

**UNITED STATES  
EARTHQUAKES  
1951**

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**SERIAL No. 762**

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

**U. S. DEPARTMENT OF COMMERCE**

SINCLAIR WEEKS, Secretary

**COAST AND GEODETIC SURVEY**

Robert F. A. Studds, Director

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Serial No. 762

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# **UNITED STATES EARTHQUAKES 1951**

By

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and

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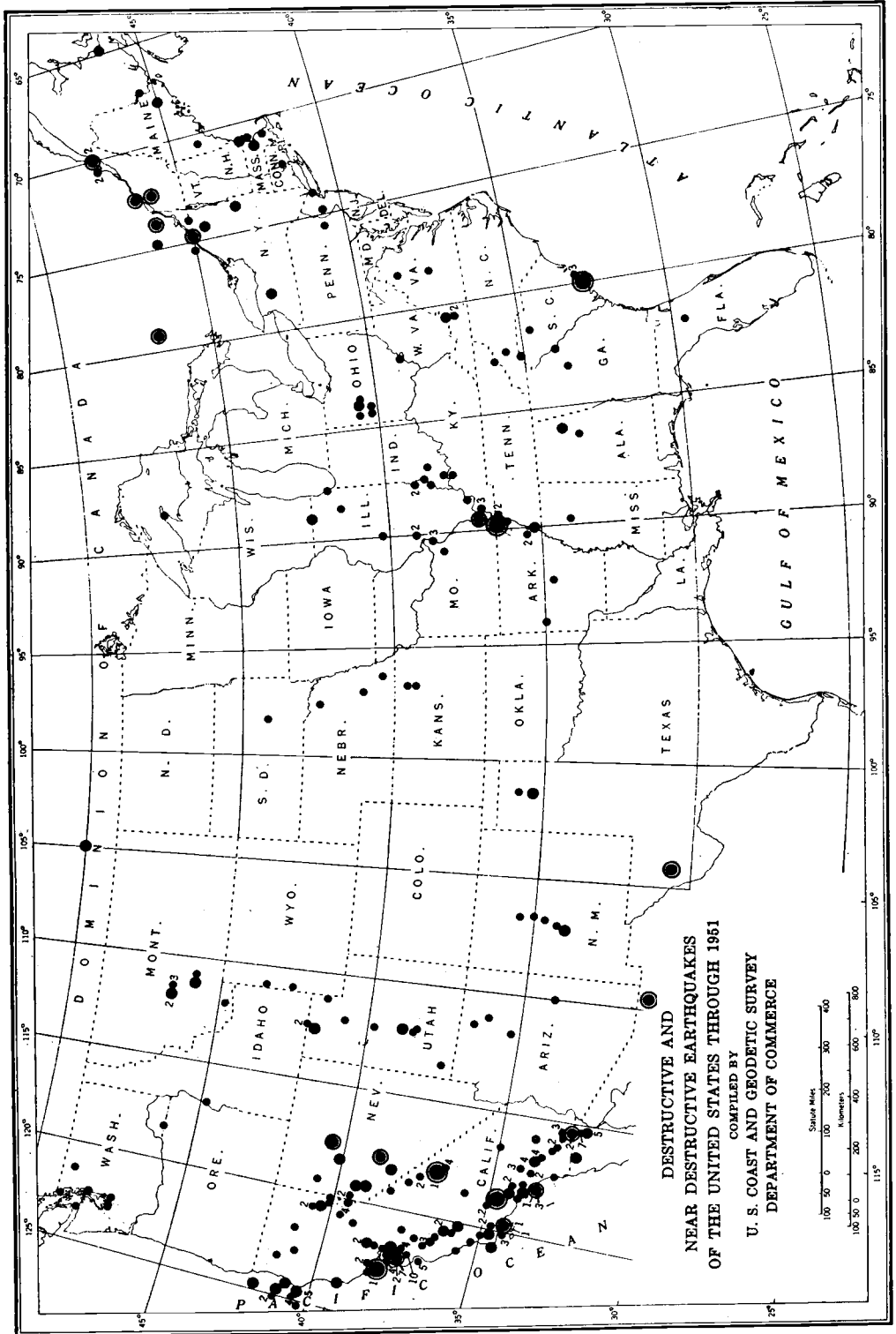


FIGURE 1.—Destructive and near destructive earthquakes in the United States through 1951.

# UNITED STATES EARTHQUAKES, 1951

## INTRODUCTION

This publication is a summary of earthquake activity in the United States and regions under its jurisdiction for the calendar year 1951. The sources of noninstrumental information used in the compilation include the United States Weather Bureau, whose observers prepare periodic reports on local seismic activity; telegraphic information collected by Science Service, Washington, D. C.; Bulletins of the Seismological Society of America; special reports of the Jesuit Seismological Association and the Northeastern Seismological Association; the *Hawaiian Volcano Letter*; newspaper clippings; and reports from interested individuals. Instrumental data used in locating earthquakes are obtained from the network of Coast and Geodetic Survey stations listed on page 25 and from other cooperating seismological stations in the United States and throughout the world.

The Coast and Geodetic Survey endeavors to coordinate efforts in collecting all types of earthquake information with the special object of correlating instrumental earthquake locations with noninstrumental reports received from the epicentral areas. This is done by local organizations making intensive regional investigations in California and elsewhere, and, when necessary, by the Coast and Geodetic Survey. This information serves to adequately map the seismic areas of the country and promote public safety through a better understanding of earthquake phenomena. Since the success of the general information service depends largely on the cooperation of local officials and citizens, all are urged to fill out and return earthquake questionnaires.

*Earthquake information services.*—The Coast and Geodetic Survey maintains a Seismological Field Survey in San Francisco to collect earthquake information and make field investigations of strong shocks in the Pacific coast and western mountain States. Details concerning damage, destruction, and other effects are enumerated in the quarterly *Abstracts of Earthquake Reports for the Pacific Coast and the Western Mountain Region*. This report is available on request from the Director of the Coast and Geodetic Survey, Washington 25, D. C. Active cooperation in this work is received from the University of California Seismographic Station, Berkeley (Dr. Perry Byerly, in charge); and the Seismological Laboratory, Pasadena (Dr. Beno Gutenberg, Director); as well as State Collaborators in Seismology. The following Collaborators served as agents of the Coast and Geodetic Survey in their respective States in 1951:

*Arizona.*—Dr. Eldred D. Wilson, University of Arizona, Tucson.

*Colorado.*—Prof. C. A. Heiland, Heiland Research Corp., Denver.

*Montana.*—Prof. Stephen W. Nile, Montana School of Mines, Butte.

*Nevada.*—Prof. Vincent P. Gianella, University of Nevada, Reno.

*New Mexico.*—Prof. Stuart A. Northrop, University of New Mexico, Albuquerque.

*Oregon.*—Dr. Ira S. Allison, Oregon State College, Corvallis.

*Utah.*—Prof. J. Stewart Williams, Utah State Agricultural College, Logan.

*Washington.*—Prof. Howard A. Coombs, University of Washington, Seattle.

*Wyoming.*—Prof. Horace D. Thomas, University of Wyoming, Laramie.

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 manufacture of earthquake-resistant building materials are also active together with various organizations of structural engineers and architects.

In other parts of the country the Jesuit Seismological Association with central office at St. Louis University collects information in the central Mississippi Valley area (Rev. Dr. James B. Macelwane, S. J., Dean of the Institute of Technology). The Northeastern Seismological Association with headquarters at Weston College, Weston, Mass. (Rev. Daniel J. Linehan, S. J., in charge), undertakes similar work in the northeastern States.

*Modified Mercalli Intensity Scale of 1931.*—All intensities used by the Coast and Geodetic Survey refer to the Modified Mercalli Intensity Scale of 1931.<sup>1</sup> The abridged version of this scale is given here with equivalent intensities according to the Rossi-Forel scale.

<sup>1</sup> Modified Mercalli Intensity Scale of 1931. Harry O. Wood and Frank Neumann, *Bulletin of the Seismological Society of America*, Vol. 21, No. 4, December 1931.

**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 motorcars may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale.)
- IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars 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 motorcars. (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. Persons driving motorcars disturbed. (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 pipelines 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 air.

*Epicenter maps.*—Figure 1 is designed to show the existence of destructive and near destructive earthquakes in the United States through 1951. The smallest dot indicates the shock was strong enough to overthrow chimneys or affect an area of more than 25,000 square miles (intensity VII to VIII); the largest solid dot may be associated with damage ranging from several thousand dollars to one hundred thousand dollars, or to shocks usually perceptible over more than 150,000 square miles (intensity VIII to IX); the smaller encircled dots represent damage ranging from approximately one hundred thousand to one million dollars, or an affected area greater than 500,000 square miles (intensity IX to X); the larger encircled dots represent damage of a million dollars or more, or an affected area usually greater than 1,000,000 square miles (intensity X to XII).

Figure 2 shows earthquake distribution in the United States during 1951. In a few cases where instrumental control is not satisfactory or where results of investigations are inadequate, the plotted epicenters should be considered as showing the existence of the earthquake rather than the precise location.

In figures 1 and 2, those earthquakes occurring in the California area are plotted when felt reports are received from several places. 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 number after a dot indicates the number of shocks which have occurred at or near the location shown. Bulletins of the University of California Seismographic Station, Berkeley, and the Seismological Laboratory, Pasadena, should be consulted for further details regarding epicenters and often for data on additional shocks.

The selection of isoseismal or "felt area" maps (figs. 3-6) is governed largely by the size of the area affected, the minimum radius generally being of the order of 50 miles. In the case of sharp localized shocks this means that some earthquakes of intensity VI (mostly in California) will not be shown on such maps whereas others of intensity IV and V (largely in the eastern and central areas) will be shown.

*Teleseismic results.*—On page 25 is a list of Survey and cooperating teleseismic stations for which the Survey publishes results. During the year the locations of 152 epicenters were announced promptly on *Preliminary Determination of Epicenter* cards and an additional 536 locations were reported weekly on *Supplement* cards. Those desiring to receive these cards should request addition of their name to the *PDE* mailing list. All seismogram interpretations are published in the quarterly *Seismological Bulletin*, MSI series, available on mailing list *CGS-7* from the Director, U. S. Coast and Geodetic Survey, Washington 25, D. C. During the year 1952, MSI-127 for the third quarter of 1946, and MSI-139 and MSI-140 for the last half of 1949, and MSI-141 for the first quarter of 1950, were issued.

*Magnitude-intensity correlation.*—Magnitude is given according to the Richter-Gutenberg scale used extensively as a measure of the energy of an earthquake. An explanation of this scale is given in the *Bulletin of the Seismological Society of America*, volume 32, No. 3, 1942. This scale, derived from an empirical formula based on instrumental results, should be distinguished from the intensity scale which is a measure of the effects on animate and inanimate objects, including damage to buildings. The following comparison is given between the magnitude and intensity designations for normal depth earthquakes in southern California.

Magnitude	2.2	3	4	5	6	7	8	8.5
M-M Intensity	1.5	2.8	4.5	6.2	7.8	9.5	11.2	12.0

*Strong-motion seismograph results.*—The maintenance of a network of strong-motion seismographs and analysis of the records of destructive earthquake motions thus obtained are functions of the Bureau in connection with a broad cooperative program of research being carried out on the Pacific Coast with a number of local organizations and institutions interested in the engineering aspects of the earthquake problem. The details of this program are described in S. P. 201, *Earthquake Investigations in California, 1934-35*.

The preliminary analyses of strong-motion records are published in the *Quarterly Engineering Seismology Bulletin* which is available upon request from the Director of the Coast and Geodetic Survey, Washington 25, D. C. The revised analyses are given in table 1.¶

*Earthquake history.*—A history of the more important shocks of the country appears in Serial 609, *Earthquake History of the United States*. Part I covers continental United States and Alaska, exclusive of California and western Nevada; Part II covers the stronger earthquakes of California and western Nevada. The first part was revised in 1947 and the latter in 1951.

A history of minor activity is covered largely in a series of references listed in Serial 609, in recent reports of the Coast and Geodetic Survey, and in the *Bulletin of the Seismological Society of America*, volume 29, No. 1, January 1939. The last two references give detailed information for all California earthquakes. The last one contains all information appearing in early catalogs published by the Smithsonian Institution.

A summary of the earthquake program as carried out in the United States is briefly outlined in S. P. 282, *Earthquake Investigation in the United States*. The major organizations and stations are listed together with a list of the independent and/or privately operated stations. This publication is available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., for 20 cents.

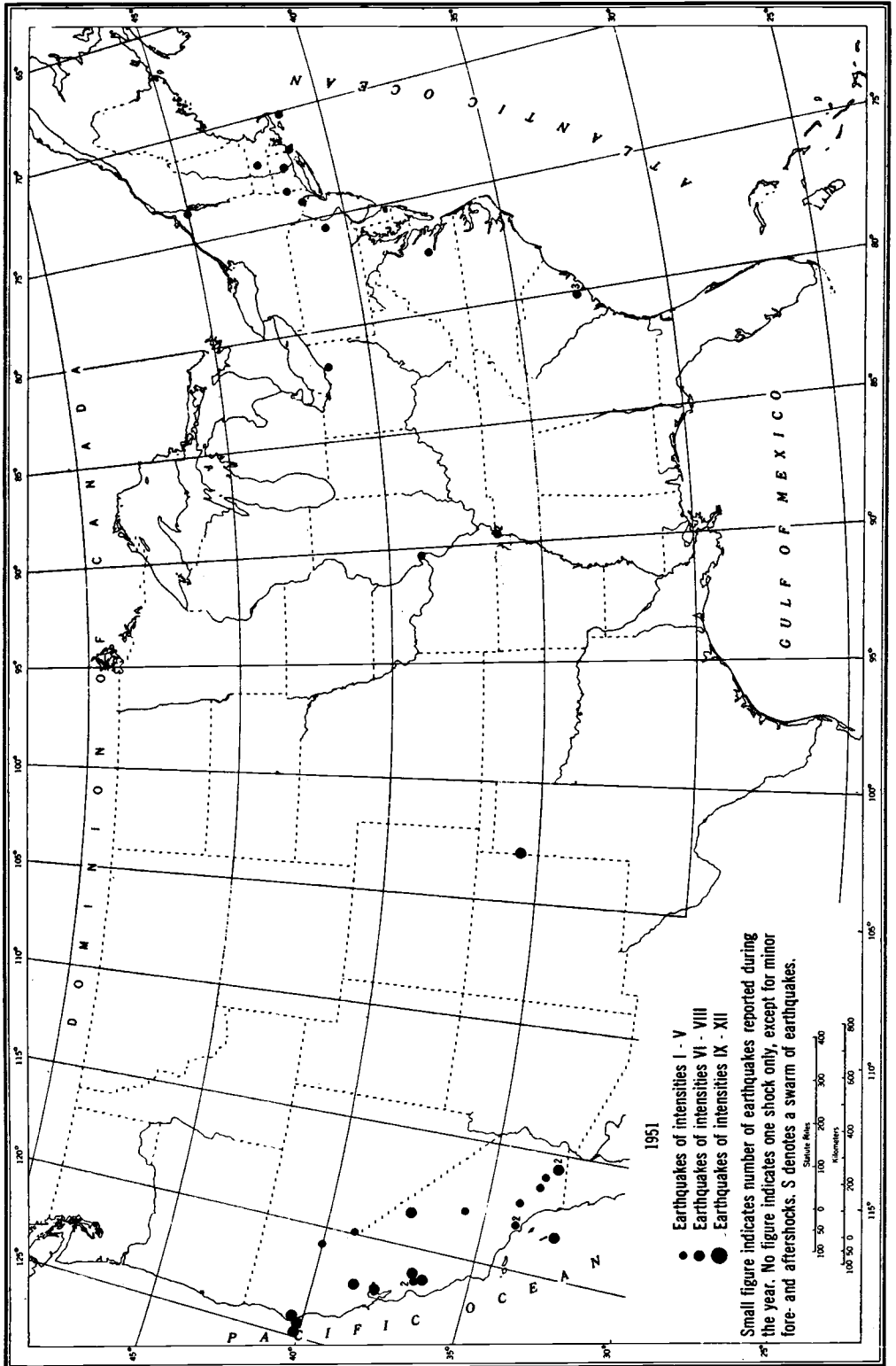


FIGURE 2.—Earthquake epicenters, 1951.



## NONINSTRUMENTAL RESULTS

NOTE.—The following symbols are used to indicate authority for times or reported epicenters: P, reported by the Seismological Laboratory, California Institute of Technology, Pasadena; B, reported by the Seismographic Station, University of California, Berkeley; BC, reported by the Boulder City office of the United States Coast and Geodetic Survey; NESA, reported by the North-eastern Seismological Association, Weston, Mass.; JSA, reported by the Jesuit Seismological Association, St. Louis, Mo.; and W, reported by the Washington Office, United States Coast and Geodetic Survey.

An asterisk (\*) indicates instrumental origin time of the earthquake when coordinates of the epicenter are given. Otherwise, instrumental times shown with asterisks are those of first motions.

When more than one degree of intensity is reported from a town, the town is listed under the highest intensity reported. More details will be found in the quarterly *Abstracts of Earthquake Reports for the Pacific Coast and the Western Mountain Region*, MSA series, issued on mailing list *CGS-3* by the United States Coast and Geodetic Survey, Washington 25, D. C.

### EARTHQUAKE ACTIVITY IN THE VARIOUS STATES

NOTE.—The intensities of the earthquakes for which no ratings are given range from I to IV.

**Arizona:** March 5.  
**California:** January 23, VII, January 25, VI; February 19, VI; March 10, VI; July 23, VI (2), July 29, VI; August 6, VI; October 7, VII; October 16, VI; October 31, VI; November 14, VI; December 5, VII; December 25, VI; and December 27, VI.  
**Connecticut:** January 25.  
**Illinois:** September 19.  
**Massachusetts:** March 31 and September 21.  
**Missouri:** December 17.  
**Montana:** January 15, 28, 29; April 23; May 20; August 5; September 11; November 11, 14; December 9, V; and December 11.  
**Nevada:** February 5, 9, 10, 11 (2), 14 (2); June 14, (2), 15, 16, 17; August 13 (2), 17, 23, 28; September 22, 23; October 4, 19, and 24.  
**New York:** September 3, V; October 25; November 6; and December 7.  
**Ohio:** December 3.  
**Oregon:** January 7, V; April 3.  
**Pennsylvania:** November 23.  
**Rhode Island:** June 12.  
**South Carolina:** March 3 and December 30.  
**Texas:** June 20, VI.  
**Utah:** January 23 (2); March 5; August 11, V.  
**Virginia:** March 9.  
**Washington:** January 4, V; October 9.  
**Wyoming:** February 21.

### EARTHQUAKE ACTIVITY OUTSIDE THE UNITED STATES

**Alaska:** January 16, 22; February 8, 12, 25; March 6, 15 (2), 28, 30 (2); April 3, 9; May 7, 13; June 25, V; July 19 (2); August 16; September 11, 26 (2); November 4, 15, 23; December 30 and 31.  
**Hawaiian Islands:** February 14, 16; March 14, 20; April 13, 22, VII (2), 23, 26; May 6; June 7, 11; August 21, IX (6), 22 (3), 28, 29, 30, 31; September 4 (2), 12, 15, 16, 23, 24 (2), 25 (2), 26; October 5, 6, 7, 9 (2), 11, 14, 17, 19, 23, 24; November 8 (2), 11, 17, 18 (2), 23; December 6 and 29.  
**Panama Canal Zone:** January 4, 5, 6, V (2), and 7.  
**Puerto Rico:** September 15.

### NORTHEASTERN REGION

(75TH MERIDIAN OR EASTERN STANDARD TIME)

**January 25:** 22:27. Felt in Connecticut River Valley from Old Lyme to East Hartford. Sleepers were aroused and pictures were shaken from walls.

**March 30:** 22:50:37\*. Epicenter 42. 2° north, 72.2° west, south central Massachusetts, NESA. Massachusetts. Felt in Ware, Palmer, and Belchertown. Many residents were awakened. A few broken teacups and minor cracks in foundations of homes were the only reported damage.

**June 10:** 12:20:36\*. Offshore quake felt 75 miles inland on southern New England coast, and from New London, Conn., to Falmouth on Cape Cod, Mass. A second shock was recorded at Harvard 15 seconds following the first tremor. The center was 3 to 5 miles off Westerly, R. I. Westerly, Narragansett, and Newport bore the brunt. Windows rattled and walls shook in Narragansett, dishes were knocked from racks, and ceilings and walls cracked in Newport. At Westerly many people left their homes. Telephone lines were jammed with calls from frightened residents.

The shock was felt in Massachusetts in New Bedford, Fairhaven, Dartmouth, Harvard, Fall River, and Mills; and in Rhode Island in suburbs of Providence, Newport, Westfield, and North Kingstown; and in Connecticut in Norwich and Westbrook. No damage was reported.

**September 21:** 12:23. Nantucket, Mass. Several distinct tremors shook buildings, rattled windows, and moved furniture about slightly. Felt strongly at the Civil Aeronautics Administration station at Nantucket Airport where lighting fixtures and venetian blinds swayed slightly.

## EASTERN REGION

(75TH MERIDIAN OR EASTERN STANDARD TIME)

**March 3:** 21:55. Summerville, S. C. "One good thump and shaking with rattling of windows." Another slight shake was reported on the 7th at 19:20 and still another was reported on the 10th at 03:18.

**March 9:** 02:00. Richmond, Va. Felt about 8 miles east of Richmond, lasted 3 minutes. Picture frames were shifted in home, no damage was reported.

**September 3:** 20:26:28\*. Rockland County, N. Y. V. Results of questionnaire coverage indicate a felt area of approximately 5,500 square miles extending from Windsor, Conn., southwest to Pompton Lakes and Dover, N. J., and from the north shore of Long Island Sound to Walden and Middletown, N. Y. See map. The maximum intensities were reported along the Bernardsville Fault, from eastern New Jersey across southeastern New York to New England. Maximum intensity V was reported in Greenwood Lake and Tomkins Cove, N. Y., where many were alarmed, buildings creaked, and loose objects rattled.

Intensity IV in New York in Briarcliff, Croton, Elmsford, Haverstraw, Highland Falls, Monroe, Ossining, Pearl River, Peekskill, Scardsdale, Spring Valley, Suffern, Tarrytown, Thornwood, Tuxedo Park, and Warwick; in New Jersey in Oakland and Riverdale; and in Connecticut in Norwalk.

Intensity I and III in New York in Armonk, Bedford, Bedford Hills, Brewster, Chappaqua, Cold Spring, Cornwall, Goldenbridge, Goshen, Hollis (Long Island), Irvington, Katonah, Middle-

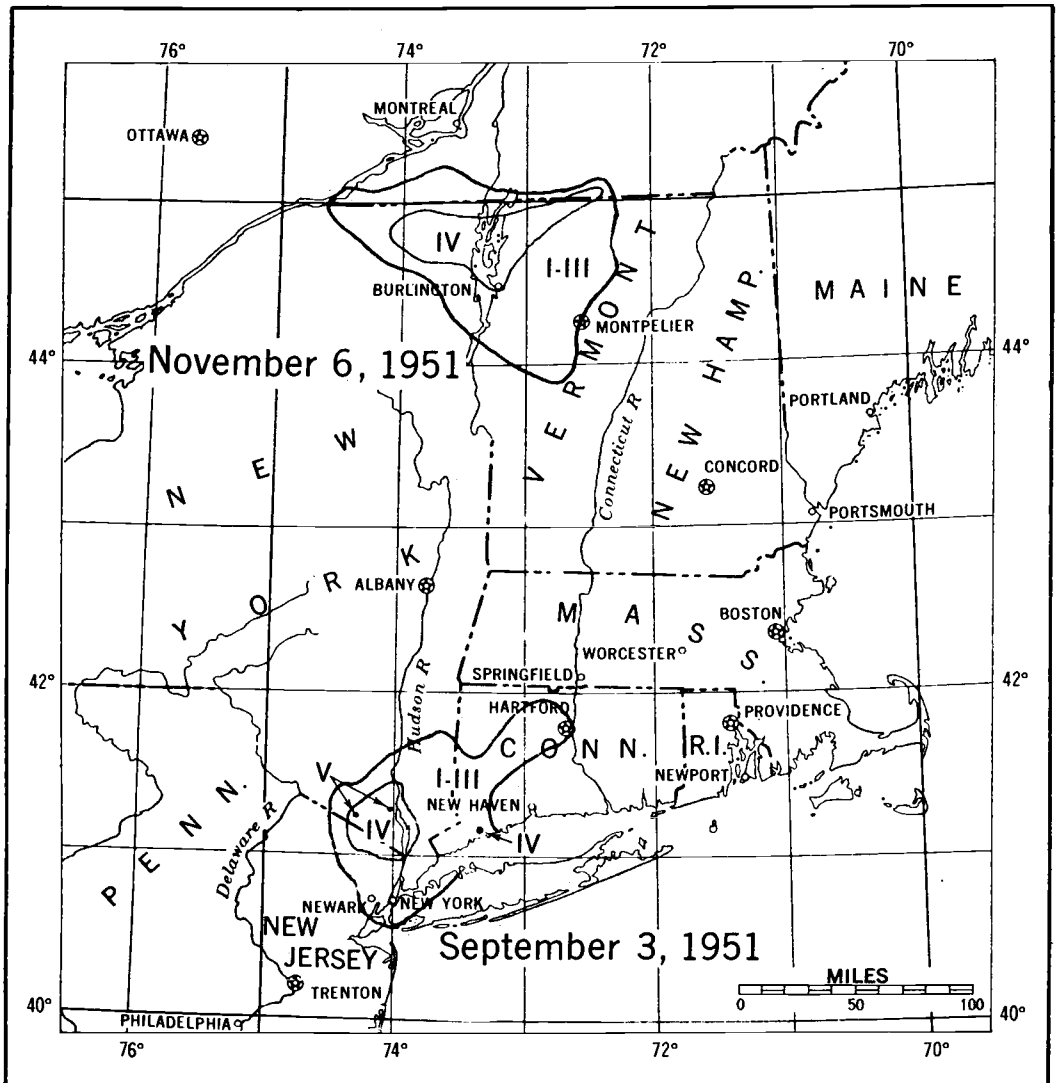


FIGURE 3.—Areas affected by the earthquakes of September 3 and November 6.

town, Millbrook, Mt. Kisco, Mount Vernon, New York City (Fordham), Newburgh, New Windsor Pelham, Sloatsburg, Staten Island, Verplanck, Walden, Yonkers, and Yorktown Heights; in New Jersey in Bloomingdale, Boontown, Butler, Dover, Franklin Lakes, Haskell, Mahwah, Midvale, Millville, Montville, Mountain Lakes, New Foundland, Oakland, Pompton Lakes, Pompton Plains, Ringwood, Riverdale, Rumson, Vernon, and Wanaque; and in Connecticut in Bethel, Brookfield, Danbury, Fairfield, Granby, Greenwich, Hartford, Kent, New Canaan, New Fairfield, New Milford, Newton, Sherman, Stamford, Torrington, Washington, Wilton, Windsor, and Winsted.

**October 25:** 02:09. Massena, N. Y. Slight earth tremor awakened many people and rattled dishes. Two other minor tremors followed, the last occurring about 02:31. Also felt in Cornwall, Canada and in other vicinity villages of Lunenburg, St. Raphael West, and Malone, N. Y. At the last-named place dishes rattled and articles were shaken from shelves and stands.

**November 6:** 12:54:41.5\*. Epicenter 45.0° north, 73.6° west, Clinton County, N. Y., W. IV. Felt over an area of approximately 8,000 square miles in northeastern New York, northern Vermont, and adjoining area in Canada. See map. In Isle La Motte a sharp report sounded like a big gun, starting with a vibration ring and continuing with greater intensity; a house and cinder-block garage shook. Buildings shook slightly; windows, dishes, and glassware disturbed in Burlington, Richford, and Swanton, Vt.; in Altona, Au Sable Forks, Chateaugay, Dannemore, Ellenberg, Lyon Mountain, Malone, and Plattsburg, N. Y.; and in Brome, Quebec Province, and Lancaster, Ontario Province, Canada.

As descriptive reports were incomplete some of the following towns may have been affected greater than listed.

Intensity I to III in Vermont in Alburg, Alburg Springs, Colchester, East Alburg, Enosburg Falls, Essex Junction, Hardwick, Huntington, Jeffersonville, Middleburg, Milton, Northfield, Randolph, Richmond, South Hero, and Underhill; in New York in Champlain, Merrill, Mountain View, Rouses Point, and Standish; and in Canada in Abercon, Aubrey, Brucy, Lacolle Junction, Masonville, Noyan, and Richfield, Quebec Province; and Summerstown, Ontario Province.

**November 23:** 01:45:36\*. Allentown, Pa. Reported in Greenwald section to Ridge Avenue in Allentown. Awakened many, moved a bed 6 to 7 inches, knocked a vase off a wall, and put pump out of order. Water in well dropped 60 feet after having been used 25 to 30 years.

**December 3:** 02:02. Willoughby, Ohio. IV. Earthquake felt by most residents, many thinking their furnaces had exploded. Homes shaken and windows rattled. Also felt in Eastlake, Mentor, Mentor-on-the-Lake, and Wickliffe.

**December 7:** 23:37\*. Poughkeepsie, N. Y. Light shock felt.

**December 30:** 02:55. Summerville, S. C. Light shock felt by many and windows shaken.

## CENTRAL REGION

(90TH MERIDIAN OR CENTRAL STANDARD TIME)

**September 19:** 20:38:43\*. JSA. Southwestern Illinois. St. Louis University reported a shock about 25 miles from Florissant, Mo. Felt in Madison and St. Clair Counties in Illinois, and in St. Louis County, Mo. Greatest intensity reported from Alton, Collinsville, Edwardsville, and Wood River, Ill.

