SEISMOLOGY

Eavesdropping on Faults to Anticipate Their Next Move

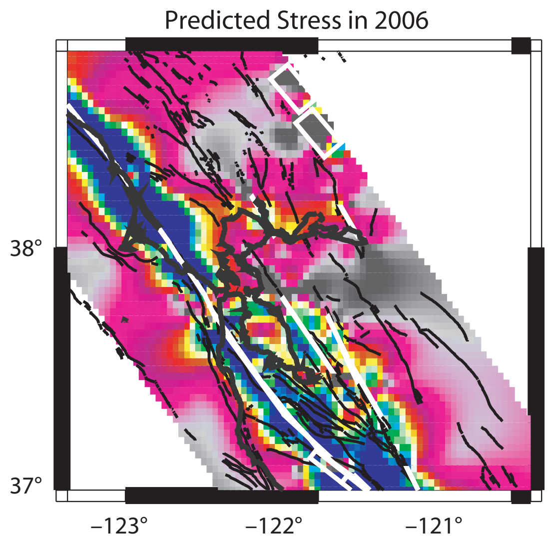
Any active earthquake fault talks to its neighbors, urging some to rupture and cautioning restraint among others. The language of faults is stress (*Science*, 22 October 1999, p. 656). The more of it a fault hears, the more likely the fault is to fail, causing an earthquake; take away the stress, and a fault's failure is delayed. Seismologists studying this language of stress have now come out with their most comprehensive attempt to reconstruct past conversations among faults, with an eye toward forecasting where the next moderate to large quakes will strike. Drawing on 160 years of quake history, this latest model builds the most detailed picture yet of present-day crustal stress across the San Francisco Bay area. It's a cautionary picture for residents of the East Bay.

The Bay Area effort "is the first attempt to build a complete model" of evolving crustal stress, says Roland Burgmann of the University of California, Berkeley. "It's an important step and really is the way to go with earthquake hazard forecasting."

Forecasting stress on faults is something like forecasting the weather using computer models. Both involve Earth systems that evolve over time, given relevant driving forces. In the Bay Area stress model described by seismologists Fred Pollitz, William Bakun, and Marleen Nyst of the U.S. Geological Survey (USGS) in Menlo Park, California, in the 30 November online *Journal of Geophysical Research*, the system is a 100-kilometer-thick block of crust and underlying mantle. It spans the 130-kilometer-wide boundary where the great Pacific tectonic plate is trying to push past North America. The model's chunk of Earth has a San Andreas fault slicing through the upper crust just west of San Francisco, with secondary faults splaying off the San Andreas to the east.

The Menlo Park model also includes the usual processes that determine how high stress gets at any one spot. The two plates move by each other while locked together, deforming the crustal block as if it were so much rubber and steadily loading stress evenly across it. Episodically, earthquakes release and redistribute some of that stress. When a segment of fault ruptures, it relieves stress around the fault—forming a "stress shadow"—but adds stress to the crust beyond the ends of the ruptured segment.

Unlike its predecessors, the Menlo Park model's lower crust and mantle can not only deform as stress changes but also slowly flow, redistributing crustal stress farther afield and weakening a stress shadow faster than in previous models. Pollitz also included 15 earthquakes since 1838, not just the great San Francisco quake of 1906.



Stress quilt. Earthquakes have cast "shadows" of low stress (blue) over the Bay Area, but growing pockets of high stress (gray) remain.

With its greater realism, the Menlo Park model painted a fairly accurate picture of stress accumulation, to judge by where quakes struck. All but one of the 22 moderate or large quakes of the past 160 years struck on faults the model indicates were under higher-than-average stress. The 1906 quake started in a high-stress area, according to the model. The huge 1906 stress shadow shrank back across many area faults, which presumably triggered the jump in seismic activity around 1980. And there have been no substantial quakes in the sizable shadow that the model predicts was cast by the 1989 Loma Prieta quake.

In the model's rendition of current stress, two areas of highest stress stand out. Each runs east-west, with its western end overlapping the Rodgers Creek fault north of the bay and the northern Hayward fault (essentially the southern extension of Rodgers Creek) just east of the bay, around densely populated Oakland and Berkeley. In 2002, the Working Group on California Earthquake Probabilities established by the USGS gave the Hayward–Rodgers Creek fault its highest probability for a single fault.

Despite reservations about some details, seismologist Robert Simpson of USGS in Menlo Park (not a co-author of the paper) calls the new stress map "quite an impressive achievement." Such modeling could point to the most likely places for the next quakes, but researchers will still have to do more than eavesdrop if they are going to forecast not just where, but when, the next quake is going to strike. –RICHARD A. KERR

CREDIT: F. POLLITZ