# UNITED STATES EARTHQUAKES

## 1935

SERIAL No. 600



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

U. S. DEPARTMENT OF COMMERCE
Daniel C. Roper, Secretary
COAST AND GEODETIC SURVEY
R. S. Patton, Director



Serial No. 600

# UNITED STATES EARTHQUAKES 1935

BY

FRANK NEUMANN
Senior Mathematician

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1937

For sale by the Superintendent of Documents, Washington, D. C. - - - Price 15 cents

# CONTENTS



## ILLUSTRATIONS

# UNITED STATES EARTHQUAKES, 1935

## INTRODUCTION

This publication is a summary of earthquake activity in the United States and the regions under its jurisdiction for the calendar year 1935. The period up to 1927 for the United States is covered, for all except minor earthquakes, by Special Publication No. 149 of the Bureau, "Earthquake History of the United States Exclusive of the Pacific Region", and by several publications for the Pacific region. These include the Holden and McAdie catalogs,[1] Special Publication No. 191 of the Bureau, "Destructive and Near-Destructive Earthquakes in California and Western Nevada, 1769–1933", and a forthcoming publication of the Seismological Society of America. The period from 1928 on is covered by the series to which the present publication belongs.

Earthquakes of volcanic origin in the Hawaiian and Philippine Islands are not included, and only severe shocks are included in the case of the Philippine Islands as complete reports are published by the Manila Central Observatory. Earthquakes adjacent to the United States and felt within its borders are described only in a general way when detailed descriptions are published elsewhere.

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

The noninstrumental information has been furnished by a large number of individuals and organizations whose voluntary cooperation has made it possible to prepare descriptions of the earthquakes of this country with a completeness and accuracy never before attained. Lack of space prohibits giving individual credit to all of the cooperators. The principal sources of information are as follows:

United States Weather Bureau.
Central office of the Jesuit Seismological Association of St. Louis, Mo.

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

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. 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.

### MODIFIED MERCALLI INTENSITY SCALE OF 1931

(Abridged)

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

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

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

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

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

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

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

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

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

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

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

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

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

In the case of California, earthquakes reported as feeble are not plotted on the epicenter map of the United States nor are minor aftershocks plotted for heavy earthquakes in California or any other region. The reader should bear in mind that the information service in California has been developed to a point not approached in any other section of the country. When the coordinates of epicenters are given, the sources of information are stated when the epicenters are determined by other organizations such as the seismological station of the University of California under the direction of Prof. Perry Byerly or the seismological laboratory of the Carnegie Institution and the California Institute of Technology, at Pasadena, under the direction of H. O. Wood. The bulletins of these institutions should be consulted for further details and often additional shocks.

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

Within the United States the same regional arrangement has been followed as in Special Publication No. 149, previously mentioned, except that Washington and Oregon have for convenience been treated separately from California.

*Special report.*—Attention is invited to a special quarterly report issued by the Bureau's seismological 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 57 have been determined at the Washington office unless otherwise stated. Quite often they represent the mean of the positions determined by the Bureau and the Central Station of the Jesuit Seismological Association cooperating with Science Service. Immediate epicenter determinations from telegraphic reports are frequently made through the cooperation of these institutions and individual seismograph stations and the results broadcast without delay to Europe and points in the Pacific. As the published epicenters are based on only a portion of the available data, they must be considered provisional.

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

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

The interpretation of strong-motion results is one of the duties assigned to the Bureau in connection with a broad cooperative program of seismological research being carried out on the Pacific coast between the Bureau and a number of local organizations and institutions interested in the engineering aspects of the earthquake problem. The details of this program are fully described in the Bureau's Special Publication No. 201, "Earthquake Investigations in California, 1934–1935."

Preliminary reports on strong-motion results are issued in quarterly mimeographed bulletins and sometimes in special mimeographed reports. They appear in revised form in this publication because it provides a ready means of recording them in permanent form.

# NONINSTRUMENTAL RESULTS

## EARTHQUAKE ACTIVITY IN THE VARIOUS STATES

**Arizona**: Fairly strong earthquakes on January 2 and 10, and weak shocks on January 1, 3, 4, 5, and 15, October 27, and December 5.

**California**: A strong earthquake off Cape Mendocino on January 2. Moderate shocks on January 2, 3, and 23, February 23, March 3 and 7, May 10, June 19 (two shocks), July 13, September 10 and 16, October 24 and 25, November 3, and December 19 and 25. In addition to these, the usual number of minor tremors were reported.

**Canadian earthquake**: A widely felt earthquake of intensity about IX centered at Timiskaming, Quebec, on November 1. There was little damage of consequence in the United States. It was felt in Connecticut, Delaware, the District of Columbia, Illinois, Indiana, Iowa, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, and Wisconsin. A weak aftershock on the same date was felt in New York and Vermont, and another on the next day was felt in New York, Pennsylvania, and probably Massachusetts.

**Connecticut**: An explosion or a weak earthquake on August 9. Canadian earthquake of November 1 also felt.

**Delaware**: Nothing except the Canadian earthquake of November 1.

**District of Columbia**: Nothing except the Canadian earthquake of November 1.

**Florida**: Weak or moderate shocks on November 13 and 14.

**Georgia**: Moderate earthquake on the North Carolina border on January 1.

**Idaho**: Two weak earthquakes on October 31. In addition, the strong Montana earthquakes of October 18 and 31, and of November 28, were felt.

**Illinois**: Weak shock on January 5. Canadian earthquake of November 1 also felt.

**Indiana**: Nothing except the Canadian earthquake of November 1.

**Iowa**: Weak shocks on January 5 and February 26. The Nebraska earthquake of March 1 and the Canadian earthquake of November 1 were also felt.

**Kansas**: Nothing except the Nebraska earthquake of March 1.

**Kentucky**: Nothing except the Canadian earthquake of November 1.

**Maine**: Slight shocks on January 14 and March 3. The Canadian earthquake of November 1 was also felt.

**Maryland**: Nothing except the Canadian earthquake of November 1.

**Massachusetts**: Weak earthquakes on January 30 and April 23. The Canadian earthquake of November 1 and perhaps an aftershock the next day were also felt.

**Michigan**: Two slight earthquakes, the first about the middle of October and the second on October 30. The Canadian earthquake of November 1 was also felt.

**Minnesota**: Nothing except the Canadian earthquake of November 1.

**Missouri**: Nothing except the Nebraska earthquake of March 1.

**Montana**: Destructive earthquakes occurred at Helena on October 12, 18, and 31. There was also a strong shock on November 28. There were a few foreshocks and hundreds of aftershocks. In addition to the shocks in the neighborhood of Helena there were other moderate earthquakes in Montana on March 29, April 16, October 7, 21, 23, 30, and 31 (seven or eight shocks) and November 5.

**Nebraska**: Moderate to strong earthquake on March 1, and a weak one on March 22.

**New Hampshire**: Weak shock on September 12. The Canadian earthquake of November 1 was also felt.

**New Jersey**: Nothing except the Canadian earthquake of November 1.

**New Mexico**: Two fairly strong earthquakes, on February 20 and December 21, and a large number of weak shocks, notably on January 17 and 19, and December 12, 14, 17, 18, 19, and 30.

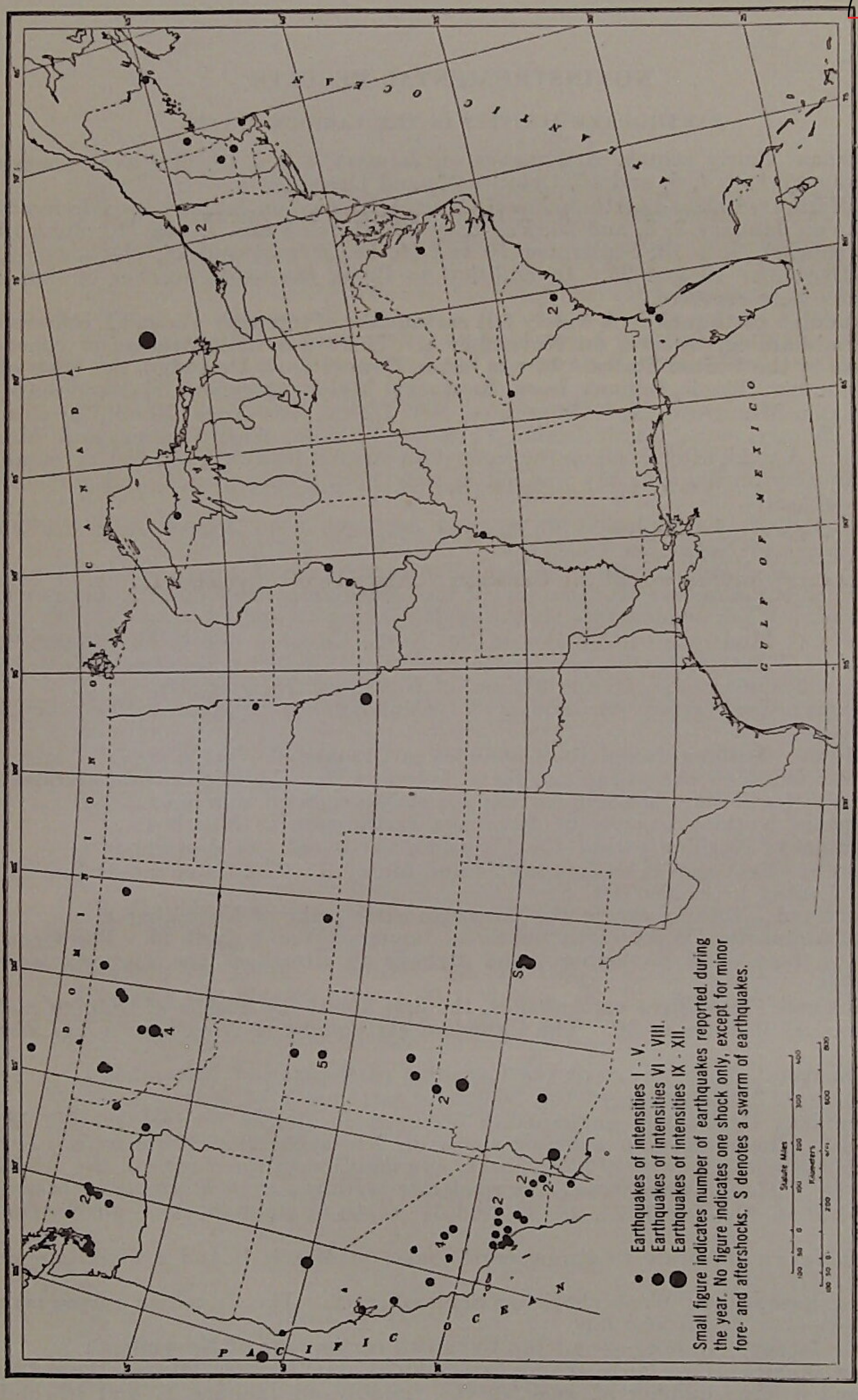



FIGURE 1.—Earthquake epicenters, 1935

**New York**: Two slight earthquakes on January 28. The Canadian earthquake of November 1 and aftershocks on November 1 and 2 also were felt in New York.

**North Carolina**: Moderate earthquake near the Georgia border on January 1. The Canadian earthquake of November 1 was also felt.

**Ohio**: Nothing except the Canadian earthquake of November 1.

**Pennsylvania**: Nothing except the Canadian earthquake of November 1 and the aftershock of November 2.

**Rhode Island**: Nothing except the Canadian earthquake of November 1.

**South Carolina**: Slight shocks on February 6 and October 20.

**South Dakota**: Weak earthquake on November 1.

**Tennessee**: A slight earthquake on July 23.

**Utah**: Weak earthquakes on May 29, June 4, July 9 (three shocks), October 5, November 6, and December 5 (one or two shocks).

**Vermont**: Nothing except the Canadian earthquake of November 1 and an aftershock on the same day.

**Virginia**: Slight earthquake on February 10. The Canadian earthquake of November 1 was also felt.

**Washington**: Weak earthquakes on February 6 and 16, July 9 and 24, October 11, 24, and 31, and November 7. The strong Helena, Mont., earthquakes of October 18 and 31 also were felt.

**West Virginia**: Weak earthquake on November 1. The Canadian earthquake of same date was also felt.

**Wisconsin**: Nothing except the Canadian earthquake of November 1.

**Wyoming**: A weak shock on November 10. The Helena, Mont., earthquakes of October 18 and 31 were also felt.

**Alaska**: Moderate earthquakes occurred on January 22, April 9 (volcanic) and 21, and August 14 (two) and 23. There was a volcanic eruption on July 14, but no earthquakes were reported. In addition, there were many minor tremors.

**Hawaiian Islands**: Moderate to strong earthquakes occurred on June 28 and September 30. There were moderate earthquakes on January 2, June 25, September 30, October 1 (two), and November 21. There were many weak shocks of volcanic origin.

**Puerto Rico**: Weak shock occurred on August 29 and September 18.

**Philippine Islands**: Strong earthquakes occurred on January 8, February 1 and 8, April 3 and 24, May 24, August 1, and October 15. There were moderate shocks on January 25, May 19, June 4, and September 1, and many minor shocks.

**Panama Canal Zone**: There was a strong earthquake on November 29, and weaker ones on April 27, June 16, July 25, and December 11.

## NORTHEASTERN REGION

[75th meridian or eastern standard time]

NOTE.—For local earthquakes recorded at the Harvard Seismological Station, see paper entitled "Local Earthquakes in New England" by Mary P. Collins, in the Bulletin of the Seismological Society of America, volume 27, no. 1, January 1937, page 41.

***January 14:*** 20:15. Lewiston, Maine. Slight shock lasting 30 seconds.

***January 28:*** Shortly after 1:00. Malone, N. Y. Slight shock, felt also in northern part of Franklin County. Many awakened by sharp rumble. Homes shook; pictures and dishes rattled; no damage reported.

***January 28:*** 4:03.* Malone, N. Y. Slight local shock, felt also in northern part of Franklin County. Many awakened by sharp rumble. Homes shook; pictures and dishes rattled; no damage reported. Recorded on the Harvard seismograph.

***January 30:*** 15:20.* Billerica, Mass. Tremors felt in vicinity of town, exact place not reported. Recorded on the Harvard seismograph.

***March 3:*** 21:40. Eastport, Maine. Two slight shocks lasting about 5 seconds. Rumbling sounds.

***April 23:*** 20:24.* Weak shock off Cape Cod. Epicenter 42°10′ north, 70°13′ west, according to an article, "The Provincetown, Massachusetts, Earthquake of April 23, 1935, and Data for Investigating New England's Seismicity", by L. D. Leet, Proceedings of the National Academy of Sciences, volume 21, no. 6, (June 1935), page 308. IV at Provincetown, Race Point Coast Guard Tower, and Truro, Mass.; III and under at Cahoon's Hollow Coast Guard Station and Wellfleet, Mass.; not felt at Annisquam, Beverly Farms, Cohasset, Eastham, Gloucester, Hull, Ipswich, Manomet Point, Marblehead, Marshfield, Nahant, Nanset, Orleans, Pamet River, Sandwich, or Yarmouth, Mass. (Early press reports that the shock was felt in Gloucester, Mass., could not be verified.)

***August 9:*** Between 2:30 and 3:00. New London, Conn. "Terrific explosion or earthquake." Not felt at Hartford, Conn.

***September 12:*** 22:49.* Concord, N. H. Distinct shock felt in the north end of Concord and outlying towns.

***November 1:*** 1:04.* Timiskaming, Canada, earthquake. Felt generally over the northeastern United States and in Canada. Epicenter near Timiskaming, Quebec, Canada, at about 46°47′ north, 79°04′ west, according to the "Preliminary Report of the Earthquake of November 1, 1935", published by the Dominion Observatory at Ottawa, Canada. The depth of focus is believed to have been normal or very slightly greater.

The earthquake was felt over an area of nearly 1,000,000 square miles in the United States and Canada. The map facing page 8 shows the intensity distribution in the United States. A report for Canada is in preparation at the Dominion Observatory.

In the epicentral region the damage was relatively slight, largely because of the sparsity of population. Cracks were found in gravel, sand, and soft earth, but none in bedrock. A severe rock slide occurred on the railroad near Parent, Quebec, but it is believed by Dr. E. A. Hodgson, who surveyed the region and prepared the preliminary report for the Dominion Observatory, that the slide was about to go anyway and that the earthquake merely acted as a trigger force to start it.



INTENSITIES IN CANADA:

A few reports have been received from scattered localities in Canada in addition to the report of the Dominion Observatory mentioned above, but these are omitted in the present report. This information is expected to be covered in detail in the final report of the Dominion Observatory.

INTENSITY VI IN NEW YORK:

*Cortland.*—Rocking and swaying motion began rapidly. Felt by many; many alarmed. Bricks loosened from old chimneys; 100 square feet of plaster fell from Y. W. C. A. Stacks of steel conduits collapsed and tore out part of building. One crack in made ground. Pendulum clocks stopped.

INTENSITY V IN NEW YORK:

*Albany.*—Bumping, then east-west wave motion, began abruptly. Felt by most; most alarmed. Distinct swaying of houses and trees; objects displaced; steam pipe jarred out of place; three filing cabinets spilled contents on floor of State office.

*Amsterdam.*—Trembling motion began gradually; two shocks. Felt by many; many alarmed. Rattling sounds; some plaster fell; lights flickered. Damage slight.

*Attica.*—Trembling motion began gradually and lasted 1 or 2 minutes. Population alarmed. Buildings swayed slightly; plaster cracked slightly in some brick buildings.

*Baldwinsville.*—Trembling and swaying east-west motion began rapidly; three shocks. Felt by several; people were alarmed but not panic-stricken. Pendulum clock stopped. Building damage slight.

*Bath.*—Swaying east-west motion began gradually and was felt by several. Building swayed; window broke; several chimneys fell.

*Brooklyn.*—Trembling and swaying motion began gradually and lasted 20 seconds. Felt by many; few alarmed. Pictures, mirrors, and beds vibrated. Fissures in 25 buildings.

*Buffalo.*—Trembling motion began abruptly and lasted 1½ minutes. Many alarmed. Ceilings and sidewalk cracked; some plaster on walls cracked; chandelier fell.

*Camden.*—Swaying motion began abruptly; three shocks. Felt by many; few alarmed. Hanging objects swung; pendulum clock stopped. Plaster cracked.

*Cincinnatus.*—Rocking motion began rapidly; two shocks a few seconds apart felt by many; many alarmed. Flower vase overturned; windows broken in several houses; slight damage to buildings.

*Fort Edward.*—Trembling motion began abruptly. Felt by many; many alarmed. Objects disturbed.

*Glens Falls.*—Many windows broke.

*Gloversville.*—Swaying and trembling motion began gradually. Felt by large proportion of population; many left homes. Furniture swayed and rattled; windows broke; chimney bricks fell.

*Gouverneur.*—Trembling and bumping motion began gradually; several shocks. Felt by practically all; general alarm. Rumbling and whistling sounds; objects displaced north; pendulum clock stopped.

*Herkimer.*—Rolling motion felt by 90 percent of the population; some rushed to streets. Electric refrigerator moved.

*Hunter.*—Rapid bumping north-south motion began rapidly; probably two shocks. Felt by quite a few. Walls cracked very slightly. Very slight damage.

*Ithaca.*—Rocking and swaying motion began rapidly. Felt strongly on the delta, less on adjacent hills. Furniture moved mostly north-south; walls on alluvium cracked; pendulum mantel clocks stopped. Two or three cracked buildings reported.

*Johnstown.*—Residents ran into streets. Window displays disarranged.

*Malone.*—Trembling, bumping, and swaying motion began abruptly and was felt by 95 percent of population; general alarm. Objects swayed on east-west walls. Slight damage to buildings.

*Montour Falls.*—Slight damage to buildings.

*Mt. Morris.*—Trembling motion began rapidly and was felt by 90 percent of population; general alarm. Furniture moved northeast-southwest. Damage to buildings very slight.

*Moira.*—Shock began abruptly. Felt by about half of population. Four-inch cracks in roads; slight building damage.

*North Norwich.*—Number of henhouse windows broken.

*Norwich.*—Swaying north-south motion began rapidly. Felt by many; many alarmed; several thrown from beds. Furniture moved; pendulum clock stopped. Plaster slightly cracked.

*Ogdensburg.*—Trembling motion began gradually and lasted 2 minutes. Felt by 25 percent of the population; many frightened. Old chimneys tumbled over; building damage slight.

*Oneonta.*—Bumping and trembling motion began abruptly; lasted less than 1 minute. Felt by half of population; general alarm. Damage to telephones.

*Oswego.*—Swaying east-west motion lasted 2 minutes. Felt by many; many left homes. Buildings swayed; objects swung northeast-southwest; twenty-inch water main broke; animals disturbed.

*Oxford.*—Trembling motion began rapidly and was felt by many. Pendulum clock stopped. Plaster slightly cracked; damage to buildings slight.

*Palatine Bridge.*—Five people shaken from chairs; one man thrown to ground.

*Pine Valley.*—Many left shaking homes. Articles fell.

*Plattsburg.*—Trembling east-west motion began rapildy; two shocks lasting 1 minute. Felt by many; many alarmed. Plaster fell from ceilings; street signs fell.

*Poland.*—Rocking motion; two shocks. Felt by 90 percent of population. Plaster slightly cracked; chickens disturbed.

*Port Jervis.*—Swaying motion began abruptly and was felt by many. Pendulum clocks stopped. Walls slightly cracked; damage to buildings slight.

*Potsdam.*—Bumping motion began gradually; two shocks. Felt by many; many left homes. Furniture shook; chimneys fell. Building damage slight.

*Queens Village.*—Much excitement. Pictures fell; very minor damage.

*Richland.*—Swaying and trembling east-west motion began abruptly. Felt by many; many left homes. Dishes broke; window glass damaged. Chimney cracked. Building damage slight.

*Rome.*—Lasted 30 seconds. Long-distance telephone lines out of order.

*Syracuse.*—Swaying east-west motion began rapidly. Felt by many; some left homes; woman injured. Dishes broke; plaster cracked; pendulum clocks stopped.

*Tonawanda.*—Trembling motion began abruptly; two shocks. Felt by many; few alarmed. Objects disturbed; structural damage slight.

*Tupper Lake.*—Bumping and swaying motion felt by 50 percent of population; many alarmed. Buildings swayed slightly; cement blocks cracked in building under construction.

*Warsaw.*—Swaying motion began rapidly; two shocks. Felt by 50 percent of population. Many pendulum clocks stopped; small cracks in plaster.

*Watertown.*—Trembling motion; two or three shocks. Felt by many; hundreds ran into streets. Box about 12 x 20 x 30 inches high tipped over; plaster cracked and fell; some chimneys fell.

INTENSITY V IN MICHIGAN:

*Alpena.*—Trembling, southeast-northwest swaying motion began rapidly; felt by most. Dishes were broken; chimney fell; concrete floor cracked. Damage slight.

*Hillman.*—Trembling and rocking motion began rapidly. Felt by several; general alarm. Surface sounds; chandelier swung; very slight damage.

*Mount Clemens.*—Trembling motion began abruptly and was felt by 10 percent of population. Small objects disturbed, or fell from ledges. Plaster on a few old walls cracked.

*Pellston.*—Back-and-forth east-west motion began gradually. Observed by greater portion of population; many alarmed. Clocks chimed; hanging objects swung east-west. Objects fell southeast. Chimneys had to be rebuilt or repaired.

*Port Huron.*—Swaying motion lasted 2 minutes. Observer awakened. Objects disturbed; three windows broken.

INTENSITY V IN VERMONT:

*Bennington.*—Swaying north-south motion began gradually; four slight shocks. Felt by many. Windows rattled; stairs creaked; rocking chair rocked; some cracks in walls.

*Brattleboro.*—Shaking motion began abruptly; three shocks lasted 1 minute. Felt by many. Bed shook; plaster cracked.

*St. Johnsbury.*—Two shocks of trembling and rocking north-south motion felt by most of the population; many alarmed. Beds shook; windows and dishes rattled; door and light globe swung north-south.

*White River Junction.*—Swaying north-south motion was felt by family of six. Water in radiators swished.

INTENSITY V IN PENNSYLVANIA:

*Kane.*—Trembling and swaying motion began abruptly and was felt by many. Foundation wall in one building cracked.

*Kingston.*—Water mains broke in several sections of town.

*Merion.*—Broke windows.

INTENSITY V IN OHIO:

*Akron.*—Trembling southwest-northeast motion began gradually; two shocks. Felt by many; few alarmed. Furniture moved. Small ornament toppled from theater building; floor cracked slightly. Slight damage to a few buildings.

*Centerburg.*—Trembling motion began abruptly; two shocks felt by many. Door knob trembled; building damage slight.

*Walhonding.*—Swaying north-south motion began abruptly and was felt by several. Pendulum clock stopped. Walls cracked, chimneys damaged. Building damage slight.

INTENSITY V IN NEW HAMPSHIRE:

*Keene.*—Shaking motion felt by large number of people; great alarm in tall buildings. Bell rung; objects disturbed.

*West Manchester.*—Trembling and short quick swaying north-south motion began rapidly; two shocks. Felt by many; many alarmed.

*Woodsville.*—Swaying motion lasted three seconds and was felt by most of population. Objects disturbed. Small cracks in brick building. Very little damage.

INTENSITY V IN MASSACHUSETTS:

*Cheshire.*—Rocking and swaying motion began rapidly; two shocks. Felt by 95 percent of population; a few instances of great alarm. Objects disturbed. Hanging objects swung north-south; pendulum clocks stopped.

INTENSITY V IN CONNECTICUT:

*Cornwall.*—Rocking and swaying east-west motion began rapidly; one or two shocks. Felt by seven-eighths of the population. Building damage slight, several window panes cracked.

INTENSITY V IN NEW JERSEY:

*Hackensack.*—Swaying east-west motion began rapidly and lasted 10 seconds. Felt by many; many panic-stricken. Buildings shook; pictures knocked awry; dishes fell; lights swayed from east to west.

*Haddonfield.*—Windows broke.

*Morristown.*—People left homes. Dishes and glassware fell.

*Newark.*—Trembling motion began rapidly; two shocks. Many left houses. Windows and china closet on west side of house trembled. Foundation of house cracked; house tilted against neighboring house.

INTENSITY V IN RHODE ISLAND:

*Cranston.*—Crack in cellar wall.



Intensity IV in New York: Akron, Alexandria Bay, Alfred, Andover, Angelica, Arcade, Auburn, Au Sable Forks, Avon, Babylon, Batavia, Belfast, Belmont, Benson Mines, Binghamton, Bombay, Boonville, Bridgehampton, Brockport, Caledonia, Canandaigua, Canisteo, Canton, Cape Vincent, Carthage, Catskill, Central Square, Chatham, Chautauqua, Clayton, Cobleskill, Cooperstown, Corning, Croghan, Cuba, Dannemora, Dunkirk, Earleville, East Rochester, Edmeston, Edwards, Elmira, Fishkill, Franklinville, Fredonia, Genoa, Glenfield, Goshen, Greenpoint, Halfmoon, Hamburg, Hammondsport, Homer, Hornell, Ilion, Jamaica, Jamestown, Jeffersonville, Kendall, Kill Buck, Kingston, Lake Placid, Lake Pleasant, Lewiston, Little Falls, Little Valley, Livonia, Lockport, Lowville, Lyon Mountain, Lyons, Mannsville, Massena, Matteawan, Medina, Middlesex, Morrisville, Newark, New Berlin, New Hackensack, New Hamburg, New Rochelle, New York, Niagara Falls, Nineveh, Niverville, North Creek, Norwood, Old Forge, Olean, Oneida, Penn Yan, Pittsford, Port Chester, Poughkeepsie, Pulaski, Race Rock Light Station, Raquette, Red House, Remsen, Richfield Springs, Richmondville, Riverhead, Rochester, Roxbury, Sackets Harbor, Salamanca, Sammonsville, Saranac Lake, Scarsdale, Schenectady, Schoharie, Seneca Falls, Smyrna, Spencerport, Sterling Station, Summerville, Summount, Ticonderoga, Troy, Utica, Wampsville, Waterloo, Wayne, Williamsville, Winthrop, Yonkers. Upperville (?).

Intensity IV in Michigan: Alba, Bad Axe, Bay City, Boyne City, Brimley, Caro, Cheboygan, Crosswell, Crystal Falls, Dighton, East Lansing, Escanaba, Gladstone, Harrison, Hillsdale, Indian River, Lachine, Le Roy, Manistee, Marine City, Marquette, Mesick, Negaunee, Newberry, Onaway, Otter Lake, Oxford, Palms, Petoskey, Port Austin, Rudyard, Saginaw, Sault Sainte Marie, Sebewaing, Smiths Creek, Tawas, Traverse City, Trout Lake, Vanderbilt, Wetmore, Wolverine.

Intensity IV in Vermont: Barre, Barton, Bellows Falls, Bethel, Bondville, Bradford, Bristol, Burlington, Cambridge, Castleton, Derby Line, Dorset, East Berkshire, Enosburg Falls, Essex, Essex Junction, Ludlow, Manchester, Middlebury, Montpelier, Newport, Northfield, Pittsford, Rutland, Stowe, Swanton, Waterbury, Wells River, Williamstown, Windsor, Woodstock.

Intensity IV in Pennsylvania: Bradford, Brockway, Canton, Corry, Coudersport, DuBois, Emporium, Erie, Foxburg, Franklin, Galeton, Greenville, Hazelhurst, Homestead, Honesdale, Huntingdon, Kittanning, Laceyville, Ligonier, Linesville, Ludlow, McClellandtown, McKeesport, Mahoningtown, Mauch Chunk, Meadville, Monroeton, Mount Jewett, Palmerton, Philadelphia, Port Allegany, Reading, Renovo, Saltsburg, Sayre, Scranton, Sharon, Shickshinny, Smithport, Stoneboro, Stroudsburg, Susquehanna, Tionesta, Titusville, Towanda, Union City, Watsontown, Wellsboro, Wilcox, Wilkes-Barre, Williamsport, Wysox. Olean (?).

Intensity IV in Ohio: Andover, Ashtabula, Canton, Cleveland, Clinton, Columbus, Coshocton, Creson, Dennison, Dover, Dunkirk, Elyria, Fremont, Hudson, Leetonia, Mansfield, Massillon, Minerva, Norwalk, Sherrodsville, Toledo, Upper Sandusky, Wapakoneta, Washington Court House, Wellington, Zanesville.

Intensity IV in New Hampshire: Claremont, Colebrook, Conway, Groveton, Hanover, Hinsdale, Laconia, Lebanon, Lee, Lincoln, Littleton, Manchester, Peterborough, Plymouth, Rochester, Whitefield, Winchester, Wolfeboro.

Intensity IV in Massachusetts: Adams, Boston, Charlemont, Clarksburg, Framingham, Greenfield, North Adams, Northampton, Pittsfield, South Vernon, Springfield, Warren.

Intensity IV in Maine: Alfred, Bangor, Portland, St. Francis, Waterville.

Intensity IV in Connecticut: Baltic, Bethel, Canaan, Hartford, Manchester, New Haven, Norwalk, Saybrook, Southington, Winsted.

Intensity IV in West Virginia: Moundsville, Wheeling.

Intensity IV in New Jersey: Asbury Park, Barnegat, Camden, Dover, Hamburg, Hoboken, Jersey City, Monmouth, Trenton.

Intensity IV in Maryland: Chestertown.

Intensity IV in Rhode Island: Block Island, Providence, Woonsocket.

Intensity IV in Delaware: Townsend.

Intensity III and under in New York: Albion, Andes, Ballston Spa, Belvidere, Bolivar, Cairo, Candor, Carmel, Castle Point, Cayuga, Chenange Forks, Clinton, Cranberry Lake, Delhi, Dolgeville, East Greenbush, Eastport, Fine, Freeville, Greenport, Grove, Haverstraw, Hempstead, Hinckley, Horseheads, Hudson Falls, Lake George, Middletown. Millerton, Mt. Vernon, Palenville, Peekskill, Port Henry, Port Jefferson, Rexville, Rouses Point, Rushville, Sag Harbor, Saratoga Springs, Saugerties, Silver Springs, Sodus Point, Wappingers Falls, Waverly.

Intensity III and under in Michigan: Albion, Alexander, Alma, Almont, Amasa, Ann Arbor, Atlanta, Baldwin, Bear Lake, Beaverton, Bellaire, Benton Harbor, Benzonia, Big Rapids, Cadillac, Carson City, Caseville, Cedar Springs, Channing, Charlevoix, Chelsea, Chesaning, Clifford, Coldwater, Coleman, Detroit, Elk Rapids, Elmira, Farwell, Fenton, Fountain, Flint, Frankfort, Gladwin, Glen Haven, Grand Haven, Grand Ledge, Grand Marais, Grindstone City, Grayling, Hamilton, Harbor Beach, Harrieta, Hastings, Holland, Honor, Iron Mountain, Iron River, Ishpeming, Jackson, Kalamazoo, Kinde, Lake Arm, Lapeer, Leland, Leslie, Lewiston, Lincoln, Ludington, Luther, Mackinaw, Mancelon, Manchester, Marion, Marshall, Mikado, Milan, Milford, Minden City, Montague, Munising, Muskegon, National Mine, Niles, Norway, Otsego, Owendale, Pentwater, Pinconning, Plymouth, Portland, Presque Isle, Republic, Rochester, Rogers City, Rose City, Shelby, St. Helen, St. Louis, Southbranch, South Haven, South Lyon, Sparta, Thompsonville, Tower, Utica, Vassar, Vicksburg, Wayne, Weideman, West Branch. White Cloud, Whitefish, White Pigeon, Whittemore, east section of Barry County.

Intensity III and under in Vermont: Chelsea, Chester, Danville, Fair Haven, Island Pond, Londonderry, Milton, Poultney, Richford, Rochester, Victory, Wallingford, Wilmington, Winooski.

Intensity III and under in Pennsylvania: Allentown, Altoona, Ambridge, Antrim, Ashland, Athens, Bellefonte, Belleville, Bellwood, Bessemer, Bristol, Brookville, Carbondale, Clermont, Coatesville, Connellsville, Costello, Cresson, Delaware Water Gap, Delta, Dunmore, Freeport, Girard, Hanover, Hazelton, Indiana, Johnsonburg, Kinzua, Lakeville, Latrobe, Lewistown, Lock Haven, Masontown, Mercer, Milroy, Monongahela, Oil City, Philipsburg, Pittsburgh, Pottsville, Ridgway, State College, Thompson, Tremont, Tunkhannock, Tyre, Tyrone, Ulysses, Warren, Yatesboro, York.

Intensity III and under in Ohio: Alliance, Alvordton, Archbold, Ashland, Baton, Bellefontaine, Bellville, Beverly, Bowerston, Bryan, Burton, Cadiz, Cambridge, Chardon, Cincinnati, Clyde, Conneaut, Crestline, Finance, Delaware, Deshler, Dresden, Ellsworth, Franklin, Fredericktown, Hubbard, Huron, Ironton, Jackson, Jefferson, Kingsfield, Kinsman, Leetonia, Lima, Logan, Lorain, Malta, Manchester, Mariemont, Marietta, Marysville, Maumee, Millersburg, Montpelier, Mt. Vernon, Napoleon, Newark, Niles, Oberlin, Orrville, Ottawa, Philo, Plymouth, Ravenna, Salineville, Sidney, Spencerville, Springfield, Tiffin, Vermilion, Versailles, Warren, Wauseon, Waverly, Westerville, Willoughby, Woodsfield, Wooster, Youngstown.

Intensity III and under in New Hampshire: Berlin, Bristol, Concord, Contoocook, Dover, Farmington, Franklin, Gorham, Hooksett, Lancaster, Lisbon, Marlboro, Milford, Newbury, Newport, North Stratford, Panacook, Seabrook, Tilton, Wilton, Woodstock.

Intensity III and under in Massachusetts: Ashley Falls, Athol, Attleboro, Beverly, Brockton, Cambridge, Chatham, Concord, Fall River, Fitchburg, Great Barrington, Holyoke, Hyannis, Lanesboro, Lee, Lenox, Lowell, Malden, Marlboro, Nantucket, Newburyport, Plymouth, Provincetown, Stockbridge, Taunton, Walpole, Westfield, Williamsburg, Williamstown, Woods Hole, Worcester, Winchester, Winchendon.

Intensity III and under in Maine: Auburn, Augusta, Bar Harbor, Bath, Belfast, Bethel, Bowdoinham, Bridgeton, Canton, Castin, Churchill Lake, Farmington, Fort Fairfield, Fort Kent, Gardiner, Gilead, Hallowell, Harmony, Hartland, Hudson, Island Falls, Jackman, Kingfield, Jonesboro, Lewiston, Machiasport, Millbridge, Rockland, Saco, Searsport, Skowhegan, South Berwick, South Paris, Springvale, Stratton, Togus, Van Buren, Westbrook, Winterport, Winthrop.

Intensity III and under in Connecticut: Ansonia, Litchfield, Meriden, Norwich, Seymour, Stamford, Storrs, Vernon, Waterbury, Willimantic.

Intensity III and under in Wisconsin: Appleton, Ashland, Black River Falls, Cable, Chippewa Falls, De Pere, Florence, Fond du Lac, Green Bay, Iola, Janesville, La Crosse, Madison, Manitowoc, Marinette, Mattoon, Medford, Milwaukee,

Oconto, Pembine, Plymouth, Richland Center, Shawano, Sheboygan, Sparta, Sturgeon Bay, Tomahawk, Wabeno, Wausau.

Intensity III and under in West Virginia: Charleston, Olendenin, Fairmont, Parkersburg, Ravenswood, Sutton, Wellsburg.

Intensity III and under in New Jersey: Atlantic City, Atlantic Highlands, Barnegat City, Belvidere, Cape May, Chester, Elizabeth, Elmer, Freehold, Glassboro, Haddon Heights, Hammonton, Hightstown, Jamesburg, Lakehurst, Long Branch, Mount Holly, New Brunswick, Ocean City, Paterson, Perth Amboy, Plainfield, Sandy Hook, Sea Girt, Sea Isle City, Somers Point, Toms River, Vineland, Whiting.

Intensity III and under in Indiana: Decatur, Elkhart, Fort Wayne, Goshen, Huntington, Kokomo, La Crosse, Madison, Marion, Peru, Redkey, Richmond, South Bend, Warsaw.

Intensity III and under in Maryland: Annapolis, Baltimore, Bel Air, Cumberland, Frederick, Hancock, Havre de Grace, Laurel, Westminster.

Intensity III and under in Rhode Island: Pawtucket.

Intensity III and under in Virginia: Alexandria, Culpeper, Richmond.

Intensity III and under in Delaware: Delaware City, Dover, Milford, Red Lion, Smyrna.

Intensity III and under in the District of Columbia: Washington.

Intensity III and under in Illinois: Chicago.

Intensity III and under in Kentucky: Fort Mitchel, Prestonburg.

Intensity III and under in Iowa: Dubuque.

Intensity III and under in Minnesota: Minneapolis.

Intensity III and under in North Carolina: Louisburg.

Intensity doubtful in New York: Gotham, Oak Island Beach, Woodhull.

Intensity doubtful in Massachusetts:

*Massachusetts Shore.*—High seas kicked up by quake reported by craft offshore.

*Wellesley.*—One man hurled out of bed.

Intensity doubtful in Wisconsin: Cumberland.

Not felt in New York: Amagansett, Arkville, Mayville, McKeever, Moreau.

Not felt in Michigan: Allouez, Bango, Bentley, Bessemer, Blissfield, Calumet, Cassopolis, Centerville, Champion, Chassell, Copemish, Curtis, Dowagiac, Eagle River, Fremont, Gaastra, Gay, Hancock, Houghton, Interlochen, Keweenaw Bay, Lake Linden, Lake Odessa, Lawton, Marenisco, McMillan, Mears, Merriweather, Michigamme, Northland, Ontonagon, Orleans, Rapid River, Redridge, Reed City, Rockland, Sagola, Shingleton, Sidnaw, Soo Junction, Springport, Stanton, Sturgis, Three Rivers, Trenary, Trenton, Trout Creek, Whitehall, Williamston.

Not felt in Pennsylvania: Audenried, Berlin, Blairsville, Branchton, Chambersburg, Clarion, Confluence, Driftwood, Ebensburg, Fairchance, Falls Creek, Gettysburg, Grassflat, Hollidaysburg, Hydman, Laporte, Lawrence, Martinsburg, Middletown, Mill Hall, Mt. Pleasant, Nanticoke, Orbisonia, Ralston, Shamokin, Sinking Spring, Slate Run, Somerset, Tamaqua, Tarentum, Union Dale, Uniontown, Washington, Wharton, Williamstown.

Not felt in Ohio: Anna, Antwerp, Athens, Bellaire, Belmont, Bettsville, Blufton, Bowling Green, Brookville, Carey, Chillicothe, Coldwater, Delphos, Eaton, Edison, Fostoria, Fultonham, Galion, Gallipolis, Greenfield, Hillsboro, Hiram, Holgate, Huntsville, Kenton, Lancaster, La Rue, McArthur, Middletown, Minster, New Bremen, Peoria, Phalanx, Port Clinton, Put-in-Bay, Ripley, Sandusky, Tippecanoe City, Tontogany, Troy, Vickery, Wilmington, Putnam County.

Not felt in New Hampshire: Bennington, Portsmouth, Windham Depot.

Not felt in Massachusetts: Ayer, Barnstable, Gloucester, Lawrence, New Bedford, Newton, Rockport, Southbridge, State Line, Webster, Wellfleet.

Not felt in Maine: Albion, Ashland, Bemis, Berwick, Blue Hill, Bridgewater, Bucksport, Burnham, Caribou, Carrabassett, Centerville, Corina, Danforth, Dennysville, Dexter, Dover-Foxcroft, Eastport, Ellsworth, Eustis, Greenville, Grindstone, Harrison, Houlton, Jemptland, Jonesport, Kathadin Iron Works, Kennebunkport, Livermore Falls, Machias, Mechanic Falls, Milford, Milltown, Monson, Moosehead, New Sweden, Northfield, Orneville, Patten, Presque Isle, Richmond, Rockport, Sherman, Strong Whitneyville, Wiscasset.

Not felt in Connecticut: Danielson, East River, Jewett City, New London, Plainfield, Putnam, Stonington, Torrington.