**December 17:** 20:02:21.5\*. JSA. New Madrid, Mo. Light shock felt in vicinity of New Madrid, Mo., and Marked Tree and Le Panto, Ark. Another weak shock on December 18 at 02:00.

## WESTERN MOUNTAIN REGION

(105TH MERIDIAN OR MOUNTAIN STANDARD TIME)

**January 15:** 01:27. Helena, Mont. IV. Felt by and awakened several.

**January 23:** 06:28 and 06:33. Nephi, Utah. IV. Press reported two distinct earthquakes, the second being recorded instrumentally at Logan. The second tremor brought calls from all parts of town.

**January 28:** 07:45. Helena, Mont. II. Very light jolt, vibration, and rumble felt by one person.

**January 29:** 13:07. Helena, Mont. III. Heavy vibration.

**February 5:** 06:30:58\*. Boulder City, Nev. III. Felt by several.

**February 9:** 08:46:58\*. Boulder City, Nev. Felt by one person.

**February 10:** 09:06:12\*. Boulder City and Hoover Dam, Nev. IV. Felt by many. Windows rattled.

**February 11:** 07:45:23\*. Hoover Dam, Nev. Reported felt.

**February 11:** 08:48:16\*. Hoover Dam and Boulder Beach, Nev. Reported felt.

**February 14:** 16:13:23\* and 16:14:21\*. Hoover Dam, Nev. III. Felt by several.

**February 21:** 10:09:56\*. Epicenter 43° north, 110° west, southwestern Wyoming, W. III. Felt by three persons in Rock Springs.

**March 5:** 16:00. Fredonia, Ariz., and Kanab, Utah. IV. Felt by several in Fredonia; windows, doors, and stove pipe rattled. Felt by many in Kanab; buildings creaked and loose objects rattled.

**April 23:** 13:57. Helena, Mont. IV. Felt by several in south and west sections. Buildings creaked and loose objects rattled. Faint rumbling subterranean sounds were heard during shock.

**May 20:** 13:00. Helena, Mont. III. Felt by several in southwest section. Moderately loud subterranean sounds were heard at time of shock.

- June 14:** 15:32:59\*. Boulder City and Hoover Dam, Nev. IV. Felt by many.  
**June 14:** 23:18:21\*. Boulder City and Hoover Dam, Nev. III. Felt by several.  
**June 15:** 08:43:28\*. Boulder City and Hoover Dam, Nev. IV. Felt by many.  
**June 16:** 12:52:55\*. Epicenter 38° north, 116½° west, south-central Nevada, W.  
**June 17:** 00:59:31\*. Boulder City, Nev. III. Felt by several.  
**June 20:** 12:37:10\*. Epicenter 35½° north, 103° west, Texas Panhandle-South Plains area, W.

VI. Felt from Lubbock to Borger, Vega, and Groom. Dishes, walls, and loose objects rattled throughout area, switchboards were jammed with calls. Houses shook in the western part of Amarillo, in Canyon, and in Groom. At Borger residents reported a noise "like snow falling off the roof". Small furniture was moved in a house 2 miles west of Plainview. In Plainview and Bovina windows rattled; in Amarillo dishes rattled, houses creaked, and some plaster cracked; in Hereford, a piece of plaster fell in a furniture store. The tremors were reported as very slight in Boise City, Okla.

**August 5:** 17:37:15\*. Butte, Mont., area. V. Felt with strongest intensity just outside of and to the south of Butte. Southeast of the Municipal Airport a deep rumble was heard, cupboard doors flew open, and a hanging basket swung back and forth for several seconds. Shaking of buildings and rattling of objects were reported throughout area. At South Butte a resident reported the lounge on her porch moved. At the Saddle Club on Upper Nine Mile it felt like a large boulder had hit the building and people ran outside. Felt distinctly by residents of Floral Park. At the School of Mines, cracks in the basement wall, which had been developing for previous two years, were widened ½ inch. The tremor was recorded instrumentally at the School of Mines.

**August 11:** 17:26. Provo, Utah. V. Felt by many in western section at airport. Buildings creaked, loose objects rattled, disturbed objects were observed by several. Chandeliers swung, pictures and dishes were displaced.

**August 13:** 12:51:44\*. Boulder City, Nev. III. Felt by several.

**August 13:** 16:09:23\*. Boulder City and Hoover Dam, Nev. IV. Felt by many.

**August 17:** 18:17:12\*. Boulder City, Nev. II. Felt by few.

**August 23:** 05:04:07\*. Boulder City, Nev. III. Felt by several.

**August 28:** 21:39:35\*. Boulder City and Hoover Dam, Nev. IV. Felt by many. Windows rattled.

**September 11:** 08:19:20\*. IV. Montana. Three or four minor earthquakes felt by residents in the Deer Park community. The first shock rattled windows; later shocks were hard jars preceded by low rumbling. Heard but not felt at Hungry Horse Dam. Also reported felt about 12 miles northeast of Kalispell.

**September 22:** 01:50:04\*. Hoover Dam, Nev. Slight shock.

**September 23:** 17:45:17\*. Boulder City, Nev. II. Felt by a few.

**October 4:** 02:27:45\*. Boulder City, Nev. II. Felt by a few.

**October 19:** 09:57:22\*. Hoover Dam, Nev. Felt.

**October 24:** 10:27:19\*. Boulder City and Hoover Dam, Nev. IV. Felt by many. Windows rattled and hanging objects swung. No damage.

**November 11:** (Between 04:00 and 04:30.) Polebridge, Mont. IV. Awakened observer. Shook buildings and rattled windows.

**November 14:** 05:14. Helena, Mont. IV. Felt by many. Residents reported a dull rumble then floor vibrations. Also felt in the West Section.

**December 9:** 00:08. Helena, Mont. V. Distinctly felt by persons driving cars. Glasses fell from shelves in several bars, pictures fell from walls in the Placer Hotel. Some people were frightened. Houses were generally shaken quite noticeably.

**December 11:** 20:52. Helena, Mont. III. Three shocks a few seconds apart.

## CALIFORNIA AND WESTERN NEVADA

(120TH MERIDIAN OR PACIFIC STANDARD TIME)

NOTE.—All places are in California unless otherwise stated. The *Bulletin of the Seismological Society of America* is referred to as the BSSA.

**January 2:** 02:25. Laws. IV. Felt by several, awakened few. Walls creaked. Instrumentally recorded at Tinemaha and China Lake.

**January 2:** 04:06:57\*. Epicenter 37°20' north, 118°21' west, near Bishop, P. IV. Felt by and awakened few in home in Laws.

**January 2:** (p. m.) Vinton. IV. Felt by several in store. Bottles rattled.

**January 5:** 06:42:36\*. Epicenter 32°42' north, 115°57' west, south of Coyote Wells, P. "Residents of Brawley reported feeling a sharp earthquake at about 6:50 a. m., P. S. T., which was followed by two lesser shocks."—(BSSA, April 1951.)

**January 9:** 17:04:12\*. Epicenter 37°42' north, 118°50' west, northern Owens Valley, P. IV. Felt by several in Bishop community. Windows rattled.

**January 13:** 12:31:32\*. Epicenter 40.4° north, 125.0° west, off Cape Mendocino, B. IV. Felt by several in Arcata, by many in Eureka and Ferndale, and by few in Trinidad. Dishes rattled slightly in Arcata.

**January 22:** 07:14:53\*. Epicenter 39°05' north, 119°57' west, B. V. Felt by all in Phillips and Tahoe City. Windows rattled at both places, hanging objects swung at the latter. Felt strongly at Marlette Lake, Nev., where buildings creaked, loose objects rattled, and hanging objects swung. Intensity IV in Camino, Grizzly Flats, Las Plumas, Soda Springs (6 miles west of), and Truckee; lesser intensity in Floriston, Norden, near Vallecito, and Woodfords. Also reported felt in Reno and Carson City, Nev.

**January 23:** 23:17:01\*. Epicenter 33°07' north, 115°34' west, near Calipatria, P. Felt over approximately 14,000 square miles in southern California and southwestern Arizona. See map. Maximum intensity VII.

INTENSITY VII:

*Westmorland vicinity.*—Approximately 3½ miles southwest of town in Imperial Valley Irrigation District 100 feet of ground running NW-SE settled 1 inch; the Westside Main in vicinity of Trifolium was cracked; and canal banks were cracked at head of Lateral 13 of Westside Main. Three miles west of town many people were awakened and frightened, hanging objects swung, pendulum clocks stopped, and vases overturned. Press reported several shocks were felt.

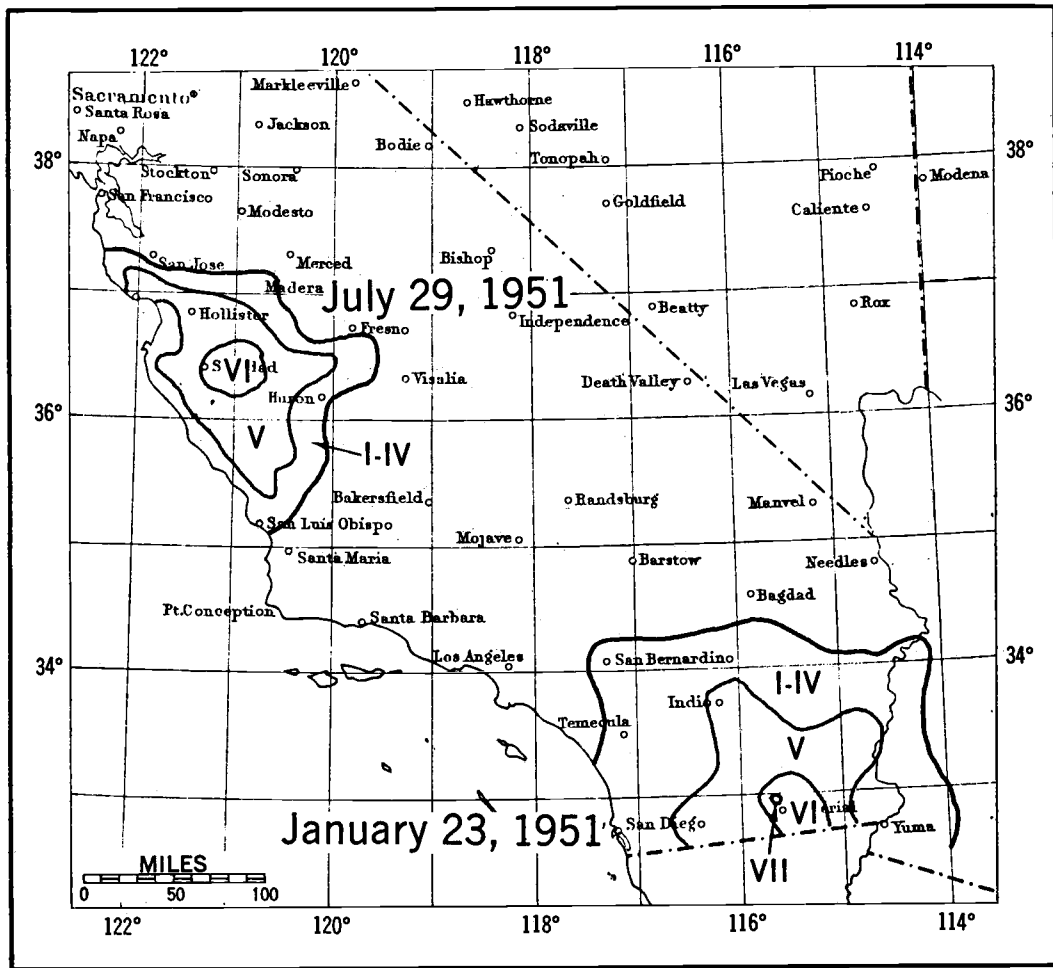


FIGURE 4.—Areas affected by the earthquakes of January 23 and July 29

INTENSITY VI:

*Brawley.*—Felt by and awakened many. Loose objects rattled, hanging objects swung, small objects and furnishings shifted. Some plaster cracks and broken dishes.

*Calxico.*—Felt by and awakened all. Press reported Heber Avenue cracked in some places. Loose objects rattled considerably, some small objects overturned. Houses creaked. Slight plaster cracks.

*Calipatria.*—Felt by all in community. Awakened and frightened all in community. Rattled loose objects, shifted small objects.

*Coachella.*—Felt by all, awakened and frightened many in community. Loose objects rattled, hanging objects swung, pendulum clock stopped. Plaster cracked and dishes broke.

*El Centro.*—Felt by all, frightened many. Press reported plaster cracked in some stores and homes, and a Grandfather's clock stopped in a downtown jewelry store. Loose objects rattled, houses creaked, and hanging objects swung.

*Holtville.*—Felt by all, awakened and frightened many. Loose objects rattled, houses creaked. Plaster cracked. Trees and bushes shaken moderately.

*Imperial.*—Felt by all. Buildings creaked, loose objects rattled, plaster cracked in a few homes. Venetian blinds swayed, chandeliers swung in clockwise motion. Four lighter shocks followed in next 20 minutes.

*Mount Laguna.*—Felt by all in area, awakened few. Loose objects rattled, houses creaked, and hanging objects swung.

INTENSITY V: Camp Angelus, Campo, Del Mar, Descanso, Dulzura, Glamis, Heber, Indio, Indio (just west of), Jacumba, Mecca (2½ miles southeast of), Mecca, Niland, Palo Verde, Pine Valley, Ramona, San Jacinto, Thermal, and Wildomar.

INTENSITY V IN ARIZONA: Yuma.

INTENSITY IV: Anza, Beaumont, Desert Center, Forest Home, Jamul, Julian (Ensign Ranch), Lake Henshaw, Mesa Grande, Midland, Needles, Oceanside, Palm Springs, Riverside, Romoland, San Diego, Valley Center, and Winterhaven.

INTENSITY IV IN ARIZONA: Parker, Somerton, and Tacna.

INTENSITY I TO III: Pearblossom, Twentynine Palms, and Warner Springs.

INTENSITY I TO III IN ARIZONA: Gadsden.

Negative reports were received from 22 places in California and from 4 places in Arizona. Felt reports, with no details, were received from El Cajon, Lakeside, La Mesa, and San Bernardino, Calif.

**January 24:** 01:38:23\*. Epicenter 33°07' north, 115°34' west, near Calipatria, P. IV. Felt by many in Imperial, where buildings creaked and loose objects rattled. Venetian blinds and chandeliers swung. Also reported felt in Bard and Winterhaven, and in Somerton and Yuma, Ariz.

**January 24:** 01:55:58\*. Epicenter 33°07' north, 115°34' west, near Calipatria, P. IV. Felt by about 25 people at Parker Dam. Awakened few.

**January 24:** 06:45:38\*. Epicenter 33°07' north, 115°34' west, near Calipatria, P. IV. Felt by perhaps one-third of the people who were awake in Imperial.

**January 25:** 13:00:18\*. Epicenter 38°45' north, 122°11' west, B. Felt over a small area of the San Francisco East Bay region. Slight damage in Oakland and San Leandro. Maximum intensity VI.

INTENSITY VI:

*Oakland.*—Press reported one window broken and another cracked in the 2700 block of Truman Avenue, also dishes knocked from shelves. Many residents in neighborhood ran into the streets.

*San Leandro.*—Press reported plaster walls of San Leandro Post Office cracked on second floor; large chunks of plaster fell in two places, one about 24 inches wide and 4 feet long and another the same width and about 30 inches long. In other parts of town loose objects rattled, hanging objects swung, plaster cracked and fell, and dishes broke.

INTENSITY IV: Pleasanton (1 mile south of).

INTENSITY III: Hayward and Moraga.

Negative reports were received from 7 places.

**January 26:** 23:20. Ocotillo Village. III. Felt by several.

**February 2:** 02:50. Valley Center. III. Bumping and rocking motion, E-W. Thunderous and roaring subterranean sounds heard.

**February 2:** 14:44. Big Bend. III. Felt by several. Two loud thunderous sounds heard.

**February 4:** 12:52:18\*. Epicenter 33°57' north, 118°28' west, near Santa Monica, P. II. Slightly felt by few at Los Angeles Weather Bureau Airport Station.

**February 13:** 09:16:00\* and 09:46:34\*. Epicenter 32°58' north, 115°32' west, near Brawley, P. V. Both shocks felt by all in Imperial where buildings creaked, disturbed objects were observed by many, and suspended lamps swung. Second shock was lighter and was noticed by few. Also felt in Campo and El Centro where loose objects rattled. In Jacumba (Carriso Gorge, Tunnel 15) the first tremor was felt in a railroad coach, roof and walls rattled. Also felt by several in San Diego and Brawley.

**February 14:** 22:00 (about). Felt by observer in Wildomar.

**February 15:** 02:47:59\* and 02:49:57\*. Epicenter 33°29' north, 116°30' west, near Santa Rosa Mountains, P. Felt over about 7,000 square miles in coastal areas of Riverside, San Diego, and Imperial Counties. Maximum intensity V.

INTENSITY V: Anza, Borego Valley, El Cajon, Hayfield Pumping Plant near Desert Center, Hemet, Indio, Mecca, Mecca (3 miles southeast of), Mesa Grande, Palm Springs, Palomar Mountain, Riverside, San Diego, San Marcos, and Thermal.

INTENSITY IV: Campo, El Centro, Jacumba (Carriso Gorge, Tunnel 15), Jamul, Lake Henshaw, Mount Laguna, Warner Springs, White Water, White Water (about 5 miles southwest of), and Wildomar.

**February 19:** 14:36:07\*. Epicenter 40°04' north, 120°42' west, B. VI. Two hard shocks felt by and frightened all in Spring Garden. Loose objects rattled, walls creaked, and small objects shifted. Also felt in Butte Valley, Caribou, and Quincy, IV, where dishes rattled and lights swung. Rattling subterranean sounds were reported from Quincy.

**February 20:** 00:33. V. Felt by observer in home at Parker Dam. Windows rattled, hanging objects swung, and small objects and furnishings shifted.

**February 21:** 04:52:17\*. Epicenter 39.0° north, 122.5° west, B. "A sharp earthquake was felt in the Ukiah area . . . apparently felt most strongly in Talmage."—(BSSA, April 1951.)

**March 4:** 05:32 and 05:33. Santa Maria. IV. Felt by many. Buildings creaked and loose objects rattled.

**March 4:** 13:03. El Cajon area. "A slight earthquake was felt in the El Cajon area . . ."—(BSSA, April 1951.)

**March 5:** 11:50. Santa Maria. IV. Felt by many in southeast section of town. Press reported a jolting earthquake at the U. S. Weather Bureau station at Hancock Field, E-W movement, and reportedly the hardest shock felt in several years. No damage.

**March 9:** 21:35. Arlight. IV. Felt by many in homes.

**March 10:** 00:10:17\*. Epicenter 40.3° north, 124.3° west, B. Felt over a small area in Humboldt County. Maximum intensity VI. Felt by and awakened all in Ferndale area. Windows and doors rattled, frame houses creaked.

INTENSITY V: Bridgeville, Carlotta, Fields Landing, Loleta, and Scotia.

INTENSITY IV: Arcata, Fortuna, Garberville, Miranda, Petrolia, and Weott.

Negative reports were received from 3 places.

**March 10:** 07:52:25\*. Epicenter 34°04' north, 116°52' west, Upper Mill Creek, P. IV. Felt by all in home in Fawnskin, windows rattled; felt by several in Hemet, awakened few, loose objects rattled, and walls creaked. Also felt by observer in Riverside.

**March 13:** 00:41. III. Felt by observer in electric generating station in San Diego.

**March 13:** 21:01:49\*. Epicenter 33°51' north, 118°41' west, Santa Monica Bay, P. IV. Press reported an earthquake felt in West Los Angeles, North Hollywood, and the San Fernando Valley. Police received a large number of telephone calls and windows rattled in homes. Felt by many and alarmed many in west section of Los Angeles.

**March 15:** 05:50:43\*. Epicenter 35°01' north, 120°29' west, near Santa Maria, P. IV. Felt by many in Los Alamos.

**March 19:** 04:26. Press reported very light shock felt in Long Beach. Faintly recorded instrumentally at Pasadena.

**March 25:** 22:07:34\*. Epicenter 34°37' north, 119°30' west, northeast of Santa Barbara, P. IV. Felt by several in Ojai where buildings creaked and loose objects rattled, and by several in Summerland where windows, doors, and dishes rattled. Press reported the tremor was also felt in Ventura.

**March 29:** 15:39:29\*. Epicenter 33°17' north, 116°02' west, west shore of Salton Sea, P. IV. Felt by observer in home in Ramona. Windows rattled. Buildings creaked and loose objects rattled in Valley Center. Felt slightly in Campo, and felt by several in Electric Building in San Diego.

**March 30:** 18:01:54\*. Epicenter 36°02' north, 117°48' west, near Coso Hot Springs, P. IV. Felt by several near South Haiwee Reservoir. Windows, doors, and dishes rattled; houses creaked. Not felt at Power Plant.

**April 1:** 11:21:08\*. Epicenter 40°28' north, 125°18' west, B. III. Felt by several in Ferndale.

**April 13:** 08:41:20\*. Epicenter 33°59' north, 118°36' west, off Santa Monica, P. IV. Felt by many at Los Angeles Airport. Also felt in other sections of western Los Angeles and slightly felt in the downtown area.

**April 20:** 21:03:15\*. Epicenter 33°29' north, 116°20' west, Santa Rosa Mountains, P. IV. Felt by several in Julian where buildings creaked and loose objects rattled. A few reported faint subterranean sounds at time of shock.

**April 27:** 03:34:53\*. Epicenter 36°40' north, 121°10' west, B. V. Felt by and awakened many 7 miles south of Hollister. Windows, doors, and dishes rattled; house creaked. Hanging objects swung.

**May 28:** 21:08:24\*. Epicenter 35°05' north, 119°39' west, Elkhorn Hills southwest of Taft, P. IV. Felt by most everyone in the Cuyama Valley. One short bumping subterranean sound reported.

**June 12:** 14:21:21\*. Epicenter 36°10' north, 117°52' west, near Haiwee, P. IV. Felt by several in home, outdoors by some, at Haiwee Powerhouse Camp near Coso Junction. Windows and doors rattled.

**June 13:** 11:39:36\*. Epicenter 36°10' north, 117°52' west, near Haiwee, P. IV. Felt at Haiwee Powerhouse Camp near Coso Junction. Windows rattled and house creaked.

**June 21:** 20:29:03\*. Epicenter 33°50' north, 117°57' west, near Anaheim, P. V. Felt by quite a number of people in Brea. Slight damage to plaster in Brea City Hall, a lime cement brick building with numerous old cracks throughout. Electrical fixtures swung. Intensity IV in Fullerton where buildings creaked and loose objects rattled.

**June 25:** 11:45:41\*. Epicenter 35°47' north, 117°57' west, west of Brown, P. V. Strongest at Lemon Cove. Buildings creaked, loose objects rattled, and plaster cracked. Disturbed objects were observed by several. Faint subterranean sounds preceded shock. Felt by all at Kern River Powerhouse No. 3; felt by several at Haiwee Powerhouse; felt by many, some outdoors, in Kernville; and felt by many in Trona. At the last-named place buildings creaked, loose objects rattled, telephone wires swayed, and cups swung on hooks. Some people reported a slight foreshock.

An intensity IV aftershock at 17:26:39\* was felt by an observer at South Haiwee Reservoir. Building creaked.

**June 27:** 21:52:51\*. Epicenter 36°49' north, 121°25' west, near Hollister, B. IV. Felt by many in Hollister. Buildings creaked, loose objects rattled, and a large mirror swung back and forth. Visible swaying of Fire House building reported.

**June 30:** 16:16:19\*. Epicenter 35°47' north, 117°57' west, west of Brown, P. III. Three quick jolts felt by two persons in powerhouse camp at South Haiwee Reservoir.

**July 16:** 02:42:00\*. Epicenter 32°35' north, 115°38' west, southwest of Mexicali, P. IV. Sharp jolt awakened few in Mt. Helix.

**July 23:** 18:25:23\* and 19:03:34\*. Epicenter 37°55' north, 122°16' west, Berkeley Hills, B. Felt over a small area of the San Francisco Bay area. Maximum intensity VI. Slight damage.

INTENSITY VI: (First shock.)

*Berkeley.*—Felt by all and frightened many. Loose objects rattled, walls creaked, and hanging objects swung. Vases overturned and knickknacks fell. Slight damage.

INTENSITY V: Oakland.

INTENSITY IV: Lafayette, Moraga, Pinole, Redwood City, Richmond, San Pablo, and Vallejo.

INTENSITY I TO III: Concord, El Cerrito, Pescadero, and Walnut Creek.

Negative reports were received from 11 places.

INTENSITY VI: (Second shock).

*Oakland.*—Felt by many. Water pipe broke and flooded street. Rattled windows, doors, and table lamp; shifted bowl in flat dish. Houses creaked.

INTENSITY V: Albany, Berkeley, El Cerrito, Orinda, Pinole, Richmond, Rodeo, San Francisco, San Pablo, and Sausalito.

INTENSITY IV: Alameda, Fairfax, Lafayette, Piedmont, Redwood City, Saint Mary's College,

San Rafael, South San Francisco, and Vallejo.

INTENSITY I TO III: Concord, Muir Woods National Monument, and Walnut Creek.

Negative reports were received from 14 places.

**July 26:** 18:05:25\*. Epicenter 35°45' north, 118°32' west, west of Kernville, P. V. Felt by entire camp at Kernville Powerhouse No. 3. Violent explosive-like motion with some sway accompanied by faint thunderous subterranean sounds. Generator ground alarm came in on annunciator at time of shock. Felt with intensity IV in Glenville. Thunderous subterranean sounds reported, trees were shaken. Also intensity IV in Kernville; felt by many indoors and rattled windows.

**July 27:** 19:44:43\*. Epicenter 34°00' north, 118°25' west, near Culver City, P. IV. Press reported the Los Angeles Wilshire District jarred. Police at Wilshire Station reported hearing a rumbling and then feeling the tremor. Windows and pictures were shaken in a home near Fairfax Avenue.

**July 29:** 02:53:45\*. Epicenter 36°35' north, 121°11' west, southeast of Mulberry, B. Felt over approximately 10,000 square miles in west-central California. See map. Maximum intensity VI. Slight damage.

INTENSITY VI:

*Bitterwater (Lonoak).*—Felt by and awakened all, frightened few. Slight damage to plastered walls and to outside stucco. Hanging objects swung.

*Pinnacles.*—Felt by and awakened all. Loose objects rattled; hanging objects swung; knickknacks, books, pictures, and plaster fell; chimneys twisted. Slight damage to concrete pipes.

*San Benito.*—Felt by all. Everything rattled, house creaked. Knickknacks, books, pictures, and plaster fell. Small objects shifted, some overturned. Road from San Benito to Hernandez Valley was covered with boulders for many miles.

*Soledad.*—Felt by, awakened and frightened many. Loose objects rattled, hanging objects swung. Trees and bushes shaken slightly. Furnishings shifted.

INTENSITY V: Aptos, Atascadero, Avenal, Ben Lomond, Bradley, Gonzales, Greenfield, Helm, Hollister, Hollister (7 miles south of), Idria, King City, Lockwood, Paicines, Robles del Rio, San Ardo, San Lucas, San Miguel, Santa Cruz, and Shandon.

INTENSITY IV: Big Sur, Caruthers, Cholame, Creston, Jolon, Lemoore, Oilfields, Parkfield, Paso Robles (9 miles east of), Pescadero, San Juan Bautista, San Luis Obispo, San Martin, San Simeon, and Watsonville.

INTENSITY I TO III: Coalinga, El Nido, Mendota, Moss Landing, Mt. Hermon, Salinas, and Volta. Negative reports were received from 28 places.

**July 29:** 14:40:26\*. Epicenter 36°34' north, 121°09' west, southeast of Mulberry, B. IV. Felt by several in home 7 miles south of Hollister. Windows and doors rattled, house creaked.

**August 1:** 21:09:25\*. Epicenter 36°21' north, 121°16' west, near Greenfield, B. IV. Felt by few in Big Sur; felt by many 7 miles south of Hollister; felt by many and frightened few in Robles del Rio. Loose objects rattled at last two places; frame house creaked at first-named place.

**August 6:** 01:05:02,\* 01:54:28,\* and 09:21:45\*. Epicenter 36°37' north, 121°13' west, southeast of Mulberry, B. First and principal shock was felt over an area of approximately 2500 square miles covering coastal region of west-central California. Slight damage.

INTENSITY VI:

*Harris Ranch.*—Felt by all in community 7 miles south of Hollister. Windows, doors, and dishes rattled; house creaked. Hanging objects swung, small objects shifted southwesterly. Vases overturned; knickknacks, books, pictures, and plaster fell.

INTENSITY V: Aptos, Gonzales, Hollister, Monterey, Morgan Hill, Redwood City, Robles del Rio, San Lucas, and Santa Cruz.

INTENSITY IV: Ben Lomond, Big Sur, Bitterwater, Capitola, Davenport, Milpitas, San Francisco, Salinas, and Watsonville.

INTENSITY I TO III: Holy City, Moss Landing, Newark, and Pacific Grove.

Negative reports were received from 15 places.

An aftershock at 01:54:28\* was felt with intensity V in Gilroy, Hollister (7 miles south of), and Monterey. Felt slightly in Hollister, San Gregorio, and Watsonville. An aftershock at 09:21:45\* was felt with intensity IV in Hollister, Parkfield, San Lucas, and Watsonville.

Negative reports were received from 12 places for each aftershock.

**August 8:** 11:42. Orcutt. IV. Felt in Post Office. Windows rattled.

**August 10:** 03:30:08\*. Epicenter 33°16' north, 115°40' west, west of Niland, P. IV. Felt by several and awakened few in El Centro and San Diego.

