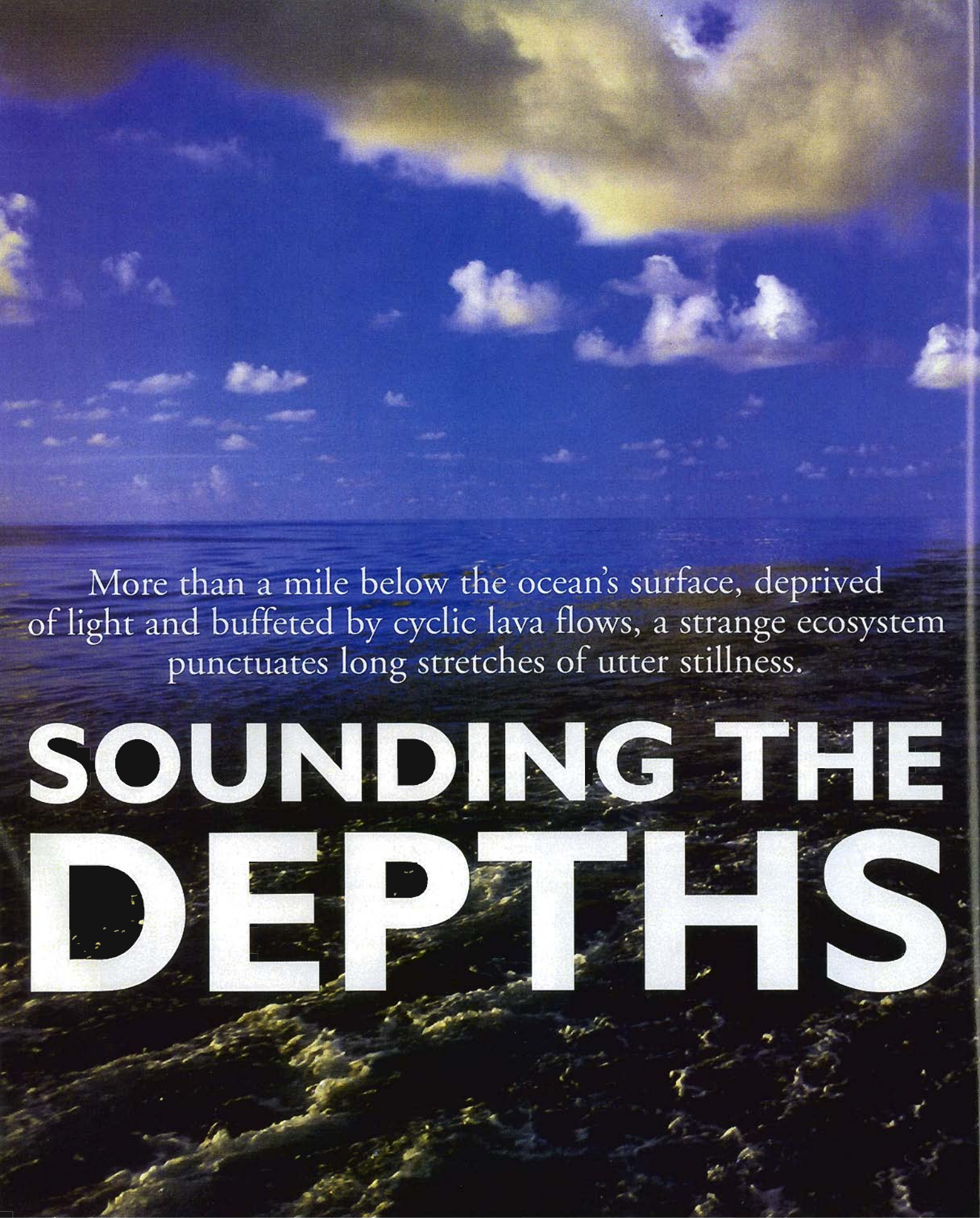

More than a mile below the ocean's surface, deprived of light and buffeted by cyclic lava flows, a strange ecosystem punctuates long stretches of utter stillness.

