On the Earthquakes of the Fuji Volcanic Chain.

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With Pls. XXXVII—XXXIX.

CONTENTS.

1. ***Introduction.*** As stated below, the submarine earthquakes of May 13, 1908 seem to have originated at a point between Cape Omaezaki (province of Totomi) and the Hachijo-jima. The latter is one of the islands belonging to the Fuji volcanic chain, and is at a distance of about 290 km due south of Tokyo. Let us first examine the relation between the activity of this chain and that of the "external seismic zone," which runs parallel to the Japan arc on the Pacific side.

2. ***Activity in recent years of the External Seismic Zone.*** The majority of the recent larger Japan earthquakes originated from the northern part of the "external seismic zone," namely, off the eastern coasts of the Main Island and the Hokkaido, ex-

tending in the south to the mouth of the Tokyo Bay. (See the *Bulletin*, Vol. I, No. 2.) Their frequency varied of course from year to year, as will be seen from the following table, which gives the annual numbers of the submarine earthquakes, whose land area of sensible motion was over 7,000 square *ri*,* and which originated from the region under consideration.

TABLE I.—YEARLY NUMBER OF THE EARTHQUAKES WHICH ORIGINATED OFF THE NORTH-EASTERN COAST OF JAPAN.

Land area of Sensible motion > 7,000 sq. *ri*.

Year.	Number of the Earthquakes.
1901	5
1902	12
1903	5
1904	3
1905	2
1906	2
1907	4

From the above table, it will be seen that the larger earthquakes of the submarine origin occurred 12 times in 1902, but were much rarer and had the average annual frequency of 2.8 in the years after 1904. This decrease of the seismic frequency for the zone in question is also clearly shown by Table II, which gives for the interval of 1892 to 1907 the yearly number of those earthquakes, each of which was felt strongly, moderately, or slightly, along the north-eastern coasts of Japan over a land area greater than 4,000 sq. *ri*.

* 1 *ri* = 2.4 miles or 3.927 km.

TABLE II.—YEARLY NUMBER OF THE EARTHQUAKES, WHICH ORIGINATED OFF THE NORTH-EASTERN COASTS OF JAPAN,

And which were each felt *strongly*, *moderately*, or *slightly* over a land area greater than 4,000 sq. *ri*.

Year.	Number of the Earthquakes.	
1892	0	
1893	1	
1894	5	
1895	1	*Mean*....**3.6**
1896	3	
1897	8	
1898	1	
1899	2	
1900	5	*Mean*....**3.6**
1901	4	
1902	6	
1903	0	
1904	2	
1905	3	*Mean*....**1.8**
1906	2	
1907	2	

According to the above table, the larger and stronger earthquakes occurred 8 and 6 times respectively in the years 1897 and 1902; the average annual frequencies during the two successive five year intervals of 1893–1897 and of 1898–1902 being each equal to 3.6. During the last 5 years, 1903–1907, the seismic activity was much smaller, the average frequency being 1.8. Thus it will be seen that the large submarine earthquakes whose origins were near Pacific coasts of the northern Japan decidedly decreased in number since 1903. It is probable that this decrease will continue for several years to come, and that

the centre of seismic activity on the outer side of Japan will be in future transferred along the "convex seismic zone" southwards to the sub-oceanic region off the coasts of Tokaido and Nankaido, between the peninsula of Izu and the Island of Kyushu. In the mean while, the activity along the Fuji volcanic zone seems to have been increasing during the recent years.

3. ***Recent activity of the Fuji volcanic zone.*** The series of the islands (see the map, Fig. 1) belonging to the Fuji volcanic chain has, within the last a few years, been unusually active in the manifestation of the subterranean energy and given rise to the three following eruptions :—

(1) The explosion of the Tori-shima in August, probably between the night of 7th and that of 9th, 1902. The total population of the island, about 125 in number, was entirely wiped away without leaving even a trace.

(2) The submarine eruption near the Minami Iwo-jima (South Sulphur Island), on about Dec. 5, 1904, resulting in the formation of a new temporal island about 145 metres in height and 5 km in circumference.

(3) The submarine eruption in the vicinity of the Bayonnaise Rock (to the south-east of the Aoga-shima), in April, probably between the 7th and 13th, 1906. The outbursts continued for about one week, a great quantity of pumice having been found floating on the sea surface.

As regards the seismic activity, there were, since 1890, fifteen larger or stronger earthquakes which originated along the Fuji zone islands; the date, time of occurrence, approximate position of the origin, and area of disturbance* for each of these shocks,

* The area of disturbance signifies here the area within which the motion was felt or recorded by the ordinary Gray-Milne-Ewing type seismographs.

numbered 1 to 16, being given in Table III. The earthquakes numbered 2′, 3′, 4′, 5′, 6′, 7′, 9′, 10′, 11′, 13′, 14′ and 15′, given for the sake of comparison, are those which do not belong to the zone in question, but which occurred within a short time interval before or after the shocks 2, 3, 4, 5, etc., respectively.

