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United States Earthquakes, 1963

By

Carl A. von Hake

and

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COAST AND GEODETIC SURVEY
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UNITED STATES EARTHQUAKES
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CONTENTS

ILLUSTRATIONS

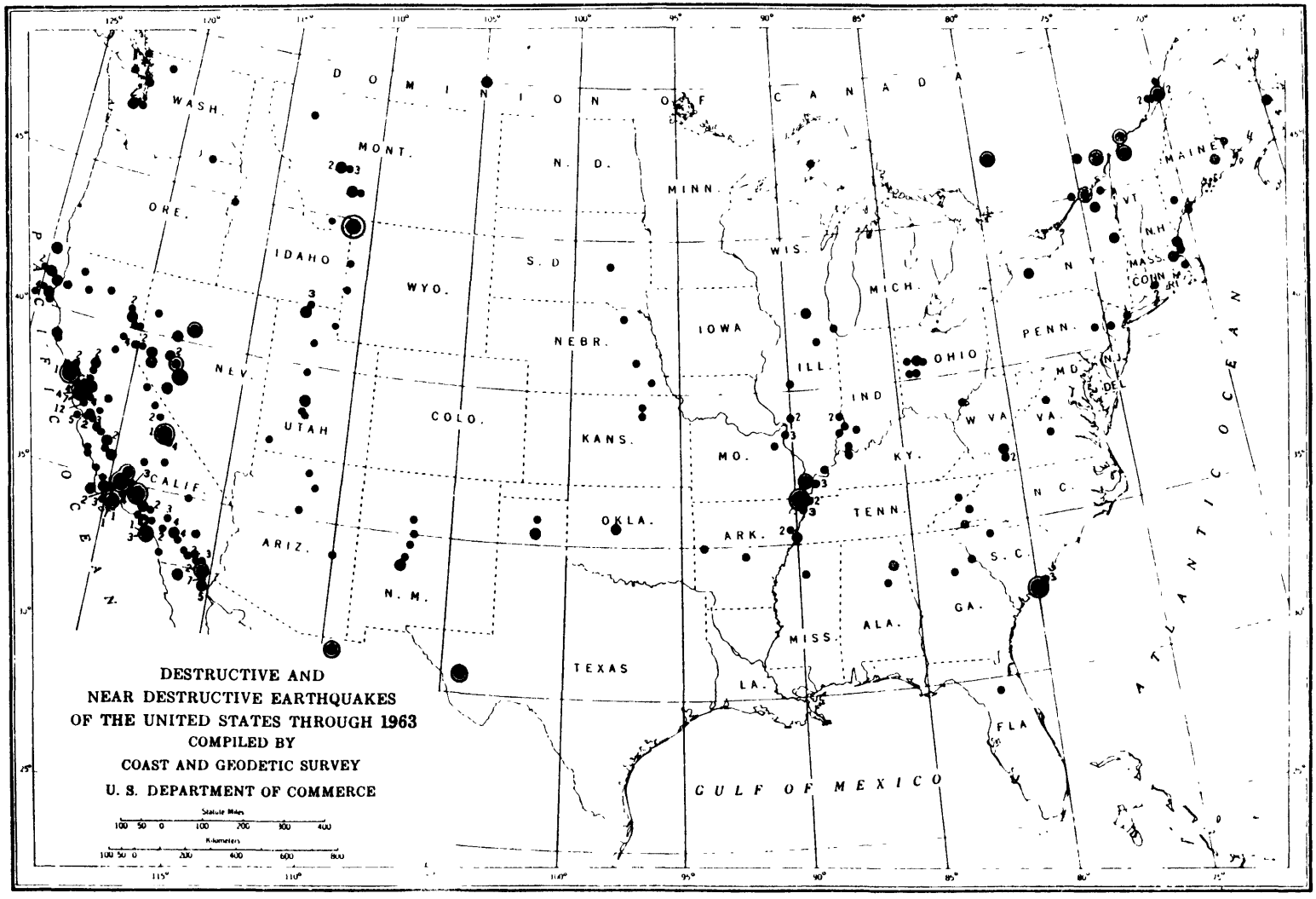

FIGURE 1.—*Destructive and near destructive earthquakes in the United States through 1963.*

UNITED STATES EARTHQUAKES, 1963

INTRODUCTION

This publication is a summary of earthquake activity in the United States and regions under its jurisdiction for the calendar year 1963. 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 Observatory Summary;* 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 52 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 map the seismic areas of the country adequately 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,* available through mailing list CGS–3. Active cooperation in this work is received from the University of California Seismographic Station, Berkeley (Dr. Bruce A. Bolt, in charge); and the Seismological Laboratory, Pasadena (Dr. Frank Press, 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 1963.

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

Colorado.—Prof. W. Warren Longley, University of Colorado, Boulder.

Idaho.—Dr. Earl F. Cook, Idaho Bureau of Mines and Geology, Moscow.

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

Nevada.—Dr. David B. Slemmons, 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 University, 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 headquarters at St. Louis University collects information in the central Mississippi Valley area (Rev. Dr. Victor J. Blum, 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. Additional information is furnished regularly by Mr. Berlen C. Moneymaker, Chief Geologist, Tennessee Valley Authority, Knoxville, Tenn., for earthquakes in the State of Tennessee, and Dr. Gerald R. MacCarthy, Department of Geology, University of North Carolina, Chapel Hill, N.C., for earthquakes in the State of North Carolina.

Modified Mercalli Intensity Scale of 1931.—All intensities used by the Coast and Geodetic Survey refer to the Modified Mercalli Intensity Scale of 1931.[1] The abridged version of this Scale is presented on the following page with equivalent intensities according to the Rossi-Forel scale.

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[1] 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 specially 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. Disturbances 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 riverbanks 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 1963. The smallest dots indicate 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 dots 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 1963. 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 Figure 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 (Figures 3–8) 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.—The Summary of Instrumental Epicenters previously published in this report has been discontinued. On page 52 is a list of Survey and cooperating teleseismic stations for which the Survey publishes results. During the year the locations of 4230 epicenters were announced promptly on *Preliminary Determination of Epicenter* 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 monthly *Seismological Bulletin*, MSI series, available on mailing list CGS–7. During the year 1963, MSI–265 through 276 for the monthly bulletins of 1963 were published.

Magnitude and intensity (damage) ratings.—Magnitude rating, stated according to the Gutenberg-Richter scale, is a measure of the energy release at the focus of the earthquake, having therefore a fundamental relation to the shock. It is estimated by the analysis of seismograph records, as explained in the *Bulletin of Seismological Society of America,* vol. 32, no. 3, 1942. Intensity (damage) rating, usually expressed on the *Modified Mercalli Intensity Scale of 1931,* is a local measure of the effects on people and objects at any affected locality. Therefore it is a result of many factors, including energy release of the earthquake, distance, geological and topographic conditions, and structural properties of buildings. It varies from place to place. The two ratings are not simply comparable.

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 Publication No. 41–2, *Earthquake Investigations in the Western United States, 1931–1964.*

The preliminary analyses of strong-motion records are published in the *Quarterly Engineering Seismology Bulletin* which is available upon request from the Environmental Science Services Administration, Coast and Geodetic Survey, Washington, D.C. 20235. The revised analyses are given in Table 7.

Earthquake history.—A history of the more important shocks of the country appears in Publication No. 41–1, *Earthquake History of the United States.* Part I, revised (1963) edition, includes stronger earthquakes of the United States, exclusive of California and Western Nevada; Part II, revised (1963) edition, covers the stronger earthquakes of California and western Nevada.

A history of minor activity is covered largely in a series of references listed in Publication No. 41–1, 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 latter reference gives detailed information for California and other Pacific Coast earthquakes and 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,* revised (1964) edition. 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, D.C., 20402, for 20 cents.

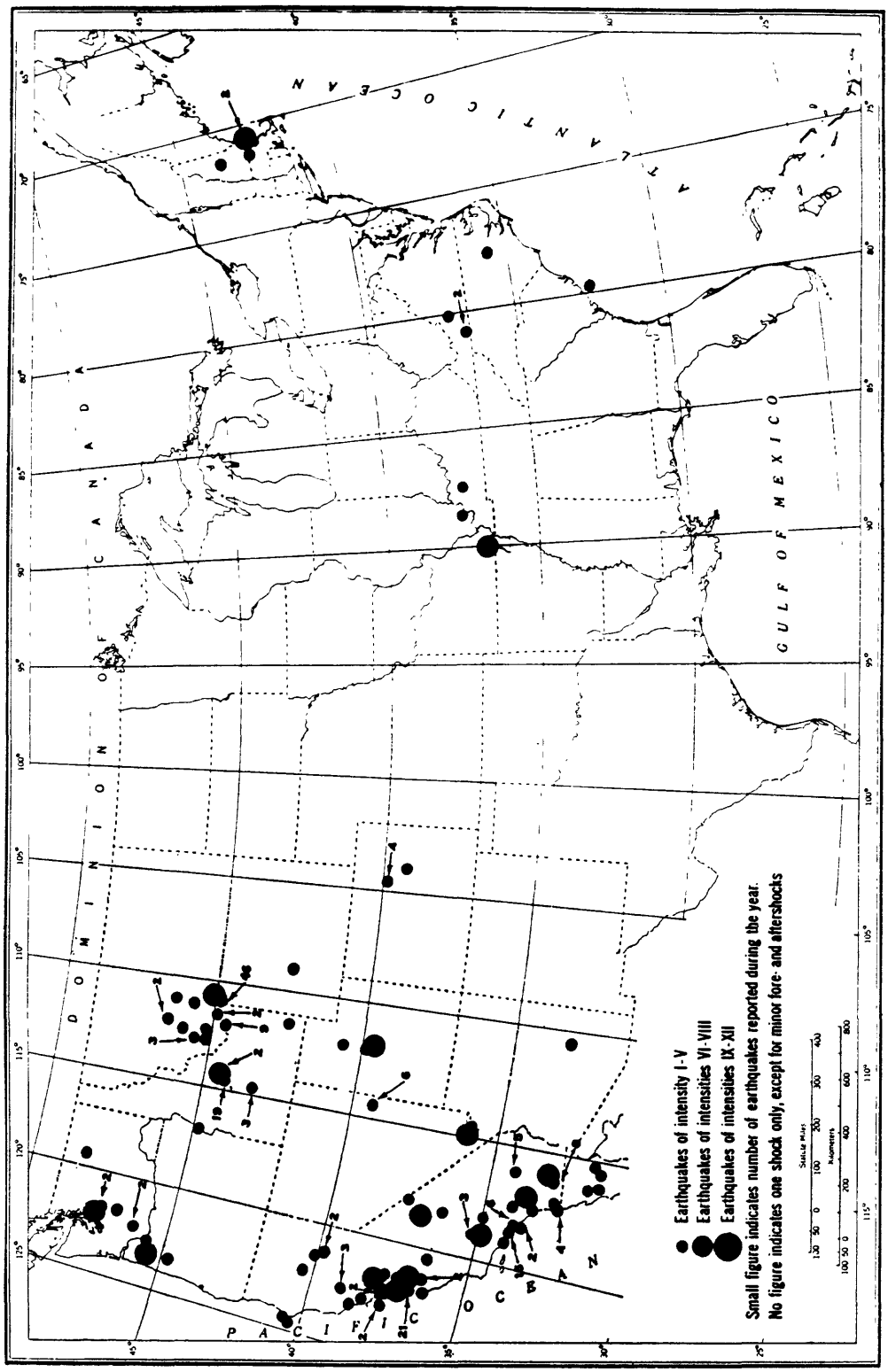

FIGURE 2.—*United States earthquake epicenters, 1963.*

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; NESA, reported by the Northeastern Seismological Association, Weston, Mass.; JSA, reported by the Jesuit Seismological Association, Saint Louis, Mo.; S, reported by the Seismograph Station, University of Washington, Seattle, Wash.; and W, reported by the Washington office of the Coast and Geodetic Survey. Magnitude as determined by the Washington office is m_B of Gutenberg-Richter computed from P phase only. The magnitude quoted is an average value determined from data forwarded by cooperative standard stations and other observatories. The abbreviation (Pal) indicates magnitude as determined by Lamont Geological Observatory, Palisades, New York.

An asterisk (*) indicates instrumental origin time of the earthquake when coordinates of the epicenter are given. Otherwise, instrumental times shown with asterisks indicate the arrival time at nearby stations.

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 Western Mountain Region*, MSA series, issued on mailing list CGS-3.

EARTHQUAKE ACTIVITY IN THE VARIOUS STATES

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

Alaska: March 13; 24; 29; April 1; 3; 10; 28; 29; 30; May 3; 7; 7, IV; 12; June 22; 23, VII; 24, IV; July 7; 26; August 10; 14; September 1; 28; October 3; 6; 12; 14; 15; 17 (2); 23; November 4 (2); December 4; 7, IV; 8; 11; 20; 23.

Arizona: March 25, V; September 11, V; 11 (2).

Arkansas: March 3, V.

California: (Intensity V and above). February 2, V (2); 12, V; 28, VI; March 25, V; April 18, V; May 6, V; 7, V; 17, V; 20, V; 22, VI; 23, VI; June 7, VI; 11, V; July 18, V; 29, V; 30, V; August 4, V; 22, V; 31, V; September 13, V (2); 14, VII; 23, VI; October 25, V; December 6, VI; 30, V.

Colorado: January 30; April 24; May 25, V; June 4; July 2, V.

Hawaii: January 8 (2); 9 (2); 23; February 27; 28; March 1; 6 (2); 11; 13; 15; 22; 24; 25 (2); 28; 31; April 7; 27; May 4; 9–12 (series of shocks); 19; 20; 31; June 1; 6 (2); 14; July 1–5 (series of shocks); 7; 10; 11 (3); 18; August 1; 3; 4; 8; 14; 26 (3); 28; September 1; 3 (3); 4; 6; 11; 15; 18; 19; 21; 22 (2); 24; 27; 28; October 5–6 (series of shocks); 6; 7; 8; 10; 11 (2); 15; 18; 22; 23 (6); 24; 25; 26 (3); 29; 30 (2); November 3; 5; 14 (2); 15; 17; 29; December 9.

Idaho: January 27, VI; February 1, V; 1 (2); 5, IV; 5; March 4; May 24, IV; June 5, IV; August 2, IV; September 7, IV; 9, V; 10, VI; 10; 11, IV; 12; 14, V; 14 (3); 16, V; October 3, IV; 7, IV; 15, IV; 16; (numerous shocks during September and October).

Illinois: March 3, V; August 2, IV.

Indiana: March 3, IV.

Kansas: March 3, IV.

Kentucky: March 3, V; August 2, V; December 14, III.

Maine: October 16, IV.

Massachusetts: October 16, VI; 17, III; 30, VI.

Mississippi: March 3.

Missouri: March 3, VI.

Montana: January 6, IV; 9, IV (3); February 15, V; March 7, IV; 9, IV; 21, V; May 11, V; 13, IV; 29; June 1; 10, IV; 21, IV; 21; 29, IV; July 19; 29, IV; August 8, IV (2); September 7, IV (2); 20; 23, V; 23; December 20, V; 21, IV; 23.

Nevada: March 25, VI; April 23, V; December 6, V; 20, IV; 25, IV; 28, IV (5).

New Hampshire: October 16, IV; 30, IV; December 4, V.

North Carolina: October 28, V; 28.

Oklahoma: March 3.

Oregon: March 2, IV; 7, V; December 26, VI.

Rhode Island: October 16, V.

South Carolina: April 11, IV; May 4, IV.

Tennessee: March 3, V.

Utah: March 25, IV; July 7, VI; August 14, IV; 15, IV.

Virginia: January 17, IV (2); October 28, V; 28, IV.

Washington: January 24, VI; 24, IV; 24; 30, IV; September 5; October 22; December 21, V; 26, VI.

Wyoming: January 24, IV; 29, V; 30, IV; February 25, V; March 8, VI; 8–12 (numerous shocks); 21, V; April 18, V; 18 (2); 26; 27; June 6, V (6); September 23, IV (2); December 16; 17, V; 17 (4); 20, V; 23; 27; 30; 31.

EARTHQUAKE ACTIVITY OUTSIDE THE UNITED STATES

Panama Canal Zone: September 5, I; December 5, I.

Puerto Rico: March 18.

NORTHEASTERN REGION
(75TH MERIDIAN OR EASTERN STANDARD TIME)

October 16: 10:31:01.8*. Epicenter 42.5° north, 70.8° west, near coast of Massachusetts, W. Depth about 20 km. Magnitude 4.5 (Pal). Felt over an area of approximately 6,800 square miles, principally in Massachusetts. (See map, p. 9.) Maximum intensity (damage) VI at Somerville where slight damage was reported consisting of fallen plaster, cracked wall, and fallen stones from building foundation. Also felt in New Hampshire, Rhode Island and Maine. Questionnaire canvass conducted by Weston Observatory.

INTENSITY (DAMAGE) VI IN MASSACHUSETTS:

Somerville—Felt. Wall cracked in southwest corner of building and loose stones fell from foundation. Plaster fell from pantry wall. Cracks in foundation and in pantry became larger. Lamp shades swung west-east. Buildings creaked, loose objects rattled. Slight rumbling earth sounds heard. Gradual onset; trembling motion.

INTENSITY (DAMAGE) V IN MASSACHUSETTS:

Amesbury.—Felt by and alarmed many. Windows and dishes rattled. Knickknacks fell and dishes broke. Trees, bushes shaken slightly. Loud earth noises heard. Rapid motion; 5 seconds duration.

Arlington.—Felt. Dishes fell; doors flung open. People ran into streets.

Beverly.—Felt by all; many alarmed. Windows and dishes rattled. Earth noises heard from east. Slow motion; 30 seconds duration.

Cohasset.—Felt by all; many alarmed. Windows rattled. Rapid motion; duration, 10–15 seconds.

Gloucester.—Felt by all. Houses shook; windows rattled. People fled into streets.

Lawrence.—Felt. Houses shook; windows rattled. People fled into streets.

Methuen.—Felt by many; few alarmed. Houses shook; windows and dishes rattled. Knickknacks fell. People fled into streets.

Middleboro.—Felt by all and alarmed few. Windows, doors and dishes rattled. Small objects shifted. Trees, bushes shaken slightly. Moderate earth noises heard. Rapid motion; duration, 2 seconds.

Natick.—Felt by several; many alarmed. Dishes broke; cabinets creaked. Rapid motion.

Rockport.—Felt by all. Objects dislodged from shelves in stores. Houses shook. Scraping earth sounds heard at beginning of quake. Abrupt onset; trembling motion. Duration, 10–15 seconds.

Whitman.—Felt by all; many alarmed. Windows and dishes rattled. Hanging objects swung; trees, bushes shaken slightly. Small objects shifted. Moderate earth noises heard. Rapid motion.

Winthrop.—Felt by several. Cracked window reported. Houses shook; windows rattled. Duration, 10 seconds.

Woburn.—Felt by and alarmed many. Cracked plaster reported. Windows, doors and dishes rattled. Moderate earth noises heard. Steady motion; duration, 60 seconds.

INTENSITY (DAMAGE) V IN RHODE ISLAND:

Chepachet.—Felt by many; few alarmed. Cracked plaster reported. Windows and dishes rattled; walls creaked. Rumbling earth sounds heard.

INTENSITY (DAMAGE) IV IN MAINE: Alfred and Manchester.

INTENSITY (DAMAGE) IV IN MASSACHUSETTS: Andover, Belmont, Billerica, Boston, Bourne, Brewster, Chatham, Chelmsford, Clinton, Concord, Danvers, Framingham, Haverhill, Holden, Hopkinton, Hudson, Hyannis, Ipswich, Kingston, Lexington, Lynn, Mansfield, Marblehead, Marlboro, Marshfield, Milford, Millbury, Monson, Newburyport, Northboro, Norwood, Orleans, Peabody, Plymouth, Quincy, Sandwich, Saugus, Scituate, Stoughton, Tewksbury, Tyngsboro, Upton, Uxbridge, Wakefield, Walpole, Wareham, and Westboro.

INTENSITY (DAMAGE) IV IN NEW HAMPSHIRE: Dover, Hudson, Keene, Manchester, Milford, Nashua, and Salem.

INTENSITY (DAMAGE) IV IN RHODE ISLAND: Bristol, Lime Rock, Pawtucket, Warren, and Woonsocket.

INTENSITY (DAMAGE) I–III IN MAINE: Kittery and Portland.

INTENSITY (DAMAGE) I–III IN MASSACHUSETTS: Back Bay, Bridgewater, Dunstable, Falmouth, Lowell, Manchester, Maynard, Mendon, Middleboro, Needham, Shrewsbury, and Wellfleet.

INTENSITY (DAMAGE) I–III IN NEW HAMPSHIRE: Derry, Exeter, and Portsmouth.

INTENSITY (DAMAGE) I–III IN RHODE ISLAND: Providence and Warwick.

October 17: 07:45. Dunstable, Mass. III. Three tremors felt at Weather Station and at a house ¼-mile east. (No details).

October 30: 17:36:57.9*. Epicenter 42.7° north, 70.8° west, near Ipswich, Mass., NESA. Maximum intensity (damage) VI at Peabody

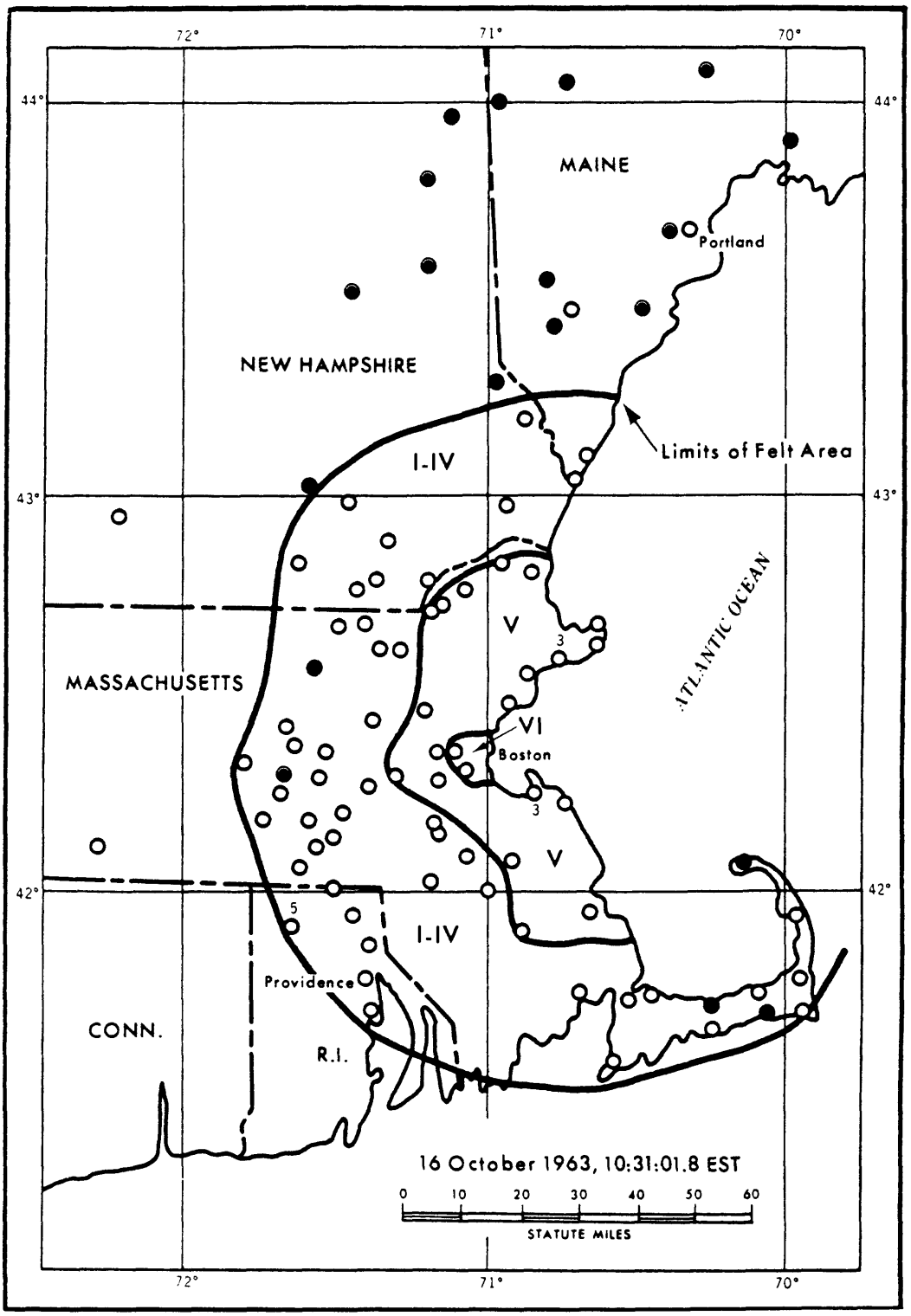

FIGURE 3.—*Area affected by earthquake of October 16.*

where wall plaster and a cement sidewalk were cracked; at Framingham where the stone foundation of an old house caved in; and at Swampscott where stairs were thrown out of line. Also felt in New Hampshire.

INTENSITY (DAMAGE) VI IN MASSACHUSETTS:

Framingham.—Felt. Ten feet of stone foundation of 155 year old house caved in. Windows, doors and dishes rattled. Rapid motion. "Sounded like a passing truck."

Peabody.—Felt by nearly all; few alarmed. Wall plaster and cement sidewalk reported cracked. Boulder rolled down hill as probable result of quake and hit an automobile. Mirror on wall swayed. Buildings creaked; loose objects rattled. Mild, thunder-like earth sounds heard at beginning of quake. Rapid onset; moderately trembling motion. Duration, 5 seconds.

Swampscott.—Felt. Basement stairs thrown ¼ inch out of line in one home according to press.

INTENSITY (DAMAGE) V IN MASSACHUSETTS:

Haverhill.—Felt by and alarmed many. Buildings creaked; loose objects rattled. Rumbling earth sounds heard by many at beginning of quake. Gradual onset; rapid motion.

Lynnfield.—Felt by all; few alarmed. Windows and doors rattled. Gradual onset; rapid motion.

INTENSITY (DAMAGE) IV IN MASSACHUSETTS:

Burlington.—Felt. Walls creaked. Gradual onset; slow motion.

Dunstable.—Felt by many. Windows, walls and doors rattled. Several pictures on east-west wall slightly tilted. Abrupt onset; trembling motion. 7 or 8 shocks.

Littleton.—Felt by several. Windows rattled. Gradual onset.

Lynn.—Felt. Dishes and windows rattled. Duration, 6–8 seconds.

Maynard.—Felt by several. Creaking of buildings and rattling of loose objects heard by many. Rumbling earth sounds heard at beginning of quake. Rapid onset; trembling motion. Duration, 3 seconds.

Rockport.—Felt by many. Buildings creaked; dishes and loose objects rattled. Moderately loud, bumping earth sounds heard. Abrupt onset; trembling motion. Duration, 8 seconds.

Salem.—Felt by many. Faint earth sounds heard at beginning of quake. Abrupt onset; trembling motion. Duration, 5–10 seconds.

Sudbury.—Felt by many. Gradual onset.

INTENSITY (DAMAGE) IV IN NEW HAMPSHIRE:

Canobie Lake.—Felt. Houses shook. Ceiling light swung back and forth.

Hampton Falls.—Felt by many. Windows, dishes and doors rattled. Slow motion.

Milford.—Felt by few. House and television set shook as if heavy truck were passing.

Salem.—Felt by several. Windows, doors and dishes rattled. Abrupt onset; rapid motion. Duration, 5 seconds.

INTENSITY (DAMAGE) I–III IN MASSACHUSETTS: Clinton, Hudson, Lancaster, Lincoln, Lowell, Lunenburg, Marblehead, and Newton.

December 4: 16:32:34.9*. Epicenter 43.6° north, 71.6° west, New Hampshire, W. Depth about 33 km. Magnitude 3.7. Maximum intensity (damage) V at Tilton where cement cracked, and at Laconia where many were alarmed and police station was flooded with calls.

INTENSITY (DAMAGE) V:

Laconia.—Felt by and alarmed many. Police headquarters flooded with calls about disturbance. Radio station jolted off air for a couple of seconds. Buildings shook; windows and doors rattled. Trees shaken slightly. Rumbling earth sounds heard.

Tilton.—Felt by many. Cracked cement reported. Rattling of loose objects heard by many. Abrupt onset; explosive onset followed by trembling.

INTENSITY (DAMAGE) IV:

Belmont.—Felt by nearly all. Creaking of buildings and rattling of loose objects heard by many. Abrupt onset; trembling motion. "Thought it was a jet at first."

Bristol.—Felt by many; few frightened. Buildings creaked; windows rattled. Abrupt onset; trembling motion, east-west. Duration, 8–10 seconds.

Gilford.—Felt. Houses shook.

Meredith.—Felt by many. Windows rattled. Abrupt onset; rapid motion.

New Hampton.—Felt. Buildings creaked; loose objects rattled. Gradual onset; swaying motion.

Plymouth.—Felt by several. Windows and dishes rattled. Abrupt onset; rapid motion. Duration, 2 seconds.

Wolfeboro.—Felt by several. Loose objects rattled. Abrupt onset; trembling motion.

INTENSITY (DAMAGE) I–III: Alton, Ashland, Franklin, Laconia (4 miles north of), Melvin Village, and Moultonboro.

EASTERN REGION

(75TH MERIDIAN OR EASTERN STANDARD TIME)

January 17: 06:40:26.8*, 14:26:50.8*. Salem, Va. IV. Felt by several. Buildings creaked; loose objects and windows rattled. Abrupt onset; trembling motion. North of Glenvar, "everything was shaking." Deep rumbling noises heard. During second shock, ground shook and coal on top of pile rolled down other side. The first shock was felt by few at Blacksburg where buildings creaked and loose objects and windows rattled. At Roanoke, house quivered and some thought furnace had blown up. Also felt at Christiansburg and Bristol. Recorded by seismograph at Virginia Polytechnic Institute.

April 11: 12:45*. Greenville, S. C. IV. Felt. Houses shook; ground trembled. Some residents reported sound like an explosion. Also felt at Marietta and Travelers Rest. Recorded by seismograph at the University of South Carolina.

May 4: 16:01:36*. Epicenter 32.2° north. 79.7° west, South Carolina, W. Depth about 15 km. Maximum intensity (damage) IV. Felt by many at Charleston where one observer on 12th floor of steel frame building reported swaying with undulating motion. About 20 seconds later, another milder swaying motion was felt. Abrupt onset. Newspaper switchboard swamped with calls about disturbance. At Summerville, buildings creaked and loose objects rattled. Earth sounds heard by several which resembled airplane breaking sound barrier. Also reported felt at Hanahan (buildings shook) and at Columbia.

October 28: 17:38:35*, 20:57*. Epicenter near 36.7° north, 81.0° west, near Galax, Va. (University of North Carolina, Chapel Hill). Maximum intensity (damage) V. Slight damage reported at Galax consisting of a cracked concrete driveway. (Report of damage believed to be in error). Felt over an area of approximately 1,300 square miles of Virginia and North Carolina. (A study of these events, by Gerald R. MacCarthy and John D. Waskom, was published in *The Journal of the Elisha Mitchell Scientific Society, vol. 80, no. 2, December 1964)*.

Reports are for the shock at 17:38:35* unless otherwise specified.

INTENSITY (DAMAGE) V IN VIRGINIA:

Fries.—Felt. Furniture shifted slightly. Lamp upset.

Galax.—Felt by nearly all; many frightened. A 16-inch concrete driveway reported cracked. Rumbling earth sounds heard.

Oldtown.—Felt by nearly all; several frightened. Houses jarred; windows and loose objects rattled. Rumbling earth sounds heard by many after beginning of termor. Light, quivering-bumping motion.

INTENSITY (DAMAGE) V IN NORTH CAROLINA:

Ennice.—Felt. Windows rattled; goods fell from shelves in stores. Loud explosion-like noise heard followed by rumbling earth sound.

Glade Valley.—Felt by many; few frightened. Press reported that some ran out of homes. Windows and dishes rattled; floor vibrated. Second quake was a jar with rumbling noise.

Sparta. Felt by many. Press reported that some people fled from buildings. Houses trembled. Windows and dishes rattled. "3 tremors, first more severe."

INTENSITY (DAMAGE) IV IN VIRGINIA:

Elk Creek.—Felt by few. Windows rattled. Earth sounds heard which sounded like a plane. Short duration.

Fancy Gap.—Felt by many. Houses shook. Rumbling-roaring sounds heard. "Most thought it was thunder or furnace trouble."

