NOTES ON THE RECENT EARTHQUAKES OF YEDO PLAIN, AND THEIR EFFECTS ON CERTAIN BUILDINGS.

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So far as I am aware only two accounts have hitherto been given of the recent earthquakes of Japan. The first of these is by Mr. E. Knipping and is entitled "Verzeichniss von Erdbeben" (see Mittheilungen der Deutschen Gesellschaft für Natur und Völkerkunde Ostasiens, April, 1878). The second is by Mr. W. S. Chaplin, and is entitled "An examination of the Earthquakes recorded at the meteorological observatory Tokio (see Transactions of the Asiatic Society of Japan, April, 1878.)

The results obtained by Mr. Chaplin appear to be as follows :

1st.—Earthquakes have been most frequent when the sun was two hours east and eight hours west of the meridian.

2nd.—There have been maxima of Earthquakes when the moon was two and nine hours east and seven hours west. At the upper transit there is a minimum.

3rd.—Considering the moon's position with regard to the sun,—at conjunction there were 32, at opposition 37, and at quadrature 74. East of the meridian the maximum was at four hours.

4th.—In summer there were 69 earthquakes, in winter 74.

5th.—When the moon was north of the equator there were 61, when south 82.

6th.—A maximum of earthquakes 7 and 11 days after the moon's perigee.

The marked manner in which these results differ from some of the results obtained by M. Perrey has been pointed out by Mr. Chaplin.

Mr. Knipping illustrates his results, some of which are analogous to those of Mr. Chaplin, by a series of interesting diagrams and tables. These tables shew the distribution of of earthquakes according to years, months, days, hours the position of the moon, wind, storms and rainfall.

In the following catalogue I have combined together the lists given by the above two writers and added to them a list of earthquakes which have occurred since January, 1878.

The first portion of this catalogue from November, 1862, to July, 1875, is taken from the valuable paper of Mr. Knipping. The remainder of the catalogue is taken from the records of the observatory at Yamato Yashiki, which records have from time to time been kindly furnished to me by Mr. Arai Ikunosuke. These records were made by one of Palmieri's instruments. My object in giving this catalogue, although partly on account of its own value as a record of seismic phenomena, is chiefly to shew the data on which I have founded conclusions with regard to certain effects which are observable in many of the buildings of Tokio.

1872.

No.	Month	Day.	Time.	Force of Shock.	Direction.
			h. m. s.		
1...	IX	14	16. 7.20	...	...
2...	XII	21	11.20.00	...	...
3...	XII	21	17.20.00	...	...

1873.

4...	I	19	13.00.00	...	...
5...	II	19	17.33.00	...	...
6...	III	28	16.45.00	...	...
7...	IV	15	11.44.00	...	...
8...	IV	18	11.40.00	...	...
9...	IV	28	10.30.00	...	...
10...	V	16	8.22.00	...	...
11...	VI	7	17.57.00	...	...
12...	VI	12	9.20.00	...	...
13...	VII	2	8.40.00	...	...
14...	VII	2	9.20.00	...	...
15...	VIII	2	14.00.00	...	...
16...	VIII	27	10.00.00	...	...
17...	IX	16	8.20.00	...	...
18...	XI	11	13.00.00	...	...
19...	XI	14	18.00.00	...	...
20...	XII	11	10.00.00	...	...

1874.

21...	II	14	0.39.00	...	...
22...	II	16	2.32.00	...	...
23...	VI	7	12.16.00	...	...
24...	VI	24	18.21.00	...	...
25...	VI	30	4.30.00	...	...
26...	VIII	19	21.00.00	...	...
27...	IX	17	17.05.00	...	...
28..	X	26	9.28.00	...	...

1875.

29...	I	14	12.30.00	...	...
30...	II	16	11.05.00	...	...
31...	IV	1	18.24.00	...	...
32...	IV	30	4.28.00	...	...
33...	IV	30	23.31.00	...	...

1 8 7 5.—*Continued.*

No.	Month	Day	Time	Force of Shock	Direction
			h. m. s.		
34...	V	8	18.22.00	...	...
35...	,,	15	10.23.00	...	...
36...	VII	8	9.52.30	...	...
37...	,,	8	17.30.00	...	...
38...	,,	9	2.05.30	...	...
39...	IX	19	10.30.00	...	...
40...	,,	21	0.45.00	...	...
41...	X	5	10.40.00	...	...
42...	,,	6	6.30.00	32.° 30′	WSW & ENE
43...	,,	7	6.26.00	...	...
44...	,,	15	19.37.00	...	...
45..	,,	22	2.37.30	...	...
46...	,,	24	15.32.00	...	...
47...	XI	3	8.23.00	2.° 00′	WNW & ESE
48...	,,	3	13.47.50	3.° 00′	WSW & ENE
49...	,,	3	19.14.00	...	...
50...	,,	12	20.02.00	...	... ?
51...	XII	8	9.49.00	10.° 30′	WNW & ESE
52...	,,	21	5.56.00	...	...

1 8 7 6.

No.	Month	Day	Time	Force of Shock	Direction
53...	I	20	8.44.30	21° 00′	WSW & ENE
54...	,,	27	7.30.00	...	...
55...	,,	28	15.55.00	...	...
56...	II	11	5.36.00	2° 15′	WNW & ESE
57...	,,	12	17.29.00	...	...
58...	,,	16	7.38.00?	...	...
59...	,,	26	8.40.00	5° 00′	{ WNW & ESE WSW & ENE
60...	III	9	12.07.30	3° 30′	WNW & ESE
61...	,,	12	4.32.00	...	...
62...	,,	13	12.39.00	2° 00′	{ WNW & ESE WSW & ENE
63...	,,	18	14.52.40?	...	...
64...	,,	22	6.18.00	...	...
65...	,,	31	7.24.00	6° 00′	WNW & ESE
66...	IV	10	14.05.30	6° 00′	WNW & ESE
67...	,,	10	14.38.30	...	...
68...	,,	11	4.01.30	...	...
69...	,,	11	19.09.00	2° 30′	WNW & ESE
70...	,,	17	1.44.00	...	...
71...	,,	17	6.17.00	2° 30′	WSW & ENE
72...	,,	20	17.30.00	2° 00′	WNW & ESE
73...	,,	23	16.55.30	...	...
74...	,,	25	1.52.00	2° 00	WNW & ESE
75...	,,	25	7.45.00	...	...
76...	,,	26	16.50.00	...	...

1 8 7 6.—*Continued.*

No.	Month	Day.	Time.	Force of Shock.	Direction.
			h. m. s.		
77...	V	2	21.45.00	...	...
78...	,,	6	21.25.00	7° 30′	WNW & ESE
79...	,,	18	20.37.00	...	...
80...	,,	18	20.38.40	...	...
81...	,,	24	9.30.00	...	...
82...	VI	16	15.15.00	...	...
83...	,,	16	20.22.00	5° 00′	WNW & ESE
84...	,,	25	6.14.00	3° 30′	WNW & ESE WSW & ENE
85...	VII	14	4.25.00	...	...
86...	,,	17	5.55.00?	...	...
87...	,,	29	22.05.00	12° 00′	WSW & ENE
88...	VIII	2	15.05.00	...	...
89...	,,	2	17.46.00	...	...
90...	,,	9	14.00.00	...	...
91...	,,	25	2.00.00	...	...
92...	,,	27	9.06.30	3° 00′	W SW & ENE
93...	IX	13	4.58.00	...	...
94...	,,	26	12.10.00	...	...
95...	,,	27	11.51.00	...	...
96...	X	6	21.06.30	...	...
97...	,,	18	15.51.00	...	...
98...	,,	21	9.08.00	...	...
99...	XI	17	9.20.00	...	...
100...	,,	18	9.00.00	...	...
101...	,,	19	10.25.00	...	...
102...	,,	24	3.44.00	...	...
103...	XII	3	18.00.00	...	...
104...	,,	5	12.00.00	...	...
105...	,,	5	12.05.00	2° 00′	WSW & ENE
106...	,,	23	12.00.00	...	...
107...	,,	29	6.12.00	...	...
108...	,,	30	8.47.00	...	...

1 8 7 7.

109...	I	10	19.38.00	...	...
110...	,,	10	22.37.00	..	...
111...	,,	20	8.16.21	4° 30′	WSW & ENE
112...	,,	20	8.21.00	...	...
113...	,,	22	18.20.00	...	...
114...	II	2	3.07.30	1° 30′	WSW & ENE
115...	,,	7	16.52.00	2° 00′	WSW & ENE
116...	,,	15	1.18.00	2° 30′	WSW & ENE
117...	,,	16	12.43.00	1° 30′	WSW & ENE
118...	,,	21	8.56.00	2° 00′	SSE & NNW
119...	III	5	12.09.00	2° 00′	WSW & ENE
120...	,,	10	10,17.00	...	...

