20. *Earthquakes of the Kwantô District.*

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Introduction.

Since the violent earthquake of September 1, 1923, which shook the southern part of the Kwantô district, the science of Seismology has made considerable progress in Japan. To enable better observations several new stations, equipped with improved or newly designed seismographs, have been established by the Earthquake Research Institute of the Tôkyô Imperial University. With the increased and more accurate data thus made available, many new studies in fields hitherto unexplored or insufficiently investigated have been prosecuted.

This paper is merely an attempt to examine these newly acquired data. It discusses the general characteristics of earthquakes that trouble the Kwantô region, their activities, and the distribution of the seismic foci during the period between 1924 and 1931.

Variation of the Yearly Seismic Frequency.

Although in the north-eastern part of Japan, the sea floor of the Pacific off the Hokkaidô, the Tôhoku, and the Kwantô districts shows marked activity, the first two are relatively quiet, so far as the land is concerned. As to the Kwantô, over 500 shocks are recorded a year, which number, in 1931, the year of the severe Titibu earthquake of September 21, rose to 1481. The yearly frequency of sensible Kwantô earthquakes since 1924 is shown in the following table.

Table I.

Year	1924	1925	1926	1927	1928	1929	1930	1931
Frequency	504	247	187	176	221	168	213	360

The yearly diminution in the frequency of sensible shocks since 1924 indicates the waning influence of the great 1923 earthquake.

The yearly frequency of sensible shocks in Tôkyô, the center of the

Kwantô district, may be seen from the following table.

Table II.

Year	1914	1915	1916	1917	1918	1919	1920	1921	1922
Frequency	19	49	24	34	25	24	12	12	57
Year	1923	1924	1925	1926	1927	1928	1929	1930	1931
Frequency	—	128	77	58	72	81	50	92	82

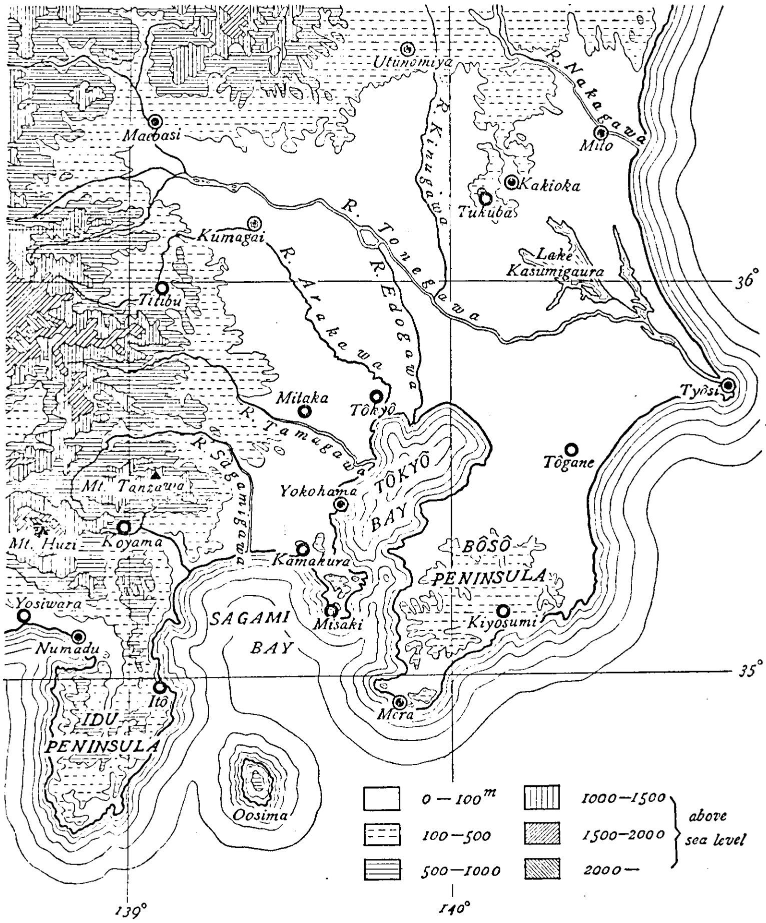


Fig. 1. Geographical features of the Kwantô District.
O Seismological Station. ◉ Local Meteorological Observatory.

