28. *Some Statistical Problems concerning Initial Earthquake Motion. (The First Report.)*

By Takaharu FUKUTOMI,

Mitsui Institute of Marine Biology.

(Read Feb. 21, 1933.—Received June 20, 1933.)

1. Geographical Distribution of Initial Vertical Motion of Earthquakes observed at a Particular Station.

The presence of similarity of "Push" or "Pull" of initial motion due to earthquakes occurring at nearly the same place in the Kwantô district and observed at a particular station, has already been pointed out by the writer[1] and Mr. F. Kishinouye.[2] As the Seismometrical Data for recent and older years were gained, and also there happened the necessity to reconsider the mechanism of earthquake occurrence, the writer came again to discuss this problem.

For this purpose, the writer selected earthquakes with distinct initial motion among those which were felt at Tôkyô with unaided sense and which occurred within, say, a circle of a radius of about 160 km., Tôkyô at its centre, during about 18 years from 1914 up to 1931. As for the epicentres, the writer adopted the results obtained by Mr. Ch. Yasuda to whom the writer is greatly indepted. The writer has selected the records of the vertical motion seismographs, on the ground of the facts[3] that the initial motion of the earthquakes originating in the Kwantô district are more pronounced in vertical component than in horizontal, and that the direction of the initial motion indicated by horizontal component was not always coincident with that of epicentre. The writer classified the earthquakes above selected into two categories according to the direction of the initial motion indicated at a particular station. According as the direction of the initial motion of an earthquake is upward or downward, he will indicate the epicentre of the earthquake with mark ○ or with ● respectively on the map as shown in Fig. 1. Table I and Fig. 1 (a), (b) are the results of Tôkyô observation. As

1) T. FUKUTOMI, *Disin*, 3 (1931), 592.
2) F. KISHINOUYE, *Disin*, 4 (1932), 18.
3) T. MATUZAWA, *Jap. Journ. Astr. Geophys.*, 4 (1926), 1-33.

the epicentres of earthquakes occurred during the ten years from 1914 to 1923 are considered to have a certain amount of error of position owning to wants of materials, they were shown in Fig. 1 (b) distingui-

Table I (a). Earthquakes of 1914–1923.

No.	Time of Occurrence at Hôngô				Direction of Initial Motion	No.	Time of Occurrence at Hôngô				Direction of Initial Motion
		h	m	s				h	m	s	
1	1914, Oct. 8th	10	38	28	upward	46	1918, July 26th	5	50	41	downward
2	„ Oct. 12th	2	28	54	„	47	„ July 30th	3	0	41	„
3	„ Dec. 20th	0	47	19	„	48	„ Oct. 4th	11	56	32	„
4	1915, Mar. 5th	15	11	49	downward	49	„ Oct. 15th	12	30	2	upward
5	„ Apr. 6th	3	31	49	upward	50	„ Oct. 17th	8	58	33	„
6	„ Apr. 25th	2	10	7	downward	51	„ Oct. 23rd	20	41	47	„
7	„ May 19th	5	45	27	„	52	1919, Jan. 24th	12	26	7	downward
8	„ May 27th	15	13	22	„	53	„ Feb. 12th	11	27	47	„
9	„ June 20th	1	0	55	„	54	„ Mar. 4th	21	4	6	„
10	„ June 25th	1	18	39	upward	55	„ Apr. 7th	10	28	36	upward
11	„ June 27th	22	16	0	downward	56	„ May 20th	9	45	22	„
12	„ Oct. 3rd	6	29	24	„	57	„ Aug. 4th	3	9	21	„
13	„ Oct. 7th	19	13	39	„	58	„ Aug. 4th	5	27	57	downward
14	„ Oct. 26th	22	55	2	upward	59	„ Aug. 4th	5	53	40	upward
15	„ Dec. 29th	9	36	26	„	60	„ Aug. 15th	11	6	42	downward
16	1916, Jan. 14th	11	57	31	„	61	„ Dec. 20th	9	28	41	upward
17	„ Aug. 21st	23	32	50	downward	62	1920, July 2nd	4	57	49	„
18	„ Aug. 28th	0	40	49	„	63	„ Nov. 9th	2	38	20	„
19	„ Oct. 8th	2	8	51	„	64	„ Dec. 3rd	8	40	27	„
20	„ Feb. 22th	18	11	49	„	65	„ Dec. 5th	4	45	40	downward
21	„ Nov. 3rd	15	4	5	„	66	„ Dec. 20th	5	11	27	upward
22	„ Nov. 6th	4	14	9	upward	67	1921, Feb. 14th	12	0	37	downward
23	„ Dec. 8th	20	10	53	downward	68	„ Apr. 18th	1	33	57	„
24	1917, Jan. 21st	2	39	1	upward	69	„ July 26th	7	45	48	upward
25	„ Jan. 23rd	0	29	9	downward	70	„ Oct. 2nd	23	58	20	downward
26	„ Jan. 27th	2	26	3	„	71	„ Nov. 29th	13	16	1	upward
27	„ Jan. 29th	12	25	18	„	72	„ Nov. 20th	17	4	45	downward
28	„ May 8th	21	48	45	„	73	„ Dec. 8th	21	31	41	upward
29	„ June 10th	7	41	23	„	74	1922, Apr. 26th	—	—	—	downward
30	„ June 29th	1	28	45	upward	75	„ May 9th	12	28	57	upward
31	„ July 29th	9	18	15	„	76	„ June 26th	3	41	23	„
32	„ Aug. 10th	3	24	26	downward	77	„ Nov. 9th	5	16	31	downward
33	„ Sept. 4th	11	41	20	upward	78	„ Dec. 27th	18	31	9	upward
34	„ Oct. 5th	11	22	57	„	79	„ Oct. 6th	1	48	38	„
35	„ Oct. 17th	3	3	42	downward	80	1923, Jan. 26th	21	35	45	„
36	„ Oct. 22nd	23	48	50	upward	81	„ Jan. 27th	14	4	17	downward
37	„ Nov. 6th	2	40	10	downward	82	„ Feb. 6th	6	27	49	„
38	„ Dec. 7th	22	12	44	upward	83	„ Feb. 12th	3	26	41	„
39	1918, Apr. 18th	11	35	32	downward	84	„ May 31st	14	56	14	„
40	„ Apr. 19th	7	22	37	upward	85	„ June 2nd	2	25	16	upward
41	„ Apr. 30th	21	46	51	downward	86	„ June 13th	1	49	47	downward
42	„ May 7th	15	28	59	„						
43	„ May 31st	13	56	50	upward						
44	„ June 24th	11	25	21	„						
45	„ June 26th	22	46	18	„						

Table I (b). Earthquake of 1923–1931.