1 8 7 7 .—*Continued.*

No.	Month	Day	Time	Force of Shock	Direction
			h. m s.		
121...	III	11	23.58.00	...	...
122...	,,	13	4.41.00	...	...
123...	,,	23	3.30.00	...	
124...	,,	29	21.37.30	3° 00′	WSW & ENE
125...	IV	5	11.14.00	2° 30′	SSE & NNW
126...	,,	5	12.35.00	2° 00′	WSW & ENE
127...	,,	10	14.16.00	...	...
128...	,,	11	8.19.00	...	...
129...	,,	12	20.25.00	...	...
130...	V	2	16.32.00	...	...
131...	,,	9	3.26.00	...	...
132...	,,	23	19.20.00	1° 15′	WNW & ESE
133...	,,	25	13.10.20	...	...
134...	,,	25	21.10.00	...	...
135...	,,	25	22.56.00	...	...
136...	,,	29	21.47.00	...	...
137...	,,	30	18.47.00	1° 30′	WNW & ESE WSW & ENE
138...	VI	4	23.31.00	...	...
139...	,,	6	5.14.00	1° 45′	WNW & ESE
140...	,,	10	20.49.00	...	...
141...	,,	10	21.00.00	...	...
142...	,,	19	12.21.00	...	...
143...	,,	23	23.15.00	...	...
144...	,,	24	22.20.00	...	...
145...	VII	18	10.17.00	...	...
146...	,,	19	0.35.00	4° 00′	WSW & ENE
147...	,,	19	9.35.00	...	...
148...	,,	22	4.49.17	11° 00′	WSW & ENE
149...	,,	23	0.29.30	3° 00′	WSW & ENE
150...	,,	31	1.37.00	...	...
151...	VIII	1	7.35.00	...	...
152...	,,	2	21.27.00	...	...
153...	,,	10	10.55.00	...	...
154...	,,	26	15.50.00	6° 30′	WNW & ESE NNW & SSE
155...	IX	16	9.21.00	...	...
156...	X	5	6.55.00	5° 00′	WSW & ENE SSE & NNW
157...	,,	5	8.22.00	...	...
158...	,,	13	11.20.30	3° 00′	WNW & ESE
159...	,,	17	20.19.00	2° 00′	WNW & ESE
160...	,,	23	5.42.00	...	...
161...	,,	24	7.52.00	2° 00′	WNW & ESE
162...	,,	27	8.32.00	...	...
163...	,,	30	14.16.00	1° 00′	SSW & NNE
164...	XI	7	8.43.00	...	...
165...	,,	8	11.01.36	...	...
166...	,,	13	3.43.00	3° 30′	WSW & ENE

1 8 7 7.—*Continued.*

No.	Month	Day.	Time.	Force of Shock.	Direction.
			h. m. s.		
167...	XI	22	3.46.30	{ 8° 0′ 7° 30′	WNW & ESE SSW & NNE
168...	,,	24	0.53.26	3° 30′	WNW & ESE
169...	,,	30	3.21.00	4° 30′	WNW & ESE
170...	XII	7	0.16.45	1° 20′	WSW & ENE
171...	,,	9	18.07.00	...	...
172...	,,	22	21.01.40	1° 20′	WNW & ESE
173...	,,	23	5.07.32	3° 00′	WNW & ESE
174...	,,	23	7.39.51	1° 00′	SSW & NNE
175...	,,	24	21.26.31	0° 30′	SSW & NNE
176...	,,	26	8.00.00	...	...
177...	,,	27	7.18.00	...	...
178...	,,	27	17.20.00	...	...

1 8 7 8.

No.	Month	Day.	Time.	Force of Shock.	Direction.
179...	I	22	3.20.00	...	...
180...	,,	23	4.24.30	2° 30′	WNW & ESE
181...	,,	23	19.17.33	3° 00′	WNW & ESE
182...	II	11	7.23.00	...	...
183...	,,	14	3.51.48	...	...
184...	,,	16	22.40.00	{ 1° 00′ 0° 50′	WSW & ENE SSW & NNE
185...	,,	22	18.03.45	{ 19° 20′ 18° 40′	SSW & NNE WNW & ESE
186...	,,	22	21.09.30	4° 40′	WNW & ESE
187...	,,	23	21.43.00	0° 40′	SSW & NNE
188...	,,	24	2.30.00	...	...
189...	,,	25	10.22.30	{ 3° 40′ 2° 20′	WNW & ESE SSW & NNE
190...	III	6	2.01.20	9° 30′	WNW & ESE
191...	,,	7	10.28.00	...	...
192...	,,	9	6.00.00	...	...
193...	,,	12	11.00.00	...	...
194...	,,	12	18.15.00	...	...
195...	,,	22	17.58.00	...	...
196...	IV	9	2.42.30	...	...
197...	,,	28	4.04.00	...	...
198...	V	4	10.20.00	0° 30′	WNW & ESE
199...	,,	10	9.09.00	0° 30′	WNW & ESE
200 ..	,,	10	19.37.00	...	...
201...	,,	11	3.05.00	...	...
202...	,,	29	5.20.00	...	...
203...	VI	11	0.12.00	6°	WNW & ESE
204...	,,	16	17.25.30	1° 10′	SSW & NNE
205...	,,	22	0.00.29	1°	WNW & ESE
206...	,,	28	6.34.00	4°	WNW & ESE
207...	VII	4	16.39.00	...	...
208...	,,	9	12.45.00	{ 8° 6°	WNW & ESE WSW & ENE

1878.—*Continued.*

No.	Month	Day.	Time.	Force of Shock.	Direction.
			h. m. s.		
209...	VII	15	3.45.00	11° 40′	WNW & ESE
210...	,,	29	9.14.00	...	...
211...	VIII	26	4.20.00	...	...
212...	IX	5	4.57.39	...	...
213...	,,	29	17.32.30	1° 30′	WNW & ESE
214...	X	9	1.18.00	3° 40′	WNW & ESE
215...	,,	9	1.45.00	...	...
216...	,,	16	22.22.00	1° 00′	WNW & ESE
217...	,,	28	1.01.00	2° 00′	WNW & ESE
218...	XI	5	0.48.20	3° 40′	WNW & ESE
219...	,,	5	0.51.30	3° 00′	NNW & SSE
220...	,,	22	11.08.05	8° 00′ 6° 50′	WSW & ENE WNW & ESE
221...	,,	22	11.18.15	...	...
222...	,,	26	8.26.05	6° 00′ 5° 30′	WNW & ESE SSE & NNW
223...	,,	26	14.13 00	3° 50′ 3° 00′	SSE & NNW WNW & ESE
224...	XII	13	17.32.00	1° 00′	WNW & ESE
225...	,,	13	22.35.00	6° 30′	WSW & ENE
226...	,,	14	11.39.00	1° 30′	WNW & ESE
227...	,,	23	19.57.35	1° 20′	SSE & NNW

1879.

No.	Month	Day.	Time.	Force of Shock.	Direction.
228...	I	2	21.56.30	4° 20′	SSW & NNE
229...	,,	12	8.50.00	...	...
230...	,,	20	10.00.00	...	...
231...	,,	22	13.45.00	1° 20′	WNW & ESE
232...	,,	26	22.45.00	3° 40′ 3° 10′	SSE & NNW SSW & NNE
233...	,,	30	5.18.22	1° 50′ 1° 30′	SSE & NNW WSW & ENE
234...	II	2	10.08.51	3° 20′	SSW & NNE
235...	,,	4	11.07.20	2° 00′	WNW & ESE SSW & NNE
236...	,,	14	19.33.00	...	...
237...	,,	19	10.01.00	...	...
238...	,,	19	23.38 00	...	...
239...	,,	26	11.20.00	...	...
240...	,,	26	14.45.00	7° 30′	WNW & ESE
241...	III	1	10.59.00	0° 30′	SSE & NNW
242..	,,	4	4.43.30	11° 10′	SSW & NNE
243...	,,	,,	4.49.20	...	...
244...	,,	,,	5.02.30	3° 40′	SSW & NNE
245...	,,	,,	6.50.00	3° 00′ 2° 40′	WSW & ENE SSW & NNE
246...	,,	9	16.34.30	2° 30′	WSW & ENE SSW & NNE
247...	,,	12	15.49.30	...	...
248...	,,	13	11.09.00	0° 40′	WNW & ESE SSE & NNW

1 8 7 9 .—*Continued.*

No.	Month	Day	Time.	Force of Shock.	Direction.	Duration.
			h. m. s			
249...	III	15	21.30.00	...	...	...
250...	,,	16	9.52.00	0° 40′	WSW & ENE	...
251...	,,	19	4.56.30	...	...	...
252...	,,	19	8.32.30	...	...	...
253...	,,	30	10.00.00	...	...	...
254...	V	1	13.45.34	3° 50′	SSW & NNE	...
255...	,,	7	17.13.00*	...	...	...
256...	,,	8	5.00.00*	...	...	...
257...	,,	12	14.59.00*	...	...	...
258...	,,	13	12.24.00	...	...	...
259...	,,	19	1.23.21	0° 30′	SSW & NNE	...
260..	,,	19	11.20.13	1° 00′	SSW & NNE	...
261...	,,	23	5.14.39	1° 00′	SSE & NNW	...
262..	,,	24	15.58.00	...	...	...
263...	VI	11	21.24.30	2° 30′	SSW & NNE	...
264...	,,	12	4.22.00	1° 10′	WSW & ENE	...
265...	,,	12	4.36.00	...	...	...
266...	,,	19	12.50.36	1° 00′ 0° 50′	SSE & NNW WNW & ESE	... *m. s.*
267...	VII	18	3.09.10	3° 20′	WSW & ENE	1. 23
268...	,,	21	21.01.34	2° 20′	SSW & NNE	...
269...	,,	24	8.18.00	1° 40′	SSW & NNE	...
270...	VIII	6	8.28.53	3° 10′ 3° 00′	WNW & ESE SSE & NNW	0. 20
271...	,,	19	1.30.00	...	...	...
272...	,,	22	22.10.55	4° 10′	SSW & NNE	...
273...	,,	28	7.32.07	2° 10′	WNW & ESE	...
274...	IX	21	3.01.10	3° 40′	SSW & NNE	...
275...	X	2	6.15.00	...	...	...
276...	,,	16	12.36.30	...	...	...
277...	,,	17	1.32.40	1° 10′	WNW & ESE	...
278...	,,	17	14. 0.11	10° 50′ 9° 50′	SSW & NNE SSE & NNW	...
279	,,	19	10.18.00	...	...	...
280	,,	24	12.39.00	2° 50′ 2° 40′	WNW & ESE SSE & NNW	...
281	,,	29	20.44.22	5° 50′	SSW & NNE	0. 40
282	XI	5	Between 15.00.00 and 16.00.00	0° 40′	SSE & NNW	...
283	,,	10	22.46.00	...	...	1. 40
284	,,	14	21.38.50	3° 30′	SSE & NNW	0. 40
285	,,	15	15.01.40?	...	...	...
286	,,	17	5.52.35	...	...	...
287	,,	20	13.55.12	1° 40′	SSW & NNE	...
288	XII	1	19.41.14	1° 00′	WNW & ESE WSW & ENE SSE & NNW	...

