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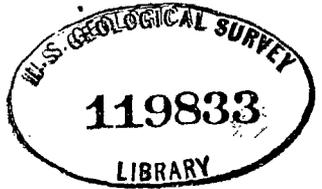
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UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

EARTHQUAKES IN CALIFORNIA

IN

1889

BY

JAMES EDWARD KEELER

ASTRONOMER IN CHARGE OF EARTHQUAKE OBSERVATIONS, LICK
OBSERVATORY



WASHINGTON
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EARTHQUAKES IN CALIFORNIA IN 1889.

BY J. E. KEELER.

INTRODUCTION.

The following paper is a continuation of the list of earthquakes in California, published by Prof. E. S. Holden, containing all the available data up to the end of the year 1888,¹ and it brings the list up to the end of 1889. It contains all the shocks recorded or felt on Mount Hamilton, and all those reported to the Lick Observatory by letter, as well as newspaper reports of such earthquakes as occurred in the State during that year. No systematic examination of the newspapers has been made, however, and reports may have escaped notice.

The instruments used for recording earthquakes on Mount Hamilton are described in vol. 1, publications of the Lick Observatory, p. 82. The largest and most complete instrument records the north and south, east and west, and vertical components of the earth's motion separately on a smoked-glass plate, which is started by the preliminary tremors of the earthquake and rotates uniformly in about three minutes, the edge of the plate being graduated into seconds at the same time by a clock, which also serves to record the time of occurrence of the shock. This instrument has been called the Ewing seismograph in the notes. Another simpler form consists of a heavy "duplex" pendulum adjusted to a long period of vibration, with a magnifying pointer or pen, which records on a smoked glass plate both horizontal components of the motion. The vertical component and the time are not recorded.

The observatory possesses other seismographs of various patterns, but they are not constantly in use.

SCALE OF MEASUREMENTS.

In the record made by the Ewing seismograph both horizontal components are magnified 3.3 times, and the vertical component is magnified 1.6 times. The measures of the vibrations as given in the notes

¹ List of recorded earthquakes in California, Lower California, Oregon, and Washington Territory. Sacramento: State Printing Office. (1887.)

Earthquakes in California, (1888). Am. Journal of Science, vol. 37, May, 1889.

are taken directly from the tracings, and therefore represent the magnified motion.

If both the period T and the amplitude a of an earthquake wave are given, the maximum acceleration due to the impulse, which may be taken as a measure of the intensity or destructive effect of the shock, is given by the formula—

$$I = \frac{4\pi^2 a}{T^2}$$

in which the motion is assumed to be simple harmonic.

DIFFERENCES OF INTENSITY.

Estimates of the intensity of shocks are also given (in Roman numerals inclosed in parentheses) according to the Rossi-Forel scale, which for convenience of reference is here inserted. Prof. Holden has suggested that for observations in California (only) a few additions should be made to this scale, and his suggestions are printed here *in Italics*. When these are in quotation marks they refer to expressions used in the newspapers, etc., in describing earthquake shocks.

I.

Microseismic shock recorded by a single seismograph, or by seismographs of the same model, but not putting seismographs of different patterns in motion; reported by experienced observers only.

II.

Shock recorded by several seismographs of different patterns; reported by a small number of persons who are at rest. "*A very light shock.*"

III.

Shock reported by a number of persons at rest; duration or direction noted. "*A shock;*" "*a light shock.*"

IV.

Shock reported by persons in motion; shaking of movable objects, doors and windows; cracking of ceilings. "*Moderate;*" "*strong;*" "*sharp*" (sometimes); "*light.*"

V.

Shock felt generally by every one; furniture shaken; some bells rung. *Some clocks stopped; some sleepers waked;* "*smart;*" "*strong;*" "*heavy;*" "*severe;*" "*sharp;*" "*quite violent.*"

VI.

General awakening of sleepers; general ringing of bells; swinging of chandeliers; stopping of clocks; visible swaying of trees; some persons run out of buildings. *Window-glass broken;* "*severe;*" "*very severe;*" "*violent.*"

VII.

Overturning of loose objects; fall of plaster; striking of church-bells; general fright, without damage to buildings. *Nausea felt*; "violent;" "very violent."

VIII.

Fall of chimneys; cracks in the walls of buildings.

IX.

Partial or total destruction of some buildings.

X.

Great disasters; overturning of rocks; fissures in the surface of the earth; mountain slides.

The relation between the intensity (I) of a shock as determined by the formula already given, and the numbers of the Rossi-Forel scale, has been deduced from all available data up to 1888, by Prof. Holden, and is given below in tabular form.

Rossi-Forel scale.	Intensity.	Diff.
	<i>mm per sec.</i>	
I	20	
II	40	20
III	60	20
IV	80	20
V	110	30
VI	150	40
VII	300	150
VIII	500	200
IX	1,200	700

One of the objects of the earthquake observations on Mount Hamilton is to obtain data for correcting this table, so that the intensity of a shock as defined mathematically by the formula $I = \frac{V^2}{a}$ can be inferred from the ordinary description of its effects. On referring to the list it will be seen that for those occasions on which records were obtained with the Ewing seismograph, the computed intensity always falls considerably below the corresponding number of the Rossi-Forel scale, obtained at the same time by an independent estimate. This is probably due to the fact that the period of the undulation has a great effect in determining the intensity, as will be seen from the formula, where T enters the denominator in the second power. Many small waves with short periods might give a greater value of I than the maximum wave measured. The motion is far from being simple harmonic.

