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No. 4, pp. 69-95 May 20, 1913

THE REGISTRATION OF EARTHQUAKES AT THE BERKELEY STATION AND AT THE LICK OBSERVATORY STATION FROM APRIL 1 TO SEPTEMBER 30, 1912

BY

E. F. DAVIS

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CONTENTS

Symbols and Notation

1. *Character of the Earthquake*—

I. Perceptible	II. Moderately strong.	III. Strong.
d (terrae motus domesticus)	Local shock (origin nearby, perceptible at the station).	
v (terrae motus vicinus)	Near shock (origin less than 1,000 kilometers distant).	
r (terrae motus remotus)	Distant shock (origin from 1,000 to 5,000 kilometers distant).	
u (terrae motus ultimus)	Very distant shock (origin more than 5,000 kilometers distant).	

2. *Phases of the Seismogram*—

P (undae primae)	First phase, or first preliminary tremors.
PR_n	Waves n-times reflected at the earth's surface.
S (undae secundae)	Second phase, or second preliminary tremors.
SR_n	Waves n-times reflected at the earth's surface.
PS	Waves changed from longitudinal to transverse oscillation, or vice versa, through reflection at the earth's surface.
L (undae longae)	Long waves, chief phase, or principal part.
M (undae maximae)	Greatest motion in the chief phase.
C (coda)	Tail or end portion.
F (finis)	End of discernible movement.

3. *Nature of the Motion*—

i (impetus)	Sudden beginning of the motion.
e (emersio)	Gradual beginning of the motion.
T (period)	Time of one complete oscillation.
A	amplitude of the motion, measured from the median line in microns ($\mu = 1/1000$ mm.).

A_E E-W component of A.

A_N N-S component of A.

A_V vertical component of A.

THE BERKELEY STATION

CONSTANTS

Latitude and longitude of the center of the seismographic room:

$\phi = 37^\circ\ 52'\ 15''.9$ N. Lat.

$\lambda = 122^\circ\ 15'\ 36''.6$ W. from Greenwich.

Time. All determinations are reduced to Greenwich mean civil time.

Altitude, 85.4 meters (280 feet) above mean sea level.

Constants of the Seismographs

	Period	Magnif.	Damping
Bosch-Omori Tronometer N-S component	15s	80	8–1
Bosch-Omori Tronometer E.W component	15s	80	8–1
Weichert Seismograph Vert. component	6s	80	8–1
Omori Tronometer N-S component	2s	60	-----
Omori Tronometer E-W component	2.5s	60	-----

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
1	6 April	I_d	e P_N ?	15 34 22					Registered by Omori seismograph. Slight thickening of the trace accompanied by a shifting of the line.
			e P_{EV}	15 34 24					
			i LM_E	15 34 25	½-¾	8			
			i LM_{NV}	15 34 27	½-¾		8	3	
			C	15 34 34					
			F	15 36±					
2	7 April	I_d	e P_{EN}	2 08 40					
			e P_V	2 08 41					
			i L_E	2 08 43					Recorded on vertical as a thickening of pen trace.
			M_E	2 08 44		1			
			M_N	2 08 45			3		
			C	2 08 50					
			F	2 09 19					
3	14 April	$I_?$	e	13 39±					Dying energy of waves of chief phase of distant shock.
			F	13 59±					
4	20 April	$I_{r\text{-}u}$	e E	2 13 51	25	3			Dying energy of distant shock.
			F	2 38±					Barely perceptible waves on North South. Not registered by vertical.
5	6 May	II_u	e P_N ?	19 18 50					Earlier phases poorly recorded.
			e P_E ?	19 18 51					
			S	not discernible					
			e L_E ?	19 31 56					
			e L_N ?	19 32 20					
			M_N 1	19 33 05	20		50		
			M_E 1	19 33 38	16	160			
			M_E 2	19 38 05	13	130			Moderately well recorded by vertical, but record illegible through overscoring.
			M_N 2	19 38 18	12		43		
			M_E 3	19 39 37	10	101			
			M_E 4	19 41 12	12	88			
			M_N 3	19 42 06	11		25		
			C	indefinite					
			F	20 26±					
6	21 May	I_d	i P_V	4 58 18					
			i P_E	4 58 19					
			i P_N	4 58 20					
			e L_E	4 58 30					
			e L_N	4 58 31					
			M_{EV}	4 58 32	unmeas'l	4		2	
			M_N	4 58 33	unmeas'l		3		
			C	indefinite					
			F	4 59 50±					
7	23 May	$I_{r\text{-}u}$		3 00±					Dying waves of a long distance shock recorded shortly after 3 o'clock.
									Record illegible on account of dragging of time markers.
8	7 June		e	10 02±	12	6	5		Dying energy of distant shock.
			F	11 29±					Barely perceptible waves on vertical.
9	7 June	$I_{r\text{-}u}$	e N	18 30 23					A few long flat waves were recorded by the vertical seismograph. Times were uncertain on account of defective action of time marking magnet.
			e E	18 30 33					
			M_N	18 40 41	13		6		
			M_E	18 41 08	15	15			
			F	19 40±					
10	8 June	$I_?$	e	0 28 30	11-15	3	4		Dying energy of distant shock; recorded on horizontal components; barely perceptible waves on vertical.
			F	1 21 30±					
11	8 June	?		7±					Records illegible due to dragging of time markers.
				14±					Beginning shortly after 7 o'clock and continuing until 14 o'clock the ground appears to have been in almost continuous motion. The amplitude of this motion increases and decreases in an irregular manner, but several distinct maxima are apparent. Periods range from 15-20 seconds. Amplitudes cannot be determined. There appear to have been several long distance shocks during this time.

