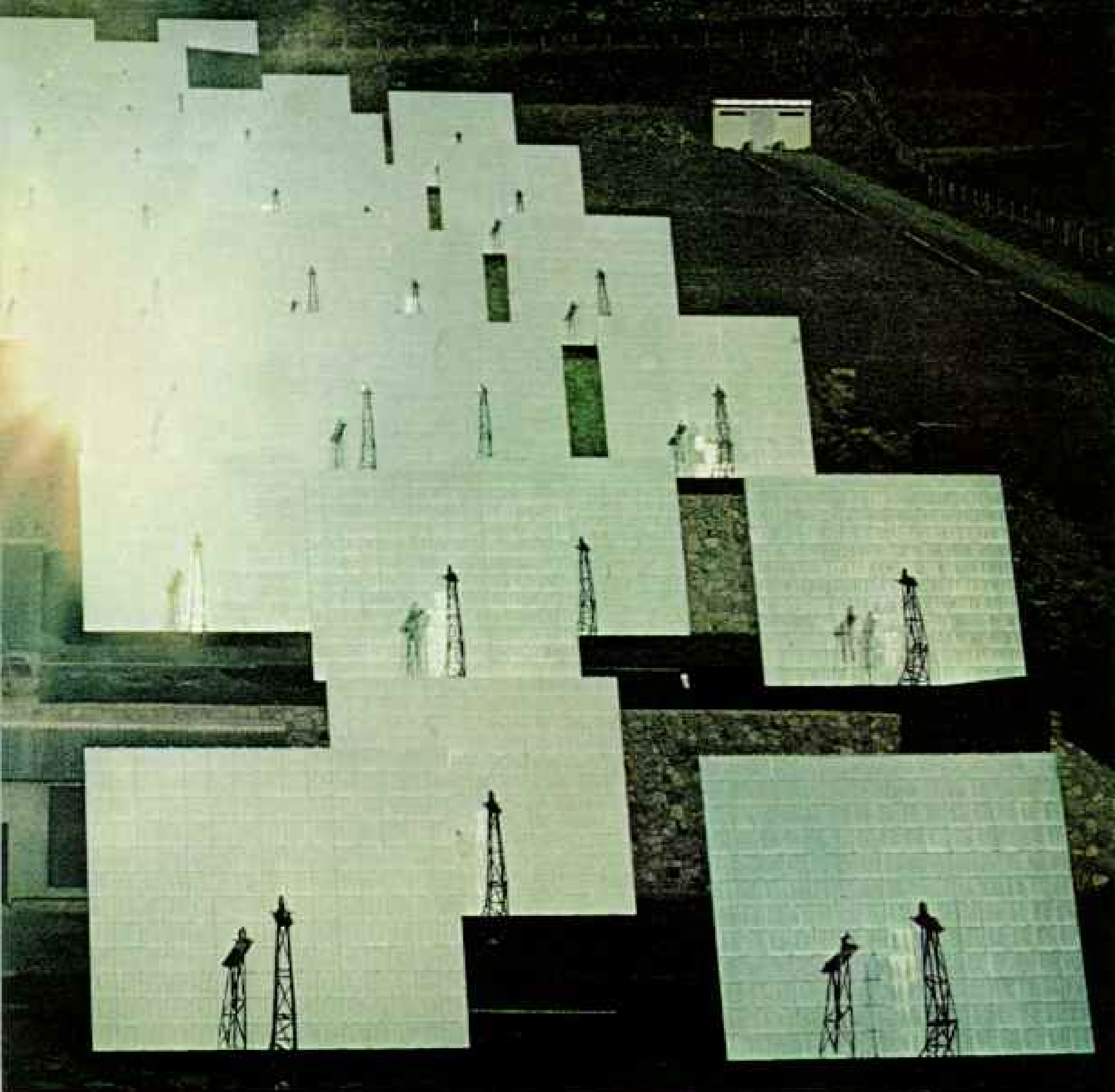
an operator was moving the heliostats on a nearby hillside. These are pivoted mirrors that feed sunlight into the parabola. Normally, of course, the 63 heliostats are all turned askew so that the furnace cannot operate until an experiment is ready.

Suddenly one of the turning mirrors caught the sun and momentarily aimed its rays into the parabola and thence into the little furnace room. Even though I was not close to the focal point of the big mirror, the intense flash of light and heat told me all I wanted to know about its awesome power.

Dr. Aden B. Meinel, director of the Optical Sciences Center at the University of Arizona, and his wife, Marjorie, propose one intriguing method of turning this solar energy into power. Their plan is to trap the sun's heat in extensive arrays of steel pipes spread out in panels above the desert floor. Nitrogen flowing through this plumbing would gather the heat and transport it to tanks of molten salts, which can maintain operational temperatures for several days. As the heat is needed, it could be used in a conventional boiler-turbine-generator to make electricity.

The secret behind the Meinel plan involves the fact that certain combinations of materials, such as silicon and silver, are excellent absorbers and very poor emitters. The Meinels would coat the steel piping with extremely thin films—about a hundred-thousandth of an inch—of these selective materials. When exposed to the sun, the films would allow steel





From dancing sunbeams, blazing power: In a pasture high in the French Pyrenees, 63 mirror panels (above), each three times a man's height, slowly swivel with the moving sun. They reflect its rays onto a 148-foot-high parabolic mirror (left) that forms one wall of an office-laboratory building near the ski resort of Odeillo. This mammoth reflector, actually a mosaic of 8,570 individual mirrors, focuses the light on a solar furnace in the small rectangular building perched just before it. Reaching temperatures of 6,300° F., the awesome radiation melts a foot-wide hole through a three-eighths-inch steel plate in 60 seconds (right).

EARL BAYENHILL, LIFE MAGAZINE







Battle for more and more fuel: A jet of flaming oil stabs the gloom at Norway's Ekofisk oil field, in the middle of the North Sea. Expelled during a line repair and burned to avoid polluting the water, the oil flows from pioneer wells tapping vast reserves of North Sea oil and gas.

Struggling on a workboat's stern (left), crew members help frogmen haul in a mooring hawser from an Ekofisk tanker. Perils of the cold, wind-whipped North Sea have claimed five lives in the Ekofisk field alone.

As industrial nations guzzle gas and oil, drillers pursue shrinking reserves into more hostile areas, incurring higher costs, greater danger, and heightened risk of spills.

pipes to absorb energy, but not permit significant losses through reradiation. Without cooling, the piping would reach a temperature of 1,500° Fahrenheit.

I had no doubt that the idea would work after Dr. Meinel showed me a small plastic box containing a metal disk, like a black mirror, with optical coatings on one side.

"One day," Dr. Meinel told me, "one of my colleagues tossed this box on the shelf just below the windshield of his car. The sun hit it before he realized what could happen. Turn the box over and you'll see the result."

A hole melted through the plastic testified to the heat-trapping ability of these films.

"Eight square miles of cloud-free land, using this technique, could produce a million kilowatts of clean, pollution-free power," said the Arizona scientist. "That is the output of a typical new nuclear plant."

Power From Generators in Space

Someday in the next century we may capture solar energy by space satellite, if Dr. Peter E. Glaser of the research firm Arthur D. Little, Inc., in Cambridge, Massachusetts, is an accurate prophet. He envisages huge collecting panels, each as much as 25 square miles in area, covered with the same kind of solar cells already used by many spacecraft to convert sunlight to electric power. The energy would be beamed to earth by microwave.

The Glaser plan depends on development of a reliable space-shuttle system to ferry the solar panels into orbit, and on much cheaper solar cells. Today the cost is about \$4 for a cell the size of your thumbnail!

Do we actually need all this energy? The question is increasingly asked by those who care about the environment and who believe that unlimited growth is not necessarily a good thing. Whatever the answer, American society will undoubtedly have to find ways to save energy—by such steps as curbing waste, putting far better insulation in the more than a million new housing units we build each year, employing more efficient appliances, and using more car pools and systems of mass transportation.

One of the most powerful forces imaginable will soon force us to take these steps seriously—the inevitable escalation of our bills for heat and power. As one engineer said to me, "When electricity costs 5 cents a kilowatt-hour instead of 2 cents, you'll turn off a lot of the lights!" □

California's Land Apart— the Monterey Peninsula

By MIKE W. EDWARDS

NATIONAL GEOGRAPHIC STAFF

TWO-THIRTY A.M. The streetlights march down the low hills to dance away the night upon Monterey Bay. As we descend the wharf's worn catwalk, the lonely bark of a sea lion—the night's only sound—rises from the breakwater.

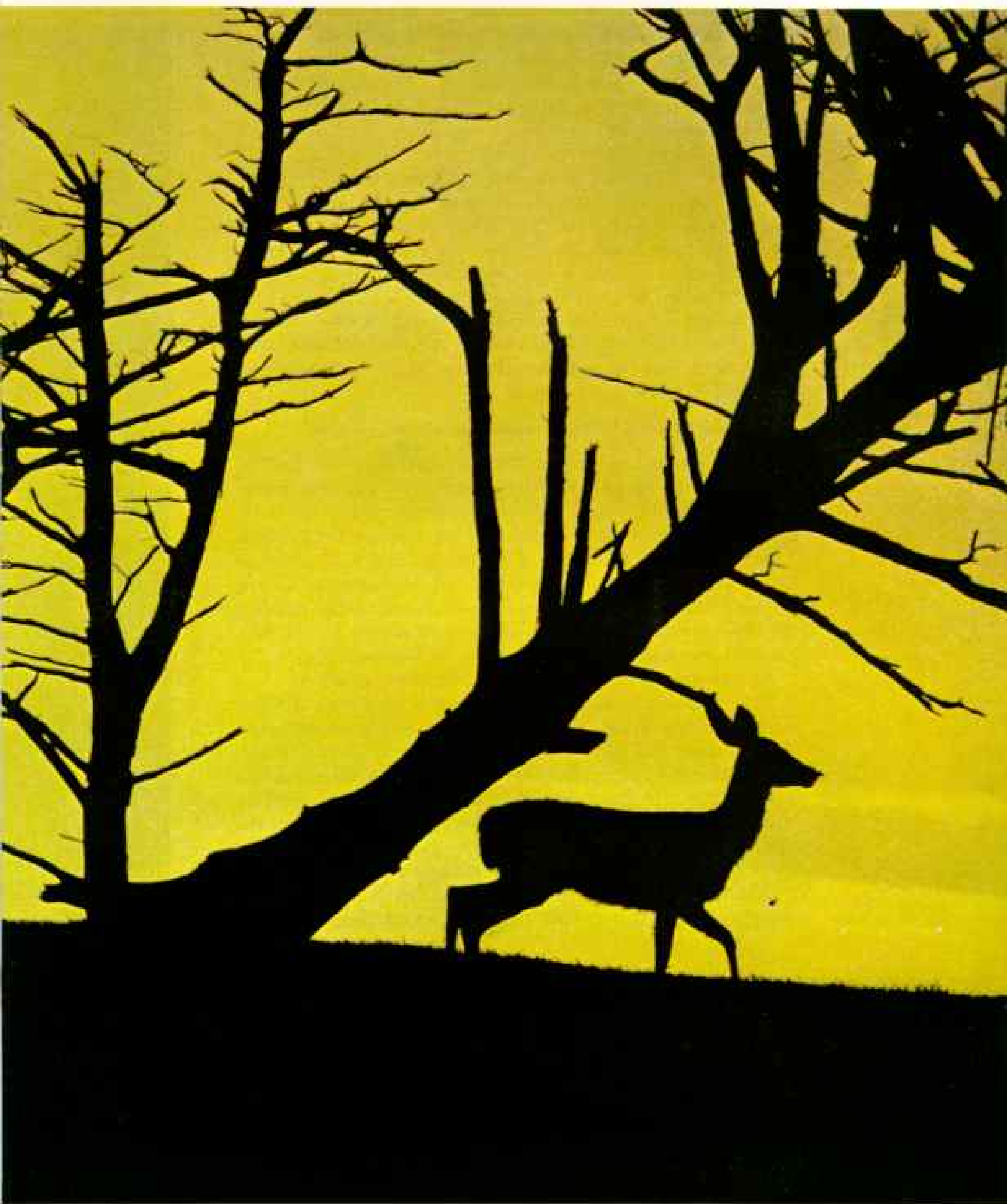
There are five of us: Carmelo, Filippo, Sal, Biagio, all fishermen, and myself, a landsman fearing seasickness. We row out and board *El Salvatore*. She smells faintly of diesel fumes and yesterday's catch.

Filippo puts coffee on the galley stove as Carmelo cranks the engine. *El Salvatore* coughs, shudders, then begins to churn the water, paying out a phosphorescent wake.

It is so old as to be a ritual, this union of men and sea where California's Monterey Peninsula breasts Pacific whitecaps a hundred miles south of San Francisco. To the same bay *El Salvatore* skimmed that morning, Spain in 1769 sent an expedition that founded her first outposts in Alta California, the California of the north. Ever since, the peninsula has seemed more akin to ocean than continent, infecting people gathered from near and far with the allure of land's end meeting sea's beginning.

New Englanders and Portuguese once ventured here to harpoon whales. Chinese scooped squid from the rich waters. Japanese dived for abalone. Italians arriving at the start of this century made Monterey the sardine capital of the world. Robert Louis Stevenson, John Steinbeck, and Robinson Jeffers, among many writers, found inspiration along these shores.





THOMAS W. BARNETT

Fleet silhouettes on a golden veil, deer roam the Monterey Peninsula, a 25-square-mile promontory of sculptured rock, pocket beaches, and

twisted trees. The rugged thumb of land offers a climate for the arts, a pleasure ground for vacationists, and a refuge for wild creatures.

Today artists by the score are drawn to the peninsula to put on canvas the restless working of wave against rock.

As dawn broke, *El Salvatore* waddled on the sea, her trawling net scraping bottom. Winched up and emptied, the bag buried the afterdeck in flopping, crawling life: rockfish and sole for market, and starfish, crabs, and small green-eyed sharks to be returned to the ocean.

"Half a ton maybe," pronounced skipper Carmelo Tringali, a chunky man with sideburns hanging like earflaps from his baseball cap. "Not so good. I got 12 tons in one haul last spring. But there's this about fishing: You can always hope the next try will be better." Such optimism comes naturally to the Tringalis, fishermen in Sicily for generations.

We lunched on potatoes and onions boiled together. Filippo laced them with olive oil and vinegar and poured coffee mugs of red wine—all this a formidable test of my seaworthiness, but a test I'd like to take again.

Boat Nets a Weighty—and Unwelcome—Catch

Soon Carmelo needed the Tringali optimism. "Rocks!" he shouted as the winch whined and strained. "The net's full of rocks!" When the toiling crew retrieved the net and the boulders were dragged out, we saw gaping holes in the cording.

So we headed home with a useless net and \$174 worth of fish. After deductions for expenses and the boat's owner, the fishermen each got only \$19.33 for 14 hours on the water. I watched Carmelo for a show of disappointment. But he only laughed and said, "Maybe tomorrow will be better."

And on the Monterey Peninsula, tomorrow usually is.

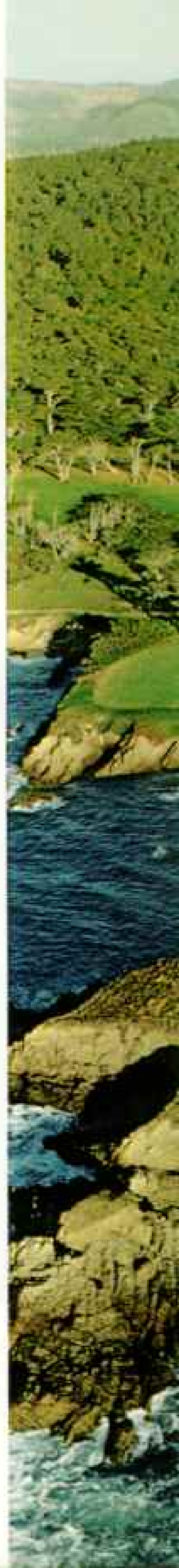
This wrinkled, roughly square thumb of land measures five miles on a side (map, pages 688-9). At the southernmost meeting of thumb and hand, the art community of Carmel nestles among Monterey pines and cypresses—elegant, wide-spreading natives. Then the shore swings out to challenge the sea, cradling mansions of Del Monte Forest in granite outcrops. To the north, at Point Pinos, begins Monterey Bay, described in 1847 by young Army Lt. William Tecumseh Sherman as shaped like a fishhook. Pacific Grove dangles from the barb, Monterey snuggles in the curve. Fort Ord and Seaside hug the sandy

