Some Characteristics of a Probabilistic Seismic Hazard Map for New Mexico

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Abstract

We have estimated probabilistic seismic hazards for New Mexico and bordering areas using instrumental data of duration magnitude 2.0 or greater for the time period 1962 through 1998. The probabilistic seismic hazard maps are presented in the format of peak horizontal ground accelerations at 10% and 2% probability of exceedance in a 50 year period. We defined two seismic source zones based on the distribution of seismicity for the purpose of hazard analysis, the Socorro Seismic Anomaly (SSA) and the rest of the state and bordering areas (RNM). As results, the seismic hazards for the region are moderate to low. The seismic hazard map for 10% probability of exceedance in a 50 year period shows that the area inside the SSA has the highest level of seismic hazard, 0.18g. Along the major population corridor of the state from Albuquerque to Santa Fe, the peak ground acceleration is ~0.08g.

We have examined the distributions of dominant earthquake magnitudes for selected sites with different hazard estimates and seismic trends. Analyses of magnitude-ground acceleration contribution plots for New Mexico and bordering areas indicated that at short return period of 500 years the dominant earthquake magnitudes are around or slightly less than 5.0. At longer return period of 2500 years the dominant earthquake magnitudes increase to the range between 5.5 and 6.5. The large discrepancies of the dominant earthquake magnitudes among selected sites reflect differences in the distributions of local seismicity. For areas with relatively high seismicity such as the Socorro area, the probabilistic seismic hazards are dominated by local seismicity. For areas with low seismicity such as Santa Fe, seismic hazards are mainly from stronger distant earthquakes and the existences of active faults become crucial to seismic hazard estimates.

Introduction

We have evaluated seismic hazards of New Mexico based on instrumental earthquake data from 1962 through 1998. The probabilistic seismic hazard maps are presented in the format of peak horizontal ground accelerations at 10% and 2% probability of exceedance in a 50-year period. While the 10% probability map is best suitable for general purposes, the 2% probability map is designed for critical installations such as hospitals and schools. During the probabilistic seismic hazard evaluation, assumptions were required in deriving parameters for hazard estimates. Parameters such as the low-end cut-off magnitude and the time-and-distance windows for removing dependent events affected the input earthquake data. Other selected parameters such as the choice of the maximum likelihood slope B and the maximum magnitude earthquake affected the outcome of hazard estimates. Sensitivity studies (Lin, 1999) for the probabilistic seismic hazard estimates indicate that these parameters were reasonably selected.

Two major concerns of the stability of the probabilistic hazard estimates for New Mexico using instrumental data are the use of a maximum magnitude earthquake of 6.5 and the exclusion of faults. In this paper we will demonstrate the contributions of high magnitude earthquakes to hazard analysis for New Mexico and the effects of faults on probabilistic seismic hazard estimates.

Probabilistic Seismic Hazard Maps

Figure 1 shows the probabilistic seismic hazard map in the format of peak horizontal ground accelerations at 10% probability of exceedance in a 50 year period. We define two seismic source zones for the purpose of hazard analysis, the Socorro Seismic Anomaly (SSA) (Sanford *et al*., 1995) and the rest of the state and bordering areas (RNM). Dependent events in the earthquake catalog were removed using a moving time and distance window of 7 days and 4 km for the SSA and 7 days and 25 km for the RNM.

We use a truncated exponential recurrence model for the probabilistic seismic hazard assessment for both the SSA and the RNM with a upper and a lower bound magnitudes of 6.5 and 2.0, respectively. The maximum likelihood slope B is derived using Bender's equation (Bender, 1983) and the selected B value of 0.76 for hazard analysis is the average of the SSA and the RNM. For computing probabilistic ground accelerations for the region, we divided the area into small blocks of 20 x 20 km^2 and evaluated seismic hazards on the basis of blocks. The size of blocks was selected to accommodate the uncertainty of earthquake epicenters. The number of earthquakes for each block is based on 75% of the seismicity within the block and 25% background seismicity. The use of background seismicity is to avoid a computational error when there is no seismicity within a block.

