

## Research on Hydrothermal Vents

We are familiar with "Old Faithful" in Yellowstone National Park. This famous geyser erupts several times a day. It spouts a column of water heated by volcanic rock deep within the Earth's crust.

A **hydrothermal vent** is a geyser on the seafloor. It continuously spews super-hot, mineral-rich water that helps support a diverse community of organisms. Although most of the deep sea is sparsely populated, vent sites teem with a fascinating array of life. **Tubeworms and huge clams** are the most distinctive inhabitants of **Pacific Ocean vent sites**, while **eyeless shrimp** are found only at vents in the Atlantic Ocean.

The first hydrothermal vent was **discovered in 1977**. They are known to exist in the Pacific and Atlantic oceans. Most are found at an average depth of about 2,100 meters (7,000 ft) in areas of seafloor spreading along the Mid-Ocean Ridge system- the underwater mountain chain that snakes its way around the globe.

**Shallow hydrothermal Vents:** D. Joaõ de Castro seamount has the seamount shoals to 13 m below sea level and has hydrothermal vents at a depth of 20 m. This is the first vent system to be described on a hyperslow spreading centre. Gas discharging from the vents is dominated by CO<sub>2</sub> (90%) with lesser H<sub>2</sub>S, H<sub>2</sub> and CH<sub>4</sub>. Two distinct vent areas were identified that had different physical and chemical characteristics. The white area had vent orifices with white bacterial mats, while the yellow area had yellowish coloured vent openings. Vents in the white area had lower temperatures (V43 8C), but higher concentrations of H<sub>2</sub>S, CH<sub>4</sub> and H<sub>2</sub>. *Beggiatoa sp.* was found in this area. The yellow area had vent temperatures up to 63 8C. No typical hydrothermal vent fauna was found at these vents. The macro species present were similar to those found in coastal and seamount areas of the Azorean Archipelago.

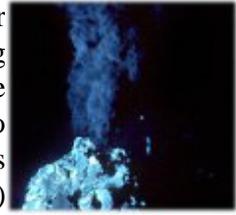
## How do hydrothermal vents form?

The earth's surface is broken up into several large and a few smaller plates. These plates include the crust and the top portion of the mantle. Together these two layers make up the lithosphere, therefore the plates are referred to as lithospheric plates. The plates can consist of ocean crust or continental crust, or more often, a combination of the two. Places where plates meet are called plate boundaries or plate margins. Convergent boundaries are places where plates come together. Divergent boundaries are places where plates pull apart.

In some areas along the Mid-Ocean Ridge, the gigantic plates that form the Earth's crust are moving apart, creating cracks and crevices in the ocean floor. Seawater seeps into these openings and is heated by the molten rock, or magma, that lies beneath the Earth's crust. As the water is heated, it rises and seeks a path back out into the ocean through an opening in the seafloor.

At the mid-ocean ridges, a 46,000 mile mountain system that circles the globe under the oceans (the longest mountain chain on the planet), the plates move apart during episodes of volcanic activity. Magma rises up from the mantle and adds new sea floor to the separating plates. Fractures develop as the plates are pulled apart. Cold sea water (2° C) seeps into the fractures and

is heated by the hot magma (1400° C) contained in shallow chambers under the sea floor. The superheated water is forced back up to the sea floor carrying dissolved minerals leached from the basalt ocean plate. A vent forms when the jet of water shoots through the sea floor and its dissolved minerals begin to precipitate out. Chimneys top some hydrothermal vents. These smokestacks are formed from dissolved metals that precipitate out (form into particles) when the super-hot vent water meets the surrounding deep ocean water, which is only a few degrees above freezing.



