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PEAK ACCELERATIONS FROM THE 17 OCTOBER 1989 LOMA PRIETA EARTHQUAKE

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ABSTRACT

Peak accelerations of the Loma Prieta main shock have been tabulated from instruments maintained by a number of organizations. We have analyzed a subset of 86 records from nominally free-field sites, which have been subdivided into rock, alluvium, and bay-mud categories according to data available in various reports. After correction for attenuation, the peak accelerations on rock, alluvium, and bay-mud sites are factors of 1.6, 1.8, and 4.5 larger, on the average, than Joyner and Boore's (1988) predicted values for a M=6.9 earthquake. The mean motions for the rock and alluvium sites are somewhat greater than one standard deviation away from the predicted value, but the mean acceleration from the bay-mud sites is well outside the range expected from analyses of data from previous earthquakes from rock and alluvium sites. Large amplitudes of motions on bay-mud sites relative to rock sites (a factor of 2.8 for the average of the recordings of the Loma Prieta main shock) has been found previously from recordings of distant earthquakes and explosions, but the Loma Prieta earthquake provided the first opportunity to study the relative amplitudes from strong-motion recordings.

INTRODUCTION

The Loma Prieta earthquake was recorded on many low-magnification, film-recording accelerographs. Most of the recordings were obtained by the California Strong Motion Instrumentation Program (CSMIP) of the California Division of Mines and Geology (Shakal *et al.*, 1989) and by a cooperative program operated by the U. S. Geological Survey (Maley *et al.*, 1989), but a number of other groups provided data as well. Although the CSMIP and USGS data are readily available in the reports referred to above, data from the other organizations responsible for accelerographs that recorded the main shock are not so easily obtained. We provide here a comprehensive compilation of the available data. We also include a preliminary analysis of the peak accelerations.

TABLE OF PEAK ACCELERATIONS

Because of its length, the table is given in the Appendix. We have made a major effort to make this table complete, but there are undoubtedly a few recordings that we are unaware of; in addition, a few recordings from instruments in buildings have not been made available by the building owners (in one case the refusal is because of a law suit over building damage). In the table, *h1* and *h2* are horizontal components, without regard to direction; *v* is the vertical component. The table contains values from structures as well as free-field sites. Many of the entries in the table are preliminary and should be used with care. Distances, for example, may not be consistent from agency to agency because of the use of slightly different epicentral coordinates. We also are unable to vouch for the accuracy of all the peak values. For example, the Branciforte Drive (Santa Cruz) station is reported to have clipped and records from the Los Gatos Presentation Center station may be inaccurate due to motion of the instrument relative to its foundation. We recommend that anyone wishing to use these records use the table as an indication of what is available and of interest, and then either contact the instrument owner or, in the case of USGS and CSMIP records, use the primary reference.

ANALYSIS OF FREE-FIELD PEAK ACCELERATIONS

For practical purposes the records are directly proportional to acceleration, and thus the peak accelerations can be easily obtained and analyzed. Figure 1 is a map of the free-field peak horizontal accelerations (defined as the larger of the two horizontal components). Study of this map reveals several areas where the peak motions vary considerably over a small distance. As an example, motions near Oakland vary from 8% *g* to 41% *g*. These variations are almost certainly due to local changes in the geologic materials underlying the recording sites. In the case of the sites near Oakland, the highest values come from sites underlain by bay mud (Alameda Naval Air Station, Oakland--Outer Harbor Wharf, and Emeryville), and the other high value comes from a site underlain by alluvium (Oakland--2-story office building). All the low values come from rock sites. (Our determinations of site classification, which are not included, are provisional; they are based on reference to geologic maps and to descriptions of sites in published reports. In the next year we will endeavor to visit all sites with a

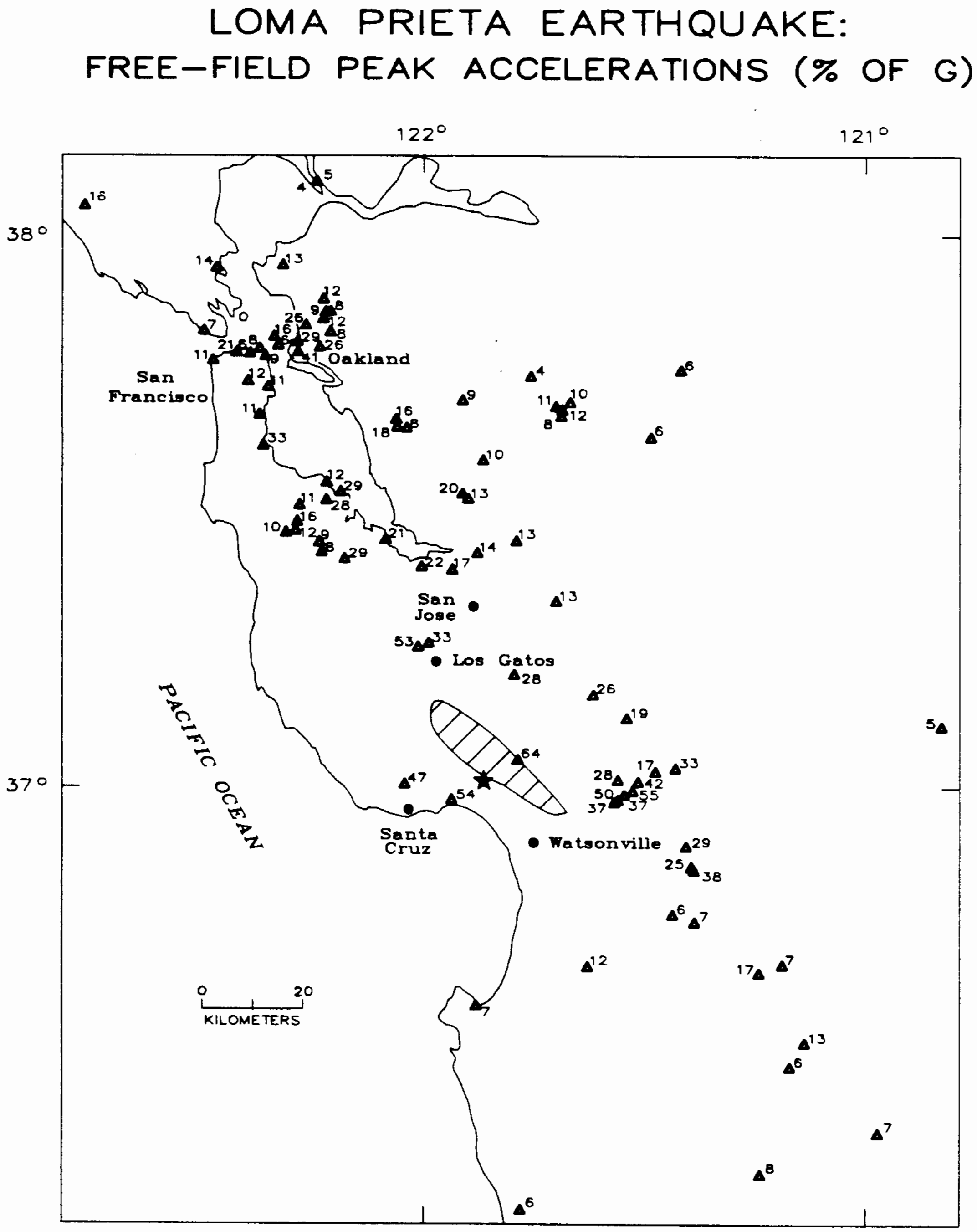

Fig. 1. Peak horizontal acceleration, in percent g (980 cm/s^2), at stations shown by the triangles. The motion is the larger of the two horizontal components; the vectorial peak motion would be even larger. The shaded region is an estimate of the rupture area of the fault, projected to Earth's surface. The star is the main shock epicenter. Data from such things as buildings 3 stories or greater in height, from dams, and from the base of freeway overpass support columns have been excluded. This is in accord with the selection criteria used by Joyner and Boore (1988) to minimize the effects of the enclosing structure.

geologist and to conduct downhole shear-velocity logging at approximately 20 selected sites).

