OCEAN explorer

For the Young Associates of Woods Hole Oceanographic Institution

Vol. I, No. 3 March, [illegible]

12,000 feet below the surface, *Alvin* carries scientists to explore volcanoes at a mid-ocean ridge. The ridge is part of a towering, underwater chain of mountains formed in part by lava oozing out of cracks on the sea floor.

UNDERWATER VOLCANOES

Bubbling up from inside the earth is a thick porridge of hot, liquid rock and gases called magma. If the magma rises to a thin, weak or cracked spot in the earth's crust, it can break through. The gases escape and the hot, liquid rock pours out as lava. A new volcano is born.

Magma passes through the earth's crust in different ways at different places. When a land volcano erupts, the fury of its explosion can cause such destruction that the world is stunned. At the bottom of the ocean, beneath the immense weight and pressure of miles of water, lava oozes out of deep cracks like toothpaste being squeezed out of a giant tube. There it cools and hardens, resulting in the creation of new sea floor.

To study underwater volcanoes and lava, oceanographers may travel in a submersible vehicle like Woods Hole Oceanographic Institution's *Alvin*, shown above, to the dark, near-freezing water of the deep ocean. There, they take pictures and use the sub's robot arms to collect samples.

In this issue, *Ocean Explorer* talks to scientists who study volcanoes on land and in the sea. You will also find out how volcanoes are part of the moving plates that have shaped and reshaped our planet for hundreds of millions of years.

ILLUSTRATION BY PATRICIA WYNNE

A Core Matter: THESE TWO SCIENTISTS ARE INTO VOLCANOES

SCOTT ROWLAND, UNIVERSITY OF HAWAII

Lava fountain, Puu O'o, Hawaii

BILL BRYAN

Bill Bryan is a deep-sea volcanologist at Woods Hole Oceanographic Institution (W.H.O.I.). Although he has studied volcanoes intently for more than thirty years, he admits frankly, "We still don't know how they work. How volcanoes turn themselves on and off is not well understood."

Until fairly recently, scientists thought there weren't many differences between one volcano and another. "Now we know that there is a whole spectrum of volcanic activity," says Bill. For instance, "each volcanic island has its own personality. Some are remarkably constant—very predictable. Others are totally unpredictable."

No one has ever seen a deep-sea volcano erupt. "We've been close, but we haven't actually seen that red stuff (lava) coming out," Bill says. "We think eruptions of deep-sea volcanoes are very benign. We don't think there are violent explosions. One reason is that the pressure of the water on top of the volcano would reduce the chance of explosions."

Bill has seen many volcanoes erupt on land. "It's a wonderful show," says Bill. "It's good, or better than any Fourth of July fireworks display." But the actual eruption of any volcano is not as important to Bill's work as you might suppose. "From the scientific point of view, we learn more after it's all over, when things have cooled and we can go and pick up the rocks."

Back in the lab, Bill studies the rocks he's gathered from underwater and above-ground volcanoes. He analyzes them to try to understand what made them.

Bill's studies of volcanoes have carried him all over the world. He has dived many times in Alvin. He has often visited the mid-ocean ridge in the Atlantic, and a ridge in the Pacific called the East Pacific Rise. Soon, he will travel to Hawaii to study the Kilauea volcano. "Part of this volcano looks a lot like a place we've been working on at the mid-ocean ridge in the Atlantic and parts of one lava flow there look like things we've seen on the Pacific seafloor."

Bill is interested in volcanoes on other planets, as well. He's excited by satellite photos he has seen of a volcano on Mars that is 70,000 feet high. "It's a spectacular thing," he says.

Studying active volcanoes on land and beneath the sea has brought Bill plenty of close calls. He was on Mount St. Helens just a couple of days before it erupted in 1980.

EMORY KRISTOF © NATIONAL GEOGRAPHIC SOCIETY

Bill Bryan (left), Bob Ballard (rear) and Jim Moore (right) study deep sea basalt on the deck of Lulu.

