

# SMOKERS, RED WORMS AND DEEP SEA PLUMBING

Sea floor oases of mineral-rich springs and amazing creatures fulfill oceanographers' dreams

BY SUSAN WEST

A scientist propounding a theory is dignified, even aloof. But the same scientist, with long-sought evidence at last in hand, becomes the poker player with a royal flush, the gold digger with yellow sparkling in the pan.

So, despite their 15-year-old predictions of the phenomenon, it is no wonder that scientists on board the submarine *Alvin* last April gaped out their porthole and said things like:

"It is like seeing a 19th century train going uphill, just pouring out smoke."

"It's like a municipal fire hose on full blast."

"Truly like Pittsburgh in the 30s."

Such images were apparently the only way to convey what they saw: Rows of 2- to 5-meter-high "chimneys" were spewing blackened, mineral-laden, hot (350° to 400° C) water onto the sea floor at the East Pacific Rise spreading center near the Gulf of California. Sulfides of copper, iron and zinc precipitated instantly when the heated mineral solution hit the surrounding 2° C seawater and fell in 20-meter mounds around the fountains.

Besides providing a spectacular underwater scene, the hot, metal-rich geysers are easily the most significant oceanographic find since the discovery of the Mid Atlantic Ridge. Their discovery marks the first time that the process of ore formation has ever been seen. The amounts and types of minerals they gush are already balancing long-inconsistent equations for ocean chemists. The strange animals surrounding them form the first geothermal-based community found on earth. They are one end of an extraordinary plumbing system beneath the ocean floor. And they are the fulfillment of predictions made more than a dozen years ago.

The existence of hot springs associated with the volcanic activity that forms new ocean crust at mid-ocean spreading centers was first suggested in 1965. Metal-enriched deep sea sediments, ocean volcanic rock that appeared to have been

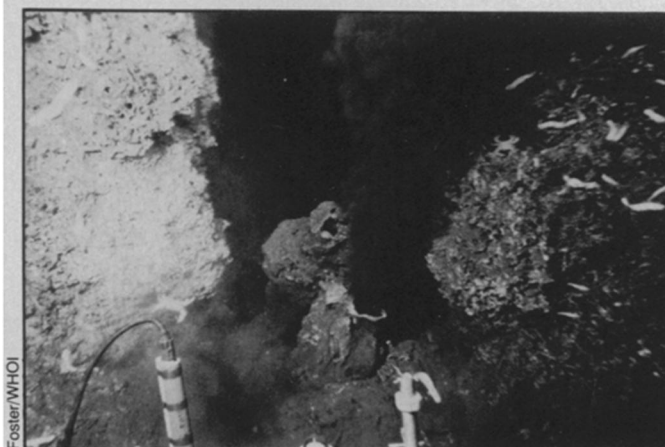
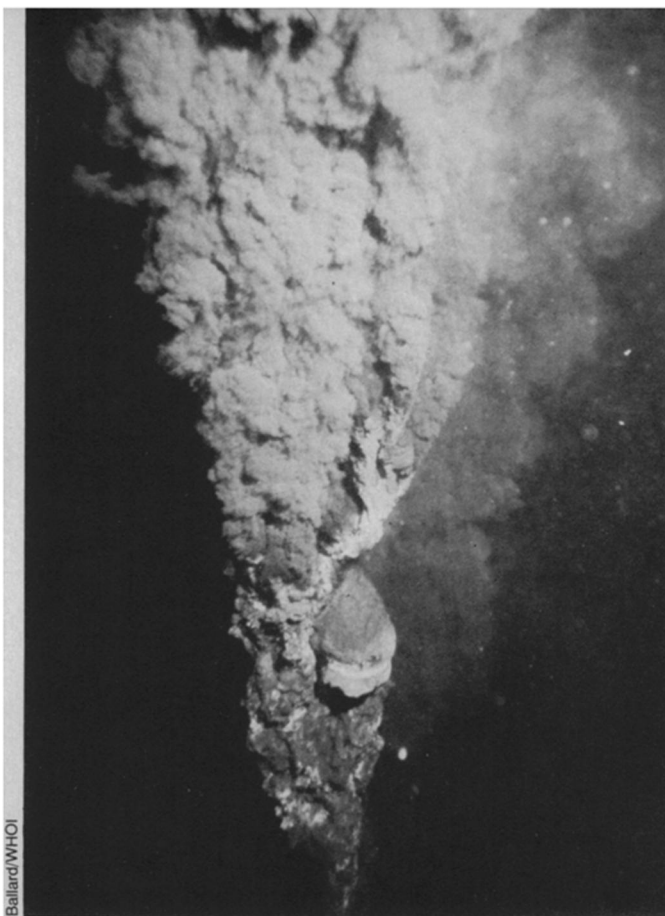
*Called "black smokers," these are examples of about two dozen hot vents found on the sea floor last May at 21° North on the East Pacific Rise. The "smoke" is mineral-laden 350° to 400° C water that has circulated through the ocean crust and picked up iron, copper and zinc. As the hot solution hits the cold seawater, it precipitates sulfide ores that coat the sides of the vents.*

