California Home

Welcome to California

Department of Conservation

California Geological Survey

search

My CA This Site

California Department of Conservation
Division of Mines and Geology
Open-File Report 96-08

U.S. Department of the Interior
U.S. Geological Survey
Open-File Report 96-706

PROBABILISTIC SEISMIC HAZARD ASSESSMENT FOR THE STATE OF CALIFORNIA

Mark D. Petersen, William A. Bryant, Chris H. Cramer, Tianqing Cao, and Michael Reichle
California Department of Conservation, Division of Mines and Geology

Arthur D. Frankel
U.S. Geological Survey, Denver, Colorado

James J. Lienkaemper, Patricia A. McCrory, and David P. Schwartz
U.S. Geological Survey, Menlo Park, California

1996

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
801 K Street, MA 12-31
Sacramento, California 95814

in cooperation with

U.S. DEPARTMENT OF THE INTERIOR:
U.S. GEOLOGICAL SURVEY
Denver Federal Center
P.O. Box 25286
Denver, Colorado 80225

U.S. GEOLOGICAL SURVEY
345 Middlefield Road, MS 977
Menlo Park, California 94025

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.
Copies of this report also are available for purchase from the Public Information Offices of the Division of Mines and Geology. Ask for DMG Open-File Report 96-08 (price: $25.00, prepaid, including tax, shipping, and handling; price subject to change).
California Geological Survey's Public Information Offices:

Southern California Regional Office 107 South Broadway, Rm. 1065 Los Angeles, CA 90012-4402 Phone: (213) 620-3560	Publications and Information Office 801 K Street, MS 14-33 Sacramento, CA 95814-3532 Phone: (916) 445-5716	Bay Area Regional Office 185 Berry Street, Suite 210 San Francisco, CA 94107-1728 Phone: (415) 904-7707

Table of Contents

Table

Figures

acceleration in %g units.

Figure 6. Areas that are thought to have experienced (or would have experienced if the area were developed) MMI VII or greater between 1800 and 1996. San Andreas and Eastern California Shear zones are noted. Boxes indicate epicenters of M>6 earthquakes for which we do not have damage data.

Figure 7. Comparison of the number of historic California earthquakes and the earthquakes used to calculate the seismic hazard. The historic earthquake numbers were normalized by the length of catalog which we used (e.g., since 1932 - 64 years; 1901 - 95 years; 1850 - 146 years) to show the variability in the historic earthquake rate.

Figure 8. Contour map of the magnitude of the earthquake that causes the dominant hazard for peak ground acceleration at 10% probability of exceedance in 50 years and alluvial site conditions. County boundaries are also shown.

Figure 9. Contour map of the distance of the earthquake that causes the dominant hazard for peak ground acceleration at 10% probability of exceedance in 50 years and alluvial site conditions. County boundaries are also shown.

Figure 10. Hazard curves for peak ground acceleration and alluvial site conditions at various cities located across California. The curves indicate the probability of exceeding the given peak ground acceleration levels on alluvial site conditions.

INTRODUCTION

This report documents a probabilistic seismic hazard assessment for the state of California and represents an extensive effort to obtain consensus within the scientific community regarding earthquake parameters that contribute to the seismic hazard. The parameters displayed in this report are not the work of any individual scientist, but denote the effort of many scientists, engineers, and public policy officials that participated in developing the statistical distributions used in the analysis. Consensus in the earth-science community is essential for developing useful public policy that may influence land-use planning, building regulation, insurance rate assessment, and emergency preparedness. This consensus is imperative because our results indicate that roughly three-fourths of the population of California live in counties that have significant hazard due to earthquake ground shaking.

The primary purpose of this report is to present the earthquake source information; a general outline of the methodology and equations used to generate the seismic hazard map; and the seismic hazard map for peak horizontal acceleration on a uniform site condition of firm rock (average shear wave velocity of about 760 m/s) at a hazard level of 10% probability of exceedance in 50 years. Independent geologic, geodetic, and historical damage data are also presented as well as a comparison of the seismic hazard for several populated regions across the state. Further information regarding the hazard model, sensitivity studies, and uncertainty analyses may also be found in papers by Frankel (1995), Frankel et al. (1996), Petersen et al. (1996a,b), Cao et al. (1996), Cramer et al. (1996), Cramer and Petersen (1996), Working Group on Northern California Earthquake Potential (WGNCEP, 1996), McCrory (1996), and a text on probabilistic seismic hazard analysis by Reiter (1990).

We chose to describe the hazard using a probabilistic seismic hazard assessment that takes into account the recurrence rates of potential earthquakes on each fault and the potential ground motion that may result from each of those earthquakes. The hazard analysis incorporates both a) historical seismicity and b) geologic information within fault zones that display evidence of displacement during late Pleistocene and Holocene times.

a) Seismicity in California

Seismic hazard in California is high in many areas, as manifested by the number of large earthquakes that have occurred during historic time (Figures 1 and 2). Many of these earthquakes occurred in a belt of seismicity located within about 50 km of the San Andreas Fault Zone. Large earthquakes with moment magnitude M ≥7 have ruptured on or near the San Andreas Fault Zone (Figures 1 and 2) in the 1812 Wrightwood earthquake, M~7-71/2; 1838 San Francisco peninsula earthquake, M ~ 7-71/2; 1857 Fort Tejon earthquake, M ~ 7.9; 1868 Hayward earthquake, M ~ 7; 1906 San Francisco earthquake, M ~ 7.9; and the 1989 Loma Prieta earthquake, M 7.0. However, a number of moderate (M ≥51/2) to large earthquakes have also occurred on faults situated well away from the San Andreas Fault (e.g., the 1872 Owens Valley earthquake, M~7.6; 1952 Kern County earthquake, M ~ 7.5; 1971 San Fernando earthquake, M 6.7; 1992 Landers earthquake, M 7.4; and the 1994 Northridge earthquake, M 6.7). Moderate to large earthquakes have not only occurred on strike-slip faults associated with the broad San Andreas Fault System, but also along reverse faults that either rupture the surface (e.g., 1971 San Fernando and 1952 Kern County earthquakes) or to some depth beneath the surface as "*blind thrusts*" (e.g., 1983 Coalinga earthquake, M 6.5; 1987 Whittier Narrows earthquake, M 5.9; and the 1994 Northridge earthquake). The 1992 Petrolia earthquake (M 7.0) is thought to have occurred on the Cascadia subduction zone and demonstrates the potential hazard of this compressional zone (Figure 1). California has had an average of about one M ≥ 6 event every 2 to 3 years and losses from many of this century's large earthquakes have resulted in several billions of dollars in damage (e.g., 1906 San Francisco earthquake, 1933 Long Beach earthquake-M6.2, 1971 San Fernando earthquake, 1989 Loma Prieta earthquake, and 1994 Northridge earthquake).

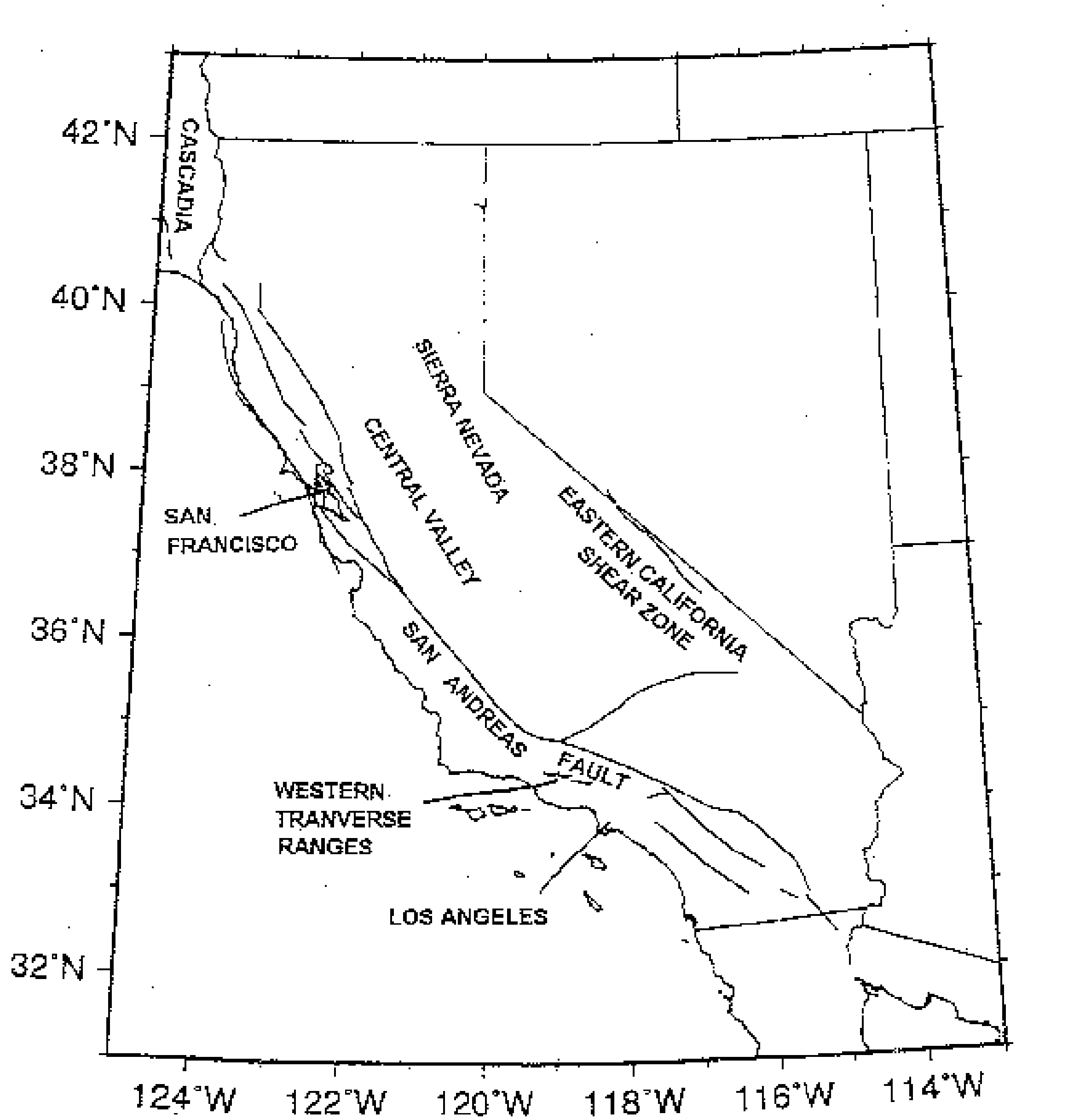


Figure 1. Index map showing names of major fault systems with slip rates greater than about 5 mm/yr and feature names referred to in text.

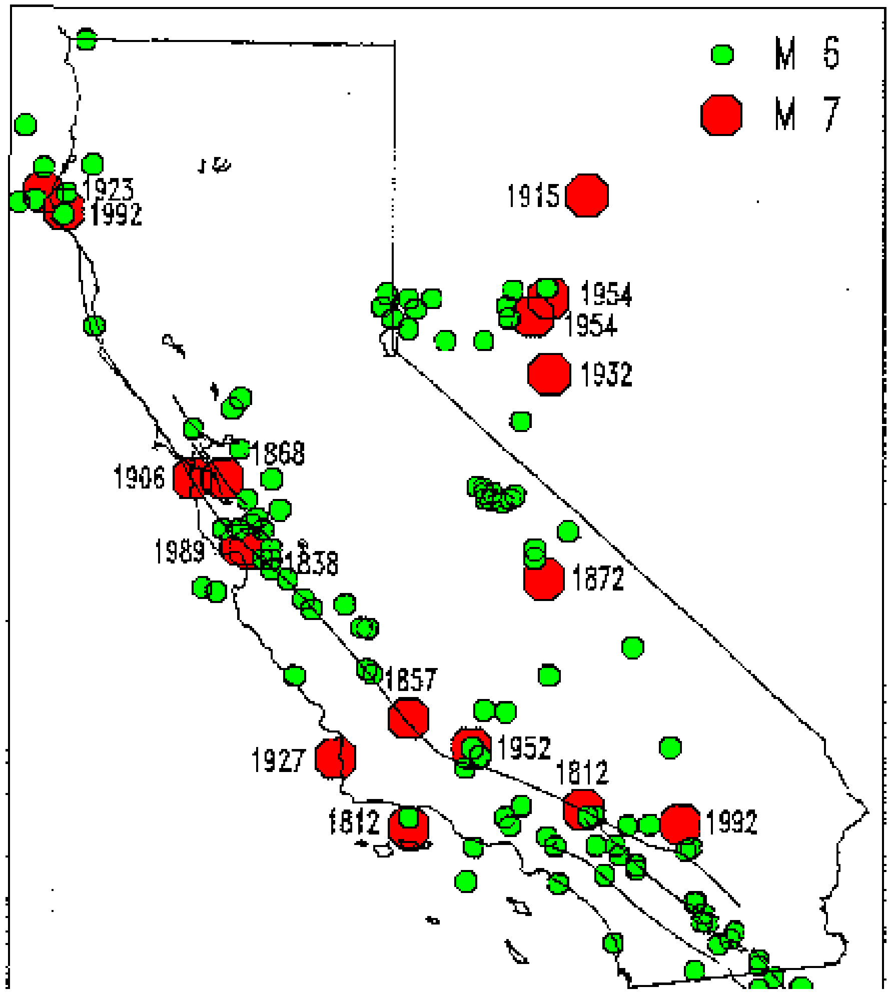


Figure 2. Seismicity M≥6 in California between about 1800 and 1994 (DMG catalog).

b) Faults in California

The earthquake catalog for California includes only earthquakes for approximately the past 200 years or so, whereas the return times for large earthquakes on many faults are at least an order of magnitude longer. Therefore, when it was available we have relied on paleoseismic data for faults in order to develop as complete an inventory of paleo-earthquakes as possible for our seismic source model. Rather than consider whether faults are "active" or "inactive," we have attempted to quantify the degree of activity of faults based on their reported slip rates and recurrence intervals. We have incorporated average recurrence times and displacement per event (when known) from paleoseismic investigations. Paleoseismic data for the majority of faults considered in this study, however, are restricted to slip-rate data of variable quality; recurrence intervals are rarely documented. Thus the majority of earthquake recurrence rates for faults has been derived from slip rate data. For this hazard assessment we have evaluated fault length, geometry, and slip rates for about 180 faults statewide with reported displacements during latest Pleistocene and Holocene times (Appendix A).

Several major fault systems accommodate high slip rates and significantly contribute to the hazard in California including: the San Andreas Fault, the Cascadia subduction zone, the Eastern California Shear Zone, and compressional faults associated with the western Transverse Ranges (Figures 1 and 3). Blind thrusts have recently been identified beneath the Los Angeles and San Fernando basins, the western Transverse Ranges, Santa Barbara Channel, and along the western flank of the Central Valley. In addition, several offshore faults have been identified and contribute significantly to the seismic hazard in coastal areas. Many late Quaternary faults are near a complex triple junction intersection of the Mendocino fracture zone, the San Andreas Fault, and the Cascadia subduction zone. Other significant faults are found in the eastern portion of California along a broad zone of portion of the state (Eastern California Shear Zone in Figure 1). Additional faults with Quaternary offsets are scattered over almost every strike-slip and normal faults distributed across the Mojave Desert, the Owens Valley, eastern Nevada, and across the northeastern region of California.

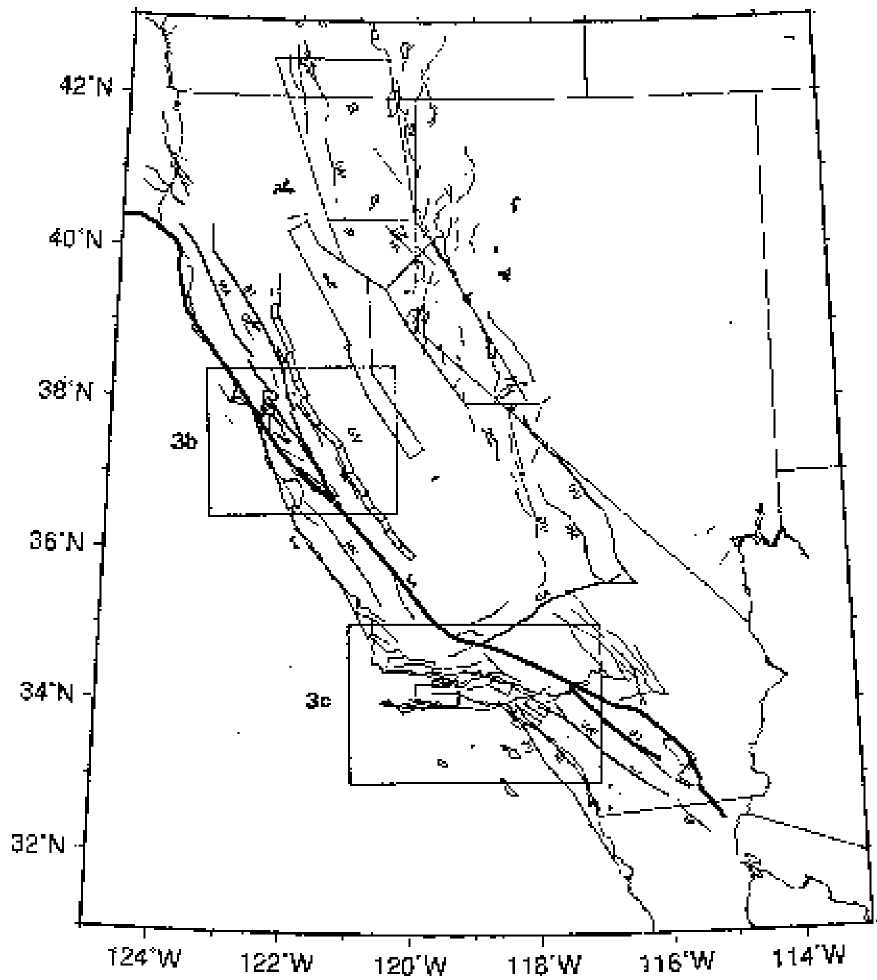


Figure 3a: Fault geometry applied in the source model. Weight of line is proportional to the slip rate. Faults and attributes are listed in Table 1. The individual fault names could not be shown on these figures but may be found on maps such as Jennings (1994). Blind thrusts are indicated by small boxes and are for the most part described in Dolan et al. (1995) and WGNCEP (1996).Large boxes located in the northeast portion of the state indicate area sources described in the text.

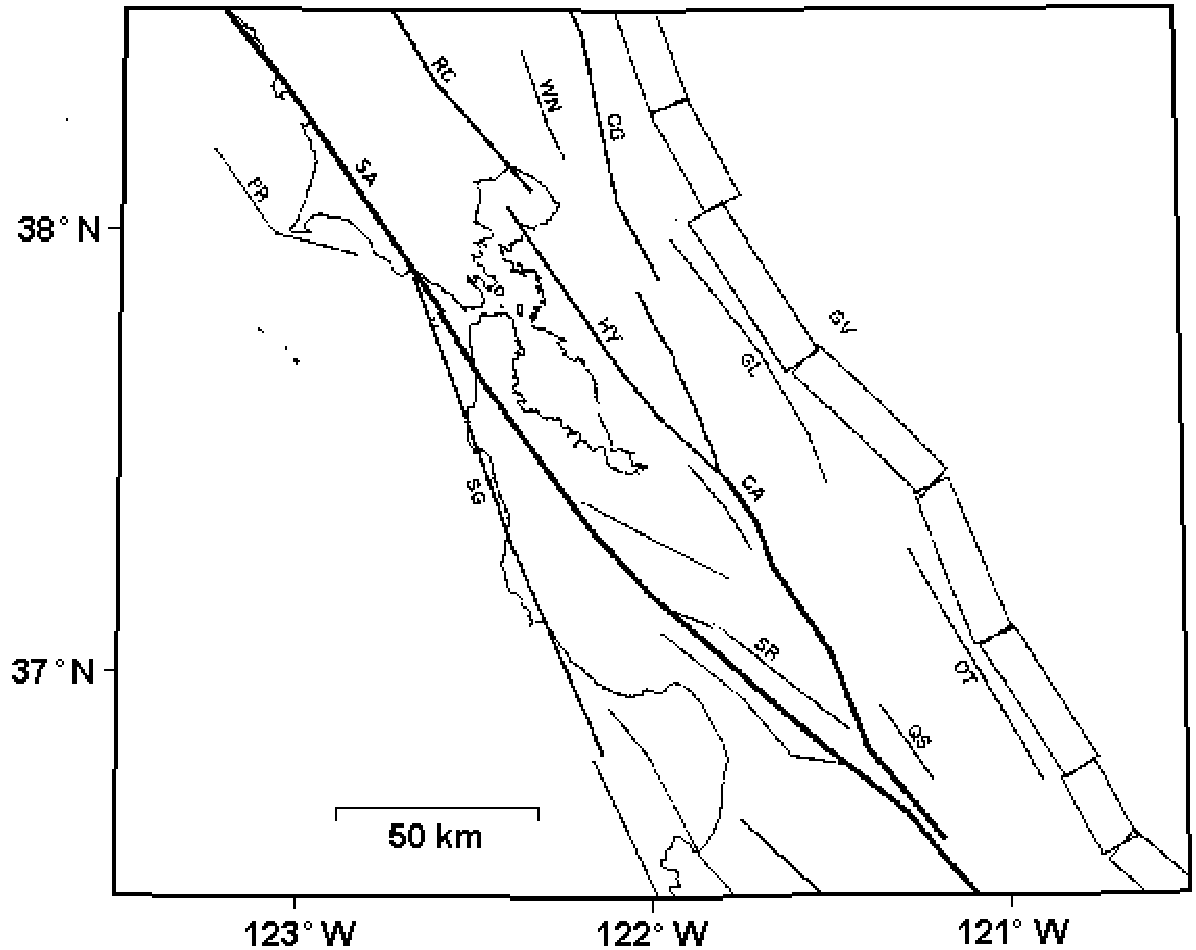


Figure 3b: Same as in Figure 3a but enlarged to show detail in the San Francisco Bay area.

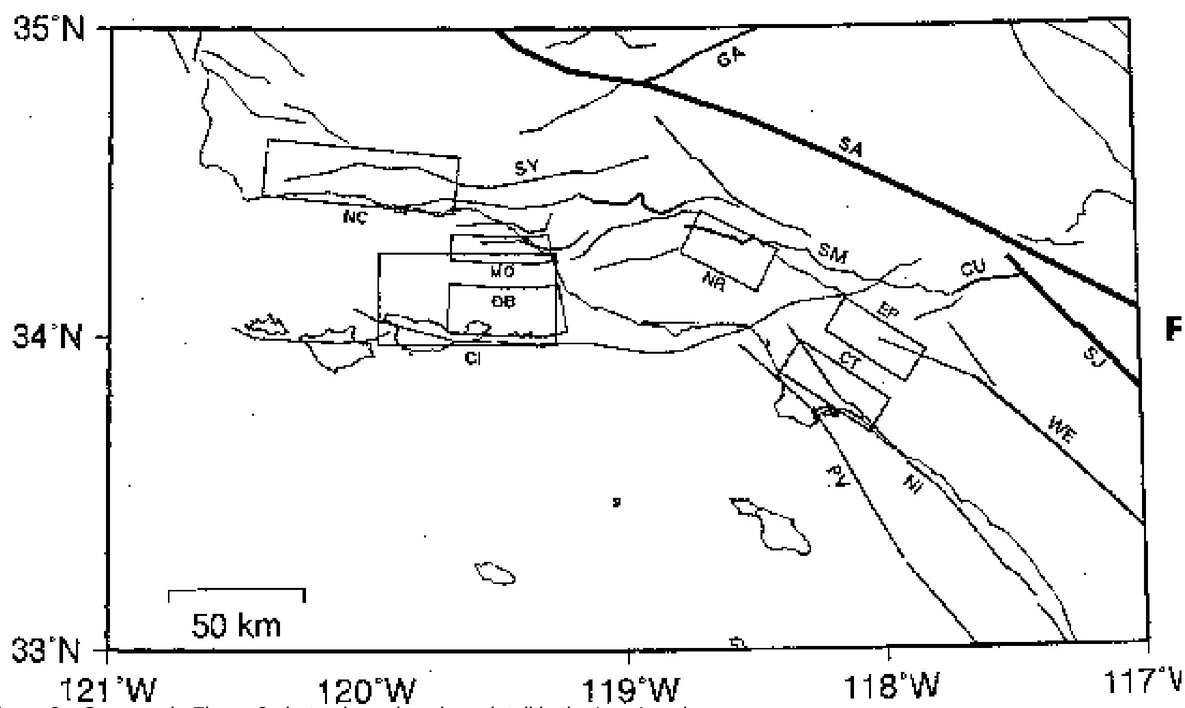


Figure 3c: Same as in Figure 3a but enlarged to show detail in the Los Angeles area.

METHODOLOGY

Development of the hazard model consists of three steps: a) delineating earthquake sources, b) defining the potential distribution of seismicity for each of these sources (magnitude frequency distributions), and c) calculating the potential ground motions from attenuation relations for all the model earthquakes.

a) Earthquake sources

For delineating the fault sources shown in Figure 3, we digitized the 1:750,000 scale fault activity map of Jennings (1994). Only a few points were digitized along faults of the Jennings map to approximate the location of each fault trace. The uncertainty in the location of the fault is approximately 1 to 2 kilometers. We digitized simplified fault traces from this map and calculated the length of each fault from these traces using Geographic Information System (GIS) analysis tools. For our uncertainty analysis, we assume a ± 10% uncertainty in the length. This uncertainty reflects the range of values obtained by measuring the length of faults depicted on several different fault maps (Ziony and Yerkes, 1985, Ziony and Jones, 1989; and Jennings, 1994). When possible, the depth of the seismogenic rupture zone was obtained from the hypocentral locations of earthquakes surrounding the faults. We used the work of WGNCEP (1996), Hill et al. (1990), McCrory (1996), and Petersen and Wesnousky (1994) to assess the depth dimension of the seismogenic zone. For many of the faults with limited historical seismicity, the depths are simply an average of all earthquake depths located in the vicinity of the fault.

