

DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

United States Earthquakes, 1965

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and

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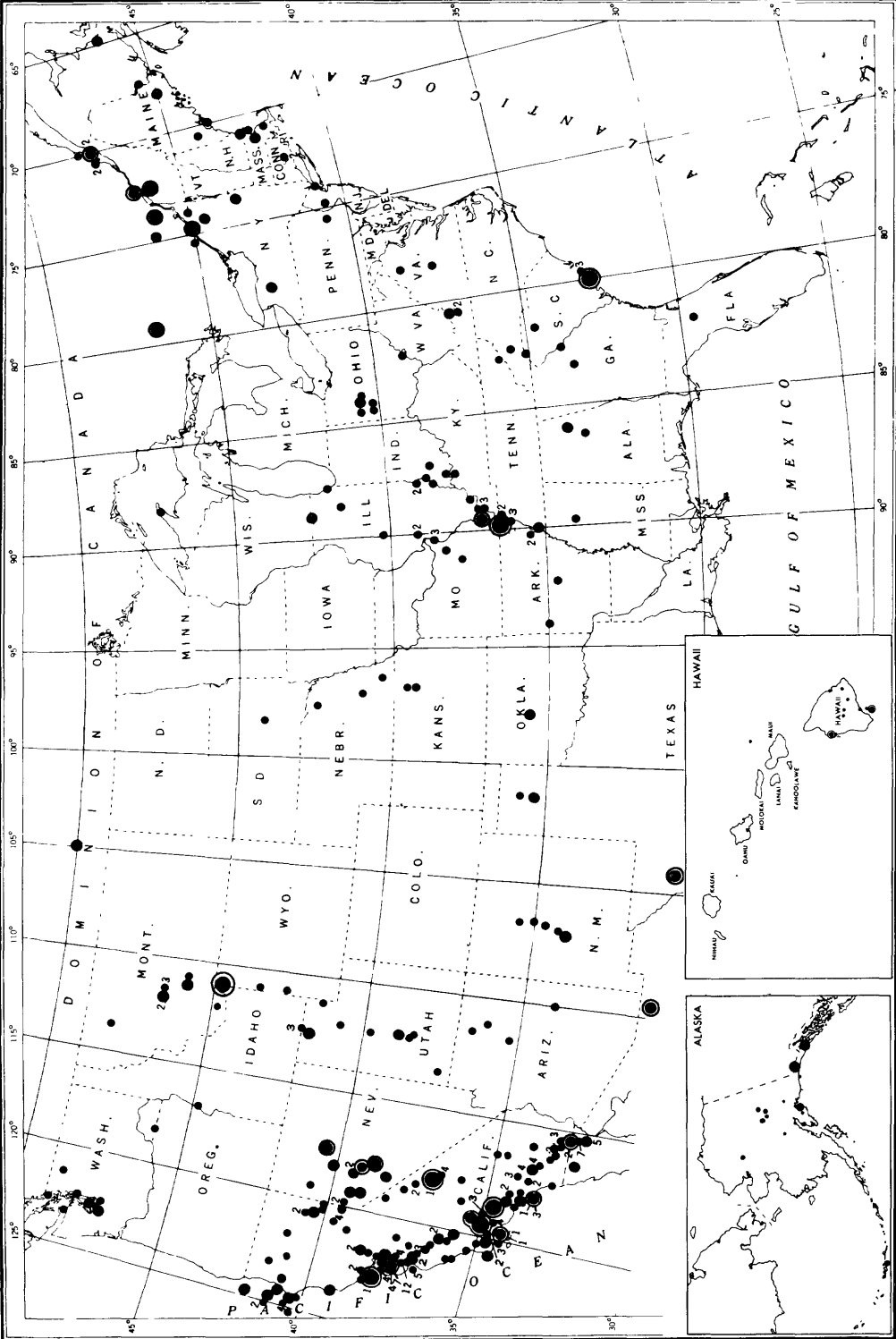


FIGURE 1.—Destructive and near-destructive earthquakes in the United States through 1965.

Introduction

This publication is a summary of earthquake activity in the United States and regions under its jurisdiction for the calendar year 1965. The sources of noninstrumental information used in the compilation include the U. S. 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 various institutions; newspaper clippings; and reports from interested individuals. Instrumental data used in locating earthquakes are obtained from the seismological observatories listed on page 73, and from other cooperating seismological stations located throughout the United States.

The Coast and Geodetic Survey endeavors to coordinate efforts in collecting all types of earthquake information with the special objective 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 by 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 complete and return earthquake questionnaire forms.

EARTHQUAKE INFORMATION SERVICES

The Coast and Geodetic Survey maintains the 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 at Berkeley, the Seismological Laboratory at Pasadena, and from state collaborators in Seismology. The following collaborators served as agents of the Coast and Geodetic Survey in their respective states during 1965:

Arizona.—Dr. Richard T. Moore, 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. Peter Dehlinger, Oregon State University, 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 insurance companies. Certain concerns interested in the manufacture of earthquake-resistive 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 at Weston College, Weston, Mass., (Rev. Daniel J. Linehan, S.J., in charge) undertakes similar work in the Northeastern States. Additional information is furnished 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.

EPICENTER MAPS

Figure 1 is designed to show the existence of destructive and near-destructive earthquakes in the United States through 1965. The smallest dot indicates the shock was strong enough to overthrow chimneys, or to affect an area of more than 25,000 square miles (intensity VII to VIII); the largest solid dot may be associated with damage ranging from several thousand dollars to one-hundred thousand dollars, or with shocks usually perceptible over more than 150,000 square miles (intensity VIII to IX); the smaller encircled dot represents 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 dot represents 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 1965. 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. Earthquakes in the California area are plotted when felt reports are received from several towns. Feeble earthquakes, and minor aftershocks of large earthquakes, are not shown on this epicenter map. The numeral 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. 3–7) 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 States) will sometimes be shown. Felt and nonfelt reports from various towns are designated on the maps by open and solid circles, respectively. Intensities higher, or lower, than those in the isoseismal zone are frequently noted and are indicated by small numerals above the circles.

TELESEISMIC RESULTS

A list of seismological observatories for which the Survey publishes results is given

on page 73 and shown in figure 8. During the year, the locations of 6,034 epicenters were announced promptly on the *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*. In 1965, bulletins MSI-289 through MSI-300 were published. These are available on the CGS-7 mailing list.

MAGNITUDE AND INTENSITY RATINGS

Magnitude rating, stated according to the Gutenberg-Richter scale, is a measure of the energy release at the focus of an 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, expressed on the Modified Mercalli Intensity Scale of 1931 (*see* next section), is a local measure of the effects on people and objects. 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.

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 given here with equivalent intensities according to the Rossi-Forel Scale.

- 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 build-

ings. 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,

¹ Harry O. Wood and Frank Neumann, in *Bull. Seism. Soc. Amer.*, vol. 21, No. 4, December 1931.

walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed. (VIII+ to IX — Rossi-Forel Scale)

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

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with their 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.

STRONG-MOTION SEISMOGRAPH ACTIVITIES

The maintenance of a network of strong-motion seismographs and the analysis of the records of destructive earthquake motions thus obtained are functions of the Coast and Geodetic Survey in connection with a broad, cooperative research program being conducted on the Pacific Coast with several local organizations and institutions

interested in the engineering aspects of the earthquake problem. More details concerning this subject may be found on page 81, "Strong-Motion Seismograph Results." In this section a list of the strong-motion stations now in operation is presented in table 3, and their locations are shown in figures 10 and 11 (excluding those located outside the United States).

The preliminary analyses of strong-motion records are published in the *Quarterly Engineering Seismology Bulletin* which is 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 Special Publication 282, *Earthquake Investigation in the United States*, revised (1964) edition. A list of the active teleseismic stations, including independent and privately owned stations, is given in this report. Publication 41-1 (Parts I and II) and S.P. 282 are available from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

Summary of Earthquake Reports

The following symbols are used to indicate authority for times or reported epicenters in the various regions; 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, St. Louis, Mo.; S, reported by the Seismograph Station, University of Washington, Seattle, Wash.; and W, reported by the Rockville office of the Coast and Geodetic Survey. Magnitude as determined by the Rockville office is m_b of Gutenberg-Richter computed from the *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

This section summarizes the earthquake data in the regions which follow. The intensities of the earthquakes for which no ratings are given range from I to IV.

Alaska: (Intensity V and above). February 3, VI (2); April 16, V; April 26, V; July 2, VI; December 22, V.

Arizona: September 25, V.

Arkansas: October 20, V.

California: (Intensity V and above). January 1, VI; 1, V; February 19, V; 25, V; 26, V; April 15, VI; June 3, V; 15, VI; July 15, VI; 29, V; September 10, VI; 14, V; 19, V (2); 25, VII; 25, V; October 10, V; 17, VI; 18, V; 21, VI; November 12, VI; December 11, V.

Colorado: February 16, VI; 16, IV (2); July 18, V; 18 (2); 31, V; August 9, IV; 9; 14, IV; 14; 18, IV; 27 (2); September 2, IV; 13; 14, VI; 14 (4); 15; 27, IV; 29, VI; 29, IV (5); November 7, IV; 14, III (2); 20, VI; 20 (3); 21.

Hawaii: January 1; 8; 13; 21; February 8; 9; 11; 13; 14; March 5 (2); 6; 15; 20; 22; April 10 (2); 16; 18; May 16 (2); 24 (2); 30; June 4; 7; July 7; 15; 18; 19; 22 (2); 28; 29; August 11; 17; 23 (2); 24; 25 (6); 31; September 1; 2; 9; 16; 18; October 20; 28; 30; November 13; 17; 19; 23; 30; December 2; 3; 5; 12; 20; 21; 24-31 (about 400 earthquakes accompanied flank eruption of Kilauea volcano).

Idaho: January 5, I-III; March 27; April 28, V; 29 (2); 30, IV.

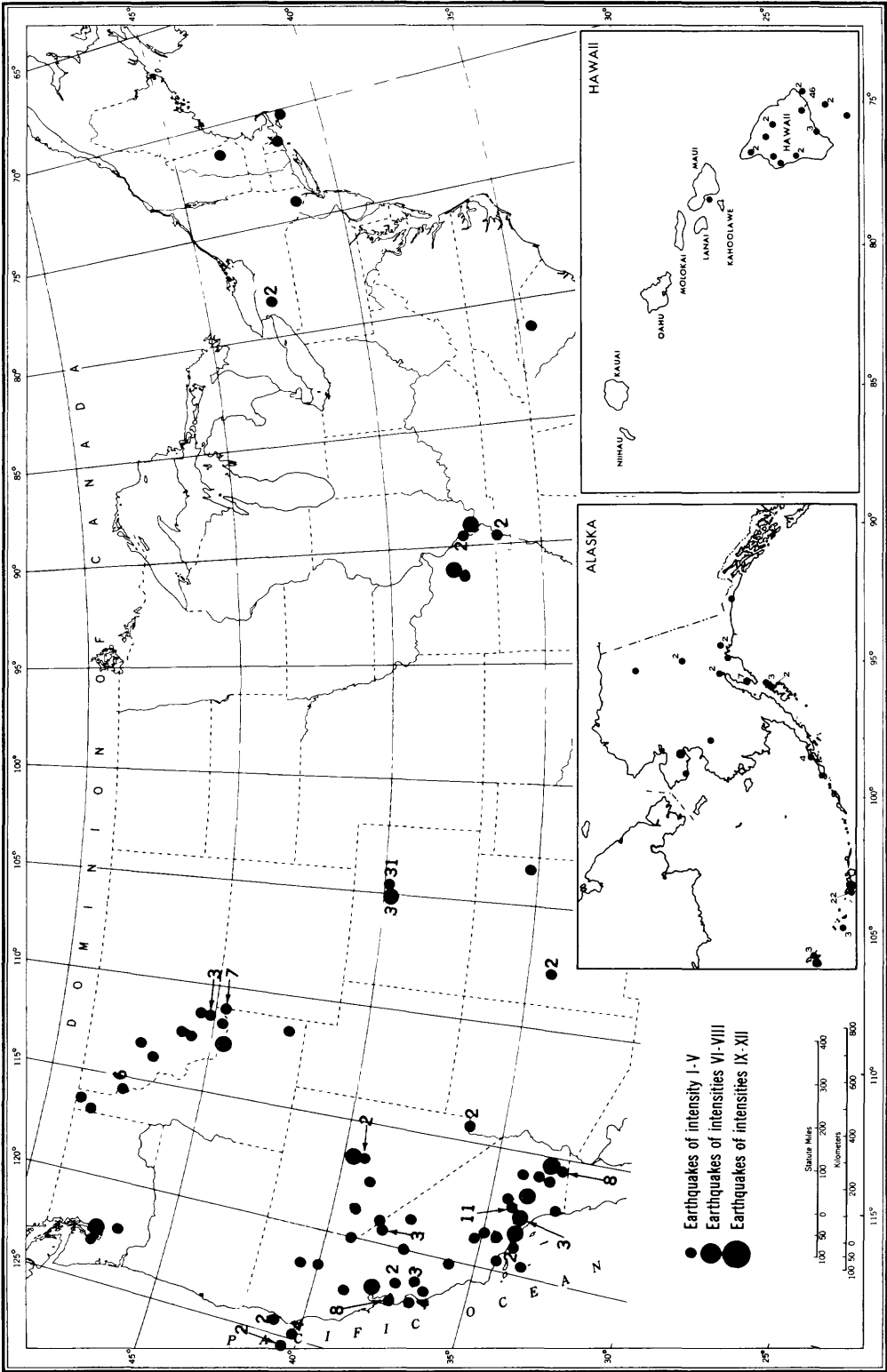


FIGURE 2.—United States earthquake epicenters for 1965.

Illinois: August 13; 14, VII; 15, V (2); October 20, V.

Iowa: October 20, V.

Kansas: October 20, V.

Kentucky: October 20, IV.

Massachusetts: October 24, V; December 7, IV.

Missouri: March 6; October 20, VI.

Montana: January 5, VI; 5 (4); 6, V; 6; 7; 12, V; April 6, V; 27, V; 27; 29, IV; 29 (2); May 11 (4); July 9, III (2); 18, V; October 8, V; 8; 9; 10, IV; 26, V; November 3, IV (2); 29, III.

Nebraska: October 20, I-III.

Nevada: January 4, V; March 8, IV; 11; May 2; 14; June 3; July 14, IV; September 25, V.

New Hampshire: January 3, IV.

New Mexico: February 3, IV; December 22, IV (2).

New York: July 16, IV; August 27, IV; September 29, IV.

Oklahoma: October 20, I-III.

Oregon: April 29, VI.

Rhode Island: December 7, V.

South Carolina: September 8; 9; 10; 12.

Tennessee: October 20, IV.

Washington: April 29, VIII; 30; October 23.

Wyoming: October 8, IV.

EARTHQUAKE ACTIVITY OUTSIDE THE UNITED STATES

Panama Canal Zone: August 2, III (2); 2, II (4); December 15, II.

Puerto Rico: No earthquakes were reported felt during 1965.

Virgin Islands: April 1; August 23.

NORTHEASTERN REGION

[75th Meridian or Eastern Standard Time]

January 3: 12:05. Laconia, N.H. IV. Felt by few. Windows, doors, and dishes rattled. Rapid motion; brief duration.

July 16: 06:00 (about). Attica, N.Y. IV. Press reported that one person was awakened by vibration of bed. Houses shook and

dishes rattled. Also shook beds in Attica Center where some thought it to be an explosion. Rumbling noises; west-east direction.

August 27: 20:57 (about). Attica, N.Y. and vicinity. IV. Press reported this shock was felt along a 20-mile stretch of Tonawanda Creek. Houses shook and a rumbling noise was heard for 4 seconds. One observer, walking, thought it was an explosion. House trailer vibrated at Batavia; vibrations were felt at Varysburg where residents thought it was a sonic boom. "Less severe than the July 16 shock."

September 29: 15:57:39.5*. Goshen-Middletown, N.Y. IV. Press reported that buildings shook and explosionlike sounds were heard. Residents called police station about disturbance. Recorded by seismograph at Ogdensburg, N.J.

October 24: 12:45 (about). Nantucket, Mass. V. Felt by many. One observer reported very slight damage, mostly to ornaments. Dishes and ornaments moved about; doors, windows, and dishes rattled; house timbers creaked and groaned. A door at police station was forced open. Press reported two distinct tremors near 14:00, 10-20 seconds apart.

December 7: 22:02:42*. Narragansett Bay, R.I. V. Felt over approximately 375 square miles of Rhode Island and Massachusetts. Windows and doors rattled and trees and bushes were shaken slightly at Warwick, R.I., where many were frightened. Abrupt onset; rapid motion. Felt by all at Bristol (V). Small objects and furnishings shifted. Rapid onset; duration about 5 seconds. Press reported that houses, windows, and glassware shook on both sides of upper Narragansett Bay. Police station dispatched officers to Warwick Neck after an explosion was reported. Questionnaire canvass conducted by Weston Observatory. Recorded by seismograph at the Weston Observatory, Weston, Mass.

INTENSITY IV IN RHODE ISLAND: Barrington

ton, East Greenwich, Tiverton, Warren, and Warwick.

INTENSITY IV IN MASSACHUSETTS: Dighton, Fall River, and Swansea.

INTENSITY I-III IN RHODE ISLAND: Cranston, North Kingstown, and Portsmouth.

INTENSITY I-III IN MASSACHUSETTS: Somerset.

EASTERN REGION

[75th Meridian or Eastern Standard Time]

September 8: 23:37:16*; September 9: 09:42:20*; September 10: 02:32:00*; and September 12: 13:25:02*. Chester, S.C., and vicinity. These earthquakes, and additional minor tremors, were reported felt over a 30-mile area in Chester County during this period. Since additional felt information was not available intensities could not be assigned to the shocks.

CENTRAL REGION

[90th Meridian or Central Standard Time]

March 6: 15:08:50.5*. Epicenter 37°50' north, 91°10' west, Missouri, JSA. Magnitude 5.3, W. Felt near Fletcher.

March 25: 06:59:28*. Epicenter 36.4° north, 89.5° west, New Madrid, Mo., region, W. Reported felt as far north as Saint Louis, but was very light and "generally unnoticed."

August 13: 23:46:17.3*. Epicenter 36°19' north, 89°28' west, southwestern Illinois, JSA. Magnitude 5.0, W. Felt at Tamms and Unity, Earth noises were heard.

August 14: 07:13:54.1*. Epicenter 37.1° north, 89.2° west, southwestern Illinois, W. Magnitude 5.0. VII. At Tamms chimneys fell, basement and walls cracked, water supplies were muddied, and groceries fell from shelves. Thunderous earth noises accompanied the shock. Rapid onset; swaying motion, northwest-southeast. At Unity many were alarmed, buildings creaked, and loose objects rattled (V). Faint, bumping earth sounds were heard. The shock was also felt at Elco, Olive Branch, and Olmsted.

August 15: (1) 00:07:28.0*; (2) 22:19:00.3*. Epicenter (1) 37°22' north, 89°28' west; (2) 37°24' north, 89°28' west, southwestern Illinois, JSA. Magnitude of first shock 5.1, W. V. These shocks were felt at Unity and were reported to have been about the same intensity and character as the shock at Unity on August 14. The earthquake at 00:07:28.0* was felt at Tamms with a probable intensity of V.

October 20: 20:04:39.3*. Epicenter 37°51' north, 91°05' west, eastern Missouri, JSA. Magnitude 5.2, W. VI. This shock was felt over approximately 160,000 square miles of nine states—Arkansas, Illinois, Iowa, Kansas, Kentucky, Missouri, Nebraska, Oklahoma, and Tennessee (*see fig. 3*). Various towns reported cracked walls, plaster, and windows. Other damage, such as broken stained-glass windows, cracked cistern, and fallen bricks, was reported from Missouri.² Questionnaire canvass conducted by Saint Louis University.

INTENSITY VI IN MISSOURI:

Augusta.—Cistern cracked and water leaked out. Dishes and windows rattled.

Illmo.—Felt by many. Basement floor cracked. Rapid onset; rocking motion.

Pacific.—Sewer ventline cracked in house. Windows and dishes rattled.

Reynolds.—Bricks fell from flue. House shook.

Saint Louis.—Press reported that plaster cracked and fell and chairs rocked.

INTENSITY V IN ARKANSAS:

Piggott.—Felt by and alarmed many. Buildings creaked; loose objects rattled; chairs and beds shook. Earth sounds heard. Rapid onset; trembling-swaying motion.

Rector.—Felt by nearly all. Buildings creaked; loose objects rattled. Lamp almost fell from table. Thunderous earth sounds. Gradual onset; trembling motion. "Alarmed residents only for a short time."

² Kisslinger, Carl and Otto W. Nuttli, "The Earthquake of October 21, 1965 [G.M.T.] and Precambrian Structure in Missouri," *Earthquake Notes*, vol. XXXVI, Nos. 3-4, 1965.

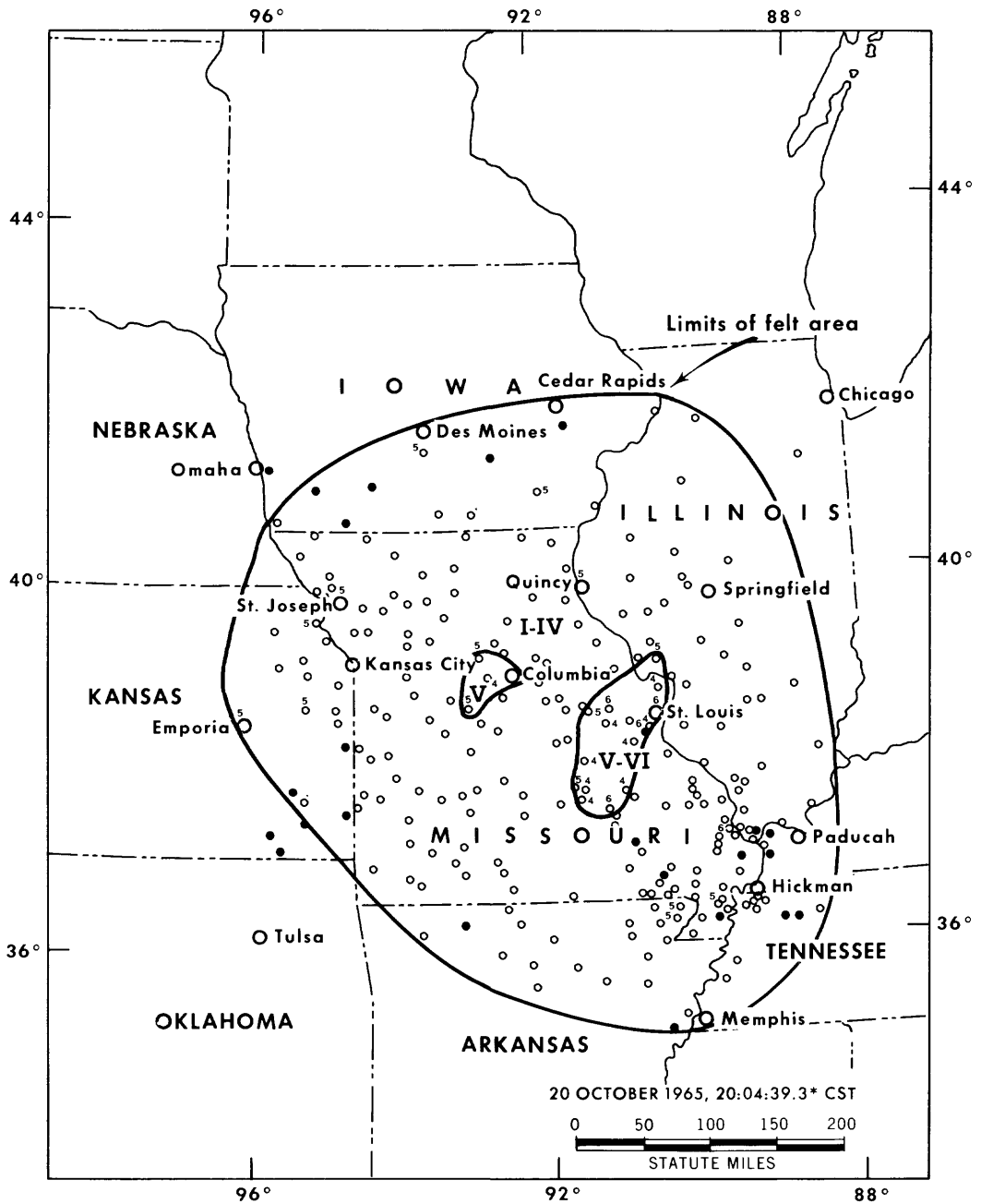


FIGURE 3.—Area affected by Missouri earthquake of October 20.

INTENSITY V IN ILLINOIS:

Jerseyville.—Window cracked (press).

Quincy.—Press reported that furniture moved, doors slammed, and dishes rattled. Low rumbling noise; slight vibration.

INTENSITY V IN IOWA:

Indianola.—Large cracks in house foundation. "Sounded like 20-gauge shotgun."

Ottumwa.—Felt by many. Press reported that beds moved and chairs rocked at St. Joseph's Hospital; mirror displaced on wall. Roaring earth sounds.

INTENSITY V IN KANSAS:

Emporia.—Press reported that furniture moved and a window cracked.

Leavenworth.—Felt by several. Doll in cabinet toppled (press). Police department received calls from all parts of the city. Buildings creaked; loose objects rattled; chairs rocked. Very faint, rumbling earth sounds at beginning of shock. Gradual onset; trembling motion, east-west.

Ottawa.—Press reported that a wall cracked. However, felt report from town did not substantiate this statement.

INTENSITY V IN MISSOURI:

Bismarck.—Plaster was damaged on second floor of brick building. Low rumble heard.

Columbia.—Cracks in solid tile house. Low noises.

Conran.—Felt by nearly all. Buildings creaked; loose objects rattled; chair moved. Rumbling earth sounds heard before shock began. Abrupt onset; swaying motion. "People were surprised and startled."

Fayette.—Press reported 13 stained-glass windows broke in a church.

New Haven.—Plaster cracked in brick and frame homes. Picture fell.

St. Joseph.—Felt by several. Wall cracked in corner of room. Houses shook, door rattled, and stairway popped and creaked.

Salem.—Felt by and alarmed many. Buildings creaked; loose objects rattled.

Thunderous earth sounds heard before shock began. Rapid onset; swaying motion.

Syracuse.—Plaster cracked in four rooms of house. Loose objects rattled; rumbling heard.

INTENSITY IV IN ARKANSAS: Batesville, Harrison (near), and Walnut Ridge.

INTENSITY IV IN ILLINOIS: Alton, Cairo, Cobden, Gale, Hardin, Hillsboro, Jacksonville, Jonesboro, Murphysboro, Nashville, Pittsfield, Pomona, and Springfield.

INTENSITY IV IN IOWA: Burlington, Cedar Rapids, Clinton, Des Moines, and Farmington.

INTENSITY IV IN KANSAS: Colony, Kansas City, La Cygne, Mission, and Topeka.

INTENSITY IV IN KENTUCKY: Hickman.

INTENSITY IV IN MISSOURI: Adrian, Arab, Arcadia, Ava, Belgique, Belleview, Bennett Springs, Berger, Bernie, Beulah, Bland, Bloomsdale, Bolivar, Bowling Green, Broseley, Caledonia, Camdenton, Campbell, Canton, Cape Girardeau, Caruthersville, Catron, Centerville, Centralia, Chaffee, Chillicothe, Commerce, Cuba, Dexter, Dutchtown, East Prairie, Edgerton, Eldon, Elkland, Ellsinore, Essex, Farber, Fenton, Fillmore, Florissant, Forest Green, Friedheim, Frohna, Fruitland, Gainesville, Grandview, Gray Summit, Harrisburg, Harviell, Houstonia, Hunter, Ionia, Jamestown, Kennett, Leopold, Linn Creek, Linneus, Manes, Maples, Marble Hill, Merwin, Millersville, Mill Spring, Monett, Montauk, Montier, Morrison, Mount Vernon, Naylor, New London, Oran, Oxly, Paris, Perryville, Pine, Pomona, Rivermines, Rush Hill, Schell City, Seaton, Sedalia, Sedgewickville, Shelbyville, Spokane, Squires, Stockton, Sturdivant, Sturgeon, Summersville, Sweet Springs, Thayer, Troy, Ulman, Versailles, Warrensburg, Warsaw, Webster Groves, Wheaton, Windsor, and Zalma.

INTENSITY IV IN TENNESSEE: Covington, Hornbeak, Memphis, Troy, and Union City.

INTENSITY I-III IN ARKANSAS: Biggers, Corning, Datto, Harrisburg, Heber Springs, Huntsville, Lafe, Marion, Marshall, Melbourne, Mountain Home, Mountain View, Newport, and Yellville. Reported felt by press (no details): Cotter, Jonesboro, Norfolk, Oakland, Paragould, and Pochontas.

INTENSITY I-III IN ILLINOIS: Benton, Carbondale, Carlinville, Carlyle, Carmi, Carrollton, Carterville, Chester, Edwardsville, Elwood, Golconda, Havana, Lincoln, Louisvill, Macomb, Metropolis, Mounds, Petersburg, Ripley, Salem, Sterling, Taylorville, Toulon, Vandalia, Virginia, Waterloo, and Winchester. Press reported the shock felt at Chicago (no details).

INTENSITY I-III IN IOWA: Centerville, Corydon, Plano, and Sidney.

INTENSITY I-III IN KANSAS: Atchison, Burlington, Erie, Grantville, Holton, Lawrence, Oskaloosa, and Paola. Reported felt by press (no details): Fairway, Olathe, Overland Park, and Prairie Village.

INTENSITY I-III IN KENTUCKY: Paducah and Wickliffe.

INTENSITY I-III IN MISSOURI: Amazonia, Auxvasse, Belle, Big Piney, Bolckow, Boonville, Boss, Brandsville, Bronaugh, Buffalo, Burfordville, Cameron, Carrollton, Cedar Hill, Cowgill, Creighton, Eagle Rock, Edwards, El Dorado Springs, Elmo, Fagus, Fairfax, Fisk, Forsyth, Foster, Fulton, Galatin, Gipsy, Gladden, Glenallen, Grant City, Grassy, Greenfield, Hale, Harrisonville, Hendrickson, Holt, Hornersville, Hurley, Irwin, Jacksonville, Jefferson, Kahoka, Kidder, La Plata, Lutesville, McCredie, Memphis, Mexico, Milan, Milford, Millcreek, Mindenmines, Montreal, Neelyville, Neosho, Nettleton, New Bloomfield, New Wells, Oak Ridge, Odessa, Oregon, Osage Beach, Ozark, Palmyra, Patton, Portageville, Purdy, Qulin, Rhineland, Rich Hill, Richmond, Rockville, Rombauer, Saco, Steedman, Stewartsville, Stoutland, Tallapoosa, Trenton, Unionville, and Vandalia.

INTENSITY I-III IN NEBRASKA: Omaha (press)

INTENSITY I-III IN OKLAHOMA: Tulsa.

INTENSITY I-III IN TENNESSEE: Elbridge, Huntingdon, Paris, Ripley, and Woodland Mills.

WESTERN MOUNTAIN REGION

[105th Meridian or Mountain Standard Time]

January 5: 15:00, 16:30, 19:01:22.2*, Epicenter 44.9° north, 112.7° west, eastern Idaho, W. Magnitude 5.1. VI. The main shock was felt over approximately 12,000 square miles of southwestern Montana and a small area of Idaho (*see* fig. 4). At Dewey, a 35-foot flagpole was broken in three places. Felt very strongly at Dell, about 70 miles south of Dewey. (Reports are for the main shock unless otherwise indicated.)

INTENSITY VI IN MONTANA:

Dewey (about 7 miles west of Divide).—A 35-foot metal-pipe flagpole was broken in three places (bottom 12 feet unbroken). Broken sections fell to the south. Dishes were thrown from shelves and a flowerpot overturned. All fell to the south.

INTENSITY V IN MONTANA:

Butte.—Press reported that hundreds of residents felt the shock. Christmas trees toppled in at least two instances. Buildings creaked; windows rattled; dishes shook. Many thought the shock was due to blasting. Several reported a slight shock at about 16:30. Motion rapid; lasted 2-15 seconds.

Dell.—Felt by and frightened all in strongly built wooden house. Small objects shifted; few cans fell in store. Windows, doors, and dishes rattled; doors swung. Loud earth noises from northeast before shock. Motion slow; lasted 10 seconds. Direction, northeast.

Divide.—Felt by nearly all; frightened few. Small objects shifted. Windows, doors, and dishes rattled; walls creaked. Hanging objects swung north-south. Motion rapid; lasted few seconds.

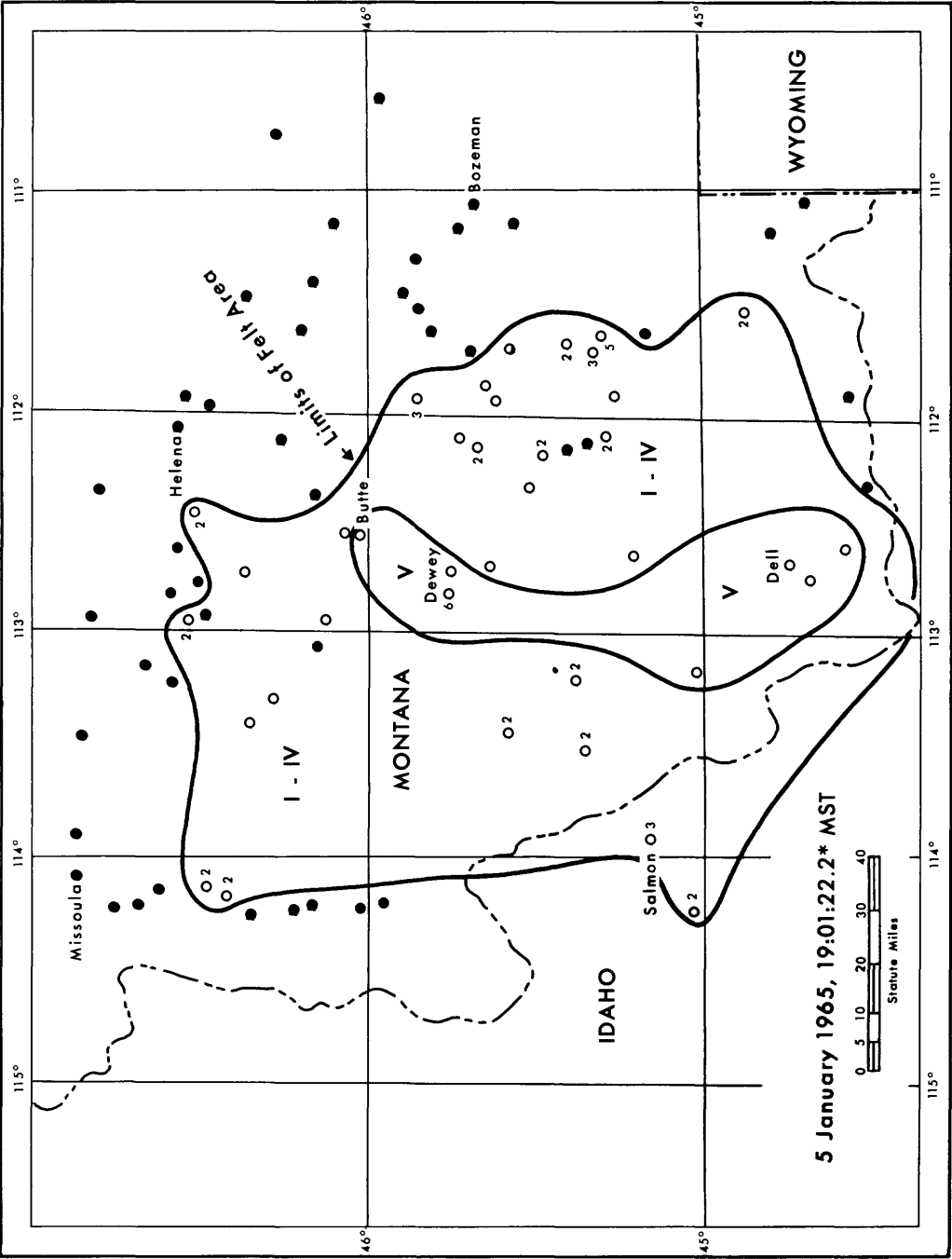


FIGURE 4.—Area affected by eastern Idaho earthquake of January 5.

Grant.—Felt by all. Lights swung; house plants shook. Windows, doors, and dishes rattled. Faint rumbling noise before shock. Motion slow; easy rocking; lasted 3 seconds. Direction, west-east.

Jeffers.—Felt by many and frightened few. Trees, bushes shaken strongly; small objects shifted. Dishes rattled; walls creaked. Moderate earth noises heard. "Also felt a shock about 15:00 the same day." Motion slow; lasted about 10 seconds. Direction, east-west.

Lima.—Frightened few in community. Dishes rattled; small objects overturned. Observer felt chair twist. Loud earth noises from south before shock. Motion rapid; lasted about 3 seconds.