TABLE III.—LIST OF THE LARGER EARTHQUAKES WHICH ORIGINATED ALONG THE FUJI VOLCANIC ZONE. 1890–1908.

Eqkes Nos. 2′, 3′, 4′, 5′, 6′, 7′, 9′, 10′, 11′, 13′, 14′, and 15′ are the larger disturbances which preceded or followed the shocks under consideration.

No.	Date.	Approximate Position of Eqke Origin.	Time of Occurrence at Origin.	Area of Disturbance. (Longer axis × shorter axis.)
1	**April 16, 1890.**	**Vicinity of Miyake and Mikura Islands.**	**^{h} ^{m} 9 30 pm.**	**(Land area of sensible motion = 4740 sq. *ri.*)**
2	**Feb. 12, 1896.**	**In the sea of Izu.**	**6 38 am.**	**150 *ri.* × 120 *ri.***
2′	„ 14, „	Tokyo Bay.	1 58 am.	110 × 60
	„ „ „	NW. part of Musashi.	2 04 am.	110 × 65
3	**May 7, „**	**Do.**	**2 37 pm.**	**150 × 140**
3′	„ „ „	Vicinity of Kyoto.	6 38 am.	120 × 60
4	**Jan. 18, 1897.**	**In the sea of Izu.**	**9 27 pm.**	**120 × 90**
4′	„ 17, „	Suzaka (Shinano).	5 36 am.	130 × 110
5	**March 27, 1898.**	**In the sea of Izu.**	**3 24 am.**	**170 × 110**
5′	„ „ „	Off the S. coast of Sagami.	11 25 pm.	120 × 100
6	**Jan. 31, 1900.**	**In the sea of Izu.**	**2 37 am.**	**180 × 120**
6′	Feb. 1, „	Off the E. coast of Mutsu.	4 22 am.	250 × 150
7	**Nov. 5, 1900.**	**$\varphi = 33°43'$ N; $\lambda = 139°06'$ E. Near the Islands of Miyake, Mikura and Kozu.**	**4 41 pm.**	**200 × 140**
7′	„ 6, „	Off the SE. coast of Awa-Kazusa Peninsula.	6 14 pm.	120 × 80
8	„ 9, „	**Some distance to the South of No. 7.**	**2 54 am.**	**180 × 140**

TABLE III. *(Cont.)*

No.	Date.	Approximate Position of Eqke Origin.	Time of Occurrence at Origin.	Area of Disturbance. (Longer axis × shorter axis.)
			h m	*ri.* *ri.*
9	**Nov. 19, 1900.**	**In the sea of Izu.**	**10 58 pm.**	**130 × 80**
9′	„ „ „	N. part of Yamato.	4 40 am.	130 × 70
10	**Feb. 20, 1902.**	**Vicinity of Hachijo-jima.**	**10 50 am.**	**190 × 150**
10′	„ 21, „	Off the E. coast of Mutsu.	0 35 am.	260 × 170
11	**June 3, 1903.**	**Vicinity of Hachijo-jima.**	**0 28 pm.**	**180 × 100**
11′	„ 2, „	Off the E. coast of Mutsu.	7 59 pm.	150 × 90
12	**Nov. 13, 1904.**	**Vicinity of Ogasawara-jima.**	**9 49 am.**	**Land area of sensible motion = 590 sq. *ri.***
13	**June 7, 1905.**	**Vicinity of Oshima.**	**2 40 pm.**	**220 × 120**
13′	„ 2, „	In the Inland Sea.	2 40 pm.	450 × 200
	„ 4, „	„	3 08 am.	90 × 50
	„ 6, „	„	8 32 pm.	80 × 40
14	**May 4, 1907.**	**Vicinity of Ogasawara-jima.**	**5 37 pm.**	**600 × 400**
14′	„ 5, „	Off the E. coast of Hitachi.	2 16 am.	220 × 180
15	**May 13, 1908.**	**Between Hachijo-jima and Omae-zaki.**	**5 23 am.**	**400 × 250**
	„ „ „	**Do.**	**5 37 am.**	**400 × 200**
15′	„ 14, „	Central part of Hitachi.	10 57 am.	40 × 30
	„ 15, „	S. part of Rikuzen.	10 40 am.	100 × 50

Of the 15 earthquakes, Nos. 1 to 15, the strongest were the three Nos. 1, 7, and 13, each of which was semi-destructive at some of the islands within the meizoseismal area, and caused some damage such as cracks of the ground, landslips of cliffs, etc. No. 1 was felt severely in the islands of Miyake and Mikura, and No. 7 in these two as well as in the island of Kozu. Eqke No. 14 originated near the island of Oshima. The positions of the origin of dis-

turbance of the 4 shocks Nos. 7, 11, 13 and 15 are indicated in Fig. 2. Of the remaining earthquakes, Nos. 10 and 11 originated in the vicinity of the Hachijo-jima, while Nos. 12 and 14 originated in the vicinity of the Ogasawara-jima.

