DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

United States Earthquakes, 1964

By

Carl A. von Hake

and

William K. Cloud

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U.S. DEPARTMENT OF COMMERCE
JOHN T. CONNOR, SECRETARY

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
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COAST AND GEODETIC SURVEY
JAMES C. TISON, JR., DIRECTOR

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Cover: Landslide effects in Turnagain area, Anchorage, from the March 27, Alaska shock. The slide extended for over 1½ miles along the bluffs fronting on Knik Arm of Cook Inlet.

ILLUSTRATIONS

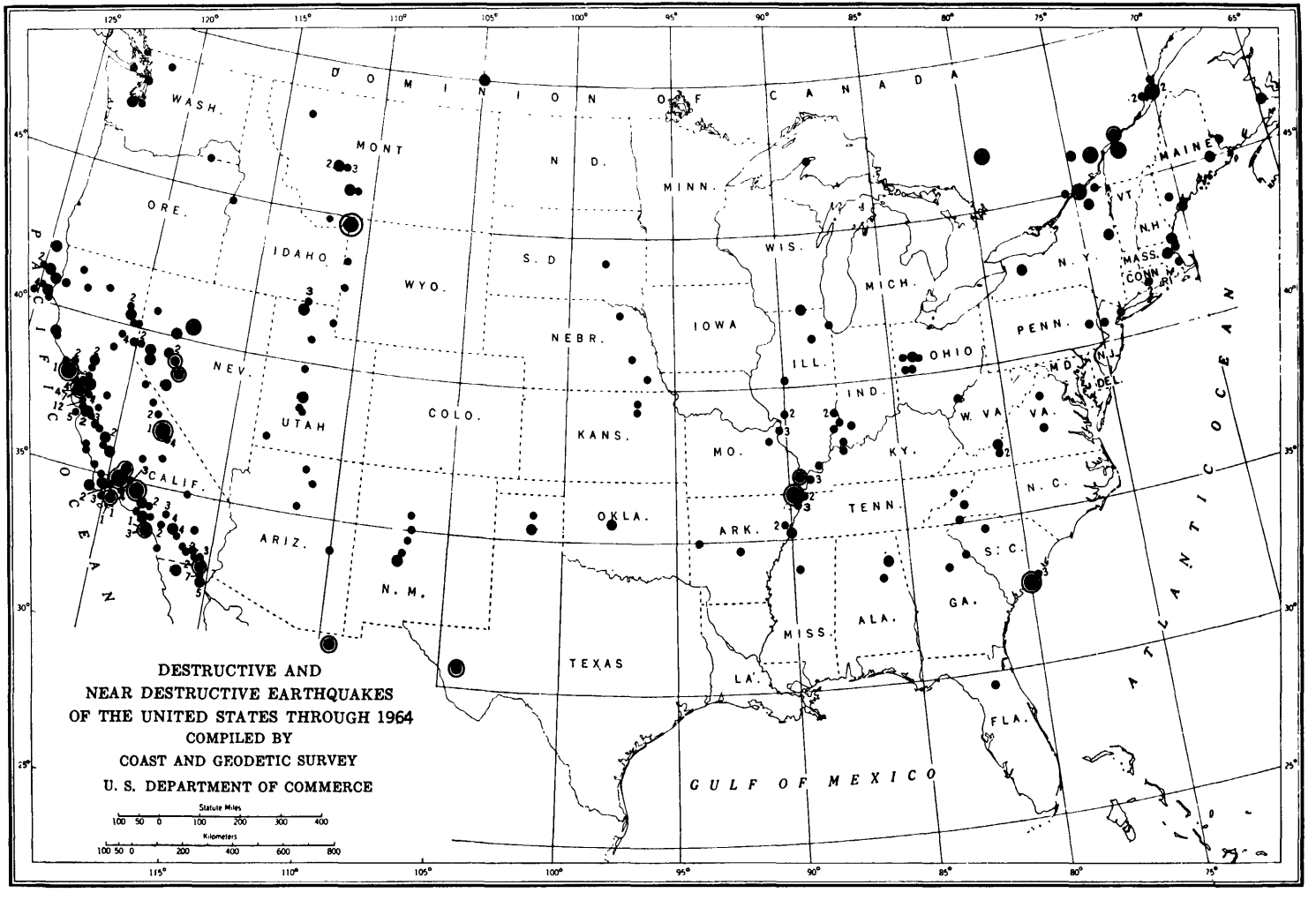

FIGURE 1.—*Destructive and near destructive earthquakes in the United States through 1964.*

UNITED STATES EARTHQUAKES, 1964

INTRODUCTION

This publication is a summary of earthquake activity in the United States and regions under its jurisdiction for the calendar year 1964. 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 seismological observatories listed on page 82 and from other cooperating seismological stations located 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 achieved through intensive regional investigations in various States by local organizations, and the Coast and Geodetic Survey. This information is used to map the seismic areas of the country, thereby promoting 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 1964:

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. (IX+ Rossi-Forel Scale.)

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

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

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

Epicenter Maps.—Figure 1 is designed to show the existence of destructive and near destructive earthquakes in the United States through 1964. 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 1964. 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 large 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 for data on additional shocks.

The selection of isoseismal or "felt area" maps (figs. 3–9) is governed largely by the size of the area affected, the minimum radius generally being about 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. Felt and nonfelt reports from various towns are designated on the maps by open and solid circles, respectively. Frequently, intensities higher or lower than those in the isoseismal zone are noted. These are indicated by small numerals above the circles.

Teleseismic results.—The Summary of Instrumental Epicenters previously published in this report was discontinued in 1963. On page 182 is a list of Survey and cooperating teleseismic stations for which the Survey publishes results. During the year the locations of 4,777 epicenters were announced promptly on *Preliminary Determination of Epicenter* cards. Those desiring to receive these cards should request addition of their names 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 1964, MSI–277 through 288 for the monthly bulletins of 1964 were published.

Magnitude and intensity ratings.—Magnitude rating, stated according to the Gutenberg-Richter scale, is a measure of the energy release at the focus of the earthquake. It is estimated by the analysis of seismograph records, as explained in the *Bulletin of the Seismological Society of America,* Vol. 32, No. 3, 1942. Intensity rating, usually expressed on the Modified Mercalli Intensity Scale of 1931, is a local measure of the effects on people and objects at any locality. It is a result of many factors, including energy release of the earthquake, distance from the epicenter, geological and topographic conditions, and structural properties of buildings. Magnitude and intensity 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,* MSP series, issued on mailing list CGS–5. The revised analyses are given in table 6.

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,* Vol. 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 privately operated stations. Publications 41–1, 41–2, and S.P. 282 are available from the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402.

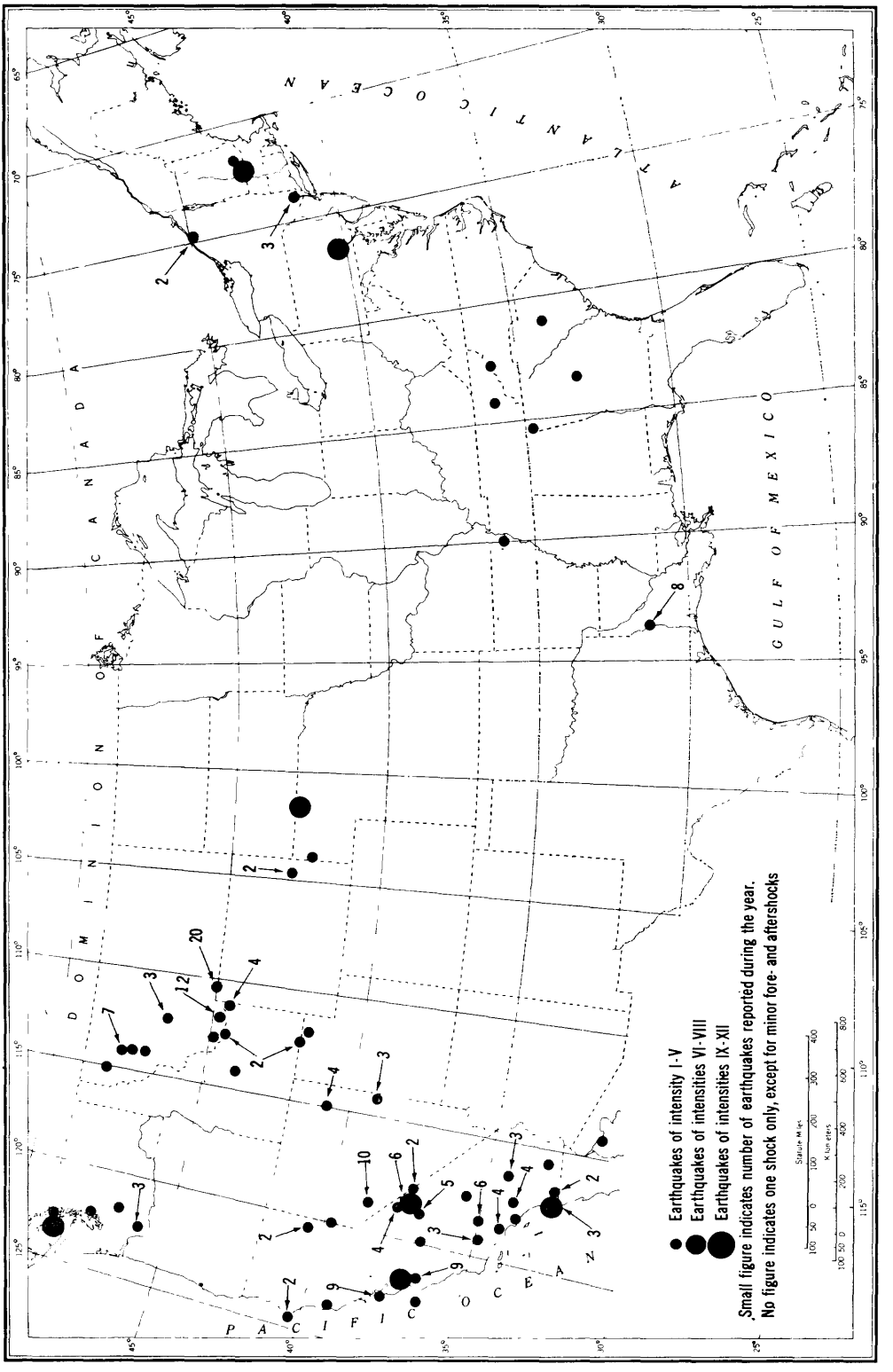


FIGURE 2.—*United States earthquake epicenters, 1964.*

SUMMARY OF EARTHQUAKE REPORTS

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, N.Y.

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 the 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.

Alabama: February 18, IV.

Alaska: January 3; 6, V; 7; 11; 19; 23; 25; February 6, V (2); March 3; 27, IX–X (numerous aftershocks); April 3, V (2); 3; 4; 10; 12, IV; 13 (2); 14, VI; 14, IV (5); 16, IV; 16; 17; 20 (4); 24; 26; 29; 30 (2); May 3; 6; 11; 14; 20; 21 (2); 22; 24; 28; 29; June 2; 5; 10; 12; 28; July 23; 24; 27; August 1; 10; 11; 14; 26, IV; 30; September 13; 15 (2); 23; 24; 28; October 18; 26; 31; November 6 (2); 20; 23; 26, IV; 26; December 12, VI; 12 (4); 17; 19; 28.

California: (Intensity V and above). January 6, V; February 20, V; 26, V; April 24, V; May 13, V; 24, V; June 12, V; 21, VI; 22, VI; July 14, V; August 30, V; September 4, V; November 15, VII; December 22, VI; 31, V.

Connecticut: November 17.

Georgia: February 18, V; March 12, V.

Hawaii: January 6; 7; 8; 16; 30; 31; February 9; 16; 20; March 1; 2; 5; 10; 11; 16; 24; 30; April 1; 2; 12; 14 (2); 20 (2); 26 (2); 28; May 16; 18; 24; 27; 28; 30; June 4 (2); 8; 17; 22; July 1; 15; 17; 18; 27; 28; August 3 (2); 7; 11 (2); 13; 14; 16; 26; 27; 28; 30 (2); 31 (3); September 1; 2 (2); 3; 6; 7 (3); 8 (2); 9; 10; 12; 14; 16; 18 (3); 22; 26; October 1; 11; 12; 14; 17; 20; 23; 27; November 4; 5; 10; 12 (2); 14; 24 (2); 29; December 2 (2); 3 (3); 10 (2); 11; 13; 14; 17; 24.

Idaho: February 6 (2); April 16, IV; October 18; 21, V.

Louisiana: April 24.

Missouri: March 16, IV.

Montana: January 1, IV; 12, IV; March 20, V; 23; 27, V; 27; 28, VI; 28, IV; April 7, IV; May 13, IV; June 26, IV; 29; August 2; 13, IV; September (several); October 8, V; 8; 14; 21, IV; 21, V; 21 (5); 22 (2); November 4; 23, IV; 23; December 18; 21.

Nebraska: March 27, IV; 28, VII.

Nevada: January 7, IV; February 3; 20, V; March 22, V; 22 (5); 23 (2); 24; 27, IV; April 10, III; September 21; 23, V; October 7, V; 23, V; 30–November 4 (about 30 shocks reported felt, maximum intensity VI); 12 (2); 23; December 20.

New Hampshire: April 1, IV; June 26, VI; 26.

New York: March 29, V; June 16, IV; September 28–29 (minor shocks); November 17, V.

North Carolina: January 20, IV.

Oregon: October 1, V.

Pennsylvania: May 12, VI.

South Carolina: April 20, V.

South Dakota: March 24, V; 27, IV; 28, V.

Tennessee: July 28; October 13.

Texas: April 23; 24; 27; 28, V; 30; May 7; June 2, IV (2); 2; August 16, V.

Utah: February 20; October 18.

Vermont: June 26, V; 26.

Washington: January 26, V; March 20; April 16, IV; July 14, VI; 30, V (2); October 1; 15, V.

Wyoming: January 4; 5; 6; 7; 9 (2); 10; 12; 13, IV; 14 (2); 15; 17; 18; 19; 21; March 23; 24, IV; 27, V; 27; 28, IV (4); 31, IV; August 21, V; October 21, IV.

EARTHQUAKE ACTIVITY OUTSIDE THE UNITED STATES

Panama Canal Zone: February 12; 21; March 10; May 26; July 29; 30.

Puerto Rico: July 14; December 22.

NORTHEASTERN REGION
(75TH MERIDIAN OR EASTERN STANDARD TIME)

March 29: 04:16 (about). Massena, N.Y. V. Press reported that three shocks in rapid succession occurred, the most severe being at about 04:16. Many residents were awakened and alarmed and police headquarters received numerous telephone inquiries. One observer commented, "It sounded like an explosion in the basement." The tremor was not observed outside Massena.

April 1: 06:21:34*. Epicenter 43.6° north, 71.5° west, near Meredith, N.H., NESA. IV. Buildings shook and loose objects rattled at Andover, Belmont, Plymouth, Sanbornton, and Tilton. Various types of earth sounds were reported. The shock was also felt (intensity I–III) at Ashland, Canterbury, Franklin, Gilmanton, Laconia, Weirs Beach, and Winnisquam. Magnitude 1.8.

June 16: 09:00. Malone, N.Y. IV. Press reported that at 09:00, many persons in various sections of Malone felt a definite shaking and heard a rumbling sound which lasted several seconds. At 15:30, a number of bricks fell from a 150-foot smoke stack at the paper mill. Some of them fell onto the street, but others tumbled to the west side of the smoke stack and crashed through the roof of the mill leaving a gaping hole. Since the press also mentioned high winds in the area during the day, it is speculated that the wind was responsible for the falling bricks in that no further disturbance was reported by residents at this hour.

June 26: 07:04:46 * and 07:50. Epicenter of first shock, 43.3° north, 71.9° west, near Warner, N.H., NESA. VI. Felt over approximately 3,000 square miles of New Hampshire and Vermont. Plaster fell at Meriden. Slight damage was reported from Bradford, N.H. and Springfield, Vt. Magnitude 2.6. Questionnaire canvass conducted by Weston Observatory.

INTENSITY VI IN NEW HAMPSHIRE:

Meriden.—Felt by many and awakened few. Plaster fell. Windows, doors, and dishes rattled. Hanging objects swung; trees, bushes shaken slightly. Rapid motion.

INTENSITY V IN NEW HAMPSHIRE:

Bradford.—Felt by and frightened many; few awakened. Slight damage reported, but observer did not list specific damage. Windows and dishes rattled. Rapid motion; duration, 30 sec nds.

Franklin.—Felt by and frightened many. Windows rattled; hanging objects swung. Gradual onset; rapid motion. Duration, 20–30 seconds.

Laconia.—Felt by and awakened many; frightened few.

Penacook.—Felt by all. Windows and doors rattled. Gradual onset; rapid motion. Duration, 20–25 seconds.

INTENSITY V IN VERMONT:

Springfield.—Felt by many; few awakened. Specific damage was not listed, although observer reported slight damage. Windows, doors, and dishes rattled. Gradual onset; slow motion. Duration, 45 seconds.

White River Junction.—Felt by and awakened many. Walls and frame creaked; windows, doors, and dishes rattled. Abrupt onset. Duration, 15 seconds.

INTENSITY IV IN NEW HAMPSHIRE:

Alton.—Felt by many; few awakened and frightened. Windows, doors, and dishes rattled. Duration, 2–3 seconds.

Belmont.—Felt by many and awakened few. Buildings creaked; windows, dishes, and doors rattled. Felt shock at 07:04:46* only.

Claremont.—Felt by several. Windows and dishes rattled. Abrupt onset.

Concord.—Felt by many; awakened and frightened few. Windows, doors, and dishes rattled at 07:04:46*. Gradual onset. Duration, 30 seconds.

Hanover.—Felt by many. Windows and dishes rattled. Thunderous earth sounds heard at beginning of shock. Rapid onset; slight trembling motion. Duration, 2–3 seconds. 2 shocks.

Newport.—Felt by many; few frightened. Windows rattled; trees, bushes shaken slightly. Abrupt onset; slow motion.

Plymouth.—Felt by several and awakened few. Dishes rattled; walls creaked. Abrupt onset; rapid motion. Duration, about 30 seconds.

Sunapee.—Felt by many. Windows rattled. Rapid motion.

INTENSITY IV IN VERMONT:

Ludlow.—Felt by many; few awakened and frightened. Windows rattled; walls creaked. Rapid motion from northeast. Duration, 3 seconds.

Montpelier.—Felt by several. Creaking of buildings and rattling of loose objects were reported. Loud, bumping earth sounds heard. "Many thought it to be a sonic disturbance as planes were near at the time." The shock at 07:50 was described as one quick motion,

such as produced by a heavy blast. Abrupt onset.

Windsor.—Felt by and awakened few. Abrupt onset. Duration, few seconds.

INTENSITY I–III IN NEW HAMPSHIRE: Hooksett, Lebanon (07:50), Newbury, Pittsfield, Tilton (07:50), and Winnepesaukee (07:04:46*).

INTENSITY I–III IN VERMONT: Barre and Bellows Falls.

September 28: 19:16:27.5 * and **September 29:** 15:26:49.5 *. Mount Kisco, N. Y. Press and radio reported minor shocks on these dates. One observer stated that shocks in September were felt from North White Plains to Yorktown and sounded like a loud blast. Recorded by seismograph at Lamont Geological Observatory of Columbia University.

November 17: 12:08. New York. V. At Armonk, Mount Kisco, and Pound Ridge, objects fell from mantels and windows and dishes rattled. Two shocks were felt at Pound Ridge; disturbed objects were observed by many at Mount Kisco. Also felt at Cross River and South Salem, N.Y., and at Georgetown, Conn. In addition, press reported the shock felt at Bedford, Chappaqua, and Windmill Farms, N.Y. and at New Canaan, Conn.

EASTERN REGION
(75TH MERIDIAN OR EASTERN STANDARD TIME)

January 20: 08:37:52.0*. Cane River, N. C. area. IV. A slight tremor was reported felt at Burnsville, Cane River, Pensacola (windows rattled), and Spruce Pine. Recorded by the seismograph at Virginia Polytechnic Institute, Blackburg, Va.

February 18: 04:31:11.5*. Epicenter 34.8° north, 85.5° west, Alabama, W. V. This shock was felt in Chattooga, Dade, and Walker counties, Georgia, and De Kalb County, Alabama. Also reported felt (intensity I–III) at Tanner, Ala. Depth about 15 km. Magnitude 4.4.

INTENSITY V IN GEORGIA:

Lyerly.—Felt by nearly all. General alarm. Buildings creaked; loose objects rattled. Loud, roaring earth sounds heard. Rapid onset; trembling motion.

Menlo.—Felt by and awakened nearly all; many alarmed. Buildings creaked; loose objects rattled; dishes fell from shelves. Loud, thunderous earth sounds heard. Abrupt onset; trembling motion.

INTENSITY IV IN ALABAMA:

Mentone.—Felt by many. Doors swung open; buildings creaked; and loose objects rattled. "Rock fell from chimney in nearby community; almost knocked a glass of water off stove in home." Abrupt onset; bumping motion.

INTENSITY IV IN GEORGIA:

Rising Fawn.—Felt by and awakened many. Buildings creaked; loose objects and windows rattled. Thunderous earth sounds heard. Abrupt onset; trembling motion.

Summerville.—Felt by and awakened many. Buildings creaked; loose objects rattled; pictures displaced. Thunderous earth sounds heard. Abrupt onset.

Trenton.—Felt by and awakened several. Houses shook; rumbling earth sounds heard.

INTENSITY I–III IN ALABAMA: Tanner.

INTENSITY I–III IN GEORGIA: LaFayette.

March 12: 20:20:18.1*. Epicenter 38.2° north, 83.4° west, Georgia, W. V. Felt over an area of approximately 400 square miles of Baldwin, Bibb, Jones, and Wilkinson counties. Depth about 40 km. Magnitude 4.4.

INTENSITY V:

Haddock.—Felt by nearly all. Buildings creaked; loose objects rattled. Thunderous earth sounds heard at onset of shock. Rapid onset; rocking-swaying motion, south-north. "Population was somewhat frightened."

INTENSITY IV:

Gordon (about 2 miles east of).—Felt. House trembled and windows rattled. "First thought that a plane had broken the sound barrier but there was no noise."

Gray (about 4 miles east of).—Felt. Car swayed. Roaring or rumbling earth sounds heard. Rapid onset.

Macon.—Felt by several and alarmed few. Buildings creaked; dishes and loose objects rattled. Several observed disturbed objects.

Milledgeville.—Felt by many. Sounds heard like plane breaking the sound barrier. Abrupt onset; rumbling-trembling motion.

Round Oak.—Felt by many. Buildings creaked; loose objects rattled. Rumbling earth sounds heard before beginning of shock. Gradual onset; slight trembling motion.

INTENSITY I–III: Huber.

April 20: 14:04:46*. Near Columbia, S.C. V. The shock was felt in Fairfield, Florence, Lexington, and Richland counties. Intensity V was reported from Gaston, Lexington County, and Jenkinsville, Fairfield County. Recorded by seismograph of the University of South Carolina, Columbia, S. C.

INTENSITY V:

Gaston.—Felt by nearly all. Buildings creaked; loose objects rattled. Disturbed objects observed. Gradual onset; trembling motion.

Jenkinsville.—Felt by all. Gradual onset; trembling motion.

INTENSITY IV:

Cayce.—Felt by many. Buildings creaked; loose objects rattled. "Thought it was an explosion." Rapid onset; trembling motion.

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

Lexington.—Felt. Buildings trembled; loose objects rattled. Rumbling noise heard. Abrupt onset; trembling motion.

INTENSITY I–III: Columbia, Florence, and Pelion.

May 12: 04:45:14.1*. Epicenter 40.2° north, 76.5° west, southeastern Pennsylvania, W. VI. At Cornwall, a wall cracked and plaster fell. Slight landslides were reported. In one building a radio was knocked from table; wall mirror moved horizontally. Workers in an iron mine about 1200 feet underground were alarmed by "quite severe jarring motion." Buildings creaked and swayed; loose objects rattled. Rumbling earth sounds heard. Abrupt onset; rocking motion. Depth about 33 km. Magnitude 4.5.

July 28: (early afternoon). Knoxville, Tenn. A light shock was reported from the Inskip-Norwood area of northwestern Knoxville at an unspecified hour in the early afternoon.

October 13: 11:30. Knoxville, Tenn. A light shock was reported felt at the University of Tennessee, at Maplehurst Park, and in the TVA offices of the Union Building.

CENTRAL REGION
(90TH MERIDIAN OR CENTRAL STANDARD TIME)

March 16: 20:15. Caruthersville, Mo. IV. One report was received which stated that a slight shock was felt by several at this time. Buildings creaked and loose objects rattled. Disturbed objects observed; gradual onset; trembling motion.

March 24: 00:12. Hot Springs, S. Dak. V. Felt by all at Wind Cave National Park. Small rocks fell in cave; buildings creaked; and loose objects rattled. Moderately loud, rumbling earth noises heard. Abrupt onset; trembling motion. Duration, 3–5 seconds.

March 27: 21:00 (about). Near Van Tassell, Wyo. V. Felt by all at Van Tassell where doors and dishes rattled and furniture vibrated. Thunderlike noise heard. Press reported that shortly after noon on this date many Fall River County residents thought their furnaces had blown up; at about 21:00, furniture moved in some houses. Also felt in Nebraska and South Dakota.

No instrumental data are available for this shock due to the proximity in time of its occurrence to the great Alaska earthquake. There was no connection between these shocks, although many persons within the felt area thought effects of the Alaska shock had been observed.

INTENSITY IV IN NEBRASKA:

Harrison.—Felt by several. Buildings creaked. Abrupt onset; swaying motion.

Hyannis.—Felt by many. Beds shook; windows and dishes rattled; pictures moved. One man driving car reported that his car shook and moved, but it is doubtful that this was caused by the earthquake.

INTENSITY IV IN SOUTH DAKOTA:

Edgemont.—Felt. Doors and windows rattled.

Hot Springs.—Felt by all at Wind Cave National Park. Buildings creaked; loose objects rattled. Moderately loud, rumbling earth sounds heard at beginning of shock. Trembling motion; duration, 3–5 seconds.

Pine Ridge.—Felt by several. Buildings creaked; loose objects rattled. Pictures displaced on north and east walls. Rumbling noise heard by few. Abrupt onset; trembling motion.

Provo.—Felt by several. Buildings creaked; loose objects rattled; chairs and beds shook. Thunderous sounds heard at beginning of shock.

INTENSITY I–III IN SOUTH DAKOTA: Keystone.

March 28: 03:08:45.0*. Epicenter 42.9° north, 101.6° west, Nebraska, W. VII. Felt over an area of approximately 90,000 square miles of Nebraska, South Dakota, and border areas of Montana and Wyoming. (See map, page 12.) Ten miles south of Merriman, 75 cracks were reported in road, and steep banks tumbled along river. Plaster fell at Rushville, and part of a chimney toppled at Alliance. Slight damage was also reported from Martin and Deadwood, S. Dak. Broken goods in homes and stores were reported from various towns. The press reported that this shock was felt as far north as Alzada, Mont. Depth about 41 km. Magnitude 5.1.

INTENSITY VII IN NEBRASKA:

Merriman.—Felt by nearly all and frightened many. Ten miles south, highway had about 75 cracks, and some steep banks along Niobrara River tumbled. Broken goods in stores; dishes broken in homes; and stucco under windows cracked. Thunderous-bumping noise heard. Rapid onset; bumping motion, north-west. Four shocks, 15 minutes apart.

INTENSITY VI IN NEBRASKA:

Alliance.—Felt by and awakened many. Part of chimney cap fell on one house. Windows rattled and beds moved. Weather Bureau received many calls about disturbance.

Rushville.—Felt by many. Plaster fell between studding; wall cracked; and several plates broke. Windows, dishes, and doors rattled. Roaring earth sounds heard before and during shock.

INTENSITY V IN NEBRASKA:

Ainsworth.—Felt by and awakened many. Creaking of buildings and rattling of loose objects heard. Earth sounds reported during shock. Gradual onset; vibrating motion.

Chadron.—Felt by, awakened, and alarmed nearly all. Knocked books from shelves. Buildings creaked; loose objects rattled; beds shook for 4–5 seconds. Abrupt onset; shaking motion, north-south.

Crawford.—Felt by and awakened many. Buildings creaked and loose objects rattled. Dresser shook. Rumbling-crashing sound heard. Abrupt onset; swaying motion.

Eli.—Felt by all. Store reported numerous items were scattered on floor.

Gordon.—Felt by many. Several plates and plaques hanging on south wall fell. Gradual onset; trembling motion.

Harrison (9 miles west of).—Felt by nearly all. Buildings creaked and loose objects rattled. Subterranean sounds heard before quake began. Abrupt onset; trembling motion.

Hemingford.—Felt by nearly all. Buildings

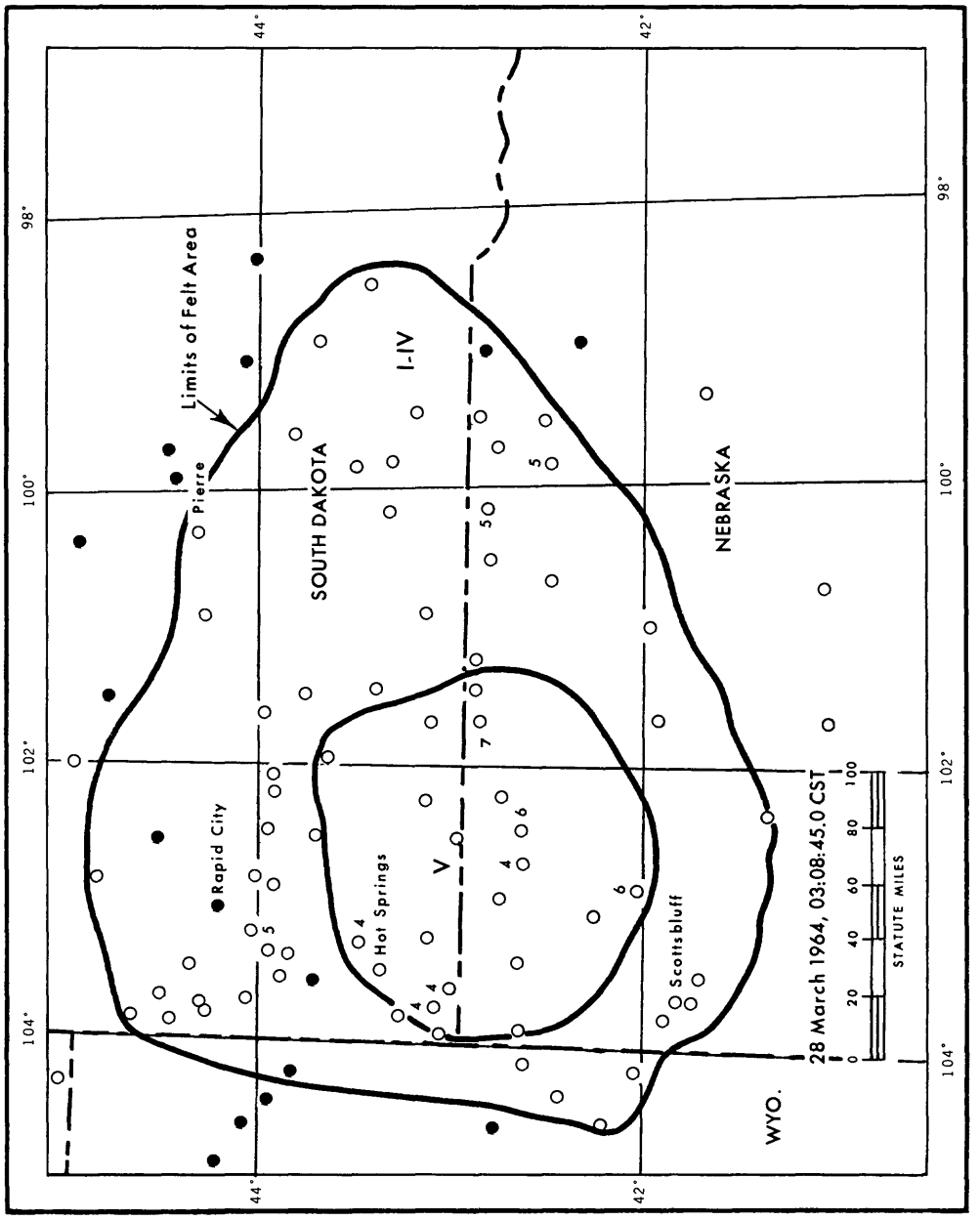


FIGURE 3.—*Area affected by earthquake of March 28.*

creaked; loose objects rattled. Earth sounds heard by many. "Sounded like passing train." Gradual onset; trembling motion.

Mullen.—Felt by and alarmed many; several awakened. Buildings creaked; loose objects rattled. Disturbed objects observed by few. Moderately loud, cracking and rattling earth sounds heard. Rapid onset; trembling-rocking motion.

Springview.—Felt by and awakened many. House shook; loose objects and dishes rattled. Roaring noise heard. Vibrating motion; duration, over 1 minute.

Valentine.—Felt by and alarmed many. Buildings creaked; loose objects, doors, and windows rattled. Disturbed objects observed. Thunderous earth sounds heard at beginning of shock. Telephone operator was swamped with calls for half an hour. Gradual onset; swaying motion. Duration, 1 minute.

INTENSITY V IN SOUTH DAKOTA:

Deadwood.—Felt by and awakened many. Retaining wall damaged. Chair with broken leg toppled. Buildings creaked; doors and windows rattled. Disturbed objects observed. Vibrating motion.

Hot Springs.—Felt by all in Wind Cave National Park; many awakened. Buildings creaked; loose objects and windows rattled. Moderately loud earth sounds heard. Abrupt onset; trembling motion. Duration, 3–5 seconds. "As a result of the March 27 or 28 tremor, two large rocks dislodged and fell on one of the trails in Wind Cave."

Interior.—Felt by several. Few slight cracks in ceiling plaster. Doors had to be removed and planed down after quake because they would not close. Objects on walls swayed east-west. Rumbling sounds were heard. Gradual onset; rocking-swaying motion. Duration, 10 seconds.

Igloo.—Felt by nearly all. Buildings creaked; loose objects rattled. "Thought it was an explosion." Abrupt onset; trembling motion.

Martin.—Felt by and awakened many. Glass container broken in market and items fell in every aisle. Several farms reported broken glass. Buildings, loose objects, and pictures rattled. Thunderous earth sounds heard by many. Gradual onset; bumping motion. 3 shocks.

Pine Ridge.—Felt by many. Wall and ceiling plaster in north room cracked. Chandeliers, hanging pictures, and curtains on north wall swayed. Buildings shook; loose objects rattled. Roaring earth sounds heard by several before quake began. Abrupt onset; trembling motion.

Rapid City.—Felt by and awakened many. Buildings shook. Doors swung open and pipes, windows, and dishes rattled. One man fell out of bed. "It felt like being in a vibrating machine."

INTENSITY IV IN MONTANA: Alzada.

INTENSITY IV IN NEBRASKA: Bassett, Broken Bow, Cody, Hay Springs, Oshkosh, and Scottsbluff.

INTENSITY IV IN SOUTH DAKOTA: Ardmore, Belle Fourche, Buffalo Gap, Carter, Chamberlain, Dallas, Edgemont, Hayes, Kadoka, Keystone, Lead, Longvalley, Owanka, Pierre, Provo, Reliance, Rockerville, Scenic, Wall, Wanblee, and Winner.

INTENSITY IV IN WYOMING: Fort Laramie, Jay Em, Torrington, and Van Tassell.

INTENSITY I–III IN NEBRASKA: Burton, Gering, Hyannis, Kennedy, Minatare, Mitchell, Norden, North Platte, Ogallala, and Taylor.

INTENSITY I–III IN SOUTH DAKOTA: Arpan, Faith, Farmingdale, Harrison, Hill City, Ideal, Mount Coolidge, New Underwood, Oelrichs, Opal, Philip, Porcupine, Quinn, Rosebud, Saint Onge, Silver City, Spearfish, and Sturgis.

April 23: 19:20:55*; **April 24:** 01:33:53.0*; **April 27:** 18:30:45.6*; and **April 28:** 15:18:40.1*. Epicenter (1) 31.5° north, 93.8° west; (2) 31.6° north, 93.8° west; (3) 31.5° north, 93.8° west; (4) 31.7° north, 93.6° west, all in Louisiana, W. V. This series of earthquakes, and numerous additional tremors, were felt at Pineland, Hemphill, and Milam, Tex. The felt reports received were difficult to separate for each shock, but most seem to have been of intensity IV–V. Residents were quite apprehensive during the series, but the only damage was reported from Hemphill on April 28 when wall paper and plaster cracked. Another report stated that a roof was cracked in county seat but no date was given. During the shocks knickknacks fell from shelves, furniture moved, buildings creaked, and loose objects rattled. Apparently, no noise accompanied the tremors. Press reported that the shock on April 24 was felt at Zwolle and Shreveport, La. Additional shocks on April 30, 14:30, and May 7, 14:10, were reported to have been felt at Pineland, Tex., but there were no details. Magnitudes 3.7, 3.7, 3.4, and 4.4, respectively.

June 2: 17:00, 19:30, 20:27:24.2*. Epicenter 31.3° north, 94.0° west, Texas-Louisiana

border region, W. IV. The third shock was generally felt 2 miles east of Bronson, on Highway 87 north of Hemphill, and at Milam, Tex. Buildings creaked; loose objects rattled; and earth sounds were heard. Press reported that a light tremor was felt by some residents at 17:00. Pineland, Tex. reported a shock at 19:30 that was felt by many and rattled windows. It was described as light and momentary. Magnitude 4.2.

August 16: 05:36. Hemphill, Tex. area. V. Felt by and awakened several at Hemphill. "Some say plaster cracked." Buildings creaked; loose objects rattled; and disturbed objects were observed. The shock was also felt at Bronson, Geneva, Milam, and Pineland.

WESTERN MOUNTAIN REGION
(105TH MERIDIAN OR MOUNTAIN STANDARD TIME)

January 1: 06:54:14.5*. Helena, Mont. IV. Slight, brief shock felt by two in home; awakened one. Drapes swayed.

January 4: 06:00, 07:00. Mammoth (Yellowstone National Park), Wyo. Considerable shaking. Almost constant shaking during the evening.

January 5: (no times given). Mammoth (Yellowstone National Park), Wyo. Considerable shaking during the night; shaking all day.

January 6: 06.15. Mammoth (Yellowstone National Park), Wyo. Successive waves at 06:15; much shaking during the night.

January 7: 04:55:34.6*. Epicenter 39.1° north, 114.2° west, eastern Nevada, W. Lehman Caves National Monument (near Baker). IV. Felt by all in building. Magnitude 3.6.

January 7: (no times given). Mammoth (Yellowstone National Park), Wyo. Two rippling shakes during the night.

January 9: 11:14:47.0*, 12:36:45.7*. Mammoth (Yellowstone National Park), Wyo. Strong vibrations around noon and during the evening.

January 10: 23:00 to 24:00. Mammoth (Yellowstone National Park), Wyo. Some "good" shocks between 23:00 and 24:00; slight shaking during the day.

January 12: (early a.m.). Mammoth (Yellowstone National Park), Wyo. "Good" shocks in early morning hours.

January 12: 21:24:56.3*. Papoose Creek at Madison River (Helland Ranch), Mont. IV. Slow, 10-second shock preceded by roaring sound. Walls creaked.

January 13: 22:05:12.0*. Mammoth (Yellowstone National Park), Wyo. IV. Thirteen consecutive bumps. Awakened observer. Eight bumps were felt later; noticeable trembling all day and evening.

January 14: 12:00 (about), 19:30. Mammoth (Yellowstone National Park), Wyo. Shaking just before noon; jar and strong vibrations at 19:30. Few gentle tremors during the night.

January 15: 10:30. Mammoth (Yellowstone National Park), Wyo. Strong vibrations.

January 17: (in a.m., before daylight). Mammoth (Yellowstone National Park), Wyo. Some shaking.

January 18: (evening). Mammoth (Yellowstone National Park), Wyo. Intermittently strong vibrations.

January 19: (near daylight). Mammoth (Yellowstone National Park), Wyo. Series of jarring motions evenly spaced.

January 21: (during night). Mammoth (Yellowstone National Park), Wyo. Series of slight waving motions.

February 6: 01:02:28.3*, 04:13:34.8*. Epicenter of first shock 42.0° north, 112.3° west; of second, 42.1° north, 112.4° west, southern Idaho, W. Felt at Malad City.

February 20: 13:19:49*. Epicenter 39.4° north, 114.2° west, eastern Nevada, W. V. At Lehman Caves National Monument (near Baker), felt by several; small objects and furnishings shifted. Rapid, 2-second shock in north-northeast direction; preceded 1 second by faint earth noises. Also felt at Garrison, Utah (IV), where rapid motion was felt by several in community (some outdoors); windows and doors rattled; house creaked; moderate to loud earth noises heard. Magnitude 3.7.

March 20: 05:20. Kerr Dam and Polson, Mont. V. Awakened many in community. Motion rapid, duration 2 minutes.

March 23: 03:22. Felt at Polson, Mont.

March 23: 20:00. Mammoth (Yellowstone National Park), Wyo. Slight quivering felt by observer.

March 24: 04:10. Mammoth (Yellowstone National Park), Wyo. IV. Moderately strong shaking motion of 2–3 seconds duration felt by and awakened observer. House creaked.

March 27: (prior to 21:00). Old Faithful (Yellowstone National Park, near Firehold River, about ½ mile from Old Faithful), Wyo. Slight tremors felt quite frequently (for several hours prior to 21:00) by winterkeeper and wife.

March 27: 19:33:44.5*. Epicenter 35.9° north, 114.9° west, southern Nevada, W. Henderson. IV. Felt by several in various sections of town. Definite jolt; house seemed to move 6 inches back and forth. Also felt at Boulder City and Las Vegas.

March 27: 19:36. Ennis, Mont. (about 7 miles south of). V. Well water muddied. Felt by few at Ennis (IV); pictures shifted.

March 27: 20:56. Bonner, Mont. (2 miles north of). IV. Felt by many in community. Rapid, 1-second shock in northeast direction; thudding noise heard.

March 28: 02:55, 03:35, 04:15. Old Faithful (Yellowstone National Park), Wyo.

