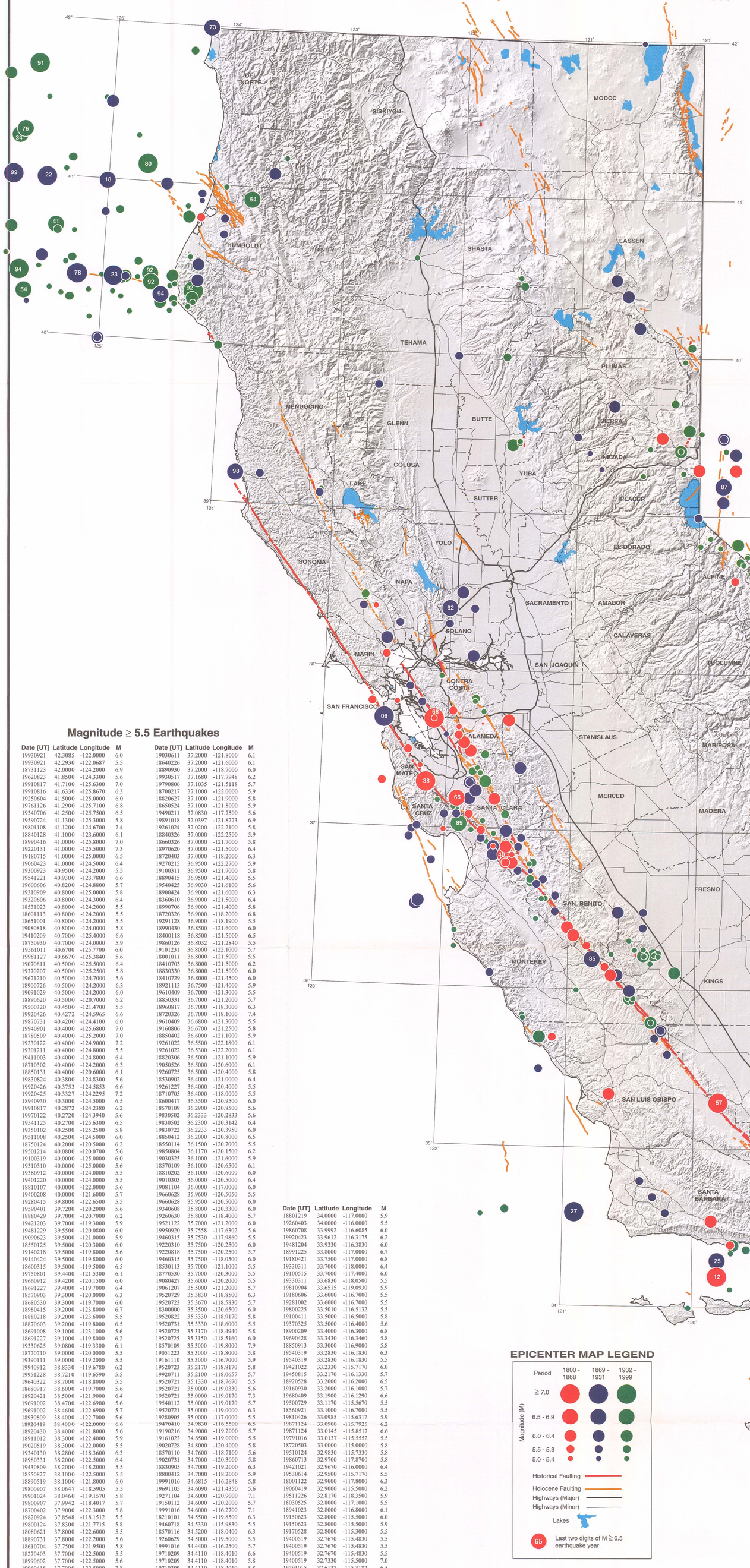
Epicenters of and Areas Damaged by M ≥ 5 California Earthquakes, 1800-1999

