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CHARLES D. WALCOTT, DIRECTOR

EARTHQUAKES IN CALIFORNIA

IN

1898

BY

CHARLES D. PERRINE

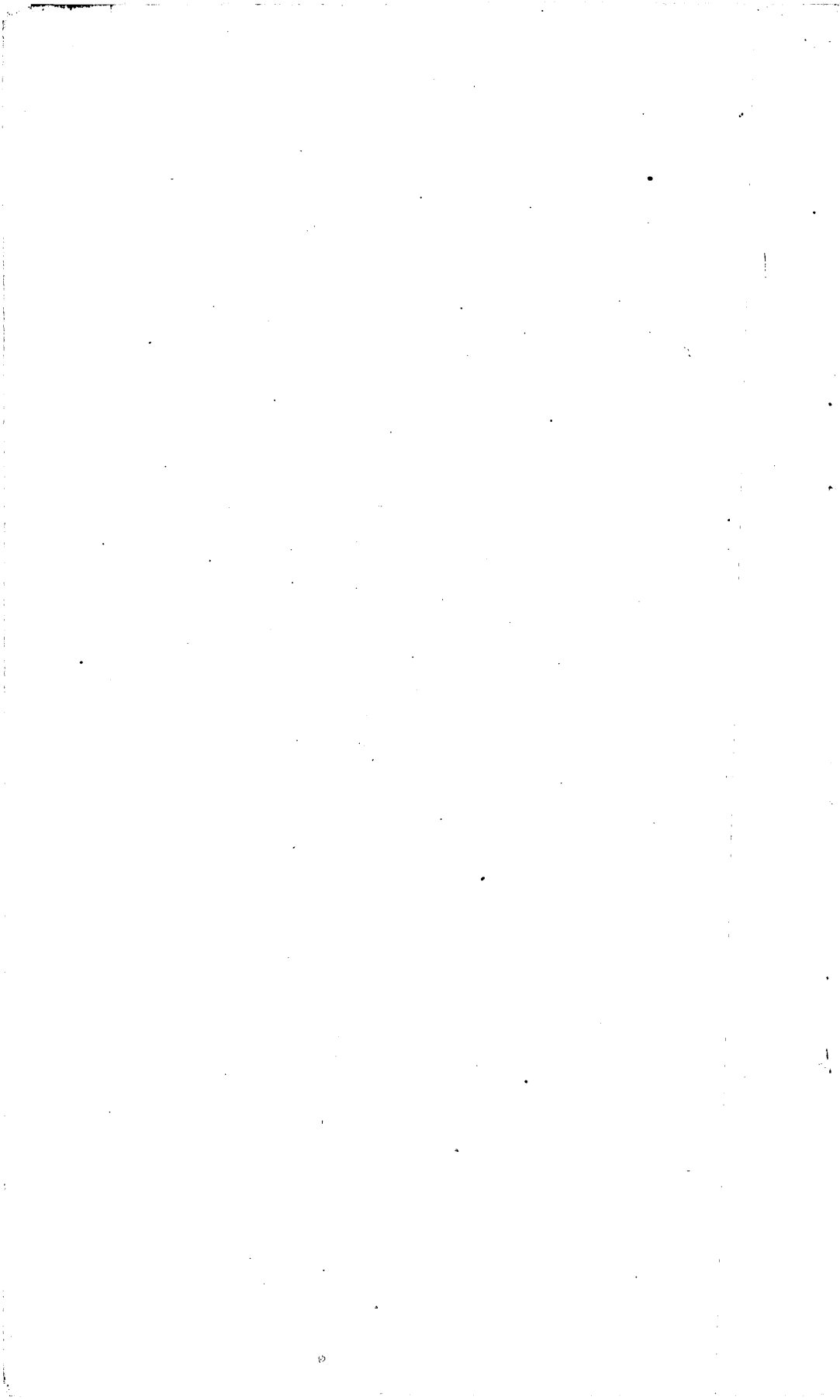
ASSISTANT ASTRONOMER IN CHARGE OF EARTHQUAKE OBSERVATIONS
AT THE LICK OBSERVATORY



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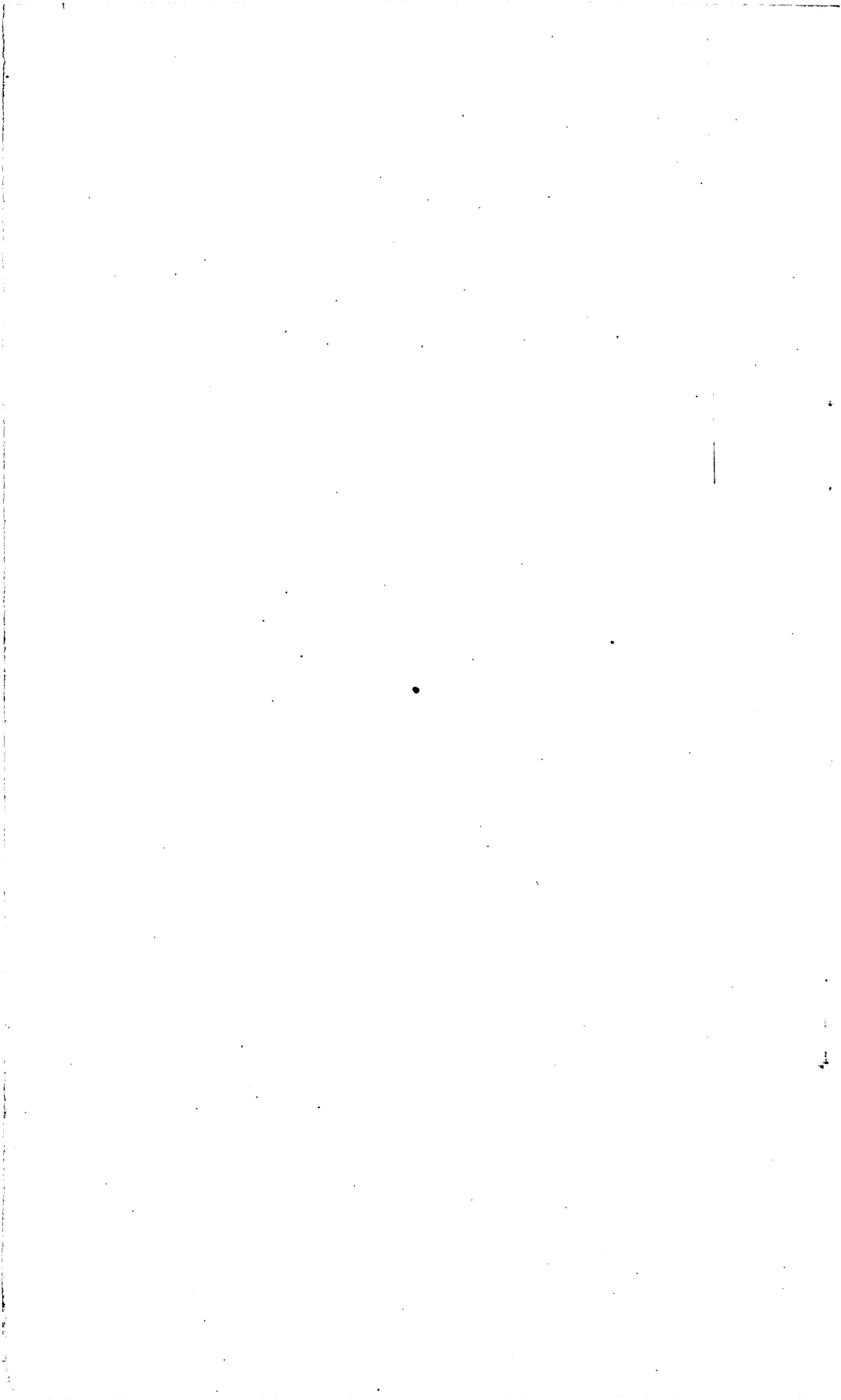
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LETTER OF TRANSMITTAL.