The following table gives some of the results of the seismographical observations at Tokyo, Osaka, and Mizusawa, relating to the earthquakes Nos. 6-14. (Eqkes No. 15 are considered later on.)

TABLE IV.—EQKES NOS. 6-14, OBSERVED AT TOKYO, OSAKA, AND MIZUSAWA.

$\left\{\begin{array}{l}\text{Time of Occurrence}=t.\\ \text{Total Duration of the Preliminary Tremor}=y.\\ \text{Duration of the 1st preliminary Tremor}=y_1.\\ \text{,, 2nd ,, ,,}=y_2.\end{array}\right.$

No.	Date.	Tokyo.		Osaka.		Mizusawa.
		t	y	t	y	t
6	Jan. 31, 1900	h m s 2 37 31 am.	s $33\{y_1=15, y_2=18$			
7	Nov. 5, ,,	4 41 42 pm.	$27\{y_1=17, y_2=10$			
8	,, 9, ,,	2 55 03 am.	$99\{y_1=56, y_2=43$			
9	,, 19, ,,	10 58 39 pm.	$25\{y_1=12, y_2=13$			
10	Feb. 20, 1902	10 49 25 am.	30.1	h m s 10 50 10 am.	s $103\{y_1=52, y_2=51$	h m s 10 50 22 am.
11	June 3, 1903	0 27 48 pm.	25.1	0 28 20 pm.	63	0 28 55 pm.
12	Nov. 13, 1904	9 48 50 am.	48.5	9 47 29 am.	—	—
13	June 7, 1905	2 39 30 pm.	17.	2 40 18 pm.	50	2 40 33 pm.
14	May 4, 1907	5 38 24 pm.	96.	5 38 53 pm.	—	5 38 54 pm.

Calculating, for each of Eqkes Nos. 11 and 13, the epicentral distances (x) by the formula $x^{km.}=6.86\,y^{sec.}+8.1^{km.}$,* we find:—

Eqke No. 11 ....Tokyo.....180^{km}; Osaka.....440^{km}

Eqke No. 13 ....Tokyo.....125 ; Osaka.....351

* This Number, p. 146.

As shown in the map (Fig. 2), the origin of Eqke No. 13, determined by the intersection of the two circles drawn about Tokyo and Osaka respectively with radii proportional to the distances here obtained, is found to be quite close to the island of Oshima, which volcano ($\varphi=34°\ 43'$ N, $\lambda=139°\ 24'$ E) was probably the real centre of the disturbance. The origin of Eqke No. 11 is similarly found to be about 70 km to the south-west of the island of Hachijo. The Tokyo epicentral distance of Eqke No. 7 was, according to the calculation, 193 km and its origin was probably near to Miyake-jima, approximately at $\varphi=34°\ 3'$ N, $\lambda=139°\ 22'$ E. These three earthquakes, together with the shock of May 13th of this year, thus seem to have originated all along the chain of the Izu volcanic islands ; the others having their centres in the same neighbourhood or southwards in the vicinity of Ogasawara-jima (Bonin Islands),

4. ***Relation between the earthquakes of the Fuji volcanic zone and those originating off the north-eastern coasts of Japan.*** According to Table III, the majority of the larger earthquakes, which belonged to the Fuji volcanic chain, and whose area of disturbance had, in each case, a longer diameter greater than 100 *ri* (=400 km), were accompanied within a day or so by similar ones originating elsewhere in Japan or off its north-eastern coasts. Before conceiving any relation between these different groups of earthquakes, however, it is necessary to examine the average frequency of larger earthquakes in the whole of Japan. This is indicated in the accompanying table, for those years in which the shocks Nos. 2, 3,.....11, 13, 14 and 15 took place.

TABLE V.—YEARLY NUMBER OF LARGER EARTHQUAKES.
WHOLE JAPAN.

Year.	Number of Eqkes, whose land area of disturbance was greater than 1,000 sq. *ri*.	Number of Eqkes, whose longer axis of the area of disturbance was greater than 100 *ri* (=400 km).
1896	38	36
1897	36	34
1898	62	54
1900		72
1902		75
1903		59
1904		50
1905		84
1907		71

The annual earthquake number in Japan during the interval under consideration varied between 34 and 84, giving the average value of 59, which is equivalent to one larger shock occurring every 6.2 days. This is 7 times longer than the average interval of **21.6** hours (Table VI) between the different earthquakes of the Fuji volcanic zone and the shocks which accompanied them. Hence it is probable that the earthquakes Nos. 2′, 3′, 4′,...., which either preceded or followed the Eqkes Nos. 2, 3, 4,...., were really related to these latter.