No.	Time of Occurrence at Hôngô	Direction of Initial Motion				
		Hôngô (Tôkyô)	Kamakura	Tyôsi	Kakioka	Kumagai
1	1923, Sept. 1st 12h 40m 20s	downward				
2	„ Sept. 1st 12 48 03	upward				
3	„ Sept. 1st 13 58 32	„				
4	„ Sept. 1st 14 22 49	downward				
5	„ Sept. 1st 16 38 21	upward				
6	„ Sept. 2nd 11 46 55	„				
7	„ Sept. 2nd 14 10 21	downward				
8	„ Sept. 2nd 18 27 04	„				
9	„ Sept. 2nd 18 49 02	„				
10	„ Sept. 2nd 23 16 46	„				
11	„ Sept. 26th 17 24 03	upward				
12	„ Oct. 5th 22 05 46	„				
13	„ Oct. 17th 3 4 05	„				
14	„ Nov. 1st 1 37 17	„				
15	„ Nov. 5th 5 45 15	„				
16	„ Nov. 22th 1 32 41	„				
17	„ Nov. 22th 2 0 26	„				
18	„ Dec. 11th 19 7 56	downward				
19	1924, Jan. 15th 5 50 24	upward				
20	„ Jan. 21st 0 33 59	„				
21	„ Mar. 5th 12 7 24	„				
22	„ Apr. 1st 4 5 58	„				
23	„ Apr. 20th 1 13 20	„				
24	„ May 14th 17 06 —	„				
25	„ May 21st 10 32 02	downward				
26	„ May 25th 12 10 5	„				
27	„ May 31st 21 2 48	upward				
28	„ May 31st 21 4 7	„				
29	„ June 1st 0 26 49	„				
30	„ June 23rd 7 32 2	„				
31	„ June 24th 3 30 31	downward				
32	„ July 4th 6 30 —	„				
33	„ July 14th 2 19 41	„				
34	„ Aug. 6th 23 22 49	„		upward		
35	„ Aug. 9th 20 45 58	upward				
36	„ Aug. 15th 3 3 10	downward		downward		
37	„ Aug. 17th 10 46 —	upward		upward		
38	„ Aug. 20th 4 29 —	„		downward		
39	„ Aug. 25th 23 31 16	downward				
40	„ Sept. 4th 15 24 13	„		upward		
41	„ Sept. 14th 19 40 —	upward		downward		
42	„ Sept. 18th 10 9 0	„		„		
43	„ Sept. 25th 3 41 —	„		upward		
44	„ Sept. 27th 13 22 26	downward				
45	„ Oct. 3rd 1 31 —	upward				
46	„ Oct. 5th 22 21 —	downward		downward		
47	„ Oct. 5th 22 46 —	„				
48	„ Oct. 8th 23 1 —	upward				
49	„ Oct. 13th 19 6 —	„				
50	„ Oct. 23rd 21 47 —	downward		upward		

(*to be continued.*)

Table I (b). (*continued.*)

No.	Time of Occurrence at Hôngô	Direction of Initial Motion				
		Hôngô (Tôkyô)	Kamakura	Tyôsi	Kakioka	Kumagai
	h m s					
51	1924, Oct. 25th 1 55 1	downward				
52	„ Dec. 29th 21 44 —	„				
53	1925, Jan. 2nd 4 30 55	„				
54	„ Jan. 9th 5 52 7	„		upward		
55	„ Jan. 9th 16 1 38	„				
56	„ Jan. 22nd 19 17 58	„		„		
57	„ Jan. 24th 17 26 57	upward		„		
58	„ Feb. 3rd 10 53 56	downward		„		
59	„ Feb. 6th 4 59 13	upward				
60	„ Feb. 13th 16 13 13	„		upward		
61	„ Feb. 14th 9 42 22	„		„		
62	„ Mar. 31st 10 6 47	„		„		
63	„ Apr. 18th 17 5 28	„				
64	„ June 3rd 1 29 8	„				
65	„ June 12th 8 2 35	„				
66	„ July 12th 11 41 5	downward				
67	„ Nov. 6th 3 42 58	upward				
68	„ Nov. 7th 0 13 35	„		upward		
69	„ Dec. 17th 12 39 13	„				
70	1926, Jan. 10th 18 3 —	downward		upward		
71	„ Jan. 15th 22 45 28	upward	upward			
72	„ Jan. 21st 15 7 22	„				
73	„ Jan. 28th 1 36 0	„		downward		
74	„ Feb. 13th 23 58 34	„				
75	„ Feb. 22th 10 20 —	downward				
76	„ Feb. 28th 5 34 5	upward				
77	„ Apr. 18th 15 54 —	downward	upward	upward		
78	„ Apr. 27th 23 17 —	„	„	„		
79	„ May 1st 2 35 —	upward	downward			
80	„ May 19th 1 59 —	„				
81	„ May 20th 20 48 —	„				
82	„ June 22nd 16 13 —	„				
83	„ July 11th 8 1 —	downward	downward	downward		
84	„ July 30th 0 41 —	upward	„			
85	„ Aug. 3rd 18 26 —	downward	„	downward		
86	„ Dec. 13th 7 1 —	„	„	upward		
87	1927, Jan. 2nd 0 20 —	„				
88	„ Jan. 9th 18 18 —	upward				
89	„ Jan. 12th 6 50 —	„				
90	„ Feb. 11th 23 27 13	downward	upward			
91	„ Feb. 25th 18 5 —	„	downward	downward		downward
92	„ May 20th 4 18 —	upward	upward			
93	„ May 26th 17 51 10	„	„			
94	„ May 31st 16 40 8	downward				
95	„ July 9th 6 11 36	„				downward
96	„ July 24th 5 26 44	upward	downward	upward		„
97	„ July 30th 23 18 51	downward	„			„
98	„ Aug. 7th 10 40 23	upward	upward			
99	„ Aug. 12th 5 53 4	downward				
100	„ Aug. 19th 21 43 41	„				upward

(*to be continued.*)

Table I (b). (*continued.*)

