

**U.S. DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY**

**INTENSITY DISTRIBUTION AND ISOSEISMAL
MAPS FOR THE NORTHRIDGE, CALIFORNIA,
EARTHQUAKE OF JANUARY 17, 1994**

by

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ABSTRACT

We present isoseismal maps, Modified Mercalli intensities, and community summaries of damage for the $M_W = 6.7$ Northridge, California, earthquake of January 17, 1994. First-person accounts of the effects of the earthquake on individual households are given for some communities. The highest intensity we assign is IX, which we assign to an area in Northridge and Granada Hills, to an area of Sherman Oaks, to an area along Interstate-5 in which freeway structures collapsed, and to two specific sites in western Los Angeles and Santa Monica. At the lowest intensities, the Northridge earthquake was felt over a land area of approximately 214,000 square km in southern California and adjacent Nevada and Arizona. The earthquake was also felt in Baja California, Mexico.

INTRODUCTION

On January 17, 1994, 04:31 A.M. Pacific Standard Time, southern California was shaken by a strong earthquake centered beneath the San Fernando Valley. The shock is referred to as the "Northridge" earthquake, after the community of that name, which is located near the shock's epicenter and which was a site of particularly intense damage. The Northridge earthquake directly caused 33 deaths; another 27 deaths are attributed to indirect effects of the earthquake, such as heart attacks triggered by the earthquake shaking (Hall, 1994). Hospitals treated approximately 7,000 earthquake related injuries during the first 10 days after the shock. Approximately 24,000 dwelling units were damaged to the extent that they were at least temporarily uninhabitable. 20,000 people, former residents of damaged dwellings and residents of undamaged dwellings who were afraid to be inside in the event of strong aftershocks, camped out in city parks and open spaces in the days following the earthquake (LA Times, 1/19/94)

The hypocenter and magnitudes of the Northridge earthquake are as follows (U.S. Geological Survey, 1994). Abbreviations are those used in the publication United States Earthquakes (e.g., Stover and Brewer, 1985).

| | |
|--------------|---|
| Origin time: | 12:30:55.3 UTC 04:30:55.3 PST |
| Epicenter: | 34.213°N., 118.537°W. |
| Depth: | 18 km |
| Magnitude: | 6.4 m_b (GS), 6.8 M_S (GS), 6.7 M_L (BK), 6.7 M_W (PS) |

The Northridge earthquake occurred as the result of predominantly reverse slip on a northwest-trending, south-

dipping, fault (Scientists, 1994). The primary fault rupture did not propagate to the surface of the ground. Ground cracks observed at several locations of the meizoseismal region represent, in some cases, superficial deformation. In other cases, the cracks may correspond to tectonic deformation that is secondary to the buried principal fault rupture (Scientists, 1994).

The purpose of this report is to describe the overall distribution of damage and felt effects in the earthquake. The spatial distribution of damage associated with the Northridge earthquake, as with most destructive earthquakes, was extremely complex. We represent the damage at several levels of generality. At the most general levels, we represent the severity of ground motion within communities or multi-block areas by means of Modified Mercalli intensities (table 1), and we use isoseismal contours to represent the distribution of average intensities (fig. 1-3). At a more specific level, in the section entitled "Description of Earthquake Effects," we summarize the damage or effects that we used to assign intensities to individual locations. Finally, at the most specific level, we report individual instances of damage and effects that, although not necessarily decisive in the assigning of intensities, are nevertheless illustrative of phenomena that were observed throughout the Los Angeles metropolitan area on the morning of January 17.

We have previously presented two preliminary versions of the isoseismal maps shown in figures 1, 2, and 3. The first version was presented on February 24, 1994, at a seminar of the Southern California Earthquake Center. The second version was presented at the Seismological Society Meeting at Pasadena, April 5 - 7, 1994 (Dewey and others, 1994). The isoseismals shown in figures 1, 2, and 3 differ from those of the second version principally for intensities V and VI. In the current maps, an intensity V isoseismal is drawn around communities near the Salton Sea (fig. 1). The intensity VI isoseismal (fig. 2) extends farther outward than previously. Isoseismals of intensities of VII and higher have been adjusted only slightly from those of Dewey and others (1994). The isoseismals of Dewey and others (1994) in turn differed from the first isoseismals presented on February 24, 1994 only by having within the VIII isoseismal a larger area of the San Gabriel Mountains to the northeast of San Fernando.

We gratefully acknowledge the contributions of the many residents of the earthquake region who answered our questionnaires or sent us first-person accounts of their experiences. We thank Arthur C. Tarr for his help in applying geographic information systems technology to important steps in the preparation of figures.

DATA SOURCES

As part of a routine intensity-monitoring procedure, the

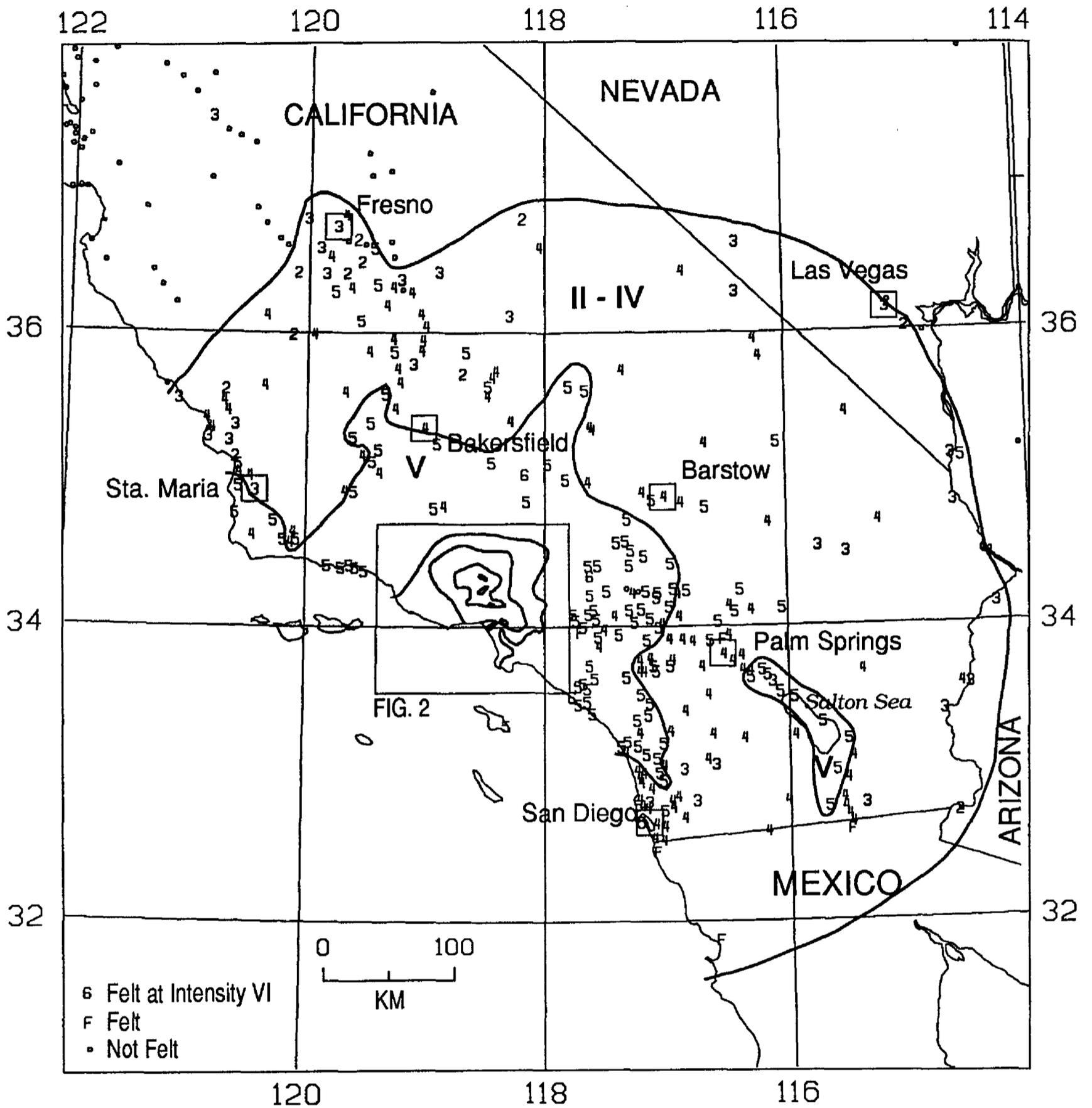


Figure 1. Isoseismal map for the Northridge earthquake. Roman numerals give average Modified Mercalli intensities for the regions between isoseismals; Arabic numerals represent intensities in individual communities. Squares denote towns labeled in the figure. Box labeled "FIG. 2" identifies boundaries of that figure.

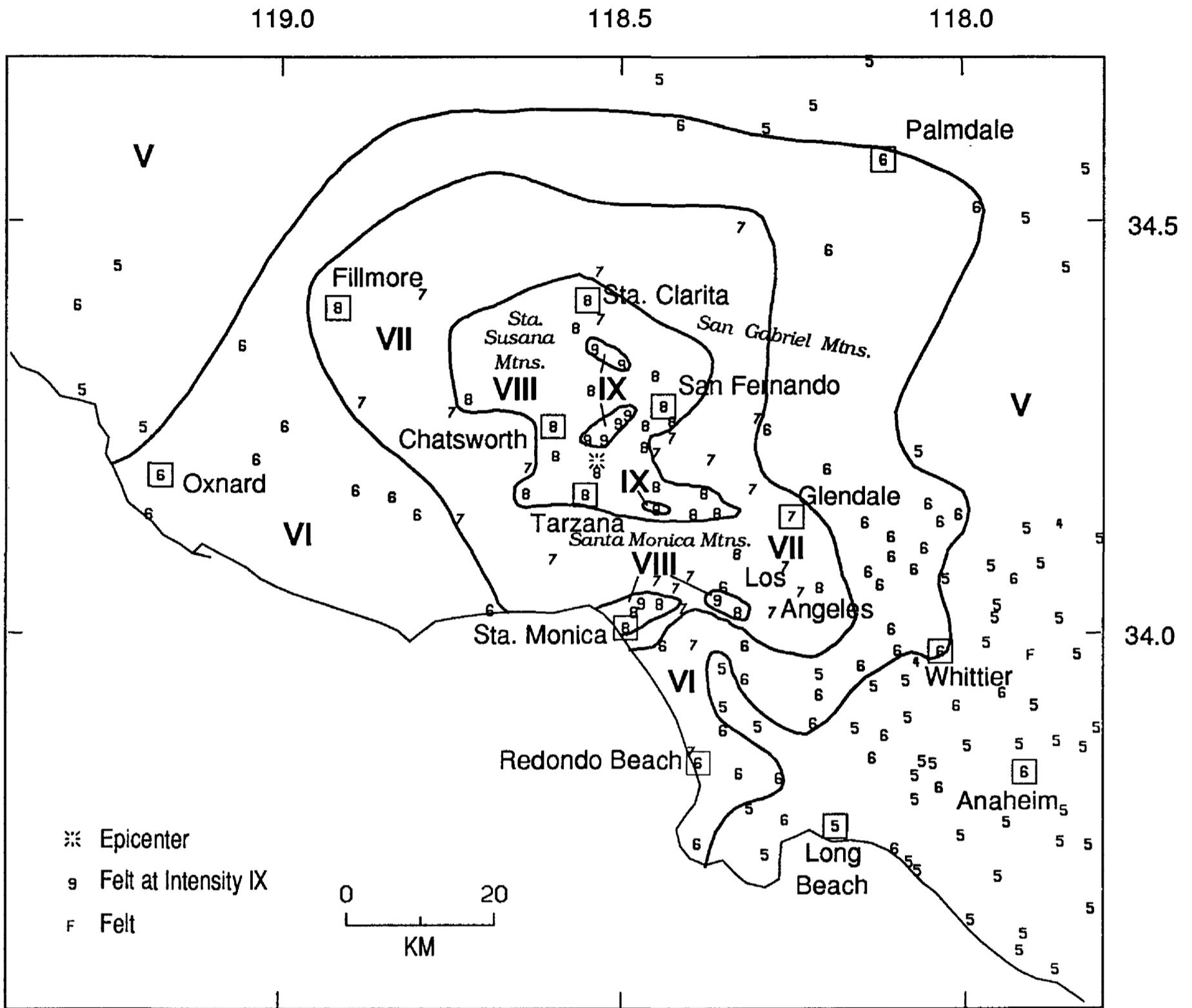


Figure 2. Distribution of Modified Mercalli intensities in the epicentral region. Roman numerals give average intensities within isoseismals. Arabic numerals represent intensities at specific locations. Squares denote towns labeled in the figure.

