

UNITED STATES EARTHQUAKES 1937

SERIAL No. 619



U. S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY - WASHINGTON

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HARRY L. HOPKINS, Secretary

COAST AND GEODETIC SURVEY

Leo Otis Colbert, Director



Serial No. 619

UNITED STATES EARTHQUAKES

1937

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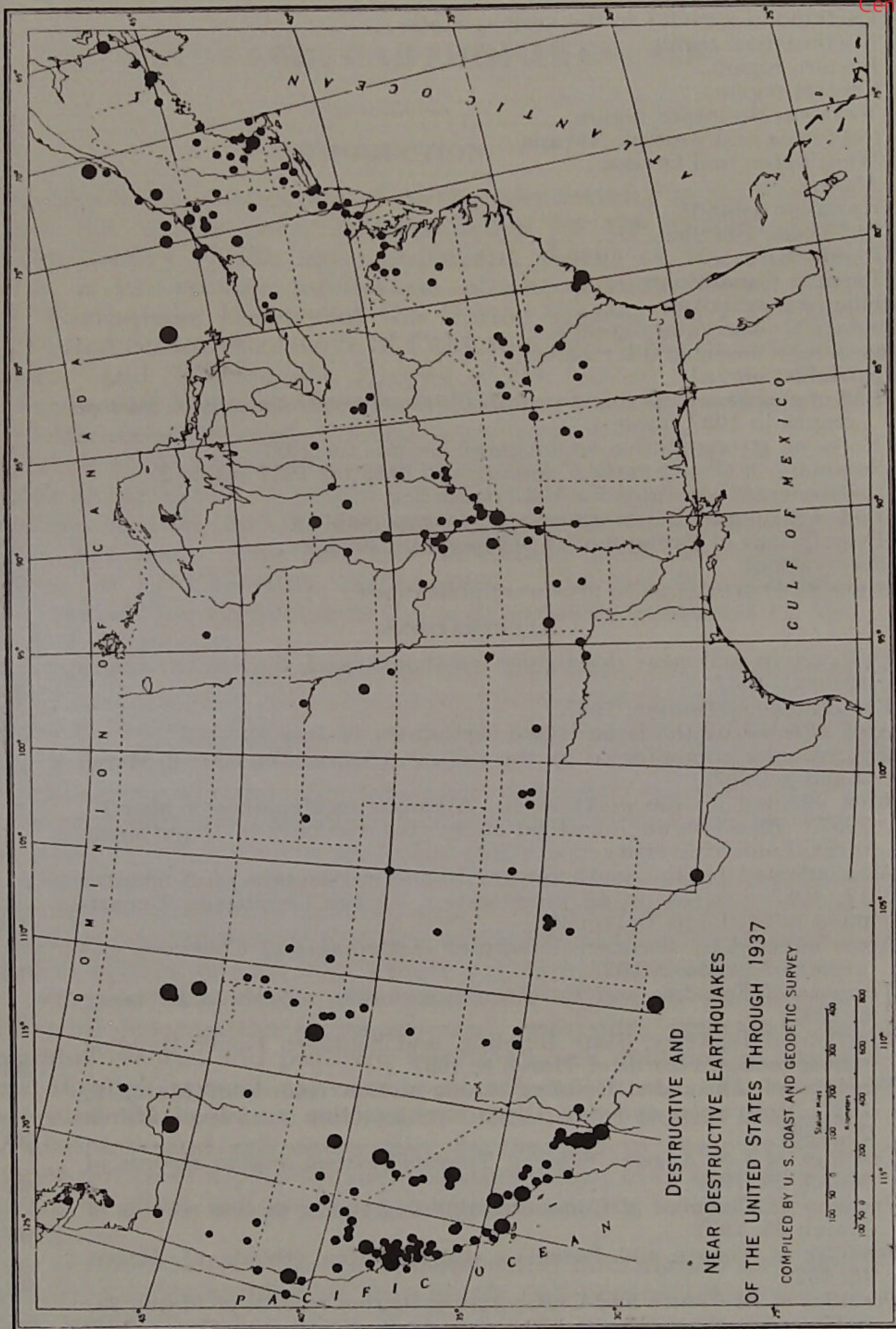


FIGURE 1.—Destructive and near destructive earthquakes of the United States through 1937.

UNITED STATES EARTHQUAKES, 1937

INTRODUCTION

This publication is a summary of earthquake activity in the United States and the regions under its jurisdiction for the calendar year 1937. The history of the more important shocks of the country appears in a two-volume publication of the Bureau, Serial 609, entitled "Earthquake History of the United States. Part I: Continental United States (Exclusive of California and Western Nevada) and Alaska," and "Earthquake History of the United States. Part II: California and Western Nevada." They are revised editions of Special Publications 149 and 191 which are now obsolete.

The history of minor activity is covered largely in a series of references listed in Serial 609, in recent reports of the United States Coast and Geodetic Survey, and in a recent bulletin of the Seismological Society of America.¹ The last two references give very detailed information for all California earthquakes. The last one contains all of the information appearing in the early catalogs published by the Smithsonian Institution.

Earthquakes of volcanic origin in the Hawaiian and Philippine Islands are not included, and only severe shocks are included in the case of the Philippine Islands, as complete reports are published by the local seismological institutions indicated in the lists of earthquakes for those regions. Earthquakes adjacent to the United States and felt within its borders are described only in a general way when detailed descriptions are published elsewhere.

Cooperation of investigators solicited.—In order that these publications may be as complete as possible in the more important details of earthquakes and in references, it is desired that investigators cooperate to the fullest extent, as such cooperation will be to the mutual advantage of everyone concerned. The Bureau is willing to furnish investigators all information at its disposal, consisting principally of seismographic records and postcard questionnaires obtained in many instances through special canvassing of affected areas. In return it is requested that advance notices be furnished of results obtained so that abstracts and references may be inserted in these reports. An advance notice of a planned investigation might save considerable overlapping of effort and would give wider publicity to the work of the investigator.

Sources of information.—The noninstrumental information has been furnished by a large number of individuals and organizations whose voluntary cooperation has made it possible to prepare descriptions of the earthquakes of this country with a completeness and accuracy never before attained. Lack of space prohibits giving individual

¹Descriptive Catalog of Earthquakes of the Pacific Coast of the United States, 1769 to 1928. S. D. Townley and M. W. Allen, Bulletin of the Seismological Society of America, Vol. 29, No. 1, January 1939.

credit to all of the cooperators. The principal sources of information are as follows:

United States Weather Bureau.

Central office of the Jesuit Seismological Association at St. Louis, Mo.

The Seismological Field Survey of the Bureau at San Francisco, cooperating with the Seismological Laboratory of the California Institute of Technology, the Seismological Station of the University of California, and Stanford University. Among the commercial agencies on the West Coast rendering valuable services are telephone, power, oil, railroad, and, especially, insurance companies. Certain concerns interested in the earthquake-resistant qualities of their products are also active, together with various organizations of structural engineers and architects.

The reports from Alaska are due largely to the efforts of Dr. C. E. Bunnell, president of the University of Alaska.

Telegraphic reports collected by Science Service, Washington.

Bulletins of the Seismological Society of America.

Interested individuals in various parts of the country.

In addition to the above sources of information, the Coast and Geodetic Survey, or its Seismological Field Survey at San Francisco, canvasses areas affected by shocks of unusual intensity, unless such work is undertaken by other organizations such as the Jesuit Seismological Association or by State and other interested geologists. In this way the extent and the maximum intensities of all heavy shocks are determined and the data are usually sufficient to construct isoseismal maps or, at least, maps of the affected areas. The Seismological Station of the University of California, Berkeley, (Perry Byerly in charge) and the Seismological Laboratory of the California Institute of Technology, at Pasadena, cooperate actively in the canvassing program of the Seismological Field Survey at San Francisco.

Note on the regional earthquake lists.—The destructive features of all shocks are enumerated in the abstracts, but otherwise the descriptive matter is reduced to a minimum. The original reports are open for inspection by anyone interested in unpublished details. More detailed descriptions of earthquakes on the West Coast will be found in the mimeographed reports available at the San Francisco Field Station of the Bureau.

Beginning with the 1931 number of this series, Serial 553, the Coast and Geodetic Survey has used and will continue to use the modified Mercalli intensity scale of 1931, in place of the Rossi-Forel scale, to designate the intensity of earthquake activity. All intensity numbers therefore refer to the new scale unless otherwise designated. The reasons for this change are set forth in an article entitled "Modified Mercalli Intensity Scale of 1931," by Harry O. Wood and Frank Neumann, in the December 1931 number of the Bulletin of the Seismological Society of America, volume 21, No. 4. This article contains the original unabridged scale and also an abridged scale. The latter is given here, together with equivalent intensities according to the Rossi-Forel scale.

MODIFIED MERCALLI INTENSITY SCALE OF 1931

(Abridged)

- I. Not felt except by a very few under especially favorable circumstances.
(I Rossi-Forel scale.)
- II. Felt only by a few persons at rest, especially on upper floors of buildings.
Delicately suspended objects may swing. (I to II Rossi-Forel scale.)



- 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. (III Rossi-Forel scale.)
- IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. (IV to V Rossi-Forel scale.)
- 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. (V to VI Rossi-Forel scale.)
- VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale.)
- 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—Rossi-Forel scale.)
- 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. Disturbs persons driving motor cars. (VIII+ to IX—Rossi-Forel scale.)
- 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. (IX+ Rossi-Forel scale.)
- 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. (X Rossi-Forel scale.)
- 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.

An asterisk (*) indicates that the time is taken from an instrumental report and is reliable. In other instances quite large deviations are frequently reported.

In the case of California, earthquakes reported as feeble are not plotted on the epicenter map of the United States nor are minor after-shocks plotted for heavy earthquakes in California or any other region. The reader should bear in mind that the information service in California has been developed to a point not approached in any other section of the country. When the coordinates of epicenters are given, the sources of information are stated when the epicenters are determined by other organizations such as the Seismological Station of the University of California under the direction of Prof. Perry Byerly or the Seismological Laboratory of the California Institute of Technology, at Pasadena. The bulletins of these institutions should be consulted for further details and often for data on additional shocks. See also "Northern California Earthquakes, January 1 to December 31, 1937," by P. Byerly and J. N. Adkins in the Bulletin of the Seismological Society of America, volume 28, No. 4, October 1938, and similar articles in earlier volumes.

Time is indicated as continuous from 0 to 24 hours, beginning and ending at midnight. Local standard time is used.

Within the United States the same regional arrangement has been followed as in Serial 609 previously mentioned.

Special report.—Attention is invited to a special quarterly report issued by the Bureau's Seismological Field Survey, with headquarters at San Francisco, entitled "Abstracts of Earthquake Reports for the Pacific Coast and the Western Mountain Region." The reports are in mimeographed form and tabulate in unabridged style all information contained in noninstrumental reports collected in the region indicated.

INSTRUMENTAL RESULTS

Teleseismic results.—On page 27 is a list of Bureau and cooperating teleseismic stations for which the Bureau publishes results. The list of epicenters which usually appears in this section has been omitted because the work for the year was not completed when this publication went to press. It is expected that the list for 1937 will appear in the 1938 publication. Immediate epicenter determinations are frequently made through the cooperation of Science Service, the Jesuit Seismological Association, the Coast and Geodetic Survey, and individual stations and the results broadcast without delay to Europe and points in the Pacific. Postal card reports are also issued.

Strong-motion results.—The introductory remarks in the chapter on this subject explain in detail the purpose of the work, which is primarily to furnish engineers exact information concerning ground movements in the central regions of strong earthquakes. The instrumental equipment is essentially different in type from teleseismic equipment although the principles involved are the same. Strong-motion instruments are installed mostly in the urban areas of California, and operate only when actuated by the movements of a strong earthquake.

The interpretation of strong-motion results is one of the duties assigned to the Bureau in connection with a broad cooperative program of seismological research being carried out on the Pacific coast between the Bureau and a number of local organizations and institutions interested in the engineering aspects of the earthquake problem. The details of this program are fully described in the Bureau's Special Publication No. 201, "Earthquake Investigations in California, 1934-35."

Preliminary reports on strong-motion results are issued in quarterly mimeographed bulletins and sometimes in special mimeographed reports. They appear in revised form in this publication.

NONINSTRUMENTAL RESULTS

EARTHQUAKE ACTIVITY IN THE VARIOUS STATES

Arizona: A fairly strong shock on July 23 with one aftershock, and a feeble shock on December 17.

California: The most widespread shock of the year was that of March 25 originating in an uninhabited part of southern California; maximum intensity VI-VII. The shock near Berkeley on March 8 was slightly destructive. Other earthquakes of V and over, felt practically only in California, occurred on January 8, February 6, March 5, April 20, July 7, 18, September 1 (2 shocks), and November 21. In the California-Nevada border region strong shocks occurred on February 19, April 24, June 18, August 5 and 18. The usual number of minor shocks were recorded.

Connecticut: Slight shock on July 27.

Delaware: Slight shock on December 3.

Idaho: Sharp localized shock on December 18.

Illinois: Moderate shock on November 17; a slight one on August 5.

Maine: Feeble shock on October 12.

Missouri: Slight shocks on January 30, May 16, August 5, and October 5. That of May 16 originated practically on the Arkansas-Missouri border.

Montana: Moderate shocks occurred in the Helena area on May 23, October 6, 15, November 19 and 27. About 150 aftershocks of the 1935 disturbances were listed in 1937 by the local office of the United States Weather Bureau. Light shocks occurred in other parts of the state on September 6, 10, and 15, those of the 6th and 15th originating close to the Montana-Yellowstone Park border.

Nevada: Moderately strong shocks occurred in the California-Nevada region on February 19, April 24, June 18, August 5 and 18. There were other shocks on September 17 and November 18, the latter rather widely felt in northeastern Nevada and northwestern Utah. A strong shock occurred at Boulder Dam on November 11. There were about 12 other moderately strong shocks out of a total of about 160 tremors reported for the year.

New Jersey: Slight local shock on September 30.

New Mexico: Slight shock on September 29.

New York: A moderately strong shock originated near the western end of Long Island on July 18. Slight shocks were reported from other sections on February 21, March 10, October 11 and 12.

Ohio: Destructive shocks near Anna, Ohio, on March 2 and 8 were the strongest in the entire country for 1937. There was a slight tremor near Cincinnati on October 16.

Oregon: Slight shocks on February 8 and December 14.

Pennsylvania: Slight local shock on June 8.

South Carolina: Slight shock on October 25.

Tennessee: Slight shock in western part on June 23.

Texas: Slight shock on March 31 near El Paso.

Utah: A series of moderate shocks of decreasing intensity occurred in the southern central part of the State in February and March. The Nevada earthquake of November 18 was widely felt in the northwestern part of Utah.

Vermont: Local shock on December 2.

Virginia: Local shock on February 2.

Washington: Slight shocks occurred in the Puget Sound area on September 28, November 1, 11, 26, and December 28; and in the Walla Walla area on February 9, June 4, and September 20. There was a local shock near Spokane on August 10.

Wyoming: Slight shocks in the Yellowstone Park area on April 27, August 7, September 6 and 15.

Alaska: A shock of destructive intensity centered near Fairbanks on July 22 and was followed by many aftershocks, some of them quite strong. Slight shocks occurred in other areas on August 22, September 3, 27, October 1, 24, November 24, 30, December 7 and 11.

Hawaii: About 15 sharp shocks centered around the volcanoes of the Island of Hawaii.

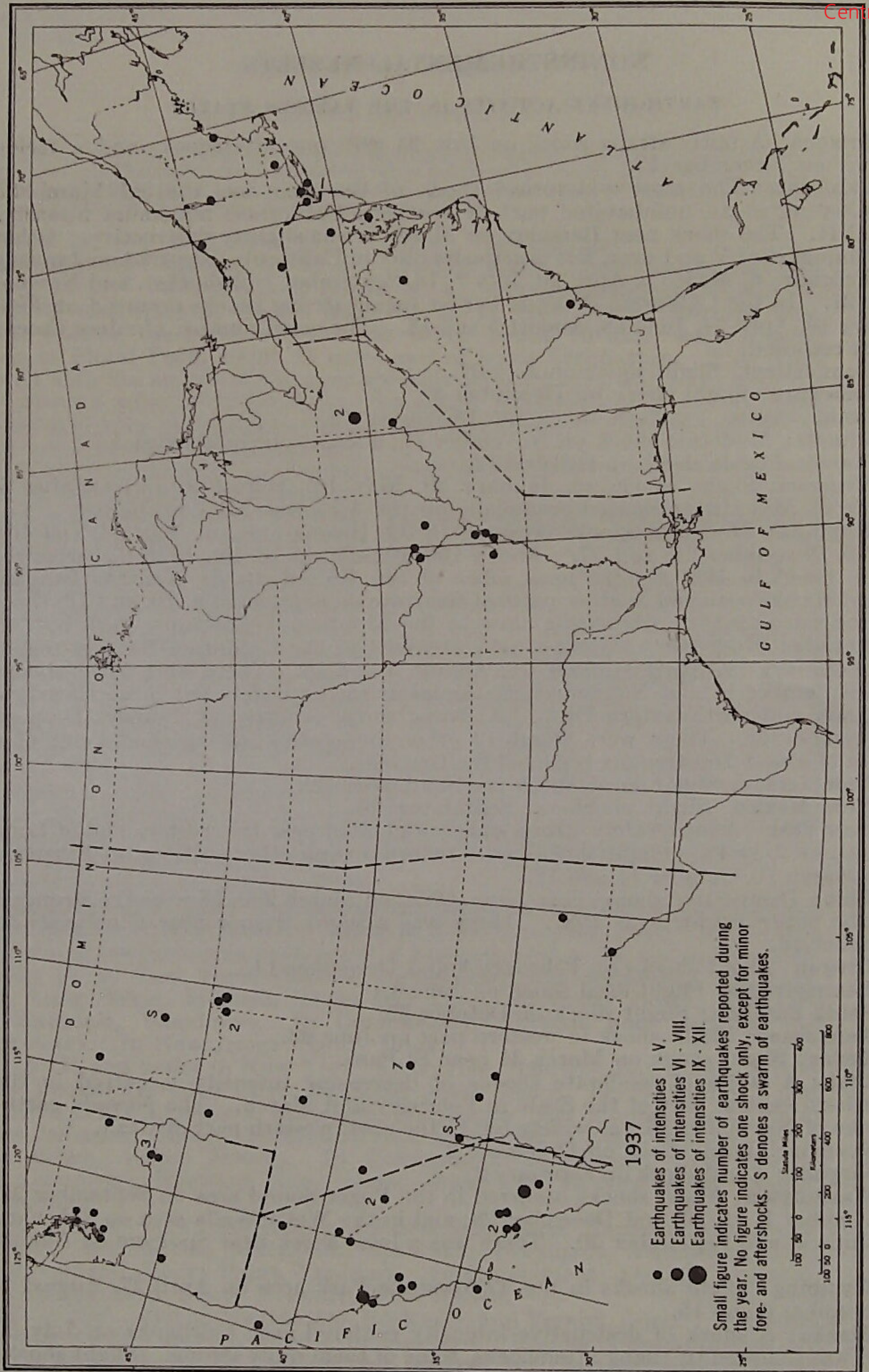


FIGURE 2.—Earthquake epicenters, 1937.

Philippine Islands: The earthquake of August 20 was reported to have been the worst since 1911. There was also the usual number of moderately strong shocks.

Puerto Rico: Five local tremors were reported.

Panama Canal Zone: Thirteen light tremors were reported, with some activity outside the Zone.

NORTHEASTERN REGION

[75th meridian or eastern standard time.]

NOTE.—In recent years a number of high-grade seismographs designed especially for recording local earthquakes have been installed in the Northeastern region greatly enhancing our knowledge of prevailing seismic activity and the accurate location of seismic foci. The bulletins of all seismographic stations in the region should therefore be consulted for additional information.

February 21: —:— Elmira, N. Y. Slight. No damage.

March 10: 0:30. Canton, N. Y., IV. Felt by many. Low rumbling sounds.

July 18: 22:51.* Western Long Island, N. Y. Maximum intensity about IV. According to instrumental studies made by L. D. Leet of the Harvard Seismographic Station the focus was close to $40^{\circ}43'$ north, $73^{\circ}42.5'$ west, a point very close to Floral Park, about 15 miles east of lower Manhattan. This point checks well with the center of the most strongly affected area which lay within a radius of about 8 miles of Floral Park. See map. A canvass made by the Coast and Geodetic Survey revealed that there were places within this area where the intensity was less than IV and quite a number of widely scattered points far beyond the epicentral area where it was reported as equivalent to IV. At Redding, Conn., 43 miles from the epicenter, a house was reported so furiously shaken that stones were loosened from the foundations and the lights went out temporarily. Such relatively high intensities at isolated distant points are believed due largely to resonance phenomena in local geological formations and in the structures themselves. In addition there is probably considerable variation of intensity because of the complex nature of the transmission of earthquake waves through the layered crust of the earth. There were no reports of seismic phenomena on Manhattan Island but it is rather likely that some isolated and very minor effects were not recognized as such or not reported. See "Earthquakes in Northeastern America, July-December 1937," by L. Don Leet, Bulletin of the Seismological Society of America, volume 28, No. 3, July 1938.

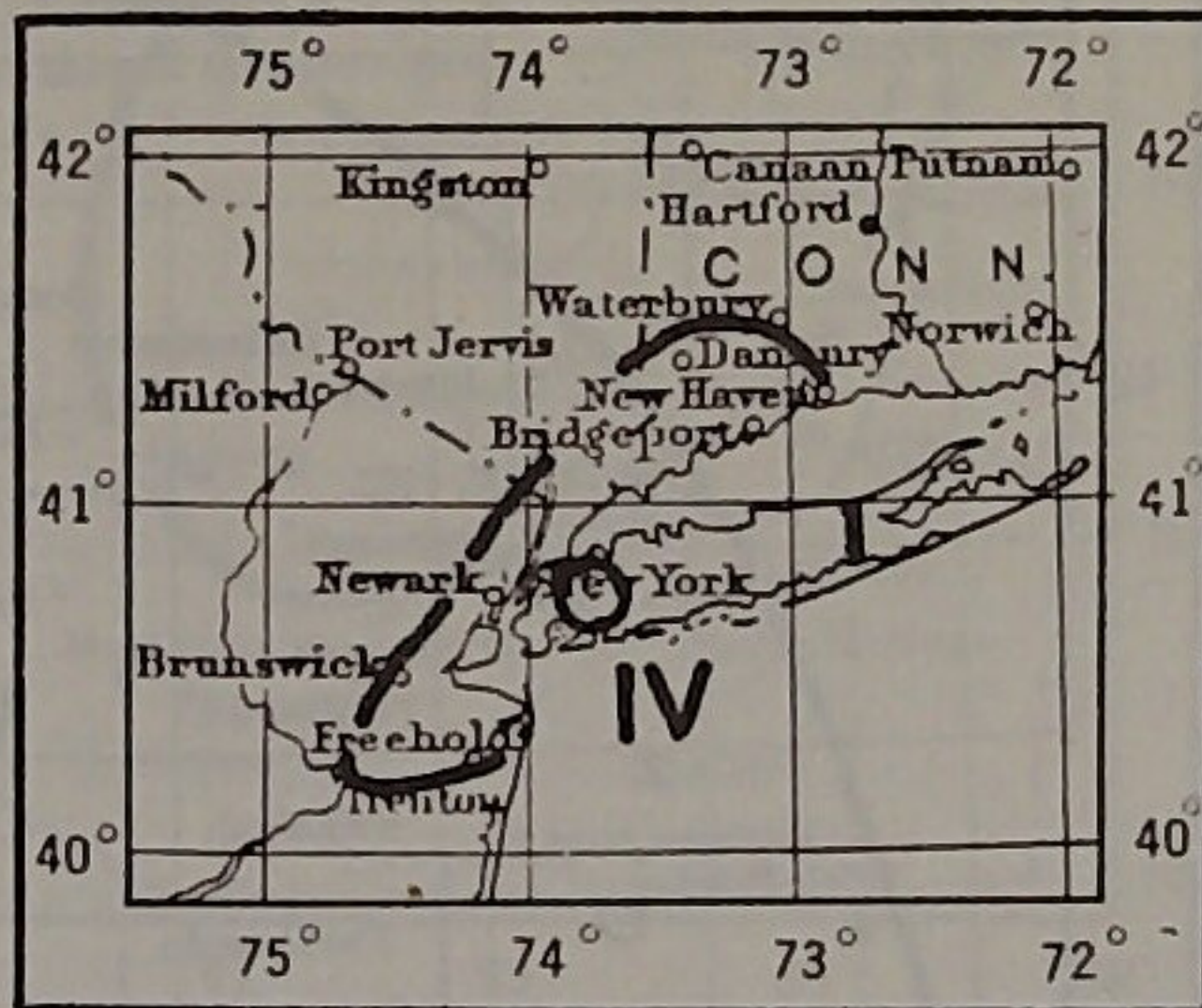


FIGURE 3.—Area affected by the Long Island earthquake of July 18, 1937.

Intensity IV in New York: Bayside, Douglaston, Far Rockaway, Flushing, Freeport, Long Beach, Mineola, Ocean Bay Park, Rockaway Beach, Rockville Center, Scarsdale, Woodmere. In Connecticut: Norwalk and Redding (see preceding note). In New Jersey: Sandy Hook.

Intensity III and under in New York: Amityville, Baldwin, Bay Shore, Brooklyn, East Rockaway, Glen Cove, Jamaica, Jones Beach, Lloyd Harbor Light Station, Kent Cliffs, Lynbrook, Malverne, Manhasset, near Mount Kisco, Oyster Bay, Port Jefferson, Queens, Richmond Hill, Rower Shoal Light Station, Westhampton Beach, Valley Stream. In Connecticut: Bridgeport, East Haven, Fairfield, Greenwich, Hartford, New Canaan, Stamford. In New Jersey: Maplewood, Trenton.

Not felt in New York: Aquebogue, Central Islip, East Hampton, Greenport, Mamaroneck, Manhattan, Mattituck, Montauk, Northport, Patchogue, Port Chester, Riverhead, Rocky Point, Yaphank. In Connecticut: Ansonia, Guilford, New Haven, Saybrook, South Norwalk, West Haven.

July 27: 4:10.* Felt at Manchester, Rockville, and Vernon, Conn. Epicenter $41^{\circ}50'$ north, $72^{\circ}26'$ west, according to Harvard. Residents awakened in the Manchester area. See L. D. Leet's article referred to in earthquake of July 18.

