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UC President’s Postdoctoral Fellow uses fractals to study erosion

In 1975, mathematician Benoit Mandelbrot named a pattern in nature that people had been noticing forever, a term for the repeating shapes within shapes that could be found in trees, crystals, even rivers and streams. The word he coined was “fractal,” and the mathematics he established for this complex geometry has given mathematicians a way to approach the evolution of complicated, intricate natural systems.

Working with UC Santa Barbara mathematics professor Bjorn Birnir, Therese Basa Landry, a 2026 UC President’s Postdoctoral Fellow, is using the power of fractals to discover the math underlying complex natural phenomena, in this case erosion.

“With Bjorn, I’ve gotten a chance to develop mathematical models for understanding how some of these phenomena happen in nature,” said Landry. Much of her work prior to the fellowship was theoretical, she added, and since receiving her Ph.D. in mathematics from UC Riverside, she built her toolkit with collaborations at the Fields Institute and at the Simons Laufer Mathematical Sciences Institute before coming to UCSB.

Landry’s main research focus with Birnir concentrates on developing a rigorous mathematical theory of erosion, the geological process by which landscapes are worn away, the material transported by wind, water and other natural forces over time. Erosion turns mountains into plains, carves valleys and pushes rivers through a landscape. A deep understanding of erosion could help scientists, researchers and engineers predict risks associated with erosion, optimize structures and vegetation in the face of it, and strengthen the understanding of how landscapes evolve over time.

Erosion as an optimal transport phenomenon

Take a look at nature and you'll find fractals everywhere: in trees and plants, lightning, waves.

"We all live in a big fractal," said Birnir, who also chairs the Department of Mathematics and directs the Center for Complex and Nonlinear Science at UCSB. Even our own bodies' branching networks of blood vessels or the bronchi and bronchioles in our lungs follow this intrinsic pattern, which is the most efficient shape given the forces involved.

Zoom out from the landscape and these shapes exist there too, from mountain ranges to river networks, sculpted by the consistent, most efficient application of forces. The main sculptor here is erosion.

This natural scenario is the perfect real-life analog for a thought experiment first conceptualized by French mathematician Gaspard Monge in 1781. Called the optimal transport problem, it challenges mathematicians to calculate what would be the most efficient way to transport mass from a pile of dirt to a target location. Originally devised in the context of earthworks for the French military, the problem is now relevant to applications in a variety of fields including economics, fluid mechanics, and machine learning in addition to pure and applied mathematics.

"Erosion is actually executing this optimal transport," said Birnir, whose work involves teasing out the mathematics that underlie natural physical phenomena. "It's taking dirt that lives somewhere up on the mountain and moving it down the watershed to another place where it deposits it, and it's doing this as an optimal transport." Multiply this process and repeat, and the resulting shape on the landscape is a fractal.

But how can these concepts, including newer ones governing optimal transport and fractals, be formalized into a rigorous mathematical framework that describes erosion? This will be the work for Landry and Birnir. They'll be pulling together and building on earlier work that describes and interrogates aspects of erosion, such as turbulent flows and landscape evolution as well as theorems for modeling erosion developed by Birnir and Landry as well as other collaborators.

They'll be working with fellow researchers at UCSB and with colleagues at Los Alamos National Laboratory to inform and test their theory and connect it to tangible phenomena. The goal is to be able to turn their theory onto a variety of real-world applications, from enabling a better understanding of how landscapes evolve over time to being able to predict with accuracy the likelihood of rain and flood-driven disasters such as landslides and debris flows.

This is just the beginning for Landry, who is also hoping to inspire other Asian American/Pacific Islander students to consider a career in mathematics. A daughter of Filipino immigrants and a nontraditional student, she started her professional career as a high school math teacher in Los Angeles after receiving her bachelor's in science in physics from Brown University. It was a way of recognizing the opportunities life in the U.S. presented and giving back to her community.

"I remember when my parents would tell me in the Philippines, to access all these opportunities, you would have to have so many family connections," she said. "That's the thing about having so much opportunity here. So when I first graduated it seemed that a natural way to give back would be to teach in an inner-city high school."

She continued on to obtain her master's degree in mathematics from San Francisco State University and her doctorate from UC Riverside. With the UC President's Postdoctoral Fellowship she hopes to teach in the UC system, one of the few but growing number of Filipino faculty teaching STEM.

"Having this whole new world of getting to be a kind of ambassador-mathematician is really exciting," she said.

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