We select the center point of each block as the representative point for the block. The probabilistic seismic hazard for the block is the combination of a temporal probability of occurrence and a spatial probability of occurrence. The temporal probability of occurrence is based on the Poisson distribution and the spatial probability of occurrence the Joyner and Fumal (1985) equation that correlates magnitude, hypocentral distance, and peak horizontal ground acceleration. By combining these two probabilities, we evaluate peak ground accelerations using 10% and 2% probability of exceedance in a 50-year period.

In general, the seismic hazards for the region are moderate to low. The seismic hazard map for 10% probability of exceedance in a 50 year period shows that the area inside the SSA has the highest level of seismic hazard, 0.18g. Along the major population corridor of the state from Albuquerque to Santa Fe, the peak ground acceleration is ~0.08g, which generates Modified Mercalli Intensity (MMI) VI effects.

Deaggregation of the Seismic Hazard Estimates

We select four cities with various levels of seismic hazards for the deaggregation analysis: Socorro, Albuquerque, Santa Fe, and Los Alamos. Figure 2 shows the probability-ground acceleration relationships for the four selected cities. At 10% probability of exceedance, Socorro has the highest level of estimated seismic hazard of 0.12g among the selected cities, and Santa Fe has the lowest level of estimated seismic hazard of 0.03g.

Maximum Magnitude of 6.5

Figure 3 shows the magnitude contribution curves at 10% and 2% probability of exceedance in a 50-year period for the selected sites using a maximum magnitude earthquake of 6.5. At 10% probability of exceedance, seismic hazards are contributed mostly from moderate magnitude (~4.5-5.5) earthquakes for all study sites despite differences in the estimated seismic hazards. Contributions from high magnitude earthquakes to seismic hazards decrease as the earthquake magnitude increases.

At 2% probability of exceedance, the range of primary contributing earthquakes is not the same for the selected cities except that the magnitude range shifts to above magnitude 5.0. This is because that at long expected return interval of 2500 years, seismic hazard estimates are contributed mostly from high magnitude earthquakes. Therefore, the use of instrumental earthquake data alone with a maximum magnitude earthquake of 6.5 might not be appropriate at 2% probability of exceedance in 50 years.

Maximum Magnitude of 7.5

Figure 4 shows the magnitude contribution curves at 10% and 2% probability of exceedance in a 50-year period for the four selected sites using a maximum magnitude of 7.5. Although the maximum magnitude earthquake has been increased to 7.5, the range of primary contributing magnitudes remains at low magnitude range of less than 5.5 for the 10% probability of exceedance curves. At 2% probability of exceedance, the range of contributed magnitudes is ~5.0-7.0.

Effects of Active Faults on Probabilistic Seismic Hazard Estimates

We chose the SSA as the test area and assumed a uniform distribution of seismicity and a single source zone for deriving the background seismic hazard map. For modeling the recurrence relationship for the source zone, we used a truncated exponential recurrence model with a maximum likelihood slope B of 0.82 and a maximum magnitude earthquake of 6.5. Shown in Figure 5 is a seismic hazard map for the SSA in the format of peak horizontal ground accelerations at 10% probability of exceedance in a 50-year period. As shown in Figure 5, contours of horizontal ground acceleration parallel the outline of the SSA and are most closely spaced along the boundary. The area within the SSA has a maximum ground acceleration of ~0.18g.

Faults in the region with late Quaternary offsets were examined and three with the latest movements were selected: the La Jencia fault (LJF), the Socorro Canyon fault (SCF), and the Coyote Springs fault (CSF) (Machette *et al*., 1998). Among selected faults, the LJF has the most recent movements with 5 to 6 episodes between 3 ka and 33 ka. The expected return interval for the fault system is roughly 6,000 years. Figure 6 shows the locations of these three faults with respect to the location of the SSA. We assigned each fault with a characteristic earthquake of magnitude 7.0 and a specific return interval for assessing seismic hazards.

