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59. *Some Features of Recent Seismic Activity in and near Japan (1).*

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1. Introduction

According to the previous paper (Mogi, 1968b), a sequence of great earthquakes ($M \gtrsim 8$) in the northwestern circum-Pacific seismic belt, if the focal regions suggested by their aftershock areas are considered, occurred covering the large part of the seismic belt in the last thirty years and these focal regions did not overlap in this time interval. The similar feature had been also pointed out by Fedotov (1965) on the Kamchatka - northeastern Japan region. Since the energy of great earthquakes is the main part of the total earthquake energy, the above-mentioned process suggests the following mechanism: The strain energy is gradually and nearly uniformly stored in the seismic belt, and when the stored energy density increases to a critical value related to the fracture strength of the region, a great sudden fracture, namely a great earthquake, takes place. If this process is general in earthquake occurrence, large earthquakes may be expected to occur to fill a gap in the spatial distribution of earthquake energy release in seismic region. In 1965, Gotō and Sakai had suggested this process in relation to the occurrence of the Tokachi-oki earthquake of 1952. In the present paper, this process of occurrence of large shallow earthquakes is systematically examined in and near Japan where earthquake data including smaller ones are available for about eighty years. Space distributions of the seismic activity in recent years show very interesting patterns which seem to correlate to following great earthquakes.

2. Procedure of investigation and materials used

To study the space and the time distributions of recent seismic activity in and near Japan, the distributions of focal regions of large earthquakes and that of the earthquake energy density were obtained

for each period. The procedure to draw these distribution maps is as follows:

Distribution of focal regions of large earthquakes (*Map I*) Focal regions of large shallow earthquakes ($M \geq 7$) are plotted at the epicenters of earthquakes. Since the aftershock region just after the main shock is thought to correspond to the focal region of the main shock (Mogi, 1968a), namely the area where the earthquake energy was accumulated, the focal region was approximately indicated by a circle with a diameter calculated from the following aftershock area - magnitude relation obtained by Utsu (1961):

$$\log D = 0.5M - 1.8 ,$$

where D is the linear dimension (in kilometer) of aftershock area. When locations of aftershock regions are known, the circles were located at the aftershock regions just after the main shocks.

Distribution of earthquake energy density (*Map II*) The investigated area is divided into square regions with a unit dimension of 60 km and the total energy of shallow earthquakes greater than magnitude 4.5 whose epicenters are located in each square is calculated. In this case, the energy of large earthquakes is distributed to square regions around the epicenters with consideration for the above-mentioned focal regions. The contour lines of equal earthquake energy density are drawn from the distribution of the total energy of each square, sometimes from the distribution of their overlapped mean values.

Earthquake data since 1885 in and near Japan have been available for the present discussion. They were adopted from *The Magnitude Catalogue of Major Earthquakes Which Occurred in the Vicinity of Japan* (*1885–1950*) by the Japan Meteorological Agency or JMA for the period (1885–1925), *Catalogue of Major Earthquakes Which Occurred in and near Japan* (*1926–1956*) by JMA and *the Seismological Bulletin of JMA* for the period (1926–1968, May). The accuracy of data is not uniform for the whole period. The epicenters and the magnitudes of earthquakes were determined by modern instrumental observations for the later period (1926–1968). On the other hand, they were estimated from insufficient observations and historical documents for the earlier period before 1926. This should be borne in mind in the discussion based on these data. The magnitudes of earthquakes in *The Magnitude Catalogue of Major Earthquakes Which Occurred in the Vicinity of Japan* (*1885–1950*) given by H. Kawasumi is somewhat higher than

the magnitudes given by JMA for the period (1926–1956), as pointed out by Tsuboi (1964). Kawasumi's magnitudes were corrected by comparison with JMA magnitudes of the same earthquakes in the later period. The correction is appreciable for smaller earthquakes, but negligible for greater earthquakes. As a special case, the magnitude of the Nōbi earthquake of 1891 was corrected to be 8.0 according to the recent study of Muramatsu (1962).

