



Hotspot or Not

BY ROBERT MONROE



Spot?

Where does Hawaii's explosive volcanism come from?

The icon of the world's most active volcanic system, Hawaii's Kilauea volcano gets its energy from sources in Earth's mantle but the path magma takes to the surface is unknown.

IT SOUNDS WEIRD TO SAY Gabi Laske's science group *wishes* for earthquakes.

But it is the truth. The members of the Plume-Lithosphere Undersea Melt Experiment (PLUME), of which Laske is chief scientist, spent a good portion of 2005 hoping for some good, yet not particularly destructive, quakes to provide raw data to the grid of instruments they placed in the waters around Hawaii. Laske, a Scripps Institution of Oceanography geophysicist, is leading PLUME through a second phase of fieldwork in an endeavor to study the shape and origin of the mantle plume beneath Hawaii. This bubbling cauldron of liquid rock created the Hawaiian island chain and it continues to fuel

the extensive volcanism on the “Big Island” of Hawaii. It is relentlessly building up seamounts that will someday join the island chain.

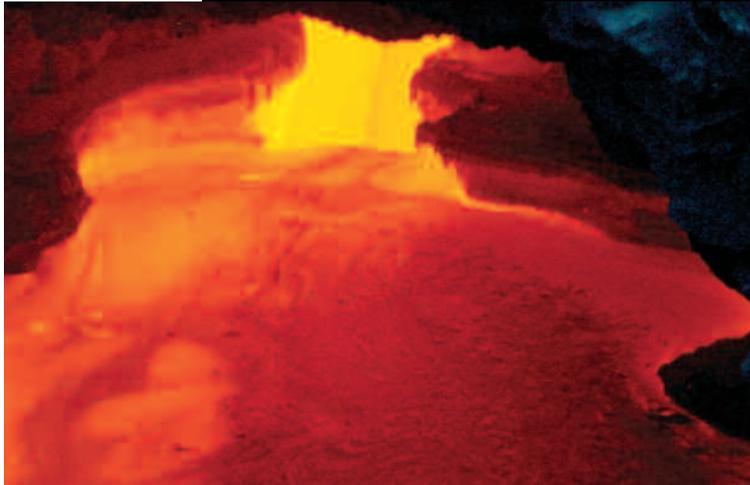
But the prevailing answer for how forces from the mantle push through Earth’s crust to create the chain—an explanation that has sufficed for decades—is more and more seeming a little too pat. Until now there had been little beyond theories, computer models, and patchy data to shore up or disprove what’s known as hotspot theory. PLUME promises to provide a breakthrough by creating the first-ever high-resolution images of deep earth layers beneath the Hawaiian islands.

Initial results from PLUME’s first phase already challenge the narrative of Hawaiian volcanism. In the end, the effort could have a societal as well as scientific payoff. In finding the origin and pathways of Hawaii’s volcanism, PLUME stands to help researchers better understand tectonic hazards such as undersea landslides and identify areas of the island chain still vulnerable to eruptions. At another deeper level, PLUME intends to resolve one of the most fundamental unknowns of geology—how Earth loses its heat—via this one-of-a-kind look at one of its main release points.

“This is a really important data set,” said Hubert Staudigel, a Scripps geologist who studies Pacific Ocean volcanoes but is not affiliated with the



Left, Geophysicist Gabi Laske, flanked in a Scripps lab by seismometers used in the PLUME project, uses seismic waves to resolve the architecture of the volcanic plumbing system beneath Hawaii.



PLUME project. “For the first time we’re looking in great detail at the root zones of this volcano system.”

But creation of a data set requires data. Thus for another nine months or so, while an array of submerged seismometers records away, the PLUME team will continue what it’s been doing—crunching numbers and quietly hoping for the Earth to move.

HOTSPOTS REDUX

Around the world, most volcanoes are found in the places where most earthquakes happen, at the boundaries of tectonic plates. Not all follow the pattern though. In 1963, Canadian geophysicist J. Tuzo Wilson came up with the hotspot theory as a way to explain why certain locations in the world featured volcanic activity despite not being located near such boundary regions.