T. Toppozada, D. Branum, M. Petersen, C. Hallstrom, C. Cramer, M. Reichle

Digital representation by G. Faneros and R. Martin

2000



EXPLANATION

Earthquake Occurrences

Epicenters of the 800 known M≥5 earthquakes from 1800 through 1999 are displayed for California and a 100 km area bordering the state. M≥5 events in urban areas can cause damage. The epicenters of the strongest earthquakes [M≥6.5] are labeled with their years of occurrence. The 383 earthquakes of M≥5.5 can be identified on the map using the table that lists them in order of decreasing latitude and longitude, and gives date and magnitude [M]. For preinstrumental [pre-1932] earthquakes M is determined predominantly from the size of the areas shaken at different intensities, calibrated using modern earthquakes [Toppozada and Branum, in press]. Seismographic values of M are used as available. Moment M is used when available, otherwise Richter local M, or surface wave M is used.

We divided the 200 year history into three nearly equal time periods, distinguished by red, blue, and green in the epicenter map and bar graph, to show the changes in earthquake occurrence and identification with time. The time distribution of M≥6 earthquake occurrences in the bar graph reflects the increased population and earthquake reporting following the 1849 Gold Rush. Since 1850, 177 earthquakes of M≥6 were identified, indicating an average rate of 1.2 per year. There is no change in this apparent rate in the post-1931 seismographic period when the M≥6 record is surely complete. However, the epicenter map shows few pre-1869 epicenters [red] in the sparsely populated northwestern, eastern, and southeastern parts of California. This suggests that earthquakes in those parts were not completely reported or identified before 1869. Accounting for such earthquakes would slightly increase the 1850-1931 rate above the 1.2 per year rate of M≥6 earthquakes since 1932.

The 1800-1868 period [red] includes the pre-1850 period when newspapers were not available and information came largely from the earthquake damage reported at the 21 Missions near the coast from San Diego to Sonoma. In the 1869-1931 period [blue] information was based largely on analysis of felt accounts reported in newspapers, with a few seismographic determinations starting in 1899 for some of the large M≥6 earthquakes. The epicenters and magnitudes in the first two periods are based predominantly on analysis and interpretation of felt effects by Toppozada and others 1978, 1981, and 1982, with revisions and additions.

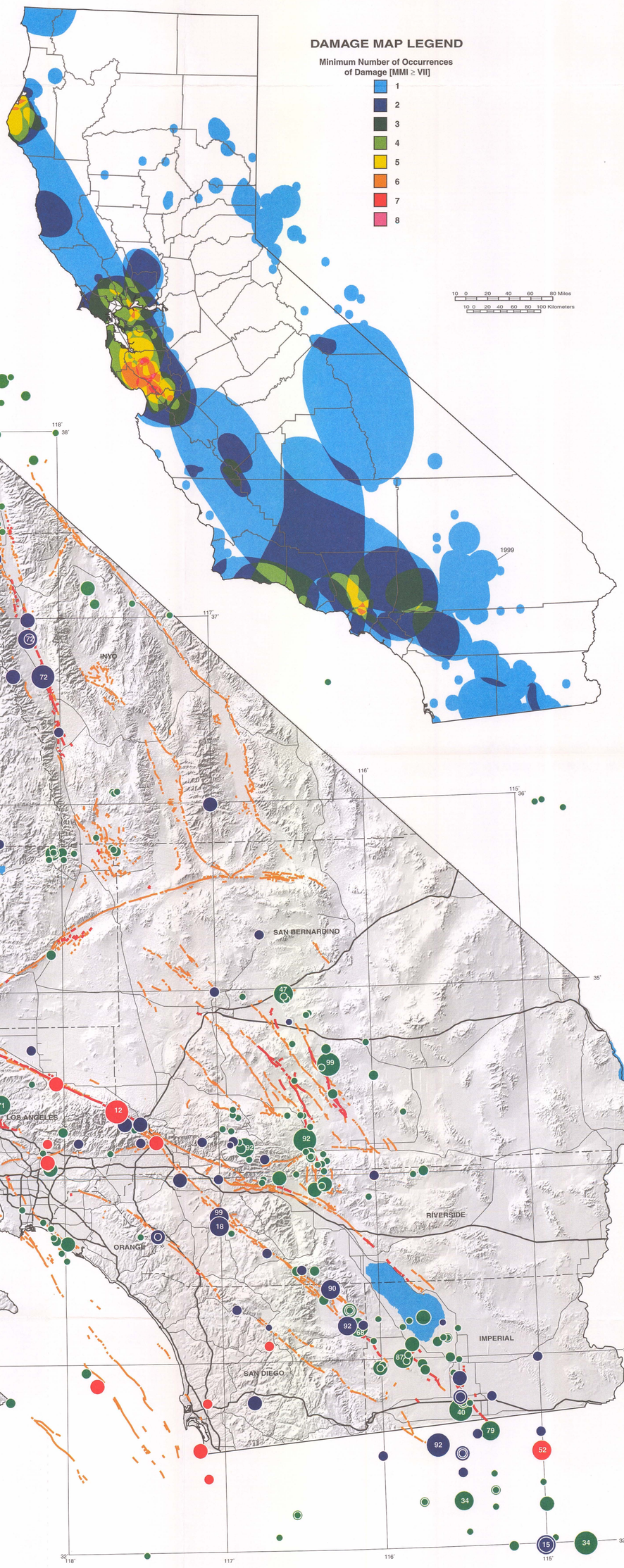
In southern California the seismographic period [green] started in 1932 with the establishment of the Caltech Seismological Laboratory. In northern California the Berkeley Seismological Laboratory operated two seismic stations from 1887, but started to routinely determine instrumental epicenters and magnitudes in 1942 [Bolt and Miller, 1975]. The U.S. Geological Survey installed seismic networks starting in 1969 in northern California and in the mid 1970s in southern California, and eventually integrated their data with those of Caltech and Berkeley. We list the main sources of information below. Toppozada and Branum [in press] list the detailed sources of information.

