

On the Distribution of Recent Japan Earthquakes.

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I. PRELIMINARY.

1. Arrangements of Earthquake Zones. Let A (Fig. 1) represent a portion of the earth's surface, which is being depressed down. Then it can easily be demonstrated that there will be formed in the surrounding region two systems of weak lines, as shown in the figure. These are, *firstly*, concentric arcs, and *secondly*, radial lines, corresponding respectively to the dislocations and the cracks in the earth's crust.

Fig. 1

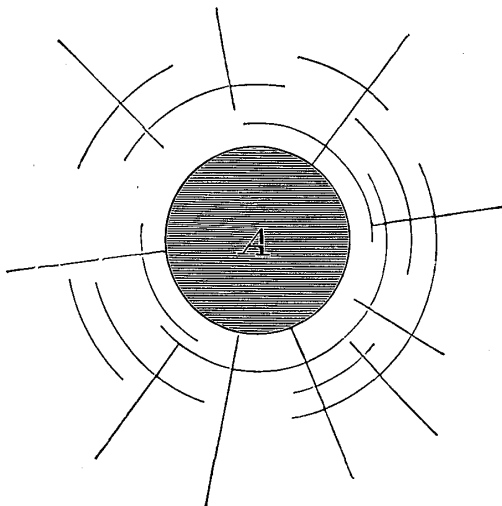
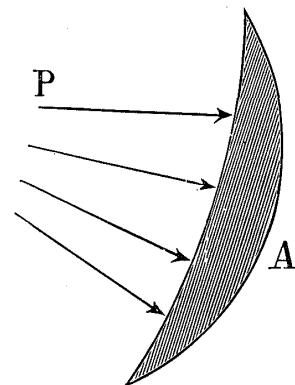


Fig. 2



Let us next vary slightly our supposition, and assume A (Fig. 2) to be a portion of the earth's surface, which is pushed from one side by a pressure P . In this case there will be formed two systems of the weak lines, similar to those mentioned above ; the

concentric lines, however, becoming in this case foldings in the earth's crust. One of the consequences of the existence of the horizontal pressure P is that the outer (or convex) and the inner (or concave) sides of the region under consideration differ materially in the topographical features ; the former being much steeper in gradient than the latter. (See also Fig. 4). A may be a great mountain chain or a series of islands, arranged in a curvilinear form.

2. Japanese Islands.

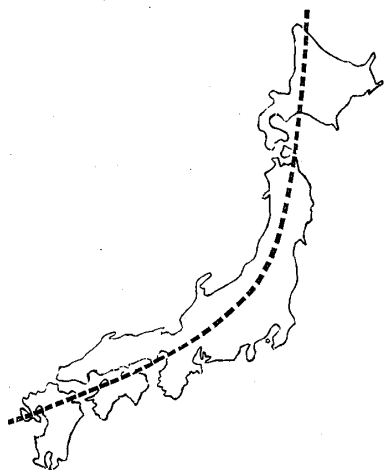


Fig. 3

The dotted line shows the general curve form of Japanese islands.

Fig. 2 is a diagrammatic representation of the Japanese islands, which, as shown in Fig. 3, forms a circular arc, whose convex and concave sides are turned toward the Pacific Ocean and Japan Sea respectively ; a glance at any map of Japan suggesting the idea that the islands were caused to assume their curvilinear form by the pressures acting from the Japan Sea side. The difference in the steepness of the gradient between the two sides of

the island arc of Japan is illustrated in Fig. 4, which gives an ideal cross section of the latter.