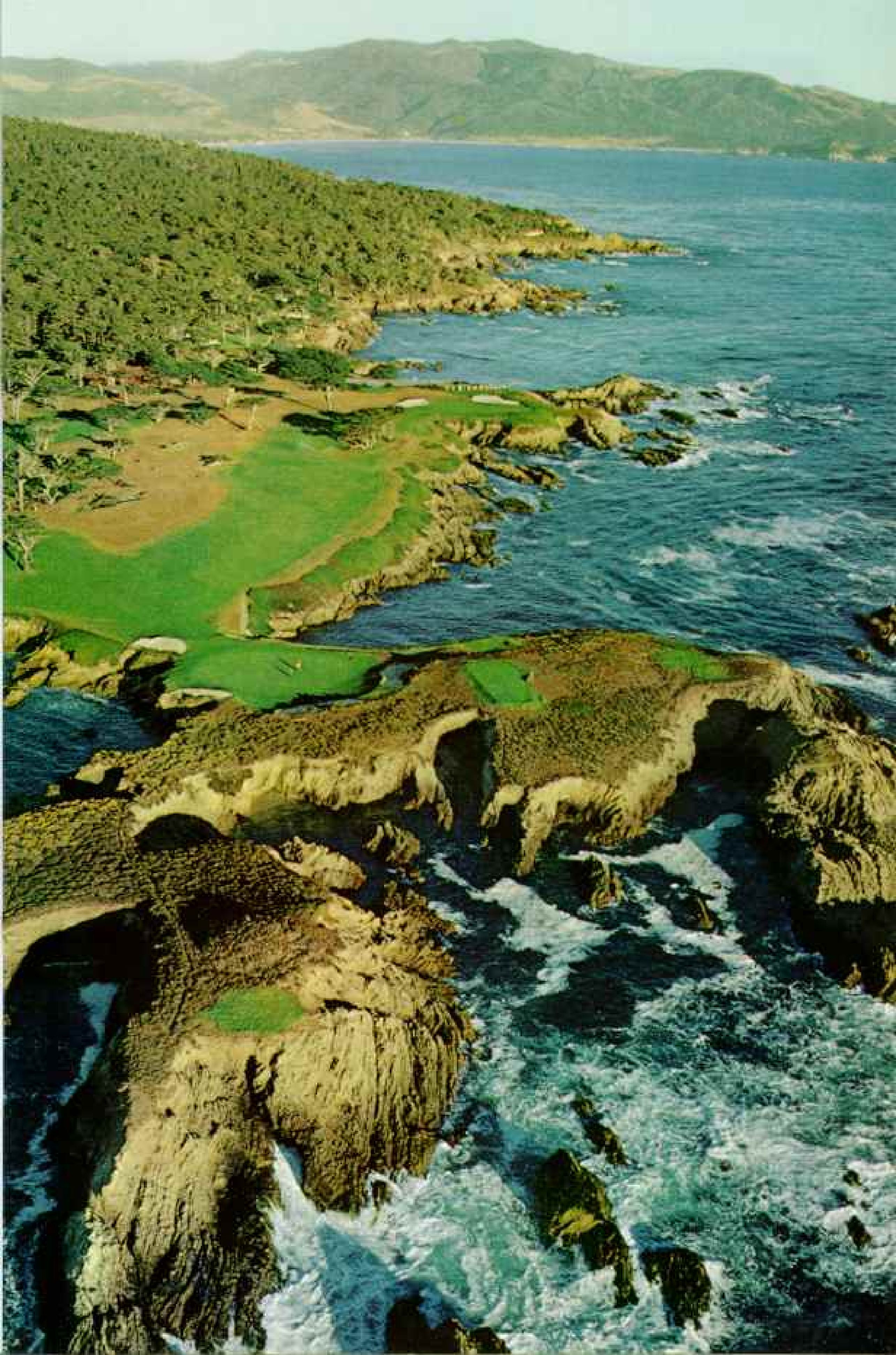


DUCK BOBBAN (ARISTO) AND THOMAS W. SHERRETT

Seething sea and stubborn rock wage thunderous war beside Del Monte Forest, a private park that embraces the challenging Cypress Point Club golf course. The 16th hole overlooks the Pacific at center.

Accustomed to sharing their domain, a bird and a squirrel ignore a ball at the famous Pebble Beach Golf Links (left).







Pine-scented garden splits the main street of Carmel, a town determined to keep the aura of a village. Ordinances forbid the cutting of trees, installation of neon signs, and construction of large buildings.

Soothed by such simplicity, inspired by the sea's rhythmic pounding, many artistic people have been drawn to the Carmel area: poet Robinson Jeffers, photographer Ansel Adams, actress Kim Novak.

shore where the hook bends away from the peninsula. Finally, Santa Cruz anchors the shank.

In the bay's shelter the Pacific justifies its name, lapping placidly at the beach. But elsewhere the peninsula's stony sides catch the ocean's unrestrained fury. For the better part of an afternoon I watched the invading waves shatter upon the unyielding rocks. Summer's fog lingered offshore, curling itself into cottony fingers that soon would probe the inland valleys. At my back a wind-splayed cypress umpired the timeless contest between sea and land. Small wonder so many people have reckoned the peninsula a special place!

Robert Louis Stevenson felt the sea's power when he visited the peninsula almost a century ago: "On no other coast that I know shall you enjoy . . . such a spectacle of Ocean's greatness, such beauty of changing colour, or such degrees of thunder in



PHOTO BY CHARLES O'BRIEN

the sound." He could not escape that crashing noise, Stevenson added—not in Monterey, not in the hills above the town. Readers of *Treasure Island* probably hear those same breakers, "these great rollers" that lashed the imaginary isle, "thundering and thundering by day and night."

Today's visitors invariably seek out that famed meeting place of sea and stone and sky, Seventeen Mile Drive (pages 700-701). There they take a leisurely trip into the Roaring Twenties.

Many a millionaire believed a prime requisite of the good life, 1920's style, was possession of a mansion—preferably built on the order of a Mediterranean villa—in Del Monte Forest. Little was spared in that resort to keep a tycoon happy.

As I followed Seventeen Mile Drive along the peninsula rim, the homes came into view: lavish monuments to their era, embraced by cypresses, looking out on an ever-changing sea.

Abalone, salmon, sole: Fresh from the sea come entrées at the Windjammer, a restaurant on Monterey's Wharf No. 2. Here the commercial fleet unloads albacore, squid, salmon, and anchovies. Sport and working boats cluster companionably in the adjoining marina.



THOMAS W. SANBROOK

Riding a skimboard, a youth glides over a comber-layed beach. Cold, treacherous currents make swimming risky.

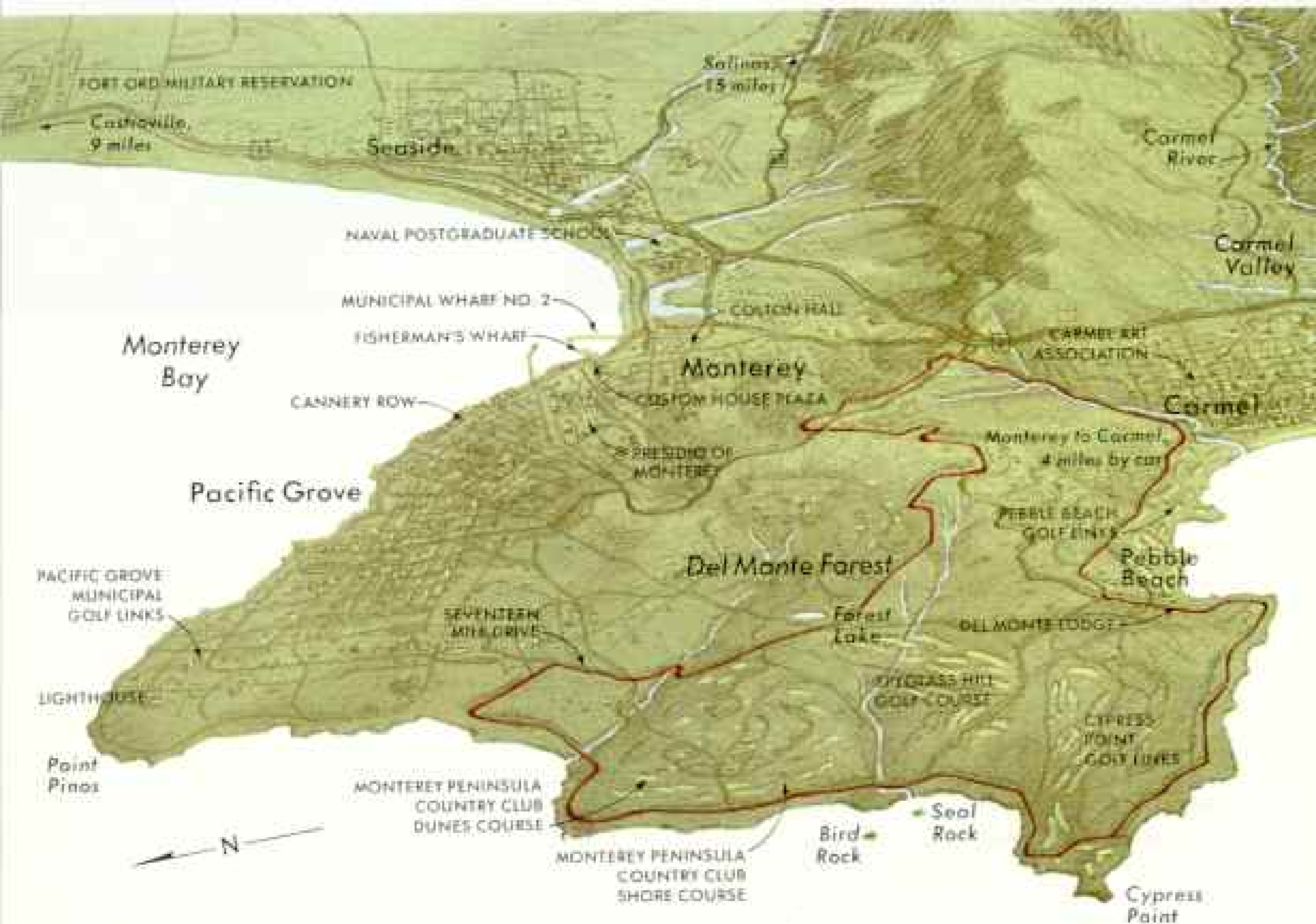
The name Del Monte has beckoned men of affluence for almost a century. Traveling in his private railroad car, Andrew Carnegie visited the old Hotel Del Monte. Charlie Chaplin leased a home while writing the script of *The Great Dictator*. Bing Crosby long resided in Del Monte Forest, and still returns to lend the prestige of his name and presence to the Bing Crosby National Pro-Amateur, played each January over three of the Forest's five championship golf courses.

California's fabled Big Four, the railroad builders Crocker, Stanford, Huntington, and Hopkins, bought most of the peninsula's vacant land in 1879. Then they built beside Monterey Bay the Hotel Del Monte, a rambling palace, unabashedly described as "the most elegant seaside establishment in the world." Twice burned and rebuilt, ever larger, it was a social citadel until the Navy took it in 1942 for a training site.

Samuel F. B. Morse, grandnephew of the inventor of the telegraph, envisioned in the Big Four's several thousand idle acres a playground so lavish as to be irresistible. Backed by a San Francisco financier, Morse bought the Del Monte real estate in 1919, just in time to help the twenties roar in.

He liked the look of the land and preserved large tracts, including much of the coast, in a natural state. Elsewhere he created polo fields, a racetrack, bridle paths, tennis courts, a trapshooting range, the Del Monte Lodge, and golf courses—in particular the water-girt Pebble Beach Golf Links, still one of the game's greatest challenges.

Templeton Crocker, scion of the railroad family, and his wife built one of Seventeen Mile Drive's grandest houses—if



you can call a Byzantine castle a house. To embellish this massive stone pile, the Crockers sent an architect to Italy to bring back 97 marble columns, and artisans to lay fine mosaics.

I called on the present owner, George Stoll, a man as fascinating as his castle. Long a musical director in Hollywood, he has twice won Oscars for scoring musical productions, the first for *The Wizard of Oz*, which he shared with a colleague, and the second for *Anchors Aweigh*.

He showed me through his home—a lengthy tour. “How many rooms are there?” I asked at last. George thought a moment, then gave up the calculation. “Twenty-one, I think,” he said. “But I’m not sure. But I do know there are 14 baths.”

Movers and shakers still reside in the Forest, and guards at the road entrances lend an air of exclusiveness, charging tourists \$3 just to tour Seventeen Mile Drive. But by far the greatest portion of the 5,000 or so residents are of more moderate means: professors, retired military men, salesmen. Sam Morse began in the 1930’s to develop communities where such people could afford quarter-acre lots.

“You used to know everybody who lived here,” complained an old-school tycoon, possessor, as he told me, of “a gross estate of a good many millions of dollars.” He puffed furiously on a cigar and added that egalitarianism has ruined the Forest.

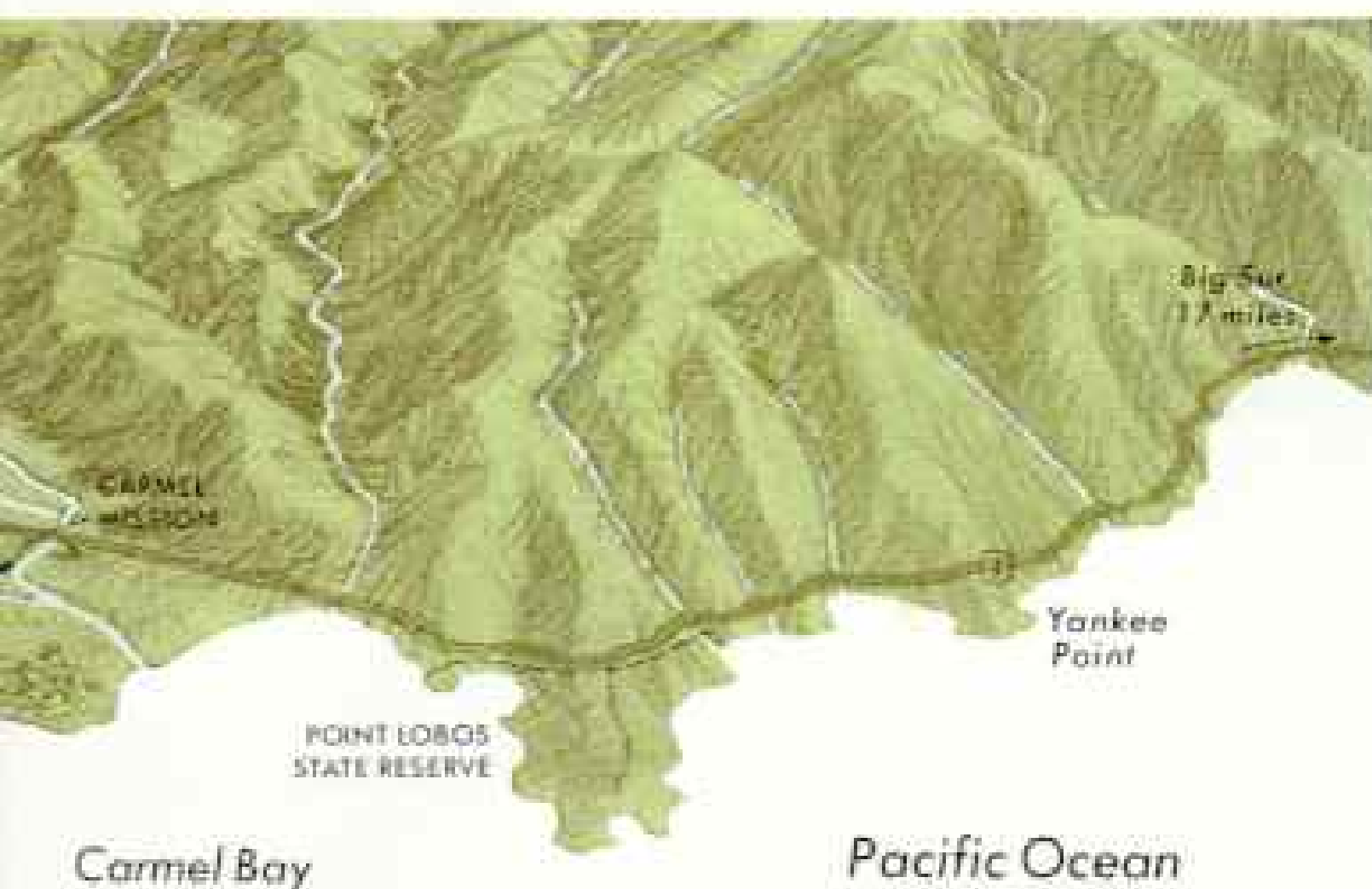
“You don’t know anybody now, except maybe your neighbor. And there’s no entertainment—at least, not like there was. We used to go to dinner parties three nights a week. For ten years this place has been as dead as an abandoned church.”

Dead? In the limited sense of the rich at play, perhaps yes.

Basking California sea lion clammers over the rocks of Point Lobos State Reserve, a haven also for sea otters and cormorants.



JOCK HOBAN



Little Spain in shape and tradition, the Monterey Peninsula attracted Spanish colonists in the 18th century. Later the town of Monterey became the capital of Alta California—a huge province where colonial dons, masters of ranchos 60 miles long, staged bull-against-bear fights and all-night fandangos.

After Mexico proclaimed its independence from Spain in 1821, citizens of the isolated colonial capital casually changed flags. In 1846, during the war between Mexico and the United States, a Yankee naval officer, John D. Sloat, declared California a U. S. possession. Three years later California’s first constitution was drawn up in Monterey’s Colton Hall, and in 1850 statehood was proclaimed.





TOMAS W. BENNETT (BELOW AND LEFT); STEPHEN FRECH

"The Row seems to hang suspended out of time in a silvery light." John Steinbeck's words in *Cannery Row* still describe a fog-washed fish cannery, typical of many where sardines were once packed in Monterey. The industry hit its peak in 1941-42 when the town processed 250,000 tons of sardines. But by the mid-1940's sardines began to disappear. Canneries were converted to gift shops, art galleries, and restaurants. Tourism now brings in more revenue for the city than the sardine industry provided at its height.

Jackpot of rockfish from the Pacific (left) heads for market in the Monterey Bay area. Fishermen such as the veteran below earn as much as \$130 in a good day on the trawlers.



Up periscope! A spectator at golfdom's United States Open Championship—held for the first time last June at Pebble Beach—monitors Jack Nicklaus on his way to the \$30,000 top prize.