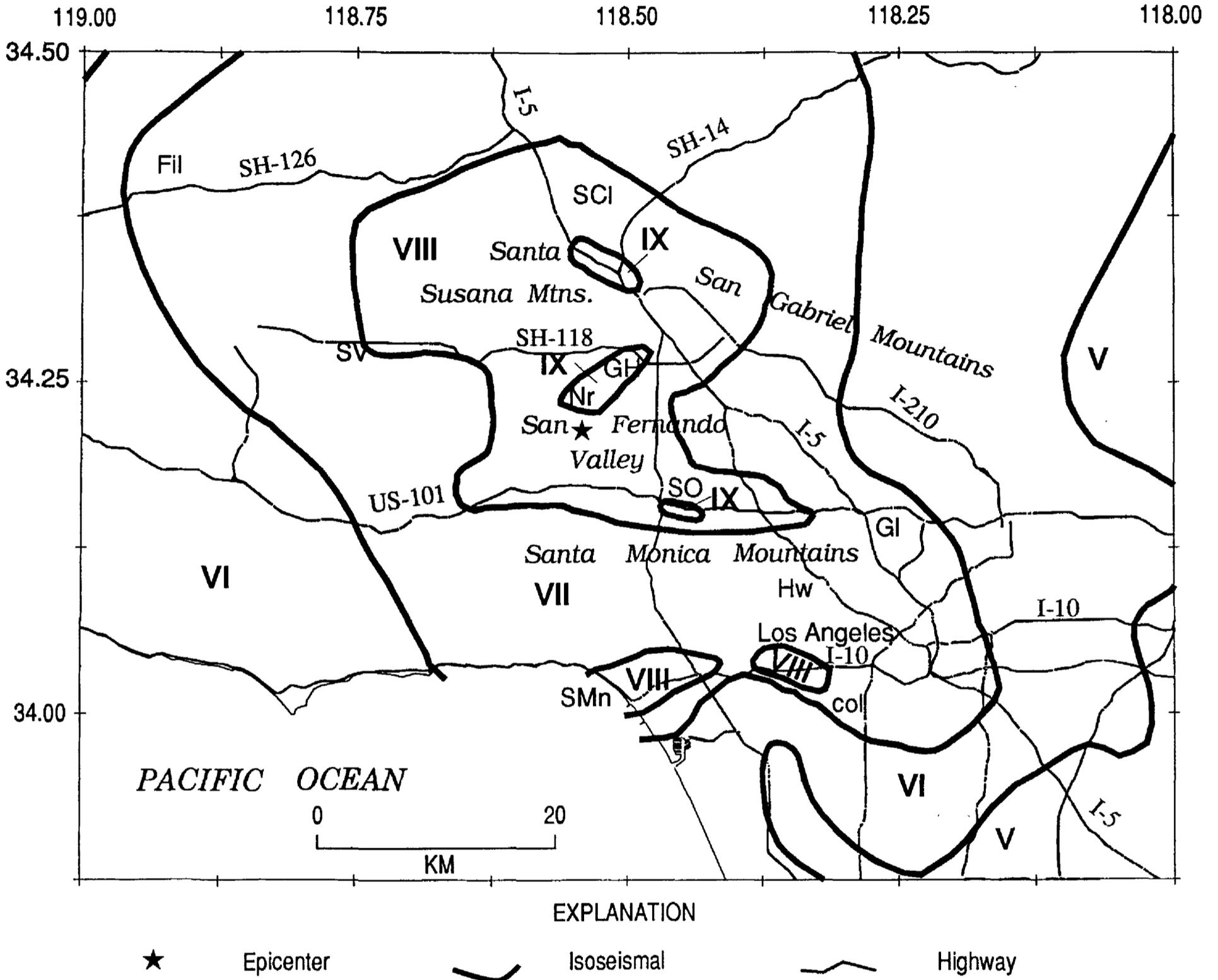


Figure 3. Location of higher isoseismals with respect to major roads. Abbreviations for towns and sites: "col" - Los Angeles Coliseum; "Fil" - Fillmore; "GH" - Granada Hills; "GI" - Glendale; "Hw" - Hollywood; "Nr" - Northridge; SCI - Santa Clarita; "SMn" - Santa Monica; "SO" - Sherman Oaks; "SV" - Simi Valley.

Branch of Earthquake and Geomagnetic Information, U. S. Geological Survey, sent out 610 mail questionnaires to post-offices situated within 600 km of the earthquake epicenter. An additional 54 questionnaires were sent to police- and fire-stations within 25 km of the epicenter. Approximately 75% of all questionnaires were returned. Those receiving the questionnaires were asked to describe damage and other earthquake effects that were characteristic of their entire communities or zip-code areas. Such postal questionnaires have, for decades, played a principal role in the assigning of intensities to U.S. earthquakes by the U.S.G.S. and, prior to 1973, by agencies of the U. S. Department of Commerce.

Two of the authors (J. W. Dewey and B. G. Reagor) conducted a reconnaissance field trip in the region of strongest shaking during Jan. 18 - Jan. 25. The area they visited is contained in a polygon bounded by Pasadena, Sylmar, Santa Clarita, Fillmore, Moorpark, Simi Valley, Chatsworth, Canoga Park, Santa Monica, the Crenshaw district of Los Angeles, and downtown Los Angeles. Within that area, they visited sites of significant damage that had been identified in the press and surveyed the general distribution of damage along major thoroughfares.

Two of the authors (L. Dengler and K. Moley) collected approximately 7500 responses to questionnaires on earthquake effects in individual households. 6000 of these responses were obtained through a randomized telephone survey; the remainder were obtained from requests for voluntary contributions of information (Dengler and Moley, 1995). The telephone survey asked a series of questions based on criteria of the Modified Mercalli scale (table 1). In the present study, these telephone survey data are used for communities outside of the area of strongest damage, and in most cases for communities for which we did not receive postal questionnaires. The telephone survey data for each community (there were commonly more than 10 data points per community) were treated as observations with which to assign a single Modified Mercalli intensity to the community. Twenty-eight percent of the observations plotted in figures 1 and 2 are derived from telephone survey data.

First-person accounts given in the following section were taken from e-mail responses to a request for information broadcast over INTERNET by the Humboldt Earthquake Education Center. The accounts are assembled from selected sentences and paragraphs, commonly non-contiguous in the original responses, that were originally written to answer specific questions in a questionnaire.

In some locations, the positions of isoseismals were determined from the distribution of red-tagged ("no occupancy") and yellow-tagged ("limited entry") buildings; these data were provided to us by the Joint California Office of Emergency Services (OES) - Federal Emergency Management Agency (FEMA) Disaster Field Office,

Pasadena. The OES-FEMA database lists only the geographic location of inspected buildings, whether the building is residential or commercial, and the tagged status [green (no restrictions on entry), yellow, or red]. The database does not indicate the inherent earthquake resistance of the building, the nature of damage, or whether damage is due to vibrations or to failure of the subsoil. We mostly used the OES-FEMA data to guide the drawing of isoseismals from areas for which we had direct damage observations to nearby areas for which we did not have direct damage observations. For two communities, Santa Paula and Los Angeles (South Central), the presence of a number of yellow-tagged buildings constituted our principal evidence for assigning intensities of VI.

We have made extensive use of press reports and preliminary reconnaissance reports published by the Earthquake Engineering Research Institute (Hall, 1994), the Earthquake Engineering Research Center (Moehle, 1994), and EQE International (1994). Detailed engineering reports of various aspects of the damage are beginning to appear at the time that this report is being written, but for the most part the results of these reports are not incorporated into the present report.

MODIFIED MERCALLI INTENSITY SCALE OF 1931 AND ITS APPLICATION TO DAMAGE FROM THE NORTHRIDGE EARTHQUAKE

The intensity of an earthquake at a location is a number that characterizes the severity of ground shaking at that location by considering the effects of the shaking on people, on manmade structures, and on the landscape.

Intensities assigned by the U. S. Geological Survey and (prior to 1973) by agencies in the U. S. Department of Commerce have for many decades been based on the Modified Mercalli Intensity Scale of 1931 (Wood and Neumann, 1931), which we usually refer to simply as the "Modified Mercalli" or "MM" scale. The scale lists criteria that permit the seismologist to represent the severity of ground shaking in a community or part of a community by a number. Experience with the MM scale in the decades since 1931 has shown that some criteria are more reliable than others as indicators of the level of ground shaking. Moreover, construction methods have changed appreciably since the scale was introduced. Assigning of MM intensity values therefore involves use of the original criteria of Wood and Neumann (1931) with amendments and modifications that have been developed in the decades since 1931. In assigning intensities to the Northridge earthquake, we follow amendments and modifications that are

summarized by Stover and Coffman (1993) and that have been used by the USGS to assign intensities in recent years. For post-1931 construction types, we follow precedent set in USGS intensity surveys of recent years.

The Modified Mercalli scale is given as originally abridged by Wood and Neumann (1931) in table 1; the unabridged scale is reproduced in Stover and Coffman (1993). Below we list the criteria, including criteria amended to or modified from the original scale, that were used most commonly in assigning intensities for the Northridge earthquake.

For intensity I, intensity II and intensity III, we used the original criteria of Wood and Neumann (1931, our table 1). We did not assign intensity I to any location for the Northridge earthquake.

Intensity IV was assigned on the basis of the following effects: felt by many to all; trees and bushes shaken slightly; buildings shaken moderately to strongly; walls creaked loudly; observer described the shaking as "strong" (Stover and Coffman, 1993).

Intensity V was assigned on the basis of the following effects: a few small objects overturned and fallen; a few items thrown from store shelves; hairline cracks in interior walls; a few windows cracked; hanging pictures tilted, out of place, or fallen; trees and bushes shaken moderately to strongly; observer reported difficulty standing or walking; felt moderately by people in moving vehicles. Most effects in the original scale that pertain to perceptions of the strength of the earthquake, or to the extent that people were frightened or awakened by the earthquake, were not used as criteria for this or higher intensities (Stover and Coffman, 1993).

Intensity VI was assigned on the basis of the following effects: some windows broken out; a few instances of fallen plaster or damaged unreinforced masonry (URM) chimneys; large cracks in interior walls; many small objects overturned and fallen; many items thrown from store shelves; many glassware items or dishes broken; light furniture overturned and moderately heavy furniture displaced. Effects on people were not used to assign intensities of VI or above (Stover and Coffman, 1993).

Intensity VII was assigned on the basis of the following effects: significant damage to unreinforced masonry (URM) buildings, including cracks in bearing walls and out-of-plane movement or fall of upper walls and parapets; many URM chimneys fallen or broken at the roofline; some masonry fences fallen or destroyed; heavy furniture overturned. Postal questionnaire reports of partial building collapse were considered evidence of intensity VII. In some areas, reports of landslide and rockfall activity (R. Jibson and E. Harp, personal communication) were used to interpolate the intensity VII isoseismal through mountainous regions that separate population centers;

otherwise effects known to be due to ground failure were not used for assigning intensity VII (Stover and Coffman, 1993).

Intensity VIII was assigned on the basis of the following effects: considerable damage to unreinforced masonry buildings, with partial collapse; old wood-frame houses shifted off foundations; damage to wood-frame apartment buildings having open first-stories, with some cases of apartments being destroyed; significant damage to reinforced, lined, masonry chimneys on single-family homes; structural damage to some reinforced-concrete buildings and parking structures that were built when a seismic code was in effect; very heavy furniture moved conspicuously or overturned. In some areas, reports of shattered earth and rockfall activity (R. Jibson and E. Harp, personal communication) were used to interpolate the intensity VIII isoseismal through mountainous regions that separate population centers. Otherwise, effects due to ground failure were not used for assigning intensity VIII (Stover and Coffman, 1993).

Intensity IX was assigned on the basis of the following effects: multiple cases of structural damage to reinforced-concrete buildings and parking structures that were built when a seismic code was in effect, with some cases of partial or complete collapse; widespread destruction of wood-frame apartment buildings having large open areas in their first stories; collapse of elevated freeway sections. Effects due to ground failure were not used for assigning intensity IX (Stover and Coffman, 1993).

The highest intensity we have assigned is IX. To assign an intensity higher than IX to a location, we would have required that the following be characteristic of that location: well-built wooden structures severely damaged, with some destroyed; most masonry and frame structures destroyed with foundations. Since 1931 it has become clear that many phenomena that Wood and Neumann (1931) originally used as criteria to define the highest Modified Mercalli intensities (X and above) are related less to the level of ground shaking than to the presence of ground conditions susceptible to spectacular failure or to the ease with which seismic faulting of different style and depth can propagate to the ground surface. Criteria based on such phenomena are downweighted now in assigning of USGS intensities (Stover and Coffman, 1993).

At some locations the earthquake was felt, but observations are insufficient to assign an intensity: the maps show an "F" at such locations.

DESCRIPTION OF EARTHQUAKE EFFECTS

The earthquake was felt over approximately 214,000 square kilometers (82,000 square miles) of the land area of

Table 1. Modified Mercalli Intensity Scale of 1931 (Abridged; Wood and Neumann, 1931, p. 282-283). As noted in the present text, some of the following criteria that describe human reactions or effects due to ground failure are no longer given significant influence in the assigning of intensity values.

-
- I. Not felt except by a very few under especially favorable circumstances.
 - II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
 - III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated.
 - IV. During the day felt indoors by many, outdoors by few. At night, some awakened. Dishes, windows, doors disturbed; walls made cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
 - V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles and other tall objects sometimes noticed. Pendulum clocks may stop.
 - VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
 - VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
 - VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars.
 - IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.
 - X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
 - XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
 - XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.
-

the United States. The earthquake was also reported felt in Ensenada, Mexicali, and Tijuana, Mexico. To the northwest, the earthquake was felt in Turlock in California's Central Valley. To the northeast, the earthquake was felt in Richfield, Utah (north and east of the area covered in figure 1) and Las Vegas, Nevada.

