DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

United States Earthquakes, 1966

By

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and

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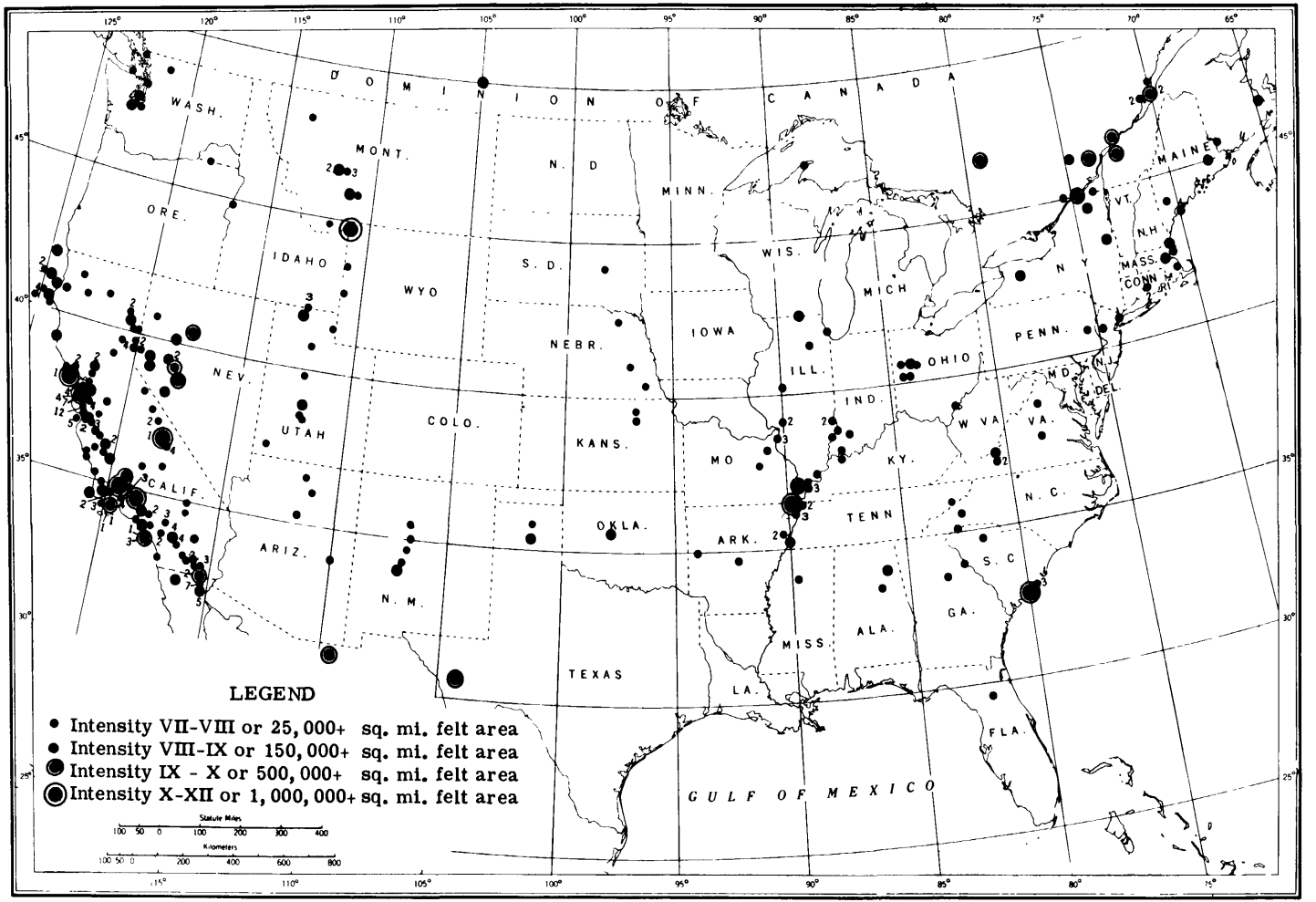

FIGURE 1a.—Destructive and near-destructive earthquakes in the United States through 1966.

Introduction

This publication, issued by the National Earthquake Information Center of the Coast and Geodetic Survey, is a summary of earthquake activity in the United States and regions under its jurisdiction for the calendar year 1966. 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 85, 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

In August 1966, the National Earthquake Information Center (NEIC) was established at the Coast and Geodetic Survey Headquarters, Rockville, Md. This Center is a focal point for the dissemination of seismic information, both immediate and historical, for technical and public uses.

The first new service from the Center was an expanded earthquake reporting system that provides accurate and rapid hypocenter locations and magnitude values to the press and other interested parties. These results are available within two or three hours for earthquakes of magnitude 6½ or larger, with smaller events treated on request or on receipt of a press report.

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 1966:

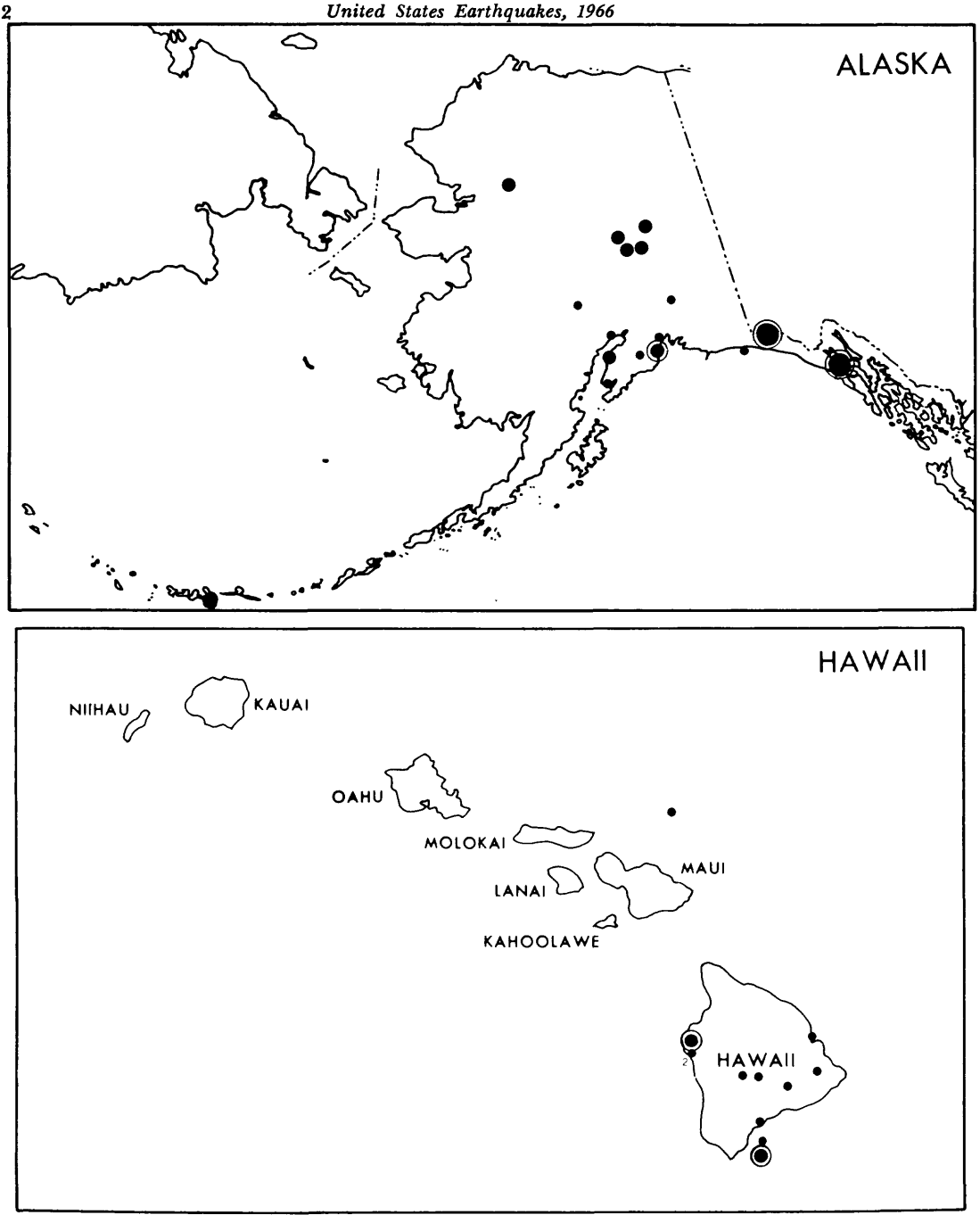

FIGURE 1b.—Destructive and near-destructive earthquakes in the United States through 1966 (continued).

Arizona.—Dr. Richard T. Moore, University of Arizona, Tucson.

Colorado.—Prof. Warren L. 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 1966. 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 shocks usually perceptible over more than 150,000 square miles (intensity VIII to IX); the smaller encircled dot represents an affected area greater than 500,000 square miles (intensity IX to X); the larger encircled dot represents 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 1966. 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, 4, 10–14, and 18) 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 85 and shown in figure 19. During the year, the locations of 4,813 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*. The 1966 material is published in bulletins MSI–301 through MSI–312. 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 buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale)

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

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

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

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

VII. Everybody runs outdoors. Damage *negligible* in buildings of good design and construction; *slight to moderate* in well-built ordinary struc-

[1] Harry O. Wood and Frank Neumann, in *Bulletin, of the Seismological Society of America*, vol. 21, No. 4, December 1931.

tures; *considerable* in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars. (VIII Rossi-Forel Scale)

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

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

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with 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 93, "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 23 and 24 (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 tables 5 and 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.

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: January 18 (2); 20; 24; 28; 29; February 6 (2); 16; 24; March 3; 8 (2); 25; April 22; May 3; 14; 15; 18, IV; June 4; 22; 27; July 4; 19; 22; August 6; 17; 26, V; 30 (2), V; September 1 (2); 8; October 1; 4; 7; 8; 12; 19; November 13; 17; 20; 26, IV; December 11; 13; 16; 19 (2), IV; 24; 25 (2).

Arizona: August 7, VI; 16.

Arkansas: February 11, IV.

California: (Intensity V and above). January 20, V; February 10 (3), V; 13, V; 15, V; 16, V; March 4 (2), VI; April 29, V; May 13, V; 23, VI; June 5, V; 11, V; 26, V; 27, VII; August 3, V; 7, VI; September 12, VII; 12, V; October 1, VI; 9, V; 11, V; 14, VI; 15, V; 27, V; December 18, V; 21, V; 22, V; 26, V.

Colorado: January 1; 4, V; 7; 22, VI (Many aftershocks felt through February are not listed here); March 18; May 25; June 6, IV; August 18; September 24; October 2, VI; 24; November 13; 14, VI.

Hawaii: January 2; 6 (2); 8; 14 (2); 19 (2); 21 (2); 26 (2); 31; February 2; 9; 12; 13 (3); 16; 21; 25; 28; March 3; 10; 12; 14; 15; 21; 30; April 2; 4 (2); 5; 21; May 6; 19; 27; June 2; 16; 18; July 1; 5 (2); 6 (2); 13; 17; 24; 27; 30; 31; August 1 (2); 6; 11; 15; 17; 18; 19 (4); 28; September 2; 5 (2); 8; 12; 16; 21; 23; 28; October 3; 7; 13; 16 (4); 17; 19; 23; 27; 28; 30; November 2; 5, V; 11; 13; 14; 15; 16; 17; 18; 23 (2); 27 (2); 28; December 1 (2); 11; 13; 15; 16; 26; 31 (2).

Idaho: February 11; March 17, V; October 11 (4).

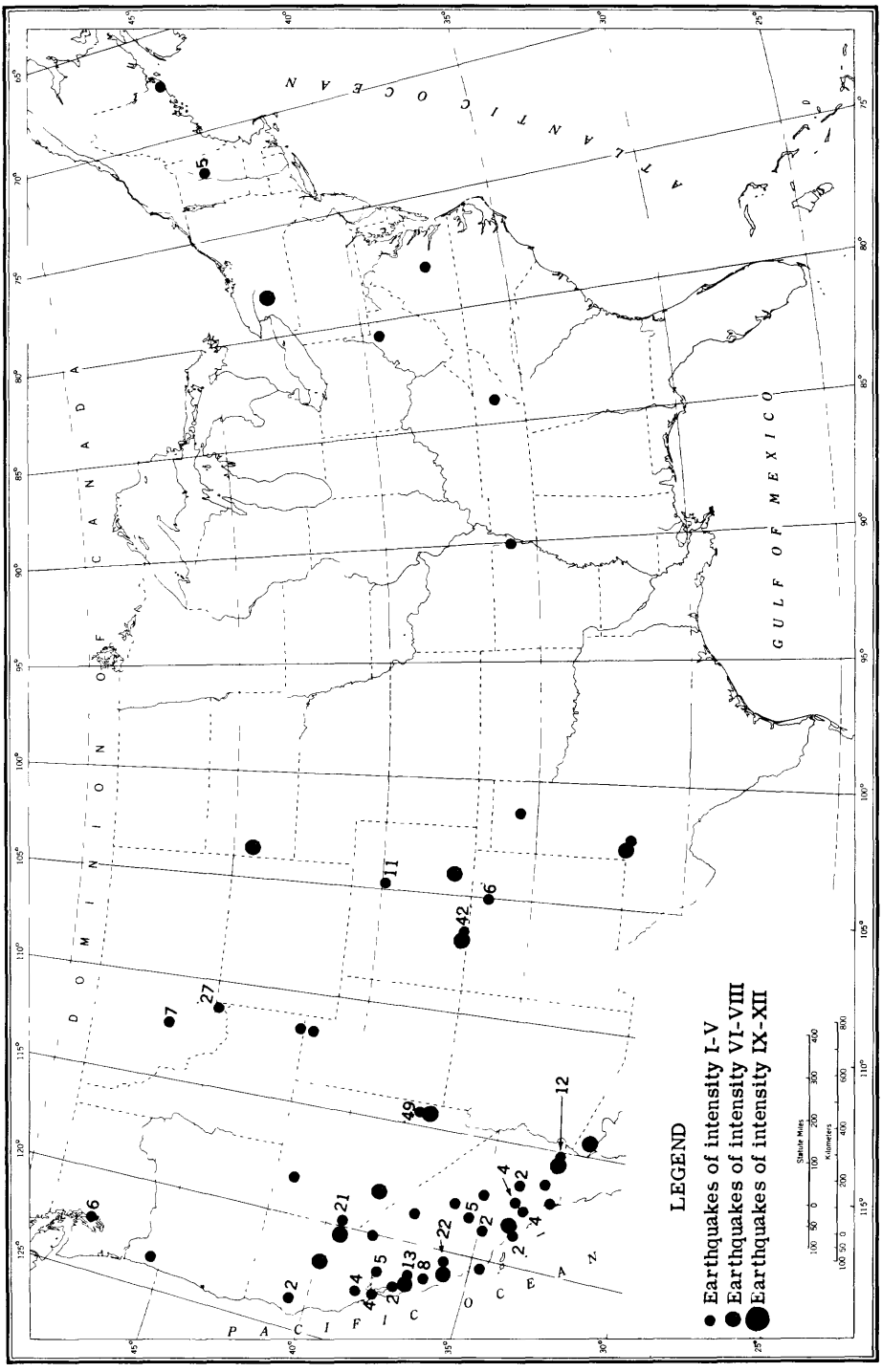

FIGURE 2a.—United States earthquake epicenters for 1966.

Maine: July 23, V.

Maryland: May 31, IV.

Montana: March 4; 7, V; April 3, IV; 29, V; May 7; September 19, V; 26, IV; October 3; 9 (3); 10; 11 (3), V; 11 (21); 14 (2); December 30.

Nevada: January 28; April 2, VI; May 13; June 26, V; August 7; 16, VI (several aftershocks felt); 17, IV; 18 (4), IV; September 12, VII; 13 (2), IV; 21; 22, V; October 22, V.

New Hampshire: April 28 (2); October 23, V.

New Mexico: January 22, VII (Many slight aftershocks felt through February are not listed here); January 23, V; May 18; September 24 (3), IV; October 2.

New York: January 1, VI; 1 (2).

Oregon: February 6.

Pennsylvania: January 1, IV.

South Dakota: June 26, VI.

Tennessee: February 13, IV; August 24, IV.

Texas: July 20, V; August 14, VI.

Utah: March 17, V; 17; August 16, VI; 17; 18 (3); 19; September 12; 22; 22, IV.

Virginia: May 31, V.

Washington: June 6; 11, IV; 24; July 30, IV; November 1; December 23.

West Virginia: September 28, IV (possible strip-mine explosion).

EARTHQUAKE ACTIVITY OUTSIDE THE UNITED STATES

Panama Canal Zone: No earthquakes were reported felt in 1966.

Puerto Rico: May 2 (3); November 3, V.

Virgin Islands: October 6.

NORTHEASTERN REGION

[75th Meridian or Eastern Standard Time]

January 1: 08:23:38.8*. Epicenter 42.8° north, 78.2° west, New York, W. Magnitude 4.7. VI. Felt over approximately 3,500 square miles of western New York, northwestern Pennsylvania, and southern Ontario Province, Canada (see fig. 3). Slight damage to chimneys and walls occurred at Attica and Varysburg. Foreshocks were reported at 05:30 and 06:30.

INTENSITY VI IN NEW YORK:

Attica.—Felt by and alarmed many. Bricks tumbled from a house on East Avenue. A few chimneys were damaged slightly and cellar walls and foundation cracked. About 1 mile south of Attica at the State Prison, plaster fell and the main smokestack was damaged. Thunderous earth sounds accompanied the shock. Abrupt onset; rocking motion. Foreshocks at 05:30 and 06:30 were felt by some residents.

Varysburg.—Felt by several. Bricks fell from chimneys; ceiling and walls cracked; knickknacks tumbled from shelves; and objects tipped over in refrigerators. Rapid onset; trembling motion, south-north direction. Duration, about 20 seconds. A foreshock was felt at 06:30.

INTENSITY V IN NEW YORK:

Belfast, Buffalo, Depew, Fillmore, Gowanda, Lancaster, Tonawanda, and Warsaw.

INTENSITY IV IN CANADA:

Bridgeworth, Cayuga, Dundas, Peterborough, Port Hope, Port Perry, and Saint Catharines.

INTENSITY IV IN NEW YORK:

Alabama, Amherst (two shocks), Arcade, Baldwinsville, Batavia (two shocks), Brockport, Castile, Marcellus, Medina, Orchard Park, Pavilion, Rochester, Salamanca, and Springville.

INTENSITY IV IN PENNSYLVANIA:

Warren.

INTENSITY I-III IN CANADA:

Arthur, Brantford, Hamilton, Jarvis, and Toronto.

INTENSITY I-III IN NEW YORK:

Alton, Barker (two shocks), Clarence, Dale, Dansville, East Aurora, Geneva, Olean, and Webster.

INTENSITY I-III IN PENNSYLVANIA:

Erie, Knoxville, and Titusville.

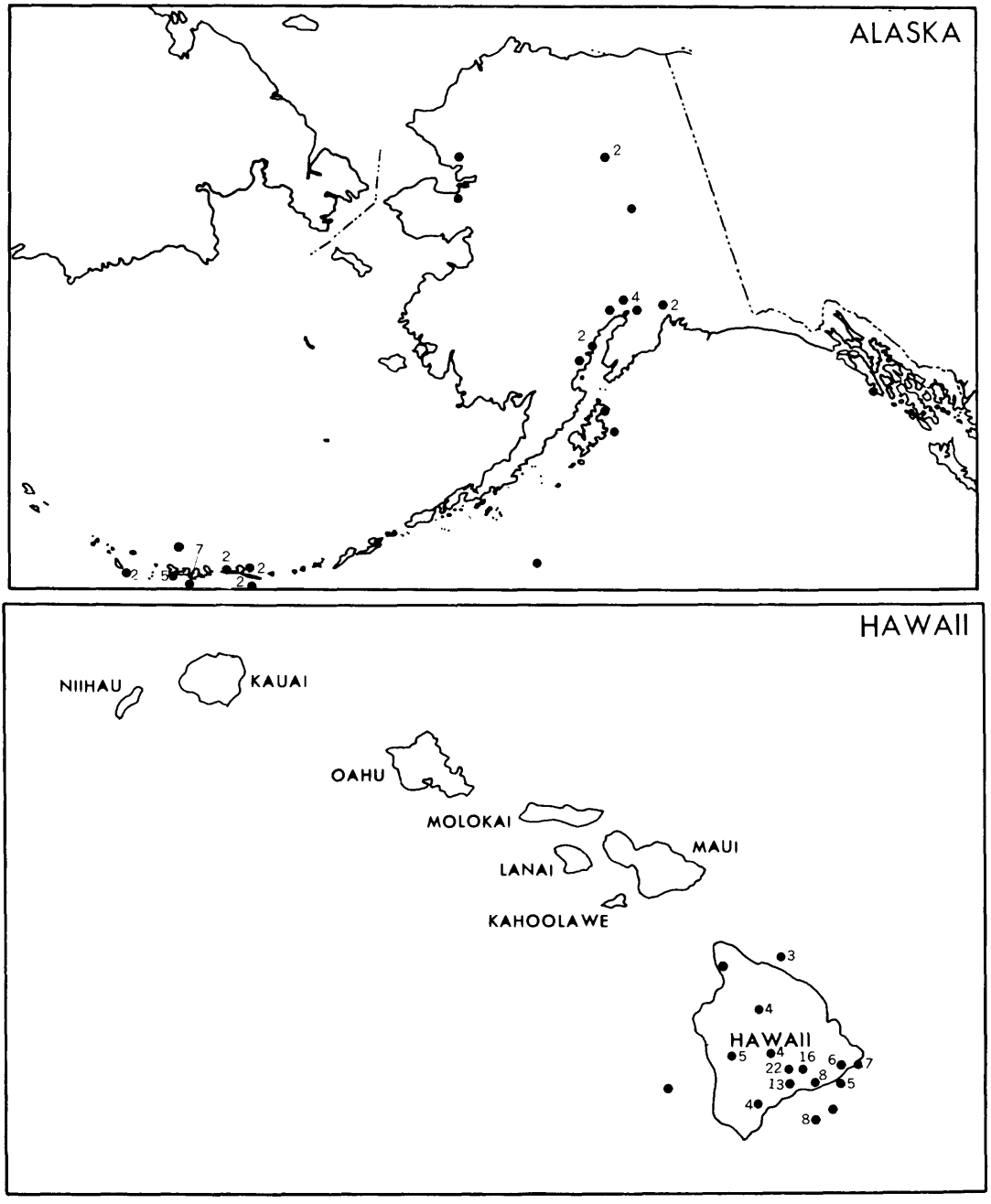

FIGURE 2b.—United States earthquake epicenters for 1966 (continued).

April 28: 07:02. Benton, N. H. IV. Two shocks less than a minute apart were felt by several residents. The shock at 07:02 was the stronger. Dishes rattled and subterranean sounds were heard. Rapid onset; trembling motion.

July 23: 20:59:58.4*. Epicenter 44.5° north, 67.6° west, Jonesport, Me., NESA. V. At Jonesport, felt by and awakened many; frightened few. Observer in strongly built wood structure reported that dishes rattled. Also reported felt by few at

Machias. Questionnaire canvass was conducted by Weston Observatory, Weston, Mass.

October 23: 18:05:34* Epicenter 43.0° north, 71.8° west, Manchester, N. H., area, NESA. Felt over a small portion of southern New Hampshire. Intensity V was reported at Goffstown, Hooksett, and Manchester; intensity IV at Hillsboro and New Boston. Questionnaire canvass was conducted by Weston Observatory, Weston, Mass.

EASTERN REGION

[75th Meridian or Eastern Standard Time]

May 31: 01:19:02*. Epicenter 37.6° north, 78.0° west, Virginia, W. Magnitude 3.1. V. Felt over most of Virginia (except in portions north and west of Lynchburg) and in southern Maryland. Many were awakened throughout the area, but only one instance of damage was noted. This occurred at Cumberland, Va., where plaster cracked in a house. Several towns reported loud, rumbling earth sounds accompanied the shock. Various additional occurrences were reported, such as a man being "dumped" out of bed at Charlottesville; a dispatcher at Chesterfield being "tossed" out of his chair; and the switchboard at a telephone office in Culpeper "flying" across the room.

INTENSITY V IN VIRGINIA:

Buckingham, Charlottesville, Chesterfield, Culpeper, Cumberland, Goochland, Powhatan, and Richmond.

INTENSITY IV IN VIRGINIA:

Amelia, Amelia Court House, Appomattox, Arlington, Ashland, Bedford, Bowling Green, Charlotte Court House, Dinwiddie, Emporia, Farmville, Fredericksburg, Henrico, Hopewell, Lovingston, Lynchburg, Midlothian, New Kent, Palmyra, Petersburg, South Boston, Spotsylvania, Stanardsville, and Wakefield.

INTENSITY IV IN MARYLAND:

Silver Spring, Great Falls, Potomac, and Rockville.

INTENSITY I-III IN VIRGINIA:

Bon Air, Hylas, Springfield, and Williamsburg.

August 24: 01:00. Eastern Tennessee. IV. The following report was received from Mr. Berlen C. Moneymaker, Tennessee Valley Authority, Knoxville, Tenn.:

> A light shock attended by a light rumbling sound was felt from west Knoxville southward to Alcoa, Maryville, and Walland. It was characterized by a trembling motion lasting several seconds and strong enough to awaken light sleepers and to rattle windows. Occurring at the time it did, the disturbance was felt by only a small fraction of the population. I am convinced it was a light shock of seismic origin.

September 28: 15:59:06*. Clarksburg, W. Va. IV. This local shock was not felt outside the suburbs of Clarksburg. Buildings creaked generally and light objects moved. Rumbling earth sounds accompanied the shock and some thought it was an explosion. Few were positive of ground movement. One observer reported the following account of the shock (from Mrs. James Griffith): "Two friends of ours who live a mile or two beyond us toward Salem discounted it as another strip-mine explosion. They, too, felt movement in their house. Another person who was walking close to the center of Clarksburg heard something like an explosion, but connected it with nearby building construction. One lady who was washing her hair reported that the water faucets moved." Recorded by the seismograph at the University of West Virginia, Morgantown, W. Va.

CENTRAL REGION

[90th Meridian or Central Standard Time]

January 15; February 1, 2, and 3: Several observers along the Texas-Louisiana border region reported tremors on these dates. None of the shocks was recorded on seismographs. After an investigation, the tremors were attributed to sonic booms.

February 11: 22:32:14.7*. Epicenter

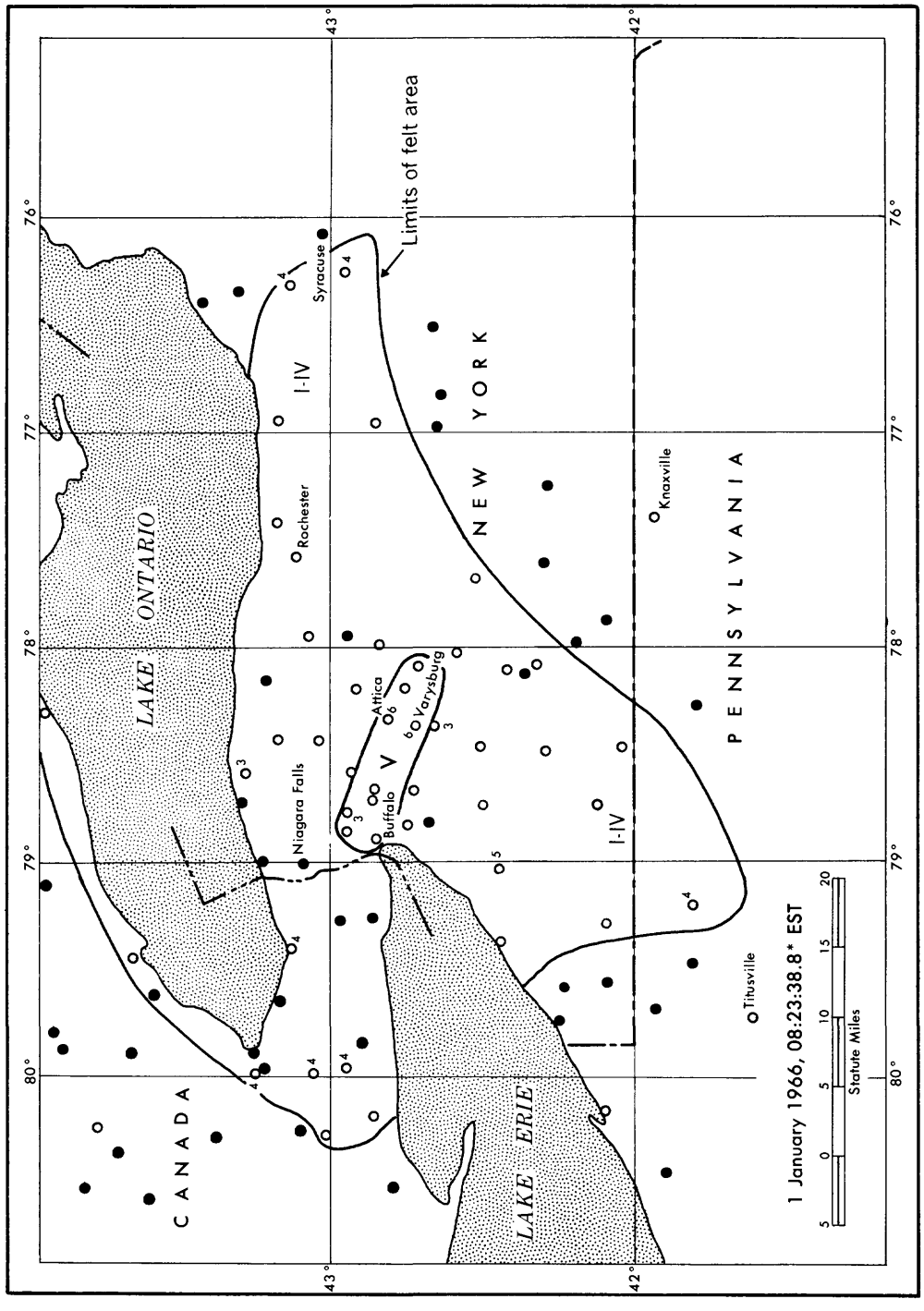

FIGURE 3.—Area affected by New York earthquake of January 1.

35.9° north, 90.0° west, Arkansas, W. Magnitude 4.3. IV. Creaking of buildings was reported by residents of Blytheville, Delbridge, Leachville, Manila, and Steele.

February 13: 18:09. Tennessee. IV. Felt by many at Covington where household articles moved, buildings creaked, and loose objects rattled. "Sound from quake was very loud." Rapid onset; trembling motion.

June 26: 05:59:44.2*. Epicenter 44.3° north, 103.4° west, South Dakota, W. Magnitude 4.1. VI. At Keystone, well water was muddied for several hours. At Rapid City, concrete steps cracked and pulled away from a house, and a patio cracked. At Deadwood, there was a fallen tree attributed to the shock.

INTENSITY VI:

Keystone.—Well water was muddied and could not be used for several hours. One observer reported, "I could see the ground moving." Pictures on walls bounced; buildings creaked; dishes rattled. Gradual onset; bumping-swaying motion.

Rapid City.—Felt by many. Buildings creaked; loose objects rattled. Rapid onset; bumping motion. Moderately loud earth sounds heard. The following report was received from Edward L. Tullis, South Dakota School of Mines and Technology, Rapid City, S. Dak.:

> We have had ninety-eight phone calls from people in Rapid City who felt the tremor, and nearly all of these report some sort of noise, such as a rumbling, a thud, an explosion, or a sonic boom. Most reported the noises preceded the shaking, although others said they were somewhat simultaneous. Some noted dishes rattling, a barometer and other objects falling from the wall, doors swinging shut and opening, and walls creaking. There were two cases of damage: Concrete steps behind a brick residence cracked and pulled away from the house, and a patio cracked (although the observer was not positive that the crack was not there before the earthquake).
>
> The reports from the northwest part of Rapid City indicate louder noise and more violent shaking of buildings than in other sections of town. A man on the 7th floor of a new 8-story steel and concrete apartment house which set on steel and concrete casings floating on gravel reported three slight movements back and forth in a north-south direction. This was immediately followed by a very slight crackling sound passing through the building. About four other structures were reported to have moved in a north-south direction.
>
> An observer, located about 8 miles west of Rapid City, described the sound as that of an approaching train, immediately followed by shaking of the house, which in turn was followed by a thud. Another reported two "sonic booms" at an interval of about 5 seconds. A number of observers said the vibration of buildings lasted about 10 seconds.
>
> There are no reports from east of Rapid City, but a few have come in from as much as 15 miles west, and 32 miles northwest of the city. At least three persons have reported that the sound seemed to come from overhead.

INTENSITY V:

Deadwood.—Felt by and awakened many; few alarmed. Buildings creaked; loose objects rattled; and earth sounds, similar to large trucks passing by, were heard at the onset of the earthquake. One unconfirmed report stated that a tree fell against a house at 22 Denver Avenue.

Silver City.—Felt by and awakened several. Buildings creaked; dishes rattled. Motion trembling. "Doors are hard to shut." Earth sounds, like jet passing overhead. Duration, 15 seconds. General alarm.

INTENSITY IV:

Lead, Piedmont, Pine Ridge, and Shannon.

INTENSITY I-III:

Black Hawk and Hill City.

July 20: 03:04:58.2*. Epicenter 35.7° north, 101.2° west, Texas Panhandle region, W. Magnitude 4.8. V. At Amarillo, an observer in the courthouse reported a chair moved 4 to 5 inches. Chairs also moved in the FAA Control Tower at the Municipal Airport. Observers thought a truck had hit the tower. Patients at the Amarillo Air Force Base Hospital were awakened. The Weather Bureau Station reported a barometer dial jumped at the time of the shock. Other observers

noted that buildings creaked, windows rattled, and a rumbling noise accompanied the shock. Abrupt onset; swaying motion. At Borger, about 50 miles northeast of Amarillo, the earthquake was felt by nearly all. The press reported books fell from a shelf in one home, and that a loud rumble was heard. Others reported that buildings creaked and windows rattled. Abrupt onset; jarring motion. Duration, 3-4 seconds.

INTENSITY IV:

Floydada, Fritch, Pampa, Sanford, and Sunray.

INTENSITY I-III:

Borger (about 15 miles east of), Dimmitt, Dumas, and Hereford.

August 14: 09:25:53*. Epicenter 32.0° north, 102.6° west, western Texas, W. Magnitude 3.4. VI. The press reported several street signs were knocked down and windows were broken at Kermit by this earthquake. Doors rattled at the police station and plaster cracked in one church. "Like a stick of dynamite being detonated several hundred feet away," was one observer's description of the shock. At Wink, about 8 miles south of Kermit, the shock was felt by many. Buildings creaked, loose objects rattled, and disturbed objects were observed. Very faint earth noises were heard; several were positive of ground movement. The shock was also reported felt at Loco Hills, N. Mex. (about 25 miles northeast of Carlsbad), where windows rattled. Residents reported the shock was similar to a sonic boom.

WESTERN MOUNTAIN REGION

[105th Meridian or Mountain Standard Time]

January 1: 17:13:41.8*. Epicenter 39.9° north, 104.8° west, Colorado, W. Magnitude 2.1 (Colorado School of Mines). III. Residents in the Commerce City-Henderson areas, northeast of Denver, reported three hard jolts and earth noises.

January 4: 17:37:17.8*. Epicenter 39.8° north, 104.7° west, Colorado, W. Magnitude 5.0. V. Small objects were knocked from cupboards and shelves in the Denver-Northglenn area. Felt by all and frightened many at Commerce City, where loud, roaring earth noises were heard. Intensity IV effects were reported at Adams City, Brighton, Broomfield, Dupont, Eastlake, Hazeltine Heights, Henderson, Irondale, Thornton, and Welby. The shock was slightly felt in the Arsenal area.

January 7: 17:17*. Colorado. Magnitude 1.5. A minor earthquake was felt at Boulder, Golden, Green Mountain, and near Cherry Creek Dam. Recorded by the seismograph at Regis College, Denver, Colo.

January 22: 18:56:38.8*. Epicenter 37.0° north, 107.0° west, New Mexico-Colorado border region, near Dulce, N. Mex., W. Magnitude 5.5. VII. This main shock of a series was felt over approximately 15,000 square miles of northwestern New Mexico and southwestern Colorado (see fig. 4). Many buildings were damaged at Dulce. Nearly every house was affected to some degree, but the principal damage was to the Bureau of Indian Affairs (BIA) School and Dormitory Complex, and to the Dulce Independent Schools. Damage was estimated at $200,000. No deaths or injuries were reported.

Between January 22 and January 28, the Coast and Geodetic Survey's Seismological Center in Albuquerque, N. Mex., recorded 119 events. Three temporary seismograph stations were installed by the Center on January 28 in the Dulce area. During the first week of operation, 218 earthquakes were recorded by these stations. All of the shocks were located in a small area near the town of Dulce.

The following are excerpts from an unpublished report prepared by the Survey's Seismological Center in Albuquerque:

By Monday morning, January 24, 1966, the Seismological Center seismograph had recorded ap-

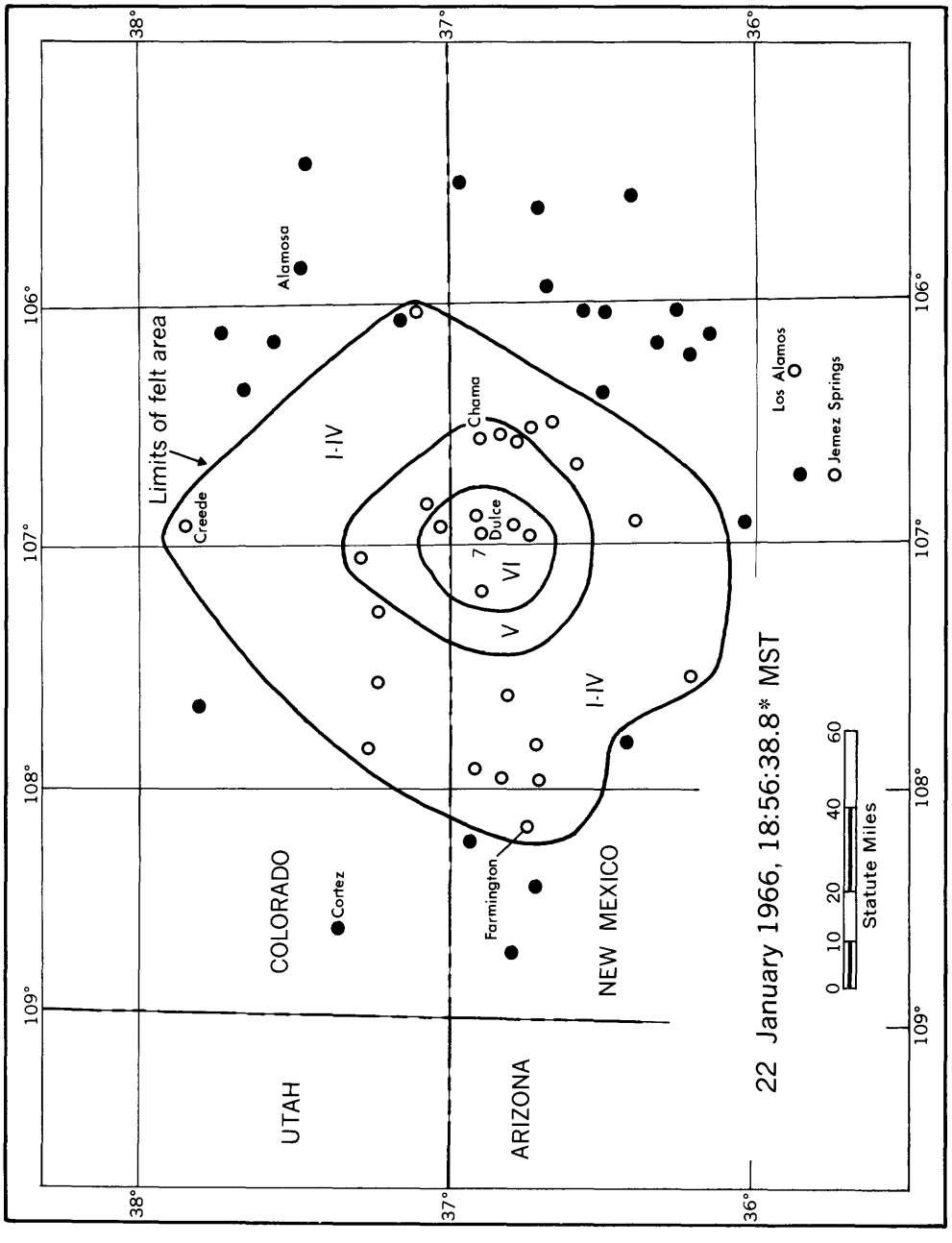

FIGURE 4.—Area affected by New Mexico earthquake of January 22.

proximately 90 aftershocks. Messrs. Frank H. Werner and John P. Hoffman, of the Center, proceeded to the epicentral area to make a field investigation and preliminary survey of the structural damage at Dulce and adjacent towns.

The greater part of the area is at an altitude of 6,000 feet or higher, mountainous, and sparsely populated; also, several feet of snow covered the ground. Because of this, the field investigation was confined to the mainly traveled roads. However, investigation determined the epicentral area to be a few miles north of Dulce, a small town with population of about 2,000.

Structural damage of any consequence was confined to Dulce and immediate area. Because of the snow conditions the epicentral region was inaccessible.

The main earthquake caused considerable damage at Dulce, where the Bureau of Indian Affairs maintains the headquarters for the Jicarilla Apache Indian Reservation.

