REPORT ON EARTHQUAKE OBSERVATIONS MADE IN JAPAN DURING THE YEAR 1886.

(A TRANSLATION, WITH PREFATORY NOTE AND GENERAL OBSERVATIONS, BY JOHN MILNE.)

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PREFATORY NOTE.

The following paper is practically a translation of a report published by the Meteorological Central Observatory in Tokio, Japan. It was drawn up by Messrs. Wada, Outska, Asakusa, and Mayeda, officers in charge of the office where earthquake observation receives special attention, under the general supervision of Mr. Arai Ikunosuke, the Director of the Observatory. The analyses in the first portion of the report refer to observations made at some 650 stations in various parts of the empire, from which after each earthquake a report is sent to the Central Observatory. From the reports on a given earthquake a map is drawn showing the area over which it extended.

The second portion of the report contains the analyses of earthquakes recorded by instruments during eleven years at the Central Observatory.

For the commencement of the general observations in the Japanese Empire, readers may refer to Trans. Seis. Soc., Vol. VII., Part II. "On 387 earthquakes observed during two years (1881-1883) in North Japan, by John Milne." In 1885 this class of observations was taken up by the Imperial Meteorological Observatory and the results of the work for that year were published by Professor S. Sekiya in Trans. Seis. Soc., Vol. X. pp. 57-82. Another paper bearing on this subject is on "The distribution of Seismic Activity in Japan," by J. Milne, Trans. Seis. Soc., Vol. IV. Analyses of instrumental records made in Tokio by the Imperial Meteorological Bureau are to be found in several volumes of the Transactions of the Seismological

Society, one very suggestive paper being "Earthquake Frequency," by C. G. Knott, D.Sc. (Trans. Seis. Soc., Vol. IX., Part I., p. 1-20).

The areas of districts shaken are given in square *ri* (1 square *ri* = 5.95 square miles).

Frequency of Earthquakes.

The total number of earthquakes which occured during the year 1886 was 472. This amounts to a daily average of 1·3. In 1885 then were 482. A map has been constructed from this total number of earthquakes with the object of showing the comparative frequency of earthquakes in different districts. *(See Plate I.)* As in the former report, a deep shade of colour shows the districts where earthquakes were most frequent, while lightly shaded portions are the districts where they were less frequent. The figures attached indicate the number of earthquakes that occurred at that spot during the year; for instance 55 in the map means that there were about 55 shakings at that district. The districts where earthquakes were most frequent were Shimotsuke, Musashi, Nemuro, Hitachi, Echigo, as in the last year. Shimotsuke was the highest, being 61. Next in order came Shimōsa, Kushiro (eastern part) Kii, Iwaki, Shinano, Mutsu, Kadzusa, Rikuzen, Kodsuke, Kai, Rikuchiu, Iyo, Satsuma (eastern part) Iwashiro, Ugo, Sagami, Idzumo, Mino, Hiuga, Bungo, Iwami, Chikuzen (named in the order of frequency). Several other provinces not mentioned in the above felt from 1 to 5 shakings. As no report was sent in from the portions left white in the map, that is the western part of Kushiro, Iburi, and Oshima, eastern part of Ishikari, and Iburi, southern part of Shiribeshi, the whole of Hidaka, Tokachi, Teshiro, Kitami, and Kaga, eastern part of Hakase, western part of Ōmi, central part of Harima, Inaba, Hoki, Minasaka, northern part of Idzumo, Oki, eastern part of Sanuki, central part of Awa, eastern part of Tosa, north-western part of Satsuma, and Tsushima, together with small islands surrounding the coast of the main land, we cannot say any-

thing definite about these districts. As we have remarked in the reports of the last year, we cannot at once conclude from such results that there were no earthquakes in those districts. We may, however, say that there was not much difference from the result of the previous year, and that the districts neighbouring the Japan Sea felt few or no earthquakes, and such as may have occurred were too feeble to be recognized without instruments. The ranges of mountains forming the backbone of the mainland, passing between Tosan, Hokuriku, Sanin, and Sanyō, seem to divide this country into two portions, one of which is constantly shaken while the other is almost undisturbed. The fact that we received no report from these districts may be taken as a proof of the absence of seismic disturbance, but there are many doubts about the northern part of Hokkaido. Even in other districts there may have been many earthquakes which have not been reported to us. Very often feeble shocks which occurred during the day when people are engaged at work, or at night when sleeping, or at the time of strong winds, pass by unobserved. To speak definitely about the frequency of earthquakes fuller observations are required.

Relations of Earthquakes to Seasons.

Earthquake seasons are not well defined. The following table shows the monthly number of earthquakes in 1885 and 1886 :—

	1885.	1886.	Average of Two Years.
January	32	38	35·0
February	44	39	41·5
March	37	49	43·0
April	37	38	37·5
May	51	58	54·5
June	46	30	38·0
July	32	36	34·0
August	30	46	38·0
September	45	41	43·0
October	41	33	37·0
November	47	22	34·5
December	40	42	41·0
Total	482	472	477·0
Monthly average.	40.2	39.3	39·75

As will be seen from the table, the total number for 1886 is 472, and the monthly average is 39·3. The number in February is almost equal to this average. Those in March, May, August, September, and December are above the average, while those in January, April, June, July, October, and November are below it. The two highest are in May and the lowest in November. The month of the highest number is the same in the two years, but that of the lowest number is different.

If we divide this number of earthquakes into four seasons, we have :—

	1885.	*1886.*	Average of Two Years.
Spring (3-5)	125	145	135.0
Summer (6-8)	108	112	110.0
Autumn (9-11)	133	96	114.5
Winter (12-2)	116	119	117.5
Total	482	472	477.0
Average	120.5	118.0	119.25

As in the list, the average number of earthquakes in a season was 118, and those in spring and winter were above the average while those in summer and autumn have been below it. The highest was in spring and the lowest in autumn. In many respects this is different from the observations of the last year.

Dividing the same observations into warm and cold seasons, we have :—

	1885.	*1886.*	*Means.*
Winter (10-3)	241	223	232
Summer (4-9)	241	249	245
Total	482	472	477
Average	241.0	236.0	238.5

We see from the list that the mean of a season is 236 for 1885, and the number in summer months is greater than the mean while in winter months it is less. The difference be*tween the two seasons is 26.* In 1885 the number was eqaul in the two seasons.

N.B.—The number of earthquakes for 1885 in this report is different from those which were given already in the report of last year. This difference results from the addition of

reports received later and corrections of errors in the former report. The numbers in this report may be taken as correct.

Time of Occurrence of Earthquakes.

The following table shows the number of earthquakes for 1885 and 1886 which occurred at different hours of the day:—

Time	A.M.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
0—	1...	0...	4...	2...	3...	2...	6...	4...	3...	0...	1...	4...	4...	33
1—	2...	2...	7...	3...	0...	2...	6...	3...	0...	4...	6...	2...	1...	36
2—	3...	4...	3...	7...	5...	8...	4...	5...	11...	11...	1...	3...	3...	65
3—	4...	4...	4...	3...	4...	10...	0...	4...	3...	5...	3...	4...	4...	48
4—	5...	1...	4...	0...	3...	6...	4...	1...	2...	3...	1...	1...	1...	27
5—	6...	2...	1...	7...	2...	10...	0...	4...	4...	1...	6...	3...	0...	40
6—	7...	4...	2...	2...	3...	4...	1...	4...	2...	4...	2...	1...	5...	34
7—	8...	3...	1...	3...	6...	3...	3...	1...	1...	1...	3...	5...	3...	33
8—	9...	4...	3...	5...	4...	4...	2...	4...	3...	8...	1...	1...	2...	40
9—	10...	4...	4...	3...	5...	2...	8...	2...	2...	3...	4...	1...	1...	39
10—	11...	6...	0...	2...	4...	0...	2...	1...	1...	2...	2...	2...	3...	25
11—	12...	2...	3...	3...	4...	6...	4...	4...	2...	4...	3...	3...	6...	44
	P.M.													
0—	1...	2...	2...	1...	1...	3...	1...	3...	2...	6...	3...	2...	2...	28
1—	2...	2...	4...	4...	3...	10...	3...	2...	3...	4...	6...	5...	3...	49
2—	3...	6...	2...	9...	3...	5...	3...	6...	4...	3...	3...	3...	4...	51
3—	4...	1...	3...	1...	5...	4...	1...	2...	5...	4...	2...	2...	3...	33
4—	5...	2...	2...	6...	2...	5...	3...	2...	2...	1...	1...	1...	2...	29
5—	6...	3...	8...	3...	2...	3...	5...	2...	0...	2...	0...	0...	1...	29
6—	7...	2...	2...	3...	3...	4...	3...	3...	3...	6...	4...	2...	4...	39
7—	8...	3...	5...	2...	4...	2...	3...	3...	4...	2...	5...	3...	3...	39
8—	9...	1...	2...	3...	4...	6...	2...	4...	4...	4...	5...	8...	7...	50
9—	10...	2...	2...	4...	1...	5...	3...	2...	4...	6...	3...	5...	6...	43
10—	11...	6...	9...	7...	2...	3...	5...	1...	4...	0...	6...	4...	9...	56
11—	12...	5...	6...	3...	2...	2...	4...	1...	7...	2...	3...	4...	5...	44
Total		70	83	86	75	109	76	68	76	86	74	69	82	954

Mean number per hour=40.

Thus we see from the table that the number of shakings at 6 and 9 a.m. is equal to the mean number or 40. Those above the mean are at 3 and 4 a.m., noon, 2, 3, 9, 10, 11, p.m., and midnight. Those below the mean are at 1, 2, 5, 7, 8, 10, 11, a.m., 1, 4, 5, 6, 7, 8, p.m. Those hours having numbers below the mean are more than those above it by 4. The maximum was at 3 a.m., and the minimum at 11 a.m. The same number of 44 is at noon and midnight, and 40 at 6 and 9 a.m. 39 at 10 a.m., 7, 4, 8, p.m. 33 at 8 a.m. and 4 p.m. In short, there were many more earthquakes at p.m. than at a.m.; the difference being 26. Although at noon and midnight the

earthquakes were equal in number, yet 11 a.m. was the least of all while 11 p.m. was the highest but one. When we compare the number of earthquakes by day and by night, taking 6 o'clock as the limit of day and night, there were 86 more earthquakes in the latter than in the former.

How the occurrence of earthquakes are related to day and night or the hours of the day, we cannot say definitely.

Area of Seismic Disturbances.

Although some seismic disturbances are of only small extent, yet there have been others extending over several thousand square *ri*, as mentioned in the report of the last year. In the following table the number of square *ri* shaken every month in 1886 together with the area shaken in the previous year is given :—

	Total Area.			Mean Area per Shock.		
	1885. Square *ri*.	1886. Square *ri*.	Average. Square *ri*.	1885. Square *ri*.	1886. Square *ri*.	Average. Sq. *ri*.
Jan.	10,020 ...	3,240 ...	6,630 ...	370 ...	80 ...	195
Feb.	16,980 ...	5,550 ...	11,265 ...	390 ...	140 ...	265
March.....	7,320 ...	4,810 ...	6,065 ...	200 ...	100 ...	150
April	4,750 ...	12,480 ...	8,615 ...	130 ...	330 ...	230
May	10,380 ...	15,380 ...	12,880 ...	200 ...	260 ...	230
June	15,890 ...	5,080 ...	10,485 ...	370 ...	170 ...	270
July.....	9,170 ...	10,490 ...	9,830 ...	290 ...	290 ...	290
Aug.	6,060 ...	10,820 ...	8,440 ...	210 ...	230 ...	220
Sept.	4,570 ...	9,500 ...	12,035 ...	320 ...	230 ...	275
Oct.....	21,340 ...	3,860 ...	12,600 ...	520 ...	120 ...	320
Nov.....	4,120 ...	2,480 ...	3,300 ...	80 ...	110 ...	90
Dec.	1,170 ...	8,360 ...	10,030 ...	290 ...	200 ...	245
Total.....	132,300 ...	92,050 ...	112,175 ...	2,310 ...	2,260 ...	2,785
Average..	11,025 ...	7,671 ...	9,348 ...	276 ...	189 ...	232

Thus the total of the area shaken in 1886 was 92,050 square *ri*, which gave the monthly mean of 7,671 sq. *ri* or 189 sq. *ri* per shock. In the same year there were 66 earthquakes which exceeded the mean value of 189 sq. *ri*. Compared with the last year, there were 40,250 sq. *ri* less area shaken, 3,350 sq. *ri* less in the monthly mean, 87 sq. *ri* less the mean area per shock, and 30 earthquakes less which exceeded the mean value.