He had another close call in Hawaii. "I was standing on an active volcano," Bill recalls. "It was spectacular! Lava splashed all over the place. The following day, the volcano's crater completely collapsed in on itself. It wasn't as if I was doing something stupid. I was standing on a good, safe place, where lots of scientists had made their observations. We all live dangerously. Volcanoes are fascinating or terrifying, depending on your point of view."

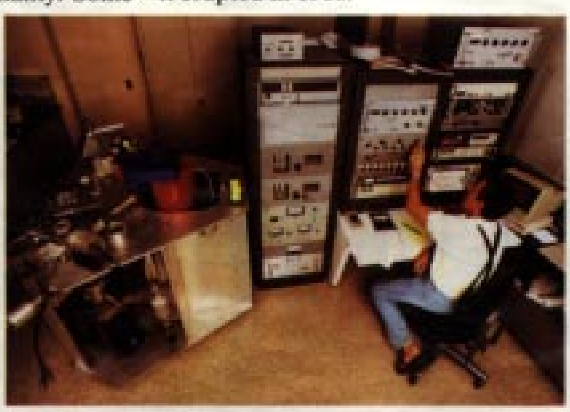
Getting to deep-sea volcanoes carries its own special risks. "People ask me if it's dangerous to dive in *Alvin,*" says Bill. "But most of us who dive in the deep sea agree that it's not any more dangerous than driving to Boston on the Southeast Expressway.

For a description of another of Bill's *very* close calls, see page 3.

STAN HART

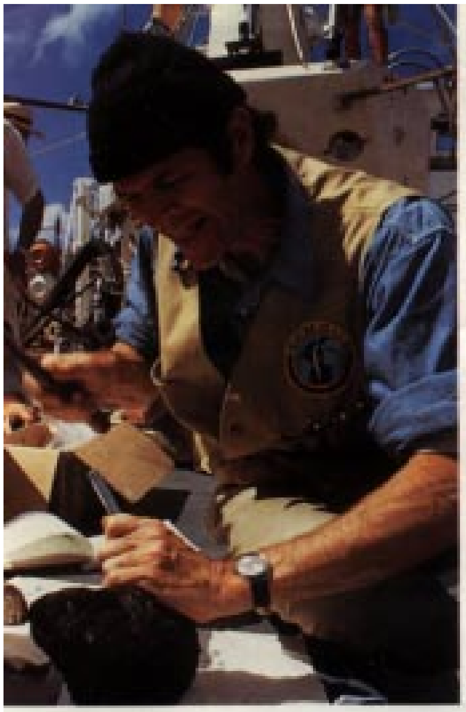
Like Bill Bryan, W.H.O.I. geologist Stan Hart wants to understand how volcanoes work, particularly, how magma arrives at the surface, and from how deep beneath the suface.

Beneath the earth's crust lies mantle, layers of rock (see page 5). For some reason not yet completely understood, at some places this mantle moves up to the crust in columns



TOM KLEINDINST

Stan Hart at the controls of a mass spectrometer.



called plumes. These plumes of solid mantle melt when they get within about 50 miles of the earth's surface. "I want to know how deep in the mantle these plumes originate," says Stan.

To try to find out, Stan studies the chemical composition of magma from volcanoes around the world. He hopes eventually to organize magma by its source, a little bit like the way biologists organize plants and animals into species. Stan compares his work to that of biologists who study DNA, the genetic code of plants and animals. "We're trying to figure out the genetic code of the planet," he says.