* These times are approximate.

1 8 7 9 .—*Continued.*

No.	Month	Day	Time	Force of Shock	Direction	Duration
			h. m. s.			*m. s.*
289...	XII	2	19.08.00	18° 30′ 15° 20′ 12° 40′ 9° 50′	WSW & ENE SSW & NNE WNW & ESE SSE & NNW	1. 50
290...	,,	2	21.58.00	...	...	...
291...	,,	6	17.10.00	1° 20′	WSW & ENE	...
292...	,,	7	15.22.40	4° 40′	WSW & ENE	0. 30
293...	,,	16	13.59.17	4° 30′	SSW & NNE	...
294...	,,	21	23.40.01	...	...	0. 30
295...	,,	26	Between 8 00.00 and 9 00.00?	...	...	...
296...	,,	28	8.05.00	1° 40′	WNW & ESE	...

1 8 8 0 .

No.	Month	Day	Time	Force of Shock	Direction	Duration
297...	I	3	11.58.00	...	...	...
298...	,,	5	23.15.00	0° 50′	SSE & NNW	...
299...	,,	6	4.37.00	2° 40′	SSE & NNW	...
300...	,,	12	23.30.00	...	...	...
301...	,,	17	7.10.00	...	...	...
302...	,,	18	10.00.00?	...	...	...
303...	,,	20	9.07.00?	...	...	...
304...	,,	23	10.01.00?	...	...	...
305...	,,	25	00.20.15	...	...	...
306...	II	1	11 00.00	0° 10′ 2° 30′	SSW & NNE SSE & NNW	0. 20
307...	,,	4	1.32.00	1° 00′ 1° 00′ 0° 50′	SSW & NNE WNW & ESE SSE & NNW	...
308...	,,	12	8.57.11	1° 00′	WNW & ESE	...
309...	,,	12	10.39.00	0° 30′ 0° 30′	WNW & ESE SSE & NNW	... ...
310...	,,	21	12.49.22	...	...	0. 14
311...	,,	21	12.50.19	28° 20′ 28° 00′ 52° 00′ 78° 00′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	1. 26
312...	,,	21	12.52.15	...	...	0. 6
313...	,,	25	6.46.14	0° 10′ 0° 20′ 0° 25′	WNW & ESE WSW & ENE SSE & NNW	...
314...	,,	27	12.28.00	...	...	...
315...	III	2	1.18.00	...	...	...
316...	,,	2	10.14.55	...	...	...
317...	,,	3	6.32.00	0° 10′ 0° 30′	WNW & ESE SSE & NNW	...
318...	,,	4	16.35.00	...	...	...

1 8 8 0 .—*Continued.*

No	Month	Day	Time	Force of Shock	Direction	Duration
			h. m. s.			*m. s.*
319...	,,	29	5.23.15	2° 20′ 0° 50′ 2° 50′ 1° 40′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	0. 10
320...	,,	30	23.13.00	1° 40′	SSE & NNW	0. 35
321...	IV	13	16.05.27	5° 10′ 9° 30′ 2° 30′	WNW & ESE SSW & NNE SSE & NNW	3. 00
323...	,,	15	17.27.30	...	...	...
322...	,,	21	0.30.14	0° 10′ 1° 40′ 1° 10′	WNW & ESE WSW & ENE SSE & NNW	...
324...	,,	26	21.48.15	2° 40′ 2° 10′ 6° 00′ 3° 10′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	...
325...	,,	30	5.13.00	0° 20′	WNW & ESE SSE & NNW	...
326...	V	10	9.50.48	1° 20′	SSE & NNW	...
327...	,,	12	19.25.00	...	...	...
328...	VI	1	22.20.35	1° 00′	SSE & NNW	...
329...	,,	5	5.07.15	2° 30′	SSE & NNW	1. 30
330...	,,	7	9.43.40	1° 50′	SSE & NNW	0. 30
331...	,,	7	12.28.55	1° 50′	SSE & NNW	0. 25
332...	,,	9	3.37.49	1° 20′	SSW & NNE	...
333...	,,	10	1.23.00	1° 20′	SSW & NNE SSE & NNW	1. 00
334...	,,	13	0.13.00	...	...	...
335...	,,	13	0.18.00	...	...	...
336...	,,	13	14.56.00	0° 40′	SSE & NNW	...
337...	VII	6	14.13.50	...	...	...
338...	,,	14	16.02.39	1° 00′	SSE & NNW	0. 20
339...	,,	18	23.49.00	1° 40′	SSE & NNW	...
340...	,,	19	8.21.11	2° 00′	SSW & NNE	0. 29
341...	,,	23	22.00.00	0° 10′	SSE & NNW	...
342...	,,	24	13.03.00	0° 30′	SSE & NNW	...
343...	,,	24	15.21.00 ?	...	...	...
344...	,,	25	2.02.32	1° 40′	SSW & NNE SSE & NNW	... 1. 00
345...	VIII	12	16.47.38	1° 10′	SSE & NNW	...
346...	,,	20	4.00.00	...	...	...
347...	,,	22	16.19.00	...	...	...
348...	,,	24	4.55.00	...	...	0. 30
349...	IX	5	4 15.00	1° 00′	SSE & NNW	...
350...	X	4	7.54 00 ?	...	...	...
351...	,,	5	11.48.00	...	...	...
352...	,,	11	19.23.00	0° 50′	SSE & NNW	...
353...	XI	2	17.46.00	2° 10′ 0° 20′	SSW & NNE SSE & NNW	...

1 8 8 0 :—*Continued.*

No.	Month	Day	Time	Force of Shock	Direction	Duration
			h. m. s.			
354...	XI	4	4.31.00	0° 10′	SSW & NNE	...
355...	”	5	18.15.00?	...	...	...
356...	”	7	4.25.30	5° 10′ 4° 20′ 3° 20′ 0° 50′	SSW & NNE WNW & ESE WSW & ENE SSE & NNW	...
357...	”	9	13.08.55	12° 10′ 8° 20′ 2° 50′ 2° 50′	SSW & NNE WSW & ENE WNW & ESE SSE & NNW	*m. s.* 0. 35
358...	”	12	6.36.00	1° 00′ 0° 40′ 2° 40′ 1° 00′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	*m.* about 1.
359...	”	24	7.27.06	0° 20′	SSW & NNE	*s.* about 30
360...	”	27	3.02.00	2° 30′ 0° 50′ 0° 30′ 0° 10′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	...
361...	”	29	00.40.10	1° 00′ 0° 55′ 0° 30′	WNW & ESE WSW & ENE SSW & NNE	...
362...	”	29	13.32.34	1° 10′ 0° 40′ 1° 10′ 0° 40′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	...
363...	XII	5	8.44.15	..	...	*m. s.* 1. 00
364...	”	18	21.43.03	...	...	...
365...	”	19	12.05.24 12.06.20	2° 00′ ...	SSW & NNE ...	0. 13 0. 27
366...	”	20	0.11.51	7° 00′ 5° 30′ 8° 10′ 0° 50′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	1. 20
367...	”	23	10,53.00	22° 50′ 19° 00′ 34° 10′ 19° 10′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	3. 18
368...	”	27	2.48.00	0° 10′	SSW & NNE	about 40
369...	”	29	18.30.30	...	...	?
370...	”	30	9.40.00	...	...	?

1 8 8 1 .