The building complex of the Reservation Headquarters is comprised of an administrative office, schools, dormitories, steam-heating plant, maintenance shops, and other facilities. With the exception of the steam-heating plant (constructed in 1909), the buildings were constructed in 1956 and are mainly of brick exterior walls and wood-frame and plaster interior partitions and tile brick fire walls. The Dulce Independent Schools, which include elementary, intermediate, and high school levels, is a multiwinged, single-story structure constructed of concrete columns, masonry filler walls, and wood-frame and plaster interior partitions with tile brick fire walls. The floors are concrete and covered with vinyl tile.

INTENSITY VII IN NEW MEXICO:

Dulce.—The following is a report prepared by the field investigating team at the Coast Survey's Seismological Center, Albuquerque, N. Mex.:

The Bureau of Indian Affairs (BIA) dormitories had extensive damage to both interior and exterior walls. The dormitories are 2-story structures, both located within 1,000 feet of the Dulce Independent Schools. Considerable plaster fell from the ceilings, and several outside brick walls had vertical fractures from ground to roof [see figs. 5 and 6]. These fractures occurred where the two wings of the building meet the center structures at angles of about 140°. Both dormitories were evacuated, and were unoccupied at the time of the field investigation on January 25.

The steam-heating plant for the BIA school complex was damaged to the extent that it will probably be condemned. This old brick building, with many cracks from deteriorated mortar, had several brick walls displaced as much as 2 inches from vertical alinement [see fig. 7]. Pipes, fittings, and hardware in the building were displaced, and two boilers weighing about 10 tons each were displaced about ¼-inch at their bases. A 60-foot smokestack buckled, and only guy wires prevented it from falling. Two large plate-glass windows were shattered and fell into the building.

The Catholic Church at Dulce, a comparatively new structure, had some minor interior damage to a false ceiling. A number of panels loosened and displaced from the frames. Light fixtures, suspended from the ceiling on about 5 feet of conduit, were moved sufficiently to tear the ceiling plasterboard. Vinyl floor tile popped from the floor in several locations, and one plate-glass window had a corner broken.

Several small ground cracks appeared in the fill across the frozen roads. There was no evidence of vertical or horizontal ground displacement or fissuring. Approximately 1 mile to the north and northwest of Dulce Valley, buttes rise abruptly from the valley floor to heights of 500 or more feet. These are locally referred to as rimrock and are badly eroded by rain and wind. It was reported that much of the rimrock fell down the slopes. In one instance, a prominent point on the horizon, generally known as Dulce Point, had a complete change of configuration by the collapse of huge masses of shale and sandstone which fell down the slopes.

In addition to the BIA school complex, there are a number of homes, some of which are of recent construction, in the Dulce area. Very little structural damage, if any, was evident in the newly constructed buildings. Considerable loss did occur from bottle and packaged goods, which fell from shelves in stores and homes. It was observed that items on shelves facing north were thrown to the floor, while items on the opposite side did not seem to be greatly disturbed [see fig. 8].

Throughout the Dulce area a number of chimneys were damaged. It was noted that chimneys of 1 or 2 feet in height were damaged, whereas others of 5 and 6 feet height appeared to be undamaged. This was quite evident on the BIA dormitory buildings, where in several cases, the two types of chimneys were only 10 to 15 feet apart.

There were also a number of cases of spalling of stucco from the walls of homes that were of wood-frame construction. Much of the damage can be attributed to poor design, inferior construction material, method of construction, and the lack of use of design factors for withstanding earthquake forces [see fig. 9].

Subterranean noises were reported by many persons in the Dulce area. They accompanied the main

FIGURE 5.—Ceiling damage in BIA School Dormitory, Dulce, N. Mex.

FIGURE 6.—Building damage to BIA School Dormitory, Dulce, N. Mex.

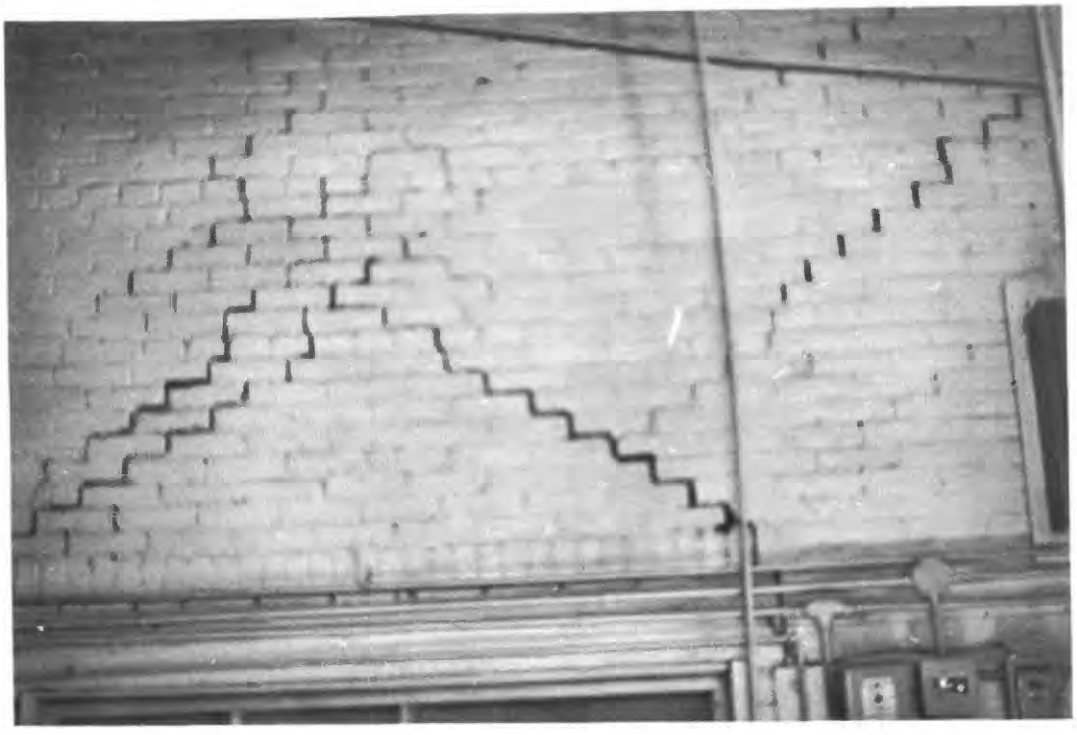

FIGURE 7.—Shear fractures in wall of steam-heating plant, Dulce, N. Mex.

earthquake and were described as "a roaring noise of considerable intensity."

Through January 27, residents of the area reported about 40 slight aftershocks, but always of a less pronounced nature.

INTENSITY VI IN NEW MEXICO:

Cachucha Ranch (7 miles south-southeast of Dulce).—At this location, the ground motion was heavy and abrupt, but no structural damage occurred. Many objects were displaced and fell to the floor. The ranch house is a single-story dwelling, of partial concrete-block and wood-frame construction. The rancher stated the ground motion was distinctly from north to south and accompanied by a roaring earth noise. Objects were observed being displaced and knocked over, first on the north wall of the room, then on the south wall, as the ground waves passed through the house.

Highway 17 (10 to 15 miles west of Dulce).—This area is very sparsely populated. The State Highway Patrol reported that rockfalls and earthslides occurred here. Some minor cracks appeared in the highway where large fills were made.

La Jara Lake (13 miles due south of Dulce).—There are few residents in this region, but a rancher reported that his old adobe ranch house was shaken considerably and objects were dislodged and displaced, but that no damage occurred. The adobe house is an L-shaped structure with a peaked roof, and probably would not withstand a great shear force.

Lumberton (about 4 miles east of Dulce).—The residents in this small town were all frightened. Minor damage consisted mainly of cracked walls and chimneys. The St. Francis Catholic Church reported minor damage to both church and school. They are constructed mainly of adobe or adobe-filled walls. Bricks fell from a short chimney of the 2-story church, but about 300 feet west, a 6-foot chimney on a single-story house was not damaged. An explosivelike noise accompanied the shock

FIGURE 8.—Fallen stock from shelves in grocery store, Dulce, N. Mex.

Through January 29, twenty-three aftershocks of varying degrees of lesser intensity were reported felt.

INTENSITY VI IN COLORADO:

Edith (about 5 miles northeast of Dulce).—This small community is comprised of five or six families living in houses of wood-frame construction. The old houses were strongly shaken, but no structural damage occurred. Some loss occurred due to fallen objects. A farmer living near Edith reported dishes broke, walls cracked, and heavy furniture moved. A rancher south of Edith stated that ground fissures more than several feet deep were visible and had been there for a number of years. The ground cracks reportedly widened after this shock, but due to the heavy snow, this area was inaccessible. Motion was from north to south, according to reports.

INTENSITY V IN NEW MEXICO:

Chama and Parkview (about 20 miles southeast of Dulce).

FIGURE 9.—Spalling of stucco and broken window, Dulce, N. Mex.

INTENSITY V IN COLORADO:

Chromo (11 miles northeast of Dulce) and Pagosa Springs (about 23 miles north of Dulce).

INTENSITY IV IN NEW MEXICO:

Bloomfield, Cedar Hill, Farmington, Llaves, Navajo Dam (about 40 miles west-southwest of Dulce), Tierra Amarilla (near), and Tierra Amarilla.

INTENSITY IV IN COLORADO:

Antonito, Bayfield, Chimney Rock, and Creede.

INTENSITY I-III IN NEW MEXICO:

Aztec, Blanco, El Vedo, Jemez Springs, Los Alamos, Lybrook, and Waco.

INTENSITY I-III IN COLORADO:

Durango.

January 22: 19:08:35*. Epicenter 37.0° north, 107.0° west, New Mexico-Colorado border region, W. III. Felt by several at Chama, N. Mex. Moderate motion of 10 seconds' duration. Also felt at Lumberton.

January 22: 19:33:13.5*. Epicenter 36.9° north, 107.0° west, New Mexico, W. Felt at Lumberton.

January 22: 21:00 (about). III. Creede, Colo. Felt by several. Trailer shook; explosivelike noise.

January 22: 23:14:15.6*. Epicenter 36.9° north, 107.2° west, New Mexico, W. Magnitude 4.2. Felt at Dulce and Lumberton, N. Mex., and at Edith, Colo. Described as "severe."

January 23: 02:00, 03:00. Slight shocks felt at Lumberton, N. Mex.

January 23: 03:53:11*. Epicenter 36.9° north, 107.2° west, New Mexico, W. Felt at Lumberton.

January 23: 04:01:07.1*. Epicenter 36.9° north, 107.2° west, New Mexico, W. Magnitude 4.3. Felt severely at Lumberton.

January 23: 05:14:36*. Epicenter 37.0° north, 107.1° west, New Mexico-Colorado

border region, W. Felt lightly at Lumberton, N. Mex.

January 23: 07:23:27.0*. Light shock felt at Lumberton, N. Mex. Recorded by the seismograph at Albuquerque, N. Mex.

January 23: 12:43:19.7*. Epicenter 36.9° north, 107.1° west, New Mexico, W. Magnitude 4.5. Felt lightly at Dulce and Lumberton, N. Mex., and at Edith, Colo.

January 23: 16:48:08.1*. Epicenter 36.9° north, 107.0° west, New Mexico, W. Magnitude 4.6. V. Although strong, this shock caused no damage. At Lumberton, furniture was moved around in one house. Felt severely at Dulce, N. Mex., and Edith, Colo.

January 23: 18:31:29*. Epicenter 36.9° north, 107.2° west, New Mexico, W. Felt lightly at Lumberton.

January 24: No time given. Lumberton, N. Mex. Several shocks, all varying in intensity, were felt.

January 25: 03:38:05.0*. Epicenter 36.8° north, 107.1° west, New Mexico, W. Magnitude 4.0. Felt severely at Dulce and Lumberton, N. Mex., and at Edith, Colo.

January 25: 08:32:49*. Epicenter 36.8° north, 107.1° west, New Mexico, W. Felt lightly at Lumberton.

January 25: 08:45, 16:30. Lumberton, N. Mex. Felt lightly.

January 26: 20:59:02*. Epicenter 36.9° north, 107.1° west, New Mexico, W. Felt lightly at Lumberton and Dulce.

January 26: 21:20:59.2*. Lumberton, N. Mex. Felt lightly. Recorded by the seismograph at Albuquerque, N. Mex.

January 27: 00:48:29*, 02:29:01*, 02:32, 05:45. Epicenter of first shock, 36.9° north, 106.9° west; of second, 36.9° north, 107.2° west, New Mexico, W. IV. "Shock at 02:32 was the heaviest, with windows rattling and buildings shaking. Several other light tremors were heard throughout the early morning hours."

January 27: 23:00. Felt by several at Lumberton, N. Mex.

January 27: 23:55:31*. Epicenter 36.8° north, 107.1° west, New Mexico, W. Felt severely at Lumberton.

January 28: 07:53:03*. Epicenter 36.9° north, 107.1° west, New Mexico-Colorado border region, W. Felt by several at Edith, Colo. Motion moderate, trembling.

January 28: 11:00:09.1*. Epicenter 41.6° north, 118.2° west, northern Nevada, W. Magnitude 4.4. The press reported a slight shock rolled through the Winnemucca area.

January 29: 04:21:51.3*. Epicenter 37.0° north, 106.9° west, New Mexico-Colorado border region, W. Felt at Edith, Colo., and Dulce and Lumberton, N. Mex.

January 29: 11:38:48*, 12:25:06*. Epicenter 37.0° north, 106.9° west, New Mexico-Colorado border region, W. Felt in the Dulce, N. Mex., area.

January 29: 13:10. Edith, Colo. III. Felt by several. Motion rapid, bumping.

January 31: 08:43:52*. Epicenter 37.0° north, 106.9° west, New Mexico-Colorado border region, W. IV. In the northern section of Dulce, N. Mex., buildings creaked and windows rattled. Jolt; abrupt onset.

February 2: 14:00. Dulce, N. Mex. (northern section). IV. Observer in brick school building heard windows rattle. Motion rapid.

February 6: 05:10. Edith, Colo. III. Several felt three consecutive shocks; motion trembling and swaying, north-south direction.

February 10: 23:22:17.7*. Epicenter 36.9° north, 106.9° west, New Mexico, W. Felt in the Dulce area.

February 11: 05:08:43.9*. Epicenter 37.0° north, 107.0° west, New Mexico-Colorado

border region, W. Felt in Dulce, N. Mex., area.

February 11: 13:36:26.0*. Epicenter 42.1° north, 111.4° west, eastern Idaho, W. Magnitude 3.5. Felt in the Bear Lake area of southeastern Idaho at Montpelier, Ovid, and Paris.

February 12: 23:01:27*. Epicenter 37.0° north, 106.9° west, New Mexico-Colorado border region, W. Felt in Dulce, N. Mex., area.

February 12: 23:21:31.0*, 23:32:21*. Epicenter of first shock 37.0° north, 106.9° west; of second 36.9° north, 106.9° west, New Mexico-Colorado border region, W. Both shocks were felt in the Dulce, N. Mex., area.

February 26: 11:07:37.0*. Edith, Colo. III. Felt by several. Buildings shook; motion trembling and swaying. Quite strong. Also felt by several at Chromo, Colo., and at Dulce and Lumberton, N. Mex. Recorded by the seismograph at Albuquerque, N. Mex.

February 27: 11:10. Edith, Colo. III. Buildings shook and a trembling-swaying motion was observed. Also felt by several at Dulce and Lumberton, N. Mex., and at Chromo, Colo.

March 4: 00:03. Helena, Mont. III. A weak jolt was felt by a few residents in the area.

March 7: 11:09:42.6*. Epicenter 46.3° north, 111.5° west, Montana, W. Magnitude 4.8. V. Felt over an area of approximately 12,500 square miles of west-central Montana (see fig. 10). With the exception of slight plaster cracking at Reedpoint, no damage was reported.

INTENSITY V:

Anaconda, Elkhorn, Maudlow area, Radersburg, Reedpoint, and Virginia City.

INTENSITY IV:

Blossburg, Bridger Canyon, Butte, Cascade, Clancy, Clarkston, Deer Lodge, Divide, Drummond, East Helena, Garrison, Great Falls, Helena, Manhattan, Maxville, Melrose, Missoula, Monarch, Ovando, Pass Creek, Philipsburg, Reese Creek, Silver Gate, Three Forks, Toston, Townsend, Trident, Willow Creek, and Winston.

INTENSITY I-III:

Avon, Bozeman, Cardwell, Carlisle Ranch (about 20 miles southwest of Great Falls), Elliston, Hall, Harlowton, Helmville, Jeffers, Lincoln, Livingston, Milligan, Power, Pray, Springdale, Twin Bridges, Warmsprings, White Sulphur Springs, and Wisdom. Reported felt by the press (no details): Corbin, Dillon, Jefferson City, and Rimini.

March 17: 04:47:50.0*. Epicenter 41.7° north, 111.5° west, northeastern Utah, W. Magnitude 4.4. V. Felt over approximately 6,000 square miles of northeastern Utah and southeastern Idaho, principally in the Cache Valley areas. A few plaster cracks were reported at Logan, Utah; otherwise, there was no damage reported. A slight aftershock was reported at Logan at about 09:02.

INTENSITY V IN UTAH:

Hyrum, Lewiston, Logan, Paradise, Providence, Randolph, Richmond, and Smithfield.

INTENSITY V IN IDAHO:

Fish Haven, Preston, and five miles east of Preston.

INTENSITY IV IN UTAH:

Brigham City, Clarkston, Garden City, Honeyville, Hyde Park, Newton, Ogden, Salt Lake City, and Wellsville.

INTENSITY IV IN IDAHO:

Clifton and Franklin.

INTENSITY I-III IN UTAH:

Provo.

INTENSITY I-III IN IDAHO:

Weston and Montpelier.

March 18: 07:18. Commerce City, Colo. III. Felt by all in home. Moderate noise; one jolt from west. "Shock was confined to 1 mile east of the Arsenal, south to 64th

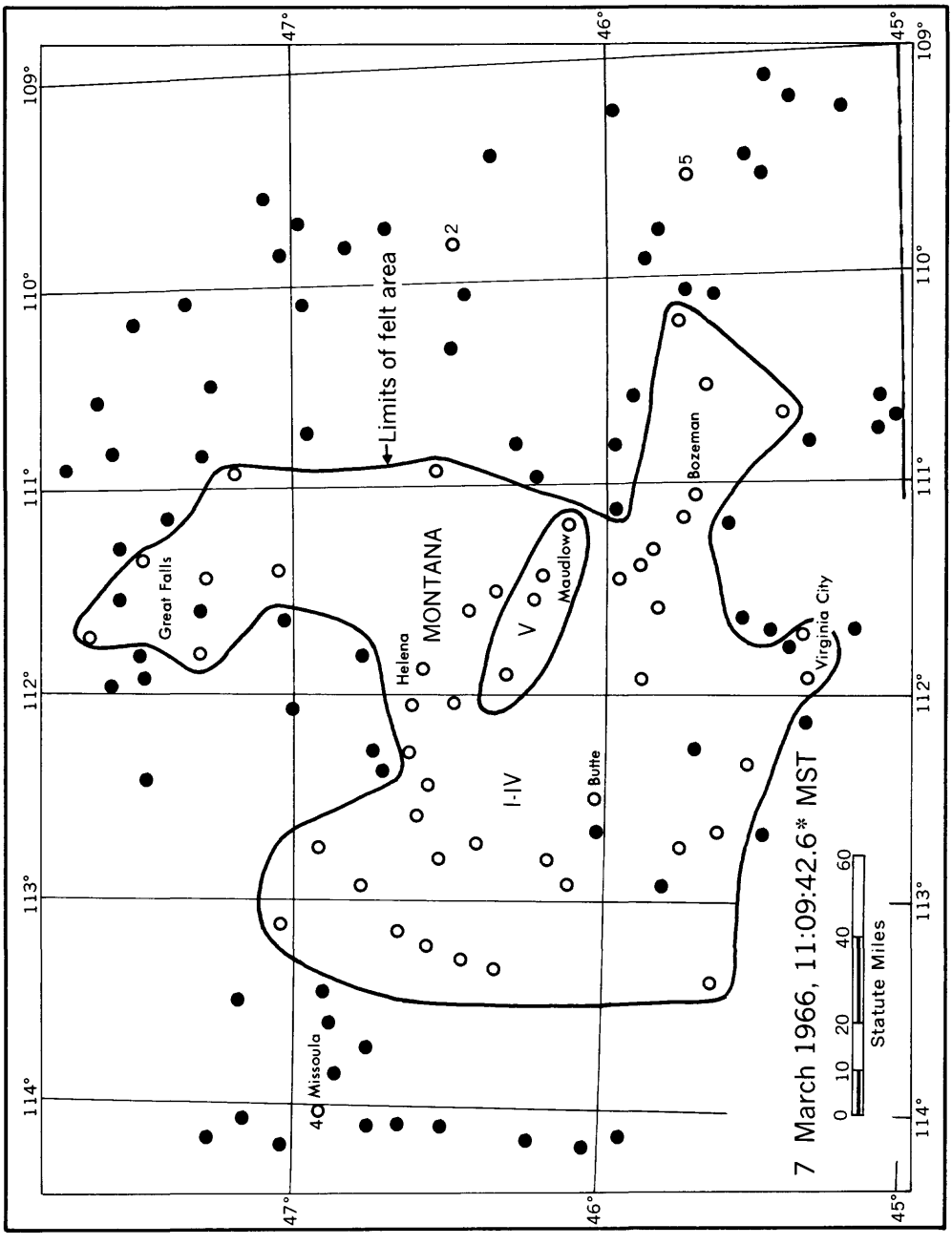

FIGURE 10.—Area affected by Montana earthquake of March 7.

Avenue, west to Highway 85, and north to Irondale."

April 3: 09:22. Helena (southeast section), Mont. IV. Felt by several. Buildings creaked and loose objects rattled. Trembling motion; abrupt onset. Faint, roaring earth noise.

April 29: 23:27:38*. Epicenter 48.0° north, 113.8° west, Montana, W. Magnitude 3.9. V. Felt over an area of approximately 500 square miles of the south and southwest Flathead Lake areas. At Big Arm, felt by and awakened many; house shook; loud rumble. Observer at Coster (on tip of peninsula extending 7 miles out into Flathead Lake, and about 8 miles northeast of Polson) reported a 5- by 5-foot-square boulder was moved 1 foot. Moderate rumbling earth noises. "Numerous shocks felt here." Awakened many at Polson, where windows and dishes rattled. Professor Nile reported: "Local residents in the Polson area report they have felt about 60 minor shocks during the past 2 years." Felt by and awakened many in community at Proctor; windows, doors, and dishes rattled; house creaked moderately; hanging objects swung moderately southwest-northeast. Loud earth noises. "One of the loudest, and the most shaking, since the Yellowstone shock of August 17, 1959." Felt with intensity IV effects at Browne (about 14 miles west of Polson), Elmo, Kerr Powerhouse (about 5 miles southwest of Polson), and Pablo.

May 7: 07:50. Bigfork, Mont. "I thought I felt a slight shock. Have found no one else who did, however."

May 18: 17:26:44*. Epicenter 37.0° north, 107.2° west, New Mexico, W. Magnitude 4.6. Press reported Dulce residents were shaken up quite a bit. "We've been having this kind of thing continuously since the big shock on January 22."

May 25: 20:21. Commerce City, Colo. II. Felt by one or two persons in the Derby area.

June 6: 12:57. Commerce City, Colo. IV. Felt by many in Commerce City and vicinity. Windows and dishes rattled in few instances. One jolt and rumble with mostly moderate shaking. Also felt at the Arsenal and northeast of; Dupont, Irondale and farmland north and east of; Northglenn, Thornton, and Welby.

August 7: 09:36:26.7* PST. Gulf of California shock. (See section on "California and Western Nevada" for felt areas in Arizona and Nevada.)

August 14: 08:25:53*. Epicenter 32.0° north, 102.6° west, W. Magnitude 3.4. This shock, centering in west Texas, was reported felt with intensity IV at Loco Hills, N. Mex. (about 25 miles northeast of Carlsbad); windows rattled; similar to sonic boom. (See p. 14.)

August 16: 11:02:36.1*. Epicenter 37.4° north, 114.2° west, southern Nevada, W. Magnitude 6.1. Main shock of a large series; 68 aftershocks were located by the C&GS in August. Observer at Caliente reported that since the main shock, nearly 40 shocks of varying intensities had been felt. VI. Felt over an area of approximately 20,000 square miles of southern Nevada, southwestern Utah, and a small area along the Arizona border (see fig. 11). No damage was reported in the sparsely settled epicentral region.

INTENSITY VI IN NEVADA:

Caliente (on ranch).—Felt by several; frightened few. Knickknacks, books, and pictures fell; small objects overturned. Trees and bushes shook moderately. Pendulum clocks stopped; hanging objects swung northeast. Rapid motion in northeast direction lasted about 1 minute; preceded by moderate earth noises from southwest. "Since the first shock, we have felt about 40 shocks of varying intensities."

INTENSITY VI IN UTAH:

Beryl.—Felt by all and frightened few in community. Ground seemed to move as

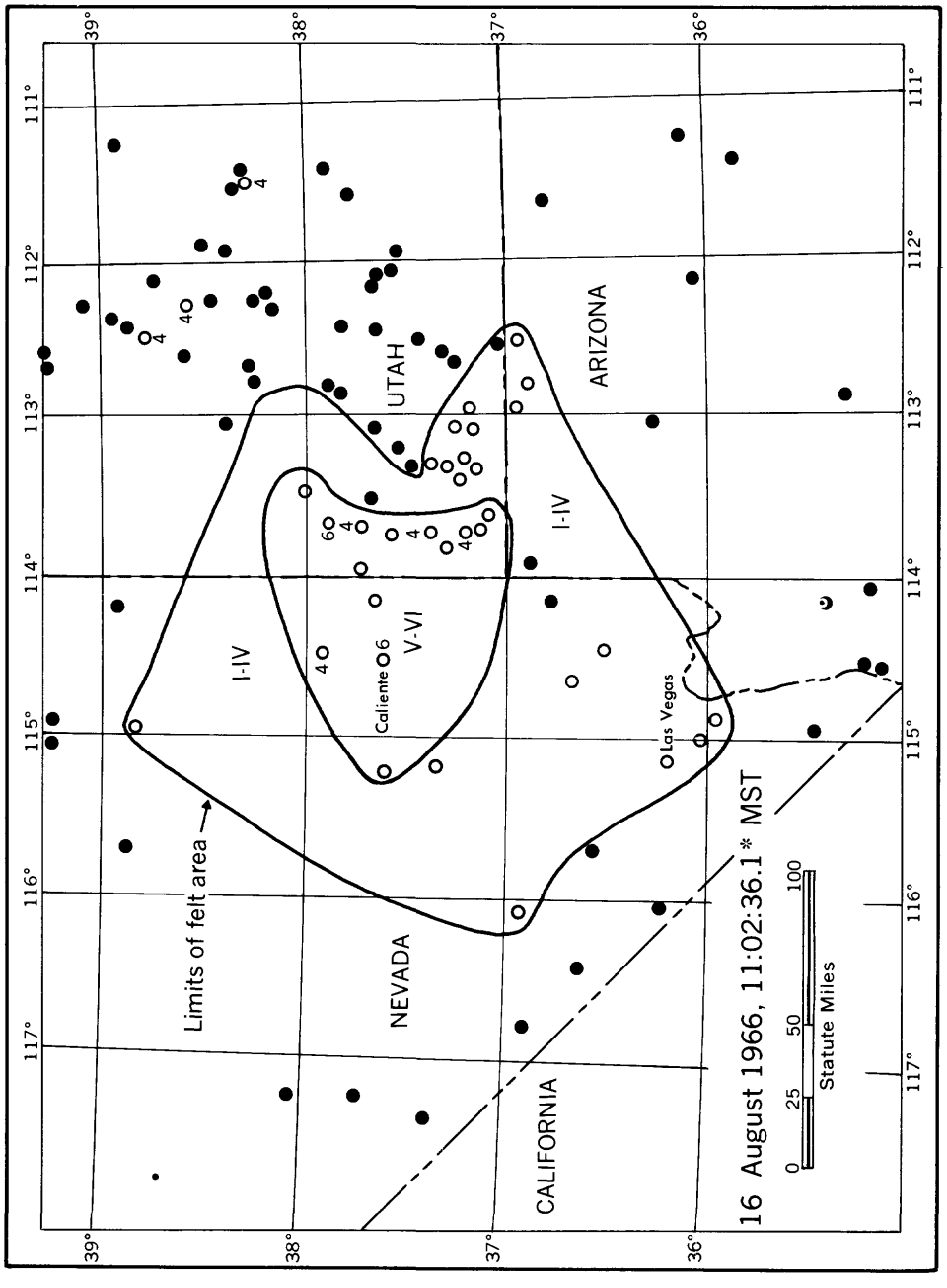

FIGURE 11.—Area affected by Nevada earthquake of August 16.

waves on ocean. Furniture and small objects shifted; hanging objects swung. Trees and bushes shook. Slow, rocking motion.

INTENSITY V IN NEVADA:

Crestline and Hiko.

INTENSITY V IN UTAH:

Enterprise, Gunlock, Lund, Saint George, Santa Clara, Springdale, and Uvada.

INTENSITY IV IN NEVADA:

Las Vegas, Moapa, and Pioche.

INTENSITY IV IN UTAH:

Beryl Junction, Ivins, Kanosh, La Verkin, Pintura, Rockville, Sevier, Teasdale, Toquerville, Veyo, Washington, and Zion National Park.

INTENSITY I-III IN NEVADA:

Alamo, Boulder City, Henderson, Nevada Test Site (south of, at 36°50′ north, 116°05′ west), and Overton.

INTENSITY I-III IN UTAH:

Hurricane (three additional shocks felt), Leeds, Minersville, and Salt Lake City.

INTENSITY I-III IN ARIZONA:

Colorado City, Fredonia, and Moccasin.

August 17: 16:07:58.9*. Epicenter 37.3° north, 114.1° west, southern Nevada, W. Aftershock of August 16 earthquake at 11:02:36.1*. Magnitude 5.2. Felt at Gunlock, Utah. "People working outdoors were not aware of the rocking motion."

August 18: 02:15:34.9*. Epicenter 37.3° north, 114.1° west, southern Nevada, W. Aftershock of August 16 earthquake at 11:02:36.1*. Magnitude 5.1. IV. People awakened at Gunlock, Utah. Awakened few at Elgin, Nev., where windows and doors rattled; moderate earth noises.

August 18: 05:00:35.2*. Epicenter 37.3° north, 114.2° west, southern Nevada, W. Aftershock of August 16 earthquake at 11:02:36.1*. Magnitude 4.4. IV. Awakened people at Gunlock, Utah. Awakened few at Elgin, Nev., where windows and doors rattled; moderate earth noises.

August 18: 06:33:20.8*. Epicenter 37.4° north 114.2° west, southern Nevada, W. Aftershock of August 16 earthquake at 11:02:36.1*. Magnitude 4.6. IV. Awakened few at Elgin, Nev., where windows and doors rattled; moderate earth noises.

August 18: 10:00. IV. Felt at Elgin, Nev. Windows and doors rattled.

August 18: 11:30. Felt at Gunlock, Utah. Not felt by people working outdoors.

August 18: 22:29. Colorado. III. Very slight shock felt by few at Commerce City and north of the Arsenal.

August 19: 11:14:33.5*. Epicenter 37.3° north, 114.2° west, southern Nevada, W. Aftershock of August 16 earthquake at 11:02:36.1*. Felt at Gunlock, Utah. Not felt by people working outdoors.

September 19: 03:06:42.4*. Epicenter 45.9° north, 111.2° west, Montana, W. Magnitude 4.4. V. Felt principally in the Belgrade, Bozeman, Gallatin Gateway, Livingston, and Manhattan areas. Weak aftershocks felt at Manhattan. At Belgrade, awakened many and frightened few; trees and bushes shook; loud, rumbling earth noises. At the airport, only one sharp jolt was felt; entire building seemed to move up and down. Felt by and awakened many in Bozeman and vicinity. At Bozeman, door seemed to jump up and down; distinct north-south motion of bed; loud earth noises. At Bridger Canyon (5½ miles northeast of Bozeman), awakened all in home; picture fell; loud booming earth noises; sharp jolt followed by shaking for about 30 seconds. Awakened many and frightened few at Gallatin Gateway; loud roaring earth noises. Awakened and frightened all in home 6½ miles west of Livingston; small objects shifted; hanging objects swung moderately. Felt by and awakened many in Manhattan and vicinity; loud earth noises from southeast-northwest seconds before shock. At a ranch about 12 miles southwest of Manhattan and about 8½ miles west of the small community of Amsterdam, felt quite

strongly; freshly poured concrete foundation was cracked in several places. Intensity IV at Gardiner, Livingston, Logan, Pass Creek, Trident, Virginia City, Waterloo, West Fork, Willow Creek, and Wilsall.

September 22: 11:56:40.9*. Epicenter 37.3° north, 114.1° west, southern Nevada, W. Magnitude 5.0. Felt at Enterprise, Utah.

September 22: 11:57:37*. Epicenter 37.4° north, 114.2° west, southern Nevada, W. Largest of a swarm in the area. Magnitude 5.3. V. At Lund, windows cracked; small objects and furnishings shifted; doors closed; motion slow, steady; lasted 5 minutes. Felt by several and frightened few at Panaca; small objects shifted; trees and bushes shook moderately; motion slow, lasted 1 minute; loud earth noises. Intensity IV at Alamo, Baker, Caliente, Elgin, Hiko, Pioche, and Sunnyside (about 30 miles south of Lund); and at Saint George, Utah. Intensity I-III at Moapa, Overton, and Searchlight; also felt at Lehman Cave National Monument (near Baker); and at Enterprise, Utah.

September 24: 00:33:46* (main shock), 03:10:41*, 05:22:40*. Epicenters (1) 36.5° north, 105.0° west; (2) 36.4° north, 105.1° west; (3) 36.4° north, 105.0° west, near Cimarron, N. Mex., W. Magnitudes 4.1, 3.8, 3.6, respectively. IV. All of the shocks were reported felt at Cimarron. The main shock was felt at Miami, Penasco, Red River, Shady Brook (about 8 miles east of Taos), Taos, and Ute Park. It was also felt by several and rattled windows, doors, and dishes at Weston, Colo., about 45 miles north of Cimarron. In a press report (relative to the shock of October 2 at Trinidad, Colo.) there was mention that some residents of Trinidad recalled having felt tremors "a week or so ago."

September 26: No time given. West Yellowstone, Mont. (Denny Creek, near U.S. Highway 191). IV. Stovepipe and walls swayed.

October 2: 19:26:01.9*. Epicenter 37.4° north, 104.1° west, Colorado, W. Magnitude 4.5. VI. Felt over an area of approximately 15,000 square miles of southeastern Colorado and northeastern New Mexico (see fig. 12). Slight damage was noted at a few places in Colorado. At Aguilar, felt by many and frightened few in community; one house was reported cracked in several places. Felt by and frightened many in community at Segundo; one house cracked; furniture and small objects shifted; earth noises like loud wind. Felt by all at Trinchera; plaster and windows cracked; furniture and small objects shifted; loud earth noises. At Trinidad, felt by all and frightened many. Press reported telephone calls flooded switchboards. There were no reports of serious damage, although some plaster cracked and pictures and dishes broke. Some persons reported feeling two shocks within a few seconds; loud earth noises.

INTENSITY V IN COLORADO:

Boncarbo, Branson, Hoehne, Model, Sopris, Starkville, Villegreen, and Walsenburg.

INTENSITY IV IN COLORADO:

Aguilar (9 miles west of), Canon City, Delhi, Fowler, Jansen (about 4 miles southwest of Trinidad), Kim, Manzanola, Pryor, Pueblo, Springfield, Thatcher, Tyrone, Utleyville, and Villegreen (25 miles north and east of, and 30 miles east of).

INTENSITY I-III IN COLORADO:

Cokedale and Two Buttes.

INTENSITY I-III IN NEW MEXICO:

Capulin, Chico, Des Moines, Farley, Folsom, Point of Rocks (between Clayton and Springer), Raton, Red River, and Roy.

October 3: 20:30. Helmville, Mont. IV. Windows and doors rattled. Motion slow.

October 9: 12:42 (about). Felt at Hebgen Lake, Mont.

October 9: 20:00 (about). Felt at Hebgen Lake, Mont.

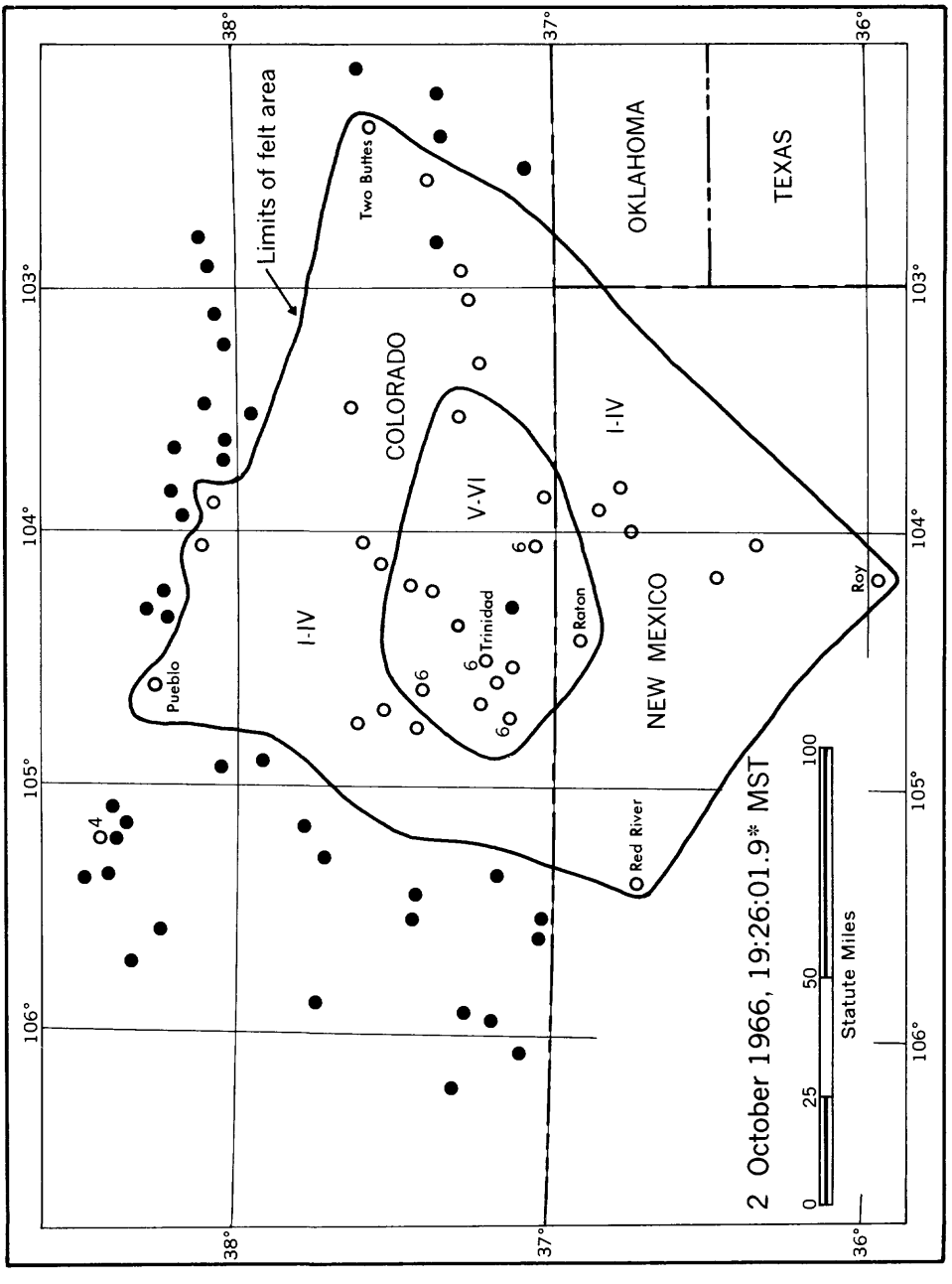

FIGURE 12.—Area affected by Colorado earthquake of October 2.

October 9: 22:48:30*. Felt at Hebgen Lake, Mont.

October 10: 22:30 or 22:45. Felt at West Yellowstone, Mont.

October 11: 00:30:04.0*, 00:31:12*, 01:23:04.3*. Epicenters (1) 44.9° north, 111.1° west; (2) 45.0° north, 111.3° west; (3) 44.8° north, 111.2° west; Hebgen Lake region, Mont., W. Magnitude of first shock 4.0. V. All of the shocks were felt in the Hebgen Lake-West Yellowstone area. At Hebgen Dam, the shock at 00:30:04.0* was described as a strong shock which awakened and frightened all in home. Motion was from south going to the north with a roar. Awakened many in community at West Yellowstone; solid jolt. Motion seemed from north; north-south movement of bed. Sound, like wind blowing through trees, preceded shock. Six shocks reported felt between 00:30 and 04:45. "We have had many shocks each day since October 11 (card postmarked October 14). An average of four or five each day. Buildings shake, but no damage. Shocks seem to be from south-north, with slight noise preceding. People awakened almost every night." Other places reporting on the early morning shocks of October 11 (no times given) were: Duck Creek Y (about 8 miles northwest of West Yellowstone), felt by and awakened all; brief shaking, followed by a light, very brief rumble. Deep Well Ranch (about 1 mile from the South Fork of the Madison River as it enters Hebgen Lake from the south shore), sharp jolts, felt by and awakened all in home; hanging objects swung moderately. Felt by and awakened few at Macks Inn, Idaho. "A few persons mentioned there must have been a shock but it was very light." At Henry's Lake, Idaho (time given as 02:00), felt by, awakened, and frightened few; windows rattled; buildings creaked; three shocks felt on October 11.

