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HARVARD SEISMOGRAPHIC STATION. THIRD ANNUAL REPORT FOR THE YEAR, 1 AUGUST, 1910—31 JULY, 1911.

By J. B. Woodworth.

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February, 1912.

No. 1.— *Harvard Seismographic Station. Third Annual Report for the year, 1 August, 1910 — 31 July, 1911.*

By J. B. Woodworth.

The list of earthquakes and seismic disturbances of the ensuing table continues that published in the Curator's Report M. C. Z., 1909–1910, p. 28–33. The numbers correspond to entries in the Record of Earthquakes kept at the Station from the beginning in 1908.

For the times heretofore given in Eastern Standard Time of the 75th meridian west from Greenwich, the Greenwich Mean Time, from midnight to midnight, has been substituted and the data have been cast in the form of a monthly bulletin instituted during the year. The adjoined short table will facilitate the conversion of Greenwich Mean Time into that locally used. E. S. T. hours between noon and midnight are in italics. For the G. M. T. hours in italics, read the 75th meridian date as one day earlier.

G. M. T.	*1*	*2*	*3*	*4*	*5*	6	7	8	9	10	11	12	13	14	15
75° T.	*8*	*9*	*10*	*11*	12	1	2	3	4	5	6	7	8	9	10
G. M. T.	16	17	18	19	20	21	22	23	*24=0*						
75° T.	11	12	*1*	*2*	*3*	*4*	*5*	*6*	*7=7*						

The Göttingen system of nomenclature or symbols has also been adopted in place of the less readily written system of Laska heretofore mainly employed in the reports. This system is as follows:—

P beginning of first preliminary tremors or longitudinal waves.
S beginning of 2nd preliminary tremors or transverse waves.
L beginning of long waves, main waves, or principal portion.
M time of maximum motion among the long waves.
C beginning of coda or trailers (seldom read).
F end of visible motion.
i impetus, initial motion well observed.
e emersion, evident belated beginning of record.
A amplitude of the maximum motion. With undamped pendulums usually given in millimeters; with damped pendulums in micra (μ).
N stands for the north-south component of motion registered by the horizontal pendulum lying in the prime vertical (east-west).
E stands for the east-west component of motion recorded by the pendulum lying in the meridian (north-south).

Under the column of Remarks in the accompanying tables the following abbreviations appear:— Q, (quake), for earthquake. Qf, a felt earthquake, the name of the place following indicating the approximate origin of the shock. Ql, a local shock. Qr, earthquake reported. O, origin or epicentre. Dp, distance from Cambridge as indicated by the pendulums. Dm, distance from Cambridge measured on a globe. Micros., masked by microseisms.

LATITUDE 42° 22′ 56″ N., LONGITUDE 71° 06′ 59″ W. Greenwich; ALTITUDE 5.367 M.

TIME: Mean Greenwich, midnight to midnight.

INSTRUMENTS: Two Bosch-Omori horizontal pendulums (mechanical registration).

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1910.		h. m. s.	s.	mm.	
80	Aug. 5	ePN	1 39 04			D. ca. 2900 mi.
		ePE	1 39 01			
		SN	1 45 23			
		SE	1 45 10			
		LN	1 52 18			
		LE	1 52 42			
		MN	1 53 35		32.5	
		ME	1 53 57		7.0	
		FN	2 55			
81	Aug. 11	PN	16 36 19			
		PE	16 36 19			
		SN	16 40 17			
		SE	16 41 00			D. 1500 mi.
		LN	16 41 41			
		LE	16 45 26			
		MN	16 46 23		2.7	
		ME	16 47 15		20.5	
		FN	17 33			
		FE	17 35			
82	Aug. 21	PN	5 56 27			D. 3100 mi.
		PE	5 57 18			
		SN	6 03 18			
		SE	6 02 05	8		
		LN	6 11 30			
		LE	6 12 22			
		ME	6 13 08		.7	
		FN	7 24			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1910		h m. s.	s.	mm.	
83	Sept. 1	PE	1 06 57			Probably Qf at Koshun
		LN	1 45 13			in Formosa.
		LE	1 43 53			D. 7700 mi. Dm. 7800
		ME	1 48 15			mi.
		FE	2 32 21			
84	Sept. 4	LN	13 43 20	20		Not reported elsewhere.
		LE	13 43 58			
85	Sept. 6	?PN	20 14 21	5.5		Qf. at Andalgalà, Cata-
		?SN	20 23 32	6.8		marca, Argentine. Dm.
						4850 mi. Qr. 20 h. 14 m.
		SE	20 23 43	10.0		Dp. 4850 mi.
		LN	20 41 24	17.5		
		LN	20 47 06			
		MN	20 50 10?		0.5	ME, A = 0.9 mm.
		FN	21 15 39			Ottawa P 20 h. 4 m. 27 s.
		FE	21 54			Strassburg ca. 20 h. 21.1
						m. Possibly 2 quakes.
86	Sept. 7	PN	7 32 21			Ottawa P 7–31–49.
		PN	7 32 23			
		LN	8 17 14			
		LE	8 18 28			
		FE	9 46			
87	Sept. 7	LE	10 42 07	11		Faint N–S; periods
		F	11			15–16s. Qr. at Rilski-
						Monastir, Bulgaria.
88	Sept. 9	PN	1 24 15			
		PE	1 24 09			Dp. 4600 mi.
		SN	1 33 05			
		SE	1 33 03			
		LN	1 48 01			
		LE	1 47 20			
		MN	1 52 45	14.5		
		ME	1 51 10	23.2		
		FE	4			
89	Sept. 9	LE	9 45 13	16.3	0.4	Very faint N–S.
		F	11			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1910		h m. s.	s.	mm.	
90	Sept. 9	LN	14 35 58	14.0		Not reported from Ot-
		LE	14 36 18	13.3	0.2	tawa. Qr. at Higüey,
		FN	14 47 35			San Domingo at 13.55.
91	Sept. 16	LN	19 28 20	14.0		e19.25.36 at Ottawa.
		LE	19 27 14	13.3		
		FN	19 41			
92	Sept. 24	PN	3 39 22			
		PE	3 39 21			D. 2500 mi.
		SN	3 44 56	9		Shocks reported at Flag-
		SE	3 44 56	13		staff and Kingman,
		LN	3 52 56			Arizona, this night.
		LE	3 50 28			O of this Q off coast of
		MN	3 55 24		3.0	Mexico?
		ME	3 52 35		5.5	
		FE	4 58			
93	Sept. 24	eN	4 22 08	4		Superposed on Record
		FE	4 28 54			92.
94	Oct. 4	PN	23 10 34			Qf. Antofagasta, Chile.
		PE	23 11 01			Dp. 4350 mi.
		SN	23 18 56			Ottawa P. 23–10–52.
		SE	23 18 59			
		LN	23 29 34			
		LE	23 25 59			
		ME	23 27		1.5	
	Oct. 5	FN	0 04			
94a	Oct. 18	eLN	3 48 20			
		LE	3 39 55		.02	
		ME	3 50			
		F	4			
95	Oct. 30	SE	8 28			N–S micros.
		LE	8 34			Qr. Scilly Islands, Eng.
		FE	9 05			at ca. 8h.
96	Nov. 6	eSN	20 47 08			S in micros.
		SE	20 45 16			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1910.		h. m. s.	s.	mm.	
		LN	20 51 29			Qr. Nevada.
		LE	20 51 31			
		MN	20 52 36		21	Strassburg eL 21h.
		ME	20 51 52		12	
		FN	21 50			
97	Nov. 9	PN	6 29 01			
		?PE	6 24 37			PE = 6–24–07?
		SE	6 27 05			Cf. Qf. in Aparri, N. W.
		SE	6 39 00			Luzon, Phillipine Ids. at
		LN	7 06 48			2h. 54 m. (local t.).
		LE	7 06 59?			
		ME	7 08 30		5.25	
		F	9 06			
97a	Nov. 10	e	12 50 13			Qf. Fura, Japan, at 12h.
		LE	12 57 38			F lost in micros.
98	Nov. 10	e	13 16 43			N masked by micros.
		LE	13 22 49			
		ME	13 32 39		5.5	
		F	14 09			
99	Nov. 12	LN	18 29 48			Micros.
		LE	18 29 54	13	0.5	Cf. Qr. Prov. Mendza,
		FN	18 34 08			Argentine at ca. 15¼ hrs.
		e?	8 22 26			
100	Nov. 14	LN	8 26 58			Qr. Taihoku, Formosa,
		LE	8 27 08	17–20		at 7h. 35m.
		MN	8 35 54		0.2	
		ME	8 34 54		0.7	
		FE	9 02 59			
101	Nov. 15	LN	0 34 15			0h. 30.3m. at Ottawa.
		MN	0 38 49		0.5	
		FN	0 53 42			
102	Nov. 15	eLN	14 45 54	12		
		LE	14 46 07	9		14h. 32m. at Ottawa.
		LN	14 49 46	17		

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1910.		h. m. s.	s	mm.	
		MN	14 55 33		1.0	Lurch to S.
		ME	14 55 36		1.3	" " E.
						F?
102a	Nov. 25	LE	19 15 15			Not reported elsewhere.
		F	19 16 33			
102b	Nov. 25	LE	20 08 16			
		F	20 11 24			Not reported elsewhere.
103	Nov. 26	?PE	5 02 03	3		Micros.
		SE	5 11 45	10		Obscure record.
		?SN	5 19 10	10		
		LN	5 45 02			Strassburg, P 5h. 00m.
		LE	5 43 01			41s.
		MN	5 46		2	
		ME	5 50 14		12.7	
		ME	5 51 01		14	Qf. Jeronimo, Spain, at
		F	5 40			4h. 50m.
104	Nov. 29	eLN	3 30 24	16–20		Ottawa eLN 3h. 18m.
		eLE	3 29 27	22		
		ME	3 39 29		0.4	
		FN	3 53 13			
104a	Nov. 29	LN	4 01 19	10		Possibly trailers of preceding.
		LE	4 09 50			
		FN	4 11 36			
		FE	4 12 34			
105	Dec. 4	eSN	11 44 07	12		
		eSN	11 44 53			Ottawa 11h. 43.5.
		LN	12 11 51	17	0.3	
		eLE	12 17 05	20	0.4	
		FN	12 51 15			
106	Dec. 10	LE	1 16 08	24	1.4	N not tracing. Not at Ottawa.
		F	1 16 32			Local disturbance?
107	Dec. 10	PE	9 47 06			
		SE	10 04 26			
		LE	10 09 10			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1910.		h. m. s.	s.	mm.	
		LE	10 23 51			
		ME	10 46		2.5	
		F	12 30			
108	Dec. 13	ePN	12 00 53			Ottawa P 11.56.10.
		SN	12 10 21			Qf. Ujiji, Lake Tangan-
		SE	12 10 59	8		yika, at 11h. 39m.
		LN	12 25 39			
		LE	12 22 21	16		
		MN	12 29 25		20.2	
		ME	12 33 32		17	
		F	14 50			
108a	Dec. 14	ePN	21 04 59			Qf. in Scotland. Reg-
		ePN	21 05 14			istered in Paisley ca.
		SN	21 11 58	6–10		20 h. 54 m.
		SE	21 14 00	13–16		
		LN	21 27 53			Obscure record.
		LE	21 32 17			No M.
		FN	21 58 08			
109	Dec. 16	PE	15 02 39			N record tangled in
		LE	15 24 17			diurnal waves.
		MN	16 00 53			ME 15.55.19, 16.00.17.
		ME	16 05 47		4	Qf. Halmaheira, Mo-
		FE	17 10 55			lucca Ids. Batavia P
						14 h. 49 m.
110	Dec. 16	e?	19 25			Obscured by micros.
		eLN	20 07 25	20	1.2	Not reported from Ot-
		F	20 27			tawa but 19h. 34m. to
						20h. 20m. at Strassburg.
111	Dec. 20	SE	18 25 56	10		
		LE	18 47 28	17		
112	Dec. 21	SE	10 40			N stylus caught on
		F	10 58			point in paper. E line
						tangled.
						Imperfect record of Ot-
						tawa P 10h. 31m.
113	Dec. 21	eP	13 06 11			Micros. N stylus tipped
		SE	13 09 19			over on joint in paper
		?LE	13 13 06			before record began.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1910.		h. m. s.	s.	mm.	
		LE	13 16 42	14		
		?F	13 25 15			
114	Dec. 29	SN	14 05 13	14		
		LN	14 19 52	20–18	0.4	L–S = 4650 mi. Laska.
		F	14 40	–		Qf. in Elis, Greece; Dm. 4600 mi.
115	Dec. 30	eSN	3 38 03			
		LN	3 41 48	17–20		Ottawa P 3.26.42.
		LE	3 42 34	16		
		FN	3 59 53			
	1911.					
116	Jan. 1	?PN	10 41 41			Micros.
		SN	10 58 58	17		
		SE	11 02 01			
		LN	11 12 17	18	0.5	No maximum.
		LE	11 12 —			
		FN	11 43 34			
117	Jan. 2	ePN	11 09 08			
		?SN	11 33 56			
		LN	11 36 10	20		
		LE	11 37 26			
		FN	11 57 34			E–W very weak.
118	Jan. 2	SE	23 50 38			
		LE	23 53 38	20		Qf. Lechainá, Greece, 23 h. 34 m.
		LN	23 54 26	20		
	Jan. 3	ME	0 06 32		.5	
		FN	1 09 58			
		FE	0 19 32			
119	Jan. 3	LN	8 14 22		.2	
		eLE	8 20 48	16–20	.1	
		F	8 35			
120	Jan. 3	PN	23 38 50	3		Qf. Vernie and Issik Kul, Turkestan.
		PE	23 38 52	4		
		SN	23 49 30	28		
		SE	23 49 30	16		D. 6200 miles or 10000

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911.		h. m. s.	s.	mm.	
	Jan. 4	LN	0 08 50	44		kms.
		LE	0 08 11	33		
		MN	0 20 07		75+	Ran off drum 3 times.
		ME	0 15		75+	Ran off drum 4 times.
		FN	2 38			Both pendulums undamped.
		FE	2 35			Motion of pendulum. excessive and irregular.
121	Jan. 7	LN	3 03 34	15–24	.3	P and S, if present, very doubtful.
		LE	3 03 33	13–20	.15	
		FE	4 09 52			
122	Jan. 11	eLN	18 35 51	17–20		
		MN	18 36 33		.5	Record E–W like microseisms.
		FN	18 38 05			
123	Feb. 5	PN	4 30 44			
		S	4 35 59			
		L	4 44 27			O = San Salvador (J. B. Goesse).
		F	4 57			
124	Feb. 6	eN	23 36 17			Ql. Local shock; felt at home in nearby house by observer. Not noticed by other people.
		FN	23 36 34			
		eE	23 36 17			
		FE	23 36 21			
125	Feb. 7	?SN	2 34 34			E–W not registered. N. tangled. O west of Cambridge.
		L	2 35 42	12–20	0.25	
		L	2 39 44			
		F	2 45			
125a	Feb. 16	eN	20 24 31			
		L	20 26 20	16		
		F	20 33 37			
125b	Feb. 17	eN	2 52 19			
		F	2 54 05			
125c	Feb. 17	eN	14 40 47			
		M	14 41 50	14–16		

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911.		h. m. s.	s.	mm.	
		F?				After some mins. —indefinite.
125d	Feb. 18	?N	2 04 24			Pendulum tilted slowly to S.
		e	2 05 29	5		
		e	2 12 28			E–W Component (12s period) undamped, not registering satisfactorily.
		LN	2 13 29	14–15		
		L	2 16 27	13		
		F	2 27			
126	Feb. 18	PN	19 04 59			Earthquake at Monastir in Macedonia.
		E	19 04 35			
		SE	19 24 31			
		LN	19 30 07			
		E	19 32 36			
		MN	19 33 11		8.5	Undamped pendulum per. 24s.
		E	19 36 13		1.7	Undamped pendulum per. 12s.
		FN	21 34			
		E	20 20			
127	Feb. 18	PN	21 49 45			Cf. Strassburg P 21.35.08.
		LN	22 07 01	20		
		F	22 37			No record E–W.
128	Feb. 19	LN	2 30 54	17–20		e 2.31.36 Ottawa.
		F	2 37			No record E–W.
129	Feb. 26	eSN	12 59 29	13		Ottawa, e 13.00.20.
		LN	13 05 43	24		No record E–W.
		F	13 23			
130	Mch. 11	LN	4 15 25	16–20		Micros.
		M	4 30 02		0.5	Ottawa eL 4–14.
		F	4 53 47			No trace E–W.
131	Mch. 19	eP?N	4 31 39	3–4		
		eS	4 37 59	22		
			4 42 41	20–28		
		LN	4 44 54	20		Dp. 2750 mi.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911.		h. m. s.	s.	mm.	
		LE	4 44 32	13	.25	
		L	4 45 46	16		Not reported from Strassburg.
		LN	4 46 41	16		
		FE	4 50 13			
		FN	5 00 11			
132	Mch. 20	LN	0 16 51	16–22		
		F	0 18 51			Not shown E–W.
133	Apr. 7	?PN	7 04 48			Weak microseisms running.
		?S	7 13 04	12		Ottawa, e 7–03–42.
		L	7 22 46	17		E–W not working well.
		F	8 09 36			
134	Apr. 7	SN	18 40 27	12		Qr. Sinaloa, Mex. ca. this time.
		L	18 41 47	16		
		?F	18 49 09			Microseisms superposed.
135	Apr. 10	PN	18 49 01	4		
		S	18 54 29	8–10		D. 5090 kms. (W. & Z.).
		L	18 56 53	18–20	1	Qr. near Bogota, U. S. Col.
		F	19 52 08			
135a	Apr. 18	eLN	2 03 33	28–30		Lost in Pendulunruhe.
		L	2 07 22			
		F	2 31			E–W not recording well.
136	Apr. 28	P	10 00 28	4		Distance about 3000 mi.
		S	10 07 03	12		E–W record illegible.
		L	10 14 08	12		
		F	10 31			
137	May 4	PN	23 48 41	3		D. 8670 kms.
		E	23 48 30	4		
		SN	23 58 15	18	(19.5)	Throw N 4.5 mm. then S 29 mm.
		E	23 58 06	20	(5.5)	Throw E 10.5 mm. then W 8 mm. F?
	May 5	LN	0 07 48			Followed by several LL.
		E	0 06 07			
		FN	1 35			(O = λ 152°30′ E. φ 51°)

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911.		h m. s.	s.	mm.	
		FE	1 32			N–(J. B. Goesse).
137a	May 9	PN	19 47 26			
		S	19 53 19			
		L	19 59 04			E–W not working.
		F	20 15			freely.
138	May 10	eLN	0 41 49	12		Began 0–23–36 Sta. Clara, Calif.
		E	0 44 26	12–14		
		F	1 — —			
138a	May 11	LN	5 17 05			Ottawa, e 5–17.
		F	5 43 28			
138b	May 25	PN	8 06 12			Not shown E–W.
		S?	8 13 42	8		
		L	8 22 06	20	0.1	F doubtful.
139	May 31	e	19 03 10			Cf. Qr. at St. George, Grenada, at 3.14 local time.
		LN	19 05 23	20		
		L	19 14			
140	June 2	MN	20 48 10	1	0.5	Possibly local traffic jars but more pronounced than usual and looks like local shock from sharp beginning of M.
		M	20 48 14			
		F	20 48 38			
		ME	20 48 08	1	0.5	
		F	20 49 30			
141	June 3	eSN?	21 08			
		LN	21 23 51	20	.5	Ottawa LN 21–18.5.
		LE	21 26 02			
		FN	22 03			Strassburg 20–40–50 to 21–20.
		FE	21 52			
142	June 7	PN	11 09 50			
		PE	11 09 39			Qf. Mexico City to Colima.
		SN	11 15 38			
		SE	11 15 48			
		LN	11 21 46			Dp. 2300–2700 miles.
		LE	11 22 17			
		MN	11 24 39		75	Off drum.
		ME	11 27 08		75	" "

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911.		h. m. s.	s.	mm.	
		MN	11		75	Off drum.
		ME	11 38 04		75	" "
		FN				After 14–30, lost in local disturbances.
142a	June 15	eSN	5 43 41	5		
		L	5 46 13	12		Very faint.
		F	6 05			
143	June 15	PN	14 39 57			
		PE	14 39 44			Ottawa 14–39–42.
		SE	14 52 44			Strassburg 14–38–22.
		LE	15 13 40			
		F	16 50 —			
144	June 16	LN	18 12 17			
		F	18 31 46		25–20	
145	July 1	SN	22 13 13	8		Ottawa P 22–07–07.
		L	22 20 47			D. 2600 miles.
		M	22 21 16		29	Qf. San Francisco, 2:01 pm. (local t.).
		F	23 13 —			Qf. Mt. Hamilton 2:00:2 pm.
146	July 4	iPN	13 46 28			Changed paper N–S between 13–51–57 and 14–27–20.
		(e)	13 48 37			Changed record E–W between 13–16–30 and 14–48–37
		LN	14 27 56			
		LE	14 27 28		14	Strassburg P 13–41–37.
		FN	15 08			
		FE	15 05			
147	July 12	ePN	4 26 52			
		S	4 38 26			4–45–57 pds. 13 20
		L	5 07 53	24–30		Qf. Isle of Salibaboe, East Indies.
		M	5 16 38		4.5	
		F	6 29 24			Batavia P 4h. 12m. 57s.
148						Artificial record.

Of the 83 recorded earthquakes in the above list, 25 or about 30 % failed to give a record of the preliminary tremors upon the times of beginning of which calculations for distance are based. That such records consisting of long or surface waves only are due to distant weak shocks is shown by their accordance in time with the occurrence of earthquakes frequently reported by the press. Such was the case for instance with that of 7 September, 1910, pertaining to the record of the earthquake at Rilski-monastir in Bulgaria, and that of 9 September, 1910, whose origin was near Higuey, Haiti. It is probable that a few cases of such records have been overlooked either because of the small amplitude of the motion of the stylus or by reason of the record being masked at times when microseisms were running. The times of beginning of these long waves as given is presumably later than their appearance at the Station.

A comparison of the times obtained at Cambridge and at Ottawa, where a photographic registration is used, brings out a frequent failure on the part of our instruments, recording on smoked paper, to give readings as early by some seconds as would be expected. In part this defect is undoubtedly to be attributed to the action of the sooty layer in which the needles work. Again the Ottawa Station is on or near bed rock while the pier at Cambridge rests on an unknown thickness of glacial sands and clays which exercise a damping effect on the preliminary vibrations. It is thus rarely possible to state that the first appearance of the P tremors represents the initial impulse of the seismic motion at Cambridge.

One of the chief reasons for installing a seismograph in the Department of Geology was the hope that local New England earthquakes and small shocks might be accurately recorded. Since the implacement of the seismograph in April, 1908, several local shocks have been reported by the press as affecting eastern Massachusetts within a radius of 20 miles from Cambridge and thence outward to northern New Hampshire and eastern Maine. None of the local shocks reported in the daily press has left a recognizable trace on our records. The one local shock felt and recorded at the Station was not reported to the daily press. The New England shocks of which I have knowledge for the year ending 31 August, 1911, are as follows:—

21 August, 1910. The daily papers reported the time as 1h. 45m. p. m., E. S. T. Lowell, Mass., and surrounding towns in the Merrimac valley felt shocks lasting several minutes. At Tyngsboro dishes were rattled several seconds and sounds like thunder were heard. A shock was distinctly felt at Chelmsford Centre. Explosive noises were

heard in Lowell in the sections known as The Highlands,Pawtucketville, and Belvidere. No damage. Not recorded at this Station.

30 August, 1910. At 9h. 30m. a. m., E. S. T., a shock was felt at Sunapee, N. H. Press accounts not seen. Not recorded at Cambridge.

6 February, 1911. Local shock felt by the observer at 51 Oxford St., Cambridge, Mass. Recorded on the seismograph at 6h. 36m. 17s. a. m., E. S. T. The N–S component was in rapid oscillation for 17 secs. probably from its own momentum. The shock felt by the observer seemed to travel from the northeast and to last not longer than one or two seconds. Apparently not noticed by others. The observer was lying on a couch on the first floor of the house.

From local newspapers issued during the year covered by this Report 33 accounts of earthquakes giving place of origin and sometimes other data have been culled. These were shocks which would have been known before the introduction of seismographs. The number thus reported is 38 % of the number of earthquakes recorded at the Station for the same period. Of those reported by the press with mention of locality, etc., 18 were local or distant shocks not recorded at this Station. Of the total number of earthquakes thus made known, 101, the seismograph gave notice of the occurrence of 82.18 % and the local press reports 17.82 %.

The efficiency of the Station has steadily increased from the beginning as the following tabulation of the number of earthquakes recorded month by month from April, 1908, will show.

Number of Earthquakes Recorded Monthly since 1908.

Year.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1908					1	0	0	3	1	0	1	1
1909	1	0	0	0	2	1	3	4	3	7	3	2
1910	5	2	5	5	12	9	8	4	10	3	11	12
1911	8	11	3	5	6	6	3					

This increase is partly due to a closer reading of the records and greater skill in picking out seismic waves among the various wanderings of the pendulums. The records for 1910 are in close agreement as regards number with those at the Dominion station at Ottawa. The discrepancies arise from long waves of distant earthquakes moving on paths near that of the great circle passing through both stations. A weak disturbance may pass through one of the stations and die out or become too faint for distinct registration at the other.

The earthquake of 3 January, 1911, which was destructive about the shores of Issik Kul in Turkestan, was of the highest order of intensity producing prompt action on the part of seismographs installed on this continent at distances varying from 6000 to 7250 miles from the epicentral tract. The following table compiled from some of the data sent to this Station in the course of its exchanges serves to illustrate the comparative working of the Station and to point out the necessity for obtaining the time of arrival of initial waves to a second.

Arcual Distance.	Station.	P	S	L	F
87°	Seattle	6 38 30	6 49 06	7 06 50	8 16 00
88°	Ottawa	6 38 36	6 49 16	6 55 40	9 50
91°	Cambridge	6 38 50	6 49 30	7 08 11	9 38
105°	New Orleans	6 42 30	6 52	7 16 30	9 09 30

The three stations first named are equipped with Bosch-Omori seismographs of different designs, that at Ottawa having photographic registration. The New Orleans station of the Jesuit Seismological Service has a Weichert seismograph. These four stations have been taken because the times show a manifest progression in general of the wave phases from north towards the south. An analysis of the rates of transit for the phases, however, shows that the seconds as given are approximations to anything like a uniform rate of transit. Another difficulty lies always in estimating the distance correctly so that while the time may be read correctly for great distances the measure cannot be given with the same degree of accuracy as the time of beginning of a wave phase at a station.

It is from such data as these that the calculations of the velocity of propagation of seismic waves must at present be made. It is obvious that accurate time and frictionless devices for registering the initial motion of the seismographic pendulum are a prerequsite of satisfactory results at every station.

The Messina earthquake of 27 December, 1909, was recorded during my absence from the University. Professor Rizzo of the Messina Observatory has shown that the times given in the Annual Report for 1908–09 begin with the second preliminaries instead of the first. On examining the record I find the first preliminary tremors present and confirmative of Dr. Rizzo's emendation. The first preliminaries were partly masked by microseisms. The revised record should then read as follows:—

75th M. Time West.	S	L	M	F
N–S	4 39 33	4 54 29	4 56 —	5 55
S–W		4 54 31	5 02 25	

Vd. Memorie delle Reale Accademie delle Scienze di Torino, 1910, ser. 2, **61**, p. 400.

From a study of our records from September, 1909, to 31 August, 1910, during which period 40 cases of determined duration of the vibration of the pendulums at Cambridge gave a total of 47h. 35mins. 32s. On the supposition that the remaining 28 cases were of the same average duration, it appears that the ground was in that year agitated by distant earthquakes $\frac{1}{100}$ths of the time.

Microseisms. At most seismographic stations and particularly at those on or near the coasts of a continent the phenomenon known as microseisms are recorded characteristically as small vibrations of about 5 secs. period. They may last for two days or more. At Cambridge they are almost invariably the accompaniment of some cyclone moving to or off the coast, a feature first described by Dr. Klotz of the Dominion Observatory at Ottawa. Rarely microseisms have appeared at Cambridge during a period of fair weather but chiefly when incoming vessels report heavy gales to the eastward in the North Atlantic. These vibrations are nearly wanting during the summer months; but from October onward well into the spring microseisms are recorded for one or more days about once a week. The cause of microseisms has not yet been sufficiently investigated to make it certain that they are in every case set up by the same agency. The hypothesis that they are initiated by the surf beating on the shores of the seas finds support in Europe in the apparent increase in the duration and intensity of the microseisms towards the coast.

At this Station microseisms are a frequent source of great uncertainty as to the time of beginning of the preliminary tremors of a distant earthquake and a small percentage of what would otherwise be good records are thus annually lost, though the main waves of the records are but little affected by microseisms. A typical case of microseisms superimposed upon waves of a longer period is thus described in the Station journal for October, 1909.

About 5h. 33m. a. m.,. 15 October, 1909, microseisms and waves of irregular periods varying from 30 to 60 seconds began, and continued on both components until ca. 1h. 51m. on 18 October, the microseisms continuing until between 8 and 9 p. m., 18 October . . . . At the same time there developed a cyclonic storm of great fury in Alabama, Tennessee, etc., which passed eastward and out to sea . . . . The weather maps show that during the microseismic storm with long flat waves from 15–19 October there was prevailing a "high" barometric area over the southern Appalachians and a "low" over the

New England region . . . . Similar conditions were repeated during the microseisms of 25 and 26 October, 1909.

Another case is that of the microseisms of 24, 25 November, 1909. A heavy cyclonic rain and snow storm passed over Cambridge. There was a slight fall of snow during the night of the 23–24th, followed by frozen rain and snow during the day of the 24th, turning to heavy rain at 8 p. m., the 24th. Cloudy and dull on a. m. of 25th. Microseisms began between 6 and 7 p. m. the 23rd and continued to the morning of the 25th, being strongest during the 26th at height of the storm. Period of tremors from 5. to 4.53 secs.

On 29 November, 1909, a bad gale in Boston harbor and off the coast was reported, the wind rising to 72 miles an hour,— also felt on the shores of Cape Cod. During the day both components of the seismograph registered waves with periods of 15 to 30 seconds. up to 4 p. m.

The long period "pulsations" it is generally thought are local wind effects. They occur at Cambridge sometimes when no marked local winds are blowing.

Inasmuch as it appears most probable that the regular diurnal swingings of the pendulums depend upon temperature and barometric changes of little immediate geological import no attempt has been made to tabulate the data to be derived from a study of the records. The same is true of the longer period wanderings of the pendulums which are associated with the passage of cyclones. The phenomena are rather pertinent to meteorology than to a direct study of earthquakes, though undoubtedly the barometric and the thermometric data thus to be obtained may throw some light on the conditions which affect the earth's crust at times of seismic disturbance. Where heavy damping of the pendulums is resorted to for the proper control of the seismograph as an instrument of precise measurement of the movement of an earth-particle, these meteorological effects are nearly if not quite eliminated from the record. From the geological point of view microseisms are likewise of little interest except so far as in common with other short period vibrations of the earth's crust characteristic of the preliminary tremors of seismic waves they may promote changes of state in the loosely compacted sediments or in magmas near the point of solidification. Doubtless these vibrations affect the rate of flow of water, the creep of loose particles on debris slopes, and if it be permissible to add another factor to the suggested causes of glacier motion we may suppose these vibrations along with those of true seismic origin work in their due proportion to the advance of glaciers and icesheets. But no investigation of these possible effects slight as they must be have as yet been undertaken. The daily records of the Station are carefully kept in files awaiting any use which may be made of them for these or other investigations of a like nature.

New England Earthquakes. By reason of the frequency and relatively high intensity of seismic shocks in the 17th and 18th centuries this region stands undesirably high among the eastern natural provinces of the continent for its seismicity. The catalogues of Brigham and Lancaster include probably nearly all of the shocks which were felt by the inhabitants of New England up to 1870. The fact that neither Brigham nor Lancaster refer to the History of Lynn by Alonzo Lewis in which a few earthquakes are noted not included in their lists makes it reasonable to suppose that the publication in recent years of diaries and personal journals of the colonial period may make known other shocks which have not yet been recorded in scientific literature. The following additional references to earthquakes are from the 1865 edition of the History of Lynn by Alonzo Lewis and J. R. Newhall. Most of the accounts are also to be found in the edition of 1844 in which Lewis states (p. 17–18) that he has corrected the years and months except when marked in quotations but has left the days untouched. Those earthquakes subscribed "Collins" are given on the authority of a journal kept by Mr. Zaccheus Collins (ed. 1844, p. 6).

Additions to the List of Brigham and Lancaster. 1639. On the fourteenth of January there was an earthquake. *Loc. cit.*, p. 182.

1730. Sunday, 12 April, there was an earthquake. *Loc. cit.*, p. 323.

1744. The shock of 3 June mentioned by Brigham and Lancaster is stated on the authority of Collins to have been repeated on the twentieth. *Loc. cit.*, p. 326.

1780. On the twenty-ninth of November there was an earthquake *Loc. cit.*, p. 345.

1805. An earthquake happened on the sixth of April at fifteen after two, in the afternoon. *Loc. cit.*, p. 367.

1814. An earthquake happened on the twenty-eighth of November at twenty past seven in the evening. *Loc. cit.*, p. 377.

1817. There was an earthquake on Sunday, 7th September, and a second on the fifth of October. *Loc. cit.*, p. 380. The first of these shocks is not given by Brigham or Lancaster.

1830. On Wednesday, 1st December, there were two shocks of an earthquake, about eight o'clock in the evening. *Loc. cit.*, p. 396.

1837. On the fifteenth of January at two o'clock in the evening, there was an earthquake. *Loc. cit.*, p. 403.

There are a few discrepancies in dates between Brigham's text and that of Lewis. In the case of the shock of September, 1732, given in Brigham's text as on the 15th, Lewis gives the date as the 5th as does Brigham also in his summary table. In the case of the shock dated Sunday, 16 February, 1737, there is some confusion. Lewis gives on the authority of Collins's Journal a shock on Sunday, 6 February, 1737 and mentions none in the year 1736. Brigham also gives a shock for 6 February, 1736. It seems better to regard the dates given by Brigham as referring to a shock the corrected date of which is that given by Lewis.

Concerning the legendary fall of rock at Pirate's Dungeon in Lynn in the earthquake of 1658, mentioned in the earlier editions of Lewis's History, see the cautious account of this unsupported statement in Newhall's edition of 1865 (p. 244–250).

Bibliography of New England Earthquakes. In this list the writings cited by Brigham and Lancaster are omitted as being readily found from the references which they give.

Lewis, Alonzo, and J. R. Newhall. The History of Lynn, Vol. 1, 1865. Vol. 2, by J. R. Newhall, History of Lynn, 1864–1893. Lynn, 1897.

Brigham, W. T. Historical Notes on the Earthquakes of New England. 1638–1869. Memoirs Boston Society Natural History, 1871, **2**, p. 1–28.

Lancaster, A. Note additionelle à Memoire de M. W. T. Brigham, intitulè "Volcanic manifestations in New England, 1638–1870. Memoirs Boston Society Natural History, 1873, **2**, p. 241–247.

Perley, Sidney. Historic Storms of New England. Salem, Mass., 1891. Gives accounts, without reference to authorities, of the earthquakes of 1638, 1663, 1727, 1744, 1755.

Woodman, J. E. The earthquake of March 21, 1904, in Nova Scotia. Proc. Trans. Nova Scotia Institut. Sci., 1895, 11., p. 227–235.

In the History of Lynn, *loc. cit.*, p. 345, there is mentioned Dr. John Perkins of Lynnfield who died in 1780. He is credited with having published in 1755 a tract on earthquakes. Not seen.

The N. Y. Tribune Annual gives many references to New England shocks continuing the lists of Brigham and Lancaster.

Ready method of approximate determination of epicentre with data from requisite number of stations.— There are several methods varying in precision and in the labor they involve employed in determining the position of epicentres. The method mentioned by Milne of drawing circles on a good globe is the simplest approximate method, but is somewhat awkward to manage and does not leave a record of the process for future reference and revision. At this Station the following method is planned for obtaining an approximate determination. On a Mercator chart of the world for each principal station exchanging data and placed in a suitable position for giving good results meridians are drawn on Lambert's projection passing through the Station and its antipodes thus giving the paths of all ways entering the Station. About the Station and its antipodes curves of equal distance say 100 kms. are drawn representing parallels in Lambert's projection. The distance curves are made the basis of the following operation for determining the position of the epicentre as in the intersection of circles. In a book of blank Mercator maps printed on the same scale as the maps for the several stations but on transparent paper, the Station maps are slipped in succession under the page on which the record is to be made in exact registration and the appropriate circles of distance traced. Their intersection solves the problem as in the use of the globe.

The same map in the Register of Epicentres may be employed for marking out several cases, *e. g.*, those of a given month. The argument for Lambert's projection and a drawing which may be enlarged to any given scale of Mercator chart is to be found in Encyclopedia Britannica, 9th edition, **10**, p. 208–209. The most expeditious way of determining the position of the curves of equal distance about a station is to draw them with compasses on a slate globe provided with suitable lines of latitude and longitude and to trace the curves through corresponding points upon the Mercator projection.

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HARVARD SEISMOGRAPHIC STATION FOURTH ANNUAL REPORT FOR THE YEAR, 1 AUGUST, 1911—31 JULY, 1912.

BY J. B. WOODWORTH.

CAMBRIDGE, MASS., U. S. A.:
PRINTED FOR THE MUSEUM.
FEBRUARY, 1913.

No. 2.— *Harvard Seismographic Station. Fourth Annual Report for the Year, 1 August, 1911 — 31 July, 1912.*

By J. B. Woodworth.

The seismic records given herewith continue the list published in the Bull. M. C. Z., **55**, p. 1–24. The constants of the Station remain as in previous years: viz.—

Latitude 42° 22′ 56″ N. Longitude 71° 06′ 59″ W. Altitude 5.36 M.
Time: — Mean Greenwich, midnight to midnight.
Instruments: — Two Bosch-Omori 100 kg. horizontal pendulums, with mechanical registration. Period of pendulums, 25 secs. Magnification: — N., 50; E., 80. Damping: — N. 4:1 (See Remarks). E., O.
Nomenclature: — Göttingen.

In the column of Remarks the following abbreviations are employed:— Q, quake, earthquake; Qf., felt earthquake; Ql., local shock; Qr., earthquake reported; O., origin or epicentre; TO., time at origin, calculated by Benndorf's tables; Δ, distance from Cambridge to origin, calculated from record. Micros., microseisms mask the record.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911		h. m. s.	s.	mm.	
149	Aug. 16	NP	23 00 38			Klotz gives O = ϕ 31° 24′ N, λ 142° 28′ E.
		S	23 19 19			
		L	23 38 31			
	Aug. 17	M	0 00 19		9.5	Qr. Eap. W. Caroline Ids.
		F	1 16			
150	Aug. 27	eNP	11 08 00			Klotz gives O = ϕ 31° 50′ N, λ 112° 15′ W. No maximum.
		eS	11 12 25			
		eL	11 21 15			
		F	11 49			
151	Sept. 6	NP	1 06 25			E–W component out of order.
		S	1 17 19			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911		h. m. s.	s.	mm.	
		eL?	1 28 59			Klotz gives O = ϕ 52° 58′ N, λ 143° 20′ E. Miyako, North Nippon, Japan. Δ 10,000 kms.
			1 37 54		.6	
		F	2 03			
152	Sept. 8	NL	23 29 00	22–23		
		F	23 41			Strassburg Δ 9320 kms.
153	Sept. 13	NP	3 23 13			Δ 4750 kms. Qf. at Tres Acequias, Bajo Mioyano, Argentina.
		eL	3 34 49			
		F	4 11			
154	Sept. 15	P	13 20 22			
		S	13 28 42			
		eL	13 43 03			
		M	13 45 31		6.5	O near Iquique, Chile. Δ 6780 kms.
		F	14			
155	Sept. 17	NP	3 36 01			Obscured by micro-seisms.
		E	3 36 31			Obscured by micro-seisms.
		NS	3 48 12	11		
		E	3 49 34			Beginning of P very uncertain.
		eNL	4 04 58			
		E	4 05 20			Klotz: O = ϕ 28° 14′ N, λ 140° 30′ E.
		NM	4 09 15		20	
		E		17–22		
		NM	4 10 58		26	2nd Q in Coda.
		E		22		
		NM	4 13 39		27	
		NF	5 45 06			
		E	5 27			
156	Sept. 20	eNL	5 34 53	28		Ottawa eL 5–32.3.
		E	5 35 12	28		
		eNL	5 36 28	20–15		
		E	5 36 02	20–15		
		NF	5 54			
		E	5 53			

No	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911		h. m. s.	s.	mm.	
157	Sept. 20	eNL	5 59 24	13–16		Probably part of preceding group.
		E	6 00			
		NF	6 01 22			
158	Sept. 22	eNP	5 10 05	3–4		Klotz gives O = ϕ 60° 26′ N, λ 146° 30′ W.
		eE	5 10 02	2		Prince William Sound, Alaska.
		NS	5 17 00	13		
		eNL	5 25 36	24		
		E	5 24 37			
		NM	5 26 46		5.7	Δ 5230 kms. (3250 mi.).
		NF	6 10 14			
		E	6 14			TO 5h. 03m. 01s.
159	Oct. 6	NP	10 20 13	6		San Domingo earthquake.
		E	10 20 53			
		NS	10 24 29	10–17		Δ 2640 kms. (1630 mi.).
		E	10 24 41			
		NL	10 29 53	20		Klotz gives O = ϕ 17° 44′ N, λ 71° W.
		E	10 30 37			
		NM	10 32 56		4.7	Tidal wave reported at Guaymas, Mex.
		E?	10 31 24		0.1	
		F	11 38			TO 10h. 16m. 19s. (Station clock out of order).
160	Oct. 10	eEP?	13 18 17	3–4		Masked by microseisms.
		S?	13 23 45	i12		Station clock electric contact out of order and times very uncertain.
		NL	13 26 38			
		E	13 26 08	22		
		NM	13 32 50		7.5	Klotz gives O = ϕ 12° 02′ N, λ 84° 36′ W.
		E	13 30 13		3.0	
		EF	14 31			N drum stopt at 14:26.
161	Oct. 13	NS	2 55 43	6		O = ϕ 48° 34′ N, λ 157° 35′ E. (Klotz).
			2 56 32	12		
		eL	3 22	20	0.5	Time uncertain by 30 secs.
		F	4 16			
162*	Oct. 14	eN	17 00 35	35–36		P lost in micros. Station clock out of order.
			17 09 39	36		

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911		h. m. s.	s.	mm.	
		L	17 12 30	24–20		Time very uncertain.
		M	17 15 37		3.0	Reported for record of
		eE	17 09 44			phases. Ottawa e17–01 –20.
		L	17 14 54	16–20	(1.0)	No decided M.
		F	17 36			Lost in micros.
163	Oct. 20	eEL	18 44 40			Batavia P 17–53–48.
		F	19 01			
164	Oct. 26	eNP	14 19 32	3		No decided M.
		?S	14 21 43	11–30	(1.5)	Began and ended
		L	14 31 21	25		masked by micros.
		EL	14 32 57	28–18	(0.25)	Irregular LL? during
		NF	15 01			forenoon of 26th.
165	Oct. 29	eNP	18 19 15			Masked by previous
		S	18 23 54	10		line.
			18 28 19	12		
		eL	18 36 20	17		No maximum.
		F	19 15			
		eEP	18 19 01	4		Ottawa P 18–17–18.
		S	18 23 54	6		LL not well defined.
			18 27 09	12–10		
		L	18 35 55	17		
			18 39 55	14		
		F	19 12			
166	Nov. 1	NP	9 33 38	3		Ottawa P–9–33–50.
		E	9 33 32	2–3		
		NS	9 39 12	12		Δ 3770 kms. (2375 mi.).
		NL	9 44 46	24	(0.2)	
		eEL	9 47 08	20		Q reported from San
		NM	9 48 26		7.0	Juan del Sur, Nicaragua
		NF	10 34 38			gua (2400 mi).
						Press gives time 3:40 a. m.
						TO = 9–27–23.
167	Nov. 7	eNS	6 12 44	8		
		L	6 15 00	9		Microseisms ?