The dependence of the motions on site conditions is clearly shown by the waveforms for closely located rock and soil sites, at comparable distances from the earthquake, shown in Figure 2. The records are plotted to the same amplitude and time scales. The Hollister recordings, to the southeast of the earthquake, were obtained from a site underlain by alluvium. The Emeryville station, to the northwest of the event, is

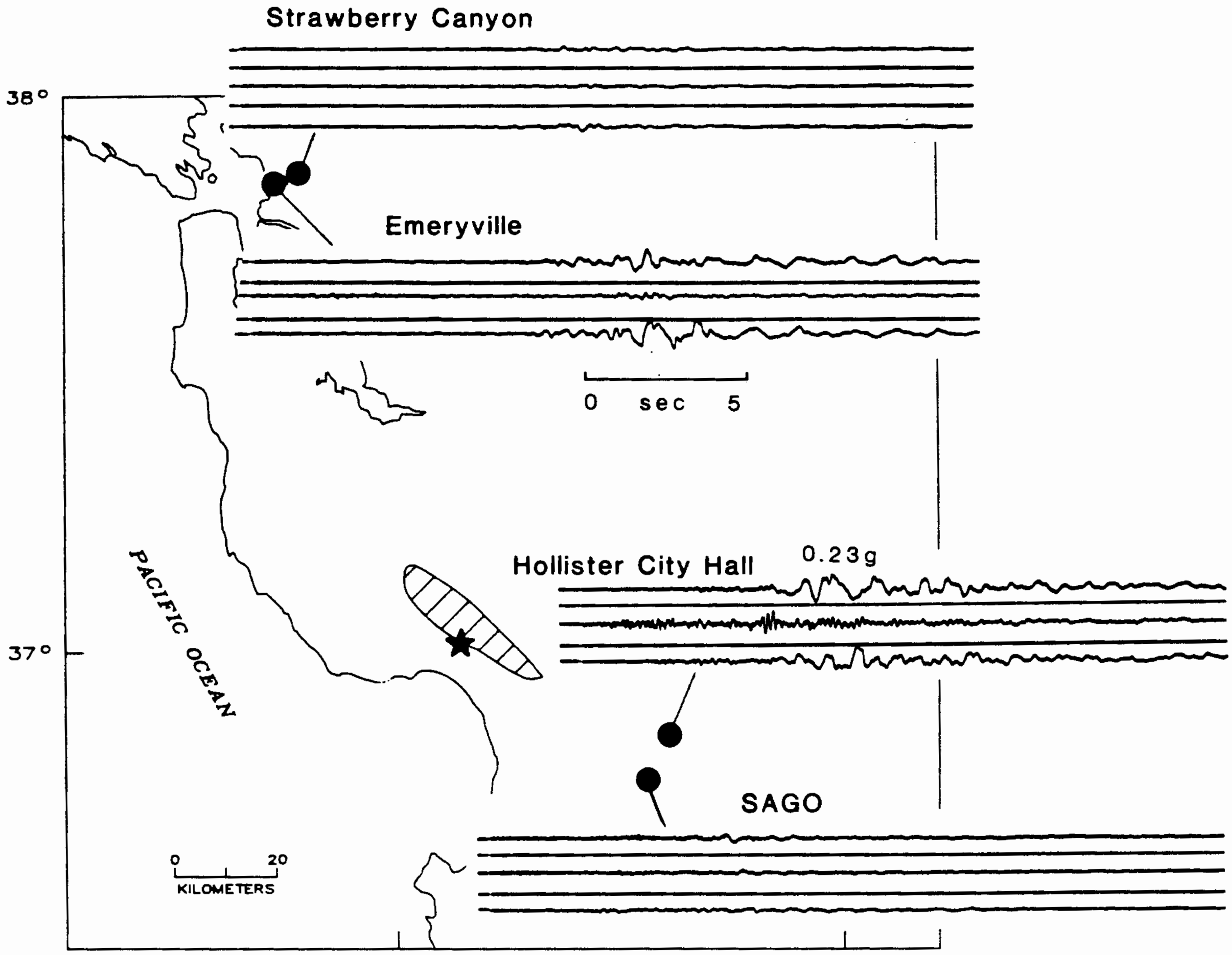

Fig. 2. 3-component accelerograms at selected rock-soil pairs (the two horizontal lines in each set are reference traces; the middle trace is the vertical component). The gains and time scales are the same for all the accelerograms. The SAGO and Strawberry Canyon recordings were obtained on rock, the Hollister station is sited on alluvium, and the Emeryville station is underlain by bay mud.

sited on bay mud. In both cases, the smaller motions are obtained from rock sites.

If all sites were underlain by similar materials, we would expect a map of peak ground motion to show a decrease in values with distance. Because of variations in site response, however, it is difficult to see distance attenuation from a study of the map alone. This masking effect can be partially overcome by plotting the motions as a function of distance from the fault, after separating the recordings into several categories depending on the geologic materials underlying the recording sites. This has been done in Figure 3, in which the equation

$$\log a = 0.49 + 0.23(\mathrm{M}-6) - \log r - 0.0027\,r,$$

where

$$r = (r_0^2 + 8^2)^{1/2}$$

and a is peak acceleration in g, r_0 is the shortest horizontal distance to the surface projection of the rupture surface in km, and **M** is moment magnitude, serves as a convenient yardstick against which to measure the ground shaking of the Loma Prieta earthquake. This equation is based on Joyner and Boore's (1988) comprehensive regression analysis of data from many past earthquakes and is widely used. The moment magnitude for the Loma Prieta earthquake is still being determined, but several analyses find it to be in the range 6.9 to 7.1. Following the results of Kanamori and Helmberger (1989), we use 6.9 (a value of 7.1 would increase the predicted motions by only a factor of 1.1).