October 11: 02:00. Henrys Lake, Idaho. IV. Three shocks were felt. Windows rattled and buildings creaked.

October 11: 02:47:34*, 04:39:20*. Felt at West Yellowstone, Mont.

October 11: 04:48:11*. V. Awakened many and frightened few at West Yellowstone, Mont. Windows and doors rattled; logs creaked. Very strongly felt. Also felt at Hebgen Lake, and weakly felt at the Black Butte Ranch (Gallatin Canyon) about 8 miles south of 320 Ranch.

October 11: 07:07:44*. Felt at Hebgen Lake.

October 11: 07:37:39*. Epicenter 44.9° north, 111.3° west, Hebgen Lake region, Mont., W. Felt in Hebgen Lake area.

October 11: 09:30:39.6*. Epicenter 44.8° north, 111.1° west, Hebgen Lake region, Mont., W. Magnitude 3.9. Felt at West Yellowstone. Reported as similar in intensity to the two shakes felt around midnight. "Six shocks felt between 09:30 and 10:20. Shocks felt all morning."

October 11: 09:39:51*. Epicenter 44.9° north, 111.1° west, Hebgen Lake region, Mont., W. Magnitude 3.9. IV. Hebgen Lake area (Grayling Creek Ranch, about 10 miles northwest of West Yellowstone). Felt by all in home. Windows, doors, and dishes rattled; building creaked. Moderate bang, like sonic boom.

October 11: 09:58:06*. Epicenter 44.8° north, 111.4° west, Hebgen Lake region, Mont., W. IV. Hebgen Lake area (Grayling Creek Ranch, about 10 miles northwest of West Yellowstone). Felt by all in home. Windows, doors, and dishes rattled; building creaked. Moderate bang, like sonic boom.

October 11: 10:10. IV. Felt by many at West Yellowstone, Mont., where doors rattled; logs creaked; moderate earth noises.

October 11: 10:20. West Yellowstone, Mont. Case rattled at post office.

October 11: 10:41:50*. Epicenter 44.8° north, 111.2° west, Hebgen Lake region, Mont., W. IV. Felt by several and frightened few at the west entrance of Yellowstone National Park (West Yellowstone); windows rattled; roaring earth noises. Felt by all in home at the Grayling Creek Ranch (Hebgen Lake); windows, doors, and dishes rattled; building creaked.

October 11: 10:52:31.3*. Epicenter 44.8° north, 111.2° west, Hebgen Lake region, Mont., W. Magnitude 4.6. V. Felt by all at West Yellowstone; windows rattled; felt like something rolled along under the floor. Felt by all in home at the Grayling Creek Ranch (Hebgen Lake); windows, doors, and dishes rattled; building creaked; moderate bang, like sonic boom. Very slight tremor felt by few at Lakeview (28 miles east of Monida).

October 11: 13:02:37*. Felt at West Yellowstone, Mont.

October 11: 13:30. Felt at West Yellowstone, Mont. Described as a jar.

October 11: 16:02:30*. Epicenter 44.9° north, 111.3° west, Hebgen Lake region, Mont., W. IV. Grayling Creek Ranch (10 miles northwest of West Yellowstone, close to Hebgen Lake). Felt by all in home. Windows, doors, and dishes rattled; building creaked. Moderate bang, like sonic boom.

October 11: 23:35. IV. Grayling Creek Ranch (Hebgen Lake). Felt by many; awakened few. Windows, doors, and dishes rattled.

October 14: 09:00 and 21:00. West Yellowstone, Mont. Reported as sharp shocks. "Other people interviewed referred to earthquakes felt at West Yellowstone on October 15."

October 22: 10:16:26.8*. Epicenter 40.6° north, 116.2° west, Nevada, W. Magnitude 4.1. V. At Carlin, felt by several; awakened and frightened few. Furnishings shifted. Trees and bushes shook slightly. Hanging objects swung. Motion slow, from west; lasted about 8 seconds. Loud earth noises from east. "If shock had lasted a little longer, damage would have resulted." Felt with intensity IV at Elko, Jiggs, and Wells. Also felt at Beowawe.

October 24: 10:14. II. Very gentle shock felt by few at Commerce City, Colo. Faint noise for about 3 seconds; then one jolt.

November 13: 08:17. III. Slight shock felt in the Commerce City, Colo., area. Moderate noise; then one slight jolt.

November 14: 13:02:45.8*. Epicenter 39.9° north, 104.7° west, Colorado, W. Magnitude 4.1. VI. At Commerce City, felt by many. Plaster cracked; old crack lengthened 1 foot. Small objects shifted, overturned, and fell; some canned goods and boxes fell in supermarket. Loud earth noises. One observer reported the rumbling noise was so loud the rattling of objects could not be heard. Motion reported as rocking; rapid up and down; lasted about 3 seconds. At Eastlake, felt by all and frightened few in community. Furniture and small objects shifted. Hanging objects swung moderately northeast-southwest. Loud earth noises. "Most earth noise and hardest shake of all to date."

INTENSITY V:

Adams City, Broomfield, Dupont, and Thornton.

INTENSITY IV:

Brighton, Central City, Dumont, Henderson, Lafayette, Louisville, and Westminster.

INTENSITY I-III:

Arsenal, Barr Lake, Boulder, Denver, Hazeltine Heights, Irondale, Lakewood, Loveland, Northglenn, and Watkins.

December 30: 20:37 (about). At the 320 Ranch, Mont. (about 55 miles south of Bozeman) two persons felt a slight vibration.

CALIFORNIA AND WESTERN NEVADA

[120th Meridian or Pacific Standard Time]

Note: All towns mentioned are in California unless otherwise stated.

January 4: 21:55:06*. Epicenter 36°58.7′ north, 121°28.2′ west, central California, B. Magnitude 2.9. III. A sharp jolt was felt by several in the Hollister area.

January 8: 16:03:21*, 16:08:01*. Epicenters 36°58.4′ north, 121°28.2′ west; 36°58.4′ north, 121°29.0′ west, central California, B. Magnitudes 2.6 and 3.3, respectively. Both shocks were felt at Hollister.

January 12: 19:40:38.6*. Epicenter 36°06.3′ north, 117°52.5′ west, Inyo County, P. Magnitude 3.1. IV. Windows rattled at Keeler. Felt by several at Haiwee and Olancha.

January 13: 17:53:35.7*. Epicenter 33°48.1′ north, 117°42.4′ west, southern California, P. Magnitude 3.0. The press reported this shock was observed by residents of Orange County.

January 16: 16:48:08*, 18:03:20* (main shock), 18:23:37*, 18:48:37*, 22:22:56*. Epicenter 36°58.9′ north, 121°28.5′ west, central California, B. Magnitudes 3.3, 4.1, 2.9, 3.0, and 2.8, respectively. IV. Windows, doors, and dishes rattled in Hollister (Fairview District), Morgan Hill, and San Martin. Also felt at Oakland, San Francisco (Children's Hospital), and Gilroy (18:23:37*).

January 20: 20:10:36* (aftershock of January 16 earthquake at 18:03:20*). Epicenter 36°59.6′ north, 121°29.5′ west, central California, B. Magnitude 3.5. V. Felt by all at San Martin (Llagas Avenue) where houses shook and faint earth noises were heard. Intensity IV was reported at Gilroy, Hollister, and Morgan Hill. Intensity I-III at Aromas and Tres Pinos.

January 21: 19:17:30.6*. Epicenter 35°35.0′ north, 118°24.6′ west, Kern County, P. Magnitude 3.0. Felt at Kernville.

January 26: 13:45:07.0*. Epicenter 33°10.2′ north, 116°30.1′ west, northeast San Diego County, P. Magnitude 3.3. The press reported this shock was felt at Borrego State Park and Culp Valley (Borrego Springs area).

February 10: 06:19:47.3*, 06:20:04*, 06:21:08.4* (main shock). Epicenters 37°50.4′ north, 121°46.4′ west (first and second shocks); 37°53.7′ north, 121°46.1′ west (main shock), B. Magnitudes 3.1, 3.5, and 3.7, respectively. V. Felt over approximately 400 square miles of Alameda and Contra Costa Counties. Plaster cracked at the Rasmussen Ranch, 5 miles north of Highway 50 on Tassajara Road (Pleasanton area). Small objects shifted and fell at Diablo and at the Ranger station on the summit of Mount Diablo. Intensity IV at Antioch (1 mile east of), Berkeley (Carleton Street), Clayton, Danville, and Walnut Creek. Intensity I-III at Saint Mary's College.

February 11: 10:56:41*. Epicenter 36.8° north, 121.5° west, central California, B. Magnitude 2.3. IV. Building creaked and windows, doors, and dishes rattled at the Harris Ranch, 7½ miles south of Hollister.

February 13: 09:10:28*. Epicenter 37°46.5′ north, 122°42.0′ west, about 10 miles off the coast of San Francisco, B. Magnitude 2.6. V. In the Richmond District of San Francisco, a few books fell from shelves. The motion was sharp and explosive. The shock was felt by a few at San Francisco State College in the Lake Merced area, and was reportedly observed by Marin County residents.

February 15: 21:37:12.0*. Epicenter 33°48.5′ north, 118°03.6′ west, southern California, P. Magnitude 2.9. V. Felt by all in Long Beach and Los Alamitos. Earth sounds accompanied the shock, and windows and dishes rattled. Intensity IV at

La Palma (Long Beach-Seal Beach area) and Seal Beach. Intensity I-III at Lakewood (about 6 miles northeast of Long Beach) and Westminster.

February 16: 23:34:16.8*. Epicenter 33°52.2′ north, 117°48.6′ west, southern California, P. Magnitude 2.6. V. The press reported that a pressure cooker, baby stroller, and several other items were knocked from rafters in a garage at Yorba Linda. Residents of Placentia reported, "It sounded like a train coming toward the house. When it hit, it jarred the entire house."

March 4: 02:52:40.2*, 04:40:06.1*. Epicenters 32°50.5′ north, 115°37.0′ west; 32°51.6′ north, 115°32.3′ west, southern California, P. Magnitudes 3.5 and 3.6, respectively. VI. Professor Clarence Allen, Director, Seismological Laboratory, California Institute of Technology reported: "The shock caused a crack 10-km long along the Imperial fault, and where the fault crosses Highway 80, the horizontal displacement was 1 cm." He estimated an acceleration of 0.06 g at Imperial. The shocks were felt in the Imperial Valley according to the press.

March 4: 06:24:47.2*. Epicenter 32°40.5′ north, 115°33.3′ west, southern California, P. Magnitude 3.3. The press reported this shock was felt at El Centro.

March 9: 16:00:44.0*. Epicenter 32°53.1′ north, 117°11.4′ west, southern California, P. Magnitude 3.2. Intensity IV effects were reported from the San Diego area, including El Cajon (about 13 miles northeast of San Diego), and Grossmont (about 10 miles northeast of San Diego).

March 16: 10:21:09.6*. Epicenter 36°45.7′ north, 121°35.6′ west, central California, B. Magnitude 3.0. Felt at Hollister and Salinas.

March 16: 10:24:03.8*. Epicenter 36°48.8′ north, 121°32.5′ west, central California, B. Magnitude 3.4. Intensity IV effects were observed south of Hollister at the Everett Mills Ranch, at Gonzales, Hollister, and Salinas.

March 31: 03:49:11.3*. Epicenter 34°10.1′ north, 117°18.2′ west, southern California, P. Magnitude 3.1. Felt at San Bernardino.

April 2: 04:48:39.8*. Epicenter 38.4° north, 118.1° west, California-Nevada border region, W. Magnitude 4.6. Nevada. VI. Felt by and awakened all in community at Luning. The shock separated two parts of an old building. Small objects shifted, overturned, and fell. "Started with explosivelike noise and hard shake, then trembled for quite a few seconds." Felt with intensity IV at Mina. Also felt at Hawthorne.

April 10: 00:51:19*. Epicenter 37°56′ north, 122°24′ west, B. Magnitude 2.1. Press reported the shock hit the San Quentin Prison and neighboring San Rafael areas.

April 16: 23:04:19.1*. Epicenter 37°14.2′ north, 118°43.9′ west, P. Magnitude 4.0. IV. Felt by several and awakened few at Benton, where windows and dishes rattled. Rapid, brief motion, ending with a slight twist; preceded by rumble from south. Walls creaked at Bishop (Control Gorge Power Plant). Rapid, 5-10 second shock, in northeast direction. Felt by many and awakened few at Long Valley Dam (Crowley Lake), about 25 miles northwest of Bishop. House creaked. Gentle, steady shake for a few seconds. Also felt at Mammoth Lakes.

April 18: 01:21:20.1*. Epicenter 33°59.8′ north, 116°39.2′ west, P. Magnitude 3.5. IV. Press reported a slight earthquake, followed by two light aftershocks, rattled windows at Palm Springs. Apparently felt only in the immediate Palm Springs area.

April 29: 00:09:27.6*. Epicenter 36°36′ north, 121°15′ west, central California, B. Magnitude 3.8. V. At Hollister, felt by and awakened many in community; fright-

ened few. Windows, doors, and dishes rattled; houses creaked. Felt by and awakened all at the Search Ranch (Jamesburg area, about 35 miles southwest of Hollister), where windows rattled; house creaked and shook. Two distinct tremors. Felt with intensity IV in the Cienega District (south of Hollister), at 7802 Cienega Road (Harris Ranch), 9970 Cienega Road (W. A. Taylor Winery), 12830 Cienega Road (Smith Ranch), 13150 Cienega Road (Contival Ranch), Gonzales, Lonoak area (1080 Lonoak Road), Mee Ranch (junction of Highways 25 and 198), Paicines (Robert Law Ranch), Pinnacles National Monument (Headquarters area), and Tres Pinos. Intensity I-III at Carmel Valley (4 miles west of) and Idria.

May 2: 19:12:00.6*. Epicenter 34°53.8′ north, 118°59.7′ west, P. Magnitude 2.8. Felt at Fort Tejon.

May 13: 09:25:55.9*. Epicenter 36°55′ north, 121°34′ west, central California, B. Magnitude 4.5. V. Felt over an area of approximately 900 square miles, principally in San Benito, Santa Clara, and Santa Cruz Counties. Felt by many and frightened few in community at Gilroy. Student at Gilroy High School reported small plaster cracks in a wall at the school. Trees and bushes shook; vehicles rocked. Felt with intensity IV at Aptos (4 miles north of), Cienega Valley (south of Hollister), Freedom, Gilroy (4 miles east and slightly north of), Gilroy Hot Springs (about 15 miles northeast of Gilroy), Hollister, Morgan Hill, and San Juan Bautista (Old Mission San Juan Bautista). Intensity I-III at Aromas, Salinas, San Francisco, San Jose, San Martin, Spreckels, and Tres Pinos.

May 23: 19:49:52.8*. Epicenter 39°41′ north, 121°49′ west, northern California, B. Magnitude 4.6. VI. Felt over an area of approximately 12,000 square miles (see fig. 13). Plaster cracked at Forest Ranch about 15 miles northeast of Chico. At Las Plumas, about 10 miles north by east of Oroville, rocks were heard rolling down hillside. Some dishes were broken at Oroville.

INTENSITY VI:

Forest Ranch.—Felt by, awakened, and frightened all in community. Plaster cracked in some houses. Some telephones knocked out. Loud rumbling earth noises.

Las Plumas.—Felt by and frightened all in community. "Could hear rocks rolling down hillside." Small objects overturned. Loud earth noises (like airplanes).

Magalia (about 8 miles southeast of Forest Ranch).—Felt by nearly all in community; frightened few. Few small objects shifted, overturned, and fell. Earth noises (like a moderate sonic boom).

Paradise.—Felt by all and frightened few in home. Bathtub moved from side to side. Very loud earth noises. Vibration increased greatly with the noise. "More of a jar than a sway."

Yankee Hill (about 6 miles northwest of Las Plumas).—Frightened many. Table shifted.

INTENSITY V:

Alta, Belden, Berry Creek (about 5 miles southeast of Las Plumas), Browns Valley, Brush Creek (about 7 miles northeast of Berry Creek), Butte City, Camptonville (about 18 miles southeast of Oroville), Centerville Powerhouse (near Paradise), Challenge, Chicago Park, Chico, Clipper Mills, Dobbins, Feather Falls, Forbestown, Grass Valley, Grimes, Oregon House, Oroville, Palermo, Pulga, Rackerby, Storrie, Taylorsville, Wheatland, and Yuba City.

INTENSITY IV:

Alleghany and surrounding area, Auburn, Bangor, Baxter, Bayliss, Beale Air Force Base (about 10 miles southeast of Marysville), Big Bend Powerhouse (NW¼, sec. 14, T.21N., R.4E., nearest town Oroville), Blairsden, Bucks Creek Powerhouse (NE¼, sec. 29, T.24N., R.6E., nearest town Belden), Bucks Lake (about 12 miles southwest of Quincy), Butte Meadows, Camino, Canyondam, Caribou, College City, Coloma, Colusa, Downieville, Durham, Feather

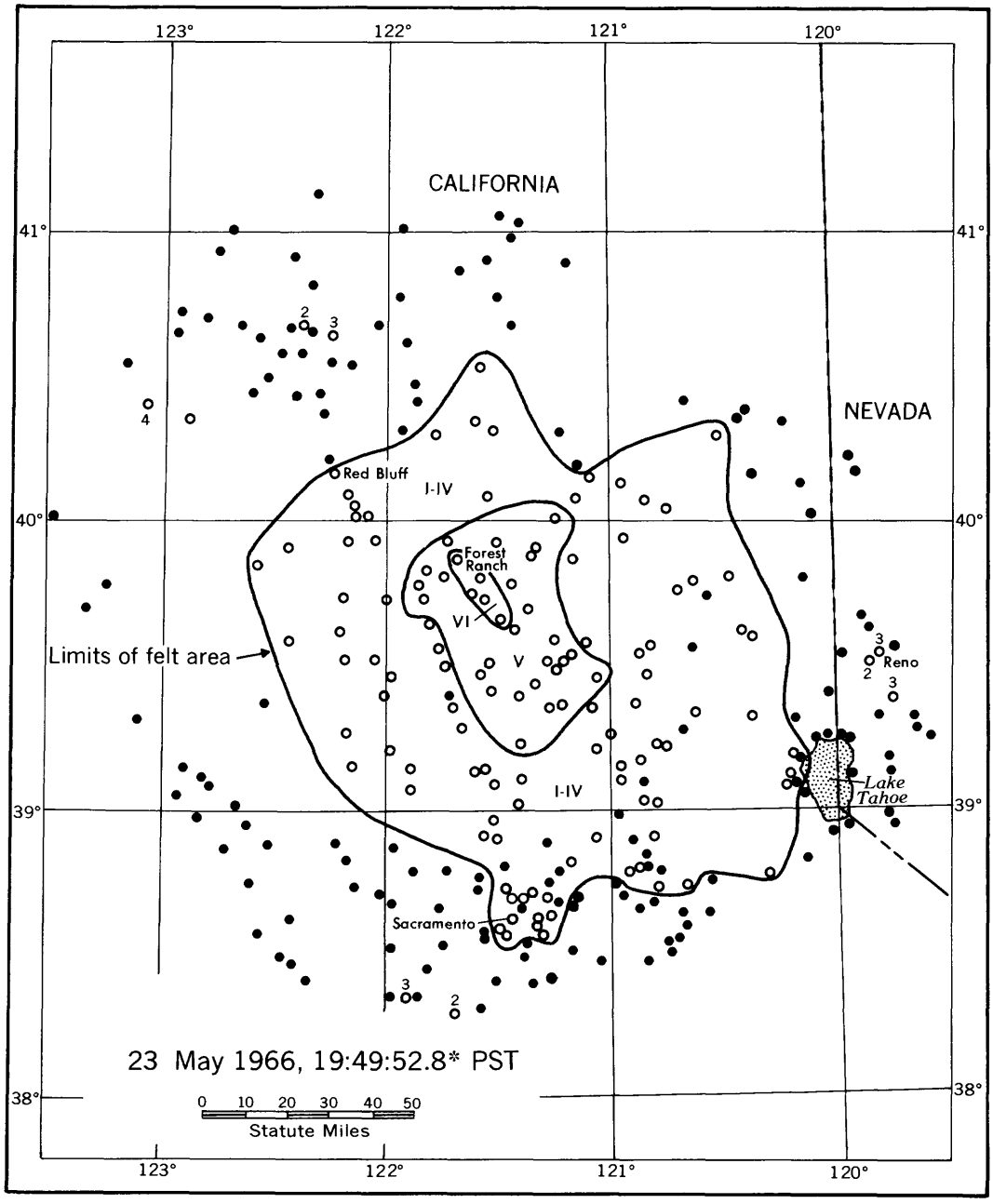

FIGURE 13.—Area affected by California earthquake of May 23.

River PG&E Powerhouses (in Butte and Plumas Counties), Fruto, Genessee, Georgetown (Ranger Station), Gerber, Glenn, Gold Run, Goodyears Bar, Greenville, Hamilton City, Iowa Hill, Lake Spaulding (Emigrant Gap Powerhouse), Los Molinos, Marysville, Meridian, Mineral, Nelson, Nevada City, North Bloomfield, North San Juan, Oak Park (about 4 miles southeast of Sacramento), Olivehurst, Orangevale, Orland, Placerville, Portola, Princeton, Quincy, Red Bluff, Richvale, Rio Linda, Rio Oso, Rock Creek Powerhouse (near Storrie), Sattley, Sierraville, Soda Springs, Stirling City, Strawberry Valley, Trowbridge, Wildwood Inn (about 10 miles northwest of Platina), Willows, Woodleaf, and Yankee Jims (about 3 miles northwest of Foresthill).

INTENSITY I-III:

Antelope, Artois, Bella Vista, Carmichael, Central Valley, Citrus Heights, Colfax (rural area), Corning, Del Paso Heights, Elmira, Elverta, Fair Oaks, Flournoy, Foresthill, Gridley, Homewood, Janesville, Johnsville, Liberty Farms, Kyburz area (30 miles east of Placerville), Live Oak, Loomis (2 miles east of), Lotus, Mather Air Force Base (about 10 miles east of Sacramento), Mill Creek, Nicolaus, North Highlands, North Sacramento, Paskenta, Proberta, Rancho Cordova (about 10 miles east of Sacramento), Sacramento, Squaw Valley, Tahoe Valley, Tehama, Vina, Weimar, and Williams.

INTENSITY I-III IN NEVADA:

Reno, Steamboat, and Washington (about 3 miles southwest of Reno).

June 5: 23:23:14.0*. Epicenter 37°19′ north, 121°45′ west, near Mount Hamilton, B. Magnitude 3.7. V. Felt by and awakened many at Mount Hamilton. Windows, doors, and dishes rattled; buildings creaked. Felt with intensity IV at Ben Lomond, Campbell, Felton, Los Gatos, New Almaden, and San Jose. Intensity I-III at Gilroy Hot Springs (about 15 miles northeast of Gilroy).

June 11: 02:08:57*. Epicenter 37°45′ north, 122°44′ west, Pacific Ocean, 12 miles west of San Francisco, B. Magnitude 2.8. V. Daly City-San Francisco area. Press reported several hundred calls flooded police and newspaper switchboards. Many of the alarmed callers reported the motion felt like a twist or jerk. Felt mainly in the area from Daly City to the Richmond District of San Francisco.

June 13: 13:05:36.9*. Epicenter 33°44.8′ north, 117°59.5′ west, Orange County, P. Magnitude 3.5. IV. In downtown Long Beach, weights swung on cuckoo clock; building creaked; loose objects rattled. Press reported the shock was felt at Anaheim, Buena Park, East Long Beach, Garden Grove, Huntington Beach, Lakewood, and Santa Ana.

June 21: 01:46:25.9*. Epicenter 34°51.4′ north, 120°28.2′ west, Santa Barbara County, P. Magnitude 4.1. IV. Awakened and frightened few in community at Guadalupe. Rolling motion. Windows, doors, and dishes rattled at Orcutt. At Santa Maria, awakened few; house creaked very slightly. Intensity I-III at Gaviota.

June 26: 22:04:20.9*. Epicenter 38°26′ north, 122°36′ west, near Santa Rosa, B. Magnitude 3.1. V. Felt over a small area of southern Sonoma County. Press reported a light but sharp earthquake startled many residents at Santa Rosa. In the new county jail a couple of water pipe leaks were found; plaster dust fell in some rooms, and metal trim bars jarred loose on some light fixtures in county buildings. Police and sheriff's office switchboards were jammed with calls. Several persons reported a roar —similar to sonic boom—preceded the distinct, single shock. One observer reported plaster cracks were observed by some people. Small objects and furniture shifted. Felt with intensity IV at Bodega, Graton, and Sebastopol. Intensity I-III at Forestville, Fulton, and Windsor.

June 26: 23:40:20.2*. Epicenter 38.7°

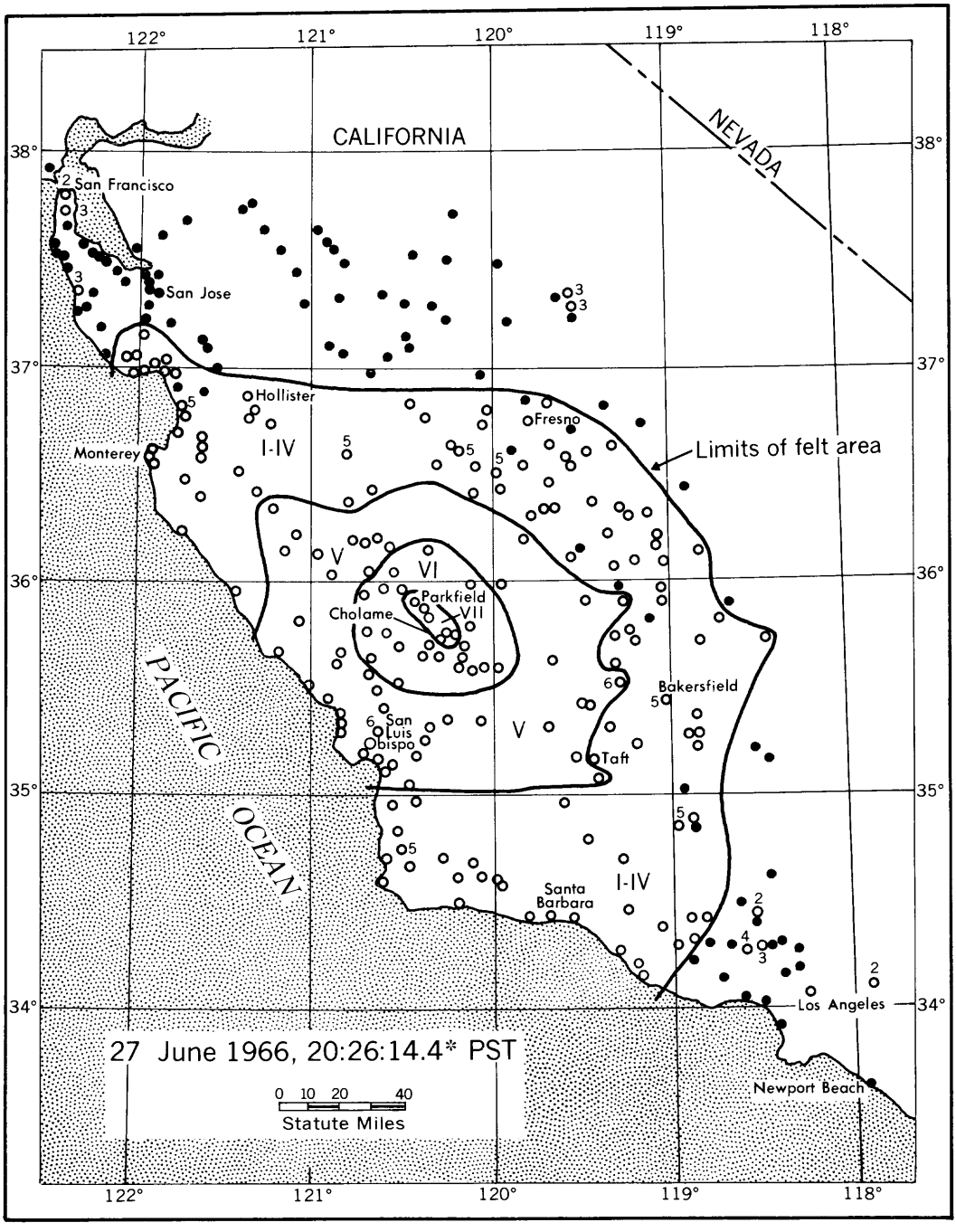

FIGURE 14.—Area affected by California earthquake of June 27.

north, 119.8° west, California-Nevada border region, W. Magnitude 4.5. V. Nevada. Awakened many and frightened few at Smith. Small objects shifted; few fell. Several reported it sounded like something ran into the house. Many were awakened at Wellington. Intensity IV effects reported at Coleville, Markleeville (near), and Topaz.

June 27: 17:00:31.5*. Epicenter 35°56.9′ north, 120°30.7′ west, B. First foreshock of the Parkfield series. Magnitude 3.1. Slight rolling motion felt at the Everett Hatch Ranch about 7 miles east-southeast of Cholame. Also felt at Parkfield (2.3 miles south of; Henry Miller Ranch on Parkfield to Cholame Road), Valleton (Indian Valley), and at the Work Ranch (about 8 miles northwest of Shandon, Hog Canyon Road, near Ellis School).

June 27: 20:08:57.0*, 20:26:14.4* (main shock of the Parkfield series). Epicenter of both shocks, 35°54′ north, 120°54′ west, W. Magnitudes 5.0 and 5.3, respectively.[2] The main shock of the Parkfield series was felt over an area of approximately 20,000 square miles (see fig. 14). A maximum intensity of VII was assigned to the minor surface faulting that occurred in a narrow zone along the San Andreas fault, from a few miles northwest of Parkfield to a few miles beyond Cholame (approximately 20 miles). There was a crack in the pavement of Highway 466, about 1 mile northeast of Cholame; the white dividing line was offset about 4 inches (see cover photo and fig. 15). At this same location, a small concrete bridge had minor cracks and pavement buckling. There was minor damage to bridges on the Parkfield-Cholame Highway. One bridge about 5 miles south of Parkfield had some buckled X-bracing. Principal building damage was the toppling of a number of brick chimneys, cracked walls and plaster, and broken windows. Tombstones were overturned in the Parkfield cemeteries, and some swimming pools were cracked. There were reports of murky water and increase in volume of water. Water splashed from swimming pools and elevated water tanks.

The following are excerpts from a preliminary report in the BSSA [3]:

Surface fault movement at the time of the June 1966 earthquakes follow precisely the most recent trace of older faulting. Surface fault fractures, as traced for some fifteen miles a few days after the earthquakes, consist of a series of large numbers of minor fractures arranged in an en echelon, chevron pattern; that is, the fault trace itself trends approximately north 30 degrees west, while the irregular fractures trend in most cases from due north, or slightly east of due north, to about north 10° or 15° west. This is the type of fracture pattern that is developed in the land surface due to shearing as a result of movement of the east block of the earth's surface toward the south relative to the block west of the fault. Many of the fractures observed were open cracks 2 to 4 inches wide developed by local tension, but some fractures were closed and the soil was forced up into pressure ridges or "mole tracks" a few inches high as a result of local compression. The amount of surface movement as measured at many points in the field was found to be on the order of 2 to 4 inches horizontal in the right-lateral sense. (Gordon B. Oakeshott, California Division of Mines and Geology, San Francisco.)

Surficial displacements had been taking place along the Quaternary trace of the San Andreas fault south of Parkfield for several years prior to the earthquake of 27 June 1966. Mr. Harlan Durham of Parkfield had earlier pointed out the asphalt of the Parkfield-Cholame road had to be repaired several times during the preceding two or three years at the point where the fault trace crossed, about 4 km southeast of Parkfield; the southwest side had evidently gone up slightly, and a zone of en-echelon cracks cross the road suggested small right-lateral movements along a nearby branch. The same area was visited on 16 June 1966 by a field-trip group of the Second U.S.-Japan Conference on Research Related to Earthquake Prediction, and very fresh-appearing en-echelon cracks —probably less than one month old—were noted at that time along the fault trace on the Taylor Ranch, 1.7 km southeast of Parkfield. These cracks were widened, extended, and multiplied during the

[2] *The Parkfield, California, Earthquake of June 27, 1966*, Environmental Science Services Administration, Coast and Geodetic Survey, Government Printing Office, Washington, D.C., 1966.

[3] Parkfield Earthquakes of June 27–29, 1966, Monterey and San Luis Obispo Counties, California—Preliminary Report. *Bulletin of the Seismological Society of America*, vol. 56, No. 4, pp. 961–971, August 1966.

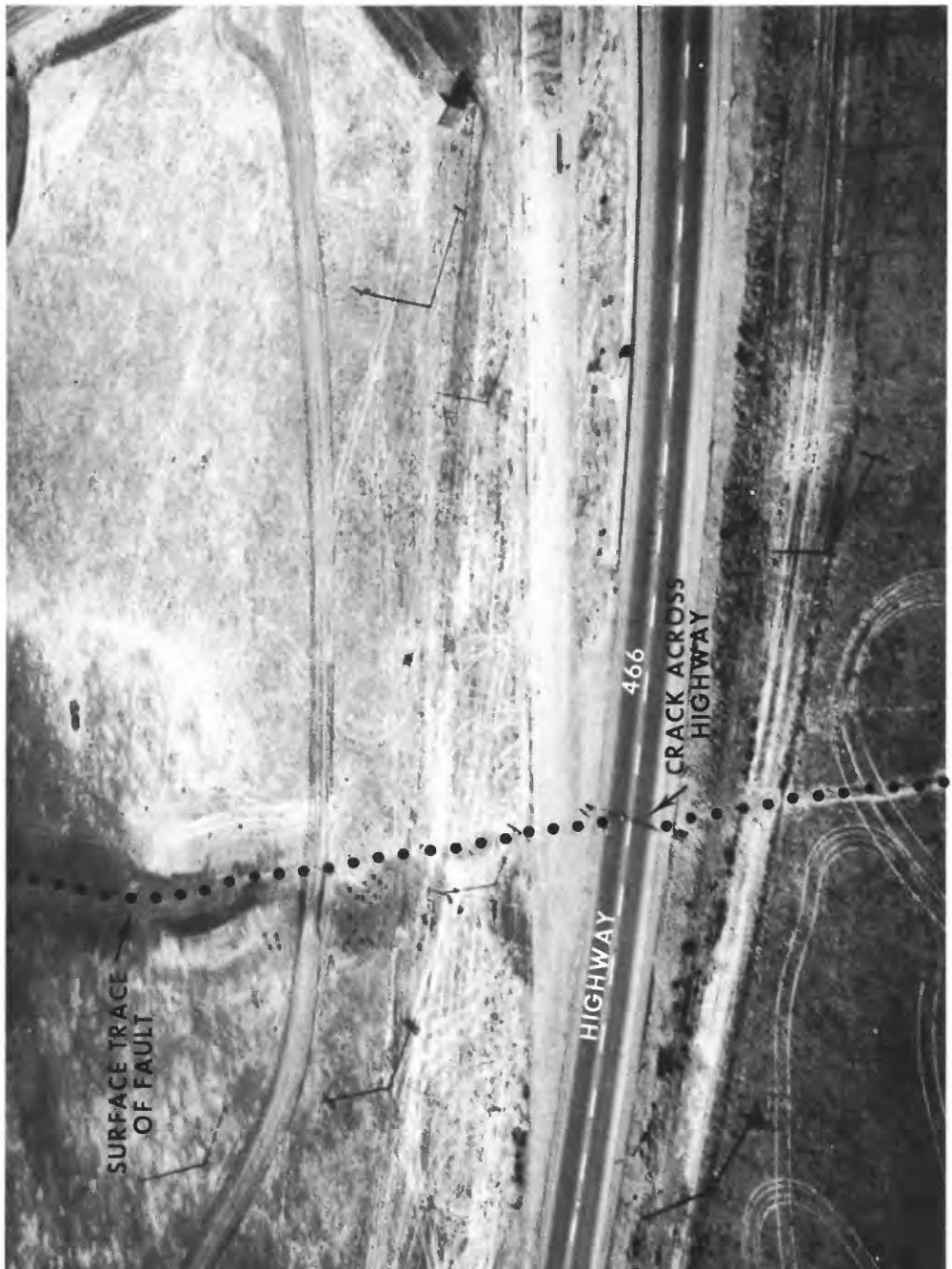

FIGURE 15.—View looking northward along San Andreas fault, showing locations of crack in Highway 466, damaged bridge, and new surface cracking.

earthquake of 27 June, 11 days later. . . .

Initial ground displacement along the fault during the earthquake is unknown, but at 07:00 (PDT) on 28 June, 10 hours following the main shock, the white line on the highway, 1.5 km east of Cholame had been offset 4.5 cm in a right-lateral sense along the Quarternary fault trace. By that evening the displacement had increased to 6.4 cm and was 7.5 cm by the following noon, when more sophisticated geodetic observations in the area commenced. Unlike the fault break farther north, the relatively new pavement here apparently was not cracked prior to the June 27th event, although very old fence lines nearby had been offset more than 30 cm along the fault sometime in the years prior to this shock. . . . (Clarence R. Allen and Stewart W. Smith, California Institute of Technology, Pasadena.)

Very little damage occurred, in part due to the wood frame construction generally found in the heaviest shaken areas. Items often fell from shelves, but some locations within a mile of the fault trace had very little damage of this type. For one example, in a restaurant less than a mile from the fault trace, only a few glass items fell from shelves despite many similar objects being located near the edge of shelving.

Several headstones overturned in the old and new Parkfield cemeteries.

A small concrete bridge adjacent to the 4-inch right-lateral fault offset in the Paso Robles-Wasco highway had some structural damage near its abutment. Bridges on the Parkfield-Cholame highway, which parallels and crosses the fault trace several times, had minor damage. For example, several steel sway-braces at one bridge located perhaps one hundred yards from the fault trace had buckled steel X-bracing. The fault trace went beneath a bridge near Parkfield; the bow in the bridge found after the earthquake may have been the result of pre- and/or post-earthquake fault creep as well as earthquake faulting, but the structural strength of the bridge had not been impaired. (Karl V. Steinbrugge, Pacific Fire Rating Bureau, San Francisco.)

Excellent records were obtained from 5 strong-motion seismographs and 16 seismoscopes installed by the ESSA, C&GS, adjacent to and within 10 miles of surface ruptures of the San Andreas fault. An unusual feature of the earthquake, judged from preliminary inspection of the records and from field investigations, was high acceleration of short duration (maximum 0.5g at Station 2) adjacent to surface ruptures but remarkably little damage to man-made structures in the epicentral area.

Strong-motion instrumentation of the area was covered by a cooperative agreement with the California Department of Water Resources. (William K. Cloud, ESSA, Coast and Geodetic Survey, San Francisco.)

The following reports are for the main shock unless otherwise stated.

INTENSITY VII:

Cholame and vicinity

Cholame.—Felt by, awakened, and frightened all in community. Water heater torn loose in kitchen; twisted water softener off lines. Furniture shifted about 1 foot from walls. Lamps overturned; desk drawers were opened; and a large amount of glassware was broken. Vehicles rocked. Lights went out. Loud earth noises. "It was like riding a bucking bronco." Several aftershocks felt.

Cholame (Rafter E Ranch).—Felt by many. Plaster cracked and fell; swimming pool and brick cracked. Dishes and glasses broke. Small objects shifted, overturned, and fell; furniture shifted. Water sloshed from swimming pool. Damage moderate "except to the swimming pool." Shock also felt at 20:08:57.0*.

Cholame.—At the Standard Oil Service Station, one window cracked near anchoring on shelter ceiling beam, and there was possibly slight buckling of metal facia. Soft drink machine shifted southeast. At the Cholame Cafe and Grocery Store, concrete slab floor of front of building separated from older wood floor on wood piers. Many objects fell from shelves. No apparent damage to wood-frame residences, wood barn, small wood-frame school, and water tanks. Owner of Cholame Cafe and Grocery Store reported he was standing in the restaurant when he felt the slab floor shake and sway a little—went home to Shandon; then the big shock came.

Cholame (about 1 mile northeast of).—Bridge cracked and pavement buckled (cement slab with cement columns); pier cracked; abutment cracked. It appeared that the entire bridge was forced southwest nearly an inch but recovered most of the movement. Entire abutment moved southwest about 2½ cm; block did not

recover the movement (see figs. 16-17). Base-ground separation at power pole (with small transformer) just east of the station indicated considerable shaking. Quart jar of water overturned at the station. Restraining cables on exposed segment of high-pressure gasline broke.

Cholame (1 mile east of).—Press reported a Union Oil pipeline along the roadside broke.

Cholame (Jack Ranch, 6.5 miles north of Highway 466, on the Cholame-Parkfield Road).—Water pipes to stock tank, and irrigation pipe broke. Chimney on bunkhouse broke and slipped ¾ inch, but did not fall. Plaster cracked in old adobe house. Milk cows "went like crazy." Strong rolling motion; duration, 45 seconds.

Cholame (1 mile west of Jack Ranch).—Dead trees fell.

Cholame (6-7 miles east of; on U.S. Highway 466).—Felt by and frightened all in home. Observer reported old, poorly built house "tore apart in two places," but also reported damage was slight. Volume of spring water increased. "Our tank is now running over. Before the shock, we had hardly any water in the tank." Small objects fell. Hanging objects swung violently. Loud earth noises at beginning of shock.

