UC SANTA BARBARA

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A Remarkable Impact

It’s a rare few scientists whose discoveries are so monumental that they leave an indelible mark upon society. Among them is UC Santa Barbara’s Tanya Atwater, who has watched her groundbreaking research transition into common knowledge.

Now, the Geological Society of London has awarded Atwater the Wollaston Medal for her contribution to the theory of seafloor spreading and the geology of western North America. This medal is given to geoscientists who have had a significant influence through a substantial body of excellent research in pure and applied aspects of earth science. First awarded in 1831, the Wollaston Medal is the society’s highest honor.

“It’s a little late,” chuckled Atwater, who has technically been retired for 14 years now. “I could’ve used it a while ago.” Atwater is accustomed to sweating hard for recognition. She was a mover and shaker at a time when women had to fight their way into the scientific profession.

Atwater’s analysis of magnetic signatures helped describe seafloor spreading, a major component of plate tectonics. She unearthed the geology and geography of California, describing the San Andreas Fault and the subduction of the Farallon plate beneath North America.

Always looking to inspire others, Atwater dove headlong into education outreach. She worked with teachers, museums, film crews — anyone interested in spreading the good word about plate tectonics. As part of the scientific advisory board for K-12

curricula, she championed geology as a grade-school subject, and once-revolutionary theories are now familiar lessons in science classes throughout the country. Although she officially retired, Atwater continues her education outreach and still helps to lead field trips for geology students.

“I am so pleased and honored to congratulate Professor Tanya Atwater on her receipt of the Wollaston Medal,” said Chancellor Henry T. Yang. “This major recognition from her peers places Professor Atwater among the ranks of eminent scientists such as Charles Darwin, Charles Lyell and William Smith. Her pioneering research on plate tectonics has expanded our understanding of planet Earth, and her continuing achievements are a source of pride and inspiration for our entire UC Santa Barbara community.”

“I congratulate Tanya Atwater on this monumental achievement,” added Pierre Wiltzius, executive dean of the College of Letters and Science and Susan and Bruce Worster Dean of Science. “Her contributions to the university and the field of geology throughout her illustrious career have been numerous and profound.”

The right time

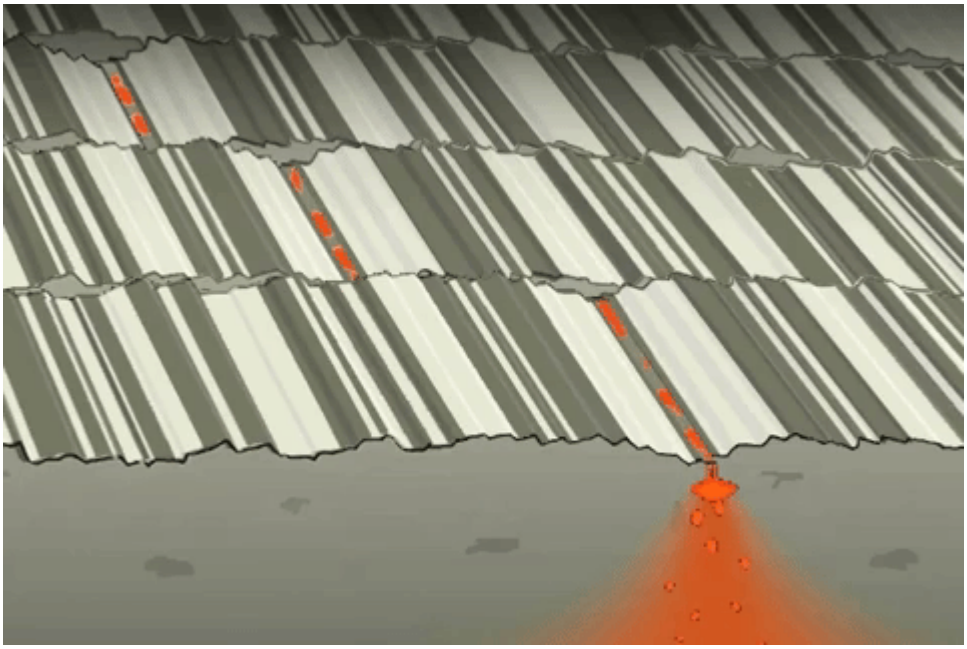
Although it’s now taught in elementary school, the theory of plate tectonics arrived relatively recently. Before the 1970s, many geologists were fixists, believing that the continents were immobile, or fixed, on the planet’s surface.