No.	Month	Day	Time	Force of Shock	Direction	Duration
371...	I	6	6.35.20	...	...	...
372...	”	6	18.25.20	1° 30′ 0° 30′ 0° 50′ 1° 20′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	0. 57

1 8 8 1.—*Continued.*

No.	Month	Day	Time	Force of shock	Direction	Duration
			h. m. s.			
373...	I	10	6.35.00	...	...	...
374...	,,	14	6.25.00 ?	...	...	...
375...	,,	16	17.38.00	0° 20′	SSE & NNW	*m.* ... *s.*
376...	,,	19	12.08.50	1° 00′ 1° 20′	WNW & ESE SSE & NNW	0. 37
377...	,,	21	23.49.45	0° 50′	SSE & NNW	0. 10
378...	,,	23	17.53.26	4° 20′ 1° 20′ 1° 10′	WNW & ESE SSW & NNE SSE & NNW	0. 28
379...	,,	23	18.22.06	...	...	...
380...	,,	23	21.35.00	2° 20′ 1° 00′ 1° 30′ 1° 20′	WNW & ESE WSW & ENE SSW & NNE SSE & NNW	...
381...	,,	27	21.11.42	...	...	0. 15
382...	,,	30	23.38.00	...	...	...
383...	,,	31	1.34.00	...	...	?
384...	II	6	11.55.50	...	..	...
385...	,,	7	3.55.40	1° 40′	WNW & ESE	...
386...	,,	11	14.39.00 ?	1° 00′	WNW & ESE	...
387...	,,	12	2.11.12	1° 10′	WNW & ESE	...
388...	,,	13	21.56.42	...	...	0. 10
389...	,,	16	8.36.00	...	...	...
390...	,,	16	9.18.22	...	...	...
391...	,,	28	3.14.28	0° 20′	SSE & NNW	...
392...	III	8	12.17.24	5° 10′	WNW & ESE WSW & ENE	1. 53
393...	,,	12	4.54.56	0° 10′ 0° 40′ 0° 40′	SSE & NNW WNW & ESE WSW & ENE SSE & NNW	0. 20
394...	,,	16	3.02.42	1° 30′	WNW & ESE	0. 29
395...	,,	29	11.24.00	1° 20′ 0° 20′	WNW & ESE SSE & NNW	... ...
396...	IV	3	19.23.55	...	...	...
397...	,,	7	5.05.30	1° on WNW and 10′ on WSW' but not known to which shock these records refer.		
398...	,,		9.09.10			
399...	,,		9.11.10			
400...	,,	17	20.03.38	2° 30′ 0° 30′ 1° 00′	WNW & ESE WSW & ENE SSE & NNW	...
401...	,,	18	3 57.00	(about)		
402...	,,	26	8.25.49 (about)	2° 10′ 0° 30′	WNW & ESE SSE & NNW	...
403...	V	2	14.08.36 (about)	0° 50′	WNW & ESE	...
404...	,,	12	47.33.12	(about)		

1881.—*Continued.*

No.	Month	Day	Time	Force of Shock	Direction	Duration
			h. m. s.			*m. s.*
405...	V	24	11.19.40	2° 30′ 0° 20′ 0° 40′	WNW & ESE WSW & ENE SSE & NNW	0. 50

In the following table these observations have been grouped together to shew their relation to the years, months and seasons, the arrangement being similar to one which has been so extensively used by Mr. Mallet:—

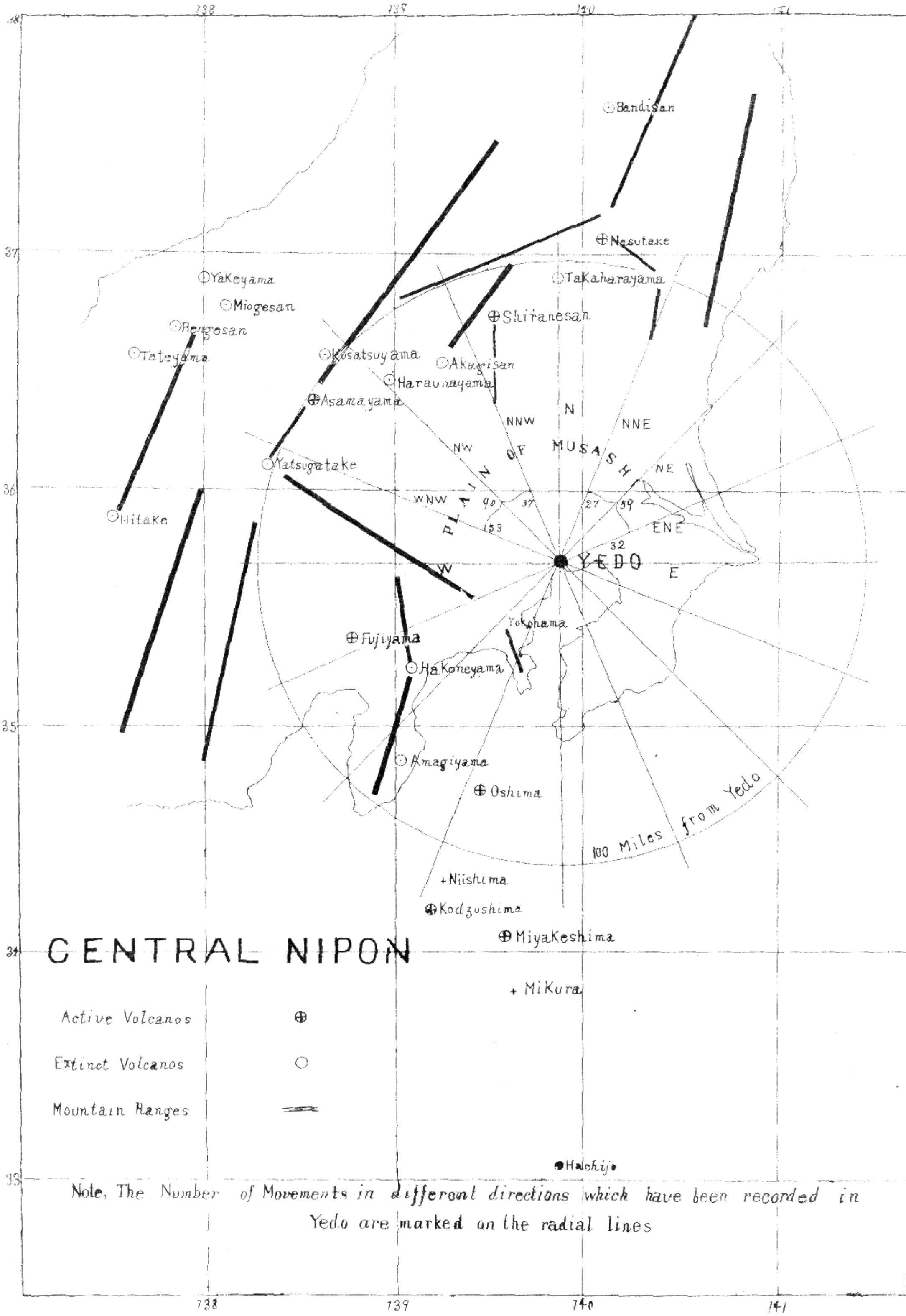
Years.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1872......	...	...	...	...	...	...	...	...	1	...	...	2	3
1873......	2	...	1	3	1	2	2	2	1	...	2	1	17
1874......	...	2	...	...	...	3	...	1	1	1	....	...	8
1875......	1	1	...	3	2	...	3	...	2	6	4	2	24
1876......	3	4	6	11	5	3	3	5	3	3	4	6	56
1877......	5	5	6	5	8	8	6	4	1	8	6	9	71
1878......	3	8	6	2	5	4	4	1	2	4	5	4	48
1879......	6	7	13	0	9	4	3	4	1	7	6	9	69
1880......	9	9	6	5	2	9	8	4	1	3	10	8	74
	29	36	38	26	32	33	29	21	13	32	37	41	370
		103			94			63			110		

Summer................................ 157
Winter.................................. 213

Total.............. 370

Note.—It will be observed that the records for the year 1872 is not complete. This however does not alter the general character of the results which the table exhibits, which results can be seen by inspection.

Other analyses of the catalogue, unless it is specially stated to the contrary, will not include earthquakes subsequent to March, 1879. My reason for this is, that it was in that month that the buildings about which I write were examined.



Note. The Number of Movements in different directions which have been recorded in Yedo are marked on the radial lines

Direction, and Origin, of the Recent Earthquakes.

As the observations on Earthquakes have up to the present time only been made in Yedo, it it somewhat difficult to determine with certainty the direction in which any given shock has travelled across the country. Thus for instance records of Palmieri's instrument tell us that a shock travelled in a North-East, South-West direction, but whether it originated in the North-East or in the South-West we are unable to determine. At first sight it might be thought that this difficulty would receive an easy solution by the use of a few small Columns. Theoretically this is true, but the difficulties to be overcome, especially when studying small earthquakes, are practically very great. After one or two seismic stations have been established on Yedo plain, a suggestion which is now being carried out, no doubt the direction and the velocity at which earthquake waves are propogated will be accurately determined.

In searching for the origin or *origins* of the shocks which so often visit us, we should at first naturally turn towards the various volcanic districts by which we are surrounded. These districts are indicated on the accompanying map. The volcanos which are there laid down are taken from a map prepared by Dr. Edmund Naumann (see Mittheilungen der Deutschen Gesellschaft &c. Vol. 15).

By looking at this map it will be seen that in a North Westerly direction from Yedo there is a large group of volcanos. With the exception of Shiraneyama and Asamayama, the latter of which is still giving off large volumes of steam and was in actual eruption in the year 1867, all appear to be extinct. This might be called the Asamayama district. In a South Westerly direction we see another group of volcanos. The most northerly of these is the far famed Fusiyama. This was last in eruption in the year 1707. To the south of this there are the solfataras of Hakone and the hot springs of Idzu, all evidences of volcanic actions. Still further south in a S. S. W. direction there are the islands of Ooshima, Koshima &c., several of which have quite recently been in violent eruption. This district might be called the Fujiyama and Ooshima district.