The eleven earthquakes, 2′, 3′, 4′,....may be divided into two groups, (i) and (ii), according as they preceded or followed those of the Fuji volcanic zone, as shown in the following table.

TABLE VI.—RELATION OF THE EARTHQUAKES OF THE FUJI VOLCANIC ZONE TO THOSE OF THE OTHER ORIGINS.

Eqke. Nos.	Origin of the Eqke by which that of the Fuji Volcanic Zone was		Time interval by which Eqke of the Fuji Volcanic Zone was	
	preceded...(i)	followed...(ii)	preceded by (i)	followed by (ii)
			day hour	day hour
2′–2	.....	Tokyo Bay.	.....	1 19
3–3′	Vicinity of Kyoto.	.....	0 8	.....
4–4′	Vicinity of Suzaka (Shinano)	.....	1 16	.....
5′–5	.....	Off the S. coast of Sagami.	.....	0 20
6′–6	.....	Off the E. coast of Mutsu.	.....	1 2
7′–7	.....	Off the SE. coast of the Awa-Kazusa Peninsula.	.....	1 2
9–9′	N. part of Yamato.	.....	0 18	.....
10′–10	.....	Off the E. coast of Mutsu.	.....	0 14
11′–10	.....	do.	.....	0 16
13–13′	Inland Sea	.....	0 18	.....
14′–14	.....	Off the coast of Hitachi.	.....	0 9
15′–15	.....	Hitachi.	.....	1 5
		Mean.....	**0 21**	**0 23**
			General Mean.....**22** hours.	

It will be seen from the above table that there is apparently a certain regularity in the order of occurrence of larger earthquakes along the different seismic zones. All the earthquakes of Group (ii) originated off the north-eastern coasts (including Tokyo Bay) of Japan, while those of Group (i) originated in the central part of the Main Island or in the Inland Sea. Whether these interesting relations are also fulfilled in the future remains to be seen. It is true that the number of the shocks of Group (i) is too few and only four. But the uniformity of the Pacific

origin of all the 12 shocks of Group (ii) is striking. Confining our attention to the latter group alone, we may, as a provisionary conclusion, suppose that, when the seismic stress along the Japan arc reaches a maximum limit, and an earthquake first occurs along the Fuji volcanic zone, an equal or greater disturbance is likely to originate after about one day off the eastern coast of the Main Island or Hokkaido. That is to say, the Fuji zone, or the series of the islands belonging to it, forms a very sensitive seismic belt, and gives rise to the earthquake or volcanic eruption, which serves as a fore-runner to another in the northern part of the principal or external seismic zone.

5. ***Volcanic eruptions.*** Of the three volcanic eruptions mentioned in § 3, the first and the third, which occurred not very far from Izu islands group, respectively at Tori-shima and near the Bayonnaise Rock, were each accompanied by a marked seismic activity. Thus, the eruption of Tori-shima took place between the night of 7th and that of 9th, in August 1902, the larger Japan earthquakes during this epoch being as follows :—

Date. (Aug., 1902)	Approximate Time of Occurrence at Origin.	Origin of Earthquake.	Longer and Shorter axes of Area of Disturbance.
7	$0^h\ 36^m$ pm.	Bay of Tokyo.	$160^{ri.} \times 70^{ri.}$
,,	6 22 pm.	Off the coast of Mutsu.	250×150
8	8 37 am.	Sahara (Shimosa).	200×120

It may be added that there was no large earthquake in any part of Japan during the 11 days preceding the 7th of August, and also during the 11 days succeeding the 8th of August.

The submarine eruption near the Bayonnaise Rock probably occurred between 7th and 13th of April, 1906, (i.e. simultaneously with the great outbursts of the Vesuvius), there having been the following six earthquakes during the 7 days from 4th to 14th (Formosa excepted) :—

Date. (April, 1906)	Approximate Time of Occurrence at Origin.	Origin of Earthquake.	Longer and Shorter axes of Area of Disturbance.
4	10h 04m am.	Off the coast of Rikuzen.	130 ri. × 70 ri.
5	11 50 am.	„ „ Iwaki.	240 × 180
6	7 29 pm.	Off the E. coast of Nemuro.	350 × ?
8	2 52 pm.	Off the E. coast of Awa-Kazusa Peninsula.	160 × 70
9	2 38 am.	Off the coast of Iwaki.	230 × 160
11	7 08 pm.	NW. part of Mino.	140 × 90

In this case again there was no large earthquake in Japan (Formosa excepted) during the 11 days preceding the 4th of April, and during the 9 days succeeding the 11th of April.