No.	Time of Occurrence at Hôngô	Direction of Initial Motion				
		Hôngô (Tôkyô)	Kamakura	Tyôsi	Kakioka	Kumagai
101	1927, Aug. 21st 7h 14m 27s	downward				
102	„ Sept. 5th 9 33 15	„			downward	downward
103	„ Sept. 7th 19 33 36	upward			upward	„
104	„ Sept. 13th 13 56 13	downward		upward		
105	„ Sept. 18th 7 22 10	„				
106	„ Sept. 18th 18 19 52	upward				
107	„ Oct. 11th 10 13 20	downward		upward	downward	downward
108	„ Oct. 12th 2 58 53	upward				
109	„ Oct. 14th 19 7 24	downward				
110	„ Oct. 25th 15 2 29	„	upward			
111	„ Nov. 6th 15 35 2	„				
112	„ Nov. 7th 7 38 11	upward			downward	downward
113	„ Nov. 18th 5 22 18	downward	downward			
114	„ Nov. 30th 7 47 0	upward				
115	„ Dec. 31st 14 51 6	„	upward	upward		upward
116	1928, Jan. 1st 16 17 —	„	downward		upward	downward
117	„ Jan. 3rd 16 31 —	downward	„			
118	„ Jan. 8th 19 6 —	„		upward		
119	„ Jan. 16th 13 8 —	upward		„		
120	„ Feb. 3rd 7 34 —	„				
121	„ Feb. 12th 6 10 —	„	downward	upward	upward	downward
122	„ Feb. 19th 0 — —	„				
123	„ Mar. 1st 1 31 —	downward				
124	„ Mar. 2nd 6 28 —	upward				
125	„ Mar. 23rd 10 21 —	downward			upward	upward
126	„ Apr. 6th 19 33 —	upward				
127	„ Apr. 8th 17 57 —	„				
128	„ Apr. 13th 1 36 —	„		upward	upward	
129	„ Apr. 16th 12 50 —	„				
130	„ Apr. 20th 5 47 —	„				
131	„ May 19th 18 32 —	downward	downward	downward	downward	downward
132	„ May 21st 1 28 —	„	„	upward	upward	„
133	„ May 21st 2 32 —	„		„		
134	„ May 21st 2 58 —	„		„		
135	„ May 21st 4 23 —	„		„		
136	„ May 29th 6 9 —	upward			upward	downward
137	„ May 24th — — —	downward				
138	„ May 30th 12 35 —	„				
139	„ May 31st — — —	„		upward		
140	„ June 2nd 7 54 —	„				
141	„ June 3rd — — —	„				
142	„ June 11th 18 6 —	upward				
143	„ June 26th 7 54 —	downward				
144	„ July 5th 7 53 —	upward				
145	„ July 5th 16 52 —	downward	upward			
146	„ July 10th 9 16 —	upward				
147	„ July 15th 17 7 —	downward	downward			
148	„ July 15th 20 32 —	„				
149	„ Aug. 14th 17 25 —	„		upward		
150	„ Aug. 27th 3 11 —	„		„	downward	downward

(*to be continued.*)

Table I (b). (*continued.*)

No.	Time of Occurrence at Hôngô	Direction of Initial Motion				
		Hôngô (Tôkyô)	Kamakura	Tyôsi	Kakioka	Kumagai
	h m s					
151	1928, Oct. 5th 15 58 —	upward	downward	upward		
152	„ Oct. 7th 22 53 —	„				
153	„ Oct. 15th 15 38 —	„				
154	„ Dec. 13th 12 44 —	„				
155	„ Dec. 14th 5 6 —	„	upward	downward	downward	downward
156	„ Dec. 21st 10 40 —	downward	downward			
157	1929, Jan. 9th 3 7 38	„				downward
158	„ Jan. 21st 11 22 16	„				upward
159	„ Feb. 4th 4 8 33	„				
160	„ Feb. 5th 9 16 32	upward				
161	„ Apr. 14th 21 14 39	„				
162	„ Apr. 16th 9 53 22	downward	downward	downward	downward	downward
163	„ Apr. 18th 3 34 —	„			„	„
164	„ Apr. 23rd 23 16 —	upward	downward		upward	„
165	„ June 8th 11 54 52	„				
166	„ June 8th 18 24 26	„				
167	„ June 14th — — —	downward				
168	„ June 18th 3 34 33	„				
169	„ June 27th 1 49 34	upward				
170	„ July 17th 19 49 33	„	downward	upward		
171	„ July 27th 7 48 26	„	upward	downward	downward	downward
172	„ July 29th 2 33 —	„				
173	„ Sept. 3rd 0 39 —	„				
174	„ Sept. 27th 0 17 —	downward	upward			
175	„ Sept. 30th 4 41 40	upward	upward ?			
176	„ Oct. 20th 1 31 40	„				
177	„ Oct. 31st 22 3 29	downward				
178	„ Nov. 20th 1 31 43	„	downward			
179	„ Nov. 26th 22 9 9	upward	upward			
180	„ Dec. 6th 13 15 52	„	downward			
181	1930, Feb. 3rd 6 1 5	upward				
182	„ Mar. 2nd 2 42 47	downward				
183	„ Apr. 21st 8 36 31	„				
184	„ May 1st 9 58 12	„	downward	upward	downward	downward
185	„ May 1st 10 16 5	„				
186	„ May 1st 13 20 44	„			downward	downward
187	„ May 5th 1 56 33	upward	downward			
188	„ May 16th 4 39 19	downward		downward		
189	„ May 21st 7 11 33	„	upward			
190	„ May 22nd 2 37 24	upward	„			
191	„ May 29th 4 32 11	downward				
192	„ May 24th 1 38 38	„			upward	upward
193	„ June 1st 2 58 43	upward		upward	downward	downward
194	„ Feb. 21st 8 37 15	„	upward			
„	„ Mar. 4th 3 50 53	„	„			
„	„ Mar. 4th 5 11 17	„	„			
„	„ Mar. 9th 4 39 53	„	„			
„	„ Mar. 9th 19 54 49	„	„			
„	„ Mar. 14th 21 5 30	„	„			
„	„ Mar. 21st 23 4 24	„	„			

(*to be continued.*)

Table I (b). (*continued.*)

No.	Time of Occurrence at Hôngô				Direction of Initial Motion				
		h	m	s	Hôngô (Tôkyô)	Kamakura	Tyôsi	Kakioka	Kumagai
194	1930, Mar. 22nd	17	50	52	upward	upward			
„	„ Mar. 26th	14	22	59	„	„			
„	„ Mar. 27th	1	41	47	„	„			
„	„ Mar. 30th	0	6	37	„	„			
„	„ Apr. 1st	23	4	44	„	„			
195	„ June 23rd	15	14	13	downward				
196	„ June 29th	9	25	21	upward				
197	„ July 5th	1	33	55	downward		downward		
198	„ Aug. 17th	18	28	45	upward	downward		upward	upward
199	„ Aug. 20th	2	41	52	downward		downward		
200	„ Sept. 30th	13	55	27	„		upward		
201	„ Oct. 5th	21	4	25	„				
202	„ Oct. 12th	17	58	8	„		upward		
203	„ Oct. 25th	7	22	4	upward				
204	„ Nov. 26th	4	3	6	„	upward	upward	upward	upward
205	„ Dec. 15th	14	22	24	downward		„		
206	„ Dec. 30th	5	57	10	„				
207	1931, Jan. 30th	10	40	30	upward	upward			
208	„ Mar. 10th	3	41	2	downward	downward			
209	„ Mar. 27th	5	25	36	„				
210	„ Apr. 4th	9	16	42	„				
211	„ May 4th	23	48	29	upward	upward ?			
212	„ May 25th	19	27	57	„				
213	„ June 9th	14	8	9	downward				downward
214	„ June 11th	15	16	20	upward				„
215	„ June 14th	7	45	43	downward				
216	„ June 17th	21	9	50	„				upward
217	„ June 17th	22	53	13	„				
218	„ June 23rd	15	15	26	„				
219	„ June 30th	1	8	56	„				
220	„ July 8th	5	46	25	„				
221	„ July 10th	22	10	42	„				downward
222	„ July 26th	10	41	20	„		upward		
223	„ July 28th	11	6	42	upward				
224	„ July 31st	4	46	21	downward				
225	„ Aug. 18th	14	40	42	„		downward		
226	„ Aug. 27th	8	49	33	„				
227	„ Sept. 7th	5	35	5	upward				
228	„ Sept. 9th	4	9	31	„		upward		
229	„ Sept. 16th	21	43	23	downward		downward		
230	„ Sept. 21st	11	20	10	upward		„		
231	„ Sept. 21st	15	21	37	„				
232	„ Sept. 21st	15	49	13	„				
233	„ Sept. 23rd	21	46	19	„				
234	„ Sept. 24th	1	22	41	„				
235	„ Sept. 24th	21	11	26	„				
236	„ Sept. 26th	12	37	43	„				
237	„ Sept. 28th	4	50	41	„		upward		
238	„ Sept. 28th	13	54	28	„				
239	„ Oct. 3rd	2	36	55	„		upward		