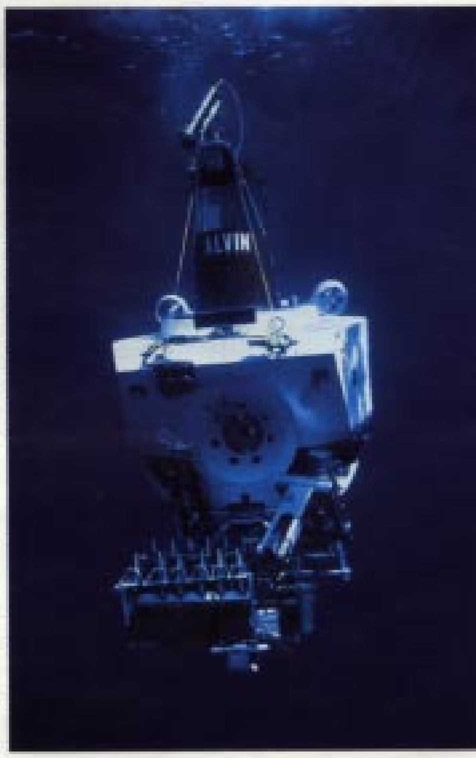
How does Stan study the geochemistry of magma? He takes a rock that comes from a particular volcano, and grinds it until it looks like "dusty talcum powder." The powder is dissolved in acids. "We're looking for lead in this powder," says Stan. "For every gram of rock we dissolve, we find one millionth of a gram of lead. That fragment of lead may contain as many as three trillion atoms."

This sub-microscopic fragment of lead is put on a filament. Electrical current is passed through the filament, which ionizes the lead (charges it electrically). This charged lead is put through a mass spectrometer, a device that does an extremely detailed analysis of the lead fragment, examining it atom by atom.

"When we understand the composition of the speck of lead," says Stan, "we can begin to create a fingerprint of the particular magma from which the speck of lead rose."

THE DAY *ALVIN* GOT STUCK

Geologists Bill Bryan and Jim Moore of the United States Geological Survey were diving in Alvin *on the Mid-Atlantic Ridge in 1974, with Jack Donnelley as their pilot. The geologists were studying lava formations. They wanted to find a spot on the seafloor where the water temperature was a little warmer than usual. They thought they might find this warmer water in a fissure, a long, deep crack in the sea floor. So, they went looking for one. This excerpt from* Water Baby *by Victoria A. Kahurl, shows how the scientists' curiosity nearly cost them their lives.*



ROD CATANACH

In spite of many safety precautions diving in *Alvin* carries risks.

"Look at that!"

"Oh...this is one we can go down into, it's so big."

"Let's do that."

"The time is 1409 [2:09 pm] and we are in the fissure. The width of the fissure..."

"Oh, my lord, the *size!* Look at that thing!"

"We've sunk down, oh maybe six feet into this fissure..."

"Depth is 2552 meters [8373 feet]. We seem to be touching both walls. The width is, ah, about twelve feet. The width of *Alvin*. Well...that's funny."

"*Alvin*, this is *Lulu*," an impatient [Robert] Ballard said from the surface. [Ballard, the W.H.O.I. geologist, was monitoring *Alvin's* dive from the deck of the mother ship, *Lulu*.] "Are you still at station four? Better get under way. Mission time is running out."

"We're trying," Jack Donnelly replied. "We don't seem to be able to rise."

Bryan later recalled: "When we crossed large fissures, we thought, gee, maybe we could actually get down inside one of these things. We circled this fissure that looked like it had plenty of room, more than enough room for us. So we swung around and settled down into it, as far as we could at the widest end.

"We sat there for a few minutes to see if the thermal sensor picked up a temperature [rise]. It didn't. So we sampled some rocks and then decided to move on up the fissure to see if there was anything there. Jack tried to lift the sub. It wouldn't go anywhere.

"It was a really spooky feeling. We would go up maybe half a meter and feel the sub bump against something. Jack tried everything, up, forward, back, and we hit something each time, not knowing what it was. It was as if somebody put a big lid over us."

When *Alvin* circled the fissure before descending, Bryan and Moore had taken detailed notes; their recorded observations saved their lives. The fissure widened to the north..... They deduced that the current ran from north to south. As *Alvin* descended into the crevasse, the current must have pushed it toward the narrow end and to the side because the submarine's nose pointed northwest. Donnelly reproduced each movement in reverse, taking more than two hours to inch *Alvin* up out of the crack.