N.B.—The total area shaken this year was 92,050 sq. *ri* which is 3.8 times larger than the total area of this country or 24,352 sq. *ri* (exclusive of many small islands and Loochoo).

The following table shows the number of earthquakes shaking different area in different months during 1885 and 1886 :—

Area.	Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.	Mean.
More than 5,000 square *ri*	1886	—	—	—	—	—	—	1	—	—	—	—	—	1	0.1
More than 5,000 square *ri*	1885	—	1	—	—	—	—	—	—	—	1	—	—	2	0.2
More than 4,000 square *ri*	1886	—	—	—	1	—	—	—	—	—	—	—	—	1	0.1
More than 4,000 square *ri*	1885	—	—	—	—	—	—	—	—	—	—	—	—	—	—
More than 3,000 square *ri*	1886	—	—	—	—	1	—	1	1	—	—	—	—	3	0.3
More than 3,000 square *ri*	1885	—	—	1	—	1	1	1	—	1	1	—	—	6	0.5
More than 2,000 square *ri*	1886	—	—	—	1	2	—	—	1	1	—	—	—	5	0.4
More than 2,000 square *ri*	1885	1	2	—	—	1	2	1	—	3	1	—	2	13	1.1
More than 1,000 square *ri*	1886	—	1	—	1	1	1	—	—	3	—	1	1	9	0.8
More than 1,000 square *ri*	1885	—	1	—	1	—	1	—	1	—	4	—	1	9	0.8
Sum	1886	—	1	—	3	4	1	2	2	4	—	1	1	19	1.6
Sum	1885	1	4	1	1	2	4	2	1	4	7	—	3	30	2.5
Comparison of 1886 and 1885.		* 1	* 3	* 1	† 2	† 2	* 3	—	† 1	—	* 7	† 1	* 2	* 11	* 0.9
More than 750 square *ri*	1886	—	1	2	1	2	1	—	2	—	1	—	2	12	1.0
More than 750 square *ri*	1885	2	1	1	—	—	2	1	1	2	—	—	2	12	1.0
More than 500 square *ri*	1886	1	1	—	2	—	—	—	1	2	2	—	4	13	1.1
More than 500 square *ri*	1885	5	4	1	1	—	1	—	2	1	2	—	—	17	1.4
More than 300 square *ri*	1886	2	2	2	1	3	4	1	1	—	2	1	1	20	1.7
More than 300 square *ri*	1885	2	1	—	2	4	1	2	1	—	6	1	4	24	2.0
More than 200 square *ri*	1886	2	—	4	1	4	2	2	2	1	—	—	2	20	1.7
More than 200 square *ri*	1885	—	1	2	1	1	4	—	4	1	2	9	2	27	2.2
More than 100 square *ri*	1886	5	3	2	3	4	4	1	5	4	3	1	4	39	3.2
More than 100 square *ri*	1885	3	6	5	6	16	7	4	2	4	—	5	5	63	5.2
Sum	1886	10	7	10	8	13	11	4	11	7	8	2	13	104	8.7
Sum	1885	12	13	9	10	21	15	7	10	8	10	15	13	143	11.9
Comparison of 1886 and 1885.		* 2	* 6	† 1	* 2	* 8	* 4	* 3	† 1	* 1	* 2	*13	0	* 39	* 3.2
Less than 100 square *ri*	1886	28	31	39	27	41	18	30	33	30	25	19	28	349	29.1
Less than 100 square *ri*	1885	19	27	27	26	28	27	23	19	33	24	32	24	309	25.7
Sum	1886	28	31	39	27	41	18	30	33	30	25	19	28	349	29.1
Sum	1885	19	27	27	26	28	27	23	19	33	24	32	24	309	25.7
Comparison of 1886 and 1885.		† 9	† 4	†12	† 1	†13	* 9	† 7	†14	* 3	† 1	*13	† 4	† 40	† 3.3
Grand Total ...	1886	38	39	49	38	58	30	36	46	41	33	22	42	472	39.3
Grand Total ...	1885	32	44	37	37	51	46	32	30	45	41	47	40	482	40.2
Comparison of 1886 and 1885.		† 6	* 5	†12	† 1	† 7	*16	† 4	†16	* 4	* 8	*25	† 2	* 10	* 0.8

*=—. †=+.

It will be seen from the above table that out of all the earthquakes which occurred during 1886, 349 shocks were local, shaking less than 100 square *ri*, 104 shocks extended over more than 100 square *ri*, and 19 had wider extension than 1,000 square *ri*. Of the latter only one extended more than 5,000 square *ri*.

In comparing these observations with those of last year, we see that of earthquakes having an area less than 100 square *ri*, there were 40 more in this year; of those shaking more than 100 square *ri* there were 29 less, and of those wider than 1,000 square *ri* there were twice less. In general we must say that in 1886 there were many earthquakes of a local nature and comparatively few which shook a large area.

Distribution of Seismic Disturbances.

We have already stated in our last report that the districts subject to seismic disturbances are not constantly fixed.

There were considerable changes observed in Echigo, Shinano, Mutsu, Kai, and Kadzusa, while all other parts were not materially different from what we had in 1885, although there were some differences in the number of shocks observed.

The districts most frequently affected by earthquakes in this year were Shimotsuke, Musashi, Hitachi, and Shimosa. Next follow Nemuro and Kushiro, after which come Echigo, Iwaki, Shinano and Mutsu.

As to Shimotsuke, Musashi, Shimosa, and Hitachi no great differences were observed as compared with last year. Fifty-five shocks were reported. The same was the case with Nemuro and Kushiro where they had 20 and 40 shocks. The same was the case in Kii.

In Echigo and Shinano the number of earthquakes in this year was much increased; in 1885 there were 3 earthquakes in Echigo and 9 in Shinano, while in 1886 there were 31 in the former and 19 in the latter. On the contrary, we had a decrease in the number in Mutsu, Kadzusa, and Kai. The increase in the num-

ber of earthquakes in Echigo and Shinano was due to the strong shocks which occurred on July 23rd and several small ones which followed them. Yet we cannot decide from these facts that those districts are seismic regions, which now and then experience severe shakings. Mutsu, Kadzusa, and Kai, although they were less frequently disturbed this year than during the last, were shaken much more than the adjacent provinces. The continual succession of disturbances in these provinces leads us to think that they are truly seismic regions.

There were more than 10 earthquakes in Iyo and Satsuma, the former being more frequently disturbed and the latter less frequently than during last year. We are not certain that Iyo may be taken as a seismic region, but we may take Satsuma as such, for there it appears that earthquakes are always frequent.

As in the last report the number of earthquakes felt in each province is given in the following table :—

NO. OF EARTHQUAKES OF DIFFERENT INTENSITY.

Name of Province.	Year.	Number of Earthquakes.	Strong.	Weak.	Feeble.
Shimotsuke	1886	61	1	5	55
	1885	58	1	18	39
Musashi	1886	54	1	15	38
	1885	68	2	18	48
Nemuro	1886	43	1	15	27
	1885	33	4	22	7
Hitachi	1886	33	1	23	28
	1885	36	0	8	9
Echigo	1886	31	3	7	21
	1885	3	1	1	1
Shimosa	1886	28	0	17	11
	1885	40	0	15	25
Kushiro	1886	23	4	13	6
	1885	15	1	8	6
Kii	1886	22	1	6	15
	1885	18	0	7	11
Iwaki	1886	19	0	16	3
	1885	19	1	13	5
Shinano	1886	19	2	14	3
	1885	9	0	5	4
Mutsu	1886	15	0	6	9
	1885	26	2	8	16
Kadzusa	1886	14	0	4	10
	1885	22	0	4	18

No. of Earthquakes of different intensity.

Name of Province.	Year.	Number of Earthquakes.	Strong.	Weak.	Feeble.
Rikuzen	1886	12	3	5	4
	1885	16	0	11	5
Kodzuke	1886	11	2	6	3
	1885	11	0	10	1
Kai	1886	11	2	4	5
	1885	21	6	6	9
Rikuchiu	1886	10	0	6	4
	1885	9	4	4	1
Iyo	1886	10	3	6	1
	1885	3	0	2	1
Satsuma	1886	10	0	6	4
	1885	10	1	4	5
Iwashiro	1886	9	0	6	3
	1885	5	0	3	2
Ugo	1886	8	2	2	4
	1885	3	0	3	0
Sagami	1886	8	1	3	4
	1885	15	1	13	1
Idzumo	1886	7	0	5	2
	1885	4	0	2	2
Mino	1886	6	0	4	2
	1885	13	3	8	2
Hiuga	1886	6	0	3	3
	1885	5	0	1	4
Bungo	1886	6	1	2	3
	1885	2	0	2	0
Iwami	1886	6	0	1	5
	1885	2	0	2	0
Chikuzen	1886	6	0	4	2
	1885	1	0	1	0
Aki	1886	5	0	1	4
	1885	5	0	2	3
Tosa	1886	5	2	3	0
	1885	3	1	2	0
Uzen	1886	5	1	3	1
	1885	7	0	6	1
Ise	1886	5	0	3	2
	1885	7	0	3	4
Mikawa	1886	4	0	1	3
	1885	10	0	3	7
Hizen	1886	4	0	0	4
	1885	3	0	2	1
Tanba	1886	4	0	3	1
	1885	7	0	4	3
Owari	1886	3	0	2	1
	1885	8	0	2	6
Nagato	1886	3	0	2	1
	1885	5	0	3	2
Suwo	1886	3	0	3	0
	1885	5	0	1	4

No. of Earthquakes of different intensity.

Name of Province.	Year.	Number of Earthquakes.	Strong.	Weak.	Feeble.
Buzen	1886	3	1	1	1
	1885	1	0	1	0
Harima	1886	3	0	2	1
	1885	2	0	1	1
Settsu	1886	3	0	1	2
	1885	5	0	1	4
Ōsumi	1886	3	0	2	1
	1885	5	0	3	2
Oshima	1886	3	0	1	2
	1885	9	2	5	2
Echizen	1886	3	0	1	2
	1885	4	0	2	2
Noto	1886	3	1	2	0
	1885	—	—	—	—
Awa	1886	3	0	3	0
	1885	9	1	8	0
Kawachi	1886	3	1	1	1
	1885	2	0	2	0
Iga	1886	3	0	0	3
	1885	3	0	2	1
Totomi	1886	2	0	0	2
	1885	5	0	4	1
Etchiu	1886	2	0	0	2
	1885	—	—	—	—
Iburi	1886	2	0	1	1
	1885	7	1	4	2
Higo	1886	2	0	2	0
	1885	4	0	3	1
Suruga	1886	2	0	1	1
	1885	8	1	2	5
Awa	1886	2	0	2	0
	1885	7	0	2	5
Yamato	1886	2	0	2	0
	1885	5	0	4	1
Yamashiro	1886	2	0	0	2
	1885	5	0	4	1
Oumi	1886	2	0	0	2
	1885	6	0	1	5
Chishima	1886	2	1	0	1
	1885	6	2	1	3
Bizen	1886	2	0	0	2
	1885	1	0	0	1
Chikugo	1886	1	0	1	0
	1885	1	0	0	1
Ishikari	1886	1	1	0	0
	1885	4	1	2	1
Shiribeshi	1886	1	0	1	0
	1885	2	0	2	0
Idzumi	1886	1	0	1	0
	1885	2	0	1	1

NO. OF EARTHQUAKES OF DIFFERENT INTENSITY.

