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# OCEAN explorer

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HOT, HOT, HOT: This "black smoker," an underwater chimney at a hydrothermal vent, sends up super-heated fluid that may be hotter than 350°C (662° F).

## DEEP-SEA SMOKE? *NOT.*

WHAT IS THIS? FACTORY smoke from a chimney in a gnome's world? You are looking at a chimney, though it is not giving off smoke as we know it. And while you could say the chimney is located *somewhere* near Middle Earth, it is not in some hidden troll's kingdom. This deep-sea chimney, or black smoker, is part of a hydrothermal vent on the sea floor, miles below the surface. Its "smoke" is actually a plume of scalding (350°C or 662° F) fluid composed of sea water and a number of extra substances, some of which are poisonous to most known forms of life. As this hot, metal-enriched fluid comes in contact with the cold surrounding seawater, the metals separate from the solution as small mineral particles. These make the water look smoky. Why doesn't this scalding water boil? Because of the immense water pressure at this depth.

You might think that nothing could live anywhere near such an incredibly hot, poisonous discharge. But many bizarre creatures do— animals with eyes in the middle of their backs, creatures that look like dandelions, or plates of spaghetti, even worms taller than the tallest basketball player.

In this issue of *Ocean Explorer* you can read about the discovery of the strange world of hydrothermal vents. You'll also learn more about the super-hot fluid that gives life to some really weird animals.

# IT'S A JUNGLE DOWN THERE

## "There was so much to learn. It was a discovery Cruise. It was like Columbus."—John Edmond.

On a single, incredible oceanographic cruise to a site near the Galapagos Islands, a series of remarkable discoveries were made that forever changed notions about the deep sea.

J. FREDERICK GRASSLE/WHOI

**Oceanographers on a cruise to hydrothermal vents are amazed by the animals *Alvin* has carried back.**

### DISCOVERY

**The deep sea floor is not entirely a desert. Areas near some hydrothermal vents teem with a variety of weird animals found nowhere else on earth.**

*The material in this article was adapted, and in some instances excerpted from* ***WATER BABY, The Story of*** **Alvin** *by Victoria A. Kaharl.*

IN THE 1960S, SCIENTISTS began to measure tiny, mysterious rises in water temperature, miles below the surface, especially near the Galapagos Islands. They wondered what was going on down there.

In 1977, a group of geochemists and geologists from places such as the Woods Hole Oceanographic Institution and Oregon State University travelled to a site 200 miles from the Galapagos Islands in the Pacific Ocean. There, they made a series of dives in *Alvin*, the deep-diving submarine based at WHOI, to see if they could solve this mystery. Nothing could have prepared them for what they were about to discover.

On February 17, 1977 *Alvin* dived at a site called the Clambake, which got its name after a deep-sea camera took pictures of large clamshells that lay there on the sea floor. The camera also noted a slight temperature change at that spot. It was the temperature change the scientists wanted to know more about. They saw no connection between the clamshells and the water temperature.

Onboard *Alvin* were pilot Jack Donnelley and Oregon State geochemists Tjeerd van Anden and Jack Corliss. A temperature sensor placed outside *Alvin* was connected to an electronic box inside the sub. The box was designed to beep with a thousandth of a degree temperature rise.

Within fifteen minutes after touchdown at 2400 meters (8000 feet), the temperature box beeped. Flashing red numbers indicated a hundredth of a degree rise in temperature. Suddenly, *Alvin* was surrounded by life. Strange animals, many never seen before, were everywhere. The *Alvin* passengers had not expected to see any living creatures here at all.

They had discovered a hydrothermal vent, a crack in the sea floor up through which travelled hydrothermal fluid: hot, chemically-altered seawater. Near this hydrothermal vent lived an incredible assortment of creatures. There were huge clams, with shells as big as dinner plates. The explorers watched a many-legged creature pump itself out of sight. They saw a pretty little pale orange ball that looked like a dandelion gone to seed, and rocks covered in white streaks, that looked like pigeon droppings. Were those worms? The water got foggy. They saw six more of these white crabs, and a whole cluster of these little peach-colored dandelions. For as far as they could see, there were more clams and mussels—or were they oysters?— tucked in among the black basalt.