Wilson proposed that certain volcanic chains come into being when tectonic plates pass over especially hot mantle regions that last for great periods of time in fixed locations. The aggregation of hot rock pushes magma through the crust and up to the seafloor, an action dramatically manifested by the Hawaiian islands, the world’s most productive volcanic system. As the Pacific Plate moves over this hotspot at a rate of seven to nine centimeters (2.8

to 3.5 inches) per year, the plume has enough time to pile up a sufficient amount of magma to create volcanic mountains.

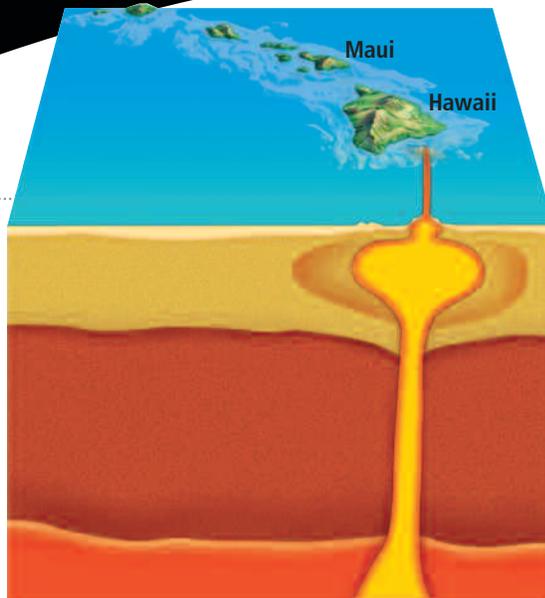
In assembly line fashion, the hotspot has created a chain of peaks heading northwest in a neat progression, making it an ideal test site for Wilson's theory. The Hawaiian chain includes seamounts that never reached the surface as well as the volcanic peaks that make up America's 50th state. It also includes seamounts yet to break the surface like Loihi, to the southeast of Hawaii. Scientists anticipate Loihi breaking the surface between 10,000 and 100,000 years from now and, no doubt, seeing the development of timeshares and golf courses soon after. The entire Hawaiian chain rests upon a 2,000-kilometer (1,240-mile) -long undersea plateau, known as a swell. Wilson noted with general veracity that the farther away the islands were from the hotspot, the older they were.



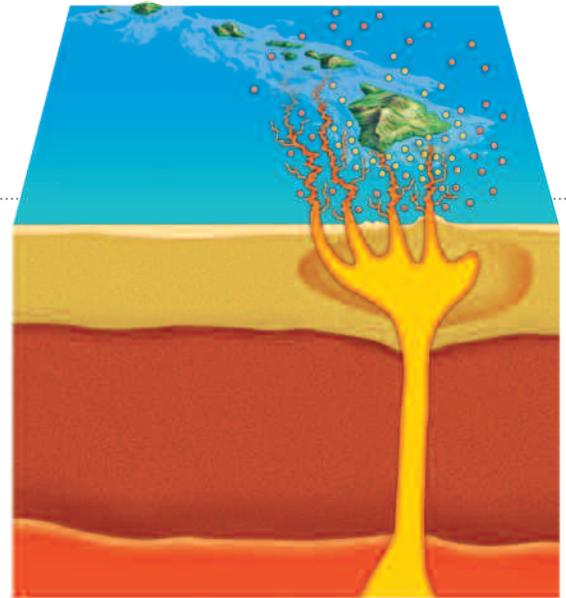
Above, Back from the depths, ocean-bottom seismometer packages await a trip back to Scripps after a year-long deployment on the seafloor.



TO THE BOTTOM OF THINGS



Where is the source of Hawaii's volcanic activity? To answer this, the PLUME project uses seismic waves to create an image of a plume head, a large chamber in Earth's mantle from which volcanoes on Hawaii and the Loihi seamount draw magma. The researchers assumed the plume head (above) would be located near observed volcanic activity, but they have not been able to place it there during a preliminary analysis. Rather, they find unusual crust between Hawaii and Maui.



