UNITED STATES EARTHQUAKES

1934

SERIAL No. 593

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

U. S. DEPARTMENT OF COMMERCE
Daniel C. Roper, Secretary
COAST AND GEODETIC SURVEY
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Serial No. 593

UNITED STATES EARTHQUAKES 1934

BY

FRANK NEUMANN
Senior Mathematician

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CONTENTS

ILLUSTRATIONS

UNITED STATES EARTHQUAKES, 1934

INTRODUCTION

This publication is a summary of earthquake activity in the United States and the regions under its jurisdiction for the calendar year 1934. The period up to 1927 for the United States is covered, for all except minor earthquakes, by Special Publication No. 149 of the Bureau, "Earthquake History of the United States Exclusive of the Pacific Region", and by several publications for the Pacific region. These include the Holden and McAdie catalogs,[1] Special Publication No. 191 of the Bureau, "Destructive and Near-Destructive Earthquakes in California and Western Nevada, 1769–1933", and a forthcoming publication of the Seismological Society of America. The period from 1928 on is covered by the series to which the present publication belongs.

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 Manila Central Observatory. 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 post-card questionnaires obtained in many instances through special canvassing of affected areas. In return it is requested that preferably advance notices be furnished of results obtained so that abstracts and references may be inserted with due credit given the sources. An advance notice of a planned investigation might save considerable overlapping of effort and would give wider publicity to the work of the investigator.

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 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 of St. Louis, Mo.

The Seismological Office of the San Francisco Field Station of the Coast and Geodetic Survey, cooperating with the Seismological Laboratory of the Car-

[1] Smithsonian Miscellaneous Collections, 1089. A Catalog of Earthquakes on the Pacific Coast, 1769–1897. Edward S. Holden. Smithsonian Miscellaneous Collections, 1721. Catalog of Earthquakes on the Pacific Coast, 1897–1901. Alexander G. McAdie.

negie Institution and California Institute of Technology (H. O. Wood, research associate, in charge), University of California (Perry Byerly in charge of the seismological station), 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 large number of reports received from Alaska is due largely to the efforts of Dr. C. E. Bunnell, president of the University of Alaska.

Press dispatches received through the courtesy of Georgetown University.

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 office at San Francisco, canvasses areas affected by shocks of unusual intensity. 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, and the seismological laboratory of the Carnegie Institution of Washington and the California Institute of Technology, at Pasadena, cooperate actively in the canvassing program arranged especially for the Pacific coast region.

Notes on the regional earthquake tabulations.—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. For 1934 more detailed descriptions of earthquakes on the west coast will be found in mimeographed reports available at the San Francisco field station.

Beginning with the 1931 number of this series, Serial No. 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 cracking 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 aftershocks 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 Carnegie Institution and the California Institute of Technology, at Pasadena, under the direction of H. O. Wood. The bulletins of these institutions should be consulted for further details and, often, additional shocks.

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 Special Publication No. 149, previously mentioned, except that Washington and Oregon have for convenience been treated separately from California.

Special report.—Attention is invited to a special quarterly report issued by the Bureau's seismological survey, with headquarters at

the San Francisco Field Station of the Bureau, 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.—Epicenters given in the noninstrumental results and in the tabulation on page 57 have been determined at the Washington office unless otherwise stated. Quite often they represent the mean of the positions determined by the Bureau and the Central Station of the Jesuit Seismological Association cooperating with Science Service. Immediate epicenter determinations from telegraphic reports are frequently made through the cooperation of these institutions and individual seismograph stations and the results broadcast without delay to Europe and points in the Pacific. As the published epicenters are based on only a portion of the available data, they must be considered provisional.

Attention is called to the mimeographed reports of the Bureau listing the detailed seismographic results obtained at its own stations and a large number of cooperating stations. The tabulated "Summary of instrumental epicenters" on page 57 is abstracted from these monthly reports.

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 region of a strong earthquake. 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, 1934–1935."

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 because it provides a ready means of recording them in permanent form.

NONINSTRUMENTAL RESULTS

EARTHQUAKE ACTIVITY IN THE VARIOUS STATES

Arizona: Slight shocks on January 4 and 11, March 12, May 14, and December 25.

California: The only shocks of destructive intensity originating within the State occurred in the thinly populated Temblor Mountains on June 5 and 7. The Lower California shocks of December 30 and 31 were rather serious along the border, and the western Nevada shock of January 30 was felt across the entire State. There was no appreciable damage in California in the latter case. There was no shock of major importance.

Connecticut: Slight shock on January 30.

Idaho: Slight shocks on March 15 and 17, April 28, and May 6. The Utah shock of March 12 was felt over a large part of the State.

Illinois: Weak shocks on October 29 and November 12. The Missouri earthquake of August 19 also was felt in Illinois.

Maine: Moderate shocks on August 2 and 26.

Massachusetts: Several light shocks on August 2.

Missouri: Slight shock on July 3. A shock approaching destructive intensity occurred on August 19.

Montana: Slight shocks on August 3 and December 2.

Nebraska: Slight shocks on May 11 and November 7. A rather strong shock occurred on July 30 in the northwestern part of the State.

Nevada: A widespread shock of intensity VIII or IX on January 30 in the Excelsior Mountains near the California border. This was one of the most important earthquakes of the year. Preceded by a strong foreshock the same day. There was also a weak shock at San Jacinto on March 12.

New Mexico: Slight shocks on January 7, February 28, and May 6 and 7.

New York: A moderate shock on April 14 in the Adirondack Mountains near Lake Champlain. Slight aftershock on June 5.

Oklahoma: The north Texas earthquake of April 11 was felt over a small area in Oklahoma.

Oregon: Slight shock on July 6.

Pennsylvania: Moderate shocks on October 29 and November 5 in northwestern part.

South Carolina: Moderate shock on December 9.

South Dakota: Slight shocks on January 29 and August 29.

Tennessee: Moderate shock in southwestern part on July 2.

Texas: Moderate earthquake on April 11 in northeastern part.

Utah: A shock of intensity VIII originating at the north end of Great Salt Lake on March 12 was one of the most important of the year. There was a strong aftershock the same day, and two others, fairly strong, on May 6 and June 2. There was a slight shock near the southern border on December 25.

Vermont: Two slight shocks in the Lake Champlain region on April 10. The New York earthquake of April 14 also was felt in Vermont.

Virginia: Slight tremors on April 2.

Washington: Fairly strong shocks occurred in the Puget Sound region on February 6, May 4, and November 3. Lighter shocks in this region and in other parts of the State occurred on January 1, February 7, March 9, 10, and 17, April 28, May 10, and September 14 and succeeding dates. The feature of the seismic activity in the State was the "swarm" type of shocks in the region of Ellensburg about the middle of September. They continued throughout the rest of the year with intensity ranging as high as V.

Wyoming: Slight shocks on March 13 and May 20, and a moderate one on November 23.

Alaska: A large number of slight shocks were reported during the year, principally in the region of the Kenai Peninsula. The stronger shocks occurred on February 11, May 3 and 14, June 6 and 17, August 1, and November 28.

Hawaiian Islands: A moderate shock on May 10 at Hawaii.
Puerto Rico: Slight shock on August 2.
Philippine Islands: Strong shocks reported on January 29, February 14, June 6, and November 26 and 27. None was of outstanding importance.
Panama Canal Zone: A number of destructive shocks occurred on July 17, 21, and 23. They were generally felt throughout the Republic.

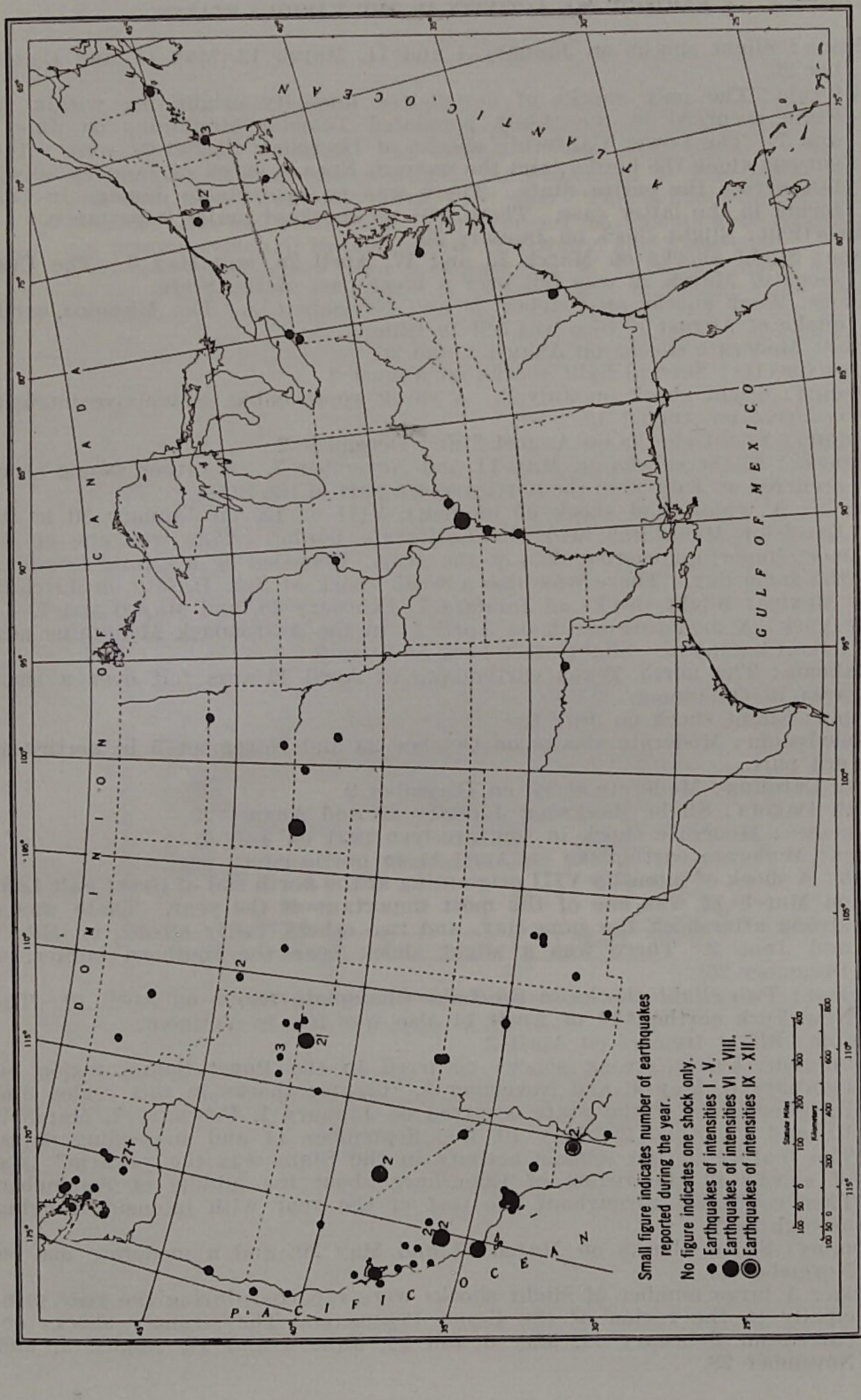


FIGURE 1.—Earthquake epicenters, 1934.

NORTHEASTERN REGION

[75th meridian or eastern standard time]

January 30: 5:30. South Windsor, Conn., IV. Three shocks accompanied by distinct rumblings awakened many South Windsor residents. No damage.

April 10: 22:00. Burlington, Vt. Slight shock of short duration. Felt also in Rutland and Montpelier, Vt., and recorded weakly on the seismograph at Burlington.

April 10: 22:24. Burlington, Vt. Another slight shock felt apparently centering further away than the shock of 22:00, according to the seismograph record.

April 14: 21:58.* Adirondack Mountains near Lake Champlain. Maximum intensity V or VI. Area affected about 8,000 square miles, including parts of New York, Vermont, and Quebec. (See map below.) The origin as determined from seismographic data obtained at Burlington, Vt., and Harvard, Mass., was 44.5° north, 73.9° west. This is about midway between Saranac Lake and Plattsburg. The strongest movements were reported from the general region of Beekmantown, Plattsburg, and Keeseville.

An unverified report from Beekmantown, N. Y., stated that a house was moved 2 inches off its foundation. This report would place the maximum intensity at VI or more on the modified Mercalli scale, but the other reports indicate a maximum of V. It was reported felt at Montreal, which is considerably outside the general limit of perceptibility.

INTENSITY V:

Beekmantown, N. Y.—House reported to have shifted 2 inches on foundation. Intensity VI?

Dannemora, N. Y.—Trembling motion felt by nearly everyone; some alarmed. Accompanied by moderately loud bumping noise.

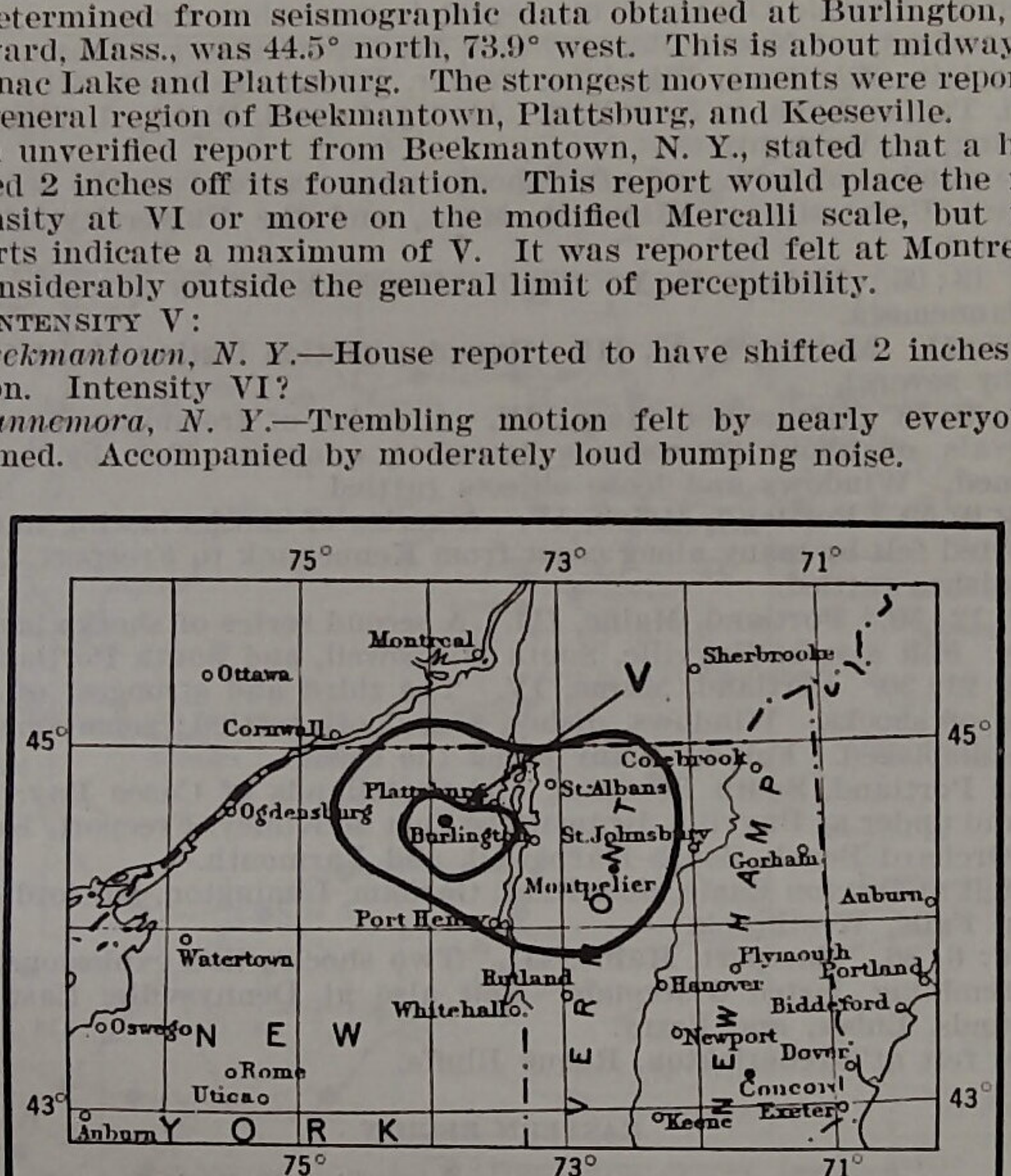


FIGURE 2.—Area affected by the northern New York earthquake of April 14, 1934.

Keeseville, N. Y.—Buildings swayed, cracking plaster slightly and breaking a few dishes; chandeliers and floor furniture noticeably disturbed.

Lake Placid, N. Y.—Houses shaken and windows rattled violently in all sections of city for 30 seconds.

Malone, N. Y.—Houses swayed and a few residents left their homes; a rapid succession of tremors lasting only a few seconds; sensation like that of a heavy truck passing along street; desk swayed on second floor of hospital; many telephone calls.

Plattsburg, N. Y.—A shock lasting about 30 seconds, generally felt; a few houses swayed slightly; some pedestrians thought road seemed to heave. There were hundreds of telephone calls. Some reported it the strongest shock felt in 9 years. The shock was accompanied by thunderous subterranean noises.

Saranac Lake, N. Y.—One sharp shock felt by everyone, followed by noise like sharp blast; buildings swayed; stoves moved; floors moved with a wavy motion as on ship at sea; plaster cracked. No serious alarm.

INTENSITY IV:

Bangor, Constable, Chateaugay, Gabriels, Lawrence, Moira, Peru, Port Henry, St. Regis Falls, Willsboro, and Westport in New York; Burlington, Cambridge Junction, Charlotte, Enosburg Falls, Fort Ethan Allen, Grand Isle, Northfield, St. Albans, St. Johnsbury, and South Hero in Vermont.

INTENSITY III AND UNDER:

Brasher Falls, Canton, Clinton, Crown Point, Rouses Point, and Potsdam in New York; Bakersfield, Barre, Barton, Bolton, Chelsea, Hyde Park, Middleburg, Milton, Montpelier, Newport, North Troy, Orleans, Rochester, Sheldon Junction, Starksboro, Swanton, and West Berlin in Vermont; Montreal in Canada.

Not felt at Ausable Chasm (This report is somewhat anomalous in view of the proximity of Keeseville, at which the report shows intensity V.—Ed.), Champlain, Ellenburg, Ellenburg Center, Ellenburg Depot, Mineville, Norwood, Tupper Lake, in New York; Alburg, Lowell, Richford, West Topham, Whiting, in Vermont.

A large number of fore- and after-shocks were recorded on the seismographs of Harvard University at Harvard, Mass., and the University of Vermont (Burlington).

April 15: 13:05. Malone, N. Y. Slight aftershock felt by several. Felt also at Dannemora.

June 5: 15:11. Malone, N. Y., III. Bumping motion lasting about 15 seconds felt by several.

August 2: 9:58. Gloucester, Mass., IV. A series of trembling movements at intervals of about 30 seconds lasted 4 minutes. Felt by many; few alarmed. Windows and loose objects rattled.

August 2: 9:59. Portland, Maine, IV. A series of shocks lasting until 10:20. Reported felt by many along coast from Kennebunk to Freeport. Windows and dishes rattled.

August 2: 12:50. Portland, Maine, III. A second series of shocks lasting until 1:10. Felt also at Bayville, South Harpswell, and South Portland.

August 2: 21:30. Portland, Maine, IV. The third and strongest of the day's series of shocks. Windows, dishes, and doors rattled; some small objects were displaced. Felt by many along the coast.

IV at Portland, South Portland, and the islands of Casco Bay.

III and under at Bayville, Brunswick, Fort McKinley, Freeport, Kennebunk, Old Orchard Beach, South Harpswell, and Yarmouth.

Not felt at Buxton Eagle, Fort Kent, Gorham, Limington, Sanford, Standish, Steep Falls, Westbrook.

August 26: 6:36. Eastport, Maine, III. Two shocks, like explosions, followed by trembling, lasted 6 seconds. Felt also at Dennysville, East Machias, Edmunds, Lubec, and Perry.

Not felt at Frederickton, Roque Bluffs.

EASTERN REGION

[75th meridian or eastern standard time]

April 2: 21:05. Near Petersburg, Va. Slight tremors lasted 20 minutes. Felt by a few persons at rest.

July 2: 21:10. Memphis, Tenn., IV. Felt in eastern section of Memphis, where windows and dishes rattled, and switchboards were flooded with calls from anxious residents. Felt also at Raleigh, Tenn.

October 29: 15:07.* Local shock of intensity V at Erie, Pa. Buildings swayed; people left theaters; dishes were shaken from cupboards. Gas blending apparatus at gas company thrown out of commission. One woman thrown from bed.

INTENSITY IV at North East and Waterford. Felt at Edinboro, Girard, and Mill Village. Not felt at Cambridge Springs, Corry, Spartensburg, or North Girard.

November 5: 15:00. Albion, Pa., III. Trembling motion.

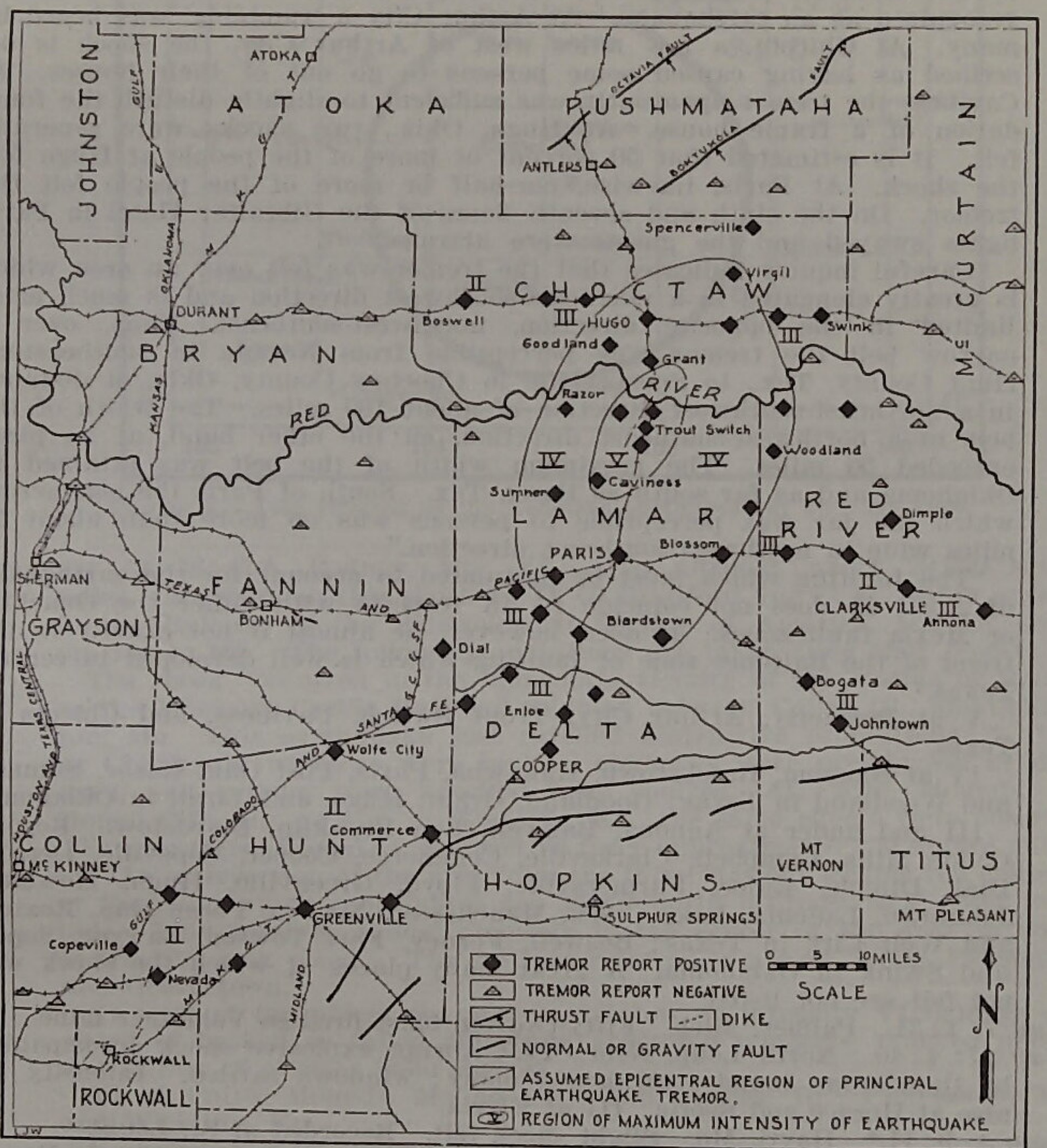
December 9: 5:00. Summerville, S. C., IV. Abrupt bump accompanied by sound like distant thunder; felt by many.

CENTRAL REGION

[90th meridian or central standard time]

January 29: 6:30. Newark, S. Dak., III. Awakened several; dishes rattled; rumbling sound.

April 11: 11:40.* Between Paris, Tex., and Hugo, Okla. Maximum intensity V. Area affected, about 3,000 square miles. Epicenter near Trout Switch, Tex. E. H. Sellards, of the University of Texas, made a personal survey of the affected territory, and the Bureau is indebted to him for the following quotations from an unpublished report on the shock. He also made a study of available seismographic records but found them too weak to be of use in locating the epicenter. H. F. Wahlgren, of the local office of the Weather Bureau at Oklahoma City, made a material contribution by canvassing the affected area soon after the shock. See map below.



MAP OF
TEXAS-OKLAHOMA EARTHQUAKE OF APRIL 11, 1934
BY
E.H. SELLARDS

FIGURE 3.

The following quotations are from Professor Sellard's report:

"The following account of this earthquake is based on observations made on May 6 to 9, supplemented by news items which appeared in the press, and information gathered by circulars by the Bureau of Economic Geology of the University of Texas and by the United States Coast and Geodetic Survey."

"In the region of maximum intensity the tremor was sufficient to be very generally felt. A few persons left their houses following the shock and others were more or less frightened or disturbed. Two shocks were recognized by many observers. No damage was done to buildings and no surface disturbance has been found. Over a small area the earthquake probably attained intensity V of the Rossi-Forel scale."

"The tremor was perhaps most distinctly felt at Powderly, Arthur City, Trout Switch, Caviness, and Chicota in the northern part of Lamar County, Tex. (area marked by V in fig. 1). Probably 90 percent of the people of these five communities felt the tremor and many report having heard a noise. At North Powderly, preceding the shock, a noise was heard described as 'like rumbling thunder a long way off.' At this place the earth jarred and quivered and dishes rattled in the houses. At Trout Switch, a few miles north of Powderly, a 'roaring' was heard followed by two tremors. Some persons were frightened and the disturbance was recognized as an earthquake. At Arthur City a 'rumbling' was heard by many. At Chicota, a few miles west of Arthur City, the shock is described as having caused some persons to go out of their houses. At Caviness the tremor apparently was sufficient to slightly disturb the foundation of a frame house. At Hugo, Okla., two shocks were generally felt. It is estimated that 50 percent or more of the people at Hugo felt the shock. At Paris, likewise, one-half or more of the people felt the tremor. On the sixth and seventh floors of the Gibraltar Hotel in Paris lights swayed and the guests were alarmed."

"Careful inquiry indicates that the tremor was felt over an area which is greatly elongated in a northeast-southwest direction and is much more limited in the opposite direction, northwest-southeast. Thus, over a narrow belt the tremor was perceptible from Nevada in southeastern Hunt County, Tex., to Spencerville in Choctaw County, Okla., a distance in a northeast-southwest direction of about 100 miles. The width of the belt in a northwest-southeast direction, on the other hand, at no place exceeded 50 miles. The maximum width of the belt was attained in Oklahoma and as far south as Paris, Tex. South of Paris the belt across which the jar was perceptible to persons was no more than about 20 miles wide in northwest-southeast direction."

"The faulting which must be postulated to account for the earthquake of April 11 does not coincide in all respects with either the Ouachita or Mexia fault zones. It does, however, lie almost if not exactly in the trend of the Balcones zone of faulting which is well developed in central Texas."

V at Powderly, Arthur City, Trout Switch, Caviness, and Chicota in Texas.

IV at Blossom, Brookstown, Kanawha, Paris, Post Oak, Razor, Sumner, and Woodland in Texas; Goodland, Grant, Hugo, and Virgil in Oklahoma,

III and under at Annona, Bagwell, Ben Franklin, Biardstown, Bogota, Caddo Mills, Campbell, Clarksville, Commerce, Cooper, Copeville, Detroit, Dial, Dimple, Enloe, Farmersville, Floyd, Greenville, Hugh, Howland, Johntown, Ladonia, Lake Creek, Manchester, Nevada, Pecan Gap, Roxton, and Wolf City in Texas; Boswell, Forney, Fort Towson, Sawyer, Soper, and Swink in Oklahoma. A great many places at which the shock was not felt are not listed.

May 7: 1:31. Palmer, Mich. Fifty-two ton blast fired in Volunteer mine.

May 11: 4:40. North Loup, Nebr., IV. Abrupt explosive shock accompanied by thunderous sounds; awakened many; windows rattled. Intensity IV also at Horace and Scotia; III at Elyria.

July 3: 9:11.* Hayti, Mo. Slight shock felt. Recorded at St. Louis.

July 30: 1:20. Chadron, Nebr., VI. A strong earthquake centering in Dawes County in the Nebraska panhandle was felt also in South Dakota, in Wyoming, and at Sterling, Colo. Area affected, approximately 23,000 square miles. See map on page 11. At Crawford and Chadron, Nebr., it reached a maximum intensity of about VI. A few chimneys were damaged; some plaster fell; dishes and canned goods were thrown from shelves and cupboards. Guests were ordered from hotels and additional telephone operators called on duty to handle many calls from alarmed residents. Recorded at Denver and St. Louis.

VI at Chadron, Nebr. V at Crawford, Gordon, Hay Springs, and Marsland, Nebr. IV at Alliance, Andrews, Antioch, Ashby, Belmont, Berea,

Hemingford, McGrew, Minatare, and Mitchell, Nebr., and at Oelrichs, S. Dak.

III and under at Agate, Angora, Broadwater, Dalton, Ellsworth, Gering, Glen, Harrison, Hyannis, Irwin, Lisco, Lodgepole, Lyman, Malbeta, Merriman, Morrill, Orella, Oshkosh, Redington, Story, Valentine, and Whitman, Nebr.; at Ardmore, Bower, Denby, Edgemont, Fairburn, Hoppner, Hillcrest, Hot Springs, Manderson, 8 miles southeast of Martin, Pine Ridge, Tuthill, and Wounded Knee, S. Dak.; at Jay Em, Lusk, Manville, Torrington, and Van Tassell, Wyo.; and at Sterling, Colo.

It was reported not felt at about 125 places.

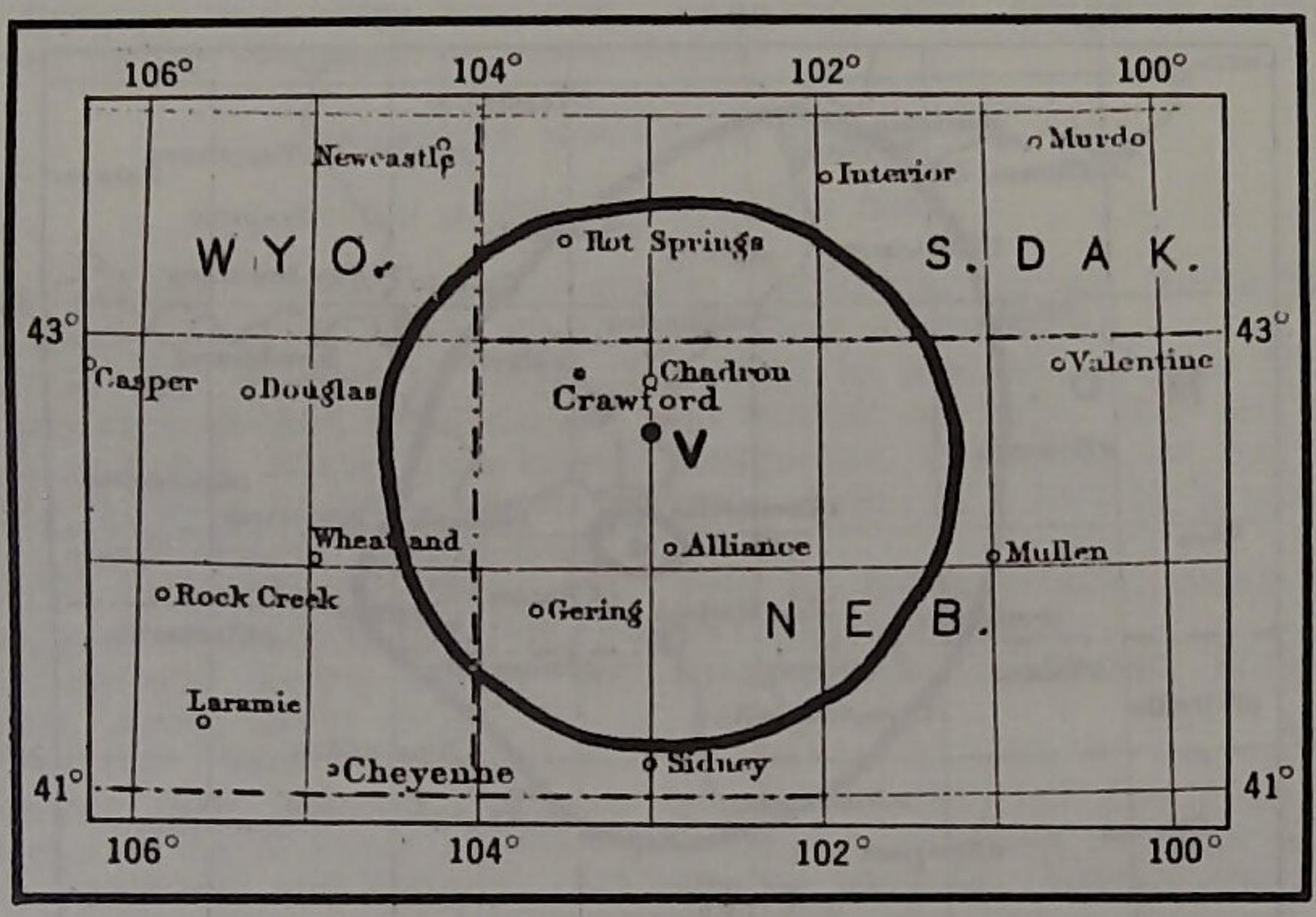


FIGURE 4.—Area affected by the Nebraska earthquake of July 30, 1934.

August 19: 18:47.* Rodney, Mo., VI. Area affected, about 28,000 square miles. A report on this shock by D. C. Bradford and C. G. Dahm appears in the Bulletin of the Seismological Society of America, vol. 25, no. 2, pp. 154 to 160. The following quotations are taken from that report:

The shock "occurred in the immediate vicinity of the station of Rodney on the Missouri Pacific Railroad midway between Cairo, Ill., and Charleston, Mo. This earthquake just reached destructive proportions * * *. At Charleston windows were broken, chimneys were overthrown or damaged, and articles were knocked from shelves. At Cairo, Mounds, and Mound City, Ill., as also in Wickliffe, Ky., the same effects were observed. The area thus affected by destructive force approximated 230 square miles."

"The intersection of the arcs from the three stations locates the epicenter at the point whose coordinates are 36.95° north latitude, 89.2° west longitude. This point is almost precisely in the center of the area in which destruction took place." The stations referred to are St. Louis, Pittsburgh, and Georgetown.

At most of the places characterized below as intensity VI damage consisted of broken or fallen chimneys, shattered windows, cracked plaster, and falling of articles from shelves.

VI at Cairo, Mounds, Mound City, and Thebes, Ill.; Charleston, Mo.; and Wickliffe, Ky.

V at Crosno, East Prairie, Henson, and Wyatt, Mo.

IV at Allenville, Anniston, Benton, Cape Girardeau, Commerce, Lilbourn, Matthews, Morehouse, New Hamburg, Oran, Samos, Sikeston, and Vanduser, Mo.; Arlington, Bardwell, Burkley, Columbus, and Cunningham, Ky.; Miston, Tenn.; and Rector, Ark.

III and under at Ancell, Annapolis, Arcadia, Bell City, Bertrand, Blodgett, Bloomfield, Caruthersville, Chaffee, Como, Crowder, Dexter, Doniphan, Festus, Frederickstown, Gray Ridge, Greeneville, Ironton, Jackson, Kelso, Kewanee, Knob Lick, Lutesville, Marston, Morley, Poplar Bluff, St. Genevieve, St. Louis, and St. Marys, Mo., at Alton, Anna, Belknap, Carbondale,

Grand Chain, Jonesboro, McClure, Metropolis, Olmstead, and Vienna, Ill., at Benton, Chayce, Clinton, Mayfield, Moscow, Oakton, and Paducah, Ky., at Clarkesville, Dyersburg, Hornbeak, Martin, Obion, Paris, Ripley, Tiptonville, and Union City., Tenn., and at Corning and Paragould, Ark.

August 19: 21:37. Cairo, Ill. Slight aftershock felt by several. Felt also at Wickliffe, Ky.

August 29: 21:50. Academy, S. Dak., IV. Abrupt trembling motion accompanied by rumbling sound felt by many; small objects moved. Felt also at Pukwanna.

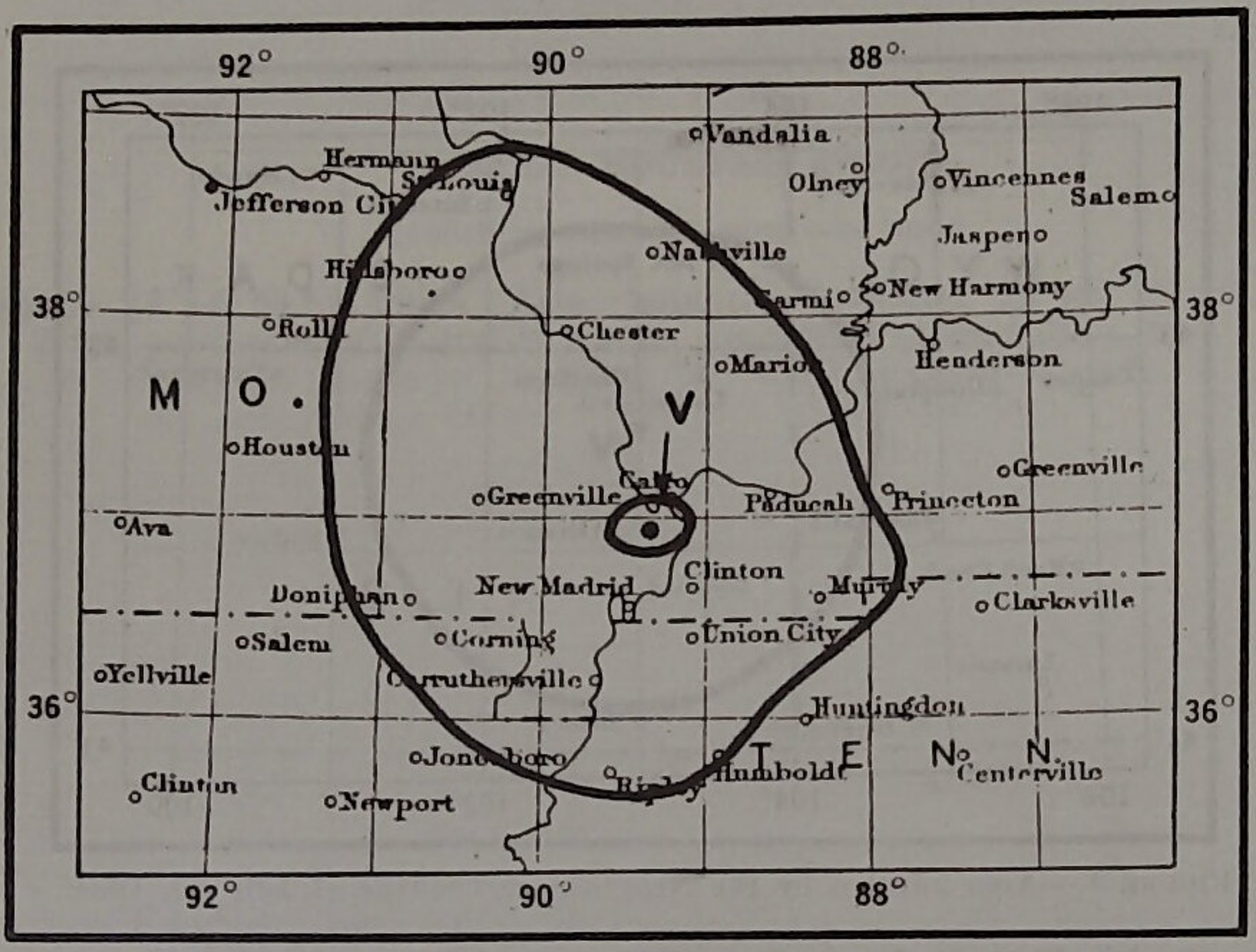


FIGURE 5.—Area affected by the Rodney, Mo., earthquake of August 19, 1934.

October 29: 20:26*. Southeastern Illinois, IV. The following quotations are from an article on this shock by Cornelius G. Dahm, which appears in the Bulletin of the Seismological Society of America, vol. 25, no. 3, July 1935, pp. 253–257.

"The earthquake was felt over about 1,500 square miles of territory. The principal part of this area is shaped like an arrowhead. Within it a maximum intensity of IV in the Wood-Neumann scale was attained, though this was rather exceptional and was not true in the center of the area. An intensity of II–III was general in the region of perceptibility, but definite gradations were difficult to establish, since the earthquake was not very strong, and, as far as is known to the writer, caused no visible damage."