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
12	10 June	I_r	e P_N	16 12 16					Well recorded on vertical, but record is illegible owing to failure of time magnet on vertical machine.
			e P_E	16 12 19					
			e S_N	16 17 22					
			e S_E	16 17 25					
			e L_E	16 21 06					
			e L_N	16 21 20					
			$M_{E\,1}$	16 22 42	15	100			
			M_N	16 23 20	14		13		
			$M_{E\,2}$	16 23 31	14	60			
			M_V					8	
			C	indefinite					
			F	17 33 30±					
13	12 June	I_r	e P	12 50 44					
			e L_N	13 00 54					
			$M_{N\,1}$	13 00 59	7		6		Barely perceptible waves on vertical. Period 12 seconds, amplitude 2 microns at maximum.
			$M_{N\,2}$	13 01 30	7		5		
			$M_{E\,1}$	13 05 41	16	6			
			$M_{E\,2}$	13 08 51	20	14			
			C	indefinite					
			F	13 28±					
14	17 June	I?	e	11 32 30					Barely perceptible waves. Not recorded by vertical.
			F	12 30 30±					
15	18 June	I_d	e P	22 26 35					
			e L_N	22 27 07					Times uncertain within ten seconds.
			e L_E	22 27 08					
			$M_{E\,1}$	22 27 30	6	4			
			$M_{N\,1}$	22 27 34	5		5		Not recorded by vertical.
			$M_{E\,2}$	22 28 07	6	6			
			$M_{N\,2}$	22 28 18	5		4		
			C	22 28 48					
			F	22 31 30±					
16	7 July	I_r	e P_N	8 03 50					
			e P_E	8 03 58					
			e S_N	8 09 08					
			e S_E	8 09 10					
			$M_{E\,1}$	8 14 06	19½	162			L cannot be distinguished with certainty.
			$M_{E\,2}$	8 17 17	15	281			
			$M_{N\,1}$	8 18 04	10		141		
			$M_{E\,3}$	8 18 10	15	218			
			$M_{E\,4}$	8 19 06	11	283			
			$M_{N\,2}$	8 19 48	11		208		No record on vertical. Due to temperature changes, steady mass had slackened against safety stops.
			C	8 32 53					
			F	10 19±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
17	8 July	I?	e	22 00 05					Dying energy of a distant shock.
			M_N	22 15 35	9		17		Not recorded by vertical.
			M_E	22 15 55	10	40			
			F	23 07 05					
18	12 July	I_d	e P_{EN}	4 06 31					
			i L_E	4 06 47					
			i L_N	4 06 53					
			M_E	4 07 04	10	19			Waves of short period superposed on waves of longer period. Period of short vibrations ¾-1 second. Vertical record illegible.
			M_N	4 07 09	5		12		
			C	4 08 27					
			F	4 14 32					
19	14 July	I_d	e P_E	22 31 25					
			e P_N	22 31 26					Registered on vertical by a distinct thickening of pen trace.
			e LM_E	22 31 37					
			i LL_N	22 31 38					
			C	not discernible					
			F	22 32 50					
20	25 July	I_d	e $_N$	6 17 40					
			e $_E$	6 17 41					
			M_N	6 17 57	2		2		Not recorded by vertical.
			M_E	6 18 00	2	3			
			F	6 19 40±					
21	6 Aug.	I?	e	21 39 30±	15-16	—	1	3	In East-West component record interrupted by changing of sheets. Barely perceptible waves about 22 o'clock.
			F	22 12±					
22	9 Aug.	I?	e $_N$	1 52 14					First half of record very poor.
			e $_E$	1 52 59					
			e L	not determin'bl					
			$M_{E\,1}$	2 18 57	26	81			Registered on vertical but time marks are obliterated by over-scoring. Phases not distinguishable. Max. amp. 30 microns, period 16-18 sec.
			$M_{E\,2}$	2 21 37	22	78			
			$M_{E\,3}$	2 23 27	21	84			
			$M_{N\,1}$	2 25 25	20		37		
			$M_{N\,2}$	2 27 20	15		44		
			$M_{N\,3}$	2 29 33	16		70		
			$M_{E\,4}$	2 29 41	16	100			
			C	indefinite					
			F	3 19±					Probable record of earthquake in Turkey.
23	17 Aug.	I ?	e	19 36 36	30	12	—	—	Barely perceptible waves in North-South component. Not recorded by vertical.
			F	21 04±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
24	18 Aug.	I_r	e P_E	21 12 28					S not distinguishable.
			e P_N	21 12 31					
			e L_E	21 14 36					No record on vertical. Steady mass against safety stop due to temperature change.
			e L_N	21 14 45					
			M_N 1	21 14 56	6		15		
			M_E 1	21 15 11	6	35			
			M_N 2	21 15 18	5		12		
			M_E 2	21 16 09	9	27			
			C	21 19 47					Arizona earthquake.
			F	21 28¾±					
25	24 Aug.	I_d	?	5 10 35					Slight thickening of line in both horizontal components. No record on vertical.
26	30 Aug.	I_v	e $_N$	4 53 34					Registered on vertical by thickening of pen trace.
			e $_E$	4 53 35					
			e L_E ?	4 53 42					
			e L_N	4 53 54					Main waves fairly well recorded by Omori, though much friction is evident. Periods and amplitudes as follows:
			M_E 1	4 53 57	2	6			
			M_N 1	4 53 06	3				
			C	not discernible				9	
			F	4 58 10±					
									N-S E-W
									Max. amp. 8 4
									Period 2 3
27	12 Sept.	III_d		East-West	Bosch	Omori			
			i P	17 27 38	½-2	18			
			i LM	17 27 48	½-¾	>188			
			C	17 30 48					Pen off paper during maximum movement.
			F	17 33 48					
				North-South	Bosch	Omori			
			i P	17 27 38	½-2		28		
			i LM	17 27 47.5	¾		110		
			M_2	17 27 57	1½		63		
			M_3	17 27 59	2		51		
			C	17 30 38					
			F	17 38 47					
				Vertical					
			i P	17 27 37	1-1½			27	
			i LM	17 27 47	2			60	
			M_3	17 28 01	1-1½			60	
			C	not discernible					
			F	17 37 30					
27	12 Sept.	III_d		East-West		Omori			
			i P	17 27 38		¾-1		28	
			i LM	17 27 48		1-1½		140	
			M_2	17 27 53		1½		154	Record "smoothed out," no minor irregularities as in case of Bosch-Omori records.
			M_3	17 28 00		2		130	
			C	17 29 33					
			F	17 32 19					
				North-South		Omori			
			i P	17 27 36		1½		25	
			i LM	17 27 45					
			M_2	17 27 52		3		166	
			C	17 29 26					
			F	17 32 30					
28	29 Sept.	I_v	e	21 04 42					No phases distinguishable.
			M_N	21 49 33		19		4	
			M_E	21 55 37		17	3		
			F	22 52±					