This table gives an idea of the great difference in seismic activities before 1923 and after, and shows how strong has been the influence of that severe earthquake of 1923 on the seismicity of the district in question during the years that followed.

Epicentral Distribution.

An ideal method of studying the seismic activity of any particular region would be to find the epicentres of all earthquakes that occur there, both sensible and insensible. But, in practise these determinations cannot accurately be made with the present network of stations and their equipments for observation, because only one or two stations could record the insensible shocks. Some of the stations may miss even the fainter shocks that come under the class of perceptible shocks. Under these conditions, determining epicentres is largely a matter of approximating, so that not more than one-tenth of the number of seismic foci determined for sensible earthquakes can be regarded as accurate.

In this paper, therefore, only earthquakes whose origins have been seismometrically determined are considered, all small earthquakes and earthquakes that have occurred in the margins of our network or outside of them having been disregarded. We shall then find that the earthquakes tend more or less to pack within the net and are scarse in the margins and outside them.

As to the determined foci, those deduced by stations belonging to the Earthquake Research Institute of the Tôkyô Imperial University will most largely be used in this paper, while references will frequently be made to those that have been deduced by the Local Meteorological Observatory. Earthquake number whose foci have been determined.

Table III.

Year	1924	1925	1926	1927	1928	1929	1930	1931
Frequency	33	25	40	43	51	28	30	57

The datum for 1931 are from the Seismometrical Report of this Institute.

The late Dr. Omori,[1] who was the first to investigate the dis-

1) F. OMORI, *Seismological Notes of the Imperial Earthquake Investigation Committee*, No. 2 (1922).

tribution of earthquake origins in this district, in examining the sensible earthquakes of Tôkyô during the period between 1914 and 1921, noticed that the earthquakes there originated chiefly from three regions, (1) the Bôsô peninsula; (2) the drainage of the rivers Tonegawa and Kinugawa; (3) the Tanzawa mountainland and the Sagami Bay and vicinity. According to Mr. Yasuda,[2] the immediate after-shocks of the earthquake of September 1, 1923, occurred almost in the same regions as found by Omori.

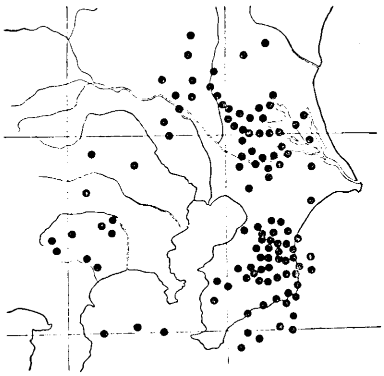


Fig. 2. Distribution of the epicentres in the period 1914–1921. (after Omori)

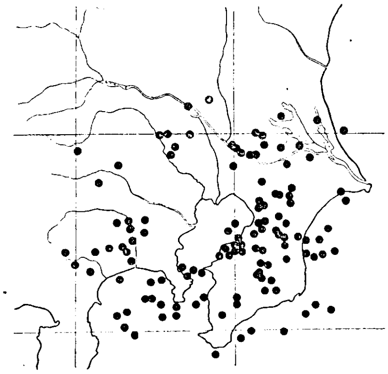


Fig. 3. Distribution of the epicentres in Sept., 1923. (after Yasuda)

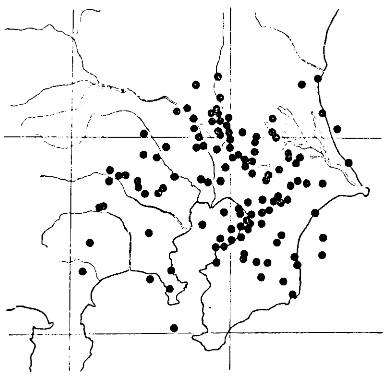


Fig. 4. Distribution of the epicentres in the period Oct.-Dec., 1923. (after Yasuda)

During September frequency was greatest in the Bôsô peninsula, with Sagami Bay and vicinity ranking next in order, although the individual shocks were severer in Sagami Bay, where the main shock had occurred. The Tonegawa-Kinugawa regions, which were the very active in the preceding period were now relatively quiet.