"The coordinates of the epicenter of the southeastern Illinois earthquake obtained by choosing the point of intersection of the arcs of Florissant and Little Rock are 37°31′ N., 88°30′ W. This epicenter lies in Pope County, Ill., about 2 miles southeast of the little town of Hartsville, and is at approximately the center of the area in which the earthquake was felt.

"Perhaps the most striking and interesting feature of this little earthquake is that it seems to be correlated with a known fault. The epicenter lies on the Herod Fault at the point of intersection of another fault apparently unnamed. Both faults are indicated on the Geologic Map of Illinois (1917) published by the Illinois Geological Survey."

The following intensities are reported in the article:

IV at Equality, Junction, and Rosiclaire, Ill.; Salem, Ky. III and under at Akin, Benton, Blairsville, Dale, Delwood, Derby, Dongola, Elizabethtown, Energy, Epworth, Gallatia, Golconda, Hamletsburg, Harrisburg, Hurst, Karbers Ridge, Ledford, Marion, McLeansboro, Muddy, New Columbia, Oak, Ridgway, Shawneetown, Simpson, and Sparks Hill, Ill.; Birdsville, Joy, Lola, Vicksburg, Ky.; Evansville, Ind.

November 7: 22:45. Wood Lake, Nebr., III. Abrupt bumping motion felt by several; building shook. Felt also 20 miles west of Wood Lake and at Johnson, Nebr.

November 12: 8:45. Rock Island, Ill., V. A sharp shock rocked buildings noticeably in the tri-cities, Davenport, Iowa, and Moline and Rock Island, Ill. Strongest in Illinois, it was felt along the Mississippi from Davenport to Galesburg. In the tri-cities, some were alarmed; bricks tumbled from a few chimneys, a trolley pole left the wire, and some pendulum clocks stopped. In Rock Island a cornice was torn from a schoolhouse.

Felt also at Le Claire, Iowa, and at Aledo, Alexis, Biggsville, Cameron, Gerlow, Gladstone, Jay, Keithsburg, Little York, Millersburg, Monmouth, New Boston, Oquawka, Reynolds, and Roseville, Ill. The shock was recorded on the seismograph at St. Louis.

WESTERN MOUNTAIN REGION

[105th meridian or mountain time]

January 4: 14:53.* Yuma, Ariz.; slight. Epicenter 32°42′ North, 115°07′ West, southeast of Holtville, Calif., according to Pasadena.

January 7: 18:32. Socorro, N. Mex., IV. Felt by several; plaster fragments fell; one vase shaken from mantel and broken on floor. Not felt in New Mexico at Belen, Engle, Luis Lopez, Magdalena, Polvadera, or San Acacia.

January 11: Between 0:00 and 0:30. Pearce, Ariz., IV. Felt by a number of people; small objects shaken from shelves.

February 28: Bernardo, N. Mex., IV. Felt by three people; small objects moved, plaster cracked and fell to floor; slight damage.

March 12: Several hours before the Utah shock, Demiston, Maqui, and Winslow, Ariz.; slight shock.

March 12: 8:06.* The Utah earthquake. An earthquake of intensity VIII originating near Kosmo, Utah, on the north shore of Great Salt Lake affected an area of about 170,000 square miles including parts of Montana, Idaho, Wyoming, and Nevada. See map on page 14. Due to the sparsity of population there were no fatalities and very little damage; mostly demolished chimneys and cracked walls in poorly constructed buildings. Two deaths, however, were attributed indirectly to the shock. The epicenter was located at 41.7° North, 112.8° West. There was considerable faulting in the epicentral area.

Through the courtesy of the Director of the U. S. Geological Survey, the Bureau is enabled to present on page 43 an excellent description of the earthquake consisting almost exclusively of extracts from an unpublished report by Philip J. Shenon, of the Geological Survey, who made a personal investigation of the affected area and gathered much information of scientific value. Mr. Shenon took an active part in the preparation of the isoseismal map presented in this publication and furnished data which could not have been obtained through ordinary channels. The illustrations are from Mr. Shenon's report.

The outstanding feature of the shock was the emission of large quantities of ground water from fissures and craterlets. This seems to be related at least to some extent to changes of level observed in the epicentral area before and after the earthquake. In 1911 a precise level line was run through the region by the Coast and Geodetic Survey and repeated in May 1934, when a maximum drop of 39 centimeters was discovered, decreasing, of course, toward the margins of the epicentral area. A special preliminary report entitled "Releveling—Vicinity of Kosmo, Utah" was issued by the Bureau in January 1935.

The onset of the shock was abrupt. There was no foreshocks but the usual aftershocks continued for two days after the main shock. Only one of the aftershocks was of outstanding intensity—that at 11:20 a. m. on the same day.

INTENSITY VIII:

Kosmo.—Fissures, holes, cracks, and springs appeared in the ground. All chimneys down. Poorly constructed brick building severely cracked. Trapper reported to have fallen and unable to rise until shock was over.

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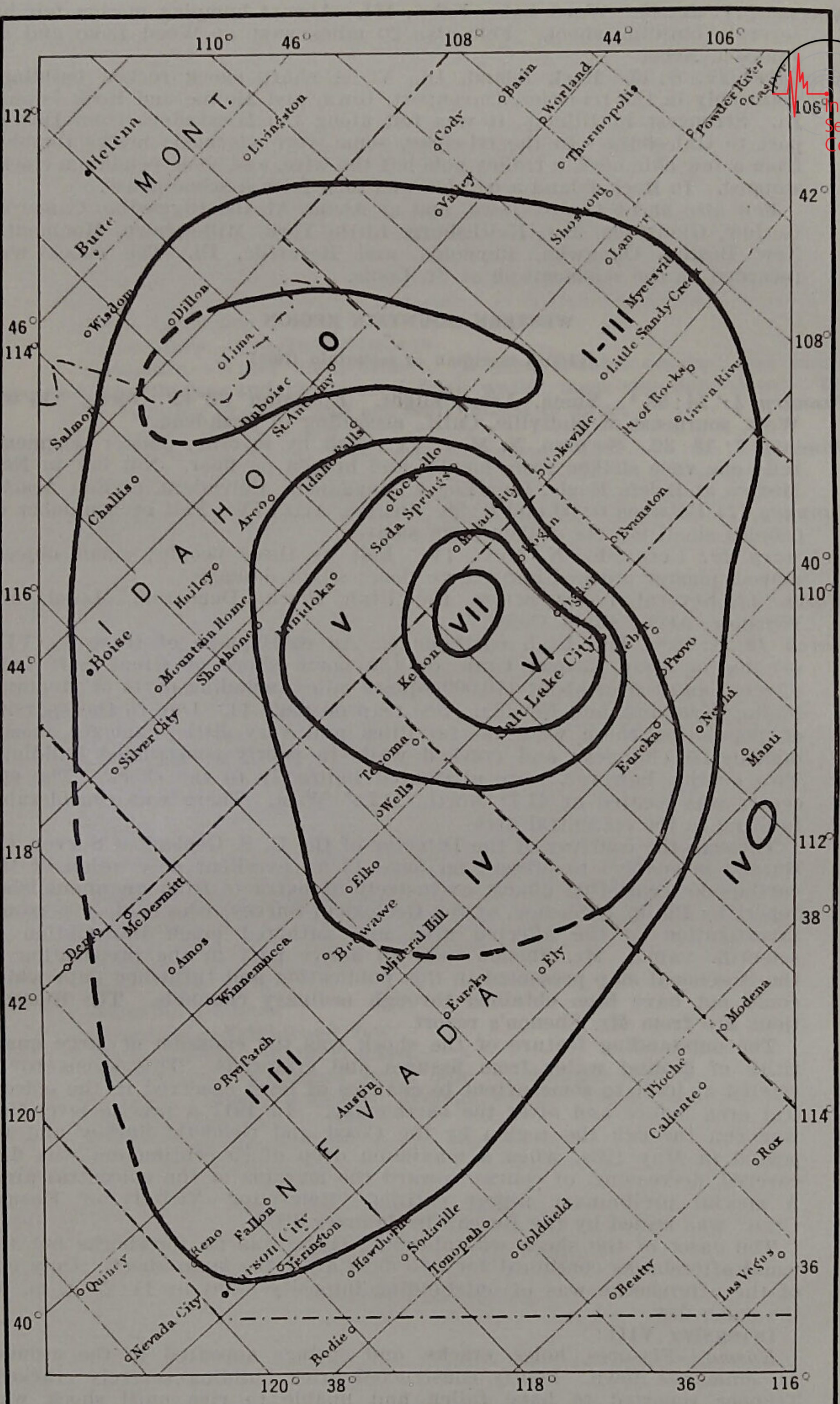

FIGURE 6.—Area affected by the Utah earthquake of March 12, 1934.

Halfway between Kosmo and Salt Wells.—Observer thrown to ground and could not rise; car rolled back and forth over ground; cracks appeared on each side of observer.

Monument.—Fissures, holes, and 40 new springs appeared; rockslides. All chimneys down.

INTENSITY VII:

Bacchus.—Cracked plaster, windows, walls and chimneys. Damage considerable.

Blue Creek.—Damage considerable.

Hooper.—Chimneys fell. Damage slight.

Kelton.—Chimneys fell. Storekeeper became frightened and tried to reach door, but ground shook so much he could not stand.

Locomotive Springs.—Chimneys fell; buildings were weakened and boards loosened from sides of house. Considerable damage. Springs increased their flow.

Promontory.—Cracked chimneys.

Snowville.—Water main broken. Wooden cornice cracked and loosened at schoolhouse, and plaster fell from walls; most chimneys down. Brick store building cracked, and one wall caused to bulge.

INTENSITY VI IN UTAH:

Aragonite.—Rock fell from face of quarry cut.

Clarkston.—Broke windows; chimneys fell; damage considerable.

Farmington.—Shenon reports intensity VII on the Rossi-Forel scale.

Grantsville.—Shenon reports intensity VII on the Rossi-Forel scale.

Lakeside.—Felt by all; spilled water; no damage. Shenon reports intensity VII on the Rossi-Forel scale.

Layton.—Shenon reports intensity VII on the Rossi-Forel scale.

Logan.—Plaster cracked and fell in many structures; a few old buildings cracked badly; plate-glass window broken; quake was accompanied by subterranean sounds.

Millville.—Chimneys fell; damage slight.

Park Valley.—Cracked plaster; autos swayed back and forth; quake accompanied by thunderous roaring sounds. School children became panic stricken and jumped from windows. Shenon reports intensity VII on the Rossi-Forel scale.

Salt Lake City.—Plaster fell; windows broken; walls cracked. Two buildings rubbed together. People fled buildings.

INTENSITY VI IN IDAHO:

Burley.—Shenon reports intensity VI on the Rossi-Forel scale.

Malad City.—Cracked plaster and damaged chimneys; damage slight.

Preston.—Walls cracked; plate-glass window broken. Wall of schoolhouse forced 6 inches away from side wall; several poorly constructed buildings damaged. Several chimneys down.

INTENSITY V IN UTAH:

Bert.—Felt by all.

Bingham Canyon.

Bountiful.—Frightened few.

Cache Valley.—Walls cracked.

Collinston.—Overturned small objects; damage slight.

Corinne.—Plaster cracked; damage slight. Faint subterranean sounds.

Cutler.—Windows broken.

Deweyville.—Overturned small objects; damage slight.

Garland.—Plaster fell; people ran from houses.

Gold Hill.

Hyde Park.—Chimneys slightly damaged.

Ibapah.

Lofgreen.—Chimneys twisted; damage slight.

Lucin.

Lynn.—Felt by all; furnishings moved.

Lynndyl.—Plaster, walls, and chimneys reported cracked, and chimneys twisted; damage slight.

Magna.—Windows broken.

Morgan.—Plaster cracked.

Murray.—Plaster and walls cracked slightly.

Newton.—Overturned vases; broke dishes; spilled water.

Ogden.—Cracked plaster. In an electric store about 35 chandeliers, hanging from the ceiling and spaced about 2 inches apart, were caused to swing clockwise in circular paths with radii of about 12 inches, both in the main shock and in the aftershock at 11:20. They swung without colliding, although their lengths were not equal. A water tank swayed "like a tree in a heavy windstorm." Much of the water was splashed out of it.

Paradise.—Cracked plaster.

Peterson.—Cracked plaster; damage slight.

Richmond.—Cracked plaster.

Roy.—Plaster fell; walls cracked; damage slight.

Toocle.—Groceries thrown from shelves; one window broken.

Wendover.

Yost.—Overturned small objects.

INTENSITY V IN IDAHO:

Albion.—One chimney down.

American Falls.—Cracked plaster slightly.

Arimo.—Cracked plaster slightly.

Chesterfield.—Cracked plaster and chimneys; damage slight.

Lava Hot Springs.—Cracked plaster; damage slight.

Milner.—Cracked plaster; damage slight.

Oakley.—Cracked plaster slightly.

Pocatello.—Cracked plaster.

Riverdale.—Stopped clocks; spilled water.

Rupert.—Cracked plaster slightly. Shook schools so hard that they were closed until inspected.

Twin Falls.—Cracked plaster slightly.

INTENSITY V IN NEVADA:

Elko.—Moved furnishings; spilled water.

Eureka.

San Jacinto.—Furnishings moved.

Intensity IV in Utah: Brigham, Callao, Cedar Fort, Cedar Valley, Delta, Devils Slide, East Promontory, Eureka, Fielding, Goshute Indian Reservation, Indian Springs, Manila, Oasis, Richfield, Silver City, Springville, Tremonton, and Willard.

Intensity IV in Idaho: Aberdeen, Bellevue, Blackfoot, Fairfield, Idahome, Mountain Home, Muldoon, Paris, Vernon, and Yale.

Intensity IV in Nevada: Arthur, Battle Mountain, Carlin, Cobre, Metropolis, Midas, Red House, Shafter, and Tobar.

Intensity IV in Wyoming: Evanston, Fossil, Granger, Kemmerer, and Rock Springs.

Intensity III or or less in Utah: Abraham, Birdseye, Charleston, Fountain Green, Hoytsville, Keetley, Laketown, Linwood, Pleasant Grove, Provo, Salem, Venice, and Woodruff.

Intensity III or less in Idaho: Arco, Boise, Castleford, Gooding, Hailey, Hammett, Hatch, Holbrook, Hot Spring, Howe, Idaho Falls, Mackay, Obsidian, and Sterling.

Intensity III or less in Nevada: Black Forest, Ely, Halleck, Lovelock, Mindosa, North Fork, Oceana, Owyhu, Palisades, Reno, Sutcliffe, Tuscarora, Unionville, and Valmi.

Intensity III or less in Wyoming: Cheyenne, Eden, Frontier, Green River, Lander, Laramie, Moran, Mountain View, Rawlins, Wind River, and Yellowstone Park.

Intensity III or less in Montana: Ennis, Twin Bridges.

Intensity III or less in Colorado: Craig.

Not felt in Utah: Altonah, Antimony, Burrville, Clear Lake, Elmo, Ephraim, Escalante, Fairview, Fillmore, Fort Duchesne, Glendale, Green River, Hanksville, Hayden, Junction, Kanosh, Kenilworth, Lasal, Lund, Manti, Mayfield, Moab, Mohrland, Mountain Home, Mt. Pleasant, Nephi, Paiute Indian Agency in Beaver County, Parowan, Randlette, Rockville, Roosevelt, Scofield, Soldier Summit, Springdale, Summit (Iron County), Torrey, Tropic, Veyo, Watson.

Not felt in Idaho: Avery, Blanchard, Broten, Burke, Calder, Canfield, Cascade, Centerville, Challis, Claystone, Clementsville, Coeur D'Alene, Cottonwood, Craigmont, Darlington, Dent, Dixie, Elk River, Ferdinand, Forest, Fruitland, Gibbonsville, Glengary, Grangerville, Guyaz, Hayden Lake, Island Park, Kamiah, Lake, Lenore, Lewiston, Lucile, Masonia,

Meadows, Medimont, Mesa, Montour, Myrtle, New Meadows, North Fork, Orogrande, Pardee, Payette, Pine, Potlatch, Princeton, Riggins, Saint Anthony, Santa, Springston, Sugar, Sweetwater, Tensed, Troy, Vay, Wallace, Weiser, White Bird, Winchester.

Not felt in Nevada: Austin, Beowawe, Carp, Flanigan, Goldfield, Jean, Las Vegas, Moapa, Panaca, Searchlight, Silver Peak, Smith, Verdi.

Not felt in Wyoming: Acme, Baggs, Bonneville, Buffalo, Clareton, Cora, Deaver, Ervay, Filmore, Garland, Garrett, Hanna, Holt, Ishawooa, Keeline, Lingle, Lucerne, Manville, Mills, Orin, Passaic, Pitchfork, Recluse, Ross, Scofield, Shawnee, Sheridan, Split Rock, Sussex, Tensed, Underwood, Wamsutter, Wilson.

Not felt in Montana: Dillon.

Not felt in Oregon: The Dalles.

The earthquake was followed by many aftershocks. The strongest of them occurred at 11:20 on the same day as the main shock. The number noted each day, as compiled from various sources, and especially from a report by Lonnie F. Ball and Claud R. Bird, of the United States Weather Bureau at Salt Lake City, based on the Locomotive Springs Radio Station log, was as follows: March 12, many weak aftershocks, too many to count, and one strong one at 11:20. March 13, 48 shocks of varying intensity. March 14, 42 shocks of varying intensity. March 15, 23 shocks of varying intensity. March 16, 4 weak shocks.

March 12: 11:20*. The intensities for this shock are very unreliable, as in nearly every instance they were reported jointly with the shock at 8:06 without any distinction as to intensity. For this reason no intensities are listed. The shock was usually reported as slightly less severe than that at 8:06 and was reported felt at the following places:

UTAH: Blue Creek, Bountiful, Bingham City, Cedar Fort, Clarkston, Collinston, Corinne, Devils Slide, Deweyville, Fielding, Hoytsville, Hyde Park, Indian Springs, Laketown, Lofgreen, Logan, Lucien, Lynn, Lynndyl, Millville, Murray, Newton, Ogden, Paradise, Park Valley, Provo, Richmond, Roy, Salt Lake City, Tooele, and Tremonton.

IDAHO: Aberdeen, Albion, Arco, Bellevue, Boise, Chesterfield, Gooding, Hammett, Hatch, Holbrook, Hot Spring, Howe, Idahome, Lava Hot Springs, Malad City, Milner, Muldoon, Oakley, Paris, Pocatello, Preston, Twin Falls, and Yale.

NEVADA: Elko, Metropolis, San Jacinto, and Shafter.

WYOMING: Cheyenne, Fossil, Green River, Kemmerer, and Mountain View.

March 12: 12:04. San Jacinto, Nev., IV. Frightened few; buildings swayed. Elko, Nev., III.

March 13: 2:13. Yellowstone National Park, Wyo., IV. Pendulum clocks stopped; small objects moved.

March 15: 5:00. Twin Falls, Idaho, IV. Windows rattled, walls creaked, hanging objects swung.

March 17: 15:48. Newton, Utah, II.

March 17: 16:30. Arimo, Idaho, slight.

April 6: 19:16. Salt Lake City, Utah, III. Felt also at Pocatello, Idaho.

April 14: 14:28. III at Newton and Salt Lake City, Utah; and at Hatch and Pocatello, Idaho.

April 28: 2:30. Burley, Idaho, IV. Windows, doors, and dishes rattled; walls creaked.

April 28: 3:00. Burley, Idaho, slight.

April 28: 23:10. Burley, Idaho, slight.

May 6: 1:10. A strong shock, apparently an aftershock of the Utah quake of March 12. It was reported most strongly from Salt Lake City, Utah, and Preston, Idaho, where the intensity probably reached VI. It was felt generally over northern Utah and southern Idaho.

All places in Utah unless otherwise stated

INTENSITY VI:

Twenty miles east of Kelton.—Much harder than at Kelton.

Locomotive Springs.—Felt strongly; walls creaked.

Preston, Idaho.—Cracked plaster.

Salt Lake City.—A few windows broken; pajama-clad crowds rushed into the streets; shock described as "worse than the one a month ago."

INTENSITY V:

Kelton.—Moved small objects and furnishings.

Ogden.—Pendulum clocks facing west stopped; spilled water N–S from indoor containers.

INTENSITY IV:

Bingham Canyon.—Windows, doors, and dishes rattled.

Burley, Idaho.—Windows, doors, and dishes rattled; walls creaked; "about six vibrations, the first hardest."

Grantsville.—Windows, doors, and dishes rattled; walls creaked.

Layton.—Windows, doors, and dishes rattled.

Lucin.—Walls creaked; small objects moved; "accompanied by dull, growling sound."

Lynn.—Windows, doors, and dishes rattled; walls creaked.

Malad City, Idaho.—Windows, doors, and dishes rattled.

Morgan.—Windows, doors, and dishes rattled; walls creaked.

Peterson.—Windows and doors rattled.

Seven miles west of Ogden.—Moved floor lamp.

Pocatello, Idaho.—Felt by many; buildings swayed.

Rupert, Idaho.—Walls creaked.

Intensity III or under: Corinne, Salt Lake Airport, Tooele, Wendover.

Not felt in Utah: American Fork, Clear Creek, Fairview, Heber, Milford, Nephi, Payson, Provo, Randolph, Roverton, Santaquin.

Not felt in Idaho: Gooding, Idaho City, Idaho Falls.

May 6: 1:30. Malad City, Idaho, IV. Vase shaken from radio.

May 6: 22:22. Silver City, N. Mex., V. Several cracks in old adobe houses; "great excitement prevailed for some time." IV at Fort Bayard, N. Mex., where small objects were moved. Felt also at Central, Hurley, and Santa Rita, N. Mex.

May 7: 18:15. Magdalena and Socorro, N. Mex., III.

May 7: 21:00. Magdalena, N. Mex. Moderate shock.

May 14: 6:14.* Yuma, Ariz., III. "Too short to set up vibrations apparently, hardly rattled the windows." Epicenter at 31°00′ north 114°30′ west, approximately (upper part of Gulf of California), according to Pasadena.

May 20: 4:30. Yellowstone Park, Wyo., III. Windows and doors rattled.

June 2: 5:49. Salt Lake City, Utah, II.

August 3: 19:20. Cascade, Mont., IV. Barn creaked, hanging objects swung.

November 23: 16:40. Lander, Wyo., V. Crack in brick building reported to have widened half an inch; furnishings moved; persons vacated office buildings. Strong also at Atlantic City, from Fort Waskakie to Dubois, at Green River, and at South Pass City, Wyo. Felt also at Riverton and Rock Springs, Wyo. Not felt at Casper, Wyo.

December 2: 6:05. Creston, Mont., IV. Loose objects rattled, bed shook; "accompanied by dull rumble like thunder." III at Kalispell, Mont.

December 25: 3:00. Kanab, Utah, IV. Loose objects rattled, small objects moved.

December 25: 5:20. Fredonia, Ariz., IV. Frightened few.

CALIFORNIA AND WESTERN NEVADA

[120th meridian or Pacific standard time]

All places are in California unless otherwise stated

January 3: 5:10. Huntington Beach, light shock.

January 5: 14:55. Huntington Park IV. Also felt at Seal Beach.

January 5: 15:08.* Eastern part of Los Angeles, IV. Also felt elsewhere in Los Angeles, at Anaheim, and at Burbank. Epicenter 33°58′ north, 118°09′ west, according to Pasadena.

January 7: 6:12. Balboa, IV.

January 8: 23:43.* Hawthorne, Nev., IV.

January 9: 6:10.* A sharp shock of intensity V felt most strongly in the southeastern section of Los Angeles and Huntington Park. Epicenter 34°06′ north, 117°41′ west, according to Pasadena. Felt over a land area of about 7,500 square miles. See map facing p. 20.

Intensity V: Southeastern Los Angeles.

Intensity IV: Cajon, Chino, El Mirage, Elsinore, Guasti, ½ miles south of Hollywood, Huntington Park, La Verne, Los Angeles (certain sections), Moreno, Riverside, San Dimas, Summit, Tujunga, and Upland.

Intensity III and under: Acton, Anaheim, Azusa, Beaumont, Claremont, Colton, El Modena, Etiwanda, Glendale, Lomita, Los Angeles (certain parts), Mentone, Pasadena, Placentia, Romona, Redlands, San Bernardino, San Gabriel, San Juan Capistrano, Santa Ana, Seal Beach, Seven Oaks, Victorville, Warner Springs, and West Hollywood.

January 9: 6:29. Montebello, IV.

January 11: 22:—. Rio Vista, IV.

January 12: 4:50. Los Alamos, IV.

January 12: 5:12(?) Huntington Park, III.

January 12: 5:30. Llano, III.

January 13: 14:26.* Keen Camp, IV. Epicenter 33°30′ north, 116°55′ west, according to Pasadena.

January 13: 21:17.* Inglewood, V. Rapid motion lasted 4 seconds. Awakened and frightened many. Overturned small objects, cracked plaster. Slight damage. Epicenter 33°58′ north, 118°35′ west, according to Pasadena.

January 14: 4:52.* Huntington Beach, slight. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

January 15: 3:30.* Huntington Beach, slight. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

January 15: 3:35.* Huntington Beach, slight. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

January 16: 22:43.* Upland, III. Epicenter 34°06′ north, 117°41′ west, according to Pasadena.

January 17: 18:14.* Chino and La Verne, III. Epicenter 34°06′ north, 117°41′ west, according to Pasadena.

January 17: 18:19. Riverside, IV. Felt also at Los Angeles, San Juan Capistrano, and Upland. Not generally felt in northern part of Orange County.

January 19: 13:20. Glendale, II.

January 20: 2:28.* Huntington Beach, slight. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

January 20: 5:45 (about). Bishop, III.

January 20: 13:17.* Two shocks close together, of intensity IV at Bell, Hynes, and Seal Beach. Epicenter 33°37′ north, 118°07′ west, according to Pasadena, Felt also at Compton, Hermosa Beach, Huntington Park, Long Beach, Los Angeles, San Juan Capistrano, and San Pedro. Not felt at Burbank, Glendale, or other San Fernando Valley cities.

January 20: 15:15. Long Beach, IV.

January 22: 23:38. Felt by a few in Eureka and Ferndale. Focus about 28 miles from the Ferndale station, according to Berkeley.

January 23: 11:50 or 23:50. Seal Beach, felt.

January 25: 14:46.* Los Angeles, III. Epicenter 33°58′ north, 118°20′ west, according to Pasadena.

January 25: 20:31.* Huntington Beach, weak. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

January 26: 4:01.* Bell, IV. Very slight at Los Angeles. Epicenter 33°55′ north, 118°10′ west, according to Pasadena.

January 26: 4:20. Bell, slight.

January 26: 4:21.* Bell, III. Epicenter 33°55′ north, 118°10′ west, according to Pasadena. At Los Angeles, fairly sharp jolt generally felt.

January 26: 15:09.* Huntington Beach, felt. Epicenter 33°35′ north, 118°10′ west, according to Pasadena.

January 27: 20:21. Huntington Beach, III.

January 28 to *January 31:* A series of blasts in the construction of the Golden Gate Bridge at San Francisco.

January 29: 19:12.* Benton, III. Hazel Creek, "three light shocks in 25 minutes." Felt at Hawthorne.

January 30: 11:05. Potts, Nev., IV. Smoky Valley, Nev., felt.

January 30: 11:17.* Hawthorne, Nev. Slight quake lasting about 5 seconds.

January 30: 11:24.* A strong foreshock of the destructive shock at 12:17 the same day. Mina, Nev., VII, broke dishes and windows, chimneys fell, damage slight, schools dismissed. Hawthorne, Nev., VI, cracked plaster; knickknacks and books fell, trees and bushes shaken strongly, damage slight.

Yerington, Nev., VI. Plaster chipped from old cracks, paint fell from shelves in hardware stores, cracked wall of courthouse.

Intensity III and under: Bakersfield, Benton, Fresno, Porterville, Sacramento, and San Jose, Calif., and at Ely, Fallon, Schurz, Stillwater, and Thorne, Nev.

January 30: 11:30. Fallon, Nev. Quite perceptible; preceded by commotion among birds. Ione, Nev., III. Felt at Hawthorne, Nev.

January 30: 11:42. Potts, Nev., IV. Sharp, Nev., III.

January 30: 12:17.* A widespread shock of intensity VIII or IX centering in the Excelsior Mountains, Nev., near the California border. The epicenter was close to 38°17′ north, 118°22′ west, which is the location of a fault reported by Engene Callaghan, of the United States Geological Survey, and Vincent P. Gianella, of the University of Nevada, in a report on the shock appearing in the Bulletin of the Seismological Society of America, Volume 25, No. 2, April 1935. The reader is referred to this report for many interesting details. The instrumental epicenter reported by Pasadena before the field survey was made was 38°23′ north, 118°07′ west.

The area affected was about 110,000 square miles on land. See map facing page 20. Although the intensity in the epicentral area was unusually high, there was very little damage because the region is practically uninhabited. The shock was recorded at teleseismic stations all over the country and on the strong-motion seismographs at Bishop and San Jose, Calif.

The following quotations of general interest are taken from the report of Callaghan and Gianella. They supplement to some extent the descriptive material given on page 21.

"This shock is of particular interest as it is the fifth of a series of six moderate to strong earthquakes, exclusive of aftershocks, originating in the Great Basin during a period of 15 months. A period of unusual seismic activity is indicated.

"The damage was relatively slight. Nevertheless, the following items may be listed: A few broken chimneys and the falling of a small section of brick wall at Mina, collapse of two walls of an adobe cabin at Marietta, partial destruction of stone cabin at Candelaria, cracks in concrete at Hawthorne, and destruction of a pipe line and pump house by rolling rocks at the Silver Dike mine in the eastern part of the Excelsior Mountains. There was no loss of life and no injuries were reported.

"Because of the sparse population and scarcity of structures no accurate determination of the strength of the shock was possible. It would probably be in the neighborhood of VIII or IX.

"The earthquake produced many of the usual effects including landslides, dust clouds, boulders rolling down slopes, changes in the flow of springs, fissures in alluvium, damage to structures, and fright and nausea among people. Springs along the northwest side of Teels Marsh were reported to show increased flow and by the middle of April the water supply to the mill at Silver Dike failed. A large landslide on the mountain west of Teels Marsh was observed by people at Marietta. Smaller rockslides were noted at various places in the Excelsior Mountains. Boulders were rolled down steep slopes almost everywhere in the Excelsior Mountains and in some of the nearby ranges. The writers observed that numerous boulders were rolled down near the foot of the mountains, but few in the summit area. This might be due to the more gentle slopes of the summit area, but may indicate a more severe shaking at the margins. Banks of the washes were shaken down in many places. The walls of a clay pit near Sodaville were reported to have caved. The desert soil was dry at the time except where covered by snow in the summit area of the mountains, and dust clouds, caused by the agitation of the surface of the ground, were noted by all persons interviewed by the writers who had a view over a considerable distance at the time of the strong shock. Observers at widely separated points reported seeing ground waves with a systematically progressing dust cloud in front of them, but this impression was not corroborated by others. A stockman who was in the mountains south of Whisky Flat stated that balanced rocks and dead trees vibrated rapidly through a small arc and that the living piñon pines swayed through a large angle."

"Earthquake fissures in alluvium were found in three localities, one about ½ mile up the wash above Pepper Spring south of Garfield Fat, another on

the northwest side of Teel's Marsh, and the third at the Endowment mine about 3 miles north of Marietta.

"A break in the surface of the ground along the trace of an old fault extends for approximately 4,500 feet across the ridges on the south side of the Excelsior Mountains 3¼ miles north-northwest of Marietta. The average trend is north 65° east. The old fault is marked by a broad crush zone within metamorphic rocks. The contact of the metamorphic rocks with the volcanic rocks lies a short distance to the north but does not reach the fault. The fault trace is deeply eroded and is followed by gulches through part of its length. There is no scarp or other indication of relative movement prior to the earthquake. The earthquake scarp has a maximum height of 5 inches, and the fissures are open as much as 3 inches. The displacement is everywhere toward the northwest, that is, the summit area of the range has dropped with respect to the south side. The dip, as shown by the curve up the gulches, is approximately 73° to the north-northwest. The fault is not a continuous break throughout, but in many places, particularly toward the ends, it consists of open fissures *en échelon* which trend approximately 10° more toward the north than the direction of the fault."

INTENSITY VII IN NEVADA:

Mina.—Broke many windows and cracked plaster and walls. Water pipes broken at joints and power lines out of commission.

Silver Dyke (near Mina).—Huge boulders dislodged causing landslides; pump moved from foundation, truck jolted off ground by vertical force; quake traveled in waves, throwing huge boulders from the hillsides and raising great clouds of dust in the valleys.

West of Sodaville.—Landslides.

INTENSITY VI IN NEVADA:

Hawthorne.—People hurried from homes, bottled goods thrown from shelves, small objects overturned.

INTENSITY V IN NEVADA:

Dixie Valley.—Moved small objects, spilled water, cracked plaster; damage slight.

Fallon.—Overturned vases in few cases, cracked plaster, trees and bushes shaken slightly, damage slight.

Goldfield.—Frightened many, moved small objects, cracked plaster.

Hazen.—Small objects moved, trees and bushes shaken moderately, damage slight.

Luning.—Frightened all, moved small objects, knickknacks fell, trees and bushes shaken strongly.

Ione.—Moved small furnishings, spilled water west.

Schurz.—Moved small objects, cracked plaster, buildings shaken slightly.

Yerington.—Moved small objects, cracked plaster, damage slight.

Intensity IV in California: Benton, Big Creek, Big Trees, Bishop, Boca, Bridgeport, Broderick, Camino, Dinuba, Douglasflat, El Portal, Fresno, Independence, Jamestown, June Lake, Kerman, Livingston, Lodi, Lone Pine, Los Banos, Manteca, Merced, Nevada City, Oakdale, Owenyo, Pine Ridge, Porterville, Sonora, Stanislaus, Stockton, Topaz, Tracy, and Tulare.

Intensity IV in Nevada: Austin, Broken Hills, Carson City, Dayton, Gerlach, Lovelock, Mason, Minden, Pyramid, Smith, Steamboat, Stillwater, Thorne, Wabuska, Wellington, and Zephyr Cove.

Intensity III and under in California: Auberry, Awahnee, Bethany, Bigpine, Carquinez, Corcoran, Georgetown, Gustine, Hanford, Herald, Hollister, Kingsbury, Mendota, Milton, Modesto, Monson, Newman, Nevada City, Oakland, Oakland Harbor Light Station, Planada, Port Chicago, Quincy, Raymond, Sacramento, San Francisco, Sequoia National Park, Tahoe City, Tipton, Valley Springs, Visalia, Volcanoville, Waterford, and Woodlake.

Intensity III and under in Nevada: Beatty, Beowawe, Cortez, Elko, Ely, Golconda, Las Vegas, Lower Rochester, Marlette Lake, Midas, Reno, Tonopah, Valmy, Verdi, and Winnemucca.

Not felt: Springville, Calif.; Boulder City, Nev.

About 30 aftershocks were felt during the next few days.

January 30: 12:30. Bridgeport. Aftershock of medium intensity lasted fifteen seconds. Hawthorne, Nev., "strong."

Not felt at Bishop, Calif.

January 30: 13:04. Weak shock felt at Benton. IV at Caliente, Nev. Felt also at Fallon, Hawthorne, and Verdi, Nev.

January 30: 15:40. Three aftershocks at about this time felt at Auberry, Benton, and Bridgeport, and in Nevada at Fallon, Ione, Dixie Valley, Schurz, and Yerington.
January 30: 19:49. Slight shock felt at Benton and at Fallon, Nev.
January 31: 11:45. June Lake, IV or V.
January 31: About 12:30. Tahoe, III.
February 1: 2:45. Potts, Nev., IV. Foreshock of earthquake at 3:48.
February 1: About 3:15. Luning, Nev., V. "Heaviest of seven shocks."
February 1: 3:48. Potts, Nev., V. Overturned small objects, spilled water, no damage.
February 1: 8:09*. Santa Barbara, II. Epicenter 34°33′ north, 119°32′ west, according to Pasadena.
February 3: Mina, Nev., aftershocks of the quake of January 30 still felt.
February 3: 18:20.* IV at Seal Beach. Epicenter 33°47′ north, 118°08′ west, according to Pasadena. Felt also at Huntington Beach, Los Angeles, and San Pedro.
February 3: 18:45. Weak shock felt at Hermosa Beach, Long Beach, Los Angeles, Redondo Beach, San Pedro, and Torrance.
February 9: 1:20.* Epicenter in Nevada, according to Pasadena. IV at Benton, Bishop, and Douglasflat, Calif., and at Broken Hills and Mason, Nev. Felt also 4 miles south of Manteca, at Mendota, and at Modesto.
February 10 to *February 18:* A series of blasts in the construction of the Golden Gate Bridge, San Francisco.
February 11: 7:15.* El Centro, felt. Epicenter 32°30′ north, 115°20′ west, according to Pasadena.
February 11: 10:01.* El Centro, felt. Epicenter 32°30′ north, 115°20′ west, according to Pasadena.
February 11: Santa Rosa, IV.
February 12: 4:40. Fortuna, IV, Upper Mattole, II. Epicenter about 40 miles west of Punta Gorda, according to Berkeley.
February 13: Shortly before midnight. Bay, slight.
February 14: 14:24.* A series of highly localized shocks felt with intensity V at Santa Rosa but only slightly in surrounding cities. Epicenter about 2 miles southeast of Santa Rosa, according to Berkeley.
February 14: 10:43. Santa Rosa, V. Plaster cracked, damage slight. Felt also at Bay.
February 14: 10:51. Santa Rosa, people driven from homes. Epicenter about 2 miles southeast of Santa Rosa, according to Berkeley.
February 14: 11:15. Santa Rosa, two shocks felt.
February 14: 11:55. Santa Rosa, V. Cracked plaster.
February 14: 14:34.* Santa Rosa, V. Cracked plaster and mirrors, damage slight. IV at Monte Rio and Sebastopol. Felt also at Bay and Modega. Epicenter about 2 miles southeast of Santa Rosa, according to Berkeley.
February 15: 14:30. Sebastopol, III.
February 15: 21:37. Santa Rosa, V. People left their homes, plaster and knickknacks fell. Felt also at Bay, Forestville, Fulton, Jenner, Kenwood, Rincon Valley, Sebastopol, and Windsor.
February 15: 21:47. Weak shocks felt at Bay, Forestville, Fulton, Glen Ellen, Eldridge, Jenner, Kenwood, Rincon Valley, Santa Rosa, Sebastopol, and Windsor.
February 15: 21:50. Santa Rosa, IV. Felt also at Bay, Forestville, Fulton, between Glen Ellen and Eldridge, Jenner, Kenwood, Rincon Valley, Sebastopol, and Windsor.
February 15: 22:45. Weak shock felt at Bay, Forestville, Fulton, between Glen Ellen and Eldridge, Jenner, Kenwood, Rincon Valley, Santa Rosa, Sebastopol, and Windsor.
February 15: 23:30. Weak shock at Santa Rosa.
February 16: 1:31.* Santa Rosa, V. Felt also at Bay, Forestville, Fulton, between Glen Ellen and Eldridge, Jenner, Kenwood, Rincon Valley, Sebastopol, and Windsor. Epicenter probably about 2 miles southeast of Santa Rosa, according to Berkeley.
February 16: 6:01. Santa Rosa, IV. Felt also at Bay, Forestville, Fulton, between Glen Ellen and Eldridge, Jenner, Kenwood, Rincon Valley, Sebastopol, and Windsor. Epicenter probably about 2 miles southeast of Santa Rosa, according to Berkeley.
February 16: 7:00. Santa Rosa, slight shock.

February 16: 7:58.* Santa Rosa and vicinity. This is reported as the strongest shock of the group of shocks at this time. Epicenter probably about 2 miles southeast of Santa Rosa, according to Berkeley. Intensity V at Santa Rosa, where all people were frightened and some plaster cracked. Felt also at Bay, Forestville, Fulton, between Glen Ellen and Eldridge, Jenner, Kenwood, Rincon Valley, Sebastopol, and Windsor. None of the Santa Rosa shocks was felt at Healdsburg, Napa, Novato, Petaluma, St. Helena, or Two Rock.

February 18: 1:03. Santa Rosa, very light aftershock.

February 18: 3:19.* Watsonville, IV. Felt also at Pacific Grove. Epicenter about 4 miles northeast of Watsonville, according to Berkeley.

February 20: 5:48. Balboa, IV. Pasadena reports a shock recorded at about this time and place.

February 23: 20:39.* Watsonville, III. Epicenter about 3 miles west of Gilroy Hot Springs, according to Berkeley.

March 2: 13:30.* Mecca, III. Felt also at Carrizo Creek. Epicenter 33°05′ north, 115°59′ west, according to Pasadena.

March 3: 7:05.* Balboa, IV–V. Huntington Beach, III. Epicenter, 33°37′ north, 118°02′ west, according to Pasadena.

March 3: 7:17.* Huntington Beach, "hard single wave." Epicenter 33°37′ north, 118°02′ west, according to Pasadena.

March 6: 13:45. Los Angeles, III.

March 10: 15:03.* Huntington Beach, IV. Los Angeles, II. Epicenter 33°57′ north, 118°38′ west, according to Pasadena.

March 12: 8:10. Weak shock at Santa Rosa.

March 13: 8:11.* Hawthorne, Nev., III. Epicenter about 38° north, 118° west, according to Pasadena.

March 13: 8:20.* Hawthorne, Nev. Slight shock. Epicenter about 38° north, 118° west, according to Pasadena.

March 13: 17:15.* Morgan Hill, III. Epicenter about 10 miles north of Watsonville, according to Berkeley.