Name of Province.	Year.	Number of Earthquakes.	Strong.	Weak.	Feeble.
Bitchiu	1886	1	0	0	1
	1885	2	0	0	2
Bingo	1886	1	0	0	1
	1885	1	0	0	1
Wakasa	1886	1	0	0	1
	1885	3	0	0	3
Sado	1886	1	0	1	0
	1885	—	—	—	—
Hida	1886	1	1	0	0
	1885	3	0	1	2
Tango	1886	1	0	1	0
	1885	1	0	0	1
Idzu	1886	1	1	0	0
	1885	5	2	2	1
Awaji	1886	1	0	1	0
	1885	2	0	1	1
Iki	1886	1	0	0	1
	1885	—	—	—	—
Shima	1886	—	—	—	—
	1885	4	0	2	2
Hidaka	1886	—	—	—	—
	1885	3	1	2	0
Hoki	1886	—	—	—	—
	1885	2	0	2	0
Teshio	1886	—	—	—	—
	1885	2	1	1	0
Mimasaku	1886	—	—	—	—
	1885	1	0	1	0
Total	1886	596	38	253	305
	1885	659	40	294	325

INTENSITY OF EARTHQUAKES.

As we have stated in the report of last year, the intensity of earthquakes was quite variable. The provinces which felt strong earthquakes were Kushiro and Rikuzen, where there were 6 strong shocks; next come Musashi, Iyo, Hitachi, Echigo, Shinano, Iwaki, Shimotsuke, each of which felt 3 to 5 shocks. Nemuro, Ugo, Iwashiro, Shimosa, Kodzuke, Kai, Tosa, Chishima, Mutsu, Rikuchiu, Uzen, Noto, Sagami, Idzu, Hida, Owari, Kawachi, Kii, Suwo, Buzen, Bungo, and Hizen had 1 or 2 strong shocks. Above all, the strongest earthquake was one which occurred on the 23rd of July in the provinces of Echigo and Shinano, where more or less damage was done.

(See plate III., map 3, and also the special record of that earthquake further on.)

Positions of Seismic Origins.

To know the exact positions of earthquake origins is rather a hard task, but a few remarks may be made as to their approximate positions.

The 472 shocks which were felt during this year have been grouped according to their approximate origins, which are indicated by small circles in Plate II. The figures enclosed within the circles mean that the spots so indicated were so many times approximately the origins of earthquakes. For instance 72 written within a circle means that within that circle 72 shocks originated. We are not, however, in a position to firmly assert that all the shocks of which we speak have necessarily originated within the spaces enclosed by circles.

There may be many shocks which came from origins more than 10 *ri* outside of a circle, especially perhaps those which had their origins under the sea.

In this year, the seismic origins in the mainland were at its central part, or between Tokaidō and Hokurokudō. Those in Hokkaidō were under the sea to the east, while in the western part they were near the coast.

Thus seismic origins were either inland, on the coasts or under the sea.

There were 228 shocks which may be traced to origins on the coast or under the sea, and they were usually extensive in their effect, while those originating beneath the land were 244. These latter merely caused limited disturbances.

The seismic origins which caused the widest disturbances were stationed either under the sea off the coasts of Hokkaido, Mutsu, Rikuchiu, Rikuzen, Iwaki, and Hitachi, or on the coast itself. These earthquakes extended over an area of from 3,900 square *ri* to 5,700 square *ri*.

The origin which gave rise to the most numerous shocks

was within Shimotsuke, Musashi, and Hitachi, where there were 72 shakings. The next was in Echigo and Shinano, where there were 52 shocks. Yet of these earthquakes, no one extended over more than 550 square *ri*. In comparing the intensity of earthquakes, there were 23 strong shocks which originated under the sea or on the coast and 19 strong shocks on the land.

Besides these there were several other important seismic origins which are inserted in Plate II. The following will show the number of shocks coming from different origins:—

	From origins under the sea or on the coast.	From origins beneath the land.	Total number.
Disturbances extending over a wide area	15	11	26
Disturbances extending over a limited area...	50	70	120
Disturbances extending over a small area.....	163	163	326
Total	228	244	472

Relation of Earthquakes to Volcanoes.

On enquiring into the relation of earthquakes to volcanoes we find that there were, as last year, many earthquakes felt in Musashi, Kazusa, Shimōsa, Kōdzuke, Shimotsuke, and Hitachi which are almost enclosed by ranges of volcanoes. There were, however, many earthquakes also in Kii, which is quite apart from any volcanoes. Among those provinces having volcanoes, Mutsu is in its northern parts the one most frequently shaken. There are also many provinces where there are volcanic peaks, but where no earthquakes have been felt. This is the same as last year, but a difference is that a severe earthquake causing considerable damage originated at the boundary of Echigo and Shinano where there is a range of volcanoes but where no earthquakes were felt during the last year. (See plate III. map 3 and the record for July 23rd.) After this earthquake there were several small ones, giving a total of 31 shocks for Shinano.

There are some volcanic districts which were comparatively free from earthquakes, while in other places where no volcano exists there have been felt quite a number of earthquakes; other places again are at once free from earthquakes and volcanoes; some districts quite close to a volcano were constantly shaken. These being the facts, we cannot hastily assent to a theory that attributes the frequency and intensity of earthquakes to the presence of volcanoes. The situation of volcanoes is indicated by ⧋ or △ on the map of Plate I. The volcanoes marked ⧋ are active ones which are sending out smoke at present or which are recorded to have been in eruption within historic times. Those marked △ are extinct volcanoes which are only inferable as such from geological reasons.

On the Monthly occurrence of Earthquakes.

As the seismic conditions of this year as a whole have already been explained in the preceding pages, the following will be devoted to a description of the earthquakes which have occurred during successive months.

JANUARY.

The total number of earthquakes in this month was 38, which was at the rate of 1 shock every 19h. 34m.

The districts disturbed were Nemuro in Hokkaido, Mutsu, Rikuchiu, Rikuzen, Iwaki, Hitachi, Kadzusa, Shimōsa, Musashi, Shimotsuke, Shinano, Totomi, Mikawa, Kawachi, Yamato, Kii, Settsu, Idzumi, and Iwami on the mainland together with Satsuma in Kiushiu.

The province shaken most frequently was Kii, where there were 4 earthquakes; next came Musashi, Shimōsa, and Rikuzen each of which had 3 earthquakes, and all the rest 2 or less.

There were only 3 strong earthquakes felt in the 3 provinces of Kai, Totomi, and Rikuzen, all the others being weak or feeble earthquakes.

The total area of the districts disturbed was 3,240 square

ri. There were 10 earthquakes which disturbed more than 100 square *ri*, and no one extended over 1,000 square *ri*.

The one which caused the widest disturbance occurred on the 26th and extended from the central part of Rikuchiu to Iwaki, embracing Rikuzen, or an area over 630 square *ri*.

FEBRUARY.

The total number of earthquakes during this month was 39, which was at the rate of 1 shock every 17h. 39m.

The districts disturbed were Chishima, Nemuro, Kushiro, Ishikari, Iburi, and Shiribeshi in Hokkaido, Ugo, Rikuchiu, Rikuzen, Iwaki, Kodzuke, Shimotsuke, Hitachi, Kadzusa, Shimōsa, Musashi, Sagami, Kai, Shinano, Mino, Kii, Harima, Iwami, and Nagato on the mainland, Tosa and Iyo in Shikoku, together with Bungo, Hizen, Higo, and Satsuma, in Kiushu.

The province most frequently shaken was Nemuro, there being 5 shocks; next came Hitachi, Shimosa, and Shimotsuke which had each 4 shocks, and all the rest had 3 or less.

There were 4 strong earthquakes, which occurred in Shinano, Ishikari, Iyo, and Musashi. All the others were either weak or feeble earthquakes.

The total area of districts disturbed by earthquakes was 5,550 square ri. There were 7 earthquakes which disturbed more than 100 square ri. One which caused the widest disturbance was on the 24th. It extended over Kadzusa, Sagami, Kai, Kodzuke, Shimotsuke and Hitachi, or an area of 1,740 square *ri*.

MARCH.

The total number of earthquakes which occurred during this month was 49, which was at the rate of 1 shock in every 15h. 11m.

The districts shaken were Nemuro and Kushiro in Hokkaido, Mutsu, Rikuzen, Uzen, Iwashiro, Iwaki, Hitachi, Kadzusa, Shimōsa, Awa, Musashi, Shimotsuke, Echigo, Suruga, Mikawa, Mino, Owari, Ise, Omi, Echizen, Tamba, Settsu, Kawachi, Yamato, Idzumi, Kii, Harima, and Idzumo

on the mainland, Awa in Shikoku, and Hizen and Satsuma in Kiushiu.

The provinces most frequently shaken were Nemuro, Kushiro, Mutsu, and Kii, which had each 4 earthquakes. Next came Shimotsuke, Shimōsa, and Musashi, which had each 3, and all the rest had 2 or less.

There were 4 strong earthquakes, occurring in Rikuzen, Iwashiro, Kawachi, and Kushiro. All the other earthquakes were feeble.

The total area of the districts disturbed was 4,810 square *ri*, there being 10 earthquakes which extended over more than 100 square *ri*. The largest disturbance occurred on the 2nd, and extended over a region having Iwaki and Shimotsuke as the northern limit and Musashi and Awa as the southern limit, and an area of 790 square *ri*.

APRIL.

The total number of earthquakes in April was 38, so that there was on the average 1 shock every 18h. 56m.

The districts disturbed were Nemuro and Kushiro in Hokkaido, Mutsu, Rikuchiu, Rikuzen, Uzen, Ugo, Iwashiro, Iwaki, Hitachi, Kadzusa, Shimōsa, Musashi, Kodzuke, Shimotsuke, Echigo, Shinano, Noto, Echizen, Ise, Owari, Mikawa, Totomi, Kii, Yamashiro, Wakasa, Tanba, Iwami, Aki, and Suwo on the mainland, Iyo and Tosa in Shikoku, Bungo, Hiuga, and Hizen in Kiushiu.

The provinces most frequently shaken were Iwaki, Shimotsuke, and Rikuzen, each having 4 earthquakes. Next came Hitachi, Shimōsa, Iwashiro, Mutsu, and Nemuro, each having 3. All the others had two or less.

There were 7 strong earthquakes, of which 5 were felt in Ugo, Kushiro, Shimotsuke, Mutsu, and Iyo; of the two others one extended over Rikuzen, Rikuchiu, Ugo, Uzen, and Iwaki, and the other over Echigo and Kodzuke. All the rest were feeble.

The total area of ground which was shaken was 12,480 square *ri*. There were 7 earthquakes which extended over more than 100 square *ri*, and 3 over more than 1,000 square *ri*. The largest, on the 13th, extended over Mutsu and Ugo in the north-east and Musashi and Shimōsa in the south, or over an area of 4,980 square *ri*.

