Analysis of the Earthquake Problem in Western United States

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One of the most important purposes of scientific research in seismology is to break down that attitude of fatalism or false optimism which seems so prevalent concerning earthquakes. Without doubt, there has been in the past some justification for the attitude of fatalism due to the fact that the average annual death toll from earthquakes is estimated to be about 30,000. Let us consider only a few reasons for this pessimistic attitude. Japan has always been one of the leading nations in carrying on earthquake research, and yet in 1923 an earthquake there killed 100,000 and injured an equal number. It is true that some progress has been made since that time, but we have only a Benevolent and Divine Providence to thank, that in 1933 the Long Beach earthquake was not one of the world's major calamities. In fact, in this country we have been so fortunate at the times of our earthquakes that we just take for granted that earthquakes will always be considerate enough to occur at a time when loss of life and property damage would be a minimum. This is no idle statement, as some short-sighted engineers (and we can be thankful that the number is small) use this particular point as an argument against earthquake resistant construction.

We know no reason why the Long Beach earthquake did not occur two hours earlier and when the public schools were in session. An examination of the public schools after the quake showed that had the earthquake occurred two hours earlier, the death toll would have run into thousands. Carrying this thought another step, we come down to the Helena earthquakes of last year. The collapse of the new high school there showed that some real serious thinking has to be done on this problem. We cannot afford to continue, as we have done in the past, to rebuild along the same old lines and hope that the old mistaken adage, "Lightning never strikes twice in the same place," might be applied to earthquakes.

For economic reasons we have strongly stressed the importance of earthquakes in California, but from a scientific viewpoint we may have over-emphasized the California quakes and under-estimated the earthquake problem in Nevada, as well as in the Northwestern part of the United States. The two earthquakes in Western Montana, occurring at an interval of ten years, have focused attention on two particular points—first, the interval between destructive shocks in any particular region, and secondly, the possibility of additional shocks in the entire Northwest. It would be impossible in a short paper to go into a lengthy discussion of the cause of earthquakes, but it is generally conceded that the majority of earthquakes are of tectonic origin.

Mountain formation and earthquakes,

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emphasize the necessity for at least two years of general academic training, two years of general training in forestry with as little of the vocational and apprentice aspects of the work as possible, and a year of minor specialization which should not lead an individual to believe that he is qualified in this day of rapidly advancing technical fields to compete with real specialists in biological, physical, or social sciences. In forestry such true specialization can only be had by post-graduate work in a school equipped, financed, and staffed to do advanced work on a high plane.

in general, appear to be closely related. These natural processes are still going on and there has been no material change in geological conditions in recent years. Hence, we can reasonably expect about the same number of earthquakes in the immediate future as we have had in the immediate past. We have a fairly good history of recent seismic activity in California and Western Nevada. Since 1769 we have a record of 43 destructive earthquakes in this region. Perhaps many more occurred as we know that 39 of these destructive earthquakes occurred in the past 100 years. These shocks were equal or greater in intensity than the Long Beach and Santa Barbara shocks. A complete history of earthquake activity in the Northwest has never been compiled, so we cannot state the exact number of quakes occurring in this region. However, Donald C. Bradford, in "Seismic History of the Western Washington Territory," lists 20 shocks in that region from 1864 to 1932 and which were classified as being sereve or heavy. Since 1925 the Coast and Geodetic Survey has been charged with the duty of making seismological investigations in the United States, and one of the important parts of the program is to maintain a complete history of seismic actviity. From 1925 to1936 we have record of 29 destructive or near-destructive earthquakes occurring in the Pacific Coast and Western Mountain States. These are listed as follows:

The Coast and Geodetic Survey has been responsible for seismological in-

Year	Day	Intensity, Rossi-Forel	Location of Epicenter
1925	June 27	IX	Three Forks, Montana.
1925	June 29	IX-X	Santa Barbara, California
1926	Oct. 22	VIII	Off Monterey Bay, Cal. (3 shocks)
1927	Jan. 1	VIII-IX	Imperial Valley, California
1927	Aug. 20	VIII	Humboldt Bay, California
1927	Nov. 4	IX-X	West Coast, Santa Barbara County, Cal.
1928	June 3	VIII	Weaverville, California
1929	July 8	VIII	Whittier, California
1930	Feb. 25	VIII	Imperial Valley, California
1930	March 1	VIII	Imperial Valley, California
1930	Aug. 30	VIII	Offshore, 8 mi. W. of Santa Monica, Cal.
1930	Sept. 22	VIII	Humboldt Bay, California
1931	Sept. 9	VII-VIII	Off Cape Mendocino, California
1932	June 6	VIII+	Humboldt County, California
1932	Dec. 20	X	Western Nevada
1933	March 10	IX	Long Beach, California
1933	May 16	VIII	Niles, California
1933	June 25	VIII	Wasbusha, Nevada
1933	Oct. 2	VI	Long Beach, California
1934	Jan. 30	VII-IX	Western Nevada
1934	March 12	VIII	Northern Utah
1934	June 7	IX	Parkfield, California
1934	July 7	VI	Off Oregon Coast
1934	Dec. 30	VII-IX)	(Imperial Valley, California, and
1934	Dec. 31	VII-X)	(Mexico
1935	Oct. 18 & 31	VIII-IX	Helena, Montana
1936	June 3	VI	Off Oregon Coast
1936	July 15	VIII	South of Walla Walla, Washington

vestigations in the United States for the past 11 years. It is felt that considerable progress has been made during that time and it might be well to consider what has been accomplished and also what remains to be done. As previously mentioned, a sesmological history of the United States was one of the first projects undertaken. This has been completed, with the exception of a satisfactory catalog for the Pacific Northwest States.