March 19: 2:41.* Luning, Nev., IV. Epicenter about 38° north, 118° west, according to Pasadena.

March 20: 3:49.* III at Hollister and Spreckels. Epicenter probably 14 miles east of Spreckels, according to Berkeley.

March 26: 17:36.* Spreckels; slight shock. Epicenter 6 miles southeast of Spreckels, according to Berkeley.

April 5: 14:34.* Santa Monica Bay; very slight. Epicenter 33°50′ north, 118°30′ west, according to Pasadena.

April 6: 19:36.* Weak shock at Seal Beach. Epicenter 33°42′ north, 118°07′ west, according to Pasadena.

April 7: 4:06.* Weak shock felt at Huntington Beach, Newport Beach, and Seal Beach. Epicenter 33°35′ north, 118°00′ west, according to Pasadena.

April 8: 6:15.* IV at Balboa, Costa Mesa, and Santa Ana. Felt also at El Modeno. Epicenter at 33°46′ north, 117°47′ west, according to Pasadena.

April 15: 22:37.* Slight shock felt at Hynes and Long Beach. Epicenter 33°45′ north, 118°10′ west, according to Pasadena.

April 16: 4:54.* Hynes, III. Epicenter 33°45′ north, 118°10′ west, according to Pasadena.

April 17: 3:36.* Hynes; slight. Epicenter 33°47′ north, 118°08′ west, according to Pasadena.

April 17: 4:30. Weak shock at Huntington Park and Long Beach.

April 17: 9:16.* Huntington Beach; slight. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

April 17: 10:33.* V at Santa Ana, where people left buildings, but there was no damage. IV at Balboa. Felt also at Anaheim, Huntington Beach, and Hynes. Not felt at Long Beach or San Juan Capistrano. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

April 17: 10:46.* Weak shock felt at Anaheim and Huntington Beach. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

April 20: 6:07.* Recorded at Ferndale only, IV at Arcata and Orick. III at Ferndale. Focus about 18 miles from Ferndale, according to Berkeley.

April 20: 20:18.* Huntington Park, IV. Felt also at Balboa, Maywood, Southgate, Vernon, and Walnut Park. Epicenter 33°57′ north, 118°08′ west, according to Pasadena.

April 21: 6:21.* Hynes, III. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

April 23: 8:08.* IV at Santa Cruz and Watsonville. Felt also at Aromas, Hollister, Salinas, Soquel, Spreckels, and Wrights. Epicenter about 37° north, 122° west, according to Pasadena.

April 23: 9:35. Weak shock felt at Aromas, Gilroy, Salinas, Spreckels, and Watsonville.

April 23: 13:10. Aromas, VI. Felt also at Salinas and Watsonville.

April 23: 13:19.* Weak shock felt at Hollister, Salinas, and Watsonville. Epicenter 37° north, 121° west, according to Pasadena.

April 28: 9:20.* Recorded at Berkeley, Mt. Hamilton, Palo Alto, and San Francisco.

Intensity IV at San Jose, Santa Clara, Willow Glen.

Intensity III at Berkeley, Oakland. Epicenter about 4 miles west of Coyote.

April 28: 9:30. San Jose, III.

May 6: 17:39.* Weak shock felt at Beverly Hills, Culver City, and West Los Angeles. Epicenter 33°59′ north, 118°23′ west, according to Pasadena.

May 9: 18:48.* Seal Beach, IV. Felt also at Long Beach and San Pedro. Epicenter 33°47′ north, 118°08′ west, according to Pasadena.

May 10: 9:48.* Huntington Beach and vicinity; slight. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

May 11: 21:33.* Five miles north of Huntington Beach; slight. Epicenter 33°37′ north, 118°02′ west, according to Pasadena.

May 12: 2:51.* Five miles north of Huntington Beach; very light shock. Epicenter 33°37′ north, 118°02′ west, according to Pasadena.

May 13: 14:33.* Balboa, IV. Felt also at Long Beach. Epicenter 33°47′ north, 118°08′ west, according to Pasadena.

May 19: 3:28.* Five miles north of Huntington Beach; very light shock. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

May 23: 14:22.* Los Angeles; very slight. Epicenter 33°55′ north, 118°20′ west, according to Pasadena.

June 5: 1:51.* Two slight shocks in Coalinga and the Kettleman Hills district. Felt also in Monterey and Santa Cruz.

June 5: 3:30. Several weak shocks at San Miguel and Shandon.

June 5: 13:30. Lemoore, V. Plaster cracked. Weak at Castroville.

June 5: 13:49.* A foreshock of the destructive quake on June 7 at 20:48 centering near Parkfield. Intensity V. It was felt over a land area of about 11,000 square miles but apparently caused little damage. See map facing p. 20.

INTENSITY V:

Adelaida: Moved stove 4 inches; heaviest shock since 1906.

Parkfield: Moved small objects; damage slight.

Priest Valley: Pendulum clocks facing north stopped.

Eight miles east of San Miguel: Felt by all, frightened many; slight damage.

Intensity IV: Atascadero, Avenal, Big Sur, Bryson, Carmel, Hanford, Kettleman City, King City, Lemoore, Lonoak, Paraiso Springs, San Luis Obispo, San Miguel, Santa Cruz, Shandon, and Templeton.

Intensity III and under: Antelope, Aptos, Arroyo Grande, Avila, Boulder Creek, Bradley, Cambria, Chualar, Coalinga, Gonzales, Helm, Hollister, Jamesburg, Mendota, Monterey, Morro Bay, Moss Landing, Mount Hermon, New Monterey, Nipomo, Oceano, Oilfields, Olympia, Paso Robles, Salinas, San Benito, Sandberg, San Francisco, San Joaquin Valley, 14 miles east of San Miguel, Santa Margarita, Seaside, Soledad, Soquel, Spreckels, Stratford, Tassajara Hot Springs, Tranquility, and Westhaven.

Not felt: Antioch, Bakersfield, Burrell, Capitola, Casmalia, Clovis, Davenport, Fresno, Gilroy, Halcyon, Kearney Park, Laurel, Livermore, Loma Mar, Lompoc, Los Alamos, Los Gatos, Lost Hills, Maricopa, Martinez, Merced, Modesto, Monolith, Morgan Hill, Pacific Grove, Pescadero, Pleasanton, Point Sur Light Station, Redwood City, San Jose, Santa Barbara, Santa Maria, Saratoga, Tulare, Ventura, Vestal, Watsonville, Wheeler Ridge, and Woodlake.

June 5: 14:15.* Newspapers report an earthquake recorded at Mineral Seismograph Station. IV at Jacksonville. Epicenter 22 miles northwest of Mineral, according to Mr. Finch at Berkeley.

June 5: 14:52.* Another strong foreshock of the June 7 quake. This shock was quite local in its effect. VI at Adelaida, where two walls and several trees fell. Strong also at Atascadero, and felt at Antelope, Paso Robles, San Luis Obispo, and Templeton.

June 5: About 15:30. Weak shock at San Miguel and to the northeast.

June 6: 14:14.* A moderate shock felt over an area of about 4,600 square miles in northern California. See map facing page 20. Epicenter about 40° north, 121° west, according to Pasadena.

Intensity IV: Caribou, Chester, Crescent Mills, Janesville, and Stirling City.

Intensity III and under: Big Meadows, Mineral, Nevada City, Lassen National Park, Old Station, Oroville, Paynes' Creek, Quincy, 30 to 40 miles east of Red Bluff, Susanville, Taylorsville, Veramont Substation, Volcanoville, and Westwood.

Not felt: Alturas, Antioch, Auburn, Bieber, Colusa, Downieville, Doyle, Feather Falls, Hobart Mills, Johnsville, Marysville, Nelson, Paradise, Paraiso Hot Springs, Placerville, Ravendale, Redding, Round Mountain, Sattley, Sloat, Stacy, Tahoe, Tahoe Pines, Willows.

Not felt in Nevada: Flanigan, Gerlach, Hazen, Reno.

June 6: 14:40.* Slight shock felt at Adelaida, Graeagle, and Paynes' Creek.

June 7: 0:43. Ano Nuevo Island Light Station, IV.

June 7: 14:30. Stone Canyon. Felt by all men in mine 600 feet beneath surface.

June 7: 20:15. IV at Gonzales and McKittrick.

June 7: 20:30.* The second strongest shock of the Parkfield, Calif., series. Epicenter very near those of June 5 at 13:48 and the strongest shock of June 7 at 20:48. Intensity VI-VII. Epicenter according to Berkeley 35°58′ north, 120°29′ west. The land area affected (between 30,000 and 35,000 square miles) was only very slightly less than that for the shock occurring 18 minutes later. See map facing page 20 . (According to Byerly and Wilson[1] it centered about 4 kilometers north of the later one, which was also on the San Andreas Fault. Some damage was done in the epicentral region; cracks appeared in the ground, and ground water was affected. Because of the short interval between this shock and the main shock 18 minutes later there is sometimes ambiguity concerning the shock to which certain reports refer. See page 48 for additional details.

INTENSITY VI-VII:

Cholame Ranch, near Parkfield.—Dishes broken; chimney fell.

Parkfield.—Cracks appeared in ground with drop of 7 to 8 inches; "change of numerous springs, one drawing mud." Walls and one chimney fell. One person thrown from bed.

Six miles from Parkfield, VII.—"More severe than at Parkfield."

Stone Canyon.—Chimneys cracked and fell, damage slight.

INTENSITY V:

Atascadero.—Cracked plaster; damage slight.

Coalinga.—Moved cars from curb, cracked plaster; damage slight.

Hollister.—Pendulum clocks facing south stopped, trees and bushes shaken moderately.

King City.—Moved small objects, broke dishes.

Lemoore.—Pendulum clocks facing east stopped.

Ten to twelve miles north of Parkfield.—Moved furniture and overturned vases and small objects; damage slight.

Twenty-five to thirty miles east of Paso Robles.—Branches broken on trees; "sharper than at Paso Robles."

San Miguel.—Pendulum clocks stopped, knickknacks fell.

Intensity IV: Adelaida, Antelope, Berros, Big Sur, Bryson, Cambria, Canoga Park, Castroville, Delano, Kettleman City, Lockwood, Monson, Monterey, Navelencia, Oilfields, Paso Robles, San Luis Obispo, San Luis Obispo Light Station, 14 miles east of San Miguel, Santa Barbara, Santa Margarita, Santa Maria, Shale Pump Station, Shandon, Soledad, Soquel, Stratford, Taft, Templeton, Ventura, Visalia, and Westhaven.

Intensity III and under: Arvin, Bakersfield, Buellton, Delano, Delpiedra, Fresno, Glenville, Gorman, Junction, Kettleman Plains, Kernville, Lindsay, Lompoc, Lonoak, Los Angeles and vicinity, Mendota, Moss Landing, Onyx, Piru, Port San Luis Pump Station, Porterville, Reseda, Salinas, Sand-

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[1] Perry Byerly and James T. Wilson. The Central California Earthquakes of May 16, 1933, and June 7, 1934. Bulletin of the Seismological Society of America, vol. 25, no. 3, July 1935.

berg, San Fernando, Sanger, San Benito, Santa Ana, Santa Barbara, Santa Monica, Scheideck, Seaside, Spreckels, Springville, Tranquility, Tulare, Van Nuys, and Watsonville.

Not felt: Academy, Acton, Agoura, Badger, Big Basin, Broun, Cajon, Caliente, Cantil, Cornell, Coyote, Ducor, El Toro, Etiwanda, Fairmont, Gilroy, Guasti, Huntington Beach, Huntington Park, Independence, Inyokern, Keene, La Crescenta, Lancaster, Little Lake, Llano, Loma Mar, Lone-pine, Merced, Mineral King, Newman, Olancha, Olive View, Planada, Pomona, Posey, Rosemond, Sandberg, San Jose, Santa Monica, Santa Ynez, Saratoga, Sequoia National Park, Somis, Squaw Valley, Swartout, Topanga, Tujunga, Woodlake.

June 7: 20:37. IV at Piedras Blancas, San Luis Obispo, and Santa Cruz. Felt also at Bryson and Los Alamos.

June 7: 20:45. Weak shock felt at Atascadero, Coalinga, Lockwood, Paso Robles, Port San Luis Pump Station, Priest Valley, San Miguel, and Westhaven.

June 7: 20:48*. Main shock of the Parkfield, Calif. series. Intensity VIII Land area affected, about 34,000 square miles. Epicenter according to Berkeley 35°56′ north, 120°29′ west, on the San Andreas Fault about 6 miles northwest of Parkfield. Instrumental records indicate that the shock was only slightly less severe than the Long Beach earthquake of 1933, but in the Parkfield shock there was only minor damage and no loss of life, largely because of the sparsely settled nature of the region affected.

The maximum surface disturbance occurred on Middle Mountain, where cracks appeared in the ground and trees snapped off. Highway bridges near Parkfield shifted slightly on their footings and in one instance an approach caved in. Most of the houses in the strongly shaken area are low frame structures admirably adapted to resist earthquake movements except for their brick chimneys, which as a rule toppled over. A house built of hollow cement blocks had its walls shaken out. The onset in Parkfield was so sudden that chimneys and other brickwork had fallen to the ground before persons assembled in a schoolhouse had time to reach the doors and suffer probable injury.

The main shock was preceded by three strong foreshocks, two on June 5 and one (the strongest of the three), on June 7 just 18 minutes before the main shock. A few others were hardly perceptible. Several aftershocks were felt, but none of them was exceptionally severe. See page 48. A number of additional foreshocks and aftershocks were recorded on seismographs. The main shock actuated the strong-motion seismographs of the Coast and Geodetic Survey at Santa Barbara, Hollywood, and Pasadena, as described in the strong-motion section of this publication.

Two investigations of the shock were made. Reference to the first report, by Byerly and Wilson, is given in the footnote on page 25. This report covers largely the instrumental and purely seismological aspects with only casual emphasis on geological phenomena. The second report (unpublished) was prepared by Graham B. Moody, of the Standard Oil Co. who made a personal survey of the epicentral tract. Through the courtesy of the company a portion of that valuable report is reproduced on page 48 of this publication.

INTENSITY VIII:

Middle Mountain, northwest of Parkfield.—Ground cracked considerably and trees snapped off. See special report on page 48.

Parkfield.—See notes above and special report.

INTENSITY VII:

La Panza and Stone Canyon.

INTENSITY VI:

Castroville.

Coalinga.—Frightened all; moved furniture; tipped over canned goods; cars moved from curb.

Kettleman City.—Cracked plaster and walls.

INTENSITY V:

Atascadero.—Cracked plaster; damage slight.

Casmalia.

Cholame.—Tipped over canned goods.

Dudley.—Overturned small objects; spilled water from tank northeast.

Hollister.—Pendulum clocks facing south stopped; trees and bushes shaken moderately.

Jamesburg.
King City.—Moved small objects.
Lemoore.—Light service disrupted for a few minutes; damage slight.
Lost Hills.
McKittrick.
Oilfields.—Broke dishes; pendulum clocks facing north stopped.
San Miguel.—Pendulum clocks facing west stopped, knick-knacks fell.
Seaside.—Pendulum clocks facing north stopped; moved small objects; lamp fell.
Section 31, township 20 south, range 13 east.—Milk slopped out of pans in ice boxes.
Shale pump station.—Pendulum clocks facing north stopped.
Shandon.—Moved small objects and furnishings, milk slopped out of pans in ice boxes; "four shakes."

Intensity IV: Adelaida, Alpaugh, Antelope, Avenal, Avila, Bakersfield, Bryson, Button Willow, Canoga Park, Carneros Station, Casmalia, Creston, Ducor, Fillmore, Gonzales, Halcyon, Hanford, Los Alamos, McFarland, Maricopa, Middlewater, Modesto, Morro Bay, Nipomo, Oceano, Oil Center, Orcutt, Paso Robles, Piedras Blancas Light Station, Pixley, Point Hueneme Light Station, Priest Valley, Salinas, San Luis Obispo, San Luis Obispo Light Station, 14 miles east of San Miguel, Santa Cruz, Santa Margarita, Santa Maria, Soledad, Soquel, Ventura, Templeton, Visalia, Westhaven, and Woody.

Intensity III and under: Alviso, Aptos, Bodfish, Castaic, Clovis, Creston, Delpiedro, Exeter, Famosa, Fresno, Glendale, Gorman, Junction, Kaweah, Kernville, Laurel, Lone Pine, Lonoak, Los Banos, Lost Hills, Mendota, Miramont, Monterey, Moss Landing, Mount Hermon, Oakland Harbor Light Station, Port San Luis Pump Station, Raisin, San Benito, Sanger, Santa Ana, Shafter, Tehachapi, Los Angeles, Modesto, Pasadena, Three Rivers, Tipton, Tranquility, Tulare, Van Nuys, Wheeler Ridge, and 3 miles east of Wooding.

Not felt: Academy, Acton, Agoura, Badger, Big Basin, Brown, Cajon, Caliente, Cantil, Cornell, Coyote, El Toro, Etiwanda, Fairmead, Fairmont, Gilroy, Guasti, Huntington Beach, Huntington Park, Independence, Inyokern, Keene, La Crescenta, Lancaster, Little Lake, Llano, Loma Mar, Lombard, Long Beach, Magunden, Merced, Mineral King, Montrose, Newman, Olancha, Olive View, Planada, Pomona, Posey, Rosamond, San Jose, Santa Ynez, Saratoga, Sequoia National Park, Squaw Valley, Swartout, Topanga, Tujunga, Woodlake.

June 7: About 21:00. Moderate shock apparently centering off the Piedras Blancas Light Station, where the tower shook sharply. Felt also at Bryson, Kernville, La Panza, Lemoore, Parkfield, 14 miles east of San Miguel, Sandberg, and San Fernando.
June 7: 21:20. Atascadero. III. Jolting motion, felt by several; "one jolt."
June 7: 21:23.* San Miguel; strong aftershock of the Parkfield quake. Felt at Atascadero.
June 7: 21:43.* Weak aftershock of the Parkfield quake felt at Atascadero, Big Sur, Coalinga, King City, Loneoak, Paso Robles, and Westhaven.
June 7: 21:50. Atascadero. IV. Felt also at Coalinga and San Luis Obispo.
June 8: 1:30.* Slight shock at Atascadero and Parkfield, according to Pasadena.
June 8: 8:30. Parkfield; slight aftershock.
June 9: 4:50.* IV at Hynes and Long Beach. Epicenter 33°47′ north, 118°08′ west, according to Pasadena.
June 10: 00:03.* Intensity IV at San Miguel.
June 10: 12:02. IV at San Miguel. Felt also at Parkfield and Woody.
June 10: 18:32. Balboa, V. Fire wall of building shifted slightly to southeast; several cemented cracks reopened.
June 12: 20:38.* Long Beach, slight shock. Epicenter 33°43′ north, 118°05′ west, according to Pasadena.
June 14: 5:39.* Huntington Beach, slight.
June 14: 6:30.* Five miles north of Huntington Beach, slight shock.
June 14: 6:55.* Atascadero, IV. Felt also at San Miguel and Templeton, according to Pasadena.
June 14: 7:54.* Slight shock felt at Atascadero and San Miguel, according to Pasadena.

June 14: 11:26.* IV at Atascadero. Felt also at Templeton, according to Pasadena.

June 14: 14:02.* Weak shock at Atascadero, according to Berkeley.

June 16: 15:03.* IV at Hollister and Monterey. Felt also at Gonzales, Parkfield, and Salinas. Not felt at San Jose. Epicenter about 36.5° north, 121° west, according to Pasadena.

June 17: 21:07.* Weak shock at Sharp, Nev. Epicenter about 38° north, 116° west, according to Pasadena.

June 19: 3:53.* Slight shock felt 3 miles north of Huntington Beach. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

June 20: 4:—. Dillion Beach, IV. Felt also at Petaluma.

June 20: 5:40. A moderate shock of intensity IV felt generally over the San Francisco Bay region. See map facing page 20. Epicenter 6 miles west of San Mateo according to Berkeley.

Intensity IV: Alameda, Alcatraz Island, Belmont, Brisbane, Burlingame, Camp Meeker, Daly City, El Granada, Half Moon Bay, Lomita Park, Montara, Monterey, Redwood City, San Bruno, San Carlos, San Francisco, San Lorenzo, and San Mateo.

Intensity III and under: Alvarado, Angel Island, Antioch, Benicia, Berkeley, Bolinas, Corte Madera, Crockett, El Cerrito, Emeryville, Forestville, Inverness, Kentfield, La Honda, Larkspur, Manor, Millbrae, Mission, San Jose, Moss Beach, Newark, Nicasio, Novato, Oakland, Palo Alto, Piedmont, Pinole, Point Reyes, Rockaway Beach, Salada Beach, San Anselmo, San Francisco, San Gregorio, San Pablo, San Rafael, Santa Clara, Southampton Shoal Light Station, Sunnyvale, Tiberon, Tomales, and Yerba Buena Island.

Not felt: Agnew, Agua Caliente, Alamo, Año Nuevo Island Light Station, Brentwood, Canville, Cazadero, Centerville, Concord, Cordelia, Cowell, Fairfield, Fallon, Fort Baker, Fort Barry, Giant, Hayward, Ignacio, Jenner, Lafayette, Lawrence, Livermore, Loma Mar, Los Altos, Los Gatos, Mare Island, Milpitas, Moraga, Mountain View, Napa, Niles, Oakland, Oleum, Penn Grove, Pittsburg, Pleasanton, Port Chicago, Rio Nido, Rodeo, Rollinsville, San Jose, San Ramon, Sausalito, Sebastopol, Stege, Stinson Beach, Sunol, Valley Ford, Vineburg, Warm Springs, and Yolo.

June 20: 6:40. Berkeley, IV. Felt also at Martinez, Olema, and Richmond.

June 21: 18:24.* Newport Beach, slight. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

June 23: 2:53.* Ramona, IV. Felt also at Martinez, Olema, and Richmond. Epicenter 33°02′ north, 116°30′ west, according to Pasadena.

June 27: 16:15.* Long Beach, IV. Epicenter 33°47′ north, 118°08′ west, according to Pasadena.

June 28: 5:55.* Slight shock felt 5 miles north of Huntington Beach. Epicenter 33°40′ north, 117°55′ west, according to Pasadena.

July 1: 1:00. Balboa, III. Pasadena reports a shock at 0:45 at 33°38′ north, 118°12′ west.

July 6: 11:26.* Long Beach, III, Epicenter 33° 37′ north, 118°02′ west, according to Pacadena.

July 6: 14:49.* Moderate shock felt along the coast of northern California and southern Oregon, apparently strongest at Eureka, Beatrice, and Crescent City. Damage negligible. Epicenter approximately 41.7° north, 124.6° west. Felt over a land area of about 8,000 square miles. Recorded on strong-motion seismographs at Eureka and Ferndale.

INTENSITY V:

Beatrice.—Pendulum clocks stopped.

Crescent City.—Small objects and furnishings moved, damage slight.

Eureka.—Frightened few; "some left buildings."

Intensity IV: Arcata, Bridgeville, Carlotta, Fortuna, Petrolia, and Scotia.

Intensity IV in Oregon: Gold Beach, North Bend.

Intensity III and under: Benbow, Cape Mendocino, Barberville, Kneeland, Orick.

Intensity III and under in Oregon: Brookings, Charleston, Grant's Pass.

Not felt: Fort Bragg.

Not felt in Oregon: Bandon, Gleneden Beach, Port Orford, Roosevelt Beach, The Dalles, Waldeport, Westlake, Winchester Bay.

July 13: 5:56.* IV at Nevada city and Sattley. Felt also at Delleker, Placerville, Portola, and Volcanoville. Epicenter probably near Portola, according to Berkeley.

July 23: 13:59.* Slight shock near Calexico. Epicenter 32°27′ north, 115°37′ west, according to Pasadena.
July 25: 15:07.* Long Beach, III. Epicenter 33°38′ north, 118°12′ west, according to Pasadena.
July 29: 21:19.* IV at Jamul, Julian, and Lakeside. Felt also at Campo. Epicenter 33°15′ north, 116°30′ west, according to Pasadena.
July 31: 21:22.* IV at Imperial. Felt also at Calexico. Epicenter 32°27′ north, 115°37′ west, according to Pasadena.
July 31: 21:38.* IV at Año Nuevo Island Light Station. Felt also at Calexico and Imperial. Epicenter 32°27′ north, 115°37′ west, according to Pasadena.
August 12: 16:57.* San Diego, IV. Epicenter 32°53′ north, 117°30′ west, according to Pasadena.
August 18: 18:54.* Slight shock at Keeler. Epicenter 36°24′ north, 118°00′ west, according to Pasadena.
August 18: 19:30.* Slight shock at Keeler. Epicenter 36°24′ north, 118°00′ west, according to Pasadena.
August 20: 19:37.* Intensity IV at Stone Canyon, according to Berkeley.
August 24: 23:06.* Huntington Beach, III. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.
August 25: 5:51.* Huntington Beach; slight.
August 29: 22:18.* Los Angeles, IV. Epicenter 33°59′ north, 118°23′ west, according to Pasadena.
August 30: 4:50.* IV at Cajon, Etiwanda, and Moreno. Felt also at Mentone and Riverside. Epicenter 34°04′ north, 117°35′ west, according to Pasadena.
August 31: 4:54.* A slight shock felt at Mentone and Riverside. Epicenter 34°02′ north, 117°19′ west, according to Pasadena.
September 1: 8:15. Twin Peaks district, San Francisco; slight. Epicenter near Mussel Rock, San Francisco, according to Berkeley.
Not felt: Belvedere, Dillon Beach, Duncans Mills, Forest Knolls, Ignacio, Lagunitas, Point Reyes, San Rafael, Santa Rosa, Stewarts Point, Vallejo.
September 12: 3:29.* Porterville, IV. Epicenter 36°08′ north, 118°48′ west, according to Pasadena.
September 13: 2:36.* IV at Balboa and Huntington Beach. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.
September 20: 23:06.* Huntington Beach, III. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.
September 24: 5:46.* Huntington Beach, II. Epicenter 33°37′ north, 118°02′ west, according to Pasadena.
September 26: 23:12.* Slight at Keddie, Quincy, and Spring Garden, according to Berkeley.
September 30: 3:39.* Huntington Beach, II. Epicenter 33°37′ north, 118°02′ west, according to Pasadena.
October 2: 12:20.* Two shocks, 10 minutes apart, were felt in the San Francisco Bay region. The second shock was generally reported as the stronger. It was felt most strongly in Colma, Sausalito, and the southwestern section of San Francisco, where it probably reached intensity V. Damage was negligible. As many observers reported both shocks on one card, it is often difficult or impossible to distinguish between the two shocks. Epicenter 37.6° north, 122.8° west, according to Pasadena. Affected land area of about 2,100 square miles.

INTENSITY V:

Colma.—Overturned small objects.

San Francisco, Portola district.—Felt by all; furniture in upper stories of tall buildings skidded considerably, dishes fell from shelves, pictures fell from walls. Woman injured when jolt caused her to lose balance in stepping from curb.

Sausalito.—Felt very strongly; dishes broken.

Intensity IV: Alcatraz Island, Alviso, Belvedere, Centerville, Half Moon Bay, La Honda, Manor, Oakland, Petaluma, Pinole, Redwood City, Rockaway Beach, Salada Beach, San Bruno, San Francisco (various parts), and San Gregorio.

Intensity III and under: Agnew, Alamo, Benecia, Bolinas, Corte Madera, Cowell, Crockett, Danville, El Cerrito, El Granada, Fort Barry, Ignacio, Kentfield, Martinez, Mile Rock Light Station, Milpitas, Montara, Moraga,

Mount Eden, Point Montara Light Station, Richmond, San Francisco (various parts), San Jose, San Leandro, Sunnyvale, San Pablo, San Rafael, Tomales, and Visitacion.

October 2: 12:30.* The second of two shocks 10 minutes apart. Generally reported stronger than the preceding one. Since this shock was, in the majority of cases, reported on the same card as the first earthquake, only the place felt will be mentioned, and for the effects reference must be made to the preceding shock. Epicenter 37.6° north, 122.8° west, according to Pasadena. A shock at about this time was recorded on strong-motion seismographs at Oakland and San Francisco.

Intensity V: Colma, Sausalito, and San Francisco, Portola district.

Intensity IV: Alviso, El Granada, Half Moon Bay, Redwood City, Rockaway Beach, San Bruno, Salada Beach, and San Francisco (various parts).

Intensity III and under: Agnew, Benecia, Concord, Danville, Hollister, Ignacio, Kentfield, Lafayette, Larkspur, Menlo Park, Mile Rock Light Station, Montara, Newark, Oakland, Point Montara Light Station, San Francisco (various parts), San Leandro, San Pablo, San Rafael, and Visitacion.

Neither shock felt: Antioch, Clayton, Cordelia, Cupertino, Decoto, East Brother Island Light Station, Eldridge, Fairfield, Inverness, Lawrence, Los Gatos, Mountain View, Miles, Olema, Oleum, Pittsburgh, Pleasanton. Port Chicago, Santa Rosa, Saratoga, Sunol, Vineburg, Walnut Creek, Warm Springs.

October 2: 22:17. Slight shock felt at Benecia, Mile Rock Light Station, Oakland, and San Francisco.

October 5: 18:17.* El Cerrito, IV. Epicenter about 3 miles northwest of the University of California campus according to Berkeley.

October 5: 20:03.* Huntington Beach; slight. Epicenter 33°37′ north, 118°02′ west, according to Pasadena.

October 6: 18:11.* Huntington Beach; slight. Epicenter 33°37′ north, 118°02′ west, according to Pasadena.

October 8: 0:40. San Francisco, IV.

October 12: 1:02.* Five miles north of Hungtington Beach; slight. Epicenter 33°45′ north, 117°53′ west, according to Pasadena.

October 12: 19:57. IV at Reno and Sparks, Nev.

October 13: 0:22.* Huntington Beach; slight. Epicenter 33°37′ north, 118°02′ west, according to Pasadena.

October 15: 19:59.* El Centro, IV. Felt in Lower California. Epicenter 32°27′ north, 115°37′ west, according to Pasadena. Recorded on the strong-motion seismograph at El Centro.

October 16: 11:33. Colma; slight.

October 17: 1:38.* A moderately strong shock in the Los Angeles area. Epicenter 33°38′ north, 118°24′ west, according to Pasadena. Huntington Park, V. Cracked windows and plaster slightly. Venice, V. Windows broken.

Intensity IV: Hynes, Lomita, Long Beach, Los Angeles, and Seal Beach.

Intensity III and under: Bell, Compton, El Segundo, Inglewood, Hermosa, Lynnwood, Maywood, Manhattan, Redondo, San Pedro, and Venice.

October 18: 2:07.* IV at Hynes, Long Beach, and Seal Beach. Felt also at Venice. Epicenter 33°46′ north, 118°06′ west, according to Pasadena.

October 21: 18:24.* IV at Jamul and Julian. Epicenter 33°00′ north, 116°40′ west, according to Pasadena.

October 22: 7:23.* Five miles north of Huntington Beach; slight. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

October 23: 10:17.* Hynes, IV. Long Beach, III. Epicenter 33°46′ north, 118°06′ west, according to Pasadena.

October 24: 19:20.* Aftershock of the San Francisco Bay earthquake of October 2, according to Berkeley. V at Presido Terrace in San Francisco. IV at Berkeley, Burlingame, Oakland, Rockaway Beach, and in parts of San Francisco. III at Ross, Southampton Shoal Light Station, and Salada Beach. Not felt at Redwood City, Sacramento, or San Jose. A shock of intensity IV is reported from Oakland at 20:21: probably the same shock.

October 25: 20:14.* Los Angeles, IV. Felt also at Beverly Hills and Culver City. Epicenter 33°59′ north, 118°17′ west, according to Pasadena.

October 26: 23:46.* Huntington Beach; slight. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

October 30: 18:42. Santa Monica; slight.
November 1: 6:04.* Five miles north of Huntington Beach; slight shock. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.
November 4: 18:38.* A moderate shock in the Long Beach area. Damage confined to a few broken windows and dishes. Epicenter 33°47′ north, 118°08′ west, according to Pasadena.

INTENSITY V:

Anaheim.—Broke windows and dishes; "one of the strongest since March 10, 1933."

Huntington Park.—A few dishes and windows broken.

Seal Beach.—Floor lamps overturned.

Long Beach.—A few windows and dishes broken; "one of the strongest since March 10, 1933."

Intensity IV: Balboa, Newport Beach.

Intensity III and under: Five miles north of Huntington Beach.

Not felt: Laguna Beach, San Juan Capistrano.

November 6: 1:32*. El Centro; slight.
November 6: 13:15. San Francisco; slight shock.
November 11: 12:34*. Five miles north of Huntington Beach; slight. Epicenter 33°37′ north, 118°02′ west, according to Pasadena.
November 15: 21:37*. IV at Eureka. Epicenter about 70 miles west of Cape Mendocino.
November 16: 13:26*. IV at Huntington Beach, Long Beach, Santa Ana, and Seal Beach. Felt also at Balboa and Los Angeles. Epicenter 33°45′ north 118°00′ west, according to Pasadena.
November 16: 15:58. Shock felt near Westminister. Epicenter 33°45′ north, 118°00′ west, according to Pasadena.
November 17: 9:42. V at Shively, where water was spilled and small objects moved. IV at Alderpoint, Petrolia, and Scotia. Felt also at Bruceland, Ettersburg, Eureka, and Fortuna. Not felt at South Fork.
November 18: 4:38. IV at Fortuna and Upper Mattole.
November 21: 14:49*. Long Beach, III. Epicenter 33°42′ north, 118°04′ west, according to Pasadena.
November 25: 0:18*. IV at El Centro, Jamul, and San Diego. Epicenter 32°05′ north, 116°40′ west, according to Pasadena. Two of four reports received from San Diego give the date as November 24. These are probably in error, but there may possibly have been two shocks.
December 1: 5:05. Walls cracked at Piedras Blancas Light Station. IV at Paraiso Springs. Epicenter about 15 miles south of Paraiso Hot Springs, according to Berkeley.
December 2: 8:07*. San Miguel; slight. Felt also at Parkfield. Epicenter 35°58′ north, 120°35′ west, according to Pasadena.
December 2: 15:19. Slight shock felt at San Jose and Santa Clara. Epicenter about 5 miles northwest of Lick Observatory, according to Pasadena.
December 2: 17:54*. IV at Bryson, King City, and Paraiso Springs. Felt also at Parkfield, Paso Robles, San Lucas, and San Miguel. Epicenter 35°57′ north, 121°30′ west, according to Pasadena.
December 10: 22:19*. Intensity IV at Upper Mattole.
December 12: 18:30. San Francisco, IV. Epicenter very near Colma, according to Berkeley.
December 15: 9:00. V at Fortuna, where all felt the shock and pendulum clocks were stopped. IV at Scotia, Shively, and Upper Mattole. III at Ettersburg, South Fork, and Whitlow. Epicenter about 6 miles from Ferndale, according to Berkeley.
December 17: 3:10*. A sharp shock felt along the coast of Santa Barbara and San Luis Obispo Counties. It was strongest at Los Alamos, which is near the epicenter given by Pasadena, viz 34°35′ north, 120°20′ west. Los Alamos also experienced several aftershocks.

Intensity IV: Avila, Buellton, Halcyon, Lompoc, Oceano, Point Concepcion, San Luis Obispo Light Station, Santa Ynez, Carneras, Casmalia, Nipomo, San Luis Obispo, and Santa Maria.

Not felt: Bakersfield, Scheideck, Ventura.

December 17: 5:51.* Los Alamos; "heavy shake." Epicenter 34°35′ north, 120°20′ west, according to Pasadena.
December 17: 19:09.* Los Alamos; light shock. Epicenter 34°35′ north, 120°20′ west, according to Pasadena.

December 17: 20:34.* Los Alamos; slight aftershock. Epicenter 34°35′ north, 120°20′ west, according to Pasadena.
December 17: 21:28.* Los Alamos; light. Epicenter 34°35′ north, 120°20′ west, according to Pasadena.
December 20: 4:37.* Los Alamos, III. Epicenter 34°35′ north, 120°20′ west, according to Pasadena.
December 21: 23:35.* Hopland, III.
December 24: 2:22.* Los Alamos; slight. Epicenter 34°35′ north, 120°20′ west, according to Pasadena.
December 24: 8:26.* IV at Los Alamos and Shandon. Felt also at Coalinga, Hanford, King City, San Luis Obispo, and Templeton. Not felt at La Panza, Epicenter 35°56′ north, 120°29′ west, according to Pasadena.
December 28: 14:31. Balboa, III.
December 30: 5:52.* Lower California. A destructive shock of intensity IX, originating about 35 miles south of Calexico, was felt over about 60,000 square miles in California and Arizona. See map facing page 20. The epicenter as determined from seismographic data was 32°.2 north, 115°.5 west. This is in the very thinly settled Laguna Salada region of Lower California. So far as known no investigation of the epicentral region has been made, so there is no verification of the epicenter given. The shock was strongly felt throughout the Imperial Valley region with slight damage at Mexicalli, Calexico, El Centro, and Brawley. It actuated the strong-motion seismographs at El Centro, Hollywood, Los Angeles, and San Diego.

Because of the short time intervals between this shock and those at 5:55 on the 30th (near Santa Cruz) and 10:46 on the 31st (Lower California), together with many intervening shocks of minor intensity, there is often difficulty in assigning the post-card earthquake reports to the proper places. It seems very probable that the Santa Cruz shock was set off by the trigger action of the shock which originated in Lower California only 3 minutes earlier.

Reports received from Lower California are very incomplete, except for a special report from W. H. Kirkbride, chief engineer of the Southern Pacific Railroad, based on a survey of the Inter-California and Inter-California Del Sur Railroads. Towns along these lines were nearer the epicentral area than any other points heard from. "At many points bridges were damaged by movement both laterally and longitudinally and by settlement of piles. Track was kinked in several locations and settlement was as much as 6 inches." Many adobe houses were wholly or partly wrecked in the area inspected.

A large number of press reports have been abstracted by Dr. C. F. Richter, of the Pasadena Laboratory, and intensities estimated. These estimates and the other reports received are given below.

INTENSITY IX IN LOWER CALIFORNIA:

Delta.—Cracks appeared in the ground up to 3 or 4 feet in width, and 8 or 10 feet in depth. There were a number of parallel cracks of this kind; their length is not reported, but they were followed for about one-half mile, and no diminution found. There were a number of such cracks, practically parallel. Immediately after the quake, water and sand spouted up from a dry canal bed. Piling was moved westerly in some cases as much as 18 inches and the piles were forced upward as much as 12 inches. Adobe structures in this vicinity were completely demolished. Houses constructed of arrowroot stems stuck about 6 inches into the ground, laced with similar stems, and roofed with poles and brush were thrown flat.

Inhabitants ran up on to the railroad at the time of the shock and sat between the rails, but found it difficult to sit upright, being thrown from side to side by the force of the shock.

INTENSITY VIII IN LOWER CALIFORNIA:

Cocopah.—Information from W. H. Kirkbride's report. The railroad station and the agent's living quarters are constructed of hollow cement blocks with secondary partitions and roof of frame construction on concrete foundation. A few cracks developed in the exterior walls of the station but nothing serious. However, movement was enough to form a crack between interior tile partitions and exterior walls. The open waiting room roof is supported on three columns of cement tile. The center one did not move, but the two outer ones hinged upon their bases, one in one direction about 8 inches and the other in the opposite direction

about 4 inches. Several areas of ceiling plaster fell. The effect on the agent's residence was about the same as on the station building.

An empty 65,000-gallon water tank was thrown sideways from its supporting columns and landed on its bottom outside the foundation area. Examination showed that one of the tie-rods was broken. Several tanks of the same construction were thrown down in the vicinity during the earthquake of 1906.

INTENSITY VII IN LOWER CALIFORNIA:

Packard.—Chimney down at station.

Paredones.—Wall cracked in station.

Sesbania.—Concrete house considerably cracked, but not rendered unsafe.

INTENSITY VI IN LOWER CALIFORNIA:

Mexicali.—People rushed into the streets partly clad; windows were broken and chimneys damaged.

Pascualitos.—Cracks in reinforced adobe.

INTENSITY VI IN CALIFORNIA:

Brawley.—Slight damage.

Calexico.—Slight damage in frame railroad station. Columns moved about one-fourth inch. Concrete platforms opened up about one-fourth inch.

Coyote Wells.—Cracks in section quarters.

Dixieland.—Plaster and windows cracked; slight cracks found in railroad station.

El Centro.—Cracked plaster and walls, broke dishes; damage slight.

Heber.—Cracked plaster and chimneys; damage slight.

Holtville.—Cracked chimneys and walls; broke windows; damage slight.

Indio.

Jasper.

Palos Verde.—Walls of concrete house cracked.

Westmoreland.—Cracked plaster and walls; damage slight.

INTENSITY V IN CALIFORNIA:

Alpine.—Cracked plaster.

Andrade.—Moved and overturned small objects; damage slight.

Beaumont.—Pendulum clocks stopped.

Blythe.

Calipatria.

Del Mar.

Imperial.—Broke dishes; dislodged a few bricks from old building.

Imperial Valley.—Broke glass.

National City.—Pendulum clocks facing west stopped.

Nyland.—Cracked plaster.

Palm City.—Spilled water from outdoor containers.

Plaster City.—Moved small objects and furnishings; spilled water.

San Diego.—Pendulum clocks stopped.

San Jacinto.—Moved small objects and furnishings; spilled water.

INTENSITY V IN ARIZONA:

Gadsden.—Moved small objects and furnishings; spilled water.

Gila Bend.—Opened door; pendulum clocks stopped.

Sentinel.—Damage slight in wood buildings.

Wellton.—"All damage done was to schoolhouse."