**August 14:** 23:23\*. Epicenter 33.5° north, 118.2° west, Terminal Island, P. Maximum intensity V at surface. Felt by scores of people in the Long Beach-Wilmington area, more pronounced in the West Long Beach area. Buildings creaked and loose objects rattled. Many oil wells were damaged at a depth of approximately 1675 feet below sea level. A subsurface survey showed 15'' of movement at this depth, the top moving north with respect to the rocks below. Damage estimates ranged upwards of \$2 million.

**August 19:** 06:40:27\*. Epicenter 33°33' north, 117°17' west, near Murrietta, P. IV. Felt by many and frightened few in Wildomar. Loose objects rattled and house creaked. Also felt about 8 miles northeast of Wildomar. A 30-foot power pole weaved about 6'' and wires swayed up and down after shock.

**August 21:** 01:04:56\*. Epicenter 33°40' north, 118°18' west, off San Pedro, P. Reported felt in San Pedro.

**August 23:** 06:08:11\*. Epicenter 33°57' north, 116°54' west, near Banning, P. III. Felt by several in home in Cabazon.

**August 24:** 16:12:12\*. Epicenter 36°38' north, 121°13' west, southeast of Mulberry, B. IV. Felt by several in home 7 miles south of Hollister. Windows rattled and walls creaked.



**August 26:** 07:23:14\*. Epicenter 34°05' north, 118°03' west, southwestern Alhambra, P. IV. Felt by observer in Glendale. Walls creaked. Felt on second floor but not on first floor. Felt by many in west section of San Marino where buildings creaked and loose objects rattled; press reported dishes and window panes rattled in Pasadena and San Gabriel.

**August 28:** 14:12:27\*. Epicenter 34.6° north, 121.0° west, off coast west of Point Arguello, P. III. One bump felt by several in west section of Los Alamos.

**September 2:** 08:27:32\*. Epicenter 31° north, 117° west, off Lower California, W. IV. Felt by many in La Mesa. Felt by many in San Diego; windows rattled and hanging objects swung.

**September 6:** 19:33:18\* Epicenter 33°57' north, 118°20' west, P. V. Strongest in Westchester District of Los Angeles, Manhattan Beach, Redondo Beach, and Torrance. Windows rattled throughout area, people were frightened in Manhattan Beach and Redondo Beach. Felt with intensity IV in El Segundo, the southwest section of Los Angeles, and Venice.

Negative reports were received from 5 places.

**September 17:** 18:30. Big Sur. IV. Felt by several in home, house creaked.

**September 19:** 14:50. Big Sur. IV. Felt by several. Walls creaked.

**September 20:** 05:55:51\*. Epicenter 33°55' north, 118°25' west, near El Segundo, P. V. Press reported sleeping residents in southwest section of Los Angeles County were alarmed. El Segundo police received numerous calls and the fire alarm went off in the Inglewood police station. Also felt in Manhattan Beach.

**September 22:** 00:22:39\*. Epicenter 34°07' north, 117°20' west, near San Bernardino, P. V. Awakened residents in Banning, Chino, Colton, Crestline, Fontana, Ontario, Redlands, Riverside, and San Bernardino. Plaster was shaken loose in parish house of Catholic church in Casa Blanca. Police received hundreds of telephone calls. Felt with intensity IV in Baldwin Park and Lake Arrowhead.

**September 28:** 21:08:12\*. Epicenter 33°58' north, 117°29' west, near Pedley, P. IV. Felt by many in Fontana. Loose objects rattled, moderate rumbling subterranean sounds similar to a heavy truck were heard by many during shock. Press reported the shock was felt in Riverside.

**September 30:** 00:20. "A slight earthquake was felt by residents of El Segundo, Redondo, and surrounding areas . . . No damage was reported."—(BSSA, January 1952.)

**October 3:** 06:45:14\*. Epicenter 36°47' north, 121°18' west, near Tres Pinos, B. Intensity IV in Hollister and 7 miles south of Hollister. Felt by many, houses creaked, and loose objects rattled.

**October 7:** 20:10:35\*. Epicenter 40°17' north, 124°48' west, off Cape Mendocino, B. Felt over approximately 9000 square miles in northwestern California. See map. Maximum intensity VII. Considerable damage to one bridge, other structural damage was moderate.

INTENSITY VII:

Alton (about 1 mile south of).—Considerable damage to the partially completed Van Duzen River bridge. Damage was done to keeper plates, anchor bolts, grout pads, diagonals bent, spans out of

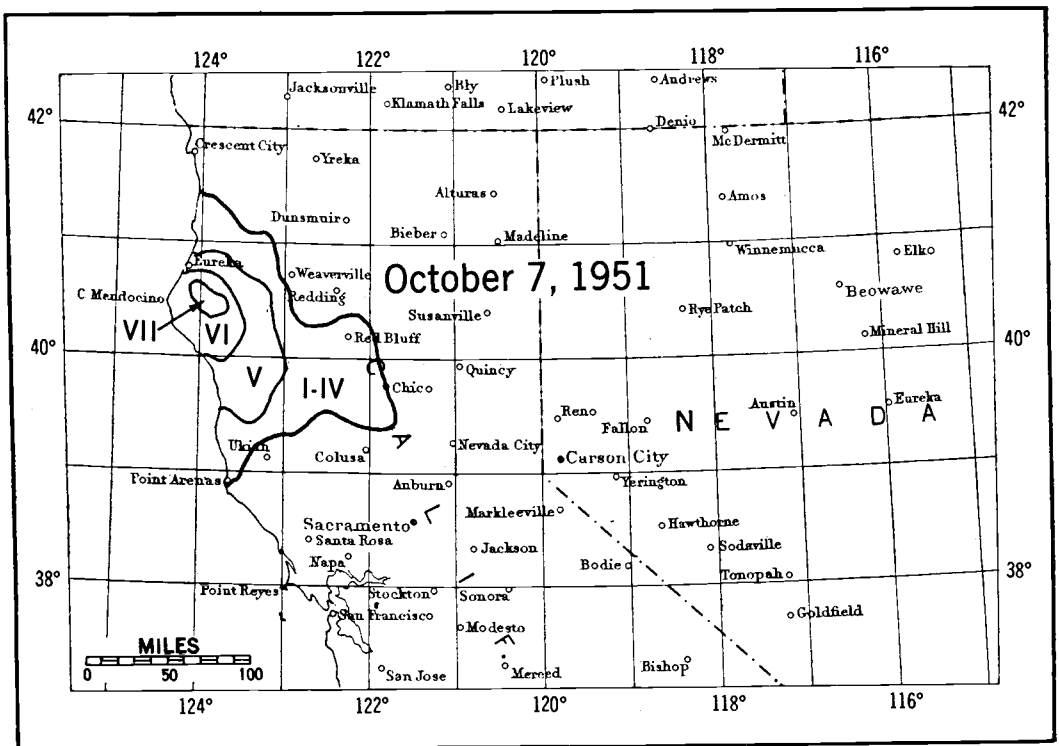


FIGURE 5.—Area affected by the earthquake of October 7.

position, columns out of plumb. Cracks were found in pavement of both approaches and in fill alongside the approaches. The majority of these cracks ran N-S and extended up to 40 yards in length. Slight damage, consisting mainly of a crack in the hip of the arch, was done to the old bridge located about 50 yards to the east of the new bridge.

*Bridgeville.*—Felt by, awakened, and frightened all. Loose objects rattled, houses creaked. Chimneys and plaster cracked, one chimney was leveled. One water pipe was broken.

*Grizzly Bluff.*—Press reported one home damaged considerably with fireplace and chimney wrecked. Another home had foundation and chimney damage. Objects fell and furniture overturned, dishes and windows broke. Some on-surface damage to water pipes.

*Metropolitan.*—Well-built house moved  $1\frac{1}{2}$  inches on foundation. A number of chimneys broke and heavy objects moved. Water pipes broke.

*Rio Dell.*—Press reported liquor and drug supplies fell in several places, causing considerable damage. Minor damage done in many homes. Some garage doors torn off.

*Scotia.*—Felt by all, awakened many, and frightened few in community. Chimneys cracked, knickknacks and pictures fell, dishes broke. Hanging objects swung. Loose objects rattled. Press reported considerable damage done to a drugstore and one home.

*Weott.*—Press reported chimneys were knocked down and dishes fell from shelves.

INTENSITY VI:

*Alderpoint.*—Felt by, awakened, and frightened all. Cracked and loosened some chimneys. Hanging objects swung, small objects shifted. Knickknacks and pictures fell.

*Bell Springs.*—Felt by, awakened, and frightened all. Walls creaked, hanging objects swung E-W. Trees and bushes shaken slightly.

*Benbow.*—Felt by all and frightened few. Loose objects rattled, houses creaked. Trees and bushes shaken strongly.

*Blocksburg.*—Felt by all, awakened all, and frightened few. Slight damage done to masonry. Small objects and furnishings shifted, a few small objects overturned.

*Carlotta.*—Felt by all and frightened many. Windows, doors, and dishes rattled. Few fruit jars knocked off shelves. Slight damage.

*Ehlersburg.*—Felt by all and frightened few. Windows, doors, and dishes rattled; house creaked. Fireplace chimneys cracked. Milk, canned fruit, etc., knocked off shelves.

*Fortuna.*—Felt by, awakened, and frightened all. Loose objects rattled, hanging objects swung. Trees and bushes shaken strongly. Plaster cracked, windows and dishes broke. Pictures, books, plaster, and knickknacks fell. Considerable damage.

*Garberville.*—Felt by and awakened all in home. Loose objects rattled, knickknacks fell. Damage slight.

*Petrolia.*—Felt by all and frightened few. Windows, doors, and dishes rattled. Small objects shifted.

*Upper Mattole region.*—A few cracked fireplaces.

INTENSITY V: Arcata, Blue Lake, Corning, Covelo, Eureka, Ferndale, Fields Landing, Hayfork, Hyampom, Laytonville, Miranda, Piercy, Red Bluff area, Red Bluff (16 miles west of), Westport, Willits, and Willows.

INTENSITY IV: Big Bar, Burnt Ranch, Comptche, Cummings, Denny, Dinsmoore, Elk, Flournoy, Fort Bragg, Glenn, Kneeland, Lake Mountain, Orick, Orland, Richvale, Rockport, Ruth, Spyrock, Trinidad, Vina, and Willow Creek.

INTENSITY I TO III: Lassen Volcanic National Park, Los Robles, Manchester, Paskenta, and Tehama.

Negative reports were received from 24 places.

October 11: 15:52. "A short earthquake rocked Gilroy . . . causing no damage."—(BSSA, January 1952.)

October 11: 17:18:08\*. Epicenter  $35^{\circ}28'$  north,  $118^{\circ}12'$  west, near Piute Peak, P. III. Felt by observer in home at Jawbone Aqueduct Station.

October 13: 21:00:14\*. Epicenter  $37^{\circ}27'$  north,  $122^{\circ}18'$  west, west of Redwood City, B. V. Press reported a sharp earthquake rattled dishes, shifted furniture, and alarmed residents in the Redwood City area. Houses were shaken severely in the Emerald Lake area, one report was received of a desk being moved. Also felt in San Carlos, Belmont, and San Mateo.

October 16: 04:41:05\*. Epicenter  $34^{\circ}10'$  north,  $116^{\circ}59'$  west, south of Big Bear, P. VI. Awakened all in Fawnskin. Windows, doors, and dishes rattled; houses creaked. Awakened few in Hemet, Moreno, and Riverside. Loose objects rattled and houses creaked.

October 18: 00:37. Hollister. Press reported moderate earthquake in area just south of Hollister.

October 20: 17:19:24\*. Epicenter  $37^{\circ}22'$  north,  $121^{\circ}46'$  west, east of San Jose, B. Reported felt in East Foothill area of San Jose.

October 22: 17:15 and 17:25. "Two sharp, short earthquakes were felt in San Bernardino. . . . The shocks were reported strongest in the north end of the city. There were no reports of damage."—(BSSA, January 1952.)

October 23: 07:47:21\*. Epicenter  $36^{\circ}55'$  north,  $121^{\circ}32'$  west, near Chittenden Junction, B. IV. Felt by several in home 7 miles south of Hollister. Windows rattled and walls creaked. Also reported felt in two homes in Chittenden area east of Watsonville.

October 25: 05:48:14\*. Epicenter  $33^{\circ}52'$  north,  $118^{\circ}05'$  west, near Artesia, P. IV. Felt by many in Long Beach. Also felt in Artesia, Bellflower, and Lakewood.

October 26: 00:50:37\*. Epicenter  $33^{\circ}52'$  north,  $118^{\circ}05'$  west, near Artesia, P. IV. Light shock felt by many in Lakewood area of Long Beach. Also felt at the Long Beach airport.

October 30: 11:55:14\*. Epicenter  $36^{\circ}54'$  north,  $121^{\circ}25'$  west, near Hollister, B. IV. Felt by several in Santa Cruz where buildings creaked and loose objects rattled. Also felt at the Hollister Fire House, and 7 miles south of Hollister.

**October 30:** 11:59:18\*. Epicenter 36°54' north, 121°25' west, near Hollister, B. IV. Felt by many and frightened few at Hollister Fire House. Rattled windows, doors, and dishes; buildings creaked. Lights and blinds swung. Plaster powder fell.

**October 30:** 13:08:46\*. Epicenter 36°54' north, 121°25' west, near Hollister, B. IV. Felt by several in Santa Cruz. Buildings creaked and loose objects rattled. Slightly felt in Gilroy, at Hollister Fire House, and 7 miles south of Hollister.

**October 31:** 08:59:50\*. Epicenter 36°54' north, 121°25' west, near Hollister, B. Very slight shock felt in Gilroy and at Hollister Fire House.

**October 31:** 12:58:19\*. Epicenter 36°54' north, 121°25' west, near Hollister, B. Felt over an area of approximately 2,500 square miles of coastal region. Maximum intensity VI. Slight damage.

## INTENSITY VI:

*Hollister Fire House.*—Felt by all, frightened many. Rattled loose objects, hanging objects swung N. Plaster dust fell, lamp overturned and broke. Press reported a large window in bank building was loosened in framework.

Intensity V in Gilroy where press reported visible shaking of walls of buildings. Pictures on walls moved back and forth.

INTENSITY IV: Big Basin, Boulder Creek, Los Gatos (5 miles west of), Morgan Hill, Newark, San Jose, Santa Cruz, San Francisco, San Martin, Sausalito, Tres Pinos, and Vallejo.

INTENSITY I TO III: Chualar, Montara, Moraga, Oakland, Redwood City, San Juan Bautista, Santa Clara, and South San Francisco.

Negative reports received from 55 places.

**November 1:** 00:08:20\*. Epicenter 36°54' north, 121°25' west, near Hollister, B. IV. Felt in Gilroy and Hollister. Felt by many, awakened and frightened few at latter place. Windows and dishes rattled, hanging objects swung N.

**November 1:** 10:23:03\*. Epicenter 34°00' north, 118°24' west, near Culver City, P. Felt in Los Angeles near Adams and La Brea.

**November 13:** 03:24:42\*. Epicenter 40.4° north, 125.3° west, off Cape Mendocino, B. V. Two shocks felt by many 7 miles northeast of Bridgeville. Buildings creaked, loose objects rattled. Disturbed objects observed by many. Also felt in Blue Lake, Fortuna, and Alton.

**November 14:** 00:39:53\*. Epicenter 40°26' north, 124°03' west, near Scotia, B. Sharp shock felt over approximately 3,000 square miles in Eel River Valley in northwestern California. See map. Maximum intensity VI. Slight damage.

## INTENSITY VI:

*Eureka.*—Press reported a large window in the Humboldt Times Building was broken.

*Eureka, Weather Bureau.*—Felt by all, awakened many, and frightened few. Loose objects rattled. Trees and bushes shaken slightly.

*Eureka.*—Awakened and frightened many. Hanging objects swung. Windows, doors, and dishes rattled; houses creaked.

*Ferndale.*—Felt by all, awakened many, and frightened few. Loose objects rattled, walls creaked, hanging objects swung. Pendulum clocks stopped.

*Fields Landing.*—Felt by and awakened all, frightened many. Rattled windows, doors, and dishes. Hanging objects swung N. Windows and dishes broke, slight damage to wood. Small objects and furnishings shifted.

*Fortuna.*—Felt by and awakened many. Press reported merchandise scattered over floors of several stores. Pictures and knickknacks fell. Plaster cracked in store. Trees and bushes shaken moderately.

*Scotia.*—Felt by and awakened many. Press reported merchandise fell from shelves in some stores. Loose objects rattled, hanging objects swung. Houses creaked.

INTENSITY V: Alton, Arcata, Blue Lake, Briceand, Bridgeville, Carlotta, Dyerville, Ettersburg, Garberville, Holmes, Kneeland, Loleta, Miranda, Pepperwood, Piercy, Rio Dell, and Trinidad.

INTENSITY IV: Alderpoint, Benbow, Denny, Hoopa, Orick, Shelter Cove, Weott, and Westport. Negative reports were received from 24 places.

**November 14:** 15:55:03\*. Epicenter 32°57' north, 116°15' west, southeast of Vallecito, P. IV. Felt by many in Campo and Hipass, felt by several in Mt. Helix and Grossmont Districts of San Diego. Windows, doors, and dishes rattled, house creaked, at first-named place.

**November 16:** 19:19.8\*. Epicenter 34.7° north, 120.5° west, near Lompoc, P. III. Felt by several in Los Alamos.

**November 16:** 20:20:28\*. Epicenter 34°55' north, 119°02' west, near Lebec, P. IV. Rattled dishes and floor lamps in Frazier Park. No damage was reported.

**November 25:** 23:21:53\*. Epicenter 38°31' north, 122°45' west, north of Santa Rosa, B. Press reported shock was felt strongest in east section of Santa Rosa.

**November 26:** 00:53:30\* and 05:21:26\*. Epicenter 38°31' north, 122°45' west, north of Santa Rosa, B. Press reported both shocks felt. Grocery store stocks of canned goods were toppled from shelves.

**November 29:** 05:05:09\*. Epicenter 37°57' north, 122°18' west, near El Cerrito, B. IV. Felt by many in Albany. Felt by several in different sections of Berkeley.

**December 3:** 10:18:46\*. Epicenter 34°02' north, 117°17' west, northeast of Riverside. Press reported shock was felt in San Bernardino. A foreshock was recorded at 10:08:54.\*

**December 4:** 07:55. Pearblossom and vicinity. V. Felt by all. Windows, doors, and dishes rattled; hanging objects swung; small objects shifted. Felt like a nearby dynamite explosion.

**December 5:** 07:53:14\*. Epicenter 33.1° north, 115.4° west, P. Felt over approximately 3,000 square miles in Imperial Valley with very limited area of maximum intensity. See map.

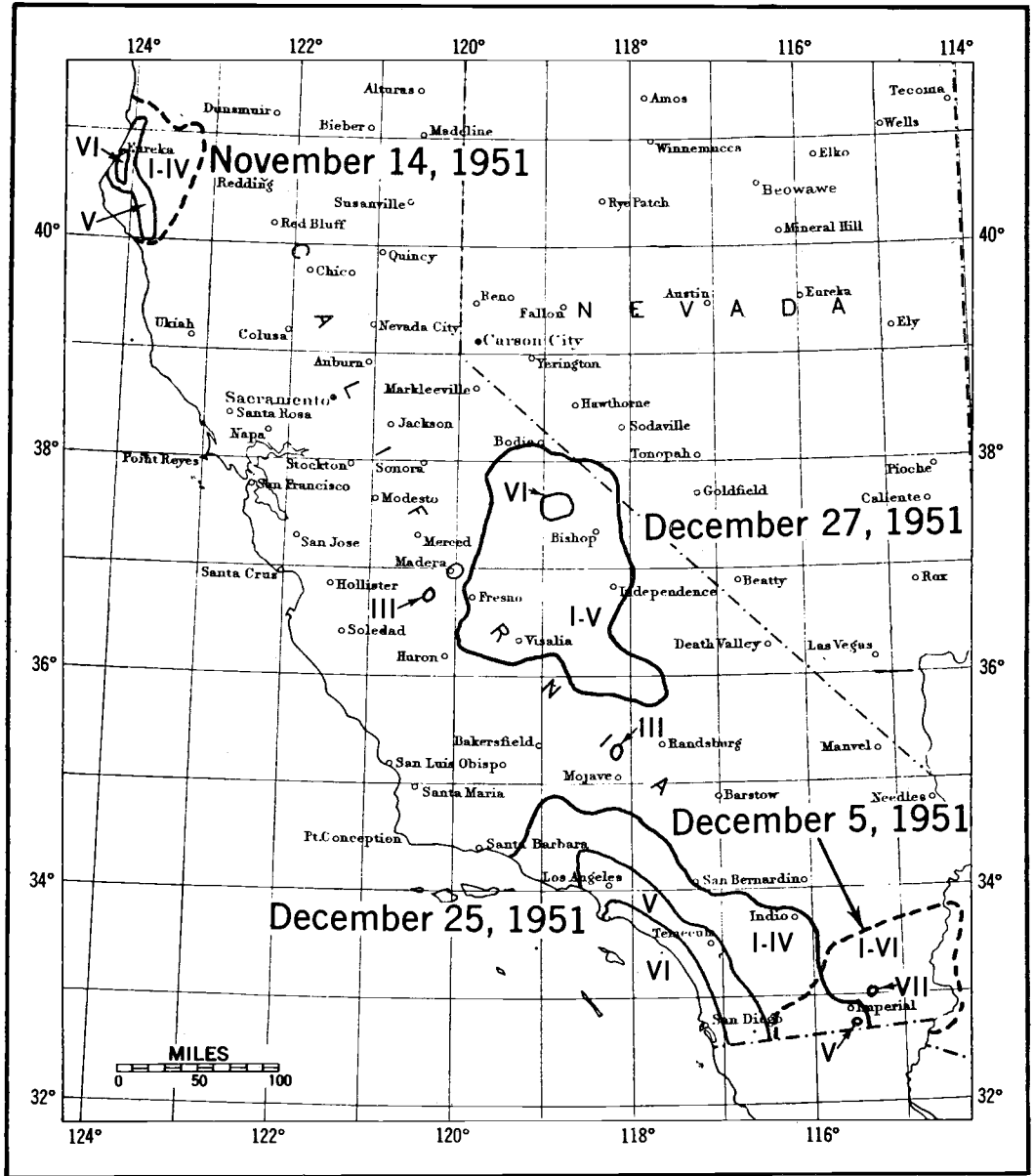


FIGURE 6.—Areas affected by the earthquakes of November 14, December 5, 25, and 27.

**INTENSITY VII:**

*Brawley (about 10 miles northeast of).*—Crack in gravel road 100 feet long and  $1\frac{1}{2}$  inches wide. Cracks and bank damage to canals. Broken plumbing in several residences. Broken windows and stucco damage. One artesian well spouted water 10 feet during shock, another ran muddy for so long it was thought the casing was broken. Stocks were thrown from shelves in grocery store. Ceiling lights crashed to floor, dishes were thrown from cupboards and broken, wall pictures were knocked off hooks, and furniture was shifted several feet. Shock was felt in all Northend cities, but only slightly in the Southend.

**INTENSITY V:** Calexico.

**INTENSITY IV:** Brawley, Blythe, Calipatria, El Centro, Niland, and Palo Verde.

**INTENSITY IV IN ARIZONA:** Yuma.

**INTENSITY I TO III:** Aguanga, Jacumba, Mountain Center, Plaster City, San Juan Capistrano, and San Diego.

Negative reports were received from 46 places in California and from 10 places in Arizona.

**December 12:** 22:44\*. Mount Laguna. III. Felt by several.

**December 14:** 03:50:09\*. Epicenter 33°56' north, 118°18' west, near Inglewood, P. V. Strongest in Huntington Park and southwest section of Los Angeles. Felt by and awakened many. Started with noise mistaken for sharp explosion. Pronounced rattling of windows, one report of a crack in ceiling in Los Angeles. Doors rattled in Huntington Park. Also felt in El Segundo and Torrance. Buildings creaked and loose objects rattled at last-named place.

**December 25:** 16:46:54\*. Epicenter 32°49' north, 118°21' west, near southeast point of San Clemente Island, P. Felt over a land area of approximately 18,000 square miles of southwestern California. See map. Maximum intensity VI. Slight damage.

**INTENSITY VI:**

*Avalon.*—Felt by all and frightened many. Loose objects rattled, hanging objects swung N-S. Some plaster and window cracks. Knickknacks, books, and pictures fell. Vases overturned. Water spilled from batteries indoors.

*Del Mar.*—Felt by all, frightened many. Loose objects rattled, houses creaked. Trees and bushes shaken strongly. Knickknacks fell.

*Laguna Beach.*—General alarm. Disturbed objects observed by many. Bird cage swayed 4 inches in E-W direction. Press reported burglar alarms were set off.

*Long Beach.*—Many frightened, some ran into streets. Buildings swayed for several seconds. Plaster fell in one home, a 2½ foot square of tile fell in bathroom of another home. Burglar alarms were set off. Floor lamps swayed, hanging objects swung.

*San Diego.*—Press reported buildings rocked and Christmas tree lights shook. Elevator in the El Cortez Hotel bounced. Chandeliers swayed, canned goods fell in some homes. A stack of hassocks was knocked over in a Point Loma store. In one home a Christmas tree toppled and short-circuited the lights causing a small fire. Telephone poles swayed strongly, automobile bounced like someone jumping on the rear bumper. Trees and bushes shaken strongly. Plaster cracked.

*San Clemente Island.*—Felt by all on island, frightened many. Rattled windows, doors, and dishes. Hanging objects swung, small objects shifted. Trees and bushes shaken moderately. Plaster and windows cracked. Slight damage.

*San Pedro.*—Felt by all in home, frightened few. Loose objects rattled, hanging objects swung E-W. Pendulum clock facing E stopped. Plaster, walls, and chimneys cracked. Slight damage. Trees and bushes shaken moderately.

**INTENSITY V:** Balboa, Barrett Dam (Dulzura), Big Bear City, Bonsall, Burbank, Compton, Dulzura, El Toro, Hawthorne, Huntington Park, Indio, Inglewood, Los Angeles and vicinity, Maywood, Mount Laguna, Newport Beach, Oxnard, Pala, Redondo Beach, Riverside, San Fernando, San Fernando Valley, Seal Beach, Somis, South Gate, Van Nuys, Venice Walnut, Wildomar, and Wrightwood.

**INTENSITY IV:** Acton, Alberhill, Alpine, Atladena, Anza, Artesia, Calexico, Compo, Coachella, El Cajon, El Centro, El Segundo, Escondido, Fall Brook, Fontana, Frazier Park, Gardena, Glendale, Hinkley, Huntington Beach, Idyllwild, Jacumba, Jamul, Julian, Lakeside, Leucadia, Lynwood, Manhattan Beach, Mecca, Oceanside, Pacific Palisades, Pasadena, Pomona, Port Hueneme, San Dimas, San Juan Capistrano, Santa Ana, Santa Fe Springs, Santa Monica, Santa Susana, Santa Ysabel, Valley Center, Valyermo, Ventura, Wilmington, and Yorba Linda.

**INTENSITY I TO III:** Agoura, Alhambra, Alta Loma, Banning, Barstow, Beverly Hills, Camarillo, Culver City, El Monte, Fillmore, Lancaster, Newhall, Perris, Palomar Mountain, Plaster City, San Fernando Power Plant, Sorrento, Tujunga, and Westmorland.

Negative reports were received from 37 places.

**December 27:** 18:49:27\*. Epicenter 37°34' north, 118°35' west, near Owens River Gorge, P. Felt over an area of approximately 10,000 square miles in east-central California. See map. Maximum intensity VI. No damage.

**INTENSITY VI:**

*Long Valley Reservoir.*—Felt by all, frightened few. Dishes rattled and knickknacks fell.

**INTENSITY V:** Bishop, Laws, Roads End, Sequoia National Park (Lodgepole Ranger Station), and Yosemite National Park (central section).

**INTENSITY IV:** Benton, Big Creek, Big Pine Power House (Big Pine), Dunlap, Fresno, Friant, Kings Canyon National Park (Grant Grove Ranger Station), Leevining, Sequoia National Park (Ash Mountain), Visalia, and Wishon.

**INTENSITY I TO III:** Cutler, Jawbone Aqueduct Station, Little Lake, Riverdale, and Tranquillity.

Negative reports were received from 32 places.

**December 28:** 05:19:39\*. Epicenter 37°50' north, 122°12' west, Montclair, B. Press reported the shock was felt in Montclair, North Oakland, East Oakland, and Berkeley (Hillcrest Road and Hillgass Avenue).

## WASHINGTON AND OREGON

(120TH MERIDIAN OR PACIFIC STANDARD TIME)

**January 4:** 05:45. Waterville, Wash. V. Felt by several in the Waterville area only. Buildings creaked, loose objects rattled, and other objects were displaced. Bumping subterranean sounds were heard by many.

**January 7:** 14:45. McNary, Oreg. V. Felt by and frightened many. Windows, doors, and dishes rattled.

**April 3:** Klamath Falls, Oreg. A small two-tremor earthquake shook a 10-mile area near Klamath Falls. State officials reported only slight damage.

**October 9:** 14:59:27.7\*. Epicenter 48°10.8' north, 122°46.2' west, near Seattle, Wash., Victoria, B. C. IV. Felt by a few persons in the downtown district, also by people in the Capitol Hill and West Seattle suburban areas. Two slight jars were felt by many at the Seattle-Tacoma Airport.

