

EARTHQUAKE OBSERVATIONS OF 1885 IN JAPAN.

BY PROFESSOR SEIKEI SEKIYA.

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In Vol. VII. Part II. of the Society's Transactions, there is a valuable paper by Professor John Milne, "On 378 earthquakes observed during two years in North Japan," in which the author describes in full the results of earthquake observations carried out between October 1881, and October 1883, in the country lying within 35° and 44° North Latitude. Subsequently, by his recommendation the authorities of the Imperial Meteorological Bureau decided to make similar observations extending over the whole Empire, and these I have had the honour of superintending.

The arrangements were certainly made on a wider scale, and it is therefore hoped that they are more complete. The Bureau published observation books furnished with directions for reporting seismic phenomena with or without the use of instruments. These were distributed among more than six hundred local officers and private observers throughout the empire, and the reports were transmitted free by the Post Office. From these reports sent in by different observers thus closely stationed, maps have been made showing the disturbed area for every shock, and general results have been published, the summary of which I am going to give in this paper.

MAPS OF TYPICAL EARTHQUAKES.

Maps I—XII. show some of the typical earthquakes which occurred in different parts of the country—small shocks as well

as large ones. More will be said about these maps when we discuss the area and grouping of shocks.

TABLE OF 482 EARTHQUAKES FROM WHICH MAPS MAY BE
DELINEATED.

In order to avoid publishing a map for each earthquake, which would involve considerable expense, Professor J. Milne suggested that the area disturbed by each shock might be determined by means of a map, like Map XIII., in which numerals are put down to show the different stations; besides which there is a table showing, by corresponding figures, the area disturbed. Actually there were over six hundred observing stations, but to avoid confusion on a small map like this, it is marked only up to 247. The table which is at the end of this paper points out stations visited by each shock. For instance, the earthquake of January 31st, 10. p.m. (No. 30 in the table) has 53, 54, 66, 67, 68, 69, 70, and 71 marked down. By referring to those portions of Map XIII. bearing the corresponding figures, we can judge the position and general character of that disturbance. Again the earthquake of March 7th, 0.40.0 a.m., has 218 only marked down, showing that the shock was local. So by similar methods the area disturbed by any other shock may be delineated. In fact the table is the complete record of the areas of disturbance for the whole year.

In the same table the time and area in square miles of each disturbance are given, the time being that near the origin of shocks.

It is very often the case that two districts considerably remote from each other are shaken simultaneously, or within a short interval of time, while the regions lying between them are entirely unaffected. In these cases it is sometimes difficult to determine whether to count the occurrence as one or more shocks. I classify them by considering the interval of time and the nature of the disturbed portion of the country.

NUMBER OF EARTHQUAKES AND THEIR DISTRIBUTION.

In the year 1885 there were in all 482 earthquakes in Japan, *i.e.*, 40 in one month or 1.3 shakings per day. From the reports of these 482 shocks Map XIV. was made, in which the seismic activity of each district is represented by shades of colours, the deepest shaded portions being regions most frequently disturbed. In those portions shaded with the same intensity, figures are put in showing the number of shocks that occurred in the same.

It appears from this map that earthquakes were most prevalent this year in the central and northern parts of the main island along the Pacific coast, while in those regions along the Japan Sea they were comparatively few. Speaking of the main island in general, the range of mountains traversing through and forming the backbone of Central Nippon appears, as pointed out by Professor Milne, to divide it into two zones of different seismic activities.

In Kiūshū, Shikokū, and in smaller islands, the number of disturbances were rather small. In Kiūshū the southern portions facing the Pacific ocean are more often shaken than the northern provinces bordering the Japan Sea, which have the same condition as that of the main island.

Earthquakes are quite numerous in the south of Yezo. From the north and central parts we have not received any reports, which may be due to the scantiness of the population and the difficulty of communication.

Those portions of Map XIV., which are uncoloured claim to be entirely free from shocks. Whether they are really so, or the observers have not felt them although there have been earthquakes, it is difficult to say at present. In Tokio the *majority* of shocks pass unfelt by people, while seismographs register them sufficiently to allow measurements, so that it is more than probable that a large number of rather feeble shocks are not reported; and I fully believe that there is no part in

Japan where the ground does not suffer shaking at least seven or eight times in one year.

AREA OF DISTURBANCE.

The areas of disturbance vary from small tracts of land to several tens of thousand of square miles. Nearly half of these shocks however are only local. Out of 482 earthquakes there were 235 local shocks. Maps II, III., IV., and XII., are examples of such disturbances. On the contrary, there are some whose area is very extensive, such as that of Map XI., which shock extended from the south of Yezo as far as the Plain of Musashi along the whole breadth of the main island disturbing a *land* area of 34,738 square miles.

This year, *large* earthquakes occurred only in Yezo, and in the north and central portions of the main island mostly along the Pacific Ocean.

If we divide 482 earthquakes according to the size of the disturbed land areas, they are :—

1 to 100 square miles	95
100 to 200 square miles	91
200 to 500 square miles	119
500 to 1,000 square miles	58
1,000 to 10,000 square miles	98
10,000 square miles and upward	21
Total	482

The average land area of one disturbance is 1,634 square miles. The aggregate area of disturbance during the year was 787,679* square miles, and taking the total area of the empire to be 147,000 square miles, it is equivalent to saying that the whole of Japan has been shaken 5.4 times in one year.