"We're clear and under way again and proceeding to our next station," Donnelly said into the underwater telephone.

Those at the surface, especially *Alvin's* other pilots, who had struggled to keep up a constant stream of calm words to those in the trapped submarine, could hardly believe the three men wanted to continue the dive.

From Water Baby, *by Victoria A. Kahurl, Oxford University Press, 1990.*

Infernos: *VOLCANOES AND THE THEORY*

For thousands of years, people have been awed by the power of erupting volcanoes. No one has ever been able to predict when a volcano will erupt, but because of the theory of plate tectonics, scientists today can explain why there are land and sea volcanoes.

This theory states that the earth's outer crust is broken into about 20 separate pieces, called tectonic plates (from the ancient Greek word *tekton*, which means builder). The thick, rigid tectonic plates fit together like pieces in a huge puzzle. According to the theory, about 200 million years ago, these plates were all connected to form one gigantic land mass surrounded by one ocean. Since that time they have been moving to form the separate continents and oceans we know today. The fastest-moving plates creep along at a speed of up to two inches a year, about as fast as one of your fingernails grows.

The action of moving plates has created many spectacular features on the earth. The Himalayas were built when two tectonic plates gradually smashed into one another over millions of years. Where two plates grind against one another, earthquakes may be common, such as along the San Andreas Fault which runs near the west coast of California. Most volcanic activity takes place at or near the edges of tectonic plates.

Because most of the earth is covered by ocean, most of the plates are covered by ocean. So most volcanic activity on earth takes place on the ocean floor, where lava rises from deep cracks between plates. Where plate edges spread apart, mountain chains called mid-ocean ridges form. Where plate edges move together, islands, mountains, and land volcanoes form.

MID-OCEAN RIDGES

Mid-ocean ridges are built in part by lava that oozes out of cracks in the sea floor where two plate edges are spreading apart. These cracks may be thousands of miles long, circling the globe like the stitches on a baseball. The oozing lava creates new sea floor, and can also build underwater mountains as tall as 6,333 m [19,000 ft] — as high as some of the tallest mountains found on the continents.

Plates 2 and 3 in the picture below are spreading — moving apart very, very slowly. In the crack between the plates, magma is oozing out as hot lava. On both sides of the crack you can see the ridge-like mountains the lava helped to build.

As plates 2 and 3 move apart, the ridges are moving apart, too, as though they were on giant conveyor belts. When the ridges move away from the lava that rises from the crack, they stop growing higher. New ridges begin to form beside the crack as lava continues to ooze out.

Just about all the ridges lie hidden under miles of water. An exception is the top of a ridge that rose out of the sea and became Iceland, a country that is filled with volcanic activity.

OF PLATE TECTONICS

ISLAND VOLCANOES

The Aleutian Islands off Alaska and the islands of Japan and the Phillipines are also volcanoes. But these volcanoes were formed near plate edges that were colliding, not spreading apart.

In the picture below, notice plate 1 and plate 2. They are moving towards one another. At the edge of each plate there is ocean. When they meet, the edge of plate 2 bends and moves down under the edge of plate 1. A trench is formed that may be as deep as 12,666m [38,000 ft] such as the Marianas Trench in the Pacific.In the trench, the moving edge of plate 2 slowly inches down inside the hot earth. Somewhere beneath the earth's crust, the edge starts melting into magma. Pockets of magma may rise, break through the sea floor and build a chain of volcanoes with tops poking out of the water as volcanic islands. (If you want to find out how some other volcanic islands were formed, see: Hawaiian Islands: An Oceanic Island Chain, page 6.)

LAND VOLCANOES

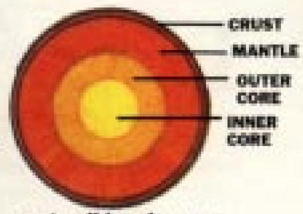
In 1980, Mount St. Helens in Washington State awoke from a 123-year sleep and blew its top in a violent eruption that destroyed a forest, killed more than 50 people, and blasted hot ash high in the sky. Mount St. Helens was built by lava flowing out of volcanoes like those shown on plate 4, below.