Independence.—Felt by several. Houses shook; dishes rattled. Rumbling earth sounds heard.

Ivanhoe.—Felt by nearly all. Windows rattled. Felt second shock only.

Woodlawn.—Felt by several. Windows rattled; buildings creaked.

INTENSITY (DAMAGE) IV IN NORTH CAROLINA:

Lowgap.—Felt by several. Dishes and windows rattled. First shock sounded like an explosion. 3 shocks felt.

Scottville.—Felt by many. Dishes rattled; floors vibrated slightly. Noises heard like thunder or a blast.

State Road.—Felt. Windows rattled. "Thought jet was passing over." Tremor was of short duration.

INTENSITY (DAMAGE) I-III IN VIRGINIA: Cana, Hillsville, Lambsburg, and Snowville.

INTENSITY (DAMAGE) I–III IN NORTH CAROLINA: Dover, Jonesville, Laurel Springs (20:57), McGrady, Piney Creek, and Traphill.

CENTRAL REGION

(90TH MERIDIAN OR CENTRAL STANDARD TIME)

March 3: 11:30:13.0*. Epicenter 36.7° north, 90.1° west, southeast Missouri, JSA. Magnitude 4½ (Pal). Felt over an area of approximately 100,000 square miles in nine States. (See map, p. 13.) Maximum intensity (damage) VI in Missouri. Also felt in Arkansas, Illinois, Indiana, Kansas, Kentucky, Mississippi, Oklahoma, and Tennessee. Plaster cracked and fell; bricks fell from chimneys; and foundations, walls, sidewalks, chimneys, and windows cra[illegible] in various towns. In Poplar Bluff, Mo[illegible]er lines were damaged and many basem[illegible]oded.

INTENSITY (DA[illegible]VI IN MISSOURI:

Arab.—Felt by [illegible]racked plaster, concrete floors, and conc[illegible]locks reported. Earth noises heard which sounded like a freight train.

Broseley.—Felt by all. General alarm. Cracks appeared in some places around basements and foundations. Light cracks in plaster. Plaster fell in older structures. Merchandise thrown to floor in stores. Water moved in large containers and ponds. "Pumps are going dry since quake." Loud, roaring subterranean sounds heard at beginning of earthquake. Rapid onset; trembling motion. 3 shocks.

Campbell.—Felt. Several brick chimneys down. Walls and ceilings cracked. Dishes and other glass items thrown to floor and broken. Dull roar heard moving west-east; became louder as it arrived, and then moved east.

Catron.—Felt by and alarmed many. Plaster and well constructed brick damaged. Light fixtures swung. Buildings creaked; loose objects rattled. Roaring earth sounds "as approaching train" heard at beginning of earthquake. Rapid onset; swaying motion. 2 shocks.

Conran.—Felt by all. Chimney and window panes cracked. Dishes broken; stove damaged. Earth noises "like a train coming" heard.

Dexter.—Felt by and alarmed many. Chimneys, plaster and plate glass window cracked; bricks fell from one chimney. Merchandise fell from shelves in stores.

East Prairie.—Felt by all. Concrete walk and plaster cracked. Buildings shook. Moderately loud earth sounds heard. Trembling motion.

Leeper.—Felt by all. Wall paper and walls cracked. People rushed from homes. Dishes rattled and turned over.

Lilbourn.—Felt by and alarmed nearly all. Several reports of cracked plaster and walls. Buildings creaked; loose objects rattled. Moderately loud, rumbling earth sounds heard during and after beginning of earthquake. Abrupt onset; trembling-rocking motion, east-west.

Malden.—Felt by nearly all. Many alarmed. Plaster on walls broken and thrown down; pavement cracked. Canned goods thrown from shelves. Chandeliers swung. Buildings creaked; loose objects rattled. Roaring earth sounds heard before and during earthquake. Abrupt onset; rocking-swaying motion, east-west.

Marston.—Felt by all. General alarm. Concrete foundation cracked. Chairs displaced. Buildings creaked; loose objects rattled. Loud rumbling earth sounds heard. Abrupt onset; swaying motion.

Poplar Bluff.—Felt by many. Plaster cracked. Water lines damaged and flooded many basements. Buildings creaked; loose objects rattled. Roaring earth sounds heard during earthquake. Abrupt onset.

Portageville.—Felt by nearly all and alarmed several. Walls cracked; items fell from shelves and broke. Electric light poles shook and the lines swayed. Chandeliers swung north-south. Buildings creaked; loose objects rattled. Roaring earth sounds heard by many at beginning of earthquake.

Tallapoosa.—Felt by nearly all. Many alarmed. Building cracked slightly. Objects fell from shelves; trees rocked. Buildings creaked; loose objects rattled. Roaring earth sounds heard. Gradual onset; trembling motion.

INTENSITY (DAMAGE) V IN ARKANSAS:

Carryville.—Felt. Cracked plaster in church. Buildings creaked. Roaring earth sounds heard.

Corning.—Felt. Windows cracked; small cracks appeared in concrete block. "Like a distant rumbling noise."

Datto.—Felt by all. Buildings vibrated; loose objects rattled. Earth noises heard that sounded like an airplane.

Edmondson.—Felt by many. Slight damage to one building. Storage bin with approximately 60,000 pounds of seed slipped off blocks and fell. House swayed east-west; bookcase swayed. Abrupt onset.

Lafe.—Felt. Concrete cracked. Windows rattled. Roaring subterranean sounds heard. Rocky motion.

Piggott.—Felt. Reports of wall damage, cracks, and leaks. Loud rumbling earth sounds heard. Buildings vibrated.

Rector.—Felt by all. Buildings shook. Rumbling earth sounds heard.

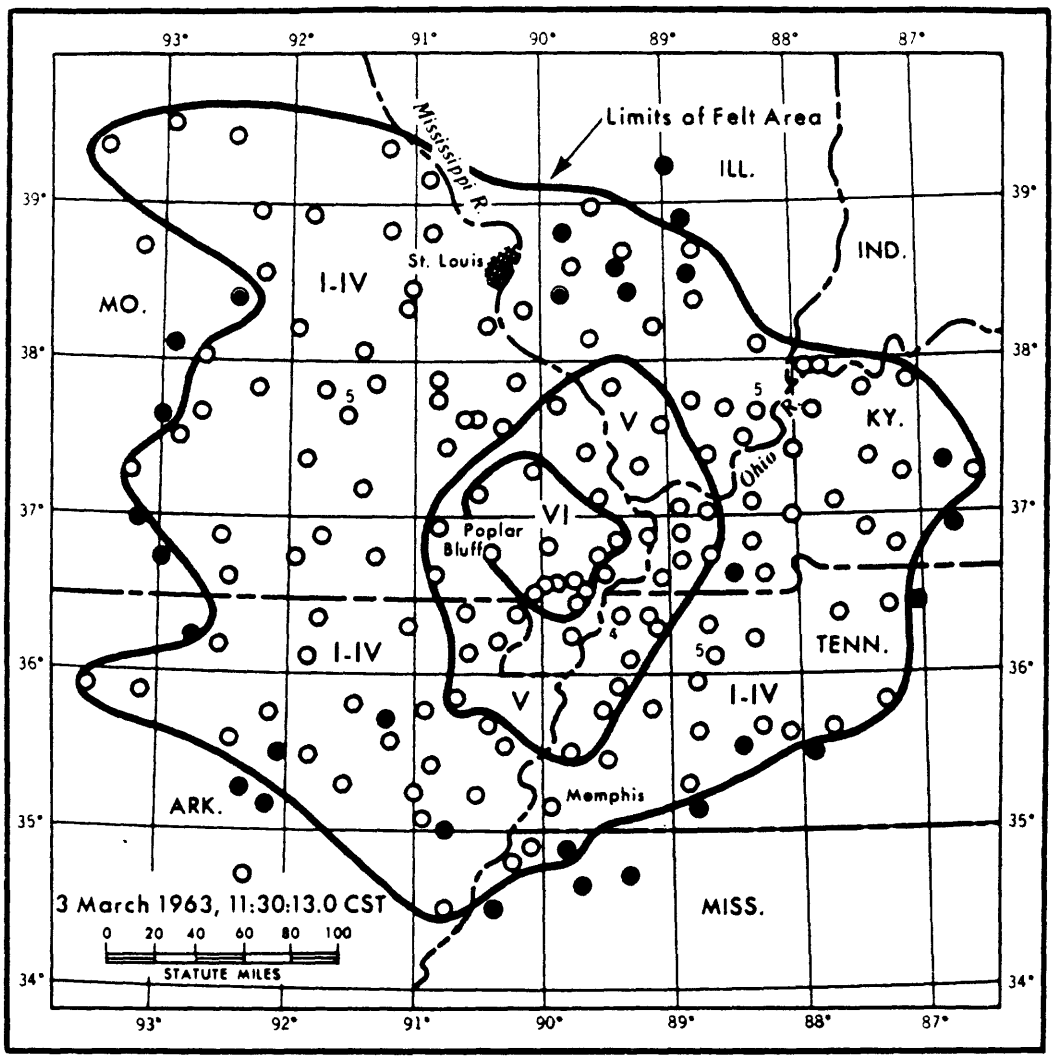

FIGURE 4.—*Area affected by earthquake of March 3.*

State College.—Felt by nearly all. Plaster cracked. Some churches evacuated. Buildings shook; light fixtures swayed.

INTENSITY (DAMAGE) V IN ILLINOIS:

Cairo.—Felt by many. Cracked wall of new educational building. Buildings creaked; loose objects rattled. Abrupt onset; trembling motion.

Carbondale.—Felt by and alarmed many. Cracked newly repaired wall. Buildings creaked; loose objects and aluminum door rattled. Rumbling earth sounds heard by many at beginning of earthquake.

Cobden.—Felt. Plaster cracked. Noise like dull roar heard.

Gale.—Felt by all. "Earth sounds like large flock of birds."

Murphysboro.—Felt by several. Plaster cracked on west wall of well constructed brick church. Thunderous earth sounds heard. Gradual onset; swaying motion, east-west.

Pomona.—Felt by several and alarmed many. Moderately loud earth sounds heard. Rapid onset; trembling-rocking motion.

Ridgway.—Felt. Plaster cracked. Dishes rattled and pictures moved on walls.

Thebes.—Felt by all. General alarm. Buildings creaked; loose objects rattled. Moderately loud, rumbling and shaking sounds heard by all before and at beginning of earthquake. Gradual onset; rumbling-rocking motion.

INTENSITY (DAMAGE) V IN KENTUCKY:

Bandana.—Felt. Plaster cracked in several rooms of church. Windows rattled.

Bardwell.—Felt by and frightened many. Buildings shook; windows rattled.

Hickman.—Felt by all. Wall cracked above and below window casing. Buildings creaked; loud roaring sounds heard before beginning of earthquake. Gradual onset; trembling-swaying motion.

Melber.—Felt by and alarmed many. Buildings creaked; loose objects rattled. Abrupt onset; trembling-shaking motion.

Water Valley.—Felt. Plaster reported fallen. Landslide at gravel pit 1 mile north. Large chunks of wall fell to floor of pit. Buildings trembled.

Wolf Island.—Felt by nearly all and alarmed few. Buildings creaked; loose objects rattled. Low, distant, roaring sounds heard.

INTENSITY (DAMAGE) V IN MISSOURI:

Bernie.—Felt by all. Basement wall cracked slightly. Rumbling noise heard.

Bloomfield.—Felt by nearly all. Loose plaster fell. Cracks appeared in masonry walls. Rumbling noise heard.

Cape Girardeau.—Felt by many. Slight damage to plaster in church. Chandeliers swung and dishes displaced. Buildings creaked; loose objects rattled. Abrupt onset; bumping motion. Several shocks for 2 or 3 minutes.

Chaffee.—Felt by many. Plaster cracked. Lamp and rocking chair rocked. Buildings creaked; loose objects rattled. Earth sounds heard. "Could feel vibration, then loud noise and movement." 2 shocks.

Charleston.—Felt by nearly all. Plaster cracked at church. Display racks swayed. Abrupt onset. "Felt like my chair moved north-south."

Commerce—Felt. "Bricks from chimney shattered off on top of piano." Buildings popped and creaked. Doors and windows rattled.

Dudley.—Felt by nearly all. Plaster cracked. Rumbling noises heard.

Gideon.—Felt. Plaster cracked in various buildings. Dishes rattled. Loud explosion and rumble heard.

Hayti.—Felt. Window cracked. Very loud rumble like freight train heard.

Hunter.—Felt. Three cracks appeared in solid concrete foundation of house. Houses creaked and popped.

Illmo.—Felt. Basement wall cracked. Buildings shook; dishes rattled.

Kennett.—Felt by many. Minor cracks in plaster and buildings. Buildings creaked; loose objects rattled. Roaring earth sounds heard. Abrupt onset; rocking motion. 2 shocks.

New Madrid.—Felt by nearly all. Many alarmed. Buildings creaked; loose objects rattled. Bumping, moderately loud earth noises heard at beginning of earthquake. Gradual onset; trembling motion.

Oran.—Felt. Mortar joints cracked in post office.

Oxly.—Felt. Sheetrock joints cracked. "Sounded like train at a distance."

Perryville (near).—"Opened a hole and drained a lake. Felt inside a cave." (From newspaper report.)

Ripley.—Felt by all. Buildings creaked. Earth sounds were as distant cannon fire or mortar bursts. Steady, vibrating motion which swung doors in and out about a foot.

Risco.—Felt. Brick walls cracked. Buildings shook. "Like a strong wind."

Salem.—Felt by all. Plaster cracked. Articles on shelves moved. Houses trembled.

Senath.—Felt by all. General alarm. Buildings creaked; loose objects rattled. Roaring earth sounds similar to a jet heard before beginning of earthquake. Abrupt onset; trembling motion.

Versailles.—Felt. Plaster cracked. Pendulum clock that had not run for years started to run. Earth sounds "as a jet was passing over very high" were heard. Picture window rattled. Gradual onset; trembling motion.

INTENSITY (DAMAGE) V IN TENNESSEE:

Covington.—Felt by nearly all. Few reports of cracked plaster. Buildings creaked; loose objects rattled. Abrupt onset; trembling motion.

Elbridge.—Felt by all. Slight damage to plaster. Buildings creaked; loose objects rattled. Thunderous earth sounds heard by several after beginning of earthquake. Rapid onset; trembling-swaying motion. 2 shocks.

Finley.—Felt by several. Slight damage to plaster. Furniture and pictures displaced. "Locked doors were opened." Rattling-bumping earth sounds heard. Gradual onset; swaying motion.

Gleason.—Felt by many. Slight damage to plaster. Cracks in church enlarged. Chandeliers swung; buildings shook; loose objects rattled. Cracking-scraping earth sounds heard. Rapid onset; trembling motion. 2 shocks.

Hornbeak.—Felt by and alarmed many. Displaced mirror on dresser and flowers on shelf.

Loose objects rattled. Moderately loud sounds heard at beginning of earthquake. Abrupt onset; rocking motion.

Sharon.—Felt by many. Few alarmed. Enlarged crack in one building. Loose objects rattled. Rapid onset; trembling motion.

Troy.—Felt by many. Slight roof damage to one building. Chandelier swung approximately 2 feet, east-west. Lamp slid 1 foot on table. Prisms jingled on candelabra. Buildings creaked; loose objects rattled. Abrupt onset; rocking motion.

Woodland Mills.—Felt by all. Slight swaying of objects. Trembling motion. 3 shocks.

INTENSITY (DAMAGE) IV IN ARKANSAS: Bexar, Blytheville, Caldwell, Clarkedale, Cord, Crawfordsville, Cushman, Dalton, Delaplaine, Dowdy, Edgemont, Glencoe, Greenway, Grubbs, Harrisburg, Jonesboro, Knobel, Leachville, Lepanto, McHue, Mammoth Spring, Manila, Marked Tree, Maynard, Melbourne, Moorefield, Mountain View, Newport, O'Kean, Osceola, Paragould, Parkin, Peach Orchard, Ravenden Springs, Reyno, Rivervale, Salem, Stonewall, Success, Sulfur Rock, Trumann, Tulot, Turrell, Tyronza, Vanndale, Warm Springs, Weona, West Memphis, Wilson, and Wynne.

INTENSITY (DAMAGE) IV IN ILLINOIS: Alma, Anna, Ava, Belle Rive, Bonnie, Creal Springs, De Soto, Dixon Springs, Dongola, Du Quoin, Edwardsville, Elco, Elkville, Emma, Energy, Evansville, Galatia, Glen Carbon, Glendale, Golconda, Ina, Jacob, Karnak, McClure, Maranda, Mayestown, Modoc, Mound City, Mount Vernon, Muddy, Nason, Olive Branch, Oraville, Posey, Prairie du Rocher, Renault, Robbs, Rosebud, Rosiclare, Salem, Sandoval, Scheller, Shawneetown, Summerfield, Tamaroa, Troy, Ullin, Unity, Villa Ridge, Waltonville, and Wolf Lake.

INTENSITY (DAMAGE) IV IN INDIANA: Evansville and Newburgh.

INTENSITY (DAMAGE) IV IN KANSAS: Kansas City and Lawrence.

INTENSITY (DAMAGE) IV IN KENTUCKY: Barlow, Boaz, Calvert City, Carrsville, Clinton, Cobb, Fulton, Hamlin, Hazel, Hopkinsville, Kevil, La Center, Lovelaceville, Lynn Grove, Mayfield, Milburn, Oakton, Pembroke, Princeton, St. Joseph, Sedalia, Sheridan, Smithland, Tolu, Uniontown, and Wingo.

INTENSITY (DAMAGE) IV IN MISSOURI: Alley Spring, Altenburg, Annapolis, Anniston, Arcadia, Augusta, Ava, Bakersfield, Belgique, Belgrade, Belvie, Benton, Beulah, Birch Tree, Bragg City, Brandsville, Brazeau, Bucyrus, Burfordville, Cabool, Caledonia, Canalou, Caruthersville, Clarkton, Conway, Crystal City, Cuba, Delta, Dora, Dorena, Doss, Dutchtown, Elk Creek, Elsberry, Essex, Eunice, Fagus, Farmington, Festus, Fisk, Fredericktown, Fruitland, Gainesville, Gerald, Gipsy, Glenallen, Glover, Grandin, Gray Summit, Hams Prairie, Hartsburg, Harviell, Holcomb, Holland, Iron Mountain, Ironton, Kewanee, Lenox, Leopold, Marble Hill, Marquand, Marthasville, Middle Brook, Millersville, Morley, Neelyville, Parma, Patterson, Peach Orchard, Piedmont, Pocahontas, Robertsville, Rombauer, St. Clair, St. Louis, Seaton, Sedgewickville, Sikeston, Steele, Sturgeon, Truesdail, Van Buren, Vichy, Wardell, Washington, Waynesville, Wesco, West Plains, Wittenberg, Wolf Island, and Wyatt.

INTENSITY (DAMAGE) IV IN TENNESSEE: Bath Springs, Beech Bluff, Bemis, Big Rock, Bogota, Bradford, Brighton, Clarksburg, Clarksville, Como, Dresden, Dukedom, Dyer, Dyersburg, Fort Pillow, Gibson, Greenfield, Halls, Henry, Humboldt, Jackson, Kenton, Livinia, Martin, Mason, Mercer, Milan, Oakfield, Obion, Ripley, Southside, Springville, Stanton, Tigrett, Tipton, Trimble, Union City, Wynnburg, and Yuma.

INTENSITY (DAMAGE) I–III IN ARKANSAS: Almond, Amagon, Balch, Barton, Bass, Batesville, Bay, Beech Grove, Beedeville, Biggers, Bono, Brookland, Bryon, Burdette, Caraway, Cash, Chatfield, Diaz, Dill, Dyess, Earle, Egypt, Etowah, Fisher, Flippin, Frenchmans Bayou, Gepp, Gilman, Grand Glaise, Heth, Huberg, Huntsville, Jacksonport, Joiner, Keiser, Lake City, Light, Little Rock, Locust Grove, Luxora, Magness, Marion, Marmaduke, Marvell, Moark, Monette, Morriston, Newark, Nimmons, Oil Trough, Palestine, Pocahontas, Pollard, Proctor, Roseland, Rosie, Saint Francis, Salado, Shoffner, Sturkie, Swifton, Tomato, Tupelo, Unionhill, Walcott, Weiner, Weldon, Wheatley, Widener, and Wolf Bayou.

INTENSITY (DAMAGE) I–III IN ILLINOIS: Alto Pass, Aviston, Baldwin, Beckemeyer, Belleville, Bluford, Cambria, Carmi, Carterville, Cave-in-Rock, Centralia, Chester, Clinton, Colp, Columbia, Cottage Hills, Coulterville, Crossville, Cutler, Dupo, East Alton, East Carondelet, East St. Louis, Eddyville, Eldorado, Elizabethtown, Ellisgrove, Equality, Freeburg, Freeman, Fults, Godfrey, Gorham, Grand Chain, Grand Tower, Grayville, Hecker, Herald, Herod, Herrin, Huey, Hurst, Junction, Kinmundy, Lenzburg, Madison, Marine, Marion, Marissa, Mascoutah, Maunie, Menard, Millcreek, Miller City, Mill Shoals, Mounds, National Stock Yards,

New Athens, New Baden, New Haven, New Memphis, Olmsted, Omaha, Opdyke, Perks, Pinckneyville, Pittsburg, Pulaski, Red Bud, Rockwood, Saint Libory, Sparta, Springerton, Steeleville, Swanwick, Valmeyer, Vergennes, Walnut Hill, Waterloo, Welge, West Frankfort, and Willisville.

INTENSITY (DAMAGE) I–III IN KANSAS: Atchison.

INTENSITY (DAMAGE) I–III IN KENTUCKY: Arlington, Benton, Blandville, Burna, Central City, Columbus, Cunningham, Dawson Springs, Delaware, Eddyville, Ennis, Farmington, Gilbertsville, Henderson, Herndon, Hickory, Kuttawa, Ledbetter, Lola, Lowes, Lynnville, Paducah, Powderly, Provo, Salem, Sturgis, Sugar Grove, Sullivan, Symsonia, Tiline, and Wickliffe.

INTENSITY (DAMAGE) I–III IN MISSISSIPPI: Banks, Horn Lake, Lake Cormorant, and Walls.

INTENSITY (DAMAGE) I–III IN MISSOURI: Alton, Arbyrd, Belle, Berger, Berryman, Bertrand, Bixby, Bloomsdale, Boss, Bowling Green, Braggadocio, Briar, Brunswick, Cape Fair, Cardwell, Carrollton, Catawissa, Cherryville, Clarksville, Clearwater, Columbia, Cook Station, Couch, Crocker, Curryville, Cyrene, Daisy, Davisville, Deering, De Soto, Dillard, Dixon, Doniphan, Elijah, Elsinore, Elvins, Farrar, Flat, Fletcher, Foley, Fremont, Friedheim, Frohna, Gatewood, Gladden, Gobler, Grassy, Hayden, Hawk Point, Hendrickson, Herculaneum, High Gate, Hollywood, Hornersville, Howards Ridge, Independence, Jackson, Jefferson City, Kansas City, Koshkonong, Labadie, Lake Spring, Leasburg, Lebanon, Lecoma, Leslie, Liguori, Linntown, Louisiana, Luebbering, Lynchburg, Matson, Menfro, Millcreek, Moberly, Mokane, Montauk, Moody, Morehouse, Morrisville, Morse Mill, Moscow Mills, Mountain View, Myrtle, New Wells, Old Appleton, Patton, Peace Valley, Pevely, Pilot Knob, Pleasant Hope, Puxico, Qulin, Rives, Saco, St. James, Sligo, Steele, Stoutland, Sullivan, Sulphur Springs, Thayer, Thomasville, Tiff, Union, Vida, Vienna, Whiteoak, Whitewater, Willow Springs, Womack, and Zalma.

INTENSITY (DAMAGE) I–III IN OKLAHOMA: Felt in eastern and northern Oklahoma according to press. (No details).

INTENSITY (DAMAGE) I–III IN TENNESSEE: Darden, Denmark, Huntingdon, Linden, McKenzie, Malesus, Memphis, Mendon, Millington, Miston, Munford, Newbern, Pinson, Primm Springs, Reelfoot Lake, Sardis, Scotts Hill, Silerton, Sugar Tree, and Woodlawn.

August 2: 18:37:50.3*. Epicenter 37.0° north, 88.8° west, Illinois-Kentucky border, W. Depth about 18 km. Magnitude 3.6. Maximum intensity (damage) V at Paducah, Ky. In Illinois, the quake was felt with intensity (damage) IV.

INTENSITY (DAMAGE) V IN KENTUCKY:

Paducah.—Felt by all. Creaking of buildings and rattling of loose objects heard by all. Windows rattled; disturbed objects observed by several. Television station received many calls. Rapid onset; trembling motion. Duration, 30 seconds.

INTENSITY (DAMAGE) IV IN KENTUCKY:

Bardwell.—Felt by many. Windows and dishes rattled. Gradual onset; trembling motion.

Boaz.—Felt by many. Rattling of loose objects heard by many. Windows rattled violently. "Some friends in country said water wells went dry afterwards." Rapid onset; trembling motion.

Mayfield.—Felt by many. Rattling of loose objects heard. Moderately loud, subterranean sounds heard by many at beginning of quake. Rapid onset; trembling-bumping motion. Duration, 30 seconds.

Water Valley.—Felt. Creaking of buildings and rattling of loose objects heard. Subterranean sounds heard before quake began.

INTENSITY (DAMAGE) IV IN ILLINOIS:

Cairo.—Felt by many. Buildings creaked; loose objects rattled. Rumbling noises heard. Abrupt onset.

Metropolis (3 miles northeast of).—Felt by several. Windows rattled. "Heard a slight rumbling noise during first tremor which appeared to come from south." 2 shocks.

INTENSITY (DAMAGE) I–III IN KENTUCKY: Hickman.

December 14: 23:31:32.9*. Beechmont, Ky. III. Felt. Disturbed objects observed. Rapid onset; swaying motion. Recorded by seismograph at Virginia Polytechnic Institute.

WESTERN MOUNTAIN REGION

(105TH MERIDIAN OR MOUNTAIN STANDARD TIME)

January 6: 11:07:46.2*. Epicenter 44.8° north, 112.2° west, Montana-Idaho border region, W. Papoose Creek at Madison River (Helland Ranch), Mont. IV. Felt by several in home and community. Walls creaked. Rapid, 30-second shock.

January 9: 12:25:21*. Papoose Creek at Madison River (Helland Ranch), Mont. IV.

Felt by several in home and community. House creaked. Rapid, 1–2 second shock.

January 9: 12:40:16*. Papoose Creek at Madison River (Helland Ranch), Mont. IV. Felt by several in home and community. Windows rattled; house creaked. Rapid, 1–2 second shock.

January 9: 12:46:29*. Montana. IV. At the Kirby Ranch (Madison River at the intersection of the West Fork of the Madison), felt by several and frightened few. Two shocks. At the Helland Ranch (Papoose Creek at Madison River), felt by several and frightened few in community. Windows and dishes rattled; house creaked; hanging objects swung. Slow, 1–2 second shock.

January 24: 07:15. Mammoth (Yellowstone National Park), Wyo. IV. Rapid, 15-second shock felt by observer. Dishes rattled.

January 27: 08:24:47.2*. Epicenter 44.4° north, 114.6° west, central Idaho, W. Felt over an area of approximately 6,000 square miles of central Idaho. Maximum intensity (damage) VI. At Clayton, plaster and windows cracked. Large boulders rolled from hillsides at Livingston Camp (14 miles south of Clayton, East Fork Salmon River area).

INTENSITY (DAMAGE) VI:

Clayton.—Felt by, awakened, and frightened many in community. Damage slight. Plaster and windows cracked. Small objects shifted. Rapid, 30-second shock; loud earth noises heard.

Livingston Camp (14 miles south of Clayton, East Fork Salmon River area).—Rapid, 20-second shock felt by observer. Large boulders rolled from hillsides; objects fell off shelves. Loud earth noises heard. Shock about half as strong felt 30 minutes later. It was reported earthquakes were felt at the rate of one to three a day for about a week, with each shock diminishing in intensity.

INTENSITY (DAMAGE) V: Atlanta, Hailey, Ketchum, Stanley, and about 9 miles southeast of Stanley.

INTENSITY (DAMAGE) IV: Challis, Crouch, Idaho City, Lowman, and Obsidian.

INTENSITY (DAMAGE) I–III: Boise and Garden Valley.

January 29: 22:50:59.5*. Epicenter 45.0° north, 110.8° west, Yellowstone National Park, Wyo., W. Mammoth (Yellowstone National Park). V. Felt by and awakened many in community. Windows rattled; walls creaked. Motion rapid, lasted about 2 seconds; moderate earth noise heard.

January 30: 06:13:46*. Mammoth (Yellowstone National Park), Wyo. IV. Felt by many; awakened few. Windows rattled; walls creaked. Rapid, jolting motion of about 2 seconds duration; loud earth noises at time of shock.

January 30: 16:05:09.6*. Epicenter 39.8° north, 104.6° west, northeast-central Colorado, W. Felt at Boulder and Denver.

February 1: 09:38:59.5*, 10:30, 11:15. Epicenter 44.3° north, 114.5° west, central Idaho, W. Clayton. V. Felt by many in community. Dishes fell off shelves and tables. Loud roar heard at beginning of shock. Shocks also felt at 10:30 and 11:15.

February 5: 04:00. Clayton, Idaho. Felt.

February 5: 12:30. Clayton, Idaho. IV. Felt by many.

February 15: 20:01.41.0*. Epicenter 46.1° north, 111.0° west, southwestern Montana, W. Magnitude 4.5. Felt over an area of approximately 6,000 square miles of southwestern Montana, principally in the Belgrade-Bozeman-Churchill areas of Gallatin County. Maximum intensity (damage) V. No damage reported. At Belgrade, felt by many and frightened few in community. Small objects shifted. Trees, bushes shaken moderately. One observer described the motion as slow, lasting 10 seconds; another, as one jolt, lasting 2–3 seconds. Felt by several in community and frightened few in home at Gallatin Gateway (about 13 miles south of Belgrade), where small objects shifted; hanging objects swung north. At Whitehall (about 45 miles northwest of Belgrade), small objects shifted; brief shock. Intensity (damage) IV at Bozeman, Churchill (and 5 miles south of), Laurin, Logan (3½ miles south of), Manhattan, Maudlow, Norris, Trident, Virginia City, West Yellowstone, and Wickes. Intensity (damage) I to III at Boulder, Clyde Park, Gardiner, Greycliff, Helena, Livingston, Madison River area (south of Ennis), Ringling (12 miles west of and 15 miles southwest of), Springdale, Three Forks, Toston (and west of in Cow Creek Valley between Toston and Radersburg), and Wilsall. Also felt at Logan.

February 25: 11:45:16.5*. Epicenter 42.6° north, 109.2° west, western Wyoming, W. Magnitude 4.3. V. At Fort Washakie, felt by all in home. Windows, doors, and dishes jarred; house creaked; bed creaked and shifted. Rapid, 2–3 second shock. Felt by all at Lander. Slow, 3-second shock in south direction; loud earth noises from north heard.

March 4: 18:50:38.7*. Epicenter 42.6° north, 111.3° west, southeastern Idaho, W. Fish Haven. III. Felt by several in community. Described as slight tremor.

March 7: 07:55. 320 Ranch, Mont. (55 miles south of Bozeman in Gallatin Canyon). IV. House and corrals creaked. Booming noise heard.

March 8: 01:35:48.9*. Epicenter 44.8° north, 110.2° west, Yellowstone National Park, Wyo., W. Magnitude 3.8. Canyon (Yellowstone National Park.) VI. At the winterkeeper's house, plaster cracked and fell; large cracks separated the walls and ceilings in several rooms. Slow roll from northwest, lasted about 3 seconds. Observer reported approximately 17 tremors were felt from March 8 to 12. The first and strongest shock occurred at 01:35:48.9* and the last shock on March 12 at about 22:00. Several of the tremors were felt as rapid jolts, most lasting 2–3 seconds and accompanied by earth noises. From March 8 to 12, numerous shocks originating in the Canyon area were recorded at Butte, Mont.

March 9: 05:43:50*. Trident, Mont. IV. Felt by several in community. Walls creaked Rapid, 4–5 second shock in northeast direction, with earth noise and shock about 1 second apart.

