Notes on the Secondary Causes of Earthquakes.

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With Pls. XXIV–XXVIII.

CONTENTS.

1. *Introduction.* Earthquakes are caused by some sudden underground disturbances, which may consist in the formation or extension of a fault, the production of a fissure or cavity, the subsidence or upheaval of a piece of ground, etc. These disturbances themselves are, however, the results of the stresses going on in the earth's crust for a considerable interval of time; a great shock at a given portion of a seismic region occurring in general only once in several years or even several centuries. When, therefore, an earthquake is about to happen, the earth's crust in the vicinity of its focus is in a critical condition and must be very sensitive to the effects of changes in the atmospheric pressure, the amount of precipitation of rain and snow, the variation in the weight of the sea water in the tidal movement, etc. These external agencies, which constitute the *secondary earthquake causes* have evidently an important bearing on the seismic phenomena, and the present paper contains some notes on the relations of these to the time distribution of the shocks in Japan.*

2. *Examples of local characteristics.* The following are some examples of the cases, in which strong or great earthquakes in a given region occurred in approximately the same parts of the year or of the day.

(*a*) The destructive earthquake of Kumamoto (Kyushu) took place on July 28, 1889. Its numerous after-shocks gradually decreased in frequency till 1894, when a strong earthquake occurred on Aug. 8. A third strong shock took place on Aug. 27, 1905, followed by a fourth on March 10, 1907. The times of occurrence of these 4 earthquakes, the three last of which were not destructive, are given in the following table.

TABLE I.—LIST OF THE SEVERE KUMAMOTO EARTHQUAKES.

No.	Date.	Time of Occurrence.
1	July 28, 1889.	11^h 40^m pm.
2	Aug. 8, 1894.	11 19 ,,
3	Aug. 27, 1902.	10 42 ,,
4	March 10, 1907.	10 03 ,,

(*b*) The severe earthquake of May 26, 1898, at 3^h 0^m 0^s am.,

* The times are always given in the 1st Normal Japan Time, or that of longitude 135° E., of Greenwich.

which caused some slight damage, originated in the District of Uonuma, near the town of Muikamachi, in the province of Echigo. Six years later, namely, in 1904, a second severe earthquake took place on May 8, at 4h 23m 49s am., the origin being close to that of the preceding shock.

(*c*) The great sea-waves of 1896 along the north-eastern coast of the Main Island, known as the Sanriku* *tsunami*, were caused by an earthquake, which took place on June 15, at 7½ pm. Five years later, namely, in 1901, there was also some tidal disturbances accompanying an earthquake which occurred on June 15, at 6½ pm.

(*d*) The great Shonai earthquake of 1894, which caused enormous damage to life and property in the city of Sakata and the vicinity (provinces of Uzen and Ugo), took place on Oct. 22, at 5h 35m pm. The great Riku-U earthquake of 1896 took place on Aug. 31, at 5h 6m pm.

Thus it will be seen that the first three Kumamoto earthquakes, (*a*), were in July or August, while all the four occurred late in the evening, namely, between 10h 03m pm. and 11h 40m pm. The two Echigo earthquakes, (*b*), took place in the month of May, at 3h 0m to 4h 23m am. The two Sanriku earthquakes, (*c*), occurred on June 15, at 6½ to 7½ pm. Finally, the two great destructive earthquakes of Northern Japan, (*d*), occurred at 5h 6m to 5h 35m pm.

From these examples it may be inferred that great and strong earthquakes in a given district often have a tendency to occur in certain months of the year, or at certain hours of the day. This is to be regarded as indicating the local peculiarities, probably

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* *Sanriku* denotes the three large provinces of Rikuzen, Rikuchu, and Mutsu, which form the north-eastern part of the Main Island.

depending on the tidal movement of the sea water and the annual and diurnal variations of the barometric pressure. As an example relating to great earthquakes occurring along an extensive seismic zone, I mention the four recent destructive shocks of San Francisco, Mexico, and Central America, whose dates were as follows :—

TABLE II.—EARTHQUAKES ALONG THE SOUTH-WESTERN COAST OF NORTH AMERICA.

Date.	Earthquake.
April 19, 1902.	Guatemala.
„ 18, 1906.	Earthquake of San Francisco.
„ 15, 1907.	Mexico.
March 26, 1908.	„

Thus the first three shocks occurred all in the month of April, between 15th and 19th, while the 4th occurred in the latter part of March.

3. *Strong earthquakes in Shimosa and Hitachi.* The following table is a list of the earthquakes felt strongly at Mizukaido, Sahara and other places along the lower course of the Tone-*gawa*, which forms the boundary between the two provinces of Shimosa and Hitachi. The land areas of disturbance, within which the motion was sensible or was recorded by the crdinary Gray-Milne-Ewing type seismographs, were in each case over 1,000 sq. *ri.*

TABLE III.—STRONG EARTHQUAKES IN SHIMOSA AND HITACHI.

No.	Date.	Time of Earthquake Occurrence.
1	March 3, 1902.	9^h 13^m am.
2	„ 25, „	2 35 pm.
3	Aug. 8, „	8 37 am.
4	Dec. 14, „	1 57 pm.
5	„ 31, „	2 38 pm.
6	May 8, 1904.	7 24 am.
7	June 30, „	8 21 am.

It will be observed that four of the seven earthquakes given in the above table, namely, Nos. 1, 3, 6, and 7, occurred at 7 to 9 am., while the remaining three, Nos. 2, 4, and 5, occurred at 1 to 2 pm. These two groups of the times of occurrence may be regarded as approximately agreeing with a pair of epochs of the maximum and minimum in the diurnal variation of the barometric pressure.

4. ***General relations of the secondary causes on earthquake frequency.*** The secondary causes of earthquakes as enumerated in § 1 make themselves sensible by the variation of the vertical pressure exerted on the earth's crust. Let us examine a few simple cases of the relations of the secondary causes to earthquake frequency.

(*a*) Suppose *ab* to be a horizontal layer of the earth's crust, which is undergoing a tension parallel to its plane. Then an increase or decrease in the pressure, *c*, applied vertically to it, will equally accelerate the formation of a vertical rupture or crack. (Figs. 1 and 2.) In the case the layer *ab* is undergoing a compression in its plane, a variation in the external pressure may tend to produce a dislocation or slipping.

(*b*) When the layer *ab* is being pushed upwards from below, a decrease in the barometric pressure, the weight of the sea waters, etc., will favour the occurrence of the rupture.

(*c*) When the layer *ab* is being pushed down, the increase in the pressure due to the secondary causes will tend to the same result.

Fig. 1.

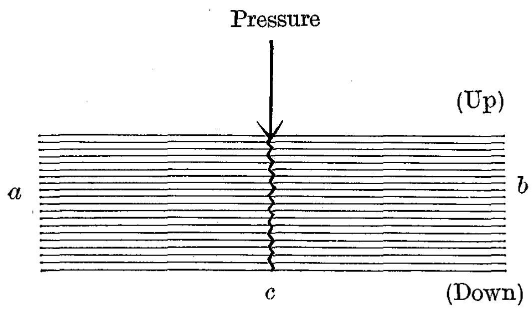
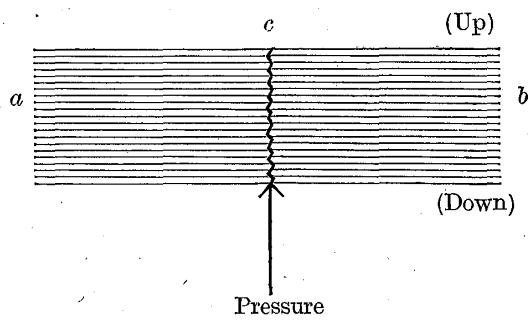


Fig. 2.



I give next a few cases illustrating some of these principles.

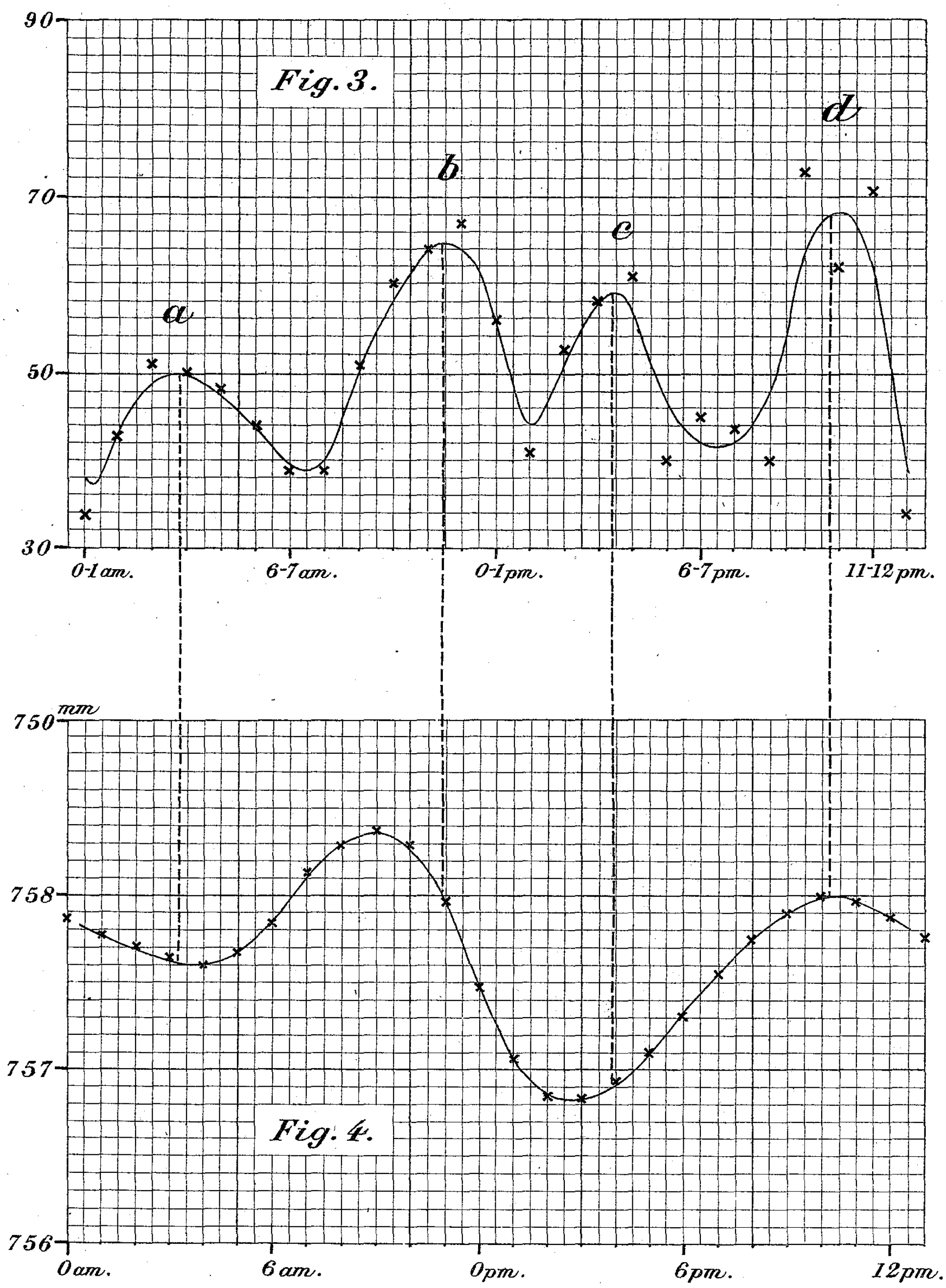
5. *Jinari* at Arima, 1899-1900.* The earth sounds, or *jinari*, at the famous hot spring place of Arima, near Kobe (province of Settsu), began on July 5, 1899, and were very numerous during the several succeding weeks. The maximum daily number, probably about 200, was reached at the beginning of August, thence the frequency gradually decreasing. After the 8th of August, the times of occurrence of these *jinari* were carefully recorded at the city office of Arima; the total number during the rest of the month being 584. In the four months of September to December