IV. Felt by six of eight persons. Wall mirror rattled; house creaked. First shock moderately strong, 1–2 seconds duration; second, quite strong jolt, 2 seconds duration; third, slight tremor, 1–2 seconds duration. Slight rumble heard.

March 28: 03:10. Swan Lake, Mont. VI. Large insulator broke. Well water muddied.

March 31: 21:50. Esterbrook, Wyo. IV. Light tremors of few seconds duration felt by observer. Dishes rattled; houses trembled. Loud earth noises heard. Also felt at Lost Springs where a rumble, like heavy truck on highway, was heard.

April 7: 08:31:23*. Epicenter 45.0° north, 111.6° west, southwestern Montana, W. Papoose Creek at Madison River (Helland Ranch), Mont. IV. Slow, 1–2 second shock felt by observer. Windows, doors, and dishes rattled. Magnitude 3.2.

April 10: 14:29:57*. Epicenter 39.2° north, 114.2° west, eastern Nevada, W. Lehman Caves National Monument (near Baker). III. Felt by several. Rapid motion in west direction, 1 second duration.

April 16: 23:53:43.6*. Epicenter 44.1° north, 114.3° west, central Idaho, W. Robinson Bar Ranch (about 15 miles west of Clayton). IV. Felt by several (some outdoors). Windows rattled; walls creaked. Trees, bushes shaken slightly. Trembling motion in south-north direction, 3 seconds duration; faint earth noises heard. Magnitude 3.6.

May 13: 06:46:15.3*. Bigfork, Mont. IV. Awakened few in community. Windows, doors, and dishes rattled; house creaked. Rapid, 2-second shock preceded by rolling earth noise.

June 26: 05:24:28.5*. Epicenter 48.2° north, 115.1° west, northwestern Montana, W. Marion (NW¼, Sec. 2, T27, R26). IV. Felt by most in the valley; awakened observer. Curtains swayed. Trembling motion in west-east direction; abrupt onset. Magnitude 4.7.

June 29: 05:14. Felt at Hungry Horse Dam, Mont. (This may be the shock recorded on June 26 at 05:24:28.5*.)

August 2: 10:30. Helena, Mont. II. Felt by few; one jolt; abrupt onset.

August 13: 14:51:02*. Epicenter 46.5° north, 112.2° west, near Helena, Mont., W. Helena. IV. Felt by several. Loose objects rattled; building creaked. Jolt, 2 seconds duration, abrupt onset. Magnitude 4.1.

August 21: 20:28:11*. Epicenter 42.9° north, 104.7° west, eastern Wyoming, W. Felt over an area of approximately 1,500 square miles. Maximum intensity V. A very slight aftershock was felt at Keeline at 21:35. Magnitude 4.5.

INTENSITY V:

Lusk.—Felt by most everyone; telephone exchange flooded with calls; frightened few. Most persons thought a furnace had blown up or that a heavy truck was moving nearby. Motion slow, several minutes duration. Thought to be the most severe shock felt in the area for many years.

Keeline.—Felt by many; frightened few (some nearly panicked); many vacated homes. Disturbed objects observed by few; buildings creaked. Explosivelike earth noises, then a bump followed by a loud thud.

Lost Springs.—Furnishings shifted; furniture moved up and down. Rapid, 1-minute shock in southwest direction; loud earth noises.

INTENSITY IV: Lance Creek.

INTENSITY I–III: Jay Em and Node (4 miles west of).

September 21: 22:05. Boulder City, Nev. Explosivelike shock.

September 23: 10:09:38*. Epicenter 35.9° north, 114.8° west, near Boulder City, Nev., W. Felt area on the order of approximately 3,000 square miles. Maximum intensity V. Reported as strongest in the Boulder City area, 25 miles southeast of Las Vegas, where it was described as explosivelike, a "real china rattler." At Henderson, about 12 miles northwest of Boulder City, lamp teetered back and forth; objects nearly toppled; door jarred open; floor seemed to rock. At Las Vegas, many calls to newspaper office. Courthouse rocked with a swaying motion for about 10 seconds, bringing spectators in courtroom from their seats. Pictures jarred from walls in some areas. Resembled sonic boom. Felt in the control towers at McCarran Field and Nellis Air Force Base. Reported as quite strong at North Las Vegas, with "quite a bit" of vibration. Magnitude 4.4.

September. Ronan, Mont. (north Crow Creek area, 4 miles northeast of Ronan). Several earthquakes, beginning in September, felt by observer. Mostly rolling motions; some were accompanied by noise.

October 8: 14:00, 19:26:02.4*. Epicenter 47.8° north, 114.2° west, Flathead Lake area, Mont., W. V. At Polson, felt by many; children frightened and cried. Rolling, 5-second motion, accompanied by loud rumble. Regarded as the sharpest in years. Much lighter shock felt at 14:00. Several light tremors felt in the area during the past three or four weeks. Felt by some in the Seeley Lake area (IV), where building creaked; radio set

shaken out of order; trembling motion in south-north direction, few seconds duration. At Kerr Dam, people thought a rockslide had occurred. Also felt at Big Arm and Yellow Bay. Magnitude 4.6.

October 14: 09.03:53.6*. Epicenter 47.9° north, 114.3° west, Flathead Lake region, Mont., W. Felt at Polson. Magnitude 4.6.

October 18: 11:33:19.9*. Epicenter 41.9° north, 111.8° west, northern Cache County, Utah, W. Felt in Cache Valley, Utah, and at Preston, Idaho. Magnitude 4.3.

October 21: 00:24. Felt at Ennis, Mont.

October 21: 00:30. Felt at Virginia City, Mont.

October 21: 00:38:31.0*. Epicenter 44.8° north, 111.6° west, Hebgen Lake region, Mont., W. Felt over an area of approximately 25,000 square miles of Montana, Idaho, and Wyoming. (See map, page 18.) Principal effects reported were falling of knickknacks, shifting of small objects and furnishings, and the awakening of many persons. Maximum intensity V. One report of cracked windows at Maxville, Mont., about 144 miles northwest of the epicenter. Magnitude 5.8.

INTENSITY V IN MONTANA:

Alder.—Felt by and awakened many in community; frightened few. Windows, doors, and dishes rattled; hanging objects swung. Motion rapid, 10 seconds duration; preceded 5 seconds by moderate earth noises.

Anaconda.—Awakened all in community; frightened few. Motion rapid, 3 seconds duration.

Bonner.—Felt by several and awakened few in community. Knickknacks fell. Rapid motion in northeast-southwest direction; loud, jarring earth noises preceded shock by ½ second.

Butte.—Felt by and awakened many in community; frightened few. Small objects and furnishings shifted. Hanging objects swung east-west. Motion slow, rolling, 4–25 seconds duration; directions east, southeast-northwest, north-south; moderate earth noises 1 second before shock.

Centennial Valley (ranch out of Monida).—Felt by and awakened all in home; frightened few. Rapid, sharp, brief motion in north direction; moderate earth noises like roaring wind.

Dell (4 miles northeast of).—Awakened few in community. Furnishings shifted. Motion rapid, 2–3 minutes duration; faint earth noises.

Dillon.—Felt by and awakened many in community; frightened few. Rapid, jolting motion.

Divide.—Awakened many and frightened few in community. Rapid, 5–10 second shock; moderate earth noises from east-west.

Elk Lake (about 44.7° north, 111.6° west).—Awakened many; frightened few. Small objects and furnishings shifted; vases, etc., small objects overturned; knickknacks fell. Trees, bushes shaken moderately. Three shakes; motion rapid, lasted 1 minute; direction northwest-southeast; moderate earth noises. "We have had slight jolts ever since the 1959 shock. Rocks roll down from a rimrock along the lake."

Ennis.—Felt by, awakened, and frightened many in community. Motion rapid, lasted 4–5 seconds; moderate earth noises from northeast-southwest.

Hebgen Dam (Hebgen Lake).—Felt by, awakened, and frightened all in home. Small objects overturned; knickknacks fell. Slow, 10-second shock in south-north direction; preceded 1–2 seconds by loud earth noises from south-north.

Jackson.—Felt by and awakened all in home. Motion slow, lasted 10 seconds; faint earth noises.

Jeffers.—Felt by and awakened many in community. Motion slow, lasted 10 seconds; faint earth noises.

Laurin.—Felt by and awakened all in home. Slow, brief motion.

McAllister.—Awakened few in community. Furnishings shifted. Lasted ½ second.

Maxville.—Awakened few in community. Windows cracked. Slow, 3-second shock; faint earth noises.

Monida.—Awakened many and frightened few in community. Motion rapid, momentary duration; moderately loud earth noises.

Nine Quarter Mile Ranch (about 5 miles up Taylor Fork of the Gallatin River, about 45.1° north, 111.2° west).—Felt by and awakened many in home; frightened all. Dishes thrown from shelves. Trees, bushes shaken moderately. Motion slow, momentary duration; preceded 2 seconds by moderate earth noises.

Papoose Creek at Madison River (Helland Ranch, about 44.9° north, 111.5° west).—Awakened most persons in community; frightened all in home. Bed "moving all over"; chandelier swung north-south for 15 minutes after shock. Motion rolling, 4–5 seconds duration.

Philipsburg.—Awakened many and frightened few in community. Slight motion in southeast direction, few seconds duration.

Polaris.—Felt by and awakened all in community; frightened few.

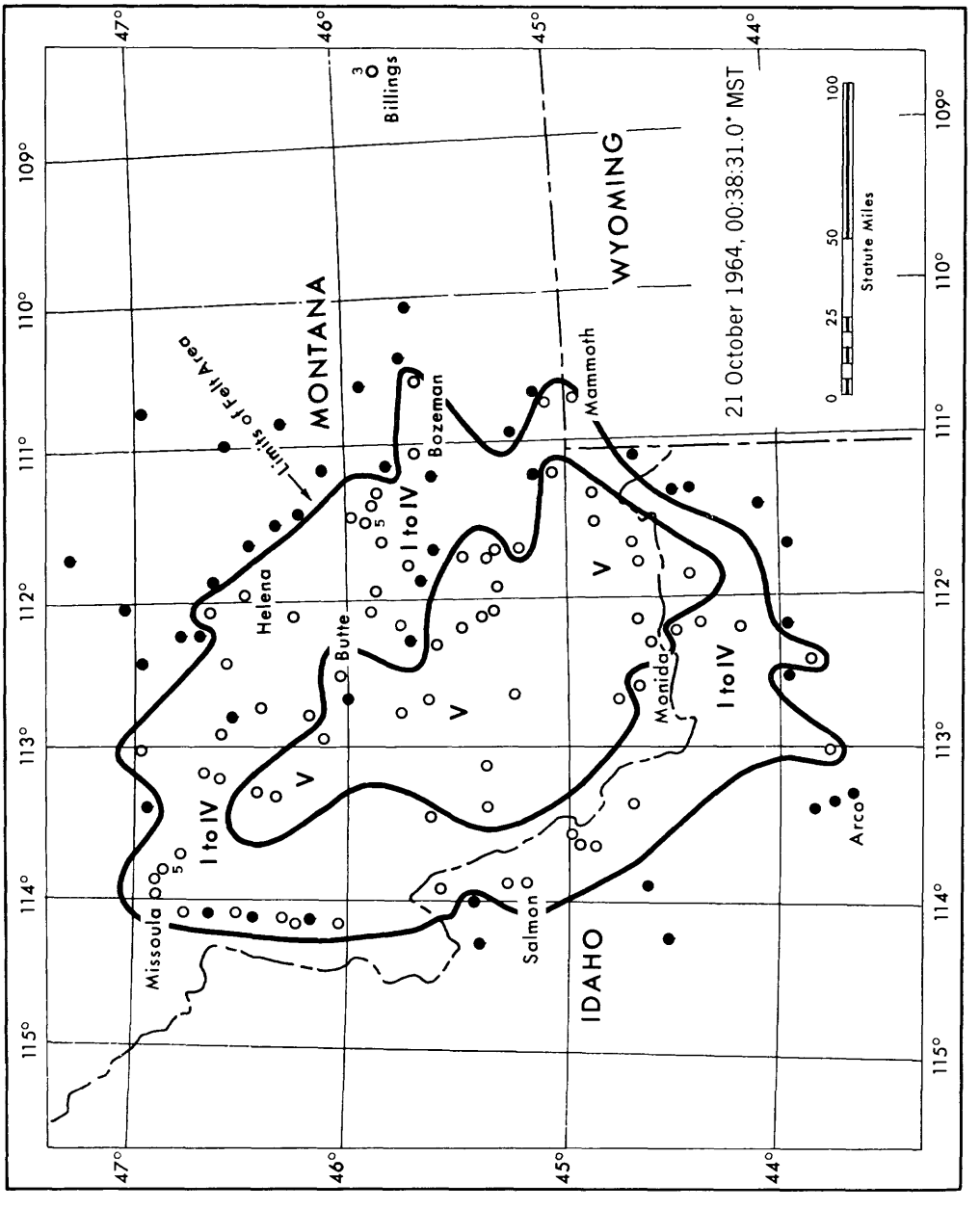


FIGURE 4.—*Area affected by earthquake of October 21.*

Red Rock Lakes National Wildlife Refuge (in area about 25 miles west of Monida).—Awakened many and frightened few in community. Pictures and fixtures on walls tilted. Slow, 20-second shock; preceded 10 seconds by moderate, roaring earth noises from east.

Three Forks.—Bed lamp fell. Motion slow, shook for 5 seconds, subsided, then shook 5 seconds longer.

Twin Bridges.—Felt by all and awakened many in community. Slow, 5–10 second shock.

Virginia City.—Awakened almost everyone; frightened many. Picture hanging on wall in courtroom knocked askew; chandeliers swung. Motion sharp, lasted 4 seconds.

INTENSITY V IN IDAHO:

Kilgore.—Felt by all and frightened many in community. Motion swaying, lasted 2 minutes; preceded by very loud roaring earth noise.

Tendoy.—Felt by several and frightened few in community. Butane tank shifted. Trees, bushes shaken moderately. Motion slow, duration 2–3 seconds, accompanied by earth noises. Also felt by hunters 5 miles northeast of Tendoy; tents and equipment shook.

INTENSITY IV IN MONTANA: Boulder, Bozeman, Cameron (Talc Mine in Johnny Gulch), Clinton, Corvallis, Darby, Deer Lodge, Drummond, Elliston, Fort Harrison, Gardiner, Goldcreek, Hall, Hamilton, Harrison, Helmville, Lima, Lolo, Manhattan, Melrose, Milltown, Stevensville, Trident, Waterloo, Willow Creek, and Wisdom.

INTENSITY IV IN IDAHO: Carmen, Dubois, Gibbonsville, Leadore, Lemhi, Salmon, Spencer, and Terreton.

INTENSITY IV IN WYOMING: Mammoth (Yellowstone National Park).

INTENSITY I–III IN MONTANA: Billings, Cardwell, Clancey, Livingston, Missoula, Sheridan, Warmsprings, and Whitehall.

INTENSITY I–III IN IDAHO: Howe (near) and Humphrey.

October 21: 00:45. Virginia City, Mont. Sharp jolt.

October 21: 01:20 or 01:30. Felt at Monida, Mont.

October 21: 03:00. Virginia City, Mont. Felt by two persons.

October 21: 13:02:20.5*. Epicenter 44.8° north, 111.6° west, Hebgen Lake region, Mont., W. Papoose Creek at Madison River (Helland Ranch). IV. Sharply felt; plants shook. Also felt at Butte and Virginia City. Magnitude 3.9.

October 22: 12:45 (about). Centennial Valley, Mont. (on ranch out of Monida). Two slight tremors, one about 12:45.

November 4: 09:48. Hebgen Dam (Hebgen Lake), Mont. IV. Felt by several; frightened one. Windows, doors, and dishes rattled; house creaked. Slow, 3–4 second shock in south-north direction; moderate earth noises.

November 23: 20:01:08*. Epicenter 45.3° north, 111.7° west, near Ennis, Mont., W. IV. At Cameron, felt by several. Windows, doors, and dishes rattled; house creaked. Motion rapid, duration 5 seconds. Felt by many (some outdoors) at Ennis where dishes rattled; walls creaked. Slow, northeast-southwest motion of 2 seconds duration, preceded ½ second by moderate earth noises. Magnitude 3.9.

November 23: 22:07. Ennis, Mont. "I thought I felt a shock about 10:07 p.m."

December 18: 20:03. Polson, Mont. Gentle, rolling motion accompanied by a rumble that was noticed by shoppers in downtown stores. Also felt in other lower Flathead Lake communities. Reported as the 40th of a series of light but noticeable shocks that began in July.

December 20: 13:56:03.2*. Epicenter 35.9° north, 114.9° west, California-Nevada border region, W. Felt at Boulder City, Nev.

December 21: 14:54:58*. Epicenter 44.9° north, 112.7° west, eastern Idaho, W. Lima, Mont. IV. Houses shook throughout the town. Sound like wind, slight tremor, then a larger tremor. Magnitude 3.9.

CALIFORNIA AND WESTERN NEVADA
(120TH MERIDIAN OR PACIFIC STANDARD TIME)

NOTE.—All places are in California unless otherwise stated.

January 2: 11:48:37.9*. Epicenter 35.0° north, 118.4° west, Kern County, W. IV. At Cantil, felt by several in home; house creaked slightly. Motion slow, slight; faint earth noises. Severe shock at Piute Lookout (about 3 miles north of Claraville in Sequoia National Forest); floor of cabin seemed to roll. Northeast-southwest direction; loud rumble. Jolting motion felt at Tehachapi where walls creaked. Also felt at Monolith; one jerk felt by several. Magnitude 4.4.

January 6: 15:15:55.7*. Epicenter 34.3°

north, 116.4° west, San Bernardino County, W. Minor shock in the Palm Springs and San Bernardino areas. Magnitude 3.5, P.

January 6: 15:47:11.4*. Epicenter 34.3° north, 116.5° west, San Bernardino County, W. Felt over an area of approximately 4,500 square miles of Riverside and San Bernardino counties. Maximum intensity V. At Forest Falls, felt by all in building; frightened many in community. Duration 2 seconds; preceded 2 seconds by loud rumble from north-northeast. At Yucca Valley (about 50 miles east of San Bernardino), felt by several working; small objects and furnishings shifted. Slow, north-south motion, duration 1 second. Felt with intensity IV at Angelus Oaks, Baker (10 miles north of), Fawnskin, Ludlow, Mountain Center, Palm Springs, Patton, Twenty-nine Palms, and Yermo. Also felt at Hemet, La Quinta, Lucerne Valley, Pinon Hills, Rancho Mirage, Redlands, San Bernardino, Victorville, White Water (White Water Canyon), and Yucaipa. Magnitude 4.4.

January 9: 08:20:17*. Epicenter 37°40′ north, 122°35′ west, offshore near Pacifica, B. Slight shock in the westernmost sections of San Francisco and the San Mateo coastal areas. Magnitude 3.0.

January 27: 02:44:09*. Epicenter 39°20′ north, 123°28′ west, southwest of Willits, B. Felt at Mendocino. Magnitude 3.1.

January 27: 03:56:10*. Epicenter 37°30′ north, 118°46′ west, northwest of Bishop, B. Long Valley Reservoir (about 25 miles northwest of Bishop). IV. Felt by several and awakened few in community. Windows rattled; frame creaked slightly. Motion slow, duration 1 second. Magnitude 2.9.

February 1: 11:51:43*. Epicenter 33.0° north, 115.9° west, Imperial County, W. San Diego. II. Hanging objects swayed slightly.

February 3: 00:43:36.3*. Epicenter 31.5° north, 114.2° west, Gulf of California, W. San Diego. III. Light suspended objects swayed. Magnitude 4.6.

February 3: 02:21:20.8*. Epicenter 39.8° north, 120.0° west, Lassen County, W. Felt over an area of approximately 300 square miles, principally in Lassen and Sierra counties. IV. At Long Valley Inspection Station (17 miles northwest of Reno, Nev., on Highway 395), awakened few in community. Motion rapid. Also felt at Loyalton, and at Carson City, Nev. Magnitude 3.4.

February 3: 06:32. San Diego. III. Light suspended objects swayed.

February 7: 14:07:49.9*, 14:10:52.8*. Epicenter of first shock 35.3° north, 118.8° west; of second, 35.4° north, 118.8° west, Kern County, W. IV. Felt by several in community at Bodfish, where walls creaked. At Caliente, felt by many; windows, doors, and dishes rattled; faint earth noises heard. At Kernville, "felt considerably." Slow, brief motion felt by observer at Rosamond; windows, doors, and dishes rattled. Magnitudes 4.3 and 3.9, respectively.

February 7: 21:29:21.0*. Epicenter 34°12′ north, 118°37′ west, near Canoga Park, P. IV. At Van Nuys, family reported feeling a strong shock. Building shook. Child fell out of bed. Very light, brief motion felt by several at Fillmore (about 25 miles northwest of Canoga Park). Magnitude 3.7.

February 20: 14:21. Long Beach. V. Police and newspaper switchboards flooded with calls. Frightened housewives reported houses shook and in some cases, furniture and refrigerators banged against walls; office workers in downtown Long Beach were alarmed and reported desks shook. The shock was described as an abrupt, sharp, jolting motion. Reports indicated it was felt only in the Long Beach area.

February 26: 12:32:54.4*. Epicenter 40.3° north, 124.6° west, W. Felt over an area of approximately 1,200 square miles of Humboldt County. Maximum intensity V at Ferndale where felt by many and frightened few in community; small objects shifted; dishes fell; car rocked. Motion slow, rapid, duration 10 seconds. Intensity IV at Fortuna, Honeydew, Loleta, Petrolia, Rio Dell, Shively, and South Fork. Also felt at Bayside, Eureka, and Weott. Magnitude 4.6.

February 27: 00:37:02*. Epicenter 36°55′ north, 121°36′ west, east of Watsonville, B. Mountain View. III. Family felt rapid jar resembling sonic boom. Magnitude 3.2.

March 8: 18:06:30.8*. Epicenter 37.6° north, 118.4° west, Mono County, W. Bishop (Control Gorge Power Plant). IV. Felt by several and frightened few. Dishes rattled; walls creaked. Hanging objects swung. Rapid, abrupt motion in east-west direction. Magnitude 3.9.

March 9: 12:49:55.8*. Epicenter 35.2° north, 118.7° west, Kern County, W. Miracle Hot Springs. III. Mild shock felt by some. Magnitude 4.3.

March 22: 07:56:19.8*, 08:30:55.2* (main shock), 08:39:50.3*, 10:14:49.6*, 10:17:43.0*, 10:30. Epicenters (1) 38.8° north, 118.8° west; (2) 38.8° north, 118.7° west; (3) 38.8° north, 118.8° west; (4) 38.8° north, 118.8° west; (5) 38.9° north, 118.7° west, W. The

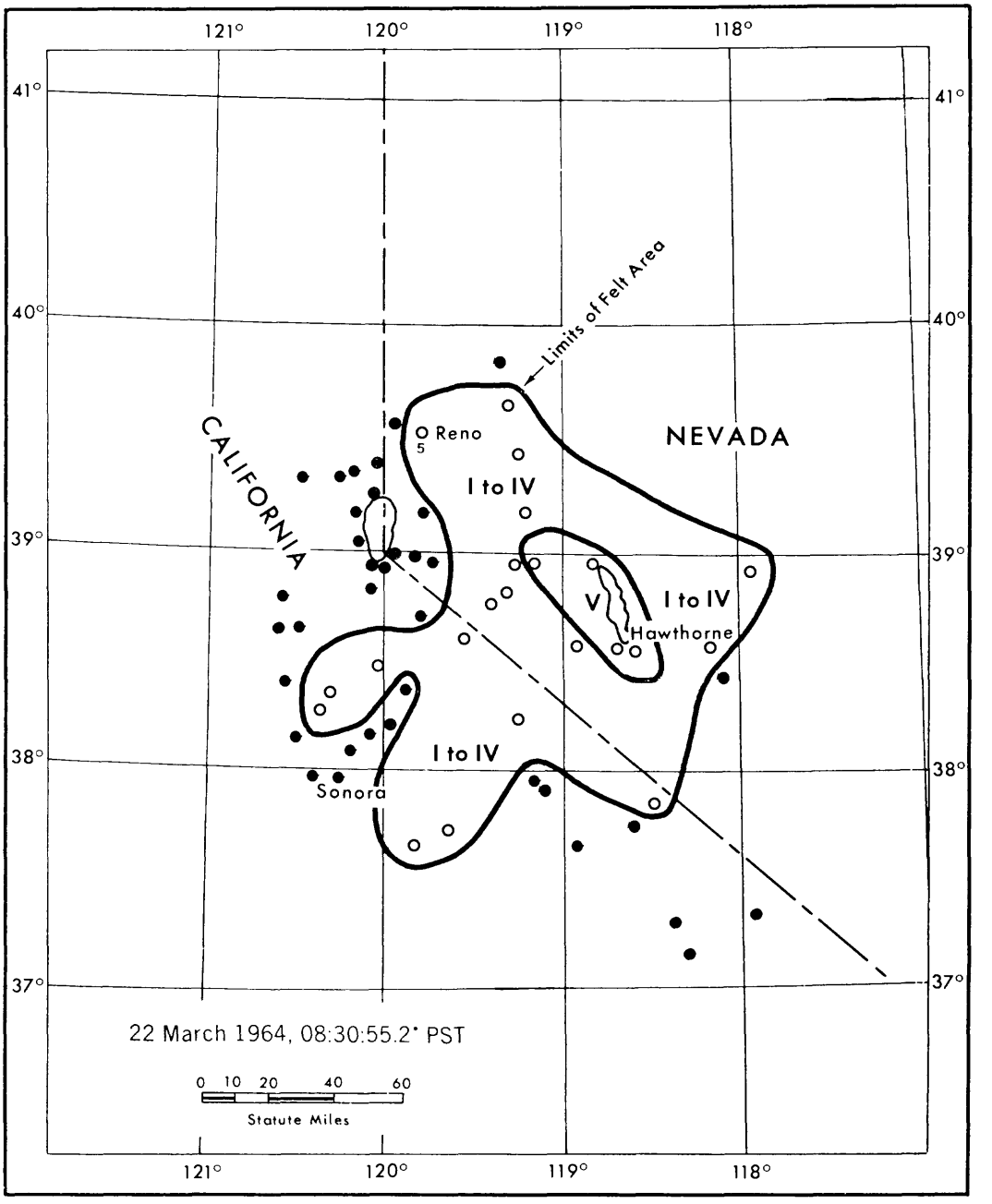


FIGURE 5.—*Area affected by earthquake of March 22.*

main shock was felt over an area of approximately 7,500 square miles of eastern California and western Nevada. (See fig. 5, above.) Maximum intensity V. No damage was reported from the epicentral area. The one report from Reno, Nev., indicated a slight "felt" intensity, but observer reported that a patio crack (across the street from his residence) was attributed to the earthquake. Reports are for the main shock unless otherwise indicated. Magnitudes of first and second shocks 3.8 and 4.5, respectively.

INTENSITY V IN NEVADA:

Babbitt.—Felt by all and frightened many

in community; awakened all in home. Trees, bushes shaken slightly. Rapid, brief motion; moderate earth noises.

Hawthorne (U.S. Naval Ammunition Depot).—Felt by and awakened many in community; frightened few. Windows, doors, and small objects rattled. Slow, 5-second shock. Shocks also felt at 07:56:19.8*, 10:14:49.6* or 10:17:43.0*, and 10:30.

Hawthorne.—Felt by many in community (some outdoors); awakened all in home. House creaked. Rapid, ½-second shock.

Reno.—Slight vibration felt by observer lying down. Hanging lamp swung northwest-southeast; bed shook slightly northwest-southeast. Motion slow, duration 4 seconds; northwest-southeast direction. "The people across the street from my house said their cement patio had a long crack from this earthquake."

Schurz.—Felt by all in community; awakened few in community. Dishes rattled; frame stopped. Motion slow, duration 5 seconds; direction east-west.

Yerington.—Felt by and awakened all in home; frightened many in community. Trees, bushes shaken moderately. Rapid motion of momentary duration.

INTENSITY IV IN NEVADA: Gabbs, Luning, Rafter 7 Ranch (East Walker River area, near Lewis), Smith, and Wabuska.

INTENSITY IV IN CALIFORNIA: Arnold, Benton Quarantine Station (about 4 miles east of Benton on Highway 6), Bridgeport, Coleville, and El Portal.

INTENSITY I–III IN CALIFORNIA: Alpine, Omo Ranch (about 14 miles southeast of Placerville), and Yosemite Valley (Park Headquarters).

March 23: 07:32:55.0*. Epicenter 38.7° north, 118.8° west, W. Felt at Hawthorne, Nev. Magnitude 3.9.

March 23: 16:00 (about). Rafter 7 Ranch, Nev. (East Walker River area, near Lewis). Light shock.

March 24: 15:57:07.8*. Epicenter 38.7° north, 118.7° west, W. Rafter 7 Ranch, Nev. (East Walker River area, near Lewis). Light shock. Magnitude 3.5.

March 25: 00:46:13.0*. Epicenter 40.4° north, 124.4° west, near coast of northern California, W. Scotia. IV. Felt by several and awakened few in community. Windows rattled. Motion slow, lasted about 15 seconds; direction northwest-southeast. Magnitude 4.5.

March 30: 22:10:02*. Epicenter 40.4° north, 120.5° west, east of Susanville, B. IV. At Greenville, felt by several and awakened few in community. Motion slow. Also light shock felt at Johnstonville and the Conservation Center. Magnitude 2.7.

April 2: 22:35:08*. Epicenter 36°43′ north, 121°31′ west, B. Hollister (7½ miles south of, Harris Ranch). III. One jolt felt by observer. Magnitude 3.0.

April 12: 02:10. Etiwanda. IV. Felt by several; awakened few. Rapid, brief motion.

April 24: 23:44:13*. Epicenter 40.1° north, 120.1° west, B. Felt over an area of approximately 900 square miles of southern Lassen and eastern Plumas counties. Maximum intensity V. One instance of slight plaster cracking at Herlong. At Doyle, awakened many in community; frightened few. Small objects and furnishings shifted; small objects overturned. Motion rapid, duration about 1 minute; loud earth noises. Felt by, awakened, and frightened all in home at Herlong. Plaster cracked slightly. Small objects shifted. Motion rapid and slow, duration 30 seconds to 2 minutes; direction west-east; loud earth noises about 10 seconds before shock. At Milford, felt by many; frightened all in home. Windows rattled. Slow, 10-second shock in northwest direction; preceded 4 seconds by moderate earth noises from northwest. Magnitude 3.7.

May 5: 13:15. Long Valley Dam (about 25 miles northwest of Bishop). III. Felt by several. Motion rapid, sharp, duration 2 seconds.

May 6: 08:54:02.0*. Epicenter 35.1° north, 118.8° west, Kern County, W. IV. Felt by several in community at Caliente where windows, doors, and dishes rattled. Motion rapid, duration 20 seconds. Also felt at Kern Canyon Powerhouse (about 10 miles east of Bakersfield) and at Miracle Hot Springs. Magnitude 4.0, B.

May 6: 16:15 (about). Benton Quarantine Station (about 6 miles east of Benton). III. Slight shock, followed a few seconds later by a sharp shock and slight twist.

May 10: 00:45. San Francisco. IV. Awakened observer. Windows and venetian blinds rattled slightly. Slight but definite movement of house.

May 13: 04:18:34.8*. Epicenter 36°33′ north, 121°08′ west, B. Felt over an area of approximately 3,000 square miles of west-central California. Maximum intensity V. Magnitude 4.4.

INTENSITY V:

Greenfield.—Awakened many and frightened few in home. Pendulum clock facing west

creaked. Slow, 2-second shock; moderate earth noises.

Harris Ranch (7½ miles south of Hollister).—Awakened many in community. Windows, doors, and dishes rattled; house creaked.

King City.—Felt by and awakened all in home. Windows rattled; frame creaked. Motion slow, lasted 3 seconds.

Libby Ranch (about 2½ miles southwest of Paicines).—Awakened all in home. House creaked. Motion slow, lasted about 1 minute.

Paicines.—Felt by and awakened many; frightened few. Frame creaked. Slow, east-west motion; faint earth noises.

Paicines Ranch (Paicines).—Felt by and awakened few in home. Small objects and furnishings shifted; pictures askew. Direction north; faint earth noises.

Pinnacles National Monument (west of San Benito).—Felt by and awakened all. Windows rattled; walls creaked. Rapid, 15-second shock; moderate earth noises.

San Benito.—Felt by all; awakened all in home. Small objects shifted. Rapid, 6-second shock; moderate earth noises.

Soledad.—Felt by and awakened many in community; frightened few. Windows, doors, and dishes rattled; house creaked. Motion slow, duration few seconds.

INTENSITY IV: Aptos, Capitola, Carmel, Carmel Valley, Cienega District (south of Hollister, 9970 and 13150 Cienega Road), Gonzales, and Hernandez area (about 16 miles southeast of San Benito).

May 13: 20:15. San Francisco. IV. Slight but definite movement of house; venetian blinds and windows rattled slightly.

May 18: 12:46. San Anselmo. IV. Rapid, 1½-second shock felt by observer. Windows rattled; building creaked. Building also creaked at 09:30 and 10:45 on same day.

May 24: 08:26:45*. Epicenter 34.9° north, 119.2° west, B. V. At Tehachapi, felt by many in community; small objects shifted; vases overturned; trees, bushes shaken moderately. Momentary duration; faint earth noises. Felt with intensity IV at Di Giorgio and Keene. Magnitude 3.9.

May 24: 12:12:23*. Epicenter 36°51′ north, 121°40′ west, B. IV. At Harris Ranch (7½ miles south of Hollister), felt by several and frightened few in home; man sitting outdoors thought it was a gust of wind. Rapid motion, duration several seconds. Felt by many at Hollister where windows, doors, and dishes rattled; walls creaked. Motion rapid, slight, lasted 10 seconds. At San Juan Bautista Mission (San Juan Bautista), felt by two; roof beams creaked. Rapid, 1-second motion in northeast-southwest direction. Magnitude 3.2.

May 30: 22:41. Slight shock felt at Kern Canyon Powerhouse (about 10 miles east of Bakersfield) and Miracle Hot Springs (about 30 miles northeast of Bakersfield).

June 12: 16:42:57*. Epicenter 37°49′ north, 122°17′ west, B. Felt over an area of approximately 500 square miles of the San Francisco Bay region. Maximum intensity V. Two instances of slight damage: at El Cerrito, plaster cracked slightly; at Oakland, concrete damaged slightly. Magnitude 3.4.

INTENSITY V:

El Cerrito.—Felt by three persons. Plaster cracked slightly. Motion slow, duration 1 minute; preceded 2 seconds by moderate earth noises from north.

Oakland.—Felt by all in community; frightened few. Damage slight to concrete. Felt like a bulldozer had rammed into building. Motion rapid, duration 10–20 seconds; loud earth noises.

INTENSITY IV:

Alameda, Berkeley, Canyon, Moraga, Orinda, Piedmont, Richmond, San Francisco, and Treasure Island (Yerba Buena).

INTENSITY I–III: Lafayette.

June 13: 14:59. Whittier. III. Slight, 1-second jolt from southeast felt by observer. Wall snapped once.

June 21: 07:32:52*. Epicenter 32°40′ north, 117°08′ west, California-Mexico border region, P. In California, the shock was felt over an area of approximately 2,000 square miles. Maximum intensity VI. Damage slight. At San Diego, plaster cracked slightly at an old fire station and the main Post Office building. Slight damage at Coronado. Burglar alarms activated. Magnitude 3.7.

INTENSITY VI:

Coronado.—Hundreds of calls to the Police Department; awakened many in community; frightened all in home. Damage slight. Small objects and furnishings shifted. Rapid, 10–30 second shock in northeast direction; loud earth noises from northeast.

San Diego.—Generally felt; awakened thousands. Damage slight. Plaster fell from a slight crack in the ceiling of a second story room of an old fire station at Fifth Avenue and Palm Street. New cracks in the beams of the inspectors' gallery in the main Post Office building; felt like exploding bomb directly underneath. Burglar alarms activated; small objects shifted. Motion rapid, bumping, duration 2–15 seconds; direction east and

southeast; loud earth noises from east, and moderate earth noises from southwest 3 seconds before shock.

INTENSITY V: Imperial Beach and Nestor.

INTENSITY IV: Alpine, Chula Vista, El Cajon, Jamul (6 miles northeast of, in Lawson Valley), Ramona (Mount Woodson area), Santee, and Solana Beach (5 miles east of).

June 22: 20:54:37*. Epicenter 32°40′ north, 117°08′ west, California-Mexico border region, P. Numerous calls to newspaper office and Police Department in San Diego from every section of San Diego County. Maximum intensity VI at Imperial Beach, where observer found four 6-inch-long plaster cracks in room after hearing a sharp, cracking sound; another observer thought this shock was stronger than the one on June 21 at 07:32:52*. Felt strongly at Chula Vista where man in trailer said it was the strongest shock felt in his 10 years of residence there. At Nestor, lamps swayed northeast; house seemed to buckle and roll. Felt generally and strongly in San Diego and vicinity. At Coronado, typewriter bounced off table; water splashed in bathtub. Fire alarms activated at the Marine Terminal and several business establishments. Ship shuddered in San Diego Harbor. Motion rocking, east-west; abrupt onset, preceded by roaring sound. At National City, many calls to Police Department. Reported as quite strong at Lakeside and Mount Helix; loud thumping noises. Magnitude 3.6.

July 5: 11:07:58.2*, 19:06:09.6*. Epicenter of first shock 26.2° north, 110.2° west; of second, 26.5° north, 110.3° west, Gulf of California, W. El Centro. Both shocks felt by observer (sitting). Motion slow. Magnitudes 6.0 and 5.2, respectively.

July 14: 19:11:06*. Epicenter 32°40′ north, 117°08′ west, California-Mexico border region, P. V. At Chula Vista, dishes and pictures fell. At San Diego, scores of calls to police stations and newspaper offices from downtown San Diego and South Bay cities. Large buildings jolted in downtown San Diego. Diners arose from chairs in the club on the 24th floor of the U.S. National Bank Building at Second Avenue and Broadway; glasses on tables shook; lamps wobbled; people stood up in shock and a few women yelled. Fire alarm activated. Motion rapid, lasted 10 seconds; direction north-south, southeast. Magnitude 3.5.

July 28: (during afternoon). San Francisco (Richmond District). Slight tremble.

August 30: 14:57:37*. Epicenter 34°15′ north, 118°28′ west, Los Angeles County, P. V. Felt over an area of approximately 750 square miles of Los Angeles County. Newspaper switchboards were jammed with calls from the downtown area of Los Angeles, Baldwin Hills, Burbank, Highland Park, Pasadena, Sunland, and the San Fernando Valley. Described as a jolt. Magnitude 4.0.

INTENSITY V:

Burbank.—Felt by all in community. Windows rattled. Motion slow, brief.

Hollywood.—Glasses jarred off table; roast knocked off pan. Rolling motion in east-west direction.

Topanga.—Felt by all in home. Small objects shifted. Rapid, 1-second shock; loud earth noises like sonic boom.

INTENSITY IV: Beverly Hills, Calabasas, Glendale, Highland Park, Los Angeles, Newhall, North Hollywood, San Fernando, South Gate, Tujunga, Van Nuys, and Whittier.

INTENSITY I–III: Maywood and Palos Verdes Estates.

September 1: 11:49:16*. Epicenter 36.8° north, 121.7° west, west-central California, B. IV. Felt over a small area, approximately 500 square miles, principally in the Gilroy area. One isolated report of the shock being very slightly felt at San Francisco. At Capitola, felt by observer sitting; windows and doors rattled; slow motion in north direction; faint earth noises. At Freedom (near Watsonville), felt by observer sitting; house creaked; motion slow; faint earth noises. Felt by all in home and by some outdoors at Gilroy; windows and doors rattled; motion rapid and slow; lasted 1 second; direction east-west; faint earth noises. Felt by all in home 2 miles east of Gilroy; motion slow; direction south; faint earth noises from south. Intensity I–III at Aptos, Aromas, Gilroy Hot Springs (10 miles northeast of Gilroy), Monterey, Moss Landing, San Francisco, and Watsonville. Magnitude 3.9.

September 4: 12:20:24.8*. Epicenter 37.4° north, 117.5° west, California-Nevada border region, B. Bishop (Control Gorge Power Plant). V. Two rapid "hardy" shocks felt by several sitting; frightened all. Direction northwest. Magnitude 4.1.

September 7: 09:40. Bishop (Birchum Canyon). II. Rapid motion felt by few.

September 9: 16:27:00*. Epicenter 33°57′ north, 118°28′ west, P. Manhattan Beach. IV. Rapid, light, 1-second shock felt by observer sitting. Windows rattled. Moderate earth noises 1 second before shock. Also felt at Culver City and Santa Monica. Magnitude 2.8.

September 23: 11:30 (about). Johannesburg. IV. Felt by and frightened two persons in home. Windows rattled. Motion rapid, duration 30 seconds.

September 30: 00:33:00*. Epicenter 36.7° north, 121.3° west, Hollister region, B. Felt by one at the Harris Ranch (7½ miles south of Hollister). Magnitude 3.1.

September 30: 09:51:35*. Epicenter 35.3° north, 118.0° west, Kern County, W. Greenfield (about 10 miles south of Bakersfield on Highway 99). II. Slow, 3-second shock felt by observer sitting. Magnitude 4.2.

October 1: 04:30:17.0*. Epicenter 36°40′ north, 122°37′ west, B. Harris Ranch (7½ miles south of Hollister). IV. Felt by and awakened observer. Windows, doors, and dishes rattled. Earth noises heard 1 second before shock. Magnitude 2.7.

October 4: 22:55. Harris Ranch (7½ miles south of Hollister). IV. Felt by and awakened observer.

October 7: 01:00. Schurz, Nev. V. Felt by and awakened many in community. Windows and dishes rattled; walls creaked. Hanging objects swung north-south. Moderate earth noises from approximately southeast heard 1 second before shock.

October 18: 18:15. Ventucopa (northwest of, SE ¼, Sec. 30, R24W, T9N, northeast Santa Barbara County). IV. Felt by six of seven persons (observer outdoors; active). Visible swaying of house trailer. Buildings creaked; loose objects rattled. Light swayed in circular motion. Heavy tremor, abrupt onset; direction vertical and east-west.