The distributions (Maps I and II) were obtained for intervals of successive five or ten years, and for other suitable time intervals in the period (1885–1968). Before 1885, earthquake data which are based on historical documents are not uniform, so that, they are unsuitable for the present discussion. Deep earthquakes were excluded in the present discussion.

3. Seismic activity before the Tōnankai earthquake of 1944 and the Nankaidō earthquake of 1946.

The space distribution of focal regions of earthquakes during the initial twenty-five years (1885–1909) (Fig. 1) shows approximately uniform activity in the investigated region, as seen in the whole period (1885–1968, May) (Fig. 11). On the other hand, the distribution in the following thirty years (1910–1939) shown in Fig. 2 shows a non-uniform distribution, that is, any large earthquake with magnitude 7 and over did not occur in a wide area in southwestern Japan. This inactive area (Region A) is indicated by a dotted curve in this figure. The distribution of the earthquake energy density also shows a marked gap in the seismic energy release in this region (Fig. 3). Focal regions of large earthquakes which occurred in the following ten years (1940–1949) are shown in Fig. 4. Now, it is pointed out that several major earthquakes including two great earthquakes, the Tōnankai earthquake ($M=8.0$) and the Nankaidō earthquake ($M=8.1$), occurred to fill this gap of the seismic activity in the preceding thirty years.

4. Seismic activity before great earthquakes in northeastern Japan.

The above-mentioned process where great earthquakes occurred at a gap in the seismic activity during the preceding period is also found for great earthquakes in northeastern Japan. Figs. 5a and b show the space distributions of focal regions of large earthquakes ($M \geq 7$) before the Sanriku-oki earthquake of 1933 ($M=8.3$) and the Tokachi-oki earth-

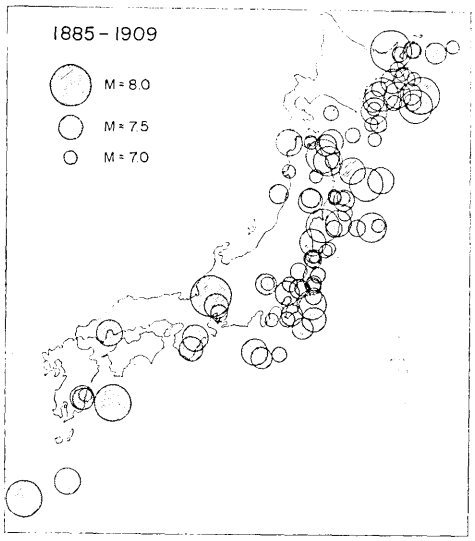

Fig. 1. Space distribution of focal regions of large earthquakes of magnitude 7 and over in the period (1885–1909).

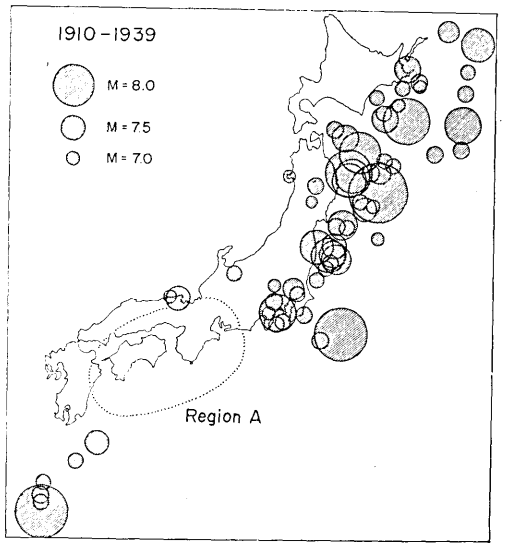

Fig. 2. Space distribution of focal regions of large earthquakes of magnitude 7 and over in the period (1910–1939).

