In Hawaii, living with lava

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An eruption from Kilauea's flank began in summer 2014. By fall, a stream of lava had reached the outskirts of the town of Pahoa, about 11 miles distant. It flowed through this farm, taking out pastures, trees, fences and the owners' house. For some reason, the detached garage in the middle was surrounded, but not touched.

When the most recent eruption of Hawaii's Kilauea volcano started last

June, Melvin Sugimoto at first did not think much of it. Hawaii, where he has lived all his life, is made entirely of hardened lava, and Kilauea, perhaps the world's most active volcano, has been adding more off and on for the last 300,000 years. "Lava is everywhere, but I never thought in a million years it would come through here," said Sugimoto, who lives in the small town of Pahoa.

The source of this eruption is the Pu'u 'O'O vent, on the vast, mostly unpopulated flanks below Kilauea's summit. The vent first came to life in 1983, and has since sent dozens of flows seaward. Eruptions have buried some 50 square miles of existing land up to 300 feet deep–much of it in Hawaii Volcanoes National Park, but also along the populous coast, where they have obliterated some 200 homes and 9 miles of coastal road. This has added about 500 acres of new land–mostly solid rock, actually–along the coast, where the lava has reached the ocean.

Previous flows headed away from Pahoa, but on June 27, 2014, new fissures opened up at Pu'u 'O'O, and the lava turned toward the town. At a slow walk, it burned through miles of the national park's rain forest, then crossed onto state land. By October it had traveled about 10 miles, to Pahoa's outskirts. It crossed a back road, and into a small farm. The owners' house burst into flames and disappeared under the flow, but for some reason the lava detoured around a detached garage and fish pond. Next door, like a river lapping against a levee, the edge of the flow piled against a berm surrounding the town transfer station, but petered out partway across the parking lot, near the recyclables containers. Meanwhile, the main flow continued downhill into the Pahoa Japanese Cemetery, where it reburied or re-cremated many residents; Sugimoto went up there and rescued his grandparents' ashes just in time, for safekeeping at home. Days later, the lava breached his own property and buried 4 acres of macadamia-nut trees. Sugimoto, an excavation contractor, rallied heavy equipment and built a series of earthen barriers to try and keep the lava from his house. "Some nights, I wasn't sure I

should go to sleep," he said. "I'd go to bed and the edge of the lava was two feet high. I'd get up in the morning, and it would be 8 feet high."

Sugimoto told this story during a visit to his place by Einat Lev, a volcanologist at Columbia University's Lamont-Doherty Earth Observatory. Lev and colleagues from the University of Hawaii were there to study how lava moves. It is a surprisingly complex business. The routes and speeds of lava flows are influenced by many factors, including slight variations in local topography; manmade structures; and the lava's own temperature, chemical composition and viscosity. Lava may head down a gully, or detour through some hidden crack. It may surge quickly, or stop somewhere, pile up and then go sideways. Secondary flows may break out behind the first one, scattering in different directions. In some cases, tunnels evolve under the cooled surface, providing unseen conduits for later eruptions to rush through at high speed. In places like Hawaii, Iceland and Italy, people have sometimes used berms or giant fire hoses to divert or cool flows, but this doesn't always work. Lev and her colleagues aim to bring more science to the table, by understanding how all these factors work together, so that residents and officials can make the best of human attempts to forecast and manage flows. "Just like water, [lava] seeks out the lowest areas," said Lev. "But then, once you add all the other factors, it gets a lot more complicated. Volcanoes present such a big hazard, it's important to understand how they behave."

Lev's journey to Pahoa began at a lab at New York's Syracuse University, where she and colleagues have been trying to understand how things work in nature by making their own artificial lava flows. They get chunks of basalt—the rock formed when lava hardens—and feed it into a furnace. Once it melts, they pour it down a ramp, put various obstacles in its way, and see what happens. They place objects parallel, diagonal and perpendicular to flows, and experiment with different volumes of

melt. Once, they put some ice in the way—a crude artificial model for volcanoes in Iceland, which often sit under glaciers. The experiments help confirm observations made in nature during eruptions from Cape Verde to Hawaii. Among them: block a lava flow, and it will often form a bow wave that quickly overtops the obstacle, especially if the obstruction runs perpendicular to the flow. Faster flows form bigger bow waves. Obstacles placed obliquely work better to rechannel lava—but this generally also will speed up the flow, sometimes by as much as 150 percent. Confining a flow to a gully also increases its velocity.