The apparent shift in the plume head led PLUME investigator Gabi Laske to hypothesize that perhaps several fingerlike pathways (above) rather than one main chamber feed Hawaii's volcanoes. If that's true, places other than the island of Hawaii could be susceptible to volcanic activity. Data gathered during a 2005 deployment of seismometers (yellow icons) and a second round taking place now (red icons) could lead to an answer.



Over the years, a few inconsistencies in Wilson's hotspot theory have been noted. Some volcanic material on Maui, for example, is younger than some material on Hawaii though Maui is farther along the chain. Still, to Laske and many others in the geophysical community, it stood to reason that the feeder to which the island chain owes its existence should be a distinguishable entity and that it should be to the southeast of Hawaii, in rough proximity to that island's visible volcanic activity.

The task of PLUME was to find it.

To do so, PLUME scientists, who come from five research institutions around the country deployed a network of seismometers around the Big Island in January 2005 to create a tomographic view of the plume head's dimensions. The instruments receive seismic waves that resonate through the mantle and crust. This means of data recovery is similar to the way a CT scan passes X-rays through the body to create an image of the tissue through which

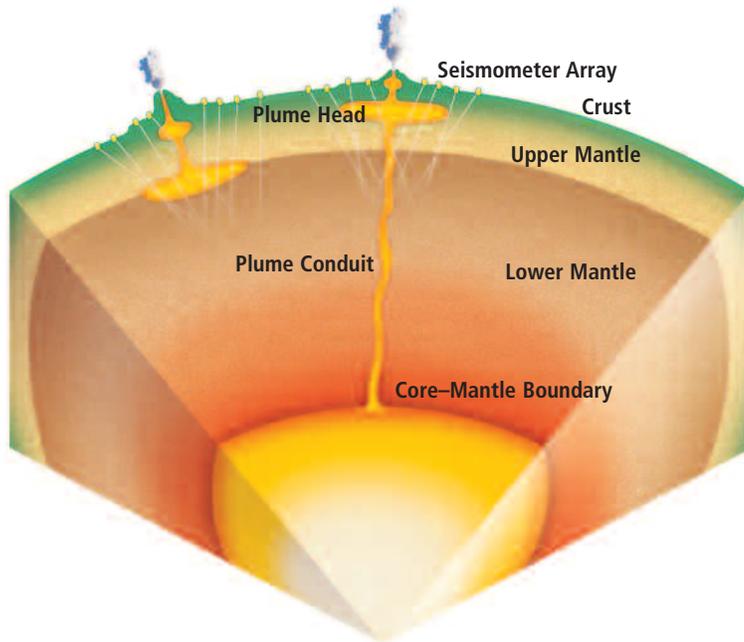
the waves pass.

For the kinds of imagery that interest geoscientists, earthquakes are needed to produce the raw wave energy that would produce recognizable signals. The bigger the shake, the better. Luckily, 2005 was, as co-principal investigator Cecily Wolfe said, "a spectacular year for earthquakes," featuring magnitude 6.7 and 7.2 temblors along the Gorda Ridge off the Oregon coast.

"Those are wonderful earthquakes because they're offshore



Opposite, Researchers retrieve a numbered seismometer and the rest of its instrument package during a January 2006 cruise. **Left and below,** Kilauea flows have been adding to Hawaii's land-mass since its most recent eruption in 1983, eliciting a corresponding flow of visitors.



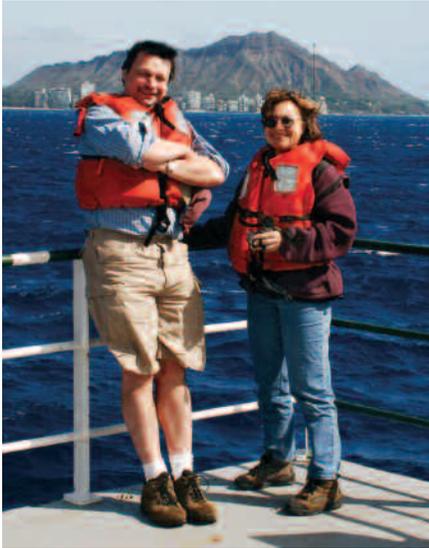
Two camps in the world of geophysics dispute the depth at which volcanic activity originates. By being able to image depths as great as 1,000 kilometers (620 miles) into Earth's mantle, PLUME's 1 million-square-kilometer (386,100-square-mile)-seismometer array should resolve the issue. If the source turns out to be deep, then upper and lower rings of Earth's mantle probably produce convection in concert with each other. If the source is shallow, it means the two layers could function more independently of each other, a conclusion that could diminish support for some tenets of plate tectonics theory.



and they don't hurt anyone but they happen at key azimuths," Wolfe said.

