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Observing the Roiling Earth

PASADENA, Calif. - In the 1960s the theory of plate tectonics rocked geology's world by determining that the first 60 miles or so of our planet--the lithosphere--is divided into about a dozen rigid plates that crawl along by centimeters each year. Most manifestations of the earth's dynamics, earthquakes and volcanoes for example, occur along the boundaries of these plates.

As a model, the theory of plate tectonics continues to serve us well, says Jean-Philippe Avouac, a professor of geology at the California Institute of Technology. But while plate tectonics provides a powerful description of the large-scale deformation of the earth's lithosphere over millions of years, it doesn't explain the physical forces that drive the movements of the plates. Also, contrary to the theory, it's now known that plates are not perfectly rigid and that plate boundaries sometimes form broad fault zones with diffuse seismicity.

Now, thanks to a $13,254,000 grant from the Gordon and Betty Moore Foundation, Caltech has established the Tectonic Observatory, under the direction of Avouac, with the ultimate goal, he says, of "providing a new view of how and why the earth's crust is deforming over timescales ranging from a few tens of seconds, the typical duration of an earthquake, to several tens of million of years."

But it's not the only goal. "Most of the outstanding questions in earth science concern processes that take place at the boundaries of the earth's tectonic plates," says Avouac, so the observatory's scientific efforts will be centered around major field studies at a few key plate boundaries in western North America, Sumatra, Central America, and Taiwan, with the goal of answering a number of questions, including:

--Tectonic plates move gradually when viewed on large timescales, but then sometimes undergo sharp "jerks" in speed and direction. What's the cause?

--Because earthquakes can be damaging events to humans, it's important to know: what physical parameters control their timing, location, and size?

--Subduction zones, where oceanic plates sink into the earth's mantle, are needed to accommodate and perhaps drive plate motion. How do these subduction zones originate and grow?

"We plan to take advantage of a number of new technologies that will allow us to measure deformation of the earth's crust and image the earth's interior with unprecedented accuracy," says Avouac. The bulk of the grant will be spent on these new technologies, along with acquiring data that will be used to observe and model the boundary zones. In addition to seismometers, other equipment and data that's needed will include space-based GPS, which will allow geologists to measure the relative velocity of two points on the earth's surface to within a few millimeters each year; satellite images to map displacements of broad areas of the ground's surface over time; geochemical fingerprinting methods to analyze and date rocks that have been brought to the surface by volcanic eruptions or erosion, thus helping to characterize the composition of the earth far below; and of course, massive computation to analyze all the data, along with advanced computational techniques, "to allow us to develop models at the scale of the global earth," says Avouac.

"The breakthroughs we will achieve will probably result from the interactions among the various disciplines that will contribute to the project," he says. "We've already begun our effort, for example, by imaging and monitoring seismic activity and crustal deformation along a major subduction zone in Mexico. As I speak, geologists are in the field and continuing to install what will be a total of 50 seismometers."

Few institutions are capable of mounting this kind of sustained, diverse effort on a single plate boundary, he says, or of mining data from multiple disciplines to create dynamic models. "That's what Caltech is capable of doing," says Avouac. "We hope to breed a new generation of earth scientist. The Tectonics Observatory will offer students an exceptional environment with access to all of the modern techniques and analytical tools in our field, along with the possibility of interacting with a group of faculty with an incredibly diversified expertise."

The Gordon and Betty Moore Foundation was established in September 2000 by Intel cofounder Gordon Moore and his wife, Betty. The foundation funds projects that will measurably improve the quality of life by creating positive outcomes for future generations. Grantmaking is concentrated in initiatives that support the Foundation's principal areas of concern: environmental conservation, science, higher education, and the San Francisco Bay Area.

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