San Francisco—April 1906

California Earthquakes

by Charles F. Richter

The known history of California earthquakes begins with Spanish exploration and settlement. On July 28, 1769, the expedition of Gaspar de Portolá, which had set out from San Diego to investigate the reported fine harbor of Monterey, was in camp on the Santa Ana River near the present site of Olive in Orange County. They were alarmed by a locally strong earthquake. It is noteworthy that they continued to feel aftershocks for several days, until they were well up the coast in what is now Ventura County. This suggests that the first known earthquake was not a local affair but possibly a major earthquake on one of the principal faults.

San Gabriel Mission was founded in 1776. Earthquakes there were then so frequent that Father Serra referred to the San Gabriel Valley as El Valle de los Temblores, or Earthquake Valley.

In December 1812 there were two important

earthquakes; accounts at first became confused together but have now been disentangled. The one on December 8 occasioned the first loss of life due to earthquakes in California; a tower at San Juan Capistrano Mission collapsed, and 40 of the congregation were killed. There was also some damage at San Gabriel. On December 21 there was a much larger earthquake farther west which wrecked the westernmost mission, Purisima, and damaged others as far east as San Fernando. This major earthquake appears to have originated in or near Santa Barbara Channel. There are unsatisfactory reports of a sea wave caused by it. The late Professor G. D. Louderback, who investigated original documents of the period, was convinced of the reality of this wave. A ship then anchored off Gaviota reported that the water was seen splashing up in the canyons —from which Louderback inferred that it might have risen to 50 feet. This whole matter has lately assumed importance in estimating possible risks to installations on the coast, but opinions differ widely.

Small waves are known to have been caused by earthquakes on our coast, notably one in 1927 which rose to about eight feet along the west coast of Santa Barbara and San Luis Obispo counties. The only recorded disaster from such waves on our coast occurred at Crescent City in March 1964, when the waves caused by the great Alaskan earthquake piled up there and caused local flooding.

Louderback clarified the history of two important early earthquakes—one in 1836 on the east side of San Francisco Bay, probably associated with the Haywards fault, like that of 1868; and one in 1838, almost certainly on the San Andreas fault, like that of 1906, and probably also a major event.

Of much public importance is the historical record of a great earthquake on January 9, 1857, which originated on the San Andreas fault in southern California; faulting probably then extended from San Luis Obispo County to a point north of San Gorgonio Pass. Fort Tejon, then an army post, now a historical monument, was near the middle of the faulted extent, and the buildings were considerably damaged. There is much evidence that this earthquake was comparable in magnitude, extent of faulting, and local intensities with that of 1906. The 1857 earthquake is now the principal factor in considering earthquake risk to existing or projected construction and development in much of southern California, since at many sites a structure which would survive a repetition of the 1857 event probably would not be critically damaged by other earthquakes.

The Haywards earthquake of 1868 was associated with displacements on the Haywards fault, which runs through the heavily settled area on the east side of San Francisco Bay (and through the grounds of the university at Berkeley). The area of damage included part of San Francisco, where this was called "the great earthquake" until 1906.

In point of magnitude, the Owens Valley earthquake of 1872 may have been the largest in our area during the short historical period. Fault scarps and other effects were produced which can still be seen. Most of the town of Lone Pine was destroyed, with a loss of 27 lives.

A little-known but widely felt earthquake in 1885 originated in the mountainous area northwest of San Luis Obispo and may have been associated with the controversial Nacimiento fault.

In April 1892 two earthquakes seriously damaged many of the towns in the Sacramento Valley, notably Vacaville, Winters, and Dixon.

Two strong earthquakes occurred in 1899 in southern California: one in July, probably on the San Andreas fault, which caused many slides in Cajon Pass; and one on Christmas day, which heavily damaged the town of San Jacinto, though its center was on the San Jacinto fault in the mountains to the southeast.

Many books and papers have been written about the great earthquake of April 18, 1906. The disaster at San Francisco was of course of great human interest and drew attention to possible preventative measures. Seismologists and geologists were greatly concerned with the conspicuous lateral displacements along the San Andreas fault. Although the relation between earthquakes and faulting had been well formulated in Japan following an earthquake there in 1891, the new observations of 1906, substantiated as they were by exact observation of the displacements of survey monuments, led to the clear formulation by Harry F. Reid of the elastic rebound theory of earthquakes.