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911		h. m. s.	s.	mm.	
		M	6 15 02		0.9	
		F	6 35			
		EL?	6 15 00	10–12		
		M	6 15 10		0.5	
		F	6 25			
168	Nov. 13	eN?				Earlier phases masked
		L	16 47 43	25		by microseisms. Bata-
		F	17 52			via P 16–25–23.
						E–W record ill defined.
169	Nov. 18	eNS?	7 45 52	8		P lost in microseisms.
			7 55 13	24		
		L?	7 56 01	14–18	(0.75)	Ottawa P? 7–37–32.
		C	7 58 41			
		F	8 31 40?			
		eE	7 46 06			
		L	7 56 02	20		
		F	— — —			Lost about 8–20 in micros.
	(Nov. 19)					(No records between 17hrs. and 21hrs. 30m.).
170	Nov. 20	eN	14 03 27			P masked by micro- seisms?
		S	14 06 40	26		Attendant was setting
		L	14 09 43			up instruments as late
		M	14 11	20	8.0	as 14h. 03m. 11s.
		F	14 24 38			Masked by micro- seisms.
		eEP	14 02 23			
		L	14 08 35	22		Qr. Martinique, W.I.
		M	14 11 06	20	8.0	
		F	15 ?			
171	Nov. 21	eP	18 53 47	3–4		
		S	18 54 36	16	1.0	E–W microseisms only.
		L	18 55 16	9	0.5	
		F	19 01 42			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911		h. m. s.	s.	mm.	
171a	Nov. 22	eN	10 28 26			
			10 29 28	7–8		
		F	10 34 36			
172*	Nov. 25	eNL	19 51 41	20		P? and F masked by micros.
		eL?	19 51 50	10		
		F?	19 56 47			St. Louis e 19–35.8.
		eEL	19 52 51			O = SW?
		L?	19 53 50	10	1.0	
		F?	19 56 40			
173	Dec. 16	O	19 14 39			Estimated time of earthquake.
		NP	19 21 22	6–3		S-P 6m. 6s. Δ 4330 kms.
		S	19 27 28			2700 mi. L–S 7m. 18s.
		L	19 34 46			
		M	19 37 38	17	45	Qf. Mexico. O = ϕ 19°
		M	19 39 24	14		10′ N, λ 102° 15′ W. (Klotz).
		F	20 34 12			Damped pendulum.
		EP	19 21 19	4–6		S–P 5m. 42s., Δ3910kms.
		S	19 27 01	10		2440 mi. L–S 8m. 13s.
		L	19 35 14	28		
		M	19 37 40	22–25	40	
		M		14		
		F	21 51			Undamped pendulum.
174	Dec. 20	eNS	6 21 13	40		N–S damped 4:1. P masked by micros.
		eL	6 28 23	20		
		F	7 04			
		eES	6 15 17	18		Undamped.
			6 21 37	40		
		L	6 25 26	20		
		M	6 28 43	20	0.5	
		F	7 19			
175	Dec. 22	eEP	13 01 51	4–5		S–P, 5m. 42s., Δ 3910 kms., 2420 mi. Undamped pendulum.
		S	13 07 33	12–14		Local jars superposed. Qr. Mexico City 6.15 a. m.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1911		h. m. s.	s.	mm.	
		F				Lost in microseisms. No record on N damped 4:1.
176*	Dec. 23	eNS	21 22 43			Records tangled E–W and masked by microseisms.
		eL	21 26 25			
		F	21 37 41			
		eEP?	21 07 09			
		S	21 16 57			
		L	21 24 56			
		F	21 45			
176a	Dec. 23	NM	22 07 28	1-		Local shock. Ice crack; not felt by persons.
		F	22 07 30			
	1912.					
177	Jan. 4	eES	16 05 39	12		Ottawa P? 15–57–14.
		L	16 22 27	24		
		M	16 25 51	18	2	L–S, Δ 5400? miles.
		F	17 44 54			N chronograph not recording.
178	Jan. 11	NM	7 25 52			Local unfelt shock at Station. Crack in ground ice.
		F	7 25 55			
179	Jan. 11	NM	10 24 58			Local unfelt shock at Station. E gives preferred reading.
		EM	10 24 59			
		F	10 25 01			
180	Jan. 19	M	0 00 54	1–		14 secs. Local weak shock. Ice coated ground.
		F	0 00 56			
181	Jan. 19	M	1 08 15	1–		4 secs. Local shock. Ice coated ground.
		F	1 08 17			
182	Jan. 21	M	12 15 17	1–	0.5	Local shock. Ice crack.
183	Jan. 26	NM	4 21 22	1–	0.05	Local shock. Crack in ground ice. Not felt by persons.
		F	4 21 24			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
184	Jan. 26	M	4 25 16	1–	0.1	Local shock. Crack in ground ice. Not felt by persons.
		F	4 25 18			
185	Jan. 26	M	10 25 28	1	0.3	do.
		F	10 25 31			
186	Jan. 26	M	10 39 29	1	0.2	do.
		F	10 39 31			
187	Jan. 26	M	11 20 48	1	0.3	do.
		F	11 20 49			
188	Jan. 26	M	11 26 24	1	0.5	do.
		F	11 26 26			
189	Jan. 26	M	11 30 19	1		do.
		F	11 30 21			
190	Jan. 31	EL?	11 51 40	10		No record N–S by damped pendulum.
			11 52 52	13		
		M	11 53 20	10	0.5	Micros.
		L	11 55 03	15–12		
		F	11 56 54			
191	Jan. 31	eLN	20 35			
		M	20 36 56	10	14.0	Damping 4:1.
		F	21 ca			
		EP?	20 20 03			Micros.
		S	20 26 47	8		Δ 5040 kms.
			20 27 06	8		
		L	20 35 35	32		Qr. near Valdez, Alaska.
		M	20 36 40	20	34.5	
		F	21 33 22			
192	Feb. 15	e	18 41 12			
		eEL	18 44 56	15		Micros. only E–W. Damped 4:1.
		F	18 48			Not reported from Ottawa.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
193	Feb. 19	EL	23 00 56	17		Micros. only N–S.
		e	23 01 02	4		Damped 4:1.
		L	23 01 06	15		Ottawa e? 23–09–27.
		F	23 11 27			
194	Feb. 22	EL	7 38 29	15–20		QQr. Costa Rica ca. this time.
			7 47 24	20		
		e	7 55 14	11		
		F	7 55 54			
195	Feb. 22	e	8 43 30			
		eE	8 46 45	24–13		Possibly connected with preceding. L interval 1h. 04m. as if set off by S of 194 reflected to epicentre.
		F	8 51 36			
196	Mar. 11	eNS	10 35 44	8		P masked by microseisms.
		L	10 38 31	18		LE–SN: 2m. 39s.: Δ
		M	10 38 47	17	3.0	1800 kms? (Laska).
		F	11 04 28			F in micros.
		eE	10 33 39			P masked by microseisms.
		eS?	10 38 04			
		L	10 38 23			Pendulum undamped.
		M	10 38 46		9.5	Cf. Batavia e 10–12.
		F	11 13 50			Ottawa P 10–30–13.
197	Mar. 11	eEL?	19 09 58	20		No record N–S on damped pendulum.
		F?	19 12 28			
198	Mar. 11	eES?	19 47 04?			Micros. 4s. pd. N–S. only.
		L	19 59 10	20		Micros. superposed.
		F	20 16			F later?
199	Mar. 29	EL?	16 10 53	19		Among long period waves from 14h. 45m. to 20h. 20m. No record on N–S damped pendulum.
		L?	16 17 04	20		

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
200	Apr. 2	eEL?	0 46 51	25–18		Microseisms N–S.
		(F)	0 47 43			
		eL?	0 55 17	17		
		F?	0 56 01			Among waves 30–50s. period.
		L?	0 58 15	19–28		
		F	0 59 31			Not reported elsewhere.
200a	Apr. 13	eEL	19 04 18?	16–17		Undamped pendulum, per 22s.
		L	19 07 08?	22–24		
		F?	19 36 20			
200b	Apr. 14	eEP?	13 40 43	4		
		eL	13 56	13–14		
		F	14 20			
200c	Apr. 14	eEL	23 38 11	20		
		F	23 54 42			
201	Apr. 15	eES?	16 51 27	12		No record N–S by damped pendulum.
		e	16 53 40	12		
		eL	17 09 29	20–24	0.1	
		F	17 16 22			
202	Apr. 17	iNP	3 57 09	2–3		S–P, 6m. 33s. Δ 4830 kms.
		S	4 03 42	6–8		
		eL?	4 08 12	14–20		
		F	4 30			
		eEP	3 57 10	2–3		
		e	4 02 55	11		
		S	4 03 54	11		
		L	4 08 54	20–26	0.38	
		F	4 45			
203*	Apr. 20	eEL	2 34 11	20–24		Not shown N–S by damped pendulum. Ottawa e 2–31.
		F	2 53			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
204	May 6	NP	19 07 07	4		S–P, 5m. 40s. Δ 3870 kms. 2400 mi.
		S	19 12 48	8		O in southern Iceland.
		EP	19 07 09?			
		S	19 12 47	11		TO = 19–00–37.
		eL	19 16 55			Strassburg reports P
		M	19 20 20	16–19	36.5	19–04–42 Qf. in southern Iceland.
		F	20 43 43			Record partly masked by jars from heavy traffic.
205	May 6	eEL	23 27 08	22–24		One of several short groups of LL among longer irregular waves on May 6th to 12th. Not reported elsewhere.
			23 34 20	24–28		
		F	23 36 23			
206	May 16	eEP?	15 01 10			
		e	15 02 35	3		
		S	15 03 21	12		L–S, 7m. 6s., Δ 5600 kms.?
		eL	15 10 27	22		
		F	15 13			N component out of commission for repairs from May 18, 21h. to 21h. 45m. E component out of commission for repairs May 18 from 21h. 45m. to 22h. 45m.
206a	May 21	eE	9 55 34			
		eL	9 20 59			
			9 34 52			
		F	10 36 30			
207*	May 23	eEP?	2 44 05	16		P masked by microseisms.
		S	2 51 34	8		Undamped pendulum; per 25s.
		eS?	2 59 17	15		
			3 03 3	16		N record faint; both obscure.
		eL?	3 06 15	28		
			3 10 27	20		

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h m. s.	s.	mm.	
			3 11 36	67		Record evidently of Q in Burma: Athens P 2–34–48.
			3 15 18	32		
			3 18 26	25		
		M1	3 22 34	31	22.5	
		M2	3 24 45	25	28.0	
		M3	3 29 09	22	27.0	
		F	4 50			
208	May 25	eN	16 29 42			Not recognized E–W. Not reported elsewhere.
		eL	16 37 42	22		
		F	16 45 52			
209	May 28	eNL	13 41	20		Ithaca, N. Y. eL 13–36.
		F	13 48 11			
		eEL	13 42 29	24–22		
		F	13 57 06			
210	June 3	eN	12 39 29			Strassburg P 12–45–18.
		eL	13 08 01		0.5	
		F	13 45			
		eE	12 39 53			
		eS?	12 55 40	15		
		eL	13 07 01	22–20	0.5	13h. 21m. changed record.
211	June 7	eE	4 05 53	9–10		
		F	4 13 37			
212	June 7	eE	5 01 14	17		
			5 03 57	10–8		
			5 05 08			
		F	5 18 41			
213	June 7	eE	7 42 02			
		eL	7 45 27	20		
		F	7 51			
213a*	June 7	Ee	8 28			
		F	8 50			
214	June 7	Ee	9 12 43	8		Ottawa M 9–23.
		L?	9 20 08	10–8		

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
			9 28 09	10		
		F	9 45 30			
215	June 7	P	10 04 29			O, Alaska. S–P. 7 m. 16s., Δ 5620 kms.
		S	10 11 26			TO 9h. 55m. 08s.
		L	10 23			F in next record.
		F?				L 1h. 02m. 52s. after L of 214 as if set off by S. of 214 reflected to epicentre.
216	June 7	eE	11 02			
		F?	12			Appears to merge into next group of waves.
217*	June 7	eES?	12 41 37			
		S	12 51 16	9		
			12 55 18	10	0.37	
		L	13 26 40	20		
		M	13 28 20	18	2.8	
		M	13 31 45	17	2.2	
		M	13 37 35	20	2.5	
		F	14 01			
218*	June 7	eE	18 49 17			
		S?	18 52 57			
		M	18 53 50			
		F	19 12			
219	June 8	eEP	7 44 44			S–P: 7m. 25s.; Δ 5790 kms.
		S	7 52 09			TO 7h. 35m. 40s.
		L	8 02 01			
		M	8 03 15			
			32			
		F?				F in next group of waves.
220	June 8	e	9 13 22			
		L?	9 16 36			
		M	9 18 31			
		F	9 18 43			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
221	June 8	e	10 26 05			Interval of 1h. 12m. after 220.
		L	10 30 07			
		F	10 34 30			
222	June 8	e	10 54 30			e at 33m. 20s. after e of 221.
		S?	10 59 25	8		Reflected P of 221 at epicentre?
		F	10 25 51			
223	June 9	eN	17 41 58			e = L?
		L?	17 46 56	16		
		C	17 48 01			
		F	18 03 31			
224	June 9	eN	22 05 22			Ottawa M 22–04.
		F	22 13 28			
225	June 9	eN	22 37			Ottawa M 22–39.
		F	23 10			
226	June 10	eNP	16 15 24			S–P: 7m. 29s.; Δ 5850 kms. or 3650 mi.
		S	16 22 53	10		Time at origin 16h. 06m.
		L	16 32 46	18		
			16 33 19	16		
		M	16 39 07	16	17.7	
		F	17 57			
227	June 12	eNL?	7 30 13	30		
		e	7 31 41			
		L?	7 35 51	13		
		F	7 49 13			
228	June 12	iNP	12 49 56	3		S–P, 5m. 17s.; Δ 3500 kms. (2175 mi.).
		R_1P?	12 50 57			T at origin 12h. 45m. 35s.
		S	12 55 13			
		eL	12 59 41			
		M	13 02 56	22	2.2	
		F	14 15			
229	June 15	eN	17 34 48			
		L	17 38 37	20		
		F	17 46 58			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
230	June 15	eL	18 50 41	20		
		F	19 01 40			
231	June 17	eN	11 39 58			P and S uncertain.
		eS?	11 49 15	28		
		L	11 51 33	20		
		M?	11 58 28	15	0.5	
		F	12 30			
		EP?	11 34 36			
		S?	11 43 22	9		
		L	11 51 42	20		
		M?	11 57 58		0.5	
		F	12 29 28			
232	June 18	eN?				
		S	12 17 01			
		L	12 34 42	20		
			12 44 32	20		
		eE				
		S	12 16 50			
		L	12 34 42			
			12 44 32			
		F?	14 30			
—	June 20	N				Long period irregular waves from ca 13h. to 16h. 15m.
233	June 28	eN	19 02 43			Irregular motion N–S from ca 13h. June 28 to ca 0h June 29. Microseisms E–W.
		F	19 10 09	8;15		
234	June 29	eNP	8 02 21	3–4		
		S	8 11 24			
		eL	8 25 53			eLE–SN, 12m. 36s., Δ 8000 kms.
			8 26 48	20		
		F?	9 10			
		ES	8 11 09			
		L?	8 23 45			
		F?	8 30			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
235	July 7	NP	8 06 27	3, 4		i Throw of pendulum N.
		S	8 13 29			S–P, 7m. 02s.; 5375
		eL	8 19 43	48		kms.
		M	8 23 13		75	Stylus went off drum
		iEP	8 06 23	4		and no further record.
		S	8 13 26			
		L	8 19 57	50		S-P, 7m. 03s.; 5390 kms.
		M	8 23 13	22	75	Stylus off drum.
			20 08			Stylus on again.
			31 42			Stylus off again.
			32 48			Stylus on again.
		C	35 02			Alaskan earthquake.
		F	10 13			TO, 7h. 57m. 26s.
236	July 7	eNP	22 51 10			
		S	23 03 02	8		
		L	23 08 11	13		
		F	23 22 28			
237	July 8	eN	3 34 58	3		
		F	3 40 31			
238	July 8	NP	22 02 32			S–P, 7m. 18s.; 5665 kms.
		S	22 09 50	8		
		L	22 18 19	15		Qr. Alaska.
		M	22 18 35		24	
		F	23 30 21			
		EP	22 02 34			
		S	22 09 44			
		L	22 19 16		31	
		M	22 18 31	15		
		F	23 02 10			
238a	July 9	eNL	9 13 39			Just visible; not shown
		F	9 21			E–W. Ottawa eL 9–11.3.
239	July 9	eN	17 05 34	3–4		
			07 52	8–10		
		F?	08 19			
240	July 11	NL	19 08 40	8–12		
		F	19 29 00			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
240a	July 22	eN	23 49 01			Masked by micro-
			23 49 31	11		seisms
			51 14	8		Micros. only E–W,
		F	57 23			pds. 3–4s.
241	July 24	NP	12 07 51	4–5		S–P, 6m. 50s.; Δ, 5150
		S	12 14 41	12		kms.
		L	12 19 51	13		Qr. Piura, Peru.
		F	13 10 ca			
		eEP	12 08 11			
		S	12 14 45	8		
		L	12 19 51	16		
		F?	12 45 ca			
242	July 25	NP?	23 28 13			
	July 26	L	0 08 12			
		F	1 04 05			
243	July 26	NP?	3 09 22			
		L	3 33	20		
		F	4 ca			
244	July 30	e?				
		eL	21 55 02	20		Ill-defined LL pre-
			22 44 19			ceded by irregular
		F	23 19 40			waves.
245*	July 31	eN?	9 51 19			Ottawa e9–51–36.
		L	10 00 19			
		F	10 01 52			

The above list where it varies from the monthly mimeographed bulletins issued from the Station is marked by an (*) asterisk, indicating some revision or correction of phase or time, made possible by comparison with the records from other stations or a rereading of the seismogram.

It will be observed in the column of Remarks that the epicentres of a few earthquakes only are determined. A more extensive list of exchanges with foreign stations would in part afford the data for such determinations, but in the case of the later records such information would not ordinarily be available until after the lapse of several months. Dr. Klotz of Ottawa is cited as authority for the location of several epicentres. The epicentres of important earthquakes are published by the International Commission, but this catalogue does not appear until four years or more after the annual report of an observatory should go to press.

The following notes supplement last year's records.

No. 126. Feb. 18, 1911. Epicentre located by Klotz in L. 41° 24′ N; L. 74° E.

No. 130. Mar. 11, 1911: agrees well with earthquake reported at Varzin, New Guinea (Vd. Monat. Uebersicht. für Marz).

No. 132. Mar. 20, 1911: appears to be record of earthquake at Marmaras-Sziget, Hungary (Vd. Monat. Uebersicht).

No. 136. Apr. 28, 1911, is put by Klotz in L. 0° 58′ N (?); L. 53° 20′ (?).

No. 143. June 15, 1911, has been placed in the Riu-Kiu Ids., Japan.

No. 145. July 1, 1911, is referred by Klotz to L. 33° 20′ N; L. 144° 50′ W. in California.

No. 146, July 4, 1911, a Turkestan earthquake, is laid by Klotz in L. 42° 58′ N; L. 75° 50′ E.

The use of the Lambert's projection drawn over a Mercator map of the world described in last year's report has been employed in the office, where data were available, for the location of epicentres. Mr. Winthrop P. Haynes, Assistant in Geology, prepared such projections for Strassburg, Ottawa, Batavia, Seattle, and redrew that for Cambridge. This method, which is confessedly approximate and designedly expeditious, requires but three or four minutes to indicate the approximate position of the epicentre and serves to show whether the elements for distance furnished by the several stations accord closely enough to warrant the labor of more refined methods of fixing the epicentre. With good records this method shows the latitude and longitude of the epicentre with an error of one or two degrees of latitude and longitude at great distances (10,000 kms. or 6,200 miles). Unfortunately the data from the three stations required to determine epicentres have not been available among our exchanges to apply the scheme for more than a few instances during the year. The following example worked out for the Turkestan earthquake of January 1, 1911, shows the position of the epicentre as determined by the approximate Lambert projection method and the more precise but somewhat more laborious graphical method invented by Dr. Klotz of Ottawa.

By Lambert's projection	L. 43° 36′ N.	L. 76° 24′ E.
By Klotz's graphic method	L. 43° 40′ N.	L. 78° 20′ E.
Difference	L. 0° 4′	L. 1° 56′

A comparison with Prince Gallatzin's determination of the same epicentre gives the following:

By Prince Gallatzin	L. 42° 59′ N.	L. 78° 00′ E.
By Lambert's projection	L. 43° 36′ N.	L. 76° 24′ E.
Difference	L. 0° 47′	L. 1° 36′

The difference in position as determined by Dr. Klotz and Prince Gallatzin is —

Position by Dr. Klotz	L. 43° 40′ N.	L. 78° 20′ E.
" " Prince Gallatzin	L. 42° 59′ N.	L. 78° 00′ E.
Difference	L. 0° 41′	L. 0° 20′

The differences in these respective comparisons are to be looked for in (1) discrepancies in the data employed for estimating the distance to the epicentre, since the data are from different groups of stations in each case: (2) errors in projection incidental to the graphic method; (3) the geodetic uncertainty as to measurements of distance on the surface of the geoid on different great circles.

The Lambert projection is weak in the second of these respects. The above determinations of the epicentre by it are subject to two refinements:— 1, a more accurate drawing of the curves of distance from the recording station upon the mercator map; 2, the use of a larger scale with a consequent closer intersection of the curves from the stations employed in determining the epicentre.

Dr. Klotz of the Dominion Astronomical Observatory at Ottawa has prepared a set of stereographic projection tables for determining epicentres in accordance with the method invented by him. These tables include the constants for this station. See Journal of the Royal Astronomical Society of Canada, May–June, 1911, p. 209.

Local or New England earthquakes. The daily press reported a slight earth tremor felt in Calais, Maine, at 7 A. M., Eastern Standard Time, on March 20, 1912. Not recorded at this Station.

Except for certain local unfelt shocks regarded as due to frost cracks during midwinter, no local shocks were recorded during the year; or, if they are shown on the records, they have been taken to be the effect of local traffic jars.

The earthquake of March 21, 1894, which was felt in Cambridge and in the region thence to the epicentre in Nova Scotia has been described by Prof. H. F. Reid in the Bulletin of the Seismological Society of America, 1911, **1**, p. 44–47, with isoseismal map.

Frost crack jars:— The unusual number of small local shocks in the list, referred to frost cracks, during the months of January and February, 1912, were so far as I am aware unfelt, though they were distinctly recorded on both components of the seismograph, invariably setting out with a sharp maximum of motion which quickly died down. In several instances the exact second of beginning of motion on one of the components was obscured by the quaquaversal oscillation of the stylus, the component being thrust to and fro in the direction of its horizontal axis as well as registering its proper lateral motion. These shocks came at times when the ground was largely covered by a sheet of ice resulting from the thawing and freezing of old snow, and during very cold nights. The night watchman reported booming noises in the courtyard surrounding the Station but none of the sounds noticed by him agreed in time with the shocks listed. Several extended wandering cracks in the frozen ground were at the time traceable on Divinity Avenue and in neighboring portions of the University grounds.

Powder explosion:— On Friday, May 24, 1912, there was a powder mill explosion at Acton, Mass., 17.5 miles (28.18 kms.) from the Station, recorded on the seismograph at 6h. 52m. 54s. P. M., (75th meridian time west). The vibrations lasted 4 secs. on the E–W component, whose steady mass was thrown relatively to the west or towards the origin of the disturbance as if the ground were thrust away from the origin. The exact time of the explosion could not be ascertained by correspondence with the officers of the company, so that nothing has been ascertained concerning the speed of propagation of the shock.

Lacunae in the records:— The north component was out of commission for repairs from 21h. to 21h. 45m. on May 18, 1912, and the east component was dismantled on the same day from 21h. 46m. to 22h. 45m. Again in June, 1912, the north component was out of commission for repairs on the regulator from 13h. 14m. on the 6th to 20h. on the 8th: the east component was not in use for the same reason from 15h. on the 10th to 2h. 35m. on the 14th, G. M. T., midnight to midnight.

NUMBER OF EARTHQUAKES RECORDED SINCE JAN. 1, 1910.

Year.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1910	5	2	5	5	12	9	8	4	10	3	11	12
1911	8	11	3	5	6	6	3	2	8	7	8	5
1912	3	4	4	7	7	25	13	—	—	—	—	—

The above table includes only the records of distant quakes or felt local shocks. With regard to the general character of the records made out during the year, they may be classified with reference to the phases (P, S, L, M) which they clearly exhibit as follows: PSLM 20%. PSL, 14%. PS, 1%. PL, 4%. SLM, 2%. SL, eL, 10%. LM, 1%. L, 29%. eF, 10%. Local (frost crack) records, 9%. The failure to recognize P, S, and possibly M in certain records has been due to microseisms and other local disturbances. The eF records are short disturbances of no regular period and are not well understood, though their seismic nature is frequently shown by their appearance at other stations at some distance, as at Ottawa and Ithaca, N. Y. If we combine those records containing the beginnings of P, S, and L and consider them good, only about 34% of the records for the year are entitled to this description. Eliminating the frost cracks from the count, this number becomes 37% of the total readings.

The reexamination of the records in the light of a knowledge of the times of occurrence of every earthquake registered at other stations would undoubtedly lead to the identification of scores of "irregular" vibrations, and "thickenings of the line" with the passage through Cambridge of one or another of the several phases of distant shocks.

Additions and alterations in equipment:— Through the generosity of Mr. Edward Wigglesworth funds were provided during the year for the purchase of a Wiechert seismographic clock, manufactured by Spindler and Hoyer of Göttingen. The electric contacts of this clock are on the outer face of the dial where they may be readily adjusted. The minute contact lasts one second; and the hour contact, adjustable to several seconds, is conveniently made to take 8 or 11 seconds as desired. So far, the contacts have worked perfectly. This clock is used as the standard station clock, while the old clock, whose electric contact for minutes is not reliable, is kept running and ready to be switched into service when needed.

The piano wire turnkey attachments of the guy wires of the booms of the pendulums of the tromometer, which were loosened in 1908 in overhauling the instrument and which could not since then be made to hold the wires taut, were replaced duiing the year by turn buckles of bronze and nickle-steel permitting a permanent adjustment of the attachment to any desired tension. A new set of indicators and styluses were purchased of Bosch Bios. to replace the original levers which had become deranged by accidents incident to the daily setting up of the instrument. It was discovered that the yoke of the north-south component had been placed upon the pier in a reversed position, preventing the lengthening of the boom to the full magnification of 100 or more times. This error should be corrected; but to do so will require the breaking down of the small concrete tablet on which the yoke stands and the construction of a new one.

Damping the tromometer: — As stated by the manufacturers, the 100 kg. tromometer works best when adjusted to a period of 25 seconds. So far the attempt to damp the east-west component with the air damping device has failed to produce the desired results. The pendulum fails to respond to seismic vibrations when the damper is attached. The period of the pendulum was reduced to 12 seconds with no better results. Better results have been obtained in the attempt to damp the north-south component. With the heavy diurnal tilt at this Station whereby the pendulums are thrown first to one side and then to other of the zero line, the horizontal pendulum is most of the time pulling or pushing the damper in such a manner as evidently to interfere with the free registration of the amplitude of motion of the instrument when actuated by seismic waves.

Setting the time tickers: — The inherent difficulty in the Bosch-Omori tromometer of setting the time tickers on the drum so as to give an interval of 60 seconds (15 mm.) between the minute mark and the stylus at the minute interval has, during the year, been successfully dealt with by swinging the stylus across the line of ticks and depressing the ticker at the instant of transit. Any variation in the space thus marked off from 60 seconds is measured in terms of seconds and applied to that record sheet as a correction for time. It is sufficient to blow against the clevis holding the stylus to produce the desired motion of the indicator.

In passing from this statement of the condition of the Station, it should be stated that many seismological observatories in this country are now equipped with two or more types of seismographs for recording horizontal motion and that in the vertical; and that the International Bureau recommends that every recording station should be provided with at least two types of seismograph. At present we have one instrument and this requires improvement as regards the damping device since at present our records are defective in not giving amplitudes free from resonance in the pendulums. This particular disqualification can probably be remedied through the purchase of an electric damping device to replace the air dampers now in part use.

Microseisms:— The microseisms of November 25, 1911, were particularly well defined and regular. During the maximum, these vibrations attained a period of six seconds. According to press reports, a furious gale prevailed over the coast of Newfoundland at the time of maximum microseismic vibration at this Station.

Macroseisms of irregular period: — During certain morning hours one or both components of the undamped pendulums have given more or less interlaced records having no regular but usually long periods ranging up to one minute, and this at times when no local winds were blowing, though such may have been the case over Massachusetts Bay. At times this motion has assumed a sinusoidal character indicating the passage of long or Rayleigh waves from a distant earthquake also registered at other stations. It has been assumed that such irregular disturbances were due to local causes of a nonseismic nature, and no account has been taken of them.

Diurnal wave: — During the month of July, 1912, both components of the seismograph were allowed to swing without damping, thus giving a good record of the "diurnal wave." The plotting of the departure of the stylus from the zero line (line of ticks on the seismogram) for each hour brought out the occurrence of a tilt from north-east to south-west and *vice versa*. The tilt towards the southwest sets in about 1 P. M. and attains its maximum about 7 A. M., when the tilt to the northeast begins and continues until about 1 P. M. This diurnal wave is superposed upon a longer period swinging of the pendulums corresponding with the passage of highs and lows of barometric pressure. These graphs are useful in determining the time of day at which the pendulums cross their respective mean positions and thus the hour at which they should be brought to the zero line if they have become placed too much to one side or the other. At this Station for July these hours would appear to be about 8.30 A. M. for the north-south component, and about 9 A. M. for the east-west component. As, however, the passage of highs and lows, cause the pendulums to wander across the theoretical zero line after an interval of several days, such adjustments should be made only when the pendulums are crossing the line in one of their long period phases. If the theory be correct that "lows" cause a broad doming up of the earth and "highs" a corresponding saucer-shaped depression, such adjustments should only be made at times when the centre of a high or low is over the station, for then only would the pier be level and a proper adjustment to the vertical be made, so as to secure a balanced elongation of the long period swing about the zero lines of the two rectangular components.

Earthquake investigations: — Seismology is a subject calling for the special knowledge of the physicist, the meteorologist, the astronomer, and the geologist, and each of these specialists best promotes the science by applying his talents to the development of his phase of the problems which earthquakes present. The study of the seismographic records of distant earthquakes concerns the physicist. The examination of the epicentral tract of an earthquake affords the geologist his opportunity for contributing to the subject as does also the survey of the geological structure of a region with reference to the occurrence and distribution of faults and rock areas liable to affect the intensity of shocks at the surface of the earth. The fact abundantly illustrated in the San Francisco earthquake of 1906 that a fault zone of geologically recent date may at any time undergo renewed motion giving rise to an earthquake makes it desirable in the interests of humanity to locate on maps such lines of danger and point out their existence for the avoidance of unnecessary risks such as arise from ignorance in the choice of location of important public works or private buildings.

Although Boston and vicinity experienced in colonial times earthquakes strong enough to throw down chimneys and the end walls of brick buildings, no evidence has been found to show that the seismic motion arose from an initial motion of the rocks along any one of the numerous faults and thrust-planes now known to intersect the region. Nevertheless, it seems to be desirable to construct a map of the Metropolitan District portraying the character of the ground with reference to its seismicity or liability to damage in case of earthquake motion. With this end in view some of the research work of advanced students in the Department of Geology has been turned to account. Mr. W. G. Foye was occupied in the fall of 1912 in mapping and studying the fault along the northern border of the Boston basin. The project involves plotting all the faults in the district, classified with reference to their relative geological age, direction of the movements upon them, and with regard to their visible and inferred extension. Upon the same map the superficial deposits having various degrees of stability, such as the glacial deposits and the areas of made-ground bordering the harbor and the Back Bay section of Boston and Cambridge, may be delineated.

The importance of engineers and architects taking into account the liability of earthquake shock strong enough to damage buildings in this district is amply shown by the history of earthquakes at Plymouth, Newburyport, and Boston in the 17th and 18th centuries. There can be little doubt that the recurrence of such shocks as were felt in Boston in 1755 would produce much damage. While the Atlantic coast of the continent is relatively immune from earthquakes, the case of Charleston in 1886 enforces attention upon the necessity of recognizing the risk of destructive shocks upon this coast at long intervals perhaps of a few centuries only. Sane precaution demands the avoidance of the mistake made at San Francisco of placing a public reservoir upon a fault zone of recent movement, and of the folly of cheap mortar and rubbly masonry which together were factors of first importance in the loss of life and property in Charleston in 1886, and in Messina in 1908. We may not be able to avoid building our houses and public edifices upon ground liable to destructive shocks, but we have abundant information as to how these structures should be built in order to reduce the risks of demolition to a minimum.

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HARVARD SEISMOGRAPHIC STATION.
FIFTH ANNUAL REPORT INCLUDING RECORDS, 1 AUGUST, 1912–31 DECEMBER, 1913.

By J. B. Woodworth.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

October, 1914.

No. 3.— *Harvard Seismographic Station. Fifth Annual Report, including records from 1 August, 1912 to 31 December, 1913, G. M. T.*

By J. B. Woodworth.

These records are a continuation of the list given in Bull. M. C. Z. **55**, p. 22–52. The constants of the Station are as follows:—

Latitude 42° 22′ 36″ N. Longitude 71° 06′ 59″ W. Altitude 5.36 M.

Subsoil: — Glacial sand over clay.

Time: — Mean Greenwich, midnight to midnight. Eye and ear comparison with Harvard Observatory through telephone.

Instruments: — Two Bosch-Omori 100 kg. horizontal pendulums, with mechanical registration.

Nomenclature: — Göttingen.

In the column of Remarks the following peculiar abbreviations are employed:— Q, Earthquake; Qf., felt earthquake; Ql., local earthquake; Qr., earthquake reported by press: O, origin, or epicentre, or time at origin when followed by time calculated by Benndorf's table. Distance in kms. indicates distance from Cambridge to origin calculated from Zeppelin and Zeissig's tables for S–P. Micros., Microseisms masked the phases.

Constants of the Instruments.	*N–S.* secs.	*E–W.* secs.
Period:	25	23
Magnification	50	80
Damping	4:1	0.

This report covers the period of a year and a half, bringing the data to the end of 1913. This has been done in order to publish the seismic registrations for a calendar year in a single list instead of dividing the matter as heretofore into lists corresponding with the fiscal year of the Museum of Comparative Zoölogy (1 August–July 31).

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
246	Aug. 2	NeL	20 25 30?	15–20		Doubtful record. Not reported from other Stations.
		F	20 41 30			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
247	Aug. 6	Ne?				
		eL?	21 40 00	15		Cf. Strassburg e 21–30–
		F	23 09			20. Near New Hebrides.
248	9	N P	1 40 16	3		Qf in the Dardenelles,
		S	1 49 24	10–8		European Turkey. O
		eL	2 00 05	35		1h–29–13.
		M	2 06 40		19.5	7765 kms.
			11 48		12.5	
			13 07		14.0	
		F	4 45			
*249	17	EeP	19 32 21			SE–PN, 9m 20s, 8000
		N	19 33 20	3		kms.
			19 38 29	8		Several groups of LL
		eS?	19 41 41	11		gradually increasing to
		L	20 18 35	33		maximum.
			20 19 26	35		E–W component re-
		F	22 09 30			strained by faulty ad-
						justment.
						Q Eastern Mindinao,
						Philippines.
*250	18	Ne	21 25 08	3		
		L?	21 29 51	8		Qr near Williams Ari-
		F	21 44			zona, from 2:05 to 2:10
		EeP	21 26 41	3		p. m. in 105th M. W.
		L?	21 29 25	8		time. Jena O, 21h–
						9m–26s.
251	21	Ne?				
		eL	18 36 17	28		Irregular motion pre-
		F?	19 07 40			ceded record. Cf. Ba-
						tavia & Parc St. Maur.
						In Borneo (Jena).
252	23	Ne?				
		L	14 53 21	20–24		Qr Peshawar, N. W.
		F	15 53			India. Cf. Strassburg
						P. 14–14–18.

No.	Date	Phase	Time	Periods	Ampli-tudes	Remarks
	1912		h. m. s.	s.	mm.	
253	Aug. 31	N L	23 04	13–17		No trace E–W. Cf. Strassburg P 22–35.5. O in Kamtschatka (Graz).
		F	23 29			Cf. Guadalajara, Mex. N. B. The Seismograph of this Station was out of commission from Sunday, Aug. 25th ca 15hrs. G. M. T. to Monday, Aug. 26th, 13h. 38m. G. M. T.
254	Sept. 1	NeS?	4 43	8		Ottawa P 4–34–26; 54. (O = 4–27–31).
		L?	4 46	20		E–W: short group of LL only.
		F	5 14			Batavia reported Q distant 4510 kms P 4–17–14. Samoa (Jena).
255	3	Ne	18 35 36	6–8		Like microseisms.
		F	18 40 50			Ottawa e 18–33–09.
		Ee	18 35 22	5–7		Ithaca-Cornell e 18–33–30.
		F?	18 40 37			
255a	10	Ne?	16 20 06	3		Records begin and end in microseisms. Cf. Ottawa.
		F?	16 23 32			
		Ee?	16 19 43	3–4		
			16 20 18	6		
		L?	16 22 51	12		
		F?	16 31 24			
256	13	NeP?	23 42 13	4		eLE–ePN? 7,800 kms.
	14	eL?	0 05 34	24		Qr Rodosto, Vilayet of Adrianople.
		F?	0 25			
	13	EeP?	23 42 21	4	0.3	N damped 3:1.
	14	eL	0 03 30	20		E damped 0.
		F	8 ca			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
257	Sept. 20	Ee?	21 48 43	3–6		e in micros. Ottawa
			21 52 47	10		e 21–41–11. Tacabayu
		F?	22 57 57	6		P 21–11–48; F. in micros.
*258	29	Ne?	21 40 35			e–F in micros 3–4s pd.
		eL?	21 50 35	22		Qf Mariana Ids. Pacific
		F	22 33 15			Ocean. 13,300 kms. from Cambridge.
		EeP?	21 10 20	3		
		eS?	21 28 35	7		Ottawa S, 21–21–18.
		eL?	21 48 13	30		
			21 50 17	24		
		F	22 54			
259	Oct. 12	Ne?L	15 57			16–02 to 16–08– changing record.
		F	16 35			
		E				Microseisms.
		e?L	16 03	18		15–55 to 16–02 changing record.
		F	16 38			Ottawa P 15–40–26. Qf Aleutian Ids.
260	Oct. 18	NeL	12 30 03	25–20		Qf Aleutian Ids.
		F	12 54 41			
		EeS	12 21 40	6		
		L	12 29 09	18		Distance 5850 kms.
		M	12 31 19			
		F	13 25 ?			
261	31	Ee	12 27 17	6–12		Strassburg P 12–20.9.
		eL	12 32 35	16		
		F	12 55 15			O, Azores.
262	31	EeL	18 21 00			Qf Philippine Ids.
		F?	19 21			Irregular pulsations for several hours before and after.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
263	Nov. 7	N P	7 49 23	2–3		Cf. Qr. Seward, Alaska
		S	7 56 43	6		10 P. M.
		eL?	8 08 19	15		
		M	8 08 44	16	1.3	Damped 4:1.
		F?	3 15			
		E P	7 49 23	3		Distance 5700 kms.
		S	7 56 53	6		
		L?	8 08 02	22		
		M	8 08 26	20		Undamped pendulum.
		F	9 27 ca			
264	7	Ne?				$L_N - eS?_E$ = 5m 1s = 4700
		L	17 02 41			kms?
		F?				Vd. Ottawa.
		EeS?	16 56 50			
		eL	17 04 45			
265	7	NeL	17 46 36			Damped 4:1.
		EeL	17 48 24	27		Undamped.
		M	17 51		15.6	Vd. Ottawa.
265a	17	NeS?	11 49 47			Damped 4:1 and so in
		eL?	11 52 35	20		December.
		L	11 52 59			
		F	11 57 37			
		EeS	11 45 29			Undamped and so in
		eL	11 52 45	20		December.
		F	12 14 29			Distance 5300? kms.
*266	19	EeP?	13 58 25	3		eS?–eP? equals 6m
		eS?	13 06 25	6		equals 4225 kms. Qr
		eL?	13 10 35	40		at Acambay, Mexico.
						N–S micros only.
		F?	14 18			O 13h 52m.
267	Nov. 27	NeS?	9 37 27			Micros.
		EiS	9 37 13	12	0.5	i throw to W.
		eL?	9 38 28	13		
		F	9 49 47			
*268	Dec. 5	NeS	12 43 53	4		Qf Alaska.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
		L	12 51 15	10		
		eL?	12 56 08	6–7		
		F?	13 28			F lost? Began to change records 13–28–13.
		EeP?	12 36 14	4–2		Micros?
		eS	12 42 32			
		eL	12 48 10	10		Dist. 4560? kms.
		L	12 58 38	16		F lost.
269	Dec. 5	Ee?	15 00 32			N–S faint. Irregular periods before and after. Wind effect? No reports.
		EL	15 01 37			
		F?	15 07 04			
270	5	NeL	18 07 19	18		Cf. Ottawa P ? 17–59–09.
			18 07 37	16		
		F	18 17 05			
		EeS?	18 04 22			
		eL	18 07 17	20–15		
			18 07 33	14		
		F	18 23 ca			
271	7	NeP	22 57 04			Dist. 6450 kms.
		iS	23 05 38	8		i throw N.
		L	23 09 04			O in S. Atlantic?
		F	23 22 05			
		EiS	23 05	12		i throw E.
		L	23 09 32			iS very strong.
		F	23 28 24			
272	9	NeL	0 40 46			e masked by micros.
		F?	0 49 52			Cf. Besancon P 0–01–44.
		Ee?	0 31 52			O in Japan. (Graz).
		eL	0 40 32			No maximum.
		F	0 56 36			
273	9	NeP?	8 37 22			In microseisms.
		e	8 38 35			
		S	8 43 13	8		Dist. 3600 kms.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1912		h. m. s.	s.	mm.	
		NeL	8 46 39	15		Off Central America?
			8 52 11			
		M	8 54 16		4.5	Damped 4:1.
		F	9 49 ca			
		E S?	8 42 46	6		e lost in micros. and
		eL	8 45 42	22		wind-quavers.
		M	8 51 40	25	14	Undamped pendulum.
			8 53 34	20	17.5	
			8 54 44	18	25	
		F	9 55 ca			
274	Dec. 12	Ee	12 05 52	52		Faint record of doubt-
		L	12 16 44	20		ful character. Unheard
		F?				from.
						N–S chronograph ran down at 17h–32m, Dec. 12. E–W stopt between 11h. 19m. and 13 h. 13m Dec. 13th.
275	22	Ee	23 45 03	6		Cf Ottawa 23–42–21.
			23 46 23	8		
		F	23 51 03			F? later? in micros.
276	23	Ee	12 44 51	16		N–S not recording.
			12 47 57	65		Faint record of doubt-
		L	12 58 37	20		ful character. Unheard
		F				from elsewhere. Record taken off at 13h 20m.
277	24	EeP	0 19 21	3		Faint. Not shown N–S
		?	0 35 36	27		on pendulum damped
		L	1 03 48	20		4:1.
		F	1 57 ca			Vd. Batavia & Strass- burg. O. in Philippines.
	1913					
277a	Jan. 1	Ne	18 32 57			Qr. in S. W. Union Co.,
		F	18 35 43			So. Carolina.
		Ee	18 31 37	6		Vd. Bull. Seism. soc.
		F	18 35 16			Amer., 3, 6–13.
						Time at O reported 1h 27m E. S. T.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
278	Jan. 7	Ee	23 52 17			Cf. Manila P 22–53–33.
		eL	23 52 25			
	8	F	0 05 15			
*279	11	EeL	13 55 39			Cf. Manila P 13–20.
		F	16 03			
280	15	NP	18 58 56			Distance 3700 kms.
		PR_1	19 00 16			
		S	19 04 26			
		L	19 13 20			O near λ 100° W, φ 17° 33′ N.?
		F	19 28			
		EP	18 59 00			Cf. Manila e 19–11.
		PR_1	19 00 18			
		S	19 04 28			
		L	19 12 57			
		F	20 07			
281	19	NEL	18 16 30			D 13,900? kms.
		F	18 50			O? near λ120°E φ 28′ N.
		EeS	17 43 54			by Harvard, Ottawa &
		L	18 12 18			Strassburg.
		F	18 52 ca			
282	19	NeL	19 12 14			Cf. Graz L19h., 28m. Falls within Record 281 at Ottawa, W[1] ? If so, Δ = 13,300 kms?
		F	19 13 28			
283	22	Ee?	18 30 06	var.		Pulsations? Unheard from.
		F	18 35 34			
284	23	Ee	12 29 07	var.		Cf. Ithaca, N. Y. e? 12–09; F 14:01.
		F	12 32			
285	23	NeS?	14 45 12	6		Cf. Sydney eP 13–59.3
		eL	15 05 02	20	0.1	D. 5800? kms. (Sydney)
		F	15 51 47			Ottawa e L 14–55.5.
		EeS?	14 46 31	8		
		L	15 04 37	20–25	0.15	
		F	15 51 48			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
286	Jan. 31	NeP	22 54 52			D. 4120 kms.
		PR_1	22 56 09			Ottawa Δ 4220 kms.
		S	23 00 46			Cornell Δ 4220 kms.
		eL?	23 10 21	10		O = 22h. 47m. 34s.
		F	23 30 ca			O, near 100 W, 16 N.
		EeL	23 08 45			
287	Feb. 9	EeS?	8 23 02	8		Doubtful record. Not reported elsewhere.
		eL	8 29 20	28–24		
		F	8 32 ca			
288	27	Ee?	20 56 36			Hour doubtful. Not heard from.
		eL	20 59 48			
		F	21 08 41			
289	Feb. 20	EeS?	9 22 53			Dist. 10,600 kms.? Japan?
		L	9 41 54			
		F	10 23			O = 8h. 57m. 08s.
289a	23	EeS?	3 08 21	6		Qr. Guayaquil, Ecuador
		M	3 22 27		0.16	P & S masked by microseisms.
		F	3 29 ca			
290	Mar. 3	Ne	3 27 41	9–8		Among microseisms of 3 to 4 secs. period.
		F	3 29 14			E record in tangled lines of undamped pendulum.
291	4	ES?	11 40 21	6		L–S? 4m. 34s.: 4500? kms.
			11 42 40	18		
		L	11 44 43	20	0.15	Micros. N–S damped 4:1.
		F	11 59 25			
291a	8	EeL	15 31 18	24–12		Very faint. Not heard from.
		F	15 35 31			
292	8	EeP	15 59 46	3		
		S	16 04 59	26		Undamped. D 3440 kms.
		eL	16 07 14			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
		M?	16 09 56	27	2.2	Qr. Guajiniquilapa, Guatemala ca 90° 17′ W. ca 14° 12′ N. L. Vd. Bull. Seism. soc. Amer., 3, p. 35.
		F	16 46 30			
		Ee	16 52 31			
		F?	16 56 09			
292a	Mar. 9	L	16 23 40	20		Faint LL N–S; masked by microseisms.
		F?	16 34			
293	10	EeL	14 45 41	18–20		Very flat waves. Micros. N–S 3.51s pd. (Cf. Sydney, N. S. W., M. 14–08–21).
		F	15 05 03			
*294–5	14	NP	9 04 19	2–3		P. pds. in groups.
			9 07 12	3		
			9 08 22	6		
			9 08 38	4–3		Qr. Sanger Id. Eastern Mindinao, ϕ 3° 30′ N. λ125° 30′ E.
			9 09 27	3–6		
			9 12 02			
			9 12 05			
			9 23 59			
		L	9 42 44			
		EP	9 04 21	2		E–W undamped comp.
			9 05 00	6		
			9 05 55	2–4		
			9 06 35	8–10		
			9 09 47	6–8		
			9 12 19			
			9 23 54	35	20	Excessive motion of undamped pendulum. i throw E.
		L	9 42 44			
		M	9 50 10			
		L	9 53 44	26–20		Sinusoidals set in.
			10 21 44	100	2	LL 100>70>46>40s.
			10 26 35	15		Sinusoidals repeated.
		(F)	11 23 30			
		L	11 24 14	36–40		
		F	11 29 12			
296	15	NP	22 37 41	4		Distance 1750? kms.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
		L?	22 41 18	6		
		F	22 47			
		EeP	22 38 16	4		vd. Ottawa, Ithaca
		eL?	22 41 50			(Cornell).
		F	22 48 ca.			
297	Mar. 17	EeS?	13 55 54			Not reported elsewhere.
		L?	13 59 48	20–13		Wind effects?
		F	14 19 30			
298	31	NP	3 51 40	2		
		S	4 02 04			Dist. 7865 kms.
		L	4 16 15	20		O, 3h. 40m. 30s.
		M	4 19 42		0.5	
			4 23 15		0.75	O near λ 180° W; φ ca.
		F	5 47 ca			49° N.
		EP	3 51 43	3–4		
		S	4 00 53	8		
		L	4 16 01	24		
		M	4 19 59		12.5	
			4 24 21		7.5	
		F	6 49			
299	31	eL	7 35 12	20		From epicentre of 298?
		F	7 48			
299a	Apr. 13	EL	7 36 26			Cf. Ottawa e 6–59.
		F	7 43 49			O in So. Japan?
299b	1	E	— — —			Tangled record, Vd. Ottawa e 10–41–12. Cornell e 11–25–30.
300	25	Ne	18 55			Qr. Mindanao.
		L	19 03 52			
		M	19 10 41			
		F	19 38			
		EeP	18 18 37	5–4		
		S	18 34 37	10		
		eL	19 01 34	20		
		F	20 36			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
301	Apr. 29	NP	0 30 03	0.4		Dist. 435 kms.
		M	0 30 53	0.5	.7	Qf. St. Lawrence Valley
		F	0 33 34			south of Ottawa.
		EP	0 30 02			
		M	0 30 50		.8	O = 0h 29 m. 7s.
		F	0 33 34			
302	Apr. 30	NeL	0 06 59	20		Vd. Ottawa & Graz.
		M	0 12 20			O in East. Hemisph.
		F	0 16 21			
		EeL	0 06 43	20		
		F	0 31 40			
303	30	NeL	12 11 31	16		
		F	12 18 49			
		EeS	11 53 48	8		5250 kms. plus.
		L	12 06 01	25		
		F	12 55			
304	May 8	EeP	18 54 00			Very faint LL. N–S
		?PR₁	18 55 05			damped 4 : 1.
		S	19 01 30	10		
			19 03 34	06		5890 kms.
		eL	19 09 32	20		
			19 16 29	24		
			19 34 50	18		
		F	20 10 ca			
305	16	Ne	12 13 42	3		Cf. Ottawa P 11–53–39.
			12 15 45	6		
		F	12 30 44			
306	18	NeL	3 08 19	24		Very faint NS micros.
		F	3 17 06			3–4s pd.
		Ee?	2 59 47			
		L?	3 02 56	24		eEW in tangled lines.
		L	3 08 07	20		
			3 11 31	20		
		F	3 43			
307	24	EeL	8 00 07	18		
		L	8 15 45			

No.	Date	Phase	Time	Periods	Ampli-tudes	Remarks
	1913		h. m. s.	s.	mm.	
308	May 30	NeL	12 24 58	25		Micros. mask P and S.
			12 39 58	42		Sydney, N. S. W. re-
			12 59 56	20		ports "S. of New Po-
		F	13 25			merania?"
		EeP?	12 09 32	2		Masked by microseisms.
		S	12 18 12	6		
		eL	12 37 42			
		M	12 42 30	38	0.9	
		L	12 52 33	20		
			13 00 21	16		
		F	14 08 30			
309	June 4	EeL	10 52 09	20		
			10 58 47	36		
			11 03 47	24		Sinusoidal waves.
		F	12 06 ca			
310	7	EeL	10 46 18	20		
		M	10 52 07	20	.2	Undamped pendulum.
		F?				Merges into next?
311	7	EL	11 36 13	20		Possibly 310 & 311 one record. Not traceable on N–S damped component.
		F	11 48 ca			
312	14	EeP	8 43 40	2		S–P : 3580 kms.
		S?	8 49 02	6		
		eL?	8 56 07	22		
		F	9 31 47			
313	14	EP	9 44 06	2		S—P:7635 kms. Qf Trnova, Bulgaria. Graz O = ϕ 42° 13′ N. λ 26° 17° E.
		S	9 53 08			
		L	10 04 30			
		M	10 10			
		F	11 29			
314	14	eP?	11 38 33	3		Micros. only N–S on damped comp. S–P: 3230? kms.
		S	11 43 32	9		
		L	11 47 24	20		
		F	12 ca			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
315	June 22	NP	14 01 06			S_E-P_N 9m. 5s. 7700 kms.
		S	14 10 43			
		L?	14 23 23			
		F?	14 28			Changed records.
		EP	14 01 11			
		S	14 10 11			Undamped pendulum.
		L	14 25 44			
		M	14 28 33			
		F	15 41			
*316	June 26	NePR	5 16 54	3		Damped 4:1. Microseisms.
		S	5 24 37	11		
			5 32 07			See note p. 75. Qf. Samoa & Tonga Ids.
			5 39 44	20		
			44 31	54		
		eL?	46 43	35		
			49 01	16		Damped amplitudes very small.
			49 49	14		
			5 51 27	26		
		F	7 15 ca			
		EeP?	5 11 46			Undamped pendulum.
		P	5 12 12			
		ePR_1?	5 16 52	7	.8	
		S	5 23 05	11		
			5 25 23	20		
			5 32 53	30	i5E	Looks like iS.
		L	5 50 33	28		
			52 47	30		Sinusoidals — well-formed.
			54 20	22		
		M	56 56	22	38E	
			57 04	22	37W	
		C	5 57 36			
		F	8 13 ca			
317	29	Ee	15 40			Doubtful record, wind?
		L?	15 42 34	24		
		F	15 49			
318	July 7	Ee?	17 47 44	11		Undamped pendulum.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
		eL?	18 30 42	30		
			18 41 19	20		
			19 16 09	16		
		F	19 53			
319	July 8	EeP?	8 54	3		
		S?	8 56	6		
		F	9 04			
320	8	EeL	22 03 10	28		
			04 00	20		
		F	22 35 ca			Lost in wind waves of long periods.
321	9	Ne	0 26 25	3		Damped 4:1.
		S?	0 26 40	6		
		F	0 39			
		Ee?	0 22 14			Undamped pendulum.
		S	0 24 10			
		L?	0 25 17			
		F	0 58			
322	9	EeL	12 47 19	10		
		F	12 54			
323	12	EeL	10 56 09			Vd. Czernowitz e P 10–36–48.
		F	12 ca			
*324	22	EP?	6 46 04			Recorded in tangled lines.
		S?	6 54 04			
		L?	6 59 55			Ottawa record differs.
		F				
325	24	EP?	9 04 28			
		S	9 09 46	8		3550 ? kms.
		eL	9 11 07	16		Vd. Ottawa.
		F	9 23			
326	25					Present, but in tangled lines. Ottawa P 12–44–46.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
327	July 26	EP?	20 58 29			
		S	21 04 24	6		4140 kms. O 20h. 51m. 47s.
		L	21 11 09			O in Roumania λ 27° 10′ E. ϕ 40° 37′ N.
		F?	21 45			
*328	28	EP?	5 49 36			6430 kms.
		S	5 57 35			O, 5h. 39m. 42s.
		L	6 07 19			O. S. Amer.?
		F	7 03			
329	Aug. 1	EeP	17 23 24			8090 kms. Vd. Pola Record.
		S	17 33 25			O, 17h. 11m. 04s.
		L	17 48 55			O in S. Atlantic?
		F	18 59			
330	5	EeS?	2 05	6		Doubtful record. Not heard from.
		NL	2 16	16		
		EF	2 52			
331	6	NP	22 24 30	4		6520 kms.
		S	22 32 34	8		O: 22h. 14m. 50s.
		L	22 46 18	22		
		M	22 49 19	25	1.25	Damped 4:1.
		F	23 49 16			Qr Caraveli and Quicacha, Peru.
		EP	22 24 36			
		S	22 32 36			
		L	22 42 12			
		M	22 50 51			
		F?				
332	7	EeP?	2 16 36	3–4		Not heard from.
		L	2 39 36	20		
		F	3 22			
*333	13	NP	4 44 19			Straits of Sunda (Batavia).
		EL	5 15 58			
		NL	5 42			
		NF	6 33			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
334	Aug. 15	EP?	19 27 24	4		Undamped pendulum.
		S?	19 35 00	8		Dist. 6000 kms?
		L	19 46 59	28		
			19 54 34	20	0.25	Pulkovo gives 26.9° N,
		F	20 39 19			141.5° E.
335	17	Ee	17 59 53	6		Ottawa L 18-04-30.
		L	18 04 08	10		
		F	18 09 43			
336	31	Ee	18 01 01	10		
		L	18 07 34	26		Ottawa eL 18-07.
		F?	18 48			
*337	Sept. 3	NeS	21 17 29?			
		EeL?	21 26 03?			
		L?	21 54 25?			
338	Oct. 2	NP	4 30 53			S-P, 5m. 45s. 3970 kms.
		S	4 36 38			
		L?	4 45 05			
		M	4 50 36			Felt on Panama.
		F	5 25			O = 4h. 24m. 14s.
		EP	4 30 36			
		S	4 36 18			
		L	4 47 36			
		F	5 35			
339	4	EP?	22 12 26			P and S in micros
		S?	22 17 57			Qr. Panama.
		eL?	22 20 53			3725? kms.
		F	22 46 ca			
339a	8	EeL?	1 50 15	34		
			1 52 09	16		
		F?	1 55 03			
340	9	EeP?	18 39 04	4-3		But Cf. Ottawa eP?
		S	18 48 07	9		18-41-52. 7670? kms.
		L	18 51 25	12		

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
		L	18 57 16	20		
		F	19 13 29			
341	Oct. 11	Ee				
		S	2 08 13			
		eL	2 13 05			
			2 29 56			
		L	3 30 47			
		F	3 49			
342	11	EeP	4 27 30	3		
			4 28 50			
		S?	4 39 32			N. W. coast of Japan.
		eL	4 45 07	20		
			5 12 02			Sinusoidals begin.
		F	6 10			E–W comp. not recording between Oct. 11d. 13h. 15m. and 12d. 14h 26m.
343	Oct. 11	EeS	9 33 34			Vienna P 9h. 22 m. 7s
		eL	10 00 02			Sinusoidals set in.
		F	10 48 ca			Japan.
344	12	Ee	17 50 12			O east of 75° W. L.
		eL	17 56 18	20		
		F	18 05			
345	14	EeP?	8 28 23			
		S?				
		eL	8 42 24	36		
		M	8 48 02			
		L	9 07 05	60		
		L	10 56 40			Vienna P 8–28–02.
		F	11 38 ca			
346	23	EeS	15 13 22			Δ 4150 kms?
		eL	15 17 10			Vienna P 15–13–46.
		F	15 39			

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
347	Oct. 26	Ee	22 46 38			Nos. 347–350 have short periods up to 15 secs. Stylus caught fuzz and dropped it during these records which may thus be artificial; but Cf. Cornell (Ithaca) No. 119 e23–17–41; F 23–25.
		F	22 52 08			
348		Ee	22 57 05			
		F	23 02 10			
349		Ee	23 16 36			
		F	23 53 30			
350	27	Ee	0 21 20			Ottawa eL 23–17–12.
		F	0 42 04			
351	Nov. 4	EeL	10 31 02	24		P and S obscured by microseisms and diurnal wave entanglement of lines. Vienna eL 10–52.
		F	10 55 ca			
352	10	EeL	22 11 32			Record faint; on undamped pendulum only. P and S obscured by microseisms. Vienna P 21–31–53.
			22 14 59	24		
		M		22–24	1.5	
		C	22 20 52			
		F	23 03 47			
353	19	EeP?	3 44 41			No record E–W from Nov. 13d. 14h. 16m. until Nov. 14d. 13h. 53m. Stylus tilted over on joint in smoked paper. No record N–S from Nov. 17d. 20h. 53m. until Nov. 18d. 13h. 45m. Ottawa S? 3–54–14.
		eS?	4 00 18	10		
		eL	4 14 18	20		
			4 23 26	40		
			4 27 00	30–24		
			5 12 33	17		
			5 13 45			
		F	5 32 ca			
354	23	Ee	21 38 36			e is eS?
		eL?	21 42 42	28–30		Cf. Innsbruck eL 21–57.
			21 52 41			
			22 02 01	31		Vienna eL 21–54.