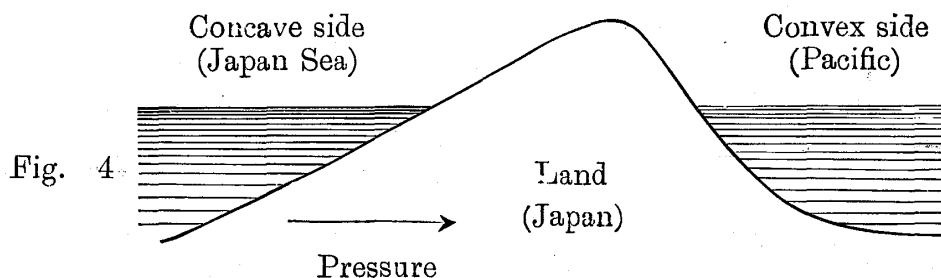


Fig. 4

As is well known, the Japan Sea is shallow and its greatest depth is only 3000 metres ; the gradient of the sea bottom, which is shallow, varying from 1 in 67 (off the coasts of Uzen and Ugo) to 1 in 110 (off the coasts of San-in Do provinces). The average gradient to the basin of 1000 metre depth from the west coasts of Hokkaido is 1 in 220. On the other hand, the Pacific Ocean is very deep, the Tuscarora basin, which lies off the northeastern coasts of Japan, reaching the depth of over 8000 metres at distances of 180 to 380 ^{km} from the coasts. The gradient of the Pacific bottom is much steeper than in the case of the Japan Sea, being, for example, as follows :—

Off the coast of Nemuro	...	...	...	...	...	...	...	1 in 27
„ NE „ „ Main Island	...	...	...	...	...	...	...	1 in 30
„ coast of Kii (to 5000 metres depth)	...	...	...	...	...	...	...	1 in 24
„ „ „ Tosa ( „ „ )	...	...	...	...	...	...	...	1 in 32
„ SE coast of Kazusa and Awa (to 3000 metres depth)	...	...	...	...	...	...	...	1 in 16

3. *Himalayas.* The Himalayan mountain ranges furnish also a good example of the relation between the curvature and the steepness of the gradient, and form, as diagrammatically shown in

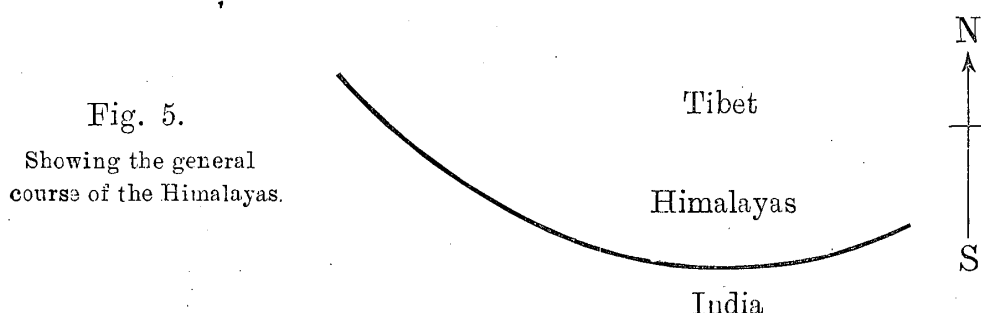


Fig. 5, a very beautiful circular arc extending in an east-west direction. The convex, or southern, side is very steep, the great mountains rising almost abruptly from the flat plane grounds of

India. On the other hand, the concave, or northern, side is not steep, constituting the plateau of Tibet.

4. Sumatra and Java. The two islands of Sumatra and Java also form together an arc, as indicated by the dotted curve in Fig. 6. The sea on the concave, or north-eastern, side is shallow (under 200 metres), while that on the convex, or south-western side is much deeper (over 5000 metres); it being also noteworthy that, in the case of Sumatra, mountain ranges lie close to the convex side.

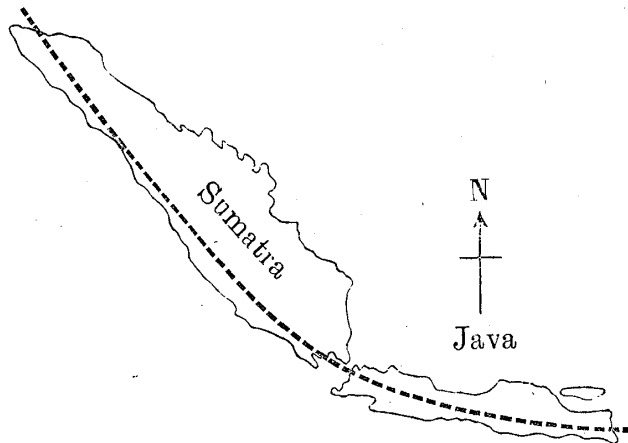


Fig. 6.

The dotted line indicates the general curvature of the two islands of Sumatra and Java.