September 30: 22:08.* Verona, N. J. See Eastern Region.

October 11 and 12: 22:—, 1:— Westchester County, N. Y. Felt.

October 12: Between 6 and 7. Felt at Kennebunkport, Maine. Not reported.

December 2: 17:01.* Burlington, Vt. Slight local shock recorded on seismograph at the University of Vermont.

EASTERN REGION

[75th meridian or eastern standard time.]

February 2: 20:26. Central Virginia in Albemarle, Nelson, Botetort, and Buckingham Counties. Slight shock accompanied by rumbling sounds. III or IV.

June 8: 19:04. Reading, Pa. and vicinity. Slight.

July 18: Western Long Island earthquake. See Northeastern Region.

September 30: 22:08.* Verona, N. J. Felt. Epicenter $40^{\circ}50'$ north, $74^{\circ}15'$ west according to Harvard Seismographic Station.

October 25: 14:01. Summerville, S. C. Light shock accompanied by booming sounds.

December 3: —:—. Lower Delaware. Earth tremors reported in several sections. No damage.

CENTRAL REGION

[90th meridian or central standard time]

January 30: 2:57.* Near Caruthersville, Mo. Epicenter 36.2° north, 89.7° west according to the Geophysics Department of St. Louis University. Felt

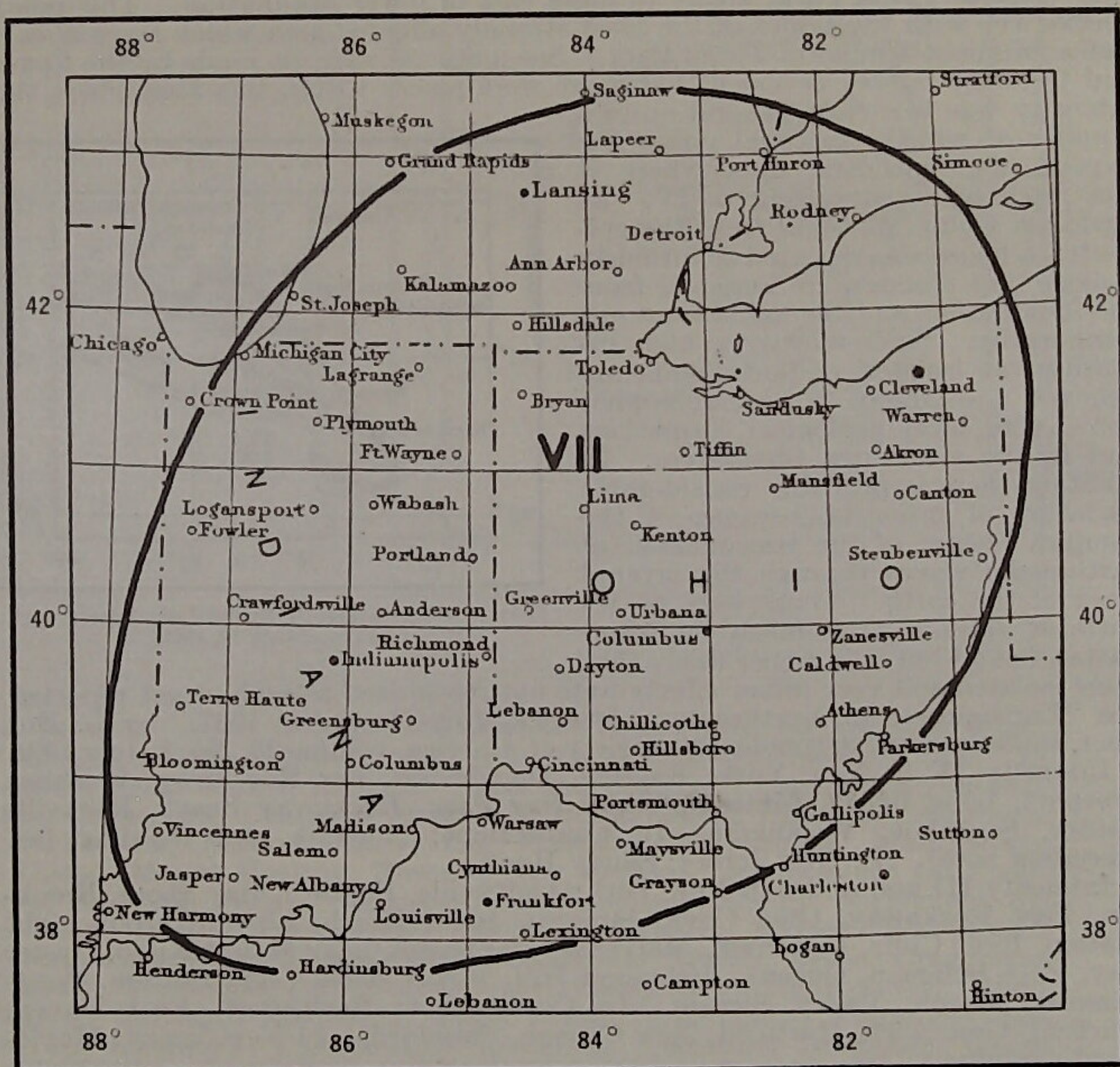


FIGURE 4.—Approximate area affected by the western Ohio earthquakes of March 2 and 8, 1937.

slightly at Caruthersville, Kennett, Marston, and Swift in Missouri; and at Dyersburg, Elbridge, Hornbeck, Tiptonville and Troy in Tennessee. Maximum intensity approximately III. Not felt at New Madrid and Pascola in Missouri; Newbern and Polk in Tennessee; and Blytheville, Ark. See "Two Recent Earthquakes in the New Madrid Region" by Florence Robertson in the Bulletin of the Seismological Society of America, volume 27, No. 3, July 1937. This shock occurred at the height of the flood of the Ohio and St. Francis Rivers.

March 2: 8:48.* Near Anna, Ohio. VI to VII. Felt over approximately 110,000 square miles in Ohio, Indiana and Michigan and at a few points in Wisconsin, West Virginia, Kentucky, and Canada. The affected area shown by

the map on page 8 is based only on partial data obtained by the Coast and Geodetic Survey. A more comprehensive report will be issued by the Geophysics Department of St. Louis University which canvassed the area for additional non-instrumental data. The results of instrumental studies made at the seismographic station of Xavier University, Cincinnati, Ohio, will probably be presented at the same time.

At Anna, Ohio, the school was damaged so badly that it was declared unsafe. Many chimneys were thrown down and other minor damage was inflicted at Anna, Sidney, and Wapakoneta.

Intensity V seems to have been reached at the following places in Ohio: Greenville, Jackson Center, Lima, Newport, North College Hills, Piqua, Sedamsville, Tippacanoe City, Van Wert, Versailles, Washington Courthouse, and Zanesfield. In Indiana: Fort Wayne, Indianapolis, Richmond, Rushville, and Union City.

In addition to reports from the above places, the Survey obtained information, sometimes inadequate, from 76 places in Ohio, 34 in Indiana, 17 in Michigan, 3 in Kentucky, 2 in West Virginia, 1 in Wisconsin, 1 in Illinois, and 1 in Canada. At all these points the intensity ranged from zero to about IV.

March 8: 23:45.* Near Anna, Ohio. VII. Perhaps slightly stronger and more widespread than the shock of March 2 but the difference was not great. At Anna additional damage was done to the school, and two small brick churches were more seriously damaged, while many dwellings suffered minor damage. In view of the partial nature of this report the map on page 8 may be accepted as roughly representing the areas affected by both the March 2 and March 8 earthquakes. It is expected that both of these earthquakes will be described in detail by the organization previously named.

Data in the hands of the Coast and Geodetic Survey indicate that the shock was felt strongest in Ohio at Anna, Botkins, Bryan, Dayton, Jackson Center, Kettlersville, McCartyville, Piqua, Sidney, Van Wert, and Wilmington. The following additional places reported the shock felt. In Ohio: Akron, Bellefontaine, Bucyrus, Caledonia, Cheviot, Cincinnati, Cleveland, Columbus, Correyville, Delaware, Findlay, Fostoria, Galion, Hamilton, Hillsboro, Lima, Lockington, Marion, Marysville, Massilon, Miamisburg, Middletown, Mount Gilead, Mount Healthy, Newark, New Bremen, Northwestern Oil Field, Ostrandes, Paulding, Philo, Prospect, Ripley, Sandusky, Shelby, Springfield, St. Marys, Tiffin, Toledo, Troy, Upper Sandusky, Urbana, Warren, Washington Courthouse, Wauseon, and Zanesville. In Indiana: Angola, Berne, Crawfordsville, Elkhart, Evansville, Fort Wayne, Gary, Indianapolis, Kendallville, Lafayette, Marion, Portland, Richmond, South Bend, Terre Haute, Vincennes, and Warsaw. In Kentucky: College Hill, Covington, Frankfort, Lexington, Louisville, and Shively. In Michigan: Adrian, Ann Arbor, Detroit, East Lansing, Escanaba, Fulton, Grand Rapids, Highland Park, Ionia, Kalamazoo, Lansing, Mason, Olivet, and Paw Paw. Also Madison and Milwaukee, Wis.; Huntington, W. Va.; St. Louis, Mo.; Pittsburgh, Pa.; and London, St. Thomas, and Toronto, Ontario, Canada.

May 16: 18:50.* Northeastern Arkansas, about 36.08° north, 90.38° west according to the Geophysics Department of St. Louis University. Felt over area of approximately 21,000 square miles. Maximum intensity about III plus. See "Two Recent Earthquakes in the New Madrid Region" by Florence Robertson, in the Bulletin of the Seismological Society of America, volume 27, No. 3, July 1937. The map of the affected area, on this page, is based on the map appearing in this article.

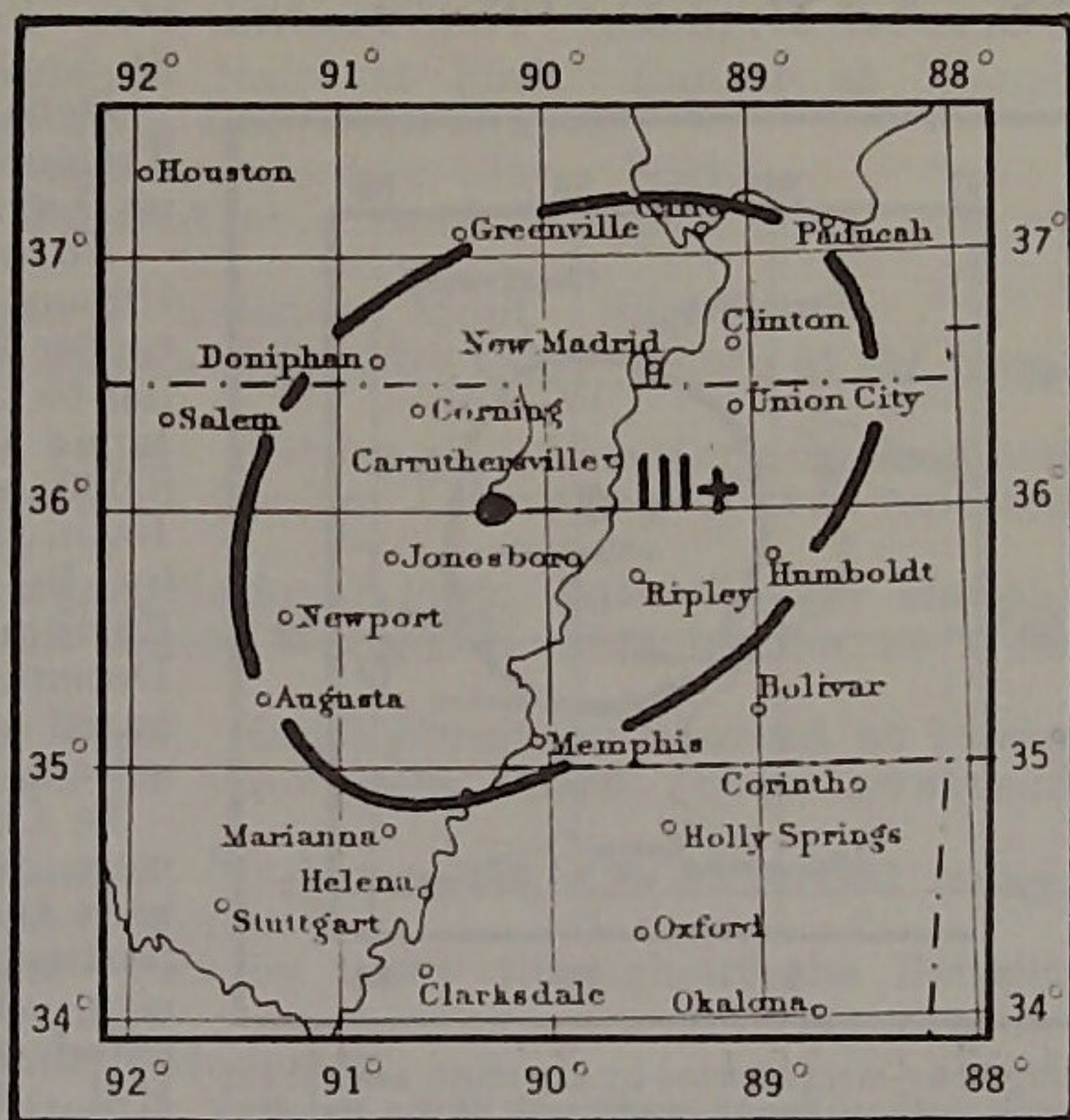


FIGURE 5.—Area affected by the Northeastern Arkansas earthquake of May 16, 1937. Based on an investigation by the Geophysics Department of St. Louis University.

The points of maximum intensity were: Ripley, Tenn.; Batesville, Ark.; Poplar Bluff, Mo.; and Hickman, Ky. It was felt at the following additional places: In Arkansas: Blytheville, Bono, Brookland, Burdette, Corning, Cotton Plant, Dell, Lake City, Leachville, Lepanto, Marianna, Monette, and Nettleton. In Tennessee: Alamo, Ashport, Crocket Mills, Curve, Fulton, Gates, Greenfield, Halls, Henning, Jackson, Tipton, and Warren. In Missouri: Broseley, Campbell, Caruthersville, Harviel, Hendrickson, Neeleyville, and New Madrid. In Kentucky: Fulton and Mayfield.

Not felt: In Arkansas: Augusta, Marion, Melbourne, Salem, Swifton, Tulot, Wynne. In Tennessee: Bolivar, Tiptonville, Trenton. In Missouri: Fagus, Fisk, Hayti, Kennett.

June 23: 9:44.* Tiptonville, Tenn. Felt.

August 5: 15:31.* South St. Louis, Mo. Felt. Recorded by St. Louis University seismographs.

August 5: 17:12.* Granite City, Ill. Felt. Recorded instrumentally by St. Louis University seismographs.

October 5: 16:58.* New Madrid, Mo. Felt. Recorded instrumentally by St. Louis University seismographs.

October 16: 22:25. Cincinnati, Ohio. Tremors felt in suburbs and recorded on Xavier University seismograph.

November 17: 11:04.* South-central Illinois. Maximum intensity V. Epicenter $38^{\circ}34'$ north, $89^{\circ}05'$ west according to the Geophysics Department of St. Louis University. Area affected, about 8,000 square miles. See "The Illinois Basin Earthquake of November 17, 1937," by R. R. Heinrich and A. Frank, in *Earthquake Notes*, volume X, No. 3, December 1938. The map on page 10 is based on the map of isoseists in this article.

In Centralia rolls of linoleum in stores were toppled over and canned goods were thrown from shelves of some stores, particularly in the northern part of the city. The same intensities were indicated at Sandoval, Odin, and Walnut Hill. At Sandoval dishes were broken and plaster fell. The authors received reports from about 160 places.

The paper previously quoted states that "the epicenter is situated on the northwestern limb of the Illinois Basin syncline, the most prominent structural feature in the region (Moulton, Gaul, and Bell . . .)."

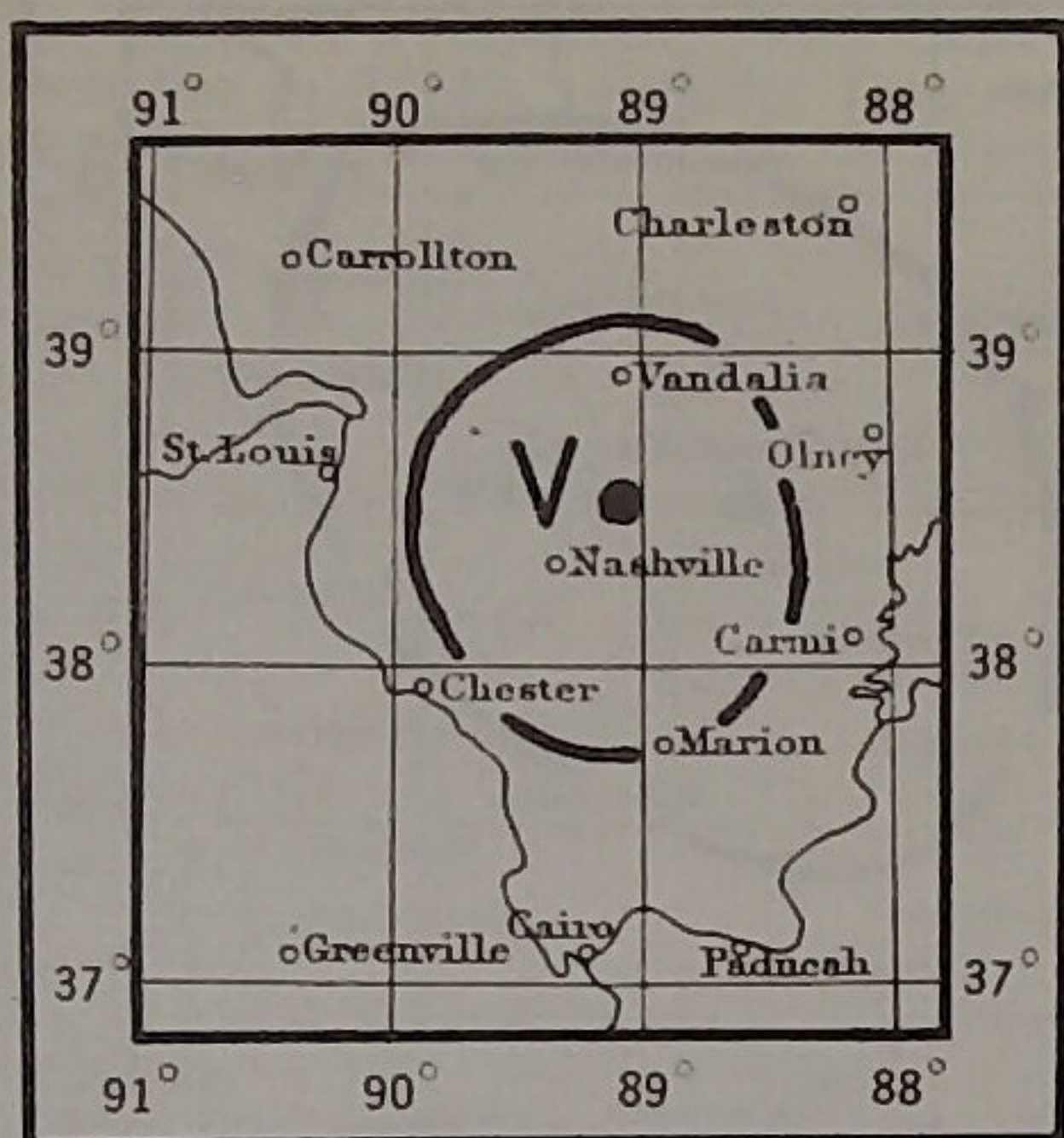


FIGURE 6.—Area affected by the south central Illinois earthquake of November 17, 1937. Based on an investigation by the Geophysics Department of St. Louis University.

WESTERN MOUNTAIN REGION

[105th meridian or mountain standard time]

NOTE.—Only the more important of the aftershocks of the Helena, Mont., earthquakes of October 1935 are listed. Complete lists of the reports received are available in mimeographed form from the Director of the United States Coast and Geodetic Survey, Washington, D. C., and from W. E. Maughan, in charge of the local office of the United States Weather Bureau at Helena, who compiled the data.

Only the more important shocks felt at Boulder Dam are listed. The unabridged list is published in "Abstracts of Earthquake Reports for the Pacific Coast and Western Mountain Region" available from the Washington office, or from the San Francisco Field Station, of the Coast and Geodetic Survey.

February 17: 21:15. Parowan City, Panguitch, and Cedar City, Utah. Felt. No damage.

February 17: 23:30. Parowan City and Panguitch, Utah. Felt generally.

February 18: 2:00. Panguitch, Utah. Felt generally.

February 21: 1:30. Panguitch, Utah. Lighter than the preceding shocks.

February 25: 18:30. Panguitch, Utah. Light shock.

March 13: 4:40. Panguitch, Utah. Very slight.

March 31: 16:45. El Paso, Tex. Slight. Felt by many.

March 31: 21:41. Panguitch, Utah. Very slight.

April 24: 21:28.* Near Potts, Nev. See California and Western Nevada section.

April 26: 11:27. Boulder Dam. Hardest of a series of four felt in various parts of the project.

April 27: 15:34. Yellowstone National Park. Slight shock felt only by those in vicinity of Old Faithful Hotel.

April 27: 21:15 and 21:56. Boulder Dam. Hard shock at Power Plant.

April 27: 23:16. Boulder Dam. Harder than preceding shock. Operated accelerograph in Intake Tower.

May 23: 1:16. Helena, Mont. Strong.

June 18: 10:18.* Boulder Dam. Felt generally at the dam; by a few at Boulder City.

July 20: 15:49. Seligman, Ariz. Noticed by everyone. Caused "pans to dance, and floors to weave." Little damage. A lighter shock felt at 20:00. Rumbling sounds accompanied both shocks. Not recorded instrumentally at Tucson.

July 21? 16:55? Phoenix, Ariz. Short heavy thud felt by all; disturbed small objects. Weaker shock at about 20:00. Possibly same as preceding shocks.

August 7: 0:30 about. Yellowstone National Park. Ranger at Mount Sheridan Lookout awakened. Wall-maps and lamps swayed.

September 1: 12:39. Boulder Dam and Boulder City. Slight.

September 6: 16:30. West Yellowstone, Mont. Slight. Also felt at Mammoth.

September 10: 6:00 (shortly after). Kalispell, Mont. Slight.

September 11: 11:29. Boulder Dam and Boulder City. Sharp at the Dam. Slight at Boulder City.

September 12: 11:22. Boulder Dam. Felt by all. Elevator and dead end weights swung. Slight in some parts of Boulder City where it was reported weaker than shock of preceding day.

September 15: 21:27. Yellowstone National Park, Lake Ranger station. Awakened many. Other shocks felt during the night. Felt by few at West Yellowstone, Mont. at 21:45.

September 21: 22:21. Boulder Dam. Small objects overturned at Power Plant; indicating-light cover thrown off supervisory board. Some awakened at Boulder City.

September 29: 23:15. Fort Stanton, N. Mex. Slight. Awakened many.

October 6: 23:43. Helena, Mont. Moderate.

October 9: 7:35. Boulder Dam. Felt by many throughout the Boulder Dam and power-house area. No damage.

October 15: 23:56. Helena, Mont. Moderate.

November 11: 17:39. Boulder Dam. Felt by all at the dam, and in Boulder City. Felt by a few in Las Vegas. At the power-house plaster was cracked at the 705-foot elevation; in the elevator tower on top of the dam a desk was moved and a paint bucket overturned, spilling paint. Rocks raveled on Kingman highway in high cuts as far away as seven miles from Boulder Dam. Shock started accelerographs in the downstream Nevada Intake Tower and in the 1215 Gallery.

November 11: 18:17. Boulder Dam. Felt by practically everyone in Boulder City. Less intense than the preceding shock.

November 18: 16:50. Near Wells, Nev. At Wells hanging objects swung north-south; also swung at Carlin, Nevada. Weaker at Elko, Ely and Montello, Nev., and at Lucin, Crouse Creek, Salt Lake City, and Wendover, Utah. Not felt at 35 other places canvassed. A rather widespread shock.

November 19: 11:30. Helena, Mont. Moderate.

November 27: 19:11. Helena, Mont. Moderate.

December 3: 16:55. Boulder Dam. Felt all over power plant and in Boulder City accompanied by loud noise.

December 7: 22:08. Boulder Dam. Hanging objects at the dam swung. Felt by some in Boulder City.

December 17: 16:30. Flagstaff, Ariz. Slight.

December 18: 4:00 about. West central Idaho. V in vicinity of Arling and Cascade. Felt over 1,200 square miles. At Arling and Cascade objects swung, small objects and furniture moved, trees and bushes were shaken and many persons were awakened. Clocks stopped at Arling. IV at Cambridge, Cascade, Council, Donnelly, Indian Valley, McCall, Mesa, Midvale, and Norwood. III and under at Nampa, Mesa, Smiths Ferry, and Starkey. Not felt at 38 other places canvassed in Idaho and Oregon.

CALIFORNIA AND WESTERN NEVADA

[120th meridian or Pacific standard time]



NOTE.— All places are in California unless otherwise stated. "B" written after the position of an epicenter means that the position was reported by the Seismological Station of the University of California at Berkeley, Perry Byerly in charge. "P" refers to the seismological laboratory of the California Institute of Technology and the Carnegie Institution of Washington at Pasadena, H. O. Wood in charge. See Introduction.

When more than one degree of intensity is reported from a town, the town is listed under each intensity reported.

January 8: 4:46. Lower California about $32^{\circ}06'$ north, $116^{\circ}30'$ west, P. Felt slightly in San Diego.

January 8: 16:47.* Monterey Bay region about 9 miles northwest of Watsonville, B. Felt over land area of about 400 square miles. Intensity V at Watsonville where it was felt by all, frightened few, damage slight.

Intensity IV at Gilroy and Watsonville. III and under at Aptos, Morgan Hill (2 miles west of), Soquel. Not felt at Castroville, Hollister, Holy City, Morgan Hill, Salinas, San Juan Bantista, Santa Cruz.

January 15: 10:35.* San Pedro channel about $33^{\circ}30'$ north, $118^{\circ}15'$ west, P. Felt at San Pedro and Long Beach.