## ALASKA

(150TH MERIDIAN OR ALASKA STANDARD TIME)

- January 16:** 22:33. Anchorage. Windows rattled in central section of city.
- January 22:** 21:00. Anchorage. Floor lamp wobbled, cups on hooks swayed visibly, and lights swayed.
- February 8:** 00:40. Anchorage. Felt.
- February 12:** 17:02. Cordova. Fluorescent lighting fixtures swayed. Disturbed objects noted by several.
- February 25:** 06:20. Homer. Three strong jerks felt by all occupants of a new 2-story well-constructed hotel. Building creaked.
- March 6:** 20:30. Puntilla. Felt.
- March 15:** 08:25. Caswell. Felt.
- March 15:** 08:30 to 09:00. Palmer. Felt by several. Light objects rocked slightly at Matanuska Experiment Station Farm. Another light shock felt on March 30 at 23:23.
- March 28:** 02:50. Teller. Felt.
- March 30:** 16:45. Teller. Felt.
- March 30:** 23:18. Valdez. Felt.
- April 3:** 03:20. Palmer. Felt.
- April 9:** 05:26. Eklutna. Felt.
- May 7:** 15:55. Caswell. Felt.
- May 13:** 16:43. Caswell. Felt.
- June 25:** 06:12:32\*. Epicenter 61° north, 150° west, near Anchorage, W. V. Sharp temblor in Anchorage caused light fixtures to sway, parked cars to bounce in the streets, and liquor containers to tumble from top shelves. Shattered light bulbs in Loussac-Sogn building and glassware in homes. Phonograph records rolled out of their files at radio station KENI. Residents were startled. In Spenard where the shock was felt strongest, grocery, clothing, and drug stocks fell off shelves. Several residents in Cordova reported feeling the shock and swaying of venetian blinds and light fixtures. In Palmer additional shocks were felt at 07:40 and 08:20.
- July 19:** 18:27. Eklutna. Felt.
- July 19:** 18:32. Caswell. Felt.
- August 16:** 19:38. Anchorage. Light shock reported felt by two persons standing in an Anchorage hotel.
- September 11:** 16:00. Valdez. Felt.
- September 26:** 00:03:19. Finger Bay. Felt by many.
- September 26:** 19:21. Finger Bay. Felt by few.
- November 4:** 05:28:22. College. Felt.
- November 15:** 03:55. Palmer. Felt by several at Matanuska Experiment Station Farm. Also felt at Panoramic View, and Anchorage. Windows rattled.
- November 23:** 19:30:38. Finger Bay. Felt by many.
- December 30:** 07:40. Palmer. Felt by many at Matanuska Experiment Station Farm.
- December 31:** 22:02. Palmer. Felt by several at Matanuska Experiment Station Farm.

## HAWAIIAN ISLANDS

(HAWAIIAN STANDARD TIME)

NOTE.—Data on the following local disturbances were determined from seismograph stations operated on the island of Hawaii by the Hawaiian Volcano Observatory of the United States Geological Survey. "Felt locally" appearing in the summary means in the vicinity of the Observatory. For additional information see *The Volcano Letter*, Nos. 511-514.

- February 14:** 10:55. Slight. Felt at Kapapala. Origin Kaoiki Fault near Ainapo, about 7 miles deep.
- February 16:** 07:26. Slight. Felt from Hilo to Naalehu. Origin northeast rift of Mauna Loa near Puu Ulaula, about 15 miles deep.
- March 14:** 20:50. Slight. Felt in Hilo and Volcano areas. Origin east rift of Kilauea, 3 miles east-northeast of Napau Crater, about 7 miles deep.
- March 20:** 06:42. Feeble. Felt in Puueo. Origin east slope of Mauna Loa, 3 miles east of Kulani Cone, about 6 miles deep.
- April 13:** 01:19. Very feeble. Felt at Waimea. Origin about 8 miles southwest of Waimea, shallow depth.
- April 22:** 04:54. Moderate. Felt at Kapapala and from Volcano district to Hilo. Origin east rift of Kilauea, 7 miles S 15° E of Glenwood, 21 miles deep.
- April 22:** 14:52:21\*. Epicenter 19° north, 155½° west, near Kilauea Caldera, Hawaii, W. VII. Generally felt throughout the island of Hawaii and by many on Maui and Oahu. Damage was slight. Dishes broke and small objects overturned on southern part of Hawaii, windows were shattered and bottles thrown off shelves in liquor and drug stores in Hilo. A water pipe broke at the Volcano Observatory, and a window at Glenwood cracked. Water slopped over rims of some tanks. Small earth slips occurred in road cuts between Kilauea Caldera and Hilo, and north of Hilo along the Hamakua coast. Several rock slides occurred on the walls of Kilauea Caldera and a large number of minor slides occurred on the walls of Halemaumau crater. Minor cracking of the highway was reported at the northeast rim of Kilauea Caldera. No surface faulting was observed.
- April 23:** 06:36. Strong. Felt in Volcano district. Origin southwest rift of Kilauea 2 miles southwest of Mauna Iki, 5 miles deep.
- April 26:** 03:58. Strong. Felt in Volcano district. Origin east rift of Kilauea near Makao-puhi, about 12 miles deep.

**May 6:** 08:53. Very feeble. Felt by one person in Volcano district, and by some in Pahala and Naalehu. Origin, Kaoiki Fault zone, 3 miles southwest of Pahala.

**June 7:** 22:50. Slight. Felt in Volcano district and by a few in Hilo. Origin, east rift of Kilauea near Pauahi crater, shallow depth.

**June 11:** 08:33. Slight. Felt generally from Hilo to Volcano district. Origin east rift of Kilauea 6 miles west of Pahoa, about 7 miles deep.

**August 21:** 00:56:57.5\*. Epicenter  $19\frac{1}{2}^{\circ}$  north,  $156^{\circ}$  west, Island of Hawaii, W. IX. A severe earthquake wrecked or damaged scores of homes on the famous Kona coast, opened cracks as wide as 6" in the main coast highway, and sent boulders plunging into the sea churning up heavy surf. A frame school and a store in Honaunau were flattened because of underpinning giving way and the buildings dropping to the ground. Walls of churches were thrown to the ground in Hookena, one-half mile north of Hookena, and Kainaliu. Napoopoo and Kealakekua were also hard hit. Pictures tumbled off walls, dishes dropped off shelves and smashed to the floor, houses moved from their foundations, and several stone walls were leveled. Two persons were injured when their house collapsed at Kai Malino. The Kona coast district, driest section of the island, lost most of its water supply through collapsing of water tanks, a critical loss with two months of normal drought ahead. Water supplies had to be hauled from Hilo.

Telephone service also was out through most of the affected area. A 12-foot wave caused by a cliff falling into the sea damaged a small boat dock at Napoopoo. A landslide covered the famed Pali Kapu o Keoua burial grounds of Hawaiian royalty, and the continuous rumble of the landslide frightened Napoopoo residents onto higher grounds. The main shock was followed by many lesser ones in the following three hours.

**August 21:** 01:29. Strong. Felt strongly in Kona. Origin near previous earthquake.

**August 21:** 03:50. Slight. Kona. Felt from Kona to Volcano district.

**August 21:** 04:00. Moderate. Kona. Felt from Kona to Volcano district.

**August 21:** 09:57. Strong. Kona. Felt from Kona to Volcano district.

**August 21:** 22:47:51\*. Strong. Kona. Felt from Kona to Volcano district.

**August 22:** 06:38. Moderate. Kona. Felt from Kona to Kapapala.

**August 22:** 17:15. Strong. Kona. Felt from Kona to Volcano district.

**August 22:** 17:28. Slight. Kona. Felt as far as Naalehu.

**August 28:** 17:48. Feeble. Felt in Mountain View and Volcano district. Origin about 3 miles east-southeast of Mountain View.

**August 29:** 21:25. Very feeble. Felt in Kona. Origin Kealakekua Fault.

**August 30:** 07:23. Very feeble. Felt strongly in Kona. Origin Kealakekua Fault.

**August 31:** 16:08. Very feeble. Felt strongly (intensity V) in Kona. Origin Kealakekua Fault.

**September 4:** 14:13. Very feeble. Kona. Felt strong (intensity IV) in Kona.

**September 4:** 22:28. Very feeble. Kona. Felt with intensity III in Kona and as far as Naalehu.

**September 12:** 01:27. Very feeble. Felt at Naalehu.

**September 15:** 23:48. Very feeble. Felt at Kapapala.

**September 16:** 01:42:57\*. Strong. Intensity V felt from Kona to Hilo. Origin Kaoika Fault about 3 miles northeast of Kapapala.

**September 23:** 19:01. Very feeble. Felt strongly in Kona.

**September 24:** 03:13. Very feeble. Felt in Kona. Origin near summit of Hualalai.

**September 24:** 23:47. Very feeble. Felt in Hilo. Origin east rift of Kilauea, 10 miles east of Kapoho.

**September 25:** 00:56. Very feeble. Felt in North Kona. Origin northwest rift of Hualalai near 5,000 foot altitude.

**September 25:** 01:23. Slight. Generally felt in Kona. Near previous shock.

**September 26:** 20:20. Very feeble. Felt in Kona. Origin south slope of Hualalai about 4 miles southeast of Holualoa.

**October 5:** 08:42. Very feeble. Felt in Kapapala and Naalehu. Origin Kaoiki Fault near Hilea.

**October 6:** 04:36. Feeble. Felt in Kapapala and Naalehu. Origin Kaoiki Fault, about 4 miles northeast of Kapapala.

**October 7:** 01:28. Very feeble. Felt in Naalehu. Origin near Hilea.

**October 9:** 04:45. Slight. Felt from Kona to Hilo. Origin central Kona.

**October 9:** 05:23. Feeble. Felt in Kealakekua. Origin central Kona.

**October 11:** 21:30. Very feeble. Felt in Kealakekua. Origin central Kona.

**October 11:** 21:30. Very feeble. Felt in Kealakekua. Origin central Kona.

**October 14:** 19:52. Very feeble. Felt in Naalehu.

**October 17:** 21:12. Slight. Felt in Volcano and Hilo. Origin northeast rift of Mauna Loa near the 3000-foot contour.

**October 19:** 01:00. Very feeble. Felt in Volcano. Origin northeast rift of Mauna Loa.

**October 23:** 10:42. Slight. Felt in Kealakekua. Origin central Kona.

**October 24:** 13:15. Very feeble. Felt at summit of Mauna Loa.

**November 8:** 09:34. Strong. Intensity VI in Kahuku. Felt throughout southern part of Hawaii. Origin on southwest rift of Mauna Loa at about 4,500-foot altitude.

**November 8:** 14:22. Very feeble. Felt in Kealakekua.

**November 11:** 07:08. Slight. Felt in Hilo. Origin east rift of Kilauea near Pauahi crater.

**November 17:** 14:50. Feeble. Felt in Kealakekua.

**November 18:** 01:31. Slight. Felt in Kealakekua.

**November 18:** 02:47. Slight. Felt in Kealakekua. Origin central Kona.

**November 23:** 08:22. Slight. Felt from central Kona to Kahuku. Origin Kealakekua Fault about 5 miles west of Napoopoo.

**December 6:** 20:19. Felt from Kapapala to Hilo and east Puna. Origin east rift of Kilauea about 7 miles southwest of Pahoa.

**December 29:** 17:32. Very feeble. Felt in Naalehu and Kapapala. Origin Kaoiki Fault near Pahala.

### PANAMA CANAL ZONE

(60TH MERIDIAN TIME)

**January 4:** 20:52:40\*. Epicenter 7° north, 81° west, near south coast of Panama, W. Felt throughout Canal Zone, including many spectators at a ball game in Balboa Stadium.

**January 5:** 15:18:33\*. Felt by a few in Canal Zone.

**January 6:** 07:51:31\*. Epicenter 7½° north, 81° west, near south coast of Panama, W. V. This was the strongest shock in the Canal Zone since May 2, 1943, and awakened most residents on both sides of the Isthmus and alarmed many. Dishes, pots, pans, and windows rattled, with some broken. Unstable objects overturned. Plaster walls in the Panama Canal Administration Building in Balboa Heights were cracked and many previous breaks reopened. Pendulum on the master clock for the seismograph stopped. In Calobre, Cocle Province, Penonome, and Veraguas Province many were frightened and ran into the streets with children in their arms.

**January 6:** 09:59:04\*. Felt with intensity II in Canal Zone.

**January 7:** 09:59:21\*. Felt with intensity II in Canal Zone.

### PUERTO RICO

(60TH MERIDIAN TIME)

**September 15:** 04:11:14\*. Strong local shock shook San Juan, and shifted one of the Wenner galvanometers and the H variometer baseline at the San Juan Magnetic Observatory.

## MISCELLANEOUS ACTIVITIES

### GEODETIC WORK OF SEISMOLOGICAL INTEREST

The program of repeating geodetic control surveys for the purpose of detecting horizontal and vertical movement in the earth's crust was continued during 1951.

A scheme of triangulation in the vicinity of Monterey Bay was reobserved during the year. Earlier observations for this network had been made in 1930. A comparison of the results of the new survey with the old shows the systematic creep of the area southwest of the San Andreas Fault relative to the area northeast of the fault. The direction of the creep is northwesterly and the magnitude is of the order of 2 feet for the 21-year interval.

Another scheme of triangulation extending from Avenal to San Luis Obispo was reobserved. Earlier observations had been made along this arc in 1932. The mathematical adjustments which will be used to determine any horizontal shift are in progress.

Observations for a comprehensive scheme of triangulation crossing the Hayward Fault near the southern end of San Francisco Bay and extending eastward to the high mountain stations, near the Nevada boundary, were begun in 1951. These observations were completed in 1952. This scheme will be used as a basis for making repeat observations at approximate 10-year intervals.

### TIDAL DISTURBANCES OF SEISMIC ORIGIN

Seismic sea waves were recorded at U. S. Coast and Geodetic Survey tide stations from only one earthquake in 1951. At Honolulu and Hilo there were a series of small waves of about one-fourth foot range following the earthquake of August 21 at 10:57 G. C. T., off the west coast of Hawaii. Records from eight other tide gages in the Pacific islands showed no disturbance from this earthquake.



# FLUCTUATIONS IN WELL WATER LEVELS

## INTRODUCTION

The following data are tabulated for the purpose of possibly associating fluctuations in well water levels with earthquakes. Complete information on earthquakes may be obtained from the *Preliminary Determination of Epicenter* and *Supplement* cards issued by the United States Coast and Geodetic Survey or from registers of seismographic stations nearest the locality. The data are made available by the Ground Water Branch of the United States Geological Survey.

Similar data for 1943 were published by the United States Coast and Geodetic Survey in Serial 672, *United States Earthquakes, 1943*, and those for subsequent years through 1949 appeared in Serial 748, *United States Earthquakes, 1949*, and Serial 755, *United States Earthquakes, 1950*. Descriptions of wells given here include only those that have not appeared in previous editions.

## WELL DESCRIPTIONS

### CALIFORNIA

Well No. 5/5-18R1, nonartesian, 38° 15' N., 122° 32' 30" W., Sec. 18, T. 5 N., R. 5 W. Owner, C. W. Stevenson. Depth, 150', diameter, 8". Aquifer, gravel, sand, and clay.

Well No. 7/8-31C1, semiartesian, 38° 25' N., 122° 47' 30" W., Sec. 31, T. 7 N., R. 8 W. Owner, Marino La Franchi. Depth, 250', diameter, 12 to 10". Aquifer, Pleistocene clays, silts, and sands and possibly U. pliocene sands.

### KENTUCKY

Well No. 8730-3750-143, artesian, 37° 49½' N., 87° 34½' W. Owner, Audie Wilson. Depth, 109.45', diameter, 6". Aquifer, white sandstone, Carbondale formation.

Well No. 8755-3735-8, artesian, 37° 35' N., 87° 56' W. Owner, Alex Parcello. Depth, 70', diameter, 6", finish, casing 17". Aquifer, in Rough Creek-Shawneetown Fault zone in Pennsylvania sandstone.

### MICHIGAN

Well No. GeFL491, artesian, NE¼ Sec. 17, T. 7 N., R. 7 E. Owner, Consumers Power Co., Flint. Depth, 223', diameter, 12", finish, end in old coal mine. Aquifer, Saginaw sandstone.

### NEW JERSEY

Well No. 34.5.4.1.6, semiartesian, Seabrook Farms, Seabrook. Owner, Seabrook Farms. Depth, 145', diameter, 12", finish, steel casing. Aquifer, Cohansey.

Well No. 26.22.4.4.4, nonartesian, Hillside Well No. 4, Union County. Owner, Elizabethtown Water Co. Depth, unknown, diameter, 16", finish, steel casing. Aquifer, Triassic red shale, Brunswick formation.

Well No. 36.14.8.2.2, artesian, Galen Hall Well, Atlantic City. Owner, Galen Hall. Depth, in excess of 800', diameter, 5", finish, steel casing. Aquifer, Kirkwood formation.

### NEBRASKA

Well No. 13-11-11ba, nonartesian, City of Dannebrog, Howard County, Sec. 11, T. 13 N., R. 11 W. Depth, 32', diameter, 8", finish, iron.

Well No. 16-11-19cb, semiartesian, City of Cotesfield, Howard County, Sec. 19, T. 16 N., R. 11 W. Depth, 96', diameter, 18", finish, galvanized iron.

Well No. 7-38-28cc, semiartesian, City of Imperial, Chase County, Sec. 28, T. 7 N., R. 6 W. Depth, 143', diameter, 18", finish, steel.

Well No. 15-9-9aa, semiartesian, City of Cushing, Howard County, Sec. 9, T. 15 N., R. 9 W. Depth 90', diameter, 18", finish, galvanized iron.

Well No. 1-6-30dd, nonartesian, City of Superior, Muckolls County, Sec. 30, T. 1 N., R. 6 W. Depth, 48', diameter, 6", finish, tile.

### NEW YORK

Well No. K-519, artesian, 40° 39' 40" N., 73° 56' 15" W. Owner, formerly New York Water Service Corp., Brooklyn. Depth 239', diameter, 28" to 18", finish, screened. Aquifer, Jameco gravel.

Well No. Q-64, artesian, 40° 44' 30" N., 73° 52' 50" W. Owner, Balex, Inc., Elmhurst, L. I. Depth, 564', diameter, 8", finish, screened in Lloyd sand and open in rock. Aquifer, Lloyd sand member of Raritan formation.

Well No. Q-273, artesian, 40° 43' 00" N., 73° 49' 35" W. Owner, U. S. Geological Survey. Depth, unknown, diameter, unknown, finish, screened from 308 to 374' and 376 to 438' below land surface. Aquifer, Lloyd sand member of Raritan formation.

Well No. N-180, artesian, 40° 40' 30" N., 73° 29' 40" W. Owner, U. S. Geological Survey. Depth, 762', diameter, 6", finish, casing. Aquifer, Magothy sand.

Well No. K-19, artesian. Owner, formerly Kew Pacific, near Atlantic Avenue and Flatbush Avenue extension, Brooklyn. Depth, 182', diameter, 8 to 6", finish, screened. Aquifer, Jameco gravel.

### NORTHERN FLORIDA

Well No. P-16, artesian, SE¼NW¼ Sec. 34, T. 25 S., R. 21 E. Owner, A. Messick. Depth, 1008', diameter, 8", Aquifer, Ocala limestone.

Well No. H-500, artesian, SE¼NW¼ Sec. 9, T. 32 S., R. 20 E. Owner, Paul Carter. Depth, 330', cased to 97', diameter, 6". Aquifer, Floridan.

Table 1.—*Fluctuations in well-water levels, January 1 through December 31, 1951*

NOTE.—Complete information on earthquakes possibly associated with the following tabulations may be obtained from the *Preliminary Determination of Epicenter* and *Supplement* cards issued by the U. S. Coast and Geodetic Survey, or from registers of seismographic stations nearest the locality.

CALIFORNIA							
Well No.	Date	Time G. C. T.	Depth to water				Amplitude of fluctua- tion
			Before distur- bance	After distur- bance	At highest point	At lowest point	
8/1W-22D5.....	5-15-51	17:15	<i>ft.</i> 39.58	<i>ft.</i> 39.58	<i>ft.</i> 39.56	<i>ft.</i> 39.60	<i>ft.</i> 0.04
8/1W-28R3.....	6- 5-51	17:25	37.49	37.51	37.49	37.575	0.085
8/1E-20G3.....	6-21-51	19:30	42.88	42.78	42.78	42.94	0.16
5/5-18R1.....	6-24-51	03:45	6.545	6.54	6.38	6.55	0.17
5/5-18R1.....	6-24-51	06:15	6.54	6.53	6.47	6.54	0.07
7/8-31C1.....	6-29-51	05:30	13.52	13.52	13.495	13.54	0.045
8/1W-22D5.....	10- 8-51	03:10	44.06	43.995	43.985	44.00	0.015
8/1W-20R2.....	10- 8-51	03:10	59.23	59.23	59.20	59.24	0.04
KENTUCKY							
8730-3750-143.....	6-21-51	01:15	32.943	32.949	32.910	32.976	0.066
8730-3750-143.....	6-24-51	20:45	33.160	33.160	33.150	33.182	0.032
8730-3750-143.....	7- 8-51	20:00	33.900	33.900	33.780	33.940	0.160
8755-3735-8.....	8-21-51	23:00	10.861	10.869	10.760	11.288	0.528
8730-3750-143.....	12- 1-51	13:30	38.578	38.577	38.564	38.595	0.031
MICHIGAN <sup>1</sup>							
GeFL491.....	1- 6-51	03:00	25.97	25.95	25.92	26.00	0.04
GeFL491.....	2-11-51	18:00	26.21	26.23	26.14	26.30	0.08
GeFL491.....	10-21-51	23:00	29.79	29.78	29.76	29.81	0.025
GeFL491.....	11-18-51	16:30	27.01	27.00	26.91	27.11	0.10
GeFL491.....	11-24-51	15:00	26.75	26.75	26.71	26.79	0.04
NEBRASKA							
13-11-11ba.....	1-21-51	08:45	27.81	27.82	27.81	27.82	0.01
16-11-19cb.....	4-27-51	05:30	41.12	41.17	41.06	41.17	0.11
16-11-19cb.....	4-27-51	07:30	41.17	41.11	40.90	41.11	0.21
7-38-28cc.....	5-24-51	03:00	74.84	74.84	74.95	74.78	0.17
15-9-9aa.....	5-31-51	15:00	31.76	31.77	31.76	31.77	0.01
15-9-9aa.....	6- 1-51	09:30	31.77	31.77	31.76	31.78	0.02
13-11-11ba.....	6-16-51	03:25	26.16	26.15	26.15	26.16	0.02
15-9-9aa.....	7- 5-51	05:30	31.47	31.48	31.47	31.49	0.02
15-9-9aa.....	7-17-51	02:00	31.42	31.40	31.34	31.52	0.18
1-6-30dd.....	8-19-51	04:30	31.14	31.15	32.52	33.26	0.74
16-11-19cb.....	8-19-51	11:00	42.59	42.57	42.57	42.60	0.03
13-11-11ba.....	9-29-51	04:30	27.57	27.57	27.56	27.57	0.01
13-11-11ba.....	9-29-51	12:00	27.56	27.55	27.55	27.56	0.01
16-11-19cb.....	10-11-51	11:45	41.59	41.60	41.58	41.60	0.02
NEW JERSEY <sup>2</sup>							
26.21.5.4.6.....	6- 1-51	20:15	+63.92	+63.92	+63.94	+63.90	0.04
31.1.6.4.8.....	6- 1-51	20:15	6.82	6.82			0.02
31.1.6.4.8.....	7- 2-51	14:00	6.39	6.39	6.38	6.40	0.02
28.5.4.8.1.....	8-26-51	20:20	+4.485	+4.485	+4.49	+4.48	0.01
34.5.4.1.6.....	10- 4-51	09:00	+50.905	+50.905	+50.915	+50.895	0.02
26.22.4.4.4.....	10-22-51	05:45	+30.45	+30.45	+30.48	+30.44	0.04
34.5.4.1.6.....	11- 9-51	22:10	+51.37	+51.38	+51.385	+51.355	0.03
28.5.4.8.1.....	11-14-51	20:45	+4.725	+4.725	+4.727	+4.720	0.07
26.22.4.4.4.....	11-18-51	09:50	+30.70	+30.70	+30.78	+30.58	0.20
34.5.4.1.6.....	11-22-51	01:00	+51.00	+51.00	+51.005	+50.895	0.10
26.22.4.4.4.....	11-24-51	19:45	+29.95	+29.95	+30.00	+29.92	0.08
36.14.8.2.2.....	12-28-51	21:15	+55.41	+55.41	+55.37	+55.43	0.06

See footnotes at end of table.

Table 1.—Fluctuations in well-water levels, January 1 through December 31, 1951—Con.

NEW YORK

Well No.	Date	Time G. C. T.	Depth to water				Amplitude of fluctuation  ft.
			Before distur- bance  ft.	After distur- bance  ft.	At highest point  ft.	At lowest point  ft.	
Sn-128	1-24-51	17:00	27.41	27.42	27.38	27.44	0.06
Sn-128	1-24-51	18:20	27.42	27.44	27.33	27.54	0.21
Sn-128	2-21-51	09:15	28.30	28.27	28.09	28.47	0.38
Mt-1	4-28-51	17:00	7.19	7.19	7.185	7.195	0.01
Q-273	4-29-51	23:30	3.770	3.835	3.759	3.835	0.076
K-519	4-29-51	23:45	-2.018	-2.020	-2.005	-2.038	0.035
Q-64	4-30-51	00:00	-5.64	-5.63	-5.62	-5.66	0.04
N-180	4-30-51	00:15	19.862	19.862	19.865	19.840	0.025
K-19	5-23-51	07:15	-11.442	-11.428	-11.428	-11.442	0.014
K-519	5-23-51	08:00	-1.914	-1.900	-1.882	-1.914	0.032
Q-273	5-23-51	08:15	3.764	3.798	3.798	3.764	0.024
K-519	11-18-51	12:40	-1.227	-1.227	-1.222	-1.230	0.008
Q-64	11-18-51	10:00	-2.429	-2.429	-2.240	-2.641	0.401
N-180	11-18-51	11:00	10.677	19.672	19.682	19.660	0.022
S-6434	12-18-51	10:45	31.555	31.555	31.561	31.551	0.010
S-6455	12-18-51	10:45	36.540	36.540	36.547	36.533	0.014

NORTHERN FLORIDA

D-206	1- 6-51	07:50	5.62	5.60	5.63	5.59	0.04
L-7	1- 6-51	07:00	165.87	165.86	165.82	165.88	0.06
M-92	1- 6-51	08:10	39.83	39.79	39.78	39.83	0.05
S-9	1- 6-51	07:45	2.18	2.17	2.18	2.16	0.02
T-35	1- 6-51	08:45	4.90	4.88	4.80	4.96	0.16
D-206	2-13-51	20:00	6.06	6.07	6.05	6.08	0.04
M-92	2-13-51	22:40	40.49	40.49	40.51	40.47	0.04
P-45	2-13-51	22:55	66.39	66.40	66.39	66.41	0.02
T-35	2-13-51	22:50	5.02	5.04	4.97	5.10	0.13
V-31	2-13-51	22:10	5.14	5.15	5.14	5.18	0.04
J-23	4- 3-51	15:45	39.12	39.11	39.08	39.12	0.04
S-9	4-20-51	20:45	2.47	2.47	2.42	2.57	0.15
T-35	5- 5-51	20:40	3.25	3.25	3.24	3.26	0.02
T-35	5- 6-51	23:10	3.36	3.36	3.35	3.37	0.02
D-206	5- 7-51	18:40	7.58	7.57	7.56	7.59	0.03
T-35	5-26-51	16:50	4.07	4.07	4.06	4.12	0.06
T-36	5-26-51	16:50	11.75	11.75	11.75	11.77	0.02
J-23	6- 6-51	16:15	38.44	38.44	38.43	38.46	0.03
T-35	6- 6-51	16:10	4.20	4.20	4.18	4.22	0.04
P-13	6-11-51	19:50	9.46	9.43	9.42	9.46	0.04
P-45	6-11-51	20:00	69.26	69.24	69.24	69.30	0.06
S-5	6-15-51	16:40	8.40	8.39	8.37	8.41	0.04
P-44	7-13-51	17:25	2.82	2.82	2.81	2.82	0.01
L-7	7-18-51	08:30	165.36	165.37	165.36	165.39	0.03
P-45	7-18-51	09:10	66.79	66.78	66.77	66.79	0.02
D-206	7-18-51	09:15	8.38	8.37	8.31	8.43	0.12
E-60	9- 5-51	07:43	9.94	9.94	9.94	9.95	0.02
E-60	9- 7-51	09:05	9.95	9.95	9.94	9.95	0.02
E-60	9- 9-51	03:50	9.94	9.94	9.93	9.95	0.02
E-60	10- 7-51	11:40	8.18	8.18	8.17	8.19	0.02
L-28	10- 7-51	22:40	143.66	143.63	143.64	143.67	0.03
T-35	10-21-51	22:45	2.70	2.70	2.68	2.71	0.03
D-206	10-22-51	04:30	7.38	7.37	7.36	7.38	0.02
T-35	10-22-51	04:40	2.70	2.68	2.64	2.74	0.10
L-7	10-22-51	05:20	165.49	165.48	165.47	165.49	0.02
M-92	10-22-51	05:20	39.52	39.53	39.52	39.54	0.02
L-7	10-22-51	06:15	165.43	165.44	165.43	165.44	0.01
T-35	10-22-51	06:40	2.69	2.68	2.67	2.69	0.02
L-7	10-22-51	07:20	165.47	165.47	165.46	165.47	0.01
P-16	11- 3-51	05:50	64.89	64.90	64.86	64.92	0.06
D-206	11-18-51	10:00	7.07	7.07	6.97	7.17	0.20
H-30	11-18-51	10:35	+8.16	+8.17	+8.18	+8.15	0.03
H-500	11-18-51	10:30	50.46	50.47	50.41	50.54	0.13
L-7	11-18-51	10:00	164.97	164.93	164.87	165.02	0.15
M-92	11-18-51	10:35	40.38	40.41	40.36	40.46	0.10
P-561	11-18-51	10:30	2.67	2.67	2.66	2.68	0.02
P-44	11-18-51	10:35	1.16	1.16	1.15	1.17	0.02
S-9	11-18-51	10:50	2.20	2.18	2.17	2.21	0.04
T-35	11-18-51	11:10	0.20	0.20	0.18	0.22	0.04
D-206	11-24-51	18:15	6.71	6.70	6.68	6.72	0.04
H-500	11-24-51	19:25	50.21	50.19	50.18	50.21	0.03
T-35	11-24-51	20:40	0.50	0.50	0.48	0.52	0.04
D-206	12-12-51	01:20	6.50	6.51	6.48	6.55	0.05
H-500	12-12-51	01:15	49.46	49.48	49.46	49.50	0.04
L-7	12-12-51	01:40	163.38	163.40	163.38	163.41	0.03
D-206	12-18-51	18:45	5.88	5.89	5.88	5.90	0.02
L-7	12-28-51	08:25	163.21	163.20	163.13	163.18	0.05
D-206	12-28-51	09:05	6.07	6.05	6.04	6.07	0.03
H-500	12-28-51	09:10	50.43	50.45	50.42	50.45	0.03
M-92	12-28-51	09:25	40.73	40.71	40.70	40.73	0.03

Table 1.—Fluctuations in well-water levels, January 1 through December 31, 1951—Con.