The following are the only shocks in 1889 which give a means of comparing the two scales :

Date.	Computed intensity.	Estimated intensity.
April 3, 2:29 a. m.	7.0=(I)	(II)
April 14, 7:28 p. m.	4.0=(I)	(III)
May 26, 7:13 a. m.	2.5=(I)	(II)
June 10, 7:34 a. m.	12.=(I)	(II)
July 25, 10:8 p. m.	53=(II-III)	{ (V) E. S. H., (IV) J. E. K., (V) E. S. H.
July 31, 4:47 a. m.	88=(IV+)	

As these are the only earthquakes observed in both ways, a comparison of the scales will be deferred until more data shall have accumulated.

A number of duplex-pendulum seismographs, quite similar to the one used at the Lick Observatory, are placed at different points on the Pacific coast, but they are not all in operation. The stations from which reports have been received during the year 1889 are as follows :

Student's Observatory, Berkeley, in charge of Prof. Soulé. *

Chabot Observatory, Oakland, in charge of Mr. Burekhalter.

Private observatory of Mr. Blinn, in East Oakland.

Observatory of the University of the Pacific, San José, in charge of Prof. Higbie.

Observatory of Mills College, near San Francisco, in charge of Prof. Keep.

Office of State Weather Bureau, Carson, Nev., in charge of Prof. Friend.

Much of the completeness of the reports is due to Mr. F. G. Blinn, who has not only furnished the records of his own instrument, and careful observations made by himself, but has collected information from various reliable sources and sent it to this observatory. I have also to thank the officers of the Geological Survey for the insertion of a number of reports furnished by the Light-House Board and the U. S. Signal Service.

CHRONOLOGIC RECORD.

1889. January 19, 1:43 a. m. Oakland.—A slight shock recorded on the seismograph of F. G. Blinn. (II.)

January 22, 7:51:58 p. m. (?), Mount Hamilton.—A very light shock suspected by C. B. Hill (I ?). No record was found on the seismographs.

February 6, 9:20 p. m. Southern California.—A distinct shock at 9:25 p. m., shaking buildings and causing people to run into the streets. Vibrations from north to south, lasting about ten seconds. (VI.) San

Bernardino papers. Colton: Two distinct shocks at 9:20 p. m. Los Angeles: Slight shock at 9:25 p. m. Shock accompanied by distinct dull rumbling. Post-office clock at San Bernardino stopped at 9:20:30, subject to an error of five or six seconds. The clock faced the east. W. C. Parmley, San Bernardino. At Kodiak Island earthquake waves were recorded from February 5, 9 p. m., to February 6, 7 a. m.

April 3, 2:29 a. m. Mount Hamilton.—A slight record was made on the Ewing and duplex pendulum seismographs. (II.) The greatest motion was from north to south, a very slight motion from east to west, and the vertical component was imperceptible. The maximum (magnified) amplitude was about one-fourth millimeter, and the period of a vibration about two-thirds of a second; hence, the computed intensity is 7.0 or (I) by the Rossi-Forel scale. This shock was not felt by any body at the observatory. The time given is that recorded by the seismograph clock.

April 14, 7:28 p. m. Central California.—Lick Observatory, time of ending 7:27:56 (E. S. Holden), 7:28½ (E. E. Barnard). Felt by many persons at the observatory, but not by all. Recorded on both seismographs. (III.)

The curve representing the north and south motion on the Ewing seismograph begins with three quite regular waves of progressively diminishing amplitudes, the period of each being 1.25 seconds. The maximum (magnified) amplitude is 0.5 millimeters. The east and west curve begins with a series of small, irregular tremors, followed by two marked and fairly regular waves which begin about where the waves of the north and south curve end. Maximum (magnified) amplitude, 0.4 millimeters. The vertical motion is very slight. The marked vibrations on all the curves end at about ten seconds, but very slight undulations extend to about one and one-half minutes. It is hard to say how much of these is real. The intensity of this shock, computed from the data above given, is 4.0 or (I) of the Rossi-Forel scale.

San José, 7:27:30 (S. W. Burnham). San José, University of the Pacific.—The record on the duplex pendulum seismograph at this place is considerably larger than that obtained at the Lick Observatory, and is very complicated. The San José Times says: "The shock was not severe but was quite plainly felt by many people. A majority of people, however, were unconscious of anything unusual."

Santa Cruz.—Quite a severe shock, with quick, jerky motion from east to west, rattling the windows in loosely built houses. Time, 7:25. Probably the heaviest shock felt in Santa Cruz in four or five years, although many people on the first floor of well built houses did not notice it.—Santa Cruz Surf.

An earthquake occurred at 7:30 p. m. The vibration was north and south and lasted several seconds.—Dispatches from Santa Cruz.

Centerville.—Slight earthquake at 7:34. Vibrations northeast to southwest.

Los Gatos.—Two slight but distinct earthquakes at about 7:15. Vibrations from south to north.

Gilroy.—Remarkably sharp but short earthquake at 7:25, making lamps, crockery, etc., rattle severely.

Merced.—A heavy, double-shock earthquake at 7:33. Oscillation, northwest to southeast, and about two seconds in duration.—Dispatches to San Francisco papers.

Oakland.—Earthquake at about 7:28, not felt by all persons.—F. G. Blinn. The record on Mr. Blinn's seismograph shows about the same amount of motion as at the Lick Observatory.

April 17, 8:32:38 p. m. Mount Hamilton.—Noted by J. M. Schaeberle, while observing the collimation constant of the meridian circle. The wires vibrated through about 10". Time noted, 8:32:40. Suspected in another part of the building by J. E. K. Time noted, 8:32:36. No perceptible record on the seismographs. (I.)

April 20, 4 a. m. University of the Pacific, San José.—Prof. Higbie sends a record obtained with his seismograph, showing a considerable disturbance. I have no other notices of this earthquake.

April 24. San Francisco.—“Heavy earthquake shock occurred at 3:37 a. m. Vibrations from north to south.”—Jenkins. Received at Washington Signal Office by General Greely.