Figure 3 shows that the accelerations at rock sites are in reasonable agreement with the predictions. The recordings at soil sites are systematically greater than the predictions, however, with the accelerations at bay-mud sites much larger than those from most of the

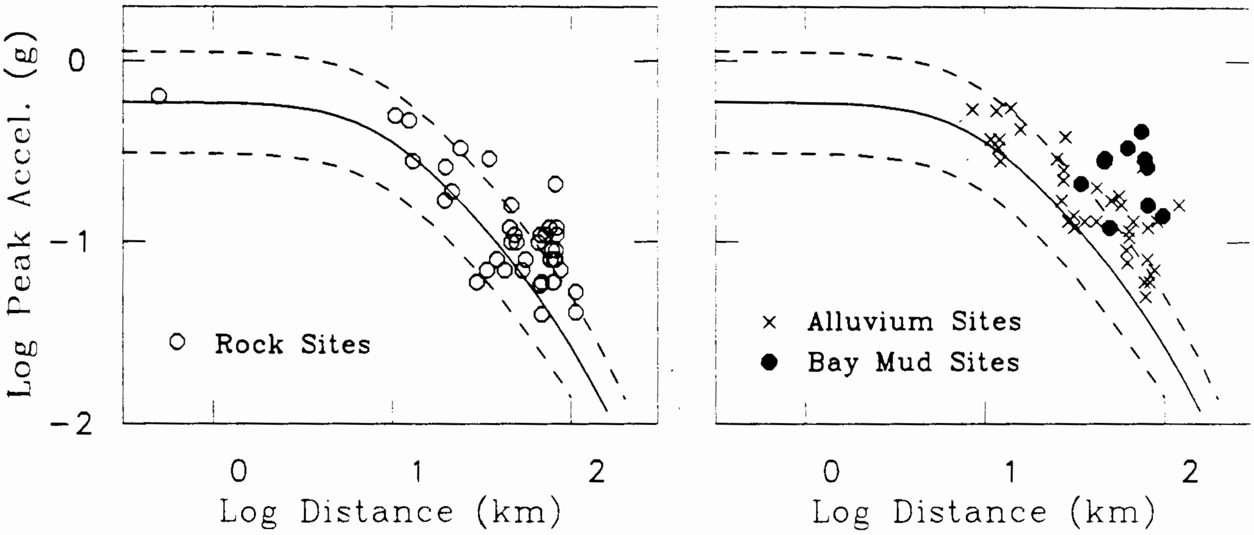

Fig. 3. Peak horizontal accelerations as a function of the closest distance from a station to the surface projection of the fault (shown in Figure 1). The solid line is the prediction of Joyner and Boore (1988), using a moment magnitude of 6.9; the dashed lines are drawn at plus and minus one standard deviation of an individual observation, as determined in Joyner and Boore's regression analysis.

alluvium sites. Relative to rock sites, ground motion at young, poorly-consolidated, water-saturated alluvium and mud sites tends to be deficient in high-frequency amplitudes and enriched in longer-period motion; this frequency-dependent amplification is presumably a function of rigidity contrasts, basin geometry, and attenuation.

The dependence on site condition is more clearly seen in Figure 4, which shows the means of the residuals, defined as the difference between the logarithms of the observed and predicted accelerations. For comparison, the variation found by Joyner and Boore for the means of the residuals (their inter-earthquake variance) is shown by the dotted lines; out of 100 earthquakes, 67 should have a mean residual within the dotted lines. The observed mean residual for rock sites is somewhat greater than one standard deviation from the expected value.

Of most interest are the means for data from the soil sites. Joyner and Boore found no difference in peak accelerations between rock and soil, but their data set, primarily from southern California, had no values from mud sites, and their soil sites were generally underlain by much greater thicknesses of sediments than is the case for stations recording the Loma Prieta earthquake (the amplification expected for waves traveling to the surface through the low velocity sediments would be offset by the attenuation of the waves if the sediment section were thick enough). Joyner and Boore (1988) did find, however, a difference between rock and soil for response spectra at frequencies less than about 3 Hz. Because peak acceleration can be controlled by different frequencies, depending on the filtering along the travel path of the waves, the difference between the rock and alluvium sites may not be inconsistent with the findings of Joyner and Boore (1988) if most of the peak accelerations are from

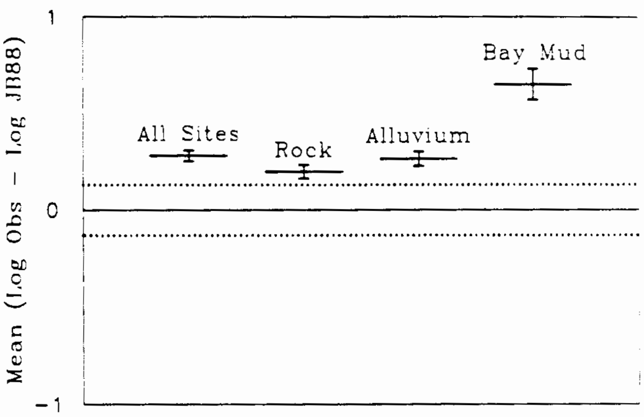

Fig. 4. The mean of the residuals (defined as the difference between the logarithms of the observed and predicted accelerations). The dotted line indicates the inter-earthquake variation obtained by Joyner and Boore (1988). The horizontal bars represent the mean residuals for the site conditions indicated. The horizontal axis has no meaning and the length of the horizontal bars has no meaning; the means were separated horizontally to aid in visual comparisons of the means to one another. The errors bars show the standard error of each mean (the standard deviation divided by the square root of the number of points used to compute the mean value). Analysis of data from many previous earthquakes finds that the residuals have a log normal distribution; as a consequence, the error bars of the means are symmetrical about the mean when the ordinate is in log units, as in this figure.