October 23: 05:57:11*. Epicenter 38.5° north, 118.4° west, California-Nevada border region, W. Luning, Nev. V. Felt by and awakened all in home. Windows, doors, and dishes rattled; house creaked. Hanging objects swung southeast-northwest. Pillow shifted from bed; chair and table moved. Rapid, strong shock, followed by trembling, duration 6–8 seconds. Also felt at Hawthorne and Schurz. Magnitude 5.0.

October 30 through November 4. California-Nevada border region. The University of Nevada reported about 30 earthquakes were felt at Dyer, Nev. from October 30 through November 4. The shocks were felt throughout the local valley, but not at other places canvassed. (See description which follows.)

October 30: 09:50:47.4*, 10:18:07*, 11:01:46*, 11:03:12.3*, 11:40:30*, 15:02:59.5*. Epicenter (1) 37.7° north, 118.2° west; (2) 37.6° north, 118.5° west; (3) 37.8° north, 118.2° west; (4) 37.7° north, 118.0° west; (5) 38.0° north, 117.7° west; (6) 37.7° north, 118.1° west, W. Magnitudes (1) 4.1; (2) 3.8; (4) 4.4; (6) 4.1. Dyer, Nev. VI. "A series of sharp earthquakes began on October 30, and by 15:00 ten shocks were felt by me. They varied in intensity and none lasted more than about 50 seconds. They were all preceded by a roaring sound, struck with a sudden jolt, then swaying motion from south-north. We also felt shocks over the weekend. A window was cracked; cement-block and cement foundation cracked. Windows rattled; loose objects swayed; pendulums on clocks swayed. No real damage so far. The shocks continued intermittently until November 4."

The shock at 11:03:12.3* was felt by several at Bishop; motion rapid, lasted ½ second; direction northeast; faint earth noises. Felt by several at Deep Springs (Deep Springs Ranch); motion rapid, lasted 1 second, direction north-northeast; faint earth noises. Also felt at Oasis.

November 2: 03:38:55.7*. Epicenter 37.6° north, 118.0° west, California-Nevada border region, W. Felt at Dyer, Nev. and Oasis. Magnitude 4.4.

November 5: 22:34 (about). Bishop (Control Gorge Power Plant). III. Felt by few.

November 12. 12:07:25.4*, 21:05:10.8*. Epicenter (1) 37.7° north, 118.0° west; (2) 37.6° north, 118.0° west, California-Nevada border region, W. Felt at Dyer, Nev. Magnitudes 3.8 and 4.2, respectively.

November 15: 18:46:42.5*. Epicenter 37°00′ north, 121°43.5′ west, about 10 miles north of Watsonville, in the Corralitos area, B. Felt over an area of approximately 12,000 square miles of west-central California. (See map, page 26.) Maximum intensity VII in the Corralitos area. Moderate to slight damage. Several chimneys fell; water service was disrupted; refrigerator and stove moved 1 foot from wall; considerable merchandise fell from store shelves. Magnitude 5–5¼.

INTENSITY VII:

Corralitos.—Several chimneys fell; chimneys twisted about 6 inches. Refrigerator and stove moved 1 foot from wall; dishes "flew" out of cupboards; deep freeze door popped open. Considerable merchandise fell from grocery store shelves. One store reported it took seven men two hours to clean up the store. In homes, neighbors helped each other clean up messes caused by fallen articles. One observer reported the shock was like a big boom and was the strongest he had felt in 40 years of residence in the Pajaro Valley. Motion

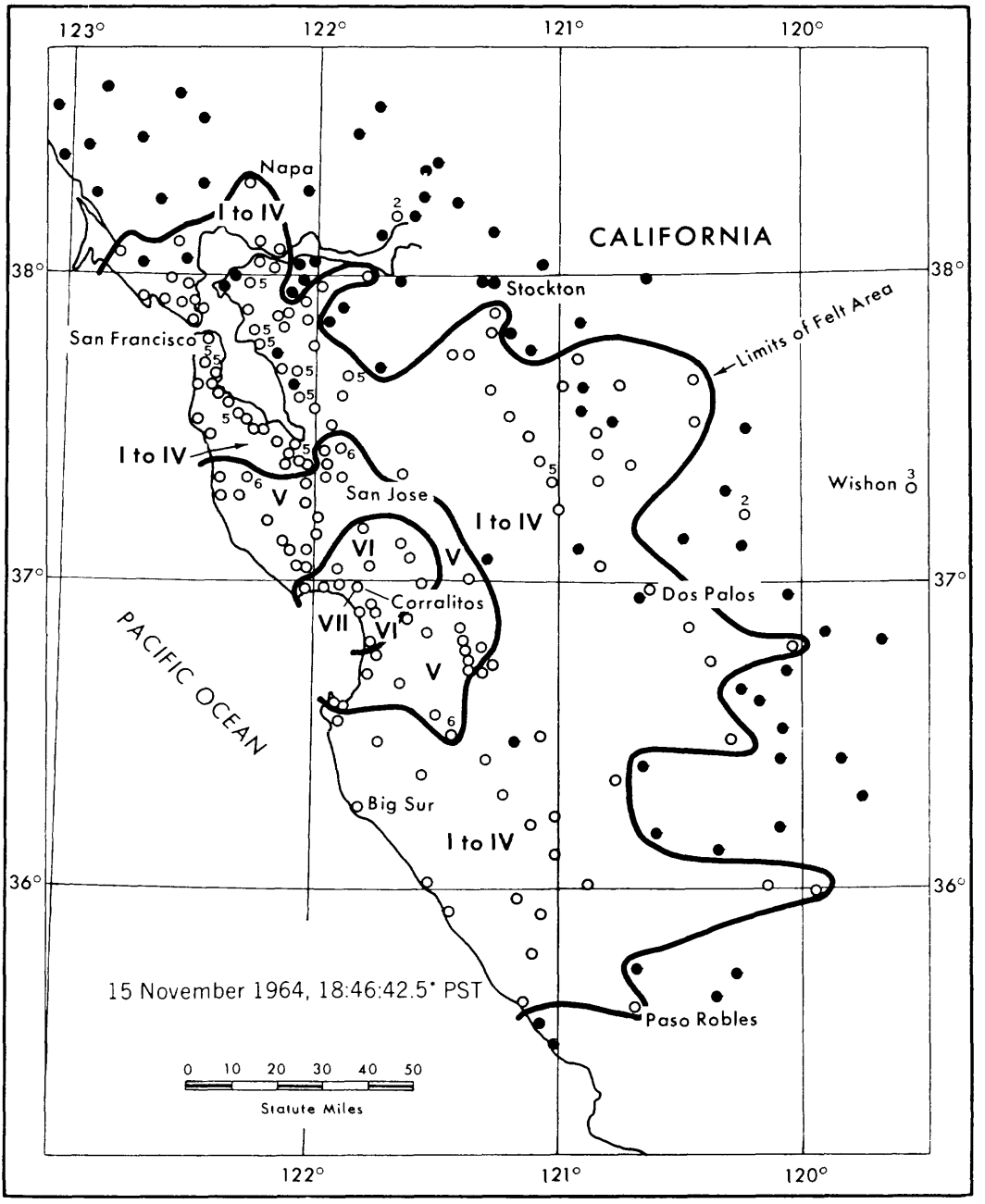


FIGURE 6.—*Area affected by earthquake of November 15.*

rapid, lasted 5 seconds; loud earth noises from northeast.

INTENSITY VI:

Alviso.—Felt by many and frightened few in community. Damage slight. Plaster cracked. Motion slow.

Aptos.—Strongly felt at Aptos and Rio del Mar. Walls of hillside home "bent like matchsticks." Water splashed from aquarium.

Aptos (3.7 miles north of).—Felt by and frightened observer. Small objects and furnishings shifted; vases, etc., small objects overturned; heavy furniture moved north-south. Seven-pound panel struck observer on

head, causing injury. One shock felt; motion rapid, lasted 30 seconds; direction north. "Most violent here in 23 years; the 1906 shock seemed no worse."

Capitola.—Frightened all in community. Stove moved back and forth a good 2 inches. Small objects shifted. Everything rattled and shook; ceiling shook violently. Motion rapid, lasted 15–45 seconds; direction northeast-southwest; loud earth noises. "Strongest shock I have felt in 30 years of reporting."

Freedom.—Felt by and frightened all in community. Damage slight to masonry; plaster cracked. Small objects shifted and overturned; knickknacks and pictures fell. Trees, bushes shaken moderately. Motion slow, lasted 25 seconds; loud earth noises from northeast 1 second before shock.

Gilroy.—Felt by all and frightened many in community. Damage slight. One chimney damaged; dishes broke. Small objects shifted and overturned; knickknacks and pictures fell. Trees, bushes shaken moderately. Motion rapid, lasted 30 seconds, direction north-south; moderate earth noises.

Gonzales.—Felt by all and frightened many in community. At school auditorium, plaster cracked and fell and baseboard was dislodged. Small objects and furnishings shifted. Motion rapid, lasted 15 seconds, direction northwest; faint earth noises.

Hollister.—Felt by all and frightened many in community. Damage slight. Plaster and walls cracked. Small objects shifted and overturned. Trees, bushes shaken moderately. Motion rapid and slow, lasted 6–10 seconds; loud earth noises from southeast-northwest.

La Honda.—Felt by many. Damage slight. Hearth cracked. Motion slow, lasted 20 seconds; faint earth noises heard.

La Selva Beach (on coast west of Watsonville).—Felt by all in home. Fifty to sixty cans fell from shelves in grocery store. Motion slow, lasted 10 seconds, direction northeast; loud earth noises from northeast preceded shock.

Morgan Hill.—Felt by all and frightened many in community. Damage slight. Plaster, windows, and walls cracked. Dishes and windows broke. Small objects shifted; vases, etc., small objects overturned; knickknacks, books, and pictures fell. Motion rapid, lasted 3 seconds, direction east-west; faint earth noises from east-west preceded shock by 1 second.

Moss Landing.—Felt by all and frightened many. Damage slight. Small objects shifted; vases overturned. Loud earth noises; motion rapid, lasted 3 seconds.

New Almaden.—Felt by all in community; awakened and frightened all in home. Damage slight. Plaster cracked. Motion rapid, lasted 5 seconds; moderate earth noises 1–2 seconds before shock.

Santa Cruz—Felt by all; frightened many—350 persons in church "managed not to panic." Several instances of broken glassware and pottery. Trees, bushes shaken strongly. Hanging light swung like a pendulum for 2 minutes. Telephone services disrupted in many areas due to overload of calls. Motion rapid and slow, lasted 10–20 seconds, various directions—north-south, northeast-southwest, south-north, then east-west; one big jolt followed by several tremors.

Watsonville.—Felt by and frightened all in community. Damage slight. Chimney fell; damage slight to brick; plaster cracked. Radio equipment fell off table; few cans fell from grocery store shelves; pictures fell; furnishings shifted; vases overturned. Sharp jolt, rolling motion, then another sharp jolt, about four jolts in all; direction north-south, northeast-southwest; loud earth noises from north.

INTENSITY V: Agnew, Alameda, Almaden, Aromas, Ben Lomond, Big Basin State Park, Boulder Creek, Cienega District (south of Hollister), Coyote, Cupertino, Daly City, El Sobrante, Felton and vicinity, Gilroy (10 miles east of), Hayward, Los Gatos, Menlo Park, Milpitas, Moffett Field (Naval Air Station), Monterey, Mount Madonna area (north of Watsonville), Newman, Oakland, Palo Alto, Pescadero and vicinity, Pleasanton and vicinity, Redwood Estates, San Francisco, San Gregorio, San Jose, San Juan Bautista, San Martin, San Mateo, San Rafael, Soquel, Tres Pinos, and Union City.

INTENSITY IV: Antioch, Avenal, Belmont, Benicia, Berkeley, Big Sur, Bolinas, Bryson (Ernest Weferling Ranch), Canyon, Carmel, Castroville, Chualar, Corte Madera, Crockett, Crows Landing, Dos Palos, Fort Baker (just south of Sausalito), Fremont, French Camp, Greenfield, Half Moon Bay, Hillsborough, Holy City, Jamesburg area (Search Ranch), Jolon (ranch on Jolon Road), King City, La Grange, Libby Ranch (about 2½ miles southwest of Paicines), Lockwood, Loma Mar, Los Altos, Los Banos and vicinity, Mendota, Millbrae, Modesto, Moraga, Mountain View, Mount Hamilton, Pacifica, Pacific Grove, Paicines (Live Oak Road), Peach Tree Ranch (about 18 miles east by south of King City), Port Costa, Redwood City, Riverbank, Saint Mary's College (Moraga), Salinas, San Ardo, San Carlos, San Lorenzo, San Lucas, Santa Clara,

Saratoga, Scotts Valley (about 5 miles east of Felton), Soledad, South San Francisco, Stevinson, Stinson Beach, Sunnyvale, Tiburon-Belvedere, Tracy, Turlock, Vallejo, Vernalis, and Walnut Creek.

INTENSITY I–III: Alamo, Banta, Biola, Cantua Creek, Carmel Valley, Circle M Ranch (about 20 miles south of Big Sur, on coast), Cowell, El Granada, Firebaugh, Gorda Station (about 6 miles south of Circle M Ranch, south of Big Sur), Gustine, Hernandez (2 miles northwest of), Hilmar, Kettleman City, Lathrop, Le Grand, Livingston, Mill Valley, Montara-Moss Beach, Napa, Novato, Paso Robles, Patterson, Point Reyes Station, Rio Vista, San Benito, San Bruno, San Ramon, San Simeon, Snelling, Sunol, Warm Springs, Waterford, Westley, and Wishon.

November 17: 06:52:26.5*. Epicenter 33.8° north, 116.5° west, southern California, W. Felt at Palm Springs. Magnitude 4.5.

November 23: 01:05:07*. Aftershock of November 15. Aptos (3.7 miles north of). IV. Awakened observer. Frame creaked. Slow, 3-second shock in north direction. Magnitude 3¼, B.

November 23: 15:52:29.7*. Epicenter 37.6° north, 118.0° west, California-Nevada border region, W. Felt at Dyer, Nev. Magnitude 4.2.

November 30: 12:44:46*, 13:16:17*. Epicenter 36°52′ north, 121°43′ west, central California, B. Watsonville area. IV. Mild shocks. Windows rattled. Also felt at the W. A. Taylor Winery in the Cienega District south of Hollister. Magnitudes 3.3 and 3.8, respectively.

December 4 or 5: Between 20:00 and 22:00. San Francisco (Twin Peaks area). Slight motion felt which observer thought was an earthquake.

December 17: (no time given). Pinon Hills (about 25 miles northwest of San Bernardino, in area west of Hesperia). Felt by observer and customers in cafe. Crack in restaurant wall was attributed to the disturbance. "There is confusion in Pinon Hills when a motion does occur. People do not know if an earthquake has occurred or a rocket has gone off at Edwards Air Force Base to the north of us."

December 22: 12:54:35*. Epicenter 31°56′ north, 117°09′ west, off coast northwest of Ensenada, Mexico, P. In the United States, the shock was felt over an area of approximately 9,000 square miles. (See map, page 29.) Maximum intensity VI. Minor damage, consisting chiefly of cracked plaster, broken windows and dishes, and damage to fallen objects. Numerous fire alarms were activated. At Ensenada, Mexico, it was reported the principal damage was two broken windows in a hardware store. At San Diego, some persons rushed from offices into halls; some went to the streets. Magnitude 5.6.

INTENSITY VI:

Boulevard.—Felt by all in community; frightened few. Plaster and walls cracked. Small objects overturned; pictures fell. Motion slow, lasted 45 seconds; faint earth noises from northeast.

Imperial Beach.—Felt by all in community; frightened few. Plaster cracked. Small objects shifted and overturned. Motion slow, lasted 1 minute; moderate earth noises. "Third hardest shock that I have felt since 1919, the other two being the Long Beach and the Imperial Valley earthquakes."

Lakeside.—Felt by many; frightened few. Canned goods fell to floor in grocery store. Parked cars shook. Motion rapid, lasted 1 minute.

La Mesa.—Felt by all; frightened few. Damage slight to brick and masonry; plaster cracked. Small objects overturned; furniture moved slightly. Motion rapid, lasted about 30 seconds; loud earth noises from south preceded shock by 10 seconds.

National City.—Many calls to police from the suburbs and outlying areas. Felt very strongly in the old City Hall. Alleys rolled in bowling alley. Motion rolling. "Hardest shock felt in 18 years."

Nestor.—Felt by all; frightened all in home and most in post office. Three miles east of Nestor, groceries fell from store shelves. At post office, table nearly toppled. Trees, bushes shaken strongly. Telephone temporarily out of order. Motion rapid, lasted 1 minute, direction west-east; loud earth noises from west or northwest preceded shock by 1 second.

Potrero.—Felt by and frightened many in community (some outdoors). Damage slight. Windows and dishes broken. Small objects and furnishings shifted; small objects overturned. Trees, bushes shaken moderately. Moderate earth noises.

San Diego and vicinity.—Generally felt over the San Diego area; frightened many; some went into the streets. Fire station temporarily evacuated due to exterior wall crack; plaster cracked at several locations; stones fell from chimney; light fixtures fell at one place; windows broke. Television set fell off chair and caught fire, spreading flames that damaged

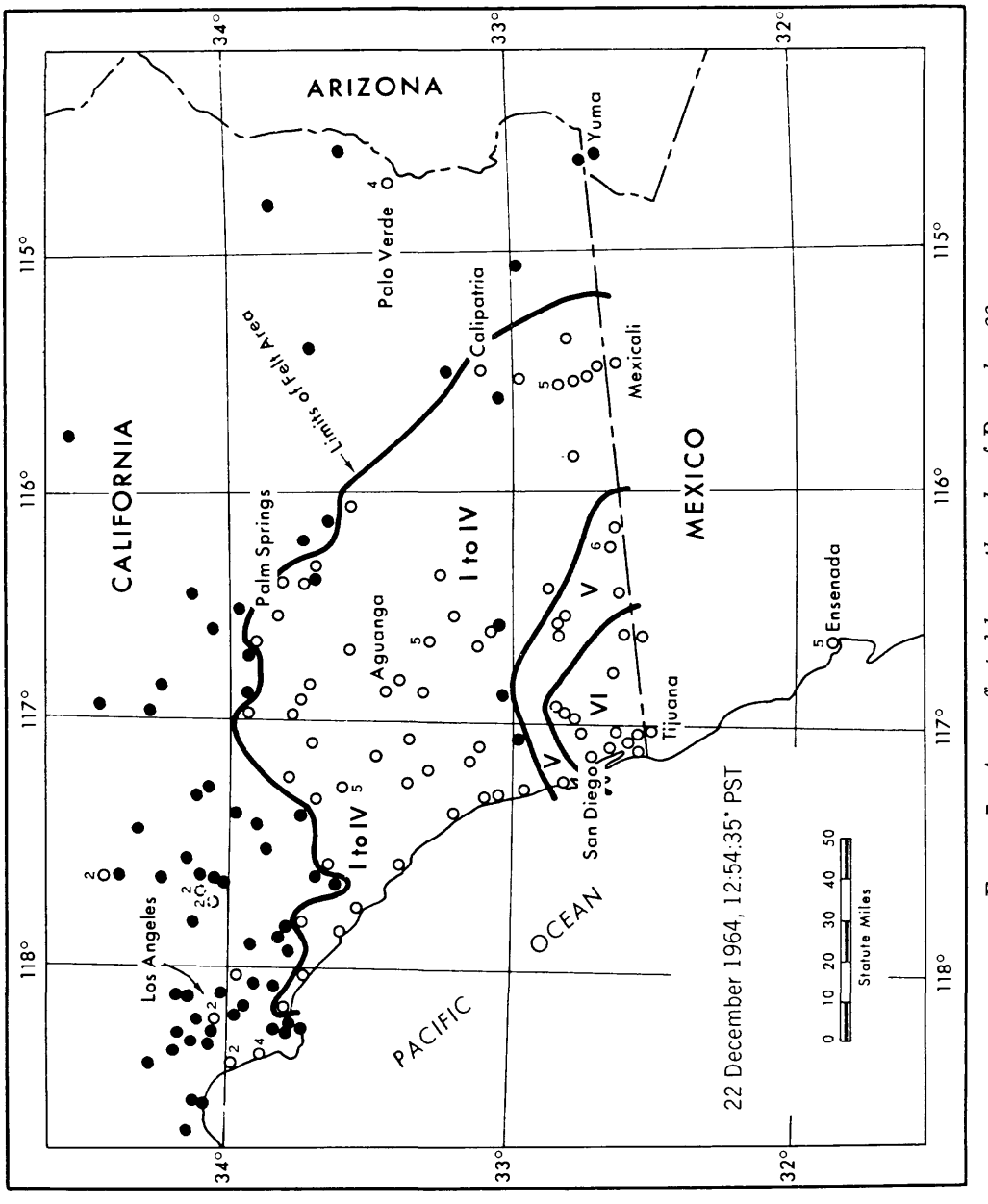


FIGURE 7.—*Area affected by earthquake of December 22.*

the apartment; dishes and pictures fell; groceries fell from store shelves; countless Christmas tree decorations were broken and fire alarms were activated all over the city. One observer reported motion was like being in a canoe with wave about 2 feet high, lasted 45 seconds, 3-minute interval, then gentle motion; followed by intermittent minor tremors for 20 minutes. Another observer reported a rapid, 15-second motion which nearly knocked him down, and that it was the strongest shock he had felt since the Long Beach shock of 1933.

INTENSITY VI IN MEXICO:

Tecate (California-Mexico border area, about 2½ miles southwest of Potrero, Calif.).—Observer from Potrero (intensity VI) reported: "I was in a store at Tecate at time of shock. The shock was considerably stronger there: more noise, motion, breakage, etc., but buildings are less stable there."

INTENSITY V: Anza-Borrego State Park (Sec. 34, T13S, R7E, Sandstone Canyon), Campo, Chula Vista, Descanso, Dulzura, El Cajon, Imperial, Jacumba, La Jolla, Pine Valley, Santee, San Ysidro, Sunnyside, Warner Springs, and Wildomar.

INTENSITY V IN MEXICO: Ensenada.

INTENSITY IV: Aguanga, Banner, Bonsall (1 mile north of, Muller Ranch on Pala Road), Borrego Springs (Anza-Borrego State Park Headquarters), Borrego Springs, Brawley, Calexico, Camp Pendleton, Del Mar, El Centro, Elsinore, Encinitas, Escondido, Fallbrook, Guatay, Heber, Holtville, Laguna Beach, La Quinta, Leucadia, Long Beach, Manhattan Beach, Mount Laguna, Newport Beach, Oak Grove Ranger Station (about 6 miles southeast of Aguanga), Pala, Palm Springs, Palomar Mountain, Palo Verde, Perris, Plaster City, Ranchita, San Jacinto, San Marcos, Santa Ana, Santa Ysabel, Tecate, Temecula, White Water, and Winchester.

INTENSITY I–III: Anza, Beaumont, Calipatria, Cucamonga, Hemet, Los Angeles, Mecca, Mountain Center, Oceanside, Pinon Hills, Pomona, Rancho Mirage, San Clemente, Santa Monica, Sunset Beach, Thousand Palms, Trabuco Canyon (Gubernadera Canyon), and Whittier.

December 23: 12:00 (about). IV. At Fort Tejon (near Lebec), felt by several. Windows and dishes rattled. Hanging objects swung. Rapid, 4–5 second shock. One rapid, brief shake felt by some (active) at Frazier Park. At Lebec, felt by all in home; frightened few. Windows, doors and dishes rattled; frame creaked. Hanging objects swung. Motion slow, lasted 10 seconds, direction north-south; moderate earth noises.

December 23: (in a.m.). Pinon Hills. Windows rattled, but no motion felt.

December 23: 15:13:55*. Epicenter 36.8° north, 119.9° west, central California, B. Fresno (Weather Bureau Airport Station, northeast section). IV. Felt by and alarmed many. Disturbed objects observed by several. Objects swung. Magnitude 3½.

December 23: 19:11:56*, 19:13:14*. Epicenter 37°43′ north, 122°08′ west, B. IV. Two small "dish rattling" earthquakes rolled through Alameda County. Police departments in Alameda, Hayward, Oakland, and San Leandro received "scare calls." Only slight damage (?) was reported. Felt by observer and neighbor at Canyon; neighbor felt both shocks. Pole lamp rattled. Motion rapid, rolling, lasted 1 second. At Oakland (Chabot Observatory, east Oakland), slight shock (III) felt by observer (sitting). Hanging objects swung east-west. Moderately rapid east-west motion, duration about 1 minute. Magnitude 2.7 for both shocks.

December 29: 13:00 (about). San Bernardino. Reported felt in San Bernardino. At Pinon Hills (about 25 miles northwest of San Bernardino), slight motion, lasted few seconds; second motion also felt.

December 31: 23:41:31*. Epicenter 34.0° north, 117.6° west, southern California, W. V. Felt over a considerable area, principally in Riverside and San Bernardino counties. At Etiwanda, felt by all in community; frightened few. Windows and doors rattled. Rapid, 3-second shock. Intensity IV at Bloomington and Rialto. Sharply felt at Fontana. Also felt at Long Beach, Riverside, and Temecula. This shock was followed by a second and stronger shock at 00:04:16.2* on January 1, 1965. Magnitude 4.6.

WASHINGTON AND OREGON
(120TH MERIDIAN OR PACIFIC STANDARD TIME)

January 26: 13:40:43.2*. Epicenter 46°06′ north, 122°24′ west, Merrill Lake, Wash., S. Felt over an area of approximately 2,000 square miles of southwestern Washington. Maximum intensity V.

INTENSITY V:

Woodland.—Felt by all. Windows and dishes rattled. Motion slow, lasted 5 seconds; faint earth noises from south-north.

INTENSITY IV: Ariel, Carrolls, Curtis, Heis-

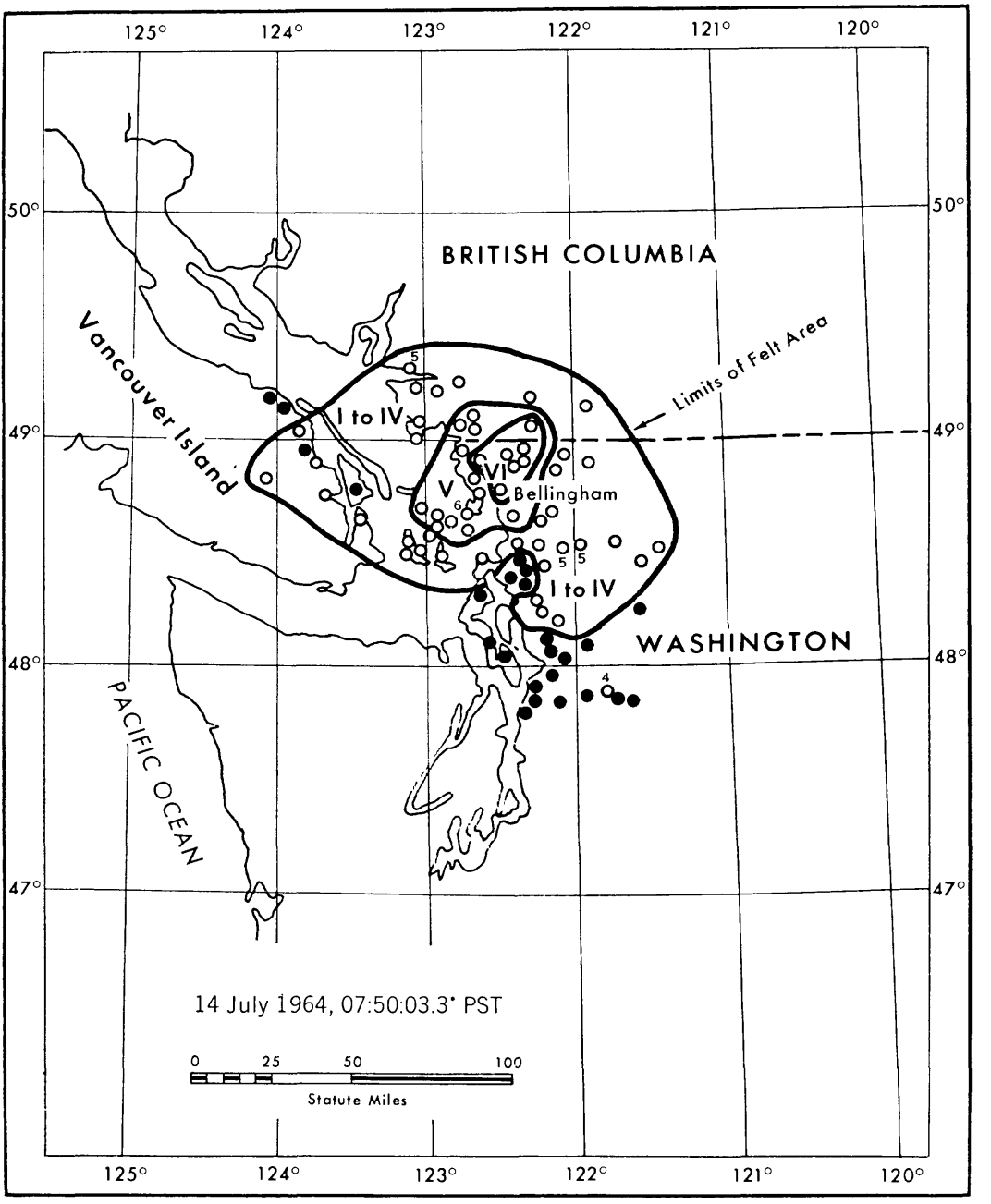


FIGURE 8.—*Area affected by earthquake of July 14.*

son, Kalama, La Center, Mossyrock, Pe Ell, Ryderwood (near), and Vader.

INTENSITY I–III: Castle Rock, Chehalis, Kelso, Longview, Napavine, Rosburg, Silverlake, Toledo (1 mile northeast of), Toutle, Winlock, and Yacolt.

March 20: 08:47. Swift Dam Powerhouse (about 5½ miles east of Cougar), Wash. Light tremor.

April 16: 16:18. Mount Rainier National Park (Nisqually Entrance), Wash. IV. Felt by several. Windows rattled. Effect like distant explosion, duration 1 second; moderate thumping earth noises.

July 14: 07:50:03.3*. Epicenter 48.9° north, 122.5° west, northwestern Washington, about 12 miles north of Bellingham, S. Felt over an area of approximately 8,000 square miles of northwestern Washington and British Columbia, Canada. (See map, page 31.) Maximum intensity VI. Damage slight. Plaster cracked slightly at several places in Washington and at two places in British Columbia. Magnitude 5.0.

INTENSITY VI IN WASHINGTON:

Bellingham.—Felt by many and frightened few in community. Damage slight. Plaster cracked. Pictures fell; small objects shifted. Motion rapid, duration few seconds to 1 minute. Loud earth noises from east.

Custer.—Felt by, awakened, and frightened all in community. Plaster cracked. Small objects and furnishings shifted; vases, etc., small objects overturned; knickknacks fell. Rapid, 5–6 second shock in east-west direction; preceded 1–2 seconds by moderate earth noises.

Lummi Island.—Felt by all and frightened few in community. Damage slight. Fireplace chimney split, mortar fell. Small objects shifted. Motion rapid, jolting, like sonic boom; lasted about 7 seconds, direction southeast; moderate roar from southeast at instant shock was felt.

Lynden.—Felt by all except persons riding in cars or walking outdoors; frightened many. Damage slight. Plaster cracked. Small objects and furnishings shifted; knickknacks fell. Light fixtures hanging on 5-foot chains swung northwest-southeast in about a half-inch arc. Motion rapid, lasted 40 seconds; direction northwest-southeast. Loud earth noises preceded shock by 10 seconds.

Nooksack.—Felt by observer. Damage slight. Wall cracked. Motion rapid, lasted 1½ seconds.

Sumas.—Felt by all, awakened few, and frightened many in community. Damage slight. Plaster cracked. Small objects shifted; knickknacks fell. Motion rapid, lasted 20 seconds, direction northeast; loud earth noises from southwest preceded shock by 5 seconds.

INTENSITY VI IN BRITISH COLUMBIA, CANADA:

Abbotsford.—Felt by all, awakened and frightened few in community. Damage slight. Plaster cracked slightly; small amounts of plaster fell. Small objects shifted; rattling and movement of small objects caused some persons to run to the streets. Motion rapid, lasted 4 seconds, direction southwest-northeast; preceded 1–2 seconds by loud earth noises.

White Rock.—Felt by all in community. Damage slight. Ceiling cracked. Trees, bushes shaken moderately. Motion rapid, lasted 30 seconds; thunderous earth noises seemed from all directions. "Strongest shock since 1946."

INTENSITY V IN WASHINGTON: Blaine, Blanchard, Clipper, Eastsound, Ferndale, Hamilton, Lopez, Lyman, Marietta, Sinclair Island, and Waldron.

INTENSITY V IN BRITISH COLUMBIA, CANADA: Cloverdale and North Vancouver.

INTENSITY IV IN WASHINGTON: Acme, Bow, Clearlake, Concrete, Deer Harbor, Deming, Edison, Everson, Glacier, Maple Falls, Olga, Orcas, Rockport, Shaw Island, Sultan, and Van Zandt.

INTENSITY IV IN BRITISH COLUMBIA, CANADA: Chilliwack, Ladner, Langley, Mission City, Sidney, and Vancouver.

INTENSITY I–III IN WASHINGTON: Anacortes, Arlington, Decatur, Friday Harbor, Marblemount, Point Roberts, Silvana, Stanwood, and Wickersham.

INTENSITY I–III IN BRITISH COLUMBIA, CANADA: Cassidy, Duncan, Lake Cowichan area, New Westminster, Port Coquitlam, and Westholme.

July 30: 04:45:15.4*. Epicenter 49.2° north, 122.3° west, British Columbia-Washington border region, S. Felt over an area of approximately 3,000 square miles in the United States, principally in Whatcom and San Juan counties. Maximum intensity V.

INTENSITY V:

Blanchard.—Felt by and awakened many. Windows, doors, and dishes rattled; house creaked. Motion rapid, lasted 1 minute.

Bow.—Awakened all in home. Definite east-west motion, duration 2 minutes.

Edison.—Felt by several; awakened and frightened few in community. Small objects shifted. Rapid, 10-second shock.

Lopez.—Felt by several in home. Pendulum clock stopped. Windows rattled. Motion slow, lasted 2 seconds, direction northeast; faint earth noises from northeast preceded shock by few seconds.

Lynden.—Felt by and awakened many in community. Sudden, rapid jolt, lasted 5 seconds; faint earth noises.

Nooksack.—Felt by all in community. House creaked. Duration few seconds; preceded few seconds by moderate earth noises.

INTENSITY IV: Anacortes, Bellingham, Custer, Decatur, Eastsound, Everson, Ferndale, Friday Harbor, Marietta, Point Roberts, Sumas, and Waldron.

INTENSITY I–III: Deer Harbor, Hamilton, La Conner, Marblemount, and Olga.

July 30: 07:33:14.7*. Epicenter 47.7° north, 122.1° west, about 13 miles northeast of Seattle, S. V. Felt in scattered communities over an area of approximately 1,500 square miles of northwestern Washington.

INTENSITY V:

Edison.—Felt by several; awakened and frightened few in community. Small objects shifted. Slow, 10-second shock.

La Conner.—Felt by all in home. Floor lamps swayed to-and-fro; hanging objects swung. Slow, 1-minute shock.

INTENSITY IV: Baring, Clinton, Granite Falls, Index, Indianola, Issaquah, Lake Stevens, Langley, Port Ludlow, Preston, Richmond Beach, Seattle, and Stanwood.

INTENSITY I–III: Blanchard, Bow, Carnation, Dockton, Duvall, Fall City, Gorst, Grotto, Kenmore, Kingston, Marblemount, Medina, Mercer Island, Midway, North Bend, Olalla, Port Townsend, Sultan, and Woodinville.

October 1: 04:31:24.6*. Epicenter 45.7° north, 122.8° west, Washington-Oregon border region, W. V. At Portland, hundreds of persons were awakened and telephoned newspaper office and police department. Windows, doors, and dishes rattled. At Swift Dam, Wash., about 5½ miles east of Cougar, and about 55 miles northeast of Portland, awakened all in home. Windows and doors rattled; house creaked. Slow, 5-second shock in northeast-southwest direction. Magnitude 5.3.

October 15: 06:32:38*. Epicenter 47.7° north, 122.1° west, east of Seattle, Wash., in the Sammamish Lake area, W. Felt over an area of approximately 900 square miles of northwest Washington, principally in King and Snohomish counties. Maximum intensity V. Magnitude 4.1.

INTENSITY V:

Bellevue.—Felt by all; awakened many and frightened few in community. Windows, doors, and dishes rattled; house creaked. Trees, bushes shaken moderately. Motion slow, lasted 30 seconds.

Kirkland.—Felt by and frightened all in home. Windows, doors, and dishes rattled. Motion rapid, lasted 1–2 minutes; moderate earth noises.

Medina.—Felt by and awakened all in home. Motion slow, very brief, preceded 10 seconds by loud, rumbling earth noises from north.

Preston.—Felt by and awakened many in community. Motion rapid, lasted 1–2 seconds; preceded 1–2 seconds by faint earth noises.

INTENSITY IV: Duvall, Mercer Island, Snoqualmie Falls, and Woodinville.

INTENSITY I–III: Bothell, Index, Issaquah, Mukilteo (4 miles south of), Pacific, Portage, Port Gamble, Rollingbay, Seattle, and Sultan.

ALASKA
(150TH MERIDIAN OR ALASKA STANDARD TIME)

January 3: 19:17. Felt on Adak.

January 6: 08:31:10*. Homer. V. Felt by all and alarmed few. Buildings creaked, loose objects rattled, and disturbed objects were observed. "Gradual movement followed by a short, medium shock."

January 7: 16:11:18*. Epicenter 51.4° north, 179.0° west, Andreanof Islands, Aleutian Islands, depth about 33 km, W. Felt on Adak. Magnitude 4.2.

January 11: 20:00:13.2*. Epicenter 53.2° north, 166.3° west, Fox Islands, Aleutian Islands, depth about 33 km, W. Felt on Umnak. Magnitude 5.5.

January 19: 14:46. Felt at Homer.

January 23: 20:42:53.9*. Epicenter 60.4° north, 146.5° west, southern Alaska, depth about 33 km, W. Felt at Homer. Magnitude 3.7.

January 25: 18:47. Felt on Adak.

February 6: 03:07:25.2*, 03:13:45.2*. Epicenters 55.7° north, 155.8° west; 55.8° north, 155.9° west, both south of Alaska at depths of about 33 km, W. V. Plaster cracked on Sitkinak Island. Magnitudes 6¾–7, P, and 5.4, respectively.

INTENSITY V:

Sitkinak Island.—Felt by and awakened all in home. Plaster cracked. Walls creaked; windows, doors, and dishes rattled. Doors swung; furnishings shifted. Slow motion; duration, 15 seconds.

Chignik.—Felt by and awakened many; few frightened. Walls creaked; windows, doors, and dishes rattled. Hanging objects swung northeast. Slow motion; direction, northeast. Two shocks.

March 3: 12:30. Felt at Tanacross.

March 27: 17:36:14.2*. Epicenter 61.0° north, 147.8° west, southern Alaska, depth about 33 km, W. Magnitude 8.5, P. Maximum intensity IX–X. Felt over approximately 700,000 square miles of Alaska, and portions of western Yukon Territory and B.C., Canada. This was one of the most violent earthquakes

ever recorded and was accompanied by vertical displacement over an area of 170,000–200,000 square miles. The major area of uplift trended northeast from southern Kodiak Island to Prince William Sound, and east-west to the east of the Sound. Releveling from Seward via Anchorage to Valdez showed vertical bench work changes ranging from a maximum upheaval of 0.55 foot and a maximum subsidence of 6.24 feet. Off the southwest end of Montague Island, there was between 42–50 feet of absolute vertical displacement. Uplift also occurred along the extreme southeast coast of Kodiak Island, Sitkalidak Island, and over part or all of Sitkinak Island. The zone of subsidence covered about 110,000 square miles and included the northern and western parts of Prince William Sound, the western segment of the Chugach Mountains and portions of the lowlands north of the mountains, most of the Kenai Peninsula, and almost all of the Kodiak Island group.

Anchorage, about 80 miles west of the epicenter, sustained the greatest earthquake damage, although it was greater than the apparent intensity due to geological features. Violent ground motion triggered numerous rockslides, snow avalanches, and landslides throughout south-central Alaska. Fractures or cracks developed, chiefly in the unconsolidated deposits; mud spouts, slumping and subsidence resulted from compaction; and sand boils were produced. Cracks and pressure ridges were observed in lake and river ice.

During the month following this great earthquake, numerous aftershocks were recorded. Through April 30, nineteen shocks, listed below, were reported with magnitude 6 or above. None was recorded in this magnitude range in May or June. The shocks on April 3 and 20 were felt in the Anchorage area. A more detailed description of these, and other aftershocks which were felt, is given later in this report.

Aftershocks, Magnitude 6 and Over, Through April 1964

Date	Local Time	Coordinates of Provisional Epicenter		Depth	Magnitude	Location
		Latitude	Longitude			
	h m s	°	°	*km*		
Mar. 27	21 10 21.4	58.8 N.	149.5 W.	20	6.2	Gulf of Alaska.
	22 33 47.0	58.1	151.1	25	6.5	Kodiak Island region.
	23 01 00.5	56.5	152.0	20	6.2	....do....
	23 52 55.7	59.7	146.6	30	6.2	Gulf of Alaska.
28	00 35 38.9	57.2	152.4	33	6.3	Kodiak Island region.
	02 20 49.8	56.5	154.0	25	6.5	....do....
	04 47 37.1	60.4	146.5	10	6.3	Southern Alaska.
	04 49 13.7	60.4	147.1	10	6.5	....do....
	10 29 08.6	59.8	148.7	40	6.6	Kenai Peninsula.
29	16 18 06.3	56.6	152.9	25	6.6	Kodiak Island region.
	21 09 34.0	59.9	145.7	15	6.2	Gulf of Alaska.
Apr. 3	12 33 42.2	61.6	147.6	40	6	Southern Alaska.
4	07 46 08.6	56.3	154.4	25	6½	Kodiak Island region.
	07 59 43.3	56.4	154.5	25	6.1	....do....
	15 22 13.3	56.2	153.5	25	6	....do....
11	15 24 31.2	56.6	152.2	22	6¼	....do....
16	09 26 57.4	56.4	152.9	30	6½-6¾	....do....
20	01 56 41.6	61.4	147.3	30	6½	Southern Alaska.
	19 01 35.7	61.5	147.4	40	6	....do....