# SOUNDING THE DEPTHS

By Katherine Millett

The round hatch closed, and we were sealed inside the submarine. Screeching hydraulic lifts raised us from the stern of the ship *Atlantis* and swung us over the Pacific Ocean. I sat cramped and cross-legged on a padded ledge and craned to look through my only window, a five-inch circle by my right knee. For the next seven hours, I would share the compact sphere and a tank of oxygen with Stephane Hourdez, a French biologist, and Pat Hickey, the curly-haired chief pilot and expedition leader of the *Alvin*, as the sub is known.

Soon we would enter a lightless realm a mile and a half deep, where tectonic plates slide apart and volcanoes erupt to make the earth's new crust. Our mission was to find animals around hydrothermal vents, the undersea geysers that support life. There, bizarre creatures cling to lava rocks and crawl on fragile chimneys. They make long tubes and live inside them, tremble when the earth quakes, and sizzle to death under cyclic lava flows. Some have no eyes; others lack mouths. No place on earth is more remote.

The 17-ton sub paused briefly before slipping beneath the ocean's skin. Bubbles surrounded my window, a flipper flashed by, and a masked face peered in at me. Two swimmers were tightening ropes on the sample basket and checking the sub's mechanical arms. At the end of the day, Stephane warned me, I might get mooned. Such are the honors extended to first-time divers.

I'd been invited by chief scientist Janet Voight, a curator at the Field Museum in Chicago, to join the 27-day cruise aboard the *Atlantis* as an observer and a journalist. Voight specializes in octopuses—not octopi, she says—the predators at the top of the food chain of the vent community. Some people look to the abyss for metals or pharmaceuticals, but biologists like Janet and Stephane seek animals. The cruise was funded by the National Science Foundation's Biotic Surveys and Inventories program to collect specimens and make them available for international research. Vent communities were discovered relatively recently, near the Galápagos Islands in 1977. Yet this was eight years after a person had walked on the moon. We know more about Mars and the lunar landscape than we do about our own deep oceans, and there simply aren't enough specimens on dry land to support scientists' burgeoning interest in studying them.

Geologists had joined the cruise to study vent chemistry and to add to the map of the world. Some stayed up all night bouncing sonar beams to the ocean floor from the hull of the ship and converting returned signals into contour maps. Two dove to a previously unexplored site where 350 earthquakes had been recorded in a single day. I suspected they loved the thrill of the risk, but they solemnly swore they wanted only to find new vents. (They didn't.)

Pat held a transmitter near his mouth and talked to the launch controller. "Coordinates set to go. Oxygen on. Scrubbers on."

"You're free to dive when the swimmers are clear," said a voice.

"Okay," Pat answered. "Bye. See you."

The swimmers disappeared and left us to our solitude.

We began to descend in the open ocean, 1,300 miles west of the Panama Canal, 675 miles north of the equator. Below us lay the East Pacific Rise, part of a submerged mountain range that winds through the Pacific Ocean, from British Columbia down the west coasts of North, Central, and South America. The ridge continues across the Indian Ocean by Antarctica, up the other side of the globe through the Atlantic Ocean, past Africa and Europe, all the way to Iceland. At 40,000 miles, it is the longest natural feature on Earth. Yet it didn't even show up in my atlas at home. My map showed blue—nothing but blue—for the oceans.

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We fell slowly through olive-green water flecked with algae. An occasional jellyfish beat its way upward, flexing its gelatinous body. The water darkened to blue green, then navy blue. I could hear nothing but the steady "plink, plink" of sonar signals emanating from the sub, as though a distant elf were tapping rocks with a metal hammer.

We were dropping 30 meters per minute, on average, but I felt no motion at all. Even Pat, a veteran of more than 500 dives, said he felt nothing. I sat on the starboard side, with Pat to my left and Stephane across the hull, on a ledge like mine. When I leaned forward to look through my window, Pat told me to get out of his way. I had been warned about his moodiness. He scowled at his clipboard, tested the joystick control, and flipped through rows of toggle switches. The atmosphere of a sterile cockpit prevailed.