SOUTHERN FLORIDA							
Well No.	Date	Time G. C. T.	Depth to water				Amplitude of fluctuation  ft.
			Before disturbance	After disturbance	At highest point	At lowest point	
G-350	1- 9-51	15:30	ft. 3.055	ft. 3.055	ft. 3.08	ft. 3.03	0.05
G-518	1- 9-51	15:30	1.76	1.76	1.78	1.74	0.04
F-210	2-13-51	22:20	1.24	1.24	1.26	1.22	0.04
F-291	2-13-51	22:40	1.615	1.615	1.62	1.61	0.01
G-221	2-13-51	23:00	1.58	1.58	1.60	1.56	0.04
S-19	2-13-51	23:00	0.74	0.74	0.75	0.73	0.02
F-210	4- 2-51	00:20	0.88	0.88	0.90	0.86	0.04
F-291	4- 2-51	01:30	0.83	0.83	0.84	0.82	0.02
G-221	4- 2-51	02:10	1.28	1.28	1.30	1.26	0.04
S-68	4- 2-51	00:30	-0.46	-0.46	-0.45	-0.47	0.02
S-329	4- 2-51	01:30	1.90	1.90	1.91	1.89	0.02
F-210	6- 6-51	15:25	1.06	1.06	1.07	1.05	0.02
F-291	6- 6-51	11:30	1.01	1.01	1.02	1.00	0.02
F-210	11-18-51	10:50	1.69	1.69	1.71	1.67	0.04
F-291	11-18-51	11:00	2.01	2.01	2.04	1.98	0.06
G-580	11-18-51	10:40	2.51	2.51	2.54	2.50	0.04
S-18	11-18-51	10:50	1.945	1.945	1.94	1.95	0.01
S-19	11-18-51	10:45	0.84	0.84	0.86	0.82	0.04
S-68	11-18-51	10:45	0.12	0.12	0.14	0.10	0.04
S-329	11-18-51	10:45	3.02	3.02	3.00	3.04	0.04
F-210	12-12-51	01:40	1.35	1.35	1.37	1.33	0.04
F-291	12-12-51	01:40	1.57	1.57	1.63	1.53	0.10
G-72	12-12-51	01:20	6.12	6.12	6.125	6.115	0.01
G-518	12-12-51	01:10	1.33	1.33	1.32	1.34	0.02
G-580	12-12-51	01:35	2.23	2.23	2.25	2.21	0.04
G-612	12-12-51	01:20	1.00	1.00	0.99	1.01	0.02
S-19	12-12-51	01:40	0.85	0.85	0.88	0.82	0.06
S-68	12-12-51	01:30	0.05	0.05	0.02	0.09	0.07
S-329	12-12-51	01:50	2.23	2.23	2.25	2.21	0.04
F-210	12-28-51	09:34	1.05	1.05	1.07	1.02	0.05
F-291	12-28-51	09:30	1.30	1.30	1.33	1.25	0.08
G-518	12-28-51	09:00	1.29	1.29	1.28	1.30	0.02
S-18	12-28-51	09:30	1.72	1.72	1.725	1.715	0.01
S-19	12-28-51	09:30	0.71	0.71	0.74	0.68	0.06
S-68	12-28-51	09:30	0.21	0.21	0.23	0.19	0.04
S-329	12-28-51	09:24	2.37	2.37	2.39	2.35	0.04

TENNESSEE							
6:200-1	2-13-51	23:00	127.587	127.589	127.569	127.600	0.031
7:1-6	2-13-51	22:30	77.575	77.575	77.560	77.589	0.029
7:1-6	6-30-51	19:00	78.909	78.892	78.912	78.890	0.022

TEXAS							
J-1-6	10-25-51	18:30	94.94	94.94	94.88	94.98	0.10
436	11-18-51	11:15	77.45	77.38	77.31	79.07	1.76
224	11-18-51	11:15	77.02	76.96	76.95	77.04	0.09

+ Water surface above mean sea level or land surface datum.

- Water surface below mean sea level.

<sup>1</sup> Single amplitudes measured.<sup>2</sup> Values refer to mean sea level datum.

## SEISMOLOGICAL OBSERVATORY RESULTS

The United States Coast and Geodetic Survey publishes the results of its teleseismic stations and cooperating stations in the quarterly *Seismological Bulletin*. 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. Instrumental results are published for the following stations:

Balboa Heights, C. Z. (The Panama Canal.)	Logan, Utah (Utah State Agricultural College.)
Bermuda (Meteorological Station and International Union Geodesy and Geophysics.)	New Kensington, Pa. (Private station.)
Boulder City, Nev.	Overton, Nev.
Bozeman, Mont. (Montana State College.)	Philadelphia, Pa. (The Franklin Institute.)
Burlington, Vt. (University of Vermont.)	Pierce Ferry, Ariz.
Butte, Mont. (Montana School of Mines.)	Rapid City, S. Dak. (South Dakota State School of Mines and Technology.)
Chicago, Ill. (University of Chicago and U. S. Weather Bureau.)	Salt Lake City, Utah (University of Utah.)
College, Alaska	San Juan, P. R.
Columbia, S. C. (University of South Carolina.)	Shasta, Calif.
Honolulu, T. H.	Sitka, Alaska
Hungry Horse, Mont.	Tucson, Ariz.
Lincoln, Nebr. (Nebraska Wesleyan University.)	Ukiah, Calif. (International Latitude Observatory.)
	Washington, D. C.

College, Honolulu, San Juan, Sitka, Tucson, Ukiah, and Washington are United States Coast and Geodetic Survey stations.

Boulder City, Hungry Horse, Overton, Pierce Ferry, and Shasta are cooperating stations of the Bureau of Reclamation. Overton and Pierce Ferry are operated by the National Park Service personnel.

Bermuda, Bozeman, Butte, Chicago, Columbia, Lincoln, Rapid City, and Salt Lake City are cooperating university stations.

Balboa Heights, Burlington, Logan, New Kensington, and Philadelphia are independent stations.

All readings were made or revised at the Washington Office except those for Balboa Heights.

For detailed instrumental data regarding these stations, including instrumentation, constants, and other information, see *Seismological Bulletin*, MSI-141, for the first quarter of 1950. Those desiring to receive this publication as issued should request addition of their name to the *CGS-7* mailing list. All requests should be made to the Director, United States Coast and Geodetic Survey, Washington 25, D. C.

Table 2.—Summary of instrumental epicenters for 1950

1950	Origin Time G. C. T.	Region, focal depth, and remarks	Coordinates of provisional epicenter	
			Latitude	Longitude
Jan.	1. 02 52 21*	Gulf of California.	25 ° N.	110 ° W.
	1. 05 25 28**	Tonga Islands region.		
	1. 09 34 20**	Fiji Islands region. Depth about 500 km.		
	1. 10 20 30**	About 700 miles south of Fiji Islands. Depth about 600 km.		
	1. 11 33 05**	Tonga Islands.		
	1. 16 04 32**	Near north coast of Luzon, Philippine Islands.		
	2. 00 42 30*	Near west coast of Puerto Rico. Felt in Mayaguez. Depth about 60 km.	19 ° N.	67½ ° W.
	2. 01 15 29*	Atlantic Ocean, off northeast coast of Brazil.	7 ° N.	34 ° W.
	2. 13 43 13**	West-central Turkey.		
	2. 15 14 52*	Santa Cruz Islands. Depth about 200 km. Mag. 7.	12 ° S.	165 ° E.
	2. 19 34 14**	New Hebrides Islands region.		
	2. 19 53 04*	Northern Utah. Felt from Preston, Idaho, to Salt Lake City, Utah.	41½ ° N.	112 ° W.
	3. 02 51 50*	Near north coast of Luzon, Philippine Islands. Mag. 6½.	18 ° N.	121½ ° E.
	3. 05 46 09**	Santa Cruz Islands region.		
	3. 06 05 14**	Philippine Islands aftershock.		
	3. 11 06 27**	Off coast of southern Chile.		
	3. 11 27 28	Pinto Basin, Calif. Mag. 3.1.	33 52 ° N.	115 50 ° W.
	4. 09 45 40**	Kurile Islands region.		
	5. 03 22 00**	Kermadec Islands region.		
	5. 04 31 25*	Off south coast of Mexico.	9½ ° N.	102 ° W.
	5. 16 00 47**	Aleutian Islands region.		
	6. 18 42 40**	Near east coast of Nicaragua.		
	7. 09 37 35	Lower California. Mag. 4.0.	32.1 ° N.	116.6 ° W.
	7. 22 36 10**	Cordoba Province, Argentina. Depth about 100 km.		
	8. 04 11 20**	Andreanof Islands, Aleutian Islands. Felt at Finger Bay.		
	8. 20 42 55*	Tonga Islands. Felt in Nukualofa. Depth about 100 km.	21½ ° S.	174 ° W.
9. 01 25 10*	Andreanof Islands, Aleutian Islands. Felt at Finger Bay. Depth about 60 km.	51 ° N.	176 ° W.	
9. 13 24 57	Near Forest Home, Calif. Felt. Mag. 3.9.	34 05 ° N.	116 58 ° W.	
9. 22 30 08	Near China Lake, Calif. Mag. 2.8.	35 41 ° N.	117 53 ° W.	
10. 03 05 47*	Off coast of Mexico. Depth about 100 km. Mag. 6¼.	11 ° N.	103½ ° W.	
10. 09 46 56**	Kurile Islands region.			
10. 16 23 37**	About 150 miles south of Falkland Islands.			
11. 18 58 26*	Sea of Japan.	42 ° N.	135 ° E.	
11. 21 41 35	Near Southgate, Calif. Felt in Los Angeles. Mag. 4.1.	33 47 ° N.	118 21 ° W.	
12. 08 31 40**	Fiji Islands region.			
12. 12 06 07*	Fiji Islands region. Depth about 550 km. Mag. 7.0.	18 ° S.	178 ° W.	
12. 17 09 53*	Off south coast of Hokkaido, Japan. Depth about 100 km.	42 ° N.	142 ° E.	
13. 00 10 59*	New Britain.	5 ° S.	152 ° E.	
13. 00 35 35*	Near east coast of Honshu, Japan. Depth about 60 km.	37 ° N.	141 ° E.	
13. 05 07 19	Near Desert Hot Springs, Calif. Felt. Mag. 4.1.	34 01 ° N.	116 29 ° W.	
13. 07 52 40**	New Hebrides Islands.			
13. 10 10 05**	Northern Chile-Argentina border.			
13. 12 18 31	Near Punta Gorda, Calif. Felt in Ferndale, Scotia, and Cape Mendocino Light Station. Mag. 4.3.	40.3 ° N.	124.4 ° W.	
13. 23 52 20*	New Britain region.	4½ ° S.	153½ ° E.	
14. 08 51 50**	Revilla Gigedo Islands, off west coast of Mexico.			
14. 13 24 37*	Off coast of northern Chile. Felt. Depth about 100 km.	21 ° N.	71 ° W.	
14. 19 52 30	Near Punta Gorda, Calif. Felt. Mag. 4.6.	40 13 ° N.	124 25 ° W.	
15. 21 02 26**	Kermadec Islands.			
15. 23 52 20*	Solomon Islands region.	7 ° S.	156 ° E.	
16. 02 24 56*	Southern Roinania. Felt in Bucharest. Depth about 150 km.	44½ ° N.	26 ° E.	
16. 20 34 43	Near Dulzura, Calif. Mag. 2.6.	32 40 ° N.	116 45 ° W.	
17. 10 58 12*	Atlantic Ocean.	0 25 ° W.		
18. 01 58 51*	Northern Utah. Felt in Colorado. Mag. 5-5½.	40½ ° N.	110½ ° W.	
19. 02 33 49	West of Big Bear, Calif. Mag. 3.1.	34 16 ° N.	117 01 ° W.	
19. 09 33 48	Near Point Vicente, Calif. Felt in Santa Monica, Beverly Hills, Hollywood, and San Pedro. Mag. 3.6.	33 45 ° N.	118 26 ° W.	
19. 17 27 18*	Near south coast of Iran. 20 killed, many injured.	27½ ° N.	53 ° E.	
19. 21 48 50**	Near south coast of Alaska.			
19. 23 10 55**	Iran aftershock.			
20. 07 24 32**	Near south coast of Alaska Peninsula.			
20. 18 37 30*	Southern Alaska. Depth about 100 km.	62 ° N.	152 ° W.	
20. 23 15 35*	Santiago del Estero, Argentina. Depth about 600 km.	28 ° S.	63½ ° W.	
21. 04 30 41*	Central Alaska.	63 ° N.	148½ ° W.	
21. 14 09 50*	Off coast of central Chile. Felt. Depth about 100 km.	36 ° S.	72 ° W.	
21. 17 11 41	Near Wichman, Nev. Mag. 3.5.	38 36 ° N.	119 09 ° W.	
22. 07 04 30**	Off south coast of Honshu, Japan. Depth about 300 km.	30 ° N.	139 ° E.	
22. 03 18 17**	Near west coast of Colombia.			
22. 04 57 15*	Near south coast of Iran.	28 ° N.	53 ° E.	
22. 07 50 41**	Tonga Islands region.			
22. 10 05 50**	Southern Alaska. Depth about 100 km.			
23. 09 30 16**	Off southwest coast of Greece.			
23. 09 50 52*	Philippine Islands.			
24. 01 46 50**	Tonga Islands region. Depth about 600 km.	10½ ° N.	125½ ° E.	
24. 01 54 00**	Near west coast of Honshu, Japan. Felt in Nagoya and Osaka.			
24. 02 51 40**	Kermadec Islands region.			
24. 05 37 50**	Fiji Islands region. Depth about 500 km.			
24. 05 52 05*	Leeward Islands.	18 ° N.	63 ° W.	
24. 16 47 12*	New Hebrides Islands. Depth about 150 km. Mag. 6½.	14½ ° S.	167 ° E.	
25. 01 56 59	South of Gorman, Calif. Felt in Filmore and Piru. Mag. 4.0.	34 40 ° N.	118 50 ° W.	
25. 00 41 09**	New Britain region.			
25. 02 09 38*	Kermadec Islands region.			
25. 06 03 41**	About 200 miles south of Panama.	27 ° S.	177 ° W.	
25. 08 04 57**	Kermadec Islands region.			
26. 03 52 21**	Fiji Islands region. Depth about 600 km.	18 ° S.	178 ° W.	
26. 11 06 11**	South of Fiji Islands.			

Table 2.—Summary of instrumental epicenters for 1950—Continued

1950	Origin Time G. C. T.			Region, focal depth, and remarks	Coordinates of provisional epicenter				
					Latitude	Longitude			
	<i>h</i>	<i>m</i>	<i>s</i>		°	'	°	'	
Jan.	27	08	25	50**	Tonga Islands				
	27	10	47	18*	Off Cape Mendocino, Calif.	42	N.	125	W.
	27	19	18	10*	Samoa Islands region. Felt in Apia	17	S.	173	W.
	27	20	36	57	Santa Rosa Mountains, Calif. Mag. 3.4	33	26 N.	116	16 W.
	28	19	28	03**	South of Fiji Islands region. Depth about 500 km.			72	W.
	30	00	56	32*	Southern Magellanes Province, Chile. Felt. Mag. about 6½	53	S.	150½	W.
	30	02	49	53*	Southern Alaska. Depth about 100 km.	61½	N.		
	30	05	32	21**	Tonga Islands region. Depth about 200 km.	43	N.	½	E.
	31	10	49	00*	Southern France. Felt in Hautes-Pyrenees Province, France, and in Lareda Province, Spain.				
	Feb.	31	11	24	40*	Northern Rhodesia-Nyasaland border	10½	S.	33½
31		22	43	24*	Kamchatka. Depth about 160 km.	51	S.	156	E.
1		11	41	39*	Northern Chile. Felt. Depth about 100 km.	20	S.	69	W.
2		10	37	24*	Southern Arizona. Mag. 4.2	32	N.	113	W.
2		23	33	37*	Southern China-Burma border. Felt. Mag. 6¼	22	N.	100	E.
3		02	51	47*	China-Burma aftershock. Mag. 6½	22	N.	100	E.
3		05	56	02*	Fiji Islands region. Depth about 600 km.	23½	N.	179	E.
3		13	03	56*	China-Burma aftershock	22½	N.	99½	E.
3		16	45	29*	Alaska Peninsula foreshock	54	N.	162	W.
3		18	27	48*	Hokkaido, Japan. Depth about 60 km.	42½	N.	142½	E.
3		18	53	43**	Alaska Peninsula foreshock				
4		00	30	58**	Atlantic Ocean, about 500 miles north of the Azores	54	N.	162	W.
4		02	07	53*	Off south coast of Alaska Peninsula				
4		22	59	15**	Andeanof Islands, Aleutian Islands				
4		01	23	30*	Off southwest coast of New Zealand. Felt. Mag. 6¾-7.	49½	S.	164	E.
5		12	18	10*	Off southern coast of Mexico. Depth about 100 km.	16	N.	94	W.
7		00	08	25**	About 500 miles off coast of southern Chile.				
7		00	25	57*	New Hebrides Islands	15	S.	166½	E.
7		10	35	06*	Northern Chile. Depth about 200 km.	18½	S.	70	W.
7		10	37	22*	Kurile Islands	46	N.	152	E.
7		21	16	11*	Central Peru-Brazil border. Depth about 150 km.	7½	S.	74	W.
8		15	02	41*	Solomon Islands	10½	S.	160½	E.
8		18	19	45*	North Atlantic Ocean	46½	N.	28½	W.
9		13	06	50**	Off south coast of Honshu, Japan				
9		18	52	41*	Jan Mayen Island region	73	N.	6	E.
9		20	18	26**	Northwestern Argentina-Chile border region. Felt in Chile. Depth about 150 km.				
10		03	32	50	Northeast of Desert Hot Springs, Calif. Mag. 3.6	34	02 N.	116	24 W.
10		18	44	00**	Philippine Islands region				
10		20	23	10**	About 350 miles southwest of El Salvador	41.2	N.	124.3	W.
10		23	41	09	Near Rocky Point, Calif. Felt in Eureka. Mag. 4.0	43	S.	41	E.
11		01	22	02*	Prince Edward Islands region	15½	S.	175	W.
11		11	29	54*	Samoa Islands region. Depth about 250 km. Mag. 6½	34½	N.	24	E.
12		09	43	47*	Off south coast of Crcte				
12		19	00	43**	200 miles southwest of Spitzbergen	19	S.	178	W.
12		22	14	54*	Fiji Islands region. Mag. 6½	22	S.	69	W.
13		05	55	00*	Northern Chile. Felt. Depth about 100 km.				
13		11	05	20**	Andeanof Islands, Aleutian Islands				
13		11	27	01**	Solomon Islands region				
14		23	12	58**	Fiji Islands region	7	N.	36	W.
15		00	12	42*	Atlantic Ocean	47	N.	154	E.
15		03	36	54*	Kurile Islands	11	N.	93½	E.
15		14	36	45*	Andaman Islands region				
16		12	50	43**	Pacific Ocean, 600 miles south of Easter Island				
16		14	21	13**	Easter Island aftershock				
17		03	47	16*	Guatemala. Mag. 6¼-6½	14½	N.	90	W.
18		05	04	23*	Easter Island region	33	E.	111½	W.
18		06	17	50**	Atlantic Ocean foreshock				
18		07	32	19*	Atlantic Ocean, southwest of Azores	31	N.	42½	W.
18		14	39	30*	Near coast of Alaska Peninsula	54	N.	164	W.
18		19	40	15**	Tonga Islands region. Depth about 300 km.				
19	08	29	44	Southwest of Arguillo, Calif. Mag. 3.5	34.5	N.	120.7	W.	
20	03	15	08**	Southern Kamchatka					
20	06	36	46	East of Palmdale, Calif. Mag. 3.3	34	36 N.	118	00 W.	
20	14	58	23**	Near Payson, Utah. Felt.					
20	20	50	06*	Southern Bolivia. Depth about 600 km.	19½	S.	63	W.	
21	20	26	35**	Kurile Islands. Depth about 400 km.					
21	20	38	03**	Fox Islands, Aleutian Islands					
21	22	36	30**	Near coast of Kamchatka. Depth about 100 km.	55	N.	160½	E.	
22	03	30	39**	Southwestern Bolivia. Felt in Chile. Depth about 200 km.					
22	06	54	30**	Fox Islands, Aleutian Islands					
22	14	13	33**	Kurile Islands. Depth about 60 km.					
22	23	59	58	East of Santa Rosa Mountains, Calif. Mag. 3.1	33	32 N.	116	14 W.	
23	03	08	17**	Fiji Islands region					
23	04	48	23*	Kurile Islands. Depth about 60 km.	44½	N.	151	E.	
23	08	31	23*	Sea of Okhotsk. Depth about 500 km. Mag. 6	50	N.	148	E.	
23	16	59	10**	Kurile Islands. Depth about 60 km.					
23	21	45	43**	Fiji Islands region. Depth about 60 km. Mag. 6½					
24	06	01	42**	Near coast of Colombia	6	N.	77½	W.	
24	12	38	50**	Indian Ocean, about 900 miles southeast of Madagascar					
24	05	47	09*	Southwestern Mongolia	45½	N.	99	E.	
25	09	51	34*	Ryukyu Islands region	28	N.	131	E.	
25	09	56	27**	Ryukyu Islands aftershock					
25	10	39	27**	do.					
25	13	37	37*	Central Utah, south of Salt Lake City	40	N.	112	W.	
25	14	02	57**	Fiji Islands region					

See footnotes at end of table.

Table 2.—Summary of instrumental epicenters for 1950—Continued

1950	Origin Time G. C. T.			Region, focal depth, and remarks	Coordinates of provisional epicenter			
					Latitude	Longitude		
	<i>h</i>	<i>m</i>	<i>s</i>		°	'	°	'
Feb. 25	21	14	52*	New Hebrides Islands. Depth about 200 km.	17	S.	168½	E.
26	00	06	22	Near Sespe Hot Springs, Calif. Minor damage in Ventura and Santa Paula. Mag. 4.7.	34	37 N.	119	05 W.
26	03	35	44*	Tibet-Bhutan border	28	N.	91	E.
26	21	01	25**	Near coast of central Chile. Felt				
27	04	01	46**	Central Nicaragua				
27	11	23	11**	Mediterranean Sea, south of Greece				
28	01	44	30**	Bonin Islands				
28	10	20	58*	Off north coast of Hokkaido, Japan. Felt. Depth about 350 km. Mag. 7.8.	46	N.	143½	E.
28	17	01	50*	Southeastern Kamchatka. Depth about 100 km.	54½	N.	159	E.
Mar. 1	03	34	05**	Tonga Islands region				
1	08	23	53*	South Indian Ocean	45	S.	96	E.
2	06	19	32**	Tonga Islands region				
2	18	39	46*	Sandwich Islands region. Mag. 6¼-7	61	S.	35	W.
3	04	12	24**	Tonga Islands region				
3	06	12	24**	Sandwich Islands aftershock				
3	07	42	13**	Near east coast of Kamchatka				
3	10	43	31*	Kermadec Islands region	28	S.	175½	W.
3	12	57	00**	Andreanof Islands, Aleutian Islands				
3	13	05	26	East of Old Woman Springs, Calif. Mag. 3.5	34	22 N.	116	29 W.
3	15	41	11*	Sandwich Islands	60	S.	35	W.
4	06	46	09*	Solomon Islands	9	S.	158	E.
4	12	59	35**	About 150 miles off coast of northern Chile				
4	15	48	36*	Sandwich Islands	59	S.	29	W.
5	00	32	40*	Southeastern Turkistan	39	N.	71	E.
5	14	15	48*	New Hebrides Islands	14½	S.	165	E.
5	18	01	16*	Northern Chile. Felt. Depth about 100 km.	22	S.	69	W.
6	22	21	44**	New Hebrides Islands. Depth about 150 km.				
7	02	07	54*	Panay Island, Philippine Islands. Felt in Iloilo. Mag. 6¼	11	N.	122½	E.
8	03	06	07**	Fiji Islands region				
8	03	23	57	Near Stonehurst, Calif. Felt in Moraga, Oakland, Lafayette, Berkeley, and San Francisco. Mag. 3.3.	37	46 N.	122	10 W.
8*	03	28	00**	New Hebrides Islands region				
9	05	01	14**	Northern Chile-Argentina Border region				
9	06	51	39**	Fiji Islands region				
9	10	03	39*	Leeward Islands	16	N.	60	W.
9	17	38	02*	Southern Alaska. Depth about 150 km.	61	N.	151	W.
10	13	38	20**	Off coast of Chiapas, Mexico				
10	20	15	59**	Fiji Islands region. Depth about 400 km.				
11	00	42	51*	Central Mexico. Felt in the Federal District	20½	N.	99	W.
12	02	38	54**	Tonga Islands region				
12	07	22	06*	North Atlantic Ocean	31½	N.	41	W.
12	18	54	23*	Off coast of Colombia	3	N.	79	W.
14	03	10	02*	Central Peru. Depth about 150 km. Mag. 6¼	8	S.	74	W.
14	16	25	03*	Mid-Atlantic Ocean	1	S.	24	W.
15	00	37	40**	Kermadec Islands region				
15	17	40	58*	Near south coast of Honshu, Japan	33½	N.	135	E.
16	19	24	56*	Fiji Islands region. Depth about 600 km. Mag. 6.2	17	S.	178½	W.
17	03	02	20**	Gulf of California				
17	05	36	18*	Samoa Islands	14	S.	173	W.
18	04	39	39*	Sandwich Islands	56	S.	23	W.
18	18	19	12*	Southwestern Bolivia. Felt in Chile. Depth about 200 km.	17½	S.	68½	W.
20	15	22	17	Near Hat Creek, Calif. Felt in Northern California and Nevada. Mag. 5.5.	40	27 N.	121	28 W.
22	01	31	57	Southwest of Corcoran, Calif. Mag. 3.7	35	58 N.	120	38 W.
22	11	00	54**	Off north coast of Venezuela				
22	12	50	22*	North Atlantic Ocean	48½	N.	28½	W.
22	15	44	32*	Northern Chile. Depth about 100 km.	23½	S.	69	W.
22	21	07	25**	Near north coast of Formosa				
23	04	16	50*	Northern California aftershock. Mag. 4.6	40½	N.	121½	W.
23	08	01	05*	Northern California aftershock	40½	N.	121½	W.
23	08	08	33**	Fiji Islands region				
23	10	41	20**	Ryukyu Islands region				
23	10	45	28**	Alaska Peninsula				
23	19	01	53**	Queen Charlotte Islands region				
24	09	17	27**	Off south coast of Mindanao, Philippine Islands				
24	12	07	29*	Near south coast of Panama. Felt	8	N.	81	W.
25	22	22	06*	Northern Chile	21½	S.	69	W.
26	04	25	34*	Northern California aftershock	40½	N.	121½	W.
26	06	44	22*	Off coast of Oregon	45	N.	129½	W.
26	07	42	50*	Colombia-Venezuela border	7½	N.	72	W.
26	16	53	13**	Southern Red Sea				
27	06	16	15*	Western Argentina. Felt in Chile. Depth about 60 km.	28	S.	67	W.
27	13	04	10*	Aleutian Islands region. Depth about 60 km. Mag. 6¼	53½	N.	173	E.
27	21	18	32*	Near south coast of Sumatra. Mag. about 7	5	S.	103	E.
27	22	06	05**	Sumatra aftershock				
28	12	32	51*	Near east coast of Honshu, Japan. Depth about 100 km.	35½	N.	140½	E.
28	20	05	16*	New Hebrides Islands region. Depth about 200 km.	14	S.	166	E.
29	12	52	55*	Kermadec Islands region	26½	S.	176½	W.
29	17	41	10*	Northern New Guinea	3	S.	138½	E.
30	01	50	06**	Fiji Islands				
30	16	47	40*	Azores Islands region	40½	N.	30	W.
30	21	53	56**	Southeastern Nevada				
30	22	01	19*	Loyalty Islands region	22	S.	170	E.
31	01	39	33**	Andreanof Islands, Aleutian Islands				
31	12	47	45**	Off central coast of Peru. Depth about 60 km.				
31	15	35	39*	Off east coast of Honshu, Japan	34	N.	143	E.
31	22	36	40**	Kermadec Islands				

See footnotes at end of table.



