Synthetic Lava Brings Eruption into the Lab

Katharine Sanderson

To learn more about lava and to mitigate its damage, scientists are creating and manipulating their own molten rock.

In early May, Kilauea, a volcano on the southeast corner of Hawaii’s Big Island, began erupting, and a suite of earthquakes, the largest with a 6.9 magnitude, shook the island. The quakes caused fissures and cracks to open in the ground, and lava has been pouring down the flanks of the volcano ever since.

The exact path the lava has taken has been as unpredictable as it has been destructive. As of early July, the encroaching lava had destroyed 700 homes and had flowed over at least 26 km², reaching the sea. Monitoring the damage from the red-hot rock is hazardous, to say the least. But that is what a number of scientists from the U.S. Geological Survey are doing, both on the summit and on the lower East Rift Zone, with help from drones.

Although this on-site data collection is invaluable to scientists seeking new information about how lava works, it’s not the only way researchers amass knowledge about which way it will flow. Armed with furnaces and some heavy-duty safety equipment, geoscientists are making their own lava in the lab and measuring its behavior. These researchers are making important contributions to efforts to understand and better manage future lava flows.

■ HOT ROCKS

In Syracuse, N.Y., a place not normally associated with volcanic activity, Jeffrey A. Karson runs a laboratory capable of generating hundreds of kilos of molten lava and flowing it across a few meters of earth.

Experimenting with lava in a lab isn’t as off the wall as it sounds, says Karson, who cofounded Syracuse University’s Department of Earth Sciences. “Lava’s just molten rock. If you have a furnace that’s hot enough, you can melt rock.” Karson and his team use a crucible, akin to a giant Crock-Pot, heated by a surrounding furnace to 1200 °C to generate lava.

The researchers don’t work with just any old rock. They collect billion-year-old basalt—ancient lava—from Wisconsin, on the Midcontinent Rift System. “We use lava that has the same composition as real, natural basaltic lava, which is a mix of crystals and glass,” Karson says. “Around half of basalt is silica, resulting in a mixture of glass and minerals, including iron-rich pyroxene and magnetite. This is similar to the composition that is erupting in Hawaii now,” he adds. It’s also typical of the lava erupted in Iceland and other major rift zones where most of Earth’s volcanic activity occurs, he explains.

Karson and his team are creating and pouring lava under various conditions to answer a range of questions about volcanic activity, both on Earth and other planets. Their work is directly relevant to the ongoing eruption in Hawaii, where lava has been creeping over the landscape, sometimes at speeds up to 35 km/h, swallowing homes and coastline.

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A research team at Syracuse University creates and pours pahoehoe-like lava from its kiln. Credit: Syracuse Lava Project.

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In particular, the Syracuse team has investigated how a shell, or crust, forms on lava as it cools and how that shell of hardened lava determines the path of a flow and the shape it takes. Understanding crust formation might help with mitigating or diverting certain kinds of flows. For instance, firefighters on the Icelandic island Heimaey successfully sprayed water on lava to accelerate crust formation when the volcano Eldfell erupted in 1973. The approach saved the island’s harbor from destruction.

Of all the different types of basaltic flows, so-called pahoehoe lava flows are the ones Karson’s team mainly mimics in the lab. These Hawaiian-named formations are smooth and have tapestry-like folds that develop as molten rock oozes across a surface. Think of syrup as it’s squeezed from a bottle onto a stack of pancakes.

Rather than focusing just on crust formation, Karson has lately worked to scrutinize lava as it flows over different surfaces to learn about its behavior.

“Lava from Kilauea is flowing over older lava, vegetated ground, and of course houses and roads,” and each different surface would make the lava flow in a distinctive way, Karson says.

He and his team have observed that lava can slip very quickly downslope on wet surfaces. “This has not been observed in nature, but then not many lava flows have actually been witnessed under the appropriate conditions,” Karson says. The researchers hope that these behaviors they’re observing in the lab will one day be used to model real-world scenarios and help disaster management officials make better decisions to keep people and property safe.

Einat Lev, a geoscientist at Columbia University, explores lava flows in her own lab by using lava proxies—wax, clay slurries, and sugar syrups—that have a viscosity similar to pahoehoe flows. She also collaborates with the researchers at Syracuse, borrowing their lava-pouring equipment to study molten basalt flows, pouring lava on scales ranging from 10 cm to 2 m and comparing results to her proxies.

The Syracuse research program is the largest of its kind in terms of the scale at which the homemade lava is created and poured, but it’s by no means the only one to take on lava in the lab.

In 2015, Lev and her colleagues used both syrup and molten basalt to investigate what happens to the path of flowing lava when obstacles get in its way. They first ran the sugary syrup down slopes and into simple flat or V-shaped obstacles and measured how the syrup diverted around either side of an obstacle to create what’s known as a bow wave. In some cases the syrup would eventually collapse over the obstacle, allowing the flow to continue. Follow-up experiments with molten basalt replicated the researchers’ findings.