Not felt in Wisconsin: Abbotsford, Allen Grove, Antigo, Arlington, Bancroft, Boulder Jct., Brillion, Brodhead, Burlington, Burnett, Cameron, Cassville,

Cedarburg, Crivitz, Darlington, Dodgeville, Durand, Eagle River, Eau Claire, Eland, Elkhorn, Elroy, Evansville, Fennimore, Fifield, Forestville, Gagen, Gordon, Hancock, Hayward, Heafford Junction, Hilbert Hudson, Hurley, Iron River, Jefferson, Kenosha, Kewaunee, Ladysmith, La Farge, Lancaster, Laona Junction, Linden, Lone Rock, Marengo, Marshfield, Mason, Meadow Valley, Mellen, Milton, Minocqua, Monroe, Necedah, New Glarus, New London, New Richmond, Oconto Falls, Oshkosh, Park Falls, Phelps, Phillips, Pittsville, Platteville, Portage, Port Washington, Prairie du Sac, Prentice, Racine, Redgranite, Rib Lake, Ridgeland, Ripon, Sauk City, Spooner, Starlake, Superior, Three Lakes, Tomah, Trego, Turtle Lake, Viroqua, Washburn, Watertown, Waukesha, Waupaca, West Bend, Weyerhauser, Williams Bay, Winneconne, Winter, Wisconsin Rapids, Wrightstown, Wisconsin Dells.

Not felt in West Virginia: Charlestown, Clarksburg, Grafton, Grantsville, Hamlin, Hinton, Huntington, Huttonsville, Littleton, Mortensburg, Orlando, Paw Paw, Petersburg, Point Pleasant, Richwood, Ripley, West Union, Windfield,

Not felt in New Jersey: Bivalve, Brigantine, Egg Harbor, Gloucester City, Holly Beach, Lambertville, Manahawkin, Mays Landing, Millville, Montclair, Ocean Grove, Passaic, Phillipsburg, Pleasantville, Red Bank, Salem, Sussex, Tuckerton, Union City.

Not felt in Indiana: Albion, Angola, Bedford, Bloomington, Bluffton, Brookville, Brownstown, Cambridge, Columbus, Crawfordsville, Danville, Elnora, Elwood, Frankfort, Franklin, French Lick, Greensburg, Jeffersonville, Kendallville, Indianapolis, LaFayette, Lawrenceburg, Lebanon, Logansport, Lynn, Michigan City, Muncie, Osgood, Rochester, Rockville, Rushville, Salem, Seymour, Shelbyville, Templeton, Terre Haute, Wabash, Worthington.

Not felt in Maryland: Brandywine, Cambridge, Centerville, Easton, Ellicott City, Mechanicsville, Oakland, Ocean City, Odenton, Princess Anne, Queenstown, Salisbury, Thurmont, Montgomery County, Prince Georges County.

Not felt in Rhode Island: Bristol, Kingston, Narragansett Pier, Newport Warren.

Not felt in Virginia: Accomac, Bristol, Cape Charles, Covington, Doswell, Elkton, Goshen, Hot Springs, Lynchburg, Manassas, New Market, Newport News, Petersburg, Quantico, Staunton, Strasburg, West Point, Winchester, Fairfax County.

Not felt in Delaware: Clayton, Farmington, Frankford, Georgetown, Seaford, Wilmington.

Not felt in Illinois: Aurora, Bloomington, Chrisman, Clinton, Danville, Decatur, De Kalb, Effingham, Elgin, Fairfield, Freeport, Galesburg, Gibson City, Gilman, Joliet, Litchfield, Mattoon, Moline, Mt. Vernon, Nelson, Peoria, Quincy, Rockford, Shelbyville.

Not felt in Kentucky: Bowling Green, Carter, Central City, Danville, Elizabethtown, Frankfort, Lancaster, Lebanon, Louisville, Winchester.

Not felt in Iowa: Algona, Atlantic, Chariton, Charles City, Creston, Davenport, Des Moines, Fort Dodge, Grinell, Iowa City, Iowa Falls, Manchester, Mount Pleasant, Ossian, Ottumwa, Sheldon, Sioux City, Spencer, Waterloo.

Not felt in Minnesota: Adrian, Aitkin, Albert Lea, Alexandria, Anoka, Appleton, Aurora, Austin, Barnesville, Bayport, Belleplaine, Bemidji, Benson, Bird Island, Blue Earth, Breckenridge, Chisholm, Cloquet, Crosby, Detroit Lakes, East Grand Forks, Ely, Eveleth, Fergus Falls, Hastings, Hopkins, Hutchinson, International Falls, Keewatin, Little Falls, Luverne, Mankato, Marshall, Montevideo, New Ulm, Owatonna, Red Wing, Winona.

There were many aftershocks, most of them too weak to be felt outside of the immediate neighborhood of the epicenter.

***November 1:*** 1:30. Weak shock reported from Richmondville, N. Y., and Montpelier, Vt. Doubtless an aftershock of the Timiskaming earthquake at 1:04.

***November 2:*** 9:32.* Another aftershock, stronger than the preceding. Reported felt at Kitchener, North Bay, Owen Sound, and Toronto in Canada; at Buffalo, New York, and Rochester in New York; at State College in Pennsylvania; and at Sudbury (probably Massachusetts) and Peterboro (probably Ontario, possibly New York).

## EASTERN REGION

[75th meridian or eastern standard time]

***January 1:*** 3:15. Border of Georgia and North Carolina, V. Felt over an area of nearly 7,000 square miles. See map, page 15. The map is reproduced from a report published by G. W. Crickmay and Lane Mitchell, in the bulletin of the Seismological Society of America, vol. 25, no. 3 (July 1935), page 247.

According to the authors "The epicentral region appears to lie between Topton, N. C., and Hiawasee, Ga., and occupies 549 square miles. In this area some objects were displaced, alarm was felt, and almost half of the residents were awakened." "The position of the epicenter was approximately 35°07′ N., 83°38′ W." The area was canvassed for information by the Geological Survey division of the Georgia Department of Forestry and Geological Development. Further data on the earthquake and on the geology of the region will be found in the report itself.



INTENSITY V IN GEORGIA:

*Dahlonega.*—"Windows were shaken out."
*Hiawassee.*—Loud roaring. Some dishes broken.
*Neels Gap.*—Lumber stacked against a wall was shaken down.
*Young Harris.*—Felt, no details.

INTENSITY V IN NORTH CAROLINA:

*Almond.*—Slight damage to light structural parts of buildings.
*Franklin.*—Unstable objects overturned.
*Gay.*—Plaster on walls cracked slightly. Slight damage to buildings.
*Shooting Creek.*—Window shaken from frame.
Intensity IV in Georgia: Blue Ridge, Cleveland, Ellijay.

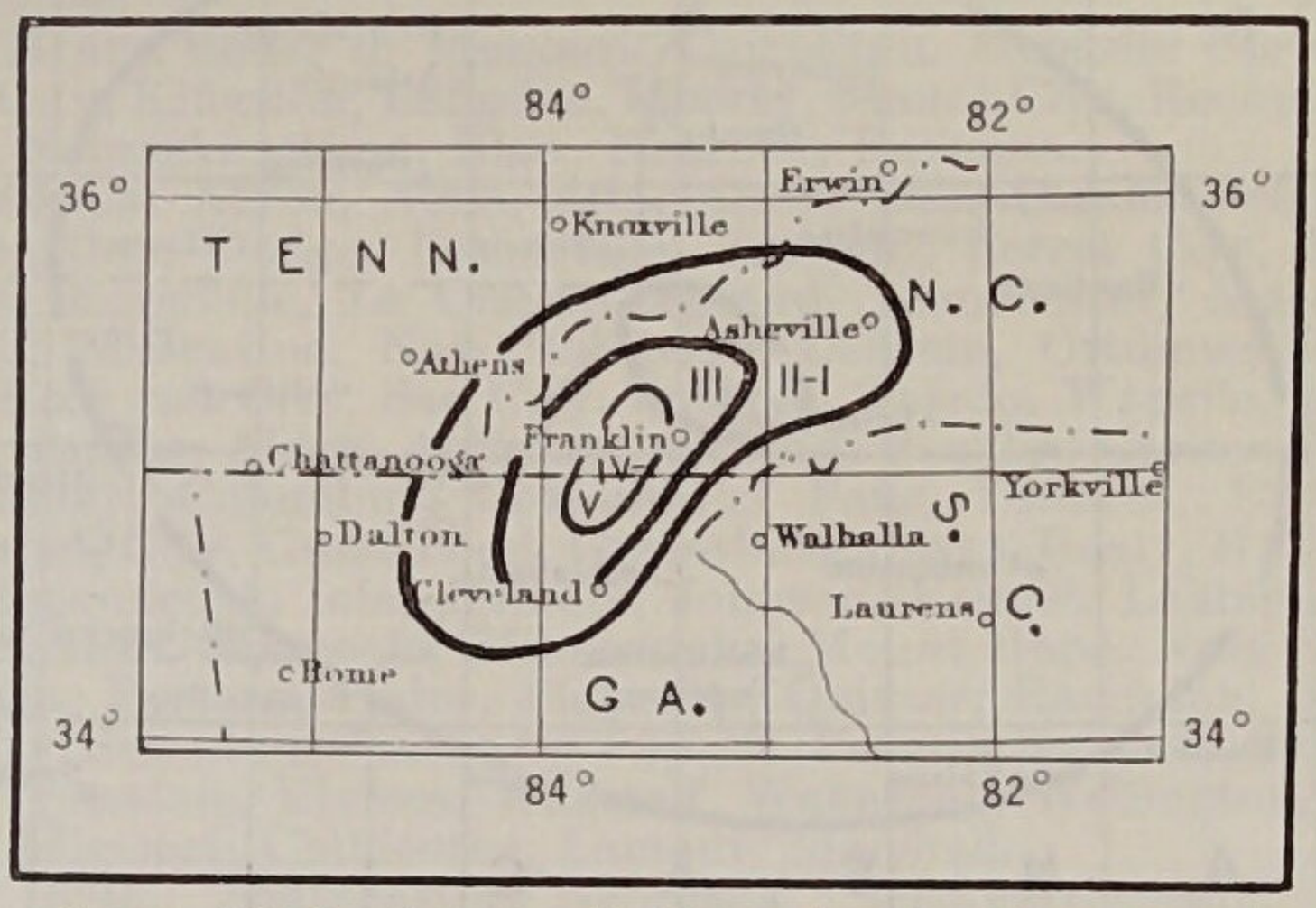



FIGURE 3.—Isoseismal map of the Southern Appalachian earthquake of January 1, 1935, based on original map by G. W. Crickmay and L. Mitchell.

Intensity IV in North Carolina: Aquone, Brasstown, Bryson City, Cherokee, Franklin, Hayesville, Marble, Murphy, Otto, Robbinsville, Tomotla, Topton, Wesser, Wests Mill, Whittier.
Intensity IV in Tennessee: Copperhill.
Intensity III and under in North Carolina: Andrews, Cullasaja, Etna.
Not felt in Georgia: Chatsworth, Clarkesville, Clayton, Cleveland, Cornelia, Dawsonville, Hemp, Jasper, Royston.

***February 6:*** 7:36. Summerville, S. C. Very loud "boom" felt by many.

***February 10:*** 18:45. Petersburg, Va. Gradual tremor lasting about 10 minutes felt by few. Windows rattled; no alarm.

***October 20:*** 11:20. Summerville, S. C. Abrupt bump ending in slight trembling felt by many.

***November 1:*** 3:30. Elkins, W. Va., V. Three trembling shocks lasting about 30 seconds each felt by several. Houses trembled; windows and dishes rattled; rocking chair facing east rocked; no damage.

***November 13:*** 22:30. St. Augustine, Fla. Two brief tremors, the second more severe; felt also in Palatka. People hurried into streets; no damage.

***November 14:*** 23:10. Palatka, Fla. Two shocks felt by many; second shock more severe. Windows rattled; no damage.

## CENTRAL REGION

[90th meridian or central standard time]

***January 5:*** 24:40. Davenport, Iowa; Moline and Rock Island, Ill. Two distinct shocks felt by several. Dishes rattled in cupboard; shook windows; no damage.

City, Nemaha, Odell, Plattesmouth, Rulo, Salem, Steinaver, Table Rock, Virginia.

Intensity IV in Iowa: Clarinda, Emerson, Keosauqua, Mt. Ayr, Tabor, Thurman.

Intensity IV in Kansas: Atchison, Bern, Burlington, Burr Oak, Clay Center, Downs, Hamlin, Havensville, Hanover, Hiawatha, Holton, Horton, Junction City, Manhattan, Marysville, Okote, Osage City, Salina, St. Mar's, Topeka, Troy, Wamego, Wheaton, White Cloud.

Intensity IV in Missouri: Oregon and St. Joseph.

Intensity III and under in Nebraska: Central City, Columbus, Franklin, Fremont, Friend, Guide Rock, Hastings, Minden, Norfolk, Omaha, Red Cloud, Superior.

Intensity III and under in Iowa: Albion, Anita, Atlantic, Bedford, Carroll, Cedar Rapids, Centerville, Chariton, Corydon, Council Bluffs, Creston, Cumberland, Davis City, Des Moines, Elkader, Glenwood, Grundy Center, Hawarden, Logan, Melrose, Missouri Valley, Oakland, Van Meter, Webster City, Winterset.

Intensity III and under in Kansas: Baldwin, Belleville, Centralia, Chapman, Clifton, Cloverbrook, Concordia, Council Grove, Elmdale, Emmett, Emporia, Everest, Fairview, Florence, Fort Scott, Garnett, Heizer, Kansas City, La Cygne, Lawrence, Leavenworth, Lindsborg, Lyndon, Marion, Minneapolis, Morrill, Norton, Onaga, Oneda, Ottawa, Paola, Pomona, Pratt, Republic, Reserve, Russell, Smith Center.

Intensity III and under in Missouri: Carrollton, Excelsior Springs, Harrisonville, Kansas City, Kingston, Langdon, Liberty, Mount City, Rockport, Savannah.

Not felt in Nebraska: Alma, Blair, Kearney, Ravenna.

Not felt in Iowa: Akron, Albia, Alta, Alton, Belle Plaine, Belmond, Clinton, Columbus Junction, Dodge, Estherville, Fairfield, Forest City, Harlan, Humboldt, Inwood, Knoxville, Le Claire, Legrand, Manchester, Marathon, Mason City, Monroe, Muscatine, New Hampton, Oelwein, Ottumwa, Osage, Perry, Pocohontas, Rockwell City, Sac City, Spencer, Toledo, Wapello, Washington.

Not felt in Kansas: Alden, Anthony, Ashland, Bucklin, Carbondale, Cimarron, Colby, Coldwater, Columbus, Cottonwood Falls, Dresden, Elkhart, Eureka, Fredonia, Garden City, Great Bend, Greensburg, Hays, Healy, Hill City, Hudson, Hugoton, Independence, Iola, Jetmore, Johnson, Kismet, Lahm, Leoti, Liberal, Larned, McPherson, Minneola, Minneapolis, Mount Hope, Ness City, Norwich, Oakley, Oberlin, Parsons, Plains, Plainville, Quinter, Randolph, Reading, Richfield, Scott City, Scranton, Sharon Springs, St. Francis, Sublette, Syracuse, Toronto, Tribune, Trousdale, Ulysses, Wagstaff, Wakeeney, Wellington, Winfield.

Not felt in Missouri: Chillicothe, Lamont, Marshall.

***March 22:*** 16:45. Southeastern Nebraska. Mild earthquake.

***July 23:*** 19:28. Tiptonville, Tenn. Two abrupt bumping shocks felt by several.

***About middle of October:*** About 11:15. Negaunee, Mich. Disturbance reported.

***October 30:*** About 22:30. Negaunee, Mich. Disturbance reported.

***November 1:*** 4:00. Egan, S. Dak. Two trembling shocks. Bed moved north to south.

## WESTERN MOUNTAIN REGION

[105th meridian or mountain time]

***January 1:*** 1:50. Grand Canyon, Ariz. Slight shock.

***January 2:*** 0:30 (?). Wellton, Ariz., VI. Felt by all; frightened few. Cracked plaster and walls; no other damage.

***January 2:*** —:— Pinacate country, in Mexico, bordering the Gulf of California. "Volcano, aroused by the quakes of December 30 and 31, 1934, in Lower California, emitted great clouds of smoke."

***January 3:*** 7:35. Fredonia, Ariz., IV.

***January 4:*** 19:00. Grand Canyon, Ariz. Very slight. Followed a few minutes later by another very slight shock.

***January 4:*** 21:25. Grand Canyon, Ariz. Duration about 1 minute. Rolling wavelike motion, quite noticeable. Accompanied by distinct rumbling. Dishes danced. Followed by two more shocks, one at 22:40, and the other on January 5 at 4:30.

***January 10:*** 1:10. Grand Canyon, Ariz., VI. Vigorous east-west motion awakened sleepers with a start, frightening many. Distinct subterranean rumble. Some windows broken and walls or plaster cracked. Minor rock slides. Attributed to the Bright Angel fault.

***January 15:*** 1:50. Grand Canyon, Ariz. Slight.

***January 17:*** 7:35 and 7:50. Socorro, N. Mex., III. Two shocks; small objects trembled; effect most pronounced in western section of Socorro.

***January 19:*** 19:25. Socorro, N. Mex., IV.

***February 20:*** 18:25. Bernardo, N. Mex., VI. Coping cracked on building; walls and plaster cracked, adobe and concrete buildings partially damaged. Accompanied by thunderous roar. Felt also at La Joya.

***February 20:*** 20:05. Bernardo, N. Mex. See above report, both quakes reported on the same card. Felt also at La Joya.

***March 29:*** 00:39. Rollins, Mont., V. Pendulum clocks facing north stopped; "most violent felt so far."

***April 16:*** 10:45. Creston, Mont. Abrupt shaking motion felt by two persons.

***May 29:*** 22:—. Newton, Utah. Weak shock.

***June 4.*** 10:09. Salt Lake City, Utah. Weak shock.

***July 9:*** 3:59. Salt Lake City, Utah. Felt by many; awakened few. Moved small objects.

***July 9.*** 4:49. Salt Lake City, Utah. Felt by many; awakened many. Moved small objects.

***July 9.*** 5:05. Salt Lake City, Utah. Felt by few; awakened few. Moved small objects.

***October 3:*** 19:47. Helena, Mont., V. The first foreshock of a long series of earthquakes which caused considerable damage and some loss of life at Helena during October and November. See special article on page 42. Hard vertical jolt, preceded by rumbling sounds, felt by many. One brick wall collapsed on building being razed.

It was felt rather strongly at Fort Harrison about 5 miles west of Helena and less strongly in the McClellan Gulch district about 11 miles east of Helena. At the latter place there was only a slight rumbling tremor.

***October 3:*** 20:21. Helena, Mont. Somewhat less pronounced than the preceding shock.

***October 5:*** 20:00. Boulder, Utah, IV.

***October 7:*** 12:30. Craig, Mont. Rocky mountains. Rocking motion felt by many. Objects fell from shelves; some pendulum clocks stopped; some plaster and walls cracked; some damage to chimneys. Accompanied by "an awful rumbling."

***October 12:*** 0:51.* Helena, Mont. A strong foreshock, intensity about VII, damage estimated at $50,000. Epicenter about 46° 37′ north, 111° 58′ west; i. e., about 2 or 3 miles northeast of the center of Helena on the southern side of Helena Valley, sometimes called Prickly Pear Valley. Area affected about 70,000 square miles. See special article on page 42.

INTENSITY VII IN MONTANA:

*East Helena.*—Plaster cracked, windows broken; some brick walls moved about one inch.

*Helena.*—Began abruptly and felt by practically everyone. Rocking, bumping, and swaying motion, mostly bumping. There was general alarm and a few people became hysterical; others nauseated. Clocks stopped. There were some cracked walls but damage in most buildings was slight. Most of the damage was restricted to relatively few structures.

The east side of the city was hardest hit. Chimneys were down in a few places and many windows were broken. Early reports that water mains were broken were not verified. A water pipe was broken in one residence. The Bryant School in the west end of town suffered severely from broken plaster.

INTENSITY VI IN MONTANA:

*Fort Harrison.*—Plaster torn from walls. Chimneys toppled and weakened. Damage to hospital between $500 and $1,000.

INTENSITY V IN MONTANA:

*Alberton.*—
*Belt.*—Plaster cracked in three-story house. Slight damage.
*Cascade.*—Many alarmed, few panic-stricken.
*Clasoil.*—Felt by all, bottles and cans knocked off shelves.
*Jefferson City.*—Felt by nearly all.
*Townsend.*—Felt by nearly all; loose articles moved.
*Winston.*—Felt distinctly by eveyone; loose objects moved.

Intensity IV in Montana: Bozeman, Cascade, Clancy, Dillon, Fort Benton, Great Falls, Kalispell, Manhattan, Pony, Stevensville, Superior, Three Forks, Vaughn, Whiteball.

Intensity III and under in Montana: Butte, Cardwell, Chinook, Columbia Falls, Craig, Cut Bank, Deer Lodge, Fort Shaw, Hamilton, Havre, Livingston, Missoula, Red Lodge, St. Regis, Shelby, Victor, Whitefish, White Sulphur Springs.

Intensity III and under in Alberta, Canada: Medicine Hat.

Felt, intensity not reported, in Montana: Loma, Nelson, Rimini.

Not felt: Big Timber, Eureka, Thompson Falls, West Yellowstone, Wolf Point, Mont.; Arco, Driggs, Wallace, Idaho.

***October 15:*** 13:30, 14:02, and 14:21. Helena, Mont. Three shocks which caused dismissal of some schools and increased the damage by at least $15,000.

***October 16:*** 0:50. Chinook, Mont. Slight.

***October 18:*** 19:40. Jefferson City, Mont. Felt.

***October 18:*** 21:48.* Helena, Mont. The strongest of the series of 1935. Intensity VIII at Helena. Damage approximately $3,000,000. Two people

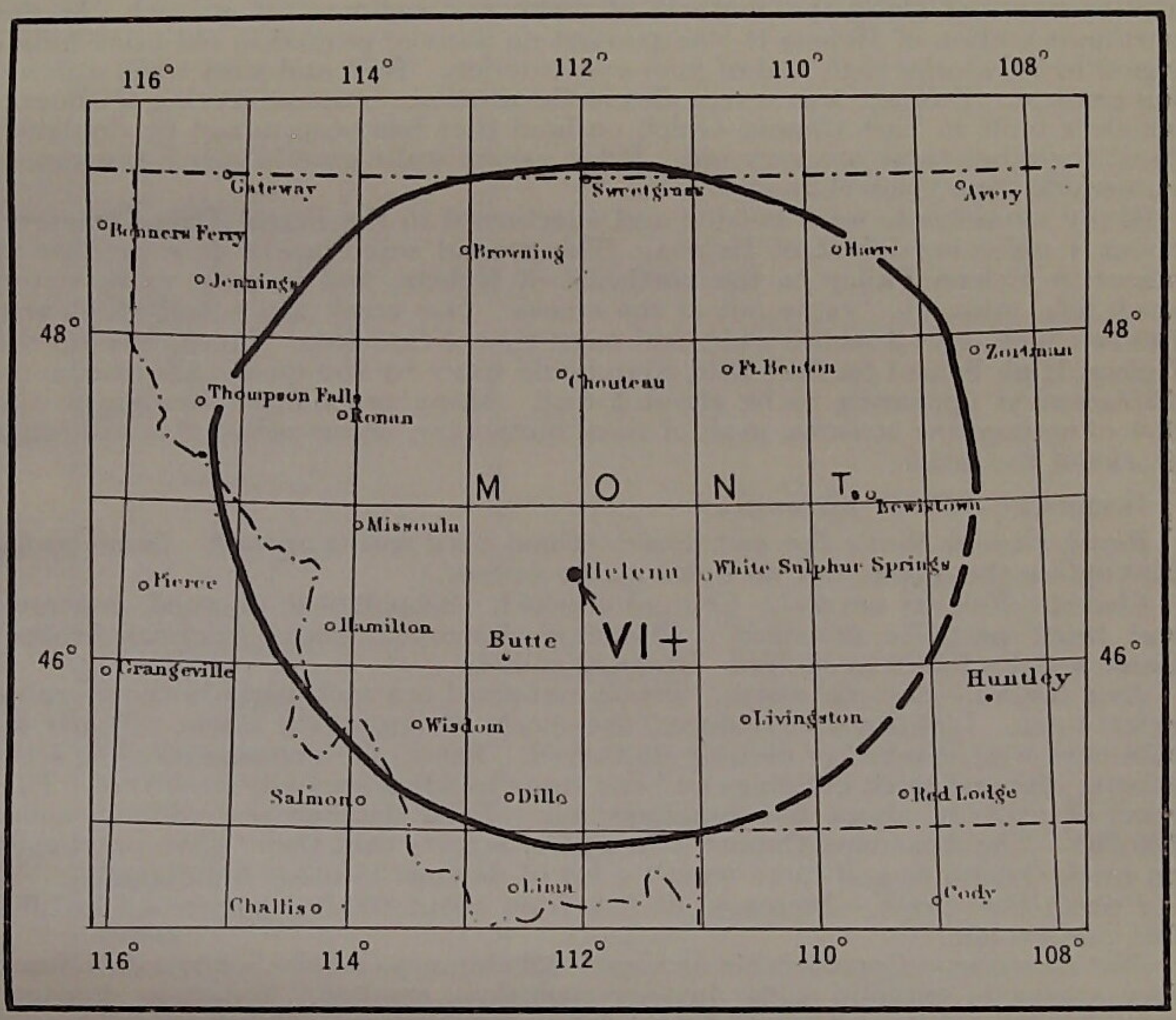



FIGURE 5.—Approximate area affected by the Helena, Mont., earthquakes of October 12, and November 28, 1935.

killed. Epicenter (same as October 12) about 2 or 3 miles northeast of Helena, about 46°37′ north, 111°58′ west. Area affected about 230,000 square miles, as shown on map, facing page 20. See special article on page 42.

In Helena most people stayed up all night, many remaining outdoors, while others left town. Dangerous streets were roped off, and the Red Cross and other organizations provided food and shelter for the homeless.

On October 19 the United States Coast and Geodetic Survey sent an accelerograph and a vibration meter from California to Helena. The instruments were set up on October 21 in time to record many aftershocks, including the strong shock of October 31. The results of this work are discussed on pages 43 and 72.

Helena is situated on a rocky mountain slope. According to Mr. Harold W. Scott of the Montana School of Mines, "The earthquakes were caused by a northwest trending fault, but because of the deep cover of gravel and sand in the Helena valley it is impossible to see the fault plane. The fault zone extends for a distance of approximately 14 miles, from a point a mile or more to the northwest of Helena to an indefinite point between East Helena and Clasoil. The fault

is probably of the normal type, and is part of the late Tertiary diastrophism. The zone of slipping is near the northern border of the Boulder Batholith."

Telegraph, telephone, and electric-light services were interrupted for about 1 hour. No gas or water lines were broken. There was little damage to well-constructed buildings with steel or reinforced concrete frames resting on solid foundations, but it was severe in commercial buildings that lacked steel or concrete frames. Many of the latter were of poor construction. On October 23 a Red Cross representative examined 338 houses on a diagonal line through the worst of Helena's quake-shaken district. Of these, 36 were undamaged, 134 were slightly damaged, 94 suffered medium damage, 45 were badly damaged, and 29 demolished. Chimneys were reported to have been destroyed on 213 buildings, interiors wrecked in 146, foundations hurt on 31, and plumbing broken in 3. These figures do not include damage in the business and industrial sections.

In some sections practically all chimneys were destroyed. Damage was especially pronounced along the contacts of rocky and sedimentary ground. In the northeast section of Helena it was greatest on alluvial ground in old brick buildings 2 to 2½ stories high and of poor construction. East and west walls suffered the greatest. Damage was severe also in the southern business section of Helena, which is built in Last Chance Gulch on land that has been mined by dredging. Most buildings there are very old. Brick veneer walls were in many cases more vulnerable than brick chimneys.

Many monuments were twisted and overturned in the Forest Dale Cemetery, about 4 miles northwest of Helena. The ground was cracked in a number of places in Helena Valley to the northeast of Helena, and in some cases water, sand, ash, mica, etc., came out of the cracks. One crack was found which was 150 feet long, 2 or 3 inches wide, and more than 3 feet deep. Lines ruled on the Helena High School football field were made wavy by the quake, the maximum displacement appearing to be about 2 feet. Many pronounced changes in the flow of springs and streams, most of them temporary, accompanied this and other shocks of the series.

INTENSITY VII IN MONTANA:

*Ranch between Bird's Eye and Silver.*—Good sized spring opened. (Some moisture before the quake, but no water at the surface.)

*Clasoil.*—Felt by several. Ground cracked. Schoolhouse of wood, concrete, and brick partially damaged. Chimneys destroyed; some windows broken. Loose articles fell from shelves. Roaring sound.

*East Helena.*—General alarm. People remained out until early in the morning or left town. Lights went out during the shock, adding to the alarm. Nearly all chimneys were cracked or entirely destroyed. Nearly all houses cracked to some extent. Several brick buildings and one stone building partially destroyed. Portions of walls of about five buildings fell. Total damage to buildings about $40,000. The Anaconda Copper Mining Co. reports that they "have practically no brick structures and there wasn't a bit of damage to other buildings."

*Prickly Pear Creek.*—Increased its flow from about 800 feet per second to 1,000 feet per second.

*Fort Harrison.*—Considerable damage. All chimneys cracked or knocked down. Few cracks in exterior walls; interior partitions cracked. Buildings damaged around brick gables and cracked over doors and windows. Chimneys fell mostly to southeast. One small water pipe broken.

*St. Ignatius.*—"Garden Wall" in the Mission range, east of St. Ignatius. A new chasm 40 feet wide and one-fourth mile long reported to have appeared. Extends from top of this high rock formation down the face of the cliff. Some geologists doubt that this cleft was caused by the quake.

INTENSITY VI IN MONTANA:

*Alhambra.*—Trembling swaying motion distinctly felt. Artesian hot springs doubled flow of water and new hot springs opened. The flow from some springs was still increasing on October 25; from others the flow had decreased to normal by October 24. One glass knocked off a drinking fountain. No material damage.

*Butte.*—There was no damage at Butte, but about 7 miles from the city a well-constructed brick house two stories high had a corner knocked down. A cold well began running hot water. Felt in mines on the third level but not below.

*Camas.*—Some cracks in stucco foundations of buildings. Water tank in tower above building groaned so much that an observer thought that it was going to come down.

*Checkerboard Canyon.*—Rock and landslides.

*Clancey.*—A few loose bricks on schoolhouse chimney fell. Soap piled in store fell. Some cracked plaster; no cracked windows.

*Dutton.*—Slight cracks in a few chimneys and in walls and plaster.

*Evans.*—Slight damage to buildings. Some bricks fell from chimneys; window glass cracked or broken; walls of store building cracked.

*Golden Messenger Mine.*—Felt underground.

*Jefferson City.*—One brick building had a couple of cracks, and a stone house was cracked. Two chimneys broke some; two were cracked all the way around half way up. Plaster cracked in some houses. A house which had recently been moved and was resting on some large planks was shifted a little by the quake. There was a little rock slide about 7 miles from Jefferson City in the direction of Helena.

*Logan.*—Slight damage to buildings; vertical cracks in walls, some damage to chimneys, plaster cracked.

*Lombard.*—Slight damage to buildings. Chimney cracked.

*Marysville.*—A number of chimneys were down, and several lost a few bricks. Two walls cracked vertically.

*Nelson.*—Some walls cracked. Another report, "no damage." One rock slide on the north ridge of Checker Board. A large block of limestone slid to the north.

*Nye.*—Slight damage to buildings. Chimneys cracked and at a coal mine located here large cracks and some rock slides appeared, and continued to appear for some days after the quake. The cracks run south, and downward at an angle of 45°.

*Townsend.*—Considerable damage to buildings. Three chimneys cracked. Some cracked plaster.

INTENSITY V IN MONTANA:

*Agawam.*—Felt by all; general alarm but no panic. Thunderous roaring. Pendulum clock stopped; vase and other small objects toppled; broom leaning upright against wall fell. No damage.

*Alberton.*—Trembling motion began rapidly and was felt by all.

*Alder.*—Swaying motion felt by all.

*Armstead.*—One clock stopped.

*Augusta.*—Sink moved from west wall of house.

*Avon.*—Some clocks stopped; one clock started and ran for a few minutes.

*Basin.*—Felt distinctly by miners at the Comet mine who were coming out to lunch. They returned to mine after lunch.

*Belgrade.*—Slight damage; some cracks in walls and plaster.

*Belton.*—Disturbed objects were observed by many.

*Boulder.*—Pendulum clocks stopped; hanging objects swung. Slight damage. Another report, "no damage." A few knicks in buildings. Quake was preceded by rumbling noise and dimming of electric lights.

*Bozeman.*—Pictures were displaced; chandeliers swung; some pendulum clocks stopped. Some plaster cracked, none thrown down.

*Cardwell.*—Felt by all; general alarm. Pendulum clocks stopped. No damage.

*Carter.*—Plaster cracked slightly and some thrown down. Grain elevator spout knocked off, and scales rocked in opposite direction.

*Casacde.*—Slight damage to buildings; a few walls cracked; slight cracks in plaster.

*Choteau.*—Gas pipes damaged in one house; no other damage.

*Clarkston.*—Felt by many; general alarm. No damage.

*Cleiv.*—Buildings creaked and rattled; plaster cracked.

*Clydepark.*—Disturbed objects were observed by many; no damage.

*Collins.*—Felt by all. Slight landslides.

*Columbia Falls.*—Felt by all. Small objects moved. Chair seemed to move about 6 inches back and forth north and south in abrupt motion.

*Comanche.*—Clock stopped. Small objects moved.

*Cordova.*—Beds, phonograph, and various objects swayed east-west. No damage.

*Corwin Springs.*—Felt by all. Spilled water from outdoor containers in northeast direction.

*Craig.*—Small objects moved; canned goods fell from shelves; clock stopped. No chimneys down. One old chimney had loose bricks at top, which were not thrown down. A few new hair-line cracks in concrete foundations of schoolhouse extended up brick walls to windows.

*Cut Bank.*—Felt by all. Disturbed objects observed by several.

*Darby.*—Two shocks. Some old frame houses seemed to sway and shake considerably, while newer and smaller ones were not affected so much. Small objects were moved; hanging objects swung; pendulum clocks stopped. Very little damage.

*Deer Lodge.*—Loose objects moved. People rushed from theater.

*Dillon.*—Felt by all; general alarm. Disturbed objects were observed by many.

*Drummond.*—Slight displacement of vases, pictures, and dishes. Two pendulum clocks stopped. Slight cracks in plaster, specially on ceilings. No other damage.

*Eldridge.*—Damage slight.

*Elliston.*—Felt by all; general alarm. Water in open containers spilled east-west. Small objects were not disturbed. No damage.

*Emigrant.*—Some damage to light structural parts such as chimneys, tile roofs, ornaments, etc. Pendulum clocks did not stop; plaster not disturbed.

*Ethridge.*—Felt by all. Small objects moved in a few cases. Brace wires on stove-pipes, radio aerials, etc., were humming.

*Fairfield.*—Many observed disturbed objects.

*Findon.*—Felt by all.

*Fishtrap.*—Felt by all.

*Florence.*—Three shocks.

*Floweree.*—Slight damage to buildings.

*Fort Shaw.*—Felt by most; people were interested but not alarmed. Hard-packed roadway in front of one house was pulverized by the shock. A coal-mine operator about 12 miles southwest of Fort Shaw reports that there was an underground rumbling like distant thunder which continued for some time after the shock was felt.

*Frenchtown.*—Many alarmed. No subterranean sounds. Hanging objects swung.

*Gallup City.*—Felt by all. Disturbed objects were observed by several.

*Gardiner.*—A few left their homes. Disturbed objects were observed by several.

*Geraldine.*—Felt by practically all; many alarmed.

*Giffen.*—Disturbed objects were observed by many.

*Havre.*—One apartment building quivered and occupants hurried out. Felt by people in standing motor cars, but not by people standing nearby. Pendulum clocks stopped.

*Hay Coulee.*—General alarm. Small objects were moved; hanging objects swung. Chimney cracked.

*Heart Butte.*—Moved furniture. No damage.

*Helmville.*—Walls cracked very slightly.

*Highwood.*—Felt by all.

*Hill.*—Disturbed objects were observed by one.

*Holter.*—Felt by all.

*Hot Springs.*—Many were alarmed.

*Hughesville.*—Felt by all.

*Jackson.*—Felt by several. Disturbed objects were observed by several. No damage to light structural parts such as chimneys, tile roofs, ornaments, etc. Objects such as chimneys, monuments, etc., fell toward the north.

*Jardine.*—Rock slides occurred in highway.

*Jeffers.*—Disturbed objects were observed by several. Chairs rocked, chandeliers swayed, one clock stopped.

*Kalispell.*—Plaster cracked in one or two cases. A large tree in school yard is reported to have broken and part fell; tree was old.

*Lingshire.*—Felt by all.

*Livingston.*—Felt by a majority of the population; no general alarm. (According to another report people dashed out frightened.) Early reports state that a few bricks were shaken from chimneys and that the city hall, an old brick structure, was somewhat damaged, having a long jagged crack over door and cracks in ceiling.

*Loma.*—Small objects moved.

*Lowry.*—Felt by most everyone that was awake.

*Manhattan.*—Disturbed objects were observed by many. Pendulum clocks stopped.

*Maxville.*—Felt by all.

*Missoula.*—Plaster cracked very slightly.

*Olney.*—Small articles were upset.

*Ovando.*—Felt by all.

*Paradise.*—Furniture moved a few inches.

*Park City.*—Plaster cracked beside chimney.

*Perma.*—Plaster not disturbed; window broke in depot; stovepipe moved from wall.

*Polaris.*—General alarm; few left houses.

*Pony.*—A few light objects fell. No damage.

*Portage.*—Pendulum clocks stopped; building observer was in felt as though it was going to fall apart.

*Ramsay.*—Some plaster cracked slightly.

*Ringling.*—Several small shocks. Plaster cracked.

*Rothiemay.*—Felt by many. Pendulum clocks stopped. Springs flow a little stronger.

*Roy.*—Hanging objects swung; tables jumped, and rocking chairs rocked even with people in them.

*Rycgate.*—Felt by practically all except those asleep or riding in automobiles.

*Sand Coulee.*—Some observed disturbed objects.

*Sappington.*—All were alarmed.

*Seeley Lake.*—Felt by many. Objects swayed and rolled off tables. Slight damage to light structural parts such as chimneys, tile roofs, ornaments, etc.; these fell to the north.

*Selma.*—Felt by several; all were alarmed who felt the quake. Disturbed objects were observed by several.

*Shelby.*—Felt by almost all; slight panic at the local movie show.

*Shonkin.*—Felt by many or all; not much alarm. Buildings and automobiles swayed. Hanging objects swung.

*Sixteen.*—Felt by all; all were awakened but none alarmed.

*Square Butte.*—One report states that one chimney was damaged and a concrete floor in another building bulged and cracked; plaster not distrubed. Another report states there was no damage.

*Stanford.*—Pendulum clocks stopped; small objects were moved. A few report slight cracks in plaster.

*Sula.*—Several shocks. Small objects were moved; pendulum clocks were not stopped.

*Sunburst.*—Plaster was cracked very slightly in east-west direction.

*Three Forks.*—Felt by all. Several observed disturbed objects.

*Trident.*—Majority of the people left houses. Books were moved on shelf.

*Ulm.*—Felt by almost all. One of two reports received states that plaster was cracked.

*Varney.*—Slight damage to buildings; mortar jarred loose.

*Vaughn.*—Several observed disturbed objects.

*Waltham.*—Felt by all; a number were alarmed. Plaster cracked.

*Warmsprings.*—Felt by about 25 percent of the people. Slight cracks in well-constructed brick.

*Watson.*—Small objects moved.

*Whitefish.*—Chair, tables, beds, and pictures moved; pendulum clocks did not stop.

*Whitehall.*—Walls cracked slightly; hanging objects swung.

*White Sulphur Springs.*—Felt by all.

*Willow Creek.*—Plaster cracked slightly.

*Winston.*—Two large thin windows cracked. Plaster in walls cracked slightly

*Wisdom.*—Furniture moved.

*Wise River.*—General alarm.

*Wolf Creek.*—Felt by all. Damage none or slight. Highway department officials state that the large crevice in the earth alongside the highway about 1 mile south of Wolf Creek was caused by an old landslide and not the earthquake, though the latter may have made some change in it.

*York.*—Some loose objects fell from shelves. Stone slides south of York.

INTENSITY V IN IDAHO:

*Kellogg.*—Felt by many.

*Sandpoint.*—Pendulum clocks facing south stopped. Slight damage.

INTENSITY V IN WYOMING:

*Yellowstone National Park.*—Felt by many; frightened few.

INTENSITY V IN WASHINGTON:

*Valley.*—Furnishings moved. Cracked plaster.

Intensity IV in Montana: Anaconda, Bercail, Big Sandy, Big Timber, Billings, Black Foot, Black Leaf, Bole, Brady, Brooks, Browning, Cameron, Cavern, Chester, Chinook, Cliff Lake, Clinton, Coffee Creek, Comrade, Corvallis, Custer, Denton, Devon, Dixon, Dover, Farmington, Fort Benton, Fowler, Frombery, Geyser, Gibbons, Gibson, Glacier Park, Glasgow, Grayling, Great Falls, Grey Cliff, Hamiltor, Harlowton, Harrison, Homestake, Hopp, Iliad, Inverness, Jens,

Kabo, Kevin, Lewistown, Libby, Limestone, Lolo Hot Springs, Lyon, Marias, Marion, Martinsdale, Maudlow, McClellan Creek Gulch, McLeod, Melrose, Melville, Menard, Merino, Monarch, Neihart, Nyack, Pendroy, Polson, Powderville, Raynesford, Red Lodge, Riebeling, Rollins, St. Peter, Saltese, Shawmut, Sheridan, Simms, Stockett, Superior, Swingley, Thompson Falls, Toston, Tuscor, Ural, Valier, Victor, Vigelle, Walkerville, Waterloo, West Yellowstone, Whitlash, Windham, Winfield, Wolf Point, Wyola.

Intensity IV in Idaho: Ashton, Avery, Coeur d'Alene, Craigmont, Elk City, Elk River, Fernwood, Headquarters, Kamiah, Lewiston, Mackay, Mullen, Nezperce, North Fork, Saint Maries, Salmon.

Intensity IV in Wyoming: Cowley, Garland, Powell, Sheridan.

Intensity IV in Washington: Chewelah, Farmington, Spokane.

Intensity IV in Alberta, Canada: Cardston, Lethbridge.

Intensity III and under in Montana: Babb, Baker, Beckett, Big Horn, Carbella, Cleveland, Como, Dodson, Dupuyer, Eagleton, Essex, Forsyth, Four Buttes, Gateway, Glendive, Hardin, Heron, Hysham, Judith Gap, Lima, Living Springs, Luther, Malta, Midale, Miles City, Miner, Moccasin, Monida, Montague, Polebridge, Poplar, Rapelje, Russell, St. Xavier, Troy, Yaak.

