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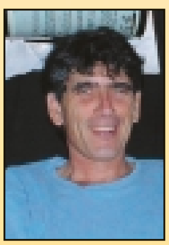
EXTREME 2000

Voyage to the Deep

Dive Mission

On January 12, a team of marine scientists at the University of Delaware will depart on their first deep-sea expedition of the millennium: "Extreme 2000."



Dr. Craig Cary

Led by chief scientist Dr. Craig Cary, the team will explore areas where underwater geysers called *hydrothermal vents* occur in the Sea of Cortés off the west coast of Mexico.

The scientists will study the unique organisms that inhabit the vent sites, take samples of the toxic chemicals released by the vents, and collect rocks and minerals for examination back home in the lab at the University of Delaware.

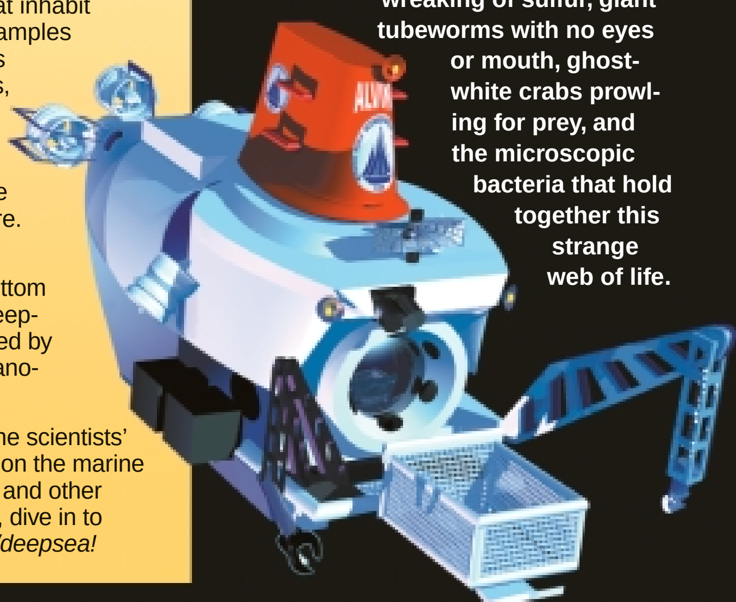
The scientists will travel to the ocean bottom aboard the famous deep-sea sub *Alvin,* operated by the Woods Hole Oceanographic Institution.

For a daily log of the scientists' activities, information on the marine life they are studying, and other Extreme 2000 details, dive in to *www.ocean.udel.edu/deepsea!*

What's Inside

The discovery of life in the deep sea was made only about a century ago. Previously, the ocean's depths were believed to be devoid of life. Today, scientists are particularly intrigued by a number of unusual marine organisms that inhabit some areas of the deep sea — at geysers called *hydrothermal vents*.

Here live foot-long clams wreaking of sulfur, giant tubeworms with no eyes or mouth, ghost-white crabs prowling for prey, and the microscopic bacteria that hold together this strange web of life.



Currently, scientists at the University of Delaware College of Marine Studies are conducting research at hydrothermal vent sites to learn more about this "extreme" environment and its bizarre community of organisms.

After all, vent dwellers thrive under some of the most demanding conditions on Earth. They live in a world of darkness where toxic chemicals abound, water temperatures exceed 113° C (235° F), and the atmospheric pressure exerted on them from the tremendous weight of the vast ocean above is more than 250 times the pressure we feel here on land.

Turn the page and learn more about this unique environment, the creatures that inhabit it, and the discoveries that scientists are making to benefit humankind. Let's dive in!

Geology of the Ocean Floor

To one who can't swim, the "deep sea" may be just a little above ankle level in the ocean. So what do scientists mean when they refer to the "deep sea"?

The ocean bottom is divided into three major areas: the continental shelf, the continental slope, and the deep ocean basin.

The continental shelf extends underwater from each of the major land masses. It is the submerged portion of the continents. The shelf has features similar to those we see on land, including hills, ridges, and canyons.

On the map below, the continental shelf is the light-blue area that edges the continents. The shelf varies in size. It may be virtually non-existent in some areas; elsewhere it may extend from shore for several hundred miles. The shelf's average distance is about 64 kilometers (40 mi).