By looking at the Catalogue of shocks which has just been given, it will be seen that they have been recorded as causing the ground to oscillate back and forth in one of the four following directions.

W. N. W. to E. S. E., N. N. W. to S. S. E., N. N. E. to S. S. W. and E. N. E. to W. S. W.

For convenience we might name shocks causing a movement in the two former of these directions N. W. or S. E. shocks, and the shocks causing a movement in the two lattec directions N. E. or S. W. shocks.

Now *if* the N. W., S. E. shocks emanated from a volcanir region, it appears at first sight probable that they had their origin in the districts near the mountains of Akagi or Asama, whilst the N. E., S. W. shocks originated from the districts near Fujiyama or Ooshima.

Although a conclusion of this description, namely that the shocks have come from districts where there were active volcanos might be born out by the results of observation in many quarters of the globe, I am hardly inclined to regard it as holding in the case of all the earthquakes of the Yedo plain. The reasons which incline me to differ from such a view are briefly as follows:—

1st.—If the N. W., S. E. shocks emanated from the volcanic region of the N. W., then before reaching Yedo they would have to travel across a plain at least 70 miles in extent, and as much of their energy would be expended in so doing, those dwelling near to the origin of these shocks ought to feel them very much more strongly than they are felt in Tokio.

Of this however we have as yet no evidence. From a few observations recently made in Yokohama it would seem that sometimes small earthquakes are felt there which fail to reach Tokio, apparently indicating that Yokohama is nearer to the origin of such shocks than Tokio is. This would seem to indicate that such shocks came from the S.W.

2nd.—On the south east and south west portions of Yedo bay we have a group of recent rocks which are very much faulted, whilst the same rocks as exhibited near Tokio and Yokohama are comparatively undisturbed. The fact that faults exist, shews us that there have been recen movements in the strata,—that such strata have been strained and that they have been sinking into a position of equilibrium.—If these movements are yet continuing, we have here a district towards which to look where we might expect to find the origin of many of the earthquakes which visit us. The last great earthquake of February 22nd appears to have come from this district. In a description of this earthquake (Transactions of the Seismological Society Vol. I) I have expressed my views why many of our earthquakes might emanate from or near to the shores of the lower portion of Yedo Bay, somewhat more fully.

Taking all things into consideration—although some of the earthquakes which from time to time alarm us may have their origin near the volcanos of the interior,—until by instrumental observation something definite has been determined, I should be inclined to think that a large proportion of the shocks we feel have their origin in the faulted districts of the south.

I will therefore *provisionally* call the N. W. S. E. shakings, *S. E.* shocks, and the N. E., S. W. shakings, *S. W.* shocks.

Grouping of Shocks.

Another point to which I would direct attention, is a relation which appears to exist between the shocks themselves. If we refer to the general catalogue of earthquakes which is given in the first part of this paper, we shall see, that whenever we had a large earthquake from any particular direction it was generally preceded, and in nearly all cases succeeded, by a number of small earthquakes from the same direction. Thus in 1876, between 11th of February and the 12th of June, we had a number of earthquakes all marked W. N. W. These culminated with the greatest shocks about the 31st March.

Again, at the beginning of 1877, a series of shocks marked W. S. W. may be seen. These series however are so clearly shewn by reference to the tables themselves, that to mention them specially will be useless repetition.

When writing about the last great shock (February 22nd, 1880) which we experienced, I pointed out the marked manner in which this phenomena was exhibited.

From these results, which I am inclined to think would be more clearly shewn if our instruments were more delicate and even perhaps if we manipulated the instruments we have with more refinement,—something appears to be indicated to us about the working of volcanic agencies. It would seem that first in one district to the S. E., and then in another district to the S. W., and now and then simultaneously at both, volcanic efforts are brought to bear upon the rocky crust, until unable to resist the strain it gradually gives away, and by the "jars" which follow, tremors are transmitted to the various districts which lie around. When more delicate instruments have been devised as I have before pointed out, we may perhaps learn something about the periodicity of TREMORS, and by them be enabled with more or less certainty to fortell the coming of our earthquakes.

On several previous occasions I have expressed views similar to these, and during the past year, with microphones and other instruments susceptible to small tremors, have experimented on the determination of these small motions. Recently I have observed with much gratification that similar ideas based upon a very much wider experience than my own have been expressed by the well known and distinguished seismologist Prof. Palmieri.

In order to form a rough estimate of the relative amount of disturbance which has taken place in the four centers which are indicated by the four directions given in our catalogue, we might be guided either by the *number* of earthquakes which have emanated from each, or by the total *intensity* which has been exhibited by the shocks of each group taken as a whole.

It must be remarked that the only measure of intensity which we have at our disposal is that given by Palmieri's instrument. Those who are familiar with this instrument will see that the relative intensities of two shocks are only obtained approximately, whilst for the actual intensity we have no measure whatsoever. Thus what was the velocity with which an earth particle moved to give an earthquake of 3° we cannot tell. All that we know about an earthquake of 3° is, that it was a movement which we might describe as being slight and caused the mercury in a certain tube to oscillate a certain height. Nor can we take an earthquake say of 3° and use it as a unit wherewith to measure others. Thus we cannot say that an earthquake of 6° had double the intensity of one of 3°, because an earthquake indicated as being of 6° might be produced by a somewhat long but gentle shock, whilst a 3° earthquake might be the result of a sharp blow and thus it is possible that the shock with the lowest index might have been the one which was the more intense. However, as a general rule, it is probable that this would not be the case, and we might in making rough approximations consider the relative intensities as proportional to the number of degrees which are indicated. Knowing the difficulties which have to be encountered by any one endeavoring to construct a seismometer which shall tell us something about the absolute intensity of a shock, I do not point this out as a criticism on Palmieri's instrument, but rather to shew the errors which enter into my own comparisons where I have taken into account the intensity of the shock. Further it must be borne in mind that to compare the disturbances taking place in two areas, we ought to measure the intensities of the shocks which emanate from such areas at a point equally distant from them. As we do not know the distance from Tokio to the several areas around from which the shocks may emanate, we are here introducing another serious error into our calculations. However, as we have no reason to believe that there is any great difference between the distances from Tokio and the various seismic areas around it, this latter consideration shall be overlooked.

The following table contains a list of all the earthquakes since 1875, which have been sufficiently strong to affect that portion of one of Palmieri's instruments which records directions and intensity,—this instrument being placed in Tokio.

If à shock is recorded as having had different intensities in different directions, only the greatest of these is taken, that being the one probably corresponding to the direction in which the shock travelled.

If a certain intensity has been registered for two directions nearly at right angles to each other, and these intensities are equal, both of them have been omitted, as it does not seem possible to determine the direction in which such a shock may have travelled. If two equal intensities are recorded for directions closely together, this intensity is only once noted, being placed under the former of the two directions.

1875 (July to December).

W. N. W. 2°, 10° 30'.
N. N. W.
N. N. E.
E. N. E. 32° 30', 3°.

1876 (January to December).

W. N. W. 2° 15, 3° 30', 6°, 6°, 2° 30', 2°, 2°, 7° 30', 5.
N. N. W.
N. N. E.
E. N. E. 21° 0, 2° 30', 12°, 3°, 2°.

1877 (January to December).

W. N. W. 1°, 15', 1°, 45', 30', 3°, 2°, 2°, 8°, 3° 30', 4° 30', 3°.

N. N. W. 2°, 2°, 30′, 1° 20′.
N. N. E. 1°, 1°, 30′.
E. N. E. 4° 30′, 1° 30′, 2°, 2° 30′, 1° 30′, 2°, 3°, 2°, 4°, 11°, 3°, 3° 30′, 1° 20′.

1878 (January to December).

W. N. W. 2° 30′, 3°, 18° 40″, 3° 40′, 9° 30′, 0° 30′, 0° 30′, 6°, 1°, 4°, 8°, 11° 40′, 1° 30′, 3° 40′, 1°, 2°, 3° 40′, 6°, 1°, 1° 30′.
N. N. W. 18° 40′, 3° 50′, 1° 20′.
N. N. E. 19° 20′, 0° 40′, 1° 10′.
E. N. E. 10°, 8°, 6° 30′.

1879.

W. N. W. 1° 20′, 3° 40′, 7° 30′, 0° 40′, 3° 10′, 2° 10′, 1° 10 2° 50′, 1° 40′.
N. N. W. 1° 50′, 0° 30′, 0° 30′, 1°, 1°, 1°, 0° 40′, 3° 30′.
N. N. E. 4° 20′, 3° 20′, 11° 10′, 3° 40′, 3° 50′, 2° 30′, 2° 20′, 1° 40′, 4° 10′, 3° 40′, 10° 50′, 5° 50′, 1° 30′, 4° 20′.
E. N. E. 3°, 2° 30′, 0° 40′, 1° 10′, 3° 20′, 18° 30′, 1° 20′, 4° 40′.

1880 (January to October).

W. N. W. 1°, 0° 30′, 0° 20′.
N. N. W. 0° 50′, 2° 40′, 2° 30′, 0° 30′, 78° 0′, 0° 25′, 0° 30′, 1° 40′, 1° 20′, 1°, 2° 30′, 1° 50′, 1° 50′, 1° 20′, 0° 40′, 1°, 1° 40′, 0° 10′, 0° 30′, 1° 40′, 1° 10′, 1°, 0° 50°.
N. N. E. 2° 50′, 9° 30′, 6° 0°, 1° 20′, 1° 20′, 2°, 1° 40′.
E. N. E. 1° 40′.