By tinkering with the shape, size, and orientation of the obstacles put in the syrup’s (and lava’s) path, the Columbia team found ways to control the flow. A long, tall barrier at roughly a right angle to the encroaching lava could slow the flow. A series of shorter barriers stacked behind one another down the slope over which the lava would flow also worked.

Lev says knowledge about how these barriers affect lava is directly applicable to the current eruption on Hawaii because it “helps to predict how much a lava flow will inflate behind a berm or a house and how fast it will move once it passes the obstacle.”
THIMBLEFULL OF LAVA

But making tons, or even grams, of lava isn’t practical for every lab. Geoscientist Olivier Namur at KU Leuven and his colleagues heat their samples inside small gold or platinum crucibles just millimeters long and weighing around 50 mg. For Namur’s purposes, those tiny amounts of molten rock are enough to understand what’s happening on a larger scale, he says. On a practical level, smaller is also better because the team’s furnace can maintain stable temperatures only on this scale, gold and platinum crucibles are costly, and a small sample can reach chemical equilibrium in the furnace more quickly, cutting down experiment times.

Namur is interested in what happens pre-eruption, deep underground in volcanoes, so technically, the material he and his team are working with could be considered magma rather than lava. He says that understanding how magma behaves in the underground pipework of volcanoes could help scientists better predict how the molten rock makes it to the surface in an eruption and how it behaves afterward.

To create its synthetic magma, Namur’s team uses a mixture of high-purity silicate, oxide, and carbonate powders, including Fe₂O₃ and K₂CO₃. The researchers stir the powders together in ethanol or acetone to make small quantities of faux magma. For larger and more homogeneous quantities, they melt the powders in a furnace at 1,600 °C over a number of cycles.

Namur’s latest study revealed some surprises about the composition of magma and could even aid mining efforts.

By recreating in their furnace the temperature and pressure of a volcanic magma chamber—1000–1040 °C and about 1000 times the atmospheric pressure of that on Earth—Namur and his colleagues found that their molten material split into two immiscible liquids: one rich in silica and one rich in iron. This observed split solves a conundrum about how certain volcanic landscapes are mysteriously rich in iron ore, the team contends.

Namur speculates that the finding could help mining operations find new iron-ore deposits: Working out what eruption conditions are needed to create this type of immiscibility could help prospectors predict where to find iron-rich ores. So far, Namur says, his team has learned that “to reach immiscibility, we need water in the magma and oxidizing conditions.”

All this work raises the question of how well synthetic lava and magma replicate the real deal, coming from actual volcanoes at scales many orders of magnitude larger than even those used by the Syracuse program. While sugary syrup seems miles away from a volcanic outpouring, the results are translatable, Columbia’s Lev argues. For instance, “Syrup is actually close in its viscosity to the runny lavas of Hawaii when they are still very hot,” she says.

For the wider volcanology community, these lab simulations provide crucial data and save geoscientists the prospect of dangerous fieldwork. “Volcanic processes happen fast and at high temperature, and in the wild can be both difficult and dangerous to access,” says David Pyle, a volcanologist from the University of Oxford. “Laboratory simulations of lava flows have the advantages that they can be carefully controlled, observed, and measured, and even if they are run on a physically much smaller scale than the real-world examples, offer scientists a safe and reproducible way of testing their simplified physical and computational models of flowing lava,” he says.

Karson says he works hard to make Syracuse’s experiments relevant for the real world. “Our large-scale experiments create lava flow lobes that are within the range of those that form in natural pahoehoe flows,” he says. “Natural flows are not just giant continuous sheets,” he adds. Rather, they are a pile of small lobes, similar to the ones he makes.

But he also contends that experiments on all different scales are necessary to form a more complete picture. “Our
experiments bridge the gap between field studies of natural lava flows, which are dangerous and impossible to make measurements on, and other types of experiments,” he says. These other experiments include studying the physical properties of much smaller amounts of lava and analog experiments like those Lev has done, as well as numerical models.

Like all models—whether analytical, computational, or experimental—lab lava studies are best thought of as offering a “toy view” of the natural world, Pyle says. “But well-designed experiments give us a chance to observe, close up, things that we would never be able to see in nature,” he adds. “Best of all, the by-products of the lava pours are wonderfully glossy pieces of volcanic glass. And who wouldn’t want one of those on their mantelpiece?”

As the eruption at Kilauea continues, and the lava flow pushes ever onward, it’s likely that lab-made lava and magma might one day inform emergency personnel’s efforts to limit lava damage and perhaps even save lives and properties from destruction.

Katharine Sanderson is a freelance contributor to Chemical & Engineering News, the weekly newsmagazine of the American Chemical Society. A version of this story appeared in C&EN.