A Better Fit for the Plate Tectonic Puzzle

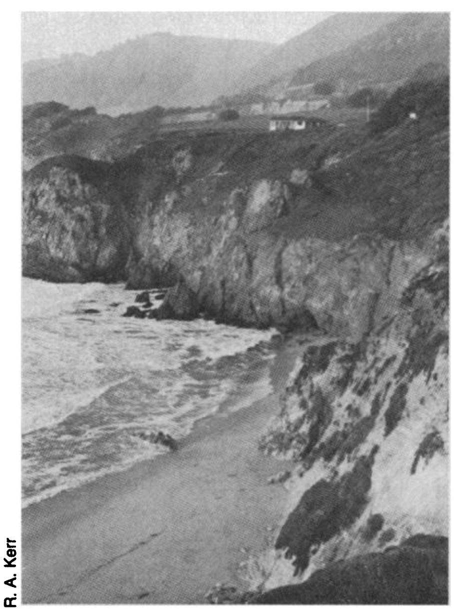
Reanalysis of geophysical data helps reconcile estimates of San Andreas fault motion and reduces the earthquake hazard

For 15 years there was no agreement on how fast the plates are moving along one of the world's most studied plate boundaries, the one in California between the North American and Pacific plates that is called the San Andreas fault. But a recent reanalysis of evidence from the sea floor greatly reduces and possibly eliminates the discrepancy between direct, land-based measurements of recent plate motion and more indirect, marine measurements of motion during the past few million years. It also reduces estimates of the likelihood that offshore faults paralleling the San Andreas will rupture in damaging earthquakes.

The problem had been that the rate at which the opposing plates slip past each other on the San Andreas seemed to depend on how one measured fault motion. If a paleoseismologist measured the slippage during the great earthquakes of the past few hundred years or a geodesist measured the imperceptible straining of one plate edge against the other during the past decade, the recent rate appeared to be about 35 millimeters per year. But geophysicists, using evidence from the ocean crust to determine velocities and directions of motion of all the globe's plates during the past few million years, came up with relative motion between the Pacific and North American plates of 56 to 60 millimeters per year.

Taking account of the skewing effect of crustal extension centered on Nevada, the difference between the two types of measurements, known as the "San Andreas discrepancy," came to about 15 millimeters per year. Bernard Minster of Science Horizons in Encinitas, California, and Thomas Jordan of the Massachusetts Institute of Technology, whose 1978 model of global plate motions has been the standard of the field, attributed the discrepancy to a combination of crustal compression perpendicular to the San Andreas and strike-slip, San Andreas–like motion on faults paralleling the boundary to the west. They recently estimated the compression to be about 9 millimeters per year, which would account for the crumpling across the fault evident in such places as central California's Coast Ranges.

The site or sites of the missing strike-slip motion, amounting to 13 ± 5 millimeters per year, was not so clear, but Minster and Jordan suggested the San Gregorio–Hosgri fault system that runs just off the coast from south of San Francisco to Point Arguello north of Santa Barbara. If all the missing motion were to occur there during fault ruptures, enough large earthquakes would result to make that fault one of the most active in California. That would be all too active for coastal residents and the controversial Diablo Canyon nuclear power plant on the coast near San Luis Obispo.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A California crumple. *The Coast Ranges are in part raised by plate motions that are not parallel to the San Andreas fault.*

Things may not be that bad after all. A group at Northwestern University now believes that its new model of global plate motions greatly reduces the San Andreas discrepancy and the consequent seismic hazard. Charles DeMets, Richard Gordon, Seth Stein, and Donald Argus have updated and reanalyzed the ocean crust data, such as plate spreading rates determined from magnetic lineations and plate directions derived from transform fault orientations. They found about the same amount of compression across the San Andreas as did Minster and Jordan, but only about 5 millimeters per year of strike-slip motion. That "implies that little strike-slip motion need be accommodated on faults west of the San Andreas . . . ," according to the group.

The protracted debate usually involved in a challenge to an entrenched model will not materialize in this case. The Northwestern model has two small but particularly significant changes that have convinced Minster and Jordan at least that it is the preferred model. One change is in the rate at which new ocean crust is forming in the Gulf of California. The Northwestern group analyzed seven magnetic profiles across the Gulf of California that reveal the rate of crustal formation recorded as new crust cools and locks in Earth's flip-flopping magnetic field. Their interpretation produces a spreading rate of 48 millimeters per year versus earlier interpretations of single profiles suggesting 58 or 65 millimeters per year.

In addition, the Northwestern group found an inaccuracy in the drafting of a figure in a 1971 paper used by Minster and Jordan to derive the rate of motion between the Pacific plate and the Cocos plate, the small, triangular plate tucked against Central America. The resulting 10% error, which was not in the original data, caused a 10% decrease in the relative motion of the Pacific and North American plates.

The San Andreas discrepancy is clearly smaller now, but it may still not be negligible, notes Jordan. "This obviously reduces the amount of strike-slip motion, roughly by a factor of 2," he says. "But there's still a potential [for significant seismic activity]. The uncertainties are large enough that the missing slip could be 0 or 10 millimeters per year. That's a big difference. I'd hate to see people become complacent and think we have no problem. We really need some firsthand, direct observations."

Useful direct observations are not that far off. Widely spaced geodetic measurements by the satellite laser ranging system that seemed to support a large discrepancy (*Science,* 10 January 1986, p. 116) are now consistent with a smaller difference. Anticipated measurements using the satellites of the global positioning system, says Jordan, should be accurate enough and closely spaced enough to resolve the question once and for all. ■ Richard A. Kerr

ADDITIONAL READING

C. DeMets, R. G. Gordon, S. Stein, D. F. Argus, "A revised estimate of Pacific–North America motion and implications for western North America plate boundary zone tectonics," *Geophys. Res. Lett.* **14**, 911 (1987).

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