The *Alvin* passengers were in shock. They did not expect to see a thriving oasis in the middle of a deep sea desert. Though the voyagers did not know it at the time, most of these creatures had never been seen before.

The excited scientists reported to the surface, using *Alvin's* underwater telephone. "Debra," said Jack Corliss, speaking to graduate student Debbie Stakes, who was monitoring the dive from the surface, "Isn't the deep ocean supposed to be like a desert?" "Yes," said Debbie. A marine geolo-

gist, she did not know very much about the creatures of the deep, except what she had learned in high school, and in an ecology course in graduate school.

"Well, there are all these animals down here," Jack said. They couldn't believe their eyes.

## DISCOVERY

**Warm sea water that passes up through the earth's crust as hydrothermal fluid seems to shimmer.**

That was only the beginning of the surprises that would be found in this bizarre environment. A few days later, Jack Corliss and MIT geochemist John Edmond returned to the Clambake area. They stopped to sample water near a purple sea anemone. As Jack looked out the porthole, he noticed that the water was shimmering like the air above a sidewalk in summer. What was going on? They measured the temperature of the water. It was 8°C (46°F) — much warmer than the normal just-above-freezing water found at that depth.

The scientists were so shocked and surprised by the discovery of this warm, shimmering water, that they began to shout and stutter. They gaped out of *Alvin's* tiny portholes, trying to understand what they were seeing. What on earth was making the water shimmer? Why was it so warm? (Later dives would find much warmer water—as hot as 350°C (662°F). But at that time, this discovery was astounding enough.) Jack and John returned to the surface with gallons of the shimmering water.

## DISCOVERY

**Seawater usually has the same chemical composition, no matter where it is sampled. But seawater at hydrothermal vents is different.**

In the lab back on the ship, John Edmond opened one of the water sample bottles. WHEW-EE! It stank like rotten eggs. He almost couldn't breathe. What was making that horrible smell?

"We realized that regular seawater was mixing with something," says John Edmond. "It was a unique solution I had never seen before. We all started jumping up and down, we were dancing off the walls. It was chaos. It was so completely new and unexpected that everyone was fighting to dive. There was so much to learn." Many more discoveries have been made at the vents since then.

# WHY ARE VENTS IMPORTANT?

Vents help cool the earth's crust. They help regulate the chemical composition of sea water. They are important in ore formation.

SEAWATER HAS PRETTY much the same chemical composition everywhere in the world. What regulates it? Where do the minerals in sea water come from?

For a long time, it was believed that seawater minerals came from river runoff and from the weathering of rocks. But this did not account for all the minerals in seawater. And it did not explain how seawater's constant chemistry was maintained.

"The books didn't balance," says WHOI geochemist Geoffrey Thompson. "We knew how much magnesium was going into seawater from runoff, we knew how much magnesium was going into the sediment." However, there was more magnesium coming into the ocean than going out to the sediment. Since the magnesium content of the ocean is constant, then the magnesium had to be going somewhere else besides the sediments. But where?

The discovery of hydrothermal vents and their chemical-rich fluids began to answer this question. Although hydrothermal vent fluid is loaded with many metals such as iron, manganese, copper, zinc and rubidium, it has no magnesium. The seawater that circulated down into the crust was heated and reacted with the crust, leaching some metals from the rock. It had, in return, deposited all its magnesium in the crust. "We've redone our bookkeeping," says Geoff. "Now we know where the magnesium goes and the books balance."


**This cutaway diagram shows a vent chimney on the sea floor. You can see how the almost-freezing deep-sea water passes down through cracks in the basaltic rock sea floor. As the water flows through the rocks, it is heated by energy from beneath the earth's crust. This water is chemically changed by the heat. It rises back up to the sea floor and passes through a crack again. The water that emerges is rich in minerals, especially sulfides, which leach above the sea floor, forming ore deposits such as chimneys.**

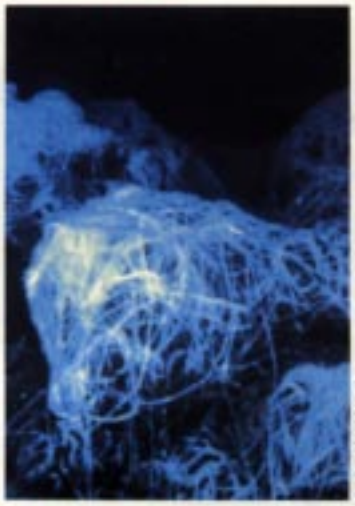
# VENT CRITTERS

Meet a few of the weird animals that call hydrothermal vents home.

