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BULLETIN OF THE

SEISMOGRAPHIC STATIONS

No. 14, pp. 297-324 May 23, 1918

THE REGISTRATION OF EARTHQUAKES AT THE BERKELEY STATION

AND

AT THE LICK OBSERVATORY STATION

FROM

APRIL 1, 1917, TO SEPTEMBER 30, 1917

BY

E. F. DAVIS

UNIVERSITY OF CALIFORNIA PRESS

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Symbols and Notation

1. *Character of the Earthquake*—

I. Perceptible	II. Moderately strong.	III. Strong.
d (terrae motus domesticus)	Local shock (origin less than 100 kilometers distant).	
v (terrae motus vicinus)	Near shock (origin from 100 to 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 or teleseism (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.

4. *Time*—

O (origin)	Time of shock at point of origin.

THE BERKELEY STATION

CONSTANTS

Latitude and longitude of the center of the seismographic room:

$\phi = 37° 52' 15''.9$ N. Lat.

$\lambda = 122° 15' 36''.6$ 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 Seismograph N-S component	15s	80	8–1
Bosch-Omori Seismograph E-W component	15s	80	8–1
Weichert Seismograph Vert. component	6s	80	8–1
Omori Tromometer N-S component	2s	60	-----
Omori Tromometer E-W component	2.5s	60	-----
Marvin Strong-motion Seismograph—			
E-W component	6.5s	5.8	1.3–1
N-S component	6.5s	5.1	1.4–1