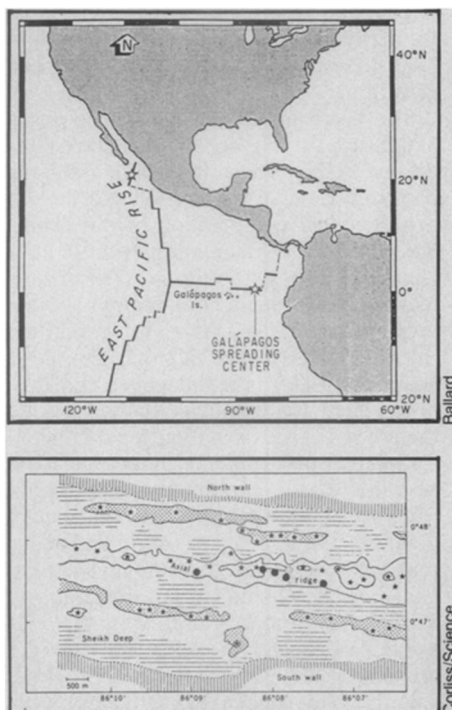
altered by hot seawater and hot brine found on the floor of the Red Sea supported the belief. In the late 1960s and early 1970s, measurements showed that the heat loss from mid-ocean ridges is uneven and, on the average, less than would be expected from a tectonic plate that is cooling by simple conduction of heat through rock. The difference, researchers postulated, could be made up by heat loss by convection of water through the newly formed ocean crust. Cracks and veins found in deep sea cores also suggested that young ocean crust was highly permeable to water. Researchers proposed that seawater enters these cracks, circulates through the young crust, picks up heat, leaches minerals from the hot volcanic rock, rises back to the surface and deposits the minerals on the sea floor. The minerals are then carried by the spreading sea floor and eventually added to the conti-

nents to form ore deposits.

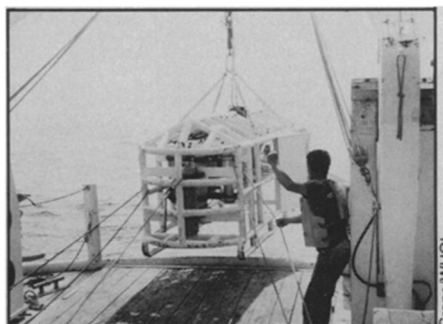
In 1972, a likely spot for such activity was pinpointed. Surveys of the ocean crust at the Galapagos Rift, a spreading center located at the equator off the coast of Ecuador, showed plumes of warm water, systematic fluctuations in heat flow and linear arrays of mounds along the spreading axis. These findings were interpreted as the results of hydrothermal circulation through the Galapagos Rift crust. Because the rift is also fairly shallow—it lies about 2.5 km below the surface—it was chosen for study by a submersible.

In February and March 1977, a team of geologists and chemists led by John B. Corliss of Oregon State University in Corvallis made 24 dives to the rift in Woods Hole Oceanographic Institution's 23-foot-long research submarine *Alvin*. Their path was guided by about 70,000 photographs taken by a camera sled called ANGUS





At left (top) stars mark location of active vents at 21°N and Galapagos Rift; (bottom) location of active vents — solid circles — along the volcanic axis of the Galapagos spreading center. Below, two-ton deep-towed camera ANGUS that first “found” the vents. Right (top to bottom) giant tube worms amidst limpet and crab-studded rocks at Galapagos; blind *Brachyuran* crab similar to shallow water species; 30-centimeter clam picked up by Alvin’s mechanical arm. With few exceptions, the same animals were found at both 21°N and at the Galapagos Rift.



(Acoustically Navigated Geophysical Underwater Survey System) that is towed along the ocean bottom. To their delight, the researchers found five warm water vents. The plumes shimmered with heat — a maximum of 20°C — and a milky white precipitate formed in the rising fluid (SN: 3/19/77, p. 182). Unexpectedly, they also found a dazzling assortment of animals — red-tipped tube worms, giant clams, mussels, crabs, seaworms, limpets and others — at depths that are usually sparsely populated (SN: 4/30/77, p. 279).

For the researchers, this was proof of the pudding; the vents could only be part of the postulated oceanic plumbing. But it was not so obvious to others, according to Massachusetts Institute of Technology's John M. Edmond. “[T]here are people who are so enamored of models that when you find the real animal it can’t be right because it doesn’t agree exactly with the models. It’s like elementary physics — for every real image there’s a virtual image.... We were talking about real hot springs. [They were] talking about virtual hot springs which you find only in experiments.” The Galapagos Rift does, in fact, lie over an anomalous hot spot; skeptics decided that was the cause of the hot springs.

So, despite the biological and geological success of the Galapagos dives, the search for the “real” hot springs continued in some minds. In January 1979, *Alvin* and *ANGUS* returned to the Galapagos Rift, this time with biologists and a film team from National Geographic Society. Fifteen more vents were found and animals — including a giant red tube worm — were retrieved for study (SN: 4/7/79, p. 231; 5/19/79, p. 327).