March 21: 21:34:42.9*. Epicenter 44.8° north, 110.5° west, Yellowstone National Park, Wyo., W. Magnitude 4.1. V. At Mammoth (Yellowstone National Park), Wyo., felt by several and awakened few in community. Small objects and furnishings shifted. Motion slow, lasted 2 seconds. At West Yellowstone (Yellowstone National Park), Mont., felt by several. Small objects and furnishings shifted; hanging objects swung north. Motion slow, lasted 1 second.

March 25: 02:28:44.1*. Epicenter 36.0° north, 114.9° west, near Boulder City, Nev., W. Magnitude 4.3. Felt over an area of approximately 9,000 square miles. (See map, page 19.) Maximum intensity (damage) VI. Considerable amount of minor damage occurred at Boulder City, consisting principally of cracked plaster and broken dishes. Several rockslides onto roads in the Boulder City area. Frequent slight aftershocks were felt at Boulder City.

INTENSITY (DAMAGE) VI IN NEVADA:

Boulder City.—Felt by and awakened all in community; frightened many. Press reported a considerable amount of minor damage occurred in the Boulder City area. Plaster cracked and fell. Plaster repairs at church estimated at about $300. Dishes broken; pictures loosened from walls; small objects and furnishings shifted; knickknacks and books fell; church flag fell from wall. Motion rapid; duration estimated from 7–8 seconds to 1 minute; loud earth noises heard by many.

INTENSITY (DAMAGE) V IN NEVADA: Hoover Power Plant and Dam, Las Vegas, Logansdale, and Overton.

INTENSITY (DAMAGE) V IN ARIZONA: Davis Dam (about 60 miles south of Boulder City).

INTENSITY (DAMAGE) V IN CALIFORNIA: Nipton.

INTENSITY (DAMAGE) IV IN NEVADA: Henderson and Searchlight.

INTENSITY (DAMAGE) IV IN ARIZONA: Colorado City (Arizona-Utah border, Canaan Ranch), Temple Bar (on south shore of Lake Mead), and Tuweep.

INTENSITY (DAMAGE) IV IN CALIFORNIA: Baker, Death Valley National Monument (Headquarters), and Kingston area (about 14 miles west of Goodsprings, Nev.).

INTENSITY (DAMAGE) IV IN UTAH: Santa Clara.

INTENSITY (DAMAGE) I–III IN ARIZONA: Kingman.

INTENSITY (DAMAGE) I–III IN CALIFORNIA: Yermo.

INTENSITY (DAMAGE) I–III IN NEVADA: Press reported the quake was felt "as far north as Ely, Nev."

April 18: 03:43:16.9*. Epicenter 44.8° north, 110.3° west, Yellowstone National Park, Wyo., W. Yellowstone National Park. V. Press reported there was minor damage to facilities and some geysers were thrown off schedule. At Mammoth (IV), felt by several; windows rattled; doors and dishes rattled very strongly. Slow, 4–5 second shock.

April 18: 07:59:12.6*. Epicenter 45.0° north, 111.0° west, Yellowstone National Park, Wyo., W. Mammoth (Yellowstone National Park). III. Felt by several; lasted 2–3 seconds.

April 18: 10:32:44*. Mammoth (Yellowstone National Park), Wyo. IV. Felt by many in community. Rapid, 5–10 second shock.

April 23: 01:13. Hoover Dam Power Plant, Nev. V. Felt by all. Windows and doors rattled. Rapid, vertical, 2-second shock preceded 2 seconds by moderate earth noises.

April 24: 15:29:34.4*. Epicenter 39.8° north, 104.7° west, northeastern Colorado, W. Felt in the Denver area.

April 26: 21:53:50.9* and **April 27:** 06:39:33.9*. Epicenter of first shock 44.8° north, 110.3° west, Yellowstone National Park,

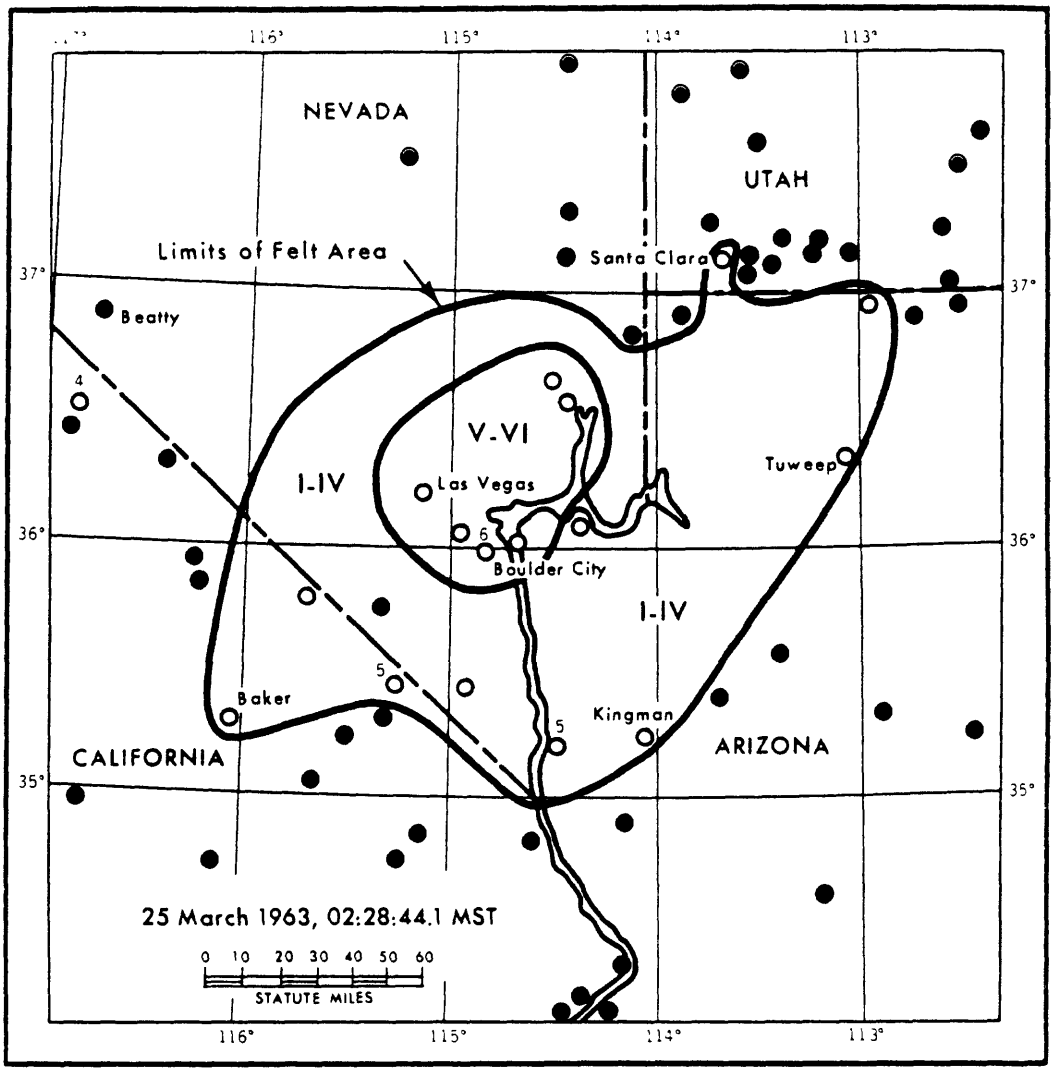

FIGURE 5.—*Area affected by earthquake of March 25.*

Wyo.; of second shock 45.0° north, 111.4° west, southwestern Montana, W. Magnitudes 4.4 and 4.0, respectively. Old Faithful (Yellowstone National Park), Wyo. Park rangers reported two minor shocks were felt in the vicinity of Old Faithful.

May 11: 16:06:33.5*. Papoose Creek at Madison River (Helland Ranch), Mont. V. Felt by all and frightened few in home and community. Windows and dishes rattled; house creaked. Hanging objects swung east. Motion rapid, lasted 5 seconds.

May 13: 17:52:41.5*. Cameron, Mont. IV. Felt by several and frightened few. Rapid, 2–3 second shock.

May 24: 21:18. Fairfield, Idaho. IV. Objects rattled in house.

May 25: 03:44:36.7*. Epicenter 39.8° north, 104.7° west, northeastern Colorado, W. Felt over an area of approximately 900 square miles. Maximum intensity (damage) V. At Adams City, felt by and awakened all in community; frightened few. Rapid, 1-minute shock in east-west direction; loud earth noises from west. Felt by and awakened many in community at Brighton; flush-box lid on toilet rattled. Motion rapid; earth noises from southwest. At Erie, felt by and awakened many in community; frightened few. Small objects shifted. Motion rapid, lasted few seconds;

preceded a few seconds by loud earth noises from east. Felt by, awakened, and frightened few in community at Hudson, where small objects and furnishings shifted; moderate earth noises heard. Intensity (damage) IV at Dupont, Eldorado Springs, Lafayette, Louisville, Pinecliffe, and Westminster. Intensity (damage) I–III at Arvada, Fort Lupton, and Frederick.

May 29: 17:45:14.0*. Papoose Creek at Madison River (Helland Ranch), Mont. III. Observer reported 10-second shock in north-south direction, accompanied by roaring earth noises.

June 1: 08:37:28*. Fort Harrison, Mont. (near Helena). Felt.

June 4: 17:13:50.6*. Epicenter 39.3° north, 104.0° west, northeastern Colorado, W. Magnitude 4.4. Felt at Denver.

June 5: 19:54. Fairfield, Idaho. IV. Objects rattled in house.

June 6: 12:40, 12:47:02*, 12:47:34*, 13:11:06*, 13:32:15*. Gibbon Meadow area (Yellowstone National Park), Wyo. V. Series of six shocks felt by all of a group of persons fishing in the Gibbon Meadow area. The first shock was felt about 12:40, with four shocks between 12:45 and 13:00, and the last shock about 13:30. All the shocks were weak to moderate in motion and rapidity, except for the last shock which was a very rapid jolt. Visible ground motion was seen during two or three of the shocks. Man sitting in Volkswagon bus reported the vehicle and various articles of fishing gear were shaken during the first and last shocks. Rumbling earth noises were heard during some of the shocks. It was reported there may have been a shock just prior to the shock at 12:40. The sharpest shocks were recorded at 12:47:34* and 13:32:15*.

June 10: 13:40. Alder, Mont. IV. Felt by persons in post office (some active). Post office boxes rattled. Motion slow; lasted 10 seconds.

June 21: 08:43:21.9*. Norris, Mont. IV. Felt by observer and others in community. Dishes rattled.

June 21: 14:45. Norris, Mont. A rather sharp shock felt at schoolhouse.

June 29: 22:35. Ennis, Mont. IV. Felt by two; awakened one. Motion slow, lasted 7 seconds.

July 2: 01:02:56.3*. Epicenter 39.8° north, 104.6° west, northern Colorado, W. Magnitude 4.6. Felt over an area of approximately 3,000 square miles of north-central Colorado. Maximum intensity (damage) V. One report of slight plaster cracking at Pinecliffe, about 10 miles west of Colorado Springs.

INTENSITY (DAMAGE) V:

Adams City.—Felt by and awakened all in community; frightened few. Small objects shifted. Motion rapid, lasted 30 seconds; loud earth noises heard by many.

Black Hawk.—Awakened many in community; frightened few. Motion slow, lasted 20 seconds; moderate earth noises heard.

Broomfield.—Felt by and awakened all in home. Loud earth noises heard.

Buffalo Creek.—Felt by and awakened many in community. Dishes rattled; hanging objects swung. Motion slow, lasted 5 seconds; north direction.

Central City.—Felt by and awakened many in community; frightened few. Small objects shifted. Motion rapid, lasted 5 seconds; moderate earth noises, which seemed directly underneath, heard by many 2 seconds before shock.

Dacono.—Felt by and awakened many in community; frightened few. Windows rattled. Motion rapid, lasted 5 seconds; moderate earth noises heard by many.

Derby.—Awakened and frightened many in community. Small objects shifted. Motion rapid, lasted 20–30 seconds; loud earth noises heard by many.

Dumont.—Felt by, awakened, and frightened many in community. Windows, doors, and dishes rattled slightly. Motion rapid; loud earth noises from northwest heard by many.

Eastlake.—Felt by and awakened many in community; frightened few. Motion rapid, lasted 1 minute; loud earth noises from northeast heard by many.

Erie.—Felt by and awakened all in home; frightened many in community. Small objects shifted. Motion rapid, lasted several seconds; direction east-west; loud earth noises from east heard by many 30 seconds before shock.

Georgetown.—Felt by and awakened many in community. Windows rattled; walls creaked. Motion rapid. Observer reported this was the strongest of the shocks felt during the past few months.

Henderson.—Felt by and awakened many in community; frightened few. Small furnishings shifted. Motion rapid, lasted 45 seconds; loud earth noises heard.

Lafayette.—Felt by and awakened many in community; frightened few. Windows, doors, and dishes rattled; house creaked. Motion rapid, lasted 15 seconds; moderate earth noises heard by many 10 seconds before shock.

Lyons.—Felt by and awakened all in home. Windows, doors, and dishes rattled; walls creaked. Motion rapid, lasted 15 seconds; faint earth noises heard by few.

Niwot.—Awakened many in community. Small objects shifted. Motion rapid, long duration; faint earth noises heard.

Pinecliffe.—Felt by and awakened many in community; frightened few. Plaster cracked slightly. Duration 5–7 seconds; loud earth noises from east-west heard.

Westminster. — Felt by, awakened, and frightened all in home. Motion slow, lasted 4 seconds; loud explosivelike earth noises heard by many 2 seconds before shock.

Wheat Ridge.—Felt by, awakened, and frightened many in community. Hanging objects swung. Rapid, 5-second shock with loud earth noises.

INTENSITY (DAMAGE) IV: Allenspark, Berthoud, Brighton, Dupont, Eldorado Springs, Empire, Fort Logan, Fort Lupton, Hygiene, Idledale, Indian Hills, Jamestown, Kittredge, Littleton, Louisville, Loveland, Morrison, Platteville, Rollinsville, and Silver Plume.

INTENSITY (DAMAGE) I–III: Boulder, Denver, Frederick, Golden, Louviers, and Nederland.

July 7: 12:20:42.4*. Epicenter 39.6° north, 111.9° west, central Utah, W. Magnitude 4.9. Felt over an area of approximately 1,600 square miles of central Utah. Maximum intensity (damage) VI. Damage slight. At Levan and Nephi, plaster, walls, and chimneys cracked; plaster fell.

INTENSITY (DAMAGE) VI:

Levan.—Felt by all and frightened many in community. Damage slight. Plaster, walls, and chimneys cracked; plaster fell. Trees, bushes shaken moderately. Small objects and furnishings shifted; vases, etc., small objects overturned; knickknacks fell. Motion rapid, lasted 10 seconds; faint earth noises heard by few 1 second before shock.

Nephi.—Felt by and frightened all in community. Damage slight. Plaster, walls, and chimneys cracked. Small objects and furnishings shifted; vases, etc., small objects overturned; knickknacks, books, and pictures fell. Visible swaying of church walls. Motion slow, rolling, lasted 20 seconds; faint earth noises from west-east heard by many 2 seconds before shock.

INTENSITY (DAMAGE) V: Wales.

INTENSITY (DAMAGE) IV: Fountain Green, Leamington, Lynndyl, and Mona.

INTENSITY (DAMAGE) I–III: Goshen, Manti, and Moroni.

July 19: 12:26:33.* Epicenter 44.9° north, 110.6° west, Yellowstone National Park, Wyo., W. Papoose Creek at Madison River, Mont. (Helland Ranch). Felt.

July 29: 09:40:15*, 09:40:25*, 09:41. Gardiner, Mont. IV. Felt by observer sitting in automobile. Motion slow, lasted few seconds each.

August 2: 02:45:42.0*. Epicenter 43.4° north, 114.5° west, southern Idaho, W. Fairfield. IV. Reported as felt only in the town of Fairfield. Dishes and household objects rattled. Duration about 2 seconds.

August 8: 02:54:37.4*, 16:53:21.0*. Epicenter of first shock 44.9° north, 111.1° west; of second, 44.9° north, 111.0° west, Yellowstone National Park, Wyo., W. Hebgen Lake, Mont. (south shore area, at Watkins Creek Ranch). IV. Windows shaken. Both shocks accompanied by roar from west or northwest.

August 14: 05:30:06.0*. Epicenter 41.5° north, 112.1° west, northern Utah, W. Magnitude 3.7 Cache Valley. IV. Slight shock reported felt by a few scattered residents of Cache Valley, from Smithfield on the north to Hyrum on the south.

August 15: 20:21:08.5*. Epicenter 39.7° north, 111.9° west, central Utah, W. Magnitude 3.4. Nephi. IV. Felt by many and frightened few in community. Windows rattled. Hanging objects swung. Motion slow; direction east.

September 7: 12:25. Idaho-Oregon border area. IV. Windows and dishes were rattled by a light shock felt at Brownlee and Oxbow dams along the Snake River.

September 7: 13:30. Papoose Creek at Madison River, Mont. (Helland Ranch). IV. Felt by several families.

September 7: 16:30. Helena, Mont. (6 miles north of, in NW¼, Sec. 36, T11N, R4W). IV. Rapid, trembling abrupt shock felt by observer sitting; wife awakened. At Marysville (about 15 miles northwest of Helena), felt by several; trembling motion with gradual onset, then a hard jerk.

September 9: 03:45:17.4*. Epicenter 44.4° north, 114.7° west, central Idaho, W. Magnitude 4.1. V. At Challis, felt by several and awakened few in community. Small furnishings shifted very slightly. Motion slow, brief duration; moderate earth noises heard. Also felt in surrounding areas of Challis. Felt by and awakened many in community at Clayton where windows rattled. Motion rapid; moderate earth noises heard. "Since September 9 through October 3 there have been several

tremors felt by me and reported to me by others. Since October 3, not so noticeable." (Report postmarked October 11.) At Obsidian, awakened and frightened all in home. Small objects shifted. Rapid, 1-second shock in northwest direction. Also felt at Stanley, where observer reported a number of very small rumbles, barely noticeable, were heard. Sometimes several at a time or closely following each other.

Numerous earthquakes, originating in central Idaho, were recorded during September. From September 9 through September 23, epicenters were determined for 55 shocks ranging in magnitudes from 3.5 to 4.9.

September 10: 19:08:44.8*. Epicenter 44.4° north, 114.7° west, central Idaho, W. Magnitude 4.9. Felt over an area of approximately 3,500 square miles of central Idaho. Maximum intensity (damage) VI. Damage slight. At Redfish Lake, about 10 miles south of Stanley, plaster jarred loose in buildings.

INTENSITY (DAMAGE) V:

Atlanta.—Felt by several in home and community. Small objects shifted. Motion slow; loud, thunderous earth noises heard.

Challis National Forest (Lookout Mountain Fire Station).—Windowpane broken.

Obsidian.—Felt by all. Hanging objects swung north-south. Rapid, 1-second shock in north-south direction.

Stanley.—Felt by many and frightened few in community. Small objects shifted. Trees, bushes shaken moderately. South-north motion preceded about 5 seconds by moderate earth noises from south-north. "More severe to the south of Stanley."

Sunbeam.—Felt by all and frightened few in community. Knickknacks fell. Rapid motion in east-west direction; duration 1 minute; moderate earth noises heard by many 1 second before shock. "We have been having a series of small shocks for the past two months. None have been serious, but most have been felt strongly by all persons living here." (Report postmarked October 25.)

INTENSITY (DAMAGE) IV: Boise, Clayton, Cobalt, Robinson Bar Guest Ranch (about 15 miles west of Clayton), and Twin Springs.

INTENSITY (DAMAGE) I–III: Challis, Cobalt (5 miles upstream), and Crouch.

September 10: 19:31:39.9*. Epicenter 44.3° north, 114.7° west, central Idaho, W. Magnitude 4.2 Felt at Clayton. Reported not as severely felt as the shock at 19:08:44.8*.

September 11: 04:59:41.0*. Epicenter 33.2° north, 110.7° west, southeastern Arizona, W. Magnitude 4.1. Felt over an area of approximately 2,500 square miles of Gila, Graham, and Pinal counties. Maximum intensity (damage) V. Damage very slight. At Globe and San Carlos, plaster cracked very slightly; at Ray, dishes broken.

INTENSITY (DAMAGE) V:

Globe.—Felt by some in community; observer awakened. Plaster cracked slightly in newly painted room. Bed jarred. Like sonic boom; abrupt onset.

Miami.—Two shocks felt, 04:59:41.0* and 05:02. Felt by many; awakened observer; people alarmed. Visible swaying of buildings and trees; disturbed objects observed by several; creaking of buildings and rattling of loose objects heard. Motion rocking, rapid onset; rumbling earth noises heard by several during and after shock.

Ray.—Awakened many in community. Dishes broken. Small objects shifted. Slow motion; duration, 1 minute.

San Carlos.—Felt by many; awakened observer; few alarmed. Three very slight vertical plaster cracks. Some objects displaced or swayed in east-west direction. Trembling motion.

INTENSITY (DAMAGE) IV: Coolidge Dam (on Gila River, southeast section of Gila County; shocks also felt at 05:01 and 05:02), Fort Thomas, Roosevelt, Sonora, Superior, and Tortilla Flat.

September 11: 23:23:50.6*. Epicenter 44.3° north, 114.7° west, central Idaho, W. Magnitude 4.4. IV. At Atlanta, objects rattled three times between 23:00 and 23:30. At Boise, felt by a number of persons; one awakened. Bed shaken; windows rattled; cabinet moved. Two tremors, the second immediately following the first. Shaking of house awakened observer at Stanley.

September 12: 02:01:09.0*. Epicenter 44.4° north, 114.8° west, central Idaho, W. Magnitude 3.6. Cobalt (Cobalt Ranger Station, about 40 miles north of Challis, and about 18 miles southwest of Salmon). Two shocks, about 30 seconds apart, felt by one person.

September 14: 08:58:02.1*. Epicenter 44.3° north, 114.8° west, central Idaho, W. Magnitude 4.3. V. At the Robinson Bar Guest Ranch (15 miles west of Clayton), a stone was knocked out of fireplace. In the Sawtooth Valley area, dishes broken; joists and rafters in new addition to home popped and jumped. Several telephones were found to be out of order on evening of the 14th, but it was not

determined if the disruption in service was caused by the shock; one observer commented, "It surely could have been." At Stanley, everything in cafe rattled. Man sitting in pickup truck reported the truck was shaken "quite a bit." Eight or ten shocks felt during the week.

September 14: 09:39:41.7*, 09:55:40.6*. Epicenter of first shock 44.4° north, 114.7° west; of second, 44.3° north, 114.6° west, central Idaho, W. Magnitudes 4.0 and 3.9, respectively. Clayton. Light shocks, lasted few minutes.

September 14: 11:48:56.4*. Epicenter 44.3° north, 114.8° west, central Idaho, W. Magnitude 3.8. Clayton. Felt. "Other light shocks felt all week."

September 16: 05:06:14.0*. Epicenter 44.3° north, 114.7° west, central Idaho, W. Magnitude 4.2. Clayton. V. Felt by all. "Very strong shock."

September 20: 14:32:09.2*. Papoose Creek at Madison River, Mont. (Helland Ranch). Felt.

September 23: 23:31:50.5*, 23:35:52.1*. Epicenter of first shock 44.8° north, 111.0° west; of second, 44.9° north, 111.0° west, Yellowstone National Park, Wyo., W. Magnitudes 3.1 and 4.7, respectively. West Yellowstone, Mont. V. The shock at 23:35:52.1* knocked out a cracked window at the checking station; pictures on wall shifted. Motion rolling during first shock at 23:31:50.5*; jolting during second shock; deep rumbling earth noises from north heard just prior to second shock. At Mammoth (Yellowstone National Park), Wyo. (IV), felt by several and awakened few in community. House creaked. Motion rapid during first shock; jolting during second shock; moderate earth noises from west heard by few 2–3 seconds before both shocks.

October 3: 00:10. Clayton, Idaho. IV. "Very noticeable."

October 7: 14:30:30.0*. Epicenter 44.8° north, 114.4° west, central Idaho, W. Magnitude 3.5. Cobalt (Cobalt Ranger Station, about 18 miles southwest of Salmon). IV. Strong shock of brief duration felt by four.

October 15: 08:15:10.6*. Epicenter 44.3° north, 114.8° west, central Idaho, W. Magnitude 3.9. Clayton. IV. "Hard shock."

December 16: 21:30 (about). Mammoth (Yellowstone National Park), Wyo. Felt.

December 17: 02:30, 03:15, 06:15, 06:18 or 06:19, 06:30. Mammoth (Yellowstone National Park), Wyo. V. Felt by two persons. Mirror and pictures shifted during one of the shocks (observer reported "first jolt"). Walls creaked. Shock at 06:30 reported as a sharp jolt. One observer reported several shocks felt between 03:15 and 06:30; three jolts; others of shaking motion; the other observer reported small shocks at 02:30, 06:15, 06:18 or 06:19. Moderate earth noises heard.

December 20: 06:00:50.3*. Epicenter 44.9° north, 111.7° west, Hebgen Lake, Montana area, W. Magnitude 4.3. Felt over an area of approximately 3,000 square miles of southwestern Montana and Yellowstone National Park, Wyo. Maximum intensity (damage) V. One very small earth and tree slide at Hebgen Dam. No damage reported.

INTENSITY (DAMAGE) V:

Ennis.—Felt by several and awakened few in community. Small objects shifted. Motion slow, lasted 8 seconds; faint earth noises heard.

Gardiner.—Awakened many in community. Windows rattled. Rapid, 3–4 second shock with faint earth noises.

Hebgen Dam.—Felt by, awakened, and frightened all in home. Snowslides and rolling rock; one very small earth and tree slide between dam and powerhouse. Master switch at powerhouse opened. Small objects shifted; vases overturned. Slow, 3–4 second shock preceded 1 second by moderately loud earth noises from south.

Papoose Creek at Madison River (Helland Ranch).—Awakened and frightened many in community. Windows, doors, and dishes rattled; house creaked. Motion rapid, lasted 1 minute. Also felt at Hutchins Bridge.

INTENSITY (DAMAGE) V IN WYOMING:

Mammoth (Yellowstone National Park.)—People awakened. Pictures on wall tilted. Everything rattled; bed strongly shaken. Motion reported as jolting; few slight jiggles then hard shaking; two jolts lasting about 2 seconds each. Several slight tremors felt prior to the shock at 06:00:50.3*.

INTENSITY (DAMAGE) IV: Black Butte Ranch (about 63 miles south of Bozeman), Bozeman, Cameron, Jardine (about 5 miles northeast of Gardiner; also jolt at 05:00), Jeffers, 320 Ranch (about 55 miles south of Bozeman), and West Yellowstone.

December 20: 20:02:23*. Epicenter 39.3° north, 114.3° west, eastern Nevada, W. Magnitude 3.3 Lehman Cave National Monument (near Baker). IV. Felt by all in building.

December 21: (about 12:00). Gardiner, Mont. IV. Objects shaken on table in drugstore.

December 23: 16:19. Belgrade, Mont. Felt.

December 23: 22:05:04.5*. Mammoth (Yellowstone National Park), Wyo. Jarring shock felt by observer; also felt at plumbing shop. Vibrations felt all day with intermittently stronger ones.

December 25: 16:55:14.5*. Epicenter 39.2° north, 114.2° west, eastern Nevada, W. Magnitude 3.6. Lehman Cave National Monument (near Baker). IV. Felt by all in building.

December 27: 4:10 (a.m. or p.m. not given). Mammoth (Yellowstone National Park), Wyo. "Eight thuds felt."

December 28: 07:26:19.5*. Epicenter 39.2° north, 114.3° west, eastern Nevada, W. Magnitude 3.4. Lehman Cave National Monument (near Baker). IV. Felt by all in building.

December 28: 21:02:03.8*, 21:06:12.2*, 21:15:04.5*, 23:38:58.2*. Epicenter 39.1° north, 114.2° west, eastern Nevada, W. Magnitudes 3.5, 3.4, 4.0, 3.7, respectively. Lehman Cave National Monument (near Baker). IV. Felt by all in building.

December 30: 14:30. Mammoth (Yellowstone National Park), Wyo. "Gentle shake."

December 31: 03:15. Mammoth (Yellowstone National Park), Wyo. "Gentle s[illegible]"

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 BSSA.

January 2: 06.00. Hollister (7½ miles south of, Harris Ranch). Sharp shock.

January 8: 01:45. Hollister (7½ miles south of, Harris Ranch). IV. Felt by and awakened all in home. Windows, and doors rattled; house creaked. Motion slow, brief; faint earth noises heard.

January 8: 07:19. Hollister (7½ miles south of, Harris Ranch). Light shock.

January 8: 20:03:29*. Epicenter 36°33′ north, 121°11′ west, B. Magnitude 2.5 Hollister (7½ miles south of, Harris Ranch). Light shock.

January 8: 22:04:04*. Epicenter 34°55′ north, 119°06′ west, near Wheeler Ridge, P. Magnitude 4.0. Wheeler Ridge. III. Slight shock felt by several.

January 12: 18:39:39*. Epicenter 33°01′ north, 116°13′ west, near Vallecito, P. Magnitude 4.2. San Diego. III. Press received several calls from persons in the Point Loma and La Jolla areas.

January 26: 19:00:37.3*. Epicenter 31.4° north, 115.6° west, near Laguna Salada, Baja California, W. Magnitude 4¾, P. San Diego. IV. Press received several calls from alarmed residents. Hanging objects swung. Rapid motion in east-west direction. Also felt in East San Diego and La Jolla.

January 30: 23:54:41*. Epicenter 33°55′ north, 118°21′ west, near Inglewood, P. Magnitude 2.6. Inglewood. IV. Reported by the press as generally felt within several miles of the epicenter. Also felt in the Crenshaw area.

February 2: 03:40, 03:51:42*, 04:09:37*. Epicenter 38°56′ north, 122°35′ west, B. Magnitudes of second and third shocks 3.0, 3.0, respectively. Felt over a small area along the southeast shore of Clear Lake in Lake County. Maximum intensity (damage) V at Clearlake Highlands. No damage reported. At Clearlake Highlands, awakened all and frightened many in community. Pendulum clock stopped. Windows, doors, dishes, and loose objects rattled; buildings creaked. Motion reported as both rolling and vertical; rumbling earth noises preceded the shock at 04:09:37* by a few seconds. Shock also felt at 03:40. Intensity (damage) IV at Clearlake Oaks, Glenhaven, and Lower Lake. Also felt at Point Lakeview (across lake from Clearlake Highlands).

February 2: 05:58:20*. Epicenter 36°49′ north, 121°25′ west, about 1¼ miles southwest of Hollister, B. Magnitude 3.5. Felt over an area of approximately 500 square miles of San Benito and Santa Clara countries. IV. At Hollister, felt by many and frightened few in community. Windows, doors, and dishes rattled; house creaked. Motion rapid, lasted 5 seconds; one jolt; west-east direction; faint earth noises heard by many. Felt by all in home at the Libby Ranch (about 2½ miles southwest of Paicines) where walls creaked; rapid motion of momentary duration. Also felt at San Martin where observer was awakened by a sudden, very slight jar.

