Earthquakes in Manchuria

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I. General View of the Earthquakes in Manchuria

It is said that earthquakes originate mainly from the folded mountain zones which were formed by the Cretaceous and Tertiary orogenic movements, so many earthquakes do not occur in Manchuria which has been relatively stable in the recent geological age. According to NIINOMY and MURATA, only 68 earthquakes have been recorded from 2 A.D. to 1888 A.D. Of these, the following three earthquakes were destructive.

(1) 1774: Tieh-ling district, Mukden Prov.
(2) 1855 (Dec. 11): Mukden—Chin-chou district, Mukden Prov.
(3) 1859: Niu-chuang—Kai-ping district, Mukden Prov.

During the period of 26 years from 1904 when meteorological observation was begun at Dairen to 1930, 20 earthquakes were felt in Dairen, Ying-kou, Port Arthur, and Mukden.

Since the Central Meteorological Observatory was established in Chang-chun and meteorological observation was begun throughout Manchuria, earthquakes have been precisely recorded, but instrumental observation was not satisfactory. According to the Monthly Report of the Central Meteorological Observatory of Manchoukuo from 1935 to 1941, even in the years when no destructive earthquakes occurred several felt earthquakes were recorded. The earthquake in the districts of Kai-lu in West Hsing-an Province and Tung-liao in South Hsing-an Province on January 19, 1940, seems to have caused a little damage. The earthquake in Hsiung-yo-cheng, Mukden Province on August 5, 1940 and the earthquake in Sui-hua, Pin-chiang Province on May 6, 1941 were destructive earthquakes which rarely occur in Manchuria.

According to the Richter-Gutenberg magniude scale, the magnitudes, M, of these earthquakes are as follows: the earthquake in Kai-lu and Tung-liao, M=5.9; the earthquake in Hsiung-yo-cheng, M=6.3; and the earthquake in Sui-hua, M=6.7. The energy of each of these earthquakes is 4×10^{22}, 2×10^{23}, and 1×10^{24} erg, respectively. These values, though rough, can be used as standards when comparing the magnitudes of these earthquakes. That is, the Sui-hua earthquake was about five times as large as the Hsiung-yo-cheng earthquake, and the Hsiung-yo-cheng earthquake was about five times as large as the Kai-lu and Tung-liao earthquakes.

In Japan, more than 1,200 felt earthquakes are recorded every year, and a destructive earthquake occurs at the rate of one a year. Compared with Japan, the occurrence of earthquakes in Manchuria is very infrequent. In the Tōnankai earthquake of 1944 and the Tokachi-oki earthquake of 1952 M=8.0, in the Kwantō earthquake of 1923 and the Nankaidō earthquake of 1946, M=8.2, and in the Sanriku-oki earthquake of 1933, M=8.5. Compared with these earthquakes, the magnitudes of destructive earthquakes in Manchuria are small. The destructive earthquakes which occurred in Manchuria in recent years, namely, the Hsiung-yo-cheng earthquake and the Sui-hua earthquake, will be outlined below.

II. The Hsiung-yo-cheng Earthquake of August 5, 1940

According to the Monthly Report of the Central Meteorological observatory of Manchoukuo, this earthquake can be summarized as follows:

(a) Damage

The damage was very severe in the area extending from Hsi-erhtai-tsu in the west to Erh-tao-ho in the east; the center of the affected area was the Chiu-chai Station of the South Manchurian Railway and its vicinity. Mud-brick houses were mainly damaged, and in some villages more than 50 percent of these houses were totally demolished. According to the investigation by the Kai-ping Prefectural Office, the damage and casualties were as follows:

Table 1. Statistics on Damages and Casualties.

Village or town	Houses		Killed	Injured
	Totally demolished	Partially demolished		
Chiu-chai	740	4,261	—	2
Lung-men-tang	135	917	—	—
Kang-ning-pu	59	448	1	2
Hsiung-yo-cheng	—	1,030	—	—
Kuei-chou	138	1,131	—	—
Hsiang-huang-chi	—	56	—	—
Shuang-tai-tsu	34	52	—	—
Fang-shen-kou	43	281	1	3
Huan-chia-pu	—	92	—	—
Chien-chia-tun	41	1,128	—	—
Total	1,190	9,396	2	7

No remarkable topographical change took place except in the low damp ground near the coast of Hsiang-lan-chi village where fissures from which water spouted were formed; and several small fissures were reported in some places. It is said that well water became slightly turbid at the time of the earthquake, but it became clear before long. There were no unusual signs in the hot spring at Hsiung-yo-cheng.

