

THE REGISTRATION OF EARTHQUAKES
AT THE BERKELEY STATION

AND

AT THE LICK OBSERVATORY STATION

FROM

April 1, 1922, to September 30, 1922

BY

JAMES B. MACELWANE
AND
PERRY BYERLY, JR.

BULLETIN OF THE SEISMOGRAPHIC STATIONS, VOL. 2, No. 4

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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) 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 at the beginning of the surface phase.
 Q (undae quartae) Shorter and more regular waves in the surface phase.
 M (undae maximae) Greatest motion in the surface phase, usually in the group here defined as Q.
 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 ($\mu = 1/1000$ mm.) for the Berkeley Station; and for the Lick Observatory Station, the unreduced seismogram amplitude measured from the median line in millimeters, + 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:

$$\varphi = 37^{\circ} 52' 15.''9 \text{ N. Lat.}$$

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

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 ₀	ϵ	$\frac{r}{T_0^2}$
1922 May 29	Bosch-Omori 100 kg	E	50	14.2	3.6	0.0022
		N	51	12.4	5.4	0.0026
	Wiechert 80 kg.	Changed Z	55 43	12.9 5.6	4.3 6.5	0.0030 0.0016
June 23	B.-O. 100 kg.	E	49	13.9	3.5	0.0023
		N	58	12.8	6.7	0.0028
	W. 80 kg.	Z	43	5.6	9.8	0.0016
Aug. 24	B.-O. 100 kg.	E	50	13.9	3.3	0.0022
		N	48	12.8	5.4	0.0029
	W. 80 kg.	Z	41	5.5	5.0	0.0022
Sept. 13	B.-O. 100 kg.	E	49	13.9	3.8	0.0027
		N	51	12.3	5.8	0.0031
	W. 80 kg.	Changed Z	42 42	5.6	5.8 6.8	0.0026 0.0019
Sept. 18	B.-O. 100 kg.	E	46	13.9		
		N	47	12.3		
	W. 80 kg.	Z	41	5.6		

The senior author takes the responsibility for the data from the Berkeley Station as here reported.

BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period s.	Amplitude			Remarks
						A _E	A _N	A _Z	
1	1922 2 April	I	e _N	1 55 3		μ	μ	μ	A more detailed analysis cannot be made because of microseisms.
			e _E	1 58 8					
			e _Z	2 00 8					
			F	2 11±					
2	2 April	I	i _Z	17 09 26					The beginning may be lost in microseisms.
			eL _E	17 21					
			F	17 29±					
3	3 April	I _r	eP _E	7 24 31					S-P = 5 ^m 12 ^s . Δ = 30°9' = 3433 km. The epicenter is in the Aleutian Islands.
			eP _Z	7 24 32					
			iS _Z	7 29 43					
			iS _E	7 29 45					
			e _N	7 32 04					
			eL _N	7 32 51					
			eL _E	7 32 53					
			eL _Z	7 33 13					
			Q _N	7 33 35					
			M _{EZ}	7 33 40					
			M _{E2}	7 33 49					
			M _{E3}	7 34 17					
			F	9 29±					
4	5 April	I _u	eP _E	10 22 13					
			i _E	10 23 49					
			e _{EN}	10 25 50					
			e _E	10 31 19					
			eL _E	10 44 40					
			F	10 50±					
5	8 April	II _u	eP _Z	20 52 56					S-P = 8 ^m 22 ^s . Δ = 63°2' = 7022 km. S may begin at 1 ^h 01 ^m 08 ^s . In that case Δ = 6800 km. The epicenter seems to be in the neighborhood of Iceland.
			eP _N	20 53 06					
			eP _E	20 53 18					
			eS _E	21 01 18					
			eL _E	21 12 30					
			i _{EN}	21 15 20					
			i _{E2}	21 15 41					
			Q _{NZ}	21 17 38					
			M _{EN}	21 17 45					
			M _Z	21 17 45					
			M _{EN2}	21 17 54					
			F	22 06±					
6	11 April	I	eL _{ENZ}	0 57 8	18				
			Q _{ENZ}	1 01 3					
			F	2 00±					
7	13 April	I	e _{EN}	15 18 25					
			F	15 40±					
8	20 April	I	e _{EN}	6 06 10					
			eL _{EN} ?	6 08 55					
			Q?	6 10 30					
			F	6 24					



BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period s.	Amplitude			Remarks
						A _E	A _N	A _Z	
9	1922 25 April	I	e _{EZ}	21 48 55		μ	μ	μ	
			e _E	21 59 05					
			e _{NZ}	22 00 35					
			e _E	22 01 30					
			e _{ENZ}	22 22 35					
			F	23 24±					
10	26 April	I	e _N	4 15 25					The phases cannot be determined because of microseisms.
			e _E	4 15 35					
			eL _{EN}	4 24					
			F	5 28±					
11	4 May	I _u	eP?	9 23 16					Δ = 6600 km.? Kurile Is.?
			eS _{EN}	9 31 18					
			eL _{EN}	9 38 26					
			M _{EN}	9 40 2					
			F	11 20±					
12	10 May	I	eL _E	10 09					
			F	10 17±					
13	12 May	I	iP _Z	18 52 15					S-P = 10 ^m 45 ^s . Δ = 9940 km.
			eS _E	19 03 00					
			eL _{EN}	19 20 2					
			Q _{EN}	19 26 1					
14	14 May	I	e _E	23 23 2					
			F	23 37±					
15	31 May	I _v	iP _Z ?	1 21 48					
			iP _Z ?	1 21 56					
			iP _{FN}	1 21 57					
			SL _Z	1 22 16					
			Q _Z	1 22 29					
			Q _N	1 22 39					
			M _{EZ}	1 22 48					
			M _N	1 22 53					
			M _E	1 22 55					
			F	1 27±					
16	2 June	I	e _{EZ}	20 41 2					
			eL _{NZ}	20 59					
			eL _E	21 00					
			F	21 36±					
17	12 June	II _r	iP _Z	4 51 54					The records of the horizontal components are almost illegible because of an accidental derangement of the timing device.
			eL _Z	4 57 15					
			Q _Z	4 58 6					
			M _{ENZ}	4 59					
			M _{E2}	5 02 2					
			M _{E3}	5 02 3					
			M _{N2}	5 02 8					
			F	6 00±					

BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.			Period	Amplitude			Remarks
				h.	m.	s.		AE	AN	Az	
18	1922 22 June	I _r	iP _Z eL Q F	10	47	38					
19	22 June	II	ez ee en iz ie in Le? iQ _{EN} iQ _Z M _{EN2} M _{EN3} F	21	01	19 36 39 15 20 25 38 05 06 10 15 52±					
20	27 June	I	ez F	14	47	9 56±					No motion is discernible on the N-S record. The E-W instrument stopped three hours before.
21	2 July	II _r	iP _Z eP _{EN} S _{ENZ} iL _{ENZ} F	13	42	4 4 5 6 30±					S-P = 5 ^m 7 ^s . Δ = 3355 km., or 30°2. The phases are clearly registered but the time correction is uncertain, as extrapolation was necessary.
22	5 July	I	eL _Z F	18	50	6 57±					
23	11 Aug.	I	ee en eLe? F	13	58	13 59 7 14 03 14 33±					
24	13 Aug.	I	ee eL _{EN} M _E F	0	48	7 03 06.8 42±					
25	16 Aug.	I	Pe Se eLeZ F	16	06	16 13 5 16 22 4 17 15±					

BERKELEY STATION

No.	Date	Character	Phase	Time G. M. C. T.			Period	Amplitude			Remarks	
				h.	m.	s.		AE	AN	Az		
26	1922 18 Aug.	II _v	eP _{EZ1} iP _{ENZ2} iz i _N iS _{ENZ1} i _{EN} iS _{ENZ2} iQ _{ENZ} M _{EN} M _N M _N M _E M _Z M _Z M _E M _N M _N F	5	12	34 44 52 55 01 09 11 14 24 26 30 31 35 37 39 48 50 26±					This seems to have been a double earthquake from the same epicenter, the second being the stronger shock. While the S-P intervals are identical for both shocks, they give a distance 2°2 that is somewhat too great as compared with the distance 1°4 determined in the same manner from the Lick records. It is probable that only P was recorded in each case. The earthquake was reported felt in Fresno and Bakersfield, Calif.	
27	25 Aug.	I	eL _E F	12	52	2 38±						
28	26 Aug.	I	ez ee eL _{ENZ} F	6	52	7 59 08 6 31±						
29	30 Aug.	I	ez eL _E ? eL _N F	22	46	6 51 1 51 7 29±						
30	1 Sept.	II _u	eP _{ENZ} iS _E eS _{NZ} eL _{EN} F	19	29	25 54 31 55 25 17±						S-P = 10 ^m 29 ^s . Δ = 9590 km., or 86°3.
31	4 Sept.	I	iP _Z eP _{EN} eS _Z iS _{EN} F	17	14	17 17 22 31 22 32 34±						Δ = 6855 km.