In order to make the results which it is intended to deduce from the above table more clear, I append, first a table shewing the *number* of shocks classified according to direction, which have been recorded in various years, and second, a table shewing the *sum* of the *intensities* of these shocks.

I. Number of Shocks.

	1875	1876	1177	1878	1879	1880	Total.	
W.N.W....	2	9	10	20	9	3	53	90 S.E. N.W. Shocks.
N.N.W. ...	—	—	3	3	8	23	37	
N.N.E. ...	—	—	3	3	14	7	27	59 S.W. N.E. Shocks.
E.N.E. ...	2	5	13	3	8	1	32	

From this table we clearly see that the S.E. N.W. shocks have been much more numerous than the S.W. N.E. shocks.

II.—Intensities of Shocks.

	1875.	1876.	1877.	1878.	1879.	1880.	Totals.	
W.N.W..	12°30'	36°45'	35°30'	89°20'	24°10'	1°50'	210°	355.30. S.E. N.W. Shocks.
N.N.W...	..	..	2°30'	23°50'	10°	105°50'	145°30'	
N.N.E....	..	...	2°30'	21°10'	63°10'	24°40'	131°30'	310.10. S.W. N. E. Shocks.
E.N.E...	35°30'	40°30'	41°50'	24°30'	35°10'	1°40'	179°10'	

From this table we see that there has been a greater degree of intensity exhibited by the S. E. shocks than by the S. W. shocks.

It must however be remarked notwithstanding the fact that the strongest shock we have recorded belongs to the S. E. group, that the average strength of a S. W. shock is a little over 5° whilst that of a S. E. shock is only about 4°.

The chief points to be observed then are.

1st. The shocks are usually arranged in groups, one group may be called that of the S. E. shocks and the other that of the S. W. shocks.

2nd. These groups in some cases have occurred at different times. In other cases they have occurred about the same period.

3rd. Whenever a large shock has taken place it has been succeeded by small shocks having the same direction, and in certain cases it has also been preceded by such shocks.

4th. The S. E. shocks appear to be not only more numerous than the S. W. shocks, but also of greater intensity.

In concluding this portion of the subject I must ask my readers to bear in mind that the classification of North West shocks and North East shocks, has been adopted simply to shew the relation which shakings approximating to these directions have had upon two sets of buildings running in corresponding lines. It is quite possible that a grouping of N.N.W. and N.N.E. shocks from the North or South, and the W.N.W. and E.N.E. shocks as shocks from the East or West, and a subsequent critical examination of these two groups as to number of shocks and their insensities, might afford valuable information respecting the actual *origin* of the disturbances. The tables given shew that an East and West group thus formed would be more numerous and of greater average intensity than a North and South group. Because an earthquake may consist of two sets of vibrations (normal and transversal) we should not be justified by assuming from the above result that Tokio was visited by two sets of earthquakes one from the North and South and the latter which were the stronger from the East and West. When we have at our command a longer series of observations in which for each earthquake the movements experienced in each of the four tubes of Palmieri's instrument have been recorded, it is possible that the analysis of the records may lead us to some definite results on this point, shewing whether there are two districts from which our earthquakes originate or only one.

Note.—Since reading the above paper important results have been obtained in the determination of the origin of several of our recent shocks. This has been accomplished by observations of the time at which earthquakes were felt in Tokio and Yokohama, and the direction of their shakings as indicated by instruments placed at several points round Yedo Bay. The result has been that these *particular* earthquakes originated in the district between Yokohama & Yokosuka. The results of these observations will shortly be published in the transactions of the Seismological Society.

CERTAIN EFFECTS WHICH ARE PRODUCED UPON BUILDINGS.

Mr. Mallet at the commencement of his first volume describing the Neapolitan earthquake, discusses the general effect produced by various shocks upon differently constructed buildings. First he shows us that if we have a rectangular building the walls at right angles to the shock will be more likely to be overthrown than those which are parallel to it. Experience teaches a similar lesson. Thus Darwin when speaking of the earthquake at Concepcion in 1835 (see Researches in Geology and Natural History p. 374) tells us that the town was built in the usual Spanish fashion with all the streets running at right angles to each other. One set ranged S.W. by W. and N.E. by E. and the other N.W. by N. and S.E. by S. The walls in the former direction certainly stood better than those in the other. The undulations came from the S.W.

Results like these however come from destructive earthquakes rather than from movements such as those with which we have to deal in Yedo. When a building is subjected to a slight movement it is assumed that the walls at right angles to the direction of the shock move backwards and forwards as a whole, and there is little or no tendency for them to be fractured at their weaker parts, these weaker parts being those over the various openings. The walls however, which are parallel to the direction of the movement are so to speak extended and contracted along their length and in consequence they may be expected to give way over the various openings. This tendency for extension and contraction of a wall along its length may be supposed for instance to be due to the different portions of a wall, owing to differences in dimensions and general structure, having different periods of natural vibration, or possibly for two portions of a long line of wall to be simultaneously affected by portions of waves in different phases.

As an illustration of the giving way of a building in the manner I have suggested I will take the case of a large brick structure which was recently being erected in Tokio, This building was at the time of my visit only some 14 or 15 feet above the surface of the ground. The length of the building stretched from N.W. to S.W. and it was intersected by many walls at right angles to this direction. Through all the walls of this building of which there were many running in various directions, there were many arched openings.

In the central part of the transverse walls, which walls were fully 5 feet in thickness, the arches which joined them together, were 4 ft. 4 in. in thickness. The arches therefore formed a comparatively lightly constructed link between heavy masses of brick work.

On March 3rd 1879 at 4.43 p.m. an earthquake was felt throughout Tokio, the strength of which as judged by our feelings was above that of an average shock. As registered at the Yamato Yashiki observatory by one of Palmieri's instruments it had a direction S.S.W. to N.N.E. and an intensity of 11°. On the same day there were several smaller shocks having the same direction, and these were succeeded by others on the 9th of the month.

Immediately after these shakings it was discovered that almost every arch in the internal walls of the building I refer to, had been cracked across the crown in a direction about N. 40° W. All the other arches of the building of which there were a great number in walls at right angles to the direction of the shock were found not to have sustained any injury. To this statement however there was one exception. This was subsequently proved to have been due to a settlement taking place.

On seeing these cracks I together with others attributed them to the series of shaking which they had just experienced.

It seemed as if the heavy walls right and left of the arches had been in vibration without synchronism in their periods and as a consequence the arches which connected them had been torn asunder.

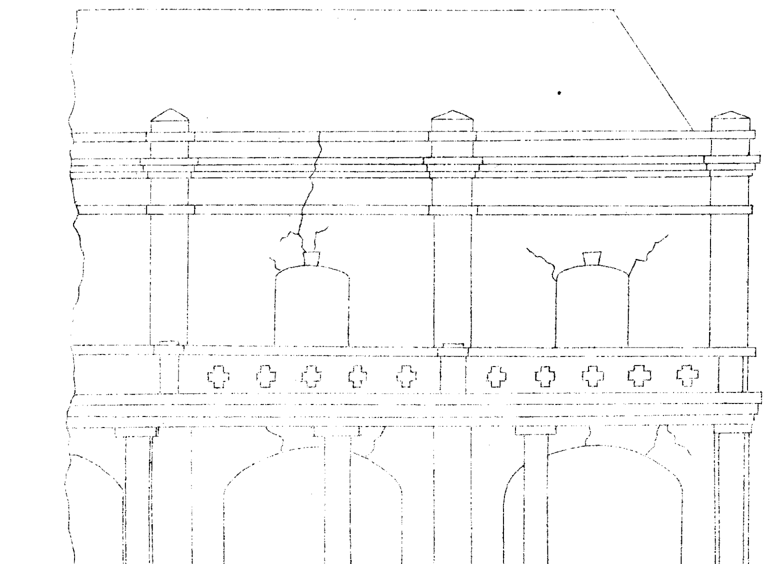
Although the time at which the cracks were formed and the peculiar positions in which they were only to be found pointed distinctly to their origin, to be certain that they were not due to settlement of the foundations, horizontal lines were rulled upon the brickwork and from time to time subsequently observed.

The points to which the various cracks extended were also marked and observed. Beneath the walls as foundations there were beds of concrete about 3 feet thick, and about 10 feet in width. These had been under the pressure of the partially built walls for 2 years before the arches had been put in. As these foundations were unusually strong, being intended to carry so very much greater weight than that to which they had been subjected, if any settlement which had been sought had been detected it would have been a matter of surprise.

Some weeks after the formation of these cracks it was observed that they were gradually closed. This I take as being due to the gradual falling inwards of the two broken portions of the arch, their position when open being one of unstability.

I may remark that if the building had been more complete at the time of the shock, and the heavy walls had been tied together at higher points, although the archways would have been points of weakness, it is quite possible that fracture would not have taken place. This illustration which I have adduced chiefly for the purpose of shewing that when a building is shaken in a definite direction there will be some rule as to the positions in which fractures occur is taken from my own observations. As another example I will take the observations of Alexander Bittner upon the buildings of Belluno after the shock of June 29th 1873 (see Beiträge Zur kenntniss des Erdbeben von Belluno vons 29th June 1873, p. 40. Von Alexander Bittner. Aus dem LXIX Bande der Sitzb. der K. Akad: der Wissensch : II Abth, April Heft. Tahrg. 1874).