Yuma.—Strong shock; slight damage.

Intensity IV in California: Balboa, Barrett Dam, Boulevard, Campo, Coachilla, Colton, Coronado, Encanto, Hipass, Indio, Jamul, La Jolla, Mecca, Mesa Grande, Mission Hills, Mount Laguna, Nestor, Ontario, Palm Springs, Pine Valley, Ramona, San Bernardino, San Marcos, Santa Ana, Santa Ysabel, Spring Valley, Sunnyside, Tecate, Valley Center, Vidal, and Vista.

Intensity IV in Arizona: Aztec, Vicksburg, and Wenden.

Intensity III and under in California: Artesia, Banning, Bonita, Bostonia, Chino, Chula Vista, Elsinore, Encinitas, Escondido, Etiwanda, Fallbrook, Harbison Canyon, Hemet, Leucadia, Los Angeles, Oceanside, Pala, Pasadena, Point Loma, Pomona, Rancho, Riverside, Rosemead, San Onofre, Shandon, Solana Beach, Temecula, Victorville, Warner Springs, Whittier, and Winchester.

Intensity III and under in Arizona: Buckeye, Kingman, Phoenix, Pichaco, Stanwix, Topock, and Tucson.

Not felt in California: Adelanto, Amboy, Baker, Barstow, Brown, Cedar-pines Park, Chatsworth, Corona, Crucero, Daggett, Hodges Dam, Gorman, Guasti, Ivanpah, Kelso, Lincoln Acres, Lomita, Maricopa, Reseda, Riverside, Sandberg, San Dimas, San Luis Rey, Santa Barbara, Swartout, and Twentynine Palms.

Not felt in Arizona: Apache, Bannon, Bisbee, Blue, Bonita, Cameron, Cascabel, Cave Creek, Chloride, Cochise, Copper Creek, Duncan, Eloy, Holbrook, Jerome, Metcalf, Navajo, Nogales, Pinedale, Safford, Sells, Springerville, Tombstone, Tukachukai, Yucca.

December 30: 5:55. **Fairly strong shock probably centering offshore near** Santa Cruz. Felt along the coast from Monterey to Sonoma County. Occurring only 3 minutes after the preceding Mexican earthquake, it caused early press reports to be confused as to whether the two shocks were the same. The Santa Cruz shock was in all probability set off by the trigger action of the Lower California earthquake. It actuated the strong-motion seismograph at San Jose. Felt over a land area of about 3,000 square miles. See map facing page 20.

INTENSITY V IN CALIFORNIA:

Alviso.—Awakened all.

Laurel.—Spilled water east-west.

Los Gatos.—Small objects and furniture moved; bulging plaster accentuated.

San Jose.—Very sharp shock; guests in hotels and apartments gathered in hallways to discuss quake.

Santa Cruz.—Cracked plaster; "damage slight in weakly built houses."

Sunnyvale.—Moved and overturned small objects; pendulum clocks stopped; spilled water north.

Intensity IV in California: Agnew, Los Altox, Miramar, Morgan Hill, Mountain View, Oakland, Pacific Grove, Palo Alto, Pescadero, Pigeon Point Light Station, Redwood City, Ross, San Anselmo, San Francisco, San Mateo, and Stanford University campus.

Intensity III and under in California: Antioch, Aptos, Corte Madera, El Granada, Half Moon Bay, Hayward, Lower Lake, Olema, Piedmont, Point Conception, San Rafael, Rockaway Beach, Soquel, Southampton, and Spreckels.

December 30: 6:19. El Centro and Imperial; aftershock of Lower California quake.

December 30: 6:30.* **Imperial; weak shock.**

December 30: 6:40. El Centro; strong aftershock.

December 30: 7:34.* **El Centro and Imperial; slight shock.**

December 30: 8:37. Wellton and Yuma, Ariz; strong aftershock.

December 30: 9:16. El Centro and Imperial; strong aftershock.

December 30: 10:19. Wellton and Yuma, Ariz.; slight.

December 30: 10:38.* **El Centro; strong aftershock.**

December 30: 10:45. Needles, V. Spilled coffee. Felt also at El Centro.

December 30: 11:10. El Centro; strong.

December 30: 11:23.* **El Centro and Imperial; strong aftershock.**

December 30: 21:06. Imperial; slight.

December 30: 21:56. Los Gatos, IV. Felt also at Agnew, Half Moon Bay, Los Altos, Pigeon Point Light Station, San Francisco, San Mateo, Stanford University, and Sunnyvale.

December 30: 22:—. Kingston, V. Moved furnishings; spilled water. Pasadena reports a shock in Nevada at this time.

December 31: 1:06. El Centro; slight aftershock.

December 31: 2:53. Araz Junction; slight.

December 31: 10:46.* **Lower California.** The second and stronger of two destructive earthquakes within 30 hours. Intensity probably X in the epicentral region, which was located from seismographic data at 31°.8 north, 115°.1 west, about 35 miles southeast of the epicenter of December 30, near the delta of the Colorado River. As in the case of the earlier shock no report of field investigations is available so that again there is no verification of the instrumental epicenter. The shock was felt over an area of about 80,000 square miles in southern California, Arizona, and the lower tip of Nevada.

Information concerning effects in Lower California is again restricted practically to the reports furnished the Bureau by W. H. Kirkbride, chief engineer of the Southern Pacific Railroad. Details concerning the effects

of this earthquake or that of December 30, or both, on towns along the Inter-California and Inter-California Del Sur Railroads are given in the report on the quake of December 30. In various parts of Lower California irrigation canals were damaged, roads were buckled and twisted, crevises were opened in the ground, and communication service was impaired. Press dispatches state that hunters near Black Butte report being thrown to the ground. At the same time they saw fissures open, geysers of hot water bubbling from the alkali, and telephone poles shaken down. The shock was strongly felt at El Alamo, Ensenada, and Tijuana in Lower California, and throughout the Imperial Valley in southern California. It actuated the strong-motion seismographs at Hollywood, Long Beach, Los Angeles, and San Diego. The record at El Centro was used up in recording the strong shock of the previous day.

As in the case of the preceding shock a large number of press reports were abstracted by Dr. C. F. Richter, of the Pasadena Seismological Labratory. His estimates of the intensities are included in the following abstracts.

INTENSITY VII IN CALIFORNIA:

Calipatria.—Windows broken; chimneys and walls down; damage slight in brick and masonry.

El Centro and vicinity.—Broke windows; snapped support on water tank.

INTENSITY VII IN ARIZONA:

Gadsden.—Cracked ground; considerable damage in brick and masonry.

INTENSITY VI IN CALIFORNIA:

Blythe.—Spilled water. Trees and bushes shook.

Calexico.—Slight damage. Pendulum clocks facing west stopped.

Holtville.—Spilled water south. Cracked plaster and walls; damage slight.

Imperial.—Broke windows; cracked chimneys; bricks fell.

San Diego.—Plaster fell; windows broke; cracks in city hall widened; workers vacated buildings.

Westmoreland.—Spilled water east-west. Slight damage in brick and adobe.

INTENSITY VI IN ARIZONA:

Casa Grande.

Sentinel.—Slight damage in wood buildings.

INTENSITY V IN CALIFORNIA:

Alpine.—Cracked plaster.

Andrade.—Small objects overturned; damage slight.

Barrett Dam.—Trees and bushes shaken moderately.

Bonita.—Spilled water northeast; trees and bushes shaken moderately.

Bostonia.—Rattled goods on shelves of store.

Brawley.—Overturned small objects and furnishings.

Campo.—Rocking chair rocked.

Coachilla.—Overturned small objects; spilled water from indoor containers.

Coronado.—Slight damage.

Covina.

Del Mar.—"Harder than that of December 30."

Heber.—Spilled water east-west; cracked plaster.

Huntington Park.—Overturned small objects; spilled water; cracked plaster; damage slight.

Jacumba.—Overturned small objects; spilled water from outdoor container; "hardest shake this locality has ever experienced."

Jamul.—Spilled water north from outdoor containers.

Lemon Grove.—Cracked plaster slightly; "severest shock in 25 years."

National City.—Pendulum clocks stopped.

Needles.—Pendulum clocks facing north stopped.

Nestor.—Spilled water east-west; damage slight.

Nyland.—"Rolled auto back and forth."

Ocean Beach.—Power lines carrying 4,000 volts sent out huge showers of sparks.

Palm City.—Spilled water.

Palos Verdes.—Small objects and furnishings moved.

Placentia.—Pendulum clocks facing west stopped.

Plaster City.—Pendulum clocks facing north stopped; moved small objects and furnishings; cracked plaster; damage slight.

Point Loma.—Vase fell; pendulum clocks stopped.
San Onofre.—Frightened all.
Santa Ysabel.—Trees and bushes shaken strongly.
San Ysidro.
Seeley.—Plaster fell; damage slight.
Spring Valley.—Trees and bushes shaken moderately.
Twentynine Palms.—One chimney cracked.

INTENSITY V IN ARIZONA:

Eloy.—Cracked plaster; damage slight.
Mammoth.—Broke dishes; cracked plaster.
Maricopa.—"Water in railroad tank set gage in motion which lasted about 5 minutes."
Phoenix.—"People in Luhr's tower fainted."
Tucson.—Moved furniture; dentist's tools slid around on table.
Yuma.—Two severe shocks.

Intensity IV in California: Araz Junction to Burbank Junction, Cardiff by the Sea, Corona, Encinitas, Escondido, Huntington Beach, Hipass, Leucadia, Lincoln Acres, Long Beach, Los Angeles and vicinity, Mecca, Mesa, Miramar, Mount Laguna, Oceanside, Ontario, Pine Valley, Ramona, San Bernardino, San Jacinto, San Marcos, San Pedro, Santa Ana, Santa Monica, Solano Beach, Sunnyside, Tecate, Vidal, Vista, and Wilsie.

Intensity IV in Arizona: Aztec, Gila Bend, and Nogales.

Intensity III and under in California: Alhambra, Anaheim, Balboa, Beaumont, Bell, Beverly Hills, Bonsall, Borego, Brea, Burbank, Chula Vista, Colton, Compton, Crucero, Elsinore, Encanto, Etiwanda, Fallbrook, Glendale, Harbison Canyon, Indio, La Habre, La Jolla, La Mesa, Las Flores, Lomita, Maywood, Mesa Grande, Pala, Pasadena, Pomona, Rancho, Rosemead, San Juan Capistrano, San Luis Rey, Santa Barbara, Santa Paula, Saugus, Seal Beach, Temacula, Valley Springs, Ventura, Victorville, Warner Springs, and Whittier.

Intensity III and under in Arizona: Buckeye, Casa Grande, Cochise, Kingman, Mohawk, Prescott, Vicksburg, and Yucca.

Intensity III and under in Nevada: Bonage Hill and Las Vegas.

Intensity III in Texas: El Paso.

Not felt in California: Adelanto, Azusa, Bakersfield, Barstow, Bethany, Brown, Calpella, Campo, Carlsbad, Cedarpines Park, Chatsworth, Cima, Daggett, Del Loma, Fairmont, Guasti, Hodges Dam, Hynes, Inyokern, Ivanpa, Kelso, Llano, Western Los Angeles, Maricopa, Piedmont, Reseda, Riverside, Rosamond, San Dimas, Seven Oaks, Tehachapi, Venice, Winchester.

Not felt in Arizona: Bisbee, Bonita, Bowie, Cameron, Cavecreek, Cascabel, Chloride, Flagstaff, Lupton, Metcalf, Paradise, Payson, Peach Spring, Pinedale, Safford, Seligman, Sells, Snowflake, Tombstone, Tukachukai, Wilcox, Winslow.

Not felt in Utah: Cedar City, Enterprise, Milford, Monticello, Panguitch, Parowan, St. George, Tropic.

December 31: 17:58. Five miles north of Huntington Beach, III. Epicenter 33°34′ north, 117°59′ west, according to Pasadena.

WASHINGTON AND OREGON

[120th meridian or Pacific standard time.]

All places mentioned are in Washington unless otherwise indicated

January 1: P. M. Acme, III. Dishes rattled.
February 6: 5:20. Puget Sound region. III to IV at Grapeview. Felt also at Bremerton, Lakebay, Olympia, Queen Anne Hill, Seattle, and Tacoma. Many were awakened at Bremerton, where two shocks were felt.
February 7: 24:00. Sultan; two slight shocks.
March 9: 8:00. Lakeside, IV.
March 10: 7:53. Chelan Falls, IV. Lakeside; distinct.
March 10: Chelan Falls; felt. Lakeside; felt.
March 17: About 16:00. Waterville, III.
April 28: 7:15. Everett, II. "Two shocks, 2 to 5 minutes apart."
April 28: 14:30. Everett, IV. Small objects moved.
April 28: 19:30. Everett, IV.

April 28: 20:00. Everett; slight.
April 28: About 24:00. Everett, slight.
May 4: 20:06.* Puget Sound region, V. A series of shocks; the first and strongest, beginning at 20:06, was followed by shocks of less intensity over a period of several minutes. It was recorded by most sensitive seismographs on the Pacific coast. The epicenter was apparently in Puget Sound just east of Victoria.

INTENSITY V:

Anacortes.—Small objects and furnishings moved; three shocks extending over a period of several minutes, 20:06 to 20:13.

Arlington.—Pendulum clocks facing east stopped; trees and bushes shaken moderately.

Bay View.—Clocks stopped.

Bellingham.—Furniture moved; plaster dust was shaken from ceilings; houses and buildings swayed.

Deming.—Desks moved; water spilled from indoor containers.

La Conner.—Doors on cupboard shaken open and dishes fell out.

Mount Vernon.—A few windows cracked; "most severe within inhabitants' memory."

Port Angeles.—People left homes and theaters.

Intensity IV: Blanchard, Bow, Bryant, Carlsborg, Clinton, Coupeville, Everett, Florence, Greenbank, Hartford, Joyce, Kennydale, Langley, McMurray, Marietta, Neah Bay, Oak Harbor, Ovington, Port Orchard, Port Townsend, Possession, Pysht, Seattle, Shelton, Tatoosh Island.

Intensity III and under: Aberdeen, Bremerton, Burley, Clearwater, Concrete, Darrington, Eatonville, Forks, Granite Falls, Hoquiam, Keyport, La Push, Lowell, Monroe, Quilcene, Quinalt, Sappho, Sedro Woolley, Sequim, Silverton, Sumas, and Tacoma.

Not felt: Alder, Black Diamond, Brinnon, Bucoda, Cedar Falls, Machias, Malone, Nagrom, Nisqually, Parkland, Puyallup, Redmond, Seattle Heights, Union, Vesta, Zenith.

May 10: p. m. Deming, III.
July 6: 14:50. North Bend, Oreg., III.
September 14: 23:00. Ellensburg, IV. Windows and doors rattled.
September 17: p. m. Ellensburg; series of slight shocks.
September 18: Midnight. Ellensburg, V; moved small objects; slight damage.
September 22: 11:30. Ellensburg, IV; some small objects fell.
September 22: 17:37. Ellensburg, IV. Moved small objects; preceded and followed by faint rumbling sound. Not felt at Moxie, Signal Peak Ranger Station, Sunnyside, Yakima.
September 26: 16:15. Ellensburg, V. Cracked plaster.
September 26: 16:45. Ellensburg, V; frightened many; shook plaster from buildings.
September 26: 21:15. Ellensburg; almost as severe as that of 16:15.
September 27: Ellensburg. Several earthquake shocks felt in Ellensburg climaxing a series of more than 20 which were felt over a period of 18 days. Damage was limited to cracked plaster.
October 4: 2:26. Ellensburg, IV. Pictures on walls disarranged; "accompanied by muffled roar." Not felt at Easton, Goose, Prairie, Kittitas, Roslyn, Trinidad, Wenas, Yakima.
October 11: 21:19. Ellensburg, IV. Windows, doors, and dishes rattled; accompanied by moderately loud explosive sound.
October 12: 6:08. Ellensburg, slight.
October 12: 6:46. Ellensburg, slight.
October 19: 23:31. Ellensburg, V. Moved small objects and furniture; bricks displaced from one chimney; "as though a heavy blast had been fired deep under the house."
October 20: 2:07. Ellensburg, slight.
October 29: 18:36. Ellensburg, IV; abrupt explosive jolt.
November 1: 7:28. Ellensburg, V. Pictures and dishes broken, plaster cracked in a few instances. Ten distinct slight earthquakes felt in Ellensburg on November 1.
November 2: 14:54. Ellensburg, slight.
November 2: 15:16. Ellensburg, slight.
November 2: 15:17. Ellensburg, V. Slight damage to chimneys and cornices.
November 2: 15:25: Ellensburg, heavier than preceding shock, probably heaviest shock so far.

November 3: 6:50*. Puget Sound region, IV. Origin possibly in the mountains east of Mt. Vernon. Felt most strongly at Rockport. Records on nearby seismographs very weak.

Intensity IV: Bow, Bryant, Concrete, Darrington, Everett, Granite Falls, Monroe, Port Townsend, and Robe.

Intensity III and under: Bellingham, Burley, Clinton, Florence, Graham, Lake Chelan, Langley, Mount Vernon, Possession, Sauk, Seattle, Sedro Woolley, Snohomish, Tacoma, and Winton.

Not felt at Ellensburg.

November 19: 7:45. Ellensburg, loose objects rattled; "accompanied by explosive or bumping sound."

November 27: 19:00. Ellensburg, distinct vertical jar.

December 1: 19:00. One and one-half miles southeast of Ellensburg; strong vertical movement; "seemed to occur right under the house."

December 1: 23:00. One and one-half miles southeast of Ellensburg; not so strong as the one at 19:00.

December 2: 5:00. One and one-half miles southeast of Ellensburg; strong vertical movement of short duration; windows rattled, bed shook.

December 2: 16:00. One and one-half miles southeast of Ellensburg; "house jerked, movement came from the west."

ALASKA

[150th meridian time]

January 15: 0:40. Anchorage; slight.

January 18: 15:55. Susitna; slight.

January 18: 16:47. Homer, IV.

January 19: 15:41. Seward, III.

January 20: 0:15. Susitna; slight.

January 25: 9:02. Anchorage, IV. Susitna; slight.

February 10: 21:35. Anchorage, sharp jolt.

February 11: 16:30. Anchorage; slight.

February 11: 21:50*. Juneau, V. Cracked plaster; rock dump of mine settled in several places wrecking stackers. Slight damage to buildings. Recorded instrumentally at Sitka.

March 5: 21:30. Seward; slight.

March 20: 9:45. Afognak and Whale Island, III.

March 26: 8:15. Susitna; slight.

March 29: 17:30. Homer; slight.

March 29: 17:42. Anchorage, IV.

March 29: 17:56. Susitna; slight.

March 29: 18:07. Anchorage, IV. Recorded instrumentally at Sitka and at Bozeman, Mont.

April 2: 13:20. Anchorage; jolt.

April 3: 0:40. Anchorage, IV. Awakened many.

April 3: 6:20. Seward, IV; Anchorage, III.

April 6: 13:55. Anchorage, slight jolt.

April 6: 19:52. Susitna, III.

April 7: 15:43. Anchorage; slight jolt.

April 7: 16:38. Anchorage; slight jolt.

April 7: 16:45. Anchorage; slight jolt.

April 9: 17:35. Kodiak, Whale Island, and Afognak, III.

April 10: 10:34. Anchorage; slight.

April 13: 10:03. Anchorage; gave observers sinking feeling.

April 19: 8:52. Anchorage V. Slight damage. Felt also at Seward.

April 19: 13:58. Anchorage; slight.

April 21: 10:59. Anchorage; slight.

April 23: 17:47. Susitna, III.

April 23: 18:07. Anchorage, III. Recorded instrumentally at Sitka. Felt also at Homer.

April 27: 17:51. Susitna; slight.

April 29: —:—. Susitna; "strong."

May 3: 18:10. Susitna; IV.

May 3: 18:36*. Instrumental epicenter 61° north, 148° west, about 125 miles northeast of Seward. Anchorage, VI. Broke windows and put some telephone lines out of commission; store goods jarred from shelves. People

left homes. "Strongest since April 26, 1933." Intensity V at Cordova, Kennecott, Long Lake, and McCarthy. Felt by many at Fairbanks, Homer, Kasilof, McKinley Park, Nenana, and Seward.

Recorded instrumentally at many stations.

May 3: 22:10. Anchorage; slight.
May 3: 23:00. Cordova; slight.
May 3: 23:30. Homer and Seward; strong.
May 4: 1:15. Anchorage, sharp; lasted 15 seconds. Local shock recorded at Sitka at 1:11.
May 4: 2:00. Cordova; slight.
May 4: 3:15. Anchorage; slight.
May 5: 2:35. Anchorage; awakened sleepers; lasted 45 seconds, Also felt at Cordova.
May 13: 15:17. Anchorage; slight.
May 13: 23:54. Anchorage; slight.
May 14: 6:43 Anchorage; slight.
May 14: 10:16. Kodiak and Afognak, IV. Felt by all but not strong. Felt slightly at Homer.
May 14: 12:13.* Kodiak, VI. Kodiak and Whale Island rocked severely. Everyone ran outdoors in Kodiak fearing buildings might collapse; merchandise fell from shelves; plaster cracked; landslide about a mile from Kodiak blocked about 60 feet of road. Shock said to have been worst since 1900. Probably almost as severe at Afognak and Whale Island.

Intensity V at Kanatak and Seward. Also felt at Anchorage, Homer, and Susitna.

Recorded at many seismograph stations; instrumental epicenter 58° north, 153° west.
May 15: 3:57. Afognak and Whale Island; slight.
May 15: 7:05. Kodiak, IV. Slight at Afognak.
May 15: 12:—. Kodiak and Seward, V. Toppled merchandise.
May 15: 13:40. Kodiak and Afognak; felt by many.
May 26: 12:32. Kodiak; two shocks felt by many. Recorded at Sitka.
May 29: 1:19. Anchorage and Susitna; slight.
May 30: 12:49. Anchorage and Susitna; slight.
June 2: 6:45*. Anchorage; fairly strong, lasted 20 seconds. Also felt at Seward. Widely recorded. Epicenter approximately 60° north, 152° west.
June 3: 20:10. Anchorage; slight.
June 11: 14:35. Seward; slight.
June 15: 9:30. Seward; slight.
June 17: 13:15. Anchorage; slight.
June 17: 22:40. Kodiak, III.
June 17: 23:14.* Anchorage, V. Frightened many; broke plate glass; knocked over light objects. Probably of same intensity at Seward. Lake Kenai, 8 miles north of Seward, was reported to have been covered with a film of sulphur. Felt also at Afognak, Homer, and Valdez. Instrumental epicenter 60.5° north, 150° west.
June 18: 5:00. Valdez; slight.
June 18: 19:55. Kodiak, IV. Also felt at Afognak and Whale Island.
June 18: 23:00. Kasilof, IV.
June 19: 5:45. Kodiak, IV.
July 14: 13:12. Anchorage; slight.
July 15: 19:25. Anchorage: slight.
July 19: 15:57.* Juneau, IV. Moved small objects. Also felt at Taku Inlet. Recorded on the seismograph at Sitka.
August 1: 21:13. Anchorage, V. Overturned small objects; broke dishes. Intensity IV at Seward and Susitna where radio reception was interfered with for a time. Instrumental epicenter 62° north, 148° west.
August 1: 21:37. Matanuska; moderate shock.
August 1: 22:00. Kennecott; slight.
August 17: 22:00. Seward; slight.
August 24: 12:45. Anchorage, IV. Matanuska, III.
September 15: 2:00. Matanuska; slight.
September 22: 2:05. Seward and Matanuska; slight.
October 3: 16:05. Susitna; slight.
October 6: 8:07. Susitna; slight.
October 10: 16:23. Fairbanks, IV.
October 14: 15:55. Seward; slight.

October 17: 16:20. College; slight.
October 27: 15:19. Anchorage; slight.
October 28: 12:04. Seward; slight.
October 28: 14:05. Anchorage; slight.
November 3: 6:00. Kobuk, IV.
November 6: 14:14. Anchorage; slight.
November 9: 6:40. Seward, IV. Felt also at Anchorage and Homer.
November 9: 8:40. Seward.
November 9: 9:41. Seward.
November 10: 10:10. Anchorage; slight.
November 11: 13:35. Seward, IV. Felt also at Anchorage and Homer. Not felt at Kennecott.
November 12: 13:45. Susitna; slight.
November 20: 0:30. Seward; slight.
November 22: 8:30. Anchorage; slight.
November 22: 8:50. Susitna; slight.
November 28: 7:13. Juneau, IV.
November 28: 19:13.* Gustavus, V. Recorded on seismographs at Sitka and elsewhere.
November 29: 15:35. Juneau, III. Felt also at Gustavus.
November 29: 17:00. Juneau, III.
December 18: 17:00. Haines; slight.
December 20: —:—. Matanuska; slight.
December 21: 14:10. Anchorage and Homer; slight.
December 22: —:—. Matanuska; slight.
December 28: —:—. Susitna; slight.
December 29: 1:—. Homer, III.
December 29: 2:20. Anchorage and Homer; slight.
December 29: 8:50. Homer, III.

HAWAIIAN ISLANDS

[157½th meridian (west) time]

NOTE.—In the case of these islands with their many earthquakes of volcanic origin, only the more severe ones are listed. Reports of the Volcano Research Laboratory under the jurisdiction of the United States Geological Survey and the Hawaiian Research Association give all details. The epicenters of seventy-five local shocks have been published by A. E. Jones in the Journal of the Washington Academy of Sciences, volume 25, no. 10, October 15, 1935.

May 10: 10:09 *. Moderate shock felt on the eastern side of Hawaii. Strongest near Hakalau, where residents ran from buildings. Strong also at Hilo, Honomu, North Kohala, and Honokaa, moderate at Hookena and Kapapala, and weak at Holualoa and Puuwaawaa. The location determined instrumentally by the U. S. Geological Survey is at a depth of 17 miles under the northeast section of Mauna Loa, at latitude 19°38′ north, longitude 155°23′ west.
September 6: 2:00. Weak tremors followed by eruption of Kilauea volcano. Further slight shocks continued for some weeks.

PHILIPPINE ISLANDS

[120th meridian (east) time]

January 29: 13:30.* Daet Camarines Norte. Intensity VI, duration 3 seconds.
February 14: 12:00.* Strong earthquake in the China Sea felt throughout all of Luzon except the southeast peninsula. Felt also in Formosa and Hong Kong. Epicenter 17°20′ north, 119°25′ east, according to Manila. The shock did some minor damage on land and ruptured a cable at sea. Small tidal wave at San Sebastian.
June 6: 17:44.* VII at Borongan, Samar; duration 8 seconds.
November 26: 20:10.* Lubang Island, intensity VI. Strong also at Manila, where numerous bamboo dwellings were wrecked and a few downtown buildings damaged. Epicenter 14°10′ north, 120°10′ east, according to Manila.
November 27: 15:48.* VI at Tacloban and IV–V at Guinan. Epicenter 11°05′ north, 125°05′ east, according to Manila.

PUERTO RICO

[60th meridian time]

August 2: 3:41.* Awakened several families and caused some alarm at San Juan. At Caguas the shock was strong but caused no damage.

PANAMA CANAL ZONE

[75th meridian time]

March 28: 11:32.* Balboa. Felt by a very few people.

July 17: 20:30.* A destructive shock originating about 20 miles off the coast of Chiriquí Province, Panama, in the Bay of David, an arm of the Pacific. Maximum intensity on shore, about VII. Epicenter 8.0° north, 82.5° west. Between July 17 and August 17, 114 shocks were recorded on the seismographs at Balboa Heights, about 200 miles away. Banana conveyors on pier at Puerto Armuelles jumped their tracks and were badly twisted but no well-built structures in the town were badly damaged. Many persons, however, spent the night outside. The well pipe of tide gage on pier at Puerto Armuelles was carried away. At David the damage was estimated at $50,000. Walls crumbled, and iron and tile roofs caved in. Nearly every house in the city was at least cracked. Apparatus was removed from the National Telegraph office. Four persons were injured in the collapse of several adobe houses. One person at Fort Davis, Canal Zone, was killed in a leap from a third-story window. The foundation of a triangulation tower near Balsa Point shifted about one-half inch down hill. The main shock and several aftershocks were strongly felt by ships anchored offshore in the epicentral region. There were no seismic sea waves.

This shock was recorded on the strong-motion seismograph at the Balboa Heights observatory.

For a more detailed account of this series of shocks see extracts on page 51 taken from an unpublished report of R. Z. Kirkpatrick, chief of surveys, the Panama Canal.

July 17: 23:01.* Aftershock. IV at Balboa.

July 18: 8:00 to 10:03. Balboa. Several shocks noticed.

July 18: 11:10.* Aftershock. III at Balboa.

July 18: 12:00.* Aftershock. IV to V at Balboa. Actuated strong-motion seismograph at Balboa Heights.

July 18: 12:56,* 21:21,* 22:26,* 23:03.* Aftershocks felt faintly at Balboa.

July 19: 11:28,* 19:56.* Aftershocks felt faintly at Balboa.

July 21: 5:39.* The most destructive shock of the Chiriqui Province earthquakes. Epicenter practically the same as for the shock of July 17, 8°.0 north, 82°.5 west. Maximum intensity on shore about VIII. At Puerto Armuelles a 400-foot length of the deep-water section of the Government pier collapsed and sank into the sea, taking with it three banana conveyors valued at $250,000. Seventeen houses and a large water tank, the main water supply of the town, were destroyed, but there was no serious injury. Some cracks appeared in the ground and there was evidence that water had flowed from them. Two mooring buoys near the dock shifted about 1,000 feet, believed to have been due to shifting of sediments on the sea floor, but there was no indication of a seismic sea wave nor was there any material settlement of the sea bottom. At Balsa Point the foundation of the triangulation station mentioned in the shock of July 17 was found to have shifted about 3 inches down hill. The damage due to this shock at Puerto Armuelles and David was estimated at $750,000. Details of the effects of the second strong shock at David are scarce but it appears that many structures weakened by the previous shocks collapsed entirely. There was no loss of life as practically the entire population was living outdoors.

For a more detailed account of the shock see page 51.

July 21: 8:19.* Aftershock felt faintly at Balboa.

July 23: 9:02.* Aftershock felt faintly at Balboa. Some damaged homes in David City were leveled and two telegraph lines between David City and Puerto Armuelles were put out of commission.

August 10: 9:27.* Aftershock felt with intensity IV at Balboa. Actuated strong-motion seismograph at Balboa Heights.

November 9: 11:12.* Aftershock felt generally throughout Panama.

MISCELLANEOUS ACTIVITIES

GEODETIC WORK

EARTHQUAKE AND SETTLEMENT INVESTIGATION, 1934

During the year 1934, the following lines of levels were run for the purpose of earthquake investigation or detection of earth movements:

Releveling, Long Beach area, California. (In progress at the beginning of the year.)
Harbor City to Redondo Beach, Calif. (In progress at the beginning of the year.)
Playa del Rey to Los Angeles, Calif.
Azusa to Coldbrook Camp, Calif.
Oakland to Martinez, Calif.
Vicinity of Goleta, Calif.
Settlement investigation, vicinity of San Jose, Calif., spring 1934.
Settlement investigation, vicinity of San Jose, Calif., fall 1934.
Redlands to Victorville, Calif.
Releveling, vicinity of Kosmo, Utah.

Releveling, vicinity of Kosmo, Utah, is the only line which has been fitted to the first-order-level net and the results issued in mimeographed form.

Elevations only for the releveling, Long Beach area (item 1 above) are available in the form of blue-print copies of the manuscript list. Descriptions for all marks included, except new ones established during the releveling, are available in older mimeographed lists.

TIDAL OBSERVATIONS

No tidal disturbances of seismic origin were noted on the gages of the Bureau and cooperating stations during the year. Disturbances due to Chiriqui Province, Panama, earthquakes in July were recorded on gages of the Naval Hydrographic Survey in the epicentral region but they were more typical of seiches than true seismic sea waves.

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.

THE UTAH EARTHQUAKE OF MARCH 12, 1934

The descriptive material given here supplements that already given in the routine manner on page 13 of this publication. As already stated the following extracts are taken from an unpublished report prepared by Philip J. Shenon of the United States Geological Survey, who made a personal survey of the affected territory. Reference should also be made to the isoseismal map on page 14, which was prepared with Mr. Shenon's collaboration.

Rock slides.—"Several hundred tons of rock slid down the hillside just north of Monument Rock. Another slide is reported to have taken place near Snowville. Ralph W. Duval reports that rock fell from the face of the quarry cut at Aragonite, Utah. J. Frank Thomas reports that several hundred yards of rock and earth were shaken down from the face of the East Quarry, which is located at Lakeside, Utah."

Ground cracks.—"A number of ground cracks were developed in the epicentral area. Most of the cracks are in the salt flats, or in poorly consolidated gravel and related rocks that probably belong to the Lake Bonneville sediments. Some cracks were formed in consolidated rocks, for example in the quartzite of Monument Rock. The ground cracks which cut the poorly consolidated rocks have been traced for over 5 miles. No one of them is continuous for a great distance; rather, there is a tendency for the cracks to develop en échelon patterns. In most places there are several more or less parallel cracks. In general the cracks strike north or slightly east of north and all of those noted by the writer had nearly vertical dips. Four distinct fractures cross the road about 3 miles north of Kosmo. They are about one-half mile apart. The vertical displacement along the fractures ranges from 2 inches to about 10 inches. Except for one of the faults, the displacements have all been down on the east side. The west side dropped about 3 inches along the fault which crosses the road nearest to Kosmo. Prof. Reed Bailey reports a vertical displacement of 20 inches along one of the faults on the salt flats northeast of Kosmo. He states that this fault stood open in places for 18 inches, and that an increase in displacement of 5 inches was noted during a period of 1 week. No horizontal movement was noted, and, because opposite sides of the fracture match, it is believed that the movements were almost entirely vertical. See figure 8. This is borne out by an observation of Prof. F. J. Pack, who was one of the first to visit the epicentral area. He reports that old automobile tracks that had been cut into roads previous to the earthquake when the roads were muddy were not offset horizontally where faults crossed the road. One graben was noted on the flat about 3½ miles north of Kosmo. This graben is about 60 feet across, but was traced for only about 400 feet along the strike. The displacement on the west side is 8 inches, and on the east side about 5 inches. The dips on both sides of the graben are about vertical."

"No displacements could be seen in the fractures that cut bedrocks. Several open fractures cut Monument Rock, which is composed of quartzite. The quartzite has been greatly brecciated and

FIGURE 9.—Mud cones developed along fractures about one-eighth mile west of Kosmo. Utah earthquake.

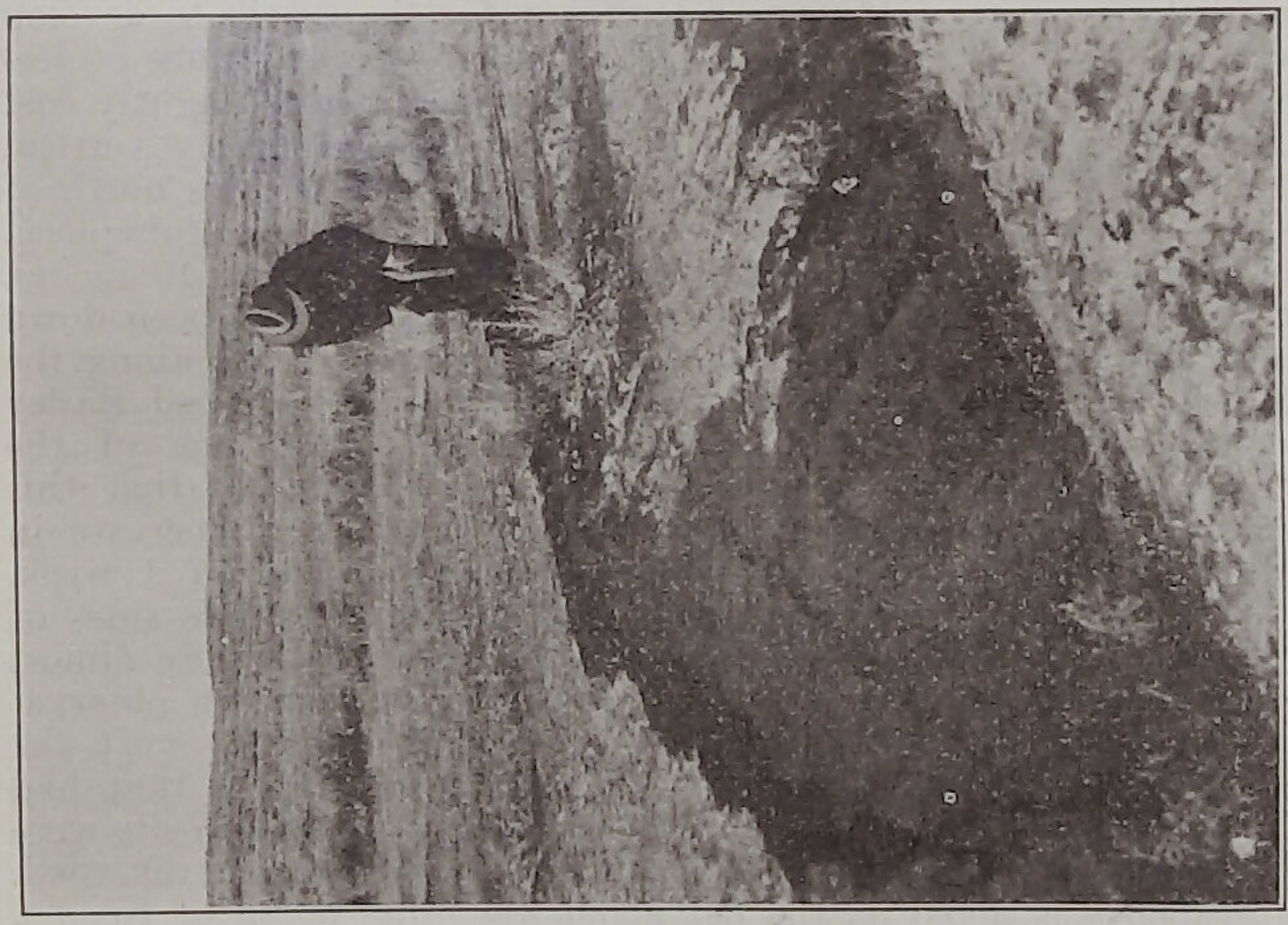

FIGURE 8.—Fault scarp north of Kosmo showing how opposite sides of scarp fit together. Utah earthquake.

recemented. Several inches of banded travertine occurs along one of the fractures which stands open for a distance of from 12 to 18 inches. This fracture strikes about north 20° east and has a ver-

tical dip. Large amounts of water flowed from the larger cracks after the earthquake."

Origin of the fractures.—"Hansel Valley is similar in appearance to many other valleys in Utah and Nevada that are commonly described as being of the Basin and Range type. Hansel Valley is several miles wide, trends north and south and is flanked by steep slopes on both east and west sides. The east front is particularly steep, whereas the steep appearance of the west front is somewhat subdued by the low gravel hills which lie in front of the range. Faceted spurs are characteristic of the mountain fronts."

"As previously stated, actual displacements were not noted in bedrock. The fractures noted in Monument Rock may have been opened by the oscillations attending the earthquake, or there may have been slight movements along the fractures. The origin of the faults in the poorly consolidated gravel and related rocks is not certain. They may be the surface expression of fault movements that occurred in the bedrocks below, or they may be secondary cracks caused by shaking and slumping. It should be pointed out, however, that the more persistent of the faults follow very closely the fronts of terraces. However, instead of following along the base of the terraces, as might be expected, as at "b" in figure 10, they follow close to the top, as at "a" in figure 10. This relationship between the faults

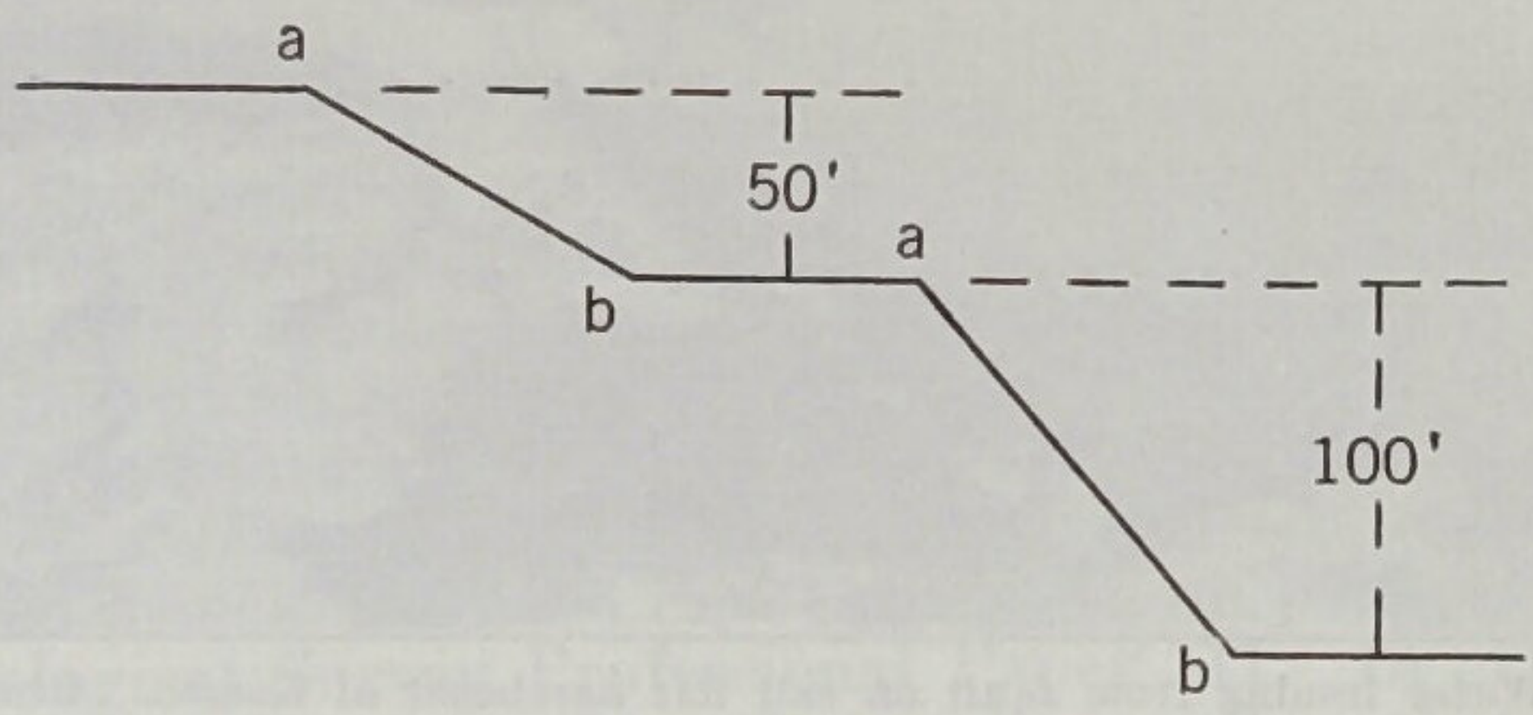

FIGURE 10.—Diagram showing relation between faults and terraces. Utah earthquake.

and the terraces is so consistent that it strongly suggests that the terraces are of fault origin and that the recent faults follow along surfaces of old displacements."