The effects of the earthquake varied significantly within individual areas between isoseismal contours. Some of this variation is revealed by the values of intensity assigned to individual communities between isoseismal contours (fig. 1 and 2), but within individual communities there were finer scale variations of earthquake effects that for the most part are not represented on the maps. Similar variations of effects have been noted in many previous studies of damaging earthquakes. Factors involved in variations of damage within a relatively small area include differences in the seismic resistance of human structures, differences in focussing of seismic energy by variations in the properties of the earth material through which the earthquake waves

travel, differences in focussing of seismic energy by the topography of the ground surface, and differences in the failure susceptibilities of the geologic formations beneath the human structures.

In the following we occasionally cite preliminary estimates of monetary losses associated with damage to particular facilities. We do this where we think that an order-of-magnitude estimate of monetary loss may provide insight into the extent of damage to the facility. Estimates of monetary loss are notoriously dependent on how the costs to repair or replace a facility are defined (Steinbrugge, 1982), and preliminary estimates would be subject to additional uncertainty resulting from limited knowledge of the precise nature of damage to the facility.

Intensity IX

The following effects were reported on most postal questionnaires received in the intensity IX zones, but we do not list them for each location: plaster walls and drywall

sustained large cracks; many small objects overturned and fell; many glassware items, dishes, and knickknacks were broken; heavy furniture and appliances were displaced or overturned; many items were shaken off store shelves; people had difficulty walking or standing; vibration was described as strong; felt by and awakened all; many people ran out of buildings; earth noise was described as loud.

We note below some communities in which there was widespread damage to wood-frame apartment buildings. Many of these buildings were poorly constructed to resist earthquake forces (Hall, 1994; Moehle, 1994). They commonly had carports in their lowest stories, with corresponding decrease in the wall area that would resist seismic motions. Where present, walls in many of the damaged buildings had depended on stucco or gypsum wallboard, instead of stronger plywood, to resist in-plane shear stresses. Destruction commonly involved collapse of the upper parts of buildings into the open areas of the underlying carports or lateral displacement of the upper parts of buildings with respect to the foundations.

Although we did not use damage to masonry garden fences as a criterion for assigning intensity IX to the locations cited below, we did use severity of destruction of these fences as a guide to extrapolating intensity IX isoseismals between sites at which other intensity IX criteria were met. The fences are typically built with little reinforcement and poor foundations (Hall, 1994). In some blocks within intensity IX areas, more than 50% of masonry fences were destroyed.

California--

Granada Hills- An east-west trending zone of cracks, with a length of 5 km (3 miles) and a width of several hundred meters developed north of the SH-118 freeway (Hall, 1994; Scientists, 1994). A 61-inch-diameter water line, a 22-inch gas line, and a 6 inch gas distribution line were broken where the cracks crossed Balboa Avenue (Hall, 1994). Escaped gas ignited and produced a spectacular fire that destroyed five homes. In addition to damaging lifelines and roads, the cracks extended through foundations and floor slabs of houses. The residential area along the zone of cracks experienced a relatively high number of damaged, reinforced chimneys and destroyed masonry fences, suggesting that the area experienced high levels of shaking in addition to ground cracking.

Externally visible damage to single-family homes elsewhere north of S.H. 118 was spatially highly variable, with several-block-long areas where severe damage to lined, reinforced chimneys was characteristic, separated by multi-block regions without such damage.

Columns failed in the Bull Creek Canyon channel bridge on the SR-118 freeway (Hall, 1994). At the Mission - Gothic undercrossing of SR-118, the structure carrying eastbound lanes collapsed and the structure carrying westbound lanes partially collapsed (Hall, 1994).

The second story of the Kaiser-Permanente office building, on Balboa near Devonshire, collapsed (fig. 4) and the end bays collapsed over the full height of the building (Hall, 1994). The building was a nonductile, reinforced concrete, frame structure.

Public schools in the Granada Hills area sustained non-structural damage and extensive damage to building contents. The three-story administration building at John F. Kennedy High School suffered structural damage and early thinking was that it would have to be rebuilt (LA Times, 2/1/94). Van Gogh Street Elementary School was damaged by ground cracks (Hall, 1994).

The Jensen Filtration Plant, a facility of the Metropolitan Water District that is situated just west of the I5/I210 junction, sustained ground cracking due to soil failure (Hall, 1994). The 85-inch-diameter inlet pipe was ruptured by a ground crack. The control building sustained moderate structural damage (EQE International, 1994). Similar, more severe, damage had occurred in the 1971 San Fernando earthquake.

There was liquefaction and ground failure at the Los Angeles Department of Water and Power's Van Norman complex (Hall, 1994). The filtration plant in the facility was put out of operation by damage to piping. The old Upper and Lower San Fernando Dams were damaged. These dams had been damaged in the 1971 earthquake and no longer contained water at the time of the 1994 earthquake.

Interstate 5 (Gavin Canyon)- Sections of the northbound bridge and the southbound bridge at the Gavin Canyon Undercrossing collapsed. The central span of each bridge remained standing, but the adjacent spans that were supported by the central spans came unseated and fell (Hall, 1994). Three vehicles in the southbound lane were stranded on the central span by the collapse of the spans on each side (LA Times, 1/20/94).

Interstate 5 (SR14 Interchange)- Spans in both the North Connector overcrossing (west SR14 to north I5) (fig. 5) and the South Connector overcrossing (west SR14 to south I5) collapsed. A Los Angeles Police Department officer died when his motorcycle plunged from a truncated overcrossing.

Spans collapsed in this interchange during the 1971 earthquake; the interchange was under construction at that time.

Los Angeles (Interstate-10 between Fairfax and La Cienega)- We assign intensity IX to this location because of three cases of collapse or partial collapse of engineered, reinforced concrete structures. The Fairfax-Washington undercrossing of I10 and the the La Cienega-Venice undercrossing of I10 collapsed. A multi-story parking structure at the Kaiser-Permanente Medical Center collapsed (LA Times, 1/18/94). Damage to other nearby buildings did not seem appreciably higher than in neighboring areas to which we assigned intensity VIII. We have not attempted to define the boundaries of the intensity IX region but rather consider the location to be an intensity IX site within a region generally characterized by intensity VIII.

Alexander Hamilton High School, situated 1.2 km (0.7 miles) west of the La Cienega underpass and within our intensity VII isoseismal, sustained structural damage to the lab building. The 3-story main building, built of brick in 1931, had suffered major damage in the 1971 San Fernando earthquake and had been retrofitted with steel structural members; the main building was not structurally damaged in the Northridge earthquake (LA Times, 1/23/94).

The following was sent several weeks after the earthquake by an observer in a single-story, single family, home just south of the I-10 freeway, about .7 km (.4 miles) west of the La Cienega underpass, near the boundary of our intensity VII and VIII isoseismals: *"We were awakened not only by the motion but by the noise — the walls were moving, furniture shifting on wood floors, books thrown from shelves, glass being thrown and breaking — it was an assault on all of the senses except visual, for it was still very dark and any remaining lights went out immediately. Objects on open shelves were thrown, kitchen cupboards and drawers opened and front half of upper cupboards dumped. Lamps were thrown and broke. One ceiling light (kitchen) was dislodged and thrown into dining room. Large wooden speakers in living room slammed into plaster and dented it, then returned to position. A couple of pictures fell off, many stayed put. We have many framed items on the walls."*

"We lost a lot of glasses, dishware, a couple of lamps, and a few sentimental items from our travels that were displayed on the fireplace mantel, but no injuries or structural damage. The kitchen

was a mess — most of the drawers and cupboards opened up, so the glasses from upper shelves broke into the drawers and lower shelves. A bottle of vanilla broke into a full drawer of kitchen gadgets, leaving a lovely aroma to the mess, and freezer contents and canned goods were strewn about. George first cleared a path to the stove with a broom, made us some instant coffee (we had gas but no electricity), and we sat down to peruse the damage before facing up to it. Chris' office, already rather untidy, was more so, with partial contents of the bookshelves strewn about. The damage was unpredictable, as it depended on the direction of the shock waves. Heavy items moved several inches — dressers, file cabinets, china cupboard, piano — yet very few pictures came off the walls, and most were still straight!"

"Unfortunately, many of the 300,000 vehicles a day that used the freeway (the busiest in the U.S.) are now zipping through the neighborhood trying to find the best way to get to downtown. Routine errands require advance planning and allowance for more time. Too many of the drivers are impatient, having forgotten one of the basic lessons of kindergarten, namely to take turns. We have a new morning coffee amusement watching the lost drivers whiz in and out of our cul-de-sac, having overlooked the 'not a through street' sign."

Northridge- Severe damage occurred to stores and parking structures of the Northridge Fashion Mall. Bullocks department store sustained failure at slab-to-column connections and collapsed (fig. 6) (Hall, 1994). Most of one parking structure collapsed, another had collapsed sections, and a third was severely damaged (Hall, 1994). Non-structural damage in stores of the mall was intense and would likely have caused casualties had the earthquake occurred during business hours (Hall, 1994). Satellite shopping areas near the Northridge Fashion Mall suffered extensive structural and non-structural damage, with some buildings experiencing partial collapse (fig. 7).

Many multi-unit wood-frame residences were destroyed. Sixteen people were killed in the partial collapse of buildings in the Northridge Meadows Apartment complex (fig. 8): the casualties occurred in apartment units that shared the first-stories with parking areas. This was the worst loss of life associated with failure of any single building complex in the earthquake.

The California State University at Northridge sustained losses estimated at \$ 350 million (Christian Science Monitor, 4/4/94). A recently built parking structure collapsed (fig. 9). The 4-

story steel-frame Oviatt Library sustained fractures of welds and base plates (Hall, 1994). Most other campus buildings did not suffer major structural damage, but many were unusable in the weeks following the earthquake due to non-structural damage and damage to contents (Christian Science Monitor, 4/4/94). A science building was damaged by fire and a hazardous materials spill (EQE International, 1994). Spring term on the campus, scheduled to begin January 31, was postponed for two weeks. The spring vacation was cancelled and the term was extended a week to make up for the delayed opening. When classes resumed, many were held in single-story temporary structures, of which the university rented 400. Students used library and computer facilities at other universities in Los Angeles.

Zones of damage due to ground deformation were mapped in Northridge, Winnetka, and Canoga Park, between Nordhoff Street and Sherman Way and between Desoto Avenue and Balboa Boulevard (Hall, 1994). Damage associated with the deformation included cracked sidewalks and roads and ruptured underground utility lines.

A Southern Pacific freight train hauling 64 cars, including 16 tank-cars containing sulphuric acid, derailed near Tampa Avenue just south of the Northridge Fashion Mall; 8000 gallons of sulfuric acid and 2000 gallons of diesel oil were spilled (Hall, 1994). The train was travelling west at 30 miles per hour at the time of the earthquake. The derailment produced no fatalities, and the spilled acid and oil were cleaned up without serious consequences.

In a preliminary report, engineers at EQE International (1994) estimated that 25 percent of concrete tilt-up structures within several kilometers of the earthquake epicenter suffered serious damage, including partial collapse. In the Northridge Middle School, light fixtures crashed to the floor, water and gas lines were damaged, and wooden arcades covering the sidewalks suffered extensive damage (LA Daily News, 1/25/94). Most windows were broken in a Vons supermarket near the intersection of Tampa and Roscoe. The suspended ceiling was bent, and ceiling tile fell. Fully stocked shelving fixtures reportedly shifted two feet. Shelves had to be emptied and fixtures set up anew.

As a result of damage in the neonatal intensive care unit at the Northridge Medical Center, 23 infants were evacuated to other facilities in the Los Angeles area. Working in near-dark, with only one

flashlight in the ward, nurses removed intravenous feeding tubes, wrapped the babies in blankets and carried them two at a time down the stairs from the fifth-floor unit to helicopters and ambulances outside (LA Times, 1/18/94; LA Daily News, 1/21/94).

An observer in a single-story, single-family home in east-central Northridge described the effects on her household. *"After getting my family to safety in front yard, checking on neighbors and triaging the house damage, I was in shock until next day; unable to keep food down, hot/cold flashes. Most furniture overturned, spilling out contents such as china and crystal. The kitchen was a big mess, with broken glass/food items all over the floor. Many pictures were fallen off; there was great deal of broken glass in carpets. Kitchen 'fridge moved across the floor, opened, spilling most contents; dishwasher likewise."*

"A large plate-glass window blew out; the chimney broke at roofline; there was chipped stucco at foundation line, but house structurally in good shape. Outside, three cinder-block property walls fell and a wooden patio covering was damaged. The water heater, housed in an exterior closet, broke loose from strapping, pulling water connections out of couplings. There was massive water loss - had to shut off house supply at street." Santa Monica (St. Johns Hospital and vicinity). We have assigned intensity IX to this location on the basis of damage to several reinforced concrete and reinforced masonry structures. We have not attempted to define the boundaries of the intensity IX region but rather consider this location to be an intensity IX site within a region generally characterized by intensity VIII. A wing of St. John's hospital, a seven-story, reinforced-concrete structure, sustained diagonal shear cracks in the second story piers and walls (fig. 10) and was closed after the earthquake. The hospital's parking structure was also damaged. The Berkeley East Convalescent Hospital, a five-story reinforced masonry building situated across a street from St. Johns hospital, had cracked piers (fig. 11) and spalled face shells at the ends of wing walls (Hall, 1994).

