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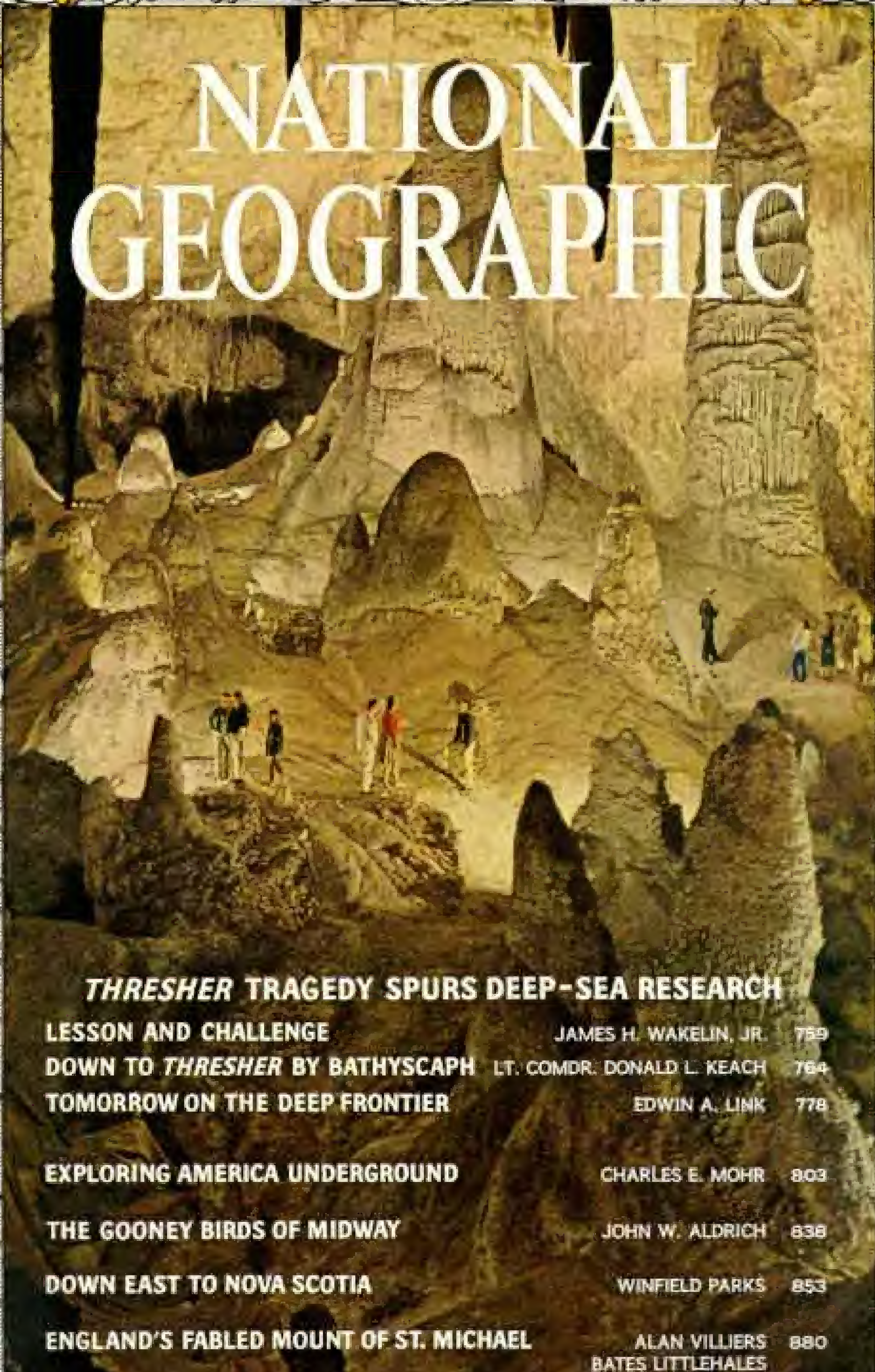

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COVER: Visitors in Carlsbad Caverns explore an underworld of fantastic formations (pages 816-17).

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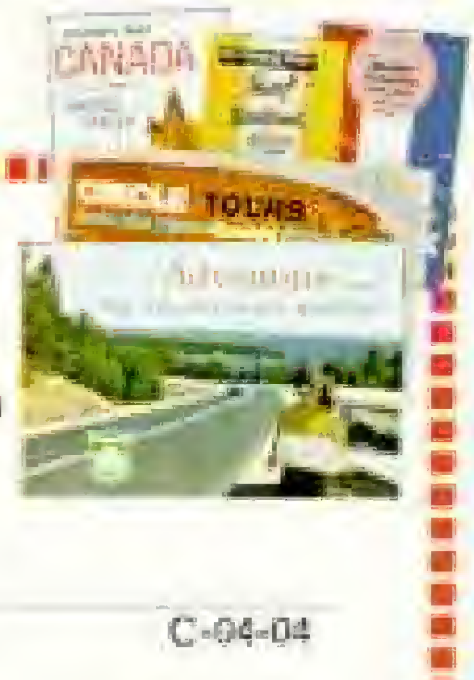

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NATIONAL
GEOGRAPHIC

THE NATIONAL GEOGRAPHIC MAGAZINE VOL. 125, NO. 6

Thresher: Lesson and Challenge

By JAMES H. WAKELIN, JR.

Assistant Secretary of the Navy
for Research and Development and
Trustee of the National Geographic Society

OUR DEEP FRONTIER, the subsurface oceans, has always been a domain of mystery. For centuries man turned away from an environment so implacably hostile, and in his mythology he populated its drowned reaches with fearsome creatures. Even when man ventured boldly upon the surface of the oceans, he shunned the depths.

Military opportunities finally lured man deep beneath the surface. His vehicle: the submarine, a formidable weapon in two World Wars.

In the years of uneasy peace following World War II, United States naval technology gave the fleet a new kind of submarine—fast, deep diving, nuclear powered. Within less than a decade our Navy was projected into a new and virtually unknown environment. Submarines had been limited to the upper few hundred feet of the ocean; now they ranged to considerably greater depths, into a frontier where our oceanographic knowledge had not kept pace with the swift development of shipbuilding technology.

Tragedy Strikes Pride of the Navy

That inevitable lag was painfully dramatized on April 10, 1963, when U.S.S. *Thresher* (right) inexplicably sank in 8,400 feet of water 260 miles off the New England coast.

Thresher was the newest of the new, the first of a class designed to find and destroy other submarines in the deep ocean. She was the most advanced nuclear submarine American science and technology could produce—the pride of the Navy and of the men who served in her.

Like all submariners, her men were carefully selected and rigorously trained. They were prepared to react instinctively and effectively in the event of an emergency. But something happened shortly after 9 a.m. on that April morning that neither training nor courage could cope with.

U.S.S. *Skylark*, a surface vessel working with *Thresher* on her test dive, received at 9:13 this message via underwater telephone:

"Experiencing minor difficulties. Have positive up-angle. Am attempting to blow. Will keep you informed."

The world does not know the exact nature of *Thresher's* difficulties. Four minutes later her last, badly garbled message was heard aboard *Skylark*. Watch standers believed they heard the words "test depth," the submarine's lowermost diving limit. Apparently *Thresher* was in serious trouble and heading toward the bottom.

Twisted brass pipe, retrieved from the ocean floor, attests the awesome might that rent the nuclear submarine *Thresher.* The author holds a new pipe for comparison by Capt. Frank A. Andrews, search force leader, and oceanographer Dr. Arthur E. Maxwell, who headed the scientific advisory group.

On the ocean bottom, the tortured pipe lies beneath 8,400 feet of water. Still attached to a bit of aluminum bulkhead, the tube once conducted hot water to the galley. Rust from a steel fitting appears yellowish to the camera. Before bringing the relic, marked with *Thresher*'s number, to the surface, the

bathyscaph *Trieste* made this beautifully clear picture, using a deep-sea camera developed by Dr. Harold E. Edgerton with National Geographic Society support.

Every resource of the United States Navy was thrown into the historic search operation that followed. Every fleet unit that could be used was made available. But even as we rushed ships to the area, it was with the bitter knowledge that rescue and recovery at that depth, if she lay on the bottom, were impossible with existing techniques and equipment. Neither the Navy nor anyone else in this country or abroad could do the job.

The Navy, I can assure you, had long been aware of the gap between operational capability of its ships and our understanding of the deep-sea environment. In 1959 we had embarked upon a ten-year oceanographic program—we call it TENOC—to provide the Navy with a more comprehensive understanding of the ocean, its submerged boundaries, its properties and processes.

The TENOC project soon became part of a larger program. Several of the Federal agencies having responsibilities in the ocean environment were directed by President Eisenhower, and subsequently Presidents Kennedy and Johnson, to prepare and coordinate the far-reaching National Oceanographic Program. A permanent group, the Interagency Committee on Oceanography, was established within the Federal Council for Science and Technology, and I was privileged to become its first chairman.

Unfortunately, knowledge of the vast and complex ocean cannot be developed as rapidly as we can design and build new submarines. While the council mobilized national resources behind its urgent program, more and more nuclear submarines had joined the fleet. When *Thresher* went down, our only hope was that we could find the hull and learn the cause of the disaster—and even that hope was slim.

Bathyscaph Brought From the Pacific

The bathyscaph *Trieste*, the Navy's only vehicle capable of surviving at the depth where *Thresher* disappeared, was immediately ordered from San Diego, California. She traveled aboard an LSD (Landing Ship Dock) through the Panama Canal to Boston, then was towed by another vessel to the site. Destroyers carrying special underwater sound gear (sonar), rescue ships, salvage ships, and even other submarines were dispatched to the scene to assist.

Early efforts sought clues that would narrow the search area. Sonar scanned the bottom for questionable "bumps" that might be *Thresher*. Ships combed the surface for debris or oil slicks. Watches were mounted around the clock to listen for any unusual noises beneath the sea.

We knew, however, that most of the search techniques and equipment that appeared most promising were still under development by scientists and engineers working in the national oceanographic program. The Navy's fighting ships, because of the nature of the equipment they carry, could assist the search in only a limited manner. Research craft—our oceanographic ships—were the vessels most capable of investigating the area all the way to the ocean floor.

Fortunately, one of the newest of these ships, *Atlantis II*, was immediately available. Operated by the Woods Hole Oceanographic Institution, *Atlantis II* had just finished sea trials and was preparing for an expedition to the Indian Ocean. She was fitted with many of the latest instruments, including a precision depth recorder with which we hoped to trace the telltale outline of *Thresher* as she lay on the bottom.

Close at hand, too, were a pair of our latest Navy oceanographic research vessels, *Conrad* and *Gilliss*. Both responded immediately.

Thus within hours after the tragic news, capabilities which had only recently been acquired as part of the national oceanographic program were ready to undertake the search.

To mobilize all capabilities, Adm. George W. Anderson, Jr., then Chief of Naval Operations, immediately set up a technical advisory group, headed by Dr. Arthur E. Maxwell of the Office of Naval Research and made up of leading civilian and Navy scientists. Every oceanographic institution offered its best people, ships, and instruments. I met with many of these men a few days after *Thresher's* loss. Their devotion to duty was an example of selfless dedication, always heartwarming when working in uncertainty and difficulties.

The advisory group quickly reviewed early search activities, evaluated clues, and prepared a painstaking search program, continually revised on new information from the area of concentrated effort—a 10-mile square.

Although we had the best of what was available, it wasn't enough. The *Thresher* tragedy dramatized facts that too few of us want to be reminded of: We know too little about the ocean; we have been too willing to tolerate our limitations in working on its surface and under it; and we must develop a capability for doing useful work at more than a few hundred feet below the surface.

So apparently simple a thing as precision navigation proved beyond us. Our systems couldn't guarantee that we were at a given point within an error margin of 300 yards. This is unimportant when you are looking for something on the scale of Boston Harbor, but it rapidly becomes important in looking for a 100-yard-long submarine hull lying on the bottom at great depth.

Camera Strays in Currents

Then, too, when a ship was directly above a selected area, our problems were just beginning. Lowering a camera to the site was equivalent to a man in a balloon, a mile and a half above the earth, unsure of his own position, trying to drop a fishline through a blizzard into a swimming pool. Ocean currents push a camera hanging from a long cable every which way before it reaches bottom. In fact, it's quite likely that the camera is anywhere but directly below the ship.

We also used underwater television, electrodes that could record electric currents set up by dissimilar metals in sea water, magne-

tometers that might detect magnetic changes caused by a large mass of metal, and underwater Geiger counters to search for possible radiation from the nuclear reactor. We obtained meaningful results from all the detectors except the Geiger counters. They never did indicate any abnormal radiation levels.

Searchers Probe 100 "Contacts"

After a painstaking two-week survey of the area, using the most advanced navigation and search methods, our plots showed about 100 possible "contacts." Each of these had to be fully investigated.

Here, again, our problem was lack of knowledge. We did not know enough about the sea floor in this area to be able to distinguish definitely between normal instrument readings and readings that might represent something foreign on the bottom. For example, we didn't know what the normal background would be on the magnetometer, nor was there any previous experience with a signal from a submarine on the bottom.

We concluded that the camera, even with its limitations, would have to be our basic tool. (The existence of cameras usable in such depths was due to brilliant work over the years by Dr. Harold E. Edgerton of the Massachusetts Institute of Technology, whose research was assisted by grants from the National Geographic Society.)

Our best evidence came in photographs of debris on the bottom. These clues allowed us to concentrate our search, and soon we had thousands of pictures of equipment, twisted metal, and other materials. One dragline brought to the surface pieces of battery plates used on nuclear submarines.

Now that we had a rough idea of *Thresher's*

KODACHROME BY HAROLD E. EDGERTON, U. S. NAVY (BELOW) © N.G.S.

Overlapping pictures plot a path of wreckage scattered over a quarter of a mile. At the Woods Hole, Massachusetts, Oceanographic Institution, Dr. J. B. Hersey shows staff members a 70-foot mosaic made by cameras towed by *Atlantis II*.

Two-ton air bottle tore loose from *Thresher*, hit the bottom at perhaps a hundred miles an hour, and drove 5 feet of its 12-foot length into hard silt.

No one could say with certainty why *Thresher* sank. The Navy Court of Inquiry last year reported the likelihood that a sea-water pipe broke. Because of the great depth, water jetted in with terrific force, smashing control panels and sweeping away wiring like cobwebs; *Thresher* then had no power to surface. Even if she were able to blow ballast tanks by using air bottles like this one, the inrushing water could drag her so deep that even her stout hull could no longer withstand the tremendous pressure of the sea.

location, we could put to good use the bathyscaph *Trieste*, which can reach the world's greatest depths but has a short radius of action. On one of its dives in August, the bathyscaph brought up a piece of brass pipe engraved "593 Boat"—signature of *Thresher*.

On the following pages *Trieste*'s captain, Lt. Comdr. Donald L. Keach, USN, tells the exciting story of how his bathyscaph found and photographed the lost submarine.

Pictures of thousands of twisted and torn pieces of wreckage gave conclusive proof that *Thresher* had imploded from the sea's relentless pressure. Although the sub's pressure hull was not sighted by *Trieste* in these dives, magnetic signals recorded in the area of the debris indicated it was probably still intact, though considerably ruptured.

Thresher left behind her the realization that we are ignorant—a condition once described by Benjamin Disraeli as a great step to knowledge. We are trying to build on this realization to become more knowledgeable.

Not long after the tragedy, Fred Korth, then Secretary of the Navy, established a special group of experts, headed by Rear Adm. E. C. Stephan, to review the Navy's abilities in deep water and recommend changes.

The famous inventor and underwater pioneer Edwin A. Link, a member of that group, reports on what we are doing and what we hope to do in the near future in the article beginning on page 778. In our world of military danger, expanding population, and widespread poverty, ability to exploit the oceans becomes vital, as Mr. Link explains in detail.

If the great task remaining is spurred on by *Thresher*'s loss, that will become the true memorial to the 129 brave men who died aboard her.

* * *

Deep in Davy Jones's locker, 8,400 feet down, *Trieste*'s metal arm picks up a length of brass pipe bearing *Thresher*'s number—593. A red rust spot spreads from a steel fitting. Lt. Comdr. Donald L. Keach, shown at the viewing port in this cutaway scene, dodged ragged mounds of metal to set down the bathyscaph in a level area. Comdr. James W. Davies, oceanographer, and Lt. Comdr. Arthur Gilmore, submariner, share the cabin.

Down to

Thresher by Bathyscaph

By LT. COMDR. DONALD L. KEACH, USN

A BIG PLACE, the Atlantic. It seemed hopelessly big as we crept along at one knot, searching the bottom 8,400 feet down, a mile and a quarter below daylight's deepest penetration.

Tracking us overhead, a "Mike Boat"—a converted landing craft—rocked gently in four-foot waves, 315 miles off Boston. The sky was overcast on a cool, late June afternoon. But we knew nothing of the sea's surface here, scientist Kenneth V. Mackenzie and I. We knelt back to back in the cramped steel sphere of the bathyscaph *Trieste*. Our floodlights swept dark bottom 20 feet below.

Mackenzie busied himself with the instruments while I piloted the craft, peering through a thick Plexiglas port no larger than an ash tray. After more than three hours of searching, I still had seen nothing but the occasional gray-white blotches of sea anemones, starfish, and other bottom creatures.

Now our battery voltage was so low that *Trieste*, powered by electric motors, was barely making steerageway. I picked up our undersea telephone.

"Mike Boat, this is *Trieste*. Request permission to surface."

Then, before the reply came, I sighted a faint yellow flash in the shadows.

"Check the background reading, Ken," I said. He scanned the magnetometer and radiation sensors for any changes.

"Nothing," he reported. Our instruments gave no hint that we were approaching the grave of a sunken nuclear submarine.

I called surface again, asking permission to stay down another 15 minutes. Reversing *Trieste*'s three propellers, I twisted her around and descended a few feet.

There I recognized a plastic shoe cover with metal snaps—the kind of safety boot worn in a reactor compartment. Now it lay only three feet from the viewport. Half of it was folded under, concealing part of some lettering stenciled on it.

"Take a look," I told my companion, and read: "S . . . S . . . N. . . ."

"Five," he finished. "SSN-5."

Thresher's number was SSN-593.

This close to the bottom—just balancing on it, in fact—we could now see other signs. Bits of paper, chips of paint, and other light material lay scattered everywhere.

We were close—very close. Although we had almost reached the limit of our endurance, Ken and I decided to use every bit of battery power left to follow this trail of debris. We turned on our four automatic cameras. Within minutes we spotted larger, more numerous pieces of light material, in some places literally covering the bottom. Now, scattered among masses of paper, light pieces of torn, twisted metal appeared. Surely *Thresher* was only yards away.

And then *Trieste* could go no farther. Her drained batteries could no longer turn the propellers. Our floodlights had faded to a dim glow. We had to surface.

So ended the third of ten dives made last summer by the bathyscaph in search of the ill-fated submarine *Thresher*, which went down with all hands on April 10, 1963.

Our mission was of tremendous importance to the United States Navy. Also, it was a chance to prove that the bathyscaph was useful for operational purposes. Previously, she had been used only for scientific dives. R/V (Research Vessel) *Trieste* was the Navy's only craft capable of reaching and maneuvering freely in the crushing depths that claimed SSN-593.

When the submarine was lost, *Trieste* was summoned from San Diego, California, to assist in the search.

The bathyscaph, designed by the famed Swiss physicist and balloonist Auguste Piccard, derives its name from the Greek words for "deep boat." It was built to plumb the greatest depths of the sea—and, in fact, had done just that more than three years earlier, in the 35,800-foot Challenger Deep near

First proof of *Thresher's* grave came with sighting of a plastic shoe cover on the bottom by the bathyscaph *Trieste* (right). "On its sole I could read clearly 'SSN-5,'" says the author. "A fold hid the final numerals, '93.' These figures do not show in color, but in our bright lights they stood out." Also visible: flecks of paint and fragments of metal.

Above, a submariner dons such a boot before entering a reactor compartment. When he leaves, boots, gloves, and plastic suit can be discarded if contaminated by radioactive particles.

Guam in the Pacific.[*] Scores of other scientific dives had erased any doubts that we could reach the floor of the Atlantic, here about a mile and a half down.

But vital questions lingered: Could *Trieste* conduct a systematic search of the bottom? And could she find the remains of *Thresher*?

Much hard, demanding work had preceded our promising third dive. When we arrived at the dive site, towed from Boston by our mother ship U.S.S. *Preserver*, surface vessels using underwater film cameras, television cameras, magnetic detectors, and sonar had narrowed the search area to a two-mile square. We readied immediately for the first descent. *Trieste* had just undergone a complete overhaul, and much of her equipment was new, designed especially for this search. So it would be a test dive as well.

At 10:35 a.m. on June 24, Giuseppe Buono gave the 350-pound steel door of the sphere his usual meticulous inspection, called in his familiar "good luck," and slammed it shut.

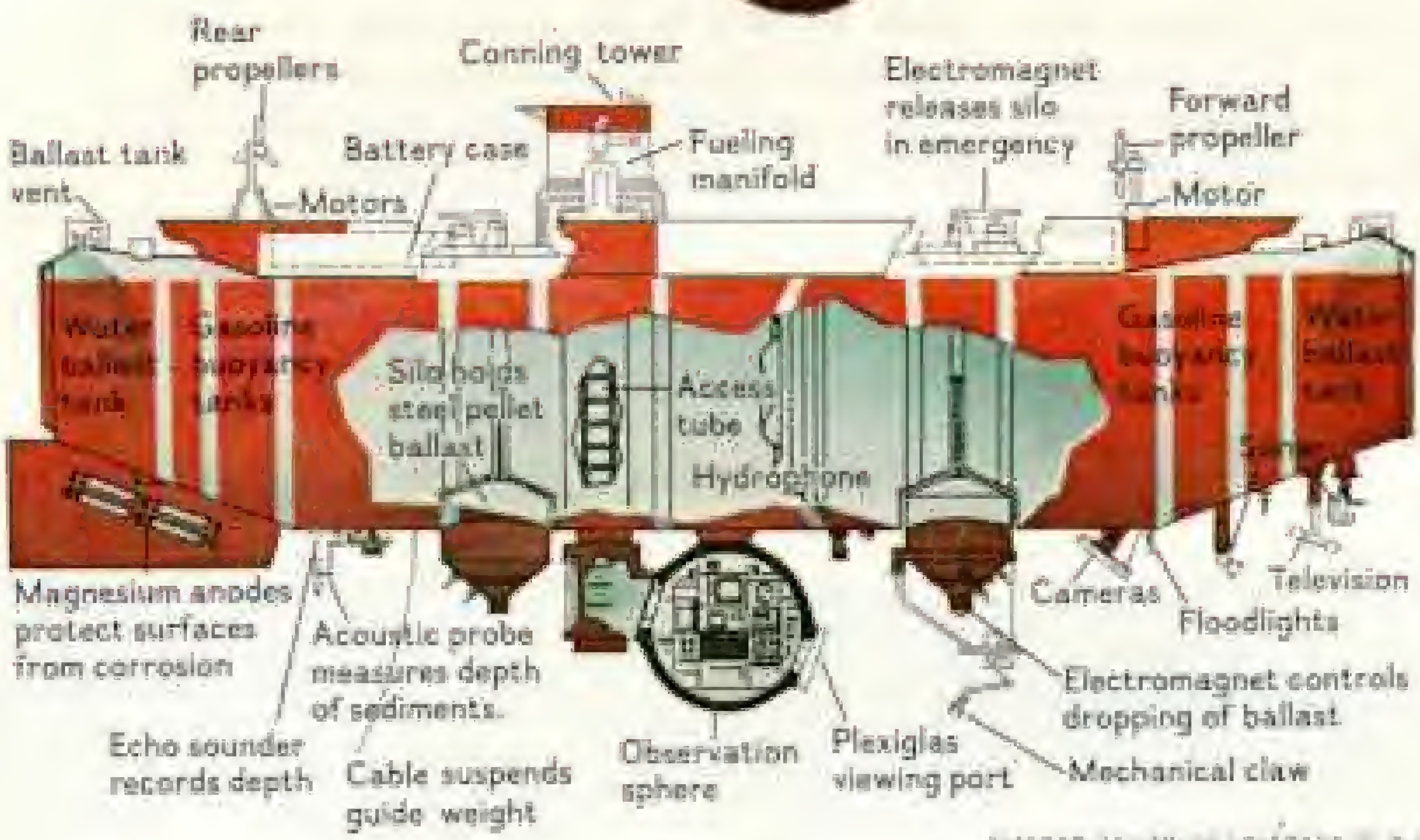
On this dive, as on the third, I was accompanied by Ken Mackenzie, chief scientist of the Deep Submersible Program of the Navy Electronics Laboratory at San Diego, California. Buono's work topside gave us added confidence. As safety engineer, he has supervised every dive since *Trieste* was built in Italy in 1953.

The weather, unusually calm for the Atlantic, was ideal for *Trieste* operations. Above, Buono opened the flood valve, allowing sea water to rush in the access tube. He opened the water ballast tank vents, allowing air to escape and water to enter, then leaped to a skiff. We were on our way down.

As we left the surface, *Trieste*'s gentle rolling ceased; the only indications of downward motion were the slow deflection of the depth gauge and the gradual fading of light coming through the two Plexiglas ports.

Mackenzie and I were too busy checking

*See "Man's Deepest Dive," by Jacques Piccard, NATIONAL GEOGRAPHIC, August, 1960.



Deep-sea Dirigible, the *Trieste* Resists Crushing Pressures

In the skies, men ride gondolas of airships beneath hulls filled with lighter-than-air gas. Undersea, Navy men brave the deep in a steel sphere buoyed by a hull full of lighter-than-water gasoline.

At *Thresher*'s depth, *Trieste*'s gondola withstood a squeeze of almost two tons to the square inch. Her buoyancy tanks are open to the sea on the underside, keeping inner and outer pressures equal, thus allowing use of a relatively thin hull.

***Trieste*'s crew** checks deck gear battered by swells. Freeboard is only two feet, and waves often spill over the deck, damaging battery boxes and even spilling into the hatch. Antenna-like radar reflector helped U.S.S. *Fort Snelling* locate *Trieste*.

equipment for conversation. As we descended, the sea-temperature graph inched downward from the 47° F. reading at the surface. As increasing pressure firmly sealed the door, grease around its rim oozed into the sphere.

The bathyscaph was beginning her descent in earnest. In *Trieste*'s thin-skinned "hull"—actually a series of tanks overhanging the sphere in which we ride—we carry 34,000 gallons of aviation gasoline, a light liquid that compresses much more readily than sea water. As we dive, increasing water pressure squeezes the gasoline, and the ocean itself enters the tanks through an opening in the bottom to replace this lost volume.

In addition to gasoline for buoyancy, we carry metal for ballast—16 tons of small steel pellets stored in two funnel-necked silos. A strong electromagnet at the mouth of each silo acts as a "stopper" to keep the pellets from pouring out. We can drop any desired amount of ballast simply by switching the electromagnets off and on. Should our current fail, all ballast immediately spills out and we surface automatically.

Now sea water flooding up into the tanks is making *Trieste* heavier by 150 pounds a minute. To maintain a steady rate of descent, I valve off steel pellets for a few seconds.

Only a soft twilight filters through the ports; the depth gauge tells me we are just passing 1,000 feet. Surface noise coming through our hull-mounted hydrophones has ceased. We hear only the occasional gurgle of water passing by.

"Conditions normal," I report periodically to Mike Boat, stationed directly above us.

Undersea "Snow" Falls Upward

As we pass 1,800 feet, all traces of sunlight vanish. I switch on our external floodlights. The upward-falling "snow" is a familiar sight. Small bits of organic material and plankton, almost stationary in the water, appear to move upward as we descend, like a winter storm in reverse.

Now the snow streaks past more rapidly. We are moving too fast. As I release more ballast, I can see the mass of steel pellets boil up past us on both sides—we are plunging

downward even faster than the weight we have cut loose. I continue to release the pellets until they fall steadily away and vanish in the darkness below.

As we sink deeper into the abyss, the thought of our mission is always on my mind. What will we find when we reach the bottom, still a mile below? What of the complex theory of massive internal waves, swift currents, and large density discontinuities within this water mass? How will our equipment perform? We will soon know.

Now we are passing 3,000 feet, a third of the way down. Although still at least half an hour from sighting bottom, we check all equipment: motors, lights, closed-circuit television, sonars, magnetometer, ambient noise recorder, radiation sensors—all operating normally. A thorough inspection of the sphere shows no leakage.

"All systems check out perfectly," I report to the surface.

This first descent after overhaul is slower than our normal one and a half knots. Failure of a single fitting can be catastrophic at our depth. We must feel our way down, monitoring instruments constantly, ready to abort the dive by dropping all steel ballast at the slightest sign of malfunction.

We are now halfway down. So far, conditions seem similar to those off the California coast, our normal home. Even the plankton types look familiar.

Animals Dance in Searchlight Glare

At 6,000 feet we see large, red, shrimplike creatures and tiny white animals dancing under the light.

At 11:29, after a 54-minute descent, our echo-sounder graph shows a few small dark streaks—first sign of the bottom, 1,200 feet below. Its true depth, I calculate, is slightly more than 8,400 feet.

Ready to release ballast and come to a stop, I maintain continuous watch at the forward port. I slow our rate of descent. Now the first visual sign of the bottom appears: Our floodlights, reflecting off the light sand-silt, seem to brighten.

As we slowly settle, I pick up more detail—

Where *Thresher* sank. Commander Keach points to the spot on a relief model of the bottom (map, page 782). Rear Adm. Edward C. Stephan, formerly the Navy's Oceanographer, came out of retirement to lead a study of salvage and rescue in deep water. Red yarn from the ocean's glass surface to its bed shows the two *Trieste* dives diagramed at right.