In October, November and December of the same year the distribution greately changed. A few shocks originated in the Tanzawa mountainland and in Sagami Bay, and fairly severe ones in the southern half of the Bôsô peninsula, but the drainage valleys—the Tonegawa and Kinugawa regions began to show activity,

2) 保田柱二 震災豫防調査會報告 第百號 (甲) (1924).

while Musasi plain and the northern part of Tôkyô Bay and vicinity, which had hitherto been very quiet, rapidly became active. The wane of energy in the Bôsô peninsula, from south to north, had however been noticed already in September.

The late Dr. Omori, in his investigations, largely used the observed results for Tôkyô with reference to those for Mito and Tyôsi, and determined the epicentres by means of the duration of the preliminary tremors and the direction of the initial motion, without paying much attention to the focal depth. The result was that, although his determinations of the origin of earthquakes of the Tonegawa and Kinugawa region were fairly correct, those for earthquakes that occurred to the south of this region are supposed to show large errors, particularly those of Tôkyô Bay, where, as will be shown later, fairly deep-seated earthquakes are known to occur. Working with present day equipments and improved methods of observation it is doubtful whether the earthquakes set down by Omori as having originated in the Bôsô peninsula, had not actually originated in Tôkyô Bay.

The epicentral distribution for each year during the period between 1924–1931 are shown in Fig. 5 and for the entire period in Fig. 6, in which the depths are also given.

We can see from this that the regions of seismic activity were not fixed, but shifted from place to place every year, with the result that sometimes they were seen in the same localities as in 1925 and 1928. Generally speaking however the earthquakes throughout the period in this district were confined to the lowlands, rarely occurring in the high

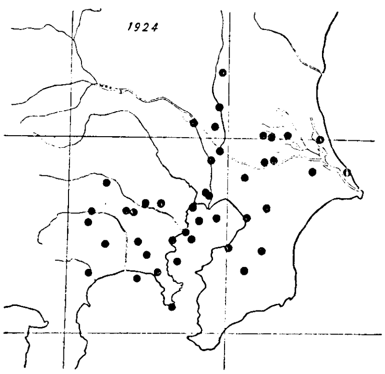


Fig. 5 a.

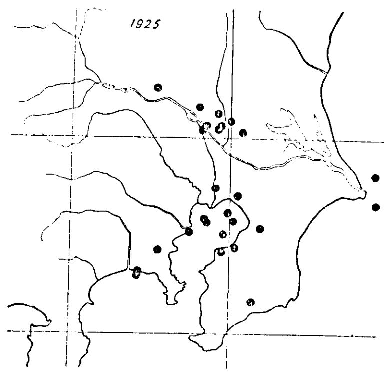


Fig. 5 b.

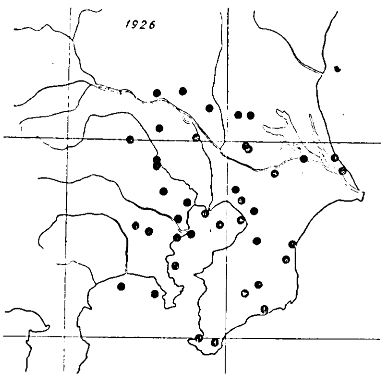
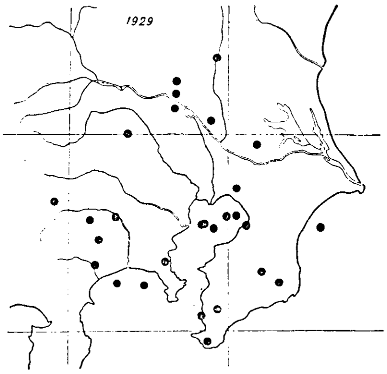