(*to be continued.*)

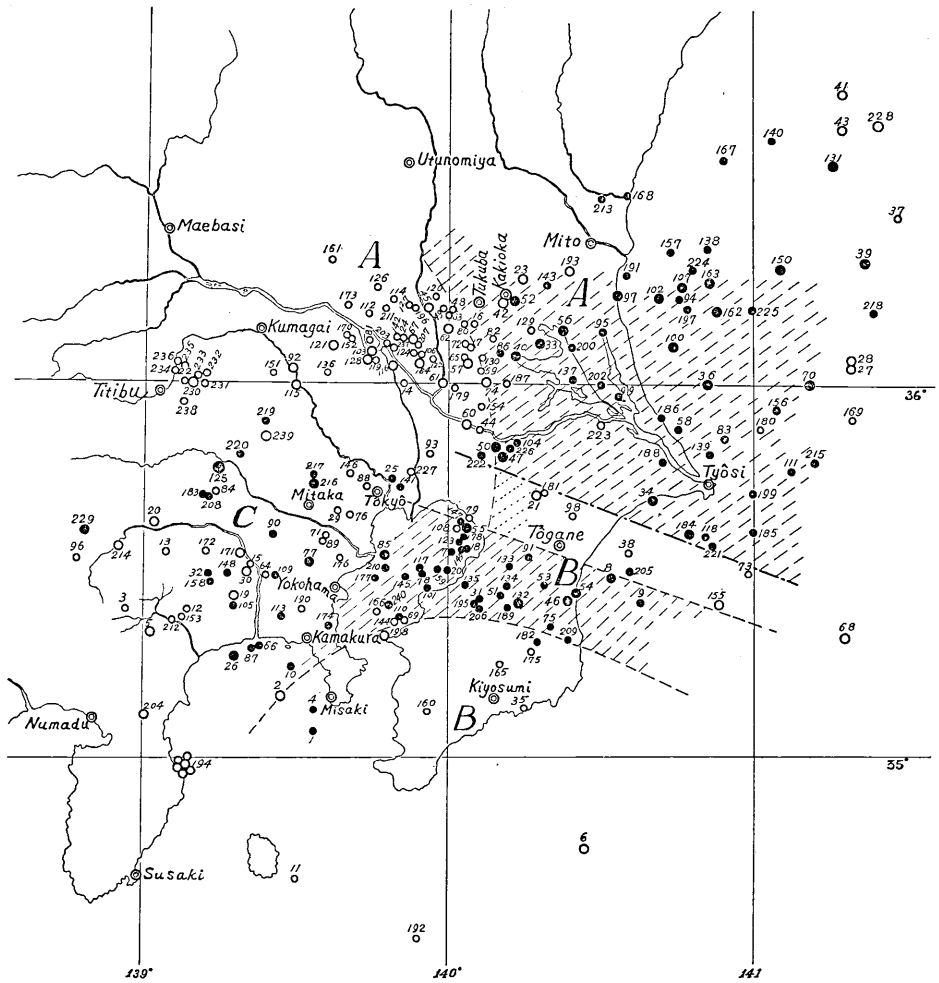

Fig. 1 (a). Distribution of initial motions of earthquakes observed at Hôngô (Tôkyô) from Sept. 1923 up to 1931.

Epicentres of earthquakes which began at Hongô with {upward ○ / downward ●} initial motions. Numerals against the circles correspond to the index number of the earthquakes in Table I. Large circles show the epicentres of larger earthquake.

Table I (b). (*continued.*)

No.	Time of Occurrence at Hôngô	Direction of Initial Motion				
		Hôngô (Tôkyô)	Kamakura	Tyôsi	Kakioka	Kumagai
	h m s					
240	1931, Oct. 13th 21 14 6	downward				
241	1926, Jan. 13th 6 59 —		upward			
242	„ June 27th 7 39 —		„	downward		
243	1927, Mar. 16th 16 46 —		„			
244	1929, Jan. 31st 21 56 —		„			
245	„ Mar. 20th 22 8 —		upward ?			
246	1926, Oct. 3rd 4 3 —				downward	
247	1929, Aug. 16th 22 21 —				„	downward
248	1930, May 17th 6 14 —				upward	upward
249	1932, Dec. 2nd					

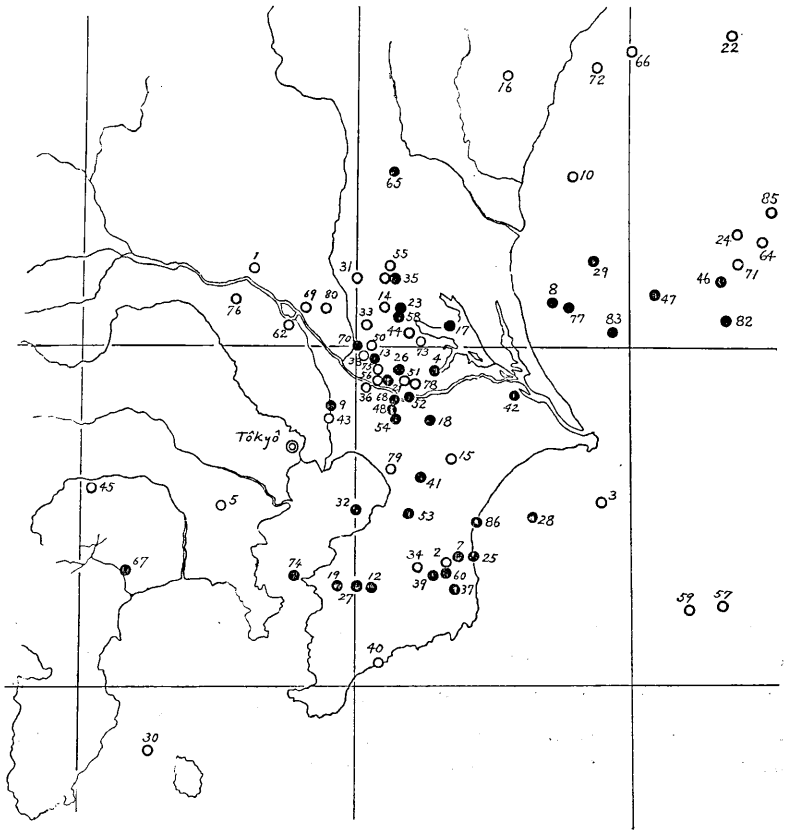

Fig. 1 (b). Distribution of initial motions of earthquakes observed at Hôngô (Tôkyô) from 1914 up to Aug. 1923.