Intensity III and under in Idaho: Boise, Bonners Ferry, Cascade, Challis, Clark Fork, Culdesac, Emmett, Fenn, Genesee, Golden, Grangeville, Idaho City, Lake Meadows, Moscow, Orofino, Stites, Troy, Wallace, Warren, Weiser Valley, Winnett.

Intensity III and under in Wyoming: Cody, Jackson, Triangle F. Ranch.

Intensity III and under in Washington: Colfax, Ione, Omak, Rosalia, Walla Walla, Waterville, Wenatchee.

Intensity III and under in Alberta, Canada: Calgary, Drumheller, High River, MacLeod, Milk River, Pincher Creek.

Intensity III and under in British Columbia, Canada: Nelson, Tadanac.

Intensity III and under in Saskatchewan, Canada: Regina, Saskatoon.

Not felt in Montana: Alta, Bainville, Belt, Briley, Broadus, Circle, Eight Point, Ekalaka, Fairview, Fife, Garryowen, Hathaway, Hogeland, Jennings, Jordan, Lavina, Lee, Lindsay, Mildred, Plentywood, Plevna, Ridgeway, Scobey, Terry, Whitewater.

Not felt in Idaho: Caldwell, Clayton, Copeland, Driggs, Du Boise, Hailey, Idaho Falls, Malad City, Midvale, Montpelier, Mountain Home, Oakley, Payette, Pocatello, Rathdrum, Rexburg, Ridgedale, Rigby, Silver City, Silver Springs, Spencer, Twin Falls.

Not felt in Wyoming: Arlington, Arminto, Auburn, Bear Creek, Buffalo, Casper, Cheyenne, Clearmont, Cody, Cokeville, Douglas, Fairview, Kemmerer, Kerby, Larimy, Manderson, Mason, Midwest, Monita, Newcastle, Pinedale, Rollins, Riverton, Savageton, Sundance, Sussex, Winchester, Worland.

Not felt in Washington: Asotin, Coulee, Davenport, Odessa, Othello, Pasco, Patterson, Prescott, Republic, Ritzville, Seattle, Tatoosh Island.

Not felt in Alberta, Canada: Alix, Camrose, Carstairs, Castor, Edson, Foothills, Ft. McMurray, Frank, Gadsby, Gleichen, Grand Prairie, Jasper, Magrath, Peace River, Raymond, Red Deer, Wainwright, Wetaskiwin.

Not felt in British Columbia, Canada: Chilliwack, Cranbrook, Donald, Kamloops, Kaslo, Merritt, Okanagen, Revelstoke, Vancouver, Vernon, Victoria.

Not felt in Saskatchewan, Canada: Aneroid, Battleford, Broadview, Hudson Bay Junction, Humboldt, Lumsden, Moose Jaw, Moosomin, Oxbow, Qu'Appelle, Swift Current, Watrous, Weyburn, Wynyard, Yorktown.

Not felt in Oregon: Arlington, Athena, Baker City, Bend, Crane, Elgin, Huntington, La Grande, Milton, North Powder, Pendleton, Pilot Rock, Prairie City, The Dalles.

Not felt in Colorado, Kansas, or North Dakota, nor in Manitoba, Canada.

For complete list of aftershocks at Helena see list prepared by W. E. Maughan described on page 56.

***October 18:*** About 22:30. Stites, Idaho. Slight aftershock. Small objects moved. Jefferson City, Mont. Aftershocks hardly noticeable.

***October 19:*** Several aftershocks felt as follows:

3:31.* Alhambra, Mont. "Felt."
4:16.* Alhambra, Mont. "Felt."
—:—. Cardwell, Mont. Light tremor.
2:—. Harlowton, Mont.

***October 19:*** —:—. Helena, Mont. Many aftershocks.
—:—. Highwood, Mont. Many very slight shocks.

***October 20:*** Slight aftershocks felt at Cardwell, Highwood, and Seeley Lake, Mont.

***October 21:*** 3:33. Aftershock broke windows at Helena, Mont. Felt also at Butte, Cardwell, and Highwood, Mont.

***October 21:*** 6:22. Helena, Mont.

***October 21:*** 13:45. Butte, Mont. Felt by few; rattled dishes and window panes for a few seconds.

***October 23:*** 10:40. Helena, Mont., V.

***October 23:*** 18:30. Whitlash, Mont. Slight movement from southwest toward northeast. Chair rocked.

***October 25.*** 16:— to 17:30. Helena, Mont. Rumbling sounds.

***October 27:*** Shortly after noon. Helena, Mont. Shook down previously loosened chimneys. Unnerved scores of visitors. See page 72.

***October 27:*** 19:09. Phoenix, Ariz. Sandy plain. Several weak shocks.

***October 30:*** 20:10. Kalispell, Mont. Felt.

***October 31:*** Between 0:— and 1:—. Blackleaf, Mont., about II or III. Another of about same intensity about one-fourth hour later.

***October 31:*** About 1:—. High River, Alberta, Canada. Observer felt bed move. Windows rattled; panes quivered.

***October 31:*** 8:— or 20:—. Culdesac, Idaho. Sloping rocky ground. Rapid east-west quiver of short duration felt by few.

***October 31:*** 8:10. Verona, Mont. Sloping ground. Slow motion lasting 12 seconds felt by few; frightened no one. Pendulum clocks facing northeast did not stop.

***October 31:*** 8:20 or 20:20. Wilborn, Mont. Windows, doors, and dishes rattled.

***October 31:*** 11:38.* Helena, Mont. The second strongest shock of the October series. Intensity VIII—. Epicenter about 46°37′ north, 111°58′ west, as on October 12 and 18. Area affected about 140,000 square miles, as shown on map facing page 26. Additional destruction increased the total damage to nearly $4,000,000. Two more persons were killed. (Six additional deaths were attributed indirectly to earthquake causes during the October series.) See special description on page 42 for other details and strong motion results on page 72.

Many buildings, weakened by previous shocks, were further damaged. Structures on alluvial ground were hardest hit but serious destruction was not confined to such localities. Destruction was most severe in the neighborhood of the city hall, and on Main Street; in the residential district, on Ninth Street. Destruction on the west side was worse in this shock than for the October 18 shock. The new high school, which was badly damaged on October 18, was almost completely demolished. Damage to frame buildings was slight except to chimneys and brick veneer facing.

The ground in Helena Valley was cracked again. Water was seen spurting a foot or two from some of the cracks, and dust came from others. All chimneys were down in this neighborhood and a bridge was shifted slightly to the west. The epicenter appears to have been in the same locality as that of October 18. This view is supported by reports from 3 miles northeast of Helena that the sound seemed to come from directly beneath, while to residents of Helena the source of the sound was north or northeast of them, and to those 5 miles northeast of the city it appeared to come from the direction of Helena.

INTENSITY VII IN MONTANA:

*Clasoil.*—Small objects and furnishings were moved; vases and small objects were overturned; water was spilled from indoor containers. Broke dishes, windows, and chimneys; pictures, plaster, and walls fell; damage considerable.

*East Helena.*—Grade school and city hall badly damaged, "will have to be razed probably." Otherwise only minor damage; slight damage to windows and chimneys. Total new damage estimated at $20,000.

*Fort Harrison.*—Walls cracked.

INTENSITY VI IN MONTANA:

*Bigfork.*—Some plaster down. A few windows broken.

*Craig.*—Cracked plaster and chimneys; damage slight.

*Dillon.*—Cracks appeared in several buildings; no serious damage.

*Dutton.*—Cracked plaster, walls, and chimneys. Chimneys, monuments, and columns twisted. Damage slight in brick, masonry, and concrete. No apparent damage other than slight cracks in tile school.

*Evans.*—Plaster, windows, and a stone wall cracked. Damage slight.

*Jefferson City.*—Cracked plaster, walls, and chimneys. Twisted chimneys. Damage very slight in brick.

*Logan.*—Cracked plaster, windows, and walls. Broke windows; chimneys fell; damage slight.

*Marysville.*—Plaster and walls cracked; books, pictures, and plaster thrown down, and dishes broken; damage slight.

*Neihart.*—Felt by all. "Foundation of one building badly cracked and probably falling."

*Schatz.*—Frightened all. Broke windows and chimneys; damage slight.

*Seeley Lake.*—Overturned small objects; cracked plaster in chimneys; damage slight.



INTENSITY V IN MONTANA:

*Agawam.*—Felt by all. Pendulum clocks facing east stopped.

*Augusta.*—Pendulum clocks facing northeast stopped; small objects moved; vases overturned.

*Austin.*—Pendulum clock facing east stopped.

*Avon.*—Overturned small objects; spilled water from indoor containers. Cracked plaster; damage slight.

*Belt.*—Cracked plaster a little; damage negligible.

*Brady.*—Cracked plaster; damage slight.

*Butte.*—Persons fled from several uptown buildings. Felt in mines down to the seventh or eighth level but not below.

*Cardwell.*—Felt by all. Pendulum clocks stopped.

*Carter.*—Damage slight.

*Cascade.*—Small objects were moved. Plaster cracked slightly.

*Cavern.*—Noticed by all.

*Clancey.*—School closed until the next Monday; no damage done except a little plaster loosened.

*Clarkston.*—Frightened all. Overturned vases and furniture; cracked plaster; damage slight in wood.

*Collins.*—Spilled water northeast. Damage slight in wood.

*Columbia Falls.*—Pendulum clocks did not stop. Damage slight.

*Corbin.*—Overturned small objects; no damage.

*Cut Bank.*—Cracked plaster slightly. Damage slight. Seemed to be stronger north of town.

*Darby.*—Small objects were moved. Damage slight.

*Deer Lodge.*—Pendulum clocks stopped; small objects were moved.

*Denton.*—Damage very slight.

*Devon.*—Small objects were moved.

*Drummond.*—In a couple of brick buildings cracks were found which had not been noticed before. Damage slight.

*Elliston.*—Overturned vases; no damage.

*Emigrant.*—Slight damage.

*Fairfield.*—Moved small objects.

*Finn.*—Pendulum clocks stopped.

*Florence.*—Overturned small objects.

*Giffen.*—Moved small objects.

*Great Falls.*—Felt by all; frightened few. Some plaster fell.

*Hall.*—Spilled water north-south. Slight damage.

*Hamilton.*—Cracked plaster; damage slight.

*Helmville.*—Felt by all. Overturned vases and furniture. Cracked plaster; no other damage.

*Highwood.*—Moved small objects and furnishings. Cracked plaster; no other damage.

*Kalispell.*—Pendulum clocks did not stop. Plaster cracked. Press reports windows broken. Damage slight.

*Kevin.*—Overturned bookcase.

*Lewiston.*—Frightened few.

*Lombard.*—Slight damage in brick.

*Loring.*—Small objects and furnishings were moved; slight damage.

*Maxville.*—Plaster cracked; damage slight.

*Missoula.*—Slight cracks in plaster.

*Nelson.*—Pendulum clocks facing north stopped.

*Ovando.*—Felt by many; frightened few. Pendulum clocks stopped. One log house spread slightly.

*Radersburg.*—Overturned small objects.

*Ramsay.*—Pendulum clocks facing southwest stopped.

*Russell.*—Small objects fell. Damage slight.

*Shelby.*—Pendulum clocks facing southeast stopped; swivel chair rocked. Damage slight.

*Simms.*—Felt by all.
*Springdale.*—Cracked plaster; damage slight.
*Sweetgrass.*—Felt by many; frightened few.
*Three Forks.*—Moved small objects. Damage slight.
*Varney.*—Slight damage in mortar. Steam observed issuing from caves on October 29 and continued for at least several days. This phenomenon was accompanied by a roaring noise when it was first observed on October 29, but this had ceased by November 2.
*Vaughan.*—Frightened all.
*Victor.*—Plaster and windows cracked; damage slight.
*Waltham.*—Cracked plaster; slight damage.
*Warm Spring.*—Overturned a few vases and small objects. Slight damage in plaster loosened by quake of October 18.
*Whitefish.*—Moved small objects; spilled water east.
*Winston.*—Felt by many; frightened many. Slight damage.
*Wolf Creek.*—Felt by all



INTENSITY V IN IDAHO:

*Saint Maries.*—Felt by many; frightened no one. Cracked plaster. Water in river agitated; made waves such as a passing boat would make.
*Sandpoint.*—Pendulum clocks stopped.

INTENSITY V IN WASHINGTON:

*Spokane.*—Three clocks stopped. Plaster reported cracked in one building.
*Valley.*—Knickknacks fell.

Intensity IV in Montana: Alder, Alhambra Hot Springs, Anaconda, Armington, Bannack, Belton, Bonner, Bozeman, Bynum, Chinook, Cleiv, Coffee Creek, Como, Comrade, Dixon, Essex, Ethridge, Evaro, Findon, Floweree, Fort Shaw, Fowler, Frenchtown, Fromberg, Gallup, Genou, Geraldine, Glacier Park, Gold Creek, Grayling, Grey Cliff, Harrison, Havre, Heart Butte, Jackson, Jens, Libby, Lingshire, Livingston, Manhattan, McLeod, Melrose, Moccasin, Monarch, Olney, Paradise, Perma, Polaris, Polebridge, Pony, Portage, Raynsford, Riebeling, Ringling, Roy, St. Regis, Sandcoulee, Sixteen, Square Butte, Stockett, Sula, Sunburst, Superior, Thompson Falls, Toston, Tuscor, Valier, Walkerville, Waterloo, Watson, West Yellowstone, White Sulphur Springs, Williams, Willow Creek, Windham, Wisdom, Wise River.

Intensity IV in Idaho: Clark Fork, Coeur d'Alene, Kellogg, Mullan, Orofino, Salmon.

Intensity IV in Washington: Chewelah, Usk.

Intensity III and under in Montana: Abe, Armstead, Babb, Big Sandy, Big Timber, Billings, Blackfoot, Blackleaf, Bole, Bonita, Box Elder, Brooks, Browning, Camas, Choteau, Cleveland, Cliff Lake, Clinton, Corvalis, De Borgia, Farmington, Gateway, Gilman, Harlowton, Homestake, Inverness, Jardine, Jeffers, Kabo, Kolin, Lima, Limestone, Martinsdale, Maudlow, Melville, Park City, Pendroy, Rockcreek, Ryegate, Saint Peter, Shonkin, Sun River, Swingley, Townsend, Whitehall, Whitlash, Winifred.

Intensity III and under in Idaho: Boise, Challis, Elk River, Fairfield, Genesee, Nezperce, North Fork, Troy.

Intensity III and under in Wyoming: Basin.

Intensity III and under in Washington: Colfax, Odessa, Pullman, Seattle.

Intensity III and under in Alberta, Canada: Banff, Calgary, Edmonton, High River, Lethbridge, Milk River, Warner.

Intensity III and under in British Columbia, Canada: Grand Forks, Nelson, Tadanac, Trail.

Not felt in Montana: Alta, Andes, Bainville, Baker, Bercail, Big Horn, Bryley, Broadus, Brockton, Brockway, Cameron, Circle, Corwin Springs, Custer, Dodson, Dover, Eight Point, Ekalaka, Fairview, Fishtrap, Forsyth, Four Buttes, Gallatin, Gateway, Garryowen, Gibson, Hardin, Hathaway, Heron, Hogeland, Hysham, Jennings, Jordan, Judith Gap, Lakeview, Living Springs, Luther, Medicine Lake, Midale, Mildred, Miles City, Monida, Nye, Phillips, Plentywood, Plevna, Powderville, Rapelje, Red Lodge, Ridgeway, Saco, St. Xavier, Soltese, Scobey, Simpson, Trail Creek, Vandalia, Whitewater, Wilsall.

Not felt in Idaho: Aberdeen, Arco, Ashton, Avery, Avon, Belmont, Big Springs, Caldwell, Clayton, Council, Darlington, Driggs, Dubois, Emmett, Fernwood, Haley, Hamer, Idaho City, Idaho Falls, Malad City, McCall, Meadows, Midvale, Moscow, Mountain Home, Oakley, Payette, Pocatello, Prichard, Rathdrum, Rexburg, Rigby, Saint Anthony, Silver City, Soda Springs, Spencer, Stites, Twin Falls, Warren.

Not felt in Washington: Asotin, Coulee, Ione, Davenport, Othello, Pasco, Patterson, Prescott, Republic, Ritzville, Rosalia, Walla Walla, Waterville.

Not felt in Alberta, Canada: Alix, Camrose, Carstairs, Castor, Edson, Foothills, Frank, Gadsby, Gleichen, Grand Prairie, Jasper, Ft. McMurray, Magrath, Peace River, Raymond, Red Deer, Wainwright, Petaskawin.

Not felt in British Columbia, Canada: Chilliwach, Cranbrook, Donald, Kamloops, Caslo, Merritt, Okanagan, Revelstoke, Vancouver, Vernon, Victoria.

Not felt in Manitoba or Saskatchewan, Canada, nor in Oregon.

***October 31:*** 12:18. Montague, Mont. III.

***October 31:*** 12:40. Fort Benton, Mont. III or IV.

***October 31:*** 20:35. Wallace, Idaho. III or IV.

***October 31:*** 21:45. Sheridan, Mont. V. Plaster cracked; damage slight in brick. (The date or time of this report may be in error.)

***October 31:*** 23:00. Hedgesville, Mont. Very slight.

***October 31:*** Night. Wolf Point, Mont. Plaster fell in several buildings sometime in the night of October 31. No one felt shocks.

***November 2:*** 10:42. Helena, Mont. Strong aftershock. Duration 3 seconds. Slight additional damage. Loose objects and bits of cornice fell. Deep rumbling.

***November 4:*** 4:23, 5:42, etc. Helena, Mont. A series of strong aftershocks, the strongest at 4:23 and 5:42, which threw down loosened construction. One additional building designated as unsafe. Walls of Federal Reserve Bank building cracked. Building not abandoned. Press reports shock at 4:23 felt also at Bozeman, Butte, Great Falls, and Livingston, Mont.; no damage at these places. Weather Bureau at Helena reports shock at 5:42 felt over all of western Montana.

***November 5:*** 4:—. Loma, Mont. Weak shock.

***November 6:*** 1:12. Salt Lake City, Utah. Slight.

***November 6:*** 8:23. Helena, Mont. Strong aftershock. Duration 3 seconds. Not felt at Butte or Great Falls, Mont. See pages 79 and 80.

***November 10:*** 20:42. Laramie, Wyo. An earthquake of short duration accompanied by an audible rumble.

***November 21:*** 20:58. Helena, Mont. Strong aftershock. Bumping and swaying east-west motion began rapidly with a sudden lurch and was felt by nearly all. There was very little alarm, as the citizens had become quake-hardened. A few left their houses but returned shortly. Many heard faint to moderately loud rumbling sounds. Damage very slight, and confined to buildings which had previously been damaged or weakened. Felt also at Bozeman, Butte, Great Falls, and Virginia City, Mont. See page 80.

***November 28:*** 7:42.* Strong aftershock at Helena, Mont., reaching intensity VI, and felt over an area of about 90,000 square miles. Epicenter about 46°37′ north, 111°58′ west. See map on page 19 and special article on page 42.

INTENSITY VI IN MONTANA:

*Helena.*—Motion consisted of two shocks separated by an interval of 9 seconds. The motion in the first shock was of a slow rolling bumping horizontal type; in the second, a noticeable swaying and twisting. Motion began gradually.

Many alarmed for several minutes. Moderately loud rumbling and bumping sound heard by many from beginning to end of shock. Brick walls of poorly constructed buildings that had been weakened by previous shocks were further weakened, and in a few instances thrown down. Slight tilting of floor noticed. Weather Bureau at Helena reports this shock as the fourth strongest of the series, being weaker than the one on October 12; but it was the more widely felt of the two shocks.

INTENSITY V IN MONTANA:

*Basin.*—Small objects moved.

*Bozeman.*—One window reported cracked.

*East Anaconda.*—Felt by many; general alarm. Some walls cracked; no damage.

*Lombard.*—Felt by all; general alarm.

*Shelby.*—Press reports windows shattered; another report states no damage.

Intensity IV in Montana: Butte, Cascade, Columbia Falls, Great Falls, Loma, Manhattan, Missoula, Riebeling, Sand Coulee, Superior, Three Forks, Townsend, Whitefish.

Intensity III and under in Montana: Billings, Chinook, Clydepark, Columbus, Craig, Deer Lodge, Dillon, Gardiner, Hamilton, Havre, Kalispell, Lewiston, Livingston, Thompson Falls, Virginia City.

Intensity III and under in Idaho: Mullan, Salmon.

Not felt in Montana: Alberton, Baker, Big Timber, Cut Bank, Forsyth, Hardin, Hysham, Malta, Plentywood, Red Lodge, West Yellowstone, Wisdom, Wolf Point.

Not felt in Idaho: Orofino, Wallace, Ashton, Challis, Clark Fork, Coeur d'Alene, Culdesac, Dubois, Lake, Mackay, Moscow.

Not felt in Wyoming.

***December 5:*** About 14:15. Tropic, Utah. Slight shock felt by several.

***December 5:*** 14:25. Fredonia, Ariz. Two shocks. Felt by many. Windows rattled; piano shook for several seconds. Recorded at Tucson.

***December 5:*** 14:30. Orderville, Utah. Weak shock. Perhaps same as shock reported at 14:15.

***December 12:*** Night. Belen, N. Mex. Weak.

***December 14:*** Evening. Los Lunas, N. Mex. Slight.

***December 17:*** 22.33*. Belen, N. Mex., V. Felt by many; some alarmed. Moderately loud subterranean sounds, bumping, and like wind. Buildings creaked, and loose objects rattled as if a truck had hit building. Brick wall of old public school building cracked; school dismissed for 2 days. Some plaster down and small objects shaken from shelves. Felt weakly at Los Lunas, Magdelena, and Socorro, N. Mex.

***December 18:*** Various times. Belen, N. Mex. Weak intermittent earthquakes. One shock, in the evening, felt at Los Lunas, N. Mex. All schools closed.

***December 19:*** Various times. Belen, N. Mex. Sixteen shocks in the monotonous series of tremors. After one of the more severe shocks a crack 1 inch wide and several feet long showed in the wall of a brick building. Freight cars rocked on the tracks.

***December 21:*** 18:56. Belen, N. Mex. Strong earthquake followed by three other strong shocks, felt as far away as Socorro and Albuquerque. These were the strongest shocks in the series of earthquakes beginning December 12. Windows and dishes rattled; small objects were thrown from shelves. All substantially built buildings withstood the tremors, although old adobe structures on the outskirts of the city began to show signs of weakening.

***December 30:*** 22:10. Belen and Albuquerque, N. Mex. Strongest shock since December 21. No damage.

## CALIFORNIA AND WESTERN NEVADA

[120th meridian or Pacific standard time]

*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 and the California Institute of Technology at Pasadena; H. O. Wood in charge.*

***January 2:*** 10:59. Los Angeles, IV.

***January 2:*** 14:41.* Epicenter about 50 miles west of Cape Mendocino, according to Berkeley. See map on page 31. Moderately strong shock. Recorded on strong-motion instruments; see page 62.

INTENSITY V:

*Alderpoint.*—Berkeley gives intensity V–VI on the Rossi-Forel scale.

*Fort Bragg.*—Berkeley gives intensity V–VI on the Rossi-Forel scale.

*Holmes.*—Felt by all, frightened few. Small objects moved, knickknacks fell.

*Korbel.*—Berkeley gives intensity V–VI on the Rossi-Forel scale.

*Orleans.*—Berkeley gives intensity V–VI on the Rossi-Forel scale.

*Shelly.*—Berkeley gives intensity V–VI on the Rossi-Forel scale.

Intensity IV: Albion, Arcata, Bayside, Benbow, Elk River, Eureka, Ferndale, Honeydew, Rio Dell, Rohnerville, Scotia, South Fork, Upper Mattole, Waddington, Weott, Whitlow.

Intensity III and under: Alton, Blocksburg, Burnt Ranch, Carlotta, Cummings, Eel Rock, Ettersburg, Fields Landing, Fort Dick, Fort Seward, Fortuna, Freshwater, Garberville, Harris, Klamath, Loleta, McCann, Miranda, Petrolia, Piercy, Samoa, Stumpville, Westport.

Not felt: Bell Springs, Bonneville, Branscombe, Calpella, Carrville, Caspar, Caution, Coffee, Comptche, Covello, Crescent City, Dedrick, Del Loma, Denny, Dos Rios, Douglas City, Elk, Forest Glen, Gualala, Hartsook, Hearst, Hoaglin, Hoopa City, Hyampom, Hydesville, Island Mountain, Junction City, Laytonville, Lewiston, Little River, Longvale, Mad River, Manchester, Mendocino, Mina, Nashmead, Novarro, Orick, Philo, Point Arena, Potter Valley, Redwood Valley, Ruth, Salyer, Santa Barbara, Smith River, Spyrock, Talmage, Trinadad,

Trinity Center, Ukiah, Weaverville, Weitchpec, Willita, Willow Creek, Yorkville, Zenia. Not felt in Oregon at Brookings.

***January 2:*** 21:45. Slight shock at Humboldt and Los Gatos.

***January 3:*** 9:36.* Aftershock of the earthquake of December 30, 1934, about 6 miles northwest of Santa Clara.



INTENSITY V:

*Santa Cruz.*—Moved small objects; spilled water.

*Sunnyvale.*—Overturned small objects; spilled water north. Also felt: Agnew, Los Gatos, San Jose, Stanford University.

***January 5:*** 20:05.* Epicenter near Parkfield, according to Berkeley. Intensity IV or V at Parkfield.

***January 5:*** 20:25. Parkfield, IV. Shandon, very slight.

***January 5:*** 20:40.* Epicenter near Parkfield, according to Berkeley. IV at Parkfield and Paso Robles. III at Shandon.

***January 7:*** 18:35.* Epicenter about 3 miles northeast of Watsonville, according to Berkeley. IV at Hollister.

***January 8:*** 7:50.* Epicenter about 8 miles south of Gilroy, according to Berkeley. Felt weakly at Hollister.

***January 18:*** 1:43.* Epicenter 4 miles east of Colma, according to Berkeley. III at San Francisco.

***January 22:*** 1:28.* Epicenter 33°53′ north, 118°09′ west, on the Norwalk Fault near Norwalk, according to Pasadena. IV at Los Angeles. Felt also at Compton, Huntington Park, Inglewood, and Lynnwood. Not felt at Long Beach or Rosamond.

***January 22:*** 19:06.* Epicenter 34°01′ north, 117°25′ west, according to Pasadena. Felt at Guasti and Riverside.

***January 22:*** 19:16.* Epicenter about 34°35′ north, 120°20′ west, according to Pasadena. IV at Los Alamos.

***January 23:*** 5:52.* Epicenter about 35°27′ north, 119°15′ west, according to Pasadena. V at Bakersfield, where small objects and furnishings were moved slightly and a few cracks were noted in an old brick building of poor construction. IV at Delano, Ducor, Oil Center, Porterville, and Taft. III and under at Button Willow, Caliente, Corcoran, Glennville, Tipton, and Tulare. Not felt at Lafayette.

***January 27:*** 21:34.* Epicenter 33°38′ north, 118°12′ west, according to Pasadena. IV at Lomita. III at Long Beach and Seal Beach.

***February 3:*** 7:35. Slight shock at Eurkea, Fields Landing, and Table Bluff Light Station.

***February 7:*** 20:22.* Epicenter 35°50′ north, 118°00′ west, according to Pasadena. V at Onyx, where plaster was cracked. IV at Brown, Kernville, and Olancha. III and under at Inyokern and Springville. Not felt at Ducor.

***February 14:*** 14:30.* Epicenter 33°42′ north, 118°04′ west, according to Pasadena. IV at Seal Beach. III at Long Beach.

***February 23:*** 17:45.* Epicenter about 31°59′ north, 115°12′ west, according to Pasadena. V at Holtville, where small objects were moved and slight damage was done. IV at Calipatria, Campo, El Centro, Hipass, Lakeside, Moreno Dam and Tocato. III and under at Alpino, Boulevard, Del Mar, Harbison Canyon, and San Diego.

***February 24:*** 6:15.* Epicenter 33°46′ north, 118°07′ west, according to Pasadena. Felt weakly at Hynes and Long Beach.

***March 3:*** 2:19.* Epicenter near Upper Mattole, according to Berkeley. Recorded on the accelerograph at Ferndale. See page 62. V at Upper Mattole, where small objects were moved. IV at Bridgeville, Shively, South Fork and Whitlow. III and under at Ettersburg, Petrolia, and Scotia. Not felt at Eureka.

***March 5:*** 20:52.* Epicenter near Horitos, according to Berkeley. IV at Ahwahnee and Chowchilla. III and under at El Portal, Le Grand, Merced, Northfork, Planada, and Raymond.

***March 6:*** 15:14.* Epicenter about 34°26′ north, 119°52′ west, according to Pasadena. III at Santa Barbara.

***March 7:*** 12:17.* Epicenter 33°47′ north, 118°08′ west, according to Pasadena. V at Compton, where dishes were thrown from shelves and a few windows broken. IV at Hynes and Seal Beach. III and under at Long Beach, Los Angeles, and South Gate. Not felt at Diamond Springs or Ducor.

***March 7:*** 19:18.* Epicenter 34°25′ north, 117°52′ west, according to Pasadena. IV at Llano.

***March 9:*** 2:42.* Epicenter 33°47′ north, 118°08′ west, according to Pasadena. Felt weakly at Long Beach.

***March 14:*** 18:25.* Epicenter 33°40′ north, 117°17′ west, according to Pasadena. III at Elsinore.

***March 23:*** 0:26.* Epicenter near Hopland, according to Berkeley. IV at Hopland. Felt also at Talmage and Ukiah.

***April 15:*** 19:42.* Epicenter near Caribou, according to Berkeley. IV at Caribou. Felt also at Canyon Dam and Prattville.

***April 24:*** 25:20.* Huntington Beach, slight.

***April 25:*** 00:12.* Epicenter 33°42′ north, 118°04′ west, according to Pasadena. Felt weakly at Long Beach. Not felt at Huntington Park or Huntington Beach.

***April 26:*** 7:33.* Ferndale, III. Focus about 25 miles from Ferndale, according to Berkeley.

***April 29:*** 12:08.* Epicenter about 31°45′ north, 116°30′ west, according to Pasadena. IV at Cairo and Julien. III and under at Alpine, Barrett Dam, Calexico, Mansion Hill, and San Diego.

***April 30:*** 21:53.* Epicenter about 33°34′ north, 117°59′ west, according to Pasadena. Felt near Huntington Beach.

***May 4:*** 3:02.* Epicenter about 33°37′ north, 118°02′ west, according to Pasadena. Felt near Huntington Beach.

***May 7:*** 17:41.* Epicenter 32°32′ north, 116°11′ west, according to Pasadena. Felt at Moreno Dam.

***May 10:*** 14:08.* Epicenter 35°42′ north, 118°22′ west, according to Pasadena. Felt at Kernville.

***May 10:*** 14:19.* Epicenter 35°42′ north, 118°22′ west, according to Pasadena. Felt at Kernville.

***May 10:*** 16:18.* Epicenter 35°42′ north, 118°22′ west, according to Pasadena. Felt at Kernville.

***May 10:*** 18:14.* Epicenter 35°42′ north, 118°22′ west, according to Pasadena Felt at South Fork of Kern River.

***May 10:*** 22:23.* Kernville, IV.

***May 10:*** 22:30.* Epicenter 35°42′ north, 118°22′ west, according to Pasadena. V at Kernville and nearby on the Kern River, where small objects were moved and plaster cracked. Felt also at Ducor. Not felt at Bakersfield.

***May 10:*** 22:44.* Ducor. "Felt."

***May 10:*** 23:06.* Epicenter 35°42′ north, 118°22′ west, according to Pasadena. IV at Inyokern. Felt also at Ducor and Kernville.

***May 11:*** 00:05.* Kernville. Felt.

***May 11:*** 1:11.* Epicenter about 35°42′ north, 118°22′ west, according to Pasadena. Felt at Kernville.

***May 13:*** 23:14.* Epicenter 33°53′ north, 117°50′ west, according to Pasadena.

***May 14:*** 00:17.* IV at Placentia and Yorba Linda. Epicenter 35°42′ north, 118°22′ west, according to Pasadena. Felt weakly at Magunden.

***May 15:*** 8:50.* Focus about 6 miles from Palo Alto, according to Berkeley. III at Mountain View.

***May 15:*** 19:25.* Epicenter northeast of Mono Lake, according to Berkeley. IV at Benton. III and under at Big Creek, Florence Lake, and Huntington Lake. Not felt at Kaweah plants or Tule No. 4 Plant.

***May 16:*** 19:22. Felt at Big Creek, Huntington Lake, and Florence Lake. No damage.

***May 17:*** 20:36.* Epicenter 34°35′ north, 120°20′ west, according to Pasadena. IV at Los Alamos.

***May 19:*** 14:34.* Epicenter about 33°34′ north, 117°59′ west, according to Pasadena. IV at Huntington Beach.

***May 27:*** 8:08.* Epicenter about 35°22′ north, 120°58′ west, according to Pasadena. III at Templeton.

***June 1:*** 19:38.* Epicenter about 33°37′ north, 118°02′ west, according to Pasadena. Felt near Huntington Beach.

***June 2:*** 21:26.* Epicenter 34°25′ north, 119°03′ west, according to Pasadena. Felt at Fillmore, Huntington Beach, Oxnard, Santa Paula, and Ventura.

***June 6:*** 3:01.* Epicenter 33°45′ north, 117°48′ west, according to Pasadena. IV at Santa Ana; III at Balboa; not felt at Huntington Park.

***June 7:*** 8:33.* Epicenter 33°16′ north, 117°01′ west, according to Pasadena Broke some dishes at Escondido.

***June 11:*** 8:20.* Epicenter 35°42′ north, 118°22′ west, according to Pasadena. V near Kernville.

***June 11:*** 10:10.* Epicenter 34°43′ north, 118°58′ west, according to Pasadena. Felt at Gorman, Grapevine, Lebec, and Maricopa. Not felt at Huntington Park.

***June 14:*** About 10:45. Salinas and Watsonville. Sharp earthquake of short duration.

***June 15:*** 00:26.* Epicenter 33°34′ north, 117°59′ west, according to Pasadena. Felt at Balboa and Huntington Beach.

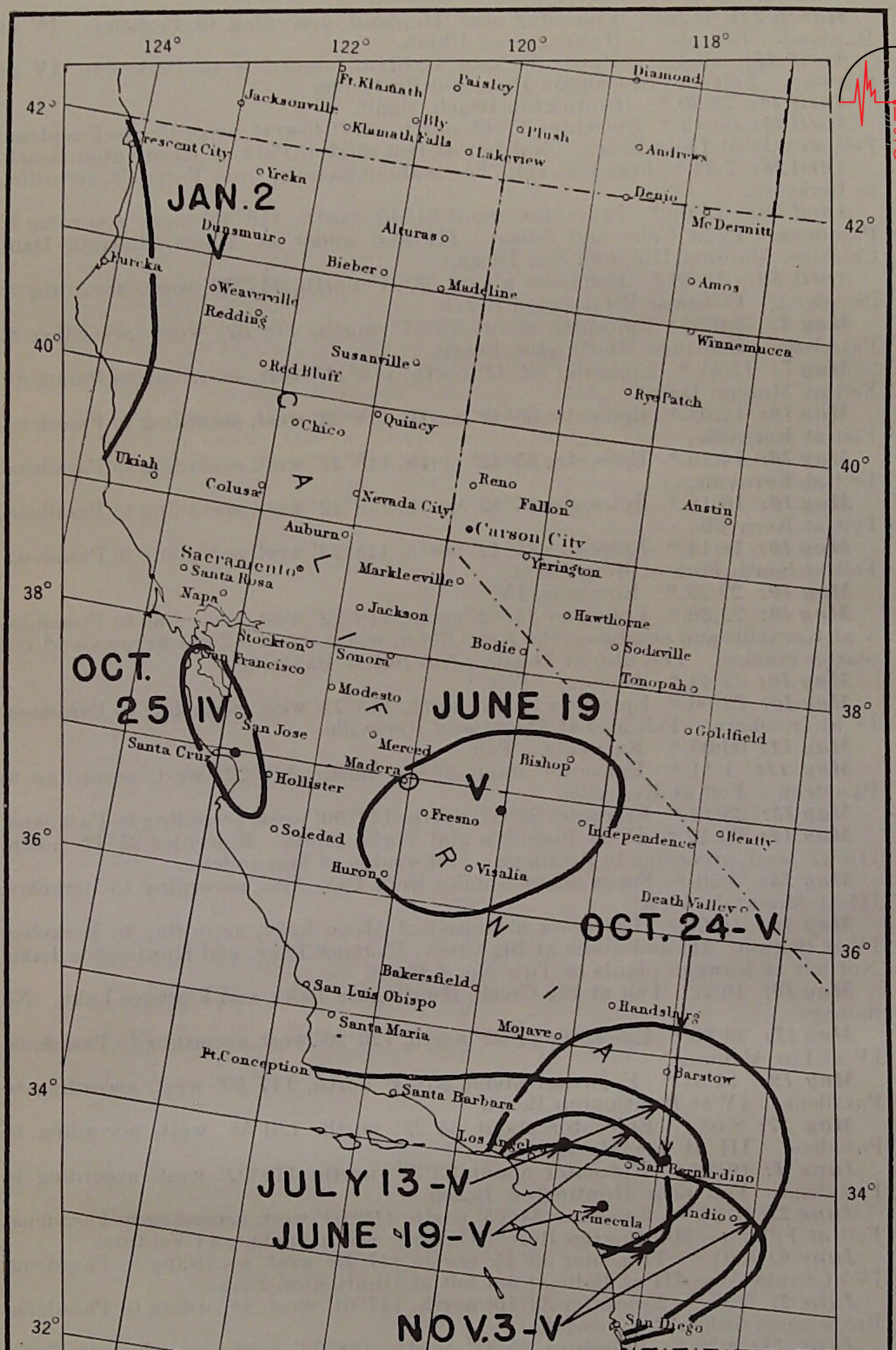



FIGURE 8.—Areas affected by the California earthquakes of January 2, June 19, 19, July 13, October 24, 25, and November 3, 1935.

***June 17:*** 20:15.* Epicenter 2 miles southeast of Gilroy, according to Berkeley. IV at Hollister.

***June 19:*** 1:55.* Epicenter in northern Owens Valley, according to Berkeley. Felt over an area of about 13,000 square miles, as shown on map on page 31.

INTENSITY V:

*Huntington Lake.*—Water spilled in an east-west direction. Two shocks noticed.

*Laws.*—Frightened many.

*Terra Bella.*—Small objects moved; plaster cracked.

Intensity IV: Big Pine, Bishop, Delpiedra, Friant, Hanford, Lakeshore, Miramonte, Mountain View, Orange Cove, Sanger, Shaver Lake, Tulare.

Intensity III and under: Balch power house on Kings River, Bass Lake, Big Creek, Bowles, Burrel, Coalinga, Corcoran, Crane Valley, Del Rey, Dinuba, Dunlap, Earlimart, Firebaugh, Fresno, Kaweah, Kirchhoff power house on the San Joaquin River, Laton, Lemon Cove, Lone Pine, North Fork, Porterville, Selma, Sequoia National Park, Stratford, Visalia.

Not felt: Academy, Alpaugh, Armona, Duberry, Badger, Diola, California Hot Springs, Calwa City, Camp Sierra, Cartajo, Caruthers, Cedar Crest, Clovis, Coarsegold, Cutler, Danvin, Deep Springs, Dinuba, Ducor, Farmersville, Figarden, Fowler, Helena, Herndon, Huron, Independence, Ivanhoe, Kearney Park, Kettleman City, Lemoore, Lindsay, Mendota, Mineralking, Reedley, Oilfields, Olancha, Oleander, Orosi, Parlier, Pinedale, Pineridge, Posey, Raisin, Richgrove, Riverdale, San Joaquin, Shoshone, Strathmore, Sultana, Tecopa, Three Rivers, Tipton, Tollhouse, Tranquility, Traner, Waukena, Westhaven, Woodlake, Yettem.

***June 19:*** 2:07.* Aftershock of the preceding. IV at Big Pine and Bishop.

***June 19:*** 2:30. Felt at Big Pine and Bishop.

***June 19:*** 3:17.* Intensity V; center on the Elsinore fault. Located by Pasadena at 33°43′ north, 117°31′ west. Felt over a land area of about 5,000 square miles, as shown on map on page 31.

INTENSITY V:

*Elsinore.*—Felt by all. Shock was followed a few minutes later by another lighter shock.

*La Verne.*—Awakened all.

*Norco.*—Awakened all; frightened few.

*Ontario.*—Awakened all but heavy sleepers; frightened few.

*Pala.*—Awakened many; frightened no one. Terrible rumbling noise reechoed. Bed moved.

Intensity IV: Anaheim, Balboa, Claremont, Etiwanda, Huntington Beach, Los Angeles, Moreno, Pomona, Santa Ana.

Intensity III and under: Azusa, Brea, Cajon Pass, Cucamonga, Del Rey, Fullerton, Hemet, Laguna Beach, Oceanside, Perris, Riverside, San Bernardino, San Jacinto, Whittier.

Not felt: Big Creek, Huntington, Posey, Seven Oaks, Shaver Lake.

***June 19:*** 3:21.* Seal Beach, slight. Aftershock of the preceding quake.

***June 19:*** 5:00. Slight shock at Big Pine and Bishop.

***June 19:*** 5:21.* Epicenter about 37°15′ north, 118°22′ west, according to Pasadena. IV at Laws.

***June 21:*** 9:17 and 9:40. Mt. Lassen emitted a puff of steam followed by two earthquakes.

***June 22:*** 9:25.* Epicenter about 32°30′ north, 117°50′ west, according to Pasadena. Felt at Mission Hills and San Diego.

***June 27:*** 3:44.* Focus about 4 miles from the University of California campus, according to Berkeley. Felt at Berkeley, North Oakland, and Oakland.

***June 30:*** 7:25.* Epicenter about 2 miles northeast of Niles, according to Berkeley. IV at East Oakland and Niles.

***June 30:*** 15:28.* Epicenter probably a few miles southeast of Salinas, according to Berkeley. III at Hollister.

***July 3:*** 7:20. A short sharp earthquake felt throughout Washington Township and in Berkeley and Oakland.

***July 11:*** 16:04.* Epicenter about 30 miles from Ferndale, according to Berkeley. IV at Briceland, Forest Glen, Scotia, and Whitlow. III and under at Ferndale, Fortuna, Petrolia, and Upper Mattole.