No.	Date	Phase	Time	Periods	Amplitudes	Remarks
	1913		h. m. s.	s.	mm.	
		L	22 05 56	18		
			22 10 31	16		
		F	22 22 07			On E-W comp. from 4h. 45m. Nov. 26 to end of run, stylus was held against rim of drum by excessive diurnal and cyclonic tilt.
355	Dec. 21	Ee?	16 32 13	12		Comp. set up shortly before 16-28-40.
		eL	16 35 12	16-34		P and S in microseisms.
			16 40 18	20		Cf. Vienna P 15-49-06.
			16 44 12	20		O east of Vienna.
		F	17 06 58			
356	25	ES	7 01 56			
		eL	7 08 56	20-16		Δ 5310? kms. Trieste Δ 4080. Vienna Δ 4280. O? in Atlantic off Africa?
		F	7 10 26			

NUMBER OF EARTHQUAKES RECORDED SINCE JAN. 1, 1910. (G. M. T).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sums.
1910	5	2	5	5	12	9	8	4	10	3	11	12	86
1911	8	11	3	5	6	6	3	2	8	7	8	5	72
1912	3	4	4	7	7	25	13	8	6	4	6	10	97
1913	9	2	10	5	5	9	10	8	1	12	4	2	77
Sums.	25	19	22	22	30	49	34	22	25	26	29	29	332
Aver.	6.2	4.7	5.5	5.5	7.5	12.2	8.5	5.5	6.2	6.5	7.2	7.2	83

Records Nos. 246, 269, 274, 276, 283, 287, 288, 291a, 297, 317, 330, are subject to some doubt. They have not been reported by other stations in the exchanges sent to the University, and several of them are associated with irregular periods characteristic of local disturbances probably caused by winds. Several similar records accord with reports from distant stations as that at Batavia, Java, as is indicated in the Remarks, and it is possible that more complete reports from very distant stations would show that these records represent the decadent maxima of long waves of distant weak earthquakes. They have been recorded because the periods of the wave motion display a seismic character.

Record 299b was too much tangled by reason of the wandering of the stylus under the impulse of the diurnal wave to be read with certainty on the E component. It was not recorded by the N damped component. It will be observed that for the 18 months covered by this report only three earthquakes were recorded whose origin was in the United States or immediately on its borders in Canada. No. 250 is correlated with shocks felt in Arizona but the records are unsatisfactory. No. 277a is evidently the record of a quake felt in South Carolina, but definite wave phases could not be determined. No. 301 is a satisfactory record of a local shock whose origin lay probably north of the St. Lawrence river on a straight line between Cambridge and Ottawa. For an account of the data compiled by Dr. Otto Klotz of Ottawa concerning this earthquake, see Publications of the Dominion Observatory, Ottawa, 1913, **1**, no. 5, p. 131–152.

Nos. 294–5 and 316 are records of the most important earthquakes of 1913, both in the Pacific island region.

Lacunae in Records. The seismograph was out of commission from Sunday, 25 August about 15h. G. M. T. to Monday, 26 August, 13h. 18m. G. M. T. 1912. Reports from other stations do not indicate that any important earthquake was elsewhere recorded during this interval.

New England Earthquakes. December 11, 1912, a moderate shock was felt at 5:15 a. m. from Augusta, Me. to beyond Fredericton, N. B. (Reid: in American Year-Book for 1913, p. 630). The shock of 28 April in the St. Lawrence valley south of Ottawa was also felt in neighboring portions of Vermont. November 3, 1913, a light shock was felt in southwestern Rhode Island. No trace of the disturbance was recognizable on the records at this Station. According to press despatches the time was variously given from 9:30 a. m. to as late as 10:14 by household clocks. Most of the reports indicate a time about 9:30 a. m. Eastern S. T. In southern Rhode Island sounds were heard in the air like the booming of guns. In the town of Carolina a chair is said to have been overturned in the office of the town clerk.

The motion was felt on the southwest as far as Watch Hill. It seems to have been felt only on the western side of Narragansett Bay and to have been most noticeable in the southern towns. The southern coast of Connecticut and Rhode Island appears to be a much dissected fault scarp, in the latter state of little elevation above the sea and much encumbered with morainal deposits. The occurrence heretofore as in 1847–8 of earthquakes along this line from eastern Rhode Island to New York City and southwestward along the "Fall Line" suggests that this earthquake had its origin in a slight slip along a fault on the northern shore of the New England Sounds. The absence of reports of a shock felt on Block Island coupled with the distance to which the shock was felt northward in western Rhode Island possibly points to a low angle of dip of this fault to the north. No faults have been detected in the rocks on the mainland in southwestern Rhode Island to which the shock may be attributed, but the region is heavily drift covered and the crystalline rocks of the western part of the state have never been delineated on a map available for study. In this connection the observation of the late Prof. W. H. Niles on the meridianal compression of the gneisses in the quarry at Monson, Mass., (about sixty miles northwest of the Rhode Island shore) and the occurrence of similar phenomena in western Rhode Island, verbally described to me by the late Professor Packard of Brown University, deserve note as indicating the existence of a superficial compression of the rocks in southern New England in a direction consonant with the above suggestion of the attitude of the supposed fault-plane bordering the south coast. At the locality described by Professor Packard a ledge of rock was reported to throw off large spalls with a loud noise, in a manner and at times favoring the supposition that it was yielding to earth pressure like that exhibited in the Monson quarry.

Condition of the Station:— From the latter part of June until about 1st December, 1913, the seismograph was greatly disturbed by the construction of the Ethnological Section of the University Museum adjoining the instrument room and also by the use of the basement of the Geological Section as a workshop.

Educational Use of the Station:— The seismograph has been regularly visited by the classes in elementary geology, and seismograms with a statement of the theory of seismic waves and their registration have formed a part of the instruction concerning earthquakes and the subject of faults in the courses in Dynamic and Structural Geology. As an adjunct to the Geological Laboratory the Station has proved to be an important object lesson in enforcing upon all classes of students the discoveries of modern seismology. Classes from the public schools of Boston, and students of geology from neighboring colleges, also visit the Station. These visits are availed of by the Professor in charge to give a brief lecture on the entire working of the Station and the results obtained by the instrumental study of seismograms. The instrument room is provided with glass windows through which the instrument may be seen by students without disturbing the records. If the plant served no other purpose than this educational adjunct to the Geological Laboratory, its installation would have been worth the relatively small cost for so impressive an exhibit and convincing demonstration of some of the properties of the earth's interior. If as an enthusiastic seismologist has stated, "The seismograph is to the earth's interior what the telescope is to the space outside our earth," any department of instruction concerned with the geophysics of the globe should have a working seismograph as a part of its apparatus.

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AT HARVARD COLLEGE.

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GEOLOGICAL SERIES. Vol. IX, No. 4.

HARVARD SEISMOGRAPHIC STATION.
SIXTH ANNUAL REPORT INCLUDING RECORDS, 1 JANUARY – 31 DECEMBER, 1914.

By J. B. Woodworth.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

September, 1915.

No. 4.—*Harvard Seismographic Station. Sixth Annual Report, from 1 January to 31 December, 1914, G.M.T.*

By J. B. Woodworth.

The records herewith presented continue the list published in Bull. M. C. Z. 55, p. 55–74. The constants of the Station are as follows: —

Latitude 42° 22′ 36″ N. Longitude 71° 06′ 59″ W. Altitude 5.36 M.

Subsoil: — Glacial sand over clay on tilted Carboniferous (?) shales.

Time: — Mean Greenwich, midnight to midnight. Eye and ear comparison with Harvard Observatory through telephone.

Instruments: — Two Bosch-Omori 100 kg. horizontal pendulums, with mechanical registration.

Nomenclature: — Göttingen; also O for time at Origin.

In the column of Remarks the following peculiar abbreviations are employed: Q, earthquake; Qf, felt earthquake; Ql, local shock; micros., for microseisms. Distance from Station to Epicentres is given in Kilometres read from Zöppritz and Zeissig's tables for the interval S–P; for eL–S from tables published by Goesse (St. Louis). O in this Report is calculated from tables of British Association based on work of Galitzin and Walker.

Constants of the Instruments.	*N–S.*	*E–W.*
	secs.	*secs.*
Period:	22.5	24.8
Magnification	50	80
Damping	var.	0

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
*357	Jan. 8	e	12 23 41		?	Record discounted; probably local wind effects.
		F	13 57			
358	13	*O*	*10 21 47*		0	Local frost crack. Nos. 358 to 361 occurred during nights with bare, frozen ground, and temperatures of −21°C. to −22°C.
		iM	10 21 47			
		F	10 21 49			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
359	Jan. 13	*O*	*12 14 26*		0	
		iMN	12 14 26			
		F	12 14 32			
360	14	*O*	*0 46 02*		0	
		iMN	0 46 02			
		F	0 46 04			
361	14	*O*	*4 44 36*	0.5	0	Stylus of E jumped 29 mm.
		iMNE	4 44 36			
		F	4 44 46			
361a	20	*O?*	*12 03 36*		6530?	P marked by micro-seisms. Pulkovo O: 12h. 00m. 13s. in φ 52.9 N., λ 159.6 E.
		S	12 21 44			
		eLE?	12 35 30			
		L	12 45 04	20		
		F	13 00			
362	30	*O*	*3 36 03*		8440	
		iPN	3 47 58	4		P–O = 11m. 55s. Shide O: 3h. 35m. 50s. S. of Santiago, Chile, in φ 34°.1 S., λ 66° W.
		PE	3 48 04	2		
		SE	3 57 40	14		
		eLE	4 09 36	20		
		LN	4 13 10	22		
		LE	4 17 05			
		MN	4 18 14	22		
		ME	4 26 01	18		
		FE	5 44			
362a	Feb. 10	*O?*	*16 22 01*		4115?	P in micros. Ottawa Δ 4150 kms. do. O 16h. 22m. 34s. Honolulu P 16–45–06 Δ 5635; gives O 16–35–54? P = S?
		eSE	16 35 25			
		L	16 39 09			
		F	17 12 40			
363	10	*O*	*18 31 02*		435	Shock in St. Lawrence Valley, 120 kms. S. E. from Ottawa. See Note p. 106.
		ePN	18 32 03			
		PE	18 32 04	0.4		
			18 32 11	0.4		
			18 32 40	0.5		

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
		SL_NE	18 32 51	8N 16E		
			18 33 07	6		
		M_E	18 33 11			
			18 33 13			
			18 33 18			
		M_N	18 33 22			
		C_N	18 33 37			
		F	18 40 05			
364	Feb. 12	*O*	*2 32 36*		0	Frost crack at Station.
		iM_E	2 32 36	0.5		
		F	2 32 38			
365	12	*O*	*7 37 52?*		0	Frost crack. Temperature ca. –28 C.
		iM_N	7 37 52?			
		F	7 38 00?			
366	14	*O*	*9 33 40*		520	In St. Lawrence Valley, S.S.E. of Sorel, Quebec. Felt near Quebec. Ottawa Δ 225 kms. O:9–33–43. Harvard time somewhat uncertain as clock contact was out of order.
		P_N	9 34 52	0.25		
		S	9 35 49	0.5		
		F	9 38 01			
367	26	*O*	*4 58 04*		6675	Felt severely at Mollendo and Arequipa, Peru. Vd. Bull. La Paz, Bolivia for Feb. 1914. Pulkovo O 4h. 57 m. 52s. φ 16 S., λ 61° W.
		eP_E	5 08 17	3		
		P_N	5 08 19	3		
		S_E	5 16 28	10		
		S_N	5 16 31	5		
		L_E	5 24 47	16		
			5 37 58	18 < 20		
		F	6 42 ca			
368	28	*O*	*5 02 54*		2470	W. I. Ids. φ 18° N., λ 67° W. Shide O: 5h. 3m. 21–23s.
		eP_N	5 08 02			
		P_E	5 08 09			
		i	5 08 13	6		
		S_E	5 12 05	6		

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
		SN	5 12 29	6		
		LE	5 15 07	4<7		
			5 19 15			
		LN	5 21 02			
		F	6 20 ca			
369	Feb. 28	ePE	5 12 05		?	2nd Q? in coda of 368.
370	Mar. 1	*O*	*10 15 02*		0	Frost crack? SE. rain storm on thick snow layer.
		iM	10 15 02	0.5		
		F	10 15 24			
371	4	*O?*	*15 +*		?	P, S in micros. Vienna, Göttingen, La Paz give discordant records. Origin appears to have been in S. hemisphere. La Paz Δ 4850.
		e?	15 57 36			
		eSE	16 17 59	46		
		L?	16 21 48			
		L?	16 23 16	22<16		
		F?	17 16 14			
372	4	*O?*	(*18* 49 +)		(8700?)	O? from Aachen, but cf. Manila e 18–40, F 19–28. eL recorded at Vienna, Königsberg, Göttingen, Heidelberg. F lost in micros.
		eLE	19 48 35	12<16		
			19 55 31	15.5		
		F?				
373	5	*O?*	(*17 58 19*)		(2800?)	O? from Heidelberg Δ 2930?
		eLE	18 12 21			
		F?	18 18 32			
*374	6	*O*	*19 05 18*		(8500)	O from Pulkovo in φ 53° N., λ 158° E. Kamtchatka. F lost in micros.
		eL?	19 39 42			
		L	19 50 15			
374a	13	*O*	*15 28 56*		3030	
		PE	15 34 57	2		Cf. Königsberg e 15–42.1; L 15–51.7.
			15 35 10			
		SE	15 39 42	6		
		eL	15 41 05	12		F lost in micros.

No.	Date	Phase	Time	Periods	s.	Remarks
	1914		h. m. s.	s.	Kms.	
374b	Mar. 14	*O*	*20 00 06*			O by Pulkovo in λ 139.8 E., φ 39.2 N, Akita Province, Japan.–E record tangled and illegible owing to J. B. W. adjusting pendulums at the time.
374c	18	*O*	*4 20 18*			O by Pulkovo in φ 53.3 N., λ 156.4 E.
		LE	4 59	22		
		F	5 14 30			
374d	21	*O*	*9 16 09*		4050	O from S–P.
		eP	9 23 34			Ottawa Δ 4300.
		S	9 26 47			Honolulu Δ 6225.
		eL	9 33 02			Königsberg eL 10–02;
		F	9 51			(Δ ca 9260?).
375	27	*O*	*0 55 46*		9500	O by Pulkovo in φ 53.1 N., λ 158.4° N. Harvard O ca. 0h. 53m. from eL–S. Kamtchatka.
		eSN	1 16 38			
		eL	1 33 00	10		
			1 33 08	18 > 14		
		F	2 09			
375a	28	*O*	*10 44 31*		(12500)	O by Pulkova in φ 23° N. λ 95° E. Upper Burma.
		L	11 38 18			
*376	30	*O*	*0 40 32*		3830	O from SN–PN. Shide O = 0–41–11, in φ 19° N., λ 96° W. Mexico.
		ePN	0 47 41			
		i	0 47 45			
		SN	0 53 18			Comp. E moved E after 0–53–23 (shift of zero).
		SE	0 53 23			
		eLN	0 55 16			
		LE	1 00 25	20		N stylus left drum at 1–07–33.
			1 02 17	23		
			1 05 20	19		
		F	2 50			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
376a	Apr. 9	*O*	*3 52 39*			O from Ottawa Δ 9600. But Graz P 3–55–38; eL 4–38 would make O earlier.
		eN	4 24 36	3		
		LE	4 35 44	24		
		LN	4 36 40	22		
		LE	4 38 19	20		
		LN	4 45 12	16		
		F	5 20 14			
377	11	*O?*	*16 31* +			
		eSE	16 57 45	8		O from Sydney record.
		L	17 30 37	28		Ottawa eL 17–16.
			17 37 13	20		F ? in next record.
378	11	*O*	*17 54 28*			O from Ottawa Δ 6100.
		L	18 35 03			Cf. Manila eL? 19–55.
			18 37 47			
379	20	*O*	*13 29 38*		4100	O from S–P.
		PN	13 37 07	2		Ottawa Δ 4450.
		ePE	13 37 21			Vienna Δ 9950; O 13–29–44.
		SN	13 43 00	6		St. Louis Δ 3750.
		SE	13 43 10			Q off Acapulco.
		LE	13 46 13?			ca. φ 12° N., λ 104° W.
		LN	13 46 57			
		FE	15 00 ca			
380	24	*O*	*8 33 53*			O from Berkeley Δ 350.
		eL	8 50 53			Qr. California. Vd. Bull. Seismog. Stations, Univ. Calif., no. 8. Dec. 1914, p. 167.
		L	8 51 53	15>8		
		F	9 12 14			St. Louis Δ 2500; O 8–33–56.
381	May 19	*O?*	— — —			Graz says this is W′ of a Q at 0–03.
		e	5 29 09	4		Aachen eL 5–20–50.
		L	5 45 32	20		Graz eL 5–37.
			5 50 01	17		Vienna eL 5–40.
		F	6 05 10			Czernowitz eL 5–45.
						Cf. La Paz e 5–01–48.

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
*382	May 26	*O*	*14 23 18*		(14,450)	O from Pulkovo in φ
		PE	14 39 13			0.3 S λ 138.8 E.
		E	14 45 21			Honolulu Δ 7580; O 14–
		N	14 45 23			23–38.
		i	14 46 25	2<4		Harvard eS should be ca.
		es	14 47 42	8		14–55–30. Shide notes
		eLE	15 30 42	23		O 14–22–13 as probably
		LN	15 32 55			correct.
		LE	15 35 21	26		
		LN	15 41 26			
		LE	15 46 26	20		
		LN		16		
		F	15 34 36			
383	28	*O*	*3 23 50*		3580	O from S–P.
		PNE	3 30 39	3		
		SN	3 35 01	7		Qf. Canal Zone, Isthmus
		SE	3 35 46	6.5		of Panama. Pulkovo
		LE	3 39 09	16		gives O 3–23–51.
		LN	3 40 37	15		
		FN	3 55 09			
		FE	4 08 09			
384	28	*O*	*17 58 09*			O by Ottawa.
		eLE	18 17 02			Qf. Fairbanks, Alaska.
		LN	18 20 04			e in micros.
		F	18 36			
385	29	*O*	*4 47 20*			O from Pulkovo. φ 1° N.,
		L	5 27 13			λ 95.6 E.
		F	6 56			Qf. Padang (Poelo-Tello)
						West coast of Sumatra.
386	June 18	*O*	*20 + ?*			Cf. La Paz e 20–39–54;
		LE	21 22 48	14		L' 21–08–55. Honolulu
			21 27 31			L 20–35–36. Frankfort
		F?	21 32 43			e 20–40; eL 21–44.
						F lost in local jars.

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
387	June 20	*O*	*7 22 45*		(11,070)	O from Manila P 7–29–44; Δ 3700.
		ePE	7 40 45			
		eS?	7 58 00	22		
		L	8 17 37	40		
			8 24 17	20		Phases indistinct.
		M	8 25 05			Batavia iP 7–30–22; eL 7–46; Δ 3000; = O 7–24–24?
		C	8 27 41			
		F	9 53			Sydney eP 20–36.6; Δ 2850; gives φ 12½° S., λ 167½° E.
*388	20	*O?*	*10 30+*			O uncertain, homocentric with 387? on reflection of L.
		e	10 56 43	2		
			11 10 09	6		
			11 22 04	30		Phases reported by several stations disagree, giving O as early as 10 h. 26m. and as late as 10h.; 40m. Sydney eP 10–29.5 Δ 2700.
		F	11 56 ca			
389	21	*O*	*23 35 17*		(13,080)	O from Batavia Δ 7200.
		e	0 38 15			Vd. Ottawa P 0–01–12.
		eLE	0 40 25			
			0 40 46	20		
			0 45 32	15		
			0 50 34	16		
			0 57 10			
			0 57 41			
			1 00 43	15		
		F?	1 00 58			
*390	21	*O?*	*18 25 27*			
		eE	18 43 41	26		O by Ottawa Δ 4700?
		F	18 52 24			No trace N. damped 4:1. No reports from Europe.
391	23	*O*	*3 28 51*			O by Ottawa Δ 3350.
		LE	3 45 36	17		La Paz Δ 9600; O: 3–18–08.
			3 52 56	16		

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
		F	4 20			Trieste e 3–52.
						Aachen e 3–51.3.
						Cf. Honolulu P 3–49–48;
						Δ 1240; O 3–47–02.
						(Another Q).
						Sydney e 4–18.2.
392	June 25	*O*	*19 07 20*		(16,000)	O from Batavia records.
		ePE	19 26 42	2		Sydney iP 19–16–46;
		PN	19 26 46			Δ 6000.
		SN	19 41 12			
		SE	17 41 13	8		Qr. S. Sumatra in φ
			19 47 54	15		4°.2 S., 102° E. at Benk-
		L	20 11 09	53		oelen (Batavia).
			20 15 05	52		Batavia P 19–08–40; Δ
		M	20 18 22			580.
			20 24 55			2.6 mm. A on record.
		F	22 10 ca			3.3 mm. A on record.
393	26	*O*	*3* + ?			O from Sydney eP3–
		eLE	4 08 45	20		15.9; Δ.
						Aachen e? 4–06.
		F	4 12 24			Cf. Batavia e 3–22; F
						3–45.
			4 53 30			Manila eL? 4–59–53.
394	26	*O*	*4 ?*		(10,062)	O by Sydney.
		eLE	5 27 01	20		Pola Δ 8800.
			5 47 57	30		Cartuja Δ 8930.
		F	7 38			Ottawa Δ 8600?
						Honolulu P 4–59–12;
						S 5–06–12; gives Δ 5320;
						O 4–50–19.
						Sydney iP 4–55–39; Δ
						2970.
						Sydney records 2nd Q
						eP 5–58.2.

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kims.	
395	July 3	*O?*	*20 37* +			O from Ottawa Δ 6000.
		eL	21 05 03?	15		F in micros. Vd. Strassburg, Aachen, Batavia,
		F?	21 37			& Manila records. Cf. Honolulu Δ 8675; O: 20–00. Manila e 20–02
396	4	*O?*	*23 50 44*		1960?	O from S–P. La Paz
		eP	23 54 56			Δ 9100, P 23–58–32 gives
		S	23 59 36	8		O 23h, 46m. 02s.
	5	L	0 02 53			Cf. Pola Δ 5010, P 23–57–47.
			0 03 54	25		
		F	1 01			Honolulu Δ 7500; O: 23–56–44. Manila eP 23–43–27 Δ 1810. Batavia Δ 370; iP 23–43–39.
397	5	*O?*	— — —			O bet. 21–51 and 22–07.
		eL	22 49 11			Pola Δ 1600, P 22–18–48.
			22 54 40	20		La Paz Δ 13,000? P
			23 02 16	19		22–11–07.
		F	23 56			Batavia Δ 370, iP 21–57–36. Probably two earthquakes.
398	6	*O?*	— — —			Origin very uncertain.
		e	3 22 14			Tucson P 3–06–00; L
		eS	3 22 54	8		3–06–38.
		L	3 25 18	7		Ottawa S 3–19–20; L
		F	3 29 45			3–42. Cornell C 3–13–03; L 3–19–39. Strassburg: several irregular waves bet. 3h. and 5h.
399	6	*O?*	— — —		2035?	Readings doubtful.

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
		ePE?	4 11 34	4		Tucson P 4–00–11; L 4–00–28.
		S?	4 15 01	7		Ottawa S 4–13–34; M 4–18–12.
		L	4 17 30	10		La Paz e 4–05–33.
		F	4 22 03			
400	July 14	*O?*	*3 21 37*		6250?	O from S–P; but Ottawa gives Δ 7300? Batavia reports iP 3–11–31, Δ 430, giving O 3–10–31, possibly an earlier Q. Aachen eP 3–24–12, Δ 10,500? = O 3–10–54.
		ePE	3 31 36	4		
		S?	3 39 26	5		
			4 04 22	12<17		
		L	4 43 22	16		
		M	4 44 26	17		
		F	5 20 ca.			
*401	17	*O*	*7 06 41*		7475	O from L–P. Ottawa P 7–17–13, Δ 6800. Aachen P? 7–18–48, Δ 8600? Ottawa O: 7–06–53. Aachen O: 7–06–45 Aleutian Ids. ca. λ 183°? Sitka Δ 3110; O: 7–05–59.
		ePE	7 17 41			
			7 34 12			
		L	7 37 53	28		
			7 41 31	20		
		eM	7 46 49	20		
		F	8 41 44			
402	21	*O?*	*22 30 43*		4280	O from S–P. Ottawa Δ 3970; O: 22–31–04. Berkeley Δ 1530; O: 22–31–05. Tucson Δ 2560; O: 22–31–16. Off S. California ca φ 25° N, λ 114° W.
		eP?E	22 38 25	2		
		S	22 44 28	6		
		LN	22 52 10	6		
		LE	22 52 27	9		
		ME	22 55 17	10		
		F	23 47 25			
403	Aug. 3	*O*	*11 25 12*		2750	O from S–P. Jamaica Weather Report no. 433 gives O: 6h. 25m. a.m. E. S. T. Little damage. Felt Jamaica, W. I. I. F lost in micros.
		PN	11 30 48			
		S	11 35 12			
		eLE	11 40 21?			
		F?				

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s	Kms.	
404	Aug. 4	*O*	*9 01 30*		(12,500)	O from Cartuja Δ 9430,
		e	9 41 51			iP 9–14–17.
		L?	10 02 36	20		
			10 04 06			Harvard (Δ?) from L–O.
		F	10 25 ca			
*405	4	*O*	*22 40 57*		10090	O from eL–S.
		eSE	23 05 20			Hamburg Δ 5720; O:
		SN	23 05 23			22–41–33.
			23 09 46			Heidelberg Δ 6540; O:
			23 10 44			22–41–27.
			23 14 45			Ottawa Δ 9560; O: 22–
		eLE	23 23 00			41–55.
			23 23 38			La Paz Δ 7820; O: 22–
		M	23 27 26			41–48.
			23 28 22			Origin near coast of
			23 33 18			French Guinea.
			23 35 31	20		A 1.7 mm. on record.
			23 38 10	17		
	5	F	0 49			
406	8	*O*	*19 08 10*		4500	O from S–P. Tucson Δ
						680; O 19–10–14.
		PNE	19 16 09			Ottawa P 19–16–07; Δ
		PN	19 16 20	4		4100; O: 17–08–38.
		PE	19 17 51	6		Berkeley P 19–13–26;
		SE	19 22 24	10		Δ 2030; O: 19–09–06.
		SN	19 22 25	6		La Paz Pe 19–18–17,
		eLE	19 29 25	20		Δ 5500; O, 19–09–13.
			19 30 21	8<6		N. B. Berkeley & La Paz
		M	19 33 23	10		gives O mean 45 ± secs.
		F	20 32			later than Ottawa &
						Harvard. Q near φ 20°
						N. λ 111° W. Cf. Q in
						Italy about this time.
407	17	?	— — —			Doubtfully seismic,
		L?	17 34 07	8<20		emerging from long
		F?	17 35 38			period pulsations.
408	19	?	— — —			Emerged from long

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
		LE?	13 47 24			period pulsations. Cf. Manila P 11–53–30; L 11–54–55. Hamburg eL 12.7.
		F?	14 14			
409	Aug. 22	*O*	*5 28 01*		4540	From S–P. Tucson Δ 2200; O 5–28–20. Ottawa P 5–35–32; Δ 3900; O: 5–28–18. St. Louis P 5–34–20, Δ 3500; O: 5–27–37. Berkeley P 5–30–20, Δ 1,180; O. 5–27–41. Mean O (from 4) = 5h. 27m. 54.2 s. Origin near 47° N, 133° W. by Berkeley, Ottawa, Heidelberg.
		PE	5 36 02	3		
		PR₁	5 37 41			
		S	5 42 19	10		
		eL	5 48 43	11		
			5 51 07	9		
		F	6 53			
410	22	*O*	*15 08 57*		(9400)	O from Cartuja eP 15–21–22; S 15–31–35; Δ 9050. Earlier phases marked by microseisms. Cf. Cornell (Ithaca) e? 15–34–20; eL 15–55–04. Harvard Δ from eL–O. But vd. Ottawa eL 15–48.
		eLE	15 55 39	25		
			15 57 43	20		
			16 03 16			
		F	16 30 24	16		
411	28	*O*	*8 26 12*			O from La Paz iP 8–30–50; S 8–33–48; Δ 1640. Cf. Cornell P 8–42–11; S 8–51–36; Δ 8080; O, 8–30–36. Harvard phases uncertain. Hamburg Δ 11,800? O? 8–29–66. Origin near 20° S. and 90° W.?
		eP?	8 41 38			
		S?	8 48 26			
		L	8 56 54	25	5125?	
			9 04 12	50		
			9 06 50	20		
		F	9 35			
412	28	*O*	*17 34 59*		(3950)	
		eS?	17 52 04	20		O from La Paz i 17–42–58; Δ 4500. Vd. Barce-
		eLE	17 54 36	12		

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
			17 59 46	10–12		lona eL 18–17–0. Ottawa Δ 3500.
		F	18 11			Harvard (Δ) from eL–O. Cornell eL 17–58–47.
413	Sept. 12	*O*	— — —			
		L	4 56			Long waves of doubtful origin to 8h. 31m.
414	12	*O*	*21 03 35?*		450?	*O* from S–P? Not reported from New England. Probably off coast.
		PE?	21 04 38			
		S	21 05 22			
		eL	21 06 33	9.5		
		M	21 06 50	20		A small.
		F	21 08 45			
415	Oct. 1	*O*	*6 23 31*		3980	Not shown E–W. e in micros.
		PN	6 30 52	3		La Paz P 6–28–58; Δ 2550; O: 6–23–41. Ottawa P 6–31–08; Δ 4200; O: 6–23–30. Pacific Ocean off Guatemala; ca φ 12.°5 N., λ 97° W. Cartuja Δ 7530; O: 6–23–54.
		S	6 36 38	7.5		
		eL	6 42 36			
			6 43 31	25		
			6 48	15		
		F	6 54			
416	3	*O*	*17–22–14*		2860	O from S–P. Tucson Δ 5300; O 17–21–59.
		PN	17 28 00	3		La Paz P 17–28–51; Δ 3500; O: 17–22–08.5.
		S	17 32 33	17		Ottawa P 17–28–24; Δ 3565; O: 17–21–36.
		eL	17 35 10			St. Louis Δ 3700; Cartuja Δ 5940.
		F	19 30 ca			Heidelberg eP 17–29–26; S 17–41–18; Δ 11,275. Press reports shock in Martinique 1:18 p.m. Felt in Fort de France (La Paz). Cartuja φ 12° N., 56° W.

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
417	Oct. 3	*O*	*22 06 54*		8175	O from S–P, but cf. Heidelberg P 22–11–31; Δ 3190; O: 22–05–16. Cartuja P 22–12–40; Δ 2900; O 22–06–59: Cornell P 22–18–55; Δ 8520; O 22–06–46. St. Louis Δ 9080; O 22–07–19. Konia, Asia Minor; Isbarta and Burdur damaged. φ 36°.6 N; λ 30°.2 E.
		PE	22 18 34			
		S	22 28 02			
			22 33 03	6		
		eL	22 42 28			
		M	22 46 09			
		F	23 35			
418	5	O?	— — —		3000?	Not reported elsewhere.
		eS?	9 31 32			
		L	9 33 34	12>8		Record uncertain.
		F	9 35			
419	5	eE	10 20 41			Connected with 418?
		F	10 21 16			
*420	9	*O*	*2 39 14*		(11,350)	O from Cartuja iP 2–49–49; Δ 7030.
		e	3 03 30	4		
		eL	3 35 37	16>15		Harv. (Δ) from eL–O.
		F	4 17			Manila Δ 6680
*421	22	*O*	*6 44 00*		(3650?)	O from Tucson P 6–44–09; Δ 70 ±. St. Louis iP 6–53–33; Δ 2500; O 6–48–22.
		eL	7 02 10	3		
		LN	7 02 26	6		
		LN	7 03 49	8		
		LE	7 05 02	8		La Paz e? 7–05–00.
		F	7 15 ca			
421a	22	*O*	10 + ?			Apparently in connection with No. 421.
		e	10 54 54			
		L	10 57 22	8–9		
		F	11 05 ca			
422	25	*O?*	*6 26* 13?		7510?	From eL–P, 20m. 35s. Heidelberg P 6–36–58; S 6–52–09; Δ 17,000?
		PN	6 37 16	2		
		i	6 40 18	4		

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
		eN	6 41 25	6		La Paz finds 2 quakes:
		eE	6 41 30	6		P 6–38–57; Δ 8,900;
			6 44 47	6		O 6–26–37; and P 6–51–
		eSN?	6 53 11	10		28; Δ 11,175; O 6–37–04.
		eSE?	6 53 13			Cornell L 7–22–18. Tuc-
		LN	6 58 11	18		son Δ 70 ± ; O 6–44 ± .
		LE	6 58 30	14		
		F	8 13			
423	Oct. 25	*O*	*19 0 49*		(6440)	From La Paz P 19–17–
		eL	19 39 48	20		27; Δ 7110; (Δ) from eL–
		F	19 40 50			O. 3 waves.
424	Nov. 10	*O*	*11 20 05*			O from Ottawa P 11–22–
		ePN?	11 24 45			06; Δ 890. Cornell eP
		ePE?	11 24 50			11–22–58.
		SE?	11 25 45	6		Harvard phases not dis-
		SN?	11 26 40	6		tinct.
		LN	11 28 52	20		
		F	11 30 ca			
425	18	*O*	*9 38 37*		4160	Ottawa Δ 5030; O 9–37–
		PN	9 46 11			39.
			9 46 14	2		
			9 47 43	7		Honolulu P 10–00.2; L
		SN	9 52 07	12		10–15.6. Δ 6000?
		SE	9 52 27	7		
			9 56 13	12>7		
		LE	9 59 22	17		
		LN	9 59 49	20		
		LE	10 01 26	14		
			10 04 12	17		
			10 07 46	18		
			10 16 28	20		
		F	10 35 ca			
426	18	LE	10 49 44	15		Probably part of 425.
			10 49 59			
		F	10 51 04			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
427	Dec. 24	*O*	*12 04 44*		3900	From S_N–P_N. Ottawa P 12–11–37; Δ 4030; O 12–04–12.
		eP_N	12 11 58			La Paz Δ 8700? Compare Honolulu Δ 3,200; O: 11–56–32.
		eP_E	12 12 24			Manila Δ 2880; O: 11–52–27 reports Qf in Guam.
		S_N	12 17 39			A 2.2 mm. on record.
		S_E	12 17 45			
		SR_2	12 20 48	10		
		eL_N	12 21 54	10		
		M_N	12 23 45	28		
		F	14 15			
428	27	*O?*	— — —			
		e	4 44 31			e = S?
		L_N	4 45 44	10		
		F	4 57 42			
*429	Nov. 28	*O?*	*10 40* ±			O from Honolulu P 10–54–24 Δ 10,320; O: 10–40–52. Strassburg P 10–44–50; Δ 12,150. La Paz e 11–05–40. Manila eP 10–49–41; Δ 2210.
		e?	11 30 10			
			11 39 22	24		
		L_N	11 48 45	20		
			11 52 49	16		
			12 05 45	20		
		F	12 08 ca			
430	Dec. 4	*O?*	*16 58 25*		3600?	
		eS?	17 10 37			
		eL	17 13 23	23		Cf. La Paz P 17–40–40; F 17–50.
			17 14 08	16		
			17 14 22	14		
			17 19 18	10		
			17 25 46	16		
		F?	17 27 03			
431	11	e_N	2 27 52			e to F in microseisms.
		L_N	2 30 48	12<18		
		to	2 36 32			
		L_N	2 45 06			
		to	2 46 06			
*432	20	*O*	*14 09 22*		11,100	
		eP_E	14 27 54	4		

No.	Date	Phase	Time	Periods	Δ	Remarks
	1914		h. m. s.	s.	Kms.	
		SN	14 33 45	9		
		SE	14 34 32	6		
			14 35 54	17		La Paz P 14–22–48; Δ 9590; O 14–09–53; Cornell e? 14–34–19 = S; eL 14–52–55; Δ = 10–450; O: 14–09–22.
			14 37 23	6		
		E	14 43 31	15		
		N	14 43 42	13		
		eL	14 54 19	43		
			14 56 57	44		On coast of S. Damaraland?
			14 57 39	40		
			14 58 20	36		
			14 58 21	28		
			15 00 37			
			15 04 54	20–18		
			15 06 08	24		
		F	15 51			
433	Dec. 25	*O*	*3 42 03*		2490	O from SE–PN.
		PN	3 47 14			Ottawa Δ 2800; O 3–41–58.
		PE	3 47 17			Cornell Δ 2500; O 3–41–58.
		SE	3 51 17			Harvard O 5 secs. late?
		SN	3 51 18			Georgetown eL 3–51.
		eLE	3 54 45			In or near W. India Ids.
		LN	3 56 37			Earthquake felt on Jamaica 10:45 p. m. Standard time (Vd. Jamaica Weather Report for Dec. 1914, No. 437, p. 4.
		F	4 07			

NUMBER OF EARTHQUAKES RECORDED SINCE JAN. 1, 1910. (G. M. T.).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sums.
1910	5	2	5	5	12	9	8	4	10	3	11	12	86
1911	8	11	3	5	6	6	3	2	8	7	8	5	72
1912	3	4	4	7	7	25	13	8	6	4	6	10	97
1913	9	2	10	5	5	9	10	8	1	12	4	2	77
1914	2	6	11	5	5	9	8	10	2	9	5	4	76
Sums	27	25	33	27	35	58	42	32	27	35	34	33	408
Aver.	5.4	5.0	6.6	5.4	7.0	11.6	8.4	6.4	5.4	7.0	6.8	5.6	81.6

In addition to the 76 records above counted for the year 1914, the list includes seven local small shocks referred to frost. Of the 76 records, 11, regarded as probably of seismic nature, have not been confirmed by reports from other observatories, and two of these records viz. Nos. 419 and 426, are possibly reflected waves of the preceding record in each case.

With the outbreak of hostilities in Europe, the monthly bulletins from stations in Germany, and of weekly bulletins from stations in Austria-Hungary, ceased to come. Later in the year reports were renewed from Heidelberg, Hamburg, and Strassbourg. In the meantime, a request to establish an exchange of data was received from the observatory at Barcelona in Spain and later from Catania, Italy. The newly established station at La Paz, Bolivia, also entered into an exchange during the year. As will be noted in the column of Remarks in the preceding lists, data bearing on the position and time of occurrence of many distant earthquakes has been limited to reports received from Manila, the U. S. Coast and Geodetic Stations at Honolulu, Sitka, Tucson, Vieques (Puerto Rico), and Cheltenham, and the observatories at Ottawa, Berkeley, Santa Clara, Ithaca, and St. Louis.

As in former years by far the greater number of shocks recorded in these lists had their origin beyond the borders of North America. Data are not at hand to determine the epicentres of most of the earthquakes registered. Notable among the earthquakes of great intensity are those of May 29 (no. 385), and June 25 (no. 392) in Sumatra, in equatorward progression.

Determination of time at Origin: — An innovation has been made in this Report in the introduction in the tables of the calculated time at which an earthquake took place. The symbol O employed for the initial phase of seismic action at the Origin is based on the transmission time of the registered phases to a given station.

In previous reports where calculations for O have been given, they were based on tables by Benndorf now some years old. The more accurate curves for the known speed of propagation of the phases P, S, and L constructed by Prince Galatzin and by Walker, and published by the Seismological Committee of the British Association in the form of tables expressing distances in degrees of arc upon the earth's surface were with suitable interpolations converted into others in which the distance appears as kilometres for this report.

The initial phase O standing at the head of the line of phases against the date should be common to all reports of the same earthquake where correct time and satisfactory registration have been secured. A variation of a few seconds in the deduced time at origin is probably to be expected and in the present state of seismology appears unavoidable. Any wide departure affecting the minute given points to a probable misjudgment in reading the phases of a record. I have printed O and its time in italics to indicate that the data are deduced times and not registered or observed phenomena. In the column of remarks O will be found in several instances as deduced from the data furnished by several stations for the same earthquake.

In several instances where the Harvard record began with the Long or Rayleigh waves (eL), O has been given as determined by data from other stations and the distance from Cambridge to the epicentre has been found from the interval eL–O (read eL minus O). On the assumption that the reading of the records for eL gives the time of appearance of this phase correctly, and from the known rate of travel of L waves, 3.53 kms. per sec. or 125.42 miles a minute, it is possible, as Milne pointed out, to obtain the distance from a station where P and S are suppressed. Where P and S have been legible the distance has been read off from the tables published by Zöpprits and Zeissig. In a few cases where the interval eL–S had to be used, the distance was taken from the admirable tables worked out and published by Professor J. B. Goesse of St. Louis University. But in this case as with the interval eL–O, error is apt to creep in from the uncertainty attending the fixation of time at which the phase eL appears in the seismogram. In both cases eL is apt to be read too late, and the distance to be made too great.

The record of amplitudes has been omitted except for an occasional note under the Remarks concerning the apparent amplitude as measured on the seismogram. Inasmuch as the air dampers provided for the Bosch-Omori tromometer suppress all but the heaviest distant records, it has seemed better to obtain the record of the phases P and S where possible then to seek to record the amplitude of the earth particle or technically the intensity under conditions which would prevent the registration of more than a few earthquakes.

Earthquakes in trains: — Earthquakes often come in groups associated in time and place. Within these groups there is observable at times a capricious progression in direction. As an example of this action, there may be cited an instructive series of earthquakes in the Mediterranean region partly registered at this Station and partly reported by the press despatches. The group began with a destructive earthquake in the province of Konia, Asia Minor, about 22 hr. 3 mins. on October 3rd, 1914 (see record no. 417). On October 17th, a strong earthquake visited Beoetia in L. 38°.3 N., a point westward along the mountain axes. On October 26th, a shock was felt at Turin in Italy, in L. 45° N., beyond the northern turn of the Apennines. On the following day, the seismic force was manifest on the south at Florence in L. 43°.7 N. Shifting southward and equatorward along the geological structure trends as if vulcanism and seismicity were in that field in causal relations, the subterranean stress found expression in the increased activity of Vesuvius on November 4th. Three days later, on the 7th, Etna yet farther south, began to rumble. On November 28th, to the east of Etna a shock was experienced in western Greece, a further step toward Etna of the Konia-Beoetia progression. A pause then ensued, long enough for one to realize that two trains of earthquakes had approached the active focus of vulcanism and seismicity in Italy, one from the east, the other from the north. On January 13th, 1915, the disaster of Lago di Fucino took place in L. 42°? N., with the destruction of Avezzano and surrounding towns, a back-step in the path of the movement which in October and November concentrated upon the toe of the boot of Italy. Six days later, on the 19th of January, a destructive shock occurred in Calabria again on the south near or at Cosenza. What this march towards Etna means, the future alone can tell. So far we are able to discern only a crustal adjustment beginning on the outskirts in Asia Minor on the east, and near the Alps on the north: trains of earthquakes follow along the geological structure as if set off by the shift of stress towards a centre.

The equatorward shift of shocks in small groups at brief intervals is not infrequent in the northern hemisphere, but the opposite behavior is not wanting. A striking case of equatorward shift of seismic stress is recorded in the Report for the year 1910. On January 22nd, a sharp shock was registered which had its origin near Seydisfjord, Iceland, at 8h. 47m. 51s. G. M. T. on the Arctic Circle. At about 8h. 30m. P.M. (1h. 30m. on the 23d, G. M. T.), a slight shock was felt near Portland, Me., in L. 43° 30′ N. On January 23rd, at 18h. 49m. 19s. G. M. T., an earthquake occurred off the Lesser Antilles which was felt at St. Vincent. Quiet reigned for weeks before and after over the North Atlantic border.

The intervals between the first and second, and the second and third of these shocks much exceeds the limit of duration of the vibrations set up in the globe by a primal great shock. On a globe recovering the normal figure of ellipticity deformed by circumpolar ice-caps, it is to be expected that adjustment in high latitudes affecting the polar flattening would meet with a response in the equatorial region. Inasmuch as the polar regions were during the glacial period the seat of the perturbation, it is natural to suppose that by reason of the disappearance of the ice, seismic disturbances would originate there and be propagated southward. The postglacial adjustment of the figure of the earth so far as it took place by faulting should give uplift in high latitudes, downsinking in low latitudes, and indifferent movements or lateral motion in middle latitudes. The uplift of 42 feet in Russell Inlet, Alaska, described by Tarr and Martin as taking place in 1899 in a region of retreating glaciers, the San Andreas fault earthquake of 1906 in California with a lateral motion of 16 feet, are accordant with this hypothesis. The Mino-Owari fault of central Japan in 1891 had a large lateral displacement, as well as an indifferent vertical movement since the motion was reversed either side of a mid-point in the length of the dislocation. But facts are wanting on which to base any conclusion as to the present tendency over the entire field of active faults.

A similar equatorward progression of small shocks is apparent in the records of New England for the years 1842–1843. The most striking instances occurred in the year 1847, during which two lines of shocks beginning on the northeast in Nova Scotia on one side and in Ontario on the other seem to have concentrated on Boston and to have been followed by an earthquake on the "fall-line" as far south as Philadelphia. The coastal series comprised a shock at Yarmouth, N. S., on January 1; at Camden, Me., on February 2nd; at Livingston, Me., April 1; from Boston to Nantucket, on August 8; from Newport, R. I., to Philadelphia, Penn., on September 2nd. Prior to the Boston shock of August 8, an interior series is recorded from north to south (-east) as follows: Grafton, Ontario, on January 8; Albany, N. Y., January 11; at Deerfield, Mass., on February 2nd; then north of Albany at Glens Falls on July 9, preceding the Boston shock of August 8.