February 12: 00:50:43*. Epicenter 37°49′ north, 122°12′ west, about 5 miles southeast of Berkeley, B. Magnitude 2.8. Felt over a small area of the Canyon-Oakland areas of Contra Costa and Alameda counties. Maximum intensity (damage) V. No damage reported other than enlarging a few plaster cracks at the Chabot Observatory in Oakland. At Canyon, felt by all in home; awakened few in com-

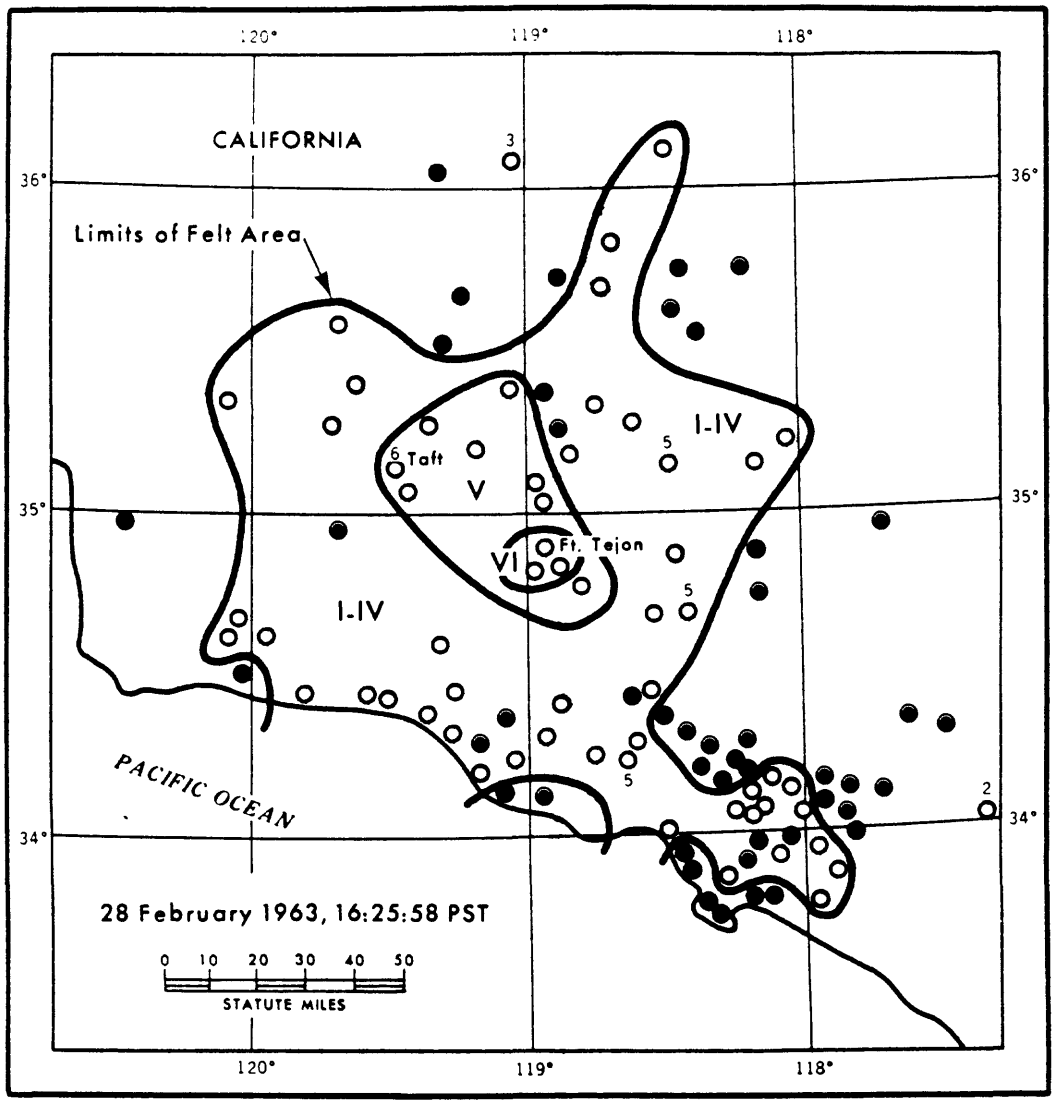

FIGURE 6.—*Area affected by earthquake of February 28.*

munity. Small objects and furnishings shifted. Sharp shakes; motion rapid, lasted up to 6 seconds; moderately loud earth noises heard 1 second before shock. At Oakland, several reports received from widely separated places, indicating the shock was rather generally felt; some awakened. Motion rapid, lasted 2 seconds; two tremors; moderately loud earth noises heard about 2 seconds before shock. At Moraga (IV), frightened few; windows, doors, and dishes rattled; rapid motion of momentary duration.

February 18: 08:58:53*. Epicenter 33°55′ north, 118°22′ west, south of Inglewood, P. Magnitude 3.4 Felt at Beverly Hills (near), Manhattan Beach, and Santa Monica.

February 28: 16:25:58*. Epicenter 34°56′ north, 118°59′ west, near Fort Tejon, P. Magnitude 5.0. Felt over an area of approximately 8,000 square miles of southern California, principally in southwestern Kern County. (See map above.) Maximum intensity (damage) VI. Damage slight at Taft, where plaster cracked.

INTENSITY (DAMAGE) VI:

Fort Tejon State Historical Monument (about 3 miles northwest of Lebec).—Felt by and frightened all in home and community.

Small objects shifted; knickknacks fell; floor moved. Rapid, 40-second shock in northwest direction; moderate earth noises from southeast heard by many at time of shock.

Frazier Park.—Felt by and frightened all in community. Cans and cereal boxes fell from shelves in grocery stores; small objects shifted. Rapid, 5-second shock in east-west direction; moderate earth noises heard by many.

Lebec (Tejon Ranch).—Felt by and frightened all in community. Trees, bushes shaken strongly. Hanging objects swung. Duration 3–4 seconds; moderate earth noises heard by many.

Taft.—Felt by all in community. Damage slight (plaster cracked).

INTENSITY (DAMAGE) V: Bakersfield, Chatsworth, Gorman, Lake Elizabeth Road (rural area west of Palmdale), Maricopa, Paloma Cycling Plant (about 20 miles southwest of Bakersfield), Tehachapi, and Wheeler Ridge.

INTENSITY (DAMAGE) IV: Arvin, Buttonwillow, Cachuma Dam (about 18 miles east of Santa Ynez), Caliente, Canoga Park, Cantil, Carpinteria, Fillmore, Fullerton, Glennville, Goleta, Johnsondale, Keene, Lake Hughes, Los Angeles, McKittrick, Mettler Station (about 5 miles northwest of Wheeler Ridge), Moorpark, Ojai, Posey, Santa Monica, Saugus (Power Plant No. 1), Simmler (Carrisa Plains), South Pasadena, Summerland, Tupman, Ventura, and about 5 miles northwest of Ventura (along Rincon Beach).

INTENSITY (DAMAGE) I–III: Antelope area (west of Rosamond), Camarillo, Colton, Compton, La Mirada, Lost Hills, Midway Substation (PG&E), Monrovia, Norwalk, Oak View, Oxnard, Pasadena, Porterville, Santa Ynez, and South San Gabriel.

March 10: 22:07:01*. Epicenter 33°45′ north, 118°21′ west, west of Wilmington, P. Magnitude 3.0. IV. At Hawthorne, building creaked and "groaned." Felt as a sharp jolt to two lying down in home at Manhattan Beach; windows rattled; house creaked; rapid, 2–3 second shock in northwest-southeast direction. At Torrance, 200 calls were received by the police department; one family reported they were awakened by two rapid jolts. Also felt at Hermosa Beach, Inglewood, Lomita, and Redondo Beach.

March 14: 04:23:47*. Epicenter 35°22′ north, 118°47′ west, east of Bakersfield, P. Magnitude 3.2. Bakersfield. IV. Felt by many, especially north and east of the city.

March 26: (in p.m.). Deep Springs (about 24 miles northeast of Bigpine). "People said they felt an earthquake in the afternoon."

April 1: 15:28:57*. Epicenter 34°00′ north, 118°21′ west, near Culver City, P. Magnitude 2.4. Los Angeles. Reported felt in the downtown area.

April 2: 13:21:00*. Epicenter 34°00′ north, 118°21′ west, near Culver City, P. Magnitude 1.7. Los Angeles. Reported felt in the La Cienega area.

April 11: 21:20:44*. Epicenter 34°55′ north, 118°57′ west, near Fort Tejon, P. Magnitude 3.9. Wheeler Ridge. Slight shock felt by woman in store.

April 18: 22:19:19.1*. Epicenter 31.8° north, 115.6° west, Baja California, W. Magnitude 4.2. Imperial Beach. V. Slight damage reported at Imperial Beach. *(BSSA, October 1963.)* (This report of "slight damage at Imperial Beach" is believed to be in error.)

April 29: 18:32:58*. Epicenter 34°01′ north, 118°07′ west, near Pasadena, P. Magnitude 3.2 IV. At Altadena, felt by many in community; frightened few; duration 1 second. Felt by many in community at Glendale, where windows and doors rattled; house creaked; rapid, sharp, sudden 1-second shock. At South Pasadena, felt by all in home; doors and dishes rattled; motion slow; duration few seconds. Felt by observer (sitting) at Tujunga, where house creaked; slow, 30 second shock. Felt with intensity (damage) I to III at Bell, Burbank, Monterey Park, Pasadena, San Gabriel, and Van Nuys. Also reported felt (no details) at Alhambra and Downey.

May 5: 19:04:29*. Epicenter 36.6° north, 121.3° west, B. Magnitude 3.3. Hollister (7½ miles south of, Harris Ranch). IV. Felt by all in home (some active). Windows rattled; house creaked. Hanging objects swung east-west. Motion slow, fairly long duration; faint earth noises heard.

May 6: 23:07:42*. Epicenter 36.8° north, 121.6° west, off coast of Monterey County, B. Magnitude 4.4. Felt over an area of approximately 3,000 square miles of the coastal region of west-central California. Maximum intensity (damage) V. At Carmel, one report of enlarged plaster cracks; at Freedom, observer reported plaster cracked (also reported no damage).

INTENSITY (DAMAGE) V:

Aromas.—Awakened many in community. Windows and doors rattled. Rapid motion.

Carmel.—Felt by many and awakened few in community. Existing plaster cracks enlarged.

Windows, doors, and dishes rattled; house creaked. Rapid, 10-second shock in east direction; faint earth noises heard from west during shock.

Freedom.—Felt by all in home and community; frightened few. Windows, doors, and dishes rattled. Plaster cracked (observer also reported no damage). Slow, 45-second shock in east-west direction; faint earth noises from east-west heard by many.

Gilroy.—Felt by all in community; awakened many; frightened few. Windows, doors, and dishes rattled. Hanging objects swung. Rapid motion in north direction; moderate earth noises heard.

Hollister.—Felt by all; most awakened. Windows, doors, and dishes rattled; house creaked. Hanging objects swung. Slow, 8–10 second shock; moderate earth noises from east heard by observer 3–4 seconds before shock. Reported as the strongest shock felt since April 8, 1961.

Morgan Hill.—Felt by and awakened many. Dishes rattled.

Moss Landing.—Felt by, awakened, and frightened all in home. Small objects shifted. Motion rapid; loud earth noises heard.

Watsonville.—Felt by all and awakened many; frightened few. Windows, doors, and dishes rattled; house creaked. Hanging objects swung east-west. Motion both rapid and slow; duration 5 seconds; moderate earth noises heard.

INTENSITY (DAMAGE) IV: Aptos (3.7 miles north of), Big Sur, Boulder Creek, Capitola, Coyote, Daly City, Gilroy Hot Springs (10 miles northeast of Gilroy), Hollister (7½ miles south of, Harris Ranch), Jamesburg area (Search Ranch), Mill Valley, New Almaden, Pacific Grove, Paicines, Redwood Estates, Salinas, San Francisco, San Jose, Santa Clara, Santa Cruz, Soquel, South San Francisco, and Tres Pinos.

INTENSITY (DAMAGE) I–III: Ben Lomond, Castroville, Felton, Gabilan (north of Salinas), Los Gatos, Oakland, San Gregorio, and San Juan Bautista.

May 7: 11:49 (main shock), 13:30, 16:47, 20:20. Felt over an area of approximately 400 square miles of southwest Los Angeles County, principally in the communities of Hermosa Beach and Manhattan Beach. Maximum intensity (damage) V. Press reported the only damage was at Manhattan Beach, where the first shock broke a water pipe at the Manhattan Beach City Pier. It was reported all the shocks were slight but noisy. One observer reported the shocks had a wrenching sound. Telephone calls were also received at the Inglewood, Hermosa Beach, Redondo Beach, and the Manhattan Beach police stations, and at the Lennox sheriff's station, from persons reporting the shock at 20:20.

Reports are for the main shock at 11:49 unless otherwise indicated.

INTENSITY (DAMAGE) V:

Hawthorne.—Felt by all in community; frightened few. Windows and doors rattled. Rapid motion of few seconds duration; direction northeast; moderate earth noises from southwest heard by many. Just rapid thumps felt at 13:30, 16:47, and 20:20.

Hermosa Beach.—Press reported filing cabinet doors at the police station flew open, and that police at the station spent the next 5 hours alternately answering phone calls and closing cabinet drawers.

Manhattan Beach.—Felt by all in community. Press reported the only damage was a broken water pipe at the City Pier. Rapid, heavy jolt of 1–2 seconds duration, followed immediately by a slighter jolt; faint earth noises heard 1 second before shock. Shocks at 13:30, 16:47, and 20:20 felt with intensity (damage) IV; brief shocks; windows, lamp, and grids on two wall furnaces rattled.

INTENSITY (DAMAGE) IV: Downey, El Segundo (16:47), Gardena, Harbor City (also 16:47), Long Beach, Palos Verdes Peninsula, Redondo Beach (shock also felt at 20:20), and Torrance.

INTENSITY (DAMAGE) I–III: Huntington Park.

May 9: 04:04:19*. Epicenter 36.8° north, 121.5° west, B. Magnitude 3.4. IV. People awakened in the Hollister area. At the Harris Ranch, 7½ miles south of Hollister, brief shock awakened all in home; windows and doors rattled; walls creaked.

May 9: 05:24:08*. Epicenter 40.6° north, 124.7° west, B. Eureka. IV. Felt by many; awakened and frightened few in community. Creaking of buildings and rattling of loose objects heard by many. Hanging objects swung; drapes swung north-south. Abrupt, rapid, bumping, settling motion of 1–2 seconds duration; one fairly loud thumping sound heard. "Seemed to have been felt mostly in the northeast portion of the city." Some persons reported feeling two shocks.

May 9: 15:00 (about). Manhattan Beach (Post Office). "Five or six shocks felt about 3 p.m."

May 11: 19:45:10*. Epicenter 37.7° north, 122.5° west, B. Magnitude 2.7. San Francisco,

IV. Very slight shock felt by several in home. Building creaked; loose objects rattled. Gradual to rapid onset; direction south-north.

May 12: 05:40. Manhattan Beach. IV. Felt by and awakened all in home. Rapid, 1-second shock in northwest-southeast direction; moderate earth noises from northwest-southeast heard by observer.

May 13: 00:40. Manhattan Beach. III. Very rapid, slight motion, lasting fraction of second, felt by observer in home. Moderate earth noises from northwest-southeast heard fraction of second before shock.

May 14: 14:56. Manhattan Beach. IV. Felt by observer sitting in home. Windows rattled. Motion rapid and shallow followed by a jolt, pause, then slightly slower and deeper motion as sound diminished; duration 1 second; direction seemed more west-east than previous recent shocks; more noise at end than at beginning of shock. Reported as a small shock in the Hermosa Beach area.

May 17: 04:28. Manhattan Beach. Observer seemed to have been awakened by two, long slow rolls; had the distinct impression of bed rolling.

May 17: 08:59. Felt over an area of approximately 300 square miles of Ventura County coastal area. Maximum intensity (damage) V. No damage reported. At Saticoy, felt by and frightened many in community. Windows, doors, and dishes rattled; hanging objects swung. Rapid, 3-second shock in southeast direction; moderate earth noises heard by few. Felt with intensity (damage) IV at Montalvo, Port Hueneme, and Ventura. Also felt at Casitas Springs and Oxnard.

May 20: 11:57:52*. Epicenter 37.6° north, 121.9° west, B. Magnitude 4.2. V. Livermore area (Collier Canyon Road). Felt by all in home and community. Windows and doors rattled. Motion slow; duration 1 minute. At Cowell (IV), very slight shock felt by observer (active); frame creaked. At Canyon (III), very slight shock felt by several; motion slow; duration 1 second.

May 22: 14:41:05*. Epicenter 37.3° north, 122.2° west, B. Magnitude 4.6. Felt over an area of approximately 1,500 square miles of the coastal areas of west-central California. Maximum intensity (damage) VI at Sunnyvale, where press reported a caved-in roof.

INTENSITY (DAMAGE) V:

Campbell.—Felt by several in community; frightened few in home. Small objects shifted slightly. Rapid, 1-second shock.

Cupertino.—Felt by several in home and community. All objects rocked; hanging objects swung east-west. Motion both rapid and slow; duration 2–30 seconds; directions north-south and east-west.

Felton.—Frightened few. Small objects shifted; record on player rejected. "Seemed to have been noticed more in Scotts Valley area, few miles southeast of Felton."

La Honda.—Felt by all and frightened few in community. Windows and dishes rattled; house creaked. Rapid, jolting motion in south direction.

Milpitas.—Felt by several in community. Pendulum clock stopped. Motion rapid; faint earth noises heard.

Monte Vista (about 1 mile west of Cupertino).—Felt by and frightened many in community. Windows, doors, and dishes rattled; walls creaked; hanging objects swung. Momentary duration.

Pescadero.—Felt by and frightened all in community. Small objects shifted; doors swung. Motion rapid; loud earth noises heard by many.

INTENSITY (DAMAGE) IV: Alviso, Big Basin, (Big Basin State Park), El Granada, Half Moon Bay, Loma Mar, Los Altos, Los Gatos, Moffett Field, Moss Beach, Palo Alto, San Francisco, San Gregorio, and San Jose.

INTENSITY (DAMAGE) I–III: Berkeley, Boulder Creek, Capitola, Millbrae, Mountain View, Mount Hermon, Oakland, Redwood City, San Bruno, San Carlos, Santa Cruz, Sausalito, South San Francisco, Warm Springs, and Woodside. (Press reported the shock was felt as far north as Martinez and that calls were received by police departments in Burlingame, Colma, Menlo Park, San Anselmo, and San Mateo. No details).

May 22: 22:37:20*, 22:43:34*. Magnitudes 4.5 and 3.0, respectively; and May 23: 01:06:50*, 07:53:02* (main shock), 09:10, 10:30, 17:30. Epicenter of main shock 33°02′ north, 115°41′ west, Imperial Valley, P. Magnitude of first shock on May 23, 3.5; of main shock, 4.7. The main shock of the series was felt over an area of approximately 4,000 square miles, principally in the Imperial Valley. Maximum intensity (damage) VI at Brawley and Westmorland. At Brawley, a 9 by 11 foot plate glass window was broken and plaster cracked. At Westmorland, plaster cracked and a considerable amount of merchandise fell in several grocery stores, with two stores estimating damage at several hundred dollars.

Reports are for the main shock unless otherwise indicated.

INTENSITY (DAMAGE) VI:

Brawley.—Felt by, awakened, and frightened many in community; proprietor and customer of barber shop ran outdoors. One 9 by 11 foot plate glass window broken at barber shop. Small objects overturned. Motion rapid; duration 30 seconds; moderate earth noises heard by many.

Brawley (2 miles south of, Agricultural Research Service, Department of Agriculture).—Felt by all, awakened many and frightened few in community. Damage slight. Plaster cracked. Jars in store broken. Small objects and furnishings shifted; small objects overturned. Motion slow; duration 10–15 seconds; moderate earth noises from south heard by many 10–15 seconds before shock.

Brawley (8 miles west of, Charles L. Wieman Ranch).—Awakened all and frightened many in home. Pendulum clock facing west stopped. Small objects and furnishings shifted; vases and small objects overturned; knickknacks and pictures fell. Rapid, 10–30 second shock in west-east direction; moderate earth noises from west-east heard by observer 5 seconds before shock. "On May 22, violent shock at 22:43; on May 23, violent shocks at 01:30 and 07:53; several tremors felt throughout the day; light tremor about 17:30."

Westmorland.—Felt by and awakened all in community; frightened many. Considerable slight damage. Plaster cracked and fell; damage slight to brick; windows and dishes broken; considerable loss from fallen merchandise in several stores; knickknacks, books, and pictures fell; furnishings shifted; trees, bushes shaken strongly. Motion rapid and slow, lasting up to 15 seconds; direction north-south; loud earth noises heard by many a few seconds before shock. Press reported two other shocks were felt at 09:10 and 10:30. One observer reported shocks continued through May 26.

INTENSITY (DAMAGE) V: Calipatria (shocks also felt on May 22 at 22:37:20* and 22:43:34* and on May 23 at 01:06:50*), Holtville, Imperial (shocks also felt on May 22 at 22:37:20* and on May 23 at 01:06:50*), Niland (two shocks also felt on May 22; on May 23 at 01:06:50*), and Salton City.

INTENSITY (DAMAGE) IV: Calexico, Campo, El Centro (shocks also felt on May 22 at 22:37:20* and 22:43:34*; on May 23 at 01:06:50* and 10:30), Escondido, Jacumba, and Mountain Center (about 18 miles southeast of, at Nightingale Camp).

INTENSITY (DAMAGE) I–III: Boulevard, Colton (series of shocks felt on May 22 and 23), Heber, Pine Valley, San Diego (01:06:50*), and Winterhaven.

May 24: 14:27. Manhattan Beach. IV. Two barely perceptible jolts in rapid succession felt by observer sitting. Windows rattled. Faint earth noises immediately preceded shock.

May 25: 00:05. Aptos (3.7 miles north of). IV. Rapid, 2-second shock awakened observer. Door tapped against partition.

May 25: 22:03. Manhattan Beach. III. Felt by observer lying down (awake). Two slight, slow rolls in west-east direction, lasting fraction of second.

June 7: 04:04:40*. Epicenter 38.0° north, 121.8° west, near Antioch, B. Magnitude 4.0. Felt over an area of approximately 1,500 square miles of the San Francisco Bay area, principally in Contra Costa County. Maximum intensity (damage) VI. Damage slight. At Antioch, it was reported the main structure of the old Antioch Junior High School had new cracks in walls and foundation; old cracks enlarged; additional twisting of beams and doors. Plaster cracked at few other places.

INTENSITY (DAMAGE) VI:

Antioch.—Felt by and awakened many. Press reported the principal of the old Antioch Junior High School observed evidence of additional damage to the main building. Roof rafter appeared to be bent more; old cracks in walls appeared to be wider and longer; additional cracks in walls and foundations. It was reported the building, built more than 30 years ago (before enactment of the Field Act), had already been declared unsafe by engineers. Rapid, 1-second shock in west-east direction.

Clayton.—Felt by and awakened all in community; frightened few. Plaster cracked. Slight shakes, a rumble, then severe shock; sensation as though something fell, then the vibrations; moderate earth noises heard by many before shock.

Concord.—Felt by and awakened all in community; frightened few. Damage slight. Plaster cracked. Small objects shifted; knickknacks fell. Trees, bushes shaken moderately. Motion rapid, jolting, explosivelike; duration 2–4 seconds; direction southwest; moderate earth noises heard.

Cowell.—Felt by and awakened all in community; frightened few. Plaster cracked; dishes broken; small objects and furnishings shifted; small objects overturned; knickknacks fell; TV aerial fell; trees, bushes shaken strongly (branches off). "Children reported

falling out of bed." Motion rapid; moderate earth noises heard by many.

INTENSITY (DAMAGE) V: Benicia, Crockett, Martinez, Pinole, Pittsburg, Port Costa, and Walnut Creek.

INTENSITY (DAMAGE) IV: Berkeley, Canyon, Diablo, Hercules, Oakland, Orinda, Port Chicago, Rodeo, Saint Mary's College (Moraga), San Francisco, and Suisun Bay Bridge area.

INTENSITY (DAMAGE) I–III: Bolinas, Daly City (Westlake area), Lafayette, Sausalito, and Vallejo.

June 8: 00:51:56.5*. Epicenter 40.6° north, 124.3° west, Humboldt County, W. Magnitude 4.0. Eureka (PG&E Humboldt Bay Power Plant). Slight shock felt.

June 11: 07:23:42.7*. Epicenter 31.8° north, 116.2° west, Baja California, W. Magnitude 5.0. Felt over an area of approximately 5,500 square miles in the United States, principally in Imperial and San Diego counties. Maximum intensity (damage) V. No damage reported, except one instance of very slight plaster cracking at Potrero.

INTENSITY (DAMAGE) V:

Alpine.—Felt by all and frightened few in community. Windows rattled; frame creaked. Motion rapid; quivering for about 5 seconds, sharp jolt, then quivering; duration 15–20 seconds; moderate earth noises heard by many.

Boulevard.—Felt by many and frightened few in community. Small objects shifted. Motion rapid; duration about 1½ seconds; direction northeast-southwest; loud earth noises heard by many a fraction of second before shock.

Descanso.—Felt by many in community. Small objects shifted. Motion slow; duration several minutes; direction north-south; moderate earth noises heard by many.

El Centro.—Felt by all. One sharp shock, then a slight rolling motion; duration 10–20 seconds; direction north.

Jacumba.—Felt by many and frightened few in community. Small objects and furnishings shifted; small objects overturned. Two rapid shocks in southeast-northwest direction; earth noises from southeast-northwest heard.

La Jolla.—Felt by many and frightened few in community. Small objects shifted.

Plaster City.—Felt by all and frightened few in community. Windows and doors rattled; walls creaked. Slow, 30-second shock; faint earth noises heard by few about 1 second before shock.

Potrero.—Felt by many and frightened few in community. Plaster cracked very slightly (adobe house). Motion rapid; direction northeast; loud earth noises heard by many about 2 seconds before shock.

Valley Center.—Felt by many in community. Light objects on shelves shifted, some fell to floor. Direction north-south.

Westmorland.—Felt by all in home; frightened few in community. Small objects shifted. Slow motion of long duration; faint earth noises heard.

INTENSITY (DAMAGE) V IN BAJA CALIFORNIA:

Tijuana.—Felt by all and frightened few in community. Windows, doors, and dishes rattled; building creaked. Hanging objects swung north-south. Motion slow; duration few minutes; moderate earth noises heard by many. "Many did not realize what it was and thought the dizzy sensation was from illness."

INTENSITY (DAMAGE) IV: Campo, Dulzura, Escondido, Heber, Lakeside, La Mesa, Palomar Mountain, Poway, Rancho Santa Fe, San Diego, Santa Ysabel, San Ysidro, Temecula, and Wildomar.

INTENSITY (DAMAGE) I–III: Bonsall, Calipatria, Imperial Beach, Leucadia, Mount Laguna, Nestor, and Ramona.

June 12: 14:15:15.3*. Epicenter 31.5° north, 116.3° west, Baja California, W. Magnitude 4¾–5.0, P. Imperial and San Diego counties. Press reported the shock was felt in Imperial and San Diego counties, but was not as widely felt as the shock on June 11.

June 17: 18:29. Wishon (PG&E Powerhouse, NE¼ and NW¼, Sec. 18, T9S, R23E). Shock of momentary duration felt.

June 20: 04:05. West Los Angeles County area. Press reported a light shock was felt in the Culver City-West Los Angeles area.

July 7: 21:35:31*. Epicenter 40.2° north, 121.0° west, Plumas County, W. Magnitude 3.5. Caribou (PG&E Powerhouse, NW¼, Sec. 25 and SW¼, Sec. 24, T26N, R7E, nearest town Belden). IV. Felt by many in community.

July 16: 01:18:21.3*. Epicenter 34.1° north, 116.1° west, San Bernardino County, W. Magnitude 4.0. Reported as the first of a series of gently rocking shocks felt in the Twentynine Palms area between July 16 and 19.

July 16: 10:17:54*. Epicenter 36°53′ north, 121°32′ west, San Benito County, B. Magnitude 3.5. San Juan Bautista (San Juan Bautista Mission). Felt quite strongly. Also felt at Hollister.

July 17: 15:05:42.5*. Epicenter 34.1° north, 116.1° west, San Bernardino County, W. Magnitude 4.2. Twentynine Palms. III. Felt by

several. Rapid, 2-second shock in north-south direction.

July 18: 02:40:30.4*, 11:37:43.7*. Epicenter 34.1° north, 116.1° west, San Bernardino County, W. Magnitudes 4.3 and 4.4, respectively. Twentynine Palms. (11:37) V. Felt by many; frightened few. Small objects shifted. Rapid, 2–3 second shock. Shock also felt at 02:40:30.4*.

July 19: 07:54:55.4*. Epicenter 34.1° north, 116.1° west, San Bernardino County, W. Magnitude 4.4. Twentynine Palms. Felt.

July 25: 00:44. San Diego. IV. Press reported police received calls from people reporting prowlers. Windows and doors rattled. On Point Loma, observer described the disturbance as a vibration through the ground.

July 25: 23:35. Colton. III. Rapid, 2-second, sudden jolt in north-south direction. Also felt in San Bernardino, Fontana, and Riverside.

July 26: (in a.m.). Pasadena (east of). IV. Press reported a small rolling earthquake rattled windows in communities east of Pasadena.

July 29: 22:34:54.8*. Epicenter 34.0° north, 116.3° west, San Bernardino County, W. Magnitude 4.7. Twentynine Palms. V. Felt by and frightened many in community. Windows, doors, and dishes rattled; walls creaked. Hanging objects swung east-west. Motion rapid; duration 6 seconds; direction east-west; moderate earth noises heard by many 2 seconds before shock.

July 30: 21:08*, 22:45*. Epicenter 36°52′ north, 121°21′ west, 3 miles east of Hollister, B. Magnitudes 2.5 and 3.9, respectively. Reports are for the shock at 22:45*. V. At Hollister, felt by, awakened, and frightened all in home; awakened few in community; felt by some outdoors (active). Pendulum clock stopped. Motion slow; duration 3 minutes; direction southeast-northwest; loud earth noises heard by many. At the Harris Ranch (7½ miles south of Hollister) (IV), felt by observer lying down. Windows and doors rattled; house creaked. Felt by several in community at Tres Pinos.

August 4: 09:35*. Epicenter 37°36′ north, 122°35′ west, B. Magnitude 4.25. Felt over an area of approximately 1,500 square miles of the San Francisco Bay area. Maximum intensity (damage) V at Lagunitas, where the shock was felt by many in community; small objects shifted; duration few seconds; faint earth noises heard. Felt with intensity (damage) IV at Berkeley, Corte Madera, Half Moon Bay, Millbrae, Mill Valley, Novato, San Francisco, San Quentin, San Rafael, and South San Francisco. Intensity (damage) I–III at Bolinas, Larkspur, Oakland, Orinda, Pacifica, Richmond, and San Bruno.

August 10: 06:32*. Epicenter 37°52′ north, 122°15′ west, within 2 or 3 miles of Berkeley, B. Magnitude about 3.0. Canyon. IV. Rapid, 1–2 second shock felt by observer lying down. Windows rattled slightly. Faint earth noises from northwest heard fraction of second before shock. Also felt at Berkeley, Oakland, and Richmond.

August 14: 13:12. Aptos (3.7 miles north of). III. Four or five very slight tremors felt by observer reclining on bed. Slow motion in east direction.

August 15: 13:21:33*. Epicenter 36°03′ north, 121°00′ west, B. Magnitude 3.8 Hollister (7½ miles south of, Harris Ranch). IV. Slight shock felt by observer sitting. Windows rattled.

August 22: 04:13:11.4*. Epicenter 33.7° north, 118.0° west, Orange County, W. Magnitude 4.3. Los Angeles County. V. Press reported a sharp earthquake awakened many and rattled windows throughout a wide area of the Los Angeles Basin. At Norwalk, the sheriff's substation received 200 calls. Two sharp jolts very close together reported felt at numerous places including Anaheim, Arcadia, Bellflower, Downey, Laguna Beach, Long Beach, Montebello, Norwalk, South Pasadena, and Whittier.

August 26: 17:20:54.6*. Epicenter 31.6° north, 116.2° west, Baja California, W. Magnitude 4.4. Descanso. IV. Felt by several lying down and sitting in home, where windows and dishes rattled; building creaked. Press reported the shock was felt in many sections of San Diego County. At San Diego, a very light shock felt by observer in home (active). Rapid motion of few seconds duration.

August 31: 08:31:14*. Epicenter 36°45′ north, 121°35′ west, B. Magnitude 4.2. Felt over an area of approximately 1,300 square miles of Monterey and San Benito counties. Maximum intensity (damage) V. No damage reported.

INTENSITY (DAMAGE) V:

Cienega District (about 8 miles south of Hollister, Bird Creek Road; Mills house).— Felt by all in home; by some outdoors (active). Small objects and furnishings shifted; small objects overturned; knickknacks and books fell. Trees, bushes shaken moderately. Rapid

motion in east-west direction; loud earth noises from east-west heard by few about 5 seconds before shock.

Salinas.—Press reported police received numerous calls from alarmed residents. Woman said she was knocked off chair. Shock described as two rather hard jolts followed by a minor one.

San Juan Bautista.—Felt by several; frightened few. Set off burglar alarm at bank.

INTENSITY (DAMAGE) IV: Almaden Winery (Cienega District, about 9.9 miles south of Hollister), Castroville, Chualar, Coyote, Harris Ranch (Cienega District, 7½ miles south of Hollister), Hollister, Monterey, Paicines, San Martin, and Tres Pinos.

INTENSITY (DAMAGE) I–III: Aromas, Carmel, and Santa Cruz.