January 16: 19:29.* Near Chino about $34^{\circ}06'$ north, $117^{\circ}41'$ west, P. Felt at Ontario and Upland.

January 18: 2:34.* Near Chino about $33^{\circ}57'$ north, $117^{\circ}39'$ west, P. Awakened few at Ontario.

January 19: 15:57.* Sierra Nevada near Weldon about $35^{\circ}42'$ north, $118^{\circ}22'$ west, P. Trees and bushes shaken at Kernville. No damage.

January 20: 3:11.* Epicenter about 6 miles south of Palo Alto (seismograph) station, B. Felt at Mountain View.

January 20: 10:05. $34^{\circ}59'$ north, $117^{\circ}12'$ west. Felt.

January 20: 23:43.* About 33.6° north, 118.0° west, P. Felt near Huntington Beach.

January 23: 6:31.* About 12 miles west of Hollister, B. Awakened few at Hollister.

February 5: 10:02.* About 12 miles west of Hollister, B. Felt slightly at Hollister.

February 5: 15:17.* About 12 miles west of Hollister, B. Frightened few at Hollister.

February 5: 18:52.* Vicinity of Indian Wells about $33^{\circ}35'$ north, $116^{\circ}18'$ west, P. Felt at Berdoo Camp.

February 6: 20:42.* Epicenter about 50 miles northwest of Ferndale, B. Intensity about V in the vicinity of Humboldt Bay. 10,000 square miles of land area affected. See map. Recorded on strong-motion seismograph at Eureka and Ferndale.

INTENSITY V:

Alder Point.—Trees and bushes shaken. Damage slight.

Arcata.—Awakened and frightened many. Damage slight.

Cape Mendocino.—Frightened all. Most severe shock in several years. No damage.

Capetown.—Pendulum clocks stopped. No damage.

Eureka.—Felt by all. Clocks stopped; trees and bushes shaken. No damage.

Eureka, central section.—Chandeliers swung east and west; clocks stopped. No damage.

Ferndale.—Some clocks stopped; small objects overturned; frightened all. Most severe in several years. One report of cracked plaster.

Fields Landing.—Water spilled from containers. Many frightened.

Orleans, northeast section.—Small objects moved; pictures displaced.

Scotia.—Prolonged wavy motion; trees and bushes shaken slightly. Awakened many.

Shively.—Lasted $1\frac{1}{2}$ minutes. Hanging objects swung. Many frightened.

Trinidad.—Clocks stopped. A few frightened.

Upper Mattole.—Trees and bushes shaken moderately. Many awakened.

Intensity IV: Alder Point, Alton, Benbow, Blocksburg, Briceland, Bridgeville, Carlotta, Cummings, Etna, Fort Jones, Fortuna, Happy Camp, Klamath, Orick, Orleans, Scotia, Smith River, Trinidad Lighthouse.

Intensity III and under: Crescent City, Crescent City Light Station, Ettersburg, Garberville, Harris, Helena, Hughes Park, Humboldt Bay, Petrolia, Sawyers Bar, Walker, Weaverville.

Not felt: Beegum, Carrville, Fort Bragg, French Gulch, Laytonville, Lewiston, Platina, Redding, nor at Brookings and Grants Pass, Ore.

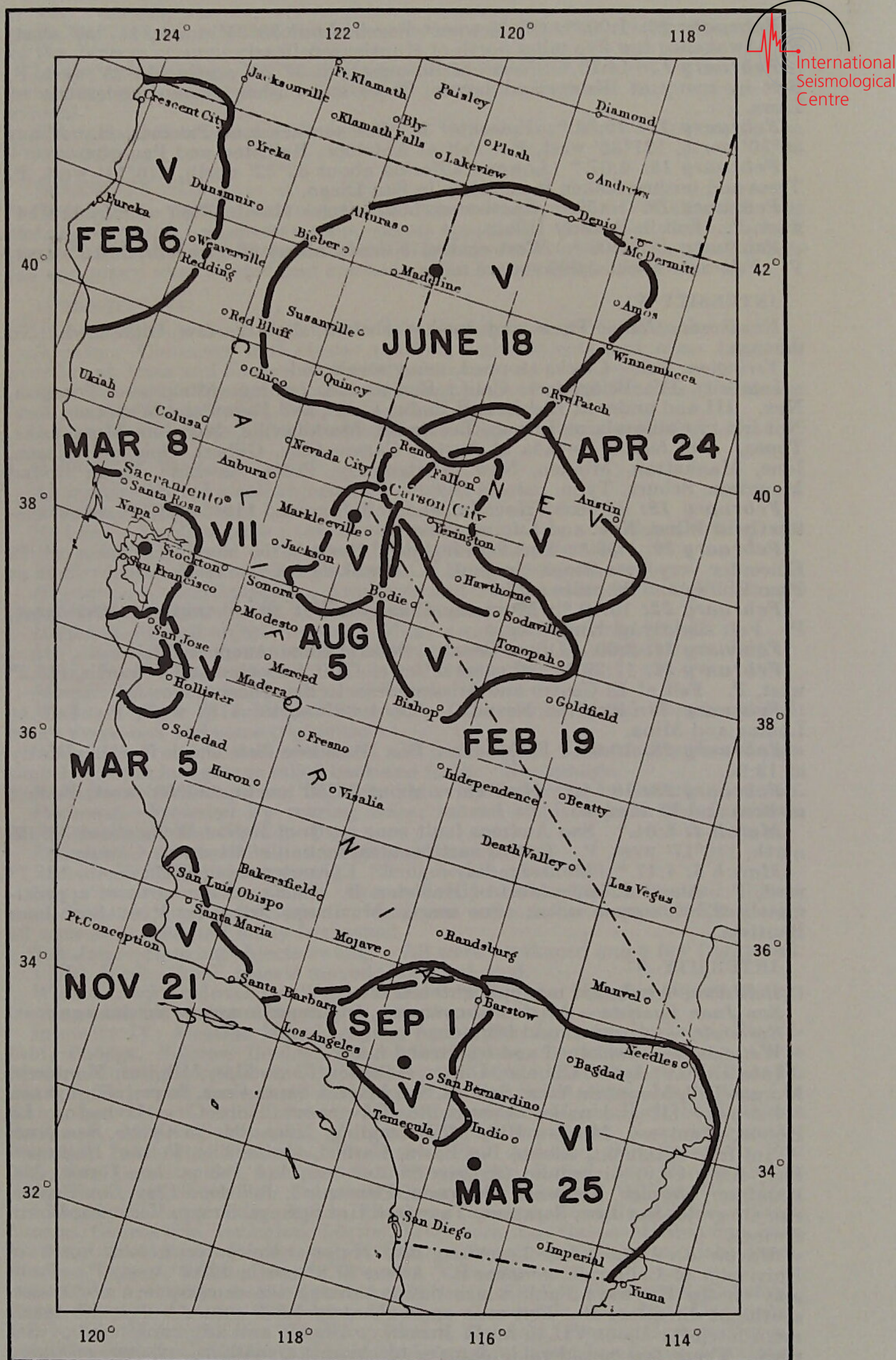


FIGURE 7.—Areas affected by the more important earthquakes of California and western Nevada in 1937.

February 12: 1:00.* Off Newport Beach about $33^{\circ}34'$ north, $117^{\circ}50'$ west, P. Awakened few five miles north of Huntington Beach.

February 12: 14:26.* North of Bishop about $37^{\circ}30'$ north, $118^{\circ}25'$ west, P. Felt by many at Bishop and Laws. Trees and bushes shaken moderately at Laws.

February 16: 19:33.* Epicenter 9 miles southeast of Paicines, B. About $36^{\circ}30'$ north, $121^{\circ}35'$ west, P. Felt at Antelope, Hollister, and Panoche.

February 18: 4:07.* Lower California about $32^{\circ}32'$ north, $116^{\circ}11'$ west, P. Trees and bushes shaken moderately in San Diego.

February 18: 16:59.* Southwest Los Angeles about $33^{\circ}56'$ north, $118^{\circ}14'$ west, P. Felt in Beverly Hills.

February 19: 1:09.* West central Nevada about 38.3° north, 118.3° west, P. Felt over about 5,000 square miles.

INTENSITY V:

Hawthorne, Nev.—Trees and bushes shaken slightly, few frightened. No damage.

Yerington, Nev.—Clocks stopped, many awakened.

Intensity IV: Bridgeport, Calif., Hawthorne, Luning, Mina, and Tonopah, Nev. III and under at Bishop and Bodie, Calif., and Fallon and Wichman, Nev. Not felt in California at Bishop, Leevining, Markleeville, Mocalno, Mono Lake, Topaz. Not felt in Nevada at Austin, Carson City, Gilbert, Goldfield, Hazen, Ione, Manhattan, Minden, New Montgomery, Potts, Rawhide, Reno, Round Mountain, Schurz, Tybo.

February 19: 15:06.* Nevada, about 38° north, 118° west, P. Felt distinctly at Mina, Nev. and Luning, Nev.

February 20: 1:58.* Parkfield region. About $35^{\circ}56'$ north, $120^{\circ}28'$ west, P. Epicenter very near Stone Canyon, B. Awakened a few in Parkfield. Felt at Paso Robles and 20 miles east.

February 22: 10:10.* Monterey County about $36^{\circ}10'$ north, $121^{\circ}32'$ west, P. Felt slightly at King City.

February 26: 2:00. Dillon Beach. Several tremors reported felt.

February 26: 17:29.* Off coast of lower California about 31.7° north, 117.2° west, P. Felt at El Centro and Mission Hills in San Diego.

February 28: 10:17.* Nevada. About 38° north, 118° west, P. Felt at Luning and Mina.

February 28: 10:04. El Modeno, IV. Pasadena lists shock in this vicinity at 13:06.

February 28: 18:14.* Near Olive about $35^{\circ}50'$ north, $117^{\circ}50'$ west, P. Felt at Brea and El Modeno.

March 4: 8:04.* San Andreas fault zone north of Indian Wells about $32^{\circ}47'$ north, $116^{\circ}17'$ west, P. Felt in north central section of Riverside County.

March 5: 4:47.* Monterey Bay region. Epicenter about 36.7° north, 121.7° west, P. About 12 miles west of Hollister, B. Felt over land area of approximately 2,000 square miles. See map. Maximum intensity V at San Juan Bautista.

INTENSITY V:

Hollister.—Awakened many, frightened few.

San Juan Bautista.—Awakened everyone, frightened many. No damages.

Spreckels.—Awakened and frightened many.

Watsonville.—Awakened and frightened many.

Intensity IV: Aptos, Chualar, Gilroy, Hollister, Loma Mar, Milpitas, Monterey, Morgan Hill, Mountain View, Salinas, San Martin, Santa Cruz, Soquel, Sunnyvale.

Intensity III and under: Castroville, Davenport, Holy City, Irvington, La Honda, Monterey, Morgan Hill, Moss Landing, Niles, Pacific Grove, San Jose.

Not felt: Altamont, Aloiso, Big Basin, Carmel, Centerville, Felton, Halfmoon Bay, King City, Livermore (Arroyo Sanitarium), Los Banos, Los Gatos, Mt. Hamilton, Newark, Newman, Patterson, Pleasanton, Redwood City, San Benito, San Gregorio, San Jose, Saratoga, Tassajara Hot Springs, Tracy, Vernalis, Warm Springs.

March 8: 2:31.* San Francisco Bay region. Epicenter 1 mile north of University of California campus, B. About 37.8° north, 122.2° west, P. Probably on the Hayward Fault which passes through the campus in a northwest-southeast direction; B. Felt over approximately 5,000 square miles with maximum intensity about VII in north Berkeley, Albany, and adjoining points. See map. There was considerable damage to chimneys, masonry, plaster, retaining

walls, and sewers. 130 cracked chimneys were reported in Albany alone, most of the damage occurring at roof levels.

In the epicentral region most observers reported the disturbance as several hard jolts of short duration. Shifting of heavy furniture one inch or more was general.

Strong motion seismographs operated at Berkeley and at two stations in San Francisco.

INTENSITY VII:

Berkeley.—In parts of Berkeley the damage was indicated as VII although over the greater part VI would be a more correct appraisal. Some walls were cracked, plaster and books fell, vases and small objects were overturned; some chimneys fell and many were twisted and cracked. One home reported \$300 damage.

INTENSITY VI:

Albany.—Pictures and knickknacks fell, plaster cracked, dishes broke.

Berkeley.—Chimneys and plaster cracked, light objects and some furniture overturned, trees and bushes moderately shaken.

Elmhurst.—40,000-gallon wood vinegar tanks moved about 3 inches on dunnage beams at Standard Brands, Inc., in east-west direction.

Oakland.—Chimneys and plaster cracked. Slight damage to concrete.

INTENSITY V:

Alvarado.—Moved small objects and cracked plaster.

Atherton.—Noise heard before motion began. Frightened all.

Berkeley.—Small objects overturned; windows, doors, and dishes rattled violently; many frightened. Trees and bushes shaken moderately.

El Cerrito.—Substation G. Felt by all. Hanging objects swung.

Hayward.—Cracked plaster. Awakened and frightened many. Slight damage.

Lafayette.—Frightened all. Walls and frames creaked.

La Honda.—Small objects moved. Many awakened; few frightened.

Los Altos.—Whole house rattled; observer awakened; one window cracked.

Menlo Park.—Awakened all. Walls and frame creaked.

Morage.—Awakened all; many frightened.

Mountain View (5 miles southwest of).—Door swung; small objects moved; many awakened and some frightened.

Oakland.—Practically all awakened and frightened. Trees and bushes shaken slightly. Cars in a garage rolled back and forth. No damage.

Pescadero.—Awakened and frightened all. Spilled water in easterly direction.

Piedmont.—Preceded by roaring noise; moved small objects and furniture. Many awakened and frightened.

Richmond.—Awakened all and frightened many.

Rodeo.—Hanging objects swung. Shook beds against walls.

San Francisco.—Some plaster was cracked; knickknacks fell; small objects were displaced; suspended objects swung and some clocks stopped. Practically all were awakened and many frightened.

San Jose.—Hanging objects swung. All were awakened and a few frightened.

Valley Ford.—Small objects moved; few awakened.

Walnut Creek.—Moved small objects and furnishings. Hanging objects swung; trees and bushes shaken moderately. Awakened many.

Intensity IV: Alcatraz Island, Alviso, Aptos, Ben Lomond, Berkeley, Bloomfield, Bodega, Bolinas, Boulder Creek, Burlingame, Centerville, Colma, Corte Madera, Cotati, Cowell, Daly City, East Brother Island Light Station, El Granada, Fairfax, Hayward, Inverness, Livermore, Arroyo Sanatorium, Los Altos, Los Gatos, Los Altos (Jesuit Retreat), Manor, Martinez, Menlo Park, St. Patrick's Seminary, Milpitas, Montara, Morgan Hill, Mount Eden, Newark, Novato, Oakland, Palo Alto, Petaluma, Pleasanton, San Anselmo, San Francisco, San Jose, San Leandro, San Lorenzo, San Martin, San Rafael, San Ramon, Santa Rosa, Saratoga, South San Francisco, Sunnyvale, Tiburon, Vallejo, Woodacre.

Intensity III and under: Byron, Clayton, Concord, Cordelia, Diablo, Gilroy, Graton, Guerneville, Irvington, Isleton, Livermore, Los Gatos, Mission San Jose, Novato, Occidental, Penngrove, Pittsburg, San Jose, Sausalito, Sebastopol, Sonoma, Soquel, Stinson Beach, Tomales, Vacaville.

Not felt: Annapolis, Antioch, Auburn, Bethany, Big Sur, Brentwood, Calistoga, Camp Meeker, Carmel, Cazadero, Chualar, Cloverdale, Danville, Davenport, Davis, Del Monte, Dixon, Elkgrove, Elmira, Fairfield, Fresno, Gerber, Geyserville, Grandview, Healdsburg, Hilton, Hollister, King City, Los Banos, Los Gatos, Madrone, Manteca, Menlo Park, Merced, Middletown, Mile Rock Light Station,

Modesto, Monterey, Monticello, Moss Landing, Mount Hamilton, Newman, Oakdale, Oakley, Point Reyes Light Station, Rio Nido, Roseville, Rutherford, Sacramento, St. Helena, Salinas, San Jose, San Juan Bautista, Santa Rosa, Sonoma, Stewarts Point, Stockton, Topaz, Turlock, Vernado, Walnut Grove, Warm Springs, Watsonville, Windsor, Yolo, Yountville, Tracy.

March 9: 5? Hawthorne, Nev. Very slight.

March 10: 22:25. Tomales, Marin County. Light tremors reported.

March 17: 5:19. Hobart Mills. Light shock. Probably same as shock reported felt in the Floriston and Boca areas, at Hobart Mills and at Reno, Nev., on the 16th.

March 18: 17:23.* Near Mira Loma about $34^{\circ}01'$ north, $117^{\circ}30'$ west, P. Felt generally in San Bernardino Valley, P. Probably same as shocks reported from San Bernardino and Riverside. San Bernardino reports two shocks on the 18th.

March 22: 4:09.* San Francisco. Slight. A few awakened. Epicenter just outside Golden Gate, B.

March 25: 8:49.* Riverside County near Terwilliger Valley. Epicenter within a few kilometers of $33^{\circ}28'$ north, $116^{\circ}35'$ west, on the active San Jacinto fault zone according to the Pasadena Seismological Laboratory. As the epicenter is in a nearly uninhabited mountain area no reports were received from the central area where the intensity must have reached about VII. The disturbed area as shown on the map covered about 30,000 square miles. There was slight to moderate damage to chimneys, plaster, and walls over a wide area. The shock was recorded at many strong-motion seismograph stations in southern California. The sensitive instruments at Pasadena recorded numerous aftershocks within the few days following, but none were large and the activity decreased rapidly.

Further details will be found in an article entitled "The Terwilliger Valley Earthquake of March 25, 1937," by H. O. Wood, in the Bulletin of the Seismological Society of America, Volume 27, No. 4, October 1937.

INTENSITY VI:

Aguanga and vicinity.—Clocks stopped; groceries fell from shelves; small objects and furnishings moved.

Anza.—Small objects overturned; water spilled from indoor containers; chimneys cracked. Trees and bushes moderately shaken. Many frightened.

Borego.—Clock stopped; canned goods fell. Trees and bushes moderately shaken. Many frightened.

Coachella.—Small objects overturned, including canned goods; pictures and plaster fell. Many frightened. Damage slight.

Garnet.—Plaster cracked; trees and bushes shaken; many frightened.

Hemet.—Clocks stopped; walls and plaster cracked. Slight damage to brick.

Hodges Dam.—Piano moved; knickknacks and books fell; trees and bushes shaken.

Keen Camp.—Beginning of shock accompanied by a rumble like thunder. Water spilled from indoor containers. Chimneys cracked. Trees and bushes shaken slightly. Awakened all.

Mecca.—Dishes and vases overturned; pictures fell. Water spilled from indoor containers. Dishes fell from shelves in a trailer. Cans and bottles fell from shelves in adobe grocery. Trees and bushes shaken moderately.

Palm Springs.—Cracked plaster and windows. Many frightened.

Ramona.—Cracked plaster. Frightened few.

Sage.—Awakened all. Trees and bushes shaken moderately. Slight damage. Reported most severe since 1918.

Warner Springs.—Bottles and canned goods knocked from shelves; plaster cracked; trees and bushes shaken slightly.

INTENSITY V:

Alpine.—All frightened.

Arlington.—Spilled liquids indoors; hanging objects swung; trees and bushes shaken moderately.

Banning.—Moved small objects; shook trees and bushes slightly.

Barrett Dam.—Awakened all and frightened many. Trees and bushes and hanging objects disturbed.

Burbank.—Hanging object swung and a few small objects moved. Trees and bushes shaken slightly.

Carlsbad.—Hanging objects swung; a few small objects and furnishings moved.

Cathedral City.—Small objects overturned; trees and bushes strongly shaken.

Crestline.—Heater moved. No one awakened.



- Del Mar*.—All frightened. Hanging objects swung.
- Desert Center, near*.—Concrete base of condenser at substation reported badly cracked. No one awakened.
- Desert Center*.—Hanging objects swung.
- Dos Palmas*.—Overturned vases and dishes; spilled water. Knickknacks and pictures fell. Trees and bushes shaken moderately.
- Edom*.—Vases, small objects, and furniture overturned; plaster cracked. All frightened.
- Escondido*.—Frightened all. Slight damage.
- Holtville*.—Knickknacks, books, and pictures fell. Many awakened and frightened.
- Huntington Park*.—Moved small objects and furnishings. Knickknacks, books, and pictures fell. Many awakened and frightened.
- Idyllwild*.—Rumbling 3 seconds before shock. Overturned vases and small objects; broke dishes. Damage slight.
- Imperial*.—Water spilled; hanging objects swung.
- Indio*.—Clocks stopped; hanging objects swung. Felt by many.
- Jamul*.—Hanging objects swung. Few frightened.
- Julian*.—Clocks stopped; trees and bushes shaken.
- Lakeside*.—Hanging objects swung; trees and bushes slightly shaken.
- Los Angeles, central section*.—Clocks stopped; small objects moved. Frightened few. No damage.
- Lucerne Valley*.—Small objects overturned and knickknacks fell. Trees and bushes shaken. Many awakened.
- Mentone*.—Hanging objects swung; small objects and furnishings moved; spilled water to west. Frightened few.
- Moreno*.—Clocks stopped. Cracked plaster; trees and bushes shaken slightly. All awakened.
- Mount Laguna*.—Awakened all. Frightened few. Walls creaked.
- Newberry*.—Hanging objects swung; small objects and furnishings moved.
- Ontario*.—Hanging objects swung; plaster cracked; trees and bushes shaken slightly.
- Palmdale*.—Walls cracked.
- Palm Springs*.—Trees and bushes shaken. Many frightened.
- Perris*.—Hanging objects swung. Felt by all; frightened few.
- Pine Knot*.—Clocks stopped; trees and bushes shaken slightly. Felt by all; awakened and frightened few.
- Pine Valley*.—Hanging objects swung; small objects and furnishings moved. Trees and bushes shaken moderately. All frightened.
- Riverside*.—Hanging objects had rotary motion. Trees and bushes shaken slightly. Few awakened and frightened.
- Romoland*.—Clocks stopped; small objects and furnishings moved. Trees and bushes shaken strongly.
- San Diego*.—Some clocks stopped; small objects moved.
- San Jacinto*.—Clocks stopped; small objects moved; liquids spilled east to west. Some plaster cracks. Trees and bushes shaken moderately. Many frightened.
- San Marcos*.—Hanging objects swung. A church bell rang once. Felt by many.
- San Pedro, central section*.—Loose objects rattled; clocks stopped. Control cable of elevators struck walls of shafts.
- Santee*.—Hanging objects swung. Trees and bushes shaken strongly.
- Santa Ysabel*.—Small objects overturned, hanging objects swung. Many frightened.
- Spring Valley*.—Hanging objects swung; small objects moved. Liquids spilled; trees and bushes shaken slightly. Felt by all.
- Stanton*.—Hanging objects swung; trees and bushes shaken slightly. Many frightened.
- Temecula*.—Trees and bushes shaken strongly; water spilled east to west. Frightened many; no one awakened.
- Thermal*.—Power poles and wires shaken. Many frightened.
- Twenty-Nine Palms*.—Hanging objects swung; moved small objects and furnishings. Felt by many.
- Upland*.—Rotary motion felt outdoors; hanging objects swung with rotary motion; clocks stopped.
- Valley Center*.—Felt by many; motion outdoors east to west. Frightened few.
- Victorville*.—Felt by all in all buildings. Hanging objects swung; trees and bushes shaken moderately. Many frightened.

White Water.—Hanging objects swung. Northward motion felt outdoors. Frightened many, awakened no one.

Winchester.—Felt by all; frightened few.

Yucaipa.—Hanging objects swung; trees and bushes shaken slightly; occupants left building.

Intensity IV: Acton, Adelanto, Alberhill, Alahambra, Amboy, Balboa, Baldwin Park, Banning, Beaumont, Bellflower, Berdoo Camp, Big Bear City, Bloomington, Bonsall, Brawley, Brea, Bryn Mawr, Cabazon, Cajon, Calabasas, Calxico, Calipatria, Camp Angelus, Campo, Cardiff By The Sea, Cedarpines Park, Chula Vista, Claremont, Colton, Corona, Coronado, Calimesa, Crucero, Del Rosa, Descanso, El Centro, El Cajon, El Toro, Encanto, Encinitas, Etiwanda, Fall Brook, Fawnskin, Fontana, Fullerton, Glendora, Glenn Ranch, Guasti, Henedale, Hesperia, Highgrove, Hipass, Hodge, Huntington Beach, Huntington Park, Imperial Beach, Jacumba, La Crescenta, Laguna Beach, Lake Arrowhead, La Mesa, La Verne, Leucadia, Loma Linda, Long Beach, Los Angeles Weather Bureau Office, Los Nietos, Maywood, Mesa Grande, Mira Loma, Miramar, Murrieta, National City, Needles, Niland, Norco, North Hollywood, North San Diego, Oceanside, Ontario, Orange, Pacific Beach, Palomar Mountain, Pasadena, Plaster City, Pomona, Potrero, Rancho Santa Fe, Redlands, Reseda, Rialto, Running Springs, San Bernardino, San Clemente, San Diego, San Juan Capistrano, San Luis Rey, San Pedro, Santa Ana, Santa Susana, San Ysidro, Seal Beach, Seeley, Seven Oaks, Silverado, Solana Beach, Summit, Sunnyside, Tustin, Twinpeaks, Vista, Westmoreland, Wildomar, Willowbrook, Witch Creek, Yorba Linda.

Intensity III and under: Adelanto, Alta Loma, Arrowhead Springs, Baker, Barstow, Beverly Hills, Blythe, Burbank, Castaic, De Luz, Doheny Park, El Monte, Fillmore, Forest Home Resort, Fresno, Heber, Hueneme, Inglewood, Laguna Beach, La Jolla, Little Rock, Lomita, Lancaster, Los Angeles, Ludlow, Moneta, Monrovia, Moorpark, Palo Verde, Phelan, Redondo Beach, San Dimas, San Fernando, San Pedro, Santa Paula, Tujunga, Valyermo, Wrightwood, Yermo, Parker (Ariz.).