* The Japanese word "jinari," which signifies *earth sound*, may be used to denote earthquake sounds as well as those sounds heard in volcanic and other districts which are accompanied only by very slight tremblings of the ground.

Diurnal Variations.

Fig. 3. ...... Frequency of the *Jinari* at Arima.

Fig. 4. ...... Barometric Pressure at Kobe.



there were altogether 650 of the *jinari*, which did not completely cease in the course of the next year.

The origin of disturbance was situated at a distance of about 2 km to the south of Arima among the Rokko Mountain, whose formation is of granite and diorite. Judging from the frequency distribution of the *jinari* in the vicinity, the focal depth was very small, and probably between ½ and 2 km. The sounds, which were sometimes very loud, were mostly like that caused by the discharge of gun at a distance, or falling of a heavy mass on the ground. The tremblings of the ground, which followed the sounds after an interval of 0.5 to 1.0 second, were generally slight. On a few occasions, however, the earthquake mevement was quite sharp, and caused the falling down of some roof tiles, rolling down of rock fragments from mountain slopes, etc.

Table IV gives the hourly distribution of the 1,234 *jinari* recorded at Arima between Aug. 8 and Dec. 31, 1899, and the mean hourly barometric height during the same interval for the meteorological observatory of Kobe, which was not much distant from the origin of disturbance.

TABLE IV.—DIURNAL VARIATIONS OF THE FREQUENCY OF THE *JINARI* AT ARIMA AND THE BAROMETRIC PRESSURE AT KOBE.

Jinari at Arima.		Atmospheric Pressure at Kobe.	
Hour Interval.	Number of *jinari*.	Hour.	Barometric Height.*
0^h— 1^h AM.	34	1^h AM.	$700+57.78^{mm}$
1— 2	43	2	57.72
2— 3	51	3	57.66
3— 4	50	4	57.61
4— 5	48	5	57.68

Jinari at Arima.		Atmospheric Pressure at Kobe.	
Hour Interval.	Number of *jinari*.	Hour.	Barometric Height.*
h h 5— 6 AM.	44	h 6 AM.	mm 57.85
6— 7	39	7	58.15
7— 8	39	8	58.29
8— 9	51	9	58.39
9—10	60	10	58.30
10—11	64	11	57.98
11—12	67	Noon	57.50
0— 1 PM.	56	1 PM.	57.07
1— 2	41	2	56.85
2— 3	53	3	56.84
3— 4	58	4	56.95
4— 5	61	5	57.11
5— 6	40	6	57.30
6— 7	45	7	57.56
7— 8	44	8	57.76
8— 9	40	9	57.91
9—10	73	10	58.02
10—11	62	11	57.98
11—12	71	Midnight.	57.88
Sum......	**1234**		
Mean.....	**51.4**		

* Reduction to standard gravity = −0.70 mm.
Reduction to mean sea level = +5.40 mm.

As illustrated in Fig. 3, the diurnal variation of the frequency of the *jinari* at Arima shows very clearly 4 maxima *a*, *b*, *c*, *d*, and the 4 corresponding minima, indicating a six-hour periodicity. Further, it will be observed from Fig. 4 that the diurnal variation of the barometric pressure at Kobe shows the two maxima and two minima, indicating as usual a 12-hour periodicity. Comparing the two figures, we see that the mutual relation between the *jinari* frequency and the barometric pressure is striking, the two maxima, *b* and *d*, and the two other maxima, *a* and *c*, of the former occurring nearly at the same hours respectively with the two maxima and minima of the latter. The epochs of the 4 maxima *a*, *b*, *c*, *d*, indicated by the mean frequency curve of the *jinari* are as follows :—

1st	Maximum,	(*a*)...........	about 3 am.
2nd	„	(*b*)...........	„ 11 „
3rd	„	(*c*)...........	„ 4 pm.
4th	„	(*d*).....	between 10-11 „

The differences between the 4 maxima *a*, *c*, *b*, *d*, and the corresponding minima (the preceding minimum in each case, say), are as follows :—

		Difference in the frequency.
1st	Max. and Min.	17
2nd	„	28
3rd	„	20
4th	„	33
Average	....	**25**

This average difference may approximately be regarded as the effect due to the barometric pressure, and corresponds to about 50% of the mean hourly frequency, namely, 51.4.

As the *jinari* are purely local phenomena of a shallow origin, it is to be quite expected that their frequency should be influenced by the barometric pressure. What was said above indicates that both the increase and the decrease of the pressure equally causes an increase in the frequency of the *jinari*, in accordance with the principle stated in § 4, (a).

6. *Diurnal variation of earthquake frequency in Tokyo.* The diurnal variation of the seismic frequency in Tokyo also shows clearly the same characteristic as the *jinari* at Arima. The following table gives the distribution in the 24 hours of the day of 2,208 earthquakes instrumentally observed during the 24 years, 1876–1899, at the Central Meteorological Observatory, and the mean hourly values of the barometric pressure at the same place.*

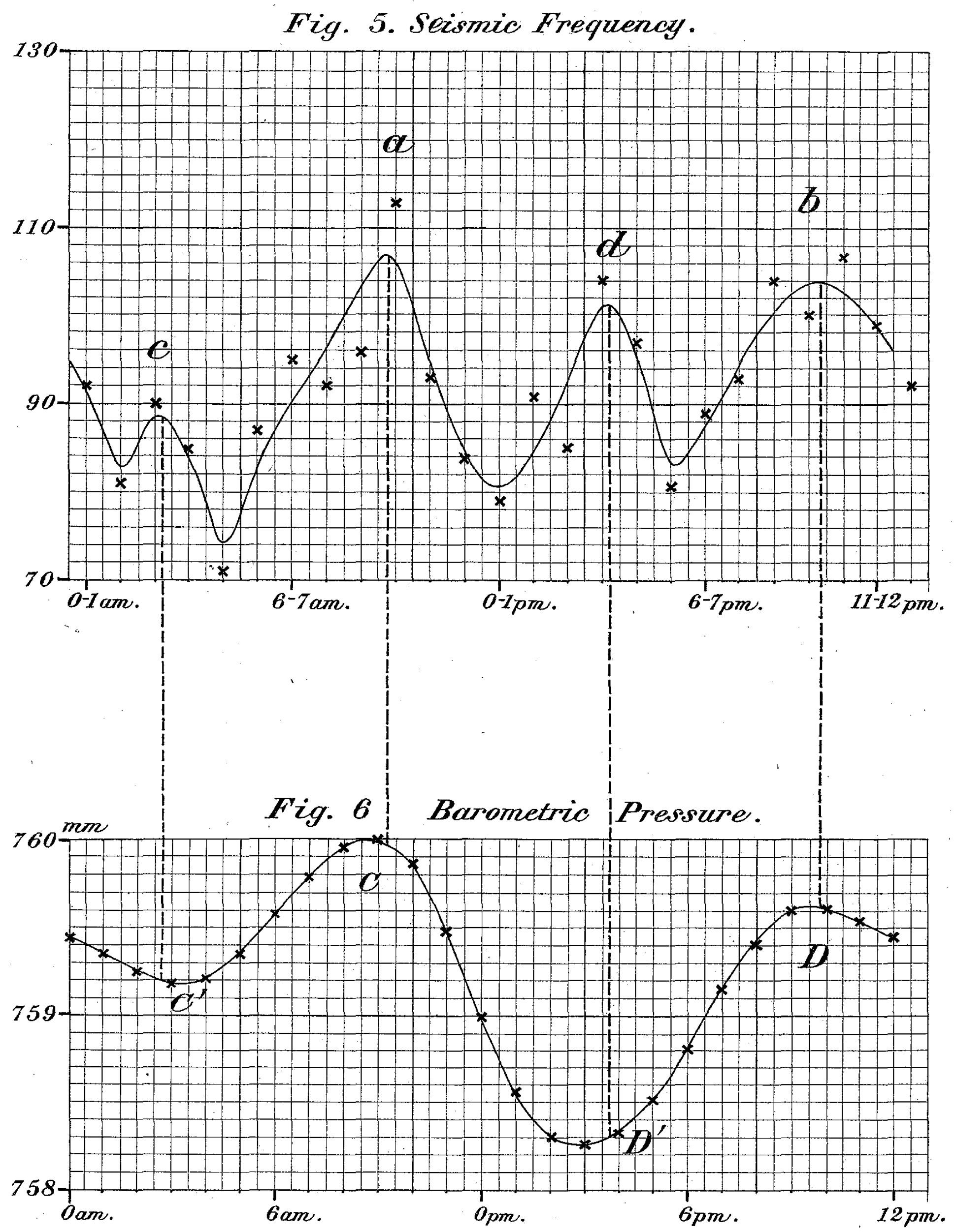
TABLE V.—DIURNAL VARIATIONS OF THE FREQUENCY OF EARTHQUAKES AND THE BAROMETRIC PRESSURE, IN TOKYO.