Beneath the continent of plate 4, the edge of plate 3 melts into magma. Magma under plate 4 rises through the continent to build a chain of volcanic mountains.

If you look at the map on page 8, you will notice that most trenches are found in the Pacific Ocean. There are so many island and land volcanoes near the Pacific trenches that the area is called "The Ring of Fire."

WHAT'S INSIDE THE EARTH?

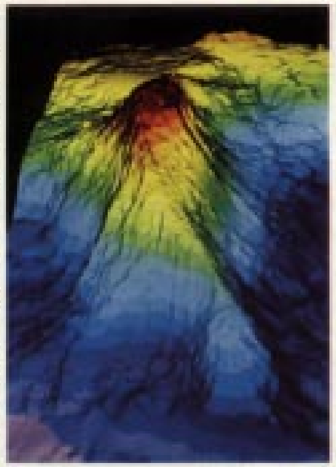
If the earth were sliced in half, you would find three main layers. The core at the center is quite hot — perhaps as hot as 10,000 degrees. The mantle, the middle layer that surrounds the core, has rigid rock at its top and bottom, but in between are red hot rocks that sometimes act solid and sometimes flow like a thick, mushy liquid, about the consistency of hot cereal. The crust above the mantle is earth's outer layer of solid rock.



WATCHING THE SLOW BIRTH OF A HAWAII

"Loihi looks a bit like Mars," says geologist Alex Malahoff, describing the underwater volcano's slopes, which are covered with orange and red bacteria. Alex, of the Hawaii Undersea Research Laboratory (HURL), has visited Loihi in *Alvin* and other submersibles. The first in-person exploration of Loihi was conducted in 1987 by scientists travelling in *Alvin*. This dive was also the first-ever dive into a submerged, active volcano.

SEABEAM, UNIVERSITY OF RHODE ISLAND



A computer-generated image of the underwater volcano Loihi.

Loihi, located just seventeen miles from Hawaii, rises more than 5500 meters (over 16,000 feet) from the sea floor. This newest Hawaiian island needs to grow just 960 meters (2880 feet) to break through to daylight. That may happen sometime in the next 10,000-100,000 years — a blink of the eye to geologists, who are used to thinking in terms of hundreds of millions of years.

HURL scientists have placed an observatory on Loihi called HUGO (the Hawaii Undersea Geo-Observatory). HUGO uses a video camera and other instruments to collect round-the-clock information, including the temperature, volcanic activity and changing environment around the volcano.