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
1	2 Apr.	I_d	i P_{ENV}	9 00 48.1					Felt in Berkeley; intensity III, R.F. Vertical record in part disarranged by time mark and record of maximum destroyed. Marvin strong-motion seismograph was started but earthquake was not strong enough to give a good record on this instrument.
			i L_{ENV}	9 00 51.3					
			M_N	9 00 52.2	$<\frac{1}{2}$		17		
			M_E	9 00 52.9	$<\frac{1}{2}$	15			
			C	9 00 54					
			F	9 01 08					
2	13 Apr.	I_V	e P_N	6 35 03					No definite maximum. F lost in microseisms after time indicated. Not registered by vertical seismograph.
			e L_{EN}	6 35 19.5					
			F	6 37 06+					
3	15 Apr.	I_V	e	19 01 45					A series of weak irregular vibrations representing the dying energy of a near earthquake. Origin in Nevada.
			F	19 05 35					
4	29 Apr.	I_{r-u}	e	8 44 05					Barely perceptible trace of a distant earthquake. on horizontal components.
			F	9 02 25					
5	1 May	III_u	*O*	*18 26 49*					Δ = 9380 km. Exact determination of L impossible because of dragging of time markers. M_N is the maximum recorded motion; pen went off paper at this time. Excellent record on vertical but times are illegible through overscoring. See discussion in text.
			e P_N	18 39 11					
			e P_E?	18 39 21					
			e S_E	18 49 25					
			e S_N	18 49 40					
			M_N	19 11 17	18			<675	
			M_E	19 12 18	14	460			
			C	19 33 52					
			F	22 34±					
6	2 May	I_u?	e	1 51 53					Trace of a distant earthquake on all three components. Barely perceptible on vertical. Simple sinusoidal waves from 2^h04^m to 2^h21^m; periods and amplitudes given opposite M.
			M		16-18	3	4		
			F	2 49±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
7	2 May	I_u?	e	3 38±					Long, nat waves; trace of a distant earthquake. Visible on all components but somewhat stronger on East-West.
			F	4 24±					
8	2 May	I_u?	e	4 54±					Long, flat waves; trace of a distant earthquake. Visible on all components but somewhat stronger on North-South component.
			F	5 44±					
9	2 May	I_u?	e	14 47±					Long, flat, barely perceptible waves; the trace of a distant earthquake. Visible on all components.
			F	15 29±					
10	4 May	I_u?	e	1 01±					Trace of a distant earthquake, visible on all components. Simple sinusoidal waves from $1^h27^m50^s$ to $1^h39^m20^s$; periods and amplitudes given opposite M.
			M		16-18	5	8	3	
			F	2 31±					
11	4 May	I_{d-V}	e	21 45 25					Series of weak irregular vibrations on all components. Barely perceptible on vertical.
			M_N	21 45 53	$2\frac{1}{2}$		4		
			M_E	21 45 58	2	4			
			F	21 48 13					
12	9 May	I_u	*O*	*15 54 47*					Δ = 9620 km.
			e P_E	16 07 30					
			e P_V	16 07 32					
			e P_E	indefinite					
			i S_N	16 18 09					
			i S_E	16 18 14					
			e L_N	16 30 09					
			e L_{EV}	indefinite					
			M_N	16 32 26	$19\frac{1}{2}$		14		
			M_V	16 43 36	17			8	
			M_E	16 43 39	25	44			
			C	indefinite					
			F	17 44±					
13	11 May	I_{d-V}	e	22 34 09					A series of very weak irregular vibrations on all three components.
			F	22 36 40					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
14	14 May	I_r,	i P_{ENV}	22 13 40					The records begin with a series of minute vibrations of short period and small amplitude. After a minute or so the period increases and the rest of the records consist of weak, barely perceptible vibrations in which no phases can be discerned.
			F	23 45±					
15	25 May	I_u?	e	14 46 36					Trace of a distant earthquake.
			F	15 03 21					
16	28 May	I_r	e	6 08 55					Series of weak irregular vibrations representing the dying energy of a near shock. Origin in southern California.
			F	6 17 00					
17	29 May	I_u?	e	6 32 34					Barely perceptible trace of a distant earthquake on all three components.
			F	7 12 44					
18	31 May	I_r	*O*	*8 47 26*					Δ = 3220 km. See discussion in text.
			e P_{ENV}	8 53 43					
			e S_N	8 58 39					
			e S_E	8 58 43					
			M_E	9 02 46	21	158			
			M_V	9 02 49	19			56	
			M_N	9 04 48	20		87		
			F	11 30±					
19	31 May	I_r?	e	19 45±					Barely perceptible, long, flat waves, the trace of a distant earthquake.
			F	19 58±					
20	1 June	I_r	e	16 53 07					Trace of a distant earthquake. Visible on all components.
			F	17 10 02					
21	3 June	I_{v-r}	e	6 53 44					Series of weak, irregular vibrations on horizontal components.
			F	7 01 14					
22	4 June	I_u?	e	1 36 02					No phases separable. Trace of a distant earthquake. Visible on all components.