May 1. Lompoc.—Quite a heavy earthquake shock was felt here at 11:55 to-day. The vibrations were from east to west. No damage was done.

Susanville.—At 9 o'clock a sharp earthquake was experienced. The vibration was north and south.

May 19, 3:10 a. m. Central California.—At the Lick Observatory nobody was awakened, although the motion as registered by the seismographs was considerable. This is probably owing to the long period of the vibrations. The time recorded by the earthquake clock was 3:9:6.

The following letter was furnished by Prof. Holden to the California Associated Press:

Lick Observatory.—The earthquake was felt at the Lick Observatory at nine minutes past 3 o'clock this morning, as a series of gentle shocks of small amplitude and slow period. It was not severe enough to awake the sleepers. The extraordinary feature of this shock was its great duration, which is registered on our instruments for no less than two minutes and twelve seconds. In this feature it resembles the great Inyo shock of March 26, 1872, as experienced in San Francisco, and for a similar reason. The observing station was in both cases far removed from the origin of the shock, and the energy of the earthquake was manifested in long waves of slow period, but lasting for an unusual time. Moreover, in this case the shock was far more severe in Santa Clara Valley than after it had traversed several ranges of hills and reached Mount Hamilton. Our earthquake machine shows that the up and down movement lasted eighty-four seconds. The period of each wave was about 1.7 seconds, which is very gentle and slow, and the double amplitude of the vertical waves was never more than 0.03 of an inch. The east and west movement consisted of strong tremors for nearly four seconds, when the waves began and lasted as strong

decided movements for twenty-nine seconds, after which the tremors continued until their trace was lost. Ninety seconds after the beginning, the period of these waves is 0.8 of a second (very slow) and the double amplitude is about 0.03 of an inch. The most remarkable motions were in the north and south direction. The tremor was felt for three seconds, ten large waves for forty-five seconds succeeded by tremors until one hundred and thirty-two seconds from the beginning. Their period was 0.6 of a second. The double amplitude is 0.05 of an inch. The duplex machine shows results agreeing with the above and indicates the very complex nature of the motion of the ground.

The vibration of greatest amplitude occurred only five seconds after the plate of the Ewing seismograph started, and is nearly as great in the east and west as in the north and south curve, while the vertical component is small. Paying due regard to the values of the different components, it appears that the maximum vibration (double amplitude) of the earth at the Lick Observatory was 2.2 millimeters, and the period being 0.6^s as stated above, the computed intensity of the shock is 120 or (V) of the Rossi-Forel scale.

Yerba Buena Island Light Station, San Francisco Bay; time, 3:14 a. m.—On a hill 220 feet above sea-level; going from dwelling to light-house to visit light when shock was observed; clay surface, 4 feet to solid rock; everybody else at rest; one shock only; from eight to twelve seconds duration; one long, rolling shock with a sort of jumping motion also, but it still can only be called one shock; 3:14 a. m.; light-house clock did not stop; the motion was certainly from east to west; no damage.—J. A. F. McFarland.

Mare Island Light Station; time, 3:9:30 a. m.—Observer was awakened from a deep sleep on second floor of wooden building with brick foundation on clay. The shock was intermittent; sudden force slightly diminishing and then increasing and slowly dying away; the windows rattling; door-bell rang in a house near by.—Kate C. McDougal, light keeper.

Berkeley.—In the valleys the shock was more severe. The seismograph tracing of the university observatory at Berkeley shows a very complex curve, which can be roughly bounded by an ellipse 8 by 6 millimeters, with one great loop extending 7 millimeters farther (magnified four times).

Oakland.—The Chabot Observatory record has some resemblance to the above, but is larger, the bounding ellipse being 22 millimeters long, also with a loop extending toward the northwest. The mean-time clock of the Chabot Observatory stopped at 3:01:44. Error of clock inappreciable.—C. Burckhalter.

East Oakland.—The record obtained at Mr. Blinn's observatory somewhat resembles that just described, and indicates a shock of about the same intensity. Several loops extend about 20 millimeters from the center.

The shock lasted from five to twelve seconds, according to some persons, while others considered that the earth shook for fully a minute;

motion great but gentle; two persons felt nausea; four regulators in jewelers' shops, on walls running west-northwest and east-southeast, stopped at about 3:10, two of them indicating 3:10:30 and 3:10:35 respectively. A clock with heavy mercurial pendulum on same wall was not stopped.—F. G. Blinn. Intensity=(VI).—William Ireland.

Three miles from Collinsville, in the region of greatest disturbance, houses rocked and pieces of plaster fell (VII); articles shaken from mantel-pieces, etc.; chickens shaken from their perches; dogs barked; two chimneys demolished, and one had the upper part twisted 45 degrees; goods thrown from shelves in stores.—F. E. Booth, manager of Black Diamond Canning Company, in letter to F. G. Blinn.

Mill's College.—In the seismograph record at this place there are great loops 80 millimeters long, which appear to have been produced by the swinging of the pendulum after the shock. It is necessary to give the seismograph pendulums some stability, but they are adjusted to swing in a long period, much longer than that of the ordinary earthquake shock. It is evident, however, that in an earthquake like this the vibrations might be nearly synchronous with those of the pendulum, which would thus be thrown into violent oscillations. In most earthquakes this is not likely to happen. Possibly the long loops in some of the other seismograph records may be due to the same cause.

San Francisco.—No damage was done in the city. The newspaper accounts seem to be exaggerated. Motion from west-northwest to east-southeast.—J. B. Trembley.

Time of shock in San Francisco, 3:10:42.—Prof. Davidson.

Fort Point Light-Station.—The shock was preceded and accompanied by a rumbling noise and lasted eight or nine seconds. The keeper felt three shocks, the first short and light, and about fifteen seconds later one more distinct; a minute afterwards, the last, which was a tremor. Doors were opened; windows and crockery rattled and people were aroused from sleep.