Earthquakes (1876–1899).		Atmospheric Pressure.	
Hour Interval.	Frequency.	Hour.	Barometric Height.†
0^h— 1^h AM.	92	1^h AM.	700+59.33 mm
1— 2	81	2	59.24
2— 3	90	3	59.18
3— 4	85	4	59.21
4— 5	71	5	59.35
5— 6	87	6	59.58
6— 7	95	7	59.79
7— 8	92	8	59.95
8— 9	96	9	60.00
9—10	113	10	59.88
10—11	93	11	59.49
11—12	84	Noon	58.98
0— 1 PM.	79	1 PM.	58.56
1— 2	91	2	58.31
2— 3	85	3	58.27

* Reproduced from the *Publications of the Earthquake Investigation Committee*, No. 8.

† With the freezing point correction. Reduction to standard gravity = −0.63 mm; reduction to sea-level = +1.94 mm.

Diurnal Variations. Tokyo.



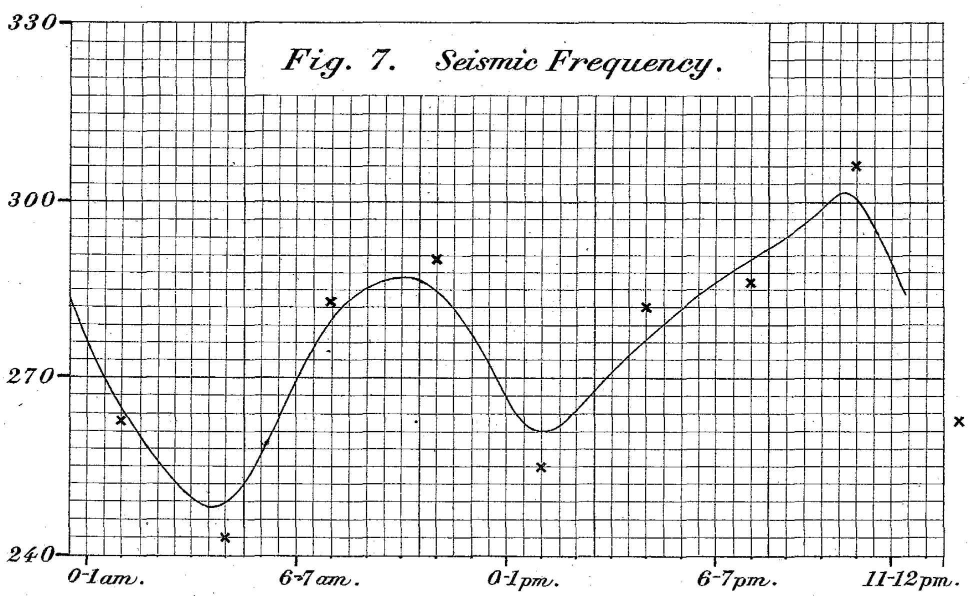


TABLE V. (*Cont.*)

Earthquakes (1876-1899).		Atmospheric Pressure.	
Hour Interval.	Frequency.	Hour.	Barometric Height.
3^h— 4^h PM.	104	4 PM.	$700+58.\overset{mm}{33}$
4— 5	97	5	58.52
5— 6	81	6	58.82
6— 7	89	7	59.14
7— 8	93	8	59.40
8— 9	104	9	59.60
9—10	100	10	59.61
10—11	107	11	59.54
11—12	99	Midnight.	59.43

Fig. 7, drawn from the 3-hourly earthquake numbers, represents the mean course of the diurnal variation of the seismic frequency, which will be seen to be on the whole parallel to that of the atmospheric pressure. That is to say, the ordinary (non-destructive) earthquakes felt in Tokyo happen more frequently with the high barometer than with the low, illustrating a case stated in § 4, (*c*). The curve of the hourly seismic frequency (Fig. 5) indicates, however, 4 maxima, namely, a pair of principal maxima, *a* and *b*, respectively at 9–10 am. and 9–10 pm., and a pair of the secondary maxima, *c* and *d*, respectively at 2–3 am. and 3–4 pm. On comparing Figs. 5 and 6, it will be noted that, according to the principle of § 4, (*a*), the two maxima, *C* and *D*, and the two minima, *C′* and *D′*, of the barometric pressure correspond respectively to the pair of the principal maxima and the pair of the secondary maxima, of the seismic frequency.

7. Precipitation and yearly earthquake frequency in Tokyo. It is quite conceivable that the yearly earthquake frequency in Tokyo is related to the amount of the precipitation of rain and snow in the plain of Musashi, on which the city is situated, or along the north-western coast of the Main Island, where a large amount of the moisture is deposited during the winter months. I give in the second column of Table VI, the yearly numbers of the earthquakes which were not teleseismic and which were instrumentally recorded during the 32 years, 1876–1907, at the Central Meteorological Observatory. The observations were made at first with Palmieri's seismograph, but since 1887 by means of a Gray-Milne-Ewing type seismograph. It will be observed that the earthquake number was minimum (=32) in 1883, and maximum (=216) in 1896, thence the frequency is on the whole decreasing. For the sake of reference, I give in Table VII, the mean barometric pressure and temperature, and the amount of precipitation in Tokyo during each of these 32 years. As a trial I have taken into consideration the amount of precipitation at Niigata and Akita, both situated along the Japan Sea coast, as the observations at these two places date since 1882 and 1883, respectively over the long intervals of 26 and 25 years (Table VI). The city of Niigata, about 260 km to the NNW of Tokyo, is situated at the mouth of the Shinano-*gawa*, the quarternary plain about the lower course of the latter and the neighbouring rivers being the largest in Japan next to the Tokyo plain. The city of Akita is at about 440 km to the north of Tokyo.

Pl. XXVI.

Fig. 8. Variation of the Yearly Earthquake Number in Tokyo compared with that of the Yearly Amount of the Precipitation at Akita and Niigata. 1876–1907.

The curve in black relates to the seismic frequency, and the curve in red to the precipitation.

y = Yearly Earthquake Number in Tokyo.
y' = Mean of the Yearly Amounts of the Precipitation at Akita and Niigata.