			F	2 46±					
23	6 June	I_u?	e	4 37 06					Barely perceptible trace of a distant earthquake. Horizontal components only.
			F	5 11±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
24	7 June	I_r?	e	3 00 35					Trace of a distant earthquake on horizontal components.
			F	3 18 25					
25	8 June	I_r	*O*	*0 51 22*					Δ = 4620 km. Newspapers report a violent earthquake in Salvador.
			e P_N	0 58 58					
			e P_{EN}	0 59 02					
			e S_N	1 05 02					
			e S_E?	1 05 14					
			e L_E	1 10 26					
			e L_N	1 10 30					
			M_{E_1}	1 13 28	19	306			
			M_{N_1}	1 13 28	22		286		
			M_V	1 14 29	18			19	
			M_{N_2}	1 15 56	18		154		
			M_{E_2}	1 16 06	18	171			
			C	1 20 39					
			F	2 36±					
26	8 June	I_r	e	3 09 55					Barely perceptible, long, flat waves, the trace of a distant earthquake. Visible on both horizontal components.
			F	3 33±					
27	9 June	I_v	e P_N	3 34 35.8					Registered by both components of Omori tromometer.
			e P_E	3 34 36.9					
			e P_V	3 34 37.5					
			e L_V	3 34 55.2					
			e L_N	3 34 56.5					
			e L_E	3 34 58.1					
			M_V	3 35 04	2			4	
			M_E	3 35 16	3	8			
			M_N	3 35 26	3		9		
			C	3 35 43					
			F	3 39 48					
28	9 June	I_u?	e	17 31 10					Barely perceptible trace of a distant earthquake. Visible on all components.
			F	18 26±					
29	10 June	I_v	e P_{NV}	4 34 19					
			e P_E?	4 34 28					
			e L_N	4 35 49					
			e L_V	4 35 55					
			e L_E	4 36 11					
			M_V	4 37 51	6			10	
			M_E	4 38 18	10	55			
			M_N	4 38 37	9		61		
			C	indefinite					
			F	6 22±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
30	13 June	I_u	*O*	*6 42 02*					Δ = 9280 km.
			i P_V	6 54 28					
			e P_E?	6 54 36					
			e P_N?	6 54 41					
			e S_E	7 04 46					
			e S_V	7 04 51					
			e S_N	7 04 52					
			e L_V?	7 21 24					
			M_V	7 27 39	17			10	
			M_E	7 27 46	20	31			
			M_N	7 32 16	18		54		
			F	8 35±					
31	13 June	I_u	e	9 30 53					Long, flat waves, the trace of a distant earthquake. Visible on all components.
			F	10 00 18					
32	16 June	I_r	e	15 49 54					Trace of a distant earthquake on all components.
			F	15 10 19					
33	16 June	I_r	e	22 47 07					Trace of a distant earthquake on all components. Slight on vertical.
			M_E	22 53 57	10	7			
			M_N	22 56 05	9		10		
			F	23 27±					
34	24 June	I_r	e	19 59 24					No phases discernible. Trace of a distant earthquake. Visible on all components.
			F	20 39±					
35	26 June	III_u	*O*	*5 49 37*					Δ = 8080 km. See discussion in text.
			i P_{EN}	6 01 02					
			i P_V	6 01 04					
			e S_N	6 10 23					
			e S_{EV}	6 10 27					
			e L_V	6 21 37					
			e L_E	6 21 49					
			e L_N	6 21 55					
			M_E	6 23 58	23	1190			
			M_N	6 24 11	23		1270		
			M_V	6 24 25	20			230	
36	28 June	I_r?	e	14 33 48					Barely perceptible, long, flat waves, the trace of a distant earthquake. Horizontal components only.
			F	14 50 08					
37	29 June	I_r	e P_E?	16 11 51					F interrupted by changing of sheet at $16^h 34^m$. Not registered by vertical seismograph.
			e P_N?	16 11 55					
			M_N	16 15 31	11		3		
			M_E	16 21 39	13	4		-	
			F	16 34±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
38	30 June	I_u?	e	18 08 40					Barely perceptible, long, flat waves, the trace of a distant earthquake.
			F	18 38±					
39	4 July	I_u	*O*?	*0 38 28*					Δ = 9880 km.? East-West component only. No definite maximum; the main phase consists of long, flat waves.
			e P?	0 51 24					
			e S?	1 02 17					
			F	2 30±					
40	11 July	I?	e	23 12 33					Barely perceptible, long, flat waves on horizontal components. Trace of a distant earthquake.
			F	23 40 30±					
41	21 July	I_r	e	16 49 34					Series of very weak irregular vibrations in which no phases are visible and in which there is no definite maximum. Not registered by vertical seismograph.
			F	16 51 17					
42	25 July	I_u	e	3 30 26					Barely perceptible vibrations on North-South components. Not visible on vertical record.
			M_E	3 34 16	22	7			
			F	3 59 46					
43	25 July	I_r	e	10 26 48					Vertical record not measureable because of overscoring.
			M_E	10 26 58					
			M_N	10 26 59					
			F	10 30 12					
44	25 July	I_u?	e	22 41 30					Trace of a distant earthquake. Measureable because of overcomponent only.
			F	23 01 10					
45	26 July	I_r	e	8 32 42					A series of very weak irregular waves. No definite maximum. Visible on all components.
			F	8 36 12					