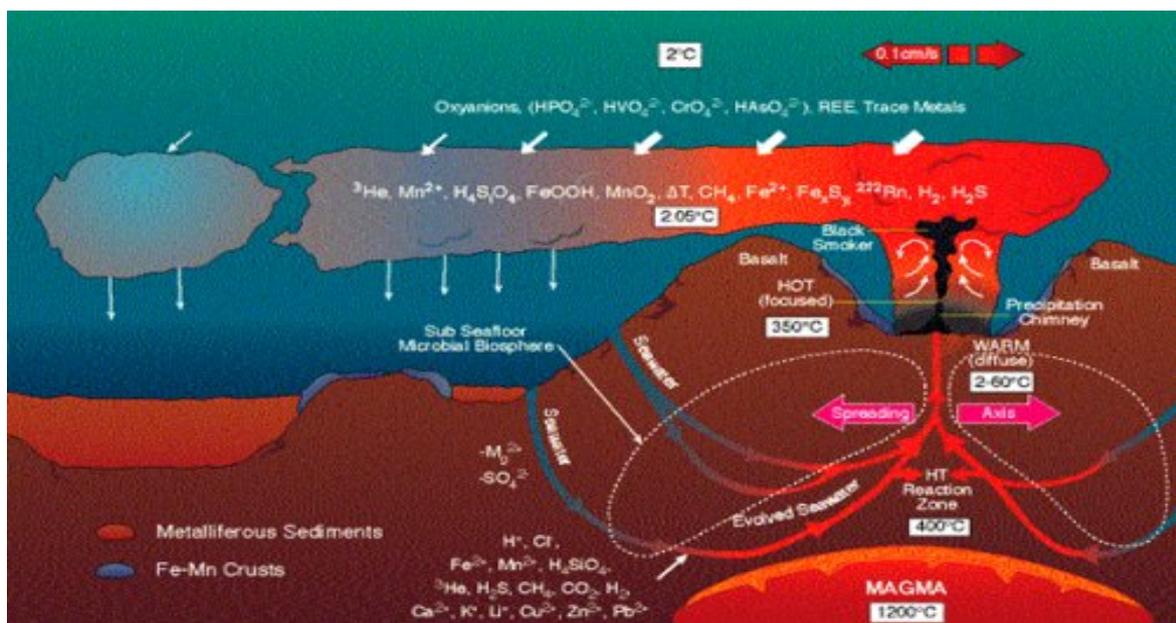
So-called "**black smokers**" are the hottest of the vents. They spew mostly iron and sulfide, which combine to form iron monosulfide. This compound gives the smoker its black color.

"**White smokers**" release water that is cooler than their cousins' and often contains compounds of barium, calcium, and silicon, which are white.

Geologists are intrigued by how rapidly vent chimneys grow - up to 9 meters (30 ft) in 18 months. A scientist at the University of Washington has been monitoring the growth of "Godzilla," a vent chimney in the Pacific Ocean off the coast of Oregon. It reached the height of a 15-story building before it toppled. It is now actively rebuilding.

There are many other reasons why scientists want to learn more about hydrothermal vents. These underwater geysers are believed to play an important role in the ocean's temperature, chemistry, and circulation patterns.

Scientists also are fascinated by the unusual life that inhabits vent sites. These creatures that live in darkness, from bacteria to tubeworms, may light the way to the development of new drugs, industrial processes, and other products useful to us all.



## **Illustration courtesy of NOAA's Vents program**

### **Physical conditions at vents**

1. tremendous pressure - 300 atmospheres
2. extreme temperatures - highest measured vent temperature is 403<sup>0</sup>C, highest temperature at which living tube worms have been observed is 100<sup>0</sup>C, sea water is about 2<sup>0</sup>C at depths where vents form, but can be up to 20<sup>0</sup>C near some vents.
3. chemicals - hydrogen sulfide, the source of energy that fuels vent food webs and the most plentiful compound in vent emissions, is toxic to most living things.
4. pH - vent fluid is very acidic with a pH as low as 2.8, which is very unhealthy for most living things.

### **Life on a hydrothermal vent**

#### **Primary producers: the base of the food web**

Most living things on earth depend on sunlight as the ultimate source of energy. Green plants use sunlight to make food by the process of photosynthesis. In the darkness of the ocean depths there is no sunlight for photosynthesis. So how do living things survive in such an environment? The answer is found in bacteria that can use another source of energy to make food.

Water coming out of a vent is rich not only in dissolved minerals but also in chemosynthetic bacteria. These bacteria are capable of utilizing sulfur compounds to produce organic material through the process of chemosynthesis. The bacteria are autotrophs that oxidize hydrogen sulfide in vent water to obtain energy, which is used to produce organic material (i.e. grow themselves).

Chemosynthetic bacteria are the primary producers and form the base of vent food webs. All vent animals ultimately depend on the bacteria for food.

#### **How does a vent community develop?**

When a vent forms, new lava on the ocean floor around the vent becomes covered with a thick mat of bacteria. Soon tiny animals such as amphipods and copepods come to feed on the bacteria. Gradually, larger animals, including grazers, scavengers and predators join in colonizing the vent.

Scientists studying a field of vents since their formation in 1991 have observed a pattern of colonization. The first organisms to populate the vents are bacteria, then other microorganisms, including amphipods and copepods appear. <http://www.botos.com/marine/tubeworms.jpg> These are followed by limpets (snails), shrimp, crabs, tube worms, fish, and octopi. Sometime later acorn worms, dandelion-like animals, and other species of shrimp and tube worms add to the expanding community. In their most advanced stages vents are home to mussels, a variety of worms, anemones, and a large population of crabs, as well as many of the earlier colonist

Some vent animals, like limpets, clams, and mussels feed directly on bacteria. Other animals, such as octopi, prey on those that eat bacteria. Vent crabs act as both predator and scavenger.