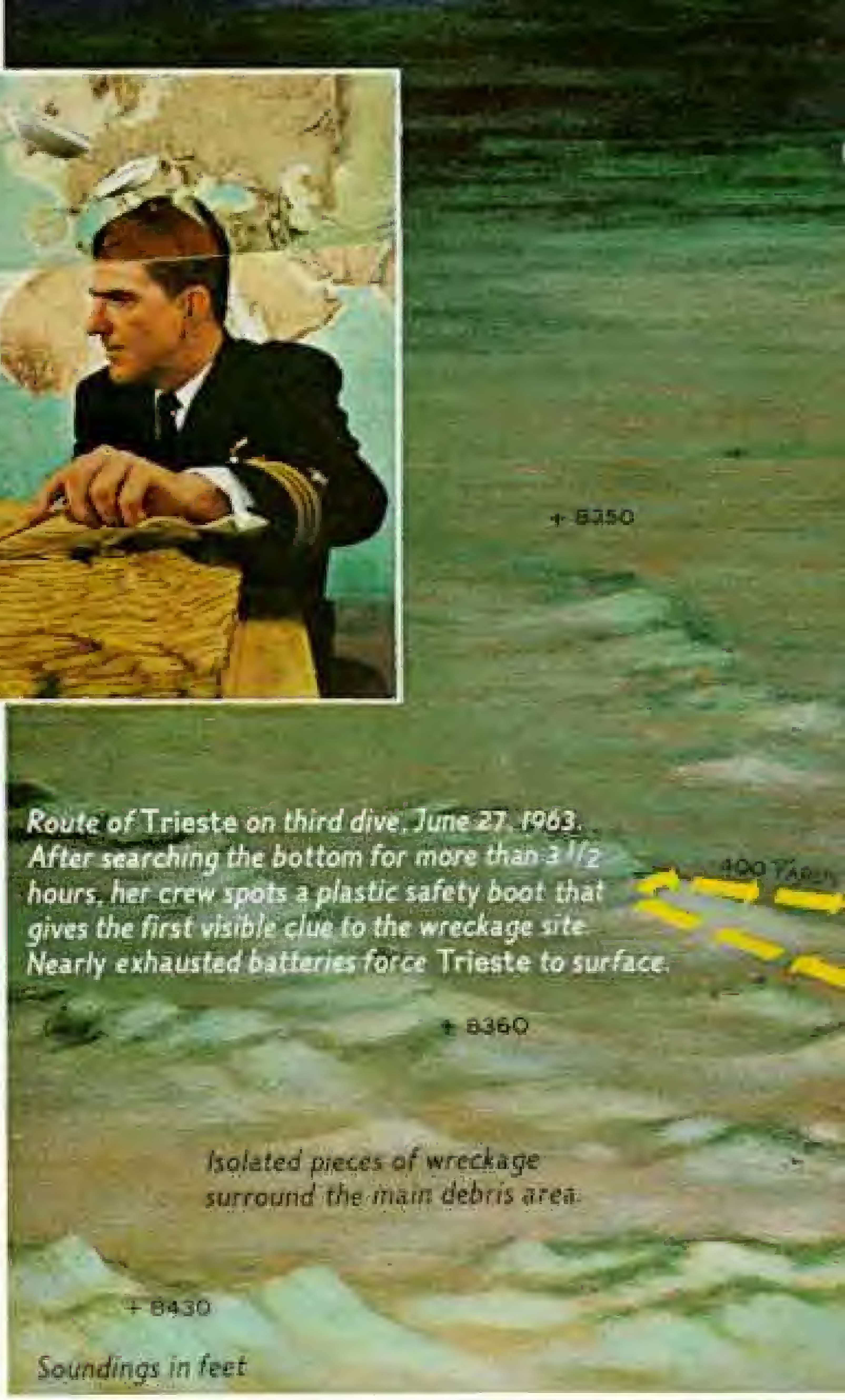


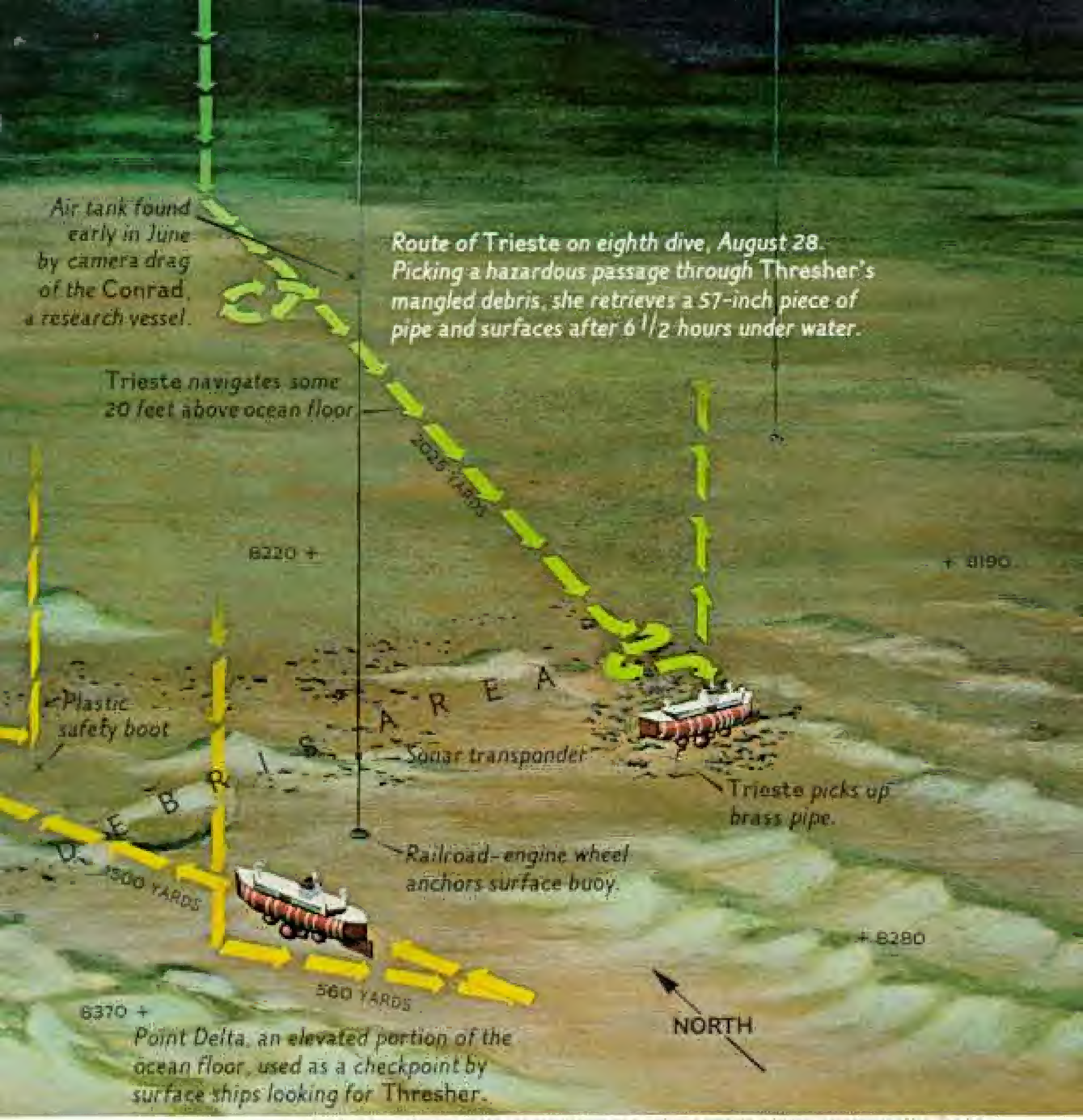
Diagram charts the wreck and two successful dives. Lighter debris, such as paper, cloth, and boot, drifted hundreds of yards. Cables anchored by railroad-engine wheels hold sonar signaling devices designed to guide *Trieste*.

sea urchins, wormholes, starfish—spread out below us on a sandy plain. Our guide weight, a 200-pound steel ball suspended on a cable 35 feet below the hull, touches bottom gently. Relieved of this weight, *Trieste* is now in near-perfect equilibrium; we float gracefully, drifting with a slow southeasterly current. The guide weight drags lightly behind us; electromagnetically fastened to the ship, its cable can be cut loose instantly should the ball become snagged.

"On the bottom, conditions normal," I report to the surface.

Our first look at the ocean floor makes it obvious that *Thresher* is not going to be easy to find. Instead of the smooth, gently sloping topography pictured by surface depth sounders, the relief here can easily hide any number of submarines. Huge boulders and steep ridges frequently obscure the picture on our sonar.

We had planned to search at the relatively safe level of 35 feet. But a dense "cloud layer" of fine organic matter suspended 25 feet above the bottom forces us to cruise lower. From time to time thick patches of these clouds obscure our vision entirely. The bottom current here is gentle, rarely exceeding one-quarter of a knot, but it shifts constantly and forces us to touch bottom occasionally to correct our navigation.



Cautiously probing this vast unknown area, we sight long ridges of loose broken rock jutting incongruously from the sand-silt floor. As a geologist, I am struck by their general north-south orientation. Then a logical explanation occurs to me: Huge glaciers of an ancient ice age could have rafted these quantities of rock far into the Atlantic before melting and dropping their heavy burden.

Sudden sharp echoes ping frequently on our constantly scanning sonar, diverting us to examine some abnormality of the sea floor hundreds of yards away. Each echo disappointingly resolves itself into a steep sediment slope or a high mass of rock.

By 2:30 p.m. our battery voltage is dropping rapidly. It is time to surface.

Although we had seen no sign of *Thresher* during our first four hours submerged, we had accomplished enough.

We had completed a transit to define the eastern limit of the search area. We had found that the rugged bottom ruled out further attempts to locate *Thresher* by surface sonar. We had seen enough firm sediment to make it appear unlikely that *Thresher* could be buried to any extent. We had pieced together a picture of deep currents in the area. And last, but not least, we had shown beyond question that *Trieste* could do more than just dive; she

Bathyscaph window held by Commander Keach offers a wide field of view. This Plexiglas cone resisted pressures of eight tons to the square inch while nearly seven miles deep in the Pacific. A thinner window and gondola were used for the *Thresher* hunt. Eye end fits the small central hole in the gondola's nose; sea pressure and a steel ring hold it tight.

Ripped and flattened in *Thresher's* death throes, a 15-foot section of curved sheet steel that supported the sonar dome, mounted on the vessel's nose, fell to the ocean floor. To it adhere strips of material that absorbed vibration.

could search effectively under a mile and a half of ocean.

Reluctantly I pressed the switch to release ballast and start us toward the surface. As I took a final look at the terrain spread out below, I could not help but feel that it was only a matter of time before we would find the final resting place of *Thresher*.

We rose slowly. The bottom faded away into darkness, and soon the only traces of its presence were the muted chirp of the sonar and a faint gray line spiraling upward on the echo-sounder graph.

Now we could stop manipulating ballast and motors; *Trieste* would carry us to the surface without guidance. Once it begins an ascent, a bathyscaph is committed to surfacing by its design. Gasoline under pressure of nearly two tons per square inch on the bottom expands as this pressure decreases, forcing water out of the tanks at an increasing rate as we rise. Finally we soar toward the surface at about five feet per second.

After nearly six hours of intense concentration, Ken and I could relax our vigil. The dive was not finished, however. We must record every detail of the dive; inspect everything on board; make notes of minor repairs; adjust sensitive equipment for the next dive. A single detail might make the difference between success and failure.

We were completely engrossed in our work when we felt the first slight rocking motion of the ocean swell, at 200 feet. Finally we bobbed to the surface. I could hear the churning propeller of a skiff as it brought our crew aboard.

Shortly afterward we swung the heavy door open and climbed quickly into the warm sunshine. After hours in cramped quarters, it was a welcome change to be able to stand, stretch, and move around.

Crew Readies Vessel for New Dives

Although *Trieste's* dive number 119 was now history, our day's work was far from finished. We had to prepare for the next dive. North Atlantic weather is seldom good for long, and we had to take advantage of fine diving conditions while we could. Although we

PHOTOGRAPHS BY UNITED STATES NAVY (ABOVE) AND KODACHROME BY JOSEPH J. SCHERSCHEL © N.G.S.

had never stayed at sea for a series of dives before, a 630-mile round-trip tow to Boston between descents was out of the question.

We worked around the clock, charging batteries, reballasting, and checking out the vital equipment. With the tremendous assistance of U.S.S. *Preserver,* our mother ship, we conducted four more dives in less than a week, each one further pinpointing the location of *Thresher.*

It was on the fateful third dive that we found the yellow plastic boot and saw our first debris from the sunken submarine.

Piloted by Lt. George Martin, *Trieste* on her fourth dive discovered larger pieces of lightweight metal and even some heavier parts, all badly torn and twisted. For the first time in this dive series, we added a third member to our crew to act as navigator.

The fifth and last dive of the series produced no further important information, and upon its completion we returned to Boston for inspection of *Trieste* and repair of equipment. We also installed additional batteries, to increase our endurance on the bottom, and a "manipulator"—a claw at the end of a long arm to lift objects off the sea floor.

Under tow by *Preserver* and escorted by the U.S.S. *Fort Snelling,* we returned to the dive site in the afternoon of August 18. Weather indications looked marginal. With *Trieste's* freeboard of less than two feet and the amount of work required to rig her for a dive, seas of more than five feet made diving operations hazardous. Our outlook for the immediate future included even higher waves.

In addition, a forecast of poor visibility was discouraging because, with her low silhouette, *Trieste* is extremely difficult to see when she surfaces.

Despite the unfavorable weather, we decided to try a dive. Navy scuba divers managed to rig the underwater cameras despite the pounding men and cameras took from the sea. But waves slopped down the entrance tunnel into the sphere itself, ending the attempt. The crew labored with buckets and sponges to dry out the interior. Finally, after five days, we were able to resume operations.

Our sixth and seventh dives in the area

Early-morning sun slants athwart *Trieste* as she sinks below the waves. A five-foot swell almost hiding the launch at left appears to swamp her. Actually, the boat crew has just opened two water tank vents to start *Trieste* down.

Polyethylene radiation shielding (below) floated to the surface. Holes held cables that apparently shorted during breakup and spewed copper on the plastic. Also found floating above *Thresher's* grave were an oil slick, pieces of cork, rubber gloves, and life-jacket pads.

Watertight compartment door (center) tore from its hinges.

Section from the sonar dome (far right) lies in what the author calls a "vast junkyard" that stretched as far as he could see.

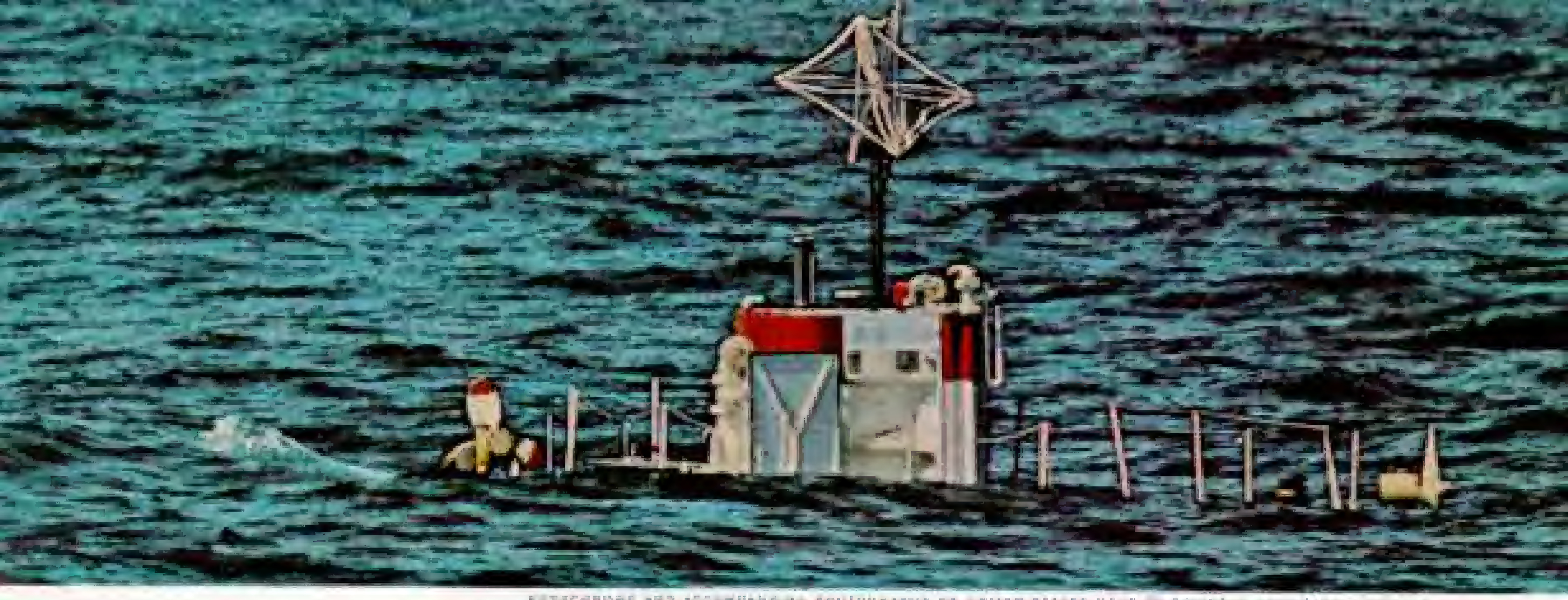
Halosaurid fish (below) with a ribbonlike tail cruises the bottom under *Trieste's* lights. Such fish, the author reports, were several feet long.

further delineated the boundaries within which *Thresher* must lie, but no debris was sighted. During the period *Trieste* was undergoing inspection, a simple but effective means of bottom positioning had been put into effect. Surface vessels had dropped more than 1,400 large-numbered plastic markers to the bottom at spaced intervals. This network of markers crisscrossed the debris area and enabled us to cover the sea floor more methodically on subsequent dives—even though most of the markers failed to unfold into legibility.

With the autumn gales rapidly approaching, we knew time was running out. We had already been through seas of 15 to 20 feet and had almost been forced to leave the area by hurricane Beulah. The high seas had made their mark on *Trieste*. With her decks awash under the best of conditions and her batteries, wiring, and most equipment fully exposed to the elements, she was taking a terrific beating. Although some repairs could be made at sea, our badly damaged battery boxes could not be repaired and would not last much longer.

On the eighth dive I was accompanied by Comdr. James W. Davies, an oceanographer, and Lt. Comdr. Arthur Gilmore, a submariner familiar with *Thresher*. Upon reaching bottom, we immediately spotted a "fortune cookie"—one of our plastic markers. Following the search plan to cover areas adjoining those of our previous dives, we cruised slowly over the bottom (diagram, pages 770-71).

After three hours on our southerly leg, investigating each unusual echo that showed up on our sonar, we were close to the turning point when I began to recognize some peculiarities of the sea floor.



KODACHROME AND ACCOMPANYING PHOTOGRAPHS BY UNITED STATES NAVY © NATIONAL GEOGRAPHIC SOCIETY

"This looks familiar," I said to the others. "We must be close."

The sea urchins here were slightly smaller and more numerous than those in other areas. Here and there we could see faint, odd-shaped flecks and little mounds of unnatural-looking sediment. Closing the bottom for a better look, I could just make out the same type of tiny particles of paint and paper I had seen on dive number three. With at least an hour of battery capacity left, I felt certain we would find the sub.

Bathyscaph Probes *Thresher's* Grave

Cautiously we moved ahead, exploring each depression and hill, each slight deviation shown by our equipment. Within minutes we were in the midst of enormous masses of torn, twisted wreckage of all sizes and shapes. Battery plates, lead ballast, shredded cables, sections of superstructure—the bottom was a mass of debris everywhere we looked.

There could be no question—this was *Thresher*. I pointed out one large plate to Art Gilmore. We could read the numbers "0," "3," and "4" on it.

"It's a bow section," he said. "Those are her 20-, 23-, and 24-foot draft marks."

We moved slowly through this field of metal, recording with our automatic cameras as much as possible.

I maneuvered *Trieste* carefully now, hands constantly on the switches, cutting her propulsion motors off and on. It would not do to become entangled in a piece of this heavy wreckage (below and pages 772-3).

Before us a mass of twisted metal loomed so high it vanished into the cloud layers overhead. I dropped about 60 pounds of steel ballast and brought the bathyscaph up gently, seeking the top of the pile. Sonar told us it lay hidden somewhere in the cloud. I valved off gasoline for 30 seconds to descend again. It would be safer to go around this mass of debris than to try to leapfrog it and come down perhaps on something else.

Below 20 feet in this area our sonars and magnetometer were useless, distorted by large pieces of metal everywhere, and blanked out by a maze of returns.

We were silent. It was a strange, sad sight—this once-proud submarine lying mangled and scattered on the sea floor. Already patches of reddish brown were visible on the dark-gray paint; rust had set in. Sea urchins and strange deep-water halosaurid fish (opposite), several feet long, had found homes amid the wreckage.

Again our batteries were running low; we would have to surface soon.

While we still could maneuver, I decided to retrieve some part of *Thresher* for surface

Cramped bathynauts sit hemmed in by batteries, echo sounder, gyroscope, TV, and controls. Lt. George W. Martin (left) telephones the surface; Commander Keach checks the sonar. Camera with 180-degree lens took the picture.

Rebuilt and refurbished after her Atlantic dives, *Trieste* rises from her pads for launching at San Diego, California, on January 17, 1964. Commander Keach's wife Betty christened the old-new craft with a Nansen bottle, which brings up samples of ocean water from the depths. *Trieste II* retains only the gondola of the earlier model. Sturdier and more powerful, she cruises at two knots—double her old speed.

analysis. I landed *Trieste* in a clear area alongside a section of twisted pipe about five feet long (page 760).

Our newly installed manipulator was designed to perform the functions of a human arm with a claw, wrist, elbow, and shoulder joint, each controlled by a separate electric motor.

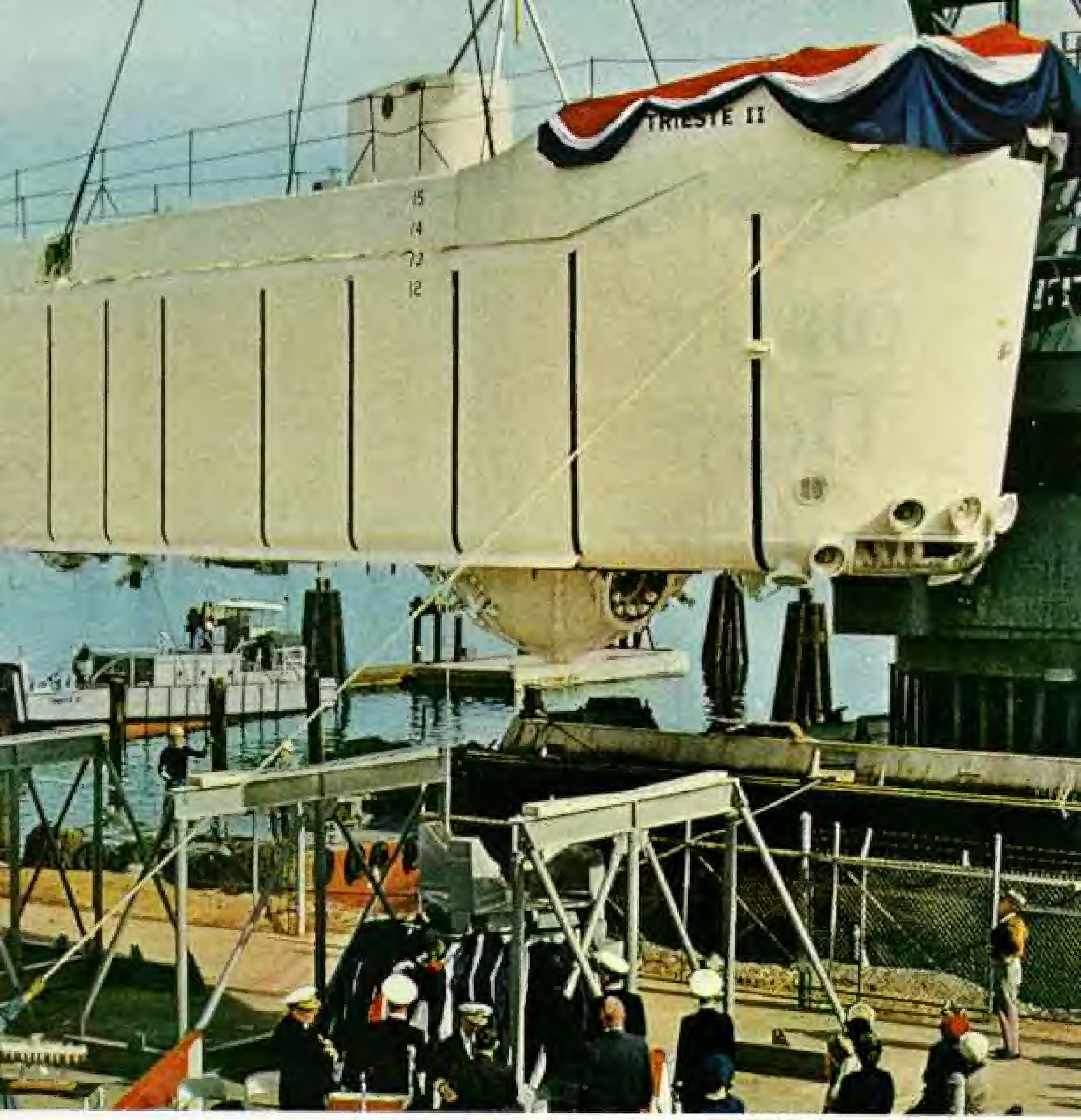
"Arthritis" Strikes Mechanical Hand

With one hand I switched propulsion motors on and off to hold the craft delicately into the current. With the other I worked the manipulator's bank of seven switches, somewhat like playing an organ console.

Lowering, raising, twisting, grasping—for fifteen minutes I attempted the pickup. Each time the claw gripped the pipe, it failed to hold. It seemed to have arthritis. Finally I managed to slide the elbow of the device under a crook in the pipe (page 764). I raised my catch gently until the arm held it against the forward metal-ballast silo.

Trieste's power was almost exhausted as we headed slowly for the surface. With our sonars blanked out by mounds of metal, the only effective method of scanning here was through the viewport, and it would take days to see all of *Thresher* visually.

Scuba divers retrieved the twisted pipe as soon as we surfaced. Close examination showed a scratched shipyard code marking—



"593 Boat"—that provided final identification.

After months of back-breaking effort, we had found her. And not a moment too soon, for the storm season was almost upon us. After just two more dives our badly damaged battery compartments finally failed; we were forced to halt operations.

New *Trieste* Will Carry On

Trieste's search for *Thresher* was her first operational mission. Previously our efforts had been dedicated entirely to research and development.

In her 70 research dives for the U. S. Navy she had gathered valuable basic knowledge about the ocean's depths. Her ten dives as a search vessel brought new and different problems. Search techniques, navigation, power, all must be improved.

A new *Trieste* (above), built and launched over this past fall and winter, will take up our task. Bigger, better powered, and carrying more advanced instrumentation, the bathyscaph is scheduled to conduct a series of research dives in the same Atlantic area as her predecessor. Perhaps in the process she will give us a clearer picture of the causes of the *Thresher* disaster.

I wish her a long and useful life, for without question she will ultimately shed more light on an even greater, older mystery—the bottom of the sea itself. * * *

Tomorrow on the Deep Frontier

By EDWIN A. LINK

The wet world—three-quarters of our planet—awaits us. A pioneer of the depths describes our exciting future undersea.

THE SINKING of the *Thresher* sent out ever-widening ripples—ripples that will not be stilled. This disaster changed the course of our study of the ocean, greatly increased its impetus, and dramatized the need for a new science: oceanology.

Oceanology is a recently coined term. It embraces both the established fields of oceanography—the understanding of the seas—and the challenging new field of ocean engineering—their use.

Ripples from the lost submarine reached me in Monaco harbor. I had just docked my research ship *Sea Diver* after a two-week cruise when I saw my friend Rear Adm. Charles Pierce, director of the International Hydrographic Bureau in Monte Carlo, pacing the pier. A veteran of the U. S. Coast and Geodetic Survey, he bore urgent news.

"Admiral Stephan has been trying to reach you from Washington. He wants you on the phone right away."

I was puzzled—and intrigued. Rear Adm. E. C. Stephan then headed the United States Navy Oceanographic Office. Could his urgent call concern the *Thresher*? Aboard *Sea Diver*

Crewmen of a disabled nuclear giant scramble to safety aboard a miniature submarine, a technique proposed by the U. S. Navy's Deep Submer-

gence Systems Review Group (DSSRG) for lifesaving at depths now unattainable. Searchlight ablaze, another rescue craft awaits its turn to lock onto the escape hatch. Two nuclear subs hover to receive the men. DSSRG hopes to use these small submersibles to depths of 6,000 feet in two years.

we had followed daily radio reports of the search. Everyone aboard had been speculating about the possibility of finding the sub. I hurried to a telephone.

"Ed," Admiral Stephan said, "I need your help on a big job I've just been given." The Secretary of the Navy, he explained, had appointed him chairman of a high-level group to study the Navy's undersea capabilities in the light of the *Thresher* disaster, and to recommend what should be done to strengthen them. Would I come to Washington immediately to act as consultant?

It was a compelling challenge. But I had plans to head for Bermuda to continue work on the deep-diving experiments I had begun off Villefranche the previous fall. Moreover, it would take at least three weeks to cross the Atlantic in *Sea Diver*, and I had no one other than myself to pilot her. But the admiral was insistent; finally I agreed to fly to Washington the next day to discuss his plans.

When I arrived, I found Admiral Stephan already had recruited about 20 of the country's best oceanographers, engineers, and naval personnel—all specialists in some form of undersea work. I could not turn down the opportunity to work with them.

Oceanology Can Change Our World

Besides, I could see without much convincing from the admiral that such a program would have far-reaching importance—not only to the Navy but far beyond.

In the near future, for example, we may be considering a "Dew Line" of acoustic warning stations in the ocean. There is already speculation about underwater installation along the mid-Atlantic ridge. In addition, mobile, bottom-hugging equipment may be used to establish control of suspected submarine routes. Neither of these advances is beyond the predictable state of technology. We are entering an era in which submerged military operations can more nearly resemble their counterparts on land.

This new era is coming, also, to nonmilitary uses of the sea. Indeed, a determined program of oceanology could change our world by focusing attention on the huge resources of the sea and by pointing the way toward their use.

The Author: Edwin A. Link, renowned aircraft pioneer, inventor of the Link Trainer, and industrialist, turned his talents to the sea after retiring as president of General Precision Equipment Corporation in 1959. He outlined his approach to the ocean and its problems in "Our Man-in-Sea Project," NATIONAL GEOGRAPHIC, May, 1963.

Steinke hood, attached to an air-filled life jacket, allows a submariner to breathe normally during a 100-foot ascent in a training tank in New London. Tank director Lt. Comdr. Harris Steinke used his wife's sewing machine to stitch the first hood. The Navy has tested his device down to 350 feet.

Buoyant life jacket pulls a man to the surface in the older free-ascent method. He must exhale slowly as he rises lest expanding air rupture his lungs. Nose clip restrains the urge to inhale.

It is a commonplace of fourth-grade geography that almost three-quarters of our planet lies beneath the oceans. And yet, phrased another way, the fact is startling: almost three-quarters of our planet is virtually unexplored; almost three-quarters of our planet is virtually unused. And this in a world afflicted with poverty and overpopulation!

Beneath the waves are food, minerals, and fuels beyond count. For example, about four-

fifths of all life on earth exists in salt water. Yet man remains, in this realm, on a par with the aborigines. We are simple hunters of the sea, rather than farmers. Our best estimate is that some 490 billion pounds of fish could be harvested each year without harming the "flocks." That is five times the world's present catch. We clearly need better fishing methods and better knowledge of the conditions that increase fish life.

Some minerals already are being taken from the bottom of the sea: tin off Thailand, magnetite off Japan, diamonds off South-West Africa. Sea water itself contains some 60 dissolved elements—most at present too expensive to extract.

And the sea contains in abundance the most obvious treasure of all—water. Not only salt water, which the world is working hard to turn fresh, but subsea springs of fresh wa-


Labrador
Newfoundland
St. John's
Canadian Shield
Gaspé Peninsula
Prince Edward I.
Cape Breton Island
St. Pierre Bank
Continental Shelf
Grand Bank
Sable Bank
Nova Scotia
Halifax
Saint John
Browns Bank
Site of sunken Thresher
Quebec
Montreal
Portland
Boston
Cape Cod
Georges Bank
New London
Long Island
New York
Philadelphia
Baltimore
Washington
Norfolk
Cape Hatteras
Wilmington
Charleston
Savannah
Jacksonville
Appalachian Mts.
Coastal Plain
Continental Shelf
NORTH ATLANTIC OCEAN
New England Seamount Chain
Kelvin Seamount
Hudson Canyon
NORTH AMERICAN BASIN
Muir Seamount
Bermuda Islands
BLAKE TERRACE
Cape Kennedy
Florida
Tampa
Miami
Florida Keys
Key West
GULF OF MEXICO
Bahama Islands
Little Bahama Bank
Nassau
Great Bahama Bank
Cuba
Havana
Guantánamo
Hispaniola
Port au Prince
Santo Domingo
Pico Duarte
Jamaica
Kingston
CAYMAN TRENCH
YUCATAN BASIN
CARIBBEAN SEA
Rangoon
Bangkok
Medan
Soundings and elevations in feet

Continental shelves offer a "new continent"

If man could work freely on the continental shelves (light areas surrounding the land masses), he would add to his realm an area nearly equal to Africa. They offer known reserves of oil, tin, diamonds, and other riches yet to be developed. Exploitation of these shelves requires the ability to conquer the ocean to a depth of 600 feet—the object of many experiments now under way.