***July:*** Various dates prior to July 13: Los Alamos. Loud reports with slight shocks in the evenings.

***July:*** During the 6 weeks prior to July 13: Weldon. Several quakes, two of them "severe" but without damage.

***July 13:*** 2:54.* A shock reaching intensity V in the Los Angeles region located by Pasadena at 34°10′ north, 117°52′ west, and felt over a land area of about 14,000 square miles; see map page 13. Recorded on accelerographs at Los Angeles. See page 62.



INTENSITY V:

*Azusa.*—Awakened many; frightened some.
*Burbank.*—Roaring sounds. Felt by many; frightened few.
*Corona.*—Felt by all; awakened many; frightened many.
*Downey.*—Desk lamp overturned.
*Duarte.*—Frightened all.
*Long Beach.*—Awakened many or all.
*Moreno.*—"Plaster cracked; walls fell; no damage."
*Palmdale.*—Felt by many; awakened many; frightened many.
*Pasadena.*—Awakened many; frightened few.
*San Dimas.*—Awakened all; frightened all.
*Tujunga.*—Frightened many; spilled water from outdoor containers.

Intensity IV: Alhambra, Balboa, Baldwin Park, Beverly Hills, Buena Park, Camp Baldy, Cajon, Claremont, Compton, Concepcion, Costa Mesa, Del Rosa, Elsinore, Gontana, Garden Grove, Glendale, Hollywood, Glendora and vicinity, Huntington Beach, Huntington Park, Hynes, La Crescenta, Mentone, Montebello, Newport Beach, North Hollywood, Olive View, Ontario, Perris, Pelan, Placentia, Pomona, Puente, Redondo Beach, Riverside, San Gabriel, Saugus, Santa Fe Springs, Seal Beach, Sierra Madre, Tustin, Upland, Van Nuys, Victorville, Whittier.

Intensity III and under: Acton, Anaheim, Banning, Beaumont, Castaic, El Segundo, El Toro, Fillmore, Fullerton, Glendale, Hemet, Inglewood, Lake Arrowhead, Llano, Los Alamitos, Los Angeles, Lucerne Valley, Mojave, Moneta, Norwalk, Olive, Orange, Oxnard, Palm Springs, Piru, Redland, Rialto, Rosamond, San Bernardino, San Fernando, San Jacinto, San Juan Capistrano, Santa Barbara, Santa Monica, Santa Paula, Seven Oaks, Temecula, Torrance, Venice, Weldon, Wilmington.

Not felt: Bakersfield, Camarillo, Cantil, Carpinteria, Helendale, Laguna, Los Almos, Maricopa, Maywood, Newhall, Ojai, Simi, Tehachapi, Twentynine Palms, Ventura, Westminister, Wheeler Springs.

***July 13:*** Two reports of weak shocks at Los Angeles, one at 3:57 and the other near 4:00. (If the time on these two reports is erroneous, they may apply to the shock of 2:54.)

***July 14:*** 2:55. San Dimas; plaster cracked, damage slight. (If the date of this report is erroneous, it may apply to the shock of July 13, 2:54.)

***July 14:*** 22:29.* Elsinore fault near Murrieta. Located by Pasadena at 33°32′ north, 117°09′ west. Felt at Elsinore.

***July 18:*** 17:22.* Epicenter very probably near Keddie, according to Berkeley. VI at Keddie and Paxton. V at Quincy and Taylorsville, where small objects were moved; slight damage at Taylorsville. Felt from Chilcoot to Storrie.

***July 20:*** 20:21. Huntington Beach; slight. Recorded on the seismograph of M. G. Murray at Huntington Beach.

***July 20:*** 20:22. Huntington Beach; slight. Recorded on the seismograph of M. G. Murray at Huntington Beach.

***July 20:*** 20:41.* Off Newport Beach. Felt near Huntington Beach. Located by Pasadena at approximately 33°36′ north, 118°00′ west.

***July 20:*** 20:42.* Off Newport Beach. Felt near Huntington Beach. Located by Pasadena at approximately 33°36′ north, 118°00′ west.

***July 20:*** 21:15. Huntington Beach, slight. Recorded on the seismograph of M. G. Murray at Huntington Beach.

***July 20:*** 21:52.* Off Newport Beach. Felt near Huntington Beach. Located by Pasadena at approximately 33°36′ north, 118°00′ west.

***July 21:*** 14:08.* Off Huntington Beach. Located by Pasadena at approximately 33°37′ north, 118°02′ west. Felt weakly at Huntington Beach, Santa Ana, and Tustin.

***July 21:*** 14:16.* Off Newport Beach. Located by Pasadena at 33°35′ north, 118°00′ west. Felt weakly at Huntington Beach.

***July 23:*** 11:11.* Southeast of Brawley. Located by Pasadena at 32°55′ north, 115°28′ west. IV at Brawley. III at El Centro.

***July 24:*** 3:00. Slight shock at Lancaster, Palmdale, and Antelope Valley in general.

***July 24:*** 20:16.* Parkfield, V. Small objects were moved slightly.

***July 26:*** 15:07.* Epicenter about 5 miles east of Paicines, according to Berkeley. Felt sharply at Mulberry. Not felt at Sandberg.

***July 27:*** 22:00.* Near San Simeon. Located by Pasadena at 35°42′ north, 121°07′ west. Felt weakly at San Simeon and King City.

***July 29:*** 4:—. Felt throughout the Eureka area. Stopped delicate clocks. No damage.

***August 6:*** 11:05.* Near Santa Barbara. Located by Pasadena at approximately 34°37′ north, 119°37′ west. III at Santa Barbara.

***August 7:*** 19:30.* Near Spadra. Located by Pasadena at 34°02′ north, 117°48′ west. Felt weakly at Ontario.

***August 9:*** 9:14.* Epicenter probably not far from Priest Valley, according to Berkeley. Felt in King City and Priest Valley.

***August 18:*** 19:22.* Approximately 18 kilometers north of Escondido. Felt there. Located by Pasadena at approximately 33°15′ north, 117°05′ west.

***September 2:*** 22:47.* San Jacinto fault near Riverside and San Bernardino. Epicenter 34°02′ north, 117°19′ west, according to Pasadena. Minor damage near epicenter. IV at Cedarpines Park, Mentone, Ontario, San Bernardino, San Dimas, Santa Ana River No. 1, Seven Oaks, and Venice. III and under at Hemet, La Verne, and Victorville. Not felt at Huntington Park.

***September 8:*** 6:40.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. IV or V at El Centro, where it was felt by all and frightened some. Operated the accelerograph. See page 64. Felt moderately throughout the county. IV at Imperial. Felt at Brawley with moderate intensity.

***September 8:*** 9:03*. San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. At El Centro the earthquake was felt by many and operated the accelerograph. At Imperial the observer estimated the intensity at VI on the Rossi-Forel scale. Felt at Brawley with moderate intensity.

***September 8:*** 10:51.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. At El Centro this shock was slightly sharper than the preceding two shocks. At Imperial observer estimates intensity at IV on the Rossi-Forel scale. "Sharp jolt" at Brawley.

***September 8:*** 14:09.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. Imperial, III.

***September 8:*** 14:37.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. Imperial, III.

***September 8:*** El Centro, other shocks than the above felt at various times during the day. Imperial, at least 5 shocks of intensity II scattered through the day in addition to those reported above.

***September 9:*** 4:37.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. Imperial, IV.

***September 9:*** 8:38.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. Imperial, III.

***September 10:*** 0:08.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. Imperial, IV or V.

***September 10:*** 15:55.* Localized earthquake of intensity V–VI in the Berkeley region. Focus about 4 miles from the University of California campus, northwest and down, probably on the Hayward fault, according to Berkeley. V at Berkeley and Cowell. IV at Sunnyvale. III and under at Alameda, Angel Island, Corte Madera, Hercules, Lafayette, Moraga, Mount Eden, Oakland, Port Costa, Rockaway Beach, Rodeo, San Francisco, Sunnyvale, Tiburon, and Woodacre. Felt, intensity not reported, at Saint Helena.

Not felt: Alviso, Antioch, Bay, Belmont, Belvedere, Bethany, Birds Landing, Bodega, Bolignas, Brentwood, Burlingame, Brisbane, Byron, Calistoga, Centerville, Clarksburg, Clay, Clements, Concord, Collinsville, Cordelia, Courtland, Cupertino, Daly City, Danville, Decoto, Diablo, Dixon, Elmira, El Granada, Elk Grove, Fairfax, Fairfield, Falon, Forest Knolls, Franklin, Fulton, Gaul, Half Moon Bay, Hayward, Holt, Hood, Ignacio, Isleton, Kenwood, La Honda, Larkspur, Lathrop, Lagunitas, Livermore, Locke, Lockeford, Lodi, Los Altos, Los Gatos, Manor, Manteca, Menlo Park, Milpitas, Montecello, Moss Beach, Mafa, Newark, Niles, Novato, Oakland, Oakville, Occidental, Olemo, Penngrove, Pinole, Petaluma, Pittsburg, Pleasanton, Pope Valley, Port Chicago, Redwood City, Ross, Rutherford, Salada Beach, San Bruno, San Carlos, San Gregorio, San Geronimo, San Jose, San Mateo, San Pablo, San Rafael, San Ramon, Sausalito, Santa Rosa, Sebastopol, Sonoma, South San Francisco, Stinson Beach, 5 miles southwest of Mountain View, Stockton, Suisun City, Sunnyvale, Thornton, Tomales, Tracy, Vacaville, Vallejo, Valley Ford, Victor, Vineburg, Warm Springs. Windsor, Woodbridge.

***September 11:*** 3:42.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. III at Imperial. Not felt at Yuma, Ariz.

***September 11:*** 6:08.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. III at Imperial. Not felt at Yuma, Ariz.

***September 11:*** 13:21.* San Andreas fault zone vicinity of Holtville. Located by Pasadena at approximately 32°54′ north, 115°13′ west. Imperial Valley, IV or V. El Centro, III. Yuma, Ariz., not felt.

***September 15:*** 12:51.* Off Bolsa Chica. Located by Pasadena at 33°42′ north, 118°04′ west. IV at Huntington Beach. III and under at Long Beach, Santa Ana, and Seal Beach.

***September 16:*** 4:28.* Epicenter 33°45′ north, 117°55′ west, according to Pasadena. V at Placentia, where all were awakened and few frightened. IV at Anaheim, Fullerton, El Modena, Santa Ana, and Yorba Linda. III and under at Huntington Beach, Orange, and Seal Beach. Felt, intensity not reported, at Brea.

***October 11:*** 6:06.* Epicenter about 32°54′ north, 115°13′ west, according to Pasadena. Campo, slight.

***October 11:*** 22:03.* Epicenter about 32°56′ north, 116°15′ west, according to Pasadena. Campo, felt by all; frightened no one; pendulum clocks did not stop. Mount Laguna, IV.

***October 14:*** 1:36.* Epicenter 34°11′ north, 117°20′ west, according to Pasadena. Hemet, felt. San Bernardino, slight.

***October 14:*** 7:50.* Epicenter 33°10′ north, 116°25′ west, according to Pasadena. Julian, IV.

***October 18:*** 1:24.* Parkfield, IV. Probably an aftershock of the earthquake of June 7, 1934, a few miles north of Parkfield, according to Berkeley.

***October 18:*** 2:47.* Sierra, Nev. Northwest of Kernville. Epicenter about 35°48′ north, 118°31′ west, according to Pasadena. Bakersfield, IV. Kernville, III or IV.

***October 18:*** Morning, later than preceding shock. Bakersfield, felt. Weaker than the preceding shock.

***October 22:*** 10:37.* Near Parkfield. Epicenter about 35°56′ north, 120°29′ west, according to Pasadena. Parkfield, duration three seconds; walls and frames creaked.

***October 24:*** 6:42. Twentynine Palms. "Felt."

***October 24:*** 6:48.* Mill Creek fault. Located by Pasadena at 34°06′ north, 116°53′ west. Maximum intensity, V. Felt over a land area of about 29,000 square miles in southern California, as shown on map, page 31. Recorded on accelerograph in Los Angeles. See page 66.

INTENSITY V:

*Beaumont.*—Landslides occurred on southwestern slopes of Mt. San Gorgonio.

*Cajon.*—Awakened all; frightened no one.

*East Highlands.*—Moved small objects. Plaster cracked slightly, and some fell. Main shock preceded and followed by slight tremors.

*Seven Oaks.*—Felt by all. Followed by tremors for 24 hours.

*Twentynine Palms.*—Small objects moved; slight damage. More severe twenty miles farther west.

*Yucaipa.*—Felt by all.

Intensity IV: Anaheim, Banning, Elsinore, Fullerton, Hemet, Indio, La Crescenta, Los Angeles, Lucerne Valley, Ludlow, Mecca, Palm Springs, Riverside, San Dimas, and Victorville.

Intensity III and under: Cardiff-by-the-Sea, Glendale, Huntington Beach, Huntington Park, Llano, Long Beach, Needles, Oceanside, Ontario, Pala, Rosamond, San Diego, San Marcos, Warner Springs, Yorba Linda.

Not felt at Venice.

***October 24:*** 6:51.* Aftershock of the preceding, according to Pasadena. IV at Beaumont, Hemet, Laguna Beach, Riverside, and San Diego. III and under at Cajon, East Highlands, and Long Beach.

***October 24:*** 6:52.* Another aftershock of the earthquake at 6:48, according to Pasadena. V at Mentone, where all felt the shock and many were frightened, and at San Diego. IV at Hemet, Laguna Beach, and Winchester. III at Beaumont, Cajon, Muroc, Santa Ana River, and Twentynine Palms.

***October 24:*** 6:57.* Aftershock of the earthquake at 6:48, according to Pasadena. Beaumont, IV; Mentone, III.

***October 24:*** 7:06.* Aftershock of the earthquake at 6:48, according to Pasadena. Banning, IV.

***October 24:*** 7:27.* Aftershock of the earthquake at 6:48, according to Pasadena. Felt weakly at East Highlands and Hemet.

***October 24:*** 8:16.* Aftershock of the earthquake at 6:48, according to Pasadena. Felt weakly at East Highlands.

***October 24:*** 8:35.* Aftershock of the earthquake at 6:48, according to Pasadena. Felt weakly at East Highlands.

***October 25:*** 11:43.* San Benito, IV. Epicenter about 13 miles west of Soledad, according to Berkeley.

***October 25:*** 12:44.* Weak shock at Gilroy and Morgan Hill. Foreshock of the next, according to Berkeley.

***October 25:*** 12:56.* San Andreas fault near Watsonville. Epicenter about 4 miles south of Gilroy, according to Berkeley. Felt in an elongated area along the fault as shown on map on page 32. Maximum intensity IV ?. Felt over a land area of about 3,300 square miles.

Intensity IV: Hayward, Hollister, Watsonville.

Intensity III and under: Aptos, Castroville, Colma, Coyote, Daly City, Gilroy, Los Gatos, Madrone, Morgan Hill, Mountain View, Five miles southwest of Mountain View, Redwood City, San Francisco, San Jose, San Juan Bautista, Santa Clara, Santa Cruz, Saratoga, Soquel.

***October 26:*** 2:46.* Hollister, slight. Aftershock of the preceding according to Berkeley.

***October 27:*** 18:50. Eureka, IV. Fields Landing III.

***October 27:*** 19:20.* Near Long Beach. Epicenter about 33°47′ north, 118°08′ west, according to Pasadena. Long Beach, slight.

***October 29:*** 2:17.* Off coast of Lower California. Epicenter about 32°10′ north, 117°40′ west, according to Pasadena. IV at Campo and San Diego. III and under at Barrett Dam, Cardiff-by-the-Sea, and Newport Beach.

***November 3:*** 19:55.* Agua Caliente fault, vicinity of Aguanga. Felt over a land area of about 8,600 square miles as shown on map on page 32. Epicenter 33°30′ north, 116°55′ west, according to Pasadena. Laguna Beach, V. Quake was very slight. Water main broken; no other damage. IV at Hemet, Seal Beach, and Warner Springs. III and under at Anaheim, Costa Mesa, Fallbrook, Hodges Dam, Huntington Beach, Los Angeles, eight miles east of Mecca, Newport Beach, San Clement, San Diego, and San Juan Capistrano. Not felt at Ducor.

***November 3:*** 23:14.* Aftershock of the earthquake at 19:55, according to Pasadena. Hemet, slight.

***November 7:*** About 3:—. Five miles southwest of Mountain View, IV.

***November 8:*** 2:02.* Aftershock of the earthquake of November 3, according to Pasadena. Hemet, IV.

***November 23:*** 16:12.* Near Santa Ana. Epicenter 33°40′ north, 117°50′ west, according to Pasadena. IV at Santa Ana and Tustin. III and under at Anaheim, Huntington Beach, and Laguna Beach.

***November 27:*** 1:28.* Epicenter 33°39′ north, 117°04′ west, according to Pasadena. San Jacinto Valley, "pronounced quake." No damage.

***November 27:*** 6:13.* Epicenter 33°39′ north, 117°04′ west, according to Pasadena. San Jacinto Valley, "pronounced quake." No damage.

***December 15:*** 11:51.* Vicinity of Chino. Epicenter about 34°06′ north, 117°41′ west, according to Pasadena. Upland, slight.

***December 19:*** 23:45.* Imperial Valley. Epicenter about 33°10′ north, 115°30′ west, according to Pasadena. Recorded on the accelerograph at El Centro. At El Centro a few rushed out. IV at Imperial. III and under at Mission Hills, National City, and San Diego. See page 80.

***December 19:*** 23:48. El Centro. A few people rushed out; no damage in El Centro or surrounding territory. At San Diego small objects moved.

***December 25:*** 9:15.* Off Newport Beach; epicenter 33°36′ north, 118°01′ west, according to Pasadena.

INTENSITY V:

*Avalon, Catalina Island.*—Frightened many. Some ran outdoors.

*Huntington Beach.*—Small objects moved. Water spilled south.

Intensity IV: Fullerton, Long Beach, Newport Beach, Placentia, Santa Ana, Seal Beach, Tustin.

Intensity III and under: Huntington Park, Laguna Beach, Los Angeles, Wilmington.

***December 27:*** Susanville. Two slight shocks, the first in the middle of the night and the second about 7 a. m.

***December 29:*** Mullett Island, Salton Sea. Observer thrown from bed. Steam well which had been spouting for several years has ceased to spout since the earthquake.

### WASHINGTON AND OREGON

120th meridian or Pacific standard time]

*All places mentioned are in Washington unless otherwise indicated*

***February 6:*** 5:20. Grapeview, IV.
***February 16:*** 22:07. Darrington, III. Windows rattled.
***July 9:*** 14:45. Chelan Falls, IV or V; felt by all and frightened many. IV at Waterville; III at Lakeside.
***July 24:*** 7:14. Shelton. Felt by several; frightened no one.
***October 11:*** 17:03. Entiat, IV or V.
***October 24:*** 3:57. Ellensburg, weak.
***October 31:*** Between 3 and 4 a. m. Wenatchee, slight.
***November 7:*** 17:57. Entiat. Just a rumble.



### ALASKA

[150th meridian time]

***January 1:*** 19:43. Susitna. Felt, no details.
***January 4:*** 14:00 and 20:00. Haines.
***January 7:*** 2:00. Seward.
***January 12:*** 20:25. Haines.
***January 22:*** 21:24.* Dutch Harbor, fairly strong. No damage. Epicenter 52.°4 N., 170.°0 W.
***January 24:*** 8:32. Anchorage. Slight.
***January 28:*** 18:38. Anchorage. Slight.
***February 23:*** 23:35. Dutch Harbor. Slight.
***March 30:*** 14:40. Homer. Felt by few.
***March 30:*** 23:45. Homer. Felt by few. Rattled windows; hanging objects swung; no damage.
***April 8:*** 21:16. Susitna.
***April 9:*** 21:25. Anchorage. Two distinct earthquakes believed to be result of volcano eruptions on Augustin Island, Cook Inlet. Noticed in many parts of the city; no damage.
***April 10:*** 2:30. Seward.
***April 10:*** 14:24. Seward. Slight.
***April 18:*** 22:12. Afognak. Distinct shock.
***April 21:*** 5:30. Seward.
***April 21:*** 5:45. Seward. Shaken by quite a heavy shock; no damage.
***May 18:*** 21:30. Annex Creek. Two slight earth tremors between 9:30 and 10:00 p. m.
***May 28:*** 22:35. Susitna. Light earthquake.
***June 11:*** 21:27. Afognak. Light earthquake.
***June 19:*** 21:30. Kennecott. Gentle east-west motion.
***July 5:*** 17:32.* Haines, felt by several. Felt also in region of upper Lynn Canal.
***July 5:*** 18:20. Haines. Felt by several.
***July 14:*** Anchorage. Augustine Volcano reported to have blown off a section of the top cone; steam and smoke hurled high in air; lava running down sides.
***August 3:*** 23:32. Anchorage. Slight.
***August 3:*** 23:42. Kodiak. Felt by several.
***August 4:*** 24:00. Matanuska.
***August 14:*** 18:43. Afognak. Heavy earth shock accompanied by roar; felt by all.
***August 14:*** 18:52. Kodiak. Two abrupt shocks, very much like an explosion, felt by entire population. Children sitting on ground felt it move; 2 cupboard doors swung open.
***August 17:*** 15:01½. Anchorage, IV.
***August 23:*** 12:05. Susitna. Strong shock.
***August 23:*** 12:08. Seward. "Rather severe" quake lasting 1 minute.
***August 23:*** 12:09½. Anchorage. Small objects moved and overturned; knick-knacks fell. Awakened many; frightened few; no damage.
***August 23:*** 12:11. Valdez. Moderate earthquake felt by many. Pendulum clocks stopped; no damage.
***August 28:*** Seward. Second earthquake in two days. Felt also at Anchorage.
***September 3:*** 15:25. Nenana and Flat. Slight shock.
***September 22:*** 7:30. Ruby.
***September 23:*** 21:09. Susitna.
***October 13:*** 2:13. Kodiak. Two shocks of intensity III or IV.
***October 26:*** 9:15. Valdez. Light tremor.

***November 6:*** 14:35. Cordova. Felt by observer. Duration about one minute.

***November 6:*** During night. Two shocks felt by observer at Valdez.

***November 17:*** 0:00. Matanuska. Slight.

***December 18:*** 16:15. Susitna. Light tremble.

***December 24:*** 23:30. Talkeetna. Light shock.

***December 24:*** 20:34. Seward. Light shock.

***December 26:*** Seward. Two sharp quakes. Buildings rocked; windows rattled; no damage.



## HAWAIIAN ISLANDS

[157½th meridian (west) time]

NOTE.—In the case of these islands with their many earthquakes of volcanic origin, only the more severe ones are listed. Reports of the Hawaiian Volcano Observatory, Hawaii, give all details. During 1935 the observatory was transferred from the United States Geological Survey to the National Park Service.

***January 2:*** 6:47.* Moderate shock centering under the Uwekahuma rim of Kilauea crater, at 19°25′.5 north, 155°17′ west, at a depth of 2 miles, according to the Hawaiian Volcano Observatory. Felt generally over the island of Hawaii. Smashed dishes and pictures, and started a landslip in Halemaumau.

***June 25:*** 0:45.* Moderate earthquake located by the Hawaiian Volcano Observatory at 19°26.5′ north, 155°16.5′ west, under the north rim of Kilauea Crater, at a depth of 2 or 3 miles. Awakened people generally on the south half of the island.

***June 28:*** 9:00.* Moderate to strong; focus at 19°36′ north, 155°11′ west, at a depth of 5 miles, on the Mauna Loa northeast rift, according to the Hawaiian Volcano Observatory. The quake did some damage in Hilo and was felt generally on Hawaii.

***September 30:*** 22:36.* Moderate shock felt generally on the island of Hawaii. Location 30 miles deep under the southwest rift of Mauna Loa at 19°22′ north, 155°39.5′ west, according to the Hawaiian Volcano Observatory.

***September 30:*** 23:58.* Moderate to strong earthquake felt over the entire island of Hawaii. Location 17.4 miles deep under the northeast slope of Mauna Loa at 19°38.7′ north, 155°26.3′ west, according to the Hawaiian Volcano Observatory.

***October 1:*** 0:02.* Moderate shock generally felt as a continuation of the preceding one. Focus probably under the Mauna Loa rift system, according to the Hawaiian Volcano Observatory.

***October 1:*** 10:22.* Moderate shock felt in Hilo and in the Kilauea district. Located by the Hawaiian Volcano Observatory under the northeast rift zone of Mauna Loa fifteen miles southwest of Hilo, at 19°38.3′ north, 155°19.2′ west.

***November 21:*** 1:11.* Moderate earthquake generally felt on the island of Hawaii and at some places on other islands. Broke one window at the Kapapala ranch. Located by the Hawaiian Volcano Observatory in the northeast rift of Mauna Loa at 19°31′ north, 155°31.5′ west; depth probably less than 5 miles. Caused by opening of the northeast rift, which resulted in the Mauna Loa eruption 17 hours later. Further shocks of slight intensity occurred with the eruption.

High seas caused some damage on the beach at about the time of the earthquake, but the tide gage record at Honolulu showed no evidence of a seismic sea wave.

## PHILIPPINE ISLANDS

[120th meridian (east) time]

NOTE.—The semiannual report from Manila for the first but not for the second half of the year is avail able as this report goes to press. See page 1.

***January 8:*** 20:52.* Northwest Luzon. Some damage in Laoag; felt in Vigan.

***Januay 25:*** 10:02. Daet. Camarines Norte, intensity V Rossi-Forel.

***February 1:*** 5:10. Romblon, Romblon. "Strong earthquake with sli ght repetition about 5 minutes later."

***February 8:*** 1:30.* Southern and southeastern Luzon, centering at 12°40′ north, 121°50′ east, at a depth of about 60 kilometers, according to Manila. Very strong in the neighborhood of Romblon. Felt over an area of about 250 kilometers radius. Intensity III Rossi-Forel at Manila.

***April 3:*** 19:11.* Tacloban, intensity VII–VIII Rossi-Forel. Center in the Gulf of Leyte, according to Manila. Felt throughout southern Samar and eastern Leyte. An aftershock was felt in Tacloban and Borongan.

***April 24:*** 8:34.* Western Luzon. Felt from Baguio to Manila. Epicenter probably in the China Sea, according to Manila.

***May 19:*** 6:06. Cagayan, Oriental Misamis, V Rossi-Forel.

***May 24:*** 13:37.* Eastern Visayas and Mindanao, very strong. Epicenter 11°15′ north, 126°05′ east, according to Manila. Intensity VI–VII Rossi-Forel

in Guiuan, Borongan, and Tacloban. General panic and some damage in these towns. Felt over an area of 450 kilometers radius. Many aftershocks.

***June 4:*** 16:36.* Tacloban, Leyte; intensity V Rossi-Forel.

***August 1:*** 22:07.* Philippine Deep, about 10°30′ north, 126°25′ east, according to Manila. Felt strongly in Samar.

***September 1:*** 1:17.* Guiuan and Tacloban, intensity V Rossi-Forel.

***October 15:*** 3:47.* Epicenter in Lingayen Gulf, according to Manila. Intensity VI Rossi-Forel at San Fernando, La Union. Felt over western Luzon from Vigan, Ilocos Sur, to Manila. Aftershock 4 minutes later.



## PUERTO RICO

[60th meridian time]

***January 10–31:*** Blasting in San Juan Harbor. Most blasts small; one, at 14:45 on January 10, consisted of 700 pounds of dynamite.

***August 29:*** 7:24.* San Juan, slight.

***September 18:*** 21:37.* San Juan.

## PANAMA CANAL ZONE

[75th meridian time]

***April 27:*** 21:36. Felt weakly at Balboa.

***June 16:*** 14:29. Felt weakly at Balboa.

***July 25:*** 23:43.* Balboa Heights, II to III. Destructive in Chiriqui Province, Republic of Panama. Recorded on the seismograph at Balboa Heights. Epicenter believed to be same as that of the destructive shocks of July 17 and 21, 1934, centering at sea off Panama at 8.0° north, 82.5° west.

***November 29:*** 22:40.* Felt throughout the Canal Zone and the Republic of Panama. V at Balboa, where hundreds ran into the streets and a few buildings were cracked. No serious damage to the Panama Canal was reported.

***December 11:*** 23:36.* Felt by a few people in the Canal Zone.

# MISCELLANEOUS ACTIVITIES

## GEODETIC WORK

During the year 1935 the following leveling was run for the purpose of detection of earth movements or in preparation for future earthquake investigation:

(1) Settlement investigation, vicinity of San Jose, Calif., spring 1935.
(2) Earthquake investigation, cross lines in Southern California.

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

The cross lines in southern California consisted of eight lines crossing known faults, and averaging 10 miles in length, 5 miles on each side of the fault. The benchmarks were placed 100 feet apart in the first mile, with an increase of 100 feet in the difference between marks for each mile of progress away from the fault.

The results of the leveling in the vicinity of San Jose, and in southern California, have not been fitted to the first-order level net, and, therefore elevations are not available for publication.

There was no triangulation in 1935 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.

# THE HELENA, MONT., EARTHQUAKES OF OCTOBER AND NOVEMBER 1935

The earthquakes at Helena, Mont., in 1935, must be ranked among the most important of the United States because of their destructiveness. History records many shocks just as severe and as widespread as the strongest at Helena, nevertheless, the Helena shocks were exceeded in destructiveness only by the Charleston earthquake of 1886, the California earthquake of 1906, and the Santa Barbara and Long Beach earthquakes of 1925 and 1933, respectively. This must be attributed to the nearness of Helena to the epicentral region. In 1869 and 1872 shocks of nearly similar intensity shook Helena; and the city was also affected by the more severe shock of 1925 which centered in the Manhattan-Lombard region 60 miles southeast; but this completes the list of destructive Montana earthquakes. These disturbances together with occasional shocks of lighter intensity mark western Montana as a seismically active region.

*Times of major shocks.*—The first sign of impending danger came at 7:47 p. m. on October 3 in the form of a hard vertical jolt. Shocks then continued intermittently until after midnight of the 11th. At 0:50:39 on October 12, M. S. T., the first destructive shock occurred. There was then a more or less active lull until October 18, when, at 21:48:02, the strongest shock of the entire series drove many who had just retired into the streets. After a steady stream of aftershocks a major disturbance of almost equal intensity occurred on October 31 at 11:37:47, just before noon. There was a cessation of major activity until November 28 when two sharp disturbances, at 7:41:48 and 7:41:58, again jolted residents. The four shocks of October 12, 18, 31, and November 28 were recorded clearly on the seismograph at Bozeman (Montana State College) making it possible to calculate the times of origin quite accurately. After November 28 there were no strong shocks until February 13 when Helena again suffered minor damage.

The times of occurrence of all shocks felt in Helena were recorded by W. E. Maughan in charge of the local office of the United States Weather Bureau at Helena. His list of shocks is described on page 56.

*Intensities and isoseismal maps.*—The following intensities have been assigned to the four strongest shocks of the series. The areas affected by the shocks of October 12 and November 28 are indefinite.

| Date | Intensity | Area affected | Date | Intensity | Area affected |
|---|---|---|---|---|---|
| | | *Square miles* | | | *Square miles* |
| Oct. 12 | VI to VII | 70,000 | Oct. 31 | VIII | 140,000 |
| Oct. 18 | VIII | 230,000 | Nov. 28 | VI to VII | 90,000 |

W. E. Maughan lists as "strong" shocks, or "greater than strong" 56 shocks out of 709 observed in October; 12 out of 370 in November, and none out of 266 in December. A total of 1,347 shocks are listed up to the end of 1935.

More than 800 questionnaires were distributed in the region affected by the major shocks of October 18 and 31. Through the courtesy of the Dominion Observatory, Ottawa, Canada, the affected area north of the border was canvassed and the data made available for publication in this report. In the cases of the destructive foreshock of October 12 and the aftershock of November 28 coverage of the affected areas was not so complete. The maps on pages 20 and 26 which were prepared in the Washington office of the Coast and Geodetic Survey show that the area affected by the shock of October 18 was slightly greater than that of October 31.

The differences in the anomalies shown on the two maps are quite obvious. They may be due in part to matters of judgment in drawing the isoseismals. They take on a more significant aspect, however, when it is recalled that the amplitude of the first impulse on the seismograph at Bozeman on October 31 is four times greater than on October 18, although the remainder of the records are quite similar with respect to average amplitude and duration. This seems to indicate that the movements were quite dissimilar especially with respect to direction, and this may account for the differences in the anomalies.

The maps are especially interesting in that coverage is fairly complete, though not ideal, and the shocks are known to be definitely of shallow focus type. A. Blake of the Bureau's seismological staff used the maps to investigate methods of determining focal depth, especially by Gassmann's formula (see Jahresberich des Schweizerischen Erdbebendiensts, 1925) and a modification of it (see Transactions of the American Geophysical Union, 1937, pt. 1, p. 120). The calculated depths ranged from 7 to 30 kilometers and were consequently inconclusive. It appears, however, that further investigation of the criteria used in constructing isoseismal maps may eventually lead to satisfactory results. As stated on page 45 the instrumental data combined with geological evidences point to a focal depth of 5 kilometers or less.

A summary of the intensities assigned to the towns reporting the shocks, with the outstanding features enumerated for those in the higher brackets, will be found elsewhere in this publication. Unabridged information obtained by means of the canvasses will be found in the mimeographed "Abstracts of Earthquake Reports" available either from the Washington office of the Survey or from its Field Station in San Francisco.

## INSTRUMENTAL RESULTS—EPICENTERS AND FOCAL DEPTHS

Because of the relative weakness of the shocks the only instrumental data worth considering are those obtained at the temporary strong-motion station in the Federal Building at Helena, and at the teleseismic station of the Montana State College at Bozeman. The accelerograph was rushed from California to Helena by a Coast and Geodetic Survey party as soon as the destructive nature of the shocks became known. At only a few of the more distant stations were the preliminary tremors definite enough to be clearly defined. Several lines of investigation can be followed using the data obtained at Helena and Bozeman, (1) a focal distance can be ascertained from the S–P interval on the strong-motion records at Helena, (2) azimuths can be obtained from a number of records at the same station, and (3) distance and azimuth can both be determined with limited precision from several of the teleseismic records obtained at Bozeman.

*The Helena accelerograph records.*—From a study of these records only very general conclusions can be drawn with regard to the exact focal points of the major shocks. This is not because of malperformance of the instruments but largely because of lack of a minimum number of seismic stations necessary for satisfactory instrumental control of the region. A factor which is also largely responsible for failure to obtain more precise results is the lack of information on the velocity of seismic waves in the formations around Helena. They could be fairly well approximated if the structure of the sedimentary layers were known, but this is subject to some conjecture.

It appears from H. W. Scott's description of sedimentary rocks in the epicentral region that the depth of the underlying granite might

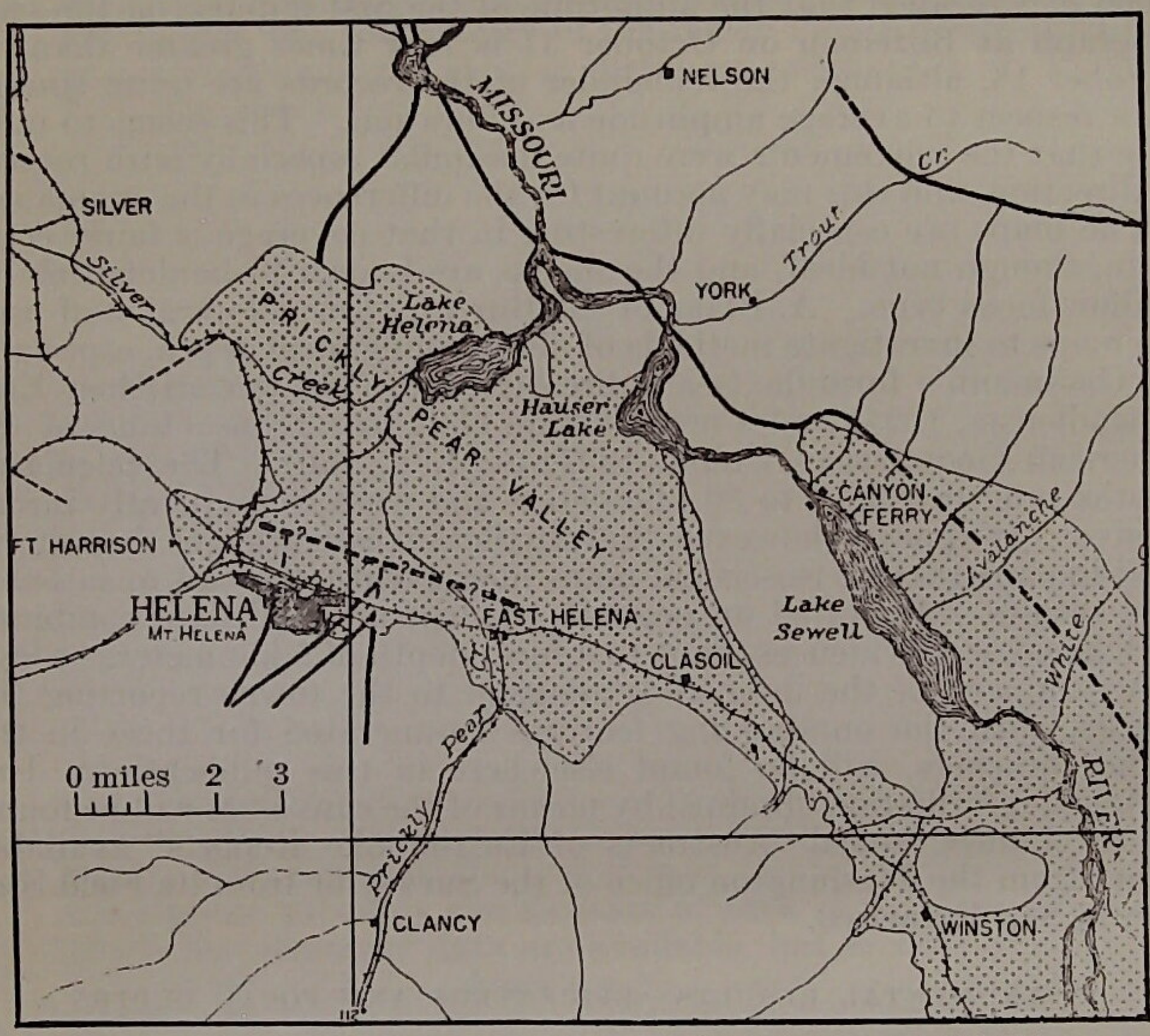



FIGURE 9.—Faults in the region of Helena, Mont., from H. W. Scott's report "The Montana Earthquake of 1935".

be of the order of 15,000 or 20,000 feet (4.5 or 6 kilometers) and that the greater part of the surface layers may be designated as Paleozoic sediments. This would indicate a rather high velocity for seismic waves, perhaps 4.0 or 4.5 kilometers per second as against 5.5 kilometers per second in the underlying granite. Overlying the outer Paleozoic sediments one might picture, for seismological purposes, a few thousand feet, perhaps a kilometer, of slower speed material, largely tertiary, in which the velocity of compressional waves may average about 2.5 kilometers per second. Although this is a rather crude picture, it is sufficient to indicate with the aid of the strong-motion data that the disturbances probably originated in the sedimentary rocks or possibly in the underlying granite very close to the top. With the

above figures the significance of the instrumental data may be discussed more in detail realizing that while no precise results are to be expected the conclusions can nevertheless be accepted as having a rational basis.

A number of records of the aftershocks under discussion will be found in figure 25 page 70. The most important information obtained from such records is the duration of the first preliminary tremor, S–P, which is a measure of the focal distance. This interval can be measured on the records of about 10 aftershocks in which no record was lost while waiting for the starting apparatus to function. In each case the recording apparatus was in operation at the outset of the first wave. The time intervals vary from 0.8 to 1.3 seconds. If the paths were all granite the distances from station to foci would vary from 6 to 10 kilometers, but the geology of the region indicates lower wave speeds and correspondingly shorter distances—perhaps 4 to 6 kilometers. This places the foci within reach of the granite mantle beneath the sediments, but if this were true, much steeper angles of emergence would be expected at the station than were actually recorded. In the four instances in which it was possible to measure emergence angles they ranged from 45° to 65°. The seismic rays must therefore have been considerably more shallow in the underlying high-speed formations following the laws of refraction as in optics. Below the tertiary formation the rays evidently subtended angles with the horizontal anywhere from 0 to 45° but not likely more than that. One must conclude, therefore, that the epicentral distances from the Federal Building may have varied from 3 to 6 kilometers, and focal depths from 2 to 5 kilometers for the few aftershocks which yielded the essential instrumental data. This would indicate that most of the slipping originated in the deeper sedimentary rocks.

The azimuths from the Federal Building ranged from N. 20° W. to N. 70° E. There is little doubt from the records that the smaller aftershocks were rather widely distributed. These bearings and the previously estimated epicentral distances all point to displacements along the buried fault about 4 kilometers north and northeast of Helena which is described in detail by H. W. Scott in his report entitled "The Montana Earthquakes of 1935." It may seem desirable to compute precisely the location of each of the four aftershocks on which the necessary data are available, but in view of the uncertainties already stated, a closer scrutiny would only tend to mislead the reader with respect to the accuracy obtainable. A more detailed study would be justified only in case the geology of the region were better known or in case more instrumental data were available.

All of the aftershocks covered in the previous discussion occurred between October 27 and 31, inclusive, except that of November 28. The latter record was different from the earlier ones in indicating the most shallow angle of emergence of all, about 45°, with an epicentral distance one of the largest in the group.

The average bearing of 10 aftershocks as judged by the relative amplitudes of the preliminary tremors on the north-south and east-west components is close to N. 55° E. This general bearing is also indicated by three of the four records on which the first movements could be measured. In three cases out of four the first movements were rarefactions; that is, the ground moved toward the epicenters.

151736—37——4

In view of the apparently wide spread of the aftershocks and the lack of precise information concerning the main shocks of the series an epicenter at 46°37′ N. 111°58′ W., is adopted as representing, as near as we know it, the central point of all activity. This is practically identical with the point of intersection of the two buried faults north and east of Helena as indicated by H. W. Scott. The wide spread of recorded aftershocks indicates, however, that any shock of the series may have easily originated several kilometers from this point and probably along the fault crossing the southern end of Prickly Pear Valley.