46	27 July	I_u	*O*	*1 01 19*					Δ = 5580 km. Indefinite. F interrupted by beginning of next earthquake.
			e P_{NV}	1 10 24					
			e S_N	1 17 38					
			e S_V	1 17 49					
			M_N	1 31 53	15		58		
			M_V	1 35 50	17			16	
			M_E	1 36 56	17	78			
47	27 July	I_u	*O*	*2 51 43*					Δ = 9300 km. No definite maxima on East-West or vertical records.
			e P_V	3 04 10					
			e P_E	3 04 17					
			e P_N	3 04 21					
			e S_N?	3 14 25					
			e S_E	3 14 35					
			M_N	3 34 43	19		6		
			F	4 26±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
48	27 July	I_{r-u}	e	16 39 50					Barely perceptible, long, flat waves. Trace of a distant earthquake. Not registered on vertical seismograph.
			F	16 57 50					
49	28 July	I?	e	1 26 00					Barely perceptible, long, flat waves on East-West component only. Trace of a distant earthquake.
			F	1 44 00					
50	29 July	I_u	e	15 01 35					Barely perceptible trace of a distant earthquake on all components.
			F	15 27 10					
51	29½ July	I_u	*O*	*21 53 23*					Δ = 9560 km. No definite maximum on North-South or vertical components.
			e P_V	22 06 03					
			e S_E	22 16 41					
			e S_N	22 16 42					
			M_E	22 44 48	20	7			
			F	1 06 30±					
52	29 July	I_d	i P_{EN}	22 31 43.5					Weak local earthquake superposed on the larger record of the preceding earthquake. Barely perceptible on vertical component.
			i L_N	22 31 48 0					
			i LM_E	22 31 48.5	½	3			
			M_N	22 31 49	½		3		
			C	indefinite					
			F	22 32 24					
53	31 July	I_u	e	0 36 10					Barely perceptible trace of a distant earthquake on all components.
			F	1 31 40±					
54	31 July	I_u	*O*	*3 53 14*					Δ = 7600 km. Beginning of preliminary tremors is fairly sharp but most of record consists of barely perceptible vibrations.
			i P_{NV}	3 34 14					
			e P_E?	3 34 21					
			e S_N	3 43 13					
			e S_E	3 43 14					
			e S_N?	3 43 20					
			F	4 51 40±					
55	5 Aug.	I_u?	e	16 33 30					Trace of a distant earthquake. Visible on all components.
			F.	17 15±					
56	21 Aug.	I_u?	e	11 19±					A few long, flat waves. Trace of a distant earthquake. Barely perceptible and only on horizontal components.
			F	11 29±					
57	23 Aug.	I_d	e P	2 29 32.2					Felt in Berkeley. Marvin strong-motion seismograph was started but earthquake was not strong enough to give a good record on this instrument.
			e L	2 29 33.3					
			M_N	2 29 33.6	½		16		
			M_V	2 29 33.8	½			4	
			M_E	2 29 34.4	½	22			
			C	2 29 35.5					
			F	2 29 57					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
58	30 Aug.	I_v?	e	1 41 57					A series of weak irregular waves. Visible on all components.
			F	1 51 30±					
59	30 Aug.	I_u	e P_E?	4 26 51					Phases uncertain. Beginning obscured by microseisms. No definite maximum on vertical.
			e P_V?	4 26 55					
			e P_N?	4 27 13					
			e S_N?	4 33 45					
			M_N	4 53 51	32		37		
			M_E	5 11 31	17	12			
			F	6 24 30±					
60	31 Aug.	I_u	*O*	*11 36 06*					Δ = 6300 km.
			e P_E	11 45 54					
			e P_V	11 45 56					
			e P_N	11 46 00					
			e S_V	11 53 43					
			e S_{EN}	11 53 46					
			e L	12 00 14					
			M_V	12 12 19	20			4	
			M_E	12 12 35	19	12			
			M_N	12 17 23	20		18		
			F	13 35±					
61	11 Sept.	I_v	e P_{EN}	9 34 23					Not registered by vertical seismograph. No definite maximum on North-South component.
			e L_N	9 35 21					
			e L_E	9 35 23					
			M_E	9 36 29	6	7			
			F	9 42 43					
62	12 Sept.	II_d	e P_{EN}	11 25 49.1					Felt in Berkeley. Intensity, III R.F. Marvin strong-motion instrument was started but earthquake was too weak to give a perfect record. Vertical record unmeasurable because of overscoring.
			e L_{EN}	11 26 00.1					
			M_E	11 26 01.0	2	13			
			M_N	11 26 01.9	3		15		
			C	11 26 19					
			F	11 28 39					
63	20 Sept.	I_u?	e	3 26 48					Barely perceptible, long, flat waves on all components. Trace of a distant earthquake.
			F	4 11±					
64	21 Sept.	I_v	e P	8 42 57					A series of weak irregular waves. No definite maximum. Not separable from microseismic movement on vertical.
			e L	8 44 01					
			F	8 51 57					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
65	24 Sept.	I_a	e P_N	21 21 36					*Monthly Weather Review* reports an earthquake at $21^h\ 21^m$, felt at Campbell, Hollister, Los Gatos, Salinas, Watsonville, Santa Cruz, and San Francisco.
			e P_{EV}	21 21 37					
			e L_E	21 21 50					
			e L_N	21 21 51					
			e L_V	21 21 52					
			M_{EN}	21 21 55	1	12	16		
			M_V	21 21 56	1			10	
			C	21 22 30					
			F	21 25 15					