Continental slopes, abrupt drop-offs into the deeps, mark the end of the shelves. The North American shelf shows canyons (like the Hudson's) where rivers or mudflows have cascaded down the slope for millenniums. Southeast Asia's shelf links Borneo, Java, Sumatra, and the Philippines to the mainland. The European shelf surrounds the British Isles.

ter on the continental shelves. Thirsts of increasing populations are sure to turn, sooner or later, to the "last water hole." We must know more about these possibilities.

Another vital fluid, petroleum, is already being wrested from beneath shallower parts of the ocean. As these easily worked deposits dry up, however, we will have to go to depths now impractical.

Hurricanes May Be Tamed

It seems a "far-out" idea now, but if we can learn enough, and work enough, under the sea, we might be able to modify the weather. For example, some scientists now believe that the formation of hurricanes is associated with high surface temperatures. Yet close by, beneath the surface, is a virtually limitless supply of cooler water. It might be possible, someday, to construct underwater baffles, or perhaps dams on the bottom, to deflect cooler water upward, thus eliminating a cause of hurricanes. Other subsurface dams, set across powerful currents, could produce electricity.

Already under discussion is an engineering project which envisions siphoning of deep, cold waters into warmer upper layers off our southern coasts. This would simulate the upwelling action so essential to high productivity of fish. Another concept calls for altering the temperature balance in northern latitudes to melt heavy ice that impedes navigation.

After discussing the possibilities with Admiral Stephan, I was eager to get to work. I postponed my own research and signed on with the admiral's Deep Submergence Systems Review Group (DSSRG) as soon as I could sail *Sea Diver* to a closer base in Bermuda.

Each member of the review group felt he had an opportunity to assist in guiding a program of tremendous scope and importance to our nation—in war or peace.

The DSSRG report is a classified document because of its material on nuclear submarines, but I can tell the Society's members some of the things we learned and our basic recommendations.

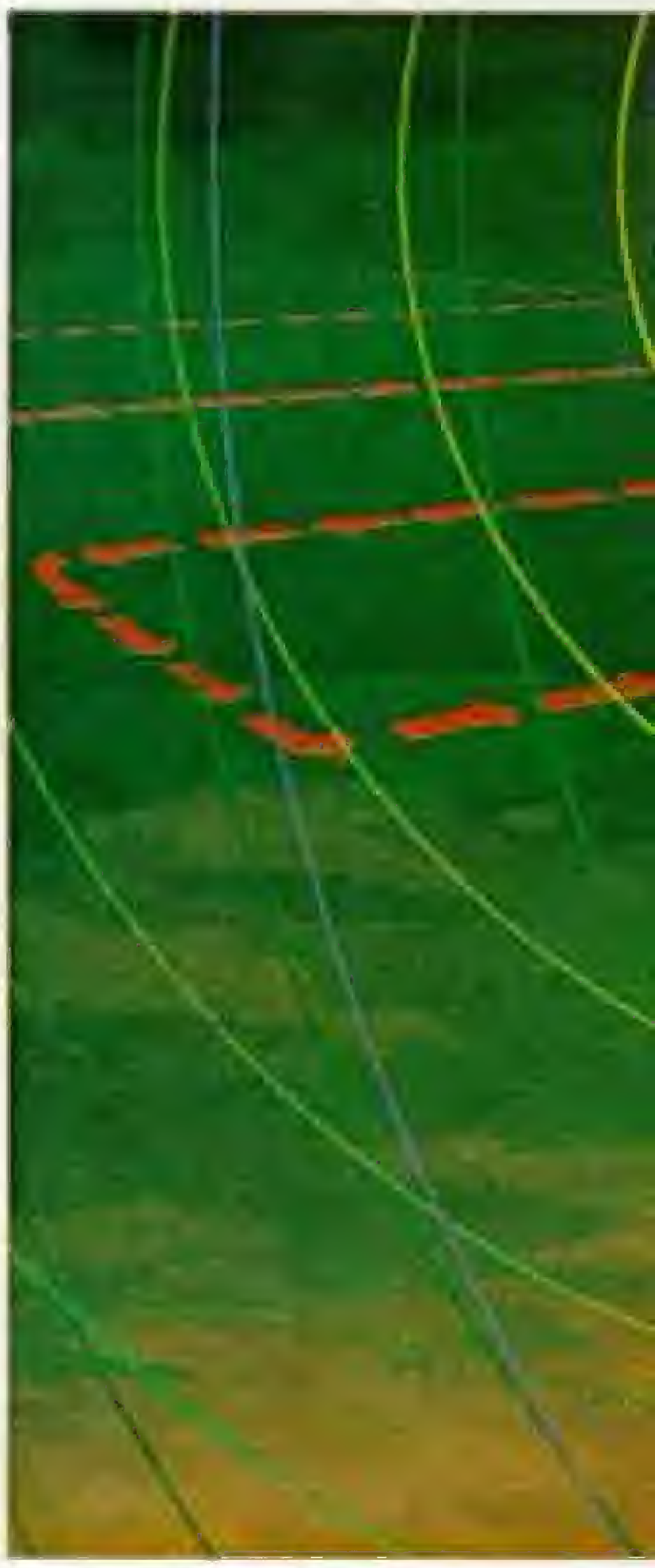
Although future civilian uses glittered in

Divers Tap an Oil Field Beyond the Reach of Surface Drillers

Artist Pierre Mion translates scientists' vision of the future: drillers at work perhaps 600 feet deep on the continental shelf. Workers with torches paddle past streets marked by reflectors. Rubber

balloons hoist 120-foot drill pipes controlled by winch operators in Link-designed igloos (cutaway, extreme left). Off-duty men relax in oxygen-and-helium-filled Link houses (cutaway, left). Navy's projected deep-rescue vehicle (above), adapted for civilian use, delivers a heavy pipe slung from a 2,000-pound buoyant tank of gas. Main pipeline crosses a submarine plateau to shore.

Sonic boomer lets scientists "see" through the bottom. Every ten seconds two circular metal plates spring violently apart, forming a vacuum that creates a "smoke ring" of bubbles. At the same time a sound pulse is sent out. It penetrates water, then sediments, rebounds off underlying rock, and returns to shipboard, giving a continuous profile of both bottom and sub-bottom. Through the viewing port, Dr. Harold E. Edgerton watches his invention under test in a tank in Boston.



the backs of our minds, we turned first to the military, as is proper for a Navy group.

Early in our work, after briefings from officers directing the *Thresher* search, we became aware of how badly the development of the seas had been neglected. Deep diving, salvage, and rescue techniques had scarcely changed in 25 years. Nuclear subs were routinely using depths far beyond our abilities in search and rescue.

New Methods Will Find Subs

If *Thresher* had sunk in less water than would crush her, her crewmen could have lived on inside the hull for months—in a world unable to save them from a prolonged and hopeless end.

But even before rescue could be considered, there was the immense problem of locating the lost sub, as told in the two preceding articles. If *Thresher* had been equipped with a "sonar transponder" which would answer a search craft's sonar with a sound pulse of its own, it would have been simpler to locate her. A distress buoy that would rise to the surface and send an SOS would have brought help in a hurry. Our group recommends that in the future all submarines carry both.

We deliberated long about the relative merits of towing search instruments from surface ships (which had proved so frustrating in the *Thresher* search) or sending down an untethered vehicle, manned or unmanned, which could be accurately maneuvered at the bottom. It would need much greater range than any existing bathyscaph. Although some group members still incline to towed instruments, the majority decided on the manned vehicle. No adequate model of one exists at the moment, although there are some approaches to it under construction.

Finding a hull is one thing, rescuing men from it quite another. The best device we have now is an eight-man diving bell called the McCann cylinder, which winches itself down from the surface on a cable to the disabled sub. It must be sealed to the sub's escape hatch—a feat that often requires diver assistance. Since about 500 feet is the emergency limit for Navy divers, this depth is the limit for the McCann when divers are used.

So for rescue as well as search, we decided a deep-diving submersible is needed. We plan a small, multipurpose vehicle that can work to 6,000 feet—and we hope to see it in the water within two years.

Navy's proposed search craft hunts a lost sub with sonar waves. Beginning the operation, aircraft or ships drop three red sonar buoys so that their signals overlap. Guided by the beams' intersection, the submariners know their precise location every moment and can steer a rectangular search pattern (red arrows). Blue rings from search craft symbolize sonar waves probing out in broadening circles. She cruises close to the bottom, most effective position for her sonars. Disabled sub lies at right.

This craft can be built with today's technology, but we are also looking ahead. In contrast to the steel or aluminum pressure sphere of the 6,000-foot model, the next step calls for a stronger, lighter material, perhaps titanium or a special glass. A titanium sphere theoretically could reach 20,000 feet—but so far no one has ever worked this metal into pieces as large as we would need. Nevertheless, we feel the problems can be solved quickly enough to give us our 20,000-foot model two years after the shallower craft.

The submersible we recommend would be small so that it could be rushed to a rescue scene by cargo airplane, aboard small Navy ships or ordinary fishing trawlers, or even carried pickaback on a nuclear sub. Its entrance hatch would be on the bottom for two reasons: to avoid swamping while on the surface, and to allow it to latch onto a submarine's escape hatch. Crewmen could enter the vehicle before or after it was put in the water. Air pressure would prevent flooding of the interior when men entered from beneath the surface of the sea (pages 778-9).

Not only could the little submersible bring disaster victims to the surface; it could transfer crewmen from one submarine to another —a vital ability in rough seas, under ice, or in time of war.

Craft Will Use New Power Sources

The first 6,000-foot model, like World War II subs, would be powered by electric batteries. Later we hope for other means of propulsion. Among those being considered are a small nuclear reactor, an engine powered by hydrogen peroxide or other chemicals, and a system of batterylike fuel cells such as those being developed for Gemini and Apollo spacecraft.

We recommend a sphere for the pressure hull because it is the strongest shape possible. It would be eight feet in diameter and weigh about 10 to 15 tons. Such a vessel could rescue between 12 and 16 men each trip. Used as a

Oil! Hard-hat Diver 240 Feet Under the Sea Completes a Wellhead

A fish flits by as Lad Handelman, breathing an oxygen-helium mixture to avoid nitrogen narcosis, plies a wrench for General Offshore Divers, Inc., of Santa Barbara, California. His firm has brought in seven new wells at about 250 feet. Fellow diver Jon M. Lindbergh, son of famed flyer Charles A. Lindbergh who made the first solo flight across the Atlantic in 1927, took this extraordinary photograph.

search craft, it could carry all the necessary electronic equipment and a crew of three or four. Or it could be fitted with mechanical arms carrying tools for salvage or other work at depths divers cannot now reach. If pressurized, it could allow a diving crew to swim out and work in the depths, then return safely in their sphere to the surface for decompression.

While we were (we hoped!) planning an ideal search-rescue-work boat for the Navy, we constantly kept in mind the civilian uses it would have. In a sense, military uses may depend on the civilian. Rescue from a sub is needed perhaps once in several decades, and cost-minded men might claim elaborate gear for such an unlikely eventuality is too expensive. Further, even highly trained crews can get rusty sitting around waiting for a job. The Navy doubtless will use its prime submersible for work outside the military field.

Economies in constructing copies of a Navy-built prototype should put the vehicles within reach of all underwater agencies. They would carry crews for exploration and research, mining, oil prospecting and drilling, fishing, aquaculture, and salvage.

These special subs, however ingenious, are not the sole answer to escape from the depths. Time is needed to locate a damaged vessel; rescuing the entire crew in loads of 12 to 16 is a long process; and sealing and resealing a rescue hatch at high pressure is difficult. If there were a leak in the disabled hull, some or all of the crew could drown before rescue was completed. It might be necessary for them to leave the disabled sub immediately.

Actually submariners have long been trained in techniques for individual escape through hatches. Formerly they wore the Momsen lung, a face mask that traps exhaled air for re-use. Now they wear the Steinke hood, a rubber sack that fits over the head and works on the same principle (page 780).

Both are effective only in relatively shallow water—the lung to 100 feet and the hood to some 350 feet. Perhaps these depths can be

Divers work and relax in oxygen-helium chambers, staying down for weeks if necessary to avoid long delays caused by decompression when surfacing. Mr. Link's work shed, the rubber igloo at left, rests its open base on the ocean floor; a trough allows men to enter. His house for men off duty holds bunks, chair, table, diving suits. Gas pressure inside both chambers equals the water pressure outside, since they are open to the sea.

On the sea's mud floor, an arc welder in the igloo joins underwater piping.

extended. Capt. George F. Bond of the Naval Medical Research Laboratory has made a free ascent from more than 320 feet, wearing only a face mask and a life vest. He believes that with a hood, and by breathing mixed gases instead of air, ascent could be made from considerably greater depths.

Even so, this method would not be usable at the operating depths of nuclear submarines. Moreover, individual escape leaves the crewmen on the surface, facing the problems of survival until rescue comes.

A radically different system, which I proposed to the DSSRG, would overcome this difficulty. I suggested we add a kind of life raft to submarines. Mounted in streamlined pods on the hull, these rubber craft, when inflated, would enclose submariners like cocoons and carry them to the surface at a carefully controlled decompression rate. Once on top, the cocoons would convert into life rafts, offering shelter and provisions until help could come (pages 792-3).

One of the prime requirements of our proposed rescue subs would be the ability to navigate accurately along the bottom. Surface ships and aircraft are expected to make errors of a mile or so in their navigation, but underwater search craft must come as close as ten feet to submerged objects for visual or camera examination.

Radio and celestial navigation cannot be used under the sea—and are not accurate enough even if they could be used. The only surface navigational tools adaptable to the depths are the magnetic compass and the gyrocompass. The underwater navigator is almost as handicapped as Columbus when he set out for the Indies.

We have recommended newer systems, including special sonar and inertial and Doppler instruments. So far, sonar navigation—sending out high-frequency sound waves and listening for echoes—has proved most accurate. Its chief handicaps are its short range and the possibility of misleading echoes from

Sea igloo enters its element. Designer Link and diver Robert Stenuit guide the inflated house into the water at Key West.

large undersea features such as rock outcrops and mountains.

During a search, the sonar system would include buoys anchored in a pattern perhaps 200 feet off the bottom. When the search craft sent out a "ping" of sound, each buoy would answer "pong," and the searcher would know his location by the differences in time and direction of the pings and the pongs.

An inertial guidance system depends on gyroscopes, is expensive, difficult to maintain, and requires constant correction in a slow-moving craft over a long period of time. However, it is the only satisfactory method near the North and South Poles, where an ordinary compass is useless.

Similar to sonar is the Doppler system—already in use on many airplanes and in tracking far-flying spacecraft. The vessel would bounce a sound signal off the bottom, record changes in the frequency of the returning sound waves, and thus determine forward speed and sideways drift. Combined with a good compass, this system would provide dependable navigational information.

New search methods, too, are needed. The DSSRG recommends development of better magnetometers, new visual techniques that might reduce back-scatter of light, perhaps the use of blue-green lasers to pierce the waters with light. Better sonars and electrical potential instruments could be used to advantage. The search craft could even look for objects sunk in the mud by use of the sediment-probing "boomer" (page 786).

Given our new craft, equipped with mechanical arms for work in the depths, could we raise from the bottom the hulk of a submarine or other ship? In shallow water, yes, but no method we know of would be practical beyond the depths at which divers can work.

To lift a submarine the size of *Thresher*, for example, might require some 200 steel cables. Surface storms or varying currents would play havoc with the complex of cables.

Attaching pontoons—either rigid or in-

Limp Link igloo swings above *Sea Diver's* deck at the Key West Naval Station. Bottles of compressed air at left will inflate the rubber house. Lead weights placed in the circular yellow collar will hold the balloonlike structure to the bottom. In March, 1964, Mr. Link was able to walk dry on the sea bottom in the air-filled igloo at a depth of 30 feet.

KODACHROMES BY NATIONAL GEOGRAPHIC PHOTOGRAPHER BATES LITTLEHALES © N.G.S.

Balloonlike Lifeboats Rescue a Crew: the Author's Proposal

DSSRG's report includes illustrations and descriptions of a "possible method of escape" recommended by Edwin A. Link and adapted from his underwater tent (page 789).

"The system is built around a rubber, inflatable, balloonlike bag which will accommodate 22 people," Mr. Link writes. Such bags would be stored in containers set into the submarine's deck surface. "When needed, the bags would be inflated ... with a high-pressure helium and oxygen mixture.... Crew members ... would be issued ... scuba-type survival apparatus to wear in making a quick transfer...." Final stage: a leisurely trip to the surface by paying out the cable to the sub.

On the surface, pontoons inflate, turning the bags into rafts. Snug survivors radio for help.

PAINTINGS BY PIERRE MION © N.G.S.

flatable—at such depths would present another web of problems. *Thresher*, for example, might require as many pontoons as cables—perhaps 200. When the sunken hull became buoyant, it might pop to the surface with such speed that the pontoons would smash or spill their air—and the wreck would plunge again.

Our group pondered, too, the possibilities of using a specially equipped surface ship for hoisting large objects. We found there is no vessel in existence that meets the requirements. To build one, or adapt an existing hull, would be extremely expensive.

Men Must Work in the Depths

Much of what we would like to do in the depths is dependent upon the ability of man to live there for long periods, venturing forth from his pressurized vehicle or undersea home to perform useful work. Achieving this is my own special interest, toward which I have been experimenting for years with the financial assistance of the National Geographic Society.

It is slow, step-by-step work keyed to experiments with the gases men must breathe under deep-water pressures.

Air consists of about 21 percent oxygen, 78 percent nitrogen, and one percent other gases. Under high pressure this nitrogen becomes narcotic. It makes a diver "drunk" and robs him of self-control. So in the depths we must use a mixture of helium and oxygen.

In 1957 at New London, Dr. George Bond and his associates began experiments that exposed animals to deep pressures for long periods. They breathed a helium-oxygen mix. Eventually the team successfully kept goats at a 200-foot pressure for two weeks.

Navy requirements postponed the continuation of the work with humans at that time. So we aboard *Sea Diver* took up the task. In 1962, our diver Robert Stenuit lived 200 feet under the sea for 24 hours, swimming out of his pressurized open-bottomed cylinder to work, returning to eat and sleep.*

Emboldened, we continued our experiments, using animals—including mice and a goat—in pressure chambers.

Meanwhile, Hannes Keller, a Swiss mathematician, had astonished the world with superdeep dives while breathing secret gas mixtures. In June of 1961, accompanied by Kenneth MacLeish, now an Assistant Editor of NATIONAL GEOGRAPHIC, he descended on an open, elevatorlike platform to 728 feet—then the world's record depth—in Italy's Lake Maggiore.

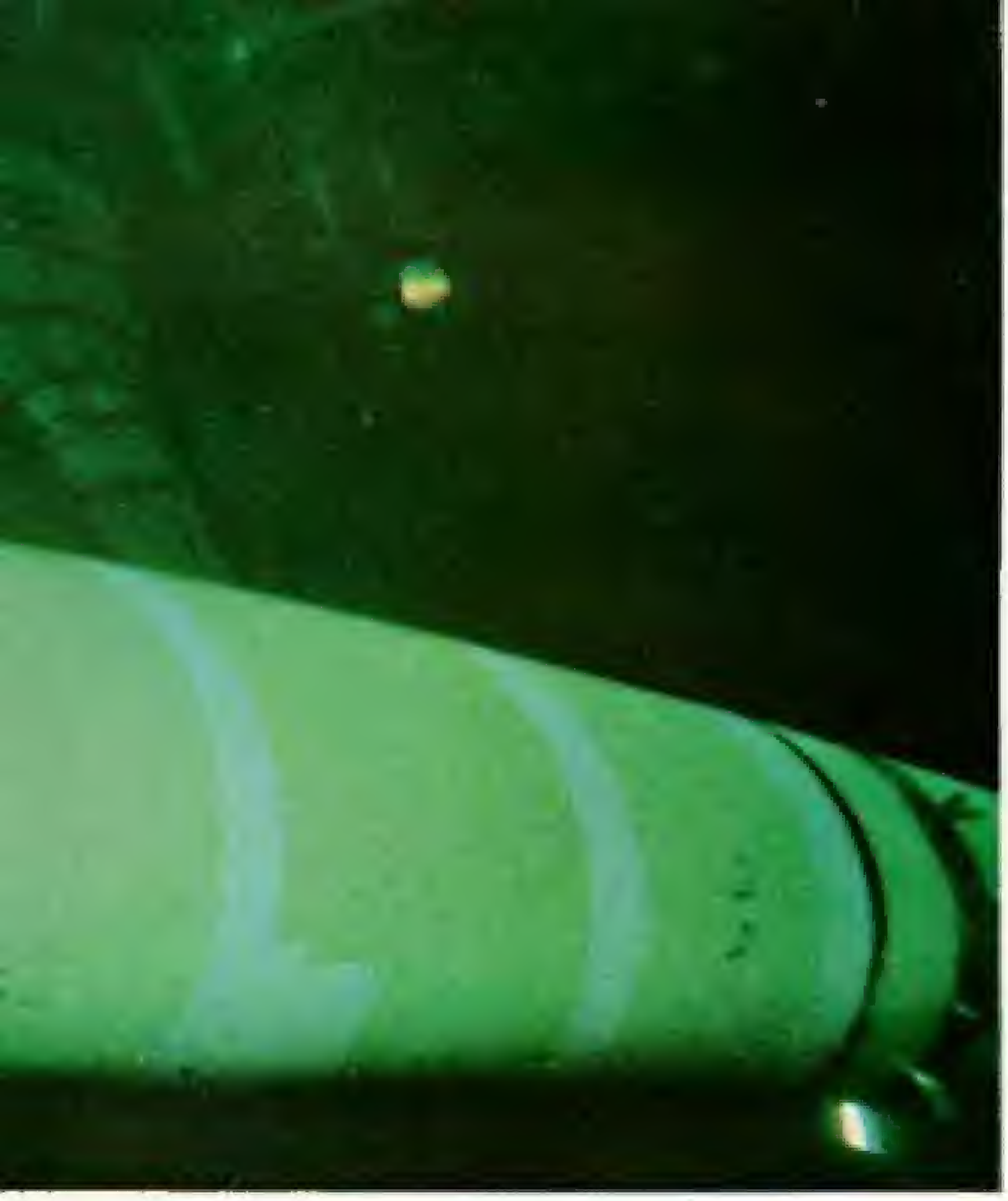
When Stenuit completed his 200-foot sustained dive, Keller was planning a 1,000-foot "bounce dive"—down and up with about a three-minute stay at the bottom. In December, 1962, near Santa Catalina Island, he succeeded, but in a series of unfortunate accidents a companion and a supporting diver died.

Since Keller survived at 1,000 feet, how deep *could* we air-breathing animals go? I determined to find out. Between sessions of

*See "The Long, Deep Dive," by Lord Kilbracken, NATIONAL GEOGRAPHIC, May, 1963.

Tandem propeller submarine undergoes tests in the Navy's David Taylor Model Basin at Carderock, Maryland. This 18-foot model wraps twin propellers around the nose and tail of the hull; adjustable blades controlled by the operator resemble spikes on a dog's collar. Comdr. Frederick R. Haselton, Jr., the designer (at right above sub), built the prototype in his cellar and tested it in a bathtub. He says the craft can hover, turn around on a dime, and even stand on its tail.

One of several small submarines privately developed for civilian use, this Perry Cubmarine cruised down to 600 feet last February. Biologists will use it to study fish. The 22-foot, two-man battery-driven craft can be hauled on an automobile trailer. Here it brings a nondiving engineer (seen in porthole) to direct a diver working on a communications cable. Dark object under hull is a 112-pound guide weight which allows the craft to "moor" just above the sea floor.



First submarine to fly the Atlantic, Capt. Jacques-Yves Cousteau's diving saucer lands in California. It carried scientists of the Scripps Institution down to sea canyons off La Jolla. The craft was built in France with National Geographic Society support.

the DSSRG, I bought white mice from a pet store and placed them in a tiny pressure chamber I designed. Its walls were strong enough to take the mice "down" to at least 3,000 feet. All opinion held that the mice would be dead long before any such pressures were reached.

But we successfully exposed 18 mice to pressures they would experience at a 2,000-foot depth. At this extreme our subjects could be seen acting normally, performing on the exercise wheel, eating, and constantly washing their already white coats with agile feet.

Mice Survive 4,000-Foot Pressure

We had completed a very interesting experiment—but we certainly had not answered the question: How far could we go? So I tried taking three mice as far as possible. At the maximum—3,000 feet—one convulsed and died. Some unknown effect of the rapid pressure change killed him. But two mice lived!

After careful decompression, they were as frisky as their unpressurized brothers and could only be told from them by red dots we had painted on their hindquarters. Today it seems possible that with proper precautions, man, too, might live and work at depths as great as 3,000 feet—maybe more.

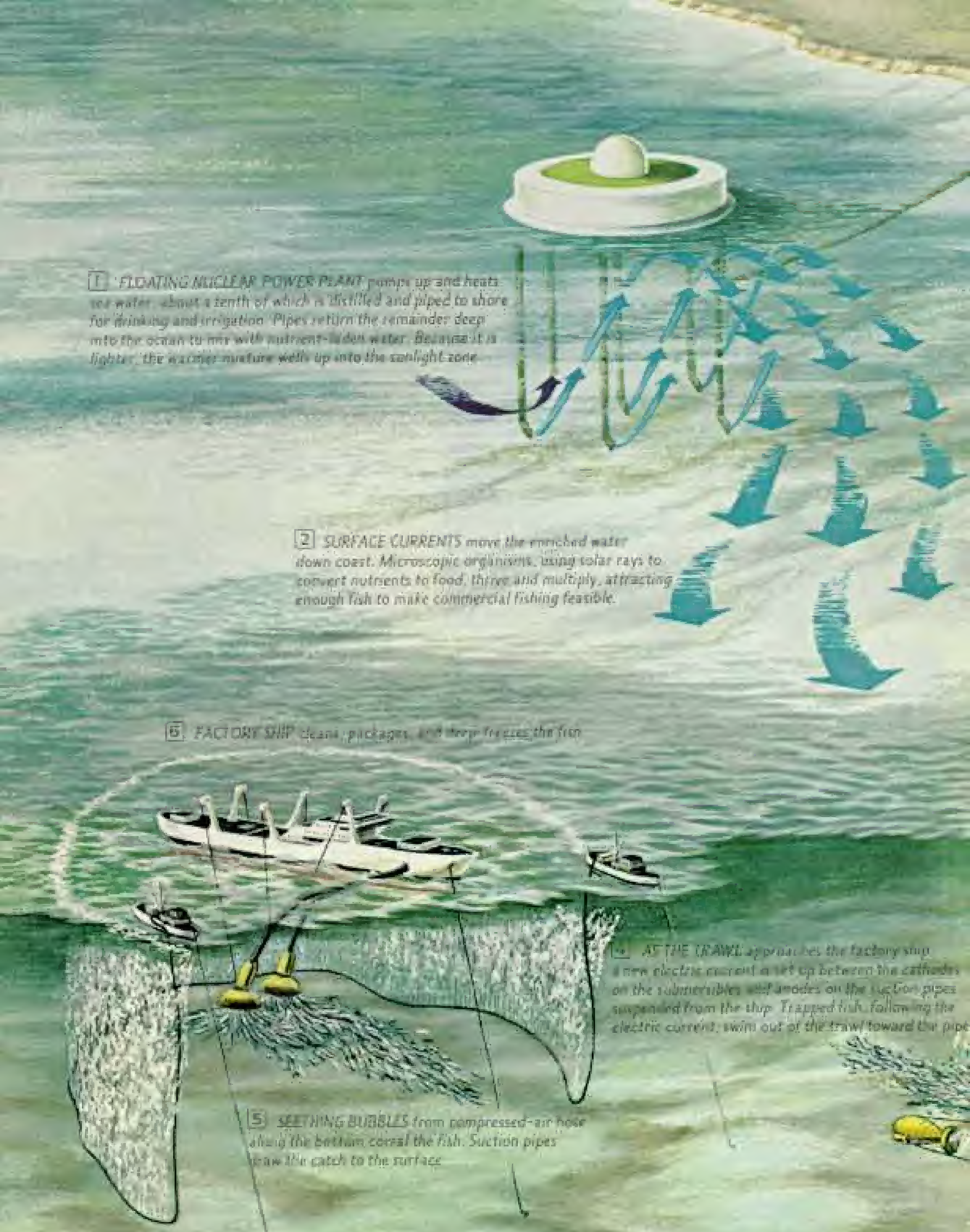
I have since loaned my miniature pressure chamber to Dr. Christian Lambertsen of the University of Pennsylvania, where the experiments continue. A score of mice have been taken successfully to 4,000 feet in the chamber.

Other experimenters, of course, are active in this exciting field. Last year Dr. George Bond successfully held three men for six days at a pressure of 100 feet; more recently they stayed at 200-foot pressure for 12 days.

At the Navy's Experimental Diving Unit in Washington last December, Dr. R. D. Workman kept two men at 300-foot pressure for 24 hours. Last March he repeated this experiment at 400 feet.

Relying on the information gained in these and other trials, I sailed recently for Key West, Florida. This June, with Navy and National Geographic Society backing, I hope to keep a diver several days at depths of 400 to 600 feet. He will live in an undersea dwelling from which he can swim out to work.

A different approach—lesser depths



Nuclear power plant fertilizes the ocean, increasing the yield of fish, while desalted water makes desert bloom: an artist's conception of the future. Scientists at Scripps Institution of Oceanography and the Oak Ridge National Laboratory envision a time when atomic piles may bring deep nutrient-rich water to the surface, creating vast new resources of fish for the world's rapidly expanding population. Bureau of Commercial

Fisheries officials forecast remote-controlled submarines to pull nets. Some fishermen already use electricity to attract menhaden to suction hoses. With bubble curtains, fish have been corralled in waters too deep for conventional seines.

EKTACHROME BY JERRY GREENBERG © N.G.S.

Flood lamp and TV camera serve as tools in the study of the schooling and feeding habits of fish and their reaction to various stimuli. The University of Miami in Florida maintains its Audio-Visual Observation Station off Bimini, in the Bahamas. Silvery margate fish flash by the installation. Manatee grass covers the sea bed.

but longer stays—has been used by Capt. Jacques-Yves Cousteau in the Red Sea.*

This July, too, Dr. Bond will attempt the first large job to be performed at depth. His four-man team will live for two or three weeks at the foot of a Texas tower off Bermuda while they inspect and clean its base—193 feet down—and perform scientific experiments as well. They will live in a steel cylinder.

Once we have proved that man can live in the deep for long periods, we must give our attention to the kind of house he will occupy. Fortunately, he will not require the heavy metal spheres and cylinders now in use.

Dry Work Space at Sea Bottom

If inside and outside pressures are equalized, the undersea house might well be made of heavy-duty rubber, and thus be easily transportable when deflated. It can be designed in a balloonlike shape with a small "door" in the bottom. Or it can be made with an open bottom like a tent. Pressure of the air or gases inside would keep the sea out.

*See "At Home in the Sea," by Capt. Jacques-Yves Cousteau, NATIONAL GEOGRAPHIC, April, 1964.

Placing the "tent" on the ocean floor, we could create a small area where men could work dry, perhaps on a broken telephone cable or oil pipeline (page 789). I am using prototypes of both types of dwelling in this summer's *Sea Diver* experiments.