Not felt in California: Andrade, Camarillo, Camp Baldy, Carpenteria, Chatsworth, Earp, El Segundo, Fairmount, Fenner, Kelso, Llano, Mojave, Montebello, Muroc, Ogilby, Ojai, Oxnard, Palm City, Rice, Rosamond, Sandberg, Santa Barbara, Santa Monica, Santa Ynez, Saugus, Shoshone, Summerland, Van Nuys, Ventura, Vidal, Wheeler Springs.

Not felt in Arizona: Bouse, Quartzsite, Tonopah, Vicksburg.

March 26: 8:50. Fullerton, V. Hanging objects swung; small objects moved. Telephone wires swung.

March 26: 21:30. Aguana, Idyllwild, and Romoland. Between IV and V. Strongest at Romoland. Felt at Warner Springs.

March 26: 23:45. Mecca and San Diego. Between IV and V.

March 26: 24:00. Idyllwild and Romoland. IV.

March 27: 2:00. Idyllwild. IV. Warner Springs, slight.

March 27: 16:57.* Off Huntington Beach, about $33^{\circ}37'$ north, $118^{\circ}02'$ west, P. Felt at Santa Ana and Balboa.

March 28: 17:51. Balboa. Slight. Pasadena reports an epicenter in the San Bernardino Mountains at 17:48.

March 28: 17:55. Balboa. Slight. Pasadena reports an epicenter in the San Bernardino Mountains at 17:57.

April 20: 7:24.* Western Riverside and southwestern San Bernardino Counties. Epicenter about $33^{\circ}55'$ north, $117^{\circ}33'$ west, P.

V at Chino and Norco. At Chino hanging objects swung, trees and bushes shook slightly and many awakened. Damage was slight. At Norco many were frightened.

Intensity IV: Alberhill, Arlington, Bloomington, Colton, Loma Linda, Highland, Mira Loma, Riverside. III and under at Arrowhead Springs, Corona, Etiwanda, Glenn Ranch, Guasti, Murrieta, Ontario, Rialto, San Bernardino, Wildomar.

Felt also at Redlands, Hemet, and San Jacinto according to Pasadena. Not felt at Alta Loma, Bryn Mawr, Cajon, Claremont, Del Rosa, Elsinore, Fontana, Perris, Pomona, Silverado, Sunnymead, Temecula, Upland.

April 24: 20:28.* West central Nevada as shown on map. Epicenter about 39° north, 117° west, P. Maximum intensity V at Potts, Nev., where many were awakened and a few frightened. West to east motion observed outdoors.

Intensity IV in Nevada: Carson City, Ione, Luning, Mina, Round Mountain, Steamboat. III and under at Carson City, Fallon, Hawthorne, Lovelock, Schurz, Wichman, Yerington.

Not felt in Nevada at Austin, Eureka, Glenbrook, Hudson, Manhattan, Mill City, Mina (Silver Dyke), Minden, Oreana, Silver City, Smith, Stillwater, Tonopah, Tybo, Wabuska, Wadsworth, Wellington, Yerington. Not felt in California at Bishop, Bodie, Bridgeport, Coleville, Mono Lake, Topaz.

April 28: 14:32. Light shocks felt at San Jose and 5 miles southwest of Mountain View.

May 11: 04:00.* Near Riverside, about $33^{\circ}55'$ north, $117^{\circ}33'$ west, P. About IV at Bloomington. Weaker at Riverside and Arlington.

May 25: 18:11.* Epicenter about 5 miles southwest of Gilroy, B. V at Gilroy.

May 31: 12:00. Luning, Nev. Short abrupt shock.

June 5: 11:52.* Caribou. IV. Recorded at Berkeley. Weaker shock felt at 13:05.

June 10: 22:10.* Off Huntington Beach, about $33^{\circ}37'$ north, $118^{\circ}02'$ west, P. About IV at Huntington Beach. Felt at Anaheim, Orange, and Santa Ana.

June 12: 8:57.* Caribou. Slight. Recorded at Berkeley. Felt at Caribou and Bucks Creek Powerhouses.

June 18: 1:08.* Near southern tip of Lower Lake, Modoc County, B. Felt over 15,000 square miles as shown on map.

INTENSITY V IN CALIFORNIA:

Eagleville.—Many frightened. East-west motion felt outdoors.

Ravendale.—Many awakened. Two other lighter shocks felt the same night.

Red Rock (Larsen Co.).—Motion eastward. Bed shaken violently. Few awakened.

INTENSITY V IN NEVADA:

Flanigan.—Awakened all. Motion northeast to southwest.

Gerlach.—North-south motion. Hanging objects swung; small objects overturned. Trees and bushes shaken moderately. Many awakened.

Lovelock.—North-south motion. Hanging objects swung; moved small objects and furnishings. Trees and bushes shaken slightly.

Mill City.—Moved small objects and furnishings.

Sulphur.—Clocks stopped. Many awakened.

Vya.—Pictures fell. Many awakened.

Intensity IV in California: Davis Creek, Likely, Madeline, Pulga, Susanville, Wendel. IV in Nevada at Jungo, Sutcliffe.

Intensity III and under in California: Adin, Burney, Cedarville, Doyle, Fort Bidwell, Quincy. In Nevada: Hazen, Nixon, Paradise Valley.

Not felt in California: Chester, Downieville, Etna, Lake City, McArthur, Meadow Valley, Mt. Hebron, Portola, Spring Garden, Tennant, Willowranch. In Nevada: Elko, Fallon, Golconda, Oreana, Orovada, Owyhee, Reno, Stillwater, Winnemucca, Yerington, McDermitt. In Oregon: Beatty, Bonanza, Fields, Lakeview, Malin, New Pine Creek, Olene, Quartz Mountain, Valley Falls.

July 5: 19:48.* Vicinity of Santa Monica Bay, $33^{\circ}57'$ north, $118^{\circ}38'$ west, P. Felt at Santa Monica.

July 7: 3:12.* Off Newport, $33^{\circ}34'$ north, $117^{\circ}59'$ west, P. See map. V at Santa Ana where pictures danced on the walls.

Intensity IV: Arlington, Artesia, Balboa, Huntington Beach, Newport Beach, Santa Ana, Seal Beach. III and under at Anaheim, Banning, El Toro, Long Beach, Silverado, Yorba Linda.

Not felt: Alberhill, Alta Loma, Arrowhead Springs, Baldwin Park, Beaumont, Bellflower, Big Bear City, Bloomington, Claremont, Colton, Corona, Crestline, Etiwanda, Fawnskin, Glendora, Guasti, Laguna Beach, La Habra, Los Alamitos, Los Nietos, Mentone, Monrovia, Norco, Norwalk, Oceanside, Ontario, Patton, Pedley, Perris, Pomona, Puente, Riverside, Sage, San Bernardino, San Clemente, San Dimas, San Pedro, Seven Oaks, Summit, Sunnymead, Temecula, Willowbrook, Wildomar, Winchester, Yucaipa.

July 18: 3:59.* San Francisco Bay region. Epicenter $37^{\circ}45.2'$ north, $122^{\circ}22.8'$ west, B. Maximum intensity IV.

Intensity IV: Larkspur, Los Altos, Mile Rocks Light Station, Mill Valley, Redwood City, San Francisco, San Jose.

Intensity III and under: Bolinas, Colma, Daly City, Fort Baker, Fort Barry, Irvington, Lagunitas, Montara, Petaluma, San Francisco, San Geronimo, Stinson Beach, Tiburon, Walnut Creek.

Not felt: Alameda, Alviso, Berkeley, Burlingame, Concord, Crockett, El Cerrito, El Granada, Elmhurst, El Verano, Grandview, Halfmoon Bay, Ignacio, Inverness, Lafayette, La Honda, Los Gatos, Martinez, Milpitas, Monterey,



Mount Eden, Mountain View, Napa, Newark, Niles, Novato, Palo Alto, Pescadero, Philo, Pinole, Point Reyes Station, Point Reyes, Oakland, Olema, San Anselmo, San Francisco, San Pablo, San Quentin, Sausalito, Selby, Sharp Park, South San Francisco, Sunol, Vineburg, Warm Springs.

July 26: 0:30. El Centro. Slight shock reported felt throughout Imperial Valley.

July 29: 8:59.* Sierra Nevada west of Owens Lake, $36^{\circ}25'$ north, $118^{\circ}10'$ west, P. Felt at Owenyo, Clough's Cave Ranger Station, and in Kern River Canyon.

August 1: 22:24.* Los Angeles region. About $33^{\circ}57'$ north, $118^{\circ}12'$ west, P. Felt in southwest Los Angeles, Burbank and Hollywood.

August 4: 23:59.* Los Angeles region. About $33^{\circ}59'$ north, $118^{\circ}10'$ west, P. Felt in southwest Los Angeles.

August 5: 19:24.* Lake Tahoe region, about 38.8° north, 120.1° west, P. Not far from Lake Alpine, B. See map. Maximum intensity V at Camp Connell, Bear River, and Salt Springs. At Camp Connell small objects and furnishings moved, liquids spilled, trees and bushes shook slightly and some were frightened. At Bear River dishes were knocked from shelves. Rock slide at Salt Spring probably caused by shock.

August 5: 19:38.* About 4 miles southeast of University of California campus, B. III in Rockridge district, Oakland.

Intensity IV in California: Blue Lakes, Coleville, Dardanella, Gorden Valley, Mather, Mokelumne Hill, Salt Springs, Bear River, Topaz, Vade. In Nevada: Minden.

Intensity III and under in California: Angels Camp, Blue Canyon, Camino, Columbia, Dardanelle, Electra, Lake Alpine, Long Barn, Pine Crest, Meeks Bay, Stanislaus, Sonora, Tuolumne. In Nevada: Gardnerville, Glenbrook.

Not felt in California: Auburn, Aukum, Avery, Bridgeport, Brockway, Burson, Chinese Camp, Copperopolis, Coulterville, El Dorado, El Portal, Emerald Bay, Grizzly Flats, Incline, Ione, Jackson, Jamestown, Kelsey, La Grange, Lotus, Milton, Moccasin, Mountain Ranch, Murphys, Natoma, Pilot Hill, Plymouth, San Andreas, Shingle, Tahoe City, Tuolumne Meadows, Valley Springs, Volcano, Wawona, Westpoint, Yosemite National Park, Youngs. Not felt in Nevada: Carson City, Smith, Wabuska, Wichman, Yerington.

August 8: 23:15. Spring Garden and Taylorsville. Slight.

August 9: 8:16.* About 6 miles southwest of Gilroy, B. IV at Moss Landing.

August 11: 23:31.* Cape Mendicino region. Felt at Cape Mendicino, Ferndale, Fernbridge, Korbel. Strongest at Cape Mendicino, about IV.

August 16: 21:03.* Near Long Beach, $33^{\circ}47'$ north, $118^{\circ}08'$ west, P. V at Long Beach, Lynwood, Wilmington. At Long Beach many awakened, and there was possibly slight damage. At Lynwood a davenport was moved. At Wilmington there was slight damage.

Intensity IV: Artesia, Bellflower, Compton, Downey, Gardena, Hondo, Huntington Park, Hynes, Long Beach, Los Alamitos, Maywood, Norwalk, San Pedro, Seal Beach, Whittier. III and under: Huntington Park, Lomita, Moneta.

Not felt: Alhambra, Baldwin Park, Beverly Hills, El Monte, Glendale, Hawthorne, Huntington Beach, Inglewood, La Habra, Los Angeles, Montebello, Monterey Park, Puente, Redondo Beach, South Gate, Stanton, Westminster.

August 16: 23:19.* Near Long Beach, about $33^{\circ}47'$ north, $118^{\circ}08'$ west, P. Felt at Long Beach.

August 16: 23:50.* Near Long Beach, $33^{\circ}47'$ north, $118^{\circ}08'$ west, P. V at Long Beach and Hondo. At Hondo many awakened and there was slight damage. At Long Beach it was felt by all and many were frightened.

Intensity IV: Artesia, Compton, Huntington Park, Hynes, Los Alamitos, Norwalk, Seal Beach. III and under: Huntington Beach, Lomita, Maywood, Moneta.

Not felt: Alhambra, Baldwin Park, Beverly Hills, Glendale, Hawthorne, Huntington Park, La Habra, Los Angeles, Montebello, Monterey Park, Palos Verdes Estates, Pico, Redondo Beach, South Gate, Stanton, Westminster.

August 18: 0:03.* Near Newhall, $34^{\circ}18'$ north, $118^{\circ}33'$ west, P. Awakened many at Olive View.

August 18: 22:06.* Near Long Beach, $33^{\circ}45'$ north, $118^{\circ}10'$ west, P. Felt at Hynes.

August 18: 23:03.* California-Nevada border, near Gilbert, Nev. About 38° north, 118° west, P. V at Gilbert, Nev., where small objects moved.

Intensity IV in California: Benton, Bishop, Laws. In Nevada: Goldfield, Mt. Montgomery, Silver Peak.

Intensity III and under in California: Bodie, Big Pine. In Nevada: Dyer.

Not felt in California: Deep Springs, Bridgeport, June Lake, Leevining, Mono Lake. In Nevada: Goldpoint, Hawthorne, Ione, Luning, Mina, Round Mountain, Tonopah, Tybo, Wichman.

August 20: 6:51.* Chualar. Epicenter about 7 miles east of Chualar, B. Felt by many in Chualar.

August 21: 4:28.* Probably off Newport Beach, about 33.6° north, 118.0° west, P. Felt slightly at Huntington Beach.

August 22: 16:32.* Nevada. About 38.0° north, 118.6° west, P. Felt in Yosemite National Park, at El Portal and probably Tuolumne Meadows. Epicenter about 10 miles west of Mariposa, B.

August 25: 10:35. Long Beach. Slight.

August 28: 21:19.* About 9 miles north of Lick Observatory, B. Felt at San Jose, Black Mountain, and Ben Lomond.

August 31: 15:52.* About 12 km. south of Riverside, $33^{\circ}50'$ north, $117^{\circ}25'$ west, P. Felt slightly at Patton, San Bernardino and possibly San Diego.

September 1: 5:48.* Near Alta Loma, $34^{\circ}07'$ north, $117^{\circ}35'$ west, P. Felt in San Bernardino Valley, See map. Intensity V at Arlington, Loma Linda and Walnut. At Arlington hanging objects swung, trees and bushes shook moderately and many were awakened and frightened. Practically the same effects reported from Loma Linda. At Walnut a piece of plaster fell and a definite rotary motion was reported.

Intensity IV: Acton, Alberhill, Alta Loma, Bloomington, Brea, Cajon, Claremont, Covina, Crestline, Elsinore, Etiwanda, Fontana, Glendale, Glendora, Guasti, Hemet, Hesperia, Huntington Beach, Llano, Los Nietos, Moreno, Muroc, Norco, Ontario, Pasadena, Patton, Pedley, Perris, Pomona, Riverside, San Bernardino, San Antonio Canyon, Sunnymead, Upland, Victorville.

Intensity III and under: Arrowhead Springs, Baldwin Park, Burbank, Colton, Daggett, Hodge, Idyllwild, Mentone, Murrieta, Phelan, Redlands, San Diego (Mission Hills), San Fernando.

Not felt: Adelanto, Aguanga, Anza, Banning, Barstow, Beaumont, Beverly Hills, Cabazon, Cantil, Compton, Corona, Culver City, Del Luz, El Toro, Fawnskin, Forest Home, Helendale, Huntington Park, Inglewood, Keen Camp, La Habra, Laguna Beach, Lucerne Valley, Mojave, Moneta, Mount Wilson, Palm Springs, Randsburg, Romoland, Rosamond, Sage, Santa Ana, San Juan Capistrano, Seven Oaks, Temecula, Torrance, Universal City, Yucaipa.

September 1: 5:50.* Near Alta Loma, $34^{\circ}07'$ north, $117^{\circ}35'$ west, P. Felt at Alta Loma, Etiwanda, and Perris.

September 1: 8:35.* Near Alta Loma, $34^{\circ}07'$ north, $117^{\circ}35'$ west, P. Felt in San Bernardino Valley. About same intensity as shock at 5:48. Intensity V at Arlington where hanging objects swung and many were awakened and frightened.

Intensity IV: Alta Loma, Bloomington, Cajon, Colton, Covina, Crestline, Etiwanda, Fontana, Guasti, Hesperia, Lucerne Valley, Ontario, Los Angeles, Patton, Perris, San Bernardino, San Antonio Canyon (Sierra hydroelectric plant), Stanton, Sunnymead.

Intensity III and under: Arrowhead Springs, Baldwin Park, Daggett, Lake Arrowhead, Maywood, Murrieta, Redlands, Riverside, Pomona, Mission Hills (San Diego), Romoland, Upland, Walnut, Wildomar.

Not felt: Acton, Adelanto, Aguanga, Anza, Banning, Barstow, Beaumont, Beverly Hills, Cabazon, Cantil, Compton, Corona, Culver City, Del Luz, Elsinore, El Toro, Fawnskin, Forest Home, Glendale, Glendora, Huntington Park, Idyllwild, Inglewood, Keen Camp, La Habra, Laguna Beach, Mentone, Mojave, Moneta, Mount Wilson, Norco, Palm Springs, Randsburg, Rosamond, Sage, Santa Ana, Santa Monica, Temecula, Universal City, Yucaipa.

September 1: 13:29.* Lower California, about 32.5° north, 115.6° west, P. Felt at Calexico.

September 1: 17:40.* Same as at 13:29.

September 2: 4:21.* Same as September 1 at 13:29.

September 6: 11:38.* Los Angeles area. About $34^{\circ}04'$ north, $118^{\circ}16'$ west, P. Felt at Los Angeles and vicinity, Alhambra, and Pasadena.

September 6: 23:36.* Off Huntington Beach, $33^{\circ}37'$ north, $118^{\circ}02'$ west, P.

September 11: 13:59.* About 9 miles southeast of Paicines, B. Frightened many at San Juan Bautista.

September 15: 18:48.* Near Parkfield, $35^{\circ}56'$ north, $120^{\circ}29'$ west, P. Slight at Bradley.

September 17: 6:00. Reno, Nev. Slight.



September 18: 5:29.* Near Salinas. About 9 miles southeast of Paicines, B. About 36.5° north, 121.5° west, P. Felt by many at Chualar. Some awakened at Spreckels and Salinas.

October 2: 19:30. Agua Caliente fault near Aguanda, $33^{\circ}14'$ north, $116^{\circ}30'$ west, P. Felt slightly at Borego.

October 20: 16:01. Alabama Gates, 5 miles north of Lone Pine, hanging objects swung. Slight at Owenyo.

October 21: 21:—. Slight at Imperial and other valley towns.

October 27: 7:41.* Hollister and Salinas. Slight. Possibly same as following shock.

October 27: 7:53.* Monterey Bay region. About 6 miles north of Gonzales, B. 37° north 122° west, P.

Intensity IV: Aptos, Big Sur, Boulder Creek, Chualar, Gonzales, Hollister, King City, Salinas, San Lucas, Spreckels, San Juan Bautista, Watsonville. Strongest at San Juan Bautista, Spreckels, Salinas, and Hollister.

Intensity III and under: Ben Lomond, Gilroy, King City, Mayfield, Pinnacles, Salinas, San Martin, Santa Cruz, Seaside, Tres Pinos.

Not felt: Almaden, Aromas, Bradley, Castroville, Coalinga, Coyote, Cupertino, Davenport, Del Monte, Felton, Glenwood, Greenfield, La Honda, Lonoak, Los Altos, Los Banos, Los Gatos, Madrone, Marina, Mendota, Monterey, Morgan Hill, Moss Landing, Mountain View, Newman, Pacific Grove, Palo Alto, Parkfield, Redwood City, San Ardo, San Benito, San Jose, San Martin, Santa Cruz, Soquel, Tassajara Hot Springs, Watsonville.

There were light aftershocks at Hollister.

October 27: 12:25.* Monterey Bay region. Epicenter same as at 7:53, B. Strongest at Spreckels and Salinas, about IV. Felt also at Ben Lomond, Gonzales, Greenfield, Hollister, King City, Santa Cruz, Seaside, Tres Pinos, Watsonville. Not felt at Big Sur, Bradley, Castroville, Coalinga, Lonoak, Parkfield, San Benito, San Juan Bautista, San Martin.

October 28: 1:03.* 4:27.* Felt at Hollister. Recorded at Berkeley.

October 29: 19:26.* Ferndale. Slight. Epicenter about 25 miles from Ferndale, B.

November 1: 20:18. San Diego and Oceanside. Slight.

November 1: Solidad. Slight. Berkeley reports an epicenter 6 miles north of Gonzales at 13:40.

November 3: 2:00.* San Lucas, V. Small objects and vases overturned, furnishings moved. At King City hanging objects swung. Felt also at San Ardo. King City reported another shock at 2:10. A few were awakened at Lonoak at 3:—.

November 4: 21:17.* Near Huntington Beach; heard and felt. $33^{\circ}47'$ north, $118^{\circ}02'$ west, P.

November 5: 6:43.* Epicenter about 8 miles east southeast of University of California campus, B. Felt feebly in Berkeley.

November 10: 4:32.* Epicenter about 6 miles east of Gilroy, B. Aptos and Gilroy, about IV. Felt also at Ben Lomond, near Mountain View, Monterey, San Martin, Soquel, Watsonville, Santa Cruz, and Carmel Valley.

November 10: 6:29.* Strongest at Gilroy and Watsonville, about IV. Also felt at Aptos, Ben Lomond, Castroville, Gilroy, Hollister, King City, Madrone, Moss Landing, Pajara Valley, Santa Cruz, Soquel. Not felt 5 miles southwest of Mountain View.

November 13: 18:51.* Hollister. Slight. Epicenter about 3 miles southwest of Tres Pinos, B.

November 16: 2:57.* San Jacinto fault west of Salton Sea, about $33^{\circ}10'$ north, $116^{\circ}10'$ west, P. V at Garnet. Many awakened at Mecca. Slight at Campo.

November 16: 4:27.* San Andreas fault near Cabezon, $33^{\circ}50'$ north, $116^{\circ}42'$ west, P. V at Garnet. Residents awakened at Palm Springs.

November 21: 20:12.* Off Point Arguello, about $34^{\circ}33'$ north, $120^{\circ}47'$ west, P. About 2,000 square miles on land affected. See map. Maximum intensity V reported from five places.

INTENSITY V:

Buellton.—Cracked wallpaper on ceilings.

Goleta.—Moved small objects and furnishings.

Pismo Beach.—Moved small objects, shook trees and bushes; knickknacks fell.

Point Conception Light Station.—Spilled liquids; broke mantle on vapor lamp; moved small objects and furnishings.

Santa Maria.—Moved small objects and furnishings.

Point Arguello Light Station.—Probably V. "Good hard shake."

Intensity IV: Arlight, Betteravia, Bicknell, Casmalia, Concepcion, Drake, Gaviota, Guadalupe, Lompoc, Los Alamos, Los Olivos, Santa Barbara, Santa Maria, Surf.

Intensity III and under: Arroyo Grande, Halcyon, Orcutt, San Luis Obispo, Santa Ynez, Santa Margarita, Summerland.

Not felt: Alamo, Atascadero, Berros, Carpinteria, Cayucos, Fellows, McKittrick, Maricopa, Morro Bay, Paso Robles, Pozo, Santa Barbara.

November 24: 11:44.* Off Newport Beach, about $33^{\circ}34'$ north, $117^{\circ}59'$ west, P. Felt at Huntington Beach.

November 24: 17:44.* Off Huntington Beach, $33^{\circ}37'$ north, $118^{\circ}02'$ west, P. Felt distinctly 5 miles north of Huntington Beach.

November 27: 12:40. Hawthorne, Nev. Slight.

November 27: 15:32.* Sierra Nevada near Weldon, $35^{\circ}42'$ north, $118^{\circ}22'$ west, P. Felt at Kern River Powerhouse No. 3, near Kernville.

December 3: Off Point Arguello, about $34^{\circ}33'$ north, $120^{\circ}47'$ west, P. Felt at Gaviota and Point Conception Light Station.

December 4: 6:—. San Jose and Palo Alto (at 7:00). Slight. Not felt at 26 other places canvassed.

December 4: 17:36.* Epicenter about 19 miles south of Los Banos, B. Probably V at Los Banos. Felt at Mercy Hot Springs.

December 4: 18:05.* Origin same as at 17:36, but a lighter shock, B. Some confusion in reports on the two shocks.

December 13: 2:15.* Epicenter about 4 miles southeast of Castroville, B. III at Hollister.

December 15: 1:58.* San Jacinto fault at Carrizo Creek, about $33^{\circ}05'$ north, $115^{\circ}59'$ west, P. Intensity V at Westmoreland where hanging objects swung and small objects and furnishings moved. Felt also at Brawley, Calexico, Calipatria, El Centro, Holtville, Niland, Seeley. Not felt at Heber and Mission Hills (San Diego).

December 22: 11:24.* Navelancia (Fresno County). Felt. Epicenter probably near Auberry, B. Not felt at Visalia, Ducor, and some other nearby points.

December 24: 3:57.* Probably off Point Arguello, 34.5° north, 120.8° west, P. Felt moderately at Point Arguello Light Station, Casmalia, Point Conception Light Station, Los Alamos.

WASHINGTON AND OREGON

[120th meridian or Pacific standard time]

NOTE.—More details may be found in "Abstracts of Earthquake Reports for the Pacific Coast and Western Mountain Region" available from the Washington office, or from the San Francisco Field Station of the Coast and Geodetic Survey.

February 8: 12:15. Ferndale, Oreg. (near Walla Walla, Wash.). Shock felt, accompanied by rumbling noise.

February 9: 14:20. Walla Walla, Wash. Light objects moved on shelves.

June 4: 6:43. Walla Walla, Wash. Slight displacement of objects on shelves.

August 10: 16:22. Spokane, Wash. Felt. Recorded on seismograph at Mount Saint Michael's Observatory.

September 20: 8:33. Walla Walla, Wash. Slight.

September 28: 0:15. Fall City, Wash. Two tremors 5 seconds apart. Awakened observer. Not noticed by others.

November 1: 5:15. Auburn, Cle Elum, Olympia, Wash. Awakened few. Not felt at Auburn (contradictory reports), Cashmere, Eatonville, Kent, Leavenworth, Morton, Naches, Renton, Snoqualmie, Wenatchee.

November 11: 8:30.* Olympic peninsula area, Washington. Slight shocks recorded on the University of Washington seismograph (Seattle) at 8:30, 8:31, and 8:38. At Olympia trees and bushes were shaken. The shocks were weaker at Centralia, Whites (4 miles east of Elma) and Shelton. Not felt at 12 other places which were canvassed.