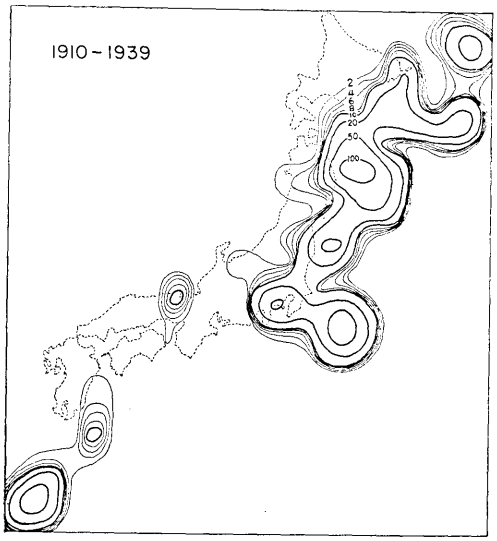

Fig. 3. Space distribution of the earthquake energy density in the period (1910–1939). Unit of values for contour lines: 10^{18} ergs/km^2.

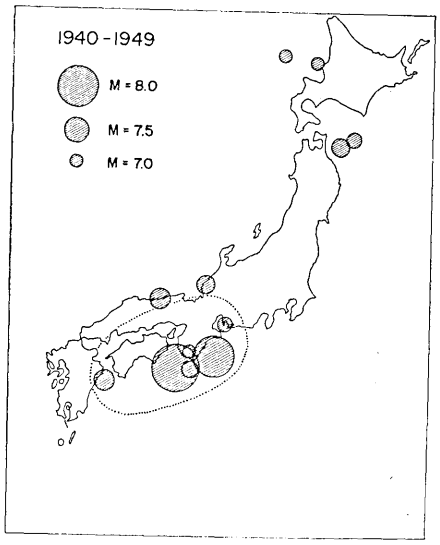

Fig. 4. Space distribution of focal regions of large earthquakes of magnitude 7 and over in the period (1940–1949).

quake of 1952 ($M = 8.1$), respectively. The region, a part of the outer seismic zone of Japan, is one of the most active regions in the world, but the focal regions of these great earthquakes estimated from after-shock areas just after the main shocks, were abnormally inactive in the preceding periods (thirty years for the Sanriku-oki earthquake and thirty-five years for the Tokachi-oki earthquake). Gotō and Sakai (1965)