Sula.—"I was sitting in a sofa chair facing northeast. Had feeling of chair moving from under me. Observer on second floor thought masonite ceiling might come down and ran down to first floor. Strongly built log house."

Walkerville (suburb of Butte).—Felt by many in home. Knickknacks fell. Windows, doors, and dishes rattled. Motion slow; lasted few seconds.

INTENSITY IV IN MONTANA: Anaconda, Deer Lodge, Dillon, Melrose, Norris, Phillipsburg, Pony, Twin Bridges, Virginia City, and Warm Springs.

INTENSITY I-III IN MONTANA: Alder, Cardwell, Elliston, Ennis, Goldcreek, Hutchins Bridge (35 miles south of Ennis), Jackson, McAllister, Polaris, Sheridan, Silverbow, Silver Star, Stevensville, Victor, and Wisdom.

INTENSITY I-III IN IDAHO: Cobalt (about 20 miles southwest of Salmon), and Salmon.

January 5: 23:10, 23:20. Mild shocks felt at Polson, Mont.

January 6: 03:25:53.0*. Flathead Lake area, Mont. V. Felt over approximately 650 square miles of the southwest Flathead Lake region of northwestern Montana. Awakened many and frightened few at Polson. Moderate earth noises heard. Res-

idents reported it was among the three strongest of 47 shocks that "rumbled" through the area in the past six months. No damage resulted from any of the tremors. Intensity IV at Big Arm, Charlo, Dayton, and Hot Springs. Intensity III near Proctor. Recorded by the seismograph at Montana State College, Bozeman, Mont.

January 6: Between 17:30 and 18:00. Walkerville (suburb of Butte), Mont. Two slight shocks; felt only by observer.

January 7: 05:35. Milltown, Mont. Brief shock, followed in about two minutes by a second one.

January 12: 20:44:23.3*. Epicenter 44.9° north, 112.7° west, eastern Idaho, W. Magnitude 3.8. V. At Virginia City, Mont., (Masonic Temple), a shock was felt by all on the second floor. Loose objects rattled; building creaked; light fixtures swayed. Framed wall pictures were knocked askew and other objects were disturbed. Motion bumping, vertical; abrupt onset.

February 3: 04:33:10.5*. Northeastern New Mexico. IV. Press reported the shock was felt at Logan, Nara Visa, and in the Gallegos area (about 30 miles north of Tucumcari). At the Bell Ranch (about 30 miles northwest of Tucumcari), windows and doors rattled; frame creaked. Motion slow, two shakes; each lasted about 1 second. At Logan, awakened and frightened few; windows rattled. Recorded by seismograph at the Coast and Geodetic Survey Seismological Laboratory, Albuquerque, N. Mex.

February 16: 12:52. Northeast Denver, Colo., area. IV. At Commerce City, felt by everyone in area. Slight jolt and shaking; lasted about 3 seconds. Direction, west. Observer reported the shock was felt over about 10 square miles, including Adams City, Commerce City, Dupont, Irondale, and the Rocky Mountain Arsenal.

February 16: 13:17:54*. Epicenter 39.9° north, 105.1° west, Colorado, W.

Magnitude 4.6. IV. Two heavy jolts reported at Adams City, Commerce City, and Henderson. Felt in the east section of Henderson and north section of Commerce City. Moderate earth noises were heard at Eastlake. Motion slow; lasted 2 seconds.

February 16: 15:21:44*. Epicenter 39.9° north, 105.0° west, Colorado, W. Magnitude 4.9. VI. Felt over about 300 square miles of the north Denver region. At Northglenn, a large crack appeared in house; some thought wall cracks were enlarged. At Commerce City, a washer moved from wall and furnishings shifted.

INTENSITY V: Adams City and Eastlake.

INTENSITY IV: Dupont, Henderson, and Rocky Mountain Arsenal.

INTENSITY I-III: Westminster.

March 27: 16:17:38.7*. Epicenter 42.6° north, 111.6° west, eastern Idaho, W. Felt at Soda Springs.

April 6: 07:46:01.2*. Epicenter 45.6° north, 111.9° west, Montana, W. Magnitude 3.7. V. Felt by many at Virginia City. "This shock was very sharp. It ran customers out of the cafe, rattled dishes, and shook down fine plaster around the tin ceiling in the Masonic Temple. Scared a lot of people quite badly." Loud earth noise accompanied shock. Motion horizontal; southeast-northwest.

April 27: 06:50:24*, 06:55. Felt over an area of approximately 450 square miles of the south and southwest Flathead Lake areas of northwestern Montana. V. The shock appeared to be strongest in the Big Arm area, and at Polson and Kerr Dam. A slight aftershock was felt at about 06:55. Recorded by seismograph at the Montana School of Mines, Butte, Mont.

INTENSITY V:

Big Arm.—Felt by all. Dishes rattled. Loud earth noises from northeast heard before shock.

Polson.—Felt by and awakened many; few frightened. Windows and doors rattled; frame creaked. Motion rapid; lasted 10 seconds.

INTENSITY IV: Dayton, Elmo, Kerr Dam, Pablo, and Proctor.

INTENSITY I-III: Ronan.

April 28: Between 19:00 and 21:00. V. At Nordman, Idaho, cans were knocked off shelves. A logger, about 7 miles from here, also experienced earth movement the same evening.

April 29: 02:30, 08:00 (about). Kalispell, Mont. Press reported two mild earthquakes rocked the Flathead Lake area. Signs along the street swayed.

April 30: Early morning. Copeland, Idaho. IV. Felt by and awakened few. A bottle fell into the sink and awakened observer. "Neighbors felt slight vibration and heard windows rattle."

May 2: 19:30:50.1*. Epicenter 36.0° north, 114.7° west, southern Nevada, W. Magnitude 3.9. Felt at Boulder City.

May 11: (1) 11:17:24.0*; (2) 11:32:44*; (3) 13:29:44*; (4) 14:40:34*. Epicenter (1) 44.7° north, 111.0° west, Hebgen Lake region, Mont., W; (2) 44.8° north, 110.5° west, Yellowstone National Park, Wyo., W; (3) 45.0° north, 110.7° west, Yellowstone National Park, Wyo., W; and (4) 44.9° north, 111.2° west, Hebgen Lake region, Mont., W. Magnitude of first shock 4.2. These shocks were all felt at West Yellowstone, Mont. No further details are available.

May 14: 22:25:01.5*. Epicenter 35.9° north, 114.8° west, California-Nevada border region, W. Magnitude 3.8. Felt at Boulder City, Nev.

July 9: 05:19:05.7*, 07:20. Epicenter 45.2° north, 111.6° west, Montana, W. Ennis. III. Felt by several. Two 1-second jolts.

July 18: 14:13, 14:19, 14:40:45*. Epicenter 39.8° north, 104.8° west, Colorado, W. Magnitude 4.6. Commerce City. V. Felt by many in community. Plaque on wall moved out on nail. House creaked loudly. Water disturbed in pan outside. Heavy, double-bouncing jolt; one shift to east felt; moderate earth noises. Shocks

at 14:13 and 14:19 were felt by few. North of Commerce City, several glasses and plates were broken. Also reported felt at Adams City, Arsenal and 2 miles east of, Denver (northeast areas), Dupont, Hazeltine Heights, Henderson, Irondale, Northglenn, Thornton, Welby, and in farmland areas 2 miles east and west of the Platte River.

July 31: 06:41:43*. Epicenter 39.7° north, 104.9° west, Colorado, W. Magnitude 4.6. Commerce City. V. Felt by and awakened many in community. Rapid movement of bed in east direction. Rapid, loud, heavy jolt. Also reported felt at Adams City, Arsenal and to the east, Dupont, Henderson, Irondale, and Welby.

August 9: 08:38, 10:18. Commerce City, Colo. IV. Felt by few in community. Heavy, sharp jolt with loud earth noises, like a rifle shot; lasted about 5 seconds. Also reported felt at Adams City, Arsenal, (small part), and Welby. Some persons at Commerce City heard rumble and felt slight shaking at 10:18.

August 14: 13:52. Commerce City, Colo. IV. Felt by very few in community. Stand rattled. Moderate earth noises. Also reported felt at Adams City (north of), Dupont, Hazeltine Heights, Henderson, and Thornton.

August 18: 08:21. Colorado. IV. At Commerce City, house heaved and creaked; then noise and jolt. House moved to east slightly; then slight shaking for about 3 seconds. Small rock collection in bookcase rattled. One "good" jolt from the northeast or north felt at Henderson. Dizzy sensation felt. Also felt at Dupont and Irondale.

August 27: 13:32, 13:33. Colorado. Commerce City. III. Felt by few in community. Two jolts; slight shaking. Also reported felt at Adams City, Arsenal, Dupont (small part), Henderson, and Irondale (small part). Slight shock also felt at 13:33.

September 2: 12:11. Colorado. IV.

Felt by many at Commerce City. At Thornton, children at school were frightened. Also reported felt at Arsenal, Dupont, Irondale, and Westminster. It was reported that the shock was felt over about a 10-square-mile area. Some persons noted two jolts. Slight shaking; loud-to-moderate earth noises.

September 13: 02:58:17.9*, 04:05. Epicenter 39.8° north, 104.8° west, Colorado, W. Magnitude 4.5. Commerce City. V. Felt by and awakened many; frightened few. Tree shook. Loud earth noise and two heavy jolts; lasted about 5 seconds. Also felt at Adams City, Arsenal and east of, Brighton, Denver (scattered places), Dupont, Henderson, Irondale, Northglenn, Thornton, Welby, and Westminster. Slight shock observed at Commerce City at 04:05.

September 14: 09:36:47*. Epicenter 39.8° north, 104.8° west, Colorado, W. Magnitude 4.7. Felt in the Denver area.

September 14: 14:14. Commerce City, Colo. Felt.

September 14: 15:46:24*. Epicenter 39.9° north, 104.6° west, Colorado, W. Magnitude 4.7. Felt over a considerable area of the Denver region, principally in the Denver-Commerce City area. Maximum intensity VI. Only slight damage—cracked chimneys and plaster and broken dishes and windows—was observed in this minor earthquake.

INTENSITY VI:

Broomfield (about 15 miles northwest of Denver).—Felt by many and frightened few. Chimneys and plaster cracked. Moderate earth noises.

Commerce City-Derby area.—Felt by all and frightened many in community. There were scattered reports of cracked plaster. "Heavy jolts; loud, roaring earth noises."

Denver.—Newspaper office was deluged with phone calls. Plaster cracked; dishes and windows broke.

INTENSITY V: Adams County (1514 West 103rd Place), Boulder, Fort Logan, Idle-dale, and Lafayette.

INTENSITY IV: Adams City, Brighton, Dupont, Erie, Henderson, Lawson, Louisville, Pinecliffe, Rollinsville, South Deer Creek Canyon (about 25 miles southwest of Denver), and Westminster. Reported felt (no details): Arsenal and "for a long way out in the plains to the east of the Arsenal," Aurora, Eastlake, El Dorado Springs, Irondale, Lakewood, Northglenn, Thornton, and Welby.

September 14: 15:53. Commerce City, Colo. Felt.

September 14: 16:16:10*. Epicenter 39.5° north, 104.9° west, Colorado, W. Magnitude 4.8. Commerce City. Felt.

September 15: 00:16. Commerce City, Colo. Felt.

September 27: 03:34*. Colorado. Magnitude 3.3. IV. Felt by and awakened few at Commerce City. Hanging objects swung west-east. Moderate-to-loud earth noise. Also awakened few at Adams City, Arsenal and east of, Dupont, Irondale, Northglenn, Thornton (and in area to east and south), and Westminster. Recorded at the Colorado School of Mines, Boulder, Colo.

September 29: 11:59:56*. Epicenter 39.8° north, 105.1° west, Colorado, W. Magnitude 4.7. Felt over a considerable area of the Denver region, principally at Denver and in the Derby-Commerce City areas to the northeast. Maximum intensity VI. Damage slight. Some plaster cracked; windows and dishes broke.

INTENSITY VI:

Commerce City.—Felt by all and frightened many in community. Plaster and windows cracked. Furniture shifted. Two crashing jolts and shaking.

Denver and vicinity.—Generally felt. Police and newspaper switchboards were flooded with calls. One downtown merchant reported seeing cracks on 15th Street that he was sure were not there before the shock. Portable stereo fell from table; cuckoo clock on wall knocked askew; tele-

phone knocked off desk; knickknacks fell. "Felt like house slid toward the east."

Northglenn.—Refrigerator moved several inches.

INTENSITY V: Boulder, Brighton, and Coal Creek Canyon (about 25 miles from downtown Denver).

INTENSITY IV: Lafayette and Nederland. Reported felt (no details): Adams City, Arsenal and east of, Dupont, Rollinsville, Thornton (also east and south of), Westminster, and Wheatridge.

September 29: 12:02, 12:20:41*, 12:33, 13:08, 16:22:58*. Epicenter of second and fifth shocks 39.8° north, 104.8° west, Colorado, W. Magnitude of second and fifth shocks 4.6. Commerce City. IV. All of the shocks were felt by many. The shock at 16:22:58* was also felt at Denver.

October 8: 12:34:59.4*. Epicenter 44.8° north, 111.1° west, Hebgen Lake region, Montana, W. Magnitude 4.9. V. Sharply felt in the Hebgen Lake-West Yellowstone area, but no damage was reported. Professor Stephen W. Nile, Montana School of Mines, Butte, Mont., visited the area on October 10 and obtained most of the reports on this earthquake from personal interviews.

INTENSITY V:

Hebgen Dam (about 20 miles northwest of West Yellowstone).—Felt by many. Motion slow; lasted about $1\frac{1}{2}$ seconds. Direction, north.

Parade Rest Guest Ranch (on Hebgen Lake).—Felt by all. Windows, doors, and dishes rattled; building creaked. Motion rapid; lasted few seconds. Loud earth noises.

West Yellowstone.—Sharply and generally felt; some frightened. Woman riding in car heard roar and felt two shocks; observed trees shaking in east-west direction. Two jars fell north-south from east-west shelf at one store. About 20 pieces of lumber fell northward from a stack along the east-west wall on the third floor of building.

Loud earth noises heard by many before the shock.

INTENSITY IV: 320 Ranch (about 55 miles south of Bozeman) and Black Butte Ranch (about 63 miles south of Bozeman).

INTENSITY IV IN WYOMING: Yellowstone National Park.

October 8: 13:05. West Yellowstone, Mont. Felt by desk clerk at Stagecoach Inn. Milder than the shock at 12:34:59.4*.

October 9: 12:30 (about). West Yellowstone, Mont. III. Felt by two persons at separate locations. Lamp shade shook.

October 10: 15:39:10.0*. Epicenter 44.8° north, 111.8° west, Hebgen Lake region, Montana, W. Magnitude 4.1. IV. Felt by several at Hebgen Dam. Windows, doors, and dishes rattled. Moderate earth noises from south. Motion slow; lasted $1\frac{1}{2}$ seconds.

October 26: 04:28:04.1*. Epicenter 47.4° north, 113.2° west, northeast of Seeley Lake in western Montana, W. Magnitude 4.0. V. Press reported that the shock was felt from the north end of the Seeley Lake area to about 15 miles south. The shock was accompanied by a roaring noise and residents were awakened; lasted 12–15 seconds. At Ovando, many were awakened and few frightened in community. House creaked. Also felt at Craig (about 75 miles east by south of Seeley Lake), Great Falls, Greenough, Helena, Lindbergh Lake, and Wolf Creek.

November 3: 05:07:55.5*, 05:11:10.6*. Epicenter for both shocks, 45.2° north, 111.9° west, southwestern Montana, W. Magnitudes 4.5 and 3.7, respectively. IV. At Cameron, house shook for about 10 seconds. Described as a very sharp tremor from southeast. "Shock at 05:11 of less intensity."

November 7: 02:25. Commerce City, Colo. IV. Felt by and awakened few. Rumble and slight shaking.

November 14: 10:16*. Commerce City, Colo. Magnitude 1.9. III. Felt by four persons. Rumble; jolt; slight shaking.

Recorded at the Colorado School of Mines, Boulder, Colo.

November 14: 11:45*. Commerce City, Colo. Magnitude 2.5. III. Felt in the Commerce City area. Also felt at Adams City, Arsenal (west of), Dupont, and Thornton. Recorded at the Colorado School of Mines, Boulder, Colo.

November 20: 20:59:59*. Epicenter 39.8° north, 104.8° west, Colorado, W. Magnitude 4.6. Felt in the Denver area.

November 20: 21:02:29*. Epicenter 39.8° north, 104.8° west, Colorado, W. Magnitude 4.5. VI. Felt over approximately 3,000 square miles of northeastern Colorado, principally in the Denver area. One injury was reported. Cracked plaster and broken windows were observed at a few locations.

INTENSITY VI:

Commerce City.—Felt by all and frightened many in community. Plaster cracked and one window broke. Small objects overturned and fell. Two jolts; heavy vibration lasted 10–15 seconds. Loud, rumbling earth noises.

Hudson.—Felt by many; awakened and frightened few. Plaster cracked and fell. Trees and bushes were shaken and vehicles rocked. Small objects shifted, overturned, and fell. Faint earth noises.

Louisville.—Felt by many in community; few frightened. Plaster cracked. Small objects shifted and hanging objects swung. Moderate earth noises.

Northglenn.—Numerous broken windows.

Thornton.—Numerous broken windows.

Westminster.—Felt by many in community. People were startled. Chair staggered and heavy furniture rolled and shook. "Three separate shocks felt. Have not heard of any damage."

INTENSITY V: Adams City, Black Hawk, Dacono, Denver, Dupont, Lafayette, and Spivak ($\frac{1}{2}$ mile south of post office).

INTENSITY IV: Dumont, Eldorado Springs, Erie, Evergreen, Fort Lupton, Foxton, Frederick, Keenesburg, Lyons, Neder-

land, and Rollinsville (1 mile south of on Highway 119).

INTENSITY I-III: Arvada, Bennett, Central City, Fort Logan, Henderson, Idledale, Kitteredge, Morrison, Ward ($\frac{1}{4}$ -mile north of), and Watkins. Reported felt (no details): Aurora, Bergen Park, Boulder and North Boulder, Brighton, Golden, Greeley, Guernsey, Idaho Springs, La Salle, Littleton, Ralston Ranch (northwest Denver area), and Table Mesa.

November 20: 21:08. Felt at Commerce City, Colo.

November 20: 21:24:49*. Epicenter 39.9° north, 104.7° west, Colorado, W. Magnitude 4.4. Felt in the Denver area.

November 20: 22:00:27*. Epicenter 39.8° north, 104.9° west, Colorado, W. Magnitude 4.7. Felt at Commerce City, Eldorado Springs, Lafayette, Louisville, Rollinsville, and Westminster.

November 21: 07:48. Felt at Commerce City, Colo.

November 29: 21:10. Melrose, Mont. III. Felt by observer sitting in strongly built wooden house. Very slight noise. Motion rapid; momentary duration.

December 21: 20:33:31.5*, 21:04:53.0*. Epicenter for both shocks $34^{\circ}09'$ north, $106^{\circ}57'$ west. IV. Windows rattled at Socorro; the intensity was similar to that of a sonic boom according to the press. The J.B. Kelly Ranch, near the center of the disturbance, felt the most severe shock. Also felt at Escondida, Lemitar, and Polvadera, all north of Socorro. Recorded at the New Mexico Institute of Mining Technology, Socorro, N. Mex.

CALIFORNIA AND WESTERN NEVADA

[120th Meridian or Pacific Standard Time]

NOTE: All places mentioned are in California unless otherwise stated.

January 1: 00:04:16.2*. Epicenter 34.0° north, 117.6° west, southern California W. Magnitude 4.5, P. VI. Felt over approxi-

mately 4,000 square miles, principally in Riverside and San Bernardino Counties. Slight damage was reported at Fontana and Lytle Creek.

INTENSITY VI:

Fontana.—The press reported that glassware and dishes broke, the ceiling of a house shattered, and a window cracked. The police station received many calls concerning the disturbance.

Lytle Creek (about 15 miles northwest of San Bernardino).—Cement sidewalk cracked.

INTENSITY V:

Alta Loma.—Many awakened in community. Windows and doors rattled.

Cedarpines.—Felt by all in strongly built wooden houses; many awakened and few frightened in community. Old crack in basement window enlarged. Explosivelike earth noises from north-south heard before shock. Motion rapid; lasted few seconds.

Etiwanda.—Awakened all in home; frightened few. Windows and doors rattled. "Some claim to have felt smaller shocks later on." Motion rapid; lasted 3 seconds.

Lake Arrowhead Village (1 mile northeast of).—Felt by many; awakened observer on first floor of well-built house. Buildings creaked; loose objects rattled; large pine cone fell off shelf. Abrupt onset; jolting motion.

Mira Loma.—Felt by all and frightened few. Windows, doors, and dishes rattled. Moderate earth noises from east heard by many before shock. Motion rapid; lasted 3-4 seconds.

Mount Baldy.—Felt by all and frightened few. Rumble heard. Motion rolling; east-west.

Patton (dairy farm).—Felt by several; awakened and frightened few in home. Windows and doors rattled; small objects shifted. Faint earth noises. Motion rapid.

Rialto.—Felt by several and awakened few. Dishes rattled. Pendulum clock facing north stopped. Faint earth noises

from north-south. Motion slow; lasted 15 seconds.

San Bernardino.—“Frightened no one in our house; some in neighborhood ran to the street. House creaked and groaned; candles swayed. Christmas tree, tied to ceiling with wire, bounced up and down 6 to 8 inches. Small candy canes strung on thread-size wire swung for 4 minutes; hanging lamps swayed west by north to east by south. Water in outdoor bird bath (1 inch from top) did not spill over.” Jolt, followed by small rolls; lasted about 15 seconds.

Sunnymead.—Awakened many; few frightened. Windows, doors, and dishes rattled. Moderate earth noises. Motion rapid; lasted 15 seconds.

Upland.—Felt by several; few awakened in strongly built wooden house. Windows and dishes rattled; hanging objects swung west-east. Pendulum clock stopped; trees, bushes shaken slightly. Faint earth noises from west-east before shock. Motion slow; lasted 1 minute. Direction, west-east.

Winchester.—Felt by observer on first floor of stucco house. Windows, doors, and dishes rattled; house creaked. Small objects and furnishings shifted; trees, bushes shaken slightly. Earth noises from east-west. Motion slow; lasted 3 seconds.

INTENSITY IV: Alberhill, Altadena, Anaheim, Atwood, Bloomington, Chino, Covina, Crestline, El Monte, Elsinore, Forest Falls, Garden Grove, Glendale, Hemet, La Puente, Lucerne Valley, Moreno, Pala, Pearblossom, Phelan, Pinon Hills, Riverside, San Dimas, San Marcos, Santa Ana, Seal Beach, South Gate, Temecula, Wilmington, Wrightwood, and Yorba Linda.

INTENSITY I-III: Buena Park, Claremont, Fullerton, Glendora, Loma Linda, Long Beach, Los Angeles, Ontario, San Jacinto, Sunland, and Warner Springs.

January 1: 11:59:38.2* Epicenter 40.3° north, 124.6° west, off coast of northern California, W. Magnitude 4.8. V. Felt

over an area of approximately 1,500 square miles of Humboldt County.

INTENSITY V:

Honeydew.—Felt by all. Dishes rattled; walls creaked. Motion slow; lasted 3 seconds. Direction, south-north.

Loleta.—Felt by many; frightened few. Windows and doors rattled; house creaked; small objects shifted. Moderate earth noises from east. Motion rapid.

INTENSITY IV: Eureka, Ferndale, Fortuna, and Scotia.

INTENSITY I-III: Blue Lake, Garberville, Kneeland, and Rio Dell.

January 4: 08:17. North Hollywood. Felt.

January 4: 23:32:26*. Epicenter 39.2° north, 120.2° west, northern California, W. Magnitude 3.4, B. Felt over about 500 square miles of Lake Tahoe region. Maximum intensity V at Crystal Bay, Nev.

INTENSITY V:

Crystal Bay (north end of Lake Tahoe). —Awakened all. House creaked. Two shocks, the second being the stronger. Motion slow, brief.

INTENSITY IV: Incline Village and Tahoe City.

INTENSITY I-III: Carson City and Genoa.

January 8: 09:00. Pearblossom. IV. Windows rattled. “Light shocks have been mentioned recently.”

January 12: 19:51:10*. Epicenter 38.1° north, 118.8° west, B. Magnitude 3.7. IV. At Lee Vining, felt by several. Windows rattled. Motion rapid; momentary duration.

January 21: 15:15. Pinon Hills (about 25 miles northwest of San Bernardino). IV. Felt by observer lying down. Windows rattled for about 2 minutes; bed moved very slightly. Also reported felt in the San Bernardino area.

January 28: 13:35:20*. Epicenter 38.0° north, 122.4° west, central California, B. Magnitude 2.5. IV. At Moraga, felt by observer sitting in chair leaning against south wall. House creaked. Faint earth

noises about 1 second before shock. Heard, but not felt, by another person standing. Motion rapid; one jolt. Also felt at East Oakland (no details).

January 28: 17:27:16*. Epicenter 37.7° north, 122.3° west, central California, B. Magnitude $3-3\frac{1}{2}$. IV. Press reported a mild shock in San Francisco Bay area. Police received calls from East Bay residents from Berkeley to Hayward. Also felt widely in San Francisco and as far south as San Bruno. Intensity III reported at Moraga.

January 28: 17:40:48*. Epicenter 36.8° north, 121.2° west, central California, B. Magnitude 3.0. IV. At the Harris Ranch, $7\frac{1}{2}$ miles south of Hollister, felt by several. Windows, doors, and dishes rattled; walls creaked. Earth noises heard before shock. Trees, bushes shaken slightly. Motion rapid. Direction, northwest-southeast.

February 6: 11:20. Pinon Hills (about 25 miles northwest of San Bernardino). IV. Felt by observer sitting. Gentle rolling of house; dizzy sensation reported. Not felt by husband nor neighbor, both active. Motion rolling, gentle; lasted few seconds.

February 12: 02:50:19.7*. Epicenter 40.3° north, 124.9° west, near coast of northern California, W. Magnitude 4.5, B. Felt at the Humboldt Bay Powerhouse in Eureka.

February 19: 09:46:28*. Epicenter $34^{\circ}10.5'$ north, $117^{\circ}28.2'$ west, southern California, P. Magnitude 3.5. V. Felt over about 1,200 square miles of Riverside and San Bernardino Counties, principally in the San Bernardino Valley areas. Police switchboards were flooded with calls from Fontana, Muscoy, Rialto, and San Bernardino.

INTENSITY V:

Cucamonga.—Felt by all. Windows and doors rattled. Moderate earth noises heard. Motion rapid; lasted 3 to 7 seconds.

Muscoy.—Felt by all. Windows, doors, and dishes rattled; frame creaked; small objects shifted. Loud earth noises heard.

Motion slow; lasted 15 seconds. Direction, west.

Patton (Post Office).—Felt by all. Windows rattled. Faint earth noises from north heard. Motion rapid. Direction, north.

San Bernardino.—Press reported that a candle, 2 feet tall and 1 foot in diameter, fell off garage shelf at 239 East 15th Street. At the post office (390 - 5th Street), windows, doors, and dishes rattled and building creaked. Faint earth noises from northwest heard before shock (IV)

INTENSITY IV: Cedar Glen, Etiwanda, Fontana, Forest Falls, Lytle Creek, Norco, and Rialto.

INTENSITY I-III: Moreno and Riverside.

February 24: 23:45. El Centro. IV. Felt by many. Windows and doors rattled. Motion rapid, loud, sharp, and brief.

February 25: 03:21:55*. Epicenter 34.0° north, 117.6° west, San Bernardino Valley, W. Magnitude 4.6. V. At San Bernardino (near mouth of Little Sand Creek Canyon), felt by and awakened many; frightened few. Windows, doors, and dishes rattled; house creaked. Loud earth noises heard. Sharp jolt, rolling; lasted about 3 seconds. At Etiwanda, many were awakened.

February 26: 18:27. San Bernardino (near mouth of Little Sand Creek Canyon). V. Felt by most in community; many frightened. Windows, doors, and dishes rattled; walls and floors creaked slightly. Faint-to-moderate earth noises. Moderate rolling motion; lasted about 3 seconds.

March 8: 14:50:56*. Epicenter 38.7° north, 118.7° west, California-Nevada border region, W. Magnitude 4.5, B. IV. Felt over approximately 2,500 square miles, principally in the Walker Lake region of western Nevada. Windows, doors, and dishes rattled at the Rafter 7 Ranch (near Lewis), and at Yerington, Nev. Felt by many at Hawthorne and Schurz, Nev., where walls creaked. Rapid motion; lasted few seconds. Also reported felt at Cole-

ville, Calif., where houses creaked and faint earth noises were heard.

March 11: No time given. Incline Village, Nev. (north end of Lake Tahoe). Felt.

March 16: 07:45. Eureka. IV. Felt by observer sitting on first floor. Dishes rattled. Motion slow; lasted about 10 seconds. Began and ended gradually. Direction, east-west.

April 6: 02:32:00*. Epicenter $36^{\circ}48'$ north, $121^{\circ}58'$ west, Monterey Bay, B. Magnitude 3.4. IV. At Aptos, felt by observer lying down. Walls creaked. Motion slow; faint earth noises. Awakened few in community at Capitola; rapid motion, very light and brief; duration, less than 1 second. At Santa Cruz (III), felt by several; slow, very brief motion in north direction; faint earth noises from north.

April 6: Between 06:15 and 06:30. Mariposa (on Whitlock Road, 2.2 miles west of Highway 140; just west of Mono Creek and Mono Camp in Mariposa County). Sidewalks cracked. "The sound of the sidewalks cracking awakened my son who got up and looked out the window to the west. My mother heard the noise while listening to the 6:15 a.m. newscast."

April 10: 17:19:10*. Epicenter $37^{\circ}45'$ north, $122^{\circ}15'$ west, near Oakland, B. Magnitude 2.7. IV. Felt by several in separate locations in Oakland; frightened one. Windows rattled. Rapid motion in north-south direction; duration, 2 seconds; moderate earth noises. At South San Francisco, felt by several; very slight creaking of building. Brief duration. Intensity I-III at Moraga, Saint Mary's College, and San Francisco.

April 15: 12:08:31.8*. Epicenter 34.1° north, 117.5° west, San Bernardino Valley, W. Magnitude 4.5, P. Felt over an area of approximately 4,000 square miles of southern California, principally in San Bernardino and Riverside Counties; also felt in several scattered communities of Los Angeles County, including Los Angeles,

and a few scattered places in Orange County. Maximum intensity VI. Slight damage, consisting of cracked plaster and broken windows. Press reported there were broken windows and items shaken from shelves throughout the San Bernardino Valley, including San Bernardino, Fontana, Rialto, Colton, and Chino.

INTENSITY VI:

Fontana.—Felt by all in building; frightened many in community. Damage slight. Plaster and windows cracked. Rapid motion of 3-4 seconds' duration; preceded 1 second by loud earth noises.

Ontario.—Felt by all and frightened many in community. Damage slight. Hot food shifted. Rapid motion in north direction; duration, 5-10 seconds; moderate earth noises.

Rialto.—Felt by and frightened many in community. Plaster cracked and windows broke. Rapid motion in north-south direction; duration, 5 seconds; preceded 5 seconds by loud earth noises.

San Bernardino.—Felt by all and frightened many in community. Plaster cracked. Small objects shifted. Trees and bushes shaken moderately. Motion slow, rapid; duration, 5 seconds to 1 minute; loud-to-moderate earth noises from east few seconds before shock.

INTENSITY V: Bryn Mawr, Cedarpines Park (about 12 miles north of San Bernardino), Chino, Colton, Corona, Crestline, Etiwanda, March Air Force Base (about 8 miles southeast of Riverside), Patton, Riverside, San Bernardino area (some point on highway between Pinon Hills and San Bernardino), and Upland.

INTENSITY IV: Alta Loma, Calimesa, Cedar Glen, Compton, Elsinore, Fullerton, Glendora, Hemet, Hesperia, Homeland, Los Angeles (downtown area), Mountain Center, Mount Baldy, Norco, Norwalk, Pomona, Redlands, San Jacinto, Summit, Valyermo, Winchester, Wrightwood, and Yorba Linda.

INTENSITY I-III: Claremont, Forest Falls

(about 20 miles east of San Bernardino), Hawthorne, Laguna Beach, Lucerne Valley, Manhattan Beach, Pinon Hills (about 25 miles northwest of San Bernardino), Santa Ana, Temecula, and Wildomar.

April 26: 21:19:16*. Epicenter 40.3° north, 124.6° west, near coast of northern California, W. Magnitude 3½, B. Arcata and Eureka vicinity. IV. Felt by several. Windows, doors, and dishes rattled. Motion rapid; settling-type shock; earth noises.

June 3: 08:26:29.0* (main shock), 08:31:02.8*. Epicenter of first shock 38.3° north, 119.2° west; of second, 38.4° north, 119.2° west, California-Nevada border region, W. Magnitudes 4.6 and 4.1, respectively, B. The main shock was felt over an area of approximately 4,000 square miles, principally in northeast-central California. Maximum intensity V at Bridgeport, where dishes broke and pictures fell. Observer at Bridgeport also reported a shock was felt later in the day on June 3 and a slight shock was felt a day or so later, possibly on June 5. The following reports are for the main shock unless otherwise stated.

INTENSITY V:

Bridgeport.—Felt by all and frightened many in community. Dishes broke. Small objects shifted; vases overturned; knick-knacks, books, and pictures fell. Trees and bushes shaken strongly. Rapid motion of 3–4 seconds' duration; preceded less than 1 second by loud earth noises, similar to sonic boom, from southwest. Shock at 08:31 felt by several.

INTENSITY IV: Arnold, Coleville, El Portal, Fresno (downtown area), and Yosemite National Park (Park Headquarters).

INTENSITY I–III: Big Creek, Bodie, Lee Vining, and Wishon.

INTENSITY I–III in Nevada: Hawthorne (Naval Ammunition Depot; also felt shock at 08:31).

June 10: 09:36:26*. Epicenter 38.2° north, 119.5° west, B. (Aftershock of June 3). Magnitude 3.5. Bridgeport. IV. Felt

by several. Heavy jolt; duration, 2–3 seconds; moderate earth noises.

June 13: 19:11. Eureka (PG&E Humboldt Substation). Slight shock.

June 15: 16:55:09.6*. Epicenter 33.0° north, 115.5° west, southern California, W. Magnitude 4¼–4½, P. Felt at Brawley, Calipatria, and Westmorland.

June 15: 18:42:04.3*. Epicenter 33.0° north, 115.5° west, southern California, W. Magnitude 4½, P. This was the main shock of the Imperial Valley series that occurred on June 15, 16, and 17. The felt area was on the order of 1,000 square miles. VI. At Westmorland, one press report stated the heaviest damage consisted of a broken plate-glass window and broken dishes. Another account stated that several buildings were damaged, including a hotel and city firehouse. At Imperial, walls were cracked.

INTENSITY VI:

Brawley (about 7 miles southeast of Westmorland).—Felt by and frightened all in community. Dishes fell from shelves in some buildings.

Imperial.—Felt by many and frightened few. Walls cracked; small objects shifted. Slow motion in north-south direction; brief duration; faint earth noises.

Westmorland.—Felt by many; frightened all in home. Damage slight. One press report stated the heaviest damage consisted of a broken plate-glass window at a cafe and a set of dishes which toppled to the floor at another cafe. Another press report stated several buildings were damaged, including a hotel and city firehouse, but no injuries were reported. Small objects shifted and overturned. Motion rapid; loud earth noises.

INTENSITY V: Calipatria and Weiman Ranch (7 miles west of Brawley).

INTENSITY I–III: Holtville, Mount Laguna, Plaster City, and Ripley.

June 15: 19:47:09.8*. Epicenter 33.0° north, 115.6° west, southern California, W. Magnitude 3¾, P. Felt at Brawley and

Westmorland. Light shock at Weiman Ranch (7 miles west of Brawley).

June 16: 01:35:16.7*. Epicenter 33.0° north, 115.5° west, southern California, W. Magnitude $3\frac{3}{4}$, P. Weiman Ranch (7 miles west of Brawley). Light shock.

June 16: 06:04:23*. Epicenter 33.0° north, 115.6° west, southern California, W. Magnitude $3\frac{1}{2}$, P. Weiman Ranch (7 miles west of Brawley). Light shock.

June 16: 07:56:04.8*, 09:40:33.4*. Epicenter 33.0° north, 115.6° west, southern California, W. Magnitude $3\frac{3}{4}$, P. Felt at Brawley and Westmorland.

June 16: 23:30:19.1*. Epicenter 33.0° north, 115.5° west, southern California, W. Magnitude $4\frac{1}{2}$, P. Felt at Brawley, Calipatria, and Westmorland; also felt (III) by several at El Centro, where hanging objects swung. Motion slow; duration, 2 minutes; direction, north-south.

June 16: 23:40:11.2*. Epicenter 33.1° north, 115.6° west, southern California, W. Magnitude $4\frac{1}{4}$, P. Felt at Brawley, Calipatria, and Westmorland.