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
April 1, 1917, to June 6, 1917.			
Wiechert Seismograph N-S component	8.0	80	4:1
Wiechert Seismograph E-W component	7.0	80	5:1
Vertical Seismograph Vertical component	2.5	80	2:1
June 6, 1917, to September 30, 1917.			
Wiechert Seismograph N-S component	7.0	80	8:1
Wiechert Seismograph E-W component	6.0	80	8:1
Wiechert Seismograph Vertical component	3.0	80	8:1

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
1	2 Apr.	I_d	i P_N	23 02 26.0					Slight disturbance on East-West component and on vertical, a thickening or pen trace.
			i LM_N	23 02 27.2	$<\frac{1}{2}$		11		
			F	23 02 35					
2	9 Apr.	I_d	e P_N	22 16 19.5					Barely perceptible on East-West record. Not registered by vertical seismograph.
			e L_N	22 16 23.5					
			M_N	22 16 25	$<\frac{1}{2}$		8		
			F	22 16 31					
3	11 Apr.	I_d	e P_N	6 34 53.6					Not registered on vertical component. East-West component out of order.
			i L_N	6 35 00.6					
			M_N	6 35 06	$\frac{1}{2}$		9		
			C	indefinite					
			F	6 36 10					
4	15 Apr.	I_r	e	19 01 33					Not registered by vertical seismograph.
			i L_N	19 01 54					
			M_E	19 01 58	1	7			
			M_N	19 02 04	1		11		
			F	19 04 55					
5	17 Apr.	I_d	e P_N	17 06 47.4					Slight thickening of pen trace on East-West component and on vertical component.
			i LM_N	17 06 52.0	$<\frac{1}{2}$		10		
			C	17 06 55					
			F	17 06 58					
6	17 Apr.	I_d	e P_N	22 58 32.0					Slight disturbance on vertical and East-West components.
			e LM_N	22 58 36.0	$<\frac{1}{2}$		8		
			C	22 58 40					
			F	22 58 48					
7	30 Apr.	I_d	e	17 40 56					Strong thickening of pen trace on North-South component. Barely perceptible on East-West and vertical components.
			F	17 41 10					
8	1 May	III_d	*O*	*18 27 10*					Δ = 9100 km. See discussion in text.
			e P	18 39 28					
			e S	18 49 44					
			e L	19 05 09					
			M_E	19 12 59	18	278			
			M_N	19 15 13	17		346		
			C	19 29 04					
			F	22 21±					
9	3 May	I_d	e	1 13 56					Strong thickening of pen trace on North-South component; weak on East-West; not apparent on vertical.
			F	1 14 06					
10	3 May	I_d	e	1 24 16					Strong thickening of pen trace on East-West component. Not apparent on vertical.
			M_E	1 24 21	$<\frac{1}{2}$	8			
			F	1 24 26					
11	3 May	I_d	e	1 25 49					Strong thickening of pen trace on North-South component; weak on East-West; not apparent on vertical.
			F	1 26 01					
12	3 May	I_d	e	1 30 59					Strong thickening of pen trace on North-South component; weak on East-West record; not apparent on vertical.
			F	1 31 09					
13	3 May	I_d	e	21 10 35					Strong thickening of pen trace on North-South component; faint disturbance on East-West and vertical components.
			F	21 10 50					
14	3 May	I_d	e	21 13 51					Marked thickening of pen trace on North-South component; weak on East-West; not apparent on vertical.
			F	21 14 01					
15	3 May	I_d	e	21 34 40					Marked thickening of pen trace on North-South component; weak on East-West; not visible on vertical component.
			F	21 34 50					
16	3 May	I_d	e	21 55 27					Thickening of pen trace on North-South component; barely perceptible on East-West; not apparent on vertical.
			F	21 55 34					
17	3 May	I_d	e_N	22 13 48					Weak disturbance on East-West and vertical records.
			M_N	22 13 58	$<\frac{1}{2}$		3		
			F	22 14 03					
18	4 May	I_{r-u}	e	1 05 32					On North-South component only. Trace of a distant earthquake. Simple sinusoidal waves from $1^h 27^m 17^s$ to $1^h 40^m 07^s$; period and amplitude given opposite M.
			M		17		14		
			F	2 26±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
19	4 May	I_d	e P_{EN}	21 45 16					A few weak vibrations are seen on vertical record but no phases are discernible.
			e L_{EN}	21 45 29					
			M_{EN}	21 45 39	1	15	13		
			C	21 45 45					
			F	21 47 17					
20	9 May	I_d	e	5 54 16					A series of minute, irregular vibrations on North-South record; a slight thickening of pen trace on vertical; no visible disturbance on East-West.
			F	5 54 41					
21	9 May	I_u	*O*	*15 55 31*					Δ = 9240 km. North-South component only. P and S appear sharply defined but after this the amplitudes decrease and the record passes into a series of barely perceptible vibrations.
			e P	16 07 55					
			e S	16 18 17					
			F	17 10±					
22	11 May	I_d	e	1 46 27					Registered on East-West and vertical records by a slight thickening of the pen traces.
			M_N	1 46 37	½		11		
			F	1 46 41					
23	11 May	I_d	e	1 47 34					Marked thickening of pen trace on North-South record; weak on East-west; no disturbance apparent on vertical.
			F	1 47 40					
24	11 May	I_d	i P	22 34 12.5					Registered on vertical component by a series of barely perceptible waves.
			i LM_{EN}	23 34 19.0	1	7	10		
			C	indefinite					
			F	22 35 35					
25	12 May	I_d	i P_{NV}	0 17 15 3					East-West component out of order.
			i L_{NV}	0 17 18.0					
			M_V	0 17 19	½			4	
			M_N	0 17 20	½		14		
			C	0 17 22					
			F	0 16 35					
26	14 May	I_r?	e	22 29±					Very faint trace of a distant earthquake. Interrupted by the occurrence of the next earthquake.
			F	23 06±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
27	14 May	I_d	i P_N	22 52 33.8					Disturbance weak on East-West and vertical records. This earthquake is superposed on the trace of the preceding earthquake.
			i LM_N	22 52 39.7	½		9		
			C	22 52 43					
			F	22 52 50					
28	15 May	II_d	i P_N	21 06 07.4					
			e P_E	21 06 08.1					
			i LM_N	21 06 08.9	½		25		
			i LM_{EN}	21 06 09.5	½	23		5	
			C	21 06 12					
			F	21 06 37					
29	16 May	I_d	e	0 14 47.8					Disturbance slight on East-West and vertical components.
			M_N	0 14 52	½		8		
			F	0 15 00					
30	16 May	I_d	e P_N	0 20 45.4					Weak on East-West and vertical components.
			e L_N	0 20 49.0					
			M_N	0 20 50	½		14		
			C	0 20 57					
			F	0 20 59					
