THE REGISTRATION OF EARTHQUAKES AT THE BERKELEY STATION

AND

AT THE LICK OBSERVATORY STATION

FROM

October 1, 1923, to March 31, 1924

BY

JAMES B. MACELWANE

AND

PERRY BYERLY

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CONTENTS

Symbols and Notations

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)	Normal first phase, or first preliminary tremors.
$\bar{P}$	Individual, or upper first preliminary tremors.
PR_n	Waves n-times reflected at the earth's surface.
S (undae secundae)	Normal second phase, or second preliminary tremors.
$\bar{S}$	Individual, or upper 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 at the beginning of the surface phase.
M (undae maximae)	Shorter and more regular waves of large amplitude in the surface phase.
M_n	Greatest motion in the surface phase, usually in the group defined as M.
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 earth motion, measured from the median line in microns (μ=1/1000 mm.) +toward the north, east, or zenith, −toward the south, west, or nadir.
A_E	E-W component of A.
A_N	N-S component of A.
A_Z	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:

$\varphi = 37° 52' 15''.9$ 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

Date	Apparatus	Component	V	T_o	ϵ	$\frac{r}{T_o^2}$
Nov. 16	Bosch-Omori 100 kg.	E	41	14.2	3.6	0.0022
	"	N	50	12.3	5.4	0.0026
	Wiechert 80 kg.	Z	46	5.5	6.5	0.0016
Dec. 14	B.-O. 100 kg.	E	40	14.5	3.5	0.0023
	"	N	51	12.6	6.7	0.0028
	W. 80 kg.	Z	45	5.5	9.8	0.0016
Feb. 27	B.-O. 100 kg.	E	48	13.7	3.3	0.0022
	"	N	54	12.5	5.4	0.0029
	W. 80 kg.	Z	45	5.6	5.0	0.0022
Mar. 28	B.-O. 100 kg.	E	42	13.7	6.2	0.0025
		Changed	46	12.5	4.3	0.0028
	"	N	39	12.2	4.2	0.0035
	W. 80 kg.	Z	45	5.4	6.4	0.0048
		Changed	44	5.4	7.0	0.0017

BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude AE	Amplitude AN	Amplitude AZ	Remarks
	1923			h. m. s.	s.	μ	μ	μ	
1	Oct. 7	I	e_E	3 54 37					
			e_N	3 54 45					
			e_E	4 02 33					
			e_N	4 13 31	22		− 6		
			e_E	4 18 47					
			M_{E1}	4 23 11	22	+ 9			
			M_{E2}	4 25 11	20	+ 11			
			F	5 02±					
2	Oct. 10	Iu	ePR_{2NZ}	7 21 38					See Report of the Lick Observatory
			iPR_{2NZ}	7 21 41	5			− 6	
			i_Z	7 21 44	5			+ 4	
			i_Z	7 21 50	5			− 6	
			e_E	7 21 55					
			e_N	7 31 08					
			eL_N	7 44 11					
			eL_E	7 45 36					
			M_N	7 47 49	13		+ 4		
			M_{Z1}	7 49 05	15			− 34	
			M_{Z2}	7 49 13	15			+ 34	
			F	8 16±					
3	Oct. 13	I	iP_{EN}	4 31 11					
			e_N	4 32 52					
			e_N	4 34 02					
			e_N	4 35 48					
			F	4 51±					
4	Oct. 14	Iv	$e\bar{P}_N$	9 50 01					△ = 104 km. Epicenter probably near Uvas, Santa Clara County, between San Andreas and Haywards faults.
			$e\bar{P}_Z$	9 50 02					
			$e\bar{P}_E$	9 50 04					
			$i\bar{S}L_E$	9 50 15	3	− 7			
			$i\bar{S}L_Z$	9 50 16					
			$i\bar{S}L_N$	9 50 17					
			M_{NZ}	9 50 21					
			M_E	9 50 23	7	− 4			
			F	9 53±					
5	Oct. 27	IIv	$i\bar{P}_N$	18 47 46					△ = 141 km.
			$i\bar{P}_E$	18 47 47					
			$i\bar{P}_Z$	18 47 48					
			i_{EZ}	18 47 51					
			i_N	18 47 52					
			i_E	18 47 59					
			iS_{ENZ}	18 48 04					
			L_Z	18 48 10					
			L_E	18 48 12					
			L_N	18 48 13					
			M_N	18 48 21	6		− 18		
			M_{EZ}	18 48 23	5	− 20			
			F	18 56±					

BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude AE	Amplitude AN	Amplitude AZ	Remarks
	1923			h. m. s.	s.	μ	μ	μ	
6	Nov. 1	I							Long waves for about 10 minutes at about 20 hours. Clock being repaired.
7	Nov. 2	Iu	eP_E	21 21 30					△ = 9200 km. Epicenter probably southeast of Caroline Islands.
			eS_E	21 31 50					
			L_E	21 48 20	47				
			M_{E1}	21 49 30	29				
			M_{E2}	21 49 45	29				
			F	23 05±					
8	Nov. 4	IIu	eP_{EZ}	0 17 45					△ = 84.2° = 9360 km. Epicenter near 154° E, 3° S.
			eS_E	0 28 45					
			ePS_E	0 29 02					
			e_E	0 30 10					
			eSR_{2E}	0 35 09					
			eL_{EN}	0 44 57	33				
			M_{EN}	0 46 23					
			M_{E2}	0 46 36	26	− 134			
			M_{E3}	0 46 49	26	+ 141			
			M_{E4}	0 47 02	26	− 154			
			M_{E5}	0 47 15	26	+ 148			
			M_{E6}	0 47 22	26	− 194			
			M_{E7}	0 47 39	26	+ 188			
			M_{E8}	0 47 52	26	− 154			
			F	1 45±					
9	Nov. 5	Iu	e_{EN}	22 03 28					Very long waves. Very short, irregular waves. Long waves. Heavy microseisms. May be more than one earthquake.
			e_N	22 31 48					
			e_E	22 34 00					
			F	23 09±					
10	Nov. 7–8	IIv	eP	23 59 03					△ = 900 km. Reported felt in El Centro, California.
			e_{NZ}	23 59 09					
			e_E	23 59 10					
			iS_{EN}	0 00 45	18	+ 14	− 22		
			eS_Z	0 00 47	2				
			i_Z	0 01 31	18			− 67	
			L_{EN}	0 01 46	14	+ 9	− 18		
			F	0 14±					
11	Nov. 9	I	e_E	3 31.5					
			e_N	3 32.5					
			M_{EN}	3 35 27	16	+ 4			
			M_N	3 35 27	15	+ 8			
			F	3 49±					

BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude RULE			Remarks
						A_E	A_N	A_Z	
	1923			h. m. s.	s.	μ	μ	μ	
12	Nov. 11	I	e_E	5 48 53					
			e_N	5 49 19					
			F	6 01±					
13	Nov. 16	Ir	iP_{NZ}	4 19 26					△=17°=1890 km. Probably S.E. in Mexico.
			ePE	4 19 34					
			eS_{EZ}	4 22 39					
			eS_N	4 22 52					
			L_{ENZ}	4 25.5					
			F	4 39±					
14	Nov. 17	I	iP_Z	3 00 59					Epicenter probably in Aleutian Islands.
			ePE	3 01 08					
			eP_N	3 01 16					
			e_N	3 10.5					
			eL_{EN}?	3 13.5					
			F	4 33±					
15	Dec. 26	Ir	iP_N	8 01 45					△=22°6=2500 km.
			eS_{EN}	8 05 50					
			eL_N	8 06 51					
			eM_{EN}	8 08 29					
			F	8 21±					
	1924								
16	Jan. 7	Ir	eP_N?	10 02 09					△=3256 km. Alaska?
			e_N	10 03 07					
			eS_N?	10 07 00					
			e_N	10 08 28					
			eL_N?	10 10 40					
			M_N	10 12 19					
			F	10 36±					
17	Jan. 9	Id	$i\bar{P}_N$	10 24 37					△=80 km. ca.
			$i\bar{P}_E$	10 24 38					
			$\bar{S}_N$	10 24 48					
			i_N	10 24 54					
			F	10 29±					
18	Jan. 14	Ir	iP_{EN}	21 02 05					Nothing on the *Z* component. △=8150 km. Epicenter in Japan.
			iS_N	21 11 33					
			iS_E	21 11 41					
			eL_{EN}	21 21 41					
			M_E	21 25.7					
			F	23 08±					
19	Jan. 21	Ir	iP_E	2 03 04					Waves of very small amplitude on all components. △=4670 km. Epicenter probably in Bering Sea.
			iP_N	2 03 06					
			ePZ	2 05 09					
			iS_E	2 09 19					
			iS_N	2 09 23					
			i_{EN}	2 13 18					
			eL_{NE}	2 16 12					
			F	2 37±					

BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude			Remarks
						A_E	A_N	A_Z	
	1924			h. m. s.	s.	μ	μ	μ	
20	Jan. 25	I	e_N	6 06 40					
			e_E	6 10 39					
			i_N	6 11 23					
			eL_{EN}	6 17 38					
			F	7 41±					
21	Jan. 29	Ir	iP_Z	2 07 10					△=9050 km. Epicenter in northern Chile.
			iP_N	2 07 11					
			ePE	2 07 12					
			eS_E	2 17 22					
			eS_{NZ}	2 17 41					
			eL_N	2 26 29					
			M_{EN}	2 33 57					
			M_Z	2 34 13					
			F	3 32±					
22	Jan. 30	I	eL	21 19.5					
			F	1 31±					
23	Feb. 8	Id	$e\bar{P}_N$	6 48 19					△=31 km.
			$e\bar{P}_E$	6 48 20					
			$i\bar{S}L_N$	6 48 24					
			$i\bar{S}L_E$	6 48 25					
			F	6 48 42					
24	Feb. 21	Iv	eP_N	13 17 10					△=385 km.
			ePE	13 17 15					
			iS_{EN}	13 17 49					
			i_{EN}	13 17 53					
			M_{EN}	13 18 09					
			F	13 42±					
25	Feb. 22	I	e_N	10 56					The phases are masked by microseisms.
			e_E	10 57					
			F	11 02±					
26	Feb. 24	IIv	eP_{NE}	5 47 13					There is no movement discernible on the vertical component. The amplitudes on E are very small. △=910 km. Epicenter near Oregon–Idaho line at about 117° W. and 45° N.
			eS_N	5 48 53					
			eS_E	5 49 01					
			eL_N	5 49 47					
			M_{N1}	5 50 09	10		− 23		
			M_{N2}	5 50 14	10		+ 21		
			M_{N3}	5 51 42	8		+ 28		
			M_{N4}	5 51 46	8		− 31		
			M_{N5}	5 51 51	8		+ 26		
			F	6 14±					
27	Mar. 4	IIr	iP_Z	10 15 56					△=5056 km. Costa Rica.
			i_Z	10 15 58	6			− 4	
			eS_E	10 22 35	50	+ 27			
			eS_N	10 22 41					
			eS_Z	10 22 48					

BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude AE	Amplitude AN	Amplitude AZ	Remarks
	1924			h. m. s.	s.	μ	μ	μ	
27	Mar. 4 (contd.)	IIr	eL_N	10 28 27					
			eL_E	10 28 33					
			iE	10 28 55	40				
			M_{ENZ}	10 31 13					
			M_{N1}	10 31 36	24		− 24		
			M_{E1}	10 31 38	27	+ 27			
			M_{E2}	10 34 53		+ 36			
			M_{N2}	10 35	21		− 27		
			F	11 32±					
28	Mar. 4	I	eL_E	12 07 13					The preliminary phases cannot be separated from the heavy microseisms. It may be an aftershock of the preceding.
			eL_N	12 07 31					
			eL_Z	12 08. 13					
			M_{EN}	12 10 37	19				
			F	12 29±					
29	Mar. 9	Iv	$i\bar{P}_{NZ}$	11 33 46	3	+ 4		+ 4	△=100 km. Felt at Spreckels (R. F. 4–5) and Salinas (R. F. 3) according to H. O. Wood. Felt at Santa Clara. Probably on San Andreas Fault near Loma Prieta, California.
			$e\bar{P}_E$	11 33 47					
			$i\bar{S}_N$	11 33 59	2.5		+ 5		
			$i\bar{S}_E$	11 33 59	2.5	− 20			
			$i\bar{S}_Z$	11 34 00					
			iM_N	11 34 03					
			M_{N1}	11 34 04	8		− 12		
			M_{N2}	11 34 08	8		+ 18		
			M_{N3}	11 34 12	8		− 15		
			F	11 38±					
30	Mar. 10	I	e_N	15 14 12					The microseisms are so heavy that it is impossible to tell whether these waves are really seismic in character or not.
			i_Z	15 17 51					
			e_N	15 19 26					
			i_N	15 20 12					
			F	15 29±					
31	Mar. 11	I	e_N	10 52.5					
			eL_N	11 04 52					
			e_E	11 05					
			e_Z	11 06					
			F	11 27±					
32	Mar. 15	Iu	eP_N?	10 41 52					The time of beginning of P is rendered uncertain by the heavy microseisms. Nothing recorded on Z. △=7600 km. Epicenter, Kurile Islands.
			eS_N	10 50 55					
			e_N	10 59 11					
			eL_N?	11 01 17					
			L_E	11 02 41					
			F	11 50±					

BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude AE	Amplitude AN	Amplitude AZ	Remarks
	1924			h. m. s.	s.	μ	μ	μ	
33	Mar. 24	I	e_N	20 47 10					The amplitudes are very small. The vertical component is illegible because of tangling of the lines on that portion of the record.
			e_E	20 53.9					
			F	21 12±					
34	Mar. 25	I	iP_Z	14 15 09					The amplitudes on all components are very small.
			eL_E	14 32 09					
			eL_N	14 33 57					
			F	14 46±					
35	Mar. 26	I	eL_N	20 37 08					No movement is discernible on either E or Z.
			F	21 04±					
36	Mar. 30	Ir	iP_N	0 12 20					△=1733 km.
			iP_Z	0 12 21					
			iP_E	0 12 22					
			iS_{EZ}	0 15 14					
			eS_N	0 15 24					
			iL_N?	0 16 18					
			iL_E?	0 16 32					
			M_N	0 17 26					
			M_{N1}	0 17 31	8			− 2	
			M_E	0 17 38					
			M_{EN2}	0 17 41	10	+ 17		+ 23	
			M_{EN3}	0 17 46	10	− 25		+ 18	
			M_{Z1}	0 18 15					
			F	0 42±					

THE LICK OBSERVATORY STATION

CONSTANTS

Constants of the Station

Latitude and longitude of the center of the seismographic room:

$\varphi = 37° 20' 24''.5$ 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

Date	Apparatus	Component	V	T_o	ϵ	$\frac{r}{T_o^2}$
Oct. 1	Wiechert 160 Kg. H.	E	102	9.5	6.8	0.0036
		N	81	8.2	3.4	0.0051
	Wiechert 80 Kg. V.	Z	52	3.4	7.2	0.0139
Jan. 8	160 Kg. H.	E	101	9.6	4.5	0.0046
		N	79	7.5	5.8	0.0044
	80 Kg. V.	Z	59	3.1	5.8	0.0209
Mar. 5	160 Kg. H.	E	83	10.0	4.6	0.0043
		N	98	6.9	8.0	0.0053
	80 Kg. V.	Z	60	3.1	5.0	0.0106

Note:—There are registered on the Lick Observatory seismograms numerous small earthquakes of the "swarm" type. These are registered sometimes as a slight broadening of the line for about one second and sometimes as a single impulse. Phases are never distinguishable. These swarms are not entered in this bulletin.

LICK OBSERVATORY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude			Remarks
						A_E	A_N	A_Z	
	1923			h. m. s.	s.	μ	μ	μ	
1	Oct. 7	Iu	i_E	3 54 31					
			e_N	3 54 39					
			e_E	3 57 39					
			e_E	4 02 35					
			e_N	4 13 40					
			e_E	4 19 04					
			M_{E1}	4 23 25					
			e_Z	4 23 25					Long waves; barely perceptible.
			F	5 24±					
2	Oct. 10	Iu	iPR_{2N}	7 21 41					No record on Z. Heavy microseisms on this date. $\Delta = 4810$ km. Epicenter off west coast of Central America.
			iPR_{2E}	7 21 44					
			iSR_{1E}	7 29 29					
			e_E	7 42 55					
			i_N	7 44 59					
			F	8 18±					
3	Oct. 13	I	iP_E	4 31 54					
			e_E	4 32 49					Barely perceptible on E. No record on N nor Z.
			e_E	4 35 17					
			M_{E1}	4 37 19					
			F	4 51±					
4	Oct. 14	Id	$i\bar{P}_{NZ}$	9 50 34					Different phases cannot be distinguished on Z. $\Delta = 30$ km.
			$i\bar{P}_E$	9 50 35					
			$i\bar{S}_E$	9 50 38					
			iL_{EN}	9 50 40					
			M_{EN1}	9 50 41					
			F	9 54±					
5	Nov. 2	Iu	eP_E	21 21 25					No record on Z nor N. See Report from Berkeley Station.
			ePR_{1E}	21 24 08					
			eS_E	21 31 16					
			eL_E	21 37 03					
			M_{E1}	21 48 00					
			F	23 02±					
6	Nov. 5	Iu	e_E	21 42 26					No vertical record.
			i_E	21 47 46					
			i_E	21 51 16					Very long waves.
			L_E	22 03 35					Very short waves.
			e_{EN}	22 12 00					Impetus in short waves on N.
			i_N	22 13 33					Long waves. No long waves on N, so may be separate quake.
			e_E	22 20 13					
			F	23 5±					