UNIVERSITY OF CALIFORNIA,
LICK OBSERVATORY,
Mount Hamilton, March 30, 1899.

DEAR SIR: I send you herewith Mr. Perrine's report of earthquakes for the year 1898, in continuation of the series published by the Geological Survey.

Yours very truly,

JAMES E. KEELER,
Director.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.



EARTHQUAKES IN CALIFORNIA IN 1898.

By CHARLES D. PERRINE.

INTRODUCTION.

The following paper is a continuation of similar records¹ furnished by officers of the Lick Observatory, and completes the list up to the end of 1898. It records all the shocks observed 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 the year.

It also includes a number of shocks in various localities on the Pacific coast which it was thought might not have been recorded in other reports. No systematic examination of newspapers has been made, however, and some reports of earthquakes may have escaped notice.

INSTRUMENTS.

The instruments used for recording earthquakes on Mount Hamilton are described in Publications of the Lick Observatory, Vol. I, p. 82. The largest and most complete instrument records the north-and-south, east-and-west, and vertical components of the earth's motions separately on a smoked glass plate, which is started by the preliminary tremors of the earthquake and rotates in about three minutes, the edge of the plate being graduated into seconds by the 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 form consists of the 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 motion of the earth

¹List of recorded earthquakes in California, Lower California, Oregon, and Washington Territory, from 1769 to 1887, by Edward S. Holton, Sacramento, State Printing Office, 1887. Earthquakes in California in 1888, by Edward S. Holden: *Am. Jour. Sci.*, 3d series, Vol. XXXVII, May, 1889. Earthquakes in California in 1889, by James E. Keeler: *Bull. U. S. Geol. Survey* No. 68, 1890. Earthquakes in California in 1890 and 1891, by Edward S. Holden: *Bull. U. S. Geol. Survey* No. 95, 1892. Earthquakes in California in 1892, by Charles D. Perrine: *Bull. U. S. Geol. Survey* No. 112, 1893. Earthquakes in California in 1893, by Charles D. Perrine: *Bull. U. S. Geol. Survey* No. 114, 1894. Earthquakes in California in 1894, by Charles D. Perrine: *Bull. U. S. Geol. Survey* No. 129, 1895. Earthquakes in California in 1895, by Charles D. Perrine: *Bull. U. S. Geol. Survey* No. 147, 1896. Earthquakes in California in 1896 and 1897, by Charles D. Perrine: *Bull. U. S. Geol. Survey* No. 155, 1898.

is magnified 4.6 diameters in the duplex seismometers. 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 the horizontal components are magnified about 4 diameters, and the vertical component is magnified 1.8 diameters. The measures of the vibrations as given in the notes are taken directly from the tracings, and therefore represent the magnified motion, unless otherwise mentioned.

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 the measure of the intensity (I), 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 harmonic.

DIFFERENCES OF INTENSITY.

Estimates of the intensity of shocks are given also (in Roman numerals inclosed in parentheses) according to the Rossi-Forel scale, which for convenience of reference is inserted below. Experience has suggested that for observations in California a few additions should be made to this scale, and these are printed here in italics. When these are in quotation marks also they are expressions actually used in newspapers, etc., in describing earthquake shocks whose intensity is otherwise known. The scale as amended is as accurate as anything of the kind can be.

I.

Microseismic shocks 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.

Shocks recorded by several seismographs of different patterns; reported by a small number of persons 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; falling of plaster; striking of church bells; general fright, without damage to buildings; nausea felt: "violent;" "very violent."

VIII.

Falling 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 ground; mountain slides.

The relation between the intensity of a shock as determined by the formula already given and the numbers of the Rossi-Forel scale has been reduced from all available data up to 1888 by Professor Holden, and is given below in tabular form. It is, of course, a rough approximation only:

Intensity, Rossi-Forel scale.	Intensity, millimeters per second.	Difference.
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 (I) of a shock, as defined mathematically by the formula

$$I = \frac{V^2}{a}$$

(where V is the maximum velocity of the vibrating particle), can be inferred from the ordinary description of its effects.

STATIONS.

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 are:

Students' Observatory, Berkeley, in charge of Professor Leuschner.

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

Private observatory of Mr. Blinn in East Oakland.

Observatory of the University of the Pacific, San Jose, in charge of Professor Curtis.

Observatory of Mills College, near Oakland, in charge of Professor Keep.

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

Alameda, Cal., at the residence of Mr. P. Perrine.

Esquimault, British Columbia, at the Meteorological Station, Mr. E. Baynes Reed in charge.

Tacoma, Wash., at the residence of Mr. F. G. Plummer. (Mr. Plummer's seismograph is not a duplex.)

The reports of the United States Weather Bureau and of the United States Light-House Board should be consulted in this connection, as they record disturbances felt at their stations, which may not be included in this list.

THE MAGNIFYING RATIOS OF SEISMOGRAPHS.

For a discussion of this subject and the derivation of the necessary formulæ, see Bulletin No. 155 of the United States Geological Survey, page 12.

CHRONOLOGICAL RECORD, 1898.

January 1.—**SANTA ROSA.**—Two distinct shocks of earthquake, the most severe which have been felt here for many years, awoke the residents of this city and vicinity shortly after 5 o'clock this morning. The shocks were of about twenty-five seconds' duration, and the vibrations were from west to east. No damage has been reported.—*San Francisco Chronicle*, January 2, 1898.

February 7.—**MOUNT HAMILTON.**—0^h 38^m 3^s a. m., Pacific standard time. A single tremble at above time; after an interval of 2^s two rather long waves north and south, lasting 1½^s to 2^s. Rossi-Foré I and II. Second story of brick dwelling.—C. D. P.

The duplex instrument has considerable "creep," but the shock is discernible as a single line 1^{mm} long nearly northeast and southwest.