The following account came from an observer near St. Johns hospital: *"Very loud noise during the shaking from the floor boards and house moving and bricks falling from the chimney (narrowly missing my car) and contents of shelves, closets and cupboards coming down on floor. I felt endangered enough after about five seconds of*

shaking to dive (like I was diving into a pool) into a doorjamb for the duration of the quake. Large potted plants were knocked over inside and outside house. Stove, refrigerator, shelves moved one to two and a half feet from their original position. A four drawer file cabinet fell over. All fallen or moved items were displaced along a more or less East-West direction. Electricity, and phone immediately went off and stayed off for hours. A water pipe leading to our home sprang a leak and water spurted out all over our back area."

Sherman Oaks- The area along Ventura Boulevard in Sherman Oaks sustained costly damage. One hundred sixty-five buildings were damaged, of which 19 were judged unsafe for entry and another 30 were restricted to limited entry (LA Times, 2/19/94). Some reinforced concrete columns in the 13-story Radisson Hotel were badly cracked (fig. 12) and exterior wall panels were loosened; concrete was fractured in some columns of the hotel's parking structure, with vertical reinforcing steel-bars bowed outwards. Shear walls in a 13-story commercial building were cracked (Moehle, 1994). Losses on this section of Ventura Boulevard were estimated at \$27 million (LA Times, 2/10/94).

The Four Seasons building sustained punching shear failures at slab-to-column connections (Hall, 1994). Six reinforced concrete parking structures in or near the Sherman Oaks Fashion Square were heavily damaged, with some partial collapse (EQE International, 1994). The four-story Bullocks department store in the Fashion Square was declared unsafe after the roof collapsed into the top floor; 30 percent of the storefront windows in the mall were broken (LA Times, 2/20/94). The parking structure at the Sherman Oaks Galleria was damaged (LA Daily News, 1/25/94). The University of Judaism was extensively damaged (LA Daily News, 1/25/94).

There was extensive damage to wood-frame apartment buildings in an area north of Ventura Boulevard and south of US 101, between Kester Avenue and Woodman Ave (fig. 13 and 14). One person in this area was electrocuted by a fallen power line.

There was damage to single family dwellings at locations in the Santa Monica Mountains in Sherman Oaks and Studio City. Fourteen houses supported by stilts collapsed; four lives were lost in these collapses (EQE International, 1994). Damage was concentrated along ridge-crests, suggesting amplification of shaking by the local

topography. Among ridge-top locations, a strong correlation has been reported between high damage and weak underlying rock formations (Hall, 1994).

Ground cracking occurred near the intersection of Mulholland Drive and Beverly Glen Boulevard, at the crest of the Santa Monica Mountains (Hall, 1994).

Some soundwalls along the northern edges of US 101, just east of I405, were damaged, and one section collapsed (Hall, 1994).

Intensity VIII

The following effects were reported on most postal questionnaires received from the intensity VIII zones, but we do not list them for each location: plaster walls and drywall sustained large cracks; many small objects overturned and fell; many glassware items, dishes, and knickknacks were broken; heavy furniture and appliances were displaced or overturned; many items were shaken off store shelves; people had difficulty walking or standing; vibration was described as strong; felt by and awakened all; many people ran out of buildings; earth noise was described as loud.

As with intensity IX, we did not use destruction of masonry fences as a criterion for assigning intensity VIII to individual locations, but for some regions we did use the pervasiveness of such destruction to guide the drawing of isoseismals between locations in which criteria for intensity VIII were met.

Although we attempted to encompass within the IX isoseismals the regions of most widespread and severe damage to wood-frame apartments, wood-frame apartment buildings were also destroyed in some of the communities cited below. Many of these damaged buildings had the seismic-resistance deficiencies that were cited at the beginning of the discussion of intensity IX effects, and the modes of damage were similar.

California—

Canoga Park- Buildings in Topanga Plaza Mall sustained cracking in reinforced masonry shear walls and damage to the top 12 inches of concrete columns in infilled shear walls (Hall, 1994); a facade crumbled on the Robinsons-May store (LA Daily News, 1/25/94). A facility of Rockwell International Corporation sustained broken water pipes, shattered windows, and buckled floor tiles (LA Times, 1/18/94). The Canoga Park Elementary school sustained badly cracked walls and missing ceiling tiles; an outside pavilion under which students ate their meals was damaged beyond repair (LA Daily News, 1/25/94). In zones of concentrated ground breakage there were cracked sidewalks and roads, and ruptured underground utility lines (Hall, 1994). Some seriously damaged wood-frame apartment

buildings had to be vacated. Masonry fences were toppled; many chimneys were cracked, lost bricks, or were broken at the roof line.

Chatsworth- A person died from head injuries caused by falling objects in his house (Pasadena Star-News, 1/19/94). A beverage-can plant, one of the largest industrial facilities in the San Fernando Valley, sustained extensive damage to manufacturing equipment and had to cease operation for an estimated ten weeks while repairs were made (Hall, 1994). In a 160,000 square-foot industrial facility, older equipment suffered moderate damage, but newer equipment that was designed for seismic loads was not significantly damaged (Hall, 1994). Some tilt-up industrial buildings were badly damaged.

Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roadways sustained large cracks; many chimneys were broken at the roofline or fallen.

An observer in a single-family home in north Chatsworth sent the following observations several weeks after the earthquake: *"Everything that could fall either north or south did so, but not everything that could only fall east or west did so. All cabinets opened and dropped their contents, especially from shelves high off the ground. The refrigerator slid forward but did not topple. There are cracks in all interior walls; there are no broken windows; floor tiles (vinyl squares) came unglued; the stairway rail is loose; a few roofing tiles and facade bricks fell to the ground; the driveway and garage floor show definite cracking (large enough to stick a pencil down less than an inch); the pool shows about a 1/4 inch tilt over its 20 foot width; block walls crumbled away; the kitchen upper cabinets came loose from the ceiling; most door jambs show rips in the frame and surrounding plaster."*

"This is the single scariest time in my life. In under 30 seconds, my home turned from a show place into ...I'm not sure what... the damage has been estimated at \$150K. After the quake I ran to my children through broken glass barefoot. I'm not the only parent to do so. I haven't yet stopped shaking. Although the aftershocks have abated, I have yet to return surviving crystal to my breakfront or pictures to my walls. I need to find a rental house and move out during reconstruction. For me the earthquake is not over."

Fillmore- The picturesque old part of town along and near Central Avenue, which contained many unreinforced brick buildings from the early decades of the twentieth century, suffered

extensive damage. Upper walls and corners of many brick buildings collapsed, and some walls completely collapsed. Among heavily damaged buildings were the Fillmore Hotel, the Masonic Temple, and the original movie theatre (Hall, 1994). Some single-family wood-frame homes in the old part of town were shifted off their foundations (fig. 15).

Natural gas from a damaged pipeline on the east edge of town ignited; the fire spread to a nearby mobile home park, where one home was destroyed and two others damaged (LA Times, 1/19/94; O'Rourke and Palmer, 1994).

Hollywood- An area extending 3 km (2 miles) along, and several blocks north and south of, Hollywood Boulevard was characterized by major damage to unreinforced masonry buildings. Damage included large cracks in bearing walls, collapse of upper walls and parapets, and collapse of building corners (fig. 16). Historically or architecturally significant buildings that experienced costly damage include the Brown Derby Restaurant, the Egyptian Theater, the Hollywood-Western Building, and Frank Lloyd Wright's Hollyhock House (LA Times, 1/20/94). Some wood-frame apartments in this area shifted on their foundations. A water leak in the cinema buildings at Los Angeles City College damaged cameras and other equipment; damages at the college were estimated at \$285,000 (LA Times, 1/23/94).

Other community effects: a few tombstones were displaced; masonry fences and retaining walls were partially fallen; some roads were cracked; many chimneys were broken at the roof line, lost bricks, or fell; ceramic tiles fell from roofs.

Los Angeles (West Adams)- There was major damage to unreinforced masonry buildings, including large cracks in bearing walls, collapse of upper walls and parapets, and collapse of building corners (fig. 17). Some wood-frame, single-family homes and wood-frame apartments in this area shifted on their foundations. The Southern Missionary Baptist church, on Adams Boulevard, was severely damaged (fig. 18).

Los Angeles (USC/County Hospital complex) - Eight buildings, most of them at least thirty years old, sustained significant damage; most damaged were the pediatric and psychiatric hospitals (LA Times, 2/3/94). The new University of Southern California (USC) Healthcare Consultation Building suffered a small amount of non-structural damage (Hall, 1994). The seven-story USC Hospital, a base-isolated, steel-braced frame structure built in 1988, sustained no structural or non-structural

damage (Hall, 1994).

Mission Hills- The Holy Cross Medical Center was temporarily out of service due to damage to the heating-ventilation-air conditioning system; the center also experienced other non-structural damage, including water damage from broken pipes (Hall, 1994). A patient on life-support systems died when his ventilator failed in the earthquake-caused power outage (LA Times, 1/19/94). The Holy Cross Medical Center had been damaged in the 1971 San Fernando earthquake and subsequently repaired.

The Indian Hills Medical Center, which had also been damaged in 1971 and repaired, sustained cracked shear walls (Moehle, 1994); the center in addition suffered water damage and other non-structural damage (Hall, 1994). The Rinaldi substation of the electric power distribution network sustained significant damage (LA Times, 1/19/94). Nine of twelve buildings on the campus of Alemany High School were declared unsafe (LA Times, 1/22/94). The historic Andres Pico Adobe was badly damaged (LA Times, 2/6/94).

Masonry fences fell; underground pipes were broken; highways sustained large cracks; many chimneys were damaged.

North Hills- The Veterans Administration Medical Center sustained structural and non-structural damage. Ceilings fell in the auditorium and theater. Several buildings were temporarily evacuated (Hall, 1994).

Many ceiling tiles and some lighting fixtures fell in the gym at Monroe High School; 1,200 textbooks were destroyed when overhead pipes burst (LA Times, 2/7/94). Los Angeles Baptist High School sustained an estimated \$100,000 in damages, mainly in the gymnasium (LA Times, 1/22/94).

Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roads sustained large cracks or buckled; a few chimneys were cracked or broken at the roof line.

An observer who was in a townhouse in eastern North Hills reported: *"I would describe the ground shaking as violent, and I reacted with panic. It bolted me upright in bed and the noise was terrifying. It was difficult to stand or walk. Everything fell off shelves except on the south walls downstairs. Furniture tipped over but kitchen appliances did not slide. It was strange that this earthquake had enough force to knock over an entire entertainment center, face first, and all bookcases, lamps, and even knocked some videos out of their cardboard covers. But the aquarium*

on the south wall of the living room did not fall over. In the upstairs bathroom the lid on the toilet tank was broken in two pieces and on the floor."

North Hollywood- A several-block stretch of Lankershim Boulevard between Weddington and Cumpston was characterized by major damage to unreinforced masonry buildings, including some collapses. The El Portal Theatre, built as a vaudeville house in 1926, was severely damaged (LA Times, 2/6/94). A four-story steel frame building on Lankershim and Magnolia sustained buckling and fracture of some braces (Hall, 1994).

Masonry fences were destroyed; underground pipes were put out of service; sidewalks and streets sustained large displacements and were buckled; many chimneys were damaged or fallen.

Pacoima- Shear cracks developed in columns supporting a connector of the I5/SR118 interchange (Hall, 1994). The Valley Generating Station, an electric power plant located near Hansen Dam, sustained minor damage (Hall, 1994).

Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roads sustained large cracks, displacements, and buckling; exterior walls sustained partial collapse; many chimneys fell.

Reseda- Wood-frame apartment buildings were damaged; some collapsed into ground-floor carports (fig. 19). Brick cladding fell from one side of a five-story commercial building on Sherman Way near Lindley Avenue (fig. 20). Plaster fell from the ceiling of the auditorium at Reseda High School and lay "like a white blanket on top of the chairs" (LA Times, 1/19/94).

Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roads were cracked and buckled; many chimneys were damaged.

San Fernando- According to preliminary estimates 25 percent of concrete tilt-up buildings in the northern San Fernando valley had serious structural damage, including partial collapse (EQE International, 1994). A three-story, reinforced-masonry building under construction sustained significant damage (Hall, 1994). Minor ground cracking occurred at the San Fernando Valley Juvenile Hall; the site had sustained more severe liquefaction and lateral spreading in the 1971 earthquake (Hall, 1994).

An oil pipeline broke, and oil seeped into a street. The oil ignited, destroying 17 parked cars, damaging or destroying 4 homes, and burning a motorcyclist (LA Daily News, 1/21/94).

Masonry fences were partially fallen; underground pipes were cracked; sidewalks and roads sustained large cracks or were buckled; a few chimneys fell or had bricks fall from them.