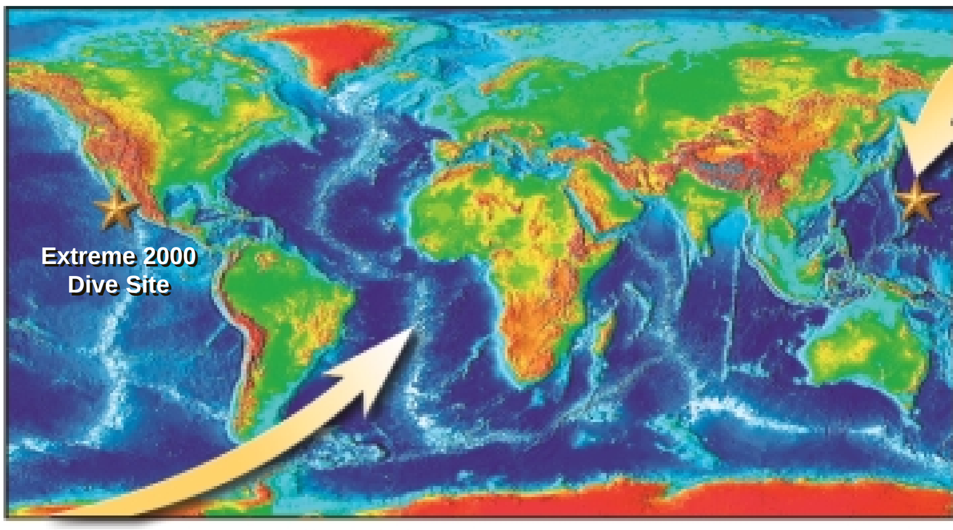
It is beyond the continental shelf that the "deep sea" begins. The shelf ends at a depth of about 200 meters (660 ft), giving way to the steeper continental slope, which descends about 3,700 meters (12,000 ft) to the deep ocean basin.

Here, the ocean floor deepens sharply and its features again resemble those on land, only on a much larger scale, with great plains and mountains.

In fact, the Earth's longest mountain range lies under the sea. Over 56,000 kilometers (35,000 mi) long, this mountain range, called the Mid-Ocean Ridge system, snakes its way around the globe.

The Mid-Ocean Ridge marks the areas where the Earth's crustal plates are moving apart. It is one of the most geologically active areas on Earth. It is where new seafloor is being born, giving rise to hydrothermal vents and volcanoes.

Adapted from NOAA



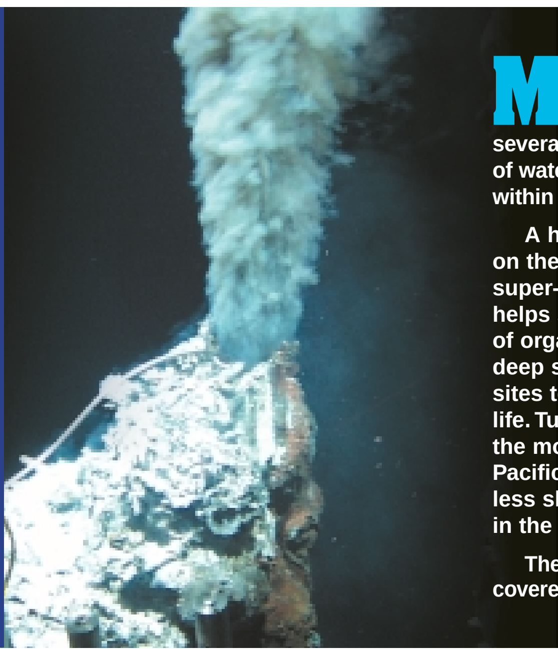
Did you know that the Earth's longest mountain range is underwater? The Mid-Ocean Ridge system, shown above snaking its way between the continents, is more than 56,000 kilometers (35,000 mi) long. This series of mountains and valleys marks the areas where the Earth's crustal plates are moving apart. This is where most hydrothermal vents are located. The University of Delaware's Extreme 2000 deep-sea dive site is in a vent field in the Sea of Cortés off the west coast of Mexico.

How Deep Is the Ocean?

The deepest known point on Earth is at the bottom of the Mariana Trench, a depression in the floor of the western Pacific Ocean, just east of the Mariana Islands. This trench is 1,554 miles long and 44 miles wide. Near its southwestern extremity, 210 miles southwest of Guam, lies the deepest point on Earth. This point — referred to as the Challenger Deep — plunges to a depth of nearly 7 miles. In 1960, the *Trieste,* a manned submersible owned by the U.S. Navy, descended to the bottom of the Mariana Trench. There, the pressure from the weight of the vast ocean above is tremendous. At more than 8 tons per square inch, it's the equivalent of one person trying to hold 50 jumbo jets!

? Students, can you convert the units above into metric units?

Hydrothermal Vents



Most of us 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 2100 meters (7,000 ft) in areas of sea-floor spreading along the Mid-Ocean Ridge system — the underwater mountain chain that snakes its way around the globe.

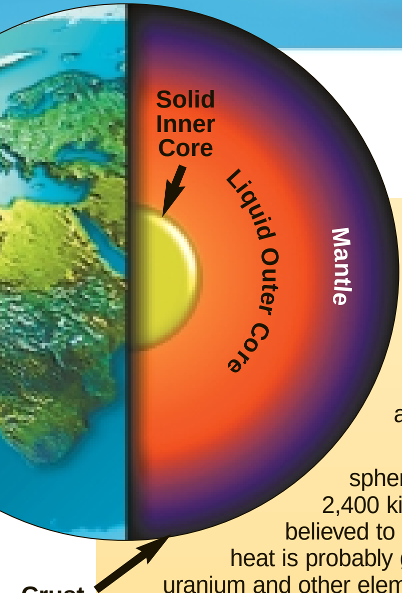
How do hydrothermal vents form? In some areas along the Mid-Ocean Ridge, the gigantic plates that form the Earth's crust are moving apart, creating cracks and crevices in the ocean floor. Seawater seeps into these openings and is heated by the molten rock, or *magma,* that lies beneath the Earth's crust.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

As the vent water bursts out into the ocean, its temperature may be as

Visit us at www.ocean.udel.edu/deepsea

Voyage to the Deep — EXTREME 2000

DOWN TO EARTH



Earth's Structure

Understanding how and where hydrothermal vents occur on the seafloor requires a closer look at the Earth's structure and the forces at work deep within the planet.