November 26: 22:20. Darrington, Hartford, Silverton, Snohomish, Wash. Slight. Not felt at 11 other places reporting.

December 14: 1:00 about. Dallas, Oreg. Seismic origin doubtful. Disturbances reported from Fall City, Tillamook, and 3 miles southeast of Sheridan; thought by some to have been due to meteor. Houses shook and there were rumbling sounds.

December 28: 18:01. Possession, Wash. Slight.



ALASKA

[150th meridian time]



July 22: 7:09.* Central Alaska. Maximum intensity about VIII, 30 miles southeast of Fairbanks. Epicenter 64.6° north, 147.1° west. Felt within a radius of approximately 300 miles, and recorded at distant seismograph stations. As the epicentral region is thinly settled, very little damage occurred.

An informative article on the earthquake is "The Central Alaska Earthquake of July 22, 1937," by E. H. Bramhall, appearing in the Bulletin of the Seismological Society of America, volume 28, No. 2, April 1938. Dr. Bramhall is in charge of the seismographic station at the University of Alaska, near Fairbanks. The following information is taken largely from his article.

An effort was made by Dr. Bramhall to locate the epicenter by a field survey shortly after the main shock. At Salcha Bluff, near mile 34, the highway was completely blocked for several hundred feet by a landslide. Near this point there were mud boils and long cracks up to 15 inches in width. Water in the nearby slough arose considerably above its normal level and did not subside for several days. Water covered the highway in a number of places a foot or more. A homesteader in this vicinity reported the shock extremely violent; his antenna wires were broken and his radio set pitched to the floor from a table. At mile 33 station of the Alaska Road Commission a solidly built two-story log structure was knocked askew by the first shock, several windows being broken. It appeared to lean toward the south at an angle of about 5° . As near as 14 miles from Fairbanks small cracks appeared in the road, and near the 18-mile roadhouse silt and sand from numerous cracks covered the highway.

A subsequent study of about 75 aftershocks recorded at the University of Alaska revealed that about 50 percent indicated an S-P interval of 6 seconds (29 miles); 25 percent measured 7 seconds (34 miles); 15 percent measured 5 seconds (24 miles); 5 percent measured 4 seconds (19 miles); and another 5 percent, 8 seconds (39 miles). The distance computations are based on the assumption that the waves are propagated through a normal slow-speed granitic layer and that the foci were shallow. The mean of 14 azimuth determinations based on the first impulsive motions recorded on the seismographs was S. 51° E. The azimuth of the main shock was estimated to be S. 49° E. The aftershock azimuths varied, however, from S. 30° E. to S. 70° E. with tendencies to bunch at 33° , 45° , and from 60° to 70° . These data indicate that the aftershocks occurred within a radius of 10 miles of a point about 26 miles S. 50° E. of Fairbanks. They also appear to check very well the facts as reported by Dr. Bramhall as a result of his field survey. Prof. Perry Byerly of the University of California is making a detailed study of the teleseismic records of the main shock on July 22.

Fairbanks suffered considerable minor damage. Estimated damage of \$5,000 was due to broken windows and bottled goods. Electric-light, water, and sewage services were undamaged. Anchorage reported slight damage. The following additional places reported feeling the shock: Circle, Coal Creek, Cordova, Fort Yukon, Hot Springs, Jack Wade, Livengood, McGrath, Nenana, Purgatory, Ruby, Tanana, Valdez, Wiseman; also Dawson and Mayo in Canada. All stations along the Alaska Railroad felt it. The disturbance was reported not felt at Nulato, Bethel, Kanakanak (Bristol Bay), Seward.

Some aftershocks were felt within a radius of 125 miles of the epicentral area. Several hundred aftershocks were recorded.

September 3: 18:48.* Greenwich Civil Time. At Sea, 52.5° north, 177.5° west, near the Aleutian Islands. Reported felt by five ships scattered over a wide area south of the Aleutians.

September 27: 17:29. Juneau and Hoonah. Moderate at Juneau. No damage.

October 1: 0:15. Juneau. Slight.

October 24: 11:36.* Seward. Dishes knocked over. Little damage.

November 24: 0:22. Anchorage. Slight.

November 30: 12:10. Anchorage. Slight.

December 7: 4:35. Anchorage. Slight.

December 11: 9:50. Juneau. Slight.

HAWAIIAN ISLANDS

[157½ meridian (west) time]



NOTE.—In the case of these islands with their many earthquakes of volcanic origin, only the stronger ones are listed. Reports of the Hawaiian Volcano Observatory under the jurisdiction of the National Park Service give all details. "HVO" indicates that the epicenter given was determined by the Hawaiian Volcano Observatory.

January 10: 22:50.* Felt in Hawaii National Park. 19°20.5' north, 155°09.2' west, 7.0 miles deep, HVO.

February 26: 20:04.* Felt by many in Hilo and Hawaii National Park. 19°20.0' north, 155°23.3' west, 10.0 miles deep, HVO.

March 17: 12:29.* Felt by many in volcano area. 19°24.5' north, 155°16.6' west, 1.0 mile deep, HVO.

March 18: 12:10.* Felt strongly at Puuwaawaa Ranch and at Kailua. Dismantled the Kona seismograph. 19°41.0' north, 155°44.5' west, 16.0 miles deep, HVO.

March 19: 8:39.* Felt at C. C. C. camp. 19°24.4' north, 155°16.2' west, 1.4 miles deep, HVO.

April 1: 17:31.* Felt in Hookena. Hanging objects swung. 19°13.3' north, 155°30.2' west, 20.0 miles deep, HVO.

April 18: 4:10.* Felt very strongly at Puuwaawaa Ranch House; also felt on Volcano Road, at Hilo and Kamuela. Origin under Hualalai Volcano.

June 16: 4:52.* Felt rather strongly at C. C. C. camp. 19°24.5' north, 155°16.7' west, 1.0 mile deep, HVO.

July 22: 11:40.* Felt in park headquarters area and at Kilauea Military Camp. 19°23.5' north, 155°15.8' west, 1.8 miles deep, HVO.

August 23: 3:02.* Kilauea Crater. 19°25.0' north, 155°15.9' west, 0.5 mile deep, HVO. Dismantled pit seismograph.

August 27: 0:12.* Felt near park headquarters and C. C. C. camp. 19°24.4' north, 155°15.8' west, 1.5 miles deep, HVO.

October 18: 0:14.* Felt at park headquarters and Hilo. 19°26.3' north, 155°25.0' west, 28.0 miles deep, HVO.

October 25: 5:43.* Felt by many at park headquarters and Hilo. 19°19.8' north, 155°15.0' west, 9.0 miles deep, HVO.

November 27: 18:35.* Felt at C. C. C. camp, southeast rim of Kilauea crater, and park residential area. Pit seismograph dismantled and supports of one instrument broken. 19°24.4' north, 155°16.7' west, 1.1 miles deep, HVO.

PHILIPPINE ISLANDS

[120th meridian (east) time]

NOTE.—In the case of these islands with their many minor earthquakes, only the stronger ones are listed. Reports of the Weather Bureau of the Philippine Islands give all details. Instrumental times given below are arrival times of the first preliminary tremors recorded at Manila unless otherwise stated. The intensities are according to the R-F scale.

January 1: 9:19.* Tacloban and Guinan. IV.

March 8: 21:21.* Infanta V. Manila II.

March 26: 15:45.* Cagayan, Oriental Misamis. IV.

April 20: 6:25.* Virac. IV.

April 20: 18:55.* Irosin. Strong.

June 20: 18:30.* Borongan, V. Felt also at Calbayog and Tacloban.

July 17: 18:26.* Central and eastern Luzon, centering in the Cordillera northeast of Manila. V at Baler. Reported felt from eight other places.

August 4: 1:24.* Legaspi, Albay, IV.

August 8: 17:42. (Time by local observer) Legaspi, Albay, IV.

August 10: 12:18.* Probably Philippine Deep. V in northeastern part of Mindanao at Dapa.

August 12: 16:34.* Eastern Luzon. IV at Santa Cruz and Laguna. Felt in Manila.

August 15: 4:28.* Northern Luzon. V at Appari and Calayan.

August 20: 11:59.* South and southeastern Luzon. Epicenter 14°10' north, 122°05' east, according to the Manila Observatory, in the island of Alabat. Intensity VIII to IX (R-F) in central region and VII at Manila where there was much property damage. There were 2 deaths and 110 minor injuries in the affected area. Several old churches were destroyed; 123 aftershocks were recorded at the Manila Observatory. See the Manila Observatory Seismological Bulletin covering this period for a very complete account of the shock.

September 20: 14:09.* Northern Mindanao. IV at Cagayan (Misamis Oriental) and Jimenez (Misamis Occidental).

September 22: 3:12.* Epicenter in Samar Sea near Masbate. Very strong in southern Masbate; V in northern part.

PUERTO RICO

[60th meridian time]

September 6: 6:59.* Slight tremor at San Juan and San German.

September 9: 20:20 and 24:—, Two slight shocks at San German.

September 11: 6:38.* Slight shock at San German.

September 19: 18:10. Slight tremor at San Juan.

October 4: 4:47.* Tremors at Ponce and San German awakened observers.

PANAMA CANAL ZONE

[75th meridian time]

February 27: 22:43.* Balboa Heights, III–IV.

March 9: 10:41.* Balboa Heights, II–III. Felt throughout Pacific section of Canal.

March 20: 12:57.* Balboa Heights, III–IV. Some slightly alarmed.

March 20: 22:00.* Balboa Heights, II.

March 24: 8:58.* Balboa Heights, II.

March 29: 1:19.* Balboa Heights, II. Felt in David.

March 29: 7:08.* David, Panama. Felt.

June 29: 10:19.* Balboa Heights, II.

October 14: 13:00.* Balboa Heights, II.

December 18: 14:17.* Balboa Heights, II. Felt by many.

December 18: 15:45.* Balboa Heights. Felt.

December 18: 15:49.* Balboa Heights, II–III. Felt by many.

December 18: 17:10.* Balboa Heights, II–III.

MISCELLANEOUS ACTIVITIES

GEODETIC WORK

During the year 1937 the following leveling was run for the purpose of detecting earth movements:

Settlement Investigation, vicinity of San Jose, Calif., spring 1937.

Settlement Investigation, vicinity of San Jose, Calif., winter 1937–38 (in progress at end of year).

The leveling in the spring of 1937 was the fifth complete releveing of the net which was established for the investigation of abnormal settlement in the area centered around San Jose. The sixth releveing was in progress at the end of the year. The results of the releveing have not been fitted to the first-order level net, and therefore elevations are not available for publication.

TIDAL OBSERVATIONS

No tidal disturbances of seismic origin were noted on the gages of the Bureau and cooperating stations during the year.

HYDROGRAPHIC WORK

Vessels of the Coast and Geodetic Survey are directed to make reports of visible or felt effects of earthquakes. No shocks were reported.

SEISMOLOGICAL OBSERVATORY RESULTS

The Coast and Geodetic Survey publishes the results of its teleseismic stations and cooperating stations monthly in mimeographed form. In these reports all seismogram interpretations are tabulated, together with epicenters based on the published data and instrumental results received from seismological stations in all parts of the world. These reports will be furnished upon request to the Director of the Bureau.

Instrumental results are published for the following observatories:

Balboa, Canal Zone (The Panama Canal).
 Bozeman, Mont. (Montana State College).
 Burlington, Vt. (University of Vermont).
 Butte, Mont. (Montana School of Mines).
 Chicago, Ill. (University of Chicago and United States Weather Bureau).
 College, Alaska (University of Alaska).
 Columbia, S. C. (University of South Carolina).
 Des Moines, Iowa (Private station, M. M. Seeburger, Director).
 East Machias, Maine (Massachusetts Institute of Technology).
 Honolulu, Hawaii (University of Hawaii).
 Huancayo, Peru (Carnegie Institution of Washington).
 Montezuma, Chile (Smithsonian Institution).
 Philadelphia, Pa. (The Franklin Institute).
 San Juan, P. R.
 Seattle, Wash. (University of Washington).
 Sitka, Alaska.
 Tucson, Ariz.
 Ukiah, Calif. (International Latitude Observatory).

San Juan, Sitka, Tucson, and Ukiah are Coast and Geodetic Survey stations; Bozeman, Butte, Chicago, College, Columbia, and Honolulu are cooperative stations; Balboa, Burlington, Des Moines, East Machias, Huancayo, Montezuma, Philadelphia, and Seattle are independent stations. All readings are made or revised at the Washington office except those for Balboa.

As the epicenter results for 1937 are not available as this publication goes to press it is expected that they will be published in "United States Earthquakes, 1938."

STRONG-MOTION SEISMOGRAPH RESULTS

INTRODUCTION

During the latter part of 1932, the Coast and Geodetic Survey inaugurated a program of recording strong ground movements in the seismically active regions of the country to obtain data needed in the design of earthquake-resisting structures. Notes pertinent to the development of this program will be found in the four preceding issues of this series, Serials 579, 593, 600, and 610 and in Special Publication 201, "Earthquake Investigations in California, 1934-35." Material in the "United States Earthquakes" series is restricted to the analysis of strong-motion seismograph records. Special Publication 201 is much broader in scope, containing data on structural and ground vibration and detailed descriptions of the various activities which comprise the seismological program as a whole. The reader is also referred to Special Publication 206, "Selection, Installation, and Operation of Seismographs," for descriptive material on strong-motion instruments and vibration meters in addition to similar information on teleseismic instruments.

Interpretation of records.—The following analyses are based on the assumption of simple harmonic motion. This refers especially to the computation of displacement from accelerograph records. As most accelerograph records are of irregular character, and the character of the longer-period waves is often obscured by the superposing of shorter-period waves of relatively large amplitude, the estimates of displacement must be considered as only approximate. One must refer to the illustrations of the curves themselves to evaluate the probable accuracy of the estimated displacements.

The reader is referred to the preceding publication, Serial 610, for further comments on the interpretation of strong-motion seismograph records, especially with reference to the use and evaluation of integration methods. No records for the current year were subjected to this type of analysis. Because of the press for time it has not been possible to entirely complete the projects in strong-motion analysis mentioned in the preceding issue.

Units used.—Quantitative results are expressed in c. g. s. units; centimeters or millimeters for displacement; centimeters per second for velocity, and centimeters per second per second for acceleration. It is sometimes desirable to express acceleration in terms of the acceleration of gravity, indicated by "g," which is equal to 980 cm/sec.^2 . For practical purposes it is only necessary to point off three decimal places to convert cm/sec.^2 to "g."

Sensitivity of the seismographs is expressed as the deflection of the trace, or light spot, in centimeters for a constant acceleration of 100 cm/sec.^2 . This means that the seismometer pendulum is tilted sideways until the effective component of the earth's gravitational field is equal to 100 cm/sec.^2 , or practically 0.1 g.

The following are constants which may be used in converting c. g. s. units to the customary English units:

$$\begin{aligned} 1 \text{ cm} &= 0.3937 \text{ in.} = 0.03281 \text{ foot.} \\ 1 \text{ cm/sec.} &= 0.03281 \text{ ft./sec.} \\ 1 \text{ cm/sec.}^2 &= 0.03281 \text{ ft./sec.}^2 \\ 1 \text{ cm} &= 10 \text{ mm.} \\ 0.1 \text{ g} &= 98 \text{ cm/sec.}^2 = 3.215 \text{ ft./sec.}^2 \end{aligned}$$

Damping ratio of the pendulum is the ratio between successive amplitudes when the pendulum oscillates under the influence of the damping forces alone.

Seismogram illustrations.—Reproductions of seismograms are usually tracings of the original record and must not be accepted as genuine copies. The illustrations are intended to show the nature of the data rather than furnish a means through which the reader can make his own measurements. It is realized that the slightest variations in the copy can easily lead to misleading conclusions. Those who desire true copies for critical study should address the Director of the Bureau for further particulars.


The tabulated instrumental constants refer to the original records. The tracings appearing in this publication are reduced so that if the constants are applied to them a correction will be necessary because of the reduction. The reductions are approximately in the ratio of 1.6 to 1.

TABLE 1.—List of shocks recorded and records obtained on strong-motion seismographs in 1937

Date, epicenter, and recording station	Records		
	Accelerograph	Displacement-meter	Weed strong-motion seismograph
Feb. 6; off Humboldt Bay:			
Eureka	1	1	
Ferndale	1		
Feb. 19; near Hawthorne, Nev.: Hawthorne	1		
Mar. 8; near Berkeley:			
Berkeley	1		
San Francisco, Alexander Bldg	3		
San Francisco, S. P. Bldg	2	1	
San Francisco, State Bldg	1	1	
Mar. 25; southern California, Terwilliger Valley:			
Los Angeles Subway Terminal	2	1	
Los Angeles Chamber of Commerce	2		
Hollywood	3		
Pasadena	1	1	
Vernon	1		
Colton	1	1	
El Centro	1		
San Diego	1		
San Bernardino			1
April 24; near Hawthorne, Nev.: Hawthorne	1		
April 27; Boulder Dam, Nev.: Intake tower	1		
July 7; near Santa Ana: Santa Ana			1
Nov. 11 Boulder Dam, Nev.:			
Intake tower	1		
1215 gallery	1		
Dec. 15; Imperial Valley: El Centro	1		

NOTES ON STRONG-MOTION SEISMOGRAPH RECORDS

The previous practice of attempting to describe the seismograms in detail in the text is believed to be rather superfluous because the outstanding periods are listed in tables, such as table 2 in this issue, and the illustrations provide a far better picture of the records than can be obtained in any other way. The following notes will therefore

contain only such information on the earthquakes and the records which may not be evident from table 2 or from the illustrations. For convenience certain fundamental information on the earthquakes will be repeated from the noninstrumental part of the publication. 

The records have been given a second reading and some differences will therefore be noted from the preliminary figures which appeared in the Progress Reports for the same period. It is well to repeat here that, as the measurement of periods on records of this nature is dependent largely on the judgment of the person reading them, considerable latitude must be allowed in appraising their accuracy. The aim of such analyses is primarily to give a fair picture of the magnitudes of the various elements involved, and the figures tabulated should therefore not be used for important studies without first referring to the illustrations for an idea of the nature of the original records.

EARTHQUAKE OF FEBRUARY 6, OFF HUMBOLDT BAY

Epicenter at sea about 50 miles northwest of Ferndale. Intensity V in the Humboldt Bay area. Approximately 8,000 square miles of land area affected. Recorded at the Eureka and Ferndale stations.

Eureka.—Figure 8. Station about 50 miles southeast of epicenter. Maximum acceleration occurs near start of accelerogram. Some loss of preliminary activity is indicated by comparison with the nearby Ferndale record. The displacement-meter began operating when a maximum displacement of nearly 7.0 mm was being recorded. The maximum ground displacement was very likely greater than this.

Ferndale.—Figure 8. Station about 50 miles southeast of epicenter. A much stronger acceleration record than obtained at Eureka. A relatively quiet period about 4.2 seconds before the main wave group indicates preliminary compressional wave activity.

EARTHQUAKE OF FEBRUARY 19, NEAR HAWTHORNE, NEV.

Epicenter not known accurately but considered to be about 20 miles southeast of Hawthorne where the intensity was about IV. About 4,500 square miles affected.

Hawthorne.—Figure 17. A typical record of a light nearby shock just about within the starting range of the accelerograph.

BERKELEY EARTHQUAKE OF MARCH 8

Epicenter about 1 or 2 miles north of the University of California campus on the Hayward fault. VI to VII in parts of Berkeley and surrounding areas where many chimneys were cracked. About 5,000 square miles affected. Recorded at Berkeley, and at three stations in San Francisco.

Berkeley.—Figure 9. Station about 1 or 2 miles south of epicenter. Duration of active portion only about 2 seconds. Maximum acceleration 56 cm/sec.² A time mark was made on the accelerogram through a special connection with the university clock.

Alexander Building, San Francisco.—Figure 10. Station about 12 miles southwest of epicenter. Only 2 seconds of record was obtained on the basement accelerograph due to premature stopping of the instrument. The eleventh floor accelerogram shows what appears to be a clear resonance effect on the vertical component reaching a maximum acceleration of 34 cm/sec.² the highest reading on any

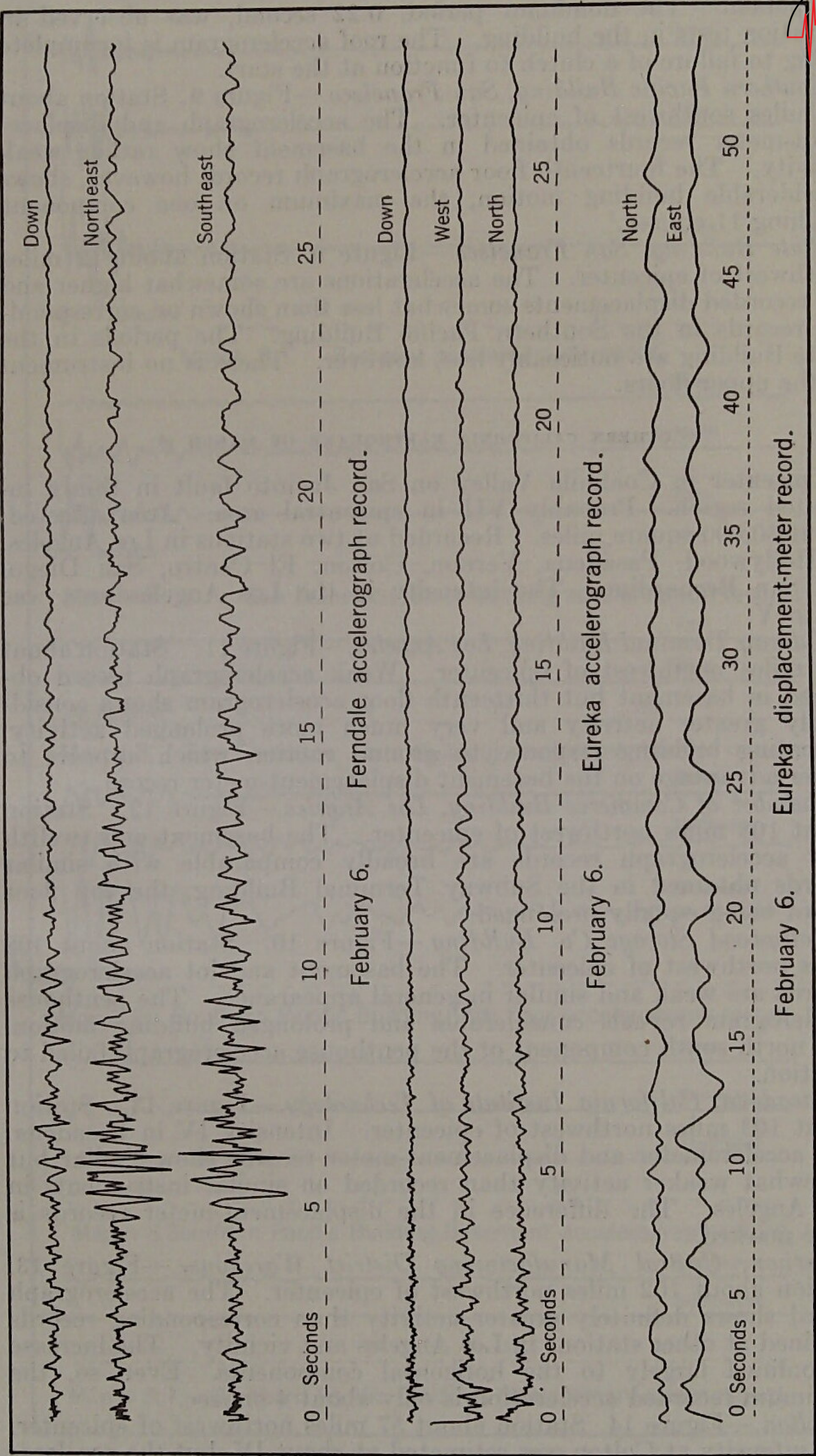


FIGURE 8.—Tracings of Ferndale and Eureka strong-motion records of February 6, 1937.

component. The dominant period, 0.22 second, was observed in vibration tests in the building. The roof accelerogram is incomplete owing to failure of a clutch to function at the start.

Southern Pacific Building, San Francisco.—Figure 9. Station about 12 miles southwest of epicenter. The accelerograph and displacement-meter records obtained in the basement show rather weak activity. The fourteenth floor accelerograph record, however, shows considerable building motion, the maximum on one component reaching 11 cm/sec.²

State Building, San Francisco.—Figure 9. Station about 12 miles southwest of epicenter. The accelerations are somewhat higher and the recorded displacements somewhat less than shown on corresponding records in the Southern Pacific Building. The periods in the State Building are noticeably less, however. There is no instrument on the upper floors.

SOUTHERN CALIFORNIA EARTHQUAKE OF MARCH 25

Epicenter in Coahuila Valley on San Jacinto fault in thinly inhabited region. Probably VII in epicentral area. Area affected, about 30,000 square miles. Recorded at two stations in Los Angeles, at Hollywood, Pasadena, Vernon, Colton, El Centro, San Diego, and San Bernardino. The intensity in the Los Angeles area was IV to V.

Subway Terminal Building, Los Angeles.—Figure 11. Station about 103 miles northwest of epicenter. Weak accelerograph record obtained in basement but thirteenth floor accelerogram shows considerably greater activity and very much more prolonged activity, indicating building response to ground motion which appears to better advantage on the basement displacement-meter record.

Chamber of Commerce Building, Los Angeles.—Figure 12. Station about 103 miles northwest of epicenter. The basement and twelfth floor accelerograph records are broadly comparable with similar records obtained in the Subway Terminal Building, the top floor record being equally prolonged.

Hollywood Storage Co. Building.—Figure 10. Station about 108 miles northwest of epicenter. The basement and lot accelerograph records are weak and similar in general appearance. The penthouse accelerogram reveals considerable and prolonged building motion. The north-south component of the penthouse accelerograph failed to function.

Pasadena, California Institute of Technology.—Figure 13. Station about 103 miles northwest of epicenter. Intensity IV in Pasadena. The accelerometer and displacement-meter records show similar but somewhat weaker activity than recorded on similar instruments in Los Angeles. The difference in the displacement-meter records is quite marked.