San Gabriel Mountains north of San Fernando- The upper thrust block on the left abutment of Pacoima Dam separated from the dam and moved downstream, resulting in a 2-inch gap at the dam crest; a similar phenomenon, with less movement, occurred in the 1971 earthquake; rocks and boulders fell on the Pacoima Canyon road near the dam; the gunnite cover on the dam abutments was severely cracked (Hall, 1994). A boulder fell and demolished part of a house on Little Tujunga Canyon Road (LA Daily News, 1/22/94).

Santa Clarita - Severe damage was observed in some steel moment-frame buildings of medium height (Hall, 1994). Damage included fracture at welded beam-to-column connections and permanent distortion of frames. Many mobile homes were shaken off their foundations; 65 were damaged or destroyed by fires resulting from broken gas lines (LA Daily News, 1/20/94). Sand boils were observed in Portero Canyon and at locations in the Santa Clara River valley between Santa Clarita and Fillmore (Hall, 1994).

A crude oil pipeline developed leaks at several locations; approximately 150,000 gallons of oil were spilled into the Santa Clara River. Cleanup operations had recovered about half of the oil within several days of the earthquake (LA Daily News, 1/21/94). The same pipeline also developed a leak in San Fernando (see entry above) and near Pyramid Lake, along I5 approximately 30 km (18 miles) north of Santa Clarita (LA Times, 1/18/94).

Santa Clarita (Valencia)- The Santa Clarita City Hall suffered an estimated \$2 million in damages (LA Times, 1/24/94). The upper story of the two-story American Automobile Association building on Valencia Boulevard was permanently shifted by several inches with respect to its ground floor. The California Institute of the Arts sustained heavy damages, with losses preliminary estimated at \$50 million (LA Times, 1/24/94). Losses at College of the Canyons were estimated to be about \$1.5 million (LA Daily News, 1/22/94).

Several million dollars' damage occurred to a U. S. Postal Service postal processing plant that was under construction; opening of the facility was delayed indefinitely (LA Times, 2/24/94).

Equipment was damaged at a sewage treatment plant; effluent was treated with chlorine to reduce health hazard (LA Daily News, 1/21/94). The I5 bridge over the Santa Clara River sustained sheared anchor bolts and failed cable restrainers (Hall, 1994).

Some wood-frame houses and apartment buildings built on fill were badly damaged (EQE International, 1994). Masonry fences were destroyed; underground pipes were broken; sidewalks and roads sustained large cracks and displacements or were buckled; many chimneys were damaged.

Santa Monica- We have assigned intensity IX to the immediate vicinity of St. Johns Hospital. Elsewhere in the city there were some cases of major damage to engineered structures that had been built when a seismic code was in effect, there was widespread major damage to unreinforced masonry buildings (fig. 21), wood-frame apartments were damaged, and there were cases of old, single-family, wood-frame buildings being shifted off their foundations.

The Santa Monica Hospital Medical Center sustained serious damage (LA Times, 2/10/94); one tower was evacuated (LA Times, 1/19/94). The Champagne Tower, a 15-story, reinforced concrete, multi-unit residence, sustained cracked columns along the longitudinal direction of the building and cracked coupling beams in a coupled shear wall in the transverse direction (Moehle, 1994).

Santa Monica College lost 40 classrooms and laboratories and one parking structure; the 3-story science building was damaged; and an early assessment was that it would have to be replaced; preliminary damage assessment was \$26 million (LA Times, 2/7/94). An estimated seventy percent of the books fell to the floor of the college library (LA Times, 1/20/94).

The Sand and Sea Club and the Sea Castle apartments on Santa Monica beach were badly damaged (LA Times, 2/6/94). St. Monica Catholic Church was badly damaged; one steeple "tumbled onto the street" (LA Times, 1/19/94; 2/6/94). Landslides in the Pacific Palisades area closed lanes of the Pacific Coast Highway and damaged several houses (Hall, 1994). Sand boils occurred in a parking area on the beach north of the Santa Monica pier.

A third of the 100,000-bottle wine collection of the restaurant Valentino was destroyed (LA Times, 1/19/94). Some private art galleries sustained extensive damage to works being

Times, 1/19/94). Some private art galleries sustained extensive damage to works being exhibited (LA Times, 1/19/94). In the Santa Monica Public Library, 350,000 books fell to the floor (LA Times, 1/20/94).

Other community effects: masonry fences were destroyed; underground pipes were cracked; highways sustained large displacements; many chimneys had bricks fall from them.

The following account was sent within several weeks of the earthquake by the occupant of a two-story townhouse in western Santa Monica: *"All bookcases fell down. My heavy maple dresser was tossed onto the end of my bed (traveling about three feet through the air). The refrigerator and stove both moved about two feet. I have lived here 10.5 years and it is the worst one I have ever experienced. I am still feeling aftershocks when I am on the road (in Salt Lake City, Atlanta, Minneapolis—taking them with me)."*

Santa Monica (Ocean Park)- Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roads sustained large cracks or buckled; many chimneys had bricks fall from them or were broken at the roof line. Some buildings were severely damaged.

Santa Susana Mountains- There were widespread rockfalls; shattered earth was observed at the tops of some ridges; several tailings-pond dams were breached in an aggregate quarry on Tapo Canyon Road, resulting in sediment washing downstream of the dams (Hall, 1994). The Aliso Canyon Gas Storage Field sustained damage to pipes and storage tanks, and the gas supply from the field was interrupted for five days (Hall, 1994; O'Rourke and Palmer, 1994). Zones of ground deformation developed along the northern flank of the mountains (Scientists, 1994).

Simi Valley (Northeast)- In some residential areas, reinforced, lined, masonry chimneys were damaged and floor slabs were cracked; people were thrown from their beds; interiors and contents of buildings were severely damaged.

The Simi Valley City Hall and East Ventura County Courthouse sustained broken windows and suffered damage from broken water lines (LA Daily News, 1/19/94). The gymnasium at Simi Valley High School was damaged (LA Times, 2/1/94). Sand boils were observed near the Simi Valley County Mobile Home Park and lateral spreading and settlement were widespread (Hall, 1994). Only about 20 of the 275 homes at Simi Country Mobile Home Estates remained on their supports after the earthquake (LA Daily News,

1/22/94).

Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roads sustained large displacements or were buckled; exterior walls of concrete slab tilt-ups bulged outward.

Stevenson Ranch- Underground pipes were put out of service; streets buckled; a few reinforced masonry chimneys broke at the roofline or fell.

The columns supporting the canopy over gas pumps in a large service-station at the Magic Mountain interchange of I-5 were damaged, and the canopy shifted by several inches with respect to its base (fig. 22).

Studio City- Losses to businesses on Ventura Boulevard were estimated at \$7.1 million (LA Times, 2/10/94). On Buena Park Drive in the Santa Monica Mountains, three homes built on stilts collapsed (LA Daily News, 1/21/94). Harvard-Westlake School, Studio City campus, sustained damages estimated at \$250,000 (LA Times, 1/22/94). Some wood-frame apartments collapsed.

Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roads sustained large cracks or were buckled; chimneys were broken at the roof line or fell.

Sylmar- Some locations along the mountain front appear to have experienced effects characteristic of intensities higher than VIII. A well-designed and recently built wood apartment complex situated along the mountain front about a mile from the Olive View Medical Center was severely damaged (Hall, 1994).

The Olive View Medical Center, built on the site of the hospital of the same name that was destroyed in the 1971 earthquake, performed well structurally, but the building had to be evacuated due to damage to the sprinkler system and chilled water pipes (Hall, 1994).

The Sylmar substation, an important component in the electric power distribution system, sustained severe damage to equipment (Hall, 1994). Over one-hundred mobile homes were consumed by fire in three mobile home parks (LA Times, 1/18/94; Pasadena Star-News, 1/18/94).

The San Fernando Road undercrossing of I5 sustained abutment and wingwall damage and minor column spalling (Hall, 1994). In the southwest connector of the I5/I210 interchange, both abutments suffered damage, and several of the columns sustained spalling and cracking (Moehle, 1994). The complex interchange of I5, I210, and San Fernando Road had sustained many collapses and failures in the 1971 earthquake.

Los Angeles Mission College sustained minor damage. Water damaged offices and first-floor classrooms in the administration building. There was structural damage to the county-owned Veterans Park building, where some college courses are taught. Damages were preliminarily estimated at \$500,000 (LA Times, 1/23/94).

At the Vons supermarket on Foothill Boulevard near Hubbard Street, the floors were covered with merchandise immediately following the earthquake; store employees described the smell from spilled liquor and vinegar as "overpowering". The heavy gondolas in which fruit is displayed moved several inches.

Tarzana- Businesses along Ventura Boulevard sustained an estimated \$2.1 million in losses, due mostly to broken windows and damaged inventory (LA Times, 2/10/94). In the residential districts south of Ventura Boulevard, there were some areas of several blocks in which many chimneys were damaged or destroyed, separated by larger areas in which houses did not sustain damage that was visible from the outside. Some building interiors were severely damaged (Hall, 1994).

Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roads sustained large cracks or were buckled.

Universal City- The major film studios in and near Universal City — Universal Pictures, Warner Brothers, and Walt Disney Studios — sustained flooding damage, broken windows, and heavy damage to office interiors (LA Times, 1/19/94). Fractures at welded beam-to-column connections were observed in a steel-frame building under construction (Hall, 1994).

The Universal Studios theme park reopened the day following the earthquake. The "King Kong" attraction remained closed due to structural damage, and the park's "Earthquake" attraction temporarily remained closed out of respect for those who had suffered in the earthquake (LA Times, 1/19/94).

Van Nuys- Two people were crushed to death by the fall of items that they had collected and stacked in

their home (Pasadena Star-News, 1/19/94).

The Holiday Inn on Orion Avenue, a seven-story reinforced concrete building designed in 1965, suffered severe damage (Hall, 1994). Columns at the fourth-story level sustained large shear cracks. Approximately 60 guests were in the building at the time of the earthquake, but none were harmed. The building had been less severely damaged in the 1971 San Fernando earthquake.

At the Van Nuys airport, glass panels of the control tower broke, but the steel-frame hangars were not significantly damaged (EQE International, 1994). Los Angeles Valley College sustained damages preliminarily estimated at \$800,000 (Los Angeles Times, 1/23/94); the floor of the men's gym was damaged, library shelving was damaged, laboratory equipment was damaged.

Masonry fences were partially fallen; underground pipes were put out of service; sidewalks and roads sustained large cracks or were buckled; several chimneys were damaged or fell.

West Los Angeles - A seven-story, reinforced concrete, medical office building on the corner of Olympic Boulevard and Barrington Avenue sustained severe damage to columns (Hall, 1994). The building was demolished four days after the earthquake (LA Times, 1/25/94).

The I405/I10 interchange showed evidence of relative motion and pounding between sections. A girder seat was cracked and the roadway was offset at a hinge. The interchange had been retrofitted with steel jackets and hinge restrainers (Moehle, 1994).

Woodland Hills- Los Angeles Pierce College sustained structural damage to the men's and women's gyms (LA Times, 1/23/94); damages were preliminarily estimated at \$2.5 million. Seventy-five percent of storefronts were broken in The Promenade Mall, and floor tiles and walls were cracked (LA Times, 2/20/94): early estimates were that repairs would cost \$1.5 million to \$2 million (LA Daily News, 1/25/94). Offices of the Los Angeles Daily News sustained extensive non-structural damage and damage to contents; the News was given use of facilities by other newspapers and maintained publication (Pasadena Star-News, 1/19/94). The eleven-story headquarters building of 20th Century Insurance suffered many broken windows, and building contents were severely disturbed (LA Times, 1/18/94). Interior walls in the El Camino Real High School buckled and slipped out of place (Daily News, 1/25/94).

In the residential area south of Ventura Boulevard, between Serrania Avenue and Topanga Canyon Boulevard, there were several-block-long areas where many lined, reinforced chimneys were damaged.

Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roads sustained large displacements or were buckled.

Intensity VII

The following effects were reported on most postal questionnaires received from the intensity VII zones, but we do not list them for each location: many small objects overturned and fell; many items were shaken off store shelves; hanging objects or doors swung violently; people had difficulty walking or standing; vibration was described as strong; felt by and awakened all; many people ran out of buildings; earth noise was described as loud.

California—

Agoura Hills- Masonry fences were partially fallen; underground pipes were put out of service; interior walls sustained large cracks; exterior walls bulged outward or partially collapsed; a few chimneys were cracked or had bricks fall from them; many glassware items, dishes and knickknacks were broken; light furniture overturned; heavy furniture and appliances were displaced.

Agua Dulce- Masonry fences were destroyed; sidewalks and roads buckled or sustained large displacements; underground pipes were broken; a few chimneys were cracked or had bricks fall from them; several glassware items, dishes, and knickknacks were broken.

Arleta- Masonry fences were destroyed; underground pipes were broken; highways sustained large displacements; interior walls sustained a few large cracks; exterior stucco walls sustained large cracks; some windows were broken out; many glassware items, dishes and knickknacks were broken; light and heavy furniture and appliances were displaced and overturned.

Beverly Hills- In the Beverly Center shopping mall, windows in nine (out of 160) storefronts were broken; some stores had water damage, escalator tracks were bent; an exterior firewall was loosened (LA Times, 2/20/94). Some old buildings in the Ceders-Sinai Medical Center sustained damage (LA Times, 1/29/94), as did a parking structure (LA Times, 1/22/94). Many books fell from the shelves of the public library (LA Times, 1/20/94).