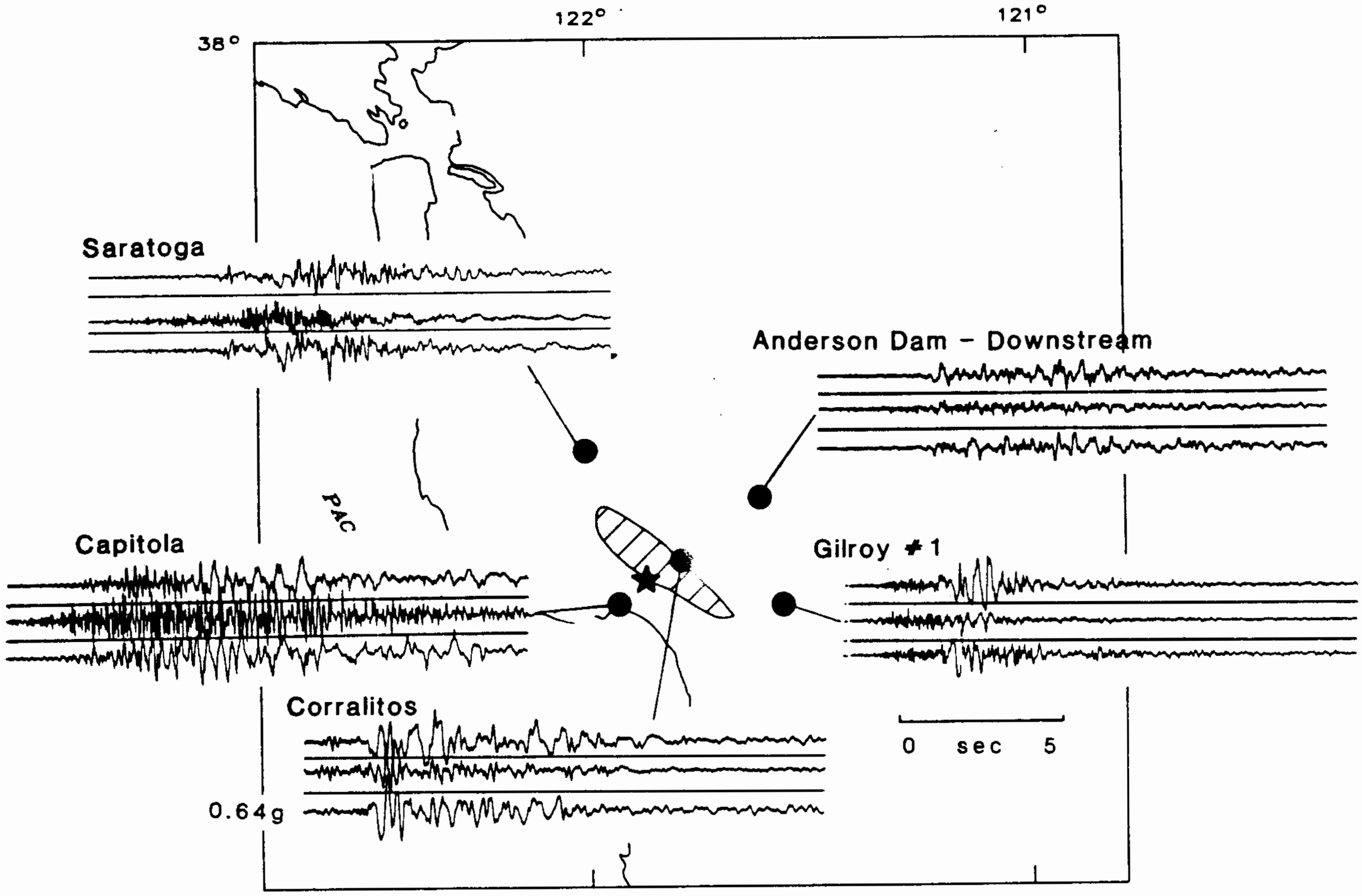

Fig. 5. 3-component accelerograms at selected sites surrounding the source (the two horizontal lines in each set are reference traces; the middle trace is the vertical component). The gains and time scales are the same for all the accelerograms.

lower frequency ground motions than was the case in the data used by Joyner and Boore.

The scatter in the residuals is very similar to that found by Joyner and Boore in their study of previous earthquakes. This scatter is undoubtedly due to a combination of many things, including variations of geologic properties within a particular site category, radiation pattern, and rupture propagation (directivity). Figure 5 shows some selected accelerograms surrounding the source region. Distinctive variations in frequency content, amplitude, and duration are obvious (and are present in other accelerograms surrounding the source). We have plotted the peak acceleration residuals against distance and azimuth for rock sites in Figure 6. There is a suggestion in Figure 6 that the residuals are high for a narrow range of azimuth and distance; these points correspond to the rock recordings along the San Francisco Peninsula and in San Francisco. Source directivity, radiation pattern, and wave propagation effects (such as critical reflections from the Moho, as suggested by Burger *et al.* (1987)) are possible explanations of the high values.

The strong-motion data from the Loma Prieta earthquake are unique and valuable for the quantification of the response of soil layers to seismic shaking. The peak-acceleration analysis here is only a preliminary attempt to understand the response. Based on experience with other earthquakes we would expect longer-period measures of ground motion to show even greater differences between rock and soil. More complete analyses, using Fourier and response spectra, await digitization of the data. Several engineered structures, including high-rise buildings and freeway overpasses, provided multiple channels of data that will be invaluable to studies of the response and design of structures. Recordings of aftershocks on digital portable instruments will complement and supplement the analysis of the soil response characteristics and will help unravel the complexities of the rupture history of the main shock..

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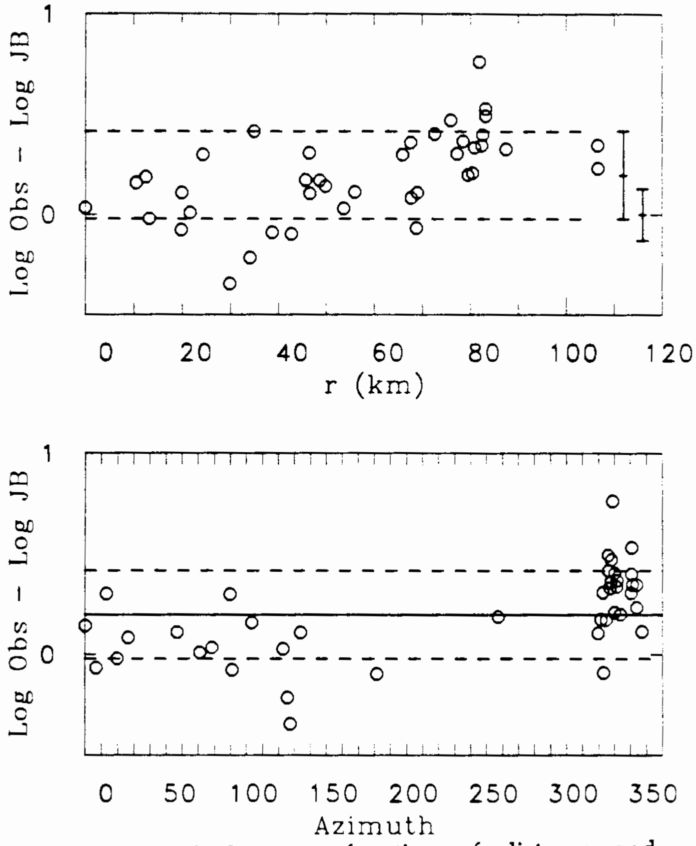

Fig. 6. Residuals as a function of distance and epicenter-to-station azimuth (clockwise from north) for free-field rock sites. The dashed lines are drawn at plus and minus one standard deviation. The larger of the two error bars on the right of the figure is the corresponding intra-earthquake variation found by Joyner and Boore (1988); it represents the scatter about the mean of the observations from a single earthquake, due to such things as variations in site conditions, radiation pattern, and travel path. The smaller error bar is the inter-earthquake variation determined by Joyner and Boore. It represents the variation in the mean residuals between earthquakes, due to, for example, a variation in average stress parameter. The horizontal placement of the error bars is arbitrary.

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APPENDIX
Table of Peak Accelerations

Recording Station†	Lat Long	Dist (km)	Peak Acc (g) h1	V	h2
Corralitos CSMIP	37.046 -121.803	7	0.50	0.47	0.64
Branciforte Drive UCSC	37.047 -121.985	8	0.46	0.50	0.50
Capitola CSMIP	36.974 -121.952	9	0.47	0.60	0.54
Santa Cruz, Walter's House UCSC	36.970 -121.996	9	0.66	0.27	0.38
UCSC Seismic Lab, Applied Science Bldg UCSC	37.000 -122.062	14	0.31	0.22	0.42
Santa Cruz - UCSC/Lick Obs Elect Lab CSMIP	37.001 -122.060	16	0.44	0.40	0.47
Watsonville - Telephone Bldg (structure) CSMIP	36.909 -121.756	18	0.81	–	1.24
Watsonville - Telephone Bldg, basement CSMIP	36.909 -121.756	18	0.28	0.66	0.39
Lexington Dam - Abutment CSMIP	37.202 -121.949	19	0.41	0.15	0.45
Lexington Dam - Crest CSMIP	37.202 -121.949	19	0.40	0.22	0.45
Los Gatos Presentation Center UCSC	37.172 -122.010	20	1.00	1.00	0.80
San Jose - 3-story Office Bldg, base CSMIP	37.212 -121.803	21	0.20	0.14	0.20
San Jose - 3-story Office Bldg, structure CSMIP	37.212 -121.803	21	0.58	–	0.67
San Jose - Santa Teresa Hills CSMIP	37.210 -121.803	21	0.28	0.22	0.27
Anderson Dam - Center Crest USGS	37.166 -121.628	27	0.32	0.16	0.43
Anderson Dam - Crest USGS	37.166 -121.628	27	0.26	0.19	0.39
Anderson Dam - Downstream USGS	37.166 -121.628	27	0.25	0.17	0.26
Anderson Dam - Left Abutment USGS	37.166 -121.628	27	0.08	0.05	0.07
Anderson Dam - Mid-dam, Center USGS	37.166 -121.628	27	0.11	–	0.14
Anderson Dam - Right Crest USGS	37.166 -121.628	27	0.32	0.23	0.38
Anderson Dam - Toe USGS	37.166 -121.628	27	0.18	0.16	0.23
Saratoga CSMIP	37.255 -122.031	27	0.34	0.41	0.53
Saratoga - West Valley College Gym (struct) CSMIP	37.262 -122.009	27	0.87	–	0.77
Saratoga - West Valley College Gym base CSMIP	37.262 -122.009	27	0.33	0.27	0.26
Gilroy - Old Firehouse CSMIP	37.009 -121.569	28	0.25	0.15	0.28
Gilroy #1 - Gavilan College Water Tank CSMIP	36.973 -121.572	29	0.50	0.22	0.43
Gilroy - Gavilan College Phys Sci Bldg CSMIP	36.973 -121.568	29	0.37	0.20	0.33
Gilroy #2 CSMIP	36.982 -121.556	30	0.33	0.31	0.37
Coyote Lake Dam - Downstream	37.124	31	0.19	0.10	0.17