In the first test, we assigned return intervals of 5,000 years to the LJF and 10,000 years to the SCF and the CSF, respectively. The probabilistic seismic hazards based solely on these three faults were determined by following the same procedure as for instrumental earthquakes. Figure 7a and 7b show peak horizontal ground accelerations at 0.2% and 0.5% probabilities of exceedance in a 50-year period (expected return intervals of 25,000 and 10,000 years). Shown on the maps are contours of ground acceleration of 0.3g or lower. Within the 0.3g contour, accelerations are higher but were not calculated because of uncertainty involved in the focal depth of earthquakes. The maps illustrate that at very long return intervals, active faults can dominate estimates of seismic hazard in the vicinity of their traces.

Figure 7c shows the seismic hazard maps after overlaying seismic hazard estimates for the faults on the map based on instrumental data. At 10% probability of exceedance, the area with the highest level of seismic hazard falls within the SSA and between the LJF and the SCF. For hazard estimates with the short expected return interval of 500 years, the increase in seismic hazard in the region is minor, from 0.18g to 0.20g.

We reexamined the effects of these three faults after reducing the expected return intervals by one half, i.e., the expected return interval for the LJF became 2,500 years, and for the SCF and the CSF, they became 5,000 years. Figure 8a and 8b show the new probabilistic seismic hazard maps for peak ground accelerations at 0.2% and 0.5% probabilities of exceedance in a 50-year period. Both maps indicate that all three faults make significant contributions to estimated hazards at these large return intervals (25,000 and 10,000 years). On the other hand, combined hazard maps based on both instrumental earthquake data and active faults for a 50-year period and 10% probability of exceedance (500-year return interval) produce only a slightly higher level of hazard estimates (Figure 8c). The highest level of seismic hazard increases from 0.18g to 0.21g and is located between the LJF and the SCF. Even though the return intervals for all three faults were reduced by one half, effects of the active faults on estimates of probabilistic seismic hazard are small. This is not a surprising result because 1) the projected return interval for a magnitude 7.0 event is ~3300 years within the SSA based on instrumental data and 2) high magnitude earthquakes ($Md > 6$) have little effect on 50-year 10% probability of exceedance hazard estimates (see Figures 3 and 4).

Summary and Conclusions

We have evaluated probabilistic seismic hazards for New Mexico and bordering areas using instrumental data from 1962-1998. Deaggregation analyses for the estimated hazards suggest that moderate magnitude (< 5.75) earthquakes contribute the most to estimated seismic hazards for a short return interval of 500 years regardless of the selected maximum magnitude earthquake. At long return interval of 2500 years, high magnitude (> 5.5) earthquakes dominate the seismic hazard estimates.

We have demonstrated the effects of active faults on probabilistic seismic hazard estimates for the SSA. At very low probabilities of exceedance in 50 years (0.2% and 0.5%), the active faults are the dominant factor in hazard estimates but at shorter return periods, e.g. 500 years, in their immediate surroundings their effects are small.

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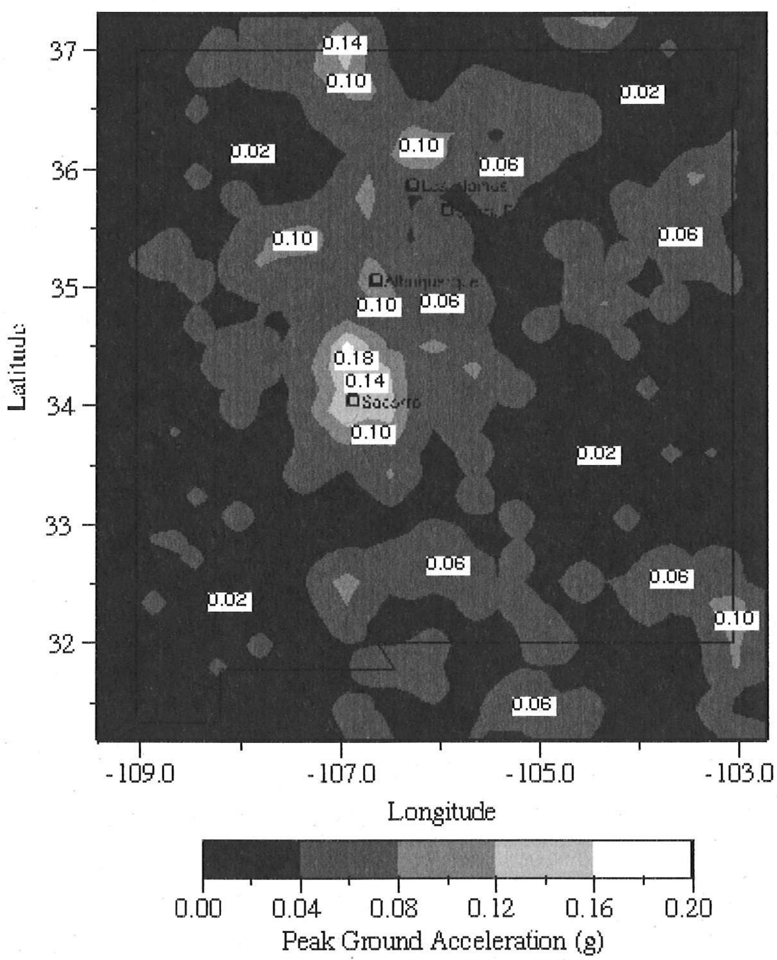

