SEISMICITY OF TAIWAN

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Abstract

Taiwan (Formosa) stands at the outskirts of Asiatic continent and lies right on the Circum-Pacific Seismic Zone where earthquakes are frequently felt. Therefore we have a well distributed seismic network of 16 stations. The data of these seismic stations have been studied and described some conclusions concerning the geographical distribution of earthquakes, secular and monthly changes of the number of earthquakes, seismic zone, the depth of hypocentre, disastrous earthquake and earthquake magnitude.

Taiwan is located in the Circum-Pacific Seismic Zone and has suffered great damage from a number of destructive earthquakes throughout her history. Therefore we maintain a seismic network of 16 stations (See Fig. 1) which are well equipped with several kinds of seismographs (3). Taiwan experienced earthquakes about 1,269 times in an average year as calculated from 1930 to 1961. Among them 1,035 times were unfelt earthquake and 234 times were felt earthquake. The number of felt earthquake is about 18% of the total. The number changed considerably from year to year (See Fig. 2) and became numerous after any big earthquake or by occasional earthquake swarms. The maximum number occurred in 1951 amounting 3,726 times and the second occurred in 1922 amounting 3,224 times. The former was caused by aftershocks of the earthquake of Hwalien and Taitung and the latter was caused by earthquake swarms which occurred near Suau, northeastern coast of Taiwan. The minimum in 1910 was only 264 times (1,2,3).

The geographical distribution of the number of earthquake which could be felt by persons and the magnitude larger than 4.8 are shown in Fig. 3 and Fig. 4 which were made on the basis of the data from 1933 to 1958. It indicates that the most frequently affected region is that along the east coast and the west side of Taiwan, and the quietest is the southwestern part of the island. The largest number of felt earthquakes were observed at the Hwalien District (See Table 1) amounting to 123.2 times per year as the mean values from 1913 to 1961. This value is equal to 44% of the total felt earthquakes in Taiwan. The largest number of unfelt earthquakes were also occurred at the Hwalien District which amount to 392.3 times, i.e., 32.7% of the total unfelt earthquakes (See Table 2). These two tables also show the monthly changes.

As mentioned above, the region most frequently affected lies along the east coast of Taiwan suggesting that there is a zone of seismic activity in this area. We called it the Eastside Seismic Zone. On the other hand, in the west plane near Hsinchu and Chiai area earthquakes also frequently occurred. We call it the Westside Seismic Zone.

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In the case of earthquake occurring in the Eastside Zone and that the epicentre is located on land, its magnitude is comparatively small and the depth of hypocentre is about 10 to 30 km. but they occur frequently and continuously. In case the epicentre located at sea, its magnitude is larger, sometimes the Gutemberg Richter's M scale reached near 8, and the depth of hypocentre is deeper, namely 50 to 200 km, so that little damage and crustal deformation occurres on land. In the Westside Zone many destructive earthquakes have occurred throughout history. Owing to the depth of the hypocentre being very shallow, that is 0 to 10 km. great damage and accompaning remarkable crustal deformation such as fault, fissure, landslide etc. occurres. The number of felt earthquakes which have occurred in the Eastside and Westside Seismic Zone are shown in Fig. 5. The seismic activity was vigourous in the years of 1913, 1916, 1919, 1922, 1925, 1929, 1935, 1937, 1943, 1947, 1951 and 1956 in the eastside and 1908, 1913, 1917, 1921, 1930, 1935, 1938 and 1941 in the westside. It is very difficult to find periodicity in both sides.