We conducted a comprehensive survey of the available slip rate information through literature searches and many discussions, meetings, and written correspondence with the authors of the fault studies to assign earthquake activity rates and slip rates along faults (Appendix A). As part of the survey, we evaluated published compilations of slip rates given by Bird and Rosenstock (1984), Clark et al. (1984), Wesnousky (1986), Ziony and Yerkes (1985), Thenhouse (personal communication), Petersen and Wesnousky, (1994), Petersen et al., (1996a), WGNCEP (1996) and McCrory (1996). We reviewed the original sources of slip rates whenever possible for constraints on the direction, amount, and timing of displacement. Mean slip rates and their uncertainties are based on these studies (see references in Appendices A and B). Slip rates are considered well constrained if the direction, amount, and timing of displacement have been demonstrated. Moderately constrained slip rates generally have significant uncertainty for one of these components. Poorly constrained slip rates have either significant uncertainty with respect to both amount and timing of displacement or else the reported slip rate is a long-term (late Cenozoic) average rate. Many of the faults in California are poorly to moderately constrained because they have not been studied sufficiently or because no available site has been found that contains appropriate stratigraphic relationships and dateable material needed to infer details of the paleoseismic history.

Figures 3a-c show the faults that were incorporated into the source model and Appendix A indicates the associated length, slip rate, quality of slip rate (Rank), maximum magnitude (moment magnitude), characteristic earthquake rate and recurrence interval (R.I.) for the maximum magnitude, down dip width of the seismogenic zone, the top and bottom of the rupture surface, as well as the rake, dip, and dip azimuth of the rupture surface, the endpoints of the fault or fault segment, and comments and references regarding the basis for these parameter values. The slip-rate table (Appendix A) reflects our "*best estimate*" of the mean and range of possible slip rates along a fault. We consider the range of slip rates to encompass about 95% of the observations and represent 2 σ in uncertainty. The range in slip rates is symmetrical about the mean for simplicity and because we found it difficult to assign more detailed uncertainty estimates based on sparse slip rate information. We assumed an uncertainty of ± 2 km for the depth of the seismogenic zone. These values and quality assessments will be updated as new geologic and seismic investigations are completed.

In addition to fault studies, geodetic, magnetic, and earthquake source mechanism data provide insights constraining the stress and strain rates on faults in California. These strain measurements have not been incorporated explicitly in this model because of lack of uniform spatial coverage and availability. This strain data, however, provide independent constraints on the slip rate information independent of the geological data. The Working Group on California Earthquake Probabilities (WGCEP, 1995) indicated that the geodetically determined moment rates obtained from Global Positioning Satellite data are similar to the geologically determined moment rates from known faults in southern California. For this report we compared the modern plate tectonic rate from NUVEL I (DeMets et al., 1990), obtained using global seismic, geodetic, and fault and fracture orientation information, with the slip rates that we have compiled from fault studies in California (Figure 4). For this comparison slip rate vectors are summed across profiles oriented nearly perpendicular to the Pacific-North American plate boundary. We find that the cumulative slip rates that we used are consistent with the NUVEL I model in amplitude (about 48 mm/yr) and generally consistent in azimuth. In southern California, however, there is a systematic discrepancy in slip rate direction between our model and the NUVEL I model. Part of this discrepancy may be related to the fact that the NUVEL I model does not take into account the bend in the southern San Andreas Fault and is only based on a concentric circle about an Euler pole. The sum of fault slip rates across the plate boundary is generally slightly less than the NUVEL I model predicts, but we assume that a relatively small amount of strain also occurs east of California.

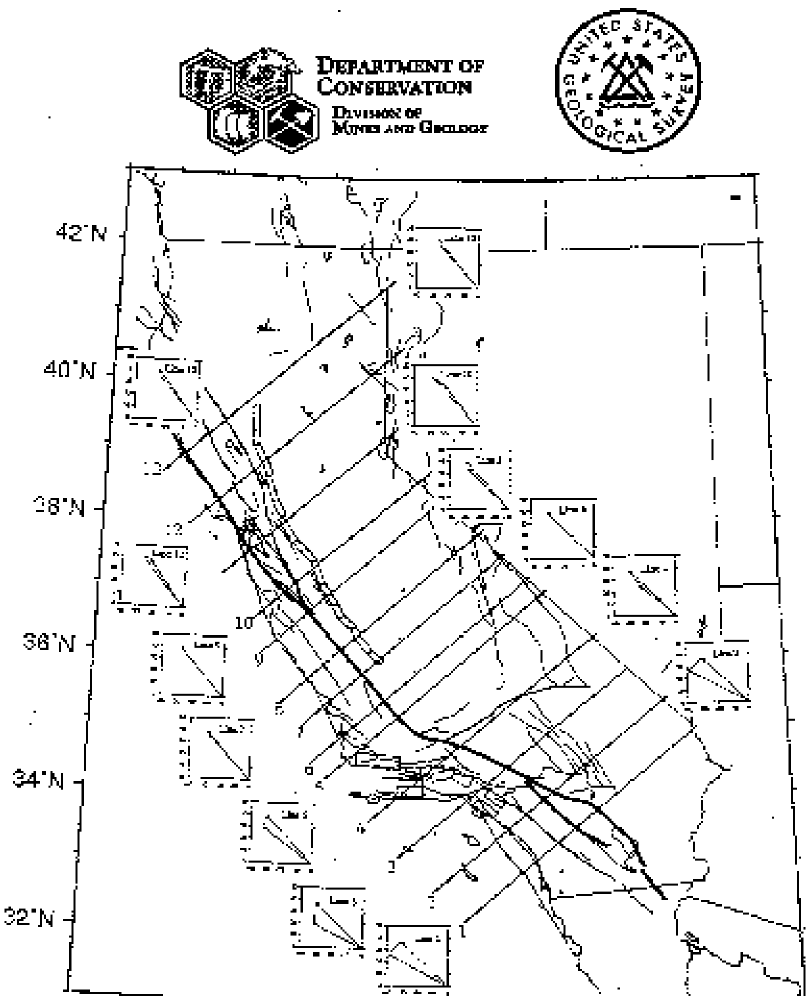


Figure 4: Comparison of the slip rates to the NUVEL I plate tectonic rates. Lines numbered 1-13 indicate profiles along which slip rate vectors were summed (from east to west) to compare with the NUVEL I model. Boxes labeled 1-13 correspond with numbered lines and indicate the slip rate in mm/yr for the resultant north and east directions of the slip rate vectors and the overall NUVEL I model for California.

b) Magnitude-frequency distributions

The annual number of earthquakes of various sizes that are assigned to each fault is based on the slip rate information and is defined using a combination of two statistical distributions: (1) the characteristic earthquake model that implies that a typical size of earthquake ruptures repeatedly along a particular segment of the fault (Schwartz and Coppersmith, 1984), and (2) the exponential model that implies that earthquakes on a given fault follow the Gutenberg-Richter relationship: $n(m) = 10^{a-bm}$ where n is the incremental number of earthquakes, *a* is the incremental number of earthquakes of *m*>0, *b* is the slope of the distribution, and *m* is moment magnitude (Richter, 1958). These two distributions have been discussed at length in the scientific literature and are both considered to be reasonable models either for specific faults or for larger areas of California. A combination of the two distributions is also thought to characterize the behavior of many fault systems. This composite model allows for more large earthquakes than predicted by the exponential distribution, and also for earthquakes of sizes different than the characteristic event.

The recurrence time of the characteristic earthquake is obtained using the methodology described in Wesnousky (1986):

$$\overline{T} = \frac{M_0^c}{\dot{M}_0^g} = \frac{\mu l w \overline{d}}{\mu l w \dot{u}} \quad (1)$$

where M_0^c is the seismic moment of the characteristic earthquake and $\dot{M}_0^g$ is the rate that the fault accumulates moment. The rigidity or shear modulus of the crust is represented by μ and for this study is taken as 3.0 x 10^{11} dyne/cm^2s. The value *l* represents the length of the fault, *w* is the downdip width (or depth) of the seismogenic zone, $\dot{u}$ is the slip rate for the fault, and $\overline{d}$ is the average displacement on the fault. The relation $1/\overline{T}$ gives the rate of earthquakes on a fault of the characteristic size.

The exponential distribution is used to partition the moment rate of the fault into events between a minimum and maximum magnitude. The geologic moment rate can be related to the exponential distribution by the following relation:

$$\dot{M}_0^g = \int_{m_0}^{m_u} \dot{n}(m)\, M_0\, dm = \int_{m_0}^{m_u} 10^{a-bm}\, 10^{d+cm}\, dm = \frac{10^{a+d}}{(c-b)\ln 10}\left[10^{(c-b)m_u} - 10^{(c-b)m_0}\right] \quad (2)$$

where $\dot{n}$ (m) is the annual number of events of moment magnitude m, M_0 is the moment of each of those events, *a* is the incremental rate of earthquakes with magnitude *m*, *b* is the slope of the distribution, *c* and *d* are constants defined by Hanks and Kanamori (1979) as 1.5 and 9.1, m_u and m_0 are the upper and lower bound magnitude truncations of the magnitude-frequency distribution. Equation 2 is used to solve for the incremental *a*-value.

$$a = \log\left[\frac{(c-b)\,\dot{M}_0^g \ln(10)}{10^d\left[10^{(c-b)m_u} - 10^{(c-b)m_0}\right]}\right] \quad (3)$$

This formulation assumes that all the moment rate from a fault is released seismically by earthquakes between the upper and lower bound magnitudes.

We categorize the faults into two classes and apply different magnitude-frequency statistical distributions for each class. The class A faults generally have slip rates greater than 5 mm/yr and well constrained paleoseismic data (i.e., the San Andreas, San Jacinto, Elsinore, Imperial, Hayward, and Rodgers Creek faults). The class B faults include all the other faults lacking paleoseismic data necessary to constrain the recurrence intervals of large events (Appendix A).

For class A faults we use characteristic earthquakes to describe the magnitude-frequency distribution along the faults. In addition to independent fault segment ruptures, we allow multiple contiguous segments to rupture together in larger events, comparable to large historical events on the San Andreas Fault System (Table 1). We use slip rate, displacement, and individual segment recurrence information provided by the WGCEP (1988, 1990, 1995) to account for multiple segment ruptures on the class A faults, except for the northernmost 1906 segment of the San Andreas Fault segment that is based on WGNCEP (1996). All the probabilities that we calculate incorporate a Poissonian model and do not consider the time since the last large earthquake.

The source model accounts for all large earthquakes including the 1857 and 1906 earthquakes along the southern and northern San Andreas Fault, respectively. We assign the paleoseismically derived recurrence rate of earthquakes along the Carrizo and North Coast segments of the San Andreas Fault as the rate of the large multi-segment ruptures (similar to the 1857 and 1906 sized earthquakes). We assign the rate of the Coachella Valley segment to that of the the multi-segment earthquake that ruptures the southernmost San Andreas Fault south of the 1857 rupture (Table 1). We subtract the annual rupture rates assigned to the multi-segment rupture from each of the other individual segment rates (from WGCEP reports) to obtain the revised rates for individual segment ruptures along the San Andreas Fault. This means that the Carrizo, North Coast, and Coachella segments are only allowed to rupture as large events and not in individual segment ruptures while the other segments may rupture as an individual segment or in conjunction with other contiguous segments in a multi-segment rupture.

For the Hayward Fault, we allow both individual segments to rupture separately as well as together in a larger event, as defined by the WGCEP (1990). We allow only single segment ruptures on the San Jacinto and Elsinore faults as defined by WGCEP (1995) and the Rodgers Creek Fault as defined by WGCEP (1990), because the single segment rupture model yielded nearly the same hazard as the multiple segment rupture model in southern California (Petersen et al., 1996a; Cramer et al., 1996).

Table 1: Class A faults with both independent and multi-segment ruptures.

Fault segment	*Magnitude*	$\bar{T}$ *independent segment recurrence (yr), 1/*	$\bar{T}$ *multi-segment recurrence (yr), 1/* $\bar{T}$ $\bar{T}$
<u>San Andreas: 1906 rupture</u>	7.9		210 / 0.00476
North coast	7.6	210 / 0.00476	0 / 0
Peninsular	7.1	138 / 0.00726	400 / 0.00250
Santa Cruz	7.0	138 / 0.00726	400 / 0.00250
<u>San Andreas: 1857 rupture</u>	7.8		206 / 0.00485
Parkfield	6.7	22 / 0.04545	25 / 0.04060
Chalome	6.9	140 / 0.00714	437 0.00229
Carrizo	7.2	206 / 0.00485	0 / 0
Mojave	7.1	150 / 0.00667	550 / 0.00182

San Andreas: Southern	7.4		220 / 0.00454
San Bernardino	7.3	146 / 0.00685	433 / 0.00231
Coachella	7.1	220 / 0.00454	0 / 0
Hayward	7.1		330 / 0.00299
Northern segment	6.9	167 / 0.00599	330 / 0.00299
Southern segment	6.9	167 / 0.00599	330 / 0.00299
Cascadia subduction zone	9.0		500 / 0.00200
California segment	8.3		335 / 0.00298

In this report the Cascadia subduction zone is treated as a class A fault. We have assumed that large earthquakes occur every few hundred to 1000 years as inferred from paleoseismic information (e.g., McCrory, 1996; Frankel et al.,1996). The entire Cascadia subduction zone was modeled as a combination of a M 9 characteristic rupture along the entire subduction zone from California to Washington every 500 years and a M 8.3 rupture along the California portion of the zone about every 335 years. The recurrence of the M 8.3 event reflects the time for the entire Cascadia to rupture all the segments in 500 years (Frankel et al., 1996). We assign a one-third weight to the M 9 event and a two-thirds weight to the M 8.3 event.

For class B faults we have chosen to use both characteristic and exponential earthquake magnitude-frequency distributions with each weighted 50%. This composite model allows for a greater number of large earthquakes than predicted by a simple exponential distribution while still accounting for the smaller earthquakes that may occur on the fault. In addition, this model also accounts for the diversity of opinion regarding these distributions within the science and engineering communities. Blind thrusts were treated as B class faults for this analysis. Some of the blind thrusts and offshore faults in the Santa Barbara Channel were weighted (Appendix A) to account for alternative scientific models after the work of Treiman (1996, written communication) that accounts for rotation of the western Transverse Ranges and Foxall (1996, written communication). In the source model presented here, earthquakes on fault sources generally have a minimum magnitude of 6.5 and a maximum magnitude consistent with the fault rupture area or displacement per event (Wells and Coppersmith, 1994). The shorter faults that have calculated magnitude less than 6.5 are described by a characteristic earthquake magnitude rather than a Gutenberg-Richter magnitude-frequency distribution.

Maximum magnitudes are an important variable in calculating the seismic hazard because they determine how much strain is released in larger earthquakes. The displacements per event were generally obtained from the WGCEP (1988, 1990, 1995) and were used to calculate maximum magnitudes and average recurrence intervals for earthquakes on class A faults. For class B faults we use a historical earthquake magnitude on a particular fault, if available, or the relation of Wells and Coppersmith (1994) between area of the fault rupture and magnitude of the event to calculate the maximum magnitude (or characteristic earthquake magnitude):

$$M=a+ b \times \log_{10}(\text{rupture area}) \quad (4)$$

where a and b are constants of 4.07 and 0.98 and the standard deviation of the magnitude is 0.24. The length, dip, and the top and bottom of the rupture of the fault are used to calculate the rupture area.

In general, alternate segmentation models were not considered in this version of the map. However, multiple segment earthquake ruptures were considered for modeling earthquakes on many of the class A faults (Table 1). In addition, alternative weighted models were considered for the blind thrusts and other faults in the Los Angeles basin and Santa Barbara Channel. These weighted models account for the lack of consensus in the earth-science community regarding these structures and their activity rates. Future versions of the map will most likely include additional alternatives for models of rupture.

Modeling the sources for faults that have known creep is not straightforward because some of the strain along these faults may not be released in earthquakes. Future seismic hazard research should focus on better ways to model such faults (e.g., creeping section of the San Andreas Fault, the Hayward Fault, the Calaveras Fault, the Brawley seismic zone, and the Maacama Fault). For constructing the source model along the creeping section of the San Andreas Fault and the creeping section of the southern Calaveras Fault we have varied the general methodology for calculating hazard. We have not added a separate source to account for the seismicity along the creeping segment of the San Andreas Fault, although we tested the sensitivity of various source models to the hazard results. The historical seismicity along the creeping segment of the San Andreas alone is quite high and contributes to a significant hazard. We modeled the earthquakes along the southern Calaveras Fault by allowing a M 6.2 event to occur anywhere along the fault. We constrained the maximum magnitude to 6.2 because several earthquakes about that size have occurred historically.

We modeled four aerial source zones along the eastern border of the state that extend from about Mammoth Lakes up into northeastern California and incorporate much of northeastern California and small portions of eastern Nevada and southern Oregon (Figure 3). These zones account for faults with poorly constrained or unknown slip rates with multiple fault strands distributed over a wide area. These source zones are shown in Figure 3 and included in Table 1. The zones were modeled using linear sources, oriented along regional structural trends. They incorporate earthquakes modeled using an exponential magnitude-frequency distribution between M 6.5 and 7.3, except for the Foothills Fault System that incorporates exponentially distributed earthquakes between M 6.0 and 7.0.

In addition to the characteristic and exponential distributions for fault sources, we also allow for background seismicity that accounts for random earthquakes between M 5 and 7 based on the methodology described by Frankel et al. (1996). We note that an overlap occurs in our source model between M 6.5 and 7 because both the background as well as the fault magnitude distributions may contain that range of events. Frankel et al. (1996) and Cao et al. (1996), however, include sensitivity studies indicating that this overlap causes only small differences to the calculated hazard values. The inclusion of larger events in the background allows for sources such as the 1994 Northridge earthquake that occurred on a previously unknown fault. The background seismicity is based on the assumption and observation that large earthquakes occur where smaller earthquakes have occurred in the past. Therefore, the background seismicity is highest near locations of M>4 events and is based on the DMG California catalog of earthquakes (1800-1994; Petersen et al., written communication, 1996). The background hazard is based on the rate of M 4 events since 1933, M 5 events since 1900, and M 6 events since 1850. The seismicity is smoothed using a Gaussian operator with correlation distance of 50 km and then the smoothed seismicity value is summed at each grid point. The a-values are calculated using the method described in Weichert (1980) for all grid points across California (Frankel, 1995, Frankel et al., 1996). The hazard may then be calculated using this a-value, a b-value of 0.9, minimum magnitude of 5, maximum magnitude of 7, and applying an exponential distribution as described by Hermann (1977).

c) Attenuation relations

Once the earthquake distributions have been calculated for all the faults, attenuation relations are applied to estimate the ground motion distribution for each earthquake of a given magnitude, distance, and rupture mechanism. We have chosen to use three attenuation relations for crustal faults and two relations for subduction zone events. The peak ground acceleration (pga) relations that we chose for crustal earthquakes are from: Boore et al. (1993, with revisions given in written communication 1995); Geomatrix-Sadigh equation found in Geomatrix (1995); and Campbell and Bozorgnia, (1994). The relations that we use for subduction earthquakes are: the Geomatrix-Youngs subduction zone interface earthquake relation and the Geomatrix-Sadigh equation both described in Geomatrix (1995). For all faults and background seismicity, except for the Cascadia subduction events, we apply Boore et al., Campbell and Bozorgnia, and Geometrix-Sadigh et al. weighted equally. For earthquakes along the Cascadia subduction zone we apply the Geomatrix-Youngs equation and the Geomatrix-Sadigh equation weighted equally for the M 8.3 event and apply only the Geomatrix-Youngs equation for the M 9 event because the Geomatrix-Sadigh equation does not apply for that size earthquake.

The Boore, Joyner and Fumal relation for random horizontal component of peak ground acceleration (pga) is given by:

$$\log_{10}(pga) = b_1 + b_2(m-6) + b_3(M-6)2 + b_4 r + b_5 \log_{10} r + b_6 G_b + b_7 G_c + \varepsilon \quad (5)$$

with $r=(d^2+h^2)^{1/2}$ and $\sigma \log_{10} Y=0.226$, $\sigma \ln Y=0.520$. In this equation b_1(reverse)=-0.051, b_1(strike-slip)=-0.136, b_1(all)=-0.105, b_2=0.229, b_3=0, b_4=0, b_5=-0.778, b_6=0.162, b_7=0.251, G_b=0.5 G_c=0.5, and h=5.57, d is the closest distance to the surface projection of the rupture, ε is the random uncertainty term, and M is moment magnitude. The firm-rock equation is used to assess ground motion for a soil condition near the boundary between soil types b and c. Therefore, we use the relation with G_b and G_c each 0.5 to account for this firm-rock condition.

The Geomatrix - Sadigh pga for strike slip style of faulting and for rock site conditions is given by:

$$\text{for } M \leq 6.5: \ln(pga) = -0.624 + 1.0M - 2.1 \ln[R + \exp(1.29649 + 0.250M)] \quad (6)$$

$$\text{for } M > 6.5: \ln(pga) = -1.274 + 1.1M - 2.1 \ln[R + \exp(-0.48451 + 0.524M)]$$

with dispersion relation: $\sigma[\ln(pga)] = 1.39 - 0.14M$, or 0.38 for M $\geq$7.25

These values are increased by 20% for reverse faults. M is moment magnitude and R is the closest distance to the source in km.

The Campbell and Bozorgnia (geometric mean of two horizontal components of pga) is given by:

$$\ln(pga) = -3.512 + 0.904M - 1.328 \ln \sqrt{R_s^2 + [0.149 \exp(0.647M)]^2} +$$

$$[1.125 - 0.112 \ln(R_s) - 0.0957M]F + [0.440 - 0.171 \ln(R_s)]S_{sr} +$$

$$[0.405 - 0.222 \ln(Rs)]S_{hr} + \varepsilon$$

with,

$$\sigma_{\ln(pga)} = 0.889 - 0.0691M \text{ if } M < 7.4 \text{ and}$$

$$\sigma_{\ln(pga)} = 0.38 \text{ if } M \geq 7.4 \quad (7)$$

where R_s is the closest distance to the seismogenic rupture, F is 1 for reverse, thrust and oblique faulting events and 0 for strike-slip and normal faulting events, *M* is moment magnitude, S_{sr}=1 for firm-rock sites and zero otherwise, S_{hr} = 1 for hard-rock sites and zero otherwise, and ε is the random error term with zero mean and standard deviation equal to $\sigma_{\ln(pga)}$. The top of seismogenic rupture is assumed to be about 3 km depth.

The Geomatrix-Youngs equation for pga from slab interface earthquakes on the Cascadia subduction zone is based on a fault depth of 20 km and is given by:

$$\ln(pga) = 0.3633 + 1.414M - 2.556(R+1.782e^{0.554M}) \quad (8)$$

with standard deviation = 1.45 - 0.1M. M is moment magnitude and R is the closest distance to the source in kilometers. Standard deviation for magnitudes greater than M 8 are set equal to the standard deviation for M 8.

In addition, deep events (depth > 35 km) in northwestern California were considered for this map, but they do not contribute significantly to the hazard probabilities because about 25 or so M>4 events have been recorded in that region. Those deeper events mostly influence the hazard north of California and for further details see Frankel et al. (1996).

HAZARD MAP

The hazard map shown in Figure 5 depicts the peak horizontal ground acceleration exceeded at a 10% probability in 50 years on a uniform firm-rock site condition. Acceleration at 10% in 50 years ranges from about 0.1 g to over 1 g. This map indicates high hazard in a belt about 50 km on either side of the San Andreas Fault Zone and along the Eastern California Shear Zone (Figure 1). The hazard is also quite high over the western Transverse Ranges, although no large earthquakes are known to have occurred in this region during the historical record. The northwest coastal portion of the state reflects high hazard from potential earthquakes on several onshore faults and the Cascadia subduction zone. The hazard is lower in the Central Valley and many portions of northeastern and southeastern California. More than three-fourths of the population of the state resides in counties that have seismic hazard above about 0.4 g, including counties near the San Francisco Bay and greater Los Angeles regions. This value is a rough estimate based on overall state population of about 32 million and county population as defined by the Governor's Office of Planning and Research (1996).

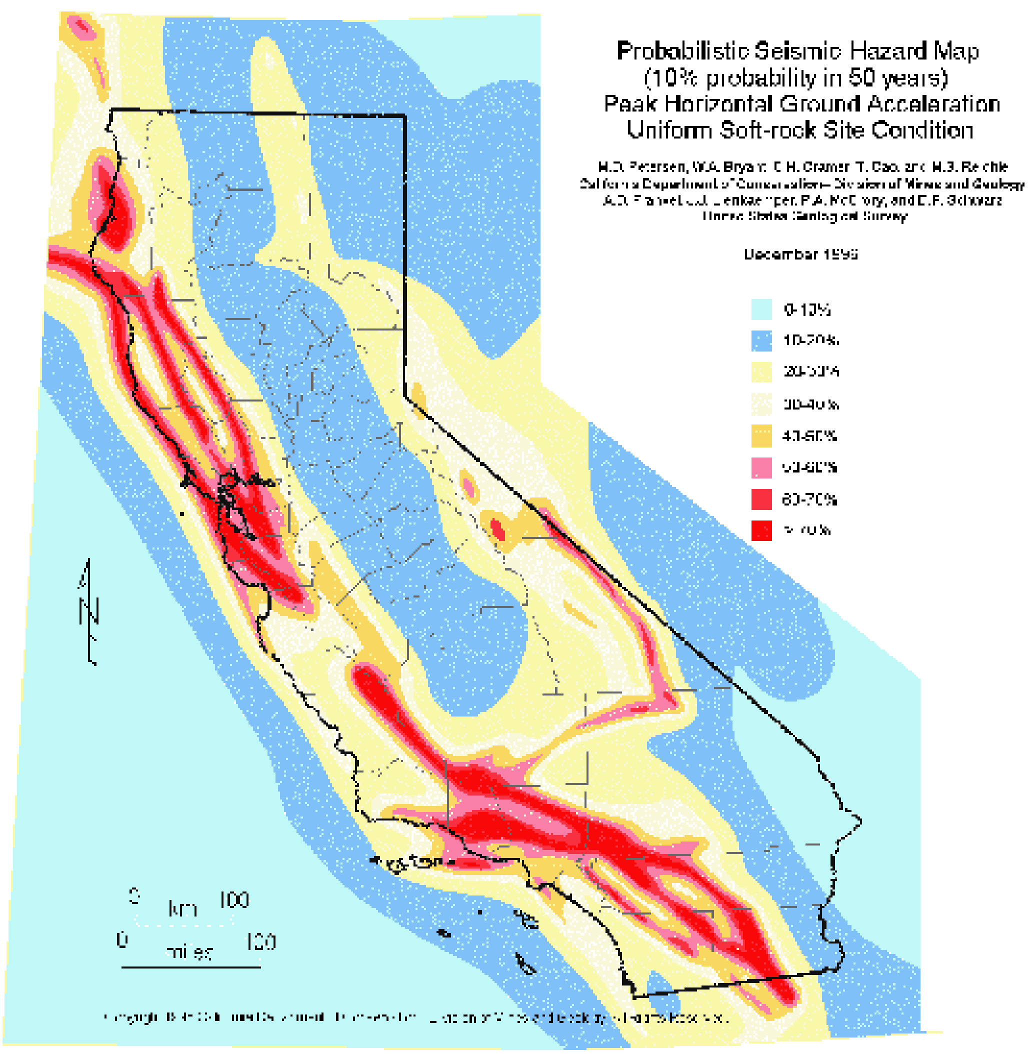


Figure 5: Probabilistic seismic hazard map for peak horizontal acceleration on firm-rock site conditions and for 10% probability of exceedance in 50 years. Contours are based on grided hazard values with spacing of 0.05 longitude and latitude. Colors indicate peak acceleration in %g units.

