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UNITED STATES EARTHQUAKES 1936

SERIAL No. 610

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

U. S. DEPARTMENT OF COMMERCE
DANIEL C. ROPER, Secretary
COAST AND GEODETIC SURVEY
Leo Otis Colbert, Director

International Seismological Centre

Serial No. 610

UNITED STATES EARTHQUAKES

1936

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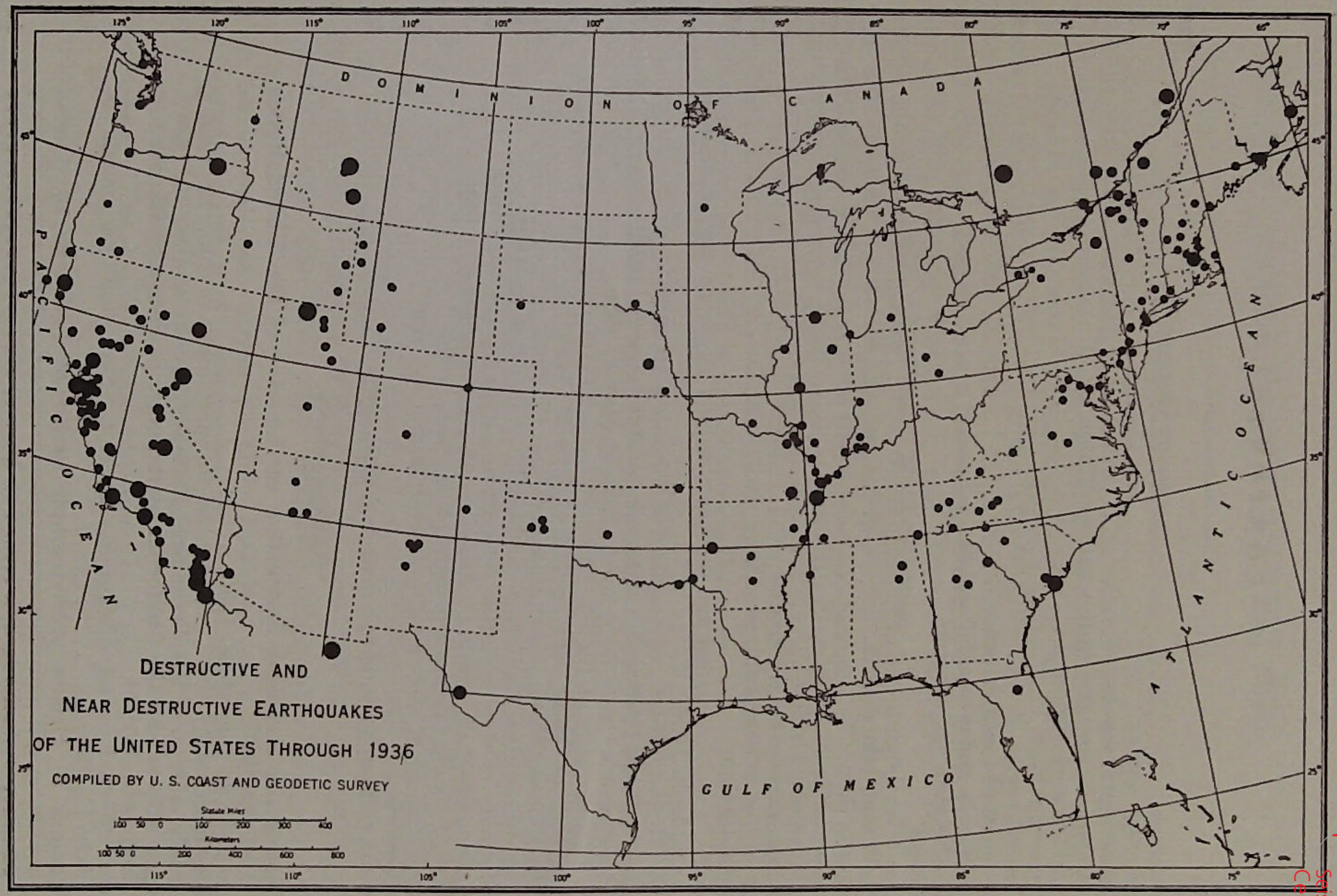

FIGURE 1.—Destructive and near-destructive earthquakes in the United States through 1936.

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UNITED STATES EARTHQUAKES, 1936

INTRODUCTION

This publication is a summary of earthquake activity in the United States and the regions under its jurisdiction for the calendar year 1936. The history of the more important shocks of the country appears in two publications of the Bureau, Special Publication No. 149, Earthquake History of the United States Exclusive of the Pacific Region, and Special Publication No. 191, Destructive and Near Destructive Earthquakes in California and Western Nevada, 1769–1933. The former publication has been revised and numbered Serial 609 and should be available for distribution about the same time this publication is released. It will cover the history of the more important shocks through 1937 and will include chapters on the Washington-Oregon region and Alaska. The title will be slightly changed so that it will clearly indicate that, combined with the California publication, it will form a complete earthquake history of the country, including Alaska, through 1937. The new title of Serial No. 609 will be "Earthquake History of the United States. Part I: Continental United States (Exclusive of California and Western Nevada) and Alaska." When a new edition of Special Publication No. 191 becomes necessary, it will also bear Serial No. 609 and be known as Earthquake History of the United States. Part II: Destructive and Near-Destructive Earthquakes in California and Western Nevada.

The history of minor activity is covered largely in a series of references listed in Special Publication No. 149, in recent serial reports of the U. S. Coast and Geodetic Survey, in the Holden and McAdie catalogs [1] of the Pacific coast earthquakes, and in a forthcoming publication of the Seismological Society of America. The last three of these publications also give very detailed information for all California earthquakes.

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 local seismological institutions as indicated in the lists of earthquakes for those regions. Earthquakes adjacent to the United States and felt within its borders are described only in a general way when detailed descriptions are published elsewhere.

Beginning with this issue an epicenter map of the United States will appear in each annual report of the series showing all of the more important earthquakes of the country through the year covered by the report.

Cooperation of investigators solicited.—In order that these publications may be as complete as possible in the more important details of

[1] Smithsonian Miscellaneous Collections, 1089. A Catalog of Earthquakes on the Pacific Coast, 1769–1897. Edward S. Holden. Smithsonian Miscellaneous Collections, 1721. Calatog of Earthquakes on the Pacific Coast, 1897–1906. Alexander G. McAdie.

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 advance notices be furnished of results obtained so that abstracts and references may be inserted in these reports. An advance notice of a planned investigation might save considerable overlapping of effort and would give wider publicity to the work of the investigator.

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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 at St. Louis, Mo.
The Seismological Field Survey of the Bureau at San Francisco, cooperating with the Seismological Laboratory of the Carnegie 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 reports from Alaska are 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 Field Survey at San Francisco, canvasses areas affected by shocks of unusual intensity, unless such work is undertaken by other organizations such as the Jesuit Seismological Association or by State and other interested geologists. In this way the extent and the maximum intensities of all heavy shocks are determined and the data are usually sufficient to construct isoseismal maps or, at least, maps of the affected areas. The seismological station of the University of California, Berkeley, 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. 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.

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MODIFIED MERCALLI INTENSITY SCALE OF 1931

(Abridged)

I. Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel scale.)

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel scale.)

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale.)

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. (IV to V Rossi-Forel scale.)

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel scale.)

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale.)

VII. Everybody runs outdoors. Damage **negligible** in buildings of good design and construction; **slight** to moderate in well-built ordinary structures; **considerable** in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars. (VIII—Rossi-Forel scale.)

VIII. Damage **slight** in specially designed structures; **considerable** in ordinary substantial buildings with partial collapse; **great** in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars. (VIII+ to IX— Rossi-Forel scale.)

IX. Damage **considerable** in specially designed structures; well-designed frame structures thrown out of plumb; **great** in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel scale.)

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks. (X Rossi-Forel scale.)

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

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

In the case of California, earthquakes reported as feeble are not plotted on the epicenter map of the United States nor are minor

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.

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Time is indicated as continuous from 0 to 24 hours, beginning and ending at midnight. Local standard time is used except in table 1, "Summary of Instrumental Epicenters."

Within the United States the same regional arrangement has been followed as in the revised edition of Special Publication No. 149, previously mentioned.

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

INSTRUMENTAL RESULTS

Teleseismic results.—Epicenters given in the noninstrumental results and in the tabulation on page 27 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 27 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 regions of strong earthquakes. The instrumental equipment is essentially different in type from teleseismic equipment although the principles involved are the same. Strong-motion instruments are installed mostly in the urban areas of California, and operate only when actuated by the movements of a strong earthquake.

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

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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.

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NONINSTRUMENTAL RESULTS

EARTHQUAKE ACTIVITY IN THE VARIOUS STATES

Arizona: A slight local shock on January 12 and a strong one on February 14.

California: Moderately strong or widespread shocks occurred on February 23, May 10, June 3, September 23 and 24, and December 25. In addition, there was unusual seismic activity during May in the Mount Lassen region. The usual number of minor tremors were reported.

Georgia: A slight shock near the North Carolina border on January 1.

Idaho: A slight shock on January 14.

Missouri: Slight local shocks on February 16 and December 20.

Montana: In the Helena area moderate to strong shocks occurred on May 13, 21, June 3, 11, 12, 14, July 29, September 4, October 9, and December 13, a few of them strong enough to cause slight additional damage. In the Marysville area there was considerable activity in March and October and a sharp jolt on June 22. Moderate shocks occurred elsewhere on January 11, February 6, 14, 15, June 27, September 7, and October 31. See page 56 of Serial No. 600 "United States Earthquakes, 1935" for chart showing total number of aftershocks recorded at Helena in 1936.

Nevada: Six shocks were reported at Reno on May 9–10; 12 weak to fairly heavy shocks in the Boulder Dam area in September, November, and December; and two slight shocks near Winnemucca on September 20 and 21.

New Hampshire: Moderate shocks on June 14 and November 8.

New Mexico: Strong local shock on January 7, two weak ones on September 9.

New York: Moderate shock on June 20.

North Carolina: A slight shock near the Georgia border on January 1. (Also listed under Georgia.)

Ohio: Local disturbance of doubtful seismic origin on January 31.

Oklahoma: Slight shocks on March 14 and July 11.

Oregon: Strongest shock of the year centered near Washington border near Walla Walla, on July 15. Affected area more than 100,000 square miles. Intensity VII with some damage. Many aftershocks.

Pennsylvania: Weak local shock on August 26.

South Carolina: Weak local shock on December 29.

South Dakota: Slight local shock on October 30.

Tennessee: Slight shock on August 2.

Texas: A widespread shock in the Panhandle region on June 19; two local shocks in El Paso on August 7 and October 15.

Utah: Moderate shocks on May 9 and September 2.

Vermont: Weak shock on November 8.

Virginia: Slight local shock on April 9.

Washington: The destructive earthquake of July 15 was felt over a large part of the State and caused slight damage in the epicentral region within the State. Aftershocks were also felt. In the Puget Sound area slight to fairly strong shocks were reported on March 22, June 20, 20, July 24, 25, and 26.

Wyoming: Slight to moderate shocks on January 14 and October 24.

Alaska: One of the strongest shocks in several years occurred on October 22 along the south central coast. About 60 other shocks reported were fairly uniformly distributed throughout the year.

Hawaii: Only five shocks are listed, all of them in the active volcanic region of the Island of Hawaii.

Philippine Islands: Fifteen shocks are listed, none of them of outstanding character.

Puerto Rico: Only two local shocks are listed.

Panama Canal Zone: Nine shocks are listed, but only one, on May 6, was strong enough to cause slight damage and considerable alarm.

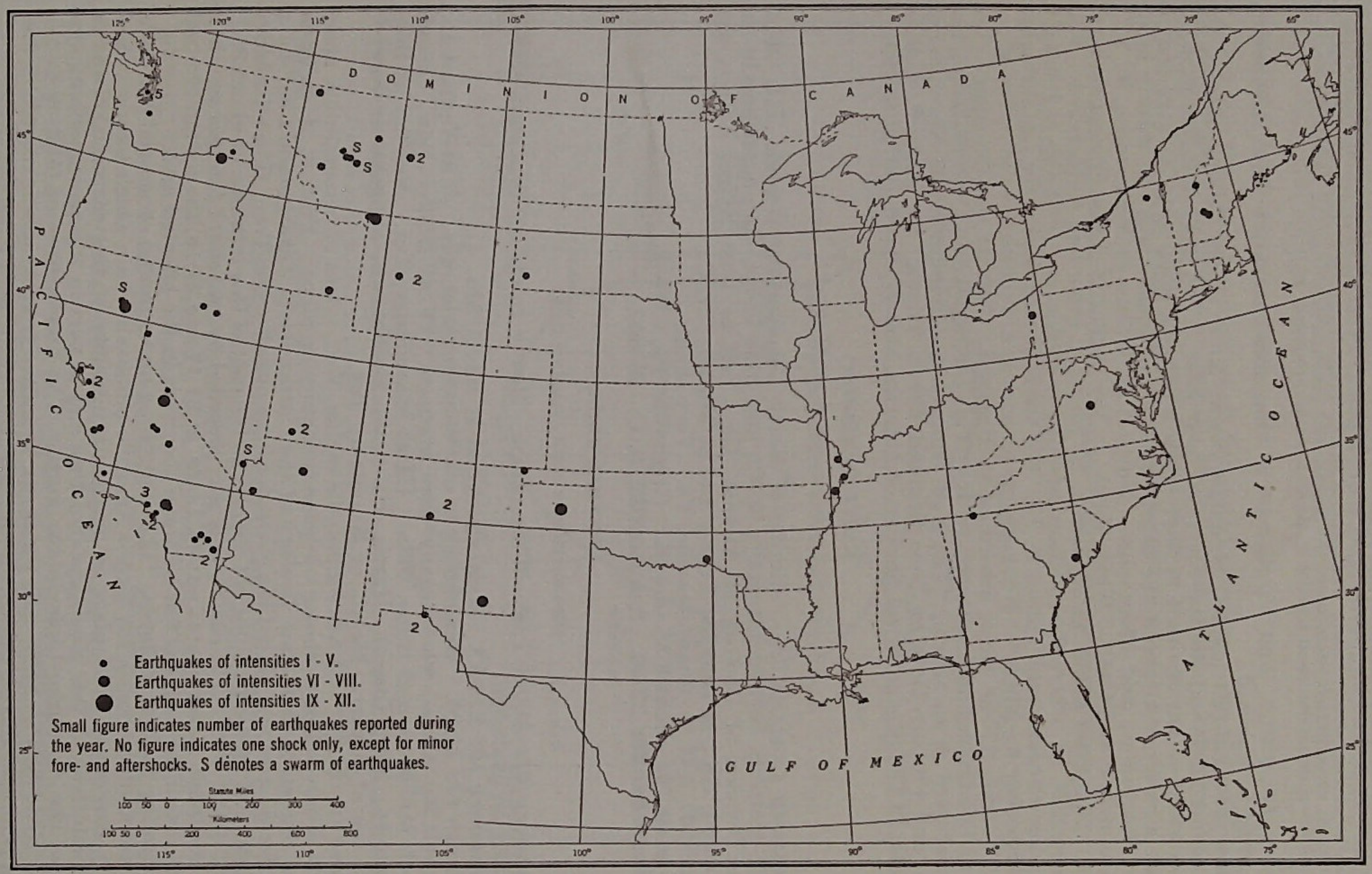

FIGURE 2.—Earthquake epicenters, 1936.

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NORTHEASTERN REGION

[75th Meridian or eastern standard time]

NOTE.—In recent years a number of high-grade seismographs designed especially for recording local shocks have been installed in the Northeastern region, greatly enhancing our knowledge of prevailing seismic activity and the locations of seismic foci. The records of all seismographic stations in the region should therefore be consulted for additional information. In the following list "Harvard" refers to reports issued by the Harvard Seismograph Station at the Oak Ridge Observatory, Harvard, Mass.

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June 14: 0:40.* Felt throughout a wide area in central New Hampshire, according to Harvard.

June 20: Late at night. Mountain View, N. Y. Five distinct shocks, the first about 22:40 and the last about an hour later. The third and fifth were the strongest: they are reported to have made a hanging lamp sway so hard that it struck a rafter. At about the same time an earthquake was felt weakly along Point Salubrious, near Chaumont. Not felt at Malone or Watertown, N. Y.

November 8: 21:46.* Weak shock in the region of Lake Winnepesaukee, N. H. Epicenter about 43°33′ north, 71°26′ west, according to Harvard. V at Lakeport, N. H., where the shock seemed like an explosion. Felt also at Belmont, Franklin, Laconia, and Tilton, N. H. See the following report for further notes.

November 8: 23:02.* Weak shock in northern Vermont. Epicenter about 44°39′ north, 71°40′ west, according to Harvard. Felt at St. Johnsbury, Vt., and at Colebrook and Lancaster, N. H. This earthquake and the preceding one are discussed in an article, "The New Hampshire Earthquakes of November 9, 1936, and Further Data on New England Travel Times," by Mary P. Collins, Bulletin of the Seismological Society of America, vol. 27, April 1937, page 99.

EASTERN REGION

[75th meridian or eastern standard time]

January 1: about 3:—. Border of North Carolina and Georgia, III. Epicenter probably between Murphy, N. C., and Blue Ridge, Ga., according to the State Division of Geology at Atlanta, Ga. Felt at Blue Ridge, Ellijay, and Cleveland, Ga.; at Isabella, Tenn.; and at Murphy, N. C.

April 9: 7:42.* Charlottesville, Va. Very slight.

August 26: about 3:55 to 4:05. Greenville, Pa. Weak.

December 29: 22:50. Summerville, S. C. Weak.

CENTRAL REGION

[90th meridian or central standard time]

January 31: About 1:30. Tiffin, Ohio. Heavy rumbling awakened scores. Possibly an explosion.

February 16: 23:05.* Local shock felt at Hayti, Mo.

March 14: 11:20. Weak shock in southeastern Oklahoma. V at Valliant and Wright City, Okla., where many were alarmed. IV at Broken Bow, Golden, Idabel, Millerton, and Rupe, Okla. III at Manchester, Tex. Not felt at Boss, Eagletown, Fort Towson, Harris, Haworth, Hochatown, Ringold, or Sawyer, Okla., nor at Bryarly, Medill, or Woodland, Tex.