Table 2.—Summary of instrumental epicenters for 1950—Continued

1950	Origin Time G. C. T.	Region, focal depth, and remarks	Coordinates of provisional epicenter	
			Latitude	Longitude
			°	'
Apr.	1.....	02 23 42**	Ryukyu Islands region.	
	1.....	11 18 22**	Off east coast of Honshu, Japan. Depth about 100 km.	
	2.....	00 58 06**	About 700 miles south of Fiji Islands.	
	2.....	02 02 50*	51	N. 173½ W.
	2.....	06 51 00**	Tonga Islands.	
	2.....	12 16 00	Southeast of Borego Valley, Calif. Mag. 3.8.	
	2.....	18 25 10**	33 05	N. 116 03 W.
	2.....	19 57 52*	Pacific Ocean, about 600 miles southwest of Easter Island.	
	2.....	23 11 02**	6	S. 149 E.
	3.....	06 32 14*	Off east coast of New Guinea.	
	3.....	10 10 22**	18	S. 169½ E.
	3.....	19 03 13*	New Hebrides Islands region.	
	4.....	02 21 11*	Andreanof Islands foreshock.	
	4.....	02 24 50	2	N. 77 W.
	4.....	03 42 50*	52	N. 173¼ W.
	4.....	11 19 35**	52	N. 173¼ W.
	4.....	18 44 09*	31	N. 131 E.
	4.....	01 17 15*	Andreanof Islands, Aleutian Islands.	
	5.....	09 26 14*	Off coast of Kyushu, Japan.	
	5.....	10 12 55*	Tonga Islands. Depth about 100 km.	
	5.....	18 13 48**	51½	N. 101 E.
	6.....	02 43 28*	52	N. 177 W.
	6.....	03 01 55**	11	N. 91½ E.
	7.....	04 31 16**	29½	S. 178 W.
	7.....	05 01 38**	Kermadec Islands.	
	8.....	11 28 07**	North Atlantic Ocean, about 600 miles south of Greenland.	
	8.....	12 10 00**	38	N. 58½ E.
	9.....	12 01 36	Persia-Turkistan border.	
	10.....	06 06 46*	Alaska Peninsula.	
	10.....	16 48 50*	Near coast of Ecuador.	
	13.....	00 23 17*	Off coast of Oregon.	
	13.....	06 45 36*	Bonin Islands.	
	13.....	11 51 13*	Santa Cruz Islands region. Depth about 100 km.	
	13.....	17 46 41	36 47	N. 122 07 W.
	14.....	11 03 46*	58	S. 160 W.
	14.....	13 20 03**	4½	N. 76 W.
	14.....	19 59 58*	Off Cape Mendocino, Calif. Mag. 2.7.	
	15.....	06 58 20**	Southeast of New Zealand.	
	15.....	11 56 32	40	N. 53 E.
	15.....	14 51 25*	13½	N. 145½ E.
	16.....	16 19 03*	38½	N. 27 W.
	16.....	18 47 32	40 25	N. 121 23 W.
	16.....	21 48 01*	48	N. 123 W.
	18.....	02 14 36**	Mt. Lassen, Calif. Mag. 3.5.	
	18.....	14 31 44*	Puget Sound, Wash. Felt from Tacoma, Wash., to Vancouver, B. C.	
	19.....	16 08 24*	About 400 miles south of Fiji Islands region. Depth about 600 km.	
	20.....	09 50 52*	36	S. 103 W.
	20.....	17 19 12*	Pacific Ocean, south of Easter Island.	
21.....	13 17 29	Tonga Islands region. Depth about 200 km.		
22.....	12 30 05**	35 45	N. 119 37 W.	
22.....	21 44 03**	Northeast of Lost Hills, Calif. Felt in San Joaquin Valley and southern Sierra, Nevada. Mag. 4.6.		
22.....	21 46 22**	14	N. 91 W.	
23.....	07 59 51**	35½	N. 140½ E.	
23.....	10 16 55**	37 56	N. 122 16 W.	
24.....	20 37 22**	49	N. 129 W.	
25.....	00 56 09*	Near east coast of Honshu, Japan. Depth about 60 km.		
25.....	15 51 54**	Northeast of El Cerrito, Calif. Mag. 3.4.		
25.....	22 38 07*	Off coast of Vancouver Island, British Columbia.		
26.....	07 04 56*	4½	S. 106 W.	
26.....	12 18 28*	17½	S. 179 W.	
26.....	14 11 01**	45	N. 150½ E.	
26.....	18 56 57**	34	N. 3 E.	
27.....	10 18 47**	East-central Peru.		
27.....	13 24 23**	Pacific Ocean. Mag. 6½.		
27.....	14 18 22**	Fiji Islands. Depth about 600 km.		
28.....	17 15 20**	Kurile Islands. Depth about 60 km. Mag. 6½.		
28.....	17 28 55**	Northern Algeria. Damage in Ksara d'El Richa and d'Enfours.		
29.....	09 57 04**	Felt in Tadgemout and Afou.		
29.....	15 17 50**	34 23	N. 119 35 W.	
29.....	20 21 58**	West of Carpinteria, Calif. Mag. 3.0.		
30.....	10 29 03*	Samoa Islands region.		
30.....	15 59 04*	do.		
30.....	17 06 46**	do.		
30.....	17 41 07**	Leeward Islands.		
30.....	18 21 36*	Fiji Islands. Depth about 550 km.		
30.....	23 49 24*	Pacific Ocean, off coast of Colombia.		
May 1.....	00 42 00*	11½	S. 166½ E.	
1.....	09 51 06*	Santa Cruz Islands. Depth about 100 km.		
1.....	13 20 51*	43½	N. 127½ E.	
2.....	04 41 43**	34	N. 135½ E.	
2.....	14 35 08*	Near coast of southern Peru.		
3.....	07 13 40*	Pacific Ocean, off coast of Oregon.		
5.....	01 05 00*	Near south coast of Honshu, Japan. Felt from Kobe to Tokyo. Depth about 60 km. Mag. 6¼.		
		52½	N. 170 W.	
		Fox Islands, Aleutian Islands. Depth about 60 km.		
		Tonga Islands region.		
		Kurile Islands region. Depth about 200 km.		
		Tonga Islands.		
		Tonga Islands region. Depth about 150 km.		
		Kurile Islands region.		
		Arctic Ocean, north of Lenin Land.		
		do.		
		Samoa Islands region.		
		Andreanof Islands, Aleutian Islands.		
		New Hebrides Islands region. Depth about 100 km.		
		24½	S. 112½ W.	
		South Pacific Ocean, about 250 miles northwest of Easter Island. Mag. about 6½.		
		36 05	N. 117 58 W.	
		South of Haiwee, Calif. Felt. Mag. 3.1.		
		Samoa Islands region.		
		Near coast of central Chile. Depth about 60 km.		
		10½	S. 75½ W.	
		6½	N. 83 W.	
		15	S. 76 W.	
		62	N. 152 W.	
		7	S. 105 E.	
		Central Peru.		
		Off southern coast of Pauama.		
		45	N. 150½ E.	
		38½	N. 27 E.	
		4½	S. 104½ W.	
		Near coast of Peru.		
		Southern Alaska.		
		Sunda Strait.		
		Near south coast of Mexico.		
		Kurile Islands.		
		Near southwest coast of Turkey.		
		Pacific Ocean, north of Easter Island.		

See footnotes at end of table.

Table 2.—Summary of instrumental epicenters for 1950—Continued

1950	Origin Time G. C. T.	Region, focal depth, and remarks	Coordinates of provisional epicenter				
			Latitude	Longitude			
May	7-----	06 36 07*	57	S.	147	E.	
	8-----	13 05 32**					
	8-----	14 01 38*	51½	N.	173	W.	
	8-----	19 40 55**					
	9-----	02 35 26**	Bolivia. Depth about 100 km.				
	9-----	06 10 32*	Off west coast of Nicaragua.				
	9-----	09 19 57*	Gulf of Aden.	13	N.	47	E.
	9-----	11 16 57*	Eastern Turkey.	38½	N.	39	E.
	10-----	10 19 49*	Southern Turkistan.	38	N.	58	E.
	10-----	23 39 19*	New Britain region.	6	S.	150	E.
	11-----	13 25 17**	Mozambique Channel. Felt in Moutsamoudou. Mag. 6½.	17	S.	41½	E.
	12-----	21 21 25*	Fox Islands, Aleutian Islands.				
	12-----	23 30 01*	Near northeast coast of New Guinea.	5	S.	145	E.
	13-----	05 06 46*	Near coast of Ecuador.	2	S.	80½	W.
	13-----	05 25 40**	Fiji Islands region. Depth about 400 km.	18½	S.	178	W.
	13-----	08 46 10	Near coast of southern Peru.				
	13-----	18 00 32**	Off Cape Mendocino, Calif. Mag. 4.5.	40.5	N.	127.5	W.
	14-----	19 17 16*	Southern Magellanes Province, Chile.				
	14-----	23 19 31	Off east coast of Honshu, Japan.	38	N.	142	E.
	15-----	03 32 45*	North of Brawley, Calif. Mag. 3.3.	33	02 N.	115	33 W.
	15-----	15 31 44*	Gulf of California. Depth about 60 km.	25	N.	110	W.
	16-----	17 21 46*	South of Fiji Islands. Depth about 600 km.	25½	S.	178½	E.
	16-----	23 20 35	New Britain region.	6	S.	152	E.
	17-----	11 46 46*	Near Upper Mattole, Calif. Mag. 3.6.	40	14 N.	124	06 W.
	17-----	13 23 00*	Sea of Japan, off coast of Korea. Depth about 600 km. Mag. 6¾-7.	39	N.	130½	E.
	17-----	18 13 18*	Near south coast of Hokkaido, Japan. Depth about 100 km.	42	N.	142	E.
	18-----	01 09 00**	Loyalty Islands. Depth about 60 km. Mag. 7.	19½	S.	168	E.
	18-----	09 47 09**	Andreanof Islands, Aleutian Islands.				
	18-----	17 00 30**	Indian Ocean, about 500 miles southeast of Madagascar.				
	19-----	02 38 08*	Kodiak Island, Alaska. Depth about 60 km.	20½	S.	169	E.
	19-----	04 38 38	Loyalty Islands. Mag. 6¾-7.	33	57 N.	115	43 W.
	19-----	07 05 30*	Pinto Basin, Calif. Mag. 3.9.	20½	S.	169	E.
	19-----	08 17 15*	Loyalty Islands aftershock. Mag. about 6½.	20½	S.	169	E.
	19-----	09 43 17*	Loyalty Islands aftershock.	19½	N.	147	E.
	19-----	13 39 59**	Mariana Islands.				
	20-----	03 09 25**	Northern Chile.				
	20-----	09 37 25*	Southern Gulf of California.				
	20-----	18 45 50**	North Atlantic Ocean.	29	N.	43½	W.
	20-----	18 53 42*	Samoa Islands region.				
	21-----	18 37 41*	Hindu Kush.	37	N.	71	E.
	21-----	21 42 48*	Central Peru. Destructive in Cuzco and San Sebastian. 83 killed, 200 injured. Mag. 6.	14	S.	72	W.
	21-----	23 14 39*	New Hebrides Islands region.	20	S.	168½	E.
	22-----	07 12 54*	New Hebrides Islands aftershock.	20	S.	168½	E.
	22-----	19 49 43*	Fiji Islands region. Depth about 600 km.	19	S.	178	W.
	23-----	19 38 23**	Queen Charlotte Islands region.	51½	N.	130½	W.
	23-----	23 56 19**	Off coast of Oaxaca, Mexico.				
	24-----	03 55 55*	Off east coast of Formosa.				
24-----	04 17 30**	New Hebrides Islands region.	20	S.	169	E.	
24-----	12 54 50*	Sandwich Islands.					
25-----	00 48 53**	Leeward Islands. Depth about 60 km.	16	N.	60	W.	
25-----	08 34 32*	Southern Alaska. Depth about 60 km.					
25-----	18 35 01*	About 100 miles north west of Fairbanks, Alaska. Felt in College. Mag. 6.	65½	N.	151½	W.	
26-----	01 17 06*	About 150 miles west of Guam. Depth about 100 km. Mag. 7.0.	13	N.	142½	E.	
26-----	01 17 24*	New Hebrides Islands foreshock.	19	S.	169	E.	
26-----	01 55 36**	New Hebrides Islands region. Mag. 7.1.	19	S.	169	E.	
26-----	02 04 25*	New Hebrides Islands aftershock.					
26-----	04 50 00**	do.	19	S.	169	E.	
26-----	09 53 08**	do.					
26-----	14 33 20**	Mariana Islands. Depth about 100 km.					
26-----	17 39 14*	New Hebrides Islands region.	20	S.	169	E.	
27-----	10 46 29*	do.					
27-----	11 44 52*	do.					
27-----	12 39 41*	New Hebrides Islands region. Depth about 200 km.	19	S.	168	E.	
27-----	13 19 45**	Central Chile. Felt. Depth about 100 km.	20½	S.	168½	E.	
27-----	14 27 06*	Fiji Islands. Depth about 550 km. Mag. 6¼.	17	S.	179	W.	
27-----	20 40 05**	Tonga Islands region. Depth about 200 km.					
28-----	01 36 44*	New Hebrides Islands region. Mag. 6½.	20	S.	169	E.	
28-----	05 06 26*	Off coast of Ecuador.	½	S.	81	W.	
28-----	16 12 17**	About 200 miles south of Honshu, Japan. Depth about 300 km.					
28-----	22 29 35**	Northern Chile.					
29-----	09 40 27*	New Hebrides Islands region.	19½	S.	168½	E.	
29-----	10 21 10	Near Mount Shasta, Calif. Mag. 3.9.	41.4	N.	122.3	W.	
30-----	01 16 16*	Island of Hawaii. Slight damage along Kona coast. Mag. 6¼.	19½	N.	156	W.	
30-----	15 04 08*	Fiji Islands region. Depth about 650 km. Mag. 6¼-6½.	19½	S.	179	W.	
31-----	09 21 45*	East-central Peru. Depth about 150 km.	8	S.	74	W.	
31-----	13 13 09*	Ryukyu Islands. Depth about 60 km.	2	N.	130½	E.	
June	2-----	Near Somesbar, Calif. Mag. 4.2.	41.3	N.	123.4	W.	
	2-----	Near Salton, Calif. Mag. 3.2.	33	31 N.	115	58 W.	
	3-----	Near Eureka, Calif. Felt. Mag. 4.0.	40.8	N.	124.4	W.	
	3-----	Central Bolivia. Depth about 250 km.					
	4-----	New Hebrides Islands region.					
	4-----	Off south coast of Puerto Rico.					
	4-----	Near east coast of Mindanao, P. I.	7	N.	126	E.	
	4-----	Philippine Islands aftershock.					
	4-----	Loyalty Islands region. Depth about 100 km.	21	S.	170½	E.	
	5-----	11 16 12*	North Polar region.	87	N.	45	E.

See footnotes at end of table.

Table 2.—Summary of instrumental epicenters for 1950—Continued

1950	Origin Time G. C. T.	Region, focal depth, and remarks	Coordinates of provisional epicenter	
			Latitude	Longitude
			° ' "	° ' "
Jun 5	13 08 21**	Island of Hawaii aftershock		
5	22 29 23*	Bonin Islands region. Depth about 300 km	22 N.	144½ E.
7	16 52 34*	Northern Peru. Depth about 100 km. Mag. 7.0	4 S.	76½ W.
8	09 28 13	Southeast of Ventura, Calif. Felt in Ventura and Fillmore. Mag. 3.9.	34 15 N.	119 15 W.
8	16 07 33*	Atlantic Ocean, south of Tristan da Cunha. Mag. 7.1	44½ S.	14½ W.
9	08 19 55*	Mariana Islands region	14½ N.	146½ E.
9	13 07 45*	Off coast of northern California. Mag. 4.8	41 N.	125½ W.
10	04 22 06*	Solomon Islands region	8 S.	156 E.
11	13 34 47*	Northern Chile. Felt. Depth about 100 km	21½ S.	69 W.
11	17 19 44*	Off south coast of Honshu, Japan	32 N.	139 E.
11	20 15 52*	Off coast of central Chile. Felt	28½ S.	72 W.
11	22 11 07*	About 900 miles south of Tasmania	57½ S.	147 E.
12	14 09 42**	Solomon Islands region		
13	07 09 04*	Salta Province, Argentina. Depth about 200 km	24 S.	67 W.
13	07 37 29**	Guapore, Brazil		
13	08 11 37	Northeast tip of Amador County, Calif. Mag. 3.5	38 42 N.	120 05 W.
14	00 03 43**	Island of Hawaii aftershock		
14	03 44 09**	Tonga Islands region		
14	04 41 56*	New Hebrides Islands	17 S.	169 E.
14	05 47 47*	Island of Hawaii aftershock	20 N.	155½ W.
14	06 41 48**	Loyalty Islands region		
14	07 27 52*	Off east coast of Honshu, Japan. Felt	37½ N.	144½ E.
14	07 59 22*	Southeastern Peru. Depth about 300 km	14½ S.	70 W.
14	08 10 44*	New Hebrides Islands	17 S.	166 E.
14	08 24 56**	New Hebrides Islands. Depth about 200 km		
14	11 55 00**	Andreanof Islands, Aleutian Islands		
15	07 21 22*	Mid-Atlantic Ocean	14 N.	45 W.
15	17 57 45*	Near north coast of Dominican Republic. Depth about 100 km	19 N.	69 W.
15	23 47 17**	About 300 miles south of Fiji Islands. Depth about 600 km		
16	05 38 01*	Off coast of northern Chile. Depth about 100 km	20½ S.	71 W.
16	13 34 10**	Tonga Islands region		
17	09 38 24*	Hokkaido, Japan	43 N.	143 E.
17	11 50 20**	Off coast of northern California		
17	12 03 46**	do		
17	22 16 06*	Northern Argentina. Depth about 200 km	25 S.	67 W.
17	22 37 26*	Near east coast of Honshu, Japan. Felt	36 N.	141 E.
18	02 10 23*	Northern Argentina. Depth about 200 km	24 S.	67 W.
18	10 01 30**	Sandwich Islands		
18	12 46 28*	Chinghai Province, China	36 N.	99½ E.
19	12 36 51*	Java Sea, near northeast coast of Java. Destructive in Surabaya, Grisse, and Sedaje. 17 killed, 50 injured, and 50 houses destroyed. Mag. 6½.	6 S.	113 E.
19	18 30 13*	Off coast of Oregon	44 N.	127 W.
19	20 12 17*	Leeward Islands	19 N.	61 W.
20	01 18 36*	Romania	46 N.	27 E.
20	14 11 44*	Southwest of Spitzbergen	74 N.	8 E.
21	06 55 39*	New Hebrides Islands. Mag. 6.9	21 S.	169 E.
21	09 56 00*	Off northeast coast of New Guinea	3½ S.	147 E.
22	08 27 30**	Off coast of Colima, Mexico		
22	12 44 46	Near Summit, Calif. Mag. 3.6	39.7 N.	120.4 W.
22	17 13 18	Near Summit, Calif. Mag. 4.1	39.7 N.	120.4 W.
22	20 43 01*	Central Ecuador. 2 killed in Saquisile. Buildings cracked in Latacunga and Pujili. Depth about 100 km.	1 N.	78½ W.
22	22 53 22**	Off coast of southern Peru. Depth about 100 km		
23	03 48 25*	Near coast of Chiapas, Mexico. Depth about 60 km	14½ N.	93 W.
23	17 43 34	Southeast of Catalina Island. Mag. 3.3	33 25 N.	118 11 W.
24	11 39 57**	Fiji Islands. Depth about 600 km		
24	22 25 29*	New Hebrides Islands region. Mag. 7.2	20 S.	168½ E.
24	22 46 44**	New Hebrides Islands aftershock		
25	11 05 51*	Off southeast coast of Mindanao, P. I. Mag. 6½	5½ N.	127½ E.
25	15 43 55**	Solomon Islands region		
25	20 57 30**	Loyalty Islands		
26	00 34 39**	New Caledonia region		
26	01 56 53**	Central Peru. Depth about 100 km		
26	03 04 02**	Kurile Islands region		
26	11 32 30**	Near southwest coast of Turkey		
26	21 07 58**	New Caledonia region		
27	01 39 22**	Near north coast of Java		
27	04 31 38**	Off east coast of Honshu, Japan. Depth about 100 km		
27	10 15 03**	Andreanof Islands, Aleutian Islands. Depth about 100 km		
27	15 41 44*	Off west coast of Hokkaido, Japan. Mag. 6½-6¼	43½ N.	139½ E.
27	16 36 30**	Mariana Islands region		
28	04 31 04*	West Yellowstone, Mont. Felt	44¾ N.	110½ W.
28	16 23 33**	Near southwest coast of Sumatra		
28	23 31 26**	Kurile Islands		
29	00 15 32*	Northern Chile. Felt. Depth about 60 km	25 S.	70 W.
30	00 18 04**	Solomon Islands region		
30	10 54 13**	Northern Peru. Depth about 150 km	6 S.	74½ W.
30	21 13 13**	Off coast of northern Chile		

\*Indicates probable error of ¼ minute. \*\*Indicates probable error of ½ minute.

TABLE 3.—Principal earthquakes of the world from January through December 1951

[NOTE.—This table lists (1) the strongest shocks of the period as revealed by seismographic records, particularly those of the Western Hemisphere stations; (2) important destructive and near destructive earthquakes; (3) earthquakes of unusual interest outside the two preceding categories; and (4) magnitudes as determined by Pasadena.]

1951	Origin Time G. C. T.	Region	Coordinates of provisional epicenter				Remarks
			Latitude		Longitude		
	<i>h m s</i>		°		°		
Jan. 6	07 51 31*	Near south coast of Panama.....	7½	N.	81	W.	Minor property damage in Canal Zone. Panic in Penonome, Santos, and Santa Fe. Felt on SS Wayne at 7°05' N, 80°47' W. Depth about 100 km. Mag. 6.9.
Feb. 13..	11 55 48*	Samoa Islands region.....	15	S.	175	W.	Depth about 250 km. Mag. 6.9.
13..	22 12 56*	Near south coast of Alaska Peninsula.	56	N.	156	W.	Mag. 7.1.
17..	21 06 47*	Eastern New Guinea.....	7	S.	146	E.	Depth about 175 km. Mag. 7.3.
Mar. 4..	11 17 33*	Near coast of southern Peru.....	15½	S.	74	W.	Depth about 150 km. Mag. 6¾-7.
5..	20 11 45*	Ryukyu Islands.....	28½	N.	128	E.	Depth about 150 km. Mag. 6.9.
10..	10 38 28*	Southern Spain.....	37½	N.	4	W.	Minor damage in Bailen, Granada, and Jaen.
10..	21 57 25*	New Hebrides.....	15	S.	167½	E.	Depth about 100 km. Mag. 7.2.
23..	21 38 42*	Kermadec Islands.....	32	S.	179	W.	Depth about 225 km. Mag. 7.0.
24..	00 17 36*	Santa Cruz Islands.....	10½	S.	166	E.	Depth about 150 km. Mag. 7-7¼.
Apr. 8..	21 38 08*	Near south coast of Turkey.....	36½	N.	35½	E.	Six killed, 10 injured, and 13 buildings destroyed in Iskenderon.
16..	19 52 55*	Off southwest coast of Honshu, Japan.	31	N.	137	E.	Felt in Kwanto district. Depth about 500 km. Mag. about 7.
May 1..	05 02 37*	South of Tasmania.....	50½	S.	148½	E.	Mag. 7.0.
6..	23 03 33*	El Salvador foreshock.....	13½	N.	88	W.	Depth about 150 km. Mag. 6-6¼.
6..	23 08 04*	El Salvador.....	13½	N.	88	W.	Series of shocks killed 400, injured 4,000, and made 25,000 homeless. Chinameca, Jucuapa, and San Buenaventura virtually destroyed. Major damage in Berlin, Lolotique, and Nueva Guadalupe. Depth about 150 km. Mag. 6-6¼.
21..	08 27 20*	Solomon Islands.....	6	S.	154½	E.	Depth about 150 km. Mag. 7.0.
June 6..	16 10 52*	Jan Mayen Island region.....	71½	N.	9	W.	Mag. about 7.
July 11..	18 21 52*	Bonin Islands region.....	27½	N.	139½	E.	Depth about 500 km. Mag. 6.9.
Aug. 3..	00 23 58*	Near south coast of Nicaragua.....	13	N.	87½	W.	Earthquake released water from dormant Conseguiuna Volcano virtually destroying Potosi. Depth about 100 km. Mag. 6.
13..	18 33 28*	North-central Turkey.....	41	N.	33	E.	Fifty killed, 208 injured, and 3,400 houses destroyed in Kursunlu area. Felt throughout northern Turkey. Mag. 6.7.
21..	10 56 57.5	Near west coast of Hawaii.....	19¾	N.	156	W.	Extensive property damage on Kona coast. Mag. 6.9.
Oct. 21..	21 34 12*	Off east coast of Formosa.....	23½	N.	121½	E.	Mag. 7.3.
22..	03 29 25*	Formosa aftershock.....	23½	N.	121½	E.	Series of shocks killed 123 and injured 800. Destructive in Hualien and minor damage in Hsinkang. Mag. 7.1.
Nov. 6..	16 40 06*	Kurile Islands.....	47	N.	154	E.	Mag. 7.2.
18..	09 35 41*	Eastern Tibet.....	30	N.	90½	E.	Felt north of Lhasa. Mag. 8.0.
24..	18 47 13*	Formosa foreshock.....	23	N.	121½	E.	Mag. about 6¼.
24..	18 50 19*	Near east coast of Formosa.....	23	N.	121½	E.	Series of shocks killed 17, injured 250, and damaged 800 buildings in Hualien, Taitung, and Kaosiung. Mag. 7.3.
Dec. 8..	04 14 20*	Indian Ocean, about 900 miles southeast of Madagascar.	34	S.	56½	E.	Depth about 100 km. Mag. 7.7.
12..	01 37 34*	Oaxaca, Mexico.....	17	N.	94½	W.	Slight property damage in Oaxaca and Tehuantepec. Depth about 100 km. Mag. 7.
28..	09 20 22*	Guerrero, Mexico.....	17	N.	98½	W.	Depth slightly greater than normal. Mag. 6.9.

\*Indicates probable error of 1/10 minute.

# STRONG-MOTION SEISMOGRAPH RESULTS

## INTRODUCTION

During 1932, the Coast and Geodetic Survey inaugurated a program of recording strong ground movements in the seismically active regions of the country to obtain basic data needed in the design of earthquake-resistant structures. Notes pertinent to this program will be found in the preceding issues of the *United States Earthquakes* series and in S. P. 201, *Earthquake Investigations in California, 1934-35*. The latter is much broader in scope than the former, and contains data on structural and ground vibrations with detailed descriptions of the various activities which comprise the seismological program as a whole. Additional descriptive material on strong-motion instruments and vibration meters will be found in S. P. 206, *Selection, Installation, and Operation of Seismographs*.

*Interpretation of records.*—The analyses appearing in tables 5 and 6 are based on the assumption of simple harmonic motion. This refers especially to the computation of displacement from accelerograph records. As most accelerograph records are of irregular character, and the character of the longer period waves is often obscured by the superposition of shorter period waves of relatively large amplitude, the estimates of displacement must be considered only rough approximations. These analyses are essentially condensations of material appearing in the *Quarterly Engineering Seismology Bulletin* available through mailing list CGS-5 from the Director, United States Coast and Geodetic Survey, Washington 25, D. C.

For the more important records, those involving destructive ground motions, the use of integration methods in computing velocity and displacement curves has become established practice. The accelerograms from Seattle and Olympia for the destructive Puget Sound earthquake of April 13, 1949, have been thus analysed, and a preliminary report prepared. The latter is now available for very limited distribution and will appear in final form in the *Bulletin of the Seismological Society of America*. An outline of the double integration process is contained in S. P. 250, *The Determination of True Ground Motion from Seismograph Records*.

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

Most of the instruments have been adjusted so that each will register the maximum acceleration to be expected on the particular type of geological formation beneath the instrument. The following expectable earthquake accelerations were used in determining the accelerograph sensitivities: (a) rock foundation, 25 percent of gravity, (b) conglomerate foundations, 40 percent of gravity, (c) alluvium, 70 percent of gravity, and (d) top floors of tall buildings, 100 to 200 percent of gravity. The four sensitivities may be roughly listed as 26, 19.5, 13, and 6.5 mm. per 0.1 g., respectively.

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.<sup>2</sup> 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.<sup>2</sup> 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 ft.
1 cm/sec.		=0.03281 ft/sec.
1 cm/sec. <sup>2</sup>		=0.03281 ft/sec. <sup>2</sup>
1 cm.		=10 mm.
0.1 g.		=98 cm/sec. <sup>2</sup> =3.215 ft/sec. <sup>2</sup>
1 (statute) mile		=1.609 km.

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

*Seismogram illustrations.*—Reproductions of records in this publication are tracings of the original records and must not be accepted as genuine copies. The tabulated instrumental constants refer to the original records. The tracings are reduced approximately in the ratio of 1.6:1, so that the same scales do not apply. They are intended to show the nature of the data rather than furnish a means through which the reader can make his own measurements. Those who desire true copies for critical study should make request to the Director of the Coast and Geodetic Survey, Washington 25, D. C.

Acceleration scales are indicated on the tracings of acceleration curves by two dots, the distance between them representing the equivalent of 100 cm/sec.<sup>2</sup> when applied to the curves over which they appear. These dots provide a quick means for making auxiliary scales in cases where an investigator desires to make rough measurements on the published curves. The measurements of periods on records of this nature are dependent largely on the judgment of the person reading them and considerable latitude must be allowed in appraising their accuracy. The aim of such analyses is primarily to give a fair picture of the magnitudes of the various elements involved, and the figures tabulated should therefore not be used for important studies without first referring to the illustrations for some idea of the nature of the original records.