BERKELEY STATION

No.	Date	Chara- cter	Phase	Time			Period	Amplitude			Remarks
				G	M.	C. T.		AR	AN	Az	
				h.	m.	s.	s.	μ	μ	μ	
32	5 Sept.	I _v	P _E ?	9	06	47					P or \bar{P} ? The earthquake was not reported felt.
			P _Z ?	9	06	48					
			S _{EZ}	9	07	12					
			Q _E	9	07	32					
			F	9	10±						
33	9 Sept.	I	e _E	0	32	1					
			F	0	40±						
34	16 Sept.	I	e _Z ?	23	34	48					
			e _E	23	45						
			e _{LE}	23	53	08					
	17 Sept.		F	0	10±						
35	22 Sept.	I	e _E	20	12	00					
			F	20	24±						
36	17 Sept.	I _d	i _{PN}	9	31	44	<0.5		+13		
			i _P	9	31	46	<0.5	-6			
			M _N	9	31	47	<0.5		-20		
			F	9	32	26					
37	18 Sept.	I _v	i _{PZ} ?	12	54	21					
			i _{PN} ?	12	54	22					
			e _E	12	54	31					
			i _Z	12	55	05					
			i _N	12	55	12					
			i _E	12	55	25					
			i _N	12	55	31					
			i _E	12	55	55					
			i _Z	12	55	58					
			i _E	12	56	23					
			i _E	12	56	39					
			F	13	11±						
			38	29 Sept.	I	e _{EN}	21	41	21		
e _{LEN}	21	43				56					
F	21	52±									
39	30 Sept.	I	e _{EN}	23	39	19					
			F	23	50±						

THE LICK OBSERVATORY STATION

CONSTANTS

CONSTANTS OF THE STATION

Latitude and longitude of the center of the seismographic room:

$$\varphi = 37^{\circ} 20' 24.5'' \text{ N. Lat.}$$

$$\lambda = 121^{\circ} 38' 34'' \text{ W. from Greenwich.}$$

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

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

The junior author is responsible for the measurement of the seismograms of the Lick Observatory Station as here reported.

LICK OBSERVATORY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude			Remarks
						A _E	A _N	A _Z	
				h. m. s.	s.	mm.	mm.	mm.	
1	1922 2 April	I	eP _N	19 24 36	17			-0.2	Only on the N-S component. O = 11 ^h 17 ^m 51 ^s . Δ = 31°9, or 3545 km.
			eS _N	19 29 56					
			eL _N	19 32 55					
			M _N	19 34 23					
			F	19 48±					
2	8 April	II _u	i _N ?	21 05 28	22				
			Q _N	21 16 13					
			M _N	21 20 28					
			F	21 31±					
3	11 April	I	i _N ?	1 00 24					
			F	1 07±					
4	24 April	I _d	iP _E	23 50 10					
			F	23 50 14					
5	25 April	I _d	iP _{NEZ}	1 15 30	<0.5	0.2	0.1	-0.2	
			iSL _{NEZ}	1 15 31	<0.5	0.2	-0.2	+0.2	
			F	1 16 21					
6	25 April	I	c _N	22 00 7	17				
			i _N	22 23 38					
			F	22 38±					
7	25 April	I _d	iP _{NEZ}	22 32 55					Δ is about 0°1.
			iSL _Z	22 32 57					
			iSL _{EN}	22 32 58					
			F	22 33 10					
8	26 April	I	eP _Z	4 14 41					
			i _N	4 23 55					
			F	4 57±					
9	28 April	I _d	i _{NE}	23 10 13					This local shock and the following five seem to belong to a swarm.
			i _Z	23 10 15					
			F	23 10 21					
10	29 April	I _d	i _{EN}	4 04 23					
			F	4 04 24					
11	29 April	I _d	i _N	8 37 50					
			F	8 37 51					
12	29 April	I _d	i _N	10 48 04					
			F	10 48 05					
13	29 April	I _d	i _{EN}	13 10 04					
			F	13 10 05					
14	29 April	I _d	i _N	19 40 42					
			F	19 40 43					
15	4 May	I _u	eL _N	9 39 26					
			F	10 11±					

