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SEISMOGRAPHIC STATIONS

No. 17, pp. 357-370 April 21, 1920

THE REGISTRATION OF EARTHQUAKES AT THE BERKELEY STATION

AND

AT THE LICK OBSERVATORY STATION

FROM

OCTOBER 1, 1918, TO MARCH 31, 1919

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 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.

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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
Wiechert Seismograph Vertical 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
	1918			h m s	s	μ	μ	μ	
1	11 Oct.	I_u	*O*	*14 14 23*					Δ = 5820 km.
			e P_{EV}	14 23 43					Origin in Porto Rico. *F* interrupted by changing of the records.
			e_N	14 24 02					
			e S_N	14 31 08					
			e S_E	14 31 09					
			e L_N?	14 38 09					
			e L_E?	14 38 35					
			M_N	14 48 11	14		130		
			M_E	14 50 44	14	130			
			C	14 56 35					
			F	16 51±					
2	13 Oct.	I_v	e P_{EN}?	2 56 38					Record of near shock. Phases indefinite. *F* lost in microseisms about $3^h 11^m$.
			M_V	2 57 52	3			8	
			M_N	2 57 55	3		16		
			M_E	2 58 00	2	10			
			F	3 11+					
3	14 Oct.	I?	e	12 11 58					Trace of a distant earthquake. A series of irregular vibrations from $12^h 11^m 58^s$ to $12^h 14^m 07^s$, after which there is a group of barely perceptible long flat waves.
			F	12 44					
4	15 Oct.	I_{v-r}	e	23 33 33					Barely perceptible trace of an earthquake.
			F	23 43 03					
5	19 Oct.	I_u	e_E	3 30 01					Barely perceptible on north-south and vertical components.
			e S_E?	3 35 50					
			M_E	3 47 08	17	14			
			F	4 20±					
6	25 Oct.	I_u	e	3 50 50					Trace of a distant earthquake on all components.
			F	4 55±					
7	27 Oct.	I?	e P?	15 39 54					No definite maxima. Chief phase consists of a series of long flat waves. Registered on all components but extremely weak on north-south component.
			e L?	16 02 32					
			F	17 09±					
8	27 Oct.	I?	e	17 29 27					Trace of a distant earthquake on all components; very weak on north-south.
			F	19 14±					
9	2 Nov.	I?	e	10 13 50					Trace of a distant earthquake on all components.
			F	11 16 30±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1918			h m s	s	μ	μ	μ	
10	3 Nov.	I?	e	12 00 30±					
			F	12 34 30±					
11	8 Nov.	I_u	*O*	*4 37 51*					Δ = 7020 km.
			e P_V	4 48 20					The first few vibrations on the vertical components are notably larger than the rest of the preliminary tremors.
			e P_E	4 48 23					
			e P_N	4 48 24					
			e S_N?	4 56 42					
			e S_E	4 56 50					
			e L_E	5 03 38					
			e L_N	5 03 54					
			M_N	5 07 30	11		244		
			M_E	5 07 40	10½	85			
			M_V	5 13 22	11½			8	
			C	indefinite					
			F	8 40±					
12	12 Nov.	I_u	e	21 55 05					Trace of a distant earthquake on all components.
			F	22 40±					
13	18 Nov.	I_u	*O?*	*18 40*					Δ = 14,400 km.
			e P_V?	18 56 07					No definite maximum.
			e S_E	19 09 48					
			e S_V?	19 09 53					
			e L	indefinite					
			F	21 25±					
14	23/24 Nov.	I?	e	23 22 27					Trace of a distant earthquake on all components.
			F	0 28±					
15	1 Dec.	I?	e	3 24 45±					Trace of a distant earthquake on horizontal components.
			F	4 04 15±					
16	2 Dec.	I?	e	10 01 15±					Trace of a distant earthquake on all components.
			F	11 12 15±					
17	4 Dec.	I_u	*O*	*11 47 58*					Δ = 8800 km.
			e P_N	12 00 00					Not registered by vertical seismograph. Newspapers report a destructive earthquake at Vallenar and Copiapo in Chile.
			e P_E	12 00 04					
			e S_N	12 10 00					
			e S_E?	12 10 20					
			e L	indefinite					
			M_N	12 29 58	19			23	
			M_E	12 32 35	18	28			
			F	15 05±					
18	6 Dec.	I_r	*O*	*8 41 08*					Δ = 1330 km.
			e P_{EN}	8 44 01					Origin off coast of Vancouver Island. See discussion in text.
			e S_N	8 46 21					