The 35 seismometers simultaneously recorded these seismic events. The relative distance of the seismometers from a quake epicenter determines when they receive the signal in part but not entirely. The other influencing factor is the composition of the rock through which those waves are passing. Waves travel slower through areas of hot liquid rock seething with volcanic activity and faster through solid, cold areas where there is no activity. The researchers recovered the seismometers in January 2006 after 12 months of data-gathering on the seafloor. The recorded speed of the waves should have produced a three-dimensional image of the plume head somewhere to the southeast of the island of Hawaii.

Instead there was nothing there.



Left, Laske and co-investigator John Collins of Woods Hole Oceanographic Institution set out past Honolulu's Diamond Head landmark. **Above,** Maui's Haleakala volcano, quiet for 400 years and counting. **Opposite,** Woods Hole's Victor Bender, John Collins and Ken Peal examine an OBS unit after it spent a year on the seafloor.

MISSING MAGMA

Laske isn't yet ready to unequivocally report that her plume head has gone missing. The evidence that it isn't where it's supposed to be is very preliminary, she cautions, but if it holds, it must give rise to alternate theories.

It is possible that the plume head feeding Hawaii's volcanoes is located in a different place altogether. The waters between Maui and the Big Island are the most likely locale, Laske said. It is also possible that there is no plume head at all, that the source of magma isn't a dome but a network of harder-to-see conduits lurking below the islands like fingers.

Both hypotheses create their own problems. The northwesterly movement of the Hawaiian chain is not in question, so how could a plume head in Maui feed Loihi, which is 250 kilometers (155 miles) away in the wrong direction. Any theory about fingers raises similar questions.

"You still have to find a plumbing system that has a plume here,"

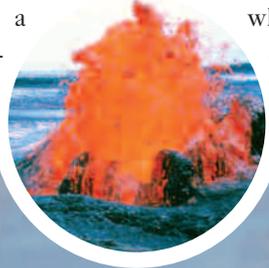


said Laske, pointing to the strait between the Big Island and Maui, “and fingers that go out to Loihi.”

One possible explanation is that the plume head is less like a narrow chimney focusing hot rock on specific areas of the surface and more like a broad pot of boiling pasta sauce, its seething bubbles capable of popping up anywhere over a wide surface. In this case the pot could encompass Maui and Hawaii. Another possibility is

that the kind of hot region of rock that PLUME could image seismically has been dragged to Maui over millions of years by the moving crust, leaving behind volcanic spots like the Big Island’s Kilauea volcano as kinds of skidmarks left behind.

“In essence, one explanation could be that what we see in the seismic images is the still-cooling plumehead dragged along from when Maui was where Kilauea is now. It



is, so to speak, a snapshot into the past and not what's happening today," Laske said.

Both theories have other implications as well. One of those many fingers could be under Maui just waiting to reactivate and punch through. It's probably been at least 400 years since Maui's Haleakala volcano erupted but the island's time as a volcanically active one is almost certainly not over.

"People have the perception that volcanic activity on Maui is totally extinct but that is a misconception," Laske said. "Sometimes we need to be careful saying it will never happen again."

A DEEPER ISSUE

Despite the shudder it might send through Maui's real estate community, the hunt for the missing plume head is but one component of PLUME. More significant breakthroughs

are expected to come from the data collected in the field-work phase currently under way.

The seismometer array stretches over 1 million square kilometers (386,100 square miles) of ocean and encompasses nearly the entire state of Hawaii. It is geographically the largest deployment of ocean-bottom seismome-



Right, Laske oversees deployment of OBS units. **Top**, Seismometers arranged for a return to the lab.

