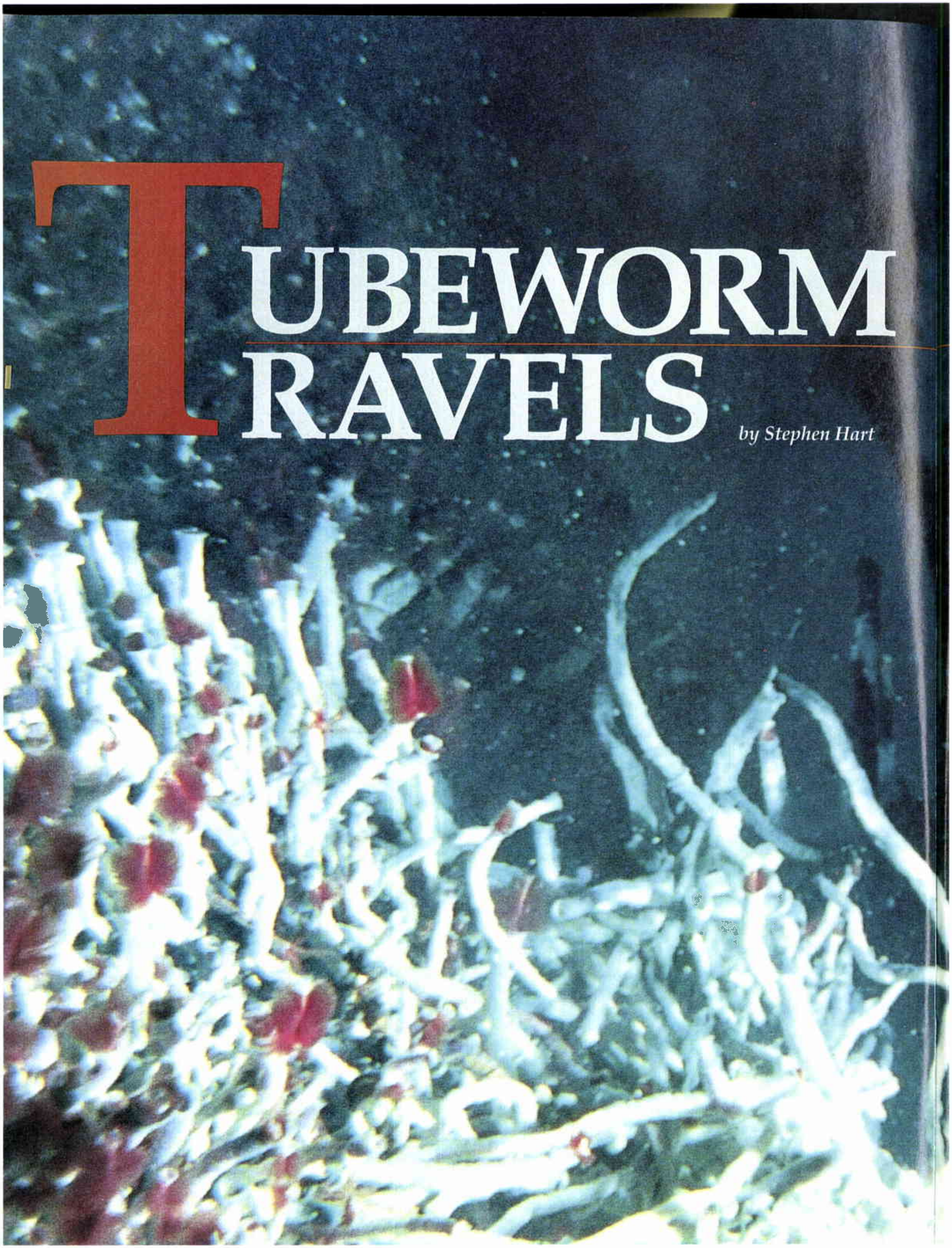