COMPARISON WITH HISTORICAL DAMAGE

The area of California where ground shaking during historical earthquakes has exceeded Modified Mercalli Intensity (MMI) VII is shown in Figure 6, revised after the work of Toppozada et al. (1986) to include the 1992 Landers sequence, the 1987 Superstition Hills events and the 1994 Markleeville earthquake. MMI is a scale that measures the effects of earthquake ground motion on people and structures. MMI VII effects are characterized by significant damage to weak structures. Therefore, the map depicts all areas that either experienced damage or would have experienced damage to structures if the area had been developed at the time of the earthquake. The damage pattern extends about 50 km on either side of the San Andreas Fault Zone and extends up through the Eastern California Shear Zone. This pattern is very similar to the hazard pattern shown in the hazard map of Figure 5. Differences between the historic damage and the map we produced can be observed near the Cascadia subduction zone and near the Transverse Ranges of southern California. In these areas, few large earthquakes have occurred historically but geologic and geodetic data indicate high strain rates.

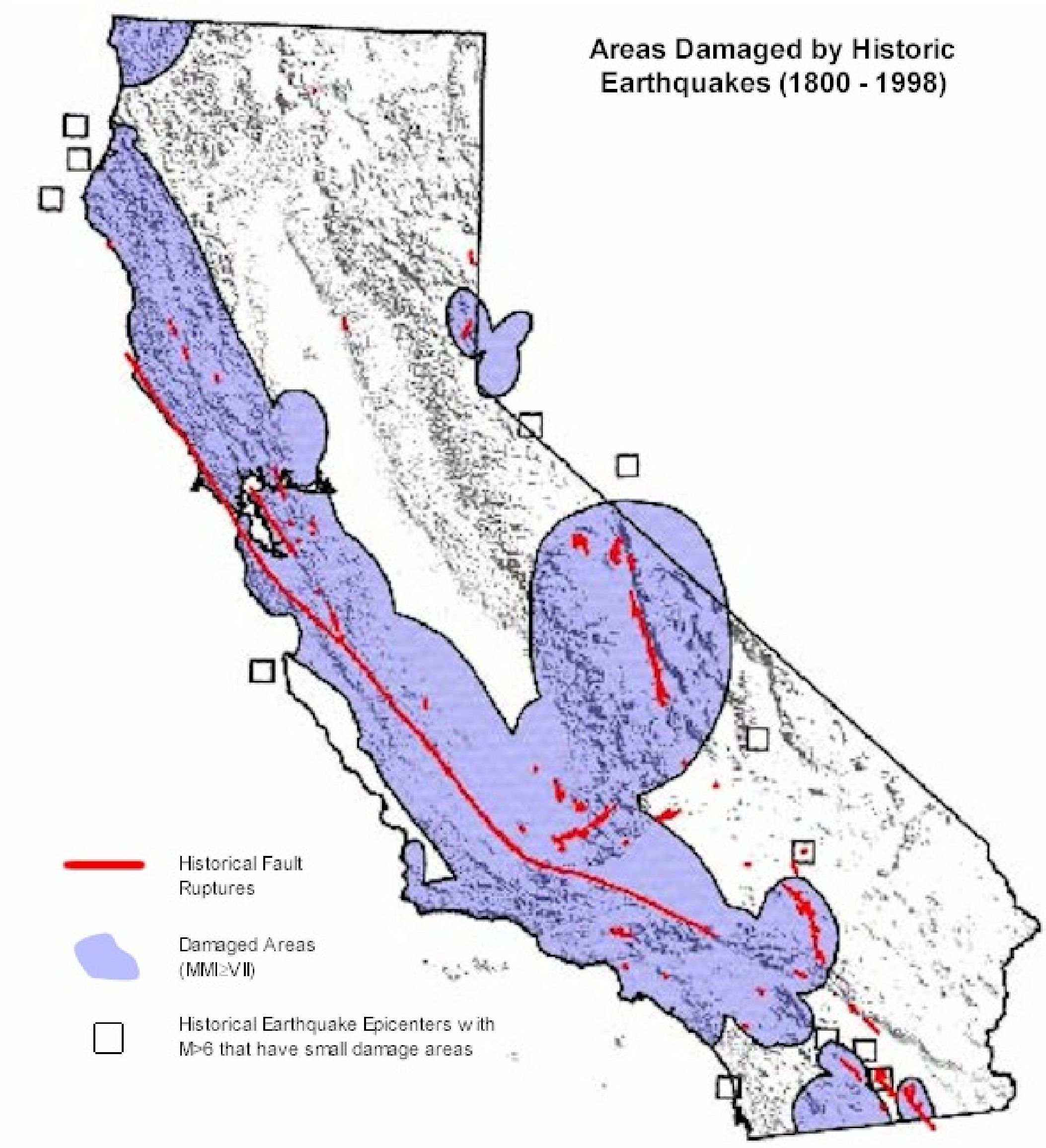


Figure 6: Areas that are thought to have experienced (or would have experienced if the area were developed) MMI VII or greater between 1800 and 1996. San Andreas and Eastern California Shear zones are noted. Boxes indicate epicenters of M ~ 6 earthquakes for which we do not have damage data.

COMPARISON WITH HISTORICAL SEISMICITY

The seismic hazard was calculated by inferring a suite of representative earthquakes for each fault, calculating the ground motion from these events, and summing the hazard from all the earthquakes. An important constraint on the hazard model is a comparison of the model earthquakes with the historical rate of earthquakes. This comparison is shown in Figure 7. The hazard model matches very well from M 5 to M 6 and M 7 to M 8. However, there is an excess of events, on the order of a factor of 2, for M 6 to M 7 across the entire state. Overall the match between the model seismicity and the historical seismicity is fairly good. The mismatch between the historical and model seismicity indicates the discrepancy between the geologic fault information and the historic earthquake catalog. As mentioned earlier, the historic earthquake catalog covers only about 200 years, while recurrence of earthquakes on many faults are at least an order of magnitude longer. Therefore, we would not expect to have seen all the earthquakes during the past 200 years that would be expected in the future. We cannot say how much the rate of seismicity fluctuates over time scales of hundreds to thousands of years.

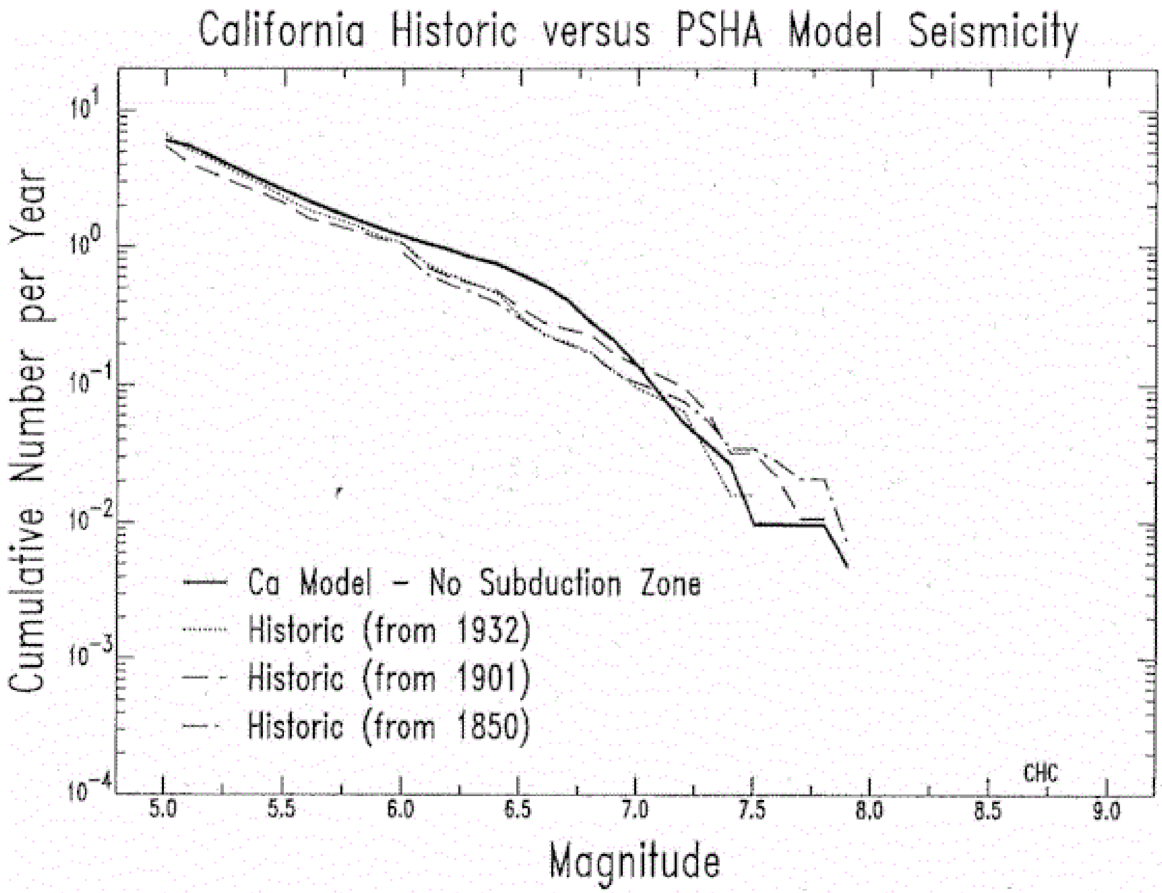


Figure 7: Comparison of the number of historic California earthquakes and the earthquakes used to calculate the seismic hazard. The historic earthquake numbers were normalized by the length of catalog which we used (e.g., since 1932 - 64 years; 1901 - 95 years; 1850 - 146 years) to show the variability in the historic earthquake rate.

DEAGGREGATION OF THE HAZARD MODEL

We have deaggregated the hazard model to determine the size and distance of the earthquakes that contribute most to the hazard at specific sites throughout California. The deaggregation process compares the probabilities of exceeding a certain ground motion level from each event used in the model to determine the event(s) that contribute most to the hazard at each site. This should enable engineers, geologists, and public policy makers to identify the predominant hazardous earthquakes in any region and provide guidance in choosing strong motion records or scenario earthquakes in their design and planning.

The modal (most probable) magnitude for earthquakes that dominate the hazard is contoured and displayed in Figure 8. The map indicates hazard in the northwest from great earthquakes along the Cascadia subduction zone, the hazard near the San Andreas and the Central Valley from large earthquakes along the San Andreas Fault, and the hazard in the east San Francisco Bay area and greater Los Angeles region from moderate to large events along local faults. The modal distance map indicates the distance to the earthquake that contributes most to the hazard at each site. This map is shown in Figure 9 and indicates that for most areas the fault that is nearest the site causes the highest hazard. For the Central Valley, few faults have been identified that contribute to the hazard and so the distances are considerably longer than for coastal areas and generally these longer distances correspond to the distance from the San Andreas Fault.

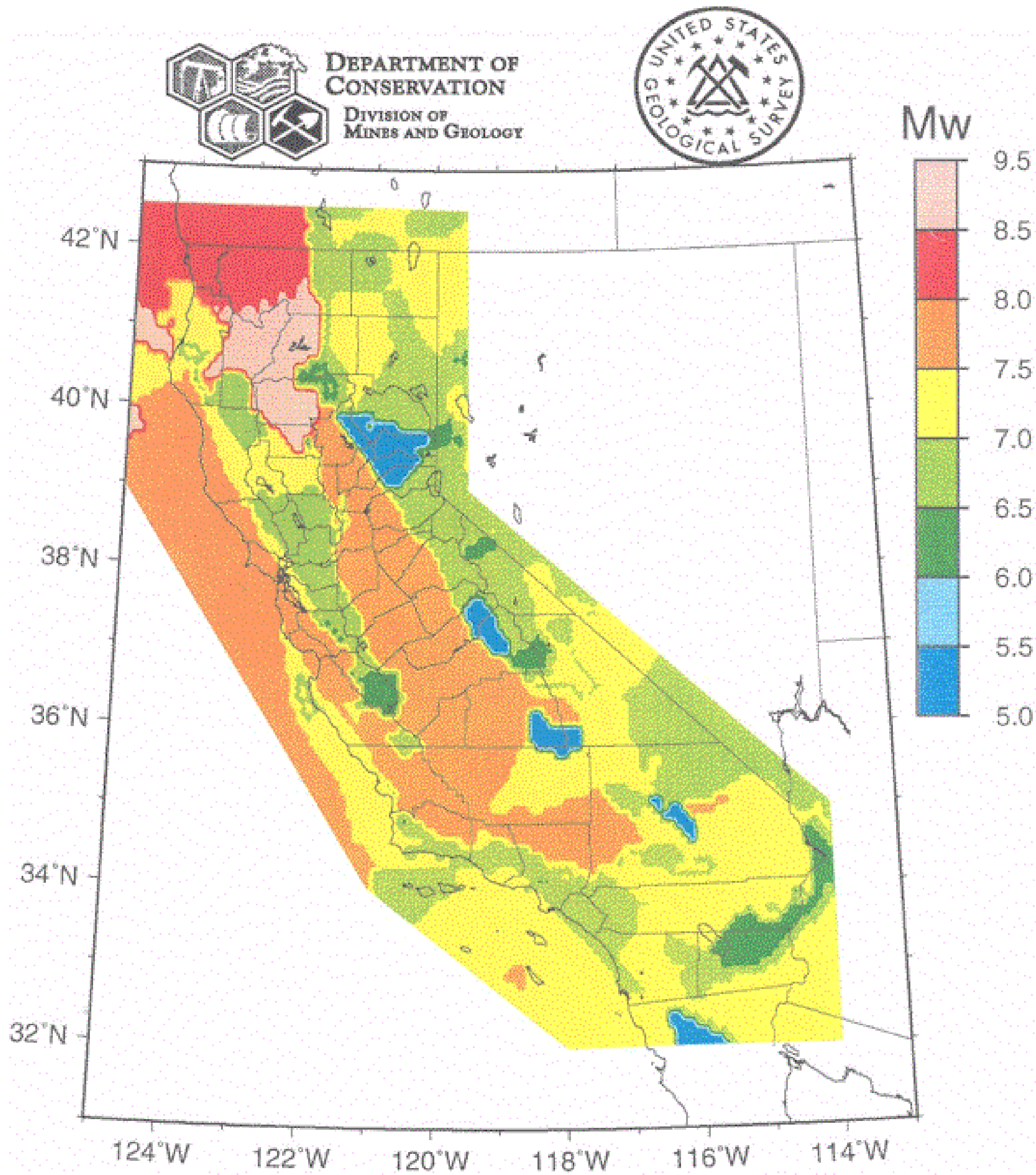


Figure 8: Contour map of the magnitude of the earthquake that causes the dominant hazard for peak ground acceleration at 10% probability of exceedance in 50 years and alluvial site conditions.

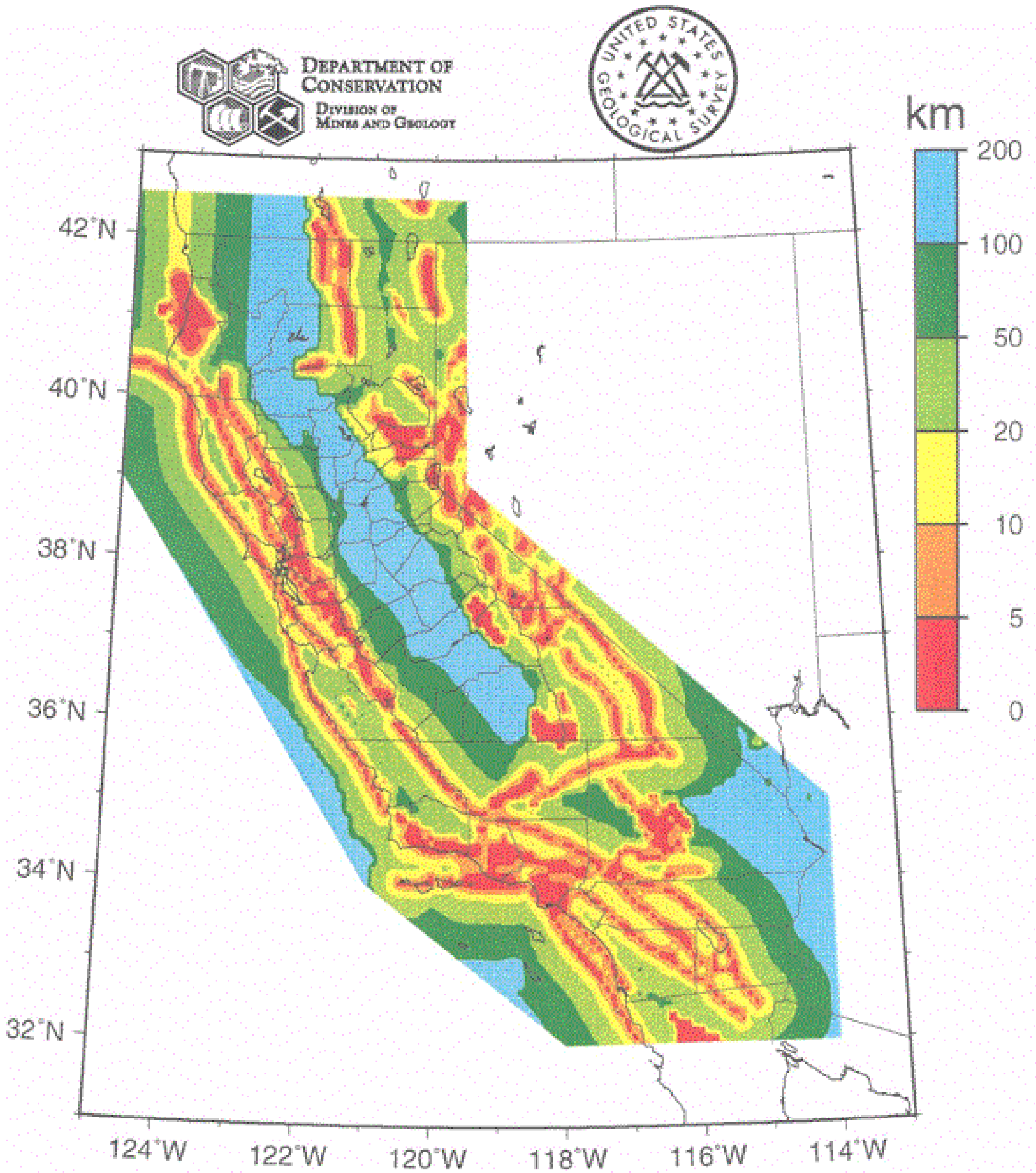


Figure 9: Contour map of the distance of the earthquake that causes the dominant hazard for peak ground acceleration at 10% probability of exceedance in 50 years and alluvial site conditions.

COMPARISON OF HAZARD ACROSS CALIFORNIA

The hazard map in Figure 5 indicates the hazard at a 0.0021 annual probability level. Figure 10 shows the hazard curves at six sites across the state and indicates the annual probability of exceeding a given level of ground motion at each site (the 0.0021 probability is represented by a single point on each of the curves). Probabilities of exceeding low ground motions less than 0.1 g are the highest and the probabilities of exceeding high ground motions near 1 g are generally 2 or 3 orders of magnitude lower. The hazard is quite high near San Bernardino because of proximity to two very active geologic structures, the San Andreas and San Jacinto faults. Eureka is located near several moderately active crustal faults (e.g., the Little Salmon, Mad River, Trinadad, and Fickle Hill faults) and directly over the Cascadia subduction zone that is thought to be capable of great (M 8 to 9) earthquakes. San Francisco is situated about 10 km from the segment of the San Andreas Fault that has slip rate about 17 - 24 mm/yr and about 20 km from the Hayward fault that has slip rate of about 9 mm/yr. These high slip rate faults combine to produce a significant seismic hazard in the San Francisco Bay area. Los Angeles is located near several faults and blind thrusts that have slip rates between 1 and 3 mm/yr and about 50 km from the section of the San Andreas Fault System that has a slip rate between 25 and 35 mm/yr. San Diego is located about 30 km from the offshore Coronado Bank Fault with slip rate of about 3 mm/yr and adjacent to the Rose Canyon Fault that is characterized by a slip rate of about 1.5 mm/yr. Therefore, the hazard levels at San Diego are somewhat lower than at the Los Angeles site. Sacramento has the lowest hazard levels of the cities shown (i.e., the probability of all levels of ground motions is lower than in many other regions of the state). Few known faults and low historical seismicity have been observed in this region. However, we cannot preclude the possibility that future earthquakes will occur in any of these areas of low hazard. In fact, the possibility of earthquakes up to M 7 have been included in the random background seismicity that is distributed everywhere across this map. Thus, the probability of exceeding large ground motions in Sacramento or any other site in California is never zero.

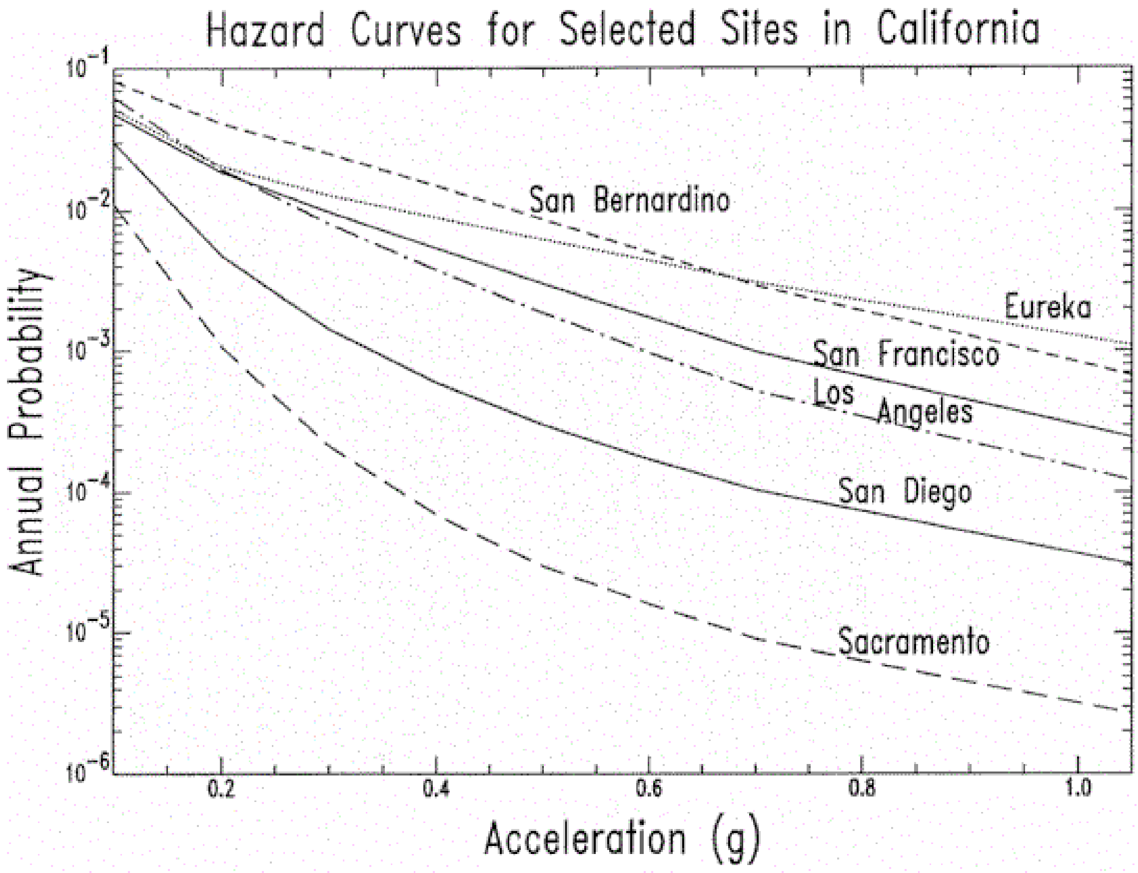


Figure 10: Hazard curves for peak ground acceleration and alluvial site conditions at various cities located across California. The curves indicate the probability of exceeding the given peak ground acceleration levels on alluvial site conditions.

CONCLUSIONS

The seismic hazard map and model presented in this report indicate that the hazard is high in many regions across the state, especially within about 50 km of the San Andreas fault system, the Eastern California Shear Zone faults, the western Transverse Ranges, and the Cascadia subduction zone. Earthquakes in populated regions have already caused considerable losses during the past 2 centuries that span California's recorded seismic history. The hazard map is consistent with this historical seismicity, the historical damage patterns, and with geologic information regarding the slip rate and pre-historic earthquakes.

This study indicates that about three-fourths of California's population resides in counties that have significant seismic hazard. This level of hazard reaffirms the need to examine existing infrastructure and verify that it is adequate to withstand the expected seismic shaking to prevent loss of life from structural collapse during an earthquake. The seismic hazard maps and models presented in this report should be useful for assisting policy makers, engineers, and scientists to plan for strong earthquake ground shaking.

ACKNOWLEDGMENTS

We wish to thank the hundred or so individuals who reviewed and provided input for the source model and hazard mapping methodology. In particular we would like to thank George Saucedo, Siang Tan, Gary Taylor, Jerry Treiman, and Chris Wills for reviewing and compiling the geologic information across the entire state and the Working Group on Northern California Earthquake Potential for compiling the fault information for northern California. The Southern California Earthquake Center group led by Jim Dolan provided important review and input of the geologic parameters for southern California. Many scientists, engineers and public policy officials participated in the U.S. Geological Survey review meetings and committees including the Applied Technology Council that gave guidance regarding what parameters should be mapped. We also thank staff at DMG for drafting figures, assisting in GIS analysis, and editing text. We especially thank Lena Dida at DMG and Bob Simpson at USGS for reviewing the text. In addition we thank the Office of Emergency Services and Federal Emergency Management Agency for their support of the mapping in portions of southern California.