JOHN FORTOUS/WHOI

**HOTHOUSE WORM**
This vent creature, admittedly not a textbook beauty, is *Alvinella pompejana*, also known as the pompeii worm. It lives in a tube that it builds directly on top of a smoker spewing out 350°C (662°F) hydrothermal fluid. Though the smoker itself is probably not as hot as the fluid it gives off, it is still plenty hot. How does the worm keep from being fried to a crisp? Like so many vent mysteries, nobody knows the answer. Perhaps it will be revealed as more pompeii worms are recovered from their deep, dark, *hot* homes.

**IS THAT SPAGHETTI?**
"Spaghetti worms" like these were first discovered by *Alvin* explorers during a journey to the Galapagos. At first, the divers thought they saw bushes. Then they realized that they were looking at a whole field of rocks covered with sticky worms, varying in size from a few millimeters up to a meter. The scientists carried samples of this living spaghetti up to the surface, where the worms were later identified as a new genus and species of acorn worms.



JIM CROSSLEY/UC-SB

**TICKLE, TICKLE**
Though these brachyurian crabs (one of which is being touched by *Alvin's* probe) are pretty much like crabs found elsewhere on the ocean floor, these crabs get around without using their tiny eyes, since the world they live in is almost totally dark. When scientists spot a group of them in the relative emptiness of the deep, dark sea, they suspect that a hydrothermal oasis is somewhere nearby. Often, when *Alvin* dives at a hydrothermal vent, it returns to the surface with some of them still clinging to it.

ROBERT HESSLER/SIO

J. FREDERICK GRASSLE/WHOI

**MAKE A WISH AND BLOW**
Though it looks like a flower gone to seed, this pretty orange "dandelion" is actually an animal, or rather, a group of animals, probably related to the Portuguese man-of-war. This type of animal was discovered for the first time by *Alvin* divers who were exploring hydrothermal vents in the Galapagos. Scientists have never been able to preserve a good specimen of this "dandelion," because every time they scoop one up and bring it to the surface, it turns to mush, either as it is carried up from the sea floor, or a little while later.

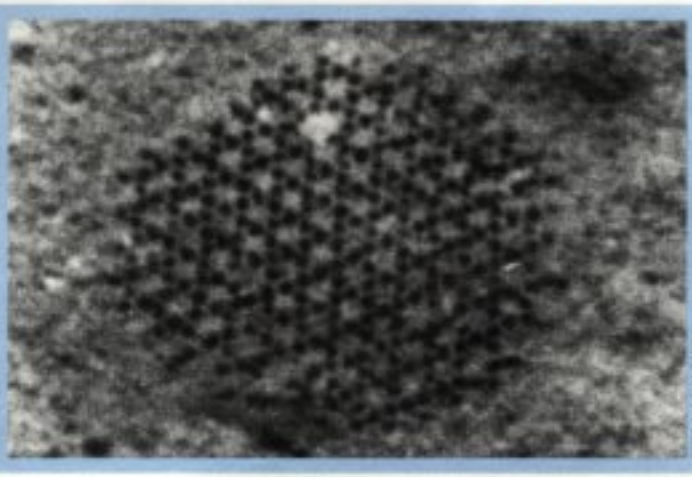
AL GIDDINGS © NATIONAL GEOGRAPHIC SOCIETY

**A "FLOWER" BLOOMS IN THE DEEP SEA**
This sea anemone could be mistaken for one of its relatives found in much shallower water, except that a vent anemone's favorite meal contains a hearty portion of hydrogen sulfide emitted from vent plumes, toxic to most living things

# Wazzat?

Believe it or not, this is a real, live animal. This "Chinese checkerboard creature," a living fossil whose scientific name is *Paleodictyon nodosum*, was found living near a hydrothermal vent in the Atlantic Ocean. When it was first seen in a photograph, it looked so strange to scientists that they thought their camera was broken.