Leaving the Galapagos hot vents in March, *Alvin* traveled north about 2,000 miles to 21°N on the East Pacific Rise, a

spreading center near the mouth of the Gulf of California. There, the researchers hoped to make surveys of the seismic, magnetic and gravity characteristics of a “typical” spreading center. But in the words of Robert Ballard of WHOI: “If that’s typical, then — wow — there’s a lot to be learned.” First with *ANGUS*, then with *Alvin*, the researchers found about two dozen hot springs stretched along 6 km of the half-kilometer-wide spreading center. But next to these angry-looking, superheated geysers — called “smokers” — the Galapagos Rift vents looked like tepid sprinklers. Not only was the gushing water about 300° C hotter (the first attempt to measure the water temperature melted *Alvin*’s heat probe), but around the chimneys lay mounds of minerals including copper, iron, zinc and sulfur with lesser amounts of cobalt, lead, silver and cadmium. Like the Galapagos, however, the same animals, with the exception of the mussels, were clustered in fields near the vents. Obviously the areas are kith and kin, though somehow different in development. Moreover, as Edmond notes, the discovery of even more spectacular vents at an area thought typical makes the Galapagos findings quite believable.

Simply the existence of the vents settles some arguments but their geology, chemistry and biology also have significance. Geologically, the vents appear related to the volcanic cycle of the spreading center. Early in the 10,000-year cycle, lava pours out in impermeable sheets. Late in the cycle, lava forms loose pillow-like deposits that are more permeable. According to Edmond and others, if the circulating water is forced through impermeable sheet flows, it may emerge with more force and deposit most of the leached minerals on the surface. If, however, the water circu-

lates through a “leakier” pillow flow system, it may mix below surface with cooler water, drop most of its minerals there, and emerge cooled from its original temperature. A “leaky” system — like the Galapagos — may become a “tight” system — like 21°N — if the deposited minerals plug the leaks between pillow basalts. Ballard suggests that may occur at some time at the Galapagos, provided the volcanic cycle doesn’t shut down first. But little is known about the lifetime of an individual vent. Ballard and Ken MacDonald of the University of California at Santa Barbara suggest, based on the amount of heat given off, that a vent may last only a few years before its heat source gives out or the precipitating minerals clog the vent.

That the vents are intimately associated with the volcanic cycle is also evident in magnetic, seismic and gravity surveys done by MacDonald, Fred Spiess of Scripps Institution of Oceanography and others. These surveys across the spreading center at 21°N show that the vents occur directly over a low-density area, probably a magma chamber that lies very close to the surface. It is unclear if the water circulates deep enough to reach the chamber. But Spiess and MacDonald’s seismic refraction studies (which used *Alvin* as a “thumper”

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to produce the seismic signal) may show the extent of fracturing of the rock and help determine how deep the water can circulate.

The discovery of the vents also has a major impact on ocean chemistry. Traditionally, the river runoff from continents has been thought responsible for the entire chemical composition of the ocean. But some of the calculations were a little contrived, says MIT's Edmond. The oceans had too much manganese and not enough magnesium, for example, to match the river deposits. When Edmond examined water samples for the Galapagos and 21°N, however, he found they contained exactly the proper minerals in the proper concentrations to make up the difference. "The amounts that are coming out are exactly what you'd want to eliminate the special pleading and appeals to magic and so on that were going on before." In addition, based on the chemistry and the heat loss from the system, Edmond estimates that the entire ocean recycles through the crust approximately every 8 million years.

Perhaps the most unexpected discovery of Alvin's recent dives is the community of creatures associated with the vents. Two miles below the surface, the animals thrive where no light can reach. An analysis of the sulfurous vent water and the stomachs of some of the animals reveals the secret — sulfur-oxidizing bacteria. Apparently, say the researchers, this is the first community of animals not based on photosynthesis. And, though related species live elsewhere, "this is not the usual list of deep sea animals," says Robert Hessler of Scripps.

Several of the recovered specimens, such as the tube worms, the clams and the crabs, represent additions to their respective groups. Especially interesting are an apparently new family of polychaete worms called Pompeii worms because they live on the chimneys directly beneath the shower of precipitates. Several of the animals contain high amounts of hemoglobin, a possible adaptation, suggests one scientist, to the toxicity of the abundant hydrogen sulfide in the vents.

The researchers agree that the vents will probably only be found at "fast" spreading centers such as the East Pacific Rise, which spreads about 6 cm per year. A fast spreading rate seems to set up the necessary combination of energy and violent activity to stoke the "smokers." Farther south, near Easter Island, the ridge spreads at 18 cm per year. Anxious to see what effect a three-fold higher spreading rate will have, researchers from several U.S. institutions are proposing a five-year study of that area that may begin in 1981 or 1982. In the meantime, Ballard will accompany a French expedition that plans to explore the area next May using their submersible *Cyana* and the French equivalent of ANGUS. As one researcher said, "Just think what's happening at a really fast one. I can't wait." ☐