FINAL TECHNICAL REPORT

AWARD NUMBER: 00-HQ-GR-0039

CRUSTAL DEFORMATION IN THE SAN FRANCISCO BAY AREA

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PROGRAM ELEMENTS: I & II

TECHNICAL ABSTRACT

The primary goal of this project was to study the deformation field in northern California, with emphasis on the populated San Francisco Bay region. We analyzed GPS and Geodolite trilateration observations to study inter-seismic strain accumulation on the principal Bay area faults, analyzed deformation following the 1906 San Francisco and 1989 Loma Prieta earthquakes to better understand post-seismic relaxation and stress transfer, and performed time-dependent inversions and finite-element calculations to improve our understanding of the structure and rheology of the sub-seismogenic crust in the Bay Area.

Geodolite trilateration measurements were used to constrain inter-seismic strain accumulation in the San Francisco Bay area. Several regions significantly deviate from the expected right-lateral shear across the San Andreas fault system. Higher rates of strain are evident in regions with complex, non-parallel fault geometry and high topographic relief. Methods for assessing the highly correlated uncertainties of fault slip and geometry models were developed and applied to the northern San Andreas fault system. A simple method for modeling broadscale crustal deformation as a combination of plate tectonic motions and inter-seismic elastic strain accumulation on faults was developed and applied to continuous GPS data collected in northern California and Nevada. Deformation in this region is consistent with a simple 10-parameter model using 6 rigid plates and 3 locked San Andreas system faults.

The Network Inversion Filter was modified to investigate time-dependent slip following the 1989 Loma Prieta earthquake using GPS and leveling data. The data suggest that triggered after-slip can occur off the main rupture zone on adjacent faults, that shallow after-slip dominated the first 8 years of post-seismic deformation, and that post-seismic slip on the Foothills thrust may account for a significant portion of its total slip budget. Triangulation data following the 1906 San Francisco earthquake was re-evaluated using improved methods and more recent geodetic data. The post-seismic deformation has an effective relaxation time of 36+/-16 years, but accelerated deep after-slip models cannot fit the breadth of the observed deformation field northeast of the San Andreas fault.

Finite-element models of time-dependent stress transfer between Bay Area faults indicate that a 1906 type event on the San Andreas fault would produce a greater stress shadow effect on the Hayward fault if the faults are connected via lower crustal structures with time-dependent

rheology. A variety of finite-element visco-elastic models were developed to explain the observed 1906 post-seismic deformation patterns. Preferred models used discrete shear zones embedded in elastic crust or visco-elastic lower crust.

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NON-TECHNICAL SUMMARY

This project focuses on integration and modeling of geodetic measurements in the San Francisco Bay area. We combine previously collected Geodolite (precise laser distance measurements) and Global Positioning System (GPS) measurements to determine the deformation field in the Bay area and northern California and to study how seismic strain accumulates on the principal faults. We also study deformation following the 1906 San Francisco and 1989 Loma Prieta earthquakes to characterize post-seismic relaxation and stress transfer, and perform time-dependent inversions and finite-element calculations to study the geometry of faults in the lower crust and the rates of stressing on Bay area faults.