Speaking generally he remarks that "Houses similarly situated have suffered in corresponding walls and



Brick Houses in Tokio

corners in a similar manner. In Belluno there is a certain kind of damage which is repeated everywhere making a peculiar system of splits in the S. W. and N. E. corners of the houses."

Buildings in Tokio.

For the purpose of finding out what has been the effect produced by earthquakes upon the buildings of Yedo, and at the same time for ascertaining whether blocks of buildings ranging in different directions suffered to the same extent, in company with Mr. Josiah Conder, I examined a large number of foreign built houses in the neighborhood of the Ginza. My chief reason for choosing this district was because it was the only district where a large number of *similar* buildings could be found. By examining houses or buildings of different constructions, the effects produced upon them by earthquakes are very often likely to shew so many differences, that it becomes almost an impossibility to determine what the general effect has been.

A number of similarly constructed buildings in a district may be regarded as a number of seismographs, the effect upon any one of them being judged of by the average of the general effect which has been produced upon the whole. The general form of two of these houses which have been examined is shewn in Fig. 1. In this figure the general character of the fractures which have been produced can also be seen. The buildings are built of brick, being in many cases faced with a thin coat of white plaster. Projecting from the level of the upper floor there is a balcony fronted by a low balustrade. This is supported by small beams which at their outer extremity are carried on a row of cylindrical columns. This forms a covered way in front of each row of houses. The roofs are covered with thick tiles. It will be observed that the arching of the upper windows spring *sharply* from their abutm ents and at their crown they carry a heavy key stone. The lower openings which have a span of 9 feet have evidently been constructed in imitation of the open front of an ordinary Japanese house. These archways curve out *gently* from their abutments. The outside walls have a thickness of $13\frac{1}{2}$ inches.

The cracks which were observed in these houses were, as might naturally be expected, confined to the weakest points, namely the archways. Out of 127 cracks in the arches of the upper windows, there were no less than 113 which ran from the springing.

Out of 250 cracks observed in the lower arches, 110 ran down from the the beams supporting the balcony, whilst the remaining 140 ran through some portion of the arch usually near the crown. By comparing together the cracks of these two sets of openings a strongly marked distinction is to be observed. In the upper arches almost every crack commences from the springing which forms an *angle* with the abutments, but below, where the arches *curve* into the abutments, not a single crack was observed.

Another point which is very striking is the fact that so many cracks appear at the points where joints or beams have been built into the wall for the purpose of carrying a weight. In many cases cracks had probably been disguised by the walls having been covered with a fresh coat of plaster.

The occurrence of cracks in the peculiar positions which I have pointed out may be also seen in the illustrations which accompany the account of almost any great earthquake. For example in the illustrations accompanying Mr. Mallet's account of the Neapolitan earthquake, or in Bittner's account of the Belluno earthquake, just referred to. The following table will give the number of houses which were examined and the cracks which were observed in them.

I. Out of 174 houses in streets running N.E. by N. to S.W. by S.

Top windows.

Arch	3	cracks.
Abutments...........	61	„

Bottom windows.

Beams	51	„
Arch	55	„
Total	170	„

II. Out of 156 houses in streets running S.E. to N.W.

Top windows.

Arch	11	cracks.
Abutment	52	„

Bottom windows.

Beams................................	59	„
Arch	85	„
Total............	207	„

From table I. we see that in streets running in a direction N.E. by N. the number of houses were to the number of cracks as 1 : .97 ; whilst in the streets running S.E. we see from table II. that the proportion is as 1 : 1.32.

That is to say, the cracks in the houses of the streets running N.E. by N. are to the cracks in the houses at right angles to them, that is in the streets running S.E., as .97 : 1.32 or 1 : 1.36.

As the cracks in the lower windows were more easily observed than those in the upper ones, it might perhaps be a fairer test to take these former by themselves.

In the houses running N.E. by N. we have therefore 106 cracks in 176 houses, or 6 cracks per house.

In the houses running S.E. we have 144 cracks in 156 houses or .92 cracks per house. From this estimate it follows that the cracks in the N.E. by N. direction as compared with the cracks in the S.E. direction, are as 1 : 1.5.

On the whole therefore, although there is no strong demarcation between the damage which has been caused in the two sets of streets, yet if we judge of the damage by the cracks, the streets which run in a direction from S.E. to N.W. have suffered more than those in the streets at right angles.

The time at which the examination giving the above results was made, was during the month of March 1879.

If we now turn back to the analyses of the recent earthquakes which have just been given, we shall see that the effects which have been produced upon the buildings hold a remarkable relation to the shakings to which they have been subjected; namely, that the streets which have suffered the most are those which are parallel to the direction in which the city has been traversed by the greater number of shocks. As, however, the cracks which I have spoken about, hold no relation to the earthquakes which took place subsequent to March, 1879, I give the following two tables as an analysis of the earthquakes which took place previous to that date.

TABLE I.

To shew the number of shocks classified according to their direction, which have been registered in Tokio, from January, 1876, to March, 1879 :—

	1876.	1877.	1878.	1879.	Total.	
W.N.W. ...	12	11	23	5	51	N.W., S.E., shocks, 57.6 per cent.
N.N.W.......	0	5	5	3	13	
N.N.E.	0	4	5	8	17	N.E., S.W., shocks, 42 per cent.
E.N.E.	8	15	4	3	30	
	20	35	37	19	111	

In making the above table, it must be pointed out that if one shock produced a certain effect in a W.N.W. direction and also an effect in a N.N.W. by causing certain degrees of intensity to be registered in these directions, the single shock has been recorded as two shocks. The reason that we do this, is because these tables are drawn up to shew the different effects to which lines of buildings running in different directions have been subjected. The reasons for classifying shocks in this way will be seen when speaking of their different intensities.

From this table we see a result similar to that which we obtained when considering the whole of the shocks of which we have any record, namely, that the S.E. shocks have been more numerous than the S.W. shocks.

TABLE II.

In the following table the sums of the intensities as given for shocks in the same direction are shewn.

	1876.	1877.	1878.	1879.	Totals.	
W.N.W.	47° 15'	36° 45'	102° 50'	14° 30'	201° 10'	253° 20'
N.N.W.	...	17° 20'	32° 20'	2° 30'	52° 10'	S.E. shocks.
N.N.E.	...	9° 30'	28° 30'	30° 50'	68° 50'	205° 40'
E.N.E.	51°	48° 20'	30° 30'	7°	136° 50'	S.W. shocks.

From this we see that, so far as the effects of different shocks were perceived in Tokio, those travelling in a N.W. S.E. direction were the most powerful.

This same result is expressed in the following table in a somewhat different manner.

	From 1876 to March 1879.	
	S.E. shocks.	S.W. shocks.
Between 1° and 3°	34	26
,, 3° and 7°	22	13
Above 7°	8	8

The conclusion therefore is, notwithstanding the fact that we have had two sets of shocks working at right angles to each other, the more powerful set in spite of the masking effect of those at right angles to them, has left a distinct record of itself in the damage done to the houses. In other words, in the streets of Yedo we have found that different effects have been produced in sets of streets at right angles to each other, and the greatest effects are to be seen in the streets which have been traversed by the more severe shocks.

It may of course be urged that the buildings about which I have spoken are structures which are not only weak but are built upon bad foundations, and further it might be argued that the position of the cracks which have been pointed out, are identical to the positions in which we find cracks in buildings in countries where earthquakes are unknown. Suppositions of this description, however, do not shew why there should have been more giving way in those streets parallel with the direction of the greater number and more powerful set of shocks. It might of course be stated that this coincidence was one of chance. Suppositions of this latter description would I thinke reqnire us to admit that an earthquake acting in a definit direction along a line of buildings was as likely to produce fractures upon one side of them as upon another,—a result which I have already shewn to be contrary not only to our expectation but to our actual experience. Had there been no earthquakes in Tokio, it is quite probable that the buildings in the Ginza would have given way and produced fractures in positions similar to those where they are now to be observed. Under these circumstances however I do not think that these fractures would have been so numerous as we now observe them, nor is it likely that there would have been any striking difference between the number of cracks existing in one street as compared with those existing in another.

Measurements of the Relative Motion of Parts of a Building at the Time of an Earthquake.

I. *Experiment*—Since the end of last year I have made a series of observations to determine whether at the time of an earthquake the various parts of the arched openings which we see in many buildings synchronised in their vibrations, or for want of synchronism, were caused to approach and recede from each other. The arches I experimented on were the heavy brick arches forming the two Corridors of the Imperial College of Engineering. The direction of one set of these corridors is N. 40° E. and that of the other N. 50° W.

The thickness of the walls in which these arches are placed, is 1 ft. 11 in. They are built of Japanese bricks, bound together with ordinary lime. The span of the arches is 8 ft. 3 in. and the height of the arch from the springing line to the crown 4 ft. 1 in. The height of the abutments is 7 ft. 1½ in. The *Voussoirs* of the arch are formed of a light grey soft volcanic rock, and on their faces shew a depth of 12 in. The width of the intermediate columns between the arches is 4 ft. 6⅞ in. To determine whether at the time of an earthquake there was any variation in the dimensions of these arches I proceeded as follows.