Epicentres of earthquakes which began at Hongô with {upward ○ / downward ●} initial motions.

shing from those occurred after that. The discussion of the distribution of initial motion may be chiefly made regarding to Fig. 1 (a), because similar distribution is found between Fig. 1 (a) and Fig. 1 (b), though it is more or less indistinct in the latter. Figures and large circles in Fig. 1 indicate the number of earthquakes in Table I and the epicentres of distinct earthquakes respectively. Total numbers of the earthquakes adopted here are 337 and the numbers of earthquakes which fall into the groups with the mark ○ and • are 176 and 161 respectively. Thus it seems apparently that the earthquakes that indicate upward direction in the initial motion at Tôkyô are nearly equal to those that indicate downward direction. The geographical distribution of epicentres of the earthquakes seems to be more or less systematic, that is, the epicentres specified with the same sort of mark swarm together into rather definite local groups. Thus, the earthquakes originating in the drainage basin of the River Kinu and Ogai, the southern part of the Bôsô Peninsula, far off the coast of Kasima,

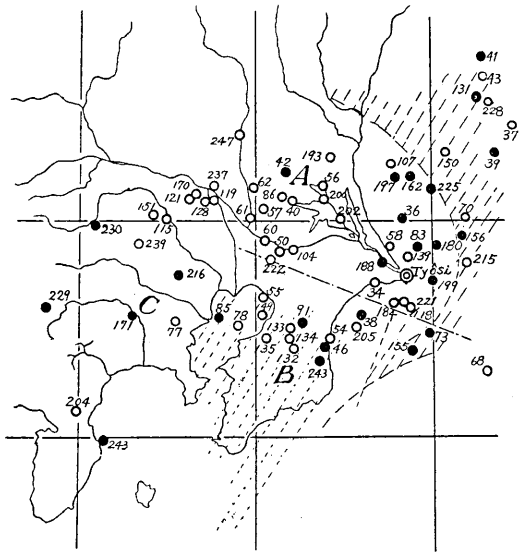

Fig. 1 (c). Distribution of initial motion observed at Tyôsi.
○ upward motion,
● downward motion.

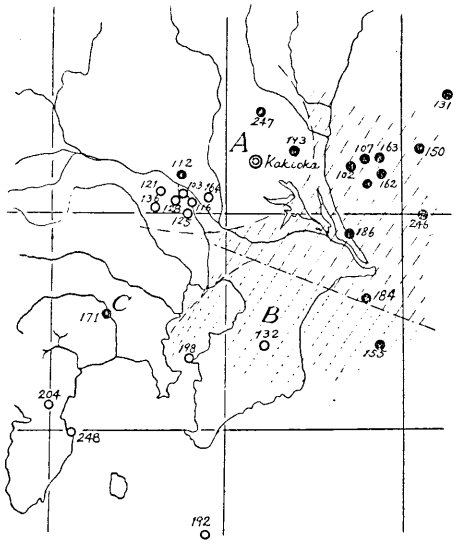

Fig. 1 (d). Distribution of initial motion observed at Kakioka.
○ upward motion,
● downward motion.

Titibu mountain land and the Idu Peninsula bigin with upward movement at Tôkyô, while those generated in the locality containing the Kasumigaura and the littoral of Kasima, Tôkyô Bay and the central part of the Bôsô Peninsula bigin with downward movement.

The results of observation of other seismological stations such as Tyôsi, Kakioka and Kumagai etc. are shown respectively in Fig. 1 (c), (d), (e) and (f). In these results of observation, the geographical distribution of the epicentres specified with the same mark seems to be more or less systematic, though each of them shows different distribution compared with that of Tôkyô observation.

To give the reason for the above-mentioned results, the writer studied the distribution of the initial motions of some earthquakes which were observed at seismological stations sourrounding the epicentre, adopting comparatively distinct earthquakes. The earthquakes are classified into 3 classes, A, B and C according to the position of their epicentres as shown in Fig. 1.

(A) The earthquakes originating in region A (Tone,

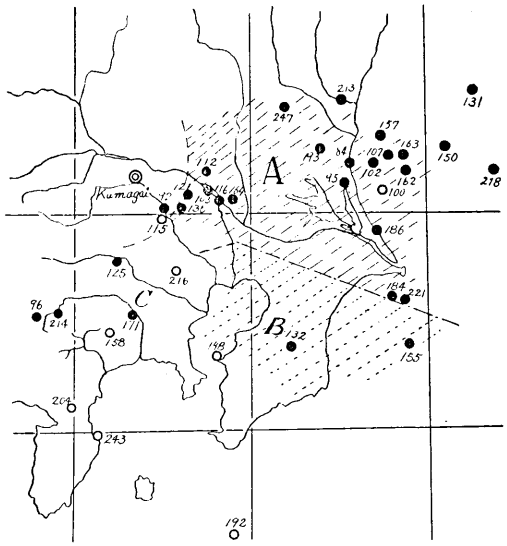

Fig. 1 (e). Distribution of initial motion observed at Kumagai.
○ upward motion,
● downward motion.

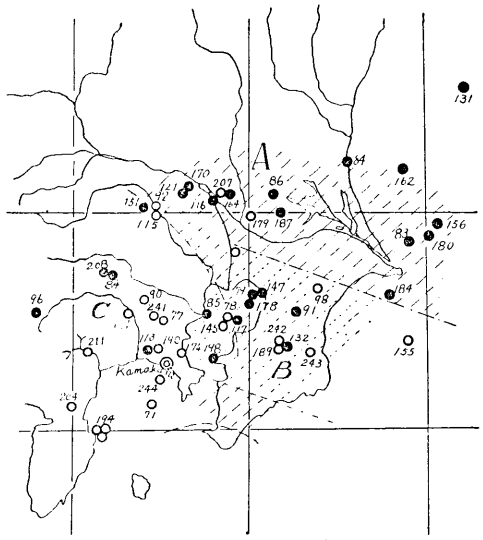

Fig. 1 (f). Distribution of initial motion observed at Kamakura.
○ upward motion,
● downward motion.

Kasima).

Most earthquakes originating in region A show upward or downward motion according as the observatory is situated inside or outside of the nodal ellipse in which the epicentre is included. Fig. 2 (a), (b), (c) indicate the typical examples which occurred in the drainage basin of the River Kinu on Jan. 1, 1928,[4] on Feb. 12, 1928 and off the coast of Tyôsi on May 1, 1930. Some examples of this type were earthquakes of Dec. 13, 1926 (86), May 20, 1927 (92), Sept. 5, 1927 (102), Sept. 7, 1927 (103), Jan. 1, 1928 (116), Feb. 12, 1928 (121), May 19, 1928 (131), Aug. 27, 1928 (150), Oct. 5, 1928 (151), April 16, 1929 (162), April 18, 1929 (163), April 23, 1929 (164), July 17, 1929 (170), May 1, 1930 (184), June 9, 1931 (213), June 9, 1931 (221). The mean dimension of the nodal ellipses is

$$a=100\text{ km.}, \quad b=65\text{ km.} \quad \left(\begin{array}{l}\text{mean co-ordinates of epicentres}\\ \text{relative to the ellipse.}\end{array}\right.$$
$$x=-60\sim 80\text{ km.}, \quad y=0\text{ km.} \quad \left.\right)$$

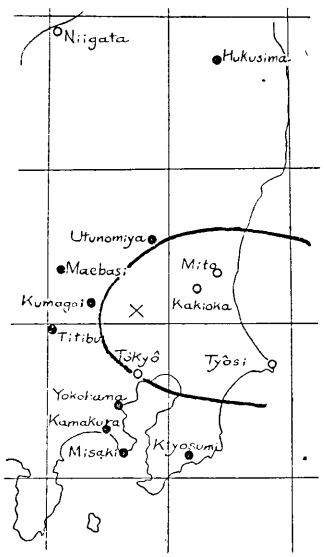

Fig. 2 (a). Distribution of initial motion of the earthq. occurred on Jan. 1, 1928.
× epicentre,
○ upward motion,
● downward motion.