REFERENCES

Bird, P. and R. Rosenstock, 1984, Kinematics of Present Crust and Mantle Flow in Southern California*: Geol. Soc. Am. Bull*., **95**, 946-957.

Boore, D.M., W.B. Joyner, and T.E. Fumal, 1993, Estimation of Response Spectra and Peak Accelerations From Western North American Earthquakes: An Interim Report, *U.S. Geological Survey Open-File Report 93-509*, 72 pp.

Campbell, K.W. and Y. Bozorgnia, 1994, Near-source Attenuation of Peak Horizontal Acceleration from Worldwide Accelerograms Recorded from 1957 to 1993: in *Proceedings of the Fifth U.S. National Conference on Earthquake Engineering, July 10-14, 1994*, Chicago, Illinois, Earthquake Engineering Research Institute, V. 3, 283-292.

Cao, T. M.D. Petersen, and M.S. Reichle, 1996, Seismic Hazard Estimate from Background Seismicity in Southern California: *Bull. Seismol. Soc. Amer.*, **86**, 1372-1381.

Clark, M.M., K.K. Harms, J.J. Lienkaemper, D.S. Harwood, K.R. Lajoie, J.C. Matti, J.A. Perkins, M.J. Rymer, R.V. Sarna-Wojcicki, R.V. Sharp, J.D. Sims, J.C. Tinsley, and J.I. Ziony, 1984, Preliminary slip-rate table for late Quaternary faults of California: *U.S. Geol. Surv. Open-File Report 84-106*, 12pp.

Cramer, C.H. and M.D. Petersen, 1996, Predominant Seismic Source Distance and Magnitude Maps for Los Angeles, Orange, and Ventura counties, California: *Bull. Seismol. Soc. Amer*., **86**, 1645-1649.

Cramer, C. H., M.D. Petersen, and M.S. Reichle, 1996, A Monte Carlo Approach in Estimating Uncertainty for a Seismic Hazard Assessment of Los Angeles, Ventura, and Orange Counties, California, *Bull. Seismol. Soc. Amer*., **86**, (Dec. issue).

DeMets, C., R.G. Gordon, D.F. Argus, and S. Stein, 1990, Current Plate Motions: *Geophys. J. Int*., **101**, 425-478.

Frankel, A., 1995, Mapping Seismic Hazard in the Central and Eastern United States: *Seismol. Research Lett.,* **66,** 4, July/August.

Frankel, A., C. Mueller, T. Barnhard, D. Perkins, E.V. Leyendecker, N. Dickman, S. Hanson, and M Hopper, 1996, National Seismic Hazard Maps, June 1996 Documentation: U.S. Geological Survey Open-File Rpt. 96-532. see web site at : http://gldage.cr.usgs.gov/eq/

Geomatrix Consultants, 1995, Seismic Design Mapping State of Oregon: prepared for Oregon Dept. of Transportation, Transportation Building, Salem, OR, Section 3, 17 pp.

Governor's Office of Planning and Research - State of California, 1996, The California Planners' 1996 Book of Lists, Dept. of General Services Publication Section, P.O. Box 1015, North Highlands, CA, 95660, 64 pp.

Hanks, T.C., and H. Kanamori, 1979, A moment magnitude scale: *J. Geophys. Res*., **84**, 2348-2350.

Hermann, R.B., 1977, Recurrence Relations: *Earthquake Notes*, **48**, 47-49.

Hill, D.P., J.P. Eaton, and L.M. Jones, 1990, Seismicity, 1980-86: in The San Andreas Fault System, California, ed. by R.E. Wallace, U.S. Geol. Surv. Prof. Paper 1515, 115-152.

Jennings, C.W., 1994, Fault Activity Map of California and Adjacent Areas: California Dept. of Conservation, Division of Mines and Geology, *Geologic Data Map No. 6*, Scale 1:750,000

WGCEP- Working Group on Northern California Earthquake Potential, 1996, Database of Potential Sources for Earthquakes Larger than Magnitude 6 in Northern California: U.S. Geological Surv. Open-File Report 96-705, 40 pp..

McCrory P.A., 1996, Evaluations of Fault Hazards, Northern Coastal California: U.S. Geological Survey Open-File Report 96-656, 87 pp..

McGuire, R.K., 1995, Probabilistic seismic hazard analysis and design earthquakes: closing the loop: *Bull. Seismol. Soc. Amer*., **85**, 1275-1284, 1995.

Petersen, M.D., C.H. Cramer, W.A. Bryant, M.S. Reichle, and T.R. Toppozada, 1996a, Preliminary Seismic Hazard Assessment for Los Angeles, Ventura, and Orange Counties, California, Affected by the 17 January 1994 Northridge Earthquake, *Bull. Seismol. Soc. Amer.,* **86**, 1B, S247-S261.

Petersen, M.D., W.A. Bryant, C.H.Cramer, C. Cao, M.S. Reichle, A.Frankel, J. Lienkaemper, P. McCrory, D.P. Schwartz, 1996b, Probabilistic Seismic Hazard Assessment for the State of California, EOS Transactions, AGU, (abstract).

Petersen, M.D. and S.G. Wesnousky, 1994, Fault Slip Rates and Earthquake Histories for Active Faults in Southern California: *Bull. Seism. Soc. Am*., **84**, 1608-1649.

Real, C.R. and M.D. Petersen, 1995, Provisional Seismic Zoning of Portions of Los Angeles and Ventura Counties Following the 17 January 1994 Northridge Earthquake: in The Northridge, California, Earthquake of 17 January 1994, edited by M.C. Woods and W.R. Seiple, California Dept. of Conservation, Special Publication 116, 231-240.

Reiter, L., 1990, Earthquake hazard analysis: issues and insights, Columbia University Press, New York, 254 pp.

Richter, C.F., 1958, *Elementary Seismology*, W.H. Freeman, New York, 768 pp.

Schwartz, D.P. and K.J. Coppersmith, 1984, Fault behavior and characteristic earthquakes: examples from the Wasatch and San Andreas faults: *J. Geophys. Res*., **89**, 5873-5890.

Toppozada, T.R., C.R. Real, and D.L. Parke, 1986, Earthquake History of California: California Geology, February 1986, 27-33, 1986.

Weichert, D.H., 1980, Estimation of Earthquake Recurrence Parameters for Unusual Observation Periods for Different Magnitudes: *Bull. Seismol. Soc. Amer*., **70**, 1337-1356.

Wells, D.L. and K.J. Coppersmith, 1994, New Empirical Relationships Among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement: Bull. Seism. Soc. Am., **84**, 974-1002.

Wesnousky, S.G., 1986, Earthquakes, Quaternary faults, and seismic hazard in California: *J. Geophys. Res.*, **91**, p. 12,587-12,631.

Working Group on California Earthquake Probabilities, 1988, Probabilities of Large Earthquakes Occurring in California on the San Andreas Fault System: U.S. Geological Surv. Open-File Report **88-398**, 62 pp.

Working Group on California Earthquake Probabilities, 1990, Probabilities of Large Earthquakes in the San Francisco Bay Region, California: U.S. Geological Surv. Circular, **1053**, 51 pp.

Working Group on California Earthquake Probabilities, 1995, Seismic Hazards in Southern California: Probable Earthquakes, 1994 to 2024: *Bull. Seismol. Soc. Amer*., **85**, 379-439.

Ziony, J.I. and L.M. Jones, 1989, Map showing late Quaternary faults and 1978-84 seismicity of the Los Angeles region, California: *U.S. Geological Survey Miscellaneous Field Studies Map MF-1964*, scale 1:250,000.

Ziony, J.I. and R.F. Yerkes, 1985, Evaluating earthquake and surface-faulting potential: in Ziony, J.I., editor, Evaluating earthquake hazards in the Los Angeles region - an earth-science perspective: *U.S. Geological Survey Professional Paper* **1360**, p. 43-91.

Back to Top of Page

Last edited on September 26, 2003
Contact: webmaster@consrv.ca.gov | Copyright © California Department of Conservation, 2003. All rights reserved.
The Department of Conservation makes no warranties as to the suitability of this product for any purpose.
© 2000 State of California. Gray Davis, Governor. Conditions of Use Privacy Policy

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
OPEN-FILE REPORT 96-08

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 96-706

APPENDIX A

CALIFORNIA FAULT PARAMETERS

FAULT NAME AND GEOMETRY (ss) strike slip, (r) reverse, (n) normal (rl) rt. lateral, (ll) left lateral, (o) oblique	LENGTH (km)	+/-	SLIP RATE (mm/yr)	+/-	RANK (1)	Mmax (2)	CHAR. RATE (events/yr)	R.I. (3)	Down dip Width (km)(4)	+/-	ruptop (5)	rupbot (6)	rake	dip	daz (7)	Endpt N	Endpt S	COMMENTS
A FAULTS																		
SAN ANDREAS FAULT ZONE																		
San Andreas - Coachella (rl-ss)	95	10	25.00	5.00	P	7.1	0.00000	n/a	12	2	0	12	180	90	0	-116.48; 33.92	-115.71; 33.35	Slip rate based on Sieh and Williams (1990); Sieh (1986); Keller et al. (1982); Bronkowski (1981). Model assumes slip only in S. San Andreas events.
San Andreas - San Bernardino (rl-ss)	107	11	24.00	6.00	M	7.3	0.00231	433	18	2	0	18	180	90	0	-117.53; 34.31	-116.48; 33.92	Slip rate reported by Weldon and Sieh (1985).
San Andreas (southern) (rl-ss)	203	20	24.00	6.00	P	7.4	0.00454	220	12	2	0	12	180	90	0	-117.53; 34.31	-115.71; 33.35	Rupture of San Bernardino and Coachella segments. Slip rate based on Coachella segment.
San Andreas - Mojave (rl-ss)	99	10	30.00	7.00	P	7.1	0.00182	550	12	2	0	12	180	90	0	-118.50; 34.70	-117.53; 34.31	Slip rate based on Sieh (1984), Salyards et al. (1992), and WGCEP (1995).
San Andreas - Carrizo (rl-ss)	145	15	34.00	3.00	W	7.2	0.00000	n/a	12	2	0	12	180	90	0	-119.86; 35.31	-118.51; 34.70	Slip rate based on Sieh and Jahns (1984). Model assumes slip only in 1857-type events.

San Andreas - Cholame (rl-ss)	62	6	34.00	5.00	P	6.9	0.00229	437	12	2	0	12	180	90	0	-120.29; 35.75	-119.86; 35.31	Slip rate based on analogy with Carrizo segment.
San Andreas Parkfield Segment (rl-ss)	37	4	34.00	5.00	P	6.7	0.04060	25	12	2	0	12	180	90	0	-120.56; 36.00	-120.29; 35.75	Slip rate reported by WGCEP (1995).
San Andreas (1857 rupture) (rl-ss)	345	35	34.00	5.00	W	7.8	0.00485	206	12	2	0	12	180	90	0	-120.56; 36.00	-117.53; 34.31	Rupture of Parkfield, Cholame, Carrizo, and Mojave segments. Max. magnitude based on 1857 event (Ellsworth, 1990). Slip rate based on Carrizo segment.
San Andreas (creeping segment) (rl-ss)	125	13	34.00	5.00	P	*	0.00000	n/a	12	2	0	12	180	90	0	-121.51; 36.82	-120.56; 36.00	Background seismicity.
San Andreas (Pajaro) (rl-ss)	22	2	14.00	3.00	P	6.8	0.00000	n/a	18	2	0	18	180	90	0	-121.69; 36.95	-121.51; 36.82	Pajaro segment assumed to rupture only in 1906-type events. Max. magnitude based on 1.6 m displacement.
San Andreas (Santa Cruz Mtn) (rl-ss)	37	4	14.00	3.00	P	7.0	0.00250	400	18	2	0	18	180	90	0	-122.00; 37.18	-121.69; 36.95	Slip rate based on Lienkaemper, et al. (1991) and assumption that 3 mm/yr rate transferred to Sargent fault. Max. magnitude based on 1.6 m displacement.
San Andreas (Peninsula) (rl-ss)	88	9	17.00	3.00	M	7.1	0.00250	400	14	2	0	14	180	90	0	-122.60; 37.81	-122.00; 37.18	Slip rate is based on Clahan, et al. (1995) and assumptions by WGNCEP (1996). Max. magnitude based on 1.6 m displacement.
San Andreas (North Coast) (rl-ss)	322	32	24.00	3.00	M	7.6	0.00000	n/a	12	2	0	12	180	90	0	-124.41; 40.25	-122.59; 37.82	Assumption that North Coast segment ruptures only in 1906-type events. Slip rate based on Niemi and Hall (1992) and Prentice, et al, (1991).
San Andreas (1906) (rl-ss)	470	47	24.00	3.00	M	7.9	0.00476	210	12	2	0	12	180	90	0	-124.41; 40.25	-121.51; 36.82	Slip rate based on Niemi and Hall (1992) and Prentice, et al (1991). Assumption that 1906 events rupture North Coast, Pennisula, and Santa Cruz Mtns. segments to San Juan Bautista. Max. magnitude based on 1906 average 5 m displacement (WGCEP, 1990; Lienkaemper, 1996).

SAN JACINTO - IMPERIAL FAULT ZONE

Imperial (rl-ss)	62	6	20.00	5.00	M	7.0	0.01258	79	12	2	0	12	180	90	0	-115.57; 32.91	-115.17; 32.47	Slip rate based on study by Thomas and Rockwell (1996). Max. magnitude based on M 6.9 event that occurred in 1940 (Ellsworth, 1990).
Superstition Hills (rl-ss)	22	2	4.00	2.00	P	6.6	0.00400	250	12	2	0	12	180	90	0	-115.84; 33.01	-115.64; 32.89	Slip rate and fault length reported by WGCEP (1995). Max. magnitude based on 1987 Superstition Hills earthquake (Wells and Coppersmith, 1994).
Superstition Mountain (rl-ss)	23	2	5.00	3.00	M	6.6	0.00200	500	12	2	0	12	180	90	0	-115.92; 33.99	-115.70; 32.89	Slip rate based on Gurrola and Rockwell (1996). Max. magnitude earthquake based on 1968 Borrego Mtn. earthquake (Wells and Coppersmith, 1994).

San Jacinto - Borrego (rl-ss)	29	3	4.00	2.00	M	6.6	0.00571	175	12	2	0	12	180	90	0	-116.19; 33.20	-115.98; 33.01	Slip rate and fault length reported by WGCEP (1995).
San Jacinto - Coyote Creek (rl-ss)	40	4	4.00	2.00	M	6.8	0.00571	175	15	2	0	15	180	90	0	-116.51; 33.46	-116.19; 33.20	Slip rate and fault length reported by WGCEP (1995).
San Jacinto - Anza (rl-ss)	90	9	12.00	6.00	M	7.2	0.00400	250	18	2	0	18	180	90	0	-116.92; 33.74	-116.12; 33.26	Slip rate and fault length reported by WGCEP (1995).
San Jacinto - San Jacinto Valley (rl-ss)	42	4	12.00	6.00	P	6.9	0.01205	83	18	2	0	18	180	90	0	-117.24; 34.02	-116.92; 33.74	Slip rate and fault length reported by WGCEP (1995).
San Jacinto - San Bernardino (rl-ss)	35	4	12.00	6.00	P	6.7	0.01000	100	15	2	0	15	180	90	0	-117.51; 34.25	-117.24; 34.02	Slip rate and fault length reported by WGCEP (1995).

ELSINORE FAULT ZONE

Laguna Salada (rl-ss)	67	7	3.50	1.50	M	7.0	0.00297	336	15	2	0	15	180	90	0	-115.88; 32.73	-115.40; 32.29	Slip rate reported by Mueller and Rockwell (1995).
Elsinore-Coyote Mountain (rl-ss)	38	4	4.00	2.00	M	6.8	0.00160	625	15	2	0	15	180	90	0	116.36; 32.97	-116.01; 32.78	Slip rate and fault length reported by WGCEP (1995).
Elsinore-Julian (rl-ss)	75	8	5.00	2.00	P	7.1	0.00294	340	15	2	0	15	180	90	0	-117.01; 33.38	-116.36; 32.97	Slip rate and fault length reported by WGCEP (1995).
Elsinore-Temecula (rl-ss)	42	4	5.00	2.00	M	6.8	0.00417	240	15	2	0	15	180	90	0	-117.35; 33.64	-117.01; 33.34	Slip rate and fault length reported by WGCEP (1995).
Elsinore-Glen Ivy (rl-ss)	38	4	5.00	2.00	M	6.8	0.00294	340	15	2	0	15	180	90	0	-117.64; 33.85	-117.35; 33.64	Reported slip rates vary from 3.0-7.2 (Millman and Rockwell, 1986)
Whittier (rl-ss)	37	4	2.50	1.00	M	6.8	0.00156	641	15	2	0	15	180	90	0	-118.02; 33.97	-117.64; 33.85	Slip rate based on Rockwell et al. (1990); Gath et al. (1992) description of offset drainage.

HAYWARD - RODGERS CRK FAULT ZONE

Hayward (total length) (rl-ss)	86	9	9.00	1.00	M-W	7.1	0.00600	167	12	2	0	12	180	90	0	-122.41; 38.05	-121.81; 37.45	Well constrained slip rate for southern segment reported by Lienkaemper, et al. (1995) and Lienkaemper and Borchardt (1996). Recurrence (167 yrs) and slip per event (1.5 m) are based on WGCEP (1990). Model weighted 50%.

Hayward (south) (rl-ss)	43	4	9.00	1.00	W	6.9	0.00600	167	12	2	0	12	180	90	0	-121.13; 37.73	-121.81; 37.45	Well constrained slip rate reported by Lienkaemper, et al. (1995) and Lienkaemper and Borchardt (1996). Recurrence (167 yrs) and slip per event (1.5 m) are based on WBCEP (1990). The southern segment can be projected to Calaveras fault along prominent zone of seismicity. Net slip rate of 9mm/yr can be resolved into 3mm/yr vertical and 7.6mm/yr r.l. along postulated Mission Link blind thrust of Andrews, et al (1992) along this southern connection. Model weighted 50%.
Hayward (north) (rl-ss)	43	4	9.00	1.00	M	6.9	0.00600	167	12	2	0	12	180	90	0	-122.41; 38.05	-122.13; 37.73	Well constrained slip rate for southern segment reported in Lienkaemper, et al. (1995) and Lienkaemper and Borchardt (1996). Recurrence (167 yrs) and slip per event (1.5 m) are based on WGCEP (1990). Model weighted 50%.
Rodgers Creek (rl-ss)	63	6	9.00	2.00	M	7.0	0.00450	222	10	2	0	10	180	90	0	-122.77; 38.54	-122.34; 38.09	Slip rate is composite of slip rate reported by Schwartz, et al. (1992) and slip rate from Hayward fault (Lienkaemper and Borchardt, 1996). Recurrence (222yrs) and slip per event (2.0 m) are based on WGCEP (1990).

1. W — well-constrained slip rate; M — moderately constrained slip rate; P — poorly constrained slip rate; U — unconstrained slip rate.
2. Maximum moment magnitude calculated from relationships (rupture area) derived by Wells and Coppersmith (1984).
3. R.I. — recurrence interval.
4. Down-dip width = (rupture bottom minus rupture top) divided by sine of dip angle.
5. Top of rupture.
6. Bottom of rupture.
7. daz — dip azimuth.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Straigraphic Code. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
OPEN-FILE REPORT 96-08

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 96-706

APPENDIX A

CALIFORNIA FAULT PARAMETERS

FAULT NAME AND GEOMETRY (ss) strike slip, (r) reverse, (n) normal (rl) rt. lateral, (ll) left lateral, (o) oblique	LENGTH (km)	+/-	SLIP RATE (mm/yr)	+/-	RANK (1)	Mmax (2)	CHAR. RATE (events/yr)	R.I. (3)	Down dip Width (km)(4)	+/-	ruptop (5)	rupbot (6)	rake	dip	daz (7)	Endpt N	Endpt S	COMMENTS
B FAULTS																		
ELSINORE AND SAN JACINTO FAULT ZONES (NON A FAULTS)																		
Brawley Seismic Zone (rl-ss)	42	4	25.00	5.00	P	6.4	0.04231	24	6	2	2	8	180	90	0	-115.71; 33.35	-115.51; 32.96	Slip rate and fault length reported by WGCEP (1995).
Chino - Central Ave. (rl-r-o) (65 SW)	28	3	1.00	1.00	U	6.7	0.00113	882	17	2	0	15	180	65	225	-117.75; 34.03	-117.57; 33.83	Unconstrained slip rate based on assumptions of slip transfer between Elsinore and Whittier faults.
Earthquake Valley (rl-ss)	20	2	2.00	1.00	U	6.5	0.00285	351	15	2	0	15	180	90	0	-116.58; 33.18	-116.41; 33.08	Slip rate based on Rockwell (p.c. 1996).
Elmore Ranch (ll-ss)	29	3	1.00	0.50	M	6.6	0.00444	225	12	2	0	12	0	90	0	-115.66; 33.23	-115.85; 33.03	Late Holocene slip rate based on Hudnut, et al. (1989). Fault length includes eastward extent of zone of seismicity.

GARLOCK FAULT ZONE

Garlock - west (ll-ss)	97	10	6.00	3.00	P	7.1	0.00100	1000	12	2	0	12	0	90	0	-118.92; 34.83	-118.01; 35.27	Slip rate based on offset late Qt. stream channel (McGill, 1994; p.c. 1996). We use a 1ka recurrence, based on 700-2700 yr recurrence reported by McGill.
Garlock-east (ll-ss)	155	16	7.00	2.00	M	7.3	0.00100	1000	12	2	0	12	0	90	0	-118.02; 34.29	-116.39; 35.60	Slip rate based on McGill and Sieh (1993). Average recurrence of about 1ka, based on McGill and Sieh (1991).
Owl Lake (ll-ss)	25	3	2.00	1.00	M	6.5	0.00200	500	12	2	0	12	0	90	0	-116.64; 35.73	-116.88; 35.61	Slip rate based on offset stream channel. Timing of offset based on radio-carbon and rock varnish dating of alluviual fan surface reported by McGill (1993).

SAN GREGORIO-HOSGRI FAULT ZONE

Hosgri (rl-ss)	172	17	2.50	1.00	M-P	7.3	0.00155	646	12	2	0	12	180	90	0	-121.73; 36.15	-120.69; 34.86	Slip rate based on San Simeon fault slip rate reported in Hanson and Lettis (1994).
San Gregorio (Sur region) (rl-ss)	80	8	3.00	2.00	P	7.0	0.00244	411	12	2	0	12	180	90	0	-122.16; 36.81	-121.74; 36.18	Late Qt. slip rate of 1-3 mm/yr based on assummed transfer of slip from Hosgri flt. Slip rate from San Simeon flt. (Hanson and Lettis (1994) and Hall et al (1994)..

San Gregorio (rl-ss)	129	13	5.00	2.00	P	7.3	0.00250	400	15	2	0	15	180	90	0	-122.67; 37.89	-122.13; 36.81	Weber and Nolan (1995) reported Holocene slip rate of 3-9mm/yr; latest Pleistocene slip rate of 5 mm/yr (min) and lt. Qt. slip rate of about 4.5mm/yr reported by Simpson, et al. (written communication to J. Lienkaemper, 1995).

CALAVERAS FAULT ZONE

Calaveras (s. of Calaveras Reservoir) (rl-ss)	106	11	15.00	2.00	P-M	6.2	0.03030	33	5	2	5	10	180	90	0	-121.79; 37.43	-121.18; 36.62	Includes Paicines fault south of Hollister. Slip rate is composite based on slip rate for a branch of Calaveras fault reported by Perkins & Sims (1988) and slip rate of Paicines fault reported by Harms, et al. (1987). Creep rate for fault zone approximately 15 mm/yr. Maximum earthquake assumed to about 6.2 (Oppenheimer, et al., 1990).
Calaveras (north of Calaveras Reservoir) (rl-ss)	52	5	6.00	2.00	M	6.8	0.00684	146	13	2	0	13	180	90	0	-122.03; 37.86	-121.81; 37.45	Slip rate based on composite of 5mm/yr rate reported by Kelson, et. al. (1996) and 6mm/yr creep rate from small geodetic net reported by Prescott and Lisowski (1983).

SAN DIEGO AREA

Coronado Bank (rl-ss)	185	19	3.00	1.00	P	7.4	0.00153	653	13	2	0	13	180	90	0	-117.93; 33.27	-116.84; 31.89	Slip rate for Palos Verdes fault assummed to extend to SE along Coronado Bank flt.
Newport-Inglewood (offshore) (rl-ss)	66	7	1.50	0.50	P	6.9	0.00154	651	13	2	0	13	180	90	0	-117.91; 33.60	-117.43; 33.16	Slip rate based on assumption that slip from Rose Canyon zone transfers to offshore Newport-Inglewood (WGCEP, 1995).
Rose Canyon (rl-ss)	55	6	1.50	0.50	M	6.9	0.00128	781	13	2	0	13	180	90	0	-117.42; 33.13	-117.13; 32.71	Mininum slip rate reported by Lindvall and Rockwell (1995).