The Earth's inner core is a solid sphere composed mostly of iron. It is about 2,400 kilometers (1,500 mi) in diameter and is believed to be as hot as 6650° C (12000° F). This heat is probably generated by the radioactive decay of uranium and other elements. The inner core is bordered by a liquid outer core that is 4700° C (8500° F).

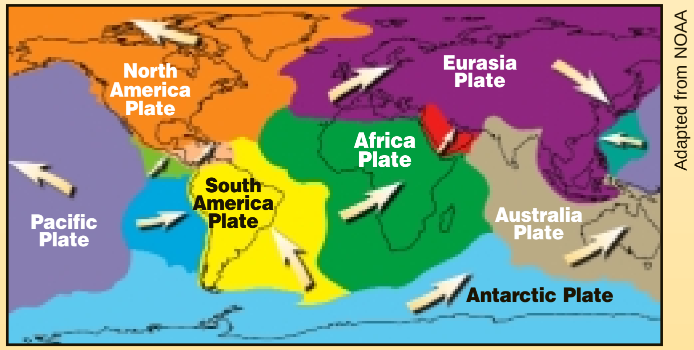
Surrounding the outer core is the mantle, which is composed of hot, molten rock called *magma.* The churning of the magma caused by the core's rising heat generates pressure on the Earth's surface layer, or crust. The crust is very thin compared to the other layers, ranging in thickness from only about 3.2 kilometers (2 mi) in some areas of the ocean floor to some 121 kilometers (75 mi) deep under mountains. If enough force is generated, the crust cracks, producing an earthquake.

Plate Tectonics

Simply defined, the term "plate tectonics" refers to how the Earth's surface is made up of plates. In geology, a *plate* is a large slab of rock, while *tectonics* is a word of Greek origin meaning "to build."

The theory of plate tectonics became widely accepted by scientists in the 1960s and 1970s. It revolutionized our understanding of the Earth and unified the Earth sciences, from the study of fossils (paleontology) to the study of earthquakes (seismology).

According to this theory, the Earth's crust is made up of about a dozen plates on which the continents and oceans rest. These plates are continually shifting because the surface beneath them — the hot, soft mantle — is moving slowly like a conveyor belt, driven by heat and other forces at work in



▲ *This map shows the major tectonic plates that make up the Earth's crust and the directions in which they are moving.*

the Earth's core. The plates currently move about a centimeter (0.5 in) to 15 centimeters (6 in) per year in different directions.

Vents, Volcanoes & Quakes

The Earth's tectonic plates can move apart, collide, or slide past each other. The Mid-Ocean Ridge system — the Earth's underwater mountain range — arises where the plates are moving apart. As the plates part, the seafloor cracks. Cold seawater seeps down into these cracks, becomes super-heated by magma, and then bursts back out into the ocean, forming hydrothermal vents. As the plates move farther apart, magma from the Earth's interior percolates up to fill the gap, sometimes leading to the eruption of undersea volcanoes. This process, called *seafloor spreading*, is how new seafloor is formed.

Conversely, when tectonic plates meet, the force causes mountains to rise and deep trenches to form. When the edge of one plate is forced under another — a process called *subduction* — it causes intense vibrations in the Earth's crust, producing an earthquake. One of the most violent earthquakes related to plate tectonics struck northeast China in 1976. The disastrous Tangshan quake, registering 7.8 on the Richter scale, killed more than 240,000 people.

high as 400° C (750° F). Yet this water does not boil because it is under so much pressure from the tremendous weight of the ocean above. When the pressure on a liquid is increased, its boiling point goes up.

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.

