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Ripple Marks

The Story Behind the Story

BY CHERYL LYN DYBAS

Pele's Tears: "Lava Fingerprinting" Reveals Geochemistry of Hawaii's Volcanoes

Pele. Her name brings visions of fire, lightning, wind—and volcanoes. Of all the ancient Hawaiian gods and goddesses, Pele, the "lady in the red dress," is the best known.

Locals believe that her powers formed Hawaii's chain of volcanic islands. The word *pele* means molten lava in Hawaiian. Volcanic eruptions, it's said, are Pele's way of expressing a longing to be with her true love. Lava is Pele's tears.

Science may offer another explanation.

The island volcanoes of Hawaii are the most recent evidence, geologists say, of an ancient process that created the 6,000 kilometer-long Hawaiian-Emperor Seamount Chain.

Hawaii's volcanoes—including the active Kilauea, which means "spewing" or "much spreading" in Hawaiian—were formed as the Pacific Plate moved over the Hawaiian hotspot in Earth's underlying mantle.

Like other Hawaiian volcanoes, Kilauea began life as a young submarine volcano, gradually building up through subsurface eruptions before emerging from the sea some 50,000 to 100,000 years ago. Since then, the volcano's activity has likely been as it is now: a steady stream of tears falling from Pele's eyes.

Over the past five million years, Kilauea and other Hawaii volcanoes took an unexpected turn in their development: they began to form parallel chains that are distinct geographically and, it turns out, geochemically. The two chains, or Loa and Kea trends, are named after their tallest volcanoes, Mauna Loa and Mauna Kea (higher than Mount Everest when measured from their underwater bases).

Kilauea, along with volcanoes such as Haleakala, is part of the Kea trend. The Loa trend includes Loihi, Kauai, and several other well-known Hawaii volcanoes.

The Loa and Kea trends have distinct sources of magma and unique plumbing systems connecting them to Earth's deep mantle, according to research conducted by geologist Dominique Weis of the University of British Columbia and colleagues. The results were reported in the November 2011 issue of the journal *Nature Geoscience*.

"Chains of volcanic ocean islands are one of the most distinctive features on our planet," says Weis. "The longest, the Hawaiian-Emperor Chain, has been active for 80 million years. Through plate tectonics, it has moved, centimeter by centimeter, across the Hawaiian mantle plume, the hottest and most productive of Earth's mantle plumes."

Mantle plumes bring material from deep within Earth to the surface, Weis says, and are an important means of heat transport.

Pele's reach runs deep.

Volcanoes fed by Hawaii's mantle plume show strikingly different geochemical characteristics. The discovery is among the first to relate surface lava rocks to their mantle sources 2,800 kilometers below at the core-mantle boundary.

"By studying oceanic island lavas, we can 'see' into the mantle, which is 80 percent of Earth's volume," says Weis.

The results of the study suggest that the increase in Hawaii's volcanism over millions of years is related to a shift in the composition and structure of the source region of the Hawaiian plume, or hotspot.

The chemistry of lavas from such hotspots holds the key. Geochemical analyses of these lavas using isotopes, or variants of chemical elements, show that they offer a new way of looking at deep Earth evolution.

Weis and colleagues call the method "lava fingerprinting." It's a means of tracking lavas' mantle sources. Differences in isotopic ratios, the scientists found, are the result of millions of years of evolution from distinct mantle regions with different histories.

Radioactive isotope "parents" decay, with a very long half-life, into daughter isotopes. The isotopic ratios between the two reflect the history of lava reservoirs in the mantle. "In essence," says Weis, "they bear the 'fingerprints' of their sources."

Results show that there's very little geochemical overlap between lavas in volcanoes from the Loa and Kea trends. "The composition of Mauna Loa lava is distinct from that of Mauna Kea lava," says Weis.

The rising plume of magma may divide in two, feeding the Loa trend and the Kea trend separately. The magma could be remelting different rock types as it splits and flows toward the surface.

The researchers' next step is to fingerprint lavas along the entire Hawaiian chain and on other oceanic islands. They hope to cement the relationship between lavas and the composition of the deep mantle.

They're also asking: how far back in time do Hawaii's Loa and Kea trends extend?