Earthquake Damage

The epicenters are the points where fault rupture initiated. They are not necessarily the points of most intense shaking or damage, because the entire fault rupture radiates strong shaking. For example, the epicenter of the M 7.8 great 1906 San Francisco earthquake indicates that rupture initiated near San Francisco. Within seconds, the 1906 rupture propagated along the San Andreas Fault ~130 km to the southeast to San Benito County, and ~290 km to the northwest to Humboldt County. This earthquake damaged weak structures significantly [Modified Mercalli Intensity VII or greater] between San Benito and Humboldt counties, and up to 80 km away from the fault. The area damaged in 1906 on the damage map overlaps smaller areas damaged by other earthquakes.

The damage map shows the areas shaken at MMI VII or greater, and the minimum number of times such damage has occurred since 1800. The number of such occurrences is high in the San Francisco Bay Area due to the major 1838, 1868, 1906, 1989 and associated earthquakes. Earthquakes of M≥5.5 having no definable damaged area are shown by light blue circles of size proportional to M to simulate damaged areas, only if they occurred outside the colored damaged areas. The M 7.1 Hector Mine earthquake is such an event, and its circle is labeled 1999 for illustration. These circles are not shown where they would overlap other colored damaged areas. Consequently, the number of times damage has occurred can be higher than indicated by the colors on the damage map.

For further information on how earthquakes and their effects are measured, see DMG Note 32, or visit our website at www.consrv.ca.gov/dmg/pubs/notes/32/index.htm.