March 7.—**PACIFIC OCEAN**, midway between Mazatlan and Hawaiian Islands.—April 2, Captain Larsen, of the barkentine *Portland*, reported to the branch hydrographic office to-day that four distinct shocks of earthquake were felt by him on March 7. The observations were made about halfway between Mazatlan and the Hawaiian Islands. The first shock, at 10.12 p. m., Greenwich mean time, was very severe and lasted twenty seconds. Exactly half an hour later a milder shock was felt, and there were two more during the afternoon. The weather was nearly calm.—*San Francisco Examiner*, April 3, 1898.

March 17.—**HIGHLAND SPRINGS.**—There was the sharpest earthquake felt for years here at midnight last night. The vibrations were from west to east, and lasted fully a minute. No damage was done.—*San Francisco Bulletin*, March 17, 1898.

March 30.—The heaviest shock of earthquake in California since the severe one of April, 1892, occurred in the night of March 30 of the present year. The greatest disturbance was felt at the Mare Island Navy-Yard, Vallejo, and Benicia. The shock was very heavy in all of the bay counties, although little actual damage was reported outside of the places mentioned above. At the navy-yard a number of buildings were partially destroyed and much damage done to the machinery. After a survey the commanding officer of the yard estimated the damage at \$342,000. Besides this there would be needed repairs to the extent of several thousand dollars in a number of the towns in the disturbed area. In San Francisco a number of chimneys were cracked and some masonry fell from several buildings. The only building seriously injured was one at 445 Clementina street, which partially collapsed owing to the underpinning giving way. The Girls' High School

was damaged to the extent of \$2,000, the wall on the north side of the building under the roof having been displaced nearly 2 inches. The plastering was cracked in different parts of the building. The Whittier School, on Harrison street near Fourth, was considerably injured by the earthquake, owing principally to the fact that the building stood partly on made ground. The cost of the repairs on this building was estimated at \$3,000. Chimneys on the Jefferson and Denman schools were twisted to such an extent as to require rebuilding.

MOUNT HAMILTON.—11^h 42^m 22^s to 11^h 43^m 2^s p. m. Duration, forty seconds. Light tremors in all azimuths for first 12^s to 15^s; then heavy waves for 10^s to 15^s, followed by light tremors. The greatest motion was northeast and southwest Rossi-Forel V. In the second story of brick dwellings doors and windows rattled, although not loudly; walls creaked. Waves generally slow. The duplex seismograph gave a complicated record of motions in all azimuths, the greatest disturbance being northeast and southwest, 24^{mm} by 15^{mm} at right angles.

Heaviest shock at 11^h 42^m 45^s Pacific standard time. The meridian circle building quivered and the walls creaked for half a minute preceding the heaviest tremor, which was estimated of four seconds' duration. The observing clock on the west wall of the room stopped entirely. Of the five clocks, Dutch clock No. 8 on east face of its pier, pendulum swinging nearly north and south (magnetic), stopped for twenty-six seconds and then continued running. But No. 4, No. 1, and No. 7, all on east faces of respective piers, and No. 3, on north wall of clock room, continued to run without interruption. There is no evidence of permanent disturbance in the adjustments of the meridian circle.—R. H. Tucker.

BERKELEY.—11^h 42^m 26^s p. m., Pacific standard time. The seismographs at the Students' Observatory gave a complete record of the shock. The following particulars of the shock as felt in Berkeley are extracted from an article on "The Earthquakes of March 30 and April 14," by Professor Teuschner, published in the University Chronicle No. 2, 1898.

"The earthquake of March 30, according to the consensus of opinion, was the severest experienced in this vicinity since the great earthquake of October 21, 1868. The records of the Students' Observatory begin August 11, 1887, under the direction of Prof. Frank Soulé, and this is the most severe recorded. The large astronomical clock in the Students' Observatory was stopped at exactly 11^h 42^m 26^s Pacific standard time; but it is difficult to say just how many seconds after the beginning of the disturbance this occurred. Mr. Seares noted the time of disturbance at 11^h 42^m 44^s, which he estimates to have been fifteen or twenty seconds after the sharpest part of the shock. * * * The greatest east-west and north-south displacements in the Duplex record correspond to actual displacements of the ground of 0.53 inch (13^{mm}) and 0.63 inch (16^{mm}). The corresponding figures from the Ewing seis-

mograph are 0.35 inch (9^{mm}) and 0.73 inch (19^{mm}). The maximum vertical displacement, as recorded on the Ewing, was 0.81 inch (21^{mm})."

ALAMEDA.—11^h 42^m p. m. Mr. Perrine's seismograph gave a record which is remarkable for its extent. A plate 4 by 5 inches was used, the pen when at rest not being in the center, but about an inch to one side. The excursions of the pen extend almost over the entire plate, and on the two nearer sides much of the record is lost. It is estimated that if the pen when at rest had been in the center of the plate that some of the longer excursions even then would have carried the pen off the plate. The record is a mass of lines in all directions, as is to be expected from the great duration of the shock.

COLLEGE PARK.—11^h 42^m 35^s p. m. "The shock at College Park was very long and quite severe, but lacked intensity, perhaps, and so did comparatively little damage. Before I could rise and light a lamp to see my watch I had counted fifty-six seconds, and the building was still shaking violently and continued seven or eight seconds longer. As I may not have awakened at the first shock, I am certain that the shock lasted nearly sixty-five seconds here. I made the time about 11^h 42^m 35^s Pacific standard time. The direction as given by the seismograph was mainly east and west."—H. D. Curtis.

A print of the record at College Park shows an area of 3 by 4 inches well filled with lines, much of the record evidently extending beyond these limits.

CARSON CITY, NEV.—11^h 45^m p. m. Professor Friend sends a tracing from the duplex seismograph, showing an area of 13^{mm} diameter completely filled with lines.

MILLS COLLEGE.—11^h 44^m p. m. Professor Keep sends a tracing from the duplex seismograph which shows the disturbance to have been a severe one. An area of 3 inches in diameter is thickly strewn with lines, and it is evident that all of the excursions are not contained therein.

ANTIOCH.—The earthquake last night was the heaviest ever felt in this vicinity.—San Francisco Examiner, April 1.

AUBURN.—There was not the slightest evidence of an earthquake here last night.—San Francisco Examiner, April 1.

BENICIA.—About 11.40 last night a heavy shock of earthquake occurred here, the severest since 1868. The worst damage was at the cannery of W. R. Hume & Co. The cannery stands on piles on the water front. Cans, tin, boxes, bricks, and a part of the chimney were piled up promiscuously. The damage will probably be from \$400 to \$500. No damage was done to the buildings in the arsenal or barracks.—San Francisco Examiner, April 1.

BOLINAS.—The most severe earthquake shock ever experienced in this city occurred to-night at 11.43 o'clock. It was of seventeen seconds duration. The vibrations were from north to south and the shocks short and sharp. Clocks in many residences were stopped, goods thrown

from store shelves, and chimneys in all parts of the town shaken from roofs. The chimney on one residence was hurled a distance of 20 feet. No loss of life is reported.—San Francisco Call, March 31.