Springs and wells.—"Numerous springs developed in the epicentral area as a result of the earthquake. So far as known, all of the springs rose along well-defined fractures and most of them formed in the salt flats. The springs in Monument Rock are the notable exceptions. Individual centers of flow developed along some fractures and, because the water carried considerable sediment, mud cones were built up where the flows came to the surface. See figure 11. At other places water did not tend to flow out at localized points, but rather flowed out in about equal volume for some distance along certain fissures as in figure 11. Considerable water flowed from the fractures that cut Monument Rock. Previous to the earthquake, water did not flow from these fractures. All of the water flowing from the springs had a strong salty taste. This would be expected because the water flowed through salt beds.

"Most of the fractures from which water flowed trend northerly. The principal exception is the fracture about 200 feet south of Kosmo which trends north 70° west and has a nearly vertical dip. This fracture is situated at the edge of a terrace about 6 feet high.

"In places large holes formed around the springs due to cavings of the soft material through which the water flowed. Two such holes were formed in the salt flats immediately northeast of Monument Rock. These holes had diameters of from 8 to 10 feet on March 16, 1934, and about one-half second-foot of water was flowing from one of them. Less water flowed from the other. Prof. Reed Bailey states that one of these holes was 37 feet deep.

FIGURE 11.—Water issuing from fault on salt flat northeast of Kosmo. Utah earthquake.

"In addition to the springs, water flowed from an old well near Kosmo immediately after the first disturbance. The well is said to be 350 feet deep. Casing projects above the ground for about 1 foot. On March 16 water was not flowing from the well, but considerable wet mud around it showed that it had flowed a short time before.

"The springs have formed largely in loosely consolidated material along the old shore line of Great Salt Lake and hence the material is probably well saturated with water. It is believed that settling and slumping of this material as the result of the earthquake forced the water to the surface along the fractures.

"An observation by Professor Pack indicates that the water in some places must at first have been forced from the ground under considerable pressure. He reports that he found pieces of sod some distance away from old seeps from which they clearly had come.

"Airway officials at Locomotive Springs Landing Field report that Locomotive Springs dried up at first and then flowed red water for 8 hours. They report that the spring probably increased its

flow 30 percent after the earthquake. George H. Taylor reports that automatic gages on all wells in the Salt Lake and Ogden districts were noticeably affected. The effects apparently different in the various wells. For example, one well at Ogden quit flowing at first, and then started spurting. Water level in another well rose about 9 inches, and remained there. One pressure recorder in Ogden showed a maximum fluctuation of 12 feet, 7 feet of which was represented by increased pressure."

Oil seeps.—"It was reported that oil seeps about 10 miles south of Promontory Rock were greatly increased. However, E. G. Lawson, who visited the seeps, reports that no particular changes were noted."

Nature of motion and sounds.—Mr. Shenon states that reports varied greatly concerning the direction of the ground motion. (Students of earthquake phenomena are generally agreed that motion in any one direction is not to be expected.) In the epicentral region it was reported as a bumping motion. A farmer near Kosmo stated that movements in his pasture resembled waves on water. Many reported sounds of a roaring, rumbling, thunderous nature like the passing of a train and a few as far away as Salt Lake City reported hearing them. Reports on the duration of the shock varied greatly around an average value of about 30 seconds.

Isoseismal map.—With reference to the most prominent feature of the isoseismal map, Mr. Shenon writes as follows: "The isoseismals show a striking irregularity at the southeast and a less pronounced irregularity at the northeast. On the southeast the isoseismals are crowded inward within an area that follows very closely the trend of the Uinta Mountains. Apparently this group of mountains, which represent a domed uplift, acted as a buttress to the earthquake vibrations."

Causes of the earthquake.—"Utah is traversed by many large faults. The principal known ones are shown on plate 14 of United States Geological Survey Professional Paper 111. In general these faults define the large north-south trending valleys that characterize the western half of the State. The fault fronts in general are steep and show many faceted spurs.

"The map referred to above does not show faults bordering Hansel Valley. However, detailed work in this region would probably show the presence of faults on both sides of the valley. The valley sides have the same type of steep fronts and faceted spurs that are so well developed elsewhere in Utah along known faults.

"A number of faults in Utah are known to have been active in comparatively recent times. For example, the Wasatch fault near Salt Lake cuts and displaces glacial moraine of probable Pleistocene age at the mouth of Little Cottonwood Canyon. After the earthquake near Beaver, in 1901, observers state that large cracks were opened in the ground, but do not indicate the cracks showed displacements.

"All of the fractures showing displacements near Kosmo which developed during the recent earthquake were in gravel or related rocks. Hence, it cannot be definitely stated that the fractures were not formed by slumping and settling as a result of the earthquake

vibrations. However, as previously stated, the close association of the fractures with terraced forms and lines of old springs strongly suggests that the recent displacements followed along old surfaces of movement. This, in turn, suggests that the fractures may have been caused by adjustments in the bedrocks below, and that the faults that define Hansel Valley are still active, and that the recent earthquake was caused primarily by movements along these faults. This is borne out by the seismic record of the vicinity which shows that it has been an active center for earthquakes for many years."

THE PARKFIELD, CALIF., EARTHQUAKES OF JUNE 7, 1934

The following extracts are taken from an unpublished report on the shocks by Graham B. Moody, of the Standard Oil Co., who made a survey of the epicentral area between June 26 and 30, inclusive. The Standard Oil Co. has kindly consented to permit publication of this material, which is of inestimable value to the seismologist and others interested in such investigations. Without it, information concerning effects in the epicentral area would be practically negligible.

In addition to this report, attention is called to an investigation of the shocks by Byerly and Wilson, of the University of California (see footnote reference, p. 25) and to the data in this publication on pages 24 to 27.

The following extracts are from Mr. Moody's report, omissions not being indicated.

Introduction.—"A field examination was made from June 26 to 30, inclusive. Numerous people were interviewed at various localities (from Bakersfield to Coalinga to Priest Valley to Cholame to Paso Robles to Ventura) in order to obtain 'eyewitness' versions of the earthquake. The country between Priest Valley and Cholame along the San Andreas Fault Zone was examined for indications of surface displacement at the time of the earthquake."

Geology of the area.—"Northwest-southeast trending faults split the region into long, comparatively narrow blocks and slivers. The topography has been greatly affected by movement and subsequent erosion along the faults."

"The San Andreas fault zone is of greatest interest because it is along it that the most recent movements have occurred. This zone varies somewhat in this area but is about 2 or 2½ miles in width. It is composed of several en échelon faults. Maximum displacement has not occurred along any one fault but steps from one fault to another in proceeding along the zone.

"Kew reports that he observed from the air a northwest-southeast trending fault which passes through the southwest corner of the fence at Cholame Ranch. This area is covered by valley fill. The fault cannot be mapped from surface evidence. It is in the San Andreas zone and is a probable locus of earthquake epicenters."

The earthquake.—"Foreshocks. The first foreshock occurred on June 5 at 3:47 a. m., and the last one on June 7 at 8:31 p. m. A complete list of the foreshocks follows:

Date	Time	Magnitude
June 5	3:47 a. m.	3
	5:47 a. m.	3
	1:49 p. m.	5
	2:53 p. m.	4
	4:56 p. m.	3
June 6	8:40 a. m.	2.5
	2:40 p. m.	3.5
June 7	8:31 p. m.	5

"The figures under 'Magnitude' designate the relative destructive capacities of the shocks. The magnitude scale has been developed by Wood and Richter from a long study of the effects of shocks of varying intensities at varying distances on the instruments at Pasadena and other seismological stations."

The Wood-Richter "magnitude" scale is described in the Bulletin of the Seismological Society of America, volume 25, no. 1, pages 1 to 32.

"The Parkfield earthquake, in comparison to other California earthquakes, had an unusually large number of foreshocks. The Long Beach earthquake, for example, had only one foreshock. None of the Parkfield foreshocks caused any damage but did create a great deal of alarm. The two heaviest ones occurred at 1:49 p. m. June 5 and at 8:31 p. m. June 7, and were felt strongly at San Luis Obispo, Kettleman City, and other distant points.

"Major shocks. The major shock occurred on June 7 at 8:48 p.m., 17 minutes after the last foreshock. This shock had a magnitude of 6 on the Wood-Richter scale. The intensity was high in grade VIII, Rossi-Forrel scale. It was only slightly less intense than the Long Beach earthquake of March 10, 1933.

"The Parkfield area is thinly populated. Most of the houses are old wood-frame structures built low on the ground and are capable of withstanding severe vibration without suffering great damage. Not one of these buildings was seriously injured except for broken chimneys. A 'modern' house constructed of hollow cement blocks had its walls shaken out. Brick chimneys were snapped off at the roof lines of all houses located a distance of about 5 miles northwest and southeast of Parkfield. The only building situated more than 5 miles from Parkfield to suffer damage was the fire-observation cottage on Smith Mountain, 16 miles northwesterly from Parkfield. This house was moved slightly on its foundation and its door and window openings were twisted out of square. Highway bridges as far as 2 miles northwest and southeast of Parkfield were moved slightly on their footings. The approach to the bridge on the Coalinga road, about 2.8 miles northwest of Parkfield, caved in about a foot due to settling of the filled ground.

"The most interesting results of the earthquake were observed on Middle Mountain, northwest of Parkfield. Two zones of cracks were developed in the soil on the northeast and southwest edges of the crest of Middle Mountain for a distance of about 2 miles northwest of Parkfield. These zones paralleled and were close to the surface traces of two faults in the San Andreas zone. The zones of cracks were about 25 feet wide. The individual cracks were arranged en

échelon. The largest single crack was about 55 feet long, 9 inches wide, and 18 inches deep. There was no evidence that the cracks penetrated into the underlying sandstones and shales, nor of vertical or horizontal displacement along the cracks. Heavier shaking would have started extensive landslides along the northeast and southwest sides of the mountain.

"The soil on top of Middle Mountain is residual. The cracks cannot be attributed to settling but should be considered as incipient fault trace phenomena. It is probable that they indicate a condition closely approaching actual surficial displacement on June 7 along the San Andreas zone.

"Several dead pine trees about 13 inches in diameter were snapped off on Middle Mountain, about 1 to 1½ miles northwest of Parkfield. These trees had not rotted through but had hard centers. The breaks occurred about 2 feet above the ground. They were fresh breaks and were caused almost certainly by the severe shaking at the time of the earthquake.

"There were no casualties resulting from the earthquake. The people in Parkfield, nearest the epicenter, were gathered in an old wood frame building, celebrating the closing of school for the year. The major shock was over before they could get out of the building to be hit by bricks from the falling chimney. It was fortunate that an earthquake of this magnitude centered in a thinly populated region where the houses were built of wood instead of unit masonry. The small property damage and lack of injury to persons in comparison to the damage and deaths during the Long Beach earthquake suggest that the latter shock was much stronger than the Parkfield earthquake. The two earthquakes were, however, of about the same magnitude."

Epicenter.—"The distribution of damage as outlined in the preceding paragraphs and the occurrence of incipient fault trace phenomena and broken trees on Middle Mountain northwest of Park field, fix the epicenter quite definitely on the San Andreas fault about 1½ miles northwest of Parkfield. The epicentral area may be considered to extend about 7 miles northwest and about 5 miles southeast of Parkfield. The northeast and southwest extension of the epicentral area cannot be determined as satisfactorily due to lack of dwellings in those directions. It seems probable that the epicentral area was elongated parallel to the San Andreas fault. Movement at depth may have occurred for a considerable distance along the fault."

Aftershocks.—"The major shock was followed by a large number of aftershocks. None of these was strong enough to cause damage. A list of the aftershocks of magnitude 4 or greater follows:

Date	Time	Magnitude
June 7	9:43 p. m	4.5
June 8	1:30 a. m	4
	3:23 p. m	4
June 10	0:03 a. m	4.5
June 14	6:55 a. m	4
	7:45 a. m	4
	11:26 a. m	4.5

THE PANAMA EARTHQUAKES OF JULY AND AUGUST, 1934

In addition to the usual information given on page 41, a large quantity of interesting material has been made available in a special unpublished report prepared by R. Z. Kirkpatrick, chief of surveys, The Panama Canal. The Bureau is enabled to quote here some of the more important parts of that report through the courtesy of The Panama Canal authorities. An unusually valuable account of the shocks and their effects on structures in the epicentral area was prepared by Henry W. Bigelow, Jr., a junior cartographic engineer of the United States Naval Hydrographic Survey, who was on duty in the area at the time of the heaviest shocks. Mr. Bigelow's account appears as a part of Mr. Kirkpatrick's report.

The report begins as follows, with emphasis on observations in the Canal Zone rather than in the epicentral region, some 200 miles away, where most of the damage was done.

"In the month between July 17 and August 17, 1934, the Republic of Panama and the Canal Zone had an unusual series of earthquakes, 114 shocks being instrumentally recorded at Balboa Heights, Canal Zone. There were but 78 in the calendar year of 1933; 5 of these were generally felt by Canal Zone populace, and are rated as intensity IV to V, modified Mercalli scale as follows:

I.	On July 18 at	1h 36m 16s	(Greenwich time), intensity V
	or July 17 at	8h 36m 16s	pm (local time).
II.	On July 18 at	4h 01m 32s	(Greenwich time), intensity IV
	or July 17 at	11h 01m 32s	pm (local time).
II.	(a) On July 18 at	17h 00m 29s	(Greenwich time), intensity IV to V
	or	12h 00m 29s	pm (local time).
III.	On July 21 at	10h 40m 06s	(Greenwich time), intensity IV
	or	5h 40m 06s	am (local time).
IV.	On August 10 at	14h 27m 08s	(Greenwich time), intensity IV
	or	9h 27m 08s	am (local time).

Shock effects as reported by observers.—"During July 17, 1934, the United States naval houseboat *No. 1*, attached to the U. S. S. *Nokomis*, was anchored near the northeast end of Parida Island (about 20 miles from the epicenter). The U. S. S. *Hannibal*, the other Naval Hydrographic Survey ship, was farther easterly from the epicenter; also S. S. *Point Sur* and S. S. *Tuscaloosa City*, off Burica Point and Montuoso Islands, respectively, reported to this office by radio having felt heavy shocks at sea."

"The 1,000-foot movement of the buoys in the harbor seems to indicate a tidal wave of the translatory type though he (Cartographer Bigelow) says 'at no time was there the slightest indication of a tidal wave'; his idea of a mud slide about the anchors is likely correct."

"Mr. Devine, engineer in charge of the survey work on the U. S. S. *Hannibal*, reports a crack formed through the long axis of the island of Montuosa about 2 feet to 3 feet wide and 20 feet deep; it is adjacent to one of their triangulation towers. Mr. Devine furnished drawings of tide curves for Bahia Honda for July 17 and 18, 1934, showing definite seiches there during the earthquake. Montuosa and the Ladrones Islands are close to and easterly of the lanes of shipping between Balboa and points on the Pacific coast."

Under the caption, Lessons to the Canal Zone, Mr. Kirkpatrick concludes his part of the report with some of the following pertinent statements:

"(*a*) Virtually no Canal Zone major structure would have seriously suffered from shocks like those at Puerto Armuelles and David, i. e., intensity VII to VIII. However, there would have been some broken plaster, mirrors and dishes, stopping of clocks, cracked and broken curtain walls and maladjustments in machinery and equipment; some cables, sewers and water lines would be broken; in Panama and Colon, probably considerable structural damage would occur.

"(*b*) Buildings, particularly if tall, should not be close to escarpments or over water fronts, especially with relatively fragile and high supports.

"(*c*) Attention is here directed to the need for cross bracing the long underpinnings which are always necessary in houses built on hillsides, and in designing the concrete bases to prevent slipping off of the underpinnings."

In a final statement caution is urged in the practice of removing bracing beneath residences to make way for garages. Substitutes should be found other than that of cross bracing the outside lines of support posts which alone is not sufficient.

The following quotations are from Mr. Bigelow's report which appears as an appendix to Mr. Kirkpatrick's report:

"At the time of the first quake, 20:38, July 17, 1934, I was on board the U. S. Navy *Houseboat No. 1*, attached to the U. S. S. *Nokomis*, and anchored near the northeast end of Parida Island, Republic de Panama.

"The sensation was of a series of pounding shocks on the bottom of the vessel, such as would be made if the vessel were pounding on the rocks. We felt another quake at 23:00, and a third at 23:30, but these were not as severe. Several days later, two or three landslides were observed on Parida Island which must have occurred at this time. The natives were much frightened, and left the island. The next day I joined the ship (U. S. S. *Nokomis*) off Armuelles. The ship had been anchored off Balsa Point, about 10 miles south of Armuelles the night before, and had had much the same experience that we had had.

"My knowledge of what happened at Armuelles is largely second hand, but I talked with many people who were on the beach at the time and all accounts seem to indicate a shock of an intensity between six and seven. It was specifically mentioned by many people that the light fixtures, suspended on long cords, about 3 feet long, swung wildly, in some cases striking the overhead with sufficient force to cause them to ring. It was also reported that the big electric fans in the clubhouse, suspended on piping from the overhead, were swinging wildly. At the end of the dock there was a piece of railroad iron, about an 80-pound rail, I should judge, which supported a locomotive headlight to serve as the dock beacon. After the quake, this rail was bent in a curve, to approximately an angle of about 45° from the vertical. The four heavy banana conveyors on the dock had all jumped from their rails, and were rather badly bent, and twisted. None of the well built structures in the town was

badly damaged, but the people were badly frightened, and many of them spent the night outside.

"Mr. Ullom, one of the engineers on the *Nokomis*, occupied one of our triangulation towers near Balsa Point the next day, and reported almost continual tremors. He also reported that the tower foundations had shifted about half an inch down hill (eastward) away from the earth. Nothing of any moment was reported for the next couple of days, though many minor tremors kept everybody stirred up. I had a tide gage in operation on the dock at Armuelles, and carried records up to about 20:40 on the 17th. The quake carried away the well pipe of the gage, and, while observations were made until the morning of the 21st, the float was in the open sea, and no definite record of the quakes could be obtained from it.

"On the morning of the 21st I was asleep in my room on the *Nokomis*, when I was awakened by a heavy pounding. I realized at once that it was another quake—looked at my watch, which showed 05:40, and ran to the port. I was just in time to see the lights on the dock go out, and to hear a low groaning and rumbling. This must have been when the dock collapsed. I went ashore at about 07:40. The outer three-eighths of the dock was entirely missing, except for the buffer piles, which were not attached to the dock proper, and which were still standing. Three of the banana conveyors were gone. As we came up to the dock, another quake occurred, though we could not feel it in the launch. The remaining conveyor swayed wildly, and seemed about to topple over, and the people on the dock ran wildly for the shore, some of them screaming—though I am not sure of this.

"We landed and looked around the town. There seemed to be very little damage in the native village, but in the company town quite a few of the quarters were down. One house, that of the manager, Mr. Blair, was a total wreck. The construction of these houses is much like that in the Canal Zone, frame houses on wooden pilings, the piles standing on concrete blocks. Quite a few of the houses had slid off the piles, and were resting on the ground, and in some cases they were rather badly damaged in the process—though several were still quite habitable. The clubhouse was in a peculiar position, one end being on the ground and the other still on the piles, and although the building was badly racked, it remained intact. The water tank some hundred yards up the railroad from the dock had collapsed almost exactly in place, and blocked the main line, and had carried away the telephone and telegraph lines. The water and sewerage mains were broken, as was the oil line in the dock. These had been broken in the first quake and repaired in the interval. I could not undertake to say how many houses had been damaged, but most of them had been pretty well racked, and at least a dozen were on the ground. The administration building, also a frame building on piling, but which had a concrete vault in the rear, seemed to be entirely untouched. The hospital, which was built down to the ground, seemed to be in excellent shape, although I understand that it had been rather badly racked. I would say that those houses which were well built had stood, and that the others, which had fallen, were of poorer construction. That, however, is merely an opinion. A number of the houses rested at

an alarming angle, and seemed ready to topple over at any moment, though the last that I heard, August 4, they were still standing.

"In the native village there were several cracks in the ground, about an inch wide and a foot or two deep, and there were several places that looked like geysers—that is where underground water had spouted up out of the ground. It would appear that the dock collapsed more or less in place, and by sections, the outboard section first, and so on, to the section just before the middle of the dock—

FIGURE 12.—Wrecked water tank. Puerto Armuelles yard. Panama earthquake.

FIGURE 13.—Railroad track shifted out of alinement at Puerto Armuelles. Panama earthquake.

where the dock bends. From later inspection, it was seen that the outboard section of the remaining dock had slid about 5 feet to the southward—the dock floor remaining more or less level, but the piers being canted about 5 feet out of plumb. The inshore section was canted about the same amount to the northward, while the center of the remaining portion remained about in place.

"There were two big mooring buoys just off the northern side of the dock and these were found to have shifted about 1,000 feet seaward—that is, a little south of east—maintaining their relative positions as to distance and alignment. One of our launches had been moored to one of these buoys and at the time of the quake

they reported that the buoy had spun around violently and that something below the water seemed to be dragging it seaward. There was at no time the slightest indication of a tidal wave. However, the tides were the highest that I have ever seen them, during a period when they should have been rather lower than usual. The seaward row of houses in the native village was washed out completely, and the main street of the village was under water several times. This was after the main quake was over.

"Two parties from the *Nokomis* made check surveys of the vicinity of the dock, but were unable to discover any indication of a change in depth. The buoys were located in water varying from 20 fathoms at the inshore buoy to 45 at the outboard buoy—and it is possible that the layer of soft mud, about 6 to 7 feet in depth, which overlies the stiff blue clay of the vicinity, might have slid bodily seaward, carrying the anchors of the buoys with it. It is doubtful if we would have been able to discover this fact in our check soundings, as this area is really beyond the range of our hand leadlines.

"Some days after the last serious quake I occupied our triangulation station at Limones, near Balsa Point, and found that the foundations appeared to have slid about 3 inches downhill away from the ground around them. There were several considerable cracks in the ground, all of them about an inch and a half to two inches wide, and a foot or more deep; they seemed to extend in a general SW.–NE. direction. The cracks noticed in the native village at Puerto Armuelles extended in a generally east and west direction. I would estimate that the quake on the morning of the 21st was of an intensity of from seven to eight. It was by far the most serious of the lot. Not alone from the damage done, which was considerable, but from the general effect brought about. The inhabitants of the town were all pretty well frightened, and several pretty well unnerved. The native population was badly frightened, but remained quiet, and lived out of doors for the next week. Nearly all the people in the town spent Saturday night out of doors, most of them in tents supplied by the Army, and by the *Nokomis*. Most of the people whose houses were not badly damaged were back in them by the 26th, but there were quite a few people still living in tents on the 4th of August. There were minor tremors off and on nearly every day and seemed to be gradually dying out the last that I heard, the 4th of August.

"There are one or two points remaining—the track at the end of the dock was bent in the shape of a broken down Z; it looked as though the track had been snapped. Further, I am told that the sensation on the beach was of a sharp, lateral motion, not at all the pounding sensation experienced on the ship. I also heard several statements expressing astonishment at the small amount of breakage to china and glassware in the several houses."

Additional information in Mr. Kirkpatrick's report indicates that there is good evidence that cracks appeared in the mountains near a place called Bongo, a farm of the Chiriqui Land Co. The crack was about 6 inches wide and quite long, evidently extending across the border into Nicaragua. Rains were quickly obliterating it.

An interesting sidelight on the 8:30 a. m. shock of July 21 concerning the visibility of ground waves at Puerto Armuelles is sub-

stantiated by two persons. L. Moreno A. states, "It shook so strongly as to cause the ground to roll in swells, making it difficult to keep one's balance; it impressed me that the direction of the ground swells was from the open sea toward the land; it shook the telegraph poles violently, and visibly." H. Peterson states: "While standing out on the lawn in front of the house another good shake was felt. The land rolled before me like so many ocean waves. Telephone poles shook like so many trees in a stiff wind. This was sufficiently strong to wobble all of us who were on the lawn."

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. In the summary of epicenters in this report attempts are sometimes made to improve epicenters already published, especially in the case of those in North America.

Instrumental results are published for the following observatories:

Balboa, Canal Zone (The Panama Canal).
Bozeman, Mont. (Montana State College).
Charlottesville, Va. (University of Virginia).
Chicago, Ill. (University of Chicago and U. S. Weather Bureau).
Columbia, S. C. (University of South Carolina).
Des Moines, Iowa. (Private station, M. M. Seeburger, Director).
Honolulu, T. H. (University of Hawaii).
Huancayo, Peru (Carnegie Institution of Washington).
Montezuma, Chile (Smithsonian Institution).
Philadelphia, Pa. (Franklin Institute).
Pittsburgh, Pa. (University of Pittsburgh).
San Juan, P. R.
Seattle, Wash. (University of Washington).
Sitka, Alaska.
Technology, Maine (Massachusetts Institute of Technology).
Tucson, Ariz.
Ukiah, Calif. (International Latitude Observatory).

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

In future issues of this serial the station at Technology will be known as East Machias.

TABLE 1.—*Summary of instrumental epicenters*

1934	Greenwich civil time at origin[1]	Region and focal depth	Coordinates of provisional epicenter	
			Lat.	Long.
	h. *m.*		°	°
Jan. 3	H- 9 45.5	West Kamchatka Peninsula. Depth 250 kilometers.	53.0 N.	156.0 E.
Jan. 11	O-10 21.8	South of Aleutian Islands. Probably normal depth.	48± N.	117± W.
Jan. 14	O-12 00.4	Off tip of Lower California	21± N.	110± W.
Jan. 15	O- 8 43.5	Ganges Valley, India	26.0 N.	85.5 E.
Jan. 19	O- 9 55.7	Off tip of Lower California	22± N.	109± W.
Jan. 28	H-19 10.1	Felt in state of Guerrero, Mexico. Depth normal	17 N.	108 W.

[1] O indicates time at epicenter: H time at focus.

TABLE 1.—*Summary of instrumental epicenters*—Continued

1934	Greenwich civil time at origin		Region and focal depth	Coordinates of provisional epicenter	
				Lat.	Long.
	h.	*m.*		°	°
Jan. 30	O-20	16.5	Western Nevada. Epicenter from field study by the U. S. Geological survey.	38 19′ N.	118 22′ W.
Jan. 31	O-10	06.6	Pacific Ocean, southwest of Samoa	16± S.	174± W.
Feb. 3	O-14	33.4	Pacific Ocean, northeast of New Guinea	5± S.	151± E.
Feb. 12	O- 6	43.0	Probable epicenter. Felt at Balboa, Panama	9± N.	84± W.
Feb. 14	O- 3	59.6	Coordinates and time at focus given in special report from Manila.	17 30′ N.	119 25′ E.
Do	O-22	18.2	Off Colima, Mexico. Depth probably normal	17± N.	106+ W.
Feb. 20	O- 3	18.8	Pacific Ocean, Southwest of Galapagos Islands	5± S.	103.5 W.
Feb. 24	H- 6	23.9	Pacific Ocean Southeast of Japan	23 N.	144 E.
Mar. 1	H-21	45.5	Felt in Chile. Depth about 160 kilometers	40 S.	73.5 W.
Mar. 4	O- 5	55.2	Near New Hebrides Islands	16± S.	167± E.
Mar. 5	O-11	46.0	Felt in New Zealand. Coordinates reported by Wellington.	41.0 S.	176.5 E.
Mar. 7	H-22	41.8	Near Honduras-Nicaragua boundary. Depth normal.	13.5 N.	87.5 W.
Mar. 12	O-15	05.8	Utah. Depth probably less than 80 kilometers	41.7 N.	112.8 W.
Do	H-18	20.2	Aftershock	41.7 N.	112.8 W.
Mar. 13	O-13	12.9	East of New Guinea, according to Wellington	12 S.	163 E.
Mar. 15	O-10	46.7	Felt in New Zealand. Coordinates according to Wellington.	39.6 S.	177.4 E.
Mar. 18	H- 4	33.3	Kamchatka. Depth uncertain	49.5 N.	156.0 E.
Mar. 20	O- 2	38.7	Near New Guinea	4± S.	149± E.
Mar. 22	O-22	47.7	Probably off west coast of Guatemala	14± N.	95± W.
Mar. 24	H-12	04.5	Near New Guinea. Depth normal	10.3 S.	161 E.
Apr. 6	H-19	09.6	Pacific east of Japan. Epicenter according to Tyosen.	37.3 N.	141.7 E.
Apr. 10	H-10	22.9	Java Sea	6 S.	116 E.
Apr. 11	H-21	11.9	Near New Hebrides Islands	19 S.	170 E.
Apr. 14	O-21	26.8	Utah. Felt	----------	----------
Apr. 15	H-22	15.1	South of Philippine Islands	7.5 N.	128.0 E.
Apr. 26	H- 5	31.7	North of New Zealand. Epicenter according to Manila.	23 S.	173 E.
Do	O- 7	56.6	North of New Zealand	23 S.	173 E.
Do	O-21	00.3	West of Fiji Islands	15 S.	167 E.
Apr. 27	H-20	46.9	Probably north of New Zealand	23 S.	173 E.
May 1	H- 7	05.1	Sumatra. Depth approximately 160 kilometers	4 N.	98 E.
May 3	O- 1	30.4	Bonin Island in western Pacific, according to Manila.	27.7 N.	145 E.
May 4	H- 4	36.1	Alaska, south oast	61 N.	148 W.
May 5	O-14	32.5	New Zealand. Epicenter according to Wellington	37 S.	175 W.
May 6	O- 8	09.7	Utah. Felt	41.7 N.	112.8 W.
May 13	H- 9	02.5	Solomon Islands About 240 kilometers	4 S.	154 E..
May 14	O-13	14.5	Off Lower California	29 N.	115 W
Do	H-22	12.9	Alaska, south coast	58 N.	153 W
May 19	H-10	47.7	Guatemala	14.9 N.	91.2 W
May 21	H-10	07.2	Arctic Ocean, east of Greenland	71.2 N.	5.1 W
May 22	H-11	01.6	Middle Atlantic Ocean	1 N.	30 W
May 24	O-11	46.5	Peru, probable epicenter	4 S.	73 W
June 2	H-13	42.6	Iceland	65.8 N.	18 W
Do	H-16	45.1	Alaska, south coast	60 N.	152 W.
June 8	O- 4	47.8	Near Parkfield, Calif. Felt. Coordinates according to Berkeley.	35 56′ N.	120 29′ W.
June 9	H-12	59.0	New Guinea. Depth, 200 kilometers	6 S.	148 E.
June 12	H- 9	32.3	Off Mexico, probable epicenter	14.5 N.	95.5 W.
June 13	H- 1	50.8	North of Japan	44 N.	147 E.
Do	H-22	10.4	Afghanistan	28.5 N.	63 E.
June 18	H- 9	13.8	South central Alaska	60.5 N.	150 W.
June 22	H-18	33.5	Off west coast of Mexico	17 N.	106 W.
June 24	H- 1	40.0	Pacific Ocean off Ecuador	1.5 S.	106 W.
Do	H- 5	59.6	Northern Chile	21.8 S.	69.2 W.
June 28	H- 0	56.1	Queen Charlotte Islandsi n South Pacific Ocean	11 S.	165 E.
June 29	H- 8	25.3	East of Borneo. Depth, 700 kilometers, according to St. Louis.	6.2 S.	123.3 E.
July 4	O- 1	42.8	South Atlantic. Approximate epicenter Sandurdi Island.	54 S.	38 W.
July 6	O-22	49.1	Off northern California. Felt at Eureka	41.7 N.	124.6 W.
July 10	O- 1	02.1	Caribbean Sea, off Cuba	19 N.	80 W.
July 16	H- 8	18.9	West coast of Mexico	17 N.	100 W.
July 18	H- 1	36.3	Panama. Destructive at David and Puerto Armuelles.	8.0 N.	82.5 W.
Do	H- 4	00.6	Panama. Felt	8.0 N.	82.5 W.
Do	H- 6	35.3	Panama	8.0 N.	82.5 W.
Do	H-16	09.8	----do	8.0 N.	82.5 W.
Do	H-16	59.6	----do	8.0 N.	82.5 W.
Do	O-19	40.3	Solomon Islands, South Pacific Ocean	13 S.	167 E.

[1] O indicates time at epicenter: H time at focus.

TABLE 1.—*Summary of instrumental epicenters*—Continued

1934	Greenwich civil time at origin		Region and focal depth	Coordinates of provisional epicenter			
				Lat.		Long.	
	h.	*m.*		°		°	
July 19	H- 0	06.7	----do	13	S.	167	E.
Do	H- 1	27.5	New Guinea	1	S.	133	E.
Do	H- 2	21.0	Panama	8	N.	83	W.
Do	H- 5	45.4	Solomon Islands. Approximate epicenter	13	S.	166	E.
Do	H- 7	36.9	Solomon Islands, South Pacific Ocean	12.5	S.	167.5	E.
July 20	H- 2	10.7	Aleutian Islands	51	N.	174	W.
July 21	H- 6	18.3	Solomon Islands, South Pacific	10	S.	165.5	E.
Do	H-10	39.0	Panama	8.0	N.	82.5	W.
Do	H-13	19.3	----do	8.0	N.	82.5	W.
July 22	O- 2	57.7	Probably New Hebrides Islands				
July 23	H-18	21.5	Atlantic Ocean, south of Cape Verde Islands	7	N.	25	W.
July 24	O- 2	47.3	Probably off west coast of Nicaragua				
July 27	H- 2	25.7	Off west coast of Guatemala	15	N.	92	W.
July 28	H-21	37.0	Southwest of Kodiak Island	55.6	N.	156.8	W.
Aug. 2	H- 7	13.2	Alaska, south central	62	N.	148	W.
Aug. 3	O-19	29.6	Panama. Approximate epicenter	7.5	N.	83	W.
Aug. 6	O-12	07.3	Colombia, S. A	3	N.	77.5	W.
Aug. 7	H- 3	40.2	New Hebrides, South Pacific	12.5	S.	167.5	E.
Aug. 9	O-19	34.0	Solomon Islands. Approximate epicenter	4	S.	152	E.
Aug. 11	H- 8	18.3	Formosa. Destructive. Epicenter by Manila	24.7	N.	121.7	E.
Do	H-11	57.7	Solomon Islands, South Pacific	5.5	S.	151.5	E.
Aug. 12	H-23	49.2	East of Philippine Islands	8	N.	127	E.
Aug. 14	H- 8	49.2	Fiji Islands, South Pacific	19	S.	175.5	E.
Aug. 15	H-11	04.1	Off west coast of Nicaragua	12	N.	89	W.
Aug. 26	H- 1	31.3	Off west coast of Mexico	22	N.	108	W.
Aug. 28	H-11	23.0	Near west coast of Mexico. Approximate epicenter.	17	N.	106	W.
Aug. 31	H- 5	02.8	Baffin Bay	73	N.	71	W.
Do	H-14	57.7	Afghanistan. Depth 80 kilometers	35	N.	71.0	E.
Sept. 4	H-16	34.5	North of New Zealand	23	S.	172.5	E.
Sept. 15	H- 6	56.8	Colima, Mexico	20	N.	105	W.
Sept. 23	H- 7	58.6	Northeast of New Zealand	32	S.	175	W.
Sept. 25	H-19	14.5	Solomon Islands, South Pacific	2	S.	154	E.
Sept. 26	H- 7	27.5	North Atlantic, southwest of Cape Verde Islands	5	N.	32.5	W.
Oct. 10	H-15	42.2	South Pacific, Tonga Islands region. Depth 700 kilometers.	24.5	S.	180	W.
Oct. 18	H- 7	48.3	New Hebrides Islands. Depth normal. Epicenter according to Manila.	11	S.	167	E.
Oct. 21	H-17	53.4	Marianas Islands. Depth uncertain	16	N.	147	E.
Oct. 26	H-17	11.2	South of Japan. Depth about normal	29	N.	132	E.
Oct. 29	H- 2	34.4	Off Lower California. Depth probably normal	23.8	N.	112	W.
Do	H-23	25.4	Near Peru-Ecuador border. Depth uncertain, probably normal.	5	S.	79.5	W.
Nov. 2	O-18	49.8	Near head of Gulf of California. Epicenter according to Pasadena.	32	N.	114	W.
Nov. 4	H- 1	53.7	South Pacific. Near Fiji Islands. Depth probably near normal.	22	S.	176	E.
Do	H- 3	14.4	----do	22	S.	174	E.
Nov. 5	H-23	02.4	Aleutian Islands. Depth normal	51.5	N.	175.5	W.
Nov. 7	H- 9	32.9	Mexico. Depth probably about 60 kms. Approximate epicenter.	17.5	±N.	95	±W.
Do	H-15	30.3	Gulf of California	26.5	±N.	112.5	±W.
Nov. 9	O- 3	59.0	South Pacific. Samoa Islands	14.5	±S.	175	±W.
Do	H-16	11.7	Pacific Ocean off Costa Rica	7	N.	89	W.
Nov. 12	O- 7	19.2	Eastern Turkey. Epicenter according to Strasbourg.	37	N.	40	E.
Nov. 16	O-13	43.5	New Guinea region. Probable epicenter	3	±S.	146	±E.
Nov. 18	H- 3	21.4	Turkistan. Depth probably normal	41	N.	71	E.
Do	H- 9	18.6	Kamchatka. Depth uncertain, probably normal	55	N.	160	E.
Do	O-15	03.4	Probably off coast of Lower California				
Do	H-22	40.4	Solomon Islands. South Pacific. Depth normal	4.5	S.	153	E.
Nov. 24	H-12	34.1	South of Tasmania. Depth about normal	57	±S.	146	±E.
Nov. 25	O- 8	18	Lower California. Felt. Epicenter according to Pasadena.	32.1	N.	116.7	W.
Nov. 26	H-12	09.4	Philippine Islands. Felt. Epicenter according to Manila.	14.2	N.	120.2	E.
Nov. 27	H- 6	14.1	North Celebes Islands. Felt	1.5	N.	128.5	E.
Nov. 30	H- 2	05.4	West coast of Mexico. Depth probably normal	18.8	N.	105.5	W.
Dec. 2	O-14	55.7	Probably off Colima, Mexico				
Dec. 3	H- 1	35.6	Guatemala. Depth about normal	15	N.	89	W.
Do	H- 2	38.6	Guatemala. Depth probably normal	15	N.	89	W.
Dec. 4	H-17	24.6	Southwest Bolivia. Depth near normal	18.9	N.	68.5	W.
Dec. 8	H- 9	35.0	Region of Colima, Mexico				
Dec. 15	H- 1	57.6	Tibet. Depth normal	32	N.	90	E.
Dec. 17	H-15	53.2	New Guinea. Depth probably normal	2	S.	145	E.

[1] O indicates time at epicenter: H time at focus.

TABLE 1.—*Summary of instrumental epicenters*—Continued

1934	Greenwich civil time at origin	Region and focal depth	Coordinates of provisional epicenter	
			Lat.	Long.
	h. *m.*		°	°
Dec. 22	H-14 29.6	Nicaragua. Depth uncertain	11 N.	87 W.
Dec. 23	H- 9 52.5	Bolivia-Chile border. Depth probably less than 80 kilometers.	21 ±S.	68 ±W.
Dec. 24	H-14 35.8	Guatamala. Depth uncertain	15 N.	91 W.
Dec. 29	O- 4+38.2	Off Pacific coast of Panama		
Dec. 30	H-13 52.3	Near head of Gulf of California. Depth near normal.	32.2 N.	115.5 W.
Dec. 31	H-18 45.8	----do----	31.8 N.	115.5 W.

[1] O indicates time at epicenter: H time at focus.

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 furnish engineers and architects requisite data for designing structures to resist earthquake forces. This required the development of special instruments designed to operate automatically whenever a strong earthquake occurred. In the fall of 1934 about 35 assemblies were in operation, most of them in California. They have been distributed mostly in the Los Angeles and San Francisco Bay regions in structures selected for special study by local engineers.

The instruments used are described in Serial No. 579, "United States Earthquakes, 1933" and in Special Publication No. 201, "Earthquake Investigations in California, 1934–1935", the latter containing quite a number of illustrations which are entirely missing in the first-named publication.