*The Bozeman record.*—Epicentral distances from Bozeman may be estimated by measuring the duration of the first preliminary tremor, S–P, and assuming that the seismic rays for the preliminary waves traverse only the granitic layer. Standard seismological practice assumes the velocity of compressional waves in granite to be 5.5 kilometers per second. The transverse wave velocity is about 3.2 kilometers per second. An error of 1 second in the S–P interval, therefore, corresponds to an error of 7.6 kilometers in focal distance. For various reasons this may be considered a probable error. The S–P intervals for the shocks of October 12, 18, and 31 averaged close to 17.0 seconds, indicating a distance of 130 kilometers which checks well

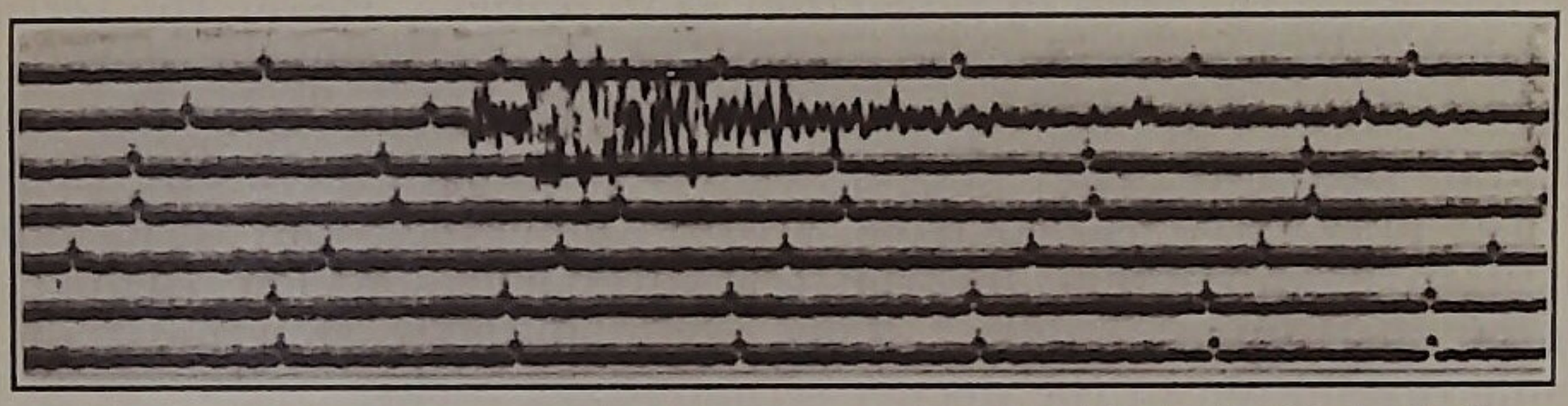


FIGURE 10.—Seismograph record of the Helena earthquake of November 28, obtained at the Montana State College, Bozeman.

with the adopted epicenter northeast of Helena. The interval for the November 29 shock is 2 seconds less, indicating an epicentral distance 15 kilometers shorter. This cannot be reconciled with the strong-motion data at Helena and should apparently be charged to questionable instrumental performance. The accelerograph data in this instance must be given the preference because of more precise time control. One millimeter corresponds to 4.0 seconds on the teleseismic record at Bozeman, but only 0.1 second on the Helena accelerograph.

The azimuth of epicenter is indicated quite well by the first impulsive movements recorded at Bozeman on October 12, 18, 31, and November 29. The computed azimuths are 30°, 35°, 33°, and 30°, west of north, respectively. The adopted epicenter bears 35° west of north. The 30° values are based on relatively small displacements of the light spot. The smallest light spot displacement was 1.2 millimeters on November 29 on the E–W component; the largest 30.8 millimeters on October 31 on the N–S component. It is noteworthy that the first horizontal movement at Bozeman on October 31 was nearly four times greater than on October 18 despite the fact that the most destructive shock was that of the 18th. The first movements on all of the records just discussed were rarefactions. It will be recalled that three out of the four first motions measured at Helena were also rarefactions.

Figure 10 is a reproduction of the record obtained on the east-west component of the McComb-Romberg seismograph at Bozeman on November 29. Despite the fact that the Helena accelerograph record shows that this is really the record of two separate shocks less than 10 seconds apart, it illustrates quite well the outstanding features of all the Bozeman records of the Helena shocks, especially the preliminary waves. Because of the excessive speed of the light spots, large portions of the records of the stronger shocks of October 18 and 31 are almost illegible and difficult to reproduce. The amplitudes in those records are of course much greater than shown in this illustration.



## CASUALTIES

The following quotations are from H. W. Scott's report entitled, "The Montana Earthquakes of 1935":

> The loss of life during the entire earthquake period was remarkably low. Only four people lost their lives, two on October 18 and two on October 31. Six additional deaths were attributed to nervous shock as a result of the earthquakes; however, from reliable sources it is learned that not more than two of the six can be attributed directly to the earthquakes. The deaths on October 18 were due to falling bricks and those on the 31st to the collapse of a large smokestack at the Kessler Brewery. The lack of greater casulaties is unquestionably due to the fact that the first severe shock occurred at night when schools were closed and few people were standing on the streets; and that at the time of the second severe quake the schools had been closed by farsighted authorities and that Helena residents were more careful.
>
> The exact number of injured cannot be definitely ascertained but it is estimated that not more than 50 persons were treated for major and minor cuts and bruises.

## DAMAGE

The damage for the entire series of shocks evidently did not exceed $4,000,000 and was restricted mostly to Helena, its environs, and nearby towns. A broad perspective of structural damage from the engineering standpoint is given briefly in the report of the city engineer as summarized by F. P. Ulrich in his paper entitled "Helena Earthquakes", Bulletin of the Seismological Society of America, volume 26, no. 4, page 329:

> Because the two destructive earthquakes occurred so close together it was impossible to estimate accurately the damage caused by each, and hence any statement concerning damage would have to include the damage caused by the swarm of shocks. The personnel of the city engineer's office in Helena has made a survey and finds that more than half the buildings in Helena were damaged from 2.5 to 100 percent and that the total damage would be between $3,000,000 and $4,000,000. Of the damaged buildings, 62 percent were in the class of those sustaining minor damage, such as fallen chimneys and small cracks; 24 percent were in the class having fallen walls and structural damage up to 50 percent; and 14 percent were in the class in which the damage was from 50 percent to total destruction.

A large scale map prepared by the city engineer showing the distribution of damaged buildings in Helena accompanies the article.

Quoting from one of F. P. Ulrich's unpublished reports the influence of geological formation on damage is readily apparent:

> The major shock occurred at 9:48 p. m. on October 18. This shock did considerable damage—especially to old masonry buildings. Damage was to a great extent confined to buildings on alluvium. Buildings constructed on firm foundations suffered very little damage in most cases. The southern business section of the town was hit quite severely. This section was in general built in the Last Chance Gulch on ground that had been mined by dredging operations. Most of the damaged buildings were very old, and an engineer remarked that

they were about ready to come down anyway. Heavy damage under these conditions was to be expected. In addition to the southern business section of the town, the northeast section was also hit very hard. This section was also built on alluvial ground that had been worked over by mining, but in general the buildings were more modern and better constructed, although there were some old brick buildings in this section. In the eastern part of the town on firm foundation, the St. Helena Cathedral suffered only slight damage. The main structure, about 50 feet high, was damaged very little, but there was some damage to the towers above the main structure. The old high school, a three and one-half-story, rock building apparently suffered very little damage on the outside, but it was reported that considerable damage was done inside. The State Capitol, a fire resistant, three-story building with a 5-story dome, suffered very little damage. The Federal Building, a well constructed, four-story, reinforced-concrete building with brick and stone facing and steel supports for the first floor and roof, suffered no exterior damage and the interior damage was confined to some cracked plaster. The Montana Club, a six-story building well constructed, suffered no damage. These latter two buildings were in the west central part of the town on good foundations.



Commenting on the more general aspects of the damage in Helena, H. W. Scott writes:

In Helena, a city of approximately 12,000, the earthquake of October 18 caused total property damage estimated to be $3,500,000. The overthrow of chimneys and cracking of plaster was general throughout the city. In some sections practically all chimneys were destroyed. Gables were generally damaged regardless of the structural material used or the location of the building. Notable examples of gable failures are the west end of Carroll College and warehouses in the neighborhood of the Northern Pacific depot. Brick-veneer walls were severely affected. It seems well to point out the fact that the brick-veneer walls cannot stand as strong a shock as some unbraced chimneys. Numerous buildings were observed where the brick sidings had fallen, but the chimneys remained in place. In general, frame buildings covered with wood siding and buildings having a framework of reinforced concrete or steel suffered little damage. The greatest damage to any single structure was that suffered by the new Helena High School which was completed in August 1935 at a cost of approximately $500,000. C. D. Wailes, Jr., states that "Unquestionably, failure of this building is attributable to lack of consideration of earthquake forces in the design. Heavy loose walls, long-span beams resting upon small-banded columns, designed for direct vertical loads only, and a very irregular and unsymmetrical plan, are the reasons back of failure."

Considerable illustrative material is available to the reader who wishes to study the details of damage to individual structures. A 45-page paper entitled, "Earthquake Resisting Structures", by E. R. Dye, of the civil engineering department of the Montana State College at Bozeman, covers the structural lessons learned and discusses earthquake-resistant design. A 129-page publication entitled "Montana Earthquakes", by C. R. Anderson and M. P. Martinson, of the Helena public schools, covers practically all aspects of the earthquakes in some detail and includes many illustrations. "The Montana Earthquakes of October 1935: Structural Lessons", by H. M. Engle, is a 10-page illustrated article in the Bulletin of the Seismological Society of America, volume 26, no. 2, April 1936, page 1.

A large number of pictures taken by F. P. Ulrich, of the Coast and Geodetic Survey, are available for inspection at the office of the Seismological Survey of the Bureau, 75 Appraisers Building, San Francisco, Calif., and at the Washington office of the Bureau.

### MISCELLANEOUS

*Monuments and chimneys.*—The following quotation is from F. P. Ulrich's report in the Bulletin of the Seismological Society of America:

At Forestvale Cemetery, about 4 miles north of Helena, the damage was greater than at any other cemetery. Many slab monuments were twisted, and

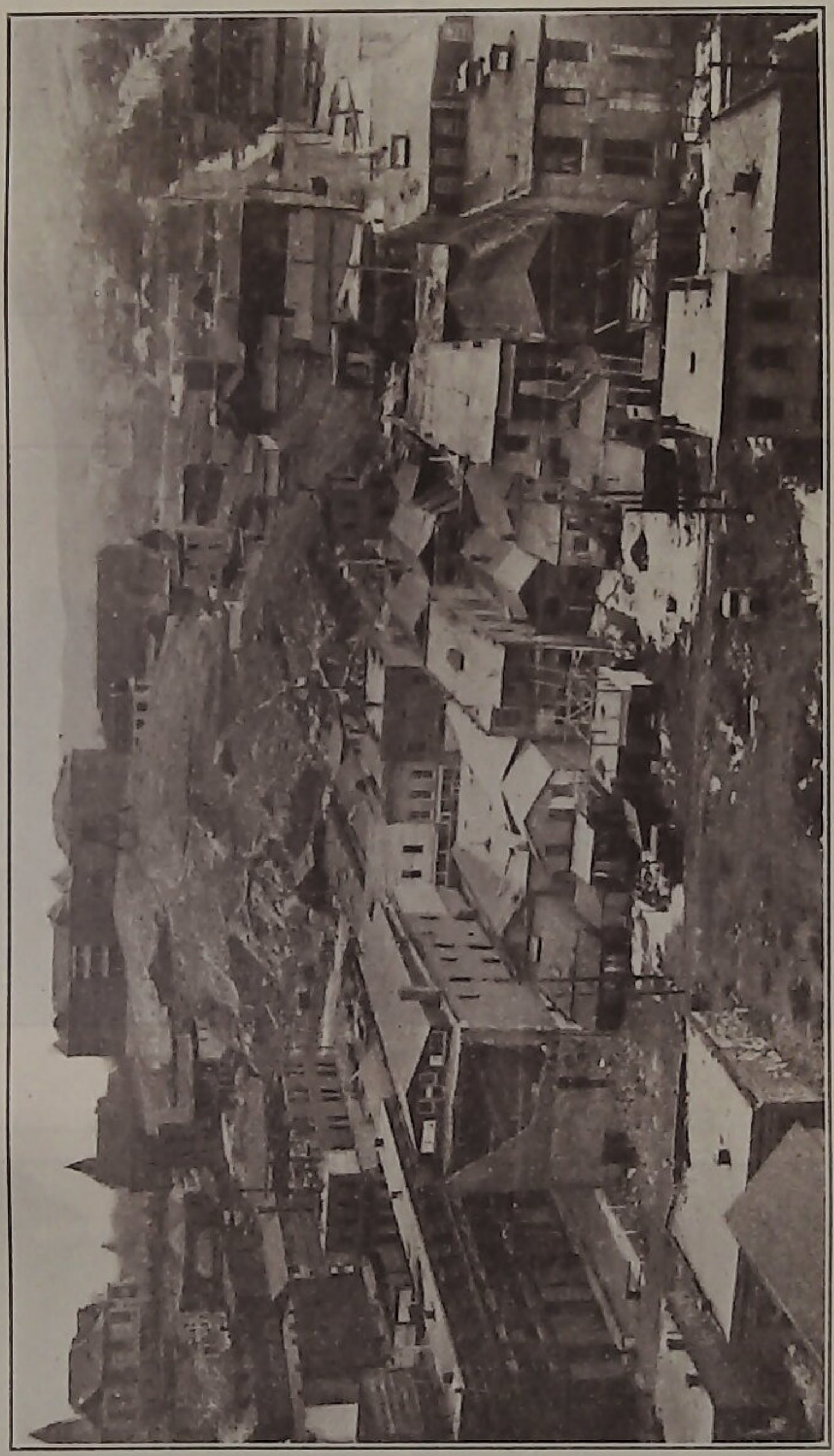


FIGURE 11.—South Main Street, looking east. Helena.

FIGURE 12.—North wing of high school. Helena.

FIGURE 13.—Bryant school. Helena.

FIGURE 14.—County poor farm. Two miles north of Helena.

FIGURE 15.—Shrine Temple. Helena.

FIGURE 16.—State Armory. Helena.

FIGURE 17.—Residence, Twelfth and Ewing Streets. Helena.

FIGURE 18.—National Biscuit Co. Helena.

FIGURE 19.—Crack which spouted water and sand. Six miles northeast of Helena.

some, especially the taller ones, were knocked over. There was no general direction for the fall or twist of these monuments. This would seem to indicate that they were in the epicentral region. At Resurrection Cemetery, about 4 miles northwest of Helena, there was less damage. Here the pedestal-type monuments moved counterclockwise. At the Benton Avenue Cemetery, about 1 mile northwest of Helena, the slab stones were twisted in a counterclockwise direction and the pedestal-type monuments in general moved clockwise.

After the shock of October 31, observers reported that, in general, chimneys, stacks, and tombstones moved in a counterclockwise direction in or near Helena and that several miles north of Helena the rotation was in a clockwise direction.

H. W. Scott makes the following interesting statement:

> Apparently there was not as much rotary motion on October 31, because the gravestones in the Resurrection Cemetery and others generally fell in the same direction without any twisting; whereas, on October 18 few stones fell, but many were twisted clockwise and a few counterclockwise. One gravestone composed of three parts, a square base about 18 inches high, a tall central portion, and a large cross at the top, showed twisting in both directions. The central portion twisted clockwise 1½ inches and the cross counterclockwise five-eighths of an inch.

*Changes in water flow.*—F. P. Ulrich's published report on this subject is as follows:

> About 6 miles northeast of Helena there were a number of ground cracks after the shock of October 18, through which water carrying sand was forced. The flow continued less than 2 days. See figure 19.
>
> At Alhambra Hot Springs, about 12 miles south of Helena, a new hot spring was opened and the old hot springs doubled their flow after the shock of October 18. By October 24 the flow was back to normal. After the 1925 earthquakes, the flow of these springs was doubled and remained above normal for about 30 days.
>
> At East Helena, weir measurements show that Prickly Pear Creek increased from about 800 second-feet to 1,000 second-feet, an increase of 25 percent, as a result of the October 18 shock. No accurate information is available concerning how long this increased flow continued.
>
> At Gumprecht's ranch, about 11 miles northwest of Helena, new springs were opened up and old springs started to flow where there had been very little water before the shock of October 18.

The following quotations are from H. W. Scott's report:

> Changes in the volume of flow of many wells and springs were reported by many people. The most noticeable change was an increase in flow of springs or the development of new springs where none had previously existed. The upper level of ground water in Helena Valley is only a few feet below the surface in many places. Where surface cracks developed, water was forced out and carried with it small quantities of mud and sand. Seven Mile Creek which was practically dry before the shock of October 18 was visited on October 31 and at that time was about 5 feet wide and 12 to 18 inches deep. Farmers in the valley of Seven Mile Creek reported an increased flow in irrigation ditches.
>
> Prickly Pear Creek, running through the center of East Helena, increased its flow at least one-third within 12 hours after the shock on the 18th. A few springs in the area drained by McClellan Creek, which had been dormant for at least 4 years, were revived. The flow slowly decreased and it is altogether probable that the springs will return to a state of dormancy. At Alhambra Springs, 10 miles south of Helena, the flow of water was thought to have doubled, but no accurate check was possible. The proprietor also reports that the larger aftershocks seem to cause a change in volume. No changes occurred in either the volume or temperature of Pipestone hot springs. At Nissler, a point about 75 miles southwest of Helena, a cold spring was changed to a warm one, and the flow increased; both characteristics returned to normal in a few days. The flow of water increased in several mines, but was not so great that the pumps could not conveniently handle it. Contrary to many persistent rumors, there was no change in the character of the hot springs or geysers in Yellowstone National Park.

*Ground cracks.*—Quoting further from H. W. Scott's report:

> The development of ground cracks is not an unusual feature of any earthquake of moderate or major intensity. No cracks were observed at a distance greater than 15 miles from the faulted zone. All were shallow, narrow surface cracks due

to the shaking of the ground and none represent an actual slip along the fault plane.

The largest crack found was on the gravel road leading into the Stanchfield Gun Club. The crack had a maximum width of 5 inches, an average of about one-half inch, and a length of 300 feet. It was developed parallel to the road. The road is about 3 feet above the ground-water table. The ground-water table comes to the surface in several places and forms swampy land in the vicinity of Lake Stanchfield. The surface cracks were most numerous in areas where the ground-water table was near the surface.

Narrow and short cracks were also common near the south and east banks of Lake Stanchfield. For a short time (not more than 2 hours) water flowed from these cracks and carried out small amounts of sand which was deposited on each side of the fissures. The sand is part of the valley fill and it is believed that the material came from a depth of only a few feet. The cracks were less than an inch wide, averaged about 15 feet in length, and were parallel to the lake shore line. It is probable that all of them were less than 25 feet deep. Other fissures of a similar nature were found about 2 miles northeast of Stanchfield Lake.

A few small cracks were observed near Clasoil and other small ones were reported to have been observed in the Missouri River Valley east of Clasoil. All the fissures observed or reported occurred in alluvial materials and the majority of them in Helena Valley.

D. S. Carder writes in an unpublished report:

Ernest Brown was hunting in the field where cracks were abundant at the time of the October 31 earthquake. He claims he saw water spurting a foot or two high from some of the cracks. A girl from a nearby farm visited the crack crossing the road 2 minutes after the earthquake. Water was issuing from the crack about 6 inches high. It was cold and carried granitic sand. Farmers in a field 4 miles northeast of Helena saw dust issuing from narrow cracks crossing the road and in a nearby field at the time of the earthquake. These cracks follow no definite direction. The strikes of the larger ones are N. 50° E. and N. 48° W. They are found in the dry crust of the marshy region toward the center of the valley.

*Visible ground waves.*—Quoting again from D. S. Carder's report:

Mr. Tom Herrin, farmer in Prickly Pear Valley reports that he and a companion were driving toward Helena and were about 3 miles out of town when they noticed two waves in the field coming toward them from the direction of the city at an estimated rate of about 50 miles per hour. He said "There's an earthquake." Just then the waves passed beneath them and they felt the shock. A farm hand avers he saw waves moving to and fro in the field. Other observers claim they saw similar waves in the pavement of the city streets.

*Rock slides.*—H. W. Scott reports:

No rock slides of any importance occurred as a result of the Helena earthquakes. On October 18, a small slide covered the highway near the Great Northern viaduct about 7 miles south of Helena. It was not large enough to disrupt traffic. Loose rocks and boulders resting on steep slopes were generally shaken down. Ranchers in the Belt Mountains reported that rolling stones could be heard. One rockslide occurred south of Livingston, about 10 miles southeast of Helena, but its cause cannot be definitely charged to the earthquakes. It was probably caused by the normal agents of erosion.

*Sounds.*—Quoting H. W. Scott again:

Sounds accompanied all of the more important shocks. Mr. W. E. Maughan, Meteorologist at Helena states: "Noise accompanied almost any shock of consequence. It was roaring with the three heavy shocks. On the 18th the sounds seemed to come from deep down in the earth. On the 31st subterranean noises were less pronounced." About 50 percent of the people within a radius of 60 miles report sounds similar to those made by a passing train or heavy truck. The sounds in Butte on October 31 were comparable to the heavy, dull roar which precedes a spring rainstorm. The rumble was so audible that the writer had time to stop in the midst of a lecture and call attention of a geology class to the approaching earthquake. The most distant points from Helena where sounds were reported are: Dillon, 102 miles south; Hamilton, 108 miles southwest; Havre, 174 miles northeast; Harlowtown, 110 miles east; and Livingston, 102 miles southeast. Many persons report that earth sounds, without accompanying tremors, could be heard in Helena.

From D. S. Carder's unpublished report comes among other things an interesting relation between sound effect and epicenter location:

The sound phenomena were utilized to locate the epicenter of the shocks. Observers in Helena are agreed that most of the sounds come from the north or northeast. Farmers 5 miles northeast of the city say that they come from the direction of Helena. Farmers 3 miles northeast say they come directly from beneath.

*Lights.*—D. S. Carder reports:

The lighting system of Helena failed toward the end of the major shock of October 18. At the same time, a blue sulphurous light was observed around the mountain tops south of the city. This was traced to a short circuit in a high tension line.

Residents of Prickly Pear Valley noticed a glow on the horizon on the night of October 31. It was reported that forest rangers traced this to a fire.

## GEOLOGY AND STRUCTURE

In view of the important bearing of the local geology on earthquake effects and the location of the focal point of the disturbances the following selected paragraphs are quoted from H. W. Scott's report:

Along the south slope of Prickly Pear Valley the Marsh shale, Helena limestone, and Empire shale crop out in narrow belts that pass through the city of Helena. In general, the Empire shale is partially covered by alluvium and "lake-bed" material. On the north side of Prickly Pear Valley the low rounded hills between Missouri River and United States Highway No. 91 are composed of dark-gray shales of the Greyson formation. North and northwest of the Scratch Gravel Hills, the Greyson, Spokane, Empire, Helena, Marsh, and Hellgate formations have been recognized. Clapp and Deiss measured a section along Little Prickly Pear Creek (not to be confused with Prickly Pear Creek at East Helena) and determined the total thickness of exposed Belt sediments at that place to be 14,900 feet. Pardee and Schrader measured about 12,000 feet of upper Beltian sediments in the Belt Mountains east of Prickly Pear Valley.

Tertiary rocks consisting of clay, sand, and gravel, and volcanic effusives are common in the southern and eastern part of Prickly Pear Valley. These rocks are commonly referred to as "lake-beds" and are characteristic of most of the intermontane valleys of the Rocky Mountains. These Tertiary sediments underlie the relatively thin covering of Quaternary alluvium in Prickly Pear Valley. A well bored near the center of the valley shows them to be at least 1,200 feet thick. As shown in figure 5 the Tertiary sediments are thought to be as much as 2,000 feet thick near Helena. The true nature of these sediments and the determination of certain geologic boundary lines needs further investigation. The Belt sediments northwest of the Scratch-gravel Hills have not been mapped in detail.

The known faults south of Helena probably continue northward and are hidden by the alluvium and Tertiary "lake-beds" of Prickly Pear Valley. It is believed that they are secondary faults which may intersect a major fault that trends northwest along the south side of the valley.

The earth movements which caused the Helena earthquakes probably took place along this zone which will hereafter be called the Prickly Pear fault. Of course, the exact position of this fault is unknown because of the thick cover of unconsolidated sediments in Prickly Pear Valley. Various lines of evidence indicate that its trace on the surface would extend from Fort Harrison on the northwest to a point near East Helena on the southeast. It would pass just to the north of Helena. Many of the major valleys in southwestern Montana are caused by down dropped fault blocks. Townsend Valley, Summit Valley near Butte, parts of Jefferson Valley, and many others can be given as examples.

The evidence for the existence of a major fault along the south side of Prickly Pear Valley is:

1. The presence of a deeply buried erosional surface below the present surface of Prickly Pear Valley. In places the valley fill is known to be 1,200 feet deep and is estimated to be as much as 2,000. Such conditions require that the valley be a down-dropped block.
2. Character of the dispersion of the recent earthquake waves.
3. Changes in former drainage systems and development of the present discordant physiographic provinces.
4. Seismograph records.

The rocks in the Belt Mountains to the north and east of Helena are also folded and faulted. The Scout Camp overthrust which extends from Canyon Ferry northwest toward Wolf Creek is probably a southward division of the Lewis overthrust of Glacier National Park. Pardee measured its vertical displacement near the north end of Hauser Lake to be a minimum of 12,000 feet, and the horizontal movement is to be measured in miles. This and other thrust faults in the area are much older than the normal faults which produced the major valleys.



The report itself should be consulted for other important details.

## FORESHOCKS AND AFTERSHOCKS

Due to the efforts of W. E. Maughan, in charge of the Helena office of the United States Weather Bureau, and his associates, there has been made available the most complete record ever obtained in this

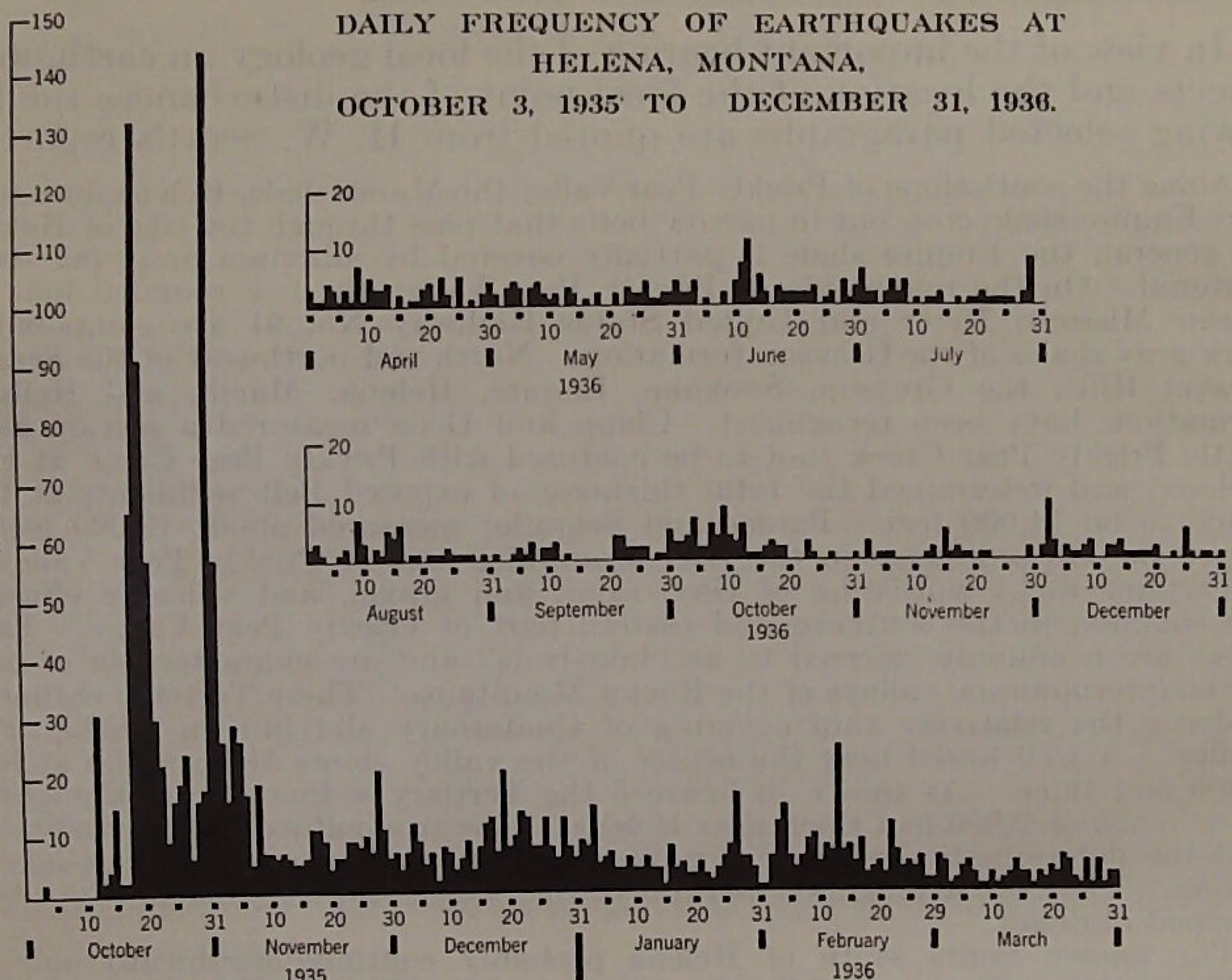



FIGURE 20.—Daily frequency chart of earthquakes at Helena. Based on observations by W. E. Maughan, United States Weather Bureau.

country of a long series of fore- and aftershocks, excluding, of course, records made with sensitive instruments. It is the longest list of "swarm" earthquakes recorded outside of Japan.

The original list includes the date, time (to the nearest minute), intensity, and duration of each shock. A total of 2,281 shocks were recorded up to December 31, 1936. The list is available only in mimeographed form either from the local office of the Weather Bureau at Helena or from the Washington office of the Coast and Geodetic Survey. Figure 20 is a daily frequency diagram covering the period from October 3, 1935, to December 31, 1936.

It will be noted in the chronological record in this publication that four shocks of destructive proportions began 6 days before the strongest shock of October 18. Previous to the 12th there was only a slight disturbance, on October 3. On page 42 there are brief comments on the distribution of intensity of the shocks.

## SEISMOLOGICAL OBSERVATORY RESULTS

The Coast and Geodetic Survey publishes the results of its teleseismic stations and cooperating stations monthly in mimeographed form. In these reports all seismogram interpretations are tabulated together with epicenters based on the published data and instrumental results received from seismological stations in all parts of the world. These reports will be furnished upon request to the Director of the Bureau. In the summary of epicenters in this report attempts are sometimes made to improve epicenters already published, especially in the case of those in North America.



Instrumental results are published for the following observatories:

Balboa, Canal Zone (The Panama Canal).
Bozeman, Mont. (Montana State College).
Charlottesville, Va. (University of Virginia).
Chicago, Ill. (University of Chicago and U. S. Weather Bureau).
College, Alaska (Universtity 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, Territory of Hawaii (University of Hawaii).
Huancayo, Peru (Carnegie Institution of Washington, Department of Terrestrial Magnetism).
Montezuma, Chile (Smithsonian Institution).
Philadelphia, Pa. (The Franklin Institute).
Pittsburgh, Pa. (University of Pittsburgh).
San Juan, P. R.
Seattle, Wash. (University of Washington).
Sitka, Alaska.
Tucson, Arizona.
Ukiah, Calif. (International Latitude Observatory).

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

In view of the uncertainties involved in distinguishing between time at the focus and time at the epicenter in provisional epicenter work of this kind, it has been decided to omit the distinction between them. In general the time at origin as tabulated may be accepted as the time at the focus, or "H", but in many cases the data are too indefinite to make a decision.

A description of the new station at College, Alaska, appears in the Bulletin of the Seismological Society of America, volume 26, number 2, April 1936, page 125.

**Table 1.—*Summary of instrumental epicenters***

| 1935 | Greenwich civil time at origin | Region and focal depth | Coordinates of provisional epicenter [1] | |
|---|---|---|---|---|
| | | | Lat. | Long. |
| | *h.* *m.* | | ° | ° |
| Jan. 1 | 13 20.9 | Pacific ocean southwest of Samoa. Depth about 160 kilometers. | 15 S. | 174.5 W. |
| Jan. 2 | 22 41.1 | Off northern California. Depth normal | 40.6 N. | 125.0 W. |
| Jan. 3 | 1 50.3 | Tibet. Depth normal | 31.3 N. | 88.1 E. |
| Jan. 4 | 14 41.5 | Turkey. Depth normal | 40.7 N. | 28.0 E. |
| Do | 16 20.0 | Turkey. Aftershock | 40.7 N. | 28.0 E. |
| Jan. 17 | 2 08.2 | New Hebrides Islands. Depth probably normal | 20 S. | 169.5 E. |
| Do | 8 29.9 | Local in Puerto Rico | | |
| Jan. 23 | 7 24.1 | Aleutian Islands. Depth normal. Felt | 52.4 N. | 170.0 W. |

See footnote at end of table.

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

| 1935 | Greenwich civil time at origin | Region and focal depth | Coordinates of provisional epicenter | |
|---|---|---|---|---|
| | | | Lat. | Long. |
| | *h.* *m.* | | ° | ° |
| Jan. 31 | 17 45.9 | New Hebrides region. Depth normal | 13 S. | 165 E. |
| Feb. 4 | 17 24.5 | Friendly Islands in South Pacific | 20 S. | 175 W. |
| Feb. 6 | 1 54.9 | North Atlantic Ocean. Depth normal | 30 N. | 42 W. |
| Feb. 13 | 17 22.1 | Felt in region of Montezuma, Chile | 24± S. | 69± W. |
| Feb. 20 | 11 26.5 | Region of Oaxaca, Mexico | (17) N. | (97) W. |
| Feb. 22 | 17 06.1 | Bering Sea. Depth normal | 52 N. | 175 E. |
| Feb. 24 | 1 45.0 | Felt in southern California. Approximate epicenter by Pasadena. | 32.0 N. | 115.2. W. |
| Feb. 25 | 2 51.4 | Greece. Depth normal. Epicenter by Strasbourg | 35.5 N. | 24 E. |
| Feb. 27 | 9 09.5 | Palau Islands southeast of Philippines according to Manila. | (7) N. | (135) E. |
| Do | 15 27.2 | Pacific Ocean off Panama | 7± N. | 83± W. |
| Feb. 28 | 7 10.0 | Northern Argentina | 23.5 S. | 64± W. |
| Mar. 13 | 18 37 | Region of Bougainville Islands in Solomon Islands group according to Manila. | ---------- | ---------- |
| Mar. 17 | 21 33.3 | Guatemala. Depth normal | 14.5 N. | 90.5 W. |
| Mar. 20 | 22 57.5 | Solomon Islands. Depth probably normal | 8± S. | 158± E. |
| Mar. 26 | 21 32.2 | Caribbean Sea | 17± N. | 83± W. |
| Mar. 29 | 12 24.3 | Karmadec Islands northeast of New Zealand | 30 S. | 177 W. |
| Mar. 30 | 21 19.6 | Pacific Ocean off Japan. Depth near normal | 37 N. | 142 E. |
| Apr. 3 | 12 05.3 | Aleutian Islands | 51 N. | 168 W. |
| Apr. 5 | 17 48.6 | Guerro, Mexico. Probable epicenter | 17.5 N. | 100.5 W. |
| Apr. 11 | 23 14.7 | Persia. Depth normal | 35.9 N. | 53.1 E. |
| Apr. 18 | 22 15.4 | Probably Baffin Bay | 71.5 N. | 73 W. |
| Apr. 19 | 15 23.4 | North Africa. Depth normal | 31 N. | 15 E. |
| Apr. 20 | 5 11.0 | ----do | 31 N. | 15 E. |
| Do | 22 02.0 | Destructive in Formosa. Depth normal | 24 N. | 121 E. |
| Apr. 24 | 18 51.7 | Probably Guatemala | ---------- | ---------- |
| May 1 | 10 24.7 | Destructive in Kars-Digor, Transcaucasia. Depth normal. | 40.4 N. | 42.4 E. |
| May 13 | 19 53.6 | Indochina. Depth normal | 19.9 N. | 101.0 E. |
| May 14 | 23 23.0 | Sandwich Islands in the South Atlantic. Slightly deep. | 59.0 S. | 27.0 W. |
| May 21 | 6 51.7 | New Guinea. May be slightly deep | 5.6 S. | 146.0 E. |
| May 23 | 17 59.1 | Mid-Atlantic. Depth normal | 23.5 N. | 45.0 W. |
| May 24 | 5 36.5 | Philippines. Depth probably near normal | 12.5 N. | 125.5 E. |
| May 26 | 22 03.0 | Probably an aftershock of the preceding | ---------- | ---------- |
| May 28 | 12 08.7 | Mendoza region, northwest Argentina | ---------- | ---------- |
| May 30 | 21 32.8 | Destructive in Baluchistan, India; 30,000 to 40,000 killed. Depth normal. | 29.1 N. | 66.6 E. |
| May 31 | 8 18.5 | Japan Sea. Felt in Japan. Depth about 250 kilometers. | 41.9 N. | 134.5 E. |
| June 2 | 9 16.5 | Baluchistan, India. Depth normal | 31.0 N. | 67.0 E. |
| June 11 | 21 55.9 | Pacific Ocean off Colombia. Depth near normal | 3.4 N. | 82.9 W. |
| June 24 | 23 23.1 | New Hebrides. Probably slightly deep | 15 S. | 168 E. |
| June 25 | 12 33.6 | Sea of Okhotsk off Kurile Islands. Depth normal | 47 N. | 149 E. |
| June 28 | 2 00.5 | Pacific Ocean off Chile. Depth probably normal | 37 S. | 74 W. |
| Do | 19 30.2 | Hawaii. Depth about 5 miles according to the Hawaiian Volcano Observatory. | 19.6 N. | 155.2 W. |
| June 29 | 6 49.0 | Felt at Acapulco, Mexico. Depth probably normal | 18.6 N. | 103.4 W. |
| July 5 | 17 53.0 | Turkestan. Depth normal | 39 N. | 67 E. |
| July 6 | 3 31.7 | Alaska. Felt. Depth probably normal | 59± N. | 139± W. |
| July 7 | 13 23.2 | Philippines. Felt. Epicenter by Manila | 18.2 N. | 119.4 E. |
| July 8 | 12 58.0 | Chile. Probable depth 240 kilometers | 27.5 S. | 71.0 W. |
| July 9 | 6 41.0 | Chile | 27.0 S. | 72.5 W. |
| Do | 12 21.6 | Possibly Chile | 28 (?) S. | 73 (?) W. |
| July 10 | 9 41.3 | West coast of Mexico | 19 N. | 106 W. |
| July 11 | 8 24.7 | Japan. Felt. Approximate location | 35 N. | 139 E. |
| July 15 | 14 13.5 | Polynesia. Depth about 500 kilometers | 21 S. | 179 W. |
| July 16 | 16 18.8 | Formosa. Depth normal | 24.0 N. | 121.0 E. |
| July 17 | 4 31.6 | Atlantic Ocean. Depth normal | 0.5 S. | 18.5 W. |
| Do | 10 46.2 | Sandwich Islands, South Atlantic. Depth normal | 60 S. | 24 W. |
| July 19 | 0 49.8 | East coast of Japan. Depth normal | 38 N. | 141 E. |
| July 20 | 10 22.9 | Peru. Depth probably normal | 13 S. | 73.5 W. |
| July 26 | 4 43.4 | Panama. Depth probably normal | 8.0 N. | 82.5 W. |
| Do | 8 03.5 | Sea of Okhotsk. Depth 400 kilometers | 45.0 N. | 145.5 E. |
| July 29 | 7 38.9 | Near Tonga Islands. Depth 500 kilometers | 22.0 S. | 177.1 W. |
| Aug. 1 | 14 06.6 | Philippine Deep. Epicenter by Manila | 10.5 N. | 126.4 E. |
| Do | 16 08.3 | Pacific Ocean off Central America. Depth normal | 10.8 N. | 86.5 W. |
| Aug. 3 | 1 10.0 | Sumatra. Depth normal | 4.1 N. | 96.7 E. |
| Aug. 5 | 23 50.1 | Chile. Depth normal | 35.2 S. | 72.2 W. |
| Aug. 7 | 9 02.2 | Destructive in Colombia. Depth normal | 1.0 N. | 77.5 W. |
| Aug. 17 | 1 44.5 | Near Tonga Islands. Depth normal | 22.0 S. | 172.0 E. |
| Aug. 21 | 13 48.9 | Probably near Tonga Islands. Probable depth, 240 kilometers. | 18.5 S. | 172.5 W. |
| Aug. 22 | 20 30.6 | Baffin Bay. Depth normal | 73.0 N. | 70.3 W. |
| Aug. 25 | 5 07.9 | Northwest of Spitzbergen. Depth near normal | 79.0 N. | 2.5 E. |
| Aug. 31 | 17 39.8 | Pacific Ocean near Kurile Islands. Depth normal | 42± N. | 151± E. |
| Sept. 1 | 0 48.8 | Nicaragua. Depth normal | 12 N. | 87.5 W. |

See footnote at end of table.