To be sure, the idea of continental drift had been kicking around since Alfred Wegener first proposed it in 1912, but it was mostly shunned. The thing was, no one knew what was going on under the ocean. “Scientists knew there were rocks beneath the ocean,” Atwater said, “so how could the continents plow through the rocks? They just couldn’t get their minds around how the continents could be moving.”

It took all of two minutes to convince Atwater that the theory of plate tectonics was a winning horse. After finishing her undergraduate degree partly at the Massachusetts Institute of Technology and then UC Berkeley, she took an entry-level geophysics job in Chile. One day, she attended a marine geophysics lecture reporting the magnetic patterns that were being discovered in seafloor rock.

Local magnetism can affect the measurements of Earth’s magnetic field ever so slightly. Scientists and the military started noticing these magnetic anomalies while

conducting surveys of the ocean late in World War II and the early Cold War, as they scouted for submarines. Eventually, researchers began to compile quite a record.



As new crust spreads from mid ocean ridges, it’s magnetic signature records the strength and orientation of Earth’s magnetic field. Because the magnetic field changes, the magnetic anomaly profile of the seafloor forms stripes stretching away from the spreading center.

Photo Credit: Atwater Animations

“This profile in the South Pacific was so symmetrical and so clear,” Atwater recalled. “The reversals of the Earth’s magnetic field matched the stuff they’d seen on land so well — and no one has ever come up with any other way to explain the stripes except seafloor spreading.”

Seafloor spreading was the key to solving continental drift, she realized. The continents don’t need to plow through the oceanic crust if the seafloor itself moves out of the way.

“I just went, ‘Wow, there’s a revolution going on and I’m missing it.’”

A field in disarray

Atwater quickly applied to a doctoral program at Scripps Institution of Oceanography in San Diego. “The plate tectonics revolution arrived there two weeks before I did,”

she recalled.

Geologist Fred Vine, then at Princeton, had just given a lecture about magnetic anomaly profiles and plate tectonics. So, when Atwater arrived at Scripps to begin her Ph.D. work, the whole place was in disarray. “This august oceanography institute had all these records rolled out on the hallway floors,” she said. “Everybody was just so excited.”

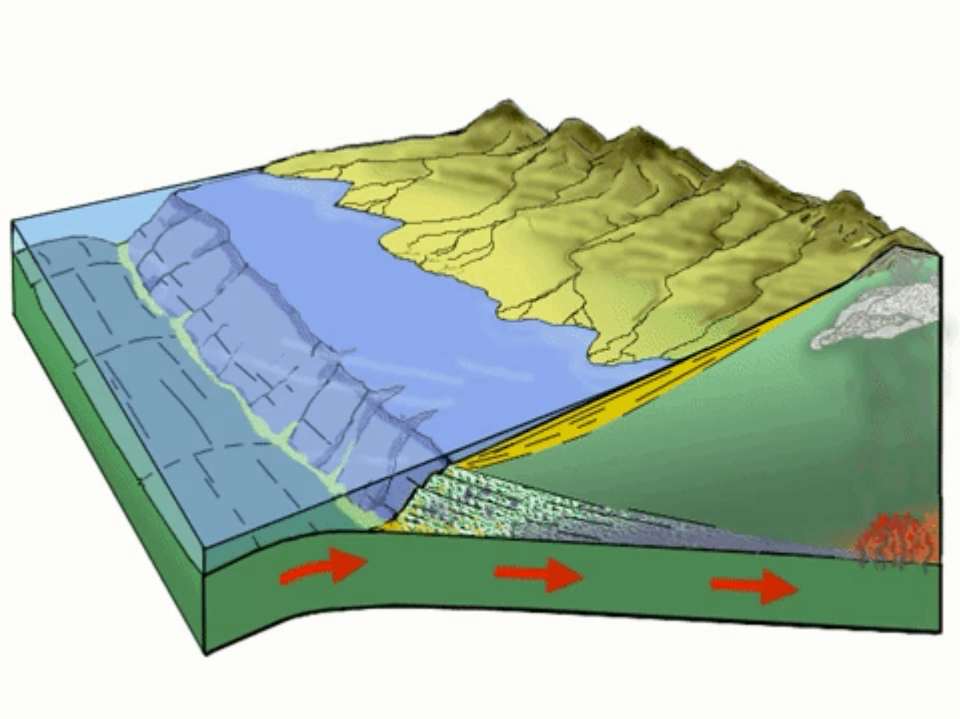
Scientists and the military had been collecting magnetic anomaly profiles of the seabed for years since it was relatively easy to do. But they were full of unreadable wiggles, so they often sat rolled up on shelves. Suddenly, researchers realized that these records of the Earth’s magnetic field were their best tools for uncovering the geologic processes happening deep beneath the waves.