June 17: 01:53:59*. Epicenter 33.1° north, 115.7° west, southern California, W. Magnitude $3\frac{1}{2}$, P. Felt at Brawley, Calipatria, and Westmorland.

June 28: 03:15:12.1*. Epicenter $37^{\circ}31'$ north, $121^{\circ}45'$ west, central California, B. Magnitude 3.7. IV. At Livermore, felt by many; awakened few in home. Two rapid jolts. At the Vallecitos Reactor, near Pleasanton, seismic switch was tripped. At Milpitas, a few "thought they felt a slight shock."

July 3: 07:35:31.4*. Epicenter 36.8° north, 121.5° west, central California, B. Magnitude 2.6. Hollister ($7\frac{1}{2}$ miles south of, Harris Ranch). IV. Very light shock felt by observer sitting. Windows, doors, and dishes rattled.

July 14: 00:26:45.9*. Epicenter 39.0° north, 117.6° west, Nevada, W. Magnitude 3.9. IV. At Fallon, felt by observer (awake); dishes rattled; frame walls creaked. Awakened few at Frenchman

Station, where moderate earth noises were heard. At Nevada Scheelite Mill, felt by several; awakened and frightened few. Windows rattled. Motion slow; gentle shaking.

July 15: 17:18:24.2*. Epicenter 34.1° north, 117.4° west, southern California, W. Magnitude 4.1. San Bernardino (San Bernardino Valley College). IV. Felt by many. Windows and doors rattled; walls creaked. Rapid motion in northwest direction; duration, 4–5 seconds; faint earth noises. Also felt by several at Etiwanda; brief duration.

July 15: 23:46:21.5*. Epicenter 34.4° north, 118.6° west, southern California, W. Magnitude 4.5. Felt over an area of approximately 3,000 square miles of Kern and Los Angeles Counties. Maximum intensity VI at Saugus where stucco was cracked.

INTENSITY VI:

Saugus (Sunshine Tract).—Felt throughout the Tract. Stucco cracked in several places; old cement-slab crack extended in garage. Jars toppled on shelves in garage. Trees shook; vehicles rocked; hanging objects swung. Twisting type of motion; rumbling earth noises followed by violent explosivelike sound. "I am an exceptionally heavy sleeper, but with first sound of shock I was out of bed."

INTENSITY V: Acton, Castaic, Glendale, La Canada, Lake Hughes, Lancaster (west of, Fairmont Station area), Los Angeles, Newhall, and Palmdale.

INTENSITY IV: Altadena, Arvin, La Crescenta, Lancaster, Northridge, Olive View, San Fernando, South Gate, South Pasadena, Sun Valley, Tehachapi, and Tujunga.

INTENSITY I–III: Frazier Park and Keene.

July 18: 11:03:43.3*. Epicenter 36.6° north, 121.6° west, central California, B. Magnitude 3.6. Hollister ($7\frac{1}{2}$ miles south of, Harris Ranch). IV. Felt by all in home and by some outdoors. Windows, doors, and dishes rattled; house creaked. Slow motion in northeast-southwest direc-

tion; duration, 15 seconds; preceded 2 seconds by faint earth noises.

July 19: 13:45:02*. Epicenter 40.8° north, 125.5° west, off coast of northern California, W. Magnitude 4.5. Eureka. IV. Felt by observer, active. Windows rattled. Rapid motion in south-north direction; few seconds' duration. "The other shock in late afternoon, around 5 p.m., was not noticed in our vicinity."

July 29: 19:01:32*. Epicenter 33.5° north, 119.7° west, off coast of southern California, W. Magnitude 4.3. Felt over an area of approximately 600 square miles of Ventura County. Maximum intensity V. Slight plaster cracking reported from one place at Port Hueneme; cans fell from grocery store shelves at Oxnard.

INTENSITY V:

Oxnard.—Felt by all and frightened many in community. Cans fell from grocery store shelves. Small objects shifted and overturned. Hanging objects swung moderately. Motion rapid; one large jolt; accompanied by loud earth noises.

Port Hueneme.—Felt by two in home. Plaster cracked slightly. Hanging fixtures swung moderately. Swaying motion; accompanied by earth noises like gust of wind.

Somis.—Felt by all in community. Small objects shifted. Hanging objects swung moderately; building creaked severely. Trees and bushes shaken.

INTENSITY IV: Santa Paula, Saticoy, and Ventura.

August 13: 05:46:15*. Epicenter 34.4° north, 119.7° west, southern California, W. Magnitude 4.3. IV. Felt by many at Carpinteria. House creaked slightly. Brief duration. At Santa Barbara, felt by several. House creaked slightly. Moderate motion of 3 seconds' duration. "Felt like a typical little Santa Barbara earthquake."

August 13: 08:19:27.7*. Epicenter 36.7° north, 121.6° west, central California, B. Magnitude 2.8. Hollister (7½ miles south of, Harris Ranch). IV. Felt by

observer sitting. House creaked very slightly. Motion slow, brief; faint earth noises.

August 15: 15:06:53.2*. Epicenter 36.5° north, 121.2° west, central California, W. Magnitude 3.2, B. Paicines. Felt in the Emmet District east of Paicines and at the Melendy Ranch, southeast of Paicines, on the San Benito River in Willow Creek District.

August 22: 19:50:12*. Epicenter 36.7° north, 121.5° west, central California, B. Magnitude 2.6. Hollister (7½ miles south of, Harris Ranch). IV. Felt by observer sitting. Windows and doors rattled; house creaked. Hanging objects swung northeast. Motion slow; brief duration.

August 26: 05:38:13.1*. Epicenter 33.2° north, 116.0° west, southern California, W. Magnitude 4½, P. Felt at Indio.

September 10: 06:55:14.9*. Epicenter 34.4° north, 117.6° west southern California, W. Magnitude 3.9. Pinon Hills (about 25 miles northwest of San Bernardino). IV. Felt by two in cafe on Highway 138. Cafe shook.

September 10: 13:28:35*. Epicenter 38°00' north, 121°54' west, central California, B. Magnitude 4.8. Felt over an area of approximately 3,000 square miles of the San Francisco Bay region, principally in Contra Costa County. Maximum intensity VI. Damage slight. Slight window breakage at Concord and Pittsburg; slight plaster cracking at Clayton; chimneys cracked at Cowell. At Mount Diablo, minor rockslides were observed and a few rotted limbs broke off trees.

INTENSITY VI:

Clayton.—Felt by all and frightened few in community. Damage very slight. Plaster cracked. Some articles fell in grocery store. Furniture shifted; small objects shifted, overturned, and fell. Trees, bushes shaken; vehicles rocked. Shaking and several severe shocks, seemed in north-south direction; faint earth noises. "It was very

severe in all of the Clayton area near the foot of Mount Diablo."

Concord.—Felt by all and frightened few. Windows broke in two houses. Radio station tower swayed. Ceiling lights swung. Loud earth noises heard.

Cowell.—Felt by all and frightened few in community. Chimneys cracked. Dishes broke; plates fell off stand. House shook very strongly. Rumbling earth noises heard.

Mount Diablo State Park (Ranger Station, summit of Mount Diablo).—Minor rockslides. Trees shook; few rotted limbs broke off. Figurines overturned.

Mount Diablo (east side).—Refrigerator moved; pictures turned on walls. Motion seemed east-west.

Pittsburg.—Felt by many and frightened few. Large display window shattered in furniture store; window broke at shop. Building shook violently several times. Hanging objects swung moderately north-south. Very loud, explosivelike earth noise accompanied the shock.

Pleasant Hill.—Felt by many and frightened few in community. Furniture shifted.

INTENSITY V: Alamo, Benicia, Bethel Island, Daly City, Danville, Diablo, Lodi, Martinez, Port Costa, Saint Mary's College, and Walnut Creek.

INTENSITY IV: Antioch, Bolinas, Brentwood, Byron, Canyon, Courtland, Isleton, Lafayette, Lagunitas, Livermore, Morgan Hill, Oakley, Orinda, Pinole, Pleasanton, San Francisco, San Gregorio, San Ramon, Sunol (near, on Vallecitos Road), and Walnut Grove.

INTENSITY I-III: Berkeley, Crockett, Fremont, Hayward, La Honda, Mill Valley, Moraga, Pacifica, San Mateo, and Sunol.

September 14: 01:09:24*. Epicenter 36.6° north, 121.3° west, central California, B. Magnitude 4.0. Felt principally in the Hollister-Salinas area. Maximum intensity V. Windows cracked at ranch south of Hollister.

INTENSITY V:

Harris Ranch ($7\frac{1}{2}$ miles south of Hollister).—Felt by and awakened all in home. Windows, doors, and dishes rattled; house creaked. Sharp shock.

Hollister.—Felt by and awakened many in community; frightened few. Windows, doors, and dishes rattled; jail shook.

Libby Ranch (about $2\frac{1}{2}$ miles southwest of Paicines).—Felt by all in community; awakened all in home. Doors rattled; house "groaned." Hanging objects swung moderately. Fairly severe; brief duration.

Mills Ranch (7391 Cienega Road, south of Hollister).—Felt by and awakened many in community. Damage slight. Windows cracked. Loud earth noises heard.

Paicines.—Felt by, awakened, and frightened all in home. Windows rattled; house creaked (strong twists). Hanging objects swung moderately.

W. A. Taylor Winery (about 9 miles south of Hollister).—Felt by and awakened many. Windows, doors, and dishes rattled; house creaked slightly.

INTENSITY IV: Salinas and Tres Pinos.

INTENSITY I-III: Monterey.

September 15: 20:10:22.8*. Epicenter 40.4° north, 125.7° west, off coast of northern California, W. Magnitude 5.6. IV. Felt by several at Eureka where windows rattled and walls creaked. Slow motion of 5 seconds' duration; faint earth noises. At Ferndale, felt by several. House creaked; bushes shook. Slow motion of 2 minutes' duration. Felt by many at Petrolia; brief duration. Felt by several at Scotia. Walls creaked. Slow motion of 30 seconds' duration. Intensity I-III at Fortuna and Whitethorn.

September 19: 07:42:09.7*. Epicenter 35.9° north, 120.1° west, south-central California, W. Magnitude 4.9. Felt over an area of approximately 3,500 square miles of south-central California, principally in Kings County. Maximum intensity V.

INTENSITY V:

Armona.—Awakened many in community. Small objects shifted.

Avenal.—Felt by and frightened all in community. Trees, bushes shaken; vehicles rocked. Windows, doors, and dishes rattled; houses creaked.

Cholame area (sec. 24, T. 27 S., R. 17 E.).—Felt by and awakened few. Furniture shifted slightly. Hanging objects swung north-south. Windows, doors, and dishes rattled; house creaked slightly.

Kettleman City.—Felt by all in community. Windows, doors, and dishes rattled; house creaked.

Stratford.—Felt by, awakened, and frightened all in home. Windows, doors, and dishes rattled. Moderate earth noises heard.

INTENSITY IV: Huron, Laton, Lemoore, Riverdale, Walti Ranch (in Slack Canyon, about 8 miles northwest of Parkfield), and Wishon.

INTENSITY I-III: Five Points, Hanford, Parkfield Route (east of San Miguel), and Visalia. Reported felt (no details): Burrel, Coalinga, and Fresno.

September 19: 09:20:49*. Epicenter 36.6° north, 121.4° west, central California, B. Magnitude 2.3. Harris Ranch ($7\frac{1}{2}$ miles south of Hollister). IV. Felt by several. Very faint motion. Windows rattled.

September 19: 17:15:48*. Epicenter 37.8° north, 122.2° west, west-central California, B. Magnitude 3.4. V. At Oakland, felt by several. Small objects shifted. Telephone poles and wires "got a good shake." Slow motion in north-south direction; duration, 30 seconds. Felt with intensity IV at Berkeley and Canyon; intensity I-III at Albany, El Cerrito, Lafayette, and San Francisco.

September 22: 13:49:25.9*. Epicenter 37.4° north, 118.6° west, northwest of Bishop, W. Magnitude 4.3, B. Felt over an area of approximately 4,500 square miles of east-central California. Sparsely pop-

ulated epicentral area. Maximum reported intensity IV. At Benton, felt by few in community; windows and doors rattled; moderate earth noises. Felt by many in community at Big Creek; windows, doors, and fluorescent light fixtures rattled; two distinct shocks. Felt by observer and others outdoors at the Control Gorge Power Plant at Bishop; windows and doors rattled; trees, bushes shaken slightly; rapid motion, accompanied by moderate earth noises. At Dunlap, felt by many; felt chair move; windows and doors rattled. Felt by very few at June Lake; hanging objects swung violently northeast-southwest; windows, doors, and dishes rattled. In Kings Canyon National Park at Cedar Grove, felt by observer sitting. Windows, doors, and dishes rattled; walls creaked; trees, bushes shaken slightly. Slow motion of 30 seconds' duration. At Grant Grove in the Park, felt by and frightened few. Windows rattled; slow motion in northwest direction; duration, 20 seconds. Felt by few at Miramonte. Windows, doors, and dishes rattled slightly. Felt by very few at Yosemite National Park. Windows rattled; floor shook. Intensity I-III at Big Pine and Long Valley Dam (Crowley Lake, about 25 miles northwest of Bishop). Also felt at Bishop (no details).

September 25: Early morning. Boron. Slight, but definite shock felt by observer.

September 25: 09:43:44* (main shock), 09:48:01*. Epicenter of first shock, $34^{\circ}43'$ north, $116^{\circ}30'$ west; of second, close to that of the main shock, but less definite due to seismograms being disturbed by the first earthquake, P. Magnitudes 5.3 and 5.0, respectively. The main shock was felt over an area of about 25,000 square miles of southern California, southern Nevada, and along the Colorado River area of Arizona (see fig. 5). A maximum intensity VII was observed at the Camp Cady Ranch, about 4 miles south of Manix Station. Here the flow of a spring was affected, first increasing and then decreasing. A

large dust cloud was reported at Pisgah Crater about 18 miles west of Ludlow. At Hodge, an underground water tank was cracked, and at Kelso, plaster cracked and fell. Gas pipes were damaged at Newberry, causing an explosion. It was reported that a geology class examined the epicenter area October 16–17 without finding any identifiable surface effects.³

On April 10, 1947, a magnitude 6.8, intensity VII earthquake occurred at $34^{\circ}58'$ north, $116^{\circ}32'$ west, very near the epicenter of the present shock. Although the earlier earthquake was of larger magnitude and was felt over a much wider area (75,000 square miles), it is noteworthy since these are the only intensity VII earthquakes of recorded history with epicenters in this immediate vicinity.

The following reports are for the main shock at 09:43:44* unless otherwise noted:

INTENSITY VII:

Camp Cady Ranch (about 4 miles south of Manix Station).—Felt by and frightened observer. Furniture shifted and everything rattled. Trees and bushes shaken; vehicles rocked. "I operate the Camp Cady Ranch. After the earthquake, my spring flowed four times as much water for three days; then the water decreased to less than normal. One well has flowed about 4 gallons a minute since 1929; now it has stopped flowing."

INTENSITY VI:

Hodge (about 12 miles southwest of Barstow).—Felt by many. Underground water tank cracked. Windows, doors, and dishes rattled; house creaked strongly. "Two shocks close together. Felt another around midnight."

Kelso (Union Pacific Railroad Station).—Felt by all and frightened many. Plaster cracked; furniture moved; small objects fell. Trees and bushes shaken; vehicles rocked. Another report stated that plaster cracked and fell, but damage was slight.

Ludlow.—Felt by all. Small objects fell; windows, doors, and dishes rattled; trees and bushes shaken; vehicles rocked. Light poles and wires swayed and earth noises heard. Lighter shock felt at 09:48:01*.

Newberry.—Felt by many in community. "One cracked cement floor. May have some broken gas pipes. Man lighting gas furnace next day was badly burned by explosion. Many leaks were apparent at that house when the outside valve was turned off, so it is thought the shock broke or loosened the pipes." Small objects fell; vehicles rocked.

Paradise Springs (northeast of Barstow).—Earthquake affected the flow of a warm spring, which became intermittent. Cold springs were not affected.

Pisgah Substation (15 miles west of Ludlow).—Felt by and frightened the security officer (only person at substation). Large dust cloud observed at Pisgah Crater, 3 miles west of the substation. Small objects shifted, overturned, and fell. Hanging objects bounced up and down. Sudden, brief, severe shock accompanied by loud earth noises. Lighter shock at 09:48:01*.

INTENSITY V: Amboy, Apple Valley, Baker, Barstow (shock also felt at 09:48:01*), Big Bear City, Cadiz (shock also felt at 09:48:01*), Hinkley, Lucerne Valley, Needles, Phelan (shock also felt at 09:48:01*), Twentynine Palms (shock also felt at 09:48:01*), Valyermo (shock also felt at 09:48:01*), Vidal (shock also felt at 09:48:01*), Yermo, and Yucca Valley.

INTENSITY V IN ARIZONA: Bullhead City and Davis Dam.

INTENSITY V IN NEVADA: Paradise Valley (southeast Las Vegas suburb).

INTENSITY IV: Adelanto, Alberhill, Altadena, Angelus Oaks, Boron, Cantil, Cedar Glen, China Lake, Cima, Claraville area (Bodfish Road), Fawnskin (shock also felt at 09:48:01*), Fenner (shock also felt at 09:48:01*), Glendora, Hesperia, Joshua Tree (also 09:48:01*), Lake Arrowhead, La

³ Lander, James F., "Seismological Notes," *Bull. Seism. Soc. Amer.*, vol. 56, No. 2, p. 611, 1966.

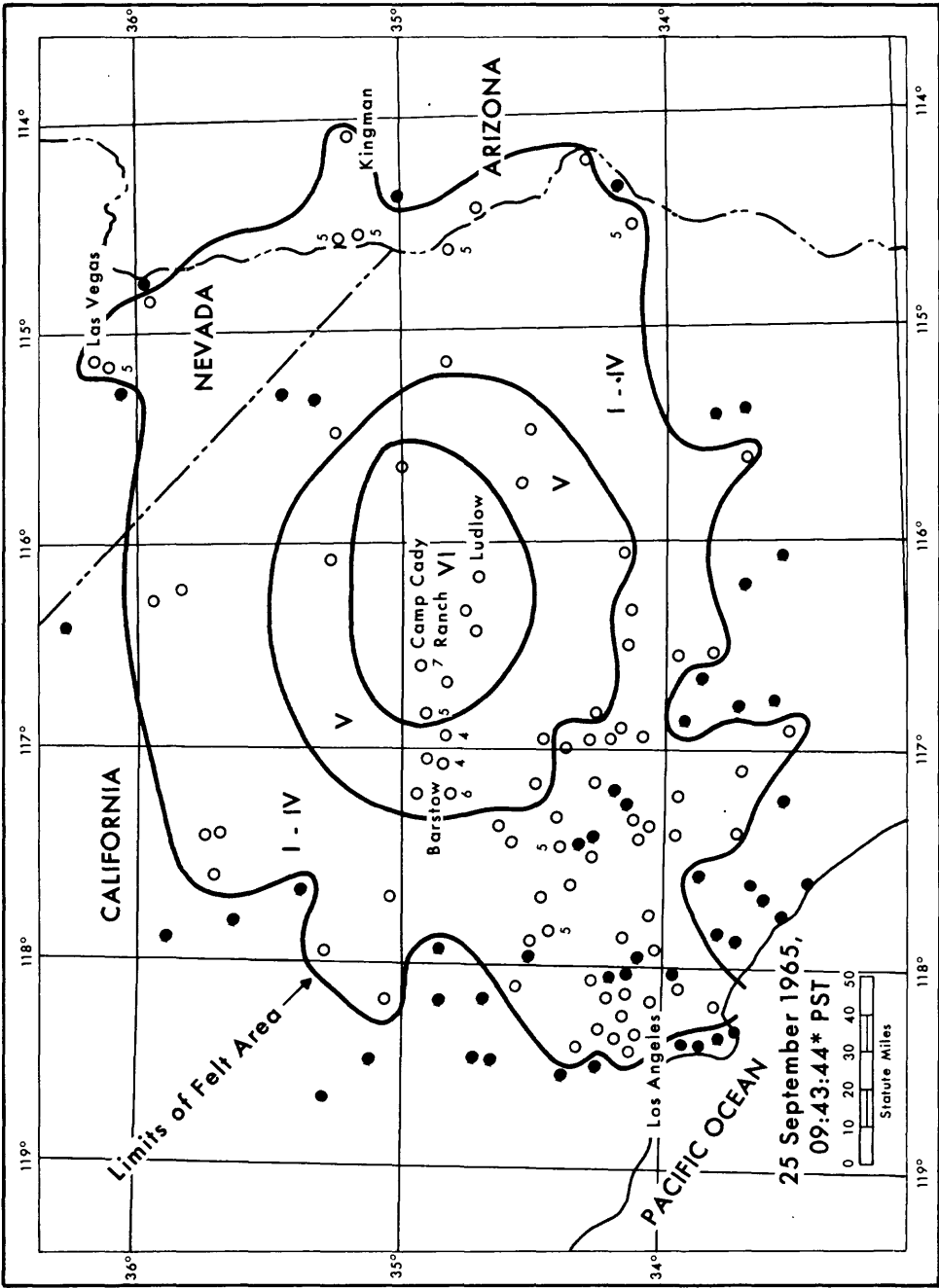


FIGURE 5.—Area affected by southern California earthquake of September 25.

Puente, Lenwood, Lytle Creek, Moreno, North Hollywood, Oro Grande, Parker Dam, Pearblossom area (corner Valyermo Road and Bob's Gap Road; light shock at 09:48:01*), Pinon Hills (milder shock at 09:48:01*), Pioneertown, Riverside, Sherman Oaks, Sierra Madre, Tecopa, Trona, Wild area (about 10 miles up the Mojave River at Silver River Ranch), Wrightwood, and Winchester.

INTENSITY IV IN ARIZONA: Topock.

INTENSITY IV IN NEVADA: Boulder City.

INTENSITY I-III: Aguanga, Big Bear Lake, Colton, Desert Center (12 miles west-northwest of), Forest Falls, Glendale (lesser shock at 09:48:01*), Hollywood, Long Beach, Los Angeles, Maywood, Mojave, Morongo Valley, Palmdale, Palm Springs, Pomona, Rialto, San Bernardino, Shoshone, South Pasadena, Sunland, Victorville, and Westend (near Dry Lake).

INTENSITY I-III IN ARIZONA: Kingman.

INTENSITY I-III IN NEVADA: Las Vegas.

September 25: 09:50. Pisgah Substation (15 miles west of Ludlow). Slight shock.

September 25: 18:37:51.7*. Epicenter 34.7° north, 116.4° west, southern California, W. Magnitude 3.4, P. Well-defined shock felt at Pisgah Substation. Also felt at Barstow and Pasadena.

September 25: 23:00:02*. Epicenter $34^{\circ}43'$ north, $116^{\circ}31'$ west, southern California, P. Magnitude 5.0. Felt over a large area of southern California, awakening many persons at widely separated localities. V. Awakened all at Kelso. Awakened many at Angelus Oaks, Barstow, Big Bear City, Forest Falls, Lucerne Valley, Newberry, Phelan, Wild area (about 15 miles southwest of Barstow), Wrightwood, and Yermo. Sharp shock at Pisgah Substation. Felt with intensity IV at Daggett, Fawnskin, Hemet, Hesperia, Lake Arrowhead, Ludlow, Lytle Creek, Pinon Hills (about 25 miles northwest of San Bernardino), Twentynine Palms, and Victorville. Intensity I-III at Glendora, La Puente, and Pasadena. Also felt (no

details) at Adelanto, Elsinore, Fenner, Fontana, Highland Park, Hodge, Hollywood, Long Beach, Los Angeles, Pioneertown, Riverside, Sierra Madre, and Vidal.

September 72: 05:32:59*. Epicenter 37.2° north, 121.7° west, central California, B. Magnitude 3.1. Felt at Mount Hamilton.

September 27: No time given. Valyermo. "There have been three or four other shocks felt since September 25. The last one was on September 27. They were all mild and felt only by persons sitting or lying still."

September 29: 19:07. San Diego (Point Loma area). III. Felt by two in home. Three distinct jolts from southeast, like subterranean explosions or settling shocks; duration, 2 seconds.

October 5: 20:47, 20:58. Malibu. IV. Felt by several in home. Windows rattled. Motion slow; duration of first shock, 5 seconds; second shock, 1 second; preceded 1-2 seconds by faint earth noises from northwest.

October 7: 23:08:49.2*. Epicenter $37^{\circ}53'$ north, $122^{\circ}20'$ west, central California, B. Magnitude 2.4. Berkeley. IV. Felt by several and awakened few in the Kensington area. Very light, brief tremor. Either the noise or shaking awakened observer in central section of Berkeley; moderate earth noises. Also felt at Oakland.

October 8: 18:26:59.3*. Epicenter $37^{\circ}53'$ north, $122^{\circ}20'$ west, central California, B. Magnitude 2.2. Berkeley. III. Felt by observer sitting. Doors creaked very slightly. Faint earth noises heard.

October 10: 15:23:11.3*. Epicenter $34^{\circ}08'$ north, $117^{\circ}27'$ west, southern California, P. Magnitude 3.7. V. Widely felt, principally in Riverside and San Bernardino Counties.

INTENSITY V:

Bloomington.—Felt by all and frightened few in community. Small objects shifted. Trees and bushes shook; flowerpots

bounced. Hanging objects swung east-west. Motion seemed vertical; loud earth noises.

Crestline.—Felt by all. Trees, bushes shook; vehicles rocked slightly. Hanging objects swung moderately. Faint earth noises heard.

Fontana.—Felt by all. Windows, doors, and dishes rattled.

Mount Baldy.—Felt by all in community.

Pedley.—Felt by all in community. Windows, doors, and dishes rattled.

West Covina.—Awakened two. Pictures knocked askew; knickknacks on shelf shifted. Windows rattled; furniture creaked. Sharp jolt in northeast-southwest direction; duration, about 2 seconds.

INTENSITY IV: Arrowbear Lake, Colton, Etiwanda, Hesperia, Lytle Creek, Ontario, Phelan, Pinon Hills, Rialto, Riverside, San Jacinto, Summit, and Valyermo.

INTENSITY I-III: Angelus Oaks, Chino, Forest Falls, Loma Linda, San Bernardino, and San Dimas. Reported felt (no details): Devore and Muscoy.

October 13: 22:30. Twentynine Palms. IV. Felt by many and awakened few in community. Window curtains moved. Slow motion of 3 seconds' duration; preceded 2 seconds by four thudlike earth noises about 1-2 seconds apart.

October 17: 00:25. Berkeley. IV. Felt by and awakened few in community. Windows rattled. Moderate earth noises heard.

October 17: 01:45:19*. Epicenter $33^{\circ}58.5'$ north, $116^{\circ}46.5'$ west, southern California, P. Magnitude 4.7. Felt over an area of approximately 6,000 square miles of southern California, principally in Riverside and San Bernardino Counties. Maximum intensity VI. Slight damage. At Palm Springs, windows cracked; chinaware fell and broke. At Cathedral City, about 5 miles southeast of Palm Springs, garden wall cracked.

INTENSITY VI:

Cathedral City.—Felt by and awakened all in community; frightened many. Damage slight. Garden wall cracked.

Small objects shifted. Hanging objects swung violently. Moderate earth noises heard.

Palm Springs.—Felt by and awakened two in home. Police received calls reporting minor damage due to cracked windows and fallen chinaware. Moderate earth noises heard.

INTENSITY V: Angelus Oaks, Anza, Beaumont, Big Bear City, Bryn Mawr, Colton, East Highlands, Fallbrook, Fontana, Forest Falls, Highland, Homeland, Idyllwild, Lake Arrowhead, Lucerne Valley (1 mile south of Highway 18), Moreno, Mountain Center, Ontario, Perris, Riverside, San Bernardino, Twin Peaks, Wildomar, Winchester, and Yucca Valley.

INTENSITY IV: Aguanga, Alberhill, Calimesa-Yucaipa, Hemet, Lakeview, Norco, Pala, Pauma Valley, Redlands, San Diego, San Juan Capistrano, and Warner Springs.

INTENSITY I-III: Alta Loma, Rancho Mirage, San Jacinto, and Trabuco Canyon. Reported felt (no details): Alhambra, Banning, Desert Hot Springs, Hollywood, Indio, and South Pasadena.

October 17: 06:49. Felt at Riverside.

October 17: 07:36:53*. Epicenter $34^{\circ}00'$ north, $116^{\circ}48.5'$ west, southern California, P. Magnitude 3.8. Felt at Big Bear City, Palm Springs, Riverside, and San Bernardino.

October 17: 08:10 or 08:15. Felt at Riverside and Yucca Valley.

October 18: 04:19:59.7*. Epicenter $37^{\circ}54'$ north, $122^{\circ}20'$ west, central California, B. Magnitude 2.9. At Alameda, felt by and awakened many in community; house creaked slightly; faint earth noises. At Berkeley, felt and awakened all in homes at separate locations; windows rattled; frame creaked. Rolling motion followed by short, sharp vibration; loud, rumbling earth noises. At Oakland felt by, awakened, and frightened many; windows rattled; hanging objects swung moderately; bump, preceded few seconds by slight noise. Felt by and awakened all in home at

Orinda; one big bump; felt like car had hit south end of the house. Felt by and awakened all in home at Piedmont; windows, doors, and dishes rattled; house creaked; rolling, jolting motion. Felt with intensity IV at Albany, Moraga, San Francisco, and South San Francisco. Intensity I-III at Canyon and El Cerrito.

October 21: 00:43:02*. Epicenter $33^{\circ}59'$ north, $116^{\circ}45'$ west, southern California, P. Magnitude $3\frac{1}{2}$. Widely felt in southern California, principally in Riverside and San Bernardino Counties. Maximum intensity VI. Slight damage. At Coachella, plaster cracked slightly; at Yucaipa, cement shifted.

INTENSITY VI:

Coachella.—Felt by and awakened all; frightened many in community. Damage slight. Plaster cracked slightly. Small objects and furniture shifted. Hanging objects swung moderately. Trees, bushes shook; vehicles rocked. Moderate earth noises heard.

White Water.—Felt by and awakened all in community; frightened few. Small objects swung violently. Moderate earth noises heard.

Yucaipa.—Awakened and frightened many in community. Damage slight. Cement shifted. Small objects shifted. Hanging objects swung moderately. Moderate earth noises heard.

INTENSITY V: Cabazon, Desert Hot Springs, Idyllwild, Indio, La Quinta, North Palm Springs, Oceanside, Thermal, Twentynine Palms, Valley Center, and Winchester.

INTENSITY IV: Aguanga, Anza, Escondido, Mecca, Nuevo, Palm Springs, Romoland, and San Jacinto.

INTENSITY I-III: Mountain Center and Perris.

October 21: 17:41:34*. Epicenter $34^{\circ}08.5'$ north, $117^{\circ}26.5'$ west, southern California, P. Magnitude $3\frac{1}{4}$. Felt in San Bernardino and vicinity.

October 25: 08:50:08*. Epicenter $37^{\circ}43'$ north, $122^{\circ}34'$ west, offshore near

Fort Funston, southwest of San Francisco, B. Magnitude 2.9. San Francisco. V. Sharp, explosivelike shock awakened observer in the Richmond District, where five books fell off shelf; objects fell off cabinet; pictures were knocked askew. Sharply felt at the San Francisco State College in the Lake Merced area.

October 28: 18:49. Aptos (3.7 miles north of). III. Mild jolt in east-west direction felt by observer; duration, fraction of second.

October 31: 13:56:16*. Epicenter $34^{\circ}13'$ north, $117^{\circ}23'$ west, southern California, P. Magnitude $3\frac{1}{2}$. Felt at Devore and San Bernardino.

November 2: 04:41:01.5*. Epicenter 33.4° north, 116.1° west, southern California, W. Magnitude 3.7, P. Thermal. IV. Felt by several and awakened few. Brief jerk, accompanied by faint earth noises.

November 7: 19:30:01.1*. Epicenter $40^{\circ}00'$ north, $121^{\circ}22'$ west, northern California, B. Magnitude 3.4. Caribou (Caribou Powerhouse, near Belden, Plumas County). III. Felt by few. Trembling motion. Also felt by resident at Caribou Camp and at Rock Creek Powerhouse, near Storrie.

November 10: 13:01:35.3*. Epicenter $34^{\circ}04'$ north, $118^{\circ}35'$ west, southern California, P. Magnitude 3.2. Felt at Hollywood, in the San Fernando Valley, and at Santa Monica.

November 12: 15:55:09.6*. Epicenter 34.0° north, 118.2° west, southern California, W. Magnitude 3.0, P. Felt over approximately 800 square miles of southwestern Los Angeles County. Maximum intensity VI. At Glendale, plaster cracked slightly. There were some minor concrete cracks on the 30th floor of the Occidental Center Building in Los Angeles.

INTENSITY VI:

Glendale.—Felt by many and frightened few in community. Damage slight. Plaster cracked in the Federal Building. Faint earth noises,

Los Angeles.—Felt by many and frightened few. Slight damage was reported from the Occidental Center Building where some minor cracks in concrete were observed on the 30th floor. Small objects shifted; hanging objects swung moderately south-north; sharp, jolting shock. Felt by several in the 28-story City Hall where small objects shifted. To observer on the 5th floor, motion seemed undulating in east-west direction. In a building at 3223 West 6th Street, those on 11th floor reported a vigorous north-south sway. On the second floor, a strong jiggling was observed for about 4 seconds. Chandeliers swayed on the 13th floor of the Merchandise Mart. In the Vernon District, felt by many in a 2-story building. Slight, sharp, jolt. Windows, doors, and bookcases rattled slightly. In the Wilshire District, lamps jiggled and dishes rattled.

INTENSITY I-III. Altadena, Culver City, Huntington Park, Inglewood, Long Beach, Maywood, Pacific Palisades, San Gabriel, and Walnut. Reported felt (no details): Baldwin Hills, Inglewood, and Santa Monica.

November 14: 18:02:13.8*. Epicenter 37°44' north, 122°09' west, central California, B. Magnitude 2.5. Felt at Berkeley and Oakland.

November 25: 16:58:39*. Epicenter 40.5° north, 125.0° west, off coast of northern California, W. Magnitude 4.0, B. Eureka. Reported as "not felt by all."

December 2: 23:34:58.4*. Epicenter 35.3° north, 118.5° west, south-central California, W. Magnitude 3¾, P. Keene. IV. Felt by many in community. Building creaked slightly. Slow motion of 3 seconds' duration; preceded 2 seconds by moderate earth noises.

December 3: 03:00. Keene. IV. Felt by many in community. Slow motion; lasted 1 second; preceded by faint earth noises.

December 3: 14:49:50.9*. Epicenter 34.2° north, 117.1° west, southern California, W. Magnitude 3.5, P. Felt at San Bernardino.

December 11: 10:09:02*. Epicenter 34.7° north, 118.7° west, south-central California, W. Magnitude 4.2. Keene. V. Felt by all in community. Windows, doors, and dishes rattled; building creaked. Rapid motion in southwest-northeast direction; duration, 4 seconds; moderate earth noises from southwest-northeast.

December 20: 10:30:59.0*. Epicenter 40.7° north, 121.4° west, northern California, W. Magnitude 3.7, B. Felt at Mineral.