			e S_E	8 46 22					
			i_N	8 46 47					
			e L_E	8 47 33					
			M_{E_1}	8 47 55	19	170			
			e L_N?	8 48 08					
			M_{N_1}	8 49 06	15		170		
			M_{E_2}	8 50 36	15	145			
			M_{N_2}	8 53 03	12		137		
			C	8 57 10					
			F	10 00±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1918			h m s	s	μ	μ	μ	
19	6 Dec.	I_r	e	12 06 05					Trace of a distant earthquake on horizontal components.
			F	12 30±					
20	9 Dec.	I?	e	18 23 30±					Trace of a distant earthquake on all components.
			F	20 44 30±					
21	23 Dec.	I?	e	20 01 30±					Trace of a distant earthquake on all components.
			F	20 35 30±					
	1919								
22	1 Jan.	I?	e	1 52 00					Trace of a distant earthquake on horizontal components. *F* interrupted by beginning of the next earthquake.
			F	3 11 45+					
23	1 Jan.	I_u	*O*	*3 00 06*					Δ = 8280 km. See discussion in text.
			e P_N	3 11 41					
			e P_E	3 11 45					
			e S_N	3 21 15					
			e S_E	3 21 16					
			M_{E_1}	3 21 28	16	160			
			M_N	3 21 30	22		690		
			M_{E_2}	3 24 58	22	325			
			F	6 09±					
24	5 Jan.	I?	e	20 34 40±					Trace of a distant earthquake on horizontal components.
			F	21 10 40±					
25	6 Jan.	I?	e	22 47 35					Trace of a distant earthquake on all components.
			F	23 52±					
26	17 Jan.	I?	e	12 01 21					Trace of a distant earthquake on horizontal components.
			M_E	12 09 20	13	4			
			M_N	12 09 38	12		5		
			F	12 31±					
27	20 Jan.	I_v	e P_N	9 24 58.5					Vertical record illegible through overscoring. *Monthly Weather Review* reports this shock felt at Napa, St Helena, and Vallejo.
			e P_E	9 24 59.0					
			i L_{EN}	9 25 04.5					
			M_E	9 25 12	1	9			
			M_N	9 25 16	2		12		
			C	indefinite					
			F	9 28 15±					
28	27 Jan.	I?	e	21 53±					Trace of a distant earthquake on all components.
			F	22 20±					
29	31 Jan.	I_{v-r}	e	23 44 27					Phases not separable; record confused by microseisms.
			M_{V_1}	23 46 58	7			14	
			M_N	23 47 59	9½		115		
			M_{E_1}	23 48 18	10	43			
			M_{V_2}	23 49 46	6			16	
			M_{E_2}	23 50 00	7½	53			
	1 Feb.		F	0 11 00					
30	16 Feb.	I_v	e P_N	15 58 41					Phases indefinable. Good record on vertical but illegible through overscoring. Origin in Southern California.
			e P_E	15 58 42					
			M_N	16 00 13	3½		15		
			M_E	16 00 21	5	26			
			F	16 12 15±					
31	19 Feb.	I_v	e	4 59 08					Trace of a near shock on all components. Beginning obscured by strong microseisms. *Monthly Weather Review* reports a series of earthquakes felt at Calexico on February 19, one of which came at $4^h 55^m$.
			F	5 08 18					
32	25 Feb.	II_u	i P_E	22 38 51.6					Δ = 63 km. Felt in Berkeley. First shift of ground *down*, north and west; a wave of contraction. Origin therefore northwest of Berkeley. Origin probably on San Andreas Rift just northwest of Point Reyes. Recorded by both components of Omori tromometer. Marvin seismograph started.
			i P_N	22 38 52.0					
			i P_V	22 38 52.2					
			i L_V	22 38 59.5					
			i L_N	22 39 00.0					
			i L_E	22 39 00.4					
			M_{EN}	22 39 02.2	½	29	50		
			M_V	22 39 05.7	½			17	
			C	indefinite					
			F	22 42 49					
33	2 Mar.	I?	e	4 03 27					Record of a distant earthquake. No phases discernible. Weak records on east-west and vertical components.
			M_N	4 12 45	19		11		
			F	5 14 15±					
34	2 Mar.	I?	e	12 07 48					Record of a distant earthquake. Phases not separable. Weak on east-west and vertical.
			M_N	12 31 08	18		26		
			F	13 47±					
35	9 Mar.	I?	e	3 [illegible] 30±					Trace of a distant earthquake on all components.
			F	4 49 30±					
36	16 Mar.	I?	e	8 17 54					Trace of a distant earthquake on all components.
			F	8 40 30±					
37	21 Mar.	I?	e	16 42 07					Long flat waves on east-west component only. Possibly not an earthquake.
			F	17 06 30±					