Vernon, Central Manufacturing District Warehouse.—Figure 13. Station about 102 miles northwest of epicenter. The accelerograph record shows definitely greater activity than corresponding records obtained at other stations in Los Angeles and vicinity. The increase is confined largely to the horizontal components. Even so, the maximum recorded acceleration is only about 4 cm/sec.²

Colton.—Figure 14. Station about 57 miles northwest of epicenter. The intensity at Colton was estimated at about IV, but the accelera-

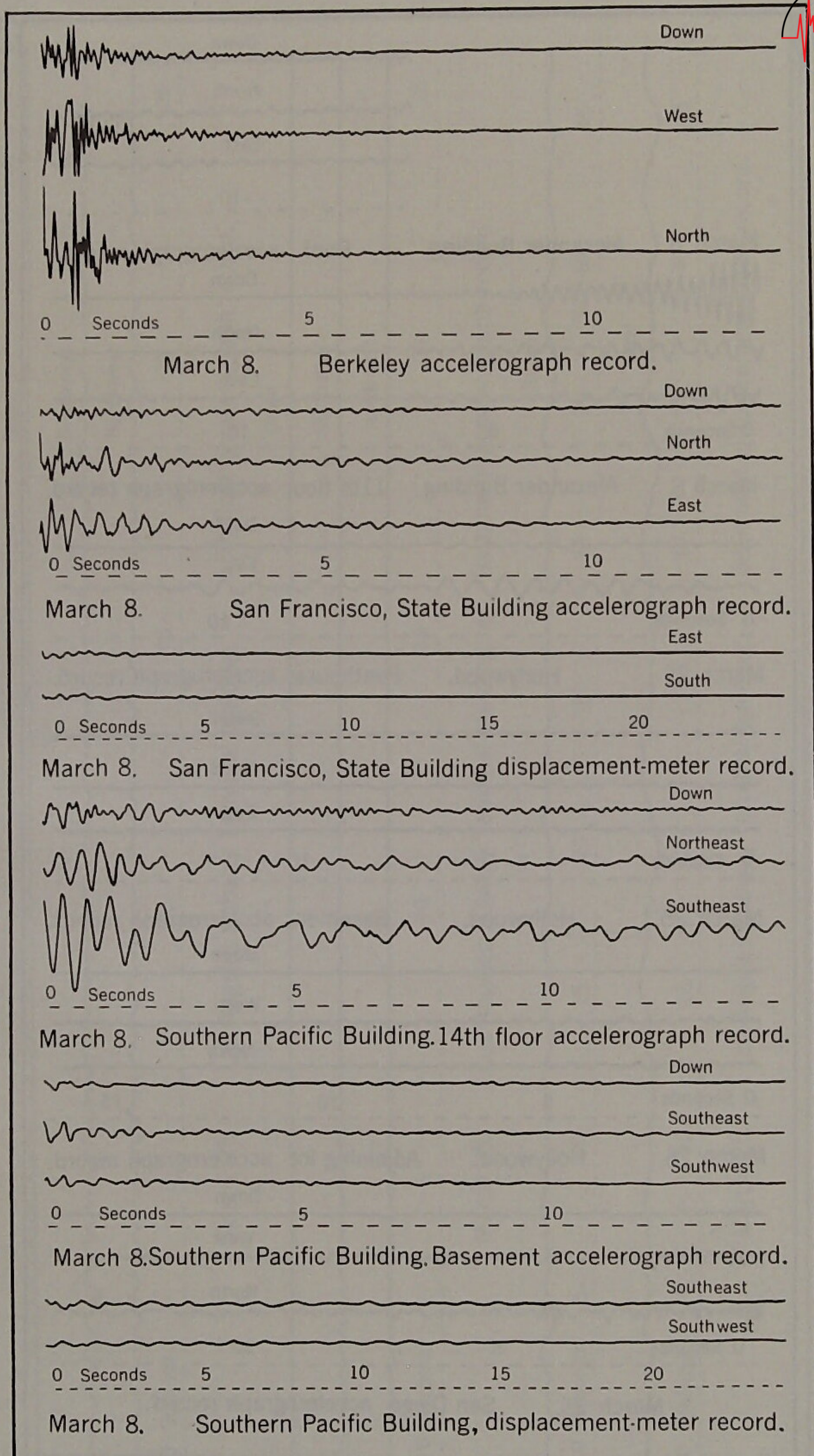


FIGURE 9.—Tracings of Berkeley, State Building, and Southern Pacific Building strong-motion records of March 8, 1937.

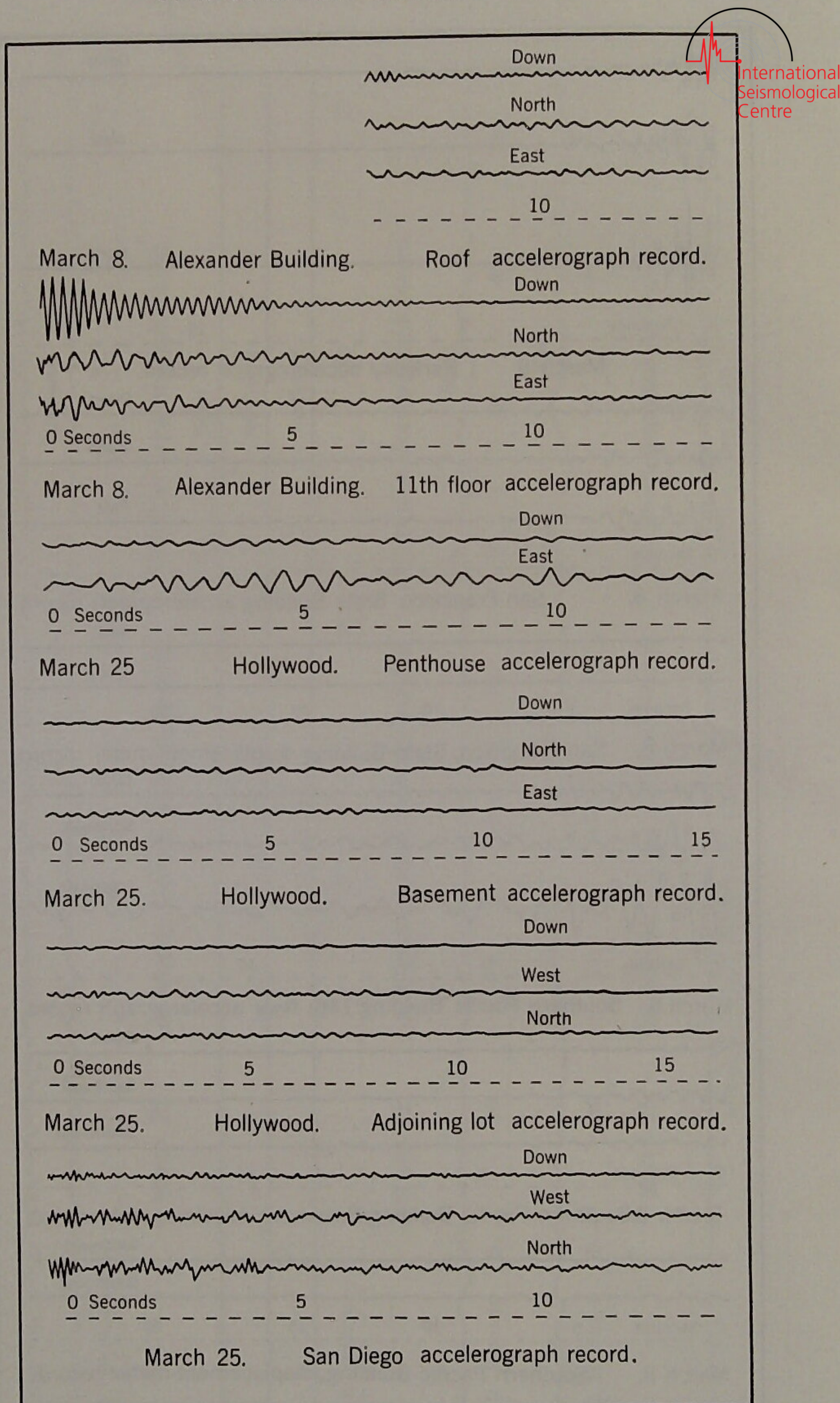


FIGURE 10.—Tracings of Alexander Building strong-motion records of March 8, 1937; Hollywood and San Diego strong-motion records of March 25, 1937.

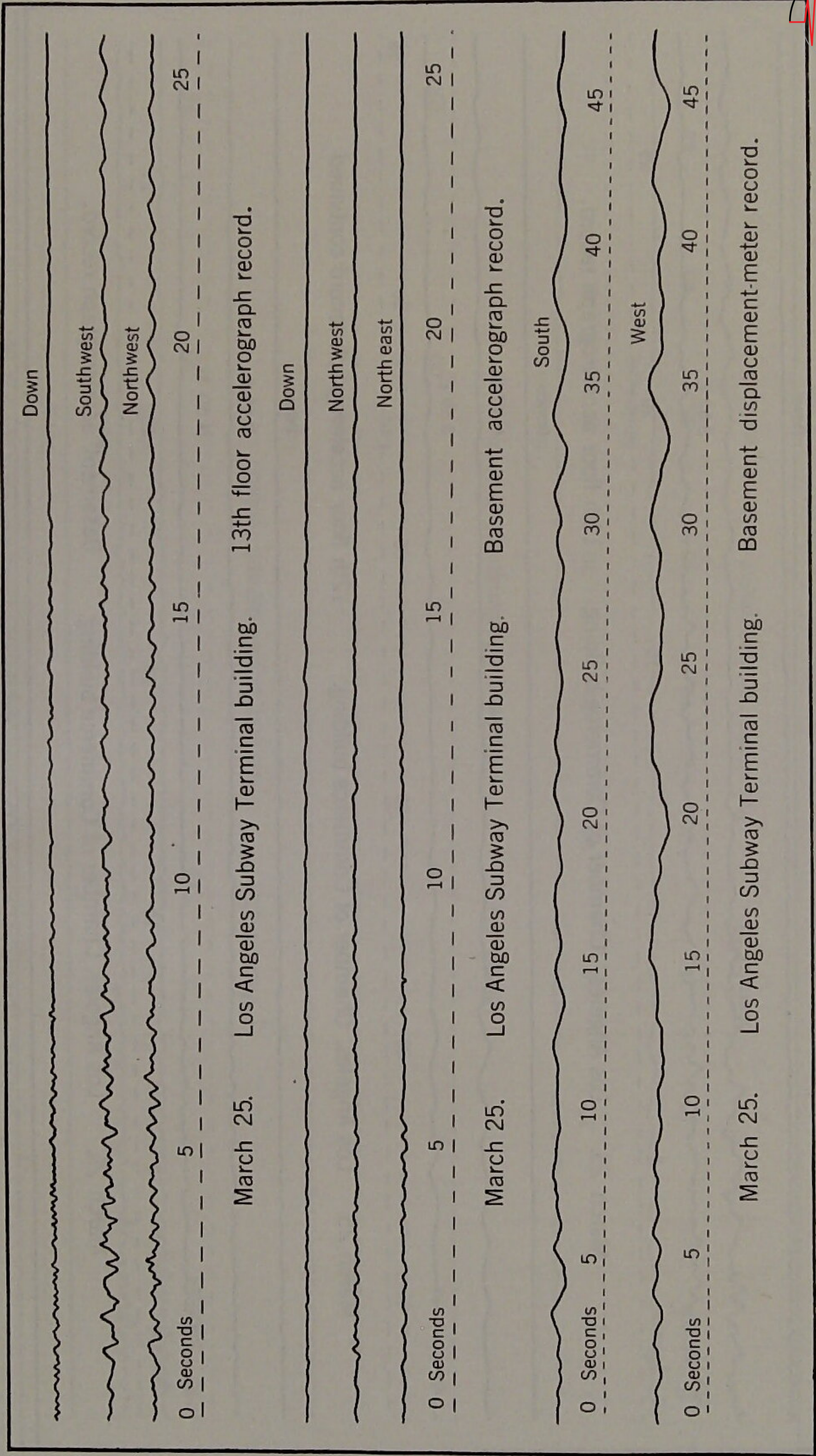


FIGURE 11.—Tracings of Los Angeles Subway Terminal strong-motion records of March 25, 1937.

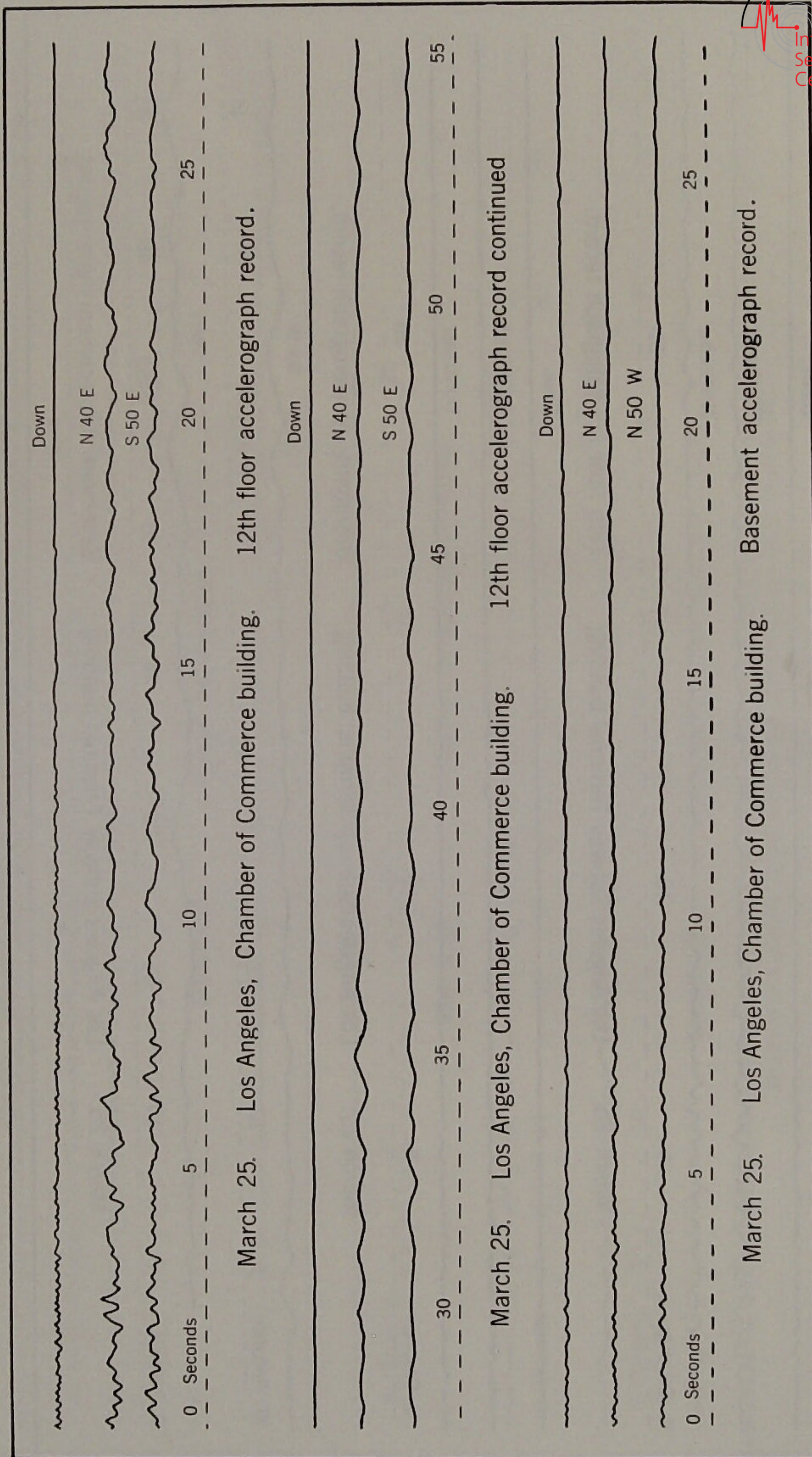
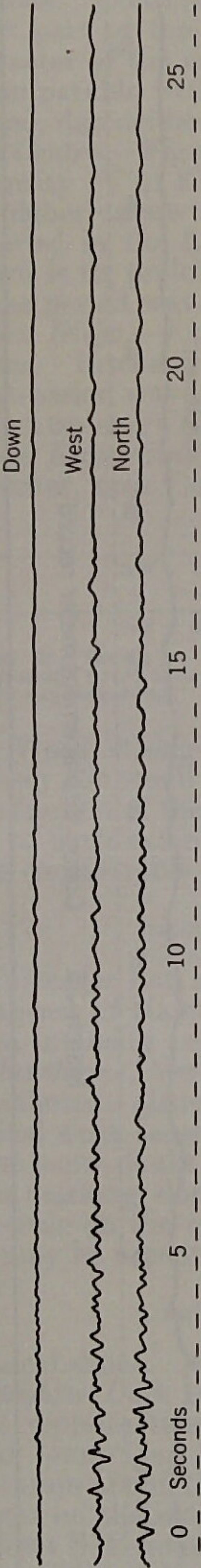
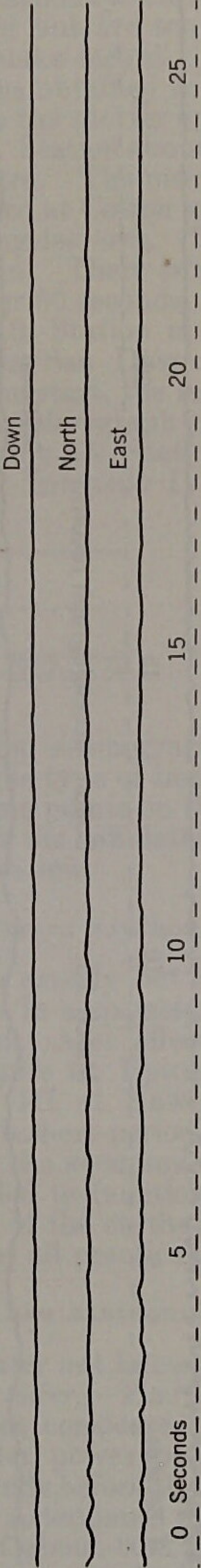


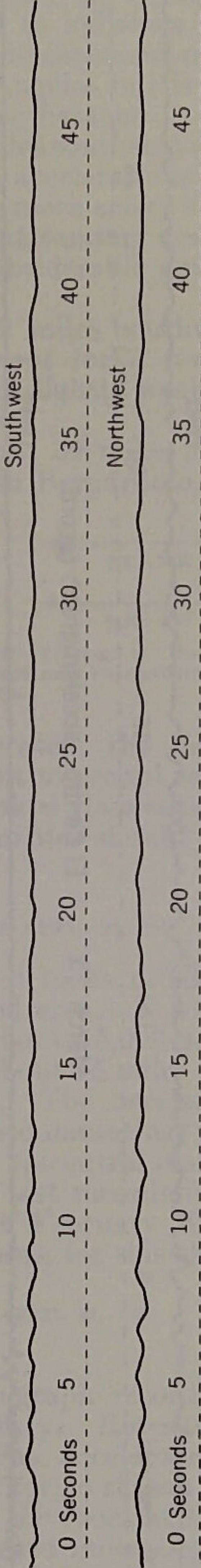
FIGURE 12.—Tracings of Chamber of Commerce Building strong-motion records of March 25, 1937.



March 25. Vernon accelerograph record.

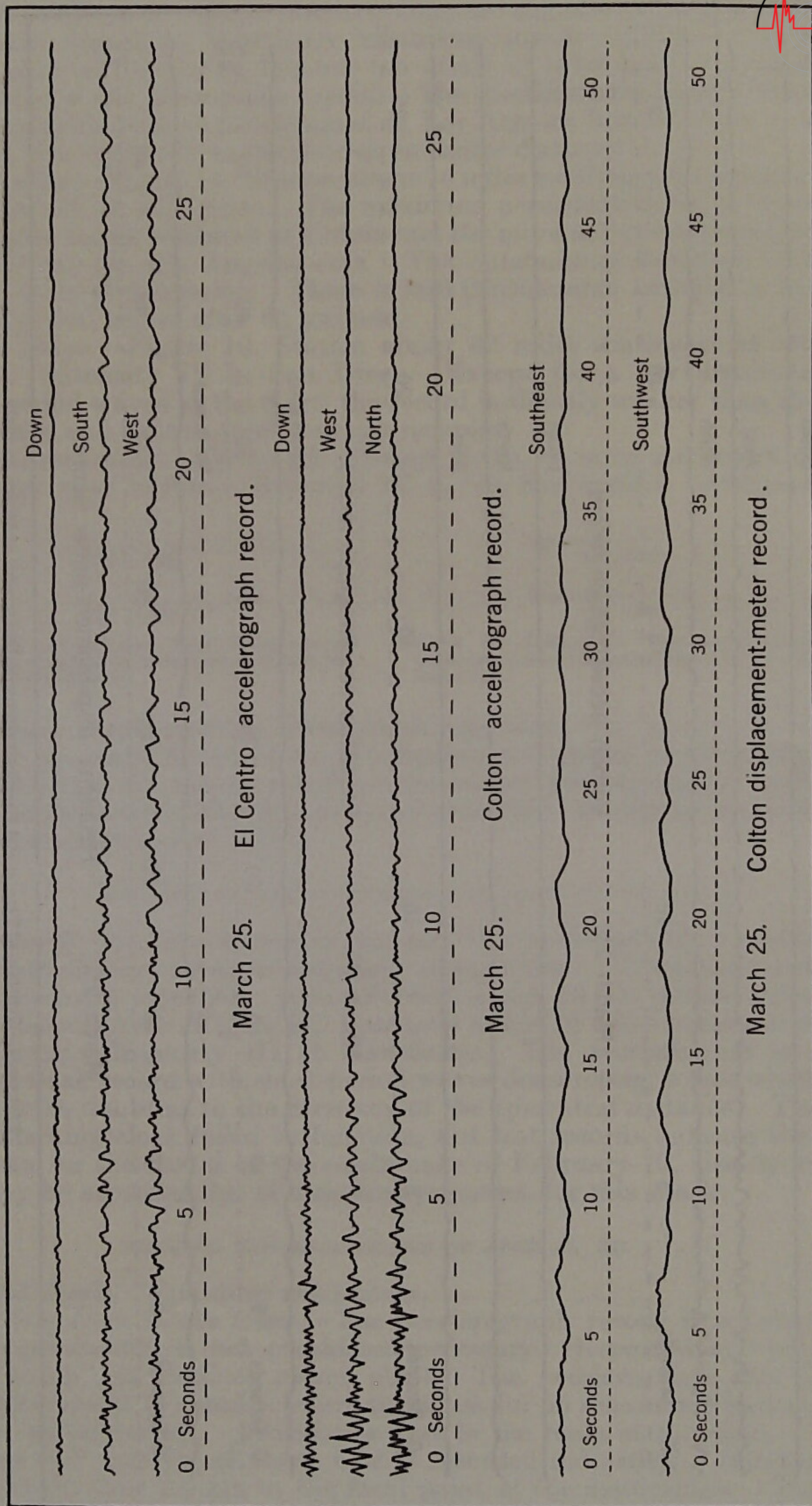


March 25. Pasadena accelerograph record.



March 25. Pasadena displacement-meter record.

FIGURE 13.—Tracings of Vernon and Pasadena strong-motion records of March 25, 1937.



March 25. Colton displacement-meter record.

FIGURE 14.—Tracings of El Centro and Colton strong-motion records of March 25, 1937.

tion records show greater activity than at any of the Los Angeles stations. Continual machinery vibrations are in evidence in the quiet part of the record but are too small to influence the general character of the earthquake record. The displacement-meter record is comparable with those obtained in Los Angeles but is not so prolonged, due evidently to the shorter epicenter distance.

El Centro.—Figure 14. Station about 76 miles southeast of epicenter. Intensity IV in El Centro. The maximum accelerations lie between the higher values obtained at Colton and the more active accelerations recorded in the Los Angeles area. The outstanding feature of the record is its prolongation. There is still considerable activity in the longer period waves after 60 seconds.

San Diego.—Figure 10. Station about 62 miles southwest of epicenter. Intensity IV in San Diego. Except for a few dominant short-period waves at the start, the record is slightly weaker than the El Centro and Colton accelerograph records.

San Bernardino.—Figure 15. Station about 59 miles northwest of epicenter, near Colton. Intensity IV in San Bernardino. Although

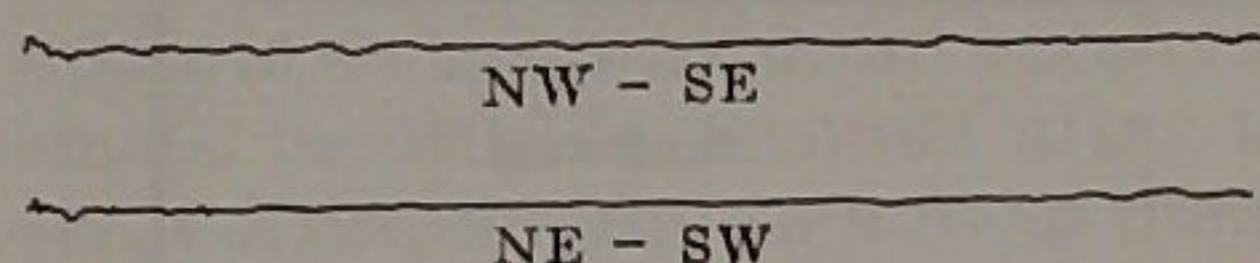


FIGURE 15.—Tracing of Weed strong-motion seismograph record of earthquake of March 25, 1937. San Bernardino.

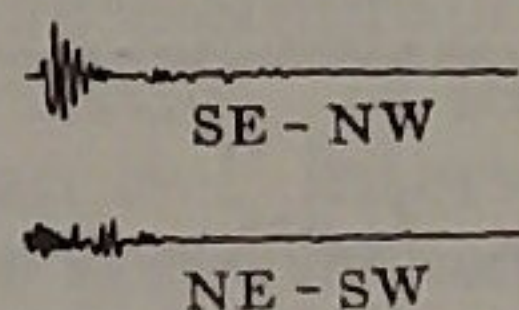


FIGURE 16.—Tracing of Weed strong-motion seismograph record of earthquake of July 7, 1937. Santa Ana.

the Weed strong-motion seismograph operated, the motions were entirely too small for this type of instrument to record satisfactorily. The friction of the writing points on the smoked glass enters the problem to such extent that the tabulated quantities should be accepted with considerable reservation.