Cholame (William Alley Ranch).—(VI) Stock water tank (not very full) showed indication of slight motion. Domestic water tank (volume about 4,060 gal and kept rather full) showed evidence of oscillation of not over 1 mm about one edge of base, direction about south-southeast. Tank rests on 18 timbers on a level concrete base—tank did not move on wood; wood slid on concrete base. Some plaster cracked; objects knocked from shelves. Observer standing in yard sat down on ground in fear of being knocked down. Shock lasted about 1½ minutes. Observer sitting indoors during shock at 20:08:57.0*. Was not bothered too much. Motion rolling, lasted few seconds.

Cholame (Everett Hatch Ranch on Ming Road).—(VI) Felt by and frightened all in home. Tank tower moved about 3 inches off base. Kitchen cabinets doors opened, and some dishes and glasses fell out; jars and canned goods knocked off shelves. Many bottles broke. Pictures askew. The only furniture movement was a table, which slid 10 inches in a westward direction. Doors were difficult to close after the shock. Electricity and phone service disrupted. Loud earth noises. Motion described as "several, big, hard jolts." Strongest shock felt in 30 years. "We had two small shocks before the hard one." The first was a little after 17:00; rolling motion. The second was a little after 20:00; rolling motion, just a little stronger than the first.

Cholame (about 8 miles southeast of).—(VI) Back porch slipped down about 6 inches from rest of house. Few dishes broke. Phone was out for about 36 hours. Trembled a few seconds, then rolled; ended with hard shaking for a few seconds; lasted about 30-45 seconds.

Cholame (about 3 miles southwest of).—(VI) "The light went out so I could not see what was going on. I just sat there in the dark and listened to things crashing down inside the house and trees swishing outside." Texture paint was shaken off one wall. Hanging objects swung east-west.

Cholame (10 miles east of; on U. S. 466).—(VI) Felt by and frightened all in home. Water increased in two springs. "The house seemed to roll from east-west; then at the last very severe shudder the dishes and supplies fell from shelves." Dishes broke. Shock also felt at 20:08:57.0*.

Cholame (10 miles northeast of; on Highway 41).—(VI) Felt by all. Plaster cracked. Damage slight. Water tank swayed. Small objects shifted, overturned, and fell. Trees and bushes shaken; vehicles rocked. Hanging objects swung north-south. Earth noises. Three shocks reported felt. Times given as 20:00, 20:15, and 20:30; probably time errors.

FIGURE 16.—Crack in east abutment of bridge on Highway 466.

FIGURE 17.—Crack in concrete pier of bridge on Highway 466.

Cholame (about 6 miles south of).—(VI) Felt by and frightened all in community. Extensive minor plaster cracks. Damage slight. Power and phones out. Small objects shifted and overturned; furniture shifted. Hanging objects shook violently. Trees and bushes shook; vehicles rocked.

Cholame (X-D Ranch).—(VI) Felt by and frightened all in home. Water heater knocked hole in plaster. Damage slight. Small objects shifted, overturned, and fell. Hanging objects swung violently (fell off wall). Trees and bushes shook. Loud earth noises. House moved with jerking motion.

Cholame (Star Route).—(VI) Felt by and frightened all in home. Landslides. Trees and bushes shook; vehicles rocked. Small objects overturned. Hanging objects swung moderately. "There were also two small shocks felt on June 29."

Cholame (10 miles from).—(VI) Felt by several; frightened few in home. Ground cracked in some places. Electricity out for one hour or more. Hanging objects swung moderately. Loud earth noises.

Parkfield and vicinity

Press reported water pipes and windows broke at the Parkfield Episcopal Church. Light fixtures broke at the Parkfield School. Floor dropped out of a trailer house. Heavy damage to merchandise at the Parkfield Store. There were numerous reports of minor damage to homes in the rest of the Little Cholame Valley, and in Bear Valley which runs to the west of Parkfield. A 12,000-volt, PG&E powerline was torn loose and fell across the phone-line serving the forestry station. Fifteen of the 70 telephones in Parkfield were out of service. The forestry service also reported live oak trees were toppled, pulling down wires. The forestry station was slightly damaged by fire touched off by a "hot" wire. It was also reported that several tombstones were overturned in the Parkfield cemeteries. At the Parkfield Meeting Hall, a chimney was damaged, and the west wall was cracked at the fire station. About 5 miles south of Parkfield, the X-bracing of a bridge buckled.

Parkfield.—Some landslides. Several large limbs broke off trees. Wall cracked some; plaster cracked, broke, and fell. Furniture shifted. Much glassware breakage. "All my clocks broke."

Parkfield.—Felt by and frightened all in community. Water muddy. Piano shifted 2 feet. Small objects overturned and fell; dishes and radio broke. Loud earth noises.

Parkfield.—Felt by and awakened all in community; frightened many. Ground cracked; landslides; water disturbed. Water source murky for several days; several water wells showed signs of disturbance. Chimneys fell; windows cracked; plaster cracked, broke, and fell. Furniture shifted, overturned, and broke. Hanging objects swung violently east-west. Trees and bushes shook; vehicles rocked.

Parkfield.—Felt by all and frightened few in community. Ground cracked; landslides; water disturbed. Chimneys and elevated water tanks cracked and twisted. Trees and bushes shook; vehicles rocked.

Parkfield.—Felt by, awakened, and frightened all in community; general panic. Ground cracked; landslides; water disturbed. Chimneys and elevated water tanks cracked and twisted. Damage slight. Small objects shifted, overturned, and fell; furniture shifted and overturned. Hanging objects swung violently east-west. Loud earth noises. Shock also felt at 20:08:57.0*.

Parkfield.—Felt by all in community. Ground and chimneys cracked. Damage great. Small objects fell; dishes broke; windows cracked.

Parkfield.—Felt by many. Ground and chimneys cracked. Dishes and water pipes broke. Damage moderate. Furniture shifted. Small objects shifted, overturned and fell. Hanging objects swung violently.

Parkfield.—Plates and glasses were knocked from shelves in kitchen; refrigerator door opened, spilling contents to floor. Damage slight. Bed against east wall slid

across trailer to west wall. Trees and bushes shook; vehicles rocked. "If it had continued it would have rolled the trailer on its side." Both shocks were of a rolling motion and seemed from east-west. Second shock much stronger than first.

Parkfield.—Felt by, awakened, and frightened all. Limbs fell from trees. Water became very dirty. Some cracks appeared in joints of plasterboard, but damage was slight. Furniture shifted and overturned. Small objects shifted, overturned, and fell. Hanging objects swung violently. Loud earth noises.

Parkfield (about 1 mile south of; Raymond Miller residence).—Brick chimney fell. Dishes broke; other minor damage.

Parkfield (1 mile south of; Robert H. Durham residence).—Felt by and awakened all in community; frightened few. Water disturbed. Chimneys and tombstones cracked. Trees swayed (touched the ground). Plaster cracked; one window cracked. Much china broke. Damage moderate. Furniture shifted. Trees and bushes shook; vehicles rocked. Loud earth noises. Shocks also felt at 20:08:57.0* and 20:40. "For two nights, three really, we have had shocks all night long."

Parkfield (2.3 miles south of; Henry Miller place on Parkfield to Cholame Road).—Very violent shock. Ground crack, about 1.3-cm wide, was observed about 30 feet behind the house, running parallel with the house (N.25°W.) and through the swimming pool. Damage to the pool was estimated at about $1,000. Water sloshed from pool. Two water tanks, part of the filter system and about the size of a standard home hot water heater, were shifted about 18 cm in a northeast direction, toward the crack. The tanks are set on a concrete pad about 5 feet south of the crack. Several landslides occurred along a stream behind and to the southeast of the house. Kitchen cabinet doors, facing N.15°E., opened and all dishes fell out, with about 80 percent breakage. No cracked windows or plaster, and no damage to large stone fireplace. Strongest shock felt during 30 years of residence in the Valley. Motion seemed north-south and lasted about 30 seconds. Shock at 20:08:57.0* was described as a "pretty good little shock," with rolling motion.

Parkfield (about 5 miles south of).—X-bracing on bridge buckled.

Parkfield (about 5.8 miles south of; Art Wilson residence on Parkfield to Cholame Road).—This house sustained the most damage. A brick chimney fell through the kitchen roof.

Parkfield (0.8 mile north of).—Bridge. Chunk of concrete off at anchor bolt; steel deck pounded about 1 mm into the concrete abutment.

Parkfield (1 mile north of).—Felt by all and frightened many in community. Ground cracked; landslides; water disturbed (considerably). Two brick chimneys damaged; windows broke. Damage moderate. Heavy upright deepfreeze (full of meat) overturned. Considerable glassware breakage. Electricity disrupted. Trees and bushes shook; vehicles rocked. "The breaking of glass and buckling of walls blotted out any earth noises."

Parkfield (2.8 miles north of).—Old wooden bridge, concrete abutments, with additional steel-supporting framework of I-beams. Roadbed separations indicated longitudinal shaking of possibly several centimeters. Diagonal cracks in south abutment were perhaps due to the earthquake. Longitudinal and lateral movements at wood and steel contacts.

Parkfield (3.3 miles north of).—Culvert. Roadbed cracks.

Parkfield (4.1 and 4.8 miles north of).—Wooden bridges. Roadbed separations.

Parkfield (about 4.5 miles north of; Clyde F. Taylor Ranch).—Chimney snapped off at roof line; foundation cracked; water pipes broke; plaster cracked. Damage moderate. Much dish breakage. Furniture shifted. Water disturbed. Hang-

ing objects swung violently. Trees and bushes shook; vehicles rocked. Shock also felt at 20:08:57.0*.

Parkfield (5 miles north of, on Coalinga Road).—(VI) Felt by and frightened all in community. Ground cracked. Water disturbed. Small objects shifted, overturned, and fell; furniture shifted. Hanging objects swung violently. Trees and bushes shook; vehicles rocked. Shock also felt at 20:08:57.0*.

Parkfield (midway between Parkfield and Cholame, about 7 miles southeast of Parkfield).—(VI) Felt by and awakened all in community; frightened few. Plaster cracked and fell. Dishes and glassware broke. Damage moderate. Small objects shifted, overturned, and fell. Hanging objects swung violently. Loud earth noises.

Parkfield (midway between Parkfield and Cholame).—(VI) Felt by and awakened all in community. Small objects overturned and fell. Damage slight. Hanging objects swung violently east-west. Trees and bushes shook; vehicles rocked.

Parkfield (7 miles southeast of).—(VI) Felt by all and frightened many in community. Ground and chimneys cracked. Damage slight. Furniture overturned. Small objects overturned and fell. Hanging objects swung violently. Trees and bushes shook; vehicles rocked.

INTENSITY VI:

Annette (about 10 miles southeast of Cholame, and about 1 mile from San Andreas fault; Old Annette School location).—Felt by and frightened many in community. "I was walking down the hall and was pushed back and forth against the walls." Hanging objects swung violently north-south. Two bottles rolled from shelf.

Annette Lookout.—Felt by all and frightened few in community. Water splashed from elevated water tank. Power cut off. Press reported the Lookout was without power for an hour and 12 minutes. The shock swayed poles so hard that one wire snapped. Shock also felt at 20:08:57.0*.

Avenal (about 23 miles northeast of Cholame).—Felt by, awakened, and frightened all in community. Furniture and small objects shifted. Hanging objects swung violently. Trees and bushes shook; vehicles rocked. Damage slight (no details). Faint earth noises.

Bitterwater Pumping Station (about 15 miles southeast of Cholame).—Felt by and awakened all; frightened few. Small objects shifted. Hanging objects swung violently west-east. Water disturbed. "We have had numerous tremors since the first one on June 27. The last one felt of any importance was on June 29 at 11:54 a.m."

Bitterwater Valley (in area to east of Bitterwater Pumping Station).—Felt by all and frightened few. Exterior hairline house cracks. Two objects shifted. Water disturbed. Hanging objects swung east-west during shock at 20:08:57.0*; north-south during shock at 20:26:14.4*. "First shock not so bad here; second was the worst I have ever experienced—more earth noise; sounded like rocks grinding together."

Coalinga (about 15 miles from San Andreas fault).—Felt by all and frightened many. Plaster cracked. Merchandise fell from grocery store shelves. Water in swimming pool disturbed. Hanging objects swung moderately. Trees and bushes shook; vehicles rocked. "Fairly good shake." Shocks also felt at 20:08:57.0* and 22:35. Observer about 16 miles northwest of Coalinga in Los Gatos Canyon, 36°14′ north, 120°34′ west, reported: "There are some large cracks in our jeep road which we cannot remember seeing before. The soil is dry bog-type. The strip is about 8-feet wide. These strips run through our place and cross the jeep road." Abrupt onset, sharp rolling and trembling; direction southwest-northeast; lasted longer and heard longer than the shock at 20:08:57.0* which was also sharp and in southwest-northeast direction.

Creston.—Felt by all and frightened many in community. House swayed from side to

side. Small objects shifted. Trees and bushes shook. Hanging objects swung moderately. Moderate earth noises.

Hidden Valley Ranch (17 miles from Parkfield).—Press reported the shock was the heaviest ever felt by observer during her long residence at the ranch. Knickknacks fell off the wall. The shock "rolled and ruffled," but did not appear to have damaged any walls.

Paso Robles.—Police Department reported they had received no reports of damage in the city. A few cans and bottles were knocked from shelves in some stores. At cafe, few new cracks were observed in plaster ceiling. At fire station (second floor), coarse concrete spalled off along a previous crack near the ceiling along edge of an I-beam. Water sloshed from swimming pool at motel. Police officer reported telephone poles swayed. Second shock strongest, lasted about 1 minute, and was preceded by rumble. Press reported soldiers at Camp Roberts (about 20 miles northwest of Paso Robles) felt a sharp shock, with several aftershocks.

Paso Robles (12 miles northeast of).—Felt by all in community; frightened few in home. Water tower rocked violently; water disturbed. Small objects shifted. Pendulum clock on north-south wall stopped, but clock on east-west wall did not. Hanging objects swung moderately.

San Luis Obispo.—Felt by many. Plaster cracked. Abrupt onset; rocking motion; faint, roaring earth noises during shock. Two shocks felt.

San Miguel (west side of town, next to freeway).—Felt by all and frightened many in community. Few dishes broke. Lamps and stands almost toppled. One small object overturned. Trees and bushes shook. House has 12-foot ceiling. Walls seemed to twist. Hanging objects swung moderately.

Shafter.—Felt by all and frightened many in community. Minor plaster cracks. Damage slight. Lighting fixtures moved rather violently. Small objects shifted, overturned, and fell. Trees and bushes shook; vehicles rocked.

Shandon and vicinity

Shandon.—Felt by all and frightened few in community. Plaster cracked. Damage slight. Water sloshed from pool in Shandon park. Shock at 20:26:14.4* was much heavier than the one at 20:08:57.0*.

Shandon.—Some cracks enlarged. Little damage. Few dishes off shelves. Cabinet doors opened. Phoneline to restaurant at Cholame was out. Rumbling earth noise.

Shandon (½ mile west of).—Felt by all in community. Plaster cracked. Damage moderate. Small objects fell. Hanging objects swung violently east-west. Trees and bushes shook; vehicles rocked. Entire house shook. Loud earth noises.

Shandon (Standard Oil Pumping Station on Highway 466, 1½ miles northeast of Shandon).—Felt by all in community; frightened all in home. Hanging objects swung violently. Forty-pound mirror fell off wall; kitchen cupboard doors popped open and items "flew" out; objects fell from window sills and off tables; pictures fell from walls; pepper shaker on stove turned completely upside down. Attic dust fell on beds from ceiling movement. Faint earth noises. Shock at 20:08:57.0* also felt.

Shandon (about 4 miles northeast of).—No damage. Several cylinders in the garage fell northeast; tank in the garage shifted northeast. Tall cylinders in an outside shed (raised off the ground on skids and alined approximately parallel to the fault) fell to the southwest. Many tires were thrown southeast out of an overhead rack in the garage. Ground contact to the concrete slab floor of the garage was generally broken. Two soda-water fire extinguishers hanging on wall were set off, but did not fall. Steel-frame building.

Shandon (about 3½ miles northeast of).—Slight shifting of storage tank ladders on back fill. Evidence of shaking at base of small water tank (about 1,000 bbl) on a low mound.

Shandon (about 1¾ miles northeast of).—Only damage was shifting of one of the eight boilers. The two southwest boilers were filled with water; the end boiler shifted southwest, probably ½ cm, forcing out caulking around the southwest boiler front. Water in each boiler was roughly estimated to be 350 bbl or about 11,000 gal. One window broke and one cracked on south side of wood-frame house. A mirror, 24 by 30 inches, on dressing table fell to floor without disturbing small perfume bottles on dressing table. Motion rolling, south-north, then at the very end, west-east. Lasted at most 1½ minutes.

Shandon (about 2 miles southwest of).—Kitchen cabinet doors opened and a few items spilled onto the floor. Trees swished back and forth; house groaned. Strong rolling motion of 2 to 3 seconds' duration. Floor heaved and houses made cracking sounds during the shock at 20:08:57.0*.

Slack Canyon (about 12 miles north by west of Parkfield; Slack Canyon Camp, Division of Forestry).—Felt by all and frightened many in community; awakened all in home. Ground cracked; landslides occurred; water was disturbed. Trees and bushes shook; vehicles rocked. Moderate earth noises.

Valleton (Indian Valley).—Felt by and awakened all in community; frightened many. Cracks appeared around windows and in west walls. Furniture shifted; small objects fell. The needle was knocked off the chart of the Weather Bureau rain gage, and the arm was bent. Hanging objects swung northeast-southwest. Loud rumbling earth noises were heard. Shocks at 17:00:31.5* and 20:08:57.0* were also felt.

Walti Ranch (about 10 miles northwest of Parkfield).—Felt by and awakened all; frightened many. Hanging objects swung violently; small objects shifted. Very little damage (no details). Trees and bushes shook; vehicles rocked. Loud earth noises.

Work Ranch (about 8 miles northwest of Shandon; Hog Canyon Road, near Ellis School).—Felt by all in community; did not awaken infants. Plaster cracked, broke, and fell. Damage moderate in east portion; severe in west wing. Furniture shifted slightly. Small objects shifted, overturned, and fell. Hanging objects swung moderately east-west. Small slides of soil and rock onto road. Trees and bushes shook slightly; vehicles rocked slightly. Series of explosivelike jolts. Rumbling earth noises. Four shocks felt. Times given as 17:00, 20:09, 20:26, and 20:40.

INTENSITY V:

Adelaida (about 10 miles west of Paso Robles; all later shocks felt), Adelaida area (Bonnheim Corner, about 2 miles southwest of Adelaida), Adelaida area (about 4½ miles southeast of Adelaida, N½NW¼, sec. 35, T.26S., R.11E.), Alpaugh, Arroyo Grande, Atascadero, Avila Beach (two shocks felt), Bakersfield (shock also felt at 20:08:57.0*), Baywood Park, Bryson area (about 15 miles west of Bradley), Burrel, Buttonwillow (shock also felt at 20:08:57.0*), Cholame (12 miles southeast of; Bitterwater Road, close to Choice Valley School; Star Route, Bitterwater Road), Earlimart, Fellows, Frazier Park and Cuddy Valley area west of Frazier Park, Greenfield, Harmony, Indian Valley (20 miles north of San Miguel), Kettleman City, King City, La Panza, Lost Hills, Maricopa, Mee Ranch (about 15 miles northeast of San Lucas, junction of Highways 198 and 25), Morro Bay, Moss Landing, Musick (about 15 miles southeast of San Luis Obispo), Nipomo, Oceano, Old River (about 10 miles southwest of Bakersfield), Panoche (about 15 miles north-northwest of Idria), Pine Canyon (about 8 miles southwest of King City), Pismo Beach, Pozo Guard Station (Pozo, about 15 miles east of San Luis Obispo), Priest Valley (36°11′ north, 120°42′ west), San Ardo, San Joaquin (shock also felt at 20:08:57.0*), San Lucas, San Simeon, Simmler (about 10 miles east of La Panza), Stratford, Templeton (shock also felt at 20:08:57.0*), and Vandenberg

Air Force Base (about 10 miles north-northwest of Lompoc).

INTENSITY IV:

Armona, Big Sur, Cachuma Recreation area (24 miles northwest of Santa Barbara), Cantua Creek (shock also felt at 20:08:57.0*), Capitola (shock also felt at 20:08:57.0*), Carmel, Carmel Valley, Carpinteria, Caruthers, Casmalia, Cayucos, Chatsworth, Corcoran, Corralitos (shock also felt at 20:08:57.0*), Cuyama Peak Lookout (northeast Santa Barbara County), Delano, Farmersville, Felton, Fillmore, Firebaugh, Five Points, Fresno, Gaviota, Goleta (shock also felt at 20:08:57.0*), Gonzales, Guadalupe, Halfway Inn (70 miles south of Monterey on Highway 1), Hanford (shock also felt at 20:08:57.0*), Helm, Hernandez (2 miles northwest of; shock also felt at 20:08:57.0*), Hollister (shock also felt at 20:08:57.0*), Holy City, Idria, Jamesburg area (shock also felt at 20:08:57.0*), Kernville, Lamont (rural area), Laton, Lemoore (shock also felt at 20:08:57.0*), Lompoc, Los Alamos (4 miles south of), Los Olivos, Los Osos (shock also felt at 20:08:57.0*), McFarland, McKittrick (4 miles west of), Marina, Monterey (shock also felt at 20:08:57.0*), Moorpark, Ojai (20:08:57.0*), Oxnard, Ozena Guard Station (near junction of Highway 33 and Lockwood-Ozena Road, sec. 19, T.7N., R.23W.), Pacific Grove, Paicines, Piru, Pond, Porterville, Posey, Riverdale, Salinas, Salinas (8 miles south of, on River Road; only felt shock at 20:08:57:0*), Santa Barbara and Goleta (shock also felt at 20:08:57.0*), Santa Margarita, Santa Maria, Santa Paula, Santa Ynez (shock also felt at 20:08:57.0*), Seaside (shock also felt at 20:08:57.0*), Selma, Soledad, Somis, Spreckels, Springville, Surf, Taft, Terra Bella, Tipton, Tranquillity, Tulare, Tupman, Ventura, Visalia, Wasco, Woodville, and Woody.

INTENSITY I-III:

Aptos (3.7 miles north of; shock also felt at 20:08:57.0*), Aptos (20:08:57.0*), Arvin, Bass Lake, Biola, Buellton, Cachuma Dam (34°35′ north, 119°59′ west, about 10 miles east-southeast of Santa Ynez), Castroville, Clovis, Cuyama, Daly City-Colma, Di Giorgio, Ducor, Edison (about 8 miles southeast of Bakersfield), Exeter, Fort Tejon, Fowler, Goshen, Granada Hills, Harris Ranch (6.8 miles south of Hollister; shock also felt at 20:08:57.0*), Kerman, Kingsburg, Lindsay, Los Angeles County (shock also felt at 20:08:57.0*), Mendota, Mount Hermon, Newport Beach, Orange County, Orange Cove, Point Arguello Light Station (southwest of Lompoc), Port Hueneme, Reedley, San Francisco, San Gregorio (shock also felt at 20:08:57.0*), Santa Cruz, Saugus, Soquel (shock also felt at 20:08:57.0*), Strathmore, Tres Pinos, West Covina (shock also felt at 20:08.57.0*), and Wishon.

June 27: 20:18:34.0*. Epicenter 35°56.6′ north, 120°31.5′ west, B. Magnitude 2.6. Felt at Cantua Creek and Soquel. (Observers give time as 20:15.)

June 27: 20:32:48.0*. Epicenter 35°48.9′ north, 120°16.8′ west, P. Magnitude 4.0, B. Felt at Cantua Creek, Cholame (10 miles northeast of, on Highway 41), and Hernandez (2 miles northwest of). (Times given as 20:30 and 20:31.)

June 27: 20:39:07.4*. Epicenter 35°51.7′ north, 120°15.2′ west, P. Magnitude 3.0, B. Felt at Parkfield (1 mile south of). "For two nights, we have had shocks all night long." Also felt at the Work Ranch about 8 miles northwest of Shandon on Hog Canyon Road, near Ellis School.

June 27: 22:32:17.9*. Epicenter 35°56.2′ north, 120°31.0′ west, B. Magnitude 3.4. Press reported a hard shock was felt in the Parkfield-Cholame areas. Also felt at Coalinga.

June 27: 23:45:48.3*. Epicenter 35°53.5′ north, 120°27.6′ west, B. Magnitude 3.0 Press reported a hard shock was felt in the Parkfield-Cholame areas.

June 28: 12:46:56.4*. Epicenter 35°46.0′ north, 120°23.9′ west, B. Magnitude 3.1. IV. The shock, described as sharp, shook tables and rattled windows at the Bar B Ranch (southern San Benito County, about 12 miles north-northwest of Priest Valley). Short, hard jolt reported felt at the Work Ranch (about 8 miles northwest of Shandon on Hog Canyon Road, near Ellis School). (Time given as 12:00; may relate to some other shock.)

June 28: 18:19:39.9*. Epicenter 35°54.6′ north, 120°31.3′ west, B. Magnitude 3.6. Press reported the shock was felt in the Parkfield-Cholame areas. At the Work Ranch (about 8 miles northwest of Shandon on Hog Canyon Road, near Ellis School), the shock was felt as a hard jolt followed by minor settling motion.

June 28: Evening. Adelaida (about 10 miles west of Paso Robles). "All other later shocks felt. One jolt on evening of 28th."

June 29: 05:11:59.7*. Epicenter 35°48.7′ north, 120°22.9′ west, B. Magnitude 3.1. Press reported the shock was felt in the Parkfield-Cholame areas.

June 29: 11:53:25.9*. Epicenter 35°56.6′ north, 120°31.5′ west, B. Magnitude 5.0. IV. Buildings creaked and loose objects rattled at Coalinga (about 16 miles northwest of; Los Gatos Canyon, 36°14′ north, 120°34′ west). At the Mee Ranch (about 15 miles northeast of San Lucas, junction of Highways 198 and 25), observer reported the shock was of slightly less intensity than the shock of June 27 at 20:26:14.4*. Observer in car at Shandon (about ¾ mile north-northeast of) felt jolt and gentle rocking of car. At the Work Ranch (about 8 miles northwest of Shandon on Hog Canyon Road, near Ellis School), a long, hard series of jolts was observed. Also felt at Adelaida (about 10 miles west of Paso Robles), Bitterwater Pumping Station (about 15 miles southeast of Cholame), Fresno, Morrow Bay (PG&E Power Plant), San Luis Obispo, San Miguel, and Santa Margarita.

July 1: 01:41:21.9*. Epicenter 35°55.8′ north, 120°30.5′ west, B. Magnitude 3.2. Mild shock felt at the Work Ranch (about 8 miles northwest of Shandon on Hog Canyon Road, near Ellis School).

July 2: 04:08:33.5*. Epicenter 35°54.9′ north, 120°18.1′ west, P. Magnitude 3.6. Felt in the Parkfield area.

July 2: 04:16:15.4*. Epicenter 35°42.0′ north, 120°13.8′ west, P. Magnitude 3.2. Felt in the Parkfield area.

July 2: 04:25:06.8*. Epicenter 35°46.6′ north, 120°13.9′ west, P. Magnitude 3.1. Felt in the Parkfield area.

July 3: 10:21:55*. Epicenter 40.6° north, 123.6° west, northern California, W. Magnitude 3.6, B. Press reported a sharp earthquake hit Rio Dell. No damage was reported.

July 5: 10:54:54.5*. Epicenter 35°54.9′ north, 120°28.9′ west, B. Magnitude 3.0. Felt in the Parkfield area.

July 11: 08:22:24*. Epicenter 36°50′ north, 121°35′ west, central California, B. Magnitude 2.7 to 3.0. Felt by highway patrolman in the San Juan Bautista area.

July 13: 20:29 (about). Hollister (7 miles south of, Harris Ranch). IV. Felt by several; frightened small child. Windows rattled quite a bit before shock struck.

July 19: 02:44:18*. Epicenter 36°46.5′ north, 121°21.2′ west, central California, B. Magnitude 2.7. Hollister. III. Felt by at least two persons in Hollister.

July 19: 04:57:41*. Epicenter 37°39′ north, 121°37′ west, central California, B. Magnitude 3.5. Livermore. IV. Felt by many; awakened and frightened few in community. Windows, doors, and dishes rattled.

August 3: 01:41:37.3*. Epicenter 35°54.8′ north, 120°30.4′ west, B. Magnitude 2.9.

Felt at Parkfield and 4 miles north of (Clyde Taylor Ranch), and at the Work Ranch (about 8 miles northwest of Shandon on Hog Canyon Road, near Ellis School).

August 3: 04:39:05.8*. Epicenter 35°47.9′ north, 120°23.4′ west, B. Magnitude 3.4. V. Felt over an area of approximately 1,700 square miles, principally in San Luis Obispo County. No damage reported. At Cholame, felt by and awakened many; house creaked; sort of a jolt. About 3 miles southwest of Cholame, bed jiggled; very slight tremor. Midway between Cholame and Parkfield, felt by and awakened all in home; windows, doors, and dishes rattled; house creaked; trees and bushes shook; vehicles rocked. Hanging objects swung moderately. Moderate earth noises. At Parkfield, felt by and awakened many; small objects and furniture shifted; loud rumbling earth noises; hanging objects swung moderately northeast-southwest. "Shocks have been felt nearly every day these last few weeks, but no apparent damage in the neighborhood." Felt by, awakened, and frightened few 4 miles north of Parkfield at the Clyde Taylor Ranch; small objects shifted. Hanging objects swung moderately north-south; house shook back and forth. "We have been having short jerks in home on average of every day or so, but no damage so far." At the Work Ranch (about 8 miles northwest of Shandon on Hog Canyon Road, near Ellis School), felt by many; heavy east-west movement of house; loose plaster fell. "This shock was long enough to cause concern." Felt with intensity IV at Atascadero, Paso Robles, San Miguel, Santa Margarita, Shandon, and Templeton. Intensity I-III at Avenal and Walti Ranch (about 10 miles north-northwest of Parkfield, Slack Canyon Headquarters).

August 7: 09:36:26.7*. Epicenter 31.8° north, 114.5° west, Gulf of California, W. Magnitude 6.3. VI. Widely felt in southern California and southwestern Arizona; also reported felt at Boulder City, Nevada. Plaster cracked at Blythe, Holtville, and Winterhaven. In Arizona, plaster cracked at Picacho; driveway cracked at Somerton. Plaster and windows cracked at San Luis. Press reported sidewalk sagged about 4 inches and the facades of several buildings were cracked at Yuma. Observer at San Luis, Ariz., reported there were reports of earth cracks about 30 miles south of San Luis in Mexico. A press report stated only minor damage occurred in Sonora, Mexico, where some windowpanes were broken. Some cracks appeared in the earth in the El Golfo area. At Rocky Point, hard shocks were felt, but there was no damage.

INTENSITY VI IN CALIFORNIA:

Bard.—Felt by all in community; awakened and frightened all in home. Paint cracked. Small objects and furniture shifted; small objects fell. Hanging objects swung violently east-west and north-south. Trees and bushes shook; vehicles rocked. Building swayed back and forth. Loud earth noises.

Blythe.—Felt by all in community. Plaster cracked. Palm trees swayed. Hanging objects swung moderately north-south. Faint earth noises.

El Centro.—Felt by all in community; frightened few. Press reported few cans toppled from grocery store shelves. Parked vehicles rocked. Hanging objects swung moderately north-south. Faint earth noises. Rolling motion.

Holtville.—Felt by all in community; awakened and frightened few. Plaster cracked slightly. Small objects and furniture shifted. Hanging objects swung moderately in all directions. "Could see earth movements from the window. Only rolling motion was felt; slight to large movements, then slight movements, like a small boat on the ocean."

Winterhaven.—Felt by all and frightened few in community. Plaster cracked. Damage slight. Small objects shifted. Hanging objects swung north-south. Loud earth noises.

INTENSITY VI IN ARIZONA:

Picacho.—Felt by several in building. Plaster cracked. Damage slight.

San Luis.—Felt by all. Small plaster cracks; some windows cracked. Damage slight. Small objects fell; furniture shifted. Hanging objects swung moderately. Trees and bushes shook; vehicles rocked. "There are reports of earth cracks about 30 miles south of here."

Somerton.—Felt by all in community; awakened and frightened few. Driveway cracked. Damage slight. Hanging objects swung violently south-north. Vehicles rocked. Loud earth noises.

Yuma.—Felt by, awakened, and alarmed many in community; few women fainted. Slight damage. Press reported sidewalk sagged about 4 inches and the facades of several buildings were cracked. Plaster and stucco cracked. Some objects fell from walls and shelves. Residents said the shock had an up-and-down motion and lasted about 8 seconds. Parked cars swayed. The press also reported that a spokesman from the Yuma Public Works Department said there was no verifiable damage in the city from the tremor.

INTENSITY V IN CALIFORNIA:

Agua Caliente, Calipatria, Coronado, Fallbrook, Imperial, Ocotillo (27 miles west of El Centro), Palo Verde, Plaster City, San Diego, Santee, Seeley, and Spring Valley.

INTENSITY V IN ARIZONA:

Agua Caliente Springs (2 miles north of), Aztec (5 miles east of Dateland), Dateland, Gadsden, Gila Bend, Maricopa, Palo Verde (rural area, old Highway 80), and Tacna.

INTENSITY V IN BAJA CALIFORNIA, MEXICO:

Tijuana.

INTENSITY IV IN CALIFORNIA:

Calexico, Campo, Descanso, El Cajon, Encinitas, Glamis, Hemet, Jacumba, Jamul, Laguna Beach, La Jolla, Live Oak Springs (3 miles west of Boulevard), Oceanside, Pauma Valley, Pine Valley, Ramona (4 miles southwest of), Salton City, San Clemente, San Dimas, San Luis Rey, Temecula, Vidal, and Westmorland.

INTENSITY IV IN ARIZONA:

Ehrenberg, Higley, Phoenix, and Sells.

INTENSITY I-III IN CALIFORNIA:

Guatay, Imperial Beach, Lakeside, Leucadia, Los Angeles, Mount Laguna, North Shore (north shore of Salton Sea), Parker Dam, and Rancho Santa Fe.

INTENSITY I-III IN ARIZONA:

Ajo, Lukeville, Nogales (4 miles north of), Parker, Payson, Quartzsite, Tucson, and Wickenburg.

INTENSITY I-III IN NEVADA:

Boulder City.

August 29: 09:30:10*. Epicenter 37.7° north, 121.9° west, B. Magnitude 3.1. Danville. V. Felt by several in building. Small objects and furniture shifted.

August 29: 21:56:07.8*. Epicenter 34°01.0′ north, 118°29.7′ west, P. Magnitude 2.6. Press reported the shock was felt in the Santa Monica area.

September 2: 03:06:29.9*. Epicenter 34°06.8′ north, 117°25.5′ west, P. Magnitude 3.7. IV. Felt by several and awakened few in community at Etiwanda. Also felt at Fontana, Redlands, Rialto, Riverside, and San Bernardino.

September 2: 03:58:12.9*. Epicenter 34°08.2′ north, 117°22.3′ west, P. Magnitude 2.2. Etiwanda. II. Very slight shock. Felt by very few.

September 2: 09:47:46.2*. Epicenter 34°07.6′ north, 117°25.2′ west, P. Magnitude 3.4. Press reported the shock was felt at Fontana, Riverside, and San Bernardino.

September 10: Between 13:30 and 14:00, late afternoon and during night. September 11: 09:20 and 15:00 (about). IV. Press reported the Imperial Valley trembled about 15 times Saturday and Sunday from a series of mild earthquakes. Three shocks were observed between 13:30 and

14:00 on September 10, followed by more in the later afternoon. Some persons were awakened by mild shocks during the night. On September 11, another jolt came at 09:20, followed by two more around 15:00. A few of the tremors were accompanied by a muffled roaring sound.

September 12: 05:00 (about). Wildomar (Riverside County). II. Felt by very few.

September 12: 05:17:29.1*. Epicenter 33°57.5′ north, 118°33.5′ west, P. Magnitude 3.4. Press reported the shock was felt in the Santa Monica area.

September 12: 05:25. Imperial Valley. Press reported the most recent earthquake of the Imperial Valley series was recorded in Brawley at 05:25.

September 12: 08:41:01.7*. Epicenter 39.4° north, 120.1° west, northern California, W. Magnitude 6¼-6½, P. Main shock of the series centering near Boca. VII. Felt over an area of approximately 45,000 square miles of California and Nevada (see fig. 18). Minor but extensive ground fractures were observed in the area northeast of Truckee, from Prosser Reservoir northeast to Hoke Valley, and principally in Russell Valley. Ground cracks in Boca and Prosser earthfill dams. Railroad lines distorted by fallen boulders at Boca, Floriston, and Farad. A 20-ton boulder rolled down the hillside and crashed through the brick wall of the power plant at Farad. Several bridges on Highway 80, between Donner Lake and Floriston, sustained minor damage, with most damage occurring to the Union Mills bridge about 5 miles northeast of Truckee. Chimneys fell; masonry and plaster walls cracked.

The following is from a report received from J. R. Filson, University of California:

Chimneys were observed down and walls cracked at Boca, Sierraville, and Loyalton; additionally, masonry and plaster walls were cracked in the towns of Verdi, Truckee, Vinton, Floriston, and Gateway. Homeowners and merchants in all of the above towns reported items and merchandise knocked from shelves. Persons interviewed all felt a rolling or swaying motion, which in some cases followed a sharp east-west jolt. The forest ranger at Verdi Peak Lookout related, ". . . two or three strong east-west jolts, then the whole mountain started rolling round and round." He also noted dust rising from rockslides.

Individual rock movements down the east flank of Boca Ridge caused the well-publicized damage to the Farad Powerhouse and superficial damage to U.S. 80 along the Truckee River Canyon.

Secondary cracks due to settling were observed on and below the Boca and Prosser Reservoir dams. Notable at each dam were two quite straight, transverse, parallel cracks at the contacts between the rectangular concrete spillways and the earth fill. The cracks were fine and the differential settling was not more than 0.5 cm.

Fresh cracking was observed along the western edge of Forest Development Road 19N04 about 1½ miles north of the Woodchoppers Spring turnoff. The cracking was discontinuous and ran north-northeasterly for about 150 feet with no vertical or strike-slip displacement discernible. Maximum openings were about 3 mm.

Cracks due to hillside slumping and causing an underground cable break were observed about 2 miles east of BM5976 on road 19N04A. The cracks, showing a maximum of 5-cm vertical offset, ran irregularly around the side of a steep hill.

INTENSITY VII IN CALIFORNIA:

Boca Dam and Reservoir (about 7 miles northeast of Truckee, north of Highway 80; report from Lydia Kirby, caretaker's wife).—Felt by and frightened all in community. Ground cracked; landslides; water disturbed. Chimneys overturned; foundation demolished. Plaster cracked, broke, and fell. All windows and dishes broke. Furniture overturned and broke. Damage great. Hanging objects swung violently east-west. Loud earth noises.

Boca Dam and vicinity.—Press reported there was a crack in the earth between the ruined house (watermaster's house) and the dam. In the Boca area, Southern Railway tracks on the main line were twisted and covered with rockslides; huge boulders fell.

Farad Powerhouse (just off Highway 80, about 2 miles north-northwest of Floriston).—Press reported a 20-ton boulder rolled down the hillside, wiped out a pow-

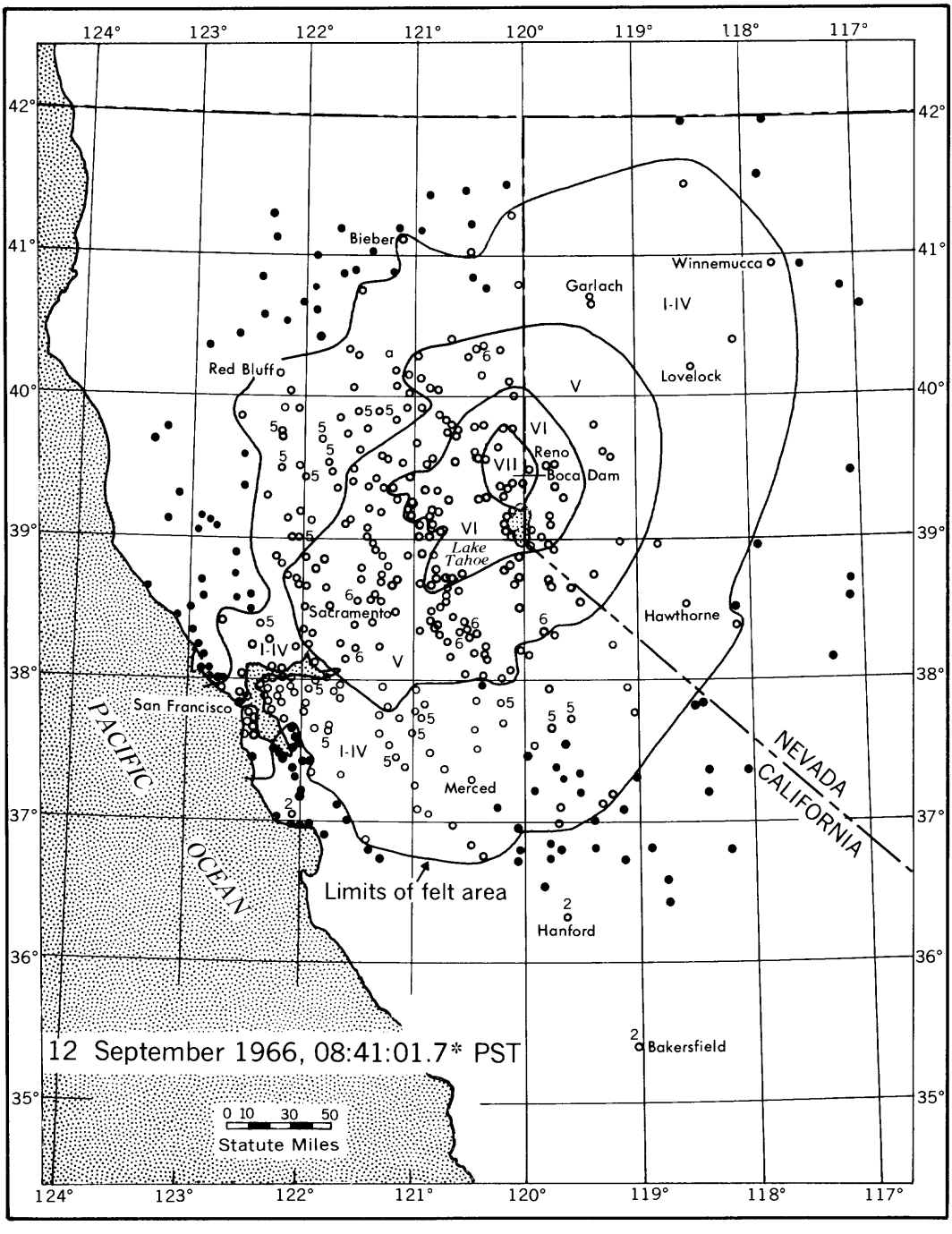

FIGURE 18.—Area affected by California earthquake of September 12.

erline pole, and crashed through the brick wall of the hydroelectric plant. Wooden flumes were also damaged by fallen rock.