The earthquake magnitude is classified according to the radius of the felt area on the assumption of a circle as follows:

i) Remarkable earthquake: The radius of the felt area 'r' is greater than 300 km. (M is larger than 6.4)

ii) Moderate earthquake: r is smaller than 300 km but greater than 200 km. (M = 6.4 - 5.7)

iii) Earthquake of limited area: r is smaller than 200 km. but greater than 100 km. (M = 5.7 - 4.8)

iv) Local earthquake: r is smaller than 100 km. (M is smaller than 4.8)

Where 'M' is the Gutemberg-Richter's magnitude scale and the relation between 'M' and 'r' is given by Gutember and Richter (4) as

$$r = 2.3\ (M - 1.3)^3 - 1.7 \qquad (1)$$

The distribution of the epicentre of remarkable earthquakes is shown in Fig. 6. The number amounts to 53 times during the years from 1900 to 1961. It indicates that remarkable earthquake frequently occurred along the east coast and Chiai area. The distribution of the epicentre of moderate earthquakes is shown in Fig. 7. The number amounts to 152 times during the years from 1900 to 1961. This also shows that the district of their frequent occurrence is along east coast and Chiai area. The distribution of earthquake of limited area is shown in Fig. 8. The number amounts to 617 times during the years from 1930 to 1961. The area of their most frequent occurrence is off the coast of Hwalien. The number of occurrence of local earthquake is 6,662 times during the years from 1930 to 1961. A formula (2) has been found to express the relation between the number of occurrence of 'Remarkable', 'Moderate', 'Limited area' and 'Local' earthquake 'M' and its representative redius of felt area 'r' (measured in km.) being 350, 250, 150 and 50 km respectively.

$$\log N = 8.38 - 2.63\ r \qquad (2)$$

Another formula (3) has been found usefull for calculating the Gutemberg-Richter's magnitude scale of an earthquake occurring in or near Taiwan from seismometrical data at Taipei.

$$M = \log a + 2.24 \log\Delta - 1.77 \qquad (3)$$

where 'M' is the magnitude, 'a' is the maximum displacement amplitude of the ground due to that earthquake (measured in micron) observed at an epicentral distance 'Δ' (measured in km.) (5).

Some of the earthquake of the order of 7 to 8 which occurred off the east coast caused seismic sea wave (Tsunami) but not sufficient to cause damage since 1896 when seismological observation began. But according to Davidson (6) there was a great earthquake occurred off Keelung on December 18, 1867 and accompaning severe seismic sea wave caused great damages and several hundreds persons were drowned.

The distribution of earthquakes of magnitude larger than local earthquake classified by the depth of the hypocentre is shown in Fig. 9. It shows that the depth of the hypocentre in the westside is shallower than those occurring in the eastside.

From the view point of earthquake engineering, it is more important to discuss the disastrous earthquake which caused great damage to man-made structure and human being. The earthquakes by which damage was cuased in Taiwan during 1900 to 1964 have amounted to 72 in number, and among them 18 earthquakes brought more than 100 death and wounded or more than 1,000 houses totally destroyed and damaged. The earthquake which resulted the greatest casuslities in Taiwan was the Hsinchu-Taichung earthquake of 1935 in which 3,276 persons were killed and 12,053 were hurt, and 17,909 houses were totally destroyed and 36,781 were damaged. The next is the Chiai earthquake of 1906 in which 3,643 persons were killed or hurt and 20,987 houses were destroyed. These two earthquakes were accompanied by very remarkable crustal deformation such as fault, fissure, landslide, sand-crator and collapse of the ground. The recent strong earthquake occurred in the Tainan-Chiai area on January 18, 1964, in which 756 persons were killed and hurt and 15,808 houses were destroyed.

The distribution of the epicentre of disatrous earthquakes is shown in Fig. 10 and it also shows that the regions frequently occurred are the east coast of Taiwan and the west plane near Hsinchu and Chiai area. There is a remarkable feature of the epicentral region of disastrous earthquakes that is the repetition of earthquake's occurrence. For instance, in the Chiai area among the 18 large earthquakes 7 times have occurred almost in same region in the past 60 years. It suggests that the place where people have experienced severe earthquakes will probably be visited some day by another earthquake of a similar intensity. In such place the earthquake-proof construction must be payed special attention.