Interpretations.—The following analyses are based mostly on the assumption of simple harmonic motion and are practically reproductions of preliminary statements published in the monthly progress reports of the Bureau. They are not discussed in greater detail because in many cases the severity of the recorded movements does not seem to justify it, and because reproductions of the records themselves give a better picture of the types of activity recorded than any word picture could possibly do. Some of the records indicate destructive intensities and these deserve more consideration than given in these brief analyses but only a limited amount of such work has been accomplished in time to be included in this report. In view of the newness of the work and its research aspects it is more than likely that some of the earlier records will be further discussed in forthcoming issues of this series or in special reports.

The analysis of the Bishop record of the earthquake of January 30, page 64, represents a departure from the usual assumption of simple harmonic motion. The original acceleration record was integrated once to produce a velocity curve, and the velocity curve integrated to produce a displacement curve. It is evident from the computed curves that practically the entire spectrum of earthwave periods is clearly shown. In the case of ultra-long-period waves, however, a certain amount of doubt arises as to their validity because of the extreme precision required in reading the original acceleration curves. The results obtained by double-integrating the Bishop record and later records indicate that the long-period waves which are so prominent on teleseismic records have their origin in the immediate vicinity of the epicenter. The large displacements indicated on all computed displacement curves naturally arouse concern in the eyes of those who desire precise data. The present status of the problem is that while such displacements are questioned there has been no positive evidence to disprove their existence.

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In order to improve the quality of acceleration records with a view of obtaining more reliable results in the work of double-integrating, baseline mirrors were placed in all accelerographs so that a fixed line of reference appears within a centimeter of each acceleration curve. Subsequent results obtained from such records continue to yield long-period waves of large amplitude. The results are discussed to some extent in Special Publication No. 201. A detailed description of the process of double-integrating accelerograph records used in the Bureau is described in the mimeographed report mentioned in the discussion of the Bishop analysis on page 64.

Tabulations of data and instrumental constants.—In the preceding publication covering the results for 1933 the results of measurements made on the strong-motion records and the corresponding instrumental constants were tabulated at the end of the report on each earthquake. This practice has been discontinued in favor of composite tables which appear in the end portion of the entire strong-motion report.

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 all 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:

1 cm=0.3937 in.=0.03281 foot.
1 cm/sec.=0.03281 ft./sec.
1 cm/sec.^{2}=0.03281 ft./sec.^{2}
1 cm=10 mm.
0.1 g=98 cm/sec.^{2}=3.215 ft./sec.^{2}

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 may 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 1.61 to 1.

In the illustrations the direction of a recorded element is indicated *above* the trace; thus, in the case of the vertical component accelerograph, upward motion of the trace always indicates downward acceleration.

TABLE 2.—*List of shocks recorded and records obtained on strong-motion seismographs in 1934*

Date, epicenter, and recording stations	Records [1]	
	Accelerograph	Displacement meter
Jan. 30; Western Nevada:		
Bishop	1	
San Jose	2	
June 7; Parkfield, Calif.:		
Santa Barbara	1	
Hollywood	2	
Pasadena	1	1
July 6; At sea, off Eureka:		
Eureka	1	1
Ferndale	1	
July 17; Chiriqui Province, Panama:		
Balboa Heights	1	
Oct. 2; San Francisco Bay region:		
Golden Gate Park	1	
Oakland	1	
Oct. 15; Imperial Valley:		
El Centro	1	
Dec. 30 (5:52 a. m.); Lower California:		
El Centro	1	
San Diego	1	
Los Angeles Subway Terminal	2	1
Hollywood Storage Co. Building and adjoining lot	3	
Dec. 30 (5:52 a. m.); Near Santa Cruz:		
San Jose	2	
Dec. 31; [2] Lower California:		
San Diego	1	
Long Beach	1	
Los Angeles Chamber of Commerce	1	
Vernon	1	
Edison Building, Los Angeles	1	
Westwood (University of California)	1	
Hollywood Storage Co. Building and adjoining lot	3	
Los Angeles Subway Terminal	2	
Total number of records	33	3

[1] No records were obtained on Weed strong-motion seismographs.
[2] In cases where there is confusion as to whether a record was made on Dec. 30 or Dec. 31, it is assigned to the stronger earthquake of Dec. 31.

THE WESTERN NEVADA EARTHQUAKE OF JANUARY 30, 1934

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Excelsior Mountains in western Nevada about 15 miles southwest of Mina. 38°17′ north, 118°22′ west.

Maximum intensity and damage.—VIII or IX. Damage and casualties negligible because the epicentral area is uninhabited. At Mina there was considerable damage to plaster and light structural parts.

Area affected.—110,000 square miles on land.

Summary of strong-motion records.—

BISHOP: About 65 miles south 4° east of epicenter. Recorded on the accelerograph in the garage of the Los Angeles Department of Water and Power.

SAN JOSE: About 190 miles south 70° west of epicenter. Recorded on the accelerographs in the basement and on the thirteenth floor of the Bank of America building.

ANALYSIS OF THE BISHOP RECORD OF JANUARY 30

Accelerograph records.—Figure 16. The records of the horizontal components are relatively weak with generally uniform trace amplitudes throughout the first 30 sec. of operation corresponding to a maximum acceleration of about 0.005 g. The values are associated mostly with waves of 1.2 sec. period having estimated displacements of 1.8 mm, based on the assumption of simple harmonic motion.

There are a few waves of 0.5 and 0.6 sec. period, but they are greatly outnumbered by others of 0.3 sec. and 0.15 sec. Following the usual experience the amplitudes of the shorter period waves decrease with period so that for the 0.15 sec. period waves the estimated displacements are only 0.01 mm.

In the end portion of the acceleration record there are some poorly defined waves of about 2.2 sec. period and 0.5 mm trace amplitude corresponding to an acceleration of 0.0018 g and an estimated displacement of 2.2 mm.

The vertical record is very irregular, but there is a persistent period of 0.65 sec. with amplitude comparable with similar waves on the horizontal components. There is a sprinkling of 0.4, 0.2, and 0.1 sec. waves with amplitudes roughly only one-half the magnitude of those on the horizontal component.

Integration of accelerograph record.—This record was used to investigate the practicability of integrating accelerograph records with a view of obtaining more precise measures of period and displacement than heretofore obtained on the assumption of simple harmonic motion. A complete description of the method employed is given in a mimeographed report of the Bureau entitled "Analysis of Strong Motion Seismograph Records of the Western Nevada Earthquake of January 30, 1934, with Description of a Method of Analyzing Seismograms by Precise Integration."

The most obvious conclusion, upon first inspection of the computed curves, is that the original accelerograph record is best for the study of the very short period waves, say up to 0.2 or 0.3 sec. As a matter of fact, the increment of time in the work of integration was not made small enough to properly outline these waves. As the time increment was only 0.06 sec., there are only three points to outline a 0.2 sec. wave, and this is obviously too few. On the other hand, their displacements are so small compared with the longer period waves that the two groups could be properly represented on a single curve only if it were drawn to unusually large scale; so it must be concluded that they are more conveniently studied on the original accelerogram. If the time increment were made small enough to define the ultra-short-period waves it would increase the work of integration five times. For short-period waves, then, the periods and estimated amplitudes already given must be accepted as better than anything which can be obtained from the computed displacement curves.

The intermediate *velocity* curve, figure 14, gives an excellent picture of the intermediate and longer period ground waves. The outstanding period on this set of curves is close to 1.3 sec. A representative value of the maximum velocity is 3.5 cm/sec., which corresponds to a computed displacement of 1.1 mm. These are

probably the best data on waves of this period range obtainable from any source. In figure 14 the vertical scale is 1.90 cm=1 cm/sec.

Next in order of prominence are waves of 0.5 sec. period with a representative maximum velocity of 1 cm/sec. corresponding to a computed maximum displacement of 0.07 mm. These are better

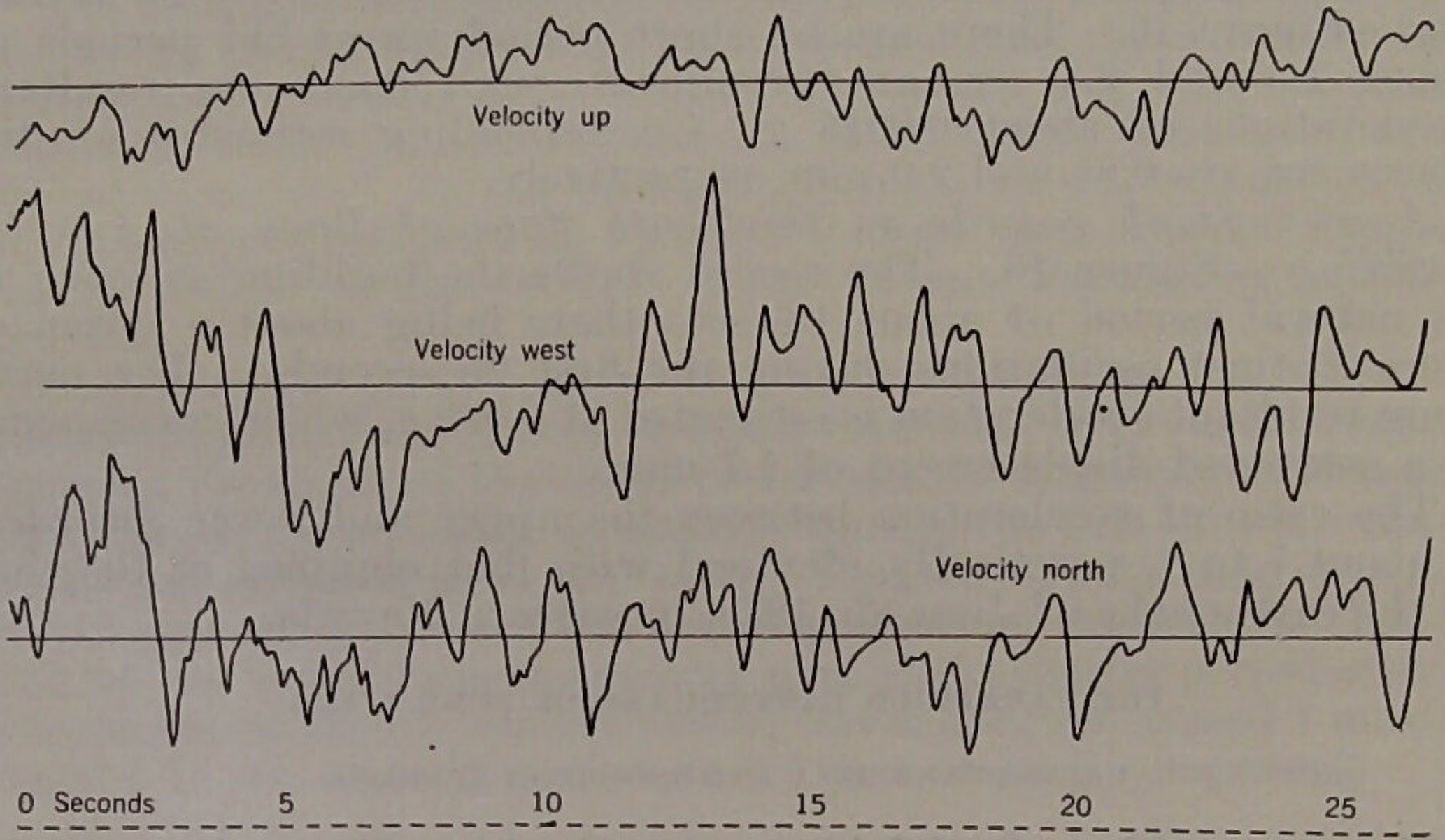


FIGURE 14.—Velocity curves computed from Bishop accelerograph record of January 30.

defined on the accelerometer record, from which a displacement of 0.07 mm is estimated on the basis of 0.003 g for maximum acceleration. The only other period on the set of velocity curves is a very long period which is better defined on the computed displacement curve.

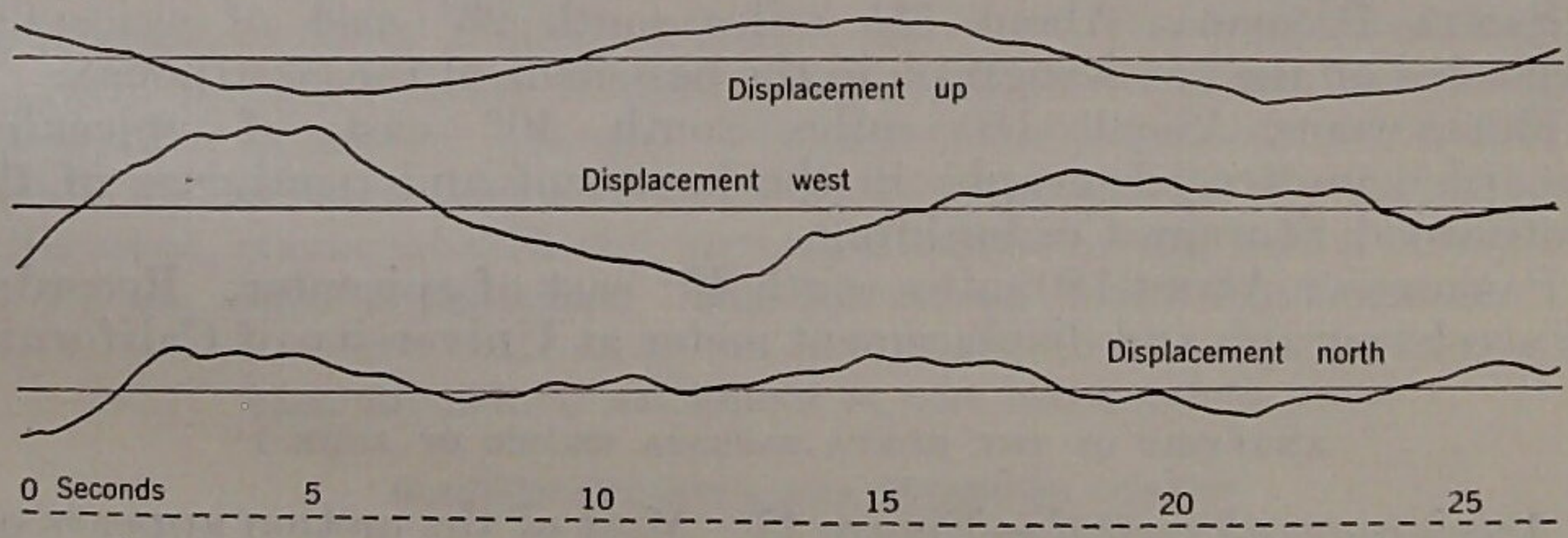


FIGURE 15.—Displacement curves computed from Bishop accelerograph record of January 30.

On the computed *displacement* curves, figure 15, the outstanding feature is the presence of a wave of 12 to 16 sec. period which is not synchronous on the several components. The maximum resultant displacement is about 2.5 cm. (Waves of similar characteristics were recorded on the displacement meters at Eureka on July 7.) The resultant earth particle path suggests one of the complex screw-like motions which characterize certain theoretical waves of Uller. While not of special engineering interest the curve seems to afford a solution to important seismological problems, especially so as all three components, including the vertical, are made available for study. In figure 15 the vertical scale is 0.27 cm=1 cm.

Waves of 1.0 and 1.3 sec. period are strongly in evidence with trace amplitudes of about 1.0 mm corresponding closely to the value of 1.1 mm, for 1.3 sec. period waves, computed from the velocity curves.

ANALYSIS OF THE SAN JOSE RECORDS OF JANUARY 30

Accelerograph records in basement of Bank of America Building.—Figure 16. There are no short period waves but periods of about 1.5 and 2.3 sec. are prominent, with maximum resultant accelerations of about 0.0015 g. Corresponding estimates of displacement are 0.84 and 2.0 mm, respectively.

Accelerograph records on thirteenth floor of Bank of America Building.—Figure 16. The record shows the building swaying in its natural period of about 1.6 sec., there being about a dozen or more distinct oscillations during the first 25 seconds. The maximum resultant acceleration is estimated at 0.009 g, which corresponds to a computed displacement of 5.7 mm.

The ratio of acceleration between the upper and lower recorders is about 7 to 1, practically identical with that obtained at the time of the earthquake of June 25, 1933, in western Nevada.

THE PARKFIELD EARTHQUAKE OF JUNE 7, 1934

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Near Parkfield in the Temblor Mountains. 35°58′ north, 120°29′ west.

Maximum intensity and damage.—VIII. Damage was confined largely to broken-off chimneys, but in a few instances it was more serious. Epicentral area very thinly settled.

Area affected.—34,000 square miles on land.

Summary of strong-motion records.—

Santa Barbara: About 115 miles south 23° east of epicenter. Recorded on the accelerograph in the basement of the courthouse.

Hollywood: About 180 miles south 40° east of epicenter. Recorded on accelerographs in the basement and penthouse of the Hollywood Storage Co. building.

Pasadena: About 180 miles south 46° east of epicenter. Recorded on accelerograph and displacement meter at University of California.

ANALYSIS OF THE SANTA BARBARA RECORD OF JUNE 7

Accelerograph record.—Figure 17. Most of the motion appears on the horizontal components. The maximum acceleration, 4 cm/sec.^{2}, appears on the north-south component in some very poorly defined waves of periods in the neighborhood of 1 second. Waves of slightly shorter period and slightly less aceleration are discernible in the first few seconds of the record. Most of the motion is over after about 10 secs., but weak 1 and 2 sec. waves continue perceptible for about 60 secs. or more.

The motion on the east-west component is of the same character but with smaller amplitudes, the maximum acceleration being a little less than 3 cm/sec.^{2} The vertical component shows very little motion, the maximum acceleration being hardly more than 1 cm/sec.^{2}

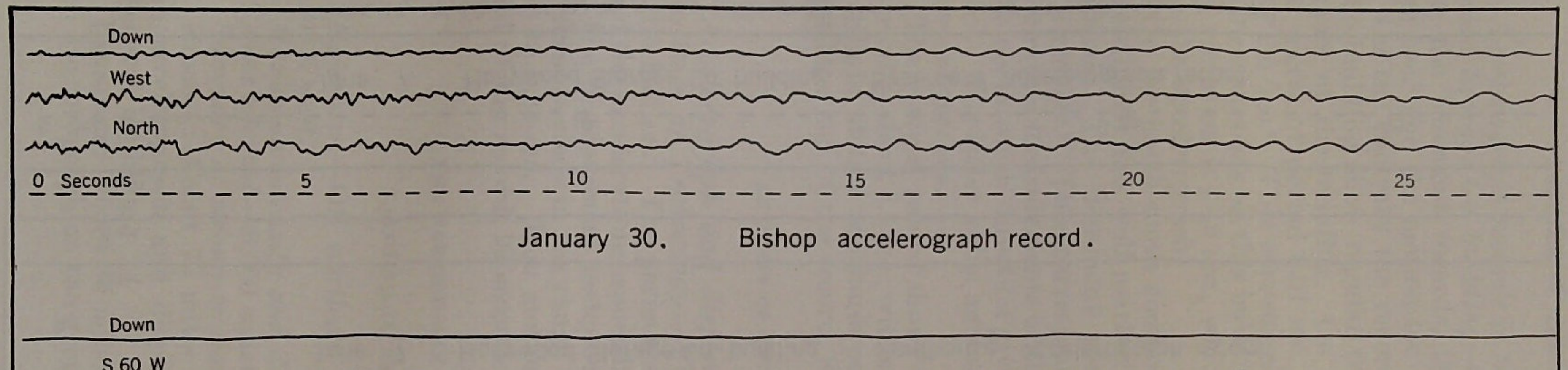


FIGURE 16.—Tracings of strong-motion seismograph records of western Nevada earthquake, January 30.

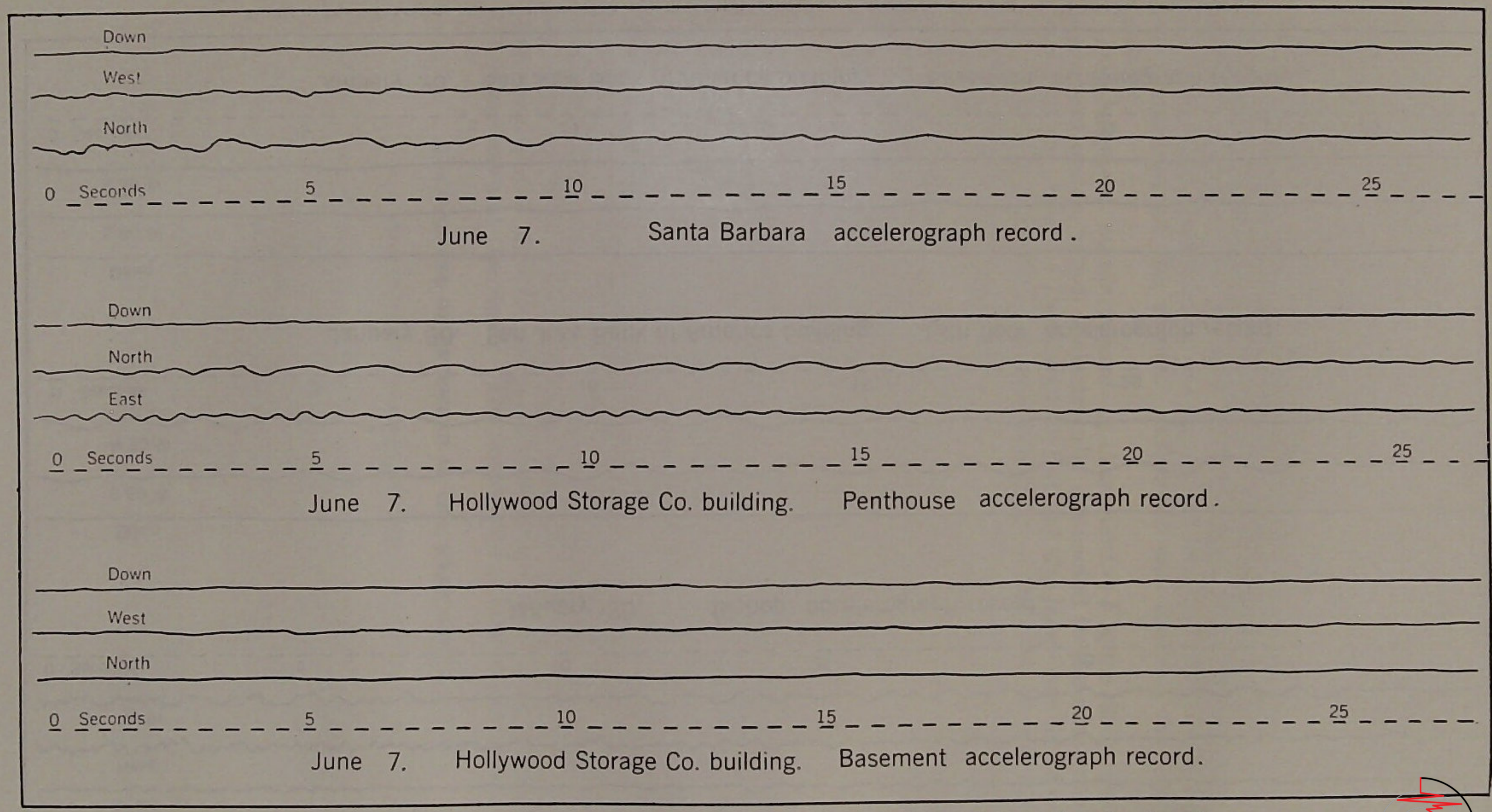


FIGURE 17.—Tracings of strong-motion seismograph records of Parkfield earthquake, June 7.

ANALYSIS OF THE HOLLYWOOD RECORDS OF JUNE 7

Accelerograph records in the basement and penthouse of the Hollywood Storage Co. building.—Figure 17. The motions are very weak on the basement records, the highest accelerations being about 1 cm/sec.^{2} and the motion too irregular for periods to be discerned.

On the contrary the records obtained at the penthouse on top of the building show regular trains of well-marked waves due to resonance of the building. On the east-west component several trains of waves of period 0.51 sec. appear, with maximum acceleration of 2.1 cm/sec.^{2} This corresponds to a displacement of about 0.014 cm. Vibration tests on this building reveal that one of its natural periods of vibration is 0.49 sec., which agrees well with the period observed on the accelerogram.

On the north-south component of the penthouse record the waves are slightly less well marked than on the east-west, and have longer periods. The dominant period is 1.29 sec., with acceleration of 2.5 cm/sec.^{2} This corresponds to a displacement of about 0.1 cm. Vibration measurements of the fundamental period of the building in the north-south direction give results ranging from 1.15 secs. to 1.28 secs. The latter value agrees well with the period obtained from the present records.

The vertical record shows very little motion. The most noticeable period is about 0.5 sec., with maximum acceleration about 0.7 cm/sec.^{2}.

Slight motion continues perceptible on the north-south component until the end of the record, 82 secs. after the start.

ANALYSIS OF THE PASADENA RECORD OF JUNE 7

Accelerograph and displacement-meter records at the California Institute of Technology.—Figure 18. The accelerogram shows very little motion. The periods seem to be in the neighborhood of 1 sec. and the accelerations somewhat less than 1 cm/sec.^{2}

The displacement meters recorded motion showing rather poorly defined periods in the range from 1 to 2 sec., the amplitudes varying up to 0.21 cm. This motion had not completely died down at the end of the record, 92 seconds from the start.

THE EARTHQUAKE OF JULY 6, 1934, NEAR EUREKA

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Off northern California near Eureka. 41°.7 north, 124°.6 west.

Maximum intensity and damage.—V. Damage slight.

Area affected.—8,000 square miles on land.

Summary of strong-motion records.—

EUREKA: About 70 miles south 20° east of epicenter. Recorded on accelerograph and displacement meter in the basement of the Federal Building.

FERNDALE: About 80 miles south 13° east of epicenter. Recorded on accelerograph on the ground floor of the town hall.

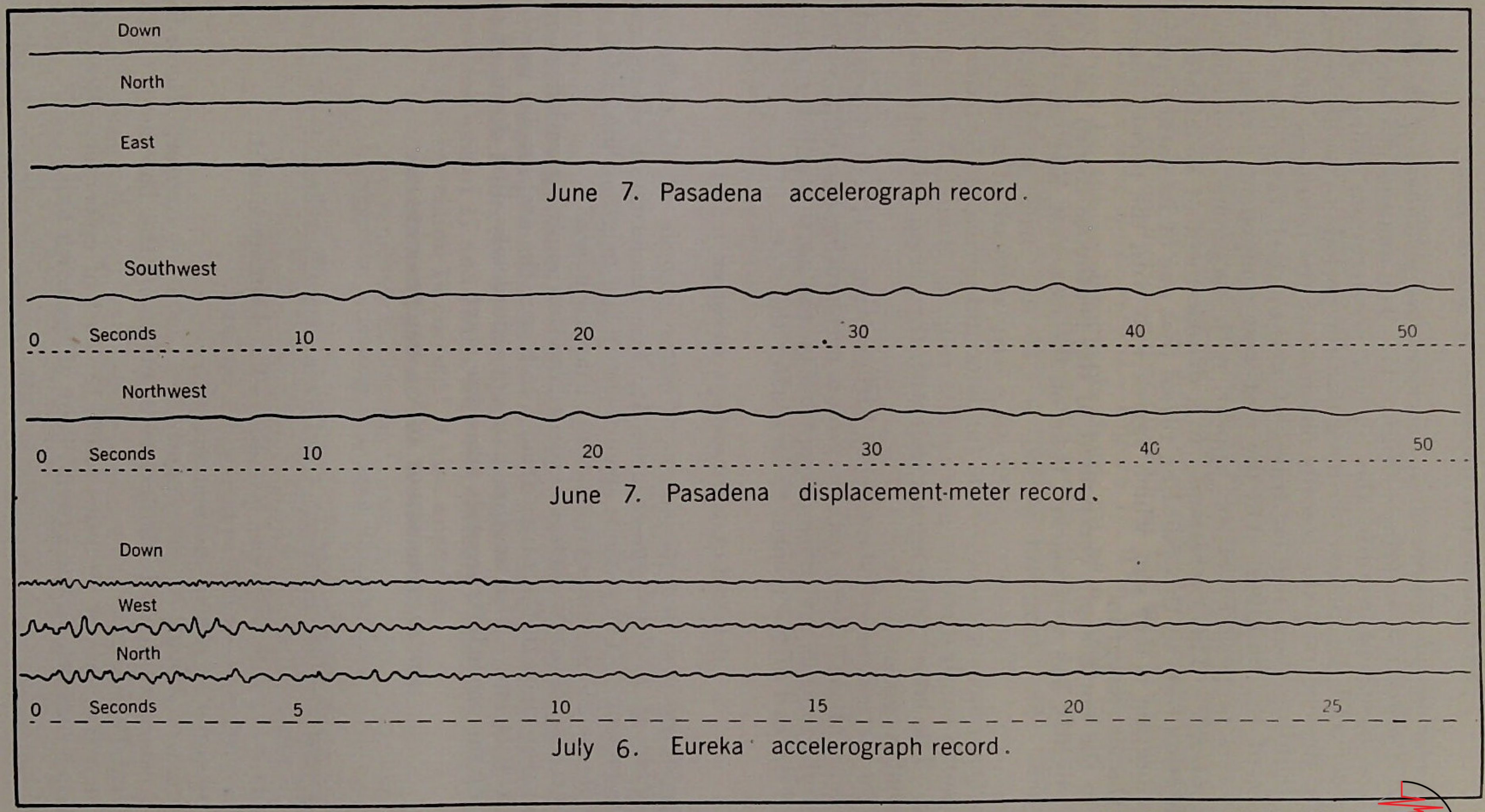


FIGURE 18.—Tracings of strong-motion seismograph records of Parkfield earthquake, June 7, and Eureka earthquake, July 6.

ANALYSIS OF THE EUREKA RECORDS OF JULY 6

Accelerograph record.—Figure 18. The accelerogram shows fairly regular activity continuing for about 10 or 20 seconds, and then dying out slowly, but perceptible for nearly a minute. The period of the motion on the east-west component is about 0.32 sec., and the maximum acceleration of these waves about 19 cm/sec.^{2} The period is the same on the north-south component but the acceleration only about 11 cm/sec.^{2} On the vertical component there are only occasional traces of motion of the 0.32 sec. period, but there are many waves of shorter period, about 0.12 sec., and smaller acceleration, about 4 cm/sec.^{2} The horizontal components show traces of this short-period motion superimposed on the larger waves.

Displacement-meter record.—Figure 19. The short-period motion recorded by the accelerograph shows up as a weak ripple in the first 15 seconds of the displacement-meter record. The main motion is of much longer period, and continues throughout the length of the record, 90 sec.

This motion is not very regular. The waves which most clearly approximate simple harmonic motion on the north-south component are some of period 3.5 sec. and ground amplitude 0.5 cm. Waves of period about 12.4 sec. and amplitude about 0.8 cm. are also discernible on this record. The most regular waves on the east-west component are some of period 2.8 sec. and amplitude 0.5 cm. This record shows also motion of period about 10.4 sec. and amplitude about 0.8 cm; also motion of period about 15.3 sec. and amplitude about 0.8 cm.

ANALYSIS OF THE FERNDALE RECORD OF JULY 6

Accelerograph record.—Figure 19. The motion is rather weak at the beginning of the record, and continues so for about 10 seconds, when a stronger but irregular motion builds up and continues for about 10 or 20 seconds more, after which the motion dies down gradually, continuing perceptible for more than a minute.

The irregular motion on the northwest component appears to be compounded largely of waves of periods 0.41 and 0.20 sec., with accelerations of 17 and 13 cm/sec.^{2} respectively. Motion of period 0.9 sec. and acceleration 13 cm/sec.^{2} is also apparent.

On the northeast component the acceleration of the short period motion is larger, about 25 cm/sec.^{2}, and the period 0.22 sec. The motion of period 0.4 sec. is practically imperceptible, but there is some motion of period 0.67 sec. and acceleration 7 cm/sec.^{2}

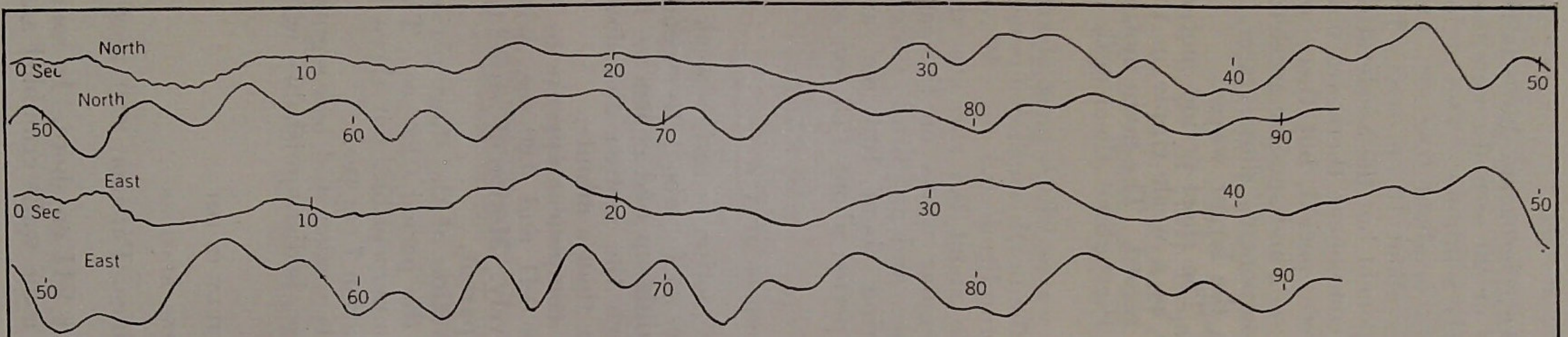
The motion on the vertical component is weaker and less regular than on the horizontals, but a period 0.43 sec. is distinguishable, with acceleration 5 cm/sec.^{2}

THE PANAMA EARTHQUAKE OF JULY 17, 1934

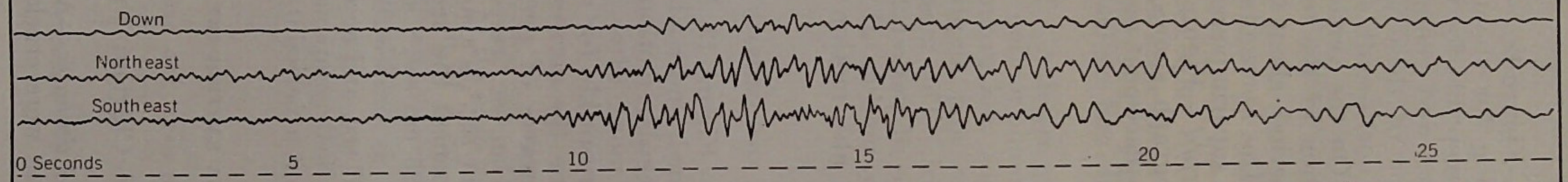
EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—At sea off Chiriqui Province, Panama. 8°.0 north, 82°.5 west.

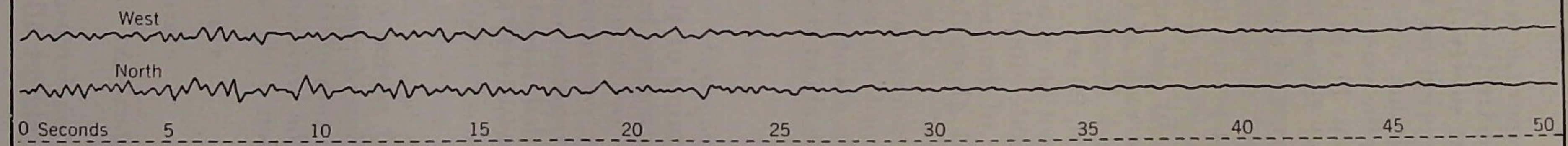
Maximum intensity and damage.—About VII on shore. In some localities almost all houses were cracked, some walls crumbled and



July 6. Eureka displacement-meter record.



July 6. Ferndale accelerograph record.



July 17. Balboa Heights accelerograph record.

FIGURE 19.—Tracings of strong-motion seismograph records of Eureka earthquake of July 6 and Panama earthquake of July 17.

iron and tile roofs caved in. An elevated water tank collapsed. Several adobe houses also collapsed.

Area affected.—Unknown.

Summary of strong-motion records.—

BALBOA HEIGHTS: About 210 miles north 73° east of epicenter. Recorded on the accelerograph in the basement of the Administration Building.

ANALYSIS OF THE BALBOA HEIGHTS RECORD OF JULY 17

Accelerograph record.—Figure 19. The maximum horizontal acceleration recorded is 7 cm/sec.^{2} or 0.007 g. associated with waves of 0.6 sec. period. Other prominent periods in the record are, in the order of their frequencies, 0.35, 0.80, 0.25, and approximately 2.0 sec. Visible activity ceases after about 50 sec. The vertical accelerometer pendulum was obstructed. The displacement due to the 0.6 sec. waves is about 0.6 mm. but for the longer 2 sec. waves may be as much as 4 mm.

Aftershocks started the strong-motion apparatus on two occasions, but the records are weak.

THE SAN FRANCISCO BAY REGION EARTHQUAKE OF OCTOBER 2, 1934

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Off shore near San Francisco Bay. 37°.6 north, 122°.8 west.

Maximum intensity and damage.—V. Practically no damage.

Area affected.—2,100 square miles on land.

Summary of strong-motion records.—

GOLDEN GATE PARK: About 20 miles north 60° east of epicenter. Accelerograph in the waterfall switch house.

OAKLAND: About 30 miles north 65° east of epicenter. Accelerograph in basement of City Hall.

ANALYSIS OF THE GOLDEN GATE PARK RECORD OF OCTOBER 2

Accelerograph record.—Figure 20. The maximum acceleration is 5 cm/sec.^{2} at the beginning of the east-west component, after which a few groups reach a maximum of 4 cm/sec.^{2} Periods of 0.08 sec. prevail. On the north-south the maximum waves have a period of 0.11 sec. with 0.08 sec. dominating in the end portion. Maximum displacement is less than 0.01 mm.

On the vertical component the accelerations are only about one-third as large as on the horizontal, the maximum occurring in waves of 0.11 sec. period. Tremors of period 0.08 sec. are in evidence in the end portion. After 15 sec. visible activity ceases.

ANALYSIS OF THE OAKLAND RECORD OF OCTOBER 2

Accelerograph record.—Figure 20. There is a somewhat discontinuous series of 0.11 sec. waves in which the principal portion lasts only a few seconds and all apparent activity ceases after 15 sec. The true periods may be better described as ranging from 0.10 to 0.12 sec. Maximum acceleration is 2 cm/sec^2. The estimated dis-

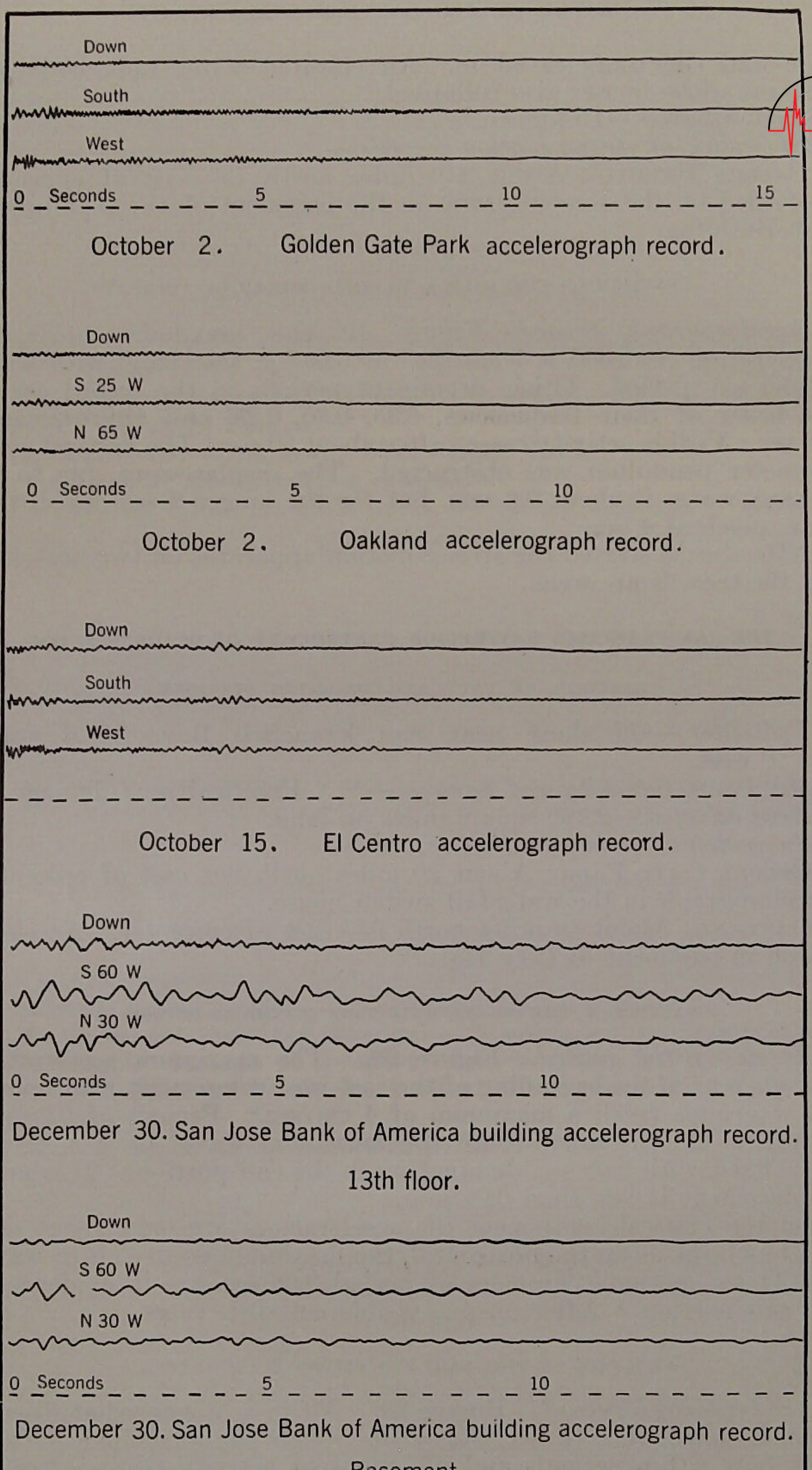


FIGURE 20.—Tracings of strong-motion seismograph records of the San Francisco Bay region earthquake of October 2, the Imperial Valley earthquake of October 15, and the Santa Cruz earthquake of December 30.

placement is 0.005 mm. In the end portion there are traces of a 0.6 sec. waves diminishing to 0.5.