This earthquake generated a seismic sea wave (tsunami) that devastated towns along the Gulf of Alaska and left serious damage at Alberni and Port Alberni, Canada, along the west coast of the United States, and in Hawaii. (See "Tidal Disturbances of Seismic Origin," page 68.)

Only the sparse population and time of occurrence when schools were closed, business areas uncrowded, and tides low prevented the death toll from surpassing 131. (Civil Defense estimates included 122 deaths from the tsunami and 9 from the earthquake.) Total damage from the earthquake and tsunami was between $400 and $500 million.

The following references may be consulted for further information on this earthquake and tsunami: *Prince William Sound Earthquake of March 27, 1964 and Aftershocks, Volume I,* Coast and Geodetic Survey, Rockville, Md., 1965 (Volumes II and III will be published in the future); *Alaska's Good Friday Earthquake, March 27, 1964,* Geological Survey Circular 491, USGS, Washington,

D. C., 1964; *The Alaska Earthquake-March 27, 1964—Effects on Communities*, Geological Survey Professional Paper 542-A, W. Hansen, USGS, 1965; *Response to Disaster*, Federal Reconstruction and Development Planning Commission for Alaska, Washington, D. C., 1964; and *Anchorage and the Alaska Earthquake of March 27, 1964*, Glen V. Berg and James L. Stratta, American Iron and Steel Institute, New York, N.Y., 1964.

INTENSITY IX–X:

Montague Island and vicinity (at entrance to Prince William Sound).—From report by USC&GS: Apparent alterations in the elevation of the island in relation to mean sea level indicate Montague Island was raised as much as 31.5 feet by the earthquake. Oceanographic soundings southwest of the island provide good evidence of extensive fractures in the ocean floor—some marked by 50-foot cliffs or escarpments. Readings at Wilby Island tide station showed an uplift of 10.6 feet. A leveling team from the USC&GS Ship HODGSON computed an uplift of 31.5 feet at Macleod Harbor, and 15 feet at Patton Bay. A profile of the ocean floor taken about 7 miles southwest of Cape Cleare indicated submarine faulting might exist. Three 6-mile profiles run by the HODGSON, 3.5, 6, and 8.5 miles southwest of Cape Cleare, confirmed the presence of faulting. On the basis of the Ship HODGSON'S discovery, the Coast and Geodetic Survey assigned one of its Class I oceanographic research vessels—the SURVEYOR—to conduct a detailed investigation of the faulted area. Three 20-mile profiles run by the SURVEYOR, 1.5, 7, and 10 miles southwest of Cape Cleare, further confirmed the existence of submarine faulting. Additional northwest-southeast profiles run by the SURVEYOR between Montague Island and Kodiak Island, more than 100 miles to the southwest, show a 35-mile-long submarine extension of Montague Island faulting. For the first 15 miles, this extension is marked by a nearly vertical escarpment approximately 50 feet high; thereafter, the fault passes across a mud sea-bottom and appears as gentler slopes, depressions, and interrupted layers of bottom sediments.

The U. S. Geological Survey reported fault escarpments extended for miles along both sides of the island, reaching heights of 16 feet in many places. Ground motion was so violent near the faults that living spruce trees up to 42 inches in diameter were snapped off and toppled. Along the island's interior ridges, faults were traced by the line of landslides that swept away trees and covered other vegetation. The slides continued unbroken for 5–10 miles and were easily observed from low-flying aircraft. On the ground, the Geological Survey team discovered great cracks, and in many cases, earth displacements which were not readily visible from aerial photography or aerial observation.

Portage.—Damage great. Spectacular mud and water spouts from fissures were observed. Highway displaced 3 feet by lurching action; bridge collapsed due to compaction and subsidence. Railroad facilities were seriously damaged by earth fractures, and most buildings were destroyed.

At Diamond Jim's Place, damage was great to wood, brick, and masonry. Chimneys, walls, columns, and monuments twisted and fell. Dishes, windows, and furniture broke; furniture overturned. Motion rapid, duration 4–5 minutes; direction east; loud earth noises from east. *(Anchorage Daily Times, 4–6–64):* The community of Portage now consists of an old log lodge called "Diamond Jim's," according to a report by a team of Army engineers who spent four days opening a temporary road into the stricken area. As the only building not condemned by Civil Defense inspectors, the lodge is community center, hospital, kitchen, and bedroom for the 35 persons remaining in Portage. It was reported that the town was almost "a total loss." In opening the highway in the Portage area, Army engineers cut through a dozen snow and rock slides, laid temporary bridges over three streams, and repaired at least ten other bridges. A causeway across tidal flats, which was still under construction, was destroyed.

(Anchorage Daily News, 4–14–64): Spring tides neared their peak on April 14th forcing the evacuation of Portage, washing out a section of the Alaska Railroad, and inundating homes at scattered points. Water and ice sloshed into Portage and flooded the Diamond Jim Lodge and the Federal Aviation Agency Building. Men were working to fortify the ARR [Alaska Railroad] bridge over 20-Mile Creek. Several places along the road bed were washed out. The washouts will delay the reopening of a 60-mile stretch of railroad from Anchorage to Whittier that had been tentatively scheduled for today. The condition of the Seward Highway cannot be determined until after this morning's tide goes out. A road block was set up at Bird Creek Point, Milepost 98, with only residents and emergency vehicles allowed to pass.

INTENSITY VIII:

Anchorage.—Excerpts from various reports.

The most dramatic scenes of destruction here were found in four major slide areas: (1) Turnagain Heights; (2) L Street; (3) Fourth Avenue; and (4) Government Hill. The Turnagain slide affected a bluff area of about 1,000 feet in width and over 1½ miles long adjacent to Knik Arm. This huge mass of earth separated into thousands of sections and moved outward toward Knik Arm. At the head of this slide there was a scarp with a height of about 50 feet. Over 70 houses were destroyed by this mass earth movement. The L Street slide was adjacent to Knik Arm and west of the main business district in a housing and apartment development. It extended over an area of 800 feet wide and nearly ½ mile long. An unusual feature here was the 200-foot wide trough at the head of the slide which dropped about 8 feet. The main slide block moved horizontally, shearing off some of the structures at the head of the slide and dropping the foundations of others from under them. The Fourth Avenue slide was located in the main business area. Here, the ground movement was northward toward Ship Creek. Buildings dropped 10–11 feet almost vertically along the head of the slide. All of these buildings had to be removed. The Government Hill slide moved southward toward Ship Creek. The head scarp passed under the school building, leaving part of it on the unmoved ground and dropping the remainder into the wide tension trough.

The earthquake damage was very selective, damaging the taller buildings more severely than the lower ones. A few low buildings and industrial structures collapsed or partially collapsed, but the majority of such structures were practically unaffected if located outside slide areas. All of the buildings of 10–14 stories survived the shock with moderate to heavy damage. Of those in the 4–9 story category, four suffered extreme damage. This damage pattern appears to be attributable to the distance that Anchorage was from the epicenter, with the longer period ground motion having a dominant effect at this distance. (According to an article in the *Anchorage Daily Times* dated April 9, 1964, 215 homes were destroyed and 157 commercial buildings were destroyed or damaged beyond repair.)

The Control Tower at the International Airport, a reinforced concrete structure, collapsed killing one person and injuring another. Damage to the terminal building was slight except in the portion adjacent to the collapsed tower. A 6-story lift-slab reinforced concrete apartment house adjacent to the L Street slide collapsed into a pile of rubble. The building was structurally complete but unoccupied. It appeared that neither the nearby ground fissures nor the L Street slide contributed to the destruction of this edifice. The J. C. Penney Building, a reinforced concrete flat plate structure, partially collapsed and had to be razed. The Hillside Apartment Building, a steel framed structure, was damaged beyond repair.

Roads and railroad facilities received serious damage. Differential settlement caused marginal cracking along scores of highway fills throughout the Anchorage Lowland. Cars and equipment were overturned and car shops were badly damaged at the Alaska Railroad Yards. Bridges failed, fills settled, and tracks were bent along the main line of the railroad.

Water mains and gas, sewer, telephone, and electric systems were damaged to the extent of about $15 million.

Nine deaths were reported in this city as direct result of the earthquake, a very low number considering the damage incurred.

(Fairbanks Daily News-Miner, 3–30–64): Many buildings throughout the Anchorage business area were damaged beyond repair and almost all buildings received substantial damage. The city's two large apartment houses were twisted and leaned precariously. One nearly new office building was twisted so hard that its entranceway was almost squashed closed. The multimillion dollar new J. C. Penney Store simply seemed to "come apart at the seams," according to observers. Concrete slabs sheared off the side of the building and came crashing down onto the street, autos, and people. The whole front corner of the building tottered and fell into the intersection of 5th Avenue and D Street.

A few hundred yards away, the whole block between C and D Streets on 5th Avenue dropped about 20 feet below street level. The Denali Theater marquee was resting at street level and the bars and pawnshops along the area were completely demolished. Buildings farther up and down 4th Avenue were also broken and twisted by the shifting earth. The Anchorage Westward Hotel withstood the tremendous tremors and shocks, perhaps better than any other large building in the area, but did show bad breaks about halfway up the building. The large 14-story, L Street Apartment Building at 12th and L Streets was twisted and tilted. The building had cracks from side to side and top to bottom. Its sister building, the 14-story Mt. McKinley Apartments, received the same fate. A new apart-

ment building, still under construction, near 10th and M Streets, simply collapsed into a pile. The Hill and Cordova buildings were damaged. The new First Federal Savings and Loan Building had all windows broken out and was structurally damaged. The Northern Commercial Company Store, Franklins, and the Post Office Building were hard hit. Many small shops along 4th and 5th Avenues showed little damage along their frontage but had roofs collapse into their interiors. The E and E Apartment Building between B and C Streets on 3rd Avenue was reportedly evacuated. The earth west of L Street also dropped away inflicting serious structural damage on many buildings in the area; homes were tilted and twisted.

(Anchorage Daily Times, 4–6–64): Ten of the area's 20 elementary schools reopened today, and the junior high schools and East Anchorage High School are scheduled to reopen Wednesday. The District Corps of Engineers completed its initial safety survey of the Anchorage, Chugiak, and Eagle River schools. It was reported that, except for the Government Hill School which was virtually destroyed and the Denali School which suffered as yet undetermined structural damage, the elementary schools appeared to be in fairly good condition. According to the survey, Abbot Loop, Airport Heights, Creekside Park, Fairview, Northwood, Nunaka Valley, Sand Lake, Williwaw, Willow Crest, and Woodland Park were safe for occupancy without extensive repairs. Minor repairs were being completed at Inlet View, Mountain View, and Scenic Park schools. Other schools scheduled to reopen on Tuesday were the Chugach, Lake Otis, Rabbit Creek, and Turnagain. The Chugiak and Eagle River elementary schools suffered some structural damage but both were also scheduled to reopen Tuesday. The Orah Dee Clark Junior High School fared best among the secondary schools; with the exception of the gymnasium the school was fit for occupancy. Central Junior High was found safe for immediate use except for the multipurpose room, library, band room and showers. Wendler Junior High was safe for occupancy except for the multipurpose room, chorus, band and chemistry rooms, and the gymnasium which can be repaired within a short time. The entire second floor of West High School classroom wing is a total loss and a definite safety hazard. East High School is safe for occupancy except for the gymnasium.

(Jessen's Weekly, 4–1–64): Report from a cab driver: "I was driving up C Street and had just crossed 3rd Avenue near the top of the hill, when suddenly there was no hill. With the first tremor I felt the back wheels spin and stopped the car. The movement of the earth was across my direction of travel. I just sat there and watched the ground open up." C Street, a main cross-town thoroughfare, was one of Anchorage's most badly devastated streets in the section between the Alaska Railroad Yards and 4th Avenue. A car speeding up the hill plunged into a huge chasm after passing the cab. Another car was hung up on its rear bumper by a huge paving block thrust up by the shock. A row of store buildings on one side sank. Street intersections in either direction were impassable.

Anchorage (Turnagain Heights).—Excerpts from a report by Robert B. Atwood, Editor and Publisher of the Anchorage Daily Times, appearing in the *Daily Alaska Empire, 3–29–64:* "In a few short moments it was obvious that this earthquake was no minor one; things were falling that had never fallen before. I headed for the door. At the door I saw walls weaving and tall trees falling in our yard. Pieces of ground in jigsaw-puzzle shapes moved up and down, tilted at all angles. I noticed that my house was moving away from me, fast. As I started to climb the fence to my neighbor's house, the fence disappeared. Deep chasms opened up. Table-top pieces of earth moved upward and some were turned at crazy angles. A chasm opened beneath me; I tumbled down, ducking pieces of trees, fence posts, mailboxes, and other odds and ends. Then my neighbor's house collapsed and slid into the chasm. When the earth movement stopped, I climbed to the top of the chasm, finding angular landscape in every direction. My neighbor's wife was alone, marooned with her car atop one of the high mushroom-like promontories. We climbed up and down chasm walls and under dangerous overhanging pieces of frozen ground to safety. Helicopters were overhead but they could not land near us. After what seemed to be an endless time, rescuers came and helped us out of the quagmire that had once been a home."

Excerpts from SPOTLIGHT, Universal Services, Inc.: One woman reported: "My husband and I were in the Chart Room at the Westward Hotel. By the time we reached the front door, people were pouring out of the buildings into the street. As we got outside, the plate glass windows of an office building across the street popped out. All the ground was weaving like an ocean wave. It seemed

like trying to balance yourself on a ball. We could see pavement breaks. All the glass was out of the Northern Commercial Building and there was debris all over. We looked down 5th Avenue and could not believe the crazy angle of the J. C. Penney Store. It was like we were in a daze, and could not believe the things we saw. A new 2-story office building had sunk into the ground. We got home and changed into warm clothing, not even realizing we were wet from falling and sitting in the snow. We were very lucky; no damage except a few broken dishes and a few scratches."

Another observer reported: "I had just arrived at the Hofbrau and was sitting in the cocktail lounge when the shock hit. We ran into the parking lot and by the time we got there, sections of the lot had already fallen in and the cars were rolling back and forth as much as 50 feet, with cracks opening all around. I happened to be looking toward the Anchorage Hardware Store when it fell. Then the building adjoining the Hofbrau started falling, and I could hear the kitchen and bar of the Hofbrau falling, although the back wall stood up. The next thing I can remember is looking toward the Westward Hotel and seeing it sway what seemed to be 20 feet, and wondering what was keeping it from falling. I will probably always remember the screams of the people on the top floors of the hotel. It seemed as though the ground was moving in all directions—sideways, in circles, and up and down."

Two additional personal experiences were related as follows: "At the start of the quake, we were across the street from the 1200 L Street Apartment Building. After a few seconds we knew this was something worse than we had ever experienced. Dishes were thrown from the shelves and pictures fell from the walls. We had to have our feet planted 2–3 feet apart to keep from falling. The windows of the 1200 L Street Apartment Building were all popping out and the concrete was falling like snowflakes to the ground. Our house came through without a scratch, inside and out, but we lost most of our glassware."

"I had just entered my apartment when I noticed a slight shake; then the shake intensified until everything—furniture, dishes, clothes, lamps, and papers—were flying in all directions. After 4–5 minutes of this violent shaking, rolling, swaying, and heaving, the 32-apartment building finally settled down, and I went outside to take a look around. The four apartments at the far end had broken off the building and fallen into a crevasse which was previously B Street. All the cars in the building had been thrown through their respective doors and were piled in a huddle in the parkway covered with debris. Those who had run out of the building were thrown on the ice-covered sidewalks, suffering broken arms and ribs."

Excerpts from Weather Bureau Regional Newsletter: To those of us who experienced it, the earthquake remains a never-to-be-forgotten nightmare. During the shock, the FAA Control Tower at the International Airport was demolished and fell, causing the death of one FAA controller. The Terminal Building, in which the Weather Bureau Airport Station was housed, was irreparably damaged. Cement-block walls toppled, making the Weather Bureau office a shambles. Miraculously, the employees on duty managed to evacuate the building without injury. The Central Building, in which the Regional Office quarters were located, was not structurally damaged to a great degree; however, furnishings, office equipment and machines were thrown about. Total damage to office furnishings and equipment at the Airport Station is estimated at $10,000; damage at the Regional Office, about $2,500.

Anchorage and Spenard (The Daily Alaska Empire, 3–29–64).—The 50 persons in a large Spenard supermarket were all outside in 15 seconds when the 2-story, brick building began buckling. Plate glass cracked and showered down onto the sidewalk; bricks fell. Every building over 1-story high on Spenard's "miracle way" was smashed. Plate glass windows were heaped on the ground. "There are only three entrances to Anchorage from Spenard—Romig Hill, C Street, and Gambell Street. Romig Hill Road was blocked by a buckled area about 8 feet wide. Detouring around we saw the Hillside Apartments, 6 stories of devastation. Cutting back to L Street, we saw the 1200 L Street Apartments, now showing huge cracks on its corner; glass was broken. St. Mary's Residence and the new Presbyterian Hospital, both large buildings, showed little outside damage, but to the left, a block away, rubble lay where the Four Seasons Apartments had been standing. We drove on, but suddenly our car bumped into a 4-foot-deep ditch. Less than 100 feet away, we saw another deeper hole. It was cut from L Street across the St. Mary's Residence grounds across M, parallel with Cook Inlet, across Ninth Avenue, and out toward the Turnagain area. The cut was at least 20 feet deep and in some places 200 feet wide. Homes had dropped into the crevasses."

Chitina.—Felt by entire population; general

alarm. Ground cracked in business and residential areas. Huge boulders rolled onto road 1 mile south of town. Ground split through hotel, causing wall splits in dining room. Floor buckled up in homes and many windows broke. Visible north-south sway of power poles and 2-story buildings. All unsecured objects thrown around; objects on south walls displaced the most. "Chitina received severe shocks. One side of the mountain directly west of town fell off as we watched. The ground split as our children ran three ways. The splits closed, sending dirt into the air. Cracks ran east-west across Copper River; channel opened, running north-south. Continuous tremors for three weeks." Gradual onset; thunderous, roaring, whistling earth noises heard by all at beginning and during shock.

Chitina.—Felt by and frightened all in community. Warehouse collapsed (foundation of welded railroad rails). Walls fell; plaster, windows, walls, chimneys, and ground cracked. Furniture overturned and broke; dishes and windows broke. Considerable damage to the warehouse, grocery and hotel supplies. A safe, which took eight men to move on skids, overturned to the south. Drugstore leaned toward south; hotel leaned toward north. Observers were pushed toward north; could not stand up straight. "About 7 miles north of here, on the Copper River, there was a large riverbank slide (trees erect)." Strong smell of sulfur after shock. Motion rapid, duration 5–7 minutes; direction northeast; loud earth noises from south preceded shock by 1 second.

(Cordova Times, 4–9–64): The salmon spawning beds were badly shaken up and faulted on Long Lake.

Glennallen.—Felt by and frightened all. One long crack, 4 inches wide and 200 feet long; healthy trees as large as 8 inches in diameter broken; three wells in area went dry (USGS). Hundreds of ground cracks in area, some 12 inches wide. Water gushed from many fissures but stopped within 24 hours. One of the 100-foot-deep wells went dry; other deep wells were unaffected. Damage great to wood, brick, masonry, and concrete. Plaster, chimneys, walls, columns, and monuments fell. Dishes and windows broke and furniture overturned and broke. Well casing also broke. Large house trailer moved 1 foot off blocks.

(Fairbanks Daily News-Miner, 4–2–64): An Alaska Communications System building was shaken from foundation. Motion rapid and slow, duration 2½–6 minutes; various directions. Loud earth noises from north-south, southwest heard by some; one observer reported moderate earth noises from west 2 seconds before shock. A woman running from house in Glennallen area was knocked down, and as she fell, a deep fissure opened under her face. House slid off foundation; the earth appeared to move, dumping the house into a small lake. (The lake had been 30 feet behind the house before the shock.) Fissures all over the property; owner reported there appeared to be no area solid enough on which to rebuild the house.

Glenn Highway (Snowshoe Lake, Milepost 147).—Felt by all in community. Most building damage was light, but some severe in area; chimney cracked slightly; small cracks observed in ground; many minor cracks in roadway. Trees swayed wildly. Bookcases, furniture, loose household items, and objects on shelves displaced; water splashed from buckets. Very difficult to walk or stand during shock. Lake ice upheaved. Pressure ridges to 2½ feet high—generally follow shoreline, but many farther out in lake. Cracks 6–8 inches wide, depth of ice. Mud and ice thrown through cracks in more shallow areas of lake (3–5 feet) and water in areas over 10 feet deep. Very strong gaseous odor from lake. South shore of lake appears to have settled 6–8 inches. Rocking, swaying, twisting motion generally from northeast-southwest with rapid onset; rumbling and creaking earth noises. "At Milepost 158.8 the lake shore settled 3–5 feet. Ice pulled out from under airplane tied down by shore, leaving plane in water. Entire site of three acres (Al Lee property) so cut up by cracks and crevasses that there is no area large enough on which to rebuild house; house damaged severely. Some areas much more severely shaken than here; rumors of lakes emptied, etc." At Milepost 77 (King Mountain Lodge), damage considerable to masonry and concrete. Columns twisted; block building under construction cracked on corners and two piers fell. Cars bounced up and down. "Tremendous slides on King Mountain." Dishes and bottles broke; small objects and furnishings shifted; knickknacks and pictures fell. Trees, bushes shaken strongly. Motion rapid, duration about 5 minutes. At Milepost 95 (east of Chickaloon), face of one of the peaks on Anthracite Ridge fell. Broke 18-inch ice on Index Lake at base of ridge. Strelshla Mountain, [61°50″ N., 147°59″ W.] east of Anthracite Ridge, had a large slide during and after the shock.

Hope.—Felt by and frightened all in community. Observer knocked down to knees

twice. Damage considerable to great. Chimneys cracked and fell; windows and dishes broke; plaster cracked and fell. Everything shifted; furniture overturned and broke; knickknacks, books, and pictures fell; most bottled stock in bar and grill broke. Motion rapid, slow, duration 4–5 minutes; direction north-south, east-west. Loud earth noises from west preceded shock by 1 second. Reported to USGS: Many cracks, most only a few feet long, but one was ½-mile long and 6 inches wide. Entire town evidently subsided 4–6 feet. Water spouts formed; the highest one was 8 feet and lasted 4–5 seconds. Water level in wells rose and became somewhat salty during high tides. New springs formed and other springs increased in flow. Another observer reported: "The first extremely high tide was at 7:00 a.m., Easter Sunday. This was when we first suspected the land had subsided. Tide was on schedule, not a wave, and continued on schedule. About one-half of the town must be abandoned to the tide because of land subsidence."

Moose Pass.—Felt by and frightened all. Observer ran from house and held on to car to keep from being thrown to the ground. Wood and concrete damaged. Plaster, windows, walls cracked; wall twisted; windows broke; chimneys fell. Foundation bricks loosened; refrigerator and dressers fell. Deep freeze and heavy bed moved. Full-size piano on east-west wall shifted 2½ feet to south. Stove and oil heater on west wall shifted about 6 to 8 inches northeast. Three chests of drawers on north wall fell to floor. Oil barrel on 5-foot rack rocked north-south but did not go over 2 by 4 inch chock. Snow avalanche on mountain to west of Seward-Anchorage Highway, about ½ mile west of Moose Pass. Motion rapid, duration 3 to 5 minutes; direction north-south and east-west; loud earth noises. "Could hear roar but was so dazed by shock, cannot say how loud. Low noises at first, something like thunder; then ran out of house and heard shrill vibrations and low rumbling noise during shock." Reported to USGS: Many ground cracks up to 50 feet long with average width of 1 inch in vicinity of one home. Water level in well rose; streams in the vicinity decreased in flow. Six miles south of Moose Pass, a house and building almost sank out of sight (believed to have been built on alluvial fan). Several landslides were observed 8 miles north of Moose Pass.

Seward.—Felt by and frightened all; general alarm. Damage great to masonry and concrete. Ground cracked; chimneys, walls, columns, and monuments fell. Furniture overturned and broke; windows broke. Much damage to household articles and merchandise. Trees whipped; difficult to stand upright. Parked cars rolled and bounced. One observer reported chimneys, etc., fell north-south; another reported merchandise fell from east-west shelves but not from north-south shelves. Motion slow, rapid, rocking, bumping; direction north-south, east-west, from all directions; duration 2–5 minutes; loud earth noises. Many shocks felt.

The following report is from *Safety Bulletin*, April 1964, California Shipping Company, and is an excerpt from the log of MS ALASKA STANDARD, dated March 27, 1964: Earthquake hit about 17:35 and oil docks collapsed; 17:40 power on main propulsion; 17:43 lost steering; 17:45 regained steering, slow ahead, attending to injured, and clearing up debris and wreckage on deck. Smoking lamp out throughout the ship; 18:55 another tremor; 23:10 decks cleared and secured for night. Excerpt from Master's Report: The MS ALASKA STANDARD was moored at the dock at Seward. First shock was followed shortly by a series of violent quakes. Almost immediately fire broke out on shoreside. A seismic wave heeled the ship to starboard, suddenly and dangerously. The vessel rose to such a height that hoses and lines either broke or took shore risers and part of pipelines and mooring piles with them. All this happened within about 1 minute. What the quake had not destroyed along the shoreline, the seismic wave demolished and obliterated. We were underway within about 5 minutes after the first quake was felt, and were practically surrounded by fire on the water surface. After we got clear of the fire and turned the vessel about to head out of the bay, we noticed a large circular area in the middle of the bay where the water looked muddy and was rolling and boiling. It is miraculous that we and the vessel were able to escape.

At Seward, a stretch of the waterfront about 3,500 feet long and as much as 300 feet wide, including all waterfront facilities from the Standard Oil Company dock north to the San Juan dock, slid into Resurrection Bay shortly after the earthquake started and while the shaking was still intense. The slide drew water out from the shoreline and created one or two boil-like disturbances at distances of from several hundred feet to perhaps ½ mile from shore from which waves spread in all directions. These waves picked up burning fuel from waterfront fuel storage tanks which

had been ruptured by the earthquake and immediately ignited and spread it along the waterfront.

The ground which slid into Resurrection Bay was watersoaked alluvium. According to charts of the harbor, the preearthquake offshore slope was between 30° and 35°. The instability of this slope under the earthquake-induced vibration was vividly demonstrated. The slide and the tsunami wiped out almost the entire economic foundation of Seward and caused 12 deaths. In addition to the fuel tanks which were ruptured by the quake, the slide carried away the Standard Oil docks and warehouses, the Army docks and warehouses, the city dock, the small boat harbor, the San Juan dock, the cement plant, and the marine ways.

The wave generated by the slide caused considerable damage to the railroad yards and reached a maximum height of perhaps 30 feet at Lowell Point. Approximately ½ hour later a wave, probably the first of the major tsunami series, struck Seward destroying the Alaska Railroad docks, washing out railway and highway bridges, and piling railway rolling stock into giant windrows of wreckage. It spread the flaming petroleum over the waterfront, igniting railroad rolling stock, the electrical generation plant, and some residences. This wave also swept many dwellings from the vicinity of the small boat harbor and washed boats into the lagoon north of Seward and onto the tidal flats at the head of Resurrection Bay.

Valdez and vicinity (Fairbanks Daily News-Miner, 4–16–64).—A massive underwater landslide caused the havoc at Valdez, Robert Chapman told an earthquake symposium at the University of Alaska. Chapman made the evaluation last week after a preliminary study of the Valdez area. Confirmation of the evaluation has been made by another geologist who has been working in the Valdez area for almost a week. The water depths fall off rapidly in the bay and go as deep as 600 feet. The following is from a report by R. R. Migliaccio, District Geologist, Valdez, to R. G. Sherman, Chief Geologist, College: "Since I was not in Valdez at the time of the quake, I have gathered the following information from the most reliable witnesses available:

"The ground surface was heaving in much the same manner as a swell in the open ocean, except that the swells were much more rapid and frequent. These waves or heaves have been literally frozen in places in the highway east of Valdez. Large cracks were opening and closing all over the area, accompanied by water and silt which were spurting from the cracks and reaching as high as 4 to 5 feet into the air. Trees were pitching in much the same manner as they do in a strong wind. This was also the case with buildings as they rode the ground waves. Sewer lines were breaking and sewage was flowing on the surface, and in some cases, into houses. Water mains were breaking and sending large amounts of water into the streets. During this period, the principal damage was to masonry and cinder-block buildings. Merchandise was thrown from shelves; dishes fell from cupboards in houses.

"Two structures, the Gibson Building and the Alaskan Hotel, were severely damaged. The front walls of both structures broke away from the remainder of the buildings. The west wall of the Gibson Building leaned without collapsing, but the east wall of the Alaskan Hotel collapsed, leaving upstairs rooms exposed. Other walls of the latter structure are cinder-block and were badly fractured. Several buildings, namely the Peterson Garage, Stitch Motors, Port Valdez Motel, and Dieringer's Chevron Service, were of similar construction and were nearly demolished. They have not collapsed but are still settling and are so badly fractured that they could fall at any time. Most wooden structures in Valdez survived the tremors. That is, they are still standing. Most have suffered at least one or two of the following: Moved off foundations; broken in two pieces; wall boards buckled; walls warped; walls cracked; floors cracked; building settled differentially; foundations cracked; building broken by crevice extending under building. It is remarkable to note that some of the buildings, houses only, show no damage whatsoever.

"A fishing boat was anchored just outside the Valdez Narrows (about 10 miles west of Valdez) when the tremors began. The owner backed away from the beach and turned the boat toward Valdez. Shortly thereafter, a huge wave came into the Narrows moving out to sea. The witness informed me that the wave looked like it was 35–60 feet high while confined in the Narrows. Upon emerging from this obstruction, the wave spread laterally with subsequent lowering and the boat was able to ride over the top. This description is confirmed by the fact that the upper portions of a lighthouse, located in the center of the Valdez Narrows, were swept away. I estimate that this would require a wave at least 20–25 feet high. In addition, water marks were

noted which were considerably higher but have not yet been measured. This wave was moving very rapidly and was undoubtedly a true tsunami.

"A group of fishermen were in Unakwik Inlet when the quake struck. They stated that their boat seemed to run aground, but a check of the fathometer showed there was over 300 feet of water beneath the keel. The boat was severely rocked even in this depth of water. A large wave inundated the beaches almost immediately. In addition, these men observed large numbers of dead fish while returning to Valdez, particularly in the Valdez Narrows. These fish were principally bottom dwellers in an area where there is some 600–800 feet of water. It is apparent that waves or tremors caused severe disturbance at depth in the Valdez Arm. Glaciers in College Fiord and Unakwik Inlet have calved small bergs, and lake ice was shattered. The Columbia Glacier showed no effects from the earthquake, and bergs were entirely absent in Glacier Bay.

"At this time (April 10), tide fluctuation in the Valdez area appears to be normal. However, normal high tides are inundating areas which were previously high and dry. Since tides are not exceptionally high at this date, it would appear that the Valdez waterfront has settled between 4–6 feet."

Valdez.—Felt by and frightened all; some panic stricken. One observer reported that people were too dazed and shocked to panic. Snow and rock slides north of town. In town, the earth opened up and shot dirt as high as houses. Damage great in wood, brick, masonry, and concrete. Building swayed back and forth 2 feet; trees whipped. All objects—refrigerator, range, beds, dressers, etc.—moved generally north-south; piano moved from north wall, then back and forth. Furniture overturned and broke. Several observers reported only slight damage to houses and furnishings. Motion rapid, swaying, duration up to 15 minutes; direction north-south, east-west, southwest, southeast-northwest, and from all directions; loud, thunderous earth noises from various directions heard few seconds before and during shock.

From report by Charles H. Clark, Geologist, State of Alaska, Department of Highways: "I was in Valdez at the time of the quake and the following is an attempt to describe the earthquake as it occurred. The first tremors were hard enough to stop a moving person and shock waves were immediately noticeable on the surface of the ground. These shock waves continued with a long frequency which gave the observer the impression of a rolling feeling rather than abrupt hard jolts. After about 1 minute the amplitude or strength of the shock wave increased in intensity and failures in buildings as well as the frozen ground surface began to occur. Cracks in the roadway surface opened and closed again as the trough and crests passed the failure. These cracks opened as much as 3 feet but the most frequent failures were only opened several inches. As these cracks closed due to passing of a shock wave trough, water from both the ground water sources and broken sewers and water pipes squirted in a spray about 20 feet into the air. These occurred at intervals of several seconds between sprays, but no other timing of the waves was attempted by me. The amplitude of the waves was estimated by observance of my son standing about 410 feet away. He is 6 feet tall and was in plain sight during most of the earthquake. As a crest passed him, he would appear in full sight with one depression between himself and me. As he entered a trough, he would appear to sink out of sight up to about 1 foot below belt line. This would indicate that he rose and fell about 3 to 4 feet, and that the waves had a fairly large amplitude. Other features in the vicinity viewed by other qualified observers seem to substantiate this estimation.

"Failures in buildings became apparent and power poles began going down after about 2–2½ minutes. After about 3½ minutes, the severe shock waves ended and people began to react as could be expected. Buildings of wooden frame construction swayed and rocked as if on a high sea. The frame structures evidently were flexible enough to give and sway with very little structural damage. Damage to foundations occurred under these structures, but in general, they held together very well for a shock of this intensity and duration. Structures of concrete-block or other masonry construction suffered severe damages to both bearing walls and foundations. Glass breakage was very limited. Also, it should be noted that the cracks mentioned previously extended under almost every building in town, causing damage to plumbing and foundations."

Local waves were generated by slides in two separate areas of Port Valdez, one at the Town of Valdez, and one near the mouth of Shoup Bay. The wave, generated near Shoup Bay by large submarine slides of portions of the terminal moraine that occupies the mouth of the bay, deposited driftwood at a height of 170 feet near the site of the Cliff Mine and splashed silt and sand up to an elevation of

220 feet above lower low water at the same place. Waves from this source washed the Middle Rock Light in Valdez Narrows off the 35-foot reinforced concrete pedestal on which it was mounted.

Whittier.—Felt by and frightened all in community. Damage great to total. Ground cracked; chimneys, walls, columns, and monuments fell. Dishes, windows broke; furniture overturned and broke. Knickknacks, books, and pictures fell. Pendulum clocks stopped, one facing northeast. Trees, bushes shaken strongly. Motion rapid, duration up to 6 minutes; direction northeast and from all directions; moderate to loud earth noises from north and northeast preceded shock by 10 seconds.

According to witnesses, three waves struck Whittier, with the second one causing most of the damage. One of the waves, probably the same one that caused the major damage in Whittier, reached a height of 104 feet above lower low water. The waves destroyed two sawmills, the Union Oil Company tank farm, wharf and buildings, the Alaska Railroad Depot, numerous frame dwellings, and the railway ramp-handling towers at the Army pier, and caused great damage to the small boat harbor. As at Seward and Valdez, fire broke out at the tank farm and contributed to the destruction. Thirteen people were killed at Whittier by the tsunami. After the dissipation of the locally generated waves, the tsunami did not reach above the extreme high water line.

Excerpt from report by USC & GSS SURVEYOR: Vertical obstruction in the harbor covered by about 12 feet at high water was two railroad rails connected by ties. Deep fissure found in bottom of marginal wharf. Large concentration of heavy debris noted, consisting of timbers bolted together, with lengths up to 30 feet. Logs, 2 feet in diameter, 20 to 30 feet long, disappeared on outgoing tide. Twenty-four-hour tide gage record indicated mean sea level had risen, with respect to land area, about 6½ feet. Steel pier blocked by sunken barge along its side. Sea appeared to have risen with respect to land. No wave reported during major earthquake, but water rose rapidly with recession more violent and damaging than the in-rush of water.

Excerpts from press reports: Buildings adjacent to docks and piers destroyed. Thousands of gallons of fuel oil burned. State Civil Defense officials reported the Buckner Composite Building and the 14-story Hodge Building came through in good shape. Officials also reported the Alaska Railroad tunnel between Whittier and Portage sustained no major damage.

INTENSITY VII:

Cape Yakataga.—Felt by and frightened all. Ground, plaster, windows, walls, and chimneys cracked. Knickknacks, books, pictures, and plaster fell. Dishes and furniture broke; furniture overturned. High line wires running east-west swung, causing breakers to drop out on engine generators. Pendulum clock facing west stopped. Trees, bushes shaken strongly. Motion rapid, duration 3–4 minutes; direction north-south, west-east; loud earth noises from west-east preceded shock by 3 seconds. Reported to USGS: Many cracks, some several hundred feet long in Cape Yakataga area. One area, approximately 1 mile square, sank 2–3 feet. The Kaliak River delta area was checkered with cracks and appeared to have been lowered slightly. Quite a large landslide on Duktoth Mountain.

Cooper Landing.—Landslides; cracks 18 inches wide and 6–8 feet deep in ice, mud, and pavement (USGS).

Copper Center area:

Copper Center.—Felt by and frightened all. Ground cracked. Fireplace cracked; furniture overturned and broke; dishes and windows broke. Warehouse, 140 by 40 feet, had all stock thrown to the floor. Trees and bushes shaken strongly. Pendulum clock stopped. Shaking was quite severe. Motion rapid, duration 3½–5 minutes; direction northeast-southwest; moderate earth noises.

Milepost 82½ (Pippin Lake on Richardson Highway).—Felt by all. Ground cracked; ice shattered; water and mud pumped on east side of lake. Full-length fissure (running north-south) on west side of lake; also on a small lake 1 mile east. Dishes broke; small objects and furnishings shifted; knickknacks, books, and pictures fell. Trees and bushes shaken strongly. "Roads cracked on both the Richardson and Edgewater Highways. Worse in low places. Spring in Bernard Creek area lost water." Motion rapid, duration 4–5 minutes; direction north-south; loud earth noises from north-south.

Milepost 83½ (Pippin Lake on Richardson Highway).—Felt by and frightened all. Ground cracked. Small objects and furnishings shifted; knickknacks and books fell; dishes broke. Trees and bushes shaken violently. Motion rapid, duration 4–5 minutes; direction north; loud crushing, grinding, breaking earth noises. "I was clearing timber with a 'cat'

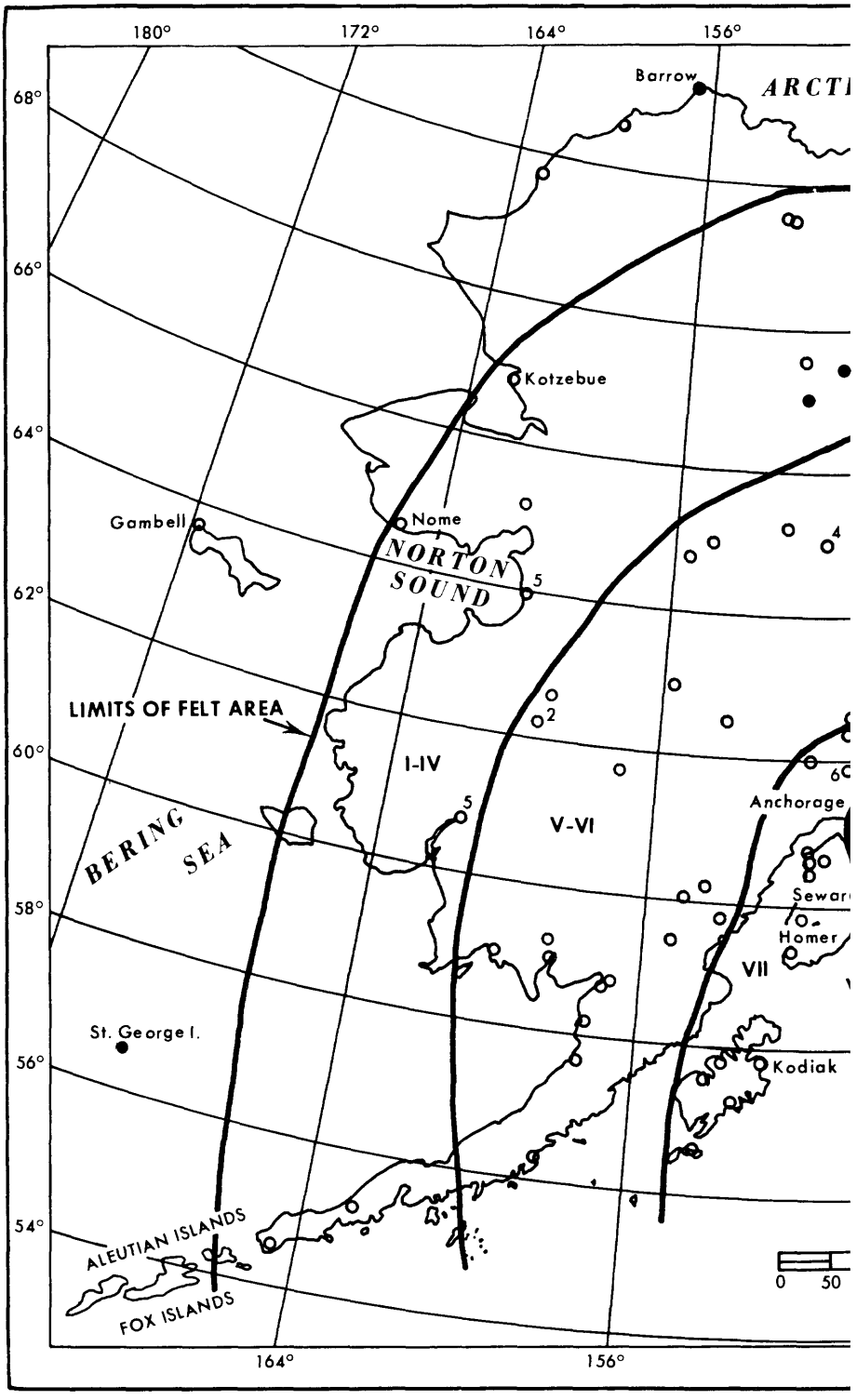
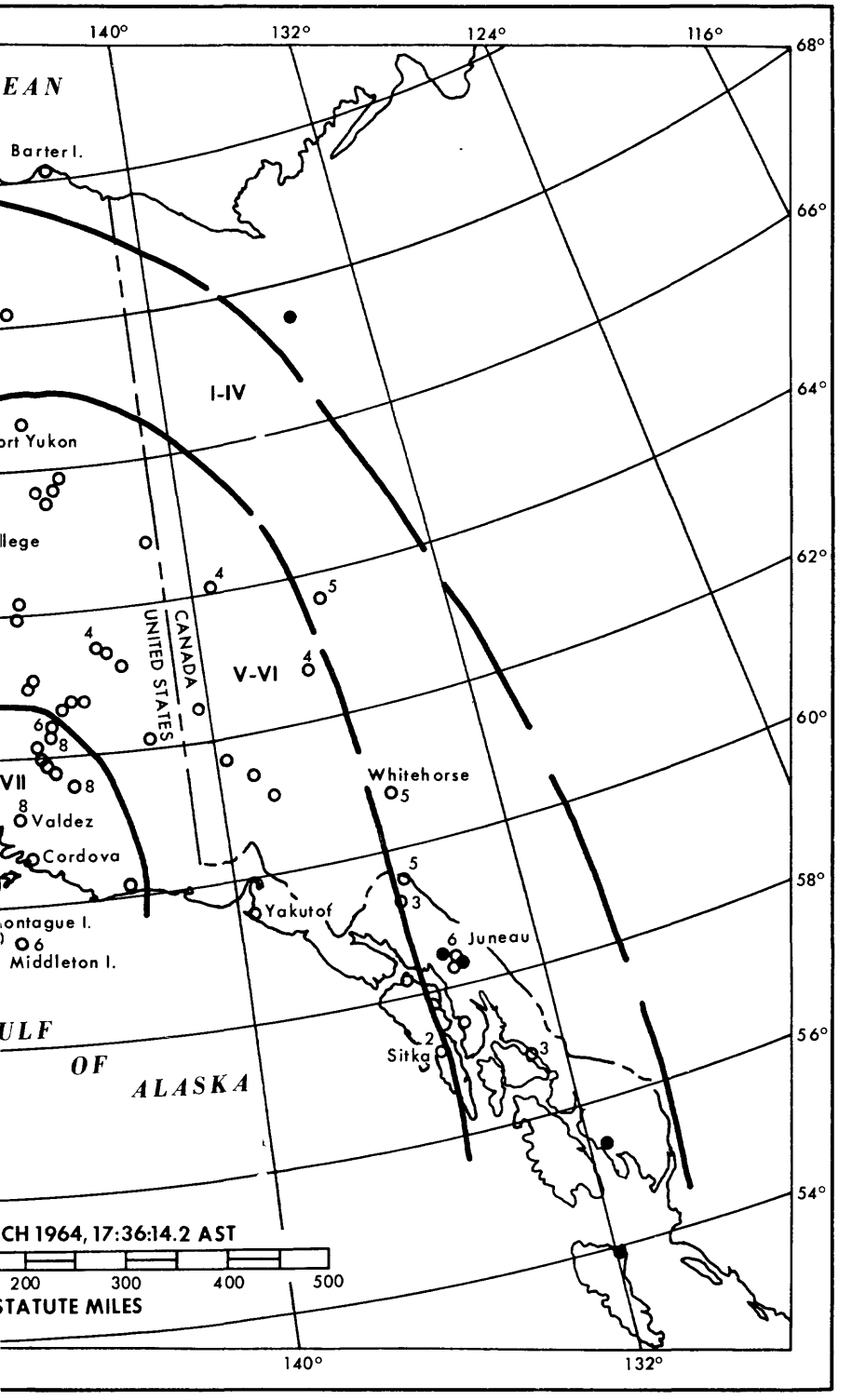


FIGURE 9.—*Area affected by Prince W*



nd, Alaska earthquake of March 27.

over soil and marshy ground about 50 yards from Pippin Lake shore; the earth had rolling wave motion, like water waves."