Magnitude ≥ 5.5 Earthquakes

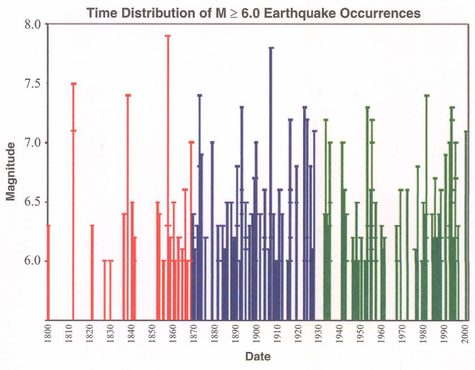
Date [UT]	Latitude	Longitude	M
19930921	42.3085	-122.0000	6.0
19930921	42.2930	-122.0687	5.5
18731123	42.0000	-124.2000	6.9
19620823	41.8500	-124.3300	5.6
19910817	41.7100	-125.6300	7.0
19910816	41.6330	-125.8670	6.3
19250604	41.5000	-125.0000	6.0
19761126	41.2900	-125.7100	6.8
19340706	41.2500	-125.7500	6.5
19590724	41.1300	-125.3000	5.8
19801108	41.1200	-124.6700	7.4
18840128	41.1000	-123.6000	6.1
18990416	41.0000	-125.8000	7.0
19220131	41.0000	-125.5000	7.3
19180715	41.0000	-125.0000	6.5
19060423	41.0000	-124.5000	6.4
19300923	40.9500	-124.2000	5.5
19541221	40.9300	-123.7800	6.6
19600606	40.8200	-124.8800	5.7
19310909	40.8000	-125.0000	5.8
19320606	40.8000	-124.3000	6.4
18531023	40.8000	-124.2000	5.5
18601113	40.8000	-124.2000	5.5
18651001	40.8000	-124.2000	5.5
19080818	40.8000	-124.0000	5.8
19410209	40.7000	-125.4000	6.6
18750930	40.7000	-124.0000	5.9
19561011	40.6700	-125.7700	6.0
19981127	40.6670	-125.3840	5.6
19070811	40.5000	-125.5000	6.4
19370207	40.5000	-125.2500	5.8
19671210	40.5000	-124.7000	5.6
18900726	40.5000	-124.2000	6.3
19091029	40.5000	-124.2000	6.0
18890620	40.5000	-120.7000	6.2
19500320	40.4500	-121.4700	5.5
19920426	40.4272	-124.5965	6.6
19870731	40.4200	-124.4100	6.0
19940901	40.4000	-125.6800	7.0
18780509	40.4000	-125.2000	7.0
19230122	40.4000	-124.9000	7.2
19301211	40.4000	-124.8000	5.5
19411003	40.4000	-124.8000	6.4
18710302	40.4000	-124.2000	6.3
18850131	40.4000	-120.6000	6.1
19830824	40.3800	-124.8300	5.6
19920426	40.3753	-124.5853	6.6
19920425	40.3327	-124.2295	7.2
18940930	40.3000	-124.5000	6.5
19910817	40.2872	-124.2380	6.2
19970122	40.2720	-124.3940	5.6
19541125	40.2700	-125.6300	6.5
19350102	40.2500	-125.2500	5.8
19511008	40.2500	-124.5000	6.0
18750124	40.2000	-120.5000	6.2
19501214	40.0800	-120.0700	5.6
19100319	40.0000	-125.0000	6.0
19310310	40.0000	-125.0000	5.6
19380912	40.0000	-124.0000	5.5
19401220	40.0000	-124.0000	5.5
18810107	40.0000	-122.0000	5.6
19400208	40.0000	-121.6000	5.7
19280415	39.8000	-122.6500	5.5
19590401	39.7200	-120.2000	5.6
18880429	39.7000	-120.7000	6.2
19421203	39.7000	-119.3000	5.9
19481229	39.5500	-120.0800	6.0
19090623	39.5000	-121.0000	5.9
18550125	39.5000	-120.3000	6.0
19140218	39.5000	-119.8000	5.6
19140424	39.5000	-119.8000	6.0
18600315	39.5000	-119.5000	6.5
19750801	39.4400	-121.5300	6.1
19660912	39.4200	-120.1500	6.0
18691227	39.4000	-119.7000	6.4
18570903	39.3000	-120.0000	6.3
18680530	39.3000	-119.7000	6.0
18980415	39.2000	-123.8000	6.7
18880218	39.2000	-123.6000	5.5
18870603	39.2000	-119.8000	6.5
18691008	39.1000	-123.1000	5.6
18691227	39.1000	-119.8000	6.2
19330625	39.0800	-119.3300	6.1
18770710	39.0000	-120.0000	5.5
19390111	39.0000	-119.2000	5.5
19940912	38.8330	-119.6780	6.2
19951228	38.7210	-119.6590	5.5
19640322	38.7000	-118.8000	5.5
18680917	38.6000	-119.7000	5.6
18920421	38.5000	-121.9000	6.4
19691002	38.4700	-122.6900	5.6
19691002	38.4600	-122.6900	5.7
18930809	38.4000	-122.7000	5.6