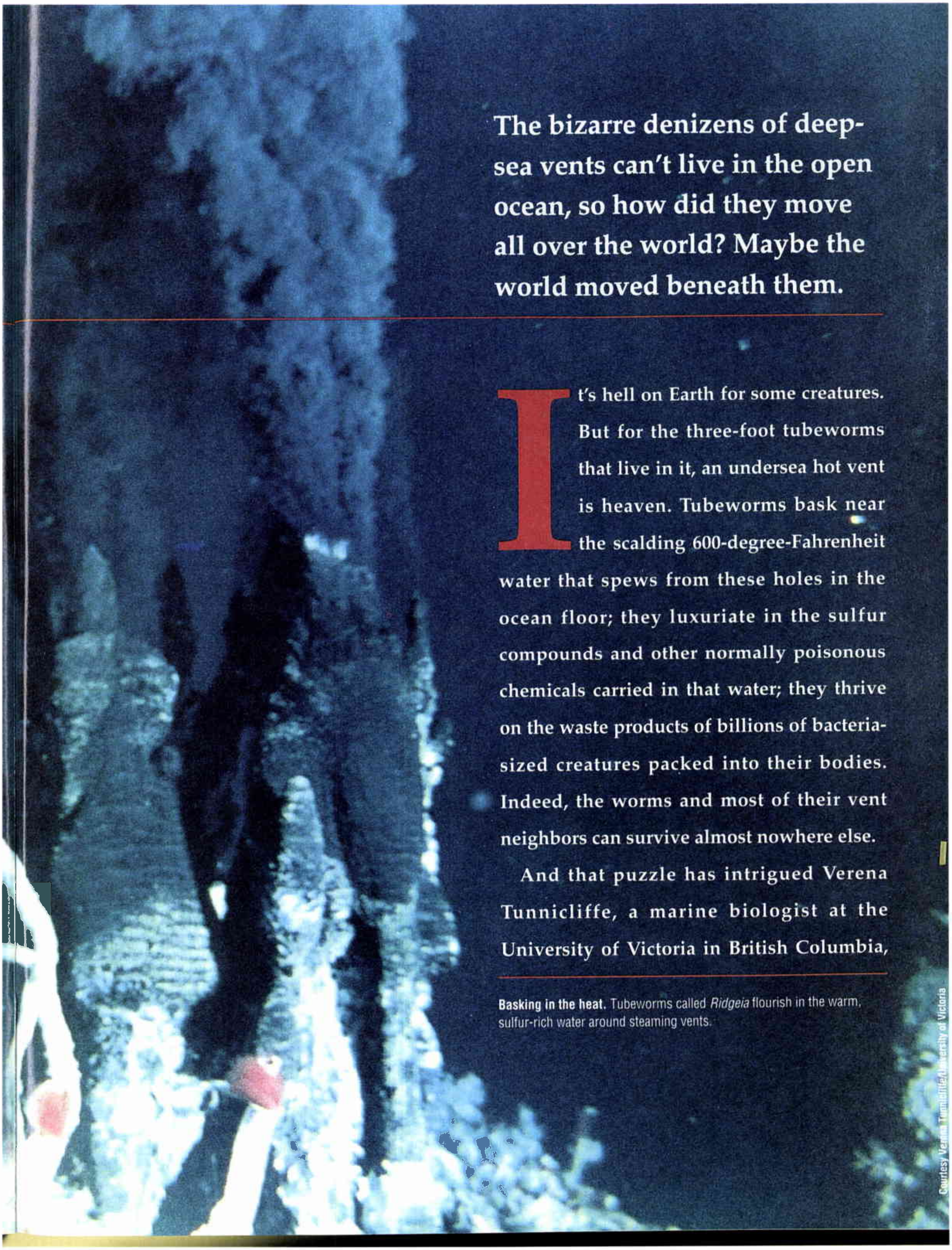


