The Light at the Bottom of the Ocean

Oceanographers struggle to explain a strange glow from seafloor vents

By RICHARD MONASTERSKY

Thousands of meters below the ocean waves, an exotic source of light shines softly in the stygian depths. Though imperceptible to human eyes, this pale illumination has nonetheless served as a beacon, drawing biologists, physicists, and chemists down to the seafloor in search of an explanation for the enigmatic shimmer.

Discovered 8 years ago, the light issues from ridge-top vents that spew out volcanically heated brines laden with metals and caustic compounds. At first, scientists attributed the light to thermal radiation emitted by the 350°C water, much as hot electric elements on a stove give off an angry orange glow. But recent measurements conducted from the submersible *Alvin* reveal that thermal radiation alone cannot explain the light. What's more, the new data suggest that there might be enough light to power photosynthesis on the ocean floor—which would make it the first known case of photosynthesis divorced from the sun's rays.

"They've got some very funny light down there. There are some very odd and interesting things going on, and we do not understand them," says Euan G. Nisbet, a marine geologist at Royal Holloway College in Egham, England.

Cindy Lee Van Dover, a marine biologist at the University of Alaska, Fairbanks, first found evidence of the light in the late 1980s, while studying a seemingly blind species of shrimp, *Rimicaris exoculata*, discovered just a few years earlier. These shrimps swarm around hydrothermal vents on the volcanically active mid-Atlantic ridge, which forms part of an underwater mountain range encircling the planet like the seam on a baseball.

Oceanographers had named the shrimp *exoculata* because it appeared to lack eyes, but Van Dover and her colleagues discovered that the animal actually does have vision organs, just not in the usual place. Instead of eyes attached to its head, *R. exoculata* has evolved oversized light-sensing patches on the back of its shell (SN: 2/11/89, p. 90).

Suspecting that the shrimp uses these eyes to see light coming from the hydrothermal vents, Van Dover, Milton Smith, and John R. Delaney of the University of Washington in Seattle and their colleagues made a rough attempt to take digital pictures of the hot plumes. Although far from ideal, their camera recorded an extremely faint glow coming from the vents. The scientists surmised that the light came from the intense heat of the vent water.

Woods Hole Oceanographic Institution

Smoke in the water: Scorching brine shoots out of a sulfide chimney on the submerged mountain ridge known as the East Pacific Rise. The hydrothermal fluids are initially clear but turn black almost immediately as dissolved metals precipitate out of solution.

As news of the light spread, physicists and chemists started proposing more extraordinary explanations for the radiation. Their ideas propelled Van Dover to probe deeper into the question by collaborating with geophysicist Alan D. Chave of the Woods Hole (Mass.) Oceanographic Institution and astrophysicist J. Anthony Tyson of AT&T Bell Laboratories in Murray Hill, N.J. Although they could not secure any funding to study the light, the scientists jury-rigged a photometer that measures radiation at four different frequencies, ranging from visible red light into the invisible near-infrared. Piggybacking their experiment on unrelated *Alvin* dives, Van Dover managed to collect some data during free moments at the tail end of expeditions to hydrothermal vents in the Atlantic and Pacific Oceans.

The scientists found more light coming off the vents than they could attribute to thermal radiation alone. At one location, they recorded 19 times the expected amount of visible red light and shorter-wavelength infrared.

At another location, the photometer measured more light 10 centimeters above the vent, where the water is cooler, than at the blistering opening of the vent, report Van Dover, Chave, Tyson, and physicist George T. Reynolds of Princeton University in the Aug. 1 GEOPHYSICAL RESEARCH LETTERS.

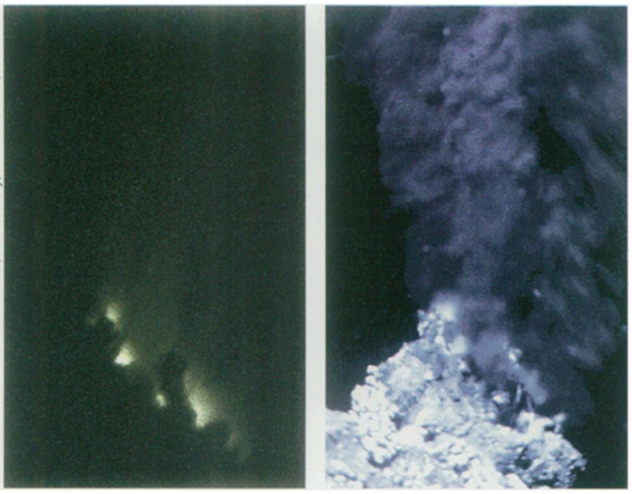
These observations suggest sources of light potentially more important than thermal radiation, contend Van Dover and her colleagues.

On that point, scientists can agree. "It's pretty clear there is something more going on there than just thermal radiation," comments Steven C. Chamberlain, a neuroscientist at Syracuse (N.Y.) University who has studied the shrimp eyes. "But just what is going on is not clear."

Van Dover and her colleagues focus in their report on four of the most likely sources of additional light. One is crystalloluminescence, or light emitted as the 2°C seawater quenches the 350°C brine, causing dissolved minerals to crystallize and drop out of the solution. Somewhat similar is chemiluminescence, in which energy is released by chemical reactions in the vent water.

A third mechanism, triboluminescence, could occur when mineral crystals crack from the cold or bang together in the turbulent erupting plume. Finally, sonoluminescence may produce light when microscopic bubbles in the hot fluid collapse.