Milepost 89 (12 miles south of Copper Center).—Felt by all; frightened all in home. Ground cracked. Damage slight. Small objects shifted and overturned; knickknacks and books fell. Trees and bushes shaken strongly. House swayed north-south; hanging objects swung north-south.

Milepost 101.5 (south of Copper Center).—Felt by and frightened all; observer ran outdoors. Ground cracked; highway had small cracks. Considerable shelf damage in store. Bookcase (facing north) torn from wall and contents spilled; sink (facing west) completely emptied of water. Vases and small objects overturned. Pendulum clock (facing north) stopped. Rapid, 30-second shock in south-north direction.

Excerpts from report by Ralph B. Lane, Maintenance Foreman, Ernestine Camp: "I was on my way to Copper Center with my family. While driving, the quake hit us at Milepost 83. The road began to roll and cracks were visible in several places. We did not know at first just what was happening. After it was over, we proceeded past the Wolf Homestead, where everyone was in the yard and seemed to be alright. We went on to Copper Center and upon arriving, found that the power was off. I immediately went to Copper River Cash Store to use the telephone, but when I arrived I could see that a great amount of damage had been done and the phone was out of order. When we returned to Ernestine Camp, the radio transmitter and receiving units were on the floor. The following is my personal view of damage done to the Richardson Highway:

"Tonsina Hill slipped down as much as 18–24 inches in places, leaving one-way traffic; large cracks across the road; great quantities of water pushed through the ground. Little Tonsina Bridge was damaged and impassable; bridge pushed together, causing the deck to rise above the pavement and pushing the pavement 3–4 feet in the air. Traffic was maintained by breaking down the deck and building an earth bridge over the top. Little Tonsina and Squirrel Creek Campgrounds appeared to be alright. At Kendall Cache, damage to building appeared slight; merchandise was all over the floor. At Milepost 29, large heave; 37 to 64, very minor damage; 38, 39, 42, snowslides; 40, Tosina River blocked off and water backed up to a depth of 10 feet. These slides closed the road for 6 hours. Milepost 44, rockslide; 50, the extra amount of water coming down the Tiekel River had been blocked off at Milepost 50 by a large snowslide. A channel through the snow, 12 feet deep and 70 feet long, had to be blasted to let the water through. Great numbers of cracks opened between Mileposts 64 and 85, some as large as 8 inches wide. Many parts were raised on one side and dropped on the other, with a difference of as much as 6–8 inches; 67, road heaved and cracked in many places; 74, ice broken on the Little Tonsina River, causing a jam; 76 and 77, water flowed down roadway and washed fill; jam had to be blasted. Milepost 78½, ice jams on Tonsina River caused a great deal of water to back up and was very close to road level."

Excerpts from letter to Dr. Carl Benson, Geophysical Institute, College, from Jack Wilson, Wilson Air Service, Glennallen: "I finally got up to Mt. Wrangell at a time when it was clear, April 11. There appeared to be little activity at the volcano. There was so much vapor rising out of the cone that I could never see down into it at all. There was much more activity it seemed than I had ever seen before and it seemed unlikely that atmospheric conditions could have caused it all. The fissures around the rim of the Big Basin appeared to be very active too. One noticeable thing was the amount of bare ground over the northeast side where the higher peaks and jagged cliffs are. The ash there had melted so much snow there was really a lot of bare ground on the sides. There are a few new cracks which run sort of crosswise to the older crevasses, but none of them are more than a few inches wide. Other than that, the old mountain held up very well. Tazlina River is not running any more than a very poor head of water. It remained completely dry until about a week ago (letter dated April 13). There is a small tributary glacier which runs into Sherman Glacier near Cordova. Sherman is in the Chugach Mountains between Copper River delta and the Town of Cordova. This side glacier, which comes in from the south, took off and really headed out. It tore down its own valley and slid clear out across Sherman Glacier finally coming to a stop almost down at the terminal of Sherman which is a slothful glacier in itself with a receding end."

Copper River Highway (Fairbanks Daily News-Miner, 4-6-64).—Authorities estimated total damage to the Copper River Highway at about $34.6 million. From Cordova about 40 miles of road had been completed. Nearly every bridge (most of concrete and set on steel pilings down to bedrock) was damaged

or destroyed along that stretch of the highway. Scores of rockslides and avalanches buried many miles of that portion of the road which clings precariously to the rocky cliffs one the west shore of the Copper River. On the first 13 miles, from Cordova to the airport, nearly every bridge was damaged severely. The road heaved and settled 1 to 5 feet below bridge levels.

A Weather Bureau report stated that from Milepost 6 through Milepost 50, numerous ground fissures were observed, some up to 4 feet wide and 50 feet long.

Cordova (The Cordova Times, 4-2-64).—People rushed from homes as the tremors continued for a full 4 minutes. Shock waves were seen traveling across the mud flats. It was not until early morning that the waves came. The first wave, hardly higher than a large tide, roared into the small boat harbor tearing loose pilings already loosened by the shock. The second wave was about 10 feet higher and caused most of the damage. One man died of a heart attack when his waterfront house was washed off its foundation. The old wooden water pipeline from Meals Lake was destroyed. Murcheson Falls, the main water source, had been only a trickle and the city was being supplied from the deep well. When the shock occurred, Murcheson Falls opened up and filled the main, with a sizeable creek from the overflow.

(Anchorage Daily News, 4–18 and 4–20–64): Canneries, boat yards, and clam beds were left high and dry by the massive uplift of the earth.

Other press reports: About 1,500 crab pots were lost. Extensive damage to docking facilities. Cannery docks will have to be extended 30 to 40 feet to accommodate ship moorage; extensive resurvey of shipping channels must be made. Some of the shacks and other buildings close to the waterfront were destroyed by the waves. There was little or no damage to the old frame houses on the hills around the bay.

Excerpts from Weather Bureau reports: Slight tremors were felt for about 20 seconds, increasing steadily for another 20 seconds, then becoming abruptly violent. The violent shaking continued for several minutes, and was accompanied by noise similar to distant cannon booms. Because of the excitement, many persons did not notice the noise. The City of Cordova and vicinity, which is apparently located over solid rock, was not damaged, though badly shaken. Substantial buildings were unaffected, fissures did not appear in the ground, and no personal injuries occurred. Some merchandise was lost, even in some of the newly constructed stores, when shaken from shelves. The Weather Bureau Airport Station, located on Mile 13 of the Copper River Highway, received some damage. The airport runway sustained minor damage. The newly built FAA-WB Control Building settled somewhat, causing door to stick; the cement-slab floor of the Weather Bureau office cracked along the walls; the Weather Bureau apartment building also settled, causing doors to stick; no significant damage. Plumbing facilities were disrupted since nearly all of the underground pipes were broken. The underground power cable to the ceiling light was severed. Weather Bureau instruments were not damaged.

Other observers at Cordova reported: Felt by and frightened all in community. Damage slight to buildings; slight damage to concrete in post office; plaster cracked slightly; dishes broke. Large fluorescent light swung north-south like a pendulum (building on solid rock); pendulum clock (facing east) stopped. Trailer shook violently. Floor seemed to undulate. Motion rapid, duration 3½ to 8 minutes; direction east-west and north-south; loud earth noises from north-south preceded shock by 1 second.

At Cordova, the tsunami caused extensive damage to the docks and floated away some houses near the waterfront. Maximum height reached by the tsunami here was about 5 feet above the highest high tide line. At Whitshed, near Cordova, 10 cabins were washed away and one person, who had returned to his cabin believing the danger had ended, was drowned.

Eagle River.—Felt by and frightened all. Several cracks in pavement and other materials, with average length of 30 feet and width of 1 inch; water level rose in well; several wells in vicinity went dry (USGS). Damage slight. Chimneys and walls cracked; slight damage to masonry. Dishes broke; small objects and furnishings shifted; vases, etc., small objects and furniture overturned; knickknacks and pictures fell. Pendulum clock stopped. Motion rapid, duration 5 minutes; direction west-east and southwest; loud earth noises from southwest.

Eagle River Valley.—From SPOTLIGHT, Universal Services, Inc. An observer reported: "I was almost to my home in Eagle River Valley when the shock occurred. Since going over our pioneer access road always feels as though one were in an earthquake, I did not get to experience much of the shock.

However, the quake did trigger many avalanches in the valley, and a terrible roar was heard. The glacier that my husband was standing on at the time started cracking beneath him and he ran for the nearest tree and hung on. Our mountain A-frame house came through without a scratch."

Eklutna (Anchorage Daily Times, 4–6–64).—Huge concrete pier, set deep in the bed of the Knik River, shifted about 8 inches out of line with its opposite pier at the construction site of the new highway section near Eklutna. Only other damage at the construction site was to a temporary wooden work bridge which had damaged piling and broken deck.

Girdwood-Portage areas (Anchorage Daily Times, 4-2-64).—It was reported that the Cooper Lake Line and the Knik Arm Steam Plant on Ship Creek suffered the most severe damage. Major damage to the Cooper Lake Line occurred between Girdwood and Portage. Approximately 200 poles fell in this area. Three structures were damaged at the Silvertip section of the line. The Chugach Electric Association reported losses at about $4 million.

Glennallen area:

Air Traffic Control Station (6 miles east of Glennallen).—Felt by all and alarmed many. Small ground cracks running east-west directly outside of building. Water main running east-west broke about 5 feet below surface. Swivel chair rolled back and forth across floor. Pendulum clock on north wall stopped (pendulum 2 feet long, swinging east-west). Trees swayed north. Disturbed objects observed by all. Trembling motion, then rocking like ocean swell; rapid buildup. Rumbling and roaring earth noises heard.

Copper Valley School.—Felt by all; general alarm; few panic stricken. Landslides. Ground, chimney, and plaster cracked. Slight damage to some buildings; considerable to one structure. Corners out of a 2-story, cement-block building. One water main broke. Six-foot cross on dome of building bent. Bookcases, statues, cupboards, wall lockers, and library shelves displaced. Several shocks. Trembling motion, then swaying; gradual onset; loud roaring earth noises heard just before and during shock.

Milepost 111 (Richardson Highway).—Felt by and frightened all. Damage slight to concrete. Ground cracked; dishes and windows broke; furnishings shifted; small objects and furniture overturned. Motion rapid, rolling, duration 10 minutes; direction north-south; loud earth noises from north-south at beginning of shock. Tremors felt all day and all night.

Milepost 111½ (Richardson Highway).—Felt by all. Damage considerable. Ground cracked. Dishes broke; small objects and furnishings shifted; vases, small objects overturned; knickknacks, books, and pictures fell. Trees and bushes shaken strongly southeast-northwest. Motion rapid, duration 5 minutes; direction east-west; loud earth noises heard from east.

Tazlina (7 miles south of Glennallen).—Felt by all and frightened many. Damage considerable. Heavy objects moved; vases, small objects, and furniture overturned; knickknacks, books, and pictures fell; dishes broke. Motion rapid, duration 4 minutes; direction west-east; loud earth noises from west-east.

(Fairbanks Daily News-Miner, 4–2–64): The ice cover of Tazlina Lake was shattered into chunks the size of tables over its entire 2-mile length. Water in the lake was greatly lowered. Water stopped flowing from the lake into Tazlina River. Normally, many streams and small rivers flow into Tazlina Lake, but a man flying over the lake on April 2 reported he saw only one of them carrying water.

Glenn Highway area:

Milepost 42.—Felt by and frightened all in community. Water completely disappeared from 18-foot-deep well. Damage slight. Basement walls cracked. Powerlines swung; trees and bushes shaken strongly. Furnishings shifted; small objects overturned; knickknacks fell; dishes broke. Motion rapid, rocking, rolling; duration 2–3 minutes.

Milepost 55.5.—Felt by all in community; frightened many in home. Damage slight. Chimneys fell; plaster, windows, walls, chimneys, and ground cracked. Dishes and furniture broke. Knickknacks, books, pictures, and plaster fell. Trees and bushes shaken strongly. Motion rapid, duration about 3 minutes; direction seemed from east; rumbling earth noises.

Milepost 72.—Felt by and frightened all. Damage slight. Dishes and glass broke. Small objects and furniture overturned; knickknacks, books, and pictures fell. "No ground cracks appeared. Violet up-and-down motion. I had just left home and was traveling north on Glenn Highway. Car almost turned over from heaving motion. All trees, poles, and land were in strong up-and-down motion." Motion rapid, duration 5 minutes; direction northeast; loud earth noises from all directions.

Milepost 94.—Felt by and frightened all.

Damage slight. Ground cracked. Trees and bushes shaken strongly. Small objects and furnishings shifted; vases and knickknacks fell. Motion rapid, duration 2 minutes; direction east-west; loud earth noises from west preceded shock by 1 second.

Milepost 95 (east of Chickaloon).—Felt by all and frightened few in community. Ground cracked; chimney fell. Slight crack in concrete; dishes broke. Trees and bushes shaken strongly. Small objects and furnishings shifted; furniture overturned; knickknacks, books, and pictures fell. Motion rapid, duration 2–3 minutes; direction northeast (quonset hut shook north-south and east-west); moderate earth noises.

Milepost 113 (Sheep Mountain Lodge).—Felt by several; frightened few. Damage considerable to glass, toilet bowls, and one underground water pipe. Dishes and windows broke. Ground cracked. Trees, bushes shaken strongly. Furniture overturned; knickknacks, etc. fell. Motion slow, duration 6 minutes; direction north-south; moderate earth noises.

Milepost 127 (Eureka).—Felt by many; people alarmed. Every pavement joint showed some effect. Barrel of water on porch emptied. Disturbed objects observed. Visible swaying of buildings and trees (everything seemed to move several feet back and forth). Lamps and dishes fell to floor. Motion rocking, swaying northeast-southwest, abrupt onset. Many shocks felt.

Sutton (about 20 miles northeast of Palmer).—Reported to USGS: Many cracks, some ⅛ mile long and 18 inches wide. One area of the highway, about ¼ mile long, subsided about 3 feet. Water level in well fell.

Homer (Diamond Ridge).—Felt by and frightened all in community. Damage slight. Pipeline broke; chickenhouse foundations damaged; ground cracked; dishes broke. Trees and bushes shaken strongly. Small objects and furnishings shifted, including freezer; vases and small objects overturned. "After the shock, I heard noises at frequent intervals which sounded like blasting or big guns firing." Motion rapid, duration 3–5 minutes; direction east-west.

At the head of Kachemak Bay, ground cracked, furniture overturned, and dishes broke. Trees and bushes shaken strongly (some broke). "Huge landslides on bluffs near the bay. Road to beach blocked by much earth, trees, etc. Large cracks, 3–18 inches, all over the ridge and flats." Motion rapid, duration 3–5 minutes; direction south-north.

Along Kachemak Bay, 14½ miles east of Homer, damage was slight. Dishes broke. Ground cracked. Trees, bushes shaken strongly. Hanging objects swung in all directions. Furnishings shifted; knickknacks and books fell. Motion rapid, duration about 5 minutes; moderate earth noises from northeast. "Large dirt or rock slide along Greenwich Glacier across the bay from me. Looks to be about ¼ mile wide."

Report from Weather Bureau: Several buildings in Homer area were so badly damaged they were unuseable; otherwise, damage was moderate—few walls cracked; some plaster damage; some chimneys damaged; foundations cracked, a few beyond repair. One control cable, running north-south, was ruined (52-pair, lead covered, armored, underground). All objects in houses not fastened down were knocked to the floor, including some heavy furniture. Some grocery stores suffered very heavy damage in loss of stock. Roads cracked; landslides on cliffs adjacent to Homer. Well water muddied (108 feet deep). Trees swayed violently. Tide approximately 6 feet higher than normal.

Reported to USGS: Many ground cracks, some as wide as 6 inches. Mole tracks or pressure ridges observed. One landslide, 800 by 1500 feet, occurred 6 miles east of Homer. Approximately 5 square miles of ground subsided as much as 6 feet. Water spouts, some up to 10 feet high, lasted as long as 5 minutes and formed several craters in a line. Water level in wells fell; some wells went dry and did not refill with water immediately. Water level in nearby lake dropped 5 feet. Motion rapid, bumping, rocking, duration 2–6 minutes; directions north, north-south, west; moderate bumping earth noises 3 seconds before shock, at time of shock, and during shock. Seventy to 100 cracks across road from Anchor Point to Homer. Ground apparently opened and closed. One observer reported hearing loud noises like gunshots as the road cracks closed again.

Kasilof (about 6 miles south of Kenai).—Reported to USGS: Many cracks several feet long and 1 inch wide in mud, sand, tundra, and ice. Also, mole tracks, or pressure ridges, were formed. One landslide, 300 by 100 feet, on the north bank of the Kasilof River. One area, approximately 100 feet wide, subsided 1 inch to 4 feet. Water level in wells fell; new springs were formed; and streams decreased in flow. About 10 miles south of Kasilof at Clam Gulch, many cracks were observed in all areas. Few water spouts. One well in area

fell in level. Kasilof River reportedly went dry for two weeks.

Kenai.—Felt by all; general alarm. One man reported he was forced to crawl from building. Damage considerable to great. City Clerk reported a damage survey team estimated damage to private facilities at about $100,000. Most concrete walls cracked, some severely; walls fell. Twisting and fall of chimneys and columns. Extensive damage to light structural parts such as chimneys, etc. Plaster, ground, and windows cracked; windows and furniture broke. Radio towers and poles appeared ready to collapse; building seemed like it would tip over. Trees swayed so far north-south it appeared they would break. Helium tank from cabinet fell east; meters and radio equipment thrown to floor; hundreds of radio tubes thrown from shelves to floor in westerly direction. Furniture overturned; cars rolled and bounced. Motion very rapid, rocking, rolling, duration 3–5 minutes. Direction north-south, east-west, southeast-northwest; loud earth noises from north, east, east-west.

Kenai (Wildwood Station, about 6 miles north of Kenai).—Felt by all; general alarm. Damage considerable to buildings. Wooden water tower, 151 feet high with 150,000-gallon capacity, collapsed (tower appeared to dance, then split; seemed to come straight down). Cement-block walls cracked and broke; wooden buildings loosened between walls and ceilings. Minor damage to water mains (numerous), structural foundations, cables, etc. Chimneys generally fell north-south; some fell east. Lamps, bottles, books, small objects, and TV sets thrown to floor; most everything displaced and swung; light fixtures swung 90° in each direction; trees swayed about 10 feet. Most items on east-west walls slid out north-south. One observer reported: "Almost no real inconvenience as result of shock. Electricity was off 4 to 6 hours; no running water for about 2 days. Little true damage in this area." Motion trembling, rocking, bumping, swaying; three shocks about 30 seconds apart; direction north-south, east-west, southwest; earth noises, variously described as faint, moderately loud, bumping, scraping, roaring, rumbling, 3 seconds before, at time of, and during shock. Several shocks in one day; numerous shocks.

Kenai Peninsula areas (Anchorage Daily Times, 4–2–64).—Oil production in the Swanson River field had returned to normal on 4–2–64, about 30,000 barrels a day.

(Anchorage Daily Times, 4–6–64): High tides expected April 14-15 posed a flooding threat to business, tourist resort, port installations and other facilities, mostly in the Seldovia to Homer areas. The greatest flooding was feared on the 5-mile Homer Spit, which appeared to have subsided as much as 6 feet in some places. High tide flooding was also a threat for some 30 businesses on a boardwalk at Seldovia, across Kachemak Bay from Homer. Water was expected to be above floor levels at these places. Four or five families may be forced to evacuate their homes at Hope, just south of Anchorage at Turnagain Arm.

(Anchorage Daily News, 4–10–64): Light traffic began moving across the Snow River Bridge near Seward and Kenai River Bridge at Cooper Landing, providing the first ground access to Seward in nearly two weeks. District highway engineer reported the highway between Seward and Homer will be open in another 10 days. Traffic was to be reopened on the portion between Moose Pass and Homer on April 9. The U.S. Army provided a Bailey bridge—flown in 17 plane loads to Soldatna and trucked to the bridge site—to help restore the highway bridge at Kenai River.

Kodiak.—Felt by and frightened all; general alarm; many evacuated buildings. Ground cracked; small landslides on Base Road and at Base gravel pit; landslide on east face of Old Womans Mountain. Difficult to walk or maintain balance. Observer reported: "Had the impression of seeing transverse ground waves in a vertical plane, perhaps 2-foot amplitude, moving southeast-northwest through Pillar Mountain during the initial disturbance." In most cases, buildings were slightly damaged. Some cinder- and concrete-block walls cracked; few foundations cracked; some windows broke; few chimneys fell. Buildings and trees swayed strongly. Buildings 1 foot apart collided; 2-inch-diameter trees swayed 20°–25° each side of vertical. Person bathing in basement of home (tub oriented northeast-southwest) was thrown back and forth lengthwise and 85 percent of water sloshed from tub; water in aquarium also sloshed out. Merchandise fell in stores; dishes fell from table; food fell from cabinets; closet shelves emptied. Motion rapid, rocking, swaying, rolling (continuous buildup), all directions; duration 2½–5 minutes or more. Merchandise fell more from counters running east-west; chimneys, etc., fell east-west, in all directions. Loud thunderous rumbling, bumping, earth noises before and during shock. One observer reported no earth noises during main shock, but that loud cracking and

splitting noises (like high-speed train passing by) were heard 8 to 10 days after. Many shocks felt (continuous). "Aftershocks caused more panic than the main shock."

Excerpts from *All Hands*, Bureau of Naval Personnel Publication, July 1964: At the Naval Air Base, an ensign at the Bachelor Officer's Quarters (BOQ) related the following experience: "I was cinching up my tie when the world began to shake. At first I was stunned and tried to think of some easy, everyday explanation for the crazy gyrations. When I realized what was happening—that we were experiencing a full-scale earthquake—I knew I had to get out of the building into the open. The building sounded like a wooden matchbox being crushed underfoot. Every joint and brace was creaking and groaning under the strain. Light globes were falling from the ceiling, bottles were shaken from shelves and dressers, and mirrors crashed from the walls. Fortunately, the building stood up as all ran outside." Another observer reported that he was having dinner when the tremors began. One of the officers at his table noted that it was "just another earthquake, which happens here all the time, rarely anything serious." As the tremors increased, the officers went outside. "Everything was chaotic," a lieutenant said. "It was difficult to walk or even stand. With everything shaking the way it was we became dizzy. Buildings seemed to swing and jump up and down. Light poles swayed like saplings in a breeze; chimneys toppled. Landslides kicked up dust from the sides of surrounding hills. Cars and trucks were bouncing around as though they were on a trampoline." At the hangar area, aircraft bounced with all three wheels leaving the ground. A large paved ramp around the hangars cracked and buckled. One person said he did not know which way to jump after one of the cracks ran across the ramp between his legs. Another observer started to cross the hangar ramp, then turned and ran in the opposite direction as it buckled about 20 feet in front of him, spouting water 10 feet into the air. Duration of earthquake was about 4½ minutes.

The heart of the Kodiak business district, an area about three blocks long and three blocks inland, was destroyed by 35 feet of onrushing water. The seismic sea wave carried large fishing boats a quarter-mile inland, crushing buildings and leaving a soggy mess of debris. At the base, damage to three aircraft hangars was estimated at $1 million, but the major blow was the temporary loss of power. The power plant was flooded repeatedly as tides remained 6 to 8 feet above normal. Station cargo docks were partially floated loose and their approaches were swept away.

Old Harbor (southeast shore of Kodiak Island).—Felt by and frightened all in community. Damage great, most of which was caused by the sea wave. House cracked in half; walls cracked and fell; chimneys twisted and fell (4 homes); dishes and windows broke. Furniture overturned and broke; stoves, etc., shifted; and some overturned. Knickknacks, books, and pictures fell; bushes shaken strongly. Motion rapid, duration 3–5 minutes; loud earth noises from all directions at beginning of shock.

Palmer.—Felt by and frightened all. Damage considerable. Chimneys, plaster, ground, and lake ice cracked; plumbing and windows broke; plaster fell. Stationary washtubs pulled out and "broke all to pieces." Furniture overturned and broke; dishes broke. Furnace smokepipe detached from chimney. Water splashed from toilet bowl. Knickknacks, books, and pictures fell. Trees and bushes shaken strongly. Motion slow and rapid, duration 3–6 minutes. Moderate to loud earth noises from east, southeast 15 seconds before shock.

Port Wells (Cordova Times, 4–9–64).—Men checked ten streams on the Prince William Sound and reported finding eight in good shape; two were damaged by upheavals and silting. It was reported about 70 percent fish mortality was found in Pirates Cove and Pigot Bay. These two streams are big producers of pink salmon. The following is from a report by Ralph R. Migliaccio, District Geologist, Valdez, to R. G. Sherman, Chief Geologist, College: "I made two flights by helicopter over the reported epicenter and in one instance, landed on the western side of Port Wells at the site of the Granite Mine. Wooden buildings at this point were damaged, but generally intact. Waves in this area rose 6–8 feet above the normal high tide level."

Seldovia.—Felt by and frightened all in community. Shock damage reported as slight. Walls fell; chimneys, columns, and monuments twisted; ground, chimneys, plaster, walls, and windows cracked. Furniture overturned; dishes broke. Some vases, small objects shifted and overturned. Trees, bushes shaken strongly. (Most of the damage was from the sea wave.) Motion slow, undulating, rapid; duration, 1½–5 minutes; directions north, southeast; moderate to loud earth noises from north, north-south 15 seconds before shock.

Sitkinak Island (Trinity Islands group, south of Kodiak Island).—U.S. Coast Guard Station. Felt by and frightened all in community. Damage great to brick, masonry, and concrete. Barracks condemned. Road, airstrip, etc., cracked. Prestressed concrete beams cracked; parts of walls cracked and fell; plaster cracked. Furniture overturned and broke; dishes and windows broke. Heavy "X mtrs" and power supplies, weighing 8 tons, shifted more than 1 foot in an easterly direction; also caterpillars and trucks shifted; trucks bounced up and down, sometimes clearing the ground. Station flagpole whipped 4 feet from side to side. Cattle fell down. Extremely hard and long shock. Motion slow to rapid, duration 4 to 10 minutes; directions north, south, northeast, south-southwest; moderate to loud earth noises from north, all directions, 10 to 20 seconds before and during shock. Tremors felt for 9 days after first shock.

Skwentna and vicinity.—Very slight damage to buildings. Minute cracks in corners and around ceiling and doors, mostly on north side of building. Oil storage tanks spilled over to north; drill press, etc., in garage fell; solvent, etc., in containers spilled. Alarms activated due to partial power outage; fuses blown out on power line. Dishes and other items fell. Buildings and trees swayed. Pictures, lamps, etc., swung south-north; building swayed south-north. Muskeg cracked and small cracks appeared in runway. "On March 28, we flew over the area and noticed all rivers and creeks had many cracks, some huge; also many lakes sank 2–3 feet. Could see cracks on side of Mt. Yenlo and throughout the general area in swamps and muskeg." Motion rocking, gradual onset.

Soldatna.—Reported to USGS: Many cracks in gravel and pavement. Water level in well fell; streams increased in flow.

Spruce Cape (about 3 miles southeast of Kodiak).—Felt by and frightened all in community. Furniture overturned; dishes broke. Small objects and furnishings shifted; vases, etc., overturned. Trees, bushes shaken strongly; hanging objects swung northeast. The loudest noise was made by ice breaking on the lakes (500 feet away) and this noise was even louder when the ocean broke into the lakes and forced the ice out. Noise lasted about 5 minutes, then suddenly stopped. Motion slow, duration 5 minutes; direction northeast-southwest.

Sterling.—Reported to USGS: Two cracks, average length 20–40 feet and average width ½–2 inches. Pressure ridges along margins of lake where ice piled up 6–10 feet. Trees in the area whipped back and forth and almost touched the ground. Water level in well fell; streams decreased in flow. Slight damage to frame houses; dishes broke.

Susitna River Valley (Fairbanks Daily News-Miner, 4–1–64).—Spider-web patterns of cracks and fissures were observed in the lower Susitna River Valley across from Cook Inlet.

Wasilla.—Reported to USGS: Pressure ridges in ice along banks of lake. Five or six healthy trees, as large as 8 inches in diameter, were broken; crowns fell mainly in southerly direction. Water level in some wells in the area rose; in some, the water level fell. Slight damage to frame houses; dishes broke.

Wingham Island (Cordova Times, 4–2–64).—One vessel found herself high and dry in the deep sheltered anchorage in the lee of Wingham Island during the terrific ebb of the tidal wave. Oil geysers spouted all about them. Clam diggers at Copper Sands reported sand spouted higher than their heads. Their skiff began to sink in the sand and then was heaved back up.

INTENSITY VI:

Birch Creek (about 6 miles from Circle City and about 12 miles downstream from the Steese Highway crossing of the Birch).—Felt by two trappers, who quickly felt seasick and had to sit down until things quieted down. Trees swayed and whipped back and forth; tent sagged and bagged. Ice on Birch Creek waved and buckled. Duration more than 1 minute.

Central and Circle Hot Springs.—"At Central and Circle Hot Springs, jolts seemed sharper than we felt at Circle." At Central, one well lost water immediately; dishes broke. Visible swaying of buildings and trees. Motion swaying, gradual onset; cracking earth noises after shock.

Christochina.—Felt by all in community (some outdoors active). Ground cracked. Furnishings shifted. Trees, bushes shaken strongly. Hanging objects swung north-south. Motion slow, duration 5 minutes; direction south-north; moderate rumble from south 3 seconds before shock.

Chugiak area (Birchwood, about 20 miles northeast of Anchorage).—Felt by all; awakened one; frightened all in home. Trees, bushes shaken strongly. Knickknacks and books fell; one wall plaque broke. Motion rapid, duration few minutes; moderate earth noises.

College and vicinity.—Felt by all and frightened some in community. Damage slight. Walls cracked slightly due to foundation shift;

damage slight to considerable in concrete (no details). TV set and antenna swung around. Suspended signs, shelves, lamps, etc., swayed in changing directions. Small objects and furnishings shifted slightly; vases, etc., small objects overturned. Pendulum clock stopped. Hanging objects swung north-south. Motion slow, rolling, swaying, duration 5 to 10 minutes; direction north-south, and changing directions.

Delta Junction.—Felt by and frightened all in community. Damage slight. Plaster cracked; dishes and jars of baby food broke. Knickknacks and pictures fell; small objects and furnishings shifted; vases, small objects overturned. Trees, bushes shaken strongly. Hanging objects swung east-west. Motion slow, duration 3 to 5 minutes. Faint earth noises from north, south during shock.

Denali Lakes (10 miles south of McKinley Park).—Felt by all (some outdoors active). Trees swayed in all directions. Definite movement of rocks could be heard. Three boxes shifted 4 inches. Clock pendulum facing east-west banged against north wall. Heavy swell-like motion, slow, duration 2½ minutes; direction south-north.

Egegik.—Felt by and frightened all in community. Ground cracked. Hanging objects and doors swung north-south. Motion slow, steady, smooth, rapid, rocking, duration 4 to 5 minutes; directions north-south, southwest-northeast, southeast; moderate to loud earth noises from north-south, northeast-southwest. Ice in river broke; ice cakes bobbed up and down. Small cracks, about ½ inch wide, and one larger crack, about 2½ inches wide and 100 yards long, on the mud flats. Reported to USGS: Many small cracks 10 to 15 feet long and ½ to 1½ inches wide.

Fairbanks and vicinity.—Felt by all; many alarmed and left homes and public buildings. Rather severe and prolonged shock, but no major damage in the Fairbanks area.

(Fairbanks Daily News-Miner, 3–28–64): Slight damage at the Eielson Air Force Base. Tall radio towers on top of buildings swayed. Ground almost seemed to ripple. A market reported one small jar fell from shelf and broke. International Airport (4 miles west of Fairbanks), Weather Bureau Airport Station: Strong visible swaying of buildings, trees, and ground. "I would say that the ground movement in swaying was at least 5 to 6 inches, moving north-south and that it rose at least 2 to 3 inches up and down." Few items fell off shelves. Most all objects that could swing did so rather sharply. Many doors flew open. A man in the waiting room at the airport reported the most conspicuous effect was a wide swinging back and forth of electric signs suspended by wires from the ceiling, mostly north-south, sometimes east-west; at 5:43 p.m. the signs were still swinging but essentially in a rotary and clockwise motion. Motion slow, rolling, like being on a moderately rough sea (made some dizzy), duration 4 to 5 minutes; direction north-south, from all directions.

At Milepost 4½ on Steese Highway (Fairbanks area), felt by and frightened all in community. Small objects shifted; doors, etc. swung. Trees, bushes shaken strongly. Motion slow, duration 6 minutes; moderate earth noises from south-northeast.

Fort Yukon.—Felt by and frightened all in community. Plaster, windows, walls, chimneys, wood, and ground cracked. Small objects and furnishings shifted. Trees, bushes shaken moderately. Water sloshed in barrels and noise could be heard from ice cracking. Motion slow, rolling, producing a feeling of nausea; duration 30 seconds to 15 minutes; directions north-south, east-west; moderate earth noises from northeast. Reported to USGS: Many cracks in the area. One crack, 1 inch wide, and broken pipeline discovered after shock (not certain if related to earthquake).

Gakona.—Felt by and frightened all in community. Damage slight. Water main broke; plaster cracked. Two-foot hill of dirt thrown up north of FAA runway; runway and highway cracked. Furniture overturned; knickknacks, books, and pictures fell; dishes broke. Small objects and furnishings shifted; vases, small objects overturned. Trees, bushes shaken strongly. Pendulum clock facing south stopped. Motion slow and rapid, duration 5–6 minutes; direction north-south and northeast; moderate earth noises after shock.

In the vicinity of Gakona at Tok Cutoff, Milepost 6, observer was forced to stop car; thought he had flat tire. Small cracks observed in road. Trees and telephone wires swung as if by strong wind.

Healy Fork.—Felt by all and frightened few in community. Cement basement cracked. Telephone wires swung furiously. "I dashed out the door. Seemed like a bad dizzy spell." Motion slow, rolling, steady, duration 3–4 minutes; direction south-north; faint earth noises from south-north.

Hope Junction (about 13 miles southeast of Hope on Seward Highway).—Felt by and frightened all in community. Damage slight. Trees, bushes shaken strongly. Motion rapid,

duration 10 minutes; direction north; moderate earth noises from north.

Hurricane.—Felt by and frightened all. Damage slight to concrete (no details). Small objects shifted. Trees, bushes shaken strongly. Motion rapid, duration 5 minutes; faint earth noises.

Juneau and vicinity.—Felt by many; frightened few. Felt principally in the northwest section of Juneau. The Weather Bureau reported numerous cracks up to ½ inch wide in the Municipal Airport runway with most oriented along the axis of the valley. Visible swaying of trees, light poles, houses, and light fixtures. Door thrown off tracks; wall clock tilted; mantel swayed; water in fish tank and water cooler agitated. Objects on north-south walls displaced the most. Disturbed objects observed by many. Excerpts from report by Meteorologist in Charge, Weather Bureau, Juneau: "The earthquake was felt principally in the Gastineau Channel area, with the heaviest rolling shocks apparently concentrated in the Mendenhall Valley. Shocks were felt in other parts of the Channel, too, but they were lighter, and in some areas, no discernible shock was felt. The airport tower was abandoned for a time. Several of the Valley residents reported moderate tremors which displaced and moved objects. Perhaps the most alarming effect was the long-line communications blackout which immediately followed the shock." Five shocks, close together, motion swaying, rolling, rocking, abrupt onset, duration about 5 minutes. Weather Bureau observer at the airport reported: "First shock was so strong it nearly knocked me off my feet. I became quite dizzy, almost to the point of being sick. Following shocks were of the rolling type and of slight intensity." Tides 4 to 8 feet higher than normal. At Douglas (on Douglas Island) across from Juneau, the *Daily Alaska Empire, 3–30–64,* reported a plane flipped over and sank at Kenny Loken's float.

Kandik River area (at Charlie Creek 1 mile up the Kandik from the Yukon).—Man staggered by earth motion when leaving cabin. Cabin creaked to a frightening degree. Duration about 1 minute.

King Salmon (central section, Weather Bureau Airport Station).—Felt by all in community; general alarm; many people went outdoors. Slight damage to one building. Concrete floor cracked in store. Telephone poles swayed. Suspended objects swayed; doors swung back and forth. Pendulum clocks on walls stopped, oriented north-northwest and south-southeast, and weights were held to avoid breaking glass window of clock; weights on all clocks swung violently. Motion rolling, abrupt onset.

McGrath.—Felt by all; many alarmed. Slight damage to buildings. Slight movement of chimneys, etc. Trees, antennas, etc., swayed. Plants on shelf shifted 6 inches. All suspended objects swayed; hanging objects swung north-south and east-west. Movement of water in all filled water vessels. Pendulum clock (pendulum swinging north-south) stopped. Trees, bushes shaken strongly. Radio at FAA Station off for duration of shock. Motion slow, rolling, moderate to severe swaying for about 4 minutes, then gradually diminishing tremors for about 2 minutes, gradual onset; direction north-south, north, northeast, and east.

Middleton Island (about 65 miles southeast of Cape Cleare, Gulf of Alaska).—Felt by and frightened all in community. Damage slight. Walls cracked. Dishes broke. Small objects and furnishings shifted; vases, etc., small objects overturned; knickknacks fell. Trees, bushes shaken strongly. Towers shaken. Hanging objects swung north. "Our island has evidently risen several feet. We had a second strong shock about 25–30 minutes after the main shock, and a third strong series of jolts about 9:00 p.m. No tidal action noticed at the time. Shocks felt for days afterward. Now, seven weeks later, we are still feeling definite aftershocks, about one a day."

Minto.—Reported to USGS: Many cracks reported in ice on sloughs and on the Tanana River. Mud and moss forced to the surface on most of the cracks.

Mount McKinley National Park.—Felt by and frightened all in community. Damage slight. Block wall, plaster and snow and ice cracked. Small objects shifted. Trees, bushes shaken strongly. Hanging objects swung north-south; 9-foot-long swing in house swung about 3½ feet north-south; cupboard doors swung. Motion slow, rolling, rapid, duration 3 to 4 minutes; direction north-south; faint earth noises.

(Anchorage Daily News, 4–16–64): Pilot observed scars on the south face of Mount McKinley "indicating the hanging glaciers were uprooted and pretty well shaken loose."

Naknek and South Naknek.—Frightened few. Deep wells muddied but soon cleared. Motion slow, duration 2 to 3 minutes; direction northeast. Reported to USGS: Many cracks; water level in wells fell. At South Naknek, several cracks, some as wide as 3 inches and 300 feet long; water level in well fell.