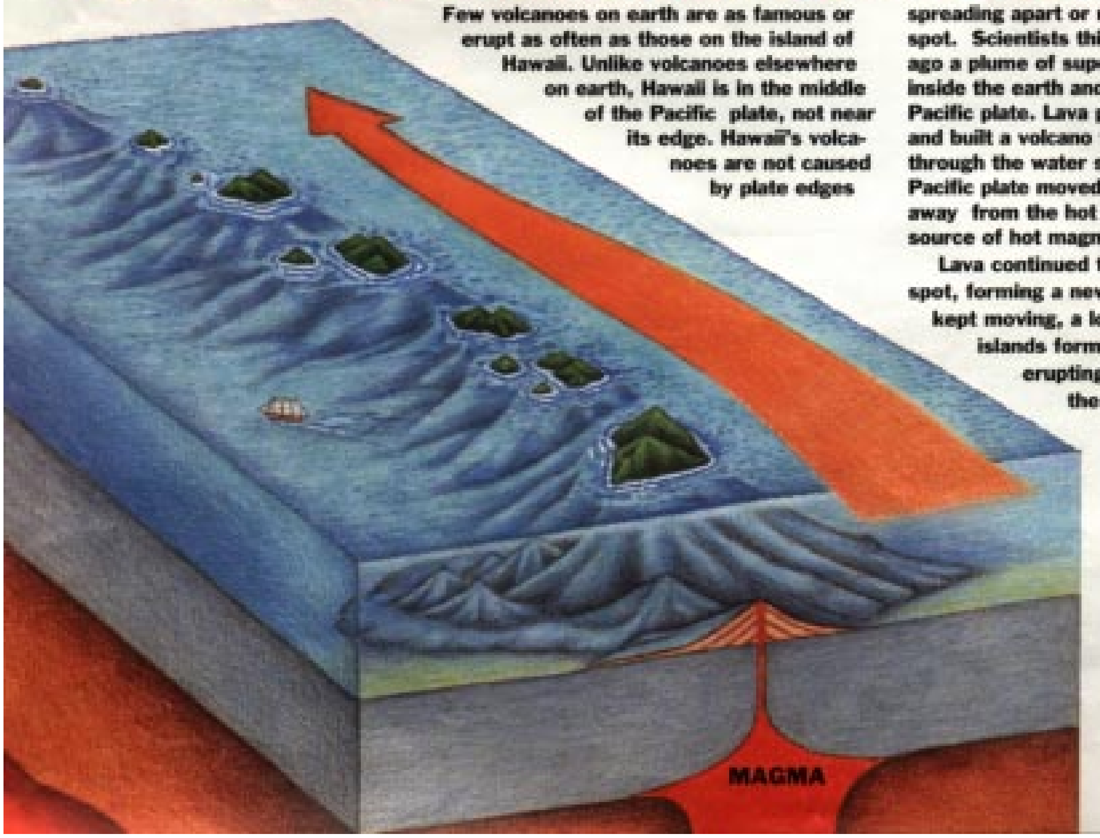
"Loihi is the first hard-wired volcano," says geochemist Gary McMurtry. Information gathered by HUGO helps Gary study the chemicals given off by the volcano.

Thanks to HUGO, Loihi might also be the first underwater volcano ever observed erupting, providing answers to many more questions. "When magma travels up through Loihi, we want to know what else happens there," says Alex. "Do we get earthquakes? Does the water temperature increase? Does the volcano inflate like a balloon when magma is injected into it?"

Meet HUGO (the Hawaii Undersea Geo-Observatory), stationed on Loihi.

By studying Loihi, these and many other questions may be answered. Says Alex, "This is a golden opportunity to understand an underwater volcano."

The Hawaiian Islands: An Oceanic Island Chain



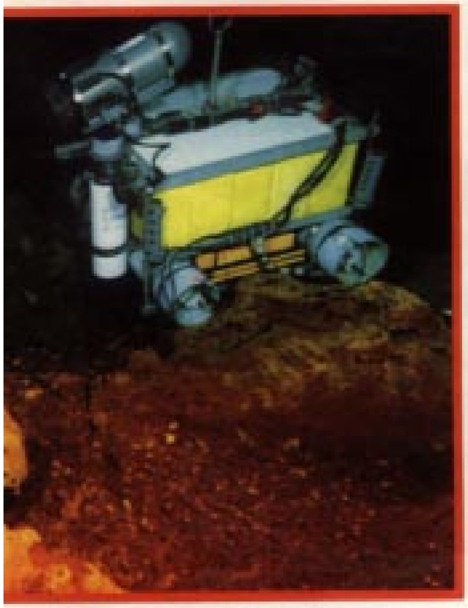
Few volcanoes on earth are as famous or erupt as often as those on the island of Hawaii. Unlike volcanoes elsewhere on earth, Hawaii is in the middle of the Pacific plate, not near its edge. Hawaii's volcanoes are not caused by plate edges spreading apart or meeting, but by a hot spot. Scientists think that millions of years ago a plume of superhot magma rose from inside the earth and melted a hole in the Pacific plate. Lava poured out of the hole and built a volcano that eventually broke through the water surface. Over time, the Pacific plate moved, taking the volcano away from the hot spot; cut off from its source of hot magma, it stopped erupting.