Interior and exterior walls sustained large cracks; many chimneys lost bricks, were broken at the roof line, or fell; some windows were broken out; glassware items, dishes and knickknacks were broken; light furniture and appliances were

overturned; heavy furniture and appliances were displaced.

Burbank- Police reported that the southwest section of town suffered the most damage. The Burbank/Glendale/Pasadena airport sustained cracks and fallen ceiling tiles; several flights were delayed or cancelled due to the earthquake (Pasadena Star-News, 1/18/94). The Burbank power plant sustained minor damage (Hall, 1994).

Masonry walls were destroyed; underground pipes were broken; sidewalks and roads sustained large cracks; interior and exterior walls sustained large cracks; many chimneys were damaged or fell; many windows were broken out; many glassware items, dishes and knickknacks were broken; light and heavy furniture overturned.

Century City- Windows in ten out of 140 storefronts were broken in the Century City Shopping Center and Marketplace, and a few wall tiles cracked (LA Times, 2/20/94).

Tombstones were cracked; masonry fences were partially fallen; many chimneys had bricks fall from them or were broken at the roof line; light and heavy furniture and appliances were displaced.

Culver City- West Los Angeles College sustained non-structural damages preliminarily estimated at \$105,000; a pedestrian bridge was damaged (LA Times, 1/23/94). Some walls of unreinforced masonry buildings partially collapsed (Moehle, 1994). Columns were cracked in the Jefferson Boulevard undercrossing of I405 at the SR90 interchange (Moehle, 1994).

Masonry fences were partially fallen; underground pipes were put out of service; some plaster walls sustained large cracks; many chimneys fell; many windows were broken out; several glassware items, dishes, and knickknacks were broken.

Glendale- In the Glendale Galeria shopping mall, storefront windows were broken, ceilings and walls sustained cracks, and shops sustained water damage (LA Times, 2/20/94). Plaster cracked and fell in the Alex Theatre, and the historic Casa Adobe de San Rafael was badly damaged (LA Times, 2/6/94). A 6-story unreinforced masonry building on Glendale Avenue near the city hall sustained cracks in bearing walls. The Glendale power plant sustained minor damage (Hall, 1994).

Parking structures at the Glendale Galeria, the Glendale Fashion Center, and City Hall were seriously damaged. A section of the third-level at the City Hall structure collapsed; the fall of this section took out the underlying section of the

second-level. Columns failed in the Fashion Center parking lot.

Questionnaire respondents reported that some windows were broken out; many glassware items or dishes broke; furniture and appliances displaced; strongly felt in moving vehicles; masonry fences and retaining walls were cracked.

Hermosa Beach- Masonry fences were partially fallen; exterior brick walls partly collapsed; several chimneys lost bricks or were broken at the roof line; several glassware items, dishes, and knickknacks were broken; light and heavy furniture and appliances were displaced.

The following account is from an observer who was in the top floor of a three-story townhouse in southern Hermosa Beach: *"I leapt from the bed to the doorway in one motion. I was in bed one second and in the doorway the next second calling if my roommate was okay because I was hearing so much noise (he couldn't get to the door because the dresser that toppled was between his bed and the door. There was a jar of pennies on top which made quite a racket when it fell). A bookcase on the middle floor lost all its shelves. A wicker cabinet tore the mounting brackets out of the wall but did not topple (the brackets weren't in studs). It was very dark and very noisy and it took forever to get light outside (we lost power until around noon)"*.

Los Angeles (Downtown)- The roof partially collapsed in the City Hall Parking Structure (Moehle, 1994). Water Lines broke in the City Hall and in the Parker Center.

Interior and exterior walls sustained large cracks; some windows were broken out; a few small objects overturned and fell.

Los Angeles (Echo Park)- Masonry fences or retaining walls were destroyed; sidewalks and roads buckled or sustained large displacements; interior walls sustained large cracks; exterior walls sustained partial collapse; many chimneys fell or had bricks fall from them; many windows were broken out; many glassware items, dishes or knickknacks were broken; light and heavy furniture and appliances were displaced.

Los Angeles (Exposition Park and Olympic Park)- Many unreinforced masonry chimneys were thrown down in some blocks, whereas other multi-block areas sustained little damage that was evident from the outside. A masonry mansion on the grounds of Mt. St. Marys College lost four chimneys, and a tower in the building was damaged.

At the Los Angeles Trade Technical College a pedestrian bridge between the culinary arts and business trade buildings was damaged. Damage at the college was preliminarily estimated at \$475,000. (LA Times, 1/23/94).

The Los Angeles Memorial Coliseum sustained major damage (Hall, 1994): a crack developed around the lower bowl; the concrete slab of the upper concourse around the stadium cracked and was displaced several inches; reinforced concrete beams and columns supporting the upper concourse were cracked; estimates for repair of the facility were preliminarily put at \$33 million (Boulder Daily Camera, 2/13/94). The swimming stadium adjacent to the Coliseum was damaged. The Sports Arena suffered non-structural damage.

Los Angeles (Palms)- Twenty-five percent of storefronts were broken in the Westside Pavilion shopping mall; there was water damage and a fallen neon sign at the movie theater (LA Times, 2/20/94).

Masonry fences or retaining walls were destroyed; underground pipes were cracked; highways sustained large displacements or buckled; many chimneys fell or had bricks fall from them; many windows were broken out; many glassware items, dishes, and knickknacks were broken; light and heavy furniture and appliances were displaced and overturned.

Moorpark- Thirty-five residences were damaged, and three mobile homes knocked off their supports (LA Daily News, 1/22/94). The library and gymnasium were damaged at Moorpark College (LA Times, 1/19/94). Part of the upper wall of a one-story unreinforced masonry building collapsed. A few masonry fences were knocked down.

Panorama City- Damage to the Kaiser-Permanente Hospital required that some patients be moved within the hospital (LA Times, 1/19/94). Masonry fences were partially fallen; stucco exterior walls sustained large cracks; several chimneys were damaged or had bricks fall from them; some windows were broken out; many glassware items, dishes, or knickknacks were broken; light and heavy furniture and appliances were displaced.

Piru- The historic Piru mansion was damaged. Chimneys fell, a porch pillar was jarred loose, and several Italian garden statues were broken. Damage at the mansion was similar to that experienced in the 1971 San Fernando earthquake (LA Times, 1/23/94).

Masonry fences were partially fallen; underground pipes were out of service; streets sustained large cracks; interior walls sustained a

few large cracks; exterior walls suffered partial collapse; some windows were broken out; many glassware items, dishes, or knickknacks were broken; light furniture and small appliances overturned; heavy furniture and appliances were displaced.

Although we have drawn the intensity VIII isoseismal line so that it passes south of Piru, we note that landslide and rockfall activity was at least as intense in hills around Piru, north of the Santa Clara River, as in the intensity VIII regions of Santa Susana Mountains to the south (R. Jibson and E. Harp, personal communication).

Santa Clarita (Newhall)- The gymnasiums at Hart High School sustained structural damage and the asbestos ceiling of the auditorium was damaged (LA Daily News, 1/22/94). The William S. Hart Union High School District had taken earthquake mitigation measures prior to the shock; these measures are credited with significantly reducing damage to content of the district's buildings (LA Times, 2/7/94).

Masonry fences were destroyed; underground pipes were put out of service; roads sustained large displacements; interior walls sustained large cracks; exterior stucco walls sustained large cracks; a few chimneys fell or had bricks fall from them; many windows were broken out; many glassware items, dishes, and knickknacks were broken; light and heavy furniture and appliances were overturned.

Santa Clarita (Saugus)- Three of ten schools in the Saugus Union School District sustained damage to asbestos ceilings (LA Times, 1/22/94).

Masonry fences were destroyed; sidewalks and roads sustained large cracks and displacements or were buckled; interior walls sustained large cracks; a few chimneys were cracked or broken at the roof line.

Simi Valley (southwest)- A homeowner reported cracks in walls, cracked windows, cabinet pulled away from walls, and chimney pulled slightly away from house. Many mobile homes in the Friendly Village Mobile Home Park were knocked from their supports.

Sunland- A few tombstones cracked; masonry fences partly fell; underground pipes broke; plaster walls sustained large cracks; many chimneys were cracked; many windows were broken out; many glassware items, dishes, and knickknacks were broken; light furniture and appliances were overturned; heavy furniture and appliances were displaced.

Sun Valley- Masonry fences were destroyed; underground pipes were put out of service; sidewalks and roads sustained large cracks or buckled; interior walls sustained large cracks; exterior brick and stucco walls sustained large cracks; a few chimneys were damaged or fell; some windows were broken out; many glassware items, dishes, and knickknacks were broken; light and heavy furniture and appliances were displaced.

Topanga- Masonry fences were destroyed; underground pipes were broken; sidewalks and roads sustained large cracks or buckled; some chimneys were damaged or fell; some windows were broken out; light furniture and appliances were overturned; heavy furniture and appliances were displaced.

West Hills- Windows in fifty percent of the storefronts in the Fallbrook Mall were broken, and shops in the mall suffered water damage (LA Times, 2/20/94).

Masonry fences were destroyed; underground pipes cracked; sidewalks and roads sustained large cracks; drywall sustained large cracks; many windows were broken out; many glassware items, dishes, and knickknacks were broken; light furniture and appliances were overturned; heavy furniture and appliances were displaced.

Westwood Village- On the UCLA campus, Royce Hall was closed because of damage to its two masonry towers. A 15 by 75 ft section of heavy ceiling fell in a campus auditorium, damaging the seats below. About one-third of the books in the University Research Library fell from shelves, piling in places to depths of three feet on the floor (LA Times, 1/20/94). Some unreinforced masonry infill walls of hollow tile were damaged (Hall, 1994).

Masonry fences and retaining walls were destroyed; underground pipes were out of service; plaster walls sustained large cracks; exterior walls were partially collapsed; some chimneys were damaged or fell.

Widely separated neighborhoods on the southern slope of the Santa Monica Mountains north of Westwood Village experienced damage characteristic of intensity VIII. Reinforced masonry chimneys were destroyed and some houses shifted from foundations (fig. 23). This damage may reflect topographic amplification of seismic waves or localized ground failure (Dames & Moore, 1994).

Intensity VI

The following effects were reported on most postal questionnaires received from the intensity VI zones, but we do not list them for each location: buildings shook strongly; hanging pictures swung out of place or hanging pictures fell; trees and bushes shook moderately; people had difficulty walking or standing; vibration was described as strong; felt by and awakened many or all. About a third of the respondents reported that earth noise was loud.

Los Angeles International Airport, within the intensity VI isoseismal, was closed for two hours due to power failure and as a precautionary measure (Pasadena Star News, 1/18/94).

California—

Acton- Many objects fell from shelves; many homes sustained minor damage; pictures fell; a few windows cracked; light furniture and small appliances were displaced.

Alhambra- A chimney collapsed onto a car. Windows were broken on Main Street (Pasadena Star-News, 1/19/94).

Anaheim- A scoreboard structure at Anaheim stadium collapsed, damaging over 1000 seats (Hall, 1994); plaster walls sustained large cracks; exterior walls sustained hairline cracks; a few windows cracked; a few small objects overturned and fell; a few people ran out of buildings; water splashed onto sides of swimming pools.

Arcadia- Interior and exterior walls sustained large cracks; a few chimneys were cracked; some windows were broken out; a few small objects overturned and fell; a few items were shaken off store shelves.

Bellflower- Plaster walls sustained a few large cracks; a few windows cracked; several small objects overturned and fell; knickknacks were broken; a few people ran out of buildings; trees and bushes shook strongly; standing and moving vehicles rocked strongly; underground pipes were put out of service.

Bell Gardens- Many small objects overturned and fell; many homes sustained minor damage.

Camarillo-Drywall sustained large cracks; exterior concrete block walls sustained hairline cracks; a few chimneys were cracked; a few windows cracked; several small objects overturned and fell; light furniture overturned; heavy furniture was displaced; hanging objects and doors swung violently; many items were thrown from store shelves; many people ran out of buildings; strongly felt in moving vehicles; water splashed onto sides of swimming pools; masonry fences or retaining walls were partially fallen; underground pipes were broken.

Carson- Many small objects overturned and fell; several homes sustained minor damage.

Compton- Plaster walls sustained hairline cracks and separated from ceiling or floor; concrete block exterior walls sustained hairline cracks; a few chimneys were cracked; a few windows cracked; several small objects overturned and fell; several items fell from store shelves; a few people ran out of buildings; water splashed onto sides of swimming pools.

Cypress- Many small objects overturned and fell; many homes sustained minor damage.

Green Vally- Many items fell from shelves; some homes sustained minor damage.

La Canada Flintridge- Plaster walls sustained a few large cracks and split at seams; exterior walls sustained hairline cracks; a few windows cracked; several small objects overturned and fell; a few knickknacks were broken; small appliances were displaced; several items were thrown from store shelves. A few chimneys collapsed (LA Times 2/6/94).

Laguna Beach- Many objects fell from shelves; several homes sustained minor damage.