6. ***Note on volcanic earthquakes.*** The earthquakes originating along the Fuji volcanic chain are probably of the volcanic origin, that is to say, they are the effects due to the activity of the volcanic energy, resulting in the sudden formation or extension of a subterranean cavity and other disturbances. Earthquakes of this nature need not necessarily be small, and are sometimes quite different in magnitude from those, which accompany actual volcanic eruptions or explosions and which are of purely surface origins. As instances of strong volcanic earthquakes of moderate extension, I may mention the shocks on April 21st and 22nd, 1792, which preceded the final catastrophe

of the Unsen-*dake* (in the province of Hizen, Kyushu),* which caused in the town of Shimabara some damage to buildings and cracks of the ground about 1 inch in width. The earthquake of April 2, 1868, in the island of Hawaii, which attended the eruption of Mauna Loa in that year, is another example. It caused some damage to buildings in the vicinity of the mountain, in addition to a landslip which produced a remarkable mud stream. The shock at Pompeii, which had caused a considerable amount of damage to the buildings in that city 16 years prior to its final destruction by the eruption of the Vesuvius, was also evidently of the same category.

The proper volcanic earthquakes are thus sometimes strong, semi-destructive, or even locally destructive, but seem as a rule not to attain the magnitude of a large destructive shock.

Earthquake of May 13, 1908.

7. *Different shocks on May 13, 1908.* As is usually the case with stronger earthquakes of the Fuji volcanic zone, the principal shock of May 13th, 1908, at about 5h 23m am., was accompanied by many minor ones, the earliest of which occurred at 4h 44m am. on the same day. The following table is a list of 13 of the shocks of this group, which were sensible or were recorded by the ordinary Grey-Milne-Ewing type seismographs on the Main Island, during the course of the next 24 hours; the numerals within the brackets in the first column corresponding to those of the fore-shocks (Table on page 99) and after-shocks (Table X) observed at Hachijo-jima.

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* See my "Note on the Eruptions of the Unsen-dake in the 4th year of Kansei (1792)." The *Bulletin*, Vol. I, No. 3.

TABLE VII.—LIST OF THE EARTHQUAKES ON MAY 13th AND 14th, 1908, WHICH WERE SENSIBLE, OR WERE RECORDED BY THE ORDINARY GRAY-MILNE-EWING TYPE SEISMOGRAPHS.

No.	Approximate time of Occurrence at Origin.	Time of Occurrence in Tokyo.*	*Strong.*	*Moderate.*	*Slight.*	Slight (insensible) **
	[May 13th]					
a (1)	h m 4 44 am.	h m s ——	——	——	——	Numazu Matsumoto.
b (2)	5 06¾ am.	5 07 06 am.	——	——	——	Hachijo-jima, Numazu, Kofu, Kumagae.
c (6)	5 23 am.	5 23 22 am.	Hachijo-jima, Nagatsuro, Numazu.	Yokohama, Iida, Mera, Hamamatsu Matsumoto, Tsu, Kofu, Takayama, Kyoto.	Tokyo, Yokosuka, Hikone, Osaka, Nagoya, Gifu, Niigata.	Fukushima, Mito, Yokosuka, Fukui, Yagi, Wakayama, Tokushima, Okayama.
d	5 30 am.	——	——	Matsumoto.	Yokosuka.	Numazu.
e (7)	5 37 am.	5 37 22 am.	Hachijo-jima, Nagatsuro.	Numazu, Tsu.	Tokyo, Mera, Kofu, Nagoya.	Fukushima, Mito, Yokosuka, Gifu, Hikone, Kyoto, Osaka.
f (1′)	5 54 am.	——	——	——	Kofu.	Yokohama, Numazu.
		5 57 17 am.	——	——	Yokohama.	Yokosuka, Numazu.
g (5′)	6 34 am.	——	——	——	——	Kofu.
h (8′)	7 03¾ am.	7 04 05 am.	——	——	Kofu.	Numazu.
i (10′)	7 28 am.	——	——	——	——	Kofu.
j	8 17 am.	——	——	——	——	Kofu.
k	9 23 am.	——	——	——	——	Kofu
l	9 54 am.	——	——	——	Kofu.	Numazu.
	[May 14th]					
m	1 33 am.	——	——	——	Hachijo-jima Yokohama, Kofu.	Matsumoto, Numazu, Hikone.

* The times of occurrence in Tokyo have been taken from the seismograms furnished by the horizontal pendulum tromometer of 120 times magnification.

** A *slight* (*insensible*) shaking means an earthquake which is insensible, but is recorded by an ordinary Gray-Milne-Ewing type seismograph.

The shock at 5h 23m am. was felt *strongly* at Hachijo-jima and within an area of 110 sq. *ri* on the Main Island, which covered the major part of Izu and a portion of Totomi, causing stoppage of pendulum clocks, overflow of liquids, etc. The area of *moderate* motion, about 1,780 sq. *ri*, extended over the provinces of Mikawa, Totomi, Suruga, Kai, Sagami, Awa, and Kazusa ; the total land area within which the motion was sensible or was recorded by the Gray-Milne-Ewing type seismographs being 8,640 sq. *ri*. At the Hachijo-jima itself, the second shock, which followed 14 minutes later, was felt much more strongly than the first. Again, of the 13 earthquakes tabulated above, only 8 were sensible on the Main Island. The earthquake at 5h 37m am., which was, according to the seismographic records at the different stations, of a magnitude practically equal to that of the principal shock, had a much smaller land area of disturbance than the latter. This was probably due to the removal of the origin of the second earthquake further southwards. The areas of disturbance of these two earthquakes are indicated in Pl. XXXIX.