Fig. 5 c



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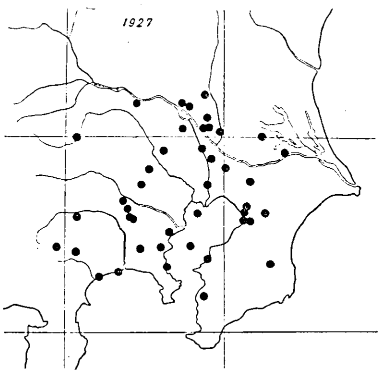

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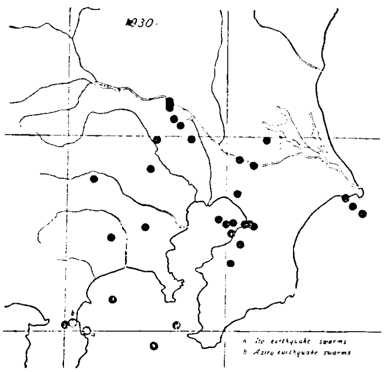

Fig. 5 g.

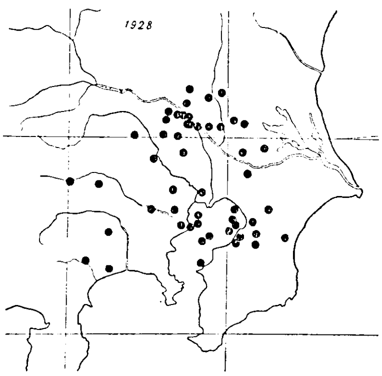

Fig. 5 e.

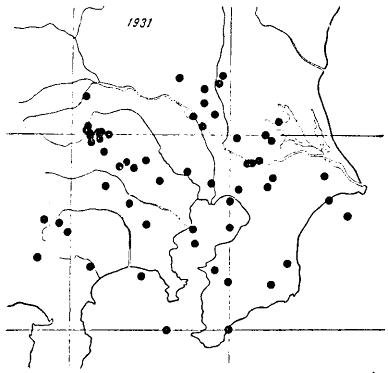

Fig. 5 h.