Figure 1. Peak horizontal ground accelerations for New Mexico and bordering areas at 10% probability of exceedance in a 50-year period.

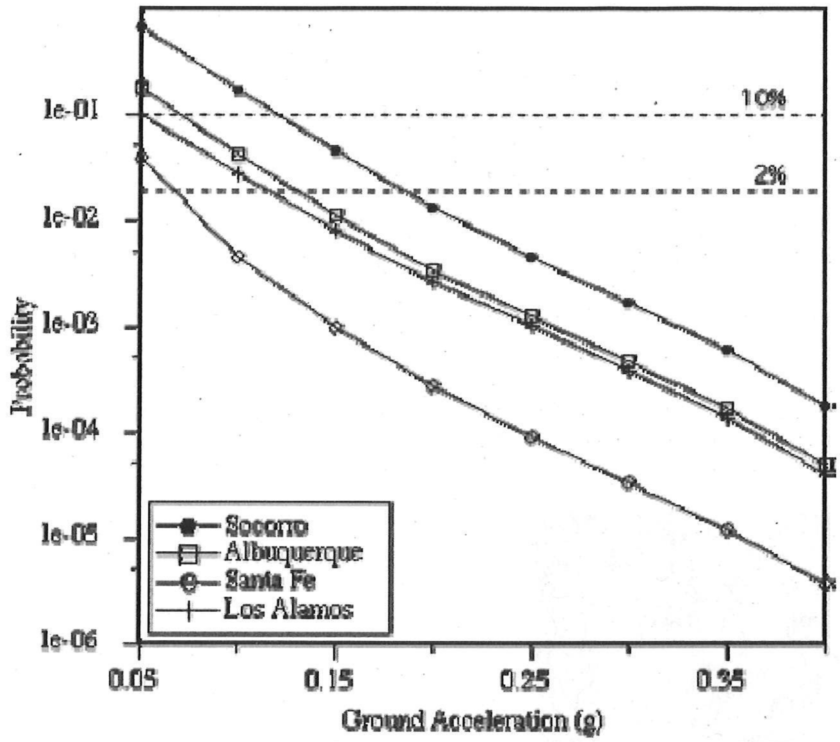

Figure 2. Probability-ground acceleration curves for four cities for a period of 50 years. Socorro has the highest level of seismic hazard of 0.12g at 10% probability of exceedance among selected cities. At the same probability, Santa Fe has the lowest level of seismic hazard of ~0.03g.

