

Questions erupt with discovery of two active undersea volcanoes. For Instance: What are a bunch of eels doing there?

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In 1889, Robert Louis Stevenson sailed into the Samoan islands and fell in love with their rugged, verdant peaks and palm-studded, white-sand beaches. With his wife, he purchased 314 acres of jungle, built a house and remained for the rest of his life.

Stevenson, of course, was the author of "Treasure Island" and other literary classics, but it's unlikely that he imagined or could fully appreciate the value of a different kind of treasure buried beneath the islands: not gold, jewels or pirate's booty, but new and fundamental knowledge about how the world works.

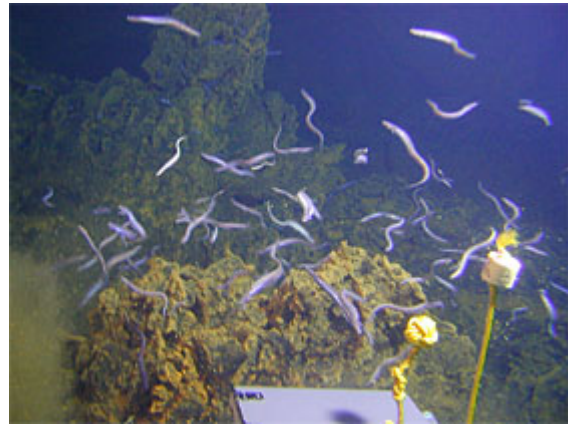
For beneath Samoa and its surrounding seas, a pair of volcanoes – one less than 5 years old – is changing the face of the planet and stirring new questions about everything from plate tectonics to the lifestyles of eels.

The islands, midway between Hawaii and Australia in the South Pacific, have long puzzled earth scientists. Among the foundations of geology is the "hot spot model," a theory that describes how plumes of rising molten rock occasionally poke through the Earth's moving crust, creating strings of volcanoes the way pulling a sheet of paper across an open candle might burn a line of holes. When this happens beneath the ocean, volcanic chains such as the Hawaiian Islands result.

"Charles Darwin noticed the result," said Hubert Staudigel, a research geologist at UCSD's Scripps Institution of Oceanography. "He observed that in some island chains, there would be islands at one end with young volcanic cones, middle islands with cones in different stages of erosion, and at the other end, nothing left but coral reefs."

But the six Samoan islands seemingly defied the traditional hot-spot model of diminishing volcanism. At either end of the chain are islands – Savaii and Ta'u – with records of recent volcanic activity. On Ta'u, the last known eruption was in 1866. To conform to the hot-spot model, there should have been a new, active hot spot east of Ta'u. But there wasn't.

As it turns out, the hot spot wasn't missing; it was just overlooked. In the mid-1970s, Rockne Hart Johnson, an American geophysicist, arrived to investigate a series of undersea explosions that had been recorded on hydrophones. Using an echosounder and magnetometer, which measures the strength of magnetic fields, Johnson concluded there was indeed a major seamount just east of Tau.



HUBERT STAUDIGEL

/ Scripps Institution of Oceanography

A video camera captures a surprisingly abundant community of eels (left) living in rocky crevices and caves atop Nafanua, a new volcano rising in the crater of another volcano called Vailulu'u.

"He found the volcano, but he didn't know whether it was active," said Stan Hart, a senior scientist at Woods Hole Oceanographic Institution in Massachusetts. "He got the location right and the depth right, but he didn't have the tools or resources to do more."

Hart says he didn't know about Johnson's work until much later. His interest began when he saw a satellite map of the Earth's seafloor developed by David Sandwell and colleagues at UCSD. Inadvertently overlaid on the map were data recording temblors off the coast of Samoa in 1995.

"That caught my eye, because the cluster was sitting where there shouldn't be any quakes," Hart said.

Hart contacted Staudigel, a longtime research collaborator. Staudigel was organizing a 1999 cruise into the South Pacific using the Scripps research vessel Melville. With last-minute funding, the scientists tacked on seven days to investigate Hart's earthquake mystery.

Sonar mapping of the sea bottom soon revealed a massive surprise: a 14,300-foot submarine volcano rising from the ocean floor 27 miles east of Tau. The volcano looked a bit like Mount Fuji or Mount Rainier, with a classic cone shape capped by a caldera or crater just 2,000 feet below the sea's surface.

Dredging indicated the volcano was likely active. The rock was glassy and smelled of sulfur. The volcano was eventually dubbed Vailulu'u after the sacred rain that reportedly fell before any gathering of Samoa's last king, Tuimanua.