At 100 meters, our windows were completely dark. I had been waiting for this moment—worrying about it, actually. During the weeks before the dive, I had pictured myself trapped in the little vehicle, suspended in water, poking around in a void. The only warmth would be the diminutive beam of light pointing the sub's way into darkness—spooky, eerie, and ominous.

I knew I wouldn't feel claustrophobic, as I had been in small spaces before without panic. And I had faith in Pat and the *Alvin*, a 40-year-old workhorse that had made 3,937 dives before mine and, to the best of my knowledge, had brought everyone back alive. I didn't expect the sub to get stuck on the bottom, but if it did—oh, my God—the loneliness. Our oxygen would last 72 hours. Would we share life stories, or agree to remain strangers?

In any event, we could forget about a proper burial. If the Navy decided not to recover its sub, our bodies could remain intact for a restless forever. We could be like the bologna sandwich, a famous artifact of the *Alvin*'s history.

In 1968 the sub unexpectedly slid off its host ship in deep water near home, the Woods Hole Oceanographic Institution on Cape Cod, Massachusetts. All three passengers escaped, but the sub spent ten months on the ocean floor with its hatch open. Eventually another sub caught it by fishing with a T-bar, and the *Alvin* was towed back to Woods Hole. While inspecting the vessel for damage, the staff found the sandwich. An engineer took a bite. It was soggy and salty, he said, but it tasted pretty good. The sandwich had survived the ten months underwater, and the engineer survived the bite.

Stephane, Pat, and I might lack some of the chemical advantages of white bread and bologna, but we could retain our recognizable forms and facial expressions for a long time. It was a gruesome prospect. The idea especially offended Stephane, whose French aesthetics rebelled at the very concept of a bologna sandwich.

"In the French sub *Nautile*," he said, his low voice resonating in the metal ball like an announcer's on FM radio, "we have always a first course, then a warm dish for a second. In the early years, there was a bottle of wine. Dessert—just something simple," he concluded, with a pout and a dismissive shrug.

At 440 meters, the temperature cooled suddenly. We had reached the thermocline, where warm water meets cold. Stephane pulled on sweatpants, I put on a wool sweater, and Pat, comfortable in his shorts and T-shirt, slid a Patty Larkin CD into the player. The sound of music warmed us more than the extra clothes.

At 700 meters, we reached the "level of eternal darkness," as William Beebe called it in his 1934 book, *Half Mile Down*. We had passed the ultimate point of light penetration and entered the world beyond photosynthesis. From here on, any living thing we saw would be an animal.