COLUSA.—A heavy shock of earthquake was felt at 11.45 last night, but no damage is reported in this or neighboring towns.—San Francisco Bulletin, March 31.

LODI.—There was a severe earthquake here just before midnight. Frame buildings shook and quivered alarmingly. Two distinct shocks were felt. There was no damage.—San Francisco Examiner, April 1.

MARTINEZ.—At 11.42 last night this town experienced the worst earthquake since 1868. The vibrations were northeast to southwest and lasted forty seconds. About 5 o'clock this morning there was another slight shock. Chimneys were shaken from houses last night and contents of stores thrown to the floor. The library building, a brick structure, was cracked. The worst damage is to the court-house, which was built in 1856. The north wall was cracked in several places.—San Francisco Examiner, April 1.

MONTEREY, PACIFIC GROVE, DEL MONTE.—A decided earthquake shock was felt here [Monterey], at Del Monte, and at Pacific Grove last night. It was more severe at Del Monte than elsewhere. No damage is reported.—San Francisco Examiner, April 1.

MODESTO.—Two distinct shocks were felt here. There was no damage.—San Francisco Examiner, April 1.

NAPA.—The first motion was from north to south and then from east to west. It was one continuous shock, with no break except a general increase in intensity and then a decline. No serious damage was done, except that the stocks of grocery stores and drug stores were badly mixed up, and windows were broken all along the line of the main street. The shock far exceeded the heavy shock of 1891, which established a record.—San Francisco Chronicle, March 31.

The heaviest earthquake shock ever experienced in the Napa Valley was that of to-night. The shock lasted fully one minute. The hands of the electric clock stopped at 16 minutes to 12 o'clock.

Many people say that at the time of the shock they saw a bright light, not unlike a flash of lightning, in the northeastern heavens, and then came the sound as if a great explosion had taken place.

There was no serious damage done here, so far as could be ascertained to-night, but windows were broken in many buildings, plastered walls were badly shaken, and several chimneys came tumbling down when the shock was heaviest.

A large wine tank at Migliazacca's wine cellar was badly damaged.

At the State Asylum for the Insane the long shock aroused everybody, but perfect order was maintained among the hundreds of patients, although they were badly frightened. No damage was done except that the plastering in some of the rooms was broken up and a few bricks were thrown out of place.—San Francisco Examiner, March 31.

PORT COSTA.—The earthquake shock here was long continued and very heavy. Everybody appeared to have taken to the streets. Bottles were broken in saloons and windows were shattered in stores. As there are no high buildings in the town, no damage was done to such property.—San Francisco Chronicle, March 31.

BENICIA.—There was felt here, about ten minutes before midnight, an earthquake which old residents declare the most severe since the one in 1868. No damage is known to have been done. As the street lights were all out, the condition of windows in the business portion could not be seen.—San Francisco Chronicle, March 31.

PETALUMA.—The damage done by the earthquake is estimated at \$10,000. Fully 300 chimneys have to be rebuilt. The brick tower of the Carbon Currier Silk Mills was damaged to the extent of \$500. The city hall was also damaged. Nearly all the plate-glass windows in the business portion of the town were broken.—San Francisco Examiner, April 1.

SONOMA.—Considerable damage was done in both town and valley by the earthquake. Chimneys fell and broke and stone walls were cracked. The show windows in Clewes' store were broken and the south side of the large building is seamed and cracked to an alarming extent. Sonoma Valley Bank building is badly fractured and the vault seriously damaged. The chimney on the handsome residence of William McElroy fell. The high-school building was also badly cracked. A strange thing happened on the farm of Capt. H. E. Boyes. The water in a reservoir was lifted bodily and cast to one side, as though the reservoir was a washbowl, leaving it dry.—San Francisco Examiner, April 1.

SANTA CRUZ.—The earthquake, at 11.40 last night, awakened everybody in town and frightened many people. It was a veritable twister, but the damage was slight. There were two disturbances following each other almost immediately.—San Francisco Examiner, April 1.

ST. HELENA.—A peculiar phenomenon was witnessed by those who were outdoors at the time of the earthquake shock. Just before the earth began to tremble the sky was perfectly clear, but in an instant not a star was visible, the heavens being hidden from view by dark clouds. A low fog immediately drifted over the entire valley.—San Francisco Examiner, April 1.

SUISUN.—A prolonged shock of earthquake occurred here to-night at 11.45 o'clock, and, although not so severe as the shocks of several years ago, was longer in duration. The vibrations seemed north and south, but the shake was so confusing that it was hard to determine the exact direction.—San Francisco Chronicle, March 31.

SAN RAFAEL.—The heaviest earthquake that Marin County has ever experienced occurred here at 11.44 o'clock to-night. It lasted fully fifteen seconds. In the town of San Rafael, when the first shock was felt, women and children rushed into the street praying for mercy.

Telegraph and telephone communication was interrupted for a time, but otherwise little damage was done. Fred Peterson, a night watchman, was lighting lamps at the first shock, and was thrown from the ladder on which he was standing and badly bruised.—San Francisco Examiner, March 31.

The earthquake caused the earth to open in several places in the county road between Novato and Nicasio, forming miniature gorges 4 and 5 inches wide and several feet deep. The damage in this town was slight. A trestle on the San Francisco and North Pacific Railway, 4 miles north of here, sank several inches and the rail was twisted.—San Francisco Examiner, April 1.

SAN QUENTIN.—During an exceptionally severe and long-continued earthquake felt here about 11.40 o'clock last night the rattling of the prison buildings could be heard a long distance away, but no sound came from the 1,400 convicts. All was unexpectedly quiet within the prison walls. No damage is known to have resulted to person or property.—San Francisco Chronicle, March 31.

When the convicts were released from their cells this morning it was discovered that the earthquake had damaged the prison buildings to a greater extent than was at first estimated. The new prison hospital, which is built of brick, suffered the greatest damage. The walls of this building are cracked in several places. The old furniture factory, on whose top floor the gallows stands, swayed back and forth with the shock, and the guards who were stationed near by believed the building was going to topple over.—San Francisco Examiner, April 1.

SACRAMENTO.—At 11.38 o'clock to-night three slight shocks of earthquake were felt here. They were of an easy, undulating motion and seemed to be from southeast to northwest. Chandeliers were made to swing and doors to rattle, but no damage was done so far as heard from.—San Francisco Examiner, March 31.

SAN JOSE.—The earthquake shocks that occurred here to-night at 11.42 were the most severe experienced in the history of the city. The tremors opened mildly and as they increased in severity many, especially women and children, became alarmed and ran, screaming, into the streets. The hallways in the Hotel Vendome, the St. James, and other hotels presented a lively appearance as they filled with the guests, many of them half clad, rushing from their apartments toward the entrance. Numbers reached the outside of the building before the extraordinary long series of tremors closed and the fright was over. Hanging lamps of all kinds were swung violently, many clocks stopped, but there are no reports of any serious damage.—San Francisco Chronicle, March 31.