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
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
	1918			h m s	s	μ	μ	μ	
1	1 Oct.	I_d	e	23 49 00					Strong thickening of pen traces on all components.
			F	23 49 07					
2	11 Oct.	I_u	*O*	*14 14 18*					$\Delta = 5860$ km.
			e P_N	14 23 40					Only a very weak record on east-west component. *F* interrupted by changing sheets.
			e P_V	14 23 43					
			e S_{NV}	14 31 08					
			e L	indefinite					
			M_N	14 44 33	14		330		
			M_V	14 46 08	15			22	
			C	indefinite					
			F	16 27+					
3	13 Oct.	I_v	e_N	2 57 02					Slight disturbance on east-west and vertical components.
			M_N	2 58 35	4		15		
			F	3 06 43					
4	19 Oct.	I_d	e	0 08 52					Strong thickening of pen traces on all components.
			F	0 09 01					
5	19 Oct.	I?	e P_{NV}	3 29 59					Phases not separable.
			M_N	3 44 45	18		21		†Actual displacement of pen.
			M_V	3 44 58	18			*150*†	
			M_E	3 46 11	14	11			
			F	4 24±					
6	7 Nov.	I_d	e	16 25 53					Strong thickening of pen traces on all components.
			F	16 25 58					
7	8 Nov.	I_u	*O*	*4 37 47*					$\Delta = 7180$ km.
			e P_V	4 48 24					The vertical record begins with a group of large waves, which are notably larger than the rest of the first preliminaries.
			e P_N	4 48 31					
			e P_E	4 48 34					
			e S_V	indefinite					
			e S_E	4 57 02					
			e S_N	4 57 07					
			e L	indefinite					
			M_{E_1}	5 09 23	9	90			
			M_{N_1}	5 09 49	11		90		
			M_{E_2}	5 12 11	9	100			
			M_{N_2}	5 13 33	9		81		
			F	7 00±					
8	18 Nov.	I?	e	19 00 44					Trace of a distant earthquake on all components.
			F	21 05±					
9	20 Nov.	I_d	e	16 47 47					Phases not discernible. Registered on horizontal components as a thickening of the pen traces.
			M_V	16 47 56	½			12	
			F	16 48 00					
10	21 Nov.	I_d	e	18 51 40					Strong thickening of pen traces on horizontal components.
			M_{V_1}	18 51 47	½			9	
			M_{V_2}	18 51 51	½			9	
			F	18 51 57					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1918			h m s	s	μ	μ	μ	
11	2 Dec.	I?	e	9 58 36					Trace of a distant earthquake on horizontal components.
			F	11 05±					
12	4 Dec.	I_u	*O*	*11 48 08*					Δ = 8680 km.
			e P_{EN}	12 00 04					
			e S_N	12 09 58					
			e L	indefinite					
			M_E	12 31 30	22	37			
			M_N	12 32 19	15		31		
			F	14 50±					
13	6 Dec.	I_r	*O*	*8 41 02*					Δ = 1460 km.
			e P_{NV}	8 44 11					The point called e S_E is probably the equivalent of a large wave which follows *S*; there is considerable friction apparent in the record of the east-west component.
			e P_E	8 44 12					
			M_{V_1}	8 44 20	5			*6500*†	
			M_{E_1}	8 44 30	6	*4000*†			
			M_{N_1}	8 44 44	4		*6500*†		
			i S_N	8 46 44					
			e S_V	8 46 45					
			e S_E	8 46 50					
			e L_{EV}	8 47 52					
			e L_N	8 47 57					
			M_{E_2}	8 48 17	22	*3700*†			
			M_{N_2}	8 49 15	13		*7500*†		
			M_{V_2}	8 49 37	12			*800*†	
			M_{E_3}	8 50 57	13	*3350*†			
			M_{N_3}	8 52 14	9		*7400*†		
			C	8 55 20					†Actual displacements of pen on paper.
			F	10 00±					Origin off the coast of Vancouver Island. See discussion in text.
14	6 Dec.	I_r	e	12 05 12					Trace of a distant earthquake on all components.
			F	12 21±					
15	7 Dec.	I_d	i P	22 42 36.8					Strong thickening of pen trace on vertical component.
			i LM	22 42 38.4	½	8	10		
			C	22 42 41					
			F	22 42 52					
16	30 Dec.	I_d	e	16 36 44					A series of very closely spaced pen strokes which almost completely remove the smoke from the paper, giving a very strong thickening of the pen trace.
			M_E	16 36 51	½	7			
			M_V	16 36 52	½			6	
			M_N	16 36 54	½		6		
			F	16 36 57					
17	30 Dec.	I_d	e	23 50 56					Closely spaced pen strokes. No phases discernible.
			M	23 51 05	½	12	6	11	
			F	23 51 08					
	1919								
18	1 Jan.	I?	e	1 57±					Trace of a distant earthquake. *F* interrupted by the beginning of the next earthquake.
			F	2 11 37+					
19	1 Jan.	I_u	*O*	*2 59 50*					Δ = 8500 km. See discussion in text.
			e P_V	3 11 37					
			e P_N?	3 11 42					
			e S_{NE}	3 21 22					
			e S_V	3 21 25					
			M_E	3 21 32	6	33			
			M_N	3 21 30	8		23		
			F	5 20±					
20	4 Jan.	I_d	e	4 47 15					Trace of a local earthquake. A series of very minute vibrations on all components.
			F	4 48 09					
21	6 Jan.	I?	e	23 05±					Trace of a distant earthquake on horizontal components; very weak on north-south.
			F	23 36±					
22	13 Jan.	I_d	e	17 55 58					Strong thickening of pen traces on all components.
			F	17 56 09					
23	14 Jan.	I_d	i P	19 35 58.0					Thickening of pen trace on vertical component.
			i LM	19 35 59.5	½	10	11		
			C	19 36 03					
			F	19 36 07					
24	20 Jan.	I_v	e	9 25 10					Trace of near shock. Not registered by vertical seismograph. See No. 27 in Berkeley list.
			F	9 26 53					
25	25 Jan.	I_v?	e	22 30 07					A series of very minute irregular vibrations on horizontal components.
			F'	22 32 15					
26	30 Jan.	I_d	e	21 27 26					Strong thickening of pen traces on all components.
			F	21 27 39					
27	31 Jan.	I_{V-r}	e	23 45 10					Phases not separable. No definite maximum on east-west component. Not recorded by vertical seismograph.
			M_N	23 48 32		8		66	
			F	23 55 39					
28	11 Feb.	I_d	e	4 58 08					Trace of a local shock. A series of very faint vibrations visible on all components.
			F	4 58 53					
29	16 Feb.	I_v	i P_E	15 58 38.0					First shift east and south. Not registered by vertical seismograph. Origin in Southern California.
			i P_N	15 58 38.5					
			i S_N	15 59 12.5					
			e L_N	15 59 35					
			M_E	15 59 44		4	58		
			M_N	15 59 46		4		61	
			C	indefinite					
			F	16 08±					