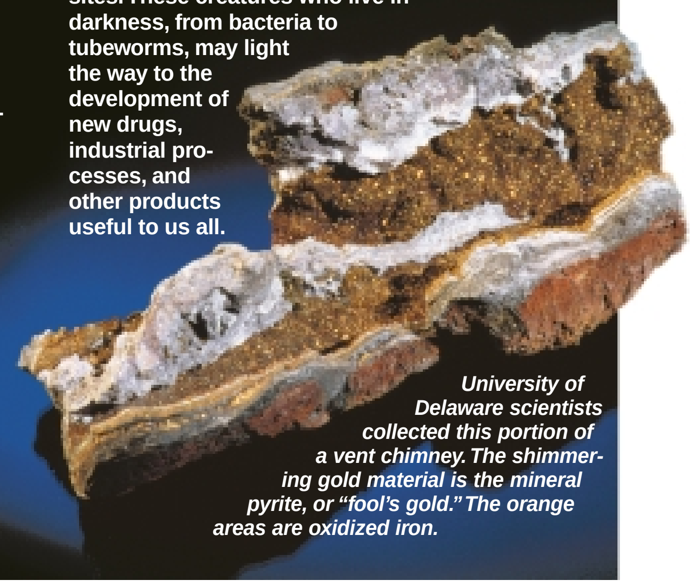
So-called "black smokers" are the hottest of the vents. They spew mostly iron and sulfide, which combine to form iron monosulfide. This compound gives the smoker its black color.

"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 who 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.



University of Delaware scientists collected this portion of a vent chimney. The shimmering gold material is the mineral pyrite, or "fool's gold." The orange areas are oxidized iron.

Biology of Deep-Sea Dwellers

They can withstand a broad range of temperatures — some close to the boiling point, eat toxic chemicals for breakfast, bear the weight of the ocean on their shoulders, and never see the light of day. Such is the life of the organisms that inhabit deep-sea hydrothermal vent sites!

These creatures, from microscopic bacteria to towering tubeworms, thrive under some of the most demanding conditions on the planet. And what further distinguishes them from other life on Earth is their energy source. They are the only complex ecosystem known to live on energy from chemicals rather than energy from the sun.

On land, our food chain is based on photosynthesis, the process by which green plants use the energy from the sun to make food. However, at deep-sea vent sites, where the sun's rays never reach, organisms make food from chemicals — a process called *chemosynthesis.*

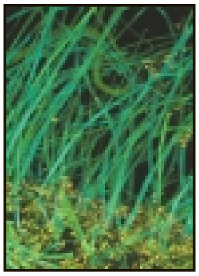
Tiny Bacteria Play Mighty Role

The hydrogen sulfide and other chemicals that rocket out of hydrothermal vents would be poisonous to most organisms. But tubeworms and other animals flourish here thanks to special adaptations and the relationship they have with the tiniest life at the vents: bacteria.

Bacteria hold the key to life at the vents because these microscopic organisms can convert the toxic chemicals released by the vents into food and energy.

So in order to survive, vent-dwelling animals, such as clams and tubeworms, must either consume bacteria or harbor bacteria in their bodies so that the microbes can make food for them.

For example, tubeworms have no mouth, eyes, or stomach ("gut"). Their survival depends on a symbiotic relationship with the billions of bacteria that live inside of them. These bacteria convert the chemicals that shoot out of the hydrothermal vents into food for the worm.



▲ *Magnified view of bacteria that inhabit vents.*

HOT STUFF

Deep-Sea Vents Harbor Earth's Hottest Animal

University of Delaware marine scientist Craig Cary recently discovered that an inhabitant of the deep sea is the most heat-tolerant animal on Earth. The Pompeii worm *(Alvinella pompejana)* can survive an environment as hot as 80° C (176° F) — nearly hot enough to boil water. How the worm survives this heat remains a mystery.

▲ *The Pompeii worm can live at temperatures up to 80° C (176° F). It is about 13 centimeters (5 in) long.*

Robert Cohen

Dr. Craig Cary

Formerly, the Sahara desert ant was believed to be the most heat-hardy creature, foraging briefly in the desert sun at temperatures up to 55° C (131° F).

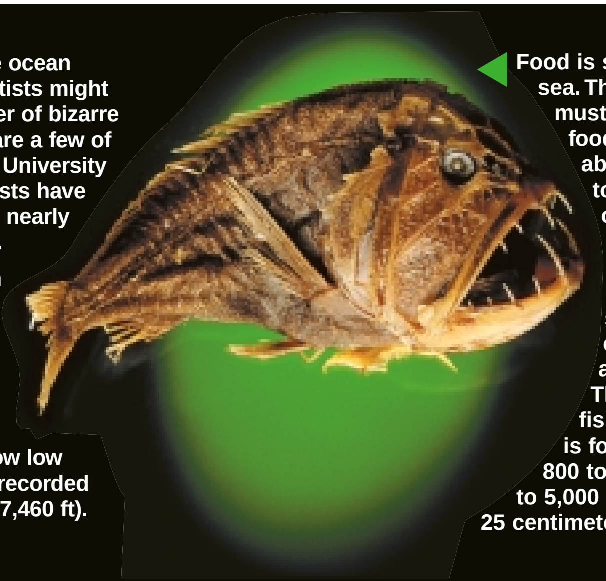
Cary's research was conducted onboard the submersible *Alvin* at hydrothermal vent sites in the Pacific Ocean west of Costa Rica. Using a long temperature probe called "the Mosquito," he found that the worm's rear end sits in water as hot as 80° C (176° F), while its head, which sticks out of the worm's tube home, rests in water that is much cooler, about 22° C (72° F).