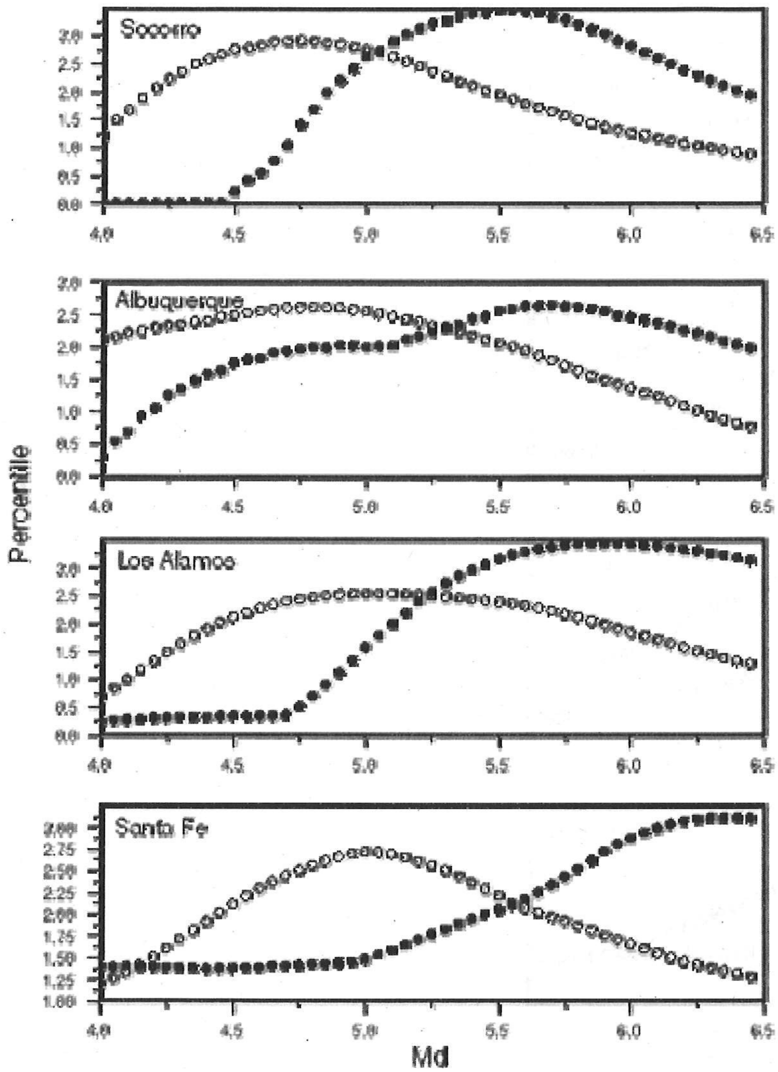

Figure 3. Magnitude contribution curves for 10% (open circle) and 2% (solid circle) probability of exceedance in a 50-year period for selected cities using a maximum magnitude earthquake of 6.5.