1. W — well-constrained slip rate; M — moderately constrained slip rate; P — poorly constrained slip rate; U — unconstrained slip rate.
2. Maximum moment magnitude calculated from relationships (rupture area) derived by Wells and Coppersmith (1984).
3. R.I. — recurrence interval.
4. Down-dip width = (rupture bottom minus rupture top) divided by sine of dip angle.
5. Top of rupture.
6. Bottom of rupture.
7. daz — dip azimuth.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Straigraphic Code. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
OPEN-FILE REPORT 96-08

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 96-706

APPENDIX A

CALIFORNIA FAULT PARAMETERS

FAULT NAME AND GEOMETRY (ss) strike slip, (r) reverse, (n) normal (rl) rt. lateral, (ll) left lateral, (o) oblique	LENGTH (km)	+/-	SLIP RATE (mm/yr)	+/-	RANK (1)	Mmax (2)	CHAR. RATE (events/yr)	R.I. (3)	Down dip Width (km)(4)	+/-	ruptop (5)	rupbot (6)	rake	dip	daz (7)	Endpt N	Endpt S	COMMENTS
B FAULTS (Continued)																		
TRANSVERSE RANGES AND LA BASIN																		
Big Pine (ll-ss)	41	4	0.80	0.80	P	6.7	0.00102	984	13	2	0	13	0	90	0	-119.01;34.82	-119.40;34.66	Poorly constrained Plio-Pleistocene slip rate > 0.8 mm/yr from Kahle (1966).
Clamshell-Sawpit (r, 45 NW)	16	2	0.50	0.50	U	6.5	0.00068	1461	18	2	0	13	90	45	315	-117.85;34.24	-118.00;34.18	Unconstrained slip rate reported by Dolan, et al (1995), based on geomorphic expression of fault.
Cucamonga (r, 45 N)	28	3	5.00	2.00	M	7.0	0.00154	650	18	2	0	13	90	45	0	-117.73;34.13	-117.43;34.18	Slip rate based on cumulative vertical displacement across three strands reported by Morton and Matti (1987, 1991). Maximum magnitude and recurrence of about 650 yrs based on 2 m average displacements.

Hollywood (ll-r-o, 70 N)	17	2	1.00	0.50	P	6.4	0.00160	626	14	2	0	13	0	70	0	-118.41;34.08	-118.23;34.12	Slip rate estimated by authors, based on similar rationale for Santa Monica fault zone. Dolan, et al (1995) reported a slip rate of 1.0-1.5 mm/yr.
Holser (r, 65 S)	20	2	0.40	0.40	P	6.5	0.00053	1878	14	2	0	13	90	65	180	-118.75;34.44	-118.55;34.42	Slip rate estimated by authors based on offset of base of Plio-Pleistocene Saugus Fm. reported by Stitt (1986).
Malibu Coast (ll-r-o, 75 N)	37	4	0.30	0.20	P	6.7	0.00034	2908	13	2	0	13	0	75	0	-118.93;34.05	-118.53;34.03	Slip rate is horizontal component of slip based on left-laterally deflected drainages incised in terrace surface (Stage 7? or 9?) reported by Treiman (1994).
Mission Ridge-Arroyo Parida-Santa Ana (r, 60 N)	65	7	0.40	0.20	M	6.7	0.00093	1076	15	2	0	13	90	60	0	-119.90;34.43	-119.17;34.47	Minimum dip-slip rate based on Rockwell, et al (1984). Assumption that half of 65 km length ruptures. Total length includes More Ranch fault.
Newport-Inglewood (rl-ss)	64	6	1.00	0.50	P	6.9	0.00099	1006	13	2	0	13	180	90	0	-118.37;34.03	-117.92;33.61	Mio-Pliocene slip rate of 0.5mm/yr reported by Freeman, et al. (1992). Offsets observed in the Huntington Beach area indicate significant Holocene displacement. Apparent vertical separation of 0.46 m of 3-4ka A soil horizon is suggestive of higher slip rate. If apparent vertical separation reflects actual vertical displacement, then H:V ratio of 20:1 for fault (Freeman, et al., 1992) would suggest Holocene rate of 2 to 3 mm/yr. We use 1 mm/yr for fault, based on WGCEP (1995).
Oak Ridge (onshore) (r, 65 S)	50	5	4.00	2.00	P	6.9	0.00334	299	14	2	1	14	90	65	180	-119.21;34.25	-118.72;34.4	Dip-slip rate estimated by authors is composite of several published rates (Yeats, 1988; Levi & Yeats, 1993; Huftile, 1992; Yeats, et al., 1994; WGCEP, 1995)..
Palos Verdes (rl-ss)	96	10	3.00	1.00	M	7.1	0.00154	650	13	2	0	13	180	90	0	-118.56;33.97	-117.94;33.28	Fault is predominantly rlss (H:V is 10:1) according to Henyey (1994). Slip rate is based on rl offset of ancestral channel of Los Angeles River (Stephenson et al., 1995). McNeilan, et al., (1996) reported an average recurrence of 650 yrs.
Pleito Thrust (r, 20 S)	44	4	2.00	1.00	M	7.2	0.00142	706	38	2	0	13	90	20	180	-119.30;34.94	-118.87;34.95	Holocene slip rate based on offset Tecuya alluvial fan reported by Hall (1984).

Raymond (ll-r-o, 75 N)	21	2	0.50	0.30	P	6.5	0.00065	1541	13	2	0	13	0	75	0	-118.22;34.12	-118.00;34.17	Slip rate estimated by authors is poorly constrained, based on focal mechanism of 1988 Pasadena earthquake and assumed vertical component of offset reported by Crook et al. (1987). Crook, et al. reported average recurrence interval of 3000 yrs. Dolan, et al. (1995) reported 0.4mm/yr slip rate for Raymond flt.
Red Mountain (r, 60 N)	39	4	2.00	1.00	P	6.8	0.00197	507	15	2	0	13	90	60	350	-119.65;34.36	-119.28;34.40	Slip rate based on summation of two strands of Red Mtn. flt at Punta Gorda reported in Clark, et al., 1984).
San Cayetano (r, 60 N)	44	4	6.00	3.00	P	6.8	0.00668	150	15	2	0	13	90	60	10	-119.17;34.46	-118.76;34.44	Dip-slip rate estimated by authors is composite of several published rates (Rodkwell, 1983, 1988; Yeats, 1983; Molnar, 1991; Levi & Yeats, 1993; Huftile, 1992; WGCEP, 1995).
San Gabriel (rl-ss)	72	7	1.00	0.50	P	7.0	0.00079	1264	13	2	0	13	180	90	0	-118.88;34.71	-118.28;34.32	Poorly constrained long term slip rate reported by Yeats, et al. (1994). Slip rates range from 1-3 mm/yr but Holocene slip rates are thought to be closer to the lower value.
San Jose (ll-r-o, 75 NW)	22	2	0.50	0.50	U	6.5	0.00068	1471	13	2	0	13	0	75	315	-117.88;34.04	-117.69;34.11	Unconstrained slip rate reported by Dolan, et al (1995), based on geomorphic expression of fault.
Santa Monica (ll-r-o, 75 N)	28	3	1.00	0.50	P-M	6.6	0.00123	816	13	2	0	13	0	75	0	-118.41;34.08	-118.69;33.99	Published slip rate (0.3mm/yr; Clark et al.,1984) is for Potrero Canyon fault, a branch of Santa Monica fault zone. Slip rate of 1mm/yr is based on 2 assumptions: 1). H:V is 1:1 and 2). slip rate for Potrero Canyon is half of entire Santa Monica fault.
Santa Ynez (west segment) (ll-ss)	65	7	2.00	1.00	M	6.9	0.00202	495	13	2	0	13	0	80	180	-120.31;34.51	-119.63;34.49	Slip rate is preferred left-lateral, based on offset stream channel reported by Darrow and Sylvester (1984).
Santa Ynez (east segment) (ll-ss)	68	7	2.00	1.00	M	7.0	0.00149	669	13	2	0	13	0	80	180	-119.63;34.49	-118.91;34.59	Slip rate is preferred left-lateral, based on offset stream channel reported by Darrow and Sylvester (1984).
Santa Susana (r, 55 N)	27	3	5.00	2.00	P	6.6	0.00727	138	16	2	0	13	90	55	0	-118.77;34.36	-118.50;34.32	Dip-slip rate estimated by authors is composite of several published rates (Yeats, 1987; Levi & Yeats, 1993; Huftile, 1992; WGCEP, 1995).

Sierra Madre (San Fernando) (r, 45 N)	18	2	2.00	1.00	P	6.7	0.00100	1000	18	2	0	13	90	45	0	-118.48;34.30	-118.30;34.28	Dip-slip rate is combination of rate reported by Clark et al (1984) and estimate by authors for the Dunsmore alluvial fan (of age 2-10 ka) reported in Crook et al. (1987). Max. magnitude based on 1971 San Fernando earthquake (Wells and Coppersmith, 1994). Recurrence (about 1 ka) of San Fernando segment based on USGS (1996).
Sierra Madre (r, 45 N)	57	6	3.00	1.00	P	7.0	0.00260	384	18	2	0	13	90	45	0	-118.29;34.28	-117.80;34.16	Dip-slip rate is combination of slip rate reported by Clark et al (1984), estimate by authors for the Dunsmore alluvial fan (of age 2-10 ka) reported in Crook et al. (1987), and slip rate reported in WGCEP (1995).
Simi-Santa Rosa (r,60 N)	30	3	1.00	0.50	P	6.7	0.00107	933	15	2	1	14	90	60	0	-119.11;34.22	-118.80;34.29	Slip rate reported by Gonzalez and Rockwell (1991) is for Springville fault, a branch of Simi-Santa Rosa fault. Slip rate of 1mm/yr assumed in order to account for entire fault zone.
Ventura-Pitas Point (r-ll-o, 75 N)	41	4	1.00	0.50	M	6.8	16 0.00090	1112	13	2	1	14	90	75	0	-119.55;34.31	-119.14;34.34	Focal mechanism for M 3.0 earthquake presumably on Ventura fault suggests 1:3 H:V ratio of slip. Slip rate is estimated by authors based on height of scarp across Harmon alluvial fan mapped by Sarna-Wojcicki, et al (1976) and assumed slip components.
Verdugo (r, 45 NE)	29	3	0.50	0.50	U	6.7	0.00062	1608	18	2	0	13	90	45	45	-118.42;34.26	-118.15;34.13	Unconstrained slip rate based on report of scarps in alluvial fans (Weber, et al., 1980). fault zone may complexly join Raymond fault along Eagle Rock and San Rafael flts.
White Wolf (r-ll-o, 60 S)	67	7	2.00	2.00	P	7.2	0.00119	839	21	2	0	18	90	60	180	-119.10;35.08	-118.48;35.39	Poorly constrained long term slip rate, based on Stein and Thatcher (1981), is suggestive of about 5mm/yr. WGCEP (1995) used slip rate of 2 mm/yr. Dip of fault based on 1952 earthquake focal mechanism and modeling by Stein and Thatcher. Max. magnitude (7.2) based on seismic moment for 1952 earthquake reported in Stein and Thatcher. Hutton and Jones (1993) reported M 7.5 for 1952 earthquake.
Los Angeles Blind Thrusts																		

Compton Thrust (r, 20 NE)	39	4	1.50	1.00	P	6.8	0.00148	676	15	2	5	10	90	20	30	-118.49;33.78	-118.14;33.59	Slip rate and fault geometry reported by Shaw and Suppe (1996) and comparison with the Elysian Park fault. Model weighted 50%. End point coordinates are for surface projection of rupture plane.
Elysian Park (r, 20 NE)	34	3	1.50	1.00	P	6.7	0.00182	549	15	2	10	15	90	20	30	-118.39;33.8	-118.08;33.64	Slip rate and fault zone geometry reported by Shaw and Suppe (1996), Bullard and Lettis (1993). Model weighted 50%. End point coordinates are for surface projection of rupture plane.
Northridge (r, 42 S)	31	3	1.50	1.00	P	6.9	0.00122	818	22	2	5	20	90	42	180	-118.68;34.45	-118.38;34.32	Slip rate based on Yeats and Huftile (1995). End point coordinates are for surface projection of rupture plane.

1. W — well-constrained slip rate; M — moderately constrained slip rate; P — poorly constrained slip rate; U — unconstrained slip rate.
2. Maximum moment magnitude calculated from relationships (rupture area) derived by Wells and Coppersmith (1984).
3. R.I. — recurrence interval.
4. Down-dip width = (rupture bottom minus rupture top) divided by sine of dip angle.
5. Top of rupture.
6. Bottom of rupture.
7. daz — dip azimuth.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Straigraphic Code. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
OPEN-FILE REPORT 96-08

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 96-706

APPENDIX A

CALIFORNIA FAULT PARAMETERS

FAULT NAME AND GEOMETRY (ss) strike slip, (r) reverse, (n) normal (rl) rt. lateral, (ll) left lateral, (o) oblique	**LENGTH (km)**	**+/-**	**SLIP RATE (mm/yr)**	**+/-**	**RANK (1)**	**Mmax (2)**	**CHAR. RATE (events/yr)**	**R.I. (3)**	**Down dip Width (km)(4)**	**+/-**	**ruptop (5)**	**rupbot (6)**	**rake**	**dip**	**daz (7)**	**Endpt N**	**Endpt S**	**COMMENTS**
B FAULTS (Continued)																		
SANTA BARBARA CHANNEL																		
Anacapa-Dume (r,-ll-o 45 N)	75	8	3.00	2.00	U	7.3	0.00189	529	28	2	0	20	90	45	0	-119.50;33.99	-118.69;33.98	Unconstrained slip rate, based on assumption by authors that fault carries 1 mm/yr sinstral slip rate from Santa Monica flt and 3.0 mm/yr dextral slip rate from Palos Verdes fault is carried as contractional slip rate.
Channel Islands Thrust (eastern) (r, 17N)	65	7	1.50	1.00	P	7.4	0.00070	1420	34	2	5	15	90	17	0	-119.95;33.98	-119.27;33.98	Blind thrust fault based on modeling by Shaw and Suppe (1994). Slip rate is based on deformation of 1 my old horizon and is considered poorly constrained. Model weighted 25%. End point coordinates are for top of rupture plane.
Montalvo-Oakridge trend (r, 28 N)	37	4	1.00	1.00	P	6.6	0.00137	730	11	2	5	10	90	28	0	-119.67;34.25	-119.28;34.25	Poolry constrained slip rate based on modeling of detachment zone by Shaw and Suppe (1994). Model weighted 25%. End point coordinates are for top of rupture plane.
North Channel Slope (r, 45 N)	60	6	2.00	2.00	P	7.1	0.00165	605	23	2	10	20	90	26	0	-120.40;34.46	-119.67;34.40	Slip rate based on assumption that slip rates from Red Mtn.-Javon Cn. and Pitas Pt. flts transfer to N-dipping thrust. Model weighted 50%. End point coordinates are for top of rupture plane.
Oakridge (blind thrust offshore) (r, 30 S)	37	4	3.00	3.00	P	6.9	0.00265	377	20	2	5	15	90	30	180	-119.67;34.25	-119.28;34.25	Alternative model based on Huftile and Yeats (1995). Replaces slip on eastern Channel Island Thrust and Montalvo-Oakridge trend. Model weighted 25%.
Santa Cruz Island (ll-r-o)	50	5	1.00	0.50	M	6.8	0.00110	912	13	2	0	13	90	90	0	-120.04;34.10	-119.52;33.99	Moderately constrained Qt. slip rate (0.75mm/yr) based on offset streams incised into Stage 11 (?) terrace (Pinter, et al., 1995).

Santa Rosa Island (ll-r-o)	57	6	1.00	0.50	M	6.9	0.00088	1130	13	2	0	13	90	90	0	- 120.51;34.03	- 119.91;34.02	Moderately constrained Qt. slip rate (1mm/yr) based on offset incised stream channels (Colson et al., 1995).

E. TRANSVERSE RANGES AND MOJAVE

Blackwater (rl-ss)	60	6	0.60	0.40	P	6.9	0.00056	1789	13	2	0	13	180	90	0	- 117.41;35.45	- 117.02;35.02	Mojave slip rates based on Holocene rates reported for Homestead Vlly., Emerson, and Johnson Vlly. flts (Hecker, et al., 1993; Rubin and Sieh, 1993; Herzberg and Rockwell, 1993), similar geomorphic expression, and geodetic constraints across Mojave shear zone (about 8mm/yr).
Burnt Mtn. (rl-ss)	20	2	0.60	0.40	P	6.4	0.00020	5000	13	2	0	13	180	90	0	- 116.41;34.12	- 116.38;33.95	See Blackwater fault for slip rate assumptions. Minor triggered slip associated with 1992 Landers earthquake.
Calico-Hidalgo (rl-ss)	95	10	0.60	0.40	P	7.1	0.00020	5000	13	2	0	13	180	90	0	- 116.92;34.99	- 116.26;34.36	See Blackwater fault.
Cleghorn (ll-ss)	25	3	3.00	2.00	P	6.5	0.00464	216	13	2	0	13	0	90	0	- 117.46;34.31	- 117.20;34.28	Slip rate based on Meisling (1984).
Eureka Peak (rl-ss)	19	2	0.60	0.40	P	6.4	0.00020	5000	13	2	0	13	180	90	0	- 116.39;34.12	- 116.34;33.97	See Blackwater fault for slip rate assumptions. Triggered slip associated with 1992 Landers earthquake. April 1992 Joshua Tree earthquake swarm (M6.1) may have been along this fault zone.
Gravel Hills-Harper Lk. (rl-ss)	66	7	0.60	0.40	P	6.9	0.00020	5000	13	2	0	13	180	90	0	- 117.45;35.26	- 116.92;34.87	See Blackwater fault.
Gravel Hills-Harper Lk. (rl-ss)	66	7	0.60	0.40	P	6.9	0.00020	5000	13	2	0	13	180	90	0	- 117.45;35.26	- 116.92;34.87	See Blackwater fault.
Johnson Valley (northern) (rl-ss)	36	4	0.60	0.40	P	6.7	0.00020	5000	13	2	0	13	180	90	0	- 116.69;34.56	- 116.45;34.32	Slip rate based on Herzberg and Rockwell (1993). Fault segment assumed to rupture independently of Landers event.
Landers (rl-ss)	83	8	0.60	0.40	P-M	7.3	0.00020	5000	13	2	0	13	180	90	0	- 116.84;34.79	- 116.42;34.16	992 Landers earthquake rupture (Hauksson, et al (1993). Max. magnitude based on average 3 m slip.
Lenwood-Lockhart-Old Woman Springs (rl-ss)	149	15	0.60	0.40	P	7.3	0.00020	5000	13	2	0	13	180	90	0	- 117.76;35.22	- 116.64;34.35	See Blackwater fault.
North Frontal Fault zone (western) (r, 45 S)	50	5	1.00	0.50	P	7.0	0.00076	1314	18	2	0	13	90	45	180	- 117.27;34.32	- 116.85;34.37	Reported slip rate of 1.2 mm/yr for Sky High Ranch fault, a RLSS segment of fault zone (Meisling, 1984). Other reported slip rates range between 0.1 and 1.3 mm/yr.
North Frontal Fault zone (eastern) (r, 45 S)	27	3	0.50	0.25	U	6.7	0.00058	1727	18	2	0	13	90	45	180	- 116.80;34.34	- 116.53;34.31	Flt. zone east of intersection with Helendale flt. Unconstrained slip rate based on assumption that some slip transferred to NW-striking flts.
Pinto Mountain (ll-ss)	73	7	2.50	2.00	P	7.0	0.00201	499	13	2	0	13	0	90	0	- 116.72;34.06	- 115.97;34.11	Long term slip rate based on Anderson (1979). Reported slip rates range from 0.3-5.3.
Pisgah-Bullion Mtn.-Mesquite Lk. (rl-ss)	88	9	0.60	0.40	P	7.1	0.00020	5000	13	2	0	13	180	90	0	- 116.49;34.82	- 116.00;34.14	Slip rate based on rl offset of drainage developed on Sunshine lava flow (Hart, 1987).

S. Emerson-Copper Mtn. (rl-ss)	54	5	0.60	0.40	P	6.9	0.00020	5000	13	2	0	13	180	90	0	-116.54;34.53	-116.18;34.16	Slip rate based on Rubin and Sieh (1993). Fault segment assumed to rupture independently of Landers event.

1. W — well-constrained slip rate; M — moderately constrained slip rate; P — poorly constrained slip rate; U — unconstrained slip rate.
2. Maximum moment magnitude calculated from relationships (rupture area) derived by Wells and Coppersmith (1984).
3. R.I. — recurrence interval.
4. Down-dip width = (rupture bottom minus rupture top) divided by sine of dip angle.
5. Top of rupture.
6. Bottom of rupture.
7. daz — dip azimuth.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Straigraphic Code. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
OPEN-FILE REPORT 96-08

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 96-706

APPENDIX A

CALIFORNIA FAULT PARAMETERS

FAULT NAME AND GEOMETRY (ss) strike slip, (r) reverse, (n) normal (rl) rt. lateral, (ll) left lateral, (o) oblique	LENGTH (km)	+/-	SLIP RATE (mm/yr)	+/-	RANK (1)	Mmax (2)	CHAR. RATE (events/yr)	R.I. (3)	Down dip Width (km)(4)	+/-	ruptop (5)	rupbot (6)	rake	dip	daz (7)	Endpt N	Endpt S	COMMENTS
B FAULTS (Continued)																		
SOUTHERN AND CENTRAL COAST RANGES																		
Casmalia (Orcutt Frontal fault) (r, 75 SW))	29	3	0.25	0.20	P	6.5	0.00034	2901	10	2	0	10	90	75	225	-120.65;34.93	-120.37;34.82	Poorly constrained slip rate based on deformation of terraces (Clark, 1990).
Lions Head (r, 75 NE)	41	4	0.02	0.02	P	6.6	0.00003	36230	10	2	0	10	90	75	45	-120.61;34.87	-120.24;34.70	Poorly constrained slip rate based on offset marine terraces (Clark, 1990).
Los Alamos - W. Baseline (r, 30 S)	28	3	0.70	0.70	P	6.8	0.00066	1512	20	2	0	10	90	30	180	-120.32;34.76	-120.06;34.63	Poorly constrained slip rate based in part on dip slip displacement of A soil horizon (Guptil, et al, 1981).
Los Osos (r, 45 SW)	44	4	0.50	0.40	P	6.8	0.00052	1925	14	2	0	10	90	45	225	-120.87;35.30	-120.46;35.12	Poorly constrained late Quaternary slip rate based on uplift of marine terraces and assumed flt. dip of 30-60 degrees (Lettis & Hall, 1994).

Monterey Bay - Tularcitos (r-rl-o)	84	8	0.50	0.40	P	7.1	0.00035	2841	14	2	0	14	90	90	0	-122.12;36.92	-121.53;36.37	Slip rate is composite of flts in Monterey area (Tularcitos, Chupines, Navy, flts in Monterey Bay). Rates of individual flts. estimated to be about 0.1mm/yr (Rosenberg & Clark, 1995).
Rinconada (rl-ss)	189	19	1.00	1.00	P	7.3	0.00057	1764	10	2	0	10	180	90	0	-121.76;36.68	-120.51;35.31	Long term slip rate of about 3mm/yr based on Hart (1985). Lacks obvious Holocene offset.

GREAT VALLEY

Battle Creek (n, 75 S)	29	3	0.50	0.40	P	6.5	0.00076	1319	11	2	0	11	-90	75	180	-122.18;40.40	-121.85;40.47	Slip rate based on Clark, et al. (1984) and Page and Renne (1994).
Great Valley 1 (r, 15 W)	44	4	0.10	0.05	P	6.7	0.00010	9537	10	2	7	9.6	90	15	270	-122.30;39.68	-122.28;39.28	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994). End point coordinates for all Great Valley segments are for top of rupture plane.
Great Valley 2 (r, 15 W)	22	2	0.10	0.05	P	6.4	0.00015	6768	10	2	7	9.6	90	15	270	-122.28;39.29	-122.29;39.09	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 3 (r,15 W)	55	6	1.50	1.00	P	6.8	0.00139	718	10	2	7	9.6	90	15	270	-122.28;39.12	-122.00;38.67	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 4 (r, 15 W)	42	4	1.50	1.00	P	6.6	0.00212	472	10	2	7	9.6	90	15	270	-122.05;38.65	-121.89;38.30	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 5 (r, 15 W)	28	3	1.50	1.00	P	6.5	0.00200	501	10	2	7	9.6	90	15	270	-121.90;38.30	-121.75;38.08	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 6 (r, 15 W)	45	5	1.50	1.00	P	6.7	0.00161	622	10	2	7	9.6	90	15	270	-121.80;38.06	-121.52;37.72	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 7 (r,15 W)	45	5	1.50	1.00	P	6.7	0.00161	622	10	2	7	9.6	90	15	270	-121.52;37.73	-121.16;37.45	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 8 (r, 15 W)	41	4	1.50	1.00	P	6.6	0.00207	483	10	2	7	9.6	90	15	270	-121.16;37.43	-120.99;37.09	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 9 (r, 15 W)	39	4	1.50	1.00	P	6.6	0.00197	508	10	2	7	9.6	90	15	270	-120.99;37.10	-120.75;36.81	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).