THE LICK OBSERVATORY STATION

CONSTANTS

Constants of the Station

Latitude and longitude of the center of the seismographic room:

$\phi = 37° 20' 24''.5$ N. Lat.
$\lambda = 121° 38' 34''$ W. from Greenwich.

Time. All determinations are reduced to Greenwich mean civil time.

Altitude, 1281.7 meters (4202.25 feet) above mean sea level.

Constants of the Seismographs

	Period	Magnif.	Damping
From April 1 to June 18, 1912—			
Wiechert Seismograph N-S component	7	80	8:1
Wiechert Seismograph E-W component	7	80	8:1
Wiechert Seismograph Vert. component	5	80	8:1
From June 18 to August 9, 1912—			
Wiechert Seismograph N-S component	5.5	80	8:1
Wiechert Seismograph E-W component	5.5	80	8:1
Wiechert Seismograph Vert. component	3.5	80	8:1
From August 9 to September 13, 1912—			
Wiechert Seismograph N-S component	4.5	80	8:1
Wiechert Seismograph E-W component	4.5	80	8:1
Wiechert Seismograph Vert. component	3.5	80	8:1
From September 13 to September 30, 1912—			
Wiechert Seismograph N-S component	4.0	80	8:1
Wiechert Seismograph E-W component	4.0	80	8:1
Weichert Seismograph Vert. component	3.5	80	8:1

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
1	20 April	I?	?	2 00±	18	3	3		Simple sinusoidal waves.
2	21 April	I_d	eP_{EN}	6 16 13					eP_V not distinguishable.
			i LM_V	6 16 13.5	$< \frac{1}{4}$			1	
			iLM_{EN}	6 16 14.5	$< \frac{1}{4}$	8	6		
			C	6 16 18					
			F	6 16 25					
3	25 April	$I_{d\text{-}V}$	e	0 27 53					Phases not distinguishable. Registered in all components.
			F	0 31 55	7	1	—	—	
4	27 April	I_d	i P	6 05 07					Not recorded by vertical.
			i LM	6 05 08.5	$< \frac{1}{4}$	5	3		
			$M_{N\,2}$	6 05 10	$< \frac{1}{4}$		2		
			C	6 05 13					
			F	6 05 17					
5	27 April	I_d	i P_V	17 10 47					Recorded in all components. Time on horizontal records is uncertain.
			i LM_V	17 10 48	$< \frac{1}{4}$	19	14	3	
			C_V	17 10 53					
			F_V	17 11 02					
6	6 May	I_u	e	19 17 35					Recorded by East-West machine. No disturbance apparent on North-South record except a few long flat waves about time of $M_{E\,1}$ Not recorded by vertical.
			e L?	19 30 25					
			M_1	19 32 57	18	39			
			M_2	19 36 35	14	19			
			M_3	19 37 40	16	20			
			M_4	19 39 47	11	19			
			F	19 33 30±					
7	7 May	I_d	i P	11 50 56					Not recorded by vertical.
			i LM	11 50 59		6	4		
			C	indefinite					
			F	11 51 17					
8	9 May	III_d	i P_V	17 17 19					Felt by several persons on mountain. Accompanied by sounds.
			i P_{EN}	17 17 20					
			i LM	17 17 21.5	$< \frac{1}{4}$	22	36	5	
			C	17 17 26					
			P	17 17 55					
9	21 May	III_d	i P_V	4 58 04					Felt by nearly every one on the mountain. Recorded by Ewing duplex seismograph.
			i P_{EN}	4 58 05					
			iLM_{EV}	4 58 06	$< \frac{1}{4}$	63		27	
			i LM_N	4 58 07	$< \frac{1}{4}$		69		
			C	4 58 29					
			F	5 00 58					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
10	28 May	II_d	i P_{EN}	21 45 13					
			i P_V	21 45 14					
			i LM_{EN}	21 45 14.5	$< \frac{1}{4}$	22	25		
			i LM_V	21 45 16	$< \frac{1}{4}$			3	
			C	21 45 18					
			F	21 46 17					
11	7 June	I_d	i M	21 59 05		6	8	1	Sudden displacement of the pen in all components.
12	7 June	I_d	i M	22 15 50		—	10	—	Sudden disturbance in all three components.
			F	22 15 51					
13	9 June	I_d	i P_N	23 53 12					
			i P_V	23 53 12.5					
			i P_E	23 53 13					
			i LM	23 53 16.5	$< \frac{1}{4}$	11	15	1	
			C	23 53 24					
			F	23 53 57					
14	11 June	I_d	i P	0 38 57					On vertical slight shift of pen and thickening of trace at $0^h 38^m 57^s$ o'clock.
			i LM	0 38 59	$< \frac{1}{4}$	8	9	—	
			C	0 39 02					
			F	0 39 15					
15	12 June	I?	e	12 50 48					North-South component only. Dying energy of chief phase of a distant shock.
			M	13 03 49	20			6	
			F	13 $25\frac{1}{2}$ ±					
16	13 June	?	P	not discernible					Doubtful shock. Not recorded by vertical. Not reported as felt. No report of any artificial disturbance at this time.
			i LM	17 35 05	$< \frac{1}{4}$	200	56	—	
			C	not discernible					
			F	17 35 42					
17	13 June	I_d ?	i P	18 22 53					Doubtful shock. Horizontal components only.
			i LM	18 22 54	$< \frac{1}{4}$	9	—	—	
			C	not discernible					
			F	18 22 56					
18	13 June	I_d	i P	18 57 40					
			i P_V	18 57 41					
			i LM	18 57 42	1-4	19	55	—	
			C	18 57 46					
			F	18 57 59					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
19	14 June	I_d	e P	0 37 51					
			e L_V	0 37 54					
			e L_{EN}	0 37 55					
			M	0 37 56	$< \frac{1}{4}$	< 1	2	2	
			C	0 37 58					
			F	0 38 02					
20	15 June	I_d	i P	20 37 32					Slight thickening of pen trace on vertical.
			i LM	20 37 33	$< \frac{1}{4}$	8	6	—	
			C	indefinite					
			F	20 37 36					
21	23 June	?	e $_V$	18 07 38					Slight microseisms running may obscure record on horizontal. N.B.—Blasting was going on on road below observatory, and while time of blasts, on this date, was not recorded it is possible that this is result of a blast.
			M_V	18 08 44	$2\frac{1}{2}$	—	—	3	
			F_V	18 09 04					
22	25 June	I_d	i P	14 26 20					Driving clock of vertical machine out of order.
			i LM	14 26 21	$< \frac{1}{4}$	8	7	—	
			C	14 26 25					
			F	14 26 40					
23	26 June	I_d	i P_S	21 40 09					i P not discernible on East-West or on vertical.
			i M	21 40 10	$< \frac{1}{4}$	16	8	1	
			F	21 40 12					
24	29 June	I_d	i M	22 49 56					No preliminary motion apparent.
			C	22 49 58	$< \frac{1}{4}$	9	19	2	
			F	22 50 00					
25	30 June	I_d	e P	3 21 06					No vertical record at this time.
			i LM	3 21 07.5	$< \frac{1}{4}$	2	2		
			C	3 21 10					
			F	3 21 23					
26	30 June	I_d	i M	19 37 56.5	$< \frac{1}{4}$	6	2		Slight thickening of vertical pen trace about $19^h 37^m 58^s$.
			C	19 37 58					
			F	19 38 03					
27	1 July	I_d	e P	2 23 37					Not recorded by vertical.
			i LM	2 23 38.5	$< \frac{1}{4}$	3	4		
			C	2 23 40					
			F	2 23 44					
28	3 July	I_d	i M	0 58 15		17	22	2	Shift of pen in all components.