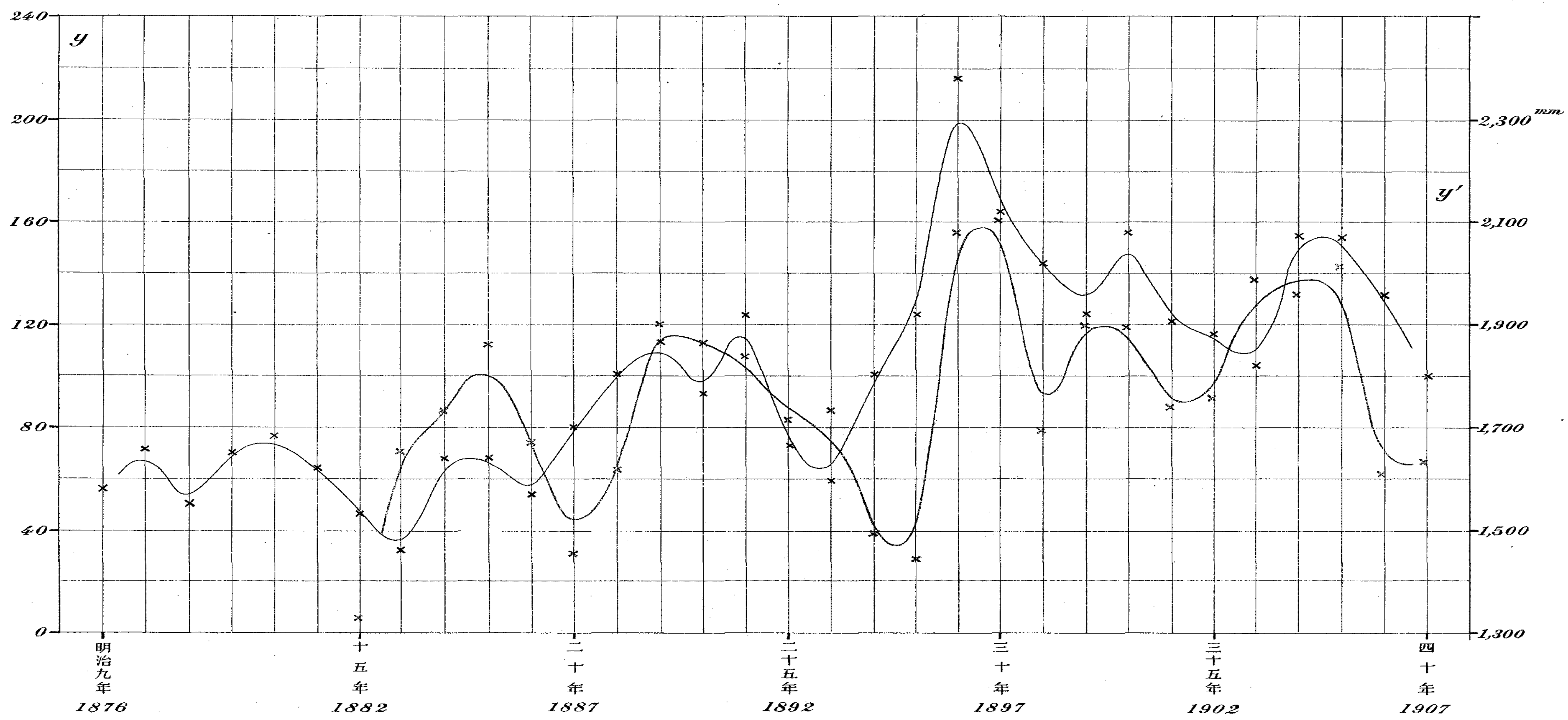
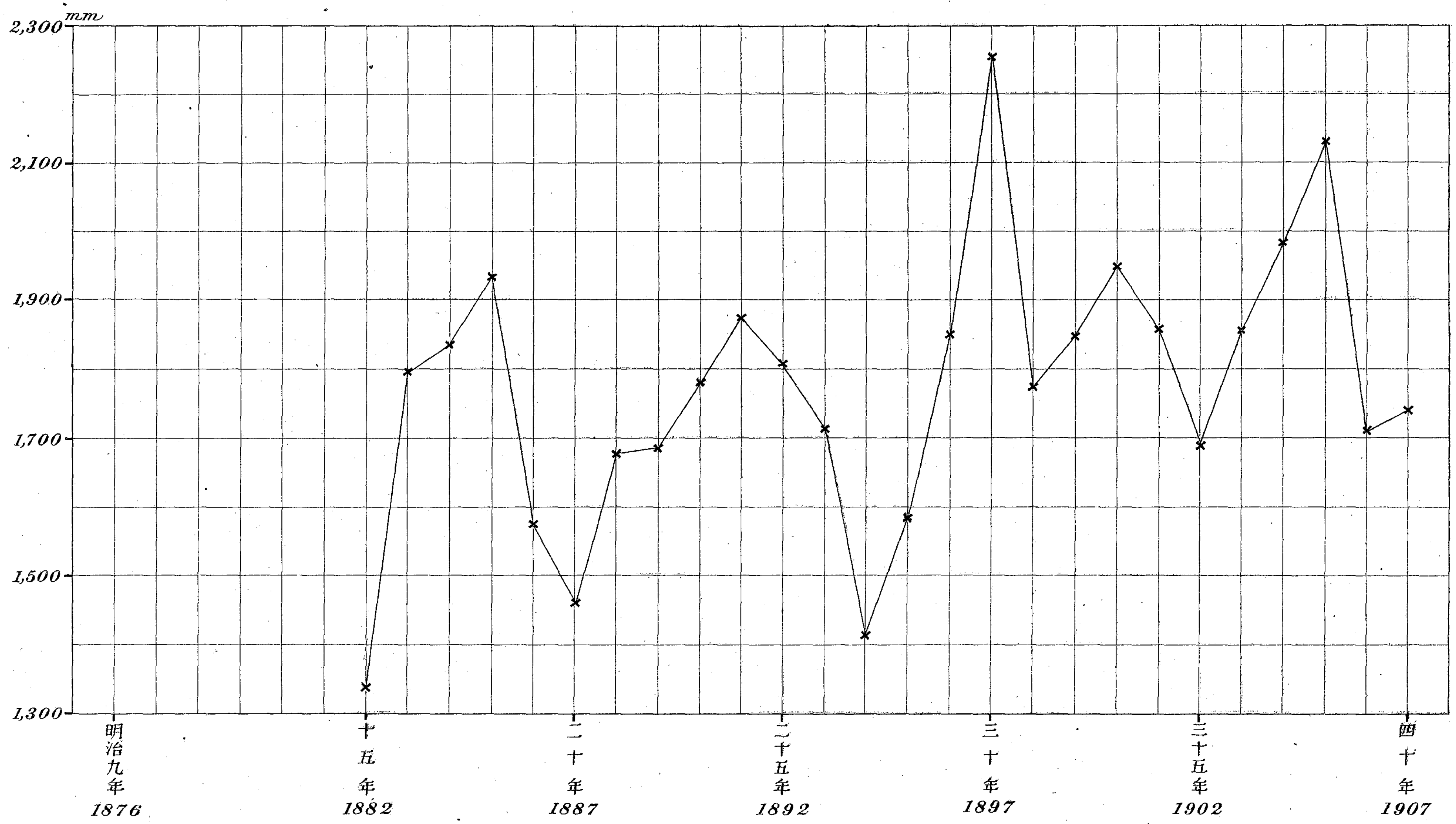


Fig. 9. Variation of the Yearly Amount of the Precipitation at Niigata.
1882–1907.



Pl. XXVIII.

Fig. 10. Variation of the Yearly Amount of the Precipitation at Akita.
1883-1907.

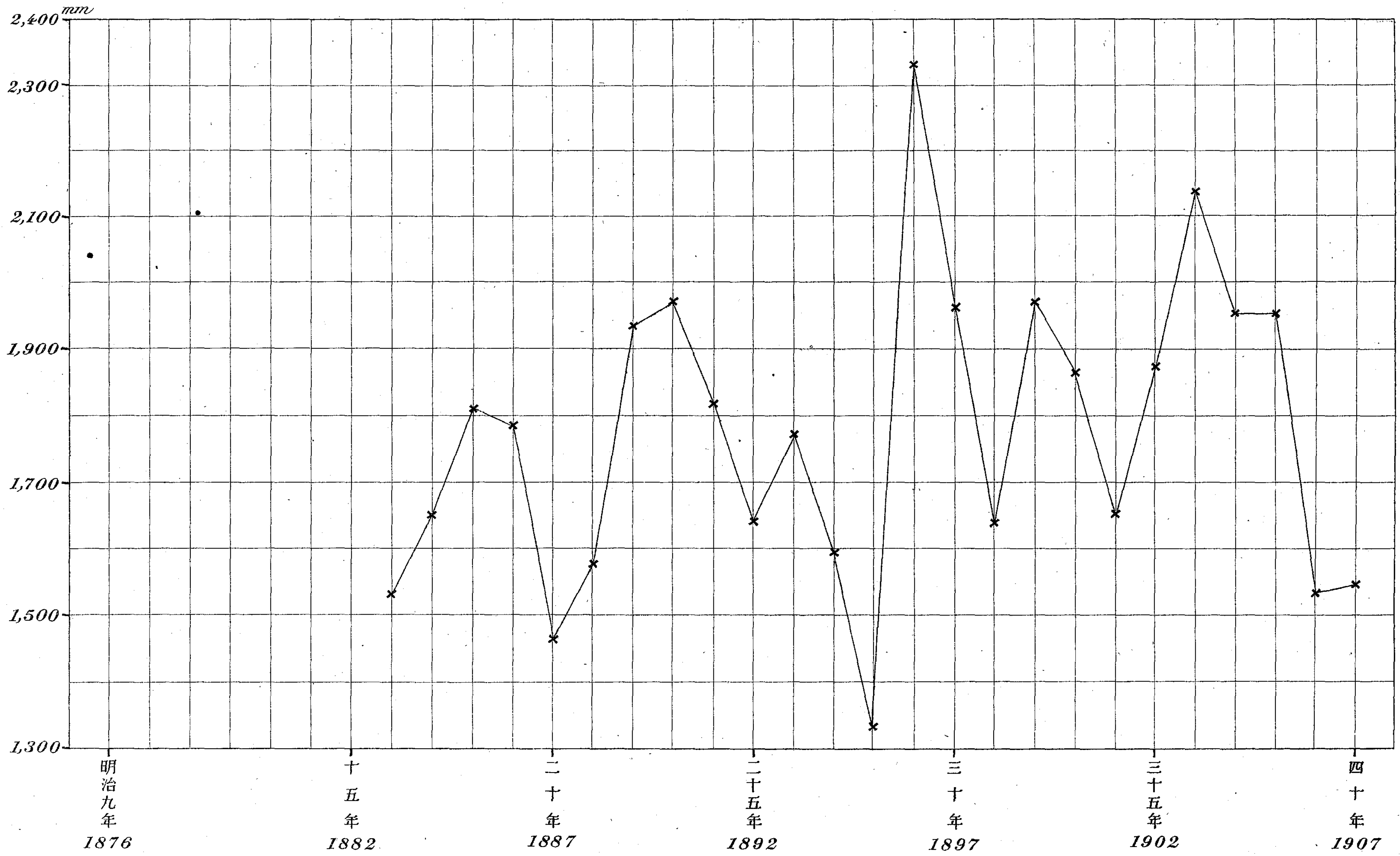


TABLE VI.—YEARLY NUMBERS OF EARTHQUAKES IN TOKYO, (1876–1907) AND THE AMOUNT OF PRECIPITATION AT NIIGATA AND AKITA (1882–1907.)

Year.	Number of Earthquakes in Tokyo.	Amount of Precipitation.		
		Niigata.	Akita.	*Mean.*
1876	56			
1877	71			
1878	50			
1879	70			
1880	77			
1881	64			
1882	46	1341.3mm	— mm	— mm
1883	32	1796.5	1536.4	1666.5
1884	68	1839.3	1650.1	1744.7
1885	68	1935.9	1809.5	1872.7
1886	54	1580.1	1786.0	1683.1
1887	80	1467.9	1465.3	1466.6
1888	101	1681.3	1579.6	1630.5
1889	113	1889.3	1937.6	1913.5
1890	93	1784.0	1971.6	1877.8
1891	123	1877.7	1820.0	1848.9
1892	73	1809.9	1641.4	1725.7
1893	59	1717.9	1775.2	1746.6
1894	101	1418.0	1596.1	1507.1
1895	122	1586.7	1331.0	1458.9
1896	216	1854.1	2335.1	2094.6
1897	164	2257.8	1964.5	2111.2
1898	144	1777.6	1639.0	1708.3
1899	124	1853.0	1972.3	1912.7
1900	156	1953.3	1864.0	1908.7
1901	121	1861.4	1651.6	1756.5
1902	116	1693.3	1853.8	1773.6
1903	104	1858.9	2141.4	2000.2
1904	155	1986.5	1956.2	1971.4
1905	154	2133.5	1957.2	2045.4
1906	132	1713.2	1535.0	1624.1
1907	100	1741.7	1548.8	1645.3

TABLE VII.—MEAN BAROMETRIC PRESSURE AND TEMPERATURE, AND THE AMOUNT OF PRECIPITATION.

TOKYO. 1876—1907.

