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An Underwater Frontier

Occasionally, planet Earth will grab the headlines: Underwater volcanic eruptions send ash into the air, or earthquakes generate massive waves that send people running for safety as the rest of us watch, stunned. Other processes, meanwhile, happen so slowly as to be unnoticeable: oceans widen, mountains grow.

All these processes are due to plate tectonics, the glide of solid rock “plates” over viscous mantle softened by primordial heat leftover from planet Earth’s formation. How these plates bump into, slide along or under, or separate from each other dictates the natural resources, hazards and landscapes around us … and beneath the waves.

But while the theory of plate tectonics has been widely accepted for more than half a century, fundamental mysteries remain beneath our feet. How do these plates form? How do they interact with the underlying mantle? How do they move? Earth scientists, led early on by plate tectonics pioneer, UC Santa Barbara Professor Emerita Tanya Atwater, have “the basic framework of understanding,” said UCSB structural seismologist Zach Eilon, but many details remain poorly understood.

“Our understanding of some of these fundamental processes is still incredibly young,” Eilon said. “There are people that I’ve worked with who remember learning from textbooks that pre-date the theory of plate tectonics.” Nowhere is this more true than in the oceans, where, as Eilon puts it, “the tectonic plates are covered by miles of water, that have kept oceanic seismologists decades behind our land-based friends.”

The relative newness of plate tectonics theory, combined with modern advances in ocean-bottom seismic technology, puts Eilon in a research sweet spot: Many questions to ask and the means to find the answers. His target? The cradle of the tectonic plates: the underwater mid-ocean ridges. As a recipient of a National Science Foundation Faculty Early CAREER Award, he'll be peering into the planet with an array of seismographs to be deployed at the very bottom of the eastern Pacific Ocean.

"I'm absolutely thrilled to receive this award," Eilon said. "I'm very thankful to the NSF for supporting an early-career principal investigator with an experiment of this magnitude."

"I congratulate Zach Eilon on receiving an NSF CAREER award," said Pierre Wiltzius, dean of mathematical, life and physical sciences at UCSB. "This honor, given to promising young scholars at the beginning of their careers, will help him conduct research that promises to advance our understanding of tectonic plate motion. I couldn't be prouder to call him a member of our faculty, and I look forward to his continued success."

The Factories of the Deep

Located a few hundred miles west of the Galápagos Islands at the bottom of the equatorial Pacific Ocean, the Galapagos Triple Junction is where three tectonic plates touch: the Cocos, the Nazca and the Pacific plate. Here, as the plates move away from each other, Earth's crust is being actively created as magma from the planet's hot mantle wells up, cools and hardens in a continuous underwater plate-building process.

"Mid-ocean ridges like these are the factories where 70% of our planet's surface is created," Eilon said, in a "constant conveyor belt" of material being pushed up as plates separate.

"Without this process, we don't have plate tectonics," he said. Yet we know very few details of what's going on, largely because it occurs roughly a mile and a half (2.6 kilometers) beneath the ocean's surface, where seawater, cool temperatures, high pressure and darkness conspire to create a difficult environment for the observation of this most fundamental Earth process. In fact, Eilon said, we know more about the surface of the moon than we do about the seafloor of this planet.

But, with advances that have increased the durability, longevity and sensitivity of instrumentation, we are poised to understand in greater detail the interior workings of these ridges.

Eilon's task involves deploying two arrays of temporary ocean bottom seismometers around the triple junction in the first experiment to record energy from earthquakes in that geologically active area. Not only is there a meeting of three plates, he said, this experiment footprint is large enough to span segments of two quite different mid-ocean ridges which provide Eilon a "natural laboratory" to understand how these systems work.

"We are specifically hoping to learn how the mantle rises, melts and produces new tectonic plate material at the mid-ocean ridges," Eilon said. To do this, he will lead teams of scientists on four research cruises over three years to deploy the seismographs and leave them to gather data for 12 to 15 months, retrieve them, and do it again.

"We use the information they record to construct 3D images of the Earth's interior immediately beneath where that array was," he continued. The data gathered, and Eilon's expertise with multiple analytical methods, can also reveal characteristics such as temperature, rock fabric and composition, and can reveal flow patterns in the mantle, which in turn illuminate the forces responsible for the movement of the tectonic plates. As part of an international research collaboration, this data will be available to scientists worldwide.

When not cruising the open ocean or analyzing data, Eilon will also be involved in the project's educational component, which aims to strengthen the pipeline into marine geophysics through a combination of outreach, training and network building. This will include classroom activities for local high schoolers, as well as field training for early career faculty, graduate students and undergraduates.

"One of the problems with this particular sub-branch of marine geosciences is that it's quite exclusive," he said. "Like with lots of sciences, we struggle with recruiting people from demographics that have been historically underrepresented and underserved."

Data shows few new scientists are entering the field as project leaders, a phenomenon Eilon believes is partly due to the difficulty in gaining the skills needed to run a research cruise. By training inexperienced but interested junior scientists in

both the logistical and mentorship aspects of conducting a successful research cruise, he hopes that more marine geoscientists will be around to unravel the mysteries that lie beneath the waves.

Things are still just getting started.

“We’ve really come a tremendous way, and the improved technology is opening up these incredibly exciting avenues of possible research,” he said. “The potential for more of these experiments is enormous.”

About UC Santa Barbara

The University of California, Santa Barbara is a leading research institution that also provides a comprehensive liberal arts learning experience. Our academic community of faculty, students, and staff is characterized by a culture of interdisciplinary collaboration that is responsive to the needs of our multicultural and global society. All of this takes place within a living and learning environment like no other, as we draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.