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
29	7 July			8 13+					A large distant earthquake was recorded after this time, but owing to binding of dampers the horizontal records are meaningless. Vertical clock interfered with by sheet.
30	9 July	I	i $_V$	20 26 01					No horizontal record; due probably to binding of dampers.
			M_V	20 26 03	2			23	
			F	20 26 09					
31	11 July	I-II$_d$	i P	8 53 42					All components.
			i LM	8 53 43	1-2	46	27	7	
			C	not discernible					
			F	8 54 36					
32	12 July	II$_d$	i P	4 06 13					
			i L_{EV}	4 06 23					
			i L_V	4 06 24					
			M_V	4 06 26	1			33	
			M_{EN}	4 06 28	3-4	291	336		
			C	4 06 54					
			F	4 08 01					
33	12 July	I$_d$	i M	18 06 37	$<\frac{1}{4}$	3	2	1	Sharp shift of pen in all components.
34	12 July	I$_d$	i M_V	21 37 36	$<\frac{1}{4}$			3	
			i M_{EN}	21 37 38	$<\frac{1}{4}$	16	9		
			C	not discernible					
			F	21 37 40					
35	12 July	I$_d$	i M_V	22 30 06	$<\frac{1}{4}$			1	
			i M_{EN}	22 30 07	$<\frac{1}{4}$	12	9		
			F	22 30 09					
36	13 July	I$_d$	e	19 43 53					
			i M	19 43 54	$<\frac{1}{4}$	12	9	3	
			C	19 43 56					
			F	19 43 59					
37	14 July	III$_d$	i P_V	22 31 09					Felt by a number of people.
			i P_{EN}	22 31 10					
			iLM_{EN}	22 31 12	3-4	197	412		
			i LM_V	22 31 13	$1\frac{1}{2}$			37	
			C	22 31 19					
			F	22 31 46					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
38	18 July	I$_d$	i P	10 49 17					
			i LM_V	10 49 19	$<\frac{1}{4}$			1	
			i LM	10 49 19.5	$<\frac{1}{4}$	10	6		
			C	10 49 21					
			F	10 49 38					
39	19 July	I$_d$	e P	21 23 32					Not recorded by vertical.
			i M	21 23 33.5	$<\frac{1}{4}$	3	—		
			C	21 33 55					
			F	21 23 38					
40	22 July	I$_d$	i P_V	18 47 27					
			i P_{EN}	18 47 28					
			i LM	18 47 29.5	$<\frac{1}{4}$	19	—	3	
			C	18 47 32					
			F	18 47 44					
41	22 July	I$_d$	e P_E	22 12 09.5					Vertical record illegible through over-scoring. Displacement of pen on N-S component at $22^h\,12^m\,09^s5$.
			i LM_E	22 12 10	$<\frac{1}{4}$	6			
			C_E	22 12 11					
			L_E	22 12 15					
42	23 July	I$_d$	i P_E	3 38 21					
			i LM	3 38 22.5	$<\frac{1}{4}$	3	3	1	
			C	3 38 24					
			F	3 38 29					
43	23 July	I$_d$	e_N	19 59 31.5					Confused chattering of pen on E-W at time of maximum.
			i M	19 59 34	$<\frac{1}{4}$	>11	11	3	
			C	19 59 36					
			F	19 59 44					
44	23 July	I$_d$	i M_{EN}	20 05 39	$<\frac{1}{4}$	>19	16		Confused chattering of pen at time of maximum on East-West component.
			i M_V	20 05 40	$<\frac{1}{4}$			3	
			F	20 05 41					
45	23 July	I$_d$	i M	20 05 46	$<\frac{1}{4}$	6	8	1	
			C	20 05 47					
			F	20 05 49					
46	23 July	I$_d$	i M	20 05 55	$<\frac{1}{4}$	?	15	3	Confused chattering of pen on East-West record.
			C	20 05 58					
			F	20 06 05					
47	23 Jnly	I$_d$	i M	23 19 06	$<\frac{1}{4}$	?	11	1	Confused chattering of pen on East-West record.
			F	23 19 07					
48	24 July	I$_d$	i M	0 57 35	$<\frac{1}{4}$	?	13	2	Confused chattering of pen on East-West record.
			F	0 57 37					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
49	24 July	I_d	i M	7 30 32	$<\frac{1}{4}$	7	4		Sudden shift of pen on vertical at 7 30 33.
			C	7 30 34					
			F	7 30 39					
50	24 July	I_d	i M	17 57 38	$<\frac{1}{4}$	9	3		Sudden shift of pen on vertical at $17^h\,57^m\,38^s$.
			C	17 57 39					
			F	17 57 43					
51	24 July	I_d	i M	20 02 40	$<\frac{1}{4}$	?	9	2	Confused chattering of pen on East-West record.
			C	20 02 41					
			F	20 02 44					
52	24 July	I_d	i M_V	22 09 56	$<\frac{1}{4}$			3	
			i M_{EN}	22 09 57.5	$<\frac{1}{4}$	10	9		
			C	22 09 59					
			F	22 10 05					
53	25 July	I_d	e P	18 00 05					
			i M	18 00 06.5	$<\frac{1}{4}$	11	5	<1	
			C	18 00 07					
			F	18 00 08					
54	26 July	I_d	i M	23 44 52	$<\frac{1}{4}$	9	4	2	Registered in all components.
			C	23 44 54					
			F	22 34 57					