31	16 May	I_d	e	0 26 00					Marked thickening of pen trace on North-South component; weak on East-West and vertical.
			F	0 26 07					
32	24 May	I_d	e P	21 54 26					Disturbance weak on East-West and vertical components.
			i LM_N	21 54 30	½		6		
			F	21 54 36					
33	24 May	I_d	e P	22 15 40.0					Registered on East-West component by a marked thickening of pen trace; weak disturbance on vertical.
			e L	22 15 43.7					
			M_N	22 15 46	< ½		11		
			F	22 15 49					
34	24 May	I_d	e P	23 58 13.7					Registered on East-West and vertical components by a thickening of the pen traces.
			i LM_N	23 58 17.9	< ½		11		
			F	23 58 23					
35	28 May	I_v	e	6 07 46					Trace of a near shock. On East-West component it is very weak; on vertical it is not apparent.
			M_N	6 09 00	1		8		
			F	6 13±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
36	31 May	I_r?	e_N	8 54 59					East-West record is incomplete, due to binding of the damping device. Not registered by vertical seismograph.
			e S_N	8 59 16					
			e L	9 02 00					
			M_E	9 03 14	14	280			
			M_N	9 03 29	19		200		
			F	11 05±					
37	31 May	I_d	e	19 34 06					Marked thickening of the pen traces on the North-South record; weak disturbance on the East-West and vertical records.
			F	19 34 20					
38	31 May	I_d	e	19 48 05					Registered on East-West and vertical components by a slight disturbance of the pen traces.
			M_N	19 48 13	½		8		
			F	19 48 18					
39	4 June	I_r?	e	1 18 08					Barely perceptible, long, flat waves. Trace of a distant earthquake.
			F	2 20±					
40	8 June	I_r?	e	1 03 45					Trace of a distant shock. Very faint on North-South component. Not registered by vertical seismograph. Origin in Salvador.
			M_E	1 14 59	13	23			
			F	2 00±					
41	9 June	I_d	i P_{EN}	3 34 27.6					
			i P_V	3 34 28.9					
			i L_{EN}	3 34 38.1					
			i L_V	3 34 39.8					
			M_V	3 34 40	1		24		
			M_{EV}	3 34 54	1	51		15	
			C	3 35 09					
			F	3 37 38					
42	10 June	I_r?	e	4 26 13					Trace of a distant shock. No phases discernible. No definite maximum on East-West component. Not registered by vertical seismograph.
			M_N	4 40 32	7½		25		
			F	5 55±					
43	11 June	I_d	e	3 35 24					Marked thickening of pen traces on all components.
			F	3 35 35					
44	11 June	II_d	i P_{EN}	16 04 58.9					M_N is greater than 56μ but neither the exact time of occurrence nor the amplitude is certain, because of the chattering of the pen.
			i LM	16 04 59.8	½	73	<56	21	
			C	16 05 06					
			F	16 05 12					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
45	13 June	I_u	*O*	*6 42 10*					Simple sinusoidal waves from $7^h 24^m 51^s$ to $7^h 39^m 11^s$ with periods and amplitudes given opposite M. * Amplitude of trace on record.
			e P_{EN}	6 54 37					
			e S_{EN}	7 05 02					
			e L	indefinite					
			M		17½-18½	25	27	*150	
			F	8 48±					
46	13 June	I_u?	e	9 33 01					Dying energy of chief phase of a distant earthquake.
			F	9 58 01					
47	13 June	I_d	e	16 14 37					Marked thickening of pen traces on horizontal records. Sheet on vertical seismograph was being changed at the time of this shock.
			F	16 14 51					
48	14 June	I_d	e	18 33 01					Marked thickening of pen traces on all components.
			F	18 33 15					
49	15 June	I_d	i P_N	15 34 41.9					Registered on vertical by a thickening of the pen trace.
			i P_E	15 34 42.2					
			i LM_{EN}	15 34 44.0	½	15	13		
			C	15 34 47					
			F	15 35 01					
50	16 June	I_r?	e	15 48±					Barely perceptible trace of chief phase of a distant earthquake. Horizontal components only.
			F	16 09±					
51	16 June	I_d	e	16 45 08					No phases discernible. Registered on East-West component by a thickening of the pen trace.
			M_{NV}	16 45 15	½	6		5	
			F	16 45 21					
52	18 June	I_d	e	23 55 54					Marked thickening of pen traces on all components.
			F	23 56 06					
53	19 June	I_d	e	0 14 23					No phase discernible. Registered on East-West and vertical components by a thickening of the pen traces.
			M_N	0 14 31	½		9		
			F	0 14 34					
54	20 June	I_d	i P	18 40 12.2					Registered on vertical component by a marked thickening of the pen trace.
			i LM_{EN}	18 40 13.4	<½	8	16		
			C	18 40 16					
			F	18 40 28					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
55	26 June	III_u	*O*	*5 49 29*					Δ = 8080 km. See discussion in text.
			e P_N	6 00 54					
			e P_E	6 00 56					* Amplitude measured on the record.
			e S_N	6 10 16					
			e S_E	6 10 20					
			e L_N	6 20 15					
			e L_E	6 20 17					
			M_E	6 24 36	19	*10,700	*17,700		
			M_N	6 24 51					
			C	6 41 50					
			F	7 05±					
56	28 June	I_d	e	23 29 06					Phases not separable. Not apparent on vertical record.
			M_{EN}	23 29 09	½	8	9		
			F	23 29 16					
57	29 June	I_d	e P_N	23 38 19.2					Registered on East-West component as a thickening of the pen trace. No disturbance apparent on vertical record.
			i LM_N	23 38 20.7	½		8		
			C	23 38 24					
			F	23 38 27					
58	4 July	I_u?	e	1 02 25					Barely perceptible trace of a distant earthquake. Horizontal components only.
			F	1 35±					
59	5 July	I_d	e	21 39 10					Marked thickening of pen traces on all components.
			F	21 39 19					
60	9 July	I_{d-v}	e	22 22 26					Series of weak, irregular vibrations on both horizontal components. No disturbance visible on vertical component.
			F	22 23 50					
61	20 July	I_d	e P	23 16 47.2					Marked thickening of pen trace on vertical.
			e L	23 16 52.0					
			M_{EN}	23 16 53	½	9	5		
			C	23 16 55					
			F	23 17 01					
62	21 July	I_d	i P	21 39 06.6					Not registered by vertical seismograph.
			i L	21 39 09.3					
			M_{EN}	21 39 12	½	6	9		
			C	21 39 14					
			F	21 39 16					
63	25 July	I_u?	e	3 25±					Long, flat, barely perceptible vibrations on horizontal components. Trace of a distant earthquake.
			F	4 02±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
64	25 July	I_v	e	10 26 42					Not registered by vertical seismograph.
			e L	10 26 51					