One bothersome problem will be how to hold the gas-filled dwellings down. This can be done with weights or by fastening houses to the sea floor.

We also foresee a mobile home—a self-propelled vehicle that could both shelter and move a team of divers as they inspect and repair undersea installations.

Present goals are set at depths of 400 to 600 feet. To the uninitiated, this may seem modest—but if we can work at these depths, we can exploit the continental shelves. They would add 10 million square miles to man's domain—an area almost as large as the entire

White mice "dive" to 3,000 feet

TWO OF THE THREE survived this experiment, conducted by Mr. Link and Dr. Joan Membery with a small pressure chamber aboard *Sea Diver*. Later, at the University of Pennsylvania, all of 16 mice subjected to 3,000-foot pressure, and 21 of 24 mice at 4,000 feet, lived through the experiments.

Whiskey, the mongrel at lower left, frisks about the New London Submarine Base although he lived 23 minutes without air. He breathed saline solution saturated with oxygen at 257-foot pressure.

Two Navy volunteers, under 300 feet of pressure in a chamber at the Washington, D. C., Navy Yard, breathed 5 percent oxygen and 95 percent helium for 24 hours. James G. Koskimaki (left) and Nicholas Simeone lived almost normally, yet a can of peaches collapsed under the pressure of ten atmospheres. This picture was taken with a 180-degree-angle lens, set up in the tank by NATIONAL GEOGRAPHIC photographer George Mobley and triggered by the subjects.

continent of Africa! (See map, pages 782-3.)

But for the future we must also look to the eventual conquest of unknown greater depths. We must learn to control rigidly the artificial atmosphere we use. This means development of accurate and safe breathing and gas-analyzing equipment, needed within a dwelling as well as by the diver who works from it.

Rebreathing System Required

For these purposes today's Aqua-Lung is outmoded, since it is impossible for a diver to carry with him the quantities of gases needed to remain at great depths for any useful period of time. "Hard-hat" diving is also impractical here. Not only would it be difficult to supply gases by a hose from the surface; it would be impossible for the diver to eat or sleep during long periods of decompression.

Helium is expensive, and getting it to the depths is difficult. We expect to re-use the same helium supply, adding oxygen as needed and removing carbon dioxide. Although we already have workable gear for this, more development is needed.

When our diver, Robert Stenuit, made his long, deep dive in the Link cylinder, one of the most difficult problems we faced was how to provide him enough heat to keep him comfortable both in the chamber and outside.

A helium atmosphere conducts heat away from the body quickly. To feel comfortable in helium, we discovered, the temperature must be raised to at least 86° F. Even that, I found, felt a little chilly.

Outside the dwelling another temperature problem comes up. The usual "wet suit" worn by divers—a sponge-rubber affair so effective as insulation that it permits diving among Arctic ice floes—doesn't work in the depths.

Submarine's Spotlight Reveals Art Works of an Ancient Argosy

During the summer, archeologist George F. Bass hopes to explore in this submersible. Electric Boat Division of General Dynamics has designed for him and the University of Pennsylvania Museum a 16-foot craft to operate ten hours as deep as 600 feet. With a National Geographic Society grant, Dr. Bass will continue to search for wrecks containing classic Greek bronzes in waters off Turkey. Twin cameras map the bottom, and a jet of water pumped through a hose from the surface removes loose sediment. In this painting Dr. Bass, beside a Turkish copilot, manipulates a mechanical arm to the hose, which uncovers an amphora. Wolf fish swim above the headless bronze statue at left. Coral and sponges decorate the sea bed.

Under heavy pressure, the air cells collapse, and the suit is valueless. Body heat is carried away faster than the body can create it.

I believe I have found a satisfactory answer in a new kind of material I developed with the United States Rubber Company. It looks like today's suit, but the insulating air cells are joined together and sandwiched between thin layers of rubber. This suit, in effect, carries its own Aqua-Lung. Air cells are kept at the same pressure as the outside water by a regulator valve.

But since the suit needs little air, the diver will not be burdened with still another tank. One capsule, slightly larger than the charges used to make soda water, will keep the air cells filled. For long exposures at great depths, even this suit will have to be augmented by electric or chemical heat.

Wet World Offers Vital Challenge

Now I want to put aside, for a moment, my membership in the DSSRG, and speak for myself alone. I strongly believe that riches await us under the sea and that we can harvest them. If three-quarters of our planet awaits us, then the great age of discovery certainly did not end with Columbus, Magellan, or Cook. It may well lie in the future.

Nor is our only horizon overhead in space. We have resolved to put human footprints on the moon, yet our effort to understand the seas consists of a limited program which stresses only the scientific description of the oceans. We have not awakened to the exciting challenge of the wet world.

The report of the DSSRG is a first attempt to analyze this important challenge. Its conclusions, I believe, point the way toward the ocean engineering program we need so badly—both as Americans and as residents of this planet.

Although President Kennedy recommended $2.3 billion to fund the Interagency Committee on Oceanography (ICO) and carry out a ten-year program, few persons realize that this sum, even if appropriated, can be used only for research—not exploitation.

Admiral Stephan suggests the word "oceanology," for the combined study and use of the seas. We must be active in both branches of oceanology, but at present we are doing relatively little in ocean engineering, or use of the seas.

I strongly feel that we need a national pro-

gram, well-coordinated, to achieve our hopes. I remember in the 1930's the great work done by the National Advisory Committee for Aeronautics in exploring and promoting the uses of the sky. With this impetus there grew a huge industry employing hundreds of thousands of people.

Needed: an Underwater NASA

Development of atomic power was encouraged by the formation of the Atomic Energy Commission. Achievements of the United States in space increased rapidly after creation of the National Aeronautics and Space Administration.

I believe that a similar national agency in the field of oceanology—an underwater NASA if you will—is imperative.

It would be far less expensive than NASA because its prime function would be to coordinate and encourage activities in the field by other agencies. It should be a high-level agency, able to make best use of the Navy's strong abilities in building and executing the program, as well as the researches of the Interagency Committee on Oceanography and the work of the 22 government bureaus with undersea interests.

With such a program, the United States could increase its own security and wealth while leading the world to more bountiful and peaceful times. THE END

CAVES REVEAL A STRANGE NEW WORLD

Exploring America Underground

By CHARLES E. MOHR

THROUGH A NATURAL MANHOLE in the middle of a Missouri cow pasture, where pools lay after a thunderstorm, Ken Dearolf and I climbed down into Blindfish Cave.

Descending the cool throat of the cave into darkness, we came to a stream that fell away into a well-like chamber. Our flashlights showed water splashing on rocks 15 feet below.

Posting Ken on the brink, I tied a rope around a rock slab beside the waterfall and started down, hand over hand. The wall curved away, out of reach of my groping feet.

Like the weight of a pendulum, I began to swing, and a moment later I arced under the falls. Drenched and blinded, pounded and with my boots filled with water, I lost my grip on the rope and fell.

The fall left me flat on the pitch-black floor of the pit. Soaking wet, choking, and bruised, I stood up and reached for the rope, ready to call it a day. But the wavering beam of my electric head lamp revealed the line dangling just out of reach.

This miserable little Stygian bathtub, with no handle to turn off the shower, had made a fool of me. I had violated basic rules of caving. There were only two of us—too small a party for this venture. And we had

Dangling in parachute harness, a spelunker rides down into 407-foot-deep Devil's Sinkhole in Texas, one of 11,791 known caves in the United States. Rope tied to a car bumper lowers the explorer; a lighter line steadies him. A popular sport, caving attracts housewives as well as scientists and rock climbers.

dismissed the need for a second rope —a safety stand-by—for a descent of a mere 15 feet. Why? I am a biologist, and the prospect of capturing a blindfish had blocked all else out of my mind. I had searched dozens of Ozark caves in vain, but local gossip "guaranteed" the rare fish's presence in this little grotto.

Ken peered down, saw my predicament, and went back to the car for a longer rope. While I waited I saw that the water was getting muddy. The falls roared louder. I realized that the water was rising—it was now knee-deep. Storm runoff had begun to pour in through some unknown opening.

By the time Ken's light reappeared at the ledge above, the pool was lapping at my waist. The rope that came down was dry and knotted. I was out of there like a monkey up a stick.

Defeat, however, was unacceptable. Three weeks later we were back on the floor of Blindfish Cave. Dipping my net into a pool near the waterfall, I captured the prize.

Scarcely two inches long, the blindfish, *Amblyopsis rosae*, was translucent white, with a flush of pink around the gills. I could see its red heart pulsating through the skin. Rows of vibration sensors ran along

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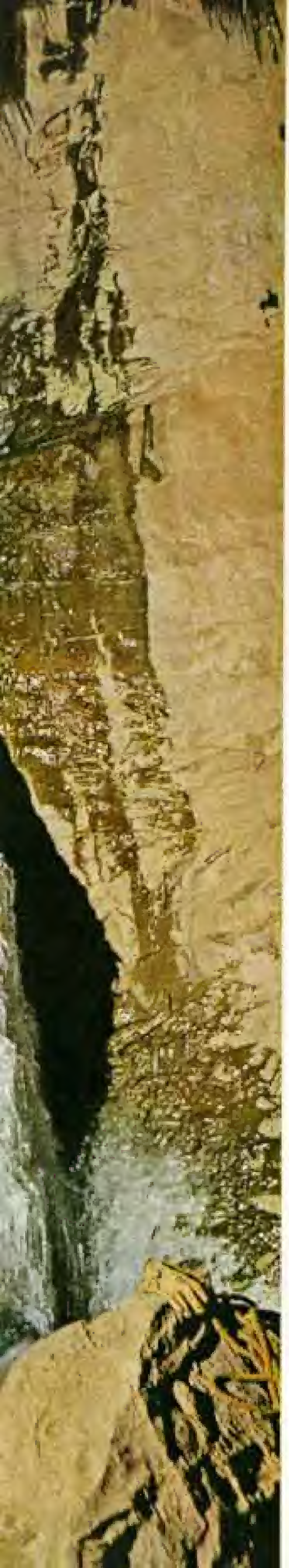
The Author: Charles E. Mohr, former President of the National Speleological Society, is Education Director of the Kalamazoo, Michigan, Nature Center. With Howard N. Sloane, who helped in assembling photographs for this article, he co-edited the popular book *Celebrated American Caves* (Rutgers University Press, New Brunswick, N. J., 1955).

Geologist-caver Inches Past a Frozen Waterfall

Descent into this 100-foot pit gives entry to Crookshank Cave in West Virginia. George Moore of the United States Geological Survey works his way down a ladder of aluminum-alloy rungs strung on aircraft cable. Winter-chilled air freezes the falls. In summer the threat of flash floods makes the little-known cave perilous to visitors.

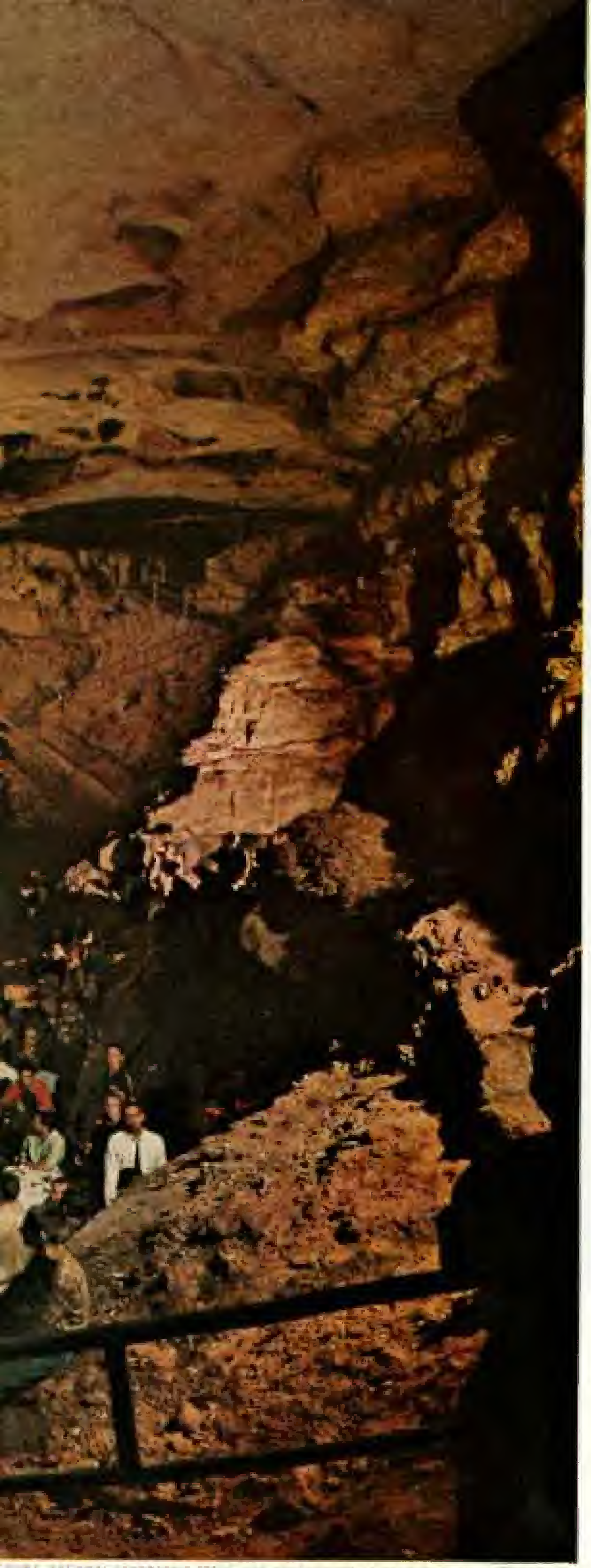


Determined caver, his elbows in mud and water, squeezes from a 15-foot-long crawlway in Aitkin Cave, Pennsylvania.

Straining toes push an adventurer into a tiny slit in Gage Caverns, New York. Such passages lure explorers on with visions of undiscovered wonders.

Deep mud challenges a struggling team in Carroll Cave in Missouri's Ozarks. Flash floods at times fill the mouth.

"It was like sitting in the best concert hall, the sound was so full." Thus spelunker Leonard Munson reacted to the deep tones of organ music echoing through the Volcano Room of Cumberland Caverns, Tennessee, scene of the National Speleological Society's annual convention in 1961. The Chattanooga Boys Club choir stands in a recess used as a stage. Dwarfed by the 250-foot-long room, the cavers dine on fried chicken under a ceiling textured and sculptured by water.



the top and sides of head and jaws, and the sides of body and tail. Tipped with nerve endings, these sensors detect disturbances and guide the sightless fish to its food of isopods or other tiny organisms.

Spelunking Offers Fun and Knowledge

Today, Americans by the thousands go cave crawling. Curiosity to learn how creatures survive in the lightless world below first drove me underground. But what motivates the nonspecialist, man or woman, to endure the cramped miseries of playing mouse in a blacked-out Swiss cheese?

The chief attraction, I'm sure, is simply that cavern exploration is fun, an acceptable kind of hide-and-seek for grownups. Cavers have been called underground alpinists, and spelunking (from the Latin *spelunca*, a cave) has been likened to mountaineering on a moonless night.

For thousands of years, particularly while surviving the Ice Age in Europe, prehistoric man lived in caves. His use of fire made caverns habitable, and his developing esthetic sense transformed some of them into the first art galleries. Early man, perhaps 30,000 years ago, drew the famous prancing bison on the walls of France's Lascaux Cave.*

In America, evidence of early human habitation of caves is scant. Recently, however,

*See "Lascaux Cave, Cradle of World Art," by Norbert Casteret, NATIONAL GEOGRAPHIC, December, 1948.

Stony basin in Haynes Cave, West Virginia, intrigues Jani Mohr, the author's daughter. Lime-charged drops of water created the formation, encrusting a wooden trough left behind by nitrate miners a century ago.

Dense inverted forest of stalactites spikes the ceiling of Lone Hill Onyx Cave.

carbon-14 dating of artifacts and bones from Utah, Nevada, and New Mexico indicates that prehistoric creatures related to the musk ox were eaten by American cave dwellers some 7,400 years ago. And in Russell Cave, Alabama, presented to the people of the United States by the National Geographic Society as a cross section of American prehistory, artifacts and carbon dating have established man's occupancy as early as 9,000 years ago.*

Two miles inside Mammoth Cave and nearby Salts Cave in Kentucky, modern explorers have found bundles of reeds bound with bark thongs. Evidently they served early Indians as torches to light the search for the white crystals of gypsum, still abundant there, which were apparently valued by the aborigines as medicine and pigment. Carbon dating of sooty material from the

*See, in NATIONAL GEOGRAPHIC: "Life 8,000 Years Ago Uncovered in an Alabama Cave," October, 1956, and "Russell Cave: New Light on Stone Age Life," March, 1958, both by Carl F. Miller, and "National Geographic Society Presents Russell Cave to the American People," by Melville Bell Grosvenor, March, 1958.

Missouri. Only the intrusion of man relieves the pitch darkness and utter silence here.

flares—it still cakes walls and ceilings—puts the time within the Late Archaic-Early Woodland period, 2,400 years ago.

A falling five-ton boulder trapped one Indian gypsum gatherer in the bone-dry heart of Mammoth Cave. His shrunken body is a shivery display for modern visitors.

The relatively new sport of underground exploration attracts many biologists, geologists, and other scientists, but they are a minority. Most spelunkers seek something less tangible than glimpsing a rare crystal formation, a scarce fossil, or a strange blind salamander. The true cave crawler seeks adventure, the unknown, the thrill of discovery.

Discovery? Listen to veteran spelunker Bill Varnedoe, a rocket engineer at the Marshall Space Flight Center in Alabama.

"We all dream of a 500-foot pit, a record vertical drop," Bill told me. "It's like the goal of the three-and-a-half-minute mile, unlikely but possible. We came close, though, with Fern Cave. That's in northern Alabama, 20 miles from here.

"The topographic map showed a hollow halfway up a mountain that led to a cave opening with a stream tumbling into it," Bill said. Members of the Huntsville Grotto of the National Speleological Society followed the stream 400 feet underground, then stopped—the water plunged into a huge black well.

"There was so much mist we couldn't see bottom. The real puzzler, though—there was no roar as the water hit. We threw in some rocks. Not a sound! Finally we flung down a forty-pound boulder. Four or five seconds later we heard a thud.

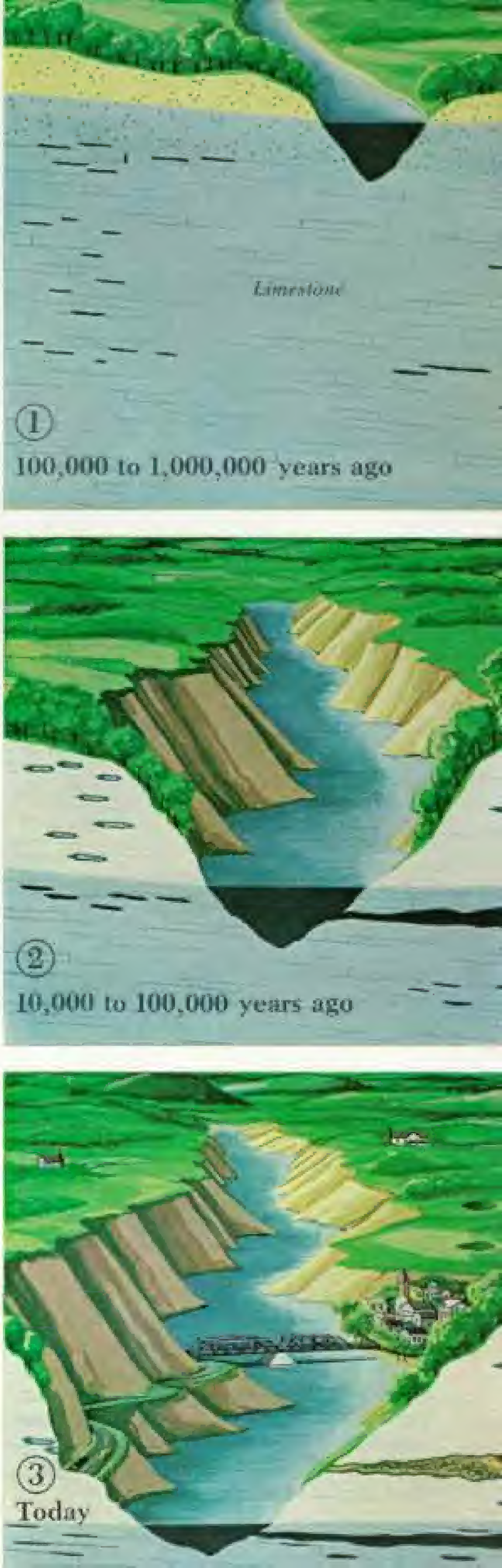
Light Vanishes Into Abyss

"The next Friday we returned with a magnesium flare, the kind made to light up the landscape for night aerial photography. We tied it to a line, pulled the pin, and tossed it over the lip.

"When the flare exploded, the flash was blinding. Then we saw the light falling, through the cascading water, lots of smoke and spray, and finally the light went out.

"How deep the cave was we still didn't know. But we lowered 375 feet of calibrated cord with a rock tied to the end. The stone snagged on a ledge, and when we tried to jerk it free, the cord broke."

The pit of Fern Cave, as finally plumbed,



Water and Acid Fashion a Cave; Nature's Work Takes Millenniums

As geologists interpret evidence written in the rocks, this is how limestone caves form:

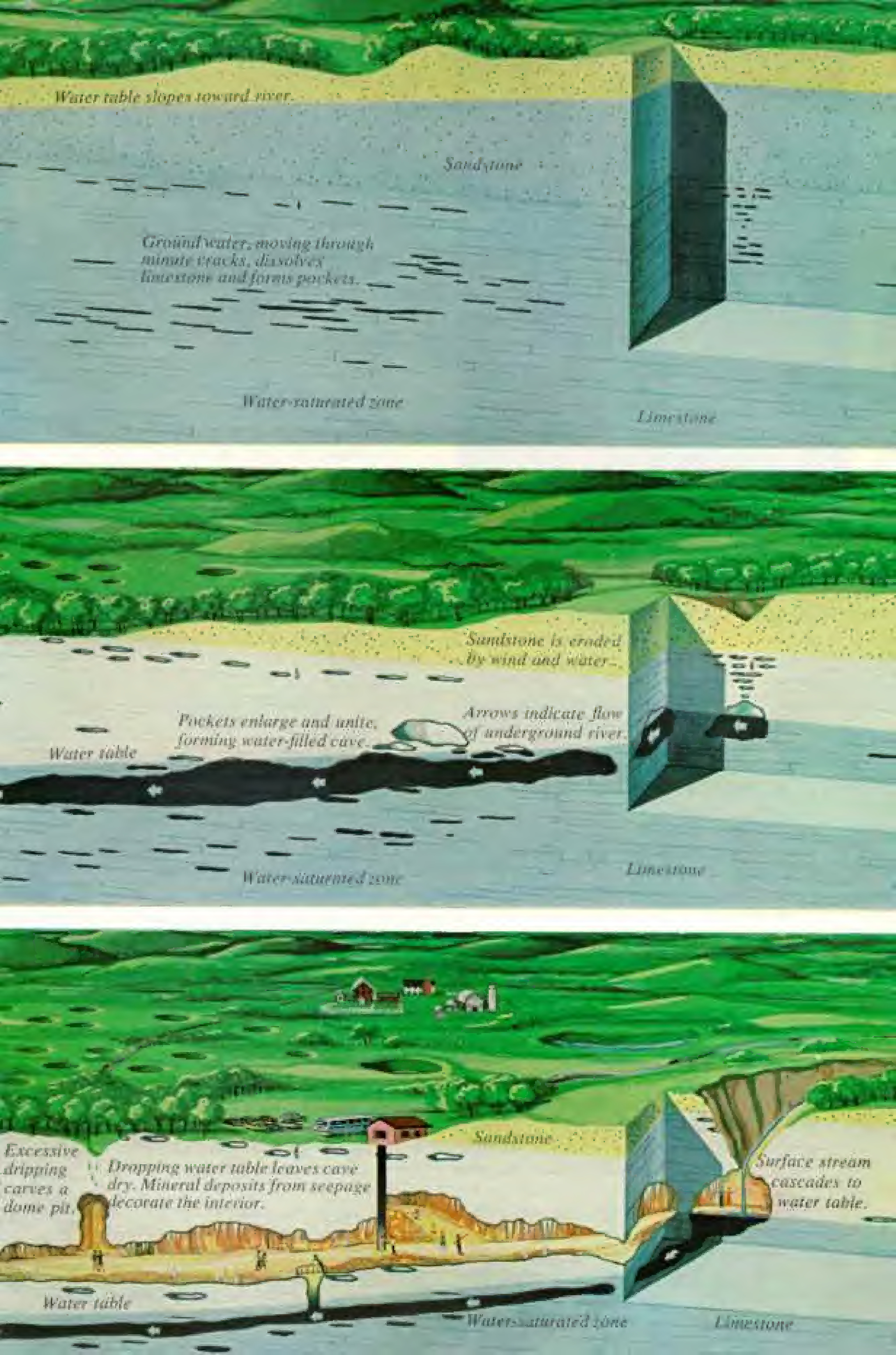
1. Isolated pockets occur where slightly acid water, seeping through fissures, dissolves and carries away soluble minerals.

2. In the second stage, stream erosion deepens the valley, bringing the river's action into play. Underground water now flows faster and hastens cavern building. Pockets enlarge and connect; the cave takes shape. Sinkholes dot the surface.

3. In the final stage, the water table drops below the cave, leaving it dry. Water now has a new task: interior decoration. Trickling down into the air-filled cave over thousands of years, it gradually deposits minerals on ceilings (stalactites) and on floors (stalagmites). Now an ornamented wonderland, the cavern attracts explorers and visitors.

This is a living cave—one with water. When dripping ceases, the cave is defined as dead. Surface erosion ultimately will destroy it—eventual fate of most caverns.

A pit in the floor drops into a younger cave, a water-filled sub-basement.


Water table slopes toward river.
Sandstone
Ground water, moving through minute cracks, dissolves limestone and forms pockets.
Water-saturated zone
Limestone
Sandstone is eroded by wind and water.
Arrows indicate flow of underground river.
Pockets enlarge and unite, forming water-filled cave.
Water table
Water-saturated zone
Limestone
Excessive dripping carves a dome pit.
Dropping water table leaves cave dry. Mineral deposits from seepage decorate the interior.
Sandstone
Surface stream cascades to water table.
Water table
Water-saturated zone
Limestone

Beads of water on finger-length stalactites hold the growth secret of speleothems, the all-inclusive name for cave formations. Each drop, percolating from the surface, dissolves calcium carbonate from limestone layers above the cave. As the droplets slowly form and fall, microscopic deposits of mineral remain, imperceptibly lengthening and thickening the stony icicles. Shaping these carrotlike stalactites in Endless Caverns, Virginia, water seeps through tubes in the centers and more trickles down the outside. Through millenniums, this process may create speleothems weighing hundreds of tons.

Wishing Well in Luray Caverns, Virginia, sparkles with an estimated 600,000 coins weighing two tons. More than $15,000—in pennies, pesos, and even bus tokens—lies two feet thick on the bottom of the scenic pool. Contributions by well-wishers go to national health organizations.

measured 426 feet, the height of a 39-story skyscraper. It thus took rank as the deepest vertical pit yet found in North America. The yawning emptiness of Fern Cave reaches more than 100 feet deeper than the former record abyss, the Mystery Hole in Lookout Mountain, Chattanooga, Tennessee.

First to the bottom of Fern Cave was noted pit explorer "Vertical Bill" Cuddington of Roanoke, Virginia, by profession an IBM machine operator. Bill estimates that he has explored 500 pits deeper than 100 feet.

Six days after Cuddington's descent, I was one in a party of nine that heard the booming "Bo—bo-bo-bo" (code for reaching bottom) as 19-year-old Francis McKinney became the second to set foot on the floor of Fern Cave.

On that trip McKinney's partner, Bill Garrison, No. 3 to the bottom, stood drowned in the darkness of the pit for 90 minutes. McKinney was halfway up the rope on the climb-out. As Garrison waited his turn at the rope, his carbide light suddenly failed. He had spares in his knapsack, set down somewhere in the darkness. But his cigarette lighter wouldn't catch, and the danger of searching blind on wet and broken rock kept him pinned helpless.

"No light!" he shouted up at McKinney. "Send - me - down - a - *burning* - light."

Garrison heard McKinney answer, though the words were indistinguishable.

McKinney went on up the 426 feet with the aid of Prusik knots—movable loops on the rope—which serve as stirrups. We sent down a long rope to Garrison with an electric lamp, switch on, tied to it.

"That was a beautiful light!" Garrison told us. "First it was such a faint pinpoint that I thought it must be a mirage."

Adventure Begins in a Country Store

"How do you manage to find so many new caves?" I asked Bill Cuddington after we had both been into Fern Cave.

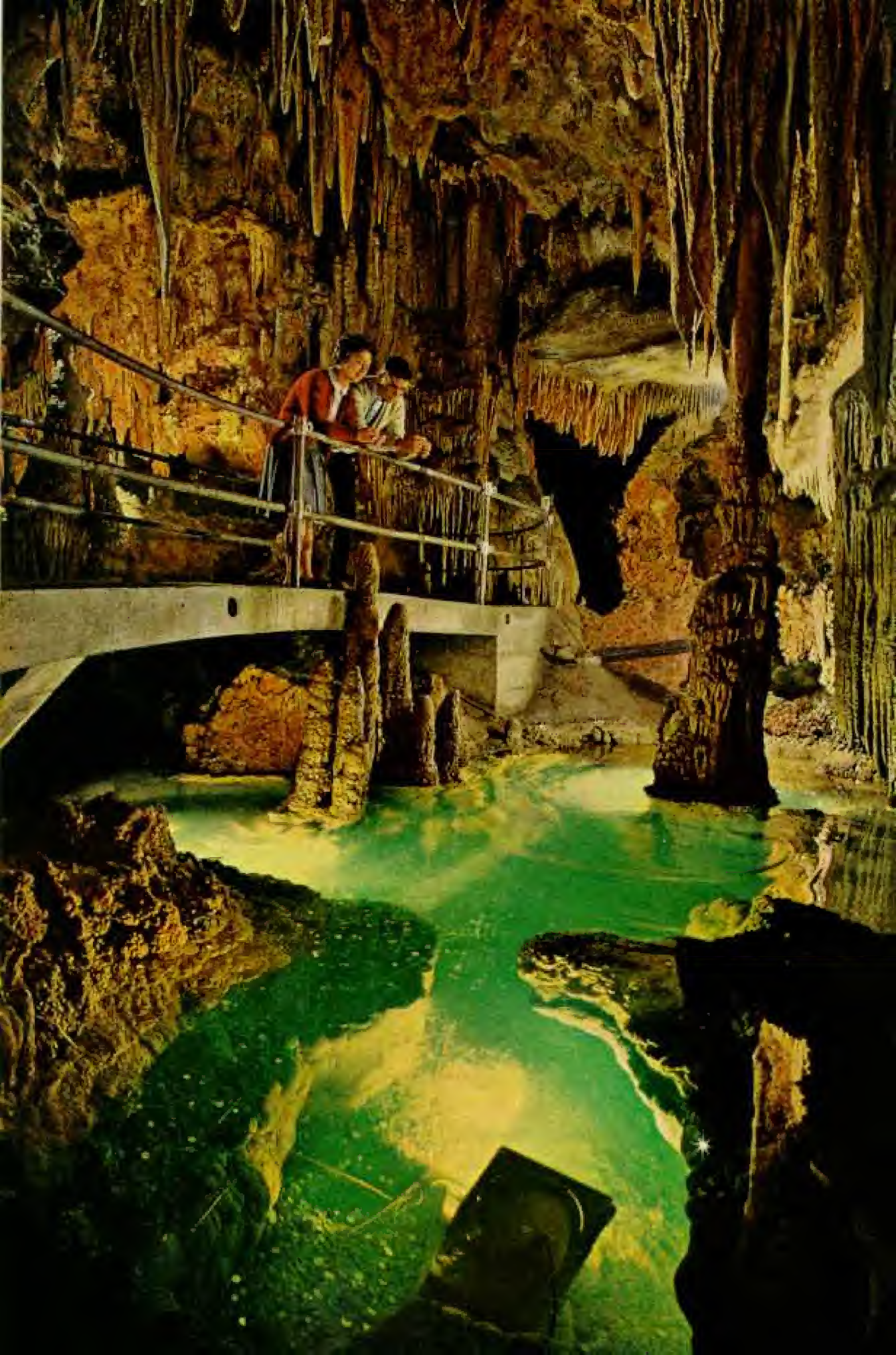
"I let the geologic structure lead me into likely country," Bill answered. "Then I head for the nearest general store. All the men of the neighborhood are there, if it's Saturday or Sunday."