(b) Seismological observation

The seismic intensity observed at various meteorological offices was as follows:

III: Ying-kou, An-shan
II: Chin-chou, Lien-shan-kuan, Fu-shun
I: Mukden, Chin-feng, Chang-chun, Fu-shen, Kai-lu, Liao-yang, I-hsien, Hsing-cheng, Pyong-yang

This earthquake was felt even in Chang-chun which was 500 km from the epicenter. The results of instrumental observations are shown in Table 2.

Table 2. The Results of Seismological Observations.

Locality	Time of occurrence	Duration of preliminary tremors	Maximum amplitude micron
Ying-kou	$18^h\ 55^m\ 18^s$	8.0^s	—
Pi-tsu-wo	18 54 54	11.0	—
Dairen	18 55 32	18.0	980
Port Arthur	18 55 35	20.8	—
Mukden	18 55 58	29.2	1650
Hsin-ching	18 56 18	57.1	31
Yen-chi	— — —	78.0	330
Pyong-yang, Chosen	18 55 57	—	—
Inchon, 〃	18 56 16	—	—
Seoul, 〃	18 56 18	—	—
Singalli, 〃	18 56 55	—	—
Taegu, 〃	18 57 06	—	—

Based on these results of observations, the epicenter of this earthquake was judged to be located at a point abaut 10 km southwest of Hsiung-yo-cheng, precisely speaking, 122.1° E, 40.1° N. Based on the time of occurrence and the duration of preliminary tremors at each place, the time of occurrence at the hypocenter was estimated at $18^h55^m6^s$.

The depth of the hypocenter is considered to have been less than 10 km, which is very shallow, so, if it is assumed that the depth of the hypocenter is 0 and if the previously mentioned times of occurrence are adopted, the travel time curves of the P-wave and the S-wave shown in Fig. 1 are obtained. In this graph only the observation values from the observatories in Manchuria were adopted, and the values from Mukden and Pi-tsu-o were excluded, as they were considered untrustworthy. The black dots on the graph are the values observed at Chang-tung in the cases of the Chi-lin earthquake of June 1, 1937, and the Sui-hua earthquake of

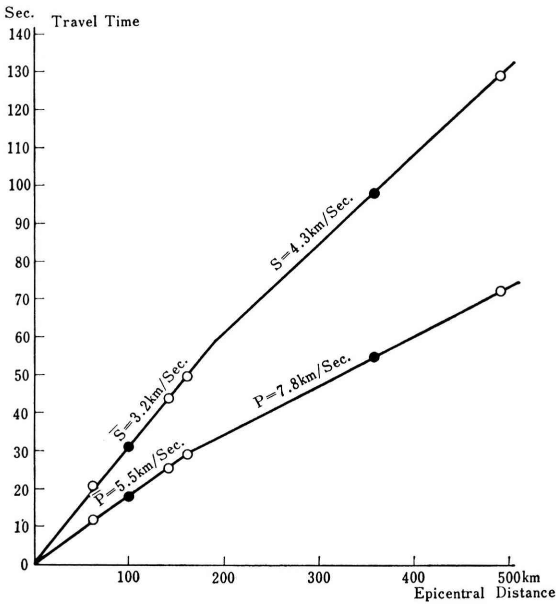

Fig. 1. Time-distance curve.

May 6, 1941. These were plotted for reference. In the cases of these earthquakes, the time of occurrence at the hypocenter of each earthquake was obtained from the time of occurrence and the duration of preliminary tremors at each place, and it was considered that the hypocenters of the two earthquakes were very shallow.

As seen in the graph, there were not many observation values, so the graph has little value. But, if the points are connected with straight lines, two straight lines can be obtained for both the S-wave and P-wave. The velocity of the earthquake waves can be determined from the inclination of these straight lines. That is, in the upper layer the velocity of the P-wave was 5.5 km/sec and that of the S-wave 3.2 km/sec, while in the lower layer the velocity of the P-wave and the S-wave was 7.8 km/sec and 4.3 km/sec, respectively. If these travel time curves are trustworthy, the thickness of the earth's crust must be 35 km, but it is regrettable that these values are not very trustworthy.

(c) The magnitude of the Earthquake

The Richter-Gutenberg magnitude scale, which expresses the magnitude of earthquakes, has recently become practical and has come into general use. This is a method to determine the magnitude of earthquakes by a function on the maximum amplitude of earthquake motion, and at the same time it serves to clarify the relationship between the magnitude and the toal energy of earthquake waves. Consequently, the magnitude of earthquakes can be compared based on the amount of energy of the earthquakes.

