Point Reyes Fault: Changing Our Bay Area Earthquake Watch

by Sarah Kotcher

Grove’s research is posing new questions as well as providing new clues: If Point Reyes Fault is in fact an active deep-water dip-slip fault, does it have the potential to create a tsunami?
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Many of local fault types. Holly Ryan, research scientist at the USGS and collaborator on Grove’s project, explains the three basic types of faults: normal faults, reverse faults, and strike-slip faults. Faults occur when two separate rock bodies, or tectonic plates, move next to each other in different directions. Normal faults form when two rock bodies pull apart from each other, downward and outward. Reverse faults—which are the opposites of normal faults—form when rock bodies move towards each other, one climbing onto the other’s back. Scientists call both normal and reverse faults “dip-slip faults” because their movement is vertical, either up or down. Dip-slip faults lying offshore near continental margins such as off the coast of Japan create tsunamis: Rock bodies moving up or down vertically in deep water cause a rapid displacement of water that creates a huge wave. Like the massive tsunami that struck Japan in March 2011, the rushing wall of water can move onto shore and wreak havoc, sometimes with very little warning.

Whereas dip-slip faults move vertically, strike-slip faults move horizontally. Because strike-slip faults carry rock bodies past each other on the same horizontal plane, they create very little vertical displacement of water and don’t usually cause tsunamis.

The Bay Area’s three major faults are the San Andreas Fault, the Hayward Fault, and the San Gregorio Fault. All are horizontally moving strike-slip faults. The San Andreas Fault runs for roughly 1200 km through northern and southern California. It acts as a long boundary between the Pacific and the North American Plate and moves 25–35 mm per year—one inch or so. The Hayward Fault lies east of, and parallel to, the San Andreas Fault: It stretches for 66 kilometers and moves approximately 9 mm per year (about one-third of an inch). The Hayward Fault originates in the San Francisco Bay northwest of Berkeley, grinds directly through Hayward and Livermore, and tapers off south of San Jose. The San Gregorio Fault is the least well-known. It splits off from the San Andreas Fault south of Bolinas Lagoon and continues subparallel to the San Andreas, running southward for 240 kilometers before tapering off near Monterey Bay, where it continues to the south as the Hoggs fault. It moves just 3–6 mm per year. Only in Bolinas Lagoon at the split-off point do two of the three faults—The San Gregorio and San Andreas—actually touch at Earth’s surface.

Faults need not touch, however, to put stress or pressure on each other. As points out Brian Stozek, Karen Grove’s research student who recently completed his Master’s degree at SF State, fault activity is much more complicated than that. Explains Stozek, a slim, dark-haired young man who favors fitted jeans and dark hooded sweatshirts, “The (San Andreas) Fault could be slipping and there could be a reverse fault that’s taking into account other stresses. The uplift (of the Point Reyes Peninsula) is not just due to horizontal stresses that are along the San Andreas fault. Stress could be coming in other angles.” Stozek provided this reporter with detail on that complexity. Although most seismic activity happens along large faults, he says, small faults are important because, while they move more slowly than large ones, they absorb and relieve stress from larger faults. They have a part to play in the fault zone, he concludes, but currently that part is little researched, little mapped and little understood.

Years ago, Grove noticed that most movement on Bay Area faults takes place on strike-slip faults, with activity on dip-slip faults being much rarer. “The ratio of strike-slip to dip-slip [activity] in the Bay Area is about 25 to 1,” Grove says. One place that dip-slip faults do appear, however, is around Grove’s main research area: the Point Reyes Peninsula. This unusual activity piqued Grove’s interest and led her to investigate how all the faults in the area affect each other.

Northern California—from the peaks of the Sierra Nevada to the cool waters of the Pacific—is spider-webbed with big and small faults. “Everybody knows this area because of the San Andreas Fault; it’s super famous,” Grove notes. She goes on to explain that the San Andreas Fault is remarkable because it moves more than any other fault in the area—approximately 25 mm per year—and this creates larger and more newsworthy earthquakes. Compared with the Point Reyes Fault, which moves only 1 mm or so per year, the San Andreas is a record-breaking marathon runner.

Although 25 mm per year seems small, Grove insists that it is actually substantial. “If you think about 25 mm per year over 5 million years,” she points out, “it’s a lot.” In order to relieve the stress of that cumulative creep on the San Andreas Fault, she says, a major earthquake must suddenly “catch up” with 5 to 7 meters of movement approximately every 200 years on that fault. The other faults in the area move more slowly, but also must eventually relieve built-up stress. Stozek notes that scientists believe faults have the potential to set each other off, in a domino effect. Looking at the Bay Area’s many faults, each one like a marathon runner connected to all the other runners as if by rubber bands of tautness, elastic earth, one can imagine the potentially disastrous pile-up that could occur if one runner takes a major fall.

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Grove’s husband, Jay Ach, points to a thrust fault—left side moved up relative to the right side—along the coast at Montara Beach.