June 19: 21:24.* Texas Panhandle region, V+. Area of perceptibility about 40,000 square miles, as shown on the accompanying maps. Prof. E. H. Sellards, of the Bureau of Economic Geology of the University of Texas, made a survey of the affected area and placed the epicenter in or near Borger, Tex. The seismological station at St. Louis reports it slightly to the east of this location, at about 35.7° north, 100.3° west. The earthquake was preceded by two slight foreshocks, which were recorded instrumentally at St. Louis, at 21:14 and 21:18, the second of which was the stronger and was felt by some observers in the affected area.

According to Prof. Sellards, "The controlling underground structural feature of the Panhandle region is the buried Amarillo mountain chain which trends aproximately east-west. The place of maximum intensity of this earthquake was on the north flank of this mountain structure and in part in the accompanying syncline of the Anadarko basin to the north. The known lines of faulting in this region trend WNW–ESE.[1] So far as can be judged from available records, it does not appear that this earthquake represents slippage on any known line of faulting."

The earthquake was recorded by seismographs at Austin, Tex.; St. Louis, and Florissant, Mo.; Des Moines, Iowa; and Tuscon, Ariz.

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[1] See structural map accompanying University of Texas Bulletin 3401, The Geology of Texas, vol. II, Structural and Economic Geology, 1935 (1936).

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INTENSITY V IN TEXAS:

Gruver.—Shook old rock house severely.

White Deer.—House felt as if it would come to pieces if quake lasted much longer.

Whittenberg.—Press reports that the shock seemed severest here. One man reports being thrown to ground.

INTENSITY V IN OKLAHOMA:

Kenton.—Anomalous reports: Felt by several, few or none alarmed, article-shook and rattled slightly, no damage to buildings. Some plaster cracked and loosened, vertical cracks in some stone walls, also some cracks in rocks of the Black Mesa; a spring which had been giving a good flow went dry after the earths quake.

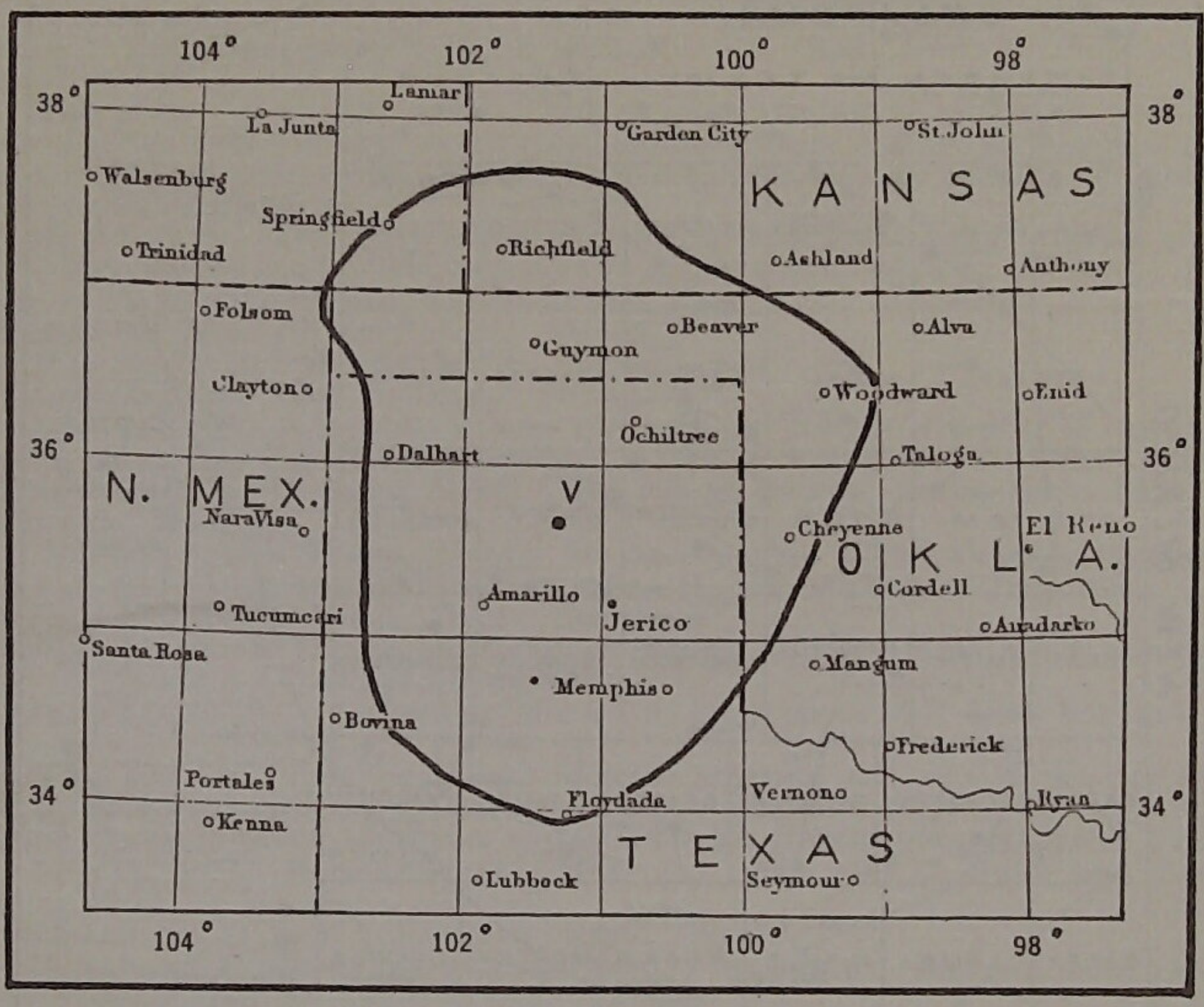

FIGURE 3.—Area affected by the Texas Panhandle earthquake of June 19, 1936.

INTENSITY V IN KANSAS:

Elkhart.—Felt by many. Objects displaced. Slight damage to buildings.

Intensity IV in Texas: Amarillo, Boydston, Farnsworth, Hunton, Sefors, Memphis, Pampa, Panhandle, Sanford, Turkey.

Intensity IV in Oklahoma: Elmwood, Guyman, Texhoma.

Intensity IV in Kansas: Liberal.

Intensity III and under in Texas: Darraugett, Kingsville, Mendota, Morse, Plainview, Roxanna.

Intensity III and under in Oklahoma: Beaver, Boise City, Hardesty, Hooker, Shattuck, Woodward.

Intensity III and under also in Sublett and Ulysses, Kans.; and Richards, Colo. Felt, intensity not reported, at Goodwill and Optima, Okla., and at Borger and Hereford, Tex. Not felt at Abilene, Dallas, El Paso, or San Antonio, Tex.; at Arnett, Okla.; at Concordia, Dodge City, or Plains, Kans.; nor in New Mexico.

July 11: 18:23. Kenton, Okla., slight. Also felt a few miles to the east and north. Not felt at Clayton or Moses, N. Mex., nor at Campo, Colo.

August 2: 16:15? Tiptonville, Tenn., and Cairo, Ill., slight shock felt.

August 7: 19:40. El Paso, Tex. Weak shock not felt elsewhere.
October 15: El Paso, Tex. "Earth tremor" shortly before noon. No details.
October 30: About 4:30. Hot Springs, S. Dak. Slight shock not felt elsewhere.
December 20: 16:41.* Cape Girardeau, Mo. Slight.

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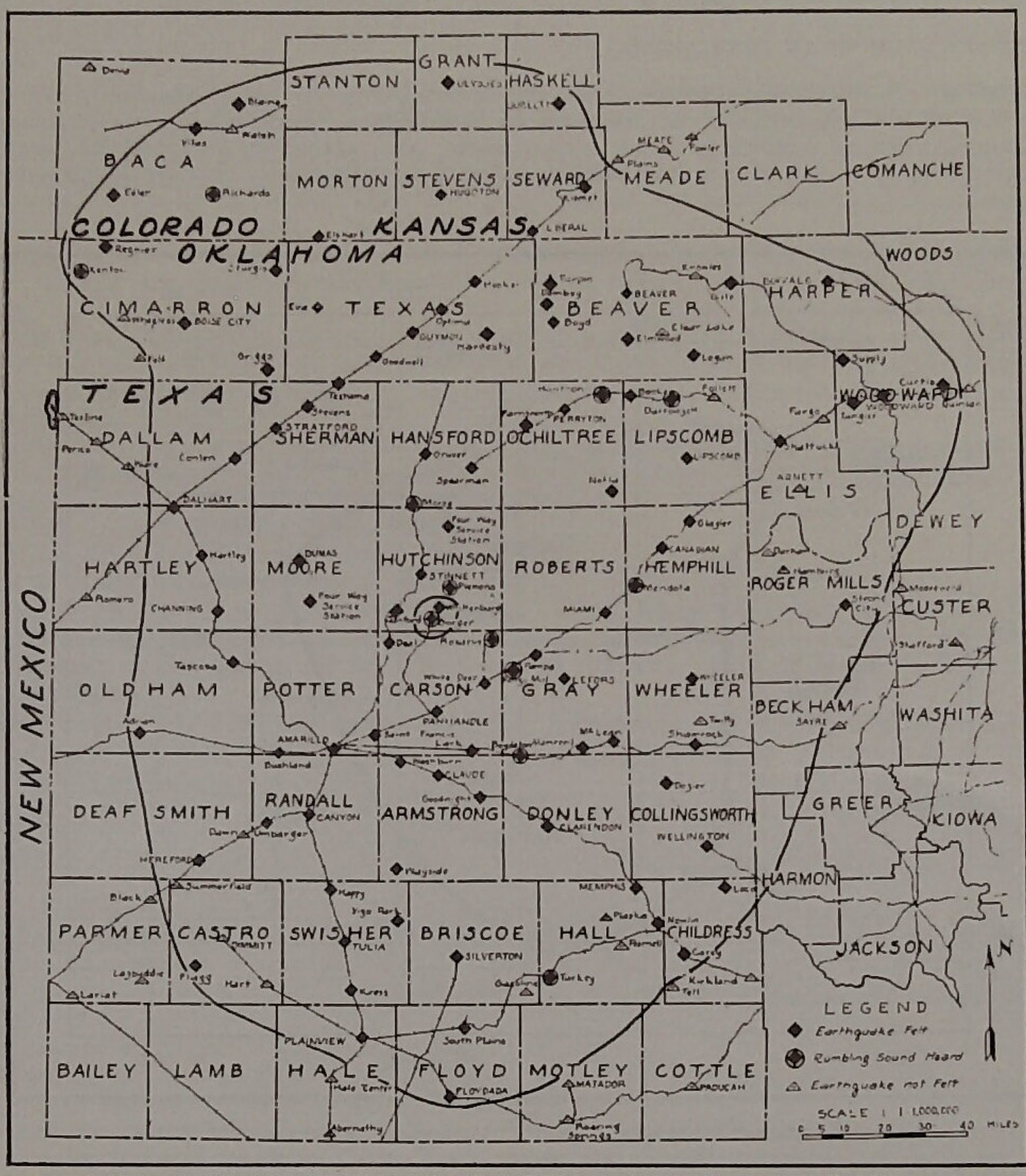

SKETCH MAP SHOWING LOCATION OF THE BORGER, TEXAS EARTHQUAKE OF JUNE 19, 1936
BY E. H. SELLARDS

FIGURE 4.—Isoseismal map of the Texas Panhandle earthquake of June 19, 1936.

WESTERN MOUNTAIN REGION

[105th meridian or mountain time]

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

January 7: 23:44.* Carlsbad, N. Mex. Felt by few; press reports some property damage.
January 11: 11:02. Great Falls, Mont. V. Felt also at Highwood, Mont., but not at Augusta, Cascade, Fairfield, Havre, or Helena, Mont.
January 12: —:—. Grand Canyon, Ariz. Noticeable earth tremor lasting about 5 seconds, with decided rumbling noise. Continued vibrations for about 10 minutes.
January 14: 11:05. Malad, Idaho. Weak.

January 14: 21:40. Yellowstone Park, Wyo., south entrance. Cracked two brick chimneys for several feet and moved small objects. Rocked beds at Moran, Wyo. Not felt at Jackson, Wyo.

February 6: 16:10. Eight miles east of Corvallis, Mont. Far more severe than any previously felt here. Sounded like a subterranean explosion. Felt weakly at Deer Lodge, Hamilton, and Philipsburg, Mont.

February 13: 10:30. Lewistown, Mont. Felt. No details.

February 13: 16:55. Helena, Mont. Strong. Felt also at Butte, Great Falls, and Hamilton.

February 13: 17:30. Helena, Mont. Strong. Caused some minor damage and much alarm. Felt also at Lewistown, Livingston, and Missoula. Recorded on the accelerograph at Helena.

February 14: 10:30. Lewistown, Mont. Slight.

February 15: —:—. Polebridge Ranger Station on west border of Glacier National Park, Mont. Felt. No details.

February 24: —:—. Shortly before midnight. Kingman, Ariz. Slight shock. Telephone communication with Needles, Calif., broken. Not felt at Needles.

March 25: Marysville, Mont. Felt a great number of quakes in past few weeks, often at intervals of as little as 5 minutes, three of them as long and hard as the shock of October 12, 1935. Subsided considerably, to about six or eight a day, in the last week.

May 9: 3:25. Two earthquakes at Zion National Park, Utah, where a crack in a rock wall of one building opened and a vase was knocked to the floor. Felt also at Cedar City, Kanab, and Orderville, Utah.

May 13: 7:06. Helena, Mont. Strong.

May 21: 19:19. Helena, Mont. Strong.

June 3: 1:31. Helena, Mont. Strong.

June 11: 16:13. Helena, Mont. Strong. Very slight widening of cracks in walls previously damaged. Recorded on the accelerograph at Helena. Felt quite strongly at Birdseye, Mont. Not felt at Billings, Butte, Great Falls, or Missoula, Mont.

June 12: 4:40. Helena, Mont. Strong. Caused slight widening of cracks in walls previously damaged. Recorded on the acclerograph at Helena.

June 14: 8:03. Helena, Mont. Strong.

June 21: 11:15. Seven miles east of Lincoln, Mont. Weak shock generally felt in Blackfoot Valley but not at Helena.

June 22: 20:30. Marysville, Mont. A hard shock felt here but not at Helena.

(This and the preceding shocks indicate separate and smaller seismic foci. Their northerly position points to a possible condition of progressive faulting along the fault which continues northward from Helena toward Glacier Park.)

July 29: 4:27. Helena, Mont. Moderate. Felt also at Butte and Great Falls, Mont.

September 2: 16:37. Kimberly, Utah. Weak.

September 4: About 2:00 and afterward. Greenfields' ranch, 5½ miles north-northwest of Helena. Considerable rumbling.

September 7: 4:48.* Boulder Dam. Weak. Several rocks fell in road about 1 mile toward Boulder City, Nev., from the plant. Awakened some at Boulder City.

September 7: 16:30. Weak shock at West Yellowstone, Mont., and at Mammoth Hot Springs, Wyo.

September 8: About 10:48. Boulder City, Nev. Very slight.

September 9: 5:55 and 5:57. Albuquerque, N. Mex. Two weak shocks.

September 18: 20:38.* Boulder Dam power plant. Weak.

September 18: 20:50. Boulder Dam power plant. Weak. (Pasadena reports two shocks at about this time and place, namely, one at 20:38 of intensity 3.5 on the Pasadena scale; the other at 20:51 of intensity 3.)

September 19: 5:29.* Boulder Dam power plant. Weak.

September 19: 21:13.* Boulder Dam power plant. "Fairly heavy."

September 20: 22:27. Boulder Dam. Weak. (Pasadena reports an earthquake at 22:28 in the general region of northern Nevada.)

September 20: 23:22.* Winnemucca, Nev. Slight.

September 21: 0:32.* Beowawe and Winnemucca, Nev. Weak.

October 9: 3:21.* Helena, Mont. Strongest shock since June 12.

October 24: 2:—, and 5:34. Star Valley in western Wyoming experienced two shocks, each accompanied by a rumble.

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October 31: 22:00 to 23:00. Kenwood, Mont. Loud roars and mild quivering during practically the entire hour.

October. Lost Horse Gulch, west of Marysville, Mont. Earthquake tremors being felt almost daily.

November 25: 0:28. Boulder Dam power plant. Slight.

December 5:. 23:23. Boulder Dam power plant. "Sharp shock."

December 5: 23:25. Boulder Dam power plant. Slight.

December 7: 23:48. Boulder Dam power plant. Very sharp. Preceded by pronounced rumble. Felt at Boulder City.

December 7: 23:49. Boulder Dam power plant. Slight.

December 13: 23:53. Helena, Mont. Moderate. Felt at several places in the valley.

CALIFORNIA AND WESTERN NEVADA

[120th meridian or Pacific standard time]

NOTE.—All places are in California unless otherwise stated. "Berkeley" refers to the seismological station of the University of California at Berkeley; Perry Byerly in charge. "Pasadena" refers to the Seismological Laboratory of the Carnegie Institution of Washington and the California Institute of Technology at Pasadena; H. O. Wood in charge.

January 1: 6:10. Mullett Island, Salton Sea, VI. Most severe of a series of nearly 50 shocks felt in past week. Windows shattered; plaster cracked. IV or V at Calipatria. Felt at Niland. Felt slightly at Brawley and other Imperial Valley towns.

January 1: 7:57*. Epicenter 33°37′ north, 118°02′ west, according to Pasadena. Felt weakly at Huntington Beach, Long Beach, and Seal Beach.

January 3: Niland, four minor shocks. One mile west of the city and near the mud pots, which are believed to be the center of the tremors, a brick chimney was hurled over the roof of a house. Walls cracked in brick hotel and adobe store building. Five miles south of the mud pots new ones opened up and mud was thrown 100 feet.

January 6: 22:30. San Francisco, IV. Not reported from outside San Francisco.

January 6: 22:36.* Epicenter 34°06′ north, 117°24′ west, according to Pasadena. IV at San Bernardino. Felt throughout the orange belt.

January 6: 22:58.* Epicenter very near Lake Merced, San Francisco, according to Berkeley. Felt by several in San Francisco. Felt in San Raphael as a single vertical jolt.

January 21: 5:42*. Epicenter 33°43′ north, 118°05′ west, according to Pasadena. IV at Seal Beach.

