California's Shifting Crust: Slip Sliding Away

Pop historians often comment on social mobility in southern California, but as scientists and laymen alike know, there is another kind of mobility that must be dealt with, the crustal kind. At the American Geophysical Union meeting last week in San Francisco, three new experimental measurements were reported that dramatically confirm the degree to which different parts of southern California are moving with respect to one another. In addition, an intriguing but puzzling new pattern of seismic activity in the now-famous Palmdale area was reported, and recently identified variations in seismic events prior to the disastrous 1971 San Fernando earthquake were described.

California is an earthquake-conscious area, and deservedly so since it sits astride the slip boundary between the North American and Pacific crustal plates. Seafloor spreading history over millions of years indicates that adjacent plates move with respect to each other at rates of a few centimeters per year. But measurements of very recent movements on land are extremely difficult to make. The newly reported measurements use three completely different techniques, and they all reveal relative movements across parts of California that equal or exceed the rates expected from sea-floor spreading theory.

One of the studies compared geodetic measurements made parallel to the U.S.-Mexico border in southern California in 1941 with results of another detailed geodetic survey in 1975. The line of measurements extends on either side of a north-south fault zone in the Imperial Valley. John G. Gergen of the National Geodetic Survey reports that between 1941 and 1975 points west of the fault have moved as much as 3.8 meters northward relative to points east of the fault. This is an average movement of about 11 centimeters a year.

The other two measurements make use of advanced space-age technology developed only in the last few years. The ARIES technique, developed by scientists at the California Institute of Technology (SN: 8/24-31/74, p. 136), records arrival times (to an accuracy of a tenth of a billionth of a second) of radio signals from quasars. By comparing arrival times at antennas at two different locations, the distance between them can be measured and, by repeating the same measurement several years later, any change in that distance can be determined.

In the first major experimental result of the ARIES program, the Caltech scientists (including K. M. Ong, Peter MacDoran and A. E. Niell, among others) have determined that the distance between the Goldstone station in the Mojave desert and a point 180 kilometers away on the grounds of the Jet Propulsion Laboratory in Pasadena has increased by 13 centimeters in the past three years. The data show that the south side of the San Andreas fault south of the San Gabriel mountains (where the San Andreas takes a bend to the west) has moved westward relative to the north side somewhere between 12 and 20 centimeters during those same three years.

The third recent measurement was initially reported not at the AGU meeting but at a symposium at Stanford University this summer, but it was referred to so often by the scientists at the AGU that it might as well have been reported there. It is a laser ranging experiment, bouncing laser beams off a satellite between two widely separated ground stations in southern and northern California. This work by David Smith of the NASA Goddard Space Flight Center shows that between 1973 and 1976 there has been a 9-centimeter-per-year reduction in the distance between San Diego and the town of Quincy, 800 kilometers away northeast of Sacramento.

Session chairman and NASA geophysicist Edward A. Flinn, who is also editor of the solid planets section of the JOURNAL OF GEOPHYSICAL RESEARCH, notes that all three of these measurements are consistent with the geology of the situation. All are consistent with right-lateral movement along the San Andreas as the Pacific plate on which the coast of California rides continually slides northward along the edge of the North American plate. The rates of movement may seem a little high —a usual value of long-term average plate motions is 5 to 6 centimeters a year— but Flinn points out that those figures are based on averages over millions of years. Little is known about how the rates vary on the scale of just a few years.

The advent of the laser ranging and the ARIES radio astronomical interferometric surveying techniques has ushered in a new era in plate motion studies. "This type of geodesy," says Flinn, "is now one of the most important and exciting areas of research today."

There is also considerable interest in reports of unusual patterns of recent seismicity in the Palmdale area north of Los Angeles. Karen M. McNally of Caltech reports that, starting November of 1976 and continuing to the present, there has been a very high frequency of small earthquakes along a 30-kilometer section of the San Andreas fault east-southeast of Palmdale. About 700 small quakes of magnitude zero to 3 have been recorded in those 12 months. Such a clustering has never been observed in the area before in records going back to 1932. The frequency is 10 to 30 times as high as the average since 1932.

What's puzzling is that, because the quakes are small, the total amount of energy being released is no greater than average. It is the pattern of high frequency that is unique. "It's unusual, it's interesting, and it's not been observed before," says Flinn. But what it all means, if anything, he says, is not at all clear. McNally and Kanamori note that the earthquakes may represent either a long-term change in seismic activity or an unusual "swarm" episode of a year's duration, resulting from conditions of stress or weakness that didn't exist previously.

Seismologists are also looking back intensively at records of seismic events prior to past earthquakes in an attempt to find identifiable patterns. Mizuho Ishida, also at Caltech, and Kanamori have discovered a pattern within 35 kilometers of the 1971 San Fernando earthquake. From 1932 to 1961, seismicity was relatively low and random. A remarkable northeast-southwest-trending alignment of activity occurred from 1961 to 1964 (the onset of the Palmdale bulge uplift). From 1965 to 1968 activity was extremely low. Not a single event occurred within 13 kilometers. Then, from 1969 until the San Fernando earthquake hit, activity resumed again. Five quakes in this latter period were different from those previously seen and may have been foreshocks that heralded the main quake.

In still another study, McNally reports that six moderate earthquakes (magnitude 5 to 6.5) in central and southern California since 1955 were preceded by relatively large clusters of small earthquakes. The earthquake clusters occurred 1 to 20 kilometers from the larger quakes and from a few months to 10 years before. Furthermore, they were distinct from the usual background level of small quakes in the area.

McNally says her results suggest a means for monitoring the buildup of stress and for predicting earthquakes, but much still has to be learned before that point is reached. Kanamori, however, says he feels that the activity before the San Fernando quake might have enabled a prediction if the seismic network currently in place had been as extensive then as it is now.

All in all, California demonstrably is on the move, in ways that on the large, regional scale are as expected and on the small, local scale are an intriguing challenge to understanding and prediction. The situation continues to keep citizens edgy and scientists busy. □