Recording Station†	Lat Long	Dist (km)	Peak Acc (g) h1	 V	 h2
CSMIP	-121.551				
Coyote Lake Dam - SW Abutment	37.118	31	0.49	0.08	0.15
CSMIP	-121.550				
Gilroy #3	36.987	31	0.37	0.38	0.55
CSMIP	-121.536				
Gilroy #4	37.005	32	0.22	0.17	0.42
CSMIP	-121.522				
San Jose - G.W. Savings (struct)	37.338	33	0.26	--	0.38
CSMIP	-121.893				
San Jose - G.W. Savings, base	37.338	33	0.09	0.09	0.11
CSMIP	-121.893				
San Jose - Town Park Towers (struct)	37.338	33	0.37	--	0.24
CSMIP	-121.888				
San Jose - Town Park Towers, base	37.338	33	0.10	0.09	0.13
CSMIP	-121.888				
San Juan Bautista - 101 Overpass, (structure)	36.862	33	0.94	0.27	0.61
CSMIP	-121.578				
San Juan Bautista - 101 Overpass, Base	36.862	33	0.15	0.10	0.14
CSMIP	-121.578				
San Jose 101/280/680 Fwy Interchange	37.340	34	0.18	0.08	0.13
USGS	-121.851				
Gilroy #6	37.026	35	0.17	0.10	0.13
CSMIP	-121.484				
San Jose - Santa Clara Co Bldg, base	37.353	35	0.11	0.10	0.10
CSMIP	-121.903				
San Jose - Santa Clara Co Bldg, structure	37.353	35	0.35	--	0.36
CSMIP	-121.903				
Halls Valley	37.338	37	0.11	0.06	0.13
CSMIP	-121.714				
San Jose, Fairmont Office Tower - 17th floor	37.334	37	0.07	0.05	0.10
Bldg	-121.892				
San Jose, Fairmont Office Tower - 1st floor	37.334	37	0.11	0.04	0.09
Bldg	-121.892				
San Jose, Fairmont Office Tower - 9th floor	37.334	37	0.09	0.04	0.08
Bldg	-121.892				
Agnews - State Hospital	37.239	40	0.16	0.10	0.17
CSMIP	-121.952				
Gilroy #7 Mantelli Ranch	37.033	40	0.33	0.12	0.23
CSMIP	-121.434				
Fort Ord - Hayes Hospital	36.650	41	0.11	0.09	0.16
USACE	-121.783				
Calaveras Array - Cherry Flat Reservoir	37.396	42	0.09	0.06	0.07
USGS	-121.756				
Milpitas - 2-story Bldg (struct)	37.430	43	0.34	--	0.58
CSMIP	-121.897				
Milpitas - 2-story Bldg, base	37.430	43	0.10	0.08	0.14
CSMIP	-121.897				
Sunnyvale - Colton Ave	37.402	43	0.22	0.10	0.19
USGS	-122.024				
Hollister Diff Array - Airport	36.888	45	0.29	0.16	0.27
USGS	-121.413				
Monterey Sheraton - 11th floor	36.602	45	0.27	0.18	0.31
Bldg	-121.894				
Monterey Sheraton - 9th floor	36.602	45	0.13	0.13	0.08
Bldg	-121.894				
Monterey Sheraton - garage	36.602	45	0.08	0.03	0.08
Bldg	-121.894				
Salinas	36.671	46	0.12	0.11	0.09
CSMIP	-121.642				
San Justo Dam - Crest of Dike	36.827	46	0.23	0.18	0.29
BuRec	-121.445				

Recording Station†	Lat / Long	Dist (km)	Peak Acc (g) h1	V	h2
San Justo Dam - Downstream Mid-Slope Face	36.815	46	0.30	0.20	0.35
BuRec	-121.447				
San Justo Dam - Left Abutment Face	36.815	46	0.30	0.24	0.24
BuRec	-121.447				
San Justo Dam - crest	36.815	46	0.39	0.32	0.50
BuRec	-121.447				
San Justo Dam - inside the dam	36.815	46	0.30	0.17	0.27
BuRec	-121.447				
San Justo Dam - toe	36.815	46	0.16	–	0.26
BuRec	-121.447				
Calaveras Array - Calaveras Reservoir South	37.452	47	0.13	0.07	0.08
USGS	-121.807				
Hollister City Hall Annex - Basement	36.851	47	0.23	0.22	0.25
USGS	-121.402				
Palo Alto VA Hospital, Basement	37.400	47	0.34	0.20	0.38
USGS/VA	-122.140				
Palo Alto VA Hospital, Roof (7th level)	37.400	47	1.09	0.64	0.79
USGS/VA	-122.140				
Hollister - South & Pine	36.848	48	0.18	0.20	0.38
CSMIP	-121.397				
Hollister, SAGO Vault	36.765	49	0.06	0.05	0.04
USGS	-121.446				
Monterey - City Hall	36.597	49	0.07	0.03	0.07
CSMIP	-121.897				
Palo Alto - 2-story Office Bldg (struct)	37.453	50	0.38	–	0.55
CSMIP	-122.112				
Palo Alto - 2-story Office Bldg, base	37.453	50	0.20	0.09	0.21
CSMIP	-122.112				
Stanford University - SLAC Test Lab	37.419	51	0.29	0.10	0.19
USGS	-122.205				
Menlo Park VA Hospital	37.468	54	0.12	0.11	0.27
USGS/VA	-122.157				
SAGO South	36.753	54	0.07	0.06	0.07
CSMIP	-121.396				
Fremont - Mission San Jose	37.530	55	0.11	0.09	0.13
CSMIP	-121.919				
Woodside	37.429	55	0.08	0.05	0.08
CSMIP	-122.258				
Fremont - Emerson Court	37.535	56	0.15	0.07	0.20
USGS	-121.929				
Redwood City - Canada Campus Bldg (struct)	37.448	57	0.19	–	0.17
CSMIP	-122.265				
Redwood City - Canada Campus Bldg, base	37.448	57	0.05	0.04	0.09
CSMIP	-122.265				
APEEL Array #9, Crystal Springs Reservoir	37.470	62	0.11	0.06	0.12
USGS	-122.320				
APEEL Array #2, Redwood City	37.520	63	0.23	0.08	0.28
USGS	-122.250				
Calaveras Array - Sunol Fire Station	37.597	63	0.07	0.03	0.10
USGS	-121.880				
Foster City - Redwood Shores	37.550	63	0.29	0.11	0.26
CSMIP	-122.230				
Upper Crystal Springs Res - Kings Mtn	37.465	63	0.09	0.04	0.10
CSMIP	-122.343				
Upper Crystal Springs Res.	37.490	63	0.09	0.06	0.16
CSMIP	-122.310				
Belmont - 2-story Office Bldg	37.512	65	0.10	0.04	0.11
CSMIP	-122.308				
Belmont - 2-story Office Bldg (struct)	37.512	65	0.20	–	0.19
CSMIP	-122.308				
Del Valle Dam - Crest	37.615	66	0.08	0.07	0.08