January 25: 9:49*. Weak or moderate shock, centering about 4 miles southwest of the University of California campus. Depth of focus very small, according to Berkeley.

Intensity III and under at Alameda, Berkeley, Hayward, Lafayette, Martinez, Orinda, Richmond, Ross, San Francisco, San Raphael, and Suisun Bay Bridge.

Not felt at Agnew, Alvarado, Angel Island, Antioch, Belmont, Belvedere, Brisbane, Centerville, Clayton, Colma, Concord, Corte Madera, Daly City, Danville, Decoto, Diablo, El Granada, Grandview, Ignacio, Irvington, Lagunitas, La Honda. Larskpur, Los Gatos, Manor, Menlo Park, Mill Brae, Mill Valley, Milpitas, Moss Beach, Mountain View, Newark, Nicasio, Niles, Novato, Oakland, Oleum, Palo Alto, Pinole, Pittsburg, Pleasanton, Redwood City, Rockaway Beach, Rodeo, San Anselmo, San Bruno, San Geronimo, San Gregorio, San Jose, San Leandro, San Lorenzo, San Pablo, San Ramon, Sausalita, Santa Clara, Sharp Park, South San Francisco, Stinson Beach, Sunnyvale, Warm Springs, or Woodacres.

January 25: 10:—. Slight shock at Berkeley and Lafayette.

February 8: 19:06.* Epicenter about 30 miles from Ferndale, according to Berkeley. III or IV at Ettersburg.

February 17: about 15:30. Long Beach, IV. (Pasadena reports a shock in this neighborhood at 15:20.)

February 20: 2:28. El Centro. Slight. Not felt in other Imperial Valley towns.

February 22: 15:18.* Epicenter probably on the Elsinore fault at about 32.6° north, 116.0° west, according to Pasadena. IV at Imperial.

February 22: 19:02.* Epicenter probably on the Elsinore fault at about 32.6° north, 116.0° west, according to Pasadena. IV at Imperial, where aftershocks are reported to have occurred at 19:35 and 22:35.

February 23: 14:20. Epicenter 34°07′ north, 117°25′ west, near Colton, according to Pasadena. Felt over an area of approximately 11,000 square miles, as shown on map, page 14. Recorded on the accelerograph and displacement-meter at Colton.

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INTENSITY V:

Cedarpines Park.—Felt by all; frightened few. Vases were overturned.

Colton.—Felt by many; frightened many. Small objects were moved slightly. Broke two plates standing on edge. Damaged one chimney slightly.

East Highlands.—Loosened some rock from walls of mountains causing slide.

Loma Linda.—Frightened all.

Mentone.—Felt by all; frightened many.

Montrose.—Press reports shock most pronounced here.

Moreno.—Felt by all; frightened many.

San Bernardino.—Frightened all.

Intensity IV: Alta Loma, Anaheim, Arrowhead Springs, Claremont, Del Rosa, Fontana, Forest Home, Glenn Ranch, Hemet, Hesperia, Laverne, Lucerne Valley, Ontario, Redlands, San Dimas, Sierra Madre, Victorville.

Intensity III and under: Acton, Anza, Azusa, Banning, Barstow, Baumont, Brea, Compton, Daggett, Elsinore, Del Monte, Glendora, Guasti, Huntington Park, Idyllwild, Jamul, Laguna Beach, Lakeside, Los Angeles, Orange, Oxnard, Palm Spring, Pasadena, Perris, Placentia, Pomona, Riverside, 8 miles west of Riverside, San Diego, San Jacinto, Santa Ana, Seven Oaks, Tujunga, Twenty-Nine Palms, Universal City, Upland, Van Nuys, Whittier.

Not felt in Alhambra, Alpine, Bonita, Buena Park, Amarillo, Camp Baldy, Castaic, Coachella, Costa Mesa, Covina, Culver City, Del Mar, Downey, El Cahon, Encanto, Encinitas, Escondido, Fall Brook, Filmore, Fullerton, Garden Grove, Glendale, Gorman, Helendale, Huntington Beach, Imperial Beach, Indio, Inglewood, La Crescenta, La Habra, Lancaster, Llano, Long Beach, Moneta, Moorpark, National City, Nestor, Newhall, North Hollywood, Norwalk, Oceanside, Olive, Pacific Beach, Palomar Mountain, Romona, San Fernando, San Juan Capistrano, San Onofre, San Pedro, Santa Monica, Santa Susana, Saugus, Seal Beach, Spadra, Spring Valley, Temecula, Tustin, Venice, Ventura, Vista, Walnut, Westminister, Wheeler Springs, Yorba Linda.

February 23: 19:45. Hemet and San Jacinto. Slight.

February 26: 1:33.* Near Colton. Epicenter 34°07′ north, 117°25′ west, according to Pasadena. Felt weakly at Fontana, Hemet, Riverside, San Bernardino, and Victorville.

March 1: 11:25.* Southwest Los Angeles. Epicenter 33°59′ north, 118°18′ west, according to Pasadena. Felt weakly at Huntington Park and Los Angeles.

March 1: 11:27.* Southwest Los Angeles. Epicenter 33°59′ north, 118°18′ west, according to Pasadena. V at Hunting Park, where small cracks appeared in plaster, and at Moneta, where it was felt by all. IV at Beverly Hills, Compton, Los Angeles, and Redondo Beach. III and under at Inglewood and Long Beach.

March 1: 11:31.* Southwest Los Angeles. Located by Pasadena at 33°59′ north, 118°18′ west. Felt in Los Angeles.

March 1: 11:37. Los Angeles. Weak.

March 1: 11:42.* Southwest Los Angeles. Located by Pasadena at 33°59′ north, 118°18′ west. V at Huntington Park, where dishes were broken, and at Moneta, where it was felt by all. IV at Los Angeles. III at Lomita and San Pedro. Not felt at Long Beach.

March 1: 11:55. Southwest Los Angeles, IV. North Hollywood, III.

March 1: 11:59. Huntington Park. Felt.

March 1: About 24:—. San Pedro. Slight.

March 11: 5:56.* Epicenter about 4 miles east of Coyote, according to Berkeley. Felt over an area of about 1,600 square miles, as shown on map, page 14. V at Coyote Dam, where there was some rattling of slide material in the 244-foot cup of the spillway. IV at Gilroy, Mount Hamilton, and San Martin. III and under at Agnew, Aptos, Ben Lomond, Brookdale, Coyote, Hollister, Madrone, Morgan Hill, Perry Station, San Jose, Santa Clara, Watsonville.

Not felt at Alma, Alviso, Aromas, Blanco, Boulder Creek, Campbell, Capitola, Castroville, Chualar, Crows Landing, Cupertino, Davenport (?), Del Monte, Dos Palos, Felton, Glenwood, Gonzales, Laurel, Los Altos, Los Banos, Los Gatos, Marina, Milpitas, Monterey, Mountain View, Mount Hermon, Newman, Olympia, Pacific Grove, Palo Alto, Redwood Estates, Salinas, San Gregorio, San Juan Bautista, Santa Cruz, Saratoga, Seaside, Spreckels, Sunnyvale, Tres Pinos, Volta.

March 16: 17:55.* San Benito County, centering at about 36.6° north, 121.2° west, mean of positions reported by Berkeley and Pasadena. IV at Chualar, Hollister, and Tres Pinos.

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FIGURE 5.—Areas affected by the California earthquakes of February 23, May 10, and June 3, 1936.

March 27: 4:29.* Near Point Dumi. Located by Pasadena at approximately 34°03′ north, 118°55′ west. IV at Camarillo.

March 30: 0:05. San Jose and East San Jose foothill district, slight.

April 3: 4:54.* Mojave Desert, centering at 34°54′ north, 117°00′ west, according to Pasadena. Moved small objects at Barstow.

April 3: 9:17.* Epicenter about 9 miles northwest of Hollister, according to Berkeley. Weak momentary shock felt by many at Hollister.

April 3: 15:11.* Epicenter about 7 miles northwest of Hollister, according to Berkeley. Heavy jar felt by many at Hollister; no damage.

April 6: 23:38* Epicenter about 32°54′ north, 115°13′ west, according to Pasadena. IV at Calexico, where a sharper shock was felt later, but observer did not know the time of it.

April 7: 1:35. El Centro, IV. Two shocks of intensity IV about half an hour apart were felt at Holtville at about this time.

April 7: 14:14.* Epicenter about 32°54′ north, 115°13′ west, according to Pasadena. IV at El Centro.

April 7: 14:53.* Epicenter about 32°54′ north, 115°13′ west, according to Pasadena. V at El Centro, where some ran from buildings and small objects were overturned in some cases, and at Holtville, where slight damage was done and tremors of less intensity followed. IV at Calexico. Felt also at Heber.

April 7: 15:27.* Epicenter about 32°54′ north, 115°13′ west, according to Pasadena. IV at El Centro; very slight at Calexico.

April 8: 10:25. El Centro. IV.

April 8: 10:41.* Epicenter about 32°54′ north, 115°13′ west, according to Pasadena. El Centro, V; window displays disarranged. Felt also at Calexico and Heber. Not felt at Mecca.

April 17: 21:36.* Epicenter about 32°54′ north, 115°13′ west, according to Pasadena. IV at El Centro and Imperial.

April 19: 8:17.* Near Long Beach, centering at 33°46′ north, 118°10′ west, according to Pasadena. Felt weakly at Long Beach, San Pedro, and Wilmington.

April 24: 20:58.* Epicenter about 33°59′ north, 118°23′ west, according to Pasadena. Two slight tremors rattled windows and doors in Culver City, Pacific Palisades, Santa Monica, and West Los Angeles. Felt as far south as Redondo Beach. At Manhattan Beach, an explosive sound was reported heard at the same time.

April 26: 8:25.* Near Haiwee, centering at 36°09′ north, 117°57′ west, according to Pasadena. IV at Olancha, where an aftershock is reported to have occurred 2 minutes later.

May 3: 23:15.* Epicenter 34°11′ north, 118°15′ west, according to Pasadena. Felt weakly at Eagle Rock, Glendale, Los Angeles, Montrose, and Pasadena.

May 7: 3:47.* Epicenter 33°08′ north, 116°05′ west, according to Pasadena, V at Imperial, where small objects were moved. IV at Lakeside. Felt also at Carrizo Gorge, Hemet, and San Diego.

May 8: 23:44.* Mount Lassen National Park. Weak.

May 9: 0:12.* Mount Lassen National Park. Weak.

May 9: 1:40; 4:30; and 12:21.* Mineral. The 3 strongest of 41 earthquakes felt here recently, 18 of which occurred on May 8 and 9. The earthquake of 12:22 was felt with intensity about V at Manzanita Lake in Lassen National Park. A report on this swarm of weak earthquakes is given in an article, "Recent Seismic Disturbances in Lassen Volcanic National Park," by Carl R. Swartzlow, Bulletin of the Seismological Society of America, vol. 27, No. 1, January 1937, Page 35. Only the stronger of these shocks are listed below.

May 9: 3:04.* Mount Lassen National Park. Weak.

May 9: 10:41.* Mount Lassen National Park. Weak.

May 9: 18:18. Manzanita Lake, Mt. Lassen National Park, about V.

May 9: 23:44, to ***May 10:*** 12:19. Reno, Nevada. Six earthquakes.

May 10: 9:40.* North of Bishop, at about 37°30′ north, 118°32′ west, according to Pasadena. Felt over an area of about 6,000 square miles in east central California and Nevada, as shown on map. Possibly VI 20 miles south of June Lake, where timbers were wrecked in East Portal tunnel. V at Bishop where small objects were moved in a few cases, and there were a few rock slides. IV at Benton, Bigpine, Burgyn's Road Camp (25 miles northeast of Bishop), Crestview Lodge (4 miles east of Mammoth Lakes), Deep Springs, Delpiedra, Independence, June Lake Junction, Keeler, Little Round Valley, McGee Creek, Miramonte, Mocalno, Mono Lodge, Onyx, Owens River Gorge, Porterville, and Stratford.

Intensity III and under in California: Big Creek, Bridgeport, Camp Curry, Conway Summit (12 miles south of Bridgeport), Corcoran, Crestview, Dinuba, Earlimart, Fresno, Grant Lake Camp, Hanford, Semoore, Lonepine, Madera, Mammoth Lakes, Navelencia, Olancha, Pinedale, Sanger, Sequoia National Park, Visalia, Wiwona, Woodlake, and Yosemite III and under in Nevada: Luning, Mina.

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Felt, intensity doubtful, in California: Adams Plant (120 miles north of Olancha), 2 miles north of Exeter, Florence Lake, Huntington Lake, Shaver Lake, Venida Substation.

Not felt in California: Ahwahnee, Badger, Bakersfield, Clovis, Coalinga, Coarsegold, Delano, Ducor, Hanford, Helm, Huron, June Lake, Lakeshore, Lost Hills, Mendota, Tiogo Lodge, North Fork, O'Neils, Posey, Prather, Raisin, Reedley, Tulare, Wasco. Not felt in Nevada: Gilbert, Goldfield, Goldpoint, Hawthorne, Hot Creek, Mount Montgomery, Silver Peak, Wichman.

May 14: Mineral. Six more earth shocks, the strongest in the series on May 14 and the preceding night, bring the total since May 4 to 125.

May 14: 3:15.* Manzanita Lake, Mount Lassen National Park. Weak. (Perhaps same as one of the shocks mentioned in the foregoing report.)

May 14: 20:34.* Epicenter about 37°30′ north, 118°32′ west, according to Pasadena. V at Adams plant (120 miles north of Haiwee Power Plant), where it was felt by all. IV at Benton, Crestview, and Yosemite.

May 14: 23:04.* Manzanita Lake, Mount Lassen National Parrk, about V.

May 16: 5:37.* Near Rialto, centering at 34°03′ north, 117°17′ west, according to Pasadena. Felt at Highland and San Bernardino.

May 22: 20:41.* Epicenter near King City, at about 36°10′ north, 120°55′ west, according to Pasadena. IV at King City, where three successive shocks were felt.

May 26: 23:18.* Mineral. Two more shocks, the heavier of intensity IV. These shocks were the first felt here in 10 days. Felt also at Manzanita Lake.

May 28: 22:56.* Epicenter about 4 miles north of Panoche, according to Berkeley. III or IV at King City.

May 29: Manzanita Lake, about V.

May 30: 2:08.* Epicenter about 4 miles northwest of Morgan Hill, same as shock of May 16 at 11:51 according to Berkeley. IV at Morgan Hill and San Martin.

May 31: 18:21.* Off Huntington Beach, centering at 33°37′ north, 118°02′ west, according to Pasadena. Felt at Huntington Beach.

June 2: 6:30. Manzanita Lake, about V.

June 3: 1:15.* Off Cape Mendocino, at 40.16° north, 126.45° west, according to Berkeley. Felt over a land area of about 1,800 square miles, as shown on map, page 14. Recorded on the accelerograph at Ferndale.

INTENSITY V:

Beatrice.—Frightened many. Moved small objects slightly.

Ferndale.—Cracked chimneys according to one report. The same report and several others state that there was no damage.

Punta Gorda Light Station.—Spilled mercury in light.

Upper Mattole.—Moved small objects a little and spilled water from outdoor containers.

Weott.—Moved small objects.

Intensity IV: Arcata, Bayside, Benbow, Blocksburg, Briceland, Bridgeville, Cape Mendocino, Capetown, Eureka, Fernbridge, Fields Landing, Fort Bragg, Fortuna, Garberville, Harris, Holmes, Korbel, Soleta, Philo, Rohnerville, Samoa, Scotia, South Fork, Trinidad, Westport, Weymouth Inn, and Whitlow.

Intensity III and under: Alderpoint, Alton, Bell Springs, Branscomb, Carlotta, Comptche, Crescent City, Dos Rios, Ettersburg, Hackett Ranch, Hyampom, Hydesville, Little River, Manchester, Petrolia, Piercy, Redwood Valley, Rio Del, Salyer, Smith River, Waddington, Willets, and Willow Creek.

Not felt: Boonville, Caution, Dedrick, Elk, Etna, Forest Glen, Forks of Salmon, Fort Dick, Grenada, Happy Camp, Hayfork, Hurst, Hoaglin, Hornbrook, Island Mountain, Junction City, Klamath, Longvale, Mad River, Montague, Nashmead, Navarro, Orick, Orleans, Sawyers Bar, Scott Bar, Ukiah, Walker.

June 11: 22:20. Santa Rosa. Slight. Two clocks stopped.

June 14: 14:26.* Mount Lassen National Park. Weak.

June 24: 4:23.* San Luis Obispo County, centering at about 35° 07′ north, 120° 05′ west, according to Pasadena. IV at Los Alamos.

June 29: 4:45, 7:05, and 11:52. Manzanita Lake, IV or V. A number of earthquakes were recorded on June 29 and 30 on the seismograph at Manzanita Lake, and a few at Mount Harkness.

June 29: 22:30. Earthquakes of intensity V occurred at intervals until 15:50 on June 30 at Mineral, Mount Harkness (where the seismograph needle was knocked off four times), and Susanville. Said to be the strongest of the numerous shocks felt in Lassen National Park thus far this year.

June 30: 2:27.* Manzanita Lake, V. Caribou, IV.