18920419	38.4000	-122.0000	6.6
18920430	38.4000	-121.8000	5.6
18911012	38.3000	-122.4000	5.9
19020519	38.3000	-122.0000	5.5
19340130	38.2800	-118.3600	6.3
18980331	38.2000	-122.5000	6.4
19430809	38.2000	-118.2000	5.5
18550827	38.1000	-122.5000	5.5
18890519	38.1000	-121.8000	6.0
18800907	38.0647	-118.5905	5.5
19901024	38.0460	-119.1570	5.8
19800907	37.9942	-118.4017	5.7
18700402	37.9000	-122.3000	5.8
19820924	37.8548	-118.1512	5.5
19800124	37.8300	-121.7715	5.8
18080621	37.8000	-122.6000	5.5
18890731	37.8000	-122.2000	5.6
18610704	37.7500	-121.9500	5.8
18270403	37.7000	-122.5000	5.5
18990602	37.7000	-122.5000	5.6
19060418	37.7000	-122.5000	7.8
18681021	37.7000	-122.1000	7.0
18660715	37.7000	-121.5000	6.0
19830107	37.6637	-119.0082	5.6
19800525	37.6275	-118.9273	6.0
19800525	37.6250	-118.8592	5.7
19800525	37.6090	-118.8468	6.2
18640521	37.6000	-121.9000	5.8
19810930	37.5852	-118.8665	5.7
19830107	37.5788	-118.9043	5.6
19410914	37.5670	-118.7330	5.5
19410914	37.5670	-118.7330	5.5
19800525	37.5607	-118.8310	5.9
18640305	37.5528	-121.8550	6.0
19860721	37.5388	-118.4425	6.4
19781004	37.5295	-118.6608	5.8
19800527	37.5057	-118.8262	5.9
18560215	37.5000	-122.3000	5.9
18581126	37.5000	-121.8000	6.2
19270918	37.5000	-118.7500	5.5
18720411	37.5000	-118.5000	6.8
19860331	37.4790	-121.6847	5.6
19841123	37.4697	-118.5968	5.8
19381203	37.4530	-118.6040	5.7
19841126	37.4487	-118.6475	5.6
19841123	37.4372	-118.6070	5.5
18810410	37.4000	-121.4000	6.3
19100506	37.3300	-118.4200	6.0
19120105	37.3300	-118.4200	5.5
19840424	37.3097	-121.6767	6.2
18560102	37.3000	-122.5000	5.7
18380600	37.3000	-122.1500	7.4
18910102	37.3000	-121.8000	5.8
19030803	37.3000	-121.8000	6.2
19110701	37.2500	-121.7500	6.4
18651008	37.2000	-121.9000	6.6
19030611	37.2000	-121.8000	6.1
18640226	37.2000	-121.6000	6.1
18890930	37.2000	-118.7000	6.0
19930517	37.1680	-117.7948	6.2
19790806	37.1035	-121.5118	5.7
18700217	37.1000	-122.0000	5.9
18820627	37.1000	-121.9000	5.8
18650524	37.1000	-121.8000	5.9
19490211	37.0830	-117.7500	5.6
19891018	37.0397	-121.8773	6.9
19261024	37.0200	-122.2100	5.8
18840326	37.0000	-122.2500	5.9
18660326	37.0000	-121.7000	5.8
18970620	37.0000	-121.5000	6.4
18720403	37.0000	-118.2000	6.3
19270215	36.9500	-122.2700	5.9
19100311	36.9500	-121.7000	5.8
18890415	36.9500	-121.4000	5.5
19540425	36.9030	-121.6100	5.6
18900424	36.9000	-121.6000	6.3
18360610	36.9000	-121.5000	6.4
18990706	36.9000	-121.4000	5.8
18720326	36.9000	-118.2000	6.8
19291128	36.9000	-118.1900	5.5
18990430	36.8500	-121.6000	6.0
18400118	36.8500	-121.5000	6.5
19860126	36.8032	-121.2840	5.5
19101231	36.8000	-122.1000	5.7
18001011	36.8000	-121.5000	5.5
18410703	36.8000	-121.5000	6.2
18830330	36.8000	-121.5000	6.0
18410729	36.8000	-121.4500	6.0
18921113	36.7500	-121.4000	5.9
19610409	36.7000	-121.3000	5.5
18850331	36.7000	-121.2000	5.7
18960817	36.7000	-118.3000	6.3
18720326	36.7000	-118.1000	7.4
19610409	36.6800	-121.3000	5.5
19160806	36.6700	-121.2500	5.8
18850402	36.6000	-121.1000	5.9
19261022	36.5500	-122.1800	6.1