Covering the Pompeii worm's back is a fleece of bacteria that can also "take the heat." These bacteria are of particular interest to industry because they may harbor enzymes that are useful in such high-temperature applications as processing food and drugs, making paper, and dislodging oil inside wells. By learning more about the unique biology of the Pompeii worm and other "extremophiles" — organisms that thrive in extreme temperature and pressure conditions — scientists may open the door to beneficial new products and processes.

Creature Feature

On their descent to the ocean bottom, marine scientists might encounter any number of bizarre organisms. These photos are a few of the deep-sea dwellers that University of Delaware marine scientists have seen en route to vent sites nearly 3.2 kilometers (2 mi) down.

While few deep-sea fish live at hydrothermal vent sites — with the exception of a white, snake-like species called the eelpout — fish have been recorded at great depths elsewhere in the ocean. How low can they go? The deepest recorded fish was at 8,370 meters (27,460 ft).



◀ Food is scarce in the deep sea. The fish that live there must rely on what little food floats down from above — often referred to as "marine snow" — or eat their neighbors! Deep-sea fish typically have big mouths, long sharp teeth, and stretchy stomachs to catch prey in the dark and swallow it whole. This ferocious-looking fish, called "fangtooth," is found at depths of 800 to 1,524 meters (2,600 to 5,000 ft). It grows to about 25 centimeters (10 in) long.

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Vents Sprout Weird Worms!

Resembling huge lipsticks, tubeworms (Riftia pachyptila) *live over a mile deep on the Pacific Ocean floor near hydrothermal vents. They may grow to about 3 meters (8 ft) long. Tubeworms have no mouth, eyes, or stomach. They get their energy from bacteria that live inside their bodies. These bacteria convert the chemicals that spew out of the vents into food for the worms. Sometimes tubeworms provide food for other deep-sea dwellers. Fish and crabs may nibble off the tubeworm's red plume.*

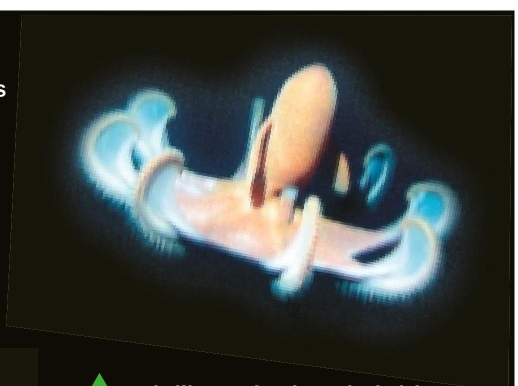
Since a tubeworm has no mouth, how do bacteria enter the worm? Scientists have found that, during its earliest stages, the tubeworm does have a mouth and gut for bacteria to enter. But as the worm grows, these features disappear!

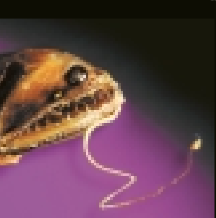
New Scientific Discoveries

Scientists are particularly interested in bacteria from hydrothermal vents because these microscopic organisms possess enzymes that can withstand high temperature and pressure, giving them many valuable uses in industry. For example, some bacteria can convert harmful chemicals to safer forms, making them ideal for cleaning up oil spills and hazardous waste.

Scientists are also curious about the deep sea's tiniest life because these organisms are among the oldest on Earth. In fact, Archaea (pronounced "ark-ee-uh"), an ancient life form, recently was found at vent sites. Previously, these microscopic organisms had been discovered in another "extreme environment" — hot springs in Yellowstone Park. Like bacteria, Archaea consist of cells without a nucleus, yet more than half of their genes are unlike anything else on Earth!

s no natural light below 1,000 meters eep-sea fish rely g organs to find prey. This slender arbel that glows ntists believe ng ability, called , is a common dwellers.



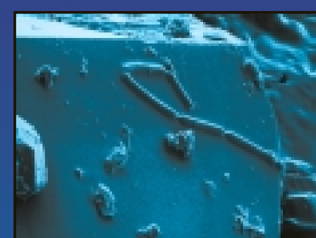


▲ Hair-like projections ("cirri") line the webbed arms of this deep-sea octopus. These projections may help it sense food in the darkness. This species is also equipped with paddle-like fins to help it swim.

Using Chemistry to Track Down the Oldest Life on Earth

Recent evidence suggests that life originated in extreme environments, for example, at high temperatures. The National Science Foundation (NSF) has initiated a program called Life in the Extreme Environment (LExEn) that is dedicated to finding new and exciting organisms that live in harsh environments.

The Extreme 2000 research expedition, at hydrothermal vent sites in the Sea of Cortés, is led by marine scientists George Luther and Craig Cary from the University of Delaware and Anna-Louise Reysenbach from Portland State University. Their chief objective is to make real-time chemical measurements at the vents using microsensors developed by Dr. Luther's group, which will guide the microbiologists and molecular biologists in Dr. Cary's and Dr. Reysenbach's groups in finding organisms that are descendants of early life forms.