55	30 July	I_d			$<\frac{1}{4}$	12		—	The record from July 29, 1912, $17^h\,33^m$ to July 30, 1912, $17^h\,40^m$ is for the most part illegible on account of failure of time markers to act. During this time three small disturbances occurred. One of these is *recorded by the vertical.*
56	1 Aug.	I_d	e	2 43 27					
			M	2 43 27.5	$<\frac{1}{4}$	17	4		No record on vertical. Doubtful shock.
			F	2 43 29					
57	7 Aug.	I_d	i M	0 23 29		19	9	3	Shift of pen in all components.
58	10 Aug.	I_d	e P_E	5 29 09					Thickening of pen trace at $5^h\,29^m\,10^s$ on both North-South and vertical records.
			i LM_E	5 29 10	$<\frac{1}{4}$	1			
			C_E	5 29 12					
			F_E	5 29 16					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
59	10 Aug.	I_d	e P	20 14 06					Shift of pen on vertical at $20^h\,12^m\,05^s$.
			i LM	20 14 08	$<\frac{1}{4}$	2	—		
			C	20 14 09					
			F	20 14 22					
60	11 Aug.	I_d	e	5 08 10					Not recorded by vertical. Thickening of pen trace on North-South.
			F	5 08 25		—	2		
61	17 Aug.	I_d	e	3 49 56	$<\frac{1}{4}$	2	3	—	Thickening of pen trace on vertical component.
			M	3 50 09					
			F	3 50 21					
62	22 Aug.	I_d	e	6 27 23					Shift of pen on vertical at $6^h\,27^m\,30^s$ followed by a thickening of the pen trace.
			M	6 27 34	$<\frac{1}{4}$	3	4		
			F	6 27 40					
63	23 Aug.	I_d	e	2 36 14	$<\frac{1}{4}$	1	2		No phases distinguishable. Not registered by vertical.
			F	2 36 29					
64	24 Aug.	II_d	i P_{EN}	5 10 17					Confused chattering of pen on East-West component.
			i P_V	5 10 18					
			i LM_N	5 10 18.5	$<\frac{1}{4}$		26		
			i LM_V	5 10 19	$<\frac{1}{4}$			6	Felt by at least a dozen people.
			C	5 10 26					
			F	5 10 53					
65	28 Aug.	I_d	e_{EN}	2 30 33					Thickening of pen trace on East-West and vertical components.
			e_V	2 30 35					
			M_N	2 30 41	$<\frac{1}{4}$		3		
			F	2 30 57					
66	29 Aug.	I_d	e	18 31 48					Thickening of pen trace on East-West. No record on vertical.
			M_N	18 31 57	$<\frac{1}{4}$		1		
			F	18 32 06					
67	3 Sept.	I_d	i P_V	9 13 36					
			i P_{EN}	9 13 38					
			i LM_V	9 13 38.5	$<\frac{1}{4}$			3	
			i LM_{EN}	9 13 40	$<\frac{1}{4}$	9	4		
			F	9 13 44					
68	8 Sept.	I_d	i P_E	20 37 59					Not recorded on North-South. Recorded on vertical by a slight thickening of the pen trace.
			i LM_E	20 38 00.5	$<\frac{1}{4}$	3			
			F	20 38 09					
69	9 Sept.	I_d	i P	3 14 23					
			i LM	3 14 25.8	$<\frac{1}{4}$	44	27	4	
			C	3 14 28					
			F	3 14 47					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
70	9 Sept.	Id	e $_E$	17 38 13					Thickening of pen trace on North-South and vertical components.
			M	17 38 21	$<\frac{1}{4}$	3	—	—	
									Beginning doubtful. Microseisms running at this time.
71	10 Sept.	Id	i P_E	1 10 23					Recorded on vertical and North-South components as a thickening of pen trace at $1^h\,10^m\,29^s$.
			i LM_E	1 10 29	$<\frac{1}{4}$	3	—	—	
			C_E	indefinite					
			F_E	1 10 43					
72	10 Sept.	Id	i M	16 37 48	$<\frac{1}{4}$	4	—	—	Shift of pen trace in all components.
73	10 Sept.	Id	c	19 43 21					Shift of pen on vertical and North-South components at $19^h\,43^m\,22^s.5$.
			i LM	19 43 22.5	$<\frac{1}{4}$	4	—	—	
			C	indefinite					
			F	19 43 33					
74	10 Sept.	Id	?	23 16 53					Slight disturbance of pens in all three components.
75	11 Sept.	Id	e_E	1 51 01					Not certainly recorded by vertical.
			eL_E	1 51 08					
			M_{NE}	1 51 09	$<\frac{1}{4}$	4	1		
			C_E	1 51 10					
			F	1 51 15					
76	12 Sept.	Id	i	0 35 05		6	5	1	Sudden displacement of pens in all three components.
77	12 Sept.	Id	i	9 32 26		4	3	—	Displacement of pens in all three components.
*78	12 Sept.	IId		East-West					
			i P	17 27 28					
			i LM	18 27 33.2	$<\frac{1}{4}$	—			Pen dismantled.
				North-South					Recorded by Ewing duplex machine. Complex motion in all components. Minute vibrations superposed on vibrations of longer period and greater amplitude.
			i P	17 27 28					
			i LM	17 27 33.2	$\frac{1}{4}$-1		501		
			C	17 27 43					
			F	17 28 30					
				Vertical					
			i P	17 27 27					
		*	i LM	17 27 33.3?	$<\frac{1}{4}$			>200	Motion limited by safety stops.