WASHINGTON AND OREGON

[120th Meridian or Pacific Standard Time]

April 29: 07:28:43.6*. Epicenter 47.4° north, 122.3° west, northwestern Washington, W. Magnitude 6.5. Felt over an area of approximately 130,000 square miles of the United States and British Columbia, Canada (*see* figs. 6 and 7). Three persons were killed by falling debris—one in downtown Seattle on South King Street, and two on Harbor Island at the Fisher Flouring Mills. The deaths of four elderly women from heart failure in Olympia, Port Townsend, Seattle, and Tacoma were attributed to the earthquake. There were numerous injuries, but most were minor. It was reported that more than 30 persons were treated at hospitals in the Seattle area and dozens suffered minor injuries elsewhere. Damage was estimated at approximately \$12.5 million by the State Civil Defense Department, with most of it occurring in King County. Although a maximum intensity of VIII was assigned to some pocket areas of West and South Seattle and at Issaquah, this earthquake is best described as one with a maximum intensity of VII. Some of the more spectacular damage was difficult to evaluate since many buildings in Seattle and other Puget Sound areas had been damaged by previous earthquakes, notably the April 13, 1949, shock. The following paragraphs are excerpts from pages 27-39 of the Preliminary Report, issued by the

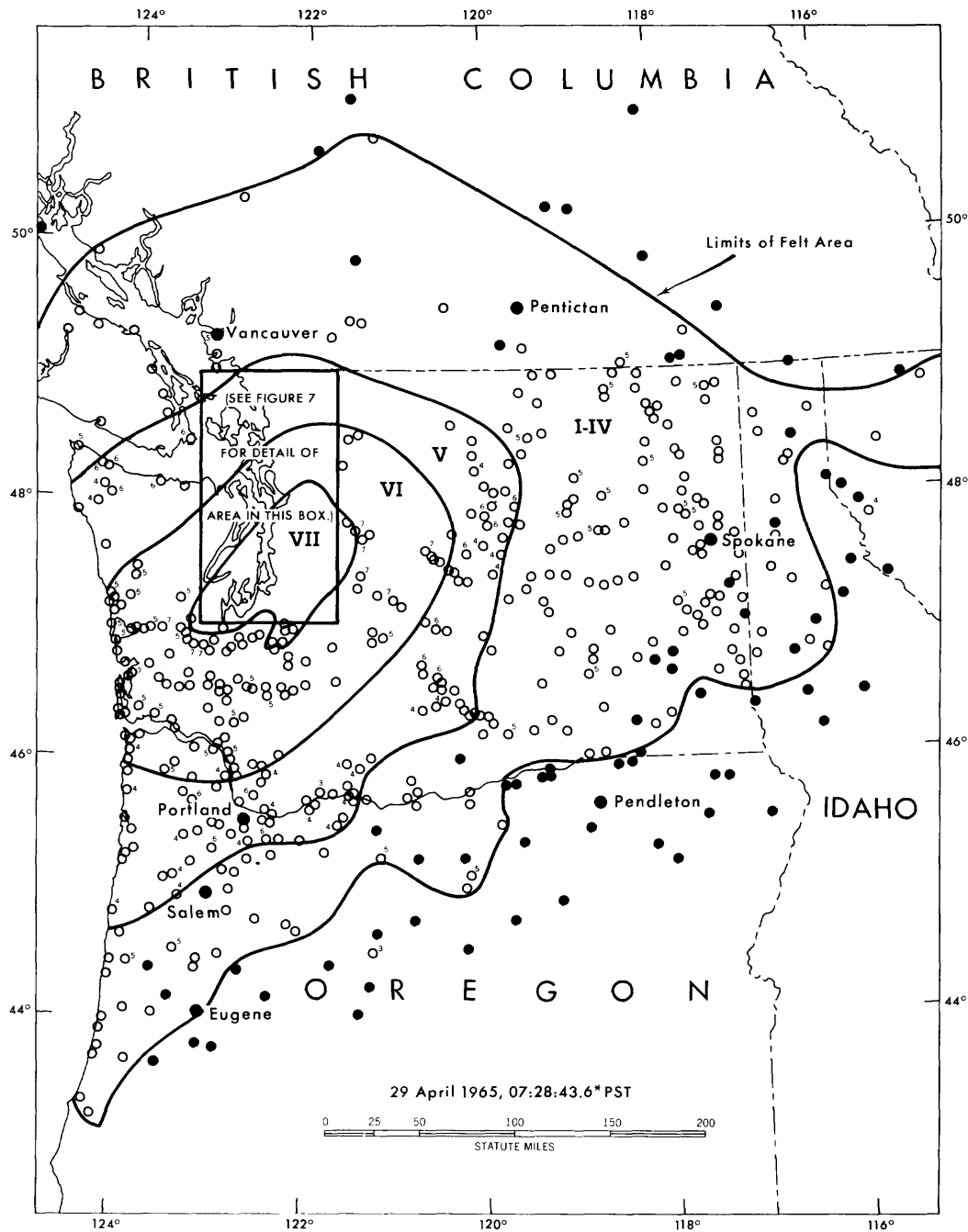


FIGURE 6.—Area affected by Puget Sound, Wash., earthquake of April 29.

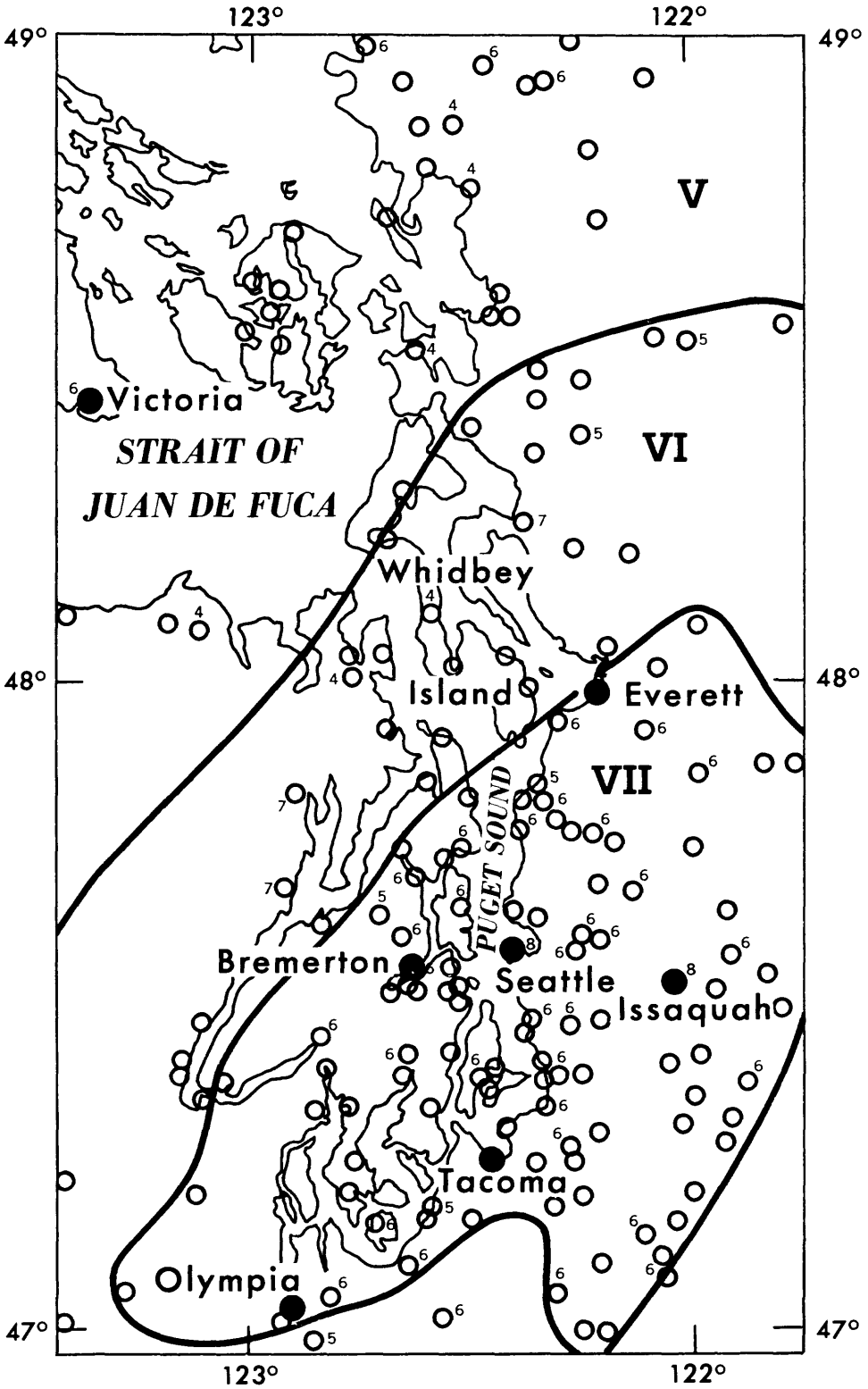


FIGURE 7.—Epicentral area of Puget Sound, Wash., earthquake of April 29.

Coast and Geodetic Survey, covering this earthquake.⁴

Building damage was generally light, although it was spectacular in many cases. Total collapses did not occur as far as is known to the authors. In general, damage patterns repeated those of the 1949 shock. Buildings which apparently had been damaged in 1949 often sustained additional damage in 1965. This reoccurring earthquake damage was sometimes intermixed with preearthquake settlement cracks which opened wider or caused failure in the 1965 earthquake.

Single family dwellings in the affected areas are generally of wood-frame construction, and are rarely more than two stories high. Chimneys are usually brick masonry. Interior partitions are generally plaster or gypsumboard on wood studs. Performance of the wood-frame dwellings was almost always excellent, and when damage occurred it was confined to plaster cracking and to unreinforced brick chimney failure at, or above, the roof line. By no means was the dwelling damage uniform throughout the city. For example, pockets of intense chimney damage to dwellings were found in Seattle (notably in the West Seattle section) while nearby areas of similar construction had no chimney damage. The damage pattern would sometimes change radically within several city blocks. As a rule, wood-frame dwelling damage rarely approached as much as 5 percent of building value.

One exception to the foregoing rule was unit masonry veneered wood-frame structures, particularly brick veneer. Four-inch brick veneer peeled off a number of wood-frame structures even though the veneer was anchored to the wood-backing wall with galvanized metal anchors. The anchors usually remained nailed to the wood frame when the brick peeled off, and an examination of the mortar indicated that the mortar could be crushed by hand. This type of veneer damage has been noted in many previous earthquakes . . .

Multistory buildings generally had slight or no damage, with the damage reported to new and to old structures. Plaster cracking and other non-structural damage was found in multistory buildings in Seattle as well as in Tacoma (these cities being about 30 miles apart). The spectacular damage reported by the press to a 10-story building in Tacoma may have been entirely confined to exterior window glass in a structure having essentially all glass on three sides, with the fourth side solid.

Unreinforced brick-bearing wall buildings with sand-lime mortar, as usual, bore the brunt of the damage. This type of building generally has wood

roofs and wood-supported floors, and is not earthquake resistive in any sense. Numerous instances of parapet and gable failure occurred, and death and injury resulted from this type of damage. As previously mentioned, some of this could be associated with the 1949 earthquake damage as well as with settlement damage which was not related to earthquakes . . .

A classic case of cumulative damage was found on the mud flats of Tacoma. A two-story brick bearing wall building was significantly damaged in the 1949 shock and the second story was subsequently removed. It was apparent when inspected after the 1965 shock that differential settlements also had been occurring, and the 1965 shock found a building which had been weakened by both previous earthquakes and settlement. The high apparent intensity at this location requires careful attention before being taken at face value.

Modern buildings which were designed and constructed to be earthquake resistive performed well, as indeed they should in a moderate earthquake. Not all modern structures performed well and four exceptions warrant mention. A one-story warehouse, having a precast prestressed reinforced concrete roof and precast concrete tilt-up walls with poured-in-place pilasters, had no anchorage between the roof diaphragm and its end shear wall. The roof moved back and forth over the end shear wall, damaging the side walls. A second instance of damage to a building presumably intended to be earthquake resistive occurred at a one-story market in which the steel angle earthquake X-bracing was embedded in a hollow concrete block wall; the relative rigidities of the elements were such that the hollow concrete block had to fail before the steel X-bracing could function. Additionally, the X-bracing was so located as to cut in two most of the wall reinforcement. A third instance of note was a large manufacturing facility having a very large floor area; the second-story precast reinforced concrete panels appeared to have worked loose from their supporting frame. The fourth example was a four-story hollow concrete-block apartment house in which the block shattered at several locations, and a remarkable absence of vertical reinforcing steel was noted . . .

Utility damage was not severe. Excerpts (pages 41-42 of the Preliminary Report) of the summary prepared by the Washington Surveying and Rating Bureau follow:

Service from the various public utilities was, on the whole, uninterrupted. Damage at the Spokane Street Substation interrupted service in a small area. The Washington Natural Gas Company reported one minor break in the Puyallup area.

⁴ *The Puget Sound, Washington Earthquake of April 29, 1965*, U.S. Department of Commerce, Coast and Geodetic Survey, 51 pages, 1965.

The Seattle Water Department had one break in a 12-inch main in the Harbor Island area and minor breaks in small pipes in residential areas of unstable ground. Four days after the earthquake, a break in a 20-inch main on Western Avenue at Spring Street resulted in water supply impairment for about one day to four sprinklered buildings supplied off this main.

In Everett, two of the three 48-inch main supply conduits to the city failed. These failures occurred where the lines are carried on trestles over Ebey Slough . . . Full service was restored the following day. One other break was reported in a 4-inch line in a residential district.

A number of breaks occurred in underground mains on plant sites and to overhead sprinkler piping. These were mainly to those properties located on artificial fills in the southern part of Seattle, particularly Harbor Island, resulting in varying periods of impairment . . . Damage to overhead sprinkler piping was mainly to older systems without earthquake bracing and flexible couplings. An exception was to a number of newer systems in buildings located on artificial fill where suspended ceilings and light fixtures damaged sprinkler heads and piping.

The following are excerpts from a letter report written by Fire Chief Gordon Vickey (pages 42-43 of the Preliminary Report):

In the day or two following the earthquake, it became evident that the Fire Department, working in conjunction with the Building Department, might be in a position to render valuable service by conducting a building-by-building survey, to more accurately assess the extent of damage from the quake. The effort was coordinated between the Fire Department, Building Department, and representatives of the U.S. Army Corps of Engineers. On May 3, four days after the earthquake struck, our personnel were out in force actually conducting this survey.

One survey was conducted on a continuous basis from May 3 through May 21. During this time, a total of 1,440 man hours were expended, and 1,405 buildings were surveyed from roof to basement. As a result of the survey, 91 buildings were found to have sustained apparent serious or extensive damage, and were recommended to the Building Department for resurvey by experts as rapidly as possible. One hundred and thirteen buildings were found to have sustained apparent moderate damage, and were recommended for resurvey as time and personnel would permit. Two hundred and fifty buildings were found to have sustained superficial or light damage only. In this group there was no apparent need for a follow-up survey, as damage

consisted of plaster cracks, missing chimney bricks, and things of this nature. The remaining 951 buildings were either found to have suffered no apparent damage, or damage was so slight that it could not be readily recognized.

Strong-motion earthquake records were obtained from Coast and Geodetic Survey stations located at Olympia, Ross Dam, Seattle, and Tacoma, Wash., and from Portland, Oreg.

Temporary seismograph stations were installed by the Coast and Geodetic Survey at Bremerton, Issaquah, Seattle, Pacific, and Enumclaw to record aftershocks. During the 14 days of operation of the temporary seismograph stations, only one aftershock was recorded at a sufficient number of stations to permit an epicentral location. Twenty-seven aftershocks were reported but could not be located because of insufficient data. No aftershocks were reported felt.

INTENSITY VIII:

Issaquah (about 15 miles southeast of Seattle).—Felt by and frightened all in community. Brick garage partially collapsed. Both of the old, 2- and 3-story, brick junior high schools were extensively damaged. There were long jagged cracks in exterior and interior walls. Daylight could be seen through some of the cracks. At ground level, there were long, broken separations in concrete walkways. Light fixtures were tilted and askew. Chimney damage was very prevalent in the area and extensive damage was reported to liquor stock in stores. Rapid motion in north-south direction; loud earth noises.

Seattle.—Felt by all and frightened many in community. Extensive damage to chimneys was noted in West Seattle. In 188 city blocks, it was found that 1,712 chimneys of the 5,005 were damaged. Two schools in West Seattle were also extensively damaged. Slumping was observed along a steep slope adjacent to 36th Avenue S.W., near Admiral Way. Eight Seattle public schools were closed until their safety could be

established. Of these schools, the West Alki School was the most severely damaged. Its 60-foot brick stack fell into the boiler room; X-cracks were found in the unreinforced sand-lime mortar brickwork in the 1914 wing; stairs shifted; and the north wall of the new wing moved outward. However, not everything fell from the shelves. (This school was located in a pocket of high earthquake intensity.)

In Seattle, a particularly noticeable damage pocket was the Alki Beach section of West Seattle where virtually every chimney was down. Similar intensified damage reportedly occurred here in 1949. The low-lying filled areas along the Duwamish River and its mouth settled and were the locations of considerable building damages.

Harbor Island, at the mouth of the Duwamish River, was a special high-damage location. Much, if not all, of this island was man-made, perhaps 50 or more years ago. The soils were not seismically stable by any standard. A newly built precast reinforced concrete building was structurally damaged. On this island were located a number of major industrial facilities. The Fisher Flouring Mills had extensive damage to its various buildings. One instance was a 50,000-gallon wood-roof tank on top of a 15-story structure which fell seven stories onto the roof of a grain bin, breaking the grain bin roof and spilling water onto the grain. Elsewhere, portions of the unreinforced brick walls fell from the sixth story. An examination of this structure showed pre-1965 cracks in the brick walls, some of which apparently opened further in this earthquake. Underground piping around the plant also broke and equipment in the building shifted and was out of alignment. This plant reportedly had \$50,000 damage in the 1949 shock, and it appears to be even greater in 1965.

Piers 15 and 16 on Harbor Island shifted toward the water by about 1 foot due to the soil losing much or all of its strength, or partially liquifying and pushing the

dock toward the water. An exception was the northern extension of the pier which was under construction and did not yet have its soil backfill.

Seattle (from press reports).—Port of Seattle damages were estimated at \$200,000-\$250,000. Much of this damage occurred to facilities where construction was in progress. Nearly every waterfront facility was damaged to some extent. Pier 5, where construction projects were underway, was hardest hit. The bulkhead and the fill behind it settled, the fill dropping 6 inches to 2 feet for a width of 25 to 40 feet. The bulkhead was reported to be 6 to 8 inches out of line. Several Port piers suffered similar damage. Pier 20 at the East Waterway Terminal settled. At Pier 36, light fixtures were torn loose in the 5-story, concrete Engineers' Headquarters Building. File cabinets tipped over and the library was a mess. At the Naval Supply Depot, damage was reported to Pier 90 waterline and a Pier 91 steamline. Several heavy light fixtures in the Depot offices were shaken down; others dangled precariously.

A number of bridges were closed temporarily due to slight damage. A major span on the Spokane Street viaduct could not be opened for boat traffic because of bent interlocking pins. The 14th Avenue South drawbridge across the Duwamish River had some pier damage. Navy officials closed the Magnolia Bridge to traffic because of damage to the underside of the structure. Both of the Southwest Spokane Street bridges were jammed shut when the shock threw them out of line. Shipping up the Duwamish Waterway was halted. East-bound lanes of a drawbridge across the Duwamish Waterway were closed to all traffic except transit coaches because of a drop in the road level.

At Carkeek Park, South Seattle areas, an earthslide uncovered an underground stream that overflowed the creek and broke a water main. At Green Lake and vicinity in North Seattle, the lake sloshed under

the force of the shock, crinkling blacktop around the Aqua Theater and opening zig-zag fissures in the ground. A concrete wall buckled at the junior crew house at the Aqua Theater, wrecking it possibly beyond repair. Other Park buildings suffered minor cracks and small patches of dislodged plaster. Water spurted 15 feet in the Lower Woodland baseball field due to a water main break. Another smaller main split at Evans Pool at Green Lake, but the pool remained open. Maplewood Place S.W., near Three Tree Point, settled. The following building damage was reported by the press:

Art's Food Center (9999 Holman Road N.W.).—Gaping holes in four concrete walls. Merchandise fell from shelves.

Ballard City Hall (Ballard Avenue N.W. and 22nd Avenue N.W.).—Sidewalks adjacent to the old Ballard City Hall were barricaded due to bricks falling from the old structure.

Boeing Aircraft Company facilities.—Many windows broke in the south side of the Boeing Administration Building and the adjoining Engineering Building. Minor damage was reported in Plant No. 2, mostly broken windows and cracked walls. Some damage was reported at other Boeing facilities, including the Development Center, south of Plant No. 2. There were no reports of injuries other than scratches and bruises.

Federal Office Building.—Extensive damage was reported to the upper floors of the 10-story building. Employees above the third floor were sent home.

First Avenue S.—Sidewalks south of Yesler Way were littered with bricks cracked loose from the tops of older buildings. At 2716 - 60th Avenue S.W., an entire chimney and front wall fell, leaving the living area exposed.

Medical Dental Building (509 Olive Way).—An 8-pound piece of cornice fell on the sidewalk on the Fifth Avenue side of the building. Small chunks of masonry

fell from the front of the 16-story building, but were prevented by ledges from reaching the sidewalk. At the Frederick & Nelson Store, minor damage was reported to the store and stock. Some walls were cracked and mannequins toppled. A spokesman reported: "Our building and the adjoining Medical Dental Building teetered apart a bit, then came back together with a loud clap."

Trans-World Airlines Building (opposite the Olympic Hotel).—Severe damage on ground floor. The middle of one ground wall was severely cracked. A front panel window, about 8 by 12 feet, slipped away from its casement.

Union Pacific Railroad Station.—A section of heavy cornice atop the west side of the station fell and crashed through the sidewalk. The third floor sagged, and walls and ceilings were cracked. The station was evacuated.

Press reported the following school damage:

Ballard High School.—Damage was confined to the auditorium, where a ceiling arch was bent and a study wall twisted.

Broadview Elementary School.—Part of the east, brick-exterior wall fell at the old section of Broadview's plant.

Colman Elementary School.—Chimney damage; part of the masonry gables at the entrance fell; front wall damaged.

Franklin High School.—Parts of cornices on four corners of the building fell; lunchroom ceiling cracked; hallway and stairwell were damaged. All fire alarms were short-circuited and activated.

Gatewood Elementary School.—Gables fell.

Leschi Elementary School.—Gables fell.

Madison Junior High School.—Chimney collapsed and masonry fell at the entrance. Several cracks occurred in upstairs rooms at the Administrative and Service Center. Waterline was broken also.

Queen Anne High School.—Walls cracked.

St. Joseph's School.—Pieces of cornices fell from front of building.

University of Washington.—New cracks appeared in partitions of the Mechanical Engineering Building, under repair since early in the year. Three large planks were bolted to the cement-block wall of a second-floor classroom after inspection. Damage to the structure was reported as minor. In the crew house, the section where the new sleeping quarters adjoined the older section was cracked about an inch. Minor cracks on the fourth floor of the new library were observed. Electric cable broke in the Mechanical Engineering Buildings. It was reported that the tops of 60-foot trees swayed 3-4 feet, and that a fissure opened in the practice field at the University. Underground pressure from the shock sent sand spurting in a 100-foot-long zig-zag stretch on the lower football field. Behind the men's pool, areas of the ground dropped as much as a foot. Dirt floor sections in the Hec Edmondson Pavilion also sank slightly. At the Wesley Foundation, a car was badly damaged by falling bricks from a chimney.

West Seattle High School.—Severe cracking of walls throughout the school. Both exterior and interior walls of the auditorium were cracked.

Whittier Elementary School.—Pupils were evacuated from second floor due to structural damage.

Additional press reports of minor damage are as follows:

Bayview Manor Retirement Home.—Doors jammed. Elevator inoperative. Large crack in ceramic mural.

Blessed Sacrament Church (9th Avenue N.E. and 50th Street N.E.).—Possibly serious damage to the tower.

Bon Marche Store.—Major damage occurred to china. "You can see where the sky bridge (connecting the Bon Marche and the Third and Stewart parking garage) moved about 2 inches out of line."

King County Court House.—Consider-

able plaster damage, particularly in the middle floors.

Providence Hospital.—Many interior wall cracks. The sixth-floor surgery department was closed for two hours due to plaster dust in the operating rooms. Two doctors were trapped when an elevator jammed after dropping from the sixth to the third floor.

St. James Cathedral.—Low-hanging chandeliers swayed violently. Priest left the sanctuary when he was showered by falling debris. Minor damage.

Seattle Times Building.—This 2-story concrete building shook "like an electric vibrator." Plaster sifted down in rooms and teletype printers stopped work briefly.

Smith Tower.—Woman in penthouse on top the tower reported she was rocked out of bed. Extensive cracks and plaster damage were reported on the 33rd floor.

Substation at 4th Avenue S. and South Spokane Street.—City Light Company reported damage at its substation cut off service to some industrial plants, including the Seattle Foundry.

Todds Shipyards Corporation (1801 - 16th Avenue S.W.).—Bricks from fallen chimney damaged parked automobiles and broke a second-floor window.

INTENSITY VII:

Allyn.—Felt by and frightened all in community. Damage to brick, masonry, and concrete. Chimneys twisted and fell. Plaster, chimneys, and ground cracked. Dishes broke. Furnishings shifted; small objects overturned. Person outdoors saw the house sway north-south "about 2 feet each way." Rapid motion in northeast direction; loud noises from north heard.

Auburn.—Felt by all; awakened and frightened many in community. Damage slight. Few chimneys twisted and fell. Few dishes and windows broke. Plaster, windows, and chimneys cracked. Knickknacks fell. Small objects shifted and overturned. Press reported Auburn schools were closed until buildings were checked. The city

hall was closed for an hour until inspectors declared the building safe; plaster fell from ceilings. Chimneys and window damage was reported throughout the area. Slides were reported on the Lake Holm Road east of Auburn. Motion slow; duration, 10 seconds.

Black Diamond.—Felt by all; awakened and frightened many in community. Damage slight to considerable in wood and brick. Chimneys twisted and fell. Dishes, windows, and furniture broke. Plaster, windows, and chimneys cracked. Small objects and furnishings shifted; vases, small objects, and furniture overturned. Trees and bushes shaken strongly. Hanging objects swung north. Rapid motion in east-west direction; duration, 45 seconds; loud earth noises from east-west 5 seconds before shock.

Brinnon.—Felt by all, awakened few, and frightened many in community. Damage slight to masonry and concrete. Chimneys twisted and fell. Dishes and windows broke. Plaster, windows, walls, and chimneys cracked. Knickknacks, books, and pictures fell. "Center beam moved $\frac{1}{4}$ inch and split. Lots of cracks in pumice walls and concrete floor. Dumped the stock on shelves to the floor." Hanging objects swung north-south. Rapid motion in north-south (?) direction; duration, 30–60 seconds; preceded 2 seconds by moderate earth noises.

Buckley.—Felt by and frightened all in community. Damage considerable. Chimneys, columns, and monuments twisted and fell. Dishes and windows broke. Knickknacks, books, pictures, plaster, and walls fell. Plaster, windows, walls, and chimneys cracked. Small objects shifted; vases overturned. Trees and bushes shaken strongly. Slow, rolling motion in southwest direction; duration, 30 seconds; loud earth noises from southwest.

Carnation.—Felt by and frightened all in community. Damage considerable. Chimneys twisted. Windows broke. Walls and

chimneys cracked. Small objects overturned; furnishings shifted. Trees and bushes shaken strongly. Hanging objects swung north-south. Rapid motion in north-south direction; duration, 1 minute; preceded 3 seconds by loud earth noises from north.

Cumberland.—Felt by and frightened all in community. Damage considerable to brick and concrete. Chimneys, columns, and monuments twisted and fell. Dishes, windows, and furniture broke. Knickknacks, books, pictures, plaster, and walls fell. Plaster, windows, walls, chimneys, and ground cracked. Vases, small objects, and furniture overturned; small objects and furnishings shifted. Trees and bushes shaken strongly. Rapid motion; duration, 1 minute; preceded few seconds by loud earth noises from north.

Dash Point (about 7 miles north of Tacoma).—Felt by and frightened all in community. Damage considerable. Chimneys, columns, and monuments twisted and fell. Dishes, windows, and furniture broke. Knickknacks, books, pictures, plaster, and walls fell. Walls, chimneys, and ground cracked. "There is a crack across Sound View Drive." Small objects and furnishings shifted; vases, small objects, and furniture overturned. Trees and bushes shaken strongly. Pendulum clock, facing south, started. Hanging objects swung west-east. Rapid motion in west-east direction; duration, 45 seconds; moderate earth noises from west-east.

Des Moines.—Felt by all in community; frightened few. Damage slight. Some dishes and windows broke. Plaster cracked and fell. Knickknacks and books fell. Small objects shifted; vases and small objects overturned. Trees and bushes shaken strongly. Rapid motion; preceded few seconds by loud earth noises.

Dockton.—Felt by all; awakened and frightened many in community. Damage slight. Chimneys twisted and fell. Dishes and windows broke. Knickknacks, books,

pictures, and plaster fell. Plaster, windows, walls, chimneys, and ground cracked. Small objects and furnishings shifted; vases and small objects overturned. Trees and bushes shaken strongly. Motion rapid; loud earth noises.

Duvall.—Felt by all and frightened many in community. Damage slight to wood, brick, masonry, and concrete. One chimney fell. Plaster and chimneys cracked. Knickknacks, books, and pictures fell; small objects shifted; vases and small objects overturned. Hanging objects swung east-west. Rapid motion in east-west direction; duration, 1 minute.

Eatonville.—Felt by and frightened all. Damage slight. Plaster and walls fell. Dishes, windows, and furniture broke. Plaster, windows, walls, chimneys, and ground cracked. Knickknacks, books, and pictures fell; small objects and furnishings shifted; vases, small objects, and furniture overturned. Pendulum clock stopped. Slow motion in north direction.

Elbe and vicinity.—Felt by all and frightened many in community. Damage slight to brick. Chimneys cracked, twisted, and fell. Knickknacks and pictures fell. Furnishings shifted. Trees and bushes were shaken strongly. "Some people seemed to think that the motion was in several directions. Parked cars jumped up and down. Dishes did not fall from east-west facing cupboards. Two people reported feeling a light tremor on April 30, about 9:10 a.m." Motion rapid; duration, 1 minute; moderate rumbling.

Electron (near Orting).—Felt by and frightened all in community. Damage to masonry. Chimneys, columns, and monuments twisted and fell. Dishes, windows, and furniture broke; walls fell. Ground cracked. Trees and bushes shaken strongly. Rapid motion in northeast direction; duration, 10 seconds.

Enumclaw.—Felt by all and frightened many in community. Damage considerable to brick. Chimneys twisted and fell; dishes

and windows broke; pictures and plaster fell. Furniture shifted; small objects overturned. Rapid motion in east-west direction; duration, 1 minute; preceded by moderate earth noises.

Everett.—Felt by and frightened all in community. According to press reports a State Patrol radio tower toppled and streets buckled. A water main broke between Everett and East Everett. Chimney damage and downed power lines were reported from various areas. The Bonneville Power Administration reported three major lines went out of operation. Two 230,000-volt lines from Chief Joseph Dam to the Snohomish substation near Everett were toppled. Another 300,000-volt line from Grand Coulee Dam to Olympia was broken. Other observers reported: Plaster and chimneys cracked. Knickknacks and books fell; small objects shifted and overturned. Motion rapid; duration, 45 seconds; preceded 5 seconds by moderate earth noises.

The following is an excerpt from a report by the Washington Surveying and Rating Bureau:

In Everett, two of the three 48-inch main supply conduits to the city failed. These failures occurred where the lines are carried on trestles over Ebey Slough. Industrial supply to the large consuming pulp mills was then shut down, the mills either closing down or going to river pumps. Full service was restored the following day. One other break was reported in a 4-inch line in a residential district.

Gate.—Felt by many and awakened few. Damage slight. Chimneys cracked, twisted, and fell. Small objects shifted and overturned. Slow motion north-south; preceded several seconds by loud earth noises.

Gig Harbor (Kitsap Peninsula).—Press reported a part of Crescent Lake Road, west of Gig Harbor, sank out of sight and was covered with water.

Gold Bar.—Felt by all and frightened many in community. Damage moderate. Chimneys twisted and fell. Dishes, windows, and furniture broke. Knickknacks,

books, pictures, plaster, and walls fell. Plaster, windows, walls, chimneys, and ground cracked. Small objects and furnishings shifted; vases, small objects, and furniture overturned. Trees and bushes shaken strongly. Motion rapid; duration, 45 seconds to 1 minute; loud earth noises.

Goest.—Felt by all and frightened many in community. Damage considerable. Chimneys twisted. Dishes broke. Small objects and furnishings shifted; vases and small objects overturned; knickknacks, books, and pictures fell. Motion rapid; duration, 40 seconds; preceded 40 seconds by moderate earth noises.

Granite Falls.—Felt by all and frightened many in community. Damage slight. Chimneys twisted and fell. Dishes broke. Small objects shifted; knickknacks, books, pictures, and plaster fell. Trees and bushes shaken strongly. Hanging objects swung east-west. Duration, 45 seconds; east-west direction; moderate earth noises.

Grapeview.—Felt by and frightened all in community. Damage to brick, masonry, and concrete. Dishes broke. Plaster, chimneys, and ground cracked. Knickknacks, books, and pictures fell. Small objects and furnishings shifted; vases, small objects and furniture overturned. Trees and bushes shaken strongly. Rapid motion in north-south direction; duration, 40 seconds.

Grotto.—Felt by and frightened all in community. Damage slight to brick and masonry. Chimneys twisted and fell. Plaster and chimneys cracked. Small objects and furnishings shifted, including piano; small objects overturned. Pendulum clock, facing south, stopped. Motion rapid; duration, 1 minute; faint earth noises.

Hobart.—Felt by all in community. Chimneys fell. Dishes, windows, and furniture broke. Knickknacks, books, pictures, plaster, and wall fell. Plaster, windows, walls, chimneys, and ground cracked. Small objects and furnishings shifted; vases, small objects, and furniture overturned.

Trees and bushes shaken strongly. Duration, 45 seconds; east-west direction; earth noises from east-west.

Kapowsin.—Felt by all and frightened many in community. Damage slight. Chimneys twisted and fell. Windows broke. Plaster, windows, and chimneys cracked. Knickknacks, books, and pictures fell. Small objects shifted; vases and small objects overturned. Trees and bushes shaken strongly. Motion rapid; duration, about 1 minute; loud earth noises from north.

Kenmore.—Felt by all in community; frightened few. Damage considerable to masonry. Some chimneys, columns, and monuments fell. Dishes, windows, and furniture broke. Knickknacks, books, pictures, plaster, and walls fell. Some plaster, windows, walls, chimneys, and ground cracked. Small objects and furnishings shifted; vases, small objects, and furniture overturned. Trees and bushes shaken strongly. Hanging objects swung east-west. Rapid motion in east-west direction; duration, 45 seconds; moderate earth noises.

Kent.—Felt by all and frightened few in community. Press reported general building and window damage. Bricks fell off the old Armory onto parked cars, but no one was injured. One water main broke and several wires snapped. Plaster and walls cracked. Furnishings shifted; vases, small objects, and furniture overturned. Hanging objects swung east-west. Motion slow; preceded 10 seconds by loud earth noises from east-west.

Kingston.—Felt by and frightened all in community. Damage considerable. Chimneys twisted and fell. Dishes and windows broke. Plaster, windows, walls, chimneys, and ground cracked. Knickknacks and pictures fell. Small objects and furnishings shifted; vases, small objects, and furniture overturned. Trees and bushes shaken strongly. Rapid motion in north direction; duration, 1 minute; loud earth noises from north. Press reported the road-

way 2 miles west of Kingston on Highway 104, near the Wolfe School, was damaged, but not closed.

Kirkland.—Felt by all and frightened many in community. Damage slight to brick, masonry, and concrete. Chimneys twisted and fell. Dishes and windows broke; windows cracked. Knickknacks, books, and pictures fell. Motion slow; duration, about 30 seconds; moderate earth noises.

La Grande.—Felt by and frightened all in community. Damage considerable. Chimneys twisted and fell. Shelves in store fell both north-south and east-west. Dishes broke. Knickknacks, books, pictures, and plaster fell. Plaster, walls, chimneys, and ground cracked. Earth cracks along canyon of the Nisqually River; slides into rivers and onto roads. Small objects and furnishings shifted; small objects overturned. Cars outdoors rocked north-south. Trees and bushes shaken strongly. Pendulum clock facing east stopped. Rapid, sharp motion in north-south direction; duration, nearly 1 minute; loud earth noises at beginning of shock.

Lakebay.—Felt by all and frightened many in community. Damage slight to brick. Chimneys twisted and fell. Small objects overturned; knickknacks fell. Motion slow; duration, 2 minutes; direction north-south; sharp vibration at first; ending with gentle sway; moderate earth noises.

Lake Stevens.—Felt by all and frightened many in community. Damage slight. Chimneys twisted and fell. Plaster and walls cracked. Trees and bushes shaken strongly. Pendulum clock stopped. Hanging objects swung east-west. Slow motion in east-west direction; duration, 50 seconds; preceded 7 seconds by loud earth noises from east.

Lakeview.—Felt by all and frightened many in community. Damage considerable to brick and masonry. Plaster, windows, walls, and chimneys cracked. Dishes and windows broke. Knickknacks, pictures,

and plaster fell. Small objects shifted; vases and small objects overturned. Trees and bushes shaken strongly. Slow motion in steady, rolling, north-northwest direction; duration, about 1 minute; preceded 2–4 seconds by moderate-to-loud earth noises from north-northwest.

Leavenworth.—Felt by all and frightened many in community. Damage slight. Chimneys, columns, and monuments fell. Dishes, windows, and furniture broke. Knickknacks, books, pictures, plaster, and walls fell. Plaster, windows, walls, chimneys, and ground cracked. Small objects and furnishings shifted; vases, small objects, and furniture overturned. Motion rapid; moderate earth noises.

Longbranch.—Felt by all and frightened many in community. Damage considerable. Chimneys twisted and fell. Dishes broke. Knickknacks, books, pictures, and plaster fell. Plaster and chimneys cracked. Small objects shifted; vases and small objects overturned. Trees and bushes were shaken strongly. Rapid motion in east direction; duration, 30 seconds; preceded about 12 seconds by moderate earth noises from east. "After shock had quieted down, light fixtures and other hanging objects were swinging east-west."