TUBEWORM TRAVELS

by Stephen Hart



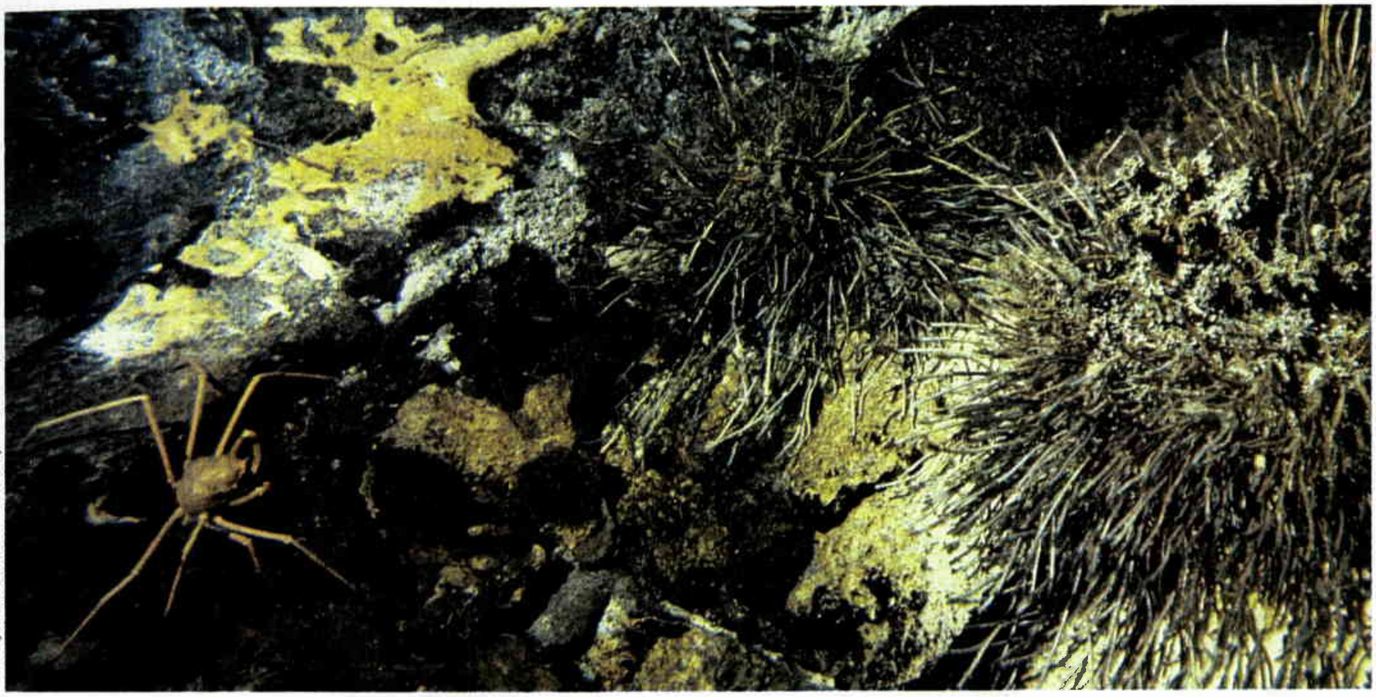
The bizarre denizens of deep-sea vents can't live in the open ocean, so how did they move all over the world? Maybe the world moved beneath them.

It's hell on Earth for some creatures. But for the three-foot tubeworms that live in it, an undersea hot vent is heaven. Tubeworms bask near the scalding 600-degree-Fahrenheit water that spews from these holes in the ocean floor; they luxuriate in the sulfur compounds and other normally poisonous chemicals carried in that water; they thrive on the waste products of billions of bacteria-sized creatures packed into their bodies. Indeed, the worms and most of their vent neighbors can survive almost nowhere else.

And that puzzle has intrigued Verena Tunnicliffe, a marine biologist at the University of Victoria in British Columbia,

Basking in the heat. Tubeworms called *Ridgeia* flourish in the warm, sulfur-rich water around steaming vents.

Courtesy Verena Tunnicliffe/University of Victoria



Courtesy James Childress/University of California, Santa Barbara

and other researchers for years. Hot vent oases are scattered in clusters along deep mid-ocean ridges. Between two ridges there may be hundreds of miles of barren terrain containing none of the essential ingredients for tubeworm survival. Even along a single ridge there can be miles of desolate ocean floor between hydrothermal vents. Yet the same types of animals — limpets, giant white clams and red-tipped tubeworms — show up at vent after vent.

If the animals can't live between the vents, Tunnicliffe asks simply, "How do they get there?"