CHARLES O'BRIEN, DECLAN HAIN (OPPOSITE)

Up audience! The very air exudes joy during the Monterey Jazz Festival, since 1958 an annual autumn happening (opposite). Jazz buffs come from across the world to hear Dizzy Gillespie's soaring trumpet, Roberta Flack's throaty voice, and talented jazzmen from Europe. The peninsula offers a different attraction each month, ranging from a Bach festival to the United States Road Racing Championship.

But dull? Not as long as wind, wave, and shore stage their unending contest.

I had not expected a Hollywood goddess to discover deep personal meaning in the magnificent seascape; sometimes stereotypes mislead all of us.

I called on Kim Novak at her home near Carmel—essentially two large circular stone rooms stacked like cheeses on a point above the ocean. The strikingly beautiful actress met me in jeans and a suede vest over a flowered blouse. After fixing me a cup of coffee, she talked for an hour in her famous husky voice about the satisfaction of living beside the sea.

"This house was for sale when I was making a movie close by a few years ago," she said. "The fog was so thick when I came to see it that I couldn't tell much about it, and the door was locked. But I could feel a certain magic in this setting. I bought the house without seeing the inside."

She walked to a window and looked down on the foamy crests. Gulls wheeled over rocks. Cormorants skimmed the sea. "The sea has become my closest relative," she reflected. "And my greatest teacher. It teaches you that there's always something stronger than you are, and that's important to know."

Creative Arts Flower Along a Rugged Shore

Arts and letters, and particularly paintings, have been Carmel's products ever since the early 1900's, when a few San Francisco bohemians and Stanford University professors moved into the pines. About 800 artists paint full-time or part-time now; some 65 galleries attract buyers.

In the commodious rooms of the Carmel Art Association, Keith Lindberg, a burly man in a woolly turtleneck sweater, bore the air of one who has reached a certain plateau in life. Thirty of his paintings decorated the walls in a one-man show. A hundred friends and collectors had come to honor him at a reception, some, perhaps, to invest \$400 or so in one of his oils.

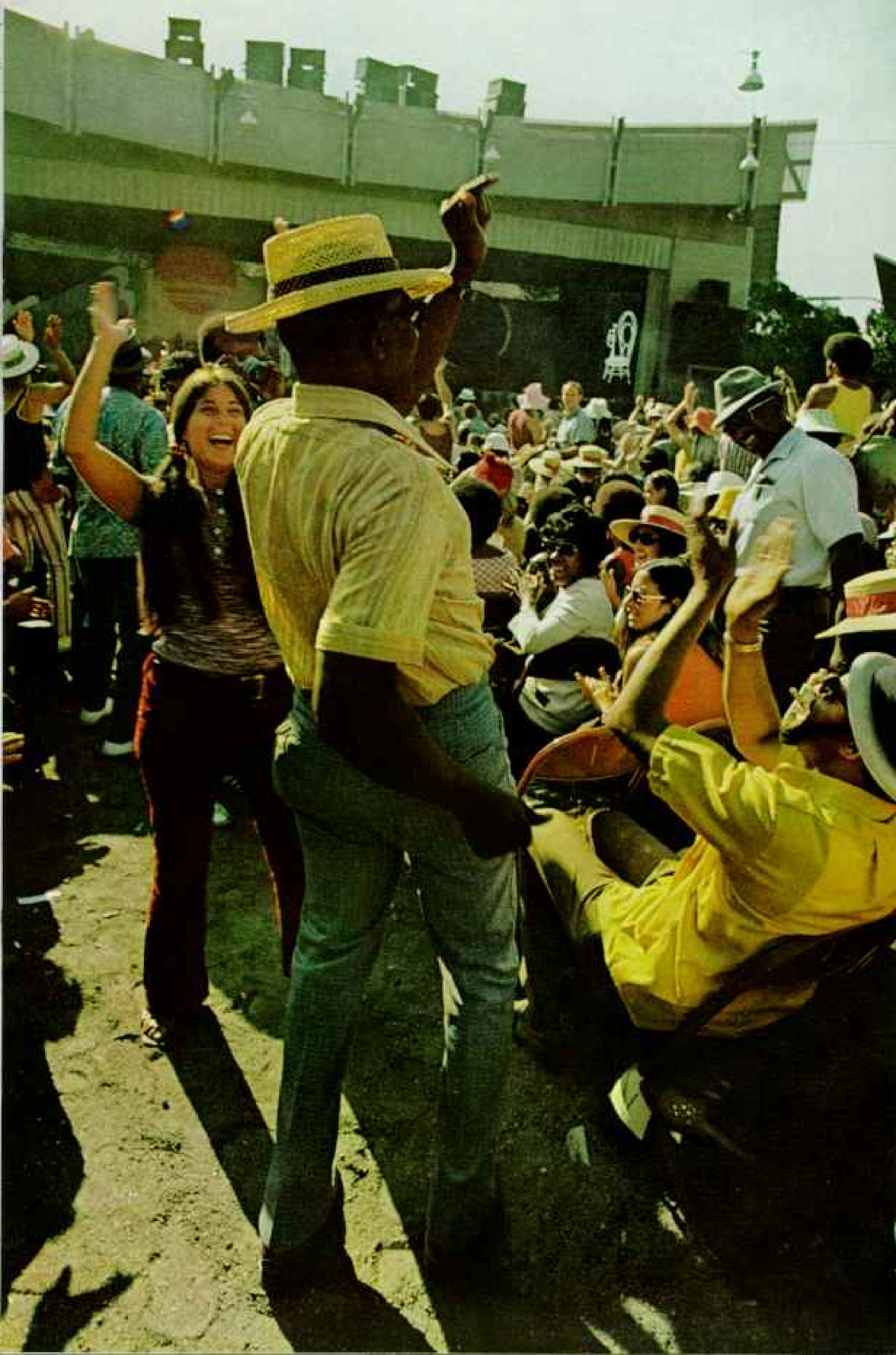
It's a competitive marketplace, and Keith well remembers the struggle to succeed. "Six years ago my paintings brought \$25," he told me. "I sold on the streets. I traded art for food."

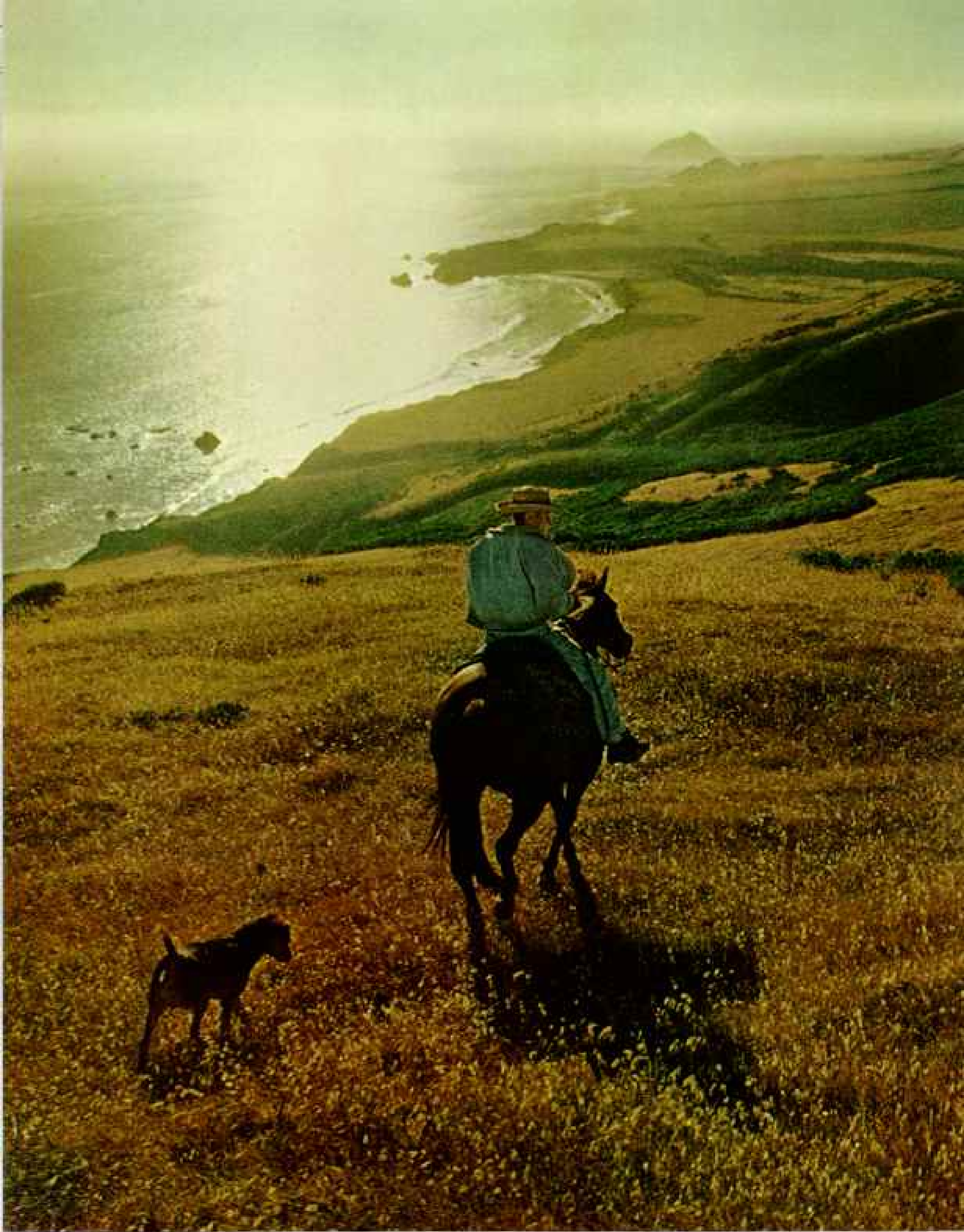
With vigorous strokes Keith paints still life and everyday scenes. He has never tried to paint the sea, but he is in the mold of the dozen artists to whom I talked, in that he finds the peninsula a calming influence, conducive to good work.

Lois Bennett, an artist who depicts the sea, summed up its contribution to creativity: "Every wave that hits the shore, even though it isn't painted, is felt by someone." She was working on still another seascape when I dropped by her studio.

Such luminaries as Jack London and photographer Edward Weston found inspiration in Carmel. Robinson Jeffers tramped the coast and the mountains, forming word images that earned him a place among the greatest 20th-century American poets. Jeffers wrote of "old cypresses the sailor wind works into deep-sea knots." He saw the hills as "jagged country which nothing but a falling meteor will ever plow."

He bought "a furlong of cliff on which the Pacific leans its wild weight" and built there a stone house and then, beside it, a tower, grim and medieval, three levels high, with a tiny observation platform atop.





High land above a shining sea, the rugged wilderness called Big Sur bespeaks man's dream of sanctuary. Expanses of rangeland alternate with steep ridges and deep canyons, a

landscape that inspires photographers, writers, and artists. These sparkling meadows are part of the Andrew Molera State Park, a unit of California's Big Sur area park system.



TOMAS W. CERNETT

I climbed its steep steps with Donnan Jeffers, the late poet's son. "Father built this mostly for the exercise," he said. "Mother sort of had the feeling she'd like a tower, and he wanted to do something besides sit at his desk all day. He got a great deal of satisfaction out of working with his hands."

To preserve an atmosphere in which poets and painters thrive—and which any mere lover of tranquillity will enjoy—Carmel-by-the-Sea, to use its proper name, has remained an un-city, doggedly defying the stereotype of small towns trying to grow big. Many of the 4,600 residents dwell in cottages, drawing a pointed distinction between themselves and their more exclusive neighbors at Pebble Beach. Neon and traffic signals aren't allowed. A full-time forester cares for the 11,000 trees on municipal property. Ordinances forbid large buildings.

"Usually the people who move to Carmel have lived in a big city, such as Los Angeles," said Vice Mayor Gunnar Norberg, himself a refugee from New York. "They've seen all the development they want to see. They come here to get away from it." A graying man of serious mien, Mr. Norberg runs a travel agency when he isn't proposing ordinances, issuing treatises, or otherwise sallying forth to save his town from what most of the world calls progress. He worries that someday the bulldozers will come, followed by high rises soaring over the pines.

"The area around our city limits is being developed to such an extent that the pressure on us may become too great to resist," he said. "So far, there've always been enough people here—sometimes just barely enough—to win the fight to keep Carmel as it is."

Fate of Artichoke Fields Stirs Carmelites

When I met him, Mr. Norberg was worried about 292 acres of artichoke plants. In smart green rows they march across a flat plain that carries the Carmel River to the sea, just south of town. A proposal to replace the plants with houses, a large resort hotel, and a motel greatly disturbed Mr. Norberg and many other Carmelites.

Fred Farr, an attorney and former state senator active in conservation matters, took me to a grassy hill overlooking the fields. "This place is close to my heart," he said. "I fished near here when I was a boy. We need to keep this as open space. It would be a disaster to put 4,000 or 5,000 more people on Carmel's doorstep. The traffic and the demand for services would be more than we could stand."

Fred helped organize a campaign to raise money—\$200,000 in cash and almost as much in pledges thus far—to buy 150 acres of the artichoke ranch nearest the sea. The land would become a park. The gifts flow from many sources. One citizen is donating a chunk of real estate. A boy of 11 gave \$50 earned selling lollipops. A pharmacy offered to contribute five cents for each empty pill bottle turned in, and added \$104. The city of Carmel pledged \$100,000. As I write this, Fred and other campaigners are hoping that a county bond issue and federal conservation funds will provide the rest.

Bruno and Emilio Odello, brothers whose family has grown artichokes for 48 years, were surprised at the furor that erupted when they proposed to sell their land to a developer.



Sparks fly as Monterey sculptor Jim Crane welds a steel figure for a memorial to Anne Frank, the Jewish girl who wrote a now-classic diary while hiding from the Nazis in Amsterdam. Crane hopes the finished work will evoke "the triumph of innocence over war's brutality."



DONALD W. BENNETT (BOTTOM); CHARLES O'NEAL (TOP)



"We've been telling people for a long time that the day would come when we had to stop farming," Bruno said. "We had a lot of chances to sell. Maybe we should have gotten out long ago. But we're just stubborn farmers. We love this land. This is our lifeblood. Now our backs are against the wall."

While taxes on the Odello land have gone steadily up, productivity has gone down. Bruno cut off a fat artichoke with his pocketknife, slit it to the heart, and showed me one of the reasons the brothers want to sell. "See that worm? That's the larva of the plume moth. All we can do with these damaged artichokes is feed them to cattle."

The only remedy for the ever-increasing infestation is a pesticide so toxic it cannot be applied by hand. Aerial spraying is required. "But there are so many houses around us now that we can't take a chance. The dust might kill a child."

There's another problem: a fungus attacking the artichoke roots. "We have to dig up about 25 percent of the plants every year to try to get rid of it," Emilio said. He shrugged. "We just can't compete anymore."

As I write this, the brothers are considering a request from Farr and the conservationists for an option on the 150 acres.

No visit to the peninsula is complete without a pilgrimage to the earth-colored buildings of Mission San Carlos Borromeo del Rio Carmelo, not far from the Odello artichoke fields.

Cabinetmaker Harry Downie came to the mission from San Francisco in 1931 to repair a few wooden statues. "And here I am, 41 years later," he shrugged. His task became the complete

Art, life, and a lovely day compete at the Monterey Arts and Crafts Festival. Three times each summer the outdoor event fills Custom House Plaza in front of the Pacific Building, built in 1847 as a seamen's hotel-saloon. In Carmel some 65 galleries vie the year round for the collector's eye. The largest—the Carmel Art Association—displays the paintings and sculpture of its 200 artist-owners. Some galleries offer classes and a chance to watch a variety of craftsmen at work.



WILLIAM R. CURTIS/GETTY IMAGES

Fists full of flower buds, a farm worker loads a basket near Castroville, which calls itself the artichoke capital of the world. The buds of these thistlelike plants, prized by gourmets, grow plump and meaty in California's midcoastal counties. But plume moth and root disease threaten fields south of Carmel, and the only effective pesticides are too perilous for inhabited areas; much of the crop may go to the feedbins of livestock instead of to the tables of artichoke lovers.

restoration of the mission church and surrounding buildings.

Father Junipero Serra began the mission in Monterey but transferred it to Carmel in 1771. The fervent Franciscan was 57 years old then and in frail health, but he lived to establish another seven of California's 21 missions. A stone slab in Carmel's basilica marks his final resting-place.

The mission quadrangle was in ruins when Mr. Downie came. The much-repaired stone basilica bore little resemblance to the original, and walls of adobe structures had melted away.

Mr. Downie became historian, architect, and, on occasion, pious thief: "Most of the silver and other paraphernalia had been taken away from the Carmel Mission to the church in Monterey. I was gradually restoring these to their original setting—unofficially, you understand—and then my efforts drew the enthusiastic approval of the bishop. He ordered everything returned that belonged in the Carmel church."

In a chapel off the basilica's nave we stood before a richly gowned statue of the Virgin. "She came with the first expedition to Monterey," Mr. Downie said. "When I tracked her down in a local home, she was in a bride's gown of the 1880's."

He replaced the termite-riddled dress form, found authentic raiment in Mexico, and built an altar for the Virgin.

Steinbeck Touch Transforms Cannery Row

In contrast to quiescent Carmel, Monterey, on the opposite side of the peninsula, bustles and gets bigger. The navigator Sebastián Vizcaíno cast a practical eye upon the large bay when he found it in 1602. In a report that fixed the course of California's early history, he described a "noble harbor" bordered by fertile lands and inhabited by people "docile and very fit to be reduced to the Holy Church. . . ." He named the bay for the Count of Monterey, viceroy of New Spain.

It was to find Vizcaíno's "noble harbor" that Spain sent Don Gaspar de Portolá from Lower California in 1769. He failed to perceive nobility on first sight. But the next year, with a few soldiers and the redoubtable Father Serra, he founded a settlement near where downtown Monterey stands today.