19261022	36.5300	-122.2000	6.1
18820306	36.5000	-121.1000	5.9
19050526	36.5000	-120.6000	6.1
19260725	36.5000	-120.4000	5.8
18530902	36.4000	-121.0000	6.4
19261227	36.4000	-120.4000	5.5
18710705	36.4000	-118.0000	5.5
18600417	36.3500	-120.9500	6.0
18570109	36.2900	-120.8500	5.6
19830502	36.2333	-120.2833	5.6
19830502	36.2300	-120.3142	6.4
19830722	36.2233	-120.3950	6.0
18850412	36.2000	-120.8000	6.5
18550114	36.1500	-120.7000	5.5
19850804	36.1170	-120.1500	6.2
19030325	36.1000	-121.6000	5.9
18570109	36.1000	-120.6500	6.1
18810202	36.1000	-120.6000	6.0
19010303	36.0000	-120.5000	6.4
19081104	36.0000	-117.0000	6.0
19660628	35.9600	-120.5050	5.5
19660628	35.9500	-120.5000	6.0
19340608	35.8000	-120.3300	6.0
19260630	35.8000	-118.4000	5.7
19521122	35.7000	-121.2000	6.0
19950920	35.7558	-117.6302	5.6
19460315	35.7530	-117.9860	5.5
19220310	35.7500	-120.2500	6.0
19220818	35.7500	-120.2500	5.7
19460315	35.7500	-118.0500	6.0
18530113	35.7000	-121.1000	5.5
18770530	35.7000	-120.3000	5.5
19080427	35.6000	-120.2000	5.5
19061207	35.5000	-121.2000	5.7
19520729	35.3830	-118.8500	6.3
19520723	35.3670	-118.5830	5.7
18300000	35.3500	-120.6500	6.0
19520822	35.3330	-118.9170	5.8
19520731	35.3330	-118.6000	5.5
19520725	35.3170	-118.4940	5.8
19520725	35.3150	-118.5160	6.0
18570109	35.3000	-119.8000	7.9
19051223	35.3000	-118.8000	5.8
19161110	35.3000	-116.7000	5.9
19520723	35.2170	-118.8170	5.8
19920711	35.2100	-118.0657	5.7
19520721	35.1330	-118.7670	5.5
19520721	35.0000	-119.0330	5.6
19520721	35.0000	-119.0170	7.3
19540112	35.0000	-119.0170	5.7
19520721	35.0000	-119.0000	6.3
19280905	35.0000	-117.0000	5.5
19470410	34.9830	-116.5500	6.5
19190216	34.9000	-119.2000	5.7
19161023	34.8500	-119.0000	5.5
19020728	34.8000	-120.4000	5.8
18570110	34.7600	-118.7100	5.6
19020731	34.7000	-120.3000	5.8
18830905	34.7000	-119.2000	6.3
18800412	34.7000	-118.2000	5.9
19991016	34.6815	-116.2848	5.8
19691105	34.6000	-121.4350	5.6
19271104	34.6000	-120.9000	7.1
19150112	34.6000	-120.2000	5.7
19991016	34.6000	-116.2700	7.1
18210101	34.5500	-119.8500	6.3
19460718	34.5330	-115.9830	5.5
18570116	34.5200	-118.0400	6.3
19260629	34.5000	-119.5000	5.5
19991016	34.4400	-116.2500	5.7
19710209	34.4110	-118.4010	6.6
19710209	34.4110	-118.4010	5.8
19710209	34.4110	-118.4010	5.8
18060325	34.4000	-119.7000	5.5
19780813	34.3970	-119.6820	6.0
19410701	34.3700	-119.5800	5.9
18121208	34.3700	-117.6500	7.5
19940117	34.3263	-118.6983	6.0
19250629	34.3000	-119.8000	6.8
19260218	34.3000	-119.5000	5.5
18930404	34.3000	-118.6000	5.8
18940730	34.3000	-117.6000	6.2
18990722	34.3000	-117.5000	6.4
19910628	34.2615	-117.9995	5.8
19940117	34.2580	-118.4738	6.2
19940117	34.2133	-118.5370	6.7
19920628	34.2002	-116.4367	7.3
18121221	34.2000	-119.8000	7.1
18030000	34.2000	-118.1000	5.5
18890828	34.2000	-117.9000	5.6
18920614	34.2000	-117.5000	5.5
18581216	34.2000	-117.4000	6.0
18990722	34.2000	-117.4000	5.9
19070920	34.2000	-117.1000	5.8
19300116	34.2000	-116.9000	5.5
19920628	34.1670	-116.8268	6.5