TABLE 4.—*U. S. Coast and Geodetic Survey strong-motion stations in operation as of December 31, 1951*

NORTHERN CALIFORNIA

Station	Accelerograph	Displacement meter	Weed
Berkeley, University of California	1		
Eureka	1		
Ferndale	1	1	
Hollister, Library	1		
Monterey, City Hall	1		1
Oakland, City Hall, basement	1		
Oakland, City Hall, 16th floor	1		
Oakland, Chabot Observatory			1
Sacramento, Federal Building			1
San Francisco, Alexander Building, basement	1		
San Francisco, Alexander Building, 11th floor	1		
San Francisco, Alexander Building, 16th floor	1		
San Francisco, 450 Sutter St., basement	1		1
San Francisco, 450 Sutter St., 29th floor	1		1
San Francisco, Golden Gate Park	1		
San Francisco, Shell Building, sub-basement			1
San Francisco, Shell Building, 21st floor			1
San Francisco, Shell Building, 29th floor			1
San Francisco, Southern Pacific Building, basement	1	1	
San Francisco, Southern Pacific Building, 14th floor	1		
San Francisco, State Building, basement	1	1	
San Jose, Bank of America, basement	1		
San Jose, Bank of America, 13th floor	1		
Suisun Bay Bridge	1		

SOUTHERN CALIFORNIA

Bishop	1		
Colton	1	1	
El Centro	1		
Hollywood Storage Co., basement	1		
Hollywood Storage Co., Penthouse	1		
Hollywood Storage Co., adjoining P. E. Lot	1		
Long Beach	1		
Los Angeles, Chamber of Commerce, basement	1		
Los Angeles, Chamber of Commerce, 11th floor	1		
Los Angeles, Edison Building, basement	1		
Los Angeles, Subway Terminal, sub-basement	1		
Los Angeles, Subway Terminal, 13th floor	1	1	
Los Angeles, Vernon, C. M. D.	1		
Pasadena, California Institute of Technology	1		1
San Bernardino	1		1
San Diego	1		
San Luis Obispo	1		
Santa Ana	1		1
Santa Barbara	1		
Taft	1		
Westwood, University of California, Los Angeles	1		

TABLE 4.—U. S. Coast and Geodetic Survey strong-motion stations in operation as of December 31, 1951—Continued

OUTSIDE CALIFORNIA

Station	Accelerograph	Displacement meter	Weed
Bozeman, Mont., Montana State College	1		
Butte, Mont., Montana School of Mines	1		
Columbia Falls, Mont., Hungry Horse Dam, Bureau of Reclamation	1		
Hawthorne, Nev., U. S. Naval Ammunition Depot	1		
Helena, Mont., Carroll College	1		
Hoover Dam, Nev., 1215 Gallery	1		
Hoover Dam, Nev., Intake Tower	1		
Hoover Dam, Nev., Oil House	1		
Logan, Utah, Utah State Agricultural College	1		
Olympia, Wash., Highway Test Laboratory	1		
Seattle, Wash., Army Base	1		

OUTSIDE UNITED STATES

Balboa Heights, Canal Zone	1		
Bogota, Colombia, South America	1		
Guatemala City, Guatemala, Central America	1		
Lima, Peru, South America	1		
Quito, Ecuador, South America	1		
San Jose, Costa Rica, Central America	1		
Santiago, Chile, South America	1		
Totals	53	5	11

TABLE 5.—List of shocks recorded and records obtained on strong-motion seismographs in 1951

Date	Region and recording station	Records		
		Accelerograph	Displacement meter	Weed
Jan. 6	Panama, Central America, Balboa Heights	1		
Jan. 23	Imperial Valley, California, El Centro	1		
Jan. 31	Peru, South America, Lima	1		
June 15	Costa Rica, Central America, San Jose	1		
July 23	Northern California, San Francisco Southern Pacific Building	2	1	
July 29	Northern California, Hollister	1		
	San Francisco Southern Pacific Building	2	1	
	San Jose Bank of America	2		
Aug. 6	Northern California, Hollister	1		
	San Francisco Southern Pacific Building	2	1	
	San Jose Bank of America	2		
Aug. 9	Peru, South America, Lima	1		
Oct. 3	Northern California, Hollister	1		
Oct. 7	Northern California, Eureka	1		
	Ferndale	1	1	
Oct. 30	Northern California, Hollister	1		
Oct. 31	Northern California, Hollister	1		
	San Francisco Southern Pacific Building	2	1	
Nov. 14	Northern California, Eureka	1		
	Ferndale	1	1	
Dec. 25	Southern California, Hollywood Storage Company	2		
	Long Beach	1		
	Los Angeles Chamber of Commerce	2		
	Los Angeles Subway Terminal	2		
	San Diego	1		
	Santa Ana			1
	Vernon	1		
	Westwood	1		
Dec. 27	Southern California, Bishop	1		
	Total	37	6	1

Table 6.—*Summary of outstanding instrumental and noninstrumental data for 1951*

PANAMA EARTHQUAKE OF JANUARY 6					
Epicenter	Recording station and position <sup>1</sup>	Location of instrument	Intensity <sup>2</sup>	Maximum acceleration	Computed maximum displacement
7½° N., 81° W., southern Panama.	Balboa Heights, 130 miles NE. 45°.....	Basement.....	-----	cm/sec. <sup>2</sup> 10	cm. 0.058
IMPERIAL VALLEY EARTHQUAKE OF JANUARY 23					
33°07' N., 115°34' W., near Calipatria, VII*.	El Centro, 19 miles SE. 174°.....	Sub-basement.....	VI	32	0.0461
PERU EARTHQUAKE OF JANUARY 31					
12° S., 78° W., near west-central coast of Peru.	Lima, 60 miles NE. 70°.....	1st floor.....	-----	73	0.022
COSTA RICA EARTHQUAKE OF JUNE 18					
11° N., 85° W., Costa Rica-Nicaragua border.	San Jose, 100 miles SE. 140°.....	1st floor.....	-----	11	0.038
NORTHERN CALIFORNIA EARTHQUAKE OF JULY 23					
37°55' N., 122°16' W., Berkeley Hills, VI*.	San Francisco, Southern Pacific Building, 11 miles SW. 225°.	Basement..... 14th floor..... DM <sup>3</sup> .....	V	8 5	0.177 0.020
NORTHERN CALIFORNIA EARTHQUAKE OF JULY 29					
36°35' N., 121°11' W., southeast of Mulberry, VI*.	Hollister, 21 miles NW. 326°.....	Basement.....	V	21	0.066
NORTHERN CALIFORNIA EARTHQUAKE OF AUGUST 6					
36°37' N., 121°13' W., southeast of Mulberry, VI*.	Hollister, 20 miles NW. 327°.....	Basement.....	V	46	0.078
PERU EARTHQUAKE OF AUGUST 9					
14° S., 77½° W., off coast of Peru..	Lima, 150 miles NE. 10°.....	1st floor.....	-----	-----	-----
NORTHERN CALIFORNIA EARTHQUAKE OF OCTOBER 3					
36°47' N., 121°18' W., near Tres Pinos, IV*.	Hollister, 7 miles NE. 300°.....	Basement.....	IV	6	0.015
NORTHERN CALIFORNIA EARTHQUAKE OF OCTOBER 7					
40°17' N., 124°48' W., off Cape Mendocino, VII*.	Ferndale, 33 miles NE. 53°.....	1st floor..... DM <sup>3</sup> .....	V	88 76	0.431 0.46
NORTHERN CALIFORNIA EARTHQUAKE OF OCTOBER 30					
36°54' N., 121°25' W., near Hollister, IV*.	Hollister, 3 miles SE. 175°.....	Basement.....	IV	11	0.021
NORTHERN CALIFORNIA EARTHQUAKE OF OCTOBER 31					
36°54' N., 121°25' W., near Hollister, VI*.	Hollister, 3 miles SE. 175°.....	Basement.....	VI	38	0.066

See footnotes at end of table.



Table 6.—*Summary of outstanding instrumental and noninstrumental data for 1951—Con.*

NORTHERN CALIFORNIA EARTHQUAKE OF NOVEMBER 14

Epicenter	Recording station and position <sup>1</sup>	Location of instrument	Intensity <sup>2</sup>	Maximum acceleration	Computed maximum displacement
40°26' N., 124°03' W., near Scotia, VI*.	Eureka, 26 miles NW. 345°-----	Basement-----	VI	cm/sec. <sup>2</sup> 41	cm. 0.183

SOUTHERN CALIFORNIA EARTHQUAKE OF DECEMBER 25

32°49' N., 118°21' W., near southeast San Clemente Island, VI*.	Santa Ana, 78 miles SW. 200°-----	Weed, 1st floor....	IV	30	0.073
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SOUTHERN CALIFORNIA EARTHQUAKE OF DECEMBER 27

37°34' N., 118°35' W., near Owens River Gorge, VI*.	Bishop, 21 miles SE. 150°-----	1st floor-----	V	22	0.008
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<sup>1</sup> Position of station in respect to epicenter.

<sup>2</sup> Reported intensity of earthquake at recording station.

<sup>3</sup> All displacement meter readings should be assumed as recorded maximum displacement and computed maximum acceleration.

\*Following intensity designation in epicenter column, indicates maximum reported intensity of earthquake.

Table 7.—*Composite of strong-motion instrumental data for 1951*

PANAMA EARTHQUAKE OF JAN. 6

Station and component <sup>1</sup>	Instrument number	T <sub>0</sub>	V	Sensitivity <sup>2</sup>	ε	Earth wave period	Maximum acceleration	Maximum displacement	Remarks
Balboa Heights accelerograph: Vertical-up-----	V-338	sec. 0.054	117	cm. 2.11	11	sec. 0.38 0.19	cm/sec. <sup>2</sup> 3 3	cm. 0.011 0.003	Irregular motion.
E. 90°-----	L-337	0.082	121	2.07	9	0.33 0.24	10 4	0.028 0.006	Irregular motion.
S. 180°-----	T-343	0.091	130	2.71	9	0.48 0.24	10 9	0.058 0.013	Irregular motion.

IMPERIAL VALLEY EARTHQUAKE OF JAN. 23

El Centro accelerograph: Vertical-up-----	V-208	0.064	121	1.26	8	0.08 0.33 0.31	15 16 3	0.002 0.044 0.007	Irregular motion.
N. 0°-----	L-206	0.064	123	1.28	8	0.72 0.42 0.78	2 32 30	0.026 0.143 0.461	Irregular motion.
E. 90°-----	T-207	0.065	122	1.29	5	0.94 1.00 0.21 0.66 0.13 0.47	20 5 18 21 10 29	0.447 0.126 0.020 0.232 0.004 0.162	Irregular motion.

PERU EARTHQUAKE OF JAN. 31

Lima accelerograph: Vertical-up-----	V-286	0.064	126	1.32	6	0.13	29	0.012	Maximum amplitudes at beginning of record.
NW. 278°-----	L-287	0.064	125	1.28	8	0.05 0.11 0.08	19 73 19	0.001 0.022 0.003	
NE. 8°-----	T-288	0.064	126	1.29	4	0.06 0.10 0.05	12 64 25	0.001 0.016 0.002	

See footnotes at end of table.

Table 7.—Composite of strong-motion instrumental data for 1951—Continued

## COSTA RICA EARTHQUAKE OF JUNE 18

Station and component <sup>1</sup>	Instrument number	T <sub>0</sub>	V	Sensitivity <sup>2</sup>	ε	Earth wave period	Maximum acceleration	Maximum displacement	Remarks
		<i>sec.</i>		<i>cm.</i>		<i>sec.</i>	<i>cm/sec.<sup>2</sup></i>	<i>cm.</i>	
San Jose accelerograph:									
Vertical-up.....	V-280	0.066	122	1.33	8	0.18 0.87	5 2	0.004 0.038	Irregular motion.
SE. 171°.....	L-281	0.064	121	1.27	8	0.20 0.25	7 10	0.007 0.016	Irregular motion.
SW. 261°.....	T-282	0.065	122	1.31	8	0.21 0.22	11 9	0.012 0.011	

## NORTHERN CALIFORNIA EARTHQUAKE OF JULY 23

SF Southern Pacific Building:									
Basement accelerograph.....									Very small motion.
Fourteenth floor accelerograph:									
Vertical-up.....	V-184	0.048	116	0.69	12	0.20	3	0.003	
SW. 225°.....	L-185	0.047	121	0.67	13	0.42	3	0.013	Irregular waves.
NW. 315°.....	T-186	0.046	126	0.67	10	0.45 0.06 1.18	8 3 5	0.041 0.070 0.177	
Basement displacement meter:									
R-NW. 315°.....	18R	10.0			14	1.07 1.01	1 1	0.020 0.020	
L-NE. 45°.....	18L	9.8			11	1.02	5	0.010	Very small motion.

## NORTHERN CALIFORNIA EARTHQUAKE OF JULY 29

Hollister accelerograph:									
Vertical-up.....	V-238	0.067	111	1.25	8	0.19 0.16 0.22	7 5 3	0.006 0.004 0.004	Irregular waves.
SW. 181°.....	L-239	0.065	122	1.30	6	0.38 0.22 0.28 0.37 0.45	2 11 9 5 4	0.007 0.013 0.019 0.017 0.021	Single sinusoidal wave.
NW. 271°.....	T-240	0.065	122	1.30	10	0.29 0.23 0.36 0.72	21 8 8 5	0.045 0.011 0.026 0.066	Single sinusoidal wave.
SF Southern Pacific Building:									
Basement accelerograph.....									Very small motion.
Fourteenth floor accelerograph:									
Vertical-up.....	V-184	0.048	116	0.69	12				Weak motion.
SW. 225°.....	L-183	0.047	121	0.67	13	0.74 0.94	3 2	0.042 0.045	
NW. 315°.....	T-182	0.046	126	0.67	10	0.76 0.97	3 5	0.044 0.120	
Basement displacement meter:									
R-NW. 315°.....	18R	10.0			14	0.99	1	0.02	
L-NE. 45°.....	18L	9.8			11	1.30	1	0.01	
San Jose Bank of America:									
Basement accelerograph.....									Very small motion.
Thirteenth floor accelerograph:									
Vertical-up.....	V-175	0.044	117	0.64	8				Very small motion.
NE. 59°.....	L-174	0.044	120	0.64	7	1.03	2	0.054	
SE. 149°.....	T-173	0.046	118	0.65	8	1.06	2	0.057	

See footnote at end of table.

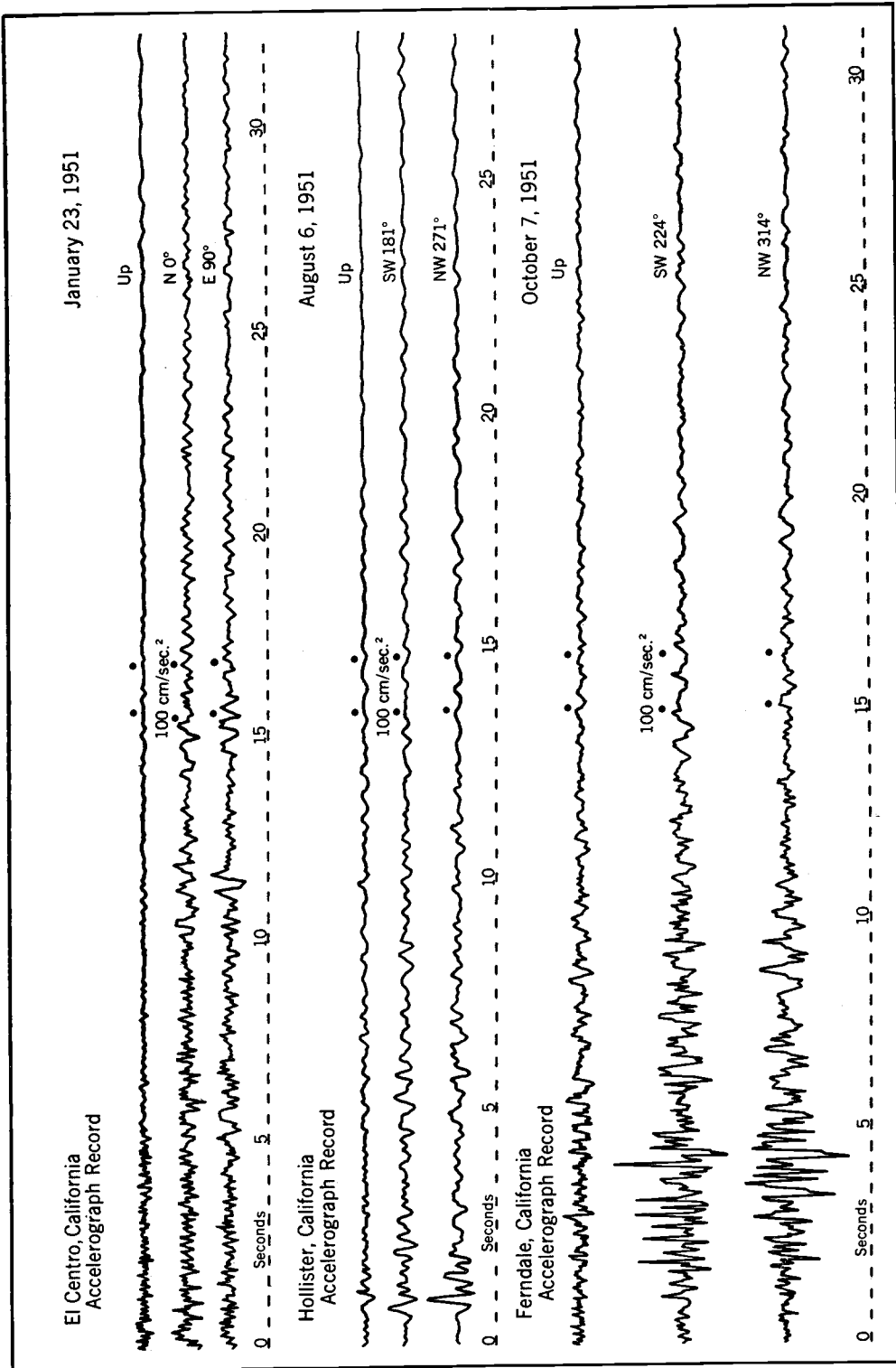


FIGURE 7.—Tracings of accelerograph records obtained at El Centro on January 23, Hollister on August 6, and Ferndale on October 7.

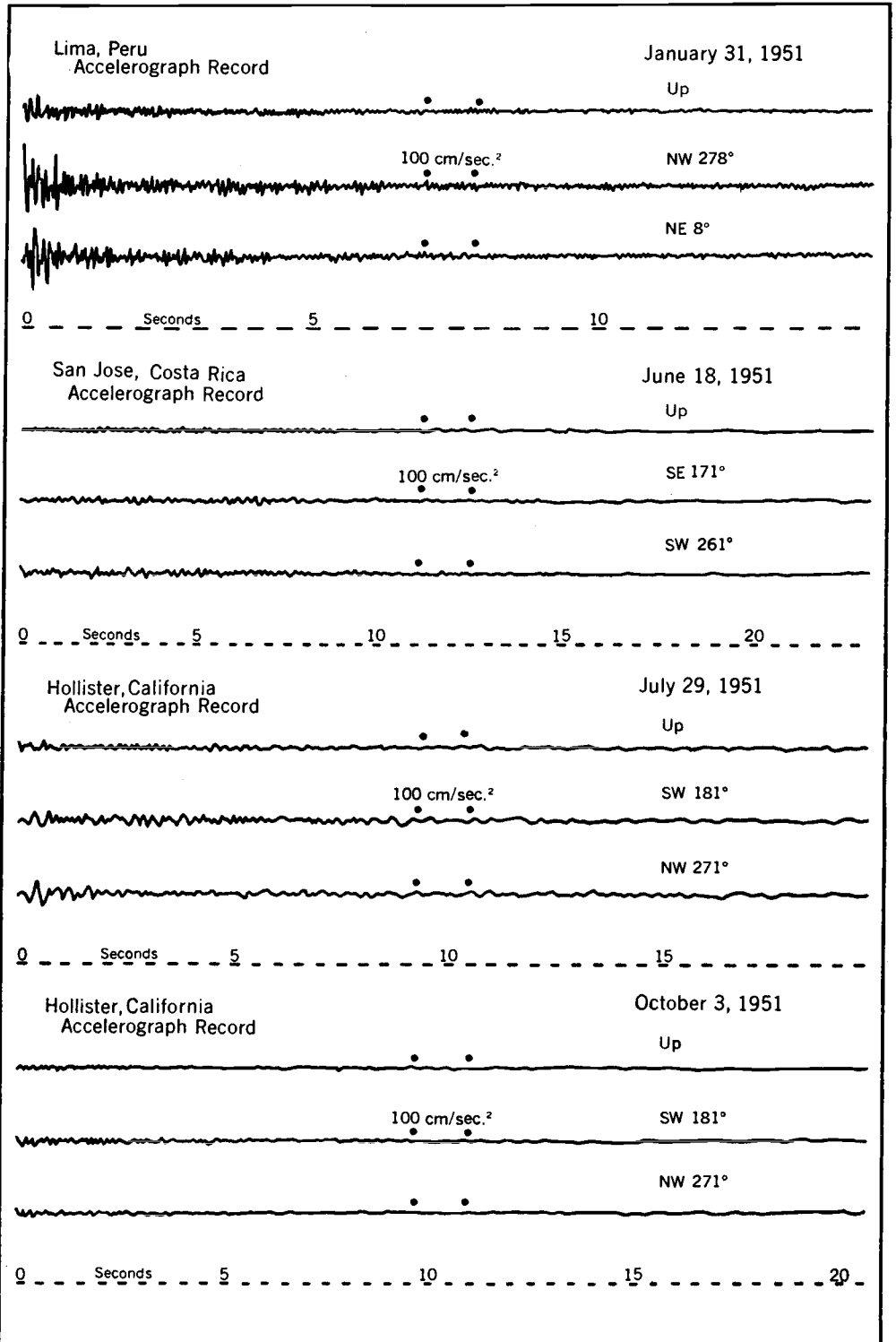


FIGURE 8.—Tracings of accelerograph records obtained at Lima, Peru, on January 31; San Jose, Costa Rica, on June 18; and Hollister on July 29 and October 3.

Table 7.—Composite of strong-motion instrumental data for 1951—Continued

NORTHERN CALIFORNIA EARTHQUAKE OF AUG. 6

Station and component <sup>1</sup>	Instrument number	T <sub>0</sub>	V	Sensitivity <sup>2</sup>	ε	Earth wave period	Maximum acceleration	Maximum displacement	Remarks
Hollister accelerograph: Vertical-up.....	V-238	sec. 0.068	113	cm. 1.32	8	sec. 0.19	cm/sec. <sup>2</sup> 15	cm. 0.014	Single sinusoidal wave.
						0.30	8	0.018	
						0.35	10	0.031	
SW. 181°.....	L-239	0.066	122	1.33	7	0.49	6	0.037	Single sinusoidal wave.
						0.35	25	0.078	
						0.33	17	0.047	
						0.33	16	0.044	
NW. 271°.....	T-240	0.066	122	1.33	10	0.70	6	0.075	Strong sinusoidal wave.
						0.25	46	0.073	
						0.32	18	0.047	
						0.29	10	0.021	
						0.66	5	0.055	
SF Southern Pacific Building: Basement accelerograph.....									Very small motion.
Fourteenth floor accelerograph: Vertical-up.....	V-184								Very small motion.
SW. 225°.....	L-183	0.047	121	0.67	13	0.79	5	0.079	
						1.09	3	0.091	
NW. 315°.....	T-182	0.046	126	0.67	10	0.38	3	0.011	
						0.98	3	0.073	
Basement displacement meter: R-NW. 315°.....	18R	10.0			14	1.14	1	0.02	
L-NE. 45°.....	18L	9.8			11	1.02	1	0.02	
San Jose Bank of America: Basement accelerograph: Vertical-up.....									Very small motion.
NE. 59°.....	L-201	0.066	122	1.36	7	0.53	1	0.007	
SE. 149°.....	T-200	0.067	122	1.40	10	0.54	1	0.007	
Thirteenth floor accelerograph: Vertical-up.....	V-175	0.044	117	0.64	8				No recording.
NE. 59°.....	L-174	0.044	120	0.64	7	1.29	2	0.085	
SE. 149°.....	T-173	0.046	118	0.65	8	1.31	2	0.087	

PERU EARTHQUAKE OF AUG. 9

Lima accelerograph.....									Very weak record.
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NORTHERN CALIFORNIA EARTHQUAKE OF OCT. 3

Hollister accelerograph: Vertical-up.....	V-238	0.067	113	1.29	9	0.25	2	0.003	Weak record.
SW. 181°.....	L-239	0.066	122	1.36	7	0.16	6	0.004	Do.
NW. 271°.....	T-240	0.066	121	1.32	10	0.54	2	0.015	Do.

NORTHERN CALIFORNIA EARTHQUAKE OF OCT. 7

Eureka accelerograph: Vertical-up.....	V-250	0.070	114	1.39	8	0.39	2	0.008	Weak record.
NE. 79°.....	L-251	0.068	119	1.37	11	0.46	6	0.032	Irregular waves.
						0.54	3	0.022	
SE. 169°.....	T-252	0.068	119	1.40	11	0.36	5	0.016	Irregular waves.
						0.77	2	0.030	
Ferndale accelerograph: Vertical-up.....	V-247	0.066	121	1.34	12	0.16	9	0.006	Very irregular waves.
						0.36	19	0.062	
						0.57	2	0.016	
SW. 224°.....	L-248	0.066	130	1.45	9	0.17	88	0.064	Very irregular waves.
						0.24	44	0.064	
						0.67	14	0.159	
NW. 314°.....	T-249	0.065	119	1.26	10	0.17	23	0.017	Very irregular waves.
						0.20	70	0.071	
						0.67	38	0.431	
Displacement meter: R-SE. 134°.....	13R	9.9			10	0.40	76	0.31	Irregular waves.
						0.73	34	0.46	
L-SW. 224°.....	13L	10.0			11	0.52	41	0.28	Irregular waves.
						1.41	11	0.56	

See footnotes at end of table.

Table 7.—Composite of strong-motion instrumental data for 1951—Continued

## NORTHERN CALIFORNIA EARTHQUAKE OF OCT. 30

Station and component <sup>1</sup>	Instrument number	T.	V	Sensitivity <sup>2</sup>	ε	Earth wave period	Maximum acceleration	Maximum displacement	Remarks
Hollister accelerograph:									
Vertical-up.....	V-238	<i>sec.</i> 0.068	113	<i>cm.</i> 1.31	9	<i>sec.</i> 0.25	<i>cm/sec.<sup>2</sup></i> 11	<i>cm.</i> 0.017	Weak record.
SW. 181°.....	L-239	0.066	122	1.33	7	0.27	7	0.013	Do.
NW. 271°.....	T-240	0.066	121	1.32	11	0.37	6	0.021	Do.

## NORTHERN CALIFORNIA EARTHQUAKE OF OCT. 31

Hollister accelerograph:									
Vertical-up.....	V-238	0.068	113	1.31	9	0.22	9	0.011	Irregular waves.
						0.27	15	0.028	
SW. 181°.....	L-239	0.066	122	1.33	7	0.33	12	0.033	Irregular waves.
NW. 271°.....	T-240	0.066	121	1.32	11	0.29	15	0.032	Irregular waves.
						0.24	38	0.055	
						0.43	14	0.066	
SF Southern Pacific Building:									
Basement accelerograph:									
Vertical-up.....	V-196	0.068	125	1.47	10	0.39	1	0.004	Very weak record.
NW. 315°.....	L-195	0.067	123	1.40	6	0.56	1	0.008	
NE. 45°.....	T-194	0.067	122	1.40	9	0.33	1	0.003	
Fourteenth floor accelerograph:									
Vertical-up.....	V-184	0.047	116	0.64	12	0.26	2	0.003	Very weak record.
SW. 225°.....	L-183	0.047	121	0.66	13	0.41	5	0.021	
NW. 315°.....	T-182	0.046	126	0.69	10	0.51	8	0.053	Simusoidal waves.
Basement displacement meter:									
R-NW. 315°.....	18R	9.9	-----	-----	18	0.71	2	0.02	Very weak record.
L-NE. 45°.....	18L	9.8	-----	-----	9	0.85	1	0.02	

## NORTHERN CALIFORNIA EARTHQUAKE OF NOV. 14

Eureka accelerograph:									
Vertical-up.....	V-250	0.066	112	1.24	8	0.48	3	0.017	Weak record.
NE. 79°.....	L-251	0.065	119	1.29	11	0.42	41	0.183	
						0.52	10	0.068	First motion may have been larger.
SE. 169°.....	T-252	0.065	119	1.28	11	0.31	11	0.027	
						0.41	11	0.047	
Ferndale accelerograph:									
Vertical-up.....	V-247	0.065	121	1.30	-----	0.30	9	0.020	Irregular waves.
SW. 224°.....	L-248	0.066	130	1.45	-----	0.43	8	0.037	
						0.13	23	0.010	First motion may have been larger.
NW. 314°.....	T-249	0.065	119	1.26	-----	0.63	14	0.141	
						0.11	23	0.007	Irregular waves.
						0.53	2	0.014	
Displacement meter:									
R-SE. 134°.....	13R	9.8	-----	-----	11	0.79	11	0.18	First motion may have been larger.
L-SW. 224°.....	13L	10.0	-----	-----	19	0.66	14	0.15	

See footnotes at end of table.