Atwater devoted many months of her life to deciphering these records. “It wasn’t very hard to make sense of them once we had the key,” she said.

The stripes of magnetic signatures told a story of crust spreading outward as new crust emerged from rifts in the centers of the oceans. The width of these stripes could even tell scientists how quickly the crust was spreading. Much like how Newton’s laws of gravity demystified the motions of the heavenly bodies, the magnetic anomaly profiles were elucidating the motions of the Earth’s surface plates.

The San Andreas

The magnetic anomaly profiles off of California were particularly clear. The trouble was, there was only one side of the pattern. It was almost as though the spreading center was under North America. Atwater noticed that this irregularity occurred only in the zone spanned by the San Andreas Fault, which scientists were fairly sure was a plate boundary by that time.



Oceanic crust dives beneath a continental plate as a subduction boundary. The process gives rise to a chain of volcanoes called a volcanic arc.

Photo Credit: Atwater Animations

Meanwhile, her colleagues studying the continents had a quandary of their own. Generally, when a continental plate like North America meets an oceanic plate like the Pacific, the dense ocean crust dives under the continent forming a subduction zone. And while it was clear that the San Andreas was the boundary between the two plates, it is a strike-slip fault, where motion is primarily horizontal.

“I realized that we could answer a bunch of these questions the terrestrial geologists had about the San Andreas with this seafloor data,” Atwater said.

She also recognized that cracking these quandaries would require obtaining the ages of each stripe in the magnetic anomaly profiles off the California coast. But it seemed there was no way to get them. The researchers needed more precise dating techniques, but all the rocks were beneath the ocean floor, under thick layers of mud.

Fortunately, deep-sea drilling was on the rise, and the techniques used to drill for oil and natural gas could easily penetrate the mud and sample the rock below. Unfortunately, the deep ocean lava rock itself was not amenable to available dating

techniques. But there was another way. By identifying the fossil microorganisms in the first layer of sediment, the scientists could discern when the rock had first been covered, and thus when it had formed. The case was cracked.

For more than 100 million years, the North American plate had been running over the oceanic Farallon plate. Around 25 to 30 million years ago, it finally reached the spreading boundary between the Farallon and Pacific plates, leaving only the western side of the record for scientists to find in the 20th century. The Juan de Fuca plate, in the Pacific Northwest, and the Cocos plate, west of Central America, are remnants of the ancient Farallon plate.

It was only after the subduction of the spreading center between the Farallon and Pacific plates that North America could begin interacting with the Pacific. And thus was born the San Andreas Fault, which stretches from the Gulf of California to Cape Mendocino.

In 1970, Atwater authored a paper that laid all this out. “To this day, there are generations of geologists who cite that paper I wrote as the definitive text where you learn about plate tectonics,” she said.

She immediately departed from Scripps for a lecture tour around the Western U.S. to spread the news about seafloor spreading, plate tectonics and the San Andreas Fault. The room filled up wherever she went.

Not only had Atwater made a major breakthrough in geology but she was also the only woman in geophysics, as she recalled. When asked if it was lonely, her response was, “Uh … it was fun.