McCleary.—Felt by and frightened all. Damage slight to masonry and concrete. Chimneys twisted and fell. Dishes and windows broke. Knickknacks, books, pictures, and walls fell. Plaster, windows, walls, and chimneys cracked. Small objects and furnishings shifted; vases, small objects, and furniture overturned. Merchandise fell from store shelves. Light fixtures hanging from ceiling in post office were loosened. "To me, the shake seemed more severe than that of 1949. This time I was in a masonry building; in 1949 I was in a wooden building."

Manchester.—Felt by all and frightened many in community. Damage considerable to brick, masonry, and concrete. Chimneys twisted and fell. Plaster, walls, chimneys,

and ground cracked. Knickknacks, books, and pictures fell. Dishes broke. Small objects shifted; furnishings shifted 3 inches; vases and small objects overturned. Rapid, intense motion in east-west direction; moderate earth noises from north-northwest or east.

Maple Valley.—Felt by all and frightened many in community. Damage slight. Chimneys twisted and fell. Plaster, windows, and chimneys cracked. Knickknacks, books, and plaster fell. Dishes and windows broke. Small objects and furnishings shifted; vases and small objects overturned. Trees and bushes shaken strongly. Slow motion in west (?) direction; moderate earth noises from west (?). Press account stated the County Engineer reported fairly extensive damage to the county's South Road District shops. The water system, electrical shop, and service station were hard hit. Damage to the shops was estimated at \$10,000 or more. Slides were reported on the Jones Road and Devils Elbow Road near Maple Valley.

Milton.—Felt by all and frightened many in community. Damage slight. Chimneys, columns, and monuments fell. Knickknacks, books, pictures, plaster, and walls fell. Dishes, windows, and furniture broke. Plaster, windows, walls, and chimneys cracked. Small objects and furnishings shifted and overturned. Trees and bushes shaken strongly. Hanging objects swung north. Rapid motion in north direction; duration, 45 seconds; moderate earth noises from north.

Mineral.—Felt by all and frightened many in community. Damage slight. Chimneys twisted and fell. Dishes broke. Chimneys cracked. Knickknacks, books, and pictures fell. Small objects shifted and overturned. Trees, bushes shaken strongly. Slow motion in north-south direction; duration, 50 seconds; moderate earth noises from north-south.

Montesano.—Felt by and frightened all in community. Damage slight. Few chim-

neys cracked; one fell. Small objects shifted and overturned in few instances. Slow motion in northeast direction; duration, 1 minute; moderate earth noises from northeast.

North Bend.—Felt by all and frightened many in community. Damage considerable to brick, masonry, and concrete. "This shock caused more damage in this area than any shock during the past 50 years." Chimneys twisted and fell. Plaster, windows, walls, and chimneys cracked. Knickknacks, books, pictures, plaster, and walls fell. Dishes, windows, and furniture broke. Small objects and furniture overturned. Trees and bushes shaken strongly. Rapid motion in east direction; duration, 1 minute; preceded 10 seconds by loud earth noises from east. Press reported an extensive slide occurred on the southwest slope of Mount Si near North Bend; heavy damage to liquor stock at North Bend.

Oakville.—Felt by all and frightened few in community. Damage slight to concrete. Chimneys twisted and fell. All chimneys were down on a hill in the northwest corner of town. New fireplace moved 1 inch and chimney broke and twisted. Dishes and windows broke. Plaster, windows, walls, and chimneys cracked. Knickknacks, books, and plaster fell. Small objects overturned. Two shocks about 1 minute apart; preceded by moderate earth noises. Power poles swayed north-south during first shock and east-west during second shock. Several persons at first thought it was a sonic boom.

Olalla.—Felt by and frightened all in community. Chimneys twisted and fell. Chimneys and ground cracked. "Our home on hill next to post office had main chimney knocked down and house pulled away about 3 inches from fireplace chimney (half-way up). House sunk in several places. There are quite a number of chimneys gone in this area." Merchandise fell from shelves in grocery store; knickknacks, books, and pictures fell. Small objects and furnishings shifted; vases and small objects

overturned. Rapid, jerky motion; loud earth noises.

Olympia.—Felt by and frightened all in community. The following is from press reports: The Union Pacific Railway reported a hillside fill slid away from beneath a 400-foot section of a branch line just outside of Olympia. In the Temple of Justice, cracks developed in the walls of the law library; cabinet tipped over; books scattered around the floors; pictures fell from walls. In the Legislative Building, there was a crack about 3 feet long on the inside of the inner dome of the rotunda. The 5-ton chandelier swung on its 110-foot chain, like a pendulum clock, in a 1-foot orbit for half an hour after the shock. There were reports the dome had shifted. The building superintendent reported some stones weighing 25 pounds or more had broken loose. Cracks, due to the 1949 shock, were reopened in the Executive Mansion. Glass from chandeliers in the ballroom cascaded to the floor. Light fixtures were torn out of the ceiling on the top floor of the Health Building. The water-pollution laboratory was a tangled mess of broken bottles and other equipment. The new post office was damaged considerably and ordered closed. A road around Capitol Lake, at the base of the Capitol complex, was damaged, allowing water to flow beneath the road. St. Peter's Hospital reported four persons were treated for minor injuries. Damage to light fixtures and elevator shafts in the Capitol Building was about \$200,000; damage to the road and railroad was estimated at the same amount.

The following is from a report by the Washington State Division of Mines and Geology:

The questionnaires (newspaper canvass) verified our personal observations that the greatest damage occurred in the area between 15th Avenue and 20th Avenue and between Capitol Way and Cherry Street. Damage was rated as none or light (interior plaster cracks and mortar cracks in chimneys) versus moderate to heavy. This latter classification

means that chimney bricks were dislodged or chimneys were destroyed and interior plaster cracked and fell. About 15 percent of the Eastside and Westside reported moderate to heavy chimney damage and there were a few reports of plaster damage. Five percent of the Carlyon-Eskridge area reported moderate to heavy chimney damage, and roughly 10 percent reported plaster damage. The Capitol area seemed to have fared considerably worse than the other three areas, at least as far as chimney damage was concerned. About half the responses from this area reported moderate to severe chimney damage. Fifteen percent reported moderate plaster damage. Both north-south and east-west directions of motion were reported.

Other observers in Olympia reported the following: Most objects in the General Administration Building, 3rd floor, fell from shelves facing north-south; east-west facing shelves lost few objects. Files and bookcases shifted up to 3.5 inches. Motion seemed to start abruptly. No aftershocks were felt. No agitation could be seen on the surface of Capitol Lake about 100–150 yards away. At the post office, light fixtures fell. Small objects and furnishings shifted; small objects overturned. Rapid, explosive-like motion in east-west direction; loud earth noises. Four miles south of Olympia (Municipal Airport), felt by many; general alarm. Damage was slight to buildings. Some chimneys cracked and pulled away from houses; a few north-south and vertical cracks in airport building. Slight displacement of hanging electrical fixtures. One jarred loose from ceiling. Many objects were displaced or knocked to the floor throughout the area. Plaster cracked in a few localities, and pieces were thrown down in some instances. "No landslides in this area, but there were some in the surrounding area." Motion bumping, swaying, rapid onset; loud, rumbling earth noises.

Orting.—Felt by all; awakened and frightened many in community. Damage considerable to brick. Chimneys twisted and fell; windows and furniture broke. Plaster, windows, walls, and chimneys cracked. Small objects and furnishings shifted; vases, small objects, and furniture overturne'

Rapid motion in north-south direction; duration, 35 seconds; preceded 2-3 seconds by loud earth noises from north-south.

Pacific.—Felt by and frightened all in community. Chimneys twisted and fell; chimneys cracked. Knickknacks and pictures fell. Furnishings shifted; furniture overturned. Trees, bushes shaken strongly. Slow motion in north-south direction; duration, $2\frac{1}{2}$ minutes; preceded by loud earth noises from north-south.

Palmer.—Felt by all and frightened many in community. Damage slight. Chimneys twisted and fell; chimneys cracked. Knickknacks, books, and pictures fell. Small objects and furnishings shifted; vases, small objects overturned. Trees, bushes shaken strongly. Motion rapid; duration, 30 seconds; loud earth noises.

Peshastin.—Felt by all and awakened few. Damage considerable. Chimneys twisted and fell. Plaster and chimneys cracked. Knickknacks and pictures fell. Small objects shifted and overturned. Motion rapid; duration, 1 minute; moderate earth noises from northwest.

Portage.—Felt by all and frightened many in community. Damage slight. Chimneys fell; chimneys cracked. Dishes broke. Small objects shifted; vases and small objects overturned. Rapid motion in east-west direction; duration, 1 minute; loud earth noises.

Port Orchard.—Felt by all and frightened many in community. Damage considerable in masonry and concrete. Brick chimneys fell. Walls, floors, chimneys, and ground cracked. Windows broke. Telephone service disrupted. "Many homes and businesses reported fallen pictures from walls and broken dishes from cabinets and shelving." Pendulum clock, facing east, stopped. Rapid motion in southwest direction; duration, 45 seconds; preceded about 6 seconds by moderate earth noises from southwest. Press reported the highway a mile east of Port Orchard was cracked.

Poulsbo.—Felt by and frightened all in community. Damage slight. Chimneys twisted and fell. Plaster, walls, and chimneys cracked. Dishes broke. Knickknacks and pictures fell. Small objects and furnishings shifted; vases and small objects overturned. Trees, bushes shaken strongly. Pendulum clock, facing west, stopped. Rapid motion in southerly direction; duration, 45 seconds; moderate earth noises from southerly direction.

Preston.—Felt by all; awakened and frightened many in community. Damage slight to brick. Chimneys fell; chimneys cracked. Dishes broke. Knickknacks and books fell. Small objects shifted and overturned. Trees, bushes shaken strongly. Motion rapid; duration, 45 seconds. "Shock began with several seconds of vibration in north-south direction, rapidly increasing in speed and intensity; then followed heavy shocks of undulating and rocking motion, accompanied by earth noises. Rocking continued for several seconds after rumblings ceased."

Puyallup (about 30 miles south of Seattle).—Felt by and frightened many in community; awakened few. Damage considerable. Chimneys and walls fell. Plaster and chimneys cracked. Dishes and windows broke. Knickknacks, books, and plaster fell. Small objects and furniture overturned. Trees, bushes shaken strongly. Pendulum clock, facing south, stopped. Rapid, rolling motion in north-south direction; loud earth noises from north. The Washington Natural Gas Company reported one minor break in the Puyallup area.

Quilcene.—Frightened all in community; awakened many. Damage considerable. Plaster and walls fell; plaster, windows, walls, chimneys cracked. Dishes, windows, and furniture broke. Knickknacks, books, and pictures fell. Small objects and furnishings shifted; vases, small objects, and furniture overturned. Trees, bushes shaken strongly. Pendulum clock stopped.

Rocking motion in north-south direction; loud earth noises.

Ravensdale.—Felt by all (except people in cars) and frightened many in community. Damage slight. Chimneys twisted and fell; plaster fell; plaster and chimneys cracked. Knickknacks, books, and pictures fell. Small objects shifted; vases and small objects overturned. Motion slow; duration, 30 seconds; moderate earth noises.

Renton.—Felt by all and frightened many in community. At the Boeing Aircraft Plant (reported by Dr. Gordon B. Oakeshott, California State Division of Mines and Geology), floors settled away from the foundation piling; much interior concrete block cracked; fluorescent light fixtures down; acoustical ceiling tile fell, and concrete tiles fell away from structural steel members. Press reported fireplace collapsed, injuring three members of family. Large boiler broke at the Pacific Car and Foundry Company. Motion rapid; duration, 45–50 seconds; preceded few seconds by loud earth noises.

Retsil.—Felt by all; awakened and frightened many in community. Damage considerable. Chimneys twisted and fell. Dishes, windows, and furniture broke. Knickknacks, books, pictures, plaster, and walls fell. Plaster, windows, walls, chimneys, and ground cracked. Small objects and furnishings shifted; vases, small objects, and furniture overturned. Trees, bushes shaken strongly. Rapid motion in north-south direction; moderate earth noises.

Ronald.—Felt by all and frightened many in community. Damage slight to brick and masonry. Chimneys twisted and fell. Windows broke. Plaster and chimneys cracked. "Most damage confined to toppled chimneys and broken windows." Small objects and furnishings shifted; vases, small objects, and furniture overturned. Large rock dump started to slide and cave. Rapid motion in south direction; duration, 5–10 seconds; faint earth noises.

Roslyn.—Awakened and frightened many

in community. Damage slight. Chimneys cracked and fell. Pictures fell; small objects and furnishings shifted; vases, small objects, and furniture overturned. First shock fairly light; second, rapid strong shaking in east direction; duration, 45 seconds; accompanied by earth noises.

Shelton.—Felt by many. "Most building damage was to chimneys—fell southwest. Have heard of three cracked walls. Main return line broke on southwest side of my public pool. Objects displaced by jumping." Bumping motion in northwest to south direction; gradual onset; roaring earth noise heard at time of shock.

Skykomish.—Felt by and frightened all in community. Damage slight to brick. Chimneys fell. Walls and chimneys cracked; plaster fell. Vases and small objects overturned. Rapid motion in west-east or east-west direction; duration, 30–45 seconds; moderate earth noises from west-east.

Snoqualmie.—Felt by all and frightened many in community. Damage considerable to brick. Chimneys twisted and fell. Dishes and windows broke. Knickknacks, books, pictures, and plaster fell. Plaster, windows, and chimneys cracked. Small objects and furnishings shifted; vases and small objects overturned. Hanging objects swung northeast. Rapid motion in northeast direction; duration, 30 seconds; moderate earth noises from northeast.

Snoqualmie Falls.—Frightened many in community. Damage considerable. "Many chimneys and fireplaces down or not useable." Walls, chimneys, flues and fireplaces cracked. Dishes and windows broke. Small objects and furnishings shifted. Books out of bookshelves and bookcases; mail out of boxes and everything on floor at post office. Slides on Mount Si. Rapid, rolling motion in east-west direction; moderate earth noises from east west. "It was like being on a small boat on choppy water."

South Bend.—Felt by all and frightened many. Damage slight. Chimneys twisted

and fell; chimneys cracked. Knickknacks fell. Small objects shifted; vases and small objects overturned. Motion slow; duration, 1 minute.

South Colby.—Felt by and frightened all in community. Damage considerable to brick and masonry. Chimneys twisted and fell. Dishes and windows broke. Knickknacks, books, pictures, stock on store shelves, and plaster fell. Plaster, windows, walls, and chimneys cracked. Small objects and furnishings shifted; vases and small objects overturned. Hanging objects swung and fell. Rapid motion in north-south direction; duration, 45 seconds; preceded about 4 seconds by loud earth noises.

Stanwood.—Felt by many in community. "One of the heaviest shocks ever felt in this locality." Damage slight. Chimneys twisted and fell; chimneys cracked. Knickknacks, books, and pictures fell. Small objects and furniture shifted; vases and small objects overturned. Moderate motion in northwest direction; duration, 20 seconds.

Sultan.—Felt by and frightened all in community. Chimneys twisted and fell. Dishes and windows broke. Knickknacks, books, pictures, plaster, and walls fell. Plaster, walls, and chimneys cracked. Small objects and furnishings shifted; vases overturned. Trees and bushes were shaken strongly. Pendulum clock stopped. Rapid motion in east-west direction; duration, 35–45 seconds; preceded 3–4 seconds by loud earth noises.

Sumner.—Felt by several and frightened few in community. Damage slight to masonry. Chimneys twisted and fell. Plaster and chimneys cracked. Small objects shifted. Rapid motion in east direction; duration, 45–60 seconds; moderate earth noises.

Suquamish (about 15 miles northwest of Seattle).—Felt by all; awakened and frightened many in community. Damage slight. The press reported the shoreline of Suquamish, in northeast Kitsap County, heaved

up 15 feet in places. A 2-story beach house was demolished and trees were uprooted. Fill dirt for a road slid down a 100-foot bank. A nearby resident reported the beach below the bank heaved in a wave-like motion and rolled like a wave toward the bank. The beach close under the bank seemed to sink several feet. "The earthquake left a high beach, most of which was washed out by the high tide." Ground cracked. Books and plaster fell. Trees and bushes were shaken strongly. Rapid motion in northeast direction; duration, 40–50 seconds; preceded 5 seconds by moderate earth noises from the east.

Tacoma.—Felt by and frightened all in community. Damage considerable. Press reported the Union Station was evacuated due to extensive damage. Huge chunks of concrete fell from the roof. No one was injured, but most activity at the old depot was halted until damage could be determined. Tacoma police said preliminary reports indicated no major damage. About 60 windows were broken at Schoenfeld's Furniture Store, near the depot. Many walls and chimneys throughout the city and suburbs were toppled; many windows shattered; gas and water mains broke. Damage to schools was very light. One of the main downtown streets, Pacific Avenue, was littered with bricks and debris. A cross fell from one church. The Narrows Bridge shook violently for 3–5 minutes, but no serious damage resulted. An official reported bolts on the bridge were sheared and one light pole was down. A cashier at the toll plaza reported vibrating cables scarred concrete blocks, and that light standards shook, dislodging glass fixtures. All glass in the roadway lights was broken. Cables rippled the length of the span. Two liquor stores reported broken merchandise. Rapid motion in west direction; duration, 1 minute; loud earth noises.

Tahuya.—Felt by all. Damage slight to concrete. Chimneys twisted and fell. Ground cracked. Small objects and fur-

nishings shifted; china closet nearly overturned. Trees and bushes shook strongly. Hanging objects swung north-south. Rapid motion in north-south direction, duration, less than 1 minute; preceded 2-3 seconds by loud earth noises. "This earthquake was much stronger than the 1949 shock."

Tumwater (about 2 miles south of Olympia).—Landslide caused breakage of a sewer line and railroad tracks. The Union Pacific Railroad reported that a hillside fill slid away from beneath a 400-foot section of a branch line just outside of Olympia (press). Damage was estimated at about \$200,000.

Vashon Island.—Considerable chimney loss, wall cracks, and fallen plaster were reported from practically all parts of the island. The southern and western sections seemed to have been most severely damaged. Press reports stated the Burton-Tahlequah Road settled. Stock was thrown from shelves in markets and bottles broke. Home waterpipe broke. Felt very strongly at Vashon. At Ellisport, east shore, the shock was felt by all, awakened few, and frightened many. Trees and bushes were shaken strongly; hanging objects swung northeast. Rapid motion in northeast direction; duration, 30 seconds to 1 minute; loud earth noises.

Vaughn.—Felt by, awakened, and frightened many. Damage slight. Chimneys twisted and fell; some chimneys cracked. Knickknacks, books, and pictures fell. Trees and bushes were shaken strongly. Slow motion in west-east direction; duration, 45 seconds. This was preceded by loud earth noises from the south.

Wauna.—Felt by all and frightened many in community. Damage considerable to brick and masonry. Chimneys twisted and fell. Knickknacks, books, and pictures fell. Plaster, walls, and chimneys cracked. Small objects shifted and overturned. Trees and bushes were shaken strongly. Pendulum clock stopped. Rapid motion in north-

south direction; duration, 45 seconds; moderate earth noises from north-south.

NOTE: Since additional data have been received subsequent to the printing of the report, "*The Puget Sound, Washington Earthquake of April 29, 1965*," some towns that were listed in the report at lower intensities have been re-evaluated at higher intensities.

INTENSITY VI: Adna, Alder, Algona, Aloha, Amanda Park, Amboy, American River, Anderson Island (47°09.8' north, 122°42.0' west), Ardenvior, Arlington, Bainbridge Island, Baring, Bay Center, Beaver, Belfair, Bellevue, Blaine, Bothell, Bremerton, Bridgeport, Brooklyn, Brush Prairie, Bucoda, Burien, Burley, Burlington, Burton, Carbonado, Cashmere, Castle Rock, Cathlamet, Centralia, Chehalis, Chelan, Chelan Falls, Cinebar, Clallam Bay, Clearlake, Cle Elum, Clinton, Concrete, Conway, Copalis Beach, Copalis Crossing, Cosmopolis, Cougar, Coupeville, Darrington, Dryden, Dupont, Easton, Edmonds, Ellensburg, Elma, Ethel, Fall City, Fort Steilacoom, Fox Island, Frances, Freeland, Galvin, Gig Harbor, Glenoma, Gooseprairie, Graham, Hadlock, Hansville, Harper, Hoodport, Hyak, Ilwaco, Index, Indianola, Joyce, Kelso, Keyport, Kosmos, La Center, Lacey, La Conner, Langley, Lebam, Lester, Lilliwaup, Littlerock, Long Beach, Longview, Lowell, Lyman, Lynden, McKenna, Marblemount, Marysville, Mayfield, Medina, Menlo, Mercer Island, Midway, Monroe, Morton, Mossyrock, Mountlake Terrace, Mount Rainier National Park, Mount Vernon, Mukilteo, Naches, Nahcotta, Napevine, Nooksack, Nordland, Omak, Onalaska, Orondo, Oysterville, Pacific Beach, Packwood, Pe Ell, Porter, Port Gamble, Port Ludlow, Potlatch, Rainer, Randle, Raymond, Redmond, Redondo, Richmond Beach, Rochester, Rollingbay, Roy, Ryderwood, Satsop, Seabeck, Seahurst, Seattle Heights, Sekiu, Selah, Selleck, Shelton, Silvana, Skamokawa, Snohomish, South Cle Elum, South Prairie,

Southworth, Startup, Stevens Pass (Mount Persis region), Swift Dam (about 5½ miles east of Cougar), Tokeland, Toledo, Toutle, Tracyton, Tukwila, Union, Vader, Wilkeson, Winlock, Woodinville, Woodland, and Zenith.

INTENSITY VI IN OREGON: Astoria, Birkenfeld, Boring, Buxton, Clatskanie, Clifton, Hammond, Knappa, Newberg, Seaside, and Vernonia.

INTENSITY VI IN BRITISH COLUMBIA, CANADA:

Victoria.—Plaster cracked; china broke. Many vacated houses. Piles shifted at the harbor. (Questionnaire canvass by Dr. W. G. Milne, Dominion Astrophysical Observatory, Victoria, B. C.)

INTENSITY V IN WASHINGTON: Aberdeen, Acme, Aeneas, Ajlune, Ariel, Ashford, Big Lake (about 6 miles southeast of Mount Vernon), Blanchard, Bow, Brewster Buena, Bumping Lake, Carlsborg, Carrolls, Chewelah, Chinook, Cliffdell, Colfax, Connell, Cook, Cowiche, Creston, Crewport, Curlew, Curtis, Custer, Decatur Island, Deep River, Deer Harbor, Deming, Doty, East Olympia, Eastsound, Edison, Electric City, Everson, Ferndale, Ford, Friday Harbor, Gardiner, Gifford, Glenwood, Grayland, Grays River, Greenbank, Hamilton, Heisson, Hoquiam, Humptulips, Inchelium area, Kalama, Keller, Kittitas, Lakewood, Lamont, La Push, Loon Lake, Lopez, Lummi Island, Lynnwood, Malaga, Malone, Malott, Maple Falls, Marietta, Matlock, Mazama, Metaline, Methow, Millwood, Moclips, Monitor, Moxee City, Naselle, Neah Bay, Neilton, Nespelem, North Bonneville, Oak Harbor, Ocean City, Ocean Park, Olga, Orcas, Port Angeles, Port Townsend, Prosser, Riverside, Rock Island, Rockport, Rosburg, Salkum, Shaw Island, Silver Creek, Silverdale, Silverlake, Steilacoom, Stevenson, Sumas, Tenino, Thorp, Tumtum, Underwood, Vancouver, Vantage, Waldron, White Salmon, Wiley City, Winthrop, Withrow, Yakima (and 6 miles north of at Glead), Yelm, and Zillah.

INTENSITY V IN OREGON: Aloha, Beaver, Brightwood, Cannon Beach, Cape Meares Lighthouse (about 8 miles northwest of Tillamook), Fairview, Gales Creek, Hebo, Hillsboro, Jewell, McMinnville, Mayville (3 miles east of), Milwaukie, Monmouth, Mosier (2 miles southeast of), Mount Hood, Odell, Philomath, Portland, Rainier, Sandy, Scappoose, Tidewater, Tigard, Timber, Tygh Valley, Valsetz, Warrenton, and Willamina.

INTENSITY V IN BRITISH COLUMBIA, CANADA: Abbotsford, Grand Forks, and Huntingdon.

INTENSITY IV IN WASHINGTON: Addy, Airway Heights, Albion, Almira, Anacortes, Azwell, Bellingham, Benton City, Beverly, Bingen, Boyds, Brownstown, Camas, Carlton, Chattaroy, Cheney, Clayton, Chima cum, Colbert, Colville, Conconully, Coulee City, Coulee Dam, Cusick, Douglas, Edwall, Elberton, Elmer City, Ewan, Fairfield, Forks, Four Lakes, Fruitland, Grand Coulee, Granger, Harrah, Hartline, Hatton, Hunters, Husum, Ione, Irby (about 10 miles northwest of Odessa), Kahlotus, Kiona, Lamona, Lancaster, Laurel, Laurier, Lincoln, Lind, Loomis, Lyle, Mabton, Malden, Malo, Manson, Marcus, Markin, Marshall, Maryhill, Medical Lake, Mohler, Molson (10 miles south of, on Dry Gulch Road), Moses Lake, Northport, Odessa, Oroville, Othello, Outlook, Palisades, Pasco, Pateros, Point Roberts, Pullman, Richland (Hanford Project), Roosevelt, Sappho, Schwarzer (5 miles south of Yakima), Sequim, Spokane, Steptoe, Stratford, Sunnyside, Synarep, Thornton, Tiger, Tonasket, Touchet, Trout Lake, Twisp, Union Gap, Uniontown, Usk, Valley, Veradale, Walla Walla and vicinity, Warden, Washougal, Washtucna, Waterville, Waukon, Wenatchee, Westport, White Swan, Wilbur, Wilson, and Yacolt.

INTENSITY IV IN OREGON: Arlington, Aurora, Bonneville, Cascade Locks, Cherry Grove (7 miles west of Gaston), Coos Bay, Dallas, Depoe Bay, Detroit (Detroit Ranger Station, 1 miles west of Detroit), Estacada,

Gardiner, Gaston, Gearhart, Goble, Government Camp, Hood River, Idanha, Ione, Lebanon, Mapleton, Marquam, Mill City, Mulino, Nehalem, North Powder, Oregon City, Pacific City, Parkdale, Prineville, Rufus, Salem, Scottsburg, Shedd, Sheridan, Sublimity, Tillamook, Walton, Westlake, West Linn, and Woodburn.

INTENSITY IV IN IDAHO: Athol, Bonners Ferry, Bovill, Coeur D'Alene, Elk River, Moscow, Nordman, Potlatch, and Saint Maries.

INTENSITY IV IN MONTANA: Eureka.

INTENSITY IV IN BRITISH COLUMBIA, CANADA: Agassiz, Alberni, Cache Creek, Duncan, Ganges, Hope-Princeton Highway, Ladner, Ladysmith, Oliver, Port Renfrew, Powell River, Shawnigan Lake, Silver Creek (3 miles west of Hope), and Vancouver.

INTENSITY I-III IN WASHINGTON: Benge, Bluecreek, Carson, Cedonia, Clearwater, Colton, Cunningham, Danville, Dayton, Deer Park (2 miles north of), Denison, Entiat, Ephrata, Evans, Farmer, Freeman, Glenwood, Goldendale, Grandview, Kettle Falls, Kewa, Larson Air Force Base (about 8 miles north by west of Moses Lake), Liberty Lake, Locke, Mansfield, Mead, Mica, Metaline Falls, Nine Mile Falls, Okanogan, Orient, Otis Orchards, Pine City, Reardan, Rice, Rosalia (5 miles north and west of), Saint John, Soap Lake, Snake River (5 miles north of), Springdale, Tekoa, Toppenish, Urban (Sinclair Island), Waitsburg, Wallula, Wapato, Wawawai (7 miles north of, on Snake River), Wellpinit, Winchester, Winona, and Wishram.

INTENSITY I-III IN OREGON: Clackamas, Coquille, Culver, Eugene (Mahlon Sweet Field, about 8 miles north-northwest of Eugene), Florence, Fossil, Gresham, Halsey, Saint Helens, Silverton, The Dalles (4 or 5 miles west of), Toledo, Waldport, Winchester Bay, and Yachats.

INTENSITY I-III IN IDAHO: Calder, Coolin, Dover, Harrison, Kootenai, and Sandpoint.

INTENSITY I-III IN MONTANA: Hot

Springs, Kalispell, Noxon, Trout Creek, and Whitefish (5½ miles west of Bissel community).

INTENSITY I-III IN BRITISH COLUMBIA, CANADA: Bowser, Castlegar (west side of Columbia River), Denman Island (west-central section), Gabriola (Gabriola Island, northwest section), North Bend, Parksville, Pemberton, Princeton, Ucluelet, and Union Bay.

April 30: 09:10 (about). Elbe, Wash. Light tremor reported felt by two.

October 23: 08:27:59.8*. Epicenter 47.5° north, 122.4° west, Washington, Puget Sound area, W. Magnitude 4.8. Felt at Bremerton, Everett, Olympia, Tacoma, Seattle, and Waterman.

ALASKA

[150th Meridian or Alaska Standard Time]

January 3: 13:13:50.4*. Epicenter 60.2° north, 151.2° west, Kenai Peninsula, depth about 76 km, W. Magnitude 5.3. Felt at Homer.

January 3: 17:41:23*. Epicenter 59.9° north, 153.6° west, southern Alaska, depth about 76 km, W. Magnitude 5.3. Felt at Homer.

January 6: 08:27:36.0*. Epicenter 60.1° north, 151.8° west, Kenai Peninsula, depth about 93 km, W. Magnitude 5.6. Felt at Homer.

January 6: 20:23. Felt at Homer.

January 27: 11:12. Felt on Adak.

February 3: (1) 19:01:21.8*; (2) 21:40:27*. Epicenter (1) 51.3° north, 178.6° east, Rat Islands, Aleutian Islands, depth about 40 km, W. Magnitude 7¾, P; (2) 50.9° north, 177.7° east, Rat Islands, Aleutian Islands, depth about 33 km, W. Magnitude 5.0, W. VI. Buildings cracked and objects fell on Adak and Shemya Islands. Hairline cracks appeared in runways on Attu. The first shock generated a tsunami that was recorded at several tide stations (see "Tidal Disturbances of Seismic Origin," page 61). Slight flood-

ing damage was reported on Shemya and Amchitka Islands.

INTENSITY VI:

Adak.—Felt by all and alarmed many. Slight cracks were observed on some buildings of prefabricated wood construction. Objects fell from walls; roaring-rumbling earth sounds. Gradual onset; rocking-swaying motion, southwest-northeast. "One-foot fall in tide in 15 minutes observed in Sweeper Cove."

Attu.—Felt by all. At the U.S. Coast Guard Loran Station, hairline cracks appeared in runways. Lockers and wall pictures were displaced. Tidal disturbances were observed, ranging from 8 feet above normal level to 8 feet below. Abrupt onset; trembling-swaying motion. Additional shocks were felt at 22:13, 22:59, and on February 4 at 02:06, 04:20, and 05:56.

Shemya.—Felt by all and alarmed many. "Everything not nailed down was swinging or fell. Cracks were observed in asphalt. On pads, the cracks ran mostly north-south, but on runway, an east-west direction was observed." Plaster cracked; drawers on dressers opened; books fell. Gradual onset; rolling motion. "Section of beach road was washed out by sea wave."

February 5: 15:41. At the Scotch Cap Light Station on Unimak Island, three sharp tremors were felt. At 15:50, slight movement was felt for about 40 seconds at Cold Bay.

February 6: 06:50:29*. Epicenter 53.3° north, 161.8° west, south of Alaska, depth about 33 km, W. Magnitude $6\frac{1}{2}$, P. IV. Felt by many at Cold Bay. Buildings swayed very gently. Gradual onset; slight swaying motion, northeast-southwest.

February 11: 20:22. Earth tremor felt on Adak.

February 18: 13:13:36.3*. Epicenter 51.4° north, 179.1° east, Rat Islands, Aleutian Islands, depth about 28 km, W. Magnitude 6, P. Felt on Adak.

February 24: 00:50. Earth tremor felt on Adak.

March 16: 08:24:15.2*. Epicenter 52.1° north, 175.0° east, Rat Islands, Aleutian Islands, depth about 36 km, W. Magnitude 4.9. Felt on Shemya.

March 16: 18:33:41*. Epicenter 51.1° north, 178.3° west, Andreanof Islands, depth about 33 km, W. Magnitude 4.2. Felt on Adak. A second tremor was felt at 21:29 that lasted about 10 seconds.

March 17: 04:27:12.4*. Epicenter 52.8° north, 171.9° east, Near Islands, Aleutian Islands, depth about 23 km, W. Magnitude 6.0. Felt on Shemya.

March 23: 13:35. Light tremor felt at McGrath that lasted 10–15 seconds.

March 27: 21:23. Adak. Ten-second earth tremor observed.

March 29: 16:27:07.2*. Epicenter 50.6° north, 177.9° east, Rat Islands, Aleutian Islands, depth about 51 km, W. Magnitude 7.3, P. Felt on Amchitka and Adak. A minor tsunami, generated by this earthquake, was recorded in Alaska and Hawaii (see "Tidal Disturbances of Seismic Origin").

March 30: 16:00. Slight earthquake felt at Venetie.

April 9: 14:12:44*. Epicenter 50.8° north, 175.8° east, Rat Islands, Aleutian Islands, depth about 33 km, W. Magnitude 5.1. Felt on Amchitka.

April 16: 13:22:18.6*. Epicenter 64.7° north, 160.1° west, central Alaska, depth about 5 km, W. Magnitude $5\frac{3}{4}$ –6, P. VI. Slight damage was reported at Elim. At Kaltag and Unalakleet, river ice was cracked by the shock.

INTENSITY VI:

Elim.—Felt by many. Some people ran outside. Walls pulled loose at seams and moved about one-quarter inch; a few dishes broke; some objects fell from shelves. Buildings creaked and loose objects rattled. Faint earth sounds were heard. Gradual onset; trembling motion.

INTENSITY V:

Kaltag.—Felt by several. "Some were on the Yukon River and reported that ice

was cracking and they were swaying." Buildings creaked and loose objects rattled. Thunderous earth sounds were heard. Rapid onset; swaying motion, east-west.

Koyuk.—Felt by nearly all. Buildings creaked; loose objects rattled; tea kettle on stove moved and made noise. Thunderous subterranean sounds were heard before the shock began. Gradual onset; swaying motion, northeast-southwest.

Unalakleet.—Felt by nearly all. Ice on river cracked. Small cracks were observed in the corner of house and a few doors tightened somewhat. Buildings creaked and loose objects rattled. Rumbling earth sounds were reported. Abrupt onset; bumping motion. Additional shocks were felt at 15:30 and 22:30.

INTENSITY IV:

Kotzebue.—Felt by several. Buildings creaked; loose objects rattled. Clothes hanging on line swung. "Fuel in tanks sloshed around for about 40 minutes after the shock." Suspended objects swung. Gradual onset; swaying motion, east-west.

Nome.—Felt by several. Buildings creaked; loose objects rattled. "Everything in store was swaying." Gradual onset; trembling motion, east-west. About 1½ minutes after main shock, another slight shock was felt.

Ruby.—Felt by several. One stovepipe, not fastened together, fell over. Buildings creaked and loose objects rattled. Gradual onset; swaying motion.

Selawik.—Felt by several. Dishes were displaced and one cup fell from table. Cracking sounds were heard. Gradual onset; rocking motion.

INTENSITY I-III: Buckland, Crooked Creek, Deering, Teller, and Pilot Station.

April 16: 14:00:29.7*. Epicenter 52.6° north, 173.1° east, Near Islands, Aleutian Islands, depth about 43 km, W. Magnitude 5.1. Felt on Shemya.

April 19: 20:43:08.8*. Epicenter 52.4° north, 172.0° east, Near Islands, Aleutian Islands, depth about 35 km, W. Magni-

tude 5-5¼ (Pal). Felt on Amchitka and Adak.

April 26: 01:58. Yakutat. Moderate earth tremor.

April 26: 10:29:07.4*. Epicenter 54.5° north, 162.6° west, Alaska Peninsula, depth about 53 km, W. Magnitude 5-5¼, B. V. Felt by nearly all at Cold Bay. Buildings creaked; loose objects rattled. Rapid onset; swaying motion, east-west. Duration, about 30 seconds.

May 11: 07:37:38.3*. Epicenter 61.4° north, 149.6° west, southern Alaska, depth about 58 km, W. Magnitude 5¾, P. IV. Numerous reports were received of pictures tilting on walls, windows rattling, and dishes jiggling from Anchorage, Seward, and Kenai. Duration, about 20 seconds.

May 27: 09:55. A mild, brief earthquake was felt at Eielson Air Force Base, near Fairbanks.

June 1: 09:41:37.9*. Epicenter 65.1° north, 147.0° west, Alaska, depth about 33 km, W. Magnitude 4.0. Felt in vicinity of Fairbanks.

June 12: 12:08. Earth tremor felt on Adak.

June 24: 08:25. Earth tremor felt on Adak.