As a lone volcano, Kilauea may be 300,000 to 600,000 years old, but how ancient is the pattern of which it's a part? What can the pattern's age tell us about current and future volcanic eruptions?

Kilauea's most recent major eruption is by far her longest-lived. It began on January 3, 1983. Fountains of lava quickly built up into what's known as the Pu'u 'O'o cone, sending flows down Kilauea's slope. The Pu'u' 'O'o cone is the longest eruption of the last 200 years in what's called a volcanic rift zone.

A rift zone—a series of fissures or cracks—allows lava to erupt from a volcano's flank instead of its summit. On Kilauea, lava flows from rift-zone flank vents some 15 kilometers east of the crater.

Rift zones extend tens of kilometers outward from Kilauea's summit. Most Hawaiian volcanoes have two or sometimes three rift zones. The accumulated lava of repeated eruptions from these rift zones results in the volcanoes' elongated shapes.

As of January 2011, Kilauea's modern-day eruption had covered 123 square kilometers of existing land, added 206 hectares of new land, and "resurfaced" 14 kilometers of highway with lava as thick as 35 meters.

How much longer will Kilauea shed embers and tears? The geochemistry of her lava may tell the tale.

Photos courtesy of Ilya Raskin, Rutgers, the State University of New Jersey

Ocean Sunfish: Feeding on Jellyfish…or Something Else?

Just when beachgoers on Maine's Wells Beach thought it was safe to go into the water…a fin appeared 30 to 50 meters offshore. It was Labor Day weekend, 2012. Beach and shallows were teeming with people. But lifeguards ordered everyone off and out as they worked to determine whether the fin, some 20 to 25 centimeters above the waterline, was that of a shark.

The fin turned out to belong to a giant silver pancake of a fish, the ocean sunfish or common mola, *Mola mola*. The heaviest known bony fish in the world, molas have an average adult weight of 1,000 kilograms. The species is native to tropical and temperate waters around the globe and looks like a fish head with a tail, its main body flattened laterally. Ocean sunfish can be as tall as they are long when their dorsal and ventral fins are extended.

Would they have posed a hazard to the swimmers at Wells Beach—or anywhere else? In the few instances in which people have been injured by molas, it's usually because these huge fish have collided with swimmers in the surf, a very unlikely occurrence.

Would a mola prey upon a human? Hardly, says marine scientist Jonathan Houghton of Queen's University Belfast Marine Laboratory in the UK. Ocean sunfish live on a diet that consists mainly of jellyfish.

That jellyfish statement has been dogma in the mola world. But a 2011 paper published by Houghton and colleagues in the *Journal of Fish Biology* challenges that view. "These fascinating fish likely feed broadly in coastal food webs," says Houghton.

There's an urgent need to reconsider the trophic position of *Mola mola*, he believes. The species is removed en masse each year as bycatch in fisheries—with little or no understanding of the ecological consequences. For example, between 1992 and 1994, molas made up as much as 93 percent of the total fish catch in Spanish gillnet fisheries targeted at swordfish (*Xiphias gladius*) in the Mediterranean Sea. The Spanish fishery was closed in 1994, but an illegal Moroccan fleet continued to operate until 2007. Its estimated annual bycatch of *Mola mola* was 37,000 fish.

"When you consider the implications of such wholesale removal of a species from a marine ecosystem, it's vital that the mola's prey be identified," says Houghton.

Molas have long been considered primary consumers of gelatinous zooplankton. "While that view has pervaded the literature," says Houghton, "it has little support." Field guides and reference books offered clues that the mola's diet might extend well beyond jellyfish. Various stomach contents have been listed, including algae, crustaceans, ophiuroids, mollusks, hydroids, and fishes. But how these observations were obtained is rarely specified.

Houghton and colleagues turned to isotopic analysis to find out more about what molas are in fact eating. They analyzed carbon and nitrogen isotope ratios of young Mediterranean Sea molas—and of various crustacean zooplankton, the mussel *Mytilus edulis,* the jellyfish *Pelagia noctiluca,* and two benthic species, the limpet *Patella caerulea* and the gastropod *Nucella* sp. The scientists also looked at samples of fish obtained from local fishers: barracuda (*Sphyraena* spp.), black scorpionfish (*Scorpaena porcus*), and conger eel (*Conger conger*), among others.