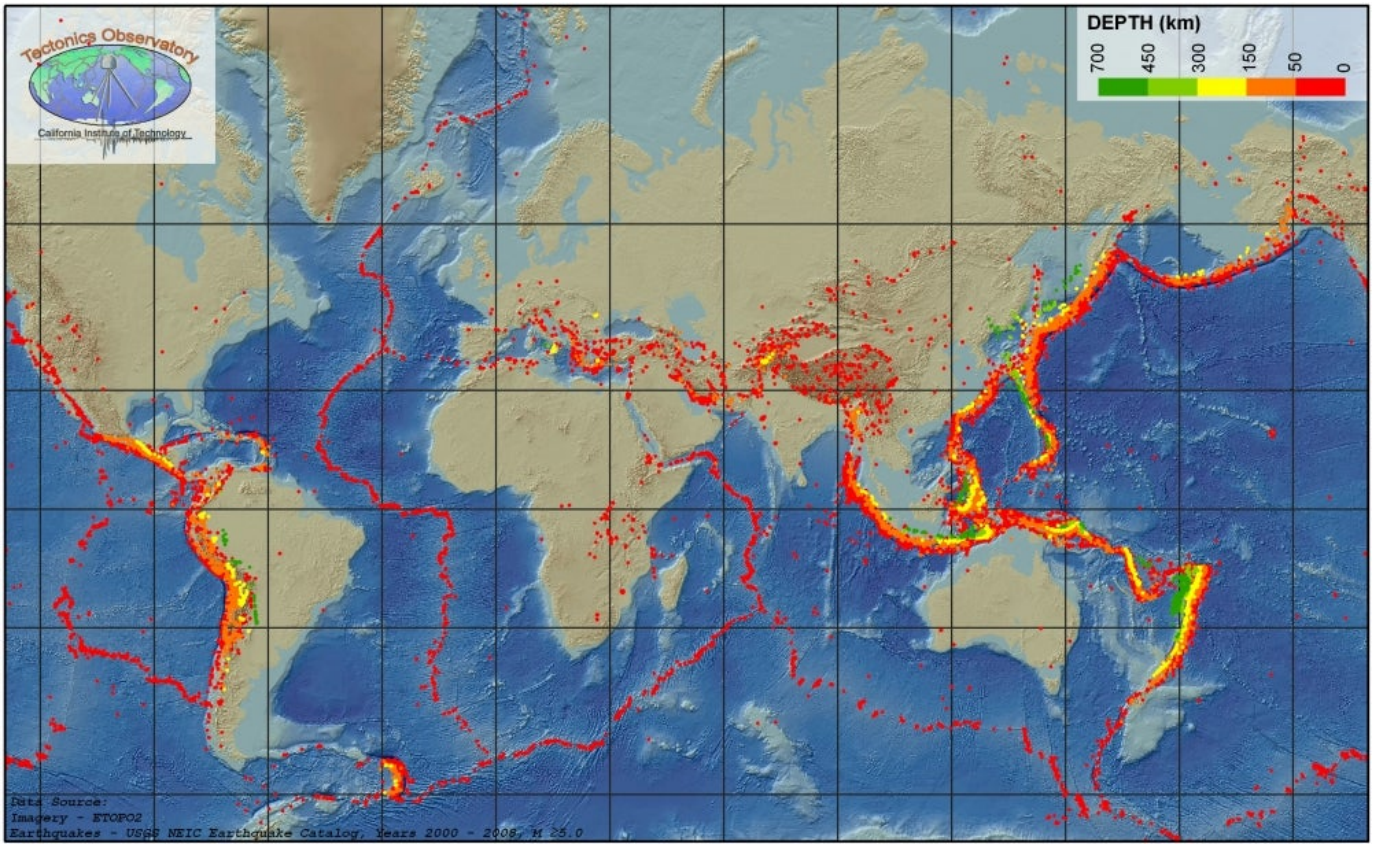
“I was right out of Berkeley, and women didn’t wear suits in those days,” she continued, “so there I was, in my flowers and beads and bare feet, being a total hippie in these meetings full of men in suits.”

A long time coming

Plate tectonics is a fundamental aspect of geology on Earth. So how is it that these questions weren’t solved until the 1970s?

“The answer is essentially technology,” Atwater said. “We just didn’t know what was underwater in the ocean. I hate to give wars any credit, but in World War II, all sorts of things were developed to try to find the submarines that were wreaking such

havoc on shipping. This included the magnetometer.” This period also saw the refinement of deep-sea echo sounders, which could accurately measure the ocean’s depth using sound and a precise clock.



A map of earthquakes from 2000 to 2008 of magnitude of 5.0 and above. The locations reveal the boundaries of Earth’s major tectonic plates.

Photo Credit: LISA CHRISTIANSEN, CALTECH TECTONICS OBSERVATORY

What’s more, the signatories of the nuclear test ban treaties needed a way to monitor compliance. So the United States sent a standard set of seismometers to many institutions around the world asking only that they send the records back every few months, Atwater explained. Suddenly, we were monitoring all the earthquakes in the world.

“And have you seen a map of the earthquake locations?” Atwater asked. “They just outline the plates perfectly. It’s like a connect-the-dots game in kindergarten.”