September 3: 21:16:52*. Epicenter 40.4° north, 122.0° west, east of Anderson, B. Magnitude 3.3. Felt over an area of approximately 900 square miles of southern Shasta and northern Tehama counties. Maximum intensity (damage) IV. Houses vibrated and windows rattled at Anderson. At Bella Vista, felt by many in community; windows, doors, and dishes rattled; motion slow; duration several seconds; north-south direction; moderate earth noises heard. Windows rattled at Manton. Felt by all and awakened few in home at Millville, where windows and doors rattled; rapid, 2-second shock. At Paynes Creek, felt by two; house shook; motion rapid. At Redding, press described the shock as mild, vibrating houses and rattling windows; building creaked; doors rattled; motion slow; duration 2 seconds. Felt like the distant explosion of a heavy charge of dynamite to one observer. At Shasta Dam, felt by several in home; windows, doors, and dishes rattled; motion slow; duration 30 seconds; faint earth noises heard. Felt with intensity (damage) I–III at Cottonwood, Summit City, and Whitmore.

September 13: 05:05:35*. Epicenter 36°45′ north, 121°40′ west, B. Magnitude 2.6. Hollister (7½ miles south of, Harris Ranch). III. Brief shock felt by several.

September 13: 14:42:15*. Epicenter 40.0° north, 121.7° west, B. Magnitude 3.25–3.5. Felt over an area of approximately 1,200 square miles of Butte and Plumas counties. Maximum intensity (damage) V.

INTENSITY (DAMAGE) V:

Belden.—Felt by all in community. Windows and doors rattled; walls creaked. Motion slow; duration 1 second; moderate earth noises heard by many.

Cohasset (about 17 miles northeast of Chico).—Frightened few. Small objects and furnishings shifted. Rapid, 5-second shock in south direction; preceded 3 seconds by moderate earth noises from south.

INTENSITY (DAMAGE) IV: Berry Creek, Las Plumas, Storrie, and Virgilia.

INTENSITY (DAMAGE) I–III: Big Bend (PG&E Powerhouse, NW¼, Sec. 14, T21N, R4E, nearest town Oroville), Caribou, Rock Creek (PG&E Powerhouse, SW¼, Sec. 30, T24N, R6E, nearest town, Belden), and Twain (about 7 miles southeast of Caribou).

September 13: 19:51:16.2*. Epicenter 33°32.6′ north, 118°20.4′ west, P. Magnitude 4.6. Felt over an area of approximately 150 square miles of southern Los Angeles County. Maximum intensity (damage) V. No damage reported, except enlargement of hairline cracks at one place in Long Beach. Press reported a lesser shock was felt at 20:17.

INTENSITY (DAMAGE) V:

Long Beach.—Felt by all in home at several locations. Hairline cracks enlarged. Windows, doors, and dishes rattled; house creaked. Motion reported as slow, rolling, rapid, jarring; duration 3–5 seconds; direction east; faint earth noises from east heard.

Palos Verdes Peninsula.—Felt by all in building; by observer outdoors (quiet); frightened many. Windows, doors, and dishes rattled; house creaked. Hanging objects swung. Rapid, 3-second shock in west direction, faint earth noises heard.

Portuguese Bend.—Felt by all in home and community; frightened few in home. Windows, doors, and dishes rattled; frame creaked. Hanging objects swung. Motion rapid; duration 6 seconds; moderate earth noises, like sonic boom, from southwest heard by many 3 seconds before shock.

INTENSITY (DAMAGE) IV: Harbor City, Lomita, Redondo Beach, San Pedro, and Westminster.

INTENSITY (DAMAGE) I–III: Manhattan Beach and Sunset Beach.

September 14: 11:46:17* (main shock), 12:28:08*. Epicenter 36°51′ north, 121°38′ west, B. Magnitude of main shock 5.4; of second, 4.6. The main shock was felt over an area of approximately 5,000 square miles of west-central California. (See map, page 33.) Maximum intensity (damage) VII. Minor damage occurred in a small area along the San Andreas

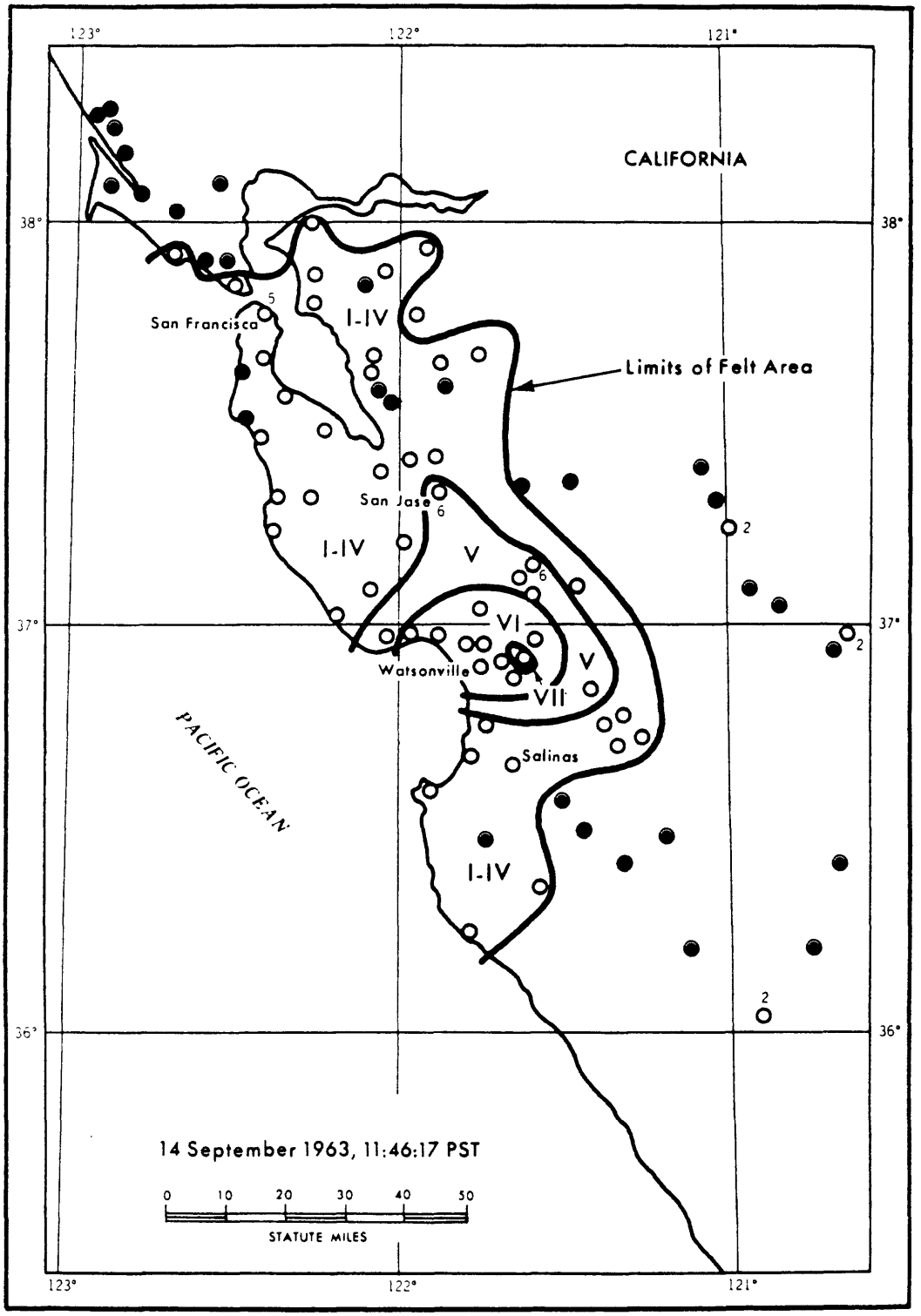

FIGURE 7.—*Area affected by earthquake of September 14.*

fault about 7½ miles east of Watsonville in vicinity of Chittenden and Soda Lake.

INTENSITY (DAMAGE) VII:

Chittenden and vicinity.—The following was abstracted from a report of the seismic field investigation conducted by Dr. Earl E. Brabb, U.S. Geological Survey, Menlo Park, California: "Second floor of wood frame house moved about 2 inches southwestward away from retaining wall; upper part of another wood frame house moved relative to foundation, causing ceiling to separate slightly from wall; water tank shifted on foundation; legs and ladder of feed silo bent and twisted; bridge footings of highway bridge across the Pajaro River slightly damaged; water pipes broken; stone and brick chimney cracked, one stone shaken loose; plaster cracked. In the Soda Lake and Pajaro Gap areas, landslides of loosely consolidated material occurred along steep road cuts and loose crushed rock slid from steep quarry cuts. Road cracked at Chittenden Pass. Stove, hot water heater, dresser and other furniture moved; dishes, vases, and lamps overturned and broken."

INTENSITY (DAMAGE) VI:

Aromas and vicinity.—Felt by all and frightened many in community. Damage slight. Plaster cracked. Small objects and furnishings shifted; small objects overturned. Many cans shaken off shelves in grocery store; 1 mile southwest of Aromas, jam jars shaken off shelf (from USGS report).

Capitola.—Felt by many in community; frightened all in home. Damage slight to concrete; plaster cracked. Slow, 1-minute shock. "First shock moderate; second, somewhat stronger."

Morgan Hill (near, Anderson Reservoir).—Felt by observer and wife fishing from boat in the reservoir. Boat rocked. Rocks and pebbles slid down sharp banks into lake. Lake appeared to lurch at shoreline. Trees, bushes shaken moderately. "First shock stronger than the shock at 12:28:08."

Salinas (15 miles north of, on ranch).—Man reported he had to hold onto sink to keep from falling.

San Jose.—Felt by many (observer outdoors) and frightened few in community. Damage slight. Plaster cracked. Pendulum clock stopped. Motion rapid; duration 20 seconds; moderate earth noises heard by few.

Watsonville.—Felt by all and frightened many in community. Furnishings shifted. Pendulum clock stopped. Trees, bushes shaken moderately. Rapid motion in northeast direction; duration 10–15 seconds; moderate earth noises heard.

Watsonville (about 4 miles north of, at Freedom).—Felt by many in community (some outdoors; active); frightened few. Damage slight. Plaster and ground cracked. Small objects shifted. Pendulum clock stopped. Trees, bushes shaken moderately. Motion slow; duration about 1 minute; faint earth noises from northeast heard by many.

Watsonville (northeast of, Madonna Park).—(From USGS report) Park rangers reported an increase in the flow of a spring within the park, commencing two days after the earthquake and lasting for two or three days.

Watsonville (about 4 miles northeast of, on Hecker Pass Rd.).—Felt by all; frightened few. Furnishings shifted. Rapid, 30-second shock. A number of other observers in areas a few miles north, northeast, and east of Watsonville reported dishes, cans, bottles, and other objects were shaken off shelves (from USGS report).

INTENSITY (DAMAGE) V: Hollister (shock also felt at 12:28:08*), Morgan Hill, San Francisco (shock also felt at 12:28:08*), and Santa Cruz (shock also felt at 12:28:08*).

INTENSITY (DAMAGE) IV: Alviso, Aptos and 3.7 miles north of (also shock at 12:28:08*), Ben Lomond, Big Sur, Bolinas, Burlingame, Davenport, Gilroy Hot Springs (shock also felt at 12:28:08*), Harris Ranch (about 7½ miles south of Hollister), Hayward, Libby Ranch (about 2½ miles southwest of Paicines), Livermore, Marina, Mount Eden, Pacific Grove, Paicines, Pinole, Pleasanton, Redwood City, Salinas, San Martin, Search Ranch (Jamesburg area), South San Francisco, and Tres Pinos.

INTENSITY (DAMAGE) I–III: Castroville, Clayton, Dos Palos, Gustine, Half Moon Bay, La Honda, Los Gatos, Milpitas, Oakland (shock also felt at 12:28:08*), Pescadero, San Ardo, San Gregorio, San Juan Bautista, San Mateo, Sausalito, and Walnut Creek.

September 20: 20:32*. Epicenter 37°16′ north, 121°40′ west, 15 miles east-southeast of San Jose, B. Magnitude 4.5. IV. At Aptos (3.7 miles north of), felt by and awakened observer. Doors rattled and swung north. Slow, 4-second shock in northeast direction. Felt by many and frightened few in community at Morgan Hill, where windows and doors rattled; hanging objects swung east-west; direction east-west. Felt with intensity (damage) I to III at Gilroy and Milpitas.

September 23: 06:41:52*. Epicenter 33°50′ north, 117°00′ west, near San Jacinto, P. Mag-

nitude 5.3. Felt over an area of approximately 10,000 square miles of southern California. (See map below.) Maximum intensity (damage) VI. Damage occurred principally at Hemet and San Jacinto, where plaster cracked and fell; windows and dishes broken; damage to fallen merchandise in stores. At Hemet, chimneys cracked and twisted.

INTENSITY (DAMAGE) VI:

Anza.—Felt by all and frightened many in community. Damage slight. Plaster cracked. Small objects shifted; vases fell. Moderate earth noises heard.

Hemet and San Jacinto.—Press reported several plate glass windows were broken in Hemet and San Jacinto stores. Canned goods and supplies fell in markets. Hundreds of dishes fell from trailer cabinets and broke in Hemet's 27 trailer parks. Clock fell from wall at Hemet courthouse.

Hemet.—Felt by all and frightened many in community. Damage slight to considerable in brick and concrete. Plaster, windows, and chimneys cracked; chimneys twisted. Dishes and windows broken. Furnishings shifted; vases, etc., small objects overturned; knickknacks, books, and pictures fell. Trees, bushes shaken strongly. Rapid, 10-second shock in north-south direction; loud earth noises from north-south heard.

Homeland.—Felt by and awakened all in community; frightened many. Damage slight. Small objects shifted and overturned; knickknacks fell. Very strong, rapid shock; duration 1½ minutes; direction northwest; loud roaring earth noises heard by many before shock.

Murrietta.—Felt by, awakened, and frightened all in community. Plaster cracked. Trees, bushes shaken strongly. Slow, 20-second shock; faint earth noises heard.

Nuevo.—Felt by, awakened, and frightened all in community. Damage slight. Plaster cracked; dishes broken. Small objects shifted and overturned; knickknacks fell. Trees, bushes shaken strongly. Rapid motion; loud earth noises heard.

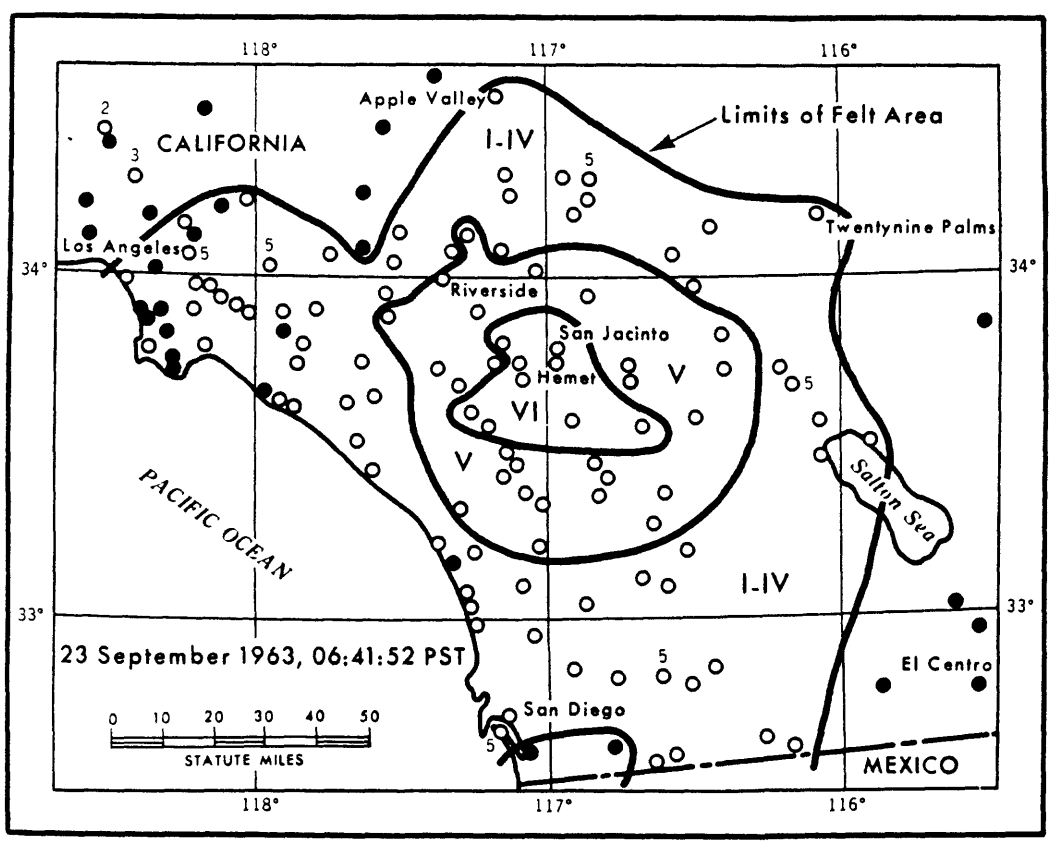

FIGURE 8.—*Area affected by earthquake of September 23.*

S[illegible] Fire Control Station (about 12 miles south of Hemet).—Felt by all at station; frightened many in community. Damage slight to building. Rapid, 10-second shock; loud earth noises heard.

San Jacinto.—Felt by, awakened, and frightened all in community. Plaster cracked and fell; windows broken; vases and mirrors broken in homes; stock damaged in stores. Rapid, 6-second shock in northeast-southwest direction; loud, blastlike earth noises heard by many 1 second before shock.

Wildomar.—Felt by all and awakened many in community. Damage slight. Plaster cracked. Many small objects shifted. Trees, bushes shaken strongly. Small amount of water sloshed from fish pond. Rapid, 4-second shock in southeast-northwest direction; moderate earth noises from southeast-northwest heard by many.

Winchester.—Felt by all and frightened many in community. Plaster and windows cracked. Small objects and furnishings shifted; vases and small objects overturned. Trees, bushes shaken strongly. Moderate earth noises from southwest heard.

INTENSITY (DAMAGE) V: Aguanga, Banning, Big Bear City, Camp Pendleton (about 8 miles south of Fallbrook), Coachella, Corona, Coronado (San Diego area), Descanso, Elsinore, Fallbrook, Idyllwild, La Jolla, La Puente, Los Angeles, March Air Force Base (about 10 miles southeast of Riverside), Mountain Center, Oak Grove Ranger Station (about 7 miles southeast of Aguanga), Palomar Mountain and Palomar Observatory, Pearson area (about 15 miles southeast of Aguanga), Rancho Mirage, Riverside, Romoland, San Bernardino, Temecula, Thousand Palms, Valley Center, and Warner Springs.

INTENSITY (DAMAGE) IV: Alberhill, Alpine, Angelus Oaks, Apple Valley, Balboa, Boulevard, Cedar Glen, Colton, Compton, Downey, El Toro, Encinitas, Escondido, Fawnskin, Fullerton, Glendale, Indio, Julian, Laguna Beach, Lakeside, La Mirada, Leucadia, Long Beach, Maywood, Mira Loma, Morongo Valley, Mount Laguna, Mount Wilson, Newport Beach, Nightingale Camp (Pinon Flats, about 18 miles southeast of Mountain Center), Norco, Norwalk, Orange, Pala, Palos Verdes Peninsula, Pauma Valley, Pine Valley, Playa del Rey (about 2 miles south of Venice), Rainbow (about 6 miles northeast of Fallbrook), Ramona, Ranchita, Redlands, Running Springs, Salton Sea (north shore), San Clemente, San Diego, San Juan Capistrano, Santa Ana, Santa Ysabel, Seven Oaks, Solana Beach, Sunnymead, Tecate, Trabuco Canyon, Vista, and Yorba Linda.

INTENSITY (DAMAGE) I–III: Calimesa, Desert Hot Springs, Eagle Rock (about 5 miles west of Pasadena), Etiwanda, Huntington Park, Jacumba, La Habra, Lakeview, Los Alamitos, Mecca, Monrovia, Oceanside, Pomona, Potrero, Poway, San Fernando, Saugus, Silverado, Temple City, Twentynine Palms, and Yucca Valley.

October 8: 16:04. Wildomar. IV. Felt several in community (some outdoors; act[illegible] Trees, bushes shaken slightly. Sharp, shake with rapid motion; duration abo[illegible] seconds.

October 21: 17:18. Bucks Lake (Plu[illegible] County, about 19 miles southwest of Quinc[illegible] Very slight shock of 1 second duration.

October 25: 04.08*. Epicenter 37°44′ north, 122°33′ west, B. Magnitude 2.3 San Francisco. V. Press reported a sharp, brief shock awakened thousands of persons. Police reported the Hall of Justice switchboard was flooded with calls. Sharpest effects were reported from the Ingleside, Parkside, Richmond, Seacliff, and Sunset districts, where it was described as like a sonic boom without the sound.

October 27: 06:50:19.7*, 06:56:55.0*, 10:12:49.2*, and 10:22:05.3*. Epicenter of first shock, 33.1° north, 115.6° west; of second, 33.0° north, 115.7° west; of third, 33.2° north, 115.7° west; of fourth, 33.0° north, 115.7° west, W. Magnitudes 4.3 (CGS), 4–4¼ (P), 4¼ (P), and 4.5 (CGS), respectively. Niland. All four shocks reported felt at Niland. *(BSSA, April 1964.)* Press reported Niland was the only place to report feeling the series of shocks. Man in cafe reported feeling several strong shakes about 07:00.

November 18: 01:31:35*. Epicenter 36°26′ north, 120°21′ west, B. Magnitude 3.2. IV. At the Walti Ranch (about 15 miles northeast of San Miguel, in Slack Canyon), felt by several in home. Windows and doors rattled; house creaked. Slow, 3-second shock; faint earth noises heard. Slight shake felt at Five Points.

November 18: 06:38:28.9*. Epicenter 29.9° north, 113.6° west, Gulf of California, W. Magnitude 5.7. San Diego. III. Press reported the shock was felt by some persons. Hanging objects swung. Rapid motion in northeast direction.

November 20: 17:14. Buttonwillow (1 mile east of, PG&E Midway Substation). III. Rapid, 3–5 second shock felt by observer.

November 21: 04:43:50*. Epicenter 37°13′ north, 122°03′ west, B. Magnitude 3.3. Felt over a small area of the coastal region of Santa Cruz and northern Monterey counties. IV. At Ben Lomond, awakened and frightened few; windows rattled; walls creaked; hanging objects swung. Rapid, 10-second shock. Awakened few at Mount Hermon. Also felt at Castroville and Santa Cruz.

November 21: 11:45. Felton. IV. Windows and doors rattled.

November 27: (no time given). Felt at Hollister.

November 29: 12:49:34.3*. Epicenter 36.8° north, 121.5° west, W. Magnitude 4.5. Hollister (7½ miles south of, Harris Ranch). IV. Felt by some in home. Windows rattled; walls creaked.

November 30: 15:00 (about). Hollister (7½ miles south of, Harris Ranch). IV. Felt by some in home. Windows rattled; walls creaked.

December 1: 07:10 (about). Hollister (7½ miles south of, Harris Ranch). IV. Felt by some in home. Windows rattled; walls creaked.

December 6: 00:34:24*. Epicenter 37°33′ north, 118°41′ west, B. Magnitude 4.4. Felt over an area of approximately 10,000 square miles of east-central California and western Nevada. Maximum intensity (damage) VI. Damage slight. Plaster cracked at Bishop and in the Paradise area (about 15 miles northwest of Bishop); 230 kv transformer bushing cracked at Bishop.

INTENSITY (DAMAGE) VI:

Bishop.—Felt by and awakened many in community; frightened few. Damage slight. Plaster cracked; 230 kv transformer bushing cracked. Slow and rapid motion in east-west direction; duration 1–3 seconds; moderate earth noises heard.

Paradise area (about 15 miles northwest of Bishop).—Felt by, awakened, and frightened all in community. Damage slight. Plaster cracked. Small objects and furnishings shifted; small objects overturned. Trees, bushes shaken moderately. Rapid motion; moderate earth noises heard.

INTENSITY (DAMAGE) V: Benton Inspection Station (near Benton), Big Creek, Deep Springs, Friant, Long Valley Dam (about 25 miles northwest of Bishop), Miramonte, Round Valley (about 12 miles northwest of Bishop), and Tom's Place (on Highway 395 about 20 miles northwest of Bishop).

INTENSITY (DAMAGE) V IN NEVADA: Dyer.

INTENSITY (DAMAGE) IV: Auberry, Balch Powerhouse and Camp (PG&E, NE¼, Sec. 12, T12S, R26E, nearest town, Trimmer), Bass Lake, Dunlap, Keeler, Kings Canyon National Park (Grant Grove), North Fork and North Fork PG&E Powerhouse No. 2, Reedley, Sequoia National Park (Ash Mountain), Tinemaha Reservoir (about 10 miles south of Bigpine), Tollhouse, Wishon, and Yosemite National Park (Park Headquarters).

INTENSITY (DAMAGE) I–III: Fresno, Kingsburg, Lone Pine, and Oakhurst.

December 6: 05:54:22*. Epicenter 36.4° north, 118.2° west, W. Magnitude 4.1. IV. At Lone Pine, felt by many. Reported as stronger than shock at 00:34:24*. Also felt at Keeler.

December 13: 18:48. San Diego. IV. Press reported many telephone calls were received at newspaper office and police station from many sections of the city, including the downtown district. Chair wobbled at police station. Explosivelike motion then rumble; to observer on Point Loma, motion felt like it was directly underneath.

December 19: 10:15. IV. At Fort Ross, felt by several. Porch furniture rattled. Moderately loud rumbling earth noises from west heard. Windows rattled 9 miles north of Fort Ross; felt by two; rumblings heard. Also felt at Santa Rosa. Two rumbling sounds heard at Sebastopol.

December 30: 05:47:08.2*. Epicenter 38.8° north, 122.9° west, W. Magnitude 4.7. Felt over an area of approximately 800 square miles of Lake County, principally in the Clear Lake area. Maximum intensity (damage) V. One report of slight plaster cracking at Seigler Springs.

INTENSITY (DAMAGE) V:

Clearlake Highlands.—Felt by and awakened all in community; frightened few. Few small objects shifted. Rapid motion; loud earth noises from northeast-southwest heard by many.

Clearlake Oaks.—Felt by most in community; awakened all in home. Small objects shifted. Rapid, 5-second shock in east or southeast direction; loud earth noises from west or northwest heard.

Glenhaven.—Felt by and awakened many; frightened all in home. Small objects shifted. Rapid, 3-minute shock; moderate earth noises heard.

Lower Lake.—Felt by and awakened many;

frightened few. Windows, doors, and dishes rattled; house creaked. Hanging objects swung. Slow, 2-second shock; moderate earth noises heard.

Lucerne.—Awakened many in community. Dishes rattled. Trees, bushes shaken slightly. Rapid motion; faint earth noises heard by few.

Seigler Springs.—Felt by and awakened all in community; frightened many. Plaster cracked slightly. Slow motion; duration several seconds; moderate earth noises heard by many.

INTENSITY (DAMAGE) IV: Anderson Ranch (about 10 miles northwest of Seigler Springs), Finley (about 12 miles northwest of Seigler Springs), Kelseyville, and Middletown.

INTENSITY (DAMAGE) I–III: Barlett Springs (near) and Upper Lake.

WASHINGTON AND OREGON

(120TH MERIDIAN OR PACIFIC STANDARD TIME)

January [illegible]4: 13:43:11.8*. Epicenter 47°23′ north, 122 [illegible]6′ west, 2 miles due west of Maple Valley, Wash., S. Felt over an area of approximately 5,500 square miles of western Washington. Maximum intensity (damage) VI. Damage slight. Plaster and walls cracked at Maple Valley and Tacoma.

INTENSITY (DAMAGE) VI:

Lake Desire (about 7½ miles southeast of Renton and about 2 miles west and 1 mile north of the epicenter).—Observer ran outdoors. Everything movable moved; refrigerator moved north-south; objects fell from shelves and table; cupboard doors opened; power pole swayed; trees trembled. Motion north-south. "This was the sharpest shock I have ever felt and I am familiar with earthquakes, having been reared in California."

Maple Valley.—Felt by all except persons driving cars; frightened few in community. Plaster and wall cracks at grocery store; ceiling joists danced; canned goods and glassware fell to floor. Trees, bushes shaken moderately. Rapid, 10–15 second shock; moderate earth noises from east heard by many.

Tacoma.—Felt by many and frightened few in community. Damage slight. Plaster and walls cracked. Small objects and furnishings shifted. Rapid motion in all directions; duration as long as 1 minute; moderate earth noises heard by many 1 second before shock.

INTENSITY (DAMAGE) V: Buckley, Carbonado, Fall City, Issaquah, Kenmore, Kent, McMillin, Orillia, Orting, Pacific, Portage, Preston, Renton, Snoqualmie Falls, and Tukwila.

INTENSITY (DAMAGE) IV: Alderton, Algona, Baring, Black Diamond, Bremerton, Burton, Carnation, Cumberland, Dash Point, Des Moines, Dockton, Eglon, Elbe, Gig Harbor, Harper, Index, Indianola, Kapowsin, Kennydale, Keyport, Kirkland, Kosmos, Lester, Manchester (Manchester Naval Base), Medina, Mercer Island, Midway, Milton, North Bend, Palmer, Port Orchard, Puyallup, Ravensdale, Redmond, Retsil, Riffe, Rollingbay, Seahurst, Seattle, Selleck, Silverdale, Skykomish, Snoqualmie, South Prairie, Spanaway, Sultan, Sumner, Vashon (Ellisport), Wauna, Wilkeson, Woodinville, and Yelm.

INTENSITY (DAMAGE) I–III: Alder, American Lake (U.S. Veterans Hospital), Ashford, Auburn, Burley, Centralia, Cougar, Duvall, Eatonville, Ellensburg, Enumclaw, Fort Steilacoom, Gorst, Graham, Hoodsport, Kingston, La Grande, Lilliwaup, Longmire, Olalla, Port Gamble, Roslyn, Salkum, Seabeck, South Cle Elum, South Colby, Southworth, Suquamish, Tenino, Troutlake (Trout Lake Valley), Union, and Vail.

January 24: 13:54. Lake Desire, Wash. (about 7½ miles southeast of Renton). IV. Cupboard door rattled.

January 24: 22:35. La Grande, Wash. III. Slight shock reported felt with about same effects as the shock at 13:43:11.8*.

January 30: 05:50. Longmire, Wash. IV. Felt by several; awakened few. Motion slow.

March 2: 08:30*. Portland, Oreg. IV. Press reported a sharp earthquake, apparently centering in the city, rattled the Portland area. No damage was reported.

March 7: 15:53:25.0*. Epicenter 44.9° north, 123.5° west, northwestern Oregon, west of Salem, W. Magnitude 4.6. Press reported the earthquake, described as minor, was felt from Portland south to Eugene, a distance of about 110 miles, and in some coastal areas. Maximum intensity (damage) V. Only damage reported was a few instances of slight plaster cracks and broken dishes in the west Salem area.

INTENSITY (DAMAGE) V:

Salem.—Felt by many; few alarmed. Few persons reported slight plaster cracks in the west Salem area. Trembling motion with rapid onset.

INTENSITY (DAMAGE) IV: Corvallis, Elmira (about 10 miles west of Eugene), Eugene, and Junction City (about 15 miles north of Eugene).

INTENSITY (DAMAGE) I–III: Portland.

September 5: 07:55. Swift Dam Powerhouse (about 5½ miles east of Cougar, Wash.). One slight tremor felt.

October 22: 10:43. Swift Dam Powerhouse (about 5½ miles east of Cougar, Wash.). Loud rumble heard.

December 21: 18:54:01.9*. Epicenter 48°20′ north, 119°20′ west, about 10 miles southeast of Omak, Wash., S. Magnitude 4.4. Felt over an area of approximately 3,000 square miles of Okanogan County, Wash. Maximum intensity (damage) V. No damage was reported.

INTENSITY (DAMAGE) V:

Loomis.—Felt by all and frightened few in community. Windows and doors rattled; hanging objects swung. Slow, 25-second shock; moderate earth noises heard.

Malott.—Felt by all. House creaked. Rapid, 45-second shock; moderate earth noises heard by many 10 seconds before shock.

Okanogan.—Felt by all. Hanging objects swung. Slow motion; duration 30 seconds; moderate earth noises heard.

Omak.—Felt by several. Small objects shifted; chair seemed to move up and down. Christmas tree shaken moderately. Rapid, vertical, 10–15 second shock; loud earth noises heard by many 1–2 seconds before shock.