June 26: 12:14:36.5*. Epicenter 51.4° north, 178.6° west, Andreanof Islands, Aleutian Islands, depth about 43 km, W. Magnitude 5.2. Felt on Adak.

July 2: 10:58:40.3*. Epicenter 53.1° north, 167.6° west, Fox Islands, Aleutian Islands, depth about 60 km, W. Magnitude 6.9, P. VI. On Umnak Island, dishes were broken in one home and books were tossed all over the room. At Cold Bay, felt by nearly all. Slight creaking was heard and buildings swayed. Lamps swayed 4-6 inches in an east-west direction. Duration, 40 seconds. A minor tsunami was generated with an 0.3-foot amplitude at Unalaska.

July 5: 15:12:47.6*. Epicenter 59.9° north, 149.3° west, Kenai Peninsula, depth

about 44 km, W. Magnitude 3.9. Slight earthquake observed at Homer.

July 8: 11:48. Minor earthquake felt at Whittier.

July 13: 05:10. Slight tremor felt on Adak.

July 14: 19:45:04*. Epicenter 61.8° north, 148.8° west, southern Alaska, depth about 64 km, W. Magnitude 3.8. Light earthquake felt at Anchorage.

July 27: 01:20:27.5*. Epicenter 51.2° north, 177.6° east, Rat Islands, Aleutian Islands, depth about 31 km, W. Magnitude 5.4. Felt on Shemya.

July 28: 22:29:21.2*. Epicenter 50.9° north, 171.4° west, Fox Islands, Aleutian Islands, depth about 22 km, W. Magnitude 6¾, P. Slight tremor felt on Adak. The press reported the shock was felt at military installations in the area.

August 8: 02:49:23.4*. Epicenter 51.8° north, 175.2° west, Andreanof Islands, depth about 53 km, W. Magnitude 4.5, B. Felt on Adak.

September 3: No time given. Earthquake was reported felt at High Lake Lodge on this date.

September 4: 04:32:46.7*. Epicenter 58.2° north, 152.7° west, Kodiak Island region, depth about 10 km, W. Magnitude 6¾-7, P. Felt at Anchorage, Homer, and Kodiak, and over a wide area of south-central Alaska. Also felt onboard USC&GS Ship *Surveyor* located at 58°57' north, 151°23' west.

September 5: 02:11:02*. Epicenter 51.8° north, 176.3° west, Andreanof Islands, Aleutian Islands, depth about 44 km, W. Magnitude 4.2. Earth tremor felt on Adak. Duration, 15 seconds.

September 7: 17:26:20.8*. Epicenter 57.5° north, 152.2° west, Kodiak Island region, depth about 25 km, W. Magnitude 5, B. Three sharp jolts were felt at Kodiak.

September 8: 21:38:26*. Epicenter 60.1° north, 153.2° west, southern Alaska, depth about 104 km, W. Magnitude 3.9. Felt at Homer.

September 22: 21:17:18*. Epicenter 59.8° north, 152.3° west, southern Alaska, depth about 57 km, W. Magnitude 3.9. Felt strongly at Homer.

September 30: 22:52:04.4*. Epicenter 50.1° north, 178.2° east, Rat Islands, Aleutian Islands, depth about 23 km, W. Magnitude 6½, P. Felt on Adak.

October 7: 09:51:57.2*. Epicenter 51.7° north, 176.0° west, Andreanof Islands, Aleutian Islands, depth about 63 km, W. Magnitude 4.7. Felt on Adak.

October 9: 14:35:59.3*. Epicenter 51.8° north, 175.4° west, Andreanof Islands, Aleutian Islands, depth about 53 km, W. Magnitude 5.2. Felt on Adak.

October 11: (1) 20:27:16.8*; (2) 20:38:08*. Epicenter (1) 52.1° north, 174.8° west, Andreanof Islands, Aleutian Islands, depth about 18 km, W. Magnitude 5.1; (2) 51.9° north, 176.4° west, Andreanof Islands, Aleutian Islands, depth about 126 km, W. Magnitude 4.1. Both shocks were reported felt on Adak.

October 15: 06:43 and 06:45. Valdez. Felt.

October 15: 15:44:06*. Epicenter 65.2° north, 164.2° west, Alaska, depth about 33 km, W. Magnitude 4.4. Felt at Nome.

October 23: 17:39:09.4*. Epicenter 52.1° north, 176.1° west, Andreanof Islands, Aleutian Islands, depth about 98 km, W. Magnitude 4.9. Felt on Adak. Duration, 25 seconds.

October 24: 14:47:30*. Epicenter 51.5° north, 178.5° west, Andreanof Islands, Aleutian Islands, depth about 44 km, W. Magnitude 4.0. Felt on Adak. Duration, 10 seconds.

November 5: 20:38:39.3*. Epicenter 60.7° north, 147.3° west, southern Alaska, depth about 21 km, W. Magnitude 5.2. IV. Felt by many in the Anchorage area. "Two rolling swells, concluded by a sharp jolt."

November 8: 02:41:10*. Epicenter 51.6° north, 177.0° west, Andreanof Islands, Aleutian Islands, depth about 64

km, W. Magnitude 4.3. Felt on Adak. Duration, 10 seconds.

November 22: 04:00:27.2*. Epicenter 51.9° north, 176.1° west, Andreanof Islands, Aleutian Islands, depth about 49 km, W. Magnitude 5.6. Earth tremor felt on Adak. Duration, about 60 seconds.

November 22: 16:17:49.7*. Epicenter 51.4° north, 179.7° west, Andreanof Islands, Aleutian Islands, depth about 49 km, W. Magnitude 5.6. Earth tremor felt on Adak. Duration, 10 seconds.

November 22: 20:16:29*. Epicenter 51.4° north, 179.6° west, Andreanof Islands, Aleutian Islands, depth about 45 km, W. Magnitude 4.2. Felt on Adak. Duration, 14 seconds.

November 23: 22:22:39.0*. Epicenter 63.2° north, 150.9° west, central Alaska, depth about 129 km, W. Magnitude 5.0. Railroad employees at Curry reported they felt a heavy jolt that lasted about 15 seconds.

December 1: 12:25. Slight earthquake felt at Intricate Bay.

December 11: 14:48:02.1*. Epicenter 51.5° north, 178.9° west, Andreanof Islands, Aleutian Islands, depth about 49 km, W. Magnitude 5.2. Felt on Adak. Duration, 35 seconds.

December 22: 09:41:23.1*. Epicenter 58.4° north, 153.1° west, Kodiak Island region, depth about 51 km, W. Magnitude 6¾-7, P. V. Light damage, consisting of a few broken glasses, was reported at the Kodiak Naval Air Station. Also felt at Homer and at Koti Bay.

December 29: 16:06:29.0*. Epicenter 54.1° north, 164.3° west, Unimak Island region, depth about 13 km, W. Magnitude 5.5-5.7, B. Felt at Homer.

December 30: 06:33:43.8*. Epicenter 58.2° north, 152.4° west, Kodiak Island region, depth about 33 km, W. Magnitude 5.3. Slight tremor felt at Kodiak.

HAWAII

[150th Meridian or Hawaiian Standard Time]

NOTE: Data on the following local disturbances

were determined from seismograph stations on the Islands of Hawaii and Maui by the Hawaiian Volcano Observatory of the U.S. Geological Survey. For additional information see the *Hawaiian Volcano Observatory Summaries* 37 through 40.

January 1: 04:57:45.4*. Epicenter 19° 48.5' north, 155°25.4' west, 14 km north-east of Pohakuloa at a depth of 13 km. Felt Island-wide. Magnitude 3.9.

January 8: 14:51:07.9*. Epicenter 19° 23.5' north, 155°15.0' west, beneath Kilauea summit at a depth of 27½ km. Felt in Kilauea summit region. Magnitude 3.1.

January 13: 20:25:20.2*. Epicenter 20° 05.7' north, 155°50.5' west, 16 km north-west of Kamuela at a depth of 20 km. Felt at Kamuela and Kohala. Magnitude 3.6.

January 21: 17:29:25.8*. Epicenter 19° 22.5' north, 155°18.2' west, beneath Kilauea summit at a depth of 30 km. Felt at Pahala and in Kilauea summit region. Magnitude 3.1.

January 24: 22:08:13.2*. Epicenter 19° 45.9' north, 155°34.2' west, 5 km north-west of Pohakuloa at a depth of 13 km. Felt at Kamuela, Pahala, and in Kilauea summit region. Magnitude 3.9.

February 8: 09:40:31.0*. Epicenter 19° 53.0' north, 155°35.4' west, 8 km east-northeast of Waikii at a depth of 13 km. Felt at Kamuela and Pahala. Magnitude 3.7.

February 9: 10:53:21.1*. Epicenter 19° 29.5' north, 155°51.1' west, 8 km east-southeast of Kealakekua at a depth of 8 km. Felt at Kona. Magnitude 3.3.

February 11: 17:36:12.4*. Epicenter 19°20.7' north, 155°05.3' west, 11 km east-southeast of Makaopuhi seismometer at a depth of 10 km. Felt at Keaau. Magnitude 2.1.

February 13: 13:06:29.0*. Epicenter 18°45' north, 155°16' west, 48 km south-east of Naalehu at a depth of 13 km. Felt Island-wide. Magnitude 4.5.

February 14: 01:28:21.0*. Epicenter 19°14.8' north, 155°14.0' west, 5 km west-southwest of Apua Point at a depth of 8

km. Felt in Kilauea summit region. Magnitude 3.0.

March 5: 10:55:14.3*. Epicenter 19°24.2' north, 155°17.6' west, 2 km south of Uwekahuna seismometer at a depth of 5 km. Felt in Kilauea summit region. Magnitude 2.7.

March 5: 11:15:25.8*. Epicenter 19°24.9' north, 155°17.2' west, 1 km south of Uwekahuna seismometer at a depth of 5 km. Felt in Kilauea summit region. A press report stated that the eruption of the Kilauea volcano was accompanied by sharp earthquakes which cracked a paved road in front of the crater where the eruption occurred. Magnitude 2.7.

March 6: 01:12:12.0*. Epicenter 19°15.0' north, 155°13.3' west, 3 km west-southwest of Apua Point at a depth of 5 km. Felt at Pahala. Magnitude 4.0.

March 15: 05:37:44.0*. Epicenter 19°10.0' north, 155°28.6' west, 4 km south of Pahala at a depth of 8 km. Felt at Pahala. Magnitude 2.8.

March 20: 19:37:15.2*. Epicenter 19°21.9' north, 155°24.7' west, Kaoiki fault system at a depth of 8 km. Felt at Pahala. Magnitude 3.7.

March 22: 09:33:12.8*. Epicenter 19°13.3' north, 155°32.3' west, 7 km west-northwest of Pahala at a depth of 30 km. Felt Island-wide. Magnitude 4.6.

April 10: 05:48:35.3*. Epicenter 19°22.0' north, 155°18.0' west, beneath Kilauea summit at a depth of 35 km. Felt in Kilauea summit region. Magnitude 3.3.

April 10: 06:09:18.1*. Epicenter 19°21.5' north 155°19.3' west, beneath Kilauea summit at a depth of 25 km. Felt in Kilauea summit region. Magnitude 3.0.

April 16: 16:17:27.9*. Epicenter 19°21.6' north, 155°16.7' west, beneath Kilauea summit at a depth of 30 km. Felt in Kilauea summit region. Magnitude 3.7.

April 18: 19:55:20.6*. Epicenter 19°24.2' north, 155°24.4' west, Kaoiki fault system at a depth of 8 km. Felt in Kilauea summit region. Magnitude 2.9.

May 16: 04:27:30.7*. Epicenter 19°

43.2' north, 156°02.3' west, 10 km northwest of Kailua at a depth of 8 km. Felt. Magnitude 3.5.

May 16: 09:09:42.4*. Epicenter 19°20.2' north, 155°26.7' west, Kaoiki fault system at a depth of 8 km. Felt at Hilo, Pahala, and in Kilauea summit region. Magnitude 3.5.

May 24: 01:28:08.0*. Epicenter 19°22.5' north, 155°25.0' west, Kaoiki fault system at a depth of 8 km. Felt. Magnitude 3.3.

May 24: 20:17:26.4*. Epicenter 19°23.5' north, 155°24.6' west, Kaoiki fault system at a depth of 10 km. Felt at Hilo, Pahala, and in Kilauea summit region. Magnitude 3.6.

May 30: 03:00:27.1*. Epicenter 19°22.8' north, 155°18.2' west, beneath Kilauea summit region at a depth of 25 km. Felt in Kilauea summit region. Magnitude 3.1.

June 4: 02:39:48.4*. Epicenter 19°23.4' north, 155°16.6' west, beneath Kilauea summit at a depth of 40 km. Felt in Kilauea summit region. Magnitude 3.1.

June 7: 15:40:43.8*. Epicenter 19°22.6' north, 155°19.4' west, beneath Kilauea summit at a depth of 25 km. Felt at Pahala and in Kilauea and Mauna Loa summit regions. Magnitude 3.5.

July 7: 00:31:36.8*. Epicenter 20°43' north, 156°30' west, 11 km west-southwest of Haleakala at a depth of 13 km. Felt in Haleakala National Park. Magnitude 3.6.

July 15: 13:32:04.1*. Epicenter 19°22.8' north, 155°14.3' west, 3 km east of Ahua at a depth of 30 km. Felt at Volcano, Hilo, Pahala, Puna, and Mauna Loa Observatory. Magnitude 3.8.

July 18: 04:56:15.6*. Epicenter 19°23.1' north, 155°30.7' west, 14 km west-northwest of Desert seismometer at a depth of 3 km. Felt at Hilo. Magnitude 2.3.

July 19: 17:05:09.8*. Epicenter 19°22.6' north, 155°24.2' west, 5 km north-northwest of Desert seismometer at a depth

of 8 km. Felt at Kapapala and Puna. Magnitude 2.5.

July 22: 07:15:44.0*. Epicenter $19^{\circ}16.8'$ north, $155^{\circ}13.3'$ west, 11 km south-southwest of Makaopuhi seismometer at a depth of 5 km. Felt at Hilo and in Kilauea summit region. Magnitude 3.0.

July 22: 12:27:04.2*. Epicenter $19^{\circ}20.1'$ north, $155^{\circ}30.6'$ west, 14 km west of Desert seismometer at a depth of 3 km. Felt Island-wide. Magnitude 4.3.

July 28: 10:40:23.7*. Epicenter $19^{\circ}24.1'$ north, $155^{\circ}29.9'$ west, 14 km north-west of Desert seismometer at a depth of 5 km. Felt at Hilo and Pahala. Magnitude 3.1.

July 29: 21:19:47.6*. Epicenter $19^{\circ}21.5'$ north, $155^{\circ}05.5'$ west, 10 km east of Makaopuhi seismometer at a depth of 3 km. Felt at Hilo. Magnitude 2.9.

August 11: 12:18:16.5*. Epicenter $19^{\circ}05.7'$ north, $155^{\circ}06.4'$ west, 20 km south-southeast of Apua Point at a depth of 3 km. Felt at Pahala, Mauna Loa Observatory, and Haleakala National Park. Magnitude 3.7.

August 17: 12:28:17.4*. Epicenter $19^{\circ}21.2'$ north, $155^{\circ}18.0'$ west, 4 km southwest of Ahua at a depth of 30 km. Felt in Kilauea summit region. Magnitude 3.3.

August 23: 11:25:07.0*. Epicenter $19^{\circ}16.8'$ north, $155^{\circ}11.9'$ west, 2 km north of Apua Point at a depth of 8 km. Felt at Hilo, Mountainview, and in Kilauea summit region. Magnitude 3.6.

August 23: 11:43:19.6*. Epicenter $19^{\circ}15.9'$ north, $155^{\circ}11.2'$ west, 2 km northeast of Apua Point at a depth of 3 km. Felt at Hilo and Mountainview. Magnitude 3.4.

August 24: 22:35:20.2*. Epicenter $19^{\circ}20.5'$ north, $155^{\circ}08.5'$ west, 5 km southwest of Makaopuhi seismometer at a depth of 5 km. Felt at Pahala and in Kilauea summit region. Magnitude 3.0.

August 25: 00:38:19.5*. Epicenter $19^{\circ}20.5'$ north, $155^{\circ}11.7'$ west, 3 km southwest of Makaopuhi seismometer at a depth of

5 km. Felt in Kilauea summit region. Magnitude 2.1.

August 25: 01:34:17.0*. Epicenter $19^{\circ}19.2'$ north, $155^{\circ}09.8'$ west, 7 km south-southeast of Makaopuhi seismometer at a depth of 8 km. Felt at Hilo, Pahala, and in Kilauea summit region. Magnitude 3.6.

August 25: 02:07:12.0*. Epicenter $19^{\circ}20.0'$ north, $155^{\circ}10.1'$ west, 5 km south-southeast of Makaopuhi seismometer at a depth of 5 km. Felt at Pahala and in Kilauea summit region. Magnitude 2.7.

August 25: 02:15:34.0*. Epicenter $19^{\circ}19.5'$ north, $155^{\circ}10.8'$ west, 5 km south of Makaopuhi seismometer at a depth of 5 km. Felt in Kilauea summit region. Magnitude 2.8.

August 25: 02:59:35.5*. Epicenter $19^{\circ}19.0'$ north, $155^{\circ}09.1'$ west, 7 km southeast of Makaopuhi seismometer at a depth of 5 km. Felt in Kilauea summit region. Magnitude 3.5.

August 25: 09:06:29.1*. Epicenter $19^{\circ}19.9'$ north, $155^{\circ}09.9'$ west, 5 km south-southeast of Makaopuhi seismometer at a depth of 5 km. Felt at Pahala and in Kilauea summit region. Magnitude 3.0.

August 31: 18:00:57.0*. Epicenter $19^{\circ}21.8'$ north, $155^{\circ}20.0'$ west, 7 km northeast of Desert seismometer at a depth of 32 km. Felt at Hilo, Naalehu, and in Kilauea summit region. Magnitude 3.8.

September 1: 09:34:28.7*. Epicenter $19^{\circ}25.0'$ north, $155^{\circ}26.0'$ west, 11 km northwest of Desert seismometer at a depth of 5 km. Felt in Kilauea summit region. Magnitude 2.7.

September 2: 01:42:48.0*. Epicenter $19^{\circ}14.1'$ north, $155^{\circ}03.8'$ west, 15 km east-southeast of Apua Point at a depth of 3 km. Felt at Hilo and in Kilauea summit region. Magnitude 3.7.

September 9: 11:04:22.2*. Epicenter $19^{\circ}13.2'$ north, $155^{\circ}35.2'$ west, 17 km north of Naalehu at a depth of 8 km. Felt at Pahala. Magnitude 2.5.

September 16: 14:21:40.7*. Epicenter $19^{\circ}22.8'$ north, $155^{\circ}17.2'$ west, 3 km west-

northwest of Ahua seismometer at a depth of 30 km. Felt at Pahala. Magnitude 3.0.

September 28: 03:25:53.5*. Epicenter 19°19.1' north, 155°08.6' west, 8 km south-east of Makaopuhi seismometer at a depth of 5 km. Felt at Hilo and in Kilauea summit region. Magnitude 3.3.

October 20: 05:50:52.0*. Epicenter 19°22.4' north, 155°18.7' west, 6 km south-southwest of Uwekahuna at a depth of 30 km. Felt at Kapapala and in Kilauea summit region. Magnitude 3.2.

October 28: 09:48:24.8*. Epicenter 19°29.9' north, 155°48.0' west, 13 km east-southeast of Kealakekua at a depth of 3 km. Felt at Kona. Magnitude 3.3.

October 30: 22:25:05.9*. Epicenter 19°16.4' north, 155°07.1' west, 12 km southeast of Makaopuhi at a depth of 10 km. Felt at Hilo. Magnitude 3.3.

November 13: 07:29:01.8*. Epicenter 19°13.9' north, 155°09.8' west, 15 km south-southeast of Makaopuhi at a depth of 3 km. Felt at Hilo and in Mauna Loa summit region. Magnitude 3.2.

November 17: 04:14:42.0*. Epicenter 19°22.8' north, 155°27.8' west, 10 km west-northwest of Desert seismometer (Kaoiki fault) at a depth of 10 km. Felt at Kapapala. Magnitude 3.0.

November 19: 11:28:28.5*. Epicenter 19°25.7' north, 154°52.9' west, 10 km south-east of Pahoa at a depth of 3 km. Felt at Pahoa. Magnitude 3.1.

November 23: 09:09:59.3*. Epicenter 19°22.8' north, 155°19.7' west, 6 km south-west of Uwekahuna at a depth of 30 km. Felt at Hamakua, Hilo, Kapapala, and in Kilauea and Mauna Loa summit regions. Magnitude 3.9.

November 30: 19:38:13.8*. Epicenter 19°58.1' north, 155°39.5' west, 8 km south-southeast of Kamuela at a depth of 13 km. Felt at Kamuela. Magnitude 3.3.

December 2: 02:38:17.7*. Epicenter 19°46.7' north, 154°56.4' west, 17 km east-northeast of Hilo at a depth of 45 km.

Felt at Hilo, Kapapala, and in Kilauea summit region. Magnitude 3.8.

December 3: 04:13:19.0*. Epicenter 19°22.2' north, 155°27.1' west, 8 km north-west of Desert seismometer (Kaoiki fault) at a depth of 10 km. Felt at Hilo, Kapapala, and in Kilauea summit region. Magnitude 3.3.

December 5: 19:05:08.5*. Epicenter 19°35.2' north, 154°57.8' west, 10 km north-northwest of Pahoa at a depth of 30 km. Felt at Hilo, Hamakua, Kamuela, Kapoho, Pahoa, and in Kilauea and Mauna Kea summit regions. Magnitude 3.8.

December 12: 09:18:47.1*. Epicenter 19°25.3' north, 155°24.9' west, 10 km north-northwest of Desert seismometer at a depth of 8 km. Felt in Mauna Loa summit region. Magnitude 2.6.

December 20: 12:16:37.7*. Epicenter 19°22.1' north, 155°25.8' west, 5 km north-west of Desert seismometer at a depth of 8 km. Felt at Kapapala. Magnitude 2.3.

December 21: 15:49:19.6*. Epicenter 19°21.5' north, 155°17.5' west, 4 km south-west of Ahua seismometer at a depth of 31 km. Felt at Kona, Kapapala, and in Kilauea and Mauna Loa summit regions. Magnitude 3.2.

December 24-31: Accompanying the flank eruption and summit subsidence of the Kilauea volcano, many earthquakes (about 400) with magnitudes of $\frac{1}{2}$ to $4\frac{1}{2}$ were felt in the vicinity of Kilauea caldera. According to the press, earth tremors opened a 6-foot hole in one of the crater roads that leads to Volcano National Park.

PANAMA CANAL ZONE

[60th Meridian Time]

NOTE: Data on the following local disturbances were compiled by the Panama Canal Company, Engineering and Construction Bureau, Meteorological and Hydrographic Branch, Balboa Heights, Canal Zone.

August 2: 10:34:21.4*. Epicenter 7.4° north, 78.7° west, Panama, at a depth of

20 km, W. Magnitude 5.5. Intensity III at Balboa Heights.

August 2: 11:08:07.2*. Epicenter 7.4° north, 78.6° west, Panama, at a depth of 26 km, W. Magnitude 4.3. Intensity II at Balboa Heights.

August 2: 11:36:12*. Intensity II at Balboa Heights.

August 2: 12:43:11.7*. Epicenter 7.4° north, 78.7° west, Panama, at a depth of 17 km, W. Magnitude 5.2, B. Intensity II at Balboa Heights.

August 2: 13:01:41.8*. Intensity III at Balboa Heights.

August 2: 13:51:06*. Intensity II at Balboa Heights.

December 15: 19:05:22.6*. Epicenter

7.5° north, 82.2° west, south of Panama, at a depth of 26 km, W. Magnitude 6¾, P. Intensity II at Balboa Heights.

PUERTO RICO

[60th Meridian Time]

No earthquakes were reported felt during 1965.

VIRGIN ISLANDS

[60th Meridian Time]

April 1: 14:05. A press report stated that St. Thomas was "jarred" by an earthquake, but no damage was reported.

August 23: 03:53:04*. A report from the press stated that a sharp tremor was felt on St. Thomas. Instrumental time by Washington.

Miscellaneous Activities

GEODETIC WORK OF SEISMOLOGICAL INTEREST

During the year 1965, the Coast and Geodetic Survey accomplished surveys for the study of horizontal movement in the earth's crust in the following areas of Alaska and California:

Alaska

- (1) Thompson Pass to Glennallen
- (2) Valdez to Whittier
- (3) Prince William Sound
- (4) Seward to Resurrection Bay to Homer
- (5) Vicinity of Anchorage, monitoring system

The surveys listed under (1) through (4) are extensions of those initiated after the Prince William Sound earthquake of March 1964. When the results of these resurveys were compared with the preearthquake triangulation, significant movements were detected in certain areas. A complete report of these resurveys will be published in *The Prince Williams Sound, Alaska, Earthquake of 1964 and Aftershocks*, Volume III.

California

Winery survey, vicinity of Hollister: This resurvey showed right-lateral movement of about 1.5 cm per year during the two-year interval since the previous survey. This relative movement between stations on opposite sides of the fault is in close agreement with results obtained from previous surveys, 1957 through 1961.

Camp Parks survey, vicinity of Pleasanton: Three small nets in this area were established and observed in 1964. The 1965 resurvey was in close agreement with the original observations and no movement was indicated during this interval.

Aqueduct surveys: In cooperation with the State of California Department of Water Resources, seventeen small nets were established along the San Andreas fault system of southern California in 1964. Results obtained from the 1965 resurveys did not show conclusively that any significant movements occurred during this interval.

Four additional nets of this type were established in the San Francisco Bay area. Repeat surveys will be made at intervals of approximately one year.

From May to August 1965, 623 miles of first-order leveling was undertaken in Alaska. Of this total 469 miles was releveling and 154 miles was original leveling. This was a continuation of the leveling which was begun following the earthquake in March 1964 to update elevation data.

The maximum subsidence, located 27 miles north of Glennallen, was 7.03 feet. Upheaval was noted in the Alaska Range, south of Big Delta along the Richardson Highway, and also north of Cantwell along the railroad. The maximum upheaval was about 0.9 foot.

Releveling from San Pedro to Lebec, Calif., in 1965 indicated an upheaval of about 0.82 foot, since 1953, in the vicinity of Tejon Pass when comparing observed values. A releveling was undertaken to study subsidence in the Arvin-Maricopa area of California.

TIDAL DISTURBANCES OF SEISMIC ORIGIN

Three tsunamis were recorded on Coast and Geodetic Survey tide gages in the Pacific during 1965. Two additional

tsunamis were reported from the Pacific, and two were reported from Greece.

On January 24, newspapers reported that an earthquake in Indonesia (2.4° south, 126.0° east) caused a tsunami which destroyed 90 percent of the houses in Sanana and was damaging on Buru and Mangole Islands.

On February 3, an earthquake in the Rat Islands (51.3° north, 178.6° east) caused a tsunami that was recorded widely across the Pacific. Minor flooding damage was reported from Amchitka, and from Shemya where wave heights were reported to have reached 30 to 35 feet along the southern shore of the island. Maximum recorded wave heights are as follows:

	<i>ft.</i>
Attu, Alaska	10.4
Adak, Alaska	2.3
Sitka, Alaska	0.5
Crescent City, Calif.	1.8
Santa Monica, Calif.	0.5
Hilo, Hawaii	1.9
Midway Island, Pacific Ocean	0.8
Pago Pago, American Samoa	0.9
Kwajalein Atoll, Marshall Islands	0.7
La Libertad, Ecuador	1.2
La Punta (Callao), Peru	1.1
Talara, Peru	0.8
Shimizu (Tosa), Japan	2.5
Kushimoto, Japan	3.7
Hachinohe, Japan	2.6

On March 9, an earthquake in the Aegean Sea (39.4° north, 24.0° east) reportedly caused a tsunami which was noted on Pelagos and Skiathos Islands.

An earthquake in the Rat Islands (50.6° north, 177.9° east) on March 29 caused a minor tsunami which was recorded at several stations. Maximum amplitudes were: Attu, Alaska, 0.7 foot; Kahului, Hawaii, 0.7 foot; Hilo, Hawaii, 0.5 foot; and Nawiliwili, Hawaii, 0.4 foot.

On July 2, an earthquake in the Fox Islands (53.1° north, 167.7° west) generated a minor tsunami with an amplitude of 0.3 foot at Unalaska.

An earthquake on July 6 in Greece (38.7° north, 22.6° east) reportedly caused a tsunami at Eratini.

On August 11, an earthquake in the New Hebrides Islands (15.8° south, 167.2° east) caused a damaging tsunami. Although no tide gage records of the tsunami have been obtained by the Coast and Geodetic Survey, wave heights of 8 feet at Tongoa and 4 feet at Vila were reported.

TILT OBSERVATIONS

Two Merritt tiltmeter stations—Table Mountain and Santiago Peak—continued in routine operation.

Fluctuations in Well-Water Levels

In 1943, the Coast and Geodetic Survey first published the section "Fluctuations in Well-Water Levels" in its annual *United States Earthquakes* series. Data for the years 1944 through 1949 appeared in the 1949 issue of this report; from 1950 through 1964, this section was published annually.

The following material was compiled by Mr. George A. LaRocque, Jr., Hydraulic Engineer, Water Resources Division, U.S. Geological Survey. Table 1 lists only the fluctuations in well-water levels that may be associated with specific earthquakes. Table 2 lists the date, time, and location of these earthquakes along with the states recording the fluctuations.

The well descriptions listed below are for the wells enumerated in table 1 that have not previously been reported in the *United States Earthquakes* series, or that have recently had a change in well number. A complete listing of the well descriptions published since 1943 may be obtained upon request.

WELL DESCRIPTIONS

Alaska

Well No. ED:A-8:2:1 (formerly ANC-51A). Owner, U.S. Air Force at Elmendorf Air Force Base, 61°14'21" N., 149°47'23" W. Depth, 16 feet; diameter, 10 feet by 10 feet; finish, perforated concrete. Aquifer, sand and gravel of Pleistocene age.

Well No. ED:A-8:2:2 (formerly ANC-64), artesian. Owner, U.S. Geological Survey, Elmendorf Air Force Base, SE-NW sec. 11, T. 13 N., R. 3 W. Depth, 617 feet; diameter, 8 inches; cased to 140 feet and filled with silt to 142 feet. Aquifer, sand and gravel of Pleistocene age.

Well No. ED:A-8:2:7 (formerly ANC-114A), artesian. Owner, City of Anchorage, Third and Concrete Avenue, Anchorage, SW-NE sec. 17, T. 13 N., R. 3 W. Depth, 210 feet; diameter, 8 inches. Aquifer, sand and gravel of Pleistocene age.

Georgia

Well No. 487. Owner, U.S. Geological Survey, 32°01'22" N., 80°50'01" W., Chatham County. Depth, 600 feet; diameter, 10 inches; open hole, 571 to 600 feet. Aquifer, principal artesian aquifer.

Well TW-1 (J-52). Owner, U.S. Geological Survey, 31°09'45" N., 81°29'45" W., Glynn County. Depth, 600 feet; diameter, 3 inches; open hole, 535 to 600 feet. Aquifer, upper zone of principal artesian aquifer.

Well TW-3 (33H127). Owner, U.S. Geological Survey, 31°10' N., 81°30' W., Glynn County. Depth, 950 feet; depth of casing, 823 feet. Aquifer, Ocala limestone and possibly part of Claiborne group.

Well TW-6. Owner, U.S. Geological Survey, 31°10'07" N., 81°30'17" W., Glynn County. Depth, 790 feet; diameter, 4 inches; open hole, 520 to 790 feet. Aquifer, upper zone of principal artesian aquifer.

Well Valdosta #1. Owner, City of Valdosta, 30°49'50" N., 83°16'55" W., Lowndes County. Depth, 342 feet; diameter, 20 inches; open hole. Aquifer, Suwannee limestone.

Well No. 14E15. 30°50' N., 83°58' W., Thomas County. Depth, 548 feet. Aquifer, Ocala limestone.

Well Jessup. Owner, Jerome Harvey, 31°37' N., 81°54' W., Wayne County. Depth, 600 feet; diameter, 4 inches; open

hole, 480 to 600 feet. Aquifer, principal artesian aquifer.

Idaho

Well No. 5N-31E-28ccl. Owner, U.S. Atomic Energy Commission, 43°43'40" N., 112°46'20" W., Butte County. Depth, 717 feet; diameter, 12 to 8 inches; depth of casing, 535 feet; open hole. Aquifer, basalt of Snake River group, Quaternary age.

Well No. 7S-17E-6acl. Owner, U.S. Bureau of Reclamation, 42°50'55" N., 114°30'30" W., Jerome County. Depth, 345 feet; diameter, 6 inches; depth of casing, 345 feet; perforations, 322 to 345 feet; open end. Aquifer, Snake River group.

Well No. 5S-23E-17cal. Owner, U.S. Bureau of Reclamation, 42°59' N., 113°45' W., Lincoln County. Depth, 332.7 feet; diameter, 6 inches; depth of casing, 332.7 feet; perforations, 312 to 332 feet. Aquifer, basalt with interbedded clay of Snake River group, Quaternary age.

Well No. 8S-25E-24bd1. Owner, U.S. Bureau of Reclamation, 42°42'45" N., 113°29'02" W., Minidoka County. Depth, 180 feet; diameter, 8 to 6 inches; 8-inch casing to 15 feet; 6-inch casing, 120 to 180 feet; perforations, 160 to 180 feet. Aquifer, Snake River group.

Well No. 11S-19E-17aa1. Owner, H. H. Butler, Jr., 42°28'32" N., 114°15'09" W., Twin Falls County. Depth, 860 feet; diameter, 14 inches; no casing data available. Aquifer, Snake River group.

Indiana

Well No. A14. Owner, Paul Henebry, 41°07'59" N., 85°53'16" W., Allen County. Depth, 43.6 feet; diameter, 4 inches; depth of casing, unknown; open hole. Aquifer, Silurian limestone.

Well No. A15. Owner, Noah Gerig, 41°04'26" N., 84°49'52" W., Allen County. Depth, 100 feet; diameter, 4 inches; depth of casing, about 45 feet; open hole. Aquifer, Silurian limestone.

Well No. Ba4. Owner, City of Columbus, 39°15'37" N., 85°53'44" W., Bartholo-

mew County. Depth, 93 feet; diameter, 6 inches; casing data not available.

Well No. Ba6. Owner, City of Columbus, 39°14'30" N., 85°54'22" W., Bartholomew County. Depth, 74 feet; diameter, 6 inches; casing data not available.

Well No. Ha5. Owner, U.S. Government, 40°00'01" N., 86°30'00" W., Hamilton County. Depth, 100 feet; diameter, 6¼ inches; depth of casing unknown.

Well No. Mi2. Owner, U.S. Government, 40°39'57" N., 86°08'08" W., Miami County. Depth, 165 feet; diameter, 4 inches; depth of casing, 66 feet. Aquifer, Silurian limestone.

Nevada

Well No. S17/50-36dcl. 36°25'45" N., 116°17'30" W., Nye County. Depth unknown (but more than 300 feet). Aquifer, limestone.

Well No. S19/53-32aaa1. 36°15'30" N., 116°02'00" W., Nye County. Depth, 300 feet. Aquifer, alluvium.

New Jersey

Well No. 25.14.9.4.1. Owner, Borough of Madison, 40°45'03" N., 74°23'55" W., Morris County. Depth, 100 feet; diameter, 8 inches. Aquifer, Wisconsin drift.

Well No. 26.21.5.4.6. Owner, Union County Park Commission, 40°41'03" N., 74°17'26" W., Union County. Depth, 290 feet; diameter, 6 inches. Aquifer, Brunswick shale.

Well No. 26.21.5.9.2. Owner, White Laboratories, Inc., 40°40'38" N., 74°16'15" W., Union County. Depth, 250 feet; diameter, 8 inches. Aquifer, Brunswick shale.

Well No. 26.22.4.5.8. Owner, Elizabethtown Water Company, 40°40'48" N., 74°13'02" W., Union County. Depth, 200 feet; diameter, 6 inches. Aquifer, Brunswick shale.

Well No. 28.13.2.6.2. Owner, Forsgate Farms, Inc., 40°21'09" N., 74°30'18" W., Middlesex County. Depth, 104 feet; diameter, 6 inches; 0.025-slot screen at 93 to 104.0 feet. Aquifer, Raritan-Magothy formation.

Well No. 27.24.2.3.2. Owner, State of New Jersey, 40°15'52" N., 74°50'18" W., Mercer County. Depth, 300 feet; diameter, 6 inches; steel casing, 0 to 30 feet; open hole, 30 to 300 feet. Aquifer, Stockton formation.

Well No. 25.4.4.9.7. Owner, International Pipe and Ceramic Corporation,

40°52'21" N., 74°26'31" W., Morris County. Depth, 155 feet; diameter, 6 inches. Aquifer, Wisconsin drift.