8. ***Preliminary tremor and epicentre.*** Table VII gives the times of occurrence and the durations of the preliminary tremor of the two principal earthquakes, deduced from the records furnished by the Omori horizontal pendulum seismographs at Tokyo, Osaka, Mito, Mt. Tsukuba, Nagano, and Hachijo-jima, whose multiplication ratios varied from 10 to 300 times. The determination of the moment of commencement of the second shock was rendered uncertain by the superposition of the vibrations forming the end portion of the first.

TABLE VIII.—TIME OF OCCURRENCE AND DURATION OF PRELIMINARY TREMOR OF THE TWO PRINCIPAL EARTHQUAKES, OBSERVED WITH OMORI HORIZONTAL PENDULUMS.

Station.	Time of Occurrence. (am.)	Component.	Duration of Preliminary Tremor.	Instrument.	
				Proper Period.	Multiplication.
1st Earthquake.					
Tokyo.	5h 23m 22s	NS	32.9 sec.	28.0 sec.	10
		,,	34.5	48.5	20
		EW	27.4	4.7	300
		,,	25.2(?)	26.5	120
		,,	24.8(?)	61.5	15
Osaka.	5 23 35	NS	46.7	30.0	20
		EW	44.8	25.0	20
		NS	42.9	4.0	90
		EW	—	4.0	90
Mt. Tsukuba.	5 23 41	EW	40.3	4.0	90
Mito.	5 22 48	EW	45.0	28.8	20
Nagano.	—	EW	39.7	13.0	20
Mizusawa.	5 24 20	—	—	—	—
Hachijo-jima.	5 19 09(?)	EW	15.2	4.5	150
2nd Earthquake.					
Tokyo.	5 37 00	NS	30.5(?)	28.0	10
		,,	32.3(?)	48.5	20
Osaka.	5 37 00	NS	46.1	30.0	20
		EW	45.7	25.0	20
		NS	48.0	4.0	90
		EW	48.5	4.0	90
Mito.	—	EW	47.0	28.8	20
Nagano.	—	EW	34.0(?)	13.0	20

The duration of the preliminary tremor at Tokyo seems to be somewhat shorter in the EW component than in the NS. As a provisionary measure I have adopted the value for the latter component, which corresponded nearly to the longitudinal wave. The duration for Osaka does not much differ in the two components, which may therefore be taken together. Table IX gives the mean durations of the preliminary tremor at the different places obtained by averaging the results relating to the two earthquakes.

TABLE IX.—MEAN DURATION OF THE PRELIMINARY TREMOR AT THE DIFFERENT PLACES.

Station.	Duration of Preliminary Tremor = y (*mean value*).	Epicentral Distance = x, calculated by Eq. (3), page 146.
	sec.	km
Tokyo	33.7	239
Osaka	46.4	326
Mt. Tsukuba	40.3	284
Mito	46.0	323
Nagano	39.7	280
Hachijo-jima.	15.2	112

The epicentral distances (x) given in the 3rd column of the above table have been calculated from the duration (y) of the preliminary tremor by the equation $x^{km} = 6.86\, y^{sec} + 8.1^{km}$.* Drawing on the map (Fig. 4) the circles about the 6 different places as centres, with the radii proportional to the x thus obtained, the points of the mutual intersection are found to be quite close to one anothers, except those relating to Nagano. The approximate position of the epicentre marked on the map by a small cross

* This Number, p. 146.

(×), is at about $\varphi = 33° 53'$ **N**, $\lambda = 138° 55'$ **E**, nearly midway between the island of Hachijo and Cape Omae-zaki of Totomi. (See Fig. 3.)

9. ***Fore-shocks.*** The earthquake at 5h 23m am. was preceded by 5 minor precursory disturbances. These furnish a very interesting example of the occurrence of the "fore-shocks" of earthquakes, and have been discussed in another article. (This Number, p. 99.)

10. ***After-shocks.*** Table X gives the time of occurrence, the duration of the preliminary tremor, and the maximum range ($=2a$) of motion in the EW direction for the 12 after-shocks, which immediately followed the two principal earthquakes, the observation having been made at the meteorological observatory of Hachijo-jima with an Omori horizontal tremor-recorder of 150 times magnification.

TABLE X.—AFTER-SHOCKS OBSERVED AT HACHIJO-JIMA.