Synarep.—Felt by all. Doors rattled. Motion rapid; duration 2–3 minutes; loud earth noises heard by many.

INTENSITY (DAMAGE) IV: Brewster, Carlton, Conconully, Mazama, Methow, Nighthawk, Riverside, Twisp, Wauconda, and Winthrop.

INTENSITY (DAMAGE) I–III: Elmer City (about 5 miles northeast of Coulee Dam).

December 26: 18:36:21.6*. Epicenter 45.7° north, 123.4° west, northwestern Oregon, W. Magnitude 4.5. Felt over an area of approximately 4,000 square miles of northwestern Oregon and southwestern Washington. Maximum intensity (damage) VI. Damage slight. Plaster cracked at few places.

INTENSITY (DAMAGE) VI IN OREGON:

North Plains.—Damage slight. Plaster cracked. Small objects and furnishings shifted. Rapid motion.

Tillamook-Portland Highway.—Car swayed and went to opposite side of highway before being controlled (fill section of highway).

Timber.—Felt by all and frightened many in community. Damage slight. Plaster cracked. Small objects shifted; trees, bushes shaken moderately. Loud earth noises heard by many.

INTENSITY (DAMAGE) VI IN WASHINGTON:

Toutle.—Felt by five of six persons contacted by observer. Damage slight. Plaster cracked. Small objects shifted; books and pictures fell off piano. Indoor plants swayed strongly.

INTENSITY (DAMAGE) V IN OREGON: Nehalem, Rockaway, Seaside, and Warrenton.

INTENSITY (DAMAGE) VI IN WASHINGTON: Longview.

INTENSITY (DAMAGE) IV IN OREGON: Astoria, Brownsmead, Buxton (near, rural area), Clifton, Columbia City, Deer Island, Manzanita, Tolovana Park, Vernonia, Westport, and Wheeler.

INTENSITY (DAMAGE) IV IN WASHINGTON: La Center and Woodland (2 miles northeast of).

INTENSITY (DAMAGE) I–III IN OREGON: Arch Cape, Banks, Cannon Beach, Goble, Roy, and Scappoose.

INTENSITY (DAMAGE) I-III IN WASHINGTON: Brush Prairie, Castle Rock, Swift Dam Powerhouse (about 5½ miles east of Cougar), Underwood, and Vancouver.

ALASKA

(150TH MERIDIAN OR ALASKA STANDARD TIME)

March 13: 14:32. Felt at Homer. Slight tremor.

March 24: 10:35. Felt on Adak.

March 29: 03:29:30*. Felt at Valdez.

April 1: 12:56:57*. Felt at Umnak. Light tremor.

April 3: 06:05. Felt at Valdez.

April 10: 14:13:44.3*. Epicenter 51.9° north, 176.2° west, Andreanof Islands, Aleutian Islands, depth about 70 km, W. Magnitude 4.4. Felt on Adak.

April 28: 05:15. Felt at Valdez.

April 29: 22:46. Felt on Adak.

April 30: 14:07. Felt on Adak.

May 3: 06:57. Felt on Adak.

May 7: 03:08. Felt on Adak.

May 7: 22:50:56.0*. Epicenter 54.9° north, 163.9° west, Fox Islands, Aleutian Islands, depth about 89 km, W. Magnitude 5.6. Cold Bay. IV. Felt by several. Loose objects rattled; windows and lampshades trembled slightly. Abrupt onset; trembling motion.

May 12: 10:08:43.0*. Epicenter 57.4° north, 153.9° west, Kodiak Island, depth about 80 km, W. Magnitude 5.9. Slight tremor reported at Wide Bay. Lazy Bay reported a sharp tremor; duration, 10 seconds.

June 22: 17:00. Felt at Homer. "Started as a loud sound and was followed by a lot of vibration. Lasted about 3 minutes."

June 23: 18:26:37.9*. Epicenter 59.5° north, 151.7° west, Cook Inlet, depth about 52 km, W. Magnitude 6¾ (Pas). Maximum intensity (damage) VII at Barbara Point (5 miles north of Seldovia), Homer, and Seldovia where slight damage was reported.

MAXIMUM INTENSITY (DAMAGE) VII:

Barbara Point.—Felt. "Almost everything fell from shelves in frame home." Two hundred pound shaft fell. Heavy pulleys were shaken off nails. Moved 6000 pound fireplace slab 6 inches. Cracked concrete foundation and sill. Rocks and tree broke loose from bluffs. Preceded by dull roar which became very loud. "21 aftershocks felt."

Homer.—Felt by all; many frightened. Posts torn from ground. Ceiling plaster cracked and ceiling beam burst. Hauling trailer "tossed around" for 3 minutes. "Tore kitchen stove apart." Knickknacks and books fell; dishes broken. Pendulum clock stopped. Earth noises from southwest heard 5 seconds before beginning of earthquake. Rapid onset; duration, 40 seconds.

Seldovia.—Felt by all; many frightened. Brick chimney toppled. Clouds of dust observed from rockslides. Operator of small cruiser in Seldovia Bay said he thought he had hit something in water when tremor began. Two hundred cases of canned goods fell from shelves in store. Small objects and furnishings overturned; some broken. Buildings creaked. Rapid onset; duration, 1 minute.

INTENSITY (DAMAGE) V:

Anchorage.—Felt by all. Buildings creaked; loose objects rattled. Poles and towers swayed. Rapid onset; swaying motion, north-south.

Homer (5 miles northwest of).—Felt by all. Small objects shifted and overturned. Houses shook; loose objects rattled. Hanging objects swung north-south. Rapid onset; duration, 45 seconds. 6 aftershocks.

INTENSITY (DAMAGE) IV:

Cordova.—Felt by several. Light fixtures swayed. Disturbed objects observed. Gradual onset; swaying motion, north-south.

June 24: 06:25. Juneau. IV. Felt by several. Houses shook; loose objects rattled. Trembling motion.

July 7: 16:15:05.9*. Epicenter 57.0° north, 134.5° west, southeastern Alaska, depth about 28 km, W. Magnitude 3.7. Felt at Sitka and Baranof.

July 26: 23:56. Felt at Umnak. Slight tremor.

August 10: 10:03:39.2*. Epicenter 49.6° north, 179.2° east, Rat Islands, Aleutian Islands, depth about 33 km, W. Magnitude 4.3. Felt on Adak.

August 14: 21:48. Felt on Adak.

September 1: 05:30. Felt at Trim's Camp.

September 28: 16:04. Felt at Homer.

October 21:34:33*. Felt on Adak.

October 18:26. Felt at Puntilla.

October 12: 08:09:59*. Felt at Mile 1202 Alaska Highway.

October 14: 23:26:09.4*. Epicenter 59.0° north, 136.8° west, southern Alaska, depth about 33 km, W. Magnitude 4.3. Two quakes felt at Juneau; four felt at Gustavus (50 miles west). No details.

October 15: 23:26:18*. Felt at Linger Longer.

October 17: 16:34. Felt on Adak.

October 17: 22:05:22.1*. Epicenter 62.6° north, 146.6° west, central Alaska, depth about 51 km, W. Magnitude 4.2. Felt at Talkeetna.

October 23: 18:15:37*. Felt at Moose Creek. Slight tremor.

November 4: 12:20. Felt at Manley Hot Springs. Medium quake; duration, 15 seconds.

November 4: 12:38. Felt at Manley Hot Springs. Light quake; duration, 4 seconds.

December 4: 16:27. Felt on Adak.

December 7: 18:18:30*. Fairbanks. IV. Felt by many. Loose objects rattled; buildings creaked. Moderately loud, bumping earth noises heard. Several disturbed objects observed. Gradual onset, then abrupt jolt. Swaying motion, east-west. At College, buildings and ground trembled. Glass fell off shelf on east wall; chairs rocked. Thunderous, rumbling earth sounds heard. Also felt at Fort Wainwright.

December 8: 22:51:05*. Felt at College.

December 11: 06:08:12.3*. Epicenter 51.2° north, 179.3° west, Andreanof Islands, Aleutian Islands, depth about 32 km, W. Magnitude 5.3. Felt on Adak.

December 20: 09:30. Felt at Moose Creek. Slight tremor.

December 23: 07:15. Felt at Moose Creek. Slight tremor.

HAWAII

(150TH MERIDIAN OR HAWAIIAN STANDARD TIME)

NOTE.—Data on the following local disturbances were determined from seismograph stations on the islands of Hawaii and Maui by the Hawaiian Volcano Observatory of the U. S. Geological Survey. For additional information see the Hawaiian Volcano Observatory Summary 29 through 32.

January 8: 09:39:44.9*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt Island-wide and on Maui and Oahu. Magnitude 4.3.

January 8: 15:41:06.2*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt Island-wide. Magnitude 4.2.

January 9: 04:36:24.0*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt in Kilauea region. Magnitude 3.2.

January 9: 09:23:08.9*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt on southern half of Island. Magnitude 3.1.

January 23: 06:12:41.0*. Epicenter 19°27.0′ north, 155°52.8′ west, 10 km southeast of Pahoa at a depth of 8 km. Felt on eastern sector of Island. Magnitude 2.8.

February 27: 15:44:28.5*. Epicenter 20°08.4′ north, 155°50.6′ west, 18 km northwest of Kamuela at a depth of 12½ km. Felt at Kamuela. Magnitude 2.9.

February 28: 11:21:50.8*. Epicenter 19°26.8′ north, 155°00.1′ west, 8 km southwest of Pahoa at a depth of 8 km. Felt at Pahoa. Magnitude 2.1.

March 1: 01:48:26.6*. Epicenter 19°19.8′ north, 155°45.0′ west, 17 km southeast of Hookena at a depth of 3 km. Felt in south Kona. Magnitude 3.2.

March 6: 02:23:55.1*. Epicenter 19°28.5′ north, 154°54.9′ west, 5 km southeast of Pahoa at a depth of 5 km. Felt at Pahoa. Magnitude 2.8.

March 6: 05:46:14.3*. Epicenter 19°28.5′ north, 154°54.9′ west, 5 km southeast of Pahoa at a depth of 5 km. Felt at Pahoa. Magnitude 2.9.

March 11: 10:06:25.0*. Epicenter 19°57.0′ north, 155°21.9′ west, 15 km west-southwest of Laupahoehoe at a depth of 8 km. Felt at Hilo. Magnitude 2.6.

March 13: 10:57:26.9*. Epicenter 19°24.2′ north, 155°30.0′ west, 15 km southwest of Mauna Loa seismometer at a depth of 5 km. Felt on southern half of Island. Magnitude 3.5.

March 15: 18:10:07.0*. Epicenter 19°31.0′ north, 155°03.3′ west, 11 km northwest of Pahoa at a depth of 8 km. Felt at Pahoa. Magnitude 2.7.

March 22: 10:59:40.5*. Epicenter 19°32.6′ north, 155°49.9′ west, 10 km east-northeast of Kealakekua at a depth of 12½ km. Felt Island-wide. Magnitude 3.8.

March 24: 22:31:51.8*. Epicenter 19°47.0′ north, 155°33.8′ west, 14 km southeast of Waikii at a depth of 12½ km.. Felt on islands of Hawaii and Maui. Magnitude 4.5.

March 25: 06:57:05.6*. Epicenter 19°28.7′ north, 155°48.5′ west, 13 km east-southeast of Kealakekua at a shallow depth. Felt at Kealakekua. Magnitude 2.7.

March 25: 07:18:35.0*. Epicenter 20°47′ north, 156°14′ west, 3 km northeast of Haleakala seismograph at a depth of 35 km. Felt on Maui. Magnitude 3.9.

March 28: 13:08:27.1*. Epicenter 19°47.9′ north, 155°34.6′ west, 8 km northwest of Pohakuloa at a depth of 8 km. Felt at Kamuela. Magnitude 2.6.

March 31: 16:35:57.5*. Epicenter 20°01.0′ north, 155°52.9′ west, 6 km southwest of Kawaihae at a depth of 8 km. Felt at Kamuela. Magnitude 3.7.

April 7: 08:24:14.8*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Hilo and Pahala. Magnitude 3.3.

April 27: 01:49:38.4*. Epicenter 19°32.8′ north, 155°14.8′ west, 15 km north-northeast of Uwekahuna seismograph at a depth of 15 km. Felt on southern half of Island. Magnitude 3.4.

May 4: 16:11:25.0*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt on southern half of Island. Magnitude 3.4.

May 9–12: Beginning at approximately 20:50:00, accompanying the summit subsidence of Kilauea, several thousand small shallow earthquakes occurred, about 12 of which were mildly felt in the Kilauea summit region.

May 19: 02:21:25.5*. Epicenter 19°14.7′ north, 155°31.1′ west, 6 km northwest of Pahala at a depth of 8 km. Felt on southern half of Island. Magnitude 3.9.

May 20: 04:11:16.0*. Epicenter 19°14.3′ north, 155°31.6′ west, 7 km northwest of Pahala at a depth of 8 km. Felt at Pahala. Magnitude 2.8.

May 31: 00:09:40.2*. Epicenter 19°26.5′ north, 155°36.5′ west, 9 km southwest of Mauna Loa seismometer at a depth of 8 km. Felt at Pahala and in Kilauea summit region. Magnitude 3.3.

June 1: 02:45:04.8*. Epicenter 19°33.6′ north, 155°55.7′ west, 5 km north of Kealakekua at a depth of 3 km. Felt at Kealakekua. Magnitude 2.7.

June 6: 19:19:40.8*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt in Kilauea summit region. Magnitude 2.8.

June 6. 22:25:38.8*. Epicenter 19°11.9′ north, 155°33.1′ west, 15 km north-northeast of Naalehu at a depth of 3 km. Felt on southern half of Island. Magnitude 4.2.

June 14: 11:17:57.0*. Epicenter 19°26.2′ north, 155°16.7′ west, 2 km northeast of Uwekahuna seismometer at a depth of 30 km. Felt at Kulani, north Kona, and in Kilauea summit region. Magnitude 3.7.

July 1–5: Accompanying summit subsidence of Kilauea, thousands of earthquakes of magnitudes ranging from ½ to 3½ occurred near the summit region, along the upper east rift of Kilauea and along adjacent fault systems southward from the caldera. Several of these earthquakes were felt in the Kilauea summit region.

July 7: 01:42:19.0*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt in Kilauea summit region. Magnitude 2.8.

July 10: 16:32:44.0*. Epicenter 19°55.5′ north, 155°28.8′ west, 18 km south-southwest of Honokaa at a depth of 12½ km. Felt at Kamuela. Magnitude 3.4.

July 11: 01:39:26.0*. Epicenter 19°16.5′ north, 155°16.2′ west, 12 km south of Ahua seismometer at a depth of 8 km. Felt in Kilauea summit region. Magnitude 3.3.

July 11: 02:43:57.5*. Epicenter 19°15.2′ north, 155°10.1′ west, 3 km east-southeast of Apua Point at a depth of 3 km. Felt at Hilo and in Kilauea summit region. Magnitude 3.8.

July 11: 03:10:14.7*. Epicenter 19°22′ north, 155°14′ west, 2 km south of Aloi crater at a depth of 3 km. Felt at Hilo and in Kilauea summit region. Magnitude 3.5.

July 18: 11:27:46.0*. Epicenter 19°22.0′ north, 155°52.3′ west, 18 km south-southwest of Kealakekua at a depth of 8 km. Felt at Honaunau. Magnitude 3.3.

August 1: 01:10:52.4*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt at Glenwood and in Kilauea summit region. Magnitude 2.9.

August 3: Accompanying small Kilauea subsidence, several shallow earthquakes were feebly felt in the Kilauea summit region.

August 4: 08:53:35.3*. Epicenter 20°02.3′ north, 155°18.8′ west, 9 km northwest of Laupahoehoe at a depth of 12½ km. Felt at Kamuela. Magnitude 3.4.

August 8: 16:14:20.8*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt in Kilauea summit region. Magnitude 3.3.

August 14: 05:25:38.1*. Epicenter 21°28′ north, 158°06′ west, Waianae Mountains near Kolekole Pass, Oahu at a depth of 30 km. Felt by several at Makaha and Waianae where moderate earth noises were heard and loose objects rattled. Also felt at Kahaluu. Magnitude 3.5.

August 26: 08:49:17.6*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt Island-wide. Magnitude 4.9.

August 26: 09:48:23.3*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala and in Kilauea summit region. Magnitude 3.1.

August 26: 21:35:00.0*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala and Naalehu. Magnitude 3.3.

August 28: 05:14:03.8*. Epicenter 19°29.8′ north, 155°56.0′ west, 3 km southwest of Kealakekua at a shallow depth. Felt at Kealakekua. Magnitude 2.7.

September 1: 11:31:15.1*. Epicenter 19°11.9′ north, 155°39.3′ west, 17 km northwest of Naalehu at a depth of 3 km. Felt at Pahala. Magnitude 3.3.

September 3: 12:54:30.6*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala. Magnitude 3.6.

September 3: 13:51:57.2*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala. Magnitude 3.0.

September 3: 18:25:04.5*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala. Magnitude 2.9.

September 4: 21:58:37.4*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt in Kilauea summit region. Magnitude 3.1.

September 6: 03:30:01.6*. Epicenter 19°29.1′ north, 156°02.9′ west, 15 km west-southwest of Kealakekua at a depth of 3 km. Felt at Kealakekua and Captain Cook. Magnitude 3.6.

September 11: 08:00:39.5*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt at Kapapala. Magnitude 3.2.

September 15: 02:22:58.3*. Epicenter 19°16.5′ north, 155°12.6′ west, 3 km northwest of Apua Point at a depth of 5 km. Felt in Kilauea summit region. Magnitude 2.9.

September 18: 08:07:57.5*. Epicenter 19°50.9′ north, 155°32.2′ west, 11 km north-northwest of Pohakuloa at a depth of 12½ km. Felt at Pohakuloa. Magnitude 3.5.

September 19: 06:23:23.7*. Epicenter 19°28.3′ north, 155°54.5′ west, 5 km south-southeast of Kealakekua at a depth of 3 km. Felt at Kona and Hilo. Magnitude 3.4.

September 21: 06:24:26.5*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt Island-wide. Magnitude 4.8.

September 22: 06:26:17.4*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt on southern half of Island. Magnitude 3.5.

September 22: 06:27:24.4*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt on southern half of Island. Magnitude 3.5.

September 24: 01:48:04.9*. Epicenter 19°26.6′ north, 154°57.1′ west, 6 km south-southwest of Pahoa at a depth of 5 km. Felt at Pahoa and Kapoho. Magnitude 3.4.

September 27: 17:09:24.7*. Epicenter 19°25.8′ north, 154°57.3′ west, 7 km south-southwest of Pahoa at a depth of 3 km. Felt at Pahoa. Magnitude 2.9.

September 28: 02:45:33.9*. Epicenter 19°21.8′ north, 154°56.1′ west, 6 km south of Pahoa at a depth of 3 km. Felt at Kapoho. Magnitude 3.0.

October 5–6: Kilauea east rift eruption was accompanied by several hundred small, shallow earthquakes and a continuous tremor.

October 6: 12:26:28.8*. Epicenter 19°21.8′ north, 155°09.5′ west, 3 km east of Makaopuhi crater at a depth of 10 km. Felt on southern half of Island. Magnitude 3.4.

October 7: 22:20:33.7*. Epicenter 19°12.5′ north, 155°10.5′ west, 7 km south-southeast of Apua Point at a depth of 5 km. Felt in Kilauea summit region. Magnitude 3.7.

October 8: 11:44:35.3*. Epicenter 19°18.6′ north, 155°05.1′ west, 45 km south of Hilo at a depth of 8 km. Felt in Kilauea summit region. Magnitude 3.3.

October 10: 20:02:18.2*. Epicenter 19°11.2′ north, 155°28.1′ west, 2 km southeast of Pahala at a depth of 35 km. Felt at Pahala. Magnitude 2.3.

October 11: 13:40:48.9*. Epicenter 19°15.4′ north, 155°20.1′ west, 11 km southeast of Desert seismometer at a depth of 3 km. Felt at Kapapala. Magnitude 2.6.

October 11: 16:52:47.8*. Epicenter 19°08.3′ north, 155°05.0′ west, 64 km south of Hilo at a depth of 8 km. Felt in Kilauea summit region. Magnitude 3.8.

October 15: 13:57:01.2*. Epicenter 19°24.1′ north, 155°17.1′ west, Kilauea summit region at a depth of 30 km. Felt at Kapapala. Magnitude 2.8.

October 18: 14:19:51.0*. Epicenter 19°12.5′ north, 155°20.9′ west, 13 km east of Pahala at a depth of 8 km. Felt at Pahala. Magnitude 2.9.

October 22: 19:08:11.7*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt in Kilauea summit region. Magnitude 3.2.

October 23: 10:24:06.4*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt Island-wide. Books fell from shelf in Hilo. Magnitude 5.3.

October 23: 11:24:47.0*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt on southern half of Island. Magnitude 3.8.

October 23: 12:36:16.9*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala. Magnitude 2.9.

October 23: 13:28:10.1*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala and in Kilauea summit region. Magnitude 2.7.

October 23: 18:25:28.6*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt on southern half of Island. Magnitude 3.5.

October 23: 20:52:57.6*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala. Magnitude 2.8.

October 24: 16:07:53.7*. Epicenter 19°24′ north, 155°25′ west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala. Magnitude 2.7.

October 25: 15:29:34.0*. Epicenter 19°24' north, 155°25' west, Kaoiki fault system at a depth of 5 km. Felt on southern half of Island. Magnitude 3.8.

October 26: 00:03:54.7*. Epicenter 19°24' north, 155°25' west, Kaoiki fault system at a depth of 5 km. Felt in Kilauea summit region. Magnitude 3.5.

October 26: 02:29:04.8*. Epicenter 19°24' north, 155°25' west, Kaoiki fault system at a depth of 5 km. Felt in Kilauea summit region. Magnitude 3.3.

October 26: 06:57:53.9*. Epicenter 19°24' north, 155°25' west, Kaoiki fault system at a depth of 5 km. Felt in Kilauea summit region. Magnitude 3.2.

October 29: 13:01:45.3*. Epicenter 19°17.5' north, 155°23.3' west, 6 km south of Desert seismometer at a depth of 30 km. Felt at Kapapala. Magnitude 3.3.

October 30: 12:57:04.2*. Epicenter 19°24.1' north, 155°17.1' west, Kilauea summit region at a depth of 30 km. Felt at Kapapala. Magnitude 2.7.

October 30: 14:02:22.7*. Epicenter 18°56.8' north, 155°22.8' west, 26 km southeast of Naalehu at a depth of 35 km. Felt at Pahala. Magnitude 3.0.

November 3: 21:23:25.4*. Epicenter 20°09.3' north, 155°27.0' west, 8 km north-northeast of Honokaa at a depth of 12½ km. Felt on half of Island. Magnitude 3.7.

November 5: 06:45:27.0*. Epicenter 19°24' north, 155°25' west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala and in Kilauea summit region. Magnitude 3.4.

November 14: 01:37:12.0*. Epicenter 19°24' north, 155°25' west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala and in Kilauea summit region. Magnitude 3.2.

November 14: 09:33:31.5*. Epicenter 19°24' north, 155°25' west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala. Magnitude 2.6.

November 15: 09:01:26.5*. Epicenter 19°24.1' north, 155°17.1' west, Kilauea summit region at a depth of 30 km. Felt on half of Island. Magnitude 3.8.

November 17: 11:16:14.0*. Epicenter 19°24' north, 155°25' west, Kaoiki fault system at a depth of 5 km. Felt at Kapapala. Magnitude 2.5.

November 29: 18:02:58.0*. Epicenter 19°20.1' north, 155°07.8' west, 12 km northeast of Apua Point at a depth of 8 km. Felt at Puna, Kulani and in Kilauea summit region. Magnitude 3.6.

December 9: 18:47:55.5*. Epicenter 19°53.1' north, 155°31.3' west, 26 km southeast of Kamuela at a depth of 8 km. Felt on half of Island. Magnitude 3.4.

PANAMA CANAL ZONE

(60TH MERIDIAN TIME)

September 5: 22:30:41.5*. Intensity (damage) I at Balboa Heights.

December 5: 07:29:49.4*. Epicenter 7.4° north, 77.3° west, Colombia, W. Depth about 33 km. Magnitude 4.7. Intensity (damage) I at Balboa Heights.

PUERTO RICO

(60TH MERIDIAN TIME)

March 18: 03:47:55*. Felt at Bayamon.

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 in 1963. The following are the results of surveys made in five areas along the San Andreas Fault in California:

Vicinity of Hayward.—The triangulation net in this area straddles two faults which are approximately parallel. The Haywards Fault crosses the middle of the area and the San Andreas crosses the western edge. Observed directions in the 1963 survey are in good agreement with observations made in 1951 and 1957. A least squares adjustment will be made of each set of observations to compare positions at each station in the net.

Winery Survey South of Hollister.—Four monuments forming a quadrilateral straddling the San Andreas Fault were established in 1957 and repeat surveys were made each year from 1959 through 1963. The surveys showed systematic right-lateral movement averaging 1.7 cm per year through 1961. The 1962 survey was in very close agreement with these observations, but between surveys of February 1962 and October 1963, the observations showed right-lateral movement of 1.3 cm per year.

Salinas River Valley.—In 1962, an area survey was established in the vicinity of San Benito County to extend the national control net. The western side of the area was connected to stations established in 1944 along the San Andreas Fault. Angles in the 1962 survey, involving lines crossing the fault approximately at right angles, failed to check the 1944 observations by 6–8 seconds of arc. In order to determine the extent of movement in this area, the 1944 net west of the fault was reobserved in 1963. This net extends from the 36th parallel northwesterly along the fault, a distance of about 60 miles. The results from adjustments of the 1944 and 1963 observations show right-lateral movement all along the fault. The magnitude of the movement is on the order of 2–3 cm per year.

San Fernando to Bakersfield.—The north-south part of this net extends to the north from San Fernando and crosses the San Andreas Fault a few miles west of Palmdale. Observations in 1963 are in close agreement with previous surveys in 1932 and 1952–53. Small changes in the observations do not indicate any significant movement.

The northern portion of the net extends to the east from Wheeler Ridge and crosses the Garlock and White Wolf faults. The original survey of this section was made in 1932, repeated in 1952, and again repeated in 1953 after the July 1952 earthquake. The results from adjustments of the 1952 and 1953 observations indicate left-lateral movement of 1–2 feet along the Garlock Fault. Observations of 1952 are in good agreement with those of 1932. The 1963 and 1953 results show small differences which are within the accuracy limits of the surveys. Future surveys of this area should indicate whether or not the small differences represent earth movement.

Cajon Pass.—Original surveys in this area were made in 1949 and it was resurveyed in the latter part of 1963. A comparison of the observations indicated irregular changes and recommendations were made to reobserve two adjacent quadrilaterals of previous surveys. This extension will be completed in the Spring of 1964.

Precise releveling was undertaken in the San Joaquin Valley along 653 miles of first-order and 827 miles of second-order lines as follows:

3 miles south of Stanford University via Palo Alto to Lick Siding.

Los Banos-Kettleman City area, Calif.

10 miles southwest of Kettleman City to 6 miles east of Simmler, Calif.

Blackwells Corner to Lost Hills, Calif.

2.6 miles south of Kettleman City via Buttonwillow to McKittrick, Calif.

Continuing changes in elevation were noted in several areas. Releveling of the lines in the Stockton-Sacramento area was begun in November 1963.

TIDAL DISTURBANCES OF SEISMIC ORIGIN

Four tsunamis, listed below, were reported in the Pacific during 1963; two were widely recorded and two were of local interest only.

An earthquake near the north coast of Taiwan on February 13 (24.5° north, 122.1° east), generated a tsunami with a 16-inch range at Hwalien.

Earthquakes in the Kurile Islands on October 13 (44.8° north, 149.5° east), and October 20 (44.7° north, 150.7° east), generated tsunamis that were widely recorded in the Pacific. Maximum amplitude of the October 13 tsunami was 13 to 16 feet over approximately 300 km of coastline in the Kurile Islands. Representative amplitudes elsewhere were: Acapulco, Mexico, 4.8 feet; Hokkaido, Japan, 4.0 feet; Crescent City, Calif., 3.0 feet; Avila, Calif., 3.0 feet; Attu, 2.4 feet; Midway, 2.0 feet; and Honolulu, Hawaii, 1.0 foot. The second tsunami had heights locally in the Kuriles of up to 50 feet. Other representative amplitudes of this tsunami were: Crescent City, Calif., 1.3 feet; Midway, 1.2 feet; and Kwajalein, 1.0 foot.

Following an earthquake on December 16 near the west coast of Sumatra (6.4° south, 105.4° east), a slight tsunami was reported at Labuan.

On February 7 a sea wave, probably caused by submarine landslides associated with a series of light shocks centered at 38°25′ north, 22°03′ east, caused considerable damage to coastal settlements on the Gulf of Corinth between Patras and Aiyion. Wave amplitudes were 8 to 10 feet.

A disturbance was reported from the Dixon Entrance region of the Queen Charlotte Islands during the night of March 30–31. The wave heights reached from 12 to 18 feet above high water and caused minor damage at Langara Island, Wiah Point, and Port Simpson. The disturbance was not recorded on any tide gage and was not reported from any other area. No correlation between this event and any seismic or atmospheric disturbance has been found.

FLUCTUATIONS IN WELL WATER LEVELS

INTRODUCTION

The following data are tabulated for the purpose of associating fluctuations in well water levels with earthquakes. The material was compiled by Robert C. Vorhis and made available by the Water Resources Division of the U. S. Geological Survey.

Similar data for 1943 were published by the Coast and Geodetic Survey in *United States Earthquakes,* 1943, and those for 1944 through 1949 appeared in *United States Earthquakes,* 1949. Data for the years subsequent to 1950 were published annually in *United States Earthquakes,* 1950 through 1962.

WELL DESCRIPTIONS

GEORGIA

Well No. 10G313, Mitchell County, 31°05′ north, 84°26′ west. Depth, unknown. Aquifer, Ocala limestone.

Well No. 143A, Chatham County, 32°00′ north, 81°50′ west. Depth, 386 feet. Aquifer, Ocala limestone.

Well No. 12–3, Dawson County, 34°22′ north, 84°10′ west. Owner, U. S. Geological Survey. Depth, 400 feet; depth of casing, 0–79.2 feet. Aquifer, mica schist and/or scattered quartzite veins.

Well No. 13L4, Dougherty County, 31°30′ north, 84°00′ west. Owner, U. S. Marine Corps Supply Center. Depth, 240 feet; diameter, 6 inches. Aquifer, Ocala limestone.

IDAHO

Well No. 14S–15E–28ba2, non-artesian, Twin Falls County, Rogerson, 42°11′ north, 114°43′ west. Owner, U. S. Bureau of Reclamation. Depth, 445 feet; diameter, 6 inches; depth of casing, 0–331 feet; finish, perforated 231–331 feet. Aquifer, sand, ash, and welded tuff; silicic volcanic rocks of Pliocene age.

Well No. 8S–23E–2ba1, Minidoka County, NE¼ NW¼ Sec. 2, T. 8S, R. 23E, 42°46′ north, 113°44′ west. Depth, 254 feet; depth of casing, 0–80 feet. Aquifer, Snake River group; basalt.

MICHIGAN

Well No. 5N12W4–7, Kent County, Sec. 4, T. 5N, R. 12W, 42°50′ north, 85°44′ west. Depth, 227 feet; depth of casing, 0–182 feet. Aquifer, Marshall formation of Mississippian age.

Well No. 3N9E36–1, Oakland County, Sec. 36, T. 3N, R. 9E, 42°38′ north, 83°12′ west. Depth, 134 feet. Aquifer, glacial drift.

Well No. 3N10E13–2, Oakland County, Sec. 13, T. 3N, R. 10E, 42°40′ north, 83°13′ west. Depth, 183 feet; depth of casing, 0–173 feet. Aquifer, glacial drift.

Well No. 3N10E31–1, Oakland County, Sec. 31, T. 3N, R. 10E, 42°38′ north, 83°12′ west. Depth, 173 feet; depth of casing, 0–153 feet. Aquifer, glacial drift.

Well No. 3N10E32–1, Oakland County, Sec. 32, T. 3N, R. 10E, 42°38′ north, 83°11′ west. Depth, 160 feet; depth of casing, 0–7 feet. Aquifer, glacial drift.

NEW JERSEY

Well Hillside 4, artesian, Union County. Owner, Elizabethtown Water Company. Depth, 400 feet; diameter, 12 inches; finish, rock, open hole. Aquifer, Brunswick shale.