The town served Spain and then Mexico as Alta California's capital. On July 7, 1846, eight weeks after the Mexican War began, Commodore John D. Sloat raised the American flag, having landed 250 seamen and Marines without opposition.

Forty-five adobe, wood, and stone buildings sustain the memory of Monterey's years as a seat of government. But I like best the landmarks of her other capital era, the great era of the sardine, which began early in this century and continued until the silvery schools disappeared in the 1940's. Again and again I was drawn to the derelict sheds—part corrugated metal, part masonry, part rusting clutter—that stand along the seven blocks of Cannery Row (page 691).

I'm hooked because I remember so well John Steinbeck's first book about the Row. Do you recall his captivating opening sentence? "Cannery Row in Monterey in California is a poem, a stink, a grating noise, a quality of light, a tone, a habit, a nostalgia, a dream."

Steinbeck frequented the row in the 1930's—"a large, thick-set man," as Jean Ariss remembers, "usually wearing jeans and

a shabby sheepskin coat." I spent an interesting afternoon in the company of Jean, author of two novels, and her husband, Bruce, a writer, editor, and artist well known for his murals.

They saw Steinbeck often in Edward Ricketts's laboratory on the Row. Almost as much a local legend as Steinbeck, Ricketts was a marine scientist and a friend to hundreds of Cannery Row citizens. To Steinbeck he also was critic, tutor, and, on the book *The Sea of Cortez*, a collaborator. His personality inspired the *Cannery Row* character called "Doc."

Jean recalls spending a day in 1939 with Ricketts and John and Carol Steinbeck, reading the manuscript of another Steinbeck work, which as yet had no title. She remembers Ricketts saying to John: "This is a fine book—your best. It will win you the Nobel Prize." The group spent the afternoon trying to think up a title, finally agreeing on *The Grapes of Wrath*. And in 1962, six years before his death, John Steinbeck went to Stockholm to receive the Nobel Prize for Literature.

Monterey old-timers—including those who never read *Cannery Row* or its less well-known sequel, *Sweet Thursday*—speak with deepest nostalgia of the Row's heyday.

The explanation of that attitude lies not in the canning process—dreary work—but in the era. Cannery Row reached its zenith during the depression of the 1930's and World War II. Fishermen's wives earned extra cash in the packing rooms, and itinerant fruit pickers knew a cannery job would see them through a few months after harvest.

Eighteen canneries clanked and tooted; reduction plants converted leftovers and surplus fish into fertilizer and stock feed. A hundred boats brought in their catch. Soon after Pearl Harbor, a jittery pilot spotted part of this armada and radioed that a Japanese fleet was bearing down on the mainland. Luckily, the mistake was corrected promptly.

Former Sardine Packers Welcome Tourists

What happened to the sardines? They were fished to death, many persons believe. Others say pollution killed the fry, and still others think that a change in ocean currents carried the schools to an undiscovered happy fishing ground.

Now restaurants and shops cater to tourists drawn by Steinbeck's prose. At one end of the Row a single cannery still operates, packing squid mainly for Greece and the Philippines.

"When we can get the squid," said Tony Souza, the manager. He showed me through the spotless but silent packing room; no squid had been caught that week. "It's pitiful," he said, "what Cannery Row's come to." But the tourists see it through Steinbeck's eyes, with fondness for its robust past.

As fishing declined, the peninsula's future looked bleaker than one of her own foggy summer mornings. Fortunately the military—long a part of the peninsula scene—took up much of the slack. Today three installations contribute vital payrolls: Fort Ord, an Army basic-training center; the West Coast Branch of the Defense Language Institute, located at Monterey's Presidio, once the site of a Spanish fort; and the Naval Postgraduate School, a university for career officers, headquartered in the famous old Hotel Del Monte. The Armed Forces not only are the largest employer, but they also bring

Italian verve accents both dish and service at the Abalonetti Restaurant and Liberty Fish Market. One of the most popular on Monterey's Fisherman's Wharf, the restaurant specializes in squid. In her left hand Mrs. Rosalie Liguori—cook, waitress, and wife of one of the owners—offers the "Marty Special," baked squid and eggplant. The other platter holds Sicilian-style, lemon-accented squid sautéed in wine, garlic, and parsley.



JAMES P. BLAIR



SEANUS P., FLEISCHER; 2 INCHES; JAMES P., BLAKE



MESEMBRYTHEMUM, WILLIAM H. COBURNER



HERMISTONIA CRASSICORNIS, UP TO 2 INCHES, PUM WYLER

Nature's serendipity: In Pacific Grove—"Butterfly Town, U.S.A."—winter visitors find trees filled with monarch butterflies, fluttering and drifting like sunlight come alive (above). Spring-blooming ice plant (top right) carpets peninsula cliffs. In a Point Lobos tide pool, a nudibranch (right) sparkles like a jeweled pin.

in officers and noncommissioned officers who find the peninsula a fine place to retire, fueling a continuing boom in real estate.

Early on a chilly morning, as the wind blustered, the sea roared, the sun sparkled, and fog scudded toward the land—which is to say, a typical summer morning—I descended a jagged scarp to see life between the tides.

As it retreats, the ocean exposes shallow pools alive with interesting creatures. I visited pools at Point Lobos State Reserve, a tongue flicking into the Pacific seven miles south of the peninsula. Nearly a hundred persons descended to the water's edge to hear naturalists talk about the tidal denizens.

Sea gulls eyed us with studied disdain. Through the fog, unseen sea lions barked like a kennel of hoarse bloodhounds. We broke into groups and settled around the numerous pools. Our arrival caused crabs to skitter into niches, periwinkles to close their trapdoors, and hermit crabs to withdraw into their borrowed shells. But soon all reappeared.

We found starfish, limpets, chitons, sea urchins, turban snails, barnacles; the tidal community is large and varied. Someone fetched up a young abalone, its black shell the size of an egg sliced longways. In my hand it crept determinedly upon its one wide foot. "Be sure to put things back where you found them" called Dorothy Bell, a young naturalist working the summer at Point Lobos. "We're here to look, not to destroy."

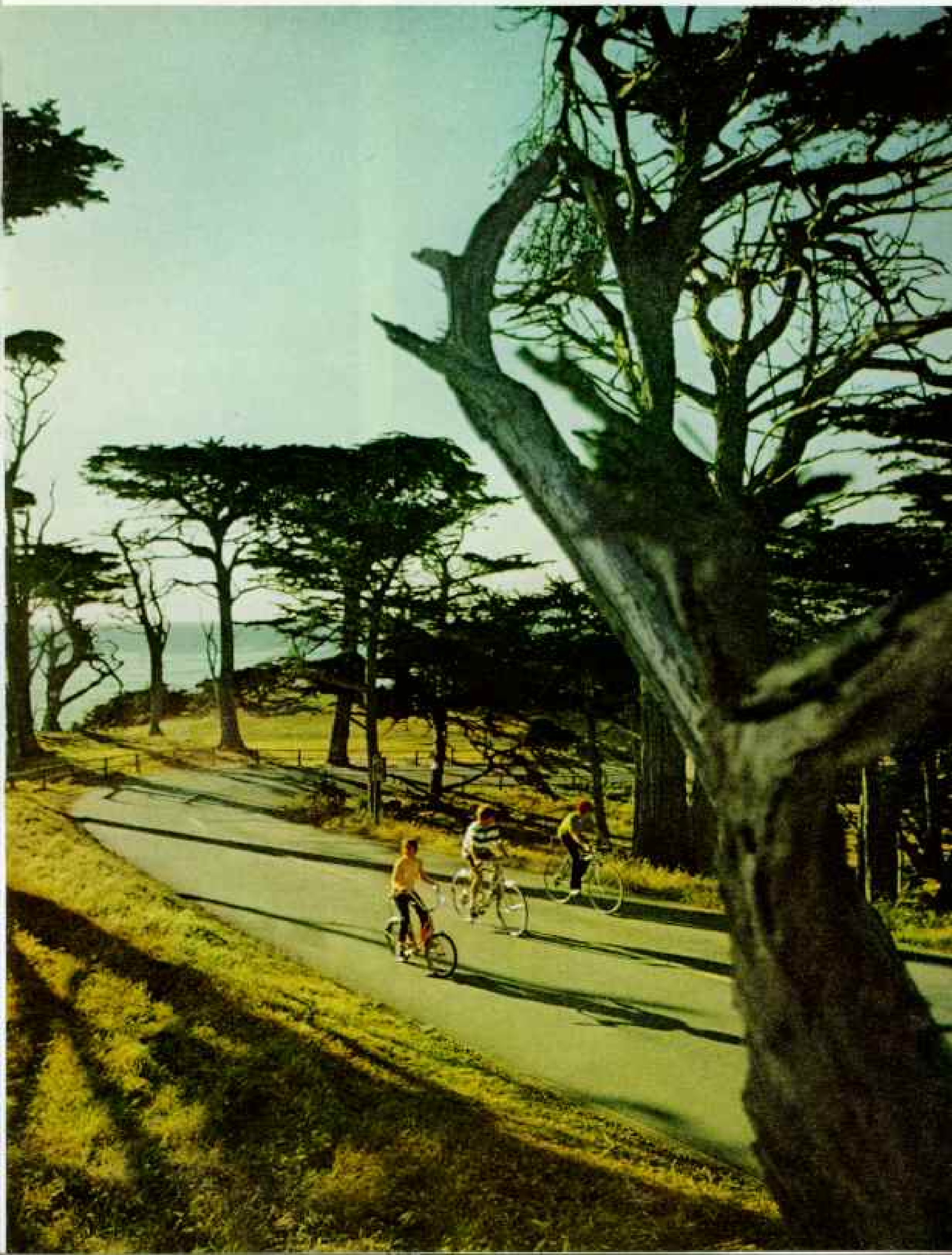
I discovered a baseball-size anemone in a crevice. With mouth agape and tentacles poised, this green carnivore was ready for the serious business of eating. When I inserted the tip of my pen, the mouth quickly closed. But then it opened wide



Haunting sentinels of the headlands, gnarled Monterey cypresses guard Seventeen Mile Drive, a coast-hugging scenic road dotted with elegant

mansions of the 1920's. The centuries-old trees, native only to a few miles of windswept shore, have become symbols of the peninsula.

CHARLES O'NEAL





Ocean sings a lullaby to the wife and infant daughter of Richard Clements, who designed this cliff-hung Big Sur home.

—with some disgust, I think—to await more palatable fare.

When a turban snail wanders into that trap, the result often is that one more hermit crab has a home. Digesting the snail's body, the anemone discards the shell. A homeless hermit coming on this bonanza claims squatter's rights—unless he too passes over the anemone's mouth.

Southward from Point Lobos, the Big Sur's wild coast stretches 90 miles to San Simeon. Headlands plummet precipitously into the waves, a jumble of rock, sand, and chaparral, testing the violence of the sea (pages 694-5). Along the twisting coastal highway, I occasionally passed a house or a small settlement—nothing more, for Monterey County laws protect Big Sur's primitive beauty.

One Sunday morning I met Will Shaw, a Monterey architect, on a tract of land a few miles south of the Big Sur River. As we walked beside a creek, under a Parthenon of redwoods, Will



TOMAS W. BERNHETT (OPPOSITE); DECLAN HANNA

observed, "This land once was logged and ranched, but fortunately never successfully. Its greatest attribute is its natural beauty." The Shaws and five other families bought 4,000 acres in the Big Sur headlands just to enjoy, binding themselves legally not to develop the property in this century.

After lunch we climbed 1,500 feet into the hills, emerging on a pinnacle of tawny grass plunging toward the sea. White stitchery appeared below, vanished, and reappeared as waves battered offshore rocks. But at that elevation I could, for once, hear no thundering crash.

That evening, as I drove back to the peninsula, fog obscured the ocean. Sunset rays suffused the swirls with gold.

I awoke late that night in my hotel room. Through the window came a throaty drumbeat—Stevenson's ocean, Jeffers's ocean, Kim Novak's ocean, mine—still on the job, hurling its fury at the coast. I went back to sleep reassured. □

"Like smoke above a battle," Robert Louis Stevenson wrote of the spray that hangs over the wave-bombarded coast, seen here at Big Sur's Pfeiffer Beach south of the peninsula. "The one common note of all this country," he said, "is the haunting presence of the ocean."

Drought Bedevils Brazil's Sertão

By JOHN WILSON

Photographs by

GORDON W. GAHAN

NATIONAL GEOGRAPHIC PHOTOGRAPHER

Wandering a wasteland where the cracked earth thirsts for rain, a family stops to fish and fill gourd canteens at a water hole. They flee the Brazilian backland known as the *sertão*—heart of the Drought Polygon, an area larger than France and West Germany. About every ten years, the summer rainy season in the *sertão* mysteriously breaks its cycle; then the land withers under the tropic sun, and its people suffer thirst, hunger, and occasionally even death. But rains always come again, and the *sertanejos* cling courageously to the land they love.

“LAST SUMMER Our Lord granted us no winter, senhor. For us, this is the greatest of calamities.”

The lone cowboy who uttered this startling contradiction appeared to be clad in time-darkened armor, as did his short-legged mount. He looked like a tattered Don Quixote astride a skinny Rosinante.

I met him in the pasture that sometimes doubles as an airport at Quixeramobim, deep in the Brazilian hinterland known as the *sertão*, part of the vast region officially called the Drought Polygon. Roughly 750 miles wide and 1,000 long, the polygon occupies the extreme northeast bulge of Brazil, except for a narrow, well-watered strip along the coast.

Studying the cowboy, I saw that his armor was the traditional uniform, the “leather,” of the *sertão vaqueiro*: a chestnut-brown leather coat scarred with crudely hand-stitched patches; leather breeches and leather gloves; a leather hat, heavy and black with sweat. Thick leather protected the horse’s chest, and a leather apron shielded the rider.

The *vaqueiro*’s speech was as distinctive as his garb, a regional dialect flavored with Portuguese phrases long antiquated in the rest of Brazil.

“Yes, this is a sad land,” he said, gesturing toward his scrawny herd tucked into the surrounding brush, and, beyond that, to burned-out fields of corn carved out of a withered scrub forest. “No winter last summer,” he sighed. “Will we have no winter this summer, too?”

Sometimes the Disaster Doubles

Later, in the home of Jorge Simão, a storekeeper of Quixeramobim, I heard the explanation of this odd confusion: “The people here, the *sertanejos*, call the rainy season—roughly late January to early May—‘winter’ because then clouds and rain normally bring us relief from the tropical sun. But of course we are south of the Equator here, and those months are really summer.

“Every decade or so, ‘winter’ does not come to the *sertão*,” Jorge went on. “That happened last year, and you have seen the desolation it brings. Our agriculture is geared to planting in December and January, so that the crops will grow with the rain and we can harvest in May and June. Then we can ride out the annual dry season. But when there is no rainy season, our crops die, our herds starve, and our people, who love their land, are scattered to the winds.”

It was then January 1971, and so the *sertão* had been parched for more than a year. Next winter was at hand. If it did not come, the *sertão* faced catastrophe.

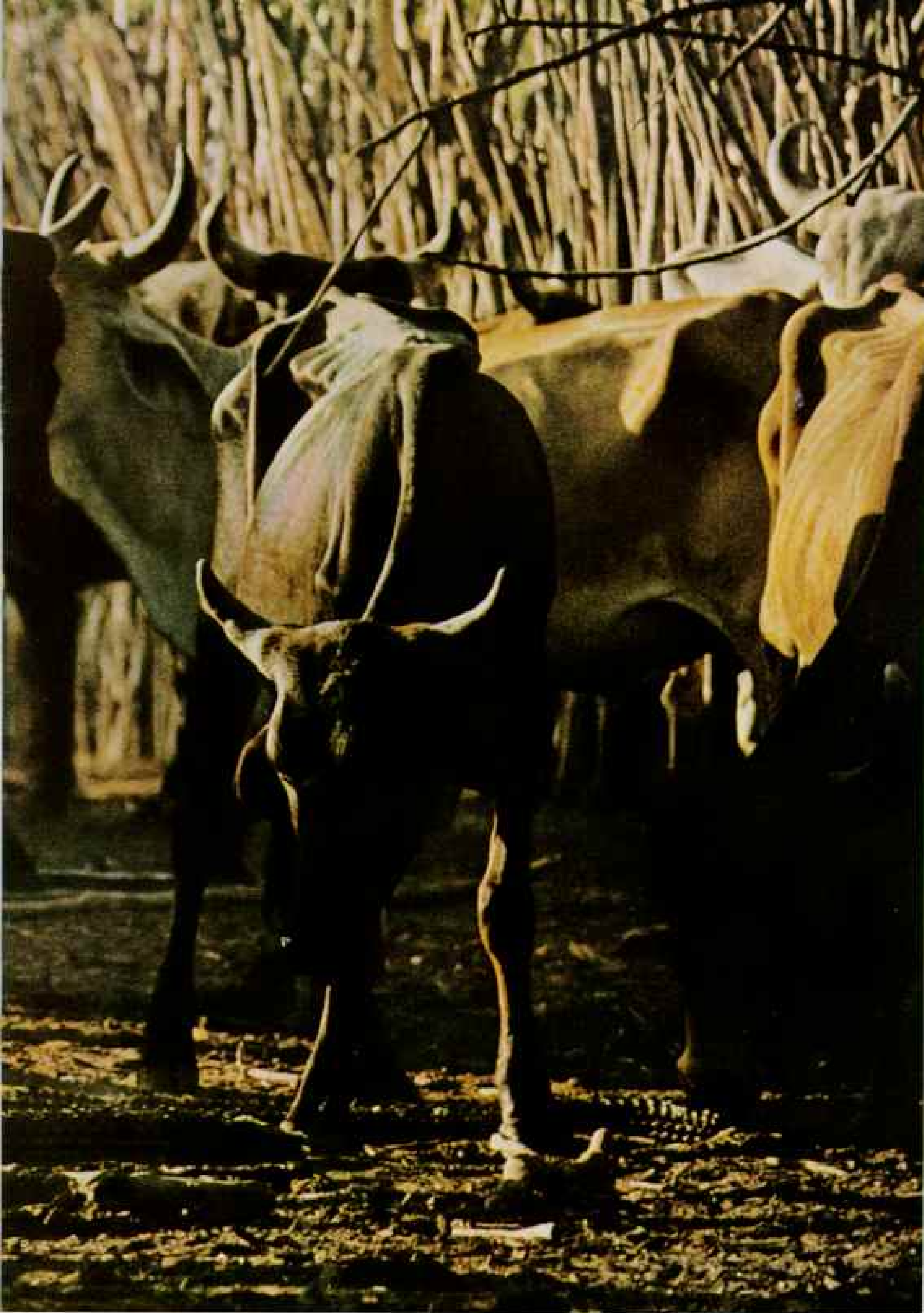
As if reading my thoughts, Jorge said, “Sometimes there is even a double drought—two years in a row without enough rain. One of the worst was nearly a century ago.”