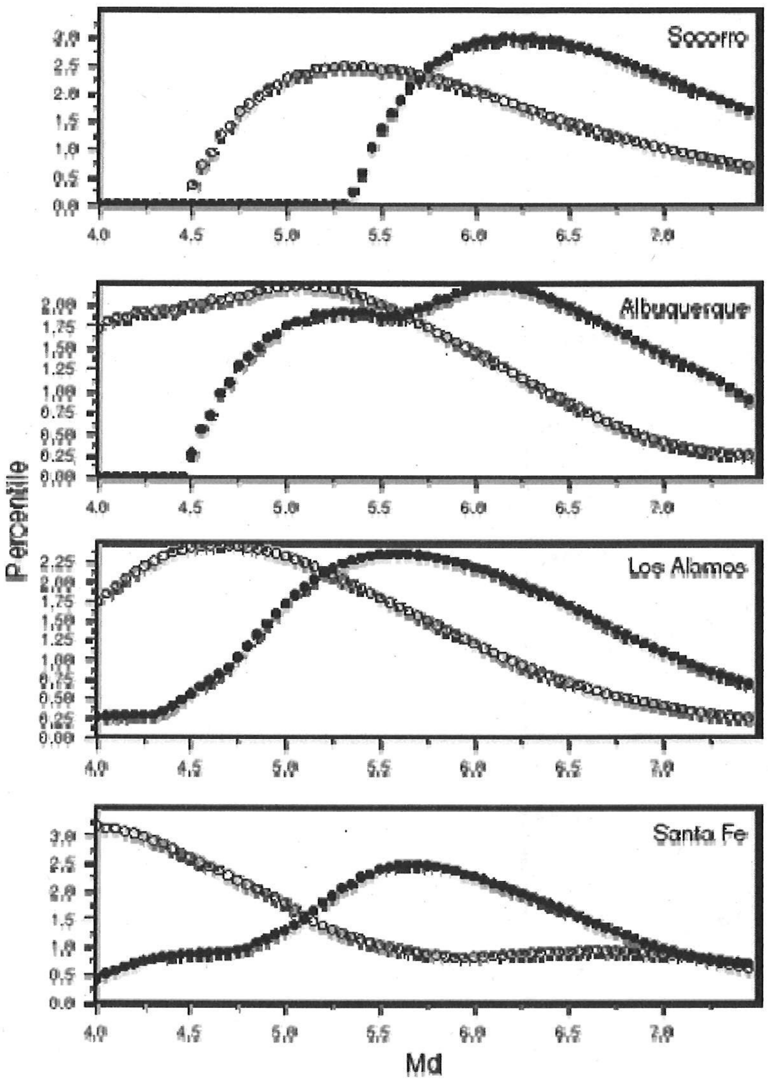

Figure 4. Magnitude contribution curves for 10% (open circle) and 2% (solid circle) probability of exceedance in a 50-year period for selected cities using a maximum magnitude earthquake of 7.5.

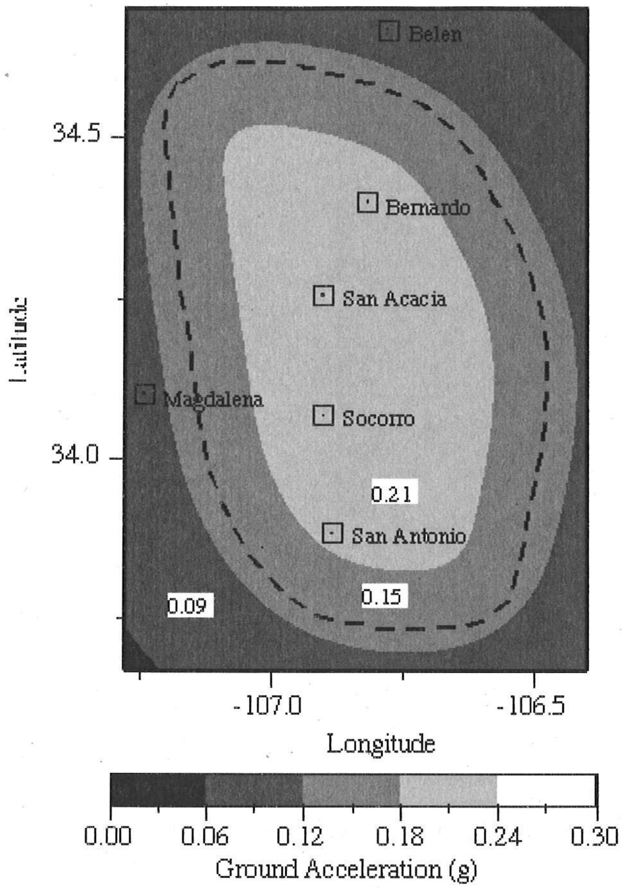

Figure 5. Peak horizontal ground accelerations for the SSA at 10% probability of exceedance in a 50-year period.