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June 30: 4:47.* Manzanita Lake, Mineral, and Prattville; about IV.
June 30: 4:50. Caribou. Slight.
June 30: 12:36.* Manzanita Lake, about V.
June 30: 15:50.* IV at Manzanita Lake and Mineral.
June 30: Mount Harkness. Fire lookout reported over 100 slight quakes on this date.
July 1: 3:50, 4:43, and 23:20. Three shocks of intensity about V at Mount Harkness.
July 1: 7:50. Manzanita Lake, about V. Another shock of about the same intensity the same day.
July 2: 9:38. Mineral, V–VI. Disturbed furniture and dishes. A few rock slides were reported on the slope of Lassen Peak and on Chaos Crags. Other less severe shocks were felt. Seven shocks of intensity V were reported on this day from Mount Harkness.
July 5: Mount Harkness. One shock of intensity about V.
July 6: 2:16, 3:11, 7:41, and 9:35. Mount Harkness, four shocks of intensity about V.
July 9: Mount Harkness, about V.
July 10: Mount Harkness, two shocks of intensity about V.
July 10: 3:45. IV at Lonepine and Owengo.
July 10: 7:30. Sequoia National Park. Sharp quake followed by loud roar, causing the lookout tower at Cahoon Rock to sway and dishes to fall from cupboards. Two other shocks rocked the region near Clough Cave at 12:43 and 12:45. The shocks were also felt in Owens Valley.
July 10: 19:47.* Owens Valley. Located by Pasadena at about 36°40′ north, 118°06′ west. IV at Lonepine and Owenyo. III at Sequoia National Park.
July 11: 0:30. Lonepine, aftershock.
July 11: 0:43.* Aftershock, according to Pasadena. IV at Owenyo. Three short shocks at Sequoia National Park.
July 11: 2:00.* Aftershock, according to Pasadena. IV at Owenyo.
July 11: between 2:— and 7:30. Owenyo, three additional light shocks.
July 11: 3:30. Lonepine, aftershock.
July 11: About 7:—. Lonepine, aftershock.
July 13: 2:43. Mount Harkess, about V.
July 14: 10:39.* Off Huntington Beach. Located by Pasadena at 33°37′ north, 118°02′ west. III at Seal Beach.
July 15: 20:39.* San Diego. Felt by few. Recorded on seismograph. Followed by two weaker shocks which were recorded but not felt.
July 21: 23:06.* Near Riverside. Located by Pasadena at 33°58′ north, 117°34′ west. IV at Fontana.
July 24: 1:04. IV at Huntington Beach and Santa Ana.
July 25: 1:02.* Off Newport Beach, at 33°34′ north, 117°59′ west, according to Pasadena. Felt at Balboa, Corona del Mar, Costa Mesa, Huntington Beach, and Santa Ana.
July 25: 11:39.* Epicenter about 38° north, 118° west, according to Pasadena. IV at Luning and Mina, Nev.
August 8: 6:21* Lower California, at about 32°27′ north, 115°37′ west, according to Pasadena. III or IV at Imperial.
August 19: 5:18.* Agua Caliente fault near Aguanga, at 33°30′ north, 116° 55′ west, according to Pasadena. IV at Hemet.
August 20: 8:49.* Epicenter about 2 miles south of Gilroy, according to Berkeley. III at Hollister.
August 21: 21:21.* Epicenter 33°46′ north, 117°49′ west, according to Pasadena. IV at Anaheim, Fullerton, Los Angeles, Ontario, and Placentia. Felt also at Belvidere Gardens, Brea, Claremont, Glendale, Orange, Pasadena, San Antonio Canyon, Santa Ana, Santa Fe Springs, and Whittier.
August 23: 2:02.* IV at Arcata, Fields Landing, Fortuna, and Samoa. III at Eureka. Not felt at Garberville, Orich, or Petrolia.
September 8: 5:54.* Off Newport Beach. Located by Pasadena at approximately 33°34′ north, 117°59′ west. V at Seal Beach, where all were awakened. IV at Fullerton, Huntington Beach, and Long Beach. Felt also at Anaheim, Los Angeles, Newport Beach, and Santa Ana.
September 8: 20:55. Los Alamos, V. Felt also southeast of Orcutt.
September 10: 2:53.* Near Acton, Los Angeles County, at about 34°28′ north, 118°13′ west, according to Pasadena. IV at Lancaster.
September 23: 9:14. Manzanita Lake. Strongest shock thus far this year. Knocked needle off seismograph. Preceded by a slight tremor at 2 a. m. These

earthquakes occurred at the opposite end of the park from the center of the series of tremors earlier in the year.

September 23: 19:09.* San Francisco Bay region, centering at 37°36′ north, 121°53′ west, according to Berkeley. V at Irvington, where canned goods fell, and at Menlo Park, where a patch of plaster 10 feet square fell from one ceiling. IV at Alvarado, Boulder Creek, Burlingame, Centerville, Hayward, Livermore, Milpitas, Mission San Jose, Morgan Hill, Mount Eden, Newark, Niles, Pleasanton, Redwood City, San Jose, San Lorenzo, Sunnyvale, Warm Springs. III and under at Alviso, Colma, Cupertino, Daly City, East Oakland, El Granada, La Honda, Los Altos, Los Gatos, Millbrae, Moss Beach, Mountain View, Oakland, Palo Alto, Rockaway Beach, San Carlos, San Francisco, San Gregorio, Santa Clara, Santa Cruz, Saratoga, Soquel, Sunol. Felt, intensity doubtful, at Berkeley. Not felt at Alameda, Aptos, Belmont, Corte Madera, Gilroy, Half Moon Bay, Ignacio, Montara, San Martin, San Mateo, San Pablo, San Ramon, South San Francisco, Tassajara Hot Springs, Tracy, Walnut Creek, Watsonville.

September 24: 6:11.* San Francisco Bay region, centering at 37°36′ north, 121°53′ west, according to Berkeley. V at Redwood City, where slight damage was done. IV at Alvarado, Alviso, Aptos, Centerville, Irvington, Livermore, Milpitas, Mission San Jose, Newark, Niles, Pleasanton, Redwood City, Sunnyvale, Sunol, and Warm Springs. III and under at Boulder Creek, Burlingame, Colma, Daly City, East Oakland, Hayward, La Honda, Los Altos, Los Gatos, Moss Beach, Mount Hamilton, Mountain View, Oakland, Rockaway Beach, San Francisco, San Gregorio, San Jose, San Lorenzo, San Rafael, Santa Clara, Saratoga, and Warm Springs. Not felt at Alameda, Belmont, Berkeley, El Grandee, Half Moon Bay, Lagunitas, Menlo Park, Montara, San Martin, San Mateo, San Pablo, San Ramon, Soquel, South San Francisco, Tassajara Hot Springs, Tracy, Walnut Creek, Watsonville.

September 26: 17:56. Bakersfield, IV. Two earthquakes a few seconds apart. Felt also 5 miles east of Bakersfield, but not at Ducor.

October 4: 1:31.* Kernville, 6 miles north of, centering at about 35.8° north, 118.0° west, according to Pasadena. Slight.

October 6: 2:30. Laws. Weak.

October 6: 4:30. Bishop. Five distinct earthquakes reported at about this time. No damage.

October 6: 4:55. Laws. Weak.

October 6: 19:00. Laws. Weak.

October 9: About 7:—. Martinez. Slight.

October 10: 10:49.* Northwest of Bishop, at about 37°52′ north, 118°30′ west, according to Pasadena. IV at Laws and Bishop. Not felt at Benton, Big Pine, Bridgeport, Clovis, Del Piedra, June Lake, Keeler, Knowles, Mono Lake, Oasis, Olancha, Reedley, Visalia, Woodlake; nor at Goldpoint or New Montgomery, Nev.

October 10: 11:00. Laws. Light shock. East and west motion.

October 10: 12:10.* Northwest of Bishop at about 37°52′ north, 118°30′ west, according to Pasadena. IV at Laws. Not felt at Benton, Big Pine, Bishop, Bridgeport, Del Piedra, June Lake, Keeler, Knowles, Mono Lake, Oasis, Olancha, Reedley, Visalia, Woodlake; or at Goldpoint or New Montgomery, Nev.

October 13: 22:30. Thirteen miles north of Indio, centering at 33°37′ north, 116°14′ west, according to Pasadena. One shock felt by many working in tunnel. Frightened no one. Vertical cracks appeared in gunite walls of tunnel. Damage slight. Felt weakly at Indio.

October 23: 18:58. Felt at Riverside, Colton, San Bernardino, and other towns in the valley.

October 25: Los Angeles. Two earthquakes in this vicinity; no damage.

October 27: 19:20. Long Beach. One shock. No damage.

October 29: 14:38. Ocean Park. Weak. Felt also at Hollywood (northern part), Long Beach, and Los Angeles.

November 5: 6:30. Hollister. Slight.

November 10: 18:25.* Pittsburg, IV or V. Epicenter about 6 miles south of Antioch, according to Berkeley. Felt weakly in Antioch. Not felt in Bethany.

November 18: 9:15. Weak shock felt at San Luis Obispo, Santa Margarita, and Pozo.

November 18: 10:02.* Northwest of Santa Barbara, centering at about 34°42′ north, 120°15′ west, according to Pasadena. IV at Arroyo Grande, Atascadero, Betteravia, Los Alamos, Oceano, Pozo, San Luis Obispo, and Santa Margarita. III at Santa Maria.

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November 22: 19:54.* Fortuna. Felt by all inside, outdoors by others. No damage. Felt weakly at Ferndale.

November 23: 7:53.* Centerville, III. Sunol, II. Epicenter about 6 miles southeast of Niles, according to Berkeley.

November 24: 2:02. Mission Hills, San Diego. Felt by few. North and south component only, according to observer. Two sharp shocks, approximately 2 seconds.

November 29: 22:23. Bell. Windows and doors rattled.

December 4: 7:51.* Epicenter about 5 miles southwest of the Palo Alto station, according to Berkeley. IV at Mountain View.

December 4: 8:14.* Mountain View, III. Aftershock of the preceding.

December 25: 8:05.* To the north, approximately 500 km from Tinemaha, according to Pasadena. Felt over an area of about 1,000 square miles in north central California.

INTENSITY V:

Lake Almanor, vicinity of.—Awakened many. Hanging objects swung north. Moved small objects. No damage.

Manzanita Lake.—Direction of motion outdoors northeast. Felt by many. Hanging objects swung with a circular motion. Christmas trees noticed to move with a twisting motion.

Taylorsville.—Direction of motion outdoors north to south. Felt by few. Moved furnishings and curtains. Bushes shaken slightly. Awakened few.

Intensity IV and under: Las Plumas, Westwood, Caribou, Meadow Valley, Chester, Mineral, Taylorsville.

Not felt at Belden, Blairsden, Hat Creek, Paynes Creek, Princeton, Quincy, Susanville, Whitmore.

WASHINGTON AND OREGON

[120th meridian or Pacific standard time]

March 22: 8:30. Alder, Wash. Weak.

May 8: Early. Roseburg, Oreg. Meteor exploded, awakening many.

June 20: 2:57.* Seattle, Wash. Weak.

June 20: 3:50. Bothell, Wash. Weak shock.

July 15: 20:30. White Salmon, Wash. Weak foreshock of the north Oregon earthquake at 23:08.

July 15: 22:20. Mottinger, Wash. Slight foreshock of the north Oregon earthquake at 23:08.

July 15: 23:08.* "State Line earthquake" near Walla Walla, Wash., and Milton, Oreg. VII+. Epicenter within a few miles of 45°58′ north, 118°18′ west. Damage about $100,000. Area affected, about 105,000 square miles. See map on page 21, which is based on a mail canvass of the affected area by the Bureau's Seismological Field Survey operating from San Francisco. According to B. J. Brown, "The buildings in the earthquake area are so irregularly distributed and their character and condition so varied that it has been impossible to fix with accuracy the destructive limits." Mr. Brown is author of an article entitled "The State Line Earthquake at Milton and Walla Walla" which appears in the July 1937 number (vol. 27, No. 3) of the Bulletin of the Seismological Society of America and covers many important aspects of the earthquake.

The shock was strongest at Freewater, State Line, and Umapine, Oreg., where the intensities reached VII. The ground was badly cracked and there were marked changes in the flow of well water. In the cemeteries about 70 percent of the stones rotated clockwise, viewed from above. Some stones in close proximity to each other rotated in opposite directions.

Mr. Brown's report also reveals interesting facts concerning the geology of the epicentral region:

"A spur of the Blue Mountains, known locally as the Touchet Ridge, extends from Milton west-northwest, crossing into Washington about 5 miles east of Wallula. The ridge crossed the Columbia River at one time, damming the water to form a large lake. The north edge of Touchet Ridge in places is very abrupt, the layers of basalt being broken square off at Milton, and marks an old fault line. North of the Ridge lies the valley of the Walla Walla River and its tributaries. Superposed on the old fault is a more recent fault extending from Milton about 20 miles down the valley. The basalt floor underlying the Milton-Walla Walla region has dropped 600 feet below the average gradient of the valley. The south edge of the depression lines up closely with the old fault line, while the other sides of the depression slope up gradually to surface exposures of basalt 4

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miles east of Walla Walla, 6 to 8 miles north of Walla Walla, and 2 miles west of Touchet. No evidence of fracture has been found on the east, north, and west sides.

"This local depression has been the site of three successive lakes, as described in a paper presented before the Northwest Science Association, December 30, 1930. Alternating layers of lake sediments and river gravels have accumulated to fill the area so that it now meets the common gradient of the valley. A fourth lake in glacial times covered the depressed area with a layer of sediments, the maximum depth of which is known to exceed 100 feet."

After giving a composite log of 35 wells he states:

"Most other sediments have been carried away by the Walla Walla River system. Thus, the depressed arc has been subjected to varying loads of some magnitude." Much of the descriptive matter which follows is taken from Mr Brown's report.

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INTENSITY VII IN OREGON:

Freewater.—Plaster and windows broken. Practically all chimneys that had been built for a period of 10 years were damaged at the roof level. Some were damaged below the roof level, but not many. Flues and walls were cracked in the Post Office Building. Two or three thousand dollars worth of damage was done to canned goods, bottled goods, furniture, fixtures, and plate glass windows at a cannery and at a drug store. Damage to school buildings amounted to about $8,500.

A fine new house about 4 miles west of Freewater was almost completely wrecked. Two cement houses about 20 years old, 7 miles west of Freewater, were practically demolished.

Most wells in the neighborhood of Freewater increased their flow; a few decreased. Dry Creek, which heads about 9 miles south and east of Freewater, and which had been dry at this season in previous years, began running a very nice stream of water.

Four miles west of Freewater the ground was cracked over an area 1,200 to 1,500 feet long by 50 to 100 feet wide along the base of a little hill running east to west. There were a number of little cracks running parallel to the hill. One crack some 200 or 300 feet long was from 1 to 6 feet wide.

At Freewater there were 20 or more aftershocks continuing intermittently all night.

State Line.—The shock was most severe here according to reports from the Milton-Freewater district. Concrete pavements were cracked.

Umapine.—Many walls and chimneys were cracked and a few demolished. The upper floor of one two-story concrete house was ruined; holes appeared in the walls. One stucco house was badly damaged, and a concrete residence fell to the ground. The grade and high-school buildings, which are joined, were pulled apart about 3 inches. Well water changed. Cracks appeared in the ground ranging in size from less than pencil width to a 3-foot crack which was 8 feet deep.

Large cracks appeared about 3 miles southeast of Umapine. At a ranch between Umapine and Freewater, nine cracks appeared ranging up to 6 inches in width, and water was forced out of the ground in a dozen places. A large stucco farmhouse near Umapine was so badly damaged that the family moved out onto the lawn.

At Umapine one observer counted the tremors the first night and reported 38 aftershocks with other very slight quakes mixed in. For some time a few shocks occurred each night and some in the daytime.

INTENSITY VI IN OREGON:

Athena.—Windows and furniture broke; plaster cracked and some fell. Cornices and other light structural parts damaged. A number of chimneys down; two buildings pulled apart by the quake; one house damaged beyond repair.

Ferndale.—In one house a brick chimney broke at the roof and at the ceiling. Part rotated and part fell.

Milton.—A few instances of broken windows and cracked plaster; several instances of fallen plaster; a few instances of broken furniture; many chimneys cracked; few walls demolished. Two freight cars thrown off track. Some increases in well water.

INTENSITY VI IN WASHINGTON:

Waitsburg.—Felt by practically all; many alarmed. Small objects moved; clocks stopped; plaster cracked. Several chimneys fell.

INTENSITY V IN OREGON:

Arlington.—People ran out in alarm.

Haines.—Water spilled northeast to southwest. Small objects not moved.

Helix.—Eight shocks, the first strongest, two others severe, and the last weakest, all occurring between 23:15 and 24:00. Felt by all; awakened all; frightened few. Moved but did not overturn small objects. Plaster cracked, some fell; damage slight.

Hermiston.—Three shocks. Felt by 80 percent of population; many alarmed. Some cracks in concrete cellar walls of a farmhouse 5 miles east of Hermiston.

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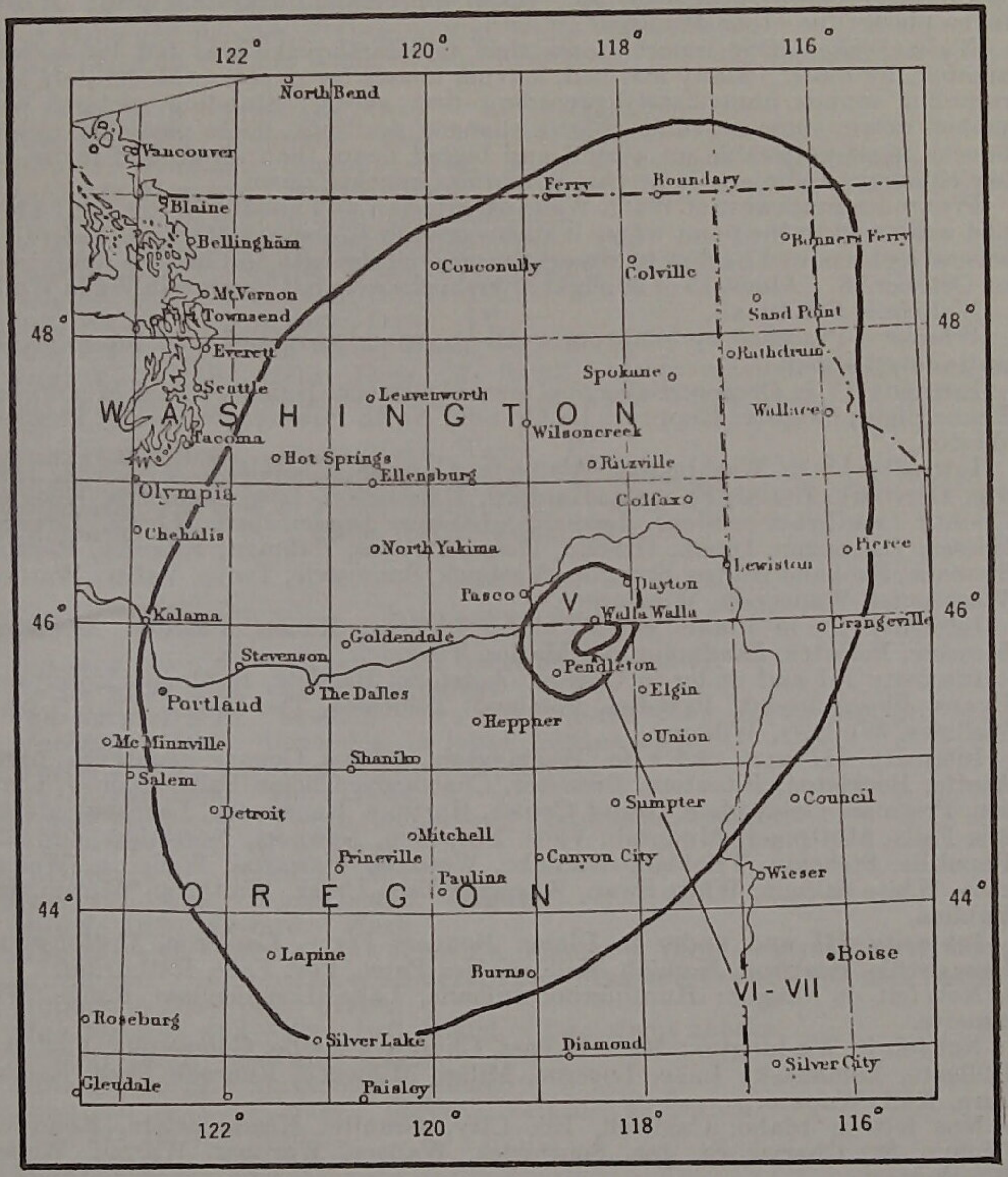

FIGURE 6.—Area affected by the Oregon-Washington "State-line" earthquake of July 15, 1936.