RELATION OF EARTHQUAKES TO SEASONS.

The number of earthquakes and their areas in the different

* A preliminary account of this paper was given by the present writer in "Nature" No. 861, Vol. 33. By closely examining the earthquake reports sent in, he has been induced to make some alteration in the figures given in the above named journal.

months and in the different seasons of the year are shown in the following tables :—

MONTHS.	No.	AREA IN SQUARE MILES.
January	32	59,643
February	44	101,080
March	37	43,562
April	37	28,263
May	51	61,828
June	43	94,590
July	32	54,589
August	29	36,103
September	45	86,738
October	41	127,074
November	51	24,529
December	40	69,675
Total	482	787,679

SEASON.	No.	AREA.		No.	AREA.
Spring	125	133,658	Hot months	237	362,116
Summer	104	185,282	(April-Sept.)		
Autumn	137	238,341	Cold months		
Winter	116	230,398	(Oct.-March)	245	425,563
Total	482	787,679		482	787,679

In February, May, June, September, October, and November the number was larger than, and in January, March, April, July and August it was less than, the average number (40) for one month in the year, while December had its value equal to the average.

If we group these numbers together according to seasons, autumn represents the maximum and summer the minimum. Again, if we group them into hot and cold months we have 237 for the former against 245 for the latter, the difference being only 8.

It has been shown on many previous occasions that earthquakes are much more frequent in cold months than in hot seasons, but in the present year the difference has only been very slight. It must be noted, however, that the request of the Meteorological Bureau to the local offices to send in observations was made at the end of the previous year, and in some provinces the report system might not have been in full

working order, which may account for the smallness of the number—and the area—in January. If that were so, it may cause some slight changes in the above table.

As to the area disturbed, February, June, September, October, and December had larger value than the average area (65,640 square miles) for one month, while the remaining months were under that value. Autumn had the maximum and spring the minimum area of disturbance. Again the area of hot months to that of cold months was in the ratio of 1 to 1.2, the difference being more clearly marked than in the case of the number of shocks.

GROUPING OF EARTHQUAKES AND THEIR ORIGINS.

In a great many instances, the extent of disturbance in certain portions of the country is limited to that portion alone, and it does not extend beyond certain boundaries.

In the Plain of Musashi there were 43 disturbances of this nature, in which the shaken portions assumed the somewhat circular form or a segment of a circle with their centres near the shore (stations 82-91, and 98-111) or out in the sea. Maps I. and VI. are examples of these earthquakes. In Kii (stations 168-169) seven earthquakes had very nearly the same area over that part, also shaking Awaji (station 211) and part of Shikoku (212-213); the origin was probably in the straits between these stations or in the sea beyond. Map IX. is an example. Similar examples may be cited in other parts of the country.

Map XIII. shows the origins of all earthquakes. Figures (in large type) in circular or elliptical curves approximately denote the number of earthquakes that have originated from those origins.

In speaking of these origins the curves are not meant necessarily to be the limits within which these origins lay; in some cases the origins may have been very extensive in length and breadth.

Most large earthquakes originate under the sea or near the

shore. Out of 482 earthquakes 305 were of littoral or submarine origin, while the remaining 177 shocks were of land origin, and were mostly local or small disturbances (see Maps II. and III.). There were not many cases in which large earthquakes originated in the interior of the country. Professor Milne arrived at a very similar conclusion.

RELATION OF EARTHQUAKES TO VOLCANOES.

In speaking on the above subject, Professor Milne observed that in the immediate vicinity of active and extremely recent volcanoes the seismic activity has been small, and those two phenomena are not directly connected.

The above remark applies, on the whole, to other parts of Japan although there are many exceptions to this statement. In Kiūshū where both active and extinct volcanoes abound, the seismic disturbances are not very frequent, while on the contrary, in Kii (stations 166, 169) and Mino (stations 141, 142, 150, 154) where active volcanoes are unknown, a large number of shocks have been recorded. On the other hand, the district round the Bay of Kagoshima (stations 233, 234, 236), which is itself supposed to be an old crater, with an active volcano in its centre, has been shaken nine times (probably oftener) in a year while the other parts of the island were comparatively at rest. In the vicinity of Osoreyama (a volcano, station 22), in the northern extremity of the main island the people felt 21 local shocks. In the province of Shinano (stations 120, 129) which has one famous volcano besides many extinct ones, several shocks which in a few cases were tolerably severe.

RELATION OF UPHEAVAL AND SUBSIDENCE TO EARTHQUAKES.

It was pointed out by Professor Milne that earthquakes are more numerous in Eastern Japan where there is abundant evidence of a recent and rapid elevation.

If we travel from the northern extremity of the main island along the Pacific coast toward the south-west as far as Kiushū one can not fail to see many historical and geological evidences

of upheaval, whereas, if we cross to the Japan Sea side, a gradual sinking of the shore, though not so distinct as the elevation on the other side, is to be noticed. In 1885 the seismic disturbances were more numerous on the Pacific or the rising side and less on the Japan Sea or the sinking side.

In conclusion I am glad to add that the authorities of the Imperial Meteorological Observatory are continuing these observations, and the results to be obtained from more years' work of this nature will, I hope, greatly assist the progress of Seismology in general.

NOTE.—By looking over the reports of 1886, which we have thus far received, we expect to get results somewhat different from those of the previous year.