Some of the most successful vent animals, tube worms and giant clams, form symbiotic relationships with chemosynthetic bacteria. The bacteria live within the animals' tissues and provide a built-in food supply. Tube worms have no mouth, gut, or anus. Nutrients are absorbed directly into tissues. Two species of tube worms inhabit hydrothermal vents. [http://www.botos.com/marine/tube\\_worm\\_colony.jpg](http://www.botos.com/marine/tube_worm_colony.jpg) The smaller of the two, *Tevnia jerichonana*, which grow at a rate of 30 centimeters per year, are among the first animals to colonize and dominate the vent ecosystem. Giant tube worms are one of the most amazing animals that live in vent ecosystem. They grow up to 3 m long and 10 cm in diameter and more than 33 inches per year, making them the fastest growing marine invertebrate. They have a head, collar, trunk, and anchor, but no mouth, eyes or gut. Tubeworms contain a unique form of haemoglobin that transports both H<sub>2</sub>S (absorbed by the worm's plumes from vent fluid) and O<sub>2</sub> (absorbed from cold water) to endosymbiont bacteria. Billions of bacteria living inside the tubeworm produce sugars from CO<sub>2</sub>, H<sub>2</sub>S and O<sub>2</sub>. *Riftia pachyptila*, which grow much faster (85 centimeters per year) and reach over 2 meters in length, eventually replace *Tevnia* as the dominant species. Over 300 new species of animals have been discovered at vents. Many are found nowhere else on earth, and could not exist outside the conditions at vents.

#### **Scientific studies can be done:**

**New Fauna:** Vents usually have very extreme conditions and they always have new species and fauna that usually never described yet and all the organisms are new to world so they need very keen observation for that. We can also work how animals can survive in such extreme environment. There is plenty of research need to verify the organisms and their faunal diversity in vents system.

**Comparison between shallow water hydrothermal vents and nearby sea:** This kind of study can be very useful and we can find some very interesting results how the vent environment affects the ocean community.

**Comparison between shallow water hydrothermal vents and deep water hydrothermal vents:** This can be also one very useful study how these two vents systems vary from each other. Because there are several reasons for the variations like as their formation, their chemical composition, smog formation, species diversity and their environment. We can know about these phenomena very well when we will be able to study both kinds of systems and we can also do some long term study for the changes during these recent years and long term basis.

**Industrial and medical applications:** Vent organisms have wide industrial and medical applications. They may be useful to combat industrial pollution (H<sub>2</sub>S) and cleanup sites contaminated with Cu, Cd, and Hg etc. They may help in development and manufacture of new heat resistant industrial chemicals and new drugs to combat germs now resistant to plant and soil based drugs. Methanogenic (methane-producing) archaea could provide a renewable source of natural gas. Giant tube worms may help us understand and combat deadly human iron deficiencies. Extremozymes—enzymes produced by heat loving extremophiles like vent microbes have great potential in biotechnology. Proteins and enzymes of ultrathermophilic archaea in hot vent waters have unusually high thermal stabilities and hence, such enzymes are expected to have longer shelf life, produce less waste, and have lower risk of contamination.

They will also permit reactions to run hotter, faster and purer, and will be biodegradable. Extremozymes may thus help (i) make dry oil wells productive by thinning oil now too thick for extraction (ii) convert corn starch to sugar (iii) allow anaerobic bioremediation (iv) production of a biocomputer chip and (v) a host of other industrial processes by speeding up biological and chemical reactions.

Vent bacteria possess special proteins - eurythermal enzymes that function effectively in a wide range of temperatures. They find applications in pharmaceutical, textile, paper and detergent industries. They act as catalysts to break down fats, wood etc, as well as DNA and operate in organic solvents. The most commonly used DNA polymerase in PCR (Polymerase Chain Reaction – a technique used to amplify and clone DNA) is Taq DNA polymerase, isolated from *Thermus aquaticus*, a bacteria from hot springs of Yellow Stone National Park. But, for a few PCR applications, the lack of proof reading by Taq DNA polymerase is a problem. DNA polymerase isolated from *Thermococcus littoralis*, a microbe from deep-sea hydrothermal vents have proof reading activity. This DNA polymerase, marketed as 'Vent DNA polymerase' has now 30% market share in DNA polymerase sales. The discovery of life in deep sea hydrothermal vents revolutionized ideas about where and how life could exist. But it also raised questions that never entered our minds before: How can so much life thrive at the sunless sea floor? What special features do the organisms have to live at deep sea vents? What else might be living at the sea floor or below it, or in environments in other planets that once we thought were too extreme to support life?