The great drought of 1877-1879 spread ruin in all nine Brazilian states that, in whole or in part, comprise the *sertão*. Ceará, in which Quixeramobim lies, lost half its

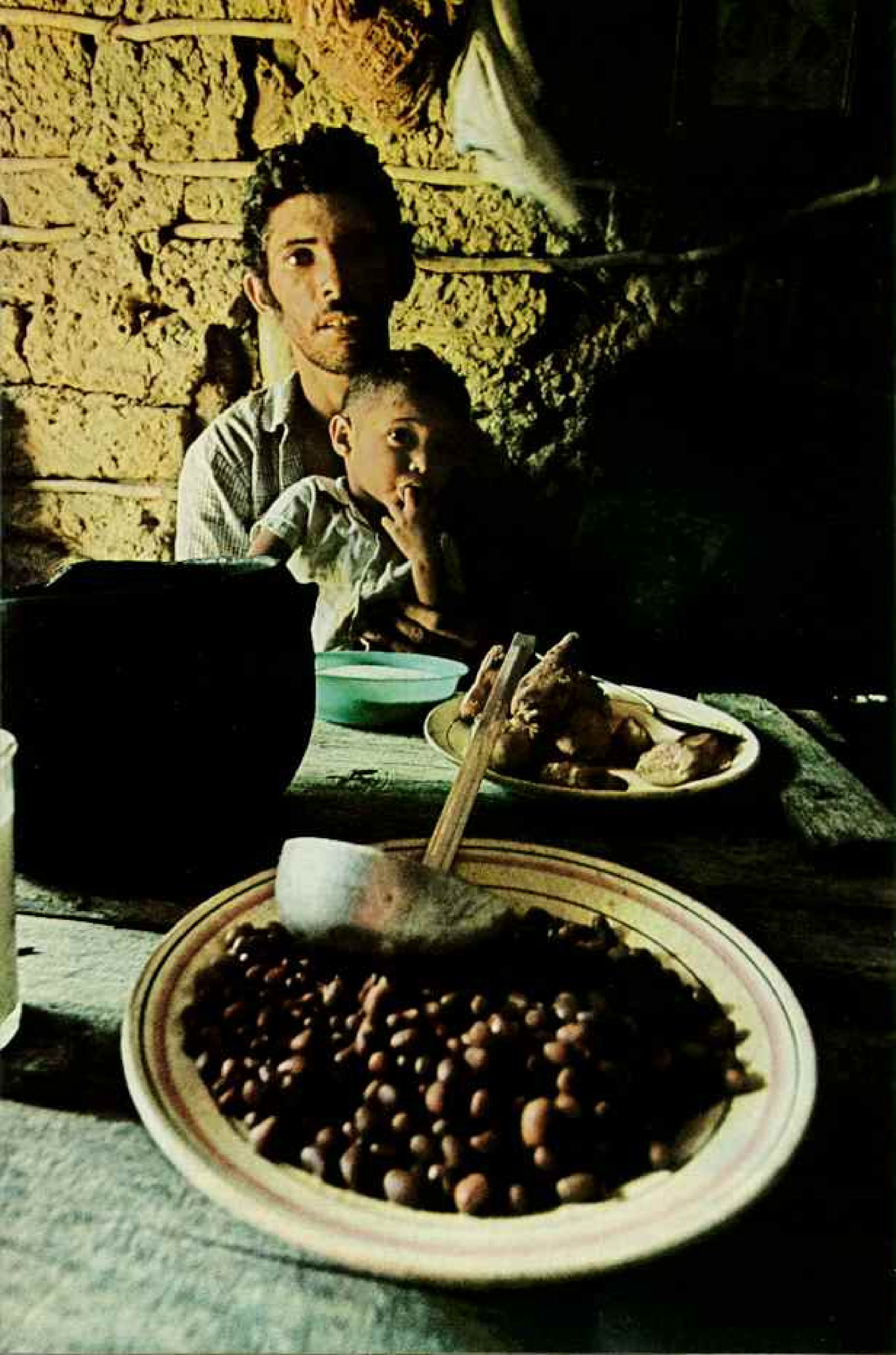




Lean as his hungry herd, a cowboy singes spines from cactus so his cattle can eat it. Nature makes life hard in the sertão, a land of thin soils, sporadic moisture, and rough terrain. This sertanejo has slowly built his mixed-breed herd since the last



drought wiped him out a decade ago. Now each searing day brings closer the heart-break of selling out again—another step in the vicious cycle that has trapped the region's people for centuries. To ward off thorny brush, horsemen wear traditional leather garb.



Sunday is full-belly day for a family of Quixadá. The weekly feast, filling but heavy on starches, includes beans, yams, a bowl of manioc, and a pot of thin fish stew. With a diet chronically lacking in proteins and vitamins even in green years, sertanejos suffer extreme malnutrition during droughts.

A spineless cactus (below) may offer a fatter future for the sertão. Cultivation of the North American plant could provide forage for cattle in dry times. Here, after the drought broke, a cactus pad becomes a perch for a rain-drenched finch.



population; half a million people died of thirst, starvation, or disease while trekking to water on the coast, and thousands more fled to the south or to the Amazon River. Today the sertão's 13,800,000 people are the poorest in Brazil.

I asked Jorge whether a double drought appeared to be in store.

"No one can tell. But the countryfolk are worried. They see that the little *fura barreira*—the bank-borer bird, whose arrival foretells rain—has not appeared. Other signs from age-old lore also warn of drought: Beehives along the riverbed, quince seeds lying sterile, no song of the thrushes in January. But, really, no one knows just when the drought will come, or even why it comes."

Jorge was well informed. Meteorologists who are studying the drought phenomenon of the sertão have found no definite cause. During summer, moist and unstable masses of air over the Caribbean and Atlantic normally push southward toward Brazil and move inland. Cloudbursts may drench the sertão and beyond, and the land thrives. But about once in a decade, the sertão gets only a few pitiful sprinkles, for some unexplained reason. The studies of this puzzle go on, but meanwhile, so do the droughts.

Countryfolk Flee a Stricken Land

"If you want to see what the drought really means," Jorge told me, "go deep into the *caatinga*." From a Tupi Indian word, *caatinga* means "white forest." It is a tortured thicket of low scrub, of thorns and prickly leaves, and twigs as sharp as lances.

When I saw it, I understood its name, for it was the ghostly gray of old bones. I thought the vegetation dead, but I was wrong.

Young Jorge Simão, Jr., who was driving me in the family jeep, explained: "Some of these trees may be centuries old. When the sun has no pity, they drop their leaves but send taproots deep into the cracked earth, seeking that last drop of moisture.

"When the rains did not fall and the crops died," Jorge, Jr., said, "many people followed the dusty trails out of the *caatinga*, carrying on a burro what possessions they planned to sell, with the family strung out behind, the goats and possibly a pig following along. They sold everything to get away from the sertão, to go to industries in the south—in São Paulo and Rio de Janeiro. Those without money had to sign up as field hands in the



rugged frontier lands of Mato Grosso. We call them *flagelados*—the whipped ones.”

Ten miles out of Quixeramobim, the jeep could go no farther. We walked two miles through rocks and sand, ducking under thorny bushes, along what was once the bed of a stream. We climbed over the wall of a dried-up reservoir and found Senhor Horacio Meneses, a vaqueiro and farmer who had refused to become a *flagelado*. He stood with a pick in his hands at the bottom of a hole 14 feet deep, where a trickle of moisture appeared to reward his efforts.

Senhor Meneses, his walnut skin dyed even darker by 52 years in the brutal sun, told us, “This spot always gives water. I found it here in '42, and again in '51 and '58, but now it's running pretty thin. I've just got to keep digging. The truck can't get in here.” SUDENE, the Brazilian Government's northeast development agency, has a fleet of tank trucks that bring water to thirsty ranchers.

Saint's Day Brings a Gloomy Omen

Senhor Meneses told us of his battle against the drought. “I wore another man's leather for 22 years,” he said, using the local term for a hired hand. “I am not going to run away now and lose all I have. Last December I had 19 cattle, and corn and beans in the field by the pond. Light rains fell in January and February. Sometimes they did not even hit the ground before the sun burned them off. My leather got stiff—no moisture in the air. By St. Joseph's Day all pasture was gone. That day—March 19—the saint forecasts our weather for the months ahead. If we are to have a winter, it will rain on that day. We got up with the sun and prayed, but the sun rose in a blaze and burned our land till night-fall. Drought for certain.

“I sold off nine cattle, and all the goats I could catch. I got a miserable price because the animals were thin. I dug and sometimes I would uncover water beds, but they lasted at most a few days. Many times I dug to rock 20 feet down, to find nothing.”

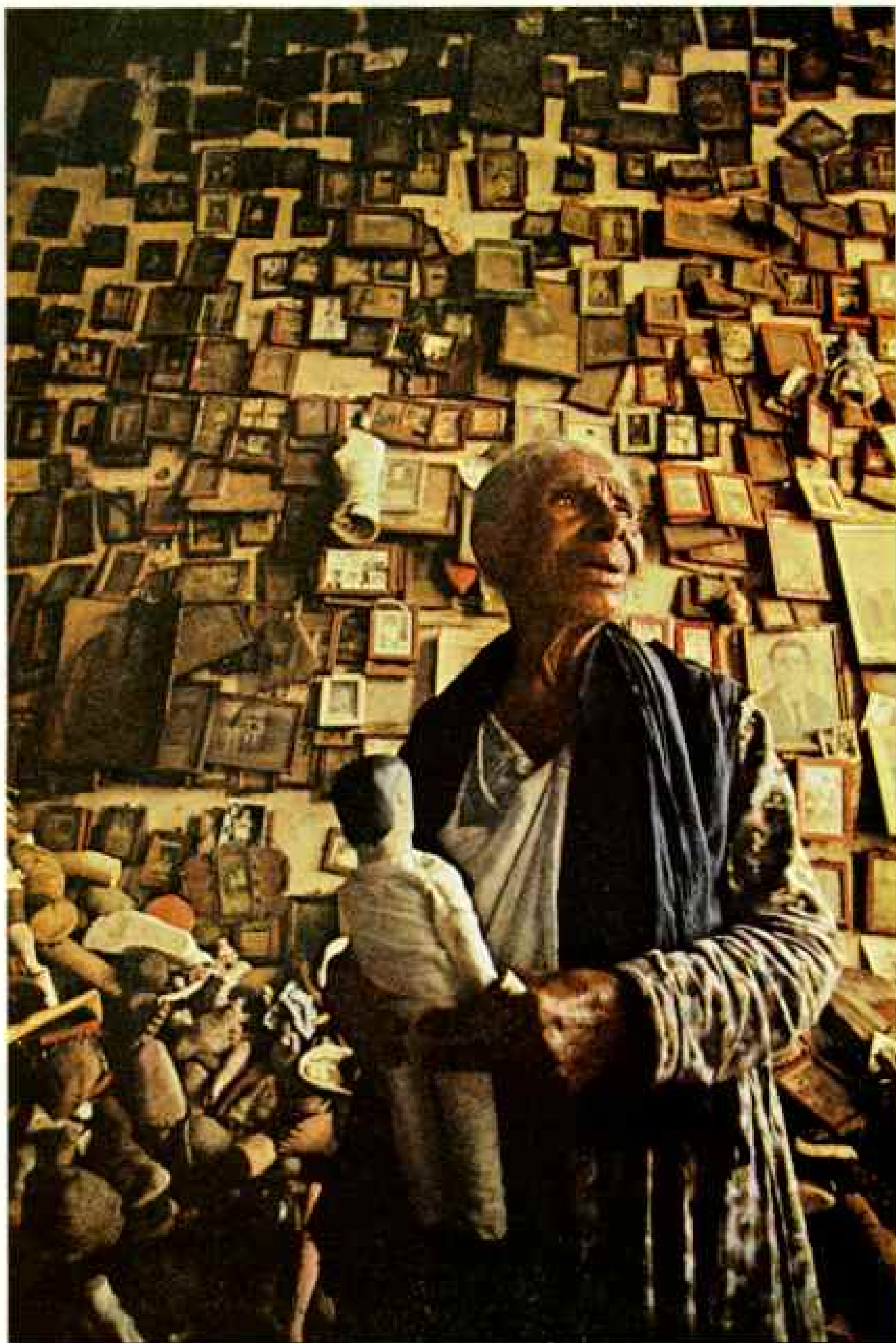
As we said good-bye, Senhor Meneses summed up. “The main thing is to keep the cattle alive. But if we don't have a winter again, we'll be liquidated.” The vaqueiro obviously found no humor in that ironic word, “liquidated.”

Many penniless *flagelados* had, of course, already been liquidated. In May, when there were no crops to harvest, they flocked to the



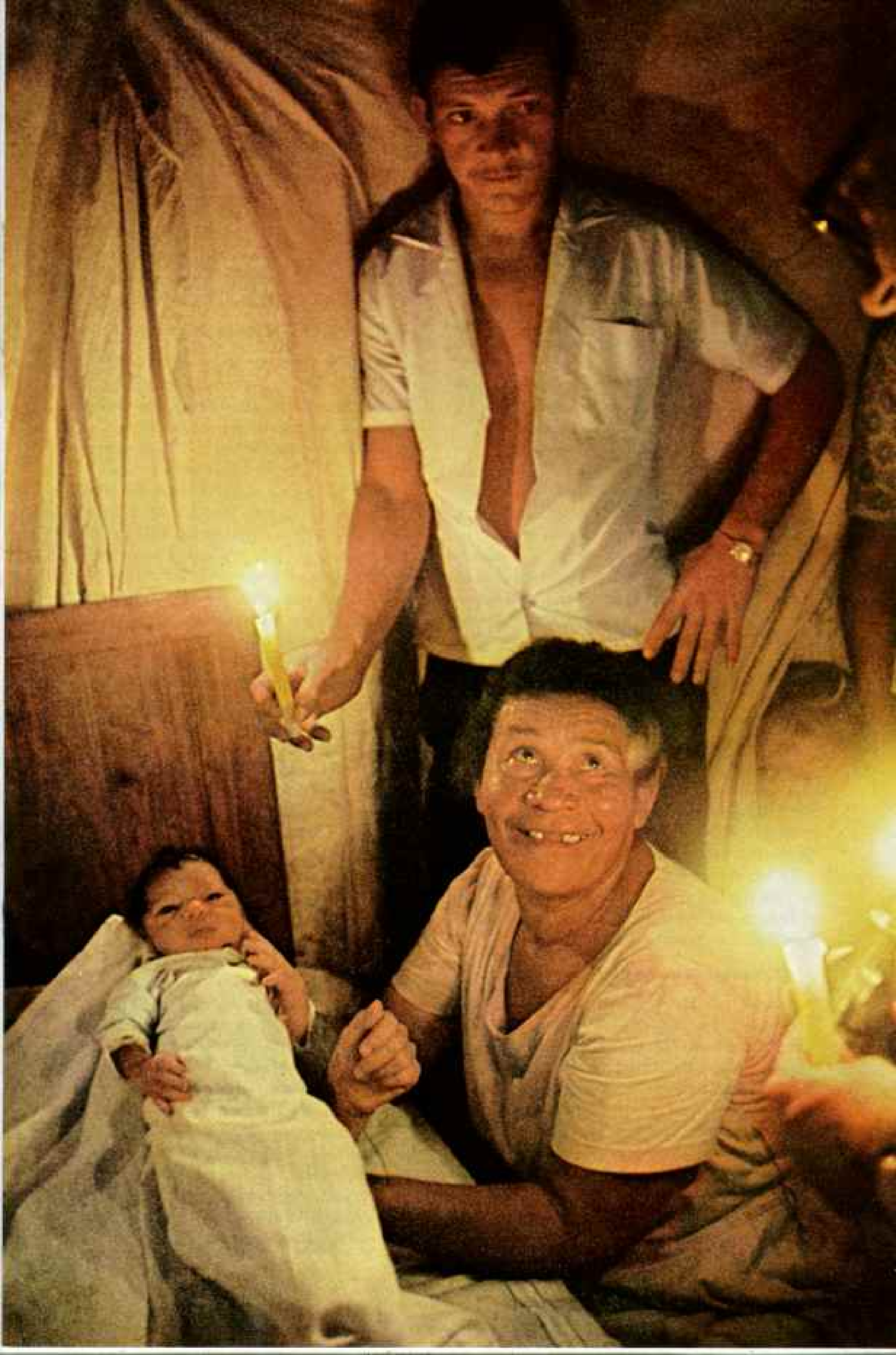
Dug ever deeper in pursuit of vanishing moisture, a water hole (facing page) swallows a boy with a pail as a woman waits her turn.