Year	Mean Barometric Pressure.*	Mean Temperature.	Annual Amount of Precipitation.
	mm	°	mm
1876	761.1	13.6 C	1756.4
1877	61.5	13.9	1317.3
1878	61.5	13.6	1764.2
1879	61.0	14.4	1492.7
1880	61.3	13.9	1685.7
1881	61.4	13.6	1444.4
1882	61.5	13.8	1478.3
1883	61.4	13.2	1552.6
1884	61.2	12.8	1314.8
1885	61.3	13.0	1531.7
1886	61.5	13.9	1286.3
1887	60.8	13.8	1250.0
1888	61.0	13.5	1378.5
1889	61.2	13.3	1319.3
1890	61.0	15.0	1958.2
1891	61.2	14.4	1220.8
1892	61.0	14.0	1715.1
1893	61.2	13.8	1161.3
1894	61.5	14.8	1320.8
1895	61.1	13.8	1397.8
1896	61.5	14.0	1373.9
1897	61.6	13.2	1497.2
1898	61.2	13.9	1711.9
1899	60.7	13.8	1649.1
1900	61.0	13.6	1188.0
1901	60.3	13.8	1588.9
1902	60.7	13.7	1753.7
1903	61.1	13.7	1912.2
1904	60.8	13.7	1381.8
1905	61.2	13.5	1330.1
1906	60.3	13.1	1519.5
1907	60.7	13.5	1640.4

* With the freezing point, sea level, and gravity corrections.

The variation from year to year of the earthquake number in Tokyo seems to have no marked general relation to that of the amount of the precipitation, or to the mean temperature and barometric pressure, at the same place. The Tokyo seismic frequency varied, however, in a close parallelism with the amount of the precipitation at Niigata and Akita. As will be seen from Figs. 9 and 10, both the absolute amount of the precipitation and the general course of its variation with years were nearly alike for these two places; the annual amount of precipitation being in each case taken to be a function of the time. Fig. 8 illustrates the variation of the yearly seismic frequency in Tokyo, and of the mean amount of the precipitation at Niigata and Akita (Table VI). The curve for the seismic frequency will be observed to be, on the whole, similar to that for the precipitation (drawn in red); the highest values in both occurring in the two years 1896 and 1897. In fact the different maxima in the frequency correspond to those in the amount of the precipitation, and the two curves run nearly parallel to each other. This coincidence is probably not accidental, and the variation of the yearly number of the earthquakes felt in Tokyo may be taken to be approximately proportional to the amount of precipitation along the north-western side of the Main Island.

8. ***Weather and destructive earthquakes.*** In Japan, India, America, and probably also in some other countries, earthquakes are popularly supposed to occur specially in the so-called *earthquake weather*, namely, on sultry days. This is, however, not true, at least not generally. On the other hand, Carlyle says in his *French Revolution*: "Hope ushers in a Revolution,—as earthquakes are preceded by bright weather." Whatever may be the authority in seismological matters of the great British author, there were certainly many earthquakes which occurred in bright weather.

Indeed the relation of earthquakes to weather is a very complicated question, as it involves the considerations of the atmospheric pressure, temperature and moisture, and the precipitation. Large shocks and small shakings are often governed, in their time distribution, by entirely opposite laws. So are also earthquakes of inland origin and those of submarine origin. For the present, I shall confine myself to the consideration of some of the great destructive earthquakes in Japan, of which we have the record of the state of the accompanying weather. There were 18 of these shocks, as follows.

TABLE VIII.—RELATION TO WEATHER OF THE DESTRUCTIVE EARTHQUAKES.

No.	Date.	Time of Occurrence.	Provinces strongly shaken.	Remarks on the Weather.
1	正平十六年六月廿四日 Aug. 3, 1361.	4 am.	Kinai Provinces,* Kii, Awa. (Accompanied by *tsunami*.**)	Fair (Kyoto)
2	明應七年八月廿五日 Sept. 20, 1498.	9 am.	Ise, Totomi, Mikawa, Kai, Suruga, Sagami, Izu. (Accompanied by *tsunami*.)	Do.
3	永正七年八月八日 Sept. 21, 1510.	3 am.	Settsu. The *torii*, or temple gate of Shitenno-ji, overthrown.	Do.
4	天正十三年十一月廿九日 Jan. 18, 1585.	Midnight.	Kinai Provinces, Omi, Mino, Owari, Ise, Mikawa. (Accompanied by *tsunami*.)	Snowy (Kyoto).
5	慶長元年閏七月十二日 Sept. 4, 1596.	1 am.	Yamashiro, Settsu, Izumi. (The great Keicho Earthquake, which destroyed the castle of Fushimi.)	Fair (Kyoto). Continued to be fair till 8th; rain and wind on 9th.
6	寛文二年五月一日 June 16, 1662.	11 am.	Kinai Provinces, Tanba, Wakasa, Omi, Mino, Ise, Suruga, Mikawa, Shinano. (The Kwanbun Earthquake).	In Kyoto, occasional rains from the previous evening; heavy rainfall at the time of the shock.

* The Kinai Provinces are Yamashiro, Yamato, Kawachi, Izumi, and Settsu.

** *Tsunami* denotes the great tidal disturbances, which may be caused by submarine earthquakes, volcanic eruptions, or by barometric depressions.

TABLE VIII. *(Cont.)*

No.	Date.	Time of Occurrence.	Provinces strongly shaken.	Remarks on the Weather.
7	寛文五年十一月廿七日 Feb. 1, 1666.	5 pm.	Takata (Echigo.)	Heavy snow fall, to the amount of some 15 feet.
8	元祿十六年十一月廿三日 Dec. 31, 1703.	3 am.	Yedo (Tokyo), Sagami, Awa, Kazusa. Accompanied by *tsunami*. (The Genroku Earthquake.)	Fair in Yedo (Tokyo). Calm and clear in Kyoto.
9	寶永四年十月四日 Oct. 28, 1707.	1 pm.	Kyushu to Tokaido. (The Hoei Earthquake, the greatest of the disturbances that ever shook Japan in the historical times.)	In Kyoto, clear and calm. In Tosa (Shikoku), very clear and bright, with no cloud at all; no wind throughout the day, and warm as in summer.
10	享和二年十一月十六日 Dec. 9, 1802.	Early morning.	Ogi (province of Sado.)	On the 8th, very clear and calm.
11	文政十一年十一月十二日 Dec. 18, 1828.	7 am.	Sanjo and vicinity (province of Echigo). (The Bunsei Earthquake.)	Great snow storm in the night of the 17th, and some rain and strong winds in the morning of the 18th.
12	天保元年七月二日 Aug. 19, 1830.	4 pm.	Kyoto and the Kinai Provinces. (The Tenpo Earthquake.)	Fair on the 18th—20th; heavy rain on the 21st; fair on the 22nd and 23rd; some rain on the 24th.
13	弘化四年三月廿四日 May 8, 1847.	10 pm.	Shinano and Echigo. (The great Zenkoji Earthquake.)	Clear, calm and warm, in the day time and the evening of the 8th.
14	安政元年六月十五日 July 9, 1854.	2 am.	Kinai Provinces, Iga, Ise, Kii. (One of the Ansei Earthquakes.)	On the 8th, fair during the day time, with rain and thunder in the evening (Kyoto).
15	安政元年十一月四日 Dec. 23, 1854.	9 am.	Tokaido. (One of the Ansei Earthquakes.)	Fair in Kyoto, Kii, and the Tokaido provinces.
16	安政元年十一月五日 Dec. 24, 1854.	5 pm.	Saikaido and Nankaido. (One of the Ansei Earthquakes.)	Same fair weather as on the provious day.
17	安政二年十月二日 Nov. 11, 1855.	10 pm.	Yedo (Tokyo.)	During the day, cloudy and slightly rainy. Cleared up in the evening, the wind being unusually calm.

TABLE VIII. (*Cont.*)

No.	Date.	Time of Occurrence.	Provinces strongly shaken.	Remarks on the Weather.
18	明治廿四年十月廿八日 Oct. 28, 1891.	6.37 am.	Mino-Owari Eqke.	At Gifu, the amount of precipitation during October 1891 was unusually small, there being no rain fall at all between the 1st and 22nd of the month. Since the 23rd, there were some occasional rains, which ceased completely at about 6h 40m am. on the 28th. The sky began to clear up from about 8h 15m am. in the same morning. The great earthquake took place at 6h 37m am., while the barometer was falling.

The relation to weather of the 18 earthquakes mentioned in the above table was as follows :—

Fair or clear weather	....	12	earthquakes.
Cloudy „	....	2	„
Rainy or snowy „	....	3	„
Rainy and windy „	....	1	„

Thus it will be observed that 12 *out of the* 18 *earthquakes occurred in fair or clear weathers.* There was only one case, No. 7, in which the weather was rainy and windy. This, however, took place in Echigo, where there is during the winter months much wind and precipitation, so that it is not at all surprising that a strong earthquake should occur at Takata in a bad weather. Again, of the 18 destructive earthquakes, none occurred in a wet sultry weather, which is a contradiction to the popular belief before referred to. It is extremely probable that *great shocks do not occur in very bad weathers.*

The two great earthquakes of Hoei and Zenkoji (Nos. 9 and

13) and the Ogi earthquake (No. 10), whose dates were from Oct. 28 to May 8, took place each on a very clear, calm and warm day. It is probable that these destructive seismic disturbances happened when, after the passage of the atmospheric depressions, the whole of Japan was covered by the high pressure, so that the weather was fine and calm, and consequently warm in the day time; just in the same way as a snow storm in Tokyo is generally followed by a bright and warm day.

9. ***Earthquake weather and fires.*** None of the destructive earthquakes in Japan ever happened in the midst of a violent storm. This is a very fortunate circumstance in connection with the disastrous fires which so often break out after great shocks. Thus, on the occasion of the Yedo (Tokyo) earthquake of the 2nd year of Ansei, (No. 17), which took place at 10 pm., and which caused a loss of about 7,000 lives, fires broke out at 32 different places in the city. Owing, however, to the stillness of air, all these fires were put out before the day-break, the aggregate area of the burnt districts being about 1 square mile. This amount of the damage is much smaller than in the cases of some of the metropolitan fires, which were not connected with earthquakes. For instance, the famous Maruyama fire of the 3rd year of Meireki, on March 2, 1657, caused the loss of 107,046 lives; while the great fire of April 1, 1772, began at Meguro and reached, within 24 hours, to the Koishikawa, Shitaya, and other northern districts, reducing to ashes all the buildings within an area 24 km in length and 4 km in width. These and other gigantic fires in Yedo (Tokyo) all occurred on the occasion of great stroms, and, in the case of the Meireki catastrophe, the wind velocity is supposed to have reached 60 miles per hour. As, however, the destructive earthquakes never occurred on stormy days it is to be expected that the fires following these would not extend so enormously, provided means be properly taken for subduing the flames.*

10. ***Effects of barometric pressure and tides.*** Let us next consider the effects on the seismic frequency of the tides combined with the barometric pressure, confining our attention to the stronger or larger earthquakes, which originated in the vicinity of Tokyo or off the north-eastern coast of the Main Island. The times of the high or low waters of the tide given in the subsequent tables, relate to the tide-gauge station of Reigan-jima, Tokyo, and are practically identical to those for Yokohama. The tidal movements along the north-eastern coast of the Main Island take place some half an hour earlier than those at Tokyo and Yokohama.