Lime Point Fog-Signal Station.—Time, 3:10:32, corrected the previous day by time-bell on Telegraph Hill, San Francisco. Lasted about five seconds, and was accompanied with a noise like the rumbling of distant thunder. An undulatory movement that appeared vertical.

Forest Hill.—In the Mayflower mine no sign of an earthquake at 600 or 800 feet underground. Directly over the mine the shock was strong enough to rattle a wash-bowl against a pitcher.—S. E. Reamer, San Francisco.

San José, University of the Pacific.—Prof. Higbie sends a record which shows about the same amount of motion as at Oakland, the greatest oscillations being northeast and southwest.

San Francisco.—Various reports from the San Francisco papers are given below, the date, May 19:

At 3:12 a. m. Sunday morning a severe shock of earthquake was experienced here. It lasted twenty seconds and was followed by peculiar shivers continuing five sec-

onds longer. The motion was from east to west, and the shock is said to have been the sharpest experienced here for the past fifteen years. Half of the door-bells in the city were set ringing, and glassware and mirrors damaged. A slight shock was also experienced about eighteen minutes past 10 o'clock on Friday night. The motion was also from east to west.

Stockton.—A heavy shock of earthquake was felt here at 3:15 this morning. It lasted about ten seconds, with vibrations from north to south. A large number of people hurried into the streets. One man jumped out of a second-story window. A number of buildings were heard to crack, but no damage has been reported.

Lodi.—The heaviest earthquake that has been felt here for twenty years occurred at 3:15 this morning. The wave was north and south, and so severe that goods were shaken from shelves in one of the stores here, and dishes rattled in the houses.

Antioch.—The most severe earthquake shock experienced since the famous one of 1868 visited this place about 3:10 this morning. It shook off the tops of many chimneys in the town. The vibrations were from north to south. The entire population was aroused and many people in their night-gowns rushed into the streets, thinking their houses were coming down. No serious damage is reported, but the harvest of broken crockery and glassware, cracked plaster ceilings and chimneys, is abundant.

Modesto.—The people of this section were awakened by a heavy shock of earthquake at 3:15 this morning. The vibration was from north to south and lasted several seconds. The windows and doors rattled and chandeliers vibrated. A second shock, less pronounced, followed ten minutes later. No damage is reported.

Napa.—The severest earthquake experienced here in twenty years occurred at 3:10 this morning. It lasted twelve seconds. No damage is reported beyond the cracking of plaster. The vibrations were from west to east.

San Leandro.—The heaviest shock of earthquake felt here for years was experienced at 3:11 this morning. The vibrations were from north to south and lasted about one minute.

Petaluma.—This morning at 3:15 there were three distinct shocks of earthquake. They followed each other in quick succession, the vibrations being from east to west. The second shock was exceedingly heavy.

Rio Vista.—This community was startled at 3:15 a. m. by the most severe shock of earthquake since 1868, the duration of the shock being several seconds. People jumped from their beds, chickens were thrown from their roosts, and some chimneys were slightly damaged. The direction was from west to east.

Newark.—The most startling earthquake experienced for many years was felt here this morning at 3:05. There appeared to be three shocks, vibrating from east to west.

Nevada City.—Three distinct and rather heavy shocks of earthquake were felt here this morning at 3:30. Their direction was from west to east.

Calistoga.—An earthquake occurred at 3:03 this morning. It was not remarkably heavy, but the vibrations, which were from east to west, continued longer than those of any earthquake felt in many years.

Vacaville.—The earthquake shock this morning at 3:10 lasted fully half a minute. It was the most severe shock ever experienced here. The vibrations were from north-east to southwest.

Santa Cruz.—Quite a sharp shock of earthquake was felt here at 3:20 this morning, vibrating from west to east.

Sacramento.—An earthquake shock was felt here at 3:10 this morning. The wave came from the southeast and was quite severe. No damage was done.

Mountain View.—A heavy shock of earthquake, with vibrations north and south, was felt here at 3:10 this morning. No damage was done.

San José.—The earthquake passed through here at 3:12 to 3:14 a. m., the wave seeming to pass from southeast to northwest. There was but one distinct wave, followed by a rumbling and a backward motion, due to the reaction.

Pleasanton.—At 3:15 this morning there was felt here the worst earthquake shock

since 1868. The vibrations were north and south, and continued for fifteen seconds. They were so severe that buildings creaked and tottered.

Haywards.—A severe shock of earthquake startled the people of this town and valley this morning about fifteen minutes past 3 o'clock. It was strong enough to throw many out of bed, and lasted several seconds.

Los Gatos.—Three sharp earthquake shocks were felt here at 3 o'clock this morning. The first was much more severe than the two succeeding ones. The vibrations were north and south.

Fairfield.—Three heavy shocks of earthquake in quick succession were felt here at 10 minutes past 3 o'clock this morning, vibrating east and west. They were the heaviest since 1868.

Woodland.—There was quite a heavy earthquake felt here this morning at 15 minutes past 3 o'clock. The vibrations were from east to west, and the duration about fifteen seconds.

Santa Rosa.—Three distinct shocks of earthquake in close succession were felt at 3 o'clock this morning. The vibrations were from east to west.

Ione.—Many citizens were aroused at 3:10 this morning by an earthquake shock, lasting several seconds. The vibrations were north and south.

Suisun.—At 3:10 this morning a severe shock of earthquake was felt here, accompanied by a rumbling noise.

May 26, 7:13 a. m. Central California.—Lick Observatory. A very slight shock was recorded by the seismographs at $7:12 \pm 1$. The extreme motion of the earth's surface did not exceed 0.5^{mm} . The greatest disturbance was in a north and south direction, and the vertical component was very small. Although this shock was recorded on both instruments, it was not felt by any one on the mountain.