Monument.—Moved small objects and furnishings and broke dishes near Monument. Some damage on hillside farm about 7 miles south of Monument. Timbers fell in bridge under construction at Monument.

Pilot Rock.—People ran out in alarm.

Primeville.—Awakened few; frightened all. Furnishings moved.

Umatilla.—Felt by about half of those who were at rest indoors and by about one-fifth of those who were moving about; a few ran outdoors in alarm. Furniture was displaced in a few instances; clocks stopped.

INTENSITY V IN WASHINGTON:

Colfax.—Felt by all or nearly all; frightened few. Roaring sounds. Loose objects moved; liquids spilled. Some slight cracks in plaster and wall paper.
Hooper.—Felt by practically all; several alarmed. Small objects moved. No sounds.
Page.—Duration 2 minutes. Plaster cracked.
Pomeroy.—Felt by nearly all; few alarmed. Small objects moved.
Prescott.—Pendulum clocks did not stop. Overturned small objects. Broke plaster. Slight damage to chimneys.
Prosser.—Felt by all or nearly all. Plaster cracked in a few instances.
Touchet.—Felt by practically all. Small objects and furniture moved. A little fallen plaster; no other damage.
Walla Walla.—One report states that the earthquake was felt by several; another, by most. Many alarmed, leaving houses for streets. Moderately loud rumbling sounds immediately preceding first shock. Standing pictures were shaken down, some movable objects changed positions, doors partially opened. Shocks more noticeable on second and higher floors than on ground floors. A few chimneys and many loose chimney bricks knocked down.
Five miles southwest of Walla Walla an artesian well about 600 feet deep which had weakened to the point where it was necessary to pump water from a depth of several feet renewed its flow to almost the original strength and had not diminished by October 18. About 15 or 20 slight aftershocks were felt by some in Walla Walla.
Wallula.—Felt by all.
Wheeler.—Preceded by loud roar. All the windows rattled, and things on the wall moved about.
Intensity IV in Oregon: Baker; between Courtrock, Hamilton, and Monument; Echo; Elgin; Granite; Heppner; La Grande; North Powder; Pendleton; Promise; Weston.
Intensity IV in Washington: Alameda, Cedonia, Cheselah, Davenport, Dayton, Deerpark, Entiat, Ephrata, Hanford, Harrington, Irby, Kahlotus, Klickitat County (southeast section), Lakeside, Laurier, Leavenworth, Locke, Lowden, Odessa, Okanogan, Omak, Othello, Pasco, Pateros, Pullman, Ritzville, Rosalia, Spokane, Spokane Bridge, Sprague, Starbuck, Sunnyside, Twisp, Valley, Warden, Washtucna, Wauconda, Winchester.
Intensity IV in Idaho: Bovill, Coeur d'Alene, Hauser Junction, Lewiston, Moscow, Potlatch, Sandpoint, St. Maries, Troy.
Intensity III and under in Oregon: Antelope, Bartlett, Bordman, Enterprise, Evans, Flora, Joseph, Paradise, Portland, Telocaset, The Dalles, Troy, Ukiah, Wellowa, Whitney, Willows.
Intensity III and under in Washington: Adams County (southern part), Asotin, Beckleton, Bluestem, Brewster, Chattaroy, Chelan Falls, Cheney, Clayton, Freeman, Goldendale, Grand Coulee, Hartline, Kennewick, Lacrosse, Mettaline Falls, Mottinger, Mountain View, Nespelem, Newport, Northport, Oroville, Republic, Stehekin, Trinidad, Wahluke, Waukon, Wawawai, Wellpinit, Wenatchee, White Salmon, White Swan, Wilbur, Wilson Creek, Winthrop, Winton, and Yakima.
Intensity III and under in Idaho: Bonners Ferry, Cameron, Cottonwood, Grangeville, Harrison, Kamiah, Kellogg, Nez Perce, Post Falls, Rathdrum.
Not felt in Oregon: Huntington, Imnaha, Lake, Lookingglass, Range, Willamette.
Not felt in Washington: Blewett Pass, Chesaw, Colville, Conconully, Fishtrap, Hellgate, Lemanasky Lake, Lucerne, Milan, Millwood, Rimrock Dam, Rogersburg, Ruff, Wapato.
Not felt in Idaho: Caldwell, Elk City, Granite, Headquarters, Kendrick, Orofino, St. Charles, St. Joe, Southwick, Wallace, Wardner, Warren, Weiser, Winchester.
July 15: 23:13. Waitsburg and Walla Walla, Wash. Slight aftershock.
July 15: 23:23. Walla Walla, Wash. Aftershock.
July 15: 23:25. Waitsburg, Walla Walla, and Wenatchee, Wash. Slight aftershock.
July 15: 23:30. Walla Walla, Wash. Aftershock.
July 15: 23:37. Athens, Oreg., and Waitsburg, Wash. Slight aftershock.
July 15: 23:56. Walla Walla, Wash. Aftershock.
July 15: 23:58. Sprague and Waitsburg, Wash. A few slight aftershocks.
July 16: 0:10. Waitsburg and Walla Walla, Wash. Slight aftershock.
July 16: 0:25. Mason City, Wash. Another series of delayed tremors which shook windows of house. Felt also at Walla Walla, Wash.
July 16: 0:27½. Walla Walla, Wash. Aftershock.

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July 16: 0:38. Walla Walla, Wash. Aftershock.
July 16: 1:06. Walla Walla, Wash. Aftershock.
July 16: 1:10½. Walla Walla, Wash. Aftershock.
July 16: 3:00. Walla Walla, Wash. Light aftershock.
July 16: 4:30. Athens, Oreg. Slight aftershock. Lowden, Wash. Two small shocks felt.
July 16: 8:30. Dayton, Wash,? "Other towns report a slight shock on the 16th at 8:30 a. m.—it was not noticeable here."
July 17: 10:27. Mottinger, Wash. Slight aftershock.
July 17: 20:30. Lowden, Wash. One small shock.
July 18: 7:10. Milton-Freewater, Oreg. Slight aftershock.
July 18: 8:30. Milton-Freewater, Oreg. V. Heaviest aftershock thus far. IV at Helix and Pendleton, Oreg. and at Walla Walla, Wash.
July 18: 9:30. Walla Walla, Wash. Aftershock, duration 4–5 seconds. Stove rattled.
July 20: 4:10. Freewater, Oreg. "Little jiggle."
July 20: 9:30. Freewater, Oreg. "Little jiggle."
July 21: Morning. Umapine, Oreg. Eight aftershocks. No damage.
July 24: Morning. Seattle, Wash. Numerous reports of a series of very slight tremors felt only in high office buildings.
July 25: 0:45. Bothell and Seattle, Wash. IV.
July 26: 0:00.* Seattle, Wash. Very slight.
July 30: 3:20. Freewater, Oreg. IV.
July 30: 4:—. Freewater, Oreg. IV.
July 30: 4:20. Walla Walla, Wash. III or IV.
August 4: 1:19. Helix, Oreg. V. Small objects moved. Quake not so strong as on July 15, but lasted longer. IV at Walla Walla, Wash., III at Colfax, Wash.
August 27: 20:38. Walla Walla, Wash. IV.
August 28: —:—. Walla Walla, Wash. Aftershock.
November 17: 2:00 to 2:30. Walla Walla, Wash. III.
November 17: 4:—. Walla Walla, Wash. III.

ALASKA

[150th meridian time]

January 22: 0:45. Alexander, in lower Susitna valley.
January 31: 4:44. Cordova. Slight.
February 4: 3:25. Seward. Two sharp shocks which did no damage.
March 3: 10:35. Alexander, in lower Susitna valley.
March 4: 3:25. Seward. Two slight shocks.
March 10: 23:30. Holy Cross.
March 10: —:—. Two miles north of Matanuska. Slight.
March 12: 3:45. Holy Cross.
April 9: 16:01. Seward. Slight.
April 15: 18:23. Whale Island. Slight.
May 8: 7:17. Seward. Weak.
May 29: 4:43.* Sitka. Awakened a number of people by rattling of dishes and furniture. Recorded on seismographs at Sitka and College, and at a number of stations in the United States.
May 30: 5:45 and 5:48. Bell Island. Two slight shocks.
June 1: 16:31. Seward. Slight.
June 21: 18:10. Matanuska. Sharp.
June 21: 19:33. Portage. Severe. Felt also at Seward.
June 21: 19:50. Susitna.
June 23: p. m. Rapids.
June 29: 6:00. Portage. Slight.
July 2: 17:58.* Richardson. Violent. Nenana, duration 30 seconds. Felt at College and recorded on the seismograph.
July 2: 18:30. Rapids. Severe.
July 3: 20:05. Portage. Slight.
August 26: 14:45. Matanuska. Duration eight seconds.
September 9: 13:02. Seward. Very light.
September 18: 17:45. Susitna.
September 18: 17:58. Anchorage, III. Seward, light.
September 29: 8:32. Anchorage, IV. Seward, light.
October 22: 20:24.* Instrumental epicenter 61.4° north, 149.7° west. Anchorage VI. Strongest shock for 3 years. Damage about $500. Heavy at Seward;

strong at Susitna; felt at Valdez; slight at Cordova(?). Aftershocks: 20:32 at Anchorage; 20:46 at Seward; 20:49 at Anchorage, Seward, and Susitna; 20:58, 20:59, 21:25, 21:45, and 22:15 at Susitna; 22:22 at Anchorage and Seward (medium heavy); 22:43 at Anchorage.

October 23: Further aftershocks of the preceding activity: About 3:— at Anchorage; 5:34 at Anchorage (slight), Seward (medium heavy), and Susitna; 6:15 at Anchorage; 6:24 at Anchorage (slight) and Seward (medium heavy); 6:38 at Anchorage and Susitna; 10:25 at Anchorage; 13:07 at Anchorage (slight) and Seward (medium heavy); 17:30 at Susitna; time not reported at Homer.

October 24: 20:25 and 22:30. Chinitna Bay. Strong.
October 24: —:—. Homer.
October 25: 11:05. Seward. Heavy. Felt also at Anchorage.
October 25: 11:20. Susitna.
October 26: 9:31. Anchorage.
October 26: 10:02. Seward. Light.
October 26: 12:56. Anchorage.
October 27: 10:16 and 15:01. Anchorage.
October 28: 16:40. Seward. Light. Felt also at Susitna.
October 28: 21:02. Seward. Light.
October 29: 11:04. Anchorage, east-west motion.
October 30: 11:23. Seward. Medium heavy.
October 30: 11:35. Susitna.
November 2: 8:16. Anchorage, east-west motion.
November 2: 23:00. Susitna.
November 5: 13:03. Anchorage, east-west motion.
November 11: 7:29. Anchorage, east-west motion.
November 11: 7:40. Susitna.
November 13: 20:30. Rapids. Severe.
November 15: 23:16. Talkeetna, east-west motion. Felt also at Seward.
November 15: 23:30. Susitna.
November 16: 19:15. Rapids.
November 24: 11:08. Anchorage, IV.
November 25: 11:07. Seward. No damage.
November 29: 13:00. Anchorage. Slight.
November 29: 13:15. Susitna. Slight.
December 12: 15:10. White Mountain.
December 14: 23:20. Anchorage, III.
December 16: 3:43. Anchorage, III or IV.
December 19: 16:55. Susitna.
December 21: 22:30 and 23:45. Rapids.
December 22: 23:43. Big Delta, IV or V.

HAWAIIAN ISLANDS

[157½th meridian (west) time]

NOTE.—In the case of these islands with their many earthquakes of volcanic origin, only the stronger ones are listed. Reports of the Hawaiian Volcano Observatory under the jurisdiction of the National Park Service give all details.

March 11: 16:15.* Slight earthquake sharply felt in the Volcano district by many people. Located 1.1 miles deep on the east rim of Kilauea Crater 0.6 mile south of Kilauea Iki, according to the Hawaiian Volcano Observatory.

March 11: 16:54.* Slight earthquake sharply felt in the Volcano district by many people. Located 1.5 miles deep, 0.7 mile south of Kilauea Iki, and 0.6 mile east of the east rim of Kilauea Crater, at 19°24.4′ north, 155°15.0′ west, according to the Hawaiian Volcano Observatory.

March 11: 16:55.* Slight earthquake sharply felt in the Volcano district by many people. Location same as the preceding according to the Hawaiian Volcano Observatory.

April 15: 8:27.* Moderate earthquake felt generally on the island of Hawaii. Definite reports were received from Olaa, Hookena, and the Hamakua district. Felt rather strongly in the Volcano district. Focus 18 miles under the southeast portion of Kilauea Crater at 19°24.0′ north, 155°15′ west.

November 16: 13:08.* Slight to moderate earthquake located immediately to the southeast of Kilauea Iki Crater, at 19°24.8′ north, 155°14.4′ west, according to the Hawaiian Volcano Observatory. Felt very strongly in the vicinity of Puu Koae on the Kau Desert southwest of Kilauea Crater; felt by a few in the Kilauea area.

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PHILIPPINE ISLANDS

[120th meridian (east) time]

NOTE.—In the case of these islands with their many minor earthquakes, only the stronger ones are listed. Reports of the Weather Bureau of the Philippine Islands give all details. Instrumental times given below are in many cases arrival times of the first preliminary tremors recorded at Manila.

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April 12: 7:38.* Felt throughout Samar and southeastern Luzon. Slight damage at Catbalogan, Samara Island. Epicenter 12°05′ north, 125°50′ east, according to Manila.

July 6: 2:55.* Felt strongly in Davao and Cotabato, and moderately in Surigao, Agusan, Zaniboanga, and Jolo. Epicenter 6.3° north, 127.0° east.

July 23: 15:19? Glan, Cotabato. Strong.

July 30: 16:45. Tigaon, Camarines Sur. Strong.

August 4: 22:11.* Strong earthquake felt throughout northern Luzon and Batan Islands.

August 10: 0:08.* Bangui, Ilocos Norte. Strong.

August 14:. 4:05.* Leyte and Mindanao. Strong.

September 19: 17:49. Cantilan, Surigao. Strong.

November 20: 6:00. Samar. Strong at Tinambacan.

December 3: 3:18.* Northern Luzon. Strong.

December 5: 11:29.* Cabalian, Leyte. Strong.

December 8: 0:28.* Northern Luzon. Strong.

December 8: 18:26.* Very strongly felt at Ormoc, Leyte. Felt also at Hinundayan, Leyte. Epicenter probably in Ormoc Bay, according to Manila.

December 14: 12:04.* Felt in southwestern Luzon. Strong, but no damage, at Manila. Epicenter probably 14°16′ north, 119°47′ east, according to Manila.

December 26: 12:00. Tabaco, Albay. Strong.

PUERTO RICO

[60th meridian time]

February 2: 15:06.* Utuado, IV.

December 11: 22:19.* Mayaguez, IV.

PANAMA CANAL ZONE

[75th meridian time]

February 26: 4:18.* Balboa Heights, II.

April 22: 19:50.* Felt by a few people on the Atlantic side.

May 6: 3:21.* Balboa Heights, V. General alarm throughout the Isthmus. Due to the loud noise and sudden beginning, most people thought it was a heavy explosion. No damage reported except for a few cracks and some loosened tile. Recorded on the accelerograph at Miraflores.

October 11: 15:54.* Balboa Heights, III. Felt at both the Atlantic and the Pacific entrances of the canal.

October 12: 13:28.* Balboa Heights, I.

October 29: 0:53.* Balboa Heights, III. Reported felt at David and Santiago, Panama.

November 22: 19:36.* Balboa Heights, III.

November 28: 6:59.* Balboa Heights, III.

December 10: 8:00.* Balboa Heights, II.

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MISCELLANEOUS ACTIVITIES

GEODETIC WORK

During the year 1936 the following leveling was run for the purpose of detecting earth movements or for earthquake investigation:

Settlement Investigation, vicinity of San Jose, Calif., spring, 1936.
Releveling, vicinity of Helena, Mont.

The leveling in the vicinity of San Jose was the fourth complete leveling of the net which was established for the investigation of abnormal settlement in the area centered around San Jose.

The releveling near Helena, Mont., was run for the purpose of detecting possible earth movement resulting from the earthquakes of October and November 1935. A part of a first-order line was rerun from Amazon, through Helena, to Wolf Creek, a distance of 71 miles. Part of one second-order line was rerun for a distance of 10 miles west of Silver City, and also part of another from East Helena, southeast and east, to the vicinity of Johnson. In addition, a total of 46 miles of new first-order leveling, with closely-spaced bench marks, was run across fault lines, from 4 miles south of East Helena to York, and from the vicinity of Iron, via Broadwater and Fort Harrison, to Helena, together with several crosslines to connect with the other work.

The results of the leveling in the vicinity of San Jose have not been fitted to the first-order level net, and therefore elevations are not available for publication. The leveling in the vicinity of Helena has been adjusted, but has not yet been studied in detail.