La Habra- Interior walls sustained hairline cracks and separated from floors or ceilings; a few windows cracked; many small objects overturned and fell; several glassware items, dishes, or knickknacks were broken; a few items were shaken off store shelves; a few people ran out of buildings; trees and bushes were shaken strongly; water splashed onto sides of swimming pools.

Lakewood- Plaster walls sustained hairline cracks; some windows were broken out; many small objects overturned and fell; several glassware items, dishes, or knickknacks were broken; furniture and appliances were displaced; several items were thrown from store shelves; a few people ran out of buildings; masonry fences or retaining walls were cracked; underground pipes broke.

La Mirada- Interior walls sustained large cracks; a few small objects overturned and fell; many items were shaken off store shelves; masonry fences and retaining walls were destroyed.

Lawndale- Interior walls sustained large cracks; exterior brick and stucco walls sustained hairline cracks; a few windows cracked; several small objects overturned and fell; several glassware items, dishes, or knickknacks were broken; furniture and small appliances were displaced; several items were thrown from store shelves; a few people ran out of buildings; moving vehicles rocked moderately; masonry fences or retaining walls were cracked.

Littlerock- Many items fell from shelves; many homes sustained minor damage.

Los Angeles (Hancock Park) - Four pieces fell and were seriously damaged at the Los Angeles County Museum of Art; numerous ceiling fixtures fell from tracks in the museum (Hall, 1994).

The Los Angeles Community College Administration Building sustained water damage from broken pipes. Damages were estimated at \$55,000 (LA Times, 1/23/94). The Los Angeles Center for Enriched Studies lost most of its science materials (LA Times, 2/7/94).

Los Angeles (South Central)- A number of buildings in south central Los Angeles were damaged to the extent that they were yellow-tagged (limited access) by authorities.

A few windows cracked; several small objects overturned and fell; a few glassware items, dishes, or knickknacks broke; a few items were thrown from store shelves.

Los Angeles (West Central)- At the Baldwin Hills - Crenshaw Plaza Mall, thirty-five percent of the storefronts were broken. An anchor store was temporarily closed. Some stores had water damage. Floor and ceiling tiles were loosened (LA Times, 2/20/94).

The Audubon Middle school lost books and computer equipment when two water lines burst (LA Times, 2/7/94). Plaster walls sustained large cracks; a few small objects overturned and fell.

Lynwood- Masonry fences and retaining walls were partially fallen; plaster walls sustained hairline cracks; some windows were broken out; several small objects overturned and fell; a few glassware items, dishes, and knickknacks were broken; a few items were shaken off store shelves; a few people ran out of buildings; standing vehicles rocked moderately; moving vehicles rocked moderately; water splashed onto sides of swimming pools.

Malibu- Sand boils were observed at Malibu Beach (Hall, 1994). At the J. Paul Getty Museum, display mounts and storage facilities designed to prevent earthquake damage to art worked effectively (Hall, 1994); several artifacts in transit from storage to display were reportedly damaged.

Masonry fences and retaining walls were cracked; interior and exterior walls sustained hairline cracks; a few chimneys were cracked; a few windows cracked; a few small objects overturned and fell; a few glassware items or dishes broke; a few items were shaken off store shelves.

Mar Vista- Interior walls sustained a few large cracks; many small objects overturned and fell; many glassware items, dishes, and knickknacks were broken; light furniture was overturned; heavy appliances were displaced; many items were shaken off store shelves; many people ran out of buildings.

Mojave- Masonry fences were cracked; underground pipes were cracked; highways sustained large cracks; drywall sustained large cracks; exterior brick walls bulged outward; several chimneys were broken at the roofline; some windows were broken out; several small objects overturned and fell; a few dishes were broken; light furniture was displaced; a few items were shaken off store shelves.

Monrovia- Several chimneys were cracked or twisted; plaster walls sustained hairline cracks; masonry fences and retaining walls were cracked; a few windows cracked; several small objects overturned and fell; a few knickknacks were broken; a few items were shaken off store shelves; standing vehicles rocked moderately; moving vehicles rocked moderately; water splashed onto sides of swimming pools.

Montebello- Interior walls sustained a few large cracks; concrete block exterior walls sustained hairline cracks; some windows were broken out; several small objects overturned and fell; a few knickknacks were broken; light furniture overturned; several items were thrown from store shelves; water splashed onto sides of swimming pools.

Monterey Park- East Los Angeles College incurred damages preliminarily estimated at \$110,000 (LA Times, 1/23/94).

Masonry fences or retaining walls were cracked; interior walls sustained a few large cracks; brick and concrete-block exterior walls sustained hairline cracks; a few small objects overturned and fell; a few windows cracked; a few dishes were broken; small appliances were displaced; a few items were shaken off store shelves; standing vehicles rocked moderately; moving vehicles rocked slightly.

Newbury Park- Many items fell from shelves; several homes sustained minor damage.

Oak View- Masonry fences and retaining walls were cracked; plaster walls sustained hairline cracks; many small objects overturned and fell; several knickknacks were broken; several items were thrown from store shelves; a few people ran out of buildings; standing vehicles rocked moderately; moving vehicles rocked moderately.

Oxnard- Interior walls sustained a few large cracks; a few chimneys were cracked; a few windows cracked; several small objects overturned and fell; several knickknacks were broken; light and heavy furniture and appliances were displaced; several items were thrown from store shelves; a few people ran out of buildings; standing vehicles rocked strongly; moving vehicles rocked moderately; water splashed onto sides of swimming pools.

Palmdale- Masonry fences were cracked; sidewalks and streets sustained large cracks; drywall sustained hairline cracks; stucco walls sustained hairline cracks; a few chimneys were cracked; a few windows cracked; a few small objects overturned and fell; a few knickknacks broke; light furniture and small appliances were displaced; a few items were shaken off store shelves; a few people ran out of buildings; water splashed onto sides of swimming pools. The Vincent electric power substation south of Palmdale was significantly damaged (Hall, 1994).

Pasadena- City inspectors identified over one hundred damaged buildings, most of which had cracks or fallen bricks (Pasadena Star-News, 1/21/94). Walls buckled and bricks fell in an apartment complex, and approximately one-hundred residents were evacuated. Bricks and part of a fire-escape fell from a building in Old Pasadena (Pasadena Star-News, 1/19/94). Card-operated electronic doorlocks in a hotel were damaged and had to be replaced. In grocery stores, many items fell off shelves and some ceiling panels fell.

Pico Rivera- Many objects fell from shelves; many homes sustained minor damage.

Port Hueneme- Interior walls sustained hairline cracks, split at seams, and separated from ceilings or floors; a few windows cracked; many small objects overturned and fell; many glassware items, dishes, and knickknacks were broken; furniture was displaced; hanging objects or doors swung violently; many items were shaken off store shelves; many people ran out of buildings; trees and bushes shook strongly; standing vehicles rocked strongly; moving vehicles rocked moderately; masonry fences or retaining walls were cracked; underground pipes were put out of service.

Rancho Palos Verdes- Many objects fell from shelves; several homes sustained minor damage.

Redondo Beach- The Kings Harbor Marina sustained damage due to spreading and subsidence of fill (Hall, 1994). Subsidence of two- to three- feet

occurred in an area about 300 feet long. Spreading caused a lateral bulge of twenty feet in an 400- to 500-foot section of retaining wall.

Plaster walls sustained hairline cracks; a few small objects overturned and fell; heavy appliances overturned; water splashed onto sides of swimming pools.

Rosemead- A few tombstones fell; several small objects overturned and fell.

San Gabriel- Three downtown store windows were broken; The bell tower and museum at San Gabriel mission were cracked; City Hall and Civic Auditorium sustained damages estimated at \$50,000 (Pasadena Star-News, 1/20/94).

Plaster walls sustained hairline cracks; some windows were broken out; many small objects overturned and fell; light furniture was displaced; a few items were shaken off store shelves; trees and bushes shook strongly; standing vehicles rocked moderately; moving vehicles rocked slightly.

San Marino- Plate glass windows broke in two businesses; about 1,000 books fell in the Huntington Library Art Collection and Botanical Gardens (Pasadena Star-News, 1/19/94).

Masonry fences and retaining walls were cracked; a few knickknacks were broken; a few items fell from store shelves.

Santa Paula- Thirteen commercial buildings were damaged to the extent that they were yellow-tagged (limited access).

Seal Beach- Interior walls sustained a few large cracks and separated from ceilings or floors; several small objects overturned and fell; a few glassware items, dishes, and knickknacks fell; light furniture and small appliances were displaced; several items fell from store shelves; a few people ran out of buildings; standing vehicles rocked moderately; moving vehicles rocked slightly

Sierra Madre- Sidewalks and streets sustained large cracks; plaster walls sustained hairline cracks; some windows were broken out; several small objects overturned and fell; several glassware items, dishes and knickknacks were broken; light furniture and small appliances were displaced; several items were thrown from store shelves; a few people ran out of buildings; standing vehicles rocked moderately; water splashed onto sides of swimming pools.

An observer in a single-family home in Sierra Madre reported: *"We were all (2 sons, wife, and I) in our beds and were all awakened by the Northridge quake. My reaction was "oh oh!" wondering (a) if it was going to get stronger, and*

(b) when it was going to stop. The jolting was fairly harsh. Not too many sounds. I could see some flashes as though transformers somewhere in the area were arcing. We did not lose power at all, not even to VCR clocks. The most frightening aspect was when I turned on radio almost immediately and could not pick up any local stations. Stations (in Hollywood) came back in a few minutes. After we grouped in the playroom, we decided to stay in the house. I reconnoitered outside, making sure gas meter/pipes and water pipes were OK."

Somis- Interior walls split at seams; exterior walls sustained hairline cracks; a few tombstones fell; masonry fences and retaining walls were cracked; some windows were broken out; many small objects overturned and fell; several dishes and knickknacks broke; light and heavy furniture and appliances were displaced; hanging objects and doors swung violently; several items were thrown from store shelves; a few people ran out of buildings; standing vehicles rocked strongly; moving vehicles rocked moderately; water splashed onto sides of swimming pools.

Temple City- Many objects fell from shelves; many homes sustained minor damage.

Thousand Oaks- Several hundred homes sustained damage, most of which consisted of cracks in interior walls. There were isolated locations of stronger damage in some residential areas in northern Thousand Oaks (LA Daily News, 1/22/94).

Masonry fences and retaining walls partially fell; drywall sustained hairline cracks; concrete exterior walls sustained hairline cracks; some windows were broken out; many small objects overturned and fell; several dishes and knickknacks were broken; light furniture and small appliances were displaced; a few items were thrown from store shelves; many people ran out of buildings; standing vehicles rocked moderately; moving vehicles rocked slightly.

Torrance- Organ pipes at Lutheran Church of the Resurrection fell into pews in the choir balcony (The Daily Breeze, 1/19/94). Masonry fences and retaining walls were cracked; a few chimneys were cracked; underground pipes broke; several small objects overturned and fell; a few knickknacks broke; light furniture was displaced; hanging objects and doors swung violently; many items were shaken off store shelves; a few people ran out of buildings; water splashed onto sides of swimming pools.

Tujunga- Masonry fences partially fell; underground pipes were cracked; plaster walls sustained hairline cracks; exterior walls sustained hairline cracks; a few chimneys were cracked; a few windows cracked; several small objects overturned and fell; several dishes and knickknacks were broken; light furniture and small appliances were displaced; several items were thrown from store shelves; a few people ran out of buildings; felt strongly in standing and moving vehicles; water splashed onto sides of swimming pools.

West Covina- Interior and exterior walls sustained hairline cracks; a few chimneys were cracked; a few windows cracked; many small objects overturned and fell; several glassware items, dishes, and knickknacks were broken; small appliances were displaced; a few items were shaken off store shelves; felt strongly in standing and moving vehicles; water splashed onto sides of swimming pools.

Whittier- Many objects fell from shelves; many homes sustained minor damage.

Wilmington- Drywall sustained large cracks; exterior walls sustained hairline cracks; a few small objects overturned and fell. Harbor College sustained damages estimated at \$50,000 (LA Times, 1/23/94). Earthquake-induced liquefaction caused damage in the Port of Los Angeles (Hall, 1994).

Wrightwood- Several small objects overturned and fell; several knickknacks were broken; many items were thrown from store shelves.

Intensity V

Postal questionnaires from a large majority of intensity V sites reported: a few small objects overturned and fell; felt by many or all; awakened many or all. A majority reported: hanging pictures swung out of place or fell; trees and bushes shook slightly or moderately. Most postal questionnaire respondents described the vibration as strong. Other effects commonly reported: a few windows cracked; a few glassware items or dishes broke; a few items were shaken off store shelves; moving vehicles rocked slightly or moderately; interior walls sustained hairline cracks. Some postal respondents reported difficulty in standing or maintaining balance. Reports of moderate or strong earth noise were received from about one-fifth of the sites, substantially fewer than for higher intensities.

A Rancho Cucamonga woman, rushing to be with her baby, was killed when she slipped on a toy and hit her head on the child's crib (LA Times, 1/18/94). In other communities that were assigned intensity V there were isolated instances of damage that would be characteristic of higher intensities: a shopping-center garage bridge was crumpled in Hawthorne (LA Times 2/6/94); the Hollywood Park Race Track, Inglewood, sustained \$25,000 damage in

broken windows (LA Times, 2/6/94); Los Angeles Southwest College in Athens sustained damages estimated at \$50,000 (LA Times, 1/23/94).