Lava continued to pour out of the hot spot, forming a new volcano. As the plate kept moving, a long chain of volcanic islands formed, with each volcano erupting only when it was over the hot spot. The island of Hawaii is the most recent of these volcanoes to rise above the water.

Today the volcano Loihi is forming over part of the hot spot. Scientists expect Loihi will become the next Hawaiian island some time in the future.

PATRICIA WYNNE

AN ISLAND



Marine Iguanas

TEEN ARGONAUT IN THE GALAPAGOS

When Jennifer Thomas, 16, went to the Galapagos Islands last December, she was amazed at the variety of plant and animal life. "We saw sea lions, land and marine iguanas, fur seals with babies, and all kinds of birds," says Jennifer, a junior at Nauset High School in Orleans, MA. "We saw blue-footed boobies, pelicans, tropical birds, finches, and a Galapagos hawk. We weren't supposed to touch the animals, but it's amazing how close they came to us."

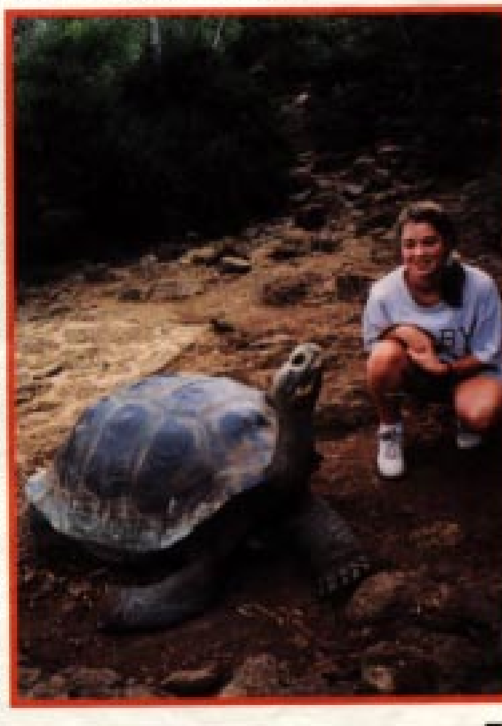
Jennifer was one of twelve Student Argonauts selected by the JASON Foundation for Education from a national pool of 300 10th- and 11th-graders because of her exceptional interest in science. The JASON Foundation was established by W.H.O.I. geologist Dr. Robert Ballard and a number of sponsors to show students the excitement of scientific exploration. Bob has led three JASON Project expeditions, where, via satellite hookup, hundreds of thousands of students have watched scientists at work at remote sites around the world.

The Galapagos islands are volcanic. They were formed by lava that rose from a hot spot on the Pacific plate — far away from any continent. Because the Galapagos are so isolated, they contain many species found nowhere else on earth. In the 19th century, the scientist Charles Darwin studied plants and animals on the Galapagos, which led to his theories of evolution and natural selection. Jennifer and the other Argonauts saw one clear example of natural selection. "On most of the islands, the prickly pear cacti are short. Iguanas chew on the cacti to get moisture. But on one island they were tall, and surrounded by a protective layer, which keeps them from being eaten by the land tortoises."