Photo by Karen Grove

Grove studies the sea floor, looking for clues. She wants to know how the fault moved, if it moved recently, and if it still affects the land above it. She south, to the Point Reyes Peninsula. What makes it such an interesting area for her is the fact that it is a special kind of fault—a reverse-fault, which moves land up and down.

The fault has been active for a long time, and its movements have created a series of uplifts and depressions along the coastline. These uplifts have been important in the development of the region, and they continue to shape the landscape today.

Grove is studying the fault using seismographs, which are devices that detect and record earthquakes. She is interested in the way that the fault interacts with other faults in the region, and how it might affect the area in the future.

She is also interested in the way that the fault affects the land above it. She wants to know if it is still active, and if it could cause an earthquake. She is studying the fault using data from the USGS, and she is also working with other scientists to gather more information.

Grove’s work is important because it helps us to understand how the Earth works, and how it changes over time. It also helps us to predict earthquakes and other natural disasters, and to protect people and property in the region.

The Point Reyes Peninsula is a special place for Grove. She has been studying it for many years, and she is excited about the new findings that she has made. She is looking forward to sharing her research with others, and to seeing what new questions it will raise.

Tertiary-aged sedimentary units

Seismic profile created from bouncing sound waves off of layers beneath the sea floor. Profile oriented southwest (SW) to northeast (NW) across the Point Reyes Peninsula. The Tertiary-aged sedimentary units are visible in a seismic profile. Profile is comprised of two-way-travel time (TWTT in milliseconds); 3000 ms is about 3500 m depth. Left side of profile shows layered Tertiary-aged sedimentary units.

When studying faults on land, geologists can get direct views of the faults and the layers that have been offset by the fault’s movements. These observations are used to estimate how much the fault moves during earthquakes and how often those earthquakes occur. Studying faults buried beneath ocean water is a different challenge that requires less-direct, higher-tech methods to collect data remotely via sonar and drilling.

Sonar is used to collect data over large areas using a ship that can generate sound pulses and record the signal generated after the sound pulse bounces off of layers beneath the sea floor and then returns back to the ship. Sonar data are processed to produce seismic profiles that are images of the layers beneath the sea floor. If the layers are offset, the fault’s location and amount of offset can be estimated. The vertical axis can be converted to depth using density and sonar velocity data obtained by drilling a seafloor well.

Drilling from a ship can collect sediments and rocks from beneath the sea floor. Samples can be “cuttings”—bulk samples that are collected every several meters—or “core”—continuous samples that are collected every few centimeters. In this document, we can use this data to match the sediment/rate type with the layers that are visible in a seismic profile.

Grove is interested in the Point Reyes fault is that (the computerized) model of the interaction between the San Andreas and San Gregorio faults showed no uplift of the Point Reyes Peninsula. The model did not agree with (Grove’s) work, which showed uplift rates as high as 1 mm per year. Thus, we plan to rerun the model, adding the Point Reyes Fault (data) that bends to the west around the Point Reyes Peninsula causing uplift. Grove and Stozek believe that works their newly compiled data in place, Parsons’ model will mirror the movement and uplift that Grove has found and that she predicts will continue in the Point Reyes region. This will support her hypothesis that the Point Reyes Fault is active and that it both affects and reacts to other faults in the region.

Grove, Stozek, Ryan, Parsons, and the USGS are all interested in confirming any activity on the Point Reyes fault because this would place it on the new state hazards maps coming out in 2012. “Reducing fault trends (by adding new data) is probably going to require edits to the (earthquake models) and tsunami hazards off the Pacific coast,” Grove adds.

Scientists and researchers are anxious to forestall any earthquake that will affect the heavily populated and seismically-active Bay Area. Fault interactions that set each other off would necessitate revisions to current hazard warning. Stozek recalls an earthquake in Alaska a decade ago: “There was a big earthquake that started on a strike-slip fault and propagated to... a reverse fault. It was like a domino effect.” Evidence from the Grove lab suggests that the many small and large faults in the compact Bay Area could create similar potential interaction.

Grove’s research is posing new questions as well as providing new clues. If Point Reyes Fault is in fact an active deep-water dip-slip fault, does it have the potential to create a tsunami? Grove considers it possible, although the wave action would not be as large as the recent one in Japan. Historically, scientists have predicted potential tsunami activity in the Pacific Northwest but not in the Bay Area. As Stozek points out, “If Point Reyes is indeed an active dip-slip fault, it is, as Grove points out, “One more... active structure to add to the (Bay Area’s) earthquake risk (model).” Although the Point Reyes Fault moves infrequently, its links to more quickly moving faults could be significant.

Grove, Stozek, and Ryan do believe that Bay Area faults interact. As they further research small active faults in the San Andreas zone, their finding will surely expand scientific understanding and improve earthquake forecasts. However, until Stozek finishes compiling enough data points from the old and new research to impact Tom Parsons’ USGS model, Grove says, and until Parsons incorporates the data into his model, it will continue to spit out flawed results. The update, she adds, “Isn’t going to solve everything. But [it will] add one more piece to the overall understanding” of how all the faults in the area—constantly pushing, stretching and stepping on each other—will react when the next one of them takes its next big fall.