Misapprehensions and misstatements about the disaster of 1906 still persist. One of these consists in underplaying the losses in San Francisco due directly to earthquake damage; while much less than those due to fire, they were nevertheless large. Of course the fire losses were due in large part to failure of the water supply by disruption of the main supply lines from the reservoirs, which ran along the San Andreas fault line, and by breaking up of lines from local tanks and reservoirs due to shaking and sliding of the ground in the city.

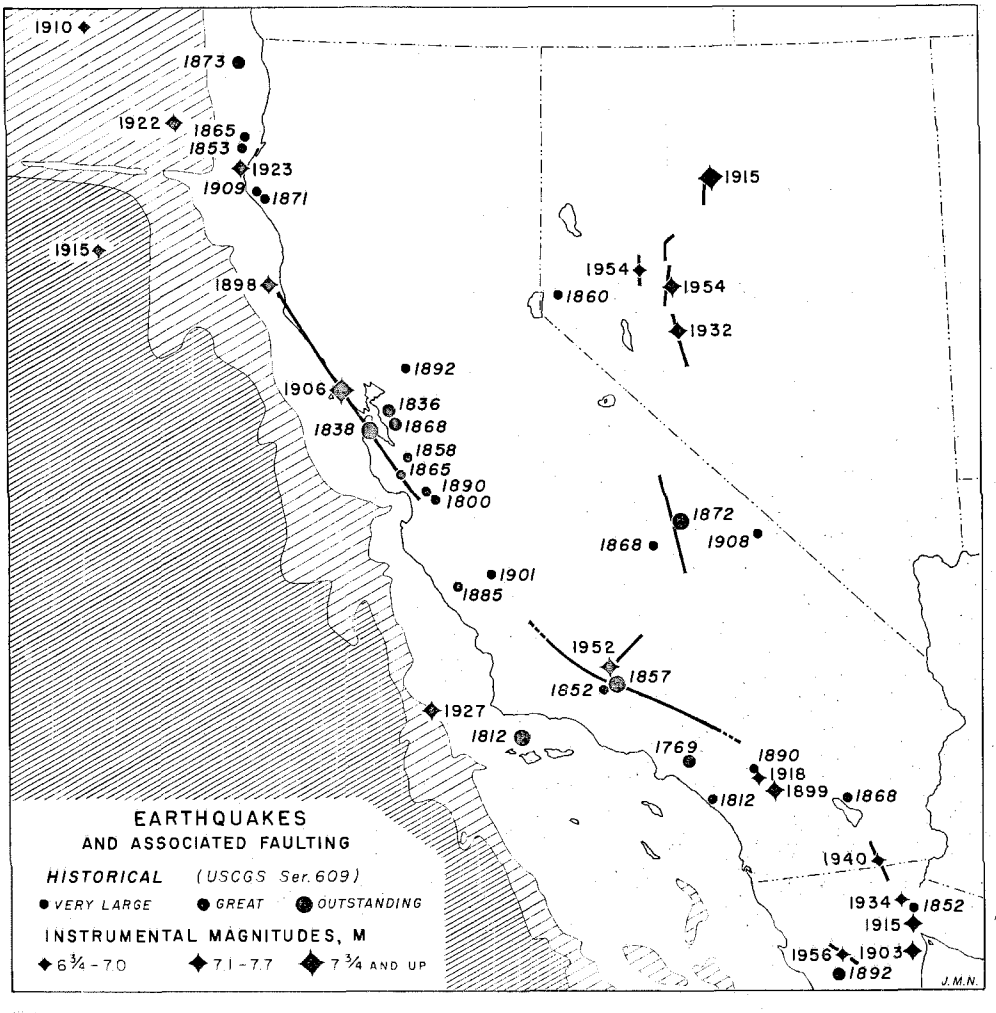
Loss of life is sometimes estimated as low as 390, though 700 is probably a better guess. We shall never know how many perished in the fire-swept areas, from which bodies could not have been completely recovered. Outside San Francisco

the loss of life is better documented; it amounts to over 200, including 61 at Santa Rosa, 19 in San Jose, and the shocking figure of at least 112 at Agnews State Hospital near San Jose.