Kirk Czymmek

Magnified view of microbes on the surface of pyrite. The bacteria are about 4 microns long.

Chemical Detective Work at the Bottom of the Sea

Are hydrothermal vents home to the closest relatives of the oldest life on Earth? Using special tools housed in a wand on the sub *Alvin,* researchers will be testing the chemistry of vent water in search of microscopic organisms. The wand houses a thermometer, an apparatus called "the Sipper" to collect small water samples, and a super-sensitive chemical analyzer.

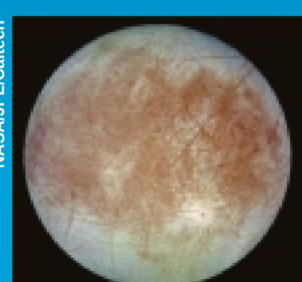
The analyzer is like a sophisticated underwater "snooper." It can be used near the vents and, from its chemical readings, tell scientists what kind of microbes might live there. While our food chain is based on energy from the sun, the sun's rays never reach the deep sea. There, organisms must rely on a different energy source: the chemicals that rocket out of the vents.

During a previous expedition, the Extreme 2000 scientific team found that the presence of two compounds — hydrogen sulfide (H_2S) and iron monosulfide (FeS) — may be an important indicator of the oldest microscopic vent life. These compounds react to form the mineral pyrite ("fool's gold") and hydrogen gas. The hydrogen provides the energy that these microbes need to grow.

With the analyzer's help, marine scientists may be able to track down the nearest descendants of the first life on Earth, and perhaps on other planets.

Europa, one of the moons of Jupiter, is deeply frozen. It's completely covered in ice. However, recent findings suggest that portions of the ice move, which is strong evidence that liquid water lies beneath the ice. The water may be maintained in its liquid state by hydrothermal vents. If hydrothermal vents exist on Europa, there's a possibility that ancient microbes could live there, too.

NASA/JPL/Caltech



Do hydrothermal vents, and microbes, lie beneath the ice-covered surface of Europa, one of Jupiter's moons?

Exploring the Deep

Carol Di Meo, a graduate student at the UD College of Marine Studies, looks out of *Alvin*'s porthole as the sub travels along the ocean floor.

Throughout history, scientists have relied on a number of specialized tools to measure, map, and view the ocean's depths. These are a few highlights.

One of the first instruments used to investigate the sea bottom was the *sounding weight.* Viking sailors took measurements of ocean depth and sampled seafloor sediments with this device, which consisted of a lead weight with a hollow bottom attached to a line. Once the weight reached the ocean bottom and collected a sample of the seabed, the line was hauled back onboard ship and measured in the distance between a sailor's outstretched arms — a 1.83-meter (6 ft) unit called a *fathom.* This term is still used today for nautical depth.

Cornelius van Drebel, a Dutch inventor, is usually credited with building the first submarine. His underwater vessel consisted of a wooden frame sheathed in leather. Oars extending out the sides propelled the craft through the water, at depths up to 4.6 meters (15 ft). The oar openings were sealed with tight-fitting leather flaps. Drebel tested the sub in the Thames River in England between 1620 and 1624. King James I is said to have taken a short ride in the craft.

From 1872 to 1876, a landmark ocean study was undertaken by British scientists aboard HMS *Challenger,* a sailing vessel that was redesigned into a laboratory ship. The *Challenger* expedition covered 127,653 kilometers (68,890 nautical miles) and is credited with providing the first real view of major seafloor features such as the deep ocean basins. The researchers used wire-line soundings to determine depths and collected hundreds of water, sediment, and biological samples from all the oceans except the Arctic. They discovered more than 4,700 new species of marine life, including deep-sea organisms.

Deep-sea exploration advanced dramatically in the 1900s with a series of inventions, ranging from *sonar* — a system for detecting the presence of objects underwater through the use of sound — to manned deep-diving submersibles such as *Alvin.*

Operated by the Woods Hole Oceanographic Institution, *Alvin* can carry a crew of three people to depths of 4,000 meters (13,124 ft). The sub is equipped with lights, cameras, computers, and highly maneuverable arms for collecting samples in the darkness of the ocean's depths.

However, the voyage to the ocean floor takes time in a submersible — it's a cold, four-hour roundtrip to hydrothermal vent sites 2.4 kilometers (1.5 mi) below the surface — and scientists are working to find ways to observe this extreme environment without being in it. With the expanded use of fiber optics, satellites, and remote-controlled robots, scientists someday may explore the deep sea from a computer screen in the lab rather than out of a porthole.

This wand extended from the deep-sea sub Alvin *houses a thermometer, electrodes for taking chemical measurements (see below), and an apparatus called the Sipper for collecting small water samples at hydrothermal vents.*

Robert Cohen

Dr. George Luther, a marine chemist at the University of Delaware, has developed needle-like sensors for use in deep-sea research. The sensors are encased in protective polymers. Once connected to computers and deployed in a protective wand from Alvin *(see above), the sensors can provide instantaneous readings of the different chemicals that spew out of the vents.*

Facts about Alvin

How did *Alvin* get its name?