There was no triangulation in 1936 for earthquake investigation.

TIDAL OBSERVATIONS

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

HYDROGRAPHIC WORK

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

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

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

TABLE 1.—*Summary of instrumental epicenters*

1936	Greenwich civil time at origin	Region and focal depth	Coordinates of provisional epicenter	
			Latitude	Longitude
	h *m*		°	°
Jan. 2	0 37.2	Arctic Ocean. Depth normal	79.4 N.	1.0 E.
Do	3 54	Southern California. By Pasadena	33.3 N.	115.5 W.
Do	4 05	----do	33.3 N.	115.5 W.
Do	17 27.0	East of Java. Depth about 240 km	10.8 S.	122.0 E.
Do	22 34.4	Felt in western Sumatra. Depth normal	0.2 S.	98.8 E.
Jan. 3	14 07	Lower California. By Pasadena	32.4 N.	115.6 W.
Jan. 4	14 31.7	Pacific Ocean off Panama. Depth near normal	5.7 N.	82.5 W.
Jan. 14	5 36.5	Off Sandwich Islands. Depth normal	60.0 S.	22.5 W.
Do	14 12.2	Argentina. Depth about 600 km	29 S.	63 W.
Do	15 09.8	Felt in Greece. By Strasbourg	37.0 N.	23.2 E.
Do	17 41.2	New Hebrides Islands. Depth normal	19 S.	168 E.
Jan. 15	14 43.5	South Pacific near New Hebrides. Depth normal	19 S.	171 E.
Jan. 18	1 19.9	Alaska. Depth normal	62 N.	153 W.
Jan. 20	16 56.3	Southeast of the Philippines. Slightly deep	5.7 N.	127.0 E.
Jan. 21	4 54.3	Pacific Ocean off Central America. Depth normal	7.5 N.	108 W.

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

1936	Greenwich civil time at origin	Region and focal depth	Coordinates of provisional epicenter	
			Latitude	Longitude
	h *m*		°	°
Jan. 30	17 14	Southern California. By Pasadena	33.3 N.	116.3 W.
Do	18 32	Nevada? By Pasadena	38 N.	118 W.
Feb. 7	8 56.4	China. Depth normal	35.4 N.	103.3 E.
Feb. 8	12 11.2	New Guinea. Depth about 240 km	5.9 S.	145.4 E.
Feb. 10	18 05.6	Pacific near Fiji Islands. Depth 500 km	18 S.	178 W.
Feb. 15	12 46.9	Banda Sea. Depth normal	4.5 S.	133.0 E.
Feb. 16	3 08.9	Argentina	28± S.	66± W.
Do	14 17.8	Near New Caledonia. Depth probably about 200 km.	20 S.	169 E.
Feb. 21	6 20.9	Burma-China border Depth probably about 80 km.	24.2 N.	98.2 E.
Do	16 57.1	New Guinea. Depth normal	5.0 S.	144.5 E.
Feb. 22	15 31.6	Southwest of New Zealand. Depth normal	51.5 S.	165.5 E.
Do	19 22.6	----do	50.5 S.	165 E.
Feb. 27	10 04.0	Felt on Timor Island, Banda Sea. Slightly deep	8 S.	127± E.
Feb. 28	3 03.4	Aleutian Islands. Depth normal	55 N.	163 W.
Mar. 2	3 19.1	Hokkaido Island, northern Japan. Depth nearly normal.	43.5 N.	144 E.
Mar. 5	6 06.1	South Pacific Ocean. Depth normal	9 S.	108 W.
Mar. 6	14 25.5	Friendly Island region. Depth normal	21.0 S.	174.4 W.
Mar. 7	20 35.7	Pacific off Costa Rica. Depth probably normal	9.6 N.	86.7 W.
Mar. 10	12 05.0	Aleutian Island region. Depth probably normal	51.5 N.	170 W.
Do	20 35.8	Off Hokkaido Island, Japan. Depth normal	41.2 N.	144.5 E.
Mar. 20	18 46.4	Nicaragua. Depth normal	11 N.	85 W.
Do	23 53.1	Southwest of Samoa. Depth probably normal	16.5 S.	175.0 W.
Mar. 22	12 16.1	Solomon Islands. Depth normal	6.5 S.	156.5 E.
Do	22 57.2	Aleutian Islands. Depth about 80 km	52 N.	176.5 W.
Mar. 25	8 58.8	North Atlantic Ocean. Depth probably normal	58 N.	32 W.
Apr. 1	2 09.5	Southeast of Mindanao Island, Philippines. Depth normal.	4.5 N.	127.2 E.
Do	20 10.4	----do	3 N.	130 E.
Apr. 2	6 16.8	Near New Ireland. Depth normal	3 S.	151 E.
Apr. 9	16 02.0	Felt on Santa Cruz Island	11 S.	166 E.
Apr 12	20 51.1	Near Isle of Yap. Depth normal	9.4 N.	138.0 E.
Apr. 19	5 07.2	Solomon Islands. Depth normal	7.3 S.	156.6 E.
Do	9 01.1	Near Andaman Islands	13± N.	93± E.
Apr. 23	23 14.3	Aleutian Islands. Depth normal	49.0 N.	179.5 E.
Apr. 26	23 59.0	Destructive in China. Depth probably normal	28.5 N.	103.0 E.
Apr. 27	6 31.0	Gulf of Honduras. Depth normal	16.8 N.	86.9 W.
Apr. 28	5 39.1	Solomon Islands. Depth normal	9 S.	160 E.
May 4	22 07.0	Northern Italy. By Strasbourg	40.8 N.	7.2 E.
May 5	19 43.2	Northeast of New Guinea	3 S.	149 E.
May 6	3 39.0	Peru. Depth about 120 km	8.3 S	74.9 W.
May 7	10 02.7	Region of Colima, Mexico	19.5 N.	105.5 W.
May 8	9 11.5	Java Sea. Depth about 500 km	6 S	112 E.
Do	17 22.2	Alaska. Depth about 80 km	61 N.	153 W.
May 10	17 40.2	California. By Pasadena	37.5 N.	118.5 W.
May 11	17 27.4	Region of New Ireland. Depth normal	5 S.	153 E.
May 16	7 05.7	Felt in Szechwan, China. Depth normal	28.7 N.	104.0 E.
May 19	7 22.3	Java Sea. Depth about 580 km	6 S.	111.5 E.
Do	20 49.8	Arafura Sea southwest of New Guinea	9 S.	128 E.
May 20	3 05.3	Solomon Islands	9 S.	160 E.
May 22	0 15.9	North Central Argentina	32.1 S.	64.5 W.
Do	23 21.0	South of the New Hebrides. Depth normal	21.5 S.	170 E.
May 25	3 02.7	Northeastern New Guinea	4± S.	145± E.
May 27	6 19.4	Nepal, India. Depth slightly less than 80 km	28.9 N.	83.5 E.
May 28	18 49.0	Pacific Ocean off Mexico	10 N.	104 W.
May 29	14 42.7	Felt at Sitka, Alaska	----------	----------
June 3	2 55.4	Felt in northern Japan. By Zinzen	41.3 N.	142.3 E.
Do	9 15.2	Off Northern California. By Berkeley	40.2 N.	126.4 W.
Do	17 55.5	Andes Mountains. By La Plata	----------	----------
June 6	16 21.8	North Atlantic Ocean	30± N.	43± W.
June 7	4 38.2	Arctic northeast of Jan Mayen	73.7 N.	6.0 E.
June 10	3 29.2	Near Persia-Balchustan border. By Baku	27.5 N.	63.5 E.
Do	8 23.4	East of New Guinea. Depth 160 km	5.5 S.	147.5 E.
June 14	2 27.7	Kamchatka. By Vladivostock	54.0 N.	161.0 E.
Do	17 01.4	Asia Minor	37 N.	36 E.
June 16	0 33.3	Probably near Friendly Islands in south Pacific Ocean.	----------	----------
June 20	3 24.1	Felt in Texas. By St. Louis. See p. 8	35.7 N.	100.3 W.
June 22	10 28.1	Probably northern Argentina	----------	----------
June 27	3 22.6	North Atlantic Ocean	60± N.	30± W.
Do	21 13.4	Felt in northern Japan	43.8 N.	146.4 E.
June 28	8 10.4	East of Japan. By Sverdlovsk	32.5 N.	145.5 E.
June 29	14 30.2	Afghanistan. Depth about 220 km	37.0 N.	70.9 E.
June 30	15 06.7	Off Kamchatka	51.0 N.	160.8 E.
Do	19 26.1	Near Afghanistan-Persia border	34.8 N.	60.3 E.
July 2	16 29.0	Nevada. By Pasadena	39.2 N.	117.5 W.
July 3	2 58.6	Solomon Islands. Depth normal	10.0 S.	161.1 E.
July 4	8 52.5	Bolivia	17.2 S.	68.0 W.

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

1936	Greenwich civil time at origin	Region and focal depth	Coordinates of provisional epicenter	
			Latitude	Longitude
	h *m*		°	°
July 5	18 55.4	Off Mindanao, Philippine Islands. Depth 120 km	6.3 N.	127.0 E.
July 6	18 20.8	Region of Celebes Island. By Manila	1 S.	127 E.
July 12	2 42.0	South of Tonga Islands. Depth normal	23.3 S.	173.1 W.
July 13	11 12.3	Near Taltal, Chile. Slightly deeper than normal	25.0 S.	69.9 W.
July 16	7 07.8	Oregon-Washington border [1]	46.0 N.	118.3 W.
July 19	2 36.9	Western Colombia. Depth normal	1.0 N.	77.3 W.
July 22	6 18.9	Near Friendly Islands. Depth normal	14 S.	172 W.
July 23	6 20.8	Northwest of Samoa	10± S.	173± W.
July 26	7 36.8	Destructive north of Taltal, Chile. Depth nearly normal.	24.4 S.	70.5 W.
July 28	5 18.4	Near northeast coast of New Guinea. Depth normal.	3.0 S.	143.1 E.
Do	7 52.6	Near northeast coast of New Guinea.	2.5 S.	143.5 E.
July 31	17 41.2	Gulf of California	24.8 N.	110.0 W.
Aug. 1	6 24.5	Kansu, China. Destructive	34.1 N.	106.7 E.
Do	8 05.8	Off Lower California	25 N.	110 W.
Aug. 4	2 32.5	Gulf of California	30.5 N.	113.5 W.
Do	3 50.8	West coast of Mexico	16± N.	93± W.
Aug. 9	12 53.8	Lower California. By Pasadena	32.4 N.	115.6 W.
Aug. 10	7 59.4	Southern California. By Pasadena	33.7 N.	116.3 W.
Aug. 11	7 17	Central California. By Pasadena	36.6 N.	117.8 W.
Aug. 13	5 15.4	Lower California. By Pasadena	32.4 N.	115.6 W.
Do	20 02.6	East coast of Mindanao, Philippines	8.5 N.	127.2 E.
Aug. 16	18 07.3	Hawaii About 10 miles east of Hilo, Hawaii, according to Hawaiian Volcano Observatory	----------	----------
Aug. 17	13 59.9	Solomon Islands	6.0 S.	154.2 E.
Aug. 18	7 07.1	Pacific Ocean off Mexico	18 N.	105 W.
Aug. 19	13 18	Southern California. By Pasadena	33.5 N.	116.9 W.
Aug. 22	5 21	Felt in southern California. By Pasadena	33.8 N.	117.8 W.
Do	6 51.5	Formosa. Destructive	22.3 N.	121.0 E.
Do	13 16.9	Off west coast of Mexico	15± N.	98± W.
Aug. 23	21 12.2	Destructive in northern Sumatra	5.5 N.	95.0 E.
Aug. 24	22 22.2	South of Australia	53± S.	140± E.
Aug. 25	18 43.2	Probably Tonga Islands	20 S.	174 W.
Aug. 26	11 34.8	Near Japan	45 N.	153 E.
Do	21 19.5	Off Peru	5 S.	106 W.
Aug. 28	6 38.6	Solomon Islands	10± S.	157± E.
Aug. 30	8 15	Southern California. By Pasadena	32.9 N.	116.4 W.
Sept. 2	9 15.8	Off Kurile Islands	45 N.	151 E.
Sept. 3	5 06	Probably south of Mexico in region of Chiapas State.	----------	----------
Sept. 4	8 09.6	Pacific southeast of Tokyo	30.5 N.	142.0 E.
Sept. 6	17 39.5	Near Tonga Islands	22.0 S.	174.3 W.
Sept. 18	18 38.4	Southeast of Tokyo	30.5 N.	142.5 E.
Sept. 19	1 01.9	Near west coast of Sumatra. Depth about 80 km	3.0 N.	97.9 E.
Sept. 22	10 40.8	Western Nevada	38.3 N.	117.5 W.
Sept. 23	7 40.9	Gulf of California	29.2 N.	113.5 W.
Do	17 16	Lassen Park, California, according to Berkeley	----------	----------
Sept. 24	0 56	California. By Pasadena	34.2 N.	117.9 W.
Do	14 11.1	6 miles northeast of Niles, Calif., according to Berkeley.	----------	----------
Sept. 25	12 53.6	Off Oregon	43.0 N.	129.0 W.
Sept. 28	13 01	Probably northwest of Yakutat Bay, Alaska	----------	----------
Oct. 3	21 50.2	Celebes Sea	2 N.	123 E.
Oct. 4	23 53.9	North of New Zealand	28± S.	179± E.
Oct. 5	9 44.4	East Indies	2 N.	127 E.
Oct. 8	11 29	Gulf of California. By Pasadena	29± N.	113± W.
Oct. 10	3 08.4	Philippine Islands	7 N.	127 E.
Do	18 49	California. By Pasadena	37.9± N.	118.5± W.
Oct. 12	13 56	Lower California. By Pasadena	32.6± N.	116.0± W.
Do	17 07	----do	32.6± N.	116.0± W.
Oct. 13	6 32.5	Celebes	1 N.	126 E.
Oct. 15	21 08.8	Concepción, Chile	37 S.	73 W.
Oct. 16	11 56.5	Solomon Islands	6 S.	153 E.
Oct. 18	3 10.1	Alps. Epicenter by Strasbourg	46.2 N.	12.5 E.
Oct. 19	12 04.3	Moluccas	3 S.	128 E.
Oct. 21	0 40	Southern California. By Pasadena	34.2 N.	117.2 W.
Oct. 23	6 24.4	Anchorage, Alaska	61.4 N.	149.7 W.
Oct. 26	19 32.1	Sumatra	0 N.	99 E.
Do	23 05.7	Jan Mayen Island	71.6 N.	6.6 W.
Oct. 29	5 53.1	Off western Panama	7 N.	82 W.
Do	18 38.9	Near Guam	14 N.	145 E.
Do	22 35	Southern California. By Pasadena	33.7± N.	118.7± W.
Oct. 30	18 09.9	Central Chile	38 S.	72 W.
Nov. 1	16 10.0	Argentina-Chile border	38± S.	71± W.
Nov. 2	14 58.0	Kurile Islands. Depth about 80 km	47.4 N.	154.0 E.
Do	20 46.0	East of Japan. Depth about 80 km	38.1 N.	141.8 E.

[1] Epicenter based on field studies. Instrumental estimates varied by 0.2° east and west of this location.

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

1936	Greenwich civil time at origin		Region and focal depth	Coordinates of provisional epicenter			
				Latitude		Longitude	
	h	*m*		°		°	
Nov. 5	20	46.3	Off Oregon coast	43±	N.	131±	W.
Nov. 6	11	38.0	Probably off west coast of Mexico	33?	N.	108?	W.
Nov. 12	2	15.5	Marianas Islands in western Pacific	17.0	N.	146.7	E.
Do	8	28.3	Pacific Ocean near Guam	13.5	N.	145.5	E.
Do	20	04.8	North Japan. Depth about 80 km	45.5	N.	148.8	E.
Nov. 13	12	31.5	Pacific Ocean off Kamchatka	55.5	N.	163.0	E.
Nov. 14	1	37.1	Pacific Ocean off Guatemala	14±	N.	92±	W.
Nov. 15	21	50.4	Tonga Islands. Depth about 550 km	21	S.	177	W.
Do	22	20.8	Probably Aleutian Islands	54?	N.	170?	E.
Nov. 18	18	02	Northwest of Santa Barbara, Calif. By Pasadena.	34.7	N.	120.2	W.
Nov. 19	21	10.3	West coast of Guatemala	14.0	N.	90.7	W.
Nov. 22	18	19.4	West coast of Guatemala. Depth about 80 km	13.8	N.	90.8	W.
Nov. 23	20	06.3	Venezuela	12.2	N.	70.1	W.
Nov. 26	2	12.0	Costa Rica	10.5	N.	84.3	W.
Nov. 30	11	13	Gulf of California. By Pasadena	29	N.	113	W.
Do	23	45.8	Banda Sea	2.0	S.	126.5	E.
Dec. 1	6	09.2	Southern Japan. Depth about 240 km	30.5	N.	129.4	E.
Dec. 5	0	38.1	Off nothern Chile. Deep	22	S.	74	W.
Do	2	05	Lower California. By Pasadena	32.4	N.	115.6	W.
Dec. 13	21	30.9	Guam	14	N.	145	E.
Dec. 14	4	03.7	Felt in Luzon. By Manila	14.3	N.	119.8	E.
Dec. 19	2	57.4	Western Argentina	29±	S.	69±	W.
Dec. 20	2	43.4	Destructive in El Salvador	13.3	N.	88.9	W.
Do	13	23.5	El Salvador	13	N.	89	W.
Do	18	09.5	Off Sumatra	6	S.	104	E.
Dec. 21	19	03.3	Queen Charlotte Islands	53.1	N.	131.5	W.
Do	19	27.9	----do	53.1	N.	131.5	W.
Dec. 22	9	17	California. By Pasadena	35.2	N.	118.2	W.
Dec. 25	8	31	Lower California. By Pasadena	31.7	N.	115.1	W.
Do	20	03.9	Off Mexico	16	N.	105	W.
Dec. 26	22	52.6	Kermadec Islands	30	S.	178	W.
Dec. 27	0	14.7	Destructive in Japan. Epicenter by Tokyo	34.4	N.	139.2	E.
Dec. 29	13	58.7	Off Central America	5±	N.	90±	W.
Do	14	47.9	East Indies. Depth about 80 km	5	S.	154	E.