Well County Park, Cape May County, 39°06′ north, 74°48′ west. Depth, 252 feet; depth of casing, 0–242 feet. Aquifer, Cohansey sand.

Well Esterbrook, artesian, Camden County, 39°57′00″ north, 75°07′30″ west. Owner, Esterbrook Pen Company. Depth, 300 feet; diameter, 6 inches; finish, cased to rock. Aquifer, Raritan formation; Cretaceous.

Well Hatfield, Union County, 40°37′ north, 74°16′ west. Depth, unknown. Aquifer, Brunswick shale.

Well Runyon 50, non-artesian, Middlesex County, 40°25′14″ north, 74°19′40″ west. Owner, Perth Amboy Water Works. Depth, 24 feet; diameter, 6 inches. Aquifer, Old Bridge sand; Raritan formation.

Well Wharton 2G, Atlantic County, 39°40′ north, 74°40′ west. Depth, 76 feet. Aquifer, Cohansey sand.

Well Whippany, artesian, Morris County, about 3 miles east of Whippany Power Plant, 40°49′00″ north, 74°23′00″ west. Owner, Jersey Central Power Company. Depth, 170 feet; diameter, 6 inches; finish, steel casing-screened. Aquifer, Wisconsin drift.

SOUTH CAROLINA

Well No. 46, artesian, on SAL RR 3 miles

south of Okatie, Jasper County, 32°17′ north, 81°58′ west. Owner, Seaboard Airline Railroad. Depth, 334 feet; diameter, 8 inches. Aquifer, Ocala limestone.

Well No. 101, Beaufort County, 32°10′ north, 80°44′ west. Depth, 69[illegible] feet; diameter, 1[illegible] inches. Aquifer, Ocala [illegible]stone.

Well No. 304, Beaufor[illegible]unty, 32°08′ north, 80°50′ west. Depth, 6[illegible]2 feet; diameter, 8 inches. Aquifer, Ocala limestone.

TABLE 1.—*Fluctuations in well water levels, January 1 through December 31, 1963*

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

ALASKA

County and Well No.	Date 1963	Time at Recorder G.M.T.	Depth to Water before Disturbance	Water Level Fluctuations		
				From Prequake Level		Double Amplitude
				Upward	Downward	
Anchorage, Anc 50	Oct. 13	09:00	58.35	0.21	0.31	0.52

FLORIDA

Dade, S19	Aug. 15	17:00	−0.54	0.01	0.03	0.04
Dade, S68	do	17:00	−2.25	.01	.01	.02
Broward, F291	do	17:00	+1.04	.03	.02	.05
Broward, G820	do	17:00	−1.54	.02	.07	.09
Dade, S19	Sept. 4	13:30	+0.78	.04	.07	.11
Dade, S68	do	13:30	−0.90	.02	.02	.04
Broward, G820	do	13:30	−0.84	.01	.02	.03
Dade, S19	Oct. 13	06:30	+0.90	.06	.07	.13
Dade, S68	do	06:30	−0.77	.01	.04	.05
Broward, S329	do	06:30	+3.81	.04	.04	.08
Broward, G820	do	06:30	+4.55	.20	.23	.43

GEORGIA

Dawson, 12-3	Aug. 3	11:00	25.87	.....	.....	trace
Dougherty, 13L4	do	11:00	40.00	0.01	0.01	0.02
Mitchell, 10G313	do	11:00	53.65	.01	.01	.02
Dawson, 12-3	Aug. 15	18:00	26.50	.01	.0	.01
Dougherty, 13L4	do	18:00	40.49	.02	.01	.03
Mitchell, 10G313	do	18:00	53.91	.04	.03	.07
Dougherty, 13L4	Aug. 29	15:00	41.06	.03	.0	.03
Dougherty, 13L4	Sept. 4	13:50	41.33	.01	.02	.03
Mitchell, 10G313	do	14:15	54.55	.01	.05	.06
Chatham, 63	Oct. 13	05:30	119.70	.15	.16	.31
Chatham, 99	do	06:00	88.27	.25	.25	.50
Chatham, 143A	do	05:30	32.96	.27	.26	.53
Chatham, 317	do	06:00	26.32	.17	.18	.35
Chatham, 382	do	05:30	108.51	.25	.20	.45
Dawson, 12-3	do	05:45	27.57	.20	.20	.40
Effingham, 7	do	06:00	17.46	.25	.25	.50
Dawson, 12-3	Oct. 20	02:00	27.79	.013	.012	.025
Mitchell, 10G313	do	01:30	55.90	.01	.01	.02
Dawson, 12-3	Nov. 9	21:30?	27.79	?	?	.022
Dawson, 12-3	Nov. 18	15:00	28.15	.005	.005	.01
Dougherty, 13L4	do	15:00	43.35	.025	.025	.05
Mitchell, 10G313	do	14:30	56.75	.05	.06	.11

See footnotes at end of table.

TABLE 1.—*Fluctuations in well water levels, January 1 through December 31, 1963*—Con.

IDAHO

County and Well No.	Date 1963	Time at Recorder G.M.T.	Depth to Water before Disturbance	Water Level Fluctuations		
				From Prequake Level		Double Amplitude
				Upward	Downward	
Madison, 7N-38E-23db1	Feb. 13	10:00	42.44	0.01	0.03	0.04
Madison, 7N-38E-23db1	Mar. 28	02:00	43.30	.09	.08	.17
Madison, 7N-38E-23db1	July 29	20:00	40.83	.03	.02	.05
Madison, 7N-38E-23db1	Aug. 29	14:00	40.30	.02	.03	.05
Madison, 7N-38E-23db1	Sept. 4	10:00	40.18	.06	.06	.12
Blaine, 1S-19E-3cc2	Oct. 13	06:30	11.51	.03	.03	.06
Cassia, 13S-21E-18bb1	do.	06:30	428.33	.07	.05	.12
Teton, 4N-45E-13ad1	do.	06:30	190.21	.13	.11	.24
Blaine, 1S-19E-3cc2	Nov. 18	14:30	11.27	.03	.04	.07
Butte, 3N-29E-14ad1	do.	14:15	458.81	.11	.09	.20
Jefferson, 7N-34E-4cd1	do.	14:00	15.87	.03	.04	.07
Jerome, 8S-19E-5da1	do.	14:00	270.10	.02	.02	.04
Madison, 7N-38E-23db1	do.	14:00	40.28	.19	.07	.26
Minidoka, 8S-23E-2ba1	do.	?	209.57	.03	.03	.06
Minidoka, 8S-24E-20db1	do.	?	154.20	.05	.07	.12
Teton, 4N-45E-13ad1	do.	?	194.84	.04	.04	.08
Twin Falls, 14S-15E-28ba2	do.	13:00	94.63	.02	.02	.04

INDIANA

Marion, 32	Mar. 26	10:30	9.661	0.01	0.002	0.012
Marion, 32	Mar. 28	00:30	9.760	.057	.041	.098
Pulaski, 6	do.	00:20	13.882	.005	.007	.012
Pulaski, 6	June 24	04:45	14.004	.002	.01	.012
Marion, 32	Sept. 4	13:30	13.49	.08	.04	.12
Marion, 32	Oct. 13	05:30	13.59	.32	.30	.62
Miami, 2	do.	05:30	38.35	.12	.06	.18
Parke, 5	do.	05:30	32.62	.12	.14	.26
Pulaski, 6	do.	05:30	18.861	.144	.08	.224
Marion, 32	Nov. 4	01:30	13.23	.03	.03	.06
Pulaski, 6	do.	01:45	19.024	.012	.024	.036
Marion, 32	Nov. 9	21:40	13.20	.03	.03	.06
Pulaski, 6	do.	21:35	19.165	.01	.006	.016
Marion, 32	Nov. 18	14:55	13.26	.06	.06	.12
Pulaski, 6	do.	14:50	20.53	.008	.022	.03
Pulaski, 6	Dec. 18	00:50	19.797	.007	.011	.018

MICHIGAN

Genesee, 7N7E17-1	Feb. 13	11.00	25.15	0.02	0.02	0.04
Kent, 5N12W4-7	do.	11:00	9.12	.005	.005	.01
Genesee, 7N7E17-1	Mar. 19	20:00	25.10	.03	.04	.07
Kent, 5N12W4-7	do.	20:00	9.365	.15	.15	.30
Oakland, 3N10E32-1	do.	20:00	124.98	.....	.15	.....
Oakland, 3N10E31-1	do.	20:00	124.25	.06	.06	.12
Oakland, 3N9E36-1	do.	20:00	98.35	.11	.12	.23
Oakland, 3N10E13-2	do.	20:00	85.18	.07	.07	.14
Genesee, 7N7E17-1	Mar. 28	00:00	25.480	.035	.045	.08
Kent, 5N12W4-7	do.	00:00	8.760	.015	.020	.035

See footnotes at end of table.

TABLE 1.—*Fluctuations in well water levels, January 1 through December 31, 1963*—Con.

NEVADA

County and Well No.	Date 1963	Time at Recorder G.M.T.	Depth to Water before Disturbance	Water Level Fluctuations		
				From Prequake Level		Double Amplitude
				Upward	Downward	
Clark, S19/60-9bcc1	Aug. 16	06:00	108.58	0.05	0.09	0.14
Clark, S19/60-9bcc1	Sept. 13	17:00	109.06	.15	.14	.29
Clark, S19/60-9bcc1	Sept. 17	20:45	109.30	.02	.03	.05
Clark, S19/60-9bcc1	Sept. 21	22:45	109.28	.01	.01	.02
Clark, S19/60-9bcc1	Oct. 13	06:30	108.61	.18	.17	.35
Clark, S19/60-9bcc1	Oct. 16	17:15	107.27	.01	.02	.03
Clark, S19/60-9bcc1	Nov. 4	02:45	107.93	.02	.02	.04
Clark, S19/60-9bcc1	Nov. 18	14:45	107.26	.16	.14	.30
Clark, S19/60-9bcc1	Nov. 23	07:30	106.56	.03	.04	.07

NEW JERSEY

Union, Hillside 4	Jan. 28	13:30	+25.17	0.01	0.03	0.04
Union, Hillside 4	Mar. 16	08:45	+22.43	.....	.....	trace
Camden, Esterbrook	Mar. 28	01:15	−5.14	.01	.01	.02
Union, Hillside 4	do.	00:30	+22.26	.02	.03	.05
Union, Hillside 4	May 19	22:10	+19.46	.02	.02	.04
Camden, Esterbrook	June 24	05:30	−6.32	.....	.01	.01
Morris, Whippany	do.	05:15	+174.65	trace	trace	trace
Union, Hatfield	do.	05:15	+13.09	.01	.....	.01
Union, Hillside 4	do.	05:10	+18.53	.02	.03	.05
Union, Hillside 4	Aug. 3	11:15	+22.19	.03	.02	.05
Union, Hillside 4	Aug. 15	18:15	+20.24	.01	.04	.05
Union, Hillside 4	Sept. 15	02:00	+21.33	.02	.04	.06
Union, Hillside 4	Sept. 17	20:50	+19.87	.04	.04	.08
Union, Hillside 4	Oct. 12	13:00	+22.21	.02	.04	.06
Atlantic, Wharton 2G	Oct. 13	06:00	+91.75	.005	.005	.01
Camden, Esterbrook	do.	06:25	−5.98	.05	.03	.08
Cape May, County Park	do.	06:00	+4.09	.01	.01	.02
Union, Hatfield	do.	06:00	+11.63	.01	.02	.03
Union, Hillside 4	do.	06:40	+23.27	.22	.23	.45
Union, Hillside 4	Oct. 20	01:45	+21.92	.03	.03	.06
Union, Hillside 4	Nov. 4	02:15	+22.11	.09	.06	.15
Union, Hillside 4	Nov. 18	15:00	+21.80	.05	.06	.11
Middlesex, Runyon 50	do.	15:00	+2.97	.04	.....	.04
Union, Hillside 4	Dec. 18	01:00	+20.23	.02	.01	.03

SOUTH CAROLINA

Beaufort, 101	Oct. 13	05:30	15.72	0.09	0.10	0.19
Beaufort, 304	do.	05:30	20.82	.15	.15	.30
Jasper, 46	do.	06:00	18.89	.09	.11	.20

+ Water surface above mean sea level.

— Water surface below mean sea level.

TABLE 2.—*Earthquakes of 1963 believed to have caused fluctuations in well water levels*

Date 1963	Origin Time G.M.T.			Epicentral Area	States Recording Fluctuations
	h	*m*	*s*		
Jan. 28	13	00	48.1	Alaska Peninsula	New Jersey
Feb. 13	08	50	04.5	Taiwan region	Idaho and Michigan
Mar. 16	08	44	51.1	Kurile Islands region	New Jersey
Mar. 26	09	48	20.3	Kermadec Islands	Indiana
Mar. 28	00	15	51.4	Iceland region	Idaho, Indiana, Michigan and New Jersey
May 19	21	35	47.0	North Atlantic Ridge	New Jersey
June 24	04	26	37.9	Cook Inlet, Alaska	Indiana and New Jersey
Aug. 3	10	21	36.6	Mid-Atlantic Ocean	Georgia and New Jersey
Aug. 15	17	25	05.9	Peru-Bolivia border	Florida, Georgia and New Jersey
Aug. 16	07	01	03.7	Northern Utah	Nevada
Aug. 29	15	30	31.4	Off coast of Peru	Georgia and Idaho
Sept. 1	13	32	12.3	Baffin Island region	Florida, Georgia, Idaho and Indiana
Sept. 13	17	00	00.1	Nevada Test Site	Nevada
Sept. 15	00	46	54.1	Santa Cruz Islands	New Jersey
Sept. 17	19	20	08.2	do.	Nevada and New Jersey
Sept. 22	00	50	36.1	Central Idaho	Nevada
Oct. 13	05	17	57.1	Kurile Islands	Alaska, Florida Georgia, Idaho, Indiana, New Jersey and South Carolina
Oct. 16	15	36	32.1	Central Idaho	Nevada
Oct. 20	00	53	07.2	Kurile Islands	Georgia and New Jersey
Nov. 4	01	17	08.9	Banda Sea	Indiana, Nevada and New Jersey
Nov. 9	21	15	30.4	Western Brazil	Georgia and Indiana
Nov. 18	14	38	28.9	Gulf of Mexico	Georgia, Idaho, Indiana, Nevada and New Jersey
Nov. 23	07	50	46.3	Gulf of California	Nevada
Dec. 18	00	30	02.6	Tonga Islands	Indiana and New Jersey

SEISMOLOGICAL OBSERVATORIES

The Summary of Instrumental Epicenters previously published in this report has been discontinued. The Coast and Geodetic Survey publishes the results of its teleseismic stations and cooperating stations in the monthly *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:

Albuquerque, N. Mex.
Balboa Heights, Canal Zone
(The Panama Canal Co.)
Boulder City, Nev.
(Bureau of Reclamation)
Bozeman, Mont.
(Montana State College)
Butte, Mont.
(Montana School of Mines)
Byrd, Antarctica
Chicago, Ill.
(University of Chicago and U.S. Weather Bureau)
College, Alaska
College-Outpost, Alaska
Columbia, S. C.
(University of South Carolina)
Eureka, Nev.
(Eureka Corporation Limited)
Flaming Gorge, Utah
(Bureau of Reclamation)
Glen Canyon, Ariz.
(Bureau of Reclamation)
Guam, Mariana Islands
Honolulu, Hawaii
Hungry Horse, Mont.
(Bureau of Reclamation)
Kipapa, Hawaii
Philadelphia, Pa.
(The Franklin Institute)
Rapid City, S. Dak.
(South Dakota State School of Mines and Technology)
Salt Lake City, Utah
(University of Utah)
San Juan, Puerto Rico
Sitka, Alaska
South Pole, Antarctica
Tucson, Ariz.
Ukiah, Calif.
(International Latitude Observatory)
Washington, D. C.

Albuquerque, Byrd, College, College-Outpost, Guam, Honolulu, Kipapa, San Juan, Sitka, South Pole, Tucson, Ukiah, and Washington are Coast and Geodetic Survey stations.

Balboa Heights, Boulder City, Bozeman, Butte, Chicago, Columbia, Eureka, Flaming Gorge, Glen Canyon, Hungry Horse, Philadelphia, Rapid City, and Salt Lake City are cooperating stations.

For detailed instrumental data regarding these stations, including instrumentation, constants, and other information, see *Seismological Bulletin,* MSI–277, January 1964. Those desiring to receive this publication as issued should request addition of their name to the CGS–7 mailing list.

TABLE 3.—*Principal earthquakes of the world from January through December 1963*

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) earthquakes of magnitude greater than 6¾ determined by Pasadena and earthquakes of smaller magnitudes which were locally destructive.

Date 1963	Origin Time G.M.T.			Region	Coordinates of Provisional Epicenter				Remarks
					Latitude		Longitude		
	h	*m*	*s*		°		°		
Feb. 13	08	50	04.5	Taiwan region	24.5	N.	122.1	E.	4 killed, 18 injured, and widespread but moderate damage in Taipei and Hsinchu. Seismic sea wave generated with 16-inch range at Hwalien. Depth about 47 km. Mag. 7¼.
Feb. 21	17	14	30.7	Near coast of Libya	32.6	N.	21.0	E.	Over 300 killed, 500 injured, and 10,000 homeless. Barce (El Marj) destroyed. Depth about 5 km. Mag. 5.3 (CGS).
Feb. 26	20	14	07.0	East New Guinea region	7.5	S.	146.1	E.	Depth about 156 km. Mag. 7¼–7½.
Mar. 16	08	44	51.1	Kurile Islands region	46.6	N.	154.8	E.	Felt on northern Hokkaido. Depth about 46 km. Mag. 7.
Mar. 26	09	48	20.3	Kermadec Islands region	29.7	S.	177.9	W.	Felt on Raoul Island. Depth about 48 km. Mag. 6¾–7.
Mar. 26	13	25	01.2	do	29.9	S.	178.0	W.	Depth about 40 km. Mag. 7¼.
Mar. 28	00	15	51.4	Iceland region	66.1	N.	20.1	W.	Slight damage and several injured in northern Iceland. Depth about 33 km. Mag. 7–7¼.
Mar. 31	02	27	06.5	Northeastern Iran	37.0	N.	57.9	E.	4 killed, several injured, and 100 homes destroyed in village of Hendojan. Depth about 33 km.
Apr. 13	02	20	57.9	Northern Peru	6.3	S.	76.7	W.	Depth about 125 km. Mag. 6¾–7.
Apr. 19	07	35	22.7	Tsinghai Province, China	35.7	N.	96.9	E.	Depth about 33 km. Mag. 7.
May 1	10	03	20.2	New Hebrides Islands	19.0	S.	168.9	E.	Felt. Depth 142 km. Mag. 7.
May 20	11	38	05.3	Kermadec Islands region	30.7	S.	178.3	W.	Depth about 68 km. Mag. 6¾–7.
July 26	04	17	12.5	Southern Yugoslavia	42.1	N.	21.4	E.	Approximately 1,028 killed, 4,038 injured. Skopje almost destroyed. Depth about 5 km. Mag. 5¾–6.
July 29	06	10	22.6	Southern Iran	27.8	N.	55.6	E.	5 killed, 8 injured, and 350 mud huts destroyed in Gahgum. Depth about 37 km. Mag. 5.2 (CGS).
Aug. 15	17	25	05.9	Peru-Bolivia border	13.8	S.	69.3	W.	Depth about 543 km. Mag. 7¾.
Aug. 22	19	52	25.0	Solomon Islands	9.4	S.	158.0	E.	Felt. Depth about 33 km. Mag. 6¾–7.
Sept. 2	01	34	31.6	Northern India	33.9	N.	74.7	E.	79 killed, 400 injured, and major property damage in Kashmir. Depth about 44 km. Mag. 5.1 (CGS).
Sept. 4	05	06	47.0	Near coast of Algeria	36.1	N.	5.3	E.	1 killed, 10 injured in Beghala village. Depth about 38 km. Mag. 5.2 (CGS).
Sept. 15	00	46	54.1	Santa Cruz Islands	10.3	S.	165.6	E.	Felt at Vanikoro, Luganville, and Honiara. Depth about 43 km. Mag. 7¼–7½.
Sept. 17	19	20	08.2	do	10.1	S.	165.3	E.	Felt in eastern Solomon Islands. Depth about 17 km. Mag. 7¼.
Sept. 18	16	58	12.5	Turkey	40.9	N.	29.2	E.	1 killed and several injured at Istanbul Depth about 33 km. Mag. 6¼.
Oct. 12	11	26	57.9	Kurile Islands	44.8	N.	149.0	E.	Depth about 40 km. Mag. 6¾–7.
Oct. 13	05	17	57.1	do	44.8	N.	149.5	E.	Felt on Hokkaido and Honshu, Japan. Tsunami generated with maximum amplitude of 13–16 feet over approximately 300 km of coastline in the Kurile Islands. Light damage to USN ship located at 44°29′ N., 152°01′ E. Depth about 60 km. Mag. 8¼.

See footnote at end of table.

TABLE 3.—*Principal earthquakes of the world from January through December 1963*—Con.

Date 1963	Origin Time G.M.T.	Region	Coordinates of Provisional Epicenter		Remarks
			Latitude	Longitude	
	h *m* *s*		°	°	
Oct. 20	00 33 07.2	Kurile Islands	44.7 N.	150.7 E.	Tsunami generated with wave heights locally in the Kurile Islands of up to 50 feet. Depth about 25 km. Mag. 6¾–7.
Nov. 4	01 14 33*	New Hebrides Islands	15.1 S.	167.3 E.	Widely felt. Depth about 154 km. Mag. 6¾–7.
Nov. 4.	01 17 08.9	Banda Sea	6.8 S.	129.6 E.	Slight damage at Darwin. Felt in western and northern Australia and Papua. Depth about 80 km.
Nov. 9.	21 15 30.4	Western Brazil	9.0 S.	71.5 W.	Depth about 600 km. Mag. 6¾–7.
Dec. 16.	01 51 30.6	Near west coast of Sumatra	6.4 S.	105.4 E.	Felt at Djakarta. Slight damage at Labuan and Menes. Small seismic sea wave reported at Labuan. Depth about 64 km. Mag. 6.0 (CGS).
Dec. 18	00 30 02.6	Tonga Islands	24.8 S.	176.6 W.	Felt in Tonga, Fiji and Kermadec Islands. Depth about 46 km. Mag. 7¼–7½.

* Indicates estimated accuracy of ½° in latitude and longitude and 50 km in depth.

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 Publication No. 41-2, *Earthquake Investigations in the Western United States, 1934-1964*. 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.

Interpretations of records.—The analyses appearing in Tables 6 and 7 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.

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.^{2} For practical purposes, it is only necessary to point off three decimal places to convert cm/sec.^{2} 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) residual clay and shale, 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 0.1 g.

Damping ratio of the pendulum is the ratio between successive amplitudes when the pendulum oscillates.

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 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 Environmental Science Services Administration, Coast and Geodetic Survey, Washington, D.C. 20235.

Acceleration and displacement scales representing the equivalent of 0.1 g. and 1 inch are indicated on the tracings of the acceleration and displacement curves. The scales provide the investigator with a quick means for making

rough measurements on the published curves. The measurements of period 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.—*Coast and Geodetic Survey strong-motion stations in operation as of Dec. 31, 1963*

NORTHERN CALIFORNIA

Station	Accelero-graph	Displacement Meter	Weed
Berkeley, University of California	1	1	
Chilcoot, Frenchman Reservoir	1		
Delta	1		
Eureka, Federal Building	1		
Ferndale, City Hall	1	1	
Hollister, Library	1	1	
Livermore, Bldg. 110, Vault D, basement	1		
Monterey, City Hall			1
Oakland, City Hall, basement	1	1	
Oakland City, Hall, 16th floor	1		
Oakland, Chabot Observatory			1
Oroville, Department of Water Resources Seismograph Station	1	1	
Pleasant Hill, Diablo Valley College	1	1	
Sacramento, Federal Building			1
San Francisco, Alexander Building, basement	1	1	
San Francisco, Alexander Building 11th floor	1		
San Francisco, Alexander Building 16th floor	1		
San Francisco, Bethlehem Pacific Building, basement	1	1	
San Francisco, Bethlehem Pacific Building, 12th floor	1	1	
San Francisco, 450 Sutter St., basement			1
San Francisco, 450 Sutter St., 29th floor			1
San Francisco, New Mint Building	1	1	
San Francisco, Shell Building, 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, State Building, basement	1	2	
San Jose, Bank of America, basement	1		
San Jose, Bank of America, 13th floor	1		
San Pablo, Contra Costa Junior College	1	1	
Suisun Bay Bridge	1		
Tracy, Pumping Plant, basement	1	1	

TABLE 4.—*Coast and Geodetic Survey strong-motion stations in operation as of Dec. 31, 1963*—Con.

SOUTHERN CALIFORNIA

Station	Accelero-graph	Displacement Meter	Weed
Bakersfield, Harvey Auditorium	1	1	
Bishop	1		
Cachuma Dam, Crest	1	1	
Cachuma Dam, Valve House	1	1	
Colton	1	1	
El Centro	1	2	
Fairmont Station	1	1	
Long Beach, Public Utilities Building	1	1	
Long Beach, Terminal Island	1		
Los Angeles, Edison Building	1		
Los Angeles, Hollywood Storage Co., basement	1		
Los Angeles, Hollywood Storage Co., penthouse	1		
Los Angeles, Hollywood Storage Co., adjoining P.E. lot	1		
Los Angeles, Occidental Life Building, basement	1		
Los Angeles, Occidental Life Building, 11th floor	1		
Los Angeles, Subway Terminal, sub-basement	1	1	
Los Angeles, Subway Terminal, 13th floor	1		
Los Angeles, Vernon, C.M.D.	1		
Los Angeles, Westwood Engineering Building, University of California	1	1	
Pasadena, California Institute of Technology	1		1
Port Hueneme, California Navy Laboratory	1	1	
San Bernardino, Federal Building			1
San Diego	1		
San Luis Obispo, City Recreation Building	1		
Santa Ana	1	1	
Santa Barbara, Court House	1		
Taft, Lincoln School Tunnel	1		
Wheeler Ridge, General Store	1	1	

OUTSIDE CALIFORNIA

Bozeman, Mont., Montana State College	1		
Butte, Mont., Montana School of Mines	1		
Columbia Falls, Mont., Hungry Horse Dam, Bureau of Reclamation	1		
Flaming Gorge, Utah	1	1	
Glen Canyon, Ariz.	1	1	
Hawthorne, Nev., U.S. Naval Ammunition Depot	1		
Helena, Mont., Carroll College	1		
Hoover Dam, Nev., 1215 Gallery	1	1	
Hoover Dam, Nev., Intake Tower	1	1	
Hoover Dam, Nev., Oilhouse	1	1	
Logan, Utah, Utah State University	1		
Olympia, Wash., Highway Test Laboratory	1		
Portland, Oreg., State Office Building	1		
Ross Dam, Wash., Block 16	1		
Ross Dam, Wash., Right Bank	1		
Seattle, Wash., Federal Office Building	1	1	
Tacoma, Wash., County-City Building	1	1	

OUTSIDE UNITED STATES

Balboa Heights, C.Z.	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		
Total	75	35	10

TABLE 5.—*List of shocks recorded and records obtained on strong-motion seismographs in 1963*

Date 1963	Region and Recording Station	Records			
		Accelerograph	Survey Displacement Meter	Carder Displacement Meter	Weed
Feb. 28	Southern California, Bakersfield	1	1		
	Wheeler Ridge	1		1	
	Taft	1			
	Cachuma Dam, Crest	1		1	
	Cachuma Dam, Valve House	1		1	
Mar. 25	Southern Nevada, Hoover Dam, Oil House	1		1	
	1215 Gallery	1		1	
	Intake Tower	1		1	
May 23	Southern California, El Centro	1	1	1	
June 11	Baja California, El Centro	1	1	1	
Aug. 31	West-central California, Hollister	1		1	
Sept. 13	Southern California, Long Beach, Terminal Island.	1			
Sept. 14	West-central California, Hollister	1		1	
	Oakland, City Hall, 16th floor	1			
	Oakland, City Hall, basement	1		1	
	San Francisco, Southern Pacific Building, basement.	1		1	
	San Jose, Bank of America, 13th floor	1			
	San Jose, Bank of America, basement	1		1	
	Tracy	1		1	
	Total	19	3	14	0

TABLE 6.—*Summary of outstanding instrumental and noninstrumental data for 1963*

SOUTHERN CALIFORNIA EARTHQUAKE OF FEBRUARY 28

Epicenter	Recording Station and Distance	Location of Instrument	Intensity[1]	Acceleration	Displacement[2]
				cm/sec²	*cm.*
34°56′N., 118°59′W., near Fort Tejon, Calif., VI*. Mag. 5.0.	Wheeler Ridge, 5 miles.	1st floor	V	57	0.25

SOUTHERN NEVADA EARTHQUAKE OF MARCH 25

36.0°N., 114.9°W., near Boulder City, Nev., VI*.	Hoover Dam, 10 miles.	Intake Tower	V	209	0.92

[1] Reported intensity of earthquake at recording station.

[2] Displacement is the maximum recorded at the station reporting the maximum acceleration of the earthquake. If displacement is much greater at another location it is given along with the maximum acceleration at the same location.

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

TABLE 7.—*Composite of strong-motion instrumental data for 1963*

SOUTHERN CALIFORNIA EARTHQUAKE OF FEBRUARY 28

Station and Component	Instrument No.	T_0	V	Sensitivity	s	Acceleration		Displacement		Remarks
						Period	Amplitude	Period	Amplitude*	
		sec.		*cm./g*		*sec.*	*cm./sec²*	*sec.*	*cm.*	
Cachuma Dam (Crest Station):										
Vertical	361	0.063	118	11.9	9	0.41	0.08	.....	0.003	
North	362	.061	117	11.2	11	.36	3.5	.....	.....	
East	363	.060	118	10.9	10	.43	4.0	.....	.....	
South	CDM-14	2.2	0.8	.....	10	.....	.....	0.51	.032	
East	CDM-15	2.5	0.8	.....	10	.....	.....	.72	.032	
Cachuma Dam (Valve House Station):										
Vertical	364	.061	117	11.1	10	.....	.....	.....	.....	No discernible trace.
North	365	.062	119	11.4	10	.48	2	.....	.010	
East	366	.063	122	12.2	10	.29	2	.....	.003	
Bakersfield:										
Vertical	342	.068	114	13.3	8	.....	.....	.....	.....	No discernible trace.
South	352	.067	119	13.7	9	.81	2	.....	.....	
West	353	.065	120	13.0	10	.51	1	.....	.....	
South	SDM-18	9.8	1	.....	7	.....	.....	2.1	.07	
West	SDM-18	10.2	1	.....	10	.....	.....	2.4	.05	
Wheeler Ridge:										
Vertical	2004	.071	123	15.7	9	.18	35	.....	.03	
N.48°E	2018	.071	123	15.9	10	.20	57	.....	.....	
S.42°E	2019	.072	125	16.4	9	.15	44	.....	.....	
N.48°E	62	4.92	1	.....	10	.....	.....	.43	.10	
N.42°W	61	4.43	1	.....	10	.....	.....	.45	.25	
Taft:										
Vertical	298	.079	114	18.0	10	.15	6	.....	.003	
N.21°E	299	.080	122	19.9	10	.15	7	.....	.004	
S.69°E	300	.081	121	20.2	9	.12	8	.....	.003	

SOUTHERN NEVADA EARTHQUAKE OF MARCH 25

Hoover Dam (Oil House):										
Vertical	334	0.079	121	19.3	9	0.11	22	.....	.....	
N.45°W	335	.080	123	19.9	9	.08	55	.....	.....	
N.45°E	336	.080	122	20.2	10	.08	75	.....	.....	
Vertical	CDM-1	2.45	1	.....	6	.....	.....	0.45	0.11	
N.45°W	CDM-20	6.19	1	.....	10	.....	.....	.75	.45	
S.45°W	CDM-21	5.59	1	.....	10	.....	.....	.90	.29	
Hoover Dam (Intake Tower):										
Vertical	328	.079	126	19.7	9	.08	134	.....	.02	
N.45°W	329	.081	125	20.7	9	.12	209	.....	.....	
N.45°E	330	.082	124	21.1	8	.12	194	.....	.....	
N.45°W	CDM-24	5.89	1.1	.....	10	.....	.....	.92	.55	
S.45°W	CDM-25	5.09	1	.....	10	.....	.....	.92	.92	
Hoover Dam (1215 Gallery):										
Vertical	331	.081	123	20.5	10	.06	73	.....	.006	
S.45°E	332	.079	123	19.7	10	.07	145	.....	.....	
S.45°W	333	.079	123	19.4	10	.19	202	.....	.....	
S.45°E	CDM-22	5.86	1	.....	10	.....	.....	.60	.29	
N.45°E	CDM-23	6.25	1	.....	10	.....	.....	.45	.32	

See footnote at end of table.