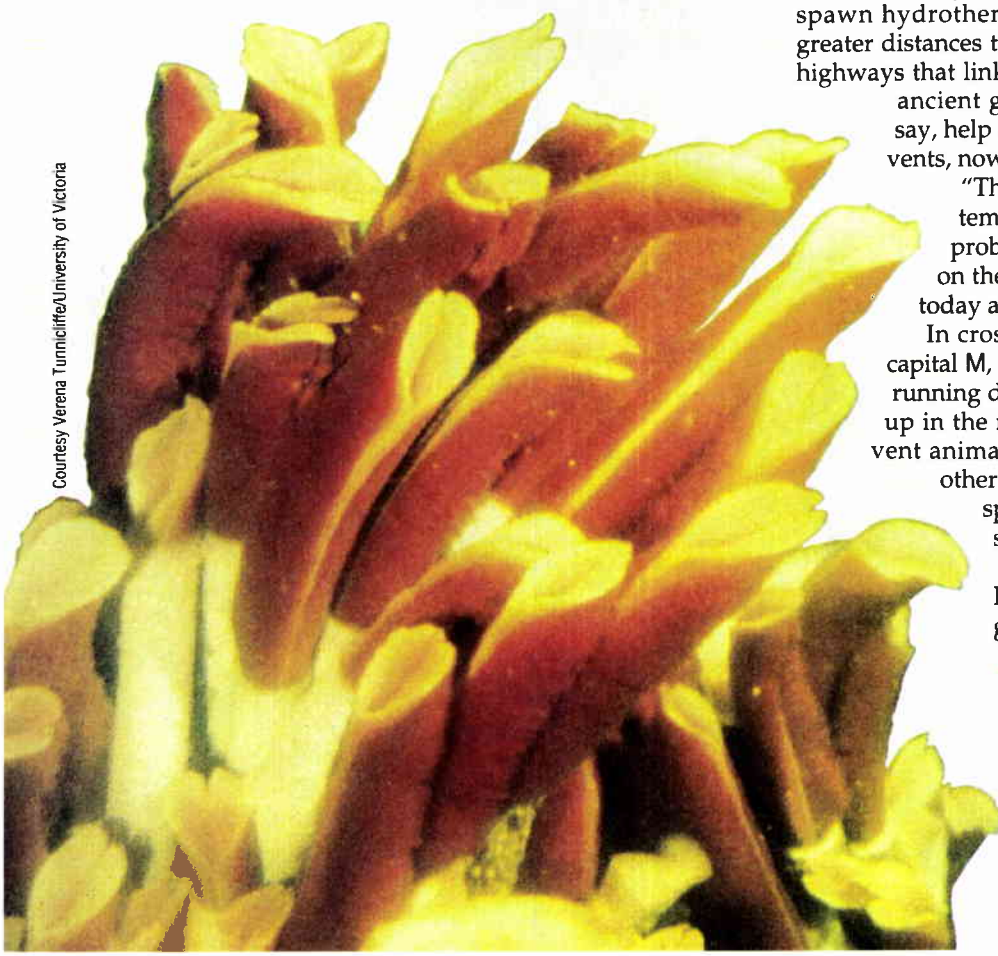
Now Tunnicliffe and Mary Fowler, a geologist at Royal Holloway, University of London, think they've found the answer, or at least part of it, in the planet's distant past. By re-creating the movements of plates that make up the seafloor, the duo has learned that some fields of vents were not always as isolated as they are today.

Millions of years ago, some of the mid-ocean ridges that spawn hydrothermal vents ran continuously for much greater distances than they do today, forming underwater highways that linked vent to vent in longer chains. These ancient geological connections, the researchers say, help explain why the animal oases at modern vents, now disjointed, nevertheless look similar.

"The geometry of the mid-ocean ridge system over the last 100 million years or so has probably been the most important influence on the broad distribution of the fauna we find today at hydrothermal vents," Fowler says.

In cross section, mid-ocean ridges look like a capital M, with a rift valley about a half-mile wide running down the center. Currents can get caught up in the ridges and sweep the drifting larvae of vent animals from one hot sulfurous home to another along the ridge. When larvae hit a good spot, they can settle down, reproduce and send off their own offspring.