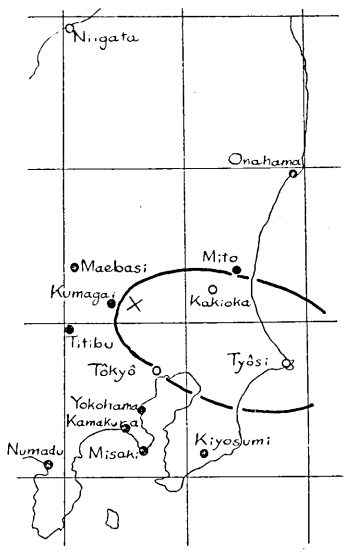

Fig. 2 (b). Distribution of initial motion of the earthq. occurred on Feb. 12, 1928.
× epicentre,
○ upward motion,
● downward motion.

4) M. Ishimoto, *Bull. Earthq. Res. Inst.*, 10 (1932), 449.

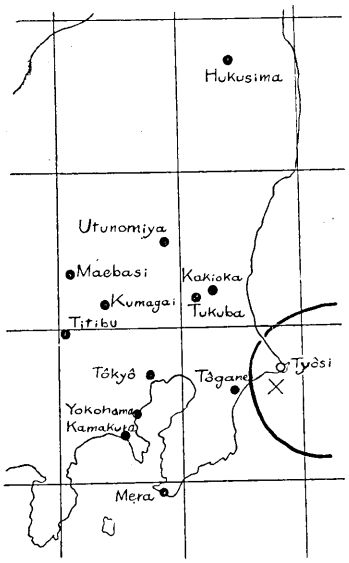

Fig. 2 (c). Distribution of initial motion of the earthq. occurred on May 1, 1930.
× epicentre,
○ upward motion,
● downward motion.

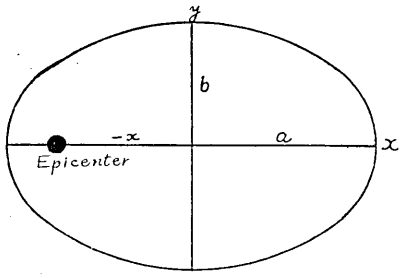

Fig. 3. The nodal ellipse.

h (focal depth) = about 40 km.
Azmuth of the x axis = nearly N 70°W

The above-mentioned results seem to suggest that earthquakes originating in particular region of the Kwantô district have similar mechanism of occurrence. To ascertain this further, the writer has constructed, under the assumption that the earthquakes having the mean nodal ellipse above mentioned occurred in region A, the map of theoretical distribution of initial motions at every observatory in the Kwantô district as shown in Fig. 1. Regions marked with ▭, ▨ and ▩ respectively indicate those in which earthquakes may begin with upward, downward and either upward or downward motion. Now, we can recognized that the theoretical distributions seem to be in fair agreement with the actually observed distributions, so that the above-mentioned assumption may not be so absurd.

(B) The earthquakes originating in region B (Tôkyô Bay, Bôsô Peninsula).

There are three types of earthquakes in the B region. The first of them is similar to the type of earthquakes originating in the A region as shown in the earthquake occurred in the central part of the Bôsô Peninsula on May 21, 1928[5] (Fig. 4). The earthquakes of this type are frequent in the western and the central part of the region and have nearly equal focal depth of about 60 km. The second type of them begins with upward or downward motion according as the observatory

5) M. ISHIMOTO, *loc. cit.*

is inside or outside of the nodal hyperbola which have an asymptote of about N 70°W as shown for the earthquake occurred off the coast of Kuzyûkuri on Dec. 14, 1928 (Fig. 5). The earthquakes of this type are

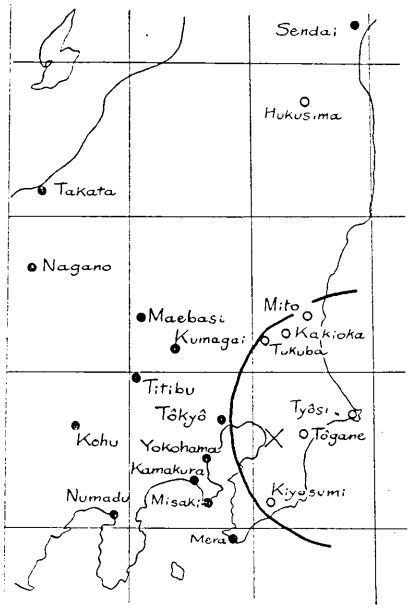

Fig. 4. Distribution of initial motion of earthquake occurred on May 21, 1928.
× epicentre,
○ upward initial motion,
● downward initial motion.

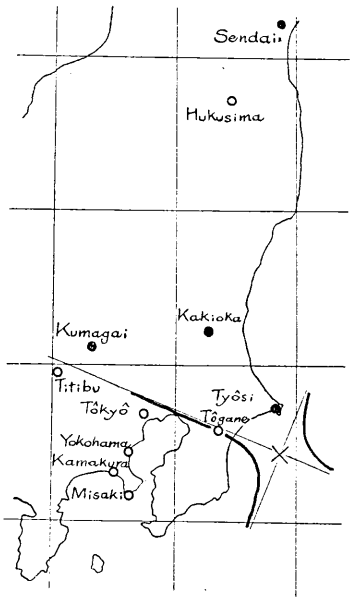

Fig. 5. Distribution of initial motion of earthq. occurred on Dec. 14, 1928.
× epicentre,
○ upward motion,
● downward motion.

frequent in the north-eastern and the eastern parts of the region and have very shallow focal depth of nearly 20 km. The third type bigins with upward or downward motion according as the observatory is within or without of the nodal hyperbola which have asymptotes of N 32°E and N 60°W as shown for the earthquakes of off the coast of Haneda on Aug. 3, 1926[6] and that of the Uraga channel on Aug. 17, 1930 (Fig. 6 & 7). The earthquakes of this type are frequent in the central and south-western parts of the Bôsô Peninsula and have nearly equal focal depth of 70–100 km.