Recording Station†	Lat Long	Dist (km)	Peak Acc (g) h1	 V	 h2
USGS	-121.745				
Del Valle Dam - Toe	37.615	66	0.06	0.03	0.04
USGS	-121.745				
Foster City, 355 Menhaden Ct.	37.555	66	0.12	0.09	0.11
USGS	-122.248				
Livermore VA Hospital - Bldg 62, Roof (7th)	37.625	67	0.08	0.03	0.15
USGS/VA	-121.762				
Livermore VA Hospital - Bldg 62, basement	37.625	67	0.06	0.03	0.05
USGS/VA	-121.762				
Hayward - 6-story Office Bldg, basement	37.635	69	0.10	0.05	0.12
CSMIP	-122.104				
Hayward - 6-story Office Bldg, structure	37.635	69	0.24	–	0.25
CSMIP	-122.104				
Lower Crystal Springs Dam - Crest	37.529	69	–	0.03	0.07
CSMIP	-122.361				
Lower Crystal Springs Dam - abutment	37.529	69	0.06	0.03	0.09
CSMIP	-122.361				
Bear Valley #12 - Williams Ranch	36.658	70	0.17	0.10	0.16
USGS	-121.249				
Hayward - CSUH Admin Bldg (struct)	37.655	70	0.21	–	0.24
CSMIP	-122.056				
Hayward - CSUH Admin Bldg, base	37.655	70	0.08	0.05	0.09
CSMIP	-122.056				
Hayward - CSUH FF	37.657	70	0.08	0.05	0.08
CSMIP	-122.061				
Hayward - CSUH Science Bldg	37.657	70	0.05	0.03	0.04
CSMIP	-122.053				
Hayward - CSUH Science Bldg (struct)	37.657	70	0.18	–	0.08
CSMIP	-122.053				
Hayward - Muir School	37.657	71	0.14	0.10	0.18
CSMIP	-122.082				
APEEL Array #2E, Hayward, John Muir School	37.660	72	0.13	0.06	0.16
USGS	-122.080				
Bear Valley #5 - Callens Ranch	36.673	73	0.07	0.04	0.07
USGS	-121.195				
Hayward - Bart Elevated Section	37.671	73	0.15	0.05	0.15
CSMIP	-122.087				
Hayward - Bart Elevated Section FF	37.670	73	0.16	0.08	0.16
CSMIP	-122.086				
Hayward Bart Elevated Section (struct)	37.671	73	0.26	–	0.60
CSMIP	-122.087				
Hayward City Hall, 12th Floor, Center	37.679	74	0.10	–	0.13
USGS	-122.082				
Hayward City Hall, 12th Floor, West	37.679	74	0.10	–	–
USGS	-122.082				
Hayward City Hall, 3rd Floor, Center	37.679	74	0.07	–	0.08
USGS	-122.082				
Hayward City Hall, 3rd Floor, Southwest	37.679	74	0.05	–	0.04
USGS	-122.082				
Hayward City Hall, 7th Floor, Center	37.679	74	0.08	–	0.09
USGS	-122.082				
Hayward City Hall, 7th Floor, West	37.679	74	0.09	–	–
USGS	-122.082				
Hayward City Hall, Ground Floor	37.679	74	0.05	0.03	0.06
USGS	-122.082				
Hayward City Hall, Ground Floor, West	37.679	74	0.07	–	–
USGS	-122.082				
Hayward City Hall, Ground Site North	37.679	74	0.06	0.02	0.06
USGS	-122.082				
Hayward City Hall, Ground Site South	37.679	74	0.09	0.03	0.10
USGS	-122.082				

Recording Station†	Lat Long	Dist (km)	Peak Acc (g) h1	 V	 h2
San Luis Dam - Right trashrack DWR/BuRec	37.060 -121.070	74	0.31	0.06	0.52
San Luis Dam - left crest DWR/BuRec	37.060 -121.070	74	0.26	0.04	0.18
San Luis Dam - left toe DWR/BuRec	37.060 -121.070	74	0.04	0.02	0.06
San Luis Dam - left trashrack DWR/BuRec	37.060 -121.070	74	0.31	0.06	0.46
San Luis Dam - right crest DWR/BuRec	37.060 -121.070	74	0.14	0.05	0.17
San Luis Dam - right toe DWR/BuRec	37.060 -121.070	74	0.09	0.03	0.09
San Luis Pumping Plant - Level 2 DWR/BuRec	37.070 -121.080	74	0.06	0.03	0.04
San Luis Pumping Plant - level 5 DWR/BuRec	37.070 -121.080	74	0.05	0.03	0.05
Calaveras Array - Dublin Fire Station USGS	37.709 -121.932	75	0.08	0.03	0.09
Sandia National Lab LLNL*	37.674 -121.704	76	0.05	0.03	0.05
LLNL East Gate LLNL*	37.687 -121.701	77	0.12	–	0.09
LLNL NW Corner LLNL*	37.693 -121.714	77	0.06	0.03	0.11
O'Neill Forebay Dam - left crest DWR/BuRec	37.080 -121.040	77	0.15	0.07	0.12
O'Neill Forebay Dam - left downstream toe DWR/BuRec	37.080 -121.040	77	0.10	0.05	0.08
O'Neill Forebay Dam - right crest DWR/BuRec	37.080 -121.040	77	0.11	0.07	0.16
Orestimba Siphon F.F. DWR	37.310 -121.120	77	0.07	0.03	0.07
Site 300 LLNL*	37.639 -121.497	78	0.05	0.02	0.06
Patterson Pass Road LLNL*	37.702 -121.684	79	0.08	0.04	0.08
San Francisco - Intl Airport CSMIP	37.622 -122.398	79	0.33	0.05	0.24
Livermore - Fagundes Ranch CSMIP	37.753 -121.772	80	0.04	0.02	0.04
San Bruno - 6-story Office Bldg, (struct) CSMIP	37.628 -122.424	81	0.25	–	0.46
San Bruno - 6-story Office Bldg, base CSMIP	37.628 -122.424	81	0.14	0.12	0.12
San Bruno - 9-story Bldg, g.l. SMIP	37.627 -122.424	81	0.11	0.14	0.16
San Bruno - 9-story Bldg, structure CSMIP	37.627 -122.424	81	0.32	–	0.36
Burlingame Hyatt - 9th floor Bldg	37.593 -122.363	82	0.51	0.14	0.30
Burlingame Hyatt - ground level Bldg	37.593 -122.363	82	0.20	0.12	0.12
San Ramon Marriott - 1st floor Bldg	37.760 -121.964	83	0.05	0.04	0.08
So. S.F. - Sierra Pt. Overpass, (struct) CSMIP	37.674 -122.388	84	0.41	0.11	0.22
So. S.F. - Sierra Pt Overpass, base CSMIP	37.674 -122.388	84	0.09	0.03	0.05
So. San Francisco - Sierra Point CSMIP	37.674 -122.388	84	0.11	0.05	0.06
So S. F. - 4-story Hospital	37.660	85	0.14	0.08	0.15