"Bill tickles me when he goes into a country store," put in Mickey, his attractive young wife. "He says 'Howdy!' and slouches around, never talking scientific.

"First thing you know, they're telling him about a couple of mile-deep caves, and then they want to show him."

"Yes, they're dying to see *me* go down," said Bill. "None of the local people have ever been into one of these pits. They don't have the equipment or technique, of course, so it's good they don't try."

Because of the presence at Huntsville of the Marshall Space Flight Center, the town is thick with scientists. They find adventurous recreation and challenge in the hundreds of caves that underlie northern Georgia and



Booth's Amphitheater in Mammoth Cave, Kentucky, offers guide Young Hunt a convenient platform to address Boy Scouts. From this rock actor Edwin Booth delivered Hamlet's soliloquy in 1876. Part of the largest known cave system in the world, Mammoth began forming more than 100 million years ago. Early Americans prowled it in 400 B.C.; later Indians gathered its gypsum, probably for body paint and

Alabama and eastern Tennessee, probably the "hottest" area in the country for important discoveries.

"Most of us can only dream of going into orbit," said Bill Varnedoe, "but tomorrow any of us could be standing where no man has been before—in a new cave."

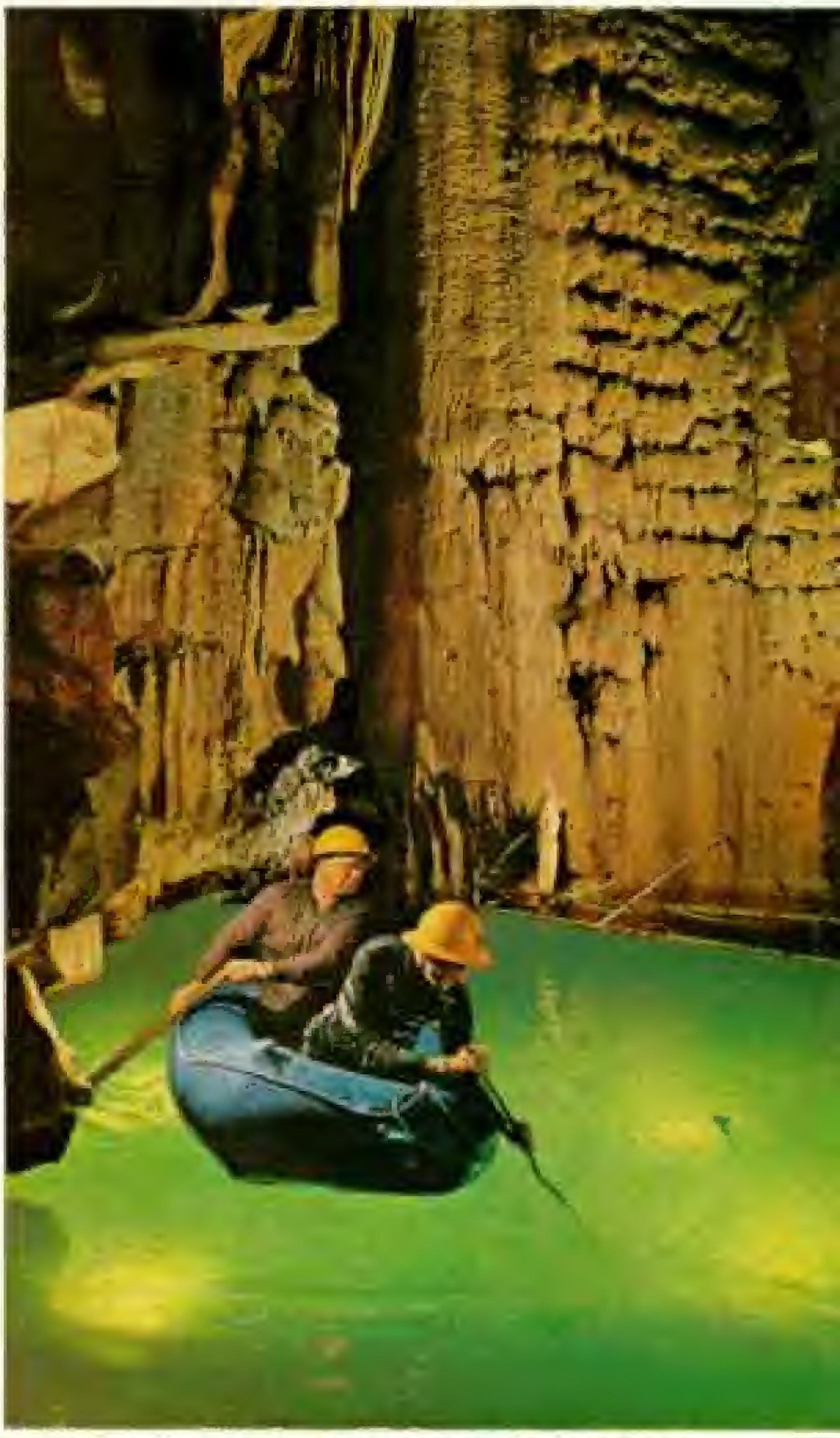
Finding the Unknown Remains a Lure

Every state except tiny Rhode Island possesses known caves. A recent poll conducted by the National Speleological Society showed 11,791 caves in the United States already located and rather fully explored. Some experts believe several times as many more caves remain to be discovered.

Countless caves—even some developed as commercial attractions—are not fully explored. This fact, combined with the awesome silence and impenetrable blackness, adds to the mystery and allure of a visit underground. I remember having to choke off a laugh upon hearing one cave visitor inquire tremulously, "How many miles of unexplored passages are there in this place?"

Our American caves fall into three principal categories. Drainage tubes formed by the outflowing of molten rock from active volcanoes become sinuous tunnels and blisterlike grottoes. They are the lava caves familiar in the Far West. Sea caves are sandblasted by wave action out of ocean cliffs.

medicine. Continuing a tradition, guides move beyond charted courses to explore Mammoth's limitless labyrinths. In the early 1800's the cave and 200 acres above ground sold for $40.



On Mammoth's Crystal Lake, boaters replace burned-out underwater light bulbs. Attesting the water's clarity, the darkened bulb at right, two feet below the surface, appears to float.

The vast majority of caverns, however, are the product of the leaching away of limestone, dolomite, or gypsum bedrock by acid-charged ground water.

Erosion by underground rivers once was believed the chief agency of cave making. Speleologists today dispute this theory.

Caves Take Shape Under Water

Helping William E. Davies of the United States Geological Survey collect samples of silt in Tennessee's Cumberland Caverns, I asked about the latest theories of cave origin (diagrams, pages 810-11).

"A number of caves—Mammoth in Kentucky is a good example—feature underground rivers that were thought to have carved the great chambers out of solid rock," said Mr. Davies, a leading theoretician on cave formation. "But most caves consist of large, essentially disconnected rooms with domed ceilings. Many have mazelike passageways running at right angles to each other. Such features are unlikely to occur along a watercourse.

"Recent evidence suggests that most caves form under water. They may develop at almost any level within the so-called phreatic zone, which is the region of the earth's surface below the water table, where rock and soil are completely saturated.

"Cave formation likely takes place also in some areas of the less saturated vadose zone, just above the water table."

"Does the water circulate in caves as they are forming?" I asked.

"Yes, but very slowly," Mr. Davies said. "It moves through pores and tiny cracks and along fissures or joints resulting from movements of the earth."

Openings are gradually enlarged, he explained, by the dissolving of the limestone. But only in the next stage, when the land surface above ground becomes eroded into deeper and deeper valleys, does the water drain out into the open-air channels of brooks and rivers. As the water table drops, air fills the caverns.

Clay, sand, and gravel may then be washed or blown into the passages. Frequently, mineral-bearing waters seep down from above, forming deposits on the caves' walls, floors, and ceilings, formations called speleothems. This is the inclusive name given to stalactites, stalagmites, and the rest of nature's interior decoration.

We stopped under a thicket of slender tubes resembling soda straws. "You see these drops?" My companion indicated glistening pendants along a hairline crack. "That water is slightly acid from contact with carbon dioxide in the soil. While seeping through to this point, it has dissolved some of the limestone—calcium carbonate.

"Before a drop falls, either evaporation or direct loss of carbon dioxide to the atmosphere causes some of the minerals in the solution to be deposited on the ceiling. That's the start of a stalactite, but thousands of drops may fall before a perceptible ring forms, tens of thousands more before the ring elongates into one of those hollow soda straws."

As a straw grows, the center channel often clogs up, Mr. Davies ex-

Mountains of stone dominate Carlsbad Caverns' Hall of Giants, relegating surrounding stalagmites to foothill status. Giant Dome (right) soars 62 feet. A stroll through the Big Room to the Rock of Ages (smaller dome at far left) takes 30 minutes, the average walking time between White House and Capitol in Washington, D. C.

Cave pearl of golf-ball size has spun for centuries in its individual nest. These spheres of calcium carbonate took shape in a Carlsbad pool around grains of sand or fragments of bat bones. Agitated by water movement, they added concentric layers, like pearls in an oyster.

Gypsum flower adorns an Ozark cave in Arkansas; silver dollar shows scale. Of pencil thickness and five inches long, the flower could be marred by a touch. "It is as fragile as a peppermint stick," says photographer Earl Neller. Gypsum flowers sprout from walls, ledges, and ceilings, their crystals extruding through porous rock like toothpaste from a tube.

Helictites wreathe a five-foot archway in the Caverns of Sonora, Texas. To guard against falling rock, Scott Moore wears a hard hat with carbide lamp. Helictites grow by the millions here. For years the discoverers kept the cave secret to protect its bizarre formations.

Snake-dance helictite, since collapsed, thrusts 2½ feet of crystal growth from a sheet of flowstone in the Caverns of Sonora. A tiny tube is thought to carry mineral-laden water from the helictite's base to its extreme end, where calcite is deposited. Changes in air flow, climate, and chemicals determine the erratic shape.

Needles of gypsum so fragile that they break under their own weight grow in lovely disarray in Fitton Cave, Arkansas.

plained. The water trickles down the outside. The stalactite may then become carrot- or icicle-shaped.

My fellow caver touched a hanging curtain of stone with folds like the garment of a marble-cut Greek goddess. "When water seeps out and runs down an inclined ceiling," he said, "it builds a thin drapery like that."

Next he pointed down at a columnar mound directly below a stalactite. "Underneath most stalactites you find stalagmites. That's because drops from overhead carry minerals to the floor. Where water hits, it leaves a growing mound of calcite. The process is fantastically unhurried: A stalagmite 40 feet tall takes scores of thousands of years to grow."

Spelunkers Probe Floyd Collins's Cave

With the founding of the National Speleological Society in 1941, exploration of caves in the United States got under way in earnest. Hikers and rock climbers, canoeists and clerks, secretaries and schoolteachers, scientists and businessmen swelled the ranks.

The N.S.S. fielded a 64-man party in February, 1954, to test the theory of some geologists that Floyd Collins's Crystal Cave and other caves in the Mammoth Cave National Park system are actually part of one huge, interconnected labyrinth. The first objective was a probe of the unexplored extensions of Crystal Cave.

Supplies had to be pulled and pushed along an agonizing 1,400-foot crawl under a low ceiling. Pack sacks and duffel bags snagged and tore, especially while threading a ten-inch-high "keyhole." So John L. Spence and Russell H. Gurnee designed a bullet-shaped metal container that could be dragged by a line attached to its pointed nose. The ingenious Gurnee can, exactly ten inches in diameter and three to four feet long, is now standard gear for cavers when threading tight crawlways.

Among reporters and newscasters attracted by the 1954 expedition was William Burke "Skeets" Miller, who has since retired after

34 years of service with the National Broadcasting Company.* As a young newspaper reporter, Miller had won a Pulitzer Prize for his stories of the vain attempt to rescue ardent cave explorer Floyd Collins, pinned down by a dislodged rock in nearby Sand Cave in February, 1925.

Miller, a courageous newsman of slender build, had been one of the few to reach Collins, carrying hot coffee and soup to the doomed man. Collins lived for two weeks, dying an estimated two to four days before a rescue shaft reached his body.

The National Speleological Society team unraveled a whole network of new and forgotten passageways in Crystal Cave. Since then, the Cave Research Foundation has put in a decade of remarkable exploration and mapping in the Mammoth Cave area. In August, 1961, climbers reached an aperture on the far wall of a deep shaft in Colossal Cave. It led to a half-mile tunnel that opened at last through an insignificant crack into known portions of Salts Cave.

Within a year, Salts Cave again was linked to Crystal Cave by the discovery of a pair of passages. The giant underground system now totals 41 miles of mapped tubes and tunnels in the Flint and Joppa Ridges. The explorers have linked Crystal, Colossal, and Salts—major caves by any standards—and very likely will fit this many-fingered system into the equally extensive Mammoth Cave in the ridge to the southwest.

Drowned Boneyard Yields a Bonanza

Today spelunkers go under water with Aqua-Lungs in caves that afford the special thrills of submarine exploration. Divers risk the siphons, or water-filled portions, seeking dry-cavern reaches beyond.

Where sizable underground rivers reach the surface, as in Missouri and Florida, permanently flooded caves are common.

In 1958, Stanley J. Olsen, vertebrate paleontologist, organized a scuba attack on Wakulla Springs Cave in Florida. Knowing that a complete mastodon skeleton had been found there 27 years earlier, Olsen sought a richer "strike" of fossil bones. In a deep cavern, he hit a bonanza. As a result of many daring forays, Olsen's fine collections in the Florida Geological Survey Museum include bones and teeth of giant sloth, armadillo, tapir, and other prehistoric mammals.

In 1962, I headed for Wakulla with Stan Olsen and geologist William Reves. I lowered my camera gear in a floating rig that allowed picture-taking through a submerged glass panel.

"We're going to bring up one of those mastodon femurs," Olsen told me as Reves swam down to a couple of long, dark objects nearly as big as himself. They lay in front of the cave entrance, 75 feet below (pages 836-7).

With a flip Olsen went under, and soon I watched the two men pry a bone loose from the silt, where it had lain for 10,000 years or more. Slowly they propelled their burden upward with rhythmic kicks of their flippers.

Submarine Would Aid Fossil Harvest

"The whole floor of the main 'cemetery' is littered with bones," said Olsen. "The greatest concentration lies deep in the cave, about 500 feet from the entrance. The submerged cavern slopes downward, away from the doorway on the wall of the spring pool. It reaches a known level 250 feet below ground.

"At that depth we use up half our air supply just to reach the bones. This gives little time to work. We need better gas mixtures to penetrate these extensive, drowned caverns. What would be really useful is a one-man submarine. Then we could carry more air tanks."

Exactly how these prehistoric mammals came to their watery grave remains a mystery. Some scientists speculate that the beasts fell into the cave through a sinkhole, now plugged. Others believe that most of the tunnel may have been high and dry, and hence accessible, during a period of lower ocean levels.

Whether in water or in the chill air of cramped passages, cavers remember the tragedy that resulted from Floyd Collins's risky practice of solo ventures underground.

The cardinal rule of organized spelunkers today is: "Never go caving alone." They have learned also to heed the hazards of fatigue and poorly conceived cave diets.

Though a dislodged rock trapped Floyd Collins, caves almost never collapse on explorers; the formations are remarkably stable. The dangers of spelunking lie in human negligence and in faulty equipment. Most serious hazard: loss of light. Major cause of injury and death: unsound rope.

Nylon rope that will hold a ton is now standard for underground mountaineering. As for light, cautious cavers usually carry three sources: carbide head lamp, flashlight

*William Burke Miller, one of the first two passengers to fly the Pacific in Pan American Airways' famed Clippers, wrote of the epochal flight in "Flying the Pacific," NATIONAL GEOGRAPHIC, December, 1936.

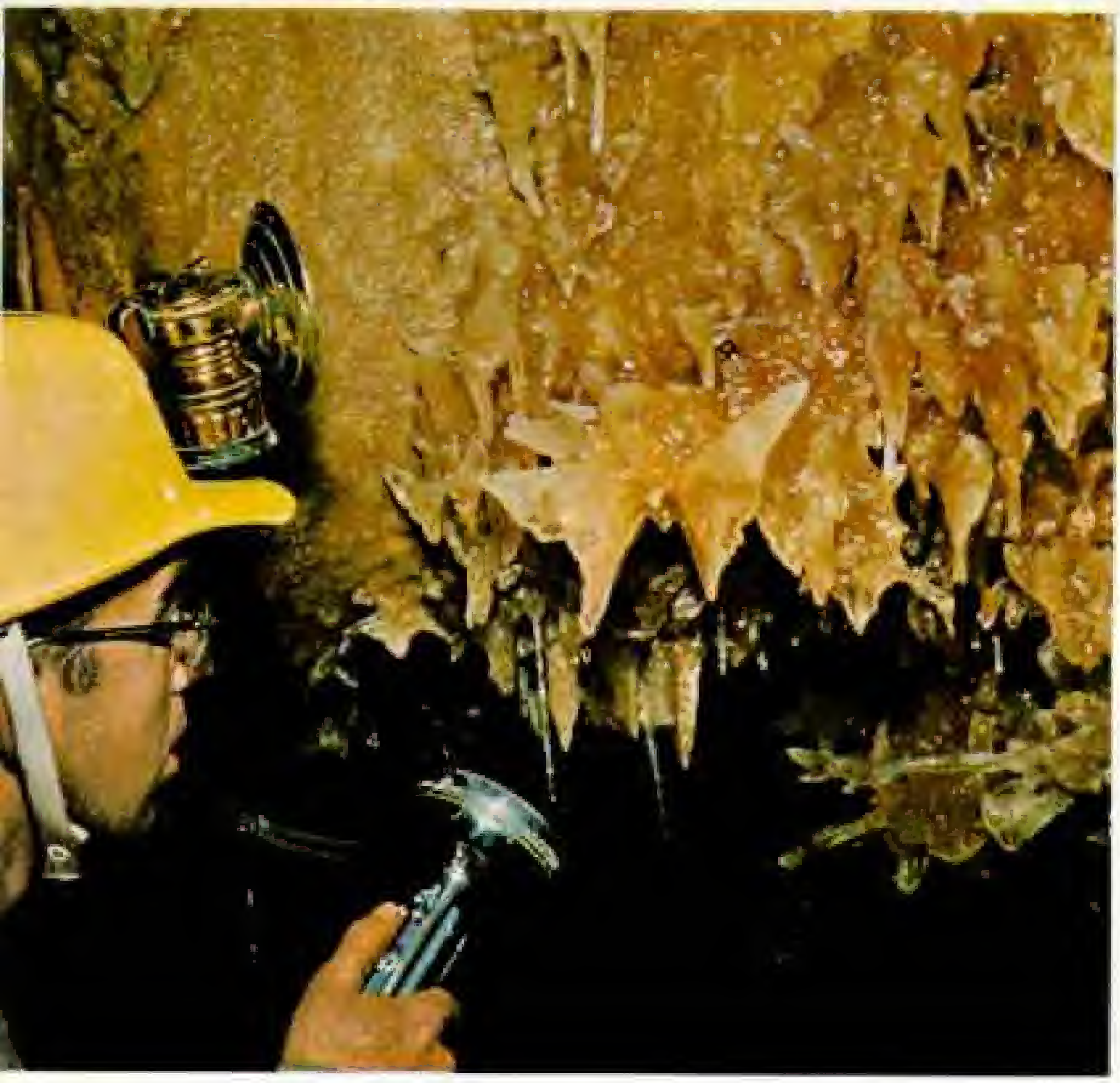
Strips of bacon—lean and fat, but pure stone—hang from a ceiling in Shenandoah Caverns, Virginia. Calcium carbonate was deposited as the "fat" when trickling water evaporated. Water tinged with iron oxide left the red-and-brown "lean meat."

Breakfast in bedrock offers two "fried eggs" in Luray Caverns. Minerals laid down in the "pans" of broken stalagmites color the yolks; the whites remain free of impurities.

KODACHROMES BY DAVID S. BOYER, NATIONAL GEOGRAPHIC STAFF © N.G.S.

"**We felt as if we were inside a huge snowball**—cold and damp and white," says photographer Fred Kissell (right), who explored the Crystal Room of Fossil Mountain Ice Cave, Wyoming, with fellow spelunker Bill Jones. As he looked up at the delicate geometric patterns on the sparkling ceiling, "the flame of my carbide lamp melted the crystal supports, and ice flakes rained down on my head." Leaving 90-degree heat above ground, Kissell and Jones "zigzagged down slippery corridors, skirted deep pits, and shivered through icy crawlways."

Stone butterfly spreads crystalline wings on its perch in the Caverns of Sonora. This rare, symmetrical helictite immobilized photographer Bart Crisman, who discovered it. "I stared for a long time and then I shot all my flashes. It was too beautiful to wait another minute."



(with fresh batteries), candle, waterproof matches, or matches in a tight container.

Much recent effort has gone into the design of lightweight, strong, functional gear. The hardware—wire ladders, pitons, ropes, mooring pins, carbide lamps, hard hats, canteens, matchboxes—has won picturesque identification as "spelunk junk."

Snag-proof clothes, feather-light sleeping bags, and tasty food concentrates have relieved the caver of weight and worry.

Spelunkers often use cable ladders. Made with twisted steel wire and aluminum rungs, these ladders easily sustain test loads of 2,000 pounds. They come in sections not more than 50 feet long, joined by clasps.

I know of one near tragedy that resulted from a weak clasp.

Bart and Bob Crisman, brothers from Abilene, Texas, were tackling a sheer 220-foot pit in the Guadalupe Mountains of New Mexico. The access tunnel opened high on the wall of the pit.

They linked four wire ladders together to

reach a shelf 130 feet below. Having climbed down to this ledge, Bob Crisman looked up to follow the slow descent of his brother, a firefly on a spider's web. Bart reached the top of the lowest ladder section 35 feet above the landing. Suddenly a clasp broke; the climber plunged down.

Reaching out, Bob was able to break the force of Bart's fall and keep him from rolling off the ledge to the pit floor 90 feet below. Bart escaped with no more than a broken ankle, a chipped elbow, and minor scratches. A rescue team strapped him to a wire-frame litter and neatly hoisted him from the cave.

Astute caving groups, in the showery summer season, place weather watchers outside any cavern with a sinkhole or valley-bottom entrance. The danger of flash floods from sudden rains can never be disregarded.

I remember how dry my mouth went in a wet Texas cave when a friend and I were collecting crickets and salamanders along an underground stream. All at once we grew conscious of a low but persistent noise that

Lacy Suicide Falls Tumbles 140 Feet Down a Wall of Cass Cave, West Virginia. Climber Takes the Only Way Out

Systematic investigation of the cave began in 1947. Explorers since have mapped the 830-foot-long Big Room and probed two miles of tortuous passages. To take the picture, the photographer covered a slope with aluminum foil to make a huge reflector for 12 bulbs.

Author Hunts Cave Creatures With a Kitchen Strainer

Biologist Mohr nets specimens in underground streams and pools for research and photographic studies (pages 828-9). In central Missouri's Piquet Cave, he caught Ozark blind salamanders.

Swaying gently above a measuring stick, a strip of aluminum foil tests the pressure of air currents that pulse in and out of Breathing Cave, Virginia. During each cycle, air flows in for several minutes, then reverses direction and flows out.

Breathing caves remain enigmas. Changes in barometric pressure and temperature, wind blowing past the entrance, and a chimney effect inside a passage offer possible explanations.

This young speleologist reads air currents by movements of the foil, her improvised anemometer. Deeper within the cavern, a second length of foil gauges the pulse of air at a side passage.

started as a whisper and grew into a roar.

"A flash flood!" we both exclaimed almost with one voice. There was no escape—nothing to do but stand there and face our fate.

Then around a bend in the passage came, not a racing wall of water, but a mass of flying bats. The whir of their multitudinous wings, amplified and distorted by cavern echoes, perfectly simulated the sound of a stream rushing through a tunnel.

Unseen "Beast" Startles Explorer

Spelunkers are a carefree, happy-go-lucky lot. They tend to jest about difficulties and dangers. Comical situations pop up frequently.

Wet and muddy after a long crawl into New York State's mile-long Tri-County Cave, southwest of Albany, my friend Howard Sloane started back out, belly whopping his way through a succession of pools left by spring rains. Too tired to crawl beneath the three-foot ceiling, he snaked along on his stomach through water six or eight inches deep. Suddenly something moved beneath his body, twitching violently.

Howard catapulted himself up and out of the water, slamming his hard hat against the low ceiling so violently that he was stunned, and fell back onto the splashing, wriggling object. His head clearing, he summoned courage, reached into the pool, and pulled out a four-pound catfish, undoubtedly washed in by flood waters.

I'll never forget a trip Howard and I made into Jones Quarry Cave in West Virginia. A local farmer was our guide.

Many dead-end tunnels led off the twisting passageway, and we three groped along in tight file. Very soon we noticed a burning smell and wondered if some cave crawler ahead of us had lighted a fire. The acrid odor persisted until I noticed a black patch with a faint orange ring around it on the farmer's overalls. Howard had been following-the-leader so closely that his carbide head lamp had burned a hole as big as a pancake in the seat of our guide's pants. The farmer never felt a thing!

Hordes of enthusiasts, of course, enjoy the underground world without having to squirm, shinny, claw, and slither through blind and often muddy alleys. Some 145 caves in 35 of the United States offer the underground sightseer de luxe tours of many of the largest and most gorgeous caverns. In them, the way is eased with electric lighting, manicured paths, bridges, stairs, tramways, and even boats to traverse underworld lakes and streams.

Without such aids to sightseeing, how many thousands would have been denied the tingling sense of mystery in boating on Echo River in Mammoth Cave? Without the hand of commercial enterprise, there would be no Great Stalacpipe Organ in Virginia's Luray Caverns, an instrument which produces brilliant melody by striking electrically driven hammers against stalactites tuned to true pitch by careful grinding of their tips.

Without development for visitors, few would ever see New Mexico's Carlsbad Caverns, king of caves (page 817). It spellbinds half a million viewers annually with such extravagances as a single room with 14 acres of floor space and a high point 285 feet above

KODACHROME BY CHARLES E. MOHR © N.G.S.

Daubed with blue shellac, a cave cricket clings warily to a cavern ceiling. *Hadenoecus subterraneus*, one of four thousand crickets marked in Kentucky's Cathedral Cave, will provide scientists with clues to its habits and life span. Long, probing antennae twitch unceasingly as the insect moves in total darkness. Unlike its chirping surface relatives, *subterraneus* is silent.

Eyeless cave fish glides among rocks with easy assurance. Exposed nerve endings along lips and head detect faint disturbances in the water and lead *Typhlichthys subterraneus* toward its prey. It rarely exceeds three inches.

Pincers extended, a crayfish forages for crustaceans such as the isopod (opposite, upper). Slow-paced *Orconectes pellucidus,* six inches in length, may live to twice the age of surface kin.

Cave tenants share a dark netherworld

CREATURES that never venture from the unending night below ground are called *troglobites.* Most are blind and colorless. Some, such as the insects, live on food brought from the surface by bats or streams. Others—fish, salamanders, and crayfish—devour smaller neighbors. Remote ancestors of cavern creatures lived above ground. Crickets and spiders entered caves in search of a dark, humid environment. Certain fish went underground with floods. Their descendants became adapted to total darkness.

Rare Transparent Shrimp Carries Pea-green Eggs

Only Squirrel Chimney, a flooded sinkhole near Gainesville, Florida, yields *Palaemonetes cummingi.* Divers net the inch-long shrimp in dimly lighted water in the 80-foot-deep shaft. To study its behavior, biologists place specimens in tanks at 70° F — the temperature of Squirrel Chimney—and feed them bits of raw liver.

KODACHROMES BY CHARLES E. MOHR AND HOWARD N. SLOANE © N.G.S.

Inch-long crustacean thrives in underground pools and streams. Similar appendages make head (left) and tail of this *Asellus* isopod look alike.

Ozark blind salamander begins life with eyes and plumelike gills. As *Typhlotriton spelaeus* matures, eyelids fuse together and gills disappear.

KODACHROME BY HOWARD N. SLOANE © N.G.S.

Cave mushroom sprouts from cottony mycelium that grows atop guano, the rich droppings of bats. Branching filaments combine the functions of plant body and root system.

KODACHROMES BY WILLARD R. CULVER (BELOW) AND ROBERT W. MITCHELL © N.G.S.

Stiltlike legs mark the eyeless harvestman *(Phalangodes armata)*. Found in Kentucky, Tennessee, and Alabama, the subterranean daddy longlegs feeds on plant debris. This white troglobite never ventures from the cool darkness of caves; a few seconds' exposure to sunlight would prove fatal. To protect the delicate arachnid, the photographer used cool strobe lights.

In 1924 geologist Willis T. Lee led the National Geographic Society exploration that first surveyed Carlsbad's inner reaches. Dr. Lee's explorations laid the groundwork for opening the caverns to the public.*

"Pearls" Form in Pools

In the winter of 1961-62, I was able to sign on briefly with naturalist James Kenneth Baker to study life in nonpublic areas of the country's most spectacular cave. A series of ladders took us down to a level Carlsbad passageway nearly 900 feet below ground.

Here I saw bed after bed of cave pearls, or pisolites, some half an inch in diameter, but most the size of buckshot. These decorative objects form in underground pools, around grains of sand, like pearls in oysters. Limestone slowly encases each sand particle, but constant dripping keeps the pool water agitated enough to prevent the growing concretions from cementing themselves to the bottom or each other (page 816).

I noticed we were following a string. It was one Dr. Lee had used 38 years earlier; it led us to the spectacular New Mexico Room, containing a forest of slim stalactites, green pools with encrusted yellow "lilypads," and pure white "Christmas tree" stalagmites.

The ceiling of Carlsbad's Bat Cave, when

*See, in NATIONAL GEOGRAPHIC: "Visit to Carlsbad Caverns," January, 1924, and "New Discoveries in Carlsbad Caverns," September, 1925, both by Willis T. Lee, and "Carlsbad Caverns in Color," by Mason Sutherland, October, 1953.

Cloud of free-tailed bats flecks the Texas sky above Bracken Cave, home to millions of the furry mammals. Forays for insects usually begin in late afternoon, giving the vast population time to clear the cave for the night's hunt. Although bats can see, they do not depend on sight to snare food on the wing. Emitting high-pitched beeps similar to sonar's, they evaluate the echoes and swoop upon their prey. The same sound equipment enables them to avoid collisions. *Tadarida brasiliensis* uses a 12-inch wingspread to carry half an ounce of weight.