Very little is known about this living checkerboard, except that it is similar to creatures that lived hundreds of millions of years ago. That it is still alive today supports the idea that the deep sea, less than one percent of which has been explored to this day, contains many mysteries yet to be revealed.



PETER A. RONA/NOAA

# The Symbionts

Eight-foot tall tube worms. Jumbo clams, with shells the size of dinner plates. How did they grow so big? By making a home for bacteria.

J. FREDERICK GRASSLE/WHOI

BESIDE A HYDROTHERMAL vent, deep down on the ocean floor where the sun never shines, a tall white tube worm, one of a forest of *Vestimentifera*, waves its red head. Is it eating? Yes, and no. This worm doesn't eat like other animals. It has no mouth, not gut, no anus. Says WHOI biologist Holger Jannasch, "It has given up eating altogether." It nourishes itself by taking in hydrogen sulfide gas from the hydrothermal vent fluid that passes up from a crack in the sea floor and mixes with oxygen from the surrounding seawater. Through a series of capillaries (very small blood vessels), both gases travel to the inside of the worm, where a colony of bacteria live. The worm actually eats the bacteria that it feeds.

EMORY KRISTOF © NATIONAL GEOGRAPHIC SOCIETY

**Vent clams are very big – about ten times as big as clams we eat.**

If the worm has no mouth, how do the bacteria get inside? Nobody knew the answer to this question for a long time. Then, in 1985 a zoologist named Meredith Jones from the Smithsonian Institution found a microscopic opening in a baby tube worm, which was itself no bigger than the white at the tip of your fingernail. Meredith said that the opening was "a single snout-like structure that appears to sort of snuffle up bacteria." It closes up as the animal gets bigger.

Another vent creature that makes a home for bacteria is the giant clam called *magnifica*. This clam feeds the bacteria that live inside it by taking in hydrothermal fluid through its foot, which it sticks directly into a crack on the sea floor.

**Tube worms and other creatures living in a cluster near hydrothermal vents.**

# PEEK-A-BOO

At least one kind of vent shrimp has an "eye" in the middle of its back. But what does it look at?

GEOFFREY THOMPSON/WHOI

**Bees at a hive: shrimp on a chimney.**

TO ME, THEY LOOK LIKE bees dancing on a hive," says biologist Cindy Lee Van Dover, describing the odd white shrimp, called *Rimicaris exoculata* (Latin for "eyeless rift shrimp") that she travels deep into the ocean, to the Mid-Atlantic Rift, to study. These shrimp gather at hydrothermal vent chimneys. Sometimes, as many as 1500 shrimp, all moving and wiggling in a frenzy of feeding, have been counted in just one square meter (about one square yard) of a chimney's surface. These shrimp don't remind everyone of dancing bees. MIT chemist John Edmond once described these shrimp as looking "disgustingly like swarming maggots on a hunk of rotten meat."

Like most vent animals, vent shrimp make their living by eating bacteria that live in the poisonous vent fluids. Do shrimp that chow down on bacteria that live off poison taste good to eat? Cindy cooked one once. It did not turn pink. Gray to begin with, it turned an even uglier shade of gray. It tasted like a rotten egg, and had the texture of a rubber band.

How do these shrimp find the chimneys that hold their food? How did they come to live at the vents in the first place? Scientists are trying to answer these questions.

Though the shrimp have no eyes, they do have a bright reflective spot on their backs, right behind their heads. When studied in the laboratory, scientists discovered that this spot contains rhodopsin, a light-sensitive material found in the eyes of many creatures.