Professor Atwater

In 1972, Atwater joined the faculty at MIT. While there, she was able to visit the seafloor features that, until then, had been merely data on charts. MIT has a very active joint program with the Woods Hole Oceanographic Institution, the home base for Alvin, the famous deep-sea submersible.



Atwater ventured to the to the seafloor to study, first hand, geologic features she had known only from data.

Photo Credit: COURTESY IMAGE

“We decided after a while that everybody who studies the ocean floor needs to go down there,” Atwater said. “It’s an instant education to see the seafloor with your eyes. It doesn’t even matter if you mess up the data; you’re changed for life.”

Deep-sea adventures aside, Atwater had a tough time as an assistant professor. “The whole setup was for a man’s career,” she reflected. Young academics are often

pushed toward productivity overdrive, but this is precisely when many women choose to have kids. “It was very inappropriate for a woman if she wanted to have a family just when you’re supposed to be powering up the science highway.” The two demands were hard to reconcile.

Society still struggles to address the work-family conundrum that young women face. Atwater, for one, thinks it will always be a challenge. Fortunately for her, MIT’s geology department chair was ahead of the curve on this matter, and Atwater’s career continued to blossom alongside her young son.

But after seven years in Boston, the Los Angeles native was growing weary of the East Coast.

In 1980, she was visiting her family for Christmas in Santa Barbara, where they had moved while she was in high school. “I went out to the university and said, ‘Any chance I could get a job here?’” she recalled. “And they made one for me.”

At UC Santa Barbara, Atwater was able to truly embrace her love of teaching. She always chose to teach one of the intro geology or oceanography courses. “It’s a couple hundred students, and a lot of them are just in there to check off their science requirement,” she said. “But there were always some who just caught fire, and it was so exciting to be able to take that ride with them.” She created an honors section for particularly enthusiastic students and continued leading field trips years after she stopped officially teaching classes.

Sharing her passion

Atwater began leading teacher workshops on plate tectonics in the 1980s and ’90s. Geology was finally being added to the required curriculum, and many teachers hadn’t a clue about the subject, Atwater recalled.

She also became more involved with education and policy outreach around 2000, after being elected to the National Academy of Sciences. She served on the academy’s advisory committee for K-12 science standards. One victory was finally earning earth and space science — previously regarded as a stepsister of physics and chemistry — its own place among the standards.

Atwater was eager to consult with anyone who would ask, and she struck up some particularly fruitful relationships with the natural history museums in San Francisco,

Los Angeles, San Diego and Santa Barbara. She also helped make a movie for a museum on the Chesapeake Bay, and she helped rework the signs for the Earthquake Trail in Northern California.

Atwater made herself available to publishers and filmmakers alike. She edited a book for Time/Life about plate tectonics, one of a set on earth science. “I’ve stood up in front of lots of camera crews,” Atwater said, “mostly U.S., but also German and Japanese, and talked about the revolution.” In fact, the veteran scientist even won an Emmy for her work on “Geology Across the American Landscape,” released in 2011 as part of a city college educational project.



Atwater uses illustrations, models and animations to bring plate tectonics to life in her presentations.

Photo Credit: UC SANTA BARBARA

During these endeavors, Atwater began to devote more and more time to developing educational materials. She collaborated with John Iwerks — grandson of pioneering Disney animator Ub Iwerks — to create multimedia pieces including videos, illustrations and infographics under the label Atwater Animations.

For years, Atwater spoke about plate tectonics and the excitement of working on this revolution. She continued giving invited lectures, almost always coupling them with a public talk. “Pretty soon the students started saying: ‘What’re you talking about? I learned about this in kindergarten,’” she recalled. The new generation thought plate tectonics was so obvious that they couldn’t see how scientists were ever hung up on the matter.

Atwater considers herself profoundly fortunate to have made such an important contribution to human knowledge and to have helped so many students discover their passions. “I was just in the right place at the right time with the right tools,” she said. “For a discovery like the San Andreas, that doesn’t happen more than once in a lifetime.”

Tanya Atwater is a revolutionary scientist and natural-born teacher; at her core she is curious, enthusiastic and eager to share the spirit of discovery with any kindred spirit. “Sure, I do plate tectonics and the San Andreas and the ocean floor,” she said, “but what I really do is try to make sense out of the world and help as many people as I can also see the logic of it.”

“It’s so exciting when you break through,” she said. “I love that, and I just love it when I see it happen for somebody else. It’s such a privilege to help people discover.”

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.