From 1848 to 1851 the seismic action played back and forth, on the whole with shocks on the south preceding occurrences on the north. The southward march along the coast from Nova Scotia was repeated in 1853. The records begin with a shock in the interior on the western slope of the Adirondacks at Lowville, on March 13. Next there was a shock at Ottawa on May 24. Ten days later, on June 3rd, at Bridgeton, Nova Scotia. 44 days later, on July 17, in southwestern Maine; after 52 days, on September 7, at New Bedford, Mass. In short, an analysis of the data from 1840 to 1870 exhibits midst a jostling interaction in various directions marked periods of steady southward progression of shocks in series.

The Anglo-Saxon Chronicle mentions six earthquakes which took place in England during the 10th and 11th centuries. The first one on the calends of May 1048 was felt at Derby, Wick, in Worcester, and elsewhere. There was a "great" earthquake in the year 1060 on the Translation of St. Martin's (Nov. 11), the place of which is not stated. Again on the eve of St. Michaelsmas (September 29) in 1119, Worcestershire and Gloucestershire were shaken. On the eighth day before the calends of August 1122, Gloucestershire and Somersetshire were shaken. Lastly, in this group, on the night of the mass of St. Nicholas (December 6), 1129, a little before day, "there was a great earthquake," the locality of which however is not given. Now Derby, Worcester, Gloucester, and Somerset are shires succeeding each other from north to south in the order in which they were visited by earthquakes in this mediaeval account in the years 1048, 1119, and 1122, at long and irregular intervals within the space of a man's life. I have cited this document in order to show that the phenomenon of southward shift of epicenters in the northern hemisphere is not peculiar to our own time or a single region.

Hours at which Earthquakes have been registered at the Harvard Station.— The International Catalogue for 1907 includes a list of more than 6400 earthquakes. The Harvard records show an average of about 81 per annum, too small a proportion of the total annual registration for the world to be made the basis of other than a few limited problems in seismology. This $1\frac{1}{4}\%$ of the total however reveals upon a statistical study certain features having a practical utility in the conduct of the station. The following table has been drawn up showing the G. M. T. hours at which earthquakes have been registered for the years 1910–14.

Hours of Earthquakes registered at Harvard.

G.M.T.	0	1	2	3	4	5	6	7	8	9	10	11
Local	7	8	9	10	11	12	1	2	3	4	5	6 A.M.
1910	3	1	1	1	3	1	4	2	5	1	2	2
1911	2	2	6	1	5	4	3	1	1	1	3	3
1912	1	1	2	3	3	0	0	7	3	6	4	2
1913	4	4	2	5	3	2	1	4	6	4	5	3
1914	3	0	3	8	8	4	3	3	2	5	8	2
Sums	13	8	14	18	22	11	11	17	17	17	22	12

G.M.T.	12	13	14	15	16	17	18	19	20	21	22	23
Local	7	8	9	10	11	12	1	2	3	4	5	6 P.M.
1910	0	2	1	1	0	0	3	4	1	1	0	1
1911	2	4	3	0	3	1	7	3	2	3	3	5
1912	9	3	3	3	5	7	8	2	2	8	4	5
1913	5	3	2	4	2	8	7	2	2	4	2	4
1914	4	2	2	3	3	6	3	4	3	1	4	2
Sums	20	14	11	11	13	22	28	15	10	17	13	17

The table shows a tendency to maximum frequency at 4hr., 10hr., and 18hr. When the 6400 earthquakes of the 1907 list for the world are analyzed in the same way as to the hour of their occurrence, maxima of frequency appear at 3hr., 10hr., and 17hr. It thus comes out that the records of this Station within five years, though only about 6 per cent in number of those for the world in the year 1907, bring out a peculiarity of the horary occurrence in absolute time.

Obviously it is wise to avoid disturbing or adjusting a seismograph at the hours of maximum expectancy of earthquake registration. As the registration may take one or more hours, the hour succeeding to those named should also be set aside for that purpose. As there is a maximum registration at 18 hours G. M. T., i. e. between 1 and 2 P.M. in 75th meridian time west, in eastern North America, that hour is the best during which to observe the registration of earthquakes on seismographs with mechanical registration if it is desired to witness this sight. The observer who watches his instruments during that hour will sooner or later be rewarded by the exhibition of his seismograph in action.

The large earthquakes originating during the 18 hr. interval G.M.T., midnight to midnight, are according to Milne's lists for 1904–1910 not less than 10 in various latitudes north and south of the equator between 135° and 150° east longitude as compared with six, the highest number occurring at any other hour in the same sensitive gore of the globe. In 1910 alone five large earthquakes were traced to the same gore at the same hour of the day. The persistence of this 18 hour maximum is presumably due to an ascertainable relation between the state of the crust in the gore of maximum frequency and some regularly recurrent phenomenon, such as the passage of a change in atmospheric pressure. This hour in longitude 135 to 150 East corresponds within 40 degrees of the equator to the time of passage of the morning minimum of atmospheric pressure from 4 to 5 A.M. local time counted from one standard meridian to another.

The chief morning minimum of pressure passes round the globe in advance of the sun traversing gore after gore at successive hours of standard time Greenwich. That this auroral epoch is characterized by frequent destructive earthquakes witness San Francisco at 5h. 13m. local time on the morning of April 18, 1906, Messina at 5h. 24m. on the morning of December 28, 1908, not to mention earthquakes unassociated with the devastation of populous towns and cities. Early rising and an out door life are much to be recommended in earthquake countries!

The modern seismograph has shown that the crust of the earth is sensitive to vibrations imperceptible to human senses and the times at which earthquakes occur agree with the indications of the same delicately poised instrument in indicating that the movements of the atmosphere made manifest by the barometer are not without their effect on sensitive gores of the globe. If the time and place at which certain earthquakes occur are under atmospheric control, the future of seismology is brighter than it would be if the prediction of seismic disasters depended entirely upon the progress of the geologist's researches in the impenetrable depths of the solid globe.

New England Earthquakes: —A brief account of North American earthquakes for the year is given by Professor Harry Fielding Ried in The American Year Book for 1914, p. 596–598. From this work it appears that a light shock was felt at St. Stephen, N. B., and Calais, Me., early on January 15th. Not recorded at this Station.

Press despatches describe tremors felt at Eustis and in the neighboring towns Rangely, Phillips, and Flagstaff, in southwestern Maine, on the evening of February 21, at 7: 15, 7: 20, and 7: 35, E. S. T. The second shock tumbled down a woodpile. Mr. Ralph Sawyer of White Rock, Me., states that a northeast-southwest fault traverses these towns.

On February 10th (see record no. 363) a widely felt shock was registered at the Station whose origin appears to have been in northern New York somewhere between Watertown and Ogdensburg 120 kms. distant from Ottawa. The Ottawa record makes the time at origin according to existing formulae for speed transmission 1h. 30m. 42.5s. P.M. The Harvard record gives the time at origin 1h. 30m. 43s. when the long waves appearing at 1h. 33m. 07s. are employed in the calculation, but the record shows a motion at 1h. 32m. 51s. which has the same characters. In the first case the distance would be 580 kms. from Cambridge, intersecting with Ottawa's distance curve near or on the 45th parallel in Ontario about 75 miles west by south from that city. The shorter reading gives the Harvard distance 435 kms., and places the origin in northern New York, but making the time at origin 1h. 31m. 02s. The Cornell (Ithaca, N. Y.) record beginning P 1h. 32m. 10s. with distance 300 kms. meets the distances from Harvard and Ottawa also near the 45th parallel in Ontario, but the time at origin comes out 1h. 31m. 27s., differing as much from the Harvard record as the Harvard record on one interpretation differs from that of Ottawa. Reid places the origin in northern New York.

The earthquake was felt from Boston to Buffalo, and from Montreal to Philadelphia. In the Connecticut and Hudson valley towns furniture was said to have been moved in houses, school children were alarmed, and bric-a-brac was knocked from shelves to the floor. A man was killed in Binghampton, N. Y., according to the statement given to the press, by the fall of earth in a trench in which he was at work. Reid estimated the area shaken at 150,000 square miles. The hour, between 1 and 2 P.M. corresponds to the hour of the day at which shocks near and distant are most frequently registered at this Station.

In Cambridge, Professor Faxon and Mr. Clapp of the Museum of Comparative Zoölogy, felt a rocking motion on the top floor of that building at the maximum of motion. The open doors of collection cases swayed gently to and fro. In Boston a lady recognized seismic motion on the second floor of the house in which she was at the time. By most people the shock passed unobserved.

The slight shock registered February 14th (see no. 366) was felt along the St. Lawrence River near Quebec. With Ottawa distance = 225 kms. and Harvard distance = 520 kms., the origin comes out on the south bank of the St. Lawrence River near Sorel.

Frost Cracks: — Several frost cracks were registered during January and February, again during cold nights with nearly bare ground. On the night of January 13th when several of these disturbances were registered in Cambridge, Mr. J. H. Cowdrey of 722 Webster St., Needham, Mass., felt a shock at his home between 7 and 7:15 P.M., another about 15 mins. later. Other similar shocks were noticed by him still later in the evening. Record no. 37 of March 1 was registered during a southeast rain storm on old snow.

Bulletin of the Museum of Comparative Zoölogy

AT HARVARD COLLEGE.

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HARVARD SEISMOGRAPHIC STATION. SEVENTH ANNUAL REPORT INCLUDING RECORDS, 1 JANUARY–31 DECEMBER, 1915.

By J. B. Woodworth.

With One Plate.

CAMBRIDGE, MASS., U. S. A.:

PRINTED FOR THE MUSEUM.

November, 1917.

No. 5.— *Harvard Seismographic Station. Seventh Annual Report, from 1 January to 31 December, 1915, G. M. T.*

By J. B. Woodworth.

The records herewith presented continue the list published in Bull. M. C. Z., **55**, p. 78–108. The constants of the Station are:

Latitude 42° 22′ 36″ N. Longitude 71° 06′ 59″ W. Altitude 5.36 M.
Subsoil: — Glacial sand over clay on tilted Carboniferous (?) shales.
Time: — Mean Greenwich, midnight to midnight. Eye and ear comparison with Harvard Observatory through telephone.
Instruments: — Two Bosch-Omori 100 kg. horizontal pendulums, with mechanical registration on smoked paper.
Nomenclature: — Göttingen: also O for time at origin.

Constants of the Pendulums:	*N–S.*	*E–W.*
Period	22.5 *secs.*	24.8 *secs.*
Magnification	50	80
Damping ratio	4:1 ca.	0:0

In the column of Remarks entries are confined to an explanation of the Harvard record, the source of Δ and O, and conditions of registration throwing light on the accuracy or inaccuracy of the data. Additional notes concerning the earthquakes listed in the tabulated times of phases are appended at the end of the Harvard list.

The distance (Δ) of the epicentre from the Harvard Station, in kilometers, is given usually on the basis of the interval S–P, in accordance with the tables of Wiechert and Zöppritz with interpolations by Zeissig, published in 1910, and available for distances up to 13,000 kms. Where O is given with P and S present in the Harvard record, the transmission time P–O (Ip as suggested by Dr. Otto Klotz) has been taken directly from the Hodograph der Normalen P Wellen für eine mittlere Herdtiefe der Erdbeben elaborated by Mohorovicic of Agram. These and other tables necessary for the determination of Δ, O, and the epicentre (*), have been recently published by Dr. Klotz in Seismological Tables (Publications of the Dominion observatory, Ottawa, 1916, **3**, p. 19–61, 2 plates). In a few instances early in the year, Δ, and hence O, was determined from eL–S (Is of Klotz) from the admirable tables of Prof. J. B. Goesse, S. J., of the

St. Louis observatory. An asterisk (*) prefixed to the number of a record indicates that some revision of the data issued in the monthly mimeographed bulletin of the station has been made. Such revision affects also the Harvard records published in the Monthly weather review, Washington, D. C., vol. 43, for 1915.

EARTHQUAKES REGISTERED DURING THE YEAR 1915.

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
434	Jan. 5	*O*	*23 37 41*		3950	
		eP_N	23 44 56			
		S_E	23 50 40			
		eL	23 54 01	10–15		
	6	M_E	0 18 22	24		
		L_N	0 32 36	20		
		F	0 56			
435	10	eL?	23 24 26	20–15		
		F	23 45 ca			
436	13	*O*	*6 52 31*		6750	Verazzano destroyed.
		eP_E	7 02 45			
			7 04 17	4		
		S_E	7 11 01			
		eL_E	7 19 21	35		
		L	7 22 24	25		
		L	7 26 25	20		
		M_E	7 27 48	26		
		F	8 05 ca			
437	27	*O*	*(1 09 48)*		(7400)	O from Shide.
		e_N	1 37 44			
		L_E	1 40 30	40		
		L	1 41 14	22		
		L	1 43 37	16		
		L	1 45 42	20		
			to			
			1 48 18			
		L	1 49 04	20–16		
		L_N	1 51 33			
		F	2 12			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
438	Feb. 7	*O*	*5 16 30*		15	Local shock: Not reported by laymen.
		iP$_N$	5 16 32			
		iM	5 16 34			
		F	5 16 5			
439	16	*O*	*17 05 26*		85	Not heard from.
		iP	17 05 38			
		M	17 05 48			
		F	17 05 54			
440	16	*O*	*19 24 39*		100	Not heard from.
		P	19 24 53			
		M	19 25 05			
		F	19 25 18			
441	19	*O*	*22 24 58*		90	Not heard from.
		P	22 25 10			
		M	22 25 20			
		F	22 26 52			
442	20	*O*	*15 36 37*		20	Not reported as felt.
		iP	15 36 40			
		M	15 36 42			
		C	15 36 50			
		F	15 37 06			
443	20	*O*	*19 54 13*		95	Not heard from.
		iP	19 54 18			
		L	19 54 37			
		C	19 55 02			
		F	19 55 18			
444	20	*O*	— — —		?	Not heard from.
		P$_N$	23 08 38			Deflection N. No M.
		F	23 09 48			
445	21	*O*	*0 39 08*		?	Not heard from.
		iP$_N$	0 39 15			
		L	0 39 21	6		
		M	0 39 34			$A_N = 6\mu$.
		F	0 39 42			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
446	Feb. 21	*O*	— — —		70?	Not heard from.
		P.	1 20 11			
		L	1 20 19			
		F	1 21 01			
447	21	*O*	*1 56 58*		40	Felt in Haverhill, Mass. (45 kms.) at "8.55." p. m.
		P	1 57 06			
		L	1 57 10			
		M	1 57 12			
		F	1 57 22			
447a	21	*O*	*1 57 49*		45	Cf. 447.
		P	1 57 57			
		L	1 58 05			
		F	1 58 16			
448	21	*O*?	— — —		?	Phases indistinct. No M. Lowell, Mass. reported shock felt at 9.05 p. m.
		P	2 02 46			
		F	2 03 46			
449	21	*O*	*2 20 53*		20	Felt at Andover, Mass. Lowell reported shock felt at 9.30 p. m. (2.30) G.M.T.
		P	2 20 55			
		L	2 20 58			
		F	2 21 17			
449a	21	*O*	*2 35 14*		30	$A_N = 5\mu$. Felt at Andover, Mass. (30 kms.). Another at 9.35 p. m. of which there is a trace on records (N). Also 9.45 at Andover (trace on N).
		P	2 35 18			
		L	2 35 21			
		F	2 35 38			
450	21	P_N	3 09 30			Phases indistinct.
		F	3 09 36			
451		O	20 18 ca			P 20–18–15; L 20–18–29; F 20–18–48.
452	23	*O*	*23 13 05*		145	
		P	23 13 25			
		L	23 13 42			
		F	23 14 10			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
452a	Mar. 25	*O?*	*9 03 43.5*		3440?	O from S–P?
		PE?	9 10 19	3		Phases masked by micro-
		S	9 15 32	6		seisms.
		LE	9 25 19	12		A 0.25 mm. on record.
		LN	9 26 06	16		A 0.25 mm. on record.
		M	9 28 53			
		F	9 48			
452b	25	*O*	*20 47 19*		9200	
		P?	20 59 42			Phases masked by micro-
			21 01 34			seisms.
		iS	21 10 02	6		
		eLN	21 23 36	13		
			21 24 38	20		
		LN	21 46 07	20		
		F	21 48			
452c	25	*O*	*22 14 06*		260	Unheard from.
		P	22 14 48			
		L	22 15 17			
		F	22 15 49			
453	28	*O*	(*18 59 23*)		(10140)	O from Manila Δ 900.
		e	19 38 20	7		(Δ) from L–O.
			19 39 30	6		P and S in micros.
		LE	19 49 34	40		
		L	19 54 02	30		
			19 58 03	26		
		M	19 59 20	22		A 0.5 mm. on record.
		F	20 49 ca			
454	5	eN	4 36 26			
		LE	4 37 43			
		LN	4 37 58	7		
		F	4 49 28			
455	12	O	(*14 48 48*)			O based on Riverview.
		eN	15 53 12			Masked by microseisms.
		LN	15 56 35	18		
			16 01 59			
		F	16 05			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
456	Mar. 20	e?	22 — —			
		LN	22 51 12?	18		F? lost in micros.
457	31	e	17 53 16			Masked by microseisms.
		LE	17 54 36			
		F?	18 01 —			
458	Apr. 3	LE	21 04 46			
			21 07 43	18		
		F	21 25 ca	16–18		Masked by microseisms.
459	7	*O?*	(15 55 35)		4300?	O from La Paz.
		e?				Masked by microseisms.
		S?E	16 11 57			N comp. restrained by friction.
			16 13 46	8		
			16 15 17	13		
		eL	16 15 59	10		
		L	16 20 44	16		
		F	16 37			
460	23	*O*	*15 29 10*		4670	P and S strong; LL weak.
		PN	15 37 21			
		PE	15 37 23			
		SE	15 43 45	6		
		SN	15 43 46	6		
		SR1?	15 46 04			
		LN	15 48 42	16		
		F?				F lost in microseisms.
461	28	eE	4 10 04			N record faint.
		L	4 13 28	20		
			4 17 38	20		
		F	4 41 ca			
462–3	May 1	*O*	*5 00 04*		8980	Mean O: 5–00–11.
		ePN	5 12 16			Kurile Islands?
		ePE	5 12 21			
		SE	5 22 25	32		
		SR1?	5 28 14			
		SR2	5 28 39			
		eLE	5 37 29			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
462–3	May 1	M1N	5 46 15			57 mm. trace.
		M2	5 50 07			67 mm. trace.
			5 53 41			
		CN	5 57 29			
		F?	8 17			
		e?	9 29 17			No trace N.
		LE	9 32 31	20		M² which has travelled
		L	9 34 06	16		48980 kms. at 180 kms. ±
		L	9 36 40	15		per min.
		F	9 38 ca			
464	May 5	*O?*	*11 17*		8730?	O? from eL–S? P in
		S?	11 39 31	8		micros.
		eL	11 53 50	18		
		LE	12 19 07			
		LN	12 19 31			
		LE	12 20 49	20		
			12 33 31	20–15		
		F?	12 50			
465	6	*O*	*12 08 02*		4820	
		ePE	12 16 26			
		?	12 19 55	6		
		S	12 22 58			
		eL	12 33 44			
		M	12 33 59			
		to	12 35 14			
		F	13 20			
466	8	*O*	*(13 42 58)*			O from Cartuja (Granada).
		e	14 44 42	var.		
		to	15 10			
467	12	*O*	*10 29 42*		6075	O from eL–P.
		ePE	10 39 29			S ill-defined.
		eE	10 42 14			
		eN	10 43 02	8		
		eLE	10 55 23			
		LE	10 57 04			
		LE	10 59 26	24		
			11 10 17	15		
		F?	11 30			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
468	May 21	*O?*	*4 19 —*			O by Cartuja (Granada).
		O?	*4 27 46*		8800?	See note p. 130.
		eN	4 40 00			
		eLE	5 04 36			S uncertain.
		LE	5 08 09	16		
			5 10 30	24		
			5 14 00	16		
		F	5 30 20			
469	June 1	*O*	*14 43 50*		5100	
		ePEN	14 52 29			
		SN	14 59 13			
		SE	14 59 17			
		SR_1N	15 02 37	15		
		SR_1E	15 02 41	15		
		eLE	15 05 06			Sinusoidals set in.
		LN	15 07 09	26		
		LE	15 08 47			
		ME	15 12 33			
		CE	15 17 03			
		F	16 15			
470	6	*O*	(*19 36 25*)			O by Riverview (Sydney). See note, p. 131.
		eE?	20 16 26			P and S in microseisms.
		LE	20 38 07	30–20		SN? 20–33–54.
		F	20 50 ca			
471	6	*O*	*21 29 37*		6450	
		PN	21 39 32			
		PE	21 39 34			SE undamped of large amplitude.
		SN	21 47 32			
		SE	21 47 34			Undamped pendulum gave MM at 24–47–53; 21–49–31; 21–50–32. No decided MN.
		eLE	21 54 14			
		eLN?	21 54 30			
		FN?	22 58			
	7	FE	0 20 ca			
472	22	*O*	*3 24 22*		6790	
		eP	3 34 40			
		SE	3 42 58	6		

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
472	June 22	L	3 43 42	10		LL indistinct.
		F?	3 50 48			
473	23	*O*	*4 00 21*		4110	O from eL–S deciphered in light of published data.
		eP?N	4 06 28			
		S	4 13 45	6		
		eL	4 17 31			
			4 18 08	10		
		F	4 54 ca			
474	23	*O*	*4 58 34*		3850	
		eS?	5 11 20			
		eL	5 14 31			
		MN	5 14 38			E comp. gives different but more doubtful readings. Short period phases.
		F	5 35			
475	27	*O?*	(*15 25 46*)			O from Strassburg.
		LE	15 51 16			
		F	16 22			
476	July 8	*O*	(*22 30 48*)		7700?	O from Honolulu.
		LE	23 08 41	15		With Harvard eL? 23–08–41, Δ comes out ca. 7700. North.
			23 12 27	28		
			23 14 45	24		
		F	23 25 56			
477	22	*O?*	*4 06 08*		7140	Readings doubtful.
		ePN	4 16 44			
		SN	4 25 20			
		SE	4 25 36			
		eLE	4 30 02			
		LN	4 32 52			
		F	4 46 00			
*478	25	*O?*	*20 47 26*		7400?	
		ePR?	21 06 56	7		eP doubtful.
		LE	21 18 12	28		Not legible on N comp.
		F	21 49 00			
479	29	*O?*	*10* — —			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
479	July 29	LE	10 55 58	20		
			10 59 46	15		
		F	11 04 22			
480	July 31	*O*	*1 31 26*		8200	
		PE	1 42 58			
		PN	1 43 00			
		PRE	1 45 48			
		PRE	1 47 20			
		SE	1 52 28			
		SN	1 52 40			
		SRE	1 58 26			
		eLE	2 03 02	60		
		LN	2 03 56			
		LE	2 10 10	22		
		LN	2 19 54	14		
		FE	4 21 00			
481	Aug. 3	*O*	(*13 04 27*)		14780	O from Honolulu Δ8920.
		LE	14 16 04			
		LR1	15 06 10			
		F	15 47 12			
482	6	*O*	(*13 12 03*)		9000	O from Sydney.
		eP?	13 23 25			eP in micros.
		S	13 35 09			
		eLN	13 55 18	20		
		LE	14 00 53	24–22		
		F	14 55			
483	7	*O*	(*15 04 16*)			O from Barcelona Δ1510.
		e	15 31 09			
		L	15 39 27	20		
			15 46 05	16		
		F	16 07 ca			
484	18	*O*	(*23 56 42*)			O from La Paz.
	19	e?E	0 21 15?			
		eL?	0 30 20			
		L	0 40 23	15		
		L	0 53 03	24		

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
484	Aug. 19	L	1 19 04	16		
		F	1 25 ca			
485	Sept. 6	*O*	(*17 20 36*)		10,300?	O from Riverview.
		e	17 53 39			
		L	18 16 55			
		L	18 22 15	15		
		F	19 22			
486	7	*O*	*1 20 30*		3580	N damped 4 : 1. E undamped. O from S–P.
		iPE	1 27 19	2		
		N	1 27 21	2		
		iR	1 27 51			
		iR	1 27 56			
		iR	1 28 33			
		iR	1 28 40			
		iSN	1 32 41			
		iSE	1 33 54			
		eLE	1 34 23	26		
		ME	1 35 54			
		eLN	1 37 01			
		ME	1 38 07			
			1 38 35			Stylus off drum.
		MN	1 39 42			Stylus off drum.
		E	1 39 44			Stylus on drum again.
			1 40 01			Off drum 2d time.
		MN	1 40 53			On drum again.
			1 40 58			Off drum 2d time.
		ME	1 41 03			On drum again.
			1 42 58			Off drum 3d time.
		MN	1 43 20			On 2d time.
		ME	1 44 05			On 3d time.
			1 44 21			Off 4th time.
		CN	1 45 03			
		ME	1 45 22			On drum 4th time.
			1 46 11			7th M on E.
			1 47 14			8th M on E.
		CE	1 50 02			
		LRN	2 35 03	12–14		
		FN	2 59 56			Damped pendulum.
		FE				in next.

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
*487	Sept. 7	*O*	*4 28 42*		3610	
		eSN	4 35 31			
		eL	4 40 50			
		L	4 44 25			
		F	5 05			
*488	7	*O*	(*4 58 07*)			O by La Paz.
		e	5 10 30			
		L	5 15 34			
		L	5 20 19	10		
		F	5 37 ca			
*489	7	*O*	*12 48 28*		3220	
		ePN	12 54 45			
		PE	12 54 59			
		SN	12 59 43			
		SE	13 00 27			eL to F lost in changing records. Hour in Bulletin given as 7 (local) instead of 12 G.M.T.
490	7	*O?*	*20 39 52*		3040?	Times uncertain from doubtful setting of ticker.
		eP?	20 45 53			
		S?	20 49 39	7		
		L	20 53 44			
		L	20 59 12			
		L	21 02 47			
		F	21 33			
491	Oct. 2	*O*	(*23 41 —*)			O from Berkeley.
		e	23 58 12			Northern Nevada. See 492.
		SE	23 59 55	6		
	3	LE	0 01 22	8, 10		N component out of commission.
		F	0 05 52			
492	3	*O*	(*1 48 35*)			O from Berkeley Δ 340.
		e	2 03 17			
		SE	2 06 35			
		LE	2 08 50	10, 12		
		F	2 25 22			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
493	Oct. 3	*O*	*6 53 12*		3780	Northern Nevada. See note p. 137.
		ePE	7 00 06			
		S	7 05 40			
		eL	7 10 36			
		M_1	7 12 11			
		F	8 57 ca			
494	11	*O*	*19 33 23*		2450	
		ePE	19 38 25	3		
		ePE	19 38 44			
		S	19 42 24	10		
		eLE	19 45 22			
		LN	19 48 51	11, 12		
		F	20 40			
495	12	*O?*	*22 (circa)*			
		e	22 19 38			
		eLE?	22 22 00	17, 24		
		L	22 28 10	15		
		F	22 43 ca			No trace on N. e in micros.
495	12	*O?*	*(21 29 35)*			O from Cartuja (Granada). e in microseisms.
		eE	22 19 38			
		eL?	22 22 00	17–24 20		
		L	22 28 10	15		No trace on N, damped 4:1.
		F	22 43 ca			
496	Nov. 1	*O*	*7 24 31*		9590	From S–P. eP in micros.
		eP	7 37 13			
		SE	7 47 06			
		SN	7 47 52	6		
		eLE	8 09 59			
		ME	8 20 28			
		LR_1	9 50 36	18–20		
		F	10 33			
496a	18	LE	4 55 49	20		
		F?	4 58 49			
497	21	*O*	*0 13 35*		3900	From eL–S. S–eP gives Δ3850; O : 0–13–39.
		ePE	0 20 46			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
497	Nov. 21	S_N	0 26 33			
		S_E	0 26 35			
		eL_E	0 29 54			
		eL_N	0 30 00			
		M_N	0 33 14	16		A trace on 'gram, 30 mm.
		M_E	0 33 58			Stylus left drum, returning
		M_E	0 35 57			at 1–35–34.
		C_N	0 36 03			Maxima of E undamped
		C_E	0 39 50			less than M_N damped 4/1.
		F	1 45 ca			
498	26	*O*	(*19 12 01*)			O from Balboa Heights.
		e?	19 27 34			e to F masked by micro-
		L	19 31 46	20		seisms.
		L	19 36 14			
			to	16–13		
			19 39 14			
498a	Dec. 3	L_N	3 42 10	25–30		
		L	3 47			
		F	4 06			
499	6	*O?*	*20 26 ca.*		16900?	Δ? from L_{R_1}–L = 30.75
		e?	21 30 35			mins.
		eL_E	21 49 15			P and S masked by micro-
		L	21 50 30			seisms.
			to	20		
			21 52 28			A decreases suddenly.
		L_{R_1}	22 20 00			
			to	12		
			22 22 22			
		F	22 59			
500	7	*O*	*10 38 26*		4500	
		P_E	10 46 20			
		S	10 52 37	6		
		L	10 57 08			
		F	11 28			
501	7	*O?*	*12 30 25*		2460	
		iP	12 35 28	2		

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
501	Dec. 7	S?	12 39 30			
		eL	12 41 36			P? 12 41 36; another quake ?
		L	12 53 34	16		
			13 10 02			F lost in microscisms.
			to	10		Changed records at 13h.
			13 11 39			35m. 30s.
		F?	— — —			
501a	Dec. 7	*O*	*(18 40 09)*			*O* from St. Louis records.
		iP	18 43 35			Reported near Cairo, Ill.
		L_E	18 47 50			
		L_N	18 48 14	4		
		F	18 50 ca			
502	8	e?	18 25 53	11		Record of doubtful charac-
		L	18 33 46	70		ter. Preceded and followed
				36		by similar disturbances.
				62		
		L	18 39 05	26		
		L	15 44 14	15		
			to			
			18 46 24			F indeterminate.
503	12	*O*	*21 02 01*		4000	
		P_N	21 09 19	3		
		iP	21 09 35	4		iP steady-mass thrown
		eP_E?	21 10 34			south.
		S_N	21 15 06			Except P_N, record much
		S_E	21 15 23			masked by microseisms.
		L_N	21 18 20			
		L_E	21 18 22			
		F?	21 35 30			F masked.
504	17	L_E	5 57 29	16		Masked by microseisms.
		F	5 58 31			
505	17	*O?*	*7 40 21*		4345?	eS? Δ from L–S?
		e?	7 54 11			
		L_E	7 58 30	20		Not registered on N.
		F	8 15 12			

No.	Date	Phase	Time	Periods	Δ	Remarks
	1915		h. m. s.	s.	Kms.	
*506	Dec. 18	*O*	(*18 26 33*)		7700?	O from La Paz.
		e?	18 48			Harv. Δ from L–O.
		LE	19 00 14	27		Record in tangled lines;
		L	19 05 13	15		deciphered on identifica-
		F?	19 30 ?			tion of hour-line with La Paz.
507	19	*O?*	(*20 23 ca*)			O from Riverview.
		LE?	21 23 ca			
		F	21 44 ca			
508	28	*O*	(*23 88 44*)			O from La Paz.
	29	LE	0 12 34			e earlier? Much masked
		F?	0 17 58			by microseisms.
509	31	*O*	*12 19 23*		4810	
		eP	12 27 38			
		PR1	12 28 57			
		SE	12 33 53			
		SN	12 34 00			
		cLN	12 40 25			
		LE	12 41 13	10–12		
		ME	12 45 03	16–14		
		F?	13 42			
509a	31	*O?*	*23 07 04*		3300?	Minute ticks failed; time
		cPE?	23 18 56?	2		interpolated. Not regis-
		S	23 18 4	6		tered N–S.
		SR1	23 20 10	8		
		eLE	23 32 50	8		

Notes on Earthquakes, with abstracts from data received from other observatories.

434. Jan. 5.— O: 23–37–41. Cf. Heidelberg Δ2920? O: 23–33–13. Athens P 23–38–30; Δ8850; O: 23–26–25; "Epicentre en Virmanie." Ottawa Δ4220; O: 23–37–33. La Paz Δ10, 040; O: 23–32–26. Batavia Δ2780; O: 23–27–44. Shide reports O: 23–26–28; and epicentre λ119° 30′ E., φ25° N. Riverview (Sydney) iP 23–37–08; Δ6900; O: 23–26–46.

435.— *Cf.* Riverview (Sydney) e(S?) 23–30.4.

436. Jan. 13. Athens Δ890; O: 6–52–43. Heidelberg Δ940; O: 6–52–36.6. Shide O: 6–52–38; epicentre λ13° 30′ E., φ42° N. (G. Agamennone). Ottawa Δ6860; O: 6–52–37. Destructive earthquake at Avezzano and about Lago di Fucino in Italy. According to the press version of an official report, 372 communes were damaged and 29,978 human lives were lost as a result of this earthquake. In an earthquake at Norcia, 55 miles northwest of Avezanno in 1703, 81% of the total population was killed. In the present instance, the death rate in Avezzano was 96%; in Cappelle 97%; in Pescina 4,500 persons were killed; at Massa d'Albe 3,300; at Celano 3,300; at Cenchio 2,450; at Magliano di Marsi 1,300; and at Paterno, 1,000. Deaths occurred also in Scanno, Campobasso, Sulmona, Popoli, Aquila, Cittaducale, and Monterotondo, and other towns within thrity-five miles from Avezzano. *Vd.* Carl H. Beal. The Avezzano earthquake of January 13, 1915. Bull. Seismological soc. Amer., 1915, **5**, pp. 1–4. C. Davidson. Nature, January 21, 1915, **94**, p. 565. Bailey Willis. The catastrophe of Avezzano. Bull. Seismol. soc. Amer., 1915, **5**, p. 168, citing M. S. Navarro Neumann, S. J.: Revista de la Sociedad astronomico, Ano v, Enero-Febrero 1915, num. 40; Essai de quelques formules aux tremblements de terre de Messina et d'Avezzanno. Modena, 1915. 8 pp.

437. Jan. 27. Preliminary tremors were largely suppressed at this station. Shide reports O:1–09–48; epicentre in λ19° 30′ E., φ38° N. Athens P 1–10–36; Δ300; O: 1–09–52. Heidelberg Δ1500; O: 1–09–51. A severe earthquake in Ithaca, Greece.

438–452. Feb. 7 to 23. Records of slight nearby shocks, of which, however, only a few were reported, felt in the Merrimac Valley in Massachusetts and in neighboring parts of southeastern New Hampshire. Nos. 447, 448, 449, 449a agree reasonably closely with the press despatches, and there can be little doubt that the records are those of the shocks reported, particularly since the distance indicated by the seismogram also accords with the area shaken. The unfelt records are confessedly puzzling and subject to doubts. They have not been counted in the number of earthquakes recorded during the year, for the reason that the instrumental evidence lacked confirmation as to the seismic origin of the disturbances. See note on New England earthquakes, p. 146.

452a. Feb. 25. O: 9–03–43.5. *Cf.* Ottawa Δ3000? O: 9–05–35. Honolulu P 9–16–54; Δ?1150; O: 9–14–23. Victoria P 9–03–37; Δ1, 050? (given as 800 kms.) Toronto P 9–13–00; Δ3350; O: 9–06–31. Berkeley e9–04–35; F 9–34. Not reported by Manila, Riverview (Sydney), Athens, La Paz. Origin probably near Victoria, British Columbia.

452b. Feb. 25. O: 20–47–19. Ottawa Δ9150?; O: 20–47–08. La Paz Δ13,000+, Barcelona Δ8530?; O: 20–43–41. Batavia Δ7240; O: 20–35–51. Riverview (Sydney) gives two earthquakes, viz.: iP 20–41–17; Δ2500; O: 20–36–10. iP 20–53–34; Δ2660; O: 20–48–10. λ179° E., φ31° S. Record 452b probably represents both of these disturbances in some respects. With the origin of the first as given at a distance of about 13,500 kms. from Cambridge the P S and L waves should have come in at P 20–52–02±: S 21–05–14±; eL 21–21–42–58±. The complete non-correspondence of the Harvard record, deciphered without prejudice arising from a knowledge of where and when an earthquake had taken place, raises the question whether the Harvard and Ottawa records may not refer to a third shock.

452c. Compare 452. No reports. Possibly these shocks arise on the sea-floor off the coast.

453. Feb. 28. O: 18–59–23; Manila Δ900. La Paz Δ13,000+; Ottawa 13,000+; Barcelona L 19–43–30. Heidelberg Δ7910; O; 19–19–45. Riverview Δ6800; O: 18–59–19? With Harvard eL 19–49–34, Δ comes out 10,140? kms. Origin in the Philippine tract.

454. March 5. 4 hrs. *plus.* A not very distant earthquake; unrecorded at Athens, Heidelberg, Riverview, Manila. La Paz L 4–41–50. Ottawa L 4–36–00. Victoria iL 4–33–38. St. Louis eP? 4–21–46; Δ3475?; O: 4–15–08? Lawrence, Kans. P 4–22–25; Δ2370; O: 4–17–31. Tucson e4–23–06; L4–25–04. Honolulu e4–37–42; L4–41–42. The data are insufficient to determine O; but the epicentre seems to have been in the Pacific Ocean, about equidistant from Honolulu and Ottawa, and between 700 and 800 kms. nearer Victoria, B. C., than La Paz, Bolivia.

455. March 12. Riverview Δ5500; O: 14–48–48. Manila eP 14–49–34; Δ1460; "West of Masbate Island." La Paz P?

15–09–00; L16–08–00. Ottawa L 15–56–00. Honolulu Δ5320; O: 14–59–53. Batavia Δ2880; O: 14–48–17. Near λ123° E., 12° N.

456. March 20. O: 22 hrs. plus. Lawrence, Kans. P 22–23–08; M 22–31–04; Δ2620. (*sic*). Ottawa e 22–31–00; L 22–31–00. Toronto P22–12–30; ?Δ4660. Origin uncertain.

457. March 31. O: 17 hrs. *plus*. Honolulu e18–32–30. Ottawa e? 17–20–26; L 17–4–04: La Paz e 17–51–34; F 18–15. Not reported from Athens, Heidelberg. Cartuja (Granada) gives a record P 17–37–00; L 17–52.

458. Apr. 3. O: 20–36–34 ca. from Honolulu P 20–41–12; Δ2230? Ottawa L 21–04–00. Northfield, Vt. L 21–04–40. Batavia e20–53. Cartuja (Granada) e 21–08.5; L 21–21.7. Not at Manila, Athens, La Paz. Not at Riverview (Sydney). Origin northwest through Ottawa–Cambridge agrees with Honolulu record.

459. Apr. 7. O? 15–55–35, from La Paz iP 15–56; Δ430. Felt in Arequipa, Peru. III. R. F. (According to L. Campbell cited by La Paz Bulletin). Recorded at Washington, Northfield, Ottawa. Honolulu eP 16–20–24; L 16–42–18 (probably same earthquake). Manila e16–15; F 16–51.

460. Apr. 23. O: 15–29–10. La Paz iP 15–31–20; reports "Probably in Arequipa." Cf. Athens P 15–45–21; Δ2010; O: 15–41–07; another earthquake? Tucson L 15–44–49. Washington eP 15–36–52; Δ4465; Georgetown iP 15–36–57; Δ4950; O: 15–28–32. Ottawa P 15–37–40; Δ5000; O: 15–32–12. Honolulu L 15–50–48. Balboa Heights P 15–33–00; L 15–36–00; Δ995 (*sic*). Northfield P15–37–30; Δ4950; O: 15–28–05.

461. Apr. 28. O: 3–26–51 by Cartuja (Granada) P 3–35–45; Δ5400; L4–01. Barcelona eL 3–58–07. Ottawa L 4–09. Harvard e possibly L 4–10–04. *Cf.* La Paz P?3–41; L 4–42. Not reported by Riverview, Manila, Honolulu, Athens, or Heidelberg. With O as given and Harvard L, Δ ca. 6700 kms. Origin near λ75° E., 67° N.? La Paz L 4–42 supports origin in this quarter of the globe.

462–3. May 1. O: 5–00–04. Sitka P5–07–54; Δ4480; O: 5–00–01. Honolulu P5–09–00; Δ5220: O: 4–58–17; Ottawa Δ8420; O: 5–00–13. Georgetown Δ8910; O: 5–00–15. Manila iP5–08–14; Δ4800; O: 5–01–59. Cartuja (Granada) iP 5–13–22; Δ10640; O: 4–59–49. Puts epicentre in Kurile Ids., λ154.8° E. φ49.8° N. Barcelona iP5–12–53: Δ9600: O: 5–00–10. Heidelberg eP5–11–56; Δ7040; O: 5–01–26. Athens P5–12–36; Δ9210; O: 5–00–13. La Paz iP5–19–25; L5–56–50. Riverview (Sydney) eP5–12.3; Δ9100; O: 5–00–00; places origin in λ165° E. 47° N.

464. May 5. O: 11–08–48 by Manila eP 11–14–22; Δ2760.

Riverview (Sydney) eP 11–17.1; Δ2400; O: 11–12–09. Honolulu P11–30–18; Δ4900? gives O: 11–21–56? La Paz iP11–29–13; L12–22: Δ?13,000+; Cartuja (Granada) L 12–09; Barcelona eL 12–16–48 Heidelberg P 11–35: S 11–51; Δ150° *plus*. Ottawa P?11–32–08: Δ8000? gives O?11–20–57. Origin in eastern Indian Ocean?

465. May 6. O: 12–08–02. Tucson P 12–12–42; L12–17–42. Sitka L 12–15–20. Washington P 12–15–42; Δ4015; O: 12–07–29. Honolulu P 12–17; eL 12–23; Δ?2800. La Paz 12–21–12; Δ9480; O: 12–08–35. Not in Manila Bulletin. *cf*. Riverview e 13–47–20; F 14 ca. Heidelberg eL12–44. Not at Athens. Barcelona eL 12–51–43. Cartuja (Granada) eP 12–21–55; Δ9510; O: 12–09–17. Evidently record of shock reported at 12h 10m. G. M. T.; felt with an intensity from II to V, Rossi-Forel scale, at Branscomb, Eureka, Fort Bregg, and Shively, California, between λ123° 56′ W. and 124° 11′, and in φ32° 38′ N. to φ35° 22′. *Vd*. U. S. monthly weather bureau. 1915, **43**, p. 242.

466. May 8. O: 13–42–58 by Cartuja (Granada) iP 13–54–20; Δ8020. Ottawa L14–41. Heidelberg eP 13–52; eS14–04. *Cf*. Honolulu L 15–09–18. La Paz P13–56–36; Δ10600; O: 13–43–05. Hence Harvard Δ ca 12100. Origin in southeast African region.

467. May 12. O: 10–29–42. Washington P10–39–58; Δ7215; O: 10–29–19. Ottawa P?10–40–13; Δ6500?; O: 10–30–13? Honolulu e11–41–36; L12–09. La Paz iP10–38–13; (putting S at 10–45–15); Δ5360; O: 10–29–12. Cartuja (Granada) Δ3770; O: 10–29–54. Barcelona Δ3900? Heidelberg Δ6720; O: 10–28–07. Athens Δ6300; O: 10–33–23. Riverview eL 11–28.8; F14–15. Mean O: 10h. 29m. 48s. from six stations. Epicentre southwest of Cape Verde Islands.

468. May 21. O?4–27–46. Ottawa eL 5–01–05; Δ7000? Honolulu eL5–48–30. La Paz Δ13000+? Cartuja (Granada) iP4–27–24; Δ4800; O: 4–19–09. Heidelberg eP4–25–41; Δ7620; O: 4–14–20. Batavia, Java eP4–30–55; Δ8200; O: 4–19–23. Athens Δ3600; O: 4–18–54. O probably 4h. 19m. ca. Origin Asiatic Turkey. Harvard Δ9500 ca.

469. June 1. O: 14–43–30. Ottawa Δ4860; O: 14–43–44. Northfield Δ4885; O: 14–44–51. Honolulu Δ11780; O: 14–44–30. Washington Δ4400; O: 14–44–50. La Paz Δ8100; might read Δ8440: O: 14–50–46. Manila Δ8620; O: 14–44–52. Barcelona Δ4010? O: 14–43–45? Athens Δ4760; O: 14–43–25. Strassburg Δ3530; O: 14–43–36. Sitka gives Δ3700; O: 14–46–38. Victoria, B. C. iP15–00–18 Δ1740; O: 14–56–26; seems to be allotrocentric; but is probably the end-phase of this quake. Epicentre north of Spitzbergen (?). John A. Curtin, S. J., at Buffalo with eP 14–50–10; Δ5150; O: 14–41–12?

notes "Reported from Alaska." (U. S. monthly weather review, 1915, **43**, p. 293.)

470. June 6. O: 19–36–25 by Riverview (Sydney) eP 19–42. Δ2850 in λ151°. 2E., φ8° S. Not in Manila Bulletin. Ottawa eL 20–38–02; F 21. According to epicentre determined by Riverview, Harvard Δ14, 450 kms. about. The L waves arriving at Ottawa and Harvard at 20h 38m. ca. starting with the Riverview determination, are L waves traveling at the rate of 217 kms. per minute. (Klotz.)

471. June 6. O: 21–29–37. Sitka eP21–43–22; Δ8210: O: 21–31–49. Tucson eP21–40–00; Δ7060; O: 21–29–29. Washington iP 21–39–09; Δ6240; O: 21–29–24. Honolulu P21–43–30; Δ2510; O: 21–38–22. Ottawa iP 21–39–53; Δ6940; O: 21–29–28. *Vd.* also Denver, Lawrence, St. Louis; Vieques P21–37–27; Δ2840; O: 21–31–45. Canal Zone. Buffalo Δ6740; O: 21–27–22. Heidelberg P21–41–49; Δ2880; O: 21–36–03. Not registered at Cartuja (Granada) or Barcelona. La Paz iP21–30–2–. Δ370. "Epicentre approximately λ69.°5 W., φ20° S." O: 21–29–30 *ca.* "Felt severely from Arequipa to Antofagasta. VII. R. F." Strassburg eP 21–42–36.

472. June 22. O: 3–24–22. La Paz iP3–25–32; Δ400; O: 3–24–36; "Felt in Arequipa, Peru, V–VI R. F., and more severely in Iquique." Washington Δ6750; O: 3–23–49. St. Louis eL3–41–48. Northfield M 3–43–35; 3–44–16. Ottawa iP 3–34–58; Δ7210; O: 3–24–18. Manila e3–44; F4–23.

473. June 23. O: 4–00–12. Felt at Yuma, Arizona, λ114° 36′ W., φ34° 25′ N. at 4–00; by common report, with intensity VI–VII R. F. *Vd.* U. S. monthly weather review, 1915, **43**, p. 289. Tucson P3–59–46; Δ580; O: 3–58–27. Washington P4–09–54; Δ3210?0 : 4–03–38. Honolulu L4–16–24. Ottawa Δ3700; O: 4–03–18. Harvard O was read in light of published reports which came to hand before the seismogram was seen. La Paz L4–34–03. Cartuja (Granada) eL4–40; F5–10. *Vd.* Carl Beal. The earthquake in the Imperial Valley. Bull. Seism. soc. Amer. v. 1915, pp. 130–149.

474. June 23. O: 4–58–34. *Vd.* U. S. monthly weather review, 1915, **43**, p. 290. Reported at 4h. 56m.; felt VIII. R. F., at Brawley, California, λ115° 40′ W., φ32° 59′ N. Tucson P4–56–33; Δ480; O: 4–55–27. Denver L5–30–00. Honolulu L5–14–24. Lawrence, Kans. P4–59–16; Δ3300; O: 4–52–52. St. Louis P5–00–00; Δ2450; O: 4–59–58. Northfield Δ3360; O: 5–50–11. Ottawa Δ3700; O: 4–59–52. At most stations in the United States distant more than 2000 kms. from the epicentre the phases were indistinctly registered, owing perhaps to the lack of instruments sufficiently sensitive for the registration of earthquakes of common occurrence in this country.

475. June 27th. O: 15–25–46.6 by Strassburg Δ8840. Honolulu P15–48–54; L15–58–54. Δ3350; 15–35–02 possibly another earthquake. Riverview e15–46.5. Nothing at Manila. La Paz P15–44; L16–31. Cartuja (Granada) L16–11. Heidelberg eL 16–05.

476. July 8. O: 22–30–48; by Honolulu P22–36–36; Δ2910. *Cf.* Batavia eP22–29; Δ5300? 0? 22–20 ca. La Paz iP22–30–40; F23–10. Manila e22–26–34; F23–12. Not at Riverview. Cartuja (Granada) e?22–26–13; L23–11. Not generally registered in the United States.

477. July 22. O: 4–06–08, doubtful readings. *Cf.* Washington P4–16–53; Δ3995? O: 4–09–35? Ottawa P4–23–00; Δ3480; O: 4–16–21. Toronto L 4–30–24. Victoria, B. C. P 4–25–54; Δ2440; O: 4–20–53. Nothing at Honolulu, Manila, La Paz, Heidelberg, Athens, Barcelona, etc.

478. July 25. O: 20–54–48, by Ottawa P 21–05–13; Δ8070. Uncertain records at Harvard and Washington. Records are generally wanting at stations in United States and Canada. La Paz gives eP21–37–35; L21–55; Δ?6600; O?21–27–30. Not at Manila, Riverview, Heidelberg, etc.; but *vd.* Strassburg e21–35; "large waves." Honolulu L21–02–24; F21–14–42.

479. July 29. O: 10 h. *plus.* Ottawa L10–55.5. La Paz eL 10–57. Washington e10–49–30; L10–51–40. Not mentioned in European exchanges; nor by Honolulu, Manila, Riverview.