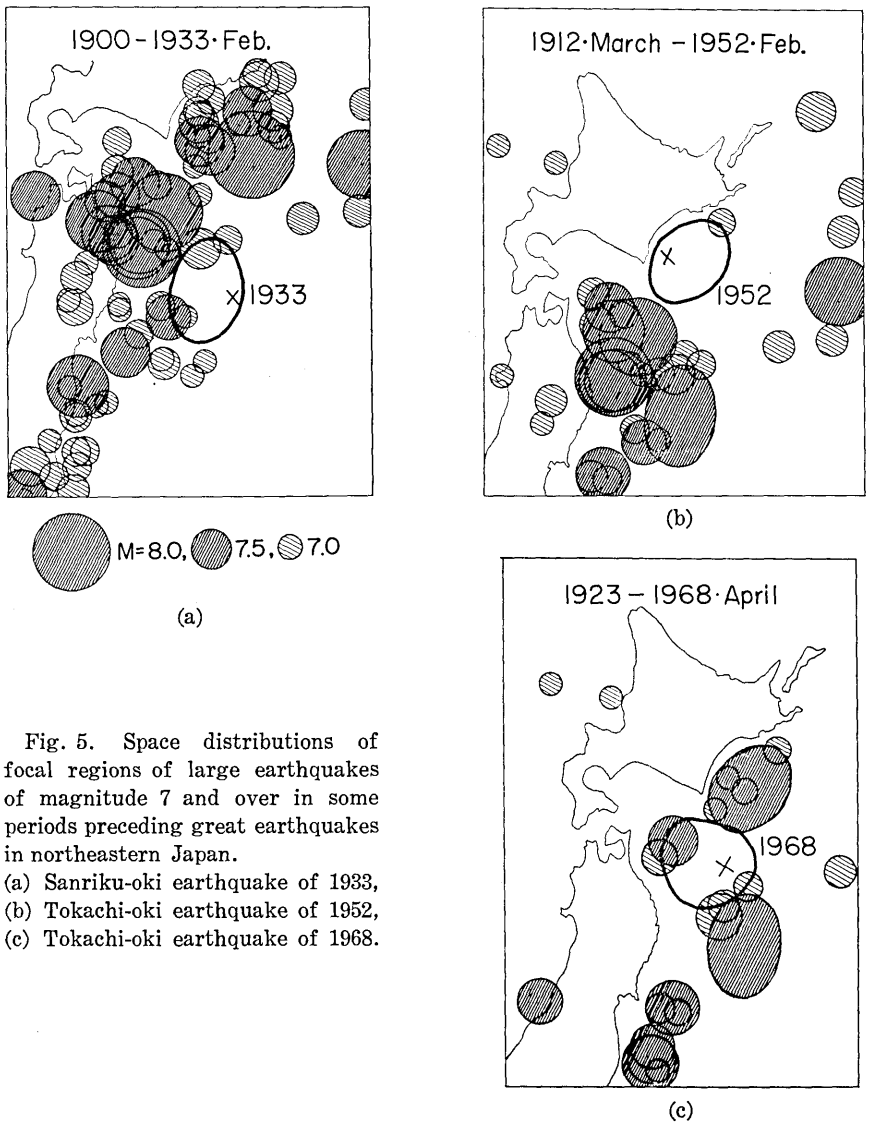

Fig. 5. Space distributions of focal regions of large earthquakes of magnitude 7 and over in some periods preceding great earthquakes in northeastern Japan.
(a) Sanriku-oki earthquake of 1933,
(b) Tokachi-oki earthquake of 1952,
(c) Tokachi-oki earthquake of 1968.

already pointed out this feature in the case of the Tokachi-oki earthquake of 1952.

On May 16, 1968, a great earthquake ($M = 7.9$) occurred in the region. This earthquake was called the Tokachi-oki earthquake of 1968. Its aftershock area developed gradually with elapsed time. The focal region estimated from the aftershock area just after the main shock (for half a day) is adjacent to the focal regions of the Sanriku-oki earthquake of 1933 and the Tokachi-oki earthquake of 1952, and these focal regions did not overlap, such as is pointed out in the Aleutian-Alaska region, etc. (Fig. 6). Fig. 5c also shows that the focal region of the Tokachi-oki earthquake of 1968 corresponds to a gap in the seismic activity in the preceding forty-five years.

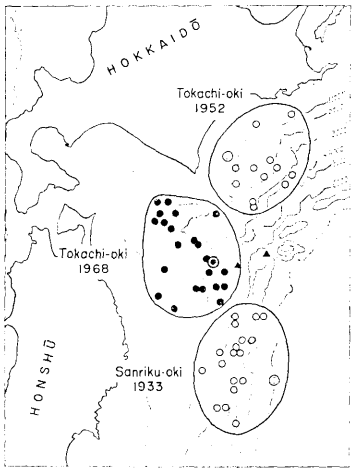

Fig. 6. Locations of focal regions of three recent great earthquakes in northeastern Japan.
Large double circle: main shock; small circle: aftershock just after the main shock.

Thus, the recent great earthquakes in northeastern Japan were also preceded by a gap in the seismic activity during thirty years and over. However, the size of the gap in seismic activity in this region is appreciably smaller than those of the western Japan and the Aleutian-Alaska region.

5. Seismic activity in the last thirty years

Now, it is very interesting to note whether or not there are gaps in seismic activity in recent years. A noticeable distribution of seismic activity was found for the last thirty years. The space distribution of focal regions of large earthquakes represented in Fig. 7 shows that no large earthquakes ($M \geq 7$) occurred in a wide area including the Kwantō and the southern Tōhoku districts in the last thirty years. This inactive area (Region B) is indicated by a dotted curve in Fig. 7. As seen in the distributions of the seismic activity during the whole period shown in Fig. 11, this region includes a very active region, a part of the outer seismic zone of Japan, where twenty-five large earthquakes ($M \geq 7$) occurred in the preceding thirty years (1909–1938). Therefore, the low activity in the last thirty years in Region B should be noticed with much attention.