SANTA ROSA.—The heaviest shock of earthquake ever felt in this city occurred at 11.45 to-night. The vibrations lasted fully one and three-quarters minutes. Scores of people rushed into the streets from their houses, screaming and praying. Several women fainted, and for

a time the greatest excitement prevailed. Heavy plate-glass windows in many business houses were broken, and throughout the city the plaster was shaken from walls and ceilings. In a room in the Roney building where some children were sleeping a huge piece of plaster fell from the ceiling, striking one of the children, a boy, and injuring him severely. Reports received here from all sections of the county state that the shock was severe everywhere, but as yet the damage is not known. Up to a late hour the streets were full of people, discussing the great shock. Few cared to again retire to their beds.—San Francisco Examiner, March 31.

STOCKTON.—The heaviest earthquake which has been felt in this city for years occurred at 11.43 to-night. Persons sleeping in the second stories were awakened by the motion. Windows rattled as if a high wind was blowing for about ten or fifteen seconds, when there was a calm of probably about forty-five seconds; then another quake occurred, but not nearly so heavy as the first. The first wave was from east to west, but the second appeared to be from southeast to northwest. While it is not positively known that much damage was done, the night watchman of the Sperry Flour Company, who was in the eighth story of the Union Mill at the time, stated that the building squeaked, and he believed it was going to fall. He had to catch hold of a beam to keep from being thrown from his feet. The Associated Press wire in the Morning Independent office was snapped, and communication was cut off for over an hour. The wave visited all parts of the city with about equal force.—San Francisco Chronicle, March 31.

Five distinct earthquake waves swept over this city to-night at 11.39 o'clock, following close after one another inside of two minutes. The vibration was from east to west, and the shocks were strong enough to stop the clocks on the walls, rattle dishes, and set chandeliers in motion. Those at work in the second and third stories of buildings felt the shock the strongest. Watchman Barber, on the eighth floor of the Union and Golden Gate Flouring Mill, said that it was hard to keep his equilibrium. Hanging lamps were started swinging, and the shocks were sufficiently severe to keep them swaying for five minutes. In portions of the State Hospital for the Insane the patients were awakened, but there was not sufficient fear expressed among them to cause any outcry. Wires were tangled up a bit, and an accident south of Stockton somewhere broke the circuit of the Associated Press leased wire, but another was substituted within half an hour. The temblor was the most severe felt in Stockton for a good many years, and the telephone calls to newspaper offices showed that the people were generally awakened by the shock. No damage was reported, though some accounts of cracked walls have been received.—San Francisco Examiner, March 31.

VALLEJO.—The earthquake to-night was one of the heaviest ever experienced in this city, and, so far as can be learned to-night, the damage will foot up nearly \$100,000. At the Mare Island Navy-Yard

damage to the extent of \$25,000 was done, demolishing the sawmill which was turning out material for repairing the war vessels now here, and will cause delay in the work. In the naval hospital there are about 50 patients. The building was badly shattered, but fortunately the walls did not collapse. The roof over the chief engineer's office was thrown to the ground, and the general storehouse was badly damaged. The residences of Rear-Admiral Kirkland and Pay Inspector Bacon were partially destroyed. None of the inmates were hurt. The water mains broke, and the supply of Vallejo was cut off. In Vallejo several stores were wrecked. Half a dozen fires were caused by lamps overturning, and the fire department was called out and kept busy. One woman was seriously burned, numerous chimneys were wrecked, and some narrow escapes are reported, but no casualties. The Bernard House suffered a loss of \$1,000 in furniture and fixtures, and other places in proportion.—San Francisco Examiner, March 31.

The earthquake of Wednesday night was accompanied by a grinding, crunching roar. People rushed in terror from their homes. The damage here resulted mostly in the breaking of bottles which were standing on shelves in the various stores. In private residences valuable china-ware and bric-a-brac were thrown from their shelves. The chimney at the Lazelle House fell, and five fires resulted from the overturning of lamps. In the public schoolhouses the damage was so great that no school was held to-day. Chimneys are down, blackboards are useless, and plastering has fallen in many places. Eight chimneys were destroyed. The damage to St. Vincent's church amounts to about \$5,000. The belfry tower will have to be torn down and rebuilt. The eight pinnacles were twisted. Candlesticks and decorations on the altar were thrown to the floor. Most of the damage in South Vallejo resulted from the falling of chimneys. On the whole, the damage in this city will amount to about \$50,000.—San Francisco Examiner, April 1.

WALNUT CREEK.—A very severe earthquake was experienced in this vicinity last night, but no damage was done. Two cars which had been standing on the switch at Danville ran down the grade toward this place for about a mile and jumped the track. The agent telegraphed to Oakland for a wrecking crew to clear the track.—San Francisco Examiner, April 1.

Reports from Anaconda (Montana), Fresno, Los Angeles, San Diego, and Ukiah are to the effect that the shock was not felt at these points.

April 12.—COLLEGE PARK.—4 p. m.

April 14.—SAN FRANCISCO.—10^h 53^m p. m.; 11^h 7^m p. m. There were two distinct shocks, the first at 10.53 and the second at 11.07, but they were of short duration and smooth and gentle, none of the ugly pitching and rocking which characterized the former shocks being noticeable. They were felt for miles around in the surrounding country, but no heavier than here. As far south as San Jose and up to Port Costa light shocks were noticed. Many people, remembering the violence of

the last shocks, feared a repetition and hurried out of their houses, and the streets were soon filled with anxious citizens. As the excitement from the first shock was about dying out the second one came, but it created little apprehension.—San Francisco Call, April 15, 1898.

Two slight shocks of earthquake were felt in the city last night. On the streets the shocks were not so noticeable. The first shock was several minutes before 11 o'clock, and the second, which was of longer duration but not so violent, followed 15 minutes later. A telephone inquiry developed the fact that the shocks were not felt at the Lick Observatory. They failed to make the slightest indication on the seismograph instrument there. A large glass was broken in a window on Sixth street. The shock stopped the clock in the Southern station.—San Francisco Chronicle, April 15, 1898.

There were three distinct earthquake shocks last evening. All were short, none of them severe, and the area affected was circumscribed. The three shocks together did not last as long as the heavy shake of a fortnight ago, and to many it will be a surprise to learn that there was an earthquake at all. The first shock was at 10.46 and lasted about five seconds; another shock followed a minute later and the duration was about three seconds; the third shock was the most severe of the three and was of about seven or eight seconds' duration. So far as this city is concerned, from all accounts, it was most severe in the Mission. Many people ran into the street, fearing a repetition of the last shake.—San Francisco Examiner, April 15, 1898.