11. ***Stronger earthquakes originating from the Izu island zone.*** Table IX is a list of the 14 recent stronger submarine earthquakes, which originated along the Fuji volcanic chain, namely, from among the Izu islands or in the vicinity of Hachijo, Ogasawara (Bonin), and other islands some distance off the coast of Izu peninsula; the moment of the high or low water at Reigan-jima (Tokyo) nearest to the time of occurrence of each earthquake being also given for the sake of comparison.

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* §§ 8 and 9 are translations of my notes in Japanese published in the "Toyo Gakugei Zasshi," Dec. 1906.

TABLE IX.—LIST OF THE RECENT STRONGER SUBMARINE EARTHQUAKES WHICH ORIGINATED ALONG THE FUJI VOLCANIC CHAIN.

(i) Date.	(ii) Time of Eqke. Occurrence.	(iii) Time of High or Low water at Reigan-jima (Tokyo).		Time Difference (ii)-(iii).
April 16, 1890.	9h 30m pm.	9h 18m pm.	Low water.	0h 12m
Feb. 12, 1896.	6 38 am.	4 43 am.	High water.	1 55
May 7, „	2 37 pm.	1 51 pm.	„	0 46
Jan. 18, 1897.	9 27 „	0 38 am. (next day).	Low water.	—
March 27, 1898.	3 24 am.	2 59 am.	„	0 25
Jan. 31, 1900.	2 38 „	0 23 „	„	2 15
Nov. 5, „	4 41 pm.	3 45 pm.	High water.	0 56
„ 9, „	2 55 am.	1 29 am.	Low water.	1 26
„ 19, „	10 59 pm.	10 30 pm.	„	0 29
Feb. 20, 1902.	10 50 am.	10 44 am.	„	0 06
June 3, 1903.	0 28 pm.	11 36 „	High water.	0 52
Nov. 13, 1904.	9 49 am.	8 55 „	„	0 54
June 7, 1905.	2 40 pm.	3 03 pm.	Low water.	−0 23
May 4, 1907.	5 37 „	4 43 „	„	0 54

With regard to the diurnal variation of the barometric pressure, the times of the earthquakes tabulated above may be grouped, except the 2nd and the last, as follows:—

(*A*).....	9h 30m pm.	(*C*).....	2h 37m pm.
	9 27 „		4 41 „
	10 50 „		0 28 „
			2 40 „
(*B*).....	10 50 am.	(*D*).....	3 24 am.
	9 49 „		2 38 „
			2 55 „

The two groups *A* and *B* occurred at the hours of the barometric maximum, while the two other groups *C* and *D* occurred at the hours of the barometric minimum.

The difference between the time of earthquake occurrence and the nearest moment of the high or low water of the tide varied, except in the case of the 4th earthquake, between 0h 12m and 2h 15m, giving the average value of 50m. This is to be regarded as the interval by which the different earthquakes followed, except in one case, the high or low water in the Tokyo Bay, which happens not much apart in time from that along the islands of the zone in question.

12. ***Recent strong earthquakes felt in Tokyo.*** In § 8 I have considered some of the great destructive earthquakes in Japan in relation to weather. Turning now our attention to the recent earthquakes felt in Tokyo, we have 14 cases, in which the motion was strong or severe; amongst others, the shock (No. 7) of June 20, 1894, was semi-destructive and caused a considerable amount of damage. The relation of their times of occurrence to the low or high water epoch of the tide and the barometric pressure is shown in the following table.

TABLE X.—LIST OF STRONG EARTHQUAKES FELT IN TOKYO.

(h)....High water; (l)....Low water.

No.	Date.	Time of Earthquake Occurrence.	Time of High or Low Water at Reigan-jima, Tokyo Bay.	Barometric Pressure. (With sea-level and freezing point corrections).
1	Feb. 22, 1880.	0h 49m am.	2h 08m am. (h)	**Min.** 754.6 mm. Pressure rose after the shock.
2	Oct. 15, 1884.	4 21 am.	2 00 am. (h)	**Min.** 754 mm, at 4 pm., on 14th.
3*	Jan. 15, 1887.	6 51 pm.	{ 9 48 pm. (h) 3 36 pm. (l)	**Min.** 754 mm, at 2 am., on 15th.
4*	April 29, 1888.	10 00 am.	{ 7 13 am. (h) 1 25 pm. (l)	Bar. height=759 mm, pressure decreasing.
5	Feb. 18, 1889.	6 09 am.	7 04 am. (h)	**Min.** 746 mm, at 2 pm., on 17th.
6*	Dec. 24, 1891.	5 30 am.	5 07 am. (l)	Bar. height=762 mm, pressure increasing.
7*	June 20, 1894.	2 04 pm.	0 42 pm. (l)	**Min.** 754.7 mm, at 3–8 pm., on 20th.
8	Jan. 18, 1895.	10 48 pm.	10 49 pm. (h)	**Min.** Mean pressure on 18th=752.6 mm.
9	April 23, 1901.	3 10 am.	3 23 am. (l)	On 23rd, Min. 757 mm, at 4 am., Pressure increasing
10	June 23, 1902.	7 43 am.	6 31 am. (h)	**Min.** 741.5 mm, at 7 am, on 24th.
11	Feb. 24, 1906.	9 14 am.	6 57 am. (h)	Mean pressure on 24th=759 mm. Barometer ascending.
12	June 11, 1907.	8 59 am.	{ 4 29 am. (h) 1 16 pm. (l)	**Min.** 746 mm, at 10 pm., on 13th.
13	Sept. 22, 1907.	4 50 am.	5 27 am. (h)	Pressure in the normal condition. Bar. height=756 mm at 6 am., on 22nd.
14*	Nov. 22, 1907.	2 17 am.	2 06 am. (l)	**Max.** 774 mm, at 6 am., on 22nd.

* Earthquakes of inland origin.

With regards to the atmospheric pressure, it is a notable fact that 8 out of the 14 earthquakes were accompanied by the marked depression of 741.5 to 754.7 mm. and one by a very high pressure of 774 mm; there being only 5 earthquakes which occurred when the pressure was in the normal condition, between 756 and 762 mm. Of the 8 cases of barometric minima above noted, 4 preceded, 2 followed, and 2 were nearly simultaneous with the respective earthquakes. These relations to the atmospheric pressure of the strong and severe shocks need not necessarily be similar to those in the case of the great destructive earthquakes (§ 8).

The difference between the time of earthquake occurrence and that of the corresponding high or low water of the tide varied in 11 out of the 14 cases, between 0h 0m and 2h 21m; only in the 3 remaining cases, earthquakes happened midway between the high and low waters. Again, of the 8 earthquakes accompanied by barometric depressions, six were of submarine origin, and five of these occurred near the time of the high waters. On the other hand, of the 5 earthquakes of inland origin, three occurred with the low water and two between the low and high waters.

13. ***List of the stronger earthquakes whose origins were not much distant from Tokyo.*** The two tables XI and XII give a list of the 145 stronger earthquakes, which happened between 1902 and 1907, and whose origins were mostly in the Kwanto provinces* or off their coasts not much distant from Tokyo. The land area of disturbance of each of these earthquakes, including that in which the motion was insensible but was recorded by the ordinary Gray-Milne-Ewing type seismographs, was greater than 1,000 square *ri*. (See also the *Bulletin*, Vol. II, No. 1.) The time of the low or high water in the Tokyo Bay nearest to that of each of the earthquakes is given in the 4th column of the two tables. The different earthquakes are divided into ten groups according to the positions of their origins.

* The Kwanto provinces are Sagami, Musashi, Awa, Kazusa, Shimosa, Hitachi, etc.

TABLE XI.—STRONGER EARTHQUAKES WHOSE CENTRES WERE NOT MUCH DISTANT FROM TOKYO. INLAND ORIGIN.

Origin of Eqke.	Date.	(i) Time of Earthquake Occurrence.	(ii) Time of the High or Low Water.	Time Difference (i)-(ii).
Group I. Musashi (eastern part excepted.)	Dec. 9, 1902	1h 53m am.	{ 5h00m am. (l) / 11 02 pm. (h) (preceding day).	h m ——
	March 13, 1903	3 04 pm.	5 23 pm. (h)	−2 19
	April 24, 1905	5 15 am.	3 33 am. (l)	1 42
	May 30, „	4 32 am.	2 33 am. (h)	1 59
	May 10, 1906	2 34 pm.	1 54 pm. (l)	0 40
	July 27, 1907	4 23 pm.	1 55 pm. (l)	2 28
	Nov. 10, „	2 03 am.	3 12 am. (l)	−1 09
	„ 22, „	2 17 am.	2 06 am. (l)	0 11
Group II. Sagami.	Jan. 17, 1902	4 18 am.	4 59 am. (l)	−0 41
	April 1, „	5 32 am.	5 03 am. (l)	0 29
	July 1, „	2 01 am.	0 40 am. (h)	1 21
	Sept. 16, „	3 19 am.	4 09 am. (h)	−0 50
	July 9, 1903	3 00 pm.	{ 0 11 pm. (l) / 5 14 pm. (h)	——
	Jan. 15, 1906	7 55 am.	8 49 am. (h)	−0 54
Group III. Western part of Hitachi, and Shimotsuke.	March 3, 1902	2 35 pm.	0 36 pm. (l)	1 59
	June 20, „	5 49 pm.	4 58 pm. (h)	0 51
	Nov. 5, „	5 49 pm.	{ 3 00 pm. (l) / 8 08 pm. (h)	——
	March 13, 1903	1 11 pm.	0 21 pm. (l)	0 50
	July 6, „	3 19 am.	2 42 am. (h)	0 37
	„ 15, „	4 51 am.	3 16 am. (l)	1 35
	„ 21, „	2 06 pm.	2 24 pm. (h)	−0 18
	April 27, 1904	3 14 am.	3 00 am. (h)	0 14
	Sept. 17, 1906	5 27 pm.	5 18 pm. (h)	0 09
	April 18, 1907	2 33 am.	2 23 am. (l)	0 10
Group IV. Kai.	May 25, 1902	8 29 pm.	7 02 pm. (h)	1 27
	Feb. 3, 1903	4 59 am.	3 27 am. (l)	1 32