Well No. 32.31.3.6.9 (formerly Wharton 2G). 39°40' N., 74°40' W., Atlantic County. Depth, 76 feet. Aquifer, Cohansey sand.

TABLE 1.—Fluctuations in well-water levels, January 1 through December 1965

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

ALASKA

County and/or well no.	Date 1965	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
ED:A-8:2:1 -----	Jan. 27	14:00	5.37	0	0.02	0.02
Do -----	Jan. 27	16:00	5.37	.010	.035	.045
Do -----	Jan. 29	09:00	5.38	.02	.01	.03
Do -----	Feb. 8	17:30	5.39	.05	.06	.11
ED:A-8:3:2 -----	Feb. 27	16:00	8.22	0	.05	.05
ED:A-8:2:1 -----	Feb. 27	22:00	5.38	.02	.005	.025
Do -----	Mar. 2	12:00	5.39	.14	.12	.26
Do -----	Mar. 2	20:00	unknown	.03	.20	.23
Do -----	Mar. 6	05:00	5.40	.08	.13	.21
Do -----	Mar. 10	20:00	5.17	.07	.07	.14
Do -----	Apr. 3	23:00	5.38	.01	.03	.04
Do -----	Apr. 22	20:00	5.30	.03	.04	.07
ED:A-8:3:3 -----	Apr. 25	16:00	7.28	.01	0	.01
ED:A-8:2:1 -----	Apr. 25	22:00	5.38	.01	.03	.04
Do -----	Apr. 26	23:00	5.34	.01	.02	.03
ED:A-8:3:3 -----	May 3	18:00	7.415	.01	.037	.047
Do -----	May 11	12:00	7.535	.015	.015	.03
ED:A-8:2:1 -----	May 11	18:30	5.35	.02	.05	.07
Do -----	June 2	15:00	4.30	.02	.02	.04
Do -----	June 8	13:00	4.42	.04	.04	.08
Do -----	June 22	06:00	4.08	.01	.02	.03
ED:A-8:2:2 -----	June 26	06:00	17.92	.01	.01	.02
ED:A-8:3:3 -----	July 17	19:00	7.737	.001	.003	.004
ED:A-8:2:1 -----	July 18	07:00	4.18	.01	.01	.02
Do -----	Aug. 6	14:00	4.48	.01	.01	.02
Do -----	Aug. 11	17:00	4.31	.03	.01	.04
Do -----	Aug. 17	22:00	4.04	0	.04	.04
ED:A-8:2:7 -----	Sept. 4	13:00	20.315	.01	.045	.055
ED:A-8:3:3 -----	Sept. 4	13:30	8.15	.011	.014	.025
ED:A-8:2:7 -----	Oct. 6	01:00	18.66	.03	.72	.75
ED:A-8:2:1 -----	Oct. 29	22:15	4.70	.04	0	.04
Do -----	Nov. 2	09:30	4.79	.01	.12	.13
Do -----	Nov. 6	06:30	5.01	.01	.02	.03
ED:A-8:3:3 -----	Nov. 6	06:30	7.432	0	.008	.008
ED:A-8:2:1 -----	Dec. 22	20:00	5.08	.03	.05	.08

ARIZONA

(D-15-11)5cccd -----	Feb. 4	06:00	324.07	0.02	0.03	0.05
(D-17-21)15ddb -----	Feb. 14	19:00	332.957	.058	.073	.131
(A-1-4)8dad -----	Aug. 12	02:00	44.58	.07	.04	.11
(D-15-11)5cccd -----	Aug. 13	20:00	326.57	0	.05	.05
Do -----	Aug. 23	20:30	326.67	.08	.07	.15
(A-2-4)23bba -----	Sept. 5	07:00	135.55	.03	.04	.07
(D-15-11)5cccd -----	Dec. 6	12:00	326.96	.01	.02	.03

CALIFORNIA

6/32-11G3 -----	Jan. 19	22:00	10.665	0.015	0.01	0.025
Do -----	Feb. 17	01:30	10.110	.005	.01	.015

TABLE 1.—Fluctuations in well-water levels, January 1 through December 1965—Continued

GEORGIA

County and/or well no.	Date 1965	Time at recorder G.M.T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
			<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>
Lowndes, Valdosta #1 -----	Feb. 4	05:00	117.48	0.07	0.07	0.14
Chatham, 99 -----	Feb. 4	05:15	77.30	.25	.25	.50
Chatham, 317 -----	Feb. 4	05:20	23.50	.15	.35	.50
Dawson, 12-3 -----	Feb. 4	05:35	26.33	.08	.09	.17
Thomas, 14E15 -----	Feb. 4	05:45	188.41	.72	.72	1.44
Glynn, TW-6 -----	Feb. 4	06:00	6.54	.26	.32	.58
Glynn, TW-3 -----	Feb. 4	06:10	+4.4	.20	.10	.30
Glynn, TW-1 -----	Feb. 4	06:30	3.42	.36	.34	.70
Dawson, 12-3 -----	Feb. 4	09:10	26.22	.02	.02	.04
Glynn, TW-1 -----	Mar. 28	16:45	3.50	.07	.01	.08
Dawson, 12-3 -----	Mar. 28	17:30	24.67	.01	.01	.02
Dougherty-USMC -----	Mar. 28	17:30	18.07			trace?
Glynn, TW-6 -----	Mar. 30	02:20	6.62	.02	.03	.05
Thomas, 14E15 -----	Mar. 30	03:00	186.30			.04
Dawson, 12-3 -----	Mar. 30	03:15	24.67	.02	.02	.04
Dougherty-USMC -----	Mar. 30	03:30	17.64	.04	.04	.08
Dawson, 12-3 -----	Apr. 29	15:50	25.04	.01	.01	.02
Dougherty-USMC -----	Apr. 29	16:00	20.35	.01	.01	.02
Thomas, 14E15 -----	Aug. 11	23:20	182.44	.08	.08	.16
Dougherty-USMC -----	Aug. 11	23:40	27.50	.05	.05	.10
Chatham, 317 -----	Aug. 23	19:50	23.60	.26	.30	.56
Chatham, 99 -----	Aug. 23	20:00	85.23	.13	.28	.41
Thomas, 14E15 -----	Aug. 23	20:00	182.32	.80	.80	1.60
Wayne, Jessup -----	Aug. 23	20:00	64.43	.02	.02	.04
Dougherty-USMC -----	Aug. 23	20:05	28.26		.59	>.84
Glynn, TW-3 -----	Aug. 23	20:05	6.1	.20	.20	.40
Glynn, TW-6 -----	Aug. 23	20:15	5.65	.23	.21	.44
Dawson, 12-3 -----	Aug. 23		28.18	.055	.055	.11
Chatham, 99 -----	Sept. 4	14:20	83.42	.12	0	
Chatham, 487 -----	Sept. 4	14:20	19.83	.08	.05	.13
Thomas, 14E15 -----	Sept. 4	15:00	182.30	.06	.07	.13
Chatham, 317 -----	Sept. 4	15:20	24.05			
Dougherty-USMC -----	Sept. 4	15:40	29.18	.09	.08	.18

IDAHO

Madison, 7N-38E-23db1 -----	Jan. 23	23:00-01:00	41.63	0.03	0.05	0.08
Cassia, 13S-21E-18bb1 -----	Feb. 4	02:00-04:00	454.53	.04	.04	.08
Madison, 7N-38E-23db1 -----	Feb. 4	04:00-06:00	42.10			1.00
Twin Falls, 11S-19E-17aa1 -----	Feb. 4	04:00-06:00	322.47	.02	.02	.04
Teton, 4N-45E-13ad1 -----	Feb. 4	04:30	195.77	.03	.05	.08
Twin Falls, 11S-20E-21dc1 -----	Feb. 4	05:00-07:00	68.43	.01	.01	.02
Jefferson, 7N-34E-4cd1 -----	Feb. 4	05:30	9.16	.04	.04	.08
Blaine, 8S-26E-33bc1 -----	Feb. 4	24:00-02:00	107.47	.07	.07	.14
Madison, 7N-38E-23db1 -----	Feb. 27	04:00-06:00	42.57	.11	.10	.21
Minidoka, 8S-25E-24bd1 -----	Feb. 27	09:00-11:00	144.70	.02	.02	.04
Gooding, 8S-14E-16bc1 -----	Feb. 27	14:45	39.17	.05	.04	.09
Madison, 7N-38E-23db1 -----	Mar. 29	23:00-01:00	42.37	.08	.08	.16
Blaine, 1S-19E-3ec2 -----	Apr. 29	14:00-16:00	16.82	.03	.06	.09
Blaine, 2S-20E-1ac2 -----	Apr. 29	14:00-16:00	151.07	.04	.02	.06
Jerome, 8S-19E-5da1 -----	Apr. 29	15:30	275.28	.02	.03	.05
Teton, 4N-45E-13ad1 -----	Apr. 29	15:30	197.79	.11	.09	.20
Jefferson, 7N-34E-4cd1 -----	Apr. 29	16:00	5.94	.06	.08	.14
Jerome, 7S-17E-6ac1 -----	May 22	06:00	315.93	.04	.04	.08
Do -----	May 23	01:00	315.95	.02	.03	.05

TABLE 1.—Fluctuations in well-water levels, January 1 through December 1965—Continued

IDAHO—CONTINUED

County and/or well no.	Date 1965	Time at recorder G.M.T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
			<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>
Twin Falls, 11S-20E-21dc1 -----	May 25	17:30	73.94	0.04	0.07	0.11
Lincoln, 5S-17E-26ac1 -----	May 27	07:00	194.02	.03	.06	.09
Lincoln, 5S-23E-17ca1 -----	June 7	23:00	310.35	.17	.10	.27
Minidoka, 8S-24E-20db1 -----	June 25	01:00	157.85	.03	.02	.05
Teton, 4N-45E-13ad1 -----	Aug. 12	01:30	153.00	.02	.03	.05
Jerome, 8S-19E-5da1 -----	Aug. 23	13:00	269.83	.03	.02	.05
Teton, 4N-45E-13ad1 -----	Aug. 23	14:00	161.37	.09	.10	.19
Twin Falls, 11S-19E-17aa1 -----	Aug. 23	19:00	321.17	.02	.02	.04
Butte, 5N-31E-28cc1 -----	Aug. 23	19:45	263.19	.13	.17	.30
Jefferson, 7N-34E-4cd1 -----	Aug. 23	20:30	22.25	.06	.02	.08
Madison, 7N-38E-23db1 -----	Aug. 23	20:30	39.11	.54	.51	1.05
Cassia, 13S-21E-18bb1 -----	Aug. 23	21:00	462.37	.05	.05	.10
Lincoln, 5S-17E-26ac1 -----	Aug. 23	23:00-01:00	182.56	.05	.04	.09
Twin Falls, 14S-15E-28ba2 -----	Aug. 23	23:30	91.70	.06	.07	.13
Butte, 5N-31E-28cc1 -----	Sept. 4	14:45	262.39	.05	.07	.12
Gooding, 8S-14E-16bc1 -----	Nov. 18	22:15	37.57	.01	.04	.05
Jefferson, 7N-34E-4cd1 -----	Dec. 6	11:15	11.68	.02	.02	.04
Madison, 7N-38E-23db1 -----	Dec. 6	11:15	40.05	.12	.10	.22
Butte, 5N-31E-28cc1 -----	Dec. 6	11:30	260.10	.45	.53	.98
Butte, 3N-29E-14ad1 -----	Dec. 6	11:45	454.08	.04	.03	.07
Madison, 7N-38E-23db1 -----	Dec. 9	05:30	40.05	.14	.12	.26
Jefferson, 7N-34E-4cd1 -----	Dec. 9	06:00	11.28	.02	.01	.03
Butte, 5N-31E-28cc1 -----	Dec. 9	06:00	259.91	.01	.09	.10
Butte, 3N-29E-14ad1 -----	Dec. 9	06:15	453.90	.01	.02	.03

ILLINOIS

DuPage, ANL-10 -----	Feb. 4	07:00	81.87	0.20	0.22	0.42
DuPage, ANL-9 -----	Feb. 4	13:00	96.02	.03	0	.03

INDIANA

Pulaski, Pu6 -----	Jan. 24	00:30	14.52	0.042	0.022	0.064
Marion, Ma32 -----	Jan. 24	01:00	10.735	.042	.010	.052
Pulaski, Pu6 -----	Feb. 4	05:00	11.954	.256	.234	.490
Marion, Ma32 -----	Feb. 4	05:00	10.733	.435	.491	.926
Marion, Ma31 -----	Feb. 4	05:00	102.50	.09	.83	.92
Allen, A1-5 -----	Feb. 4	05:15	27.74	.04	.02	.06
Bartholomew, Ba4 -----	Feb. 4	05:15	20.545	.014	.002	.016
Madison, Md8 -----	Feb. 4	06:00	25.625	.005	.035	.040
Miami, Mi2 -----	Feb. 4	06:15	37.42	.11	.13	.24
Marion, Ma32 -----	Feb. 4	08:15	10.729	.058	.046	.104
Pulaski, Pu6 -----	Feb. 4	08:45	11.892	.041	.029	.070
Marion, Ma32 -----	Feb. 6	02:00	10.716	.009	.007	.016
Pulaski, Pu6 -----	Feb. 6	02:05	11.498	0	.012	.012
Do -----	Feb. 6	16:30	11.627	.007	.007	.014
Marion, Ma32 -----	Feb. 6	16:45	10.750	.011	.011	.022
Do -----	Feb. 27	03:00	10.280	.012	.008	.020
Pulaski, Pu6 -----	Mar. 14	16:00	9.835	.005	.007	.012
Marion, Ma32 -----	Mar. 14	16:45	9.921	.012	.014	.026
Pulaski, Pu6 -----	Mar. 28	16:30	11.775	.003	.017	.020
Marion, Ma32 -----	Mar. 28	17:15	10.120	.024	.006	.030
Do -----	Mar. 30	02:30	10.195	.076	.084	.160
Pulaski, Pu6 -----	Mar. 30	02:30	11.125	.026	.044	.070

TABLE 1.—Fluctuations in well-water levels, January 1 through December 1965—Continued

INDIANA—CONTINUED

County and/or well no.	Date 1965	Time at recorder G.M.T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
			<i>ft</i>	<i>ft</i>	<i>ft</i>	<i>ft</i>
Marion, Ma32 -----	Apr. 16	24:00	9.092	0.011	0.007	0.018
Do -----	Apr. 29	15:30	9.613	.042	.032	.074
Pulaski, Pu6 -----	Apr. 29	15:50	10.119	.037	.001	.038
Do -----	May 20	01:00	12.908	.006	.002	.008
Do -----	June 11	03:30	12.413	.004	.006	.010
Do -----	June 23	11:00	12.681	.004	.009	.013
Marion, Ma32 -----	June 23	11:30	11.770	.035	.025	.060
Pulaski, Pu6 -----	July 29	09:00	14.075	.013	.007	.020
Do -----	Aug. 13	12:45	14.708	.007	.005	.012
Do -----	Aug. 23	19:30	15.635	.057	.001	.058
Bartholomew, Ba6 -----	Aug. 23	19:30	15.880	.004	.008	.012
Marion, Ma31 -----	Aug. 23	20:00	104.40	.08	.20	.28
Marion, Ma32 -----	Aug. 23	20:00	11.58	.19	.15	.34
Madison, Md8 -----	Aug. 23	20:00	23.82	.005	.015	.020
Miami, Mi2 -----	Aug. 23	20:15	37.45	.05	.03	.08
Allen, Al4 -----	Aug. 23	20:30	27.84	.02	.01	.03
Hamilton, Ha5 -----	Aug. 23	20:30	10.806	.006	.012	.018
Pulaski, Pu6 -----	Aug. 24	00:30	15.268	.02	.01	.03
Marion, Ma31 -----	Sept. 4	14:30	104.20	.02	.06	.08
Marion, Ma32 -----	Sept. 4	14:30	10.99	.075	.095	.17
Do -----	Sept. 28	05:15	11.545	.03	.01	.04
Do -----	Sept. 30	24:00	11.175	.03	0	.03
Pulaski, Pu6 -----	Oct. 12	13:15	14.52	.001	.001	.002
Marion, Ma32 -----	Nov. 13	05:30	11.622	.01	.014	.024
Do -----	Dec. 6	11:45	11.701	.047	.033	.08
Do -----	Dec. 9	07:00	11.841	.03	.024	.054
Do -----	Dec. 15	23:00	11.851	.014	.01	.024

MICHIGAN

7N7E17-1 -----	Aug. 11	21:00	32.42	0.09	0.09	0.18
5N12W4-7 -----	Aug. 11	23:00	9.40	.01	.01	.02
Do -----	Aug. 23	19:00	9.40	.04	.04	.08
5N12W4-3 -----	Aug. 23	19:00	12.46	.01	.01	.02
6N12W34-1 -----	Aug. 23	19:00	69.88	.11	.02	.13
4S16W14-1 -----	Aug. 23	19:00	22.76	.03	.03	.06
5N12W4-7 -----	Sept. 4	15:00	9.44	.02	.01	.03
6N12W34-1 -----	Sept. 4	15:00	70.26	.03	.03	.06

NEVADA

S19/53-52aaa1 -----	Feb. 3	15:00	27.52	0	0.01	0.01
S19/60-9bcc1 -----	Feb. 4	04:00	109.34	.23	.33	.56
S22/61-4bcc1 -----	Feb. 4	05:15	114.61	.05	0	.05
S19/60-9bcc1 -----	Feb. 4	09:00	109.40	.03	0	.03
Do -----	Feb. 27	07:45	111.08	.04	.02	.06
Do -----	Mar. 14	16:45	108.89	.02	0	.02
Do -----	Apr. 3	11:45	110.00	.01	0	.01
S22/61-4bcc1 -----	May 3	02:30	116.09	.03	0	.03
S19/60-9bcc1 -----	June 13	07:15	112.13	.02	.05	.07
Do -----	June 27	10:45	112.49	.04	.12	.16
Do -----	July 6	03:15	113.34	.04	.10	.14
Do -----	Aug. 13	14:00	113.70	.01	.03	.04

TABLE 1.—Fluctuations in well-water levels, January 1 through December 1965—Continued

NEVADA—CONTINUED

County and/or well no.	Date 1965	Time at recorder G.M.T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
S19/53-32aaa1 -----	Aug. 13	21:00	27.50	0.09	0.19	0.28
S19/60-9bec1 -----	Aug. 20	07:00	113.03	.03	.08	.11
S17/50-36dc1 -----	Oct. 12	14:40	2.04	.02	0	.02
Do -----	Dec. 3	15:15	1.77	.02	.04	.06
Do -----	Dec. 6	12:20	2.01	.19	.24	.43

NEW JERSEY

Mercer, 27.24.2.3.2 -----	Feb. 4	05:15	+102.42	0.12	0.11	0.23
Union, 26.21.5.9.2 -----	Feb. 4	05:15	43.24	.10	.14	.24
Atlantic, 32.31.3.6.9 -----	Feb. 4	05:15	93.80	.005	0	trace
Morris, 25.14.9.4.1 -----	Feb. 4	05:30	169.63	.05	.02	.07
Mercer, 27.24.2.3.2 -----	Feb. 4	08:00	102.41	.01	.02	.03
Do -----	Mar. 30	03:00	104.76	.03	.03	.06
Union, 26.21.5.4.6 -----	Mar. 30	03:00	59.63	0	.01	.01
Union, 26.22.4.4.4 -----	July 29	08:50	21.55	.02	.02	.04
Do -----	Aug. 11	23:15	17.35	.04	.05	.09
Mercer, 27.24.2.3.2 -----	Aug. 23	20:00	96.65	.02	.03	.05
Union, 26.22.4.4.4 -----	Aug. 23	20:00	18.75	.10	.09	.19
Morris, 25.4.4.9.7 -----	Aug. 23	20:00	287.54	.11	.11	.22
Middlesex, 28.13.2.6.2 -----	Aug. 23	20:00	74.56	.01	.01	.02
Union, 26.22.4.5.8 -----	Aug. 23	20:15	19.73	.02	.03	.05
Union, 26.22.4.4.4 -----	Sept. 4	15:00	18.68	.05	.05	.10

SOUTH CAROLINA

Beaufort, 304 -----	Feb. 4	05:30	19.55	0.25	0.25	0.50
Beaufort, 301 -----	Feb. 4	05:55	15.16	.20	.24	.44
Jasper, 46 -----	Mar. 30	02:45	4.03	.015	.015	.03
Do -----	Apr. 29	15:15	4.10	.01	.01	.02
Do -----	Aug. 11	23:30	5.28	.015	.015	.030
Beaufort, 304 -----	Aug. 23	19:45	18.96	.21	.24	.45
Jasper, 46 -----	Aug. 23	19:45	22.41	.19	.17	.36
Beaufort, 304 -----	Sept. 4	15:20	20.31	.04	.07	.11

WISCONSIN

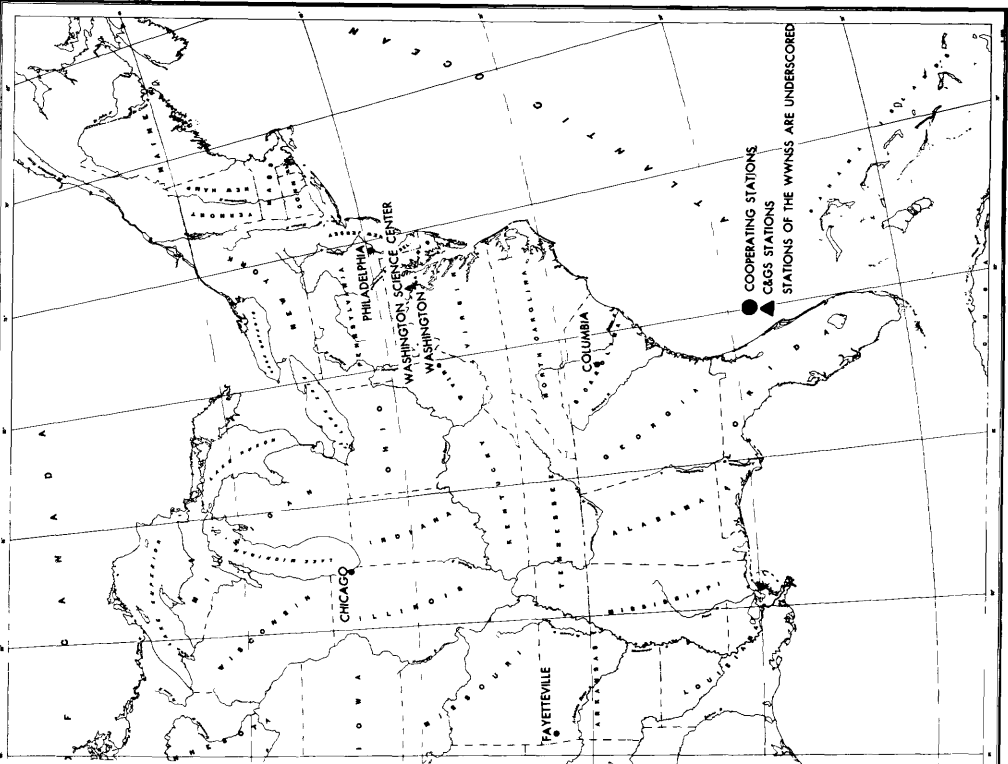
Waukesha, Wk-31 -----	Feb. 4	05:00	136.57	0	0.06	0.06
Sheboygan, Sb-19 -----	Feb. 4	06:30	4.01	.11	.04	.15

TABLE 2.—Earthquakes of 1965 believed to have caused fluctuations in well-water levels

Date 1965	Origin time G.M.T.	Location	States recording fluctuations
Jan. 24	00:11:12.1	Ceram Sea	Idaho and Indiana.
Jan. 27	13:24:09	Gulf of California	Alaska.
Jan. 27	15:31:30	Honshu, Japan	Alaska.
Jan. 29	09:35:25.7	Near east coast of Kamchatka	Alaska.
Feb. 3	15:15:29	Off coast of Michoacan, Mexico	Nevada.
Feb. 4	05:01:21.8	Rat Islands	Arizona, Georgia, Idaho, Illinois, Indiana, Nevada, New Jersey, South Carolina, and Wisconsin.
Feb. 4	08:40:40.9	do	Georgia, Indiana, Nevada, and New Jersey.
Feb. 4	12:06:04.3	Near Islands	Illinois.
Feb. 6	01:40:33.2	South of Alaska	Indiana.
Feb. 6	16:50:29	do	Indiana.
Feb. 8	17:37:24.6	Komandorsky Islands	Alaska.
Feb. 14	18:46:49	Rat Islands	Arizona.
Feb. 17	01:00:23.3	Near Islands	California.
Feb. 27	02:01:36.3	Ryukyu Islands	Indiana.
Feb. 27	04:08:22.5	do	Idaho.
Feb. 27	07:46:29.1	Gulf of California	Nevada.
Feb. 27	10:52:45	do	Idaho.
Feb. 27	14:17:25	Rat Islands	Idaho.
Mar. 2	11:42:25.9	Near Islands	Alaska.
Mar. 6	05:52:58.9	do	Alaska.
Mar. 10	20:29:34.5	Central Alaska	Alaska.
Mar. 14	15:53:06.6	Hindu Kush region	Indiana and Nevada.
Mar. 28	16:33:15.7	Near coast of central Chile	Georgia and Indiana.
Mar. 30	02:27:07.2	Rat Islands	Georgia, Indiana, New Jersey, and South Carolina.
Apr. 3	11:20:43.5	Oaxaca, Mexico	Nevada.
Apr. 16	23:22:18.6	Central Alaska	Indiana.
Apr. 25	15:23:40.1	Near Islands	Alaska.
Apr. 25	21:15:32.3	Andreanof Islands	Alaska.
Apr. 26	22:58:13.4	Rat Islands	Alaska.
Apr. 29	15:28:43.7	Washington	Georgia, Idaho, Indiana, and South Carolina.
May 3	01:09:31.5	Chile-Argentina border region	Nevada.
May 3	17:40:58.4	Rat Islands	Alaska.
May 11	12:04:36	Near Islands	Alaska.
May 11	17:37:38.3	Southern Alaska	Alaska.
May 20	00:40:10.9	New Hebrides Islands	Indiana.
May 23	01:37:00.2	Near Islands	Idaho.
June 2	14:29:29	Fox Islands	Alaska.
June 7	22:23:22	Off coast of Jalisco, Mexico	Idaho.
June 8	12:42:21.9	Off coast of northern California	Alaska.
June 11	03:33:45.8	Kurile Islands	Indiana.
June 13	07:06:13.9	Hokkaido, Japan region	Nevada.
June 22	05:49:27.7	Kashmir-Sinkiang border region	Alaska.
June 23	11:09:15.7	Kodiak Island region	Indiana.
June 25	00:18:57.7	Nevada	Idaho.
June 27	11:08:56.7	Southeastern Alaska	Nevada.
July 6	03:04:21.2	Loyalty Islands region	Nevada.
July 17	18:21:34.6	Alaska Peninsula	Alaska.
July 18	07:23:32.2	South of Alaska	Alaska.
July 29	08:29:21.2	Aleutian Islands region	New Jersey.
July 29	08:54:01.4	Leeward Islands	Indiana.
Aug. 11	20:13:59.1	New Hebrides Islands	Michigan.
Aug. 11	22:31:45.9	do	Georgia, Michigan, New Jersey, and South Carolina.
Aug. 12	01:25:01.9	Tonga Islands region	Arizona.
Aug. 12	01:33:34.6	Molucca Passage	Idaho.
Aug. 13	12:40:37.6	New Hebrides Islands	Indiana and Nevada.
Aug. 13	19:18:25.1	do	Arizona.
Aug. 13	20:51:06.0	Rat Islands	Nevada.
Aug. 17	22:18:52.5	Loyalty Islands	Alaska.
Aug. 23	13:32:37.5	Vancouver Island region	Idaho.

TABLE 2.—Earthquakes of 1965 believed to have caused fluctuations in well-water levels—Continued

Date 1965	Origin time G.M.T.	Location	States recording fluctuations
Aug. 23-----	19:46:01.8	Oaxaca, Mexico -----	Arizona, Georgia, Idaho, Indiana, Michigan, New Jersey, and South Carolina.
Aug. 24-----	00:56:21.3	----- do -----	Idaho and Indiana.
Sept. 4-----	12:33:53.5	Kurile Islands -----	Alaska.
Sept. 4-----	14:32:46.7	Kodiak Island region -----	Georgia, Idaho, Indiana, Michigan, New Jersey, and South Carolina.
Sept. 30-----	23:47:39.9	Gulf of Alaska -----	Indiana.
Oct. 6-----	00:52:10.0	Tonga Islands -----	Alaska.
Oct. 12-----	13:40:59.4	Kodiak Island region -----	Indiana and Nevada.
Oct. 29-----	21:00:00.1	Amchitka Island, "Longshot" ---	Alaska.
Nov. 2-----	09:10:40.2	Kodiak Island region -----	Alaska.
Nov. 6-----	06:38:39.3	Southern Alaska -----	Alaska.
Nov. 13-----	04:33:53.2	Northern Sinkiang Province, China.	Indiana.
Nov. 18-----	22:08:45.7	South of Alaska -----	Idaho.
Dec. 3-----	15:13:02.1	Nevada Test Site, "Corduroy" ---	Nevada.
Dec. 6-----	11:34:51.9	Off coast of Jalisco, Mexico -----	Arizona, Idaho, Indiana, and Nevada.
Dec. 9-----	06:07:47.7	Guerrero, Mexico -----	Idaho and Indiana.
Dec. 15-----	23:05:22.6	South of Panama -----	Indiana.
Dec. 22-----	19:41:23.1	Kodiak Island region -----	Alaska.



and Geodetic Survey publishes instrumental results.

(page 77 follows)

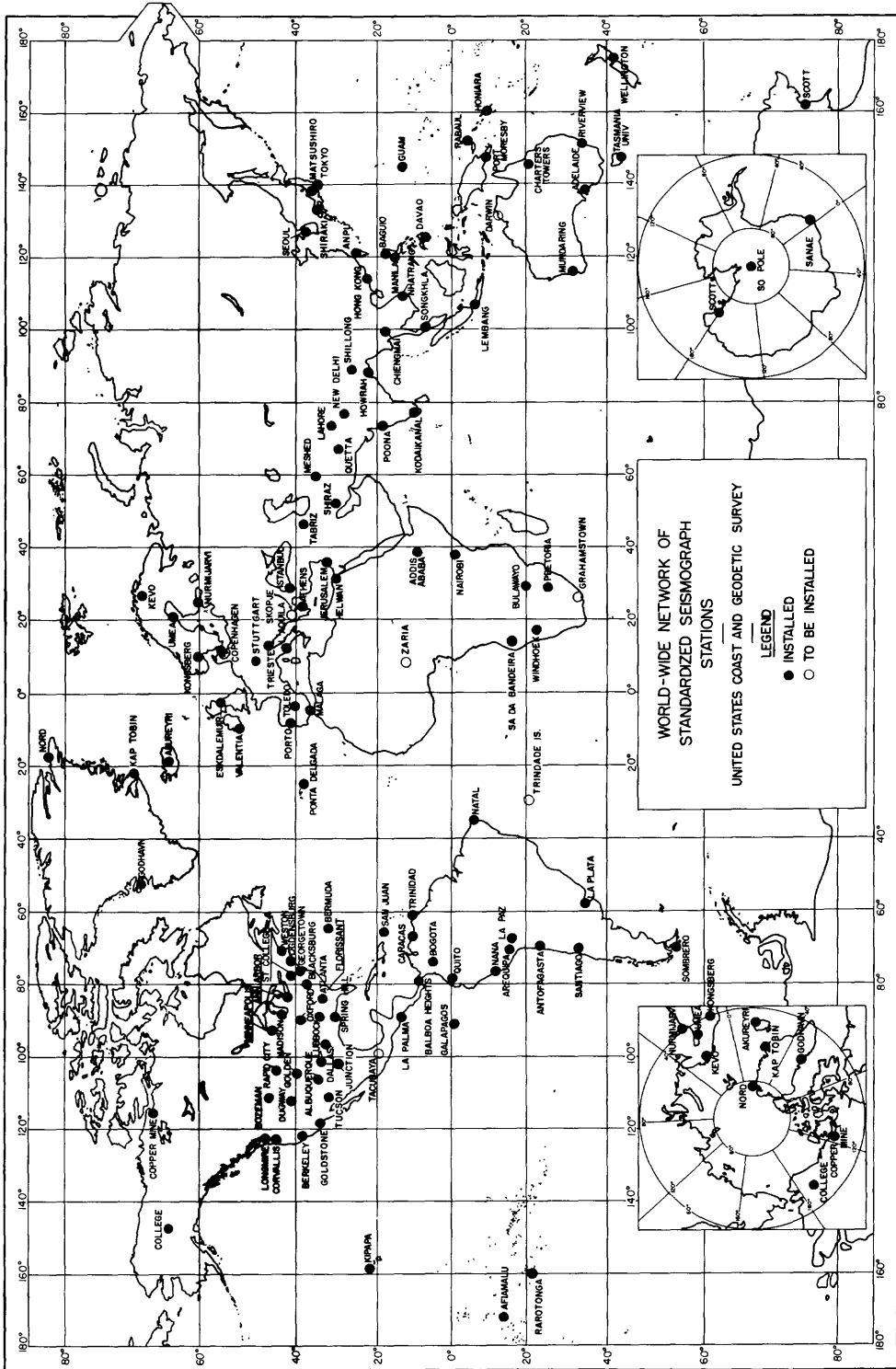


FIGURE 9.—Stations in the World-Wide Network of Standardized Seismographs (WWNSS).

Principal Earthquakes of the World During 1965

NOTE: Listed in this section are (1) earthquakes of magnitude greater than $6\frac{3}{4}$ determined by Pasadena, and earthquakes of smaller magnitude which were locally destructive; (2) earthquakes of unusual interest. All times are Greenwich (G.M.T.).

January 1: 21:38:29.2*. Epicenter 35.7° north, 4.4° east, Algeria, W. Magnitude $5\frac{1}{4}$ – $5\frac{1}{2}$. This was the culminating shock of a series which began in the latter part of December. Four persons were killed, several injured, and over 2,500 houses damaged or destroyed at M'Sila. Depth about 10 km.

January 24: 00:11:12.1*. Epicenter 2.4° south, 126.0° east, Ceram Sea, W. Magnitude 7.6. This devastating earthquake was the culmination of a series of tremors generally felt in the inland areas during the previous week. According to the press, nearly 3,000 buildings and 14 bridges were destroyed on Sanana Island. Sanana, Indonesia, reported 71 persons were killed by the earthquake and accompanying tsunami. Also inundated were Buru and Mangole Islands. Depth about 6 km.

February 4: 05:01:21.8*. Epicenter 51.3° north, 178.6° east, Rat Islands, Aleutian Islands, W. Magnitude $7\frac{3}{4}$. This earthquake generated a tsunami that was recorded at several tide stations (see "Tidal Disturbances of Seismic Origin," page 61) and caused slight flooding damage on Shemya and Amchitka Islands. The shock cracked buildings and knocked over objects on Adak and Shemya. Hairline cracks were observed in the runways on Attu. Depth about 40 km.

February 4: 08:40:40.9*. Epicenter 51.3° north, 179.5° east, Rat Islands,

Aleutian Islands, W. Magnitude 6.9. This earthquake was not reported felt, but is included since the magnitude was more than $6\frac{3}{4}$. Depth about 40 km.

February 10: 16:09:54.1*. Epicenter 37.6° north, 47.1° east, northwestern Iran, W. Magnitude 5.1. At least 20 persons were fatally injured and thousands of houses were destroyed in and near Bustanabad. Property loss included thousands of head of livestock. Depth about 52 km.

February 23: 22:11:50.2*. Epicenter 25.7° south, 70.5° west, near coast of northern Chile, W. Magnitude 7. One person was killed and five were injured in this earthquake. Cave-ins occurred in various copper mines in the region, and the walls of numerous buildings cracked. In Copiapo, power, telephone, and water lines were broken and residents fled into the streets in panic. Depth about 80 km.

March 3: 15:14:09.7*. Epicenter 5.5° south, 151.9° east, New Britain region, W. Magnitude 6.9. This earthquake was not reported felt, but is included since the magnitude is about $6\frac{3}{4}$. Depth about 44 km.

March 9: 17:57:53.7*. Epicenter 39.4° north, 24.0° east, Aegean Sea, W. Magnitude 6.3. According to press reports, 85 percent of the buildings on the Islands of Alonnisos and Skopelos were destroyed and two people were killed. The shock was felt throughout Greece, and in Canakkale and Edremit, Turkey. Depth about 18 km.

March 14: 15:53:06.6*. Epicenter 36.3° north, 70.7° east, Hindu Kush region, W. Magnitude $7\frac{1}{2}$. Light damage was reported in west Pakistan and Afghanistan.

Two persons were injured at Peshawar, Pakistan. The shock was also felt at Tashkent, Uzbek S.S.R., and New Delhi, India. Depth about 219 km.