In San Francisco the earthquake provided one of the best documented cases of relation of earthquake effects to ground condition. All the effects of heavier shaking, by which the ground was significantly deformed, were on the area of filled land surrounding the lower part of Market Street, or on small areas of fill in the hills, or on the sands toward the coast. The new post office on Market Street was just outside the area of made land; it was relatively undamaged. Much is sometimes made of the fact that the Ferry Building, with its conspicuous tower, survived; it is not generally known that the tower had to be torn down and rebuilt.

This was a truly great earthquake; it cut a broad swath of damage extending for over 200 miles along the San Andreas fault. It was felt by persons over most of California, and into Oregon and Nevada. It wrote spectacular seismograms at distant stations. One should bear these facts in mind when persons impressed by local earthquake disasters like our Long Beach earthquake of 1933, or like the one which cost 12,000 lives in Morocco in 1960, insist that these two must be listed as major earthquakes. When considered from the point of view of risk, safety, and disaster planning, such classifications are seriously misleading. Awareness of the inadequacies of the existing classification procedures led to setting up the magnitude scale. When we assign a magnitude 8.3 to the 1906 earthquake and 6.3 to the Long Beach event, this is not a vague or arbitrary estimate; it expresses the observed fact that the ground disturbance, as measured by seismograms at comparable distances from the two occurrences, was of the order of 100 times greater in 1906 than in 1933.

In many countries earthquake disasters have led to the setting up of scientific, government-sponsored agencies to work toward the prevention of future disasters. In California the events of 1906 led to the organization of the Seismological Society of America; but there was no further support either from governmental sources or from the general public. Instead, there was a public policy of hushing up discussion of earthquakes on the shortsighted excuse that it might be bad for business; and it was customary to refer to the disaster



Larger earthquakes of the California region. Extent of faulting is indicated by dark lines.

Santa Barbara Mission—after the Santa Barbara earthquake of 1925.

of 1906 as a fire only. This policy was successful in it main objectives: It remained possible to construct commercial and public buildings carelessly and cheaply, with no attention to the possibility of earthquake shaking. There was very little effective building regulation of any kind in California until the 1920's. At the same time, local insurance organizations and agents, themselves deceived and unaware of the true risk, were selling earthquake coverage without regard to actuarial soundness.

For some years following 1906 there were relatively few noteworthy earthquakes in California; the main centers of population were not affected. There was a definite increase in activity beginning about 1915. In June of that year a destructive earthquake affected most of the towns in Imperial Valley; in October there was a major earthquake with faulting in central Nevada, in a very thinly settled area. In 1918 there was a large earthquake on the San Jacinto fault, which again severely damaged the town of San Jacinto. A minor earthquake in June 1920 damaged the town of Inglewood and led to the identification and naming of the Inglewood fault, one of the principal sources of earthquake risk in the metropolitan Los Angeles area.

The Santa Barbara earthquake occurred in 1925. It had a magnitude of about 6.3, close to that of the later Long Beach earthquake. Although some millions of dollars in damage was caused, and at least 12 persons were killed, the disastrous effects were not extensive because there were few centers of population in the heavily shaken region. However, insurance organizations were disturbed by the amount of claims that had to be settled, and there was a sudden tightening with reference to earthquake insurance. Competent inspection of damaged buildings at Santa Barbara showed such serious deficiencies that considerable impetus was lent to efforts then being made by business, engineering, and scientific organizations to draft more appropriate building codes and bring about their enforcement.

The Long Beach earthquake of 1933, originating along the Inglewood fault, was a major disaster because of the relatively urbanized character of the most severely shaken area, and because of constructional deficiencies as bad or worse than those seen earlier. The conspicuous failures of school buildings at that time led to the first action by the state of California, in the form of what is usually termed the Field Act.

This legislation prescribes satisfactory standards for new construction of schools and other public buildings. It is not retroactive and does not directly lead to safety in buildings constructed prior to 1933. It does provide for proper inspection. If a school building is inspected and found unsafe, the school board members become personally responsible for any consequences. This rather rigorous provision was invalidated in practice for many years; it was held that if at an election the voters failed to authorize funds for replacement or reconstruction, responsibility was thereby removed from the school board. This way out was enthusiastically adopted, and in numerous California communities, after the failure of bond elections, unsafe buildings were returned to use. About two years ago the office of the State Attorney General issued a ruling invalidating this interpretation. The matter is not yet finally set-

tled, since no test case has entered the courts, but the immediate effect has been an effort in many communities to bring school structures up to Field Act standards.