*See discussion on page 93

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
									Beginning about 19 o'clock Sept 12 and continuing until 17 o'clock Sept. 13 there is considerable microseismic movement recorded by the seismographs. During this time there are three disturbances of the pen trace. All these disturbances are more marked on the East-West record than on North-South. In only one case is there a vertical record (see No. 79). Times of occurrence of these disturbances are approximately
									$20^h\,50^m\,05^s\pm$ Sept. 12
									$0^h\,09^m\,15^s\pm$ Sept. 13
									$2^h\,38^m\,15^s\pm$ Sept. 13
79	12 Sept.	Id	e P	20 50 03					Shift of pen on North-South and vertical components at $20^h\,50^m\,08^s.5$.
			i LM	20 50 08.5	$<\frac{1}{4}$	3			
			F	20 50 20					
80	13 Sept.	Id	e P	19 02 24					A thickening of pen trace accompanied by a shift of pen on North-South component at $19^h\,02^m\,24^s$. Not recorded by vertical.
			i LM	19 02 29	$<\frac{1}{4}$	2			
			F	19 02 34					
81	13 Sept.	Id	M_{EN}	21 53 14	$<\frac{1}{4}$	25	12		
			M_V	21 53 15	$<\frac{1}{4}$			<1	
			F	21 53 19					
82	13 Sept.	Id	e	confused by	minute	mark			
			M	21 54 01	$<\frac{1}{4}$	3	1	1	
			F	21 54 05					
83	14 Sept.	Id	i P_E	3 31 19					Not recorded by vertical.
			e P_N	3 31 19					
			i LM_N	3 31 24	$<\frac{1}{4}$		1		
			i LM_E	3 31 25	$<\frac{1}{2}$	4			
			F	3 31 34					

No.	Date	Charac.	Phase	Time G. M. C. T. h	m	s	Period s	Amplitude A_E μ	A_N μ	A_V μ	Remarks
	1912										
84	14 Sept.	Id	e P_{EN}	18	27	58					
			i $_V$	18	27	59					
			i LM_{NV}	18	28	03	< 1/4		9	2	
			i LM_E	18	28	03.5	< 1/4	16			
			C	18	28	09					
			F	18	28	23					
85	14 Sept.	Id	e P?	22	44	10					Not recorded on North-South component. Displacement of pen on vertical at $22^h\,44^m\,25^s$.
			i M	22	44	21	< 1/4	2			
			F	22	44	35					
86	15 Sept.	Id	e $_{EN}$	1	38	16					Slight shift of pen and thickening of pen trace on North-South record.
			e $_V$	1	38	18					
			M_V	1	38	22	< 1/4			1	
			M_E	1	38	29	< 1/4	4			
			F	1	38	31					
87	15 Sept.	Id	i M	16	38	13	< 1/4	8	35		Barely perceptible thickening of vertical pen trace.
			C	16	38	17					
			F	16	38	45					
88	15 Sept.	Id	i P_E	22	45	17					Registered on vertical by a thickening of the pen trace from $22^h\,45^m\,23^s$ to $22^h\,45^m\,33^s$.
			e $_N$	22	45	21					
			i L_E	22	45	24					
			$M_{E\,1}$	22	45	26	< 1/4	3			
			$M_{N\,1}$	22	45	28	< 1/4		3		
			$M_{E\,2}$	22	45	30	< 1/4	4			
			F	22	45	33					
89	16 Sept.	Id	e P_E	19	55	53					Registered on North-South and vertical components by thickening of pen traces.
			e $_V$	19	55	58					
			e $_N$	19	55	59					
			i L_E	19	55	59	< 1/2	3			
			M_E	19	56	07	< 1/4	4			
			F	19	56	11					
90	16 Sept.	Id	e	23	23	58					Registered on North-South and vertical components by a thickening of pen traces beginning at $23^h\,24^m\,10^s$.
			M	23	24	10	< 1/4	2			
			F	23	24	14					
91	17 Sept.	Id	e $_E$	2	19	07					Registered on North-South and vertical components by a thickening of pen traces.
			e $_V$	2	19	11					
			e $_N$	2	19	12					
			$M_{E\,1}$	2	19	14	< 1/4	3			
			$M_{E\,2}$	2	19	20	< 1/4	3			
			$M_{E\,3}$	2	19	21	< 1/4	2			
			F	2	19	23					