(II) Period = two seconds, hence computed intensity = 2.5 or (I).

San José and vicinity.—Not felt. San José Times.

San Francisco.—A slight shock of earthquake was felt in this city on Sunday morning at thirteen minutes six seconds after 7. The vibrations lasted but two or three seconds and were east and west. (Time noted by Professor Davidson).

Gonzales.—A heavy shock of earthquake was felt here this morning at 7:15. The tremor lasted half a minute and made the large buildings quiver. The oscillation was from northeast to southwest.

Santa Cruz.—Quite a shock of earthquake occurred at 7:15 this morning, the wave being west to east. No damage was done, the shock being much lighter than the one a week ago.

June 2, 5:54 p. m. Humboldt Light and Fog-Signal Station.—Was sitting at desk down-stairs; house on sand. It lasted about seven seconds. No previous noises; but with the quake came a noise of rushing wind or sudden gust. I would class the quake as light. It rattled crockery, but did not throw anything off shelves. It indicated itself in an undulatory motion from west-southwest to east-northeast as marked by a wicker basket suspended from the ceiling which swung 15 degrees. The pendulum clock in Light tower (pendulum 20 inches long) stopped at 5:54 p. m. sun time by almanac; the clock faces to west. Weather at the time: Little light wind all around compass, with heavy overcast sky for preceding forty-eight hours. My house being

close to the bay, I ran to the water's edge to observe if there was any disturbance in the water but could not see that the quake made any, for the ripple at the edge remained still.—William C. Price, Light-keeper.

June 6, 4 a. m. Oakland.—A sudden shock lasting one second, followed by a rumbling noise lasting five or six seconds (II).—F. G. Blinn. A slight trace was made by the seismograph. Mount Hamilton, not felt or recorded.

June 6, 8:30 p. m. San Bernardino.—Noticed by some persons, but not by all. A single shock from northeast to southwest, with some vertical motion. A few persons report rumbling noises. Times of occurrence vary somewhat; 8:14 given by one person. Estimated intensity (III).—W. C. Parnley.

There was quite a shock of earthquake in this city last evening at about 8:30. The shock was accompanied by a low rumbling, and the vibrations were northeast to southwest.—San Bernardino, California, Daily Times-Index, June 7.

June 9, 3:44:24 \pm 3 p. m. Mount Hamilton.—Very slight shock (I) noticed by J. E. K., not by others. Vibrations lasted a few seconds. A small record was made on the duplex seismograph.

June 10, 7:33:7 a. m. Mount Hamilton.—Very slight shock recorded on both seismographs, but not felt by anybody (II). Measurement of the record on the Ewing seismograph gave the following data: Duration = twenty-four seconds; maximum double amplitude (magnified) east and west = 0.52 millimeters; maximum double amplitude (magnified) north and south = 0.38 millimeters; maximum double amplitude (magnified) vertical = very small; period of complete vibration = about one-half second. Hence computed intensity is 12 or (I) of Rossi-Forel scale.

June 19, 10 p. m. Lassen County, California, and Nevada.—This shock, which does not appear to have been felt in the central and southern parts of California, is thus described in the Susanville Advocate:

Since the 19th instant the people of Susanville, Lassen County, have felt about seventy-five slight shocks of earthquake. The first shock occurred at 10 o'clock on the night of the 19th, and was the heaviest ever experienced in this section. The first great shock was followed at greater or less intervals by more or less heavy shocks for over two hours, until twenty-eight shocks had been recorded, of which the first, the thirteenth, the fifteenth, and the eighteenth were very severe. At the first shock, which was something fearful, rocking buildings from side to side and scattering crockery and glassware in all directions, people rushed out of houses with the costume, principally, that nature had provided for them. The vibrations were from south to north, but apparently did not extend much north of Susanville. The shocks were generally preceded by distinct rumbling noises.

Chico.—A slight earthquake shock was experienced here last evening about 10 o'clock. Vibrations from east to west.

Sacramento.—At 10:12 last night a slight shock of earthquake was felt here. It lasted but a few seconds, and was felt by only a few persons.

Susanville.—The heaviest earthquake ever felt here occurred at 10:05 last night, succeeded by lighter shocks at short intervals during the entire night.

Downieville.—There was an earthquake last night at 10:07 lasting about a minute. The weather is warm. The mercury this afternoon marked 90 degrees.

Grass Valley.—An earthquake was felt here at 10 o'clock last night. The shock was quite heavy.

The following is part of a letter to the San Francisco Call :

The series of earthquake shocks that commenced here on the evening of the 19th inst. have been continued at intervals up to the present. Although the first shock was by far the hardest, there have been a number since that have made things quite lively, and indicating that the force that creates these commotions is active still. Reports from different localities within a few miles of here point to the fact that this place, Willow Creek, and Eagle Lake appear to be the centers of the disturbances, the surrounding country being less disturbed. The section named above could be included in a circle twenty-five miles in diameter. Since the first shock some curious phenomena have been developed. The spring from which the town of Susanville is supplied with water has been largely increased in its volume of water, as also many others in this vicinity. The waters are of a milky whiteness. The water of Eagle Lake has been greatly disturbed and is quite muddy. At the south of Eagle Lake and extending many miles is a range of high volcanic hills, covered generally with timber and chaparral. A number of persons who were near or on these hills last Friday heard loud rumblings to the west, accompanied by loud detonations like the firing of very heavy artillery, while the earth seemed to keep up an almost uninterrupted trembling motion. A slight trembling is also noticed much of the time here in town. A farmer, who lives in Willow Creek Valley and who was at work in a large irrigating ditch at the time of one of the recent shocks, had the water thrown out of his ditch, so violent were the oscillations of the earth. A chimney in the house of S. Knudson, in Willow Creek, was thrown down by the first shock. The weather continues quite warm.