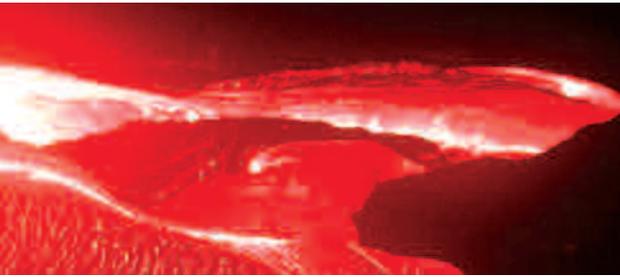


ters ever. A case can be made that it is the largest seismic array ever assembled on land or at sea.

The wide aperture of the array allows for a correspondingly deep view into the mantle, with the seismometers seeing 1,000 kilometers (620 miles) into the Earth. That depth will allow the PLUME team to see beyond the boundary separating the lower mantle from the upper mantle, the two concentric rings between Earth's core and its crust. The transition between the two mantle layers is 660 kilometers (410 miles) deep.

PLUME researchers will be looking for seismic evidence that the plume stoking Hawaii's volcanoes either originates at the greatest depths of the lower mantle or that the plume begins at a shallower point nearer to the crust.

If plumes originate at shallow points, the conclusion could change scientists's views of how heat escapes from Earth and also contradict a supporting tenet of plate tectonics theory. Like the plates themselves, tectonics theory rests in part on a state-shifting notion that heat travels from the core to the surface through one big process of convection with the two mantle layers acting in concert. Plate tectonic theory assumes that process to be the more likely explanation of mantle dynamics because it would better explain the origin the energy that drives plates into each other and



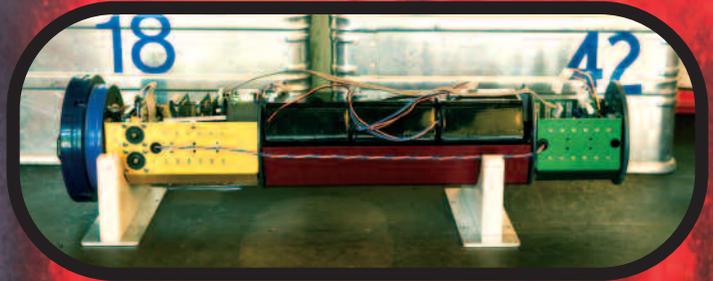
causes earthquakes.

Because if the other scenario is true and there are two distinct layers of geological activity occurring in the mantle that are independent of each other, the energy that would seem to be needed to drive tectonic plates into each other with enough force to cause earthquakes would be harder to account for. Instead, Earth would be losing its heat through a very, very slow process of conduction, like the burners of a hot stove heating up a cold frying pan.

Once the data are collected, Laske thinks a definitive answer could be ready within two years. Whatever its conclusions, PLUME results will end a fractious debate that has sprung up between two groups of geophysicists in recent years. It will give direction to one branch of geoscience that is waiting at a crossroads for more data to work with. For researchers like Wolfe, who lives in Hawaii, it gives a cause for reflection as she contemplates the ground she walks on.

“What we’re really looking for is the fundamental process behind volcanism,” Wolfe said. “I have my state of Hawaii but I don’t have a handle on what created it” 🌐

THE POWER BEHIND PLUME



Wrapped in black plastic, a trio of battery packs powers a data logger.

EVEN THOUGH THE Plume-Lithosphere Undersea Melt Experiment won a federal research grant in 2000, the project team had to wait five years to launch field work all because of a seemingly mundane part of the science package—batteries.

The project researchers needed ocean-bottom seismometers to record data over 12 months. That meant finding batteries that could keep data loggers and other components of the instrument packages running that long. Such battery packs didn’t exist when PLUME was greenlighted.

“It was a real problem for us until at least 2003,” said Laske.

In a continuing game of miniaturization, researchers at Scripps and other research centers eventually succeeded in reducing the power draw required by such instrument packages to the point where industrial-grade batteries could provide a year’s worth of charge. Each pack contains a brick of 12 DD-cell lithium batteries. There are eight bricks per seismometer package, each of which requires less power than a flashlight bulb. 🌐