Recording Station†	Lat Long	Dist (km)	Peak Acc (*g*) h1	 V	 h2
CSMIP	-122.439				
So S.F. - 4-story Hospital (structure)	37.660	85	0.57	--	0.68
CSMIP	-122.439				
Bear Valley #10, Webb Residence	36.532	86	0.10	0.05	0.13
USGS	-121.143				
Big Sur State Park	36.255	87	0.05	0.03	0.06
CSMIP	-121.782				
Bear Valley #7, Pinnacles Nat'l Monument	36.483	88	0.04	0.03	0.06
USGS	-122.180				
San Francisco, 1295 Shafter	37.728	89	0.11	0.05	0.07
USGS	-122.385				
Oakland - 24-story Bldg (struct)	37.798	91	0.38	0.14	0.25
CSMIP	-122.257				
Oakland - 24-story Bldg, base	37.798	91	0.18	0.04	0.14
CSMIP	-122.257				
Tracy - Sewage Plant	37.766	91	0.06	0.02	0.06
CSMIP	-121.421				
Oakland - 2-story Office Bldg, base	37.806	92	0.20	0.16	0.26
CSMIP	-122.267				
Oakland - 2-story Office Bldg, structure	37.806	92	0.26	--	0.69
CSMIP	-122.267				
San Benito	36.519	92	0.05	0.02	0.05
CSMIP	-121.084				
San Francisco - Diamond Heights	37.740	92	0.12	0.05	0.10
CSMIP	-122.430				
Alameda Navy Base - Hangar, g.l.	37.785	93	0.30	0.07	0.41
USN	-122.303				
Alameda Navy Base - Hangar, roof	37.785	93	0.20	0.07	0.25
USN	-122.303				
Piedmont - 3-story School Bldg (struct)	37.823	93	0.18	--	0.15
CSMIP	-122.233				
Piedmont - 3-story School Bldg, base	37.823	93	0.08	0.04	0.07
CSMIP	-122.233				
Piedmont - Jr High School	37.823	93	0.08	0.03	0.07
CSMIP	-122.233				
San Francisco State Univ - Thornton Hall	37.724	93	0.14	0.04	0.11
USGS	-122.475				
Los Banos	37.106	94	0.05	0.01	0.05
CSMIP	-120.825				
Oakland - Outer Harbor Wharf (Struct)	37.816	95	0.45	--	0.32
CSMIP	-122.314				
Oakland - Outer Harbor Wharf, Grnd	37.816	95	0.29	0.07	0.27
CSMIP	-122.314				
San Francisco - 18-story Bldg, base	37.792	95	0.17	0.04	0.14
CSMIP	-122.400				
San Francisco - 18-story Bldg, structure	37.792	95	0.27	--	0.27
CSMIP	-122.400				
San Francisco - 6-story Bldg (struct)	37.762	95	0.28	--	0.19
CSMIP	-122.459				
San Francisco - 6-story Bldg, base	37.762	95	0.09	0.04	0.07
CSMIP	-122.459				
San Francisco - Rincon Hill	37.790	95	0.09	0.03	0.08
CSMIP	-122.390				
Yerba Buena Island	37.810	95	0.06	0.03	0.03
CSMIP	-122.360				
Dos Amigos Pumping Plant - Level 4	36.920	96	0.04	0.04	0.04
DWR/BuRec	-120.830				
Dos Amigos Pumping Plant - level 1	36.920	96	0.04	0.04	0.04
DWR/BuRec	-120.830				
Oakland - Caldecott Tunnel, Hwy 24	37.857	96	0.06	0.03	0.06
CSMIP	-122.214				

Peak Accelerations from the 17 October Loma Prieta Earthquake

Recording Station†	Lat Long	Dist (km)	Peak Acc (g) h1	V	h2
San Francisco, 575 Market, 25th level, Center USGS	37.790 -122.400	96	0.23	–	0.16
San Francisco, 575 Market, 25th level, Northwest USGS	37.790 -122.400	96	0.19	–	–
San Francisco, 575 Market, 34th level, Center USGS	37.790 -122.400	96	0.16	–	0.19
San Francisco, 575 Market, 34th level, Northwest USGS	37.790 -122.400	96	0.15	–	–
San Francisco, 575 Market, 42nd level, Center USGS	37.790 -122.400	96	0.19	–	0.14
San Francisco, 575 Market, 42nd level, Northwest USGS	37.790 -122.400	96	0.22	–	–
San Francisco, 575 Market, Ground Level USGS	37.790 -122.400	96	0.12	–	0.13
San Francisco, 575 Market, basement USGS	37.790 -122.400	96	0.08	0.06	0.11
San Francisco - 47-story Bldg, base CSMIP	37.796 -122.396	96	0.13	0.08	0.20
San Francisco - 47-story Bldg, structure CSMIP	37.796 -122.396	96	0.48	–	0.39
Berkeley - 2-story Hospital CSMIP	37.855 -122.256	97	0.11	0.04	0.12
Berkeley - 2-story Hospital (struct) CSMIP	37.855 -122.256	97	0.28	–	0.30
Emeryville, 6363 Christie Ave, 13th Floor USGS	37.844 -122.295	97	0.32	–	0.27
Emeryville, 6363 Christie Ave, 21st Floor USGS	37.844 -122.295	97	0.24	–	0.23
Emeryville, 6363 Christie Ave, Ground Floor USGS	37.844 -122.295	97	0.22	0.06	0.17
Emeryville, 6363 Christie Ave, Ground Site North USGS	37.844 -122.295	97	0.20	0.09	0.22
Emeryville, 6363 Christie Ave, Roof (31st) USGS	37.844 -122.295	97	0.39	–	0.38
Emeryville - 6363 Christie Ave, Ground Site Sout USGS	37.844 -122.295	97	0.22	0.06	0.26
San Francisco, 50 Beale St, Bechtel Bldg, 12th f Bechtel	37.792 -122.395	97	0.17	0.07	0.14
San Francisco, 50 Beale St, Bechtel Bldg, 24th f Bechtel	37.792 -122.395	97	0.21	0.10	0.14
San Francisco, 50 Beale St, Bechtel Bldg, base Bechtel	37.792 -122.395	97	0.14	0.07	0.14
San Francisco, 600 Montgomery, 21st Floor USGS	37.800 -122.400	97	0.22	–	0.20
San Francisco, 600 Montgomery, 29th Floor USGS	37.800 -122.400	97	0.15	0.11	0.17
San Francisco, 600 Montgomery, 49th Floor USGS	37.800 -122.400	97	0.31	0.14	0.29
San Francisco, 600 Montgomery, 5th Floor USGS	37.800 -122.400	97	0.28	–	0.24
San Francisco, 600 Montgomery, Basement USGS	37.800 -122.400	97	0.12	0.05	0.11
San Francisco, 600 Montgomery, Foundation USGS	37.800 -122.400	97	0.17	–	0.10
San Francisco, 600 Montgomery, Ground Level USGS	37.800 -122.400	97	0.18	–	0.15
San Francisco, Rincon Center - 7th floor Bldg	37.793 -122.393	97	0.42	0.13	0.22
San Francisco, Rincon Center - P-2 level Bldg	37.793 -122.393	97	0.10	0.03	0.08
San Francisco, Rincon Center - Roof	37.793	97	0.37	0.16	0.22