MAY.

The total number of earthquakes felt during this month was 58, which is an average of 1 shock for every 12h. 49m.

The districts disturbed were Chishima, Nemuro, Kushiro, and Oshima in Hokkaido, Mutsu, Rikuchiu, Rikuzen, Ugo, Iwashiro, Iwaki, Kadzusa, Shimōsa, Kodzuke, Shimotsuke, Awa, Musashi, Sagami, Hitachi, Kai, Idzu, Echigo, Shinano, Suruga, Mino, Owari, Echizen, Iga, Settsu, Yamashiro, Yamato, Kawachi, Idzumi, Kii, Harima, Tanba, Aki, Suwo on the mainland, Iyo in Shikoku, Awaji (island), Buzen, Chikuzen, Iki, Hizen, and Chikugo in Kiushiu.

The provinces most frequently disturbed were Shimotsuke, Hitachi, Shimōsa, and Musashi. Here there were from 8 to 11 earthquakes. Next came Kai, Chikuzen, Iwashiro, Kii, Kodzuke, Iwaki, Kushiro, Mutsu, Buzen, and Nemuro which had from 3 to 5 earthquakes. All the other provinces had only 2 or less.

There were 8 strong shocks, 4 of which occurred in the provinces Kii, Nemuro, Chishima, and Hitachi. Of the 4 others, one extended over Shimōsa, Musashi, Shinano, Kai, Sagami, and Idzu, another over Buzen, Chikuzen, and Hizen the third over Hitachi, Shimōsa, Musashi, Kozuke, Shimotsuke, and Iwaki, and the last in Rikuzen. All the rest were feeble.

The area of the districts disturbed was 15,380 square *ri*; 13 earthquakes extended over more than 100 square *ri* and 4 over more than 1,000 square *ri*. The largest disturbance occurred on the 16th, and extended over Hitachi, Kozuke, Shimotsuke, Kadzusa, Shimōsa, Awa, Musashi, Sagami, Kai,

Shinano, Echigo, Iwaki, Iwashiro, and Rikuzen, or an area of 3,110 square *ri*.

JUNE.

The total number of earthquakes felt during this month was 30, or an average of 1 shock every 24 hours.

The districts disturbed were Nemuro and Kushiro in Hokkaido, Mutsu, Rikuzen, Iwaki, Hitachi, Kadzusa, Shimōsa, Shimotsuke, Musaki, Sagami, Shinano, Kii, Bizen, Idzumo, Iwami, and Aki on the mainland, Awa, Iyo, and Tosa in Shikoku, Buzen, Bungo, and Hiuga in Kiushiu.

The provinces most frequently shaken were Musashi, Kushiro, and Iyo, each having 4 earthquakes. Then come Hitachi, Shimotsuke, Nemuro, and Aki, each of which had 3 shocks, all the rest having not more than two.

There were 5 strong earthquakes; two in Iyo, one in Nemuro and Kushiro, one in Tosa and one in Hitachi. All the other shocks were feeble.

Only one shock disturbed more than 1,000 square *ri*. The one which caused the widest disturbance was on the 3rd. It extended over Musashi, Kadzusa, Hitachi, Iwaki, and Shimotsuke, or over an area of 1,010 square *ri*.

JULY.

The total number of earthquakes in this month was 36, that is on the average one shock every 20h. 40m.

The provinces disturbed were Nemuro, Kushiro, and Oshima in Hokkaido, Mutsu, Rikuchiu, Rikuzen, Ugo, Uzen, Iwashiro, Iwaki, Hitachi, Kodzuke, Shimotsuke, Shimōsa, Musashi, Kai, Shinano, Echigo, Noto, Sado, Etchiu, Mino, and Bingo on the mainland, Hiuga, Osumi, and Satsuma in Kiushiu.

The province most frequently shaken was Echigo, where there were 16 shocks. Next came Shinano, which had 8. All the others had two or less.

There were 4 strong earthquakes, of which two occurred

in Kiushiu, one in Rikuzen, and one in Echigo, Shinano, and Noto. All the other shocks were feeble.

The total area disturbed was 10,490 square *ri*; 4 shocks affected more than 100 square *ri*, and 2 more than 1,000 square *ri*. The one which caused the widest disturbance was on the 2nd; it extended from Mutsu in the north to Kodzuke, Musashi, and Shimōsa in the south, or over an area of 5,580 square *ri*.

AUGUST.

The total number of earthquakes during this month was 46, that is there was an average of 1 shock every 16h. 14m.

The provinces disturbed were Nemuro, Kushiro, and Ōshima in Hokkaido, Mutsu, Rikuchiu, Rikuzen, Echigo, Kodzuke, Shimotsuke, Hitachi, Kadzusa, Shimōsa, Musashi, Shinano, Mino, Etchiu, Noto, Hida, Iga, Ise, Kii, Tanba, Tango, Bizen, Bitchiu, Aki, Suwo, Nagato, Iwami, and Idzumo on the mainland and all over Shikoku and Kiushiu, except Ōsumi in the latter.

The province most frequently shaken was Echigo, where there were 12 shocks. Next come Musashi, Shimotsuke, Shinano, Hitachi, Nemuro, and Mutsu, each having 8 to 3 shocks. All the other provinces had only 2 or less.

A strong earthquake was felt in Shinano and Echigo, another in Iyo, Tosa, Bungo, and Suwo, one in Echigo, one in Hida, and one in Kushiro, making up 5 in all. All the others were feeble.

The total area affected by earthquakes was 10,820 square *ri*. 11 earthquakes extended over more than 100 square *ri*, and 2 over more than 1,000 square *ri*. The one which caused the widest disturbance was on the 10th, extending over Shikoku, Kiushiu, and the western parts of the mainland, or over an area of 3,440 square *ri*.

SEPTEMBER.

The total number of earthquakes during this month was 41, which gives an average of 1 shock every 17h. 33m.

The provinces affected by earthquakes were Nemuro and Kushiro in Hokkaido, Mutsu, Rikuzen, Rikuchiu, Uzen, Iwaki, Iwashiro, Hitachi, Kadzusa, Shimosa, Musashi, Kodzuke, Shimotsuke, Kai, Sagami, Shinano, Echigo, Mino, Kii, Tanba, Idzumo, Aki, Iwami, and Nagato on the mainland, Tosa and Iyo in Shikoku, Bungo, Satsuma, and Ōsumi in Kiushiu.

The province most frequently disturbed was Shimotsuke, where there were 9 shocks. Next come Musashi, Echigo, Hitachi, Nemuro, Shimosa, and Iwaki, each experiencing 3 to 7 shocks; all the rest having not more than 2 disturbances.

There was only one strong earthquake, which occurred in Musashi; all the others were feeble.

The total area disturbed was 9,500 square *ri*; 7 earthquakes extended over more than 100 square *ri*, 4 over more than 1,000 square *ri*. The one which caused the widest disturbance was on the 21st. It extended over an area of 2,285 square *ri*, from Uzen and Rikuzen in the north to Kadzusa and Musashi in the south.

OCTOBER.

The total number of earthquakes which occurred during this month was 33, which gives an average of 1 shock every 22h. 32m.

The districts disturbed were Nemuro in Hokkaido, Iwaki, Hitachi, Kadzusa, Shimōsa, Musashi, Kodzuke, Echigo, Yamashiro, Kawachi, Kii, and Harima on the mainland, Tosa in Shikoku, Bungo, Hiuga, Ōsumi, and Satsuma in Kiushiu.

The province most frequently shaken was Shimotsuke, where there were 8 shocks. Then come Nemuro, Shimōsa, Musashi, Kii, and Echigo, which had from 3 to 5 shocks, all the other provinces having only 2 or less.

There were no strong earthquakes, all being feeble.

The total area shaken was 3,860 square *ri*; 8 shocks extended over more than 100 square *ri*, but none exceeded 1,000 square

ri. The largest was on the 18th, extending over Satsuma, Ōsumi, Hiuga, and Bungo, or over an area of 820 square *ri*.

NOVEMBER.

The total number of earthquakes during this month was 22, which gives an average of 1 shock every 32h. 48m.

The provinces disturbed were Nemuro and Oshima in Hokkaidō, Mutsu, Rikuzen, Iwaki, Iwashiro, Hitachi, Kōdzuke, Shimotsuke, Kadzusa, Shimōsa, Musashi, Sagami, Echigo, Mino, Owari, Mikawa, Ise, Kii, Tanba, and Idzumo on the mainland. No earthquakes were felt in Shikoku and Kiushiu.

The provinces most frequently shaken were Shimotsuke and Hitachi, each having 3 shocks. All the others had 2 or less.

All the disturbances were feeble.

The total area of districts disturbed was 2,480 square *ri*; 2 shocks extended over 100 square *ri*, and there was only one exceeding 1,000 square *ri*. The largest was on the 22nd, extending over Musashi, Kadzusa, Hitachi, Shimotsuke, Iwaki, Iwashiro, and Rikuzen, or over an area of 1,600 square *ri*.

DECEMBER.

The total number of earthquakes during this month was 44, which gives an average of 1 shock every 17h. 42m.

The provinces disturbed were Nemuro, Kushiro, and Iburi in Hokkaido, Ugo, Uzen, Mutsu, Rikuchiu, Rikuzen, Iwashiro, Iwaki, Hitachi, Kadzusa, Shimōsa, Musashi, Kodzuke, Shimotsuke, Sagami, Kai, Echigo, Mikawa, Owari, Ise, Mino, Idzumo, and Iwami on the mainland, Iyo, and Tosa in Shikoku. Nothing was reported from Kiushiu.

The provinces most frequently shaken were Musashi, Shimotsuke, and Nemuro, each having 6 to 8. Then come Hitachi, Iwaki, Rikuzen, Mutsu, Iwami, and Shimosa, which had 3 or 4 shocks. All the rest were shaken not more than twice.

There were 4 strong earthquakes, 1 in Rikuzen, 1 in Hitachi, Iwaki, Iwashiro, and Shimotsuke, 1 in Owari and 1 in Musashi. All the others were feeble.

The total area disturbed was 8,360 square *ri*. There were 13 earthquakes which extended over more than 100 square *ri*, and only one over more than 1,000 square *ri*. The largest was on the 4th, and it extended over Iwaki, Hitachi, Shimosa, Kadzusa, Musashi, Kodzuke, Shimotsuke, Iwashiro, and Rikuzen, or over an area of 2,220 square *ri*.

Examples of Earthquakes which have been large or in some way peculiar.

The following is a short account of the most remarkable earthquakes and of those districts which were frequently disturbed during 1886. In stating the time of shocks only the hours of their beginning are noted. In very extensive earthquakes there will, of course, be some differences in the exact time of commencement at different places.

January 24th, 9.30 a.m. (No. 1, Plate III.)

A faint vibration was felt at the eastern extremity of Nemuro, and its area was not more than 10 square *ri*. In this small region the number of earthquakes which occurred this year was 28.

April 13th, 5.50 a.m. (No. 2, Plate III.)