Gentle squeeze with needle-nose pliers bands the delicate forearm of a western pipistrel. Tiny identification bracelets enable mammalogists to study the migrations, homing ability, and life span of bats. Thousands of the creatures have worn the telltale rings since 1932, when author Mohr became the first United States scientist to band a cave bat.

I had first visited it in June, 1938, was a solid gray-brown color—a tapestry of nine million bats. By the time of our 1961-62 visits, the bat population in Carlsbad was estimated at less than a twentieth of what it was before World War II. The decline may be due to drought and to wide use of poisons that have thinned the insect population on which the bats feed. Rabies also has played a part.

However, millions of people have visited Carlsbad without encountering a live bat.

Bat droppings, or guano, in the Bat Cave section of Carlsbad were mined for many years. Starting in 1903, exploiters dug deposits, some as deep as 50 feet. A windlass hauled some 100,000 tons of guano 180 feet to the surface.

No one has calculated how long it took for this highly nitrogenous bat excrement to accumulate, but its use as fertilizer for citrus groves earned fortunes for the enterprising operators in a relatively few years.

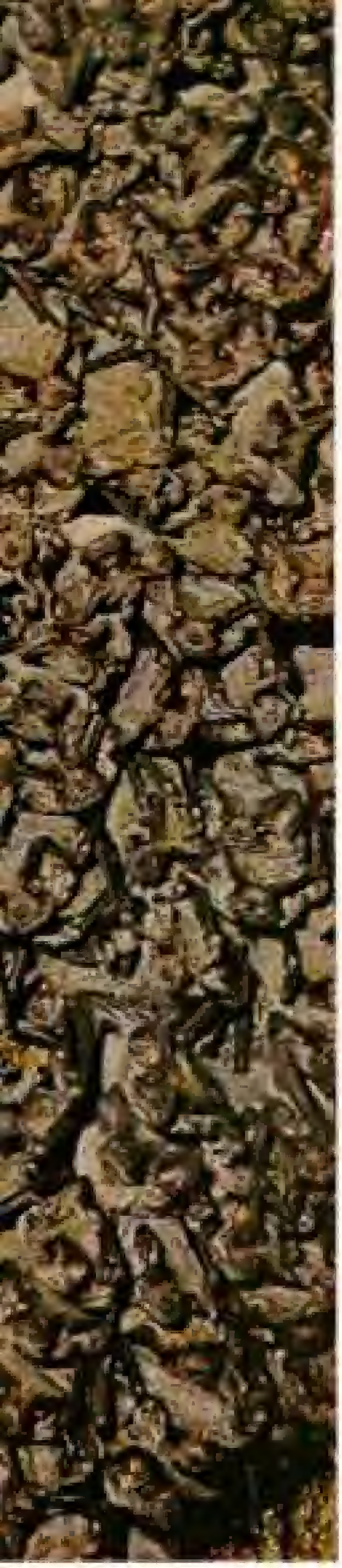
We came upon a bed of fresh guano marked off with square wire frames. Each nine-inch square was tagged with a number. On hands and knees, Ken Baker took a forceps from his pack and delicately probed the accumulation within one of the frames. Masses of guano were interwoven with silken strands.

"Moths," he said. "Each year by the thousands they lay their eggs in bat guano and die. Nowhere above ground has anyone seen such numbers of moths."

The larvae, or caterpillars, spin silken tubes.

Tiny Ogre's Teeth Spell Quick Death to Insects

Voracious bats subsist on moths, fruit flies, and other insect enemies of man. No species found in the United States bites humans except in self-defense; most have teeth too small to puncture the skin. *Myotis velifer*, shown three times life size, weighs a fourth of an ounce



Disturbed, free-tailed bats stare from the wall of Ney Cave, Texas.

Social bats of the species *Myotis sodalis* cluster on the walls of Bat Cave in Kentucky's Carter Caves State Park. During winter's long sleep, the mammals become stiff and cold; breathing almost stops. Here speleologist Howard N. Sloane seeks banded specimens among the colony of some 5,000. He took his own portrait by opening the shutter of the camera and firing two flash bulbs.

They stick out their heads to eat the guano. Baker counted as many as 150 larval cases in a single nine-inch square.

To study bat habits, longevity, and migrations, I've been engaged for 32 years in bat banding, most of it in caves. Recoveries of banded bats have documented their powerful homing instinct, which brings individuals back, year after year, to winter in the same cave (page 831 and above).

Some flights have covered hundreds of miles, and bats carried by naturalists great distances from their roosts have returned unerringly. Banding has established bats as the Methuselahs of the small-mammal world. Some live for 15, even 20, years.

Bats are important to the food chain of most forms of cave life. A host of tiny underworld creatures feeds on the guano. Floods supplement the food supply, washing in decaying leaves and scraps of wood and bark. Mushrooms and other fungi which grow on all this nutrient waste provide a daily banquet for insects, millipedes, and worms. On these, in turn, the salamanders, fish, and crayfish feast (pages 828-9).

Dabs of Color Trace Insect Travels

Cave creatures, of course, are studied in many places; for example, at Cathedral Cave. Its opening, high on a bluff, overlooks the Green River in Mammoth Cave National Park. A biological survey begun here in 1960 and still continuing has made the creatures of this cave the most fully observed wildlife population of underground America.

Christian Brother G. Nicholas, biologist at La Salle College, Philadelphia, sectioned off the cave and made a daily census of insects.

To establish the home territory and wanderings of cave crickets and blind beetles, Brother Nicholas and his assistants marked each individual insect with harmless airplane dope—pigmented shellac. A different color was used for creatures in each of seven zones. More than 4,000 insects were marked and 3,000 were seen again. Ninety-seven percent of these were on their home territories.

During many visits to Cathedral Cave, I had concluded that the big fawn-colored cave cricket, *Hadenoecus subterraneus*, never left the cave (page 827). But Brother Nicholas's marked crickets proved me wrong. Except during very cold or very dry weather, about a third of these crickets made a nightly foray outside, and returned.

Brother Nicholas's survey revealed that cave creatures segregate themselves by preference for ceiling, floor, or walls. The crickets, for example, always hang upside down on the ceiling. Brownish harvestmen, or daddy longlegs, cling only to the walls, but leave the cave en masse for about a month in early summer. Cave spiders, millipedes, and snails share the wall space.

Blind beetles a quarter inch long scamper over the floors, but almost exclusively in muddy areas. None of the 200 marked beetles were found more than ten feet from the spot where tagged. Instead of preying on insect neighbors, as had been suspected, the beetles appear to get their food from colonies of bacteria that grow on the mud.

Salamanders Rove and Prey

Big-eyed cave salamanders, bright orange with black spots, go where they please. They prey on almost every type of small cave dweller and perform a service to man by reducing the numbers of wintering mosquitoes.

Brother Nicholas and his crew have learned much about cave-creature migration, homing, mortality, mating, and predation. They are still at a loss, however, to explain what sort of biological clock gives these creatures such precise knowledge of hour and season, so that crickets know it is time for their nightly sortie, and the daddy longlegs get the urge for their summer migration. Perhaps they are sensitive to minute atmospheric or temperature fluctuations that humans cannot detect.

Caves fulfill a variety of roles, quite apart from their popularity with sightseers and biologists.

United States caves achieved their maximum industrial use during the Revolution and the Civil War. Many caverns were caked with natural saltpeter (calcium nitrate), a raw material of gunpowder. Our nation's survival in the War of 1812 hinged in substantial part on the availability of saltpeter. During the Civil War, the Union blockade of the South forced thousands of Confederates into service as niter miners.

Desperate Men Find Hiding Places

Caves have affected history by providing refuge to murderers, counterfeiters, runaway slaves, deserters, hermits, moonshiners. On a lighter note, Pennsylvania Dutch youngsters in the 1890's held clandestine dances in caves to escape strict parental supervision. In the South, candlelighted caverns—like the 96-foot hall in Manitou Cave, Alabama—served as underground ballrooms where beaux and belles twirled on board floors.

A walk in Luray Caverns, Virginia, leads past the Wishing Well, an illuminated pool carpeted with coins tossed in by visitors (page 813). Every now and again the "take" is shoveled out, cleaned, and presented to some worthy health organization. The last haul, in 1961, added up to 3,853 pounds of coins. Total value: $14,218.86. Grateful recipient: the American Heart Association.

Cave guano deposits sometimes are covered with what appears to be white fur—a mold. Mindful of the miraculous antibiotics, including penicillin, derived from molds, researchers periodically probe caves in search of new strains.

Space-age scientists study hibernating cave bats to learn if men, too, might hibernate. Ability to slow down astronauts' metabolism, pulse, and respiration could mean tremendous economies in food and fluid consumption

Icicles Form Columns From Ceiling to Floor in Crystal Ice Cave, Idaho

In the desert 150 feet above this deepfreeze, jack rabbits scamper across sagebrush country where lava fissures scar the earth. Visitors at the surface could leave summer's 90-degree heat and skate across Crystal's underground rink. Water draining into a crevice directly above the ceiling freezes as it enters the 32-degree room.

during years-long interplanetary voyages.

Study of lava caves holds promise for scientists and engineers who are preparing to land explorers on the moon. If volcanism has molded parts of the moon's surface, then lava caves and tunnels can be expected there.

Man Might Make Moon Caves Livable

Since gravity is less on the moon than on earth, it is possible that the lunar crust is more porous, hence spongier, than earth's. This may allow larger gas accumulations, and at greater depths. Huge gas bubbles may have molded giant moon caves that would furnish underground city-sites—a "troglopolis" in which an artificial, germ-free environment might be maintained.

Earthly caves hold little promise as fallout shelters: Most caverns are far too rough and broken up to accommodate people in large numbers. Besides, most caves are remote from cities and occur too close to ground surface for adequate defense against blast.

Many National Speleological Society chapters have a core of able teen-age explorers. Visiting the Black Hills of South Dakota, I made a spelunking date with Art Jones, meteorologist-announcer at a Rapid City TV station. Art is leader of an Explorer Scout post that has done a lot of cave crawling.

"We want to show you our latest discovery," Art had written me.

We left the highway not far from Mount Rushmore, drove up a red-walled canyon, and piled out of our cars at the base of a cliff.

The portal was 18 inches square, and just beyond there was a ten-inch-high ceiling that the dozen skinny scouts slid under without a pause. But only by peeling off my jacket and sweater could I follow.

Carrying a mastodon tooth, paleontologist Stanley J. Olsen approaches the surface after a dive into Wakulla Springs Cave near Tallahassee, Florida. Scientists recover bones of extinct animals from the cave's sandy floor.

Scuba diver 75 feet deep in Wakulla tugs at the femur of a mastodon. Explorers have found the bones of mammoths and tapirs and some 600 pre-Columbian bone spear points. Scientists have no conclusive proof that the weapons, made by early man, were used in hunting these large animals.

When I caught up with the fast-moving youngsters, they were gazing triumphantly around a barn-size room studded with enormous tooth-shaped pink and tan calcite crystals. I was glad I had dragged along my camera bag. My whole outfit—a Leica with wide-angle lens, tiny tripod, miniature reflector, and a handful of "peanut" bulbs—would not have filled a shoe box.

The ease of photographing cave formations has largely removed the temptation to collect specimens and thus has helped ensure the survival of the most precious features of caverns—their unique life and matchless beauty. The annual photographic salons and contests sponsored by our caving society bring together increasingly fine examples of the speleophotographer's skill. These collections have provided the nucleus for the series accompanying this article, the most extensive color coverage of caves ever published.

Today we of the National Speleological Society unequivocally condemn the collecting of animal life underground except for scientific purposes. We equally deplore depredations by vandals who destroy or deface what nature has taken ages to create. We cooperate with conservation groups to protect a number of subterranean "natural areas."

There will always be new discoveries to be made, virgin passageways to be trod. Caving never will be commonplace for any of us who have known the thrill of pioneering in places where few people venture.

We wish all who go caving would take to heart the motto that has more than once been used as a kind of spelunkers' oath:

"Take nothing but pictures.
Leave nothing but footprints."

THE END

IN THE LONG ASSOCIATION between man and birds, few species have aroused more controversy than the Midway Islands' famous albatrosses. Coleridge's Ancient Mariner ascribed supernatural power to the albatross, but the modern mariner of the United States Navy respects it for more tangible reasons—particularly if he has served at the Midway Naval Station in the North Pacific.

He knows the two species that nest there by the thousands as gooney birds, or just gooneys. The gray-and-white Laysan albatross *(Diomedea immutabilis)* he calls "white gooney," and the sooty-colored black-footed albatross *(Diomedea nigripes)* "black gooney." And he has mixed emotions about these marvelous creatures with their seven-foot wingspread.

Gooneys Imperil Planes

On the positive side, the gooneys are a morale builder on one of the key military bases in the Pacific area. Playful Laysan albatrosses, resembling overgrown sea gulls engaged in ritualistic dances, provide more genuine amusement than the double feature at the Midway movie house.

Pro-gooney sentiment runs high in the Navy homes along Midway's ironwood-shaded streets, where these magnificent sea birds build their shallow nests all over front lawns and back yards, in utter confidence. They are as much a part of the household as the family dog or cat, and anyone seeking to harm them would have an irate housewife to contend with.

Pilots and operations officers in Midway's control tower, however, see another side. These men sweat it out while the great radar-equipped picket planes, the Lockheed Super Constellations of the Pacific Fleet's Barrier Forces, roar down the runway and take off through hundreds of soaring gooneys. Even before clearing the runway, a plane may hit a goose-size gooney and have to return for repairs, leaving a gap in the radar barrier of our national defense. It is only by great good fortune that so far there have been no crashes or loss of lives.

Two decades of battle between the U. S. Navy and the albatross have seen the use of just about every weapon short of the atomic bomb: clubs and flares and rocket-launching bazookas, smoke and ultrahigh-frequency sound waves. Since 1954 the Fish and Wildlife Service of the U. S. Department of the Interior has kept a team of scientists assigned to seek an agreeable solution to the problem. Agreeable, that is, both to conservation-minded citizens, who wish to see the birds preserved, and to the Navy, concerned about safety of personnel. As the man in charge of this project, I have become closely acquainted with Midway and its beloved but troublesome gooneys.

Midway's gooneys did not become widely known until Pan American Airways built a base for its transpacific clippers on the mid-Pacific atoll in 1935. A hotel on Sand Island was appropriately called Gooneyville Lodge, and a golf course received world-wide billing as the only one with gooney birds nesting on fairways.

The Navy's airfield, constructed shortly before World War II, played a vital part in turning the tide of the war in the Pacific. The gooneys took in stride the Japanese bombings during the Battle of Midway, as well as the elimination of many thousands of their kind by defenders striving to

The Gooney Birds of Midway

By JOHN W. ALDRICH, Ph.D.

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PLANE AND ALBATROSS *compete for airspace above the Pacific's Midway Islands. Soaring gooneys cannot turn fast enough to evade craft over the naval airfield, and planes at take-off or landing also lack maneuverability. Result: collisions at closing speeds up to 200 miles an hour, often crippling the plane as well as killing the gooney. Collisions have cost the U. S. Government some $250,000 a year. By coincidence, this plane is a Grumman amphibian called Albatross.*

reduce hazards to aircraft. As Midway's postwar air traffic grew, the rate of bird-plane collisions became alarming.

When I arrived at Midway eight years ago, our plane hit two Laysan albatrosses. In the passenger cabin, I was unaware of the birds' impact until we landed and I heard of it from the flight crew. As unmistakable proof they showed me the dents in the plane's wings.

I had landed in mid-November, when birds arriving on the nesting grounds swarmed in great numbers over the runways. During this season four out of ten planes operating in daylight hours struck birds. And about one in 15 collisions caused damage: broken windshields or antennas, dented radomes and cowling; torn leading edges of wings and stabilizers; and bent propellers. Some seriously damaged planes came close to shooting off the runway and into the lagoon.

Albatross Families Refuse to Move

Nobody wanted to slaughter the albatross. We simply hoped to annoy the gooneys enough so that they would go away. But how? A report about a series of experiments conducted by Philip A. DuMont and Johnson A. Neff of our team made discouraging reading.

First they had tried smoke. Daylight flares drifted orange clouds over some 130 black-footed albatrosses that had not yet started to lay eggs. "No birds moved."

Next, a burning truck tire was placed near five black gooneys sitting on eggs. All the birds were within six feet of the flame, which produced a dense, black cloud and an acrid stench. "One bird moved because of the heat but returned to its egg within a few minutes. None of the birds left the area."

Marines fired a mortar. "Birds no more than 200 feet from the mortar continued to sleep, and none of those nearer were seen to move away."

Bazookas did no better. "Birds on eggs within range of the backflash had feathers ruffled, but none moved."

Loudspeakers sent sound waves of varying lengths toward the gooneys. "No birds left the area," said the report, which indicated that gooneys are undisturbed by ultrahigh frequencies, though sonic research continues.

On the target range, gooneys nested in the line of fire. "One black gooney continued to sit on its egg 3½ feet in front of, and a foot below, a rifle muzzle."

Why do gooneys seem not to fear man or machine—at least not enough to be scared away permanently? Perhaps because they

Effortless wings stretching seven feet from tip to tip, a Laysan albatross, or "white gooney," soars above Midway atoll. Graceful in flight but awkward on land, the albatross becomes an undignified gooney bird when it arrives at its nesting grounds.

Ignoring a four-engine neighbor, black-footed albatrosses, or "black gooneys," colonize a strip of sand near a Navy radar picket plane. Heads of chicks protrude above nests—shallow holes scooped in the sand.

Scratch 32 gooneys, says the tally outside the cockpit of a Navy plane. Though collisions have cost no planes or lives, they have canceled missions. On take-off, crewmen station themselves at windows to watch out for the wheeling birds. The more numerous Laysans constitute the major hazard. Antenna guy wires on Eastern Island also take a toll of birds—up to 50 a week in nesting season.

have had no enemies on the oceanic islands until relatively recent times. Man's first serious impact on the gooneys probably came with the Japanese plume hunters at the turn of this century, when the trade in feathers for ladies' hats was at its peak.

Feather hunters completely wiped out albatrosses on several North Pacific islands, but U. S. authorities stepped in before they could finish them off on Midway and other islands of the Hawaiian chain.*

At the end of World War II, a survey estimated Midway's Laysan albatrosses at 110,000 and the black-footed species at 53,000. A more recent estimate reported 200,000 Laysan and 17,000 black-footed gooneys, making Midway second only to Laysan Island—about 390 miles to the east—as a gooney nesting ground.

In view of this history, we knew that we were confronted with two species of wildlife lacking the usual nervous, or fear, responses. Before we could hope to propose ways to control the gooneys, we would have to find their Achilles' heel. This could only be done by a thorough study of the birds' life history and behavior. We realized that the task would take years and would require banding and observation of thousands of birds.

And so, soon after our arrival, biologists on bicycles were exploring every part of the great bird city. We grasped nesting birds by the neck—firmly, for gooney beaks can inflict painful wounds—and clamped numbered aluminum bands on their legs. Others we ran down before they could gain enough headway into the wind to take off (page 848).

Housewife Tips Off Scientist

Now, after ten years of study, we must list some experiments that looked promising at first but then failed to produce satisfactory answers.

For example, Hubert W. Frings, a professor of zoology at the University of Hawaii who investigated gooney behavior for the Office of Naval Research, heard from a sailor's wife that when she hung out her laundry the birds were frightened. Thereupon Dr. Frings kept walking toward gooneys

*See "Bird Life Among Lava Rock and Coral Sand," by Alexander Wetmore, NATIONAL GEOGRAPHIC, July, 1925.

Black-footed albatross (top) raises bill high and utters a cowlike moo during ritual dancing at the start of the breeding season. Gooneys also bleat like sheep, squeal like pigs, cackle like hens, twitter like songbirds, and shriek like children. Wings akimbo, the couple in center does a Midway mambo. Bill to bill, the partners at left bob heads in mutual admiration. Ornithologists believe that courtship inspires the displays, though the performances continue for months. Sexes look identical; hence bird watchers are unsure who is dancing with whom. Both species engage in such dances.

Flapping bed sheets, Navy men advance like bullfighters against nesting gooneys. Midway's naval commander ordered Operation Bed Sheet after ornithologist Hubert Frings found that the birds retreated before any large surface such as a coat, sheet, or cardboard. The orders sanctioned "any procedure which does not injure or kill the birds. Gooneys can bite hard, so beware of their snapping beaks." Like everything else, the sheets failed. After beating a strategic retreat, the birds quickly returned.

Refusing to budge from a grader's path, young gooneys force rescuers to carry them to safety. Grading levels dunes that create updrafts on which the albatrosses soar.


MIDWAY
ISLANDS
Coral
reef
Sand Islet
Middle Ground
North Breakers
SAND ISLAND
Approx. elev. 12 feet
Photograph below
looks west
Welles
Harbor
Airfield
Entrance channel,
depth 31 feet
EASTERN
ISLAND
Approx. elev. 12 feet
STATUTE MILES
Soundings in feet


Black-footed albatrosses occur
over the entire flight range.
Laysans within dashed lines.
Nesting islands of both
species are circled.
ASIA
Bering Sea
Aleutians
Puget
Sound
NORTH
AMERICA
San Francisco
California
FLIGHT RANGE
OF THE GOONEY BIRDS
JAPAN
Tokyo
Laysan Island
HAWAII
Honolulu
MIDWAY
ISLANDS
Islands comprising the
Hawaiian Islands National
Wildlife Refuge
PHILIPPINES
Pacific Ocean
Equator

Downy chick peers from its nest. Albatrosses mate for life and lay one egg a year.

Site of battle between man and bird lies 3,200 miles west of California, 2,500 miles east of Japan. Coral Midway consists of a reef-sheltered lagoon, Eastern Island, and 1,055-acre Sand Island (below). It is one of several leeward islands of the Hawaiian chain that comprise virtually the entire nesting range of Laysan and black-footed albatrosses. Map shows present nesting and flight ranges.

The airfield serves as a steppingstone for transpacific flights and berths Navy picket planes, part of a radar early-warning system. In 1942 the atoll gave its name to the decisive Battle of Midway, in which Navy flyers destroyed four Japanese aircraft carriers.

PHOTOGRAPHS BY ROBERT B. GOODMAN © N.G.S.

while holding up large squares of colored cloth or cardboard. "Any flat surface moving toward them seems to make them panic," he reported, "especially red surfaces." But once the panic was over, the birds were back.

Next Dr. Frings tried a grid of electrically charged wires, ten feet apart and six inches off the ground. He found that no birds would nest in that grid, even after the electricity was turned off. But the grid was judged to be more hazardous to humans than to the birds.

We tried two more noise-making schemes. First, carbide exploders. These are metal cans containing lumps of calcium carbide on which water drips, to produce a highly explosive gas. Every few minutes, automatically, a spark ignited the gas. The noise was like cannon, and it bothered lots of people on Midway. The gooneys just shook their heads.

And then there were taped distress calls, which received much attention from Dr. Frings. He had recorded sounds of birds in trouble and discovered that by playing his recordings he could scare away other birds of the same species. This technique had often worked with starlings. But the recordings to date have proved only mildly disturbing to Midway's black gooneys. To white gooneys, not at all.

Will mortars rout gooneys? Helmeted sailors prepare to fire smoke bombs against a large concentration. When the smoke blew away, the birds still held their ground.

Red smoke rolls from a hand-placed bomb among nests of black gooneys. The billowing stream turned some chicks red but caused no visible signs of annoyance. The troops retired from the field.

Birds Forget How to Land

But we were not discouraged. We felt sure that continued banding and surveillance of gooneys would reveal the facts needed to control them.

We do not yet know at what age our two species begin to breed, but evidence points to seven years, more or less. Parents spend nine months of the year incubating their single egg and rearing their offspring. They spend the other three months at sea, gliding close to waves and occasionally alighting on the water as ducks do. They range the North Pacific from America to Asia and north into the Bering Sea, catching fish and squid, and sometimes following ships for refuse (map, page 844).

The gooneys start coming back to Midway late in October. This is a great event for the people on the island. After several months at sea, the birds apparently cannot remember how to alight on land. They have to learn all over again, the hard way.

In they glide from the blue Pacific, over the line of breakers on the barrier reef. Across the pale-green lagoon and the brush-covered dunes they come, along the beach, down the main street of the residential section.

Each heads unerringly toward the spot it has used for years for nesting. We have recaptured several of the first birds banded on nests near former Gooneyville Lodge—still laying eggs on the same site 26 years later.

Rockets' red glare shows the gooneys still there. This experiment with flares fired by Very pistols proved the birds no easier to scare by night than by day.

The gooneys approach in a long, flat glide on motionless wings. Down go the wing and tail flaps, and the broad webbed feet.

But brakes aren't set soon enough. Touchdown speed is far too great. The landing gear collapses. The exquisite gliding mechanism becomes a disorganized spectacle of gyrating wings and disheveled feathers sprawling across the ground. New arrivals seem embarrassed as they pick themselves up to the noisy accompaniment of neighbors' squeals, groans, and clapping bills.

Both species of bird nest in colonies, but the black-footed albatross prefers the open beaches, while the much more numerous Laysan, or white, favors the shelter found at the edge of a clump of bushes or in the shade of an ironwood tree. Areas near runways offer many such protected sites, with the result that the Laysan suffers the heaviest toll from airplanes and is the chief menace to flyers.

Nest building differs, too. Both species scoop shallow depressions in the sand, but Laysans add weeds, sticks, and debris. The nest builds up as the incubating bird pulls in anything within reach. During storms the raised nests form little islands against the flood.

The egg is about four inches long, white or pale buff in color, and usually blotched with reddish brown. The parents sit on the egg by turns, one incubating while the other goes to sea to feed and drink, often for two weeks or more. The change-over is an amusing ceremony: The parent examines the egg closely and talks to it with a gentle cheeping sound before settling down over it.

The incubating parent never leaves the egg unattended, even though the bird may be buried up to the neck in windblown sand. It

Like a plane taking off, albatrosses need a running start upwind to get airborne.

White gooney wins a race with a leg bander, whose final lunge gets him a face full of sand instead of the bird. Navy men such as this young officer help ornithologists band albatrosses in a long-range study. Resulting knowledge about the birds' movements may help control and protect them.

may lose a quarter of its weight for lack of food and sea water. (Albatrosses cannot remain healthy by drinking fresh water; special glands at the base of their bills secrete the excess salt taken by drinking sea water.)

The off-duty parent roams far over the North Pacific. A Laysan albatross banded while incubating an egg on Sand Island was caught three weeks later, 2,300 miles away.

Gooney Tries to Hatch a Tin Can

One afternoon friends invited us to a cookout. Nearby, gooney birds sat serenely on their eggs, gabbling and going about their normal gooney business. They accepted us as part of the colony. Even the family dog received no more attention than an occasional thrust of a bill, which he respectfully avoided.

We put gooney behavior to the test by substituting briefly a tin can for an egg. The patient parent sat on it with the same solicitude it had shown for its own egg, simply shifting about more than usual in quest of comfort.

Albatross chicks appear in January, after about nine weeks of incubation. For the first two or three weeks of its life, each chick is continually attended by its parents, one of which forages for food far out over the sea while the other takes its turn at the nest. The young albatrosses are fed by regurgitation,

placing their bills inside those of their elders.

In summer the fuzzy chicks reach full size. The parents' feeding visits tend to become fewer and finally stop, and the young, having exercised and tested their wings in the wind for weeks, take off alone over the ocean.

Probably at least two years will elapse before the young again set foot on dry land, and another four to six years before they nest.

Albatrosses possess an extraordinary homing ability. Two of our team members, Dale Rice and Karl Kenyon, banded 18 Laysan albatrosses and shipped them by air to distant points in the North Pacific. Fourteen returned to their nests on Midway. One, which had been released in Puget Sound in Washington State, covered 3,200 miles in 10 days. The long-distance record was a 4,120-mile flight from the Philippines, in 32 days. We abandoned all idea of exiling nesting albatrosses from Midway to other islands.

As a step toward control, we determined to find out which segments of the white gooney population presented the most danger by soaring over the runways. We zoned the Laysan albatrosses on Sand Island according to the distance of their nest from the runways. One of us held the birds while another painted aniline dye on their breasts.

Gooneys nesting within 750 feet of the runway we dyed violet; those at a greater distance, green; birds from the still farther distant residential section, yellow. Those two miles away on Eastern Island, we dyed red.

We discovered that two-thirds of the dyed birds above the runways came from nests within 750 feet. Half of one percent came from the residential area. Only one red-marked bird came from Eastern Island.

We found, too, that albatrosses whose eggs had been destroyed now appeared far more frequently over runways than before. Deprived of their eggs, they made no effort to renest. They simply cruised aimlessly about. We calculated that these unemployed gooneys constituted a hazard to aircraft five times greater than nesting birds.

At one stage we considered reducing the nesting population, or at least eliminating the group shown by our color marking to be the greatest hazard to the planes. In an experiment, albatrosses were eliminated from a zone on each side of the most frequently used runway. But to our surprise, the number over the runway *increased.*

The explanation seems to be that non-nesting birds, seeking homesites, were attracted by the depopulated strip of land in

Gooney brings bus to a halt. Birds get in the way of everything on Midway. While coming in for landings, they sometimes spill and injure cyclists. But the islanders enjoy their antics.

a thriving gooney colony. And since they were not yet tied down to nests or young, they spent most of their time cruising about over the area. We abandoned this reducing plan.

We kept looking for exploitable characteristics of the albatross. At last we found the clue.

Gooneys seemed to concentrate over portions of runways bordering uneven terrain. Level areas had relatively few gooneys overhead. When the significance of this dawned on us, we intensified our surveillance.

For several years, team members Karl Kenyon, Dale Rice, and Chandler Robbins observed patiently. The conclusion was inescapable: Albatrosses tend to soar over dunes and old wartime revetments. These deflect the nearly continual winds upward, producing air currents ideal for gliding.

If all the land adjoining the runways could be leveled, we reasoned, the hazard to aircraft caused by flying gooneys would be very much reduced. Furthermore, if we prevented nesting for some distance from the runways—by hard-topping the surface—we would decrease bird flights over those areas.

Seabees leveled and blacktopped a stretch alongside the most frequently used runway, where soaring gooneys were numerous. Studies by Chandler Robbins immediately showed fewer bird-plane collisions over that runway.

Thus the Navy arrived at its answer to the problem: Level and pave broad strips within 750 feet of the center of each runway. Unfortunately, birds nesting beside the runways would have to be eliminated; otherwise the homeless gooneys would soar aimlessly over the traffic zone, increasing the hazard.

In January of this year some 17,000 birds—mostly Laysans—were eliminated from strips near runways. Seabees began leveling and paving, a task that should be finished this fall. Only then can we evaluate results.

Carl W. Buchheister, President of the National Audubon Society, observed the bird-strike problem on Midway at first hand as a guest of the Navy.

Bed check by gooney patrol finds birds nesting peacefully. Not everyone loves gooneys, so the Navy tries to curb vandals.

"Continued research is needed if Midway is to remain a nesting site," he said. "And the Hawaiian Islands National Wildlife Refuge, four islands of which could accommodate half a million birds, must be held absolutely inviolate [map, page 844]. The future of these two species depends on it."

The Navy's measures affected about 7 percent of Midway's Laysan and 11 percent of its black-footed albatrosses—less than 1 percent of the world population. Midway's other birds are welcome to their accustomed nests.