WESTERN NEVADA EARTHQUAKE OF APRIL 24, 1937

Epicenter not known exactly but believed to be roughly 75 miles northeast of Hawthorne in a sparsely settled area. V was the maximum intensity reported. Area affected, about 15,000 square miles.

Hawthorne, Nev.—Figure 17. Epicenter about 75 miles northeast of Hawthorne. Intensity III at Hawthorne. The accelerogram is a typical weak record with short-period waves dominating, a fact which raises some doubt as to the accuracy of the epicentral distance. The time marking clock failed to function, but test records indicate that the scale on the record of the earthquake of February 19, also figure 17, may be accepted, for all practical purposes, for this shock.

BOULDER DAM EARTHQUAKE OF APRIL 27, 1937

Local shock. Epicenter not known.

Boulder Dam intake tower.—The accelerograph record is so weak that reproduction is not considered necessary. Reported as "very hard bump" at Boulder power plant. The accelerograph was in operation about 14 seconds before the shock for no reason which is apparent on the record. Attendants were in the room at the time. A distinct S-P interval of about 0.32 is recorded indicating a distance of approximately 2.5 km to the focal point of the disturbance. The

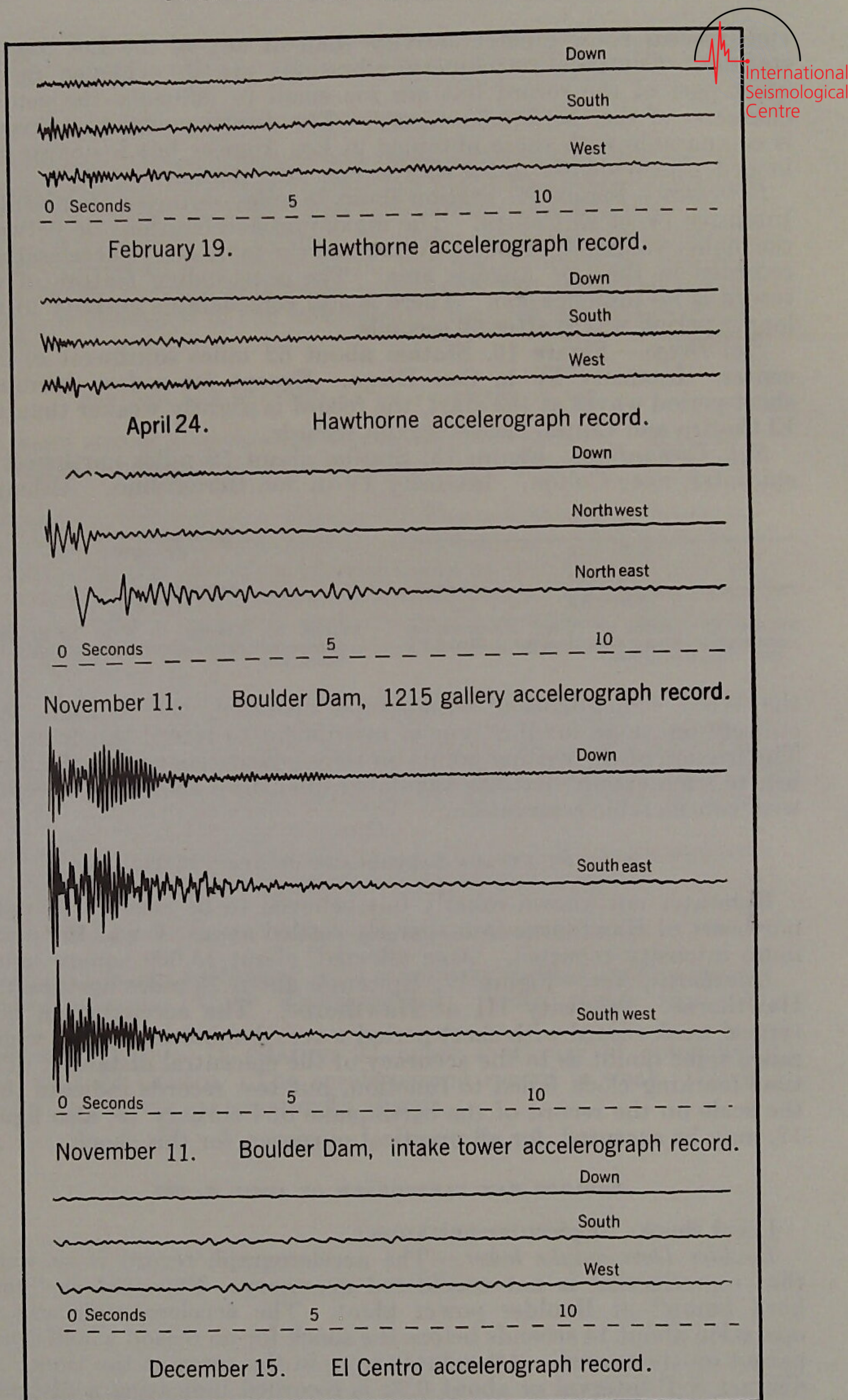


FIGURE 17.—Tracings of Hawthorne strong-motion records of February 19 and April 24; Boulder Dam records of November 11; and El Centro record of December 15, 1937.

installations in 1215 gallery and the oil house were not connected at the time for simultaneous starting with the intake tower accelerograph.

International
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EARTHQUAKE OFF NEWPORT BEACH, JULY 7, 1937

Epicenter off Newport Beach was focal point of the Long Beach earthquake of 1933. Maximum intensity V at Santa Ana. Local in character. Affected less than 1,000 square miles of land area.

Santa Ana.—Figure 16. Station 14 miles northeast of epicenter. The Weed strong-motion seismograph was set in operation but the record is weak, and the maximum amplitudes are obviously due in large part to resonance of the insufficiently damped pendulum of the instrument.

BOULDER DAM EARTHQUAKE OF NOVEMBER 11, 1937

This was a strong local shock felt over the entire project. Reported effects indicate maximum intensity about VI. Exact epicenter not known.

Boulder Dam intake tower.—Figure 17. The accelerograph began to operate as the maximum accelerations were occurring. A feeble after-shock record, 21 seconds after the start, has an S-P interval of 0.75 sec. corresponding to a focal distance of about 6 km. There is no way of knowing whether both foci were identical but it seems significant that a similar interval can be measured also on the vertical motion record of the main shock.

Boulder Dam, 1215 gallery.—This station is in the dam itself about 500 feet from the intake tower station. The first part of the accelerograph record was lost through fogging of the trace but apparently at no time did the acceleration reach the magnitude observed in the intake tower. In the case of the after-shock, the same S-P interval is observed as on the intake tower record.

Boulder Dam, oil house.—The instrument was purposely disconnected at the time because of blasting operations near the station.

IMPERIAL VALLEY EARTHQUAKE OF DECEMBER 15, 1937

Epicenter 32 miles northwest of El Centro on the San Jacinto fault. Maximum intensity V at Westmoreland. Shock rather local in character.

El Centro.—Figure 17. Station 32 miles southeast of epicenter. III or IV at El Centro. The accelerograph record is weak. High frequency vibrations are practically absent.

TABLE 2.—*Summary of strong-motion seismograph data for the year 1937*

[See the text preceding this table for additional details. Simple harmonic motion is assumed when computing displacement from an accelerogram and when computing acceleration from a displacement-meter record]

EARTHQUAKE OF FEBRUARY 6. OFF HUMBOLDT BAY

Station and component	Earth-wave period	Maximum acceleration	Maximum displacement	Remarks
	<i>Seconds</i>	<i>Cm/sec.²</i>	<i>Cm</i>	
Eureka accelerograph				Motion complex.
Vertical	0.08	5.8		Also 0.2 second waves.
	0.6	1.6	0.014	End portion.
East-west	0.10	1.5	0.004	Also 0.2 second waves.
	0.25	11.6	0.018	One wave.
	0.55	6.0	0.046	
South-north	0.09	3.7		Periods variable to 0.25 second.
		16.7		Maximum at start.
	1.0	2.2	0.055	End portion.
Eureka displacement-meter				Very irregular.
South-north			0.75	Maximum at start.
	0.7	3.3	0.04	Periods to 1.5 seconds frequent.
	4.0	0.5	0.20	
East-west			0.37	Maximum near start.
	0.5	9.6	0.06	Also 0.7 second waves.
	4.0±	0.5±	0.20	
	2.2	0.5	0.06	
Ferndale accelerograph				Record complex.
Vertical	0.1	3.2	0.001	Periods to 0.2 second.
	0.37	8.1	0.028	Frequent.
		14.2		Maximum. Short period.
	0.75	1.6	0.0023	End portion.
Southwest-northeast	0.14	5.0	0.002	Frequent.
	0.28	33.5	0.066	Several waves.
	0.9	3.3	0.037	
Northwest-southeast	0.15±	2.2	0.001±	Frequent.
	0.18	40.0	0.032	One wave.
	0.40	7.3	0.029	
	0.7±	9.6	0.118±	Frequent in end portion.

EARTHQUAKE OF FEBRUARY 19. NEAR HAWTHORNE, NEV.

Hawthorne accelerograph				Fairly smooth waves.
Vertical	0.10	3.2	0.001	Prevailing period.
North-south	0.10	9.0	0.002	Do.
	0.19	2.4	0.002	
East-west	0.10	5.9	0.001	Do.

BERKELEY EARTHQUAKE OF MARCH 8

Berkeley accelerograph:				
Vertical	0.10	23.9	0.006	Prevailing period.
N. 72° E.-S. 72° W	0.10	31.0	0.008	Do.
	0.26	1.9	0.003	Weak.
S. 18° E.-N. 18° W	0.10	45.7	0.011	Also 0.08 and 0.15 second periods.
	0.20	22.5	0.023?	
	?	56.1		Maximum at start.
San Francisco, Alexander Bldg., basement accelerograph:				
Vertical	0.22	13.4	0.016	Stopped after 2 seconds.
S. 8° E.-N. 8° W		5.7		Irregular.
	0.22	2.6	0.003	
N. 82° E.-S. 82° W	0.20	7.8	0.008	
		15.4		Maximum at start.
San Francisco, Alexander Bldg., eleventh floor accelerograph:				
Vertical	0.22	34.4	0.042	20 very uniform waves.
S. 8° E.-N. 8° W	0.2±	1.0	0.001±	End portion.
	0.45±	10.2	0.516±	Somewhat irregular.
S. 82° W.-N. 82° E	0.21	5.5	0.006	
	0.3±	12.8	0.029±	One wave.
	0.5			Trace.
San Francisco, Alexander Bldg., roof accelerograph:				
Vertical	0.20	5.4	0.005	
S. 8° E.-N. 8° W	0.40±	2.7	0.011±	Irregular. Shorter period superposed.
S. 82° W.-N. 82° E	0.47±	2.7	0.015±	Do.

TABLE 2.—*Summary of strong-motion seismograph data for the year 1937—Continued*

BERKELEY EARTHQUAKE OF MARCH 8—continued

Station and component	Earth-wave period	Maximum acceleration	Maximum displacement	Remarks
San Francisco, Southern Pacific Bldg., basement accelerograph:	<i>Seconds</i>	<i>Cm/sec.²</i>	<i>Cm</i>	
Vertical.....	0.50	3.9	0.024	
Northwest-southeast.....	0.35	1.5	0.004	
Northwest-southeast.....	0.40	11.1	0.044	
Northwest-southeast.....	0.21	1.0	0.001	
Northeast-southwest.....	0.36	4.2	0.014	
San Francisco, Southern Pacific Bldg., displacement-meter:				
Northwest-southeast.....	1.2	1.7	0.06	Variable period.
Northeast-southwest.....	1.1	1.3	0.04	Do.
San Francisco, Southern Pacific Bldg., fourteenth floor accelerograph:				
Vertical.....	0.18	4.9	0.004	Prevailing period.
Southwest-northeast.....	0.40	12.8	0.051	
Southwest-northeast.....	0.42	2.5	0.011	
Southwest-northeast.....	0.44	22.5	0.109	
Northwest-southeast.....	1.2			Badly masked.
Northwest-southeast.....	0.50	50.5	0.316	Maximum, at start, not recorded.
Northwest-southeast.....	1.2	12.8	0.460	Badly masked.
San Francisco, State Bldg., accelerograph:				
Vertical.....	0.20	5.6	0.006	
Vertical.....	0.36	2.8	0.009	
S. 8° E.-N. 8° W.....	0.11	1.7	0.001±	A few parasitics.
S. 8° E.-N. 8° W.....	0.21?	15.6	0.017	One wave near start.
S. 8° E.-N. 8° W.....	0.30?	11.7	0.026	One wave.
S. 8° E.-N. 8° W.....	0.43	3.1	0.014	Train of waves.
S. 82° W.-N. 82° E.....		20.0		Compound wave at start.
S. 82° W.-N. 82° E.....	0.20	12.8	0.013	At start.
S. 82° W.-N. 82° E.....	0.43	8.9	0.041	Train.
San Francisco, State Bldg., displacement-meter:				
N. 8° W.-S. 8° E.....	0.42±	8.9±	0.04	Prevailing period.
S. 82° W.-N. 82° E.....	0.40±	9.8±	0.04	Do.

SOUTHERN CALIFORNIA EARTHQUAKE OF MARCH 25

Los Angeles Subway Terminal, basement accelerograph:				
Vertical.....	?	1.1		Weak and indefinite.
Southeast-northwest.....	0.25	2.0	0.003	Periods variable.
Southeast-northwest.....	0.40	1.5	0.006	
Southeast-northwest.....	0.64	1.0	0.010	End portion.
Southwest-northeast.....	0.10			Weak parasitics.
Southwest-northeast.....	0.36±	1.4	0.005±	
Los Angeles Subway Terminal, displacement meter:				
North-south.....	0.50±	3.2±	0.02	Do.
North-south.....	1.5	0.7	0.04	
North-south.....	2.5±	0.6±	0.10	
North-south.....	4.6	0.2	0.13	End portion.
East-west.....	1.1±	1.7±	0.05	A few parasitics.
East-west.....	1.9	0.4	0.04	
East-west.....	4.6	0.3	0.14	End portion.
East-west.....	8.0±	0.1±	0.12	Middle portion.
Los Angeles Subway Terminal, thirteenth floor accelerograph:				
Vertical.....	0.14	1.5	0.001	
Vertical.....	0.34	1.5	0.004	
Northeast-southwest.....	0.14±	1.1	0.001	
Northeast-southwest.....	0.34	3.6	0.010	Few only.
Northeast-southwest.....	0.65	4.3	0.045	Frequent.
Northeast-southwest.....	0.75	2.2	0.031	End portion. Smooth.
Southeast-northwest.....	0.15	2.5	0.001	Few.
Southeast-northwest.....	0.33	4.5	0.012	Many.
Southeast-northwest.....	0.65	4.0	0.042	
Southeast-northwest.....	0.75	3.5	0.049	
Los Angeles Chamber of Commerce Bldg., basement accelerograph:				
Vertical.....	0.15	0.8	0.001—	Weak.
Vertical.....	0.32±	1.6	0.004	
S. 50° E.-N. 50° W.....	0.13±	0.8	0.001—	Do.
S. 50° E.-N. 50° W.....	0.36	1.2	0.004	Irregular.
S. 40° W.-N. 40° E.....	0.32±	1.8	0.004	Do.

TABLE 2.—*Summary of strong-motion seismograph data for the year 1937—Continued*

SOUTHERN CALIFORNIA EARTHQUAKE OF MARCH 25—continued

Station and component	Earth-wave period	Maximum acceleration	Maximum displacement	Remarks
Los Angeles Chamber of Commerce Bldg., twelfth floor accelerograph:	<i>Seconds</i>	<i>Cm/sec.²</i>	<i>Cm</i>	
Vertical.....	0.15±	1.1	0.001—	Many.
	0.25±	2.1	0.003	Few. Irregular.
S. 40° W.—N. 40° E.....	0.30	2.4	0.005	Many.
	0.33	5.9	0.016	One wave.
	1.42±	5.2	0.262	Many including end portion.
N. 50° W.—S. 50° E.....	0.22±	1.7	0.002	
	0.35	3.1	0.009	Many 0.40 second waves.
	1.50	3.5	0.197	Few.
	1.20	2.8	0.101	Many.
Hollywood Storage Bldg., basement accelerograph.				Traces irregular.
Vertical.....	0.40	0.9	0.004	Also slightly longer periods.
East-west.....	0.25±	1.4	0.001±	
	0.62	1.9	0.015	
South-north.....	0.30	2.3	0.097	
	0.40	0.9	0.004	
Hollywood Storage Bldg., pent-house record:				
Vertical.....	0.55±	2.8	0.21±	Irregular.
South-north.....				No record.
West-east.....	0.55±	10.0	0.077	Generally smooth.
Hollywood Storage building, near-by lot accelerograph.				All traces irregular.
Vertical.....	0.40	1.0	0.004	
East-west.....	0.22±	0.5	0.001—	Few.
	0.35±	2.4	0.007±	
South-north.....	0.26	2.0	0.003	
	0.37±	2.5	0.009±	
Pasadena accelerograph:				
Vertical.....	0.40	0.7	0.003	Weak. Also 0.60 second waves.
South-north.....	0.40±	1.2	0.006—	Also longer periods.
West-east.....	0.40±	1.1	0.004	Do.
Pasadena displacement-meter:				
Northeast-southwest.....	1.0			Few.
Southeast-northwest.....	1.6±			Many. Very irregular.
	1.5±			Very irregular.
Vernon accelerogram.....				Traces very irregular.
Vertical.....	0.13±	0.4	0.001—	
	0.20±	0.4	0.001—	Rather prevalent.
	0.32±	0.8	0.002	
East-west.....	0.18	0.8	0.001—	
	0.30	3.8	0.009	Dominant period.
	0.50±	2.6	0.016	Longer periods in end portion.
South-north.....	0.17	0.8	0.001—	
	0.30	6.5	0.015	Dominant period.
	0.50	1.9	0.012	Few.
Colton accelerograph.....				Continuous 0.1 second machine vibrations.
Vertical.....	0.10	0.8	0.001—	Probably machinery vibration.
	0.15	7.0	0.004	Dominant in first part.
East-west.....	0.12	3.4	0.001	Few.
	0.20	12.4	0.012	Dominant.
	0.28	4.5	0.009	
South-north.....	0.10	1.9	0.001—	Larger than machinery vibrations.
	0.20	11.2	0.011	
	0.33	6.6	0.018	
Colton displacement-meter:				
Northwest-southeast.....	0.25±	6.4	0.01	A few parasites.
	1.0	0.8	0.02	Also longer periods.
	4.4±	0.2	0.12	Dominant-Irregular.
Northeast-southwest.....	0.30	4.4	0.01	Few.
	0.7	1.6	0.02	Do.
	1.25	0.5	0.02	Do.
	4.7	0.2	0.09	Dominant.
	7.5	0.1	0.09	Irregular.
El Centro accelerograph.....				Record very long.
Vertical.....	0.08	0.8	0.001—	Also 0.11 second waves.
	0.21	0.8	0.001—	Few.
	0.38	1.1	0.004	Do.
	0.7	1.5	0.018	End portion.
North-south.....	0.11	1.5	0.001—	
	0.20	2.2	0.002	
	0.70±	3.7	0.046	Also some 0.6 second waves.
East-west.....	0.11	1.1	0.001—	
	0.18±	1.9	0.002	Few.
	0.50	3.7	0.023	
	0.70±	3.7	0.045	Also some 0.6 second waves.

TABLE 2.—*Summary of strong-motion seismograph data for the year 1937—Continued*

SOUTHERN CALIFORNIA EARTHQUAKE OF MARCH 25—continued

Station and component	Earth-wave period	Maximum acceleration	Maximum displacement	Remarks
San Diego accelerograph:	<i>Seconds</i>	<i>Cm/sec.²</i>	<i>Cm</i>	
Vertical.....	0.13	3.7	0.002	Also some 0.10 second waves.
	0.19±	2.1	0.002	
	0.6	0.8	0.007	Few in end portion.
East-west.....	0.13±	9.0	0.004	Dominant.
	0.65±	2.2	0.024	
South-north.....	0.13±	10.4	0.004	Do.
	0.6±	1.7	0.016	
San Bernardino, Weed strong-motion seismograph.				Extremely weak record, 0.7 mm. trace displacements at start.
Northwest-southeast.....	1.2	0.1	0.005±	Also shorter periods.
Northeast-southwest.....	0.25	0.6	0.001—	
	1.40	0.3	0.014±	Do.

WESTERN NEVADA EARTHQUAKE OF APRIL 24

Hawthorne accelerograph:				
Vertical.....	0.10±	0.8	0.001—	Also a few 0.08 second waves.
	0.13	2.0	0.001—	Dominant.
North-south.....	0.08	3.1	0.001—	
	0.10	1.9	0.001—	
	0.13	8.2	0.003	At start.
	0.16	2.4	0.002	
East-west.....	0.08	1.0	0.001—	
	0.10	1.0	0.001—	End portion.
	0.13	5.2	0.002	Dominant.

BOULDER DAM EARTHQUAKE OF APRIL 27

Boulder Dam intake tower accelerograph.				Weak record. Partly machine vibrations.
Vertical.....	0.07	3.4	0.001—	Few.
	0.103	2.4	0.001—	Long train. Artificial?
Northwest-southeast.....	0.07	6.8	0.001—	Few.
	0.09	1.0	0.001—	Group. Artificial.
Northeast-southwest.....	0.07	8.1	0.001	Few.
	0.09±	1.0	0.001—	Possibly artificial.

EARTHQUAKE NEAR SANTA ANA, JULY 7

Santa Ana, Weed strong-motion seismograph.				Record due largely to insufficient damping and resonances.
Southeast-northwest.....	0.18	3.?	0.002?	Same as pendulum period.
Northeast-southwest.....	0.19	6.?	0.005?	Do.

BOULDER DAM EARTHQUAKE OF NOVEMBER 11

Boulder Dam, intake tower accelerograph:				
Vertical.....	0.09	50.0	0.010	First motion is maximum.
	0.098	31.0	0.007	16 smooth waves.
	0.103	3.0	0.001	End portion.
Northwest-southeast.....	0.09	65.0	0.013	
	0.10	29.0	0.007	Main group.
	0.25	11.0	0.018	
	0.80	0.9	0.014	
Northeast-southwest.....	0.09	55.0	0.011	
	0.095	34.0	0.008	Main group.
	0.75	1.4	0.020	
	0.25	1.9	0.003	
Boulder Dam, 1215 gallery accelerograph:				
Vertical.....	0.3?	2.4	0.006?	Irregular.
	0.12	1.9	0.001	Do.
	0.22	0.9	0.001	
Southeast-northwest.....	0.22	17.0	0.020	
	0.18	3.4	0.003	
	0.20	1.5	0.002	
Southwest-northeast.....	0.6?	33.0		
	0.18	23.0	0.018	
	0.20	13.0	0.013	
	0.23	6.0	0.008	

TABLE 2.—*Summary of strong-motion seismograph data for the year 1937—Continued*

IMPERIAL VALLEY EARTHQUAKE OF DECEMBER 15

Station and component	Earth-wave period	Maximum acceleration	Maximum displacement	Remarks
El Centro accelerograph	<i>Seconds</i>	<i>Cm/sec.²</i>	<i>Cm</i>	
Vertical.....	0.30	0.7	0.002	Dominant.
North-south.....	0.10	0.4	0.001—	Few.
	0.15	0.6	0.001—	Do.
	0.33	2.5	0.007	Dominant.
East-west.....	0.15	0.6	0.001—	Few.
	0.32±	2.6	0.006	Dominant.
	-----	7.5	-----	Maximum acceleration at start.

TABLE 3.—*Instrumental constants of strong-motion seismographs in 1937*

EARTHQUAKE OF FEBRUARY 6. OFF HUMBOLDT BAY

Station and instrument	Orientation of instrument ¹	Pendulum period	Static magnification	Sensitivity ²	Damping ratio	Instrument number
		<i>Sec.</i>		<i>Cm</i>		
Eureka accelerograph.....	Up-Down.....	0.100	102	2.58	8	V29
	E.-W.....	0.098	107	2.66	12	L13
	S.-N.....	0.099	106	2.69	12	T8
Eureka displacement meter.....	S.-N.....	10.00	1.14	-----	13	R13
	E.-W.....	10.06	1.14	-----	12	L13
Ferndale accelerograph.....	Up-Down.....	0.097	101	2.47	10	V10
	SW.-NE.....	0.100	113	2.75	7	L4
	NW.-SE.....	0.099	107	2.72	11	T15

EARTHQUAKE OF FEBRUARY 19. NEAR HAWTHORNE, NEV.

Hawthorne accelerograph.....	Up-Down.....	0.097	100	2.50	12	V14
	N.-S.....	0.099	100	2.55	12	L35
	E.-W.....	0.100	115	2.86	9	T31

BERKELEY EARTHQUAKE OF MARCH 8

Berkeley accelerograph.....	Up-Down.....	0.098	98	2.43	11	V41
	N. 72° E.-S. 72° W.....	0.096	107	2.58	9	L42
	S. 18° E.-N. 18° W.....	0.101	106	2.67	9	T43
San Francisco, State Bldg.: Accelerograph.....	Up-Down.....	0.097	104	2.48	10	V52
	S. 8° E.-N. 8° W.....	0.097	108	2.57	10	L53
	S. 82° W.-N. 82° E.....	0.101	104	2.80	10	T54
Displacement meter.....	S. 82° W.-N. 82° E.....	10	1.14	-----	8.4	R14
	N. 8° W.-S. 8° E.....	10	1.14	-----	8.6	L14
San Francisco, Southern Pacific Bldg.: Fourteenth floor accelerograph ³	Up-Down.....	0.103	78	2.05	11	V108
	SW.-NE.....	0.102	79	2.00	10	L88
	NW.-SE.....	0.102	77	1.96	10	T98
Basement accelerograph ³	Up-Down.....	0.100	79	2.05	10	V107
	NW.-SE.....	0.099	79	1.99	6	L87
	NE.-NW.....	0.098	76	1.89	10	T97
Basement displacement meter ³	NW.-SE.....	10	1.14	-----	8	R18
	NE.-SW.....	10	1.14	-----	8	L18
San Francisco, Alexander Bldg.: Eleventh floor accelerograph ³	Up-Down.....	0.100	76	1.92	7	V118
	S. 8° E.-N. 8° W.....	0.100	79	1.96	9	L96
	S. 82° W.-N. 82° E.....	0.100	76	1.96	10	T106
Roof accelerograph ³	Up-Down.....	0.098	76	1.86	8	V110
	S. 8° E.-N. 8° W.....	0.098	77	1.88	8	L90
	S. 82° W.-N. 82° E.....	0.100	79	1.99	8	T100
Basement accelerograph ³	Up-Down.....	0.100	77	1.94	3.6	V109
	N. 8° W.-S. 8° E.....	0.097	77	1.94	7	L89
	N. 82° E.-S. 82° W.....	0.102	77	1.94	12	T99

¹ The direction on the left (up in the first case) indicates the direction of pendulum displacement, relative to instrument pier, which will displace the trace upward on the original seismogram.