This earthquake extended over the following 12 provinces, viz., Mutsu, Rikuchu, Ugo, Rikuzen, Uzen, Iwashiro, Iwaki, Kozuke, Shimozuke, Hitachi, Shimōsa, and Musashi. It was severe towards the south from the centre of Rikuchu, and all over Rikuzen; being most violent at Motoyoshi-gun along the eastern coast of Rikuzen; feeble in northern Rikuchu, Ugo, Uzen, Iwaki, and eastern Hitachi; and faint in eastern Iwashiro, more than half of Mutsu, eastern Kozuke, Shimodzuke, the western part of Hitachi, Shimōsa, and the eastern part of Musashi. Its area was 4,980 square *ri*. Its direction was not uniform, but in Motoyoshi-gun, in Rikuzen, and Nishi-hei-gun (西閉伊郡) in Rikuchu, where it was very severe, the direction was south-west and north-east. The nature of the shock was vertical in eastern Rikuzen and horizontal in other quarters. Perhaps the origin of this earth-

quake was in the Pacific, and from there it spread over the land. In Motoyoshi-gun in Rikuzen, and in Nishi-hei-gun in Rikuchu, at its beginning, there was a noise underground, and then suddenly a very violent vibration, everything on shelves being about to upset and fall down. It continued about three minutes. At Iku-gun (伊具郡), Iwaki, some liquid in a vessel was spilt. The earthquakes of Rikuzen, Rikuchiu, and Mutsu are very seldom propagated to Ugo beyond its eastern mountain ranges, but, at this time, the whole of the latter province experienced a feeble vibration. The shock was very severe in Akita, and it perhaps may have reached the Japan Sea. At about dawn of the same day there was an eruption of Mount Tarumai, in Iburi, Hokkaido ; and at Nemuro there was felt a very feeble shock. Now, how such extraordinary events occurred at just the same time in the north-eastern part of this country is unknown, but they might owe their cause to considerable changes taking place in the earth-strata or the like.

JULY 23RD, 1 A.M. (No. 3, PLATE III.)

This earthquake extended over eleven provinces, viz., Echigo, Shinano, Etchu, Noto, Musashi, Kozuke, Shimozuke, Iwashiro, Sado, Shimōsa, and Hitachi. It was strong in half the places along the north coast from the centre of Echigo, being strong in more than $\frac{2}{10}$ of north-eastern Shinano, and in $\frac{3}{10}$ of northern Noto. The shock was most violent in more than $\frac{1}{10}$ of the north-eastern corner of Shinano, and in $\frac{1}{10}$ of southern Echigo; it was weak or faint in $\frac{3}{10}$ of the eastern, and $\frac{2}{10}$ of the western parts of Echigo, in Sado (?) it was felt in $\frac{6}{10}$ of western Iwashiro (?), in Kozuke, in Shimozuke, in $\frac{9}{10}$ of northern Musashi, in $\frac{2}{10}$ of north-western Shimōsa, in a small part of western Hitachi, in more than $\frac{3}{10}$ of central Shinano, in $\frac{8}{10}$ of eastern Echigo, and in $\frac{7}{10}$ of southern Noto. The area of the strong disturbance was 470 square *ri*, and that of the weak 2,520 square *ri*, making a total of 2,990 square *ri*. This was the most violent shock since the 17th year of Meiji. After

this time there were shocks at Higashi-kubiki-gun, in Echigo, up till 6 a.m. there were 4 weak and 19 faint shocks; clock pendulums stopped and furniture was upset. At Nigami-mura (*mura*=village) (仁上村) four store-houses were damaged; one stone wall 9 *shaku* high and 2 *ken* long, and another 7 *shaku* high and more than 7 *ken* long were destroyed. One *se* (1,080 square feet) of rice-fields at the same village, a part commonly called Hirakura Yama-shiri-da (平倉山尻田), and a bridge more than 15 *ken* long across the Hōkuragawa (*gawa*=river) (保倉川) from Ushi-ga-hana-mura, in the same *gun*, were destroyed. Besides this roads were damaged. The shock was so severe that many people in these districts fled out of doors. At Shimo-Takai-gun, in Shinano, though no cloud was seen that night, yet the moon was not clear and the weather was very hot since the day before; at Toyosato-mura (豊里村), in the same *gun*, one of the Nozawa hot springs (named Kirino-yu) was stopped by this earthquake. Around Teru-oka-mura (照岡村), in Shimo-minachi-gun (水内村), Shinano, several stone walls were destroyed; the cliffs of mountains, and roads, were broken down and the walls of many store-houses cracked; one house was upset and another tilted and partly destroyed; one store-house was upset and two others tilted; besides this much damage was done to lamp-shops, drug-shops, porcelain-shops, and the like. It was reported that, in the same *gun*, there were ten more very weak vibrations after the first one; at Kami-minachi-gun, the first shock was strong, causing some of the people to run out of doors, and this was followed by another shock. At Naka-Kubiki-gun, Echigo, though not very strong, there were five or six vibrations up till 4 o'clock the next morning; at Naka-Nonuma-gun, four shocks were felt, and crows and snowy herons in their roosts screamed, and some persons fled out of doors; at Mishima-gun, there were three shocks, and at Nishi-Kubiki and Kariha-gun two each. At Kita-Unuma-gun, there were five weak disturbances, and a few people fled out of doors. In each of Koshi-gun (古志郡)

and Minami-Uonuma-gun, in Echigo, and at Azuma-gun, Kōzuke, there were two mild shocks; at Kami and Shimo Takai-gun, many shocks were felt previous to this earthquake. After the 17th July, sometimes there were more than ten in a day.

It is probable that the origin of this earthquake was in the neighbourhood of Higashi-Kubiki, and of Takai-gun, for, in these two *gun*, the vibrations were very violent and numerous, while in Nishi-Kubiki and Naka-Kubiki-gun, they were evidently very weak.

At the same hour of the day (July 23rd, 1 a.m.), there was a weak vibration in eastern Mino, and its area was 50 square *ri*, but it seems that there was no connection between this part and those regions which we have mentioned above.

AUGUST 10TH, 9.30 P.M. (No. 4, Plate III.)

The earthquake of this day extended over Iyo, Bungo, Suwō, Aki, to the western part of Tosa, a small part of the south-west parts of Izumo, Iwami, Nagato, Buzen, Chikuzen, Chikugo, the eastern $\frac{4}{10}$ of Hizen, the north-eastern $\frac{8}{10}$ of Higo, the North-eastern $\frac{8}{10}$ of Hiuga, Bingo, Bitchu, the South-eastern $\frac{5}{10}$ of Bizen, the western $\frac{4}{10}$ of Awa, and to a small part of the south-west of Tanba. Its area was 3,440 square *ri*. It was strong in $\frac{8}{10}$ of the south-west of Iyo, in small part of the south-west of Tosa, in $\frac{3}{10}$ of the north-east of Bungo, and in $\frac{2}{10}$ of the south-west of Suwō. It was feeble in the other parts of Iyo and Tosa, in a small part of the south-west of Izumo, in Aki, Iwaki, Nagato, in the other parts of Suwō, in Buzen, in the other parts of Bungo, in $\frac{2}{10}$ of the northern end of Hiuga, in $\frac{3}{10}$ of the north-east of Higo, in Chikuzen, Chikugo, in $\frac{2}{10}$ of eastern Hizen. In all other places it was only faintly felt. The nature of the vibration was mostly horizontal, and it was said that in a part of the strong shocks, and in that of weak shocks close to the former, there were rumbling noises heard during its beginning. The probable origin of this earthquake seems to have been in Bungo Channel, and thence to have spread

out in all directions. Although many earthquakes have originated in the Bungo Channel, yet their vibrations have hitherto only spread along the neighbouring coasts, and scarcely ever inland. This was the only earthquake since the 17th year of Meiji that had so wide an extension. A few moments later there were two other shocks, the latter being somewhat stronger than the former.

Review of Earthquakes for 1884 and 1885.

The map in Plate IV. is constructed to show the total number of earthquakes during two years. From this we see that the districts most frequently shaken are Musashi, Shimōsa, Hitachi, and Shimotsuke. Tokyo and its neighbourhood have recorded 122. In the northern part of the main island, Mutsu experienced the greatest number (41). Nemuro stood highest in Hokkaido (76); Wakayama highest in the central part of the main island (40). In the districts of Sanindo and Sanyodo, Aki, Suwō, Nagato, and Iwami had 7 or 8. Shikoku was most frequently shaken in its western part. Kagoshima and its neighbourhood stood highest (less than 18) in Kiushiu.

In general there were many more earthquakes in the north eastern part of Japan than in the western part, disturbances being most frequent in those parts of the country extending from Shimōsa to Mutsu. There were sometimes more than ten earthquakes in the central part of the main island, while in no region in the western part was this number reached excepting the cases mentioned above. We must here state that we had no report from the northern part of Hokkaido or from Kaga, Tajima, Inaba, the northern part of Hoki, and the eastern part of Idzumo.

The Report of Earthquakes recorded in Tokyo.

It is now eleven years since the systematic observation of earthquakes was commenced in Tokyo. This was in July, the 8th year of Meiji (1875). The number observed during these eleven years is more than 600. The results of the observations are given in the following tables. The 8th year of Meiji not being

complete, the list is commenced from the next year. During the seven years from the 9th to the 15th of Meiji (1876-1882), the observations were made at Aoicho, Akasaka, but after that date they were made at Honmaru, in the Castle. From the beginning to the 18th year of Meiji (1885), the observations were made by Palmieri's apparatus, but from the next year by the Gray-Milne Seismograph. One will at once notice that earthquakes in Tokyo have evidently been very much more frequent than they have been in other localities.

The frequency of Earthquakes and the Times of their Occurrences.

The following Table gives 658 earthquakes observed at the Imperial Meteorological Central Observatory during eleven years from the 9th to the 19th year of Meiji:—

Years. Meiji	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Average
1876... 9th.....	3	4	6	11	5	3	3	5	3	3	4	6	56	5
1877... 10th.....	4	5	6	5	8	6	6	4	1	8	6	9	71	6
1878... 11th.....	3	8	7	2	5	4	4	1	2	4	6	4	50	4
1879... 12th.....	6	7	14	0	9	4	3	4	1	7	6	9	70	6
1880... 13th.....	9	9	6	6	2	9	8	4	1	3	10	10	77	6
1881... 14th.....	13	8	8	8	4	3	3	3	2	3	3	8	66	5
1882... 15th.....	4	7	15	6	3	2	2	1	1	4	1	0	46	4
1883... 16th.....	6	0	3	3	6	2	3	1	0	1	3	4	32	3
1884... 17th.....	5	2	8	2	9	4	1	4	2	8	8	15	68	6
1885... 18th.....	7	9	8	4	3	6	0	3	8	10	3	7	68	6
1886... 19th.....	3	3	3	2	8	4	2	8	7	4	2	8	54	4
Total.....	63	62	84	49	62	50	35	38	28	55	52	80	658	54.8
Average	6	5	8	5	6	5	3	3	2	5	5	7	60	5

As shown in the Table, the average number of earthquakes in every year was 60. During six years, namely, the 10th, the 12th, the 13th, the 14th, the 17th, and the 18th year of Meiji, they were more than 60; but during five years, viz., the 9th, the 11th, the 15th, the 16th, and the 19th, less than 60. Of these, the largest number was in the 13th, and the least in the 16th year.

The average in every month was 5. So we have 5 in February,

April, June, October, and November; more than 5 in January March, May, and December; less than 5 in July, August, and September. There were most in March, and least in September.

THE NUMBER OF EARTHQUAKES DIVIDED INTO SEASONS.

YEARS.	MEIJI.	SPRING.	SUMMER.	AUTUMN.	WINTER.	AVERAGE.
1876...	9th	22	11	10	13	14
1877...	10th	19	19	15	18	18
1878...	11th	14	9	12	15	25
1879...	12th	23	11	14	22	17
1880...	13th	14	21	14	28	19
1881...	14th	20	9	8	29	16
1882...	15th	24	5	6	11	11
1883...	16th	12	6	4	10	8
1884...	17th	19	9	18	22	17
1885...	18th	15	9	21	23	17
1886...	19th	13	14	13	14	13
Average		18	11	12	19	15

The average of every season was 15. There were more than 15 in spring and winter; less than 15 in summer and autumn; most in winter, and least in summer.