Although the Coast and Geodetic Survey had been operating seismographs since about 1900, at the time of transferring the work to this Bureau in 1925, many of the instruments were obsolete and the records were not very dependable, nor did they give a satisfactory degree of accuracy. The second task was naturally to bring up to date the instrumental equipment of the Bureau and to encourage the establishment of additional seismological stations in districts which were not adequately covered. At the present time the instrumental equipment of the Bureau is in good shape and the distribution of instruments in the United States, on the whole, is fairly satisfactory except in a few districts and for special work in certain areas. The establishing of seismological instruments in the Northwest has perhaps lagged behind the rest of the country. This was no oubt due to the infrequency of earthquakes in this area. However, the two earthquakes in Montana and the Walla Walla earthquake during the past year have changed the picture. With two sensitive seismographs and four strongmotion seismographs now in operation in Montana, that State is fairly well covered. However, the Pacific Northwest ---that is, Washington, Idaho and Oregon, is not at present adequately covered to give us accurate detailed information. There is need for both the sensitive and strong-motion seismographs in this region.

The purpose of the sensitive instrument is to give dependable information on frequency and location of al earthquake shocks. Information of this kind, especially for local earthquakes, is essential to the insurance companies in fixing an equitable insurance rate and to the engineer who must have accurate data in order to design enginering projects for the development of the country. From the distant earthquakes, the sensitive seismographs provide us with a considerable amount of fundamental scientific data.

The purpose of the strong-motion instrument is to give accurate data concerning the forces set up by earthquake, the periods of oscillation, the amplitude of vibration and the duration of the shock right at the center of the earthquake or as near as possible to the center. With such information, engineers and architects have some idea of the forces against which they have to design their structures. Unless they have such information they cannot design the most economical earthquake-resistant structures. As the cost of making a structure earthquake-resistant increases the cost of that structure only from four to ten percent, as stated by the Board of Fire Underwriters of the Pacific, it is quite certain that eventually all public buildings or any buildings housing a large number of persons will have to be made to withstand earthquakes.

At the present time the Coast and Geodetic Survey operates or cooperates in the operation of 55 strong-motion instruments—50 in California, 4 in Montana and one in Nevada.

Another important phase of our work is what we call the Questionnaire Program. Thousands of cooperators throughout the United States are furnished questionnaire cards upon which to report felt earthquakes. From these cards we obtain much valuable information on the intensity of shocks at various places and the area over which damage has occurred. This program has been operating fairly well for some time. Because of the increasing importance of this work, especially here in the West, a plan is under consideration at the present time which will provide for a more detailed coverage after each earthquake.

The matter of earthquake prediction is one that often gives certain groups a great deal of worry. From an engineering viewpoint, we should assume that we can expect earthquakes and should build our structures accordingly. When that is done, the major part of our fear and worry will have been overcome. Earthquake prediction is so unreliable in this country that at present it is of little or no value. In a few cases it has been shown in Japan that tilting of the ground preceded an earthquake and this afforded an approximate prediction prior to its arrival. This method is based upon data derived from accurate measurements of earth tilts. Such effects can be more readily observed in Japan where the earth tilts have a much greater amplitude of motion as well as a much faster cycle. At the University of California we have four tiltmeters to measure these minute earth tilts. If we are to obtain definite information from these tiltmeters, it will only be after years of observations which will include several fairly sharp earthquake shocks. However, it is possible to perceive where an abnormal meteorological condition, such as an unusual high or low barometer reading or a severe storm might act as a trigger force to set off an earthquake which is about to happen anyway.

Another branch of seismology which has erceived considerable attention in California covers the purely engineering phases of the problem. Considerable work has been done in studying vibrations of buildings and structures. Information on vibration periods of hundreds of buildings has been obtained. In case of an earthquake, this information will be valuable in several ways. First, a study will be made to see if buildings of any certain period of oscillation suffered more or less damage than buildings of other periods. Secondly, if, after a severe earthquake, the period of a building is redetermined, then the relative change in the building period will be one of the best means of determining the extent of structural damage in that building. In a few cases buildings have been studied when subjected to artificial vibrations simulating an earthquake. Efforts are being made to determine periods of ground vibration in order to check up the effect of resonance between ground and structure.

In checking over accomplishments during the past few yeasr, mention should be made of the study of masonry building damage caused by the Long Beach earthquake. A considerable amount of study has been applied to checking over available seismological records in Southern California to determine if dominant ground periods are present during earthquakes. Naturally, in work of this nature, new methods and new instruments have to be developed. The development and actual construction of these instruments has been a large problem. As the program continues there develops a need for additional instruments and instruments of a different type to supply other needed information. These problems have been met and solved both in California and in Washington.

A last phase which should be mentioned in the growing interest of seismology is the interest being manifested by a number of amateurs who take up seismology as a hobby and build amateur seismographs. In Southern California, where this interest in amateur seismology is quite high, an amateur seismological league has been formed for the exchange of information and records. Plans are under way to form a similar league in Nevada, and it is hoped that ultimately a similar league will eb formed here in the Northwest.