² The sensitivity is the number of centimeters on the seismogram that corresponds to 100 cm./sec.² of acceleration. The deflection corresponding to 1/10 gravity may be obtained by multiplying the sensitivity tabulated by 0.98. (See p. 28.) Some instruments are equipped with attachments which provide auxiliary light spots of low sensitivity. All the earthquakes tabulated were too weak to require the use of the insensitive spots, and the sensitivities tabulated are values for the normal or sensitive spots. These sensitivities are less than on accelerometers not equipped with the new mirrors on account of the increased moment of inertia.

³ Instruments at these stations are wired to start simultaneously.

TABLE 3.—*Instrumental constants of strong-motion seismographs in 1937—Continued*

SOUTHERN CALIFORNIA EARTHQUAKE OF MARCH 25

Station and instrument	Orientation of instrument	Pendulum period	Static magnification	Sensitivity	Damping ratio	Instrument number
		<i>Sec.</i>		<i>Cm</i>		
Hollywood Storage Co. Bldg: Penthouse accelerograph ³	Up-Down	0.100	82	2.12	15	V113
	S.-N.	0.105	78	2.17	11	L93
	W.-E.	0.100	79	2.03	10	T103
Basement accelerograph ³	Up-Down	0.100	85.5	2.20	10	V115
	E.-W.	0.099	81.4	2.16	12	L95
	S.-N.	0.099	79.5	2.16	10	T105
P. E. Lot accelerograph ³	Up-Down	0.101	84.2	2.01	10	V114
	E.-W.	0.102	82.0	2.08	9	L94
	S.-N.	0.102	80.4	2.03	10	T104
Los Angeles, Subway Terminal Bldg.: Basement accelerograph ³	Up-Down	0.099	74.0	1.84	9	V111
	SE.-NW	0.099	80.0	2.01	10	L91
	SW.-NE	0.098	82.0	2.07	10	T101
Basement displacement-meter ³	N.-S.	10	1.14		12	R15
	E.-W.	10	1.14		11	L15
13th floor accelerograph ³	Up-Down	0.101	81.0	2.05	10	V112
	NE.-SW	0.100	83.6	2.77	9	L92
	SE.-NW	0.100	79.5	2.01	10	T102
Los Angeles, Chamber of Commerce: Twelfth floor accelerograph ³	Up-Down	0.100	109	2.69	10	V25
	S. 40° W.-N. 40° E	0.099	117	2.90	10	L3
	N. 50° W.-S. 50° E	0.100	109	2.86	8	T18
Basement accelerograph ³	Up-Down	0.099	105	2.66	10	V28
	S. 40° W.-N. 40° E	0.096	114	2.78	10	L9
	S. 50° E.-N. 50° W	0.098	104	2.63	9	T26
San Diego accelerograph	Up-Down	0.096	104	2.43	9	V70
	E.-W.	0.099	106	2.68	8	L71
	S.-N.	0.100	111	2.87	10	T72
Vernon accelerograph	Up-Down	0.096	106	2.63	8	V66
	E.-W.	0.100	107	2.65	10	L64
	S.-N.	0.098	107	2.60	10	T65
Pasadena accelerograph	Up-Down	0.100	114	2.83	11	V47
	S.-N.	0.100	107	2.59	11	L37
	W.-E.	0.101	109	2.64	11	T48
Pasadena displacement-meter	NE.-SW	9.95	1.14		25?	R17
	SE.-NW	9.95	1.14		18?	L17
El Centro accelerograph	Up-Down	0.102	104	2.61	10	V67
	N.-S.	0.100	111	2.68	11	L68
	E.-W.	0.101	106	2.68	11	T69
Colton accelerograph ³	Up-Down	0.093	100	2.40	10	V58
	E.-W.	0.102	102	2.67	9	L59
	S.-N.	0.098	104	2.58	12	T60
Colton displacement-meter ³	NW.-SE	10	1.14		10	R16
	NE.-SW	10	1.14		10.5	L16
San Bernardino Weed strong-motion seismograph.	NE.-SW	0.223	7.66	0.72	1.3	R10
	NW.-SE	0.223	7.79	0.72	1.3	L10

WESTERN NEVADA EARTHQUAKE OF APRIL 14

Hawthorne, Nev., accelerograph	Up-Down	0.097	100	2.50	11.5	V14
	N.-S.	0.097	100	2.55	11.5	L35
	E.-W.	0.099	115	2.86	9.5	T31

BOULDER DAM EARTHQUAKE OF APRIL 27

Intake tower accelerograph	Up-Down	0.102	86	2.26	9.6	V145
	NW.-SE	0.100	88	2.22	11.8	L143
	NE.-SW	0.102	79	2.07	12.0	T144

EARTHQUAKE OFF NEWPORT BEACH, JULY 7

Santa Ana, Weed strong-motion seismograph.	SE.-NW	0.195	8.52	0.70	1.5	R12
	NE.-SW	0.195	8.41	0.68	1.5	L12

³ Instruments at these stations are wired to start simultaneously.

TABLE 3.—*Instrumental constants of strong-motion seismographs in 1937*—Continued

BOULDER DAM EARTHQUAKE OF NOVEMBER 11

Station and instrument	Orientation of instrument	Pendulum period	Static magnification	Sensitivity	Damping ratio	Instrument number
		Sec.		Cm		
Boulder Dam, Nev.:						
1215 gallery accelerograph ³	Up-Down.....	0.102	78	2.06	8.3	V142
	SE.-NW.....	0.104	74	2.03	8.9	L140
	SW.-NE.....	0.103	75	1.97	9.1	T141
Intake tower accelerograph ³	Up-Down.....	0.101	81	2.09	8.8	V145
	NW.-SE.....	0.100	88	2.23	12.9	L143
	NE.-SW.....	0.101	79	2.08	15.1	T144

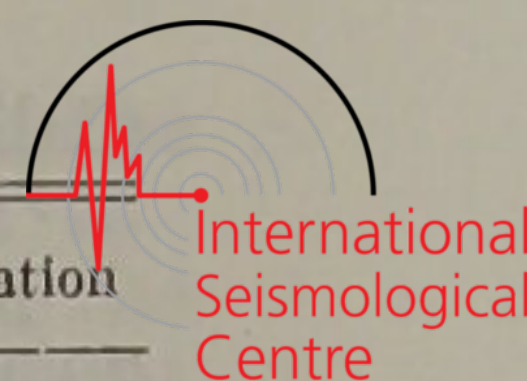
IMPERIAL VALLEY EARTHQUAKE OF DECEMBER 15

El Centro accelerograph.....	Up-Down.....	0.099	104	2.61	10	V67
	N.-S.....	0.098	111	2.68	8.5	L68
	E.-W.....	0.099	106	2.68	11	T69

³ Instruments at these stations are wired to start simultaneously.TABLE 4.—*List of strong-motion seismograph stations, 1937*

Station and foundation	Instrument	Date of installation
NORTHERN CALIFORNIA		
Berkeley: University of California: Solid rock.....	Accelerograph.....	November 1932.
Eureka: Federal Bldg.: Alluvium.....	Accelerograph and displacement-meter.	May 1933.
Ferndale: City Hall: Alluvium.....	Accelerograph.....	Do.
Oakland:		
City Hall: Alluvium:		
Sixteenth floor.....	do.....	November 1934.
Basement.....	do.....	June 1933.
Chabot Observatory: Solid rock.....	Weed seismograph.....	Do.
Sacramento: Federal Bldg.: Alluvium.....	Accelerograph.....	Do.
Salinas: County courthouse: Alluvium.....	do ¹	Do.
San Francisco:		
Alexander Bldg.: Alluvium:		
Sixteenth floor.....	do.....	November 1934.
Eleventh floor.....	do.....	October 1935.
Basement.....	do.....	November 1934.
450 Sutter: Rock:		
Twenty-eighth floor.....	Weed seismograph.....	October 1933.
Basement.....	do.....	November 1934.
Golden Gate Park: Rock.....	do.....	December 1935.
Shell Building: Rock:		
Twenty-eighth floor.....	do.....	October 1933.
Twenty-third floor.....	do.....	May 1934.
Subbasement.....	do.....	October 1933.
Southern Pacific Bldg.: Alluvium and made ground:		
Fourteenth floor.....	Accelerograph.....	October 1934.
Basement.....	Accelerograph and displacement-meter.	December 1932.
State Bldg.: Sand and gravel.....	do.....	April 1933.
San Jose:		
Bank of America Bldg.: Alluvium:		
Thirteenth floor.....	Accelerograph.....	September 1932.
Basement.....	do.....	Do.
Suisun Bay Bridge, S. P. R. R. bridge pier: Rock.....	do.....	August 1932.
SOUTHERN CALIFORNIA		
Bishop: Office Los Angeles Water Department: Alluvium.	do.....	June 1933.
Colton: Southern California Edison substation: Alluvium.	Accelerograph and displacement-meter.	January 1933.
El Centro: Southern Sierras Power Co. substation: Alluvium.	Accelerograph.....	July 1932.

See footnotes at end of table.

TABLE 4.—*List of strong-motion seismograph stations, 1937*—Continued

Station and foundation	Instrument	Date of installation
SOUTHERN CALIFORNIA—continued		
Hollywood: Storage Co. Bldg.: Alluvium:		
Penthouse.....	Accelerograph.....	June 1933.
Basement.....	do.....	Do.
Adjoining Pacific Electric lot ²	do.....	December 1931.
Long Beach: Public Utilities Bldg.: Alluvium.....	do ¹	July 1932.
Los Angeles:		
Chamber of Commerce: Alluvium:		
Eleventh floor.....	do.....	November 1934.
Basement.....	Accelerograph and Weed seismograph. ³	June 1933.
Edison Bldg.: Hardpan or clay.....	Accelerograph ¹	December 1934.
Subway Terminal: Hardpan or clay:		
Thirteenth floor.....	do.....	Do.
Subbasement.....	Accelerograph and displacement meter.	August 1932.
Central Manufacturing District Warehouse at Vernon: Alluvium.	Accelerograph.....	July 1932.
Pasadena: California Institute of Technology: Alluvium.	Accelerograph, displacement meter and Weed seismograph.	May and June 1933.
San Bernardino: County courthouse: Alluvium.....	Weed seismograph.....	June 1933.
San Diego: Consolidated Gas and Electric Co.: Alluvium.	Accelerograph.....	July 1932.
Santa Ana: County courthouse: Alluvium.....	Weed seismograph.....	June 1933.
Santa Barbara: County courthouse: Alluvium.....	Accelerograph.....	Do.
Westwood: University of California at Los Angeles: Alluvium.	do.....	Do.
MISCELLANEOUS		
Boulder Dam, Nev.:		
Intake tower: Solid rock.....	do.....	May 1937.
1215 gallery: Solid rock.....	do.....	Do.
Oil house.....	do.....	Do.
Bozeman, Mont.: Montana State College: Alluvium and glacial drift.	do.....	September 1936
Butte, Mont.: Montana School of Mines: Igneous rock.	do.....	Do
Hawthorne, Nev.: U. S. Naval Ammunition Depot: Alluvium.	do.....	November 1936.
Helena, Mont.: Federal Bldg.: Rock.....	do.....	September 1936. ⁴
Miraflores, C. Z., concrete locks: Tuff and alluvium.....	do.....	April 1935.
Missoula, Mont.: Montana State University: Sedimentary rock.	do.....	September 1936.

¹ In April and May 1937 the accelerograph was removed from Salinas to Long Beach; the Long Beach instrument was transferred to the Edison Bldg., Los Angeles; the Edison Bldg. instrument was sent to Washington, D. C. The Salinas instrument was not replaced.

² The instrument on the Pacific Electric Co. lot in Hollywood is in a separate small building several hundred feet from the Hollywood Storage Co. Bldg., and should provide data which will be free from vibrations set up by the building itself. It is connected with the two accelerographs in the Hollywood Storage Co. Bldg., making a set of three instruments in one locality operating under different conditions. They are connected electrically for simultaneous starting and time marking.

³ Weed seismograph erroneously reported removed in April 1936.

⁴ Permanent installation replacing the accelerograph from San Francisco which had been temporarily installed in October 1935.

DESCRIPTIONS OF STRONG-MOTION STATIONS

NOTE.—Descriptions of the following stations will be found in Serial 579, "United States Earthquakes, 1933": Pasadena, California Institute of Technology; San Francisco, Southern Pacific Building, Santa Ana, Courthouse annex; Vernon, Central Manufacturing District Terminal Building. Descriptions of the following stations will be found in Serial 593, "United States Earthquakes, 1934": El Centro, Southern Sierra Power Co. station; Eureka, Federal Building; Ferndale, Town Hall; Hollywood, Hollywood Storage Co. Building; Los Angeles, Chamber of Commerce Building and Subway Terminal Building; San Diego, gas plant. A description of the station at Colton, Calif., in the Southern California Edison Co. substation building, will be found in Serial 610, "The United States Earthquakes, 1936."

BERKELEY, CALIF.

UNIVERSITY OF CALIFORNIA, HAVILAND HALL

Accelerograph in subbasement

Haviland Hall, used by the Department of Education, is located on the University of California campus about 400 feet north of the university library and about 600 feet northwest of the Campanile tower. It also houses the principal instruments of the University of

California seismological station, the coordinates of which are: latitude $37^{\circ}52'15''$ N., longitude $122^{\circ}15'26''$ W., altitude 280 feet.

The building has three stories, basement and sub-basement and is 72 by 173 feet, built of reinforced concrete. The foundation is solid rock (Franciscan chert and sandstone).

The rock underlying the University of California campus is sandstone and chert of the Franciscan series, the age of which is pre-Cretaceous (possibly Jurassic). Abutting this, to the east of the Hayward rift, are upper Cretaceous and Tertiary sedimentaries and volcanics which constitute the Berkeley Hills in the form of a gentle syncline.

The cities of Berkeley and Oakland, together with San Francisco Bay, lie in a depressed block set off sharply from the higher-lying area on the northeast. Andrew Lawson, in U. S. G. S. Folio 193, applies the name "San Francisco-Marin Block" to the depressed area and "Berkeley Hills Block" to the elevated area. The Hayward rift zone forms the boundary between the two areas. The Berkeley Hills Block is from 1,000 to 1,500 feet higher than the San Francisco-Marin block.

According to Prof. J. P. Buwalda in an article entitled "Nature of the Late Movements on the Hayward Rift, Central California," in the Bulletin of the Seismological Society of America, volume 19, page 187, the movement along the Hayward rift since the present Strawberry Creek, which flows across the University campus, cut its canyon to its present depth, has been on the order of several hundred feet horizontally, the lower block moving northwest relatively to the upper one. He states that its former bed has been moved to the present site of the circle in front of the Mines Building, and the creek was forced to cut a new channel. Some of the University buildings, including the Campanile, have their foundations in the Strawberry Creek gravels.

The accelerograph in Haviland Hall lies on the depressed block about 600 yards southwest of the Hayward rift.

An auxiliary time marker is connected to the chronometer of the University seismograph station. This device places on the accelerogram the same minute marks as are shown on the teleseismic records.

BOULDER DAM, NEV.

Three accelerographs were installed at Boulder Dam in April 1937 by the Bureau of Reclamation with the cooperation of the Coast and Geodetic Survey. They are located in the Nevada intake tower, the oil house, and in the utilities gallery within the dam near its top. A description of the geology will follow the station descriptions.

Intake tower—The accelerograph is located in the downstream Nevada intake tower. The tower is upstream 143.39 feet from the axis of the dam, measuring along the center line of the bridge joining the tower and the dam. The towers are 92 feet in diameter at the base (elevation 894.0 feet) and about 66 feet in diameter at the level of the top of the dam (elevation 1,232 feet). Above this level, a circular machinery building 48 feet in diameter has been constructed. The top of the lantern housing on this building is at elevation 1,289.

The accelerograph is in a room located between the fins of the intake tower, on the east or river side. The base of the instrument is at elevation 1,226.75 feet. It is bolted to a concrete shelf with its longi-

tudinal axis running north $45^{\circ}52'$ west. The recorder is at the northwest end.

Oil house.—The accelerograph is located in a room situated on the eastern side of the oil house in the Boulder Dam switch yard, about 1,800 feet northwest of the center of the dam.

The oil house is a one-story reinforced-concrete building $47' \times 50'6''$. The roof is practically flat at elevation 1,424 and the north end of the roof is level with the surrounding ground. On top of the roof is a large group of interconnected high-tension towers. These look almost like a steel framework and extend up about 100 feet above the roof.

The inside of the seismograph room is $6' \times 7'6''$ and the elevation of the floor is 1,408. Half of the floor has been built up to elevation 1,410.5 feet and the accelerograph rests on this raised portion. The floor is really the top of a concrete pier that is separated from the walls of the building by a 4-inch air space. The pier extends down to solid rock at about elevation 1,395, or about 13 feet below floor level. The instrument is bolted to the pier with its longitudinal axis running north 45° west. The recorder is at the northwest end.

1215 gallery.—Boulder Dam is a concrete monolith on a bed-rock foundation. It is curved in plan and carries a road on top. A vertical section at right angles to the center line of the road is approximately a trapezoid, about 47 feet wide at the top and 660 feet wide at the bottom. The elevation of the road is 1,232 feet; the bottom of the dam is at elevation 505. Tunnels or "galleries" at several levels are built into the dam for inspection and other purposes.

The accelerograph is at the center of the dam in a recess chamber off the utility gallery at elevation 1,215. The recess is $3' \times 6'$ and is near the downstream face of the dam. The floor of the recess is at elevation 1,210.09. The bearing of the longitudinal axis of the instrument is south $44^{\circ}52'$ east. The recorder is at the southeast end. The three accelerographs at Boulder Dam are interconnected for simultaneous starting from any instrument and for simultaneous time marks from the master clock in the 1215 gallery.

Rock formations of the Boulder Dam area include (1) pre-Cambrian granitic and metamorphic rocks corresponding to the Vishnu schist of the Grand Canyon; (2) strata that may represent part of the late pre-Cambrian Grand Canyon series, but possibly are much younger; (3) Paleozoic strata, ranging in age from Cambrian to Permian; (4) large volumes of extrusive and intrusive porphyries and related rocks, of unknown age, but probably Tertiary; (5) a thick section of basin deposits, probably of Pliocene age, consisting of coarse breccias, siltstones, clays, gypsum, salt, and limestone, with great quantities of basalt and other volcanic rocks; (6) weakly cemented river gravel, sand, and silt, which give the earliest record of the Colorado River; (7) extensive remnants of sand, silt, and clay, with an aggregate thickness of several hundred feet, which record rapid aggradation after the river had cut its valley nearly to its present form and depth; (8) gravel in numerous terraces and in the present channels of the Colorado and its tributaries.

No faults are reported in the immediate vicinity of the dam. The Callville fault begins about $2\frac{1}{4}$ miles north of the dam, and runs northeast. A branch of this fault begins about 3 miles east of the dam and runs north to meet the other branch about 8 miles north-northeast of the dam. Boulder Canyon, beginning about 10 miles



northeast of the dam, is quite generally faulted with the faults running north and south. As stated before, no faults are reported in the immediate vicinity or immediately south of the dam. In this latter area, the failure to note definite faults does not necessarily mean that they are absent, but probably represents lack of definite information for the area.

HAWTHORNE, NEV.

U. S. NAVAL AMMUNITION DEPOT

Accelerograph in small arms building

The accelerograph is located in the northeast corner of the small arms building (officially called Ordnance Surveillance Test House No. 12) which is situated in the south central part of the United States naval ammunition depot near Hawthorne, Nev. The depot is about 2 miles northwest of the town of Hawthorne and west of the southern end of Walker Lake. Its geographical position is: latitude $38^{\circ}33'$ N., longitude $118^{\circ}38'$ W.

The small arms building is a one-story reinforced concrete structure. The instrument is located in a room about 13 feet square, at the northeast corner of the building. The pier rests directly on the concrete floor and directly over a 12-inch reinforced concrete beam.

The depot is situated upon alluvium which was once covered by the waters of an ancient lake, known as Lake Lahontan. The old lake, of which Walker Lake is a remnant, occupied much of western Nevada during a past period of higher humidity than now exists in the Great Basin. At its highest level it reached an elevation of about 4,400 feet, or about 350 feet above the present surface of Walker Lake. The alluvium is several hundred feet deep at the depot, the exact depth not being known. The depot is at an elevation of 4,300 feet, and is $1\frac{1}{2}$ miles east of the east front of the Wasek Mountains or Walker Range. The prominent peak of this range is Mount Grant, which rises 11,300 feet above sea level and is about 5 miles west-northwest of the depot. Along the base of this range is a basin range fault in the alluvial fans at the base of the escarpment. One of these recent faults is about $1\frac{1}{2}$ miles west of the station and another is about 2 miles northwest. The earthquake of December 20, 1932 (known as the Mina earthquake), had an epicenter about 40 miles to the east. The earthquake of January 30, 1934, in the Excelsior Mountains had an epicenter about 25 miles southeast of the station.

The depth to the water table at the depot is not known. At the Hawthorne Depot, about $1\frac{1}{2}$ miles southeast, the water table is between 40 and 50 feet below the surface.

The instrument was installed November 21, 1936.

SAN BERNARDINO, CALIF.

COURT HOUSE

Weed strong-motion seismograph in basement

The courthouse is a four-story reinforced concrete building, 86 by 320 feet in size. The instrument is in the basement, on the floor of the transformer vault, a few feet lower than the natural ground surface.

The material immediately beneath the station is soft alluvium many

hundred feet thick, exact thickness unknown. It is rather coarse, consisting of sand and gravel, and rests on a rough or undulating granite surface. The water table is usually some tens of feet below the surface, but less than 100 feet.

The instrument was installed in June 1933.

SAN FRANCISCO, CALIF.

ALEXANDER BUILDING

Accelerographs in basement, on eleventh floor, and on roof

The Alexander Building is at the southwest corner of Bush and Montgomery Streets. It is a rectangular 15-story building, 60 by 68 feet in plan, and independent on three sides. The frame is steel, with concrete and brick fireproofing. The foundation is on spread footings on sandy clay. See the following description of the State Building for regional geology.

The basement accelerograph is on a pier in a storeroom at the rear of the boiler room near the southwest corner of the building. Installation was made November 8, 1934. The eleventh-floor instrument is in a cabinet in room 1112 next to the elevator shaft. This accelerograph was installed October 17, 1935. The accelerograph on the roof is in a cabinet on the stair landing near the center of the north side of the building. This instrument was installed November 8, 1934. The three instruments are wired for simultaneous starting and synchronous time marks.

The material beneath the Alexander Building, as judged from adjacent borings, is sand and sandy clay. The bedrock, presumably of the Franciscan series, lies at a depth of about 150 feet.

SAN FRANCISCO, CALIF.

STATE BUILDING

Accelerograph in basement

The State Building occupies the block bounded by McAllister, Larkin, Redwood, and Polk Streets. It has six stories and basement, constructed of reinforced concrete, and is 110 by 735 feet. The concrete footings rest on unconsolidated sand. The depth of the footings vary from 5 to 8 feet below the basement floor, the average being about 6 feet. The altitude of the finished basement floor is 45 feet 3 inches.

The material underlying the building is unconsolidated sand and gravel. According to the engineer of the building who was present at the time of construction of the northeast wing, the foundation of that wing was built upon an old stream course which ran southeast across the northeast corner of the present building. Cherts and sandstones of the Franciscan series outcrop a few hundred yards north of the building.

The accelerograph is located in a room in the basement. It was installed April 26, 1933.

The earthquake geology of the San Francisco peninsula is described by Dr. H. O. Wood in Bulletin VI of the National Research Council, "Physics of the Earth" series, and the general geology by Andrew Lawson in Geologic Folio 193, United States Geological Survey. The bulk of the bedrock belongs to the Franciscan series assigned to the

Jurassic period. The series contain cherts interbedded with sandstones and intruded by serpentines. The strip of land traversed by lower Market Street and including the Southern Pacific Building is largely man-made fill. In the early days the bay extended to the foot of Montgomery Street which includes the present site of the Shell Building.

TILT OBSERVATIONS

The following quotation on tilt observations during 1937 is taken from the annual progress report of F. P. Ulrich, in charge of the Bureau's Seismological Field Survey with headquarters in San Francisco:

Three tiltmeters have been kept in operation at the University of California during the entire year. Tiltmeter No. 2 has been discontinued because of the irregular tilts produced by rainfall and apparently by underground water flow. These irregular tilts necessitated frequent adjustments of the instrument and were so large that they obscured the regular ground tilt. The automatic tilt recorder was kept in continuous operation, with the exception of a few short breaks, and hourly tilt values were obtained on tiltmeter No. 3 during the entire year.

Figure 18 shows the tiltgrams for 1937 and in addition the daily high and low tides and the daily mean temperature. The curves for tides and temperature were included this year to see if any relation existed between them and the tiltgrams. It hardly seems possible that any effect is produced by the tides, but there does seem to be some relation between the earth tilt and temperature. Tiltmeter No. 3 has given an excellent record since July 1, 1935, when a gravity drain was installed in the tiltmeter pit. The record of this instrument shows a definite annual tilt cycle with a maximum tilt to the north during the first part of July and a maximum east tilt near the middle of September. The temperature curve for 1937 shows that this period July to September represents a uniform high temperature for the year. No suitable explanation has been found for the two-months difference between these maximum tilts.

ADDITIONS AND CORRECTIONS TO PREVIOUS PUBLICATIONS

1935. Serial No. 600, "United States Earthquakes, 1935," page 65.

In illustration of basement accelerograph record, Los Angeles Chamber of Commerce, change S50E to N50W.

1936. Serial No. 610, "United States Earthquakes, 1936," page 9.

At end of eighth line change hyphen to "s."

1936. Serial No. 610, "United States Earthquakes, 1936," pages 34 and 37. Interchange the titles of figures 7 and 8.

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