In 1940 the Imperial Valley earthquake provided a good objective test of the Field Act code; schools constructed before 1933 were more or less damaged, while those constructed under Field Act provisions were hardly affected. This earthquake was accompanied by faulting similar to that of 1906 in local horizontal displacement, but much less extensive—appearing for about 40 miles along the Imperial fault, which is a minor member of the general fault system related to the San Andreas fault. Of special interest were the peculiar deflection of the fault break in crossing the open excavation for the unfinished All-American Canal, and the displacement of bicycle tracks crossing the fault line after the main earthquake, while aftershocks were going on. Only a fraction of the economic loss was due to building damage; the fault breaks disorganized the entire canal system distributing water, particularly to the west side of Imperial Valley, and expensive and hurried reconstruction was necessary. At El Centro a set of strong-motion seismographs installed by the Coast and Geodetic Survey wrote the first good records obtained of an earthquake with locally damaging intensity; these records have become a sort of standard in engineering discussion and investigation with reference to earthquake-resistant construction. The results are of great value, but sometimes have been interpreted too positively without recognizing that this is only one earthquake, and in some ways a peculiar one.

A high point in the study of earthquakes in southern California was reached with the occurrence of the major earthquake in Kern County on July 21, 1952. Of magnitude 7.6, it was the largest earthquake originating within California since 1906. It is still often referred to as the "Tehachapi" earthquake, because the town of Tehachapi had much conspicuous damage (mostly to very weak structures) and the majority of casualties. The epicenter, on the White Wolf fault, was at the edge of Caltech's network of stations, which were soon supplemented, at first by portable instruments recording aftershocks at many locations, then by new permanently established stations. One of the latter, at the fire station near Woody, Kern County, in the foothills of the Sierra Nevada, proved to be a very favorable location for recording and is one of the most sensitive seismological stations now operating.

Although the White Wolf fault had been mapped and was suspected of being associated with small recorded earthquakes in its area, no one expected it to be the seat of a major earthquake with surface faulting. Actual fault displacement was responsible for the most costly damage—the ruining of railway tunnels on the Tehachapi route, which put that line out of service for weeks.

Epicenters of all the larger aftershocks were determined and mapped in detail, giving an unusually accurate picture of the seismic event as a whole, and affording much data for discussing the mechanism of earthquakes.

Since the epicenter of the main event was determined with exceptional precision, recordings at stations all over the world were available for a new revision of the time-distance tables for seismic waves.

An event with important bearing on earthquake risk was the occurrence of a moderate aftershock (magnitude 5.8) on August 22, with the epicenter much closer to Bakersfield than the main earthquake, so that this aftershock was actually more damaging in that city. Study of the damage in both earthquakes was of much engineering value.

We set our teeth and bear with our feelings when the popular press reports that we are "overdue" for a great earthquake in southern California. If this means anything, it means that from various lines of evidence we guess the interval between such earthquakes to be, on the average, about 100 years. The last such really great earthquake was in 1857—so take it from there. Similarly, we are long "overdue" for one of the smaller but potentially damaging earthquakes, comparable to the 1933 Long Beach shock, which typically have occurred on the average of once every two to three years. The last such earthquake in southern California was in March 1954, centering in the Santa Rosa Mountains, so that it attracted relatively little public attention.

Very exciting to seismologists have been the well-observed phenomena of the earthquake in the Parkfield-Cholame area on May 28, 1966. Pre-seismic cracking; fault displacements of a few inches, continuing in aftershocks; acceleration up to one-half of the gravitational acceleration, registered by a strong-motion instrument a few hundred yards from the fault—these are reported on in publications from our own staff and from those of four or five other organizations. There has never been such a concentration of talent and equipment for the investigation of a small earthquake in this country, though such things have been done in Japan and in the Soviet Union on many occasions.

Whatever the California citizen may feel in looking forward, the seismologist is filled with hopeful anticipation as our earthquake history continues to unroll.