No.	Date	Charac.	Phase	Time G. M. C. T.	Period	Amplitude A_E	Amplitude A_N	Amplitude A_V	Remarks
	1919			h m s	s	μ	μ	μ	
30	25 Feb.	I_V	e P_{EN}	22 39 06.5					Δ = 108 km. (?) Origin probably on San Andreas Rift northwest of Point Reyes Station.
			i L_N	22 39 21.2					
			e L_E	22 39 22.5					
			M_N	22 39 22.5	2		15		
			M_E	22 39 28.3	1	9			
			C	indefinite					
			F	22 41 21					
31	2 Mar.	I?	e	4 09±					A few long flat waves on both horizontal components; the trace of a distant earthquake.
			F	4 22±					
32	2 Mar.	I?	e	12 28 26					Trace of a distant earthquake on horizontal components; very weak on east-west.
			F	12 45 15±					
33	4 Mar.	I_d	i P	0 38 01.0					Thickening of the pen trace on vertical component.
			i LM	0 38 03.8	½	9	6		
			C	0 38 07					
			F	0 38 28					
34	4 Mar.	I_d	e	22 24 43					Strong thickening of pen traces on all components.
			F	22 24 49					
35	13 Mar.	II_d	i P	17 24 22.0					
			i LM	17 24 23.3	½	35	39	11	
			C	17 24 26					
			F	17 24 39					
36	14 Mar.	I_d	i P	1 06 49					A strong thickening of the pen trace on vertical.
			i LM	1 06 53	½	10	10		
			C	1 06 56					
			F	1 07 12					
37	16 Mar.	I_d	e	0 04 46					A series of minute vibrations on horizontal components; trace of a local shock.
			F	0 05 14					
38	17 Mar.	I_d	e	22 09 06					A series of minute vibrations on all components; no phases discernible.
			F	22 09 39					
39	23 Mar.	I_d	i P	19 36 58.5					A strong thickening of pen trace on vertical component.
			i LM	19 37 00.0	½	16	23		
			C	19 37 03					
			F	19 37 22					