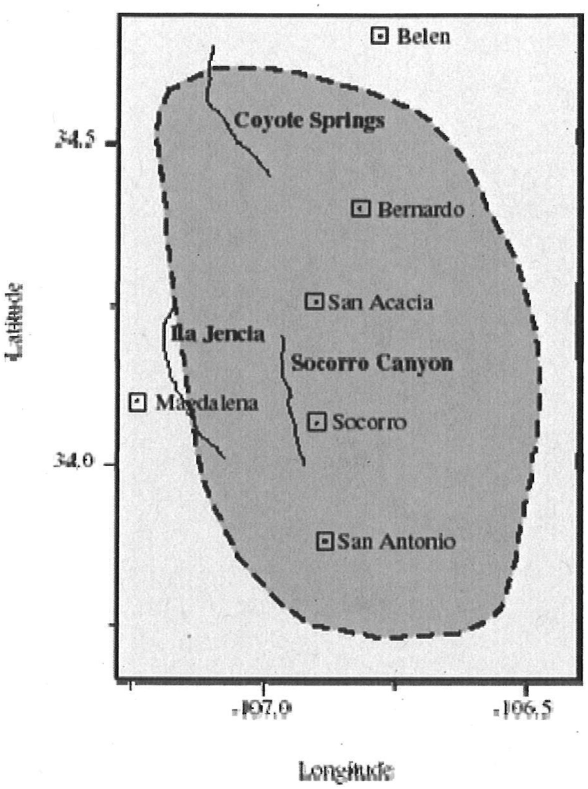

Figure 6. Geographical locations of the La jencia fault, the Socorro Canyon fault, and the Coyote Springs fault.

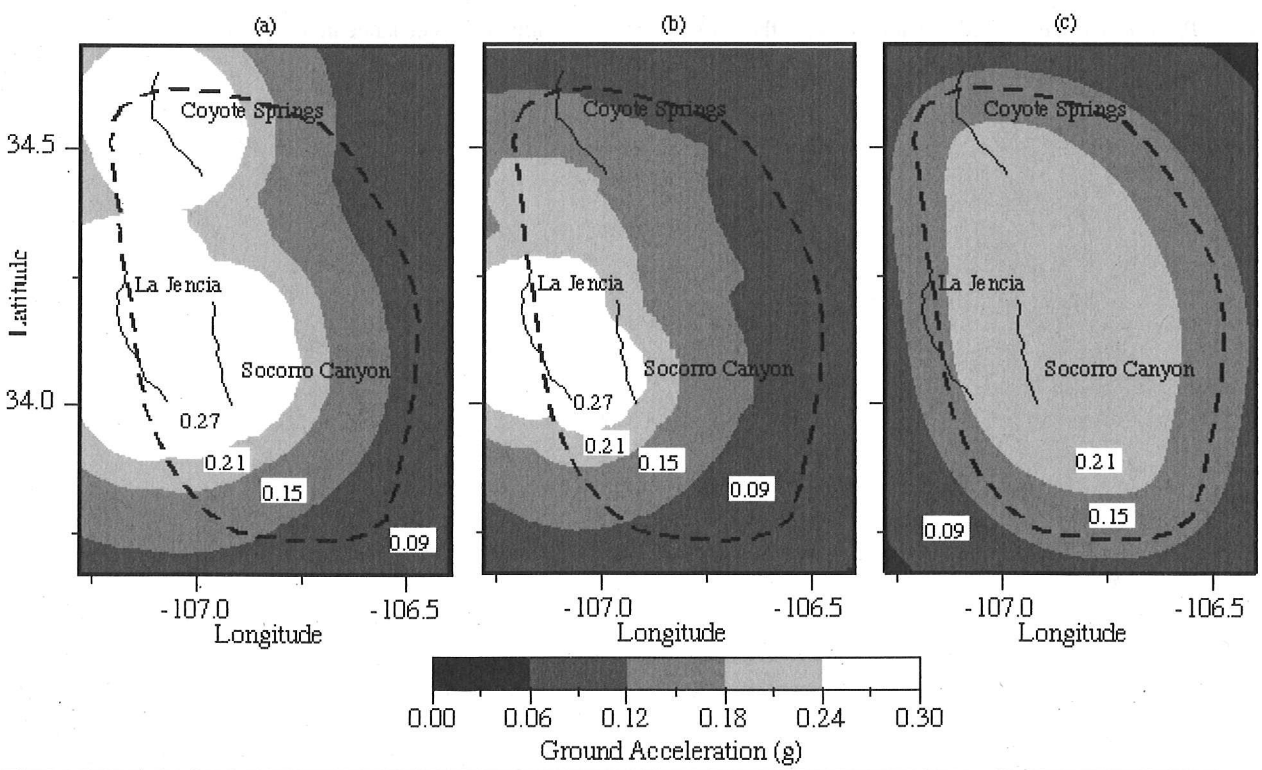

Figure 7. Peak horizontal ground accelerations at 0.2% probability of exceedance in a 50-year period based on the three

active faults: the La Jencia fault (LJF), the Socorro Canyon fault (SCF) and the Coyote Springs fault (CSF). All three faults were assigned characteristic earthquakes of magnitude 7.0, and with return intervals of 5,000 years for the LJF and 10,000 years for both the SCF and the CSF.