Lev traveled to Hawaii in March 2015, and began at the figurative eye of Kilauea—Halema 'uma 'u Crater, at the summit. Native Hawaiian religion holds Halema 'uma 'u to be the home and body of Pele, the goddess of fire, wind, lightning and lava. For all of human memory, it has been active on and off, and from time to time, it changes form. Currently, a deep pit within the crater harbors a roiling lake of lava about 600 feet across, which appeared in 2008 after a series of tremors and explosions. Lava lakes that last so long without draining or blowing up are rare; there are only about a half-dozen known in the world. Lucky for Hawaiians and park visitors, Kilauea is mainly a so-called effusive volcano; that is, its main product is lava. Destructive for sure, but rarely fatal, because lava generally moves slowly enough for people or animals to get out of the way. Worldwide, lava killed only about 100 people during the 20th century. The real killers are explosive volcanoes, such as Italy's Mt. Vesuvius or Washington state's Mt. St. Helens. These tend to erupt not lava, but sudden, fast-traveling clouds of gases, ash, boulders and mud, from which there is no escape; these can kill thousands at a time. That said, volcanoes can shift behavior, and there is evidence that Kilauea has in the past exploded. A U.S. Geological Survey observatory overlooking the crater monitors the area all around continuously with seismometers, gas sensors, GPS units, helicopter flights and live cameras.

At the lip of Halema'uma'u, volcanologist Einat Lev of Lamont-Doherty Earth Observatory prepares to study the lava lake, some 300 feet below. Constantly roiled by rising magma, it exhales hydrogen sulfide and other deadly gases. Thin plates of solidified lava blanket much of the surface; the red-hot liquid just underneath is seen swirling in the cracks. Credit: Matt Patrick, USGS

Halema 'uma 'u often jets out poisonous gases in the immediate vicinity, so the park keeps tourists at a distance—but Lev and USGS geologist Matt Patrick, armed with special training and tight-fitting gas masks, were permitted to venture within inches of the lip. Here, Lev set up a specialized camera combo to take high-definition video and infrared imagery of the liquid circulating and sputtering several hundred feet below. She and colleagues hope to add to data collected by USGS, and

compare it to other active lava lakes in Africa and Antarctica to understand what keeps them bubbling, and not troubling. One idea says that lava slowly circulates to the surface, cools off a bit, then sinks back to be replaced by fresher, hotter material. Another idea is that the lava mostly stays put, but is constantly stirred by streams of gases emerging from below. More sophisticated imagery and measurements might resolve this question. Whatever the answer, Kilauea apparently has a huge, interconnected plumbing system; sometimes the lake level in Halema 'uma 'u goes down, and a day or two later, the opposite happens 15 miles away, at Pu'u 'O'O. This may then cause lava to pour out of Pu'u 'O'O.

After consultations with USGS staff, Lev's next stop was Pahoa. The lava flow that started last year has since largely stalled—at least for now. By the time of Lev's visit, the leading edges had split into two main streams, one lurking in the woods a few hundred yards from the town shopping center and police and fire stations, the other terminating near Melvin Sugimoto's macadamia-nut orchard. But more lava was still making its way from the faraway vent, and some of it was still piling up and breaking out of older sections further from town. USGS and the Hawaii civil-defense authorities were watching things closely.