Floriston.—Felt by all and frightened many in community. Chimneys cracked and twisted; bricks down. Masonry and plaster walls cracked; some cracks in foundations. One light fixture in house loosened and hung by wiring. Furniture shifted. Press reported goods in grocery store "fell all over the place." Loud earth noises. "We have felt many tremors since the first shock."

Hirschdale (about 4 miles south-southeast of Boca Dam).—Chimney on summer house toppled into the house. Other summer houses were also damaged. Everything standing in two homes was knocked to the floor.

Hobart Mills (few miles northwest of Prosser Reservoir, on Highway 89).—Felt by all in community; people alarmed, but calm. Chimneys cracked, twisted, and overturned. Small objects shifted and fell. Hanging objects swung violently east-west. Trees and bushes shook; vehicles rocked.

Kings Beach.—Felt by all and frightened many in community. "Inside wall separated from outside wall; hairline cracks from foundation to roof—two large cracks —can see through roof down to 8 feet; hairline cracks under windows; loading platform cracked; six cracks in drainage platform around building." Small objects shifted and overturned. Trees, bushes, and vehicles shook violently. Loud earth noises. "Continuous aftershocks felt, even to this a.m., September 14." Press reported Safeway Store sustained about $600 loss from damaged merchandise.

Loyalton.—Felt by and frightened all in community. Lumber shed was so badly damaged it nearly collapsed. Chimneys fell, walls cracked, windows broke. Considerable loss from fallen merchandise in grocery stores. Furniture shifted. Loud earth noises. Very hard jolt, then hard rolling motion. "Tremors, slight, have occurred every day, several a day." (Report postmarked September 16.)

Prosser Dam (about 2½ miles southwest of Boca Dam, north of Highway 80). —Many cracks in the earthfill dam. Two cracks, one reported to be about 2 inches wide, extended over most of the crest of the dam. Slumping of dam with aftershocks. Discolored spring water.

Sierraville.—Felt by all and frightened many in community. Chimneys fell, walls cracked, fireplace collapsed. Ceiling light fixtures shaken down. Large number of hairline cracks in cement-block building. Hanging objects swung violently east-west. Much damage to glassware and other breakable items in homes. Loud earth noises.

Truckee.—Felt by and frightened all in community. Rock and earth slides. Masonry and plaster walls cracked; some stucco fell from the outside of several old buildings; windows broke. Two- by six-foot beam in ceiling cracked. One boulder, 7 feet in diameter, fell on road leading to the Flycaster's Club; the club building's chimney and porch were considerably damaged. Merchandise fell to the floor in numerous stores. Trees leaned east. Truck driver cut when jolt shattered windshield. Press reported officer at the California Highway Patrol station fell to his knees; woman clung to counter to maintain balance. Loud rumbling earth noises.

Vinton.—Felt by and frightened all in community. Masonry and plaster walls cracked. Small objects shifted, overturned, and fell; furniture shifted. Hanging objects swung violently. Trees and bushes shook; vehicles rocked; buildings rolled.

INTENSITY VII IN NEVADA:

Lemon Valley (Ferretti Ranch, near Stead Air Force Base). Two artesian wells, dry for 6 years, started flowing after the shock.

Verdi.—Felt by all in community. Landslide west of town. Well water muddied. Masonry and plaster walls cracked. Dishes were broken in homes throughout town;

few bricks fell out of chimneys. Hanging objects swung violently in circular direction. Trees and bushes shook; vehicles rocked. Loud earth noises preceded shock.

INTENSITY VI IN CALIFORNIA:

Alta (near, Drum Powerhouse on the Bear River, NW¼, sec.17, T.16N. R11E).—Press reported the shock disabled one generating unit at the powerhouse, disrupting service in the area.

Baxter.—Felt by all in community; awakened and frightened few. Water disturbed. Small objects fell. Hanging objects swung violently northeast-southwest. Food sloshed from pans to floor on second floor of restaurant. Heavy ceiling beams swayed and creaked. Vehicles rocked. Damage slight to moderate.

Blairsden.—Felt by all and frightened many in community. Few grocery items fell from shelves. Hanging objects swung moderately. Building swayed for several minutes.

Calpine.—Felt by all in home. Roofline on building thrown out of plumb. Small objects shifted, overturned, and fell; furniture shifted, overturned and broke. Motor on refrigerator thrown off brackets. Hanging objects swung moderately to violently. Trees and bushes shook; vehicles rocked. Loud earth noises.

Camino.—Felt by all; awakened and frightened few. Small objects shifted, overturned, and fell. Trees and bushes shook; vehicles rocked. Hanging objects swung moderately. Loud earth noises.

Camptonville.—Felt by all; awakened and frightened few. Plaster cracked. Small objects shifted. Hanging objects swung moderately.

Carnelian Bay.—Felt by all and frightened few in community. Press reported an 8-foot-long crack in wall of fire station. Small objects shifted. Fluorescent light on 5-foot-long chain swung violently north-south. Vehicles rocked.

Cedar Ridge.—Felt by all and frightened many in community. Plaster cracked and fell. Damage slight. Small objects shifted and fell; furniture shifted. Trees shook. Hanging objects swung east-west. "Longest shock I have felt in 20 years' residence in this locality."

Chilcoot.—Felt by all and frightened few in community. Small objects shifted and fell. Trees and bushes shook; vehicles rocked. Hanging objects swung moderately.

Dardanelle.—Felt by all and frightened few in community. Damage slight. Small objects shifted and overturned; furniture shifted. Hanging objects swung moderately.

Delleker (about 1 mile northwest of Portola).—Felt by all and frightened many in community. Chimneys and plaster cracked. Damage slight. Small objects shifted.

Dobbins.—Felt by all in community. Small objects shifted and overturned; furniture shifted. Hanging objects swung moderately east-west.

Doyle.—Felt by and frightened all in community. Small objects shifted.

El Dorado.—Felt by all and frightened many in community. One home in area had line cracks in mortar between blocks. Trees and bushes shook. Chandeliers swayed north-south. Strongest shock felt in 23 years' residence.

Emigrant Gap.—Felt by all and frightened many in community. Pulled nails in building. Visible swaying of buildings and trees; vehicles rocked. Disturbed objects observed by many. Hanging objects swung violently east-west.

Georgetown.—Felt by all and frightened few in community. Two buildings cracked. Trees and bushes shook.

Glencoe.—Felt by all and frightened few in community. Small objects and furniture shifted.

Graeagle.—Felt by all and frightened few in community. Damage slight. Small objects and furniture shifted. Trees and bushes shook; vehicles rocked. "Good shaking all around."

Iowa Hill.—Felt by all in community.

Plaster cracked, broke, and fell. Damage slight. Small objects overturned and fell; furniture shifted. Hanging objects swung violently. Loud earth noises.

Litchfield.—Felt by many and frightened few in community. Foundation cracked. Damage slight. Trees and bushes shook; vehicles rocked. Small objects fell. Hanging objects swung back and forth. Peculiar, roaring earth noises.

Lotus (1 mile from).—Felt by all and frightened many in community. Cracks in ceiling. Damage slight. Small objects overturned. Hanging objects swung violently. Trees and bushes shook. Loud earth noises just before shaking.

Mather Air Force Base (about 10 miles east of Sacramento).—Felt by all; awakened few. Plaster cracked. Small objects shifted. Hanging objects swung moderately east-west. Loud rumbling earth noises.

Meeks Bay.—Felt by all and frightened many in community. Hanging objects swung violently. Small objects shifted and fell.

Nevada City.—Felt by all and frightened few in community. Small objects shifted, overturned, and fell. Trees and bushes shook; vehicles rocked. Hanging objects swung moderately to violently.

Norden.—Felt by all and frightened many in community; awakened all asleep. Some rockslides. Plaster cracked. Damage slight. Small objects shifted, overturned, and fell. Trees and bushes shook; vehicles rocked. Loud earth noises.

North Bloomfield.—Felt by and frightened all in community. Trees and bushes shook; vehicles rocked; building rocked back and forth. Earth noises like wind blowing.

Placerville.—Felt by all and frightened few in community. Man in parked jeep reported he watched the shock moving down the street, vibrating store windows as it came. When it reached him, the jeep (brakes locked) swayed and rolled backwards in a southerly direction. Trees and bushes shook. Loud earth noises.

Portola.—Felt by all and frightened many in community. Hairline plaster cracks. Small objects shifted. Hanging objects swung violently north-south; objects also swung east-west. Trees and bushes shook; vehicles rocked. Loud earth noises. "Have felt about four aftershocks. Pans have rattled several times when nothing was felt."

Sacramento.—Felt by all in community; frightened many. Plaster cracked. Small objects shifted, overturned, and fell; chairs and bookcases shifted; ice chest moved from wall 3 inches; heavy boxes, canned goods, and books shifted in east-west direction. Trees and bushes shook (large trees swayed moderately east-west); parked vehicles rocked. Building manager of the 650 Capitol Mall Building reported the 8-story building was wrenched in a southeast-northwest direction; window wall and two sides to be inspected by structural engineer. Employees in the State Capitol Building took shelter under arches and doorways. Man in pickup truck (stopped for traffic light) thought the jolt he felt was someone jumping into the truck. Woman on duty at the County Hospital reported the motion was rapid, starting with a vibrating rumble, then a rapid east-west sway, lasting about 10-15 seconds.

Sattley.—Felt by all in community; frightened some. Chimney damaged. Plaster cracked, broke, and fell in some parts of town. Few canned items fell to floor in grocery store; small objects shifted. Trees and bushes shook; vehicles rocked. Electric wires and chandeliers swung violently; direction seemed east-west. Earth noises. "It shook me up for about an hour or so."

Shingle Springs.—Felt by many and frightened few in community. Furniture shifted at two places.

Soda Springs.—Felt by many and frightened few in community. Small objects overturned; canned goods fell from shelves. Trees and bushes shook; vehicles rocked.

Tahoe City.—Felt by and frightened all in

community. Press reported there were two small cracks in the concrete Tahoe City Dam. Plaster cracked. Small objects shifted and fell; shower of bottles fell at pharmacy; furniture shifted. Trees and bushes shook; vehicles rocked. Hanging objects swung violently.

Tahoe City (Squaw Valley, about 4½ miles west of Tahoe City).—Felt by and frightened all in community. Small objects shifted, overturned, and fell. Bushes shook; vehicles rocked. Hanging objects swung moderately to violently.

Tahoe Vista.—Felt by all and frightened many in community. Some rocks fell from chimney. Merchandise knocked from shelves in store, about $250 loss.

Tahoma.—Felt by and frightened all. Observers reported ground cracks, landslides, and disturbed water at Lake Tahoe. (Tahoma is located on the western shore of Lake Tahoe.) Chimneys twisted. Plaster cracked. Damage slight. Hanging objects swung violently east-west. Loud earth noises before shock. Dizziness and nausea experienced.

Walnut Grove.—Felt by and frightened all. Groceries and cans fell. Waves on water. Trees and bushes swayed; vehicles jolted. Hanging objects swung moderately.

Washington.—Felt by all and frightened few in community. Hanging objects swung violently. Trees and bushes shook. Rumbling earth noises.

Wilseyville.—Felt by and frightened many in community; awakened few. Waterline broke. Damage slight. Furniture shifted; small objects shifted, overturned, and fell. Trees and bushes shook; vehicles rocked. Hanging objects swung moderately. Loud, rumbling earth noises.

INTENSITY VI IN NEVADA:

Carson City.—Felt by and frightened all in community. Press reported plaster fell in the 100-year-old State Capitol Building and there were possibly a few new cracks. Sheriffs' offices in Ormsby County and surrounding areas reported damage was apparently limited to broken bottles in markets, some cracked walls and ceilings, broken dishes and glassware in residences. Woman reported her trailer home was almost overturned. Pendulum clock stopped. Hanging objects swung east-west.

Crystal Bay.—Felt by and frightened all; awakened few. Few small objects shifted at the Nevada Lodge (large building). Trees and bushes shook. Motion slow.

Fernley.—Felt by all and frightened many in community. Water pipe in wall of new home broke and water flooded room. Knickknacks and bottles fell; two cups broke in china closet. Hanging objects swung east-west. Motion rapid, even, east-west, lasted 1 minute.

Minden.—Felt by all and frightened few in community. Small objects shifted. Trees and bushes shaken strongly. All hanging objects swung. All pendulum clocks stopped.

Panther Valley (north of Reno).—Damage slight.

Reno.—Press reported the main fire station (old building) had small, new cracks in walls and a section of brick fell from above a door. Bricks were loosened from a chimney on another building. Some school officials reported hairline cracks in buildings. Plaster cracked at the Main Post Office. One or two sidewalks cracked in suburban area west of the city. One market reported it took six men 2½ hours to clean up broken bottles and other items which were strewn all over the aisles; downtown nerchants reported no major damage or breakage. Pendulum clock stopped at the university. People in tall buildings were strongly shaken—two women said they were thrown out of bed. Man working on top of a 22-story building said he was thrown out the window of the crane cab. People reported a loud roar at time of shock. "I heard a loud rumbling, like jet planes, from the mountains to the west. At the same time the ground began shaking, and I fell against the outside wall of the

house. It seemed to last for at least 15 seconds."

Reno (17 miles north of).—Felt by and frightened few. Brick cracked. Small objects fell. More of a rolling motion.

Sparks.—Felt by all and frightened many. Plaster cracked. Small objects shifted. Trees and bushes shook. Pendulum clock stopped and hanging objects swung northeast. Woman, standing, became nauseated.

Stateline.—Felt by all and frightened few. Furniture shifted; small objects overturned. Hanging objects swung moderately east-west.

Stewart.—Felt by many and frightened few in community. Plaster and walls cracked at school. Trees and bushes shook slightly. Hanging objects swung east-west. Motion rapid, east-west; lasted 30 seconds.

INTENSITY V IN CALIFORNIA:

Alta, Amador City, Angels Camp, Auburn, Avery, Beale Air Force Base (about 10 miles southeast of Marysville), Beckwourth, Berry Creek, Bijou, Brooks, Butte City, Canyondam (southeast of Lake Almanor), Capay, Carmichael, Chico, Clio, Coleville, Colfax, College, Columbia, Cresta Blanca (about 2 miles south of Livermore), Davis, Downieville, Dunnigan, Dutch Flat, Elk Grove, Elmira, El Portal, Elverta and 3 miles north of, Fair Oaks (northeast of Sacramento), Esparto, Fair Play, Feather Falls, Folsom, French Corral, Goodyears Bar, Grass Valley, Grizzly Flats, Groveland, Hathaway Pines, Herlong, Homewood, Isleton, Jackson, Janesville, Johnsville, Kelsey (about 5 miles north of Placerville), Kit Carson, Knightsen, Lake Kirkwood, La Porte, Lincoln, Little Norway (about 7 miles southwest of Tahoe Valley), Long Barn, Madison, Manteca, Modesto, Makelumne Hill, Mount Aukum, Nelson, Oregon House, Orland, Oroville, Palermo, Patterson, Pittsburg, Pleasant Grove, Pollock Pines, Rackerby, Railroad Flat, Rancho Cordova (about 10 miles east of Sacramento), Rescue, Riverbank, River Pines, Roseville, San Andreas, Sheridan, Sierra City, Sloat, Sloughhouse, Somerset, Spring Garden, Stirling City, Stockton, Storrie, Strawberry Valley, Tahoe Valley, Taylorsville, Topaz, Travis Air Force Base (near Fairfield), Trowbridge, Twain Harte, Twin Bridges, Vacaville, Verona, West Point, Westwood, Wheatland, Willows, Winters, Woodland, Yankee Jim's Place (near Foresthill), Yosemite National Park, Yountville, Yuba City, and Zamora.

INTENSITY V IN NEVADA:

Genoa, Glenbrook, Hawthorne, Nixon, Virginia City, Wadsworth, and Yerington.

INTENSITY IV IN CALIFORNIA:

Albany, Almanor, Antioch, Applegate, Arbuckle, Arnold, Bangor, Belden, Berkeley, Bieber, Birds Landing, Bloomer Hill Lookout (sec. 30, T.21N., R.5E.), Bridgeport, Browns Valley, Brush Creek (northeast of Berry Creek), Bucks Lake, Byron, Camp Connell, Canyon, Caribou, Citrus Heights, Clarksburg, Clayton, Colusa, Coulterville, Crockett, Crows Landing, Daly City, Davis, Diamond Springs, Farmington, Fiddletown, Forest Ranch, Friant, Galt, Gerber, Glenn, Greenville, Greenwood, Gridley, Guinda, Hollister, Hope Valley, Ione, Jamestown, Kennedy Meadows, La Grange, Lake Alpine, Las Plumas, Lee Vining, Liberty Farms, Markleeville, Martell (rural area), Marysville, Maxwell, Meadow Valley, Merced, Meridian, Michigan Bluff, Midpines, Milford, Mineral, Mitchell Mill (Wilseyville), Napa, O'Neals, O'Shaughnessy Dam (northwest section Yosemite National Park), Pacifica, Paradise, Paskenta, Pinecrest, Pinole, Plymouth, Port Chicago, Port Costa, Quincy, Red Bluff, Represa, Richvale, Ripon, Robbins, Rocklin, Rumsey, Saint Mary's College, San Bruno, San Francisco, San Jose, San Leandro, Shaver Lake, Sheepranch, Sites, Smartville, Snelling, South San Francisco, Strawberry, Susanville, Sutter Creek, Taylorsville (6 miles east of), Termo, Tracy and 13 miles east of, Twain, Vallejo (Mare Island), Valley Home, Volcano, Walnut Creek, Wawona, Wendel, Westley, and Williams.

north, 120°01′ west, Sierra County, on Highway 395), walls creaked slightly; rather like a sudden jolt and rolling motion in east-west direction; lasted about 5 seconds. In Nevada, sharp jolt, lasting 5 to 10 seconds, felt at Reno; walls creaked. Awakened few at Verdi; building creaked.

September 26: 17:44. Keene. IV. Felt by all in home. Rapid 2-3 second shock, preceded 2 seconds by faint earth noises.

September 27: 20:55:49*. Epicenter 39.5° north, 120.2° west, northern California, W. Magnitude 3.9, B. IV. Awakened person in Panther Valley (north of Reno), Nev. Bed moved. Also felt at Truckee.

September 27: 22:38:36*. Epicenter 39.5° north, 120.2° west, northern California, W. Magnitude 3.7, B. Felt at Truckee.

September 28: 08:37:51*. Epicenter 39.5° north, 120.2° west, northern California, W. Magnitude 3.6, B. IV. House creaked at Sierraville. Also felt near Reno, Nev.

September 28: 09:40. Felt at Truckee. (May relate to the preceding.)

October 1: 21:12:34.5*. Epicenter 33°58.1′ north, 118°19.6′ west, P. Magnitude 3.5. Felt over much of southwest Los Angeles County and in some sections of western Orange County. VI. Palos Verdes Peninsula. Felt by and awakened all. Ground pulled away from courtyard wall; split in curb and street; two windows broke. Trees and bushes shook.

INTENSITY V:

Huntington Park, Inglewood, Maywood, and Norwalk.

INTENSITY IV:

Artesia, Bell, Bellflower, Burbank, Compton, Covina, Culver City, Hawthorne, Hollywood, Lakewood, Los Angeles, Manhattan Beach, Montebello, Monterey Park, Montrose, Paramount, and West Los Angeles.

INTENSITY I-III:

Beach, South Pasadena, and West Covina. Also reported felt (no details): East Los Angeles and Pasadena.

October 9: 22:53:46.1*. Epicenter 36°35′ north, 121°14′ west, B. Magnitude 4.1. Central California. V. Felt by and awakened many at Carmel; rather sharp, low rumble. At the Harris Ranch (7 miles south of Hollister), awakened many and frightened few; windows and doors rattled; house creaked; faint earth noises. Felt by and awakened many at Hollister; cupboard door popped open; faint earth noises. Felt by and awakened many at Paicines and vicinity; small objects shifted; fixtures slightly out of line; windows rattled; walls popped. At San Juan Bautista, felt by all in home; walnuts fell on roof. Felt with intensity IV at Castroville, Contival Ranch (13 miles south of Hollister), Corralitos (2 miles from; up Eureka Canyon), Gonzales, Greenfield, Hollister (10 miles northeast of), Idria, Libby Ranch (about 2½ miles southwest of Paicines), Marina, Pebble Beach, Salinas (airport), Search Ranch (Jamesburg), and Tres Pinos. Intensity I-III at Aromas, Capitola, Moss Landing, and Spreckels.

October 11: 08:59:12.9*. Epicenter 35°06.4′ north, 117°20.8′ west, P. Magnitude 4.4. Widely felt in southern California. V. Felt by all and awakened few at Boron Air Force Station (about 10 miles east of Boron); small objects shifted; hanging objects swung away from wall. Felt by many and frightened few at Hinkley; small objects shifted. Intensity IV at Arvin, Barstow, Cantil, Green Valley, Johannesburg, Leliter (Inyokern area), Leona Valley, Onyx, Ozena Guard Station (near junction of Highway 33, Lockwood-Ozena Road), Randsburg, and Valyermo. Intensity I-III at China Lake, Inyokern, Miracle Hot Springs, Pearblossom, Pinon Hills, and Shafter. Also reported felt at Edwards Air Force Base and downtown

October 12: 21:00 (about). Quiver, lasting a few seconds, felt at Cholame.

October 14: 12:34:28.9*. Epicenter 37°00′ north, 121°45′ west, B. Magnitude 4.2. Central California. VI. At Watsonville, felt by all and frightened some in community. Some plaster cracked. Furniture shifted; trees and bushes shook.

INTENSITY V:

Aromas (near; Logan Quarry), Capitola, Corralitos, Harris Ranch (7 miles south of Hollister), Mount Madonna (Corralitos area), San Juan Bautista, San Martin, and Soquel.

INTENSITY IV:

Aptos, Aromas, Ben Lomond, Gilroy, Hollister, La Selva Beach, Marina, Morgan Hill, Moss Landing, New Almaden, San Francisco, and Seaside.

INTENSITY I-III:

Holy City, Monterey, Oakland, and Santa Cruz.

October 15: 14:59:15*. Epicenter 40.7° north, 124.2° west, near Ferndale, B. Magnitude 4.0. V. Felt by all at Arcata; windows and doors rattled; rapid, 5-10 second shock. Felt by all and frightened few at Eureka; buildings creaked; loose objects rattled; hanging objects swung; bumping east-west motion, accompanied by moderate rumbling earth noises. At Ferndale, felt by all and frightened few; windows rattled; walls creaked; rapid, 4-5 second shock. Felt by all at Fortuna; rapid, brief shock; moderate earth noises from southeast. Intensity I-III at Scotia.

October 23: 22:00 (about). IV. Reno, Nev. Windows rattled. Motion slow; 30 seconds' duration.

October 27: 04:06:03.9*. Epicenter 35°55.8′ north, 120°30.4′ west, B. Magnitude 3.8. Central California. V. Awakened many at Atascadero; slight creaking of building, then a good shake. Felt by and awakened all in home at Avenal, where windows, doors, and dishes rattled; building creaked. At Coalinga, felt by all; windows rattled; hanging objects swung moderately. Reported as strong at Parkfield. Felt by and awakened many at San Miguel; windows and doors rattled. At Templeton, felt by and frightened few; small objects shifted; hanging objects swung moderately; moderate earth noises. At the Work Ranch (Hog Canyon Road, about 8 miles northwest of Shandon), felt by all and awakened many in community; back-and-forth motion of unusually long duration. Felt with intensity IV at San Ardo, San Luis Obispo, Shandon, and Slack Canyon (Walti Ranch). Intensity I-III at Cholame and Morro Bay.

November 10: 10:00:06.4*. Epicenter 37°44′ north, 122°31′ west, off Point Lobos near the Golden Gate, B. Magnitude 1.4. Very slight shock reported felt by one person at San Francisco and by one at Oakland.

November 13: 22:49:13.6*. Epicenter 35°15.8′ north, 118°37.1′ west, P. Magnitude 2.8. IV. Keene. Felt by all in home. Slight noise and vibration, then one sharp jolt.

November 22: 12:34. IV. Harris Ranch (7 miles south of Hollister). Felt by very few; windows rattled; buildings creaked.

December 6: 02:34:30.0*. Epicenter 36°50′ north, 121°37′ west, B. Magnitude 3.3. IV. Awakened observer at San Juan Bautista; moderate earth noises. Hollister press received reports from three persons. Salinas press reported the shock was felt at Salinas and in the area just to the north of Salinas.

December 18: 05:30. V. Parkfield. Awakened many in home; frightened few; knocked bolts off window; trees and bushes shook lightly; hanging objects swung moderately.

December 21: 19:00. V. Parkfield. Felt by several and frightened few; small ob-

INTENSITY IV IN NEVADA:

Empire, Gardnerville, Gerlach, Lovelock, Mina, Schurz, Steamboat, and Unionville.

INTENSITY I-III IN CALIFORNIA:

Bakersfield, Benicia, Big Creek, Bolinas, Brentwood, Brisbane, Chester, Chinese Camp, Corning, Cromberg, Dos Palos, Eagleville, Escalon, Fairfield, Felton, Firebaugh, Fresno, Gustine, Hamilton Air Force Base (north of San Rafael), Hanford, Hat Creek, Hercules, June Lake, La Honda, Livermore, Livingston, Los Banos, Mendota, Marin County, Martinez, Moraga, Mount Hamilton, Oakland, Ravendale, San Francisco Peninsula areas, San Gregorio, San Pablo, San Ramon, Santa Rosa, Standish, Turlock, Vernalis, Vina, Vineburg, Volta, and Wishon.

INTENSITY I-III IN NEVADA:

Eureka, Quinn Ranch (32 miles south of Denio), Wellington, Winnemucca, and Zephyr Cove.

INTENSITY I-III IN UTAH:

North Salt Lake City and Salt Lake City.

September 12: 08:51:11*. Epicenter 39.5° north, 119.8° west, W. Magnitude 4.2-4.6, B. Aftershock of 08:41:01.7*. Reported felt at El Portal and Hathaway Pines.

September 12: 09:20:13.3*. Epicenter 39.4° north, 120.2° west, northern California, W. Magnitude 5.3, B. Aftershock of 08:41:01.7*. Widely felt. V. At Tahoe City, felt by and frightened many. Plaster cracked. Also reported felt at Caribou, Downieville, El Dorado, Emigrant Gap, Garden Valley, Lake Kirkwood, Meridian, Michigan Bluff, Prosser area, Sacramento, Sattley, Twin Bridges, and Volcano. Also felt at Zephyr Cove, Nev.

September 12: 09:44:41.6*. Epicenter 39.4° north, 120.1° west, northern California, W. Magnitude 4.1-4.3, B. Aftershock of 08:41:01.7*. Felt at Norden.

September 12: 22:31:45.5*. Epicenter 36°55′ north, 121°16′ west, B. Magnitude 2.6. Roaring sound and sharp jolt felt at

September 13: 01:00 and 05:00 (about). Aftershocks of September 12 earthquake at 08:41:01.7*. Felt at Boca Dam.

September 13: 12:16:24*. Epicenter 39.5° north, 120.3° west, northern California, W. Magnitude 4.0, B. Aftershock of September 12 earthquake at 08:41:01.7*. IV. Felt by several and rattled dishes at Reno, Nev. Also felt at Kyburz and Michigan Bluff, and at Verdi, Nev.

September 13: 14:25 and 14:30. Aftershocks of September 12 earthquake at 08:41:01.7*. IV. Felt by many at Crystal Bay. Nev.

September 14: In a.m. Felt at Kings Beach.

September 14: 14:00:32.5*, 14:40:26.4*. Epicenter of first shock 39.4° north, 120.3° west; of second, 39.5° north, 120.2° west, northern California, W. Magnitudes 4.7 and 4.6, respectively, B. IV. In Nevada, few alarmed at Carson City; felt by many at Reno; frightened few at Wadsworth. Also felt at Boca Dam (14:40:26.4*), Downieville (14:40:26.4*), and Sattley, and at Lovelock (14:40:26.4*) and Steamboat (14:00:32.5*), Nev.

September 15:06:20. Magnitude 3.4, B. IV. Felt by many at Boca Dam, where windows and doors rattled; house creaked. At Prosser Lake, felt by observer in car.

September 19: 20:14:54.8*. Epicenter 37°32′ north, 121°29′ west, central California, B. Magnitude 3.0. IV. At Cresta Blanca Winery (5 miles south of Livermore), windows, doors, and dishes rattled; building creaked. Also felt at Newman.

September 20: 08:03. III. Light shock felt at Ozena Guard Station (about 12 miles north of Wheeler Springs); floor rocked in east-west direction.

September 21: 23:01:29*. Epicenter 39.4° north, 120.3° west, northern California, W. Magnitude 4.5, B. IV. At the

jects fell (knocked icebox open); moderate earth noises.

December 22: 18:23:40.1*. Epicenter 38.7° north, 122.8° west, B. Magnitude 3.5-3.7. V. Press reported minor damage at Cloverdale. At Kelseyville (6 miles southwest of), felt by all in community; windows, doors, and dishes rattled; doors opened and closed; house shifted slightly on foundation; one sharp shock, accompanied by loud earth noises. Intensity IV at Hopland, Lakeport (5 miles west of), and Nice. Intensity I-III at Cobb.

December 26: 14:58:53.7*. Epicenter 33°59.6′ north, 118°35.8′ west, P. Magnitude 3.6. V. Press reported a mild earthquake jolted Hollywood, West Los Angeles, and coastal areas, knocking down Christmas trees and ornaments but apparently causing no serious damage. Police at Redondo Beach and Santa Monica received numerous telephone queries. Officer at Redondo Beach reported, "It was a sharp snapping roll and rattled windows."

December 30: 09:30 (about). IV. Keene. Felt by many in community; windows rattled. Motion slow, lasted about 10 seconds; preceded 2-3 seconds by moderate earth noises.

WASHINGTON AND OREGON

[120th Meridian or Pacific Standard Time]

February 6: No time given. The following report was received from an observer 2 miles south of Cherry Grove, Oreg. "A distinct earth shock was felt by my wife and me. I talked to no one else in this area who felt it. That made me wonder about the possibility of a sonic boom; however, it was a sustained tremor for a few seconds which felt much like a light shock."

June 6: No time given. III. Seattle, Wash. "I was just walking into the Food Circus Building when the ground shook and huge light string swayed, etc."

June 11: 09:34:30.3*. Epicenter 47°50′ north, 122°33′ west, about 4 miles southeast of Port Gamble, Wash., S. Magnitude 3.7. IV. Felt by many at Gorst. Seemed like a thud, deep in ground under the house. Frightened few at Port Gamble. Windows rattled at Silverdale; one rapid shake. Felt by many and frightened few at Tracyton; windows rattled; rapid, very brief shock. Intensity I-III at Bremerton, Indianola, Kingston, and Poulsbo.

June 24: 09:45. Tacoma, Wash. Press reported a slight earthquake was felt at Tacoma and in surrounding areas to the north and south. No damage was reported. University of Washington seismologists reported the tremor was so slight it just barely registered on the seismograph.

July 30: 10:02:38*. Epicenter 47.1° north, 122.1° west, Washington, W. Magnitude 3.4. IV. Press reported a slight tremor shook residents in the Tacoma-Auburn-Sumner area. Felt by all at Graham; felt like one far-away blast. One rapid blast effect was noted 6 miles southeast of Orting; windows rattled. "I thought a blast had gone off under my house. Resembled a stump charge." Windows rattled at Sumner; split-second shock accompanied by loud earth noises. At Wilkeson, windows rattled, walls creaked, and faint earth noises were heard. Intensity I-III at Carbonado, Kapowsin, McMillin, Milton, Orting, and Puyallup.

November 1: 03:22:53.6*. Epicenter 47.6° north, 122.3° west, Washington, S. Magnitude 3.0. Felt by few in Seattle area.

December 23: 21:02:11.5*. Epicenter 47.9° north, 121.8° west, Snohomish County, Wash., S. Magnitude 3.2. Felt by very few near Sultan.

ALASKA

[150th Meridian or Alaska Standard Time]

January 18: 11:28:59*, 11:46:00.5*. Epi-

center of first shock, 61.5° north, 148.9° west; of second, 61.4° north, 150.8° west, southern Alaska, at depths of 46 km and 61 km, W. Magnitudes 4.1 and 4.0. These minor earthquakes were both felt in the Anchorage area.

January 20: 22:13:17.2*. Slight shock felt at Homer. Recorded by seismograph at College Observatory, College, Alaska.

January 24: 12:10:01.9*. Epicenter 51.6° north, 176.4° west, Andreanof Islands, at a depth of 57 km, W. Magnitude 4.5. A slight tremor was felt on Adak. Duration, 4 seconds.

January 28: 09:07:14.4*. Epicenter 51.7° north, 177.0° west, Andreanof Islands, at a depth of 54 km, W. Magnitude 5.2. A slight earthquake of 6 seconds' duration was felt on Adak.

January 29: 06:00 (about). According to the press, a sharp earthquake jolted the Anchorage area shortly before 06:00.

February 6: 13:28:07.8*. Epicenter 60.4° north, 152.3° west, southern Alaska, at a depth of 91 km, W. Magnitude 5.3. This shock was reported felt at Anchorage, Homer, and in the Fairbanks area. A second shock was felt shortly after the first. Both were described as "sharp."

February 16: 11:52:23*. Epicenter 58.1° north, 152.2° west, Kodiak Island region, at a depth of 63 km, W. Magnitude 3.9. A minor earthquake was felt at Kodiak.

February 24: 08:54:35*. Epicenter 51.8° north, 177.3° west, Andreanof Islands, at a depth of 65 km, W. Magnitude 4.2. Felt on Adak.

March 3: 07:37:04*. Epicenter 61.4° north, 150.7° west, southern Alaska, at a depth of 51 km, W. Magnitude 4.0. Felt at Anchorage, Kenai, and Palmer.

March 8: 10:11. A 20-second tremor was felt on Adak.

March 8: 22:11:04*. Epicenter 51.9° north, 177.2° west, Andreanof Islands, at a depth of 52 km, W. Magnitude 4.6. Felt on Adak.

March 12: 22:32:37.8*. Felt on Adak. Recorded by the seismograph at Adak Observatory, Adak, Alaska.

March 25: 11:59:26.4*. Epicenter 56.6° north, 135.4° west, southeastern Alaska, at a depth of 22 km, W. Magnitude 4.7. Felt at Sitka.

April 22: 13:27:20.5*. Epicenter 57.5° north, 152.1° west, Kodiak Island region, at a depth of 22 km, W. Magnitude 5.9. Felt at Kodiak.

May 3: 02:06:54*. Epicenter 51.6° north, 176.8° west, Andreanof Islands, at a depth of 20 km, W. Magnitude 4.9. Felt on Adak.

May 14: 04:46:15*. Epicenter 51.9° north, 177.7° west, Andreanof Islands, at a depth of 66 km, W. Felt on Adak.

May 15: 04:46:06.5*. Epicenter 51.5° north, 178.4° west, Andreanof Islands, at a depth of 31 km, W. Magnitude 5¾-6, P. A slight tremor was felt on Adak.

May 18: 21:06:26.8*. Epicenter 54.1° north, 164.1° west, Unimak Island region, at a depth of 28 km, W. Magnitude 6, P. IV. At Cold Bay, a hanging lamp swayed about 4 inches in an ENE-WSW direction. The movement was very smooth. Several of those interviewed were positive of ground motion.

June 4: Late evening. An earthquake was felt at High Lake Lodge.

June 22: 01:38:53.7*. Epicenter 61.4° north, 147.6° west, southern Alaska, at a depth of 53 km, W. Magnitude 5.2. A "generally strong" earthquake was felt in the Anchorage area. Duration, 5 to 8 seconds.

June 27: 20:25. A slight shock was felt at Homer.

July 4: 08:33:35.7*. Epicenter 51.7°

north, 179.9° east, Rat Islands, at a depth of 13 km, W. Magnitude 6¾-7, P. This shock was felt at the U.S. Naval Base on Adak. It was described as "slight."

July 6: 16:13:58.0*. Felt on Adak. Recorded by the seismograph at Adak Observatory, Adak, Alaska.

July 19: 09:20:33.4*. Epicenter 51.7° north, 173.3° west, Andreanof Islands, at a depth of 47 km, W. Magnitude 5-5.4, B. Felt on Adak.

July 22: 00:17:22.5*. Epicenter 51.7° north, 173.5° west, Andreanof Islands, at a depth of 56 km, W. Magnitude 5.6. Felt on Adak.

August 6: 16:13:05.1*. Epicenter 50.6° north, 171.3° west, Andreanof Islands, at a depth of 39 km, W. Magnitude 7, B. Felt on Adak.

August 17: 10:58:35.9*. Epicenter 52.3° north, 174.9° east, Near Islands, at a depth of 32 km, W. Magnitude 5.6. Felt.

August 23: 14:50:57.2*. Felt on Adak. Recorded by the seismograph at Adak Observatory, Adak, Alaska.

August 25: 21:13:06.3*. Felt on Adak. Recorded by the seismograph at Adak Observatory, Adak, Alaska.

August 26: 00:19:34.8*. Epicenter 67.1° north, 161.5° west, Alaska, at a depth of 14 km, W. Magnitude 5.2. V. Felt at Kotzebue. Observer sitting inside old wood building on gravel ground. Two bumping shocks were felt that rattled loose objects and shook buildings. Many were alarmed. Rapid onset; motion bumping, vertical and horizontal.

August 30: 10:20:54.0*, 10:23:18*. Epicenter of first shock, 61.3° north, 147.5° west, at a depth of 36 km; of second, 61.5° north, 147.5° west, southern Alaska, at a depth of 33 km, W. Magnitudes 5¾-6 and 5.4, respectively. V. These shocks were felt over approximately 30,000 square miles of south-central Alaska. Both were quite strong and were reported felt at Anchorage, Cordova, Glennallen, Kenai, Palmer, Paxson, and Valdez. At Anchorage, pictures bumped against walls and dishes rattled continuously for several minutes. In the Turnagain area, many were frightened and one woman was almost knocked off balance in the basement of her home. Workmen repairing the McKinley Building, damaged by the March 1964 shock, hurried off scaffolds and into the basement when the shocks struck.

September 1: 13:19:09.8*. Epicenter 61.8° north, 149.6° west, southern Alaska, at a depth of 77 km, W. Magnitude 5.2. Felt at Anchorage and Girdwood. An earlier shock was felt at Girdwood at about 05:00.

September 8: 12:31:50.9*. Epicenter 52.7° north, 173.4° east, Near Islands, at a depth of 58 km, W. Magnitude 5.1. Felt on Adak.

October 1: 21:23:35.3*. Epicenter 51.6° north, 174.5° west, Andreanof Islands, at a depth of 91 km, W. Magnitude 4.8. Felt on Adak.

October 4: 16:59:59.6*. Epicenter 52.3° north, 174.0° west, Andreanof Islands, at a depth of 91 km, W. Magnitude 4.8. Felt on Adak.

October 7: 10:55:56.0*. Epicenter 61.6° north, 150.1° west, southern Alaska, at a depth of 56 km, W. Magnitude 5.7. Felt strongly in both the downtown section and surrounding areas of Anchorage. Felt slightly at Kenai, Seward, and Valdez.

October 7: 21:55:42.8*. Felt at Anchorage. Recorded by the seismograph at College Observatory, College, Alaska.

October 8: 00:03:46*. Epicenter 61.3° north, 150.7° west, southern Alaska, at a depth of 33 km, W. Magnitude 3.7. Felt at Anchorage. The shock was very mild.

October 12: 04:23. This shock awakened

many at Fairbanks. Some reported earth sounds preceded the tremor. Also felt at College, Eielson, and Fort Wainwright.

October 12: 08:35:24.1*. Felt on Adak. Recorded by the seismograph at Adak Observatory, Adak, Alaska.