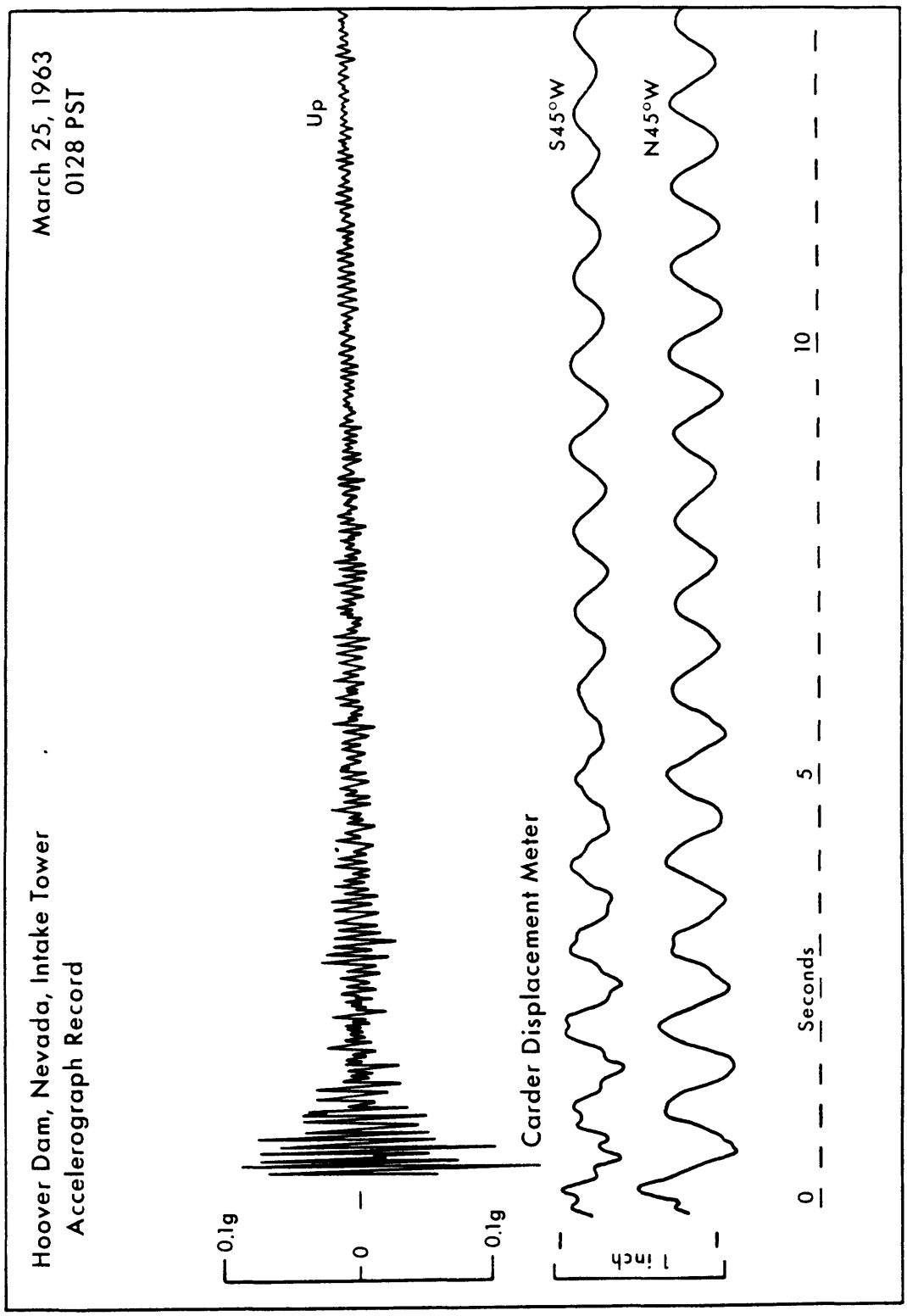

FIGURE 9.—*Tracings of accelerograph and Carder Displacement Meter records obtained at Hoover Dam on March 25.*

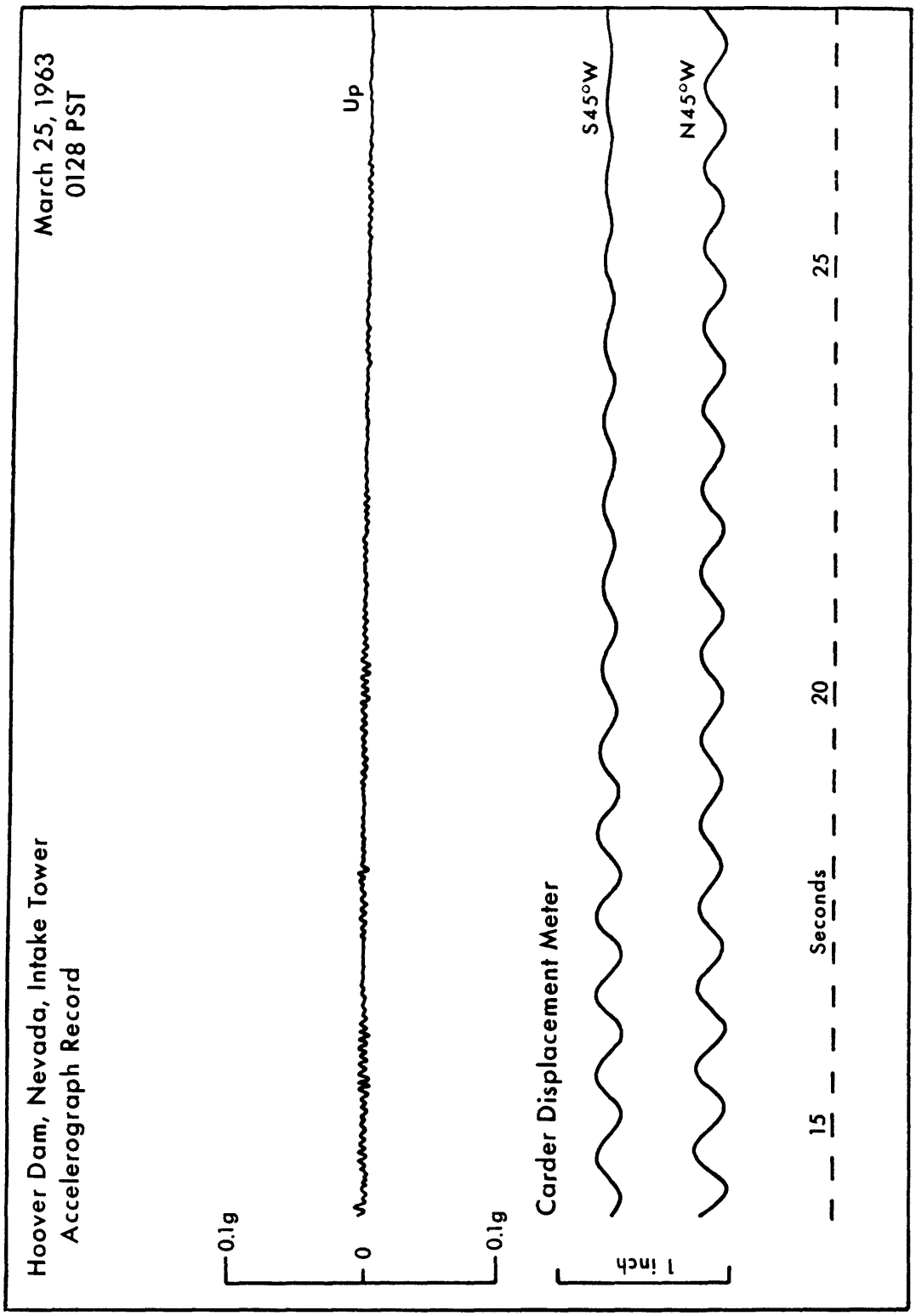

FIGURE 10.—*Tracings of accelerograph and Carder Displacement Meter records obtained at Hoover Dam on March 25.*

TABLE 7.—*Composite of strong-motion instrumental data for 1963*—Con.

SOUTHERN CALIFORNIA EARTHQUAKE OF MAY 23

Station and Component	Instrument No.	T_o	V	Sensitivity	ε	Acceleration		Displacement		Remarks
						Period	Amplitude	Period	Amplitude*	
El Centro:										
Vertical	208	0.0643	121	12.4	9					Negligible trace amplitude.
South	206	.0651	124	13.0	8	0.45	13			
West	207	.0647	121	12.5	8	.47	12			
South	CDM-28	6.60	1		10			0.75	0.12	
East	CDM-29	6.40	1		10			.80	.09	
North	SDM-17	9.98	1		10			.72	.15	
East	SDM-17	9.95	1		10			.95	.09	

BAJA CALIFORNIA EARTHQUAKE OF JUNE 11

El Centro:										
Vertical	208	0.0647	121	12.5	9	0.13	7			
South	206	.0652	124	13.2	8	.20	12			
West	207	.0646	121	12.5	8	.19	16			
South	CDM-28	6.61	1		10			1.20	0.18	Maximum displacement during initial 2 sec of earthquake.
East	CDM-29	6.45	1		10			.90	.20	
North	SDM-17	10.0	1		10			1.25	.25	
East	SDM-17	9.98	1		10			1.10	.34	

See footnote at end of table.

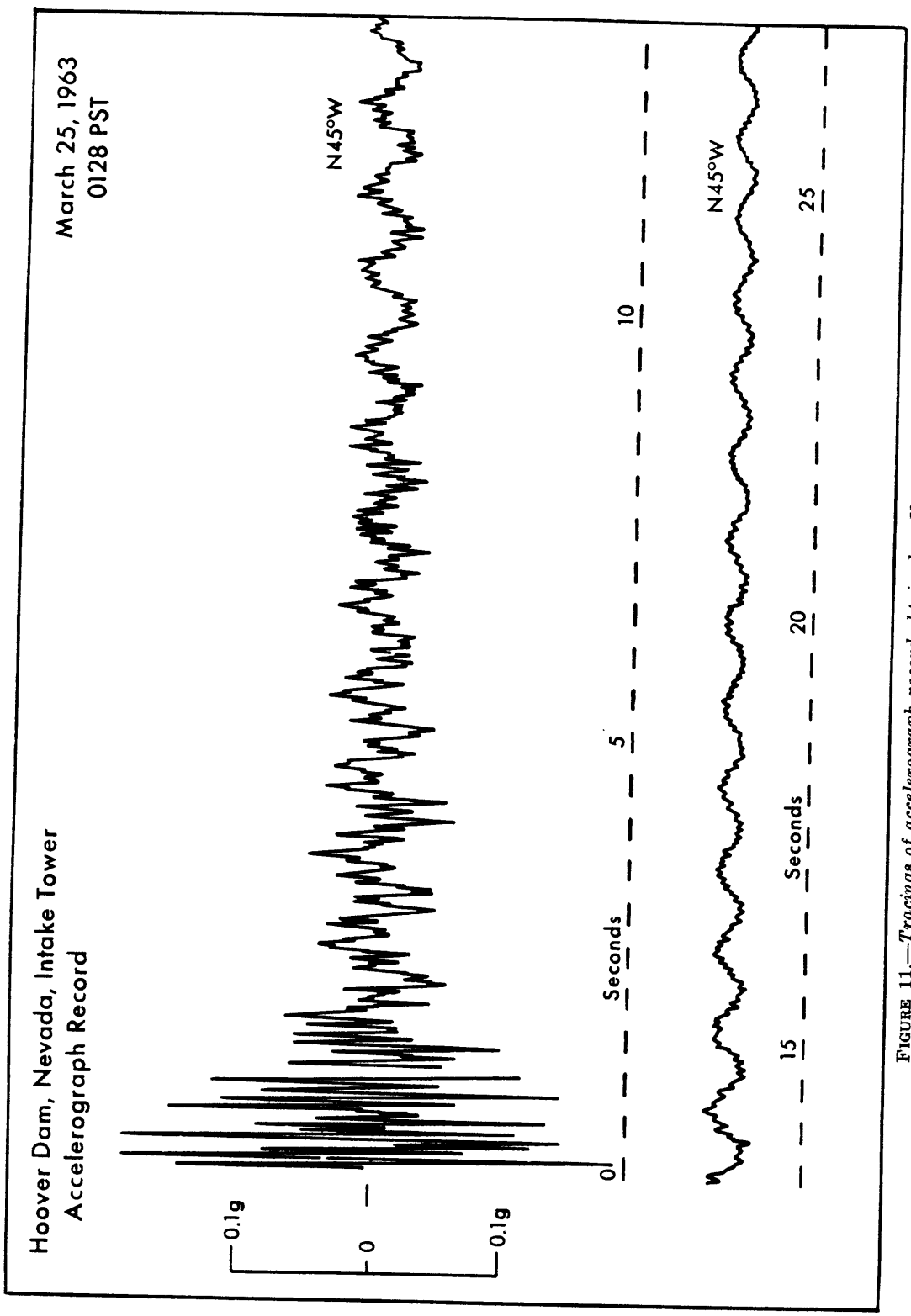

FIGURE 11.—*Tracings of accelerograph record obtained at Hoover Dam on March 25.*

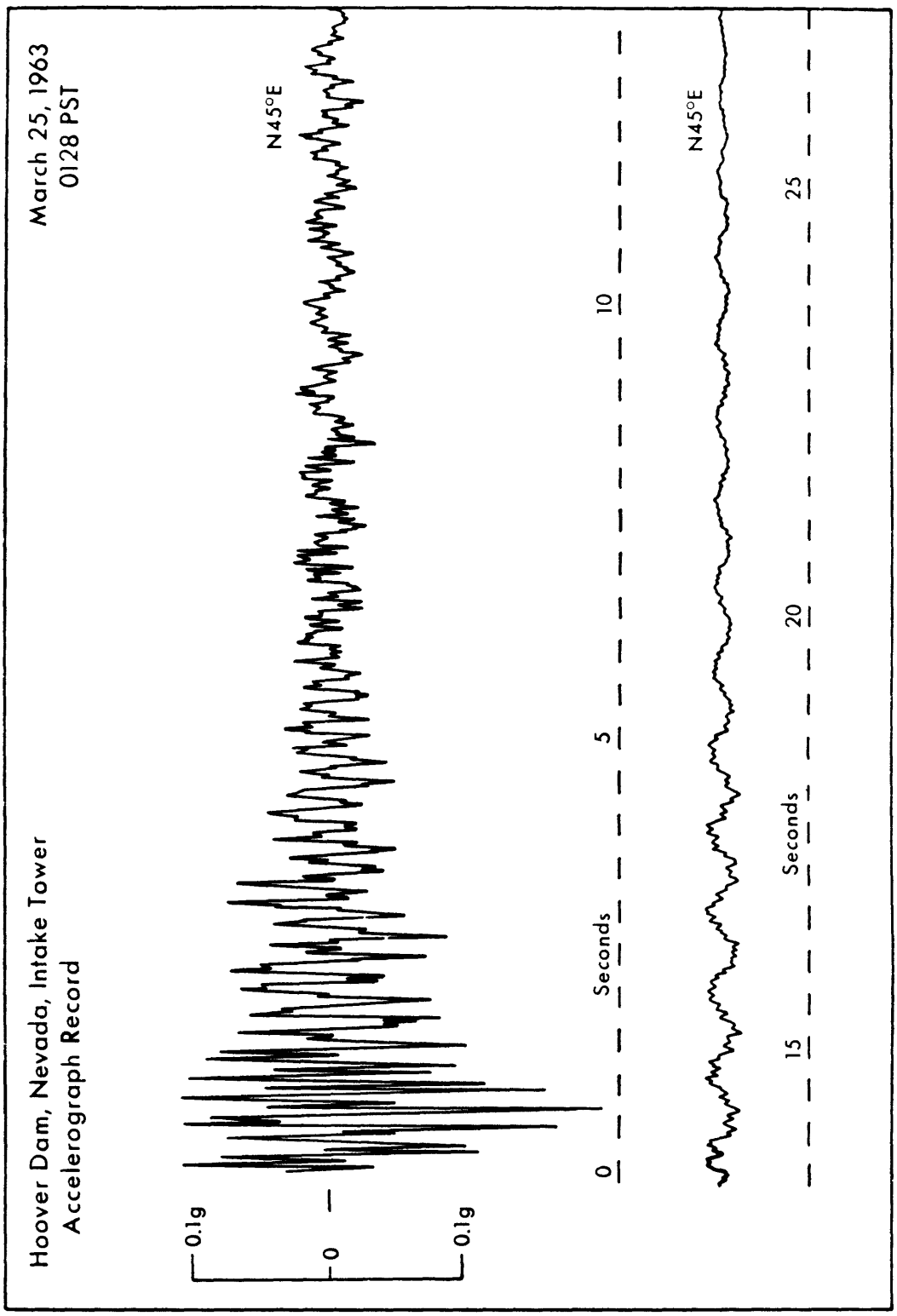

FIGURE 12.—*Tracings of accelerograph record obtained at Hoover Dam on March 25.*

TABLE 7.—*Composite of strong-motion instrumental data for 1963*—Con.

WEST-CENTRAL CALIFORNIA EARTHQUAKE OF SEPTEMBER 14

Station and Component	Instrument No.	T_o	V	Sensitivity	s	Acceleration		Displacement		Remarks
						Period	Amplitude	Period	Amplitude*	
Hollister:										
Vertical	238	0.068	123	13.9	10	0.20	10			
S.1°W	239	.066	122	13.2	9	.19	15			
N.89°W	240	.066	122	13.0	7	.30	16			
N.1°E	6	2.12	1		11			2.08	0.22	45 sec after instrument began operation.
N.89°W	5	2.12	1		11			1.52	.21	
Oakland (City Hall, 16th floor):										
Vertical	226	.046	117	6.2	10	.48	5			Dominant long period waves recorded.
N.26°E	227	.049	115	6.9	10	1.13	7			
S.64°E	228	.047	117	6.4	10	1.25	15			
Oakland (City Hall, basement):										
Vertical	235	.066	113	12.1	9					No measurable trace amplitude.
N.26°E	236	.066	120	12.8	10					
S.64°E	237	.067	111	12.3	10					
N.26°E	CDM-35	3.22	1		10			1.17	.02	
N.64°W	CDM-34	3.45	1		10			1.19	.08	
San Francisco (Bethlehem Building, 12th floor):										
Vertical	I	.045	113	5.7	10	.18	5			
West	II	.044	120	5.8	10	.50	5			
North	III	.047	120	6.6	10	.57	6			
West	CDM	3.90	0.96		11			1.60	.12	
South	CDM	3.87	.92		10			1.30	.12	
San Francisco (Bethlehem Building, basement):										
Vertical	IV	.066	115	12.3	10					No measurable trace amplitude
West	V	.065	119	12.6	12	.31	4			
North	VI	.068	118	13.3	9	.36	4			
West	CDM-B	4.96	1		13			.92	.05	
South	CDM-A	4.30	1		12			.89	.06	
San Francisco (Southern Pacific Building, basement):										
Vertical	196	.065	115	12.1	14	.64	2			
N.45°W	195	.067	117	12.9	10	.65	8			
N.45°E	194	.067	116	12.9	10	.52	4			
N.45°W	43	3.74	1		11			1.43	.10	
S.45°E	42	3.43	1		10			1.28	.05	
San Jose (Bank of America Building, 13th floor):										
Vertical	175	.046	117	5.3	8					No measurable trace amplitude.
N.59°E	174	.048	121	6.9	10	1.65	1			
S.31°E	173	.048	120	7.0	8	1.63	1			
San Jose (Bank of America Building, basement):										
Vertical	202	.060	118	10.7	10					No measurable trace amplitude.
N.59°E	201	.060	119	10.7	8					Dominant long period waves recorded.
S.31°E	200	.061	116	10.6	10					
S.59°W	CDM-8	2.34	0.95		10			2.02	.10	
S.31°E	CDM-7	2.28	.95		10			1.58	.10	
Tracy:										
Vertical	2001	.071	116	14.3	10					No measurable trace amplitude.
S.55°W	2012	.068	121	12.9	9					
N.35°W	2013	.068	117	13.5	10					
S.55°W	CDM-53	3.30	1		13			3.08	.07	
S.35°E	CDM-52	3.70	1		10			3.28	.15	

* Estimated from acceleration if no entry in displacement column.

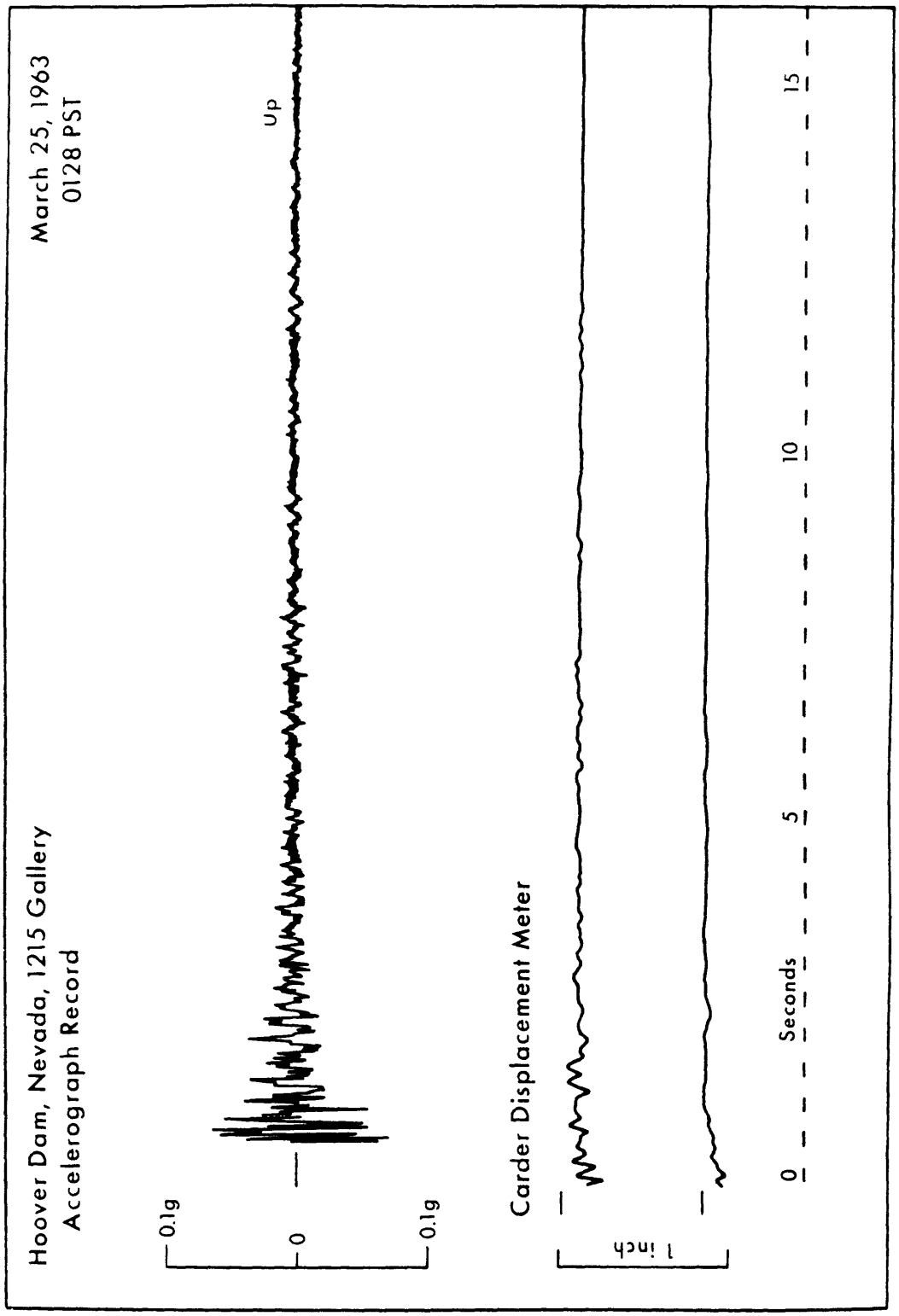

FIGURE 13.—*Tracings of accelerograph and Carder Displacement Meter records obtained at Hoover Dam on March 25.*

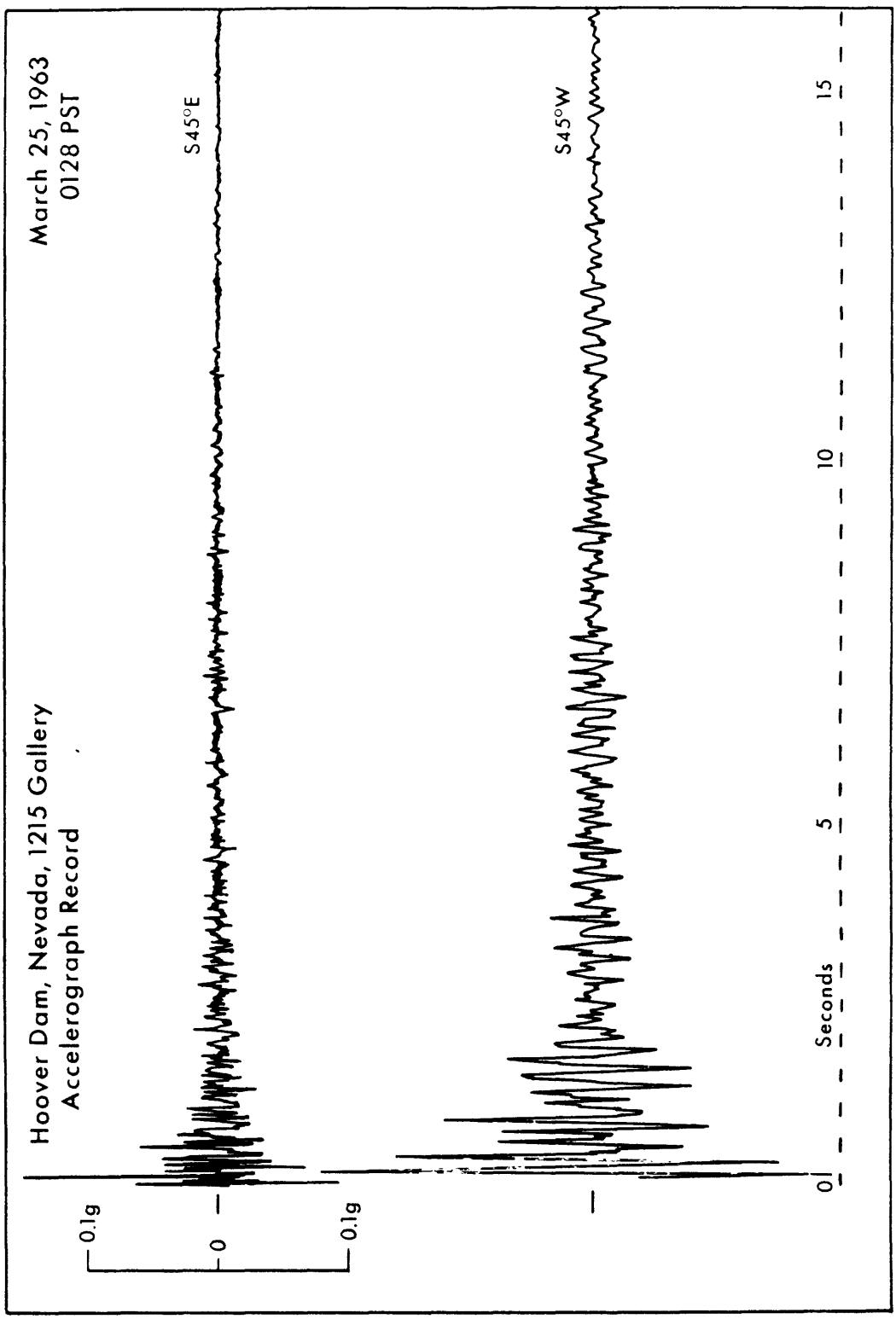

FIGURE 14.—*Tracings of accelerograph records obtained at Hoover Dam on March 25.*

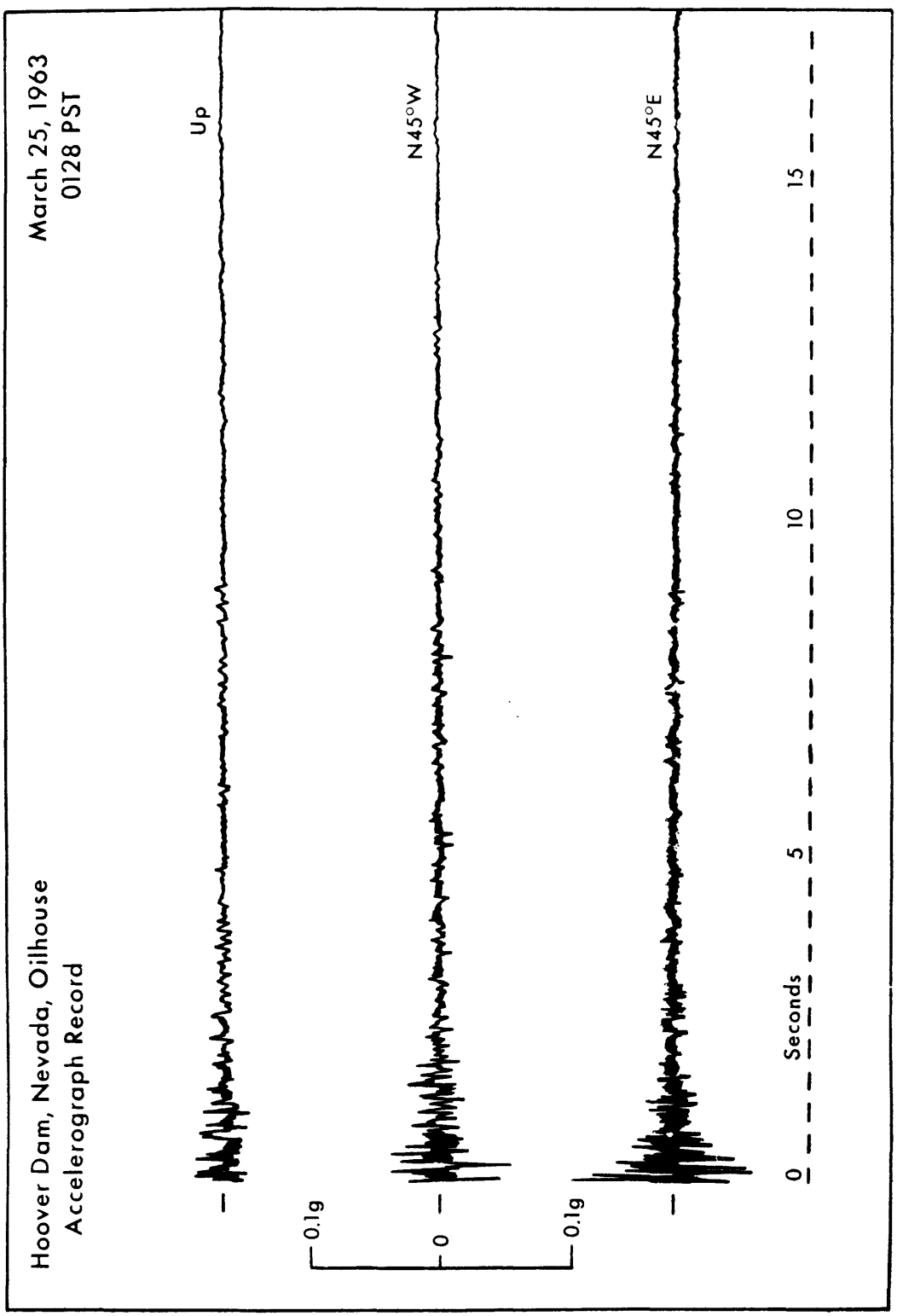

FIGURE 15.—*Tracings of accelerograph records obtained at Hoover Dam on March 25.*

TILT OBSERVATIONS

Two Merrit tiltmeter stations, Table Mountain and Santiago Peak, continued in routine operation.

PUBLICATION NOTICES

The Coast and Geodetic Survey maintains mailing lists for notices of issuance of its publications. Should you desire to receive notices of seismological publications, address your request to the Environmental Science Services Administration, Coast and Geodetic Survey, Washington, D.C. 20235.

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