Recording Station†	Lat Long	Dist (km)	Peak Acc (g) h1	V	h2
Bldg	-122.393				
San Francisco - Pacific Heights	37.790	97	0.05	0.03	0.06
CSMIP	-122.430				
San Francisco - Telegraph Hill	37.800	97	0.08	0.03	0.06
CSMIP	-122.410				
Berkeley, Strawberry Canyon	37.870	98	0.04	0.02	0.08
USGS	-122.240				
Greenfield	36.321	98	0.08	0.06	0.08
CSMIP	-121.243				
San Francisco - Presidio	37.792	98	0.21	0.06	0.10
CSMIP	-122.457				
Treasure Island	37.825	98	0.16	0.02	0.11
CSMIP	-122.373				
UC Berkeley - Memorial Stadium	37.870	98	0.13	0.03	0.07
UCB/CDMG	-122.250				
Walnut Creek - 10-story Bldg, base	37.907	98	0.10	0.05	0.05
CSMIP	-122.065				
Walnut Creek - 10-story Bldg, structure	37.907	98	0.21	–	0.25
CSMIP	-122.065				
Berkeley, 2168 Shattuck Ave, 13th Floor	37.870	99	0.23	–	0.23
USGS	-122.270				
Berkeley, 2168 Shattuck Ave, 4th Floor	37.870	99	0.23	–	0.11
USGS	-122.270				
Berkeley, 2168 Shattuck Ave, Basement, East	37.870	99	0.09	0.02	0.11
USGS	-122.270				
Berkeley, 2168 Shattuck Ave, Basement, West	37.870	99	0.10	0.03	0.09
USGS	-122.270				
Berkeley, Haviland Hall	37.870	99	0.03	0.02	0.06
USGS	-122.260				
Berkeley - Lawrence Berkeley Lab	37.876	99	0.12	0.04	0.05
CSMIP	-122.249				
San Francisco - Cliff House	37.780	99	0.11	0.06	0.08
CSMIP	-122.510				
San Francisco - Letterman Hospital	37.799	99	0.07	0.07	0.15
USACE	-122.448				
San Francisco, VA Hospital, 7th Floor	37.783	100	0.34	0.08	0.22
USGS/VA	-122.504				
San Francisco, VA Hospital, Basement	37.783	100	0.08	0.05	0.16
USGS/VA	-122.504				
San Francisco - Golden Gate Bridge Abutment	37.806	100	0.12	0.06	0.24
USGS	-122.472				
Richmond, 2501 Rydin SE, Bulk Mail Center	37.884	101	0.08	0.04	0.11
USGS	-122.302				
Pleasant Hill - 3-story Bldg, base	37.946	102	0.08	0.03	0.13
CSMIP	-122.060				
Pleasant Hill - 3-story Bldg, structure	37.946	102	0.13	–	0.23
CSMIP	-122.060				
Point Bonita	37.820	104	0.07	0.03	0.07
CSMIP	-122.520				
Concord - 8-story Residential Bldg, base	37.979	105	0.06	0.03	0.06
CSMIP	-122.032				
Concord - 8-story Residential Bldg, structure	37.979	105	0.14	–	0.24
CSMIP	-122.032				
Bitterwater	36.395	107	0.06	0.03	0.07
CSMIP	-120.982				
Contra Loma Dam - Crest	37.972	107	0.05	0.03	0.07
BuRec	-121.829				
Richmond - 3-story Gvmt Office Bldg, base	37.938	108	0.12	0.04	0.09
CSMIP	-122.342				
Richmond - 3-story Gvmt Office Bldg, structure	37.938	108	0.24	–	0.20
CSMIP	-122.342				

Recording Station†	Lat Long	Dist (km)	Peak Acc (g) h1	V	h2
Richmond - City Hall Parking Lot CSMIP	37.935 -122.342	108	0.11	0.04	0.13
Martinez VA Hospital USGS/VA	37.993 -122.115	109	0.07	0.03	0.05
Richmond - 3-story Office Bldg, base CSMIP	37.978 -122.329	112	0.10	0.07	0.12
Richmond - 3-story Office Bldg, structure CSMIP	37.978 -122.329	112	0.32	–	0.29
Martinez Dam - Crest BuRec	38.010 -122.110	113	0.15	0.03	0.13
Martinez Dam - Toe BuRec	38.010 -122.110	113	0.07	0.02	0.09
Larkspur Ferry Terminal USGS	37.946 -122.508	115	0.10	0.06	0.14
Mare Island Building 47 USN	38.090 -122.170	124	0.04	0.01	0.04
Mare Island Dry Dock #3 Pump Well (struct) USN	38.090 -122.266	124	0.06	0.03	0.07
Mare Island Dry Dock #3 Tunnel (struct) USN	38.090 -122.266	124	0.06	0.03	0.07
Mare Island Pump House USN	38.090 -122.266	124	0.05	0.03	0.04
San Rafael - 3-story Office Bldg, structure CSMIP	38.196 -122.819	124	0.10	–	0.13
San Rafael 3-story Office Bldg, base CSMIP	38.196 -122.819	124	0.04	0.03	0.04
Olema - Point Reyes CSMIP	38.043 -122.797	138	0.11	0.06	0.16
Napa College CSMIP	38.270 -122.276	141	0.03	0.02	0.03
Santa Rosa - 14-story Res. Bldg, base CSMIP	38.437 -122.707	171	0.04	0.02	0.05
Santa Rosa - 14-story Res Bldg, structure CSMIP	38.437 -122.707	171	0.21	–	0.21
Santa Rosa - Hendley and Tupper CSMIP	38.437 -122.707	171	0.05	0.03	0.04
Santa Rosa - 5-story Bldg, base CSMIP	38.439 -122.711	172	0.06	0.03	0.06
Santa Rosa - 5-story Bldg, structure CSMIP	38.439 -122.711	172	0.11	–	0.13
Bodega Head - Doran Beach CSMIP	38.311 -123.052	175	0.04	0.02	0.04
Parkfield St A (approx loc) Kyoto	35.902 -120.442	180	0.02	0.02	0.02
Parkfield St B (approx loc) Kyoto	35.902 -120.442	180	0.02	0.02	0.01
Parkfield St C (approx loc) Kyoto	35.902 -120.442	180	0.02	0.02	0.01

† Recording location, followed by abbreviations of organization responsible for or providing data. The abbreviations have the following menaings (combined symbols indicate a cooperative program):

BuRec = U. S. Bureau of Reclamation;
CDMG = California Division of Mines and Geology;
CSMIP = California Strong Motion Instrumentation Program;
DWR = California Division of Water Resources;
Kyoto = Kyoto University;
LLNL = Lawrence Livermore National Laboratory;
UCB = University of California at Berkeley;
UCSC = University of California at Santa Cruz;
USACE = U. S. Army Corps of Engineers;

USGS = U. S. Geological Survey;
USN = U. S. Navy;
VA = U. S. Veterans Administration

*Corrections to the LLNL entries were communicated to us by S. Jarpe on 23 January, 1990; although these table entries have been changed from previous drafts of this paper, there was not time to correct the figures. The corrections are minor.