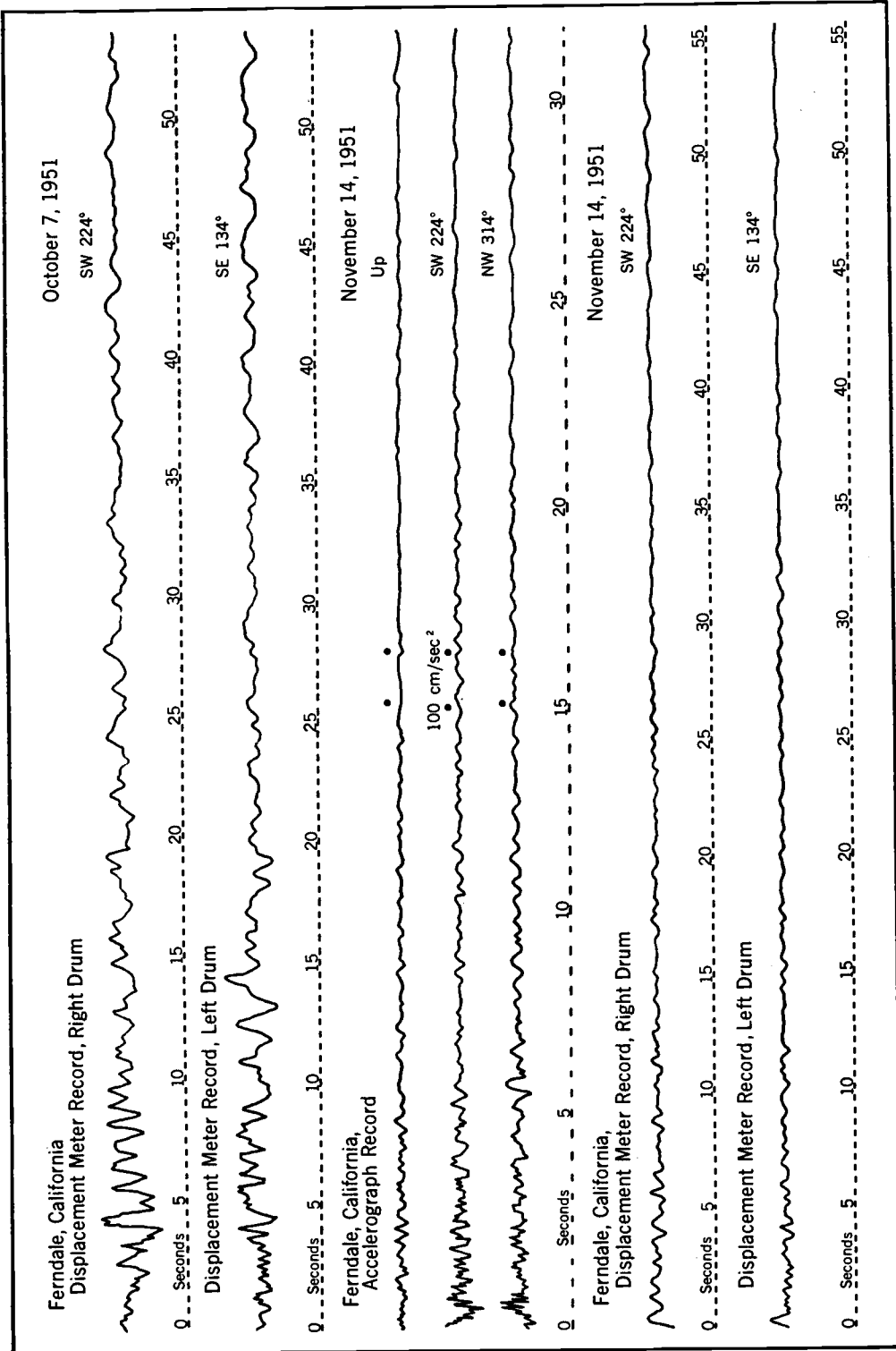


FIGURE 9.—Tracings of displacement meter records obtained at Ferndale on October 7 and accelerograph and displacement meter records obtained at Ferndale on November 14.

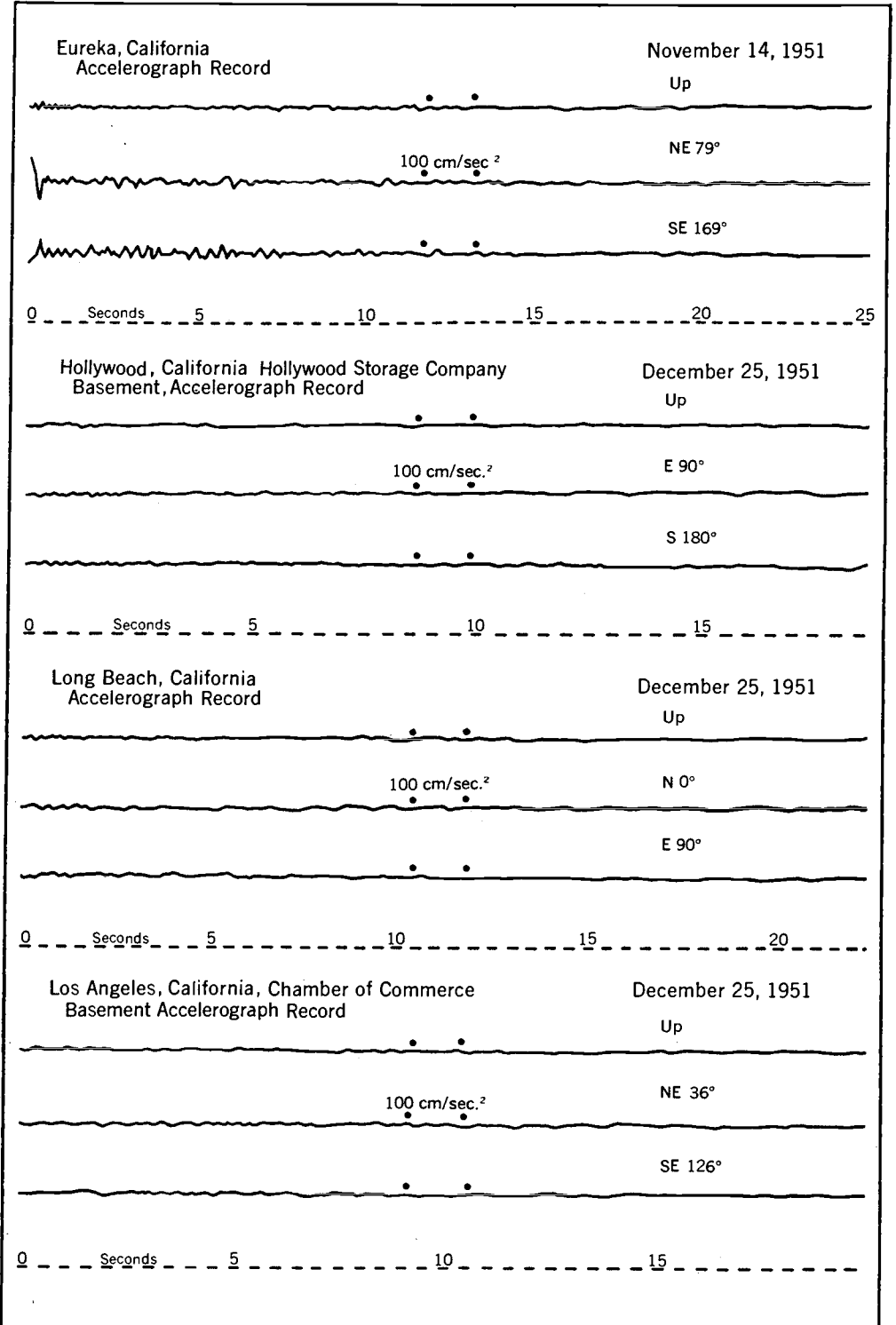


FIGURE 10.—Tracings of accelerograph records obtained at Eureka on October 7, at Hollister on October 30 and 31, and San Francisco, Southern Pacific Building, 14th floor, on October 31.



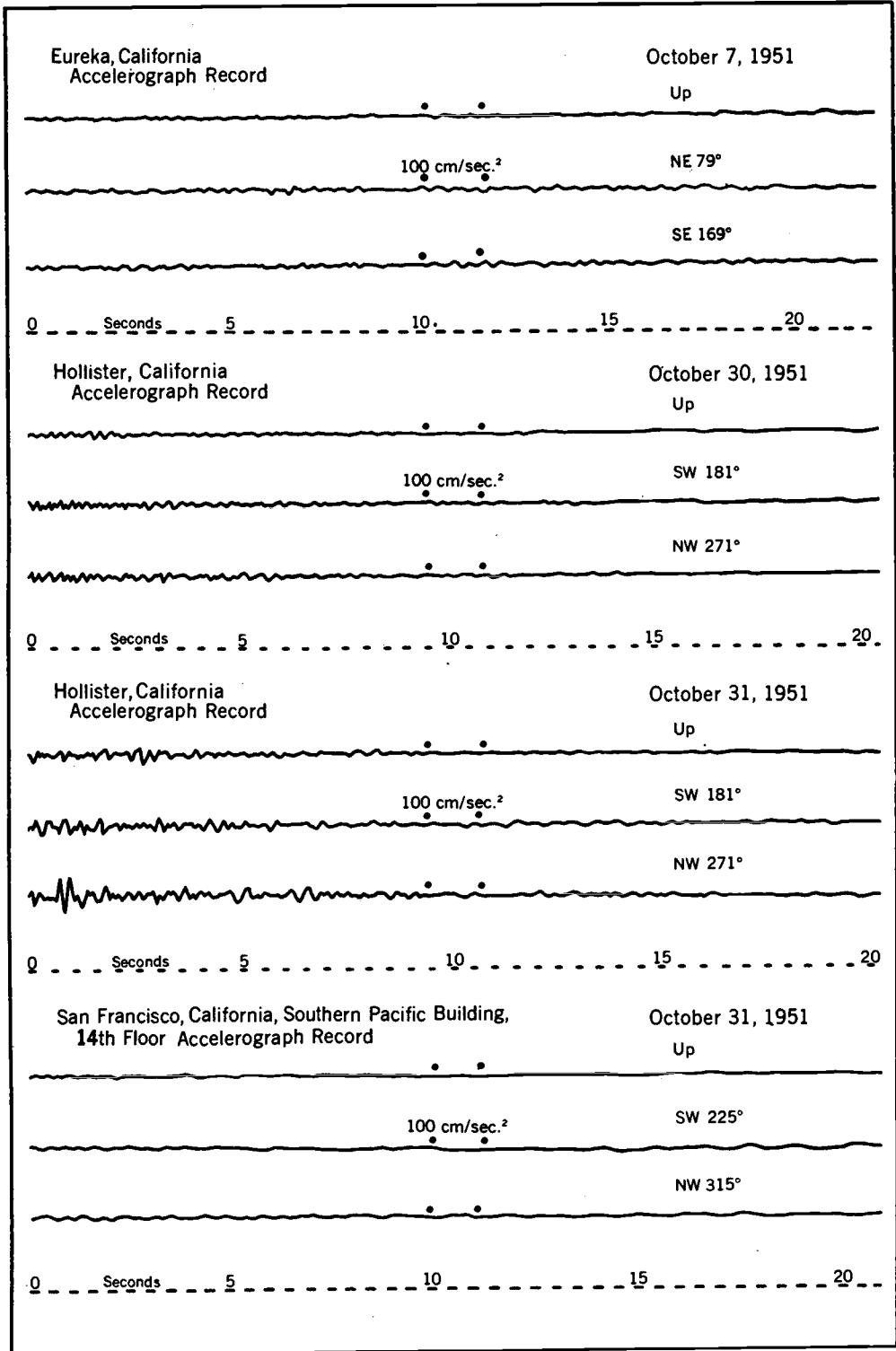


FIGURE 11.—Tracings of accelerograph records obtained at Eureka on November 14; at Hollywood Storage Company, basement; Long Beach; and Los Angeles Chamber of Commerce, basement, on December 25.

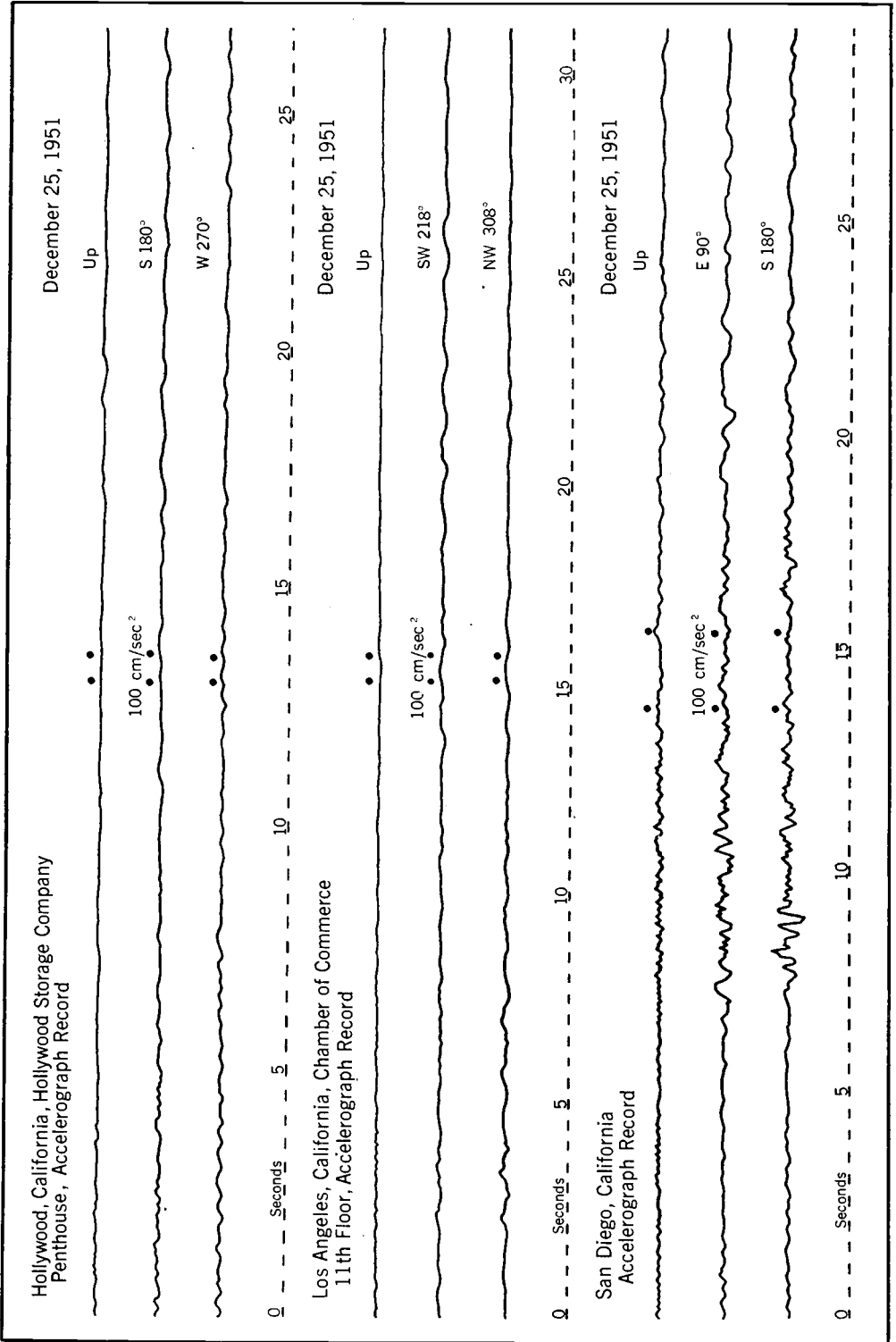


FIGURE 12.—Tracings of accelerometer records obtained at Hollywood Storage Company, penthouse; Los Angeles Chamber of Commerce, 11th floor; and San Diego on December 25.

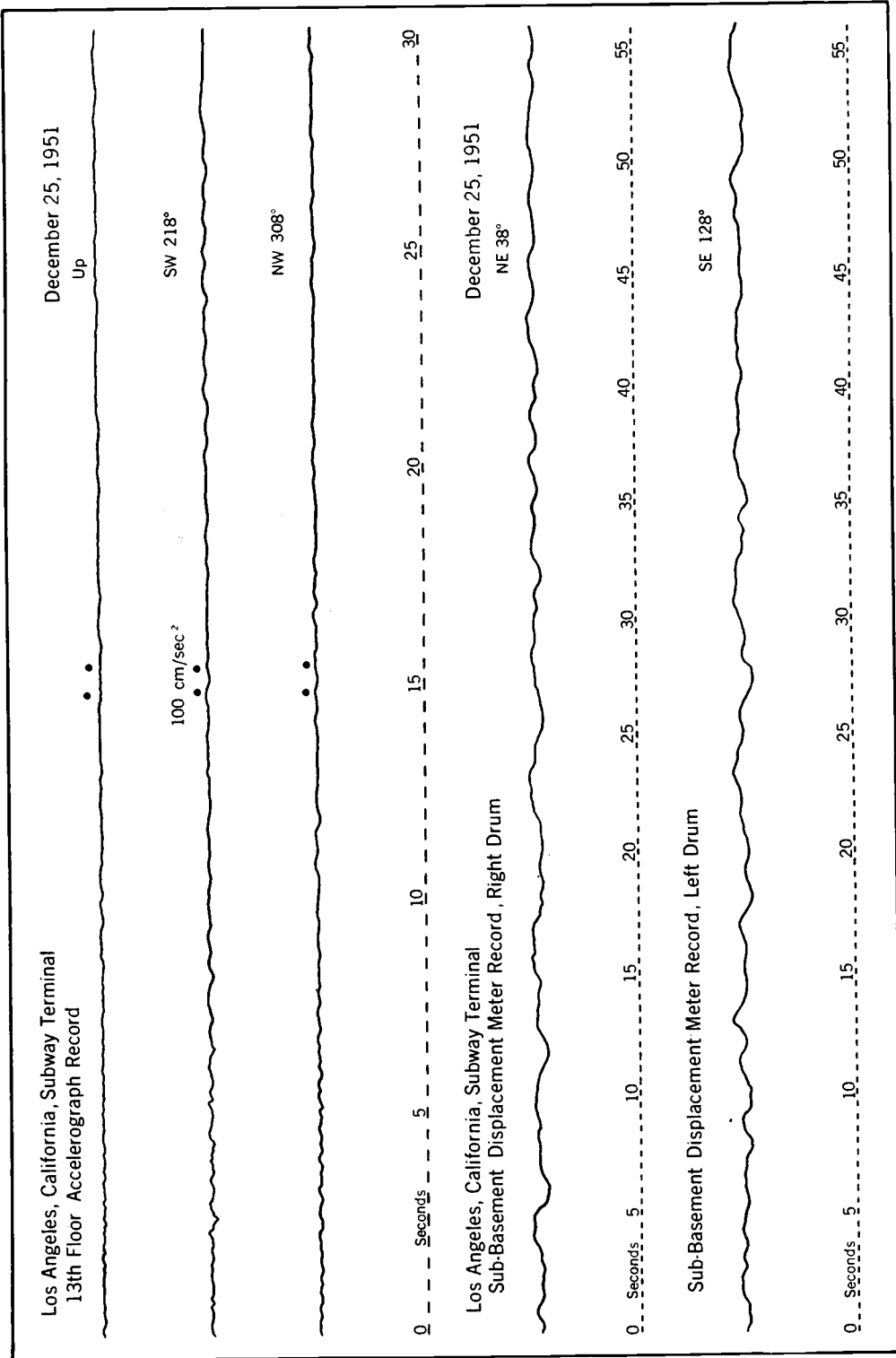


FIGURE 13.—Tracings of accelerograph and displacement meter records obtained at Los Angeles Subway Terminal, 13th floor and sub-basement, on December 25.

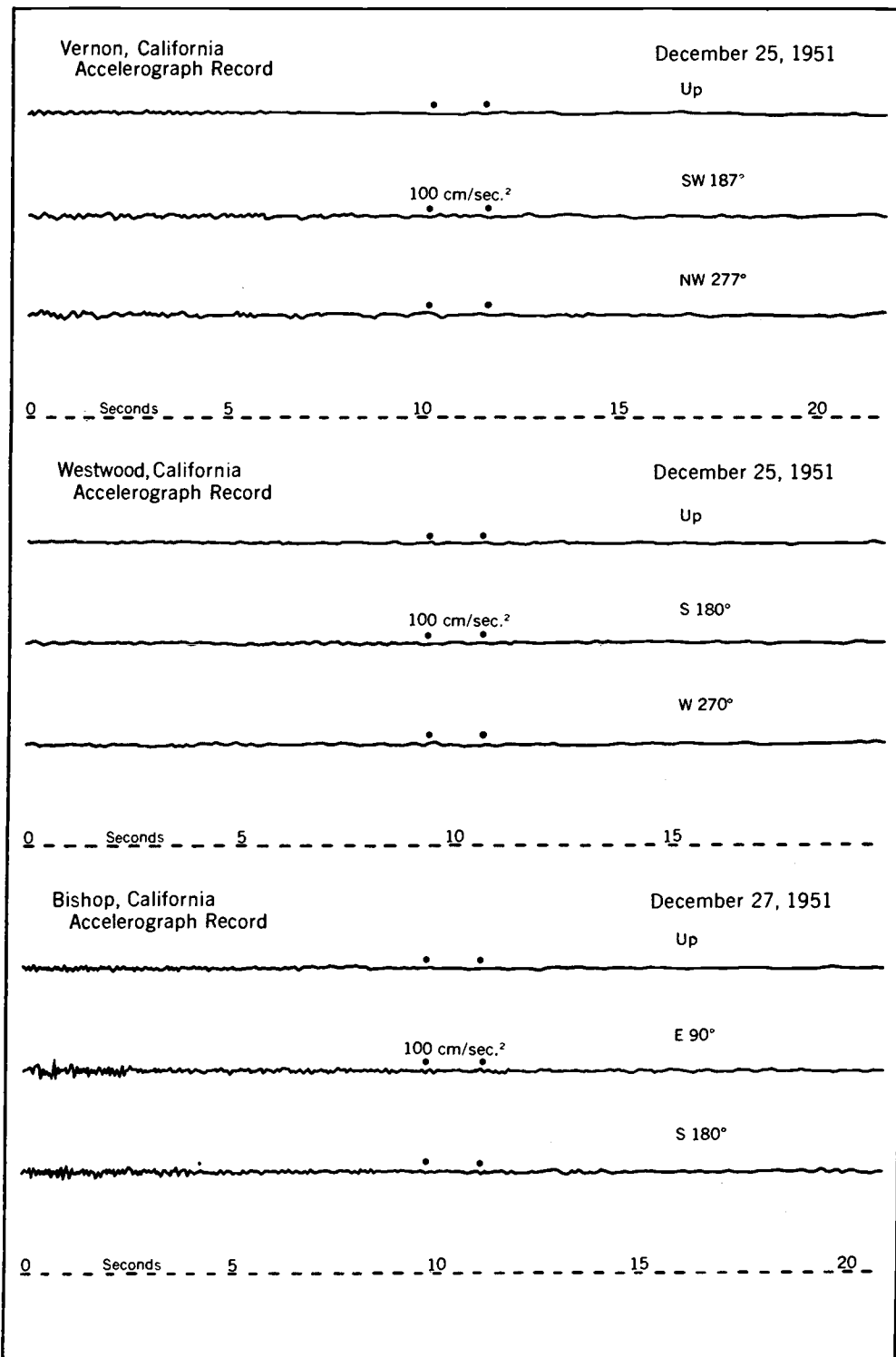


FIGURE 14.—Tracings of accelerograph records obtained at Vernon and Westwood on December 25 and at Bishop on December 27.

Table 7.—Composite of strong-motion instrumental data for 1951—Continued

SOUTHERN CALIFORNIA EARTHQUAKE OF DEC. 25

Station and component <sup>1</sup>	Instru- ment number	To	V	Sensi- tivity <sup>2</sup>	4	Earth wave period	Maxi- mum acceler- ation	Maxi- mum displace- ment	Remarks
Hollywood Stor. Co.: <sup>3</sup>									
Basement accelerograph:		<i>sec.</i>		<i>cm.</i>		<i>sec.</i>	<i>cm/sec<sup>2</sup></i>	<i>cm.</i>	
Vertical-up.....	V-217	0.065	126	1.34	13	0.42	1	0.004	Very weak record.
E. 90°.....	L-216	0.066	121	1.34	7	0.31	2	0.005	Weak record.
S. 180°.....	T-215	0.064	126	1.30	10	0.28	3	0.006	Do.
Penthouse accelerograph:									
Vertical-up.....	V-193	0.045	121	0.62	8	0.42	3	0.013	Very weak record.
S. 180°.....	L-192	0.045	126	0.65	12	1.30	8	0.342	Weak record
W. 270°.....	T-191	0.044	131	0.65	19	0.57	6	0.049	Sinusoidal waves.
Long Beach accelerograph:									
Vertical-up.....	V-265	0.066	125	1.38	11	1.60	2	0.130	Very weak record.
N. 0°.....	L-266	0.064	120	1.33	8	0.85	2	0.037	Weak record.
E. 90°.....	T-267	0.066	126	1.37	10	0.75	3	0.043	Do.
L.A. Chamber of Commerce:									
Basement accelerograph:									
Vertical-up.....	V-205	0.064	112	1.15	13	0.52	2	0.014	Very weak record.
NE. 36°.....	L-204	0.065	127	1.34	15	0.52	4	0.027	Do.
SE. 126°.....	T-203	0.066	128	1.40	13	0.61	4	0.038	Do.
Eleventh floor accelerograph:									
Vertical-up.....	V-187	0.046	118	0.63	10	0.20	3	0.003	Very weak record.
SW. 218°.....	L-186	0.045	122	0.63	12	1.35	11	0.508	Weak irregular waves.
NW. 308°.....	T-185	0.045	127	0.65	8	1.09	17	0.511	Do.
Los Angeles Subway Ter- minal Sub-basement accel- erograph:									
Vertical-up.....	V-211	0.065	125	1.35	10	0.45	1	0.005	Very weak record.
SE. 128°.....	L-210	0.065	126	1.36	8	0.31	1	0.002	Do.
SW. 218°.....	T-209	0.065	127	1.35	9	0.48	2	0.012	Do.
Thirteenth floor accelero- graph:									
Vertical-up.....	V-190	0.046	123	0.65	8	0.22	3	0.004	Very weak record.
SW. 218°.....	L-189	0.046	126	0.67	8	0.63	13	0.130	Weak irregular waves.
NW. 308°.....	T-188	0.046	120	0.68	8	0.37	7	0.024	Weak record.
Sub-basement displace- ment meter:									
R-NE. 38°.....	15R	9.9	-----	-----	18	2.74	1	0.15	Continuing irregular waves.
L-SE. 128°.....	15L	10.6	-----	-----	15	2.02	2	0.21	Do.
San Diego accelerograph:									
Vertical-up.....	V 322	0.081	123	2.03	8	0.32	3	0.008	Irregular waves.
E. 90°.....	L-323	0.079	123	1.96	8	0.89	3	0.060	
						0.73	11	0.148	
						0.39	9	0.035	
						0.15	2	0.001	
S. 180°.....	T-324	0.080	122	1.96	10	0.34	14	0.011	
						0.88	8	0.157	
						1.30	6	0.257	
Santa Ana Weed:									
SE. 135°.....	9R	0.20	6.8	0.71	4	0.27	19	0.035	
NE. 45°.....	9L	0.20	7.0	0.69	3	0.31	30	0.073	
Vernon accelerograph:									
Vertical-up.....	V-256	0.064	124	1.30	8	0.29	2	0.004	Weak record.
SW. 187°.....	L 257	0.064	128	1.35	11	0.45	7	0.036	
NW. 277°.....	T-258	0.065	130	1.38	8	0.33	5	0.014	
Westwood accelerograph:									
Vertical-up.....	V-262	0.066	121	1.31	7	0.28	2	0.004	Very weak record.
S. 180°.....	L-263	0.066	122	1.33	9	0.39	2	0.008	Do.
W. 270°.....	T-264	0.066	122	1.34	9	0.36	3	0.010	Do.

SOUTHERN CALIFORNIA EARTHQUAKE OF DEC. 27

Bishop accelerograph:									
Vertical-up.....	V-241	0.066	119	1.32	12	0.14	4	0.002	Weak record.
E. 90°.....	L-242	0.066	119	1.31	15	0.09	22	0.004	
						0.15	14	0.008	
S. 180°.....	T-243	0.065	118	1.27	15	0.12	14	0.005	

<sup>1</sup> The directions given indicate the direction of pendulum displacement relative to instrument pier, which will displace the trace upward on the original seismogram. Directions for the horizontal components are given first by quadrant followed by specific directions expressed in degrees measured from north around by east.

<sup>2</sup> The sensitivity is the number of centimeters on the seismogram that corresponds to 100 cm/sec.<sup>2</sup> The deflection corresponding to 1/10 gravity may be obtained by multiplying the sensitivity tabulated by 0.98.

<sup>3</sup> All instruments at this station are wired to start simultaneously.

## TILT OBSERVATIONS

Two tiltmeters at the University of California, Berkeley, and one at the Long Beach City Recreation Park, Long Beach, were continued in operation.

## CORRECTIONS TO PREVIOUS EDITIONS

Serial 755, *United States Earthquakes, 1950*. Table 6, page 46. The El Centro N. 0° component instrument number should read L-206.

Serial 755, *United States Earthquakes, 1950*. Page 40, 3rd paragraph. The title of S. P. 250 should read *The Determination of True Ground Motion from Seismograph Records*.

Serial 755, *United States Earthquakes, 1950*. Page 25. The well water data for Michigan are measured in single amplitudes. The data for all other wells reported in Serials 672, 748, and 755 are measured in double amplitudes.

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