			M_{EN}	10 26 54	2-3	6	10		
			F	10 29 07					
65	26 July	I_v	e	8 32 24					Horizontal components only.
			M_{EN}	8 33 18	¾	5	6		
			F	8 36 07					
66	26 July	I_d	i P	10 06 06.6					Registered on vertical by a thickening of the pen trace.
			i L	10 06 08.1					
			M_{EN}	10 06 09	½	6	4		
			F	10 06 14					
67	27 July	I_u	*O*	*1 01 28*					Δ = 5420 km.
			e P_N	1 10 23					
			e P_E	1 10 29					
			e S_N	1 17 28					
			e S_E	1 17 30					
			e L_N	1 25 27					
			M_N	1 31 27	15		82		
			M_E	1 36 30	16½	44			
			F	2 25±					
68	27 July	I_u	*O*	*2 52 04*					Δ = 9020 km. Very weak on East-West component. No definite maximum.
			e P_N	3 04 17					
			e S_N	3 14 29					
			F	4 10±					
69	29 July	I_u	e	22 16 39					Trace of a distant earthquake on horizontal components.
			M_E	22 48 09	18	80			
			M_N	22 52 48	16		40		
			F	23 47 30±					
70	29 July	I_{d-v}	e	22 31 45					A series of weak, irregular vibrations on horizontal records. Barely visible on the record of the vertical component. A weak local earthquake, superposed on record of preceding shock.
			F	22 32 18					
71	31 July	I_{d-v}	e	3 34 18					A series of weak, irregular vibrations.
			M_E	3 34 29	1	4			
			M_N	3 34 35	1		4		
			F	3 35 29					
72	1 Aug.	I_d	e P	1 02 37.0					Registered on vertical by a marked thickening of pen trace.
			i LM	1 02 39.6	½	5	9		
			C	1 02 43					
			F	1 02 50					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
73	1 Aug.	I_a	e	23 28 04					No phases discernible. Registered on East-West and vertical as a thickening of the pen traces.
			M_N	23 28 09	½		8		
			F	23 28 16					
74	13 Aug.	I_a	e P	18 17 00.0					Registered on East-West and vertical components by a thickening of the pen trace.
			i LM	18 17 06.3	½		10		
			C	18 17 12					
			F	18 17 18					
75	15 Aug.	I_a	e P	1 03 52.1					Thickening of pen trace on vertical record.
			i L	1 03 54.6					
			M_{EN}	1 03 57.0	½	9	11		
			C	1 03 58					
			F	1 04 07					
76	16 Aug.	I_a	e	0 23 48					Marked thickening of pen traces on all components.
			F	0 24 00					
77	22 Aug.	I_a	e P	13 52 48.8					Registered on East-West and vertical components by a thickening of the pen traces.
			i L	13 52 53.3					
			M_N	13 52 55	½		9		
			F	13 53 04					
78	23 Aug.	I_a	e P	18 56 19.9					Registered on vertical component by a thickening of the pen trace.
			e L	18 56 24.5					
			M_{EN}	18 56 28	½	6	8		
			F	18 56 31					
79	28 Aug.	I_a	e	0 40 58					A series of weak, irregular vibrations in which no phases are visible. Not registered by vertical seismograph.
			M_{EN}	0 41 07	1	5	5		
			F	0 42 01					
80	30 Aug.	I_a	e	0 03 09					The horizontal records consist of pen strokes so closely spaced that successive strokes interfere giving a strong thickening of the pen traces. A slight thickening of pen trace on vertical seismograph.
			M_{EN}	0 03 12	½	6	9		
			F	0 03 17					
81	30 Aug.	I_v?	e	1 42 24					Trace of a near earthquake. Visible on horizontal components only.
			F	2 05±					
82	30 Aug.	I_a	e	4 25 39					Trace of a distant earthquake. Visible on horizontal components only.
			F	4 43±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
83	31 Aug.	I_a	*O*	*11 36 16*					Δ = 6140 km.
			e P_{EN}	11 45 55					
			e S_E	11 53 39					
			e S_N	11 53 43					
			e L	indefinite					
			M_N	12 10 36					
			M_E	12 12 14					
			F	5 15±					
84	1 Sept.	I_a	e	16 00 35					Successive strokes of the pen are so close together that records consist simply of a thickening of the pen traces.
			M_{EN}	16 00 39	½	5	6		
			F	16 00 51					
85	1 Sept.	I_a	i P	16 01 06.6					Registered on vertical by a thickening of the pen trace.
			i L	16 01 07.9					
			M_{EN}	16 01 09.3	½	8	10		
			F	16 01 16					
86	8 Sept.	I_a	e	15 53 28					Strongly marked thickening of pen traces on all components.
			M_{EN}	15 53 34	½	6	5	—	
			F	15 53 42					
87	11 Sept.	I_v	e P_{EN}	9 33 53					Not registered by vertical seismograph.
			e L_{EN}	9 34 58					
			M_N	9 35 02	1		8		
			M_E	9 35 02	1	10			
			F	9 39 03					
88	11 Sept.	I_a	e	19 30 01					A series of very weak, irregular vibrations on horizontal components only.
			F	19 30 37					
89	12 Sept.	III_a	i LM	11 25 29	1	143	362		M_V unmeasureable because of chattering of the pen and shifting of the line. F interrupted by beginning of next earthquake.
			C	11 25 59					
			F	11 28 47+					
90	12 Sept.	I_a	i P	11 28 47.5					
			i L	11 28 49.0					
			M	11 28 50.0	½	21	29	6	
			C	11 28 54					
			F	11 29 16					
91	13 Sept.	I_a	e	14 56 42					Marked thickening of pen traces on all components.
			F	14 56 57					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1917			h m s	s	μ	μ	μ	
92	14 Sept.	I_d	e	0 48 22					No pnases determinable. Not registered by vertical seismograph.
			M_{EN}	0 48 28	½	9	6		
			F	0 48 33					
93	14 Sept.	I_d	e	0 58 09					Thickening of pen traces on horizontal components.
			F	0 58 14					
94	14 Sept.	I_d	e	0 58 58					Marked thickening of pen traces on horizontal components.
			F	0 59 05					
95	15 Sept.	I_d	e P	15 51 37.0					
			e L	15 51 42.0					
			M	15 51 45	½	9	10	4	
			F	15 51 52					
96	17 Sept.	I_d	e P	16 07 39					Marked thickening of pen trace on vertical record.
			e L	16 07 44					
			M	16 07 48	½	8	9		
			F	16 07 53					
97	21 Sept.	I_v	e P	18 43 46,5					Not registered by vertical seismograph.
			e L_N'	18 44 38.5					
			e L_E	18 44 39.0					
			M_{EN}	18 44 48	1	4	8		
			F	18 48 05					
98	22 Sept.	I_d	e	18 42 46					Marked thickening of pen traces on all components.
			F	18 43 02					
99	24 Sept.	I_d	i P_{ENV}	21 21 25.2					Vertical record disturbed by shifting of pen trace so that measurements of the maximum are not possible.
			i LM_{EN}	21 21 31.6					
			C	21 21 56					
			F	21 25 02					
100	30 Sept.	I_d	e P	9 39 25					Registered on vertical by a thickening of the pen trace.
			e L	9 39 30					
			M_{EN}	9 39 31	½	8	10		
			C	9 39 35					
			F	9 39 39					