However, many smaller earthquakes ($M<7$) occurred in Region B throughout the whole period. The space distribution of earthquake energy release with consideration for smaller earthquakes is shown in Fig. 8. Although the energy release by smaller earthquakes in the region is not negligible, the gap in seismic activity in Region B during the last thirty years is also noticeable.

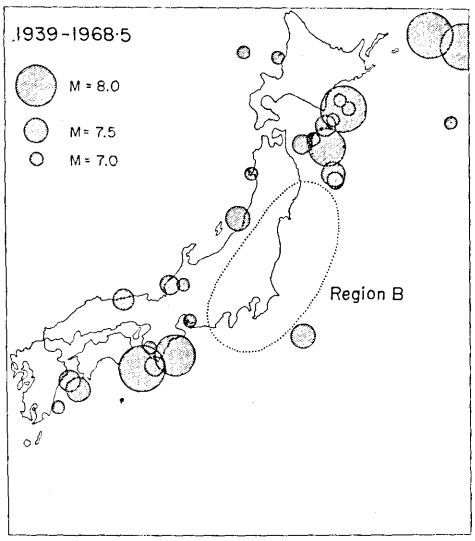

Fig. 7. Space distribution of focal regions of large earthquakes of magnitude 7 and over in the period (1939–1968, May).

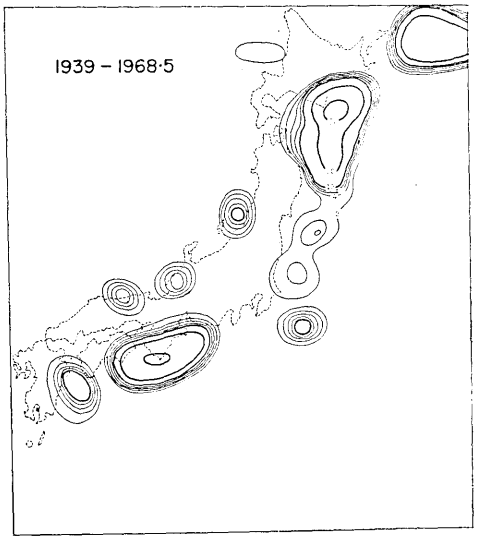

Fig. 8. Space distribution of earthquake energy density in the period (1939–1968, May). Unit of values for contour lines: 10^{18} ergs/km^2.

To show explicitly the space and the time variations of the seismic activity in the outer seismic zone of Japan, distances (D) of epicenters of large earthquakes from a fixed station projected to a line parallel to the Japanese Islands is plotted against time (Figs. 9a and b). The investigated area is limited to the outer seismic zone, and the inner seismic zone and the region far off the Bōsō Peninsula are excluded, as shown in Fig. 9a. In Fig. 9b, three marked blank areas are indicated by broken curves. The blank area at Region A corresponds to the above-mentioned gap in seismic activity before the Tōnankai earthquake of 1944 and the Nankaidō earthquake of 1946. The blank area at Region B indicates the gap in the Kwantō and the southern Tōhoku districts. Another gap is pointed out in Region C (Nanseisyotō).

The histograms of seismic energy release for each five years in

Regions A and B are shown in Fig. 10. Abnormally low energy release in Region B in the last thirty years is remarked with that in Region A in the thirty years before the two great earthquakes.

From the above-mentioned discussion, it is suggested that large seismic events may occur in Region B in the near future.