Brazil's bulge embraces 150,000 square miles of land parched by drought. New federal programs help buoy the sagging economy.



Thank-you gift: A disciple of the late Father Cicero, revered locally as a saint, holds a doll given by a mother who credited the padre with saving her dying son. Mementos symbolizing healed persons, or their limbs and organs, cram this "house of miracles" in Juazeiro do Norte, reflecting the region's thriving spirituality. Many sertanejos feel that misery's relief lies with such miracle workers.

Proud as the newborn's parents, a midwife hefts a baby girl she has just delivered. The father shows off his daughter by candlelight in his wattle hut near Tauá. As a child of the sertão, she enters a near-feudal society where great inequities exist between the landed and the landless.



towns for food. Some looted grocery stores or plundered trains of their provisions. To ease these pressures, the federal government mounted a drought-relief program. Food was shipped in, and SUDENE organized "work fronts" to keep idle hands busy.

A SUDENE official, Waldimir Leite, told me: "Within 45 days after we knew the harvest would fail, we were ready with plans for roads, dams, wells, and irrigation projects to employ 500,000 men. This was in the six-state area that was hardest hit, because most of its 2,500,000 people are just subsistence farmers. We are proud of the results—no one starved and no mass migration took place."

Ceará was one of the disaster states. There a SUDENE engineer showed me around a work front where 6,500 men labored in two shifts to build a road and a reservoir.

"We hire everyone who applies, so long as he can show a certificate from his priest that he is at least 14 years old," the engineer said. The daily wage equaled about 40 cents.

Next morning in nearby Iguatu I awoke before dawn to the sound of commotion in front of my hotel. I went down to find a dozen farmers and the hotel porter chattering excitedly about rain, rain, rain.

"Look at that beautiful sky," the porter said, pointing to a heavy black overcast.

"Will it rain?" I asked.

"Probably not," he said. "Heaven teases us some mornings but the cover soon burns off."

An hour and a half later, the sun opened a space, but by 6:30 the sky was covered right over again. Dashed spirits revived and people gathered in the street in front of their homes. "Beautiful sky!" I heard on every side.

The rain was short. By 7:10 it stopped, and by 7:40 the last puddle had dried. But people in Iguatu smiled that day. They had had a sign that the drought might end.

Cowboys Start Their Training at 12

I drove northwest to Tauá and the cattle lands along the border of the states of Ceará and Piauí. Rocks, cactus, sun—a flinty countryside. Here dwell members of the Feitosa clan, who settled the land early in the 18th century. The head of the clan, Maj. Manoel Feitosa, a tall black-haired patrician, welcomed me to his manor in the village of Cococi. He and his son hold 20 leagues of land—250 square miles.

"We are always only beginning," he told me. "The drought reduces everything to zero

and we start over again, deluded by the sertão. This year we lost all our crops, but some wells I had dug in that terrible drought of 1958 kept us in drinking water. I store a year's supply of manioc so that my tenants can last through bad years.

"My vaqueiros put on leather at 12," he said. "Fathers train their sons. Vaqueiro foremen are paid under a traditional system—one quarter of all calves they rear are theirs. But then along comes the drought, and they must sell their cattle just to survive."

Medieval Spirit Pervades the Sertão

Drought may force the sertanejo to emigrate, but he always yearns to return. I spoke to a vaqueiro who had fled a previous drought. He said he had been working in a São Paulo tire factory—"Really great. Well treated. Good pay." Then why had he returned?

"I couldn't stand it away from the sertão. You know, senhor, a sertanejo loves suffering. Two years of good times and I could not bear it anymore. So when my father wrote me it was raining here, I came back."

I explored this odd line of thought with Ariano Suassuna, professor of sociology at the Federal University of Pernambuco. A specialist in backland folkways, he advised me: "If you remember that centuries of isolation have kept the sertanejo a medieval man, you will understand his gloomy thinking. Our religion and many of our festivals and dances come from the Portugal of the Middle Ages. Folk pageants now dead in the land of their birth are preserved here across 400 years."

United Nations meteorologist Luis Aldaz amplified this: "The agriculture of the sertanejo remains medieval. The government has built hundreds of reservoirs, but the suspicious backlander, bound by poverty and wary of modern technology, does not irrigate. He will watch his crops die a few miles from water. The first recorded drought here was in 1583 when 5,000 Indians fled to the coast from the ravages of dry weather. Flight or pious resignation are still the sertanejo's chief responses to the drought. They will be until someone helps him pump the water to his fields and shows him how to use it."

The sertanejo has long fought the innovations of science. When the government tried to impose the metric system in 1874, he rose in fury, turning over market scales, proclaiming kilos the work of the devil, and, in a bloody

(Continued on page 720)



Salt foretells the future. A woman of Cococi lays out lumps of salt on the eve of St. Luzia's Day in December. Next day she will see which of six mounds, representing the rainy season of the new year, are wet with dew. Each damp lump means rain for that month.

Already flayed by a year of drought (below), a farmer of Inhamuns winces under another blow: The salt predicts light showers for January and February, then no more. In other areas, the test augured rains.

When the author returned the following April, the drought had ended in the sertão except around Inhamuns; there only a few sprinkles had fallen—in January and February.





Make-work to the rescue

STRUGGLING in dust turned to mud by a welcome shower, a work crew pushes a stalled truck loaded with stones for building a dam. The Brazilian Government organized 147 such emergency "work fronts" to discourage desperate drought victims from migrating, or ransacking shops and trains for food. The fronts attracted 500,000 sertanejos to construct roads, dig cisterns, build dams, and carve conduits for channeling runoff into reservoirs.

A week's work done, laborers line up at the project engineer's headquarters (right) for their pay, equal to about 40 cents a day and distributed partly in food. Nearing his turn in line, a lad opens his sack wide to catch an allotment of flour and beans (far right). The law forbids hiring children younger than 14, but officials wink at the rule when a family has many mouths to feed.









Rain brings rebirth to the fields of farmer José Canuto near Iguatu. At the drought's peak in December (left), sun-seared corn rattles against withered cotton planted between rows.

Canuto will burn the worthless crop to clear the land, trusting that the next rainy season will arrive on schedule.

Faith finds its reward the following April, when heavier-than-usual rains send his corn stalks surging from the soil (right), and fat kernels crowd stocky ears (above).

In some areas farmers are replacing corn with sorghum, a crop better suited to dry climates.



"Smash the Kilos" rebellion, defending the supremacy of his *libra* (about a pound) and *arroba* (about 33 pounds). He kept his arrobas for weighing his cattle, but he had to accept the kilos for smaller items.

In defense of his medieval religious concepts, the sertanejo has fought even more fanatically. In the 1890's one Antonio Maciel, called the "Counselor," gathered 20,000 simple countryfolk around him at his New Jerusalem—at Canudos in the State of Bahia. The Brazilian Government sent police detachments and 2,000 troops against the "monarchists" in three expeditions, but the tough defenders routed the professionals. Finally, in 1897, the government dispatched 10,000 troops. The sertanejos held out for three months, inflicted thousands of casualties on the army, and died to the last man.

With this fanatical strain in his makeup, the sertanejo looks to religion, rather than to science, to cope with drought. Driving south to Juazeiro do Norte, I encountered a hundred-foot statue of Father Cicero Romão Batista, whom sertanejos credit with a miracle in 1889. As the people tell it, he was praying for rain when the host turned to blood in the mouth of a devout woman. Overnight his church became a goal of pilgrims seeking miraculous healing or the blessing of moisture from the skies.

The people of the town are comfortable with miracles and herb doctors. A wizened old street vendor offered me a sea horse and sand dollar. "Grind them and boil them in tea," she said. "Cures shortness of breath."

Nature Finally Redeems Herself

I left the sertão at the nadir of its seared and searing misery. Four months later I returned. It was another land—green, green, green everywhere.

Paddle-wheel steamers on the São Francisco River and every bus and truck carried homesick sertanejos who had heard the word, "It is raining in the sertão!"

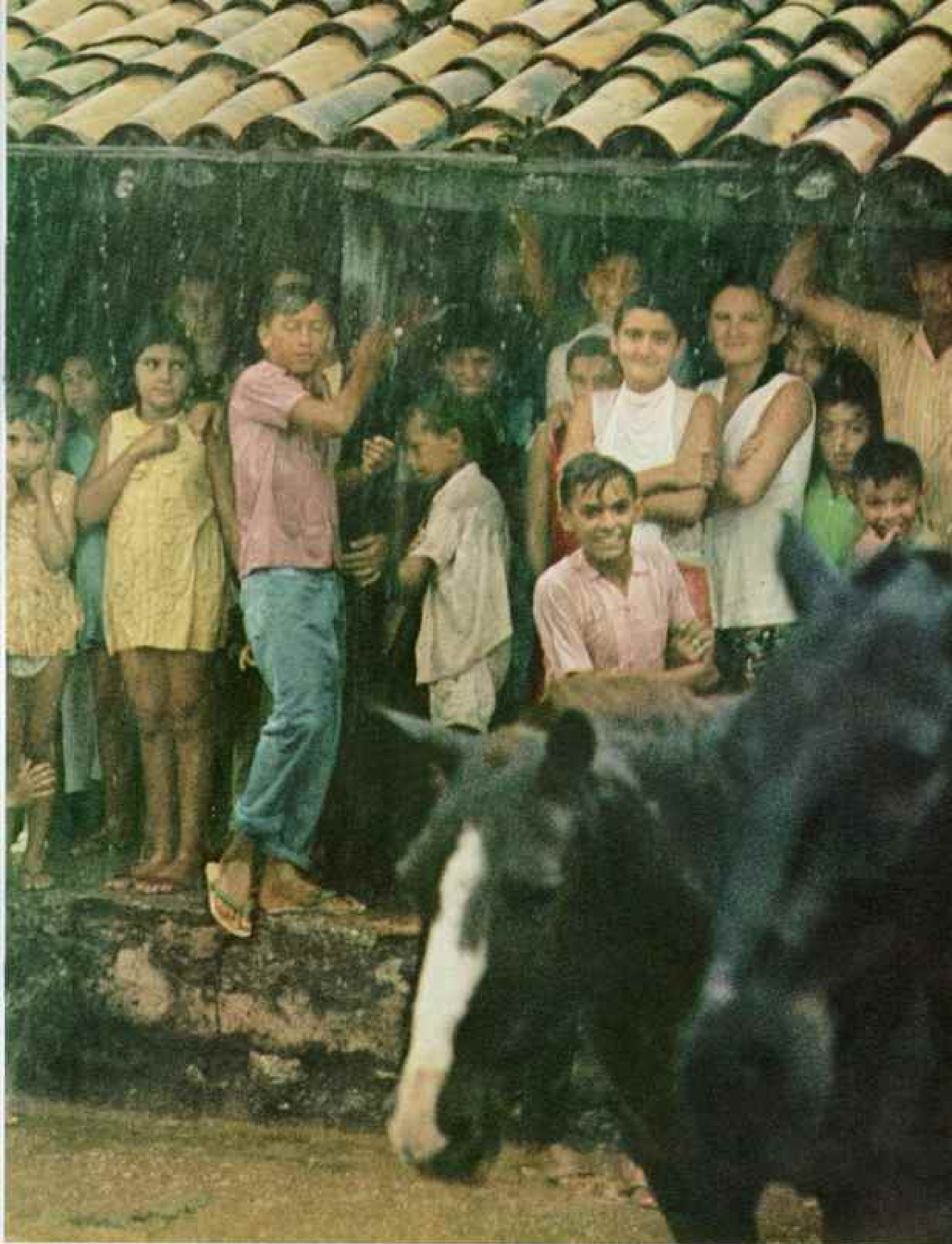
The rain had fallen generously everywhere—except around Inhamuns, where Saint Luzia, on her feast day, had sent the people a sign that their drought would not end (page 715). My friends there told me with bitter pride that the saint is never wrong.

But in the caatinga, all was aglow with life and color. Abundant blossoms in party dress brightened the rocky gray soil.

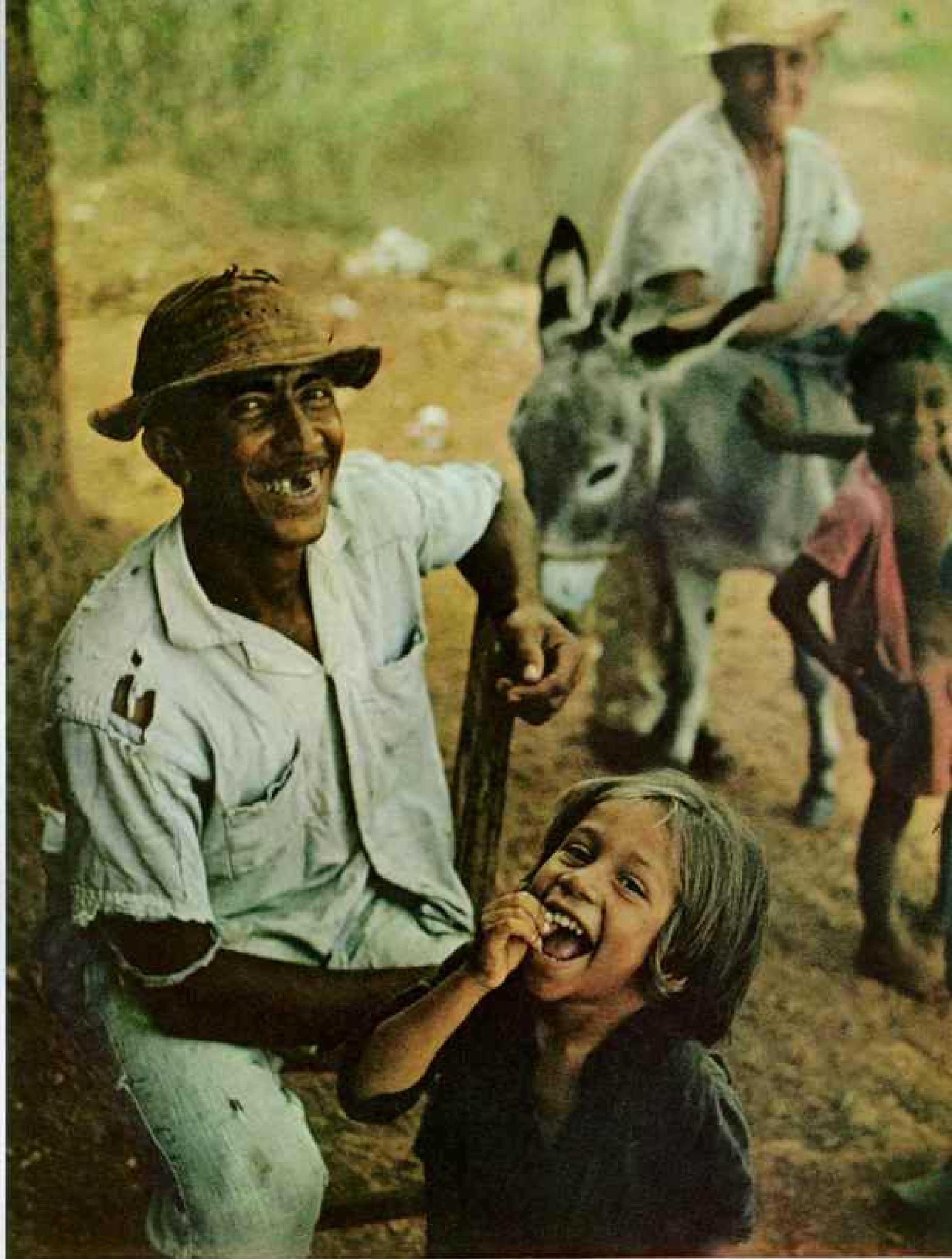
Among men, too, it was party time. To his



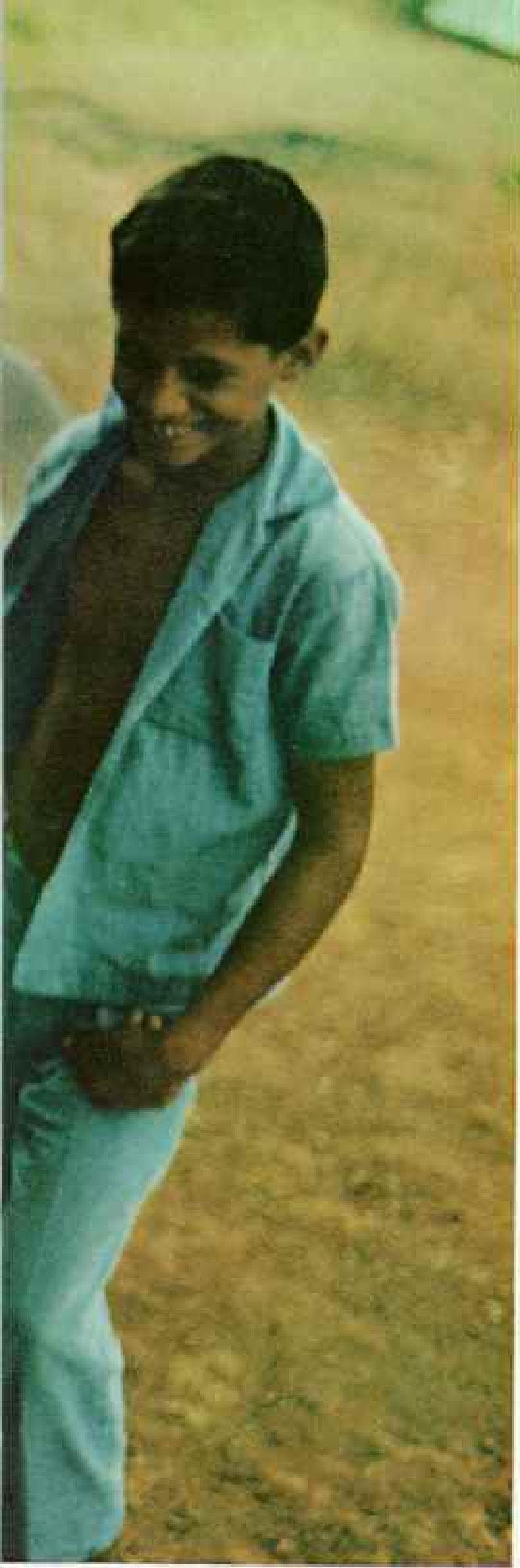
Spirits revived by a torrential rain, spectators welcome the interruption of their *vaquejada*, or rodeo. A rancher of Caraúbas



organized the festive event to celebrate the wet season. During bad droughts, sertanejos must forgo their favorite spectacle because cattle and horses grow too weak to put on a show.