LICK OBSERVATORY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude			Remarks
						A_E	A_N	A_Z	
	1923			h. m. s.	s.	μ	μ	μ	
7	Nov. 16	Ir	iP_E	4 19 39					No record on Z.
			eP_N	4 19 43					△=1767 km.
			eS_E	4 22 41					
			eS_N	4 23 00					
			iL_N	4 23 26					
			eM_N	4 25 19					
			eM_E	4 25 25					
			F	4 38					
	1924								
8	Jan. 15	Id	$i\bar{P}_N$	0 46 26					△=6 km.
			iSL_{NE}	0 46 27					Nothing on Z.
			i_N	0 46 28					
			i_E	0 46 30					
			i_N	0 46 31					
			F	0 46.3					
9	Jan. 26	Id	$i\bar{P}_{EN}$	0 55 08					△=22 km.
			$iS\bar{L}_N$	0 55 11					Nothing recorded on Z.
			$iS\bar{L}_E$	0 55 12					
			F	0 56±					
10	Feb. 22	Id	$i\bar{P}_{EN}$	1 02 47					No apparent record on Z.
			$iS\bar{L}_{EN}$	1 02 48					△=6 km.
			i	1 02 52					Short impetus after main shock. May be separate shock.
			i_{EN}	1 02 55					
			F	2 00±					
11	Feb. 24	Iv	iP_E	5 49 09					No movement recorded on Z.
			iP_N	5 49 12					△=970 km.
			i_N	5 50 04					See report from Berkeley Station.
			i_E	5 50 19					
			iS_N	5 50 53					
			iS_E	5 51 21					
			L_N	5 51 41					
			M_{1E}	5 51 45					
			F	6 17±					
12	Feb. 27	Id	$i\bar{P}_Z$	4 54 32					Phases best marked on vertical record.
			$iS\bar{E}_N$	4 54 37					Single sharp impulse on vertical.
			i_{NZ}	4 54 39					Single sharp impulse on Z.
			i_E	4 54 40					△=37 km.
			i_{ENZ}	4 54 42					
			i_Z	4 54 43					
			iM_{NZ}	4 54 46					
			iM_{1N}	4 54 51					
			iM_{1E}	4 54 53					
			F	4 58±					

LICK OBSERVATORY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude			Remarks
						A_E	A_N	A_Z	
	1924			h. m. s.	s.	μ	μ	μ	
13	Mar. 4	IIr	iP_E	10 15 54	4	+ 22			No record on vertical.
			iP_N	10 15 54	4	− 1			△=4610 km.
			ePR_{3N}	10 18 09					
			i_E	10 18 22					Probably Costa Rica.
			eS_N	10 22 06					
			eS_E	10 22 10					
			SR_{1N}	10 24 53					
			$SR_3?_N$	10 26 12					
			iL_E	10 28 00					
			iL_N	10 29 05					
			M_N	10 31 09	30		− 194		
			M_E	10 34 18	19	− 11			
			M_{1E}	10 34 37	21	+ 198			
			F	11 33±					
14	Mar. 9	IId	$i\bar{P}_Z$	11 33 37					△=39 km.
			$i\bar{P}_{NE}$	11 33 38					See report from Berkeley Station.
			iSL_{NE}	11 33 42					
			F	11 36±					
15	Mar. 15	Iu	iP_E	10 42 14					Barely perceptible and somewhat confused by microseisms. Record on Z illegible.
			eP_N	10 42 15					See report from Berkeley Station.
			iS_{EN}	10 51 07					
			eL_N	11 03 07					△=1690 km.
			eL_E	11 03 37	27				Not recorded on Z.
			F	11 18±					Record on N indistinct.
16	Mar. 30	Id	iP_E	0 12 37					
			i_E	0 12 56					
			iS_E	0 15 32					
			iSR_{1E}	0 15 49					
			i_E	0 16 12					
			iL_E	0 17.1					
			M_E	0 18.1					
			F	0 45±					