EUREKA.—Two earthquakes were felt here to-night, the first at 10.50 and the second at 11.10. The latter was the heavier. A rumbling noise accompanied the shakes. The duration was ten seconds and the direction north and south. The big city clock stopped instantly, and the shake was the heaviest for many years in this county.—San Francisco Examiner, April 15, 1898.

OAKLAND.—In Oakland two shocks were felt. The second was the most severe, but the only effect was to awaken sleepers and stop a few clocks.—San Francisco Examiner, April 15, 1898.

MENDOCINO.—Great excitement and alarm prevailed here during last night and to-day because of a series of earthquakes, causing much damage to property in the town and vicinity. At about 10.30 last night a slight tremor was felt, but little attention was paid to it and but few felt it. At 10.48 a sharp and prolonged shock was felt, shaking the buildings in such a manner as to cause great alarm. In a few minutes another shock was felt, and at 11.05 came the worst of all, heavy and prolonged, causing people to rush from their houses in alarm. Knots of men, women, and children were soon formed at various points, waiting anxiously for what might be coming. Few who had left their houses would return. Large fires were quickly built and kept burning in the streets during the balance of the night, about which gathered the frightened populace. At short intervals during

the rest of the night and to-day the earth has trembled with more or less violence. Much damage was caused to property in and near Mendocino City. Among the business houses meeting with losses were the following: Brown & Gray, the Mendocino Hospital and Drug Company, C. O. Packard, Jarvis & Nichols, Eugene Brown, A. F. Luis, and the several hotels. Many houses had chimneys thrown down or cracked. There are not over half a dozen monuments in Evergreen Cemetery which were not thrown down or twisted around on their bases. Between Brown & Gray's corner and the Occidental Hotel, on Main street, the ground opened an inch wide for nearly 100 feet; in some places more. On the flat near the mill the ground opened for 200 or 300 feet in a narrow seam.

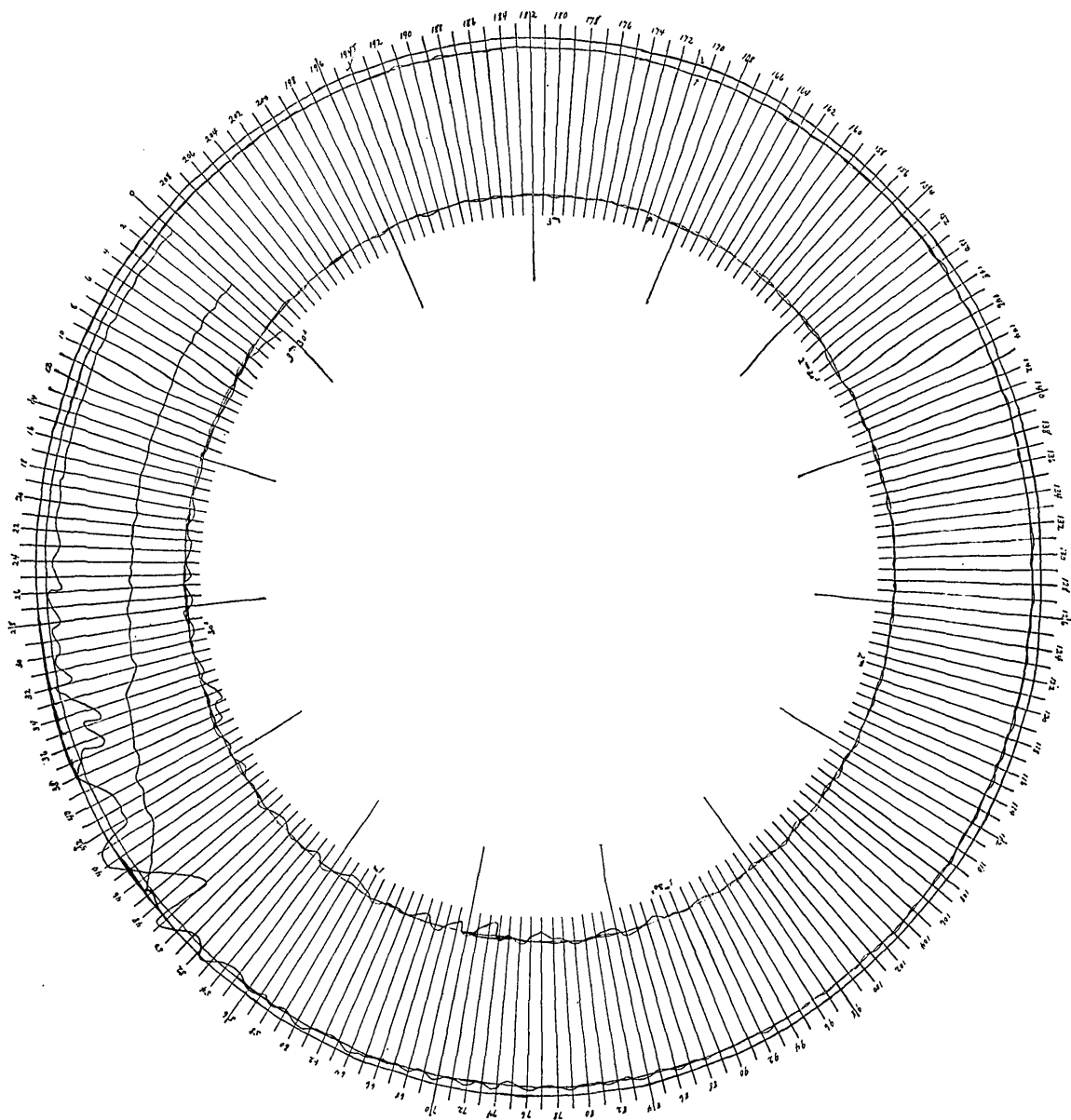
LITTLE RIVER.—At Little River hardly a chimney was left standing. On the stage road from Mendocino to Ukiah great damage was caused by trees falling in the road. In many places the whole roadbed along the grades fell away, while in other places the ground opened wide enough to thrust your arm in. At various points along the coast from Point Arena to Westport serious damage was done.

POINT ARENA.—Earthquakes last night and this morning were the most severe ever felt here. Shock followed shock in quick succession, and the earth trembled continually until after daylight. Buildings swayed in a terrible manner, causing much alarm. People rushed to the streets. Some crockery was shaken from shelves, and milk pans and water vessels were emptied of their contents. The public-school building shows signs of the severe shaking, cracks in the ceiling indicating the force of the temblor.

At 11 o'clock the heaviest shock was felt at the light-house. The tower was cracked for several feet and the lights extinguished. The vibrations were from north to south. Aside from the damage mentioned little harm was done here. It was more severe north of here.