An observer in a single family home in Buena Park, reported: *"I was very surprised when I found out that this earthquake was fairly far away, because it seemed to be large at the house. It was bad enough that my husband went out and checked for gas leaks around the house and in the neighborhood. It was also bad enough that we immediately turned on the radio to find out what had happened."*

The following communities were assigned intensity V:
Arizona— Bullhead City.

California— Adelanto, Alta Loma, Angelus Oaks, Apple Valley, Atwood, Avalon, Azusa, Baker, Baldwin Park, Big Bear City, Bloomington, Bombay Beach, Brea, Buellton, Buena Park, Buttonwillow, California City, California Hot Springs, Calimesa, Carpinteria, Cedar Glen, Cerritos, Chino, Claremont, Coachella, Colton, Corcoran, Corona del Mar, Coronado, Costa Mesa, Covina, Crest Park, Cuyama, Dana Point, Diamond Bar, Downey, Earlimart, El Monte, El Toro, Escondido, Fallbrook, Fawnskin, Fountain Valley, Frazier Park, Fullerton, Garden Grove, Gardena, Goleta, Goshen, Green Valley Lake, Grover Beach, Guadalupe, Guasti, Hacienda Heights, Hawaiian Gardens, Hawthorne, Helendale, Hemet, Hesperia, Highland, Homeland, Huntington Beach, Indio, Industry, Inglewood, Inyokern, Irvine, Julian, Laguna Hills, Laguna Niguel, Lake Arrowhead, Lake Elsinore, Lake Hughes, Lake Isabella, La Mesa, Lamont, Lancaster, Landers, La Palma, La Puente, La Quinta, La Verne, Lemoore, Lenwood, Leona Valley, Llano, Loma Linda, Lomita, Long Beach, Los Alamitos, Los Alamos, Lucerne Valley, Lytle Creek, McKittrick, Mecca, Mentone, Mission Viejo, Montalvo, Montclair, Montecito, Moonridge, Moreno Valley, Morongo Valley, Mount Baldy, Mount Wilson, Murrieta, Newberry Springs, Newport Beach, Niland, Norco, North Edwards, North Shore, Norwalk, Oceanside, Ojai, Ontario, Orange, Oro Grande, Pacific Beach, Paramount, Pearblossom, Phelan, Pinon Hills, Placentia, Pomona, Poway, Quartz Hill, Rainbow, Rancho Bernardo, Rancho Cucamonga, Redlands, Reedley, Ridgecrest, Riverside, Rosamond, Running Springs, San Bernardino, San Clemente, San Dimas, San Juan Capistrano, San Luis Rey, San Marcos, San Pedro, Santa Ana, Santa Barbara, Santa Fe Springs, Santa Ynez, Seeley, Silverado, South Gate, Spring Valley, Spring Valley Lake, Summerland, Sunset Beach, Surfside, Taft, Tehachapi, Temecula, Trabuco Canyon, Tustin, Twentynine Palms, Upland, Valley Acres, Valley Center, Valyermo, Vandenberg Air

Force Base, Ventura, Victorville, Vista, Walnut, Wasco, Westminster, Westmorland, White Water, Winchester, Yorba Linda, Yucca Valley.

Intensity IV

The following communities were assigned intensity IV:

California—Aguanga, Alpaugh, Anza, Arrowbear Lake, Atascadero, Bakersfield, Banning, Barstow, Beaumont, Big Bear Lake, Blythe, Bodfish, Bonita, Bonsall, Boron, Borrego Springs, Brawley, Cabazon, Calexico, Calipatria, Carlsbad, Caruthers, Cathedral City, Cayucos, Chula Vista, Clovis, Coalinga, Corona, Crestline, Daggett, Death Valley (Furnace Creek), Del Mar, Delano, Desert Center, Desert Hot Springs, Ducor, El Cajon, El Centro, Encinitas, Essex, Exeter, Fellows, Fontana, Forest Falls, Fort Irwin, Glendora, Grand Terrace, Hanford, Heber, Hinkley, Idyllwild, Imperial, Imperial Beach, Indian Wells, Jacumba, Jamul, Johannesburg, Joshua Tree, Kernville, Kettleman City, La Jolla, Lakeside, Lebec, Lemon Grove, Leucadia, Linda Vista, Lompoc, Lone Pine, Los Nietos, Los Olivos, Lost Hills, Ludlow, Maricopa, McFarland, Mira Loma, Mira Mesa, Mission Beach, Morro Bay, Mountain Pass, National City, New Cuyama, Nipomo, Nuevo, Oceano, Ocotillo, Palm Desert, Palm Springs, Pauma Valley, Perris, Pioneertown, Pixley, Porterville, Quail Valley, Rancho Mirage, Rancho Santa Fe, Red Mountain, Rialto, Romoland, Salton City, San Diego, San Diego (Loma Portal), San Jacinto, San Ysidro, Santa Ysabel, Santee, Shafter, Shandon, Shoshone, Skyforest, Solana Beach, Solvang, Strathmore, Sugarloaf, Sun City, Tecopa, Templeton, Terra Bella, Thousand Palms, Trona, Tulare, Visalia, Warner Springs, Weldon, Wofford Heights, Yucaipa.

Intensity III

The following communities were assigned intensity III:

Arizona— Ehrenberg, Parker.

California— Alpine, Amboy, Arroyo Grande, Biola, Blackrock Campground, Cadiz, Cambria, Camp Nelson, Clairmont, Death Valley Junction, Fresno, Holtville, Ivanhoe, Los Osos, Needles, Palo Verde, Raisin, Ramona, Richgrove, Riverdale, San Luis Obispo, Santa Margarita, Santa Maria, Thermal, Three Rivers, Turlock.

Nevada— Armagosa Valley, Las Vegas, Laughlin.

Intensity II

The following communities were assigned intensity II:

California— Avenal, Del Rey, Five Points, Glennville, Independence, Kingsburg, Laton, Paso Robles, Pismo Beach, Winterhaven.

Nevada— Henderson.

Felt:

The earthquake was reported felt in the following communities, but we did not receive information sufficient to assign an intensity.

California— Los Serranos, North Palm Springs,
Rowland Heights.

Utah— Richfield.

REFERENCES CITED

References to newspapers are given in the body of the text with the newspaper name or abbreviation followed by the date (month/day/year). The following abbreviations are used for newspapers: "LA Daily News" - Los Angeles Daily News; "LA Times" - Los Angeles Times).

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Figure 4. Kaiser-Permanente building, Granada Hills (listed in text under intensity IX), showing the collapsed second story and north end bay.



Figure 5. Collapsed overcrossing at the Interstate 5/California Highway 14 interchange (listed under intensity IX).



Figure 6. Collapse of Bullocks department store at the Northridge Fashion Mall, Northridge (listed under intensity IX). The notch on the standing column shows where a floor slab had been attached.



Figure 7. Partial collapse of a store building in a shopping center near the Northridge Fashion Mall, (listed under intensity IX).



Figure 8. Northridge Meadows apartment complex, Northridge(listed under intensity IX). Collapsed building in right foreground was formerly at same height as, and aligned with, uncollapsed building in middle background.



Figure 9. Collapsed parking structure at California State University at Northridge (listed under intensity IX).



Figure 10. St. Johns Hospital, Santa Monica (this part of Santa Monica listed under intensity IX), showing diagonal shear cracks in piers at the second story level.



Figure 11. Damage to piers in the northwest-facing wall of the Berkeley East convalescent hospital, Santa Monica (this part of Santa Monica listed under intensity IX).



Figure 12. Damage to columns of the Radisson Hotel, Ventura Boulevard, Sherman Oaks (listed under intensity IX).



Figure 13. Displacement of upper stories of an apartment building over ground-floor parking area, Sherman Oaks (listed under intensity IX).



Figure 14. Courtyard of a Sherman Oaks (listed under intensity IX) apartment building.



Figure 15. House shifted off its foundation, Fillmore (listed under intensity VIII).



Figure 16. Damage to unreinforced masonry building, Hollywood Boulevard, Hollywood (listed under intensity VIII). At the time this picture was taken, most bricks and other debris on the sidewalk had been removed.



Figure 17. Damage to unreinforced masonry building, Los Angeles (West Adams) (listed under Intensity VIII).

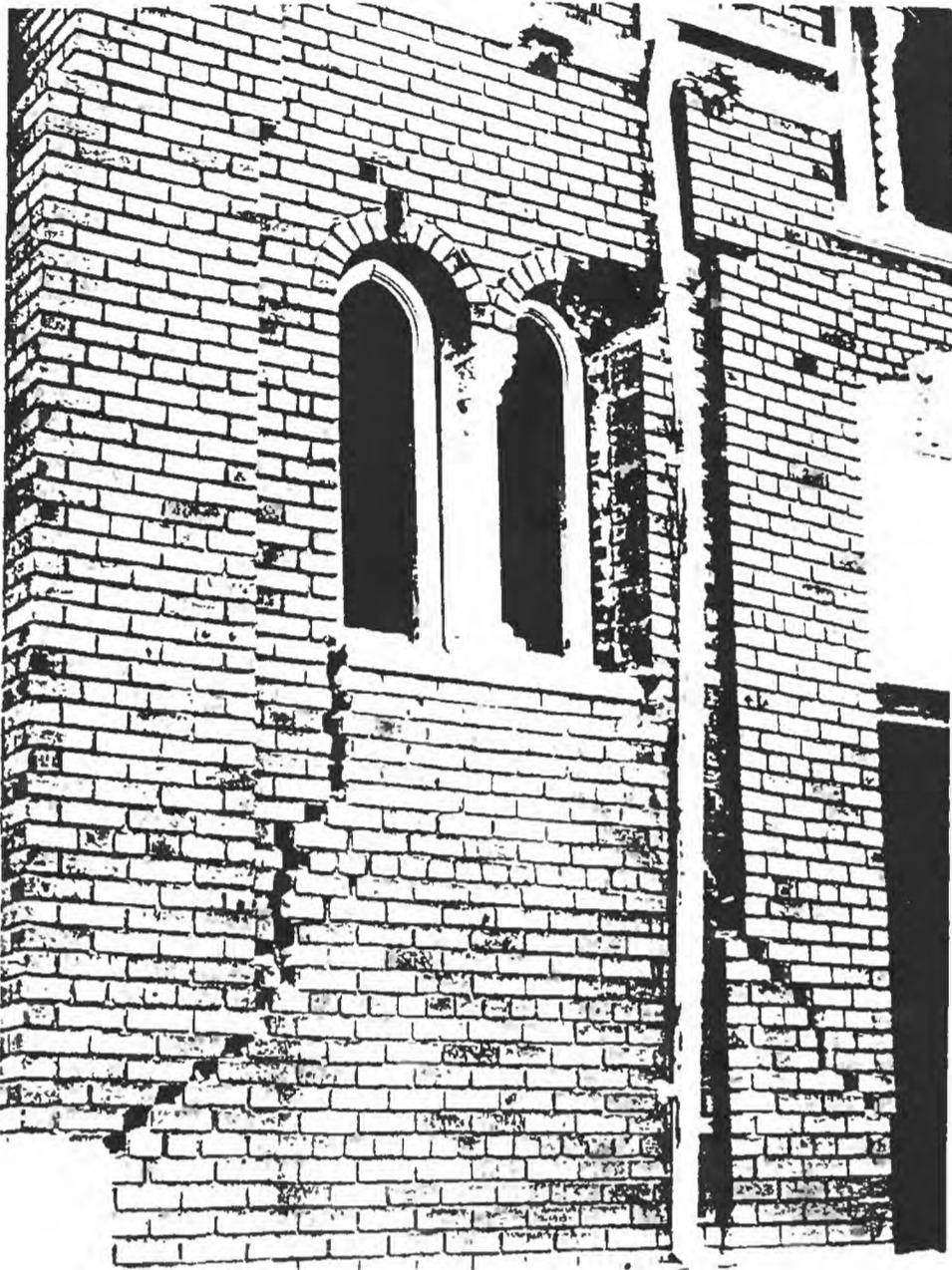


Figure 18. Damage to unreinforced masonry Southern Missionary Baptist church, Los Angeles (West Adams) (listed under Intensity VIII).



Figure 19. Collapse of apartment buildings onto underlying parking areas, Reseda (listed under intensity VIII). Debris in middle background resulted from fighting a fire in the destroyed building that was triggered by an aftershock.

Figure 20. Office building with its interior exposed after cladding was shaken down, Reseda (listed under intensity VIII).



Figure 21. Damage to unreinforced masonry walls of the First Christian Church, Santa Monica (listed under intensity VIII).



Figure 22. Damage to columns supporting a gas station canopy, near Stevenson Ranch (listed under intensity VIII).



Figure 23. Damage to a home located on a north-south ridge near the crest of the Santa Monica mountains, south of Mulholland Drive, north of Westwood Village (listed in the text under intensity VII). The house and its neighbors constitute a several block area characterized by intensity VIII effects, but such damage was not typical of most of the southern slope of the Santa Monica mountains.