San Francisco.—News from Susanville in the Sierra Nevada says slight earthquake shocks continue, and that the people have become so accustomed to the constant trembling of the earth that they pay no attention to it.—Dispatch to San Francisco papers.

Carson City, Nevada.—Prof. C. W. Friend sends a seismograph record which shows a maximum motion of 5 millimeters (magnified four times about equally distributed in all azimuths.

June 20. Susanville.—A continuation of the earthquake shocks. "There were earthquake shocks at intervals the entire day after the first heavy shock during the night. The upper heavens were filled with small meteors."—San Francisco Chronicle, June 22.

June 20, p. m. University of the Pacific, San José.—The seismograph record shows vibrations of about 3 millimeters in an east and west direction and 1.5 millimeters in a north and south direction (both magnified).

June 24, about 4 a. m. University of the Pacific, San José.—The record sent by Prof. Higbie indicates a shock of about the same intensity as the preceding one, and with vibrations in about the same direction.

June 25, 3 a. m. San Diego.—“Dr. Eigenmann reports an earthquake at San Diego at 3 a. m., June 25.” *West American Scientist*, August.

Carson City, Nevada.—A seismograph record, marked “during night, June 25–26,” is sent by Prof. Friend. The vibrations are west-north-west and east-southeast, and indicate a shock of intensity (III).

June 27–28, during night. Carson City, Nevada.—A slight shock recorded, with vibrations in same direction as the preceding one.

June 30, between 8 and 10 a. m.—Carson City, Nevada.—(II) or (III). C. W. Friend.

July 2–3, during night. Carson City, Nevada.—Slight shock recorded (II?).

July 4, 8:05 a. m. Carson City, Nevada.—Slight shock recorded. About the same as the preceding.

July 4–5, during night. Carson City, Nevada.—Record larger than the last, but pen did not return to starting point. Magnified motion perhaps 3 millimeters.

July 6–7, during night. Carson City, Nevada.—Record shows (magnified) motion of 4 millimeters in direction west-northwest and east-southeast.

July 9–10, during night. Carson City, Nevada.—Light shock. In all these records the principal motion is west-northwest and east-southeast.

July 10, and preceding days. Arroyo Grande, San Luis Obispo County.—The following report is from the *San José Times*:

The territory around Los Olivos has been troubled with an earthquake the past few days. Sunday there were six distinct shocks, one of which rattled the dishes off the shelves. The hardest shock took place at 3 o'clock this morning. The druggist at Santa Ynez has removed his bottles from the shelves to the floor. Four years ago a burning volcano was reported at Lookout Mountain, on the south side of Santa Maria valley, which was decided to be a burning asphalt bed.

July 25, 10:8 p. m. Mount Hamilton.—Sharp shock. Rattled pictures on the wall. Time, 10:8:2 (V).—E. S. H. A light, quivering shock, followed by a severe shock, shaking the observatory building, at 10:7:59.—E. E. B. Time, 10:7:59.—J. M. S. Time, 10:7:58.—C. B. Hill. Generally felt by those on the mountain who were awake and not engaged in some occupation which would disturb the attention. It did not seem to me as strong as others we have had (IV).—J. E. K.

Record obtained on both seismographs. The Ewing machine shows maximum (magnified) double amplitude = one millimeter in north and south direction, with period = one-third second. Corresponding east and west motion very small, and vertical component hardly perceptible. The vibrations are almost indistinguishable at fifteen seconds after the time of starting of the plate. The duplex pendulum record agrees well with this, but shows a slightly greater amplitude (magnified four times, about 2 millimeters). The computed intensity is 53 or R-F. (II-III).

July 31, 4:46:45 a. m. Central California. Mount Hamilton.—Shock

wakened sleepers. Time 4:46:45 a. m. (V).—E. S. H. Awakened from sleep. Time, as nearly as could be ascertained, 4:46:50 a. m.—J. E. K.

Measurement of the record made by the Ewing seismograph gives the following data:

Extreme duration, 30 seconds.

Greatest motion, north and south (double amplitude), 1.3 millimeters (magnified).

Motion east and west, a little less.

Vertical motion very small.

Period of wave = about 0.3 second.

Computed intensity = 88 = (IV +).

The duplex pendulum seismograph gave a record in close agreement with the above.

Mare Island Light Station.—Time 4:48, navy-yard time.—Was awakened from a sound sleep and took my watch and marked the time before the trembling subsided. There was a rattling of bowls and pitchers. I felt two shocks: that is, one that was continuous and a sudden heavier impetus in the midst of the general shaking. It was sharp, severe, and quick, and more vertical than that of May 19, Kate C. McDougal, light-keeper.

Santa Cruz Light Station. Time, 4:45, standard time.—There seemed one tremulous shock lasting about three seconds.—Laura J. F. Hecox, light-keeper.

Fort Point Light Station. Time, 4:47.—There was one shock lasting about twelve seconds, an undulating movement from east to west, unaccompanied by noise. The clock in the tower almost stopped but recovered itself. It faces south-southeast.

Oakland.—The shock appears to have been very much more severe than at the Lick Observatory. The magnified record at the Chabot Observatory shows irregular vibrations distributed in all azimuths over a circle about 8 millimeters in diameter, with irregular loops running out about 18 millimeters from the center. These may be due to swinging of the pendulum. Time, 4:45:30. Duration, twenty seconds. The pier of the 8-inch equatorial telescope was cracked near the top, where it was 40 by 15 inches in cross-section, and the south side was shifted one-sixteenth inch toward the east, the north side remaining in position. The pier is of brick. The ferry clock at the foot of Market street, San Francisco, stopped at 4:47:20. (Error \pm 3 seconds) The clock in the ferry-house at Oakland pier stopped 4:46:30; error unknown.—C. Burckhalter.