Great Valley 10 (r, 15 W)	22	2	1.50	1.00	P	6.4	0.00222	451	10	2	7	9.6	90	15	270	-120.76;36.80	-120.65;36.63	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 11 (r, 15 W)	25	3	1.50	1.00	P	6.4	0.00252	397	10	2	7	9.6	90	15	270	-120.65;36.64	-120.45;36.5	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 12 (r, 15 W)	17	2	1.50	1.00	P	6.3	0.00242	413	10	2	7	9.6	90	15	270	-120.44;36.48	-120.35;36.34	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 13 (r, 15 W)	30	3	1.50	1.00	P	6.5	0.00214	467	10	2	7	9.6	90	15	270	-120.37;36.34	-120.15;36.14	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
Great Valley 14 (r, 15 W)	24	2	1.50	1.00	P	6.4	0.00242	414	10	2	7	9.6	90	15	270	-120.16;36.14	-119.95;36.00	Slip rate and segmentation from WGNCEP (1996) and Wakabayshi and Smith (1994).
BASIN AND RANGE-SIERRA NEVADA																		
Antelope Valley (n, 60 E)	31	3	0.80	0.50	P	6.7	0.00089	1128	15	2	0	13	-90	60	90	-119.57;38.78	-119.48;38.51	Dip slip offset of Holocene alluvial fan reported by Bryant (1984).
Birch Creek (n, 60 E)	15	2	0.70	0.50	P	6.4	0.00106	945	15	2	0	13	-90	60	90	-118.34;36.98	-118.40;37.10	Slip rate based on Beanland and Clark (1994).
Death Valley (south) (rl-ss)	62	6	4.00	3.00	P	6.9	0.00385	260	13	2	0	13	180	90	0	-116.75;36.05	-116.38;35.60	Long term slip rate based on 35km rl. offset of Miocene volcanic rks. reported by Butler, et al, (1988).
Death Valley (graben) (n, 60 W)	54	5	4.00	3.00	M	6.9	0.00387	258	15	2	0	13	-90	60	90	-116.88;36.53	-116.74;36.06	Slip rate based on vertically offset alluvial fan surface reported in Klinger and Piety (1994).
Death Valley (northern) (rl-ss)	108	11	5.00	3.00	P-M	7.2	0.00297	336	13	2	0	13	180	90	0	-117.65;37.30	-116.88;36.55	Late Pleistocene slip rate based on offset alluvial fan near Redwall Canyon. Rate of about 4.5mm/yr estimated from 46m rl offset reported by Reynolds (1969) and estimated age of incision of fan surface (5-20ka) based on geomorphic expression of alluvial deposits and correlation of rock varnish ages in southern Death Valley by Dorn (1988). Slip rate of 5-12mm/yr reported by Klinger and Piety (1994) may be too high because of their assumption that Redwall Canyon alluvial fan surface is 40-70ka. Cation-ratio dates of

																		rock varnish in southern Death Valley reported by Dorn (1988) suggest age of 100-170ka, which would reduce mean rate from 8.5mm/yr to .5mm/yr.
Death Valley (N of Cucamonga) (rl-n-o)	75	8	5.00	3.00	P-M	7.0	0.00412	243	13	2	0	13	180	90	0	-118.19;37.83	-117.67;37.31	Late Qt. slip rate based on offset Pleistocene shutter ridge in Fish Lake Valley reported in Reheis (1994). Reheis and Dixon (1996) suggest lt. Qt. slip rate of about 5 mm/yr in the Fish Lake Valley area.
Deep Springs (n, 60 NW)	25	3	0.80	0.60	P	6.6	0.00101	990	15	2	0	13	-90	60	300	-117.93;37.42	-118.06;37.23	Dip slip rates based on offset Holocene alluvial fans reported by Bryant (1989). Long term rate of 0.3mm/yr reported by Reheis and McKee (1991).
Fish Slough (n, 60 W)	26	3	0.20	0.10	P	6.6	0.00026	3809	15	2	0	13	-90	60	270	-118.41;37.59	-118.40;37.36	Poorly constrained dip slip rate based on offset of Bishop Ash reported in Bateman (1965).
Genoa (n, 60 E)	50	5	1.00	0.60	M	6.9	0.00090	1116	15	2	0	13	-90	60	90	-119.85;39.10	-119.81;38.67	Dip slip rate based on offset of late Tioga outwash reported in Clark, et al. (1984).
Hartley Springs (n, 60 E)	25	3	0.50	0.30	P	6.6	0.00063	1584	15	2	0	13	-90	60	90	-119.08;37.85	-119.00;37.64	Slip rate (0.15mm/yr) based on dip-slip offset of late Tioga lateral moraine reported in Clark, et al (1984). Slip rate is for small branch fault; unconstrained slip rate of 0.5mm/yr assumed for entire fault zone.
Hilton Creek (n, 60 E)	29	3	2.50	0.60	M	6.7	0.00259	386	15	2	0	13	-90	60	90	-118.88;37.69	-118.73;37.46	Slip rate based on dip-slip offset of late Tioga lateral moraine reported in Clark, et al (1984).
Hunter Mountain - Saline Valley (rl-n-o)	71	7	2.50	1.00	P	7.0	0.00195	513	13	2	0	13	180	90	0	-117.95;36.92	-117.44;36.48	Long term slip rate (Pliocene) of 2.0-2.7mm/yr for Hunter Mtn. fault (Birchfiel, et al., 1987), and association with Panamint Vly flt.
Independence (n, 60 E)	49	5	0.20	0.10	P	6.9	0.00018	5696	15	2	0	13	-90	60	90	-118.30;36.88	-118.09;36.50	Slip rate based on offset Tioga outwash deposits reported in Clark, et al (1994).
Little Lake (rl-ss)	39	4	0.70	0.40	M	6.7	0.00085	1182	13	2	0	13	180	90	0	-117.88;35.91	-117.65;35.61	Minimum slip rate basd on offset channel cut in basalt (Roquemore, 1981).
Mono Lake (n, 60 E)	26	3	2.50	1.25	M	6.6	0.00328	305	15	2	0	13	-90	60	90	-119.19;38.15	-119.10;37.93	Slip rate based on offset of late Tioga lateral moraine reported in Clark, et al. (1984).

Owens Valley (rl-ss)	121	12	1.50	0.80	M-P	7.6	0.00025	4000	13	2	0	13	180	90	0	-118.33;37.24	-117.99;36.19	Slip rate reported in Beanland and Clark (1994) is composite based on Lone Pine fault and assumption that horizontal component similar to 1872 earthquake. Max. magnitude based on 1872 earthquake reported by Ellsworth (1990).
Panamint Valley (rl-ss)	108	11	2.50	1.00	M	7.2	0.00149	672	13	2	0	13	180	90	0	-117.41;36.44	-116.90;35.61	Moderately constrained slip rate based on offset drainages developed on Holocene alluvial fans reported in Zhang, et al, 1990.
Robinson Creek (n, 60 SE)	17	2	0.50	0.30	M	6.4	0.00086	1168	15	2	0	13	-90	60	90	-119.23;38.33	-119.32;38.21	Dip slip offset of late Tioga outwash in Buckeye Crk. reported in Clark, et al. (1984).
Round Valley (n, 60 E)	42	4	1.00	0.50	M	6.8	0.00106	941	15	2	0	13	-90	60	90	-118.34;37.94	-118.60;37.25	Slip rate based on dip-slip offset of late Tioga lateral moraine reported in Clark, et al (1984).
S.Sierra Nevada (n, 60 E)	76	8	0.10	0.10	U	7.1	0.00007	14655	15	2	0	13	-90	60	90	-117.99;36.19	-117.99;35.57	Unconstrained dip slip rate estimated by authors based on association with Independence fault.
Tank Canyon (n, 60 W)	16	2	1.00	0.50	M	6.4	0.00161	620	15	2	0	13	-90	60	90	-117.25;35.77	-117.25;35.64	Moderately constrained slip rate based on vertically offset Holocene alluvial fan (Clark, et al, 1984).
White Mountains (rl-ss)	105	11	1.00	0.50	P	7.1	0.00082	1224	13	2	0	13	180	90	0	-118.28;37.31	-118.17;37.05	Preferred rl slip rate reported by dePolo, 1989.
BAY AREA																		
Concord - Green Valley (rl-ss)	66	7	6.00	3.00	M	6.9	0.00568	176	12	2	0	12	180	90	0	-122.20;38.45	-121.98;37.89	Moderately constrained slip rate for Concord fault based on Snyder, et al. (1995). Slip rate of 6 mm/yr should be considered a minimum. No slip rates reported for Green Valley fault.
Greenville (rl-ss)	73	7	2.00	1.00	P	6.9	0.00192	521	11	2	0	11	180	90	0	-121.94;37.98	-121.50;37.42	Wright, et al (1982) reported a slip rate of about 1 mm/yr, based on an offset stream channel. A 10 km rl offset of a serpentinite body suggests a long term slip rate of 2-3 mm/yr.

Hayward (SE extension) (rl-r-o)	26	3	3.00	2.00	U	6.4	0.00454	220	10	2	0	10	180	90	0	-121.90;37.47	-121.72;37.28	Unconstrained slip rate based on slip budget between adjacent Calaveras flt. and assumed major slip junction of Calaveras and Hayward flt. (WGNCEP, 1996). Possible significant reverse componet not considered.
Monte Vista - Shannon (r 45, E)	41	4	0.40	0.30	P-M	6.8	0.00042	2410	15	2	0	11	90	45	90	-122.19;37.38	-121.79;37.21	Poorly constrained slip rate based on vertical separation of late Pleistocene terrace and assumptions of age of terrace (23-120ka) and flt. dip reported by Hitchcock, et al. (1994). Actual dip and fault width is variable. 15 km width approximates average.
Ortigalita (rl-ss)	66	7	1.00	0.50	P	6.9	0.00087	1153	11	2	0	11	180	90	0	-121.28;37.28	-120.91;36.76	Poorly constrained slip rate based on vertical slip rate reported by Clark, et al (1984) (0.01-0.04mm/yr), assumptions regarding H:V ratio, and geomorphic expression of flt. consistent with about 1 mm/yr.
Point Reyes (r, 50 NE)	47	5	0.30	0.20	P	6.8	0.00029	3503	12	2	0	9	90	50	45	-123.24;38.18	-122.83;37.94	Poorly constrained long term (post-Miocene) slip rate based on vertical offset of crystalline basement (McCulloch, 1987).
Quien Sabe (rl-ss)	23	2	1.00	1.00	P	6.4	00154	647	10	2	0	10	180	90	0	-121.36;36.93	-121.21;36.76	Poorly constrained slip rate estimated by authors based on vertically offset alluvial fan (Bryant, 1985) and assumptions regarding H:V ratio (6:1 to 14:1) based on 26JAN86 M5.8 earthquake (Hill et al, 1990) and age of fan surface based on soil profile development.

Sargent (rl-r-o)	53	5	3.00	1.50	P	6.8	0.00083	1200	12	2	0	12	180	90	0	-121.94;37.14	-121.45;36.87	Slip rate is rl. creep rate reported by Prescott and Burford (1976). Nolan, et al. (1995) reported a minimum Holocene rl slip rate of 0.6mm/yr in Pajaro River area, found evidence suggesting 0.8m of rl offset and a recurrence interval of about 1.2ka. However, the penultimate event about 2.9ka was characterized by about 1.7m of rl offset, suggesting max. earthquake of M 6.9. Recurrence of 1.2ka used, but further work necessary to resolve maximum magnitude, slip rate, and recurrence.
West Napa (rl-ss)	30	3	1.00	1.00	U	6.5	0.00143	701	10	2	0	10	180	90	0	-122.37;38.41	-122.24;38.16	Unconstrained slip rate based on assumption that geomorphic expression of fault is consistent with about 1mm/yr slip rate (WGNCEP, 1996).
Zayante-Vergeles (rl-r)	56	6	0.10	0.10	P	6.8	0.00011	8821	12	2	0	12	180	90	0	-121.97;37.09	-121.46;36.79	Slip rates reported by Clark, et al (1984).

1. W — well-constrained slip rate; M — moderately constrained slip rate; P — poorly constrained slip rate; U — unconstrained slip rate.
2. Maximum moment magnitude calculated from relationships (rupture area) derived by Wells and Coppersmith (1984).
3. R.I. — recurrence interval.
4. Down-dip width = (rupture bottom minus rupture top) divided by sine of dip angle.
5. Top of rupture.
6. Bottom of rupture.
7. daz — dip azimuth.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Straigraphic Code. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
OPEN-FILE REPORT 96-08

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 96-706

APPENDIX A

CALIFORNIA FAULT PARAMETERS

FAULT NAME AND GEOMETRY (ss) strike slip, (r) reverse, (n) normal (rl) rt. lateral, (ll) left lateral, (o) oblique	LENGTH (km)	+/-	SLIP RATE (mm/yr)	+/-	RANK (1)	Mmax (2)	CHAR. RATE (events/yr)	R.I. (3)	Down dip Width (km)(4)	+/-	ruptop (5)	rupbot (6)	rake	dip	daz (7)	Endpt N	Endpt S	COMMENTS
NORTHERN COAST RANGES																		
Bartlett Springs (rl-ss)	85	9	6.00	3.00	P	7.1	0.00458	218	15	2	0	15	180	90	0	-123.05;39.57	-122.50;38.93	Slip rate based on assumption that slip carried from Concord-Green Valley system (WGNCEP, 1996). Taylor and Swan (1986) and Swan and Taylor (1991) reported minimum slip rate of 1-2mm/yr for segment at Lk. Pillsbury, based on apparent vertical separation and plunge of slickensides.
Collayomi (rl-ss)	29	3	0.60	0.30	P	6.5	0.00083	1209	10	2	0	10	180	90	0	-122.86;38.99	-122.68;38.78	Slip rate based on (Clark, et al., 1984)
Garberville-Briceland (rl-ss)	39	4	9.00	2.00	U	6.9	0.00454	220	12	2	0	12	180	90	0	-124.02;40.27	-123.72;39.99	Rate based on assumption that slip carried from Maacama flt (WGNCEP, 1996). Max. magnitude based on assumed 2 m slip.

Hunting Creek-Berryessa (rl-ss)	60	6	6.00	3.00	U	6.9	0.00516	194	12	2	0	12	180	90	0	-122.50;38.93	-122.20;38.45	Slip rate based on assumption that slip is carried from Concord-Green Valley system (WGNCEP, 1996).
Lake Mountain (rl-ss)	33	3	6.00	3.00	P	6.7	0.00708	141	15	2	0	15	180	90	0	-123.46;40.28	-123.44;39.98	Slip rate based on assumption that slip is carried from Green Valley-Concord system (WGNCEP, 1996) and measurement of fault creep at Covelo (Lisowski and Prescot, 1989; M.H. Murray, written communication to J. Lienkaemper, 1996).
Maacama (south) (rl-ss)	41	4	9.00	2.00	P	6.9	0.00454	220	12	2	0	12	180	90	0	-123.00;38.86	-122.69;38.58	Slip rate of 9 mm/yr based on assumption that dextral slip from Hayward - Rodgers Crk. flt carried NW along Maacama zone (WGNCEP, 1996). Max. magnitude based on assumed 2 m slip.
Maacama (central) (rl-ss)	60	6	9.00	2.00	P	7.1	0.00454	220	12	2	0	12	180	90	0	123.29;39.34	-123.00;38.85	Flt. has creep rate of 6.9 mm/yr in Ukiah (Galehouse, 1995). 9 mm/yr slip rate based on assumption that dextral slip from Hayward - Rodgers Crk. flt carried NW along Maacama zone (WGNCEP, 1996). Max. magnitude based on assumed 2 m slip.

Maacama (north) (rl-ss)	81	8	9.00	2.00	P	7.1	0.00454	220	12	2	0	12	180	90	0	-123.72;39.99	-123.29;39.34	Flt. has creep rate of 7.3 mm/yr in Willits Galehouse, 1995). 9 mm/yr slip rate based on assumption that dextral slip from Hayward - Rodgers Crk. flt carried NW along Maacama zone (WGNCEP, 1996). Max. magnitude based on assumed 2 m slip.
Round Valley (rl-ss)	56	6	6.00	3.00	P	6.8	0.00680	147	12	2	0	12	180	90	0	-123.45;39.97	-123.05;39.57	Slip rate based on assumption that slip is carried from Green Valley-Concord system (WGNCEP, 1996) and measurement of fault creep at Covelo (Lisowski and Prescot, 1989; M.H. Murray, written communication to J. Lienkaemper, 1996).
NORTHWESTERN CALIFORNIA																	
Big Lagoon - Bald Mtn. flt zone (r, 35 NE)	88	9	0.50	0.50	P	7.3	0.00030	3294	23	2	0	13	90	35	45	-124.44;41.73	-123.99;41.11	Long term slip rate, based on vertical offset of Pliocene "Klamath sapprolite" and assumption that age of offset began about 1ma (McCrory, 1996).
Cascadia subduction zone (r, 15 E)	257	26	35.00	5.00	P	8.3	0.00667	150	58	2	5	20	90	15	90	-123.80;45.00	-123.80;40.20	Slip rate and max. mag. earthquake based on Toppozada, et al (1995). End point coordinates are for bottom of rupture plane.
Cascadia (all) (r, 15 E)	1029	50	35.00	5.00	P	9.0	0.00200	500	58	2	5	20	90	15	90	-126.60;50.00	-123.80;40.20	End point coordinates are for bottom of rupture plane.

Fickle Hill (r, 35 NE)	34	3	0.60	0.40	P	6.9	0.00056	1785	23	2	0	13	90	35	45	-124.18;40.98	-123.94;40.73	Slip rate based on Carver & Burke (1992) and McCrory (1996).
Little Salmon (onshore) (r, 30 NE)	34	3	5.00	3.00	M	7.0	0.00374	268	26	2	0	13	90	30	45	-124.23;40.76	-123.99;40.53	Slip rate based on Carver & Burke (1988, 1992) and assumption by authors that main trace has slip rate of 4 mm/yr and 1 mm/yr for eastern strand. Slip based on 30 degree dip.
Little Salmon (offshore) (r, 30 NE)	46	5	1.00	1.00	P	7.1	0.00072	1397	26	2	0	13	90	30	45	-124.64;41.00	-124.23;40.76	Poorly constrained slip rate based on vertical separation of Rio Dell equivalent strata (1 my) and base and top of Hookton Fm. (about 0.5 my) reported by McCrory (1996).
Mad River (r, 35 NE)	52	5	0.70	0.60	P	7.1	0.00050	1995	23	2	0	13	90	35	45	-124.23; 41.02	-123.90; 40.63	Slip rate based on Carver & Burke (1992) and assummed dip of 30 degrees.
McKinleyville (r, 35 NE)	48	5	0.60	0.20	M	7.0	0.00056	1785	23	2	0	13	90	35	45	-124.26;41.08	-123.89;40.74	Slip rate based on recalulation of rate by Carver & Burke (1992), with assumption that lowest terrace age is 80ka.
Mendocino fault zone (rl-r-o)	179	18	35.00	5.00	P	7.4	0.01996	50	15	2	15	30	180	90	0	-126.40;40.41	-124.34;40.23	Slip rate based on relative plate motion (McCrory, et al., 1995). Max. magnitude based on McCrory (p.c., April 1996).
Table Bluff (r, 45 NE)	49	5	0.60	0.60	P	7.0	0.00045	2235	18	2	0	13	90	45	45	-124.68;40.83	-124.18;40.65	Poorly constrained slip rate based on 700 m vertical offset of basement rocks. Age of deformation assumed to have begun about 1ma (McCrory, 1996).

Trinadad (r, 35 NE)	88	9	2.50	1.50	P	7.3	0.00152	659	23	2	0	13	90	35	45	-124.39;41.45	-123.84;40.79	Slip rate based on recalulation of slip rate reported by Carver & Burke (1992), with assumption that lowest terrace age is 80ka. Dip slip rate includes horizontal shortening rate from Trinidad anticline, resolved for 35 degree dipping fault (P. McCrory, p.c., 1996). Length includes offshore faults.
NORTHEASTERN CALIFORNIA																		
Cedar Mtn. - Mahogany Mtn. (n, 60 E)	78	8	1.00	0.50	P	6.9	0.00102	976	11	2	0	10	-90	60	90	-122.06;42.22	-121.91;41.53	Poorly constrained slip rate of 0.2mm/yr based on vertical offset of late Tioga gravels along E. Cedar Mtn. flt. reported by Bryant and Wills (1991). 1mm/yr slip rate assumed for entire fault zone, including Mahogany Mtn. flt. zone.
Gillem-Big Crack (n, 60 E)	32	3	1.00	0.50	P	6.6	0.00140	995	13	2	0	11	-90	60	90	-121.57;41.97	-121.59;41.68	Poorly constrained slip rate based on vertical separation of late Pleistocene (about 40ka) Mammoth Crater basalt (Donnelly-Nolan and Champion (1987).
Goose Lake (n, 60 W)	57	6	0.10	0.05	P	6.8	0.00011	9454	11	2	0	10	-90	60	270	-120.34;42.26	-120.19;41.79	Slip rate based on Pezzopane (1993).

Hat Creek-McArthur-Mayfield (n, 60 W)	96	10	1.50	1.00	P-M	7.0	0.00134	747	11	2	0	10	-90	60	270	- 121.59;41.47	- 121.37;40.63	Source model assumes rupture along Hat Creek, McArthur, and Mayfield faults. Hat Creek flt. has poorly to moderately constrained slip rate based on offset of Tioga lateral moraine reported by Muffler (1994) and Sawyer (p.c. 1995). McArthur flt. has poorly constrained slip rate based on offset of 'Popcorn Cave basalt' (Page, et al, 1995). Mayfield flt. has moderate to well-constrained slip rate based on vertical offset of 10.6ka basalt and surveyed scarp profiles (Donnelly-Nolan, et al, 1990).
Honey Lake (rl-ss)	55	6	2.50	1.00	M-W	6.9	0.00067	1493	11	2	0	11	180	90	0	- 120.51;40.34	- 120.04;39.99	Slip rate based on dextral offset of Holocene fluvial terrace reported by Wills and Borchardt (1993) (1.9 +/- 0.8mm/yr) At least 4 surface rupturing events have occurred in the past 6 ka, suggesting a recurrence of about 1.5 ka. Slip rate includes assummed slip from Warm Springs fault.

Likely (rl-ss)	64	6	0.30	0.30	U	6.9	0.00025	3964	11	2	0	11	180	90	0	-120.73;41.34	-120.25;40.89	Unconstrained slip rate based on assumption by authors that up to 5 m of dextral offset of latest Pleistocene shorelines at northern Madeline Plains (Bryant, 1991) may go unobserved and also overall geomorphic expression of fault zone.
Surprise Valley (n, 60 E)	87	9	1.30	0.50	M	7.0	0.00105	951	11	2	0	10	-90	60	90	-120.14;41.88	-119.99;41.13	Slip rate base on vertical offset of Holocene alluvial fans and assumptions of fan ages based on relationship to Pleistocene Lk. Surprise (Hedel, 1980, 1984).

1. W — well-constrained slip rate; M — moderately constrained slip rate; P — poorly constrained slip rate; U — unconstrained slip rate.
2. Maximum moment magnitude calculated from relationships (rupture area) derived by Wells and Coppersmith (1984).
3. R.I. — recurrence interval.
4. Down-dip width = (rupture bottom minus rupture top) divided by sine of dip angle.
5. Top of rupture.
6. Bottom of rupture.
7. daz — dip azimuth.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Straigraphic Code. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
OPEN-FILE REPORT 96-08

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 96-706

APPENDIX A

CALIFORNIA FAULT PARAMETERS

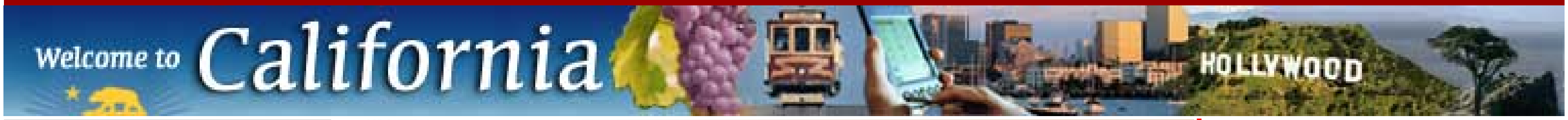
FAULT NAME AND GEOMETRY (ss) strike slip, (r) reverse, (n) normal (rl) rt. lateral, (ll) left lateral, (o) oblique	LENGTH (km)	+/-	SLIP RATE (mm/yr)	+/-	RANK (1)	Mmax (2)	CHAR. RATE (events/yr)	R.I. (3)	Down dip Width (km)(4)	+/-	ruptop (5)	rupbot (6)	rake	dip	daz (7)	Endpt N	Endpt S	COMMENTS
C ZONES																		
Foothills Fault System																		
Foothills Fault System (n-rl-o, 75 E)	360	36	0.05	0.03	P	6.5	0.00103	974	12	2	0	12	-90	75	55	n/a	n/a	Poorly constrained composite late Quaternary slip rate across Bear Mtn. and Melones flt zones (Woodward-Clyde Consultants, 1978; Clark, et al., 1984; PG&E, 1994). Areal source model assumes a maximum magnitude earthquake of 6.5.
NORTHEASTERN CALIFORNIA																		

Mohawk-Honey Lake Zone (rl-ss)	88	9	2.00	1.00	P	7.3	0.00079	1263	15	2	0	15	180	90	45	n/a	n/a	Distributed dextral shear zone carried from Western Nevada Zone.
Rate for NE CA (rl-ss)	230	23	4.00	2.00	P	7.3	0.00414	242	15	2	0	15	180	90	65	n/a	n/a	Distributed dextral shear of Sierra Nevada-Great Basin shear zone, based on VLBI data (Argus & Gordon, 1991; Argus (p.c. to J. Lienkaemper, 1995). Model weighted 50%.

1. W — well-constrained slip rate; M — moderately constrained slip rate; P — poorly constrained slip rate; U — unconstrained slip rate.
2. Maximum moment magnitude calculated from relationships (rupture area) derived by Wells and Coppersmith (1984).
3. R.I. — recurrence interval.
4. Down-dip width = (rupture bottom minus rupture top) divided by sine of dip angle.
5. Top of rupture.
6. Bottom of rupture.
7. daz — dip azimuth.

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Straigraphic Code. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

California Home



Department of Conservation

California Geological Survey

Probabilistic Seismic Hazard Assessment Home Page

PSHA Maps (1 x 2 degrees)

Earthquakes (Recent & Historic)

Probabilistic Seismic Hazard Assessment for the State of California (OFR 96-08)

Loss Estimation

Aquist-Priolo Earthquake Fault Zoning Act

CGS Links

About Us

Contact Us

Jobs

Site Map

Help/FAQ

California Geological Survey

search

My CA This Site

APPENDIX B

CDMG FAULT PARAMETER TABLE

REFERENCES CITED

CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
OPEN-FILE REPORT 96-08

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 96-706

Anderson, J.G., 1979, Estimating the seismicity from geologic structure for seismic-risk studies: Seismological Society of America Bulletin, v. 69, p. 135-158.

Anderson, J.G., 1984, Synthesis of seismicity and geological date in California: U.S. Geological Survey Open-File Report 84-424, 186 p.

Andrews, D.J., Oppenheimer, D.H., and Lienkaemper, J.J., 1993, The Mission Link between the Hayward and Calaveras faults: Journal of Geophysical Research, v. 98, no. By, p. 12,083-12,095.

Argus, D.F., and Gordon, R.G., 1991, Current Sierra Nevada-North America motion from very long baseline interferometry: Implications for the kinematics of the western United States: Geology, v. 19, p. 1085-1088.

Astiz, L., and Allen, C.R., 1983, Seismicity of the Garlock Fault, California: Bull. Seismological Soc. Am., v. 73, no.6A, p. 1721-1734.

Bateman, P.C., 1965, Geology and tungsten mineralization of the Bishop district, California: U.S. Geological Survey Professional Paper 470, 208 p., 11 plates, scale 1:62,500.

Beanland, S., and Clark, M.M., 1994, The Owens Valley Fault Zone and surface rupture in the Inyo County, California earthquake of 1872: U.S. Geological Survey Bulletin 1982, 29 p.

Bennett, R.A., Reilinger, R.E., Hager, B.H., Herring, T.A., King, R.W., Rodi, W., and Gonzalez, J., 1995, GPS constraints on fault slip rates in southern California and northern Baja, Mexico: EOS, Transactions, American Geophysical Union, v. 76, no.46, p. F143.