Cheered by a gray day that heralds the arrival of more rain, sertanejos who waited out the drought on an Iguatu farm share a joke. Even families that gave



up and fled to the cities often come back when water again greens the sertão.

Liberty Ranch in Rio Grande do Norte, Deusdete Pimenta had called the best riders of the area to a *vaquejada*, a rodeo, to celebrate the return of good times. I watched the performance with Raimundo Soares de Brito, postmaster of Caraubas and local historian. "The contests of skill you see featured here duplicate a vaqueiro's daily work during roundup time," he explained.

Just then a chocolate-brown bull charged out of a cattle chute and two mounted men set off in pursuit. Pounding hoofbeats echoed my heartbeats as one vaqueiro leaned down to grip the bull's tail, then abruptly threw and hobbled the beast.

"Prizes go to the fall closest to the chute, strongest horse, fastest fall, best rider, and best throw," said Senhor Soares de Brito.

A rainstorm broke up the *vaquejada* two hours later (pages 720-21), and everyone crowded into the ranch house for refreshments.

"No one can say rain spoiled our festival," said the rancher. "Rain always brings joy to the sertão."

In Change Lies the Sertão's Hope

I needed someone to put this morbid-joyous, parched-fertile, forbidding-beautiful land into perspective. I found my man in a Redemptorist priest from the United States who had been working in one of the sertão's bleakest regions—Sento Sé: on the São Francisco River.

Father Bernard Van Hoomissen is a hard-muscled man of 54. He has seen a lot of the sertão, and he has seen it without blinders.

"The sertão has been in the grip of economic feudalism," he said. "In area after area, one family has held the land and all the important local offices for generations. This must change. People must have education, so that they won't fear innovation and will express a larger voice in their affairs. They must learn to try irrigation projects. Even more important, perhaps, the government and the people must work together to master better dryland farming methods. Less than 2 percent of the cultivated land here can be irrigated; for the rest, the great costs outweigh the benefits. Ways must be found to provide more jobs—and the trained sertanejos to fill them.

"If all these things happen—and I am certain in my heart that they will—then this beautiful land will become a garden that not even drought can wither." □

The Red Sea's Gardens of Eels

By EUGENIE CLARK, Ph.D.

Photographs by

JAMES L. STANFIELD

NATIONAL GEOGRAPHIC PHOTOGRAPHER

and DAVID DOUBILET

THIRTY FEET BELOW the surface of the Gulf of Aqaba, I studied one of our plots of garden eels. Kneeling in a turretlike blind set amid sea grass and pale sand, I peered out through the clear blue water of this arm of the Red Sea.

The silvery-gray eels stood like plant stalks, projecting a yard above the bottom (right). Bodies arched, eyes alert for food, they curtsied and dipped, bowed and swayed. To the orchestration of invisible currents, they performed their tireless serpentine dance, like cobras spellbound by a snake charmer's flute.

Separated by a few feet—sometimes by only a few inches—from its nearest neighbor, each eel was anchored by its tail's tip to the mouth of the sea-floor burrow in which it lived. When danger threatened, it vanished tailfirst into the sand.

I thought of naturalist William Beebe, who observed a "garden of eels" in the Gulf of California. "They resembled iron rods as much as anything," he wrote, "slightly bent . . . sticking up from the sand, but, unrodlike,





swaying very slightly." He was unable to pluck any prizes from his eel garden, and skeptics questioned his veracity. But within a generation his account has been verified by the discovery of a dozen species of garden eels, which follow a colonial way of life unique among the vertebrates.

On summer expeditions to the Red Sea in 1969, '70, and '71, sponsored by the National Science Foundation, the Smithsonian Institution, and, during the third season, by the National Geographic Society, I have studied one species in this grouping of strange fishes. Co-workers were my husband Igor Klatzo and teams of my zoology students from the University of Maryland.

Though we surveyed 16 garden eel colonies—most along the east coast of Israeli-occupied Sinai—we concentrated on two large ones near Eilat at the head of the Gulf of Aqaba. Colony No. 1 lay just off Willy Halpert's Aqua Sport diving center. Colony No. 2 was located about a mile south along the Israeli coast, near Hebrew University's Heinz Steinitz Marine Biology Laboratory, our base of operations.

The subject of our study, *Gorgasia sillneri*, was discovered in the gulf by a traveling pencil salesman, Ludwig Silner. Pursuing his hobby of underwater camera work, he photographed a garden eel colony and collected an immature specimen off Aqaba. A German ichthyologist, Dr. Wolfgang Klausewitz, named the species after Mr. Silner.

We could don scuba gear inside Willy Halpert's diving center, walk out into the afternoon sun in an air temperature often above 105° F., and within moments subside into the 75° water of the Gulf of Aqaba. A short swim would take us to one of the largest known garden eel colonies. But our favorite dives took place early, when the day was relatively cool.

Undersea Desert Teems With Life

Before an August dawn Igor and I gear up and head for the gulf. Groups of campers, scattered on the beach in bedrolls, resemble colonies of sleeping seals. (The Gulf of Aqaba has become a tourists' paradise.)

Putting on our face masks, we walk into the sea. Once underwater, we turn off our flashlights and find our way by the strange gray of the day's first light.

Down the slope of sand, in the underwater desert, the burlap-covered metal frame of our

blind looms as incongruously as a spaceship on the moon. Before 5 a.m. we reach Colony No. 2. An oval nearly 300 feet long, the area supports more than a thousand eels. When we arrive, they are already swaying and writhing in their habitual ballet, but they drain away into the sand as we swim into the blind.

In a few minutes we are settled. Igor, an enthusiastic amateur photographer, adjusts his cameras. I am ready with a stopwatch on my wrist and a pencil and plastic pad at hand. Our air supply will last better than an hour and a half.

Menu Offers Minuscule Fare

We put our face masks to the viewing ports and see that the eels have risen again—hundreds of them, proudly erect as if standing on the tips of their tails. Some are so close we look right into their eyes, yet they no longer see us as objects from which to hide. They have accepted the blind, the bubbles issuing from it, and the face masks gleaming in the peepholes.

Most of the eels are feeding, facing into the gentle current. They are selectively plucking items from the menu—tiny crustaceans, minute sea squirts, fish eggs.

The hemisphere of water in which each eel feeds has a radius slightly shorter than the length of the fish's body. We have never seen one withdraw the tip of its tail from the opening of its burrow, which is a sinuous vertical hole in the sand lined with mucus secreted from the skin of the tail.

Just outside our blind a pair of eels engages in the ceremony of mating. Less than six inches of sand separates their burrows. The olive-spotted male stretches toward the female, spreading and rippling his long iridescent white dorsal fin. Distinguishing the sexes in *Gorgasia sillneri* is easy. The male is larger, darker, and has a swollen appearance on the back of his head (page 733). He reaches a length of three feet—longer than most other garden eel species.

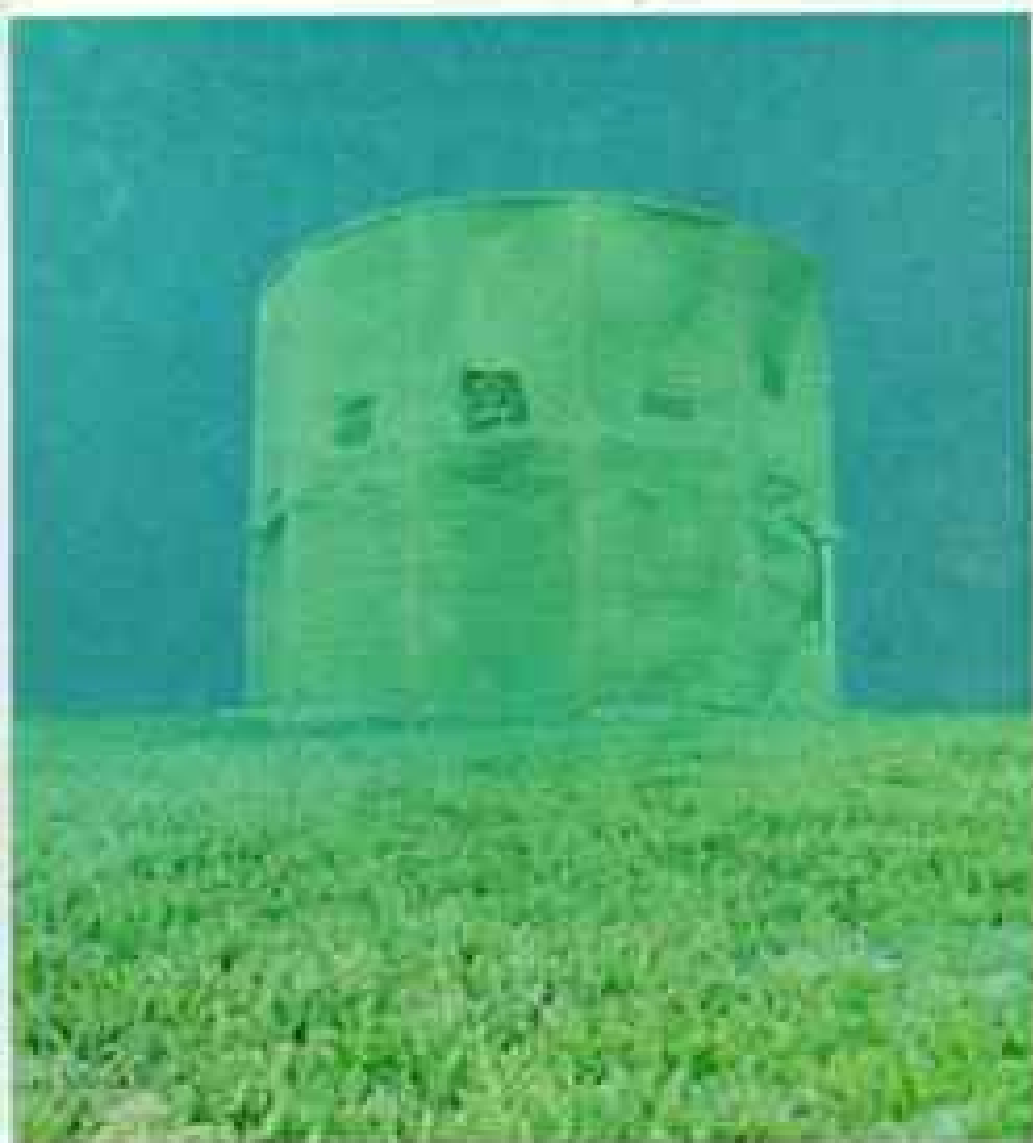
The female seems to initiate external fertilization by coming farther out of her burrow. She entwines herself around the male in a single loop. The female expels her eggs, and the male ejects his milt.

The time goes quickly. I see Igor turn on his reserve air. He reminds me with a gesture that we have to go. We return to the surface and head for the beach.

(Continued on page 732)

WILLOWY SPROUTS amid the sea grass, garden eels earn their name from their colony's resemblance to a bed of swaying plants. Moored by tail tips to mucus-lined burrows, they eat what the currents bring—fish eggs and other tiny marine life. Each male controls a territory as large as his body can reach, nipping at rivals that dare intrude.

Here the wary creatures feed while the author hovers motionless above her blind, 30 feet beneath the surface.



As flighty as a desert mirage, the animals sink into their homes when disturbed. Usually gradual, such a disappearance can also be surprisingly swift. Even when the scientists excavated a burrow, its inhabitant tunneled off faster than they could dig.





GRACEFUL AS DANCERS, eels perform a ballet of courtship. Deftness of movement and invisibility of eggs and milt prevented the author from ever recording the exact moment of fertilization, which is external as with most fishes. Often during mating, male and female entwine their bodies (below). At other times, the male



may drift and sway about his thinner mate, waving his head from side to side (left). Both ripple their filmy dorsal fins tremulously (bottom left). Responding, the female rises farther from her chamber (below), then twines again about the male. The entire drama may be repeated a dozen times in one morning.

Mature males maintain harems of several females. Except during the mating period, the males live much farther from the females than the few inches shown here. No one knows exactly how or when the eels change location.



Now the Red Sea's silken surface is truly red, reflecting the mountains that turn pink at sunrise. Bedouin passing on their camels give us a second look, but do not stop. It is nearly 7 a.m., and we just have time for a warm shower and breakfast before starting our day's work at the laboratory, where we keep captive garden eels for study in cement aquariums half filled with sand.

Eels Retire for a Midday Siesta

But the most exciting and rewarding work is always in the sea. At many of our study colonies, we follow the cycles of garden eel activity around the clock. Most of the eels emerge from their burrows at least half an hour before sunrise. At first they gingerly extend their heads, a mass of periscopes with big eyes peering around in the semidarkness. Gradually, they stand higher and higher, more and more appearing, until the whole field of eels has arisen.

A passing fish or school of fish—less often a diver or motorboat—interrupts their feeding and makes them duck for cover. But well before noon, sometimes as early as 9 a.m., the entire colony may start to sink out of sight for no apparent reason. Around 3 p.m., after their midday siesta, the eels reappear. Their activity reaches an evening peak at sundown and continues until we have to use flashlights to see the creatures.

We learned that when the eels withdraw into their burrows at night and for their midday siesta, a remarkable little fish, *Trichonotus nikii*, takes over the feeding area. I discovered this sand-diver fish in 1964 and named it after my son, Niki. Only about two inches long and adorned with plumelike filaments, it escapes predators by diving into the sand headfirst.

A series of night photographs, made by University of Maryland student Josh Wilkenfeld, showed dozens, then hundreds, of the little sand divers materializing to feed at what would be the head level of the eels when they're up, a stratum from which the tiny fish could quickly duck into the sand to evade an enemy.

With this nice arrangement of "sittings," nature has allowed eels and sand divers to feed at the same rich table of plankton without being serious competitors.

David Fridman, the Steinitz Marine Laboratory's collector and aquarist and one of Israel's most expert undersea naturalists,

worked closely with my student Phyllis Anastos and me. Catching an eel, we had all discovered, has its problems. Excavating the area surrounding the burrow was no help, for the fish could tunnel away faster than we could dig. But David knew just how much anesthetic to squirt down an eel's burrow to bring it out.

Phyllis would go to David, saying, "Will you help me catch an eel today in Colony No. 2, please?" To study the movement of eels, Phyllis was experimenting with tagging by fastening a piece of colored cork to an eel with a fine thread (page 735). Thus she could plot the fish's changes of location.

After three summers she learned it's mostly males that shift their burrows. A male moves close to a female—sometimes within an inch—for a few days, Phyllis discovered. When all the ripe eggs have been released, the male moves away and they both again occupy larger feeding hemispheres.

"But I've never been able to see the male leave his old burrow and dig the new one!" Phyllis lamented.

Not one of us has ever witnessed the change of location. Does the male leave his hole and swim to the new spot? Or does he take a sight on the female of his choice and burrow through the sand to a place next to her? We still don't know.

Big Male Bullies a Youngster

On the deep edge of Colony No. 2, Phyllis and I found 56 small eels clustered in less than four square yards. Each young eel was six or seven inches long. By the time garden eels reach a length of ten inches, they seem to separate and scatter among the adults.

A big male will often lunge toward an immature eel, sending the youngster quickly into its burrow. When the adult's back is turned, the young eel comes out again, stretching farther and farther to catch what it can of passing plankton before the large eel puts the smaller one down again.

Eventually, a young male must move away until he is big enough to challenge the established males in choice feeding areas, or find a less crowded area he can defend and share with a mate. I think the young female eel may simply join a local harem.

We learned to predict where we could find our eels. At depths of from five to eighty feet, away from coral reefs but near the mouth of a wadi, or desert watercourse, which on



Bulldog jaw and bulbous eyes—larger than those of most eels—enable leopard-skinned *G. silmeri* to select tidbits from the sea. Fleshy bulge behind the eyes proclaims this aquarium captive a male. The author caught several eels and tried to fertilize some eggs artificially. But for reasons still unclear, all attempts failed.

rare occasions would empty its temporary river into the sea—in such a place the sand usually has the right consistency for eel habitation. If plankton-rich currents wash the place, the situation is ideal for eels.

Where a Sinai wadi roughly 20 miles south of Eilat has dumped its sand into the Gulf of Aqaba, David Fridman and I saw millions of *Trichonotus nikii* swarming near the bottom. Yet as we swam along we could not spot one opening to an eel burrow. But I noticed that here and there some powerful creature had been plowing up the sand. I had stumbled onto the trail of what I believe to be the chief enemy of garden eels.