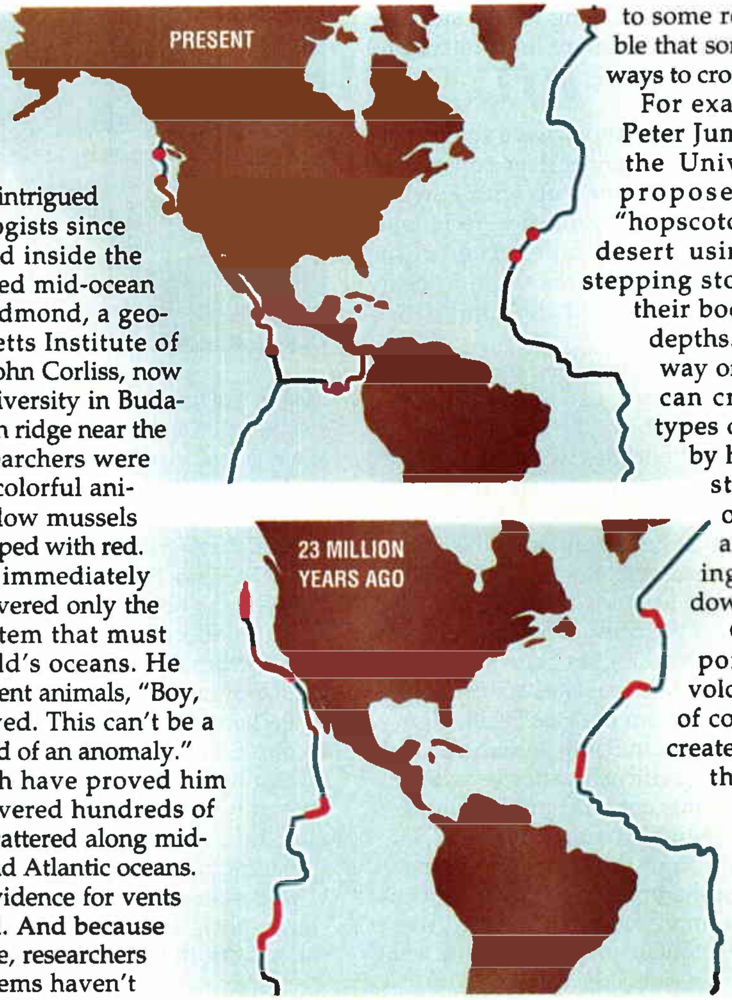
"If you have a long journey to make," Fowler explains, "you use a route with good roads, mid-ocean ridges; frequent



Courtesy Verena Tunnicliffe/University of Victoria

Octopus's garden. A garish crab skitters across the ocean floor near a hydrothermal vent in the north Pacific (top). Mats of yellow bacteria encrust the seafloor next to clumps of *Ridgeia* tubeworms. *Riftia* tubeworms (bottom), common at southern Pacific vents, flaunt their rust-red gills.

service stations, hydrothermal vents; and not too many long detours or pitfalls, the deep ocean.”



EARTH: Elisabeth Rowan

The earth moved. Today the west coast of North America isolates fields of hydrothermal vents (red dots) in the northern Pacific from those on ridges near Mexico and the Galápagos Islands. But millions of years ago, a long ridge linked the Pacific from north to south. Life-sustaining vents probably dotted the ancient mid-ocean ridge as they dot ridges today.

Vent inhabitants have intrigued biologists and geologists since researchers cramped inside the submersible *Alvin* discovered mid-ocean vent oases 1977. As John Edmond, a geochemist at the Massachusetts Institute of Technology, and geologist John Corliss, now at the Central European University in Budapest, approached a mid-ocean ridge near the Galápagos Islands, the researchers were astonished by an island of colorful animals: giant clams, huge yellow mussels and three-foot-tall worms tipped with red.

Edmond says it seemed immediately obvious that they had discovered only the first example of an ecosystem that must occur throughout the world's oceans. He remembers thinking of the vent animals, “Boy, these guys are highly evolved. This can't be a one-off, you know, some kind of an anomaly.”

Two decades of research have proved him right. Scientists have discovered hundreds of species at dozens of vents scattered along mid-ocean ridges in the Pacific and Atlantic oceans. Geologists recently found evidence for vents in the Indian Ocean as well. And because ridges are difficult to explore, researchers suspect that most vent systems haven't yet been seen.

Mid-ocean ridges form at spreading zones, places where two oceanic plates move apart and magma flows out onto the seafloor between. There, scalding streams of sulfur-rich water feed bacterialike organisms called archaea. Microscopic archaea feed tubeworms, clams and other animals, forming the base of rich food webs 500 to 1,000 times more populous than those on the neighboring ocean floor.

Many of the animals plucked from these vent sites were previously unknown to science, and almost all of them seem bound to hydrothermal vents. “I think my listing is now 400 species long,” Tunnicliffe says. “Maybe 15 of those are also found in the normal deep sea.”