GREENWOOD.—Greenwood was shaken to a great extent. Houses were lifted and thrown several inches out of place and their contents were turned over. Residents left their homes and remained in the fields until daylight. No one was hurt, but a number of ladies were so badly frightened that physicians had difficulty in restoring them to consciousness. Four houses were wrecked and a portion of the wharf was destroyed. Stages and other vehicles leaving the coast this morning for the interior were compelled to return, some of the roads having been rendered impassable. In places the country roads sunk several feet. Captains of vessels lying in the harbor here say they felt a grinding motion, as though their craft were upon the rocks.

The lumber yards present a strange sight. Stacked lumber is now scattered in every direction. No buildings in Point Arena collapsed, though brick structures were severely tested and plaster in hard-finished houses was scattered over the rooms. Two light shocks were felt this afternoon, and the people are uneasy lest last night's experience be repeated.



RECORD OF THREE COMPONENTS, EWING SEISMOGRAPH, 1898, APRIL 14, ABOUT 11 P. M., PACIFIC STANDARD TIME.

UKIAH.—The earthquake last night was the most severe ever felt in Mendocino County. There were 22 distinct shocks in this city. The stage from Mendocino to this city was compelled to return to the former place this morning, owing to caves in the road, due to the earthquake.

FORT BRAGG.—An earthquake was felt here at 11.05 o'clock last night, with vibrations from south to north, succeeded at 11.22 by a greater shock, which continued for fully 15 seconds, the vibrations being from west to east. These shocks were followed at intervals up to 6.15 a. m. to-day by 17 other shocks. A large fissure was made in the earth a mile from town. Many chimneys were demolished and considerable damage was done to property here and at other places along the coast.—San Francisco Chronicle, April 16, 1898.

BERKELEY.—The following report of this earthquake in Berkeley was extracted from Professor Teuschner's article previously referred to:

"Its intensity at Berkeley was III on the Rossi-Forel scale. Two dis-

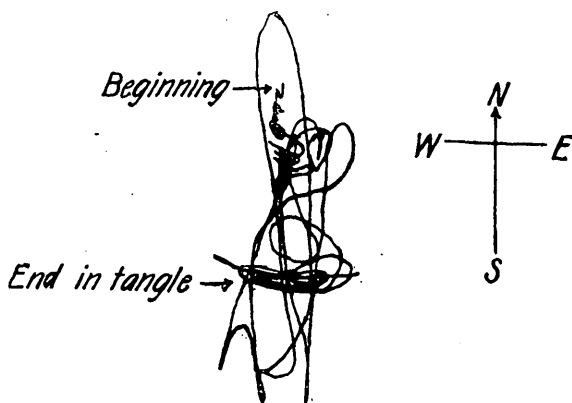


FIG. 1.—Record by the Duplex seismograph at Berkeley, April 14, 1898, about 11 p. m., Pacific standard time.

tinct shocks were felt by some persons in lower Berkeley, one several minutes before 11 the other several minutes after 11 p. m., the total interval being about fifteen minutes. At the Students' Observatory only one shock occurred, as is definitely shown by the Ewing seismograph, but it is impossible to say to which of the two it corresponds. (See Pl. I.) * * *

"The disturbance commenced with minute vibrations in all three components, which gradually increased in the north-south and the east-west components, reaching a first maximum in the east-west direction at thirty-seven seconds (reckoned from the beginning), and a second and principal one at seventy-two seconds. The principal disturbance in the north-south direction commenced at about thirty-two seconds and lasted to the fiftieth second. During this interval the intensest vibration occurred at 49 seconds, almost exactly from south to north. * * *

"By treating the displacement as belonging to a simple harmonic motion, the actual velocity of the ground at forty-nine seconds is found to be 0.47 inch (12^{mm}) per second, and its actual acceleration 1.29 inches (33^{mm}) per second per second. * * *

"In a similar manner the velocity of the greatest westerly displacement, which occurred at about 72.7 seconds, is found to be 0.13 inch (3^{mm}) per second, the acceleration being 0.32 inch (8^{mm}) per second per second. * * *

"The greatest displacements (irrespective of the time) were: For north-south, 0.34 inch (9^{mm}), and for east-west, 0.10 inch (3^{mm}) from

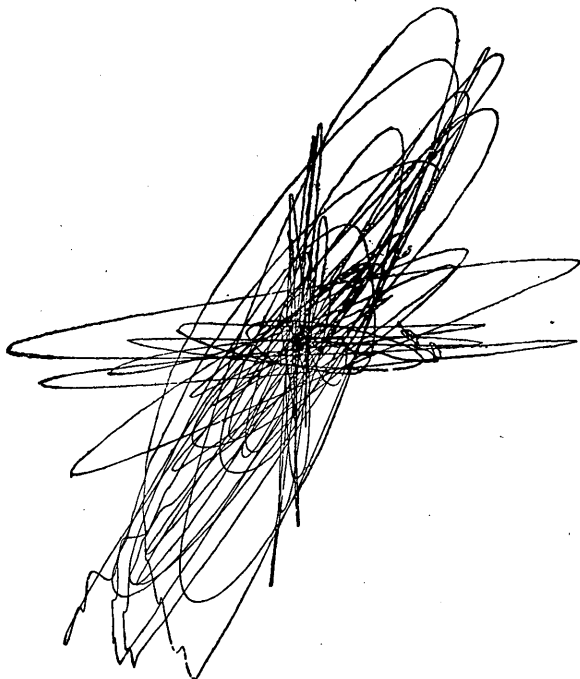


FIG. 2.—Seismograph record of earthquake of April 14, 1898, at Alameda. (Earth's motion magnified 5 diameters.)

the Ewing, and 0.43 inch (11^{mm}) and 0.11 inch (3^{mm}), respectively, from the Duplex instrument." (See fig. 1.)

MILLS COLLEGE.—11^h 5^m p. m.

ALAMEDA.—Mr. Perrine's seismograph gives a record of an extensive shock, the directions of the waves being clearly marked into east and west, north and south, and southeast and northwest. The record on the plate covers an area of 3 inches east and west by 3½ inches north and south. (See fig. 2.)

COLLEGE PARK.—11^h 10^m 39^s.

April 18.—PRAIRIE CAMP (MENDOCINO COUNTY).—There were nine severe shocks, which caused the public school to shut down.—San Francisco Chronicle, April 26, 1898.

April 25.—ALBION, MENDOCINO.—Another severe earthquake was felt at Albion and Mendocino to-day. People rushed from their homes in affright at Albion. The ground cracked in a number of places in Mendocino and vicinity. The people on the coast have been very uneasy ever since the severe shocks on April 14 and 15.—San Francisco Chronicle, April 26, 1898.

April 26.—COLLEGE PARK.—10^h 30^m p. m. ±.—Recorded on seismograph and felt also. Explosion of Santa Cruz powder works?

May 2.—COLLEGE PARK.—6^h 2^m a. m. Reported by H. D. Curtis.

SALINAS.—Two distinct shocks of earthquake were felt here at 6.05 this morning. The vibrations, which were from east to west, were very heavy and caused much alarm. Except for a few broken windows no damage was noted.