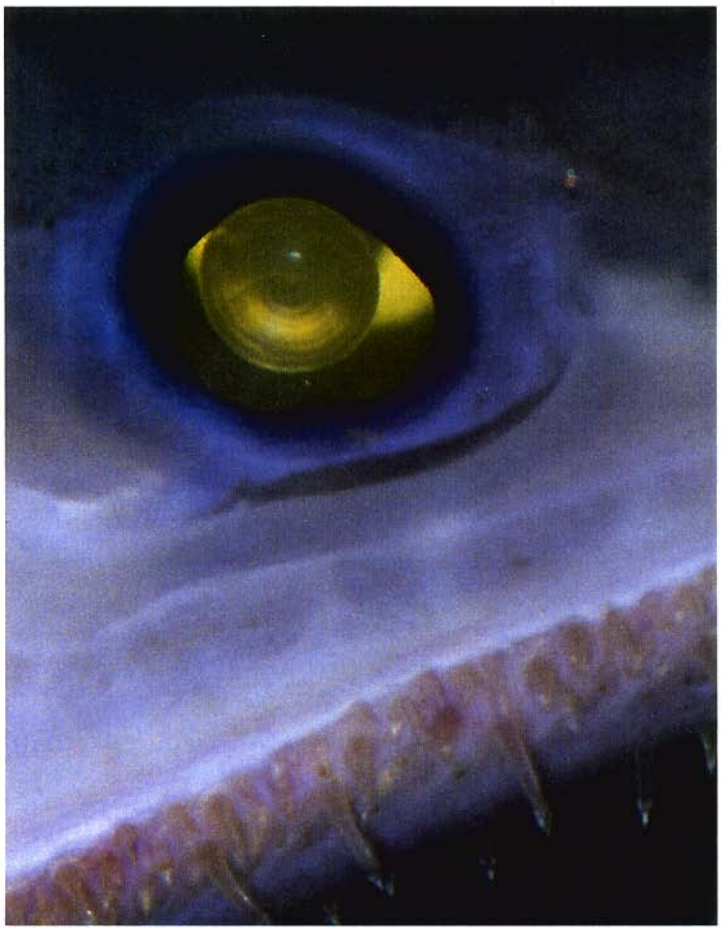
So I was startled to see specks of light appear. Tiny copepods and other bits of plankton spun in the water and glimmered. Jellyfish hung in eerie suspension, their bodies tinted green and orange. In the thick of it, Pat told me to close my eyes. He turned on the sub's lights for a minute, then turned them off and invited me to look. The effect was spectacular. A light show stretched before me, layer beyond layer of phosphorescent radiance extending deeper and deeper into the void, as resplendent as a galaxy but far more intimate.

"Amazing!" was all I could say. I recalled Beebe laughing at himself for the "unproductive 'Oh's and Ah's'" of his first submarine dives, but I hope I never lose my giddy sense of wonder about that day. At 1,700 meters the bioluminescence dimmed, and we settled into thoughtful silence.

A half hour later, Pat clicked on the transmitter and announced, "Ninety-five meters," his voice cool with confidence. He set the controls for landing and switched on the sub's lights again. I struggled to see the bottom, but it was hidden by turbid water. Suddenly a pattern of circles popped into relief, like a carpet of bubble wrap. The ground moved steadily toward us and surrounded us in a sparkling cloud.

The sub stopped at 2,630 meters, 1.6 miles below the surface. Bacterial debris hung in the water like suspended snow. I felt a heavy, enveloping stillness. The pressure squeezing the sub was 3,800 pounds per square inch. My ears didn't pop, nor did my lungs labor, but my breathing and circulation seemed to have slowed to match the languid pace of the abyss. Had I sat in a low-pressure environment and watched images of what I saw out my window, I would not have felt the myriad, subtle effects of compression, the weight of an enormous water column bearing down on our capsule and our surroundings.

A landscape of black rocks stretched ahead. Two red shrimps stood in a crevice. Their long antennae waved slowly, and their eyes shone



Where I had expected to see a jumble of rocks—what French rock climbers call a "chaos"—I found a fully featured landscape.

yellow. I was surprised they had eyes at all. Like cats and rabbits, some crustaceans have rings of mirroring tissue in their eyes to increase sensitivity to light, as I later learned from scientist Tamara Frank. She thinks the sub's lights permanently blind some deep-sea animals, based on her observations of disrupted ocular tissues. She hopes to test this hypothesis further by studying animals trapped in darkness. The shrimps didn't seem to react to our lights, though. They stood still until they sensed current from the sub, then rose in graceful arcs, their legs scurrying upward, pedaling as if to do back flips.

Pat dropped half of our weights—500 pounds of iron bricks. I imagined them clanking together, but all I heard were the plinks of sonar and the vocals of Patty Larkin. The iron would slowly rust away, and I wondered how its oxidation would affect the chemistry of the place. Higher in the ocean, tiny amounts of iron significantly increase photosynthesis by algae. Below the photic zone, no one quite knows what rusting weights do.

We lifted off. Out of the darkness, defying the boundless space, the sub's lights created a corridor and we headed down it.