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STRONG-MOTION SEISMOGRAPH RESULTS

INTRODUCTION

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

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

The analysis of accelerograms by methods of integration was discussed in "United States Earthquakes, 1935" particularly in connection with the Helena earthquake record of October 31, 1935. Although time has not permitted a more thorough study of the adjustments made in computing the displacement curves as published, a partial appraisal of integration methods is possible at this writing as a result of shaking table tests made at the Massachusetts Institute of Technology through a cooperative program arranged between the Department of Civil and Sanitary Engineering of that institution and the Coast and Geodetic Survey. Instruments similar to those in use at Helena were placed on a shaking table designed especially for engineering seismological investigations and the computed displacements, obtained by integration, were compared with the recorded motion of the shaking table. It was agreed that the accuracy of integration methods was sufficient for engineering purposes. Errors enter into the work as a result of occasional shifting of the zero positions of the accelerometer pendulums and inaccuracies in the methods of magnifying and scaling the curves but these may be considered "slow-motion" effects which may distort long-period motions appreciably but have relatively little engineering significance. Long-period wave

forms, however, may be quite unreliable, but as a result of the tests certain sources of error have been revealed and marked improvement in the accuracy of the work is anticipated.

Further investigation of irregularities in the motion of translation of the recording drum at the Los Angeles subway terminal station during the Long Beach earthquake indicated that the long-period displacements of large amplitude computed from that record (see p. 39, Special Publication 201) may be due largely to that cause. It will be recalled that base lines were later placed on all records to eliminate this type of error. A recomputation of the subway terminal record is contemplated.

In appraising the analysis of the Helena, Mont., record of October 31, 1935, as described in Serial 600 "United States Earthquakes, 1935" it now appears very probable that the slow linear deviations in the velocity curves (with corresponding parabolic effects in the displacement curves) should be charged to abrupt shifts of the zero positions of the accelerometer pendulums. Linear adjustments of the velocity curves could therefore be made which would practically eliminate the large displacements which appear in the two interpretations of the displacement curves, on pages 77 and 78 of that publication. It also appears that slow deviations of the order of 1 or 2 centimeters may be due to errors entering into the work because of paper distortions resulting from enlarging processes, a type of error which can apparently be greatly reduced, if not practically eliminated. The true form of the displacement curves may therefore very easily be pictured as simply a series of irregular oscillations about a practically straight axis. This would in no sense eliminate the wave of approximately 2-seconds period which appears within the first 5 seconds of the computed displacement curves but would develop much more clearly its true form, which, in the analysis given, is largely obscured by relatively slow and evidently spurious displacements.

With reference to the possibility of recording a permanent vertical displacement, as discussed on page 78 of Serial No. 600, a preliminary examination of the data obtained by rerunning a line of levels in the vicinity of Helena reveals that marked changes occurred at only two bench marks, roughly 15 and 30 miles south of Helena, and they are believed to have been due to frost or other action on stone markers. None of the bench marks in or close to Helena exhibited movements of an order of size greater than about 2 cm. It must therefore be concluded that no adjustment of the vertical displacement curve can be legitimately made which involves a permanent displacement of appreciable magnitude.

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

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

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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 can make his own measurements. It is realized that the slightest variations in the copy can easily lead to misleading conclusions. Those who desire true copies for critical study should address the Director of the Bureau for further particulars.

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

TABLE 2.—*List of shocks recorded and records obtained on strong-motion seismographs in 1936*

Date, epicenter, and recording station	Records [1]	
	Accelerograph	Displacement meter
Feb. 13; Helena, Mont.: Helena	1	
Feb. 23; southern California: Colton	1	1
May 6; Panama Canal Zone: Miraflores	1	
June 3; off Cape Mendocino: Ferndale	1	
June 11; Helena, Mont.: Helena	1	
June 12; Helena, Mont.: Helena	1	
Oct. 10; East central California: Bishop	1	
Total	7	1

[1] No records were obtained on Weed strong-motion seismographs.

THE HELENA, MONT., EARTHQUAKE OF FEBRUARY 13, 1936, AT 17:30

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Probably about 3 miles northeast of Helena.

Maximum intensity and damage.—Some minor damage and much alarm at Helena.

Area affected.—About 30,000 square miles.

Summary of strong-motion records.—

HELENA: Probably about 3 miles southwest of epicenter. Recorded on the accelerograph in the basement of the Federal Building.

ANALYSIS OF THE HELENA RECORD OF FEBRUARY 13

Accelerograph record.—Figure 7. The record is typical of many other aftershocks recorded at Helena. With the exception of one 0.5 sec. wave registered on a horizontal component at the start, it consists chiefly of an irregular series of 0.13 and 0.09 sec. waves gradually

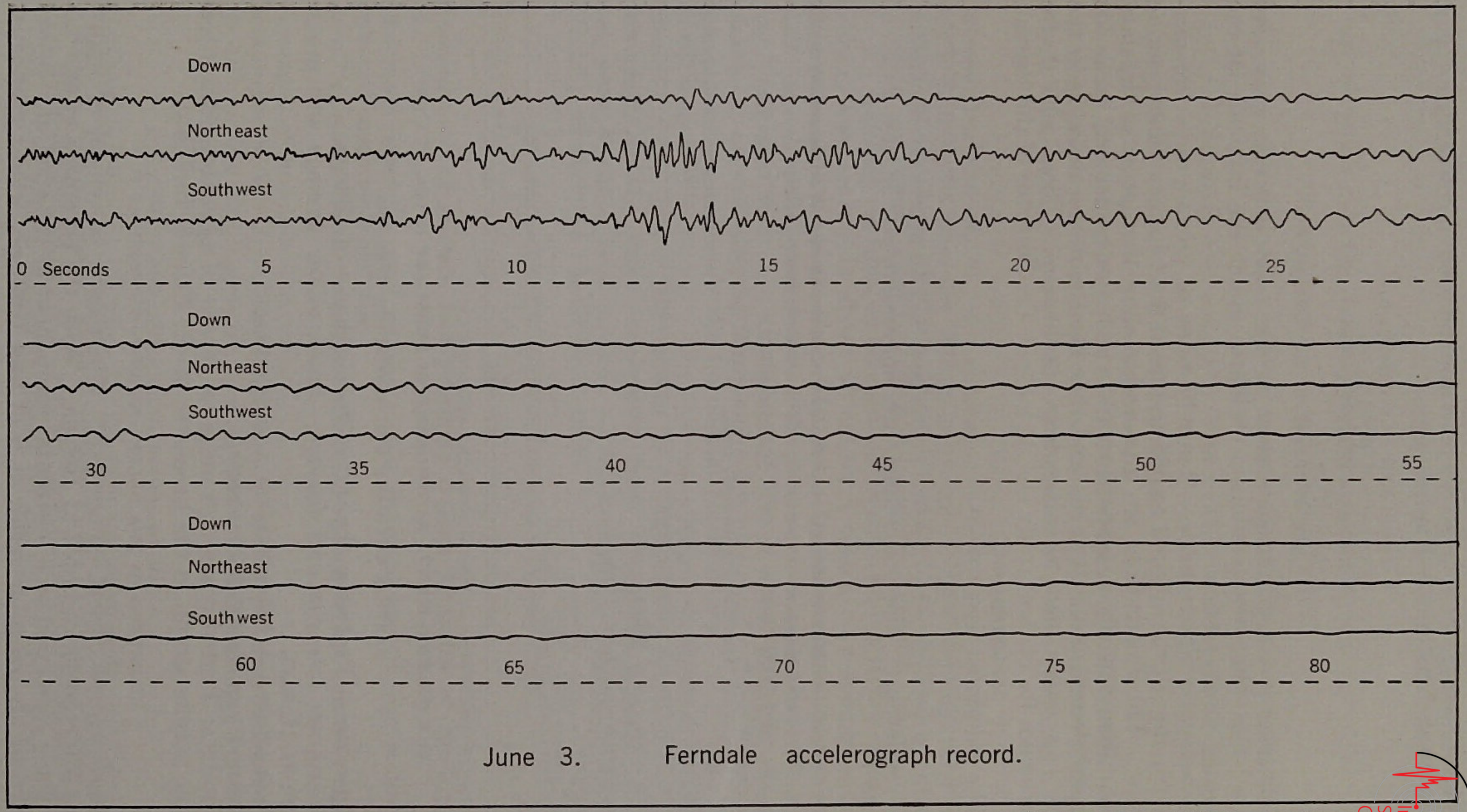

FIGURE 7.—Tracings of Helena accelerograph record of February 13, Colton accelerograph and displacement-meter records of February 23, and Miraflores accelerograph record of May6, 1936.

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tapering down from a maximum at the start to zero at about 25 sec. The maximum acceleration, attained by only one wave, is about 20 cm/sec.^{2}

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THE SOUTHERN CALIFORNIA EARTHQUAKE OF FEBRUARY 23, 1936, AT 14:20

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—34°07′ north, 117°25′ west, near Colton, according to Pasadena.

Maximum intensity and damage.—V at Colton and nearby. Damage slight.

Area affected.—About 11,000 square miles.

Summary of strong-motion records.—

COLTON: About 6 miles south 63° east of epicenter. Recorded on the accelerograph which is located on the ground floor of one of the Southern California Edison Company substation buildings.

ANALYSIS OF THE COLTON RECORD OF FEBRUARY 23

Accelerograph record.—Figure 7. The outstanding feature of the accelerogram is the prominence of waves of 0.13 sec. period. They are rather uniformly active during the first 5 seconds, thereafter gradually tapering off until at 30 seconds all apparent activity ceases. Maximum acceleration is about 25 cm/sec.^{2}, which corresponds to a displacement of little more than 0.01 cm. In one instance a period of 0.20 sec. is quite prominent with maximum acceleration of 12 cm/sec.^{2}, corresponding to a displacement also of about 0.01 cm. The accelerations on the vertical component are of roughly three-fourths the magnitude of those on the horizontal components.

Displacement-meter record.—The two components show short-period displacements of only a few tenths of a millimeter, corresponding substantially to the values estimated from the accelerogram. No longer periods than those already mentioned are apparent. After 20 seconds all activity apparently ceases.

THE PANAMA CANAL ZONE EARTHQUAKE OF MAY 6, 1936

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Not known, but probably within 50 miles of Balboa, C. Z.

Maximum intensity and damage.—No damage except for a few cracks and some loosened tile.

Area affected.—Not known. General alarm throughout the Isthmus.

Summary of strong-motion records.—

MIRAFLORES, C. Z.: Within about 50 miles of the epicenter. Recorded on the accelerograph in the Centerwell Operating Tunnel of the Miraflores Locks.

ANALYSIS OF THE MIRAFLORES RECORD OF MAY 6

Accelerograph record.—Figure 7. Motion is perceptible for only a few seconds and consists of rather regular trains of waves, especially on the horizontal components. On the north-south component the maximum acceleration shown is about 60 cm/sec.^{2} This occurs at

the beginning of the record, and may have been preceded by stronger motion occurring before the starting mechanism had time to operate. The dominant period is about 0.15 sec.

On the east-west component the maximum acceleration is about 50 cm/sec.^{2}, and occurs at the beginning of the record so that again the maximum acceleration may have been lost. The dominant period is about 0.16 sec.

On the vertical component the maximum acceleration is about 7 cm/sec.^{2}, occurring about ⅓ second after the beginning of the record. The dominant period is about 0.13 sec.

The small differences in period from component to component are more probably due to inaccuracies in measurement than to actual differences in the motion of the ground. The wave groups following the first impulsive horizontal movement are of only about one-sixth the magnitude of the first impulse. The maximum horizontal displacement was close to 0.05 cm.

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THE EARTHQUAKE OF JUNE 3, 1936, OFF CAPE MENDOCINO

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Off Cape Mendocino, at 40.16° north, 126.45° west, according to Berkeley.

Maximum intensity and damage.—V on shore. Damage none or slight.

Area affected.—About 1,800 square miles on land.

Summary of strong-motion records.—

FERNDALE: About 122 miles north 75° east of the epicenter. Recorded on the accelerograph in the basement of the Federal Building.

ANALYSIS OF THE FERNDALE RECORD OF JUNE 3

Accelerograph record.—Figure 8. Motion is perceptible throughout the 90 seconds of the record. It is for the most part rather irregular —a characteristic of strong distant shocks.

On the northwest component the most prominent motion occurs about 13 seconds after the beginning of the record. The acceleration is about 17 cm/sec.^{2}, and the period about 0.44 sec.; the motion is irregular, with shorter-period motion superposed. Other prominent periods on this component are approximately 0.35, 0.50, and 0.82 sec., with accelerations of 12, 9, and 7 cm/sec.^{2}, respectively, occurring 14, 9, and 26 seconds, respectively, after the beginning of the record. There is irregular activity of 6 or 7 cm/sec.^{2} near the beginning of the record.

On the southwest component the short-period activity at 13 seconds is more pronounced than the long-period, the maximum acceleration of 15 cm/sec.^{2} being associated with a 0.19 sec. period. There are waves of periods 0.50 and 0.17 sec., with accelerations 10 and 9 cm/sec.^{2} respectively, occurring at 9 and 16 seconds, respectively, after the beginning of the record.

The motion is weaker and less regular on the vertical component. The most prominent motion, occurring at 14 seconds, has a period of about 0.32 sec. and an acceleration of about 9 cm/sec.^{2} There are some waves of period about 0.39 sec. and acceleration 4 cm/sec.^{2}, with weak motion of about half their period superposed at about 3 seconds after the beginning of the record.

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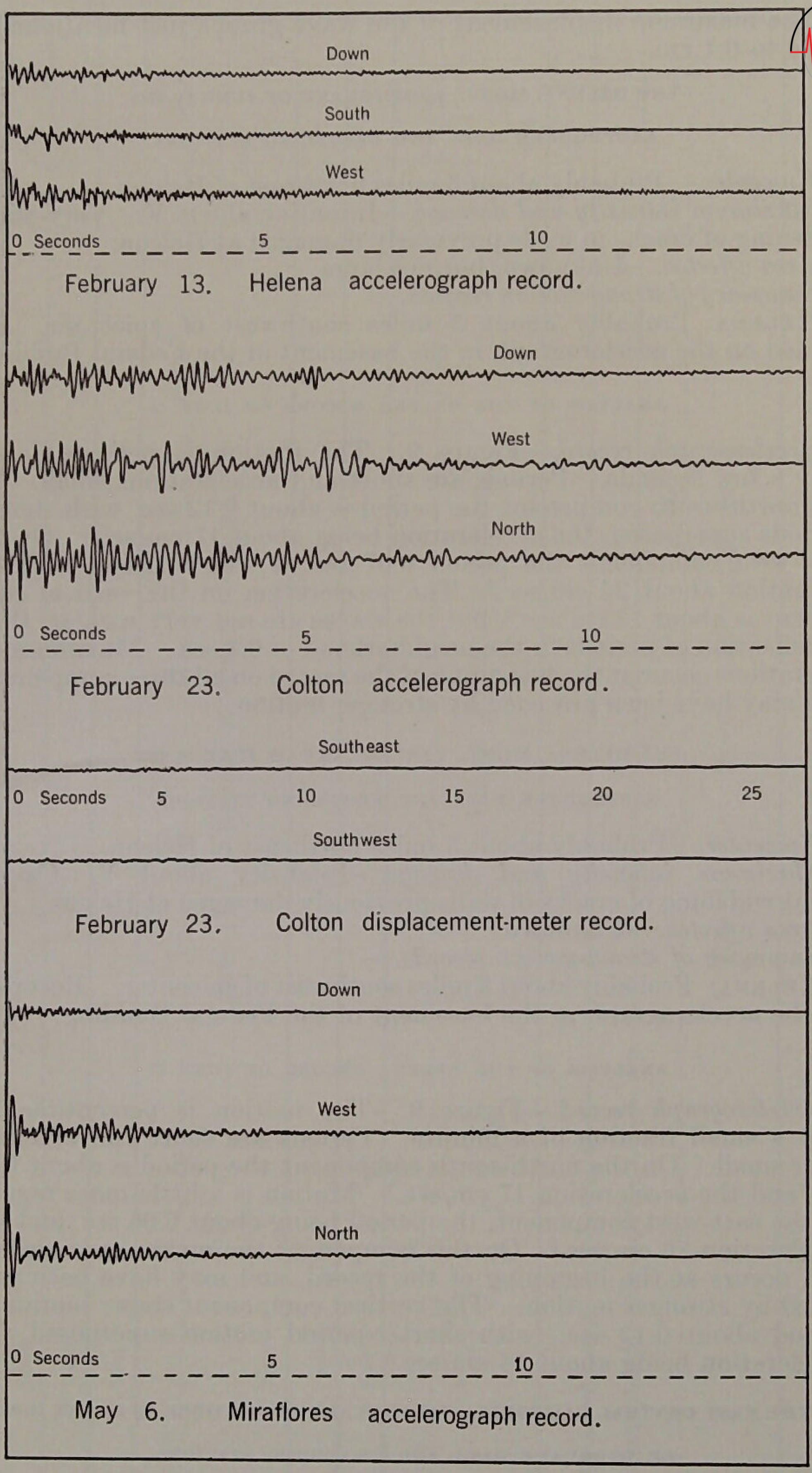

FIGURE 8.—Tracing of Ferndale accelerograph record of June 3, 1936.

The maximum displacement of the wave groups just mentioned is close to 0.1 cm.

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THE HELENA, MONT., EARTHQUAKE OF JUNE 11, 1936

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Probably about 3 miles northeast of Helena.

Maximum intensity and damage.—Intensity about V. Very slight widening of cracks in walls previously damaged at Helena.

Area affected.—Unknown, but not large.

Summary of strong-motion records.—

HELENA: Probably about 3 miles southwest of epicenter. Recorded on the accelerograph in the basement of the Federal Building.

ANALYSIS OF THE HELENA RECORD OF JUNE 11

Accelerograph record.—Figure 9. The motion is perceptible for only a few seconds. Periods are short and accelerations small. On the north-south component the period is about 0.12 sec. with shorter periods superposed, the acceleration being about 17 cm/sec.^{2} On the east-west component the period 0.07 sec. is well marked, with acceleration about 26 cm/sec.^{2} The acceleration on the vertical component is about 13 cm/sec.^{2}, but the waves are not very regular; there is indication of periods in the neighborhood of 0.1 sec. Maximum accelerations occur at the beginning of the record on all three components and may have been preceded by stronger motion.