Thus Navy families along Nimitz Avenue will enjoy seeing their gooney birds return each autumn. And the airmen appear to have won, at least temporarily, in the Navy's war with the gooneys. THE END


QUEBEC
NAUTICAL MILES
CAPE BRETON ISLAND
Beinn Bhreagh
St. Ann's
Sydney
Cape Breton
Baddeck
Bras d'Or Lakes
St. Peters
PRINCE EDWARD ISLAND
NEW BRUNSWICK
Cape George
NOVA SCOTIA
Liscomb
Halifax
Indian Harbour
Peggy's Cove
Lunenburg
Bay of Fundy
CANADA
UNITED STATES
MAINE
MARBLEHEAD - HALIFAX RACE
Atlantic Ocean
Portland
N.H.
Marblehead
BOSTON
MASS.
Plymouth
R.I.
CONN.
Newport
NEW YORK
2

Down East to Nova Scotia

Blue-water yachtsmen steer a course for the saltiest of Canada's Maritime Provinces

By WINFIELD PARKS
National Geographic photographer

"ANY CHANCE of a spare berth?" I asked at Marblehead, Massachusetts. I was watching final preparations aboard *Aries* for the Halifax race, held every other year.

"Sure! We can use an extra hand," Seward De Hart, skipper of the cutter, answered. "Stow your gear in the fo'c'sle—and shake a leg. We're shoving off soon."

The 54-boat fleet was well stocked because many of the craft planned to rendezvous at Halifax after the race for a cruise to the Bras d'Or Lakes of Nova Scotia.

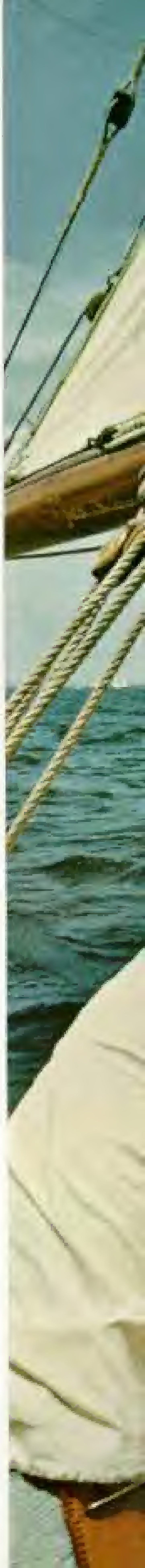
Yacht and crew are shipshape at last. Docking lines are cast off; sails are set and trimmed. *Aries* breathes with the wind and frolics with the waves. She responds quickly to the touch of the helmsman's fingertips. *Aries* is alive again, graceful and beautiful as only a lady can be.

Down comes the blue cone from atop a mast on the race com-

Chasing her spinnaker, *Niña* arrives off Halifax. The 58-foot schooner, skippered by DeCoursey Fales of the New York Yacht Club, set a record of 45 hours 25 minutes elapsed time in the race from Marblehead to Halifax—360 nautical miles

KODACHROMES BY CHARLES R. WITT (ABOVE) AND WINFIELD PARKS © N.G.S.

Forest of masts fills Marblehead Harbor, where popular little boats called Turnabouts hoist sail and prepare to pull away. The name Marblehead, long synonymous with the sea, derives from white rock outcroppings that mark the shoreline.



"Sweat that genoa sheet home!" Two crewmen of *Aries* (foreground) execute the order as the yawl *Chee Chee V* climbs up to leeward at the start of the Marblehead-Halifax race. Boston Yacht Club and Royal Nova Scotia Yacht Squadron hold the event in odd years. The Newport-Bermuda race, sailed in even years, is sponsored by the Cruising Club of America and the Royal Bermuda Yacht Club.

mittee starting boat; a five-minute warning gun sounds. Excitement mounts. Crews are nervous but calm. All are experienced seamen. Yawls, ketches, sloops, and schooners jockey for position. The skippers strive to hit the starting line right on the gun, their vessels driving hard toward Halifax.

At dusk the wind picks up. The weather turns cold, and a blanket of fog enshrouds the fleet. Masthead lights glow eerily. Water drips from the helmsman's nose or creeps down his neck as he concentrates on a compass course.

Up forward, a watchmate monotonously pumps a foghorn. Your senses sharpen in the dark night. You sniff balsam and spruce miles away on shore, and faintly you hear foghorns in the distance. The wind shrills in the rigging, the lee rail dips, and the sea gurgles.

All hands on deck! Skippers must shorten sail as a squall hits. Clothes are wet, fingers numb, and the slippery deck slides away as you gather in the flapping Dacron sail. Green water cascades over the bow and lifts you off your feet. Your safety belt, attached to a lifeline, keeps you from being washed overboard.

The three-day race ends off Halifax. Crew members fly back to neglected jobs, while the skippers' families ship aboard for an easy vacation cruise. They coast Nova Scotia's cove-fingered shore, where evergreens spice the air.

Then comes the long voyage home—under ideal conditions a broad reach, but usually a beat to windward against the prevailing westerlies. * * *

"We're off!" Yachts sail past spectator craft at Marblehead

TRIANGLES of white canvas fleck the green waters as Class B yachts—29- to 35-foot rating—head for Halifax on a fresh southerly breeze. Code flags flutter between bare masts of *Lord Jim*, the Boston Yacht Club's 72-foot flagship. *Tabor Boy*, a boys' summer school afloat, rides nearby with foresail set.

Fifty-four yachts in four classes competed in the 10th race last July. Handicap times, worked out by the Cruising Club of America, compensated for differences in sail and hull. *Niña*, first across the finish line, set the handicaps as the biggest boat in the race. *Diablo*, a 39-foot yawl skippered by John M. Robinson of Portland, Maine, had the best corrected time of 41 hours 44 minutes. Another 39-foot yawl, *Off Call* of Marblehead, finished second.

KODACHROMES BY WINFIELD PARKS (ABOVE) AND DEAN CONGER © N.G.S.

Oilskin-clad crewmen aboard 46-foot *Aries* rig a big genoa jib as the cutter hits heavy seas and fog on the second day.

"The trick of the race is catching the fair current around the southwest corner of Nova Scotia," said a seasoned skipper of Marblehead. "If you get there at the wrong time, a foul current can ruin your chances."

All hands brace

WITH HIS SAFETY BELT SECURED, a crewman has two hands free to shorten sail as *Aries* plows through heavy weather. Navigator (opposite, upper), plotting course, must allow for adverse currents and high winds—a "lop" condition of boiling seas. His skipper must decide whether to hug the coast or swing well out into the ocean. The cook, lashed upright in his galley, remains as alert as a circus juggler to prevent steaming pots from tumbling into the bilge.

Toylike village squats on the boulder-strewn shores of Peggy's Cove, one of Nova Scotia's most photographed fishing ports. Yachtsmen find the tiny inlet ideal for "gunkholing," as they call the sport of exploring coastal bights.

Fisherman Stanley Fredericks of Indian Harbour mends his nets in a loft. Nova Scotia waters teem with cod, tuna, trout, salmon, swordfish, herring, mackerel, and halibut.

All sails set, the 143-foot *Bluenose II* slices through swells. Her builders followed the original plans of her famous namesake, a Nova Scotia fishing schooner that made racing history in the 1920's and 1930's.

At her launching, unrigged *Bluenose II* slides down the ways from the same Lunenburg yard in which her predecessor took form. High dignitaries watched and thousands cheered the event in July, 1963.

Historic Halifax:

EXPLORER CHAMPLAIN, in his logbook, made note of this landlocked, ice-free inlet three and a half centuries ago. Micmac Indians called it Chebucto, chief of havens. Edward Cornwallis founded the first permanent settlement in 1749. Today Nova Scotia's capital is a bustling city of 92,000.

Large enough to accommodate the bulk of the U. S. and British Navies, the harbor welcomes more than 3,000 ships a year. It was a major British base during the American Revolution and the War of 1812. Con-

Victor's reward: C. W. McNeeley (right) wins Jones Trophy for Canadian yachts.

Canada's front door

federate blockade runners found a refuge here. In both World Wars the port served as a rendezvous for Atlantic convoys. In 1917 the city witnessed its darkest day when an ammunition ship exploded, killing 2,000 and leveling some two square miles.

Halifax Citadel appears in the foreground of this aerial view. Waterfront warehouses at right flank Her Majesty's Canadian Naval Dockyard. At left an aircraft carrier moors beneath the Angus L. Macdonald Bridge, which links Halifax and Dartmouth.

Nova Scotia lass in the MacDonald dress tartan reclines amid wild flowers.

Open the draw! Hornsman Martin Myers aboard the yawl *Elsie* signals a bridge tender.

How to box the compass: Skipper Burnham Porter of *Roarin' Bessie* instructs a young guest.

KODACHROME (ABOVE) BY A. W. HERRINGTON, ... EKTACHROME (OPPOSITE, LOWER LEFT) AND KODACHROME BY WINFIELD PARKS © N.G.S.

Boats gather for a gam in fog-hung Liscomb harbor

HALF A DOZEN prearranged anchorages at secluded coves highlighted the Cruising Club's Nova Scotia jaunt in July, 1961. Slipping close to fir-clad banks in the fog, the boats felt their way through Liscomb's narrow, twisting channel. Then the yachts rafted together for two days, giving skippers and families a chance to visit and spin yarns about their adventures. Old-time whaling captains similarly rendezvoused in mid-ocean and swapped news of home and sea in a gam.

Skipper Harold Nash ices up his ketch *Andante*.

Traffic jam in

LEAVING BEHIND the harsh Atlantic with its sudden storms and pea-soup mists, Cruising Club yachts pass through this 300-foot single lock into Cape Breton Island's beautiful Bras d'Or Lakes. Here spread tideless inland seas acclaimed by countless yachtsmen as the ideal cruising grounds.

Now the cold, clammy fog surrenders to sunny skies and water 10 degrees warmer than the sea. Stretching for some 60 miles, the lake system's many long arms provide

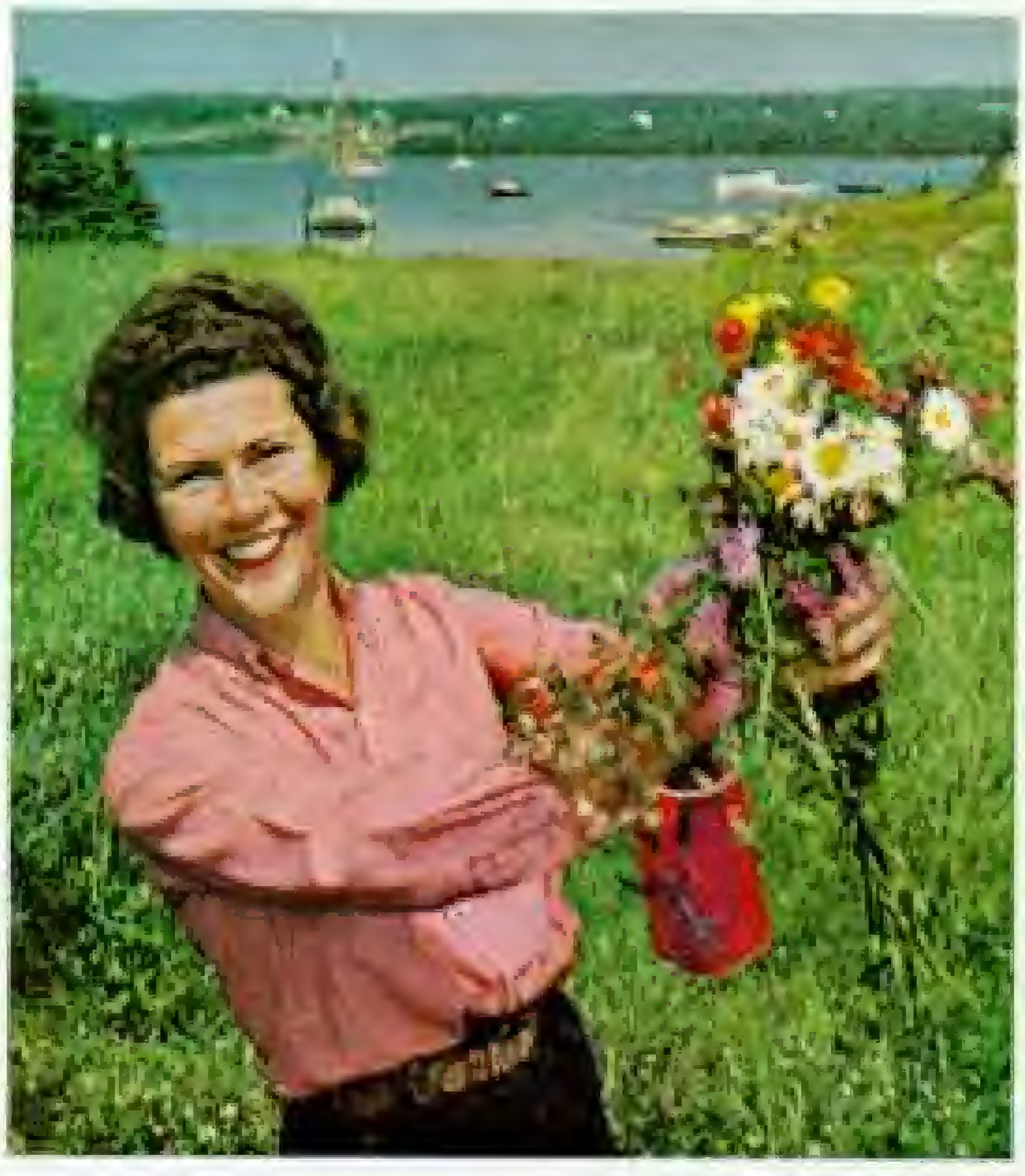
Schooner *Lord Jim* negotiates narrow St. Peters lock, which counters the tidal discrepancy between ocean and landlocked lakes. Tree trunks lining the stone walls protect hulls from damage.

KODACHROMES AND AN EKTACHROME (OPPOSITE, UPPER) BY WINFIELD PARKS © N.G.S.

St. Peters Canal

a maze of snug harbors that, in the words of a veteran yachtsman, "could not be exhausted in a summer's cruising." Low mountains slope down to the shoreline, sheep graze in waterside pastures, and the Gaelic charm of Cape Breton's people gives visitors the illusion of being transported to Scotland.

Eastern tip of Nova Scotia, Cape Breton stretches into the Atlantic toward the Irish coast, some two thousand miles away. Visiting boats display the Canadian ensign from their starboard spreaders as a mark of courtesy.



Fresh flowers for the dining table grow close by boats cruising in Nova Scotia, which has a wealth of blooms—asters, lupines, daisies. Teddie Preston, a passenger aboard *Roarin' Bessie*, picks a bouquet.

RAFTED TOGETHER *in Cape George Harbour, at the lake entrance of St. Peters Inlet, Cruising Club boats enjoy a one-night stop and singsong in an idyllic little cove that has no houses or telephones.*

Yachts ride the wind on the Bras d'Or Lakes

SUMMER SQUALL enlivens the 15-mile race for the McCurdy Cup (page 879), won by Robert Hall's *Astral.* Tan canvas identifies the yawl *Elsie*, oldest boat still owned and sailed by a charter member of the Cruising Club, Dr. Gilbert H. Grosvenor. Designed in 1916 by George Owen, a professor of naval architecture at the Massachusetts Institute of Technology, *Elsie's* lines served as a model in classrooms for many years. Dr. Grosvenor helped organize the Cruising Club in 1922. McCurdy race honors the late John A. D. McCurdy of Baddeck, who piloted the *Silver Dart*, first plane to fly in Canada. Later he became Lieutenant Governor of Nova Scotia. Local and visiting boats compete in this informal but exciting biennial contest. Leeward of *Elsie* sail the *Merry Jacks*, out of Halifax, and the *Legend* and *Javelin*, both from the United States.

Serene calls at Baddeck harbor

RELAXING MORNING finds family and friends aboard Samuel Batchelder's yawl. Wives and children accompanied many of the Cruising Club skippers in Nova Scotia waters.

Baddeck, a placid village of trim white houses overlooking the Bras d'Or Lakes, takes its name from the Micmac Indian word *abadak*, meaning "place with an island near." The island is Kidston, whose light guards the harbor.

Renowned for its beauty, Baddeck is famed as well in aviation annals. Here on February 23, 1909, J. A. D. McCurdy soared for half a mile at a speed of 40 miles an hour in the *Silver Dart*. The bay's frozen surface provided the take-off strip. Five years ago, when Baddeckers celebrated the 50th anniversary of the history-making flight, a test pilot flew a reproduction of the *Silver Dart* built by the Royal Canadian Air Force.

AGLOW in the soft summer night, the Bras d'Or Yacht Club (left) opens its doors to visiting yachtsmen. The village of Baddeck dates back to 1784, when a small band of New England Tories sailed up the Great Bras d'Or and settled along the Baddeck River. Many of their descendants still live in the area. During Nova Scotia's golden age of shipbuilding in the 19th century, Baddeck ways launched more than a score of large, seagoing ships. Even today many of the handsome vessels that scurry along the shimmering lakes reflect the artistry of local builders.

Baddeck museum houses Bell's works

ALEXANDER GRAHAM BELL, born in Scotland, paid his first visit to Baddeck in 1885 and became so enamored of the countryside that he chose the headland across the bay as the site for his summer home, Beinn Bhreagh. Today the ultramodern structure at right, erected by the Canadian Government in 1956, houses a priceless collection of memorabilia donated by the Bell family to commemorate outstanding achievements of the inventor and his associates at Baddeck.

Kites, iron lungs, airplanes, ailerons, tricycle landing gears, salt-water distillation equipment, snorkels, and hydrofoil boats—whose value has only recently been rediscovered—show the diversity of Dr. Bell's projects, which reached far beyond the telephone he gave the world in 1876. From the interior of the museum, a split-level, three-story structure, windows command a view of waters that witnessed many of the scientist's experiments.

In summer as many as 2,500 persons a day visit the museum. Here young sailors study hydrofoils.*

*See "Alexander Graham Bell Museum: Tribute to Genius," by the Hon. Jean Lesage, NATIONAL GEOGRAPHIC, August, 1956.

Partygoers ferry to shore at Beinn Bhreagh, with scarves protecting hairdos and with high heels in laps. Cruise space limits each woman to only one dress-up gown.

Host Gilbert H. Grosvenor (extreme right) welcomes Cruising Club Commodore and Mrs. Prescott Huntington from New York.

Yachts bob at anchor in Baddeck Bay, where 36 boats brought guests for the party at Beinn Bhreagh.

KODACHROMES BY MELVILLE BELL GROSVENOR (ABOVE AND OPPOSITE) AND WINFIELD PARKS © N.G.S.

Kilts swirl in a Highland fling as dancer and piper in full dress perform at the Beinn Bhreagh supper party. These lassies attend North America's only Gaelic "college," in the village of St. Ann's, which conducts summer classes in handcrafts, bagpiping, and dancing. Visiting yachtsmen later joined in a Scottish reel.

Bagpipes rend the quiet dusk

SKIRL OF PIPES greets guests assembled at Beinn Bhreagh—Scottish Gaelic for "beautiful mountain"—as purple twilight enfolds the Bell homestead. The big gabled house sits high on the slopes overlooking Baddeck Bay. Dr. and Mrs. Bell are buried at the summit.

Cape Breton steadfastly preserves its Scottish culture. Each summer at St. Ann's, a celebration known as the Gaelic Mod unites Scots of the New World for a week of singing, piping, sports, recitations, and dancing.

Ghosting along, *Elsie* sails into Boulaceet to join the fleet

BEWITCHING Bras d'Or Lakes—"Arms of Gold" in French—are the sun-sheathed paradise of sailing that every yachtsman seeks but seldom finds.

From both shores, wooded fingers poke into the blue water. Behind the promontories lie countless coves. For its scenery and snugness, many skippers consider Boulaceet, or Maskell's Harbour, the prize of them all.

A wooden lighthouse on Gillis Point marks the entrance. Swinging around a spar buoy that warns of a shoal, boats glide between Gillis and Pony's Point in the foreground. Often the lightkeeper and his family stroll down the lawn to wave a friendly greeting.

At anchorage in the inner harbor (page 878), craft can tie up against the banks without running aground, so sharply does the bottom fall away from the shore. A mere 50 feet from land the depth exceeds 20 feet.

Here time seemingly stands still. The towering firs whisper gently in the wind, and the swimming is superb. Boulaceet's varying moods—in sunshine and shadow, in cloud and mist, or under a revealing moon—stamp an indelible imprint on the memory.

KODACHROME © N.G.S.

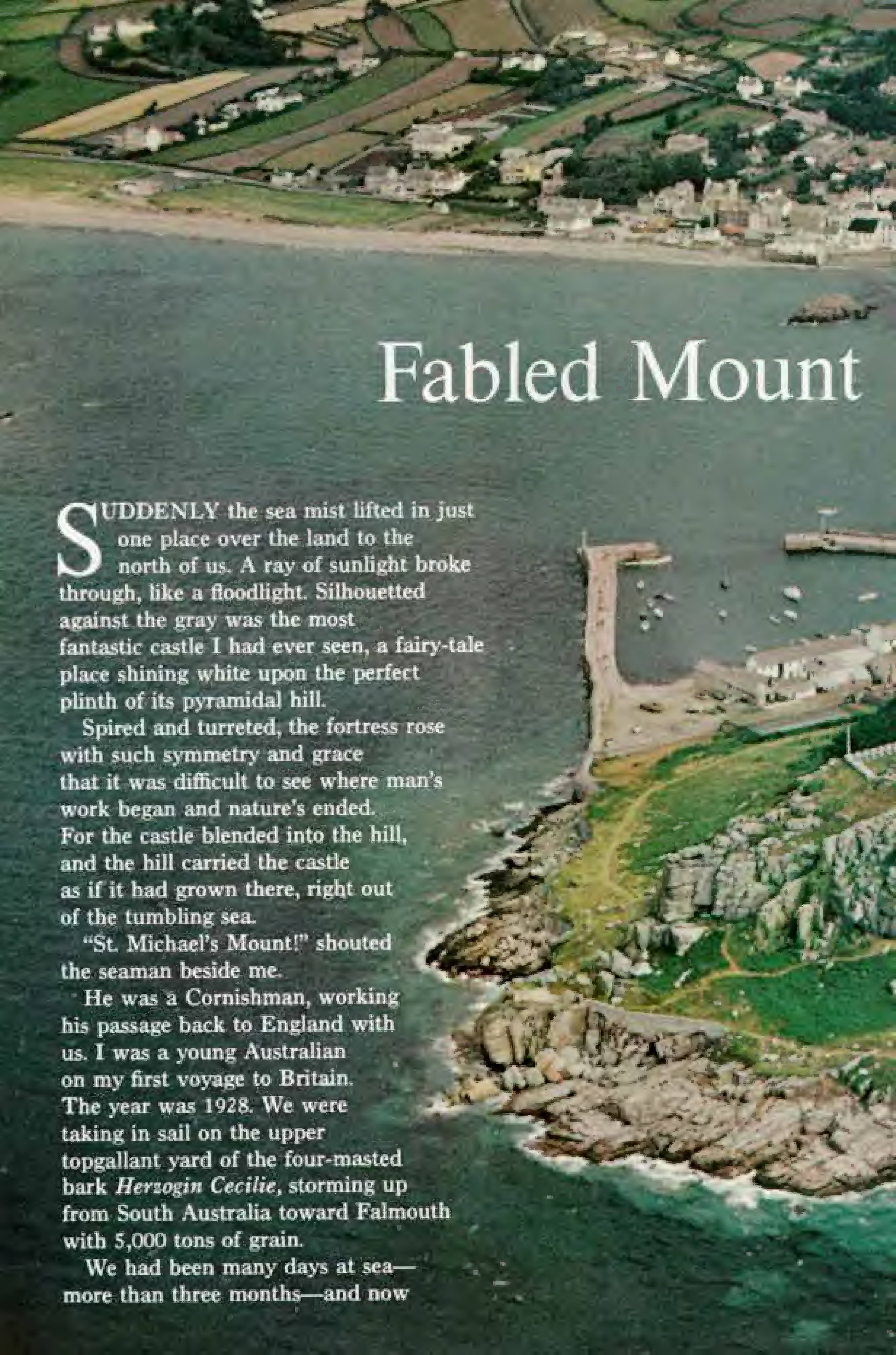
Commodore hosts a party at last port of call

FESTIVE FLAGS FLYING from halyards, Cruising Club yachts tie up deck to deck in the inner harbor of Boulaceet. Between *Cirrus* at extreme left and *Gesture* at extreme right lie *Elsie*, *Astral*, *Night Heron* (the commodore's flagship), *Gay Gull III*, *Land's End*, *White Mist*, and *Roarin' Bessie*. Aboard *Astral* (opposite, upper), Nancy Morss ad-

KODACHROMES BY MELVILLE BELL GROSVENOR (ABOVE) AND WINFIELD PARKS © N.G.S.

mires the McCurdy Cup, presented to Robert Hall at Beinn Bhreagh for winning the 15-mile race on the Bras d'Or Lakes. The fleet will now batten down gear and head out of the lakes through St. Peters Canal. Then comes the hard beat along the Nova Scotia coast to home ports in New England. THE END

Laden with passengers, dinghy and Snipe meet on Boulaceet's clear 70° waters.



Fabled Mount

SUDDENLY the sea mist lifted in just one place over the land to the north of us. A ray of sunlight broke through, like a floodlight. Silhouetted against the gray was the most fantastic castle I had ever seen, a fairy-tale place shining white upon the perfect plinth of its pyramidal hill.

Spired and turreted, the fortress rose with such symmetry and grace that it was difficult to see where man's work began and nature's ended. For the castle blended into the hill, and the hill carried the castle as if it had grown there, right out of the tumbling sea.

"St. Michael's Mount!" shouted the seaman beside me.

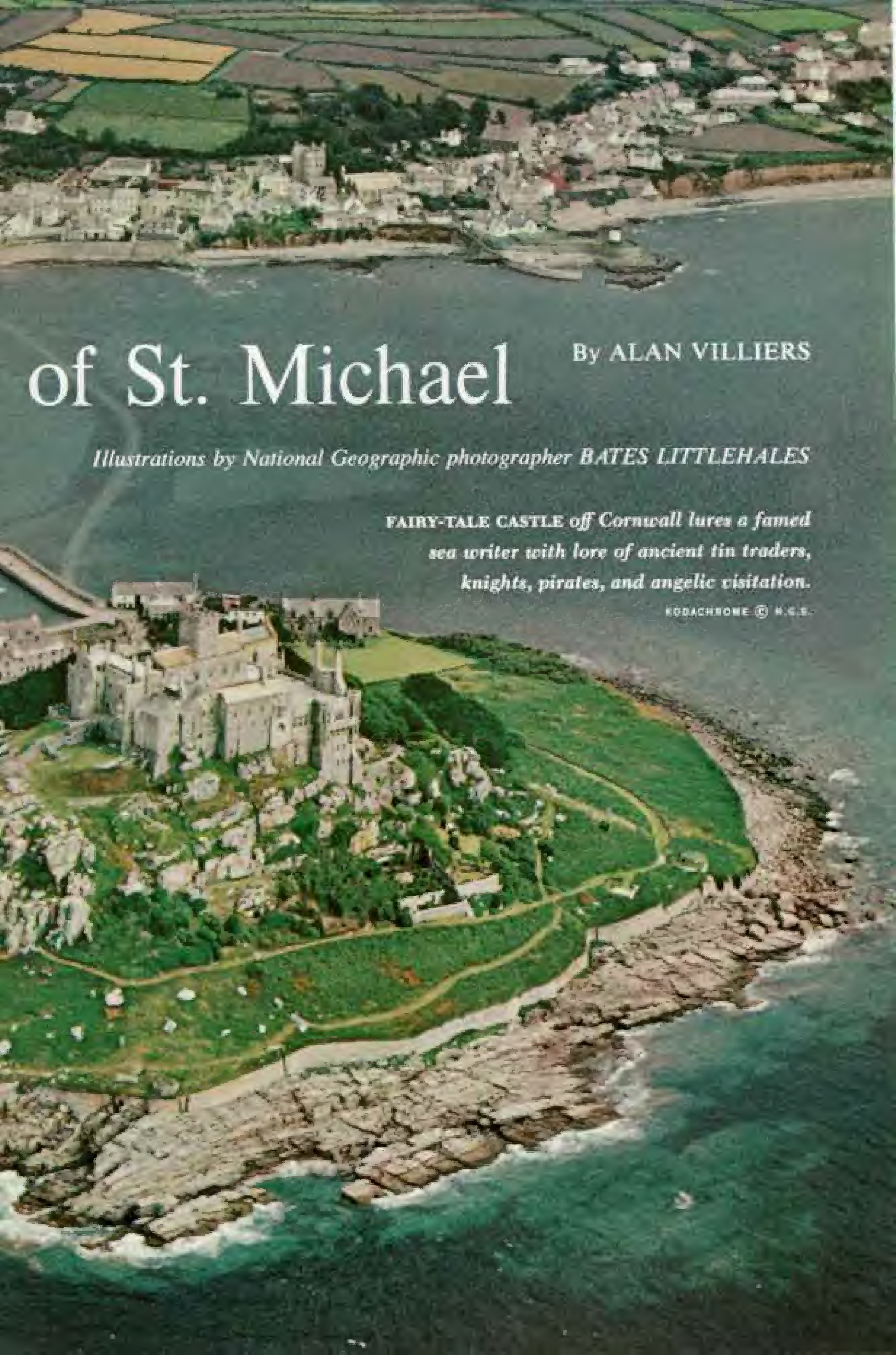
He was a Cornishman, working his passage back to England with us. I was a young Australian on my first voyage to Britain. The year was 1928. We were taking in sail on the upper topgallant yard of the four-masted bark *Herzogin Cecilie*, storming up from South Australia toward Falmouth with 5,000 tons of grain.

We had been many days at sea—more than three months—and now

# of St. Michael

By ALAN VILLIERS

Illustrations by National Geographic photographer BATES LITTLEHALES



FAIRY-TALE CASTLE *off Cornwall lures a famed sea writer with lore of ancient tin traders, knights, pirates, and angelic visitation.*

KODACHROME © N.G.S.

Battlemented terrace girdles the castle's round tower. Ebb tide exposes the half-mile causeway

a southwest gale was driving us to Falmouth, around the next headland, at 14 knots.

The big bark pitched and rolled in the heavy seas. Aloft the motion was wildly emphasized, and the high yard swung us through the gray sky in wicked circles. But we were well accustomed to this, and we had the sail almost in. There was time to look, for a moment, at the fantastic shoreline.

"St. Michael's Mount is the most wonderful castle in all England," my shipmate told me. "You must visit it. You'll learn more history there in an afternoon than you will anywhere else in a month."

The Author: Capt. Alan Villiers, world-famed for his nautical writings, has contributed many articles to NATIONAL GEOGRAPHIC and authored the Society's popular book, *Men, Ships, and the Sea.*

Far below us the ship's sharp bows sliced into the Channel seas, sending the foam rolling and hissing.

"This is the sea that drowned Lyonnesse!" the seaman said. "Below us is that lost land."

I looked down, half expecting to glimpse, somewhere in those rolling seas, the broken-off spire of a Lyonnesse church or the weed-covered remnants of a wall submerged thousands of years ago. I had heard of this legend of Lyonnesse, the lost land alleged to have existed somewhere between Cornwall and the Isles of Scilly, the southwesternmost isles of Great Britain.

No accepted history, no scientific proof vouches for the ancient story. It belongs with tales of the lost Atlantis, that other drowned land of the Atlantic. But local Cornish legend declares that 140 parishes and their churches

to the mainland town of Marazion.

Carrying their shoes, visitors splash across the causeway. Now ankle-deep, the sea will drop until the ford stands dry. Flood tide sweeps in so swiftly that those who tarry must run for shore.

sank with Lyonnesse, and the tolling of the church bells, it is said, may still be heard when the shallow seas surge furiously in some wild storm.