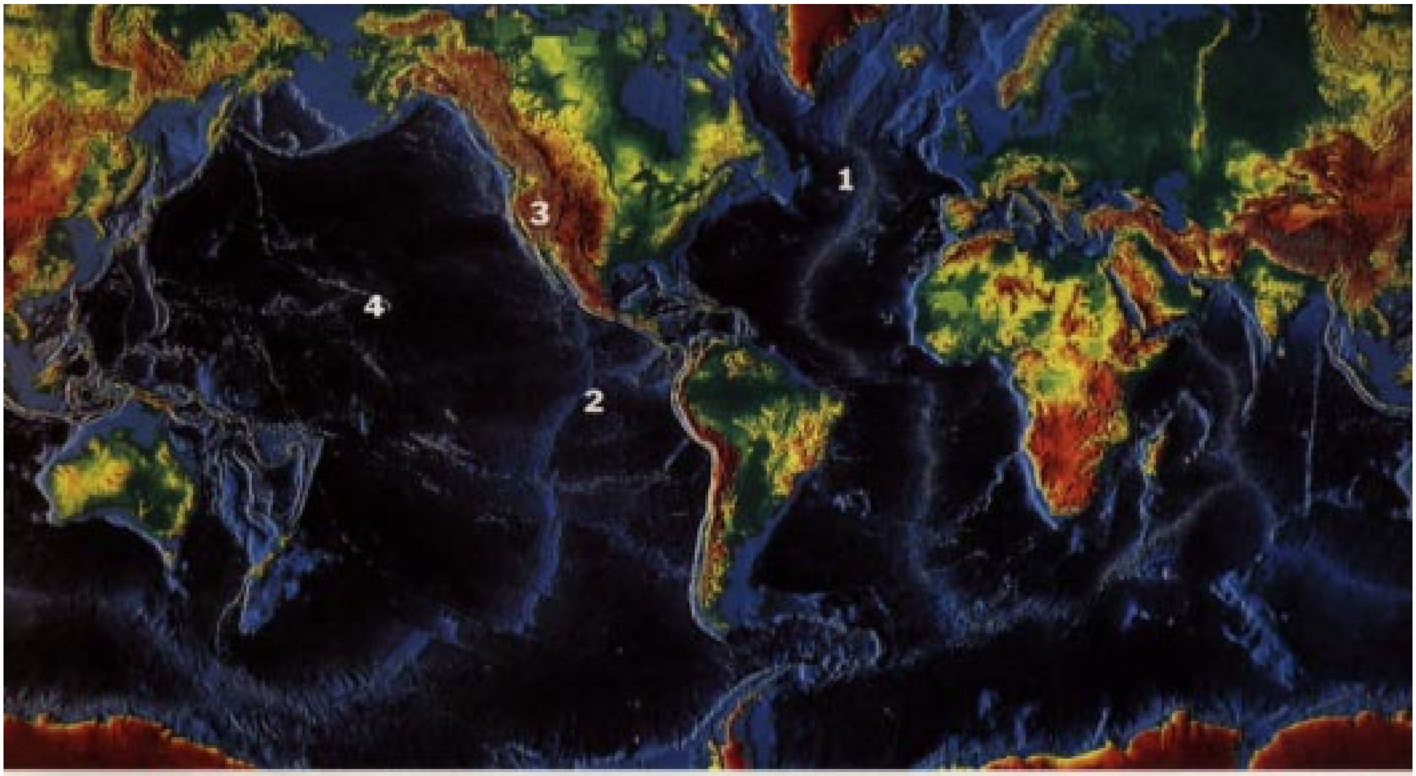
EXCERPT FROM JENNIFER'S DIARY

December 9, 1991
(Day 3)
Snorkeling off Bartolome Island was amazing! I was swimming along admiring the numerous brightly-colored fish, when all of a sudden three sea lions were directly in front of me. At first I was a little scared. But they were cute and quite friendly. Never in my wildest dreams had I imagined that one day I would be swimming alongside sea lions!

For more information on the JASON Foundation for Education and its corporate sponsors, write to The JASON Foundation, 391 Totten Pond Road, Waltham, MA 02154.



Jennifer with a Galapagos tortoise



AN OCEANOGRAPHER'S VIEW OF THE PLANET EARTH

This computer-generated map of the world shows the depth of the seas and the elevation of continents. Study this map to see if you can find some features on the ocean floor discussed in this issue. Locate: (A) the San Andreas Fault; (B) the Hawaiian Islands; (C) the East Pacific Rise; (D) the Mid-Atlantic Ridge. What other important features can you find on the ocean floors?

Answers: (A) 3; (B) 4; (C) 2; (D) 1.