Bennett, R.A., Reilinger, R.E., Rodi, W., Li, Y., Toksöz, M.N., and Hudnut, K., 1995, Coseismic fault slip associated with the 1992 M_W 6.1 Joshua Tree, California, earthquake: Implications for the Joshua Tree-Landers earthquake sequence: Journal of Geophysical Research, v. 100, no. B4, p. 6443-6461.

Berger, V., and Schug, D.L., 1991, Probabilistic evaluation of seismic hazard in the San Diego-Tijuana metropolitan region, *in* Abbott, P.L., and Elliott, W.J., eds., Environmental Perils / San Diego Region: published for the Geological Society of America by the San Diego Association of Geologists, October 20, 1991, p. 89-99.

Bilham, R., and Bodin, P., 1992, Fault zone connectivity: slip rates on faults in the San Francisco Bay Area, California: Science, v. 258, p. 281-284.

Brogan, G.E., Kellogg, K.S., Slemmons, D.B., and Terhune, C.L., 1991, Late Quaternary faulting along the Death Valley-Furnace Creek fault system, California and Nevada: U.S. Geological Survey Bulletin 1991, 23 p.

Bronkowski, M.S., 1981, Tectonic geomorphology of the San Andreas fault zone, Indio Hills, Coachella Valley, California: University of California, Santa Barbara, unpublished M.S. thesis, 120 p.

Bryant, W.A., 1984, Evidence of recent faulting along the Antelope Valley Fault Zone, Mono County, California: California Division of Mines and Geology Open-File Report 84-56, scale 1:48,000.

Bryant, W.A., 1985, Faults in the southern Hollister area, San Benito counties, California: California Division of Mines and Geology Fault Evaluation Report 164.

Bryant, W.A., 1989, Deep Springs Fault, Inyo County, California, An example of the use of relative dating techniques: California Geology, v. 42, no. 11, p. 243255.

Bryant, W.A., 1991, Likely Fault Zone, Lassen and Modoc counties: California Division of Mines and Geology Fault Evaluation Report 218.

Bryant, W.A., and Wills, C.J., 1991, Evaluation of fault activity in the Modoc Plateau region of northeastern California (abs): Geological Society of America Abstracts with Programs, 1991 Annual Meeting, v. 23, no. 5, p. A-140.

Budding, K.E., Schwartz, D.P., and Oppenheimer, D.H., 1991, Slip rate, earthquake recurrence, and seismogenic potential of the Rodgers Creek Fault Zone, northern California: Initial results: Geophysical Research Letters, v. 18, n. 3, p. 447-450.

Bullard, T.F., and Lettis, W.R., 1993, Quaternary fold deformation associated with blind thrust faulting, Los Angeles Basin, California: Journal of Geophysical Research, v. 98, no. B5, p. 8349-8369.

Burchfiel, B.C., Hodges, K.V., and Royden, L.H., 1987, Geology of Panamint Valley - Saline Valley pull-apart system, California: Palinspastic evidence for low-angle geometry of a Neogene range-bounding fault: Journal of Geophysical Research, v. 92, p. 10422-10426.

Bürgmann, R., Segall, P., Arrowsmith, R., and Dumitru., T., 1994, Slip rates and earthquake hazard along the Foothills Thrust Belt in the southern Santa Cruz Mountains, California (abs): Geological Society of America Abstracts with Programs, 1994 Annual Meeting, p. A-191.

Butler, P.R., Troxel, B.W., and Verosub, K.L., 1988, Late Cenozoic history and styles of deformation along the southern Death Valley fault zone, California: Geological Society of America Bulletin, v. 100, p. 402-410.

Carpenter, D.W., Taffet, M.J., Copland, J.R., Mateik, R.S., and Wade, W.M., 1992, Holocene faulting near closed landfill pit 6, Lawrence Livermore National Laboratory site 300, *in* Borchardt, G., Hirschfeld, S.E., Lienkaemper, J.J., McClellan, P., Williams, P.L., and Wong, I.G., (editors), Proceedings of the Second Conference on earthquake hazards in the eastern San Francisco Bay area: California Division of Mines and Geology Special Publication 113, p. 333-338.

Carter, B.A., 1980, Quaternary displacement on the Garlock Fault, California, *in* Fife, D.L., and Brown, A.R., eds., Geology and mineral wealth of the California desert: South Coast Geol. Soc., Dibblee Volume, p. 457-466.

Carver, G.A., and Burke, R.M., 1988, Trenching investigations of northwestern California faults, Humboldt Bay region: unpublished U.S. Geological Survey NEHRP Final Report, 53 p.

Carver, G.A., and Burke, R.M., 1992, Late Cenozoic deformation on the Cascadia subduction zone in the region of the Mendocino Triple Junction *in* Friends of the Pleistocene Guidebook for the Field Trip to northern Coastal California, p. 31-63.

Carver, G.A., Aalto, K.R., and Burke, R.M., 1992, Road log from Patrick's Point State Park to Bear River--Day 1 and Day 2, *in* Friends of the Pleistocene Guidebook for the Field Trip to northern Coastal California, p. 3-21.

Clahan, K.B., Hall, N.T., and Wright, R.H., 1995, Late Holocene slip rate and slip events for the San Francisco Peninsula segment of the san Andreas Fault: Geological Society of America Abstracts with Programs, v. 27, no. 5., p. 9-10.

Clark, M.M., 1967, Pleistocene glaciation of the drainage of the West Walker River, Sierra Nevada, California: Stanford, California, Stanford University, Ph.D. thesis, 130 p.

Clark, M.M., 1988, Late Quaternary slip rates on active faults of California: U.S. Geological Survey Open-File Report OFR 88-16, p. 141.

Clark, M.M., and Gillespie, A.R., 1981, Record of late Quaternary faulting along the Hilton Creek fault in the Sierra Nevada, California (abs): Seismological Society of America, Earthquake Notes, v. 52, no. 1, p. 46.

Clark, M.M., Harms, K.K., Lienkaemper, J.J., Harwood, D.S., Lajoie, K.R., Matti, J.C., Perkins, J.A., Rymer, M.J., Sarna-Wojcicki, A.M., Sharp, R.V., Sims, J.D., Tinsley, J.C., III, and Ziony, J.I., 1984, Preliminary sliprate table and map of late Quaternary faults of California: U.S. Geological Survey Open-File Report 84-106, 12 p., 5 plates, map scale 1:1,000,000.

Clark, D.G.,1990, Late Quaternary tectonic deformation in the Casmalia range, coastal south-central California: *in* Lettis, W.R., Hanson, K.L., Kelson, K.I., and Wesling, J.R., eds., Neotectonics of south-central coastal California: Friends of the Pleistocene, Pacific Cell 1990 Fall Field Trip Guidebook, p. 349-383.

Clarke, S.H., Jr., and Carver, G.A., 1992, Late Holocene tectonics and paleoseismicity, southern Cascadia subduction zone: Science, v. 255, p. 188-192.

Colson, K.B., Rockwell, T.K., Thorup, K.M., and Kennedy, G.L., 1995, Neotectonics of the left-lateral Santa Rosa Island Fault, Western Transverse ranges, southern California: Geol. Soc. Am., Cordilleran Section abstracts, v. 27, no. 5, p. 11.

Crook, R., Jr., Allen, C.R., Kamb, B., Payne, C.M., and Proctor, R.J., 1987, Quaternary geology and seismic hazard of the Sierra Madre and associated faults, western San Gabriel Mountains, *in* Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339, p. 27-64.

Crouch, J.K., Bachman, S.B., and Shay, J.T., 1984, Post-Miocene compressional tectonics along the central California margin, *in* Crouch, J.K., and Bachman, S.B., eds., Tectonics and sedimentation along the California margin: Pacific Section, SEPM, v. 38, p. 37-54.

Darrow, A.C., and Fischer, P.J., 1983, Activity and earthquake potential of the Palos Verdes Fault: unpublished Final Technical Report to the US Geological Survey, contract #14-08-0001-19786.

Darrow, A.C., and Sylvester, A.G., 1984, Activity of the central reach of the Santa Ynez Fault - continuation of investigations: Final technical report sponsored by the U.S. Geological Survey, cont. no. 14-08-0001-21367, 17p.

Davis, T.L., and Namson, J.S., 1994, A balanced cross-section of the 1994 Northridge earthquake, southern California: Nature, v. 372, p. 167-169.

DeMets, C., Gordon, R.G., Argus, D.F., and Stein, S., 1994, Effect of recent revisions to the geomagnetic reversal time scale on estimates of current plate motions: Geophysical Research Letters, v. 21, no. 20, p. 2191-2194.

dePolo, C.M., 1989, Seismotectonics of the White Mountains fault system, east-central California and west-central Nevada: Unpublished M.S. thesis, University of Nevada at Reno, 354 p.

Dolan, J.F., and Sieh, K.E., 1992, Tectonic geomorphology of the northern Los Angeles basin: Seismic hazards and kinematics of young fault movement, *in* Engineering geology field trips: Orange County, Santa Monica Mountains, and Malibu: Association of Engineering Geologists, 35th Annual Meeting, Field Trip Guidebook, p. B20-B26.

Dolan, J.F., Sieh, K., Rockwell, T.R., Yeats, R.S., Shaw, J., Suppe, J., Huftile, G.J., and Gath, E.M., 1995, Prospects for larger or more frequent earthquakes in the Los Angeles metropolitan region: Science, v. 267, p. 199-205.

Donnelly-Nolan, J.M., 1988, A magmatic model of Medicine Lake Volcano, California: Journal of Geophysical Research, v. 93, no. B5, p. 4412-4420.

Donnelly-Nolan, J.M., and Nolan, K.M., 1986, Catastrophic flooding and eruption of ash-flow tuff at Medicine Lake volcano, California: Journal of Volcanic and Geothermal Resources, v. 21, p. 177-206.

Donnelly-Nolan, J.M., and Champion, D.E., 1987, Geologic map of Lava Beds National Monument, northern California: U.S. Geological Survey Miscellaneous Investigations Map I-1804, scale 1:24,000.

Donnelly-Nolan, J.M., Champion, D.E., Miller, C.D., Grose, T.L., and Trimble, D.A., 1990, Post-11,000-year volcanism at Medicine Lake volcano, Cascade Range, Northern California: Journal of Geophysical Research, v. 95, p. 19,693-19,704.

Dorn, R.I., 1988, A rock varnish interpretation of alluvial-fan development in Death Valley, California: National Geographic Research, v. 4, p. 56-73.

Duffield, W.A., and Smith, G.I., 1978, Pleistocene history of volcanism and the Owens River near Little Lake, California: U.S. Geological Survey Journal of Research, v. 6, p. 395-408.

Ellsworth, W.L., 1990, Earthquake history, 1769-1989 *in* R.E. Wallace, ed., The San Andreas Fault System: U.S. Geological Survey Professional Paper 1515, p. 153-187.

Fenton, C.H., Wong, I.G., Sawyer, T.L., and Simpson, D.T., 1994, The Evergreen fault: an example of late Quaternary oblique thrust faulting in the southeastern San Francisco Bay Area, California (abs): EOS, Transactions, American Geophysical Union, v. 75, no. 44, p. 683.

Fischer, P.J., and Mills, G.I., 1991, The offshore Newport-Inglewood-Rose Canyon fault zone, California - structure, segmentation and tectonics, *in* Abbott, P.L., and Elliott, W.J., eds., Environmental Perils / San Diego Region: published for the Geological Society of America by the San Diego Association of Geologists, October 20, 1991, pp. 17-36.

Freeman, S.T., Heath, E.G., Guptill, P.D., and Waggoner, J.T., 1992, Seismic hazard assessment, Newport-Inglewood fault zone, *in* Pipkin, B.W., and Proctor, R.J. (eds), Engineering Geology Practice in Southern California: Association of Engineering Geologists Special Publication No. 4, p. 211-231.

Galehouse, J.S., 1992, Creep rates and creep characteristics of eastern San Francisco Bay area faults: 1979-1992, *in* Borchardt, G., Hirschfeld, S.E., Lienkaemper, J.J., McClellan, P., Williams, P.L., and Wong, I.G., (editors), Proceedings of the Second Conference on earthquake hazards in the eastern San Francisco Bay area: California Division of Mines and Geology Special Publication 113, p. 45-54.

Galehouse, J.S., 1995, Theodolite measurements of creep rates on San Francisco Bay region faults: U.S. Geological Survey Open-File Report 95-210, p. 335-346.

Gath, E.M., Gonzalez, T., and Rockwell, T.K., 1992, Slip rate of the Whittier fault based on 3-D trenching at Brea, southern California: Geological Society of America Cordilleran Section Meeting, May 11-13, 1992, v. 24, p. 26.

Gillespie, A.R., 1982, Quaternary glaciation and tectonics in the southeastern Sierra Nevada, Inyo County, California: California Institute of Technology, unpublished Ph.D. dissertation, 695 p.

Gonzalez, T., and Rockwell, T.K., 1991, Holocene activity of the Springville fault in Camarillo, Transverse Ranges, southern California; Preliminary observations, in Blake, T.F., and Larson, R.A., (editors), Engineering geology along the Simi-Santa Rosa fault system and adjacent areas, Simi Valley to Camarillo, Ventura County, California: Association of Engineering Geologists Field Trip Guidebook, Volume 2, 1991 Annual Field Trip Southern California Section, p. 369-373.

Guptill, P.D., Heath, E.G., and Brogan, G.E., 1981, Surface fault traces and historical earthquake effects near Los Alamos Valley, Santa Barbara County, CA: U.S. Geological Survey Open-File Report 81-271, 56 p.

Gurrola, L.D., and Rockwell, T.K., 1996, Timing and slip for prehistoric earthquakes on the Superstition Mountain fault, Imperial Valley, southern California: Journal of Geophysical Research, v. 101, n. B3, p. 5977-5985.

Hall, N.T., 1984, Late Quaternary history of the eastern Pleito Thrust fault, northern Transverse Ranges, California: Stanford University, California, unpublished Ph.D. thesis, 89p.

Hall, N.T., Hunt, T.D., and Vaughan, P.R., 1994, Holocene behavior of the San Simeon fault zone, south-central California, *in* Alterman, I.B., McMullen, R.B., Cluff, L.S., and Slemmons, D.B., eds., Seismotectonics of the Central California Coast Ranges: Geological Society of America Special Paper 292, p. 167-189.

Hanson, K., and Lettis, W.R., 1994, Estimated Pleistocene slip-rate for the San Simeon fault zone, south-central coastal California, *in* Alterman, I.B., McMullen, R.B., Cluff, L.S., and Slemmons, D.B., eds., Seismotectonics of the Central California Coast Ranges: Geological Society of America Special Paper 292, p. 133-150.

Harms, K.K., Harden, J.W., and Clark, M.M, 1987, Use of quantified soil development to determine slip rates on the Paicines fault, Northern California: Geological Society of America Abstracts with Programs, 83rd Meeting, Cordilleran Section, v. 19, no.6, p. 387.

Hart, E.W., 1985, Rinconada fault (Espinosa and San Marcos segments), Monterey and San Luis Obispo counties: California Division of Mines and Geology Fault Evaluation Report FER-175, 11p.

Hart, E.W., 1987, Pisgah, Bullion, and related faults, San Bernardino County, CA, Supplement No. 1: California Division of Mines and Geology Fault Evaluation Report FER-188, 4 p.

Hart, E.W., Bryant, W.A., Manson, M.W., and Kahle, J.E., 1986, Summary report, Fault evaluation program, 19841985, southern Coast Ranges region and other areas: California Division of Mines and Geology Open-File Report 86-3, 26 p., 1 plate, scale 1:500,000.

Hauksson, E., and Saldivar, G.V., 1989, Seismicity and active compressional tectonics in Santa Monica Bay, southern California: Jour. of Geophysical Research, v. 94, no.B7, p. 9591-9606.

Hauksson, E., Jones, L.M., Hutton, K., and Eberhart-Phillips, D., 1993, The 1992 Landers earthquake sequence: Seismological observations: Journal of Geophysical Research, v. 98, no.B11, p. 19,835-19,858.

Hauksson, E., Jones, L.M., Hutton, K., 1995, The 1994 Northridge earthquake sequence in California: Seismological and tectonic aspects: Journal of Geophysical Research, v. 100, no. B7, p. 12,335-12,355.

Heath, E.G., Jensen, D.E., and Lukesh, D.W., 1982, Style and age of deformation on the Chino fault, in Cooper, J.D., compiler, Neotectonics in southern California: Geological Society of America, Cordilleran Section, Annual Meeting, 1982, Volume and Guidebook, p. 43-51.

Hecker, S., Fumal, R.E., Powers, T.J., Hamilton, J.C., Garvin, C.D., and Schwartz, D.P., 1993, Late Pleistocene-Holocene behavior of the Homestead Valley fault segment - 1992 Landers, California surface rupture [abs]: EOS, v. 74, no. 43, p. 612.

Hedel, C.W., 1980, Late Quaternary faulting in western Surprise Valley, Modoc County, California: Unpublished M.S thesis, San Jose State University, 113 p., 2 appendices, 2 plates, map scale 1:62.500.

Hedel, C.W., 1984, Maps showing geomorphic and geologic evidence for late Quaternary displacement along the Surprise Valley and associated faults, Modoc County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF1429, 2 sheets, scale 1:62,500.

Helmberger, D.V., Somerville, P.G., and Garnero, E., 1992, The location and source parameters of the Lompoc, California, earthquake of 4 November 1927: Bull. Seismological Soc. of Am., v. 82, p. 1678-1709.

Henyey, T., 1994, Neotectonics of the Palos Verdes fault: Seismological Society of America Field Trip Guide, April 8, 1994, 4p.

Herzberg, M., and Rockwell, R., 1993, Timing of past earthquakes on the northern Johnson Valley fault and their relationship to the 1992 rupture: EOS, Transactions of the American Geophysical Union, v. 74, no. 43, p. 612.

Hill, D.P., Eaton, J.P., and Jones, L.M., 1990, Seismicity of the San Andreas fault system: 1980-1986, *in* The San Andreas Fault System, edited by R.E. Wallace: U.S. Geological Survey Professional Paper 1515, p. 115-152.

Hitchcock, C.S., Kelson, K.I., and Thompson, S.C., 1994, Geomorphic investigations of deformation along the northeastern margin of the Santa Cruz Mountains: U.S. Geological Survey Open-File Report OFR 94-187, 50 p.

Hornafius, J.S., Kamerling, M.J., and Luyendyk, B.P., 1995, SCEC progress report: seismic mapping of the North Channel Fault near Santa Barbara, CA: unpublished report from Institute for Crustal Studies, UCSB, 5p.

Hudnut, K.W., and Sieh, K.E., 1989, Behavior of the Superstition Hills Fault during the past 330 years: Bull. Seismological Soc. Am., v. 79, p. 304-329.

Hudnut, K.W., Seeber, L., and Rockwell, T., 1989, Slip on the Elmore Ranch Fault during the past 330 years and its relation to slip on the Superstition Hills Fault: Bull. Seismological Soc. Am., v. 79, p. 330-341.

Huftile, G.J., 1992, Convergence rates across the Ventura Basin, California: Unpublished Ph.D thesis, Oregon State University, 279 p.

Huftile, G.J., and Yeats, R. S., 1995, Convergence rates across a displacement transfer zone n the western Transverse Ranges, Ventura basin, California: Journal of Geophysical Research, v. 100, no. B2, p 2043-2067.

Hutton, L.K., and Jones, L.M., 1993, Local magnitudes and apparent variations in seismicity rates in southern California: Bulletin Seismological Society of America, v. 83, p. 313-329.

Johnson, C.E., and Hadley, D.M., 1976, Tectonic implications of the Brawley earthquake swarm, Imperial Valley, California, January 1975: Bull. Seismological Soc. Am. v. 66, p. 1133-1144.

Kahle, J.E., 1966, Megabreccias and sedimentary structure of the Plush Ranch Formation, northern Ventura County, California: University of California, Los Angeles unpublished M.A. thesis, 125 p.

Keller, E.A., Bronkowski, M.S., Korsch, R.J., and Shlemon, R.J., 1982, Tectonic geomorphology of the San Andreas fault zone in the southern Indio Hills, Coachella Valley, California: Geological Society of America Bulletin, v. 93, p. 46-56.

Kelson, K.I., Lettis, W.R., and Lisowski, M., 1992, Distribution of geologic slip and creep along faults in the San Francisco Bay region, *in* Borchardt, G., Hirschfeld, S.E., Lienkaemper, J.J., McClellan, P., Williams, P.L., and Wong, I.G., (editors), Proceedings of the Second Conference on earthquake hazards in the eastern San Francisco Bay area: California Division of Mines and Geology Special Publication 113, p. 31-38.

Kelson, K.I., Simpson, G.D., Lettis, W.R., Haraden, C.C., Williams, C.R., and Thompson, S.C., 1994, Holocene slip rate and recurrence of surface-faulting earthquakes on the northern Calaveras fault at Leyden Creek, Alameda County, California: U.S. Geological Survey, Final Technical Report, National Earthquake Hazards Reduction Program, Contract No. 1434-93-G-2338, 32 p.

Kelson, K.I., Hitchcock, C.S., Zeeb, R.B., and Lettis, W.R., 1995, Displacement of late Pleistocene glacial moraines by the Almanor fault, Plumas County, California, *in*, Page, W.D. (ed) Quaternary geology along the boundary between the Modoc Plateau, southern Cascade Mountains, and northern Sierra Nevada: Friends of the Pleistocene 1995 Pacific Cell Field Trip, 19 p.

Kelson, K.I., Simpson, G.D., Lettis, W.R., and Haraden, C.C., 1996, Holocene slip rate and recurrence of the northern Calaveras fault at Leyden Creek, eastern San Francisco Bay region: Journal of Geophysical Research, v. 101, no. B3, p. 5961-5975.

Klinger, R.E., and Piety, L.A., 1994, Late Quaternary slip on the Death Valley and Furnace Creek faults, Death Valley, CA: Geological Society of America Abstracts with Programs, 1994 Annual Meeting, p. A-189.

Larsen, S.C., Agnew, D.C., and Hager, B.H., 1993, Strain accumulation in the Santa Barbara channel: 1970-1988: Jour. Geophysical Research, v. 98, B2, p. 2119-2133.

Larson & Webb, 1992, Deformation in the Santa Barbara channel from GPS measurements 1987-1991: Geophysical Research Letters 19(14) 1491-1494.

Laviolette, J.W., Christenson, G.E., and Stepp, J.C., 1980, Quaternary displacement on the western Garlock Fault, southern California, *in* Fife, D.L., and Brown, A.R., eds., Geology and mineral wealth of the California desert: South Coast Geol. Soc., Dibblee Volume, p. 449-456.

Legg, M.R., and Kennedy, M.P., 1991, Oblique divergence and convergence in the California continental borderland, *in* Environmental Perils / San Diego Region: published for the Geological Society of America by the San Diego Association of Geologists, October 20, 1991, p. 1-16.

Lettis, W.R., and Hanson, K.L., 1992, Quaternary tectonic influences on coastal morphology, south-central California: Quaternary International, v. 15/16, p. 135-148

Lettis, W.R., DiSilvestro, L., Hanson, K.L., and Shiller, J.I., 1990, The San Simeon/Hosgri pull-apart basin, south-central coastal California: *in* Lettis, W.R., Hanson, K.L., Kelson, K.I., and Wesling, J.R., eds., Neotectonics of south-central coastal California: Friends of the Pleistocene, Pacific Cell 1990 Fall Field Trip Guidebook, , p. 91-138.

Lettis, W.R., and Hall, N.T., 1994, Los Osos fault zone, San Luis Obispo County, California, *in* Alterman, I.B., McMullen, R.B., Cluff, L.S., and Slemmons, D.B., eds., Seismotectonics of the Central California Coast Ranges: Geological Society of America Special Paper 292, p. 73-102.

Lettis, W.R., Kelson, K.I., Wesling, J.R., Angell, M,. Hanson, K.L., and Hall, N.T., 1994, Quaternary deformation of the San Luis Range, San Luis Obispo County, California, *in* Alterman, I.B., McMullen, R.B., Cluff, L.S., and Slemmons, D.B., eds., Seismotectonics of the Central California Coast Ranges: Geological Society of America Special Paper 292, p. 111-132.

Levi, S., and Yeats, R.S., 1993, Paleomagnetic constraints on the initiation of uplift on the Santa Susana fault, western Transverse Ranges, California: Tectonics, v. 12, p. 688-702.

Lienkaemper, J.J., and Borchardt, G. 1996, Holocene slip rate of the Hayward fault at Union City, California: Journal of Geophysical Research, v. 101, no. B3, p. 6099-6108.

Lienkaemper, J.J., Borchardt, G., and Lisowski, M., 1991, Historic creep rate and potential for seismic slip along the Hayward fault, California: Journal of Geophysical Research, v. 96, no. B11, p. 18,261-18,283.

Lienkaemper, J.J., Williams, P.L., Taylor, P., and Williams, K., 1995, New evidence of large surface-rupturing earthquakes along the northern Hayward fault zone [abstr.]: SEPM (Society of Economic Paleontologists and Mineralogists) Pacific Section, 70th Annual Meeting, San Francisco, California, 1995, SEPM, p. 38.

Lindvall, S.C., and Rockwell, T.K., 1995, Holocene activity of the Rose Canyon fault zone in San Diego, California: Jour. Geophysical Research, v. 100, p. 24,121-24,132.

Lisowski, M., and Prescott, W.H., 1989, Strain accumulation near the Mendocino Triple Junction, California: EOS Transactions, American Geophysical Union, v. 70, n. 43. p. 1332

Lubetkin, L.K.C., and Clark, M.M., 1988, Late Quaternary activity along the Lone Pine Fault, eastern California: Geological Society of America Bulletin, v. 100, p. 755766.

Manson, M.W., 1985, Los Alamos fault, Santa Barbara County: California Division of Mines and Geology, Fault Evaluation Report FER 165.

Martel, S.J., 1984, Late Quaternary activity on the Fish Springs fault, Owens Valley fault zone, California: Stanford, California, Stanford University, M.S. thesis, 112 p.

Martel, S.J., Harrison, T.M., and Gillespie, A.R., 1987, Late Quaternary vertical displacement rate across the Fish Springs fault, Owens Valley fault zone, California: Quaternary Research, v. 27, p. 113-129.

Matti, J.C., and Morton, D.M., 1982, Geologic history of the Banning fault zone, southern California: Geological Society of America Abstracts with Programs, v. 14, p. 184.