Most modern historians and geologists deny the story. Lyonnesse? A myth, they say. Certainly any tales of churches inundated here "thousands of years ago" must be fanciful.

Ancient Forest Comes to Light

Yet pieces of long-drowned trees have been wrested from the mud during extremely low tides close by Cornwall's shore—*local* wood from the bottom of the local sea. Experts examining these specimens and others by modern methods, including the carbon-14 dating process, have established that they were submerged about 1700 B.C.

There must have been some subsidence of the land then, but just how much is hard to say; it is not easy to detect subsidences even in our own times.

My Cornish shipmate had no doubts. He looked out for the churches, too, and listened for the bells—even in those seas.

As we lurched down the rigging with the gale in our ears, I gathered from him that St. Michael's Mount, that fantastic pile of stone rising above its offshore Cornish island, was the center, if not the origin, of half the romantic myths and stories of all that end of England.

According to my shipmate, the archangel St. Michael had appeared there. The court of King Arthur met nearby. Scholars suggest other areas, but for my friend there was no doubt—Tristram and Iseult knew the sweets and bitterness of their great romance in a

St. Michael in stained glass spears a devil in the castle's chapel. Legend says the archangel, who spoke to Moses on Sinai, appeared to fishermen on St. Michael's Mount A.D. 495. Edward the Confessor in 1044 presented the island to the Benedictine Order for the "salvation of my soul."

Thomas Luny's 18th-century painting exaggerates

lovely forest, now drowned, where our big bark raced that day.

I meant to heed my mate's advice to visit St. Michael's Mount myself. But that same strong wind that blew us swiftly into Falmouth blew us out again, with orders to take our wheat to Wales. It was many years before I passed that way again.

Meanwhile my interest had been quickened by sight of the other St. Michael's Mount, off France. Called Mont St. Michel there, the towering mass of granite, though larger, bears a strange resemblance to its counterpart across the Channel (map, opposite). From the 11th century onward for some 400 years, the two Mounts were united through the Benedictine Order and in their devotion to the archangel St. Michael. Pilgrims flocked to both, as tourists do today.

Both support villages on their less steep slopes, the French village much larger than the Cornish. In the Middle Ages both were frequent scenes of battle and siege.

At last I came back to Cornwall, cruising in the ketch *Tectona* from Cowes.* Again the Mount and its castle presented a sight indelibly impressive, the castle's granite walls

*See "Cowes to Cornwall," by Alan Villiers, NATIONAL GEOGRAPHIC, August, 1961.

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the height of the Mount; it hangs in the castle's stairway. Few ships use the harbor nowadays.

seeming to grow from the Mount's granite and slate pyramidal sides.

This time I had come by invitation from Lord St. Levan—Sir Francis Cecil St. Aubyn, Baronet, third Baron St. Levan of St. Michael's Mount, to give him his full title. Lord St. Levan is head of the family of St. Aubyn, and last in a long line of St. Aubyns to own the Mount (page 889). Lord and Lady St. Levan still live there, though in 1954 he presented the property to the National Trust, an organization dedicated to the preservation of lands and buildings of historic interest or natural beauty. In return, he is relieved of maintenance, taxation, and death duties that could have brought the property to ruin.

The gift included the 21-acre, 217-foot-high island with its neat stone houses, tidy little harbor, breakwater, castle, and church, all enclosed in its mile circumference.

Sister islands, Britain's St. Michael's Mount and France's Mont St. Michel stand where the Channel widens toward the Atlantic. The Mount lies 11 miles from the westernmost tip of England.

Map sketches the islands at low tide, when only the causeway of the British Mount is exposed, but the French Mont becomes surrounded by mud flats.

I came across the causeway, above water only at low tide, which connects the island with the Cornish shore at Marazion (pages 882-3). This is the "sandy plain of a flight-shoot in breadth, passable at the ebb on foot" of one old chronicler. His "flight-shoot" was an arrow's—about 400 yards.

A retainer in seaman's garb led me past the harbor, the little stone-built village, and up the hill. Up and up we climbed the cobbled, narrow track, steep and stepped, to the ancient stone outworks, the military lookouts and the batteries, where cannon had stood guard for centuries.

I gazed down upon the small patch of comparatively level ground back of the houses; a carpet of flowers looked grateful for the sun. There was no shipping in the breakwatered harbor—only a few small yachts.

"There haven't been any real ships there since the 1870's," my companion said. He was a handsome man, inclined to swarthiness like so many Cornishmen, brown-eyed and strong-featured, as one imagines the Phoenicians once had been.

"We used to send away tin and copper from Cornish mines up till that time, and salt fish. But the tin and copper trade has gone from here, and few markets today want our salt fish. Anyway, Penzance killed our trade. It's

Sixty Thousand Callers a Year Puff Up Rock-ribbed Slopes to the Castle

Visitors delight in tales of Jack the Giant Killer, supposed slayer of monstrous Cormoran. In some legends, Jack dug a deep hole on the grounds; when Cormoran fell in, Jack killed him. A pit on St. Michael's is still known as Jack's Well. Queen Victoria as a young woman climbed this hill in 1846; her son Edward VII struggled up in 1901.

[illegible] © NATIONAL GEOGRAPHIC SOCIETY

on the mainland. And it has the railroad."

We climbed up past plantings of bushes and flowering shrubs: rhododendron, hydrangea, fuchsia, and veronica. At last the path brought us to a great 15th-century doorway, once protected by the batteries. Inside, an elevator carried me up the last few feet, and I was grateful for that.

Lord St. Levan showed me around the castle. Though approaching his 70th birthday, he is a tall, upright man of distinguished bearing—as one would expect of a former Grenadier Guards officer trained at Eton and at Sandhurst, Britain's West Point. He had seen service in both World Wars, I knew, and in 1942 became the colonel commanding the Home Guard of west Cornwall.

His ancestors had held the Manor of Kymyell since 1398 and Clowance in Cornwall since that same century. He succeeded to the title in 1940 on the death of his uncle, and the Mount became his residence after that.

We walked about at an easy pace, stopping to admire the coastline around Mount's Bay, which stretched away to the east past Penzance, and then south past quaint Mousehole toward the rugged peninsula of Land's End.

Inside the castle we looked into airy and well-lighted apartments on different levels. Despite walls of massive masonry, there was no air of medieval gloom. Sunlight streamed in windows. There were bathrooms and modern conveniences.

We went into the old monks' refectory, the armory with its weapons and armor, the library lined with huge old books, and the drawing rooms built in a former chapel.

Stuart Arms Deck Chevy Chase Room

We lingered beneath the vaulted ceiling of the refectory, now called the Chevy Chase Room (next page). Here a plaster frieze depicted a "chase" in full cry after stags, bulls, and wild boars.

Over the fireplace at one end I noticed the Royal Arms of the Stuarts, placed there after the Restoration and the accession of Charles II in 1660. Thus Sir John St. Aubyn, second of the family to own the Mount, proclaimed his loyalty to the sovereign.

At the other end were the St. Aubyn arms—a colorful shield bearing the St. Aubyn cross on ermine and the double-headed eagle of the Godolphins, a family allied by marriage. Above the shield a helmet supported a rock with a Cornish chough—a crowlike bird with red legs and bill—about to take off. Banners and priceless paintings hung from walls.

I was intrigued by the room's name. Why "Chevy Chase?" I thought of the attractive

Castle's Chevy Chase Room has a plaster frieze showing a "chevy chase" (noisy hunt) in full cry. A Cornish chough, bird symbolic of King Arthur, perches on the coat of arms of the St. Aubyn family (cross with five circles) and the allied house of Godolphin. Company colors of the Grenadier Guards hang below the 15th-century timbered ceiling. Curator S. Ager (left), who administers the castle's public areas for the National Trust, escorts visitors. The hunting frieze is reminiscent of the 16th and 17th centuries.

His castle is his home: Sir Francis Cecil St. Aubyn, third Baron St. Levan, stands beside his wife Clementina in the drawing room of their private quarters. Portrait shows Queen Mary, wife of King William III.

Maryland suburb and country club near Washington, D. C., which use the same unusual name. Was this scene on the ancient walls inside an offshore Cornish castle the name's origin?

His Chevy Chase Room, Lord St. Levan told me, is named for the hunting frieze, but the term is older than the frieze. It means a noisy chase or hunt and probably derives from the nature of hunts in the Cheviot Hills of northern England.

"The walls of what we call the Chevy Chase Room were probably built by Abbot Bernard from the French Mont St. Michel in the 12th century," Lord St. Levan said.

"It wasn't until the middle of the 18th century that my family converted the old chapel into drawing rooms."

Pilgrims Inspired by Archangel

As we strolled and talked, a thousand years meant nothing, and even 2,000 seemed not very long ago.

"The archangel St. Michael is said to have appeared here in the year 495. Some fishermen saw him. He was described as standing suffused in heavenly light, on a ledge of rock." Lord St. Levan showed me the ledge as we looked down from the terrace of the castle. It juts out like a pinnacle by the side of the sea.

When the story of the archangel's visitation was known, St. Michael's Mount became a popular place of pilgrimage. By 1044—22 years before the Normans came to England—King Edward the Confessor authorized a grant of the Mount for a monastic cell.

"That authorization is the first record we have of any permanent structure here," my host said. "From that time on, some sort of building has stood on St. Michael's Mount—chapel, monastery, castle, and now for the past two or three centuries, a castle-home.

"In 1647, Parliament nominated my ancestor Col. John St. Aubyn to be Captain of the Mount, and some 13 years later he bought it. Then it was a place of considerable military importance. Rebellions against the English throne had started here. The place was a back door for landings from France. Remote and secure, it was at the end of a long road. Its position was almost impregnable. It has its own springs of water. It could be supplied by sea or by land.

"A rebel Earl of Oxford—John de Vere, the 13th Earl—took it once in 1473, during the Wars of the Roses, by coming with his

Boats ride sand when tide departs from St. Michael's harbor. Distant Marazion once bustled

men dressed as pilgrims. Once they got inside they drew their swords. They held the Mount for several months.

"Later the rebel Perkin Warbeck tried to launch rebellion from here. He took the castle unopposed, but he didn't get very far."

I listened enthralled as this English history I had been taught as a boy came to life so vividly in this perfect setting.

Perkin Warbeck, I knew, was an impostor who gave himself quite a career about the time that Columbus was sailing to North America—until the hangman's noose snapped it to an abrupt end when he was 25.

Pretending, in 1492, to be Richard, Duke of York (who had been murdered in London as a child, years earlier), Warbeck was entertained and financed by King Charles VIII of France. He was given Lady Catherine Gordon in marriage by James IV of Scotland. Leaving his wife at the Mount, he marched away in 1497 to proclaim himself rightful King of England and attack Exeter. Failed, imprisoned, confessed, hanged—four words complete the impostor's biography.

Well, he was at least a romantic rascal, and the Lady Catherine Gordon was a beauty. I was glad that she had come to no harm. The king gave her a pension.

Was Mount Known to Ancient Greeks?

Long before the visitation of the archangel, before the monastery, the Mount was a place of renown. Many students consider—as do I—that its shelter provided the ancient port of Iktin, or Iktis, to which the Phoenicians came from Carthage and Sidon to trade for British tin. They needed tin to blend with copper from Cyprus to make bronze. Bronze made the best weapons. Hence tin's importance. It was the uranium ore of the period.

A Greek geographer, one Pytheas, voyaged north from Massilia—Marseille—about 325 B.C. A quote from his lost writings, used some 200 years later by the Greek historian Diodorus Siculus, speaks of Iktin.

(ABOVE) AND ROBERT S. GOODMAN © NATIONAL GEOGRAPHIC SOCIETY

with tin trade. Most mines now are closed.

Silhouetted castle overlooks a water sprite on the causeway as sunlight dapples the shallows. Mount's Bay covers a forest submerged about 1700 B.C. Parts of drowned trees are still found.

"The inhabitants of that part of Britain called Belerion [identified as Land's End, in Cornwall] are very friendly to strangers, and their relations with foreign traders have civilized them more than others. They produce tin which they extract from the rocky ground, into which they drive galleries. They melt the tin into ingots which they load onto carts and convey to an island lying off Britain, called Iktin. When the tide is out, the intervening space is dry, and they transport the tin over it . . . in large quantities. . . . At high tide the passage . . . is covered with water. It is here that the traders buy the tin from the natives and ship it over to Gaul [France]."

Only St. Michael's Mount seems to fit this description. But some scholars wonder, if this is so, why no ancient relics or trade goods have ever been found in the area. They consider it likely that although Phoenicians and Pytheas probably visited Cornwall, most Cornish tin was shipped to Gaul by Bretons, thence overland to the Mediterranean.

Blurred by rain, St. Michael's shows a somber face. Island children cross the bay to school, but

KODACHROME BY NATIONAL GEOGRAPHIC PHOTOGRAPHER BATES LITTLEHALES © N.G.S.

angry whitecaps occasionally isolate their home. Stone dwellings shelter most of the 34 residents.

Seething waters of Mount's Bay fail to keep Postmaster John Matthews from his appointed rounds. Jerseyed Frank Larter, St. Michael's chief boatman, holds the tiller as the vessel swings into a jetty at Marazion. Waves beat themselves into spray on hidden rocks. Besides delivering letters, Mr. Matthews serves as harbor master, churchwarden, bell ringer, and guide.

Smiles unite a woman and her niece in a window overlooking a street in St. Michael's village.

As we looked down on the scene, it was easy to imagine the ships of the Phoenicians coming racing in from the sea, high-prowed and graceful, with the distinctive horse's head atop their high stemposts. Sun-tanned powerful Semitic seamen in long cloaks would be lowering the cedar mast and linen sail and manning the long oars which were their auxiliary power.

In they come around the islands, oars flashing, drums and oboes keeping time. Close in, they drop their stone anchors, and warp with fiber and leather lines as close as they can get.

Or the incoming mariners may be Celtic Bretons, cousins of the Cornish, sharing the same language and the same beliefs, sailing in aboard their sturdy plank-built ships of oak, with iron chains and leather sails. I see in my imagination the sun touch that wind-filled leather to a golden brown, hear the strange sound of chains clanking and rattling as strong Breton mariners clear their anchors and get the sails ready to come down on the run.

What a sight it must have been when such a fleet came in! We have scant knowledge of Phoenician ships, but Julius Caesar has left a description of the Bretons'. He fought a pitched battle with a fleet of them back in 56 B.C., when they nearly defeated him. He noted their flat hulls for beaching—a useful quality off Marazion and St. Michael's Mount—their upright bows and sterns "suited to the great size of the stormy seas." They were built solidly of oak and had "beams a foot deep fastened by iron nails as thick as a thumb."

From their beehive huts by Marazion the Britons pour, shouting to friends. Others come skimming in their coracles to offer fresh-caught fish. On the shore, Cornish ponies wait, laden with the precious tin. The visitors look up in awe at the slate and granite pile of St. Michael's Mount, fabulous abode of giants and strange spirits, center of legend and mystery. They hurry with the loading.

What a place for memories!

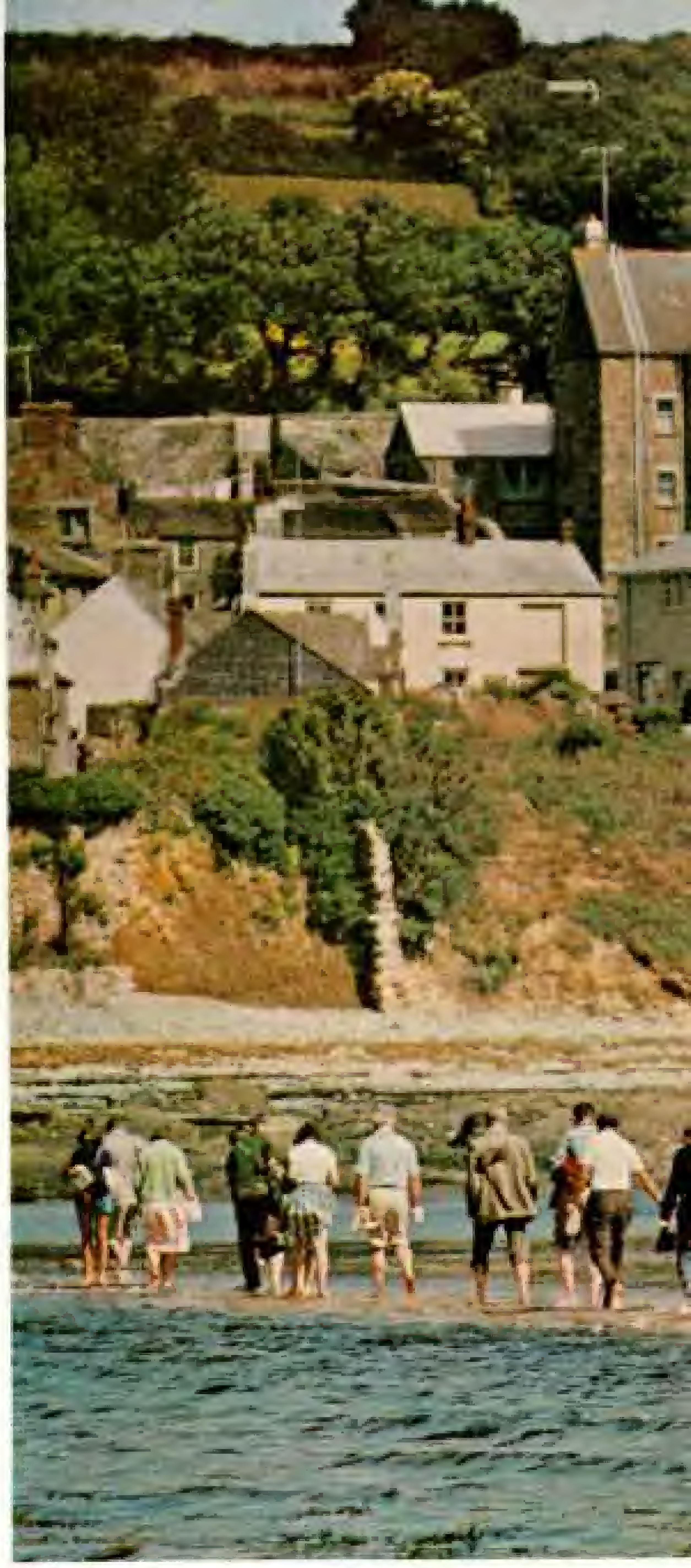
Lord St. Levan's voice broke into my pleasant reverie. "Lookouts standing up here saw the Spanish Armada sail by in 1588," he said. "Queen Elizabeth's men, a few years later, watched other Spanish ships that did not sail harmlessly by. The Spaniards landed and burned several villages. But they did not attack the Mount."

I looked at some cannon lined up there. They were last fired in anger in 1812. Some accounts say this was at pirates. But some say they were fired at a privateer trying to take a merchantman.

I thought of the Pirates of Penzance, those cheerful imaginary figures of the Gilbert and Sullivan opera—imaginary indeed! The area

Crabs lowered into Mount's Bay stay alive for market.

Trousers and skirts hiked up, departing visitors tread the stone causeway to Marazion, ahead of the returning tide.



provided its own pirates at times; there were some outstanding local families in the trade.

So much for pirates. What about ghosts, I asked Lord St. Levan, and skeletons, and clanking figures dragging chains? But there are no ghosts. Apparently the sea air does not agree with them.

There was a mysterious skeleton once. When alterations were being made to the chapel in 1820, an old doorway was discovered, blocked with masonry.

"When this was cleared away," Lord St. Levan told me, "a flight of stone steps was found leading to a sort of vault which might once have been a hermit's cell. In this were the skeletons of two men. There was nothing to identify them. The bones might have been interred there, or the men may have been left there to die. One had been a very tall man. That is all we know with certainty."

Local tradition says one skeleton might be that of the knight Sir John Arundell, who was an exceptionally tall man. Sir John, says history, was killed in battle on the beach in front of St. Michael's Mount in 1473, fighting for the king against the rebellious Earl of Oxford—the same who seized the Mount and its castle by entering with his soldiers disguised as pilgrims.

Newlyweds Seek St. Michael's Chair

Lady St. Levan joined us for a walk on the terraces and to the church. Like her husband, Lady St. Levan—a lively, vivacious woman—is a born aristocrat. She was formerly the Honourable Clementina Gwendolen Catharine Nicolson, only daughter of Lord Carnock and sister of Sir Harold Nicolson, the famous writer and critic.

Rearing a family of three sons and two daughters has not interfered with her capacity for public work. She is a Justice of the Peace, as is her husband. Festivities connected with the 300th anniversary of the St. Aubyns' direct connection with the Mount had been keeping her very busy.

We encountered groups of visitors as we strolled, for this was one of the several days a week on which the Mount is open to the public. One group was peering up at the relic on the chapel tower which is called St. Michael's Chair.

"I hope they don't start trying to climb into it," my host remarked. "That can be difficult. There is an old yarn that, if a newly married couple comes here, whichever of them can climb into it first will be the head of the household for life."

I had heard a rather horrible story of a wife who was so keen to be the first into the chair that it killed her. She did not even wait for the bells in the tower to stop pealing, and their heavy reverberations shook her out of the lofty perch.

"The story is pure fiction," Lady St. Levan told me. "The poet Robert Southey wrote about it in a ballad."

"Actually, I think it's the wrong 'chair' anyway," said her husband. "The spot on top of the chapel tower could have held a lantern used as a sort of primitive lighthouse for ships."

"The real chair that gave rise to the honeymooners' tradition is on a crag on the western side of the Mount," Lady St. Levan added, pointing out the spot. Indeed, to reach the chapel's high seat was a bit of a climb, but to get into the other chair would be a genuine feat of mountaineering. I didn't try. I'm no newlywed, anyway, and I already know who is boss in our household.

The Mount receives 60,000 visitors a year, but the public is admitted only two days of the week—Wednesday and Friday in winter, spring, and fall, and on Monday as well, in summer. On Sunday the chapel is open for divine service. The family apartments retain their complete privacy. Only the more obvious and interesting parts of the castle are available to the public, including the chapel, armory, drawing rooms, and terraces.

The St. Levan family lives now in the new east wing, complete with suites of light and airy bedrooms and modern bathrooms. As we sat in the family drawing room over a quiet pre-lunch appetizer and in the dining room for lunch, we might have been a thousand miles from a summer visitor.

"It took generations to make this castle fit for a home," said Lord St. Levan. "The family moved here permanently only in the middle of the last century."

Since the days 300 years ago when St. Aubyns first acquired the famous Mount, each head of the family has successively maintained and improved it. One of them had an architect-cousin, Piers St. Aubyn, whose challenging task it was to add a new east wing. It took five years, building in heavy granite, in places vertically down the sheer cliffs.

St. Aubyns have served Cornwall, and England, as Members of Parliament, High Sheriffs, Deputy Lieutenants, Justices of the Peace, and in many other offices through 500 years. The present Lord St. Levan has been Deputy Lieutenant of Cornwall since 1961. In addition to his duties as a Justice of the Peace, he is a hereditary member of the House of Lords. And then there are farms to be run, an estate to organize.

Against the background of this full life, I gathered that both Lord and Lady St. Levan, in their magnificent home at St. Michael's Mount, are happy people indeed.

Spanish Armada Sailed Wide of Mount

The tide was high when I left, and the causeway was submerged. Lord St. Levan took me to the little harbor, down the stone steps Queen Victoria once climbed. (There is an imprint of her shoe in brass at the top.) St. Aubyn retainers took me by motorboat to the stone pier at nearby Marazion. Again I was struck by their strong, handsome faces, swarthy and so Cornish. Could it be true that, way back, Phoenician blood had mixed with the local here?

The evening was closing in. I stood on the foreshore and looked back in reverie at the Mount, standing romantic, solitary, and grand against the misty Cornish hills.

A host of stirring figures from the past flashed before my mind's eye—rebellious Perkin Warbeck, John de Vere, the audacious Earl of Oxford, tall Sir John Arundell, fighting for his king, the poet Milton, who wrote some enigmatic verse about the Mount.

Spanish seamen were warned about the Mount in Elizabethan times. Their ships were supplied with a document called *Relación de los Puertos . . . de Inglaterra*, a Spanish pilot's survey of the English coasts.

"On one side of Mounts Bay is a strong castle with much artillery . . ." the *Relación* read. So those in Spain's raiding fleets approached it warily.

Cornish Jack Killed the Giant

All this and much else is part of history. Then there is the legendary kind, such as Jack the Giant Killer. Jack was a Cornishman. Jack is a favorite Cornish name to this day. He killed one Cormoran, master of St. Michael's Mount, by digging a well in the giant's path, then attacking him after he had fallen in.

Another legend has it that Cormoran built a house of white granite, but made his wife fetch the stones. While he slept, she tried to substitute some handier green stones. He caught her and frightened her into dropping one huge boulder on a beach, where it remained, no ordinary mortal having the strength to move it.

I learned such fanciful stories as a schoolboy in Australia, 12,000 miles away. Yet were they all fairy tales? And those stories, persistent down the centuries, of Lyonnesse and its drowned parishes. Fairy tales too?

After all, huge boulders still lie oddly strewn about the Marazion foreshore, as if they had been dropped there. It is hard to visualize how human agency could have carried them where they are.

As for the drowned parishes and churches, the chronicles left by Florence of Worcester—an English monk who recorded local history, and died in 1118—tell of this flourishing land and its sudden overwhelming by the sea. There is no hint in his writing of disbelief.

Night was coming swiftly with a mist from the sea, blotting out the lights of the modern world, ships in the Channel, the loom of Penzance. A gull cried in the gloom. A cold, bone-searching wind rose. Suddenly the sea's wash was menacing.

It was eerie and haunting—a place where almost anything might have happened. The long, event-crowded past was very vivid, and very real.

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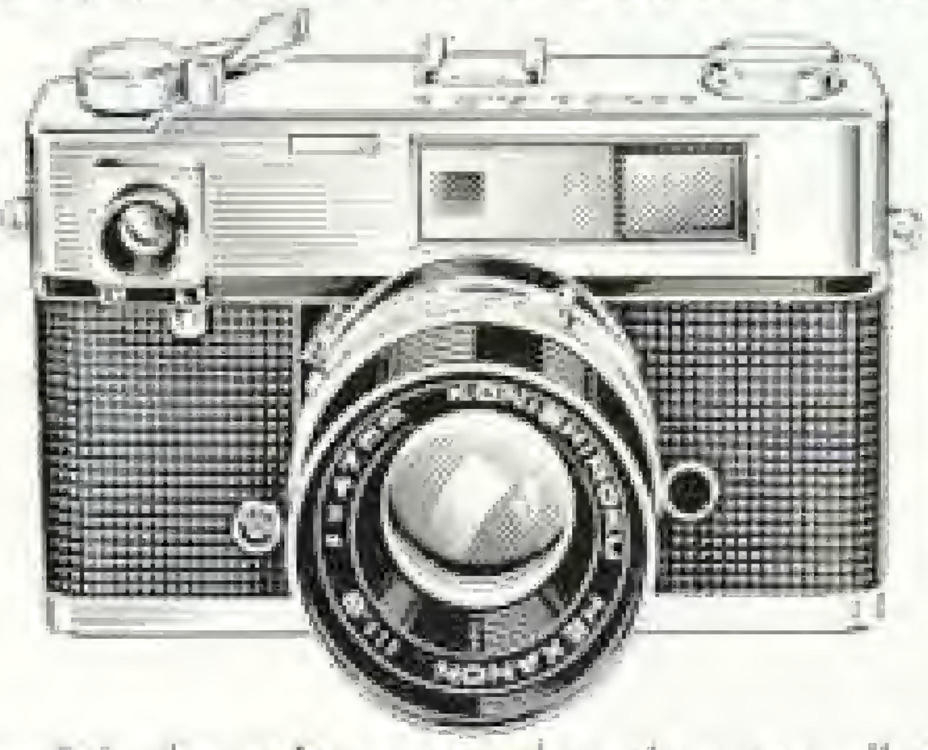

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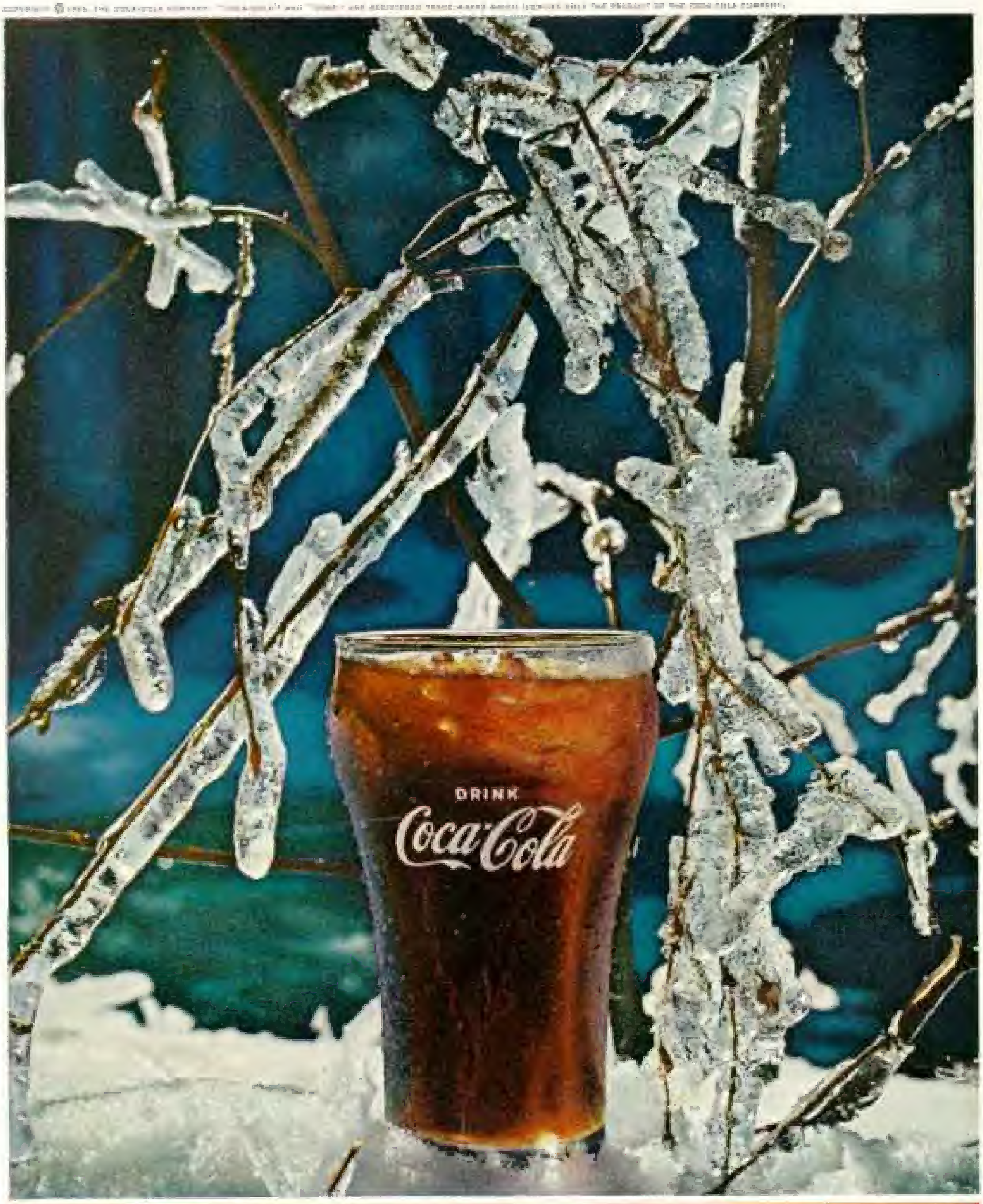
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