(Currently, Vailulu'u is a middle-sized volcano, taller than Fuji at 12,389 feet but shorter than Rainier at 14,410 feet. Fuji and Rainier, of course, are dormant while Vailulu'u is growing. Still, Vailulu'u has a long way to go to match the size of Mauna Kea and Mauna Loa in the Hawaiian Islands, both of which exceed 31,000 feet from ocean floor to summit.)

Keen to follow up on their discovery (or re-discovery, in a nod to Johnson), Hart and Staudigel finagled a ride the next year aboard a U.S. Coast Guard icebreaker, to further inspect Vailulu'u. This time they measured the conductivity, temperature and depth of water in the volcano's crater.

The water was 80 degrees, just one degree above normal.

"That doesn't sound like a lot," said Hart, "but in scientific terms, it's compelling. It's absolute proof of hydrothermal activity."

In 2001, the pair returned again to retrieve recorded data from sensors they had set up in and around the crater. They showed substantial seismic activity: an average of four small quakes daily with peak periods of 40 to 50 a day.



HUBERT STAUDIGEL
/ Scripps Institution of Oceanography
Rugged, eroded volcanic peaks (below) are characteristic of the Samoan Islands, which were created by tectonic "hot spots."

The researchers more precisely mapped the volcano and crater: It stretched 21 miles across the seafloor and rose 2-½ miles high. The caldera was 1,300-foot-deep and a mile-wide.

They also tested the water. It looked clear but was, in fact, "smoggy" with particulates churned out by volcanic activity. A halo of this liquefied smog ringed the crater, hundreds of feet thick and extending four miles beyond the volcano.

Each trip to Vailulu'u teased researchers with new findings, but perhaps the most astonishing came last year when Staudigel and Hart explored the volcano with Pisces V, a manned submersible.

They expected to see a volcano. They found two.

In just four years, from 2001 to 2005, a new volcanic cone had apparently emerged from within Vailulu'u's crater. The volcano itself was almost 1,000 feet tall, which extrapolated out to an amazing average growth rate of eight inches a day.

The new volcano is called Nafanua after the Samoan goddess of war.

(Should Nafanua ever reach the surface, it may pose a threat, Staudigel said. Seismic activity might cause undersea landslides, resulting in tsunamis. Water above the volcano can become so laden with dissolved gases that the fluid density is no longer capable of the buoyancy needed to float a ship.)

Finding Nafanua was only part of the surprise. When Pisces V began prowling around, researchers disturbed thriving communities of foot-long eels in rock caves and crevices. Not just handfuls of eels, but hundreds of them.

The eels were unexpected, since much of the water in Vailulu'u's crater seems to be fatally acidic from volcanic discharge.

"We called it the 'crater of death,' " Hart said. "We never saw any living fish, no indigenous populations of life except for some polychaete worms."

Initially, scientists hypothesized the eels were consuming the "yellow fluff" that coated the surrounding volcanic rock. The fluff was composed of microbial agglomerations that fed upon the chemical energy flowing from hydrothermal vents.

But Staudigel suggests a different answer, based in part upon the stomach contents of some retrieved eels. "They eat shrimp," he said.

Beneath the superficial tides of the ocean are deeper, internal tides that are poorly understood. Staudigel posits that these tides, combined with heated water rising from Vailulu'u and Nafanua, form convectional columns of water called "Taylor caps" that encircle the volcanoes. As upwelling water in the caps reaches the surface, it spills inward into a central, downward vortex.

"Basically, the descending water pulls down everything with it, including shrimp and larvae," said Staudigel. "The eels live at the bottom of the columns. It's like a trap. All the eels have to do is wait for the shrimp to fall down upon them."

Staudigel concedes that marine biologists might balk at his simplified eel explanation. There are plenty of holes to be plugged. But Vailulu'u and Nafanua provide a singular opportunity for answering long-held questions, not just about the lifestyles of eels but how Earth fundamentally works.

"We're at the point where we can define key experiments," said Staudigel. "What's been done so far is mostly exploration, because we didn't really know what was down there. Now that we do, we can isolate issues and really go after them."

For example, there is some evidence suggesting Vailulu'u and Nafanua may be a better archetype of an island hot-spot system than Hawaii, the traditional model. The Samoan volcanoes appear to be fueled by a single magma source, extending deep into the mantle.

This makes them an ideal laboratory for studying plate tectonics. At mid-ocean ridges, molten material from the Earth's mantle continually rises to push apart crustal plates, but, said Staudigel, "it's difficult to precisely measure and assess activity because you can't determine where a particular system begins or ends," especially when a system can extend for thousands of miles.