The scale of seismic intensity of 0 - VI is customarily adopted for use in Taiwan as follows:

0; No feeling: Shocks too weak to cause human feeling, registered only by seismographs. (Acceleration smaller than 0.8 gal)

I; Slight: Extremely feeble shocks only felt by persons at rest or by those who are observant of earthquakes (0.8 - 2.5 gal)

II; Weak: Shocks felt most persons, slight shaking of doors. (2.5 - 8.0 gal)

III; Rather Strong: Slight shaking of houses and buildings, rattling of doors, swinging of hanging objects such as electric lamps, moving of liquids in vessels. (8.0 - 25.0 gal)

IV; Strong: Strong shaking of houses and buildings, overturning of unstable objects, spilling of liquids out of vessels. (25.0 - 80.0 gal)

V; Very Strong: Cracks in the walls, overturning of gravestones, stone lanterns etc., damaging of chimneys and stone walls. (80.0 - 250.0 gal)

VI; Disastrous: Demolition of houses, landslides, faults, fissures on the ground. (larger than 250.0 gal)

Damage to houses begins to appear when the intensity attains to 5 grade, Fig. 11 shows the annual mean of the number of 4 grade, 5 grade and 6 grade. The period of statistic data used are irregular, the longest is 44 years and the shortest is 25 years. This figure is useful for estimateing the maximum intensity and its occurrence.

Aknowledgements

The author expresses his hearty thanks to Director Kenneth T. C. Cheng who gave him the opportunity to attend this conference. His thanks are also due to Messrs. H. K. Hsu and C. C. Shy for drawing the figures. This work was supported by the National Council on Science Development.

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Table 1. The Number of Annual Monthly Mean Felt Earthquakes (1913 - 1961)

District	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Monthly Mean	Ratio of District per Total Area. %
Northern	3.8	3.1	3.4	3.8	3.4	2.8	3.5	4.5	12.1	5.4	5.0	3.8	54.6	4.5	19.2
Taichung	2.0	1.4	1.1	1.3	1.0	1.2	3.3	1.4	1.3	1.3	1.8	0.7	17.8	1.6	6.8
Hwalien	10.0	8.6	11.7	8.0	8.3	16.5	5.9	7.0	8.5	16.7	14.6	7.4	123.2	10.3	44.0
Tainan	4.2	2.4	2.4	2.6	2.0	2.6	1.5	2.3	2.8	2.5	1.7	6.8	33.8	2.8	12.0
Hengchun	0.4	0.4	0.6	1.2	0.6	0.3	0.4	1.0	0.4	0.4	0.4	0.4	6.5	0.5	2.2
Taitung	4.3	2.6	3.0	3.2	2.7	4.0	2.7	4.0	8.9	3.3	3.9	6.9	44.6	3.7	15.8
Total	24.7	18.5	22.2	20.1	18.0	27.4	17.3	20.2	29.1	29.6	27.4	26.0	280.5	23.4	100.0

Table 2. The Number of Annual Monthly Mean Unfelt Earthquakes (1930 - 1961)

District	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Monthly Mean	Ratio of District per Total Area. %
Northern	12.8	11.3	10.2	13.4	15.1	13.1	14.9	20.0	29.5	21.1	12.9	12.8	187.1	15.6	18.1
Taichung	3.9	3.8	3.8	4.6	3.7	4.0	4.2	3.6	6.5	5.4	3.8	3.7	51.0	4.2	4.9
Hwalien	24.0	40.6	31.2	26.1	25.6	23.7	19.8	22.1	35.9	67.9	46.8	28.6	392.3	32.7	37.9
Tainan	18.6	7.5	7.4	9.3	4.2	3.2	3.2	4.5	5.7	3.8	5.4	16.5	89.3	7.4	8.6
Hengchun	4.2	6.6	7.1	9.0	7.5	5.2	5.2	13.6	11.3	7.0	6.0	5.8	88.5	7.4	8.6
Taitung	15.0	15.3	14.9	14.9	17.5	15.1	15.3	19.1	19.4	17.4	21.3	41.8	227.0	18.9	21.9
Total	78.5	85.1	74.6	77.3	73.6	64.3	60.6	82.9	108.3	112.6	96.2	109.2	1035.2	86.3	100.0