5. Aleutian Islands. The Aleutian islands form a regular arc stretching in an east-west direction. Here again, the sea on the convex (southern) side is much deeper than that on the concave (northern) side. (See the preceding Article.)

6. Relation between the Curvature and the Seismic Activity. In simple cases, like those above mentioned in which there is a regular arc of mountain ranges or series of islands, the convex side is often shaken by great earthquakes, while the concave side is disturbed only by occasional local shocks.

7. Distribution of Destructive Earthquakes in Japan.* The origins of the 221 destructive earthquakes of Japan proper,

* A very valuable investigation on the distribution of small Japan earthquakes of recent years has been given by Count F. de Montessus de Ballore in *Archives des Sciences Phys. et Nat.* 1897.

which happened between the 5th century and the present time, were approximately as follows:—

Inland origins	...	...	...	...	...	...	...	...	114
Pacific „	...	...	...	...	...	...	...	...	47
Japan Sea origins	...	...	...	...	...	...	...	...	17
Inland Sea „	...	...	...	...	...	...	...	...	2
(unknown	...	...	...	...	...	...	...	...	41)

Again, among the above-mentioned 224 earthquakes, there were 10, which were very extensive and violent. Of these, 3 happened in central Japan, while the remaining 7 originated off the south-eastern coast of the Japanese islands, each being accompanied by great tidal waves.

A consequence of the difference in the seismic activities of the two sides of the Japan arc is that there were on the Pacific coast, 23 great tidal disturbances of seismic origin, while on the Japan Sea coast there were only 5 small cases of such disturbances.

II. RECENT STRONG JAPAN EARTHQUAKES.

8. *Distribution of the Origins of Strong Japan Earthquakes in Recent Years.* The systematic earthquake observation in Japan was commenced in 1885, and there were, during the next 21 years, 257 earthquakes which originated in or around Japan, and some of which were destructive or semi-destructive, the rest being strong or moderate shocks, each with a land area of disturbance* greater than about 4,000 square *ri*, or 25,000 square miles. The origins of these 257 earthquakes were distributed among the following 23 groups.

* The area of disturbance signifies the area within which the earthquake motion was sensible.

Fig. 7. Map of Japan.
Giving the names and boundaries of the different provinces,
and serving as a Key to the Article on the distribution of
Earthquakes in Japan.