"I'm trying to get some velocity out of this pig," Pat said, half joking. The *Alvin* motored along at a poky 1.4 knots over convex rocks. Black and glassy, they gave a cobblestone aspect to our path. Some looked like lounging walruses, others like tortoise shells. Many were broken—cracked black eggs. The instant I realized they were hollow, the drama of the mid-ocean ridge became real to me.

These shiny, round rocks were *new*, spewed from a volcano only weeks or months before our arrival. The lava "pillows" and the flat "sheets" next to them had formed almost as fast as we moved past them. (Odd that geologists use bedding terms to describe the most restless phenomena on Earth.) As geochemist Robert "Z" Zierenberg explained to me later, magma erupted here in red-and-orange splendor, superheated to 2,200 degrees (1,200 degrees Celsius), then fell back on the ridge like a pile of honey. It oozed downhill and swelled into beads at its edges. Within a few seconds, the outer surface of each bead hardened in the near-freezing seawater. But more honey pushed from behind. The flow of lava broke through the end of each shell and left it hollow to make another pillow, and another.

Where I had expected to see a jumble of rocks—what French rock climbers call a "chaos"—I found a fully featured landscape. We passed a steep hill covered with scree, like a rock-strewn summit in the Colorado Rockies. Then we entered a winding canyon reminiscent of southern Utah, its walls about three stories high. Gloomy waters enveloped freestanding towers of igneous rock.

Moving toward a murky pattern of tall forms, we arrived at a cluster of sulfide chimneys. They seemed too thin and fragile to stand. The columns, 12 to 18 feet high, are called black smokers because hot fluid densely mixed with particles of sulfide metals (like iron, manganese, copper, and gold) shoots from their tops. The chimneys form when a vent bursts through the earth's crust and the heated mixture meets cold seawater, at which point minerals at the periphery of the fluid column precipitate and solidify.

Pat sidled up to a chimney, raised one of the *Alvin*'s arms, and flexed

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**A CLOSE-UP (opposite page) of the eye and mouth of a deep-sea lizardfish (*Bathysaurus mollis*). The barbed teeth hold its prey in place until it can be swallowed. The vent bristleworm, or polynoid, (this page), is about an inch long, and lives among its relatives, the larger tube worms.**

its metal claw to take a sample. I stared at the iconic image: machine meets rock. When the claw closed, a section of the chimney disintegrated into a billowing cloud of gray dust. The tower's conical turret was gone. Black fluid rose through the newly opened wound, a gray-and-white ring lined with glittering metal crystals. We had trespassed; scientists would study the sample; a different chimney would form.

Our journey continued along the canyon, and the ground resumed its cobblestone pattern. Soon, signs of life appeared as squiggles on rocks, the white tubes of *Serpulid* worms. Crabs and squat lobsters came next. Their shells are chalky white, pigment having lost its relevance during their evolutionary descent through the abyss. Then my view grew fuzzy. Shimmering water rose by my window. We had reached a colonized vent.

As Pat turned the sub, I saw one of the largest pillars of tube worms currently known to exist on the East Pacific Rise. Thousands of curving, waving forms covered a column of rock as thick as a redwood tree, beckoning us with their blood-red plumes. Sliding into and out of white chitin tubes, they were weird and beautiful, disturbingly sexual. Pat finessed the joystick to raise the sub, and their plumes retracted as we passed. An eyeless crab lumbered up a series of papery tubes like an old man climbing stairs.

So these were the giant tubeworms, *Riftia pachyptila*. They embrace the ultimate alternative lifestyle. If life exists on Mars or the Europa moon of Jupiter, it may resemble these creatures, which survive with no sunlight and almost no oxygen. Fossils found in a copper mine show them to be at least 95 million years old. Tubeworms don't eat. They don't have mouths. And yet, somehow, they acquire bacteria to live with symbiotically.

The heroes of this story are the bacteria. Forget photosynthesis; this is chemosynthesis. As chlorophyll metabolizes sunlight for plants, these microbes use energy from hydrogen sulfide to turn water and carbon dioxide into oxygen and organic carbon. For them, hydrogen sulfide is the stuff of life. For us, it's an ingredient in lethal injections.