THE HELENA, MONT., EARTHQUAKE OF JUNE 12, 1936

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Probably about 3 miles northeast of Helena.

Maximum intensity and damage.—Intensity about V. Caused slight widening of cracks in walls previously damaged at Helena.

Area affected.—Unknown.

Summary of strong-motion records.—

HELENA: Probably about 3 miles southwest of epicenter. Recorded on the accelerograph in the basement of the Federal Building.

ANALYSIS OF THE HELENA RECORD OF JUNE 12

Accelerograph record.—Figure 9. The motion is perceptible for only a small fraction of a minute. Periods are short and accelerations small. On the north-south component the period is about 0.09 sec. and the acceleration 17 cm/sec.^{2} Motion is a little more regular on the east-west component, the period being about 0.06 sec. and the acceleration 36 cm/sec.^{2} On this component the maximum acceleration occurs at the beginning of the record, and may have been preceded by stronger motion. The vertical component shows motion of period about 0.12 sec., with shorter-period motion superposed, the acceleration being about 14 cm/sec.^{2}

THE EAST CENTRAL CALIFORNIA EARTHQUAKE OF OCTOBER 10, 1936, AT 10:49

EARTHQUAKE DATA AND RECORDING STATIONS

Epicenter.—Northwest of Bishop, at about 37°52′ north, 118°30′ west, according to Pasadena.

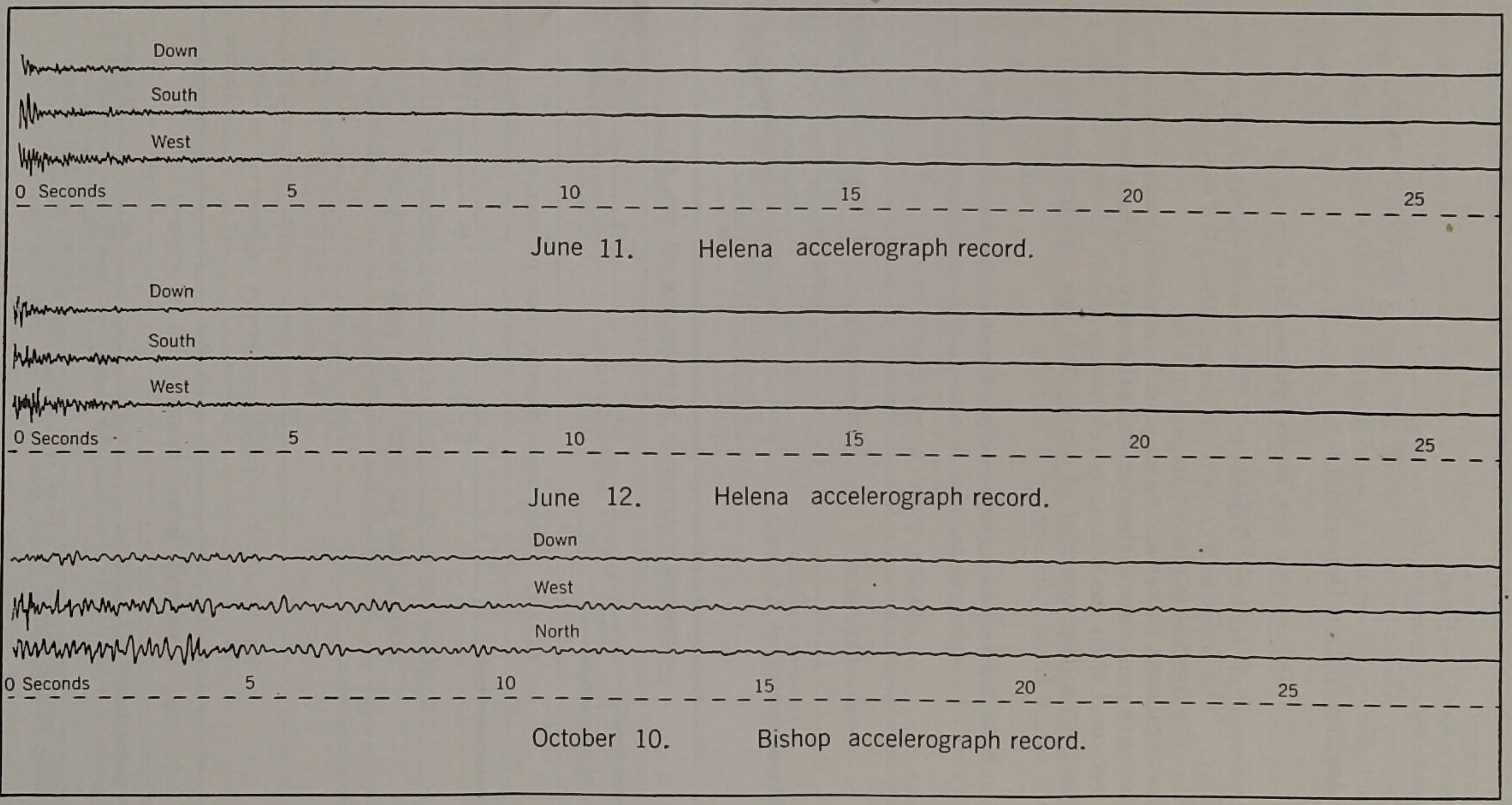

FIGURE 9.—Tracings of Helena accelerograph records of June 11 and 12, and Bishop accelerograph record of October 10, 1936.

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Maximum intensity and damage.—IV at Laws and Bishop, Calif. No damage.

Area affected.—Small.

Summary of strong-motion records.—

BISHOP: About 36 miles south 10° east of epicenter. Recorded on the accelerograph on the ground floor of the office and garage of the Los Angeles Water Department.

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ANALYSIS OF THE BISHOP RECORD OF OCTOBER 10

Accelerograph record.—Figure 9. The record shows only moderate activity. The most active portion lasted about 12 seconds; after 45 seconds the motion is almost imperceptible.

The dominant waves are more pronounced and more regular on the north-south component than on the other two. Their period is about 0.17 sec. and their maximum acceleration about 12 cm/sec.^{2}; this corresponds to a displacement of about 0.01 cm. Other periods on the record range from 0.08 sec. to 0.20 sec.

TABLE 3.—*Summary of strong-motion seismograph data for the year 1936* [1]

[See text for more detail and description of the seismograms]

Station and instrument	Earth-wave period	Maximum acceleration	Maximum displacement
	Seconds	*Cm/sec.*^{2}	*Cm*
HELENA, MONT., EARTHQUAKE OF FEB. 13.			
Helena accelerograph	0.5 [2]		
	0.13 [3]		
	0.09 [3]		
		20 [4]	
SOUTHERN CALIFORNIA EARTHQUAKE OF FEB. 23			
Colton accelerograph [5]	0.20 [6 7]	12	0.012 [8]
Colton displacement meter [10]	0.13 [6 7 9]	25 [4]	0.011 [8]
PANAMA CANAL ZONE EARTHQUAKE OF MAY 6			
Miraflores accelerograph	0.16 [11]	50	0.032 [8]
	0.15 [11]	60	0.034 [8]
	0.13 [11 12]	7	0.004 [8]
EARTHQUAKE OF JUNE 3 OFF CAPE MENDOCIN			
Ferndale accelerograph	0.82 [4]	7	0.12 [8]
	0.50	10, 9	0.06 [8]
	0.44 [3 7 13]	17	0.083 [8]
	0.35 [4]	12	0.037 [8]
	0.19	15	0.014 [8]
	0.17	9	0.006 [8]
	0.39 [12 13 14]	4	0.015 [8]
	0.32 [12 13 14]	9	0.023 [8]
HELENA, MONT., EARTHQUAKE OF JUNE 11			
Helena accelerograph [15]	0.12 [4 13]	17	0.006 [8]
	0.07 [7]	26	0.003 [8]
	(16)	13	

See footnotes at end of table.

TABLE 3.—*Summary of strong-motion seismograph data for the year 1936*—Continued

HELENA, MONT., EARTHQUAKE OF JUNE 12

Station and instrument	Earth-wave period	Maximum acceleration	Maximum displacement
	Seconds	*Cm/sec.*[2]	*Cm*
Helena accelerograph	0.09 [4]	17	0.003 [8]
	0.06 [4]	36 [17]	0.003 [8]
	0.12 [4 12 13]	14 [4]	0.005 [8]

EAST CENTRAL CALIFORNIA EARTHQUAKE OF OCT. 10

Bishop accelerograph	0.17 [4]	12 [4]	0.009 [4 8]
	0.08-0.20 [18]		

[1] This tabulation does not attempt to combine the two horizontal components.
[2] Horizontal component at the start.
[3] Irregular.
[4] Approximate value.
[5] The accelerations on the vertical component are of roughly three-fourths the magnitude of those on the horizontal components.
[6] Horizontal component.
[7] Prominent.
[8] Computed from the measured acceleration by means of the formula $A=\frac{T^2}{4\pi^2}\alpha$, in which α is the maximum acceleration, T the period, and A the displacement amplitude. In the case of waves not of simple harmonic form, the results obtained by use of this formula are only approximate.
[9] Active during the first 5 seconds of the record.
[10] The two components show short-period displacements of only a few hundredths of a centimeter, corresponding substantially to the values estimated from the accelerogram. No longer periods than those tabulated are apparent.
[11] Rather regular motion.
[12] On the vertical component.
[13] Shorter-period motion superposed.
[14] Motion less regular than on the horizontal components.
[15] Maximum accelerations occur at the beginning of the record on all three components.
[16] Irregular motion on the vertical component with indication of periods in the neighborhood of 0.1 sec.
[17] Maximum at the beginning of the record.
[18] Not so pronounced or regular as the preceding.

TABLE 4.—*Instrumental constants of strong-motion seismographs in 1936*

HELENA, MONT., EARTHQUAKES OF FEBRUARY 13 AND JUNE 11 AND 12

Station and instrument	Orientation of instrument	Pendulum period	Static magnification	Sensitivity [1]	Damping ratio	Instrument number
		Sec.		*Cm*		
Helena accelerograph [2]	Up [3]–Down	0.098	106	2.57	10	V14
	N.–S	0.098	108	2.62	13	L35
	E.–W	0.101	107	2.75	10	T31

SOUTHERN CALIFORNIA EARTHQUAKE OF FEBRUARY 23

Colton accelerograph	Up–Down	0.097	100	2.39	8	V58
	E.–W	0.100	101	2.55	8	L59
	S.–N	0.099	106	2.63	9	T60
Colton displacement meter	NW.–SE	9.9	1.14	-------	4	R16
	NE.–SW	9.95	1.14	-------	5	L16

PANAMA CANAL ZONE EARTHQUAKE OF MAY 6

Miraflores accelerograph [2]	Up–Down	0.105	110	3.08	(4)	V73
	E.–W	0.101	116	2.99	3	L74
	S.–N	0.101	112	2.89	(4)	T75

[1] The sensitivity is the number of centimeters deflection on the seismogram that corresponds to 100 cm/sec.[2] of acceleration. The deflection corresponding to 1/10 gravity may be obtained by multiplying the sensitivity tabulated by 0.98. (See p. 32.)
[2] Not equipped with tape recorder.
[3] The direction on the left (Up in the first case) indicates the direction of pendulum displacement relative to instrument pier which will displace the trace upward on the original seismogram.
[4] Doubtful.

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TABLE 4.—*Instrumental constants of strong-motion seismographs in 1936*—Continued

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Station and instrument	Orientation of instrument	Pendulum period	Static magnification	Sensitivity	Damping ratio	Instrument number
		Sec.		*Cm*		
NORTHERN CALIFORNIA EARTHQUAKE OF JUNE 3						
Ferndale accelerograph	Up-Down	0.098	101	2.47	9.5	V10
	S. 45° W.–N. 45° E.	0.098	113	2.75	6.5	L4
	N. 45° W.–S. 45° E.	0.100	107	2.72	9.5	T15
EAST CENTRAL CALIFORNIA EARTHQUAKE OF OCTOBER 10						
Bishop accelerograph	Up-Down	0.101	109	2.81	10	V23
	E.–W	0.100	107	2.71	11	L36
	N.–S	0.099	108	2.68	11	T19

TABLE 5.—*List of strong-motion seismograph stations, 1936*

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

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

TABLE 5.—*List of strong-motion seismograph stations, 1936*—Continued

Station and foundation	Instrument	Date of installation
SOUTHERN CALIFORNIA—continued		
Los Angeles:		
Chamber of Commerce: Alluvium:		
Eleventh floor	Accelograph	November 1934.
Basement	Accelerograph and Weed [2] seismograph.	June 1933.
Edison Building: Hardpan or clay	Accelerograph	December 1934.
Subway Terminal: Hardpan or clay:		
Thirteenth floor	do	Do.
Subbasement	Accelerograph and displacement meter.	August 1932.
Central Manufacturing District Warehouse at Vernon: Alluvium	Accelerograph	July 1932.
Pasadena: California Institute of Technology: Alluvium.	Accelerograph, displacement-meter and Weed seismograph.	May and June 1933
San Bernardino: County courthouse: Alluvium	Weed seismograph	June 1933.
San Diego: Consolidated Gas and Electric Co.: Alluvium	Accelerograph	July 1932.
Santa Ana: County courthouse: Alluvium	Weed seismograph	June 1933.
Santa Barbara: County courthouse: Alluvium	Accelerograph	Do.
Westwood: University of California at Los Angeles: Alluvium:	do	Do.
MISCELLANEOUS		
Bozeman, Mont.: Montana State College: Alluvium and glacial drift.	do	September 1936.
Butte, Mont.: Montana School of Mines: Igneous rock.	do	Do.
Hawthorne, Nev.: U. S. Naval Ammunition Depot: Alluvium.	do	November 1936.
Helena, Mont.: Federal Building: Rock	do	September 1936.[3]
Miraflores, Canal Zone, concrete locks; Tuff and alluvium.	do	April 1935.
Missoula, Mont.: Montana State University: Sedimentary rock.	do	September 1936.

[2] Weed seismograph removed in April.
[3] Permanent installation replacing the accelerograph from San Francisco which had been temporarily installed in October 1935.

DESCRIPTIONS OF STRONG-MOTION SEISMOGRAPH STATIONS

NOTE.—Descriptions of the following stations will be found in Serial No. 593, "United States Earthquakes, 1934": Bishop, Los Angeles Water Department office and garage; Ferndale, Town Hall. A description of the Helena, Mont., station in the Federal Building will be found in Serial No. 600, "United States Earthquakes, 1935."

COLTON, CALIF.

SOUTHERN CALIFORNIA EDISON COMPANY SUBSTATION BUILDING

Accelerograph on ground floor

The building is on South Mt. Vernon Avenue, just north of the Santa Ana River. (This river, except in flood seasons, is dry at this point, although there is considerable underground flow.) The building is a simple one-story structure of reinforced concrete. The instrument piers are set on the concrete floor, which is about 1 foot above the natural ground level. The size of the building is 45′ x 20′ x 13′3″ high.

This station is situated on the alluvial flood plain of the Santa Ana river and is underlain by not less than many tens, and possibly some hundreds, of feet of alluvium. The material consists of gravel and sand, and rests on a rough bedrock surface of granite. The water surface is at a depth of perhaps 20 or 30 feet. The station is located a mile from the San Jacinto fault; the San Andreas fault lies several miles farther to the east.

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MIRAFLORES, PANAMA CANAL ZONE

MIRAFLORES LOCKS

Accelerograph in centerwall operating tunnel

The accelerograph site is in an alcove of the centerwall on tunnel floor of the Miraflores Locks. This centerwall is 81 and 60 feet wide, and the operating tunnel floor is about 70 f the base. The neighboring lock chambers may vary in wat from empty to 75 feet deep. The centerwall sits on a fou a well-bedded tuff containing some argillitic material. The mass concrete, except that reinforced concrete was used at machinery chambers. The Miraflores Locks are surrounded tuarine deposits and alluvium at the higher levels. The accele was moved from the Administration Building at Balboa Hgts. the Miraflores Locks location on April 27, 1935.

TILT OBSERVATIONS

The following quotation on tilt observations during 1936 i from the annual progress report of F. P. Ulrich, who is in cha the Bureau's Seismological Field Survey with headquarter Francisco:

> The four tiltmeters at the University of California have been kept in o during the past year. In February 1936, an automatic recorder was ins tiltmeter No. 2. Pictures of the installation and typical records were p in the *Bulletin* of the Seismological Society (p. 220, vol. 26, No. 3). This tion has not been as satisfactory as expected, because rainfall unduly af tiltmeter. Recently the automatic recorder has been transferred to tiltm 3, where a dependable record can be obtained. Fig. 10 shows the tiltgra 1936. The record from tiltmeter No. 2 is very irregular and shows the e rainfall upon the earth's tilt. However, all the irregular tilt cannot be ascri rainfall. The period from July to December shows very marked tilt trends during this period there was practically no rainfall. The irregular tilting ma caused by a fluctuating flow of underground water at this particular location. The record from tiltmeter No. 2 has been so uncertain that the operation of the instrument was temporarily discontinued after the tiltmeter pit was flooded during the latter part of December. No hard shocks occurred during 1936 in the vicinity o the tiltmeters and no noticeable effects can be noted on the tiltgrams for the three small shocks that centered relatively close to the tiltmeters.

Figure 10 shows the tilt curves for the year 1936 with the usual seismic and meteorological data.

ADDITIONS AND CORRECTIONS TO PREVIOUS PUBLICATIONS

1929. Serial No. 511, "United States Earthquakes, 1929," page 17. For the area of the Attica earthquake read 100,000 square miles instead of 50,000 square miles.

1932. Serial No. 563, "United States Earthquakes, 1932," page 5. Earthquake of January 26 at bottom of page. For "Grovemont" read "Grovont," Wyo.

1933. Serial No. 579, "United States Earthquakes, 1933," page 7. The earthquake of May 28 at Maysville, Ky., should be listed under "Central Region" instead of "Eastern Region."

1934. See "The Earthquake of July 6, 1934: Amplitudes and First Motion," by Perry Byerly, Bulletin of the Seismological Society of America, vol. 28, No. 1, January 1938, page 1.

1935. Serial No. 600, "United States Earthquakes, 1935," page 58. For the region of the earthquake of August 17 read "Near New Caledonia" instead of "Near Tonga Islands."

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