October 19: 23:29:59.1*. Epicenter 51.4° north, 176.6° west, Andreanof Islands, at a depth of 54 km, W. Magnitude 5.1. Felt on Adak.

November 13: 14:12. Venetie. "An earthquake of considerable intensity was felt at 2:12 p.m."

November 17: 03:54:00*, 04:43:10.2*. Epicenter of first shock, 51.3° north, 176.5° west, at a depth of 56 km; of second, 51.1° north, 176.5° west, Andreanof Islands, at a depth of 45 km, W. Magnitudes 4.5 and 4.7, respectively. Both shocks were felt on Adak.

November 19: 23:29:59.1*. Epicenter 51.4° north, 176.6° west, Andreanof Islands, at a depth of 54 km, W. Magnitude 5.1. Felt on Adak.

November 20: 16:22:33*. Epicenter 51.7° north, 179.6° east, Rat Islands, at a depth of 33 km, W. Magnitude 4.6. Felt on Adak.

November 26: 19:20. Fairbanks. IV. This light earthquake rattled windows and dishes in the Fairbanks area.

December 11: 10:01:03.5*. Epicenter 52.9° north, 176.1° west, Andreanof Islands, at a depth of 216 km, W. Magnitude 5.2. Felt on Adak.

December 13: 17:44:01.9*. Epicenter 52.9° north, 177.6° west, Andreanof Islands, at a depth of 243 km, W. Magnitude 5.3. Felt on Adak.

December 16: 11:59:47*. Epicenter 61.5° north, 149.3° west, southern Alaska, at a depth of 65 km, W. Magnitude 3.8. A moderate 30-second earthquake was felt at Anchorage.

December 19: 14:26:27.8*, 14:57:53.1*. Epicenter 66.7° north, 148.7° west, Alaska, at a depth of 33 km, W. Magnitudes 4.8 and 4.9, respectively. IV. Both shocks were felt on the south slope of the Brooks Range near Bettles. Cabin shook for a few seconds. A pendulum swung in a circular motion.

December 24: 12:28:59.6*. Epicenter 59.9° north, 153.4° west, southern Alaska, at a depth of 113 km, W. Magnitude 5.1. Felt at Homer.

December 25: 13:03:22.8*. Epicenter 51.8° north, 176.1° east, Rat Islands, at a depth of 47 km, W. Magnitude 4.8. Felt on Attu.

December 25: 17:43:17*. Epicenter 64.9° north, 147.8° west, central Alaska, at a depth of 57 km, W. Magnitude 3.8. Felt at Clear.

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* 41 through 44.

January 2: 04:51:10.8*. Epicenter 19°07.5′ north, 155°13.3′ west, 15 km south-southwest of Apua Point at a depth of 8 km. Magnitude 3.3. Felt at Volcano.

January 6: 03:51:00.2*. Epicenter 19°15.9′ north, 155°25.1′ west, 9 km south-southwest of Desert seismometer at a depth of 8 km. Magnitude 1.7. Felt at the Kapapala Ranch.

January 6: 03:53:25.2*. Epicenter 19°18.8′ north, 155°26.5′ west, 6 km west-southwest of Desert seismometer at a depth of 8 km. Magnitude 1.7. Felt at the Kapapala Ranch.

January 8: 13:43:57.3*. Epicenter

19°26.3′ north, 155°28.7′ west, 11 km southwest of Mauna Loa seismometer at a depth of 8 km. Magnitude 3.5. Felt at Hilo and Volcano.

January 14: 22:30:19.0*. Epicenter 19°21.8′ north, 155°51.2′ west, 5 km east-southeast of Hookena at a depth of 3 km. Magnitude 3.0. Felt at Kona.

January 14: 06:58:42.7*. Epicenter 20°01.3′ north, 155°21.6′ west, 13 km west-northwest of Laupahoehoe at a depth of 8 km. Magnitude 2.6. Felt at Kamuela.

January 19: 02:44:12.2*. Epicenter 19°24.3′ north, 155°32.8′ west, 10 km south-southeast of North Bay seismometer at a depth of 13 km. Magnitude 4.0. Felt at Hilo, Kapapala Ranch, Kona, Naalehu, and Volcano.

January 19: 14:01:37.4*. Epicenter 19°23.8′ north, 155°33.5′ west, 11 km south-southeast of North Bay seismometer at a depth of 13 km. Magnitude 4.1. Felt Island-wide.

January 21: 07:53:49.1*. Epicenter 19°49.5′ north, 155°35.6′ west, 25 km south-southeast of Kamuela at a depth of 13 km. Magnitude 3.1. Felt at Kamuela.

January 21: 21:02:26.9*. Epicenter 19°27.9′ north, 155°52.7′ west, 7 km southeast of Kealakekua at a depth of 8 km. Magnitude 3.8. Felt at Kona.

January 26: 06:14:22.7*. Epicenter 19°10.6′ north, 155°25.7′ west, 6 km southeast of Pahala at a depth of 8 km. Magnitude 3.0. Felt at Pahala.

January 26: 16:04:20.6*. Epicenter 19°10.8′ north, 155°26.1′ west, 5 km southeast of Pahala at a depth of 8 km. Magnitude 2.0. Felt at the Kapapala Ranch.

January 31: 03:05:47.2*. Epicenter 19°26.1′ north, 155°13.1′ west, 8 km east-northeast of Uwekahuna seismometer at a depth of 27½ km. Magnitude 3.3. Felt at Hilo, Kapapala Ranch, and Volcano.

February 2: 10:38:04.6*. Epicenter 19°22.8′ north, 155°29.9′ west, 12 km west-northwest of Desert seismometer at a depth of 8 km. Magnitude 2.4. Felt at the Kapapala Ranch.

February 9: 22:14:03.9*. Epicenter 19°24.8′ north, 155°19.0′ west, 3 km west-southwest of Uwekahuna seismometer at a depth of 22½ km. Magnitude 2.9. Felt at Kapapala Ranch and Volcano.

February 12: 19:56:16.3*. Epicenter 19°22.3′ north, 155°18.6′ west, 5 km west of Ahua seismometer at a depth of 30 km. Magnitude 3.7. Felt at Hilo, Kapapala Ranch, and Volcano.

February 13: 05:27:10.5*. Epicenter 19°23.5′ north, 155°17.7′ west, 4 km south of Uwekahuna seismometer at a depth of 30 km. Magnitude 2.7. Felt at Volcano.

February 13: 06:07:57.1*. Epicenter 19°25.0′ north, 155°24.5′ west, 9 km north-northwest of Desert seismometer at a depth of 8 km. Magnitude 2.7. Felt at Volcano.

February 13: 23:06:50.0*. Epicenter 19°31.7′ north, 155°49.0′ west, 11 km east-northeast of Kealakekua at a depth of 5 km. Magnitude 2.9. Felt at Kona.

February 16: 14:41:03.1*. Epicenter 19°20.7′ north, 155°25.7′ west, 4 km west-northwest of Desert seismometer at a depth of 20 km. Magnitude 1.8. Felt at the Kapapala Ranch.

February 21: 15:59:33.3*. Epicenter 19°50.7′ north, 155°40.2′ west, 21 km south-southeast of Kamuela at a depth of 3 km. Magnitude 3.7. Felt at Kamuela.

February 25: 03:10:51.6*. Epicenter 19°22.8′ north, 155°17.5′ west, 3 km west-northwest of Ahua seismometer at a depth of 30 km. Magnitude 3.3. Felt at Volcano.

February 28: 20:00:11.0*. Epicenter 19°24.7′ north, 155°27.2′ west, 8 km northwest of Desert seismometer at a depth of 10 km. Magnitude 4.0. Felt at Hilo, Kapapala Ranch, Kona, and Volcano.

March 3: 14:39:23.8*. Epicenter 19°38.1′ north, 156°00.1′ west, 1 km southwest of Kailua at a shallow depth. Magnitude 2.8. Felt at Kona.

March 10: 08:00:23.3*. Epicenter 19°47.0′ north, 155°46.0′ west, 8 km east of Puu Waa Waa at a depth of 8 km. Magnitude 3.7. Felt Island-wide.

March 12: 18:40:02.0*. Epicenter 19°17.0′ north, 155°05.7′ west, 12 km southeast of Makaopuhi seismometer at a depth of 50 km. Magnitude 3.1. Felt at the Kapapala Ranch.

March 14: 14:04:53.6*. Epicenter 19°19.1′ north, 155°26.5′ west, 6 km west-southwest of Desert seismometer at a depth of 8 km. Magnitude 4.1. Felt at Hilo, Kapapala Ranch, Kona, and Volcano.

March 15: 14:43:02.7*. Epicenter 19°22.6′ north, 155°18.0′ west, 4 km west of Ahua seismometer at a depth of 32½ km. Magnitude 3.5. Felt at the Kapapala Ranch.

March 21: 17:56:21.6*. Epicenter 20°00.3′ north, 155°50.9′ west, 16 km west-southwest of Kamuela at a depth of 8 km. Magnitude 3.2. Felt at Kamuela.

March 30: 12:22:06.0*. Epicenter 19°22.5′ north, 155°25.1′ west, 5 km north-northwest of Desert seismometer at a depth of 8 km. Magnitude 2.6. Felt at the Kapapala Ranch.

April 2: 09:07:02.9*. Epicenter 19°22.8′ north, 155°17.5′ west, 1 km northwest of Ahua seismometer at a depth of 30 km. Magnitude 3.4. Felt at Mauna Loa Observatory and Volcano.

April 4: 16:33:50.5*. Epicenter 19°23.4′ north, 155°27.2′ west, 9 km northwest of Desert seismometer at a depth of 5 km. Magnitude 2.7. Felt at Volcano.

April 4: 23:14:16.6*. Epicenter 19°21.5′ north, 155°15.9′ west, 2 km south of Ahua seismometer at a depth of 30 km. Magnitude 2.5. Felt at Volcano.

April 5: 05:28:33.5*. Epicenter 19°20.5′ north, 155°25.7′ west, 5 km west-northwest of Desert seismometer at a depth of 8 km. Magnitude 3.3. Felt at the Kapapala Ranch.

April 21: 00:11:14.8*. Epicenter 19°21.1′ north, 155°04.1′ west, 12 km east-southeast of Makaopuhi seismometer at a depth of 8 km. Magnitude 3.2. Felt at Hilo.

May 6: 20:47:58.8*. Epicenter 19°16.9′ north, 155°04.4′ west, 14 km southeast of Makaopuhi seismometer at a depth of 5 km. Magnitude 2.7. Felt at Hilo.

May 19: 06:22:17.0*. Epicenter 19°14.1′ north, 155°37.3′ west, 20 km north-northwest of Naalehu at a depth of 8 km. Magnitude 2.9. Felt at Honaunau.

May 27: 01:05:46.0*. Epicenter 19°13.1′ north, 155°03.6′ west, 20 km southeast of Makaopuhi seismometer at a depth of 40 km. Magnitude 3.7. Felt at Kapapala Ranch and Volcano.

June 2: 19:22:08.2*. Epicenter 19°27.0′ north, 155°15.9′ west, 4 km northeast of Uwekahuna seismometer at a depth of 9 km. Magnitude 2.5. Felt at Volcano.

June 16: 03:55:07.6*. Epicenter 19°21.8′ north, 155°30.8′ west, 13 km west-northwest of Desert seismometer at a depth of 3 km. Magnitude 3.3. Felt at Kapapala Ranch and Volcano.

June 18: 21:21:26.9*. Epicenter 19°21.1′ north, 155°45.1′ west, 16 km east-southeast of Hookena at a shallow depth. Magnitude 3.5. Felt at Honaunau.

July 1: 05:04:28.5*. Epicenter 19°19.5′ north, 155°27.3′ west, 7 km west-southwest of Desert seismometer at a depth of 10 km. Magnitude 3.7. Felt at Hilo, Kapapala, and Volcano.

July 5: 23:10:58.0*. Epicenter 19°26.1′ north, 154°57.1′ west, 8 km south of Pahoa at a shallow depth. Magnitude 2.7. Felt at Pahoa.

July 5: 23:59:18.4*. Epicenter 19°19.8′ north, 155°12.9′ west, Kilauea upper east rift at a depth of 5 km. Magnitude 2.0. Felt at Volcano.

July 6: 00:02:57.7*. Epicenter 19°21.7′ north, 155°13.3′ west, Kilauea upper east rift at a depth of 3 km. Magnitude 1.5. Felt at Volcano.

July 6: 01:11:52.7*. Epicenter 19°20.5′ north, 155°13.8′ west, Kilauea upper east rift at a depth of 5 km. Magnitude 2.8. Felt at Volcano.

July 13: 02:03:44.8*. Epicenter 19°25.5′ north, 154°53.5′ west, 12 km southeast of Pahoa at a depth of 3 km. Magnitude 3.0. Felt at Kapoho.

July 17: 22:16:10.6*. Epicenter 19°28.4′ north, 154°52.2′ west, 9 km east-southeast of Pahoa at a depth of 5 km. Magnitude 2.4. Felt at Pahoa.

July 24: 15:22:03.3*. Epicenter 19°27.2′ north, 155°45.5′ west, 18 km east-southeast of Kealakekua at a shallow depth. Magnitude 3.0. Felt at Kona.

July 27: 14:04:31.5*. Epicenter 19°23.1′ north, 155°16.9′ west, 2 km northwest of Ahua seismometer at a depth of 31 km. Magnitude 3.2. Felt at the Kapapala Ranch.

July 30: 16:58:22.3*. Epicenter 19°25.0′ north, 155°28.2′ west, 13 km northwest of Desert seismometer at a depth of 8 km. Magnitude 4.3. Felt Island-wide.

July 31: 20:01:39.0*. Epicenter 19°28.5′ north, 154°54.3′ west, 5 km southeast of Pahoa at a shallow depth. Magnitude 2.3. Felt at Kapoho.

August 1: 02:25:07.1*. Epicenter 19°27.0′ north, 154°55.2′ west, 7 km southeast of Pahoa at a shallow depth. Magnitude 2.5. Felt at Kapoho.

August 1: 19:02:20.2*. Epicenter 19°27.1′ north, 154°55.1′ west, 7 km southeast of Pahoa at a shallow depth. Magnitude 2.7. Felt at Kapoho.

August 6: 20:57:37.1*. Epicenter 19°28.8′ north, 154°54.2′ west, 5 km east-southeast of Pahoa at a depth of 3 km. Magnitude 3.7. Felt at Hilo, Pahoa, and Volcano.

August 11: 18:30:32.8*. Epicenter 19°25.9′ north, 154°54.7′ west, 8 km southeast of Pahoa at a depth of 3 km. Magnitude 2.3. Felt at Kapoho.

August 15: 00:15:41.2*. Epicenter 19°27.2′ north, 154°55.1′ west, 6 km southeast of Pahoa at a depth of 3 km. Magnitude 3.5. Felt at Hilo, Pahoa, and Kurtistown.

August 17: 09:58:49.8*. Epicenter 19°24.6′ north, 155°26.9′ west, 10 km northwest of Desert seismometer at a depth of 5 km. Magnitude 3.0. Felt at the Kapapala Ranch.

August 18: 08:30:04.0*. Epicenter 19°14.1′ north, 155°25.3′ west, 12 km south-southwest of Desert seismometer at a depth of 5 km. Magnitude 2.8. Felt at the Kapapala Ranch.

August 19: 05:21:49.2*. Epicenter 19°23.0′ north, 155°18.5′ west, 5 km west-northwest of Ahua seismometer at a depth of 30 km. Magnitude 3.9. Felt at Hilo, Kapapala Ranch, Paauilo, Pahoa, and Volcano.

August 19: 05:24:54.1*. Epicenter 19°21.6′ north, 155°19.0′ west, 6 km west-southwest of Ahua seismometer at a depth of 27 km. Magnitude 2.8. Felt at Hilo, Kapapala Ranch, Kona, Naalehu, and Volcano.

August 19: 05:33:00.4*, 06:26:20.2*. Epicenter 19°20.9′ north, 155°19.4′ west, 7 km east-northeast of Desert seismometer at depths of 27 and 30 km, respectively. Magnitudes 2.7 and 3.1, respectively. The first shock was felt at Volcano; the second at the Kapapala Ranch.

August 28: 14:03:10.5*. Epicenter 19°21.6′ north, 155°27.5′ west, 8 km west-northwest of Desert seismometer at a depth of 3 km. Magnitude 2.4. Felt at the Kapapala Ranch.

September 2: 13:56:58.5*. Epicenter 20°02.2′ north, 155°53.1′ west, 5 km west of Kawaihae at a depth of 13 km. Magnitude 3.4. Felt at Kamuela.

September 5: 06:33:21.9*. Epicenter 19°21.2′ north, 155°26.2′ west, 6 km west-northwest of Desert seismometer at a depth of 8 km. Magnitude 4.5. Felt Island-wide.

September 5: 22:45:20.0*. Epicenter 19°21.2′ north, 155°28.8′ west, 10 km west-northwest of Desert seismometer at a depth of 5 km. Magnitude 3.0. Felt at the Kapapala Ranch.

September 8: 15:03:52.6*. Epicenter 19°22.3′ north, 155°28.2′ west, 10 km west-northwest of Desert seismometer at a depth of 5 km. Magnitude 2.1. Felt at the Kapapala Ranch.

September 12: 16:47:13.0*. Epicenter 19°20.8′ north, 155°11.3′ west, 3 km southwest of Makopuhi seismometer at a depth of 5 km. Magnitude 2.9. Felt at Hilo.

September 16: 12:41:54.5*. Epicenter 19°21.9′ north, 155°26.5′ west, 7 km west-northwest of Desert seismometer at a depth of 5 km. Magnitude 2.1. Felt at the Kapapala Ranch.

September 21: 01:45:48.5*. Epicenter 19°23.9′ north, 155°17.9′ west, 3 km south of Uwekahuna at a depth of 27 km. Magnitude 3.4. Felt at Honoapu and Kapapala Ranch.

September 23: 10:33:47.0*. Epicenter 19°27.9′ north, 154°56.5′ west, 4 km south of Pahoa at a depth of 3 km. Magnitude 2.8. Felt at Pahoa.

September 28: 12:03:21.4*. Epicenter 19°26.0′ north, 155°25.1′ west, 8 km southwest of Mauna Loa seismometer at a depth of 5 km. Magnitude 3.5. Felt at Glenwood and Hilo.

October 3: 03:49:17.2*. Epicenter 19°22.5′ north, 155°17.5′ west, 3 km west of Ahua seismometer at a depth of 25 km. Magnitude 3.5. Felt at Kapapala Ranch and Volcano.

October 7: 02:26:39.5*. Epicenter 19°23.1′ north, 155°27.9′ west, 10 km northwest of Desert seismometer at a depth of 5 km. Magnitude 2.3. Felt at the Kapapala Ranch.

October 13: 13:59:14.5*. Epicenter 19°21.3′ north, 155°07.9′ west, 5 km east-southeast of Makaopuhi seismometer at a depth of 10 km. Magnitude 3.0. Felt at Hilo.

October 16: 01:49:33.6*. Epicenter 19°25.2′ north, 155°25.7′ west, 10 km north-northwest of Desert seismometer at a depth of 8 km. Magnitude 1.9. Felt at the Kapapala Ranch.

October 16: 02:15:21.3*, 02:15:57.8*. Epicenter 19°16.1′ north, 155°23.4′ west, 8 km south of Desert seismometer at depths of 3 km. Magnitudes 2.4 and 2.3, respectively. Both shocks were felt at the Kapapala Ranch.

October 16: 07:46:12.5*. Epicenter 19°21.1′ north, 155°09.3′ west, 3 km southeast of Makaopuhi seismometer at a shallow depth. Magnitude 2.6. Felt at the Kapapala Ranch.

October 17: 05:05:38.3*. Epicenter 19°14.3′ north, 155°26.7′ west, 13 km southwest of Desert seismometer at a depth of 10 km. Magnitude 2.8. Felt at Kapapala Ranch and Pahala.

October 19: 12:49:46.8*. Epicenter 19°20.9′ north, 155°07.2′ west, 6 km east-southeast of Makaopuhi seismometer at a depth of 5 km. Magnitude 3.0. Felt at Glenwood and Hilo.

October 23: 02:25:59.4*. Epicenter

19°33.2′ north, 155°09.8′ west, 5 km west of Mountainview at a depth of 8 km. Magnitude 3.0. Felt at Hilo.

October 27: 20:08:57.8*. Epicenter 19°21.7′ north, 155°11.7′ west, 2 km west of Makaopuhi seismometer at a depth of 5 km. Magnitude 2.4. Felt at Volcano.

October 28: 19:18:24.4*. Epicenter 19°24.1′ north, 155°02.1′ west, 15 km east-northeast of Makaopuhi seismometer at a depth of 3 km. Magnitude 2.8. Felt at the Kapapala Ranch.

October 30: 18:49:25.5*. Epicenter 19°19.2′ north, 155°28.0′ west, 8 km west-southwest of Desert seismometer at a depth of 8 km. Magnitude 4.0. Felt Island-wide.

November 2: 09:51:11.3*. Epicenter 19°21.3′ north, 155°06.8′ west, 7 km east-southeast of Makaopuhi seismometer at a depth of 10 km. Magnitude 3.3. Felt at Hilo.

November 5: 09:42:30.0*. Epicenter 19°30.0′ north, 155°54.2′ west, 3 km southeast of Kealakekua at a depth of 3 km. Magnitude 3.8. V. Creaking of buildings and rattling of loose objects observed by many at Captain Cook. Radio tower swayed; small bottle was displaced on market shelf. Explosive jolt. Moderately loud sounds heard at beginning of earthquake. "There was only very slight alarm."

November 11: 06:37:55.3*. Epicenter 19°27.2′ north, 154°55.2′ west, 7 km southeast of Pahoa at a shallow depth. Magnitude 2.7. Felt at Kapoho.

November 13: 01:32:10.4*. Epicenter 19°26.2′ north, 154°53.4′ west, 9 km southeast of Pahoa at a depth of 3 km. Magnitude 2.5. Felt at Kapoho.

November 14: 02:58:52.3*. Epicenter 19°29.0′ north, 154°54.1′ west, 5 km east-southeast of Pahoa at a shallow depth. Magnitude 2.6. Felt at Kapoho.

November 15: 13:18:18.9*. Epicenter 19°13.6′ north, 155°49.2′ west, 35 km south-southeast of Kealakekua at a shallow depth. Magnitude 2.6. Felt at Kona.

November 16: 19:19:27.1*. Epicenter 19°25.9′ north, 154°54.6′ west, 8 km southeast of Pahoa at a shallow depth. Magnitude 3.0. Felt at Kapoho.

November 17: 05:17:09.1*. Epicenter 19°26.5′ north, 154°56.0′ west, 7 km south-southeast of Pahoa at a shallow depth. Magnitude 3.5. Felt at Kapoho.

November 18: 13:00:20.8*. Epicenter 19°30.1′ north, 155°31.6′ west, 6 km east-northeast of North Bay seismometer at a depth of 20 km. Magnitude 2.9. Felt at Mauna Loa Observatory and Volcano.

November 23: 18:47:42.4*. Epicenter 19°27.5′ north, 155°48.7′ west, 13 km east-southeast of Kealakekua at a depth of 3 km. Magnitude 2.4. Felt at Kona.

November 23: 20:59:08.5*. Epicenter 19°20.1′ north, 155°14.0′ west, 6 km southeast of Ahua seismometer at a depth of 10 km. Magnitude 3.4. Felt at Glenwood, Hilo, Kona, and Volcano.

November 27: 11:54:51.3*. Epicenter 19°18.1′ north, 155°13.8′ west, 9 km southeast of Ahua seismometer at a depth of 10 km. Magnitude 3.6. Felt at Glenwood, Hilo, Kapapala Ranch, Pohakuloa, and Volcano.

November 27: 11:57:52.3*. Epicenter 19°19.2′ north, 155°13.2′ west, 9 km southeast of Ahua seismometer at a depth of 8 km. Magnitude 2.5. Felt at the Kapapala Ranch.

November 28: 08:52:10.4*. Epicenter 19°23.4′ north, 155°24.1′ west, 6 km north-northwest of Desert seismometer at a depth of 8 km. Magnitude 2.9. Felt at the Kapapala Ranch.

December 1: 16:03:14.5*. Epicenter 19°31.6′ north, 155°44.9′ west, 17 km east of Kealakekua at a depth of 8 km. Magnitude 2.8. Felt at Kona.

Miscellaneous Activities

GEODETIC WORK OF SEISMOLOGICAL INTEREST

In 1966, surveys for the study of horizontal movements in the earth's crust were made by the Coast and Geodetic Survey in the following areas of California and Nevada:

California

Vicinity of Brea.—After the collapse of the Baldwin Hills reservoir, Los Angeles County, in December 1963, engineers in Orange County requested information relating to crustal movements in the vicinity of the reservoir northeast of Brea. In order to fulfill this request, plans were made to reobserve a small triangulation network which had been established in the area in 1938. The resurvey was accomplished during the summer of 1966.

Results obtained from the resurvey showed horizontal movement of about 3 inches at a station about 400 yards east of the reservoir. This information was reported to officials of Orange County in October 1966. At that time plans were made by the County engineers to monitor movements in the area by establishing a network of points near the reservoir, and tentative plans were made to reobserve the net at intervals of about one year.

Winery Survey, Vicinity of Hollister.—This resurvey showed right-lateral movement of about 1.5 cm since the previous survey of 1965. This relative movement, between stations on opposite sides of the fault, has been at a fairly constant annual rate since the net was established in 1957.

Aqueduct Surveys.—The cooperative project with the State of California Department of Water Resources was continued during the year, and twelve of the Hollister-type quadrilaterals, established in 1964 and 1965, were reobserved. Results at eight of these figures were in close agreement with surveys of 1964-65 and no significant changes were indicated. At the other four sites, TEM, UNION CITY, TEJON, and RANCH, results are discussed under other areas mentioned in this report.

Vicinity of Cholame.—After the earthquake in this area, which occurred June 27, 1966, a C&GS field party was instructed to reobserve a portion of the triangulation net near the fault. The net was established in 1932 and reobserved in 1951 and again in 1962. Results obtained from the 1966 survey, when compared with the 1962 results, showed right-lateral movement on the order of 6 to 8 inches. From 1932 to 1951, the maximum relative movement between stations near and on opposite sides of the fault was about 6 inches. No significant movement was indicated for the period from 1951 to 1962.

The Aqueduct survey, Site TEM, was established in 1964 and reobserved in 1965 and again after the earthquake in 1966. No significant changes were indicated between the surveys of 1964 and 1965. Results from the 1966 survey showed right-lateral movement of about 1 inch. This Hollister-type figure straddles the fault in an area about 4 miles southeast of the Cholame network.

San Francisco Bay Area.—Three Hollister-type figures were established along the Hayward fault in October 1966. These figures are located in the following areas:

University of California stadium, vicinity of Mira Vista, and vicinity of Irvington. Tentative plans have been made to reobserve each net at intervals of approximately one year.

A resurvey of the Aqueduct Site UNION CITY showed right-lateral movement of about 0.02 foot during the one-year interval between the 1965 and 1966 surveys. This result is in good agreement with previous crustal movement studies along the Hayward fault in the Bay area.

Vicinity of Gorman.—This net was established in 1938 and was reobserved in 1949 and 1966. Results of these surveys do not indicate conclusive evidence of systematic movement; however, changes between the surveys do show some small displacements.

The Aqueduct surveys at Sites TEJON and RANCH show small left-lateral movement between stations on opposite sides of the fault. Each of these figures straddles the Garlock fault in the Gorman area.

Thirteen hundred eighty miles of leveling was done in California during 1966. Most of this was releveling for the purpose of studying vertical land movement. The largest project was the Los Banos-Kettleman City area where the results indicated land subsidence in several areas of about 1 foot. Changes in the elevations of control points in many other areas were indicated by the leveling. The principal cause of the settlement is believed to be due to the lowering of ground water level, but some components, either subsidence or upheaval, are likely due to tectonic causes.

Precise leveling was done at the following Hollister-type figures: Osgood fault site; Mira Vista fault site; and Taylor Winery fault site.

Nevada

Dixie Valley Area, Vicinity of Fallon.—The 1966 resurvey in this area included stations in the basic net established in 1954-55 and a few connecting stations to the north established in 1958. Results from the 1966 survey were in good agreement with the previous survey of 1955. In the northern section of the area, stations on opposite sides of the fault show relative movement on the order of 6 to 12 inches between surveys of 1958 and 1966.

TIDAL DISTURBANCES OF SEISMIC ORIGIN

During 1966, four tsunamis were reported to the Coast and Geodetic Survey; however, only three were definitely identified on tide gages.

On October 17, an earthquake near the coast of Peru with a magnitude of 7½ and an epicenter at 10.7° S., 78.7° W., generated a tsunami which was widely recorded in the Pacific. At La Punta-Callao near the epicenter, the wave height was estimated at 11.3 feet. The maximum height recorded on the tide gage was 7½ feet since the wave exceeded the gage height. Other representative maximum recorded wave heights are as follows:

	ft
Valparaiso, Chile	1.3
Talcahuano, Chile	1.9
Galapagos Islands	1.0
Chimbote, Peru	3.5
San Juan, Peru	2.3
Quepos, Costa Rica	0.2
Wake Island	0.2
Pago Pago, American Samoa	0.7
Hilo, Hawaii	0.8
Kahului, Hawaii	1.2
Kodiak, Alaska	0.5
Attu, Alaska	0.4
Crescent City, Calif.	1.0
Los Angeles Outer Harbor, Calif.	0.2

An earthquake on December 28, located at 25.5° S., 70.7° W., magnitude 7¾, caused a small tsunami that was detected in Chile, Peru, and on a few Pacific islands. The wave was recorded at the following

December 1: 19:57:16.8*. Epicenter 19°24.3′ north, 155°23.2′ west, 8 km north of Desert seismometer at a depth of 8 km. Magnitude 2.7. Felt at the Kapapala Ranch.

December 11: 19:44:01.0*. Epicenter 19°28.5′ north, 155°52.4′ west, 7 km southeast of Kealakekua at a depth of 8 km. Magnitude 3.7. Felt at Honaunau.

December 13: 05:41:15.0*. Epicenter 19°16′ north, 156°17′ west, 47 km southwest of Kealakekua at a depth of 8 km. Magnitude 3.9. Felt on Maui.

December 15: 04:00:23.3*. Epicenter 19°24.7′ north, 155°16.8′ west, 3 km southeast of Uwekahuna at a shallow depth. Magnitude 2.5. Felt at Volcano.

December 16: 02:33:13.5*. Epicenter 19°26.0′ north, 155°28.0′ west, 11 km southwest of Mauna Loa seismometer at a depth of 8 km. Magnitude 2.6. Felt at Volcano.

December 26: 03:51:32.0*. Epicenter 19°20.3′ north, 155°07.0′ west, 8 km east-southeast of Makaopuhi seismometer at a depth of 8 km. Magnitude 3.5. Felt at Hilo.

December 31: 17:04:51.5*. Epicenter 19°23.5′ north, 155°18.5′ west, 4 km southwest of Uwekahuna at a depth of 22 km. Magnitude 3.9. Felt Island-wide.

December 31: 19:12:19.6*. Epicenter 19°23.5′ north, 155°20.0′ west, 7 km southwest of Uwekahuna at a depth of 27 km. Magnitude 3.5. Felt at Kulani and Volcano.

PANAMA CANAL ZONE

[60th Meridian Time]

No earthquakes were reported felt during 1966.

PUERTO RICO

[60th Meridian Time]

May 2: 03:00. Central San Francisco, Guayanilla. Three shocks were felt by many on this date, one at the time given above. Trembling motion.

November 3: 12:24:31.0*. Epicenter 19.2° north, 67.9° west, Mona Passage, at a depth of 22 km, W. Magnitude 6-6¼, P. V. At Ponce, several people ran into the streets and some records fell to the floor in radio studios. People also hurried into the streets in the Mariani area. Buildings shook for 6 or 7 seconds in San Juan. The shock was also felt at Caguas, Cayey, and in the Playa de Ponce area.

VIRGIN ISLANDS

[60th Meridian Time]

October 6: Evening. A press report stated that St. Thomas Island was jarred by a small earthquake on this date.

(page 75 follows)

stations with the maximum wave heights indicated below:

	ft
Caldera, Chile	2.6
Antofagasta, Chile	1.0
Arica, Chile	1.0
Matarani, Peru	0.4
Chimbote, Peru	0.3
San Juan, Peru	0.7
Galapagos Islands	0.8
Pago Pago, American Samoa	0.4
Christmas Island	0.1
Hilo, Hawaii	1.0
Kahului, Hawaii	1.1
Wake Island	0.2

On December 31, an earthquake in the Santa Cruz Islands with an epicenter at 11.8° S., 166.5° E., and a magnitude of 7.5, caused a tsunami with an amplitude of 6⅔ feet inside the lagoon at Vanikoro. The tsunami was recorded at Suva, Fiji, with a maximum amplitude of 0.3 foot and at Pago Pago, American Samoa, with a maximum amplitude of 0.2 foot. It was also questionably recorded at Christmas Island; Kahului, Hawaii; and Unalaska, Alaska. An aftershock on December 31, located at 11.3° S., 164.8° E., magnitude 7¼-7½, caused a wave with a 5-foot amplitude inside the barrier lagoon at Vanikoro. This disturbance could not be identified on any tide gage.

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. It was published annually from 1950 to the present.

The following material was compiled by the Water Resources Division of the U.S. Geological Survey. Table 1 lists fluctuations caused by various sources in wells throughout the country. Table 2 lists the date, time, and location of specific earthquakes that may have been associated with recorded fluctuations in well water. Also included are the states recording the fluctuations.

Complete information on earthquakes possibly associated with the tabulations in table 1 may be obtained from the *Preliminary Determination of Epicenter* cards or *Seismological Bulletins,* both issued by the Coast and Geodetic Survey. Another source is earthquake registers from seismograph stations nearest the locality.

TABLE 1.—*Fluctuations in well-water levels, January through December 1966*

County and/or well number	Date 1966	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
ALASKA						
			ft	*ft*	*ft*	*ft*
CQ:C-1:6:3	Jan. 15	08:30	9.342	0.005	0.008	0.013
Do	Jan. 22	10:30	9.30	.01	.01	.02
ED:A-8:3:3	Jan. 28	20:00	8.684	.003	.005	.008
Do	Feb. 7	01:00	8.801	.002	.002	.004
ED:A-8:2:2	Feb. 11	20:00	17.83	0	.02	.02
ED:A-8:3:3	----do----	22:00	8.768	.005	.012	.017
Do	Feb. 12	02:00	8.771	.001	.003	.004
ED:A-8:2:11	Feb. 18	21:00	5.34	.02	.02	.04
CQ:D-2:8:1	Feb. 21	23:00	15.14	.005	.005	.01
Do	Feb. 25	16:00	15.15	.012	.013	.025
CQ:C-1:6:3	Mar. 12	17:00	8.838	.008	.004	.012
ED:A-1:5:2	Mar. 14	17:30	249.60±	.34	.40	.74
ED:A-8:3:3	Mar. 18	17:30	9.00	.002	.002	.004
ED:A-8:2:7	Apr. 8	01:00	30.78	.03	.09	.12
ED:A-8:2:2	----do----	20:00	19.69	.002	.010	.012
ED:A-8:2:11	Apr. 18	16:30	5.22	.02	.01	.03
Do	May 12	01:00	4.98	.02	.02	.04
ED:A-8:3:3	June 13	01:30	7.08	.003	.013	.016
ED:A-8:2:2	June 14	23:00	18.76	.01	.01	.02
ED:A-8:3:3	June 17	19:00	7.135	.005	.012	.017
Do	June 18	16:00	7.265	0	.035	.035

TABLE 1—*Continued*

County and/or well number	Date 1966	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
ALASKA—Continued						
			ft	*ft*	*ft*	*ft*
ED:A-8:2:11	Aug. 15	11:00	4.55	0.02	0.02	0.04
ED:A-8:3:3	do	12:00	7.654	.005	.006	.011
Do	do	18:00	7.657	.005	.005	.010
ED:A-8:2:11	Aug. 25	01:00	4.29	.02	.04	.06
Do	Aug. 29	21:00	4.47	.05	.05	.10
Do	Aug. 30	20:00	4.43	.06	.04	.10
ED:A-8:3:3	do	22:00	7.415	.015	.017	.032
Do	Sept. 1	24:00	7.278	.015	.009	.024
ED:A-8:2:11	do	23:30	4.47	.03	.01	.04
Do	Sept. 13	02:00	4.55	.03	.02	.05
Do	Sept. 26	19:30	4.18	.01	.02	.03
Do	Oct. 4	01:00	4.17	.02	.005	.025
ED:A-8:2:7	Oct. 7	21:00	27.415	.005	.005	.010
ED:A-8:2:11	do	21:00	4.41	.03	.02	.05
ED:A-8:3:2	do	21:00	6.755	.015	.010	.025
ED:A-8:2:11	Oct. 10	23:00	4.50	.01	.025	.035
ED:A-8:3:2	Oct. 11	17:00	6.932	.003	.001	.004
Do	Oct. 14	19:00	6.960	.001	.002	.003
Do	Nov. 22	22:00	7.895	.003	.001	.004
ED:A-8:2:11	Dec. 24	22:00	5.16	.01	.01	.02
ED:A-8:3:2	do	23:00	9.075	.010	.015	.025
ARIZONA						
(A-2-4)23bba	Jan. 7	21:00	132.89	0	0.07	0.07
Do	Feb. 2	12:00	135.65	.01	.07	.08
(D-1-7)31bac	Feb. 22	04:00	200.87	.04	.14	.18
(B-2-1)2aba	Feb. 25	00:30	254.38	.07	.12	.19
Do	Mar. 6	07:00	254.05	.07	.12	.19
(B-1-2)1cbb	Apr. 1	09:00	145.87	.01	.03	.04
Do	Apr. 7	20:30	145.83	.02	.04	.06
(D-17-14)18cac	Apr. 16	16:00	85.70	.03	.04	.07
(A-2-4)23bba	May 8	13:00	136.46	.02	.02	.04
(B-1-2)1cbb	June 6	00:30	146.69	.01	.01	.02
(D-1-7)31bac	June 8	01:00	208.76	.04	.06	.10
(B-1-2)1cbb	June 9	08:30	146.77	0	.01	.01
Do	June 13	12:30	147.00	.01	.04	.05
Do	July 3	04:00	147.00	.05	.09	.14
(D-15-13)2cca	July 10	02:00	62.54	0	.02	.02
(B-1-2)1ccb	July 13	05:00	147.02	.01	.01	.02
(D-15-11)5cccd	July 16	23:00	327.50	.02	.01	.03
Do	July 17	17:00	327.58	.04	.01	.05
(B-1-2)1ccb	July 27	11:00	147.25	.01	.03	.04
Do	July 30	03:00	147.23	.03	.05	.08
Do	Aug. 4	11:00	147.32	.03	.07	.10
(C-4-10)22abb	Aug. 7	15:00	132.05	.12	.13	.25

TABLE 1—*Continued*

County and/or well number	Date 1966	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
ARIZONA—Continued						
			ft	*ft*	*ft*	*ft*
(D–15–11)5cccd	Aug. 7	16:00	327.68	0.03	0.04	0.07
(C–4–10)22abb	Aug. 16	16:00	132.08	.01	.01	.02
(A–2–4)23bba	do	22:00	133.70	.02	.03	.05
(B–1–2)1ccb	Aug. 22	19:00	147.58	.01	.03	.04
(A–2–4)23bba	Aug. 24	10:00	133.69	.03	.02	.05
(B–1–2)1ccb	Aug. 31	23:00	147.88	.01	.02	.03
Do	Sept. 10	11:00	147.85	.02	.05	.07
(A–2–4)23bba	Oct. 5	02:00	134.16	.06	.08	.14
(C–4–10)22abb	Oct. 9	09:00	132.15	.01	.01	.02
(B–2–1)2aba	Oct. 18	13:00	266.65	.15	.03	.18
Do	Oct. 19	17:00	266.61	.08	.09	.17
(B–1–2)1ccb	Oct. 30	09:30	146.02	.04	.10	.14
(B–2–1)2aba	Nov. 8	13:00	265.50	.06	.22	.28
(A–2–4)23bba	Nov. 9	09:00	134.21	.06	.02	.08
(B–1–2)1ccb	Dec. 7	17:30	144.93	.02	.04	.06
(D–17–14)18cac	Dec. 10	16:30	88.24	.01	.01	.02
Do	Dec. 16	10:30	88.30	.01	.03	.04
Do	Dec. 17	15:00	88.30	.05	.08	.13
(C–4–10)22abb	Dec. 20	15:00	132.24	.03	.05	.08
(B–2–1)2aba	Dec. 21	01:30	263.52	.07	.07	.14
Do	Dec. 26	18:00	263.32	.11	.11	.22
Do	Dec. 27	10:00	263.45	.05	.11	.16
(D–15–11)5cccd	Dec. 28	07:30	328.60	.01	.01	.02
(B–1–2)1ccb	Dec. 30	11:00	144.66	.01	.09	.10
(B–2–7)23cca	do	19:00	209.54	0	.13	.13
(D–15–11)5cccd	Dec. 31	13:30	328.46	.02	0	.02
GEORGIA						
Chatham 63	Mar. 12	17:15	91.7			0.04
Chatham 99	do	17:15	73.5			Trace
Chatham 487	do	17:30	10.30			.05
Dawson 12–3	do	17:45	25.82	0.02	0.02	.04
Glynn 34H359	July 4	16:45	−7.10	.03	.08	.11
Glynn 33H127	do	17:15	−10.72	.03	.03	.06
Glynn 33H334	do	17:45	−11.57	.03	.04	.07
Glynn 34H355	do	17:45	−11.75	.03	.02	.05
Glynn 34H125	do	18:45	−7.72	.02	.02	.04
Glynn 33H133	do	19:00	−11.30	.01	.01	.02
Thomas 14E15	do	19:15	182.8	.03	.02	.05
Dougherty–USMC	do	19:45	23.00	.03	.03	.06
Do	Oct. 17	21:45	?	.23	.22	.45
Wayne 30L3	do	21:45	64.94	.02	.02	.04
Charlton OK8	do	22:00	60.31	.29	.26	.55
Chatham 63	do	22:00	99.7			.12
Chatham 487	do	22:00	13.80			.21