6) M. Ishimoto, *loc. cit.*

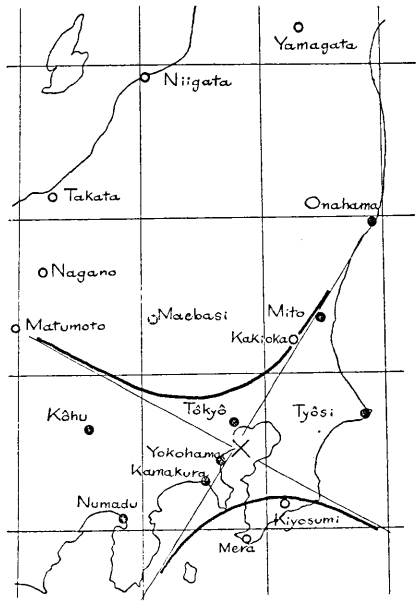

Fig. 6. Distribution of initial motion of earthq. occurred on Aug. 3, 1926.
× epicentre,
○ upward motion,
● downward motion,

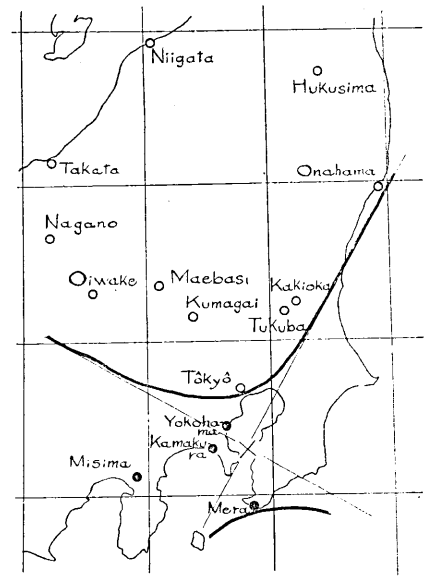

Fig. 7. Distribution of initial motion of earthq. occurred on Aug. 17, 1930.
× epicentre,
○ upward motion,
● downward motion.

The writer again constructed under the assumption that the earthquakes having one of the three nodal curves above mentioned occured in particular parts of the B region, the map of theoretical distribution of initial motions at every observatory in the Kwantô district as shown in Fig. 1. We can again recognize that the theoretical distributions seem to be in fair agreement with the actually observed distributions in the B region.

In the region except A and B, the distribution is not so systematic, especially in the Sagami region. Though it is not very obvious for the want of materials, it may be said that earthquakes occurred in this region have very shallow focal depth of less than 20 km. and show the nodal hyperbola of initial earthquake motion direction of asymptotes of which are not so constant. This may be attributable to the complicated structure of the surface layer of the earth.

The nodal curves of the earthquakes originating in any one of the three regions above quoted are shown in Fig. 8 with the mark -○- as the nodal ellipse and)×(as the nodal hyperbola. It may be interesting that

we can draw a line distinctly separating the regions where earthquakes with nodal ellipse only occur from those where earthquakes with hyperbola take place exclusively.

The writer studied above the initial motion of earthquakes originating in the Kwantô district and came to the conclusion that the earthquakes originating in the two regions A and B have respectively the constant mechanisms of occurrence of earthquake.

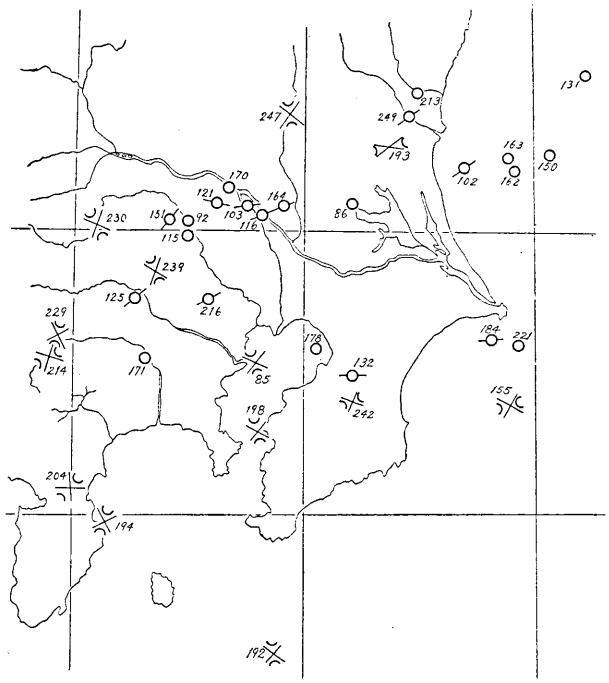

Fig. 8. Distribution of epicentres of nodal ellipse (-o-) and nodal hyperbola ()×() in the Kwantô district. Bar or crossed bar indicate direction of majer axis or asymptotes respectively. Figures refer to the number of earthquake in table I.

2. On the Relation between Mechanism and Focal Depth of Earthquakes.

Dr. T. Shida[7] investigated the distribution of displacements by two forces of equal magnitude and opposite direction acting on a line at the hypocentre, and indicated actual examples of the mechanism of earthquake occurrence. Since then, Dr. M. Ishimoto[8] ascertained that most of the earthquakes occurred in Japan may be explained as those of this mechanism. In the earthquakes of this mechanism, "pull-push" distribution of initial motion on the earth-surface has nodal curves of second degree, namely ellipse or hyperbola in general, and parabola in special cases according to the inclination of the axis of double force to the earth-surface.

7) T. Shida, Read before the meeting of Imp. Earthq. Inv. Comm. (1917).
8) M. Ishimoto, *loc. cit.*

The writer examined in this paper the relation between the nodal curves of "pull-push" of initial motion and the focal depths of the earthquakes as a first step of examing the relation between the inclination of the axis of double force and the focal depth of earthquake. For the purpose, adopting earthquakes during 8 years from 1925 up to 1932 which were sufficiently large for determination of the nodal curve, the writer assigned in the following table the mark E or H respectively according as the nodal curve of an earthquake was ellipse or hyperbola.

Table II.