Even so, she's discovered that clusters of vent animals separated by vast expanses of deep-sea desert look surprisingly similar. Somehow, the scattered populations have managed at least occasional contact.

It's relatively easy to understand how vent animals get from one vent to a neighboring one, Tunnicliffe says. Ridge currents can sweep larvae along, depositing them in new homes. Over generations, other scientists have proposed, a species could really get around that way, skipping along — and maybe even between — ridges. The deep ocean seems like a desert to vent oasis dwellers (and to some researchers) but it's possible that some creatures find unusual ways to cross the harsh landscape.

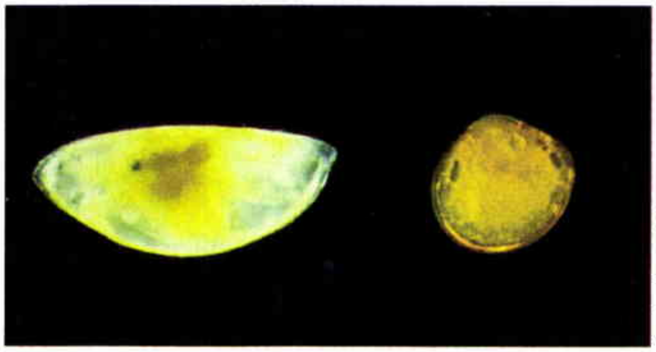
For example, a few years ago, Peter Jumars and Craig Smith of the University of Washington proposed that larvae might “hopscotch” across the deep-sea desert using whale carcasses as stepping stones. When whales die, their bodies drift down to great depths. Once there, they go the way of all flesh. Decomposition can create some of the same types of chemicals spewed out by hydrothermal vents. Such stepping stones in mid-ocean could sustain vent animals temporarily, giving larvae a place to settle down and produce offspring.

Other researchers have pointed out that deep-sea volcanic hot spots and seeps of cold methane along coasts create environments similar to those at spreading ridge vent systems. Perhaps hot spot vents and seeps also serve as stepping stones.

The problem with those ideas, Edmond explains, is that hops between vents, even nearby ones, are risky for larvae. It's likely that most of the young animals get lost and die before they find a good place to settle down. “Only a tiny percent of the larvae that are produced in the vent fields can possibly be successful,” Edmond says.

“If you're only looking at how larvae can get around the ocean now, you haven't got the whole answer,” Tunnicliffe insists. Very few of the animals found at hydrothermal vents have been discovered on whale carcasses. Some of the most widespread vent creatures, such as vent mussels, have never been found on the decaying remnants of dead behemoths — or on hot spot vents.

Jim Childress, an ecological physiologist at the University of California, Santa Barbara, agrees with Tunnicliffe. “The various other things that have been suggested just don't add up when you look at the actual distributions of animals,” he says. Groups of vent animals in northeast and southeast Pacific vents, separated by California and Baja, are strikingly similar. Even Atlantic and Pacific vents share some creatures, and the similarities are too strong to be explained by serendipity. A lot of lucky larvae would have had to drift from a vent site to a decaying whale, successfully reproduce there and send out more lucky larvae to drift on to other suitable homes.



Courtesy Lauren Mullineaux/Woods Hole Oceanographic Institution

Footless and fancy free. The tiny larvae of vent barnacles (left) and mussels (right) drift with the current until they die or are lucky enough to land in good homes.

Since these present-day explanations were so unsatisfactory, Tunnicliffe began to wonder if an explanation might lie in the past. She teamed up with Fowler, who had previously used an elegant geological technique to reconstruct ancient seafloor landscapes. Tunnicliffe hoped that by tracing the ancient paths of mid-ocean ridges, she could uncover reasons for the similarities among vent site communities.

First, Tunnicliffe and Fowler documented those similarities, compiling lists of the species, genera and families (the next broader classifications above the species level) of animals found at a number of vent sites worldwide. If two sites share many of the same types of animals, Tunnicliffe and Fowler reasoned, then larvae either must travel fairly regularly between sites or must have done so in the past.

In the eastern Pacific, for example, the researchers compared lists of creatures found in three areas: a site in the Galápagos, two vent fields off the coast of Mexico, and the northeast fields, just west of Washington State and British Columbia. The Galápagos and Mexican sites are connected directly by a ridge that juts out from the East Pacific Rise, a long ridge stretching from southern South America to Baja California. The northeastern Pacific vent sites lie within a complex of short ridge segments cut off from the southern sites by the west-wandering North American Plate.