***Alvin* is operated by the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts. The sub was christened in 1964. The Deep Submergence Group at Woods Hole named *Alvin*. It was both a contraction of their colleague Allyn Vine's name (he worked tirelessly to make the submersible a reality) and a reference to the popular cartoon chipmunk.**

How big is *Alvin*?

The sub (its official title is "deep submergence vehicle") is about 23 feet long and 12 feet high. The 6-foot-diameter sphere in which the scientists work is made of titanium.

What equipment does *Alvin* have?

Its tools include video cameras, an underwater telephone, a computer/data display/recording system, sonar, sediment corers, temperature probes, a magnetometer, and more. *Alvin* has long, clawed arms called manipulators that are used to collect scientific specimens and place them in the sub's plexiglass collecting basket. The manipulators can lift up to 250 pounds and reach up to 75 inches.

WHOI

The 274-foot research vessel* Atlantis *is the platform from which* Alvin *operates.* Atlantis *can carry up to 60 people, including crew, scientists, and technicians. The ship features hangars for* Alvin *and ROVs (remotely operated vehicles), portable labs, a machine shop, library, laundry, and inflatable rescue boats.

Alvin *Statistics*

Length: 23 feet, 4 inches
Height: 11 feet, 10 inches
Draft: 7 feet, 6 inches
Gross Weight: 37,400 pounds
Operating Depth: 13,124 feet
Cruising Speed: 1 knot
Maximum Speed: 2 knots
Range: 6 miles
Payload: 1,800 pounds
Dive Duration: 6 – 10 hours
Life Support: 216 man-hours
Complement: 3 people
Propulsion: Five hydraulic thrusters

Students, can you convert the units above into metric units?

Getting to the Bottom of It:

THE OCEAN

Because of the tremendous pressure, the depth to which a diver can descend without special equipment is severely limited. The deepest recorded dive by a skin diver is 127 meters (417 ft). The deepest recorded dive by a scuba diver is not much farther, at 145 meters (475 ft).

Revolutionary new diving suits, such as the "jimsuit," enable divers to reach depths up to about 600 meters (2,000 ft). Some suits feature thruster packs that can boost a diver to different locations underwater.

To explore even greater depths, deep-sea explorers must rely on specially constructed steel chambers to protect them. In 1934, American oceanographer William Beebe and engineer Otis Barton were lowered to about 1,000 meters (3,280 ft) in a round steel chamber called a *bathysphere,* which was attached to a ship on the surface by a long cable. During the dive, Beebe peered out of a porthole and reported his observations by telephone to a colleague, Miss Hollister, who was on the surface.

In 1948, Swiss physicist Auguste Piccard began testing a much deeper-diving vessel he invented called the *bathyscaphe.* (This word is derived from the Greek words *bathos* — "deep" and *scaphos* — "ship.") On an unpiloted dive in the Cape Verde Islands, his invention, named *FNRS 2,* successfully withstood the pressure on it at 1,402 meters (4,600 ft), but its float was severely damaged by heavy waves after the dive.

In the 1950s, Jacques Piccard joined his father in building new and improved bathyscaphes including *Trieste,* which dived to 3,139 meters (10,300 ft) in field trials. The U.S. Navy acquired *Trieste* in 1958 and equipped it with a new cabin to enable it to reach deep ocean trenches. In 1960, Jacques Piccard and Navy Lieutenant Donald Walsh descended in *Trieste* to the deepest known point on Earth — the Challenger Deep in the Mariana Trench. The two men made the deepest dive in history: 10,915 meters (35,810 ft).

Today, scientists are making exciting discoveries about the ocean floor, thanks to deep-sea submersibles such as *Alvin.* Operated by the Woods Hole Oceanographic Institution in Massachusetts, this three-person submarine made its first dive in 1964. Since then, *Alvin* has made more than 3,000 dives to average depths of 1,829 meters (6,000 ft).

Alvin has conducted a wide variety of research missions, from discovering giant tubeworms on the Pacific Ocean floor near the Galápagos Islands, to locating the wreck of HMS *Titanic* in the Atlantic Ocean.

Alvin has met some amazing life on its travels, but so far it has not encountered one of the deep sea's most mysterious inhabitants — the elusive giant squid. However, *Alvin* once was attacked by a swordfish, which became trapped between two pieces of the sub's fiberglass skin. The fish was brought back to the surface and cooked for dinner!

▲ *Deep-sea research requires the skills and knowledge of scientists from many different disciplines, from marine biology to chemistry and engineering. On a recent deep-sea expedition in the Pacific Ocean, University of Delaware scientists teamed up with researchers from eight other universities. The team is shown in front of the submersible* Alvin, *which is resting in its hangar aboard the research ship* Atlantis.

FAQs Frequently Asked Questions

Liz McCliment, a graduate student at the UD College of Marine Studies, answers your questions about working in the deep-sea sub Alvin. ▶

Q. What's it feel like when you're descending in *Alvin*?

A. You actually sense very little motion inside the sub, except when you're bobbing on the surface. Mostly, you can tell you're descending by the color of the water outside your porthole. It gets dark pretty quickly!