March 28: 16:33:15.7*. Epicenter 32.4° south, 71.3° west, near coast of central Chile, W. Magnitude 7.3. About 400 persons were killed or missing, 350 were injured, and extensive property damage was reported throughout the area. The mining village of El Cobre completely disappeared after the shock shattered a 230-foot dam, cascading two million tons of water and mud into the town. There was extensive damage to bridges, roads, and public utilities, and structural damage to thousands of buildings in Santiago and Valparaiso. At Llay-Llay, almost every building was heavily damaged by the earthquake and ensuing fires. Several other towns north of Santiago reported extensive property damage. Depth about 72 km.

March 30: 02:27:07.2*. Epicenter 50.6° north, 177.9° east, Rat Islands, Aleutian Islands, W. Magnitude 7.3. This earthquake was felt on Amchitka and Adak Islands. A minor tsunami was generated, but no damage resulted from flooding (*see* "Tidal Disturbances of Seismic Origin," page 61). Depth about 51 km.

March 31: 09:47:30.7*. Epicenter 38.6° north, 22.4° east, Greece, W. Magnitude $6\frac{3}{4}$. A series of earthquakes battered central Greece, resulting in 6 deaths, 22 injuries, and major property damage at Patras and Agrinion. The main shock was felt widely in Yugoslavia, and throughout southern Italy. Depth about 78 km.

April 5: 03:12:54.2*. Epicenter 37.7° north, 21.8° east, southern Greece, W. Magnitude 6. Central Peloponnesus sustained 32 deaths, 200 injuries, and major property damage. Many villages were extensively damaged. Depth about 34 km.

April 19: 23:41:58.8*. Epicenter 34.9° north, 138.0° east, near south coast of Honshu, Japan, W. Magnitude 6. One person was killed and 4 were injured in

Aichi Prefecture. Yokohama and areas to the north were hardest hit. Railway tracks were wrenched out of position and numerous cave-ins occurred on one express-line. Depth about 36 km.

April 29: 15:28:43.6*. Epicenter 47.4° north, 122.3° west, Washington, W. Magnitude 6.5. Three persons were killed from falling debris, four died from heart failure, and numerous injuries occurred. Property damage, estimated at about \$12½ million, was confined mostly to Seattle and King County (*see* write-up beginning on page 32). Depth about 59 km.

May 3: 10:01:35.2*. Epicenter 13.5° north, 89.3° west, El Salvador, W. Magnitude 6. This violent earthquake left 125 persons dead, about 500 injured, and an estimated 48,000 homeless. Many of the victims were from the town of Ilopango which was almost completely destroyed. Several buildings were wrecked in San Salvador, Cisneros District, San Marcos, and Santo Tomas. Depth about 23 km.

May 20: 00:40:10.9*. Epicenter 14.7° south, 167.4° east, New Hebrides Islands, W. Magnitude 7. This earthquake was not reported felt, but is listed since the magnitude is above $6\frac{3}{4}$. Depth about 16 km.

June 13: 20:01:48.0*. Epicenter 37.8° north, 29.3° east, Turkey, W. Magnitude $5\frac{3}{4}$. In the Denizli region, two persons were fatally injured and about 200 houses were destroyed. Depth about 16 km.

July 2: 20:58:40.3*. Epicenter 53.1° north, 167.6° west, Fox Islands, Aleutian Islands, W. Magnitude 6.9. Slight damage was reported on Umnak Island. A minor tsunami was generated with an 0.3 foot amplitude at Unalaska. Depth about 60 km.

July 6: 03:18:42.7*. Epicenter 38.4° north, 22.4° east, Greece, W. Magnitude $6\frac{1}{4}$. One person was killed and 6 were injured at Eratini, northern Peloponnesus. Heavy property damage was reported throughout the area. Depth about 20 km.

Principal Earthquakes of the World During 1965

August 2: 13:19:55.9*. Epicenter 56.2° south, 157.9° east, Macquarie Island region, W. Magnitude $7-7\frac{1}{4}$. This earthquake was not reported felt, but is listed since the magnitude is above $6\frac{3}{4}$. Depth about 33 km.

August 5: 19:05:08*. Epicenter 14.8° north, 91.0° west, Guatemala, W. Magnitude 4.0. One was killed and 4 were injured at a hydroelectric project when several workers were buried under dirt. The shock was felt at Guatemala City, but no damage was reported. Depth about 59 km.

August 11: 03:40:54.7*. Epicenter 15.5° south, 166.9° east, New Hebrides Islands, W. Magnitude 7. This earthquake was not reported felt, but is listed since the magnitude is above $6\frac{3}{4}$. Depth about 14 km.

August 11: 22:31:45.9*. Epicenter 15.8° south, 167.2° east, New Hebrides Islands, W. Magnitude 7.3. Some property damage was reported on Espiritu Santo and a tsunami was observed at Vila and Tongoa (4- and 8-foot waves, respectively). Depth about 13 km.

August 13: 12:40:37.6*. Epicenter 15.9° south, 167.6° east, New Hebrides Islands, W. Magnitude 7. This earthquake was not reported felt, but is listed since the magnitude is above $6\frac{3}{4}$. Depth about 94 km.

August 23: 19:46:01.8*. Epicenter 16.3° north, 95.8° west, Oaxaca, Mexico, W. Magnitude $7\frac{1}{4}$. This shock was felt throughout southern Mexico and left five persons dead in Mexico City and one in Oaxaca. Slight structural damage was reported from both cities and telephone and electric services were disrupted. Depth about 20 km.

September 4: 14:32:46.7*. Epicenter 58.2° north, 152.7° west, Kodiak Island region, W. Magnitude $6\frac{3}{4}-7$. This shock was felt over a wide area of south-central Alaska, and onboard the USC&GS Ship *Surveyor* located near the epicenter. Depth about 10 km.

December 22: 19:41:23.1*. Epicenter 58.4° north, 153.1° west, Kodiak Island region, W. Magnitude $6\frac{3}{4}-7$. Light damage was reported on Kodiak Island. Also felt at Homer and Koti Bay. Depth about 51 km.

Strong-Motion Seismograph Results

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 required 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.

INTERPRETATION OF RECORDS

The analyses appearing in tables 5 and 6 are based on the assumption of simple harmonic motion. This refers especially to the computation of displacement from accelerograph records. As most accelerograph records are of irregular character and the character of the longer-period waves are 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 representing the equivalent of 0.1 g and 1 inch are indicated on the tracings of the acceleration and displacement curves. The scales provide the investigator with a quick means for making rough measurements on the published curves. The measurements of

period on records of this nature are dependent largely on the judgment of the person reading them and considerable latitude must be allowed in appraising their accuracy. The aim of such analyses is primarily to give a fair picture of the magnitudes of the various elements involved, and the figures tabulated should therefore not be used for important studies without first referring to the illustrations for some idea of the nature of the original records.

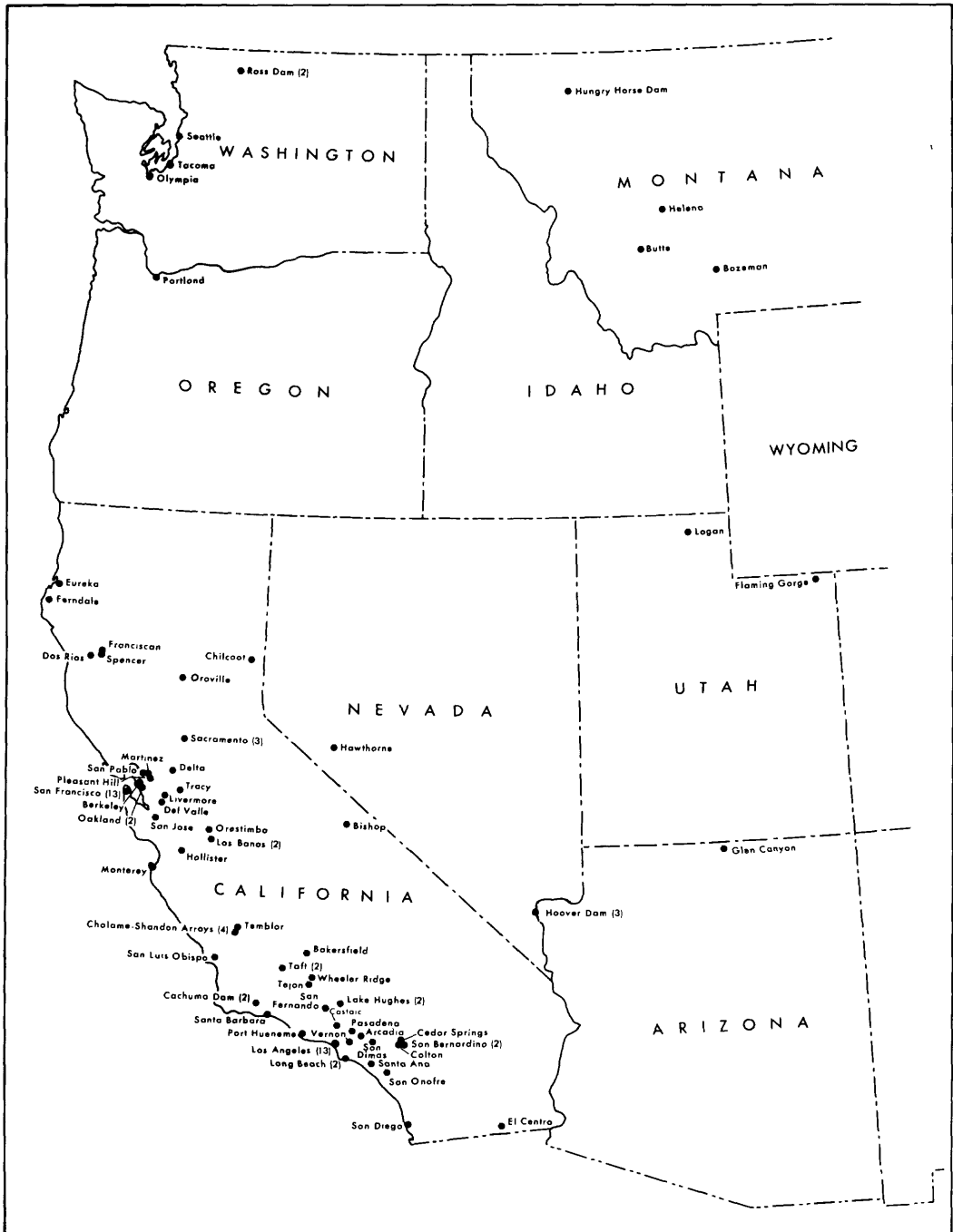


FIGURE 10.—Strong-motion stations in the western United States.

TABLE 3.—Coast and Geodetic Survey and affiliated strong-motion stations in operation as of December 31, 1965

NORTHERN CALIFORNIA

Station	Accelerograph	Displacement meter	Weed	AR-240
Berkeley, University of California, Haviland Hall	1	1		
Bishop, Los Angeles Water Department, garage	1			
Chilcoot, Frenchman Reservoir, Department of Water Resources Site	1			
Cholame-Shandon Array No. 2, Department of Water Resources Site				1
Cholame-Shandon Array No. 5, Department of Water Resources Site				1
Cholame-Shandon Array No. 8, Department of Water Resources Site				1
Cholame-Shandon Array No. 12, Department of Water Resources Site				1
Delta, Empire Tract, Department of Water Resources Site	1			
Del Valle, Sanitorium Nurses Home, basement, Department of Water Resources Site				1
Dos Rios, Department of Water Resources Site				1
Eureka, Federal Building	1			
Ferndale, City Hall	1	1		
Franciscan, Department of Water Resources Site				1
Hollister, City Library	1	1		1
Livermore, Lawrence Radiation Laboratory, Building 110, basement	1			
Los Banos, San Luis Reservoir Engineer Control, Department of Water Resources Site				1
Los Banos, San Luis Reservoir Batching Plant, Department of Water Resources Site				1
Martinez, Suisun Bay Bridge	1			
Monterey, City Hall		1	1	
Oakland, City Hall, basement	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, Pacific Telephone and Telegraph Building, basement	1	1		
Sacramento, Pacific Telephone and Telegraph 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 Building, basement			1	
San Francisco, 450 Sutter Building, 29th floor			1	
San Francisco, Federal Building	1	1		
San Francisco, Shell Building, basement			1	
San Francisco, Shell Building, 21st floor			1	
San Francisco, Shell Building, 29th floor			1	
San Francisco, Southern Pacific Building, basement	1	1		
San Francisco, State Building, basement		1		
San Jose, Bank of America Building, basement	1			
San Pablo, Contra Costa Junior College	1	1		
Spencer, Department of Water Resources Site				1
Taft, Buena Vista, Department of Water Resources Site				1
Taft, Lincoln School Tunnel	1			
Tejon, Ft. Tejon, Department of Water Resources Site				1
Tracy, Pumping Plant, Department of Water Resources Site	1	1		
Wheeler Ridge, Department of Water Resources Site				1

SOUTHERN CALIFORNIA

Arcadia, Santa Anita Reservoir				1
Bakersfield, Harvey Auditorium	1	1		
Cachuma Dam, Crest Station	1	1		
Cachuma Dam, Valve House Station	1	1		
Castaic, Old Ridge Route, Department of Water Resources Site				1
Cedar Springs, Department of Water Resources Site				1

TABLE 3.—Coast and Geodetic Survey and affiliated strong-motion stations in operation as of December 31, 1965—Continued

SOUTHERN CALIFORNIA—CONTINUED

Station	Accelerograph	Displacement meter	Weed	AR-240
Colton, Southern California Edison Building -----	1	1	-----	-----
El Centro, Imperial Valley Irrigation District Substation -----	1	2	-----	-----
Fairmont Station, Fairmont Reservoir -----	1	1	-----	-----
Lake Hughes Array No. 12, Department of Water Resources Site, Post Office Building.	-----	-----	-----	1
Lake Hughes Array No. 1, Department of Water Resources Site, Warm Springs Camp.	-----	-----	-----	1
Long Beach, Utilities Building -----	1	1	-----	-----
Long Beach, Terminal Island, Southern California Edison Plant ----	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., adjacent Pacific Electric lot ----	1	-----	-----	-----
Los Angeles, Occidental Life Building, basement -----	1	-----	-----	-----
Los Angeles, Occidental Life Building, 11th floor -----	1	-----	-----	-----
Los Angeles, Subway Terminal, subbasement -----	1	1	-----	-----
Los Angeles, Subway Terminal, 13th floor -----	1	-----	-----	-----
Los Angeles, Water and Power Building, "B" level -----	-----	-----	-----	1
Los Angeles, Water and Power Building, 7th floor -----	-----	-----	-----	1
Los Angeles, Water and Power Building, 15th floor -----	-----	-----	-----	1
Los Angeles, Westwood Engineering Building, University of California.	1	1	-----	-----
Pasadena, California Institute of Technology, Faculty Club Building --	1	-----	1	-----
Port Hueneme, Navy Laboratory -----	1	1	-----	-----
San Bernardino, Devils Canyon, Department of Water Resources Site --	-----	-----	-----	1
San Bernardino, Federal Building -----	-----	-----	1	-----
San Diego, Light and Power Company Service Building -----	1	-----	-----	-----
San Dimas, Puddingstone Reservoir -----	-----	-----	-----	1
San Fernando, Pacoima Dam -----	-----	-----	-----	1
San Luis Obispo, City Recreation Building -----	1	-----	-----	-----
San Onofre, Southern California Edison Co., Nuclear Generating Station.	-----	-----	-----	1
Santa Ana, Orange County Engineering Building -----	1	1	-----	-----
Santa Barbara, Court House -----	1	-----	-----	-----
Temblor, Cholame, Department of Water Resources Site -----	-----	-----	-----	1
Vernon, Central Manufacturing District Terminal Building -----	1	-----	-----	-----

OUTSIDE CALIFORNIA

<i>Alaska</i> (see fig. 11):				
Adak, U.S. Naval Base, BOQ Annex Building -----	-----	-----	-----	1
Anchorage, Alaska Methodist University, Gould Hall -----	-----	-----	-----	1
Anchorage, U.S. Post Office and Court House -----	-----	-----	-----	1
Cold Bay, Aircraft Control and Warning Site -----	-----	-----	-----	1
Cordova, Mt. Eccles Elementary School -----	-----	-----	-----	1
Fairbanks, University of Alaska, Duckering Hall -----	-----	-----	-----	1
Juneau, U.S. Bureau of Commercial Fisheries, Biological Laboratory.	-----	-----	-----	1
Ketchikan, U.S. Coast Guard Base, BOQ -----	-----	-----	-----	1
Kodiak, U.S. Naval Base, Building 470 -----	-----	-----	-----	1
McKinley Park, University of Alaska -----	-----	-----	-----	1
Seldovia, High School Gym, basement -----	-----	-----	-----	1
Seward, Wesleyan Hospital -----	-----	-----	-----	1
Shemya, Composite Headquarters -----	-----	-----	-----	1
Sitka, Coast and Geodetic Survey Magnetic Observatory -----	-----	-----	-----	1
Yakutat, Federal Aviation Association Hangar -----	-----	-----	-----	1
<i>Arizona:</i>				
Glen Canyon -----	1	1	-----	-----

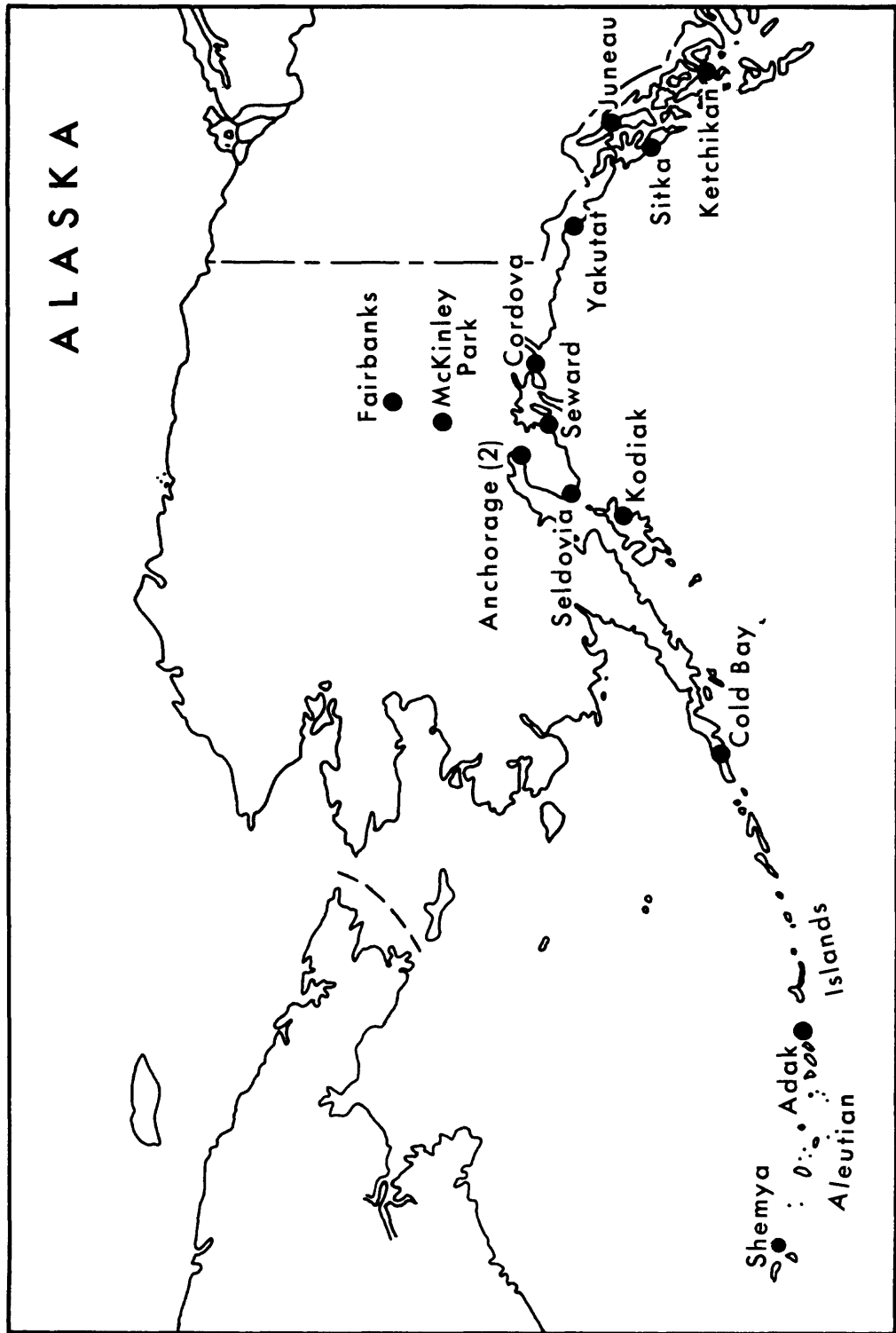


FIGURE 11.—Strong-motion stations in Alaska.

TABLE 3.—Coast and Geodetic Survey and affiliated strong-motion stations in operation as of December 31, 1965—Continued

OUTSIDE CALIFORNIA—CONTINUED

Station	Accelerograph	Displacement meter	Weed	AR-240
<i>Montana:</i>				
Bozeman, Montana State College, Engineering Building -----	1			
Butte, Montana School of Mines, Metallurgy Building -----	1			
Columbia Falls, Hungry Horse Dam -----	1			
Helena, Carroll College -----	1			
<i>Nevada:</i>				
Hawthorne, U.S. Naval Ammunition Depot -----	1			
Hoover Dam, 1215 Gallery -----	1	1		
Hoover Dam, Intake Tower -----	1	1		
Hoover Dam, Switchyard Oilhouse -----	1	1		
<i>Oregon:</i>				
Portland, State Office Building -----	1			
<i>Utah:</i>				
Flaming Gorge -----	1	1		
Logan, Utah State University, Administration Building -----	1			
<i>Washington:</i>				
Olympia, Highway Test Laboratory -----	1			
Ross Dam, Block 16, Crest Station -----	1			
Ross Dam, Right Bank Station -----	1			
Seattle, Federal Office Building -----	1	1		
Tacoma, County-City Building -----	1	1		

OUTSIDE THE UNITED STATES

Balboa Heights, Canal Zone -----	1			
Bogota, Colombia, South America -----	1			
Guatemala City, Guatemala, Central America -----	1			
Lima, Peru, South America -----	1			
Quito, Ecuador, South America -----	1			
San Jose, Costa Rica, Central America -----	1			
San Salvador, El Salvador, Central America -----	1	1		
Santiago, Chile, South America -----	1			
Total -----	74	36	10	43

TABLE 4.—List of shocks recorded and records obtained on strong-motion seismographs in 1965

Date 1965	Region and recording station	Records			
		Accelerograph	Survey displacement meter	Carder displacement meter	Weed
April 29 ---	Puget Sound, Wash., Seattle -----	1	1	-----	-----
	Tacoma -----	1	1	-----	-----
	Olympia -----	1	-----	-----	-----
	Ross Dam, Crest Station, Block 16..	1	-----	-----	-----
	Portland -----	1	-----	-----	-----

TABLE 5.—Summary of outstanding instrumental and noninstrumental data for 1965

PUGET SOUND, WASH., EARTHQUAKE OF APRIL 29

Epicenter	Recording station and distance	Location of instrument	Inten- sity ¹	Acceler- ation	Displace- ment ²
47.4° N., 122.3° W., northwestern Washington, VIII *. Mag. 6.5.	Olympia, 31 miles	Highway Test Labora- tory.	VII	cm/sec ² 197	cm 1.76

¹ Reported intensity of earthquake at recording station.

² Displacement is the maximum recorded at the station reporting the maximum acceleration of the earthquake. If displacement is much greater at another location, it is given along with the maximum acceleration at the same location.

* An asterisk following the intensity designation in the epicenter column indicates maximum reported intensity of the earthquake.

TABLE 6.—Composite of strong-motion instrumental data for 1965

PUGET SOUND, WASH., EARTHQUAKE OF APRIL 29

Station and component	Instru- ment no.	T ₀	V	Sensi- tivity	ϵ	Acceleration		Displacement		Remarks
						Period	Ampli- tude	Period	Ampli- tude *	
		sec		cm/g		sec	cm/sec ²	sec	cm	
Portland, Oreg:										
Up -----	229	0.082	121	20.6	10	0.16	5	-----	-----	
N20°E -----	230	.084	123	22.0	9	.21	7	-----	-----	
S70°E -----	231	.082	123	20.7	10	.23	7	-----	-----	
Ross Dam, Wash. (Crest Station, Block 16):										
Up -----	S-3	0.082	119	20.0	11	0.3	2	-----	-----	
S39°E -----	S-4	.087	121	23.3	10	.25	4	-----	-----	
S51°W -----	S-1	.083	122	21.4	10	.3	33	-----	-----	
Seattle, Wash:										
Up -----	360	0.084	111	19.6	10	0.19	42	-----	-----	
S32°E -----	359	.083	116	20.3	10	.27	58	-----	-----	
S58°W -----	358	.084	129	22.3	11	.50	82	-----	-----	
S58°W -----	13	2.45	0.8	-----	10	-----	-----	3.70	1.08	
N32°W -----	12	2.51	.8	-----	9	-----	-----	0.5	0.74	
Tacoma, Wash:										
Up -----	345	0.078	115	17.3	10	0.07	59	-----	-----	
East -----	346	.078	116	17.9	8	.13	74	-----	-----	
South -----	347	.076	117	17.6	10	.21	45	-----	-----	
North -----	36	4.01	1.0	-----	10	-----	-----	4.8	0.80	
East -----	37	3.90	1.0	-----	13	-----	-----	1.8	1.76	
Olympia, Wash:										
Up -----	307	0.080	117	18.8	9	0.05	83	-----	-----	
S4°E -----	275	.081	124	21.5	8	.16	161	-----	-----	
S86°W -----	309	.080	120	19.3	10	.12	197	-----	-----	

* Estimated from acceleration if no entry in displacement column.

Accelerograph Record

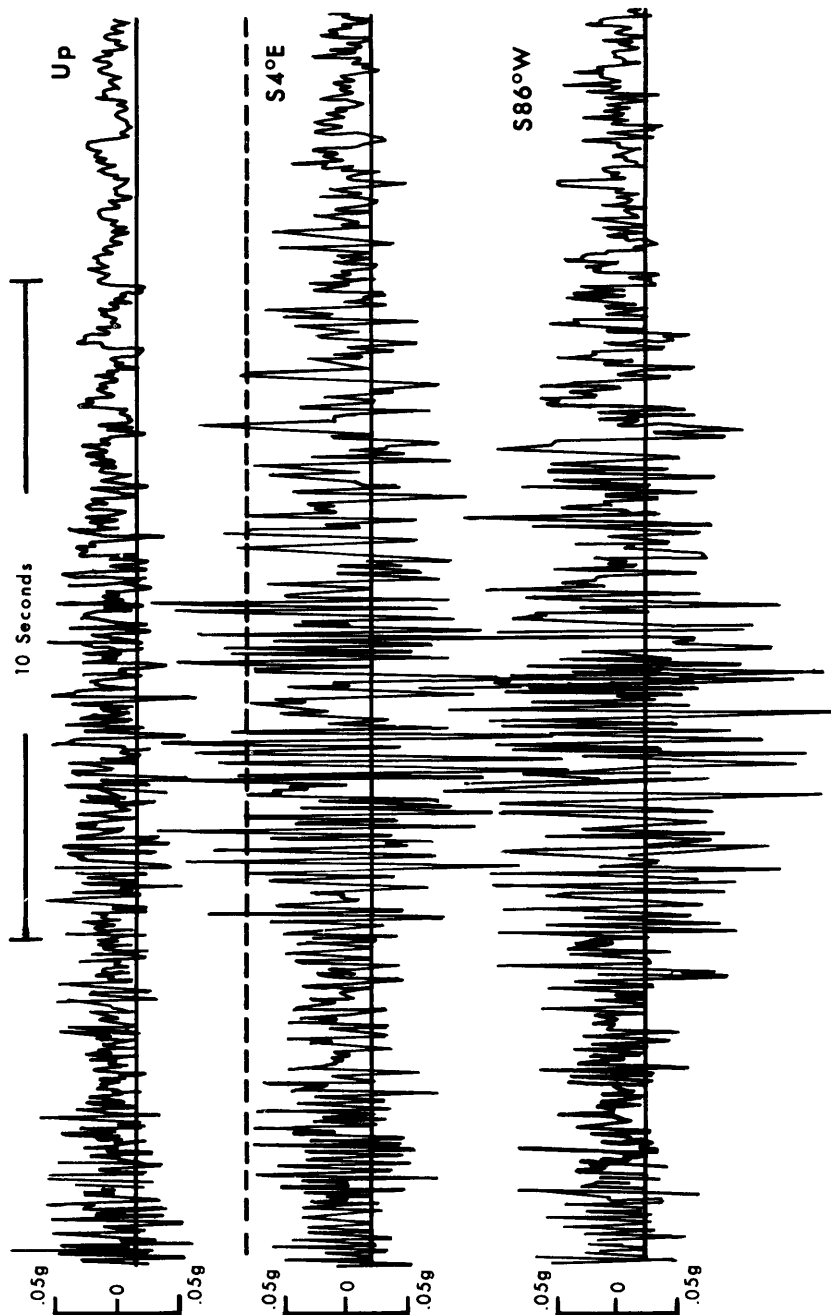


FIGURE 12.—Tracings of accelerograph records obtained at Olympia, Wash., on April 29.

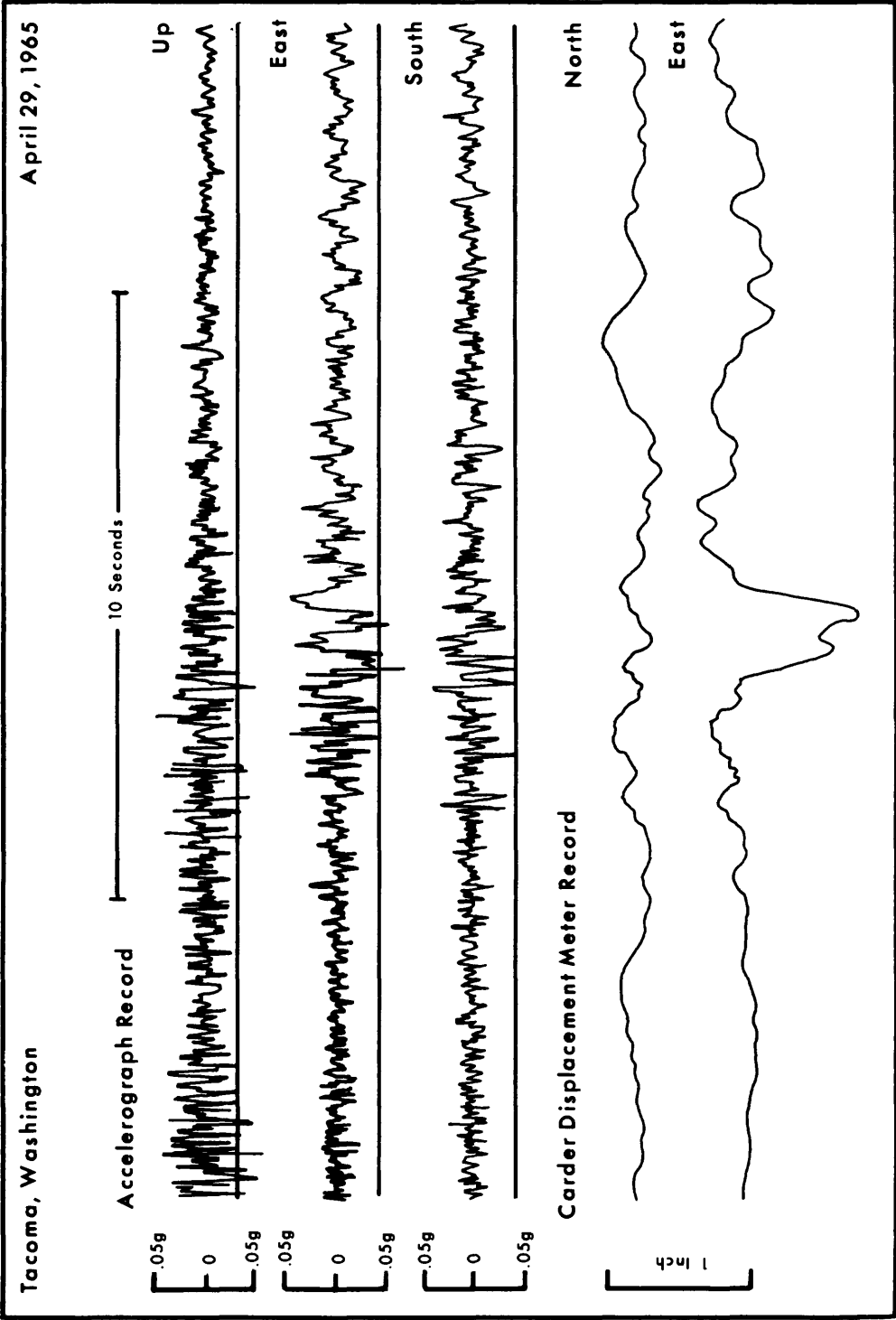


FIGURE 13.—Tracings of accelerograph and Carder Displacement Meter records obtained at Tacoma, Wash., on April 29.

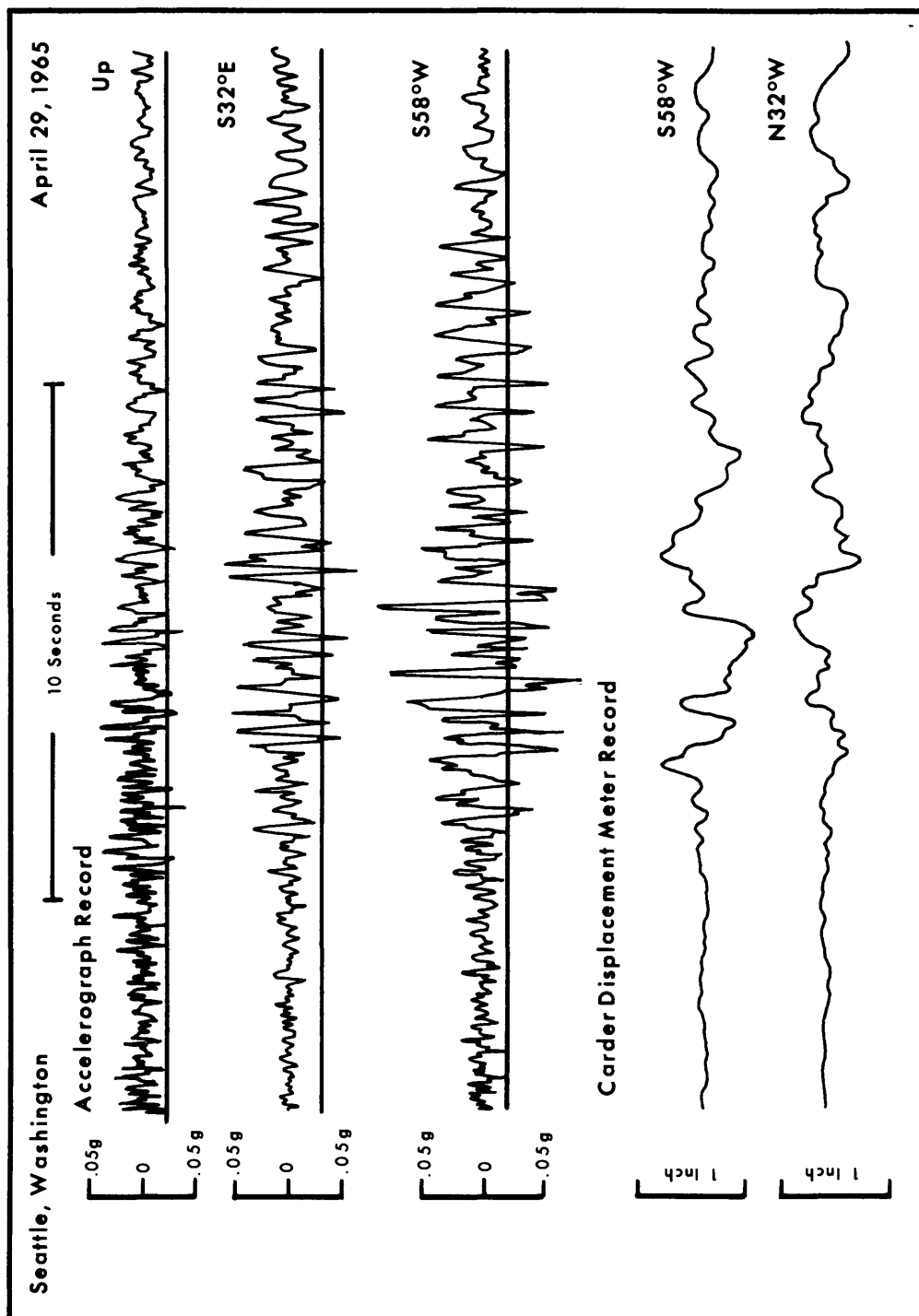


FIGURE 14.—Tracings of accelerograph and Carder Displacement Meter records obtained at Seattle, Wash., on April 29.