East Oakland.—At Mr. Blinn's observatory the record showed an indistinguishable mass of lines about 4 millimeters in diameter, with many loops roughly distributed over a circle about 18 millimeters in diameter, and finally a number of great loops extending as much as 35 millimeters from the center. The last are certainly due to swinging of the pendulum. They extended mostly in an east and west direction.

Fully (VI). F. G. B. Time about 4:47. A fresh plate was substituted immediately after the heavy shock, but the two subsequent lighter shocks made no record, and I did not feel them. They are described as being vertical and momentary.—F. G. Blinn.

The first shock awakened me at 4:46:34, which must have been very nearly the time of beginning of the earthquake. Time of ending noted by Mr. A. S. Ireland at 4:46:45. The second shock occurred at 4:54:59, and was quite slight, lasting only about three seconds. The correction of my watch was determined by transit observations by Mr. Blinn, shortly after the shocks occurred.—Wm. Ireland.

Oakland.—The first shock seemed to be from northeast to southwest, and was attended by three distinct, loud, sharp reports, followed by a rattling noise which gradually died away in the distance. No vibration of pendant objects, but rattling of windows for a longer time than I had ever before noticed.—J. B. Trembley.

Berkeley.—At the University observatory a diagram was obtained showing the effect of both shocks. The greatest oscillations are in an east and west direction. (About 13' millimeters, magnified, but the pen did not return to the starting point, stopping about midway on the diagram. The greatest motion is perhaps 6 millimeters.) Time, 4:47 a. m.—Prof. Soulé.

San Francisco.—Time, 4:46:38.—Prof. Davidson.

Carson City, Nevada.—The earthquake of July 31 was not felt here. The seismograph did not show a trace.—C. W. Friend.

Reports sent to the San Francisco papers follow, all dated July 31:

San José.—There was a heavy shock of earthquake at 4:45 this morning, the heaviest in seven years. No damage was done, and there was no excitement. The oscillations appeared to be north and south.

Oakland.—The earthquake was quite severely felt in Oakland yesterday morning. The shock was very sharp, but little damage was done.

At the students' observatory at Berkeley the shock was registered as occurring at 4:47 o'clock in the morning and lasting fifteen seconds. The vibration was from north of west to south of east. It was followed by three slight ones at short intervals. Prof. Frank Soulé says that this was the most severe earthquake that he has experienced since he came to California, in 1869. He classes it as sixth in the Rossi-Forel scale—that is, one that throws down chimneys and small articles.

Sacramento.—There was no earthquake here this morning.

Napa.—An earthquake shock was felt here at 4:45 this morning. It was preceded by tremors which continued about six seconds, and the shock which followed was quite heavy, lasting four seconds. The vibrations were north and south. No damage was done.

Petaluma.—Two heavy shocks of earthquake visited us this morning at 4:45 o'clock. The vibrations were from east to west. The weather is warm and sultry.

Martinez.—There was a severe shock of earthquake here at 4:50 o'clock this morning, lasting several seconds. No damage done as far as heard from.

Gilroy.—There was a slight shock of earthquake here at 5 o'clock this morning.

Santa Cruz.—An earthquake was felt here at 4:50 o'clock this morning, lasting several seconds. The vibrations were west to east.

Centerville.—Two heavy shocks of earthquake occurred here this morning at 4:47 o'clock of about twenty-five seconds' duration. The vibrations were east and west. No damage has been reported as yet.

Los Gatos.—A severe earthquake shock was felt this morning at 4:50 o'clock. The wave was east to west. Houses creaked, glass rattled, and many were awakened out of a sound sleep. Considerable alarm was felt.

Santa Rosa.—A sharp earthquake was felt here at 5 o'clock this morning, lasting about five seconds. The vibrations were southeast to northwest.

Benicia.—The extremely warm weather of the past three days was succeeded by three distinct shocks of earthquake at 4:50 o'clock this morning. The first shock was quite strong and lasted several seconds, and was followed by two lighter ones. The vibrations seemed to be north and south.

Newark.—A severe shock of earthquake was felt here this morning at 4:45 o'clock. The vibrations were from north to south and the duration was about ten seconds.

Concord.—At 4:40 o'clock this morning a sharp shock of earthquake was felt, succeeded by a tremble that lasted fully two minutes. The direction of the shock was southeast to northwest; duration, thirty seconds. At about 3 a. m. a light shock was felt. In the night also another.

San Leandro.—The heaviest shock of earthquake since the one of October, 1868, occurred at 4:46 o'clock this morning. A low rumbling sound preceded the first and heaviest shock, which lasted about one and a quarter minutes. The first half minute the oscillations were light and easy. Then for a quarter of a minute they were heavy, after which they gradually became less and less. Ten minutes after the first shock another slight shock was felt, and six minutes later another. The oscillations were from north to south. The damage includes one chimney thrown down and some crockery broken.

6:19:39 p. m. Oakland.—Slight shock (I) momentary.—F. G. Blinn.

August 7, 3:43:11 p. m. Mount Hamilton.—Very slight shock suspected by E. S. H. (1?).

August 13, 4:43 a. m. Oakland.—Sufficient to awaken a few sleepers (III, IV?). Appears to have been very local in character, and confined to Alameda and Central, and West Oakland, as it was not felt in San Francisco or East Oakland.

August 23, 2:32:46 p. m. Mount Hamilton.—Very slight shock. Felt by some persons and not by others in the same room; time, 2:32:46, E. S. H. Time, 2:32:48—J. M. S. Ewing machine not started. Very small record on the duplex pendulum seismograph (I).