No.	Time of Occurrence at Hachijo-jima.	Total Duration.	Duration of Preliminary Tremor.	Max. $2a$.
	h m s	m s	sec.	mm
1′	5 55 02 am.	—	16.5	0.19
2′	5 57 13	5 15	16.1	0.34
3′	6 13 14	1 30	15.1	0.037
4′	6 20 46	—	—	—
5′	6 33 44	0 30	14.6	0.030
6′	6 36 55	0 50	—	0.027
7′	6 55 14	0 50	15.3	0.037
8′	7 03 55	2 00	16.3	0.090
9′	7 23 00	1 10	15.9	0.030
10′	7 28 30	0 50	16.4	0.020
11′	7 49 00	1 40	14.6	0.020
12′	8 00 40	0 30	—	0.016

Except the first two, all these shocks were very small. The duration of the preliminary tremor for the different cases varied between 14.6 and 16.5 sec., giving the average value of 15.6 sec., which corresponds to an epicentral distance of about 107 km from Hachijo-jima, probably to the NW of the latter. The successive time intervals between the 12 after-shocks were as follows :—

2^m11^s	
16 01	..... (*)
7 32	
12 58	..... (*)
3 11	
18 19	..... (*)
8 41	
19 05	..... (*)
5 30	
20 30	..... (*)
11 40	

It will be observed that every alternate intervals, marked by *asterisks*, varied from about 13 to about 19 minutes and were much longer than the intermediate ones.

The two principle earthquakes on the 13th were followed, in accordance with the characteristic of the disturbances along the Fuji volcanic chain (§ 4), by the two following shocks which originated along the north eastern coast of the Main Island :—

May 14th: 10.57 am.....Origin, central part of Hitachi.
„ 15th: 10.40 am..... „ , S. part of Rikuzen.

There was no shock of the land area of disturbance greater than 1,000 sq. *ri* for the 8 days after the 2nd of the above earthquakes, and for 9 days 14 hours preceding the 1st shock on the 13th. (See Table III.)

Fig. 1. Map of the Islands of the Fuji Volcanic Chain.