480. July 31. O: 1–31–26. Epicentre near λ168° E., φ53° N. The following stations accord closely as to time at origin.

Stations	Δ	O	Corrections.	
	kms.	h. m. s.		
Sitka	3660	1 31 26	+ 0.6	
Victoria	4890	1 31 20	+ 7.6	
Berkeley	5870	1 31 17	+10.6	
Tucson	7100	1 31 18	+ 9.6	
St. Louis	7600	1 31 30	− 2.4	
Ottawa	7700	1 31 27	+ 0 6	
Northfield	7990	1 31 26	+ 1.6	
Washington	8165	1 31 31	− 3.4	
Harvard	8200	1 31 26	+ 1.6	
Cheltenham	8910	1 31 20	+ 7.6	
Heidelberg	8300	1 31 36	− 8.4	
Strassburg	8440	1 31 27	+ 0.6	
Athens	8950	1 31 32	− 4.4	
Barcelona	9290	1 31 26	+ 1.6	
Riverview	9400	1 31 45	−17.4	Decadent
Cartuja (Granada)	9780	1 31 35	− 7.4	P Records.
Mean O		1 31 27.6		

The stations varying more than 30 seconds from the mean of the records in closest agreement run as follows:

Stations	Δ	O	
Honolulu	4340	1 32 29	
Manila	4530	1 32 54	
Lick	5320?	1 32 49?	
Lawrence, Kans.	7900	1 30 15	
Toronto	8800	1 29 45	Δ from S–P = 10 mins.
La Paz	11400	1 36 26	
Mean O		1 31 24.1	

In this case the mean O of seven available, seemingly inconsistent records varies but 3.5 seconds from the mean O of the best records. The inclusion of the poor records with the better records, provided there is a sufficient number of each, seems therefore to follow the general law of probability as regards the measurement of quantities, which means that mistakes are made in reading seismograms in which the distance is made not only too little but too great. Ordinarily the over estimation of the distance can only arise by putting P too early among microseisms or eS too late, thereby in either case augmenting the value of Δ and making O come too early.

The mean O of the twenty-three stations listed comes out 1h. 31m. 26.5 s., or 2.1s. earlier than the mean of the sixteen stations which show the closest agreement. In the list Sitka, Ottawa, Northfield, Harvard, Strassburg, and Barcelona, vary but ½ second from this mean O. Victoria, Berkeley, and Tucson, stations on or near the Pacific coast, and, except for Sitka, nearest the epicentre give earlier times, the interpretation of which would be desirable if possible. On the whole so far as the United States is concerned, this earthquake was satisfactorily recorded, and the abnormal records reported, due to difficulties of one sort or another attendant on the reading of seismograms, were unusually small and distributed among stations at other times in the normal list.

481. Aug. 3. O: 13–04–59; by Riverview Δ2500; reporting origin in Dutch New Guinea; λ138° E., φ5° S. Batavia iP 13–10–56; Malabar Δ2970. Honolulu Δ8920; O: 13–04–27. Manila eP 13–10–06; Δ2560; O: 13–04–52. La Paz iP 13–24–55; L14–10–00; Δ13, 000+. Washington L14–09. Victoria, Toronto, Ottawa, Northfield obtained records variously interpreted. Assuming the Harvard record begins with L 14–16–04 and that L15–06–10 is L_{R_1}, the Rayleigh waves reflected from the antipodes of the epicentre, Harvard Δ may be calculated by the formula

$$20{,}000 - \left\{\frac{L_{R_1}-L}{2} \times 208\right\} = \Delta;$$

where $\frac{L_{R_1}-L}{2}$ is the time in minutes taken for certain L waves to travel from Cambridge to the antipodes of the epicentre; and where 208 is the estimated rate of transit in kms. per minute; 20000 kms. being the distance of the antipodes from the epicentre. This formula comes out 14790 kms., as compared with 14780 kms. the distance measured on an 8 inch globe. While the principle involved in the formula is of general application, the constant 208 (kms.) depends upon the times of arrival of L waves, probably eM or M, recorded later than eL, and is possibly only valid in particular records. If we use the constant 230 for eL (Klotz, 1917) an empirical formula for this and similar distant records may be written

$$\Delta = 1.0384 \left\{20{,}000. - \left(\frac{L_{R_1}-L}{2}\,230\right)\right\}$$

482. Aug. 6. O: 13–11–47; by Manila eP 13–19–33; Δ4380. Honolulu Δ8440; O: 13–11–34. Riverview (Sydney) Δ7030; O: 13–12–03. Ottawa Δ9150; O: 13–12–27. Barcelona Δ10030; O: 13–12–10. La Paz iP13–32–00; Δ13000+. Cartuja (Granada) iP13–26–43; Δ11100; O: 13–06–49. Barcelona P13–25–24; Δ10010; O: 13–12–21.

483. Aug. 7. O: 15–04–16; from Barcelona Δ1510. Heidelberg Δ1420: O: 15–04–27. Athens P15–04–17; Δ300; O: 15–03–33.8; "Epicentre in Leucadia." F15–35–57. Duration of motion at Athens 31 mins.; at Cambridge, Mass., 36 mins. ca. Ottawa Δ5600; O: 15–14–52. Putting Harvard S15–31–09; gives Δ6200; O: 15–14–52. *Cf.* Riverview Δ7930; O: 15–10–27. Cartuja gives λ21° E., φ38° .4 N. Δ2150; O:15–04–02. Heidelberg Δ1420; O: 15–04–11.7.

484. Aug. 18. O: 23–56–42; from La Paz 19d. iP 0–07–35; Δ5360. Riverview P 0–21–36; Δ9350; O: 0–19–11. Ottawa P? 0–16–32; Δ?5550; O: 0–05–29. Manila e0–20; F 1–03. Honolulu L 1–04–24. Victoria Δ13000. Washington L 1–32.

485. Sept. 6. O: 17–20–36; from (Sydney) Riverview Δ3840. *Cf.* La Paz Δ9750; O: 17–26–36. Manila e17–37; F18–16. Cartuja (Granada) iP17–45–40; Δ11150; O: 17–31–43. Not generally registered in North America. Ottawa e17–50–27; L17–54. Toronto L18–11–12. Victoria, B. C. P17–48–01; Δ10310; O: 17–34–44; with L18–01–43. Honolulu S17–42–54; L17–44–54; Δ?3100; O?17–31–58. Batavia e17–58; F18–25. Fordham (New York) L18–37–30.

486. Sept. 7. O: 1–20–30. Balboa Heights Δ1390; O: 1–20–18.7. Georgetown Δ3030; O: 1–20–27.5. Washington Δ3070; O: 1–20–29. Tucson Δ2950; O: 1–20–54. St. Louis Δ3070; O: 1–20–09. Cheltenham Δ3030; O: 1–20–40.5. Northfield Δ3435; O: 1–20–49. Ottawa Δ3750; O: 1–20–27. Honolulu Δ7490: O: 1–20–42. Cartuja (Granada) Δ8630; O: 1–20–58. Barcelona Δ9080; O: 1–20–44. Heidelberg Δ9400; O: 1–20–38. Athens eP1–31–31; L1–35–43; (Δ2590). La Paz iP1–27–57; Δ4210; O: 1–20–23.6. Batavia P 1–41–52; eL2–12. Riverview eP 1–39.7 Δ10900; O: 1–25–57. Destructive earthquake in Achuacan, San Miguel, Tepesontes and Santa Ana, San Salvador (Cartuja (Granada) Bulletin). Press despatches in United States refer to destruction of Jutiapa, 445 miles southeast of Guatemala City in Guatemala. Epicentre near λ90° W., φ14° N.

487. Sept. 7. O: 4–23–04; from La Paz iP 4–30–38; Δ4200? Also Washington P 4–29–18; Δ2910; O: 4–23–30. P as first given by Harvard, Ottawa, Cornell (Ithaca), Victoria, is evidently eS. Original records: Harvard eP 4–35–31; Δ3610; O: 4–28–42. Ottawa Δ3650; O: 4–28–25. Victoria, B. C. Δ6440; O: 4–28–47. Not distinctly registered at most stations in United States. Evidently aftershock of No. 486, after interval of about 3h. 02m. 30s. The first great shock came about midway between the tropical hours of the afternoon minimum and maximum of atmospheric pressure; the second shock at O: 4–23–04 came about 10h. 23m., local time, near the tropical hour for the afternoon maximum of atmospheric pressure. The third shock, No. 488 in the Harvard list, coming at about 35 minutes after the second shock, seems to offer one of those cases in which the P waves traversing the diameter of the globe in 17 mins. ± 1 upon reflection to their point of origin set off a shock.

488. Sept. 7. O: 4–58–07; by La Paz iP 5–05–40; Δ4200. Washington P 5–04–18; Δ2920; O: 4–58–23 ca. St. Louis e5–04–00; F 5–23. Ottawa P 5–10–30; L 5–19. Victoria P 5–28–44; F 5–36–44. Washington records another shock P 5–37–22; Δ2640? O?5–32–00. La Paz iP 5–38–43; Δ4200? Probably identical with Toronto P 5–41–00; Δ4560; O: 5–33–07. Taking 5h. 32m. 30s. as the time of this shock, which appears to have been near the epicentre of No. 486, it will be noted that it also occurs at an almost identical interval after its predecessor, *i. e.*, 34m. 18s., approximately; or looking at it in another way about 69 minutes after the first great shock, which is about equal to the time required for the S-transverse waves to be reflected from the antipodes of the epicentre to the disturbed tract in the manner Szirtzes has pointed out regarding this interval. It is difficult to understand why, however, if the P and S waves, upon reflection from the secondary shock of September 7th at 4h. 58m., set off by their trigger action aftershocks, that such action was not brought about by what must have been the more energetic impulses of P and S reflected by the larger earthquake, which took place at 1h. 20m. 30s. It is to be noted that in the cases in which reflected P and S appear to have acted, the times fall within the possible range of the afternoon maximum of atmospheric pressure. It seems likely that the reflected P and S aftershocks may not be brought about unless other slight causes, such as that mentioned concur in time at the epicentre.

489. Sept. 7. O: 12–48–28. Washington Δ2750; O: 12–48–09. La Paz Δ3700; O: 12–48–02. Ottawa Δ3750? St. Louis e12–52–48. Toronto P? 13–00–00; L 13–05–06. Cartuja (Granada) eL13–25. Victoria 13–03–46; L13–14–46, La Paz P 12–54–58; Δ3700. Probably from same origin as preceding earthquakes. This shock coming about 11h. 28m. after that at 12–48–28 (or 09) betrays a semidiurnal periodicity like that of the march of the tropical hours of the diurnal change in atmospheric pressure of the same sign; but the shocks came about midway between the tropical hours, at which times according to the earthquakes catalogued by Milne from 1904 to 1910 I find a tendency to increased frequency of occurrence.

490. Sept. 7. O: 20–39–52. Harvard record imperfect, but within 20 secs. of La Paz Δ3900; O: 20–39–32. Washington Δ3740? O: 20–38–07? Ottawa Δ3750? O: 20–38–05? St. Louis e20–46–36; F 21–06. Toronto L 20–49–24. Victoria L 21–26–38, with P? S? Probably another Guatemalan earthquake.

491. Oct. 2nd. O: 23–40–06 from Sta. Clara Δ547. Victoria, B. C. Δ220; O: 23–43–56. Tucson Δ730; O: 23–42–56. Denver Δ1120; O: 23–39–33. Lawrence, Kans. Δ1410; O: 23–41–47. Salt Lake City Δ830; O: 23–37–09 from P 23–39–00! Washington S 23–56–15. Georgetown Δ2200 ca. from L–S. Toronto L 23–57–42. Ottawa Δ3460? O: 23–44–33? Fordham (N. Y.) L 23–52–52. The mean of the above given O's comes out 23h. 41m. 10s. G. M. T. The common time given by the U. S. monthly weather review, Oct. 1915, **43**, p. 521, is 23h. 41m. It would seem in this instance that the seismographic records afford as many cases in which the time phases were read too early, as those in which they were read too late. See next record.

491–492. Destructive earthquake in northern Nevada. Epicentre on a fault at western base of Sonoma Range, at a point probably 40 miles south of Winnemucca in λ117° W. φ40° 35′ N. as plotted on the map from account of the earthquake. See H. P. Boardman. Severe earthquake in Nevada. Engineering news, New York, Dec. 23, 1915, **74**, p. 1222–1223, with 6 photographic views, show-fault-scarp, cracks, and nature of destruction.

J. Claude Jones. The Pleasant Valley, Nevada, earthquake, of October 2, 1915. Bull. Seism. soc. Amer., 1915, **5**, p. 190–205. with figures in text and sketch map of location of fault.

From local field descriptions it is known that a fault, with a maximum movement of ten feet in the vertical, took place on the west base of a fault-block, with an uplift of the eastern lip of the fault according to the account by Professor Jones.

Pleasant Valley, Nevada, Earthquake, October 3, 1915, G. M. T. Civil.

Stations	Δ	P	S	L	Aμ	O
Sta. Clara	130	6 54 25		6 54 40	50	6–54–05
Manila		e7 11 37	7 23 35	7 34 10	27	6 59 01
Berkeley, Cal.	570	6 54 31	6 55 34	6 55 51		6 53 13.6
Victoria, B. C.		6 54 55		6 57 13		
Tucson, Ariz.	1400?	6 55 40		6 58 21		
Lawrence, Kans.	1940	6 57 20	7 00 38	7 00 51		6 53 14.4
St. Louis, Mo.	2040	6 58 08	7 02 06	7 03 00		6 53 49
Sitka, Alaska	2290	6 58 09	7 01 57	7 04 33		6 53 25
Buffalo, N. Y.	3240?	6 58 00	7 03 30	7 06 00	305	6 51 41?
Toronto	3020	6 59 36	7 04 30	7 07 12		6 53 37
Ottawa	3030	6 59 34	7 04 40	7 09 12	33	6 53 44.5
Cheltenham, Md.	3360	6 59 09	7 04 17	7 09 17		6 52 39.9
Georgetown, D.C.	3050	6 59 44	7 04 41	7 08 45		6 53 42.7
Washington, D.C.	3360	6 59 37	7 04 45	7 07 29		6 53 17.9
Northfield, Vt.	3590	6 59 53	7 05 16	7 10 15		6 53 06.7
Harvard	3780	7 00 06	7 05 40	7 10 36		6 53 12
Vieques, P. R.	5320	7 02 04	7 09 04	7 16 26		6 53 21
La Paz, Bol.	8165	7 04 51	7 14 19	7 28 00	307	6 53 21
Heidelberg	9380	7 05 19	7 15 39	7 32 31		6 52 47.4
Sydney, N. S. W.	10000	7 11 24	7 22 06	7 39 30	32	6 58 06
Batavia, Java		e7 13		7 40	65.2	

According to local observers shocks were felt at 3: 40 p. m. Pacific S. T., 5: 49 p. m., and again at 10: 45 p. m., the time of the principal shock. In Greenwich meantime these hours become

Earthquake	a)	Oct.	2	23h.	40m.
	b)		3	1h	49m.
	c)		3	6h.	54m.

These three earthquakes were registered at Cambridge by the Bosch-Omori tromometer, but only the third or last one, on Oct. 3, gave a complete and satisfactory record. From this record, the distance to the epicentre figures out 3780 kms., and the time at origin as 0 = 6h. 53m. 12s., which is in local time 10h. 53m. 12s.

From this record the interval at Cambridge between S and P is 5m. 34s., from which it appears that P in the two earlier shocks failed to be registered.

From the several records obtainable the table of instrumental data, on page 138, has been constructed.

494. Oct. 11. O: 19–33–23. Mean O: 19–33–05 from 7 stations in fair agreement. Vieques P 19–34–03; Δ410; O: 19–33–06. Balboa Heights P 19–35–55; S 19–37–55; hence Δ1120; O: 19–32–28. Washington P 19–37–49; Δ2340; O: 19–32–59. Georgetown P 19–37–53; Δ2410; O: 19–32–56. Cheltenham P 19–38–03; L 19–41–51. Ottawa P19–40–00; Δ2140; O: 19–35–32. Victoria gives P 19–58–32: Δ2830; O: 19–52–50. Toronto P?19–40–06; Δ2150? O?19–35–37. La Paz Δ3450; O: 19–33–41.7. Heidelberg e 19–53; eL 2–05. Cartuja (Granada) iP19–43–04; Δ6460; O: 19–33–16.6; places epicentre in λ65° 36′ W., φ17° N.

This earthquake was felt on the island of Puerto Rico at Isabela, Lares, San Juan, in λ 67° W., and φ18° 30′ N., and thereabouts, at 19h. 35m. according to reports to the U. S. weather bureau (U. S. monthly weather review, October, 1915, **43**, p. 522). The seismographic data bearing on the time at origin would indicate that the shock took place not far from 19h. 33m. The mean O of the above named stations varying not more than two minutes from the mean is 19h. 33m. 40s. The mean O in such computations probably leans towards a time too late.

This earthquake was preceded on October 11, by a shock at O: 2h. 37m. 36s.; Δ4660 from Cartuja (Granada) with its epicentre probably in λ33° 48′ W., φ7° 48′ N. according to that Observatory. This earlier quake is given by Washington P 2–46–38; Δ5400; O: 2–37–44; which confirms this location, both as to time and position of the epicentre. There was an interval of about 16h. 56m. between the two earthquakes.

495. Oct. 12. O? 21–29–35 based on Cartuja (Granada) eP 21–42–56; Δ?10380. Record lost at Toronto. Victoria, B. C. gives P 22–06–56; M22–08–58; F22–11–55. Honolulu e21–45–48; M 21–46–42. Heidelberg eL 22–15. Athens L 22–18. Not given by La Paz, Riverview, or Manila.

496. Nov. 1. O: 7–24–31. Berkeley Δ7570; O:7–24–29. Ottawa Δ9340; O: 7–24–33. Honolulu P 7–33–36; Δ1740; O: 7–29–47. La Paz M8–56–14. Washington P7–37–12; Δ9570; O: 7–24–31. Georgetown P7–36–34; Δ11080; O: 7–22–41. Lawrence, Kans. P7–36–49; Δ9000; O: 7–24–26. St. Louis P7–41–00; Δ3240; O: 7–34–41. Buffalo P 7–48–50; 9600; O: 7–36–07. Northfield Δ?9380; O?7–24–39. Toronto Δ11780; O: 7–33–23. Manila Δ4160; O: 7–22–42; N. E. Japan; 2nd quake at e 9–06–26. Victoria, B. C. Δ7250; O: 7–33–19. Cartuja (Granada) Δ11000; O: 7–23–55; reports epicentre in λ145° 30′ E., φ38° 42′ N. Barcelona Δ11100? Heidelberg eP 7–36–15; Δ9010; O: 7–24–02. Batavia P 7–33–37; Δ5800; O: 7–24–28. Batavia records a second shock P7–33–37; Δ5800. Athens P7–36–29; Δ9200; O: 7–24–06.

496a. Nov. 18. La Paz P4–22–04; L5–13–10; Δ? Honolulu P 4–11–42; L 4–19–42; Δ?3300. Ottawa L 4–55. Cartuja (Granada) e 4–36; L4–48. Toronto L4–51–36. Victoria P4–41–48; L4–44–18. Manila records a severe earthquake eP 1–12–56, with aftershocks eP 10–26–45; eP 1–31–00; eP 2–21–39; Luzon and N Mindoro, also eP 3–50–55; L 3–51–57; N. Samar. Heidelberg eP 4–23–29; Δ9650; O: 4–10–44. Batavia, P4–12–4; Δ6150; O: 4–02–24.

497. Nov. 21. O: 0–13–35. Ottawa Δ3520; O: 0–13–62. La Paz Δ7640; O: 0–13–29. Northfield Δ3680? O: 0–13–46. Buffalo eP 0–23–20; Δ3100; O: 0–17–14. St. Louis Δ2830; O: 0–12–46. Lawrence, Kans. Δ2070; O: 0–13–20. Honolulu Δ4450; O: 0–13–15. Tucson P 0–14–44; L 0–15–57; Δ670 kms.; O: 0–13–14. The Tucson record confirms that of several outlying stations in placing the time at origin of this shock at a few seconds past 0h. 13m. Even Cartuja (Granada) gives Δ9600, and O: 0–13–44.5. The hour, 0h. 15m., reported as the time of the shocks at places in California between λ114° 38′ W. and λ118° 49′ W. and between φ32° 43′ N. and φ33° 43′ N., is probably that of the main shock making allowance for the failure to note seconds of time. Intensity as high VI R. F. at San Diego, Cal. *Vd.* U. S. monthly weather review, Nov., 1915, **43**, p. 569.

498. Nov. 26. O: 19–12–01 ca. from Balboa Heights P 19–12–30;

Δ190. Ottawa Δ4140; O: 19–12–04. Washington Δ3500; O: 19–11–53. La Paz Δ3720; O: 19–10–21. Epicentre southwest of Panama; with several aftershocks registered at Balboa Heights; *vd.* U. S. monthly weather review, Nov., 1915, **43**, p. 572.

Not at Honolulu, Cartuja (Granada), or Barcelona.

498a. Dec. 3. O?3–01–37? from Ottawa P? 3–12–32; Δ7500? *Cf.* Honolulu P 3–03–30; S 3–17–00; Δ13000—; (Shide tables put Δ 128° 30′; Δ14275 kms.; with O: 2–46!) Victoria P 3–31–23; Δ2050; O: 3–27–05. La Paz M4–05–20; F 5 ca. Cartuja (Granada) gives iP2–51–30; Δ9280; O: 2–39–03. Strassburg P2–46–02. Manila e2–46–12; S2–50–57. Batavia P 1–59–40; S 2–00–00; 180 kms.

499. Dec. 6. O: 20h. 26m. *plus* or *minus*, based on estimated distance derived from passage of L and LR_1 through Cambridge; giving Δ16900; preferably Δ16750 ca. *Cf.* La Paz eP 21–18–30; F 21–25. Not reported by other stations in North America. Honolulu P 21–15–18; L 21–23–42; Δ?3410; O?21–08–45. Cartuja (Granada) eL 21–48. Not at Batavia.

500. Dec. 7. O: 10–38–26. La Paz Δ4130; O: 10–38–09. Washington Δ5085; O: 10–38–09. Northfield L 10–58–30. Ottawa Δ5340; O: 10–38–27. Not reported by stations in western United States. Epicentre from La Paz–Harvard near λ29° W., φ5° S., in Atlantic Ocean, south of St. Paul Rocks. Cartuja (Granada) Δ4720; O: 12–38–10. Heidelburg et 11–03. Batavia e 10–56.

501. Dec. 7. O: 12–30–25. Record not confirmed by other stations in the United States.

501a. Dec. 7. O: 18–40–09, from St. Louis Δ220 kms. Felt; intensity V R. F. at Cairo; also felt at Anna, Golconda, Harrisburg, Illinois. Cairo: λ89° 108′ W., φ37° N. *Vd.* U. S. monthly weather bureau, Dec., 1915, **43**, p. 627–632, with records from various stations, not generally well registered.

502. Dec. 8. O: 18h. *plus.* Not confirmed by other stations in the United States. *Cf.* La Paz P 18–14–48; F 18–26. Not at Batavia.

503. Dec. 12. O: 21–02–01. La Paz Δ4700; O: 21–02–55. Balboa Heights P 21–06–00; Δ1320; O: 21–03–28. Vieques L 21–10–57. Washington P21–08–32; Δ4200; O: 21–00–59. Georgetown P21–08–32; Δ?2300; or Δ2410; O: 21–03–45. Lawrence, Kans. P21–08–32; Δ1730; O: 21–05–35. Δ?2750; O?21–02–36; from L–P. St. Louis P21–14–00; Δ1300; O: 21–11–51. Buffalo P 21–19–40; Δ2080; O: 21–11–48. Northfield L 21–18–42. Ottawa P21–10–25; Δ3240; O: 21–04–06. Toronto Δ2830; O: 21–03–20. O for stations westward in the United States varies greatly. With Harvard–La Paz Δ, eastern intersection, epicentre falls near λ34° W., φ8° 30′ N. in the Atlantic. Not registered at Barcelona, Manila.

504. Dec. 17. L5–57–29. Not at La Paz, Honolulu, Cartuja (Granada), or Barcelona. Not confirmed by other stations in North America. Not at Riverview (Sydney).

505. Dec. 17. O: 7–43–36? by Ottawa Δ3300? Toronto Δ4660; O: 7–44–25. Victoria, B. C. Δ6440; O: 7–41–35. Honolulu gives a record P7–44–00; Δ6560; O: 7–33–57. *Cf.* Barcelona e7–33–05; L 7–35–58. Cartuja (Granada) i7–15–28; L7–41. La Paz eP7–24–47; L 8–19; Δ13000+? Not at Riverview (Sydney). *Cf.* Heidelberg iP 7–13–42; iS?; Δ2430; 0?7–08–42. Manila e7–13–21; S 7–22–05.

506. Dec. 18. O: 18–26–33 from La Paz iP 18–36–25; Δ6370. Toronto L 19–08. Victoria, B. C. L 19–28. L motion evidently progressed westward across North America. Cartuja (Granada) Δ4630; O: 18–26–29. Barcelona L 18–46–11. Not at Riverview (Sydney). Near ?λ10° W., φ5° S. Strassburg eP? 18–36–11.

507. Dec. 19. O? 20h. 23m. ca. by Riverview (Sydney) Δ5320? *Cf.* La Paz iP 20–34–00: eL21–30. Honolulu e21–07–00; M21–14–00. Manila eP 20–19–10; Δ2000; O: 20–14–57.6. Epicentre Betuan, N. Mindanao.

508. Dec. 28. O? 23–40–48 from Balboa Heights P 23–44–21; Δ 2000. *Cf.* Ottawa Δ3800?; O: 23–45–58? Washington 29d. L?0–03–05. Honolulu 29d. e0–08–24; M 0–25–12. Cartuja (Granada) 29d. iS 0–01–30; Δ9515?; O: 28d. 23–38–16? Barcelona 29d. eL 0–33–04. Riverview (Sydney) 28d. e23–58; 1; eL 29d. 0–31.9. *Cf.* La Paz 28d. iP 23–40–08; Δ620, from L–P; O: 23–38–44. Manila e23–59; F 0–40 (29d).

509. Dec. 31. O: 12–19–23. La Paz Δ8630? O? 12–19–16. Tucson P12–23–36; Δ4225? Washington P 12–27–09; Δ3055; O: 12–21–08. Honolulu P 12–27–54; 1680; O: 12–24–19. Lawrence, Kans. Δ2750; O: 12–19–36. Cheltenham L 12–41. St. Louis Δ2850; O: 12–24–48. Northfield L 12–39–47. Ottawa Δ3200; O: 12–19–45. *Vd.* Toronto, Victoria. Barcelona eL 13–02–38. Riverview (Sydney) e 12–48.8; eL 13–05. Mean O of stations giving 19m. is 12h. 19m. 30s. Strassburg eL? 13–02. Heidelberg eL 12–55. Manila eP 13–13–22; F 13–16.

509a. (Dec. 31.) Two earthquakes: O: 22–25–17; Δ2820; and O: 23–00–36; Δ2720; according to Riverview (Sydney). Honolulu Δ1180; O: 23–00–08. But American and Canadian records point to allotrocentric disturbance; though it is possible the readings are due to the microseismic character of the preliminary tremors from the earthquakes reported by Riverview. The Harvard record displays short period L waves characteristic of a weak not distant earthquake. Ottawa Δ3200; O: 22—. Cartuja (Granada) Δ4700; O?23–06–08. Manila eP 22–54–22; F 57m. Then e 23–05–17; S 23–09–23; Δ?2510; O: 23–00–08. *Cf.* Athens P 23–14–05; Δ2320; O: 23–09–17.

An examination of the abstract of the records above given brings out the character of seismological registration at the present time in the United States. It is to be expected that very distant weak earthquakes should not be fully recorded on seismographs in this country; but it is otherwise with shocks strong enough to be made the basis of scientific investigation, when these have their origin within the contiguous territory of the United States. The fact that destructive shocks in southern California during the year were not registered satisfactorily at any considerable distance, implies that our seismographs are not sufficiently sensitive; in particular the seismographs on the Atlantic border show satisfactorily only the exceptionally strong earthquakes on the Pacific coast, and they fail to do much more than that for the weak earthquakes in the Appalachian belt; while slight shocks a few miles from seismographs are not registered at all. On the other hand earthquakes like that of July 31, 1915, O: 1–31–25 and October 3, 1915, O: 6–53–14, were widely registered over the United States in a manner to show that, with few exceptions, a fair degree of accuracy is maintained at most stations as regards standard time, and the interpretation of seismograms.

Number of Earthquakes recorded since Jan. 1, 1910 (G. M. T.)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Sums
1910	5	2	5	5	12	9	8	4	10	3	11	12	86
1911	8	11	3	5	6	6	3	2	8	7	8	5	72
1912	3	4	4	7	7	25	13	8	6	4	6	10	97
1913	9	2	10	5	5	9	10	8	1	12	4	2	77
1914	2	6	11	5	5	9	8	10	2	9	5	4	76
1915	4	7	4	4	5	7	5	4	6	5	4	14	69
Sums	31	32	37	31	40	65	47	36	33	40	38	47	477
Aver.	5.1	5.3	6.1	5.1	6.6	10.8	7.8	6.0	5.5	6.6	6.3	7.8	79.5

The earthquakes counted in this year's enumeration include four local shocks, which were reported as felt. Other shocks listed in the preceding catalogue, but not heard from, have been intentionally omitted as requiring perhaps some confirmation. With a mean annual registration of 79.5, the monthly average would be 6.6. For the first time, the data thus set forth show a tendency to develop semiannual maxima in June and December, but the capricious range of the figures indicates that this enumeration may be temporary and delusive. The middle columns of the tabulations exhibit a tendency of high monthly frequency of earthquakes to shift to later months from May, 1910 to August, 1914; but the most that can be said of the matter at present is that the amount of time required month by month to work out the seismograms at this Station varies widely within certain limits. It is to be presumed that the tabulation shows, within the range of the seismograph employed, the ordinary run of registrations during a period of least seismic action in New England. A single great nearby earthquake such as that of Plymouth in 1638, or Boston in 1755, with its train of aftershocks, would entirely alter the aspect of these statistics.

Condition of the Station. The seismograph was in continuous service throughout the year, though at times one component or the other was for short intervals out of commission. On September 13 the spring driving the registering drum on the east-west component cracked and on September 15 broke down completely. For this cause the E component was out of commission during 15–19 September. On September 29 the clock-work of the N component stopped and this component was out of commission until October 4. The E component was again out of service November 27–28, by reason of a nut working loose in the governor of the clock-work. On December 5, a change was made in the counterpoising of the stylus furnished by the manufacturers of the Bosch-Omori instrument. With the view of reducing the friction at the contact with the smoked paper, the free end of the lever-formed stylus was weighted with a small piece of beeswax, with the result that both components thus treated displayed a higher degree of sensitiveness. The results are perhaps best brought out by comparing the number of records reported at Harvard and Ottawa for the three months before and after the change in the instruments.

	1915				1916	
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Ottawa, photographic	8	5	5	8	5	9
Harvard, mechanical	6	5	4	14	11	10

Previous to this reduction of friction in the stylus contact with the smoked paper on December 5, the instruments for the three months September, October, November, fell behind the instruments at Ottawa in registering some part or all of a seismogram in the ratio 18/15, *i. e.* Ottawa registered more shocks; for the months December, 1915, and January, February, 1916, the ratio Ottawa/Harvard stood 22/35, that is, the Harvard instrument recorded a greater number of shocks. But this increased registration at Harvard was made by the undamped component for which the friction of the stylus working in the smoked paper previously had a greater damping effect. At Ottawa both components are damped. The consequence of the removal of this slight amount of damping has been to increase resonance in the pendulum and thus to obscure somewhat the earlier phases. It has come about therefore that while a greater number of earthquakes are recorded than heretofore, more difficulty is found in reading the preliminary phases in the undamped records.

Local action of distant earthquakes at the Station. In the Report for 1910–11, p. 19, an estimate was given of the time during which the ground at Cambridge was agitated during a year by the vibrations of distant earthquakes. Such an estimate naturally must vary with the sensitiveness of the seismograph depended upon for a registration of the motion. An analysis of the records of 76 distant quakes registered in Cambridge during the year 1914, yields the following figures.

Month	No. of Quakes	Duration mins.	Average mins.	Maximum mins.	Minimum mins.
Jan.	2	153.26	76.6	116.0	37.26
Feb.	6	151.	25.1	72.0	8.00
March	11	354.63	32.2	122.3	6.2
April	5	274.00	54.8	112.0	21.0
May	5	297.54	59.5	115.2	19.0
June	9	596.00	66.2	163.25	8.75
July	8	443.3	55.4	88.5	7.5
Aug.	10	477.3	47.7	103.6	1.5
Sept.	2	240.0?	120.?	——	——
Oct.	9	408.7	46.4	122.0	0.5
Nov.	5	208.3	41.6	113.0	1.0
Dec.	4	137.5	36.3	83.0	16.5

The total duration of registered vibrations for the year 1914, amounts to about 60 hrs. It will be observed that at this Station certain important earthquakes have a duration varying between 112 and 116 minutes; there is a second group lasting 122 minutes. Above and below these groups others may exist but the times range widely.

Hours at which earthquakes are registered. The hours at which earthquakes begin to be registered at the Station were tabulated in last year's report, with the result that maxima for all earthquakes near and distant came out as follows: —

	Local hours.	G. M. T. Civil.
1st Maxima	1 to 2 p.m.	18 to 19.
2nd "	11 to 12 p.m.	4 to 5.
3rd "	5 to 6 a.m.	10 to 11.

The registration hours for 1915 give a maximum of 9 records from 4 to 5 hrs. G. M. T. At no other hour did the registration rise above 5 cases. When allowance is made for the time at origin of distant shocks, it is readily understood that one or all of the hours above given would come one hour earlier in terms of the hour at which earthquakes occur.

The analysis of 638 chief earthquakes listed by the late John Milne in the Reports of the British association for the years 1904–1910, shows, upon reducing the time of occurrence to local hours at the respective epicentres, three well-marked maxima of frequency at the following hours in local time:

1st maximum	4 to 5 a.m.
2nd "	12 to 1 p.m.
3rd "	10 to 11 p.m.

Minor peaks between the hollows of the tabulation come at the following hours of minor maxima:

1st minor maximum	1 to 2 a.m.
2nd " "	8 to 9 a.m.
3rd " "	4 to 5 p.m.

The chief mimima fall between 5 and 6 p.m. and between 12 and 1 a.m. The concordance of the maxima of frequency in this list with the hours of passage of the morning minimum of atmospheric pressure, the morning maximum before noon (there is a lag of about one hour in this case), and the afternoon maximum of pressure before midnight, is too close to justify further delay in recognizing the trigger-effect of changes of atmospheric pressure sweeping round the globe before and behind the sun in setting off earthquakes, whatever the mechanism of the process may be. It will be observed that Harvard hours of maximum registration come in each case at the hour following the maxima shown in Milne's list. This is probably because most earthquakes registered at the Station originate in the hour preceding that in which they are registered.

Now if we take the 6,604 earthquakes distinctly recorded for time and place in the Catalogue of the International commission for the year 1907, we find a chief maximum from 3 to 4 hrs. G. M. T., a second high maximum between 10 and 11 hrs., and a third maximum at 17 to 18 hrs. The Harvard maxima in G. M. T. coming at 4 to 5 hrs., 10 to 11 hrs., and 18 to 19 hrs., show precisely the same belatement at 4 to 5 hrs., and 18 to 19 hrs. in regard to this table that they do to the 638 earthquakes in Milne's list, hence it is to be inferred that the 6,404 cases in the 1907 Catalogue converted to local time of the respective epicentres will reveal the same waxing and waning at critical hours of change of barometric pressure.

At the chief maximum between 3 and 4 hrs. G. M. T., the sun is passing from noon in λ135° to noon in λ125° E., over the Philippines and other islands in the most sensitive seismic gore of the globe. The morning maximum of atmospheric pressure is passing or has passed westward of the advancing sun. At the same hour in absolute time the afternoon maximum of pressure is advancing from λ75° W. to λ90° W., between 10 and 11 hrs. p. m. in local time, and the morning minimum of atmospheric pressure, broadly from 4 to 6 hrs. a. m. in local time, is sweeping the gore between λ30° E. and the meridian of Greenwich. Hence it is that the maximum frequency of earthquakes in eastern Asia, in eastern North America and western South America, and Europe-Africa, when taken together, fall between 3 and 4 hrs. in G. M. T., or broadly as a two-hour maximum between 2 and 4 hrs. G. M. T. At this hour three of the most extended meridional sensitive gores of the globe are swept over by the tropical phases of diurnal changes of atmospheric pressure.

New England Earthquakes. Several slight shocks were felt in the Merrimac Valley in Massachusetts on the night of February 21, 1915. According to press despatches shocks were felt in Andover, but more strongly southeastward towards North Reading, at 9 :20, 9 : 30, 9 : 35, and 9 : 45 p.m. Many persons ran out of their houses. Two shocks were felt in Lowell and nearby towns, at 9 : 05 and 9 : 30, according to the same reports. The first shock was felt in Billerica Centre, and the second at Cole's Crossing in Billerica. In Haverhill a shock was felt, according to one account, at 8: 55 p.m., according to another report at 8: 59. One report gives a second shock at 9: 51 p. m., and the other 20 minutes later than 8:55. The second shock rocked houses. Windows were reported to have been broken in the Farnham district of North Andover; and dishes and books were shaken off the shelves in Andover. Dishes were broken so it is stated in several houses in the Bradford and upper Main street district of Haverhill.

Mr. Preston R. Wentworth (Harvard '15) visited the district at my request and was able to verify some of the statements, but not all of them. From his investigations the intensity of the shocks appears to have risen to between IV and V in the Rossi-Forel scale, so far as can be judged by the character of the houses and objects disturbed at the time of maximum motion. The geology of this part of the state has not yet been published in sufficient detail to throw any light on the origin of these shocks. It is evident, however, that the shocks of this year were distributed along the trend of the geological formations from northeast to southwest.

Local unreported shocks. It will be observed that a number of small unreported shocks are given in the lists for the month of February, 1915. These are based on seismographic records identical in character with those identified with the shocks felt February 21 at Andover, and other nearby towns in the Merrimac Valley. They should be understood as "instrumentally recorded" shocks until confirmed by independent evidence. It is possible that these records arise from small earthquakes having their origin on the sea-floor off the coast of New England if, indeed, they are truly seismic records. Such records are not infrequent at this Station during the winter months. The motion of the instruments is quite distinct from that set up by frost cracks at the Station, and from that produced by local jars caused by vehicular traffic, or the running of machinery in the basement of the Mineralogical Museum adjoining the Station. While they have been listed, I have not counted the unconfirmed records among the earthquakes recorded for the year, and should advise that they be regarded in the enumeration of local earthquakes as negligible quantities.

It will be noted that, while a number of supposed unfelt shocks at the distance of some tens of kilometers from the Station have been recorded during the winter months, the report contains no evidence of frost cracks at the Station.

According to Prof. H. F. Reid (American year book for 1915, New York, 1916, p. 596, and personal information) the British ship "Aleppo" encountered a heavy shock at sea 300 miles southeast (not southwest) from Halifax on January 22, 1915. On that day and for several days prior thereto the instruments at the Harvard Station recorded violent jars which were not considered at the time to be of seismic origin. The vibrations were registered most clearly on the north-south component. Shocks of the same character were usually recorded, at various intervals between 8 a. m. and 4 p. m., from January on Sundays when the street traffic and movements about the building were at a minimum, as well as on week-days. None of the registered shocks were reported as felt by individuals.

The earthquake of February 14, 1914, referred to in last year's report has been fully described in a report by Dr. Klotz [1] as having its origin in 46° 15′ N. and 74° 46′ W., at a depth of 85 km. near the small hamlets of Labelle and Nominingue, Quebec, far below the known geological structure of the Laurentian rocks of that region, and "at two thirds or more of the theoretical depth of isostatic compensation" (Klotz).

Hours at which New England earthquakes occurred between 1638 and 1800. For the purpose of comparing the earthquakes of New England including the period of maximum frequency and intensity of the shocks the following table was compiled from the lists of Brigham and Lancaster. As in the previous tables 10 hrs. for instance, means at any time between 10 and 11 hrs.

0	1	2	3	4	5	6	7	8	9	10	11	G.M.T.
7	8	9	10	11	12φ	1	2	3	4	5	6	p. m.
3	7	*12*	*15*	4	4	5	6	5	6	4	*9*	Shocks

12	13	14	15	16	17	18	19	20	21	22	23	G.M.T.
7	8	9	10	11	12*	1	2	3	4	5	6	p. m.
3	7	5	*8*	2	2	3	7	4	*9*	4	2	Shocks

φ Midnight. *Noon.

Imperfect as are the data for such a table, the maximum cases 12 and 15 at the local hours from 9 to 11 p. m. correspond with the world maximum of frequency for earthquakes in the year 1907, and locally with the presumed mean hours of local passage of the afternoon

[1] Earthquake of February 10, 1914. Publications of the Dominion observatory, Ottawa, 1915, *3*, no. 1, p. 3–14, with plate and map.

maximum of atmospheric pressure. The maximum of nine cases between 6 and 7 hrs. a. m., corresponding to 11th hr. G. M. T., is also accordant with the data of 1907. The nine cases between 4 and 5 p. m. coincide with the passage of the afternoon minimum of pressure; but the data other than for the evening maximum 9 to 11 hrs. are insufficient to warrant more than the continuation of such an investigation.

The belief is quite general about Boston that this region is now practically exempt from severe earthquakes, and that the occurrences of the 17th and 18th centuries at Plymouth, Newbury, and Boston pertain to an exhausted regime in the earth's conduct. It is well to remember, however, that from the great earthquake of 1638, felt at Plymouth, to the shocks at Newbury in 1727 is an interval of 89 years; and that the interval between the earthquake of 1638 at Plymouth and that of 1755 at Boston is 117 years. The interval between the earthquake of 1755 at Boston and the Charleston earthquake of 1886 is 131 years. These long intervals of repose and minimum seismic action lull suspicions and cause the multitude to regard what has not occurred in their father's and grandfather's days as a possibility too remote to enter into their own lives. Nevertheless it behooves us to remember that the earthquake at Plymouth, Mass. in 1638, at Newbury, Mass. in 1727, at Boston in 1744 and more strikingly in 1755, and yet more impressively at Charleston, South Carolina, in 1886, and at San Francisco in 1906, offer phenomena during more than three centuries, the time of occupation of the middle latitudes of the North American continent by European peoples, of the magnitude of the local play of the seismic force. It is evident that the intervals between epochs of great destructive force in the same locality are to be measured in centuries and fractions of a century. Until science shall have discovered the signs of the return of these alarming and often diastrous earthquakes, we can only bear in mind that as we recede in the steady march of time from the epoch of one of these events we draw nearer, step by step, to the next one in the series.

In an article entitled "An earthquake in New England during the Colonial Period (1755)," Mr. Frederich Brasch (Bulletin of the Seismological society, 1916, **6**, p. 26–42) has reprinted Professor John Winthrop's lecture on Earthquakes, read in the Chapel at Harvard College on the occasion of the "great earthquake" of November 26, 1755. As a reminder of the profound impression which that earthquake made upon the inhabitants of the metropolitan district of Boston, as the region is now frequently called, the facsimile (Plate) of the title page [1] of a sermon read at the time in the South Church in Boston may not be amiss among references to the literature of the earthquakes of New England. The dates November 18th and 26th refer to the same day in old and new style, a source of much confusion in the references to earthquakes of the colonial period.

World map based on Lambert's projection. In the 3rd Annual Report of the Station, I described a mercator map of the globe on which were drawn curves of equal distance from Cambridge and great circles passing through the Station and its antipodes in accordance with Lambert's projection. I have since learned that such a map was drawn in 1907 for the Station at Hamburg [2] and earlier in unpublished form for Ischia and Rome by Dr. G. Grablowitz, Director of the Central Earthquake Station in Ischia.

The same type of map was drawn up for Tokyo, Japan and published in the Journal of geography (Tokyo), 1911, **23**, plate 15. It is reproduced by W. L. G. Joerg [3] fig. 1, p. 51, together with a proposed map of the world on the stereographic projection, drawn in the example for Apia, Samoa (Plate 17). It must be stated that while the stereographic projection is best adapted to the location of epicentres with reference to a certain station, the Lambert's projection superposed on a mercator chart of the globe is of greater use to the seismologist in determining the position of epicentres from the intersection of distance curves from three or more stations. At best, the method of direct plotting on small scale maps is but approximate, and seismologists have instinctively chosen the Lambert projection because it best suits their needs of a facile means of quickly adjusting the data concerning a distant earthquake as a preliminary to more exact calculations for the determination of the epicentre.

[1] Thomas Prince, A. M. Earthquakes the work of God....being a discourse on that subject, made public at this time on the occasion of the last dreadful earthquake which happened on the 18th of Nov., 1755. Boston, 1755, 19 pp. Appendix p. 20–23. Concerning the operation of God in earthquakes by means of the electrical substance.

Those interested in earthquakes of the Colonial Period should also consult the following:

John Cotton. A holy fear of God and his judgements exhorted to: in a sermon preached at Newton, November 3, 1727. On a day of fasting and prayer, occasion'd by the terrible earthquake that shook New-England, on the Lord's day night before. With an Appendix containing a remarkable account of the extraordinary impression made on the inhabitants of Haverhill, &c. Boston, 1727. 12 mo. 24 pp. Appendix 7 pp. giving The letter of John Brown.

[2] G. Grablowitz. Weltkarte der azimute und der entfernungen für Hamburg. Die erdbebenwarte, 1907, **7**, 4 pp.

[3] Wolfgang L. G. Joerg. On the proper map for determining the location of earthquakes. Ann. Assoc. Amer., geog. 1912, **2**, p. 49–54; with useful references to the literature of seismologic maps.

Publications.

The mimeographed monthly bulletins of the Station have been published in the U. S. monthly weather review, January–December, 1915, **43**, p. 41, 80, 142, 192, 244–5, 292, 528, 528, 528, 528, 525, 571, 620.

On O as a symbol for time at origin. Bull. Seismological society America, 1915, **5**, p. 105–106.

Seismographic Stations.

The data from other stations cited in this Report are compiled from various documents received at the Station in exchange. Several stations in the United States (Denver, Fordham, Honolulu, Lawrence, Northfield, Sitka, Tucson, Vieques), and in Canada (Toronto, Victoria), since January 1, 1915, publish their records in the Monthly weather review, Washington, D. C., but issue no bulletin to this station. Records of the U. S. coast and geodetic survey stations, also published in the Monthly weather review, since January 1, 1915, may be found for earlier years in the "Results of observations" at the several magnetic observatories. Certain necessary data concerning foreign stations will be found in the list entitled "Coördonnées des stations sismiques du globe et tableaux auxiliaires pour les calculs sismiques," by Dr. Sigismond Szirtes, Publications de Bureau central de l'Association internationale de sismologie, "Series A. Memoires. Strassbourg, 1908, pp. 23. Data concerning the French seismological service are taken from Bulletin sismologique. Bureau Central meteorologique de France, Paris. Fevrier, 1911, p. 2. Occasional records from foreign stations have been taken from the Monthly bulletin of the seismological committee of the British association for the advancement of science, beginning with January, 1913, including the records of important earthquakes registered at the Shide Observatory. A number of stations are included in the list of which only the latitude and longitude are known, for the sake of their use in determining epicentres. For the first publication of records of seismographs in North America and the Hawaiian Islands, see papers by this title by Prof. Harry Fielding Reid in Terrestrial magnetism and atmospheric electricity, June, December, 1905, for the year 1904; including records from Baltimore, Cheltenham, Honolulu, Mt.

Hamilton, Puerto Rico, Sitka, St. Louis, Toronto, Victoria, Washington.

In the following list where two observatories are located in the same city, the rule has been followed where one of them is a government institution of retaining the name of the place for the public station, and of using the name of the institution for the private observatory. Several stations in Szirtes's list have been omitted for lack of records. The stations of the British association have been included because of the records published in the Shide Bulletins since the beginning of 1913. The station included in Klotz's Seismological tables for which the epicentral constants are worked out in accordance with his method are marked by an asterisk (*).

**Aachen (Aix-le-Chapelle), Germany.* Haupstation für Erdbebenforschung der Königl. Technischen Hochschule. Station A: Wiechert photographic horizontal and vertical 80 kg. $\varphi 50° 45' 55''$ N. $\lambda 6° 4' 48''$ E. Station B: Wiechert astatic pendulumseismometer 1000 kg. $\varphi 50° 46' 49''$ N. $\lambda 6° 4' 49''$ E. Alt. of stations 179m. Seismische Aufseichungen (mimeographed bulletins) from April 1, 1913. Wandhoff.

Accra. $\varphi 5° 31'$ N. $\lambda 0° 11'$ W. *Vd.* Shide Records.

Adelaide, South Australia. $\varphi 34° 56'$ S. $\lambda 138° 35'$ E. *Vd.* Shide Records.

**Agram, Hungary.* Kgl. Land. f. M. und Geody. $\varphi 45° 49'$ N. $\lambda 15° 59'$ E. A. Mohorovicic.

**Albany, N. Y.* N. Y. state museum. Before 1913. $\varphi 42° 39' 6.4''$ N. $\lambda 73° 45' 18.5''$ W. Alt. 21m. Foundation: glacial clays. Postal notices, Dec. 1909 to July 1912. Annual reports in Report of the Director of the State museum, beginning in 1906. Station discontinued after 1912. J. M. Clarke.

Alger-Bouzareah, Algeria. Bureau Central meteorologique de France. $\varphi 36° 47' 50''$ N. $3° 02' 08''$ E. Bosch-Mainka 400 kg. Bulletin sismologique de B. C. M., from January, 1910. M. Gonnessiat.

Ann Arbor, Mich. Detroit observatory. $\varphi 42° 17'$ N. $\lambda 83° 44'$ W. *Vd.* Publications of the Astronomical observatory of the University of Michigan, 1912, **1**, p. 54–72. Records from Aug. 16, 1909. Two Bosch-Omori 100 kg. horiz. Wiechert 100 kg. horiz. and 80 kg. vertical. W. J. Huzzey. Walter M. Mitchell (on registration).

**Apia, Samoa.* Observatorium der Kgl. gesellschaft der wissenschaft zu Göttingen. $\varphi 13\ 48.4'$ S. $\lambda 171° 45.9'$ W. Records from January 1, 1913 to Sept. 24, 1913. L. Geiger, G. Angenheister, F. P. Defregger.

Ascension. °7° 57′ S. $\lambda 14° 21'$ W. *Vd.* Shide Records.

**Athens, Greece.* L'Observatoire national. $\varphi 37° 58' 20''$ N. $\lambda 23° 43' 15''$ E. Alt. 104m. Subsoil: limestone. Mainka 136 kg. Records received from Jan. 1, 1912 (mimeographed bulletin).