TABLE XI. *(Cont.)*

Origin of Eqke.	Date.	(i) Time of Earthquake Occurrence.	(ii) Time of the High or Low Water.	Time Difference (i)-(ii).
	March 3, 1902	9h 13m am.	11h 13m am. (h)	−2h 00m
	,, 25, ,,	2 35 pm.	1 09 pm. (l)	1 26
	May 15, ,,	7 38 am.	5 57 am. (l)	1 41
	Aug. 8, ,,	8 37 am.	8 05 am. (h)	0 32
	Dec. 14, ,,	1 57 pm.	4 35 pm. (h)	−2 38
	,, 31, ,,	2 38 pm.	1 14 pm. (l)	1 24
	Jan. 5, 1903	8 44 am.	9 00 am. (h)	−0 16
	March 12, ,,	5 35 am.	4 23 am. (h)	1 12
	April 22, ,,	5 02 am.	7 55 am. (l)	−2 53
	May 6, ,,	8 52 am.	7 27 am. (l)	1 25
	June 7, ,,	8 38 am.	10 11 am. (l)	−1 33
	Dec. 9, ,,	8 55 am.	8 30 am. (h)	0 25
Group V. Shimosa, vicinity of Kasumiga-ura (Hitachi), Kazusa, eastern part of Musashi.	March 12, 1904	6 12 am.	8 51 am. (l)	−2 39
	April 4, ,,	8 20 am.	7 49 am. (h)	0 31
	May 8, ,,	7 24 am.	6 03 am. (l)	1 21
	June 30, ,,	8 21 am.	6 43 am. (h)	1 38
	Aug. 4, ,,	9 49 pm.	10 34 pm. (h)	−0 45
	Oct. 5, ,,	0 35 am.	1 24 am. (h)	−0 49
	April 6, 1905	9 30 pm.	{ 6 16 pm. (h) 1 31 am. (l) (next day).	——
	May 30, ,,	4 32 am.	2 33 am. (h)	1 59
	June 11, ,,	11 51 pm.	{ 0 12 am. (h) (next day).	−0 21
	Sept. 21, ,,	10 00 pm.	10 05 pm. (h)	−0 05
	,, 24, ,,	2 08 am.	0 50 am. (h)	1 18
	Oct. 19, ,,	9 10 am.	8 18 am. (h)	0 52
	Jan. 9, 1906	6 51 pm.	{ 3 39 pm. (h) 0 42 am. (l) (next day).	——
	Feb. 18, ,,	2 15 pm.	11 22 am. (h)	2 53
	May 21, ,,	3 56 pm.	4 57 pm. (h)	−1 01
	,, 29, ,,	11 22 pm.	10 11 pm. (h)	1 11

TABLE XI. *(Cont.)*

Origin of Eqke	Date.	(i) Time of Earthquake Occurrence.	(ii) Time of the High or Low Water.	Time Difference. (i)—(ii)
Group V. Shimosa, Vicinity of Kasumiga-ura (Hitachi), Kazusa, eastern part of Musashi. *(Cont.)*	Aug. 21, 1906	5^h 42^m am.	$5^h 23^m$ am. (h)	0^h 19^m
	„ 22, „	0 08 am.	1 13 am. (l)	−1 05
	Oct. 6, „	6 35 pm.	6 43 pm. (h)	−0 08
	Nov. 12, „	11 07 pm.	10 03 pm. (l)	1 04
	Dec. 24, „	5 46 pm.	8 06 pm. (l)	−2 20
	Jan. 3, 1907	3 42 am.	2 39 am. (l)	1 03
	Feb. 22, „	9 57 pm.	8 02 pm. (l)	1 55
	March 13, „	0 38 am.	11 53 pm. (l) (preceding day)	0 45
	July 2, „	5 45 am.	4 32 am. (l)	1 13
	Nov. 28, „	11 28 am.	0 01 pm. (h)	−0 33
	Dec. 11, „	5 54 pm.	4 11 pm. (l)	1 43

TABLE XII.—STRONGER EARTHQUAKES WHOSE CENTRES WERE NOT MUCH DISTANT FROM TOKYO. SUBMARINE ORIGIN.

Origin of Eqke.	Date.	(i) Time of Earthquake Occurrence.	(ii) Time of the High or Low Water.	Time Difference. (i)—(ii)
Group VI. Off the coast of Hitachi.	May 17, 1902	1^h 18^m pm.	$1^h 50^m$ pm. (h)	-0^h 32^m
	Oct. 16, „	1 57 am.	4 16 am. (h)	−2 19
	Feb. 13, 1903	0 45 pm.	1 28 pm. (l)	−0 43
	July 1, „	9 10 am.	10 03 am. (h)	−0 53
	Dec. 18, „	11 20 am.	11 54 am. (l)	−0 34
	March 8, 1904	3 40 am.	4 31 am. (l)	−0 51
	Oct. 2, 1905	10 54 am.	7 26 am. (h) 2 42 pm. (l)	——
	Dec. 26, „	0 11 pm.	0 22 pm. (l)	−0 11
	Jan. 25, 1907	6 35 pm.	10 12 pm. (l) 1 02 pm. (h)	——
	April 30, „	0 51 pm.	2 05 pm. (l)	−1 14
	May 5, „	2 16 am.	4 51 am. (l)	−2 35
	Oct. 15, „	9 05 am.	6 02 am. (l) 1 54 pm. (h)	——

TABLE XII. *(Cont.)*

Origin of Eqke.	Date.	(i) Time of Earthquake Occurrence.	(ii) Time of the High or Low Water.	Time Difference. (i)—(ii)
Group VII. Off the coast of Shimosa.	Nov. 13, 1902	8^h 15^m am.	10^h06^m am. (l)	-1^h 51^m
	Oct. 27, 1904	6 24 am.	6 37 am. (h)	−0 13
	Dec. 12, „	9 56 am.	{ 5 29 am. (h) { 0 46 pm. (l)	——
	Oct. 10, 1905	10 54 am.	10 21 am. (l)	0 33
	Nov. 2, „	11 21 am.	8 45 am. (h)	2 36
	May 18, 1906	9 36 pm.	9 03 pm. (l)	0 33
	„ 19, „	1 31 am.	2 41 am. (h)	−1 10
Group VIII. Off the E. coast of Awa-Kazusa Peninsula.	July 26, 1902	7 51 am.	8 39 am. (h)	−0 48
	Jan. 31, 1903	1 47 am.	1 47 am. (l)	0 00
	March 26, „	0 59 am.	3 37 am. (h)	−2 38
	April 19, „	7 48 pm.	{ 5 02 pm. (l) {10 36 pm. (h)	——
	July 12, 1904	7 40 pm.	4 46 pm. (h)	2 54
	„ 15, „	3 44 am.	1 39 am. (l)	2 05
	„ 16, „	10 09 am.	7 26 am. (h)	2 43
	„ 17, „	4 27 am.	3 08 am. (l)	1 19
	„ 18, „	7 51 pm.	9 29 pm. (h)	−1 38
	„ 19, „	6 20 pm.	5 03 pm. (l)	1 17
	„ 20, „	0 30 pm.	10 58 am. (h)	1 32
	Feb. 17, 1906	6 41 am.	{ 4 20 am. (l) { 9 52 am. (h)	——
	„ 23, „	6 49 pm.	5 13 pm. (h)	1 36
	„ 24, „	9 14 am.	6 50 am. (h)	2 24
	March 6, „	1 38 am.	2 48 am. (h)	−1 10
	„ 14, „	8 32 pm.	8 13 pm. (h)	0 19
	April 8, „	2 52 pm.	0 41 pm. (l)	2 11
	May 7, „	8 01 am.	{ 3 55 am. (h) {11 27 am. (l)	——
	„ 28, „	6 59 am.	6 45 am. (h)	0 14
	Sept. 9, „	3 53 am.	3 23 am. (l)	0 30
	Oct. 19, „	9 29 pm.	{ 5 31 pm. (h) { 1 45 am. (l)	——

TABLE XII. *(Cont.)*

Origin of Eqke.	Date.	(i) Time of Earthquake Occurrence.	(ii) Time of the High or Low Water.	Time Difference. (i)—(ii)
Group VIII. Off the coast of Awa-Kazusa Peninsula. *(Cont.)*	Nov. 11, 1906	0h 33m am.	11h28m pm. (h) (preceding day).	1h 05m
	„ 23, „	3 32 pm.	5 52 pm. (l)	−2 20
	Jan. 25, 1907	0 33 am.	3 26 am. (h)	−2 53
	Feb. 6, „	5 38 pm.	5 18 pm. (l)	0 20
	June 11, „	8 59 am.	4 29 am. (h) 1 16 pm. (l)	——
	„ 14, „	1 43 pm.	2 38 pm. (l)	−0 55
	Sept. 22, „	4 50 am.	5 27 am. (h)	−0 37
Group IX. Off the coast of Sagami, and outside the Tokyo Bay.	Apri 18, 1904	8 03 pm.	6 57 pm. (h)	1 06
	Jan. 8, 1906	11 00 pm.	11 50 pm. (l)	−0 50
	Nov. 7, „	11 54 pm.	6 46 pm. (h) 4 16 am. (l) (next day)	——
	Oct. 13, 1907	1 46 pm.	2 35 pm. (l)	−0 49
Group X. Tokyo Bay, and Uraga Channel.	March 12, 1902	10 48 am.	1 53 pm. (l) 6 36 am. (h)	——
	April 5, „	7 23 pm.	10 16 pm. (l)	−2 53
	„ 6, „	2 13 am.	3 30 am. (h)	−1 17
	June 23, „	7 42 am.	6 31 am. (h)	1 11
	Aug. 7, „	0 36 pm.	2 40 pm. (l)	−2 04
	Oct. 12, „	10 24 am.	7 41 am. (l) 1 38 pm. (h)	——
	Aug. 23, 1903	9 33 pm.	5 47 pm. (h) 1 05 am. (l)	——
	Oct. 27, „	9 57 pm.	9 47 pm. (h)	0 10
	Nov. 6, „	7 04 pm.	5 53 pm. (h)	1 11
	„ 10, „	6 51 pm.	3 51 pm. (l) 9 04 pm. (h)	——
	Feb. 26, 1904	5 50 pm.	7 39 pm. (l)	−1 49
	May 17, „	4 03 pm.	1 35 pm. (l)	2 28
	„ 27, „	5 41 am.	3 28 am. (h)	2 13
	„ „ „	7 46 am.	10 36 am. (l)	−2 50
	March 4, 1905	9 18 pm.	11 53 pm. (l)	−2 35
	„ 6, „	6 08 am.	5 26 am. (h)	0 42