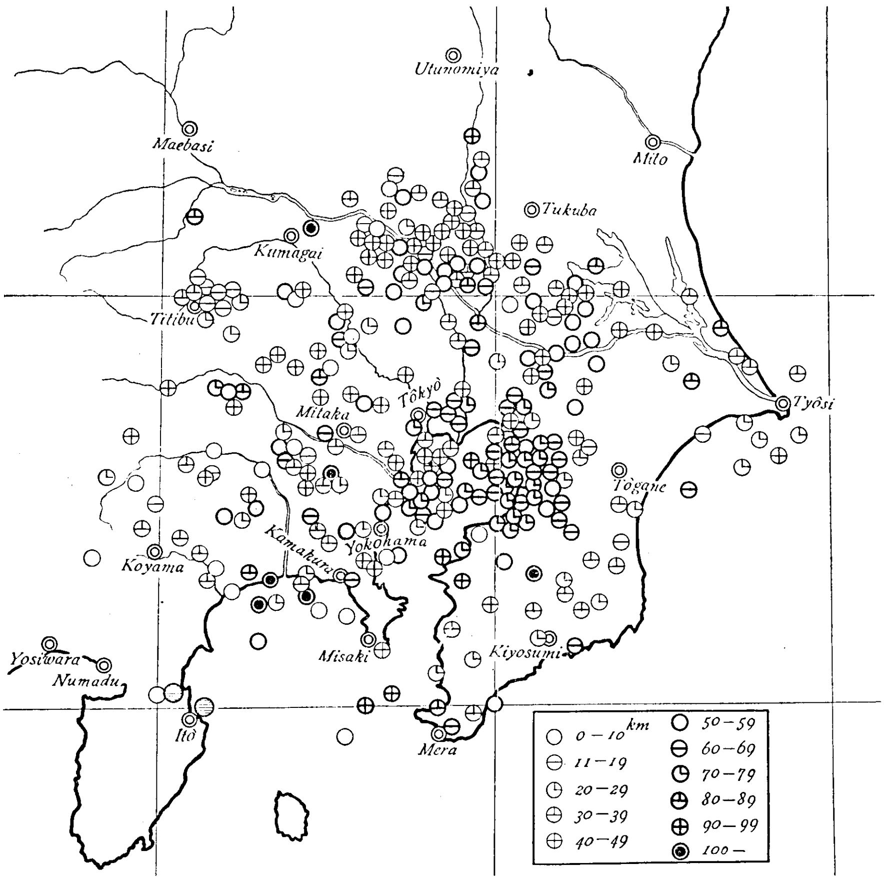

Fig. 6. Distribution of the epicentres in the period 1924–1931.

mountainous regions, especially in the Kwantô and Mikuni ranges, which form the northern and western boundaries of this district. The most active regions during this period were the Tonegawa-Kinugawa and the northern part of Tôkyô Bay.

The Musasi plain, the Tama upland, the Tanzawa mountainland, the Bôsô peninsula, and the neighbourhood of lake Kasumigaura were uniformly and moderately active. The comparatively dense distribution near Titibu is owing to the severe earthquake of September 21, 1931 and its after-shock.

In Fig. 6 will be noticed two quiet regions in the lowlands, south of Mito and north of Tôgane, where no epicentres appear. In the latter region, as a matter of fact, no earthquake of any consequence occurred during this period, whereas in the former, small shocks often originated in the neighbourhood of Kakioka and Hinuma, although the one of June 1, 1930, near Mito, is seen to have been severe, however, owing to the difficulty of accurately determing their origins on account of their small magnitude and marginal position, these earthquakes are not considered in these discussions.

Depth Distribution of the Seismic Origins.

As an aid in the quest for the cause of earthquakes in any region, a study of the vertical distribution of seismic origins is of the utmost importance. Studies made of such distributions in the case of the Tango earthquake[3] and in those of the Itô earthquake swarms[4] by Mr. Nasu have given remarkable results.

We shall now try to get the depths from which the earthquakes of this district originated. The next Table gives the frequency according to depths of origin of 318 earthquakes whose foci were determined.

Table IV.

Depth	0-10 km.	11-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-
Frequency	16	14	35	49	69	43	42	26	10	6	6

It will be seen that the number of shocks gradually increase with depth of foci, attaining maximum at 40-49 km., where it is 69, whence it deminishes with depth.

Fig. 6 shows that the focal depths of earthquakes of a certain region keep on the whole to the same order of depth. To illustrate, those originating in Tôkyô Bay generally do so at depths greater than 50 km., while most of those in the Tonegawa-Kinugawa region come from depths of the order of 40 km. For earthquakes that have originated in the Tanzawa mountainland, Sagami Bay, and the Bôsô peninsula, the depths are much under 30 km.

Generally speaking the origins are deepest for earthquakes that originate under the northern part of Tôkyô Bay, getting shallower as they originate from the margin of this district, while the very deep earthquakes, over 100 km., originate under the mouth of the river

3) 那須信治 地震研究所彙報 6 (1928), 7 (1928).

4) N. Nasu, F. Kishinouye and T. Kodaira, *Bull. Earthq. Res. Inst.*, 9 (1931).

Sagamigawa.

Next, in order to ascertain the focal distribution in detail, we have tried the method of stereometrical projection, first applied by Mr. Nasu to the investigation of after-shocks of the Tango earthquake. We shall assume two hypothetical vertical planes, extending N.W. to S.E. and N.E. to S.W. in this district, and project on these planes all the earthquake foci. The result is shown in Fig. 7.