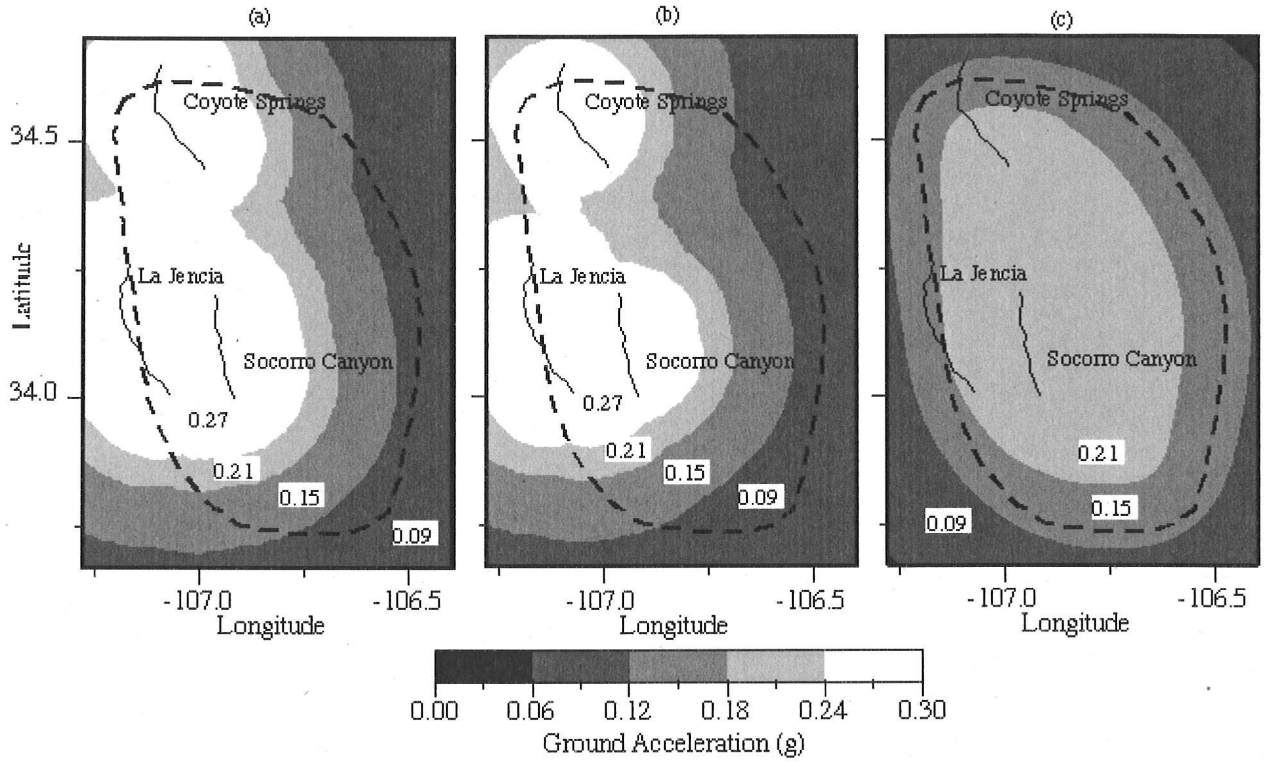

Figure 8. Peak horizontal ground accelerations at 0.2% probability of exceedance in a 50-year period based on the three active faults: the La Jencia fault (LJF), the Socorro Canyon fault (SCF) and the Coyote Springs fault (CSF). All three faults were assigned characteristic earthquakes of magnitude 7.0, and with return intervals of 2,500 years for the LJF and 5,000 years for both the SCF and the CSF.