TABLE XII. (*Cont.*)

Origin of Eqke.	Date.	(i) Time of Earthquake Occurrence.	(ii) Time of the High or Low Water.	Time Difference. (i)—(ii).
	July 19, 1905	5^h 03^m pm.	$7^h 11^m$ pm. (h)	-2^h 08^m
	Aug. 12, „	9 28 pm.	10 35 pm. (l)	−1 07
	Sept. 3, „	2 02 am.	2 42 am. (l)	−0 40
	Oct. 14, „	11 54 am.	0 44 pm. (l)	−0 50
	Dec. 30, „	7 53 pm.	8 24 pm. (h)	−0 31
Group X. Tokyo Bay, and Uraga Channel. (*Cont.*)	Jan. 9, 1906	9 56 pm.	0 42 am. (l) (next day)	−2 46
	May 21, „	2 21 pm.	4 57 pm. (h)	−2 36
	„ 24, „	2 17 pm.	1 33 pm. (l)	0 44
	„ 30, „	9 27 pm.	11 02 pm. (h)	−1 35
	Aug. 5, „	4 53 am.	5 02 am. (h)	−0 09
	„ „ „	5 32 am.	„	0 30
	Oct. 1, 1907	6 16 pm.	7 18 pm. (l)	−1 02
	Nov. 21, „	1 32 pm.	0 33 pm. (l)	0 59

Earthquakes of Inland Origin, Groups I to IV. Groups I to IV, Table XI, include the 26 earthquakes which originated, in the regions adjacent to the plain of the lower course of the Tone-*gawa* and its tributaries, namely, in the provinces of Musashi (eastern part excepted), Sagami, western part of Hitachi, Shimotsuke, and Kai. A striking feature in the diurnal distribution of these inland earthquakes is that, with the exception of the two, which occurred between 7 and 9 pm., they have all taken place between 1 and 6 am. and 1 and 6 pm., namely, at those hours when the barometric pressure is maximum. (See also Table XIII.)

The relation of the 26 earthquakes to the phases of the tide, was as follows :—

(*a*) 11 occurred with the high tide ;

(*b*) 12 occurred with the low tide;
(*c*) 3 ,, between the high and low tides.

Again of the earthquakes of (*a*) and (*b*), 17 occurred after, and 6 occurred before, the low or high water. Taking the average from the cases of these 23 earthquakes, the latter followed the high or low water by a mean interval of 31 minutes.

Earthquakes of Inland Origin, Group V. The earthquakes of Group V originated in the extensive quarternary tracts, which comprise the province of Shimosa, the vicinity of the Kasumiga-ura (Hitachi), the eastern part of the province of Musashi, and a portion of Kazusa. The positions of the origins of some of these earthquakes, all inferred from the area of disturbance and the isoseismal lines, are uncertain, and were possibly off the Pacific coast of the Awa-Kazusa peninsula.

In the diurnal distribution, the earthquakes of Group V do not show the same characteristic as those of Groups I to IV, but are similar to the submarine disturbances of Groups VI to X. Out of the 39 earthquakes, 21 occurred with the high water, 15 with the low water, and the remaining 2 between the high and low waters. Again, 23 of these earthquakes took place *before*, and 15 *after*, the high or low water.

Earthquakes of Submarine Origin. The 80 earthquakes of Groups VI to X originated off the Pacific coasts of the provinces of Hitachi, Shimosa, and Sagami, and of the Awa-Kazusa peninsula, or in the Tokyo Bay. The following table gives the hourly frequency of these earthquakes taken conjointly with those of Group V, as well as that of the inland shocks, Groups I to IV.

TABLE XIII.—DIURNAL VARIATION OF THE EARTHQUAKES OF GROUPS I to X.

Hour.	A.M. (a) Eqkes of Groups I to IV. (Inland Origin.)		A.M. (b) Eqkes of Groups V to X.		P.M. (a) Eqkes of Groups I to IV. (Inland Origin.)		P.M. (b) Eqkes of Groups V to X.	
0—1	0	14	6	28	0	10	5	24
1—2	1		4		1		5	
2—3	4		4		3		6	
3—4	3		4		2		2	
4—5	4		4		1		1	
5—6	2		6		3		5	
6—7	0	1	5	35	0	1	7	32
7—8	1		5		0		6	
8—9	0		10		1		2	
9—10	0		6		0		11	
10—11	0		5		0		1	
11—12	0		4		0		5	

As will be seen from the above table, the earthquakes of the submarine and coast origins, namely, those of Groups V to X, show a tendency of occurring more frequently between 6 and 12 am., and between 6 and 12 pm., than during the earlier hours both in the forenoon and afternoon. This is approximately the reverse of the order of occurrence of the maxima in the diurnal variation of the earthquakes of inland origin, Groups I to IV.

Of the 80 submarine earthquakes of Groups VI to X, 33 each occurred with the high and low waters, while the remaining 14 occurred between these two phases of the tide. Again, 29 of the earthquakes occurred *after*, and 38 *before*, the times of the high or low water.

TABLE XIV.—SIX-HOURLY DISTRIBUTION OF THE EARTHQUAKES.

Origin.	0–6 A.M. and 0–6 P.M.			6–12 A.M. and 6–12 P.M.		
	With High Water.	With Low Water.	Between High and Low Waters.	With High Water.	With Low Water.	Between High and Low Waters.
Inland. Groups I-IV.	9	12	3	2	0	0
Shimosa, etc. Group V.	9	8	0	12	7	2
Submarine. Groups VI-X.	15	20	0	18	13	14

From Table XIV, it will be observed that the 16 submarine and coast earthquakes of Groups V–X, whose times of occurrence were between those of the high and low waters of the tide, happened exclusively between 6 and 12 am. and between 6 and 12 pm., namely, as follows :—

6^h	35^m	pm.	9^h	29^m	pm.
6	41	am.	9	30	pm.
6	51	pm.	9	33	pm.
6	51	pm.	9	59	am.
7	48	pm.	10	24	am.
8	01	am.	10	48	am.
8	59	am.	10	54	am.
9	05	am.	11	54	pm.

Taking the average of these times of occurrence, irrespective of their being antemeridian or postmeridian, we obtain the value of 8h 58m, or about 9h am. and 9h pm. These hours, which correspond to those of the barometric maxima in the diurnal variation, may be taken as giving the probable time when a strong earthquake, in the region under consideration, is to take place intermediate between the high and low water epochs.

Diurnal Variation of the Seismic Frequency in relation to the Phases of the Tide. Table XV gives the diurnal variations of the earthquakes occurring with the high water and the low water, and between these two, the Groups I to X being taken together.

TABLE XV.—DIURNAL VARIATION OF THE SEISMIC FREQUENCY IN RELATION TO THE PHASES OF THE TIDE.

Hour.	Earthquakes occurring					
	with High Water.		with Low Water.		between High and Low Waters.	
0—1 AM.	4		2		0	
1—2	3		1		1	
2—3	3	**20**	5	**20**	0	**1**
3—4	3		4		0	
4—5	3		4		0	
5—6	4		4		0	
6—7 AM.	3		1		1	
7—8	3		3		1	
8—9	5	**18**	3	**11**	2	**8**
9—10	4		0		2	
10—11	1		2		2	
11—12	2		2		0	
0—1 PM.	1		4		0	
1—2	2		4		0	
2—3	3	**11**	6	**21**	1	**2**
3—4	2		1		0	
4—5	0		2		0	
5—6	3		4		1	
6—7 PM.	2		2		3	
7—8	4		1		1	
8—9	3	**15**	0	**10**	0	**8**
9—10	4		5		3	
10—11	0		1		0	
11—12	2		1		1	
Sum.	**64**		**62**		**19**	

Thus the earthquakes corresponding to the low water occurred twice as frequently between 0 and 6 am. and between 0 and 6 pm., as during the remaining hours. On the other hand, the earthquakes corresponding to the high water and the middle of the high and low waters, occurred not less or more frequently between 6 and 12 am. and between 6 and 12 pm., than during the other hours. It thus seems that, on the whole, the moderate earthquakes shaking the vicinity of Tokyo tend to occur more frequently with the minimum barometric pressure and the low tide, as well as with the maximum barometric pressure and the high tide. This is in accordance with one of the principles explained in § 4.

14. *Conclusion.* The results obtained in the foregoing §§, which are only fragmentary notes on the secondary seismic causes, show nevertheless that these latter play a very important part in the distribution of earthquakes during the day, the year, the lunar day, etc. As these secondary causes probably determine the ultimate moment when a long-continued underground stress gives rise to a sudden disturbances, their careful study will be, in conjunction with the observation on the *fore-shocks* (see the preceding article), and the investigation on *earthquake zones*, of help in approximately predicting under favorable circumstances the earthquakes likely to happen in a given district. For an illustrative example in this connection, I may refer the reader to my preliminary note on the Formosa earthquake of March 17, 1906 (the *Bulletin*, Vol. I, No. 2). The periodicity of earthquakes, other than the diurnal and the annual, also probably depends to a great extent on the secondary causes.