Q. How long does it take to get to the ocean bottom?

A. About one to two hours, depending on how deep you're going. You usually work for five hours or so on the bottom before ascending.

Q. Do you have to wear anything special in the sub?

A. It gets very cold in the sub. The temperature of the water is just above freezing, so you have to bring a few layers of wool or cotton clothing, including extra pairs of socks. You cannot wear shoes, jewelry, or any synthetic material (like nylon or Lycra) in the sub. Shoes would just get in the way. Jewelry might scratch *Alvin*'s window. Synthetic clothes are not permitted for fire safety reasons.

Q. How much room do you have in the sub?

A. It's very cramped. There's enough room for two scientists to sit with their legs alongside each other, and the pilot to crouch on a tiny padded bench. If you want to stretch out, it is possible for one (short) person to stand up with their head in the hatch. You also spend a lot of time laying on your side or stomach, looking out your porthole.

Q. What do you eat in the sub?

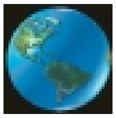
A. There's a traditional lunch served to the scientists and crew on a dive: one peanut butter and jelly sandwich, one mystery meat sandwich, a candy bar, and a piece of fruit. Since you're generally very busy and lose track of time while you're working, you tend to eat when you're in transit between sites!

Visit us at www.ocean.udel.edu/deepsea

DELVE DEEPER!

This eight-page resource guide is designed to serve as a brief introduction to the deep sea and hydrothermal vents. Additional information can be found on our Web site: *www.ocean.udel.edu/deepsea.*

The following list of suggested classroom activities and resources may help expand your deep-sea learning experience. Use it as a starting point to your own voyage of discovery!



Geology

Word Definition

Here are some terms to define:

bathymetry	ocean trench
boiling point	precipitate
continental drift	Ring of Fire
fracture zone	seismograph
ocean mapping	volcanism

Math Activities

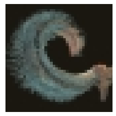
Let's test your knowledge of the metric system. Convert the British units of measure in the "How Deep Is the Ocean?" article in the Geology section to metric units.

One other article in this guide features British units. Find it, and convert the units to metric.

Extra-Credit Essay Topics

Why are hydrothermal vents important?

How does Old Faithful geyser work? Compare it to a hydrothermal vent.



Biology

Word Definition

Here are some terms to define:

bioluminescence	microbe
chemosynthesis	Pompeii
eelpout	photosynthesis
hydrostatic	sulfur
larval crab	symbiosis

Go Fishing!

Many deep-sea fish look monstrous! Your mission is to find pictures and descriptions of at least five different deep-sea fish. Why do you think so few of them live at hydrothermal vent sites?

Extra-Credit Essay Topics

Compare and contrast photosynthesis and chemosynthesis.

Oceanographer William Beebe wrote the book *Half Mile Down* about his descent to the seafloor in 1938. Read a chapter and report on his observations.

Exploring the Deep

Word Definition

Here are some terms to define:

bathyscaphe	magnetometer
bathysphere	ROV
jimsuit	scuba
electrode	sediment core
fiber optics	sonar

Design a Diving Vessel

If you could design a deep-sea diving vessel, what would it look like? Sketch it!

Extra-Credit Essay Topics

Jason is used in deep-sea research. Do some research and tell us all about it.

What other scientific tools are revolutionizing our study of the ocean?

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For more information about the University of Delaware's "Extreme 2000" deep-sea research expedition, dive into *www.ocean.udel.edu/deepsea.*

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For information about other publications available from the University of Delaware Graduate College of Marine Studies and the Sea Grant College Program, visit our on-line catalog at *www.ocean.udel.edu/seagrant*. Or contact University of Delaware, Marine Communications Office, Newark, DE 19716-3530. Phone: (302) 831-8083. E-mail: MarineCom@udel.edu.

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Resources

Many excellent resources were used to develop this guide and may help you in your search for more information.

Web Sites

The Bridge — Ocean Sciences Education Teacher Resource Center
www.vims.edu/bridge

Encyclopaedia Brittanica
search.eb.com

Jones and Bartlett Publishers — *Invitation to Oceanography* by Paul Pinet
www.jbpub.com/oceanlink2e

Neptune's Web
www.cnmoc.navy.mil/educate/neptune/student.htm

Nova Online — "Into the Abyss"
www.pbs.org/wgbh/nova/abyss

ThinkQuest — "Ocean AdVENTure!"
library.advanced.org/18828/index.html

University of Delaware Graduate College of Marine Studies
www.ocean.udel.edu

U.S. Geological Survey — *This Dynamic Earth: An Introduction to Plate Tectonics* by W. Jacquelyne Kious and Robert Tilling
pubs.usgs.gov/publications/text/dynamic.html

Woods Hole Oceanographic Institution
www.marine.whoi.edu

Books & Magazines

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