One of Stephane's areas of research is the hemoglobin that makes hydrogen sulfide work as tubeworm food. A tubeworm is red because it is full of a fancy hemoglobin that binds sulfides separately from oxygen. Its circulatory system carries sulfides to the bacteria lodged in the trophosome and delivers oxygen to the tubeworm proper. All the tubeworm has to do is to hold its red plume in the mixing zone, where vent fluid meets seawater, soaking up sulfides before they oxidize. Chemicals in its body sort nourishment from poison, just as proteins in the bodies of the other vent animals protect them from heavy metal-poisoning. No wonder pharmaceutical companies are interested in these animals. While Pat picked up specimens and secured them in boxes on the front of the sub, I stared out my window. Fifty squat lobsters clung to a flat rock, absolutely motionless. In the ten minutes I spent studying them, not one of their 500 appendages moved. As a restless human, I had trouble understanding this. More than anything else I saw or felt, their stillness informed my sense of "otherness."

Then we met the octopus. It was a *Vulcanoctopus hydrothermalis*, the only octopod species known to be unique to vents. Near this very site in 1998, *Homo sapiens* collected *Vulcanoctopus hydrothermalis* for the first time. It seemed to contemplate us as it arranged itself on open ground, spreading its pale arms gracefully around the white balloon of its body, about 24 inches from extremity to extremity. When I saw the friendly ghost face and the big black eyes, I understood why some scientists call it the puppy of the deep. But an octopus is a fierce predator. It nabs smaller animals in the webs between its arms, chemically immobilizes them, and chomps on them with its teeth and beak.

"Come here, little octopus," Pat cooed. He moved toward it with the suction tube poised for capture. As Pat teased two of its arms into the tube, the octopus felt the threat and pulled away. Closing like an umbrella, it rose in the water and glided like a bulb trailing ribbons, dancing its way into an alcove with Pat and the *Alvin* close behind. Deftly feeling along the rocky surface, it tucked itself under a ledge. Pat reached for the tips of a few exposed arms, but he was too late. The octopus prevailed.

Pat took it well. His brown eyes flashed amusement, and he said it was time to surface. We had been on the bottom for more than five hours; the basket was full. He dropped the remaining weights and shed some water ballast, and we rose drowsily through the black, blue, and green layers of ocean. Stephane dozed; Patty sang; I pondered. It took us a little more than an hour to reach the surface. We were met by the swimmers, hitched to the A-frame, and hoisted aboard the *Atlantis*. I did not get mooned; all of us made it through the voyage without having to use the sub's pee bottles; and I was christened with the buckets of ice water that typically initiate first-time divers.

We brought back an array of specimens for the Field Museum's collection, including several species never before described. There were scale worms for Stephane; octopuses for Janet; pieces of basalt and metal sulfides for Z; fluid samples, crustaceans, and temperature readings for the other scientists; and for me, a new sense of the world.

My few hours in the *Alvin* took me to awe-inspiring depths, where I met the unimaginable and witnessed a profound connection between life and stone. Animals have been living in deep-ocean communities on the energy from sulfides for eons, and yet we learned of their existence only a generation ago. We know so much less than we think we do.

It troubled me to introduce lights and weights into that environment, not knowing their impact, yet it also felt like hubris to worry about species that routinely survive volcanic eruptions. The East Pacific Rise, where new crust forms faster than anywhere else on Earth, is a landscape shaped by calamity. Sudden birth and sudden death punctuate long stretches of utter stillness.

I emerged from the ocean floor with a fatalistic sense of optimism. I know now that life exists beyond us, without us, despite us. Powerful as we are, we are no match for the metals and microbes that combine in vent fluid. Those basic bits of life and earth will endure to remake the world again and again. ■

*Katherine Millett, a contributing editor of* Plenty, *has climbed the Grand Teton, explored canyons in Utah, skied in east Greenland, and gotten lost in her own neighborhood.*