Regional Deformation and Global Tectonics Using Space Geodetic Techniques

Present-day plate tectonic motions are estimated from the space-based geodetic techniques of very long base line interferometry (VLBI) and satellite laser ranging (SLR) between sites located on seven of the major tectonic plates. The observational history for the two techniques extends back to the late 1960's, but data taken during the last decade is of sufficient quality to resolve relative motions of the observing stations to an uncertainty level of 2 to 4 mm/yr.

Shortly after the Loma Prieta earthquake occurred in the Santa Cruz Mountains of California on October 18, 1989, mobile VLBI systems visited 3 sites within 150 km of the epicenter and made measurements jointly with other sites in an intensive observational campaign to measure co- and post-seismic deformation. At Fort Ord (about 50 km south of the epicenter), the earthquake-related horizontal displacement was estimated at 49 $\pm$ 4 mm oriented in a northerly direction. At the Presidio (in San Francisco, about 100 km northwest of the epicenter), the horizontal displacement was estimated at 12 $\pm$ 5 mm oriented in a southeasterly direction, and further north, at Point Reyes (140 km northwest of the epicenter), no horizontal displacement was detected. A co-seismic slip model in which the slip on the southern segment is shallower than that on the more northern segment of the rupture zone predicts static displacements which are consistent with these results.[1]

After more than a decade of measurements VLBI and SLR tracking measurements have determined that the horizontal shortening along the line spanning the San Andreas Fault between Monument Peak, California on the Pacific Plate and Quincy, California on the North America Plate is occurring at approximately 28 mm/yr.[2,3] This amount of motion is considerably less than the rate of 45mm/yr predicted by the NUVEL-1 geologic plate motion model.[4] One source for the "missing motion" is deformation occurring well beyond the region represented by the two sites. The spreading across the Basin and Range area has also been estimated on the basis of these measurements. Between sites in western U.S. and Texas, extension has been estimated to be approximately 7 mm/yr. In central California, east of the Sierra Nevada Range, the line between Owens Valley Radio Observatory and west Texas undergoes approximately 7 mm/yr of extension. Finally, in a more east/west direction, rates between Quincy, California and a site near Platteville, Colorado suggest an extension of 6 to 10 mm/yr.

Many VLBI and SLR sites are located near plate margins. For example, the Yakataga VLBI site is located in southern Alaska where the Pacific Plate subducts under North America. Results from the VLBI data analysis indicate a large component of Pacific Plate motion with respect to North American motion.[5] Geophysical modeling of this data suggest that the observed motion is the result of elastic straining of the overriding plate. It is thought that large earthquakes on the main thrust zone or within the overlying plate will ultimately release the accumulated elastic strain. Similar components of subducting plate velocities have been noted in analysis of data taken at Kashima, Japan (a VLBI site), and Simosato, Japan (an SLR site), both located on an overriding island arc near the Japan Trench, and on the South American Plate at Arequipa, Peru (an SLR site).[2,6]

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