TABLE 1—*Continued*

County and/or well number	Date 1966	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
GEORGIA—Continued						
			ft	*ft*	*ft*	*ft*
Glynn 34H125	Oct. 17	22:00	−8.25	0.22	0.23	0.45
Glynn 33H127	----do----	22:00	+0.98	.06	.11	.17
Glynn 33H133	----do----	22:00	−11.44	.39	.30	.69
Glynn 34H334	----do----	22:00	−11.65	.27	.28	.55
Glynn 34H355	----do----	22:00	−12.20	.23	.23	.46
Glynn 34H359	----do----	22:00	−7.08	.10	.20	.30
Grady 12F36 Cairo	----do----	22:00	138.90	.12	.12	.24
Mitchell Vada	----do----	22:00	49.09	.13	.18	.31
McIntosh 35M13	----do----	22:15	4.90	.12	.13	.25
Cook 18H16 Adel	----do----	22:30	164.10	.09	.09	.18
Dooly Vienna	----do----	22:30	3.60	.04	.04	.08
Chatham 99	----do----	23:00	80.0	----------	----------	Trace
Thomas 14E15	----do----	23:00	183.75	.50	.45	.95
Chatham 143A	----do----	----------	17.3	----------	----------	.17
Dawson 12-3	----do----	?	28.58	.07	.04	.11
Charlton OK8	Dec. 10	13:30	60.10	.015	.015	.030
Dougherty-USMC	----do----	13:30	33.06	.07	.04	.11
Glynn 34H125	Dec. 10	13:30	−6.44	.02	.02	.04
Glynn 33H133	----do----	13:30	−9.83	.02	.02	.04
Glynn 34H355	----do----	13:30	−10.28	.02	.02	.04
Glynn 34H359	----do----	13:30	−6.18	.08	.03	.11
Thomas 14E15	----do----	13:30	83.20	.08	.08	.16
Chatham 487	----do----	13:50	10.65	----------	----------	.06
Mitchell Vada	----do----	?	51.68	.03	.04	.07
McIntosh 35M13	Dec. 28	08:00	5.70	.05	.06	.11
Bryan 35P57	----do----	08:30	10.80	----------	----------	.060
Dougherty-USMC	----do----	08:30	33.60	.06	.05	.11
Cook Adel	----do----	08:45	164.63	.03	.03	.06
Glynn 34H334	----do----	09:00	−3.10	.11	.11	.22
Thomas 14E15	----do----	09:00	184.7	.17	.18	.35
Mitchell Vada	----do----	09:10	----------	----------	----------	----------
Chatham 99	----do----	09:15	69.8	----------	----------	−.16
Charlton OK8	----do----	09:20	60.50	.10	.09	.19
Chatham 487	----do----	10:15	12.85	----------	----------	.12
Chatham 143A	----do----	----------	16.35	----------	----------	.10
Dougherty-USMC	Dec. 31	19:00	33.48	.03	.03	.06
Mitchell Vada	----do----	19:00	52.35	.015	.015	.030
Dougherty-USMC	----do----	23:00	33.48	----------	----------	.035
Mitchell Vada	----do----	23:00	52.40	.01	.01	.02
IDAHO						
Lincoln, 5S-23E-17ca1	Feb. 23	21:15	308.62	0.04	0.04	0.08
Butte, 5S-31E-28cc1	Mar. 12	17:00	261.52	.04	.05	.09
Madison, 7N-38E-28db1	----do----	17:00	42.79	.05	.04	.09

TABLE 1—*Continued*

County and/or well number	Date 1966	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
IDAHO—Continued						
			ft	*ft*	*ft*	*ft*
Blaine, 2S–20E–1ac2	Mar. 13	18:00–20:00	151.00	0.05	0.04	0.09
Do	Apr. 11	14:00–16:00	145.71	.02	.02	.04
Do	Apr. 14	16:00–18:00	146.53	.03	.02	.05
Twin Falls, 14S–15E–28ba2	Apr. 16	00:45	100.02	.02	.01	.03
Do	Apr. 26	00:15	99.93	.01	.02	.03
Butte, 2N–28E–35ad1	Apr. 27	22:00–24:00	602.48	.03	.03	.06
Lincoln, 5S–23E–17ca1	----do----	22:15	308.15	.03	.01	.04
Blaine, 1S–19E–3cc2	May 2	16:00–18:00	17.83	.10	.19	.29
Do	May 4	10:00–12:00	17.49	.09	.11	.20
Madison, 7N–38E–23db1	May 6	20:30	43.18	.02	.02	.04
Cassia, 13S–21E–18bb1	May 13	22:15	470.42	.02	.03	.05
Madison, 7N–38E–23db1	----do----	08:15	42.91	.02	.02	.04
Do	----do----	19:15	42.89	.02	.02	.04
Do	May 19	00:15	42.82	.08	.05	.13
Butte, 5N–31E–28cc1	May 23	18:30	262.83	.02	.02	.04
Minidoka, 4S–24E–6bb1	June 3	20:30	416.37	.06	.03	.09
Jefferson, 7N–36E–22ab4	June 4	12:00–14:00	6.21	.03	.02	.05
Butte, 3N–29E–14ad1	June 13	23:15	254.70	.04	.03	.07
Jerome, 9S–20E–1da1	June 17	02:00–04:00	364.85	.03	.03	.06
Madison, 7N–38E–23db1	June 23	20:15	41.17	.02	.01	.03
Do	----do----	21:45	41.16	.02	.01	.03
Lincoln, 5S–17E–26ac1	June 28	04:00–06:00	190.62	.02	.03	.05
Madison, 7N–38E–23db1	----do----	05:15	41.05	.04	.04	.08
Butte, 5N–31E–28cc1	----do----	06:30	263.50	.01	.02	.03
Madison, 7N–38E–23db1	June 29	04:00	40.98	.04	.03	.07
Butte, 3N–29E–14ad1	July 4	18:15	454.67	.04	.06	.10
Butte, 5N–31E–28cc1	----do----	19:00	263.82	.09	.05	.14
Teton, 4N–45E–13ad1	----do----	21:15	166.09	.01	.03	.04
Twin Falls, 14S–15E–28ba2	----do----	21:45	100.58	.01	.02	.03
Jefferson, 7N–34E–22ab4	July 7	24:00–02:00	6.71	.01	.01	.02
Blaine, 2S–20E–1ac2	July 28	16:00–18:00	143.90	.02	.02	.04
Blaine, 8S–26E–33bc1	Aug. 7	11:00–13:00	105.42	.10	.08	.18
Minidoka, 7S–25E–19ba1	----do----	11:00–13:00	245.82	.03	.03	.06
Jerome, 8S–19E–5da1	----do----	12:00	269.70	.03	.02	.05

TABLE 1—*Continued*

County and/or well number	Date 1966	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
IDAHO—Continued						
			ft	*ft*	*ft*	*ft*
Minidoka, 8S–23E–2ba1	Aug. 7.	13:00–15:00	214.48	0.05	0.04	0.09
Butte, 5N–31E–28cc1	----do----	17:30	264.64	.05	.05	.10
Butte, 3N–29E–14ad1	----do----	18:15	455.00	.10	.10	.20
Madison, 7N–38E–23db1	----do----	18:30	39.96	.24	.21	.45
Butte, 2N–27E–2dd1	----do----	18:45	761.70	.08	.05	.13
Jefferson, 7N–34E–4cd1	----do----	18:45	26.55	.04	.07	.11
Twin Falls, 14S–15E–28ba2	----do----	18:45	104.38	.02	.04	.06
Cassia, 13S–21E–18bb1	----do----	20:00	481.89	.01	.03	.04
Teton, 4N–45E–13ad1	----do----	23:15	180.77	.09	.10	.19
Jefferson, 7N–34E–4cd1	Aug. 16	19:45	26.71	.02	.03	.05
Teton, 4N–45E–13ad1	Aug. 18	00:45	183.97	.01	.02	.03
Minidoka, 4S–24E–6bb1	Sept. 10	22:00	417.61	.16	.07	.23
Butte, 3N–29E–14ad1	Sept. 12	17:00	455.22	.04	.05	.09
Madison, 7N–38E–23db1	----do----	18:00	39.52	.04	.03	.07
Jefferson, 7N–34E–4cd1	----do----	19:30	28.99	.02	.01	.03
Teton, 4N–45E–13ad1	Sept. 13	01:30	191.33	.01	.02	.03
Butte, 5N–31E–28cc1	Oct. 17	22:45	265.18	.20	.12	.32
Madison, 7N–38E–23db1	----do----	23:00	39.52	.19	.19	.38
Twin Falls, 14S–15E–28ba2	----do----	23:30	103.13	.05	.04	.09
Madison, 7N–38E–23db1	Dec. 10	15:45	41.02	.01	.02	.03
Teton, 4N–45E–13ad1	----do----	15:45	199.83	.03	.02	.05
Lincoln, 5S–17E–26ac1	Dec. 20	13:00–15:00	193.50	.03	.03	.06
Blaine, 1S–19E–3cc2	----do----	14:00–16:00	17.71	.01	.03	.04
Butte, 5N–31E–28cc1	----do----	14:30	264.86	.03	.01	.04
Jefferson, 7N–34E–4cd1	----do----	15:45	13.89	.03	.02	.05
Butte, 5N–31E–28cc1	Dec. 28	08:00	264.97	.15	.13	.28
Do	Dec. 31	18:00	264.80	.06	.05	.11
INDIANA						
Pu6	Jan. 22	14:45–15:00	11.079	0.003	0.005	0.008
Ma32	----do----	14:50–15:10	11.321	.017	.023	.040
Do	Mar. 7	21:50–22:10	11.083	.009	.013	.022
Pu6	Mar. 12	16:30	12.750	.039	.039	.078
Ma32	----do----	16:45–18:00	10.772	.092	.078	.170
Do	Mar. 20	02:00–02:10	10.800	.018	.012	.030
Do	May 18	07:15	11.145	.10	.005	.015
Do	June 7	14:30	12.300	.020	.010	.030

TABLE 1—*Continued*

County and/or well number	Date 1966	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
INDIANA—Continued						
			ft	*ft*	*ft*	*ft*
Pu6	June 7	15:00–15:15	11.730	0.003	0.001	0.004
Ma32	June 15	02:15–02:30	12.860	.03	.04	.07
Pu6	June 28	04:45	12.922	.001	.009	.010
Ma32	July 4	18:45–19:00	13.100	.090	.13	.22
Ml2	----do----	19:00	20.41	.12	.06	.18
Pu6	----do----	19:00–19:50	12.843	.032	.036	.068
Ma32	Aug. 7	17:45	14.010	.01	.03	.04
Sh2	Oct. 17	21:45	21.64	.03	.01	.04
Pu6	----do----	21:45–22:30	17.490	.097	.079	.176
Ma32	----do----	22:00–23:00	12.320	.26	.20	.46
Mi11	----do----	22:00–22:20	114.88	.07	.15	.22
Md8	----do----	22:30	25.065	.005	.015	.020
Mi2	----do----	22:30	43.5	.8	.2	1.0
Pu6	Oct. 19	08:30	17.250	.005	.001	.006
Ma32	Nov. 12	19:00	11.951	.002	.002	.004
Ma32	Dec. 28	08:40–09:30	10.740	.115	.085	.200
Pu6	----do----	09:00–09:20	10.171	.07	.022	.092
Ma32	Dec. 31	19:25–19:40	10.820	.095	.005	.100
Do	----do----	23:25–24:00	10.830	.01	.02	.03
MICHIGAN[1]						
7N7E17–1	July 4	14:00	32.75	0.07	0.07	0.14
5N12W4–7	Aug. 16	03:00	8.805	.02	.025	.045
Do	Oct. 17	20:00	8.82	.05	.04	.09
5N12W4–3	----do----	20:00	11.96	.01	.01	.02
6N12W34–1	----do----	20:00	66.87	.06	.06	.12
7N7E17–1	----do----	----------	32.70	.14	.13	.27
2S8W16–1	----do----	20:00	4.03	.03	.03	.06
42N2W7–1	Oct. 20	----------	28.67	.07	.05	.12
NEVADA						
S17/50–36dc1	Jan. 22	14:05	2.03	0.04	0.04	0.08

[1] Times estimated because of small time scale.

TABLE 1—*Continued*

County and/or well number	Date 1966	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
NEVADA—continued						
			ft	*ft*	*ft*	*ft*
S17/50-36dc1	Jan. 23	01:20	2.08	0.01	0.02	0.03
Do	Feb. 16	23:20	1.98	.01	.01	.02
Do	Mar. 4	18:30	1.79	.02	0	.02
Do	Mar. 12	16:40	1.91	.07	.07	.14
Do	Mar. 19	24:00	2.07	.03	.02	.05
Do	Mar. 30	12:10	1.98	.05	.05	.10
Do	Apr. 16	01:20	1.98	.03	.03	.06
Do	Apr. 19	22:30	1.99	.05	.02	.07
S19/53-32aaa1	Apr. 20	18:30	27.70	.04	.06	.10
S17/50-36dc1	Apr. 22	17:30	1.80	.03	.02	.05
Do	----do----	23:40	1.93	.02	.01	.03
Do	May 6	15:30	1.94	0	.02	.02
Do	May 11	20:40	1.93	.01	0	.01
Do	May 13	14:00	1.90	.02	.02	.04
Do	May 14	23:30	2.04	.03	.03	.06
Do	May 18	08:30	1.90	.03	.02	.05
Do	May 19	15:15	1.96	.02	.03	.05
Do	May 23	13:00	1.97	.01	.02	.03
Do	June 2	16:15	1.84	.02	.02	.04
S19/53-32aaa1	June 3	12:00±	27.98	.01	0	.01
S17/50-36dc1	----do----	14:30	1.91	.02	.02	.04
Do	June 5	03:00	2.04	.04	.03	.07
Do	June 15	01:45	2.03	.10	.09	.19
Do	June 16	02:00	2.08	.03	.08	.11
S21/54-28bd1	June 17	10:00	22.87	.01	.03	.04
S17/50-36dc1	----do----	01:15	2.09	.05	.04	.09
Do	June 20	07:00	2.03	.03	.01	.04
S21/54-28bd1	----do----	13:00	22.88	.02	.01	.03
S17/50-36dc1	June 22	01:00	1.85	.04	.03	.07
Do	June 28	01:15	1.93	.04	.05	.09
Do	----do----	23:15	1.81	.02	.02	.04
Do	July 1	22:15	1.95	.14	.13	.27
Do	July 4	19:00	1.73	.09	.09	.18
Do	Aug. 1	01:00	1.98	.04	.12	.16
S19/60-9bcc1	Aug. 7	17:00?	118.99	.10	.08	.18
S17/50-36dc1	----do----	17:45	1.86	.74	.36	1.10
S21/54-10aac1	Aug. 16	04:00	83.57	.08	.08	.16
S19/53-32aaa1	----do----	12:00	28.38	0	.02	.02
S17/50-36dc1	----do----	18:00	1.60	.20	.10	.30
S21/54-28bd1	Aug. 18	09:00	23.11	.02	.04	.06
S17/50-36dc1	Aug. 22	02:00	1.78	.03	.02	.05
Do	----do----	12:15	1.72	.01	.03	.04
Do	Aug. 23	01:00	1.82	.03	.02	.05
S21/54-28bd1	Aug. 27	21:00	23.18	.01	.02	.03
S19/60-9bcc1	Dec. 10	13:00	116.52	.02	.02	.04
Do	Dec. 20	14:00	115.98	.32	.27	.59
Do	Dec. 28	08:15	115.87	.07	.05	.12

TABLE 1—*Continued*

County and/or well number	Date 1966	Time at recorder G. M. T.	Depth to water before disturbance	Water-level fluctuations		
				From prequake level		Double amplitude
				Upward	Downward	
NEW JERSEY [2]						
			ft	*ft*	*ft*	*ft*
Hillside, 26.22.4.4.4	Mar. 7	22:30	+18.65	0.01	0.01	0.02
Do	Mar. 20	02:15	+20.12	.02	.02	.04
Do	Mar. 22	09:10	+19.72	.02	.02	.04
Do	June 15	01:35	+17.90	.04	.03	.07
Do	do	02:00	+17.90	.02	.02	.04
New Brooklyn No. 1, 31.23.8.9.6	July 4	19:00	−18.45	.01	.01	.02
Garden St., 33.21.3.3.5	do	19:15	+35.46	.01	.02	.03
Hillside, 26.22.4.4.4	do	19:15	+21.92	.05	.05	.10
Do	Aug. 7	18:15	+19.22	.02	.02	.04
Browntown, 29.1.4.6.9	Sept. 22	18:30	+17.00	0	.01	.01
Hillside, 26.22.4.4.4	Oct. 17	22:15	+18.43	.16	.09	.25
Salem No. 3, 30.4.2.6.1.1	do	22:15	−10.64	.02	.02	.04
Hillside, 26.22.4.4.4	do	22:20	+18.43	.09	.03	.12
Do	do	22:45	+18.45	.05	.02	.07
Do	Dec. 10	13:45	+17.18	.02	.01	.03
Do	Dec. 28	08:30	+19.68	.02	.01	.03
Do	do	08:40	+19.68	.09	.10	.19
Salem No. 3, 30.4.2.6.1.1	do	08:40	−11.00	.02	.02	.04
Hillside, 26.22.4.4.4	Dec. 31	18:45	+17.76	.16	.24	.40
Do	do	22:45	+18.28	.06	.09	.15
Salem No. 3, 30.4.2.6.1.1	do	22:45	−10.92	.01	.02	.03
SOUTH CAROLINA						
Beaufort 304	Mar. 12	17:10	5.60			Trace
Jasper 46	do	17:35–17:45	4.75			0.065
Do	July 4	18:20	5.14		0.01	.01
Do	Oct. 17	22:20	5.83	0.08	.05	.13
Beaufort 304	do	22:30	8.70			.10
Jasper 46	Dec. 10	13:20	6.90	.02	.02	.04
Do	Dec. 28	08:30	6.45			.10
Do	Dec. 31	19:00	6.23	+.01?	.04	.04
Do	do	23:00	6.21	.02	.01	.03

[2] Names listed in column 1 are area designations.

TABLE 2.—*Earthquakes of 1966 believed to have caused fluctuations in well-water levels*

Date 1966	Origin time G. M. T.	Location	States recording fluctuations
Jan. 22	14:27:07.9	South of Alaska	Indiana and Alaska.
Jan. 23	01:56:38.0	New Mexico	Nevada.
Jan. 28	19:07:14.4	Andreanof Islands	Alaska.
Feb. 6	23:28:07.8	Southern Alaska	Alaska.
Feb. 16	23:37:05	Tonga Islands	Nevada.
Mar. 7	21:29:17.0	Northeastern China	Indiana and New Jersey.
Mar. 12	16:31:21.8	Taiwan region	Alaska, Georgia, Idaho, Indiana, Nevada, and South Carolina.
Mar. 20	01:42:49.9	Uganda	Indiana, Nevada, and New Jersey.
Mar. 30	12:40:01.0	Vancouver Island region	Nevada.
Apr. 16	01:27:15.3	Kodiak Island region	Nevada.
Apr. 22	23:27:20.5	do	Nevada.
May 18	07:32:07.3	Gulf of California	Indiana and Nevada.
June 7	13:59:36.0	West Caroline Islands	Indiana.
June 15	00:59:45.8	Solomon Islands	Indiana, Nevada, and New Jersey.
	01:32:55.5		
June 28	00:59:54.4	Santa Cruz Islands	Nevada.
June 28	04:08:54.7	Central California	Idaho and Indiana.
July 1	22:12:18	Molucca Passage	Nevada.
July 4	18:33:35.7	Rat Islands	Georgia, Idaho, Indiana, Nevada, New Jersey, and South Carolina.
Aug. 7	17:36:26.7	Gulf of California	Idaho, Indiana, Nevada, and New Jersey.
Aug. 16	18:02:36.1	Southern Nevada	Nevada.
Aug. 18	09:15:34.9	do	Nevada.
Aug. 30	20:20:54.0	Southern Alaska	Alaska.
Sept. 1	23:19:09.8	do	Alaska.
Oct. 7	20:55:56.0	do	Alaska.
Oct. 17	21:41:56.3	Near coast of Peru	Georgia, Idaho, Indiana, New Jersey, and South Carolina.
Oct. 19	08:01:33.8	North of Ascension Island	Indiana.
Nov. 12	18:45:01.0	New Hebrides Islands	Indiana.
Dec. 10	13:06:32.6	Guatemala	Nevada and New Jersey.
Dec. 24	22:28:59.6	Southern Alaska	Alaska.
Dec. 28	08:18:07.4	Northern Chilean coast	Arizona, Georgia, Idaho, Indiana, Nevada, New Jersey, and South Carolina.
Dec. 31	18:23:03.9	Santa Cruz Islands	Georgia, Idaho, Indiana, New Jersey, and South Carolina.
Dec. 31	22:15:14.0	do	Georgia, New Jersey, and South Carolina.

Seismological Observatories

The Coast and Geodetic Survey publishes the results of its teleseismic and cooperating stations in the monthly *Seismological Bulletin*. All seismogram interpretations are tabulated, together with epicenters based on the published data and instrumental results received from seismological stations in all parts of the world. Instrumental results are published for the stations which follow. See figure 19 for the locations of these stations, except for San Juan, Guam, and Balboa Heights. These are included in figure 20 which contains all stations in the World-Wide Network of Standard Seismographs (WWNSS).

Adak, Alaska
Albuquerque, N. Mex. (WWNSS)
Balboa Heights, Canal Zone (WWNSS)
(The Panama Canal Company)
Barrow, Alaska
Blue Mts. Observatory, Oreg.
Boulder City, Nev.
(Bureau of Reclamation)
Bozeman, Mont.
(Montana State College)
Bozeman, Mont. (WWNSS)
Butte, Mont.
(Montana School of Mines)
Cedar Springs, Calif.
(State of California Dept. of Water Resources)
Chicago, Ill.
(Univ. of Chicago and U.S. Weather Bureau)
College, Alaska (WWNSS)
Columbia, S. C.
(Univ. of South Carolina)
Cumberland Plateau, Tenn.
Eureka, Nev.
(Eureka Corporation, Ltd.)
Flaming Gorge, Utah
(Bureau of Reclamation)
Glen Canyon, Ariz.
(Bureau of Reclamation)
Guam, Mariana Islands (WWNSS)
Honolulu, Hawaii
Hungry Horse, Mont.
(Bureau of Reclamation)
Kipapa, Hawaii (WWNSS)
Middleton Islands, Alaska
Newport, Oreg.
Palmer, Alaska
Philadelphia, Pa.
(The Franklin Institute)
Rapid City, S. Dak. (WWNSS)
(South Dakota State School of Mines)
Salt Lake City, Utah
(Univ. of Utah)
San Juan, Puerto Rico (WWNSS)
San Luis Dam, Calif.
(Bureau of Reclamation)
Sitka, Alaska
Tucson, Ariz. (WWNSS)
Ukiah, Calif.
(International Latitude Observatory)
Washington, D. C.
Washington Science Center, Md.

Coast and Geodetic Survey stations include: Adak, Albuquerque, Barrow, Blue Mts. Observatory, College, Guam, Honolulu, Kipapa, Middleton Islands, Newport, Palmer, San Juan, Sitka, Tucson, Ukiah, Washington, and Washington Science Center.

Cooperating stations include: Boulder City, Bozeman, Butte, Cedar Springs, Chicago, Columbia, Eureka, Flaming Gorge, Glen Canyon, Hungry Horse, Salt Lake City, and San Luis Dam.

Balboa Heights, Philadelphia, and Rapid

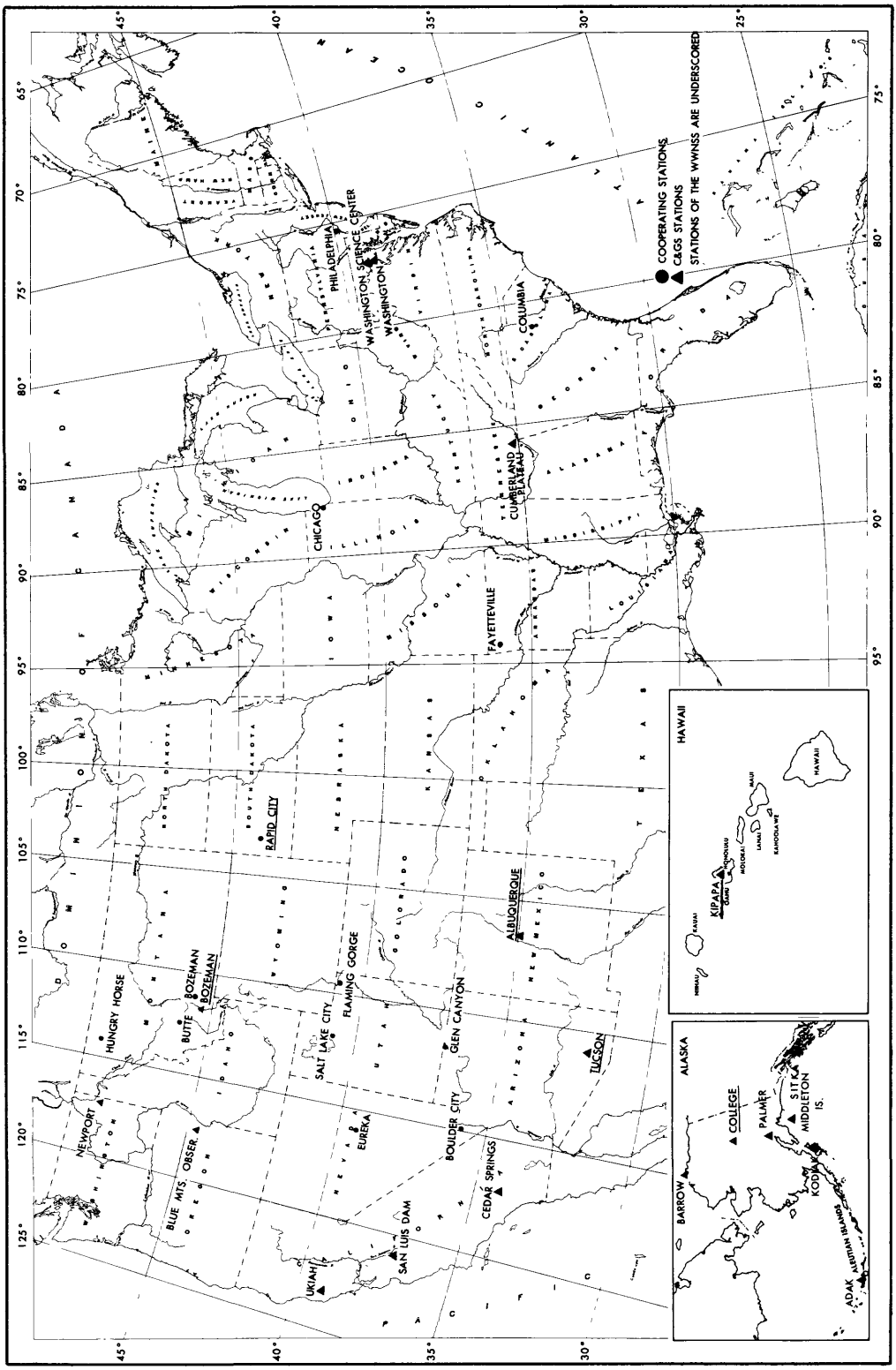

FIGURE 19.—Seismological observatories for which the Coast and Geodetic Survey (National Earthquake Information Center) publishes results.

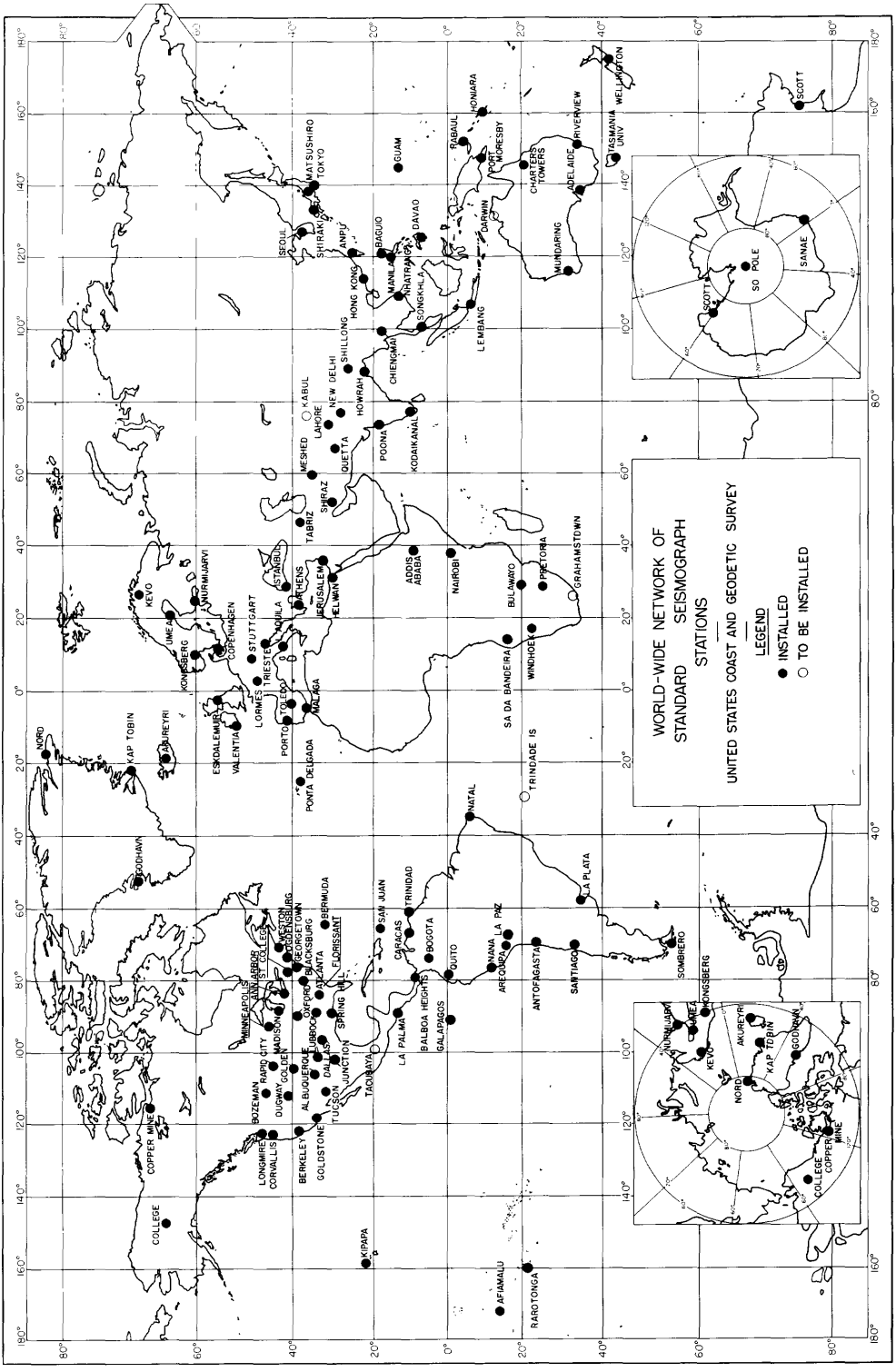

FIGURE 20.—Stations in the World-Wide Network of Standard Seismographs (WWNSS).

City are stations that operate on an independent basis.

For detailed instrumental data regarding the stations listed above, including instrumentation, constants, and other information, refer to the *Seismological Bulletin,* MSI–313, January 1967. Those desiring to receive this report as issued should request addition of their names to the CGS–7 mailing list.

Principal Earthquakes of the World During 1966

[Listed herein are (1) earthquakes of magnitude greater than 6¾ determined by Pasadena, and earthquakes of smaller magnitude which were locally destructive; (2) earthquakes of unusual interest. A description of each earthquake immediately follows the list.]

Date 1966	Origin time G. M. T.	Region	Coordinates		Depth	Mag.
			Lat.	Long.		
	h m s		°	°	*km*	
Jan. 23	01:56:38.8	New Mexico–Colorado border region.	37.0 N.	107.0 W.	------	5.5
Feb. 5	02:01:48.3	Central Greece	39.2 N.	22.0 E.	38	6¼
Feb. 7	04:26:13.9	Western Pakistan	29.8 N.	69.7 E.	33	6¼–6½
Mar. 7	01:16:05.8	Northeastern Turkey	39.1 N.	41.7 E.	13	6
Mar. 7	21:29:17.0	Northeastern China	37.2 N.	114.8 E.	33	6¾
Mar. 12	16:31:21.8	Taiwan region	24.1 N.	122.6 E.	63	7½–7¾
Mar. 20	01:42:49.9	Uganda	0.6 N.	30.2 E.	36	6¾–7
Mar. 22	08:19:33.8	Northeastern China	37.5 N.	115.1 E.	33	6¾–7
Apr. 25	23:22:52.6	Kirgiz SSR	41.2 N.	69.3 E.	33	5
June 7	13:59:36.0	West Caroline Islands	11.3 N.	139.6 E.	50	6¾–7
June 15	00:59:45.8	Solomon Islands	10.4 S.	160.8 E.	31	7½
June 15	01:32:55.5	----------do----------	10.2 S.	161.1 E.	33	7¼
June 27	10:41:08.6	Nepal-India border	29.7 N.	80.9 E.	37	5¾
June 28	08:26:14.4	Parkfield, Calif.	35.9 N.	120.9 W.	------	5.3
July 4	18:33:35.7	Rat Islands	51.7 N.	179.9 E.	13	6¾–7
July 12	00:04:12	Turkey	38.9 N.	41.3 E.	64	4.6
Aug. 1	21:02:59.6	Western Pakistan	30.0 N.	68.7 E.	33	6¾
Aug. 7	02:13:05.1	Aleutian Islands region	50.6 N.	171.3 W.	39	7.0
Aug. 15	02:15:33.8	Northern India	28.7 N.	78.9 E.	50	5.8
Aug. 19	12:22:09.6	Turkey	39.2 N.	41.7 E.	26	7
Sept. 4	22:14:49.0	Colombia	4.6 N.	74.0 W.	5	5.2
Sept. 8	21:15:52.8	Halmahera	2.4 N.	128.4 E.	96	6¾–7
Oct. 17	21:41:56.3	Near coast of Peru	10.7 S.	78.7 W.	38	7½
Oct. 29	02:39:29.4	Central Greece	39.2 N.	21.2 E.	20	5.7
Dec. 28	08:18:07.4	Northern Chilean coast	25.5 S.	70.7 W.	47	7¾
Dec. 31	18:23:03.9	Santa Cruz Islands	11.8 S.	166.5 E.	33	7.5
Dec. 31	22:15:14.0	----------do----------	11.3 S.	164.8 E.	33	7.3

DESCRIPTIONS OF PRINCIPAL EARTHQUAKES

January 23 (GMT): New Mexico-Colorado border region. See p. 14 for description.

February 5: Central Greece. One person was killed and 50 were injured by this earthquake that caused extensive property damage at Krenti, Kliston, Fourna, Alestia, and surrounding villages. Several landslides caused additional damage throughout the area by blocking roads and covering houses with tons of rock and earth. The number of homeless was reported to be in the thousands. Magnitude 6¼.

February 7: Western Pakistan. Most of the major property damage was confined to 12 small villages where 5,000 homes were damaged or destroyed. A total of 12 residents were killed in Barkhan and about 100 were injured. Five of the deaths were caused by a landslide precipitated by earth movement. Magnitude 6¼-6½.

March 7: Northeastern Turkey. At Hinis, a small town of about 2,500 inhabitants, 10 persons were killed and 1,000 houses were heavily damaged. The damage zone included a few nearby villages where 72 houses were reportedly razed and five additional villagers were fatally injured. Magnitude 6.

March 7 and 22: Northeastern China. Thirty communes were damaged by the first shock, indicating that about 300,000 Chinese were affected in the densely populated city of Singtai. A report released by the New China News Agency stated that great numbers of medical personnel had been rushed to Singtai to care for the victims, indicating a probable high casualty figure. After the occurrence of the stronger shock in the same area on March 22, a report was released stating that loss of life was lighter in the March 7 shock, indicating some fatalities in the earlier tremor. Considerable property damage was sustained on March 22, principally to buildings already weakened by the first earthquake. Magnitudes 6¾ and 6¾-7, respectively.

March 12: Taiwan region. This earthquake was centered on Taiwan, but property damage reached as far as Okinawa, about 400 miles northeast. Numerous houses were damaged on both islands, 7 persons were killed, and 10 were injured. Magnitude 7½-7¾.

March 20: Uganda. This was the most destructive earthquake in recent African history. The damage appeared to center about Bundibugyo, a one-street township 42 miles from Fort Portal, near the Congo border. About 140 fatalities and hundreds of injuries were reported from Bundibugyo, Fort Portal, and Kichwamba. At Kamango, in the Congo, a chasm 9 feet wide and 1,000 feet long opened up in the ground. Immediate relief measures were greatly impeded by landslides which severed communications and blocked highways. Magnitude 6¾-7.

March 22: Northeastern China. Since the information received on this earthquake is so interrelated with the March 7 shock in the same area, the descriptions for the two shocks were combined. (See March 7 and 22, Northeastern China.)

April 25. Kirgiz SSR. At Tashkent, USSR, 10 were killed, 1000 were injured, and about 100,000 were left homeless. Several hospitals, schools, and public buildings were destroyed in the Old Quarter of Tashkent, the principal damage area. Thousands of the ancient, one-story adobe dwellings were flattened. Additional damage was sustained from the hundreds of aftershocks which followed. Magnitude 5.

June 7: West Caroline Islands. This earthquake was not reported felt. Magnitude 6¾-7.

June 15: Solomon Islands. Two major earthquakes were felt at Guadalcanal, Malaita, and San Cristobal on this date. Magnitudes 7½ and 7¼, respectively.

June 27: Nepal-India border. Due to the dense population and weak building construction in the epicentral area, 80 persons

were killed and 5,000 houses were destroyed. Widespread destruction was reported at Baitadi, Darchula, and Chainpur, Nepal. The remoteness of the epicentral area was a great obstacle to relief operations. Magnitude 5¾.

June 28 (GMT): Parkfield, Calif. See p. 37 for description.

July 4: Rat Islands. This shock was lightly felt at the Naval Base on Adak Island. Magnitude 6¾-7.

July 12: Turkey. This earthquake was located south of the March 7 shock in Mus Province of eastern Turkey. The town of Bagici, which was almost destroyed, reported 12 deaths and 15 injuries. Surrounding villages also sustained extensive property damage. Magnitude 4.6.

August 1. Western Pakistan. Twenty villages were completely leveled, 2 persons were killed, and 15 were injured in the Duki Tehsil area. According to reports, over 1,000 houses were destroyed and gaping cracks were left in the ground in the epicentral area. Magnitude 6¾.

August 7: Aleutian Islands region. This earthquake was felt on Adak, but no damage was sustained. Magnitude 7.0.

August 15: Northern India. In New Delhi, a three-story house collapsed, killing 15 and injuring 24. This structure had already been declared unsafe and was awaiting demolition when it was flattened by the earthquake. Magnitude 5.8.

August 19: Turkey. This was the third damaging earthquake to strike Turkey during the year. It was also the most destructive, as evidenced by the 2,529 fatalities, 1,500 injuries, and 108,000 persons homeless. Twenty or more villages were completely razed in the provinces of Bingol, Erzurum, and Mus. At Varto, which was almost destroyed, 500 deaths were reported. Near Varto, surface fracturing occurred and many landslides developed. One landslide near Tepekoy measured 150 by 250 meters in area. Magnitude 7.

September 4: Colombia. This moderate earthquake centered in the residential area of Bogota where several buildings were extensively damaged, walls collapsed, and six persons were killed. Numerous injuries resulted from falling debris and from panic at theatres and bullfights. Magnitude 5.2.

September 8: Halmahera. This earthquake was not reported felt. Magnitude 6¾-7.

October 17: Near coast of Peru. This earthquake, centering just off the coast from Callao, claimed about 125 lives and injured some 3,000 persons. The town of Huacho was the most severely damaged with over 20,000 inhabitants left homeless. A religious festival was being held in Callao and several were killed when some of the churches collapsed. One street in this city was split by a chasm several feet wide. In Lima, 2,300 houses suffered severe structural damage. Landslides and huge ground cracks were reported along the Pan American Highway north of Ancon. This shock generated a tsunami with heights of 11.3 feet at La Punta-Callao (see p. 72). Magnitude 7½.

October 29: Central Greece. This area was ravaged by a damaging earthquake for the second time this year, but as in the first shock in February, the casualty figure was low in comparison to the extensive damage incurred. Although eighty percent of the one-story dwellings in the villages of Fities, Katuna, and Xiromeri were destroyed leaving 10,000 homeless inhabitants, only one fatality and 23 injuries were reported. A 300-yard-long bridge spanning two lakes north of Agrinion was toppled. Several villages were cut off from the outside world after landslides severed communications and closed highways. Magnitude 5.7.