DIVIDED ACCORDING TO COLD (OCTOBER-MARCH) AND WARM (APRIL-SEPTEMBER) WEATHER.

YEARS.	MEIJI.	COLD.	WARM.	AVERAGE.
1876...	9th	26	30	28
1877...	10th	38	33	35
1878...	11th	32	18	25
1879...	12th	49	21	35
1880...	13th	47	30	39
1881...	14th	43	23	33
1882...	15th	31	15	23
1883...	16th	17	15	16
1884...	17th	46	22	34
1885...	18th	44	24	34
1886...	19th	23	31	27
Average		36	24	30

The average of the two seasons was 30, there being more than 30 in the cold season.

THE HOURS OF EARTHQUAKES.

The 658 earthquakes mentioned in the first part of this Report are here divided according to the hours at which they occurred.

Hours.		Months.											
A.M.	A.M.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
0 to	1...	4...	4...	2...	2...	1...	2...	2...	1...	2...	2...	0...	6...	28
1 to	2...	1...	0...	2...	0...	3...	2...	1...	0...	2...	1...	4...	2...	18
2 to	3...	1...	5...	3...	4...	4...	2...	2...	3...	1...	2...	2...	1...	30
3 to	4...	1...	0...	4...	0...	1...	3...	2...	2...	1...	6...	3...	3...	26
4 to	5...	1...	2...	5...	4...	1...	0...	2...	3...	0...	1...	2...	3...	24
5 to	6...	2...	2...	2...	4...	2...	1...	0...	3...	3...	3...	2...	6...	30
6 to	7...	3...	2...	4...	0...	2...	0...	1 ..	0...	0...	0...	1...	5...	18
7 to	8...	3...	2...	2...	3...	3...	0...	0...	2...	0...	3...	0...	4...	22
8 to	9...	0...	1...	0...	2...	4...	4...	0...	0...	2...	2...	1...	1...	17
9 to	10...	4...	4...	4...	1...	5...	4...	1...	2...	0...	3...	4...	6...	38
10 to	11...	5...	1...	1...	0...	2...	3...	2...	2...	2...	3...	3...	2...	26
11 to	12...	4...	1...	3...	1...	1...	2...	1...	0...	0...	0...	0...	3...	16
P.M.	P.M.													
0 to	1...	2...	1...	2...	1...	4...	6...	3...	0...	2...	0...	4...	4...	29
1 to	2...	3...	4...	4...	3...	1...	2...	2...	1...	2...	6...	2...	2...	32
2 to	3...	2...	4...	4...	1...	0...	1...	2...	3...	0...	0...	0...	3...	20
3 to	4...	3...	5...	3...	3...	4...	2...	3...	0...	2...	0...	6...	0...	31
4 to	5...	3...	1...	9...	3...	0...	3...	2...	3...	2...	1...	2...	3...	32
5 to	6...	2...	3...	2...	2...	8...	2...	1...	1...	1...	1...	1...	2...	26
6 to	7...	3...	2...	5...	2...	2...	5...	0...	2...	0...	2...	1...	2...	27
7 to	8...	4...	3...	4...	2...	0...	0...	0...	2...	0...	3...	2...	3...	23
8 to	9...	3...	4...	4...	3...	2...	0...	3...	3...	3...	8...	6...	8...	47
9 to	10...	3...	2...	4...	4...	5...	1...	2...	2...	1...	2...	3...	3...	32
10 to	11...	3...	4...	5...	3...	2...	2...	1...	2...	1...	3...	0...	6...	32
11 to	12...	3...	5...	6...	1...	5...	3...	2...	1...	1...	2...	3...	2...	34
Total		...63	...62	...84	...49	...62	...50	...35	...38	...28	...55	...52	...80	..658

According to the Table, earthquakes are most frequent at 8-9 p.m., next at 9-10 a.m.; least at 11 a.m.-12, and next least at 8-9 a.m. The most frequent, and the second least frequent are in hours at p.m. and at a.m. The least occur at a.m., and the most at p.m., the respective percentages being 55 and 45.

The hours when earthquakes are most numerous in each month are as follows:—

January	10-11 a.m.	—	—	—	—
February	2-3 a.m.	3-4 p.m.	11-mid-night p.m.		—
March	4-5 p.m.	—	—	—	—
April	2-3 a.m.	4-5 a.m.	5-6 a.m.	9-10 p.m.	—
May	5-6 p.m.	—	—	—	—
June	0-1 p.m.	—	—	—	—
July	0-1 p.m.	3-4 p.m.	8-9 p.m.	—	—
August	2-3 a.m.	5-6 a.m.	2-3 p.m.	2-3 p.m.	8-9 p.m.
September.....	5-6 a.m.	8-9 p.m.	—	—	—
October.....	8 9 p.m.	—	—	—	—
November.....	3-4 p.m.	8-9 p.m.	—	—	—
December.....	8 9 p.m.	—	—	—	—

The hours when earthquakes are most frequent in particular months seem to be very uncertain, but generally speaking disturbances are frequent at night, especially from 8-9 p.m. during the six months between July and December.

Intensity of Earthquakes.

Tokyo ranks first or second in the frequency of earthquakes in Japan, but fortunately there has not been any severe disturbance since the observations were first made. The dates of the severest earthquakes, and their intensity since the 19th year of Meiji, are given below. The intensity is indicated by Palmieri's scale of degrees :—

Years. Meiji.	Months and Days.	Times of First Vibrations.	Degrees of Vibrations.
1876	9th.....20th January.....	8.44.30 p.m.....	21°
1877	10th.....22nd July	4.49.17 p.m.....	11°
1878	11th.....23rd February ...	6.03.45 a.m.....	19° 20′
1879	12th.....3rd December ...	7.08.00 a.m.....	18° 30′
1880	13th.....22nd February ...	0.50.19 a.m.....	78° (out-run the instrument.)
1881	14th.....18th June	10.25.0 a.m.....	8° 30′
1882	15th.....11th March	7.54.50 p.m.....	11° 20′
1883	16th.....10th June	10.15.0 p.m.....	18° 20′
1884	17th.....15th October.....	4.21.54 a.m.....	95° 10′ (out-run the instrument.)
1885	18th.....20th March	1.01.13 p.m.....	22°
1886	19th.....8th May.....	10.14.0 p.m.....	2.8 millimetres in 0.4 second.

The strongest was the one on the 15th October, 17th Meiji; the next on the 22nd February, 13th Meiji.

The first of these began at 4.21.54 a.m. and lasted two minutes. The direction of motion, though varying, was mostly south-west and north-east, and its intensity was 95°10′ (there being no graduation beyond 25° the amount was guessed.) At this time, in Tokyo, though no house was destroyed nor the ground cracked, still the outside wooden framework of several store-houses fell down, a few walls of houses were cracked, here and there tiles fell from roofs, and furniture was in several instances upset or damaged. The shock of 1880 commenced at 0.50.15 a.m., and lasted one minute 26 seconds. The direction of motion, though varying, was

chiefly south-south-east and north-north-west, and its intensity was 78°. At this time, furniture was upset or damaged, the walls of common Japanese houses, brick houses, and store-houses were more or less cracked. The others mentioned in the list were also severe, but as their periods of vibration were long no damage was caused.

Direction of Motion of Earthquakes.

The nature of earthquake motion is not very simple, there being many other movements than those which are rectilinear and constant in their direction.

At the beginning of an earthquake the direction of motion seems to be uniform, but as soon as it grows stronger it may be in almost any direction. Though so confused, the disturbance is not without a principal direction, but sometimes the same earthquake may have two or three principal directions, as is shown in the table below:—

	Palmieri's ?								Milne's.		
Directions. Years	9th Meiji	10th Meiji	11th Meiji	12th Meiji	13th Meiji	14th Meiji	15th Meiji	Total	16th Meiji	17th Meiji	18th Meiji	Total	19th Meiji	Total	Grand Total
South—North	—	—	—	—	—	—	—	—	5	6	16	27	8	8	35
S.S.W.—N.N.E.	0	3	3	15	20	1	1	43	—	—	—	—	2	2	45
S.W.—N.E.	—	—	—	—	—	—	—	—	5	10	6	21	3	3	24
W.S.W.—E.N.E.	8	15	3	10	1	3	12	54	—	—	—	—	2	2	54
E.W.	—	—	—	—	—	—	—	—	8	25	7	40	14	14	54
E.S.E.—W.N.W.	12	12	22	9	7	26	3	91	—	—	—	—	5	5	96
S.E.—N.W.	—	—	—	—	—	—	—	—	3	5	4	12	13	13	25
S.S.E.—N.N.W.	0	4	1	11	24	7	14	61	—	—	—	—	3	3	64
Direction uncertain.	38	40	21	30	32	32	19	212	12	25	38	75	4	4	291
Total	58	74	50	75	84	69	49	459	33	71	71	175	54	54	688

This table shows that the direction of motion was most often between East South-East, and West North-West.

Nature of Earthquake Motion.

Although earthquake movements are horizontal or up-and-down, the velocities of the back and fore movements are often very different. Earthquakes when this motion is rapid often damage houses and furniture, but when it is slow they have rarely produced injurious effects. Thus during the 19th year of Meiji, the severe earthquakes were 19 in all, the slow moving ones 25,

whilst those which were so faint that their nature could not be ascertained were 10.

RELATION OF EARTHQUAKES TO ATMOSPHERIC PRESSURE.

There are many opinions as to the relation of earthquakes to atmospheric pressure, but nothing definite has yet been found. The following Table shows such relations for 531 earthquakes observed in Tokyo during nine years between the 11th and the 19th years of Meiji. (The earthquakes in this Table are not only those which occurred near Tokyo, but include all those which have been reported from different localities):—

ATMOS. PRES. MILLI.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
745	1	0	0	0	0	1	0	0	0	0	0	0	2
746	1	0	0	0	0	0	0	0	0	0	0	0	1
747	1	0	0	0	2	1	0	0	0	0	0	0	4
748	0	0	0	0	0	0	0	0	0	0	0	0	0
749	0	0	0	1	1	1	0	0	0	0	1	0	4
750	3	0	2	0	1	0	0	1	0	0	0	0	7
751	1	0	1	0	0	3	0	0	0	0	0	0	5
752	3	0	2	1	0	0	0	0	0	0	0	1	7
753	0	0	0	1	3	1	0	0	0	0	1	1	7
754	2	0	0	1	2	4	4	1	0	1	1	1	17
755	2	3	1	0	1	2	6	1	1	2	0	6	25
756	0	4	1	1	2	4	1	2	1	2	0	1	19
757	3	1	1	0	2	3	4	5	2	0	2	7	30
758	0	6	2	0	4	2*	5	1	2	3	0	3	28
759	2	4	3	2	6*	4	1*	5*	0	2	6	3	38
760	3	4	6	0	5	7	3	4	2*	2	2	2	40
761	3	7	3	3	4	1	1	7	3	7	2	3	44
762	6	2	3	3	2	1	1	1	6	2	5	5*	37
763	5*	5	8*	5*	5	1	0	0	4	1	6*	4	44
764	2	3*	6	0	1	2	0	0	2	1*	3	7	27
765	2	2	6	3	5	0	0	1	0	3	2	2	26
766	3	2	4	2	1	0	0	0	1	2	5	3	23
767	0	2	9	2	1	0	0	0	0	6	2	3	25
768	1	1	4	3	0	0	0	0	0	1	0	3	13
769	4	2	1	0	0	0	0	0	0	1	1	6	15
770	4	4	4	1	1	0	0	0	0	3	0	0	17
771	2	0	4	3	0	0	0	0	0	1	0	0	10
772	0	0	1	1	0	0	0	0	0	2	2	3	9
773	0	0	0	0	0	0	0	0	0	2	0	0	2
774	2	0	0	0	0	0	0	0	0	0	0	1	3
775	0	1	0	0	0	0	0	0	0	0	1	0	2
Total	56	53	72	33	49	38	26	29	24	44	42	65	531

* Means average atmospheric pressure.