Matti, J.C., Morton, D.M., and Cox, B.F., 1985, Distribution and geologic relations of fault systems in the vicinity of the central Transverse Ranges, southern California: U.S. Geological Survey Open-File Report 85-365, 23 p., 4 figures, 2 plates, 1:250,000 scale.

McCrory, P.A., Wilson, D.S., and Murray, M.H., 1995, Modern plate motions in the Mendocino Triple Junction region: Implications for partitioning of strain (abs): EOS, Transactions of the American Geophysical Union, AGU 1995 Fall Meeting, v. 76, no. 46 p. F630.

McCrory, P.A., 1996, Evaluation of fault hazards, northern coastal California: U.S. Geological Survey Open-File Report 96-656, 87 p.

McCulloch, D.S., 1987, Regional geology and hydrocarbon potential of offshore central California in G.D.W. Scholl A., and Vedder, J.G., ed., Geology and resource potential of the continuous margin of western North America and adjacent ocean basins -- Beaufort Sea to Baja California: Circum Pacific Council for Energy and Mineral Resources, Earth Science Series 6, p. 353-401.

McGill, R.T., 1989, Geologic maps of the Pacific Palisades area, Los Angeles, California: U.S. Geological Survey Map I-1828, 2 sheets, scale 1:4,800.

McGill, S.F., 1993, Late Quaternary slip rate of the Owl Lake fault and maximum age of the latest event on the easternmost Garlock fault, S. California (abs): Geological Society of America Abstracts with Programs, v. 25, no. 5, p. 118.

McGill, S.F., 1994, Preliminary slip rate and recurrence interval for the western Garlock fault system near Lone Tree Canyon, California (abs): Geological Society of America Abstracts with Programs, v. 26, no.2, p. 72.

McGill, S.F., and Sieh, K., 1991, Surficial offsets on the central and eastern Garlock Fault associated with prehistoric earthquakes: Journal of Geophysical Research, v. 96, p. 21,587-21,621.

McGill, S., and Sieh, K., 1993, Holocene slip rate of the central Garlock Fault in southeastern Searles Valley, California: Journal of Geophysical Research, v. 98, p. 14,217-14, 231.

McLaughlin, R.J., 1973, Geology of the Sargent fault in the vicinity of Mt. Madonna, Santa Clara and Santa Cruz counties, California: Unpublished M.S., thesis for California State University, San Jose, 131 p.

McLaughlin, R.J., and others, 1990, Geologic map and structure sections of the Little Indian Valley-Wilbur Springs geothermal area, northern Coast Ranges, California: U.S. Geological Survey Miscellaneous Investigations Series Map I-1706.

McNeilan, T.W., Rockwell, T.K., and Resnick, G.S., 1996, Style and rate of Holocene slip, Palos Verdes fault, southern California: Journal of Geophysical Research, v. 101, B4, p. 8317-8334.

Meisling, K.E., 1984, Neotectonics of the north frontal fault system of the San Bernardino Mountains, southern California; Cajon Pass to Lucerne Valley: California Institute of Technology, unpublished Ph.D. dissertation, Plates 1A & 1B, scale 1:24,000.

Merifield, P.M., Rockwell, T.K., and Loughman, C.C., 1991, A slip rate based on trenching studies, San Jacinto fault zone near Anza, California, *in* McCalpin, J.P., ed., Proc. of the 1991 Annual Symposium on Engineering Geology and Geotechnical Engineering (no.27).

Millman, D.E., and Rockwell, T.K., 1986, Neotectonics of the Elsinore fault in Temescal Valley, California: Geological Society of America Guidebook and Volume, 82nd Annual Meeting, v. 82, p. 159-166.

Molnar, P., 1991, Final report to the Southern California Earthquake Center for work performed during the period from September through December, 1991: Southern California Earthquake Center Report, 126 p. (unpublished).

Moore, G.W., and Kennedy, M.P., 1975, Quaternary faults at San Diego Bay, California: U.S. Geological Survey, Journal of Research, v. 3, no. 5, p. 589-595.

Morton, D.M., and Matti, J.C., 1987, The Cucamonga fault zone: Geological setting and Quaternary history, in Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339, p. 179-203.

Morton, D.M., and Yerkes, R.F., 1987, Recent reverse faulting in the Transverse Ranges, California, Introduction, in Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339, p. 1-5.

Mueller, K.J., and Rockwell, T.K., 1995, Late Quaternary activity of the Laguna Salada fault in northern Baja California, Mexico: Geol. Soc. of America Bull. v. 107, no.1, p. 8-18.

Muffler, L. J.P, Clynne, M.A., and Champion, D.E., 1994, Late Quaternary normal faulting of the Hat Creek Basalt, northern California: Geological Society of America Bulletin, v. 106, no. 2, p. 195-200.

Niemi, T.M., and Hall, N.T., 1992, Late Holocene slip rate and recurrence of great earthquakes on the San Andreas fault in northern California: Geology, v. 20, no. 3, p. 196-198.

Nolan, J.M., Zinn, E.N., and Weber, G.E., 1995, Paleoseismic study of the southern Sargent fault, Santa Clara and San Benito Counties, California: Unpublished U.S. Geological NEHRP Final Technical Report 1434-94-G-2466, 23 p. Noller, J.S., Simpson, G.D., Thompson, S.C., and Lettis,

W.R., 1995, Geoarchaeologic and paleoseismic investigations of the San Gregorio fault, Seal Cove, California: U.S. Geological Survey Open-File Report OFR 95-210, p. 600-601.

Oppenheimer, D.H., Bakun, W.H., and Lindh, A.G., 1990, Slip partitioning of the Calaveras fault, California, and prospects for future earthquakes: Journal of Geophysical Research, v. 95, no. B6, p. 8483-8498.

Pacific Gas & Electric Co.(PG&E), 1988, Final report of the Diablo Canyon long term seismic program: Pacific Gas and Electric Company.

Pacific Gas & Electric Co.(PG&E), 1994, Characterization of potential earthquake sources for Rock Creek (Drum) Dam, report for FERC 2310, Drum Spaulding Project State Dam No. 97-43, 89p.

Page, W.D., 1995, Road Log - Day One, Lava Beds National Monument to Lake Britton *in* Page, W.D., (trip leader), Quaternary geology along the boundary between the Modoc Plateau, southern Cascade Mountains, and northern Sierra Nevada: Friends of the Pleistocene, 1995 Pacific Cell Field Trip, p. 12 (Tab 2).

Page, W.D., and Renne, P.R., 1994, 40AR-39AR dating of Quaternary basalt, western Modoc Plateau, northeastern California: Implications to tectonics [abstr.]: U.S. Geological Survey Circular 1107 [Abstracts of the Eighth International Conference on Geochronology, Cosmochronology and Isotope Geology, Lanphere, M.A., Dalrymple, G.B., and Turrin, B.D. (eds.)], p. 240.

Pampeyan, E.H., and others, 1981, Preliminary map showing recently active breaks along the Maacama Fault Zone between Laytonville and Hopland, Mendocino County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1217.

Perkins, J.A., and Sims, J.D., 1988, Late Quaternary slip along the Calaveras fault near Hollister, California: EOS, Transactions, American Geophysical Union, v. 69, no. 44, p. 1420.

Petersen, M.D., and Wesnousky, S.G., 1994, Fault slip rates and earthquake histories for active faults in southern California: Bull. Seismo. Soc. of Am., v. 84, p. 1608-1649.

Pezzopane, S.K., 1993, Active faults and earthquake ground motions in Oregon: University of Oregon, Ph.D dissertation, 208 p.

Pinter, Nicholas, and Sorlien, Christopher, 1991, Evidence for latest Pleistocene to Holocene movement on the Santa Cruz Island Fault, California: Geology, v. 19, no.9, p. 909-912.

Pinter, N., Lueddecke-Pinter, S., and Keller, E.A., 1995, Short-term and long-term activity on the Santa Cruz Island Fault, California: Geological Society of America, Abstracts with Program, v. 27, no.6, p. 375-376.

Pollard, W.J., and Rockwell, T.K., 1995, Late Holocene slip rate for the Coyote Creek Fault, Imperial County, California: Geol. Soc. Am., Cordilleran Section abstracts, v. 27, no.5, p. 72.

Prentice, C., Niemi, T.N., and Hall, N.T., 1991, Quaternary tectonics of the northern San Andreas fault, San Francisco Peninsula, Point Reyes, and Point Arena, California [field trip guide]: California Division of Mines and Geology Special Publication, v. 109, p. 25-34.

Prescott, W.H., and Burford, R.O., 1976, Slip on the Sargent fault: Bulletin of he Seismological Society of America, v. 66, no. 3, p. 1013-1016.

Prescott, W.H., and Lisowski, M., 1983, Strain accumulation along the San Andreas fault system east of San Francisco Bay, California: Tectonophysics, v. 97, p. 41-56.

Reheis, M.C., 1994, Logs of trenches across the central part of the Fish Lake Valley fault zone, Mono County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-2266.

Reheis M.C., and McKee, E.H., 1991, Late Cenozoic history of slip on the Fish Lake Valley fault zone, Nevada and California: U.S. Geological Survey Open-File Report OFR 91-290, p. 26-45.

Reheis M.C., and Dixon, T.H., 1996, Kinematics of the eastern California shear zone: Evidence for slip transfer from Owens and Saline Valley fault zones to Fish Lake Valley fault zone: Geology, v. 24, no. 4, p. 339-342.

Reynolds, M.W., 1969, Stratigraphy and structural geology of the Titus an Titanothere canyons area, Death Valley, California: University of California, Berkeley, unpublished Ph.D. thesis, 255 p.

Rockwell, T.K., 1983, Soil chronology, geology, and neotectonics of the northcentral Ventura basin, California: University of California, Santa Barbara, unpublished Ph.D. dissertation.

Rockwell, T.K., 1988, Neotectonics of San Cayetano Fault, Transverse Ranges, California: Geological Society of America Bulletin, v. 100, no. 4, p. 500513.

Rockwell, T.K., 1990, Holocene activity of the Elsinore fault in the Coyote Mountains, southern California, *in* Western Salton Trough Soils and Neotectonics: Friends of the Pleistocene Winter Field Trip, p. 30-42.

Rockwell, T.K., Keller, E.A., Clark, M.N., and Johnson, D.L., 1984, Chronology and rates of faulting of Ventura River terraces, California: Geological Society of America Bulletin, v. 95, p. 14661474.

Rockwell, T.K., Lamar, S.L., McElwain, R.S., and Millman, D.E., 1985, Late Holocene recurrent faulting on the Glen Ivy North strand of the Elsinore fault, southern California [abs.]: Geological Society of America Abstracts with Programs, Cordilleran Section, v. 17, no. 6, p. 404.

Rockwell, T., Loughman, C., and Merifield, P., 1990, Late Quaternary rate of slip along the San Jacinto fault zone near Anza, southern California: Jour. Geophysical Research, v. 95, p. 8593-8605.

Rockwell, T.K., Klinger, R., and Goodmacher, J., 1990, Determination of slip rates and dating of earthquakes for the San Jacinto and Elsinore fault zones, in Kooser, M.A., and Reynolds, R.E., eds., Geology around the Margins of the eastern San Bernardino Mountains, Volume 1: Inland Geological Society, Redlands, p. 51-56.

Rockwell, T.K., Gath, E.M., and Gonzalez, T., 1992, Sense and rate of slip on the Whittier fault zone, eastern Los Angeles basin, CA: Proceedings of the 35th Annual Meeting, Association of Engineering Geologists, 2-9 October, M.L. Stout (ed): Association of Engineering Geologists, Santa Ana, California, 679 p.

Roquemore, G.R., 1981, Active faults and associated tectonic stress in the Coso Range, California: University of Nevada, Reno, Ph.D. dissertation (also published by China Lake Naval Weapons Center as NWC TP6270, 101 p. with maps, scale 1:24,000).

Rosenberg, L.I., and Clark, J.C., 1995, Quaternary faulting of the greater Monterey area, California: Association of Engineering Geologists, Annual Meeting Abstracts, p. 81-82.

Rubin, C., and Sieh, K.E., 1993, Long recurrence interval for the Emerson fault: implications for slip rates and probabilistic seismic hazard calculations: EOS, v. 74, no. 43, p. 612.

Salyards, S.L., Sieh, K.E., and Kirschvink, J.L., 1992, Paleomagnetic measurement of non-brittle coseismic deformation across the San Andreas fault at Pallett Creek: Journal of Geophysical Research, v. 96, p. 12,457-12,470.

Sarna-Wojcicki, A.M., LaJoie, K.R., and Yerkes, R.F., 1987, Recurrent Holocene displacement on the Javon Canyon fault - a comparison of fault movement history with calculated average recurrence intervals: U.S.G.S. Professional Paper 1339, p. 124-135.

Savage, J.C., Goodreau, D.D., and Prescott, W.H., 1974, Possible fault slip on the Brawley Fault, Imperial Valley, California: Bull. Seismological Soc. Am., v. 64, p. 713-716.

Sawyer, T.L., 1991, Late Pleistocene and Holocene paleoseismicity and slip rates of the northern Fish Lake Valley fault zone, Nevada and California: U.S. Geological Survey Open-File Report 91-290, p. 114-138.

Schwartz, D.P., Pantosti, D., Hecker, S., Okumura, K., Budding, K.E., and Powers, T., 1992, Late Holocene behavior and seismogenic potential of the Rodgers Creek Fault Zone, Sonoma County, California, *in* Borchardt, G.,(chief ed.), Proceedings of the second conference on earthquake hazards in the eastern San Francisco Bay Area: California Department of Conservation, Division of Mines and Geology Special Publication 113, p. 393-398.

Sharp, R.V., 1981, variable rates of late Quaternary strike slip on the San Jacinto fault zone, southern California: Jour. Geophysical Research, v. 86, B3, p. 1754-1762.

Shaw, J.H., and Suppe, J., 1994, Active faulting and growth folding in the eastern Santa Barbara Channel, California: Geol. Soc. America Bulletin v. 106, p. 607-626.

Shaw, J.H., and Suppe, J., 1996, Earthquake hazards of active blind thrust faults under the central Los Angeles basin, California: Journal of Geophysical Research, v. 101, p. 8623-8642.

Shlemon, R.J., and Simmons, S.T., 1995, Holocene displacement of the Simi fault at Moorpark, Ventura County, California: Association of Engineering Geologists, Southern California Section, 1995 Annual Field Trip Guidebook, 10 p.

Sieh, K., 1975, An investigation of the potential for ground rupture along fault traces in the Los Altos Hills, California: Unpublished report for W.R. Cotton and Los Altos Hills Planning Commission.

Sieh, K.E., 1984, Lateral offset and revised dates of large prehistoric earthquakes at Pallett Creek, southern California: Journal of Geophysical Research, v. 89, p. 7641-7670.

Sieh, K.E., 1986, Slip rate across the San Andreas fault and prehistoric earthquakes at Indio, California: EOS, v. 67, p. 1200.

Sieh, K.E., and Jahns, R.H., 1984, Holocene activity of the San Andreas fault at Wallace Creek, California: Geological Society of America Bulletin, v. 95, p. 883896.

Sieh, K.E, and Matti, J.C., 1992, The San Andreas fault system between Palm Springs and Palmdale, southern California: field trip guidebook in Sieh, K.E., and Matti, J.C., leaders, Earthquake geology, San Andreas fault system, Palm Springs to Palmdale: Southern California Section, Association of Engineering Geologists, Guidebook and Reprint Volume, prepared for the 35th Annual Meeting, Long Beach, California, p. 1-12.

Sieh, K, E., and Williams, P.L., 1990, Behavior of the southernmost San Andreas Fault during the past 300 years: Jour. Geophysical Research, v. 95, p. 6629-6645.

Simpson, G.D., Lettis, W.R., Williams, C.R., Haraden, C.C., and Bachhuber, 1994, Paleoseismic investigation of the Northern Calaveras fault, Contra Costa and Alameda Counties, California: U.S. Geological Survey, Final Technical Report, National Earthquake Hazards Reduction Program, Contract No. 1434-93-G-2339, 38 p.

Sims, J.D., 1991, Distribution and rate of slip across the San Andreas transform boundary, Hollister area, Central California: Geological Society of America Abstracts with Programs, 87rd Meeting, Cordilleran Section, v. 23, no. 2, p. 98.

Smith, G.I., 1975, Holocene movement on the Garlock fault: U.S. Geol. Survey Prof. Paper 975, p. 202.

Smith, G.I., Troxel, B.W., Gray, C.H., Jr., and Von Huene, R., 1968, Geologic reconnaissance of the Slate Range, San Bernardino and Inyo counties, California: California Division of Mines and Geology Special Report 96, 33 p.

Smith, R.S.U., 1976, Late Quaternary pluvial and tectonic history of Panamint Valley, Inyo and San Bernardino Counties, California: California Institute of Technology, unpublished Ph.D. thesis, 295 p.

Smith, R.S.U., 1979, Holocene offset and seismicity along the Panamint Valley fault zone, western Basin and Range Province, California: Tectonophysics, v. 52, p. 411-415.

Snyder, D.L., Wills, C.J., and Borchardt, G.A., 1995, Slip rate and earthquake recurrence on the Concord fault at Galindo Creek, California: U.S. Geological Survey, Final Technical Report, National Earthquake Hazards Reduction Program, Contract No. 1434-94-G-2483, 37 p.

Sorg, D.H., and McLaughlin, R.J., 1975, Geologic map of the Sargent-Berrocal Fault Zone between Los Gatos and Los Altos Hills, Santa Clara County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF643, scale 1:24,000.

Stein, R.S., and Thatcher, W., 1981, Seismic and aseismic deformation associated with the 1952 Kern County, California earthquake and relationship to the Quaternary history of the White Wolf Fault: Journal of Geophysical Research, v. 86, p. 4993-4928.

Stephenson, W.J., Rockwell, T.K., Odum, J.K., Shedlock, K.M., and Okaya, D.A., 1995, Seismic reflection and geomorphic characterization of the onshore Palos Verdes fault zone, Los Angeles, California: Bull. Seismological Soc. Am., v. 85, p. 943-950.

Steritz, J.W., and Luyendyk, B.P., 1994, Hosgri fault zone, offshore Santa Maria Basin, California, *in* Alterman, I.B., McMullen, R.B., Cluff, L.S., and Slemmons, D.B., eds., Seismotectonics of the Central California Coast Ranges: Geological Society of

America Special Paper 292, p. 191-209.

Stierman D.J., and Ellsworth, W.L., 1976, Aftershocks of the February 21, 1973 Point Mugu, California earthquake: Bulletin of the Seismological Society of America, v. 66, no.6, p. 1931-1952.

Stitt, L.T., 1986, Structural history of the San Gabriel fault and other Neogene structures of the central Transverse Ranges, California, in Ehlig, P.L. (compiler), Neotectonics and faulting in southern California: Geological Society of America Guidebook and Volume, 82nd Annual Meeting of the Cordilleran Section of the Geological Society of America, p. 43-102.

Swan, F.H., and Taylor, C.L., 1991, Geologic and geomorphic evidence suggesting spatial and temporal clustering of paleoseismic events along the Bartlett Springs Fault Zone, northern California: Geological Society of America Abstracts with Programs, v. 23, n. 2, p. 102.

Taylor, C.L., and Swan, F.H., 1986, Geological assessment of the seismic potential of the Bartlett Springs shear zone for Scott Dam, Lake County, California: Final Report by Geomatrix Consultants for Pacific Gas and Electric Company, 51 p.

Thomas, A.P., and Rockwell, T.K., 1996, A 300- to 550-year history of slip on the Imperial fault near the U.S. - Mexico Missing slip at the Imperial fault bottleneck: Journal of Geophysical Research, v. 101, no. B3, p. 5987-5997.

Toppozada, T., Borchardt, G., Haydon, W., Petersen, M., Olson, R., Lagorio, H., and Anvik, T., 1995, Planning Scenario in Humboldt and Del Norte counties, California, for a great earthquake on the Cascadia subduction zone: California Division of Mines and Geology Special Publication 115, 157 p.

Treiman, J.A., 1992, Eureka Peak and related faults, San Bernardino and Riverside Counties, California: Division of Mines and Geology Fault Evaluation Report FER-230 (unpublished).

Treiman, J.A., 1994, Malibu Coast Fault Zone, Los Angeles County, California: California Department of Conservation Division of Mines and Geology unpublished Fault Evaluation Report FER-229.

Upp, R.R., 1989, Holocene activity and tectonic setting of the Maacama Fault Zone, Mendocino County, California: Engineering Geology, v. 27, p. 375-412.

U.S. Geological Survey, 1996, USGS response to an urban earthquake, Northridge '94: U.S. Geological Survey Administrative Report prepared for the Federal Emergency Management Agency (FEMA), p. 62.

Wakabayashi, J., and Smith, D.L., 1994, Evaluation of recurrence intervals, characteristic earthquakes, and slip rates associated with thrusting along the Coast Range-Central Valley geomorphic boundary, California: Bulletin of the Seismological Society of America, v. 84, n. 6, p. 1960-1970.

Ward and Valensise, 1994, The Palos Verdes terraces, California - bathtub rings from a buried reverse fault: Journal Geophysical Research, p. 4485-4494.

Weber, G.E., 1994, Late Pleistocene slip rates on the San Gregorio fault zone at Point Año Nuevo, San Mateo County, California, *in* Lettis, W.R. (ed), Quaternary transpressional plate deformation in the greater San Francisco Bay area: Friends of the Pleistocene Pacific Cell 1996 Fall Field Trip, P. 193-203.

Weber, G.E., and Nolan, J.M., 1995, Determination of late Pleistocene-Holocene slip rates along the San Gregorio fault zone, San Mateo County, California: U.S. Geological Survey Open-File Report OFR 95-210, p. 805-807.

Weber, F.H., Jr., Bennett, J.H., Chapman, R.H., Chase, G.W., and Saul, R.B., 1980, Earthquake hazards associated with the Verdugo-Eagle Rock and Benedict Canyon fault zones, Los Angeles, California: California Division of Mines and Geology Open File Report 80-10LA, 163 p.

Weldon, R.J., II, and Sieh, K.E., 1985, Holocene rate of slip and tentative recurrence interval for large earthquakes on the San Andreas fault, Cajon Pass, southern California: Geological Society of America Bulletin, v. 96, no. 6, p. 793-812.

Wells, D.L., and Coppersmith, K.J., 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Seismological Society of America Bulletin, v. 84, no. 4, p. 974-1002.

Wesnousky, S.G., 1986, Earthquakes, Quaternary faults, and seismic hazard in California: Journal of Geophysical Research, v. 91, p. 12,587-12,631.

Woodward-Clyde Consultants, 1978, Stanislaus nuclear project site suitability: Site safety report (unsubmitted) for Pacific Gas and Electric Company; Foothills fault study, v. 4, Appendices C.1 and C.2; v. 6, Appendices C.4 and C.4A.

WGCEP (Working Group on California Earthquake Probabilities), 1990, Probabilities of large earthquakes in the San

Francisco Bay Region, California: U.S. Geological Survey Circular 1053, 51 p.

WGCEP (Working Group on California Earthquake Probabilities), 1995, Seismic hazards in southern California: Probable earthquakes, 1994 to 2024: Bulletin of the Seismological Society of America, v. 85, no. 2, p. 379-439.

WGNCEP (Working Group on Northern California Earthquake Potential), 1996, Database of potential sources for earthquakes larger than magnitude 6 in northern California: U. S. Geological Survey Open-File Report 96-705.

Williams, R.A., Williams, R.T., Catchings, R.D., Kelson, K.I., Hitchcock, C.S., Rymer, M.J., and Odum, J.K., 1995, High-resolution geophysical profiling across the Monte Vista fault, Los Altos, California (abs): EOS, Transactions, American Geophysical Union, v. 76, no. 44, p. F399.

Wills, C.J., and Borchardt, G., 1993, Holocene slip rate and earthquake recurrence on the Honey Lake fault zone, northeastern California: Geology, v. 21, no. 9, p. 853-856.

Wright, R.H., Hamilton, D.H., Hunt, T.D., Traubenik, M.L., and Shlemon, R.J., 1982, Character and activity of the Greenville structural trend, *in* Hart, E.W., Hirschfeld, S.E., and Schulz, S.S., Proceedings, Conference on earthquake hazards in the eastern San Francisco Bay area: California Division of Mines and Geology Special Publication 62, p. 187-196.

Yeats, R.S., 1983, Large-scale Quaternary detachments in Ventura basin, southern California: Journal of Geophysical Research, v. 88, p. 569-583.

Yeats, R.S., 1987, Late Cenozoic structure of the Santa Susana Fault Zone, *in* Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339, p. 137160.

Yeats, R.S., 1988, Late Quaternary slip rate on the Oak Ridge fault, Transverse Ranges, California; implications for seismic risk: Journal of Geophysical Research, v. 93, p. 12,137-12,149.

Yeats, R.S., and Huftile, G.J., 1995, The Oak Ridge fault system and the 1994 Northridge earthquake: Nature, v. 373, p. 418-420.

Yeats, R.S., Lee, W.H.K., and Yerkes, R.F., 1987, Geology and seismicity of the eastern Red Mountain Fault, Ventura County: U.S. Geol. Survey Prof. Paper 1339, p. 161-167.

Yeats, R.S., Huftile, G.J., and Stitt, L.T., 1994, Late Cenozoic tectonics of the east Ventura basin, Transverse Ranges, California: American Association of Petroleum Geologists Bulletin, v. 78, no. 7, p. 1040-1074.

Yerkes, R.F., and Lee, W.H.K., 1987, Late Quaternary deformation in the western Transverse Ranges: U.S. Geol. Survey Prof. Paper 1339, p. 71-82.

Yu, E., and Segall, P., 1996, Slip in the 1868 Hayward earthquake from the analysis of historical triangulation data: Journal of Geophysical Research, v. 101, p. [in review].

Zhang, P., Ellis, M., Slemmons, D.B., and Mao, F., 1990, Right lateral displacements and the Holocene slip rate associated with prehistoric earthquakes along the southern Panamint Valley Fault Zone: Journal of Geophysical Research, v. 95, no. 84, p. 4857-4872.

Back to Top of Page

Last edited on September 26, 2003

Contact: webmaster@consrv.ca.gov | Copyright © California Department of Conservation, 2003. All rights reserved.

The Department of Conservation makes no warranties as to the suitability of this product for any purpose.

© 2000 State of California. Gray Davis, Governor. Conditions of Use Privacy Policy