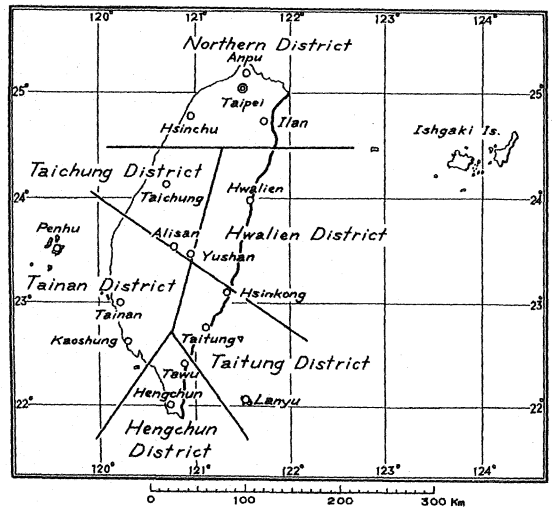


Fig. 1. The network of seismological station in Taiwan.

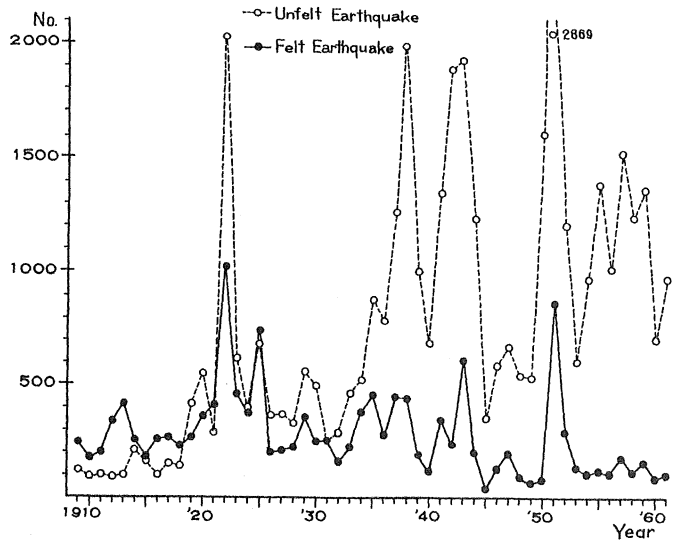


Fig. 2. The secular change of the number of earthquake in Taiwan.

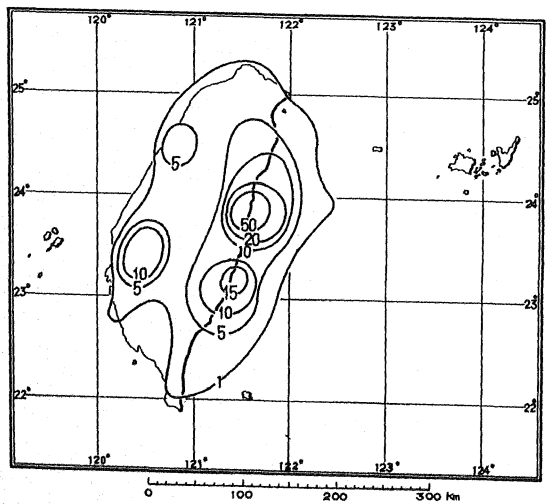
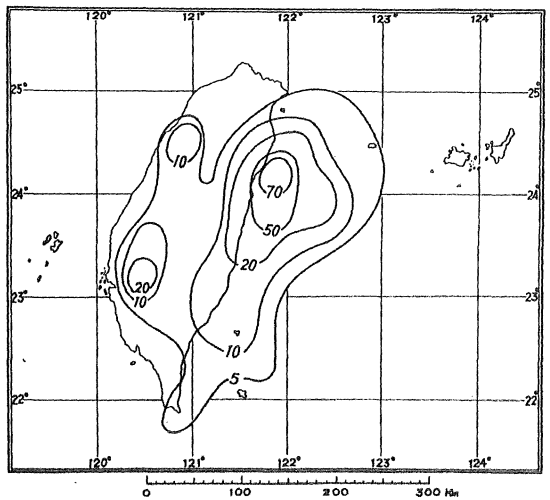


Fig. 3. The distribution of the average number of felt earthquake (1933-1958).

Fig. 4. The distribution of the average number of earthquake of which magnitude is larger than 4.8 (1933-1958).