Across the springing line of the arch I placed a light stiff deal rod, in cross section about 2 in. by ½ in. One end of this was firmly fixed to the top of one abutment by means of a spike; on the other end, which was to indicate any horizontal movement if the abutments approached each other, I placed a pointer made out of a piece of steel wire. This rested on a piece of smoked glass fixed to the ledge on which the loose end of the rod was resting. If the abutments approached or receeded from each other a line would be drawn measuring the extent of the motion. As a further indication of motion, a second smoked glass plate was fixed on the transverse rod, which plate was marked on, by a pointer attached to a vertical rod hanging down from the crown of the arch.

From very small earthquakes there was no visible record of motion, whilst with shocks of a moderate intensity the opportunities for observation were very few. As the whole of these arrangements were of necessity exposed to the atmosphere, records were often produced upon the plate at the end of the vertical rod by the action of the wind. The only records, where from having carefully adjusted the plates and pointers a short time before the shock occurred, I feel assured were really due to earthquakes having produced a motion in the arches, are the two following.

		April 27th.	Feb. 21st.
N. 40° E. Corridor	Vertical	2 m.m.	3 m.m.
	Horizontal	1.5 m.m.	2.75 m.m.
N. 40° W. Corridor	Vertical	2.75 m.m.	2.75 m.m.
	Horizontal	not working.	2 m.m.

The latter it will be observed was the shock which produced so much damage in Yokohama.

The direction of this was about N.N.W. and it had an intensity of 78°. The other shock had a N.N.E. direction and an intensity of 6°.

Both of these shocks had a direction oblique to these corridors.

As a general result of these experiments it may be said that the portions of the building which were examined usually either did not move at all, or else they practically synchronised in their movements. When they did move, the extent of motion was small, and the small differences in movement which were observed, were in every probability far within the elastic limits of the structure.

II. *Experiment.* Another means which was used whilst endeavoring to detect movement in archways was as follows.

A wire was stretched along the springing line of several arches. One end of this was fixed, whilst to the other end which hung freely over a staple, there was attached a short length of thin brass wire, and to the end of this latter a weight was hung, keeping the whole line stretched. This weight was of such a size, that if it were slightly increased, it was sufficient to break the fine wire which joined it to the thick one. It was anticipated that, if at any moment this wire should be *suddenly* stretched, by the brick work not moving as a whole, the weak wire would be suddenly snapped. From this experiment no results were obtained. Had the points of attachment been somewhat modified, I am of opinion that under favourable circumstances indications of movement by the breaking of the fine wire might possibly have been obtained. As a result like this would tell but little about the extent of the motion in the two parts of the building, this special form of experiment was given up.

III. *Observations on Cracks.*

To determine whether the walls of a building which have once been cracked, when subjected to a series of shocks, similar to those which they experienced before being cracked, still continued to give way, on the 16th of Feb. last I marked with a pencil the extremities of a considerable number of cracks in the N.E. end of the museum buildings of the Kobu-dai-Gakko (Engineering College). Although since that date there have been many severe shocks, these cracks have not visibly extended. These marks were made on the outside wall of the building. On the inside, one of these same cracks is shewn as a fissure about $\frac{1}{4}$ in. in width. Across this crack, a horizontal steel wire pointer was placed. One end of this wire was fixed in the wall. The other end which was pointed rested on the surface of a smoked glass plate placed on the other side of the crack. After small earthquakes there was no indication of motion having taken place, but after the shock of February 21st as indicated by a line upon the smoked glass plate, the sides of the crack had approached and receded from each other through a distance of about 2 mm.

By similar contrivances placed on cracks in a neighbouring building exactly similar results were obtained, namely that during small earthquakes the two sides of the crack had retained their relative positions, but at the time of a large shock this position had been changed. The building I here refer to is the Dormitory of the Kobu-dai-Gakko. Here, as in the walls of the museum, a number of cracks had their extremities marked. Many of these, dated 21st January, I find have increased their length from $\frac{1}{2}$ in. up to as much as and over 12 in. The greatest proportion of this increase was observed to have taken place after the shock of February 21st. On February 22nd the new terminations of several of the cracks were marked, but since then, the extension has been small.

These latter cracks it must be remarked have been noted on a surface of plaster covering the brick work, and in this case it is possible that the cracks in the plaster are extending, perhaps by fluctuations in temperature and the like, as much as by earthquakes, and this quite independently of the cracks in the brickwork. That these cracks extend *into* the brick work there is no doubt, for when viewed from the outside they form a ragged line cutting the brick work through from the basement to the roof, and traversing every parallel wall in a similar manner, from one side of the building to the other. The widest of these cracks is about $\frac{1}{4}$ in.

It may be remarked that one or two of the more prominent of these cracks were first observed immediately after an earthquake in December last. By attaching levers to the end of my pointers to multiply any motion that might take place, no doubt the indications would be more frequent and more definite. It would also be easier to note the relative distances of motion in two directions, namely how far the cracks had closed and how far they had opened. As to whether motion would occur or not, much would no doubt depend upon the direction of the earthquake.

One conclusion which may perhaps be drawn from these observations is, that a cracked building at the time of an earthquake shews a certain amount of flexibility. Whether a building which had been designed with cracks or joints between those parts which were likely to have different periods of vibration, would be more stable so far as earthquake shakings are concerned than a similar building put up in an ordinary manner, is a matter to be decided by experiment. Certainly some of the cracks which I have examined indicate that if they had not existed, the strain upon the portion of the building where they occur would have been extremely great.

In looking at these cracks it was interesting to note the manner of extension. The basements of the buildings about which I write, for a height of two or three feet are built of large rectangular blocks of a greyish coloured volcanic rock. In these parts the cracks pass in and out between the joints of the stone, indicating that the stones have evidently been stronger than the mortar which bound them together, and as a consequence the latter had to give way. Above this basement when the cracks enter the brick work, they no longer exclusively confine themselves to the joints, but run in an irregular line through all they meet with, sometimes across the bricks, and occasionally through the mortar joints. In places where rather than following a joint they have traversed the brick work, we can say that the mortar has been stronger than the bricks. This traversing of the bricks rather than the joints is, I think, the general rule for the direction of the cracks in the brick-work of Tokio buildings.

This brings me to the end of the few remarks which I have to make upon the effects which appear to me to have been produced by recent earthquakes upon the modern European buildings which we see rising up around us throughout Tokio.

The experiments which I have hitherto made to determine the extent of internal motion in a building at the time of a small earthquake have been few. They have, however, given. I think, indications of results which may be obtained should similar experiments be repeated on a larger scale.

The notes which I have made upon the brick buildings of the Ginza I will leave side by side with the record of the shakings they experienced to speak for themselves. Although many may be inclined to doubt whether the coincidences in the direction of maximum shaking, and that of the streets where the greater number of cracks have been produced, is anything more than accident, I hope that my observations will at least be sufficient to attract their attention to a subject which is of so much importance to all who dwell in brick or stone buildings put up in earthquake shaken countries.

APPENDIX TO CATALOGUE OF EARTHQUAKES, IN "NOTES ON RECENT EARTHQUAKES, &c."

BY J. MILNE.

No.	Month	Day	Time	Force of shock.	Direction	Duration
			h. m. s.			m. s.
406...	V	30	5.05.00	...	...	...
407...	VI	17	22.25.00	8° 30′ 2° 10′ 1° 40′	WNW & ESE WSW & ENE SSE & NNW	0. 40
408...	,,	20	15.12.44	0° 30′	WNW & ESE	0. 07
409...	VII	4	18.00.00?	1° 50′	WNW & ESE	...
410...	,,	19	15.13.59	1° 20′ 0° 10′ 0° 10′	WNW & ESE WSW & ENE ESE & NNW	0. 22
411...	,,	25	11.37.15	7° 50′ 1° 30′	WNW & ESE SSE & NNW	0. 55
412...	VIII	1	10.42.00	0° 40′	WNW & ESE	...
413...	,,	14	6.07.36	...	...	...
414...	,,	29	19.18.25	2° 40′	WNW & ESE	0. 27
415...	IX	3	22.29.41	3° 00′ 2° 20′	WNW & ESE SSE & NNW	0. 20
416...	,,	5	10.49.04	0° 40′	SSE & NNW	0. 05
417...	X	15	8.39.00	0° 30′	WNW & ESE	...
418...	,,	17	21.21.43	...	...	..
419...	,,	25	9.24.15	0° 30′ 0° 10′ 0° 10′	WNW & ESE SSW & NNE SSE & NNW	1. 30 (about)
420...	XI	10	21.10.56	...	...	0. 15
421...	,,	10	21.11.21	0° 30′ 0° 30′ 0° 40′	WNW & ESE WSW & ENE SSE & NNW	0. 29
422...	,,	15	9.47.32	...	...	0. 25 (about)
423...	XII	2	21.16.43	...	...	
424...	,,	10	23.05.14	...	...	...
425...	,,	22	16.40.00	...	...	...
426...	,,	26	1.12.30	0° 10′ 0° 20′ 0° 40′	WNW & ESE SSW or NNE SSE or NNW	...
427...	,,	28	16.24.15	0° 20′ 0° 15′	WNW or ESE SSE or NNW	00. 25
428...	,,	29	5.04.07	0° 30′ 0° 30′ 0° 10′	WSW or ENE SSW or NNE SSE or NNW	...
429...	,,	31	0.24.15	...	...	...