This record, attributed to the earthquake of October 2, might conceivably have been made by some other weak shock occurring between August 10, when the paper was placed on the recording drum, and October 15, when the record was removed.

THE IMPERIAL VALLEY EARTHQUAKE OF OCTOBER 15, 1934

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Lower California near Lake Maquata. 32°27′ north, 115°37′ west.

Maximum intensity and damage.—No reports from the epicentral region. IV at El Centro.

Area affected.—Unknown. Very light shock.

Summary of strong-motion records.—

El Centro: About 25 miles north 10° east of epicenter. Recorded on the accelerograph at the Southern Sierra Power Co. terminal station.

ANALYSIS OF THE EL CENTRO RECORD OF OCTOBER 15

Accelerograph record.—Figure 20. Maximum horizontal acceleration is recorded in waves with periods between 0.1 and 0.2 sec. and never exceeds 4 cm/sec.^{2} Some waves as short as 0.08 sec. are in evidence but none longer than 0.2 sec. Maximum displacement is 0.01 mm.

On the vertical record, which is indistinct, the acceleration appears to be only about one-quarter of that recorded on the horizontal records. After 10 seconds all activity apparently ceases.

THE LOWER CALIFORNIA EARTHQUAKE OF DECEMBER 30, 1934

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—About 35 miles due south of Calexico, according to instrumental determination. 32°.2 north, 115°.5 west.

Maximum intensity and damage.—IX estimated in epicentral area. Considerable damage to property and roadbed along the Inter-California Railroad below the border. No reports from epicentral region available.

Area affected.—60,000 square miles in California and Arizona, and an unknown area in Mexico.

Summary of strong-motion records.—

El Centre: About 40 miles north 5° west of epicenter. Recorded on accelerograph at the Southern Sierra Power Co. terminal station.

San Diego: About 105 miles north 70° west of epicenter. Recorded on accelerograph in basement of the San Diego Consolidated Gas & Electric Building.

Los Angeles: About 205 miles north 50° west of epicenter. Recorded on accelerographs in basement and on 13th floor of the Subway Terminal Building, and on the basement displacement meter.

Hollywood: About 205 miles north 50° west of epicenter. Recorded on accelerographs in the basement and penthouse of the Hollywood Storage Co. Building, and at the station on the adjoining lot.

ANALYSIS OF EL CENTRO RECORD OF DECEMBER 30

Accelerograph record.—Figure 21. The acceleration of the short-period waves was so high that it is in some places difficult to separate the overlapping traces on the seismogram. During the first 2 sec. the horizontal accelerations were relatively small and then increased to a maximum. The vertical accelerations were consistently large from the start. The principal portion lasts about 15 sec. after which the short period, high acceleration phase, gives way to longer periods. The end portion was nevertheless active enough to trip the starter two more times so that the record obtained is as long as three normal records.

The main portion consists of a hopeless mixture of waves varying from 0.1 to 0.3 sec. period, with maximum trace amplitudes apparently associated with waves close to 0.25 sec. At times the accelerations exceeded 125 cm/sec.^{2} on a single component and in one instance near the end portion it reached 175 cm/sec.^{2} on one component when the other horizontal component registered practically nothing. This wave represents the maximum trace amplitude. The displacements corresponding to the first-named acceleration are of the order of 2 mm. For the shorter periods the accelerations and displacements are considerably smaller.

Waves of intermediate period are difficult to distinguish but there is evidence of 0.5 or 0.6 sec. waves and 1 sec. waves, and quite definite indication of 1.8 sec. waves with acceleration of 25 cm/sec.^{2} and estimated displacement of 20 mm.

During the first 5 sec. of the vertical motion record the outstanding waves are those of 0.10 sec. period with accelerations of approximately 100 cm/sec.^{2} and corresponding displacements of 0.25 mm; but only a few waves reach this peak. After 5 sec. a 0.5 sec. wave becomes prominent and after a period of complex activity the principal portion ends with a spurt of a few 0.25 sec. waves with acceleration about 50 cm/sec.^{2} and estimated displacement 0.8 mm. 1.2 and 2.0 sec. periods are prominent. In the vertical motion 1.0, 1.2, and 1.9 secs. may be mentioned, but they are all of complex character immediately after the main portion.

The principal portion does not exhibit as much activity in the 0.1 sec. range of periods as the Long Beach record of March 10, 1933. Three aftershocks were recorded and these used up the remaining paper on the drum, resulting in loss of the record of the heavier shock of December 31.

ANALYSIS OF SAN DIEGO RECORD OF DECEMBER 30

Accelerograph record.—Figure 22. Activity is very moderate, the maximum acceleration being less than 4 cm/sec.^{2} On the horizontal components there are a few weak traces of 0.12 sec. period with longer waves ranging from 0.25 to 2.0 sec. They are irregular in character with the intermediate periods dominating. The vertical record is of similar character with amplitudes only about one-half as great. The more active part ends at 25 sec.

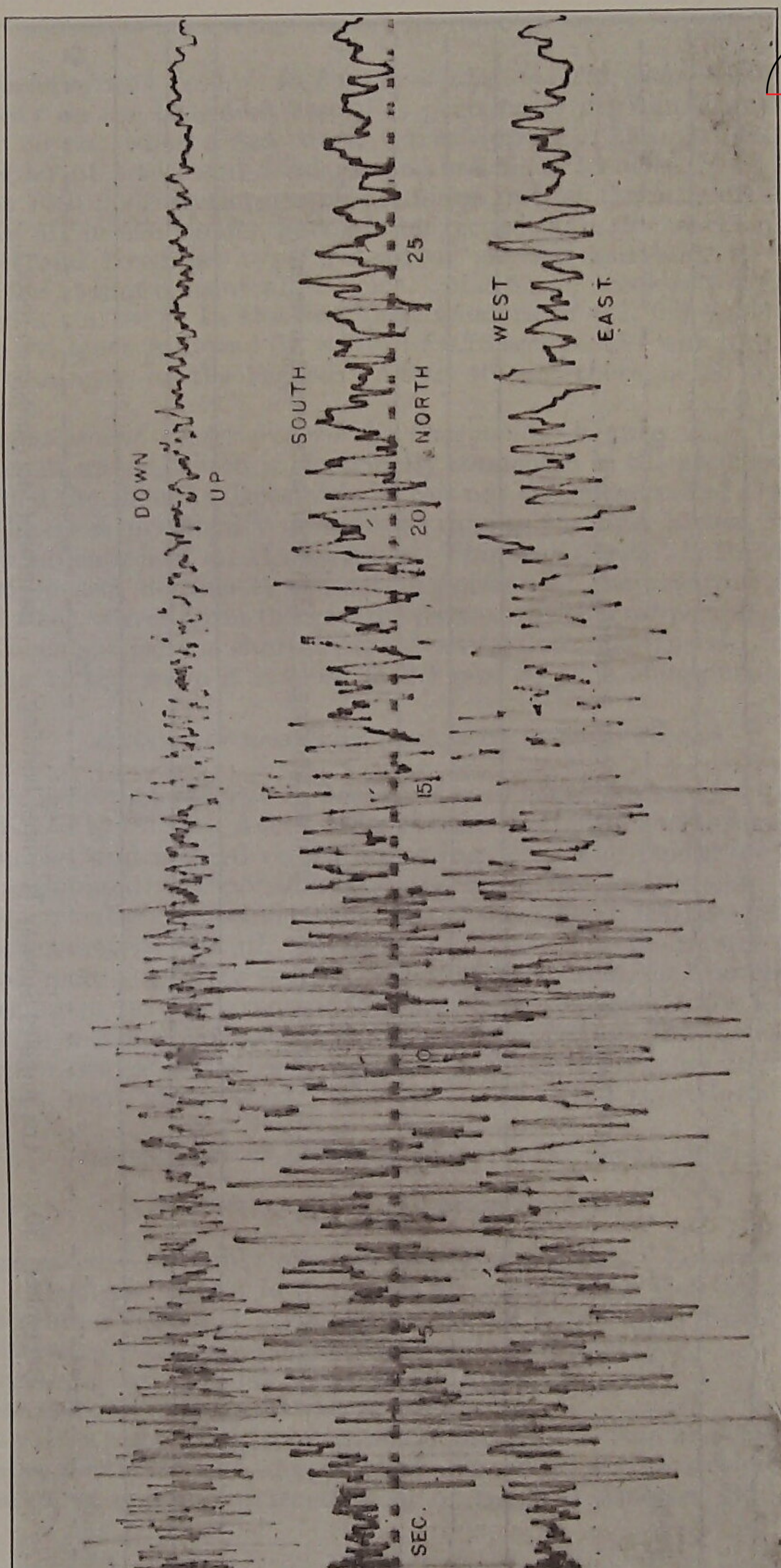


FIGURE 21.—Active portion of the El Centro accelerograph record of the Lower California earthquake of December 30.

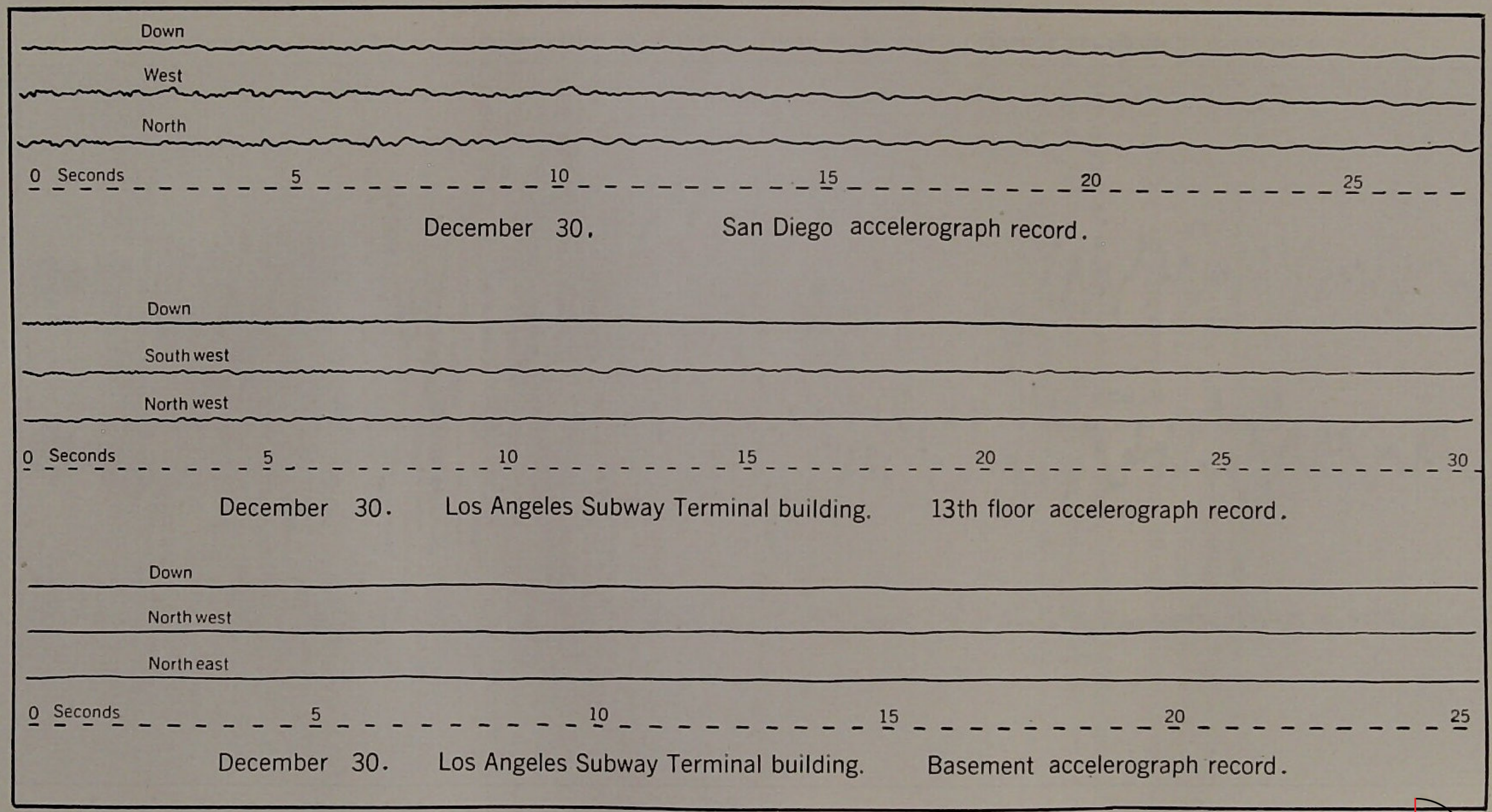


FIGURE 22.—Tracings of strong-motion seismograph records of the Lower California earthquake of December 30.

ANALYSIS OF LOS ANGELES SUBWAY TERMINAL RECORDS OF DECEMBER 30

Accelerograph records in basement and on 13th floor.—Figure 22. Activity on the basement record is practically negligible until after 29 or 30 sec. when a few weak waves appear. The periods are of the order of 1 sec. and accelerations less than 1 cm/sec.^{2}

The 13th floor accelerograph is unique in that the activity is practically all in the earlier part of the record, and the waves of short period and irregular type instead of smooth and long as usually expected at that epicentral distance. Maximum acceleration does not exceed 2 cm/sec.^{2} In the first part tremors of 0.1, 0.2, and 0.3 sec. are in evidence followed by waves of 0.75 sec. period which dominate the remainder of the record. After 40 sec. there is no apparent activity.

Displacement meter record in basement.—Figure 23. The displacement meter, which is electrically connected to the accelerograph, recorded the shock of December 30 but not the large one of December 31. There is practically no activity during the first 15 sec. except a slight indication of an 11 sec. wave. This wave, with shorter periods superimposed, dominates the active portion of the record. 1.0, 1.5, and 3.0 sec. waves form the greater part of the shorter period activity. Displacement for the shorter period waves does not exceed 1 mm, but for the 11 sec. wave it is close to 2.5 mm on each component.

ANALYSIS OF HOLLYWOOD STORAGE CO. BUILDING RECORDS

Accelerograph records in basement and penthouse, and on adjoining lot.—Figure 23. Accelerographs are located in the basement and penthouse, and a third on an adjoining lot. The penthouse starter was undoubtedly responsible for operating the instruments (which are electrically connected) because the two lower instruments show almost no activity at all, perhaps 1 cm/sec.^{2} The penthouse accelerograph recorded fairly smooth waves of 3 or 4 cm/sec.^{2} acceleration, occurring in several groups. The north-south periods are 1.2 to 1.3 sec. with waves of 0.55 sec. occasionally interfering. In the east-west direction, waves of 0.55 sec. period dominate, with some evidence of a 1.0 sec. wave at the start. The lot record is not reproduced.

EARTHQUAKE OF DECEMBER 30, 1934, NEAR SANTA CRUZ

EARTHQUAKE DATA AND RECORDING STATION

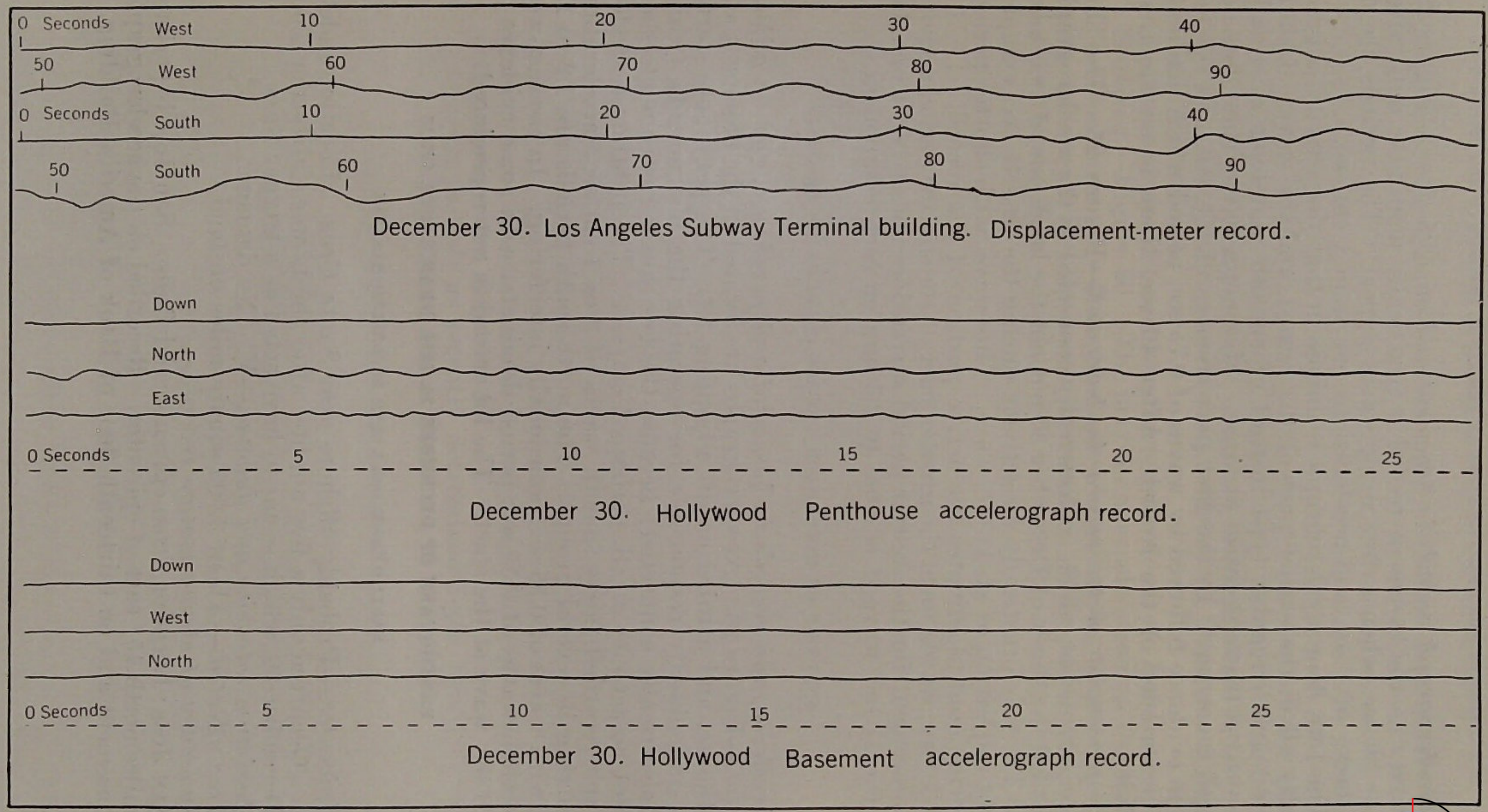
Epicenter.—Probably offshore near Santa Cruz. Location indefinite. Occurred only a few minutes after the Lower California shock of December 30, which seems to have acted as a trigger force.

Maximum intensity and damage.—V. No damage.

Area affected.—About 3,000 square miles on land.

Summary of strong-motion records.—

San Jose: Location from epicenter indefinite. San Jose is perhaps 30 miles north 15° east of epicenter. Recorded on the accelerographs in basement and on thirteenth floor of Bank of America Building.



December 30. Los Angeles Subway Terminal building. Displacement-meter record.

December 30. Hollywood Penthouse accelerograph record.

December 30. Hollywood Basement accelerograph record.

FIGURE 23.—Tracings of strong-motion seismograph records of the Lower California earthquake of December 30.

ANALYSIS OF SAN JOSE RECORDS OF DECEMBER 30

Accelerograph record in basement of Bank of America Building.—Figure 20. The principal portion lasts only about 15 secs. with accelerations gradually decreasing from the maximum of 6 cm/sec.² which occurs at the start. The outstanding periods are between 5 and 6 secs., with a few superimposed tremors of 0.2 sec. waves and a trace of 0.1 sec. waves. In the end portion a few weak 1 sec. waves emerge. Maximum displacement is estimated at 0.4 mm. The vertical motion is only about one-third that of the horizontal. See the following remarks on the thirteenth floor record for additional information.

Accelerograph record on thirteenth floor of Bank of America Building.—Figure 20. The maximum acceleration on the thirteenth floor measures only 9 or 10 cm/sec.² against 6 cm/sec.² observed in the basement for the same movement. The most obvious thing about the top floor record is failure of the building to swing through large amplitudes such as those recorded during the more distant earthquakes of June 25, 1933, and January 30, 1934, in western Nevada. Cursory inspection of the gram indicates that top floor horizontal accelerations (and this implies displacements also) are generally less than double those recorded in the basement. The prevailing period in the high acceleration zone is close to 0.55 sec., with a few 0.25 sec. waves superimposed and a tendency to drift into 1.5 sec. waves which at times becomes quite pronounced. In one of the end groups a 1.0 sec. wave emerges rather strongly. The record ends with smooth 1.4 sec. waves on the north 60° east component and 1.3 sec. waves on the south 30° east component.

Comparison between the vertical motion records obtained on the 13th floor and in the basement shows a much greater motion of the thirteenth floor; three or four times greater for waves of 0.55 sec. period or roughly 3.5 cm/sec.² against 1 cm/sec.² This happens in two separate groups of waves. The sensitivities of the two instruments are equal but the vertical instrument is continuously disturbed by minute elevator vibrations of 0.05 sec. period, which may affect the performance of the instrument, although there is no apparent reason why they should.

Building periods as recently determined from vibration tests are 1.31 secs. along Santa Clara Street; 1.20 secs. along First Street.

LOWER CALIFORNIA EARTHQUAKE OF DECEMBER 31, 1934

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Near the delta of the Colorado River in Mexico. Instrumental epicenter 31°.8 north, 115°.1 west. This is about 35 miles southeast of the computed epicenter of the shock of the preceding day, but neither location has yet been verified by surveys in the field.

Maximum intensity and damage.—Probably X in epicentral region. Considerable property damage along the border. It is often difficult to distinguish between the effects of this shock and the one of the preceding day.

Area affected.—80,000 square miles in the United States, and an unknown area in Mexico.

Summary of strong-motion records.—
San Diego: About 135 miles north 60° west of epicenter. Recorded on the accelerograph in the San Diego Consolidated Gas & Electric Co. Building.

Long Beach: About 225 miles north 45° west of epicenter. Recorded on the accelerograph in the Public Utilities Building.

Los Angeles: About 240 miles north 45° west of epicenter. Recorded on the basement accelerograph of the Chamber of Commerce Building; on the basement and thirteenth floor accelerographs of the Subway Terminal Building; and on the basement accelerograph of the Edison Building.

Vernon: About 240 miles north 45° west of epicenter. Recorded on the accelerograph in the basement of the Central Manufacturing District Terminal Building.

Westwood: About 240 miles north 45° west of epicenter. Recorded on the accelerograph at the University of California.

Hollywood: About 240 miles north 45° west of epicenter. Recorded on the accelerographs in the basement and penthouse of the Hollywood Storage Co. Building and on the adjoining lot.

ANALYSIS OF SAN DIEGO RECORD OF DECEMBER 31

Accelerograph record.—Figure 24. The record is marked by unusual duration and complexity of wave forms. Maximum acceleration is about 8 cm/sec.^{2} The most active portion lasts about 32 sec.; then there is an intermediate stage lasting 40 sec. During the end phase the automatic starter was tripped so that the record is continuous over double the length of a normal record. This marked the end of the roll.

There are small pronounced tremors of about 0.15 sec. period on all components but they appear of no consequence in comparison with the 0.6, 1.0, 1.5, and 2.0 sec. waves which dominate the record. Only approximate periods can be named because of the complexity of the record. No group stands out in any considerable degree above the others. While maximum accelerations vary from 6 to 8 cm/sec.^{2}, the displacements are estimated roughly between 0.5 and 3.0 mm, the smaller values associated with the shorter 0.6 sec. waves, and the higher with the longer period groups.

Vertical motion activity is only one-third to one-half of that registered on the horizontal components.

ANALYSIS OF LONG BEACH RECORD OF DECEMBER 31

Accelerograph record.—Figure 24. The accelerograph record is a series of smooth but somewhat irregular waves with maximum acceleration close to 2 cm/sec ^{2}. The active portions lasts about 40 sec. The prevailing periods are 1.2 and 1.5 sec. with some intermediate periods, and also a number of 2.0 sec. waves in the end portion. The record is marked by a total absence of short period waves.

ANALYSIS OF LOS ANGELES SUBWAY TERMINAL RECORD OF DECEMBER 31

Accelerograph records in the basement and on the 13th floor.—Figure 25. Activity on the basement record is almost negligible as on the preceding day. The record was not entirely completed before the end of the roll was reached. It is probable that there was some

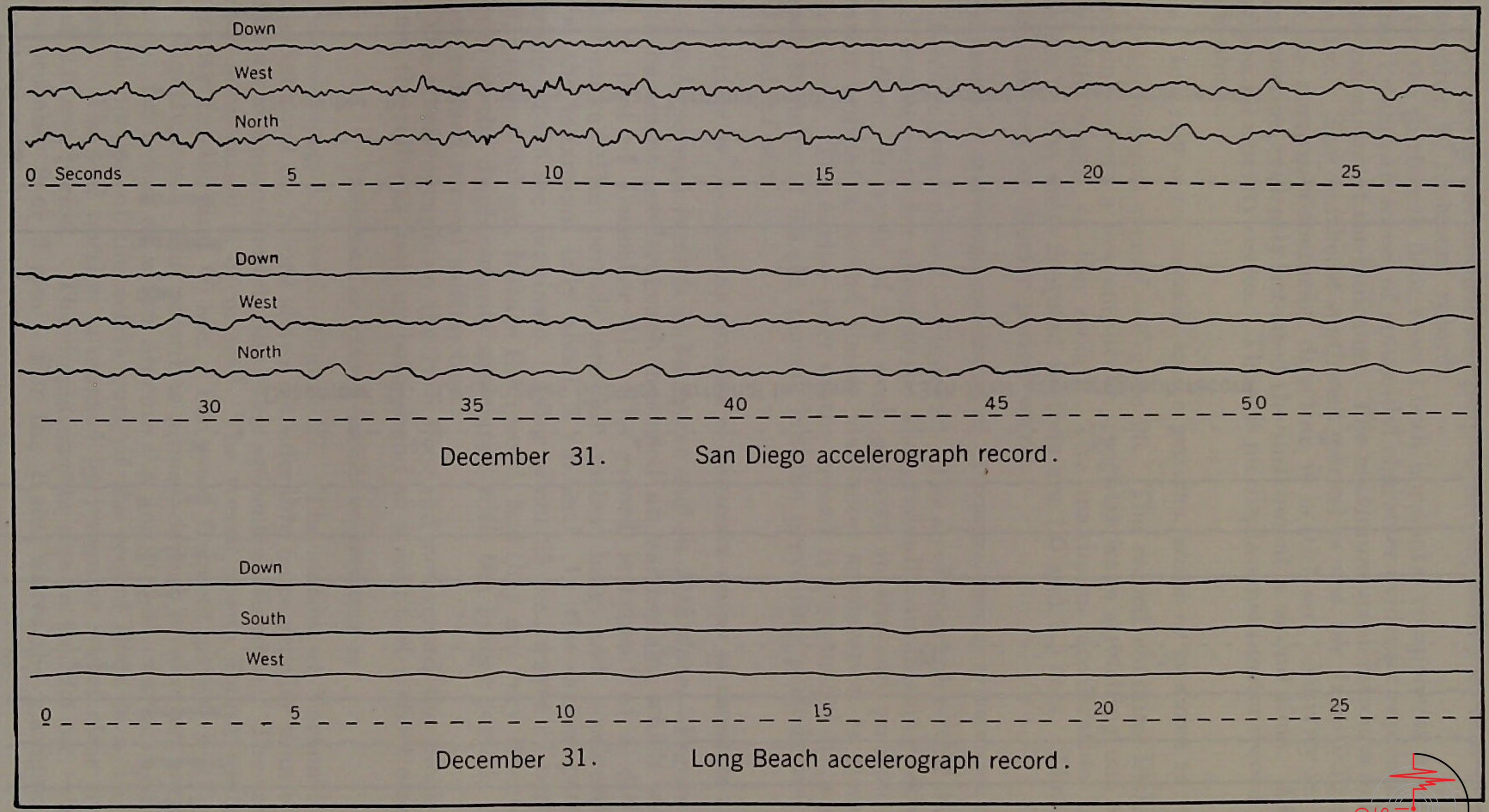


FIGURE 24.—Tracings of strong-motion seismograph records of the Lower California earthquake of December 31.

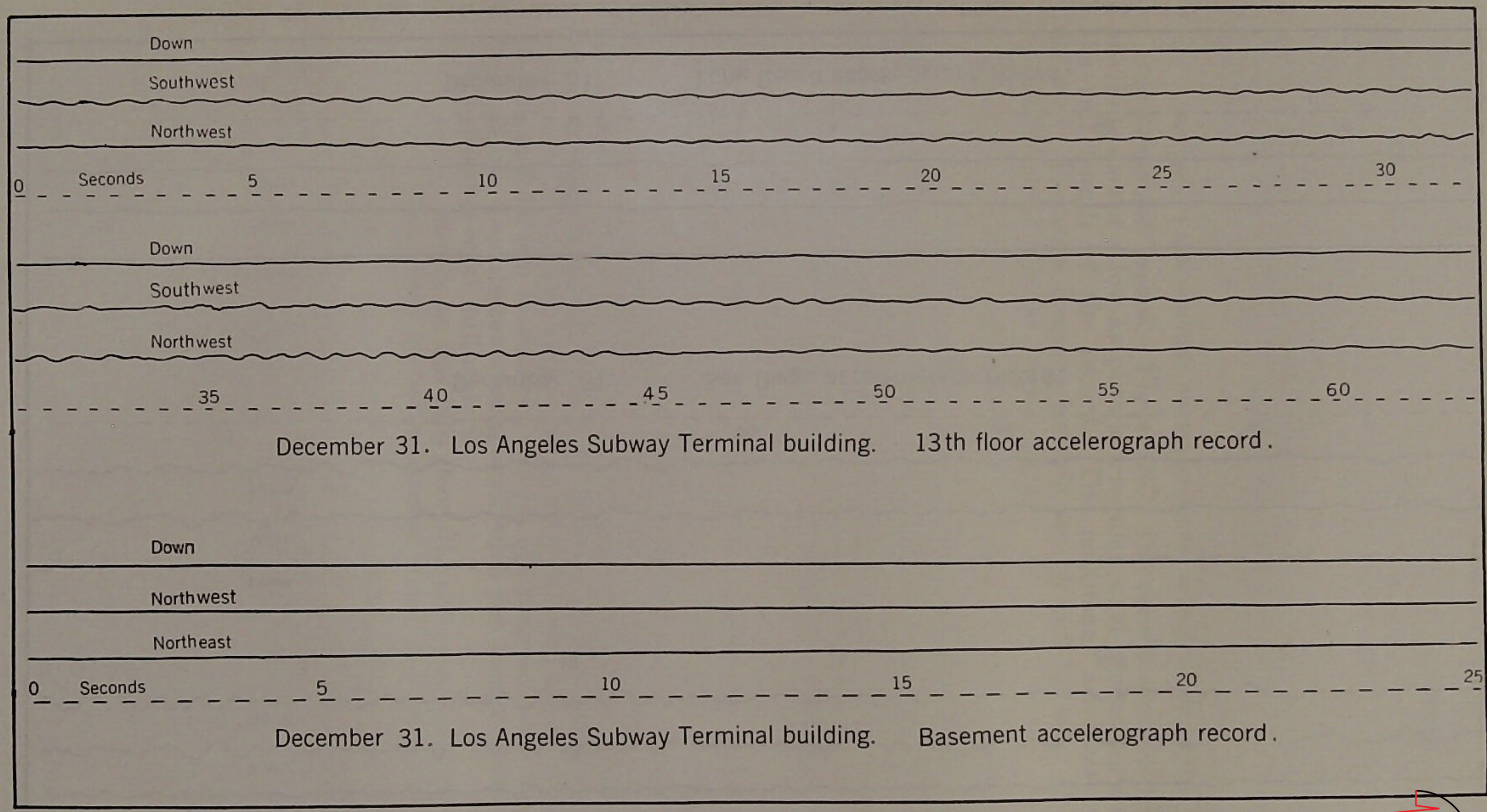


FIGURE 25.—Tracings of strong-motion seismograph records of the Lower California earthquake of December 31.

activity in the unrecorded end portion corresponding to that on the December 30 basement record.

On the thirteenth floor record both horizontal components are featured by smooth waves of sinusoidal character evidently representing free vibrations of the building. The maximum acceleration is only 2 cm/sec.^{2} The northeast-southwest period is not far from 0.75 sec. In the northwest-southeast direction it is 0.57 sec. Activity in the end portion evidently actuated the instrument a second time. After 100 sec. all activity ceases. There is no displacement meter record for this shock.

ANALYSIS OF LOS ANGELES, EDISON BUILDING, RECORD OF DECEMBER 31

Accelerograph record.—Figure 26. The record contains little of anything except a low-amplitude irregular wave stretching out over the full length of the record. The maximum acceleration is 2 cm/sec.^{2} The most frequent periods are 1.0 and 1.5 secs. There is total absence of shorter period waves.

ANALYSIS OF WESTWOOD, UNIVERSITY OF CALIFORNIA, RECORD OF DECEMBER 31

Accelerograph record.—Figure 26. The accelerograph record shows uniform activity for about 40 sec. and gradually diminishing activity thereafter. In spite of the weak activity in the end portion the starter tripped a second time. Maximum acceleration is close to 2 cm/sec.^{2} The earlier part of the record is punctuated by a few weak tremors of 0.3 sec. period, but the prevailing periods are 0.6, 1.1, and 1.7 secs.

ANALYSIS OF LOS ANGELES CHAMBER OF COMMERCE RECORD OF DECEMBER 31

Accelerograph records in basement and on 12th floor.—Figure 26. The basement accelerograph recorded an earthquake which seems to be that of December 31. The record is typical of a distant earthquake: The periods are all rather long and accelerations low, the maximum only about 3 cm/sec.^{2} In the earlier portion periods of 0.6 sec. dominate. After about 25 sec., waves of periods 1.5, 2.0, and 3.0 sec. feature the record, but they are very irregular. Some of the displacements associated with the longer periods may have reached several millimeters.

The accelerograph on the 12th floor did not record the shock because the roll was used up beforehand as a result of a short circuit.

ANALYSIS OF VERNON RECORD OF DECEMBER 31

Accelerograph record.—Figure 27. The station at Vernon is on alluvium and the record shows considerably more activity than other stations at approximately the same epicentral distance. The maximum acceleration is 3 cm/sec.^{2} The record shows almost uniform activity for the first 60 sec. The most frequent period is 1.0 sec. or slightly less. The record is almost devoid of shorter periods, except for traces of a few obscure 0.3 and 0.5 sec. waves. In the middle portion of the active part of the record there is a 2.5 sec. wave. The end portion is marked by irregular waves close to 1.5 and 2.0 sec. period. The displacements due to the 2.5 sec. waves are probably 2 or 3 mm. For the 1 sec. waves the maximum is about 0.8 mm.

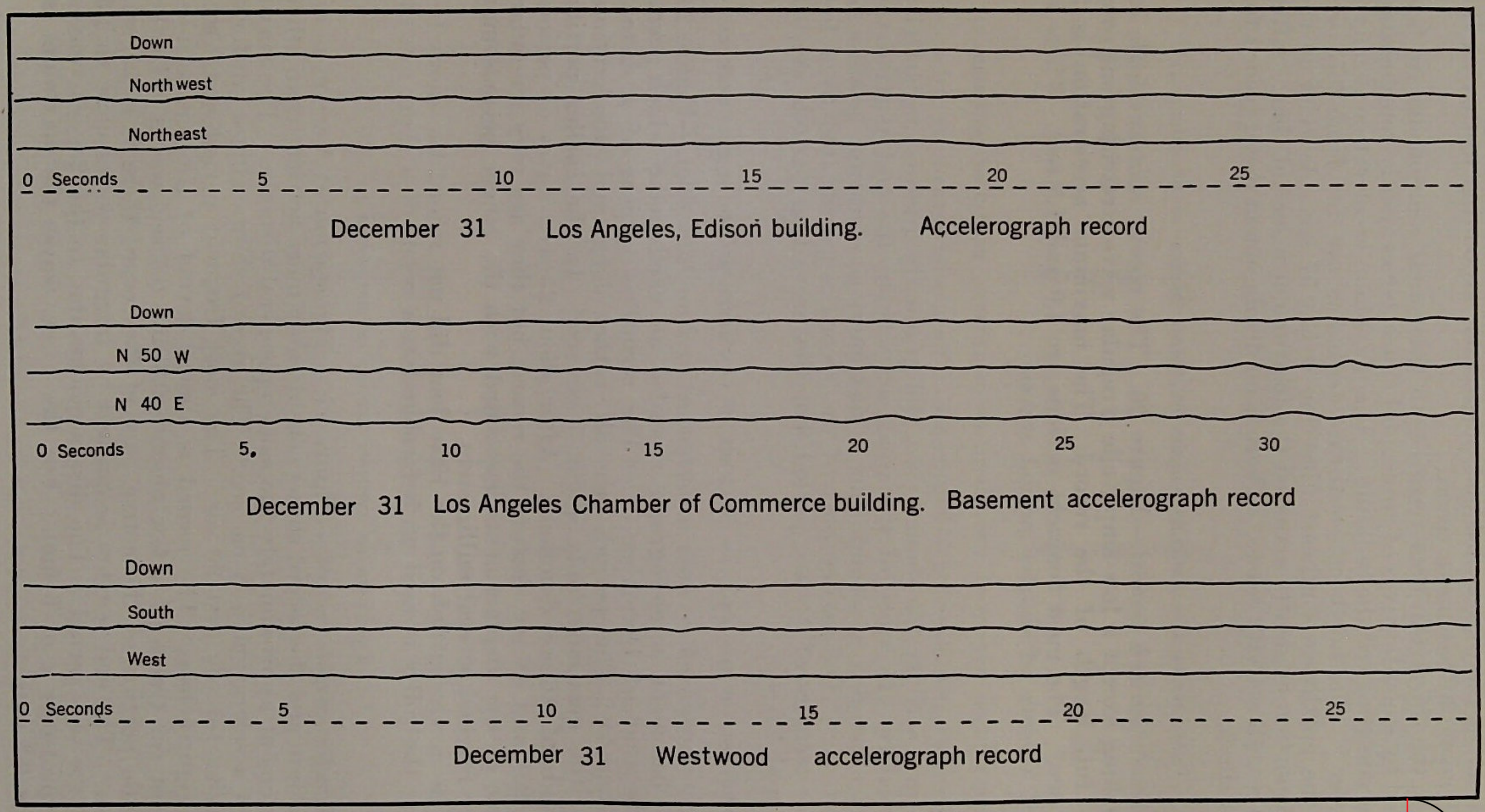


FIGURE 26.—Tracings of strong-motion seismograph records of the Lower California earthquake of December 31.