Lev and her colleagues spent a couple of days walking around on the solidified lava near town. Looming up as high as 50 feet and covering swaths as wide as a quarter mile, it had created its own jumbled topography, with plains, ravines, craters and hillocks. It was treacherous walking—razor-sharp edges everywhere, and occasional thin crusts apt to collapse several inches under the weight of a foot. It seemed more or less cool, but a thermal camera Lev pointed into one deep crack registered 350 degrees C (660 degrees F). "Something is still happening down there," she observed. Which places got overrun and which survived sometimes seemed just a matter of luck. At points, obstacles had broken the front into separate branches, but then more lava had

come from behind, and the branches had recombined. Along a partly lava-covered back road, the local utility company had tried to save its poles by surrounding them with giant piles of cinders, and wrapping them with reflective material. It worked for some—but at least one wooden pole got incinerated, without the lava directly touching it.

Hawaii Volcanoes National Park encloses much of Kilauea, and it sees 2 million visitors a year. At a popular roadside stop, tourists can get up close to a steam vent.

One day, Lev accompanied a team from the nearby University of Hawaii, Hilo, which has been regularly deploying drones to map the topography of the lava and surrounding ground at a fine scale. The aim is

to understand how subtle changes in ground elevation and the lava's own topography may influence its path, and whether manmade defenses can really work. "Thanks to drones, we're now able to make these maps practically in real time, and track how things change," said Ryan Perroy, a geographer at the university. Lev plans to deploy drones in her own studies as well.

Local people try their best to respect Madam Pele, as many call her. "Ultimately, whatever the volcano, Pele, decides to do is what we will have to obey," one Pahoa woman told a newspaper reporter in March. "If she wants to flow to the sea and she wants to create new beaches and new lava fields, then we will allow her to do that. She's the boss." That was necessarily the guiding principle a dozen miles southwest of Pahoa, where a series of flows that started in 1990 turned the former seaside communities of Kalapana, Kapa 'ahu and Kaimu into a barren plain of basalt running into the ocean. The lone surviving house in the Royal Gardens subdivision of Kalapana was buried in March 2012, its occupants evacuated by helicopter.

In June 2014, Pu'u'O'O sent a stream of lava slowly burning its way through forest. A few months later, this quarter-mile-wide arm reached the outskirts of Pahoa. It has cooled enough for researchers cross, but renewed activity could bring more lava.

One of the few places spared was the family compound of Robert Po'okapu Keli'iho'omalu, a patriarch of the local native community known to all simply as Uncle Robert. In 1990, the flow came so close, the family could feel the heat on their faces. They placed Catholic religious objects at each of their land's four corners, and prayed. The lava bypassed them. Chance? Miracle? The USGS's Patrick points out that the property was on the waterfront, at the edge of a bay. It might have been spared because the lava entered the bay sideways and filled it like a baking dish, but did not have enough energy to back up and also

take the land behind it. The flow created entirely new shoreline hundreds of yards beyond what is now the formerly waterfront property, and the coastal road now ends here. The family has taken advantage of the dead-end location by building a huge bar/restaurant, and hosting a farmers' market with parking up on the lava flow, where the bay used to be. They have claimed the new real estate for the Kingdom of Hawaii, a sovereignty movement that asserts the United States illegally annexed the islands in the 1890s. The U.S. state of Hawaii says the new land belongs to it. But at least on the surface, no one is fighting over it. The place has become a sort of cult pilgrimage destination overflowing with Hawaiian food, music and old-fashioned aloha. When Uncle Robert died in March 2015, the family put on a three-day public celebration with free meals and entertainment for whoever showed up, and buried Uncle Robert in the back yard a stone's throw from the lava flow.

As for Melvin Sugimoto, he decided to fight. As the lava crossed his land, he and a neighbor erected a series of berms. The results were mixed. One, perpendicular to the flow and only a few feet high, was easily overtopped, and the lava just kept coming. He set up a much larger one diagonal to the flow, but that only diverted it, without halting the forward motion. Down closer to his house, he made a last stand, with a big bowl-shaped earthen barrier. He never got to find out if it worked; the lava lapped up against its base and just stopped by itself. That is, at least for now. Months later, he says it still steams when it rains, and of course he knows more could come at any time. He has since bulldozed a road through the mass so he can reach his cacao patch and other parts of his land. Blocks of broken basalt boulders lie where he has piled them up with a steam shovel. "What can you do?" he shrugged with a smile. "Do you want to buy some rock? I have a lot of extra."

Provided by Columbia University