SANTA CRUZ.—This morning Santa Cruz was visited by an earthquake. The shock was not very heavy and no damage was done.—San Francisco Call, May 3, 1898.

May 9.—GILROY.—A light shock of earthquake was felt here at about 7 o'clock this morning.—San Francisco Call, May 10, 1898.

May 20.—MOUNT HAMILTON.—6^h 48^m 53^s ± ½^s a. m., Pacific standard time. Duration 1 second.—J. M. Schaeberle.

COLLEGE PARK.—6^h 49^m a. m. Reported by H. D. Curtis.

May 22.—COLLEGE PARK.—11^h 15^m a. m. "Caused the church to creak. Left a mark an eighth of an inch long on seismograph."—H. D. Curtis.

May 29.—SANTA BARBARA.—7^h 03^m p. m. A slight shock of earthquake was felt here at 7.03 o'clock last evening.—San Francisco Call, May 31, 1898.

June 3.—LOS OLIVOS.—10^h 20^m p. m.—A distinct shock of earthquake was felt throughout Santa Ynez Valley last night at 10.20. The vibration was from east to west. No damage was done.—San Francisco Call, June 4, 1898.

SANTA BARBARA.—10^h 18^m p. m.—At 10.18 o'clock to-night the heaviest earthquake for some years was experienced here. The lateral movement was from east to west.—San Francisco Call, June 4, 1898.

June 8.—POINT ARENA.—11^h 30^m (a. m.) 1^h (p. m.) Several earthquakes were felt here to-day, two severe ones at 11.30 and 1 o'clock. No damage.—San Francisco Call, June 8, 1898.

June 30.—LOS ANGELES.—An earthquake shock was experienced in this city at 11.26 o'clock last night. The vibrations were from northeast to southwest, and were of two seconds' duration. No damage is reported. The shock was not felt by neighboring towns.—Newspaper report.

At 12.28 to-night two earthquakes of a lively nature occurred in this city. The first was very mild, but the second was more pronounced. It was of the "lift-up and drop-down with a thud" nature, and alarmed the people in the upper stories of high buildings. No damage has so

far been reported. The shocks were not felt in neighboring towns.—San Francisco Examiner, July 1, 1898.

July 19.—MELROSE, ALAMEDA COUNTY.—"Powder-mill explosion at Melrose this morning. Time observed by me at Oakland, my house, 5^h 20^m 47^s \pm 2^s a. m. Shock waked us all."—A. H. Babcock.

August 7.—SAN FRANCISCO.—11^h 57^m a. m. A slight earthquake shock was felt in the city yesterday about 3 minutes before noon. The shock was of very short duration and was hardly noticeable. In the Western Addition it made windows rattle and doors creak, but so far no damage or loss has been heard of. The seismograph at the university observatory at Berkeley indicated a very slight shock, the force traveling directly north and south. The earthquake was not felt in Oakland.—San Francisco Call, August 8, 1898.

No record on Mr. Perrine's seismograph in Alameda.

Two extremely slight earthquake shocks were felt yesterday forenoon in this city. They were so feeble as to leave no record at all on the instrument which serves as a seismograph at the weather bureau. This register is a sort of combination barometer and thermom ter, and is fairly sensitive to seismic disturbances, but it does not record a shake so slight as those of yesterday, which were unnoticed by nine-tenths of the community. The first shock occurred at 11.57 $\frac{2}{3}$ o'clock a. m. by Observer Hammon's watch, and it was little more than a faint jerk. About a second later there was a repetition of the jar. That was all there was to it. No meteorological phenomena preceded, accompanied, or followed the tiny tremblings.—San Francisco Examiner, August 8, 1898.

SAN FRANCISCO, OAKLAND, BERKELEY, ALAMEDA.—A slight earthquake was felt in this city and at Berkeley, Oakland, and Alameda just before 12 o'clock yesterday. The disturbance was so slight that probably not more than one person in a thousand noticed it, and those who did had to be in the most favorable locations.

Prof. George Davidson did not know until last night that there had been an earthquake. He was in his study at the time of the temblor, but neither felt a jar nor heard the slightest rattle of delicately suspended metal trinkets that make a noise against his mirror at the slightest tremor of the building.

The shock was felt in Berkeley at 11.58 o'clock. It was more noticeable in the southwestern part of the town.

Mr. Keno, the Japanese assistant in charge of the Students' Observatory on the campus of the University of California, a man familiar with earthquakes in Japan and accustomed to note their slightest manifestations, was not aware that there had been an earthquake until someone told him. On being informed, he hastened to the observatory and found that both the seismographs there recorded a very slight earthquake, the movement having been from south to north and without any perceptible vertical motion.—San Francisco Chronicle, August 8, 1898.

August 12.—ALAMEDA.—Several vibrations, covering an area of 9^{mm} east and west by 4^{mm} north and south. Duplex seismograph.—P. PERRINE.

MILLS COLLEGE.—6^h 10^m a. m. "A slight but distinct shock of earthquake was felt at this place about 6^h 10^m this morning. No considerable record was made by the seismograph."—JOSIAH KEEP.

August 19.—ALBION.—2^h 30^m p. m. Reported by Ralph B. Funk.

October 27.—MOUNT HAMILTON.—2^h 22^m 24^s p. m., Pacific standard time. Rossi-Forel II, northeast and southwest. Duration one to two seconds. C. D. P.

2^h 22^m 25^s p. m. Pacific standard time. Duration two seconds. Rossi-Forel II. R. H. T.

The duplex seismograph shows a single nearly straight line 5^{mm} long, northeast and southwest. The pen was found at the northeast end of this mark.

November 5.—MOUNT HAMILTON.—9^h 9^m 8^s \pm 5^s p. m., Pacific standard time. "Rattled stove; slightly shook floor of brick residence."—J. E. K.

Duplex seismograph shows a straight mark 3^{mm} long in a northeast and southwest direction. This mark resembles "creep."

November 19.—MOUNT HAMILTON.—11^h 27^m 01^s a. m. "Three close vertical shocks, last two very light, first one fairly strong."—W. W. Campbell.

11^h 27^m 0^s a. m., Pacific standard time. Rossi-Forel II. Single vertical shock.—C. D. P.

Very slight mark on duplex seismograph.

December 5.—PINOLE.—There was a heavy explosion at the powder works at Pinole, Contra Costa County. It was timed by Mr. Everett Hayden, United States Navy, in the office of the Western Union Telegraph Company in San Francisco, as 3^h 28^m 58^s p. m., Pacific standard time.

The explosion was not noticed at Mount Hamilton.

December 7.—ALAMEDA.—7^h 38^m 47^s p. m., Pacific standard time. Rossi-Forel III or IV. Direction east and west. Duration four seconds. A grinding noise preceded the heaviest shock.—C. D. P.

The duplex seismograph at Mr. Perrine's residence in Alameda shows a jagged irregular mark 3½^{mm} northwest and southeast by 1½^{mm} at right angles.

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