Earthquake in British Columbia on December 6, 1918

Well written records of this earthquake were obtained on both horizontal components at the Berkeley Station. Due to defective adjustment, the vertical seismograph gave no record of this shock.

On the east-west component the first preliminaries consist of a series of vibrations of small amplitude. At $8^h\,46^m\,22^s$ there is a marked increase in amplitude and the vibrations become more irregular in character. This point seems clearly to be the beginning of the second preliminary tremors. At $8^h\,47^m\,33^s$ there is a further increase in amplitude of the vibrations and the waves become very regular.

When the record of the north-south component is examined certain differences are noted. The first preliminaries on the north-south component begin with three or four large vibrations that are followed by vibrations of small amplitude much like those on the east-west component. At $8^h\,46^m\,21^s$ there is a slight change of character of the vibrations corresponding to the point regarded as the beginning of the second preliminaries on the east-west component. The change is not marked, however, and if the north-south record had been the only one available, the beginning of the second preliminaries would have been placed at $8^h\,46^m\,47^s$. At this instant there is a marked increase in the amplitude of vibrations on the north-south component. There is nothing at all on the east-west component to correspond to this particular change on the north-south component and, in consequence, it is not accepted as the beginning of the second preliminary tremors.

A similar difficulty comes in locating the beginning of the chief phase. If either record had been examined alone the point would have been located without hesitation. On the east-west component the waves become regular and increase considerably in amplitude at $8^h\,47^m\,33^s$. On the north-south a similar change occurs later; the large, regular waves begin at $8^h\,48^m\,08^s$. No change in the character of the vibrations is noticeable on the north-south component at $8^h\,47^m\,33^s$ and further, there is no change in character of the east-west component at $8^h\,48^m\,08^s$.

The records obtained at the Lick Observatory Station, though not nearly so well written as those at the Berkeley Station, do not present the difficulty set out above. All three records are very similar in their general features.

The origin of this earthquake has been located by Dr. F. Napier Dennison* at a point just off the west coast of Vancouver Island (latitude 49° 30′ N, long. 127° 20′ W).

Teleseism of January 1, 1919

Well written records of this earthquake were obtained on the horizontal-component instruments at the Berkeley Station. The vertical seismograph was not well adjusted and gave no record of this shock.

The seismograms are of an unusual type. They begin with a series of rather irregular vibrations of small amplitude, which continue without noticeable change of character until the arrival of a phase interpreted as the second preliminary tremors. The beginning of this phase is marked by an increase in amplitude and is followed quickly by a maximum. The north-south component shows a much larger amplitude of movement at the time of this maximum.

After the occurrence of the maximum the seismograms consist of somewhat irregular waves of moderately large amplitude. In these waves there is no sign of a change of character and nothing that could be interpreted as the beginning of the chief phase of the seismogram. The amplitudes gradually decrease until the vibrations merge into the tail portion of the seismogram.

The horizontal records at the Lick Observatory show the same peculiarities that have been described for the records of the Berkeley Station. The maximum which follows the beginning of the second preliminary tremors is here also much stronger on the north-south component than on the east-west component.

On the vertical record, obtained at the Lick Observatory Station, the beginning of the second preliminaries is not so sharply marked as on the records of the horizontal components and there is no definite maximum.

* Bull. Seis. Soc. Am., vol. IX (1919), p. 20.