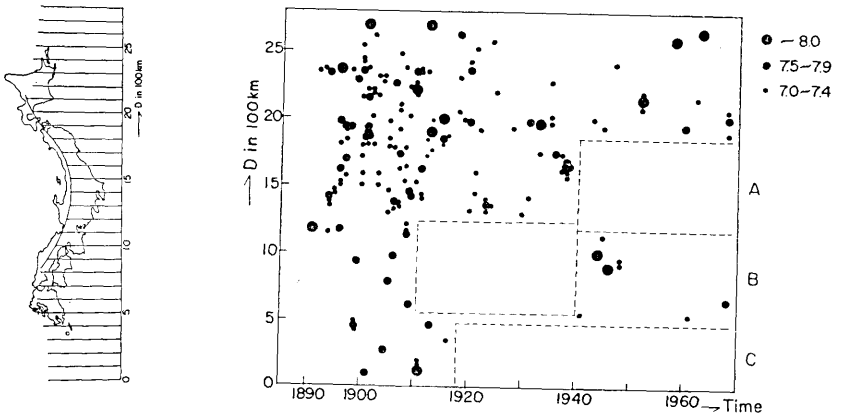

Fig. 9. One dimensional locations of large earthquakes as functions of time (b). The investigated area of the outer seismic zone is shown in (a). D: distance of epicenter of earthquakes from a fixed station projected to a line parallel to the Japanese islands.

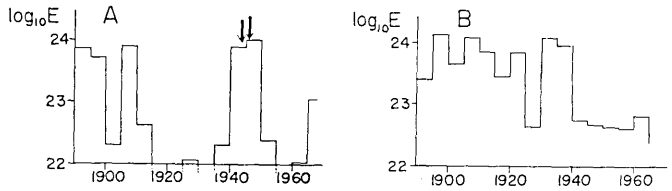

Fig. 10. Histograms of seismic energy release of five successive years in Regions A and B.

6. Seismicity in and near Japan.

The seismicity in and near Japan has been studied by many investigators (Miyamura, 1967). Recently, Sugimura (1960), Tamaki (1961), Miyamura (1962) and Katsumata (1966) discussed in detail the space distribution of seismic activity in relation to tectonic structures of the Japanese region based on the epicentral distributions of major earthquakes in recent years since 1926 or later. In this section, the seismicity

of this region is discussed based on the distributions of the focal regions of large shallow earthquakes and the earthquake energy density during the period (1885–1968, May) (Figs. 11 and 12), from the standpoint that the earthquakes energy release is more essential. A similar study had been made by Gotō and Sakai (1965). To study a relation to tectonic structures, the investigated period, about eighty years, may not be always sufficient, because the seismic activity sometimes changes with long periods, particularly in regions of low activity. However, earthquake data before 1885 are not available for the present purpose. This situation should be considered in the following discussion.

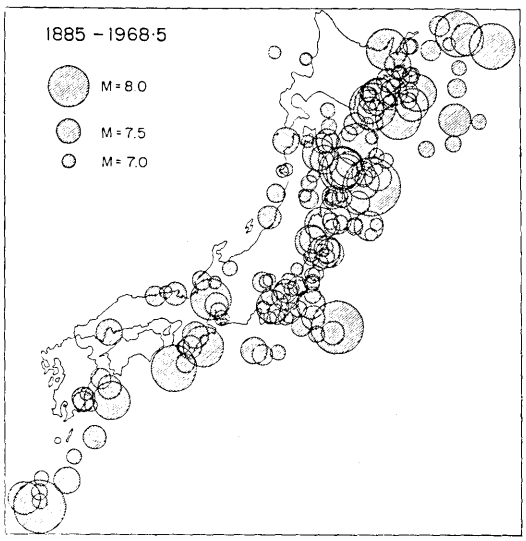

Fig. 11. Space distribution of focal regions of large earthquakes of magnitude 7 and over in about the last eighty years.

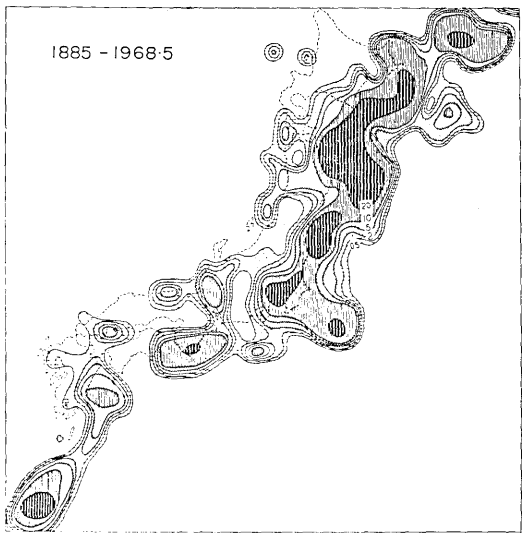

Fig. 12. Space distribution of earthquakes energy density in about the last eighty years. Unit of values for contour lines: 3×10^{18} ergs/km^2.