Time of Occurrence	Epicentre	Depth of Focus in Km	Form of Nodal Curve
h			
1925, May 23rd 11	Kinki district	33	Hyperbola
1926, Aug. 3rd 18	Kwantô district	about 70	,,
1927, Jan. 15th 23	Kinki district	about 450	,,
,, Mar. 7th 18	,,	15	,,
,, Apr. 1st 6	,,	18	,,
,, May 20th 4	Kwantô district	about 60	Ellipse
,, Sept. 7th 19	,,	0~5	,,
,, Dec. 31st 14	,,	140	,,
1928, Jan. 1st 16	,,	35	,,
,, Feb. 12th 6	,,	40	,,
,, Mar. 23rd 10	,,	32	,,
,, May 19th 18	,,	40~25	,,
,, May 21st 1	,,	about 60	,,
,, Aug. 27th 3	,,	within 50 (not so shallow)	,,
,, Oct. 5th 15	,,	about 60	,,
,, Dec. 14th 5	,,	about 20	Hyperbola
1929, Apr. 16th 9	,,	50~25	Ellipse
,, Apr. 18th 3	,,	,,	,,
,, Apr. 23rd 23	,,	about 30	,,
,, June 3rd 6	Tyûbu district	360	,,
,, July 4th 5	Kinki district	28	Hyperbola
,, July 27th 7	Kwantô district	23	Ellipse
,, Aug. 16th 22	,,	about 100	Hyperbola
,, Nov. 20th 1	,,	10	Ellipse
1930, Feb. 21st 8	,,	within 20	Hyperbola
,, Feb. 22nd 20	,,	,,	,,
,, Mar. 4th 3	,,	,,	,,
,, Mar. 22th 17	,,	,,	,,
,, May 1st 13	,,	about 30	Ellipse
,, May 17th 6	,,	within 20	Hyperbola
,, May 24th 1	,,	80	,,
,, June 1st 2	,,	about 50	,,
,, Aug. 17th 18	,,	about 50	,,
,, Sept. 29th 13	Kyûsyû district	300	,,
,, Oct. 17th 6	Tyûbu district	within 20	,,
,, Oct. 17th 6	,,	,,	,,
,, Nov. 26th 4	,,	within 10	,,
,, Dec. 20th 23	Tyûgoku district	within 25	,,
,, Dec 20th 23	,,	,,	,,
,, Dec. 21th 21	,,	,,	,,

(to be continued.)

Table II. (*continued.*)

Time of Occurrence	Epicentre	Depth of Focus in Km	Form of Nodal Curve
h			
1931, Feb. 20th 14	Northern part of the Japan Sea	about 400	Hyperbola
„ June 2nd 11	Tyûbu district	250	„
„ June 9th 14	Kwantô district	70	Ellipse
„ June 11th 15	Tyûbu district	10	Hyperbola
„ May 12th 3	Ôu district	within 50	Ellipse
„ May 26th 18	„	within 40	„
„ June 17th 21	Kwantô district	45	„
„ June 23rd 15	„	within 50	„
„ July 10th 22	„	30	„
„ Aug. 10th 23	Tyûbu district	3	„
„ Sept. 16th 21	„	20	Hyperbola
„ Sept. 21st 11	Kwantô district	about 20	„
„ Oct. 3rd 2	„	24	„
1932, June 22nd 9	„	40	„
„ Nov. 18th 5	Kyûsyû district	very deep	„
„ Dec. 2nd 2	Kwantô district	40	Ellipse

Now, classifying the earthquakes into three classes according to the focal depth, namely less than 25 km., between 25 km. and 50 km., and more than 50 km., Table III shows the frequency of earthquakes which fall into the group with mark E and that with H respectively.

Table III.

Locality / Focal depth in Km.	Kwantô district	Tyûbu, Kinki, Tyûgoku districts	Other district	Total		Calculated % $\alpha=45°$ (55°)
				Obs.	Reduced %	
0~25	E 3	E 0	E 0	E 3	13·6	29 (18)
	H 8	H 11	H 0	H 19	86·4	71 (82)
25~50	E 13	E 0	E 2	E 15	79·0	29 (18)
	H 2	H 2	H 0	H 4	21·0	71 (82)
More than 50	E 5	E 1	E 0	E 6	40·0	29 (18)
	H 4	H 2	H 3	H 9	60·0	71 (82)
Total	E 21	E 1	E 2	E 24	42·9	29 (18)
	H 14	H 15	H 3	H 32	57·1	71 (82)

If the direction of the axis of double force is equally probable in all directions, the ratio of expectation of earthquakes with nodal ellipse to that of earthquakes with hyperbola may be

$$\frac{N_E}{N_H}=\frac{1-\sin\alpha}{\sin\alpha}=\begin{cases}\alpha=45^\circ \ldots\ldots \dfrac{0\cdot29}{0\cdot71}\\ \alpha=55^\circ \ldots\ldots \dfrac{0\cdot18}{0\cdot82}\end{cases}$$

where α is the angle between the axis of double force and the generating line of the nodal cone as shown in Fig. 9 and its numerical value is considered to be 45° or 55°.

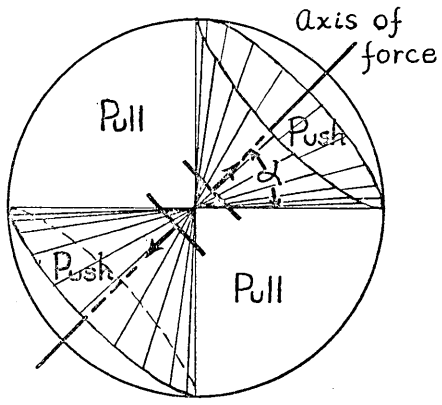

Fig. 9. Mechanism of earthquake.

Now, comparing the observed value with the calculated one, we can recognize that the earthquakes of nodal hyperbola are frequent in the uppermost layer and those of nodal ellipse also frequent in the middle layer, and observed ratio of N_E and N_H is nearly equal to the calculated value in the lowermost layer. It may be a natural consequence that earthquakes of nodal hyperbola are frequent in the uppermost layer, and the ratio of observed N_E to N_H is nearly equal to the calculated value in the lower layer, when it is taken into consideration that the normal stress is equal to zero in the earth's surface and the effect of the surface on elastic conditions may become smaller in the deeper layer. But, it may be an interesting fact, for the conjecture of the structure of middle layer that earthquakes of nodal ellipse are frequent in that layer.

In conclusion, the writer expresses his cordial thanks to Professor Akitune Imamura and Professor Takeo Matuzawa for their kind advices and the revision of this paper and to Mr. Ch. Yasuda for his kind information of the positions of epicentres.

28. 地震初動に關した二三の統計的問題

三非海洋生物學研究所 福 富 孝 治

1. 關東地方の色々な場所に起つた地震の初動の押し引きを或る定まつた觀測所例へば東京本郷で見ると，その押し，引きの分布に規則正しさがある事は既に指摘した所であつたが，其後並に其前の材料に就いても調査したし，又其説明として用ひた地震發生機構に就いても考へ改める必要を生じたので此處に再び此問題を考究した．其結果，是等の押し，引きの分布の規則正しさはその場所場所に起る地震の發生機構が相等しいと云ふ結論に達した．

2. 曾つて志田博士は地震の發生機構として震原に於て一軸上に大きさ相等しく方向相反する二力が外向きに働く場合の問題を解かれ，かゝる發生機構をもつ地震の存在を實證せられた．其後石本博士は我國に起る殆んど全部の地震が此機構で説明せられる事を研究された．此の機構の地震ではこの軸の方向が地表面と如何なる角をなすかに依つて初動の押し，引きの節線が橢圓，双曲線特別な場合として抛物線となる．筆者はこの軸の地表面となす角と地震の震原の深さとの關係を吟味する第一段として最近我國に起つた顯著な地震に就いて初動の押し，引きの節線が橢圓又は双曲線であるかに依つて地震原の深さと如何なる關係があるかを吟味した．其結果は深さ0～25粁では双曲線をなすもの多く，25～50粁では橢圓をなすものが多くあつた．又關東地方に於ては橢圓の節線を持つ地震の起る場所と双曲線の節線を持つ地震の起る場所とが區分せられる事にも注意した．