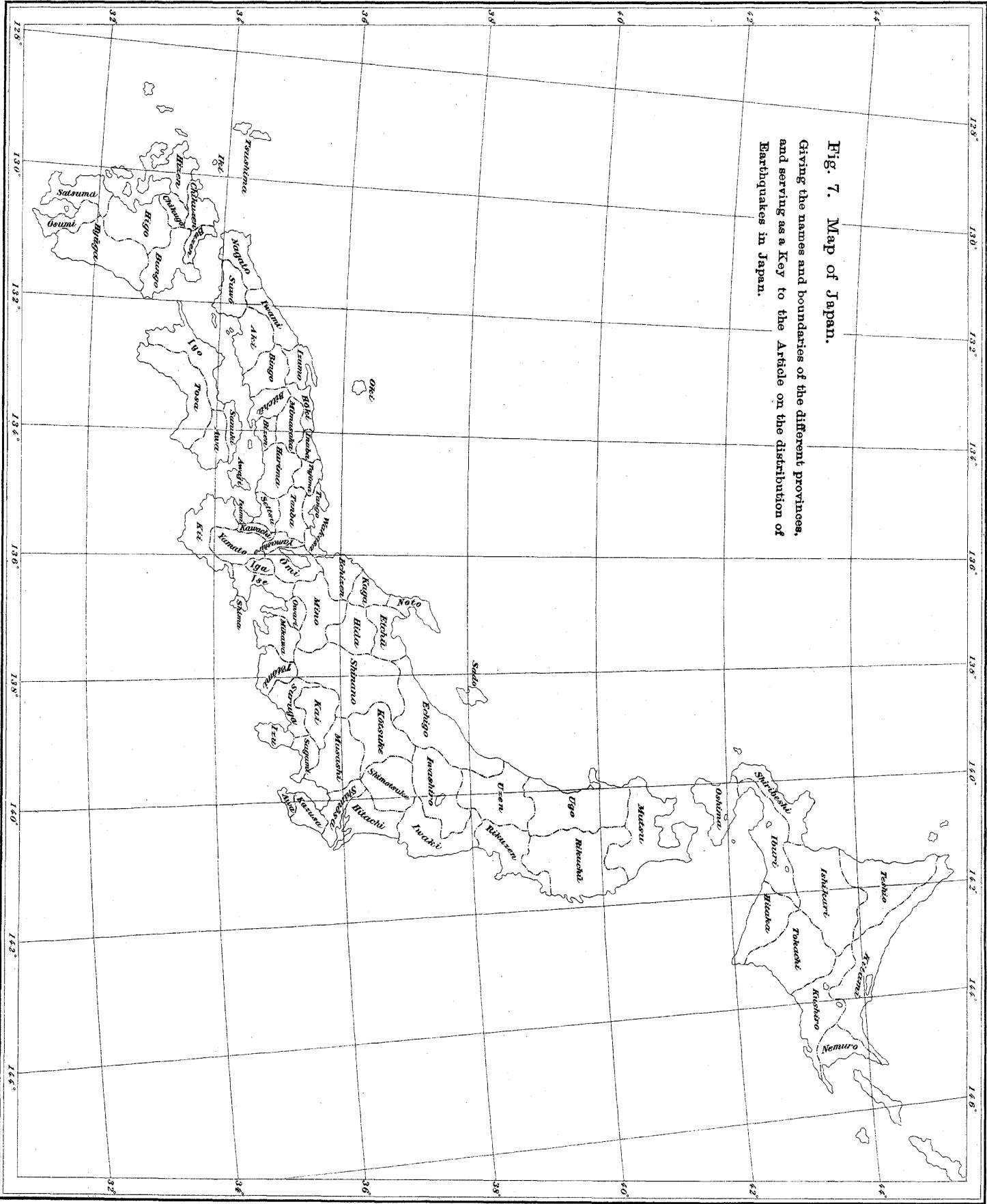