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

| 1935 | Greenwich civil time at origin | Region and focal depth | Coordinates of provisional epicenter[1] | |
|---|---|---|---|---|
| | | | Lat. | Long. |
| | *h.* *m.* | | ° | ° |
| Sept. 2 | 2 16.0 | North of Solomon Islands. Location doubtful | 1± N. | 152± E. |
| Sept. 4 | 1 27.9 | Alaska. Depth normal | 63.5 N. | 148.5 W. |
| Sept. 9 | 6 17.6 | Pacific near Caroline Islands. Depth probably near normal. | 7 N. | 142 E. |
| Sept. 10 | 6 30.3 | Off west coast of Mexico | 19 N. | 106 W. |
| Do | 7 05.2 | Off west coast of Mexico. Location approximate | 17± N. | 107± W. |
| Sept. 11 | 11 45.4 | Kermadec Islands in south Pacific. Depth normal | 31 S. | 178 W. |
| Do | 14 04.0 | Japan. Depth near normal | 43.2 N. | 146.2 E. |
| Sept. 15 | 4 01.5 | Off Puerto Rico. Depth normal | 19.0 N. | 64.5 W. |
| Do | 11 16.2 | South Pacific. Depth possibly 400 kilometers | 4.5 S. | 152.0 E. |
| Do | 14 09.1 | South Pacific. Depth normal | 27.0 S. | 113.0 W. |
| Sept. 18 | 4 57.9 | South America. Depth normal | 5.5 N. | 76.0 W. |
| Do | 8 23.8 | Japan. Depth normal | 42.3 N. | 142.2 E. |
| Sept. 19 | 9 56.0 | Epicenter doubtful. Near Samoa | 14± S. | 168± W. |
| Sept. 20 | 1 46.6 | New Guinea. Depth normal | 4 S. | 142 E. |
| Do | 5 23.0 | ——do | 4 S. | 142 E. |
| Sept. 23 | 9 18.3 | ——do | 3.5 S. | 143.0 E. |
| Sept. 24 | 5 01.1 | New Guinea. Aftershock | 3.5 S. | 143.0 E. |
| Do | 22 12.1 | North Pacific. Depth normal | 49.3 N. | 132.5 W. |
| Sept. 25 | 10 19.6 | New Guinea. Depth normal | 4 S. | 142 E. |
| Sept. 28 | 4 00.3 | Northern Argentina. Depth possibly 200 kilometers. | 24.5 S. | 66.5 W. |
| Sept. 30 | 19 00.7 | Arctic Ocean off northeast coast of Greenland. Depth normal. | 84 N. | 5 E. |
| Oct. 1 | 9 06 | Hawaii, T. H. Depth about 48 kilometers. Epicenter by U. S. National Park Service. | 19.4 N. | 155.7 W. |
| Do | 10 28 | Hawaii, T. H. Depth 28 kilometers. Epicenter by U. S. National Park Service. | 19.6 N. | 155.4 W. |
| Oct. 2 | 5 32.9 | Japan. Epicenter by Hukuoka and Mizusawa | 42.9 N. | 145.8 E. |
| Oct. 4 | 5 15.6 | Philippine Islands. Depth 400 kilometers. Epicenter by Manila. | 6.3 N. | 125 E. |
| Oct. 8 | 9 19.1 | Turkestan. Epicenter by U. S. S. R. | 37.5 N. | 67 E. |
| Oct. 9 | 22 08.5 | South of Iceland. Epicenter by Strasbourg | 62.5 N. | 22.5 W. |
| Oct. 11 | 22 15.8 | New Guinea | 5 S. | 146 E. |
| Oct. 12 | 7 50.8 | Helena, Mont. Destructive | 46.6 N. | 112.0 W. |
| Do | 16 45.4 | Off Japan. Epicenter by Hukuoka and Mizusawa. | 40.4 N. | 143.3 E. |
| Oct. 13 | 1 57.5 | ——do | 40.2 N. | 143.4 E. |
| Oct. 14 | 17 36.5 | Pacific Ocean off Panama | 5± N. | 86± W. |
| Oct. 18 | 0 12.1 | Off Japan. Epicenter by Hukuoka and Mizusawa. | 40.2 N. | 143.8 E. |
| Do | 11 05.3 | Pacific Ocean near Guam | 11 N. | 143 E. |
| Do | 14 53.9 | Near Japan. Epicenter by Hukuoka and Mizusawa. | 40.4 N. | 143.9 E. |
| Oct. 19 | 4 48.1 | Destructive at Helena, Mont. Depth shallow | 46.6 N. | 112.0 W. |
| Oct. 24 | 14 48.3 | Southern California. Epicenter by Pasadena | 34.1 N. | 116.9 W. |
| Oct. 27 | 22 05.1 | Off Colombia | 3± N. | 79± W. |
| Oct. 31 | 18 37.9 | Destructive at Helena, Mont. Depth shallow | 46.6 N. | 112.0 W. |
| Nov. 1 | 6 03.7 | Timiskaming, Canada. Epicenter by Ottawa. Depth approximately normal. | 46.8 N. | 79.1 W. |
| Do | 16 22.2 | North Indochina | 21 N. | 104 E. |
| Nov. 4 | 3 55 | Southern California. Epicenter by Pasadena | 33.5 N. | 116.9 W. |
| Do | 10 12.9 | Lower California | 24 N. | 110 W. |
| Do | 13 53.3 | Gulf of California | 25 N. | 110 W. |
| Nov. 5 | 20 57.4 | Philippine Islands. Epicenter by Manila | 5.8 N. | 126.2 E. |
| Nov. 10 | 18 27.7 | West Indies | 17 N. | 62 W. |
| Nov. 14 | 19 56.9 | Near New Guinea | 5 S. | 153 E. |
| Nov. 21 | 11 41 | Hawaii. Epicenter by U. S. National Park Service. | 19.5 N. | 155.5 W. |
| Nov. 23 | 7 52.5 | Off Ecuador | 0 N. | 85 W. |
| Nov. 25 | 10 03.0 | Off Sumatra | 5 N. | 93 E. |
| Nov. 28 | 14 41.9 | Helena, Mont | 46.6 N. | 112.0 W. |
| Nov. 30 | 3 39.9 | Panama | 10 N. | 79 W. |
| Dec. 3 | 2 17.8 | Lower California | 25 N. | 112 W. |
| Dec. 5 | 17 49.5 | South Pacific Ocean | 11 S. | 165 W. |
| Dec. 14 | 1 31.1 | Western Brazil. Depth about 370 kilometers | 8.4 S. | 70.4 W. |
| Do | 22 05.4 | Off Guatemala | 14.7 N. | 92.5 W. |
| Dec. 15 | 7 07.9 | Solomon Islands | 10 S. | 161 E. |
| Dec. 16 | 16 57.3 | Western Brazil. Depth about 400 kilometers | 8 S. | 70 W. |
| Dec. 17 | 19 17.8 | China Sea. Epicenter by Hukuoka and Mizusawa. | 23.9 N. | 125.3 E. |
| Dec. 18 | 5 33.3 | Belen, N. Mex | 34.7 N. | 106.8 W. |
| Do | 7 10.6 | Szechuan, China | 28 N. | 103 E. |
| Dec. 19 | 1 57.0 | Belen, N. Mex | 34.7 N. | 106.8 W. |
| Dec. 20 | 7 45.7 | Southern California. Epicenter by Pasadena | 33.2 N. | 115.5 W. |
| Do | 18 37.0 | Solomon Islands | 10 S. | 161 E. |
| Dec. 21 | 11 51.1 | Off Guatemala | 14 N. | 93 W. |
| Dec. 24 | 12 24.3 | Off Colombia | 3 N. | 78 W. |
| Dec. 28 | 2 35.5 | Batoe Islands. Epicenter by Batavia | 0.3 S. | 97.9 E. |
| Dec. 29 | 23 37.4 | Off Ceram Island, East Indies | 4 S. | 129 E. |

[1] Epicenters with coordinates given in parentheses are approximate values based on noninstrumenta reports.

# 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 two preceding issues of this series, Serials 579 and 593, and in Special Publication 201, "Earthquake Investigations in California, 1934–1935." Material in the "United States Earthquakes" series is restricted to the analysis of strong-motion seismograph records. Special Publication 201 is much broader in scope, containing data on structural and ground vibration and detailed descriptions of the various activities which comprise the seismological program as a whole. The reader is also referred to Special Publication 206, "Selection, Installation, and Operation of Seismographs", for descriptive material on strong-motion instruments and vibration meters in addition to similar information on teleseismic instruments.

*Interpretation of records.*—The following analyses are based largely on the assumption of simple harmonic motion. This refers especially to the computation of displacement from accelograph records. An exception is the analysis of the Helena, Mont., accelogram which was subjected to more rigorous treatment by methods of integration which are explained and discussed in most of the reports mentioned in the preceding paragraph. As this publication goes to press tests are under way to determine the accuracy of results obtained by integration, more especially the reality of ultra long-period waves which persist in all reductions of this kind. The Helena record was the first thus far integrated on which recorded base lines were available for more accurate measurement and control of the axes of the acceleration curves. The method used in the double integration work is explained in a mimeographed paper of the Bureau entitled, "Strong-Motion Report No. 4—Analysis of Strong-Motion Seismograph Records of the Western Nevada Earthquake of January 30, 1934, With Description of a Method of Analyzing Seismograms by Precise Integration."

*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 s equal to 980 cm/sec.$^2$ For practical purposes it is only necessary to point off three decimal places to convert cm/sec.$^2$ to g.

Sensitivity of the seismographs is expressed as the deflection of the trace, or light spot, in centimeters for a constant acceleration of 100 cm/sec.$^2$ This means that the seismometer pendulum is tilted

sideways until the effective component of the earth's gravitational field is equal to 100 cm/sec.$^2$, or practically 0.1 g.

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

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



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

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

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

**Table 2.—*List of shocks recorded and records obtained on strong-motion seismographs in 1935***

| Date, epicenter, and recording stations | Records [1] | |
|---|---|---|
| | Accelerograph | Displacement meter |
| Jan. 2; northern California: Eureka | 1 | 1 |
| Mar. 3; northern California: Ferndale | 1 | |
| July 13; southern California: Los Angeles, Chamber of Commerce Building | 2 | |
| Sept. 8, 6:40; Imperial Valley: El Centro | 1 | |
| Sept. 8, 9:03; Imperial Valley: El Centro | 1 | |
| Oct. 23[2]; Helena, Mont.: Helena | 1 | |
| Oct. 24; southern California: Los Angeles Subway Terminal | 2 | 1 |
| Oct. 24[2]; Helena, Mont.: Helena | 1 | |
| Oct. 26[2]; Helena, Mont.: Helena | 1 | |
| Oct. 27, 12:20; Helena, Mont.: Helena | 1 | |
| Oct. 27, 23:08[2]; Helena, Mont.: Helena | 1 | |
| Oct. 28[2]; Helena, Mont.: Helena | 1 | |
| Oct. 30[2]; Helena, Mont.: Helena | 1 | |
| Oct. 31, 11:37[3]; Helena, Mont.: Helena | 1 | |
| Oct. 31, 11:42[4]; Helena, Mont.: Helena | 1 | |
| Oct. 31, 11:50[2]; Helena, Mont.: Helena | 1 | |
| Oct. 31, 12:10 ca; Helena, Mont.: Helena | 1 | |
| Oct. 31, about 14:00[2]; Helena, Mont.: Helena | 1 | |
| Oct. 31, about 15:40[5]; Helena, Mont.: Helena | 1 | |
| Oct. 31–Nov. 1, night[2]; Helena, Mont.: Helena | 1 | |
| Nov. 4[2]; Helena, Mont.: Helena | 1 | |
| Nov. 5; Helena, Mont.: Helena | 1 | |
| Nov. 6[2]; Helena, Mont.: Helena | 1 | |
| Nov. 21; Helena, Mont.: Helena | 1 | |
| Nov. 28[6]; Helena, Mont.: Helena | 1 | |
| Dec. 19; Imperial Valley: El Centro | | |

[1] No records were obtained on Weed strong-motion seismographs.
[2] Minor.
[3] Important.
[4] Several other small aftershocks on this record.
[5] Two slight quakes.
[6] Two fair-sized shocks, one of them completely recorded.

## THE NORTHERN CALIFORNIA EARTHQUAKE OF JANUARY 2, 1935

### EARTHQUAKE DATA AND RECORDING STATIONS



*Epicenter.*—About 50 miles west of Cape Mendocino.
*Maximum intensity and damage.*—V on shore. Possibly VII at epicenter. Practically no damage.
*Area affected.*—4,000 square miles on land.
*Summary of strong-motion records.*—
EUREKA: About 70 miles north 68° east of epicenter. Recorded on the accelerograph and displacement meter in the basement of the Federal Building.

### ANALYSIS OF THE EUREKA RECORD OF JANUARY 2

*Accelerograph record.*—Figure 21. The maximum acceleration of less than 3 cm/sec.$^2$ is restricted to a few waves of 0.4 or 0.5 sec. period. The record is essentially a short-period type with values ranging from 0.15 to 0.50 sec. In the end portion weak waves of the order of 1 sec. period are in evidence. The total duration is about 60 seconds.
*Displacement-meter record.*—Figure 21. Displacements of the shorter period waves are so small that only a few of the 0.25 and 0.5 sec. waves are weakly recorded in the early part of the record; 1 sec. periods are weakly apparent throughout a large part of the record. The maximum displacements of 1.2 mm are associated with periods of 3, 5, and 10 seconds. The wave types are badly mixed, smooth sinusoidal waves being difficult to find.

## THE NORTHERN CALIFORNIA EARTHQUAKE OF MARCH 3, 1935

### EARTHQUAKE DATA AND RECORDING STATIONS

*Epicenter.*—Near Upper Mattole, according to Berkeley.
*Maximum intensity and damage.*—V at Upper Mattole. No damage.
*Area affected.*—Small.
*Summary of strong-motion records.*—
FERNDALE: About 20 miles north 9° west of epicenter. Recorded on the accelerograph on the ground floor of the town hall.

### ANALYSIS OF THE FERNDALE RECORD OF MARCH 3

*Accelerograph record.*—Figure 21. The maximum horizontal acceleration was close to 5 cm/sec.$^2$ and was associated with periods of 0.15 and 0.20 sec. The estimated maximum displacement is about 0.003 cm. A series of 0.5 sec. waves are discernible but are almost masked by tremors of 0.15 and 0.20 sec. period. On the vertical component the 0.20 sec. waves have only about one-half the amplitude which they have on the horizontal component. After 20 seconds practically all activity ends.

## THE SOUTHERN CALIFORNIA EARTHQUAKE OF JULY 13, 1935

### EARTHQUAKE DATA AND RECORDING STATIONS

*Epicenter.*—San Gabriel Mts., 34°10′ N. 117°52′ W.
*Maximum intensity and damage.*—V. Damage none or slight.
*Area affected.*—About 14,000 square miles.

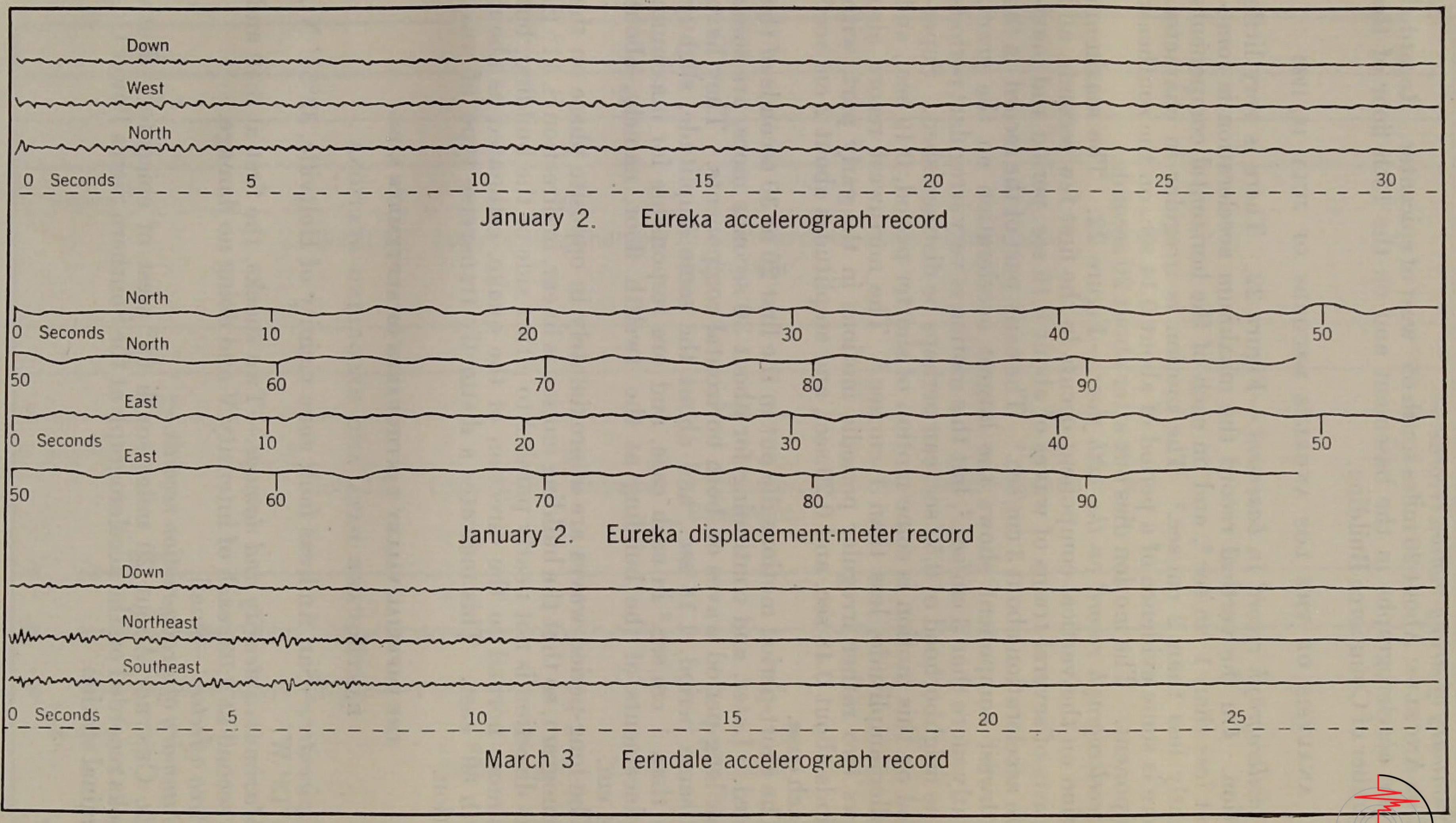



FIGURE 21.—Tracings of strong-motion seismograph records of northern California earthquakes of January 2 and March 3.

*Summary of strong-motion records.*—
Los Angeles: About 20 miles south 69° west of epicenter. Recorded on the accelerographs in the basement and on the 13th floor of the Chamber of Commerce Building.



## ANALYSIS OF THE LOS ANGELES RECORDS OF JULY 13, 1935

*Accelerograph record in basement.*—Figure 22. There is very little motion. On the vertical record the maximum acceleration is somewhat less than 1 cm/sec.$^2$, and on each of the horizontal components slightly less than 2 cm/sec.$^2$ The motion is irregular in character. There is some evidence of a period of about 0.14 sec. on the southeast component. The motion dies out after about 20 seconds.

*Accelerograph record on the 12th floor.*—Figure 22. The maximum motion on the vertical component occurs in the first few seconds, and consists of several trains of waves of about 0.16 sec. period and maximum acceleration about 3 cm/sec.$^2$ The early part of the record on the southwest component shows the largest acceleration on the gram, slightly more than 3 cm/sec.$^2$, but this motion is very irregular; periods in the neighborhood of 0.52 sec. can perhaps be distinguished. Superposed on this motion is some motion of shorter period, 0.19 sec., and smaller amplitude, less than 1 cm/sec.$^2$ The northwest record also shows two rather irregular periodic motions in the early part, with periods about 0.48 sec. and 0.20 sec., and amplitudes about 2 cm/sec.$^2$ in each case.

The short-period motions die out in the first 20 or 30 seconds of the record. Later, and continuing for about 30 seconds more, are some weak long-period waves on both horizontal components. They have the same period, 1.18 sec., and about the same amplitude, slightly less than 1 cm/sec.$^2$ in each case, and are responsible for maximum displacements of the building at the twelfth floor, namely, about 0.04 cm.

The long-period waves are approximately in opposite phase on the seismogram, so that the building motion is linear, in direction S. 11° E. This direction is not nearly parallel to either side of the building, but is almost normal to the direction of the quake, estimated as about north 69° east. This indicates a distinctly transverse type of wave motion.,

## THE IMPERIAL VALLEY EARTHQUAKES OF SEPTEMBER 8, 1935

### EARTHQUAKE DATA AND RECORDING STATIONS

*Epicenter.*—San Andreas fault zone vicinity of Holtville, 32°54′ N., 115°13′ W.

*Maximum intensity and damage.*—Two shocks, the first at 6:40 and the second at 9:03, each of intensity V and doing no damage.

*Area affected.*—Small.

*Summary of strong-motion records.*—
El Centro: About 20 miles south 65° west of epicenter. Both shocks recorded on the accelerograph at the Southern Sierra Power Co. terminal station.

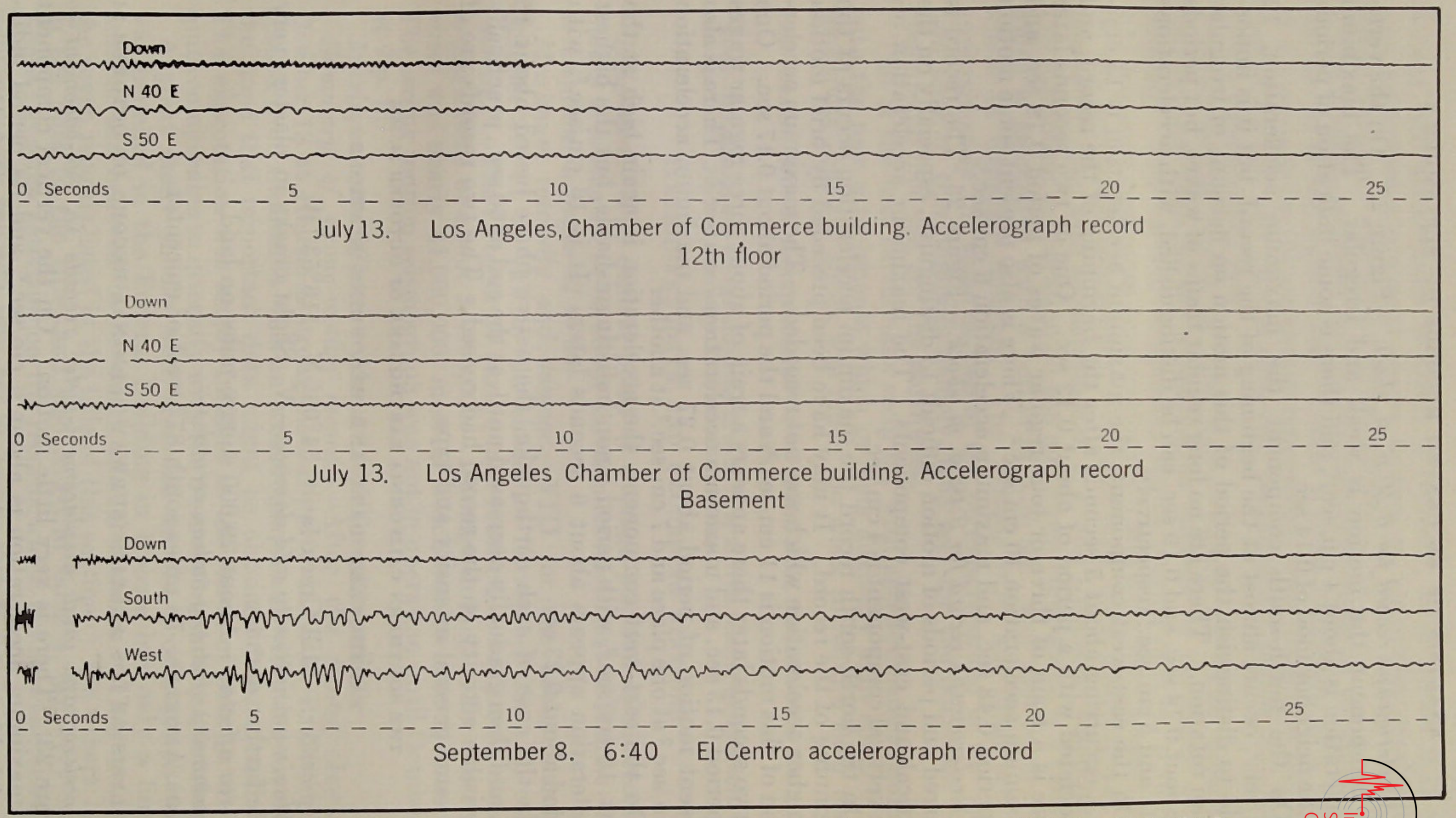



FIGURE 22.—Tracings of strong-motion seismograph records of southern California earthquakes of July 13 and September 8.

### ANALYSIS OF EL CENTRO RECORDS OF SEPTEMBER 8

*Accelerograph record for 6:40 a. m. shock.*—Figure 22. On the vertical component the motion is weak and irregular. The maximum acceleration is about 4 cm/sec.$^2$, and there is some indication of periods in the neighborhood of 0.14 sec.

On the north-south component the maximum acceleration, 12 cm/sec.$^2$, occurs almost at the beginning of the record, but it is impossible to distinguish the period of this motion on account of irregular drum rotation. There are no long regular trains of waves, but periods of about 0.14 sec. and 0.19 sec. can be distinguished, with accelerations of 11 and 5 cm/sec.$^2$ respectively.

On the east-west component, the maximum acceleration is 15 cm/sec.$^2$, occurring about 5 seconds after the beginning of the record, and associated with a period of about 0.12 sec. One or two seconds later there is a train of three or four regular waves of period 0.18 sec. and maximum acceleration 10 cm/sec.$^2$ There is also present some motion of period 0.48 sec. and maximum acceleration 6 cm/sec.$^2$

*Accelerograph record for 9:03 a. m. shock.*—Figure 23. The record is blurred and periods of motion difficult to distinguish, especially on the vertical and east-west components. The maximum acceleration on the vertical component is 4 cm/sec.$^2$

On the north-south record the maximum acceleration occurs at the beginning of the record. It may have been preceded by brief motion of higher acceleration which was not recorded. The maximum acceleration of this motion is 11 cm/sec.$^2$, and the period about 0.17 sec. One or two seconds later there appears a train of about three regular waves of period 0.15 sec. and maximum acceleration 7 cm/sec.$^2$ There is also present motion of period about 0.27 sec. and maximum acceleration 5 cm/sec.$^2$ at one place and 7 cm/sec.$^2$ at another.

On the east-west component, the acceleration is again high at the start, 10 cm/sec.$^2$, with period again indistinguishable, but the highest acceleration appears about 6 seconds later. It is 16 cm/sec.$^2$, with period about 0.23 sec.

In the case of each earthquake, the active phase lasted about 15 sec. and then gradually decreased until, at the end of 60 sec., practically all visible activity on the record had ceased. The two records are of the same general intensity and type.

## THE SOUTHERN CALIFORNIA EARTHQUAKE OF OCTOBER 24, 1935

### EARTHQUAKE DATA AND RECORDING STATIONS

*Epicenter.*—Mill Creek fault, 34°06′ N., 116°53′ W.

*Maximum intensity and damage.*—V. Slight cracks in plaster; very little further damage.

*Area affected.*—About 29,000 square miles on land.

*Summary of strong-motion records.*—

Los Angeles: 78 miles south 87° west of epicenter.

### ANALYSIS OF LOS ANGELES SUBWAY TERMINAL RECORD OF OCTOBER 24

*Accelerograph and displacement-meter records in sub-basement.*—Figure 23. There is very little motion. On the vertical component the maximum acceleration is about ½ cm/sec.$^2$, and its period indistinguishable. On the northeast (more precisely N. 40° E.) com-

ponent, the acceleration is about ⅓ cm/sec.$^2$, with period 0.12 sec. The northwest component shows motion of maximum acceleration about ½ cm/sec.$^2$ and period about 0.20 sec.

The motion recorded on the displacement-meter is so slight that the record is not reproduced. There is some indication of a period of 1.7 seconds on the northeast component, with maximum displacement 0.02 cm, and on the east-west component a period of 1.4 sec. with amplitude 0.01 cm.

*Accelerograph record on 13th floor.*—Figure 23. The motion is greater here than in the subbasement because of resonance of the building. The vertical component shows periods of 0.18, 0.16, and 0.14 sec. with maximum accelerations 1, ½ and 2 cm/sec.$^2$, respectively. On the north-east component periods of 0.70, 0.62, and 0.12 sec. are distinguishable, with accelerations of 1, 2, and 1 cm/sec.$^2$, respectively. The maximum acceleration on the northwest component is 2 cm/sec.$^2$, which is associated with a period of 0.59 sec., and also occurs elsewhere in irregular motions. The periods 0.70 and 0.59 sec. are approximately the same as two of the periods recorded in the vibration tests of this building, namely, 0.68 sec. for the northeast component and 0.56 sec. for the northwest.

This is the first earthquake recorded with accelerometers equipped with the new attachments which provide auxiliary light spots of low sensitivity, but the shock was much too weak to require their use.

## THE HELENA, MONT., EARTHQUAKES OF OCTOBER 27, 31, NOVEMBER 4, 5, 6, 21, AND 28, 1935

NOTE.—Minor shocks were recorded on October 23, 24, 26, 27, 28, 30, 31 (at 11:50), 31 (at 14:00), 31 (at 15:40), and 31 (at night). For these there are no illustrations nor analyses.

### EARTHQUAKE DATA AND RECORDING STATIONS

*Epicenters.*—The central point or average position of all recorded shocks is estimated to be about three miles northeast of Helena. See description on pages 42 to 56.

*Maximum intensity and damage.*—VIII for the heavy shock of October 31; VI to VII for the shocks of November 28. All others "strong." The October 31 earthquake resulted in additional damage to the extent of about $1,000,000. Damage in Helena for the entire series was nearly $4,000,000, most of which occurred on October 18. The strong motion seismograph was not in operation until October 21 at 9 p. m.

*Maximum area affected.*—About 140,000 square miles.

*Summary of strong-motion records.*—After the strong shock of October 18 at Helena a strong-motion party under F. P. Ulrich was rushed from California with an accelerograph and vibration meters in the hope that important data might be obtained from aftershocks. This expectation was amply fulfilled as the shock of October 31 was quite comparable in intensity with the destructive shock of October 18.

A great many shocks were recorded on the accelerograph which was installed in the Federal Building in Helena but only a limited number are believed to be worth special mention. They comprise the seven records listed in the title of this section. Ten others listed in the note to the title, and also listed in table 4, are very weak. There are some activities on the records which are so weak that it is difficult to tell whether they are of seismic origin.

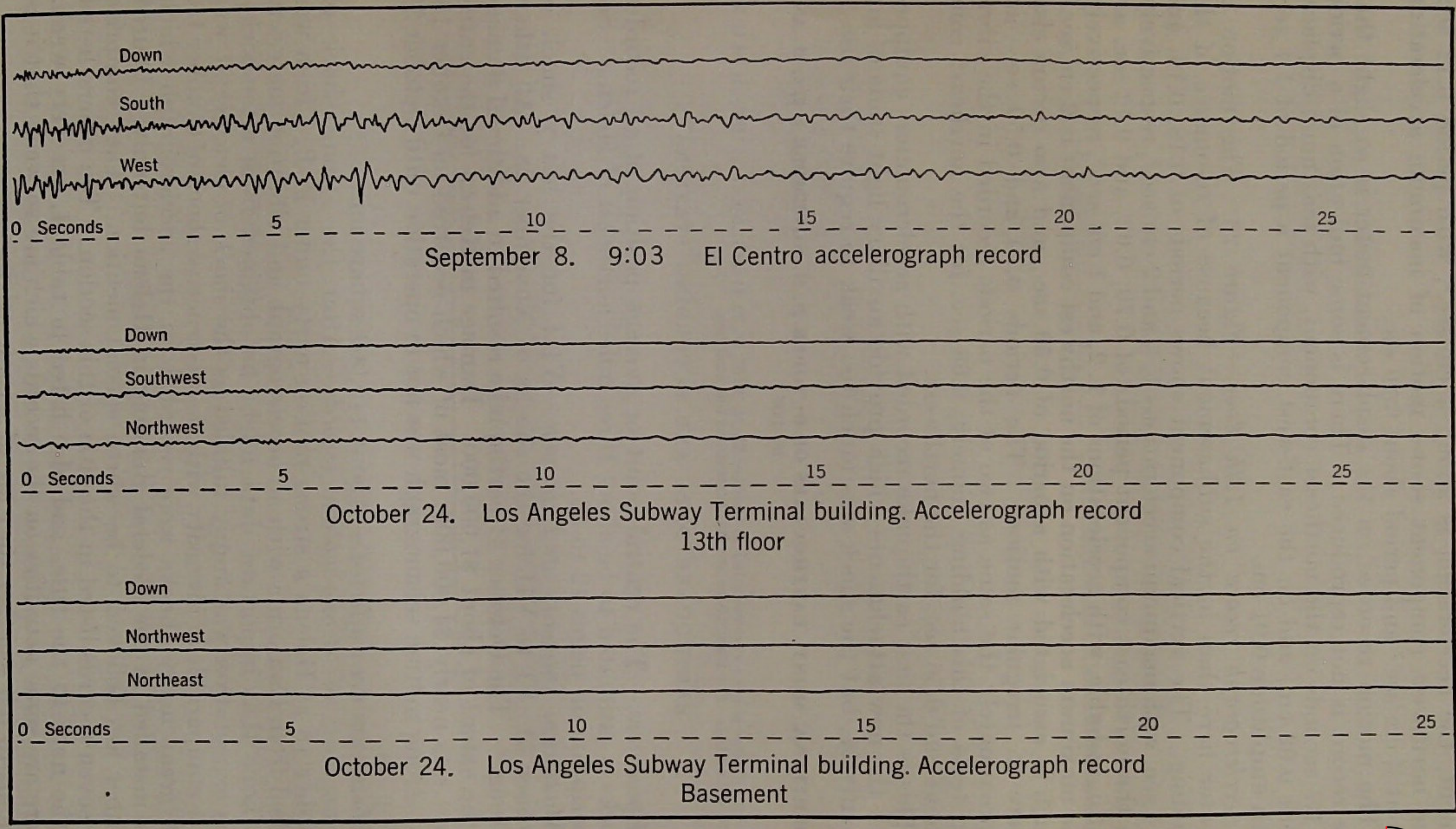



FIGURE 23.—Tracings of strong-motion seismograph records of southern California earthquakes of September 8 and October 24.

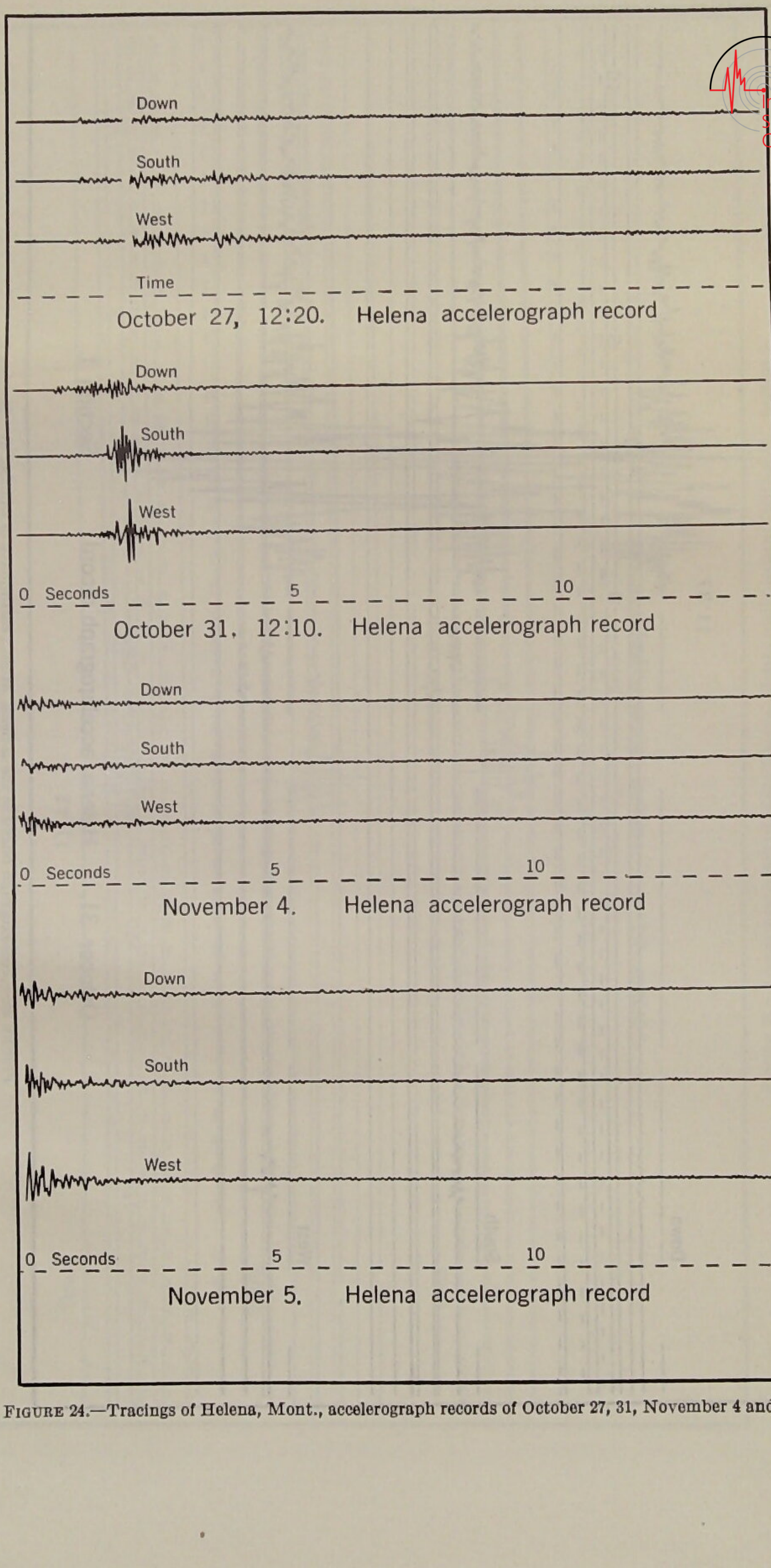





FIGURE 24.—Tracings of Helena, Mont., accelerograph records of October 27, 31, November 4 and 5.

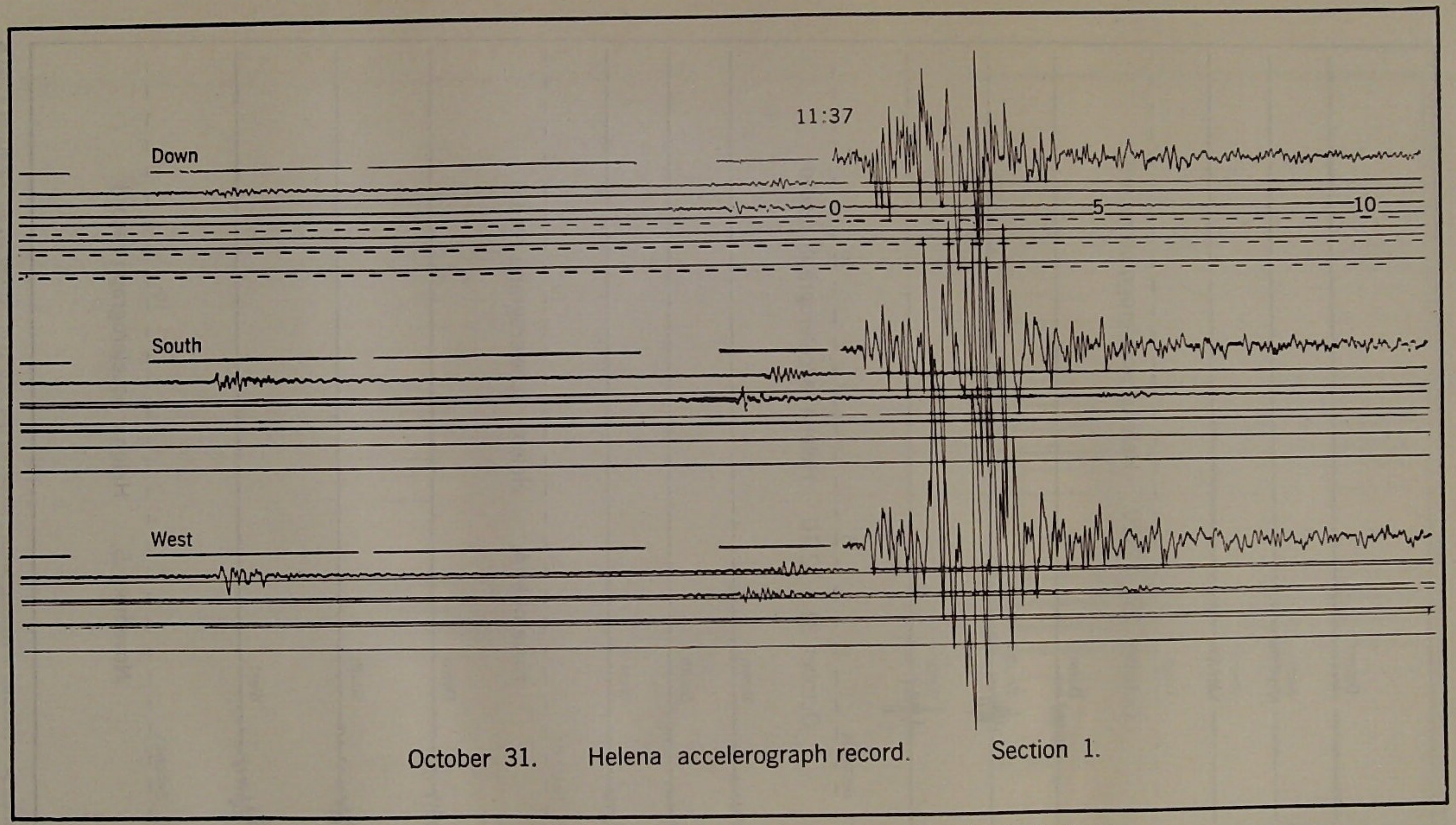



FIGURE 25.—Accelerograph record of the Helena, Mont., earthquake of October 31. Section 1.