Azores. $\varphi 37° 44'$ N. $\lambda 25° 41'$ W. *Vd.* Shide Records.

**Baku, Caucasus, Russia.* $\varphi 40° 23'$ N. $\lambda 49° 54'$ E.

**Balboa Heights, Panama Canal Zone. Isthmian Canal Commission.* $\varphi 8° 57' 39''$ N. $\lambda 73° 33' 29''$ W. Alt. 27m. Bosch-Omori 100 kg. Records in U. S. mon. weath. rev., from January, 1915.

Baltimore, Md. Johns Hopkins university. $\varphi 39° 17'$ N. $\lambda 76° 37'$ W. Records for 1904 in Terrestrial magnetism and atmospheric electricity, for June, and December, 1905. Harry Fielding Reid.

**Barcelona, Spain.* Observatorio Fabra, de la Real academia de ciencias y artes. $\varphi 41° 25' 6''$ N. $\lambda 2° 7.6''$ E. Alt. 405m. Foundation: Palaeozoic slates. Two bifilar Mainka pendulums; one three component Vicentini. Records rec'd from April 1, 1914. E. Fontseré, R. Jardi.

**Basel, Switzerland.* $\varphi 47° 34'$ N. $\lambda 7° 35'$ E.

**Batavia,* Java. Kon. magn. en meteor. observatorium te Weltvreden. $\varphi 6° 11'$ S. $\lambda 106° 49' 45''$ E. Alt. 8m. Foundation: Pleistocene alluvium. Wiechert horiz. 1000 kg. Seismological bulletin (printed) rec'd from May, 1911. W. van Bemmelen.

Beirut. $\varphi 33° 54'$ N. $\lambda 35° 28'$ E. *Vd.* Shide Records.

**Belgrade, Servia.* $\varphi 44° 49'$ N. $\lambda 20° 27'$ E.

**Berkeley, California.* University of California. $\varphi 37° 52' 15.9''$ N. $\lambda 122° 15' 36.6''$ W. Alt. 85.4 m. Bosch-Omori 100 kg.; Wiechert vertical 80 kg. Records from Oct. 30, 1911 in Univ. Calif. publ., Bull. of the seismographic stations. H. O. Wood; from April 1, 1912; E. F. Davis. *Vd.* Lick, Mt. Hamilton.

Bermuda. $\varphi 32° 19'$ N. $\lambda 64° 51'$ W. *Vd.* Shide Records.

Besancon, France. Bureau central meteor. de France. $\varphi 47° 14' 59''$ N. $\lambda 5° 59' 16''$ E. Bosch-Mainka 130 kg. Records in Bull. sismol. B. C. M. Lebeuf et Goudey.

Bidston. $\varphi 53° 24'$ N. $\lambda 3° 04'$ W. *Vd.* Shide Records.

Birmingham, England. $\varphi 52° 28'$ N. $\lambda 1° 53'$ W.

Bombay, India. $\varphi 18° 53'$ N. $\lambda 72° 48'$ E. *Vd.* Shide Records.

Breslau. *Vd.* Krietern.

**Budapest, Hungary.* Bulletin hebdomaire des Observatoires sismiques de la Hongrie. $\varphi 47° 29' 29''$ N. $\lambda 19° 03' 55''$ E. Records for June 1910. Janosi. Includes also records for Fiume, Kalocsa, Ogyalla, and Temecvar, which see.

Cairo, Egypt. *Vd.* Helwan. Shide Records.

Calcutta, India. $\varphi 22° 34'$ N. $\lambda 88° 24'$ E. *Vd.* Milne Records.

**Cartuja (Granada), Spain.* La Estacion sismologica de Cartuja (Granada). $\varphi 37° 11'$ N. $\lambda 3° 36'$ W. Alt. 768 m. Foundation: Tortonian marls. Instruments: Cartuja bifilar and vertical. Boletin mensual rec'd from No. 8, Aug., 1913. Manuel Ma. S.-Navarro Neumann.

Catania, Italy. Osservatorio geodinamico di Catania. $\varphi 37° 30' 13''$ N. $\lambda 15° 5' 15''$ E. Alt. 45m. Foundation: lava. Three component Vicentini; two component Cancani seismograph. Bulletino sismologico (printed) rec'd from October 1, 1913. A. Ricco.

**Capetown, South Africa.* $\varphi 33° 56'$ S. $\lambda 18° 29'$ E. Milne Records.

Cape Verde. φ16° 30′ N. λ24° 00′ W.

Casamicciola, Italy. G. Grablowitz. *Vd.* Szirtes's List.

Chacarita. φ34° 35′ S. λ58° 28′ W. *Vd.* Shide Records.

Cheltenham, Maryland. U. S. coast and geodetic survey, Magnetic Station. φ38° 44′ N. λ76° 50′ 30″ W. Alt. 71.6m. Bosch-Omori 10 and 12 kg. George Hartnell. Records from December, 1904; *Vd.* Results of observations at Cheltenham for 1905–06; Washington 1909, p. 92. Continued in later reports. Records from January 1, 1915, in U. S. mon. weather review.

Christchurch, New Zealand. φ43° 31′ 50″ S. λ172° 37′ 18″ E.

Clermont-Ferrand, (Puy de Dome), France. Bur. cent. meteor. de France. φ45° 26′ ca. N. λ2° 58′ ca. E. B–M 130kg. Records from November 1913. Mathias et David.

**Cleveland, Ohio.* Observatory of St. Ignatius college. Jesuit seismological service. φ41° 29′ 08″ N. λ81° 42′ 29″ W. Alt. 206m. Foundation: glacial. drift. Wiechert horizontal 80 kg. Printed Bulletin from March 4, 1911. Frederick L. Odenbach.

Cocos. φ12° 12′ S. λ96° 54′ E. *Vd.* Shide Records.

Colombo. φ6° 56′ N. λ79° 50′ E. *Vd.* Shide Records.

Copiapo, Chile. *Vd.* records in Boletin del Servicio sismologico de Chile. Montessus de Ballore.

Cordoba, Argentina.

Cork, Ireland. φ51° 53′ N. λ8° 28′ W. *Vd.* Shide Records.

**Czernowitz, Bukowina, Austro-Hungary.* Institut für kosmische physik der k. k. Universität. φ48° 18′ N. λ25° 56′ E. Alt. 243m. Mainka 450kg. Seismische Aufzeichungen (rec'd from April 21, 1913). Julian Silberhaus.

Darmstadt. *Vd.* Jugenheim.

de Bilt, Holland.* Koninklijk Nederlandsch meteorologisch institut. seismische registrierungen in de Bilt, Utrecht 1915, **1. Records from June 26, 1904 to October 5, 1904; from April 16, 1908 to December 31, 1913. φ52° 6′ N. λ5° 11′ E. Alt. 3m. Wiechert astatic horizontal 200kg. Bosch horizontal 25kg.; since 1908; earlier registration by two light pendulums after von Rebeur-Paschwitz. E. Van Everdingen.

**Denver, Colorado.* Sacred Heart college. S. S. S. J., Earthquake station. φ39° 40′ 36″ N. λ104° 56′ 54″ W. Alt. 1655 m. Wiechert astatic horizontal 80kg. Records in U. S. mon. weath. rev. since Jan. 1, 1915. A. W. Forstell.

**Disco, Greenland.* φ69° 15′ N. λ53° 23′ W.

**Durlach, Germany.* φ49° 00′ N. λ8° 29′ E.

Ebro, Tortosa, Spain. Observatorio del Ebro. φ40° 49′ 12″ N. λ0° 29′ 40″ E. Szirtes (1908) gives φ40° 49′ 14″ λ0° 29′ 38″ E.

Edinburgh, Scotland. φ55° 57′ 23″ N. λ3° 10′ 46″ W.

**Ekaterinburg, Russia.* φ56° 49′ N. λ60° 38′ E.

**Eskdalemuir, Scotland.* Meteorological office observatories. φ55° 19′ N. λ3° 12′ W. Alt. 237m. Two horizontal and one vertical Galitzin pendulums, with galvanic registration. Milne-Shaw east-west; Omori north-south.

Earthquake Bulletin (mimeographed) rec'd from Oct. 1915. L. F. Richardson. Annual report in the meteorological year book, pt. 3, no. 2.

Fanning Island. φ4° 00′ N. λ159° 50′ W. *Vd.* Shide Records.

Fiji. φ20° 00′ S. λ178° 00′ E. *Vd.* Shide Records.

**Firenze.* *Vd.* Florence.

Fiume, Hungary. φ43° 49′ 56″ N. λ14° 25′ 40″ E. *Vd.* Budapest bulletins.

Florence, Italy. φ43° 47′ N. λ11° 15′ E.

Fordham, New York, N. Y. Fordham university. S. S. S. J. φ40° 57′ 47″ N. λ73° 53′ 08″ W. Alt. 24m. Wiechert 80kg. Records in U. S. mon. weath. rev. since Jan. 1, 1915. W. C. Repetti.

**Georgetown, Washington, D. C.* Georgetown university. φ38° 54′ 25″ N. λ77° 4′ 24″ W. Alt. 42.4m. Foundation: decayed diorite. Wiechert astatic pendulums, horizontal, 200 kg.; vertical 80kg. Mainka astatic 130kg. Bosch-Omori horizontal 25kg. Francis J. Tondorf.

**Gottingen, Germany.* Seismische station des geophysikalischen Instituts der Universität. φ51° 33′ N. λ9° 58′ E. Wiechert seismographs. Wochentliche Erdbebenberichte (from January 1, 1913–). Seismische registrierungen in Göttingen im Jahre 1909, by Ludwig Geiger; same for 1911, by A. Ansel in Nachrichten der K. gesell. der wissenschaften zu Göttingen. Math.-physik. klasse, 1913.

Graz, Austria.* Physikalisches institut der universität. φ47° 46′ N. λ15° 27′ E. Alt. 369m. Foundation: Schotter. Wiechert 100kg. Records (rec'd from January 1, 1913.) Siebenter Bericht über seismische registrierungen in Graz im Jahre 1913 und die mikroseismische bewegung in jahre 1913, von Dr. N. Stücker, Sonder-abdruck aus den Mitteilungen des Naturwiss. ver. für Steiermark, jahrgang 1913, 1914, **50. A. Stücker.

Guilford. φ51° 15′ N. λ0° 35′ W. *Vd.* Shide Records.

Habana, Cuba. El Colegio de Belen. M. G. Lanza.

**Halifax, Nova Scotia.* φ44° 38′ N. λ63° 36′ W.

**Hamburg, Germany.* Hauptstation für erdbebenforschung am physikalischen staatslaboratorium zu Hamburg. φ53° 33′ 33.5″ N. λ9° 58′ 51.9″ E. Wiechert horizontal 1000 kg. Hecker horizontal pendulum. Die seismischen registrierungen in Hamburg, from April 1, 1918, by E. Tams. Mitteilungen der Hauptstation, etc. (mimeographed) from January 1, 1912. Dr. R. Schütt.

**Harvard, Cambridge, Mass.* *Vd.* p. 111.

Haslemere. φ51° 05′ N. λ0° 43′ W. *Vd.* Shide Records.

Helwan, Egypt. Khedivial observatory. φ29° 52′ N. λ31° 21′ E. B. F. E. Keeling.

**Hohenheim, Germany.* φ48° 43′ N. λ9° 14′ E. K. Mack.

**Honolulu, Hawaiian Islands.* Magnetic station, U. S. coast and geodetic survey. φ21° 19′ 12″ N. λ158° 03′ 48″ W. Alt. 15.2m. Milne seismograph. Records from April 3, 1903, in Results of observations for 1905–06, Washington, 1910-onward. U. S. mon. weather review from January 1, 1915. Wm. W. Merriman.

**Innsbruck, Austria.* Institut für kosmische physik. φ47° 16′ N. λ11°

24′ E. Alt. 582m. Foundation: Schotter. Mimeographed records from April 22, 1913.

**Irkutsk, Russia.* φ52° 16′ N. λ104° 19′ E.

**Ithaca, N. Y.* Geological department of Cornell university. φ42° 26′ 58″ N. λ76° 29′ 09″ W. Alt. 242.6m. Bosch-Omori 25 kg. Mimeographed bulletin since January 1, 1912. Pearl Sheldon.

Jena, Germany. Haupstation für erdbebenforschung zu Jena. φ50° 55′ 35.6″ N. λ11° 35′ 3.35″ E. Wiechert horizontal 1200 kg. Straubel vertical seismograph. Monatliche erdbebenberichte; 1912, January 1 to Sept. 31; all received. W. Pechau.

**Jugenheim, Germany.* Seismische station Darmstad-Jugenheim. φ49° 45′ 30″ N. λ8° 38.7′ E. Wiechert horizontal 1200 kg. Beobachtungen der Seismischen station (printed) since January 1, 1912 to June 12; Mitteilungen (mimeographed) from March 1, 1913. C. Zeissig.

**Jurjew, Dorpat, Russia.* φ58° 25′ N. λ26° 42′ E.

Kalocsa, Hungary. φ46° 31′ 42″ N. λ18° 58′ 33″ E. *Vd.* Budapest.

Kew, England. φ51° 28′ 06″ N. λ0° 18′ 46″ W.

Kilauea, Hawaii. Hawaiian volcano observatory. Whitney laboratory of seismology. φ19° 26′ N. λ155° 16′ W. (Coördinates from topographic map by U. S. G. S., 1912). Weekly bulletin of Hawaiian volcano observatory. vol. 2 (1914), 3 received. Records of local earthquakes by H. O. Wood. T. A. Jaggar.

Kobe, Japan. φ34° 41′ N. λ135° 11′ E.

Kodiakanal, India. φ10° 13′ 50″ N. λ77° 27′ 46″ E.

**Königsberg, Prussia.* Hauptstation für erdbebenforschung in Gr. Raum des geologischen instituts. φ54° 49.9′ N. λ20° 29.8′ E. Wiechert horizontal 1000 kg. Records received from July 1, 1913.

**Königstuhl, Heidelberg, Germany.* Königstuhl Sternwarte. φ49° 23′ 56″ N. λ8° 43′ 15″ E. Erdbebenberichte (mimeographed) from December 1, 1913; also for 1915, 1916–. F. Wolf.

**Krakau (Cracow), Austria.* K. k. sternwarte. φ50° 4′ N. λ19° 58′ E. Alt. 206m. Foundation: alluvium. Seismische aufzeichungen (mimeographed) from January 1, 1913. Bosch-Omori horizontal heavy pendulum. M. P. Rudzki.

Krietern, Breslau, Germany. König. Erdwarte. Szirtes gives Breslau φ51° 06′ 57″ N. λ17° 02′ 11″ N. C. Scholtz.

**Ksara, Lebanon, Asiatic Turkey.* φ33° 49′ N. λ39° 52′ E. P. B. Berloty.

**Laibach, Austria.* Erdbebenwarte. φ46° 03′ N. λ14° 31′ E. Alt. 300m. Foundation: Schotter. Galitzin aperiodic horizontal pendulum. Reports (mimeographed) from March 30, 1913.

**La Paz, Bolivia.* La Estacion sismica del Colegio de San Calixto (PP. Jesuitas.) φ16° 29′ 43″ S. λ68° 9′ 10″ W. Alt. 3700m. Records (mimeographed from January 1, 1915. Bifilar horizontal N–S 2000 kgs. E–W 450 kgs. San Calixto vertical 1500 kgs. P. M. Descotes.

Lawrence, Kansas. University of Kansas. Department of physics and astronomy. φ38° 57′ 30″ N. λ95° 14′ 58″ W. Alt. 301.1m. Wiechert horizontal. Records from January 1, 1915 in U. S. mon. weath. rev., 1915, **43**. F. E. Kester.

**Lemberg, Austria.* Technische hochschule. φ49° 50′ N. λ24° 01′ E. Alt. 308m. Foundation: sand and sandstone. Bosch-Omori horizontal heavy pendulums. Records from April 21, 1913.

Lick, Mt. Hamilton, Calif. Lick observatory station. φ37° 20′ 24.5″ N. λ121° 38′ 34″ W. Alt. 1281.7m. Wiechert horizontal N and E; also vertical. Records in University of California Publications. Bulletin of the Seismographic stations since May 23, 1911.

Loyola, New Orleans, Louisiana. Jesuit seism. service. φ29° 56′ 54″ N. λ90° 07′ 12″ W. Alt. 2 m. Wiechert horizontal and vertical 80 kg. Postal notices (occasional) from January 3, 1911. A. L. Kunkel.

**Madras, India.* φ10° 14′ N. λ77° 28′ E.

**Makejevka, Russia.* φ48° 02′ N. λ37° 59′ E.

**Manila, Philippines.* The Observatory. φ14° 41′ N. λ120° 58′ 33″ E. Alt. 2.4m. Foundation alluvium. Wiechert astatic, 1000 kgs. Records (mimeographed) rec'd from January 1, 1913. P. Miguel Saderra Maso.

Marseilles, France. Bur. cent. meteor. de France. φ43° 18′ 19″ N. λ5° 23′ 38″ E. Bosch-Mainka, 130 kgs. Records in Bulletin sismologique, Paris, since November 1, 1910. Bourget et Fabry.

Mauritius, Royal Alfred observatory. φ20° 05′ 39″ S. λ57° 33′ 05″ E.

Melbourne. φ37° 50′ S. λ144° 58′ E. *Vd.* Shide Records.

**Messina, Italy.* φ38° 118′ 45″ N. λ15° 33′ 18″ E. Bolletine sismico in 1906 (Szirtes).

Mizusawa, Japan. International latitude observatory. φ39° 38′ N. λ141° 07′ E. H. Kimura.

Mobile, Ala. *Vd.* Spring Hill.

Mount Hamilton. *Vd.* Lick.

**Munich, Germany.* 48° 09′ N. λ37° 59′ E.

New Haven, Conn. Yale university. Department of geology. Peabody museum. φ41° 19′ 22″ N. λ72° 55′ 07″ W. Bosch-Omori, 100 kg.

Northfield, Vermont. U. S. weather bureau. φ44° 10′ N. λ72° 41′ W. Alt. 256m. Bosch-Omori. Monthly reports in U. S. mon. weather review from Jan. 1, 1915. Wm. A. Shaw.

Ogyalla, Hungary. φ47° 52′ 24″ N. λ18° 11′ 32″ E. *Vd.* Budapest.

**Osaka, Japan.* φ31° 42′ N. λ135° 31′ E. *Vd.* Shide Records.

**Ottawa, Canada.* Dominion astronomical observatory. φ45° 23′ 38″ N. λ75° 42′ 57″ W. Alt. 83m. Bosch-Omori photographic. Mimeographed monthly records from January 1, 1910. Annual reports in Appendix i to Report of the Chief astronomer, from 1906. Otto Klotz.

Padova. φ45° 24′ N. λ11° 52′ E. *Vd.* Shide Records.

Paisley, Scotland. φ55° 50′ N. λ4° 26′ W. *Vd.* Shide Records.

**Parc St. Maur, France.* Bur. cent. meteor. de France. φ48° 48′ 34″ N.

λ2° 29′ 37″ E. Galitzin seismograph since June, 1912. *Vd.* Bulletin sismologique, from January 1, 1910. Bosch-Mainka, 400 kgs. since June, 1909. Ch. Dafour et L. Eblé.

Pavia, Italy. φ45° 11′ 06″ N. λ9° 09′ 13″ E. E. Oddone.

Perth. φ31° 57′ S. λ115° 50′ E. *Vd.* Shide Records.

Pilar. φ31° 40′ S. λ63° 51′ W. *Vd.* Shide Records.

Pola, Austria. K. u. k. hydrographisches amt. (Abteilung geophysik). φ44° 51.8′ N. λ13° 50.8′ E. Alt. 32m. Foundation; Kreidekalk. Wiechert horizontal, 1000 kg. Conrad seismograph. Records rec'd from May 5, 1913. W. von Kesslitz (until July, 1914).

**Pompeii, Italy.* φ40° 44′ N. λ14° 30′ E. *Vd.* Shide Records.

Poughkeepsie, N. Y. Vassar college, Department of Geology. Wiechert 200 kg. W. I. Robinson.

**Potsdam, Germany.* φ52° 22′ 51″ N. λ13° 03′ 59″ E.

**Pulkova, Russia.* φ59° 46′ 19″ N. λ30° 19′ 39″ E. *Vd.* Shide Records.

Puy de Dome, France. Bur. cent. meteor. de France. φ45° 46′ 28″ N. λ2° 58′ 01″ E. Bosch-Mainka 130 kgs. *Vd.* Bulletin sismologique; records Jan'ry 1, 1910 – Oct. 1913. Mathias et David. *Vd.* Clermont-Ferrand.

**Reykjavik, Iceland.* Station internationale, attachée á l'Ecole de navigation danoise de Reykjavik. φ64° 08′ 32″ N. λ21° 55′ 45″ W. Mimeographed records for 1910.

Rio de Janeiro, Brazil. Observatorio nacional. φ22° 54′ 24″ S. λ43° 10′ 21.15″ W. Seismograph installed prior to 1908.

Rio Tinto. φ37° 46′ N. λ6° 38′ W. *Vd.* Shide Records.

Riverview, Sydney, N. S. W. Riverview college observatory. φ33° 49′ 49″ S. λ151° 9′ 30″ E. Alt. 41.9m. Foundation: Triassic sandstone. Wiechert astatic seismometer, 1000 kg. Wiechert vertical, 80kg. Mainka conical seismometer, 450kg. Bulletin (printed sheets) from March 1, 1909; after January 1, 1912, mimeographed bulletin. E. F. Pigot.

**Rocca di Papa, Italy.* φ41° 46′ N. λ12° 43′ E. G. Agamennone.

St. Boniface, Manitoba. Jesuit seismological service. φ49° 54′ N. λ97° 07′ W.

St. Helena. φ15° 55′ S. λ5° 44′ W. *Vd.* Shide Records.

St. Louis, Missouri.* St. Louis university. The Geophysical observatory. Earthquake station. φ38° 38′ 17″ N. λ90° 58.5′ W. Alt. 160.5m. Foundation: 12 feet of clay over 300 ft. of Mississippi limestone. Wiechert horizontal, 80kg. Bulletin from December 1, 1910. Annual reports in Bulletin of St. Louis university (Tables and coördinates for St. Louis, *vd.* vol. **7, no. 5, December, 1911.) John B. Goesse, George E. Rueppel.

**Samoa.* *Vd.* Apia.

San Fernando, Spain. Inst. y obs. de Marina. φ36° 27′ N. λ6° 12′ 19″ W. Gen. D. T. de Ascárate. *Vd.* Shide records.

San Salvador, San Salvador. Seismological bureau of the Republic of San Salvador. φ13° 43′ 44″ N. λ89° 14′ 30″ W. One Vicentini microseismograph; two heavy Bosch-Omori horizontal pendulums; one Agamennone macroseismometer. Sanz. Gz. Barberena. Installed January 1, 1916.

**Santa Clara, Calif.* University of Santa Clara. Astronomical and meteorological observatory. $\varphi 37° 26' 36''$ N. $\lambda 121° 57' 03''$ W. Alt. 27.43m. Wiechert astatic, horizontal and vertical pendulums, 80 kg. Printed bulletin of records from June 1, 1911. Jerome S. Ricard.

Santiago, Chile. Servicio sismologico de Chile. Bosch-Omori seismograph in tunnel in hill of St. Lucia. Also Santiago cardanic seismograph. Records in Boletin del servicio, no. 33, for the 1910. Montessus de Ballore.

Sarajevo, Bosnia. Meteorologische observatorium. $\varphi 43° 52' 08''$ N. $\lambda 8° 25' 39''$ E. Alt. 637.13m. Subsoil; humus. Sesimische aufzeichnungen, from March 3, 1913 to December 31, 1913. O. Harrisch.

**Saskatoon, Saskatchewan, Canada.* $\varphi 52° 08'$ N. $\lambda 106° 38'$ W.

**Seattle, Washington.* University of Washington. Department of geology. $\varphi 47° 39' 06''$ N. $\lambda 122° 18' 30''$ W. Alt. 50m. Bosch-Omori, 50 kg. Postal records (occasional) from March 18, 1910. E. J. Saunders.

Shanghai. Vd. Zi-ka-wei.

Shide, Isle of Wight, England. Earthquake observatory. $\varphi 50° 41'$ N. $\lambda 1° 17'$ W. Milne seismograph. Seismological committee of the Brit. assoc. adv. of science. Monthly Bulletin (printed) from January, 1913. J. H. Burgess.

Simla, India.* Indian meteorological department. Observatory, $\varphi 30° 6'$ N. $\lambda 77° 12'$ E. Alt. 2,210m. Foundation: Boileauganj quartzite and schist. Omori-Ewing seismograph (*vd.* Publications of the Earthquake investigations committee, 1901, **5, p. 6, sec. 3). Records from June 1905 to November 1908 in Memoirs of the Ind. meteor. dept., **20**, 1909, pt. 3, p. 33 et seq. J. Patterson.

Sitka, Alaska. U. S. coast and geodetic survey magnetic station. $\varphi 57° 03'$ N. $\lambda 135° 30' 06''$ W. Alt. 15.2m. Bosch-Omori horizontal, 10 and 12 kg. Records from May, 1904, in Results of observations, for 1905–06; Washington, 1910– continued. Typewritten records for 1913, 1914. Records from January 1, 1915, in U. S. mon. weath. review. J. W. Green.

**Sofia, Bulgaria.* L'Institut meteorologique central de Bulgarie. $\varphi 42° 42'$ N. $\lambda 23° 20'$ E. Alt. 540m. Bosch horizontal, 10kg. Bulletin sismographique. Enregistrements á Sofia, No. 1, 1917, from April 16, 1916. Spas Watzof.

**Spring Hill, Mobile, Alabama.* Spring Hill college. $\varphi 30° 41' 44'$ N. $\lambda 88° 08' 46''$ W. Alt. 60m. Wiechert astatic horizontal, 80kg. Postal notices (occasional) from August, 1912. Records (mimeographed bulletin) from January 1, 1911, to August 17, 1912. Cyril Ruhlmann.

Stonyhurst, England. Observatory. $\varphi 53° 50'$ N. $\lambda 2° 28'$ W. P. W. Sidgreaves, S. J. Issues earthquake records. *Vd.* Shide Records.

**Strassburg, Germany.* Kaiserliche Hauptstation für erdbebenforschung. $\varphi 48° 35.5'$ N. $\lambda 7° 45' 57''$ E. Alt. 135m. Foundation; gravel. Wiechert astatic horizontal, 1000kg.; vertical 1200kg. Mimeographed records (rec'd) from October 6, 1910. Galitizin aperiodic, with galvanometric registration; records from February 1, 1914. Records of microseisms compared with

"Seegang" at Gris Nez, Ile d'Aix, Skudenes, Helgoland, and Borkum, from January, 1913. Mainka.

**Sydney, N. S. W.* φ33° 52′ S. λ151° 12′ E. *Vd.* Shide Records.

Sydney, Jes. Seism. Service. *Vd.* Riverview.

**Tacabayu, Mexico.* Comision geologico de Mexico. φ19° 24′ 18″ N. λ99° 11′ 37″ W.

Tadotsu, Japan. φ34° 17′ N. λ133° 46′ E.

Taihoku, Formosa. φ25° 02′ N. λ121° 30′ E.

**Tashkent, Russia.* φ41° 19′ 31″ N. λ69° 17′ 42″ E.

Taunus, Germany. Taunus-Observatorium bei Königstein i. T. Meteorologisch-geophysikalisches institut des physikalischen vereins Frankfurt a. M. φ50° 13′ N. λ8° 27′ E. Alt. 827m. Foundation: quartzite. Mainka, 450 kg.; Wiechert vertical 80kg.; Galitzin horizontal. Mimeographed "Nachrichten. Seismische aufzeichnungen der von reinach'schen erdbebenwarte," from July, 1913; to March 31, 1914, F. Mönch; from June 30, 1914, P. A. Galbas. F. Linke.

Temesvar, Hungary. φ45° 45′ 32″ N. λ21° 15′ 55″ E. *Vd.* Budapest.

**Tiflis, Russia.* φ41° 43′ 08″ N. λ44° 47′ 51″ E.

**Tokyo, Japan.* Imperial earthquake investigation committee. φ35° 42′ 29″ N. λ139° 45′ 53″ E. *Vd.* Publications, from November, 1897. *Cf.* Shide Records, 1913, et seq. Fusakichi Omori.

**Toronto, Canada.* Dominion meteor. service. φ43° 40′ 01″ N. λ79° 23′ 54″ W. Alt. 113.7m. Subsoil: sand and clay. Milne horizontal. Records from January 1, 1915, in Mon. weather review. *Vd.* Shide Records.

Tortosa, Spain. Observatorio del Ebro. *Vd.* Ebro.

**Trieste, Austria.* K. k. maritimes observatorium. φ45° 38.9′ N. λ13° 46.4′ E. Alt. 55m. Foundation: Flysch sandstone. Wiechert horizontal, 1000 kg. Microseismic Vicentini. Records from April 21, 1913 (rec'd). E. Mazelle.

Tucson, Arizona. U. S. coast and geodetic Survey. Magnetic observatory. φ32° 14′ 48″ N. λ110° 50′ 06″ W. Alt. 769.6m. Bosch-Omori, 10 and 12 kg. Records from September 22, 1910, in Results of observations, p. 58, for 1909–10, and later, from January 1, 1915, in U. S. mon. weather review. F. P. Ulrich.

**Uccle, Belgium.* Observatoire royal de Belgique. φ50° 47′ 55″ N. λ4° 22′ E. Alt. 100m. Foundation: sand. Galitzin horizontal pendulums; Wiechert astatic, 1000 kg.; vertical 1500 kg. Bulletin sismique, Bruxelles, 1914 from January 1, 1914 (to April 19, 1914). G. LeCointe.

**Victoria, British Columbia.* Dominion meteor. service. φ48° 24′ N. λ123° 19′ W. Alt. 67.7m. Subsoil; rock. Milne horizontal; Wiechert vertical. *Vd.* Shide Records. Records in Mon. weath. review, from January 1, 1915.

Vienna, Austria. K. k. zentralanstalt für meteorologie und dynamik. φ48° 14.9′ N. λ16° 21.7′ E. Alt. 198m. Foundation: loess overlying clay. Wiechert seismograph. Mimeographed records from April 28, 1913 (rec'd). Mitteilungen der Erdbeben-kommission der Kaiserlichen akademie der wissen. i. Wien. Rudopf Schneider.

**Vieques, Puerto Rico.* U. S. coast and geodetic survey. Magnetic observatory. φ18° 09′ N. λ65° 27′ W. Alt. 19.8m. Two Bosch-Omori pendulums. Records from Sept. 7, 1903, in Results of observations for 1905–06; continued in later issues; from January 1, 1915, in U. S. mon. weath. review.

Vladivostok, Russia. φ43° 07′ N. λ131° 55′ E.

**Washington, D. C.* U. S. weather bureau. λ38° 54′ 12″ N. λ77° 03′ 03″ W. Alt. 21m. Marvin vertical pendulum, mechanical registration. Records in U. S. mon. weather review from January 1, 1915. W. J. Humphreys.

**Washington, D. C.* Jesuit seismological service. *Vd.* Georgetown.

Wellington, New Zealand. φ41° 17′ S. λ174° 47′ E. *Vd.* Shide records.

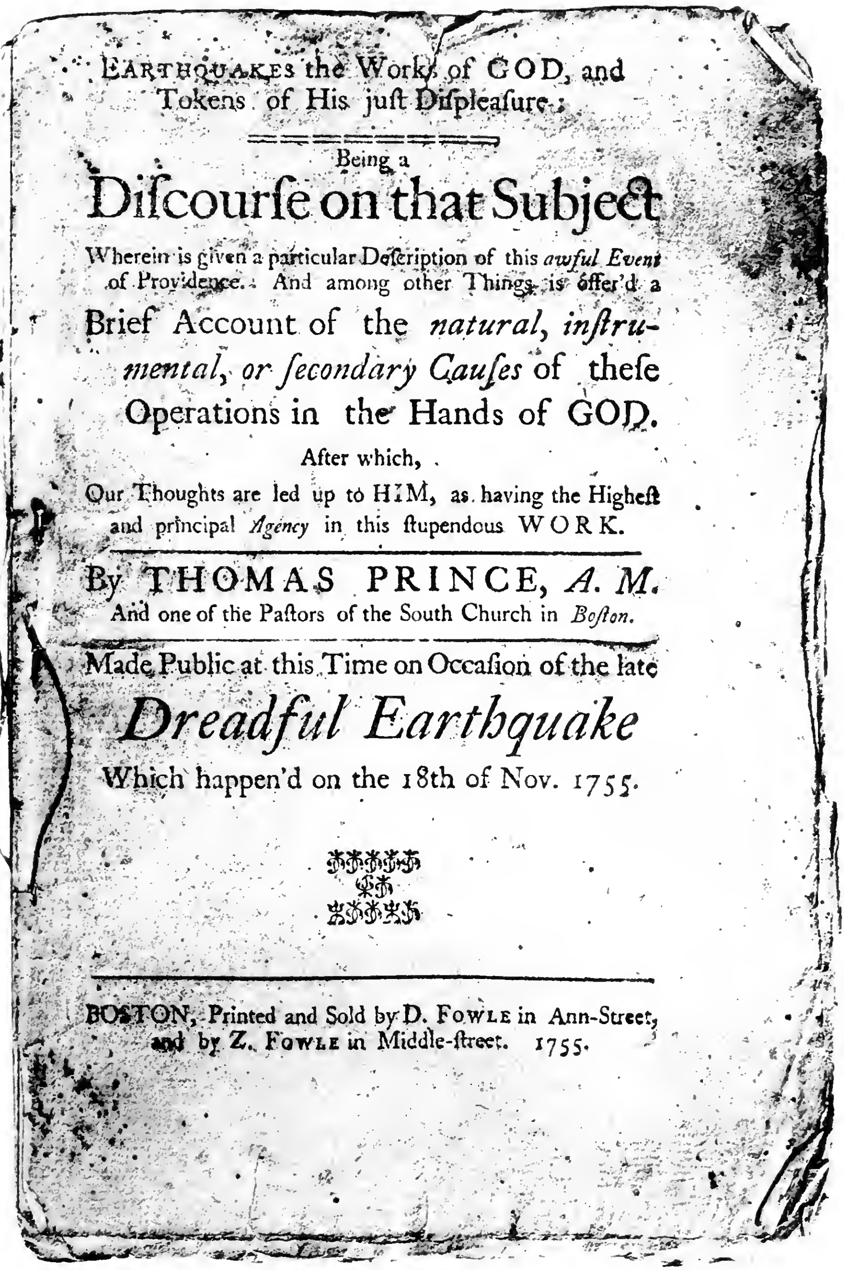
**Wien.* *Vd.* Vienna.

Zagreb. *Vd.* Agram.

**Zi-ka-wei, Shanghai, China.* φ31° 12′ N. λ121° 26′ E. Observatoire de Zi-ka-wei. Issues Seismic bulletin. P. H. Gautier.

EXPLANATION OF THE PLATE.

Title page of Thomas Prince's Discourse on Earthquakes (1755).



EARTHQUAKES the Works of GOD, and Tokens of His juſt Diſpleaſure:

Being a

Diſcourſe on that Subject

Wherein is given a particular Deſcription of this *awful Event* of Providence. And among other Things is offer'd a

Brief Account of the *natural*, *inſtrumental*, *or ſecondary Cauſes* of theſe Operations in the Hands of GOD.

After which,

Our Thoughts are led up to HIM, as having the Higheſt and principal *Agency* in this ſtupendous WORK.

By THOMAS PRINCE, *A. M.*
And one of the Paſtors of the South Church in *Boſton*.

Made Public at this Time on Occaſion of the late

Dreadful Earthquake

Which happen'd on the 18th of Nov. 1755.

BOSTON, Printed and Sold by D. FOWLE in Ann-Street, and by Z. FOWLE in Middle-ſtreet. 1755.

Bulletin of the Museum of Comparative Zoölogy
AT HARVARD COLLEGE
Vol. LV, No. 6

GEOLOGICAL SERIES. Vol. IX, No. 6

NOTES ON INVERTEBRATE FOSSILS, WITH DESCRIPTIONS OF NEW SPECIES

By Percy E. Raymond

With Five Plates.

CAMBRIDGE, MASS., U. S. A.:
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No. 6.— *Notes on Invertebrate Fossils, with Descriptions of New Species*

By Percy E. Raymond

TABLE OF CONTENTS

1. Pachytheca and Eggs of Trilobites

Several years ago I became interested in the so-called eggs of trilobites, described by Barrande from Silurian and Devonian deposits in Bohemia. One of the three types which he illustrated is represented by spherical bodies averaging about 4 mm. in diameter, and these, when sectioned, proved to have a very remarkably well preserved internal structure. Although their real nature is not yet fully understood, it is obvious that they are not eggs. After showing them to a number of zoölogists and botanists, without finding anyone who was acquainted with their nature, I stumbled upon a brief description of *Pachytheca,* and, upon looking up that genus, found that these large "eggs" must be referred to it. At this juncture the late Professor Lincoln Ware Riddle took up the study of the material with characteristic enthusiasm, and expected to describe it, but his unfortunate illness and much regretted death prevented his doing more than to make a few notes and some camera-lucida sketches. The algal nature of *Pachytheca* seems pretty generally admitted, but it does not appear possible to point to any exactly similar structure among modern plants, so that the nature of the organism has not as yet been fully demonstrated. The remarkable state of preservation of the Bohemian material permits the observation of certain facts not previously known. It is in the hope of assisting in the explanation of this curious structure that the accompanying notes and figures are presented.

Spherical Eggs

In his classic work on the trilobites of Bohemia, Barrande described three kinds of spherical bodies, which he considered to be the eggs of trilobites. All were usually black in color and the distinction was made on the basis of size. The largest were from 4 to 5 mm., the medium-sized ones were about 2 mm. and the small ones did not exceed .66 mm. in diameter. The specimens of the two larger sizes were reported as being rare and always found isolated, whereas the very small ones were abundant, great numbers occurring together in the same piece of rock.

Barrande's reasons for thinking that these objects might be the eggs of trilobites were:

1. They are never found except in localities where there are many fragments of trilobites.
2. In each of the three sorts the diameter is constant.
3. The spheroids are always black, whatever the nature of the rock, except in the red strata of Division H.
4. The shell is thin and opaque, and easily detached by a blow. The surface is brilliant as if polished. The interior, filled with semi-translucent calcite, in some cases shows black spots and at the center a crystalline nucleus.
5. Not all the specimens are preserved as spheres, but some are crushed and bent in a way to suggest great flexibility of the corneous envelope.
6. The larger spheres, the form of which is almost perfect, show, in the few examples known, a cleft of variable form, such as one would expect to find in an egg which had hatched.
7. The black external surface is always a little wrinkled in the best preserved of the specimens.

Barrande further pointed out that the smallest spheres are of exactly the same diameter as the length of the protaspis of *Sao*. Although no young are known as large as the larger ones (2–5 mm.), still it might be possible that the young of the specialized *Ceratocephala verneuili* and *Cheirurus quenstedti* were of appropriate size.

The larger spheres were reported by Barrande to have been collected from Stage E (Silurian), where they were associated with *Ceratocephala verneuili*, *Cheirurus quenstedti*, *Harpes ungula*, *Goldius edwardsi*, etc. The smallest ones were found in Stages G and H (Lower Devonian), always with the remains of *Phacops fecundus*.

Large Spheres

Plate 1, figs. 1–4, 6, 7

In the Schary collection in the Museum of Comparative Zoölogy, there are specimens of the larger spheres, 4.5 to 5 mm. in diameter, from the Silurian at Butowitz, Lochkow, Wiskocilka, Ohvadka, and Lodenitz, where they are preserved in limestone, and Borek, where they are found in a calcareous shale.

The large spheres with a diameter of 4–5 mm. (Barrande, 1852, p. 276, pl. 27, fig. 3), on sectioning, showed wonderfully preserved structure. In a slice passing approximately through the center of a specimen 4.34 mm. in diameter, there is a large, nearly circular central space filled with clear calcite containing elongate branching tubules. This is 1.8 mm. in diameter. Outside this is a zone of radially arranged, small, hollow, branching tubes, which extend to an outer covering consisting of three coats. The zone filled with radial tubes is 1.1 mm. thick. The outer covering is 0.17 mm. thick and shows an outer, dark layer which is separated only indistinctly from the matrix; a middle zone, with spine-like crystals of clear calcite; and an inner thin dark layer without structure. It is this inner layer which generally forms the coating of specimens broken from the rock, thus explaining the black polished surface remarked upon by Barrande.

The radial tubes, when highly magnified, prove to have walls made up of three coats, an outer and inner dark sheath, separated by a layer of clear calcite. The space between tubes is crossed by very thin transverse septa which are much more prominent in some sections than in others. The tubes bifurcate at least once and in some instances twice in the plane of the radial section. There is also a sort of grouping indicated by irregular polygons in the tangential section which suggests that a single tube may become divided into as many as sixteen before it reaches the outer wall.

Externally, these spheres show no topographical markings other than a single flattened or slightly concave area, which resembles the hilum of a seed. It has about one-sixth the diameter of the whole body, and appears to be the point of attachment. After repeated trials by a number of persons, Dr. H. N. Coryell was the successful operator. A section was obtained through a specimen perpendicular to this depressed area. This individual was one which had been freed from the matrix before sectioning, and, as usual with such specimens, shows only the inner of the three coats. This coat is somewhat thickened beneath the depressed area and this extra thickness extends outward from the area in question for about one-half of a quadrant. The zone of radial structure is about .65 mm. thick at the pole opposite the point of attachment, but at the latter area it is much thinned, the inner wall approaches close to the outer one, and for a distance of about .50 mm. radial elements are lacking. (See pl. **1**, fig. 4.)

Embedded in the clear calcite of the central cavity, arranged in directions approximately radial to a point near the pole opposite to the area of attachment, is a tangled mass of small tubes. Similar masses, without, however, the radial arrangement, are seen in the other slices. I at first took these scattered tubes to be disrupted fragments from the zone of radial structure, but Professor Riddle called my attention to the evidence that they are really vestiges of a disintegrating filling of the cavity in which they lie. These tubes are less straight than those in the radial zone, and seemingly of less diameter. They agree with the former, however, in having a very small lumen. The tube has an outer and an inner wall, separated by a clear structureless zone. The lumen is generally filled with a finely granular substance which appears of brownish color under the microscope. Evidence of the breaking down of the internal structure is seen in two of the slices, where the inner wall of the radial zone seems to have shrunk away from the radial elements.

This disintegration of the tissue within the organism furnishes strong support for the view that *Pachytheca* was a structure which served as a float for some seaweed, and is against the interpretation as a spore or seed.

This organism apparently belongs to the genus Pachytheca, which is supposed to be of algal nature, but about which opinion differs. The original specimens of that genus were found in the "Ludlow bone bed" near Hereford, England, but according to Barber (Ann. Botany, **5**, 1891, p. 157), it occurs at almost all localities in England and Wales where the beds transitional between the Silurian and Old Red sandstone outcrop. Individuals showing the better structure were found in the Wenlock near Malvern, and at Cardiff, Wales. The best description of the fossil is that by Barber, cited above, but the genus was named by Hooker (Ann. Botany, **3**, 1889, p. 135), though mentioned as early as 1839 as "Bufonites" by Murchison in the Silurian System.

Pachytheca, like the "trilobite eggs," is a small spherical body, the exterior marked by a single small pit, only seen in the best preserved specimens. When sectioned, a central cavity is found, surrounded by radiating, branching tubes. The cavity itself also contains irregularly arranged branching tubes like those of the specimens from Bohemia.

These bodies were supposed by Murchison to belong to the "fish" with which they are associated in the "bone bed," but Hooker (Quart. Jour. Geol. Soc., London, **9**, 1853, p. 12) described them as spore cases of Lycopodiaceae, upon which they were hailed as the oldest land plants. The same author, in his paper of 1889, changed his opinion of the nature of the fossils, and stated that they were probably of algal origin, an opinion in which Barber (1891) concurred. In the meantime, there had been considerable discussion of these objects, Dawson having considered them to be seeds, and others going to the extreme of doubting their vegetable nature. Doctor Duncan, in a comment on Dawson's paper (Quart. Jour. Geol. Soc., London, **38**, 1882, p. 108) suggested that the organism is the float or conceptacle of a seaweed.

Professor Riddle believed that the Bohemian specimens were of algal nature, and compared them with the floats of Sargassum. He called attention to the loose threads in the matrix of the central cavity as an indication of the degeneration of tissue in this region, and sections show that the air space was larger in some individuals than in others.

In Bohemia and in the Wenlock of England and Wales, Pachytheca occurs in limestones which carry an abundant and strictly marine fauna. In the Ludlow "bone bed," which consists of osseous and coprolitic matter, fish, eurypterids and a few poorly preserved brachiopods and molluscs occur with the little spheres. The shale beneath the bone bed is, according to Murchison, full of stems of "fucoids."

At the locality at Cardiff, Pachytheca was found in company with great quantities of fragments of Nematophycus, a gigantic seaweed which Dawson supposed to be a conifer. No connection between the two has, however, been proved. Scott (Encyclopaedia Britannica, 11th ed., article on Palaeobotany) states that in one case the "spherical thallus was found seated in a cup-like receptacle. There can be little doubt of the algal nature of the fossil, but beyond this it is impossible at present to carry its determination."

Spheres of Medium Size

The spheres of medium size (diameter 2 mm., Barrande, 1852, p. 276, pl. 27, fig. 2) were too few in the collection to use any of them in making sections. A fragment of limestone from the Silurian at Butowitz contains a small aggregation of them in a nearly circular area about 8 mm. in diameter. In this group there are about twenty specimens, crowded together, and many of them rather poorly preserved. The individuals exfoliate in the same way as the large spheres and probably have the same nature. They occur at the same horizon and localities as the large ones.

Spheres of Small Size

Plate **1**, fig. 5

The spheres of small size (diameter less than 1 mm., Barrande, 1852, p. 276, pl. 27, fig. 1) occur in great numbers in certain of the Devonian beds, all the specimens in the Museum of Comparative Zoölogy being from Stage G at Chotecz, Bohemia. They appear to occur in irregular aggregates, in some cases so abundantly as to be in contact with one another, in others disseminated through the rock. At first glance these specimens, of course, suggest oölites, but in thin sections it is seen that they have a definite brown to black outer envelope. This is in most cases filled with clear calcite. In very many of the sections the envelope is deformed, invaginated, wrinkled, or broken, showing that the envelope was weak. In this respect they differ markedly from the larger spheres. The outer coat of some of the best preserved specimens appears to be made up of numerous small cells, with wrinkles or spines on the surface. A few individuals show within the wall groups of smaller bodies like the containing one, but not circular in outline, and not of uniform size among themselves. In no case is the outer capsule entirely filled. One specimen contains two internal bodies, about which the outer wall has shrunk, another four, filling about one-half the area, still another has three. All these are in thin section no. 352. Such specimens suggest the sporangia described by Dr. Clarke from the Lower Middle Devonian of western New York (Amer. Jour. Sci., 1885, **29**, p. 288, figs 10, 13), and it seems not at all improbable that these Devonian "eggs" are spores or sporangia.

Capsule-shaped "Eggs"

Barrande, Syst. Sil. de Boheme, **1**, Suppl., 1872, p. 429, pl. 11, figs. 6, 11; pl. 18, figs. 30–33; pl. 35, figs. 21–32. Fritsch, Problematica Silurica, 1908, pl. 10, figs. 12, 13.

These "eggs" are elongate, cylindrical, with hemispheric ends, and are from 1.5 to 2.5 mm. in length, and 0.75 to 1 mm. in diameter. They occur always in masses, which Barrande classified as ovoid, cylindrical, discoidal, and irregular. These masses, which are usually from 10 to 30 mm. long, contain great numbers of individual capsules, and have very much the appearance of aggregates of eggs, suggesting particularly the ova of gastropods. Barrande seemed to favor the idea that these were the eggs of gastropods rather than trilobites, but Walcott, after finding similar bodies within a Ceraurus, was inclined to the belief that they were really the ova of trilobites. More recently Fritsch has figured a group of these bodies as the coprolites of an annelid or echinoderm, but has given no reason for this determination.

These specimens are all from the Ordovician, and the Museum of Comparative Zoölogy contains a number from Stage D-d_5 (Upper Ordovician) at Leiskow and Nusle. The state of preservation is such that nothing can be ascertained of the internal structure, so they must for the present remain as "problematica." It is safe to say, however, that they are of an entirely different nature from the spherical specimens described above.

Billings (Quart. Jour. Geol. Soc., **26**, 1870, p. 485), while searching for limbs of trilobites, had sections cut from enrolled specimens of *Calymene meeki* from Cincinnati. One of them, described and figured, contained large numbers of small ovate bodies in the crystalline calcite with which the interior was filled. These bodies were said to be about one-eightieth of an inch in greater and one one-hundredth of an inch in lesser diameter. Billings believed that these were eggs, but they seem to have shown no structure, being merely lighter colored and more opaque than the matrix. They were probably of the same nature as the similar bodies found by Walcott in Calymene and Ceraurus.

Walcott (Bull. Mus. Comp. Zoölogy, **8**, 1881, p. 216, pl. 4, fig. 8) has written briefly on the eggs of trilobites. The specimens which he investigated were in thin sections of Ceraurus. The individual "eggs" were much smaller than those described by Barrande, each being cylindrical, with hemispheric ends, about 0.5 mm. in longitudinal and 0.25 mm. in transverse diameter. Over two hundred such were seen in one section of Ceraurus, partly beneath the head and partly under the thorax, within the ventral membrane.

These "eggs" are seen in many sections of both Calymene and Ceraurus, and appear to be fusiform or spherical as well as cylindrical. In some specimens they are in the dark part of the matrix, but are more frequently found in the clear calcite which fills the space between the test and the ventral membrane. They do not seem to be confined to any particular region of the body, but occur beneath cephalon, thorax, and pygidium. This, and the fact that they are found in the fillings of the appendages as well as in the body cavity, suggest that they are really small oölites in the incipient stage of formation, with neither radial nor concentric structure preserved. These bodies and the ones found by Billings are of about the size one would expect the eggs of trilobites to be, but even if they are eggs, their location and preservation is such that they furnish no information about the location of the genital organs or the structure of the egg.