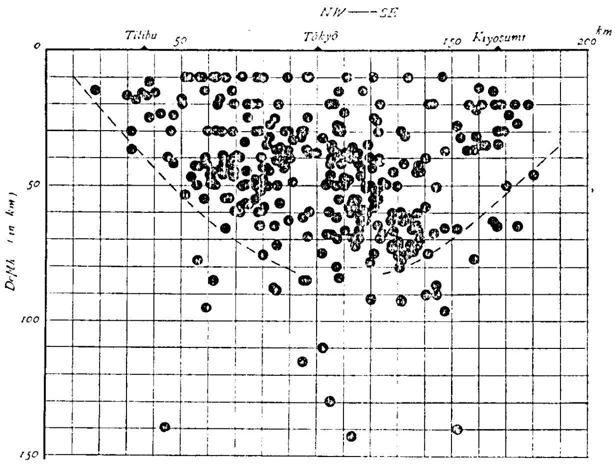

Fig. 7 a. Seismic foci projected on a vertical plane extending N.W. to S.E.

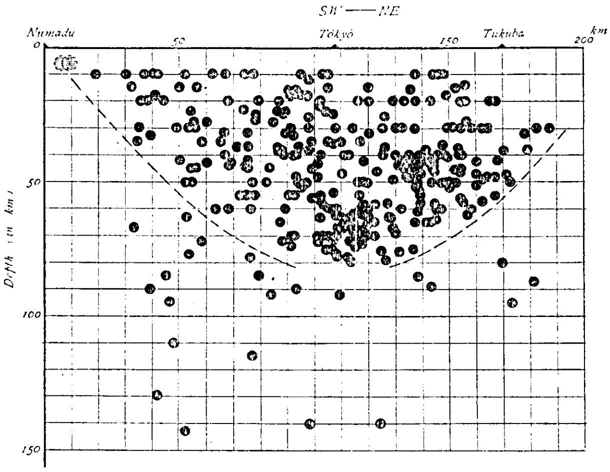

Fig. 7 b. Seismic foci projected on a vertical plane extending S.W. to N.E.

We see from these two projections that, excepting those that originated at very great depths, the majority of earthquakes felt in this district originated from a region having the shape of a shallow bowl, whose bottom would be about 70 km. beneath the northern part of Tôkyô Bay, with the slope of the bowl inclined about 45° to the earth's surface. The diameter of the surface of this bowl, from brim to brim, would be over 200 km.

It has been pointed out by Mr. C. Tsuboi, that earthquakes frequently originate from regions having remarkable gravity variation, and the Kwantô region is well known for gravity anomalies. The Tonegawa-Kinugawa region, one of the most seismically active in the Kwantô has also one of the steepest gravity gradient in this locality.

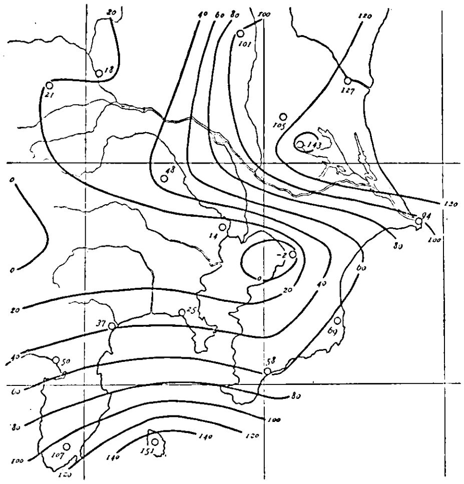

Fig. 8. Distribution of the Gravity Anormalies in the Kwantô District (unit: 10^{-3} cm/sec^2)

On the other hand, the northern part of Tôkyô Bay, another active region, corresponds to the only place in this district that shows a negative gravity anomaly, notwithstanding that its surroundings show a positive anomaly.

The inference from this is that the structure of the earth below 70 km. from the floor of the northern part of Tôkyô Bay differs markedly from that of the regions surrounding it, and that this lack of homogeneity in the structure below the earth's crust interferes with the stability of the upper layers, resulting in numerous fissures in the upper crust with consequent earthquakes along these fissures.