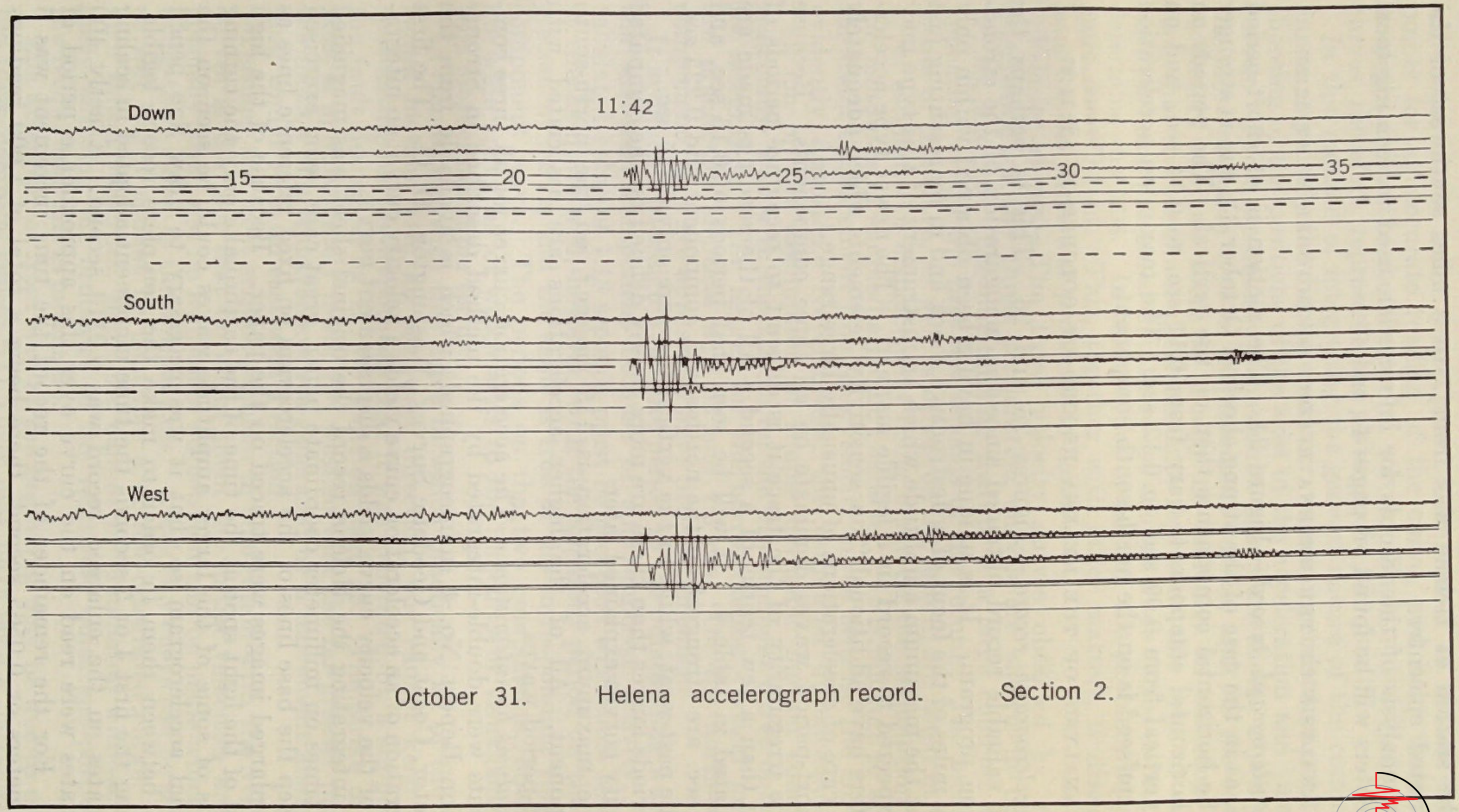



FIGURE 26.—Accelerograph record of the Helena, Mont., earthquake of October 31. Section 2.

The station at Helena was from 2 to 5 miles southwest of the estimated epicenter.

An analysis of the records for information used in locating local epicenters will be found on pages 44 and 45.



### ANALYSIS OF THE HELENA RECORD OF OCTOBER 27 AT 12:20

*Accelerograph record.*—Figure 24. The motion is of short-period type, as in the case of the strong shock of October 31, and is stronger on the horizontal components than on the vertical. The periods on the horizontal components vary from 0.11 sec. to 0.14 sec., and on the vertical from 0.09 sec. to 0.12 sec. The maximum acceleration of 7 cm/sec.$^2$ is on the north-south component.

### ANALYSIS OF THE HELENA RECORD OF OCTOBER 31 AT 11:37

*Accelerograph record.*—Figures 25 and 26. This is perhaps the most valuable record obtained since the inauguration of the strong-motion program. It is unique in having been obtained within only a few miles of the focus of a destructive shock and in representing just about the maximum amplitude which an instrument of this type may be expected to record in a legible manner. (The newer type accelerometers have additional "low sensitivity" elements which adequately take care of accelerations of unusually large range.)

Short-period waves dominate on all three components. Because of the irregularity of the trace it is difficult to recognize periods of more than a few tenths of a second. All of the readings made are tabulated in table 4. It will be seen that periods of 0.16 sec. and 0.13 sec. are strongest on the north-south component and 0.225 sec. on the east-west; while on the vertical they are only 0.125 sec.

Periods longer than these are more clearly defined on the computed velocity curves explained later.

The maximum acceleration is 115 cm/sec.$^2$, on the north-south component. All of the higher accelerations are associated with short-period waves.

*Analysis by integration.*—The acceleration curves for all three components were double-integrated by the method described in Strong-Motion Report No. 4 (mimeographed) which is available from the Director, Coast and Geodetic Survey, Washington, D. C. The first integration of an acceleration curve yields a velocity curve; an integration of the velocity curve yields a displacement curve.

In integrating the Helena record the original sheet was magnified 7.62 times on millimeter coordinate paper, great care being exercised to keep the base lines of the accelerogram on fixed reference lines as the enlarged images were traced on the paper. Because of the high speed of the light spot at the time of the earthquake only the turning points of some of the larger amplitude waves could be seen on the original accelerogram so that it was necessary to draw fine pencil lines between them in order to make the complete record legible. During the first 4 or 5 seconds the time increment adopted in scaling ordinates on the enlarged record was 0.0113 second. Exactly 400 ordinates were read on the curve over this approximate period of time. For the remainder of the record the time increment was 5 millimeters or 0.0565 second, there being a total of 1,000 readings for the larger increment. It was necessary to use the smaller time

increment in the more active part of the record to obtain enough points for an accurate reading of the curve, and have enough to properly define the shorter period waves. Each of the 6 computed curves, therefore, represents the plotting of 1,320 points.

In this method of integrating the general nature of the computed curves, especially the displacement curves, are dependent on arbitrary choosing of the positions of the axes of the acceleration and velocity curves. These are unknown constants. Axes are chosen which yield the most probable type of displacement curves, and, in the case of oscillatory motion, there is usually no difficulty in choosing axes such that the resultant displacements represent this type of movement, it being presumed that there are enough wave cycles to properly determine the axis. In other types of motion the problem becomes more complicated. This, together with other matters, is discussed later for the particular problems in hand.

*Velocity curves.*—The three velocity curves obtained by single integration of the three acceleration curves are shown in figures 27, 28, and 29. The outstanding feature is a large complex wave appearing within the first few seconds of the record. The measurements of this wave, as well as others on the record, are listed in table 4, all estimates of displacement being made on the assumption that the motion is of simple harmonic character. It is difficult to obtain the exact displacement from the velocity curve because the curve is evidently distorted. Nevertheless, the estimated displacement of 1.82 cm on the assumption of simple harmonic motion compares reasonably well with the 2.2 cm on the displacement curve obtained by integration. The figures for the corresponding vertical motion are practically identical at 1.62 and 1.6 cm. On the north-south component the wave appears to have little significance.

It is difficult to assign a definite period to the outstanding wave on the east-west component because of superimposed activity. The tabulated value of 1.18 seconds must be accepted with some reserve. It checks quite well, however, with the apparent period on the displacement curve, and the same is true of the corresponding vertical-component wave. The periods on the two components, however, are wide apart, all of which adds to the difficulty of visualizing the true motion in simple terms.

In connection with this wave in which practically all of the horizontal motion is in an east-west direction, one cannot keep from speculating on the hypothesis that it was generated by a slipping of the fault described by H. W. Scott on page 55. The strike of this fault is approximately north 75° west so that the far greater part of the motion of a transverse wave generated by a movement along the fault would be in an east-west direction.

Perhaps the most serious problem in connection with the velocity curves is the fact that on all of them the initial velocities are abnormally high, and no legitimate adjustment can be made which will bring them closer to the normal axes. A velocity curve can be shifted at will but it cannot be bent like a double-integrated curve. The high initial velocities, therefore, cannot be eliminated without seriously affecting the ordinates in the relatively quiet end-portion of the record and this is untenable.

The divergencies from zero at the beginning may be due to one of the three following causes: (1) There may have been a movement of the ground which had actually reached the computed velocities by

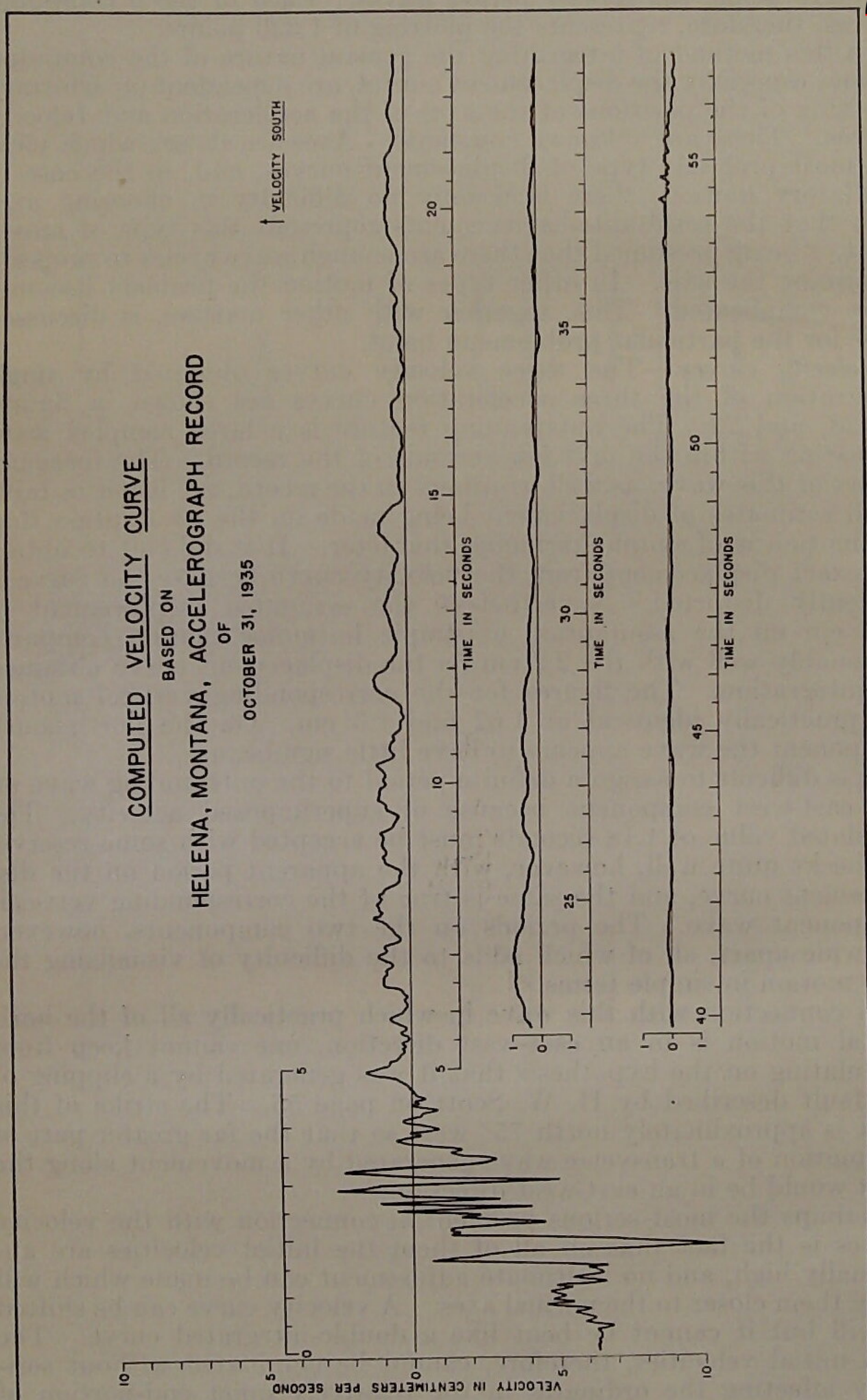



FIGURE 27.—Velocity curve computed from the Helena, Mont., accelerograph record of October 31. North-south component.

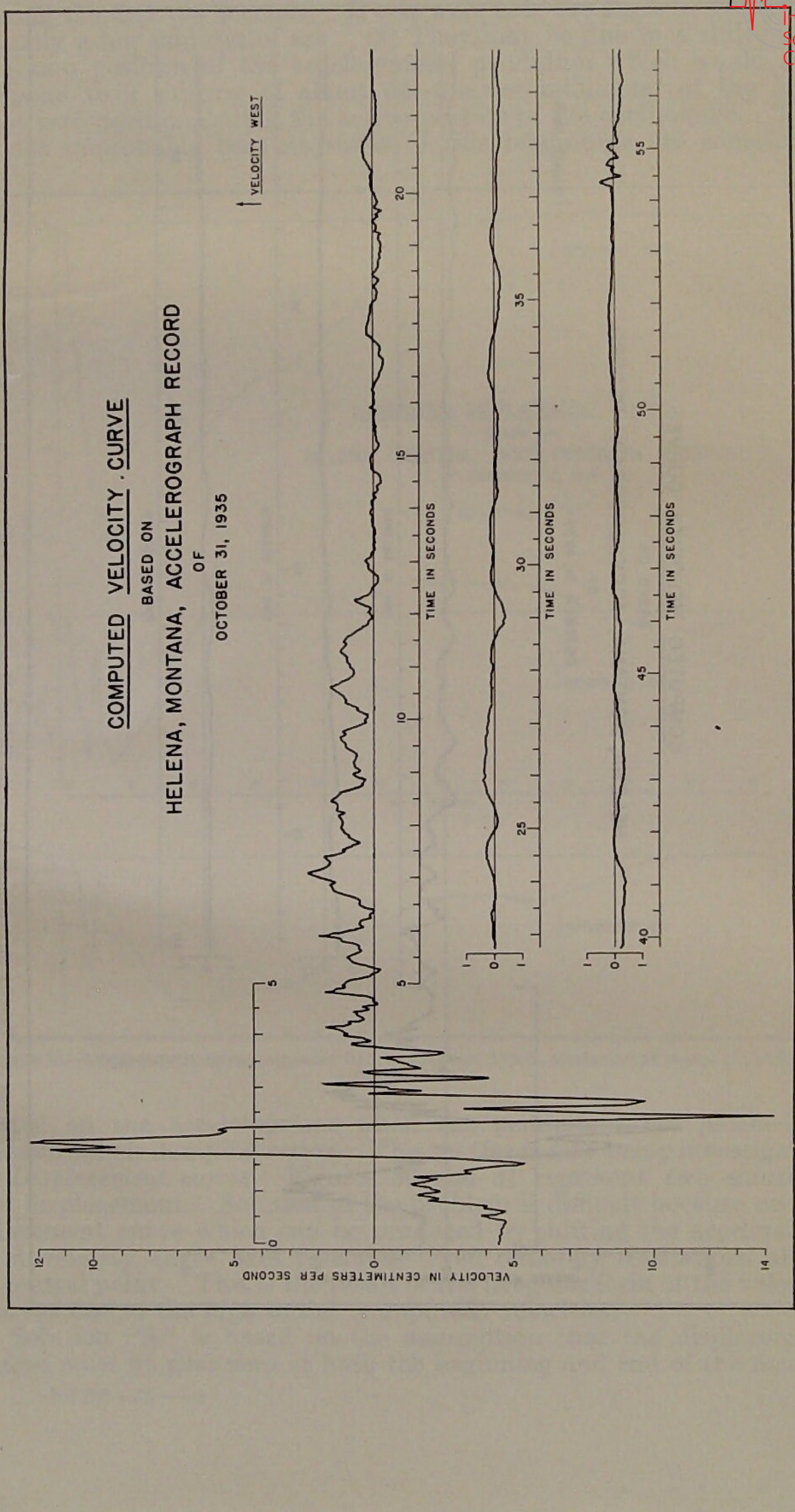



FIGURE 28.—Velocity curve computed from the Helena, Mont., accelerograph record of October 31. East-west component.

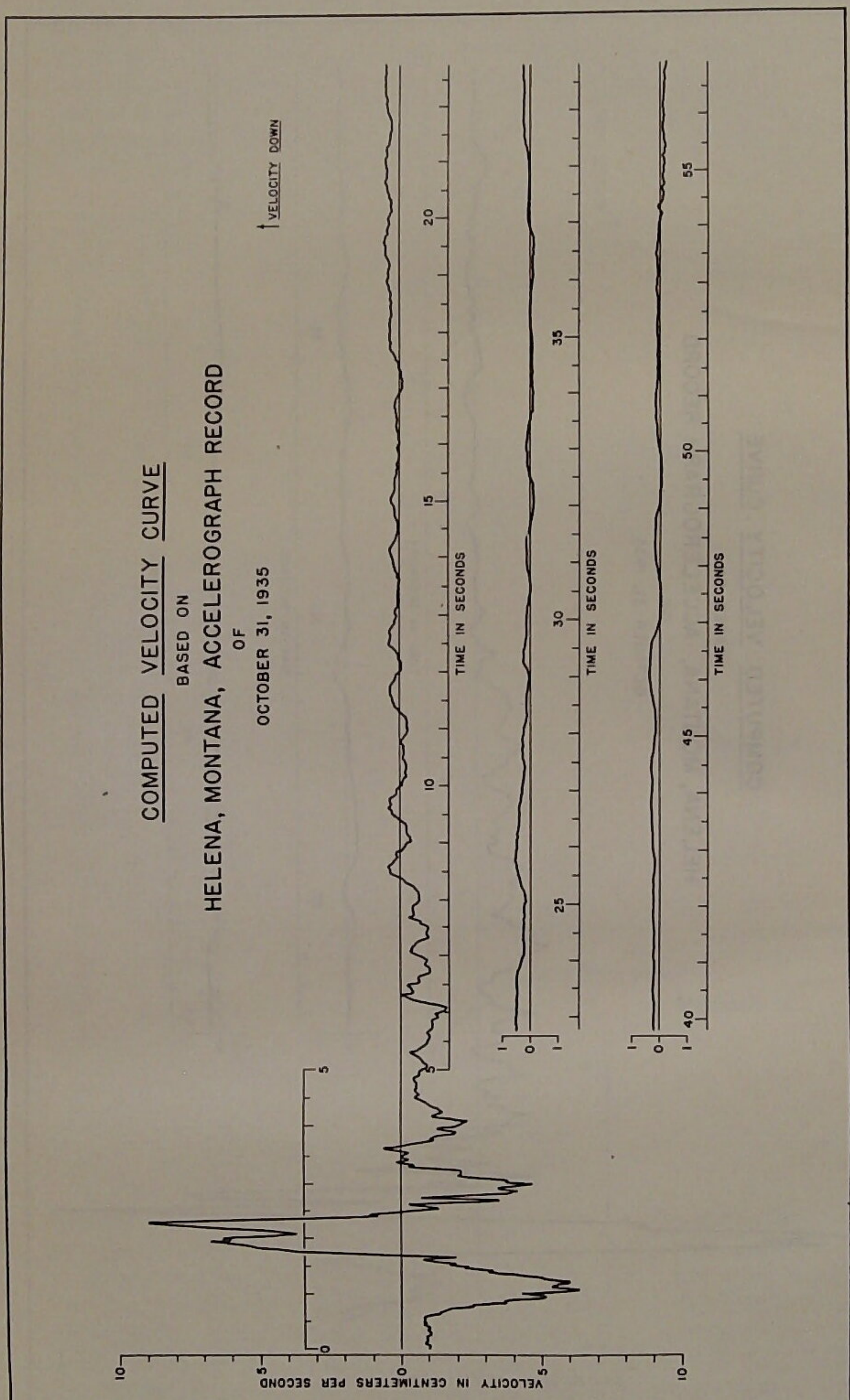



FIGURE 29.—Velocity curve computed from the Helena, Mont., accelerograph record of October 31. Vertical component.

the time the accelerograph began recording. It may be a true velocity record. (2) They may be due to a permanent tilting of the ground during the first few seconds. If this were true the angle of tilt would be only a few minutes of arc. (3) They may be due to a shifting of the zero position of the accelerometer pendulum which would correspond to a shifting of about one-quarter millimeter of the light spot zero position during the active portion of the earthquake. This is not improbable because shifts of this magnitude are sometimes

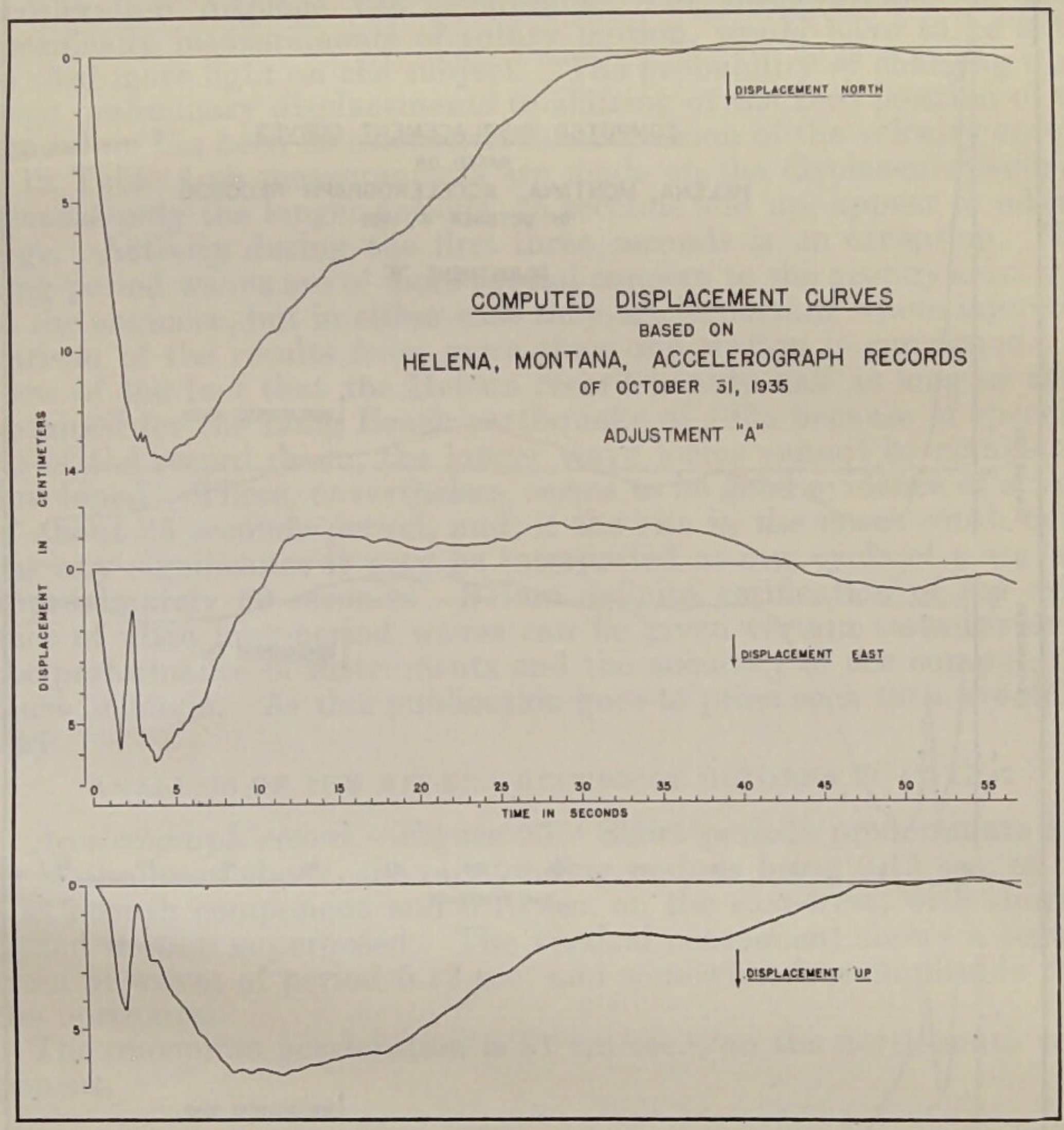



FIGURE 30.—Displacement curves computed from the Helena, Mont., accelerograph record of October 31. Adjustment "A".

noted on the accelerograms when the pendulums are plucked to measure their damping ratios. This matter is now being investigated.

*Displacement curves.*—Figures 30 and 31 represent two solutions for displacement. Solution of the problem is difficult because no displacement curve which can be produced by shifting the acceleration and velocity curve axes resembles even remotely oscillations about a central point. This is the result of the irregular form of the velocity curves due to the high initial (computed) velocities.

Solution "A" is based on the assumption that the displacement curve must be near zero at both the beginning and end of the record.

In the case of a permanent displacement this would obviously not be true. Solution "B" assumes that there is a permanent displacement during the first few seconds of the earthquake and that the axis, or final zero position of the pendulum, can be determined from the quiet portion of the record which comprises about three-fourths of the entire run.

As adjustment "A" cannot be reconciled with any type of motion thus far known in an epicentral region it should, in the author's opin-



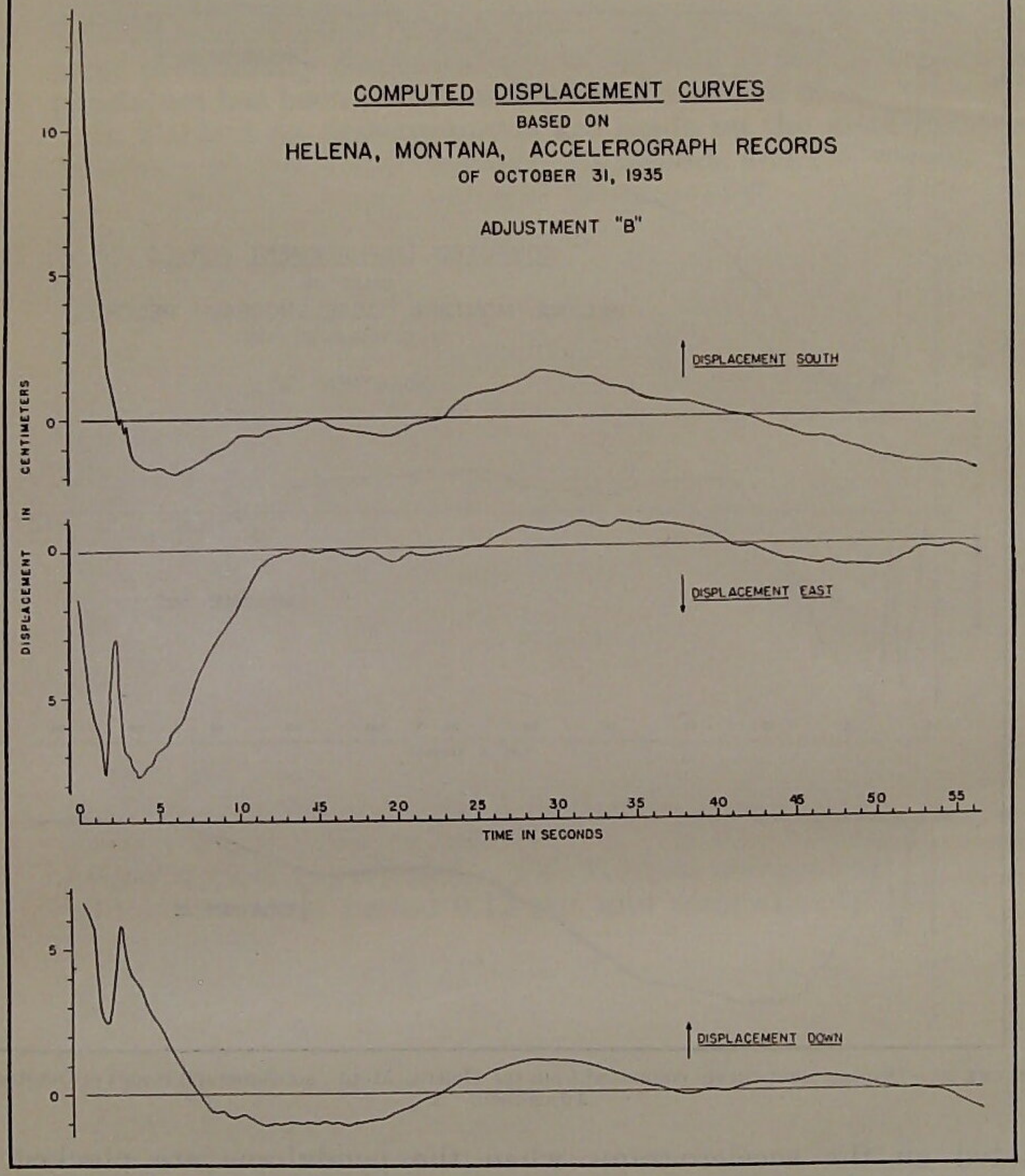



FIGURE 31.—Displacement curves computed from the Helena, Mont., accelerograph record of October 31. Adjustment "B".

ion, be ruled out at least tentatively. Adjustment "B" obtained by shifting the axes of the acceleration and velocity curves, is much more susceptible to explanation. If permanent displacement is the real answer it is possible that a verification will to some extent be available when the results of releveling operations are known. The Coast and Geodetic Survey is rerunning an old line of levels in the vicinity of Helena for the specific purpose of measuring possible changes in elevation. Adjustment "B" indicates an increase in elevation of

about 7 cm due to the disturbance of October 31 alone, and a rerunning of precise levels would detect changes of this order. With the triangulation scheme now established in the Helena region it is questionable whether even the 14-cm northward movement indicated in adjustment "B" could be detected by repeat observations.

The problem of block tilting or any other type of tilting is difficult of solution because there is no way to distinguish on a seismograph or accelerograph record between displacement of the pendulum due to tilt and displacement due to horizontal motion. Both types of acceleration displace the pendulum. Tilt observations, or more specifically measurements of rotary motion, would have to be made to shed more light on the subject. The probability of charging these large preliminary displacements to shifting of the zero position of the pendulum has been mentioned in the discussion of the velocity curves.

In Table 4 no measurements are made on the displacement curves because only the longer periods, 15 seconds and up, appear to advantage. Activity during the first three seconds is an exception. The long-period waves are of more special concern to the geophysicist than to the engineer, but in either case they are important where intercomparison of the results from more than one station is concerned. In view of the fact that the Helena record is only half as long as those obtained for the Long Beach earthquake of 1933 because of speeding up of the record drum, the longer wave forms cannot be completely developed. There, nevertheless, seems to be good evidence of a wave of about 25 seconds period, and, if the rise in the north-south curve has any significance it may be interpreted as one cycle of a wave of approximately 50 seconds. Before definite verification of the existence of ultra long-period waves can be given certain tests involving the performance of instruments and the accuracy of the computation must be made. As this publication goes to press such tests are under way.

### ANALYSIS OF THE HELENA RECORD OF OCTOBER 31 AT 11:42

*Accelerograph record.*—Figure 26. Short periods predominate here as in the main shock, the outstanding periods being 0.15 sec. on the north-south component and 0.10 sec. on the east-west, with shorter-period motion superposed. The vertical component shows a regular train of waves of period 0.12 sec. and somewhat less amplitude than the horizontal.

The maximum acceleration is 51 cm/sec.$^2$, on the north-south component.

### ANALYSIS OF THE HELENA RECORD OF OCTOBER 31 AT ABOUT 12:10

*Accelerograph record.*—Figure 24. The outstanding feature is the appearance on all components, but especially the horizontal, of regular waves of period 0.08 sec. There is also some longer-period motion, and some low-amplitude motion of very short period superposed.

The maximum acceleration is about 42 cm/sec.$^2$ on both horizontal components.

### ANALYSIS OF THE HELENA RECORD OF NOVEMBER 4

*Accelerograph record.*—Figure 24. This is a weak record of short-period type, showing a maximum acceleration of 9 cm/sec.$^2$, on the east-west component.

ANALYSIS OF THE HELENA RECORD OF NOVEMBER 5

*Accelerograph record.*—Figure 24. The maximum acceleration, about 24 cm/sec.$^2$, occurs at the beginning of the record on the east-west component and may have been preceded by stronger motion of brief duration. The periods are short, from about 0.10 sec. to 0.15 sec., with some indications of low-amplitude motions both of shorter and longer periods.



ANALYSIS OF THE HELENA RECORD OF NOVEMBER 6

*Accelerograph record.*—Figure 32. A weak record of short-period type showing maximum acceleration of 9 cm/sec.$^2$ near the beginning of the vertical component record.

ANALYSIS OF THE HELENA RECORD OF NOVEMBER 21

*Accelerograph record.*—Figure 32. A weak record with most pronounced motion having a period 0.22 sec. There are present also some waves of period 0.25 sec., and some weak vibrations of short period. The maximum acceleration is 8 cm/sec.$^2$

ANALYSIS OF THE FIRST HELENA RECORD OF NOVEMBER 28

*Accelerograph record.*—Figure 33. Short-period motion predominates, being very regular on the horizontal components. Its period is about 0.10 or 0.11 sec., and maximum acceleration about 80 cm/sec.$^2$, practically the same on both horizontal components. There is also some longer-period motion present on all components, and some traces of shorter-period motion on the vertical, but it is rather indefinite.

The smoothness of the train of large amplitude 0.10 sec. waves is an unusual feature of this record there being from four to five waves of quite uniform character on each component.

ANALYSIS OF THE SECOND HELENA RECORD OF NOVEMBER 28

*Accelerograph record.*—Figure 33. Motion of period 0.11 sec. is again prominent on the horizontal components, especially the east-west. The vertical component shows longer periods, 0.31, 0.16, and 0.15 sec., with weak short-period motion superposed.

The maximum acceleration is associated with a single wave of 0.10 sec. period on the east-west component. A few other waves on the same component have little more than half that amplitude. Although it follows the start of the preceding shock by only nine seconds the second record is much more irregular in character and the maximum portion is of shorter duration.

## THE IMPERIAL VALLEY EARTHQUAKE OF DECEMBER 19, 1935

EARTHQUAKE DATA AND RECORDING STATIONS

*Epicenter.*—Imperial Valley, 33°10′ N, 115°30′ W., according to Pasadena.

*Maximum intensity and damage.*—V at El Centro. No damage.

*Area affected.*—Small.

*Summary of strong-motion records.*—

El Centro: 23 miles south 8° west of epicenter.

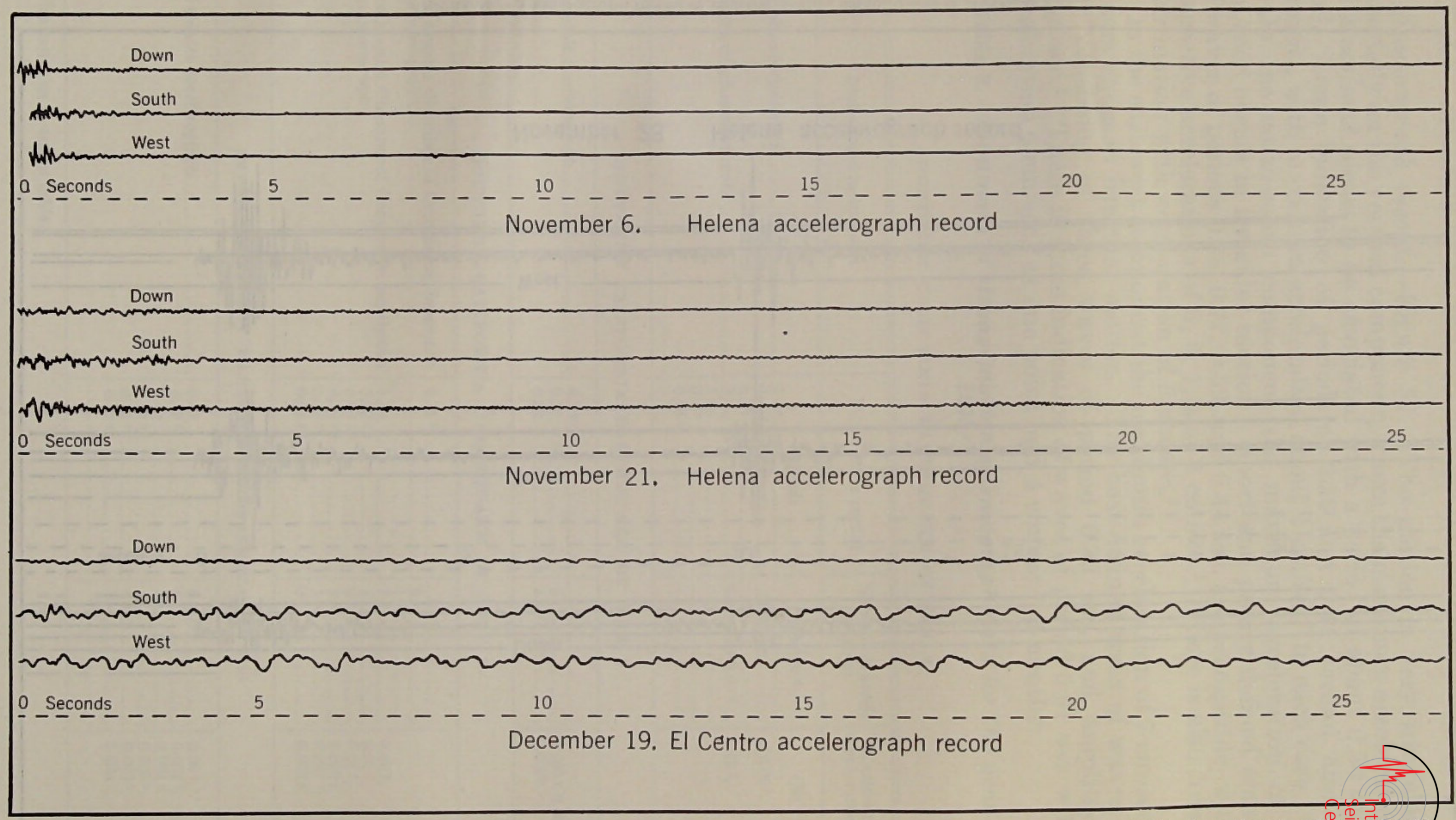
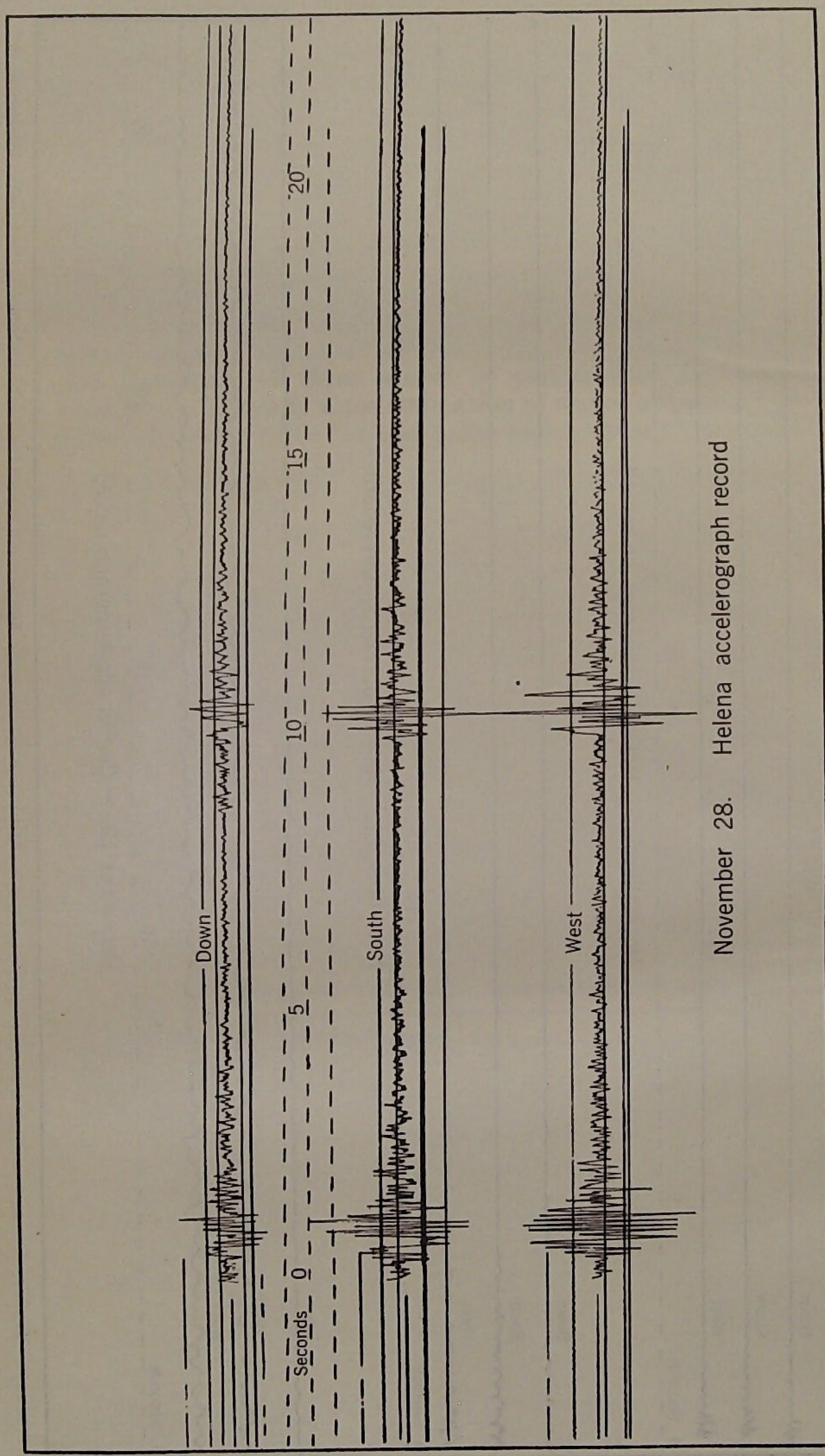



FIGURE 32.—Tracings of strong-motion seismograph records of the Helena, Mont., earthquakes of November 6 and 21, and the southern California earthquake of December 19.




November 28. Helena accelerograph record

FIGURE 33.—Accelerograph record of Helena, Mont., earthquakes of November 28.

ANALYSIS OF EL CENTRO RECORD OF DECEMBER 19

*Accelerograph record.*—Figure 32. The motion is very irregular, especially on the vertical component, where the maximum acceleration of 2 cm/sec.$^2$ seems to be associated with a period of about 0.28 second. Some indication of periods of 0.36 and 0.44 second also is present, with maximum acceleration about 1 cm/sec.$^2$ in each case.

On the north-south component the maximum acceleration of 7 cm/sec.$^2$ occurs in irregular motion. Short and poorly defined trains of waves of periods 0.88, 0.77, 0.52, and 0.44 sec. are perceptible, with respective accelerations of 5, 6, 1, and 2 cm/sec.$^2$ There is also irregular motion with acceleration of 5 cm/sec.$^2$

On the east-west component the maximum acceleration of 7 cm/sec.$^2$ occurs again in irregular motion. The best defined train of waves is one consisting of three waves of period 0.39 sec. and amplitude 4 cm/sec.$^2$ There is some indication of waves of period 0.91 sec. with acceleration 6 cm/sec.$^2$ at one point and 4 cm/sec.$^2$ at another.