19920628	34.1618	-116.8522	5.5
19920628	34.1307	-116.4082	5.7
19920629	34.1045	-116.4032	5.5
18930519	34.1000	-119.4000	5.8
18550711	34.1000	-118.1000	6.0
18890207	34.1000	-116.7000	5.6
19730221	34.0990	-119.0390	5.9
19871001	34.0670	-118.0830	6.0
19490502	34.0170	-115.6830	5.8
18270924	34.0000	-119.0000	6.0
19230723	34.0000	-117.2500	6.2
18801122	34.0000	-117.0000	5.5
18801219	34.0000	-117.0000	5.9
19260403	34.0000	-116.0000	5.5
19860708	33.9992	-116.6085	6.0
19920423	33.9612	-116.3175	6.2
19481204	33.9330	-116.3830	6.0
18991225	33.8000	-117.0000	6.7
19180421	33.7500	-117.0000	6.8
19330311	33.7000	-118.0000	6.4
19100515	33.7000	-117.4000	6.0
19330311	33.6830	-118.0500	5.5
19810904	33.6515	-119.0930	5.9
19180606	33.6000	-116.7000	5.5
19281002	33.6000	-116.7000	5.5
19800225	33.5010	-116.5132	5.5
19100411	33.5000	-116.5000	5.8
19370325	33.5000	-116.4000	5.6
18900209	33.4000	-116.3000	6.8
19690428	33.3430	-116.3460	5.8
18850913	33.3000	-116.9000	5.8
19540319	33.2830	-116.1830	6.3
19540319	33.2830	-116.1830	5.5
19421022	33.2330	-115.7170	6.0
19450815	33.2170	-116.1330	5.7
18920528	33.2000	-116.2000	6.5
19160930	33.2000	-116.1000	5.7
19680409	33.1900	-116.1290	6.6
19500729	33.1170	-115.5670	5.5
18560921	33.1000	-116.7000	5.5
19810426	33.0985	-115.6317	5.9
19871124	33.0900	-115.7925	6.2
19871124	33.0145	-115.8517	6.6
19791016	33.0137	-115.5552	5.5
18720503	33.0000	-115.0000	5.8
19510124	32.9830	-115.7330	5.8
19860713	32.9700	-117.8700	5.8
19421021	32.9670	-116.0000	6.4
19530614	32.9500	-115.7170	5.5
18001122	32.9000	-117.8000	6.3
19060419	32.9000	-115.5000	6.2
19511226	32.8170	-118.3500	5.9
18030525	32.8000	-117.1000	5.5
18941023	32.8000	-116.8000	6.1
19150623	32.8000	-115.5000	6.0
19150623	32.8000	-115.5000	5.9
19170528	32.8000	-115.3000	5.5
19400519	32.7670	-115.4830	5.5
19400519	32.7670	-115.4830	5.5
19400519	32.7670	-115.4830	5.5
19400519	32.7330	-115.5000	7.0
19791015	32.6137	-115.3182	6.5
19180501	32.6000	-115.4000	5.6
19191001	32.6000	-115.0000	5.9
18620527	32.5500	-117.1500	6.2
18920224	32.5500	-115.6500	7.3
18751115	32.5000	-115.5000	6.2
19231107	32.5000	-115.5000	5.5
19270101	32.5000	-115.5000	5.8
19270101	32.5000	-115.5000	5.5
18521129	32.5000	-115.0000	6.5
18630625	32.4000	-117.1000	5.8
19210908	32.4000	-115.5000	5.5
19540201	32.3000	-115.3000	5.6
19581201	32.2500	-115.7500	5.8
19581201	32.2500	-115.7500	5.5
19341230	32.2500	-115.5000	6.5
19800609	32.2170	-114.9830	6.4
19491104	32.2000	-116.5500	5.7
19350224	32.0000	-115.2000	5.5
18910730	32.0000	-115.0000	6.0
19151121	32.0000	-115.0000	6.6
19341231	32.0000	-114.7500	7.0
19641222	31.8000	-117.1000	5.6
19660807	31.8000	-114.5000	6.3
19630611	31.7960	-116.2690	5.8
19560209	31.7500	-115.9170	6.5
19560209	31.7500	-115.9170	6.0
19560209	31.7500	-115.9170	5.7
19560209	31.7500	-115.9170	5.7
19560209	31.6000	-115.7000	5.8
19541017	31.5000	-116.5000	5.7
19541024	31.5000	-116.0000	6.0
19541112	31.5000	-116.0000	6.3
19560214	31.5000	-115.5000	6.2
19560215	31.5000	-115.5000	6.2
19030124	31.5000	-115.0000	6.6