From Figs. 11 and 12, the seismicity in the shallow region in and near Japan may be summarized as follows:

(1) The very active areas distribute along three island arcs, namely the Kurile, the Honshū and the Ryūkyū arcs, and the active regions are situated at the continental side of deep sea trenches, and there is no active region at the oceanic side. The seismic zones are called the outer seismic zones.

(2) The outer seismic zone along the Izu-Mariana arc is not so

active except for the Kwantō region. The low activity in this zone seems to have a relation to the high activity in deeper region (Mogi, 1968c).

(3) The most active regions are located nearly continuously in the eastern part of the outer seismic zone, but discontinuously in the western part, and both regions are bounded by the Izu-Mariana arc. As pointed out by many investigators, both seismic zones are considerably different in focal depths. The activity seems to be particularly high in intersecting regions of each seismic zone, such as the region off the south coast of Hokkaidō, the Kwantō district, and the region off the east coast of southern Kyūshū.

(4) Another active zone distributes along the northwestern coastal line of the Honshū arc. This zone is called the inner seismic zone. The inner seismic zone is not clear for other arc. There are low active zones between the outer and the inner seismic zones of Honshū, and these three zones run parallel to the island arcs and the deep sea trenches.

(5) An active zone from Nagoya to Fukui and an inactive zone in the adjacent region cross the above-mentioned main parallel zones at the central part of Honshū. These zones seem to have a connection with the Izu-Mariana arc.

The active regions distribute discontinuously in the western part of the outer seismic zone and the inner seismic zone, but this pattern may be affected by the length of the investigated time interval. Some of the inactive regions shown in these maps also may change to active regions, if a long time interval is considered. However, the above-mentioned outline of the seismicity will not change.

7. Summary

To study the process of occurrence of shallow earthquakes in and near Japan, the space and the time distributions of focal regions of large earthquakes and the earthquake energy density during the period (1885–1968, May) have been investigated. The results are summarized as follows:

(1) During the last eighty years, earthquakes occurred with the space distribution showing a close relation to tectonic structures of this region.

(2) Great earthquakes in this region occurred to fill gaps of seismic activity of thirty years and over, as pointed out in other circum-Pacific

regions. It is particularly remarked that any large earthquakes of magnitude 7 and over did not occur in the focal regions of great earthquakes during the preceding period.

(3) The seismic activity in the Kwantō and the southern Tōhoku districts, including the part of the outer seismic zone, is abnormally low in the last thirty years. If the high activity in the preceding fifty years in this region is considered, this result suggests a possibility that great events may occur in the region in the near future.

Acknowledgements I wish to thank Prof. K. Kasahara and Dr. N. Yamakawa for helpful comments.

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59. 近年における日本の地震活動の二，三の特徴 (1)

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日本及びその周辺の地震活動の空間的分布並びにその時間的変化を，マグニチュード7以上の大きい地震の震源域の分布及び小さい地震を含めた地震エネルギー密度の分布から論じた．できるだけ長期間についてしらべることがのぞましいが，この目的のための地震資料は，1885年以降に限られる．この最近約80年間についての調査の結果を次に要約する：

(1) 最近80年間の平均の地震活動は，日本及び周辺地域の大規模な地体構造によく対応して起こつている．

(2) 巨大地震は，それに先立つ30年或いはそれ以上の期間の地震活動の空白地域を埋めるように起こつている．その期間には，マグニチュード7以上の地震が，その巨大地震の起こる地域にほとんど起こらない．

(3) この，大きい地震は地震活動の空白地域を埋めるように起こるという事実は，さきにアラスカ・アリューシャン等の環太平洋地震帯について指摘したことで，かなり一般的な特性とみられる．従つて，本来地震活動の高いはずの地域が異常に静かな状態をつづけているとすれば注目すべきことである．この様な観点から，関東，東北南部及びその東方海域を含む地域が，最近30年間異常に低い活動状態をつづけている事実を指摘した．