Characterization of Blind Seismic Sources in the Mt. Diablo-Livermore Region, San Francisco Bay Area, California

Award Number 99-HQ-GR-0069

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Element II: Earthquake Occurrence and Effects

Key Words: Regional Modeling, Recurrence Interval, Tectonic Structures

Investigations Undertaken

Active crustal shortening is occurring in the Mt. Diablo-Livermore region of the eastern San Francisco Bay area, California. In a recent NEHRP study, Unruh and Sawyer (1997) identified and characterized several thrust faults in the greater Mt. Diablo region as potential seismic sources. The largest structure is the Mt. Diablo anticline, which is approximately 25 km long, 22 km wide, and exhibits a minimum structural relief of approximately 7 km. Based on construction of balanced cross-sections, the Mt. Diablo anticline can be modeled as a southwest-vergent fault propagation fold above a blind, northeast-dipping thrust fault. The dimensions of the Mt. Diablo anticline are comparable to other Quaternary folds in western California such as the Coalinga anticline and the Santa Susana Mountains anticlinorium, which are underlain by blind thrust faults that have produced moderate magnitude earthquakes (the 1983 M6.5 Coalinga earthquake and the 1994 M6.7 Northridge earthquake, respectively).

Based on these initial studies, Unruh and Sawyer (1997) estimated that the blind Mt. Diablo thrust fault potentially is capable of producing a maximum M_w $6^3/_4$ earthquake. For the range of values in horizontal shortening, fault dip and timing of deformation summarized in Unruh and Sawyer (1997), the minimum slip rate on the blind Mt. Diablo thrust fault is about 1.3 mm/yr (10 km total shortening; 30° fault dip; 9 Ma onset of shortening), and the maximum slip rate permitted by available data is about 7

mm/yr (17 km total shortening; 45° fault dip; 3.4 Ma onset of shortening). Using a median value of about 4 mm/yr for the slip rate, the implied return time for moderate magnitude earthquakes that release about 1-2 m of accumulated slip on the thrust is about 250-500 yr (Unruh and Sawyer, 1997).

The goal of this current investigation is to perform new structural geologic studies and improve the preliminary characterization of the blind Mt. Diablo thrust fault and related structures. The current work incorporates new information from on-going studies of late Neogene stratigraphy and paleogeography in this region, apatite fission-track analysis of the uplift of Mt. Diablo, and oil industry data released to the U.S. Geological Survey. These data are being incorporated in a series of new balanced cross-sections to refine interpretations of the geologic structure by Unruh and Sawyer (1997), and better constrain the range of permissible horizontal shortening rates. The current work specifically is focused on evaluating minimum and maximum shortening rates across the fold and thrust belt, which in turn will constrain minimum and maximum slip rates on the blind Mt. Diablo thrust fault and, thus, return times for moderate to large magnitude earthquakes. The current work will provide better constraints on the dimensions and geometry of the blind thrust faults beneath Mt. Diablo and related anticlines, and it will form a basis for assessing segmentation of these faults by lateral ramps and tear faults. Developing well-constrained models of these structural features is important for evaluating maximum earthquakes, and for developing detailed models of ground motions that incorporate rupture directivity effects in estimates of peak ground acceleration.

Results

This study is currently in progress. Preliminary results (subject to further revision) are summarized as follows:

- Although Mt. Diablo anticline can be modeled as a southwest-vergent fault-propagation fold, evaluating the late Cenozoic fold geometry is complicated by the presence of numerous late Cretaceous-early Tertiary normal faults exposed on the northeast limb of the anticline. Structural relief on Eocene and Cretaceous marine sediments due to movement on these normal faults must be accurately depicted in any formal balanced and restored cross-section of Mt. Diablo anticline.

- Cross-sections that account for early Tertiary normal faulting in the Mt. Diablo region suggest that the maximum horizontal NE-SW shortening across Mt. Diablo anticline

is about 7-10 km, which is less than the maximum shortening of 17 km previously estimated by Unruh and Sawyer (1997).

- Stratigraphic and structural relations visible in moderately to steeply dipping Neogene strata exposed on the limbs of the anticline suggest that growth of the modern Mt. Diablo anticline began about 5 Ma, after major late Miocene-Pliocene subsidence and filling of the ancestral Livermore basin. Fold growth relations can be inferred, but not conclusively demonstrated, by the presence of unconformities in the Plio-Pleistocene section along the southwest limb of the anticline.

- Variations in structural relief and fold geometry along the axis of Mt. Diablo anticline strongly suggest that the underlying blind thrust fault is not a continuous, 25-km-long structure. The thrust may be offset by at least one northeast-striking lateral ramp or tear fault along strike that potentially limits the maximum rupture length.

Non-Technical Project Summary

The goal of this study is to use a variety of geologic data to infer the dimensions and seismic potential of a hidden or "blind" thrust fault beneath Mt. Diablo anticline in the eastern San Francisco Bay area. The Mt. Diablo fault is similar in character to the structure that produced the 1994 Northridge earthquake in southern California, and it poses a potential ground-shaking hazard to rapidly growing communities in the San Ramon-Livermore area. Specific study objectives include: (1) evaluating the maximum earthquake the fault is capable of producing; and (2) improving constraints on the fault slip rate to refine estimates of earthquake recurrence.

Reports Published

Because this study is in progress, there have been no reports published. Preliminary results from this current study, and results from two previous NEHRP-funded projects to evaluate faults in the Mt. Diablo region as seismic sources (Unruh and Sawyer, 1997; 1998), were incorporated in a recent analysis of earthquake probabilities in the Bay Area (Working Group on California Earthquake Probabilities, 1999):

Unruh, J.R., and Sawyer, T.L., 1997, Assessment of Blind Seismogenic Sources, Livermore Valley, Eastern San Francisco Bay Region: final technical report submitted to the U.S. Geological Survey, National Earthquake Hazards Reduction Program, Award no. 1434-95-G-2611.

Unruh, J.R., and Sawyer, T.L., 1998, Paleoseismic investigation of the northern Greenville fault, eastern San Francisco Bay area, California: Final Technical Report submitted to the U.S. Geological Survey, National Earthquake Hazards Reduction Program Award no. 1434-HQ-97-GR-03146, 34 p.

Working Group on Northern California Earthquake Probabilities, 1999, Earthquake probabilities in the San Francisco Bay region: 2000 to 2030 - A summary of findings: U.S. Geological Survey Open-File Report 99-517 (published on the World Wide Web, URL: http://quake.wr.usgs.gov/study/wg99/of99-517/index.html)