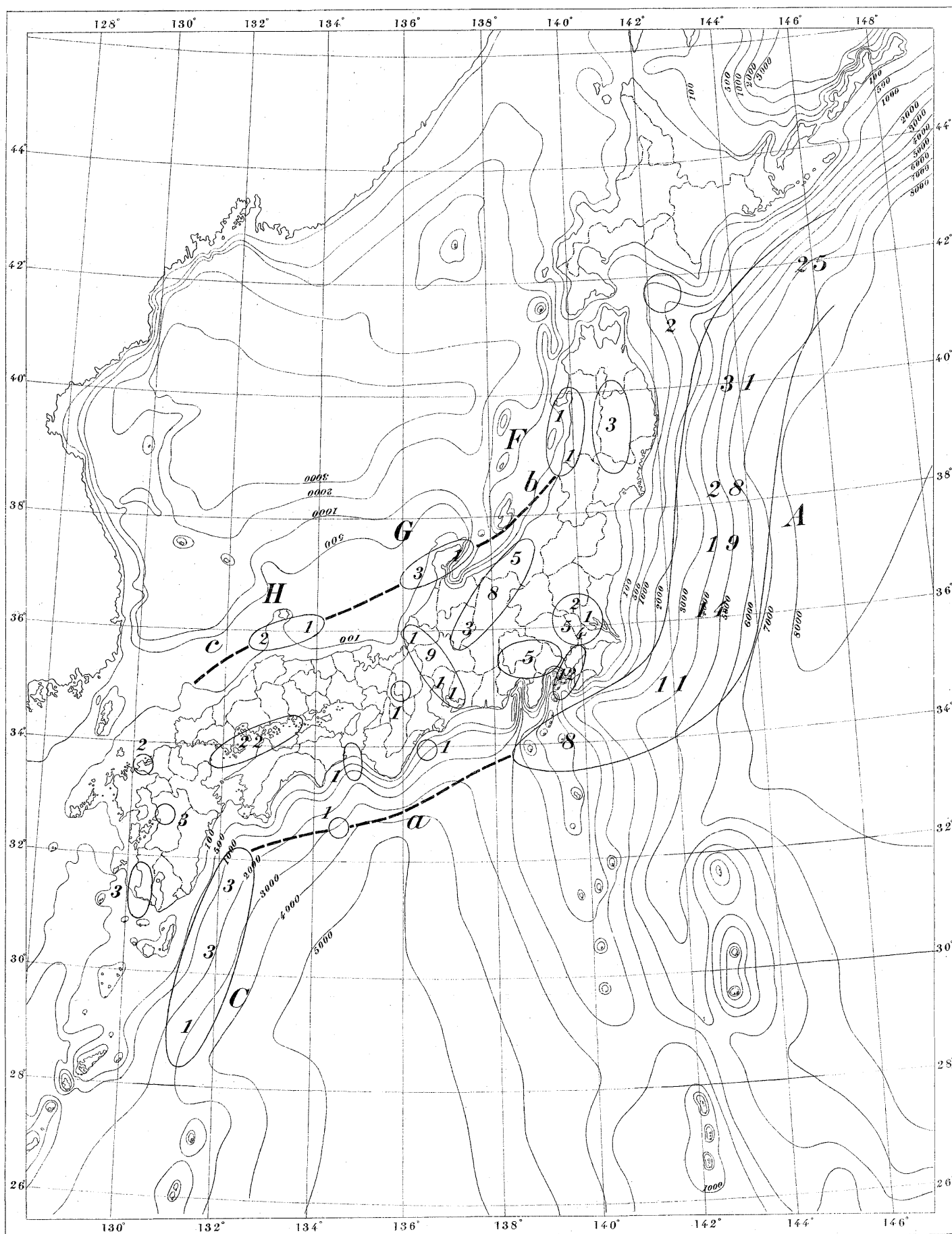