**Table 3.—*Summary of strong-motion seismograph data for the year 1935*** [1]

| Station and instrument | Earth-wave period | Maximum acceleration | Maximum displacement |
|---|---|---|---|
| | *Seconds* | *Cm/sec.*$^2$ | *Cm* |
| **NORTHERN CALIFORNIA EARTHQUAKE OF JAN. 2** | | | |
| Eureka accelerograph | 1 [2 3] | | |
| | 0.4–0.5 | <3 [4] | <0.02 [5]. |
| | 0.15–0.50 | | |
| Eureka displacement meter | 3, 5, 10 [6] | 0.5,[5] 0.2,[5] 0.05 [5] | 0.12 [7]. |
| | 1 [3] | | |
| | 0.5 [3] | | |
| | 0.25 [3] | | |
| **NORTHERN CALIFORNIA EARTHQUAKE OF MAR. 3** | | | |
| Ferndale accelerograph | 0.5 [8] | | |
| | 0.20, 0.15 | 5 [4] | 0.005 [5], 0.003 [5]. |
| | 0.20 | 2.5 [2 9] | 0.0025.[5] |
| **SOUTHERN CALIFORNIA EARTHQUAKE OF JULY 13** | | | |
| Los Angeles Chamber of Commerce, basement accelerograph. | 0.14 [8] | | |
| | | 2 [6] | |
| | | 1 [6 9] | |
| Los Angeles Chamber of Commerce, penthouse accelerograph. | 1.18 | 1 | 0.04 [5]. |
| | 0.52 [2 6] | 3 | 0.02 [5]. |
| | 0.48 [2 6] | 2 [2] | 0.01 [5]. |
| | 0.20 [2 6] | 2 [2] | 0.002 [5]. |
| | 0.19 [10] | 1— | 0.001 [5]. |
| | 0.16 [2 9] | 3 [2] | 0.002 [5]. |
| **IMPERIAL VALLEY EARTHQUAKE OF SEPT. 8 AT 6:40** | | | |
| El Centro accelerograph | 0.48 | 6 | 0.04 [5]. |
| | 0.19 [2] | 5 | 0.005 [5]. |
| | 0.18 | 10 | 0.008 [5]. |
| | 0.14 [2] | 11 | 0.005 [5]. |
| | 0.14 [2 6] | 4 [3] | 0.002 [5]. |
| | 0.12 [2] | 15 [4] | 0.005 [5]. |
| | | 12 [6] | |

See footnotes at end of table.

**Table 3.—*Summary of strong-motion seismograph data for the year 1935*—Continued**



| Station and instrument | Earth-wave period | Maximum acceleration | Maximum displacement |
|---|---|---|---|
| | *Seconds* | *Cm/sec.*[2] | *Cm* |
| **IMPERIAL VALLEY EARTHQUAKE OF SEPT. 8 AT 9:03** | | | |
| El Centro accelerograph | 0.27 [2] | 5, 7 | 0.009 [5], 0.013 [5]. |
| | 0.23 [2] | 16 [4] | 0.021 [5]. |
| | 0.17 [2] | 11 | 0.008 [5]. |
| | 0.15 | 7 | 0.004 [5]. |
| | | 10 | |
| | | 4 [9 11] | |
| **SOUTHERN CALIFORNIA EARTHQUAKE OF OCT. 24** | | | |
| Los Angeles subway terminal, basement accelerograph. | 0.20 | 0.5 [2 4] | 0.0005 [5]. |
| | 0.12 | 0.3 [2] | 0.0001 [5]. |
| | | 0.5 [2 9 11] | |
| Los Angeles subway terminal, basement displacement meter. | 1.7 [8] | 0.3 [5] | 0.02. |
| | 1.4 [8] | 0.2 [5] | 0.01. |
| Los Angeles subway terminal, 13th floor accelerograph. | 0.70 [13] | 1 | 0.01 [5]. |
| | 0.62 | 2 | 0.02 [5]. |
| | 0.59 [13] | 2 | 0.02 [5]. |
| | 0.18 | 1 | 0.001 [5]. |
| | 0.16 | 0.5 | 0.0003 [5]. |
| | 0.14 | 2 | 0.001 [5]. |
| | 0.12 | 1 | 0.0004 [5]. |
| **HELENA, MONT., EARTHQUAKE OF OCT. 27 AT 12:20 [12]** | | | |
| Helena accelerograph | 0.14 | 7 | 0.003 [5]. |
| | 0.13 | 6 | 0.002 [5]. |
| | 0.12 [9 15] | 3 | 0.001 [5]. |
| | 0.11 | 5, 6 | 0.002 [5]. |
| | 0.10 [8 9] | 4 | 0.001 [5]. |
| | 0.09 [9] | 4 | 0.001 [5]. |
| **HELENA, MONT., EARTHQUAKE OF OCT. 31 AT 11:37** | | | |
| Helena accelerograph. See special tabulations for main shock in table 5. | | | |
| **HELENA, MONT., EARTHQUAKE OF OCT. 31 AT 11:42** | | | |
| Helena accelerograph | 0.28 | 14 | 0.028 [5]. |
| | 0.21 [9] | 13 | 0.015 [5]. |
| | 0.15 | 51 | 0.029 [5]. |
| | 0.12 [9] | 19 | 0.007 [5]. |
| | 0.10 | 41 | 0.010 [5]. |
| **HELENA, MONT., EARTHQUAKE OF OCT. 31 AT ABOUT 12:10** | | | |
| Helena accelerograph | 0.14 [9] | 3 | 0.001 [5]. |
| | 0.13 | 10 | 0.004 [5]. |
| | 0.08 | 40, 43 [15] | 0.006 [5], 0.007 [5]. |
| | 0.08 [9] | 10 | 0.002 [5]. |
| **HELENA, MONT., EARTHQUAKE OF NOV. 5** | | | |
| Helena accelerograph | 0.15 | 18 | 0.010 [5]. |
| | 0.13 [9] | 12 | 0.005 [5]. |
| | 0.10 | 18 | 0.005 [5]. |

See footnotes at end of table.

**Table 3.—*Summary of strong-motion seismograph data for the year 1935*—Continued**



| Station and instrument | Earth-wave period | Maximum acceleration | Maximum displacement |
|---|---|---|---|
| | *Seconds* | *Cm/sec.*[2] | *Cm* |
| **HELENA, MONT., EARTHQUAKE OF NOV. 21** | | | |
| Helena accelerograph | 0.25 [16] | 2 | 0.003 [5]. |
| | 0.22 | 8 | 0.010 [5]. |
| | 0.14 [9] | 4 | 0.002 [5]. |
| | 0.13 [9] | 5, 3 | 0.002 [5], 0.001 [5]. |
| | 0.08 | 5 | 0.001 [5]. |
| **HELENA, MONT., FIRST EARTHQUAKE OF NOV. 28** | | | |
| Helena accelerograph | 0.31 | 22 | 0.054 [5]. |
| | 0.28 | 17 | 0.034 [5]. |
| | 0.11 [9 17] | 35 | 0.011 [5]. |
| | 0.10 | 80, 77 | 0.020 [5]. |
| **HELENA, MONT., SECOND EARTHQUAKE OF NOV. 28** | | | |
| Helena accelerograph | 0.31 [9] | 9 | 0.022 [5]. |
| | 0.16 [9] | 10 | 0.006 [5]. |
| | 0.15 [9] | 15 | 0.009 [5]. |
| | 0.11 | 91, 63 | 0.028 [5], 0.019 [5]. |
| **IMPERIAL VALLEY EARTHQUAKE OF DEC. 19** | | | |
| El Centro accelerograph | 0.91 [8] | 6 | 0.14 [5]. |
| | 0.88 [8] | 5 | 0.10 [5]. |
| | 0.77 [8] | 6 | 0.09 [5]. |
| | 0.52 [8] | 1 | 0.01 [5]. |
| | 0.44 [8] | 2 | 0.01 [5]. |
| | 0.44 [8 9] | 1 | 0.005 [5]. |
| | 0.39 [14] | 4 | 0.02 [5]. |
| | 0.36 [8 9] | 1 | 0.003 [5]. |
| | 0.28 [2 8] | 2 | 0.004 [5]. |
| | | 7 [6 4], 5 [6] | |

[1] This tabulation does not attempt to combine the 2 horizontal components. See text for more detail and descriptions of the seismograms.

[2] Approximate value.

[3] Weak motion.

[4] Maximum acceleration on the record.

[5] Computed from the measured or previously computed acceleration or displacement by means of the formula $a=\frac{4\pi^2 A}{T^2}$, in which $a$ is the maximum acceleration, $T$ the period, and $A$ the displacement. In the case of waves not of simple harmonic form the results obtained by use of this formula are only approximate.

[6] Irregular motion.

[7] Maximum displacement on the record.

[8] Poorly defined waves.

[9] On the vertical component.

[10] Superposed on the 0.52 sec. period waves.

[11] Period indistinguishable.

[12] The minor Helena earthquakes of Oct. 23, 24, 26, 27 at 23:08, 28, 30, 31 at 11:50, 31 at about 14:00, 31 at about 15:40 [?], night of Oct. 31–Nov. 1, Nov. 4 and 6 are omitted from this tabulation. These are all weak aftershocks the records of which yield very little information.

[13] Two of the periods found for this building in vibration tests were 0.68 sec. and 0.56 sec.

[14] Well defined waves.

[15] Regular waves.

[16] Short-period motion of small amplitude superposed on these waves.

[17] Some shorter- and some longer-period motion also present, but not prominent, on the vertical component.

**Table 4.—*Analysis of the Helena, Mont., accelerograph records for the main shock of October 31***

[For each group of waves a value is tabulated for the minimum (a), the mean (b), and the maximum (c) in the group]



READINGS FROM THE ACCELEROGRAM

| Component | Time after beginning or record | Number of waves in group | Period | | Acceleration [1] | Velocity [2] | Displacement [3] | Acceleration [1] |
|---|---|---|---|---|---|---|---|---|
| | *Sec.* | | *Sec.* | | *Cm/sec.²* | *Cm/sec.* | *Cm* | *Gravity* |
| NS | 0.4–1.4 | 8 | 0.131 | a | 8 | 0.17 | 0.004 | 0.008 |
| | | | | b | 19 | 0.40 | 0.008 | 0.020 |
| | | | | c | 32 | 0.67 | 0.014 | 0.033 |
| NS | 1.5–1.7 | 1 | 0.159 | a | 57 | 1.45 | 0.037 | 0.058 |
| | | | | b | 59 | 1.49 | 0.038 | 0.060 |
| | | | | c | 61 | 1.53 | 0.039 | 0.062 |
| NS | 1.8–3.3 | 11.5 | 0.130 | a | 10 | 0.20 | 0.004 | 0.010 |
| | | | | b | 54 | 1.12 | 0.023 | 0.055 |
| | | | | c | 115 | 2.41 | 0.050 | 0.118 |
| NS | 3.4–4.2 | 3.5 | 0.198 | a | 12 | 0.38 | 0.012 | 0.021 |
| | | | | b | 18 | 0.56 | 0.018 | 0.018 |
| | | | | c | 21 | 0.66 | 0.021 | 0.012 |
| EW | 1.5–3.9 | 9 | 0.255 | a | 24 | 0.97 | 0.039 | 0.024 |
| | | | | b | 62 | 2.50 | 0.102 | 0.063 |
| | | | | c | 105 | 4.26 | 0.173 | 0.107 |
| Vertical | 2.6–2.8 | 2 | 0.125 | a | 37 | 0.73 | 0.015 | 0.037 |
| | | | | b | 60 | 1.20 | 0.024 | 0.061 |
| | | | | c | 78 | 1.55 | 0.031 | 0.080 |
| Vertical | 0.8–1.1 | 3.5 | 0.104 | a | 25 | 0.41 | 0.007 | 0.025 |
| | | | | b | 33 | 0.55 | 0.009 | 0.034 |
| | | | | c | 52 | 0.86 | 0.014 | 0.053 |

READINGS FROM THE COMPUTED VELOCITY CURVES

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| NS | 0.4–1.4 | 7.5 | 0.133 | a | 8 | 0.17 | 0.004 | 0.008 |
| | | | | b | 18 | 0.39 | 0.008 | 0.018 |
| | | | | c | 38 | 0.81 | 0.017 | 0.039 |
| NS | 1.6–2.1 | 1 | 0.501 | a | 57 | 4.51 | 0.364 | 0.058 |
| | | | | b | 60 | 4.76 | 0.380 | 0.061 |
| | | | | c | 62 | 4.98 | 0.397 | 0.063 |
| NS | 2.4–2.8 | 2.5 | 0.146 | a | 59 | 1.37 | 0.032 | 0.060 |
| | | | | b | 82 | 1.91 | 0.044 | 0.084 |
| | | | | c | 105 | 2.44 | 0.057 | 0.107 |
| NS | 2.9–3.4 | 1.5 | 0.364 | a | 45 | 2.58 | 0.150 | 0.046 |
| | | | | b | 57 | 3.32 | 0.193 | 0.058 |
| | | | | c | 65 | 3.76 | 0.218 | 0.066 |
| NS | 6.8–14.4 | 6 | 1.26 | a | 0.7 | 0.14 | 0.027 | 0.007 |
| | | | | b | 1.3 | 0.26 | 0.052 | 0.013 |
| | | | | c | 1.9 | 0.38 | 0.076 | 0.019 |
| EW | 0.9–1.4 | 4.5 | 0.109 | a | 0.3 | 0.005 | 0.0001 | 0.0003 |
| | | | | b | 23 | 0.40 | 0.0070 | 0.024 |
| | | | | c | 63 | 1.09 | 0.019 | 0.065 |
| EW | 1.9–3.1 | 1 | 1.18 [4] | a | 21 | 4.00 | 0.75 | 0.022 |
| | | | | b | 36 | 6.82 | 1.29 | 0.037 |
| | | | | c | 51 | 9.65 | 1.82 [4] | 0.052 |
| EW | 1.8–2.0 | 1 | 0.148 | a | 51 | 1.19 | 0.028 | 0.052 |
| | | | | b | 58 | 1.36 | 0.032 | 0.059 |
| | | | | c | 64 | 1.52 | 0.036 | 0.066 |
| EW | 2.4–3.4 | 4 | 0.230 | a | 24 | 0.87 | 0.032 | 0.025 |
| | | | | b | 56 | 2.04 | 0.075 | 0.057 |
| | | | | c | 83 | 3.06 | 0.112 | 0.085 |
| EW | 5.8–10.1 | 3.5 | 1.22 | a | 2.0 | 0.39 | 0.076 | 0.0020 |
| | | | | b | 3.1 | 0.60 | 0.117 | 0.0032 |
| | | | | c | 5.4 | 1.04 | 0.203 | 0.0055 |
| Vertical | 0.9–1.3 | 3 | 0.961 | a | 18 | 0.38 | 0.008 | 0.018 |
| | | | | b | 26 | 0.55 | 0.012 | 0.026 |
| | | | | c | 33 | 0.70 | 0.015 | 0.034 |
| Vertical | 1.9–2.2 | 1 | 0.307 | ---- | 41 | 1.98 | 0.097 | 0.042 |
| Vertical | 2.4–2.9 | 3 | 0.940 | a | 28 | 0.71 | 0.018 | 0.029 |
| | | | | b | 70 | 1.78 | 0.045 | 0.072 |
| | | | | c | 122 | 3.10 | 0.078 | 0.125 |
| Vertical | 1.1–2.9 | 1 | 1.82 [4] | ---- | 19 | 5.58 | 1.62 [4] | 0.020 |

[1] Accelerations obtained from the computed velocity curves are computed on the assumption that the motion is simple harmonic.

[2] Velocities obtained from the acceleration curves are computed on the assumption that the motion is simple harmonic.

[3] All displacements are computed on the assumption that the motion is simple harmonic.

[4] Read text on p. 73.

**Table 5.—*Instrumental constants of strong-motion seismographs in 1935*—Continued**

| Station and instrument | Orientation of instrument | Pendulum period | Static magnification | Sensitivity [2] | Damping ratio | Instrument number |
|---|---|---|---|---|---|---|
| | | *Sec.* | | *Cm* | | |
| **NORTHERN CALIFORNIA EARTHQUAKE OF JAN. 2** | | | | | | |
| Eureka accelerograph [3] | S.[1]–N. | 0.100 | 106 | 2.69 | 8 | T8 |
| | E.–W. | 0.099 | 107 | 2.66 | 6– | L13 |
| | Up–Down | 0.100 | 102 | 2.58 | 7+ | V29 |
| Eureka displacement meter | S.–N. | 9.9 | 1.14 | | 18 [4] | R13 |
| | W.–E. | 10.1 | 1.14 | | 30 [4] | L13 |
| **NORTHERN CALIFORNIA EARTHQUAKE OF MAR. 3** | | | | | | |
| Ferndale accelerograph [3] | NW.–SE. | 0.098 | 108 | 2.63 | 10 | T15 |
| | SW.–NE. | 0.100 | 113 | 2.86 | 9– | L4 |
| | Up–Down | 0.099 | 102 | 2.53 | 12 | V10 |
| **SOUTHERN CALIFORNIA EARTHQUAKE OF JULY 13** | | | | | | |
| Los Angeles Chamber of Commerce basement accelerograph.[5] | S. 40° W.–N. 40° E. | 0.099 | 104 | 2.58 | 8.8 | T26 |
| | S. 50° E.–N. 50° W. | 0.098 | 114 | 2.77 | 9.5 | L9 |
| | Up–Down | 0.100 | 105 | 2.66 | 8.4 | V28 |
| Los Angeles Chamber of Commerce penthouse accelerograph.[5] | S. 40° W.–N. 40° E. | 0.099 | 117 | 2.91 | 9.3 | L3 |
| | N. 50° W.–S. 50° E. | 0.101 | 109 | 2.82 | 7.0 | T18 |
| | Up–Down | 0.100 | 109 | 2.76 | 8.3 | V25 |
| **IMPERIAL VALLEY EARTHQUAKE OF SEPT. 8** | | | | | | |
| El Centro accelerograph | N.–S. | 0.098 | 111 | 2.70 | 7 | L68 |
| | E.–W. | 0.101 | 106 | 2.74 | 10 | T69 |
| | Up–Down | 0.101 | 104 | 2.69 | 8 | V67 |
| **HELENA, MONT., EARTHQUAKES OF OCTOBER AND NOVEMBER** | | | | | | |
| Helena accelerograph [3] | N.–S. | 0.098 | 108 | 2.62 | 13 [4] | L35 |
| | E.–W. | 0.101 | 107 | 2.75 | 10 [4] | T31 |
| | Up–Down | 0.098 | 106 | 2.57 | 10 [4] | V14 |
| **SOUTHERN CALIFORNIA EARTHQUAKE OF OCT. 24** | | | | | | |
| Los Angeles subway terminal, [1] basement accelerograph.[5 6] | SE.–NW. | 0.100 | 80.0 | 2.03 | 9 | L91 |
| | SW.–NE. | 0.101 | 82.0 | 2.12 | 9 | T101 |
| | Up–Down | 0.100 | 74.0 | 1.87 | 8 | V111 |
| Los Angeles subway terminal, basement displacement-meter.[5] | N.–S. | 9.81 | 1.14 | | 19 | R15 |
| | E.–W. | 9.97 | 1.14 | | 16 | L15 |
| Los Angeles subway terminal, 13th floor accelerograph.[5 6] | SE.–NW. | 0.101 | 80.7 | 2.08 | 10 | T102 |
| | NE.–SW. | 0.101 | 84.3 | 2.18 | 7 | L92 |
| | Up–Down | 0.101 | 82.1 | 2.12 | 9 | V112 |
| **IMPERIAL VALLEY EARTHQUAKE OF DEC. 19** | | | | | | |
| El Centro accelerograph | N.–S. | 0.098 | 111 | 2.70 | 8 | L68 |
| | E.–W. | 0.100 | 106 | 2.68 | 9 | T69 |
| | Up–Down | 0.101 | 104 | 2.69 | 8 | V67 |

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

[2] The sensitivity is the number of centimeters on the seismogram that corresponds to 100 cm/sec.[2] of acceleration. The deflection corresponding to 1/10 gravity may be obtained by multiplying the sensitivity tabulated by 0.98. (See p. 60.)

[3] The accelerographs at Eureka, Ferndale, and Helena were not equipped with tape recorders.

[4] Approximate value.

[5] Instruments at this station wired to start simultaneously.

[6] Accelerometers equipped with new attachments which provide auxiliary light spots of low sensitivity. This earthquake was too weak to require the use of the insensitive spots, and the sensitivities tabulated are values for the normal or sensitive spots. These sensitivities are less than on accelerometers not equipped with the new mirrors on account of the increased moment of inertia.

## DESCRIPTIONS OF STRONG-MOTION SEISMOGRAPH STATIONS

NOTE.—A description of the Los Angeles Subway Terminal Building will be found in Serial No. 579, "United States Earthquakes, 1933." Descriptions of the following stations are in Serial No. 593, "United States Earthquakes, 1934": El Centro, Southern Sierra Power Co. Terminal Station; Eureka, Federal Building; Ferndale, Town Hall; and Los Angeles, Chamber of Commerce Building.



### HELENA, MONT.

#### FEDERAL BUILDING

*Accelerograph in basement*

As soon as the Helena earthquake of October 18 made it apparent that further strong shocks might be expected at Helena, a party was sent from California with one of the accelerographs that had been in operation there. The instrument was installed on October 21 in the basement of the Federal Building in time to record many aftershocks, including the strong earthquake of October 31. (Since then a number of accelerographs have been installed in western Montana and Nevada.)

The Federal Building at Helena is a four-story building, about 60 feet high. The basement columns are of reinforced concrete and the frame from the first floor to the top is steel. There is a granite base all around, as well as sandstone facing up to the second floor. The brick-filler walls have sandstone facing on the old building and terra cotta on the new. The seismograph pier rests directly on the concrete floor, and at the location of the seismograph pier the floor rests directly on the limestone bedrock.

Prior to November 15 the instrument was at another location in the basement of the same building.

Helena is located on the north edge of the Boulder Batholith, an igneous intrusion about 75 miles in diameter. The city is built partly on the low foothills and partly on the alluvium on the south side of Prickly Pear Valley. The geology of the district is very complex. Sedimentary rocks in the Helena area range in age from Beltian to recent. The range in lithology is as marked as in age: Limestone, quartzite, sandstone, shale gravel, and "lake beds" are common. The Helena area is believed to be quite complexly faulted, and is known to be so northwest of Helena.

The geology of the Helena region is discussed in more detail in the special article on the Helena earthquakes of 1935.

**Table 6.—*List of strong-motion seismograph stations, 1935***

| 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. |

See footnotes at end of table.

**Table 6.—*List of strong-motion seismograph stations, 1935*—Continued**

| Station and foundation | Instrument | Date of installation |
|---|---|---|
| NORTHERN CALIFORNIA—continued | | |
| San Francisco—Continued. | | |
| 450 Sutter: Rock: | | |
| Twenty-eighth floor | Weed seismograph | October 1933. |
| Basement | do | November 1934. |
| Golden Gate Park: Rock | Accelerograph [1] | August 1933.[1] |
| Shell Building: Rock: | | |
| Twenty-eighth floor | Weed seismograph | 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, room 18 | Accelerograph and displacement meter. | December 1932. |
| State Building. Sand and gravel, basement | do | April 1933. |
| Sanger: Residence of Maxwell Allen: Alluvium | Weed seismograph | June 1933.[1] |
| 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 Sierras Power Co. substation: Alluvium. | Accelerograph | July 1932. |
| Hollywood: | | |
| Storage Co. Alluvium: | | |
| Penthouse | do | June 1933. |
| Basement | do | Do. |
| Adjoining Pacific Electric lot [2] | do | December 1934. |
| Long Beach: Public Utilities Building: Alluvium | do | July 1932. |
| Los Angeles: | | |
| Chamber of Commerce. Alluvium: | | |
| Twelfth floor | do | November 1934. |
| Basement | Accelerograph and Weed seismograph. | June 1933. |
| Edison Building. Hardpan or clay: Basement | 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 and displacement meter. | May 1933. |
| Do | Weed seismograph (added) | June 1933. |
| San Bernardino: County courthouse: Alluvium | Weed seismograph | Do. |
| 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 | | |
| Helena, Montana: Federal Building: Rock | do | October 1935.[1] |
| Miraflores,[3] Canal Zone, concrete locks: Tuff and alluvium. | do | April 1933.[3] |

[1] The accelerograph at Golden Gate Park in San Francisco was removed in October and taken to Helena, Mont. The Weed strong-motion seismograph at Sanger was removed in September, and in December it was installed at Golden Gate Park to replace the instrument sent to Montana.

[2] The instrument on the Pacific Electric Co. lot in Hollywood is in a separate small building several hundred feet from the Hollywood Storage Co. 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.

[3] Prior to April 1935 the Canal Zone accelerograph was located at Balboa Heights in the Administration Building, resting on rock. This installation was made in March 1934.

## TILT OBSERVATIONS

The tilt observations described in Serial No. 593, "United States Earthquakes, 1934" and Special Publication No. 201, "Earthquake Investigations in California, 1934–1935" were continued during 1935. Figure 34 summarizes the observational data in graphical form as heretofore.

There were no outstanding correlations between changes in tilt and local earthquakes during the year.



## ADDITIONS AND CORRECTIONS TO PREVIOUS PUBLICATIONS

1933. November 16. See "Grover, Mo., Earthquake November 16, 1933", by J. B. Macelwane, S. J., in Earthquake Notes, vol. 5, no. 3, page 3.

1934. July 30. 1:20. Rapid City, S. Dak. Chadron, Nebr., earthquake felt here with intensity IV.

1934. November 15: Anchorage, Alaska, V.

1934. Serial No. 593,"United States Earthquakes, 1934." Add small dot to epicenter map, fig. 1, to indicate shock at Gloucester, Mass.

## PUBLICATION NOTICES

To make immediately available the results of its various activities to those interested, the Coast and Geodetic Survey maintains mailing lists of persons and firms desiring to receive notice of the issuance of charts, Coast Pilots, maps, and other publications.

Should you desire to receive such notices, you may use the form given below, checking the lists covering the subjects in which you are interested.

---

(Date)_____

DIRECTOR, U. S. COAST AND GEODETIC SURVEY,
*Washington, D. C.*

DEAR SIR: I desire that my name be placed on the mailing lists indicated by check below, to receive notification of the issuance of publications referring to the subjects indicated:

CUT ON THIS LINE

- ☐ 109. Astronomic work.
- ☐ 109–A. Base lines.
- ☐ 109–B. Coast Pilots.
- ☐ 109–C. Currents.
- ☐ 109–D. Geodesy.
- ☐ 109–E. Gravity.
- ☐ 109–F. Hydrography.
- ☐ 109–G. Leveling.
- ☐ 109–H. Nautical Charts.
- ☐ 109–I. Oceanography.
- ☐ 109–J. Traverse.
- ☐ 109–K. Seismology.
- ☐ 109–L. Terrestrial magnetism.
- ☐ 109–M. Tides.
- ☐ 109–N. Topography.
- ☐ 109–O. Triangulation.
- ☐ 109–P. Cartography.
- ☐ 109–R. Aeronautical charts.

(Name)_____

(Address)_____

---

A catalog of the publications issued by all bureaus of the Department of Commerce may be had upon application to the Chief, Division of Publications, Department of Commerce, Washington, D. C. It also contains a list of libraries located in various cities throughout the United States, designated by Congress as public depositories, where all publications printed by the Government for public distribution may be consulted.



○

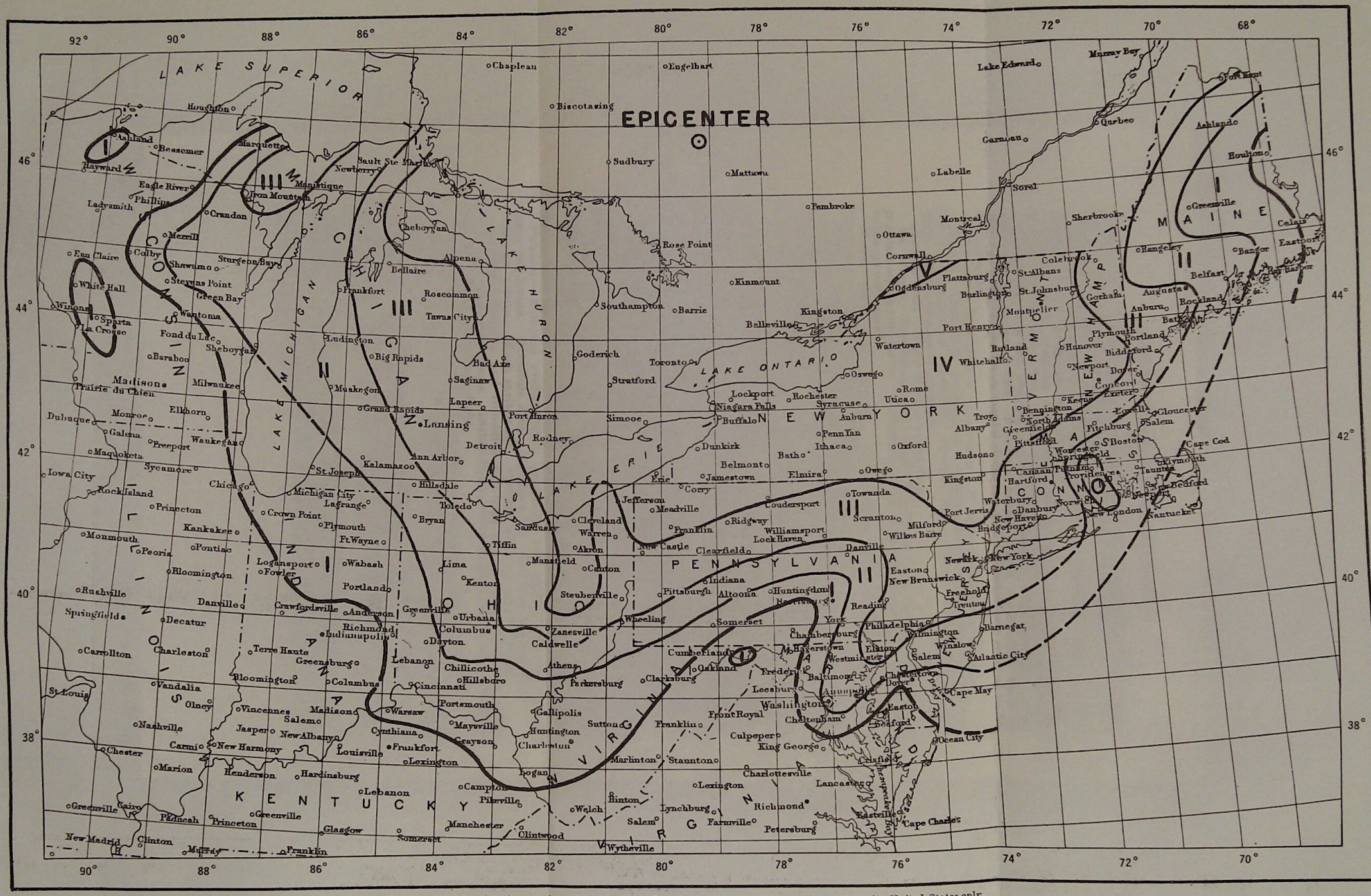



FIGURE 2.—Isoseismal map of the Timiskaming, Canada, earthquake of November 1, 1935, for United States only.

151736—37. (Face p. 8.)

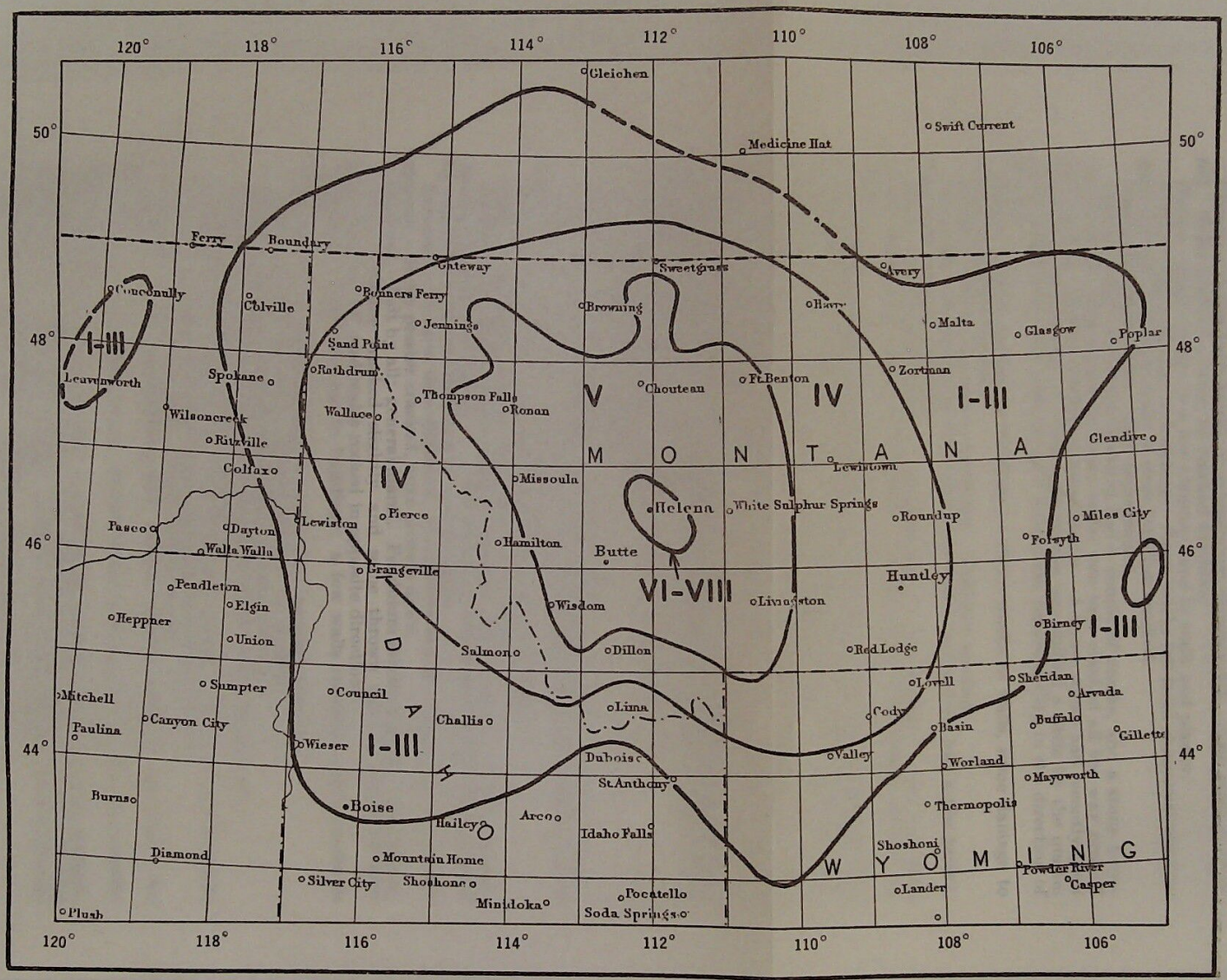



FIGURE 6.—Isoseismal map of the Helena, Mont., earthquake of October 18, 1935.

151736—37. (Face p. 20.)

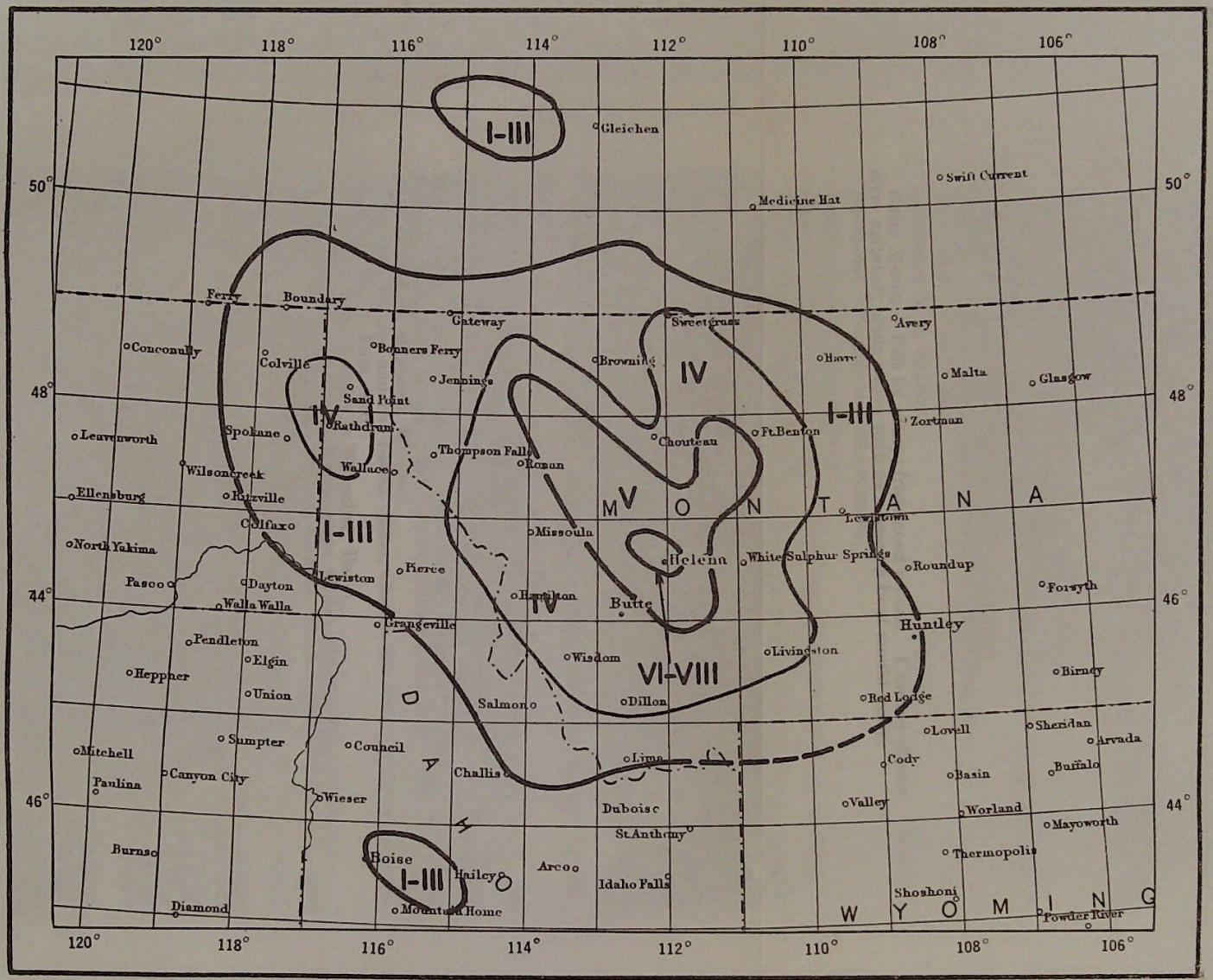



FIGURE 7.—Isoseismal map of the Helena, Mont., earthquake of October 31, 1935. 151736—37. (Face p. 26.)

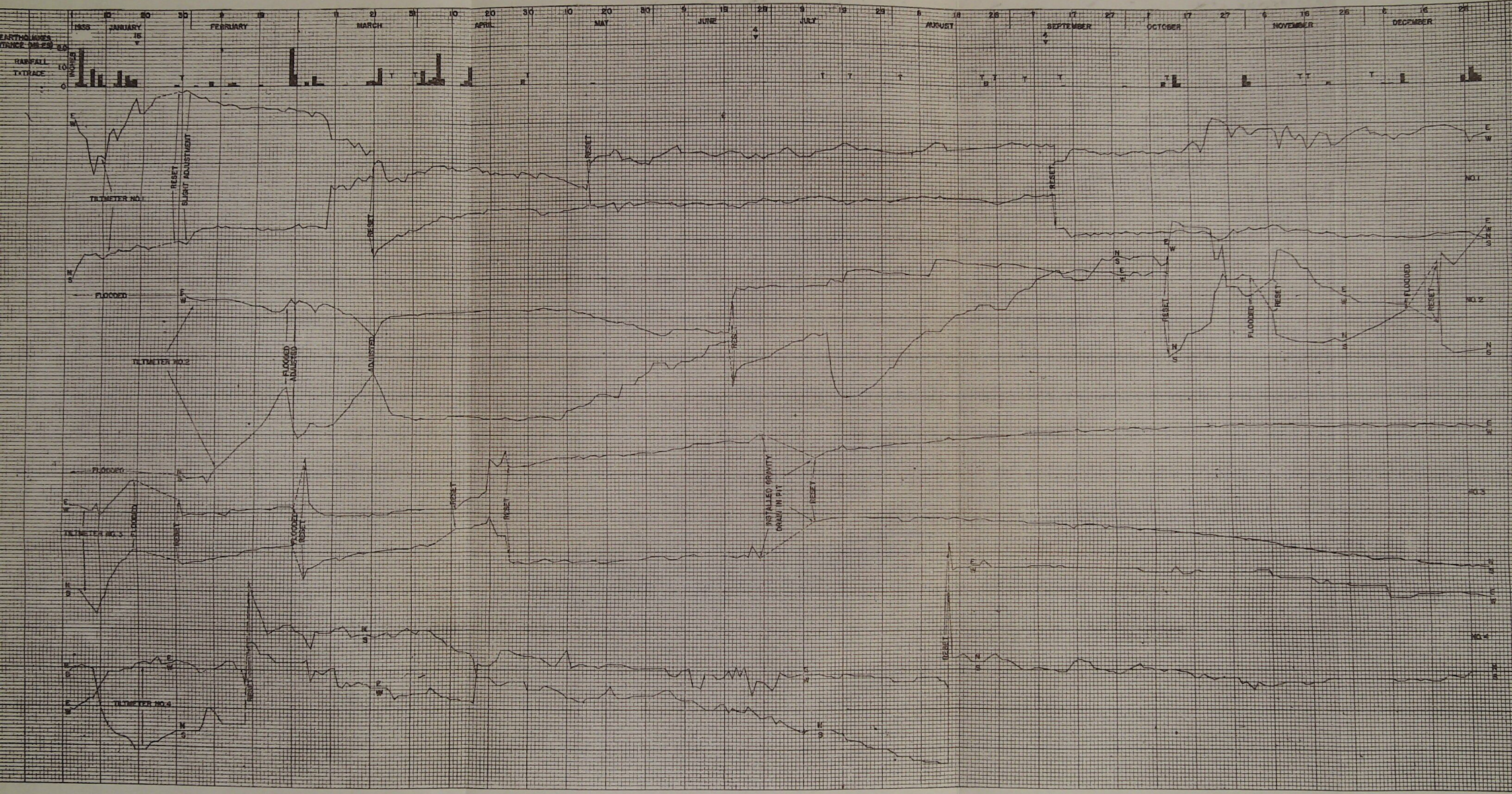



FIGURE 34.—Tilt curves for 1935.