Summary

After a review of the literature, it can only be said that none of the specimens so far described has been proved to be the egg of a trilobite. The larger bodies considered by Barrande to be ova are certainly not such, and the smaller ones, even if correctly identified, have furnished no information of any value.

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2. The Systematic Position of the Archaeocyathinae

Since the time of the description of the genus Archaeocyathus by Billings in 1861, opinions have differed as to the nature of the organisms which secreted the skeleton so named. From the original suggestion that they were intermediate between corals and sponges, opinion has ranged from the calcareous algae or Protozoa to sponges or perforate madreporarian corals. This last disposition of them seems at present to be the "official" one, as it is adopted in the Eastman-Zittel Text-book of Palaeontology, and in many American text-books of Geology.

The present status of American opinion in regard to these animals was reached before the publication by Mr. T. Griffith Taylor of his splendid monograph on the Archaeocyathinae (Memoirs Royal Soc. of South Australia, **2**, pt. 2, 1910) of Australia. He was able to show that the animals could be classed neither as sponges nor corals, but occupied an intermediate position, possibly representing a group ancestral to both the calcareous sponges and the Anthozoa.

It is partly to call renewed attention to Mr. Taylor's excellent work on the morphology and classification of this group, and partly to record certain observations which some well-preserved specimens allowed me to make, that this article is written.

Taylor has pointed out that the skeleton in this group is essentially a hollow, double-walled cone, the walls joined to each other by vertical radially arranged septa which may or may not be supplemented by tabulae, synapticulae, or dissepiments. There is a great deal of variation in form, so that specimens may be conical, tubular, cup-shaped, saucer-shaped, or in extreme cases may have no central cavity, but grow as nearly flat expansions. Many species have the proximal end in the shape of a blunt point, showing a very small base for attachment, whereas others develop considerable thickness of exothecal tissue forming a wide, solid base, within which is the conical cup.

Taylor has emphasized the fact that the walls are the essential features of the group. Both of them have the appearance of a lace-like network, the perforations in the outer wall being generally smaller than those of the inner one. The space between the walls Taylor has called the intervallum and such septa or tabulae as cross it are, like the walls, highly perforated. The intervallum is of nearly constant width in all of the parts of the cup more than a half centimeter above the proximal end, and does not increase with the expansion of the cone.

Mode of Growth of the Skeleton

It is not uncommon to find, in various genera, e.g. Archaeocyathus, Spirocyathus, Ethmophyllum, and Pycnoidocyathus, species in which more or less pronounced annulations are developed. I was fortunate enough to find in material obtained by the late Prof. J. D. Whitney many years ago at Silver Peak, Nevada, three specimens, one of Ethmophyllum and two of Spirocyathus, which show that these annulations represent resting places in the growth of the skeleton. The Ethmophyllum was, before cutting in order to determine the genus, 12 mm. high, and in the upper 2 mm. expands from a diameter of 8 mm. to one of 10.5 mm. In this genus the pores of the inner are much larger than those of the outer wall. The specimen shows clearly that the inner wall extends entirely to the margin of the cup, where it joins the outer one. The intervallum is, therefore, entirely enclosed between the two walls.

A young Spirocyathus, 17 mm. high, shows on one side a rather considerable scar of attachment, above which there are concentric lines suggestive of an epitheca for a height of 9 mm. No pores are visible in the outer walls in this area. On the side opposite to the pronounced scar, the pores begin 7.5 mm. above the base. The first distinct annulation is 8 mm. above the base and there are six in all. There is general expansion of the cup up to the last annulation, then a very sudden contraction, so that whereas the diameter at the next to the highest annulation is 7.5 mm., it is only 5.5 at the top. In this case the aperture is so contracted that only a very small oval opening remains. As in the Ethmophyllum the inner wall joins the outer one, so that the the internal structure is entirely concealed.

A larger specimen of what appears to be this same species of Spirocyathus is about 57 mm. high and approximately 11 mm. in diameter 46 mm. above the base. It shows twelve prominent annulations, the highest of which is slightly less than the maximum diameter below. As in the other specimens, the walls meet, concealing the septa and other intervallar structures.

Taylor has pointed out that in all but four of the eighty species known to him, the inner portion of the cup is empty practically to the top. Further, he found, by making thin sections, that the inner and outer walls appeared to arise simultaneously from a basal plate, and that six primary septa arose together. His observations were made on Archaeocyathus, but numerous sections of Ethmophyllum from Silver Peak, Nevada, confirm his results as to order of septation. One such section, showing six septa, is .90 mm. in diameter. Another section, close beside it, is 1.5 mm. in diameter and shows eight septa. A section 3.5 mm. across has fourteen septa. Another of the same size has eighteen, and is the smallest I have seen which showed the vesicular structure which is characteristic of the inner wall in this genus.

Taylor found no evidence of regularity in the appearance of new septa. They probably do arise in pairs, but as shown by sections of Archaeocyathus from Silver Peak, they may arise from either the inner or the outer wall. Once they have grown across the intervallum, there is no way of differentiating a new from an old septum.

From the evidence cited above from specimens from Nevada, it appears that the upward growth is by periodic additions, the place of growth being on the summit of the intervallum. In the Coscinocyathidae the perforate tabulae are deposited at the time of constriction, being merely expansions of the inner wall. In the Archaeocyathidae and other families where tabulae are absent, new growth must have proceeded by resorption of that portion of the inner wall which overlay the intervallum. Evidence of this is seen in the shelves which project into the inner cavity in some species of Archaeocyathus and Ethmophyllum.

Taylor has commented upon the parallelism which exists between species of Archaeocyathus and Coscinocyathus. He says: "It is interesting to note that almost all the forms occurring in Archaeocyathus are duplicated in Coscinocyathus. There are the same changes from 'cone' to 'saucer,' while in several species the pores of the inner wall are of the same size as those of the outer wall." He then cites six species in each genus which do not differ greatly except in the presence or absence of tabulae. Considering the fact that the tabulae can only be gotten rid of by absorption, is it not possible that some of these parallel species are really identical?

Relationship to the Corals and Sponges

Taylor has pointed out that the Archaeocyathinae can in no wise be compared with the compound corals, nor with the imperforate Rugosa of the Palaeozoic, as would be most natural, but with the perforate Madreporaria, a distinctly modern type. They lack the directive septa of the "Tetracoralla" but equally fail of possession of the cyclical septal development of the Hexacoralla. The most cogent argument of all against placing them as corals is the present observation that the inner wall covers the intervallum. Taylor has already directed attention to the fact that the septa did not pass the inner wall and that no columellar structure was developed except in Somphocyathus and Anthomorpha.

Failing to place the group among the corals one must return to comparison with the sponges. In that group two difficulties are encountered. First, entire absence of spicules; second, presence of radial septa. On the other hand, many similarities are observed. If the skeleton is to be clothed in flesh it is readily thought of as a secretion of the mesoglea of a sponge. Such an interpretation would explain the exothecal deposition in those species with large bases, and, equally well, the absence of epitheca on the more numerous forms which lack it. It would account for the unlikeness of the pores of the outer and inner walls, for the absence of calcareous deposits inside the cup, and the general perforate character of all the skeletal elements. The method of growth accords with that of a sponge and it remains only to account for the presence of septa and the absence of spicules.

Among modern sponges, absence of spicules is considered a specialized characteristic, forms with a skeleton of spongin being descended from those with a more mineralized framework. Is it not possible that the ancestor of the sponges had a continuous skeleton which became degenerated into the form of spicules? The porous walls, tabulae, and septa of the Archaeocyathinae lend themselves admirably to such a view of the history, and, as Taylor has shown, in Dokidocyathus and Dictyocyathus we have two genera of this group which in great part lose the septa. Furthermore, *Archaeoscyphia minganensis* (Billings) from the Chazy, has a form so like *Archaeocyathus profundus* that they were originally considered as one species, but the former has been shown to have a spicular skeleton.

As to the origin of the septa there seems as yet to be no very plausible suggestion. Within the group, however, there seem to be two tendencies, one to loss of septa, as mentioned above, the other toward a greater development of them, so that in Metaldetes they meet in the center in the lower part of the cup, and in Anthomorpha the skeleton is, superficially at least, very like that of such a coral as Craspedophyllum. In Spirocyathus and Protopharetra the inner wall shows a tendency to break down. Although the wall is never quite lost, a coral-like form is simulated by some members of the group. In thinking of the animal it is possible to conceive that, the inner space being protected and more or less permanent by reason of the walls, the feeding cells may have migrated inward to unite in forming an inner digestive cavity, the growing cells around the osculum may, since they were youngest and most vital, have taken on sensory and capturing functions, and somewhere in the dark ages between the Lower Cambrian and Lower Ordovician, a coral developed out of an archaeocyathinid.

In our present state of knowledge, however, it can only be said that the Archaeocyathinae are more nearly allied to the sponges than to the corals. If they cannot be ranked as a phylum intermediate between the two and possibly ancestral to both, then they should be classed with the Porifera.

The description of two new species of this group follows.

Family ARCHAEOCYATHIDAE Taylor

Genus Ethmophyllum Meek

Ethmophyllum ceratodictyoides sp. nov.

Plate **2**, figs. 1, 2

A rather large, tubular, strongly annulated Ethmophyllum is represented in the collection by a single specimen about 60 mm. long. The enlargements, of which the fragment shows seven, are narrow, prominent, annular bulges, which near the middle increase the diameter from 18 mm. to 24 mm. The lumen is about two-thirds of the whole diameter and like the outer surface shows expansions and contractions, which do not, however, correspond exactly with the position of the bulges in the outer wall.

The pores of the inner wall are much larger than those of the outer one, the vesiculose inner layer is thin, and the septa close together. At the lower end of the fragment, where it is 16 mm. in diameter, there are about 60 septa. The bulges do not seem to affect the course of the septa.

No other Ethmophyllum with pronounced annulations has been described. At least two species of Archaeocyathus, *A. concentricus* Bornemann and *A. profundus* Billings, show similar bulges, but neither has a tubular shape. Closer comparison, externally only, however, may be made with the three species of Pycnoidocyathus described by Taylor.

The chief reason for describing the specimen, however, is its peculiar parallelism with the late Devonian hexactinellid, Ceratodictya.

Horizon and locality.— From the Lower Cambrian at Silver Peak, Nevada. No. 9,298 in the Museum of Comparative Zoölogy. J. D. Whitney collection.

Family SPIROCYATHIDAE Taylor

Genus Spirocyathus Hinde

Spirocyathus constrictus sp. nov.

Plate **2**, fig. 3

Form elongate, tubular, with numerous annular constrictions. Central cavity about one-third the total diameter. Outer wall covered with small, irregularly arranged pores. Inner wall rather thick, but not vesicular. Intervallum crossed by irregular wavy septa which are strengthened by numerous tabulae and dissepiments so that the whole has a cellular structure.

This species is readily distinguished externally from the various Ethmophylla with which it is associated by the absence of longitudinal markings and the irregular nature of the pores of the outer wall.

Horizon and locality.— From the Lower Cambrian at Silver Peak, Nevada. Holotype no. 9,299; paratypes no. 9,313, Museum of Comparative Zoölogy. J. D. Whitney collection.

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3. Further Notes on Beatricea-like Organisms

Since my previous publication on this subject (Geol. Survey Canada, Mus. Bull. no. 5, 1914) I have collected a considerable amount of material, and have extended the known geographical range of *Cryptophragmus antiquatus* as far south as Virginia. It is the purpose of the present paper to record a number of new localities for that species and to describe three allied forms.

Family BEATRICIDAE fam. nov.

In erecting his family Labechidae, Nicholson (Palaeontographical Society, volume for 1885, 1886, p. 80) so worded the definition that it could include Beatricea. He considered the association a somewhat forced and temporary one, however, and ended his discussion by saying: "It may, however, be a question, whether, in view of its numerous peculiarities, it would not be expedient to regard Beatricea as the type of a special family" (loc. cit., p. 90).

The chief characteristics of the Labechidae are the "large-sized calcareous vesicles, which are usually lenticular in shape, and which are arranged in superposed strata as regards either a basal plane or an axial tube. These vesicles are traversed at intervals by 'radial pillars' directed at right angles to the plane of their strata. . . . No definitely circumscribed zoöidal tubes appear to exist."

Since the other members of the family are prostrate, encrusting growths, it seems advantageous to withdraw the elongate, upright forms from the group, and place them together under the name of their best known representative.

Beatricea Billings

Schuchert (Amer. Jour. Sci., 1919, **47**, p. 293) has questioned the validity of the name Beatricea, on the ground that Plummer (1843) gave the name Aulacera to the same kind of fossil that Billings described in 1857. Plummer did not name his species, but gave a figure which Schuchert recognizes as the fossil commonly called *Beatricea undulata*. Both *Beatricea undulata* and *B. nodulosa* are really but nominally species, as no very detailed or extensive work has ever been published on them. Since they differ considerably from one another, it seems possible that each may prove to be the type of a genus. Pending further investigation, it seems possible to retain the term Beatricea for fossils of the type of *B. nodulosa*.

An interesting observation recorded by Schuchert in this paper is in regard to the basal ends of specimens found in Anticosti. "Almost all of them are prostrate in the strata, having been broken from their basal attachments, but the latter are often seen, and some are quite large expansions, still stuck to the places where they grew" (loc. cit., p. 294).

For the present, at least, I shall continue to use the name Beatricea or species with nodose surface, unbranched habit, and no radial tubes in the outer zone. Radial pillars have been recorded in *B. nodulosa* and may prove to be generically important.

Beatricea gracilis Foerste

Plate **3**, figs. 5–7

Beatricea gracilis Ulrich (partim; nomen nudum), Bull. Geol. Soc. Amer., 1911, **22**, p. 327. Foerste, Dennison Univ. Bull., 1920, **19**, p. 195, pl. 23, fig. 7.

The first use of the name *Beatricea gracilis* in print was in connection with the description of the section at Blue Spring, a few miles southwest of Mercersburg, Pa. It was then stated that specimens were abundant in the thin limestone representing the Lowville of that locality. I visited this section in 1917, and obtained a large number of specimens and also found individuals of what appears to be the same species at Dickey, a few miles north of Mercersburg. Since those from the latter place are somewhat the better preserved, I have introduced figures of them as illustration of the species.

The name *Beatricea gracilis* was first legally published by Foerste, who credits it to Ulrich. Foerste's specimens were found in the Auburn limestone in Lincoln County, Mo., but appear to have the same characteristics as those in Pennsylvania. His brief description is as follows: "Stems 6 to 7 mm. in diameter, and several centimeters long, characterized by the presence of granules connected by the characteristic more or less anastomosing lines as in typical Beatricea. Strongly convex septal lamellae occur at intervals and occupy almost the entire width of the stems."

The following description applies to specimens found in the vicinity of Mercersburg, Pa. All of the specimens are slender, irregularly curved and so far as has been seen, unbranched. The outer surface is covered with low, elongate nodules, which appear to be arranged in a spiral fashion. In the interior, the chambered tube occupies the greater part of the diameter, and is surrounded by a thin zone of cystose tissue. The diaphragms are strongly convex upward, the chambers appearing like a series of hemispheres set one above another. These chambers are very much more regular than those of *Cryptophragmus antiquatus*. The curvature of the specimens is irregular with gentle bends, and the taper is very slight.

Measurements.— The diameter varies from 6 to 9 mm. in different specimens from Dickey. In the larger series from Blue Spring there are specimens from 6 to 12 mm. in diameter. A specimen from this latter locality, 130 mm. long, is 6 mm. wide at the lower and 5 mm. wide at the upper end. A specimen from a locality 2.5 miles east of Cumberland Gap, Tennessee, is 10 mm. in diameter. The tabulate zone of a specimen from Dickey is 2.75 mm. in diameter, and the cystose zone .875 mm. thick. A specimen from Blue Spring with a total diameter of 9 mm. has the tabulate zone 6 mm. in diameter, and there are eight chambers in 17.5 mm. along the median line. Another specimen has sixteen chambers in 30 mm. A larger one, 12 mm. in diameter, has ten chambers in 28 mm. and the cystose zone is only 1.5 mm. thick.

This species is, in external appearance, very like the type of the genus but differs internally in having a much smaller development of the cystose tissue. It is also, of course, of much less diameter.

From *Cryptophragmus antiquatus* it differs in lacking the radial zone and in being much more slender. From the form from Bellefonte, described below, it differs in lacking the branching habit and in having nodulose, spirally arranged surface markings.

Horizon and locality.— This species has so far been found only in the upper part of the Stones River. I have myself collected it at Blue Spring, Africa, and Dickey, all near Mercersburg, Pa.; at a railroad cutting 2.5 miles east of Cumberland Gap, Tenn.; one-half mile east of the station at Liberty Hill, Tenn.; and one-half mile east of the station at Lone Mountain, Tenn. One of the specimens from the latter locality is unusually large for an individual of this species and may be an imperfectly preserved Cryptophragmus. It is a large fragment, 160 mm. long, is irregularly curved, and 18 mm. in diameter at the larger and 11 mm. at the smaller end. The axial tube occupies nearly the entire diameter and the partitions are regular and rather distant, there being 9 in 44 mm. at the smaller end. A single individual of typical appearance was found in the Tyrone at Clay's Ferry, south of Lexington, Ky.

THAMNOBEATRICEA gen. nov.

Among the common fossils of the strata with Tetradium at Bellefonte, Pa. is a Beatricea-like organism which is remarkable from the fact that it branches freely, giving it a shrub-like form. In structure it has the characteristics of Beatricea, and the new name is given solely because of its branching habit. The type is *Thamnobeatricea parallela*, sp. nov.

THAMNOBEATRICEA PARALLELA sp. nov.

Plate **2**, figs. 4–9

This species occurs as slender, straight, or gently curved cylindrical branches which arise from an elongate central trunk at short intervals, and themselves branch, to some extent at least. The branching is not by bifurcation, but by lateral budding, the main stem remaining straight. The new branches tend to become parallel to the trunk, although to what extent this is true is not known, as no complete specimen has been seen. The specimens ordinarily collected occur as unbranched fragments of greater or less length.

The surface is marked by longitudinal ridges which have numerous tubercle-like crests. The ridges are close together, somewhat wavy and irregular in their course, but with no suggestion of spiral arrangement. Ridges occasionally die out and new ones begin, so that there are numerous minor irregularities. On some of the larger trunks the surface markings are decidedly nodulose and irregular.

The internal structure is much like that of *Beatricea gracilis*. There is a large central cavity crossed by hemispheric partitions with the arches convex upward, and a thin outer wall of densely cystose tissue, with distinct radial pillars. The partitions are considerably farther apart than in *B. gracilis*, and somewhat more irregular.

The type is a fragment of the main stem of a large branched colony. The trunk gives off eight branches in a length of 166 mm., two of them branched near their places of origin. The surface is not well exposed on the type, but there appear to be many large, irregularly placed nodules on some of the branches.

Measurements.— The main trunk of the type, broken at both ends, is 166 mm. long, 11 to 13 mm. in diameter at the upper end and 13 to 16 mm. in diameter 30 mm. above the lower end. The upper branch on the right hand side (of the photograph, pl. **2**, fig. 9) is 107 mm. long from the axil, nearly circular in section, 10 mm. in diameter at the base and 9 mm. at the top, where it is broken off. The branch which it gives off is 8 mm. in diameter. A fragment 19 mm. long and 9 mm. in diameter, shows only three tabulae; another, 47 mm. long has 14; and a third, 43 mm. long, has eleven. A large unbranched fragment, broken at both ends, is 200 mm. long and 18 mm. in diameter.

Horizon and locality.— This species has so far been collected only on the foot wall of the large quarry north of the road from Bellefonte to Miles Gap, Pa., and about one-half mile west of the former city. It occurs with great masses of Tetradium at about the middle of the Stones River group. It has been seen at various other places on the strike of the same beds, as at Tyrone, Pa. The type was collected by Dr. R. M. Field and the writer, and is no. 9,302 in the Museum of Comparative Zoölogy.

Cryptophragmus Raymond

Cryptophragmus antiquatus Raymond

Plate **3**, fig. 8

Cryptophragmus antiquatus Raymond, Geol. Surv. Canada, Mus. Bull. no. 5, 1914, pp. 1–10, pls. 1–4.

Since this species was described, it has been collected at a number of places somewhat remote from the original locality in Ontario.

Dr. Richard M. Field collected a single very well preserved fragment in the lower part of the Stones River at Loysburg, Pa. The weathered section is somewhat oval, 19 by 21 mm.; the axial tube is only 2 mm. in diameter, and the zone showing radial structure is 6.5 mm. thick. The structure is unusually well preserved.

The largest of several specimens collected by the writer from the Lowville at Dickey, north of Mercersburg, Pa., is also oval, and the section 12.5 by 15 mm. in diameter. The axial tube is 5 mm. in diameter.

A weathered longitudinal section from the Lowville, one and one-half miles west of Pennington Gap, Lee County, Va., is 18 mm. across at the larger end, and shows sections across some of the outer sheaths.

Cladophragmus gen. nov.

The discovery that some of the Beatricidae were of branching habit has emboldened me to describe as a new genus in that family a curious fossil which I have known for many years but have never found outside the typical locality.

This fossil has the appearance of a Thamnobeatricea stripped of its cystose tissue and is, in effect, a branching, tubular organism with hemispheric partitions, the outer wall thin, covered with small tubercles. Type, *Cladophragmus bifurcatus* sp. nov.

Cladophragmus bifurcatus sp. nov.

Plate **3**, figs. 1–4

This species occurs as short, curved tubular fragments, no specimen much over an inch in length having been found. The tubes are irregular both in diameter and curvature and in many cases show series of irregular constrictions. Some individuals expand, others contract, in an upward direction. The surface is covered with numerous small irregularly placed pustules. Seen in section (pl. **3**, fig. 2) these appear as solid outgrowths of the exterior covering, but as seen through the transparent filling of another specimen, they seem to be hollow. The partitions are convex, distant from one another, and cross the tube at the constrictions which are seen on the outer surface. The outer wall is rather stout, but shows no cystose tissue. Branching is by bifurcation, the two divisions diverging equally from the direction of the axis of the main stem, and being approximately equal in size.

Measurements.— One fragment is 34 mm. long, 7 mm. in diameter at the lower and 4.5 mm. at the upper end. Another fragment, 32 mm. long, has eleven chambers, whereas one 14.5 mm. long has but four. The best preserved individual showing bifurcation is 5 mm. in diameter, just below the place of branching, and each division has about the same diameter.

This species differs from *Thamnobeatricea parallela* in lacking cystose tissue in the outer walls, in having smaller and more irregularly placed superficial nodules, and in the method of branching.

Horizon and locality.— This species is common in one or two layers of the Lower Trenton in a quarry near the Montreal road, three miles east of Ottawa, Ontario. It occurs in layers of dark gray fine-grained limestone, in which it is associated with *Tetradium racemosum* Raymond. The cotypes are nos. 9,306–9,308, Museum of Comparative Zoölogy.

Summary

The present study has brought out some new facts in connection with the Beatricidae. It has been shown that certain forms, otherwise exceedingly like Beatricea, had a branching habit, and it thus becomes possible to confirm absolutely the previous impression that the partitions in the axial tube were convex upward. A distinct series has also been shown to exist, from Cladophragmus, with only a chambered tube, through Beatricea, in which the tube is surrounded with cystose tissue, to Cryptophragmus, which not only has the axial tube strengthened by cystose tissue, but has that surrounded in turn by sheaths pierced by radial tubes.

All of these tend to confirm the suggestion made in my previous paper, that the structure with which we are dealing was an internal axial support on which grew hydrozoan-like zoöids which in some cases secreted a calcareous framework about them, whereas in others they were supported by a gelatinous mass which was not preserved.

The following may be presented as a brief synopsis of the present taxonomic status of the members of the group:

Family BEATRICIDAE Raymond

Sessile hydromedusae with simple or branched calcareous skeleton consisting of a camerate tube which may be surrounded by cystose or by cystose and radially arranged tissue.

Genus Beatricea Billings

Colonies unbranched, axial tube surrounded with cystose tissue, often highly developed, and in some species containing radial pillars. Surface nodulose. Type, *Beatricea nodulosa* Billings.

Genus Aulacera Plummer

Similar to Beatricea, but with a strongly ribbed surface, and apparently without radial pillars. Type, *Beatricea undulata* Billings.

Genus Thamnobeatricea Raymond

Similar to Beatricea, but with branching habit, small development of cystose tissue and so far as known, no radial pillars. Type, *Thamnobeatricea parallela* Raymond.

Genus Cladophragmus Raymond

Branching camerate tubes without cystose or radial tissue. Type, *Cladophragmus bifurcatus* Raymond.

Genus Cryptophragmus Raymond

Unbranched colonies with both cystose and radial tissue surrounding the camerate axial tube. Type, *Cryptophragmus antiquatus* Raymond.

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4. Trails from the Silurian at Waterville, Maine

It is somewhat curious that a region so nearly unfossiliferous as central Maine should have furnished almost half of the organisms which, for Ebenezer Emmons, constituted the life of his "Taconic System." Professor A. Hopkins, one of Emmons' colleagues at Williams, called his attention to a piece of slate from Waterville, Maine. The fragment bore a trail which Emmons recognized as very like one illustrated in Murchison's Silurian System, a book which had appeared only two or three years previously. Shortly thereafter, probably in

1842 or 1843, Emmons visited Waterville, where Professor Justin R. Loomis showed him a large collection of trails, from which he described eight species. These he called *Nereites jacksoni*, *N. loomisi*, *N. pugnus*, *N. lanceolata*, *N. gracilis*, *N. deweyi*, *Myrianites murchisoni*, and *M. sillimani*. The types of these species cannot now be located, but the collection at Colby College contains well preserved material representing nearly all of them. Trails are rather common in loose pieces of shale along the bank of the Kennebec River, on the campus of Colby College, and also in the railroad cutting at Benton, three miles northeast of Waterville.

The interest aroused by the recent determination of the Silurian age of the Waterville shale by Professor Perkins (1924) seems to warrant a review of these oldest known fossils from Maine. My thanks are due to Professor Edward H. Perkins of Colby College for permission to study and describe the specimens.

Phyllodocites Geinitz

Phyllodocites jacksoni (Emmons)

Plate **4**, fig. 1

Nereites jacksoni Emmons, The Taconic System, 1844, p. 69, pl. 3,fig. 1. Nat. Hist. New York, pt. 5, Agriculture, 1846, **1**, p. 69, pl. 15, fig. 1.

Nereograpsus jacksoni Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, American Geology, 1855, **1**, pt. 2, p. 110, pl. 2, fig. 2.

Not *Nereograpsus jacksoni* Geinitz, Neues Jahrb. für Min., Geol. u. Pal., 1864, p. 6. pl. 2, fig. 4.

Not *Phyllodocites jacksoni* Geinitz, Verhandl. Kaiser. Leopoldino. Carol. Deutschen Akad. Naturf., 1867, **33**, p. 2, pl. 1, figs. 1, 2; pl. 2, fig. 1.

This is the largest and most conspicuous trail found at Waterville, but it appears not to be common. It is somewhat irregular, only approximately bilaterally symmetrical, showing a series of overlapping oval depressions, from two to four abreast.

Description of a Specimen

Slab no. 1,175 in the collection at Colby College has on its surface an excellent specimen, showing a termination very clearly. The trail is of the "feeding" type. It turns back upon itself very sharply, both in the original specimen figured by Emmons and the one now studied. In this respect it differs from the Bavarian specimens referred to this species by Geinitz.

The trail, where most distinct, is about 28 to 30 mm. wide, but since the outer part is but lightly impressed, the conspicuous portion is only from 15 to 18 mm. wide. The shallow central furrow is from 4 to 5 mm. in width. It is flanked on either side by pairs of low, slightly curved, spindle-shaped ridges whose long axes make an acute angle with the axis of the trail. Outside each pair of ridges is a shallow, faint, semicircular depression, which is not preserved in other than favorable locations.

At the termination there is, on the median line, a broadly elliptical, nearly circular depression, with its longer axis in line with the direction of the trail. Within this depression there is a narrow median one which appears to be a continuation of the median furrow but which does not entirely cross the elliptical scar. This depression truncates the proximal end of the ellipse. The effect produced may be likened to the inside of the shell of an inverted, very slightly convex Agnostus. The major diameter of this truncated elliptical depression is 10.5 mm. and the minor one 9.5 mm. This is the same size as some, and slightly larger than others, of the faint lateral depressions along the trail.

The elliptical impression modifies adjacent ones, and is, therefore, the terminus and not the beginning of the trail. Its similarity to the other impressions shows that it is not the result of a burrowing action of an animal descending into the mud, but is the actual impression of the lower surface of the anterior end of the animal which made the trail.

A study of the impressions adjacent to the terminal one shows that the slightly curved spindle-shaped ridges mentioned above are due to the modifications of previously made impressions by the pressure of some object of the same size and form as that which made the terminal one. They appear not to be the impressions of the lateral appendages of an elongate animal, but represent successive positions of an object such as that which made the final impression. Since the lateral depressions are all of approximately the same size, it appears that the object which made them was sufficiently rigid to maintain its shape and thus suggests a shell of some sort. The outline corresponds with that of a Patelliform gastropod, if one imagine such a snail as carrying its shell above the anterior part of the body, with a part of the body behind it. The animal which made this trail, however, appears to have crept along, moving the shelled anterior end alternately from one side to the other, leaving a deeper or shallower impression each time the test came in contact with the mud. In this way it gathered its food, thoroughly gleaning from one small area after another. So far as I can learn, no living gastropod has any such habits or power of locomotion (Parker, 1911).

Interpretation

These trails are usually supposed to be those of annelids, but that ascription is difficult to support. It originated with MacLeay and Geinitz, who supposed the markings, now called trails, to have been the actual impressions of the bodies of worms, the latter having figured a specimen of a modern Phyllodoce with his description of Phyllodocites. If this contention could be upheld, one might believe that the fossils in question were made by annelids, for the lateral markings do very much resemble the leaf-like parapodia of some Polychaeta. It should be noted, however, that the lateral markings are much larger in proportion to the width of the median furrow than are the parapodia in respect to the width of the body of any annelid. It is true that in Nereis and the Phyllodocidae the parapodia bear foliaceous outgrowths of the same form as the oval lateral markings of Phyllodocites, but these noto- and neuropodia are of small size as compared with the body of the animal. They are, in fact, used for swimming and not for crawling along the bottom. Incidentally, it should be noted that many of the Phyllodocidae are purely pelagic, although other species lurk, during the day, under stones and shells in the Laminarian zone. In general, however, they are free swimmers and not crawlers.

Nereis virens Sars is a worm with foliaceous appendages on the parapodia and is reported to live between tides where it makes burrows in the clay. Since it is commonly known as the "Creeper," this is evidently a crawling worm, and it would be interesting to know what sort of a trail it makes.

The trail known as *Phyllodocites jacksoni* can hardly be that of any polychaet, because no annelid has any terminal structure which could make the sort of impression shown by the end of the specimen under discussion. Furthermore, as has been said above, the lateral markings are too wide in comparison with the median furrow, and there are no impressions of chaetae. It also seems doubtful whether an elongate animal with numerous pairs of parapodia would leave clean-cut impressions of the appendages. Probably the impressions of the anterior parapodia would become much blurred when tracked over by the posterior ones, unless all the motion is so coördinated that perfect "step" is kept. If the latter condition obtained, then we should expect to find no blurring of the trail, yet the specimen described shows distinctly that one impression has been overlaid by another. The new impressions, however, always have the long axis at a different angle from the old, showing a turning movement not consistent with the direction of the trail. If the action of the parapodia of different parts of the body was not "in step," then one would expect to find a terminal portion of the trail equal to the length of the animal, clean cut, the other part blurred. The present specimen is a terminal part, and it is blurred.

Gastropods and annelids, being, to my mind at least, eliminated as agents in the making of these trails, one naturally turns to the Crustacea. Trilobites are not sufficiently flexible to make a trail in the peculiar way in which this one appears to have been formed, that is, by the impressing of a laterally moved anterior shield. Notostracan branchiopods of the Apus type, or discinocarid phyllocarids, on the other hand, seem to fulfil the requirements exactly. They possess an anterior carapace of the proper shape, have a narrow, elongate body, and the proper amount of flexibility. Branchiopods are mostly swimmers, but members of the Apodidae have been seen to "wriggle along the bottom on their ventral surface." Notostracans of the proper form, such as Protocaris and Burgessia, are known from the Lower and Middle Cambrian, but unfortunately we have no further representative of the group till later than the Silurian. It is, however, very probable that similar animals existed in Silurian times.

Discinocarid phyllocarids being known only as fossils, there is no direct evidence as to the habits of the animals, but the depressed disk-shaped shields of Peltocaris, Discinocaris, and Aptychopsis suggest that these animals had a form not unlike that of Apus and Lepidurus.

Discinocaris, which is found in the Llandovery of Scotland in strata with *Monograptus flemingi* (Salter), has a form that is particularly like the sort of shell which would make an impression such as the terminal one of *Phyllodocites jacksoni*. *Discinocaris browniana* Woodward, like the other members of the Discinocaridae, appears to be a single shell, without the usual median line which makes bivalves of most phyllocarids. Such carapaces undoubtedly indicate animals with forms, and possibly habits, like those of the Apodidae, and Discinocarids may have had something to do with the formation of some of the "Nereites" trails of the Silurian of Great Britain. Crustaceans of this type have not, unfortunately, yet been found in the Waterville slates.

The present evidence seems to indicate that the animal which made the trails known as *Phyllodocites jacksoni* was a branchiopod or phyllocarid crustacean with a small, oval carapace and a more or less elongate narrow body. This animal had browsing habits, crawling along the surface of the mud, into which it sank but slightly. Its progress was not continuous, but in a series of short advances, each equal to about the length of the shorter diameter of the carapace. At each feeding station the uplifted carapace was allowed to rest upon the substratum in from four to five positions, usually within an arc of 60° on either side of the axis of the trail, so that all the area on either side was searched for food.

Phyllodocites pugnus (Emmons)

Plate **4**, fig. 3

Nereites pugnus Emmons, The Taconic System, 1844, p. 69, pl. 31, fig. 2; pl. 3, fig. 4; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 15, fig. 2; pl. 16, fig. 4; Packard, Proc. Amer. Acad. Arts and Sci., 1900, **36**, p. 64.

Nereograpsus pugnus Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28; Emmons, Amer. Geology, 1855, **1**, pt. 2, p. 111.

Phyllodocites pugnus (Emmons) does not differ very greatly from *P. jacksoni*, and was apparently formed by the same sort of animal. The trails are not so wide as those of the latter species, but show the same sort of oval impressions, irregularly arranged in some portions of the trail, regularly overlapping in others. So far as can be judged from the specimens in the collection at Colby College, these trails could have been formed by smaller individuals of the same species which produced the wider one of *P. jacksoni*.

Nereites deweyi Emmons

Nereites deweyi Emmons, The Taconic System, 1844, p. 69, pl. 4, fig. 3; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 3; Manual of Geology, 1860, p. 87, fig. 64. Barrande, Bull. Soc. Geol. France, ser. 2, 1861, **18**, p. 300, pl. 5, fig. 19. Miller, N. A. Geol. and Pal., 1889, p. 519, fig. 940.

Nereograpsus deweyi Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, Amer. Geology, 1855, **1**, pt. 2, p. 110, pl. 2, fig. 3.

Myrianites murchisoni Emmons, The Taconic System, 1844, p. 69, pl. 5, fig. 1; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 1.

Myrianites sillimani Emmons, The Taconic System, 1844, p. 69, pl. 5, fig. 5. Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 5.

The trail most commonly found in the shales at Waterville is the one which Emmons named *Nereites deweyi*. It is characterized by its uniform width, regularity, and the close spacing of the meanders. The width is about 5 to 6 mm.; the median furrow is narrow, slightly less than one-third the total width, and on either side are regularly spaced, raised, leaf-like markings, about 5 or 6 in 10 mm. Some of the better preserved specimens show a slight depression in each leaf-like scar, similar to that shown in Murchison's figure of *Nereites cambrensis*. Some specimens also show, faintly, lines across the central furrow of the trail. These continue the curves of the lateral raised areas, thus giving the impression of being the imprint of a shell with a nearly semicircular outline. The very general faintness or entire absence of this line across the median furrow indicates that it was secondarily obliterated by the forward motion of the animal, hence the inwardly converging diagonal axes of the lateral lobes of the trail point forward.

The animal which made this trail was probably unlike the one which produced *Phyllodocites jacksoni*, although of about the same size. Its habits must have been different, since it went constantly forward when browsing, instead of moving the carapace from side to side. The method of production of the trail would appear to have been much the same as that which can be observed by watching the common gastropods along our shores. The animal apparently crawled along the surface, the shell in contact with the substratum, thus pushing a small amount of mud in front of it. At regular and frequent intervals the test was lifted, thus producing a low ridge, convex forward. The narrow body dragging through this ridge divided it into two oval mounds. The appendages of the animal must have been small and used under the body, otherwise the lateral markings would have been destroyed.

If this animal were a crustacean, it must have been one with a carapace broader than the body, yet one which had no appendages outspread beneath the anterior shield, a condition not supported by our knowledge of living animals of similar form. Dawson, and later Packard, published figures of the trail of Limulus, an animal with a form somewhat similar to our hypothetical crustacean. The observations show that when crawling, the markings made by the anterior appendages are obliterated by hinder ones, so that in the resultant trail, depressions made by only the last pair persist. Transverse markings are made by Limulus only when swimming. The form is totally unlike that seen in Nereites. Observations on the trails of other living animals having numerous appendages show that the markings left are usually confused and more or less indecipherable.

In this connection, one must note that actual experience is sometimes at variance with theoretical deductions. Nathorst (1881, pl. 1, fig. 1) has figured the trail of a crawling specimen of the amphipod *Corophium longicorne* Fabricius. This little crustacean is a narrow, elongate, somewhat depressed animal with several pairs of long sprawling appendages, yet it makes a narrow regular trail not very different from that which we know as *Nereites deweyi*. There is a narrow median furrow, bordered by obliquely placed, leaf-like elevations which are separated by linear depressions which meet at angles of 75° to 90°, with the apex directed forward. Evidently it is possible for a many-legged animal which does not drag the body to produce a trail in which only the posterior pair of locomotor appendages leave impressions. This trail is very similar to that produced by the gastropod Purpura, except that where best preserved all its components are more straight-sided and angular.

Although it is possible that *Nereites deweyi* was made by a crustacean it seems much more probable that the agent in making such trails was a gastropod. In this connection I have already called attention to the figure of the trail *Purpura lapillus* copied by Nicholson and Lydekker. This trail is so exceedingly similar to that known as Nereites that there can be little doubt as to the origin of the latter. *Nereites deweyi* and *N. cambrensis* Murchison are so much like the "feeding trails" of modern gastropods that any other interpretation of them seems forced.

Myrianites murchisoni and *M. sillimani* have the same habit as *Nereites deweyi*. Specimens seem to show that they merely represent different states of preservation of the same type of trail. In the forms which Emmons described as Myrianites the lateral lobes are faint or absent, but specimens show that one finds both conditions in the same trail. One specimen in particular which shows several meanders has the markings of *Nereites deweyi* on half the slab, and of *Myrianites sillimani* on the other half, changing from one to the other repeatedly.

NEREITES LANCEOLATUS Emmons

Nereites lanceolata Emmons, The Taconic System, 1844, p. 69, pl. 4, fig. 6; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 6 (*N. canceolata* on the plate).

Nereograpsus lanceolata Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, Amer. Geology, 1855, **1**, pt. 2, p. 110, pl. 2, fig. 4.

Nereites lanceolatus does not differ greatly from *N. deweyi*, except that the lateral markings are, as the name implies, somewhat more accuminate. The trail is also somewhat more irregular, as the animal in wandering about failed to cover the surface fully. It must have been made by an animal very like that which produced *N. deweyi*.

Nereites loomisi Emmons

Nereites loomisi Emmons, The Taconic System, 1844, p. 69, pl. 3, fig. 3; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 15, fig. 3. Geinitz, Verhandl. Kaiser. Leopoldino. Carol. Deutschen Akad. Naturf., 1867, **33**, p. 6, pl. 4. Packard, Proc. Amer. Acad. Arts and Sci., 1900, **36**, p. 64.

Nereograpsus loomisi Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, Amer. Geology, 1855, **1**, pt. 2, p. 110, pl. 2, fig. 5.

Crossopodia loomisi McCoy, Syst. Descr. Brit. Pal. Fossils, 1855, p. 130.

Nereites gracilis Emmons, The Taconic System, 1844, p. 69, pl. 4, fig. 3; Nat. Hist. New York, pt. 5, Agriculture, 1846, p. 69, pl. 16, fig. 3. Geinitz, Verhandl. Kaiser. Leopoldino. Carol. Deutschen Akad. Naturf., 1867, **33**, p. 6.

Nereograpsus gracilis Geinitz, Die Versteinerungen der Grauwacke-Formation in Sachsen, heft 1, 1852, p. 28. Emmons, Amer. Geology, **1**, pt. 2, 1855, p. 111 pl. 2, fig. 6.

Nereites loomisi is of the same type as *N. deweyi* and *N. lanceolatus*. It differs from them chiefly in the smaller size of the lateral lobes, 8 or 9 in 10 mm., indicating less progress of the animal at each forward movement. The habit of the trail is about the same as that of *Nereites lanceolatus*.

As Geinitz has suggested, *Nereites gracilis* is probably not to be differentiated from *N. loomisi*. It probably would be as well to include *N. lanceolatus* under the same name.

Summary

The interpretation of trails is difficult and the results often unsatisfactory. Nevertheless, some progress can be made by careful analysis of the better preserved specimens. These analyses, however, can hardly be expected to lead to anything more than the prediction of the type of animal which made the trail. Only fortunate discoveries will satisfy as to positive identifications.

In the present study I have advanced arguments which seem to me to indicate that the trails known as Phyllodocites were made by an Apus-like crustacean, and that those denominated Nereites were formed by a gastropod. Both types were originally described as impressions of chaetopod worms. Many still hold them to be the trails of such animals. Richter has recently upheld the case for the annelids. He was able to observe one of the Phyllodocidae (*Eteone longa* Fabricius) and other nereid-like worms in the act of making trails. The trails proved to be straight, irregular, or regularly and symmetrically curved. The

latter class is most interesting, as Richter argues with considerable reason, that trails up to 25 cm. in length showing repeated symmetrical curves of the same radius, turning constantly right and left, would only be made by elongate animals which progressed by rhythmic motions. This type of trail he calls the "free meander." The length of the worms creeping in these trails was from 3 to 4 cm. They were seen occupying from three to four curves of the meanders. These observations are of great importance and should enable us to identify some at least of our trails.

It should be noted, however, that these trails of chaetopods showed no trace at all of any of the lateral markings of Nereites or Phyllodocites, and confirm the theoretical conclusion that the markings of the individual parapodia would be obliterated by the passage of the body over the soft sand or mud.

The meanders traversed by these chaetopods were all open curves of comparatively large radius which do not show the sharp bends characteristic of what Richter has called "geführte Maeander," or what I prefer to call "feeding trails." In my previous paper I pointed out that such sharp turns could be negotiated readily by short animals, but could hardly be expected from elongate creatures. Richter seems inclined to think that trails of this type could be produced by annelids in spite of their similarity to the "Schneckenfrass" which he himself figures. To my mind, all the available evidence indicates that feeding trails were made by gastropods.

The question as to the naming of such things as trails remains an unsolved problem. It is, of course, absurd to give to tracks and trails generic and specific names, even if, by implication, we transfer those names to the animals which made the traces. It is obvious that a mature individual will produce a trail which will differ in some respects from that produced by the young. Observation also shows that the same individual will make very different sorts of tracks on soft mud, firm mud, soft or firm sand, and the tracks will differ whether made beneath or out of water.

As a practical matter, however, we need some sort of a name for a trail, just as much as we need a name for any kind of animal or plant. Further, we need a binominal name, if by names we hope to express any grouping by similarity. In what has been written above, I have used the term Phyllodocites, not as expressing any characteristics of any kind of animal, but to designate trails made up of overlapping, somewhat irregularly placed oval depressions on either side of a median furrow.

Nereites, as I understand it, should apply to feeding trails with a central furrow and regularly spaced, lateral, leaf-shaped elevations.

Bibliography

Burling, L. D.

1917. Protichnites and Climactichnites. A critical study of some Cambrian Trails. Amer. Jour. Sci., ser. 4, **44**, pp. 387–398.

Dawson, J. W.

1862. On the Footprints of Limulus as compared with the Protichnites of the Potsdam Sandstone. Canadian Naturalist and Geologist, **7**, p. 271.

Murchison, R. I.

1839. The Silurian System, pt. 2, London.

Nathorst, A. G.

1881. Memoire sur quelques traces d'animaux sans vertèbres, etc. et de leur portée paléontologique. Kongl. Svenska Vet. Akademiens Handlingar, **18**, no. 7, pp. 61–104, pls. 1–11.

Nicholson, H. A. and Lydekker, R.

1889. A Manual of Paleontology, ed. 3, **1**, Edinburgh and London.

Packard, A. S.

1900. On Supposed Merostomatous and other Palaeozoic Arthropod Trails, with Notes on those of Limulus. Proc. Amer. Acad Arts and Sciences, **36**, no. 4, p. 65.

Parker, G. H.

1911. The Mechanism of Locomotion in Gasteropods. Jour. Morphology, **22**, pp. 155–170.

Perkins, Edward H.

1924. A New Graptolite Locality in Central Maine. Amer. Jour. Sci., ser. 5, **8**, pp. 223–225.

Raymond, P. E.

1922. Seaside Notes. Amer. Jour. Sci., ser. 5, **3**, pp. 108–114.

Richter, Rud.

1924. Flachseebeobachtungen zur Palaeontologie und Geologie, IX. Zur Deutung rezenter und fossiler Mäander-Figuren. Senkenbergiana, **6**, pp. 141–156.

Woodward, Henry

1866. On a New Genus of Phyllopodous Crustacea from the Moffat Shales (Llandeilo Flags) Dumfriesshire. Quart. Jour. Geol. Soc. London, **22**, p. 503.

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5. On the Nature of Phytopsis Tubulosum Hall

Hall (Pal. N. Y., 1847, **1**, pp. 37, 38, pl. 7) described *Phytopsis tubulosum* as probably a marine plant. Since he included the fossil now known as *Tetradium cellulosum* in the genus Phytopsis, his hesitancy in making a definite reference to either the corals or algae is readily understood.

Vanuxem (Geol. N. Y., 1842, **3**, p. 39, fig. 3) had already presented a figure of the same fossil under Conrad's manuscript name *Fucoides demissus*. This figure was drawn by Emmons, and represented a specimen in a quarry at Fort Plain, N. Y. He unhesitatingly called it a plant, and made the observation that the distinctness of the fossil was due to "the plant having been removed, and the cavities which it occupied enlarged and filled with green and black shale, which strongly contrasted with the light dove-color of the rock." Opposite Fort Plain and near Palatine church the specimens were so numerous that Vanuxem remarked: "This vicinity appears to have been the favorite residence of this extraordinary fossil, their number there being so much greater than elsewhere."

Emmons (Geol. N. Y., **2**, 1842, pp. 108, 109, fig. 37) also discussed *Fucoides demissus*, but since in his district the fossils so called were chiefly Tetradia, his conclusion that the organism in question was a coral and not a plant does not really apply to *Phytopsis tubulosum*. He does, however, speak of the locality at Fort Plain, and explains the sudden extinction of the Fucoides there. He says, "Thus, on the immediate plane where the Trenton limestone is deposited, this fossil disappears, and no trace is to be seen in the succeeding rock; while up to the commencement of the Trenton limestone, it appears to have been in full vigor. The fact that it does not occur in the drab colored layers, though in the midst of the birdseye, throws some light upon the cause of its sudden extinction; they are impure limestones, and the matter deposited with the particles of lime exerted an unfavorable influence upon it. So the Trenton limestone, being composed of aluminous and other earthy matter in part, formed a medium which became unsuitable to their peculiar mode of living."

Since Hall's publication the *Phytopsis tubulosum* has been well known and frequently referred to, often under its pseudonym "Birdseye," but nothing of any importance has been written about it. Since *Phytopsis cellulosum* has been removed to the corals under the name of Tetradium, there seems to have been an impression prevalent that *P. tubulosum* was also a badly preserved Tetradium. This was, in fact, Emmons' view in 1842, but I find no more recent authority for such an opinion.

Since all of Hall's figured specimens were from Fort Plain, N. Y., that is to be regarded as the type locality. Typical specimens from a locality across the Mohawk from Fort Plain, consist of more or less vertical inosculating tubes usually nearly circular in section, and varying from 3 to 7 mm. in diameter. The limestone in which they occur is buff to blue-gray and weathers almost white, whereas the Phytopsis is usually brown, or has a brown outer covering and a central core of the same material as the matrix. As seen from above, the "birdseyes" appear to be scattered irregularly, although there is a suggestion of the rhombic arrangement observed by Emmons. In some cases the birdseyes are so close together that their edges touch one another; in others they are as much as 16 mm. apart in the specimen photographed (pl. **4**, fig. 4) and there is no regularity of spacing in any of the specimens studied. In one area 100 mm. square there are 30 "birdseyes."

The layer being described is about 115 mm. thick, and although many of the Phytopsis penetrate through it, there are not nearly so many "birdseyes" on the lower as on the upper surface, indicating that many of the tubes are not 115 mm. long. On examining the sides of the layer, it appears that although in a number of cases a tube starting downward from the surface unites with another below, in no case does any tube show a blind ending downward. In fact, the condition of the lower ends of the tubes remains a subject for further observation.

The filling of the tubes is, as remarked above, variable. In the majority of cases there is an outer coating of brown material, within which is a filling of material like the matrix or of crystalline calcite. Others of the tubes seem to be entirely filled, especially in the upper portion, with the brown substance. A few, hardly distinguishable from the surrounding rock, are entirely filled with the same material as the matrix. Several, all much smaller than the average, contain crystalline calcite only.

The method of branching is variable. In some cases a tube appears to bifurcate, in others two parallel vertical tubes are connected by a more or less horizontal cross-tie, and in still others, 3 or 4 vertical tubes may be connected by a diagonal tube crossing from one to another. There is some evidence, though it is not conclusive, that all the tubes on a slab such as the one photographed are connected, and that they form a bushlike mass, expanding and branching upward. A colony of Syringopora, for instance, presents a similar plan of branching.