The results showed that the molas were higher in carbon and nitrogen compared with levels that would be found in a diet of strictly gelatinous zooplankton. "The carbon and nitrogen assimilated by these *Mola mola* likely originated from another source," says Houghton.

In the Mediterranean Sea, small *Mola mola* often feed on several species that are part of the inshore food web. The trophic role of ocean sunfish therefore extends well beyond predation on jellyfish, says Houghton.

It's tempting, he says, to suggest that the availability of mixed prey types may be an important factor in the habitat preferences of molas during their early life stages. "Without comparative studies of larger individuals found in offshore areas, however, this suggestion remains speculative," the researchers write in their paper.

A potential caveat, the scientists say, is their study site's proximity to commercial fishing activities. "It may grant molas access to discards of species that may not typically form part of their diet," says Houghton. "But juvenile molas weren't enriched in nitrogen relative to other fishes sampled, so they may be feeding at a similar trophic level to these fishes."

The long-standing perception of jellyfish predation by *Mola mola*, says Houghton, needs to be turned on its head—or its fin.

For swimmers in Maine or anywhere else ocean sunfish are found, it's certainly all clear to return to the water. Unless, that is, they're limpets, small fish, or other members of the inshore food web.

If they're jellies, however, they may be completely—and surprisingly—safe.

Photos courtesy of Mike Johnson, Marine Natural History Photography

Hottest New Tracking Technique? Radioactivity in the Pacific Ocean

What's not so safe—perhaps—are other species that swim the open ocean alongside *Mola mola*.

When a tsunami flooded Japan's Fukushima Dai-ichi nuclear power plants in March 2011, the plants overheated and spilled radioactive cooling water into the nearby sea. It was the largest release of radioactivity into the ocean in the history of nuclear accidents.

Now scientists have found that radioactive cesium from the disaster was carried across the Pacific Ocean to California waters—by bluefin tuna. It's the first time radioactive materials have been transported through the sea by migrating animals.

The levels of radioactivity, considered low, don't pose a health risk to people, as far as anyone knows, but they've provided a new way of learning about the habits of marine animals that swam anywhere near the damaged reactors. The results are reported in the June 12, 2012, issue of the *Proceedings of the National Academy of Sciences (PNAS)*.

After the Fukushima spill, the Japanese government monitored radioactivity in seafood caught near shore. But cesium wasn't being tracked in migratory species that pass through Japanese waters, and the area near the Fukushima spill is a high-use zone for on-the-move juvenile bluefin tuna, found Daniel Madigan of Stanford University, lead author of the *PNAS* paper.

In June 2011, Zofia Baumann of Stony Brook University, coauthor of the paper along with Nicholas Fisher, also of Stony Brook University, measured cesium in zooplankton and small fish that live near the spill site. The scientists wondered if they would find the same radioactive cesium isotopes in Pacific bluefin tuna that made their way eastward from Japan to the California Current off the US West Coast.

Bluefin tuna spend their first year in the coastal waters off Japan, feeding and gathering strength for the transoceanic migration that lies ahead. An unknown percentage of year-old bluefin tuna embark on the journey. Were juveniles that made the trek in 2011 carrying cesium?

To find out, Madigan tested tissue samples from bluefin tuna caught off the coast of San Diego in August 2011. All had detectable levels of radioactive cesium. The results show that the young tuna ferried cesium from the Japan nuclear power plants across the Pacific. The ratio between two isotopes of cesium allowed scientists to determine that the tuna had set out on their journey about four months earlier, and had spent less than a month in contaminated waters around Japan.

The findings are a new tool that may be used to discover where marine animals' oceanic journeys take them. Scientists have used isotopes to track ocean currents; now they can employ them to trace species' movements across long distances.

It all goes to show, according to Madigan, that events like Fukushima don't happen in a vacuum. Japan's bluefin tuna brought radioactive cesium a very long way: across the largest ocean on Earth.

CHERYL LYN DYBAS (cheryl.lyn.dybas@gmail.com), a contributing writer for *Oceanography*, is a marine ecologist and policy analyst by training. She also writes about science and the environment for *Natural History, Canadian Geographic, Africa Geographic, BioScience, National Wildlife, Scientific American*, and many other publications, and is a contributing editor for *Natural History*.