No.	Date	Charac.	Phase	Time G. M. C. T. h	m	s	Period s	Amplitude A_E μ	A_N μ	A_V μ	Remarks
	1912										
92	17 Sept.	Id	i P_E	16	58	05					Registered on North-South and vertical components by a thickening of the pen traces.
			i LM_E	16	58	10	< 1/4	3			
			M? $_N$	16	58	12					
			F	16	58	14					
93	18 Sept.	Id	i P_{EN}	1	33	02.5					
			i LM	1	33	04	< 1/4	7	6	1	
			C	1	33	06					
			F	1	33	10					
94	24 Sept.	Id	e $_N$	14	45	39.5					Registered on vertical by a thickening of the pen trace.
			e $_E$	14	45	41					
			e $_V$	14	45	43					
			M_E	14	45	46	< 1/4	4			
			$M_{N\,1}$	14	45	49	< 1/4		3		
			F	14	45	58					
95	24 Sept.	Id	e $_E$								e_E confused by microseisms.
			i LM_V	21	04	04	< 1/4			1	
			i LM_N	21	04	05	< 1/4		4		
			i L_E	21	04	06					
			$M_{E\,1}$	21	04	07.5	< 1/4	6			
			$M_{N\,2}$	21	04	08.5	< 1/4		5		
			F	21	04	16	< 1/4				
96	25 Sept.	Id	e	0	51	30					North-South record blurred. Not recorded by vertical.
			M	0	51	41	< 1/4	3			
			F	0	51	44					
97	25 Sept.	Id	e $_N$	16	26	26					Registered on North-South component by a thickening of pen trace.
			e $_{EV}$	16	26	28					
			M_E	16	26	33	< 1/4	3			
			M_V	16	26	37	< 1/4			1	
			F	16	26	41					
98	25 Sept.	Id	e $_N$	19	53	37					Thickening of pen trace on vertical record.
			e $_E$	19	53	39					
			e $_V$	19	53	40					
			M_E	19	53	45.5	< 1/4	3			
			M_N	19	53	49	< 1/4		2		
			F	19	53	53					
99	26 Sept.	Id	e P_{EN}	17	03	37					Barely perceptible thickening of pen trace on vertical at $17^h\,03^m\,41^s$.
			i LM	17	03	41	< 1/4	4	3	—	
			F	17	03	52					
100	26 Sept.	Id	e $_{EN}$	22	21	47					Recorded on vertical by a thickening of pen trace.
			e $_V$	22	21	52					
			M_{EN}	22	21	56	< 1/4	4	3	—	
			F	22	22	04					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
101	27 Sept.	Id	e_E	1 19 44					Recorded on vertical by a thickening of pen trace.
			e_V	1 19 49					
			L_E	1 19 49					
			M_N	1 19 50	$<\frac{3}{4}$		4		
			M_E	1 19 53	$<\frac{3}{4}$	5			
			F	1 20 02					
102	27 Sept.	Id	e_E	23 16 15.5					Recorded on vertical by a thickening of pen trace.
			e_{NV}	23 16 20.5					
			$M_{E\,1}$	23 16 26	$<\frac{3}{4}$	4			
			M_N	23 16 27	$<\frac{3}{4}$		4		
			$M_{E\,2}$	23 16 30	$<\frac{3}{4}$	3			
			F	23 16 33					
103	28 Sept.	Id	e_E	2 12 42					Recorded on North-South by a thickening of pen trace. No record on vertical.
			e_N	2 13 01					
			M_E	2 13 13	$<\frac{3}{4}$	4	—		
			F	2 13 16					
104	28 Sept.	Id	e	16 40 18					
			i LM	16 40 26	$<\frac{3}{4}$	3	3	—	
			M_V	16 40 31	1			1	
			$M_{EN\,1}$	16 40 32	$<\frac{3}{4}$	3	3		
			F	16 40 33					
105	28 Sept.	Id	e	19 56 06					All components.
			i LM	19 56 09	$<\frac{3}{4}$	4	4	—	
			M_{EN}	19 56 12	$<\frac{3}{4}$	3	3	—	Thickening of pen trace on vertical.
			F	19 56 17					
106	29 Sept.	Id	?	1 49 09					Slight thickening of pen trace in East-West and vertical components.
107	29 Sept.	Id	?	17 20 15		—	—	—	Slight thickening of pen trace in all three components.
108	29 Sept.	Id	e_E	19 56 38					Registered on North-South and vertical components by a thickening of pen traces.
			M_E	19 56 42	$<\frac{3}{4}$	3		—	
			F_E	19 56 49					
109	29 Sept.	Id	e_E	22 35 01					Thickening of pen traces in North-South and vertical components.
			M_{EV}	22 35 09	$<\frac{3}{4}$	2	—	—	
			F_E	22 35 13					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1912			h m s	s	μ	μ	μ	
110	30 Sept.	Id	e_V	1 14 34					Registered on North-South and vertical components by a thickening of the pen traces.
			e_E	1 14 35					
			M_E	1 14 43	$<\frac{3}{4}$	2	—	—	
			F	1 14 49					
111	30 Sept.	Id	e_E	15 33 51					Registered on vertical by a slight thickening of pen trace.
			e_N	15 33 53					
			e_V	15 34 01					
			M_{EN}	15 34 00	$<\frac{3}{4}$	4	3	—	
			F	15 34 08					

NOTE.—In addition to the earthquakes which are reported here as registered at the Lick Observatory there are from seventy-five to one hundred minor displacements of the writing pens of the horizontal seismograph the nature of which is at present uncertain. These disturbances have previously been described in the bulletin of this station.* Since both components of the horizontal are derived from the same steady mass it is possible, in those cases where the disturbance is not registered by the vertical seismograph, that they are due to some instrumental defect. It is also possible that they really represent very weak focal shocks whose energy was too slight to permit the registration of their vertical component. Since their nature is unknown it is deemed inadvisable to include them in the systematic report of the station.

* Univ. of Cal. Publ. Bull. of Seismographic Stations, no. 2, p. 25.