A certain amount of light is thrown upon the nature of *Phytopsis tubulosum* by specimens collected by the writer from the Lowville on the hill north of Little Falls, N. Y. These have the form of those from the typical locality, and the same method of branching, but all are filled completely either with brown and black material, or with calcite. On examining the beds in place, it was found that as usual, the Phytopsis was in the uppermost stratum of the Lowville, upon which rests the Trenton. At the contact, the Trenton is seen to fill small hollows in the Lowville and fragments of bryozoa and brachopods, entire ostracoda and other shells of Trenton age form a part of the filling of the Phytopsis. Thin sections (pl. **4**, fig. 2) cut across the tubes some distance down in the layer show the filling to consist of brown matter somewhat concentrically arranged, but not lining the whole tube, and fine grains of quartz sand, partly angular, partly very well rounded and obviously wind-blown material. There are also a few grains of feldspar and various much decomposed fragments.

The material which fills the tubes being thus foreign to the Lowville, and, indeed, identifiable as being of Trenton age, indicates that the Phytopses at Little Falls were open holes at the beginning of Trenton deposition in this region. Apparently they were holes in firm material, for they have sharp boundaries clear to the surface. Moreover, the parting planes between the layers were well developed before the filling, for in one specimen the fillings are seen to spread out along the plane of stratification wherever a tube crosses it.

As mentioned above, many of the specimens from opposite Fort Plain show a concentric banding when seen on naturally weathered surfaces (see Pal. N. Y., **1**, 1847, pl. 8, fig. Ie), and when thin sections are made, it is found that the banding is due to a coating of fine sand grains which lines the tube. In the best of the sections, the central part of the tube is full of clear calcite, and around it is a sheath of a yellowish material in which are embedded minute grains of quartz, some of them rounded, others angular. On etching with dilute hydrochloric acid it is found that this lining is resistant. When the matrix surrounding the tube is dissolved away, the surface is smooth, and shows distinct longitudinal markings suggesting a slickensided surface, whereas faint distant constrictions suggest annulations.

The fact that these tubes from Fort Plain have a definite lining shows rather conclusively what the ones from Little Falls suggest, namely, that *Phytopsis tubulosum* is a burrow and, in all probability, the burrow of a tubicolous worm. The holes were apparently excavated while the surface of the Lowville was an exposed, partially hardened mud flat, and lined by the worm with sand brought in from the surface, cemented with mucous or perhaps a carbonate secreted by its body. One of the thin sections shows the tube lined with a substance in which small oölitic grains are the chief foreign material, and still other tubes seem to have no lining at all. This is, of course, a matter of preservation.

The probability that *Phytopsis tubulosum* was a burrow is strengthened by the fact that the specimens are always found in the highest layers of the Lowville, and also cut across the layers, never lying upon the surfaces. If it were a plant, coral, or any similar organism, one would expect to find the majority of the specimens lying prone along the parting planes, rather than in the position in which they grew.

Viewed in the light of the present interpretation, this Phytopsis comes to occupy an unusual position as the work, not of an animal which lived in Lowville or even Leray time, but in the interval between the two, and the species can be said to be characteristic, not of the upper Lowville, but of the *disconformity between it and the superjacent formation.*

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6. A Mid-Cambrian Gorgonian

Among the rarer fossils found in the Stephen shale on Mount Stephen at Field, B. C. are fragments which resemble parts of a reticulate graptolite. In 1927, one of the students in the Harvard Summer School found a nearly complete specimen, which appears to show the characteristics of a gorgonian, rather than those of a hydrozoan.

Gorgonians, rare as fossils, have not hitherto been found in strata older than the Cretaceous. Hence there is some uncertainty about the ascription of the present specimens to that family. There is, however, no *a priori* reason for supposing that the group may not be very ancient.

For fossils of this sort, it is necessary to institute a new genus, which may be called Petaloptyon, from the spreading, fan-like form.

Petaloptyon danei sp. nov.

Plate **4**, fig. 7

A sessile colonial organism whose chitinous skeleton is a fan-shaped network, apparently in one plane. Distally the margin is lobate; the proximal end is a rather broad but not expanded base, with one or more short, delicate fibrous anchoring processes.

Three of the radial elements of the network extend to the base, the median one the most prominent. The remaining radial elements appear to be branches of these. The branching is not, however, regular, although some of the radii are fairly straight; others, particularly in the middle of the fan, are irregular.

The transverse bars connecting the radial elements are evenly spaced on some parts of the fan, whereas in other areas they are somewhat irregular in arrangement. Although approximately at right angles to the radii, most of them slope somewhat backwards or forwards. The fenestra thus formed are therefore not of uniform size or shape.

Where best preserved, the skeletal elements appear to show longitudinal ridges and a spicular structure. They are partly replaced by pyrite, but the dark color suggests that they were originally chitinous. One specimen shows, near the outer margin, what appears to be a layer of disintegrated skeletal material. This contains numerous small rods, and some very small radial elements. One or two of the latter appear to be five-pointed, and suggest spicules of Eiffelia, as described by Walcott (Smithsonian Misc. Coll., **67**, 1920, pl. 86), but are very much smaller.

These spicules do not, it is true, very greatly resemble those of modern gorgonians. The latter are usually much more irregular, but this is due to the fact that they are composed of small crystals of calcium carbonate held together by organic matter. It is possible that earlier, non-calcareous forms had a simple type of horny spicule.

Measurements.— The most nearly complete specimen is about 50 mm. high and about 40 mm. broad. The fenestra vary from .75 mm. to 1.25 mm. in height. Fragments indicate that other colonies were somewhat larger.

Horizon and locality.— A rare fossil in the Stephen shale of the Middle Cambrian on Mt. Stephen, Field, B. C. Holotype (9300) collected and presented to the Museum of Comparative Zoölogy by E. B. Dane, Jr. Paratype (9301) collected by the writer.

Observations

The systematic position of this organism cannot be definitely determined, but there appear to be only three possibilities: it may be a sponge, a graptolite, or an alcyonarian. The presence of spicular elements suggests that it may be a sponge, but the fact that it is definitely planar and not conical and that it was apparently originally chitinous rather than siliceous tends to rule out this disposition of the specimen.

In general appearance it is much more like a graptolite than a sponge, and it may prove to be one of the Dendroidea. There is no evidence of thecae on any part of the specimens at hand, but this may, of course, be due to imperfect preservation. The chief reasons for thinking it is not a graptolite are that the distal margin is regularly lobed and seems to have a distinctly thickened border, and the presence of scattered spicules. Graptolites have not been found in the Middle Cambrian, but they may have been in existence at that time.

The genus Dictyonema contains those dendroid graptolites which have straight branches and regularly arranged dissepiments. The specimens here described could not be referred to that genus, because the initial portion of the colony is neither the simple nema of the true Dictyonema nor the root-like base of the shrubby types. The other dendroids have much more irregular branches and dissepiments than does Petaloptyon.

The general aspect of the fossil is that of the chitinous portion of the skeleton of a modern gorgonian. There is no evidence that it was ever invested with a calcareous coating, as are the modern forms. It may represent a primitive condition in the family. The spicular material observed in the outer portion of the fan very probably represents broken down skeletal elements. It is this structure which argues most strongly for reference of Petaloptyon to the Gorgonacea.

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7. A Middle-Cambrian Isopod-like Crustacean

Among the specimens collected by Dr. Walcott (Smithsonian Misc. Colls., 1912, **57**, p. 197, pl. 24, fig. 5) from the strata of Middle Cambrian age on Burgess Pass, B. C., was a single one which he named *Mollisonia gracilis*. In the summer of 1925 one of the students in the Harvard Summer School, Mr. J. D. Houghton, was lucky enough to obtain a second specimen which is probably of the same species, and which is now in the Museum of Comparative Zoölogy. This individual has a very well preserved anterior shield, the thorax is in fair state of preservation, but the posterior shield is considerably damaged at the distal end (Pl. **4**, fig. 6).

Description

Test very thin, elongate, narrow, parallel-sided. Head shield oval, about as long as wide, with two pairs of spines on the anterior end. The posterior part of this shield bears a narrow median ridge, which, about the middle, bifurcates, a branch extending to each of the median pair of frontal spines. The test has been slightly distorted, so that the shield is not quite symmetrical, and the right-hand branch shows an outer, submarginal fork not observable on the other side. About midway in the head, and near the sides, are elongate, crescentic markings which appear to be eyes. Each is situated on the outer slope of a very narrow sharp-crested longitudinal ridge, which, immediately in front of the eye-like spot, bifurcates, one branch turning toward each of the outer of the anterior marginal spines, the other turning inward toward the inner pair. Back of the "eye," each longitudinal ridge again bifurcates, one branch extending toward the genal angle, the other tending somewhat inward, but becoming lost before reaching the posterior margin. By combining the two outer branches of this ridge and a narrow groove forming the outer boundary of the "eye," a typical opisthoparian course of facial suture is obtained. In the middle of the shield on either side of the median ridge at the point of bifurcation, is a minute, raised, smooth-rimmed, circular, open-topped tubercle.

The median portion of the specimen has seven similar segments with short, blunt pleura. Curiously, there is no taper posteriorly. What appears to be the large flattened alimentary canal underlies the greater part of the axial lobe, and extends to the middle of the posterior shield, where there is a large circular anal opening. The posterior part of the anal shield is broken off in such a way as to give the appearance of a pair of fan-like caudal appendages, but this very probably has no structural significance.

Identification of the Species

This specimen differs in many respects from the figure of *Mollisonia gracilis* presented in Walcott's paper. His figure shows two conspicuous outer spines, enclosing five smaller ones on the anterior margin, and the cephalon is notably longer than wide. However, the correspondence in form, size and general proportions makes it seem probable that the published figure is inaccurate, and that our specimen belongs to Walcott's species.

The Generic Reference

The type of the genus Mollisonia is *M. symmetrica* Walcott (loc. cit., p. 196, pl. 24, fig. 3) described from a single specimen obtained from the Middle Cambrian on Mount Stephen, Field, B. C. The type is about 2.5 times as long as the specimens of *M. gracilis*, proportionately broader and the anterior and posterior shields are wider than long. The number of segments in the body, 7, is the same in both species. The structure of the head is, however, very different, *M. symmetrica* lacking the anterior marginal spines and longitudinal ridges. These latter features are so remarkable that it seems best to remove *Mollisonia gracilis* to another genus, which I propose to call Houghtonites, after the discoverer of the specimen here described.

Is *Houghtonites gracilis* an isopod? Walcott assigned Mollisonia to the family Microdiscidae Koken (Eodiscidae Raymond). It may be that the genotype, *M. symmetrica*, is an hypoparian trilobite. *Houghtonites gracilis*, however, although trilobite-like in its general structure, differs from any trilobite with which I am familiar in thinness of shell, thin, scalloped and spinose anterior margin, surface with longitudinal bifurcating ridges, and paired subcentral crater-like openings. Some Agnostidae do, it is true, have anterior marginal spines, but they are different in structure from those of *Houghtonites gracilis*, being extensions of the thickened border. Some trilobites also have thin shells, and it may be that this particular specimen was, at the time of death, in the soft-shelled condition following moulting. The other features are entirely unknown among trilobites.

The most primitive suborder of the Isopoda, the Asellota (Calman, in Lankester, Treatise on Zoölogy, pt. 7, 1909, p. 219) contains representatives with the same form as Houghtonites. The abdominal segments are fused into a single shield, there are seven free segments in the body, and the head in many instances shows a pair of scalloped recesses, indicating the position of attachment of the antennae and antennules. It is true that in many Isopoda there is a median rostral projection, but in this suborder there are many species in which the rostrum has a deep notch, so that there are two pairs of anterior spines. Among such species are *Jaeropsis marionis* Beddard, *Nannoniscus oblongus* Sars, *Desmosoma lineare* Sars, *Engerda tenuimana* Sars, *Echinopleura aculeata* Sars, and five species of Eurycope also described by Sars (Crustacea of Norway, **2**, 1899, pls. 50-69).

I have not found any isopod showing the system of ridges exhibited by Houghtonites, but *Janira maculosa* Leach, as figured by Sars (loc. cit., pl. 40), does show raised lines before and behind the eyes in the position of the facial suture of a trilobite, so corresponding to a part of the pattern of *H. gracilis*.

The paired median open-topped tubercles have the position but not the structure of the ocelli of eurypterids. If they were really ocelli, they would invite comparison with the Copepoda, but it is more likely that they are openings of glandular structures. Something of the sort appears to be present in Serolis, but their chief meaning at present seems to be a negative one, that is, they are structures unknown in trilobites.

In view of the fact that typical isopods are not known from strata older than the Jurassic, it would hardly be expected that the group had fully differentiated as early as the Middle Cambrian. If the appendages of Houghtonites were found, I imagine they would not be very different from those of trilobites. Even though the form is that of an isopod, it probably differed in many respects from modern members of that order. Its position then, appears to be somewhere between the trilobites and the modern isopods, in a group which, when it becomes better known, might be called the Protisopoda. The apparent fusion of the free cheeks to the median portion of the head is a feature to be expected in such a group.

The holotype of the genus is specimen No. 1811 in the Museum of Comparative Zoölogy, here identified as *Houghtonites gracilis* (Walcott).

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8. A New Reteocrinus

The genus Reteocrinus now contains five species of primitive camerate crinoids which flourished in Trenton and Richmond times. The present species, coming as it does from the Lebanon formation, is older than any previously known, and, so far as I know, is only the second crinoid which has been found in rocks of its age. The type, a single calyx with arms and about two inches of column, is exposed on the weathered surface of a small slab of limestone. The anal side adheres to the matrix, whereas the plates and three arms of the anterior side are well preserved.

Order CAMERATA Wachsmuth and Springer

Family Reteocrinidae Wachsmuth and Springer

Genus Reteocrinus Billings

Reteocrinus elongatus sp. nov.

Plate 4, fig. 5

Crown small, elongate, with strongly ridged calyx and slender arms. Column large, circular in section, columnals alternating in size with two to four small ones between each pair of plates of greater diameter. In the half inch near the calyx the columnals have thin frill-like expansions which are turned downward.

The infrabasals stand well above the column, and have on their upper borders depressions which form the lower parts of the sunken area in the lower part of the calyx. The basals are large and prominent, excavated at the top and sides. Radials longer than wide, tapering upward, very convex. Costals, four on two of the radii, five on the anterior one, all thick conical plates, with a sharp girder about the middle. Interbrachial areas depressed, covered with small irregular plates, only a few of which are preserved. Distichials, four, like the costals in appearance. Above the distichials the arms are imperfectly preserved, but in two cases bifurcate once more, the palmars being apparently four or five in number. No pinnules are preserved.

Measurements.— The crown is 27 mm. long and 7 mm. in diameter at the top of the basals. It is somewhat flattened. One of the basals is 2 mm. high and the distance on the anterior arm from the bottom of the radial to the top of the upper costal is 8.5 mm.; 45 mm. of the column are preserved. It is 2.5 mm. in diameter at the distal and 4 mm. in diameter at the proximal end.

Observations

This species is most closely allied to *Retcocrinus stellaris* Billings, the type of the genus. It differs from that, as from all other species of the genus, in having more costals. *Reteocrinus elongatus* has four or five costals, according to the arm. *R. stellaris* Billings has three, *R. alveolatus* Miller and Gurley has three or four according to the arm, *R. nealli* (Hall), *R. fimbriatus* Billings, and *R. magnificus* (Miller) all have two. It is interesting to note that all of the latter are from the Richmond, and that if the species be arranged in order of their occurrence in the geological formations, they form a regular series in which the older have the more costals. *R. elongatus* from the Lowville has four to five, *R. alveolatus* from the Lower Trenton has three to four, *R. stellaris* from the Middle Trenton has three, and all three species found in the Richmond but two.

R. elongatus agrees with *R. stellaris* also in having circular columnals, and in having depressed areas bounded above by the radials, laterally by the basals, and below by the infrabasals. Such areas are present also in *R. alveolatus*, but apparently absent from *R. nealli*, *R. fimbriatus*, and *R. magnificus*. These interbasal depressions are so prominent a feature of the three species which possess them that in most groups they would be recognized as of generic value, in which case the three species without them would be grouped in Miller's genus *Gaurocrinus*, of which *G. nealli* is the type. In any case the definition of Reteocrinus must be modified, as there are two species in which there are more than three costals.

Horizon and locality.— The single specimen on which *R. elongatus* is based was found by the writer in the Lebanon limestone in a railroad cutting about 2.5 miles east of Cumberland Gap, Tenn., in strata of Upper Stones River age, associated with *Beatricea gracilis*, Tetradium, and other fossils.

9. An Unusually Large Isoteloid Hypostoma

While collecting in the Chazy limestone on Valcour Island, N. Y., the writer happened upon the largest hypostoma he has ever seen, and a brief notice of it may be of interest to seekers after huge trilobites.

The specimen (Pl. **5**, fig. 2) is 125 mm., about 5 inches, long, and about 110 mm. in width. It was found lying dorsal (inner) side up and has been considerably weathered, so that little more than the outline can be satisfactorily made out. The prongs are nearly as long as the body, and the distance between their tips is 80 mm.

Hypostomata from 25 to 40 mm. in length are not uncommon in the Chazy, and have usually been referred to *Isotelus harrisi* (Seventh Rept. Vermont Geol. Sur., 1910, pl. 34, figs. 6, 7). These specimens are characterized by the unusual constriction of the anterior end of the body, so that it does not seem probable that the large individual here described belongs to the same species, as the anterior end is broad. A few fragments of a very large Isotelus were seen at the same horizon, and it is probable that when good specimens are recovered they will be found to differ considerably from either *I. harrisi* or *I. platymarginatus*, the two large Isoteli now known in the Chazy. As a convenient name for the animal I would suggest *Isotelus giganteus*, the hypostoma being, of course, the type. It was found at the base of the Upper Chazy on Tiger Point, Valcour Island, N. Y., and is no. 1,689 in the Museum of Comparative Zoölogy.

One cannot but speculate upon the probable size of the individual to which this hypostoma pertained. Large specimens of Isotėlus with the hypostoma in place have been but infrequently described or figured, so that the proportion of length of hypostoma to total length is but little known.

Hall (Pal, N. Y., **1**, 1847, pl. 62, fig. 2) figured a specimen of *Isotelus gigas* Dekay, 172 mm. long, in which the hypostoma was 28 mm. long. If the specimen from the Chazy had the same relative proportions, it would have been 768 mm. or about 30 inches long.

An *Isotelus megistos* Locke, from Cincinnati, Ohio, 125 mm. long, has the hypostoma 24 mm. long. With these proportions, *Isotelus giganteus* would have been 650 mm. or about 26 inches long.

An incomplete specimen of *Isotelus arenicola* Raymond estimated to have been 14 inches long (Ottawa Naturalist, **24**, 1910, p. 131, pl. 2, fig. 5) had an hypostoma 3 inches long, this being, next to the one here described, the largest hypostoma I have found recorded in the literature. With the same proportions, *Isotelus giganteus* would have been 25 inches long.

Estimates made in this way are liable to give an erroneous idea of the real size of the animal, but it seems probable that the individual to which this hypostoma belonged was not less than 24 nor more than 27 inches in length. With the breadth characteristic of all Isoteli, this great crustacean must have been truly the old man of the Chazyan sea. Would that his other appendages had been preserved to us!

Other Isoteli of approximately this size have been predicated on more or less fragmentary material. The most famous is the *Isotelus maximus* of Dr. Locke, and those fortunate enough to have one of his plaster casts can get a good idea of the probable appearance of *I. giganteus*, for the present hypostoma is of practically the right size for such an individual.

There seems, however, little doubt that Dr. Locke overestimated the size of the animal to which his fragments belonged. His first estimate of 21 inches was based upon the supposition that the pygidium would be one-third the total length, but on the basis of a specimen of *Isotelus megistos*, he later revised this to 19.5 inches (Second Rept. Geol. Sur. Ohio, 1839, p. 247; Amer. Jour. Sci., **42**, 1842, p. 366). The large fragment used by Locke was, however, very probably a small piece of an *Isotelus brachycephalus* Foerste (Bull. Denison Univ., **19**, 1919, p. 65, pls. 14, 14a, 15). In that case, the total length would have been but 18 inches.

Dr. Clarke mentioned a glabella of *Isotelus gigas* Dekay (Pal. Minn., **2**, pt. 2, 1897, p. 706, inserted fig.) from the Galena of Mantorville, Minn., which indicated an individual 17 inches long. The outline drawing gives no indication of the amount of the specimen actually preserved.

The largest known complete Isotelid is the *I. brachycephalus* recently described by Foerste. It is 368 mm. (about 14.5 inches) long. Next comes the impression of *I. arenicola* from near Ottawa, about 14 inches long. An Isotelus, probably *I. maximus*, whose estimated length was 384 mm., is represented by a thorax in the Museum of Comparative Zoölogy, and there is an *Isotelus maximus* in the Museum at the University of Toronto which is 285 mm. long.

Clark (Forty-fourth Rept. N. Y. State Mus., 1892, p. 111), reviewing the list of large trilobites some years ago, gave the palm to *Terataspis grandis* Hall, with an estimated length of 24 inches. Since that time, however, precedence has passed to the Ordovician *Uralichas ribeiroi* Delgado of France and Portugal. Oehlert (Mem. Soc. Geol. de France, no. **16**, 1896, p. 6) has estimated the total length at 700 mm. (about 27.5 inches), after allowing for the effect of crushing. Much of the length of this trilobite is, however, due to the long pygidial spine.

It is interesting to speculate on the significance of gigantism in trilobites. The most ancient of the huge fellows flourished in Mid-Cambrian time, whereas the last of them displayed his spiniferous coat in the early part of the Middle Devonian.

Trilobites a foot in length may fairly be called gigantic, for the average is probably less than 3 or 4 inches. The best known giants are listed in the following table, with the authority and country:

Middle Cambrian

Name	*Length*
Paradoxides tessini Brongniart	
Angelin. ? Sweden	About 300 mm.
P. spinosus (Boeck)	
Barrande. Bohemia	About 300 mm.
P. davidis Salter	
Salter. Wales	About 380 mm.
P. regina Matthew	
Matthew. New Brunswick	About 390 mm.
P. imperialis Barrande	
Barrande. Bohemia	About 400 mm.
P. harlani Green	
Walcott, Grabau, Raymond. Massachusetts	340–415 mm.

Ordovician

Name	*Length*
Megalaspis heros (Dalman)	
Angelin. Sweden	About 350 mm.
Schmidt. Esthonia	About 440 mm.
M. acuticaudata Angelin	
Broegger. Norway	About 403 mm.
"*Asaphus barrandei* de Verneuil"	
Barrande, Oehlert. France	400 mm.
Basilicus tyrannus (Murchison)	
Salter. Wales	About 300 mm.
B. marginalis (Hall)	
Raymond. New York	About 310 mm.
B. powisi (Murchison)	
Delgado. Portugal	400 mm.
Isotelus arenicola Raymond	
Raymond. Ontario	About 350 mm.

Name	*Length*
I. giganteus Raymond	
Raymond. New York	About 600 to 675 mm.
I. gigas Dekay	
Clarke. Minnesota	About 440 mm.
I. maximus Locke	
Locke, Foerste, Raymond. Ohio	About 460 to 480 mm.
I. brachycephalus Foerste	
Foerste. Ohio	368 mm.
Uralichas ribeiroi Delgado	
Oehlert, Delgado. France, Portugal	About 700 mm.
Brongniartella ? rudis (Salter)	
Salter. Wales	About 310 mm.

Devonian

Name	*Length*
Terataspis grandis Hall	
Clarke. New York, Ontario	About 510 to 600 mm.
Digonus gigas (Roemer)	
Beushausen. Germany	About 310 mm.
D. scrabrosus (Koch)	
Beushausen. Germany	About 350 mm.
Burmeisterella (?) armata (Burmeister)	
Beushausen. Germany	About 380 to 450 mm.
Trimerus major (Whitfield)	
Hall and Clarke. New York	390 to 400 mm.
Burmeisteria colossus (Lake)	
Lake. South Africa	About 500 mm.
Homalonotus sp. ind.	
Oehlert. France	About 400 mm.
Coronura myrmecophorus (Green)	
Hall and Clarke. New York	About 398 mm.
Dalmanites perceensis Clarke	
Clarke. Quebec	About 640 mm.

Although the above list contains a surprising number (28) of species which have furnished individuals 300 mm. or more in length, it will at once be noted that only five families are represented. In the Middle Cambrian there are six species of one genus, in the Ordovician thirteen species, representing six genera, and in the Devonian nine species belonging to eight genera. The variety of genera affording large individuals appears to increase greatly with the progress of time, although only three families are affected in the Ordovician and the same number in the Devonian. It has already been pointed out by Oehlert, that the time of maximum production of large trilobites coincided with the time of the greatest development of the group, and conspicuously large individuals were generally evolved rather late in the history of the family to which they belonged. This latter is particularly well exemplified by the Homalonotidae which differentiated from the Calymenidae in the Middle Ordovician, where most of the individuals are relatively small. Homalonotids reached considerable size in the Silurian, and then in the Lower Devonian are represented by six species of large dimensions. The Middle and Upper Devonian homalonotids are of good size, but not gigantic. Since every rule has its exception, it appears that *Brongniartella* (?) *rudis* (Salter) from the Ordovician of Wales reached a great size rather prematurely.

Another fact about the large trilobites is that there is nothing abnormal about them. The giants appear only in genera in which nearly all the individuals are large. If one should find an Agnostus, an Olenus, or a Proetus a foot in length, one would suspect it of being a monster. But so many of the Isoteli, Paradoxidae, Homalonotidae, and Dalmanitinae are large, that the huge individuals do not appear abnormal. Uralichas and Terataspis are rather exceptional, for most of the Lichadidae are relatively small, the Silurian Arctinurus being, of course, an exception. This same family produced the only really bizarre giant, Terataspis.

Burmeisterella ? armata is, it is true, provided with a certain number of spines, though not so many as Burmeister gave it, but spinosity did not, in general, accompany large size. Neither did the individuals of greatest size appear as heralds of the destruction of the group, but were rather the accompaniment of the period of greatest vitality. For example, the Asaphidae had their origin back in the Middle Cambrian, but remained rather obscure until the Ordovician, when they spread over the world in such luxuriance and variety, that they became the most common trilobites. They furnished eleven of the thirteen giants of the time, two in the Lower, seven in the Middle, and two in the Upper Ordovician. With the end of the Ordovician they disappeared, but the last of them were not so large as those of Middle Ordovician time.

10. A New Trilobite from Gaspé

Dr. C. W. Townsend of Boston has been good enough to present to the Museum of Comparative Zoölogy a very finely preserved mold of the dorsal surface of the pygidium of a Dalmanites which Mrs. Townsend collected at Gaspé. It represents an undescribed species, with an interesting ornamentation.

Dalmanites townsendae sp. nov.

Plate 5, fig. 1

Pygidium small, subtriangular, with a long median spine. The axial lobe is narrow, continuous with the terminal spine, and has seventeen rings, the posterior ones rather faint. The lateral lobes have fourteen pairs of ribs in addition to the anterior half rib. Each of the first ten pairs has a deep, narrow median furrow; the eleventh and twelfth pairs have shallow and faint ones; and the last two pairs are furrowless.

The surface is ornamented with tubercles which fall into three categories as regards size; firstly, large tubercles somewhat irregularly placed; secondly, tubercles of intermediate size symmetrically arranged; and lastly, small tubercles or granules in rows and rings.

The ornamentation of the axial lobe is regular and symmetrical. Each ring except the second, sixth, tenth and fourteenth, has an odd number (seven at the front, five near the posterior end) of tubercles of the intermediate size, the median one circular, the lateral ones elongate-oval in outline. The rings mentioned above as exceptions have no tubercles on the median line, but show a pair of large tubercles, one on either side of the axis, and a pair of the intermediate size beyond them. This regular arrangement of tubercles, in which every fourth ring has two large ones, makes a very striking and easily recognized pattern. Besides the larger tubercles, each ring has numerous small granules, some arranged in rings about the median pustules, others scattered irregularly over the surface.

The arrangement of tubercles on the pleural lobes is more easily illustrated than described. They seem at first glance to be irregularly scattered, yet when examined in detail, the two lobes are found to have their conspicuous tubercles symmetrically placed. Each of the first seven ribs on both lobes has five pustules which are located on the anterior side of the median furrow, but, when large, they interrupt it. On each segment one of the tubercles is much larger than the others, and these conspicuous ones are placed symmetrically on opposite sides of the axial lobe. If the tubercles be numbered from 1 to 5 outward from the dorsal furrows, the large pustule is number 1 on the first segment, 3 on the second, 5 on the third, 3 on the fourth, 5 on the fifth, 4 on the sixth, 5 on the seventh, 3 on the eighth. Behind the eighth pair of ribs the arrangement is not very definite, but the prominent tubercles appear to lie directly behind one another in a row parallel to the lateral margin. Besides these more conspicuous tubercles, the surface is ornamented with small granules which are arranged in more or less regular lines parallel to the furrows on and between the ribs, the line on the posterior margin of each rib being more conspicuous than the others.

The terminal spine has a deep dorsal furrow and the surface is covered with small granular tubercles.

Measurements.— The total length of the pygidium, including the spine, is 40 mm., width at front, 36 mm., length of spine, 11.5 mm., width of axial lobe at front, 9.5 mm.

Comparison with other species

It is, of course, natural to compare this trilobite first with the other species of Dalmanites which Clarke has described from Gaspé. Three only from that locality are known to have had a terminal spine of appreciable length: *D. perceensis* Clarke, *D. whiteavesi* Clarke, and *D. phacoptyx* Hall and Clarke.

The first of these has only a short terminal spine, which is not a continuation of the axial lobe, and the second has no pustules on the surface, so that detailed comparison is unnecessary. The form called *Dalmanites phacoptyx* invites closer attention. Clarke (New York State Mus., Mem., **9**, pt. 1, 1908, p. 123, pl. 7, figs. 5–10) states that pygidia referable to this species are common in the Grande Grève limestone about Grande Grève and elsewhere. The description states that there are twelve to fourteen pairs of ribs on the pleural, and thirteen to sixteen segments on the axial lobe, which is about the same as shown by our specimens. It is further stated that the caudal spine is about 15 mm. long and slender, but as the total length of the pygidium is not given, this measurement does not facilitate comparison. Nothing is said about the continuation of the axial lobe into the terminal spine, and the figures are not in agreement. Figures 9 and 10 on Plate 7 show the axial lobe terminating some distance in front of the posterior end (neither shows any trace of a terminal spine) whereas the right-hand specimen on the plate inserted in the text opposite page 124, although incomplete, indicates that the axial lobe did continue into the terminal spine. Three pygidia figured on plate 7 show the surface ornamentation. Figure 5 represents a fragment which is unlike *D. townsendae*, for there are rows of coarse tubercles on the part of each rib back of the median furrow. Figures 8 and 9 appear to show the same type of ornamentation. Each ring of the axial lobe has six tubercles, the median pair larger than the others. All the rings have the same number, so that the characteristic feature of *D. townsendae*, an interruption on each fourth ring by an odd number of tubercles, is not present.

The specimen already referred to as shown by Clarke on the inserted plate opposite page 124 is badly preserved, but the surface ornamentation is very much like that of *D. townsendae*. The sixth, tenth, and fourteenth rings on the axial lobe appear to have median tubercles, and the arrangement of conspicuous lateral tubercles appears to be as in our species. Although not definitely proven, I think the pygidia on this plate are conspecific with the one found by Mrs. Townsend. It remains to inquire as to which of the three forms described by Clarke from Gaspé is entitled to be called *Dalmanites phacoptyx*.

The original specimens of this species were more or less incomplete pygidia and a hypostoma from the Decewville at North Cayuga, Ont. (Hall and Clarke, Pal. N. Y., **7**, 1888, p. 31, pl. 11A, figs. 23–27). Only one of the pygidia (pl. 11A, figs. 23, 24) showed the terminal spine. It may now be designated as the holotype. The axial lobe is continuous with the spine of this specimen, thus agreeing with *D. townsendae* and the specimen figured in the text by Clarke, but the ornamentation, if correctly represented, is of a different type. The axial lobe appears to have eleven rings, with the tubercles on them irregularly placed, not in definite rows. The third and tenth rings each show a pair of high spine-like tubercles. The others have a median tubercle of variable size. This does not agree with the symmetrical alternation of our species, neither is it like that of either of the types of pygidia figured by Clarke (1908) on plate 7. If the name *D. phacoptyx* be restricted to forms agreeing with this one specimen, no specimens from Gaspé can be identified as that species.

The pygidium from which figure 25, plate 11A of Hall and Clarke was drawn, does, however, have the same ornamentation as that shown in figure 8 (and possibly fig. 9) of Clarke's report on Gaspé. Both appear to have paired median tubercles all along the axial lobe, which is, unfortunately, a common ornamentation in various genera of dalmanitids, hence it probably cannot be used as a specific characteristic.

Clarke (1900, p. 19, pl. 2, fig. 10) has identified *Dalmanites phacoptyx* in the Oriskany at Becraft Mt., N. Y. The incomplete pygidium figured is of about the same size and very like *D. townsendae*, but unfortunately the detail of the ornamentation cannot be made out. There appear to be more rings and ribs than in true *D. phacoptyx*, and the axial lobe lacks the conspicuous tubercles.

With our present incomplete knowledge of the species represented by these various shields, full comparisons cannot be made, but *Dalmanites townsendae* is distinguished from all the others by the symmetrical arrangement of the tubercles on the pygidium, and particularly by the positions of the large paired pustules on certain of the rings of the axial lobe.

Horizon and locality.— The holotype (Museum of Comparative Zoölogy, 1812) is a mould of the dorsal surface on a piece of yellowish, fine-grained and dense rock which does not effervesce with acids, and is probably a somewhat altered chert. The matrix contains a few fragments of brachiopods, but no recognizable fossils. It was found loose on the roadside at Grande Grève, Gaspé Co., Quebec. The exact horizon is unknown. Chert is, however, according to Clarke, very abundant in his Division 2 of the Grande Grève limestone. Exposures of it are found in many places on the southern slope of the Forillon. *Dalmanites phacoptyx* was listed from this division, whose age appears to be Oriskany. The slab figured by Clarke (1908, opposite p. 124), the specimens on which are believed to be *D. townsendae*, was found loose on the hills behind the Peninsula, so that its exact horizon is also unknown.

EXPLANATION OF PLATES

PLATE **1**

PLATE 1

Fig. 1. Pachytheca sp. A section across a large specimen, passing near the center. The actual outer boundary shows but faintly. It can be seen best in the lower left-hand corner. Note the branching of the tubes in the zone of radially arranged elements. Thin section M. C. Z. no. 138, a specimen from Butowitz, Bohemia. × 15.

Fig. 2. Pachytheca sp. A part of the same specimen shown in figure 1, enlarged to show the nature of the radial tubes.

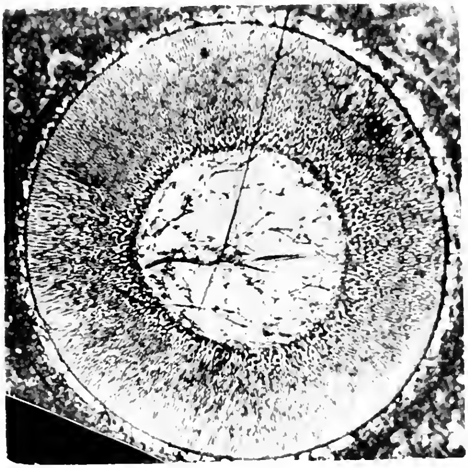
Fig. 3. Pachytheca sp. A section so cut as to avoid the central cavity, and crossing the radial elements. Note the curiously spine-like crystals of calcite in the outer zone, and the thick inner skin of this zone, as compared with the very thin outer one. Thin section M. C. Z. no. 137, a specimen from Butowitz, Bohemia. × 22.

Fig. 4. Pachytheca sp. A section through the scar of attachment and the center of a specimen. The outer zone is almost entirely removed. Note the broken-down tissue in the central cavity, and the fact that the central cavity is proportionally larger than in the specimen shown in Fig. 1. Thin section M. C. Z. no. 405, a specimen from Butowitz, Bohemia. × 7.5.

Fig. 5. A thin section of a piece of Lower Devonian limestone from Chotecz, Bohemia, containing many of the small spheres identified by Barrande as eggs of trilobites. Note the shrunken outer coats of some of the specimens. Thin section M. C. Z. no. 353. × 4.

Fig. 6. Pachytheca sp. A drawing of a decorticated specimen, showing the scar of attachment. Specimen from Ohvadka, Bohemia. × 4.

Fig. 7. Pachytheca sp. An enlargement of a part of the specimen shown in Fig. 3, showing in detail the structure of the radial elements in transverse section. Thin section M. C. Z. no. 137.



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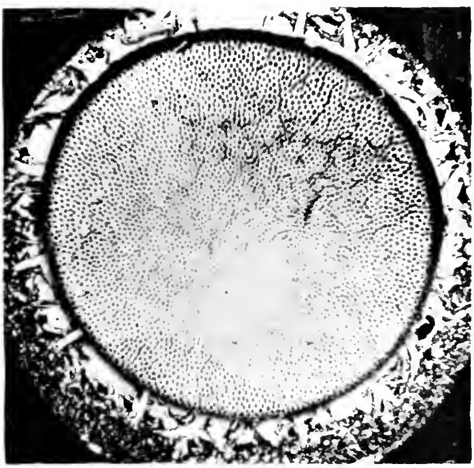

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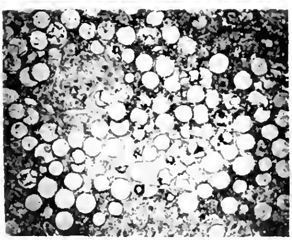

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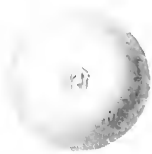

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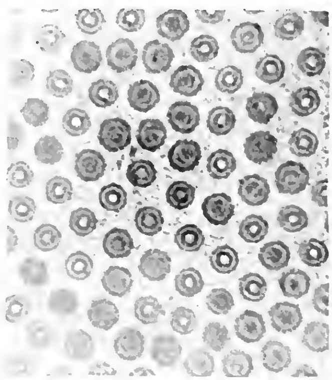

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PLATE **2**

PLATE 2

Figs. 1, 2. *Ethmophyllum ceratodictyoides* Raymond. The holotype, broken so as to show the limestone filling the inner cavity. One third less than natural size.

Fig. 3. *Spirocyathus constrictus* Raymond. The holotype. One third less than natural size.

Fig. 4. *Thamnobeatricea parallela* Raymond. A longitudinal thin section of one of the branches of the holotype. $\times 2\frac{2}{3}$.

Figs. 5, 6. The same species. Two fragments of branches, showing the ornamentation of the surface. Paratypes, M. C. Z. nos. 9304, 9305. $\times 1\frac{1}{3}$.

Fig. 7. The same species. A diagram taken from a fragment showing branching. The specimen was ground down to the axial region. A paratype, M. C. Z. no. 9303. Natural size.

Fig. 8. The same species. A thin section through a stem at the place of branching. Note the cystose tissue at the right, which is the base of the branch. Thin section M. C. Z. no. 127. $\times 3\frac{1}{2}$.

Fig. 9. The same species. The holotype. One third less than natural size.

Photographs by George Nelson.

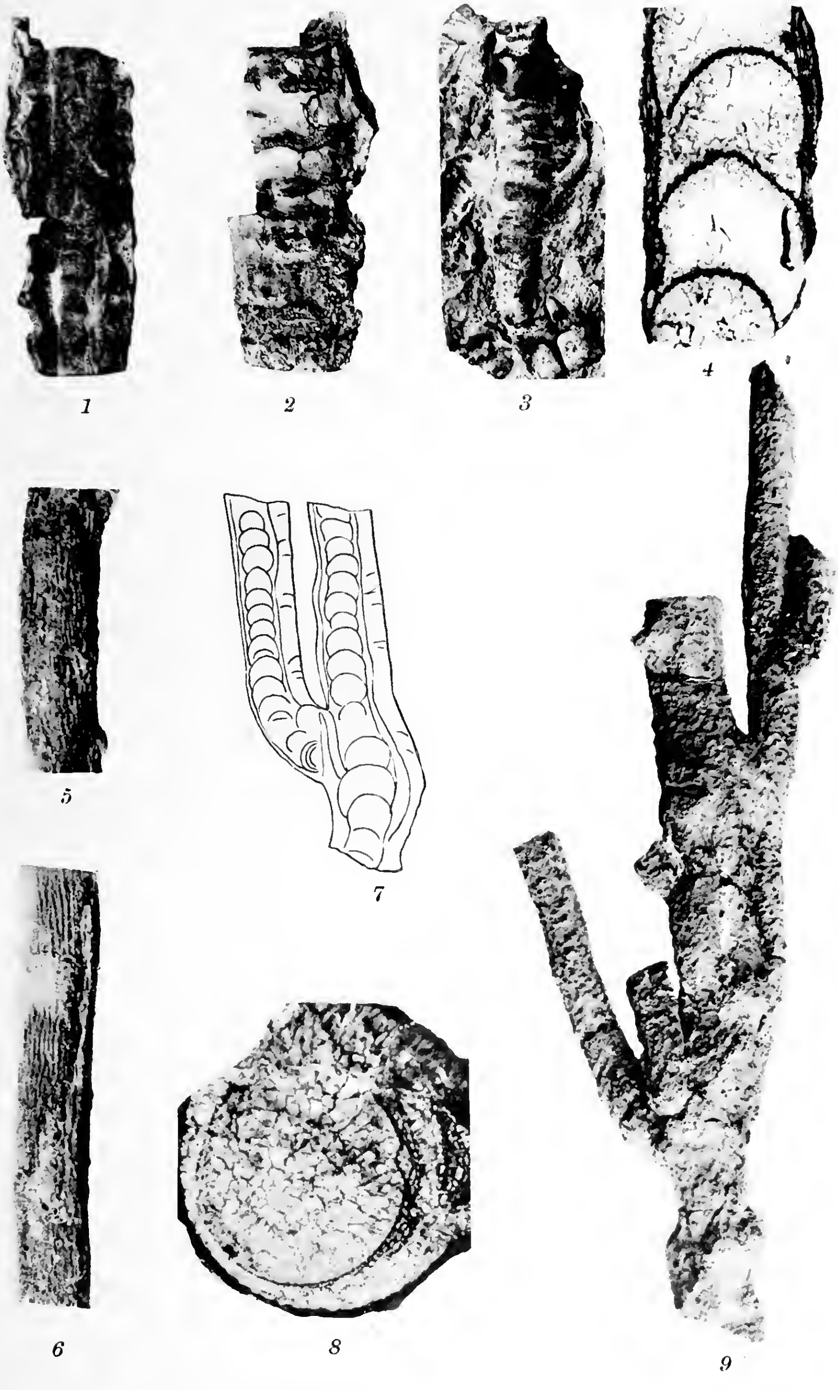
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PLATE **3**

PLATE 3

Fig. 1. *Cladophragmus bifurcatus* Raymond. An unbranched specimen, showing the small pustules on the surface. M.C.Z. no. 9308. × $1\frac{1}{3}$.

Fig. 2. The same species. A thin section, showing the nature of outer wall, and the convex septa. × 3.

Fig. 3. The same species. A drawing from a sliced specimen showing method of branching. M. C. Z. no. 9306. Natural size.

Fig. 4. The same species. A photograph of a small piece of limestone, showing several naturally weathered longitudinal sections. M. C. Z. no. 9307. About natural size.

Fig. 5. *Beatricea gracilis* Foerste. A transverse section of a specimen from Dickey, near Mercersberg, Pa., showing the inner part of the zone of cystose tissue. Thin section M. C. Z. no. 129. × 7.

Fig. 6. The same species. Weathered specimens on a piece of limestone from Dickey, Pa. The longer one shows the pustules of the surface. M. C. Z. no. 9310. × $1\frac{1}{2}$.

Fig. 7. The same species. A piece of limestone showing naturally weathered sections. From Blue Spring, south of Mercersberg, Pa. M. C. Z. no. 9309. One third less than natural size.

Fig. 8. *Cryptophragmus antiquatus* Raymond. A transverse section of a specimen from the Carlin formation at Loysburg, Pa., showing the great development of radially arranged tissue about the cystose zone. R. M. Field, collector. Thin section no. 368. Specimen M. C. Z. no. 9311. × $2\frac{1}{2}$.

Photographs by George Nelson.

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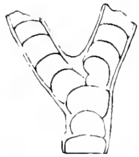

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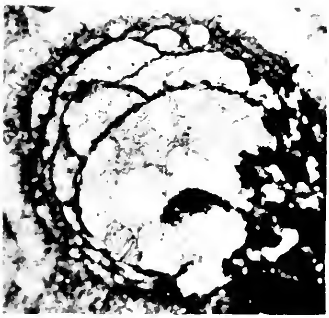

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PLATE 4

PLATE 4

Fig. 1. *Phyllodocites jacksoni* (Emmons). The best preserved trail in the collection at Colby College. Note the terminal impression at the left near the top of the picture. A little less than one half natural size.

Fig. 2. A transverse thin section across several small and one large burrow of the kind called *Phytopsis tubulosum.* Note the numerous grains of quartz sand which show as light specks in the dark lining of the tube. The larger light areas are calcite.

Fig. 3. *Phyllodocites pugnus* (Emmons). The best preserved trail in the collection at Colby College. About $\frac{2}{5}$ natural size.

Fig. 4. A weathered layer of "Birdseye" limestone, about $4\frac{1}{2}$ inches thick. It shows the way in which the tubes cross one another, and the dark material which lines the burrows.

Fig. 5. *Reteocrinus elongatus* Raymond. The holotype, with proximal portion of the column. Five sevenths of natural size.

Fig. 6. *Houghtonites gracilis* (Walcott). The genotype. $\times 3\frac{7}{8}$.

Fig. 7. *Petaloptyon danei* Raymond. The holotype. $\times 2$.

Photographs by George Nelson and H. C. Stetson.

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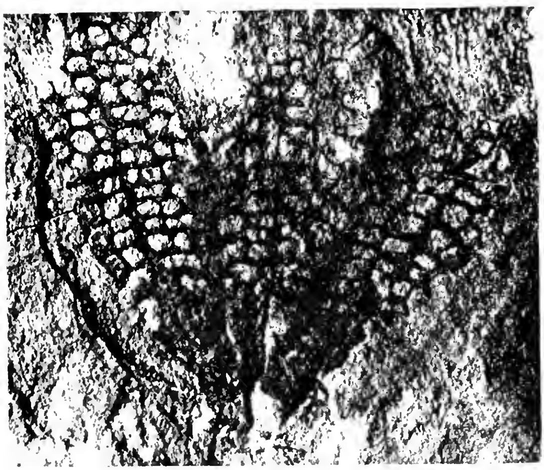

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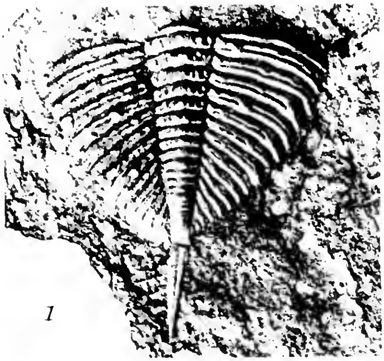
PLATE 5

PLATE 5

Fig. 1. *Dalmanites townsendae* Raymond. The holotype, which is a natural mold of a pygidium. Natural size.

Fig. 2. *Isotelus giganteus* Raymond. The hypostoma, which is the holotype. The greater part of the specimen represents a mold of the lower surface, but the prongs are natural casts of the interior. The white border about the prongs indicates the thickness of the shell. Natural size.

Photographs by George Nelson.



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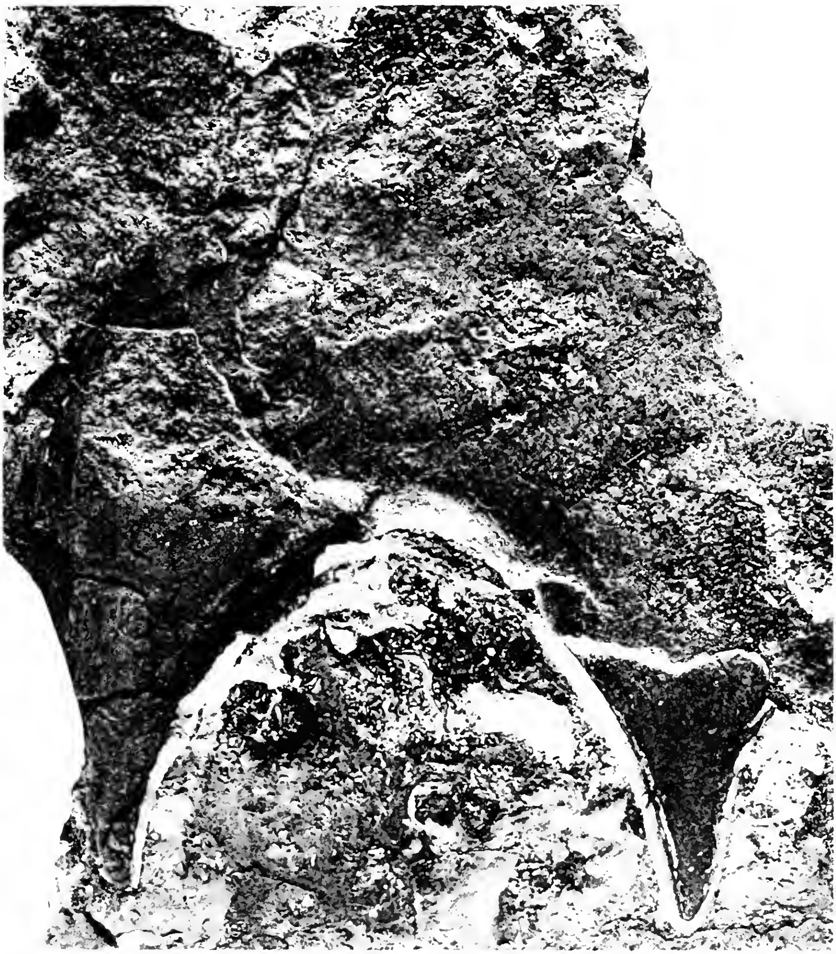

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