EPICENTER MAP LEGEND

Period	1800 - 1868	1869 - 1931	1932 - 1999
Magnitude (M) ≥ 7.0	●	●	●
6.5 - 6.9	●	●	●
6.0 - 6.4	●	●	●
5.5 - 5.9	●	●	●
5.0 - 5.4	●	●	●

Historical Faulting
Holocene Faulting
Highways (Major)
Highways (Minor)
Lakes
65 Last two digits of M ≥ 6.5 earthquake year

Time Distribution of M ≥ 6.0 Earthquake Occurrences



Main Sources of Information

Bolt, B.A. and Miller, R.D. (1975). Catalogue of earthquakes in northern California and adjoining areas, 1 January 1910 - 31 December 1972: Seismographic Stations, University of California, Berkeley, California, 567 p.

Caltech/USGS earthquake catalog, http://www.scecdc.scec.org/catalog-search.html. Southern California earthquake catalog and phase data, Southern California Seismic Network, U.S. Geological Survey, Pasadena; Caltech Seismological Laboratory, California Institute of Technology, Pasadena.

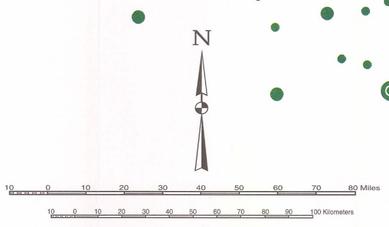
Toppozada, T.R. and Branum, D.M. (in press). California M ≥ 5.5 earthquakes, history and areas damaged, *in* Lee, W.H., Kanamori, H. and Jennings, P., International Handbook of Earthquake and Engineering Seismology, International Association of Seismology and Physics of the Earth's Interior.

Toppozada, T.R. and Parke, D.L. (1982). Areas damaged by California earthquakes, 1900-1949, California Division of Mines and Geology Open-File Report 82-17, 65 p.

Toppozada, T.R., Parke, D.L. and Higgins, C.T. (1978). Seismicity of California 1900-1931, California Division of Mines and Geology Open-File Report 135.

Toppozada, T.R., Real, C.R. and Parke, D.L. (1981). Preparation of isoseismal maps and summaries of reported effects for pre-1900 California earthquakes, California Division of Mines and Geology Open-File Report 81-11 SAC, 182 p.

UC Berkeley/USGS earthquake catalog, http://quake.geo.berkeley.edu/ncedc/catalog-search.html. Northern California earthquake catalog and phase data, Northern California Seismic Network, U.S. Geological Survey, Menlo Park; Berkeley Seismological Laboratory, University of California, Berkeley, California.



DEM modified from U.S.G.S. digital file.

Copyright ©2000 California Department of Conservation. All rights reserved. No part of this publication may be reproduced without written consent of the California Department of Conservation.

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

MINES AND GEOLOGY
CALIFORNIA CONSERVATION

OSP 00 45613