Moreover, Vailulu'u's crater concentrates rising material, allowing for easier study. Indeed, the researchers have obtained samples of helium-3, a primordial gas that may originate deep within the planet, and observed rising bubbles of liquid carbon dioxide.

Hart and Staudigel are eager to return to the volcanoes, new experiments in tow. Most of Vailulu'u's crater remains unseen and unexplored, with visibility in some places limited to 10 feet.

Turbid water and warmer-than-normal temperatures suggest the presence of "black smokers" – vents in the seafloor that violently spew out dark clouds of superheated, mineral-laden water.

Staudigel said early tests measured the heat flux equivalent of 60 smokers in the crater but the scientists have yet to actually find one.

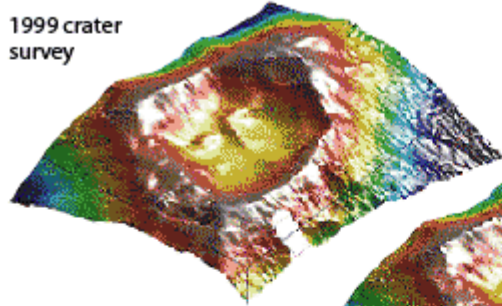
There's no telling what else the researchers might discover, the gaps in knowledge that might be filled. Hart said his "visionary dream" would be to build an observatory on Vailulu'u, fill the crater with various devices to measure seismic activity, monitor water temperature and chemistry.

"There's enough work here, enough questions to answer, to fill an entire career."

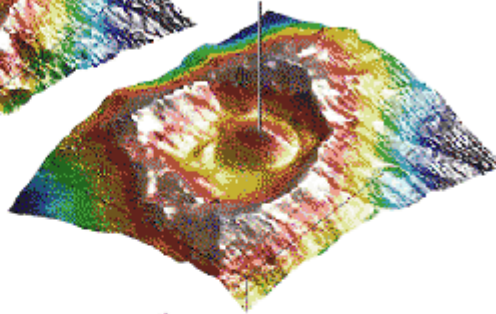
Undersea volcanoes overseen

Last year, scientists discovered a new, fast-growing submarine volcano rising out of another, larger volcano. The volcanoes offer researchers a rare peek at mid-ocean volcanism at work.

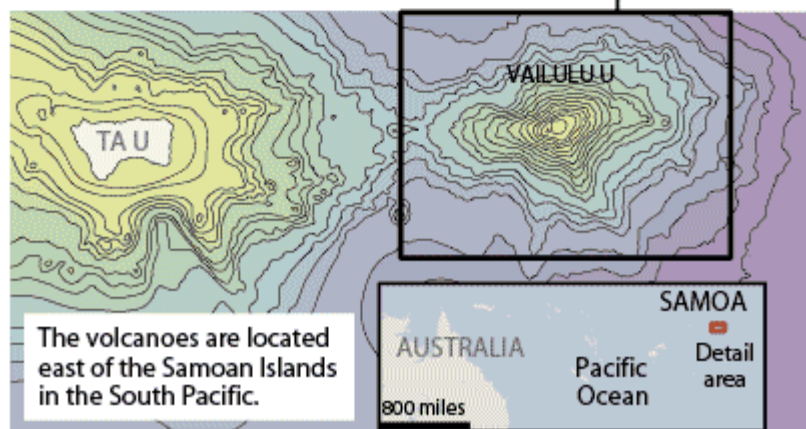
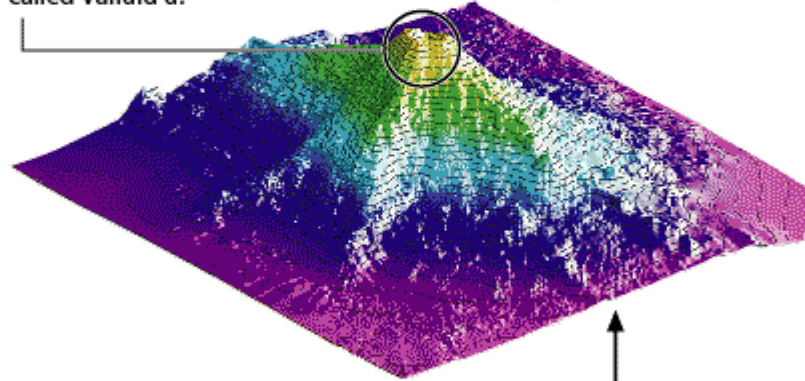
1999 crater survey



2005 crater survey
The new volcano, called Nafanua grows about eight inches a day.



Nafanua is in the crater of an older volcano, called Vailulu u.



SOURCE: Woods Hole Oceanographic Institution

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