From this Table we see that earthquakes are most frequent at 762 millimetres. This is about the average atmospheric pressure, which happens on very many days in a year. This observation therefore tells us but little. When the earthquakes which occurred when the atmospheric pressure was high or above the average, are compared with those that occurred when it was low, we find that they were rather more numerous when the barometer was low, the ratio being 46:44. Again, comparing the occurrence of earthquakes with the average atmospheric pressure of each month, the results are as follows:—

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Above average pressure	23	15	43	17	28	17	6	16	17	21	19	34	234
Below average pressure	33	38	29	16	21	21	20	13	7	23	23	31	297
Total	56	53	72	33	49	38	26	29	24	44	42	65	531

In January, February, June, July, October, and November, there were many earthquakes when the atmospheric pressure was below the average; while in March, April, May, August, September, and December, we have the reverse. Comparing the number of earthquakes occurring as above indicated, we find that they are in the ratio of 48 to 52, the greater number occurring with the low barometer.

Examined when atmospheric pressure is increasing or diminishing, the results are as follows:—

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Atmospheric pressure increasing ...	21	19	19	12	15	9	9	15	6	19	12	14	161
Atmospheric pressure diminishing..	15	20	24	12	11	7	6	1	5	13	13	26	153
Atmospheric pressure settled.....	20	14	29	9	23	22	11	13	13	12	17	25	208
Total	56	53	72	33	49	38	26	29	24	44	42	65	531

The earthquakes were most numerous when the atmospheric pressure was settled, less when it was increasing, and least when it was diminishing. Minutely speaking, in January,

August, and October there were many when it was increasing, and few when it was diminishing; in February and December there were many when it was diminishing and few when it was increasing, and in April the same in both cases. In March, May, June, July, September, and November, there were many when it was settled, and only a few when it was increasing or diminishing. This shows that the earthquakes were most frequent when the atmospheric pressure was settled.

Relation between Earthquakes and Temperature.

Temperature and atmospheric pressure have a close connection with each other. Generally speaking, the lower the temperature the greater the atmospheric pressure, the higher the temperature the less the atmospheric pressure. Whatever relation may exist between earthquakes and temperature may therefore, be simply the relation, looked at from a different point of view, between earthquakes and atmospheric pressure. In the following table 602 earthquakes observed during ten years from the 10th to the 19th years of Meiji (1877-1886) are compared with temperature:—

Temperature in Cent.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
6° below 0	0	1	0	0	0	0	0	0	0	0	0	0	1
5° zero	0	0	0	0	0	0	0	0	0	0	0	0	0
4° zero	1	0	0	0	0	0	0	0	0	0	0	0	1
3° zero	6	0	1	0	0	0	0	0	0	0	0	2	9
2° zero	3	1	0	0	0	0	0	0	0	0	0	1	5
1° zero	5	2	4	0	0	0	0	0	0	0	1	2	14
0° zero	6	5	5	0	0	0	0	0	0	0	1	6	23
1°	9	2	5	1	0	0	0	0	0	0	0	12	29
2°	3	8	6	0	0	0	0	0	0	0	0	6	23
3°	5*	5*	6	1	0	0	0	0	0	0	0	9	26
4°	7	10	8	1	0	0	0	0	0	0	2	8	36
5°	1	3	6	1	0	0	0	0	0	1	3	4*	19
6°	3	6	2*	2	0	0	0	0	0	0	2	5	20
7°	4	5	8	2	0	0	0	0	0	1	4	5	29
8°	2	7	5	5	1	0	0	0	0	0	4	2	26
9°	3	1	3	2	0	0	0	0	0	2	8	5	24
10°	0	2	8	3	4	0	0	0	0	2	5*	6	30
11°	2	0	2	0	2	0	0	0	0	1	2	0	9
12°	0	0	1	2*	2	0	0	0	0	6	2	1	14
13°	0	0	2	2	5	0	0	0	0	4	5	0	18

* Indicates average temperature.

Temperature in Cent.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
14°	0	0	2	5	1	0	0	0	0	4	3	0	15*
15°	0	0	2	3	6	0	0	0	0	8	2	0	21
16°	0	0	2	1	9	1	0	0	3	6*	0	0	22
17°	0	0	0	1	9*	6	0	0	2	4	4	0	26
18°	0	0	0	3	2	2	1	1	2	5	0	0	16
19°	0	0	0	0	3	4	0	1	1	1	0	0	10
20°	0	0	0	1	3	6*	0	0	1	1	0	0	12
21°	0	0	0	2	6	5	2	1	1	3	0	0	20
22°	0	0	0	0	4	5	3	2	8*	1	0	0	23
23°	0	0	0	0	0	6	6	5	1	1	0	0	19
24°	0	0	0	0	0	3	3*	3	0	1	0	0	10
25°	0	0	0	0	0	2	2	4*	1	0	0	0	9
26°	0	0	0	0	0	0	3	3	1	0	0	0	7
27°	0	0	0	0	0	2	2	3	1	0	0	0	8
28°	0	0	0	0	0	4	2	3	1	0	0	0	10
29°	0	0	0	0	0	1	2	2	2	0	0	0	7
30°	0	0	0	0	0	0	4	3	0	0	0	0	7
31°	0	0	0	0	0	0	2	1	0	0	0	0	3
32°	0	0	0	0	0	0	0	1	0	0	0	0	1
Total	60	58	78	38	57	47	32	33	25	52	48	74	602

* Indicates average temperature.

The average annual temperature in Tokyo is 14°. From the table we see that earthquakes were usually very frequent when the temperature was from 0° to 10°, and most frequent at 4° or 10° below the average temperature. The next was between 11° and 23°; at 17° there were 26; and above 24° not more than 10.

When compared with the average temperature of every month, the results are as follows:—

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Above average Temperature	25	36	36	19	22	31	19	18	11	20	20	26	283
Below average Temperature	35	22	42	19	35	16	13	15	14	32	28	48	319
Total.....	60	58	78	38	57	47	32	32	25	52	48	74	602

In January, March, May, September, October, November, and December there were many earthquakes occuring below the average temperature; in February, June, July, and August there were many occurring above it; in April, the same number

occurred both above and below it. Generally speaking, earthquakes were more frequent when the temperature was below the average rather than when it was above it, the ratio being as 60:40; also in every month there were more earthquakes when the temperature was below the average, the ratio being as 53:47. The following table shows the frequencies of earthquakes when the temperature was rising, falling, or settled :—

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Temperature rising	24	19	24	10	21	19	6	10	5	18	15	34	205
Temperature falling	31	29	39	18	31	22	22	21	15	27	31	35	321
Temperature settled	5	10	15	10	5	6	4	2	5	7	2	5	76
Total.....	60	58	78	38	57	47	32	33	25	52	48	74	602

As shown in the Table, earthquakes were numerous when the temperature was falling, few when it was settled, and tolerably frequent when rising. The same holds good in the case of every month. But in April and September there was the same number whether the temperature was rising or settled.

General Observations.

From a paper in this volume entitled "On the distribution of earthquake motion in a small area," it will be seen that even in Tokyo earthquakes have often occurred which have only shaken a superficial area of not more than 4 or 5 square miles. From this it follows that if observers and observations are not closely situated with regard to each other many earthquakes may pass unrecorded. Another cause tending to diminish the number of records is that many observers may be situated on low, soft ground where, partly in consequence of the length in period of the motion on soft ground, many shocks pass by unnoticed. Then again observers provided with instruments record more disturbances than those who are without instruments.

If, therefore, more instruments were distributed throughout Japan and the number of observers increased, basing my opinions upon observations made in Tokyo (see the above men-

tioned paper) I fancy that, instead of only recording about 480 shocks per year, the number might easily be increased to 1,000.

The reason that more earthquakes have been observed during the night than during the day, is probably owing to the fact that during the day people are usually moving about or so engaged that they are not so favourably situated to observe shocks as they are during the night. The figures giving the total area of ground which is shaken each year are probably very nearly proportional to the dissipation of seismic energy in the years to which they refer; and it will be interesting to notice how these figures, either as referring to the whole country or to particular seismic districts, follow each other in successive years. In seismological history we have many instances, as at Comrie in Scotland and at Kyoto in Japan, where seismic energy has become markedly less during historic times. A table of areas shaken in successive years might in cases like these indicate the *rate* at which energy was being dissipated. Farther, if we had a considerable number of seismographs giving us the number, amplitude, and period of all the vibrations which occurred in the shocks recorded during a given period, on the assumption of the disturbance as it radiated being practically superficial, as it appears to be, we should then be in a position to represent the seismic energy in mechanical units.

This leads us to ask whether the equivalent of this in heat units has any connection with the loss of heat, and consequently the heat gradient in the district where the observations have been made.

The variations in the distribution of seismic disturbances in successive years promise to yield results of considerable scientific importance.

An investigation which might be made with regard to the 228 shocks which originated on the coast or beneath the sea, would be to determine whether they had any connection with

the tides or currents on the coast. In an investigation which I made on this subject I found that the earthquakes which occurred at low water were 11.2 per cent. more numerous than those which happened at high water. (Trans. Seis. Soc., Vol. VII., Pt. II., p. 83.)

Another point of great importance in connection with any theory which may be advanced to explain earthquake action, which this report confirms, is that the ordinary earthquakes do not appear to be immediately connected with the presence of volcanoes.

A point I would suggest is that the records of a number of earthquakes coming from approximately the same origin be analysed separately. For this purpose two or three distinct sets of analysis might be made for the chief seismic *foci* in this country.

The great value of the report upon earthquakes which have been recorded in Tokio, is that it places before us a large number of trustworthy observations which are at our disposal for reference or analysis. Chaplin, Knipping, Knott, myself, and others have during previous years analysed a portion of these records, the results obtained being, so far as they can be compared with the series before us, very similar. In the present report, as in that by Prof. Sekiya for 1885, the classification of earthquakes according to four seasons, each of three months, commences with Spring, embracing March, April, and May. In my own tables and those of the late Mr. Mallet, Spring includes April, May, and June. Each season is therefore one month different in the present set of tables to the tables constructed previously. The results arrived at are, however, practically the same; namely, that during the winter and spring months, or during the cold months of the year there is a greater frequency of earthquakes than there is at other times in the year.

The comparison of earthquakes with the hours at which they have occurred, although not showing any thing very pro-

nounced, is an analysis to which Japanese earthquakes have for the first time been subjected.

In speaking of the intensity of earthquakes, the shock of October 15th, 1884, is regarded as the most severe which has during recent years been recorded in Tokio. So far as the record given by Palmieri's seismometer may be taken as a guide, this is certainly correct, but if we consider the damage which was the result of any of our recent earthquakes, then we must conclude that the most destructive earthquake was that of February 22nd, 1880.

The intensity recorded by Palmieri's instrument is simply dependent upon the height to which mercury in a tube has oscillated and moved a float connected with an indicator on a dial. This height is, as has often been pointed out, greatly dependent upon the synchronism or non-synchronism of the earthquake movements with the natural period of the mercury in the tube.