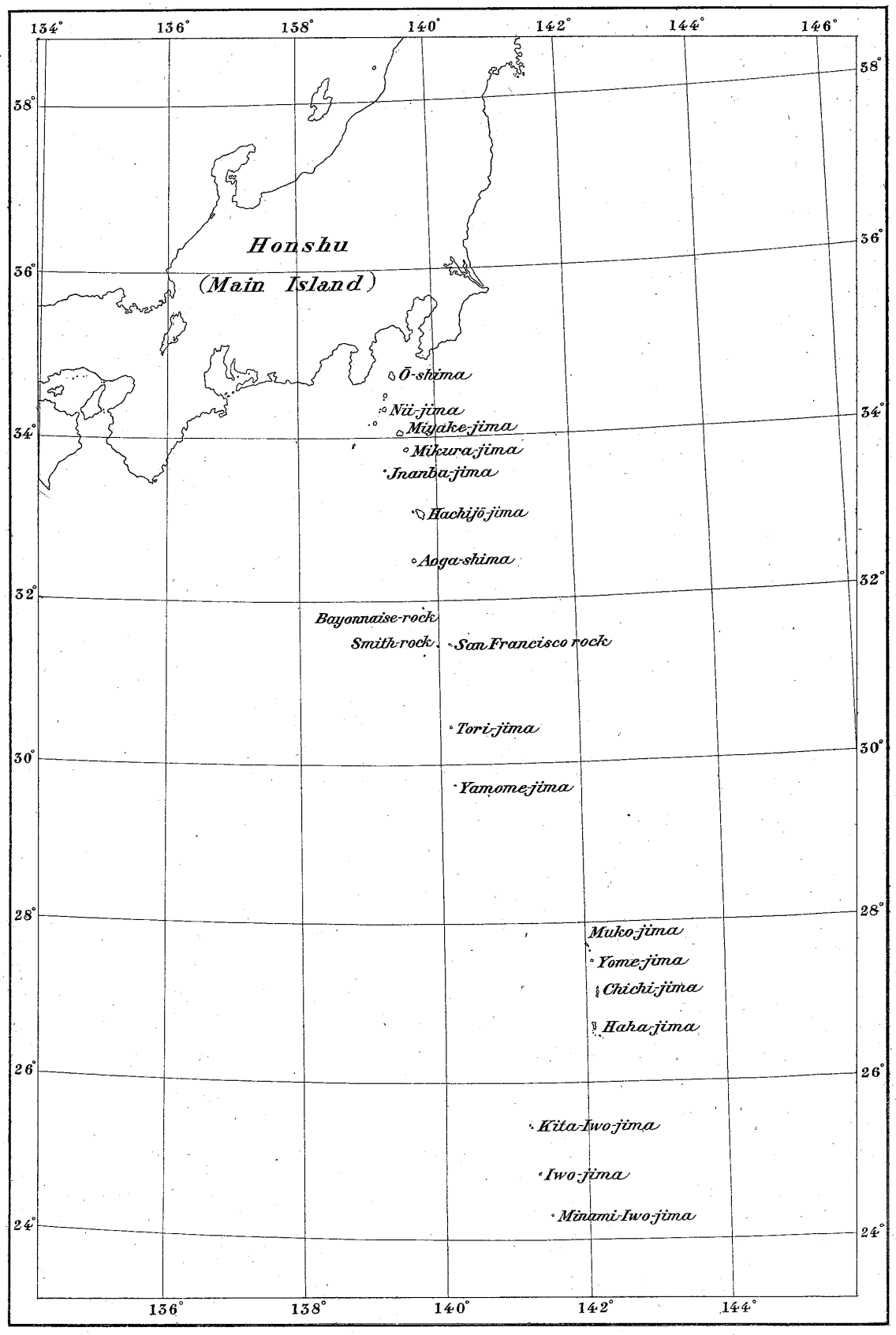

Fig. 2. Map showing the Positions of the Origins of the Earthquakes which took place along the Fuji Volcanic Zone.

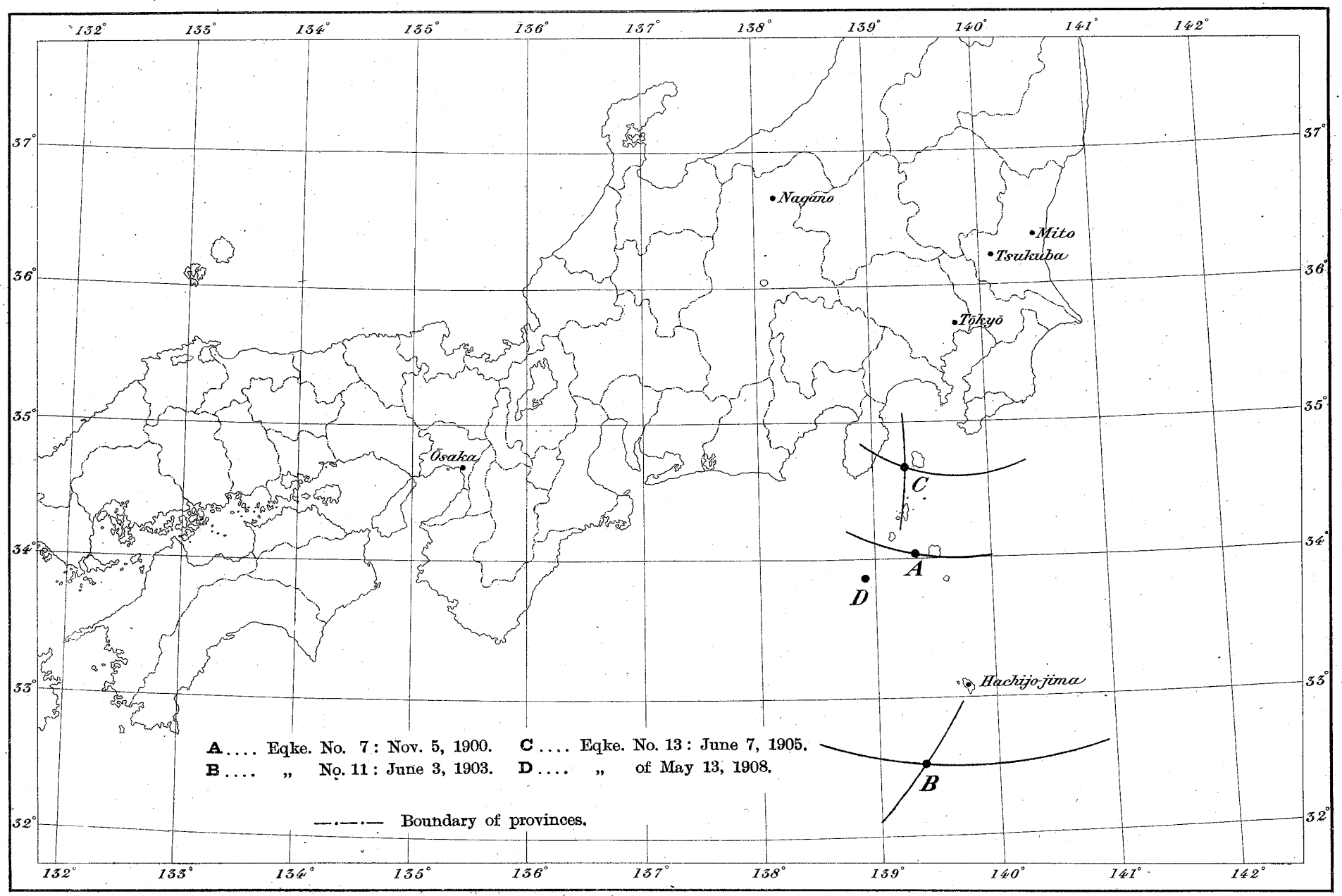

Fig. 3. Earthquakes of May 13, 1908.