Nenana.—Felt by all and frightened many in community; few panic stricken. Ground cracked; packed ice and snow in streets cracked. Buildings, trees, and poles swayed very strongly (rocking like ocean waves). House settled slightly, causing doors to stick slightly. Small objects shifted. Pendulum clocks on north walls stopped. Hanging objects swung north-south, east, and in circular motion. Disturbed objects observed by many. Motion slow, swaying, rolling, gradual onset; duration 4 to 15 minutes; directions north-south, north-west, east-west; faint bumping earth noises from north.

Nenana (8 miles south of, on new highway).—Felt by and frightened all. Difficult to maintain balance. "Walking the 24 feet to the door was like walking on the deck of a boat." Hanging objects swung northeast; bird cage swung with a rather paced motion. Trees, bushes shaken moderately. Motion slow, duration about 5 minutes; direction northeast.

Nondalton.—Felt by all; frightened few in community. Pressure crack piled ice upon lake in ridge about 3 feet high. Motion rolling, duration 2 minutes; direction east; earth noises from east.

Paxon (Paxon Lodge).—Felt by all; general alarm. Slight damage to buildings. Walls cracked; damage to chimneys, etc. Disturbed objects observed by all. Objects swung or were displaced in no definite direction. Two shocks, trembling motion, gradual onset.

Paxon Lake (Milepost 179, Richardson Highway).—Felt by several (isolated community). Few cracks, running east-west, on ice covering of Paxon Lake. Trees, bushes shaken strongly. Small objects shifted. Pendulum clock facing north stopped. Motion rapid, duration 4 minutes or more; direction southwest to east; faint earth noises at time of shock.

Pilot Point.—Reported to USGS: Many cracks in the area. Some water spouts. Water level in wells fell.

Pilot Point.—Felt by all; frightened many. Damage slight. Ground and ice on ponds cracked. Lakes used for drinking water considerably stirred up. Small objects shifted; gun rack fell. Trees, bushes shaken strongly. Pendulum clock stopped. Hanging objects swung northeast, north-south. Motion slow, duration 2 to 8 minutes; directions northwest, east-west; loud and moderate earth noises from northeast, east, west. People were staggered by earth motion as they walked outside.

Port Alsworth.—Felt by all; general alarm. One window cracked; slight crack in chimney. Buildings and trees swayed back and forth. Motion trembling, rocking, swaying, gradual onset. Loud, thunderous and roaring earth noises at time of shock.

Richardson Highway (Delta River Valley, Milepost 218).—Felt by all at Trim's Camp. Slight damage to buildings; vertical cracks in walls. Road cracked on Richardson Highway from Milepost 218 to 177. Expansion joints on bridges spread north-south. Trees, buildings, and machinery swayed; trees almost touched the ground. Bed jumped up and down. Disturbed objects observed by all. Cabinet doors and light fixtures swung north-south. Motion rolling, rapid onset, one continuous shock. Surface sounds were like a strong wind, swishing with sort of whistle, and at times a roar. Four shocks of "good" intensity felt during next 10 days; several smaller shocks felt during three weeks.

At Milepost 195, pressure ridges were observed on south and east banks of Summit Lake due to water moving back and forth.

At Milepost 150, felt by several (isolated community); some outdoors active; frightened all in home. Dishes broke; small objects shifted and overturned; knickknacks, books, and pictures fell. Trees, bushes shaken strongly. Motion rapid, duration 3–4 minutes; direction east-west; loud earth noises from southeast 15–20 seconds before shock.

Shageluk.—Reported to USGS: Cracks as wide as ½ inch and 6 inches deep.

Sinona Creek.—Felt by all and frightened many. Damage slight to concrete. Many ground and surface cracks, with water seeping up through some; large north-south crack, about ½ mile long, across Christochina River. Snow slid off mountains. Trees and bushes shaken strongly. Vases, small objects overturned; knickknacks, books, and pictures fell. People fell down. Motion rapid; earth noises after shock.

Slana.—Felt by and frightened all. Damage slight. Ground cracked. Earth waves, about 18 inches high and 50 to 60 feet apart, were observed moving across yard. Buildings rocked like a boat. Small objects shifted. Trees, bushes shaken strongly. Hanging objects swung northeast. Motion slow and rapid, very smooth; duration 5 minutes; directions north, northeast.

Summit.—Felt by all; frightened many. Ground cracked; plaster and mouldings cracked. Small objects shifted; knickknacks fell. Pendulum clock facing east stopped. Trees, bushes shaken moderately. Hanging objects swung north-south. Motion slow, du-

ration 4 to 8 minutes; direction north-south; faint earth noises from south.

Talkeetna.—Felt by and frightened all in community. Concrete chimneys and cellars cracked in two houses. Dishes broke. Small objects and furnishings shifted; small objects overturned; knickknacks and books fell. Trees, bushes shaken strongly. Doors, etc., hanging objects swung. Motion rapid, duration 3 to 6 minutes; direction north; moderate earth noises from northeast.

Tanana.—Reported to USGS: Five cracks, mostly in ice and mud. Average length 50 feet; average width ¼ inch.

Tanana.—Frightened many in community (some outdoors active); observer dizzy, unable to walk. "I knew we had a 'good' one some place nearby." Trees, bushes shaken moderately (faint noise from moving trees). Pendulum clock facing north stopped. Arm on phonograph shifted. Hanging objects swung north. Motion slow, duration 2 to 5 minutes; direction east.

Tetlin.—Reported to USGS: Slight damage to log buildings. Few cracks in area, some as wide as 3 inches.

Tok.—Felt by and frightened all in community. Damage very slight. Walls cracked. Wells at depths to 90 feet (gravel to total depth) muddied, but most cleared within few hours; one well discolored for 15 hours. Small objects shifted. Pendulum clock facing east stopped. Trees, bushes shaken strongly. Car rolled gently back and forth a few inches. Doors swung; hanging objects swung east-west. Motion slow, wavelike, very gradual onset, causing nausea; duration 3 to 5 minutes (severe for 3 minutes, minor for 2 minutes); directions south-north, east-west, northeast, southwest; faint earth noises from south-north.

Willow.—Felt by and frightened all in community. Damage slight. Ground and windows cracked; dishes broke. Small objects shifted; vases and small objects overturned; books, pictures, and pendulum clock fell. Trees, bushes shaken strongly. Doors, etc., swung north. Motion rapid, rolling, duration 1 to 5 minutes; direction north-south, north-northeast; loud earth noises from north-northeast.

Yakutat.—Felt by all; many alarmed. Buildings and trees swayed visibly. Pictures, books, and curios fell. Doors opened and closed. Water spilled. Tide fluctuated with 10-minute cycle. Motion trembling, swaying, gradual onset; direction east; loud earth noises, like cannon shots, for 20 minutes after shock. "The cannon shots, about 20 in number, were heard by people at the airfield, the Loran station, and in town. All agreed they came from Khantaak Island. Examination of the island by plane the next morning showed some slumping of a beach near Point Turner on the bay side and considerable debris, mainly kelp, in all the bays and lagoons, with the water extremely dirty looking."

INTENSITY VI IN YUKON TERRITORY, CANADA:

Snag.—Felt by all at DOT barracks. "Ground cracking." Snow cracked (could be heard). Poles and antennas whipped strongly back and forth; heavy, metal radio panel raked; fluorescent light fixtures swung. Small objects shifted. Teletype circuit temporarily out of service. Severe vibration of buildings. Motion slow, duration 10 minutes; directions northeast, east-west; moderate crackling earth noises from north.

White River (White River at Alaska Highway).—Wells polluted for many hours.

INTENSITY V: Aleknagik, Bethel, Cantwell, Chignik, Chisana, Circle City, Cobb Lake (few miles west of Slana), Curry (Milepost 248.5 Alaska Railroad), Dillingham, Eagle, Farewell, Gold Creek (150 miles north of Anchorage), Iliamna Lake (Intricate Bay), Kokrines, Kotzebue, Ruby, Sal Lake (69°20′ north, 148°35′ west), Skagway, Sleetmute, Togiak, Umiat (bush camp), and Unalakleet.

INTENSITY V IN YUKON TERRITORY, CANADA: Burwash Landing, Destruction Bay, Donjek River (Donjek River at Alaska Highway), Mayo, and Whitehorse.

INTENSITY IV: Barter Island, Canyon Village area, Cold Bay, Garner, Hoonah, Lake Chandalar and 10 miles east of, Manley Hot Springs, Steese Highway (Milepost 66), Tanacross, Unimak Island (Scotch Cap Light Station), and Wild Lake (67.5° north, 151.6° west, about 50 miles north of Bettles Field).

INTENSITY IV IN YUKON TERRITORY, CANADA: Dawson and Minto (Midway Lodge, Milepost 142.4, Mayo Highway).

INTENSITY IV IN BRITISH COLUMBIA, CANADA: Francois Lake (central British Columbia, about 10 miles south of Burns Lake).

INTENSITY I–III: Chukchi Sea (69°10′ north, 171°40′ west), Dime Landing, Gambell, Haines, Holy Cross, Livengood, Nome, Petersburg, Sitka, and Wainwright. Reported felt (no details; Weather Bureau reports): Adak, Angoon (northeast of Sitka), Arctic Village, Cooper Lake, May Creek (strongly felt), Puntilla, and Uganik.

INTENSITY I–III IN WASHINGTON: Seattle.

INTENSITY I–III IN BRITISH COLUMBIA, CANADA: (Press) East Kootenays (southeastern British Columbia), Fort St. John (northeastern British Columbia, near Alberta border), North Vancouver, Prince George (central section of British Columbia), and Prince Rupert (80 miles south of Ketchikan).

DIRECTION OF MOTION

The following are some of the more descriptive reports on direction of motion in the strongly shaken areas:

Anchorage (Federal Building, Weather Bureau).—We have an almost unquestionable record of the sequence of earth movements by the manner in which our files were displaced in the data file room at this office. A large single section open shelf file placed against the west wall of our file room was thrown violently eastward, emptying all of the contents onto the floor. A similar shelving of double files along the south wall had its contents also emptied completely onto the floor. However, the contents from the file on the west were found on the bottom of the heap while the material on the shelving along the south wall of the room was found on top. This clearly indicates that the most violent motion occurred first in the east-west direction, followed by violent motion in a north-south direction. This sequence of earth movements is also substantiated by the fact that the vertical file on the west wall broke loose and was leaning against the end of the double file which later, moving in a north-south direction, resulted in a rather deep scar in the west end of the double file at a distance of about 6 feet above the floor level. In other words, the violent north-south movement of the double file occurred after the file on the west wall had been tipped over against the double file.

Anchorage (Government Hill, 744 Sunset Drive).—Ground appeared to vibrate in a waving motion; vertical motion was appreciable; east-west horizontal motion for 2–3 minutes, then more strongly in north-south direction.

Anchorage (Hillside Apartments, corner 16th and H Sts.).—Report from John R. Williams, Geologist: The first shaking motion was followed without any noticeable quiet period by a strong rolling motion that appeared to come from east-west. Noticed nothing unusual about the small pictures on the south-facing wall. After running outdoors, observer looked at the building and observed the upper floors appeared to be swaying about 3 feet each way in an east-west direction. The east and west end walls collapsed and fell out, exposing the rooms to view. The north wall was cracked but remained relatively intact. Drum table on the north side of living room was in position and table lamp about 12 inches high (quite unstable) was upright on the table, also papers on this table were undisturbed. A wooden bookcase, 4 feet high, located on the west-facing wall of the living room did not fall, but the books spilled out.

Anchorage (2395 Campbell Place, Hidden Village, Homestead Acres).—I found the easiest way to stand was facing north-northeast. Bookcase on east wall fell; one on south wall did not; television alined east-west fell to south.

Anchorage (1040 C St.).—When I returned to my house, books and bookcases had fallen from east-west walls but not from north-south walls.

Chitina.—Visible north-south sway of power poles and 2-story buildings. Objects on south walls displaced the most. A safe, which took eight men to move on skids, overturned to the south. The Chitina Hotel leaned toward the north and also pushed us toward the north.

Copper Center (south of, Milepost 101.5, Richardson Highway).—One bookcase facing north torn from wall; sink facing west was completely emptied of water.

Cordova.—Large fluorescent lights swung north-south like a pendulum (building on solid rock).

Glennallen (Air Traffic Control Station, 6 miles east of Glennallen).—Water main running east-west broken about 5 feet below surface. Swivel chair rolled east-west back and forth across floor.

Glennallen (7 miles south of, Tazlina).—"When the shock started I was in the house. After about 1 minute, I went outside. By then it was difficult to walk. I hung onto a tree, which was shaking very strongly. Looking west, the shock waves seemed to be coming from that direction and looked to be about 6–8 inches high, traveling so rapidly that the waves seemed to be only about 20 feet from the crest to the low. Although the waves looked to be traveling east, several objects, which could fall in any direction, fell north-south."

Glenn Highway (Snowshoe Lake, Milepost 147).—Objects fell southeast generally but difficult to specify; much twisting motion, generally northeast-southwest.

Glenn Highway (Milepost 72).—Violent up-

and-down ground motion. "I had just left home and was traveling north on Glenn Highway. Car almost turned over from heaving motion. All trees, poles, and land in strong up-and-down motion."

Homer (Weather Bureau Report).—One control cable running north-south ruined (52-pair, lead covered, armored, underground cable). Most objects seemed to fall in north-south direction.

Homer.—"I remember trying to reach for my 3-year-old girl and being thrown back quite hard against the south side of the door jamb. The trees are vivid in my mind. They were heavy with a wet spring snow, and I noticed the snow being thrown straight up to land on the branches again before being shaken off. My husband returned to the house to turn off the stoves. I thought I heard him yell and hurried into the house, and I remember the floor seemed to come up and meet me one minute and drop away from my feet the next, causing me to stagger. My plates were being dealt out of the cupboard (north side of house) like cards."

Hope.—The motion was an east-west oscillation. Somewhat slower than the one in 1936 when I was knocked off my feet, but the sidewise motion was much longer.

Kenai.—Trees were swaying so far north-south it appeared they would all break. Helium tanks from cabinet fell east; hundreds of radio tubes were thrown from shelves to the floor in westerly direction.

Kenai.—Shock apparently hit this area in a north-south direction. Cars facing north rolled; those facing west-east rocked and bounded.

Kenai (Wildwood Station, 6 miles north of Kenai).—Light fixtures swung 90° north-south. Chimneys, etc., generally fell north-south. Floor lamps and other small-base objects fell north-south.

Moose Pass.—North-south and east-west direction. Our full-size piano on east-west wall shifted 2½ feet south. Stove and oil heater on west wall shifted about 6–8 inches northeast. Divider shelves, 4 by 8 by 2 feet, filled with canned goods shifted 6 to 8 inches southwest. Shelves on south and west walls were practically emptied of dishes, etc. Three chests of drawers on north wall in bedroom fell to floor. Six-foot music rack on north wall fell to floor. Bookshelves, 5 by 3 by 1 foot, on north wall were emptied of contents. Open shelves standing about 34 inches high on east and south walls (covered with potted plants) lost only four plants and none of contents came out, but potted plants on bookshelves on north wall were buried under books. Deep freeze (21 cubic feet) against west wall rocked back and forth; 500-gallon oil barrel on 5-foot rack (end of barrel east-west) rocked north-south but did not go over 2 by 4 inch chocks. Lock boxes at post office (over east-west counter) shifted 14 to 15 inches to south.

Moose Pass.—The main shock went from south to north. We saw this also by the movement of ice on the lake in front of our house.

Seward.—Direction of motion appeared to be circular, counterclockwise. Hospital furniture, such as tables, bed stands, and trays, rolled in all directions. Parked cars rolled and bounced.

Valdez.—The ground surface was heaving in much the same manner as a ground swell in the open ocean except that the swells were much more rapid and frequent. These waves or heaves have been literally frozen in place in the highway east of Valdez. The west wall of the Gibson Building leaned without collapsing, but the east wall of the Alaskan Hotel collapsed, leaving upstairs rooms exposed.

Valdez.—All objects, lamps, refrigerator, beds, dressers, range, etc., in apartment building moved, generally north-south.

Valdez.—Piano moved from north wall and then back and forth; dishes fell from north and northwest cupboards. Plaster cracked on north wall of living room.

Whittier.—The motion was generally described as seeming to come from all directions.

DURATION OF SHOCK

The following is an excerpt from a letter received from Mr. Wilfred S. Mitchell, Jr., of the Regional Weather Bureau Office at Anchorage: "My duties presently do not include filling out earthquake forms as they used to; however, I am still very much conscientious about the time element (beginning and ending) whenever I feel an earthquake. I thought that you might be interested to know that I timed the March 27th earthquake at 6½ minutes. This is the total time that I felt the shaking and rolling motions. I remained in a small building on F Street between 4th and 3rd Avenues for 4 minutes before I felt safe enough to depart the building. The remaining 2½ minutes I stood in the center of the street (F Street) and watched the Westward Hotel sway back and forth, I would guess

at about 10–15 feet distance at the top of the building. I have talked with many other persons and almost without reservation they believe that the shock lasted 5 or more minutes."

Numerous reports were received through the earthquake questionnaire coverage which appeared to substantiate the long duration of this earthquake.

March 27: 17:48 (about), 18:15. Manley Hot Springs. Mild shocks; duration 1 second.

March 27: 18:31, 21:10:21.4*. Epicenter 58.8° north, 149.5° west, Gulf of Alaska, depth about 20 km, W. Strong shock felt on Middleton Island about 25 to 30 minutes after first shock, and strong series of jolts about 21:00. Tremors felt for days afterward. Magnitude 6.2.

March 27: 21:32, 22:40. Kodiak Naval Station. Slight tremors.

March 28: (no times given). Cape Hinchinbrook. Coast Guard light station reported strong shocks continuing on March 28. "Getting shocks every 10 to 15 minutes and loud noises like cliffs falling. Building shaking badly. Have to leave station again. There is an awfully loud roar from the sea."

March 28: 00:35:38.9*, 00:37, 02:20:49.8*, 04:34, 04:40, 16:59, 19:02 (continuing at intervals until 19:30), 22:17, 22:26. Epicenter of first shock, 57.2° north, 152.4° west; of third shock, 56.5° north, 154.0° west, both in Kodiak Island region at depths of 33 and 25 km, respectively. At Kodiak Naval Station, slight tremors were reported at these times. Shock at 22:17 reported from Woody Island also. Magnitudes of first and third shocks, 6.3 and 6.5, respectively.

March 28: 02:00 (about). Copper Center. Strong rolling motion.

March 28: 11:00 (about). Anchorage (Hillside Apartments). V. "I was inside apartment recovering possessions when tremor with rocking motion began. Ran from building. Building swayed. This was apparently the strongest aftershock to date (report undated). Other minor aftershocks have caused similar motions, but were of short duration. No further damage caused by aftershocks, other than dropping of cinder blocks and collapse of a few unstable interior walls."

March 28: 18:45 and 21:00. Adak. Earth tremors felt.

March 28 and **29:** (no times given). Mount Edgecumbe. "Some aftershocks felt. Very slight."

March 28, 29, 30: (one about 06:00). Unalakleet. Strong vibrations felt.

March 29: (no times given). Cape Hinchinbrook. Observer at Kodiak Naval Station reported: "Received report at 01:25 that Cape Hinchinbrook sustained large tremors of 5 seconds duration in last hour. Severe shock reported in Prince William Sound area."

March 29: 21:57. Adak. Earth tremor felt.

March 30: 01:45, 03:19. Adak. Earth tremors felt.

March 30: 02:12, 04:10. Kodiak Naval Station. Slight tremors with rolling motion.

April 3: 12:00, 12:33:42.2*. Epicenter 61.6° north, 147.6° west, southern Alaska, depth about 40 km, W. V. At Anchorage, some previously cracked buildings were cracked a little more. Damage also reported from a foreshock at 12:00. Residents rushed into streets; caused considerable fright. Also felt at Chitina, Copper Center, Fairbanks, Girdwood, Glennallen, Glenn Highway (Milepost 94), Kodiak, Sleetmute, Tanacross, and Valdez. Magnitude 6, P.

April 3: 23:12. Kodiak Naval Air Station. Light tremor; duration, 1 minute and 40 seconds.

April 4: 12:30. Felt at Chitina.

April 10: (no time given). Shock felt at Sleetmute.

April 12: 04:35:39.2*. Epicenter 61.2° north, 151.1° west, southern Alaska, depth about 28 km, W. IV. Awakened some residents in Anchorage. Dishes and windows rattled and ground rocked. Magnitude 5.0.

April 13: 02:26. Cape Yakataga. Moderate shock; duration several seconds.

April 13: 06:00. Anchorage. Press report stated, "Tremors which have been keeping Anchorage on edge since the March 27 earthquake are continuing with the most recent one reported at 06:00 today."

April 14: 05:00, 05:55, 06:15, 07:00, 08:20. Anchorage. IV. Press reported that two strong jolts rocked dishes and rattled windows at breakfast time. Strongest shock at 05:55. Other shocks at times given.

April 14: 12:55:31.3*. Epicenter 58.0° north, 152.6° west, Kodiak Island region, depth about 30 km, W. VI. City Hall, fire station, and library building at Kodiak were further weakened. At the Kodiak School, light fixtures were damaged and several cracks appeared in building. Magnitude 4½–4¾, B.

April 16: 04:30. Anchorage. IV. Press reported that residents were awakened by a quick, sharp tremor that shook light fixtures and caused buildings to creak.

April 16: 07.00. Felt at Girdwood.

April 17: 11:16. Felt on Adak.

April 20: 01:56:41.6*, 05:52. Epicenter 61.4° north, 147.3° west, southern Alaska, depth about 30 km, W. Felt at Anchorage, Chitina, and Girdwood. Also reported felt onboard USC&GSS SURVEYOR anchored at 61°06.4′ north, 146°20.6′ west. Magnitude 6½, P.

April 20: 18:17. Felt in Anchorage. Duration, 50 seconds.

April 20: 19:01:35.7*. Epicenter 61.5° north, 147.4° west, southern Alaska, depth about 40 km, W. Felt at Anchorage and onboard USC&GSS SURVEYOR anchored at 61°06.4′ north, 146°20.6′ west. Magnitude 6, P.

April 24: 20:56:30*. Felt on Adak.

April 26: 07:45. Felt at Linger Longer.

April 29: 07:27. Cape Yakataga. Moderate to severe shock; duration about 3 seconds.

April 30: 08:03. Felt at Girdwood.

April 30: 11:45. Felt at Linger Longer.

May 3: (no time given). Sleetmute. Shock felt.

May 6: 17:09:49.6*. Felt on Adak.

May 11: 20:43:56.0*. Felt at Kenai.

May 14: 19:11:17*. Epicenter 61.4° north, 147.9° west, southern Alaska, depth about 33 km, W. Felt at Kenai. Magnitude 3.7.

May 20: 20:05. Felt in Anchorage area.

May 21: 03:35. Felt in Anchorage area.

May 21: 05:36:01.5*. Epicenter 59.0° north, 153.5° west, southern Alaska, depth about 15 km, W. Felt at Intricate Bay. Magnitude 4¾–5, B.

May 22: 04:15. Felt at Intricate Bay.

May 24: 21:30. Felt at Intricate Bay.

May 28: 12:51. Felt on Umnak.

May 29: 00:17:34.5*. Epicenter 60.2° north, 146.3° west, southern Alaska, depth about 5 km, W. Felt at College. Magnitude 5–5¼, B.

June 2: 06:09:23.5*. Epicenter 59.7° north, 144.4° west, Gulf of Alaska, depth about 15 km, W. Felt at Yakataga. Magnitude 4¾, B.

June 5: 00:15. Felt in Anchorage area.

June 10: 07:22:35.0*. Felt at Fairbanks.

June 12: 07:18:06.0*. Felt at Fairbanks.

June 28: 21:21:32.8*. Epicenter 62.7° north, 152.0° west, central Alaska, depth about 33 km, W. At McGrath, buildings and suspended objects swayed. Also felt at Anchorage, Palmer, and College. Magnitude 5.6.

July 23: 09:08:06.6*. Epicenter 59.9° north, 149.2° west, Kenai Peninsula, depth about 55 km, W. Felt at Anchorage, Seward, and Kenai. Magnitude 5.4.

July 24: 18:41:41.8*. Felt at College and Fairbanks. IV. Dishes rattled.

July 27: 13:21. Felt in Anchorage area.

August 1: 22:36:16.9*. Epicenter 56.2° north, 149.9° west, Gulf of Alaska, depth about 31 km, W. Felt at Homer. Magnitude 6, P.

August 10: 17:30. Felt at Trims Camp.

August 11: 11:57. Felt at Trims Camp.

August 14: 05:24. Felt on Adak.

August 26: (time not given). IV. Buildings shook at Larsen Bay.

August 30: 03:03. Slight shock felt at Homer.

September 13: 07:44:10*. Epicenter 61.4° north, 149.8° west, southern Alaska, depth about 33 km, W. Felt at Anchorage. Magnitude 3.9.

September 15: 15:20 and 15:30. Felt in Anchorage area.

September 23: 06:37:19*. Epicenter 61.6° north, 150.0° west, southern Alaska, depth about 33 km, W. Felt at Tolovamkorga. Magnitude 4.1.

September 24: 12:39. Felt on Adak.

September 28: 08:30. Felt in Anchorage area.

October 18: 11:45:10.4*. Epicenter 60.3° north, 152.3° west, southern Alaska, depth about 96 km, W. Felt at Homer. Magnitude 4.1.

October 26: 21:50. Felt at Tolovamkorga.

October 31: 22:46. Felt on Adak.

November 6: 20:21 and 20:50. Felt at Manley Hot Springs.

November 20: 11:27:39.5*. Epicenter 63.7° north, 146.5° west, central Alaska, depth about 80 km, W. Felt at Manley Hot Springs. Magnitude 4.6.

November 23: 01:47:54.4*. Felt at College.

November 26: 17:37:03*. Epicenter 65.3° north, 151.4° west, Alaska, depth about 33 km, W. Felt at Manley Hot Springs. Magnitude 4.2.

November 26: 21:47:07.6*. Epicenter 62.6° north, 151.5° west, central Alaska, depth about 113 km, W. IV. Dishes and small objects rattled at Anchorage. Also felt at Summit. Magnitude 4½–4¾, B.

December 12: 14:33:24.7*. Epicenter 64.9° north, 165.7° west, Alaska, depth about 15 km, W. VI. Slight damage reported at Nome and Teller. Magnitude 6 (Pal).

INTENSITY VI:

Nome.—Felt by all. General alarm. Tremors were reported at 14:32, 14:34, 14:37, 15:30, and 19:00. A beam cracked in new school; water pipe broke; ⅛-inch crack in

concrete floor; and wall and plaster cracked. "Crusted snow about ½ mile away was broken into small chunks." Merchandise fell from shelves; buildings creaked; loose objects rattled. Rumbling earth noises heard before each shock.

Teller.—Felt by all and alarmed many. Ceiling paper cracked. Buildings creaked and loose objects rattled. Observer said he thought house was going to fall apart. Hanging objects swung. 2 shocks.

INTENSITY IV: Emmonak and St. Michael.

December 17: 13:44:46.2*. Epicenter 51.4° north, 177.9° west, Andreanof Islands, Aleutian Islands, depth about 57 km, W. Felt on Adak. Magnitude 4¾, B.

December 19: 22:45:58*. Epicenter 52.1° north, 177.1° west, Andreanof Islands, Aleutian Islands, depth about 140 km, W. Felt on Adak. Magnitude 4.3.

December 28: 19:39. Felt on Adak.

HAWAII
(150TH MERIDIAN OR HAWAIIAN STANDARD TIME)

NOTE.—Data on the following local disturbance 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 Summaries* 33 through 36.

January 6: 17:11:45.3*. Epicenter 19°49.1′ north, 155°31.8′ west, 8 km north of Pohakuloa at a depth of 12½ km. Felt at Honokaa. Magnitude 3.0.

January 7: 01:06:25.0*. Epicenter 19°18.0′ north, 155°13.5′ west, 9 km south-southwest of Makaopuhi at a depth of 8 km. Felt over half of Island. Magnitude 3.7.

January 8: 03:14:55.0*. Epicenter 20°05.6′ north, 155°39.7′ west, 8 km east-northeast of Kamuela at a depth of 12½ km. Felt at Kamuela. Magnitude 2.9.

January 16: 15:40:57.0*. Epicenter 20°-06.4′ north, 155°49.8′ west, 16 km west-northwest of Kamuela at a depth of 12½ km. Felt at Waimea. Magnitude 3.0.

January 30: 05:38:43.3*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt in Kilauea summit region. Magnitude 3.2.

January 31: 00:29:00.1*. Epicenter 19°-24.1′ north, 155°17.1′ west, Kaoiki Fault system, at a depth of 30 km. Felt in Kilauea summit region. Magnitude 3.3.

February 9: 21:06:34.0*. Epicenter 19°-24.1′ north, 155°17.1′ west, Kaoiki Fault system, at a depth of 30 km. Felt near Kilauea summit region. Magnitude 2.9.

February 16: 03:10:37.5*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt in Kilauea summit region. Magnitude 3.0.

February 20: 22:31:44.5*. Epicenter 20°42′ north, 155°50′ west, 41 km east-southeast of Haleakala at a depth of 12½ km. Felt east of Maui, Kohala, Honokaa, Kamuela, and Kilauea summit region. Magnitude 4.3.

March 1: 19:22:27.0*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt near Pahala. Magnitude 2.7.

March 2: 11:12:49.2*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt near Pahala. Magnitude 2.8.

March 5: 22:19:12.3*. Epicenter 19°52.2′ north, 155°36.5′ west, 19 km south-southeast of Kamuela at a depth of 12½ km. Felt at Honokaa, Kamuela, and near Pohakuloa. Magnitude 3.0.

March 10: 00:54:38.0*. Epicenter 19°16.5′ north, 155°10.9′ west, 2 km northeast of Apua Pt. at a depth of 8 km. Felt over eastern half of Island. Magnitude 3.6.

March 11: 19:30:56.4*. Epicenter 19°17.5′ north, 155°05.8′ west, 12 km southeast of Makaopuhi at a depth of 10 km. Felt in Hilo region. Magnitude 3.7.

March 16: 23:06:46.0*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt near Pahala. Magnitude 2.8.

March 24: 12:57:07.5*. Epicenter 19°22.1′ north, 155°05.2′ west, 11 km east of Makaopuhi at a depth of 3 km. Felt at Hilo. Magnitude 3.0.

March 30: 12:15:35.0*. Epicenter 19°17.4′ north, 155°10.7′ west, 10 km south of Makaopuhi at a depth of 3 km. Felt near Hilo. Magnitude 2.6.

April 1: 02:28:53.0*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt over half of Island. Magnitude 3.9.

April 2: 22:18:51.0*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala. Magnitude 2.9.

April 12: 05:43:58.5*. Epicenter 19°44.5″ north, 155°26.3′ west, 9 km east-southeast of Pohakuloa at a depth of 12½ km. Felt at Naalehu. Magnitude 2.0.

April 14: 13:08:31.9*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Volcano. Magnitude 3.0.

April 14: 14:02:44.0*. Epicenter 19°33′

north, 155°58′ west, 7 km northwest of Kealakekua at a depth of 12½ km. Felt at Kona. Magnitude 2.6.

April 20: 06:04:04.0*. Epicenter 19°40.8′ north, 155°53.9′ west, 18 km north-northeast of Kealakekua at a depth of 3 km. Felt at Kona. Magnitude 2.8.

April 20: 14:07:13.0*. Epicenter 19°25′ north, 156°01′ west, 17 km southwest of Kealakekua at a shallow depth. Felt at Kona. Magnitude 3.4.

April 26: 00:44:50.0*. Epicenter 19°18.9′ north, 155°11.8′ west, 8 km south-southwest of Makaopuhi at a depth of 3 km. Felt at Volcano. Magnitude 2.9.

April 26: 10:20:39.6*. Epicenter 19°21.8′ north, 155°04.9′ west, 12 km east of Makaopuhi at a depth of 3 km. Felt at Hilo. Magnitude 2.9.

April 28: 06:27:15.9*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt near Pahala. Magnitude 3.2.

May 16: 09:48:46.3*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt in Kilauea summit region. Magnitude 3.0.

May 18: 07:32:56.5*. Epicenter 19°24′ north, 155°17.1′ west, at a depth of 30 km. Felt near Pahala. Magnitude 2.9.

May 24: 05:05:56.0*. Epicenter 19°15.0′ north, 155°24.4′ west, 11 km south-southwest of Desert seismometer at a depth of 3 km. Felt. Magnitude 3.2.

May 27: 15:01:45.5*. Epicenter 19°53.8′ north, 155°29.0′ west, 28 km southwest of Kamuela at a depth of 12½ km. Felt. Magnitude 2.4.

May 28: 04:06:01.5*. Epicenter 20°05.9′ north, 155°50.3′ west, 18 km west-northwest of Kamuela seismograph at a depth of 12½ km. Felt at Kamuela and Kohala. Magnitude 3.4.

May 30: 20:57:56.5*. Epicenter 19°32.0′ north, 154°52.9′ west, 5 km northwest of Kapoho at a depth of 5 km. Felt at Kapoho. Magnitude 2.2.

June 4: 08:34:31.9*. Epicenter 19°26.8′ north, 155°16.8′ west, 4 km northeast of Uwekahuna seismometer at a depth of 45 km. Felt Island-wide. Magnitude 4.0.

June 4: 13:22:30.0*. Epicenter 19°19.2′ north, 155°05.2′ west, 12 km east-southeast of Makaopuhi seismometer at a depth of 8 km. Felt at Hilo. Magnitude 3.8.

June 8: 12:00:50.5*. Epicenter 19°37.8′ north, 155°25.1′ west, 15 km north-northwest of Mauna Loa seismometer at a depth of 8 km. Felt Island-wide. Magnitude 4.1.

June 17: 14:13:31.3*. Epicenter 19°28.0′ north, 155°50.6′ west, 10 km southeast of Kealakekua at a depth of 3 km. Felt at Kona. Magnitude 3.0.

June 22: 17:30:32.8*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala. Magnitude 2.9.

July 1: 10:43:09.5*. Epicenter 19°18.8′ north, 155°06.9′ west, 10 km southeast of Makaopuhi seismometer at a depth of 5 km. Felt in Hilo, Volcano, and Puna regions. Magnitude 4.5.

July 15: 18:48:03.0*. Epicenter 19°19.0′ north, 155°07.2′ west, 9 km southeast of Makaopuhi seismometer at a depth of 10 km. Felt at Volcano. Magnitude 3.2.

July 17: 13:10:56.4*. Epicenter 19°53.5′ north, 155°59.2′ west, 43 km north-northwest of Kealakekua at a depth of 13 km. Felt Island-wide. Magnitude 4.5.

July 18: 14:31:10.1*. Epicenter 19°50.8′ north, 155°34.2′ west, 24 km south-southeast of Kamuela at a depth of 13 km. Felt at Waikii. Magnitude 2.9.

July 27: 07:04:22.0*. Epicenter 19°40.2′ north, 155°41.8′ west, 31 km northeast of Kealakekua at a depth of 3 km. Felt at Kealakekua. Magnitude 2.7.

July 28: 18:05:50.2*. Epicenter 19°25.5′ north, 155°15.6′ west, 3 km east of Uwekahuna seismometer at a depth of 25 km. Felt at Volcano. Magnitude 3.5.

August 3: 10:36:08.7*. Epicenter 19°11.9′ north, 155°33.5′ west, 15 km north-northeast of Naalehu at a depth of 8 km. Felt at Pahala, Naalehu, and Kealakekua. Magnitude 3.5.

August 3: 15:39:28.4*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Volcano. Magnitude 2.4.

August 7: 10:56:24.0*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala. Magnitude 2.5.

August 11: 15:09:20.5*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Pahala. Magnitude 2.2.

August 11: 15:14:05.9*. Epicenter 19°21.4′ north, 155°18.7′ west, 6 km west-southwest of Ahua seismometer at a depth of 30 km. Felt at Pahala. Magnitude 2.5.

August 13: 06:27:38.9*. Epicenter 19°30.1′ north, 155°16.2′ west, 8 km north-northeast of Uwekahuna seismometer at a depth of 30 km. Felt Island-wide. Magnitude 4.5.

August 14: 10:51:08.5*. Epicenter 19°23.2′ north, 155°29.1′ west, 12 km west-northwest of Desert seismometer at a depth of 8 km. Felt at Pahala. Magnitude 2.8.

August 16: 15:58:34.1*. Epicenter 19°22.8′

north, 155°30.7′ west, 14 km north-northwest of Desert seismometer at a depth of 5 km. Felt at Volcano. Magnitude 2.9.

August 26: 08:30:45.5*. Epicenter 20°14′ north, 156°09′ west, 33 km west-southwest of Upolu Point at a depth of 12 km. Felt at Hilo, Kamuela, Kealakekua, Honokaa, and Kohala. Magnitude 4.4.

August 27: 14:22:10.8*. Epicenter 19°26.5′ north, 154°52.8′ west, 9 km southeast of Pahoa at a depth of 5 km. Felt at Kapoho. Magnitude 2.8.

August 28: 21:10:16.5*. Epicenter 19°14.2′ north, 155°29.2′ west, 4 km north-northwest of Pahala at a depth of 8 km. Felt at Pahala. Magnitude 2.2.

August 30: 12:20:05.1*. Epicenter 19°25.8′ north, 154°59.0′ west, 8 km south-southwest of Pahoa at a depth of 8 km. Felt at Pahoa. Magnitude 2.8.

August 30: 12:22:55.2*. Epicenter 19°25.8′ north, 154°59.0′ west, 8 km south-southwest of Pahoa at a depth of 8 km. Felt at Pahoa. Magnitude 2.1.

August 31: 07:57:47.0*. Epicenter 19°27.1′ north, 154°56.1′ west, 5 km south-southeast of Pahoa at a depth of 5 km. Felt at Pahoa and Kapoho. Magnitude 3.2.

August 31: 13:25:27.5*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala. Magnitude 3.3.

August 31: 21:57:34.0*. Epicenter 20°01.6′ north, 155°32.1′ west, 18 km east of Kamuela at a depth of 8 km. Felt at Kamuela. Magnitude 2.6.

September 1: 06:39:13.5*. Epicenter 19°27.1′ north, 154°56.1′ west, 5 km south-southeast of Pahoa at a depth of 5 km. Felt at Pahoa, Volcano, and Kapoho. Magnitude 3.7.

September 2: 02:11:49.0*. Epicenter 19°27.1′ north, 154°56.1′ west, 5 km south-southeast of Pahoa at a depth of 5 km. Felt at Pahoa. Magnitude 2.0.

September 2: 04:03:20.0*. Epicenter 19°26.8′ north, 154°56.0′ west, 7 km south-southeast of Pahoa at a depth of 3 km. Felt at Pahoa. Magnitude 2.6.

September 3: 05:46:19.5*. Epicenter 19°28.2′ north, 154°54.8′ west, 5 km southeast of Pahoa at a depth of 5 km. Felt at Kapoho and Pahoa. Magnitude 2.7.

September 6: 08:33:17.7*. Epicenter 19°-27.0′ north, 154°52.9′ west, 9 km southeast of Pahoa at a depth of 3 km. Felt at Pahoa. Magnitude 2.4.

September 7: 06:10:39.9*. Epicenter 19°26.7′ north, 154°53.8′ west, 8 km southeast of Pahoa at a depth of 3 km. Felt at Pahoa. Magnitude 2.8.

September 7: 06:13:01.7*. Epicenter 19°26.7′ north, 154°53.8′ west, 8 km southeast of Pahoa at a depth of 3 km. Felt at Pahoa. Magnitude 3.0.

September 7: 19:42:27.6*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Volcano. Magnitude 2.7.

September 8: 08:26:40.4*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala. Magnitude 2.5.

September 8: 14:19:16.0*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala. Magnitude 2.2.

September 9: 22:17:31.8*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala. Magnitude 2.4.

September 10: 11:09:24.4*. Epicenter 19°-27.7′ north, 154°55.5′ west, 5 km south-southeast of Pahoa at a depth of 5 km. Felt at Pahoa. Magnitude 2.4.

September 12: 21:27:34.0*. Epicenter 19°-27.7′ north, 154°55.7′ west, 5 km south-southeast of Pahoa at a shallow depth. Felt at Kapoho. Magnitude 2.7.

September 14: 06:02:12.0*. Epicenter 19°-26.5′ north, 154°56.2′ west, 7 km south-southeast of Pahoa at a depth of 3 km. Felt at Volcano, Hilo, and Pahoa. Magnitude 3.8.

September 16: 06:04:41.8*. Epicenter 19°-20.1′ north, 155°04.8′ west, 13 km east-southeast of Makaopuhi seismometer at a depth of 8 km. Felt at Hilo, Pahoa, and Kalapana. Magnitude 3.3.

September 18: 00:25:29.1*. Epicenter 19°-18.9′ north, 155°06.9′ west, 9 km southeast of Makaopuhi seismometer at a depth of 5 km. Felt Island-wide. Magnitude 4.9.

September 18: 02:07:56.8*. Epicenter 19°-17.9′ north, 155°07.3′ west, 10 km southeast of Makaopuhi seismometer at a depth of 5 km. Felt at Hilo and Volcano. Magnitude 3.6.

September 18: 08:01:27.2*. Epicenter 19°18.2′ north, 155°07.5′ west, 3 km southeast of Makaopuhi seismometer at a depth of 3 km. Felt at Pahala, Volcano, and Pahoa. Magnitude 3.2.

September 22: 06:34:28.5*. Epicenter 19°55.9′ north, 155°34.5′ west, 15 km southeast of Kamuela at a depth of 13 km. Felt at Kamuela. Magnitude 2.7.

September 26: 00:36:27.5*. Epicenter 19°22.1′ north, 155°19.0′ west, 9 km northeast of Desert seismometer at a depth of 25 km. Felt at Volcano, Pahala, and Hilo. Magnitude 3.4.

October 1: 15:09:32.2*. Epicenter 19°12.1′

north, 155°35.0′ west, 15 km north of Naalehu at a depth of 8 km. Felt at Pahala and Naalehu. Magnitude 3.3.

October 11: 00:06:42.8*. Epicenter 18°47′ north, 156°37′ west, 83 km southwest of Milolii at a depth of 13 km. Felt on Hawaii, Maui, and possibly on Kauai. Magnitude 5.5.