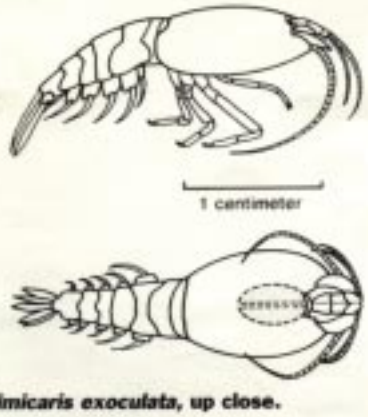
So, it would seem that these shrimp can "see"— or at least, they can tell whether or not something gives off light. But what light are they looking at? Isn't their world totally dark, except for the odd flash of light from a creature that glows in the dark?

Cindy Lee Van Dover and her colleagues wondered about this for a long time. They wondered if the vents themselves might give off some sort of glow, too faint for humans to see, but easy for a shrimp with a special deep-sea eye to detect.

The scientists thought about the ways in which such a light source could be useful to the shrimp. It could draw them to areas where they could feed, or warn them to stay away from water that was so hot it could kill them. Cindy had learned about a phenomenon called "black body" radiation, which causes hot things to glow, though that glow may be outside of the range of our visual spectrum. Might hydrothermal vents give off this "black body radiation?"

Cindy went on a cruise with other scientists to test out this idea. They used a special camera, that could photograph this very low-level glow, if it existed. When they got the pictures back and developed them, they were excited to see that they were right. Vents glow. And the shrimp may be there to see the glow.

*The preceding material is adapted from an article called "Do 'Eyeless' Shrimp See the Light of Glowing Deep-Sea Vents?"by Cindy Lee Van Dover that originally appeared in* Oceanus *Magazine, Volume 31, Number 4, Winter, 1988/89.*




WHOI GRAPHICS DEPARTMENT

***Rimicaris exoculata*, up close.**

## WHAT'S FOR LUNCH?

The diet of vent animals may seem boring to us: bacteria, bacteria, bacteria. But where that source of food is plentiful, these creatures seem to flourish.

**In most people's minds, bacteria are bad things that cause disease," says WHOI biologist Holger Jannasch, who has dived many times to hydrothermal vents. "But these tiny organisms are everywhere. They are extremely important in the recycling of matter. They are as important a part of our own food chain as trees or cows. In the deep sea, the bacteria are the basis of whole animal communities that are brand new and surprising to us. We always thought life on earth was supported by the sun. It's an important fact, it's what you learn in school. Now we know there is a big exception to this."**

WHOI

**A mat of vent bacteria.**

## FROM HERE TO THERE

How does a new vent community start? Nobody knows for sure.

**Hydrothermal vent communities come and go quickly, especially in the Pacific, where their life span is measured in tens of years. When a vent stops giving off hydrothermal fluid, what happens to the animals that live there? Most of them die. But somehow, new vent communities are settled by new organisms. Since the larvae of these animals have no way of travelling under their own power, how does this happen?**

**Lauren Mullineaux, a biologist at WHOI, thinks that the microscopic larvae of some of these animals, particularly vent clams, might rely on the flow of sea water to transport them. She thinks they may travel upward with hydrothermal vent fluid. At a certain level, the larvae may join with the current that flows throughout the ocean.**

**Nobody knows how these travelling larvae find their way to their next source of chemosynthetic bacteria. "I wish we could put a tag on one, so we could follow it," says Lauren. In fact, she and other scientists have been trying to develop a genetic tag that would tell them, even in very general terms, where a clam's ancestors came from. Someday, they hope they will know.**

# ZERO IMPACT

DALE GOBBETT/ROV/WHOI

THERE IS A PLACE ON EARTH THAT IS SO COLD, AND SO dry, it has been compared to the surface of Mars. It has no rainfall, no trees. This is Antarctica, perhaps the only pristine environment on our planet. Antarctica is so different from the rest of the earth that scientists who work there say it is probably what most of the earth was like millions of years ago — before oceans, before fish. What is it like to live in Antarctica, to work there? In the next issue, you'll travel to the bottom of the world with a hardy team of researchers who like living in a place where the sun shines 24 hours a day at some times of the year, because "you can get so much work done." (See the photo above, which was taken at 2:00 in the morning!) Find out how their "zero impact" camping style helps maintain this pristine environment. It demands that all man-made products, including human waste, be transported off the continent.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