Van Dover's team has now won funding that enables them to explore the vents with more sophisticated techniques. In April, on a submersible visit to the East Pacific Rise, they took along an improved photometer that records light at eight different wavelengths. Next year, they plan to use an extremely sensitive astronomical camera designed to capture simultaneously images of the light and information on spectra. Such measurements, they hope, will help them to discern the mechanism creating the light at the vents.



M. Smith, J. Delaney, C. Van Dover, D. Foster

First light: On the submersible Alvin, *a camera sensitive to low light provided proof of the weak glow emanating from hydrothermal vents. The left image shows the vent light as recorded by the camera. At right is a picture of the vent taken from the same spot with the aid of a strobe light.*

The solution to that mystery, however, will not satisfy Van Dover. As a biologist, she wonders what significance the light holds for life at the vents. "I want to know if there is enough light of the proper wavelengths for the organisms to use, either for vision, for photosynthesis, or for phototaxis [movement toward or away from light]. Is it a stimulus in the environment that the animals are taking advantage of?"

When Van Dover first discovered evidence of eyes on *R. exoculata*, she reasoned that the shrimps could use the light from vents to help orient themselves at a safe distance from the hot plumes. The animals need to get close enough to the vents to feed on chemosynthetic bacteria, which derive nourishment from the energy-rich sulfur compounds in the water, but they run the risk of getting cooked in the hydrothermal fluids if they get too near.

Chamberlain has found that the eyes of *R. exoculata* and some other shrimps from the vents have enlarged retinas. These structures are packed to the extreme with photosensitive pigments to capture as many photons as possible in the animals' light-starved environment. "Five of the six shrimp species we've looked at have adapted their eyes to use the light," says Chamberlain.

Despite the anatomical specializations of these shrimps, Chamberlain can't say for sure whether they actually sense the undersea light. A logical experiment would be to collect the shrimps and observe whether they react to extremely dim light. In fact, Chamberlain and his colleagues have tried that. But the spotlights from *Alvin* are so bright that Chamberlain suspects they destroyed the shrimps' sensitive retinas during the collection, making it impossible to test their eyesight. Thus far, he has not figured out a way to collect unmolested shrimps.

"I call it the *Alvin* uncertainty principle. We can't look at the shrimps without disturbing them," says Chamberlain.

Perhaps even more intriguing is the idea that deep-sea bacteria could use vent light for photosynthesis. According to Robert E. Blankenship of Arizona State University in Tempe, the light measured at the hydrothermal vents may be strong enough for this purpose. "The intensity of the light from the hydrothermal vents was within an order of magnitude of that known to support photosynthesis elsewhere," he says.

The most sensitive photosynthesizing organism known today is a green sulfur bacterium, which lives 80 meters below the surface of the Black Sea, a far cry from the 2,600-meter depths of the midocean ridges. Harvesting the pale blue rays of the sun that filter down from the surface, these Black Sea bacteria survive on a stream of light measuring only 10^{11} photons per square centimeter per second.

Van Dover's group estimates that the photon flux from the vents may reach a similar strength, but only in the infrared wavelength of 950 to 1,050 nanometers. Blankenship notes that some aquatic bacteria can harvest infrared energy, but biologists know of none that can live off infrared light so dim.

Van Dover

Rude intrusion: These deep-sea shrimps, swarming around a hydrothermal vent in the Atlantic, may be able to see the seafloor light, but scientists suspect that the submersible's lights have destroyed the animals' sensitive eyesight.

Van Dover, Blankenship, and others agree that deep-sea photosynthetic organisms—if they exist—probably subsist mostly on chemosynthesis and use the light only for supplemental nourishment. But the possibility of photosynthesis in the deep sea has led some scientists to speculate that this process—which ultimately feeds most life on Earth—may have evolved near hydrothermal vents.

Nisbet, Johnson R. Cann of the University of Leeds in England, and Van Dover raised this idea last year to address a long-standing conundrum in theories about the origin of photosynthesis. "The key evolutionary problem in photosynthesis is known as the problem of Darwin's eye—in other words, what use is half an eye?" asks Nisbet. Like vision, he continues, "photosynthesis is a very complicated process, and it's very difficult to imagine halfway stages. It either works or it doesn't work. But being halfway there doesn't much help an organism."

Nisbet and his colleagues suggested that an intermediate point to photosynthesis may have been the ability to detect light and move toward or away from it. Such phototaxis may have evolved near the deep-sea vents, where it would have helped early bacteria move toward the chemical nutrients they needed for survival.

If some of these bacteria later dispersed to hot-water vents in shallow water, this earlier adaptation would help them develop full-fledged photosynthesis using the sun's rays, suggests Nisbet.

Although extremely speculative, the photosynthesis theory fits in with other recent developments in evolutionary biology. Many molecular studies of RNA sequences in living organisms suggest that hyperthermophiles—microbes that thrive at excessive temperatures—are ancestral to all organisms alive today.

Some researchers take this as evidence that life first arose near the hydrothermal vents at the bottom of the ocean. Other scientists speculate that life evolved elsewhere initially, but the extreme heat of subsequent asteroid impacts snuffed it out everywhere except the seabed. Hyperthermophiles living near the vents would have survived to repopulate the planet.

Given that scientists only discovered deep-sea hydrothermal vents and thermophilic microbes in the last 20 years, an understanding of their significance is likely to evolve rapidly as researchers probe deeper into the extreme environments. Scientists may make new observations as surprising as the wan seafloor light now capturing their attention.

"To me, the light is an example of beautiful science," says Nisbet. "It's something that is unexpected. It is there, or we think it's there, at least, and it's a puzzle." □