October 12: 01:48:11.7*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Volcano. Magnitude 3.0.

October 14: 08:43:55.0.* Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Pahala, Puna, Volcano, and Hilo. Magnitude 3.4.

October 17: 16:20:17.2*. Epicenter 19°19.8′ north, 155°05.7′ west, 11 km east-southeast of Makaopuhi seismometer at a depth of 5 km. Felt at Volcano, Paauilo, and Hilo. Magnitude 3.7.

October 20: 11:38:22.3*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Volcano and Pahala. Magnitude 3.3.

October 23: 19:13:26.6*. Epicenter 19°01.1′ north, 155°24.8′ west, 20 km east-southeast of Naalehu at a depth of 30 km. Felt at Pahala and Naalehu. Magnitude 3.6.

October 27: 09:55:59.0*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Volcano. Magnitude 3.7.

November 4: 21:18:53.1*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala. Magnitude 3.2.

November 5: 06:16:47.5*. Epicenter 19°-25.1′ north, 155°01.1′ west, 11 km southwest of Pahoa at a depth of 5 km. Felt at Pahoa. Magnitude 2.6.

November 10: 23:25:28.7*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala and Volcano. Magnitude 3.4.

November 12: 03:00:32.7*. Epicenter 19°-23.5′ north, 154°56.4′ west, 12 km south of Pahoa at a depth of 8 km. Felt. Magnitude 3.1.

November 12: 22:08:10.7*. Epicenter 19°26.0 north, 154°54.6′ west, 8 km south-southeast of Pahoa at a depth of 3 km. Felt at Kapoho. Magnitude 2.5.

November 14: 15:53:18.5*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt. Magnitude 3.3.

November 24: 01:54:12.3*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Pahala. Magnitude 2.7.

November 24: 06:50:41.0*. Epicenter 19°27.6′ north, 155°56.7′ west, 9 km southeast of Kealakekua at a depth of 8 km. Felt at Kealakekua. Magnitude 3.2.

November 29: 16:42:39.3*. Epicenter 19°17.9′ north, 155°28.2′ west, 10 km west-southwest of Desert seismometer at a depth of 3 km. Felt at Pahala and Pahoa. Magnitude 2.0.

December 2: 22:28:40.0*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt on Hawaii, Maui, and Oahu. Magnitude 4.7.

December 2: 22:31:43.3*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Honolulu, Volcano, and Pahala. Magnitude 3.5.

December 3: 00:15:35.9*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt. Magnitude 2.8.

December 3: 07:56:00.5*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Volcano, Naalehu, and Hilo. Magnitude 4.0.

December 3: 12:17:04.0*. Epicenter 19°32.1′ north, 155°57.1′ west, 5 km west-northwest of Kealakekua at a depth of 3 km. Felt at Pahala. Magnitude 2.0.

December 10: 01:53:45.0*. Epicenter 19°18.5′ north, 155°12.2′ west, 7 km southwest of Makaopuhi seismometer at a depth of 10 km. Felt at Naalehu, Volcano, Puna, Hilo, Kona, and Laupahoehoe. Magnitude 5.0.

December 10: 05:52:04.6*. Epicenter 19°24.1′ north, 155°17.1′ west, at a depth of 30 km. Felt at Hilo, Volcano, Pahala, and Naalehu. Magnitude 3.2.

December 11: 20:07:18.0*. Epicenter 20°06.0′ north, 155°53.1′ west, 9 km northwest of Kawaihae at a depth of 10 km. Felt at Kamuela. Magnitude 3.4.

December 13: 19:30:19.7*. Epicenter 19°23.3′ north, 155°49.7′ west, 8 km east of Hookena at a depth of 3 km. Felt at Volcano and Kealakekua. Magnitude 3.8.

December 14: 04:37:27.9*. Epicenter 19°39.3′ north, 155°12.2′ west, 15 km west-southwest of Hilo at a depth of 10 km. Felt at Hilo, Volcano, and Pahala. Magnitude 3.4.

December 17: 11:47:46.9*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt at Pahala and Volcano. Magnitude 3.2.

December 24: 14:39:59.6*. Epicenter 19°24′ north, 155°25′ west, Kaoiki Fault system. Felt. Magnitude 3.2.

PANAMA CANAL ZONE
(75TH MERIDIAN TIME)

February 12: 16:38:35*. Intensity I at Balboa Heights.

February 21: 13:31:25*. Intensity I at Balboa Heights.

March 10: 18:44:11*. Intensity II at Balboa Heights.

May 26: 06:52:27.9*. Epicenter 8.4° north, 77.0° west, Panama, depth about 26 km, W. Intensity I at Balboa Heights. Magnitude 5.1.

July 29: 11:36:17*. Epicenter 7.3° north, 77.3° west, Panama-Colombia border region, depth about 33 km, W. Intensity I at Balboa Heights. Magnitude 4.

July 30: 00:16:03.3*. Epicenter 11.1° north, 86.2° west, near west coast of Costa Rica, depth about 42 km, W. Felt at Balboa Heights. Magnitude 5¾–6 (Pal).

PUERTO RICO
(60TH MERIDIAN TIME)

July 14: 05:55:24.4*. Epicenter 19.0° north, 66.5° west, Puerto Rico, depth about 46 km, W. Felt slightly on Puerto Rico. Magnitude 4¼–4½ (Pal).

December 22: 04:01:12.6*. Epicenter 18.4° north, 68.8° west, Mona Passage, depth about 115 km, W. Felt widely on Puerto Rico. Magnitude 6, P.

MISCELLANEOUS ACTIVITIES

GEODETIC WORK OF SEISMOLOGICAL INTEREST

In 1964, the Coast and Geodetic Survey and the California Department of Water Resources initiated a cooperative program for the study of horizontal crustal movement along the route of the proposed California aqueduct. Seventeen Hollister-type nets were established at locations where the route crosses, or closely parallels, components of the San Andreas Fault system. Twelve of the sites are located along the main aqueduct from San Bernardino to Wheeler Ridge, three are on the west branch to Castaic Reservoir, and the remaining two are on the coastal aqueduct in the vicinity of Santa Margarita and Cholame. Repeat surveys of each site will be made at intervals of approximately one year.

Three small nets were also established in the vicinity of Camp Parks near Pleasanton, Calif. for the Lawrence Radiation Laboratory. It is planned to resurvey these nets in 1965.

Crustal movement studies in the vicinity of Salt Lake City are being conducted by the Department of Civil Engineering, University of Utah, and by the Coast and Geodetic Survey. A traverse network of nine stations, spaced about 450 meters apart in the form of a square, was observed in 1963 and resurveyed in 1964. All distances in the figure were measured with a Model 4D Geodimeter. The adjusted results of the two surveys did not disclose any significant crustal movement. The Wasatch Fault crosses the area between stations in this net.

Following the Prince William Sound, Alaska earthquake in March, an extensive resurvey program was undertaken in south-central Alaska. The arcs of triangulation from Anchorage to Glennallen, Anchorage to Whittier, Turnagain Arm to Seward, Unakwik Inlet, and Valdez to Thompson Pass were reobserved. Also, two quadrilaterals spanning Montague Strait and connecting Montague and Latouche Islands were reobserved. Relative horizontal movements determined from preliminary results of the 1964 surveys are as follows:

Anchorage to Glennallen.—This arc spans Knik Arm from Anchorage to Palmer and continues northeasterly along the Matanuska River and Glenn Highway to Glennallen. In the vicinity of Anchorage, relative movement between points on opposite sides of Knik Arm was 7 to 9 feet. The relative movement was on the order of 4 feet in the vicinity of Palmer, and decreased to about 2 feet along the arc from Palmer to Glennallen. Along the arc from Anchorage to Palmer to Glennallen, distances between points on opposite sides of the arc were increased.

Turnagain Arm to Seward.—Beginning at Turnagain Arm, this arc extends to the south straddling Six Mile Creek to Kenai Lake, then Canyon Creek to Seward. Observed angles between points on each side of the arc were in fair agreement with the 1942 observations. East-west lines along the net increased in azimuth by about 30 seconds of arc. This angular change is equivalent to a relative displacement of about 5 feet between points on opposite sides of the scheme. These changes indicate the land mass on the west side of the valley moved north with respect to the east side, or the east side moved south relative to the west side.

Montague and Latouche Islands.—Reobservations over two quadrilaterals

spanning Montague Strait showed irregular changes when compared with the previous surveys of 1933. Three distances across the Strait were measured with a tellurometer and these measurements were 15 to 20 feet shorter than lengths determined in the original survey.

All of the values stated herein are based on preliminary studies. Additional triangulation is planned in 1965 from Thompson Pass to Glennallen and from Valdez across Prince William Sound to Whittier. Free adjustments will then be made of the old and new surveys and the resulting positions of common stations compared. It is hoped that this treatment of the data will enable us to draw more definite conclusions on the direction and magnitude of crustal movements caused by the earthquake.

For future studies of crustal movement, a network consisting of 30 stations with lines ranging in length from 1 to 5 miles was established in the vicinity of Anchorage this year. Thirty-five lines in the net were measured with a Model 4D Geodimeter. Present plans are to reobserve the network at intervals of approximately 1 year.

This year, 1,590 miles of first-order leveling and 90 miles of second-order leveling were carried out in California, mainly for the purpose of updating the leveling and investigating settlement caused by the withdrawal of underground water. Although most of this leveling may be of some interest to seismologists, the following will be of particular interest:

1. Vicinity of Camp Parks, Calif.
2. Releveling: Taft Thrust Fault, Calif.
3. California Earth Movement Surveys.
4. Releveling: Los Angeles, via Beverly Hills, to Baldwin Hills.
5. Releveling: Along three "earthquake cross-lines" which are lines of leveling, with closely spaced bench marks, crossing fault lines.

After the Alaskan earthquake on March 27, the leveling lines from Seward through Matanuska and Glennallen to Valdez with spur to Chitina, and from Glennallen to 15 miles southeast of Fairbanks were releveled. Additional new leveling on the Kenai Peninsula was done to make connections to tidal stations. In all, first-order leveling over 1,030 miles was done in the State, primarily to investigate earth movement caused by seismic action.

TIDAL DISTURBANCES OF SEISMIC ORIGIN

Two tsunamis were reported in the Pacific during 1964. The Prince William Sound earthquake of March 27 (61.0° north, 147.8° west) generated a tsunami which was recorded all over the Pacific and was of record size along much of the coast of North America. Waves generated in various arms and inlets in the epicentral area by subaqueous slides and slumps were highly destructive locally. The following is a list of casualties and dollar damage in Alaska, California, Canada, Hawaii, and Oregon due to this tsunami:

Location	*Fatalities*	*Damage*
Alaska:		
Cape St. Elias	1	$ .....
Chenega	23	100,000
Cordova	..	1,775,000[1]
Kaguyak	3	50,000
Kalsin Bay	6	.....
Kodiak	8	31,279,000[2]
Kodiak Naval Station	..	10,300,000[2]
Old Harbor	1	150,000
Ouzinkie	..	500,000[3]
Port Ashton	1	.....
Port Nellie Juan	3	.....
Port Nowell	1	.....
Seldovia	..	500,000[1]
Seward	12	14,614,000[1]
Spruce Cape	3	.....
Valdez	31	15,000,000[2]
Whitshed	1	.....
Whittier	13	10,000,000[2]
California:		
Crescent City	11	7,414,000[5]
Long Beach Harbor	..	100,000[5]
Los Angeles	..	175,000–275,000[5]
Marin County	..	1,000,000[5]
Noya Harbor	..	250,000–1,000,000[5]
Canada:		
Alberni-Port Alberni	..	10,000,000[7]
Hot Springs Cove	..	100,000
Zeballos	..	150,000
Hawaii:		
Hilo	..	15,000[6]
Maui	..	52,590[6]
Oregon:		
Cannon Beach	..	230,000[4]
Florence	..	50,000[4]
Newport	4	.....
Seaside	..	276,000[4]
Waldport-Alsea	..	160,000[4]

[1] *Anchorage Daily News*, April 18, 1964.

[2] Tudor, W. J., *Tsunami Damage at Kodiak, Alaska and Crescent City, Calif. from Alaskan Earthquake of 27 March 1964*, U.S. Naval Engineering Laboratory, Port Hueneme, Calif., Technical Note N–622, 133 pp., 1964.

[3] *Daily Alaska Empire*, March 31, 1964.

[4] Sandstrom, R. W., Letter from Director, Oregon State Civil Defense Agency, 1964.

[5] California Disaster Office, 1964.

[6] Stevenson, R. L., Letter from Director, Hawaii Civil Defense Agency, 1964.

[7] Civil Defense estimated damages of $5 million, excluding damage to heavy industry and private automobiles.

Numerous reports were received from various States, not directly affected by the tsunami, concerning seiches in rivers, harbors, channels, lakes, and swimming pools. These reports are summarized in the following paragraphs.

ARKANSAS:

Bonanza (Stone County Republican, Missouri, 4–2–64).—The Weather Bureau reported that at Bonanza, water level rose 3 feet after the earthquake.

DELAWARE:

Seaford.—Weather Bureau. Man reported water in his indoor swimming pool, and others in the neighborhood, oscillated in a north-south direction with a period of about 2 seconds. The water in the center of the pool rose and fell about 1½ inches above and below the normal level.

KENTUCKY: *(Louisville Courier-Journal, 3–31–64).* Seiches were observed on Harrington Lake and Lake Cumberland.

LOUISIANA:

Southern Louisiana area (Baton Rouge Advocate, 3–28–64).—A wide area of southern Louisiana reported shocks and minor tidal waves or water disturbances. Nervous residents of Baton Rouge, Geismar, along Bayou Lafourche, the Amite River, and Pontchartrain telephoned police, weather bureaus, and newspaper offices after witnessing strange water actions between 10:00 and 11:00 p.m., CST.

At Baton Rouge, water sloshed more than 6 inches over a 50-foot-long pool; at the Capitol House, in the center of town, the swimming pool on the 4th floor was reported "boiling." Near Baton Rouge, a man reported he was looking down at the placid Amite River when "all of a sudden, water came in waves 4 feet high." Further down the Amite, a man at Denham Springs observed the waves tear apart boathouses and ramps at a fishing camp. People standing on a fishing wharf where the water was 4 to 5 feet deep reported that "they looked down and suddenly there was no water—they were looking at the riverbed. Then the water came rushing back in. I saw that wave tear up a wharf . . . it broke an 8-inch piling." At Riverview Park, off the Hoo-Shoo-Too Road, the Amite River was suddenly disturbed by 4-foot-high waves which lasted about 20 minutes. Man reported a floating boatstore on the Mississippi River moved down the river about 10 feet and about 5 feet toward midstream. Boats bounced at moorings on Lake Pontchartrain. Police at Opelousas reported Bayou Cortableau rose some 4 feet between 10:00 and 11:00 p.m. The bayou churned with tremendous waves. A watchman at the New Orleans Industrial Canal reported water suddenly rose 6 feet above normal. "It was one of the wildest scenes I've seen in a long time. The water was rolling; barges began to move in and out and the lines began to turn and break." An 83-foot Coast Guard vessel was torn loose from its mooring.

Opelousas area (Opelousas Daily World, 3–29–64).—A series of large waves swept Bayou Cortableau, the Atchafalaya River and smaller streams—even ponds—some time after 10:00 p.m., various residents of the Opelousas area reported. Witnesses said the waves in the Bayou Cortableau were "like a great big boat went by." In Darbonne Bay, waves ranged up to 4 feet high. One Lawtell area farmer reported water from his two stock ponds spilled out over nearby fields. At a fishing camp on Darbonne Bay, just inside the West Atchafalaya spillway, boats knocked together and floated away; chain was broken on large raft by the first wave which was about 4 feet high; ropes on four or five other boats broke. "The waves washed all kinds of debris up on the bank, and we saw logs, shaken up from the bottom of the water, floating away. The disturbance lasted for about 45 minutes."

Plaquemine area (Greater Plaquemine Post, 4–2–64).—There were major disturbances in the water of Bayou Plaquemine, Bayou Grosse Tete and Grand River, similar to those reported in the Amite and Comite Rivers. No major damage was reported, but boatowners found their crafts overturned, moved downstream, resting upon land, or broken away from their moorings. Several boat sheds were damaged. At Plaquemine, it was reported a 20-ton boat broke loose and was washed up on land. The impact of water broke a ⅜-inch galvanized cable. A cottonwood water-soaked log, 7 feet in diameter and 125 feet long, to which the boat was moored, was moved downstream about 120 feet.

(Plaquemine Iberville South, 4–2–64): At Lake Long (back of Bayou Goula), waves 3 feet high splashed against a wharf. Bateau bounced wildly up and down for 10 minutes; nearby houseboat bounced up and down.

St. Francisville (St. Francisville Democrat, 4–2–64).—The only effect noted in the area was on the Mississippi River where a rapid rise on the west bank of between 2 to 3 feet was observed by ferry personnel.

Thibodaux Lafourche Parish (Thibodaux

Lafourche Parish Press, 3–31–64).—The destructive force of the earthquake was apparently felt only in the sea level area of the parish and only in a limited area from upper Golden Meadow to the vicinity of the Falgout Funeral Home at Galliano. It was reported water rose out of the bayou in different areas. It was not a solid wave from Golden Meadow to Galliano. Water remained perfectly calm for stretches of a half mile to a mile and then areas of a quarter mile were found where water had broken over the bayou banks. Minor damage was reported to the Alidor Terrebonne net shop in Golden Meadow, and three small skiffs, oil drums, and much debris were thrown up on the highway. A small barge was sunk in the bayou and a fishing boat broke loose from its mooring lines and damaged pilings at Golden Meadow.

MISSISSIPPI: *(Vicksburg Evening Post, 3–29–64).* In the Yazoo Canal, mooring lines were pulled from the showboat SPRAGUE and the wave motion caused the vessel to bob up and down and move sideways. The steel walkway was bent at a 30° angle.

MISSOURI: *(Stone County Republic, 4–2–64).* A man fishing at Table Rock late Friday night reported he had shoved his boat part way into the bank at Flat Creek and the James River off Cape Fair when the water began rolling and pulled his boat back into the lake. He said there was a whirling current where there should not have been any, and there was physical evidence all up and down the lake that the water had risen and then receded.

SOUTH CAROLINA:

Charleston.—Charles F. Mercer, Columbia Seismograph Station. A man in Charleston reported he noticed a curious "jump" in the water of his swimming pool at 22:45 EST.

Lake Murray (central South Carolina).—Charles F. Mercer. At Snelgrove's Landing, a man reported he noticed a synchronous rise and fall of the lake level at about 22:45. There were no boats on the lake, and no wind, but the lake rose and fell with an amplitude of 2 inches every 30 seconds on full cycle for some time.

TEXAS: (*The Houston Post, 3–29–64*). The strongest effects of the wave were felt in the Beaumont and Port Arthur areas where waters of the Sabine-Neches Ship Channel were churned violently. The Sabine Pass Coast Guard reported the tidal wave came through the pass and pushed the tide 3 feet higher than normal at 10:00 p.m., CST. Fishing boats and other small craft were torn from their moorings from Beaumont to Port Arthur, a Coast Guard spokesman reported, and the marine dock at the foot of Cypress Street in Beaumont was damaged to the extent of several thousands of dollars. Mooring lines on two of the Coast Guard's 40-foot launches, tied up at Sabine Pass, were broken. As the wave ranged down the Texas coast, with diminishing effects, little damage was reported until it reached the Matagorda Peninsula area. The wave reached Freeport about midnight, sending tides about a foot higher, but causing no damage. Shortly before 1:00 a.m., Saturday, the tide surged up the Colorado River at Matagorda, causing a rapid rise and fall of the water level and thousands of dollars damage to boats and piers. Owner of a fishing camp on the Colorado River between Matagorda and the Gulf reported an estimated several thousand dollars in damage to piers and boats along a 4¼-mile area. Several boats moored along the river were sunk and several unmanned boats were observed drifting downstream toward the Gulf. The wave reached the Corpus Christi area at 1:20 a.m., Saturday, with little noticeable effects, pushing the tide only about a foot higher than normal. The Tropicana Swimming Club reported a 2-foot wave splashed over the edge of the pool, causing the loss of 25,000 gallons of water.

(The Houston Chronicle, 3–29–64): Three vessels broke loose from their moorings in the Houston Ship Channel, four boats sank in the Colorado River, and two Coast Guard motor launches slipped their lines and were pushed around a bit. Damage was negligible except along the Colorado. Water at the Anchor Bait Camp on the Colorado rose about 4½ feet, then "went up and down like a yoyo." The owner of the camp said he checked along 5 miles of the river and reported three sport boats and one shrimp boat were sunk. At least $5,000 in damage to private docks and piers was reported; damage to boats was about $2,000. Further down the river, a swishing and sucking sound of the water was heard and a woman reported she saw 25 feet of river bottom as the water "got real high in the middle." Fish jumped out of the water. A 4-foot rise in water was reported at the Intracoastal Canal drawbridge, but no damage occurred. In the Ship Channel, two freighters and the Port of Houston inspection boat broke their moorings. A 3-foot wave rolled from the Sabine area up the Neches and Sabine Rivers toward Beaumont and Orange. At Beaumont, two old boats were splintered; three steel barges broke loose from their moorings,

but damage at Beaumont was slight. The Coast Guard at Galveston reported the wave caused 1½-foot tides. A 22-foot skiff and a 16-foot skiff broke loose from their moorings and sank off Bolivar Peninsula. At Caddo Lake (18 miles northwest of Marshall, in eastern Texas), the owner of a lake house on Big Cypress Bayou, which runs into Caddo Lake from the west, reported the bayou rose 2 feet and then fell more than 2 feet, with logs and trash boiling up from the bottom of the bayou.

WASHINGTON:

Seattle.—Reported by Seattle Regional Office, USC&GS: Water disturbance in Lake Union snapped a mooring line on the LESTER JONES and caused minor damage to the gangway on the PATTON. After replacing the line, the security watch on the LESTER JONES logged the event as occurring at 7:41 p.m., PST. The marigram at the Seattle tide station showed fluctuations beginning about 6 hours after the major shock. These increased to an amplitude of about 1.5 feet about 2 hours later, then diminished for 3 hours until a smooth curve was restored.

(Seattle Times, 3–28–64): Chandeliers swung and startled people in church at 32d Avenue NE and NE 62d Street. There were several reports from Northgate that fixtures swung. Motion was reported as barely perceptible at the Space Needle Restaurant. The manager compared the sway to that from a very strong wind. He said he was in the center of the restaurant and noticed it, but that patrons on the turntable did not notice it at all. Houseboat dwellers were "jolted" three times, beginning about 7:45 p.m., as the waters of Lake Union "seemed to move with the surface remaining calm." Houseboats broke loose from their moorings and water supply pipes were broken. It was reported the most severe action on the houseboats was to those moored closest to shore. One man reported: "My houseboat is out near the end of our pier at 2035 Fairview Avenue E. We did not get much motion, but one of the much larger houseboats right next to the shore broke loose and banged against a wall." A neighbor said the whole pier moved in the first tremor which rose from the lake bottom. The second and third tremors, each milder than the preceding tremor, left the lake calm but moved the houseboats. Five houseboats at the 2331-2339 Fairview Avenue E. moorage snapped their moorings and water supply lines.

The most severe damage was across Lake Union at the Four Winds Restaurant, a former ferry boat, moored at 900 Westlake Avenue N. About 55 patrons were evacuated when the north mooring line pulled a pile from the lake bottom. "We had a steel cable spring line which held when we started to swing away." Some dishes were broken when they slid to the floor. Whole back of wall torn off. The boat rocked for about 10 minutes. Nearby, at Kim's Restaurant, the manager said the restaurant rocked, but there was no damage. "It felt like logs were hitting against the pilings." At the Aqua Barn, the place rocked enough to let dancers know something was happening. At the Puget Sound Marina, several logs were torn loose from their moorings but no damage was reported to the boats. Harbor police reported that several large boats strained at their moorings in the Lake Washington Ship Canal, but no damage was reported. At Ray's Boathouse, on Shilshoe Bay, no effects of the tremor were felt.

Tacoma (Washington, D. C. Star, 3–29–64).—At Point Defiance Park Zoo, the birds and animals created a deafening din. "I was on our porch overlooking the zoo around 7:30 p.m. when suddenly there was a tremendous uproar in the zoo. First it was the ducks and geese, then the lions, coyotes, and all the rest joined in."

Numerous articles have been published on this earthquake and tsunami. *"The Tsunami of March 28, 1964 as Recorded at Tide Stations"* by M. G. Spaeth and S. C. Berkman, U.S. Coast and Geodetic Survey, is a preliminary report presenting data gathered from various tide records and a brief summary of the functioning of the Seismic Sea Wave Warning System during the event. A more complete report is in preparation.

Some of the maximum wave heights observed during this tsunami are: 35 feet at the Naval Station, Kodiak Island; 30 feet at Seward; 14.3 feet at Valdez; about 104 feet in the Whittier area; and 20.7 feet at Crescent City, Calif. Representative wave heights elsewhere are as follows:

Sitka, Alaska	14.3	feet
Tofino, B.C., Canada	8.1	feet
Neah Bay, Washington	4.7	feet

San Francisco, California	7.4	feet
San Diego, California	3.7	feet
Ensenada, Mexico	7.8+	feet
La Punta, Peru	6.4	feet
Valparaiso, Chile	6.2	feet
Hilo, Hawaii	12.5+	feet
Johnston Island	1.0	feet
Pago Pago, American Samoa	1.3	feet
Ft. Denison, Australia	1.0	feet
Aburatsu, Japan	2.4	feet
Hanasaki, Japan	2.2	feet

The Niigata earthquake of June 16 (38.3° N., 139.1° E.) caused a tsunami with an amplitude of 11.5–12.8 feet along the coasts of the northern part of Niigata Prefecture near the epicenter. This tsunami was confined to the Sea of Japan.

FLUCTUATIONS IN WELL WATER LEVELS

INTRODUCTION

The following data are tabulated for the purpose of associating fluctuations in well water levels with earthquakes. Tables 1 and 2 were compiled by George A. LaRocque, Jr. 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 1963.

WELL DESCRIPTIONS

ALASKA

Well No. Anc 50, artesian, Airport Way, Anchorage, SE¼SW¼ Sec. 9, T. 13 N., R. 3 W. Owner, City of Anchorage. Depth, 370 feet; diameter, 8 inches; depth of casing, 363 feet; finish, perforated. Aquifer, sand and gravel; Pleistocene.

Well No. 111A, artesian, Airport Heights Road, Anchorage, NE½SW½ Sec. 16, T. 13 N., R. 3 W. Owner, City of Anchorage. Depth, 470 feet; diameter, 8 inches; depth of casing, 274 feet; finish, perforated. Aquifer, sand and gravel; Pleistocene.

Well No. Anc 64, artesian, Elmendorf Air Force Base, SE NW Sec. 11, T. 13 N., R. 3 W. Owner, U.S. Geological Survey. Depth, 617 feet; diameter, 8 inches; cased to 140 feet and filled with silt to 142 feet. Aquifer, sand and gravel; Pleistocene.

Well No. Anc 114A, artesian, Third and Concrete Avenue, Anchorage, SW NE Sec. 17, T. 13 N., R. 3 W. Owner, City of Anchorage. Depth, 210 feet; diameter, 8 inches. Aquifer, sand and gravel; Pleistocene.

CALIFORNIA

Well No. 7/35–22N2, confined, Santa Ynez River Valley, 6 miles west of Lompoc, 34°40′12″ N., 120°33′35″ W. Owner, U.S. Navy. Depth, 194 feet; diameter, 8 inches; depth of casing, 194 feet; finish, natural gravel pack. Aquifer, sandy gravel; alluvium; Recent.

Well No. 7/35–33R1, confined, Lompoc Canyon, 6 miles west of Lompoc, 34°38′47″ N., 120°23′54″ W. Owner, U.S. Navy. Depth, 420 feet; diameter, 8 inches; depth of casing, 420 feet; finish, natural gravel pack. Aquifer, coarse gravel; Careaga sand; Pliocene.

Well No. 10/33–7R1, nonartesian to semiartesian, 2.75 miles east of Santa Maria, 34°57′10″ N., 129°23′10″ W. Owner, P. T. Bonnetti. Depth, 210 feet; diameter, 16 inches; depth of casing, 210 feet; finish, gravel pack (?). Aquifer, sand, gravelly sand, scattered clay layers; alluvium; Quaternary.

GEORGIA

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

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

IDAHO

Well No. 3N–29E–14adl, nonartesian, 43°35′ N., 113°00′ W. Owner, U. S. Geological Survey. Depth, 588 feet; diameter, 8 inches; finish, perforated open bottom. Aquifer, basalt.

Well No. 8S–24E–31dcl, nonartesian, 42°40′ N., 113°40′ W. Owner, U. S. Bureau of Reclamation. Depth, 194 feet; diameter, 8 inches to 85 feet, 6 inches to 188 feet; finish, perforated 158 feet to 188 feet, open bottom. Aquifer, basalt.

Well No. 5N–32E–36ad1, nonartesian, 43°43′ N., 112°38′ W., SE¼NE¼ Sec. 36, T. 5 N., R. 32 E. Owner, U.S. Geological Survey. Depth, 405 feet; diameter, 6¼ to 5 inches; finish, 40 feet perforated casing; open bottom. Aquifer, basalt.

Well No. 7S–25E–19ab1, nonartesian, Minidoka County, 42°48′ N., 113°40′ W., NE¼ NW¼ Sec. 19, T. 7 S., R. 25 E. Owner, U. S. Bureau of Reclamation. Depth, 284 feet; diameter, 5 inches; finish, unknown. Aquifer, basalt.

Well No. 1S–19E–3cc2, artesian, Blaine County, near Gannett, 43°19′ N., 114°11′ W. Owner, U. S. Bureau of Reclamation. Depth, 51 feet; diameter, 6 inches; finish, perforated casing. Aquifer, Quaternary sand and gravel.

Well No. 7N–31E–34bd1, nonartesian, Butte County, near Howe, 43°55′ N., 112°43′ W. Owner, U. S. Geological Survey. Depth, 320 feet; diameter, 6¼ inches; finish, perforated casing from 285 feet. Aquifer, Snake River basalt.

Well No. 8S–14E–16bc1, nonartesian, Gooding County, 42°44′ N., 120°50′ W. Owner, Sand Springs Ranch. Depth, 53 feet; diameter, 5 inches; depth of casing, 49.7 feet; finish, open end aluminum. Aquifer, Snake River basalt; Quaternary.

Well No. 4N–45E–13ad1, nonartesian, Teton County, about 3.5 miles SE. of Driggs, 43°41′ N., 111°5′ W. Owner, U.S. Bureau of Reclamation. Depth, 304 feet; diameter, 16 inches; depth of casing, 301 feet; finish, open end. Aquifer, sand and gravel; Quaternary alluvium.

Well No. 5S–17E–26ac1, nonartesian, Lincoln County, about 2 miles N. of Shoshone, 42°58′ N., 114°24′ W. Owner, U. S. Bureau of Reclamation. Depth, 255 feet; diameter, 16 inches; depth of casing, 202 feet; finish, open hole. Aquifer, Snake River basalt; Quaternary.

Well No. 5S–33E–35cc1, nonartesian, Power County, about 6 miles NW. of Pocatello, 42°57′ N., 112°34′ W. Owner, U. S. Geological Survey. Depth, 60 feet; diameter, 6 inches; depth of casing, 60 feet; finish, open end. Aquifer, gravel and sand; Quaternary.

Well No. 7N–34E–4cd1, nonartesian, Jefferson County, 3 miles east and 1 mile north of Monteview, 43°51′ N., 112°28′ W. Owner, U. S. Government. Depth, 57.3 feet; diameter, 6 inches; depth of casing, unknown; finish, open end. Aquifer, lava and cinders with interbedded sand, gravel, and clay; Snake River lava; Quaternary.

Well No. 8S–24E–20 db1, nonartesian, Minidoka County, 5.5 miles N. of Rupert, 42°43′ N., 113°40′ W. Owner, U. S. Bureau of Reclamation. Depth, 297 feet; diameter, 24 inches; depth of casing, 25 feet; finish, open hole. Aquifer, interbedded basalt flows; Snake River basalt; Pleistocene.

Well No. 13S–21E–18bb1, nonartesian, Cassia County, 3.75 miles north and 8.5 miles west of Oakley, Idaho, 42°18′ N., 114°3′ W. Owner, Grigg and Anderson. Depth, 850 feet; diameter, 22 inches; depth of casing, 0–20 feet; finish, open hole. Aquifer, Paleozoic limestone.

Well No. 8S–23E–2ba1, Minidoka County, NE¼NW¼ Sec. 2, T. 8 S., R. 23 E., 42°46′ N., 113°44′ W. Depth, 254 feet; depth of casing, 0–80 feet. Aquifer, Snake River group; basalt.

Well No. 2S–20E–1ac2, nonartesian, Blaine County, Sec. 1, T. 2 S., R. 20 E. Owner, R. N. Leazenby. Depth, 208.5 feet; diameter, 10 inches; cased to 207.8 feet. Aquifer, Snake River basalt; Quaternary.

Well No. 7N–38E–23db1, nonartesian, Madison County, 43°55′ N., 111°56′ W. Owner, U. S. Bureau of Reclamation. Depth, 236 feet; diameter, 16 inches; cased to 177 feet; finish, open hole. Aquifer, Snake River group; Quaternary.

INDIANA

Well No. Md8, artesian, Madison County, NW¼SE¼ Sec. 15, T. 21 N., R. 6 E. Owner, Die Casting Corporation, Elwood. Depth, 415 feet; diameter, 8 inches; depth of casing, unknown; finish, open hole. Aquifer, Silurian limestone.

Well No. Pu–6, artesian, Pulaski County, NE SW Sec. 4, T. 29 N., R. 4 W. Owner, Earl Overmeyer. Depth, 663 feet; diameter 8 inches; finish, open hole. Land surface datum is about 685 feet above msl. Aquifer, Niagaran limestone of Silurian age.

Well No. Ma32, artesian, Indianapolis, Marion County, NE SW Sec. 36, T. 17 N., R. 3 E. Owner, Indianapolis Water Company. Depth, 322 feet; diameter, 10 inches; cased to 60 feet; finish, open hole. Aquifer, Niagaran limestone of Silurian age.

NEVADA

Well No. S22/61–4bcc1, artesian, 36°3′48″ N., 115°10′20″ W. Owner, Fitzpatrick. State Engineer No. 41. Depth, 355 feet; diameter, 8 inches. Aquifer, Quaternary alluvium.

Well No. S21/54–10aac1, artesian, Clark County, 36°8′54″ N., 115°53′25″ W. Owner, Bowman, formerly H. D. Cornell. State Engineer No. 22. Depth, 800 feet; diameter, 14 inches; finish, cased to 472 feet, perforated 100 feet to 450 feet. Aquifer, Quarternary sand and gravel.

Well No. S19/60–9bcc1, artesian, Clark County, 36°18′53″ N., 115°16′43″ W. Owner, P. J. Goumond. State Engineer No. 427. Depth, 830 feet; diameter, 10 inches; finish, cased to 140 feet. Aquifer, Quaternary sand and gravel.

NEW JERSEY

Well No. 30.14.8.3.1, artesian, Gloucester County, 39°49′48″ N., 75°16′42″ W. Owner, Hercules Powder Co. Depth, about 100 feet; diameter, 6 inches; finish, unknown. Aquifer, Raritan formation of late Cretaceous age.

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

TABLE 1.—*Fluctuations in well water levels, January 1 through December 31, 1964*

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.

County	Well No.	Date 1964	Time at Recorder G.M.T.	Depth to Water before Disturbance	Water Level Fluctuations		Double Amplitude
					From Prequake Level		
					Upward	Downward	
			ALASKA				
				ft	*ft*	*ft*	*ft*
Anchorage	590	Feb. 1	02:00	2.18	0.002	0.002	0.004
Do	316b	Feb. 22	05:30	7.72	.008	.006	.014
Do	64	Mar. 28	03:36[1]	18.28	.....	+6.90	+6.90
Do	111A	do	03:36[2]	78.10	.....	.....	.....
Do	114A	do	03:36[3]	52.60	.13	1.36	1.49
Do	316b	do	03:36[4]	7.87	.517	.297	.814
Do	590	do	03:36[5]	5.016	.....	Below 23.15	18.14
Do	EAFB #1	do	03:36[6]	5.505	.....	.....	.....
Do	316b	do	16:00	7.713	.004	.003	.007
Do	do	do	24:00	7.728	.014	0	.014
Do	do	Mar. 29	02:00	7.719	0	.014	.014
Do	do	do	11:00	7.73	0	.006	.006
Do	590	do	14:00-16:00	23.03	.02	.01	.03
Do	316b	do	18:00	7.745	0	.004	.004
Do	590	Mar. 30	06:00	23.13	0	.02	.02
Do	51A	Apr. 2	11:30	5.35	.01	.01	.02
Do	64	Apr. 3	00:15	25.02	.03	.09	.12
Do	51A	do	02:15	5.26	.01	.01	.02
Do	do	do	02:45	5.26	.01	.01	.02
Do	do	do	04:15	5.26	.01	.01	.02
Do	590	do	22:00	22.25	.02	.28	.30
Do	51A	do	22:20	5.30	.14	.23	.37
Do	316b	do	22:20	7.865	.029	.035	.064
Do	51A	Apr. 4	04:45	5.26	.01	.02	.03
Do	do	do	07:00	5.26	.01	.03	.04
Do	do	do	10:30	5.29	.01	.01	.02
Do	do	do	17:50	5.34	.02	.01	.03
Do	do	Apr. 5	19:45	5.33	.04	.03	.07
Do	316b	do	22:00	7.87	.014	.017	.031
Do	do	Apr. 6	09:00	7.878	.015	.014	.029
Do	do	do	12:00	7.889	.019	.001	.02
Do	do	Apr. 7	10:00	7.91	.01	.01	.02
Do	do	Apr. 8	08:00	7.88	0	.013	.013
Do	590	do	18:00	19.54	0	.07	.07
Do	51A	do	19:30	5.18	.03	.04	.07
Do	316b	do	20:00	7.873	.003	.005	.008
Do	450	Apr. 9	19:00	261.50	.45	.05	.50
Do	590	do	22:00	19.27	.005	.02	.025
Do	316b	Apr. 10	22:00	7.763	.004	.005	.009
Do	do	Apr. 12	15:00	7.73	.005	.005	.01
Do	450	Apr. 15	09:30	261.02	.01	.17	.18
Do	51A	do	15:00	8.40	.03	.05	.08
Do	do	do	16:15	8.40	.01	.03	.04
Do	316b	do	16:15	7.38	.015	.014	.029
Do	do	do	17:45	7.377	.007	.008	.015
Do	450	do	19:00	261.12	.07	.20	.27
Do	51A	do	22:15	8.45	.01	.01	.02
Do	do	do	12:10	5.09	.06	.09	.15
Do	590	do	12:00	19.96	.02	.02	.04
Do	64	do	14:00	21.23	.005	.01	.015
Do	51A	do	16:05	5.10	.01	.01	.02
Do	do	do	16:30	5.10	.01	.01	.02
Do	do	do	18:20	5.10	.01	.01	.02
Do	590	do	19:00	19.86	.02	.02	.04

See footnotes at end of table.

TABLE 1.—*Fluctuations in well water levels, January 1 through December 31, 1964*—Continued

ALASKA—Continued

County	Well No.	Date 1964	Time at Recorder G.M.T.	Depth to Water before Disturbance	Water Level Fluctuations		
					From Prequake Level		Double Amplitude
					Upward	Downward	
				ft	*ft*	*ft*	*ft*
Anchorage	316b	Apr. 15	19:35	6.795	0.005	0.003	0.008
Do	do	do	20:30	6.805	.007	.001	.008
Do	51A	Apr. 21	04:15	5.12	.10	.07	.17
Do	316b	do	04:17	6.765	.027	.029	.056
Do	51A	Apr. 30	12:00	5.15	.01	.01	.02
Do	316b	do	12:00	6.927	.004	.005	.009
Do	590	May 1	02:00	14.42	.002	.02	.022
Do	51A	do	06:15	5.15	.03	.04	.07
Do	316b	do	08:03	6.904	.004	.006	.01
Do	450	May 3	17:00	260.50	.05	.10	.15
Do	do	May 8	12:00	260.05	.11	.03	.14
Do	316b	May 12	11:50	7.262	.002	.003	.005
Do	450	May 16	16:00	260.40	.08	.05	.13
Do	316b	May 18	23:45	7.375	.001	.005	.006
Do	do	May 19	00:45	7.38	.002	.004	.006
Do	51A	May 21	01:00	5.08	.02	.01	.03
Do	316b	do	06:05	7.415	.002	.001	.003
Do	do	do	13:35	7.418	.002	.002	.004
Do	450	May 28	17:00	260.30	.08	.05	.13
Do	51A	May 29	09:30	4.86	.02	.01	.03
Do	316b	do	09:45	7.195	.002	.003	.005
Do	do	June 5	10:15	7.015	.005	.003	.008
Do	450	June 19	02:00	257.20	.05	.05	.10
Do	51A	July 5	03:45	3.90	.01	.01	.02
Do	590	July 9	16:00	10.815	.005	.005	.01
Do	51A	July 11	21:00	3.76	.01	.02	.03
Do	do	July 17	19:00	3.93	.01	.03	.04
Do	590	July 23	14:00	11.28	.01	0	.01
Do	450	do	19:00	259.05	0	.13	.13
Do	51A	do	19:10	4.18	.02	.01	.03
Do	316B	July 27	23:21	7.32	0	.003	.003
Do	51A	July 28	19:00	4.305	.005	.015	.02
Do	FAR:D-2:1	Aug. 24	22:00	12.58	.18	.075	.255
Do	51A	Sept. 13	17:45	4.655	0	.005	.005
Do	316b	do	17:45	7.605	.001	.003	.004
Do	50	Sept. 16	01:30	64.45	.06	.08	.14
Do	51A	Sept. 28	18:30	4.75	.01	.08	.09
Do	do	Oct. 3	13:00	4.80	.02	.01	.03
Do	do	Oct. 10	19:00	4.73	.01	.03	.04
Do	316b	do	19:00	7.995	.005	.001	.006
Do	do	Oct. 12	22:00-24:00	7.79	.019	.007	.026
Do	do	Dec. 18	01:00	5.13	.01	.30	.31

[1]Recorder was shaken violently. Water dropped more than 12 feet so fast the lead counterweight was wedged tightly in the hole for it in the shelter-house floor.