LICK OBSERVATORY STATION

No.	Date	Character	Phase	Time G. M. C. T.	Period	Amplitude			Remarks
						A _E	A _N	A _Z	
				h. m. s.	s.	mm.	mm.	mm.	
16	1922 12 May	I _u	i _N ?	19 23 29					This earthquake was recorded only on the N-S component.
			i _N	19 28 55					
			F	19 36±					
17	31 May	I _v	iP _Z ?	1 21 42					The epicenter seems to have been on the San Andreas Rift east of Kings City, Calif.
			iP _N ?	1 21 44					
			iP _N ?	1 21 47					
			iSL _N	1 21 58					
			i _N	1 22 05					
			i _E	1 22 09					
			Q _N	1 22 13					
F	1 25±								
18	12 June	I _r	i _E	4 57 29					
			M _E	4 59 02					
			i _E	5 01 57					
			F	5 03±					
19	12 June	II _d	iP _{NE}	6 30 39					
			iP _Z	6 30 40					
			i _N	6 30 41					
			i _E	6 30 42					
			F	6 31±					
20	13 June	II _d	i _{NEZ}	3 42 06	<0.5			-1.2	
			i _N	3 42 07					
			F	3 42.7					
21	16 June	II _v	i _E	21 02 58					Recorded only on E.
			i _E	21 03 16					
			i _E	21 03 41					
			i _E	21 04 16					
			M _E	21 04 43					
F	21 14±								
22	2 July	I	c _E	13 47 40					
			e _E	13 50 45					
			M _E	13 51 44					
			F	13 57±					
23	27 July	I _d	i _E	9 15 34					
			i _N	9 15 40					
			i _N	9 16 06					
			i _E	9 16 09					
			i _E	9 16 21					
			i _N	9 16 24					
			F	9 17.5					
24	2 Aug.	I _d	i _Z	1 38 55					
			i _{NE}	1 38 58					
			i _{NE}	1 39 02					
			F	1 39.2					
25	11 Aug.	I _d	i _Z	21 30 05					
			i _E	21 30 06					
			i _N	21 30 07					
			F	21 30.3					

LICK OBSERVATORY STATION

No.	Date	Charac- ter	Phase	Time G. M. C. T.			Period s.	Amplitude			Remarks
				h.	m.	s.		A _E mm.	A _N mm.	A _Z mm.	
26	13 Aug.	I	c _N F	1 08 3							
				1 15±							
27	15 Aug.	I _d	i _E	23 37 29							
			i _N	23 37 30							
			F	23 37 37							
28	18 Aug.	II _v	i _{PZ1}	5 12 24							There seem to be two earth movements ten seconds apart. Δ is about 1°. The earthquake was felt in Fresno and Bakersfield.
			i _{PEN1}	5 12 27							
			i _{PN2}	5 12 34							
			i _{PZ2}	5 12 35							
			i _{PE2}	5 12 36							
			i _{SNE1}	5 12 42							
			i _{SE2}	5 12 52	3						
			i _{SZ2}	5 12 54	2	+6.8					
			M _E	5 13 00	2		-4.6				
			M _N	5 13 07	2						
			M _N F	5 13 31 5 17±	2				+2.3		
29	30 Aug.	I	c _E ?	22 51 48							Long flat waves of about nine seconds period, recorded only on E. The amplitude is barely perceptible.
			i _E ?	22 54 51							
			F	22 58±							
30	1 Sept.	I _d	i _{PENZ}	2 31 40							This was a very seismic day at Mt. Hamilton. A small swarm of slight local shocks also occurred but were not measured because the amplitudes were barely perceptible.
			i _N	2 31 42	<1						
			i _E	2 31 43	<1	-2.2	-2				
			i _{LE} ?	2 31 46							
			i _{LN} ?	2 31 48							
			F	2 32±							
31	1 Sept.	I _d	i _{NE}	2 35 21							
			F	2 35 27							
32	1 Sept.	I _d	i _{EN}	4 13 48							
			i _Z	4 13 51							
			F	4 13 56							
33	4 Sept.	I _d	c _{NE} (?)	21 06 39							
			i _N	21 06 52							
			i _{EN}	21 07 01							
			F	21 08 5							
34	17 Sept.	I _d	i _{ENZ}	4 23 45							The SL group contains one sharp impulse which dies down quickly.
			i _{SLZ}	4 23 47							
			i _{SL_{EN}}	4 23 48	<1	+3.8	-1.9				
			F	4 24 3							