DISCUSSION OF PARTICULAR EARTHQUAKES

Earthquake in the Southern Pacific Ocean, May 1, 1917

At Berkeley, this earthquake gave unusually strong records. The seismograms begin with weak vibrations of short period and these continue up to the time of arrival of the waves of the second preliminary tremors. The second preliminaries begin with sudden shifts of the pens of large amplitude. Throughout, the second preliminary tremors are of greater amplitude than the first preliminaries.

The chief phase begins with a group of regular waves that gradually increase in amplitude up to a maximum and then gradually decrease in amplitude. This group of waves covers a period of about four minutes. After this, the vibrations again increase in amplitude and the rest of the chief phase consists of long regular strokes of the pens.

The amplitudes on the North-South component are much larger than those corresponding on the East-West component. The writing pen on the North-South component was off the paper during the greater part of the chief phase.

The seismograms of this earthquake, obtained at the Lick Observatory, begin with waves of short period and small amplitude which die away gradually, so that motion ceases entirely before the beginning of the second preliminaries.

The main phase begins with a series of rather irregular waves whose amplitude is small at first, gradually increases to a maximum, and finally dies away. This phase lasts until $19^h\,10^m$. It is followed by a series of regular waves whose periods range between fifteen and twenty seconds. These begin with small amplitudes and gradually increase until $19^h\,11^m\,19^s$. After this time the amplitudes remain more or less uniform and the pen traces move back and forth across the paper in slow, regular vibrations of large amplitude. The maxima reported in the tabulations of the Lick Observatory for this earthquake represent

movements only slighter greater than the average. There is no marked difference between them and the surrounding portions of the seismogram.

At $19^h\ 20^m$ the amplitudes of movement begin to decrease gradually though the periods remain about the same. The beginning of the tail portion of the seismograms at $19^h\ 29^m\ 04^s$ is marked by a change in the character of the waves. The regular waves give place to groups of irregular waves.

The following are the values reported for the arrival times of the different phases by the stations at Berkeley, Volcano House, and Osaka, together with the values of epicentral distance and time of occurrence of the shock as calculated for these stations:

	Berkeley	Volcano House	Osaka
Latitude	37° 52′ N	19° 26′ N	34° 39′ N
Longitude	122° 16′ W	155° 15′ W	135° 26′ E
P	$18^h\ 39^m\ 11^s$	$18^h\ 36^m\ 01^s$	$18^h\ 38^m\ 43^s$
S	$18^h\ 49^m\ 40^s$	$18^h\ 43^m\ 33^s$	$18^h\ 48^m\ 34^s$
Δ	9380 km.	5920 km.	8620 km.
O	$18^h\ 26^m\ 49^s$	$18^h\ 26^m\ 36^s$	$18^h\ 26^m\ 50^s$

The epicentral distances were plotted on a stereographic projection, following the method of Dr. Otto Klotz. It was found that the three circles gave a fair intersection near the west margin of the Aldrich Deep in the south Pacific. The center of gravity of the triangle of error lies at longitude 177° 15′ W and latitude 29° 30′ S.

At the time of this earthquake a tidal wave was generated that was registered at several tide gaging stations in the Pacific Ocean.

At Honolulu Harbor, the first disturbance due to the tidal wave occurred at $2^h\ 29^m$ on May 2 (G.M.C.T.). The time of occurrence of the earthquake at the point of origin was approximately $18^h\ 27^m$, May 1 (G.M.C.T.). The distance between the origin, as determined above, and Honolulu Harbor is nearly 6020 kilometers. This distance was traversed by the tidal wave in a little over $8^h\ 02^m$. The average velocity of propogation was therefore approximately 208 meters per second.

The tidal wave reached San Francisco, at a distance of about 9400 kilometers, at $7^h\ 00^m$, May 2 (G.M.C.T.). The average velocity was nearly 208 meters per second in this case.

The tidal wave arrived at La Jolla, California, at $7^h\ 00^m$, May 2 (G.M.C.T.), having travelled approximately 9360 kilometers. The average velocity, in this case, was nearly 207 meters per second.

Distant Earthquake of May 31, 1917

This earthquake was well registered on all the instruments at the Berkeley station. There is a notable difference between the chief phases of the seismograms obtained on different instruments.

The East-West and vertical components are similar. After the first few vibrations of the chief phase, the waves become regular and gradually increase to a maximum, after which they gradually become smaller. After the first group of large regular waves, the movements are somewhat irregular and of moderate amplitude.

On the North-South component there is no group of regular waves. The record consists of a series of rather irregular vibrations of moderate amplitude. The reported maximum is separated from the other vibrations only by slightly larger amplitude.

At the Lick Observatory the earthquake was registered only on the North-South component. The damping device on the East-West component was binding and only a few strokes of the pen appear during the maximum movement.

The earthquake appears to begin with well-defined waves, but on comparing the measurements with the records of the nearby Berkeley station it is seen that the earlier portion of the first preliminaries was not registered.

Teleseism of June 26, 1917

At Berkeley, excellent records of this earthquake were obtained on all three components. All three seismograms are similar in their character.

The movement begins with waves of small amplitude and period, which gradually increase in amplitude until they reach a maximum about thirty seconds after the time of the first impulse. After the first group of large waves there is a long series of

irregular vibrations of short period and small amplitude, which continue until the time of the beginning of the second preliminary tremors.

The second phase begins with a group of large waves which reach their maximum about a minute after the arrival of the first impulse of that phase. After the first group of large waves the vibrations are of moderate amplitude and period and there are no other maxima. The vibrations which make up the second preliminaries are in every case of longer period and larger amplitude than the vibrations of the first preliminaries.

The beginning of the chief phase is distinctly marked by a change in the character of vibration. The movements of the pen become more regular and the amplitudes become larger until the maximum is reached. After this the amplitudes decrease gradually until a minimum is reached. After this the amplitudes increase and decrease in a regular way so that the whole of the chief phase consists of well defined groups of vibrations.

Excellent horizontal records were obtained at the Lick Observatory. The general character of the two components is the same.

The first preliminary tremors begin gradually with a group of strong waves which continue for about a minute. The rest of the first phase consists of waves of small amplitude.

The second preliminaries also begin with a group of large waves, lasting about a minute. After this the amplitudes become small.

The beginning of the main phase is indicated by an increase of period. After about a minute and a half of irregular vibrations, the amplitudes increase and there follows a series of large regular waves. These last about nine minutes when the amplitude decreases rather rapidly. After a period of thirty seconds, during which the amplitudes are rather small, there follows a second group of regular waves whose amplitudes are somewhat smaller than those of the first group. These continue for about ten minutes when the amplitudes again die away as the chief phase is succeeded by the tail portion of the sesimogram.