Studies of the focal distribution of the Itô and Aziro earthquake swarms lead us to suppose that these earthquakes give rise to volcanic activities that are not apparent at the earth's surface. The two regions just mentioned lie on the Huzi volcanic belt, which, as shown in Fig. 7 b. corresponds to the vicinity of the intersection of the earth's surface and some of the fissures above mentioned. It may therefore be supposed that these earthquake of the Idu district caused active movements of magma along some of those fissures in the earth's crust.

Summary.

(1) Seismic activity in the Kwantô district before and after the great earthquake of September 1, 1923, shows a marked difference, the influence of the great disturbance continuing to the present day.

(2) The earthquakes in this district have a tendency to originate far more in the lowlands than in the mountainous regions, the latter being very rarely disturbed. Of the former, the Tonegawa-Kinugawa region and the northern part of Tôkyô Bay showed the greatest activity during the period between 1924 and 1931.

(3) The earthquakes of this district originate in a region having the form of a shallow bowl with the northern part of Tôkyô Bay as its bottom and its top level with the earth's surface.

(4) From the distribution of gravity anomaly in this district it is believed that the structure under the northern part of Tôkyô Bay lacks homogeneity, which leads us to suppose that the numerous fissures due to the heterogeneity exist below 70km., extending into the upper crust of this district, and that earthquakes originate along these fresh fissures.

In conclusion, the present writer wishes to express his sincere thanks to Mr. Nobuji Nasu for his kind guidance. He is also much indebted to Mr. Chuji Yasuda for his kindness in placing the valuable data at the writer's disposal.

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20. 關東地方の地震

地震研究所 小 平 孝 雄

大正 12 年の關東大地震以來, 關東地方に於ける地震觀測の設備は次第に整備し, 且つ一方に於ては地震波傳播に關する研究も漸く進歩して來た爲に, 此の區域内に發生する地震の震原位置は大震當時に比べると遙かに正確に決定することが出來る樣になつた.

筆者は關東大地震以後の關東地方に於ける地震活動の狀態を詳にする目的を以て, 大正 13 年より昭和 6 年に至る 8 ケ年間の當地方に發生した主なる地震に就いて其の震原分布の狀態を調査し, 併せて二三の事項に關して考察を試みた.

大正 12 年の關東大地震を境として當地方の地震活動の狀態は著しい相違を示して居る. 東京に於ける有感地震の回數を見ても, 地震前 9 年間の平均 28 回に對して大正 13 年以後の 8 年間には平均 80 回に上り, 明かに同大地震が其後の當地方の地震活動に大きな影響を及ぼして居ることを知る.

鹿島灘, 房總半島沖等の太平洋底を除き, 當地方内に發生した地震の震央分布の狀態を見るに, 概して云へば山岳地方に粗で, 低地に密なる傾向がある. 殊に隣接地方との境をなす關東山脈, 三國

山脈内に於ては非常に數が少ない．最も活潑なる活動を示して居るものは利根川，鬼怒川流域地方と東京灣の北半であつて，丹澤山地，相模灣，多摩丘陵，武藏野，房總半島及び霞浦地方も多少の活動力を示し，屡々地震の發生を見て居る．

震原の深さに關して云へば，當地方の地震は極く地表近くの淺所より 140 km. 位の深所にまで發生して居る．最も多いのは 40 km. 臺である．特別に深所に發生した地震を除けば，一般に東京灣北部に發生する地震が最も深い震原を有し，其れより四方に遠ざかるに連れて次第に發生する地震の震原の深さは淺くなる傾きがある．大體東京灣北部の地表下 70 km. 附近の場所を底とし，地表に對して約 45° 位の傾きを有する線を持つ一つの椀形の部分内に大部分の地震は發生して居るのを見る．

重力殘餘分布圖によつて見ると，東京灣北部の地震の最も頻發する地方は當地方唯一の負の偏差を有する地方である．この事實は此の區域下の地殼內の構造狀態が周圍の地方とは可成り相違して居ることを暗示して居る．恐らく此の構造の異常に原因して幾つもの裂罅が此處を中心として關東地方の地殼內に生じ，これ等の裂罅に沿ふて關東地方の地震は發生するのではないかと想像される．