This being the case it is clear that a comparatively feeble earthquake might sometimes indicate a greater number of degrees than a much more destructive disturbance.

I am glad to see that more extended observations upon the principal direction of earthquake motion in Tokio confirms previous investigations (see Notes on "Recent Earthquakes of Yedo Plain, and their effects on Certain Buildings," by J. Milne; Trans. Seis. Soc., Vol. II., p. 38) these results being of importance to those who deal with construction.

A more interesting analysis respecting the occurrence of earthquakes and fluctuations of the barometer than the tables given, would be a comparison between the occurrence of earthquakes and barometric gradients, such gradients being measured across an area of considerable extent and in some known direction relatively to the centre of the districts shaken. It is not unlikely that many earthquakes will be found to accompany a steep gradient, and this may account for the observation, first pointed out by Knipping, that earthquakes

often accompany high winds. (See the paper on "Earthquake frequency," by Dr. C. G. Knott referred to at the commencement of this Report).

The chief value of the tables showing the relationship between earthquakes and changes in temperature may be to dispute a wide-spread belief that these two phenomena have an intimate connection.

Now that earthquakes at the Imperial Meteorological Observatory are altogether recorded as diagrams of motion, it is to be hoped that future reports will contain examples of these diagrams, and that tables giving amplitude, period, average period or say the number of waves in ten seconds, intensity, area shaken, distance, and direction of approximate origin may be given for all the earthquakes which are recorded.

PLATE I.

MAP SHOWING
THE SEISMIC FREQUENCY
For the Year 1886.

TESHIO
KITAMI
ISHIKARI
SHIRIBESHI
2
IBURI
TOKACHI
HITAKA
OJIMA
3
5
KUSHIRO
15
NEMURO
20
40
CHISHIMA
(Kurile Islands)
2
KOREA
OKI
MUTSU
15
3
8
UGO
RIKUCHU
10
RIKUZEN
3
UZEN
15
SADO
1
ECHIGO
IWASHIRO
9
IWAKI
3
31
NOTO
20
SHIMOTSUKE
19
KOTSUKE
ETCHU
3
KAGA
HIDA
4
SHINANO
HITACHI
55
20
MUSASHI
SHIMOSA
0
ECHIZEN
3
KAI
MINO
4
SAGAMI
8
15
KAZUSA
OWARI
2
SURUGA
AWA
5
MIKAWA
TOTOMI
IZU
OMI
4
HOKI
INABA
TAJIMA
TANGO
WAKASA
IZUMO
7
TAMBA
2
MIMASAKA
YAMASHIRO
IWAMI
HARIMA
BIZEN
BITCHU
BINGO
SETTSU
3
16A
AKI
3
YAMATO
4
ISE
IZUMI
KAWACHI
AWAJI
NAGATO
SUWO
SANUKI
22
TSUSHIMA
IKI
6
CHIKUZEN
BUZEN
IYO
7
2
TOSA
AWA
2
KII
7
HIZEN
CHIKUGO
3
6
BUNGO
HIGO
HIUGA
SATSUMA
3
OSUMI
10

+++++ Boundary line of Provinces.

▲ Active volcano.

△ Extinct volcano.

This map is constructed from observation of 472 earthquakes which occurred in Jan.–Dec. 1886. Dark shade indicates districts most frequently shaken while lighter parts were less disturbed. Numbers are inserted to show the number of earthquakes which occurred in different districts.

PLATE II.

MAP SHOWING THE POSITION
OF
SEISMIC ORIGINS
For the Year 1886.

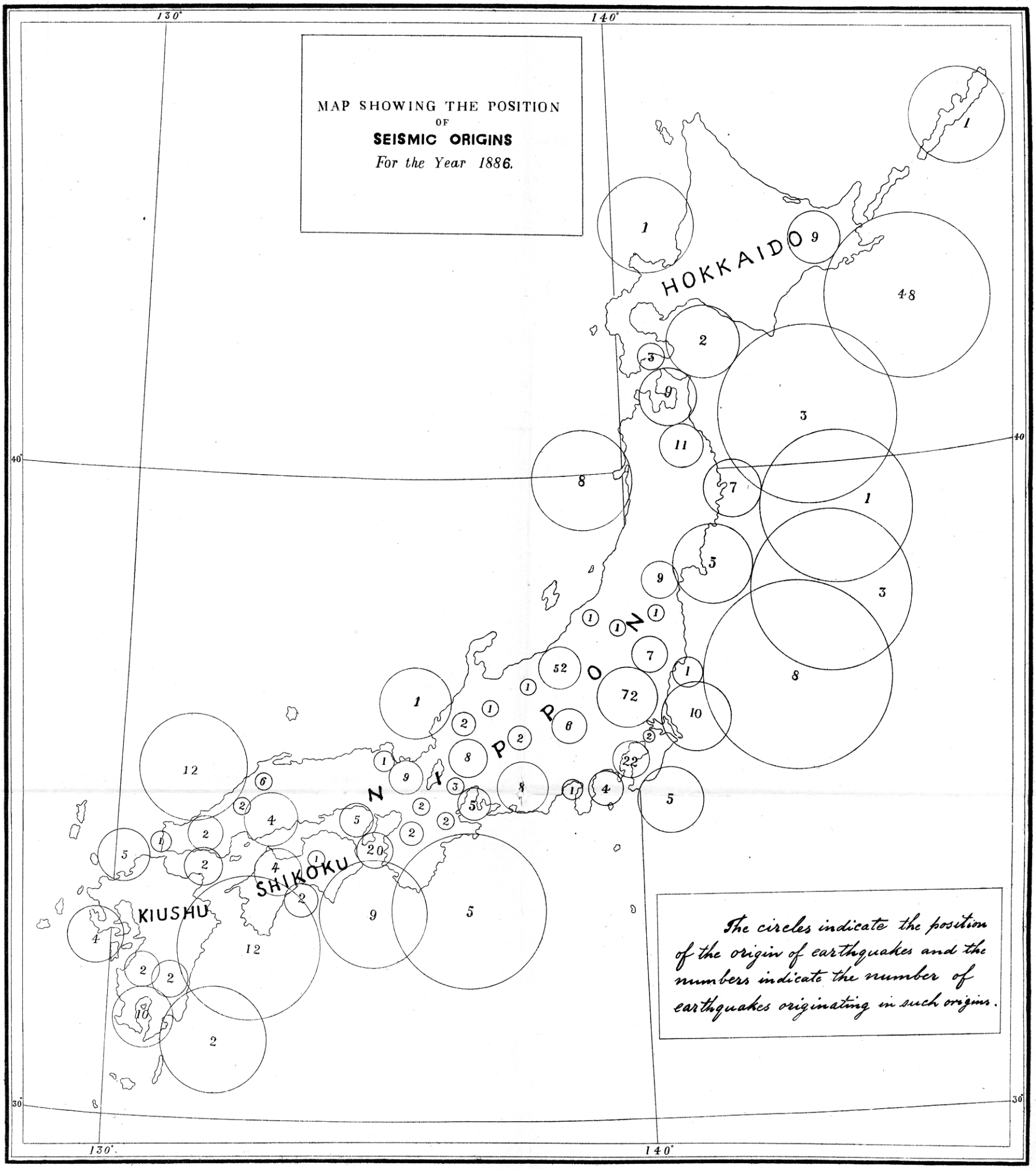
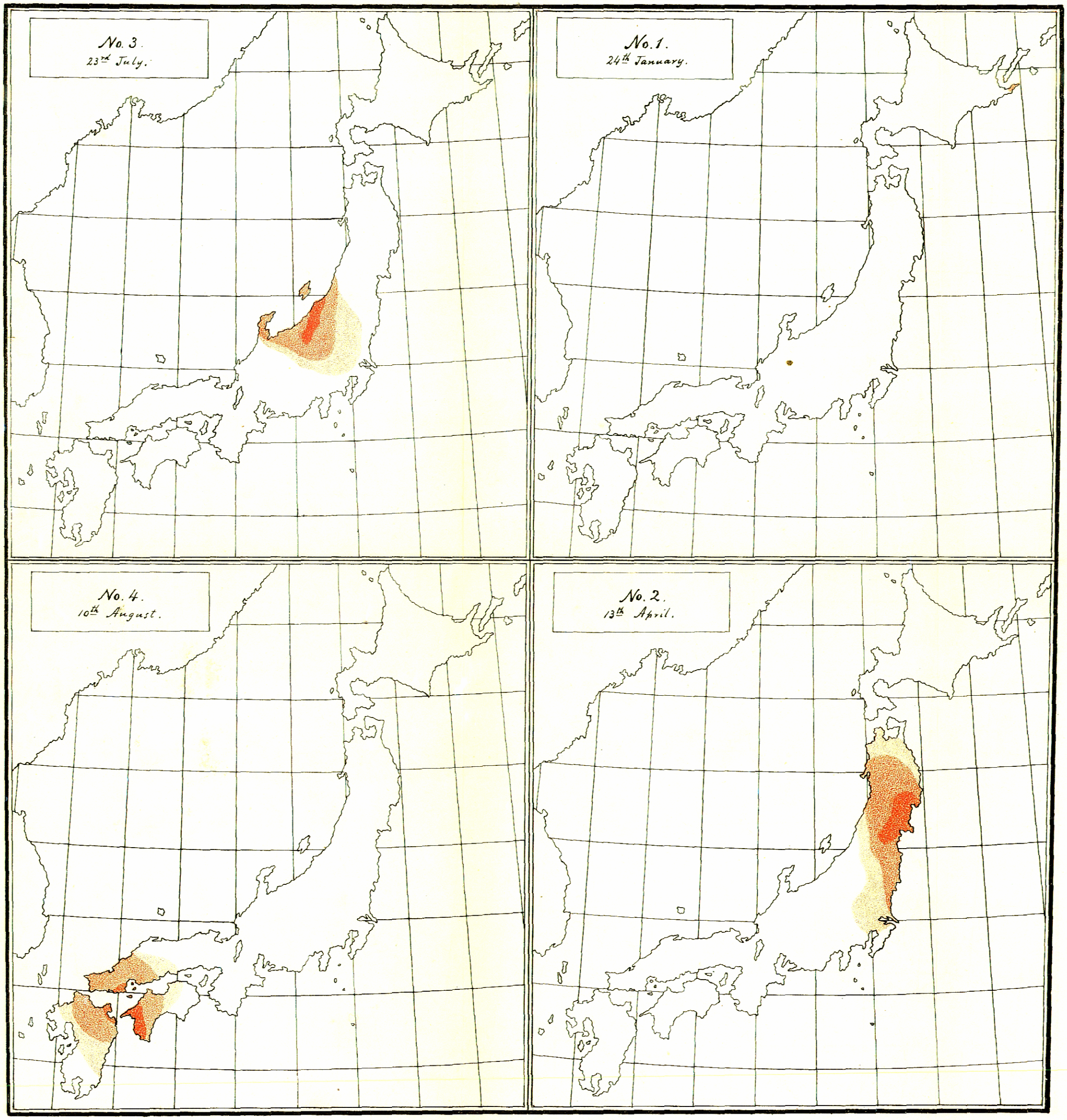


PLATE III.

MAP SHOWING

TYPICAL SEISMIC DISTURBANCES

For the Year, 1886.



The parts coloured brown were disturbed by earthquakes. Darker shade indicates strong shocks and the lighter feeble.

PLATE IV.

MAP SHOWING

THE FREQUENCY OF EARTHQUAKES

For the two Years 1885–1886.

130°

140°

40°

30°