DISCUSSION OF PARTICULAR SHOCKS

Distant Earthquake Registered July 7, 1912

This earthquake was recorded at the Berkeley station by the two horizontal component seismographs. In spite of the fact that the record appeared to be unusually well written it was impossible to determine the time of beginning of the chief phase. There was no well marked change in amplitude, period or character of the waves whereby this point could be determined with any certainty.

At the Lick Observatory the horizontal component records were meaningless on account of the improper action of the dampers on the horizontal instrument. The fact that there had been a disturbance was evident, but it was impossible to tell anything about its character. The vertical instrument was not in condition to register an earthquake since the driving clock had interfered with the sheet.

Teleseism Registered August 9, 1912

This earthquake was recorded in all components at the Berkeley Station, the main portion of the disturbance being well registered. On account of the distance of origin the first and second preliminary tremors were so poorly registered that it was impossible to make a determination of the distance of origin from this station. While it was impossible to determine the epicentral distance from the records of this station it seems practically certain that this is a record of the severe earthquake which occurred in Turkey at that time. While there was a considerable amplitude of the motion of the ground at the Berkeley Station this earthquake was not registered by the instruments at the Lick Observatory.

Moderate Earthquake of September 12, 1912

At Berkeley this earthquake had an intensity which corresponded approximately to III of the Rossi-Forel scale of intensity. The motion, as registered by the seismographs at this station, was quite complex, consisting of waves of small period and amplitude superimposed upon waves of considerably longer period and amplitude. All the records showed that there had been a considerable amount of chattering of the writing pens as they moved over the surface of the record. The vertical and North-South components of the earthquake were well registered. The writing pen on the East-West component was thrown off the recording drum at the time of the beginning of the main waves and it remained off during the registration of the chief phase. The Omori seismograph at the Berkeley Station wrote excellent records in both components but they show the effect of friction and resonance to a considerable degree. These records were considerably "smoothed out" by the friction, only the larger vibrations being recorded, and they show no evidence of the smaller vibrations of shorter period which were exhibited by the more sensitive instruments. Further, a comparison of the records of the same component as written by this instrument and by the Bosch-Omori seismograph shows that there is a considerable difference in the character of the seismograms aside from the effect of the greater friction in the Omori seismograph. This difference is undoubtedly due to the lack of damping on the Omori seismograph.

At the Lick Observatory the earthquake was felt by most of the people around the main building. The following are the times of occurrence as given by various observers at this place:

	h	m	s
H. D. C.	9	27	34
W. W. C.	9	27	37
J. H. P.	9	27	42
R. H. T.	9	27	47

The earthquake was registered by the Ewing Duplex Pendulum seismograph. Only one of the three components was completely recorded by the Wiechert seismographs at this station and the shock appears to have been too strong to be properly registered

by instruments of this type. The writing pen on the East-West component was dismantled at the time of the beginning of the chief phase so that no further record of the motion in that component was obtained. The vertical component machine was apparently much affected by the motion. The first part of the vertical record is clear and distinct, but immediately after the beginning of the main phase the pen shifted a considerable distance to one side and thereafter the record is imperfect, being limited on one side by the safety stop. Besides this the driving clock of the instrument appears to have been considerably disturbed by the motion. The velocity of rotation of the drum during the time of the earthquake was greater than the normal rate and it is quite probable that the clock ran irregularly during the whole time of motion. For this reason the time of beginning of the main phase in the vertical component is regarded as uncertain. In the North-South component the record was complete, the main portion consisting of a series of long chattering swings of short period.

The distance of the origin of this earthquake from the Lick Observatory and Berkeley Stations was calculated by the aid of Omori's formula for origin distances from 50 to 200 kilometers distant. The formula is $x^{km} = 6.86\ y^{sec} + 8.1^{km}$ *
Where x is equal to the distance of the origin from the observing station and y is the interval (L–P) between the time of arrival of the first preliminary tremors and the time of arrival of the chief phase.

At the Berkeley Station, the average value of (L–P) was found to be 9.7 seconds. Substituting this value in the formula given above, the distance of the origin from the Berkeley Station is found to be 74.6 kilometers.

At the Lick Observatory the only reliable value of (L–P) was that shown by the horizontal component records. This value was 5.2 seconds. Substituting this value in the above formula we obtain a value of 43.8 kilometers for the distance of the origin from the Lick Observatory.

By reference to a map of this region it is seen that two circles having centers at Lick Observatory and at the Berkeley Station

* Bulletin I. E. I. C., 2, 2, 144–147 (1908).

and having radii, respectively equal to the distances given above; will intersect in two points. One of these points lies near the San Andreas Rift in a direction almost North of Santa Cruz while the other lies to the East of Livermore. Due to some trouble with the instruments at Santa Clara Station, the first preliminary motion was not properly recorded so that the distance of the origin from that station cannot be calculated. However, the character of the record there was such that it indicated that the origin of the disturbance was near Santa Clara. This, in connection with the fact that no disturbance was reported as being felt in the region around Livermore, seems to indicate that this earthquake had its origin on the San Andreas Rift at the location mentioned above.

During the time following the 12th of September there is an unusually large number of minor disturbances registered by the seismographs at the Lick Observatory. Many of these appear to be after shocks of the earthquake of September 12th. For the most part they are poorly recorded and their energy is comparatively slight. They show, as a general rule, a longer period of duration of preliminary motion than the usual run of weak shocks registered at the Lick Observatory and in those cases where the energy of these shocks is sufficiently great so that they are well registered it is found that they have very nearly the same duration of preliminary tremors that was observed in the case of the principal earthquake of September 12th. These earthquakes were not registered at the Berkeley Station and it seems that their original energy was so slight that they could be recorded only at stations close to their origin. Besides those shocks actually reported it is possible that there are many more which are too weak to be recorded by the vertical. In several cases there are slight disturbances present on the records of the horizontal seismographs consisting of a thickening of the pen trace lasting several seconds but the disturbance is so slight that it is impossible to ascertain whether they are actually earthquakes or due to some instrumental defect. The disturbances here spoken of are altogether different from those sudden displacements of the pen which are mentioned in the first part of this discussion.