December 28: Northern coast of Chile. This predawn earthquake destroyed, or seriously damaged, about half of the dwellings in Taltal. Three persons were killed and about 3,000 were made homeless. All of the structures in Catalina, about 50

FIGURE 21.—Damage caused by the December 28, Chilean earthquake in the small village of Catalina.

FIGURE 22.—Damage at Taltal, Chile, caused by the December 28 earthquake in northern Chile.

miles east of Taltal, were heavily damaged (see figs. 21–22). A Coast and Geodetic Survey (ESSA) inspection team was dispatched to the epicentral region shortly after the shock occurred. Magnitude 7¾.

December 31: Santa Cruz Islands. Two major earthquakes, less than four hours apart, struck an uninhabited area on this date, but no damage was reported due to their location. However, two slight tsunamis were generated. The first wave reached an amplitude of 6⅔ feet at Vanikoro, Santa Cruz Islands, and 0.3 foot at Suva, Fiji Islands; the second registered 5 feet at Vanikoro (see p. 72). Magnitudes 7.5 and 7.3, respectively.

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.

A list of the strong-motion stations in operation is presented in table 3, and their locations, excluding those outside the United States, are shown in figures 23 and 24. Table 4 gives a list of earthquakes recorded and records obtained on strong-motion instruments in 1966.

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 amplitudes, 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 cm per 1.0 g, respectively.

Sensitivity of the seismographs is expressed as the deflection of the trace, or light spot, in centimeters for a constant acceleration of 1.0 g.

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

SEISMOGRAM ILLUSTRATIONS

Reproductions of records in this publication (figs. 25–28) 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.

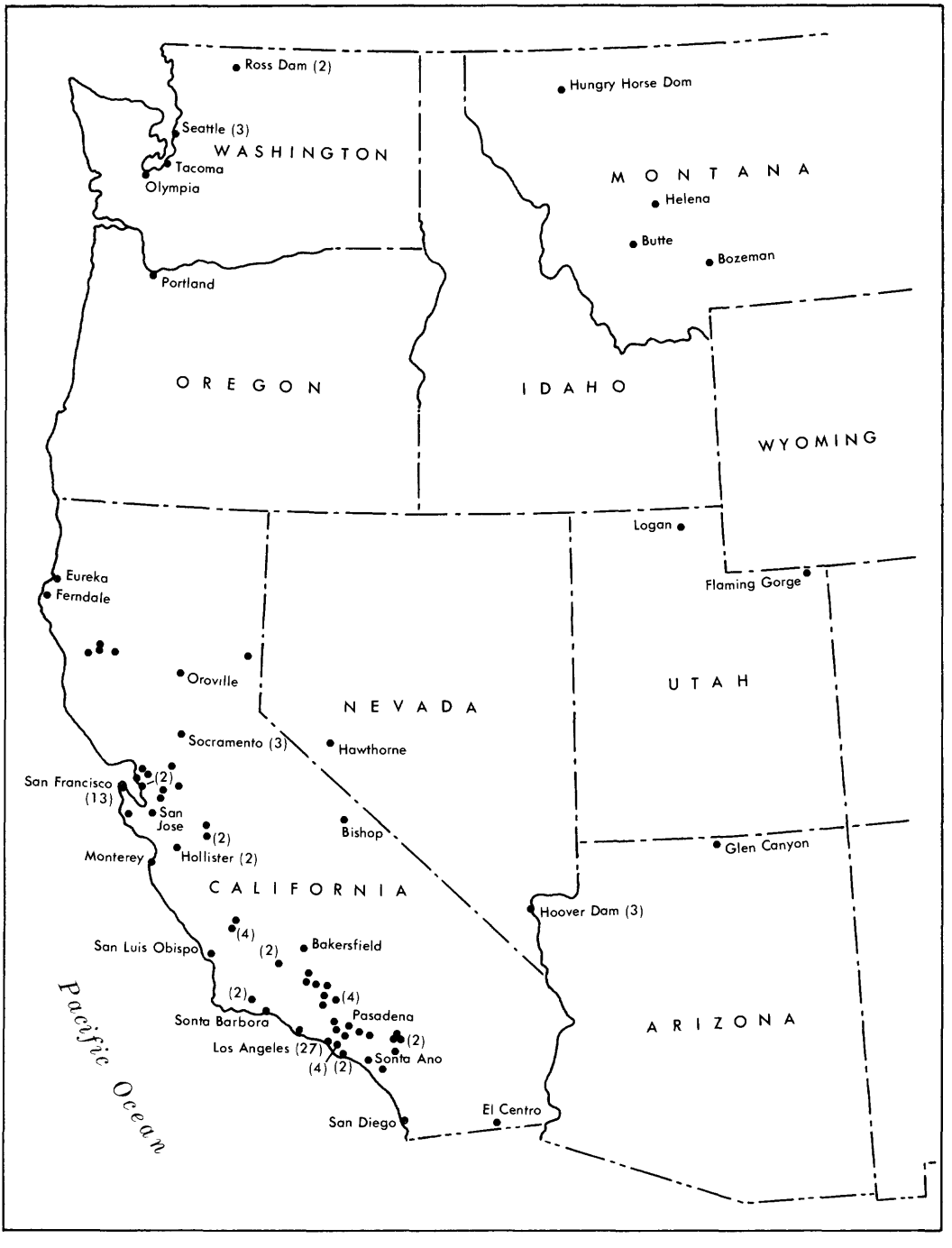

FIGURE 23.—Strong-motion stations in the western United States.

TABLE 3.—*Coast and Geodetic Survey and affiliated strong-motion stations in operation as of December 31, 1966*

Station	Accelero-graph	Displacement Meter	Weed	AR-240
NORTHERN CALIFORNIA				
Berkeley, University of California, Haviland Hall	1	1		
Bishop, Los Angeles Water Department, garage	1			
Chilcoot, Frenchman Reservoir, CWR	1			
Cholame-Shandon Array No. 2, CWR				1
Cholame-Shandon Array No. 5, CWR				1
Cholame-Shandon Array No. 8, CWR				1
Cholame-Shandon Array No. 12, CWR				1
Del Valle, Sanitorium Nurses Home, basement, CWR				1
Dos Rios, CWR				1
Eureka, Federal Building	1			
Ferndale, City Hall	1	1		
Franciscan, CWR				1
Gorman, Oso Pumping Plant				1
Grapevine, Tehachapi Pumping Plant, CWR				1
Hollister, San Andreas Geophysical Lab., University of California, Harris Ranch				*
Hollister, City Hall	1	1		1**
Livermore, Lawrence Radiation Laboratory, Building 110, basement	1			
Los Banos, San Luis Reservoir Pumping and Generating Plant, CWR				1
Monterey, City Hall			1	
Newville, CWR				1
Oakland, City Hall, basement	1	1		
Oakland, Chabot Observatory			1	
Orestimba, CWR	1	1		
Oroville, Seismograph Station, CWR	1	1		
Pleasant Hill, Diablo Valley College	1	1		
Redwood City, KGEI Radio Station				1
Redwood City, Sequoia Hospital				1
Redwood City, Yacht Harbor				1
Sacramento, Federal Building			1	
Sacramento, Pacific Telephone and Telegraph Building, basement	1	1		
Roof				1
San Francisco, Alexander Building, basement	1	1		
11th floor	1			
16th floor	1			
San Francisco, Bethlehem Pacific Building, basement	1	1		
12th floor	1	1		
San Francisco, 450 Sutter Building, basement			1	
29th floor			1	
San Francisco, Federal Building	1	1		
San Francisco, Shell Building, basement			1	
21st floor			1	
29th floor			1	
San Francisco, Southern Pacific Building, basement	1	1		
San Francisco, State Building, basement		1		

* Mark II Prototype accelerograph.
** MO-2 Prototype accelerograph.

TABLE 3—*Continued*

Station	Accelero-graph	Displacement Meter	Weed	AR-240
NORTHERN CALIFORNIA—Continued				
San Jose, Bank of America Building, basement	1			
San Pablo, Contra Costa Junior College	1	1		
Spencer, CWR				1
Stockton, Empire Tract, CWR	1			
Temblor, Cholame, CWR				1
Tracy, Delta Pumping Plant, CWR	1	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, CWR				1
Cedar Springs, Allen Ranch, CWR				1
Colton, Southern California Edison Building	1	1		
El Centro, Imperial Valley Irrigation District Sub-station	1	2		
Encino, 16661 Ventura Blvd., basement				1
4th floor				1
8th floor				1
Fairmont Station, Fairmont Reservoir	1	1		
Glendale, 633 E. Broadway, Municipal Services Building				1
Lake Hughes Array No. 1, Post Office Building, CWR				1
Lake Hughes Array No. 4, CWR				1
Lake Hughes Array No. 9, CWR				1
Lake Hughes Array No. 12, CWR				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			
Penthouse	1			
Adjacent Pacific Electric lot	1			
Los Angeles, Occidental Life Building, basement	1			
11th floor	1			
Los Angeles, Subway Terminal, subbasement	1	1		
Los Angeles, Water and Power Building, "B" level				1
8th floor				1
15th floor				1
Los Angeles, Westwood Engineering Building, University of California	1	1		
Los Angeles, 808 S. Hill				1
4th floor				1
8th floor				1
Los Angeles, 1640 Marengo, 1st floor				1
4th floor				1
Penthouse				1

TABLE 3—*Continued*

Station	Accelero-graph	Displacement Meter	Weed	AR-240
SOUTHERN CALIFORNIA—Continued				
Los Angeles, 445 Figueroa, subbasement				1
19th floor				1
39th floor				1
Los Angeles, 3407 W. 6th, basement				1
4th floor				1
Penthouse				1
Los Angeles, 3710 Wilshire, 5th floor				1
10th floor				1
Los Angeles, Univ. of Southern California, Vivian Hall, basement				1
4th floor				1
Roof				1
Pasadena, California Institute of Technology, Faculty Club Building	1		1	
Pearblossom, Pumping Plant, CWR				1
Perris, Perris Reservoir, CWR				1
Port Hueneme, Navy Laboratory	1	1		
San Bernardino, Devils Canyon, CWR				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 Company, Nuclear Generating Station				1
Santa Ana, Orange County Engineering Building	1	1		
Santa Barbara, Court House	1			
Taft, Buena Vista, CWR				1
Taft, Lincoln School Tunnel	1			
Tejon, Fort Tejon, CWR				1
Vernon, Central Manufacturing District Terminal Building	1			
Wheeler Ridge, CWR				1
OUTSIDE CALIFORNIA				
Alaska:				
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, Auke Bay				1
Ketchikan, U.S. Coast Guard Base, BOQ				1
Kodiak, U.S. Naval Base, Building 470				1
McKinley Park, University of Alaska				1

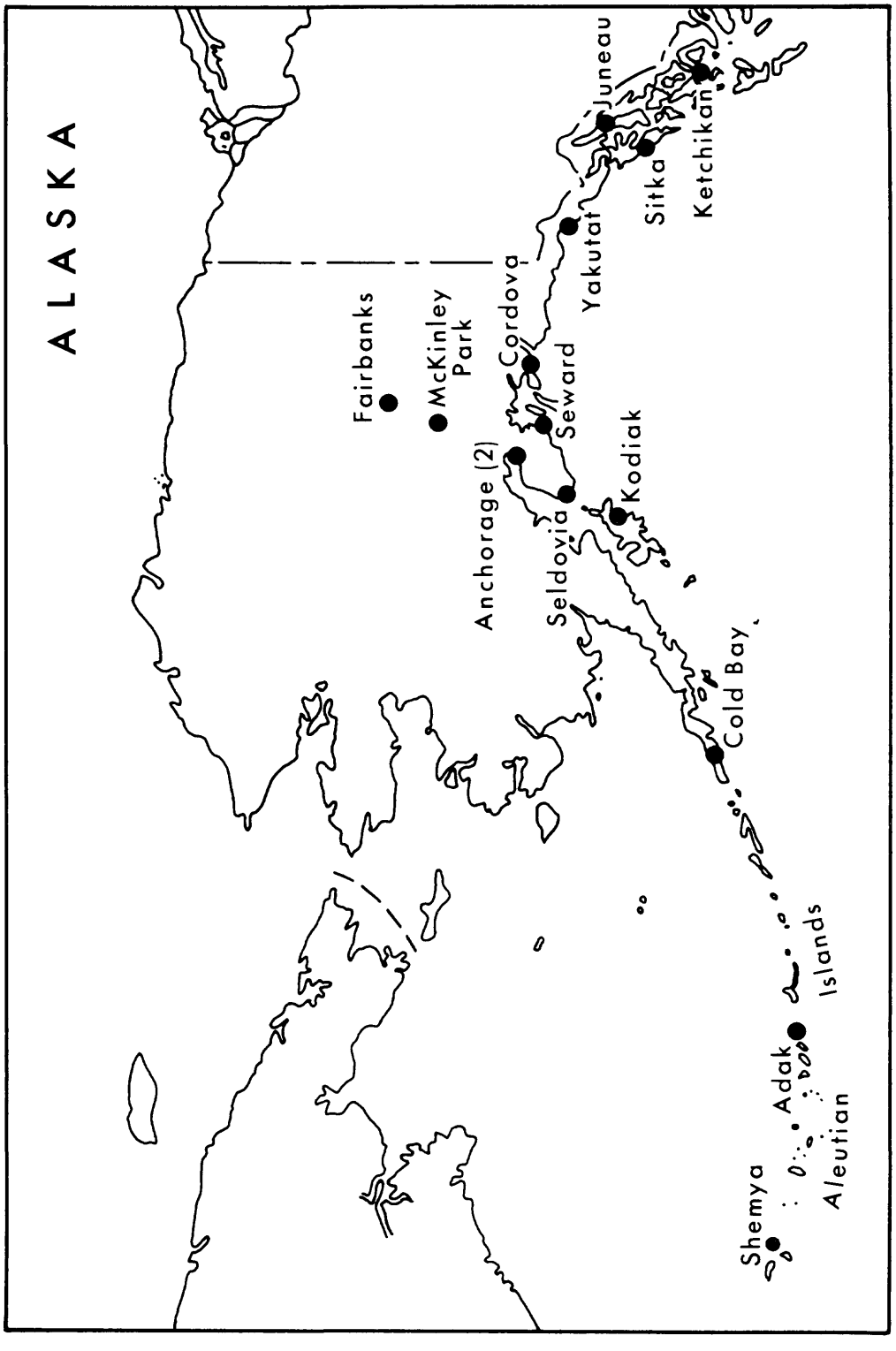

FIGURE 24.—Strong-motion stations in Alaska.

TABLE 3—*Continued*

Station	Accelero-graph	Displacement Meter	Weed	AR-240
OUTSIDE CALIFORNIA—Continued				
Seldovia, High School Gym, basement				1
Seward, Wesleyan Hospital				1
Shemya, Composite Heights				1
Sitka, Coast and Geodetic Survey Observatory				1
Yakutat, Federal Aviation Association Hangar				1
Arizona:				
Glen Canyon	1	1		
Montana:				
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			
Nevada:				
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		
Oregon:				
Portland, State Office Building	1			
Utah:				
Flaming Gorge	1	1		
Logan, Utah State University, Administration Building	1			
Washington:				
Olympia, Highway Test Laboratory	1			
Ross Dam, Block 16, Crest Station	1			
Ross Dam, Right Bank Station	1			
Seattle, Federal Office Building	1	1		
Seattle, Port of Seattle Dry Commodity Building	1			
Seattle, First National Bank, 4825 Rainier Avenue, S	1			
Tacoma, County-City Building	1	1		
OUTSIDE THE UNITED STATES				
Bogota, Colombia, South America	1			
Caracas, Venezuela, 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	73

TABLE 4.—*List of shocks recorded and records obtained on strong-motion seismographs in 1966*

Date 1966	Region and Recording Station	Records			
		Accelero-graph	Survey Displacement Meter	Carder Displacement Meter	Weed
June 27	Northern California, Cholame-Shandon Array No. 2	1 *			
	Cholame-Shandon Array No. 5	1 *			
	Cholame-Shandon Array No. 8	1 *			
	Cholame-Shandon Array No. 12	1 *			
	Hollister, City Hall	1		1	
	Temblor, Cholame	1 *			
	Southern California, Bakersfield	1	1		
	Cachuma Dam, Crest Station	1		1	
	Cachuma Dam, Valve House Station	1		1	
	Castaic, Old Ridge Route	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 Bldg., basement	1			
	Los Angeles, Occidental Life Bldg., 11th floor	1			
	Los Angeles, Water and Power Bldg., "B" level	1			
	Los Angeles, Water and Power Bldg., 7th floor	1			
	Los Angeles, Water and Power Bldg., 15th floor	1			
	Los Angeles, Westwood Engineering Bldg., University of California	1		1	
	Pasadena, California Institute of Technology, Faculty Club Bldg	1			
	Port Hueneme, Navy Laboratory	1		1	
	Santa Barbara, Court House	1			
	Taft, Buena Vista	1 *			
	Taft, Lincoln School Tunnel	1			
Oct. 17	South America, Lima, Peru	1			

* Instrument is AR–240.

TABLE 5.—*Summary of outstanding instrumental and noninstrumental data for 1966*

Epicenter	Recording station and distance	Location of instrument	Intensity[1]	Acceleration	Displacement[2]
		PARKFIELD, CALIF., EARTHQUAKE OF JUNE 27			
				cm/sec²	*cm*
35°54′ N., 120°54′ W., central California, W., VII*. Mag. 5.3.	Cholame-Shandon Array No. 2, 0.05 mile.	Small metal building, about 1 mile northeast of Cholame.	VII	490	----------
		LIMA, PERU, EARTHQUAKE OF OCTOBER 17			
10.7° S., 78.7° W., near coast of Peru, W., IX*. Mag. 7.5, P.	Lima, 140 miles----	Exposition Park, Lima, in wood-frame building.	VIII	397	----------

[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 the maximum reported intensity of the earthquake.

TABLE 6.—*Composite of strong-motion instrumental data for 1966*

Station and component	Instrument No.	T_0	V	Sensitivity	ϵ	Acceleration		Displacement		Remarks
						Period	Amplitude	Period	Amplitude*	
PARKFIELD, CALIF., EARTHQUAKE OF JUNE 27										
		sec		*cm/g*		*sec*	*cm/sec²*	*sec*	*cm*	
Cholame-Shandon Array No. 2:										
N 65° E	210	0.0643	77	7.91	9.0	0.60	490			
Down	254	0.0557	102	7.07	7.5	0.10	343			
N 25° W	211	0.0634	78		8.5					Not in operation
Cholame-Shandon Array No. 5:										
N 85° E	258	0.0531	119	7.61	10.5	0.30	451			
Down	156	0.0540	102.5	8.07	6.5	0.10	176			
N 5° W	164	0.0510	108.5	7.68	3.5	0.30	392			
Cholame-Shandon Array No. 8:										
N 50° E	313	0.0506	118	7.64	10.5	0.10	265			
Down	396	0.0520	109	7.20	10.5	0.10	137			
N 40° W	368	0.0511	113	7.54	8.0	0.20	274			
Cholame-Shandon Array No. 12:										
N 50° E	241	0.0583	91	8.00	10.0	0.30	59			
Down	140	0.0570	94	7.59	9.0	0.10	49			
N 40° W	237	0.0558	99	7.70	8.5	0.20	59			
Temblor:										
N 65° W	201	0.0601	85	7.64	7.0	0.30	284			
Down	214	0.0601	85	7.57	9.5	0.20	157			
S 25° W	200	0.0582	88	7.81	9.0	0.20	392			
San Luis Obispo:										
Up	295	0.0804	114	18.7	9.5	0.20	7			
S 54° E	296	0.0792	120	19.1	9.0	0.14	15			
N 36° W	297	0.0799	116	18.7	9.5	0.30	15			
Los Angeles, UCLA:										
Up	262	0.0850	120	22.0	10					Not measurable
North	263	0.0820	119	20.4	10					
East	264	0.0820	123	21.2	10					
West	60	4.63	0.96		11			2.82	0.13	
North	71	4.55	0.97		13			2.43	0.06	

TABLE 6—*Continued*

Station and component	Instrument No.	T_0	V	Sensitivity	ϵ	Acceleration		Displacement		Remarks
						Period	Amplitude	Period	Amplitude*	
PARKFIELD, CALIF., EARTHQUAKE OF JUNE 27—Continued										
		sec		*cm/g*		*sec*	*cm/sec²*	*sec*	*cm*	
Taft:										
Up	298	0.0792	115	17.9	10	0.69	3			
N 21° E	299	0.0800	122	19.4	9	0.62	10			
S 69° E	300	0.0813	122	20.0	9	0.58	11			
Santa Barbara:										
Up	259	0.0637	115	11.7	10	0.69	2			
N 42° E	260	0.0635	116	11.6	7.5	0.60	4			
S 48° E	261	0.0640	119	12.1	8.5	1.09	4			
Port Hueneme:										
Up	1001	0.0810	118	19.2	10	0.47	1			
South	1002	0.0800	120	19.1	9	0.78	3			
West	1003	0.0810	119	19.4	10	0.99	5			
West	32	2.50	0.95		10			2.49	0.47	
North	33	2.33	0.95		10			1.85	0.19	
Pasadena:										
Up	325	0.0820	122	20.2	9					Not measurable
South	326	0.0791	118	17.8	10	0.87	1			
West	327	0.0808	119	19.3	8	0.84	1			
Los Angeles (Occidental Life Bldg., basement):										
Up	205	0.0634	123	12.3	7					Not measurable
N 36° E	204	0.0642	122	12.4	11					
S 54° E	203	0.0652	123	13.0	7	1.25	1			
Los Angeles (Occidental Life Bldg., 11th floor):										
Up	187	0.046	120	6.5	9					Not measurable
S 38° W	186	0.046	122	6.4	9	1.34	5			
N 52° W	185	0.046	122	6.5	10	1.27	7			
Los Angeles (Water and Power Bldg., basement):										

N 50° W	323	0.0520	115	7.71	10					Not measurable
Down	346	0.0535	108	7.66	11					
S 40° W	288	0.0549	106	7.95	10.5					
Los Angeles (Water and Power Bldg., 7th floor):										
N 50° W	242	0.0571	96	7.75	9.5					Not measurable
Down	233	0.0562	99	7.75	10.0					
S 40° W	316	0.0520	117	7.85	10.0					
Los Angeles (Water and Power Bldg., 15th floor):										
N 50° W	285	0.0519	113	7.55	10.5	2.48	1			
Down	290	0.0528	111	7.68	9.5					Not measurable
S 40° W	310	0.0521	113	7.61	9.5	2.08	2			
Hollywood Storage Co. (basement):										
Up	217	0.0648	121	12.6	10					Not measurable
East	216	0.0667	122	13.5	10	0.85	1			
South	215	0.0634	122	12.1	7					Not measurable
Hollywood Storage Co. (penthouse):										
Up	193	0.0451	121	6.1	10					
South	192	0.0458	123	6.4	10	1.37	4			
West	191	0.0448	124	6.2	10	0.50	3			
Hollywood Storage Co. (adjacent P. E. lot):										
Up	214	0.0643	121	12.4	10					Not measurable
East	213	0.0655	121	12.9	8	0.95	1			
South	212	0.0662	120	13.0	12					Not measurable
Hollister (City Hall):										
Up	238	0.0678	122	13.9	8.0					Not measurable
S 1° W	230	0.0655	124	13.2	7.5	0.44	3			
N 89° W	240	0.0657	122	13.0	8.0	0.67	3			
N 89° W	5	2.20	1.0		10			0.15	0.15	
N 1° E	6	2.12	1.0		12			0.80	0.09	
Castaic:										
South	165	0.0512	123	8.00	10.0	0.65	4			
Down	159	0.0509	123	7.89	7.5					Not measurable
East	172	0.0501	123	7.65	8.5					
Cachuma Dam (valve house):										
Up	364	0.0612	117	10.9	8.5	1.06	2			
North	365	0.0615	119	11.2	8.0	0.67	1			
East	366	0.0633	121	12.1	8.0	1.07	2			
West	9	5.60	1.0		8.5			2.52	0.24	

TABLE 6—*Continued*

Station and component	Instrument No.	T_0	V	Sensitivity	ϵ	Acceleration		Displacement		Remarks
						Period	Amplitude	Period	Amplitude*	
PARKFIELD, CALIF., EARTHQUAKE OF JUNE 27—Continued										
		sec		*cm/g*		*sec*	*cm/sec²*	*sec*	*cm*	
Up	2	1.90	1.1		4.0			1.27	0.08	
North	30	5.47	1.0		9.5			1.71	0.17	
Cachuma Dam (Crest Station):										
Up	361	0.0638	118	12.0	7.0	0.77	2			
North	362	0.0626	117	11.5	8.5	0.95	6			
East	363	0.0604	118	11.8	8.5	0.77	5			
East	15	2.55	0.83		9.0			1.23	0.15	
South	14	2.32	0.89		7.5			1.16	0.13	
Buena Vista:										
South	135	0.0508	101	6.46	7.5	0.53	2			
Down	133	0.0510	101	6.52	8.0					
East	169	0.0516	94	6.20	5.5	1.08	6			
Bakersfield:										
Up	342	0.0673	114	12.8	8.5					Not measurable
South	352	0.0663	119	12.9	8.5	0.70	2?			
West	353	0.0648	120	12.6	10.0	0.34	1?			
West	LDM	10.2	1.0		14.0			7.10	0.60?	
South	RDM	10.2	1.0		10.0			7.20	0.90?	
Hollister (City Hall):										
N 1° E	AR-240	0.058	89	7.5	10.0	0.39	2			
Down	AR-240	0.059	88	7.5	14.0					Not measurable
N 89° W	AR-240	0.058	89	7.5	14.0	0.44	3			
LIMA, PERU, EARTHQUAKE OF OCTOBER 17										
Lima, Peru (Exposition Park):										
Up	286	0.065	120	12.4	7	0.13	128			
N 82° W	287	0 064	123	12.6	8	0.10	264			
N 8° E	288	0 064	122	12.5	10	0 08	397			

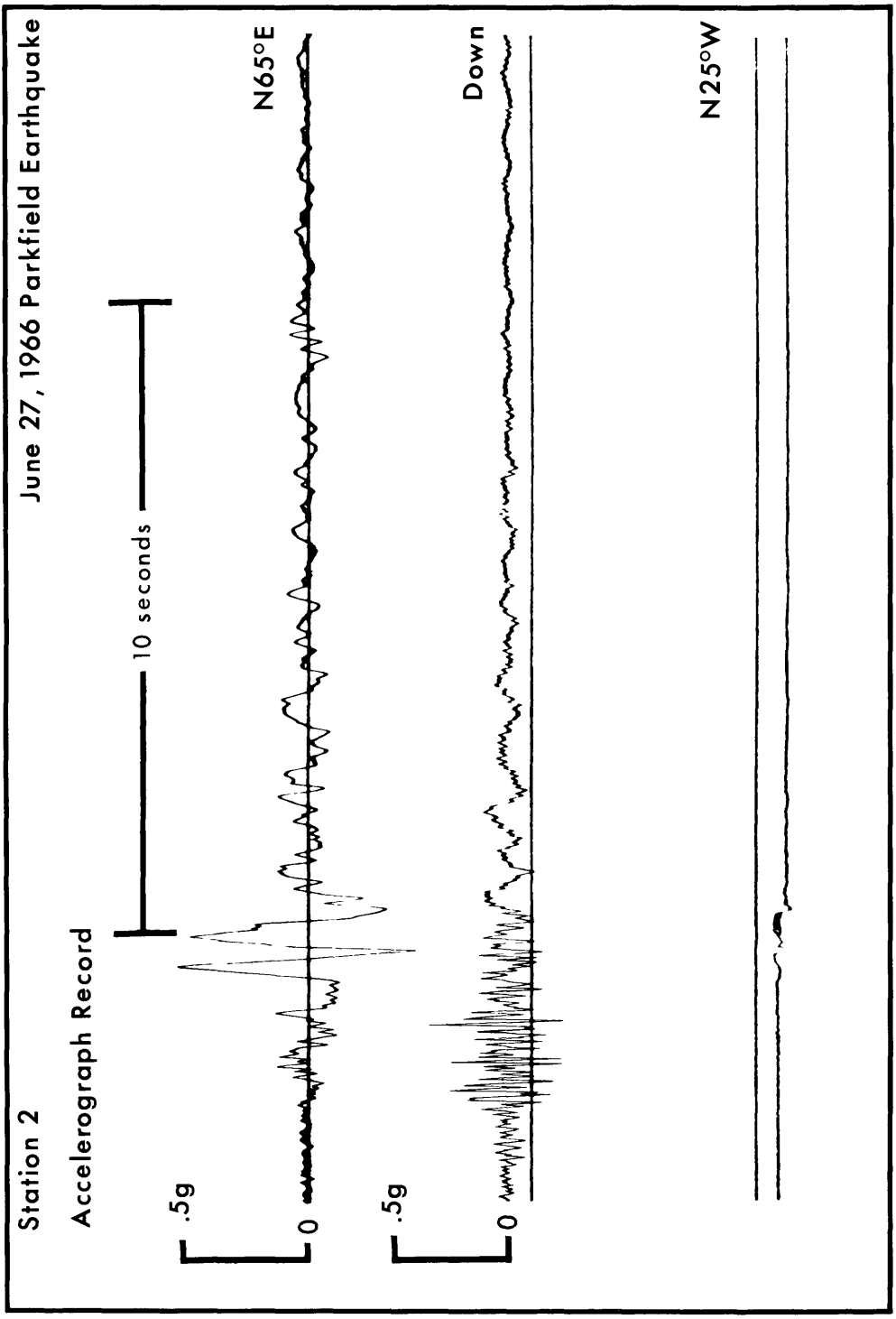

FIGURE 25.—Photocopy of Cholame-Shandon Array No. 2 accelerogram. Pendulum recording lower N.25°W. Trace was not in operating condition during the earthquake at Parkfield, Calif., on June 27.

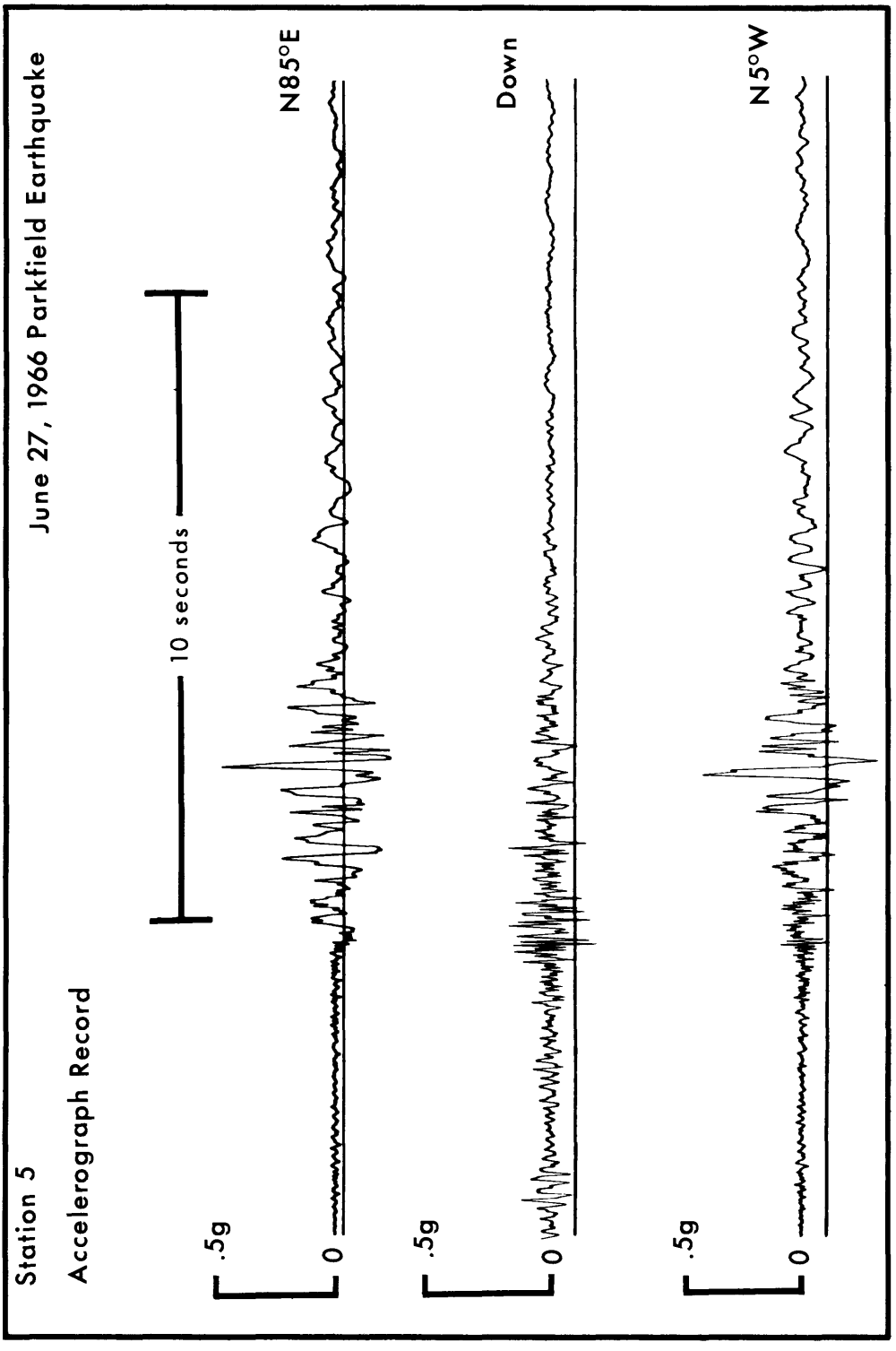

FIGURE 26.—Photocopy of Cholame-Shandon Array No. 5 accelerogram.

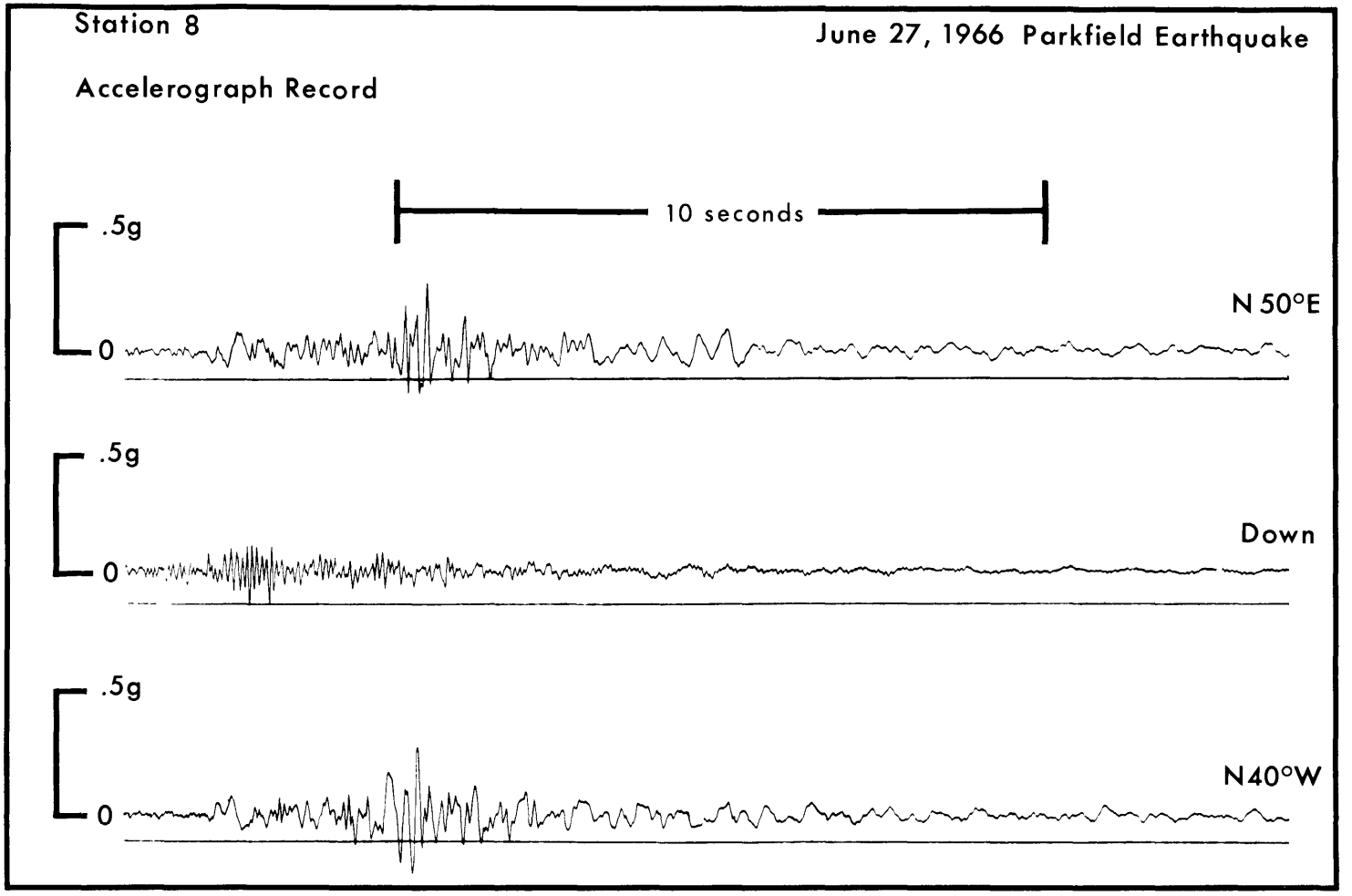

FIGURE 27.—Photocopy of Cholame-Shandon Array No. 8 accelerogram.

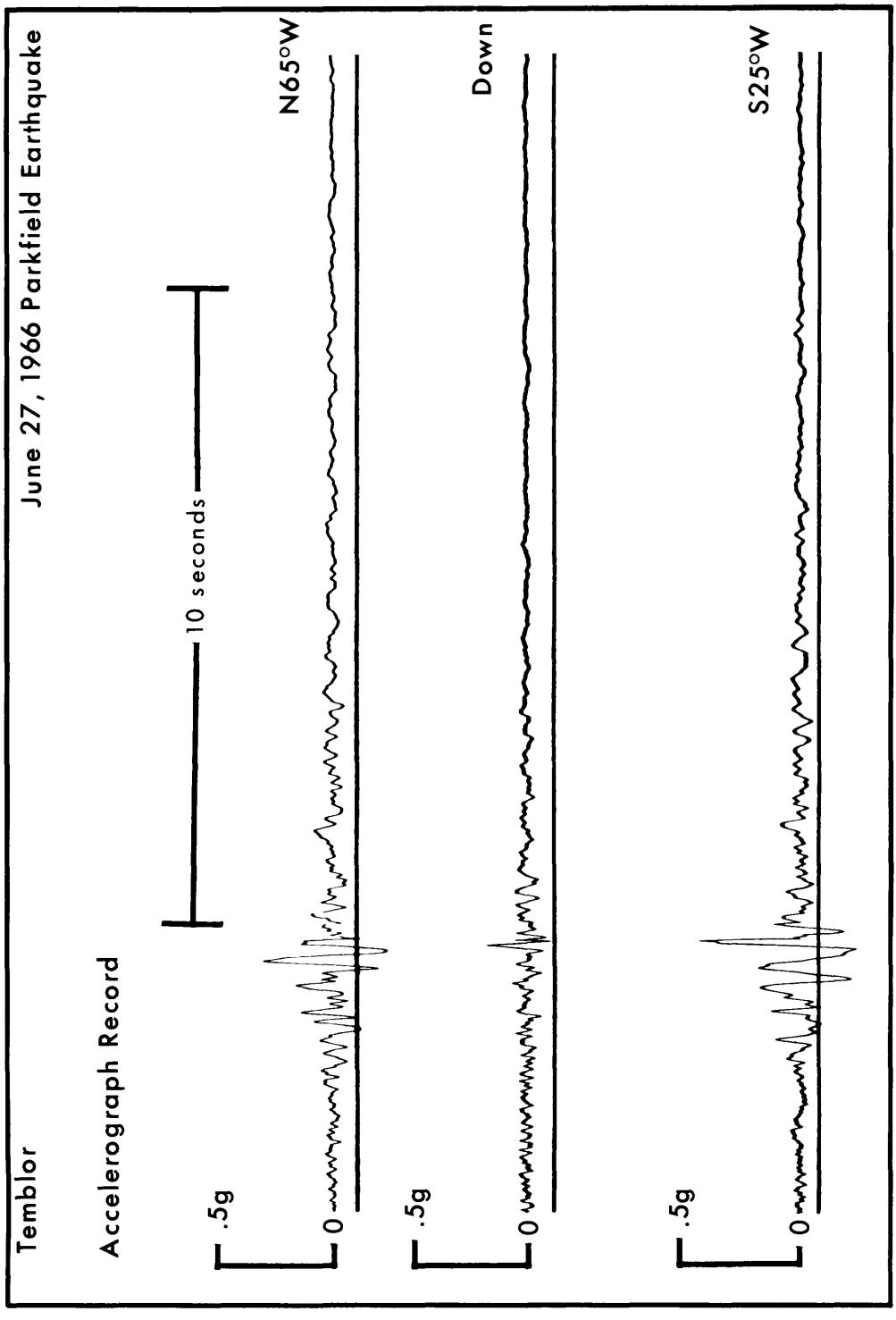

FIGURE 28.—Photocopy of Temblor accelerogram.

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