Fig. 8. Distribution of Strong Earthquakes in and about Japan.
(1885-1905.)

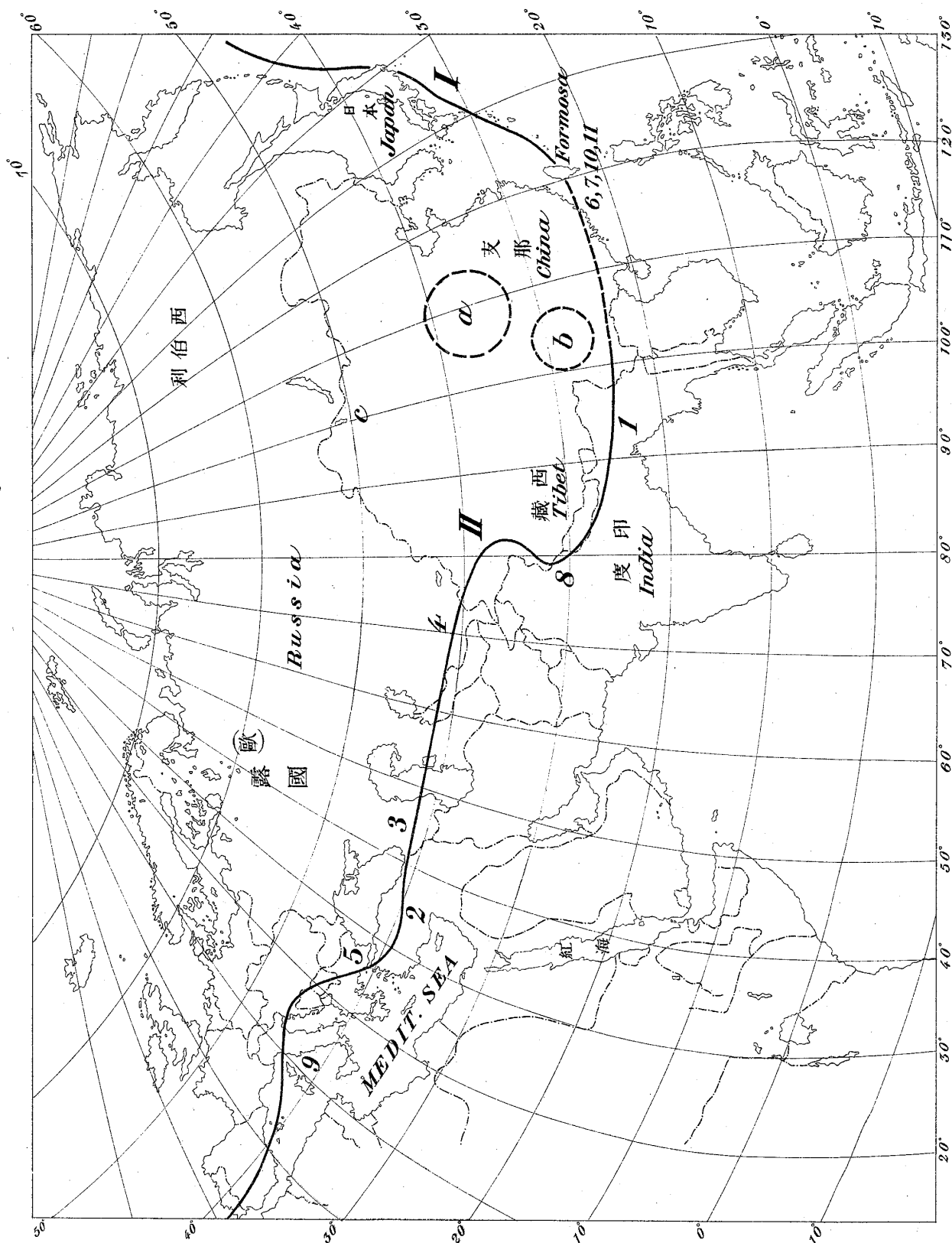


Boundary of provinces.

Blue curves are lines of equal depth, the figures giving the depth in metres.

Figures in red give the numbers of strong earthquakes which originated in the different parts.

Fig. 9. Map Showing Recent Seismic Activity along the
Mediterranean and Himalayas Zone.



A. *Off the SE coast of Hokkaido and the E coast of the Main Island.* The 138 earthquakes belonging to this group may be subdivided as follows:—

i.	Off the coasts of Nemuro and Kushiro	25
ii.	Between Hidaka and Mutsu	2
iii.	Off the coasts of Mutsu and Rikuchu	31
iv.	„ „ Rikuzen	28
v.	„ „ Iwaki	19
vi.	„ „ Hitachi	14
vii.	„ eastern coast of the Kazusa-Awa Peninsula	11
viii.	„ coast of Izu... ..	8

B. *Off the E coast of Kii* 1

C. „ *SE coast of Kyushu:—*

i.	In the S part of the Hyuga Nada	3
ii.	„ Vicinity of Yaku and Tane Islands	3
iii.	To the E of Ōshima... ..	1

D. *Off the W coast of Kii* 1

E. „ *Cape of Murcto (Tosa)* 1

F. *Akita and Shōnai District:—*

i.	Off the coast of Akita	1
ii.	Vicinity of Sakata	1

G. *Vicinity of Noto:—*

i.	Off the coast of Toyama (Etchu)	1
ii.	„ W coast of the Peninsula	3

H. *Hoki and Izumo:—*

i.	Off the coast of Hoki	1
ii.	„ „ „ Izumo	2

I. *Western part of Rikuchu and Eastern Part of Ugo* 3

J. *Musashi and Shimōsa District:—*

{	i.	NE Part of Musashi	5
	ii.	W Part of Shimosa	4
	iii.	W Part of Hitachi	1
	iv.	S Part of Shimotsuke	2
K. <i>Tokyo Bay and Sagami-Nada:—</i>			
{	i.	In Tokyo Bay	9
	ii.	„ Sagami-Nada	2
	iii.	„ Uraga Channel	1
L. <i>Sagami, Kai and Suruga District</i>			
M. <i>Echigo, Shinano, and Hida District:—</i>			
{	i.	Central and W Parts of Echigo	5
	ii.	N Part of Shinano	8
	iii.	E and S Parts of Hida	3
N. <i>Mino, Owari, and Echizen District:—</i>			
{	i.	Mino	9
	ii.	Mino and Echizen	1
	iii.	Owari and Mikawa	1
	iv.	In Owari Bay	1
O. <i>Vicinity of the Lake Biwa... ..</i>			
P. <i>Western half of the Inland Sea... ..</i>			
Q. <i>W Part of Chikuzen</i>			
R. <i>Vicinity of Kumamoto... ..</i>			
S. <i>In the S Part of Satsuma, and off the W coast of the Peninsula</i>			
T. <i>Vicinity of the Ishigaki Island (Loo Choo)</i>			
U. <i>„ „ Yaeyama „ („)</i>			
V. <i>Off the E coast of Formosa</i>			
W. <i>In the SW Part of Formosa</i>			