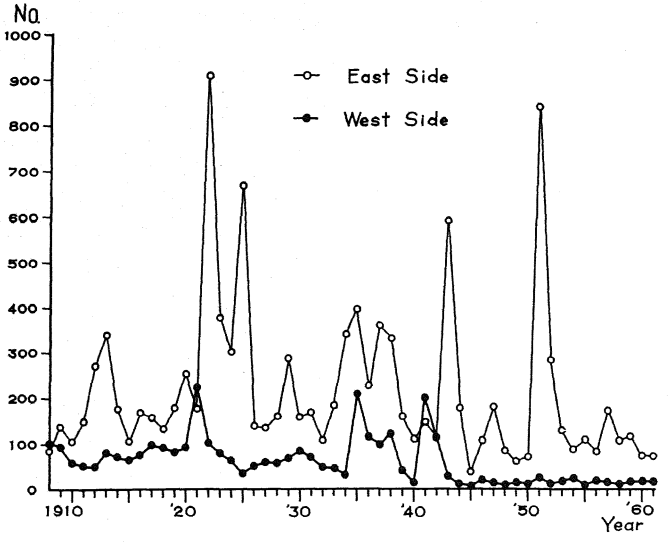


Fig. 5. The secular change of the number of felt earthquakes in the Eastside Seismic Zone and the West Seismic Zone (1908-1961).

Fig. 7. The distribution of the epicentres of Moderate Earthquake (1900-1961).

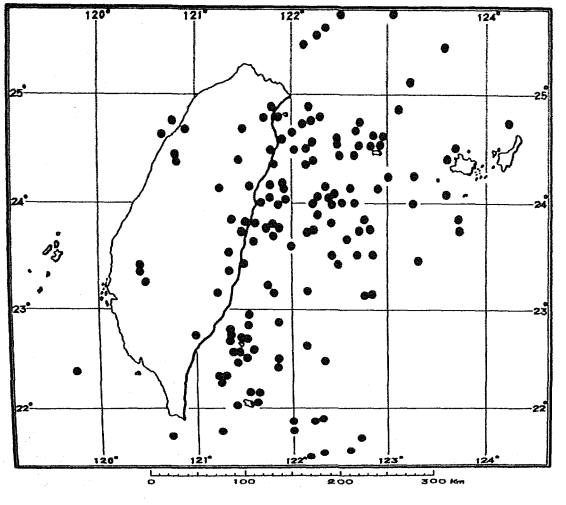
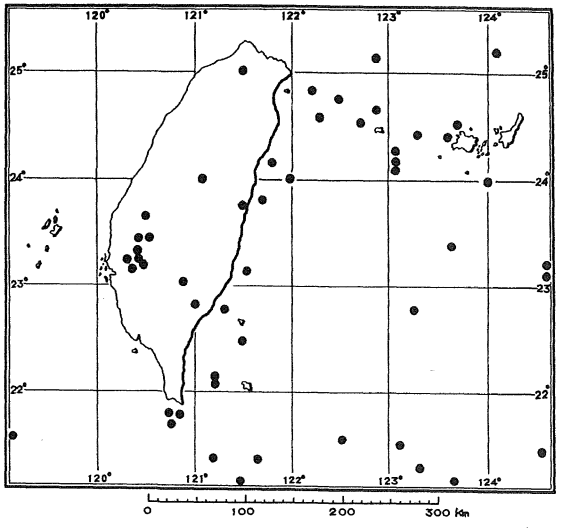


Fig. 6. The distribution of the epicentres of Remarkable Earthquake (1900-1961).



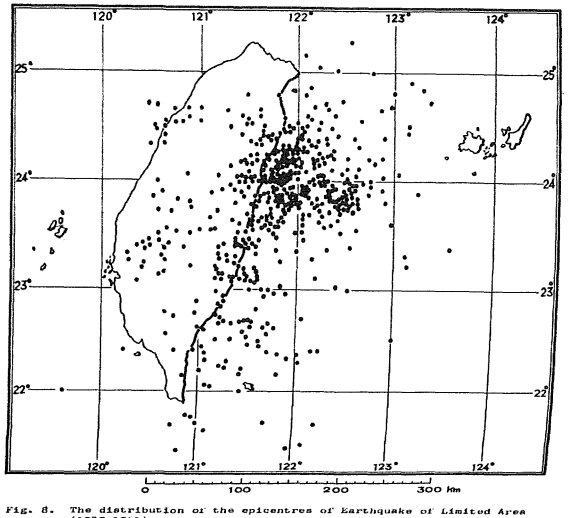


Fig. 8. The distribution of the epicentres of Earthquake of Limited Area (1930-1961).