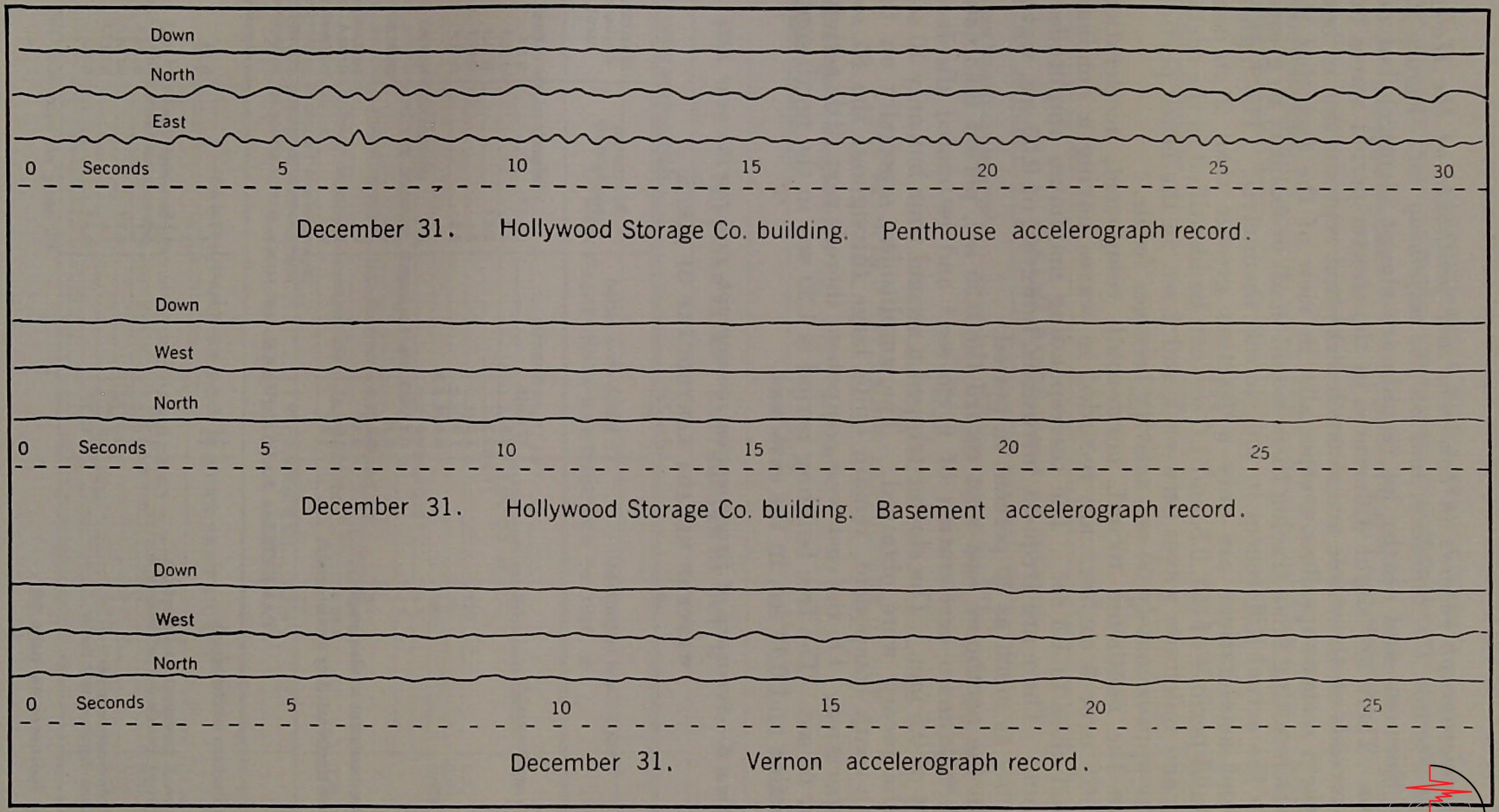


FIGURE 27.—Tracings of strong-motion seismograph records of the Lower California earthquake of December 31.

ANALYSIS OF HOLLYWOOD RECORD OF DECEMBER 31

Accelerograph records in basement and penthouse of the Hollywood Storage Co. building, and on the adjoining lot.—Figure 27. The basement and nearby lot records are almost identical, but not quite. There are slight differences in the shorter-period waves but the records on the whole are so much alike that reproduction of both of them seems superfluous, especially in view of the fact that the errors resulting from tracing them would in all probability be greater than the actual differences in the records themselves. The highest ground accelerations are only a fraction greater than 2 cm/sec.^{2} Ground periods of 0.5, 0.8, and 1.0 sec. can be identified in the earlier part and indefinite waves between 1 and 2 sec. in the latter portion. After approximately 60 sec. activity becomes feeble.

On the penthouse record, north-south component, accelerations slightly over 6 cm/sec.^{2} are recorded in waves having a dominant period close to 1.3 sec. The corresponding maximum amplitude is 2.5 mm. There are frequent intrusions, however, of 0.55 sec. waves, varying as much as 20 percent in period.

On the penthouse east-west record the 0.55 sec. period dominates with maximum acceleration of 6 cm/sec.^{2} and estimated displacement of 0.5 mm. The starter tripped a second time but only 10 sec. of the record were obtained. The amplitudes, especially on the north-south component, remain quite large throughout the 85 sec. of operation. On the east-west component there is very little activity after 60 sec. The free building period is 1.20 sec. in the north-south direction and 0.49 sec. in the east-west.

TABLE 3.—*Summary of strong-motion seismograph data for the year 1934*[1]

Station and instrument	Earth-wave period	Maximum acceleration	Maximum displacement
	Seconds	*Cm/sec.*^{2}	*Cm*
WESTERN NEVADA EARTHQUAKE OF JAN. 30			
Bishop accelerograph	12 to 16	0.5 [2 3]	2.5.[4]
	2.2	1.8	0.22.[3]
	1.3	2.6 [3]	0.11.[4]
	1.2	5	0.18.[3]
	1.0	4.3	0.11.[4]
	0.65 [6], 0.6		
	0.5	3	0.01.[4]
	0.4 [6], 0.3, 0.2 [6]		
	0.15	2	0.001.[3]
	0.1 [6]		
San Jose basement accelerograph	2.3 [2]	1.5	0.02.[3]
	1.5 [2]	1.5	0.084.[3]
San Jose thirteenth-floor accelerograph	1.6 [7]	9	0.57.[3]
PARKFIELD EARTHQUAKE OF JUNE 7			
Santa Barbara accelerograph	2 [8]		
	1 [5]	4	0.1.[3]
		1 [6]	
Hollywood, basement accelerograph		1 [2 9]	
Hollywood, penthouse accelerograph	1.29 [7]	2.5	0.11.[3]
	0.51 [7]	2.1	0.014 [3]
	0.5 [2 6]	0.7 [2]	0.004.[3]
Pasadena accelerograph	1 [2]	1 [2]	0.02.[2 3]
Pasadena displacement meter	1 to 2	3.7 [3]	0.21.

See footnotes on page 90.

TABLE 3.—*Summary of strong-motion seismograph data for the year 1934*—Con.

Station and instrument	Earth-wave period	Maximum acceleration	Maximum displacement
	Seconds	*Cm/sec.*[2]	*Cm*
EARTHQUAKE OF JULY 6 NEAR EUREKA			
Eureka accelerograph	0.32 [2]	19 [2]	0.05.[2 3]
	0.12 [2 6]	4 [2]	0.001.[2 3]
Eureka displacement meter	15.3 [2]	0.14 [2 3]	0.8.[2]
	12.4 [2]	0.21 [2 3]	0.8.[2]
	10.4 [2]	0.29 [2 3]	0.8.[2]
	3.5	1.6 [3]	0. 5.
	2.8	2.5 [3]	0. 5.
Ferndale accelerograph	0.9	13	0. 27.[3]
	0.67	7	0.08.[3]
	0.43 [5 6]	5	0.02.[3]
	0.41	17	0.07.[3]
	0 22	25	0.031.[3]
	0.20	13	0.013.[3]
PANAMA EARTHQUAKE OF JULY 17			
Balboa Heights accelerograph	2.0	4 [2]	0.4.[2 3]
	0.8		
	0.6	7	0.06.
	0.25 [2]		
SAN FRANCISCO BAY REGION EARTHQUAKE OF OCT. 2			
Golden Gate Park accelerograph	0.11, 0.08		
		5	
Oakland accelerograph	0.5 to 0.6 [5]		
	0.10 to 0.12	2	0.0005.[3]
IMPERIAL VALLEY EARTHQUAKE OF OCT. 15			
El Centro accelerograph	0.1 to 0.2	4	
	0.08		
LOWER CALIFORNIA EARTHQUAKE OF DEC. 30			
El Centro accelerograph	2.0, [6 7] 1.9 [6]		
	1.8	2.5	2.0.
	1.2, [6] 1.[5] 1.0[6], 0.5 or 0.6. [5] 0.5 [6 7].		
	0.25 [7]	175	0.3.[3]
	0.25 [6]	50	0.08.
	0.10 [6 7]	100	0.025.
San Diego accelerograph	0.20 to 2.5,[5] 0.12 [8]	4 [2]	
Los Angeles subway terminal, basement accelerograph.	1 [2]	1 [2]	
Los Angeles subway terminal, 13th-floor accelerograph.	0.75, 0.3, 0.2, 0.1	2 [2]	
Los Angeles subway terminal, basement displacement meter.	11, 3.0, 1.5, 1.0	0.08 [3]	0.25.
Hollywood, basement accelerograph		1 [2]	
Hollywood, penthouse accelerograph	1.2 to 1.3, 1.0, 0.55	3 or 4	
Hollywood, lot accelerograph		1 [2]	
EARTHQUAKE OF DEC. 30 NEAR SANTA CRUZ			
San Jose basement accelerograph	5 to 6, 0.2, 0.1		
San Jose 13th-floor accelerograph	1.5, 1.4, 1.3, 1.0	6	0.04. [3]
	0.55 [7]	9 or 10	0.07. [3]
	0.55 [6]	3.5 [2]	0.03. [3]
	0.25, 0.05 [6 8 10]		

See footnotes on page 90.

TABLE 3.—*Summary of strong-motion seismograph data for the year 1934*—Con.

LOWER CALIFORNIA EARTHQUAKE OF DEC. 31

Station and instrument	Earth-wave period	Maximum acceleration	Maximum displacement
	Seconds	*Cm/sec.*[2]	*Cm*
San Diego accelerograph	2.0,[2] 1.5,[2] 1.0 [2]		
	0.6 [2]	6	0.05.[2 3]
	0.15 [2]		
		8	
			0.30.[2 3]
Long Beach accelerograph	2.0, 1.5, 1.2		
		2	
Los Angeles Chamber of Commerce, basement accelerograph.	3.0,[5] 2.0,[5] 1.5,[5] 0.6		
		3	
Vernon accelerograph	2.5	2	0.2 or 0.3.[3]
	2.0,[5] 1.5 [5]		
	1.0	3	0.08.[2 3]
	0.5,[5] 0.3 [5]		
Los Angeles Edison Building, basement accelerograph.	1.5, 1.0		
		2	
Westwood accelerograph	1.7,[7] 1.1,[7] 0.6,[7] 0.3 [8]		
		2	
Hollywood, basement accelerograph	1 to 2,[5] 1.0, 0.8, 0.5		
		2	
Hollywood, penthouse accelerograph	1.3	6	0.25.[3]
	0.55 [2]	6	0.05.[3]
Los Angeles subway terminal, basement accelerograph.[8]			
Los Angeles subway terminal, 13th-floor accelerograph.	0.75,[7] 0.57 [7]		
		2	

[1] This tabulation does not attempt to combine the 2 horizontal components. See text for more detail and descriptions of the seismograms.
[2] Approximate value.
[3] Computed from the measured or previously computed acceleration or displacement by by means of $a=\frac{4\pi^2 A}{T^2}$, in which a is the maximum acceleration, T the period, and A the displacement. In the case of waves not of simple harmonic form the results obtained by use of this formula are only approximate.
[4] Computed by integration.
[5] Poorly defined waves.
[6] On the vertical component.
[7] Clearly defined motion.
[8] Very weak waves.
[9] Too irregular for periods to be discerned.
[10] Due to machinery.
[11] Record lost.
[12] Similar to basement record.

TABLE 4.—*Instrumental constants of strong-motion seismographs in 1934*

WESTERN NEVADA EARTHQUAKE OF JAN. 30

Station and instrument	Orientation of instrument [1]	Pendulum period	Static magnification	Sensitivity [2]	Damping ratio	Instrument number [3]
		Sec.		*Cm*		
Bishop accelerograph [4]	S.[1]–N	0.100	108	2.74	10:1	T19
	E.–W	.100	107	2.71	8:1	L36
	Up–Down	.100	109	2.75	8:1	V23
San Jose basement accelerograph [5]	S. 30° E.–N. 30° W	.098	107	2.61	(6)	T51
	N. 60° E.–S. 60° W	.100	110	2.78	(6)	L50
	Up–Down	.098	103	2.51	(6)	V49
San Jose 13th floor accelerograph [5]	S. 30° E.–N. 30° W	.099	106	2.62	7:1	T1
	N. 60° E.–S. 60° W	.100	107	2.71	12:1	L22
	Up–Down	.098	102	2.45	[7] 10:1	V27

See footnotes on page 92.

TABLE 4.—*Instrumental constants of strong-motion seismographs in 1934*—Con.

Station and instrument	Orientation of instrument [1]	Pendulum period	Static magnification	Sensitivity [2]	Damping ratio	Instrument number [3]
		Sec.		*Cm*		
PARKFIELD EARTHQUAKE OF JUNE 7						
Santa Barbara accelerograph	S.–N	0.099	107	2.66	7:1	T6
	E.–W	.098	108	2.61	6:1	L24
	Up–Down	.100	102	2.57	7:1	V11
Hollywood basement accelerograph [5]	S.–N	.099	111	2.77	8:1	T26
	E.–W	.098	116	2.82	10:1	L9
	Up–Down	.100	108	2.75	9:1	V28
Hollywood penthouse accelerograph [5]	S.–N	.099	113	2.78	6:1	L3
	W.–E	.100	111	2.81	6:1	T18
	Up–Down	.101	106	2.73	8:1	V25
Pasadena accelerograph [4 5]	S.–N	.099	107	2.67	9:1	L37
	W.–E	.101	110	2.82	9:1	T48
	Up–Down	.099	113	2.82	5:1	V47
Pasadena displacement meter [5]	NE.–SW	10.0	1.14	-------	8:1	R17
	SE.–NW	10.0	1.14	-------	7:1	L17
EUREKA EARTHQUAKE OF JULY 6						
Eureka accelerograph [5]	S.–N	0.102	111	2.92	8:1	T8
	E.–W	.098	109	2.65	6:1	L13
	Up–Down	.098	101	2.47	8:1	V29
Eureka displacement meter [4 5]	S.–N	10.0	1.14	-------	25:1	R13
	W.–E	9.7	1.14	-------	18:1	L13
Ferndale accelerograph [4]	NW.–SE	.099	107	2.67	6:1	T15
	SW.–NE	.099	113	2.81	7:1	L4
	Up–Down	.097	101	2.42	10:1	V10
PANAMA EARTHQUAKE OF JULY 17						
Balboa Heights accelerograph [4]	S.–N	0.101	112	2.89	([6])	T75
	E.–W	0.101	116	2.99	3:1	L74
	Up–Down	0.105	110	3.08	([6])	V73
SAN FRANCISCO BAY REGION EARTHQUAKE OF OCT. 2						
Golden Gate Park accelerograph	N.–S	0.099	108	2.68	7:1	L35
	E.–W	0.103	104	2.79	8:1	T31
	Up–Down	0.098	106	2.58	10:1	V14
Oakland accelerograph	N. 25° E.–S. 25° W	0.102	107	2.82	8:1	L33
	S. 65° E.–N. 65° W	0.099	106	2.63	11:1	T16
	Up–Down	0.100	103	2.60	11:1	V12
IMPERIAL VALLEY EARTHQUAKE OF OCT. 15						
El Centro accelerograph	N.–S	0.098	110	2.68	8:1	L68
	E.–W	0.101	105	2.72	10:1	T69
	Up–Down	0.100	103	2.61	13:1	V67
LOWER CALIFORNIA EARTHQUAKE OF DEC. 30						
El Centro accelerograph	N.–S	0.098	110	2.68	12:1	L68
	E.–W	0.100	105	2.66	10:1	T69
	Up–Down	0.100	103	2.61	10:1	V67
San Diego accelrograph	S.–N	0.101	111	2.37	12:1	T72
	E.–W	0.100	106	2.68	9:1	L71
	Up–Down	0.096	104	2.43	11:1	V70
Los Angeles subway terminal basement accelerograph.[5]	SE.–NW	0.097	109	2.60	10:1	L91
	SW.–NE	0.101	105	2.71	11:1	T101
	Up–Down	0.097	109	2.60	16:1	V111
Los Angeles subway terminal basement displacement meter.[5]	N.–S	9.94	1.14	-------	12:1	R15
	E.–W	10.00	1.14	-------	21:1	L15
Los Angeles subway terminal 13th floor accelerograph.[5]	NE.–SW	0.094	114	2.55	8:1	L92
	SE.–NW	0.100	112	2.83	9:1	T102
	Up–Down	0.100	104	2.63	6:1	V112
Hollywood basement accelerograph [5]	S.–N	0.097	100	2.38	9:1	T105
	E.–W	0.097	108	2.57	23:1	L95
	Up–Down	0.097	112	2.67	22:1	V115

See footnotes on page 92.

TABLE 4.—*Instrumental constants of strong-motion seismographs in 1934*—Con.

LOWER CALIFORNIA EARTHQUAKE OF DEC. 30—Continued

Station and instrument	Orientation of instrument [1]	Pendulum period	Static magnification	Sensitivity [2]	Damping ratio	Instrument number [3]
		Sec.		*Cm*		
Hollywood penthouse accelerograph [5]	S.–N	0.099	112	2.78	8:1	L93
	W.–E	0.098	106	2.58	8:1	T103
	Up–Down	0.097	113	2.69	6:1	V113
Hollywood lot accelerograph [5]	S.–N	0.096	101	2.35	8:1	T104
	E.–W	0.101	107	2.76	11:1	L94
	Up–Down	0.098	107	2.60	7:1	V114
SANTA CRUZ EARTHQUAKE OF DEC. 30						
San Jose basement accelerograph [5]	N. 60° E.–S. 60° W	0.102	107	2.82	10:1	L50
	S. 30° E.–N. 30° W	.098	109	2.65	10:1	T51
	Up–Down	.099	103	2.56	10:1	V49
San Jose 13th floor accelerograph [5]	N. 60° E.–S. 60° W	.101	104	2.69	12:1	L22
	S. 30° E.–N. 30° W	.100	105	2.66	9:1	T1
	Up–Down	.099	102	2.53	11:1	V27
LOWER CALIFORNIA EARTHQUAKE OF DEC. 31						
San Diego accelerograph	S.–N	0.101	111	2.37	12:1	T72
	E.–W	.100	106	2.69	9:1	L71
	Up–Down	.096	104	2.43	11:1	V70
Long Beach accelerograph	N.–S	.098	110	2.68	10:1	L56
	E.–W	.098	101	2.46	8:1	T57
	Up–Down	.098	107	2.60	8:1	V55
Los Angeles Chamber of Commerce basement accelerograph.	S. 40° W.–N. 40° E	.099	103	2.56	9:1	T26
	S. 50° E.–N. 50° W	.098	116	2.82	9:1	L9
	Up–Down	.100	109	2.74	9:1	V28
Vernon accelerograph	S.–N	.098	107	2.60	10:1	T65
	E.–W	.099	107	2.66	9:1	L64
	Up–Down	.099	106	2.63	9:1	V66
Los Angeles, Edison building accelerograph.	SE.–NW	.098	110	2.68	12:1	L61
	SW.–NE	.100	106	2.68	13:1	T62
	Up–Down	.100	104	2.63	10:1	V63
Westwood accelerograph	S.–N	.097	107	2.55	12:1	T34
	E.–W	.100	107	2.71	9:1	L35
	Up–Down	.100	106	2.69	12:1	V30
Hollywood Storage Co. basement accelerograph.[5]	S.–N	.097	100	2.38	9:1	T105
	E.–W	.097	108	2.57	23:1	L95
	Up–Down	.097	112	2.67	22:1	V115
Hollywood Storage Co. penthouse accelerograph.[5]	S.–N	.099	112	2.78	8:1	L93
	W.–E	.098	106	2.58	8:1	T103
	Up–Down	.097	113	2.69	6:1	V113
Hollywood Storage Co. adjoining lot accelerograph.[5]	S.–N	.096	101	2.35	8:1	T104
	E.–W	.101	107	2.76	11:1	L94
	Up–Down	.098	107	2.60	7:1	V114
Los Angeles subway terminal basement accelerograph.[5]	SE.–NW	.097	109	2.60	10:1	L91
	SW.–NE	.101	105	2.71	11:1	T101
	Up–Down	.097	109	2.60	16:1	V111
Los Angeles subway terminal 13th floor accelerograph.[5]	NE.–SW	.094	114	2.55	8:1	L92
	SE.–NW	.100	112	2.83	9:1	T102
	Up–Down	.100	104	2.63	6:1	V112

[1] The direction on the left ("S" 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 an acceleration of $\frac{1}{10}$ gravity may be obtained by multiplying the sensitivity tabulated by 0.98. See last paragraph on page 62.

[3] All accelerometers have been changed over to the pivot type.

[4] The accelerographs at Balboa, Eureka, Ferndale, and Pasadena had not yet been equipped with tape recorders.

[5] Instruments at this station wired to start simultaneously.

[6] Very high.

[7] Approximate value.

[8] No good measurements.

DESCRIPTIONS OF STRONG-MOTION SEISMOGRAPH STATIONS

NOTE.—Descriptions of the following stations will be found in the preceding publication of this series, Serial 579, United States Earthquakes, 1933: Long Beach, Public Utilities Building; Pasadena, California Institute of Technology; San Jose, Bank of America Building; Vernon, Central Manufacturing District Terminal Building; and Westwood, University of California at Los Angeles.

BALBOA HEIGHTS, CANAL ZONE

ADMINISTRATION BUILDING

Accelerograph in basement

This building is located in lat. 8°57′39″ north, long. 79°33′29″ west, on a spur of the north slope of Ancon Hill, just off Ancon Boulevard, the principal avenue of the Pacific terminal of the Panama Canal. The ground floor is 180 feet by 330 feet and is shaped like the letter "E", the long axis being north 52°45′ west, true bearing. The accelerograph is in the basement of the northwesterly end of the building, in the regular seismograph room, which is 21 by 22 feet.

This three-story and basement building is of steel mill building framework, with concrete block partition walls, reinforced concrete floors, and plaster walls and ceilings. The foundation is a concrete slab on rhyolite rock; the whole hill is an intrusion of igneous material, the source of all concrete material in the Pacific Locks, and there are no signs of estuarine deposits and fills of the more usual Isthmian physiography down to sea level. The basement elevation is 36 meters above the ocean, which is less than ½ mile away. Operation of instrument was begun on March 22, 1934.

BISHOP

LOS ANGELES WATER DEPARTMENT OFFICE AND GARAGE

Accelerograph on ground floor

The building is one story high, of frame construction, well built, with a concrete floor. The accelerograph is located on the ground floor. The building is 48 by 100 feet, and is built directly on the ground which is alluvium, made up of a fairly tight clay.

The alluvium, which is at least several hundred feet deep, consists of river gravels and sands and lake beds in alternating horizontal layers, and rests on granite. The general structure is a basin produced by the dropping of a slice several miles wide between two north-south faults. On this depressed slice the alluvium has accumulated. The uppermost bed is soft soil. The ground-water level lies only 20 or 30 feet below the surface.

EL CENTRO

SOUTHERN SIERRA POWER CO. TERMINAL STATION

Accelerograph on first floor

The building is two stories high of massive concrete construction, heavily reinforced. The accelerograph is on the first floor under the stairway. On the same floor are two 5,000-kilovolt-ampere synchronous condensers, but they do not noticeably disturb the instrument, perhaps because of the heavy construction of the building. The building is 60 by 80 feet.

The alluvium beneath El Centro is certainly hundreds of feet deep, and perhaps several thousand. The surface material is soft silt. The alluvial strata consist mainly of silt and other soft lake beds with some beds of gravel and sand. This is material deposited by the Colorado River on its alluvial fan or delta. The alluvium at El Centro is part of a huge bed of loose detritus laid down in a trough formed by subsidence of slices several miles wide between branches of the San Andreas fault.

EUREKA

FEDERAL BUILDING

Accelerograph and displacement meter in basement

The building is brick and stone tied in to reinforced concrete girders. The dimensions are about 95 by 68 feet. There are three stories and a basement. The foundation is set directly on firm ground. The instruments, an accelerograph and a displacement meter, are located in the basement.

The material beneath the building is sand, clay, and gravel, principally terrace and estuarine deposits. The geology of the region is not well known. The bedrock surrounding Eureka is believed to belong to the Mesozoic era. Some of the rock is Chico sandstone of the Cretaceous, and some of it may belong to the Franciscan series—probably Jurassic. The active earthquake belt extends northward from the San Francisco Bay region off the coast of Eureka.

FERNDALE

TOWN HALL

Accelerograph on ground floor

The building is a two-story frame structure 70 by 33 feet, whose foundation rests directly on the ground. The accelerograph is located on the ground floor.

The material underlying the structure consists of unconsolidated sediments, probably alluvial. The vertical distance to bedrock is unknown, but the rock constituting the nearby hills is loosely cemented sandstone and shale. The rock of the region is believed to belong to the Wildcat formation of the Pliocene. The active earthquake belt of the San Francisco area extends into the sea off the coast near Ferndale.

HOLLYWOOD

HOLLYWOOD STORAGE CO. BUILDING

Accelerograph in basement, in penthouse, and adjoining Pacific Gas & Electric Co. lot.

The building is located on the west side of Highland Avenue just south of Santa Monica Boulevard, about one-half mile south of the business section of Hollywood. It is 14 stories high, 150 feet from ground to roof, with 2 penthouses and radio towers. The floor of the penthouse in which the accelerograph is installed is about 3 feet above the roof. The floor of the basement in which the other accelerograph is installed is about 12 feet below street level. The

building is of reinforced concrete construction, 50 feet by 217 feet, and is of simple rectangular plan with the longer sides directed east and west. The foundation is built on piles. The accelerograph on the adjoining Pacific Gas & Electric Co. lot is housed in a light, 6- by 9-foot galvanized-iron building. This building is located 112 feet west of the west wall of the Hollywood Storage Building. The three accelerographs are wired for simultaneous starting and time marking. The lot station was not established at the time of the June 7 earthquake.

The station is on rather coarse alluvium some tens of feet, or quite possibly several hundreds of feet in thickness resting on some hundreds or several thousands of feet of Tertiary sedimentary formations, which in turn rest on slates or possibly other crystalline bedrock. The material immediately beneath the station is soft alluvium. Deep parts of the alluvium consist of sands and gravels deposited as fan material by streams issuing from the south slope of the Santa Monica Mountain. The water table is probably some tens of feet below the surface.

LOS ANGELES

CHAMBER OF COMMERCE BUILDING

Accelerograph and strong-motion seismograph in basement; accelerograph on twelfth floor

The Chamber of Commerce Building is on the north side of Twelfth Street and extends from Broadway to Hill Street. The building proper is 10 stories high and has a 2-story penthouse on top of the roof. It is of steel frame construction, and is, roughly, 230 by 185 feet. The Weed seismograph is on a pier at the base of one of the columns in the exhibit room in the basement of the building. The accelerograph in the basement is in a room behind the display cases on the southwest side of the assembly room. The accelerograph on the twelfth floor is in a room east of the water tanks. The two accelerographs are wired for simultaneous starting.

The material immediately beneath the station is soft alluvium. Its thickness is probably at least some tens of feet and may attain several hundreds of feet. Beneath this alluvium lie some thousands of feet of late Tertiary unconsolidated marine sediments, folded and tilted. Beneath these may lie a considerable thickness of early Tertiary and possibly Cretaceous consolidated sediments and underlying these are the slates or other old bedrock formations. The water level is probably not more than a few tens of feet below the land surface.

LOS ANGELES

EDISON BUILDING

Accelerograph in semibasement

The Edison Building is situated on the corner of Fifth Street and Grand Avenue, which is one block west of the northwest corner of Pershing Square. The building is constructed of reinforced concrete with a steel frame, the foundation resting upon hardpan, which is a blue clay about 365 feet in thickness. The building is 150 feet in height, and has 13 floors. The instrument room is located near the center of the building on the basement level. The building is of the set-back type and approximately square plan.

The 365 feet of blue clay rests upon late Tertiary unconsolidated marine sediments which are highly folded and tilted, several thousands of feet in thickness. Below this is a considerable thickness of consolidated marine sediments of early Tertiary and Cretaceous, resting upon older bedrock. The water table is not far below the surface.

LOS ANGELES

SUBWAY TERMINAL BUILDING

Accelerograph and displacement-meter in train shed; accelerograph on 13th floor

The building is in the block bounded by Fourth, Fifth, Hill, and Olive Streets. The Subway Terminal Building is 186 by 241 feet, the upper stories consisting of several independent units. One accelerograph and displacement-meter are located in the portion of the train shed under Olive Street, west of the Subway Terminal Building, the portion of the shed housing the instrument being structurally independent of the main building. This instrument room is 64 feet below the street level and is constructed of reinforced concrete. It is on the station platform only a short distance from the track. The second accelerograph is located in the north wing near the center of the building, on the thirteenth floor. The instruments are wired together for simultaneous starting and synchronous time marks.

Alluvium is relatively thin or wanting at this station. At or immediately below the surface are the late Tertiary marine sediments, folded strongly, and beneath these is a section of rocks similar to that at the chamber of commerce station. Since alluvium is so thin or wanting here, a statement regarding water conditions is not particularly pertinent, but the water table is doubtless not far below the surface.

OAKLAND

CITY HALL

Accelerograph in basement

The instrument is located beneath the Fourteenth Street entrance, between sidewalk and building line, of the city hall, which faces eastward on Washington Street and lies between Fourteenth and Fifteenth Streets. The elevation of the ground is about 30 feet.

The building has 15 floors in addition to the mezzanine, the basement, and the cupola. It is constructed of reinforced concrete with facing of blocks of granite. The dimensions at the ground floor are 175 by 125 feet. The foundation is on piles which have been driven to a depth of about 50 feet in unconsolidated sediment.

Unconsolidated sediments, probably estuarine in character, underlie the city hall. The exposed rock west of the Hayward fault in Oakland, Piedmont, and Berkeley belongs to the Franciscan series, which is probably pre-Cretaceous. The Berkeley Hills east of the fault lie in a syncline of Tertiary sedimentaries and volcanics. The Hayward rift, a very active fault, passes along the base of the Berkeley Hills about 3½ to 4 miles east and a little north of the city hall. There is another fault in San Francisco Bay about 2 miles from the city hall, and other faults farther away.

SAN DIEGO

GAS PLANT

Accelerograph on ground floor

The San Diego Consolidated Gas & Electric Co. building, located between Eleventh and Twelfth Streets and between L Street and Imperial Avenue, is a one-story building, about 46 by 44 feet, built of brick, with good cement mortar, but not reinforced. There is a basement under part of the building. The accelerograph is in the calorimeter room on the first floor.

The foundation is upon sedimentary material of fairly hard sand and clay. Soft alluvium immediately underlies this locality, and its thickness is not less than some tens of feet. It presumably rests on a somewhat more consolidated alluvium which in turn probably rests on a thickness of some hundreds or thousands of feet of Tertiary and Cretaceous compact marine sediments. Beneath these is granite, but the depth to it is not known, other than that it is presumably not less than some hundreds of feet and probably not in excess of a few thousands of feet. The water table is not more than 20 feet below the surface.

SAN FRANCISCO

GOLDEN GATE PARK

Accelerograph

The accelerograph is located in the switch house for the illuminated waterfall of Golden Gate Park, which is situated just above the crest of the waterfall. The building is a small frame structure, 11 feet square and about 6½ feet high. It is built on solid rock.

The rock immediately under the building as exposed at the illuminated waterfall is sharply folded thin bedded chert of the Franciscan series. The San Andreas fault runs out into the ocean about 5 miles west of the station.

SANTA BARBARA

COURTHOUSE

Accelerograph in basement

The building is located in the block enclosed by Anacapa, Anapamu, Santa Barbara, and Figueroa Streets. It has two stories, a basement, and a tower. Its dimensions are approximately 370 by 300 feet. It is constructed of class "A" steel frame throughout with reinforced concrete exterior walls, floors, and roofs. The interior partitions are metal lath and plaster on steel studding. The accelerograph is located in the basement below the tower.

The foundation soil is alluvium, which is probably some tens of feet thick. It rests on Tertiary marine formations of compact type having a thickness of not less than several thousand feet. These rest, possibly at depths as great as fifteen or twenty thousand feet, on granite or other crystalline bedrock. The tertiary formations are highly faulted and stand at steep angles. The water table is probably 20 or 30 feet below the surface.

TILT OBSERVATIONS

The tilt observations described in "United States Earthquakes, 1933" were continued through 1934. The results are published in the Bureau's Special Publication No. 201, "Earthquake Investigations in California, 1934–1935."

ADDITIONS AND CORRECTIONS TO PREVIOUS PUBLICATIONS

1932. June 6. See The Eureka Earthquake of June 6, 1932 by Neil R. Sparks. Bulletin of Seismological Society of America, Vol. 26, No. 1, January 1936, page 13. Epicenter by Sparks 40°45′ north, 124°30′ west.

1932. December 20. See The First Preliminary Waves of the Nevada Earthquake of December 20, 1932, by Perry Byerly. Bulletin of the Seismological Society of America, Vol. 25, No. 1, January 1935, page 62. Epicenter by Byerly 38°48′ north, 117°59′ west.

1933. January 12: 22:20.* Berkeley reports Rossi-Forel IV at Ben Lomond, Boulder Creek, Felton, and Santa Cruz; Rossi-Forel III at Moss Landing and San Jose. Epicenter near Wrights.

1933. February 2: 19:25.* Berkeley reports Rossi-Forel IV at The Pines. Felt at Woodlake.

1933. February 26: 1:35.* Berkeley reports epicenter near San Juan.

1933. March 27: 2:45.* Berkeley reports 2 separate shocks.

1933. March 27: 5:02.* Berkeley reports Rossi-Forel IV at Knowles and Pineridge, Calif., and at Candelaria, Nev.

1933. April 11: 22:30 approximately. Felt slightly at Lindsaya and Porterville.

1933. April 12: 2:03. Berkeley reports Rossi-Forel IV at Tulare and Strathmore. Aftershock about 4:00.

1933. April 18: 23:26. Berkeley reports epicenter about 5 miles northwest of Danville. Windows rattled in San Leandro and East Oakland.

1933. May 16: 3:45.* Berkeley reports Rossi-Forel VI–VII at Mission, San Jose, and Walnut Creek; V at Irvington, Palo Alto, and Southampton Shoal Light; IV at Benicia, Burlingame, Gilroy, Healdsburg, Lodi, Pittsburg, and St. Helena; III at Brentwood, Calistoga, and Sonoma.

1933. May 26: 21:29. Aftershock of May 16 earthquake according to Berkeley. Felt in Niles.

1933. June 3: 18:44. Epicenter about 3 miles from Lick Observatory according to Berkeley. Rossi-Forel IV at Burlingame.

1933. June 19: 22:02. Berkeley reports Rossi-Forel IV at Paraiso Springs and epicenter about 15 miles southeast of Monterey.

1933. June 22: 4:37. Berkeley reports epicenter probably in Mono County. Rossi-Forel IV at Burton Valley; III at Bakersfield.

1933. June 23: 11:55. Berkeley reports Rossi-Forel IV at Fairfield, Mariposa, Quincy, Verona, and Wolf; III and under at Big Oak Flat; I–II at Camp Rogers.

1933. June 25: 12:45. Berkeley reports Rossi-Forel IV at Agua Caliente, Camino, Campo Seco, Corning, June Lake, Mendocino, Merrimac, Monte Rio, North Fork, and Southampton Shoal Light; III at Cisco; I–II at Maxwell, Pinnacles, and Selma. In United States Earthquakes, 1933, page 16, change area affected from 40,000 square miles to 70,000 square miles.

1933. July 16: 16:32.* Berkeley reports Rossi-Forel V–VI at Carmel. Epicenter a few miles north of Watsonville.

1933. July 18: 1:06.* Berkeley reports Rossi-Forel IV at Berkeley and Livermore. Epicenter about 6 miles west of Livermore.

1933. August 10: 15:41.* Berkeley reports Rossi-Forel IV at East Oakland and Hayward. Epicenter very near Niles.

1933. September 22: 20:48. Berkeley reports Rossi-Forel II–III at Hollister. Epicenter about 30 miles from Lick Observatory.

1933. September 28: 3:55. Berkeley reports Rossi-Forel IV at Harris.

1933. October 2: 1:10.* Rossi-Forel VI at Fullerton, Long Beach, San Pedro, and Walnut Park; IV at Altadena, Burbank, and Eagle Rock; III or less at Imperial.

1933. November 10: 9:01. Felt by a few in Eureka.
1933. November 13: 13: 22. 2 slight shocks felt at Long Beach, Los Angeles, and Pasadena.
1933. December 2: 15:19. Felt slightly at Santa Clara. Epicenter about 5 miles northwest of Lick Observatory according to Berkeley.
1933. December 11: 1:57.* Berkeley reports epicenter about 7 miles southeast of Watsonville; Rossi-Forel IV at Gilroy, Salinas, and San Jose.
1933. December 13: 7:35.* Berkeley reports epicenter about 7 miles southeast of Watsonville; Rossi-Forel II–III at Boulder Creek, Oakland, and Point Pinos.

1934 and earlier. See Seismic History of the Puget Sound Basin by D. C. Bradford. Bulletin of the Seismological Society of America, Vol. 25, No. 2, April 1935, page 138.

PUBLICATION NOTICES

To make immediately available the results of its various activities to those interested, the Coast and Geodetic Survey maintains mailing lists of persons and firms desiring to receive notice of the issuance of charts, Coast Pilots, maps, and other publications.

Should you desire to receive such notices, you may use the form given below, checking the lists covering the subjects in which you are interested.

(Date) _____

DIRECTOR, U. S. COAST AND GEODETIC SURVEY,
Washington, D. C.

DEAR SIR: I desire that my name be placed on the mailing lists indicated by check below, to receive notification of the issuance of publications referring to the subjects indicated:

- ☐ 109. Astronomic work.
- ☐ 109–A. Base lines.
- ☐ 109–B. Coast Pilots.
- ☐ 109–C. Currents.
- ☐ 109–D. Geodesy.
- ☐ 109–E. Gravity.
- ☐ 109–F. Hydrography.
- ☐ 109–G. Leveling.
- ☐ 109–H. Nautical Charts.
- ☐ 109–I. Oceanography.
- ☐ 109–J. Traverse.
- ☐ 109–K. Seismology.
- ☐ 109–L. Terrestrial magnetism.
- ☐ 109–M. Tides.
- ☐ 109–N. Topography.
- ☐ 109–O. Triangulation.
- ☐ 109–P. Cartography.
- ☐ 109–R. Aeronautical charts.

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CUT ON THIS LINE

A catalog of the publications issued by all bureaus of the Department of Commerce may be had upon application to the Chief, Division of Publications, Department of Commerce, Washington, D. C. It also contains a list of libraries located in various cities throughout the United States, designated by Congress as public depositories, where all publications printed by the Government for public distribution may be consulted.

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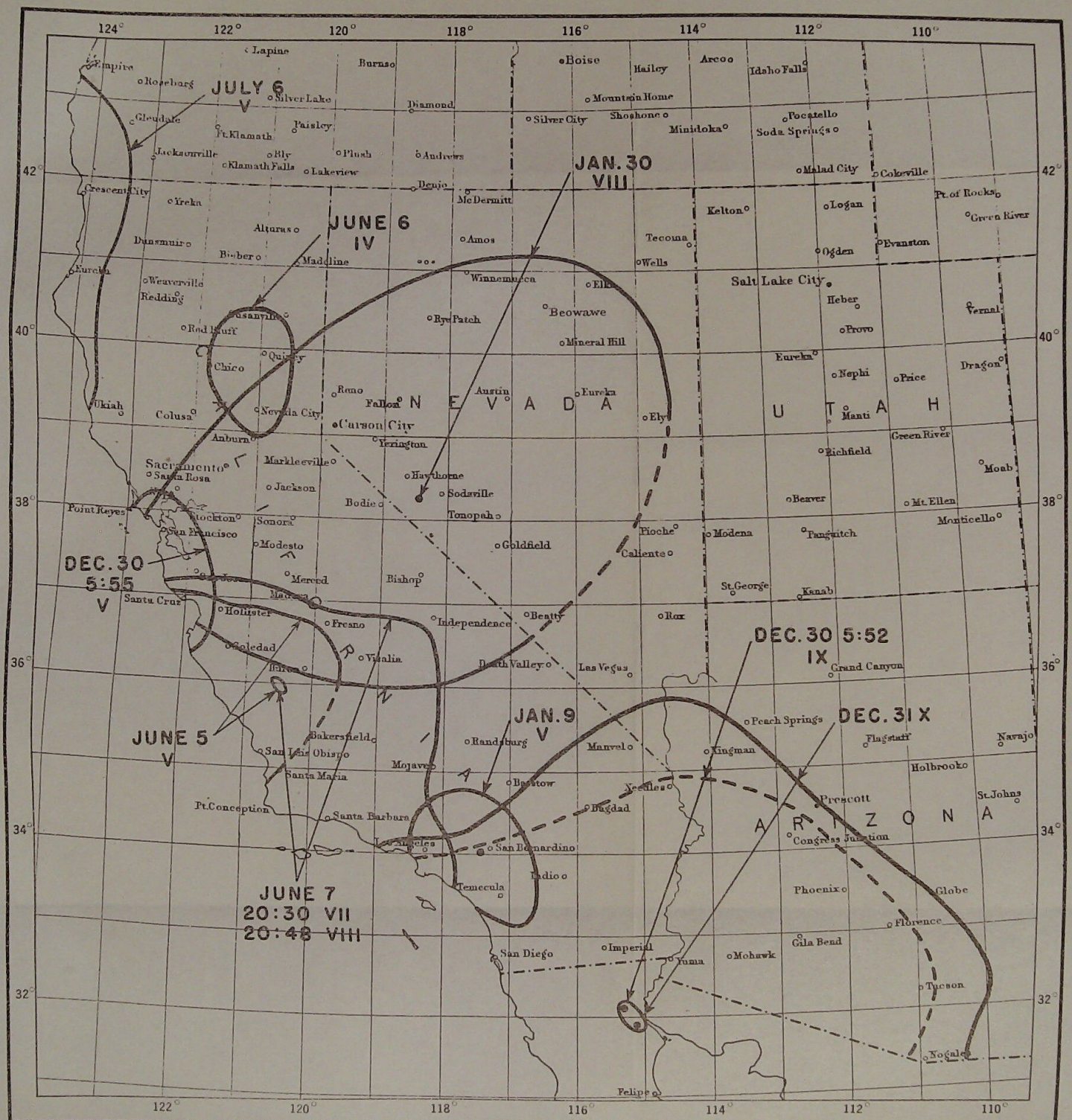

FIGURE 7.—Areas affected by the California earthquakes of January 9, June 5, 6, 7, 7, July 6, December 30; Lower California earthquakes of December 30,