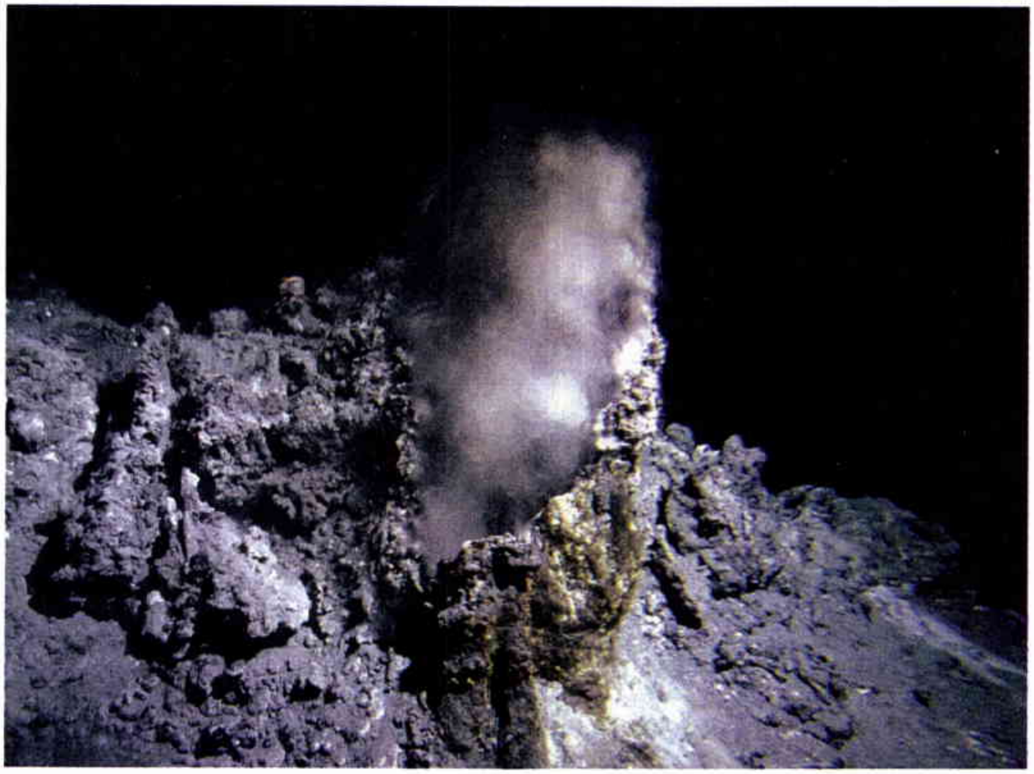
By the shortest route through the ocean, the Mexico sites are closest to vents in the northeast Pacific. But the vent inhabitants off Mexico more closely resembled those at the Galápagos sites. The conclusion: Many more vent animals traverse the ridge between the Galápagos and Mexican vents than the shorter but more desolate sea route between the northeast Pacific and Mexico.

But modern ridge maps couldn't explain everything. The northeast Pacific and Mexican sites do harbor some similar organisms, despite the absence of a linking ridge.

Perhaps, Tunnicliffe and Fowler thought, there used to be one. So to search for ancient connections between now-distant hydrothermal vent sites, the scientists took advantage of two geological processes: magnetic field reversals and the orderly process of crust formation at oceanic spreading ridges.

In the ocean, a spreading ridge creates new crust, which slowly flows away to each side of the ridge as new magma pushes up in the middle. Any magnetic grains in this molten rock point in the direction of the planet's magnetic pole, just as compass needles do. When the molten rock cools, the magnetic orientation is permanently frozen into it.

Occasionally, Earth's magnetic field flips: One million years ago, compasses, had they existed, would have pointed toward Antarctica. Such reversals happen every hundred thousand or million years, and the flip-flops leave alternating magnetic signatures in the rocks that flow



Courtesy James J. Childress/University of California, Santa Barbara

Submarine mist. A cloud of scalding, mineral-rich water and gases streams from a vent on the Juan de Fuca Ridge near Vancouver, British Columbia.