August 27, 6:15 p. m. Southern California.—Not felt at Mount Hamilton. The following are dispatches to the San Francisco papers:

Pomona.—This evening at 6:15 the most severe earthquake shock that has been felt in this locality for fifteen years was observed. There were two distinct shocks, accompanied by a peculiar noise that sounded as though houses and buildings were falling. The shocks were about a second apart. Several people were thrown to the floor and nearly every one ran out of doors in a moment. Dishes were rattled from shelves, and in the stores goods were thrown down on the floor. Many windows were cracked and broken and buildings shook, but no damage was done to them. At the Pomona Progress office the type was pried, and at the Hotel Palomares glassware and crockery was broken.

Los Angeles.—A sharp shock of earthquake occurred here at 6:13 this evening. It began with a light tremor, which lasted a few seconds. Then the vibrations grew stronger and ended with two heavy shakes. The entire duration of the disturbance was about ten seconds. Clocks stopped and ceilings cracked. Much alarm prevailed for a time and many people ran into the streets. So far as now known no damage was done, but the quake was the most severe experienced here in many years.

Santa Ana.—Two very marked shocks of earthquake occurred here this afternoon

at 6:12. The vibrations were from southwest to northeast and followed each other in quick succession. Crockery rattled, chandeliers and swinging signs vibrated, and people in the second and third stories of buildings were considerably frightened in some cases. The quaking continued for seven seconds, but no damage whatever resulted.

Santa Monica.—There was an earthquake here at 6:16 p. m., lasting eight seconds. It was very noticeable in all buildings, but not strong enough to do any damage. The vibrations were from north to south. It was the first known here for many years.

Pasadena.—A very perceptible earthquake shock was observed in this city at 6:20 p. m., lasting from five to six seconds. Dishes on the dinner-tables were shaken and some were broken.

San Bernardino.—“Quite a distinct shock of earthquake was felt in this city last evening at about 6:15. The vibrations lasted several seconds and were from east to west.”—San Bernardino Times-Index, August 28.

A light shock (III). Time noted by George Jordan, jeweler, at 2:12:20 p. m. Clock one minute fifteen seconds slow by Signal Office signals, hence Pacific Slope time = 6:13:35. A slight rumbling noise before the shock is generally reported. The shock is described as a single impulse, lasting but one or two seconds, but reports disagree as to direction of the vibration.—W. C. Parmley.

September 24, 8 a. m.—Reported in San Francisco papers :

Napa.—There was a slight earthquake at 8 o'clock this morning.

Winters.—There was a slight shock of earthquake here this morning just before 9 o'clock. The direction of the shock was from west to east.

Woodland.—Quite a heavy earthquake was felt here to-day at 8 o'clock this morning. There were two distinct vibrations and they were from north to south.

September 29, 8:10 p. m. Wawona.—There were heavy shocks of earthquake at 8:10 Sunday night and at Yosemite followed by two lighter ones. The vibrations were east and west and lasting twenty-two seconds. Other light shocks were reported at Yosemite. A special dispatch from J. H. Lawrence, at the Big Tree Grove, says there was a severe shock of earthquake at 9:30 Sunday evening, continuing about twenty seconds. The vibration was distinctly east and west, accompanied by a rumbling noise resembling a heavy train of cars crossing a bridge, followed by two lighter shocks. Hollow logs and trees oscillated.

Rancho Laguna de Tache, Kingsburg.—A slight shock in section 29, T. 17 S., R. 21 E., at 9:20 p. m.—S. C. Lillis.

September 30, 12:17:30 p. m.—Kingsburg, same place as above. A slight shock.—S. C. Lillis.

October 24, 7:20 a. m. East Oakland.—Tracing obtained with seismograph shows (magnified) vibrations of about 1.6 millimeters. The pen did not return to the starting point. Light shock (II) noticed by several persons. Time noted by Mr. Ireland at 7:19:45 (wrongly given in the Oakland papers as 7:15). Felt by one or two persons in Oakland and Alameda.—F. G. Blinn.

November 14, 6:54 p. m. San Lorenzo.—The telegraph operator reports an earthquake at above time. East Oakland. The seismograph record shows a (magnified) motion of 1 millimeter. The shock was not felt here by anybody.—F. G. Blinn.

November 15, 7:55 p. m.—East Oakland.—A slight shock (II) felt by three persons in the vicinity. No record on seismograph, hence motion was probably vertical. The shock was felt in San Francisco, and noticed in the daily papers.—F. G. Blinn.

Healdsburg.—“A very severe shock of earthquake was felt in this city last night at 7:55. It was the heaviest experienced here in many years.”—Dispatch to San Francisco papers.

December 2, 6:30 p. m.—East Oakland.—The seismograph record (magnified) shows a number of nearly circular tracings about two millimeters in diameter, inclosing short irregular lines in different azimuths. The time was noted by a neighbor, as I was not at home when the shock occurred.—F. G. Blinn.

The present bulletin is to be regarded as little more than a list of reported earthquakes in California in 1889 and a collection of such data as are available for estimating the intensities of the different shocks. Accurate observations of earthquakes are difficult to obtain, as the instruments employed require some skill in the observer and a certain amount of attention to be always in working condition. The sensations experienced during an earthquake shock vary greatly for different persons, and descriptions based on the feelings alone are apt to be extremely unreliable. It is hoped, however, that other stations provided with suitable instruments can be established in different parts of the State, and that eventually sufficient data can be accumulated for a more complete study of earthquake phenomena on the Pacific coast than the material now available would permit.

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[Bulletin No. 68.]

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II. Second Annual Report of the United States Geological Survey, 1880-'81, by J. W. Powell. 1882. 8°. 1v, 568 pp. 62 pl. 1 map.

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IX. Ninth Annual Report of the United States Geological Survey, 1887-'88, by J. W. Powell. 1889. 8°. xiii, 717 pp. 88 pl. and maps.

The Tenth and Eleventh Annual Reports are in press.

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