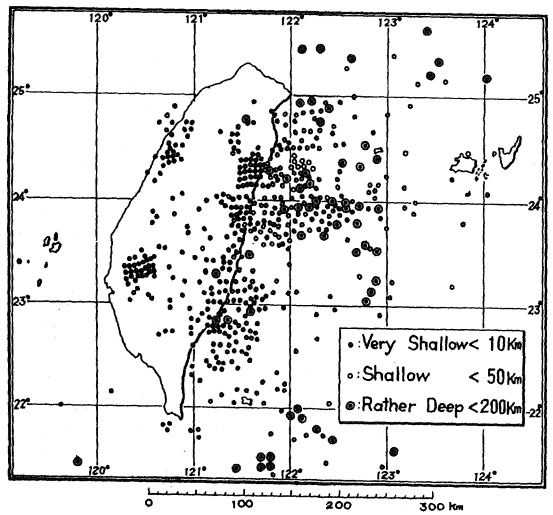
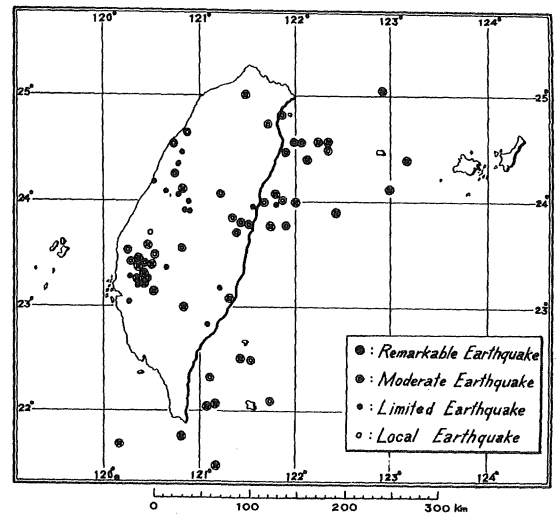


Fig. 9. The distribution of earthquake of M larger than 4.8, classified by the depth of the hypecentre (1909-1958).

Fig. 10. The distribution of the epicentre of disastrous earthquake (1900-1964).



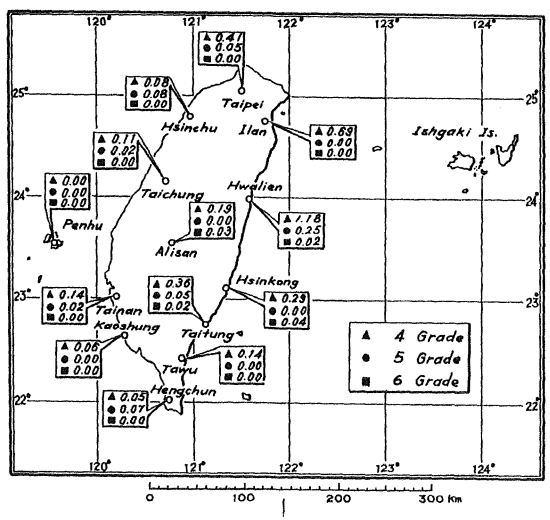


Fig. 11. Annual mean number of the intensity 4, 5 and 6 grade.

SEISMICITY OF TAIWAN

BY HSU, MING-TUNG

QUESTION BY: A.W. SMITH - NEW ZEALAND

The diagrams show a large number of epicentres differentiated for magnitude and depth and there are significant peaks with time. Has the data been analysed for any correlation of type of earthquake with time i.e. is there any sequence in the magnitude of earthquakes or their epicentral depth?

AUTHOR'S REPLY: This problem has not been studied as yet.