[2]Observation well temporarily destroyed during quake. The casing was bent into flat S, approximately 8 to 10 feet from the surface. The top was at least 4 feet west from original vertical position.

[3]Quake was so strong the recorder pen was flipped off the chart. On a later aftershock on Sunday (29 Mar. local) the pen was jarred down onto the chart again.

[4]The recorder moved around several times on shelter-house floor. The pen mark indicates several passes on the same line, showing intense vertical movements.

[5]Well casing and recorder received violent shaking. Recorder stylus pen marks indicate at least 12 horizontal movements, in addition to 10 vertical marks for water subsidence. It is impossible to tell if these horizontal marks were made during the major quake or during the many aftershocks.

[6]Well was not being pumped. When the major quake struck, the water dropped and the recorder counterweight caught on something or was snapped off, so could not give accurate reading other than for time purposes, as the float was reacting and the counterweight end of cable was sufficient to show the change, but not accurately. The recorder charts indicate aftershocks on March 28 at 19 30 and 22:30, on March 29 at 02:45, 13:45, 17:00 and 17:30. These fluctuations were not measured due to improper counterweight action.

TABLE 1.—*Fluctuations in well water levels, January 1 through December 31, 1964*—Continued

County	Well No.	Date 1964	Time at Recorder G.M.T.	Depth to Water before Disturbance	Water Level Fluctuations		
					From Prequake Level		Double Amplitude
					Upward	Downward	
CALIFORNIA							
Santa Barbara.	7/35-28R1	Mar. 28...	03:00	60.328	0.017	0.018	0.035
Do.	7/35-33R1	.....do.....	03:00	112.157	.08	.068	.148
Do.	10/33-7R1	.....do.....	03:00	113.210	.06	.07	.13
Do.	7/35-22N2	.....do.....	05:00	7.240	.18	.31	.49
Do.	6/32-11G3	.....do.....	06:00	7.349	.002	.01	.012
Do.	.....do.....	May 27...	20:00	8.276	.014	.024	.038
GEORGIA							
Dawson.	12-3	Feb. 6...	13:00+	25.08	0.025	0.025	0.05
Thomas.	14E15	.....do.....	13:20	194.82?	.22	.08	.30
Mitchell.	10G313	.....do.....	13:30	52.64	.085	.085	.17
Dougherty.	USMC	.....do.....	13:45	34.90	.02	.04	.06
Do.	.....do.....	May 26...	10:45	25.74	.035	.035	.07
Mitchell.	10G313	.....do.....	12:15	36.40	.01	.01	.02
Thomas.	14E15	.....do.....	13:00	193.77	.02	.02	.04
Dawson.	12-3	.....do.....	13:00	24.8	.022	.022	.044
Do.	.....do.....	June 16...	05:00	25.73	.01	.01	.02
Mitchell.	10G313	.....do.....	05:20	38.90	.01	.01	.02
Dougherty.	USMC	.....do.....	05:30	28.40	.025	.025	.05
Thomas.	14E15	.....do.....	06:30	193.43	.03	.03	.06
Mitchell.	10G313	July 5...	19:00	41.07	.06	.06	.12
Thomas.	14E15	.....do.....	19:15	192.80	?	?	.06
Dougherty.	USMC	.....do.....	19:15	29.82	.022	.022	.044
Dawson.	12-3	.....do.....	19:45	26.39	?	?	.012
Mitchell.	10G313	July 6...	02:00	41.11	.08	.08	.16
Dougherty.	USMC	.....do.....	02:25	29.87	.035	.035	.07
Dawson.	12-3	.....do.....	02:45	26.53	?	?	.025
Thomas.	14E15	.....do.....	03:00	192.78	?	?	.09
Mitchell.	10G313	.....do.....	07:00	41.13	.06	.06	.12
Thomas.	14E15	.....do.....	07:22	192.98	?	?	.07
Dougherty.	USMC	.....do.....	07:30	29.87	.03	.03	.06
Dawson.	12-3	.....do.....	07:45	26.45	?	?	.03
Glynn.	J-35(34H91)	Aug. 25...	13:40	16.70	.1	0	.1
Do.	TW3(33H127)	.....do.....	13:40	7.4	.4	.2	.6
Do.	TW4(34H334)	.....do.....	13:45	5.0	0	.1	.1
Mitchell.	10G313	.....do.....	14:20	42.24	?	?	.05
Dougherty.	USMC	Oct. 6...	15:30?	31.72	.01	.01	.02
Dawson.	12-3	Nov. 17...	09:40	27.00	.0075	.0075	.015
IDAHO							
Bingham.	5S-31E-27ab1	Mar. 28...	01:00-03:00	24.70	0.04	0.05	0.09
Cassia.	13S-21E-18bb1	.....do.....	01:00-03:00	430.92	.66	.76	1.42
Lincoln.	5S-17E-26ac1	.....do.....	01:00-03:00	202.20	.44	.42	.86
Minidoka.	8S-23E-2ba1	.....do.....	01:00-03:00	208.65	.62	1.14	1.76
Do.	8S-25E-24bd1	.....do.....	01:00-03:00	145.13	.11	.09	.20
Power.	5S-33E-35cc1	.....do.....	01:00-03:00	25.29	.04	.....	.....
Twin Falls.	11S-19E-17aa1	.....do.....	01:00-03:00	321.92	.23	.28	.51
Do.	11S-20E-21dc1	.....do.....	01:00-03:00	69.85	.24	.32	.56
Jefferson.	7N-36E-22ab4	.....do.....	02:00-04:00	7.09	.33	.40	.73
Jerome.	7S-17E-6ac1	.....do.....	02:00-04:00	314.53	.02	.02	.04
Minidoka.	7S-25E-19ab1	.....do.....	02:00-04:00	244.38	.82	.96	1.78
Twin Falls.	11S-19E-17aa1	.....do.....	02:00-04:00	321.92	.02	.03	.05

TABLE 1.—*Fluctuations in well water levels, January 1 through December 31, 1964*—Continued

IDAHO—Continued

County	Well No.	Date 1964	Time at Recorder G.M.T.	Depth to Water before Disturbance	Water Level Fluctuations		
					From Prequake Level		Double Amplitude
					Upward	Downward	
				ft	*ft*	*ft*	*ft*
Blaine	1S-19E-3cc2	Mar. 28	03:00-05:00	17.97	.81	.75	1.56
Do	2S-20E-1ac2	do	03:00-05:00	151.24	.56	.47	1.03
Cassia	13S-21E-18bb1	do	03:00-05:00	430.92	.07	.05	.12
Minidoka	8S-24E-31dc1	do	03:00-05:00	153.53	.09	.16	.25
Power	7S-30E-28bb1	do	03:00-05:00	198.14	.04	.04	.08
Butte	7N-31E-34bd1	do	03:15	369.44	.04	.05	.09
Jefferson	5N-32E-36ad1	do	03:20	330.07	.71	.50	1.21
Latah	39N-5W-5c1 (University of Idaho #3)	do	03:30	255.11	2.61	2.39	+5.00
Butte	3N-29E-14ad1	do	03:30	459.02	2.27	1.71	3.98
Do	do	do	03:35	14.10	.29	.27	.56
Gooding	8S-14E-16bc1	do	03:45	39.55	.02	.02	.04
Latah	39N-5W-5c1	do	04:00	255.11	1.80	1.65	3.45
Do	do	do	04:15	255.11	.74	.66	1.40
Minidoka	8S-24E-20db1	do	04:20	154.10	.15	.15	.30
Latah	39N-5W-5c1	do	04:30	255.11	.51	.49	1.00
Do	do	do	04:45	255.11	.43	.38	.81
Do	do	do	05:00	255.11	.23	.17	.40
Cassia	13S-21E-18bb1	do	05:00-07:00	430.92	.08	.08	.16
Teton	4N-45E-13ad1	do	05:00	201.46	2.46	2.54	+5.00
Latah	39N-5W-5c1	do	05:15	255.11	.11	.11	.22
Teton	4N-45E-13ad1	do	05:30	201.46	.13	.18	.31
Do	do	do	06:00	201.47	.04	.06	.10
Latah	39N-5W-5c1	do	06:15	255.11	.24	.20	.44
Do	do	do	06:30	255.11	.27	.21	.48
Do	do	do	06:45	255.11	.19	.17	.36
Do	do	do	07:15	255.11	.06	.04	.10
Power	7S-30E-28bb1	do	09:00-11:00	198.86	.06	.06	.12
Latah	39N-5W-5c1	do	09:45	255.08	.02	.04	.06
Do	do	do	12:15	255.06	.05	.05	.10
Do	do	do	15:00	255.08	.02	.03	.05
Do	do	do	20:30	255.15	.07	.07	.14
Do	do	Mar. 29	17:00	255.12	.03	.02	.05
Do	do	Mar. 30	02:30	255.02	.04	.05	.09
Do	do	do	07:30	255.05	.02	.03	.05
Do	do	Mar. 31	09:00	254.83	.05	.08	.13
Twin Falls	11S-20E-21dc1	June 25	06:00-08:00	73.46	.03	.04	.07
Madison	7N-38E-23db1	July 5	14:00-16:00	40.94	.08	.09	.17
Minidoka	8S-23E-2ba1	do	21:00-23:00	212.55	.02	.02	.04
Madison	7N-38E-23db1	do	22:00-24:00	40.89	.35	.33	.68
Blaine	8S-26E-33bc1	do	23:00-01:00	108.56	.04	.05	.09
Jefferson	5N-32E-36ad1	do	23:00	331.43	.01	.02	.03
Minidoka	8S-23E-2ba1	July 6	02:00-04:00	212.59	.02	.01	.03
Jefferson	7N-36E-22ab4	do	02:00-04:00	6.67	.01	.01	.02
Madison	7N-38E-23db1	do	03:00-05:00[1]	40.88	.....	.....	+1.00
Jefferson	7N-34E-4cd1	do	03:15	30.61	.06	.03	.09
Blaine	8S-26E-33bc1	do	04:00-06:00	108.59	.03	.03	.06
Twin Falls	11S-19E-17aa1	do	06:00-08:00	319.94	.02	.01	.03
Jefferson	7N-34E-4cd1	do	08:30	30.66	.06	.03	.09
Jerome	8S-19E-5da1 do	July 15	07:30	272.50	.06	.07	.13
Madison	7N-38E-23db1	Oct. 6	14:00-16:00	39.48	.02	.03	.05
Do	do	Oct. 21	05:00-07:00	39.51	.06	.07	.13
Butte	6N-30E-30ab1	do	06:00-08:00	55.48	.02	.02	.04
Do	3N-29E-14ad1	do	08:00	459.17	.04	.03	.07
Jefferson	7N-34E-4cd1	do	08:30	20.53	.07	.06	.13
Teton	4N-45E-13ad1	do	11:30	186.22	.04	.05	.09
Madison	7N-38E-23db1	Oct. 22	23:00-01:00	39.56	.06	.05	.11

[1]More than 1.0 foot. Pen retraced mark on turning of drum; unable to determine highest or lowest point. One complete revolution is equal to 1.0 foot. F electric 30-day recorder, stage ratio 1:1.

TABLE 1.—*Fluctuations in well water levels, January 1 through December 31, 1964*—Continued

INDIANA

County	Well No.	Date 1964	Time at Recorder G.M.T.	Depth to Water before Disturbance	Water Level Fluctuations		
					From Prequake Level		Double Amplitude
					Upward	Downward	
				ft	*ft*	*ft*	*ft*
Marion	Ma-2	Feb. 6	13:15-14:30	10.808	0.076	0.092	0.168
Pulaski	Pu-6	do	13:45-14:50	16.525	.024	.036	.06
Marion	Ma-32	Mar. 15	23:00-23:10	9.503	.01	.01	.02
Madison	Md-8	Mar. 28	03:30-04:00	18.90	.27	.36	.63
Marshall	Ml-2	do	03:30-04:00	22.03	.29	.25	.54
Posey	Py-2	do	03:30-04:00	11.60	.04	.06	.10
Spencer	Sp-14	do	03:30-04:00	7.309	.014	.021	.035
Vanderburgh	Va-3	do	03:30-04:00	21.070	.035	.042	.077
Clinton	Ct-4	do	03:30-04:30	17.508	.028	.102	.13
Parke	Pa-3	do	03:30-04:30	48.57	.06	.02	.08
Jasper	Jp-4	do	03:30-04:40	4.53	.055	.219	.274
Marshall	Ml-4	do	03:30-04:40	46.24	.03	.03	.06
Allen	Al-5	do	03:30-05:00	23.71	.....	.....	>1.00
Porter	Pt-9	do	03:30-05:00	25.155	.....	.....	>1.00
Ripley	Ri-4	do	03:30-05:00	3.595	.033	.047	.08
Miami	Mi-2	do	0330:-05:30	44.28	1.78	1.38	3.16
Pulaski	Pu-6	do	03:30-06:30	15.93	.....	.....	>1.00
Starke	Sk-2	do	03:30-06:30	4.045	.218	.184	.402
Marion	Ma-32	do	03:40-07:40	9.915	.....	.....	>1.00
Tippecanoe	Tc-7	do	03:45-04:15	168.997	.168	.11	.278
Jefferson	Jf-4	do	04:00-04:15	25.71	.06	.08	.14
Marion	Ma-1	do	04:00-04:15	101.70	3.65	4.60	8.25
Allen	Al-4	do	04:00-04:50	30.53	.37	.34	.71
Benton	Be-2	do	04:00-05:00	12.67	.118	.07	.188
Newton	Ne-3	do	04:30-05:30	36.57	1.14	.8	1.94
Allen	Al-5	do	05:30-05:45	23.702	.002	.002	.004
Marion	Ma-32	do	20:15-20:45	19.072	.024	.02	.044
Pulaski	Pu-6	do	20:45-20:50	15.636	.011	.011	.022
Marion	Ma-32	Mar. 30	02:20-03:20	10.188	.16	.05	.21
Pulaski	Pu-6	do	02:30-03:30	15.072	.033	.017	.05
Marion	Ma-32	do	07:15-07:45	10.138	.021	.022	.043
Pulaski	Pu-6	do	07:40-07:50	14.986	.011	.011	.022
Marion	Ma-32	Apr. 3	22:30-22:45	9.895	.005	.012	.017
Do	do	Apr. 4	18:30-19:15	9.685	.032	.03	.062
Do	do	July 5	19:30-20:00	12.27	.04	.07	.11
Pulaski	Pu-6	do	19:30-20:00	10.895	.018	.017	.035
Do	do	July 6	02:30-02:45	10.947	.035	.035	.07
Marion	Ma-32	do	02:30-03:00	12.34	.09	.06	.15
Pulaski	Pu-6	do	07:00-08:00	10.937	.034	.034	.068
Marion	Ma-3	do	07:45-08:15	10.16	.09	.03	.12
Pulaski	Pu-6	Oct. 6	15:25-15:35	16.015	.005	.011	.016
Marion	Ma-32	Oct. 23	02:00-02:30	11.23	.01	.03	.04
Pulaski	Pu-6	do	02:10-02:20	16.599	.004	.013	.017

NEVADA

Clark	S21/54-28bd1	Jan. 20	18:00	22.78	0.02	0.03	0.05
Do	S19/60-9bcc1	Feb. 6	13:15	104.74	0	.04	.04
	S17/50-36dc1	do	13:45	0.52	.11	.09	.20
Do	S22/61-4bcc1	Mar. 28	02:30?	109.85	.18	.29	.47
Do	S21/54-10aac1	do	03:00±	71.69	.51	1.22	1.73
	S19/59-32aaa1	do	04:00±	27.11	.02	.01	.03
Do	S19/60-9bcc1	do	04:15	106.02	.....	.....	>1.00
Do	do	May 15	21:00	108.00	.02	0	.02
Do	do	June 16	04:00	109.77	.02	.01	.03
Do	S21/54-10aac1	July 5	18:00	73.97	.08	0	.08
Do	S19/60-9bcc1	do	19:15	110.66	.05	.04	.09
Do	do	July 6	02:30	111.44	.12	.12	.24
Do	do	do	07:45	111.43	.14	.14	.28
Do	do	Nov. 17	09:30	110.49	.05	.01	.06

TABLE 1.—*Fluctuations in well water levels, January 1 through December 31, 1964*—Continued

NEW JERSEY

County	Well No.	Date 1964	Time at Recorder G.M.T.	Depth to Water before Disturbance	Water Level Fluctuations		
					From Prequake Level		Double Amplitude
					Upward	Downward	
				ft	*ft*	*ft*	*ft*
Union	26.22.4.4.4	Feb. 5	12:00	+22.81			0.01
Camden	31.1.6.4.8	Feb. 6	13:30	—6.04	0.01	0.01	.02
Union	26.22.4.4.4	Mar. 15	22:50	+22.21	.01	.02	.03
Do	do	Apr. 3	23:30	+21.70	.01	0	.01
Do	do	May 26	12:00	+23.79	.02	.01	.03
Do	do	do	12:15	+23.79	.03	.02	.05
Do	do	July 5	24:15	+24.12	.03	.02	.05
Do	do	July 6	07:40	+24.25	.05	.03	.08
Gloucester	30.14.8.3.1	July 9	17:30	—3.18	.01	.04	.05
Union	26.22.4.4.4	Oct. 23	03:00	+17.74	.02	.02	.04

+ Water surface above mean sea level.
— Water surface below mean sea level.

TABLE 2.—*Earthquakes of 1964 believed to have caused fluctuations in well water levels*

Date 1964	Origin Time G.M.T.			Location	States Recording Fluctuations
	h	*m*	*s*		
Jan. 20	17	08	37.4	New Hebrides Islands	Nevada.
Feb. 1	01	47	52.1	Fox Islands, Aleutian Islands	Alaska.
5	11	30	16.2	Near east coast of Honshu, Japan	New Jersey.
6	13	07	25.2	South of Alaska	Georgia, Indiana, Nevada, and New Jersey.
22	05	58	32.3	Southern Yukon Territory, Canada	Alaska.
Mar. 15	22	30	26.0	Straits of Gibraltar	Indiana and New Jersey.
28	03	36	14.2	Southern Alaska	Alaska, California, Georgia, Idaho, Indiana, and Nevada.
Mar.-June				Numerous aftershocks from Mar. 28 Alaskan earthquake.	Alaska, Idaho, Indiana, and Nevada.
Mar. 30	02	18	06.3	Kodiak Island region	Idaho and Indiana.
30	07	09	34.0	Gulf of Alaska	Idaho and Indiana.
31	09	01	30.2	Vancouver Island region	Idaho.
Apr. 3	22	33	42.2	Southern Alaska	Alaska, Indiana, and New Jersey.
4	17	46	08.6	Kodiak Island region	Alaska and Indiana.
21	05	01	35.7	Southern Alaska	Alaska.
May 15	21	20	42	Gulf of California	Nevada.
26	10	59	12.3	South Sandwich Islands	Georgia and New Jersey.
27	19	02	02.4	do	California.
June 16	04	01	44.3	Near west coast of Honshu, Japan	Georgia and Nevada.
25	05	58	47.1	Near coast of Chiapas, Mexico	Idaho.
July 5	03	14	33.3	Southern Alaska	Alaska.
5	19	04	58.2	Gulf of California	Georgia, Idaho, Indiana, and Nevada.
5	23	39	10.3	Kurile Islands	New Jersey and Idaho.
6	02	14	36.0	Gulf of California	Georgia, Idaho, Indiana, and Nevada.
6	07	22	10.3	Guerrero, Mexico	Georgia, Idaho, Indiana, Nevada, and New Jersey.
9	16	39	49.3	New Hebrides Islands	Alaska and New Jersey.
11	21	05	49.9	Gulf of Alaska	Alaska.
15	07	26	01.4	Fox Islands, Aleutian Islands	Idaho.
17	18	39	46	Gulf of Alaska	Alaska.
23	14	19	01.1	do	Alaska.
23	19	08	06.6	Kenai Peninsula	Alaska.
27	23	20	56	do	Alaska.
28	18	40	04.3	South of Australia	Alaska.
Aug. 24	21	56	54.2	Gulf of Alaska	Alaska.
25	13	47	20.6	East of Severnaya Zemlya	Georgia.
Sept. 13	17	44	10	Southern Alaska	Alaska.
16	01	50	33.9	do	Alaska.
28	18	30	20.2	do	Alaska.
Oct. 3	13	39	39.9	do	Alaska.
6	14	31	19.2	Turkey	Georgia, Idaho, and Indiana.
10	19	38	47.7	Southern Alaska	Alaska.
12	21	55	33.2	Easter Island region	Alaska.
21	07	38	31.0	Hebgen Lake, Mont. region	Idaho.
23	01	56	03.2	North Atlantic Ocean	Idaho, Indiana, and New Jersey.
Nov. 17	08	15	39.3	New Britain region	Georgia and Nevada.
Dec. 17	23	44	46.2	Andreanof Islands, Aleutian Islands	Alaska.

SEISMOLOGICAL OBSERVATORIES

The Summary of Instrumental Epicenters previously published in this publication was discontinued in 1963. mental results are published for the lishes 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 stations listed below. For detailed instrumental data regarding these stations, including instrumentation, constants, and other information, see *Seismological Bulletin,* MSI–289, January 1965. Those desiring to receive this report as issued should request addition of their names to the CGS–7 mailing list.

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

*Indicates a cooperating station.
**Indicates a station operating on an independent basis.
Stations without asterisk(s) are observatories of the Coast and Geodetic Survey.
Stations that are part of the World-Wide Network of Seismograph Stations are indicated by (WWNSS).

LIST OF PRINCIPAL EARTHQUAKES OF THE WORLD FROM JANUARY THROUGH DECEMBER 1964

NOTE.--This list contains (1) earthquakes of magnitude greater than 6¾ determined by Pasadena, and earthquakes of smaller magnitude which were locally destructive; (2) earthquakes of unusual interest.

Date 1964	Origin Time G.M.T.	Region	Coordinates of Provisional Epicenter		Remarks
			Latitude	Longitude	
	h m s		°	°	
Jan. 8.....	22 30 49.7	Celebes.....	3.7 S.	119.4 E.	8 killed, 27 injured, and extensive property damage at Pinrang. Depth about 90 km. Mag. 5.2(CGS).
18.....	12 04 40.0	Taiwan.....	23.1 N.	120.5 E.	107 killed, 479 injured, and about 3,000 homes destroyed. Depth about 33 km. Mag. 6¾.
Feb 6.....	13 07 25.2	Southern Alaska.....	55.7 N.	155.8 W.	Depth about 33 km. Mag. 6¾-7. Felt.
Mar. 15.....	22 30 26.0	Straits of Gibraltar.....	36.2 N.	7.6 W.	Felt in Portugal, Spain, and Morocco. Depth about 27 km. Mag. 6¾-7.
21.....	03 42 19.6	Banda Sea.....	6.4 S.	127.9 E.	Felt at Darwin, Australia. Depth about 367 km. Mag. 7±.
28.....	03 36 14.2	Southern Alaska.....	61.0 N.	147.8 W.	131 killed and $400-$500 million property damage. Anchorage sustained great earthquake damage. Tsunami severely damaged port towns of Alaska; Alberni and Port Alberni, B.C.; west coast of U.S.; and Hawaii. Depth ablut 33 km. Mag. 8.5.
Apr. 2.....	01 11 43.5	Northern Sumatra.....	5.8 N.	95.6 E.	Moderate property damage on Sumatra. Depth about 33 km. Mag. 7.
13.....	08 30 03.6	Yugoslavia.....	45.3 N.	18.1 E.	2 killed, 100 injured, and extensive property damage in northern Yugoslavia and southern Hungary. Depth about 33 km. Mag. 5¾-6.
23.....	03 32 50.3	Aroe Islands region.....	5.3 S.	134.0 E.	Felt at Darwin, Australia. Depth about 33 km. Mag. 6¾-7.
May 7.....	05 45 29.5	Tanganyika.....	4.0 S.	34.9 E.	1 killed at Babati, 19 injured at Mbulu, and extensive property damage. Depth about 33 km. Mag. 6-6¼, B.
7.....	07 58 14.3	Near west coast of Honshu, Japan.	40.4 N.	139.0 E.	Felt in northern Honshu and on Hokkaido. Depth about 33 km. Mag. 7.
26.....	10 59 12.3	South Sandwich Islands region.	56.2 S.	27.8 W.	Depth about 120 km. Mag. 7½-7¾.
June 14.....	12 15 31.3	Turkey.....	38.0 N.	38.5 E.	1 killed, 15 injured, and extensive property damage at Malatya and Adiyaman. Fissure about 800 meters long at Malatya. Depth about 8 km. Mag. 5¾-6.
16.....	04 01 44.3	Near west coast of Honshu, Japan.	38.3 N.	139.1 E.	26 killed, 447 injured, and extensive property damage at Niigata. Tsunami observed along coastal areas. Depth about 57 km. Mag. 7¼-7½.
23.....	01 26 37.0	Kurile Islands.....	43.3 N.	146.1 E.	Depth about 77 km. Mag. 7.
July 6.....	07 22 10.3	Guerrero, Mexico.....	18.2 N.	100.4 W.	About 30 killed, many injured, and extensive property damage. Depth about 82 km. Mag. 6¾-7.
9.....	16 39 49.3	New Hebrides Islands.....	15.5 S.	167.6 E.	Depth about 121 km. Mag. 7¼.
Sept. 12.....	22 07 03.2	Auckland Islands region..	49.1 S.	164.2 E.	Depth about 33 km. Mag. 7¼.
Oct. 6.....	14 31 19.2	Turkey.....	40.3 N.	28.2 E.	36 killed, several injured, extensive property damage in western Turkey. Crevasses and hot springs appeared in epicentral area. Felt widely throughout Black Sea region. Depth about 10 km. Mag. 6¾-7.
Nov. 17.....	08 15 39.3	New Britain region.....	5.7 S.	150.7 E.	Strongly felt. Depth about 45 km. Mag. 7¼.

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, 1931–1964*. 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 5 and 6 are based on the assumption of simple harmonic motion. This refers especially to the computation of displacement from accelerograph records. As most accelerograph records are of irregular character, and the character of the longer period waves is often obscured by the superposition of shorter period waves of relatively large amplitude, the estimates of displacement must be considered only rough approximations. These analyses are essentially condensations of material appearing in the *Quarterly Engineering Seismology Bulletin* available through mailing list CGS–5.

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 request them from the Environmental Science Services Administration, Coast and Geodetic Survey, Rockville, Md. 20852.

Acceleration and displacement scales relatively large amplitude, the estimates 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 3.—*Coast and Geodetic Survey and affiliated strong-motion stations in operation as of December 31, 1964*

NORTHERN CALIFORNIA

Station	Accelero-graph	Displacement Meter	Weed	AR-240
Berkeley, University of California	1	1	.....	.....
Chilcoot, Frenchman Reservoir	1	.....	.....	.....
Delta, Empire Tract	1	.....	.....	.....
Del Valle, Sanitorium, basement	.....	.....	.....	1
Eureka, Federal Building	1	.....	.....	.....
Ferndale, City Hall	1	1	.....	.....
Hollister, Library	1	1	.....	.....
Livermore, Bldg. 110, Vault D, basement	1	.....	.....	.....
Martinez, Suisun Bay Bridge	1	.....	.....	.....
Monterey, City Hall	.....	.....	1	
Oakland, City Hall, basement	1	1	.....	.....
Oakland, Chabot Observatory	.....	.....	1	
Orestimba, Department of Water Resources Site	1	1	.....	.....
Oroville, Department of Water Resources Seismograph Station	1	1	.....	.....
Pleasant Hill, Diablo Valley College	1	1	.....	.....
Sacramento, Federal Building	.....	.....	1	.....
Sacramento, PT & T Building, basement	1	1	.....	.....
Sacramento, PT & T Building, roof	.....	.....	.....	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, 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 Pablo, Contra Costa Junior College	1	1	.....	.....
Tracy, Pumping Plant, Department of Water Resources Site	1	1	.....	.....

TABLE 3.—*Coast and Geodetic Survey and affiliated strong-motion stations in operation as of December 31, 1964*—Continued

SOUTHERN CALIFORNIA

Station	Accelero-graph	Displacement Meter	Week	AR-240
Bakersfield, Harvey Auditorium	1	1		
Bishop, Los Angeles Water Department	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, Devils Canyon, Department of Water Resources Site				1
San Bernardino, Federal Building			1	
San Diego, Light and Power Co., Service Building	1			
San Luis Obispo, City Recreation Building	1			
Santa Ana	1	1		
Santa Barbara, Courthouse	1			
Taft, Buena Vista, Department of Water Resources Site				1
Taft, Lincoln School Tunnel	1			
Tejon, Ft. Tejon, Department of Water Resources Site				1
Temblor, Cholame, Department of Water Resources Site				1
Wheeler Ridge, Department of Water Resources Site				1

OUTSIDE CALIFORNIA

Anchorage, Alaska, Alaska Methodist University				1
Anchorage, Alaska, Post Office Building				1
Bozeman, Mont., Montana State College	1			
Butte, Mont., Montana School of Mines	1			
Columbia Falls, Mont., Hungry Horse Dam, Bureau of Reclamation	1			
Cordova, Alaska, FAA Flight Center				1
Fairbanks, Alaska, Post Office Building				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		
Kodiak, Alaska, Navy Weather Central				1
Logan, Utah, Utah State University	1			
Olympia, Wash., Highway Test Laboratory	1			
Portland, Oreg., State Office Building	1			
Ross Dam, Wash., Block 16, Crest	1			
Ross Dam, Wash., Right Bank	1			
Seattle, Wash., Federal Office Building	1	1		
Tacoma, Wash., County-City Building	1	1		

TABLE 3.—*Coast and Geodetic Survey and affiliated strong-motion stations in operation as of December 31, 1964*—Continued

OUTSIDE THE UNITED STATES

Station	Accelero-graph	Displacement Meter	Weed	AR-240
Balboa Heights, Canal Zone	1			
Bogota, Colombia, South America	1			
Guatemala City, Guatemala, Central America	1			
Lima, Peru, South America	1			
Quito, Ecuador, South America	1			
San Jose, Costa Rica, Central America	1			
San Salvador, El Salvador, Central America	1	1		
Santiago, Chile, South America	1			
Total	74	36	10	12

TABLE 4.—*List of shocks recorded and records obtained on strong-motion seismographs in 1964*

Date 1964	Region and Recording Station	Records			
		Accelero-graph	Survey Displacement Meter	Carder Displacement Meter	Weed
Feb. 26	Northern California, Ferndale, City Hall	1			
Mar. 22	Western Nevada, Hawthorne, U.S. Naval Ammunition Depot.	1			
Aug. 30	Southern California, Los Angeles, Hollywood Storage Co., penthouse.	1			
	Hollywood Storage Co., basement	1			
	Hollywood Storage Co., adjoining P.E. lot	1			
Nov. 15	Central California, Livermore, Bldg. 110, basement	1			
	San Francisco, State Building, basement	1	1	1	
	San Francisco, Bethlehem Building, 12th floor	1		1	
	San Francisco, Bethlehem Building, basement	1		1	
	San Francisco, Southern Pacific Building, basement		1		
	Hollister, Library	1	1		
Dec. 22	Baja California, San Diego Light and Power Co. Service Building.	1			
	El Centro			1	
	Total	11	3	4	0

TABLE 5.—*Summary of outstanding instrumental and noninstrumental data for 1964*

NORTHERN CALIFORNIA EARTHQUAKE OF FEBRUARY 26

Epicenter	Recording Station and Distance	Location of Instrument	Intensity[1]	Acceleration	Displacement[2]
40.3° N., 124.6° W., near coast of northern California, V *. Mag. 4.6.	Ferndale, 32 miles.....	City Hall, 1st floor.....	V	23	0.05
WESTERN NEVADA EARTHQUAKE OF MARCH 22					
38.8° N., 118.7° W., western Nevada, V *. Mag. 4.5.	Hawthorne, 16 miles...	Naval Ammunition Depot, 1st floor.	V	20	0.10
SOUTHERN CALIFORNIA EARTHQUAKE OF AUGUST 30					
34° 15′ N., 118° 28′ W., southern California, V *. Mag. 4.0, P.	Los Angeles, 15 miles..	Hollywood Storage Co., penthouse.	IV	48	0.01
CENTRAL CALIFORNIA EARTHQUAKE OF NOVEMBER 15					
37° 00′ N., 121° 43.5′ W., central California, VII *. Mag. 5-5¼, B.	Hollister, 32 miles.....	Library, 1st floor.....	VI	37	0.30
BAJA CALIFORNIA EARTHQUAKE OF DECEMBER 22					
31° 56′ N., 117° 09′ W., off west coast of Baja California, VI *. Mag. 5.6, P.	San Diego, 50 miles....	Light & Power Co. Service Building, basement.	VI	34	0.12

[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 displacemen 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 6.—*Composite of strong-motion instrumental data for 1964*

SOUTHERN CALIFORNIA EARTHQUAKE OF AUGUST 30

Station and Component	Instrument No.	T_o	V	Sensitivity	ϵ	Acceleration		Displacement		Remarks
						Period	Amplitude	Period	Amplitude *	
		sec.		*cm/g.*		*sec.*	*cm/sec.*[2]	*sec.*	*cm.*	
Los Angeles (Hollywood Storage Co., penthouse):										
Up	193	0.045	121	6.1	10	0.10	29	.....	0.01	
West	191	.045	124	6.2	10	.08	48	.....	.017	
South	192	.046	123	6.4	10	.10	32	.....	.01	
CENTRAL CALIFORNIA EARTHQUAKE OF NOVEMBER 15										
Hollister (City Library):										
Up	238	0.068	123	14.2	10	0.20	20	.....	0.02	
S.1° W	239	.066	123	13.5	9	.26	24	.....	.....	
N. 89° W	240	.066	122	13.3	10	.42	37	.....	.....	
N. 1° E	6	2.1	1.0	.....	11	.....	.....	1.3	.30	
N. 89° W	5	2.2	1.0	.....	11	.....	.....	0.7	.26	
BAJA CALIFORNIA EARTHQUAKE OF DECEMBER 22										
San Diego (Light and Power Co. Service Building):										
Up	322	0.080	124	20.3	9	0.34	14	.....	0.04	
East	323	.079	122	19.5	11	.46	27	.....	.14	
South	324	.080	124	20.1	9	.38	34	.....	.12	

*Estimated from acceleration if no entry in displacement column.

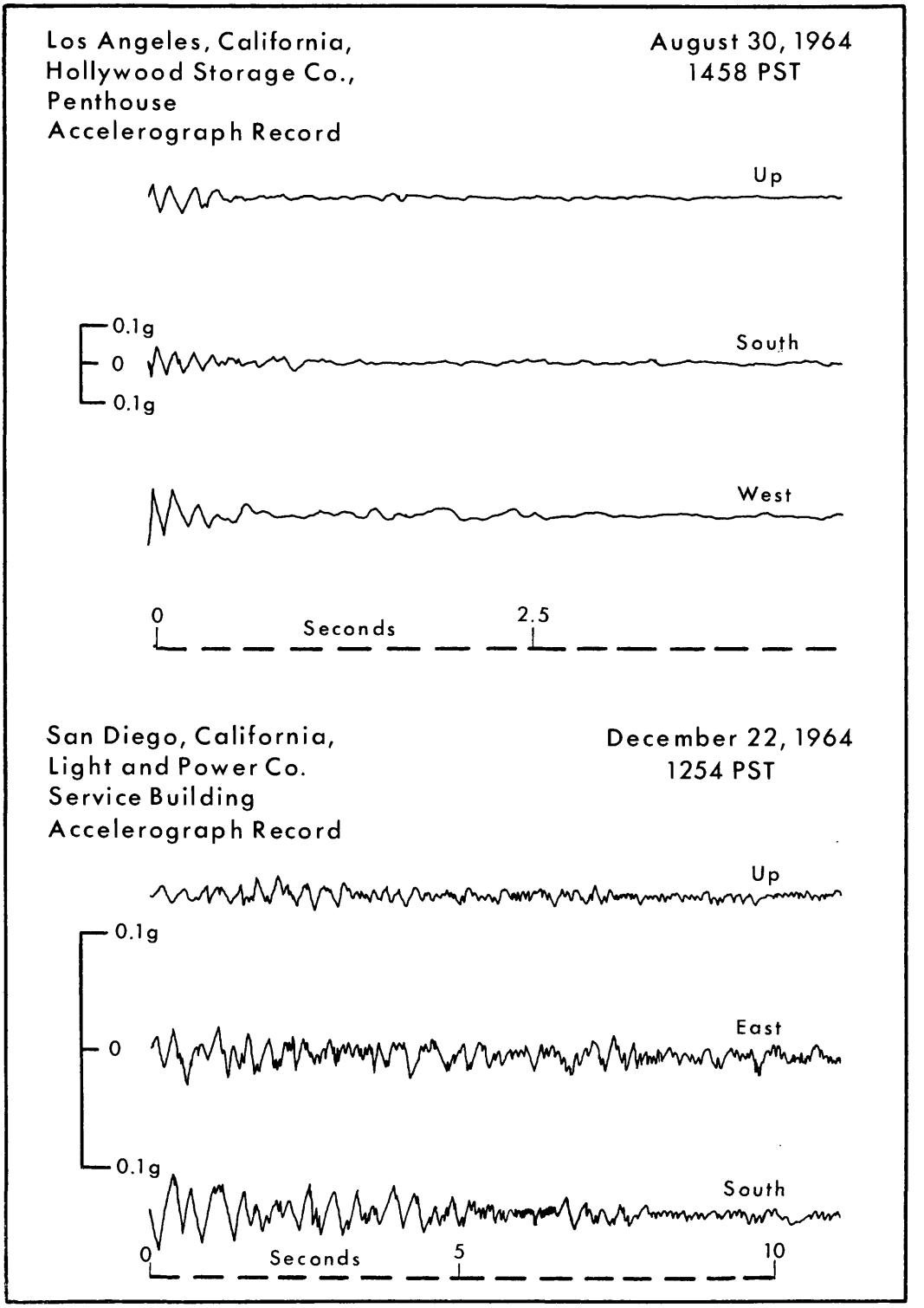


FIGURE 10.—*Tracings of accelerograph records obtained at Los Angeles on August 30 and at San Diego on December 22.*

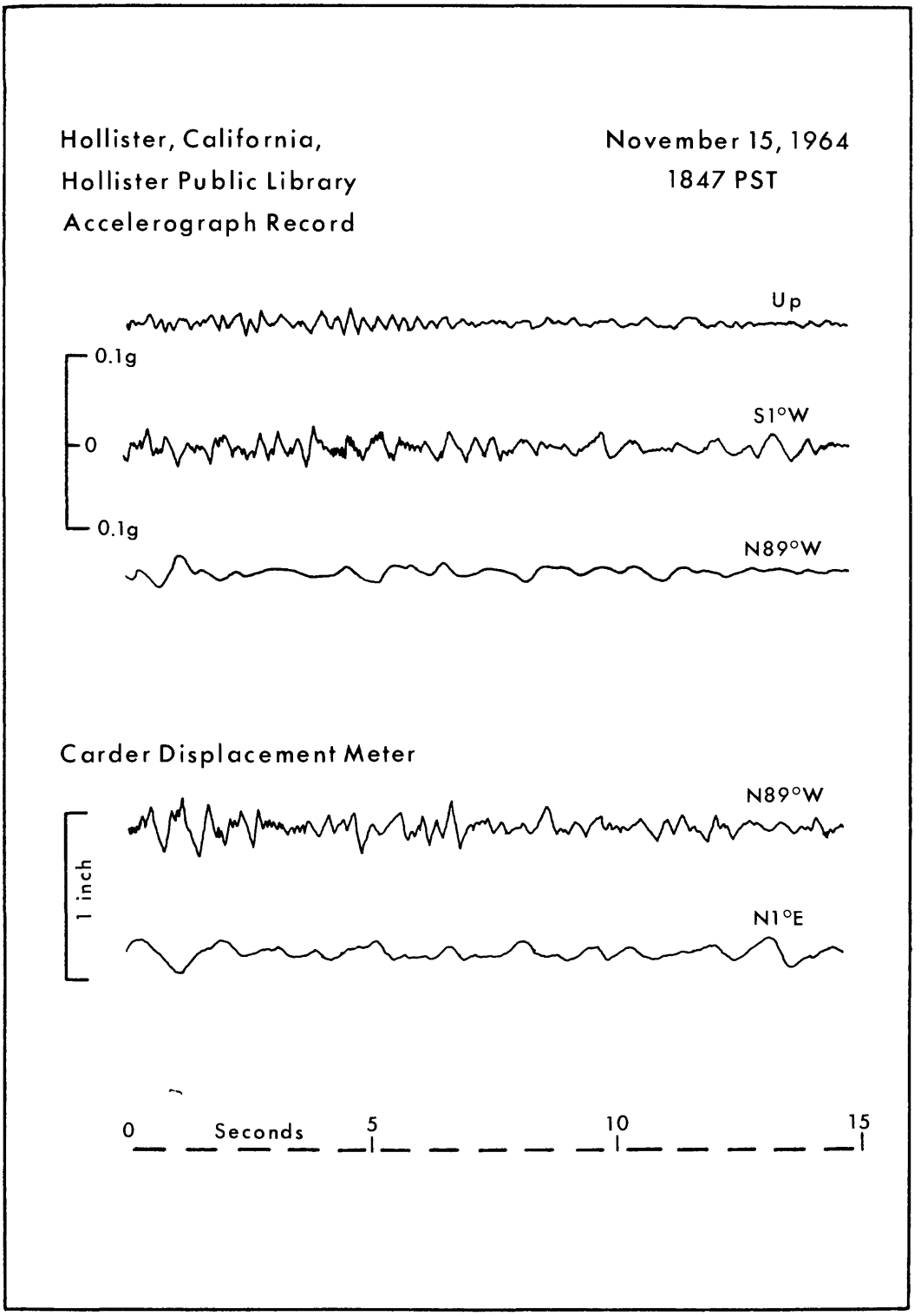


FIGURE 11.—*Tracings of accelerograph and Carder Displacement Meter records obtained at Hollister on November 15.*

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. If you desire to receive notices of seismological publications, address your request to the Environmental Science Services Administration, Coast and Geodetic Survey, Rockville, Md. 20852.

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