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Deep Under the Sea, Boiling Founts of Life Itself

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What started as a hunch is now illuminating the origins of life.

A few years back, Dr. Derek R. Lovley and colleagues at the University of Massachusetts found that a few kinds of bacteria used iron as a means of respiration (just as humans use oxygen to burn food) and that a surprising but common byproduct of this form of microbial breathing was magnetite, a hard black magnetic mineral.

The scientists wondered if hidden swarms of microbes might account for the vast deposits of magnetite that dot the earth and sea.

So they turned to one of the strangest, most ancient of environments — the deep sea's volcanic gashes, where mineral-rich waters hot enough to melt lead gush forth to nourish riots of life ranging from microbes to eight-foot-long tube worms. From the deep Pacific and other sites, the scientists obtained many samples of hot fluids.

To their surprise, they found that all the heat-loving microbes, known as hyperthermophiles, could breathe iron and make magnetite. Not only that, but one type broke the high-temperature record, thriving at an astonishing 250 degrees — far above the boiling temperatures usually associated with sterilization. The alien organism was judged to be among the most primitive forms of life ever discovered.

"It was a crapshoot," Dr. Lovley said of the hunt. "The surprising thing was that all the hyperthermophiles turned out to use iron."

That discovery, he and other scientists say, suggests that all life on earth may have originated from a microbe that breathed iron — potentially a key insight to learning about the chemical pathways that eons ago led to the dawn of biologic evolution.

In the quarter century since the discovery of the hydrothermal ("hot water") vents, scientists have found a world's worth of life: hundreds of unfamiliar species, new genera, new families and whole new orders. Together, they constitute major gains in measures of global biologic diversity, and they have gained a name: the dark biosphere.

Today in Los Angeles, filmmakers, drawing on waves of such excitement, are releasing a big-screen movie that celebrates the vents.

"It has been a passion for a number of us," said Dr. Richard A. Lutz, a Rutgers biologist who aided the film and the original discovery. "We've been enamored by the vents ever since."

The ocean floor was once thought to be a wasteland that possessed no light, no heat, no plants and very little life, if any.

That image shattered in 1977, when oceanographers working deep in the Pacific found bizarre ecosystems lush with clams, mussels and long tube worms.

When brought to the surface, the creatures smelled of rotten eggs, a sign of sulfur. It turned out that the ecosystem's main energy source was sulfur compounds emitted by the hot vents, in particular hydrogen sulfide. The primary producers (like plants on land) were tiny microbes thriving on volcanic heats and chemical energies rising from the earth's interior.

The dark ecosystems forced scientists to conclude that not all life on earth depends on the sun's energy or on photosynthesis.

As similar communities were found in the deep, intrigued scientists theorized that the vents were perhaps windows on a deep microbial world, a hidden biosphere extending for miles into the earth's crust, with a total mass rivaling or exceeding that of all surface life. Even stranger, they suggested that life on earth might have begun in such realms, nurtured by a steady diet of hot chemicals.

Since those frenetic early days, ocean scientists have found not only scores of such deep oases but strong evidence that they do in fact represent the tip of a very old, very large ecosystem. Recent papers report censuses of the tribe's most fundamental members — microbes.

"We find bugs pretty much everywhere we look," said Dr. John A. Baross, a biologist at the University of Washington who studies hyperthermophiles and used a deep-sea robot to retrieve the water sample containing superhot organism.

Much of the exploration focuses on the West Coast — offshore from California to Canada — because a long volcanic gash fairly close to shore makes scientific visits there relatively easy. The National Science Foundation has financed much of the work, along with the National Oceanic and Atmospheric Administration.

Five years ago, in a first, scientists off Vancouver Island raised from the depths parts of four rocky vent chimneys, two dead and two live ones spewing hot smoke rich in chemicals and microbes. Dark and rough, they were up to seven feet tall and weighed up to two tons, the hot ones teeming with worms, sea spiders and limpets.

In the June issue of Applied and Environmental Microbiology, the scientists, including Dr. Baross as well as Matthew O. Schrenk, Dr. Deborah S. Kelley and Dr. John R. Delaney, all of the University of Washington, reported the dissection of a chimney that had been venting fluids of 575 degrees. Despite the temperature, it was riddled with signs of life.

"Direct microscopic observation indicated that micro-organisms were attached to mineral surfaces throughout the structure," they wrote, adding that the discovery suggested that further research would expand "the known upper temperature limits of life."

A different census focused on a volcanic gash off Oregon that erupted in 1998, 1999 and 2000, the outbursts monitored by undersea microphones. Each time, the scientists took samples more than a mile down. Such eruptions are windfalls for biologists since not only molten rock but large volumes of hot, microbe-rich water spew forth. The huge clouds of life — thought to originate deep within the cracks, fissures and pores of the rocky seabed — allow experts to glimpse a normally invisible world.

Julie A. Huber, Dr. David A. Butterfield and Dr. Baross, all of the University of Washington, reported their census of microbes up to third of a mile down in the April issue of Microbiology Ecology, published by the Federation of European Microbiological Societies.

They said that even at the greatest depths, under crushing pressures, the rocky seabed was composed of about 30 percent open pores, giving it plenty of living space for diminutive organisms.

The scientists zeroed in on the raw genetic material of the collected microbes, thus finding more than methods of culturing them with special foods could ever discern. (The science of what hyperthermophiles like to eat and breathe is still young.)

To the scientists' surprise, they found a huge diversity of organisms whose composition swung wildly over time. The 1998 eruption produced 35 species of bacteria, compared with 37 and 57 from 1999 and 2000.

But the numbers of archaea — ancient organisms often found in hot places like those thought to exist on the ancient earth — went in the opposite direction, declining from 63 to 60 to 52, according to paper by the same authors in the April 2002 issue of Applied and Environmental Microbiology.

The reason behind the swings is still murky. "We're straining to understand better how these systems work," Dr. Baross said in an interview. "It's a very complicated puzzle. Until a couple of years ago, we had no pieces. Now, to some extent, we're starting to put the puzzle together."

Three years ago, scientists told of finding fossil microbes that lived near vents formed 3.2 billion years ago, confirming that hyperthermophiles were among earth's earliest inhabitants. That discovery has quickened the search for descendants of primordial vent life.

Biologists say the recent discovery of the extremely high-temperature, iron-breathing organism by the University of Massachusetts scientists, who included Dr. Kazem Kashefi, suggests that the dark biosphere runs deeper and hotter than previously documented. And sulfur, they add, may turn out to play a smaller role than previously believed. The iron finding is reported in the Aug. 15 issue of Science.

Dr. Lovley and Dr. Kashefi are betting that the common metal (the earth's most abundant element) will prove important. Its transformations, they wrote, "may have been the first form of microbial respiration as life evolved on a hot, early earth."