Fig. 8 illustrates the distribution of the earthquake origins as tabulated above ; Fig. 7, which serves as a key map, giving the names of the different provinces. It will be seen that the most active seismic zone at present is **A**, or that stretching off the eastern coasts of Hokkaido and Main Island, the number of the earthquakes which occurred in these parts of the Pacific Ocean amounting to 138, or more than half of the total number of the shocks relating to whole Japan. The zone, **a**, marked by a thick dotted line, represents the approximate focus of the great earthquake* of the 4th year of the Hōei period (Oct. 28, 1707); the two great shocks in the 1st year of the Ansei period (Dec. 23 and 24, 1854) originating respectively at the eastern half (between Kii and Izu) and the western half (between Kii and Kyushu) of this zone. **A** is evidently continued to **a**, which is itself again continued to the zone **C**, stretching from the southern part of Hyuga Nada to the east of Ōshima.

A, **a**, and **C** together form the principal sub-oceanic earthquake zone of Japan, which runs parallel to the convex side of the latter and may be named *external seismic zone*. In former times **a** was most active, but at present **A** is very active.

On the Japan Sea side, there are three seismic regions **F** (Akita and Shōnai), **G** (vicinity of Noto), and **H** (Hōki and Izumo), whose activity is far less than that of the *external seismic zone* above mentioned. Of these three regions, the most important is **F**, which in historical times produced some violent shocks. **b** and **c** represent respectively the approximate positions of the great Sado and Shōnai earthquake of Dec. 7, 1833, and the Hamada (Iwami) earthquake of March 14, 1872. These two latter regions form, together with **F**, **G**, and **H**, a continuous band along

* This was the greatest among the earthquakes which ever shook Japan.

the concave side of the Japanese islands, and may be termed the *inner seismic zone*.

Among the other earthquake districts, the most active are:—**M**, which mainly coincides with the valley of the Shinano-gawa and extends from the middle part of Echigo to the northern part of Shinano and the eastern part of Hida; **K**, Tokyo Bay and Sagami-Nada; **N**, Mino, Owari and Echizen District; and **P**, the western half of the Inland Sea.

The different earthquake districts shown in Fig. 8 may be divided into two systems, namely, the “concentric” and the “radial,” as mentioned in §1. To the “concentric” system belong the *external* and *inner seismic zones*; **M** (Echigo, Shinano and Hida); **K** (Tokyo Bay and Sagami-Nada); **P** (Inland Sea), etc. Among the “radial” districts, the most conspicuous is **N**, or the Mino, Owari and Echizen zone.

9. Seismic Activity along the Mediterranean-Himalayan Zone. Fig. 9 indicates the approximate positions of 11 recent destructive earthquakes belonging to the Mediterranean-Himalayan Zone (marked II), provisionally supposed to extend eastwards to Formosa,* as follows:—

1. Assam and Bengal, June 12, 1897.
2. Aidin (Smyrna), Sept. 20, 1899.
3. Schemacha (Caucasus), Feb. 13, 1902.
4. Kashugar (Turkestan), Aug. 22, 1902.
5. Saloniki (Macedonia), April 4, 1904.
- 6, 7, 10, 11. Formosa, April 24 and Nov. 6, 1904, and March 17 and April 14, 1906.

* See the *Bulletin*, No. 1, p p. 20—24.

8. Kangra Valley (Punjab, India), April 4, 1905.
9. Calabria (Italy), Sept. 8, 1905.

a, *b* and *c* in the figure indicate the existence of seismic centres in China and the Baikal district, the two former being for the present in a quiet condition. Of the 11 earthquakes, Nos. 1, 2, 4, 5, 8 and 9 were very great disturbances and happened at *different* places along the zone in question.

10. Relation of Japan Arc to Mediterranean-Himalayan and American Zones. The most active, or external, seismic zone of Japan (I, Fig. 8) forms a connecting link between the Mediterranean-Himalayan zone and the great American zone, which latter stretches along or off the Pacific coast from Chile on the south to Alaska on the north;‡ the Aleutian Island earthquake of Aug. 17, 1906, having finally brought the manifestation of the great seismic activity to within 2000^{km} of the north Japan.

‡ See this Number, p. 100.