Suddenly we saw the diggers approaching us. Five huge stingrays, each the size of a tabletop, came soaring past. We followed them, and all at once they stopped flapping their “wings” and plunged headfirst into the upper layer of sand. Twisting from side to side and rippling the edges of their huge pectoral fins, they stirred the bottom into a

cloud of flying sand grains. The hordes of little fish fled in all directions.

I am not certain what the ugly predators were hunting, but eel colonies could hardly develop in an area regularly devastated by these shovel-nosed rays.

Dockside Explosion Leaves a Grim Wake

Garden eels evidently benefit from their colonial way of life: Many eyes can spot danger more readily than just two. To certain enemies, a thousand animals appear more formidable than a few. Amid such numbers it's easier to find a mate, warn a companion, allow the young to survive.

But being sedentary poses disadvantages, too. A single environmental disaster can destroy the whole colony. An explosion at the port of Eilat in 1969 dumped chemicals in the sea that left a wake of dead fish covering a quarter-mile area and wiped out an entire eel garden. Also, food and oxygen may be exhausted faster. And, of course, enemies find

it easy to prey upon a stay-put population.

After all our study of garden eels, we are left with one major gap in our knowledge. What happens from the moment an egg is released and fertilized until it develops into a young eel trying to find its place in a colony? We can only speculate.

The garden eel belongs to the same group of fishes, Anguilliformes, as the common American, European, and Asian eels. A true eel—like some of its distant relatives, including the tarpon and bonefish—at one stage assumes an unusual form known as a leptocephalus, or “slender head.” This is a flat, gelatinous larva generally a few inches long. Transparent and leaflike, it lives as a part of the plankton and shows little more resemblance to an adult eel than a caterpillar does to a butterfly.

Elusive Larva Spurs Further Study

Marine biologists have brought up the leptocephali of many kinds of eels in plankton nets. By such characteristics as the number of vertebrae (which may run higher than 600, but is fairly uniform within each species) some larvae can be matched with known adult species. However, many eel leptocephali described in scientific journals have yet to be paired with their adult forms.

Hoping to raise leptocephali, I've attempted artificial fertilization of garden eels. No luck! The eggs never developed embryos. But even success with that experiment would not complete the garden eel story.

For how many months or years does the garden eel leptocephalus live in the plankton before it settles into the sand to join or start a colony? Over what ranges do the known species extend their sway? How far south into the Red Sea does *Gorgasia sillneri* reach? Will we find it in the Indian Ocean?

As I ponder the many remaining questions about the Red Sea's gardens of eels, and the future trips it will take to get the answers, I find myself remembering one particular dive. Strong current has speeded up the eel's dance rhythms to a jerky jazz step as they stretch to grab passing morsels of food and then brace themselves again, head-in to the moving sea. They curve their slender bodies in high arches, all pointed one way, like so many big question marks.

It is almost as if these graceful, mysterious creatures are telling me that there is still much to learn. □



To make the hand quicker than the eel, the scientists resorted to a harmless anesthetic. Beside a cloud of the drug (above), Robin Solomon marks a burrow he has just squirted. In 20 minutes the occupant groggily emerged and was caught.

Student Phyllis Anastos (right) hovers above an anesthetized eel she has tagged painlessly with a thread tied to a cork bobber. Recovering, the fish promptly disappeared; the cork revealed that it lay in hiding: only a couple of inches below the burrow entrance. Nylon lines divide the sea floor into a grid for plotting eel positions, which can change daily. Burrows filled with liquid epoxy produced sinuous casts (below) only slightly longer than the residents.







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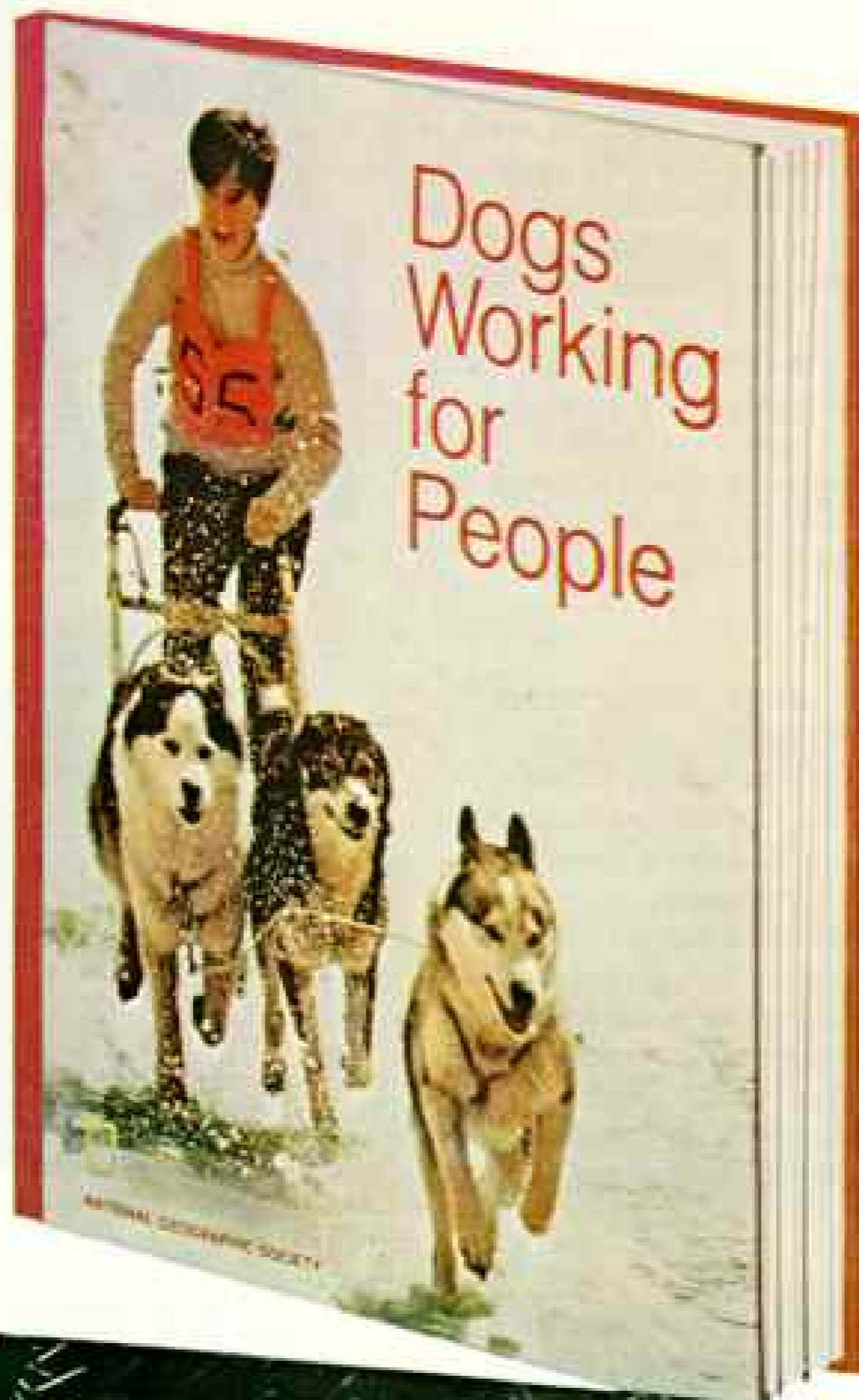
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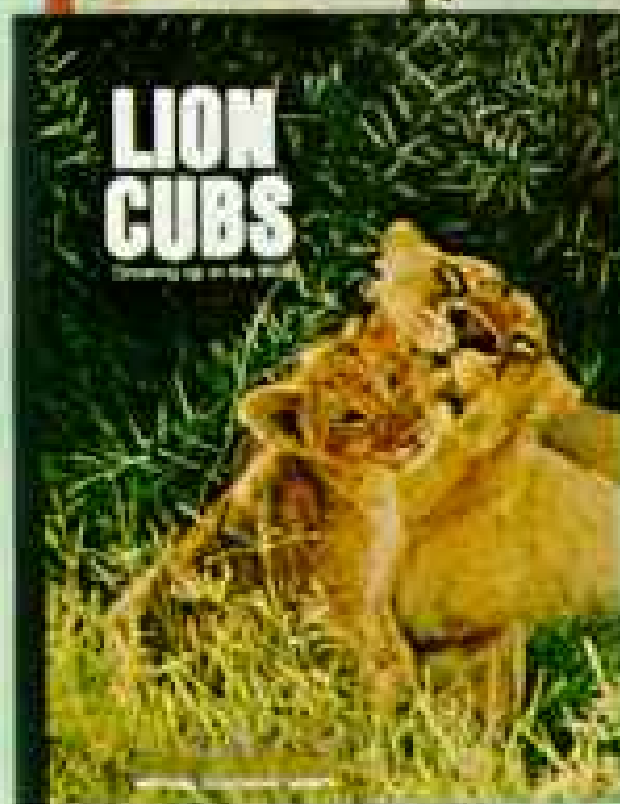
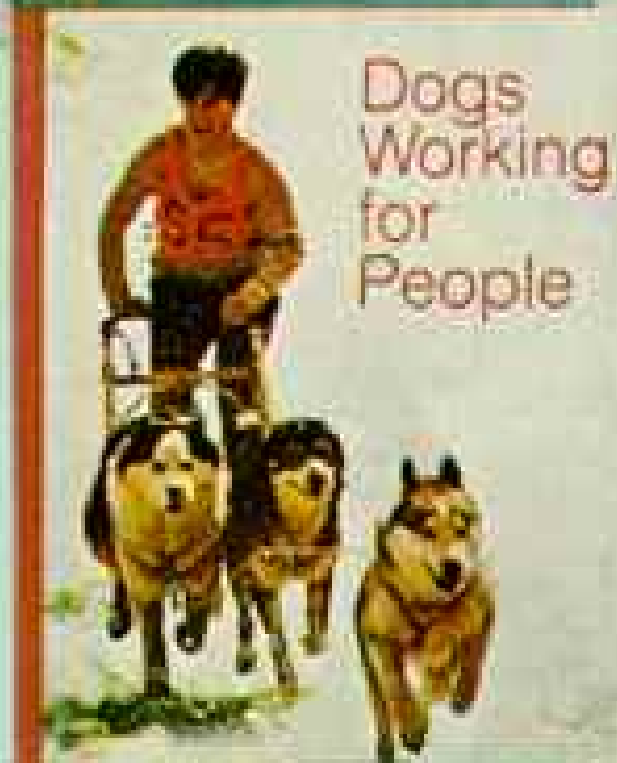
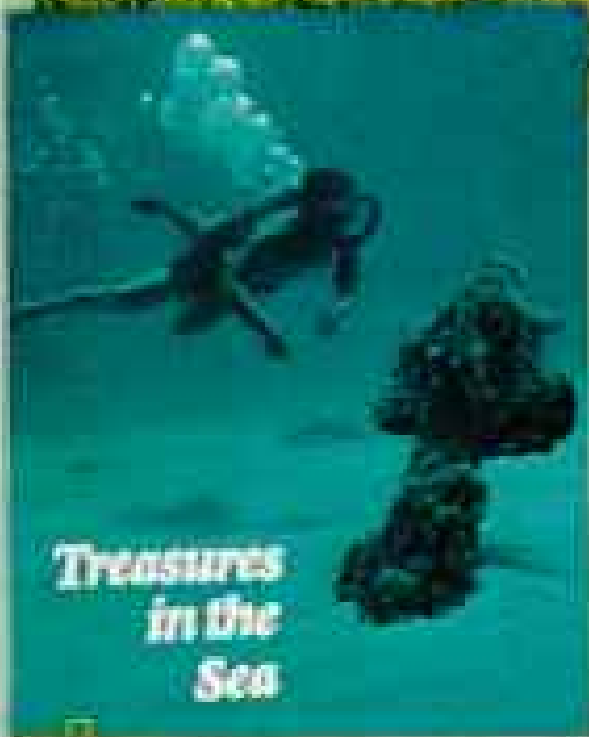
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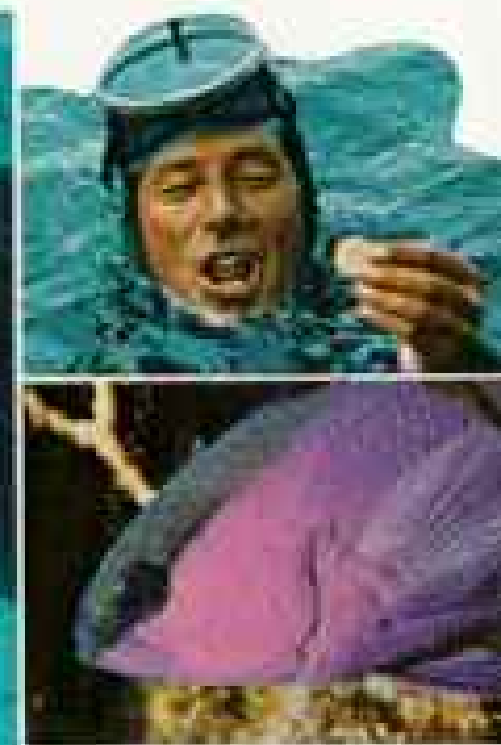
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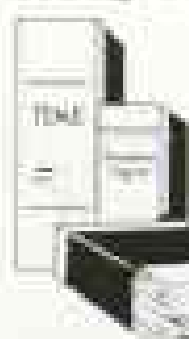
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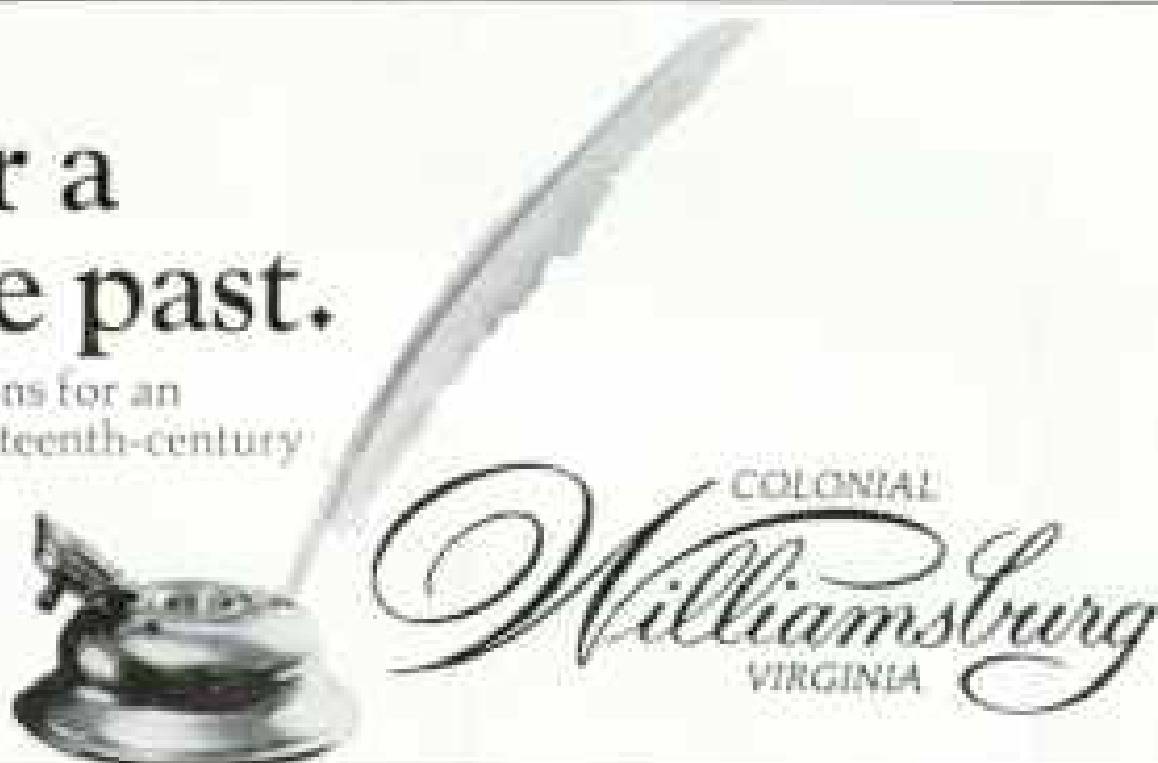
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You're surrounded by personally selected colors, fabrics, carpeting and appointments, marvelling at the quiet comfort and unbelievable scenery. And you're moving into a weekend of fun and adventure at 200 miles an hour.

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be weekends when you'll want to stick around home base. And just fly. For the fun and beauty and solitude of it.

Next time you're staring at a dull weekend, start out on the biggest adventure of your life. Head for your Beechcraft Dealer. Or maybe you prefer to go the route of the un-coupon below. It really doesn't matter which way you go. As long as you go up, in your own Beechcraft Bonanza.



the lake? Join the chain gang on the highway for five hours both ways. Some fun, huh? Or how about a 16-hour pilgrimage to see the big game. Worth it? You decide not. Game's on TV, anyway. Yawn.

Then one day you happen to look up from your hedge clipping and see the answer far above your buttoned down boredom.

The answer is a Beechcraft Bonanza. Flying off to all kinds of freedom. All kinds of intriguing places. All kinds of adventure.

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JUDGMENT FROM THE BENCH

Those who sit in judgment of a piano come from many branches of musical achievement. But they all look for the same signs of truth to emerge.

Responsiveness, for instance, is always called upon—especially when a new concerto is being tried.

Clarity must come forth—as in the case of enunciating vs blurring the inner voices of

Bach's fugues. Reliability, above all, will figure hard in the outcome of every rock concert.

To all these points, Yamaha pianos plead guilty as charged.

Judge one at your nearest Yamaha dealer. But whatever you do—don't sentence yourself to life without a piano. In fact, we'd rather you buy another piano than no piano at all.



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