According to a study by Tsuboi, the relationship between the magnitude, M, and the maximum amplitude, A (unit; micron), in the epicentral distance $\triangle$ (unit; 100 km) is represented by the following formula,

$$M = 0.20\ \triangle - 0.67 \log A - 3.80\ (\triangle < 5)$$

$$M = 0.03\ \triangle - 0.61 \log A - 5.00\ (\triangle > 5).$$

The mean magnitude of this earthquake based on the observation values at Dairen, Yen-chi, Mukden, and Chang-chun and calculated by this formula was $M=6.3$.

The relationship between the magnitude, M, and the energy of the earthquake, E, has been given by Gutenberg in the following formula,

$$\log E = 12 + 1.8\ M.$$

If the value M is substituted in the above formula,

$$E = 2 \times 10^{23}\ \text{erg}.$$

That is, the magnitude of this earthquake is considered to be almost the same as that of the destructive earthquake which occurred in the valley of the Chikuma River northeast of Nagano city on July 15, 1941.

(d) Foreshocks and Aftershocks

A foreshock occurred 10 to 30 minutes before the principal shock, and it was felt everywhere in the vicinity of Hsiung-yo-cheng. According to the Hsiung-yo-cheng Police Station 69 aftershocks occurred in August, 33 in September, 5 in October, 5 in November, and 1 in December.

The magnitudes of the main aftershocks calculated on the basis of the maximum amplitude recorded at Ying-kou were as follows:

Sept. 14, $11^h\ 36^m$	$M=4.9$
Sept. 17, $14^h\ 10^m$	$M=4.9$
Sept. 21, $16^h\ 10^m$	$M=4.6$
Nov. 5, $15^h\ 08^m$	$M=5.1$
Nov. 22, $22^h\ 01^m$	$M=4.9$

That is, the magnitudes of the main aftershocks are smaller than the magnitude of the principal shock by more than 1 for the value of M. That the magnitude was smaller by 1 means that the energy was about 1/60.

III. The Sui-hua Earthquake of May 6, 1941

(a) Seismological Observation

The earthquake which originated from a point near Sui-hua on May 6, 1941 at about $0^h\ 18^m$ was a large earthquake which occurs very rarely in Manchuria. According to the Chang-chun Meteorological Observatory, the time of occurrence was $0^h\ 19^m\ 12.8^s$, the duration of preliminary tremors 43 seconds, and the epicentral distance 375 km. Assuming the Poisson's ratio to be 0.27, the time of occurrence at the hypocenter was $0^h\ 18^m\ 18^s$. Based on the time of occurrence at Dairen ($\triangle=995$ kg) and Seoul ($\triangle=1040$ km), and assuming the depth of the hypocenter to be 0, according to the travel time table prepared by Wadati, SAGISAKA, and MASUDA, the calculated time of occurrence at the hypocenter was $0^h\ 18^m\ 18.5^s$. The epicenter was estimated to be 127° 04′E, 46° 42′N from the results of field observations in the meizoseismic area, though the epicenter could not accurately be determined by instrumental observation. The hypocenter was considered to be shallower than 10 km from the extent of the meizoseismic area.

(b) The Magnitude of the Earthquake

The maximum amplitude in each place in Manchuria was 620 microns in Chang-chun, 690 microns in Mukden, 453 microns in Yen-chi, and 323 microns in Ying-kou. If the magnitude of this earthquake is calculated on the basis of these amplitudes and by using TSUBOI's formula, the result is $M=6.7$. Consequently, $E=1\times10^{24}$ erg. In short, the magnitude of this earthquake was of the same degree as that of the Tajima earthquake on May 23, 1925, the Nishi-saitama earthquake on September 21, 1931, and the Imaichi earthquake on December 26, 1949.

(c) Aftershocks

Two minutes after the principal shock the first aftershock occurred and it was followed by six aftershocks on that day. Table 3 shows the number of aftershocks recorded at the prefectural office of Sui-hua.

Table 3. The Number of Aftershocks.

Date	Number	Date	Number
May 6	6	May 10	1
〃 7	4	〃 11	0
〃 8	1	〃 12	1
〃 9	2	〃 13	3

On June 3, when I arrived in the town of Sui-hua, it was said that two aftershocks were felt. On the night of June 6, I felt two slight shocks.

(d) Damage

The meizoseismic area was a diluvial tableland 230 to 250 m in altitude with a point 10 km northeast of Sui-hua town as the center. Figure 2 shows the percentage of totally demolished houses in this area. As seen in the figure, the area where houses were totally demolished was an elliptical area 17 km E–W and 25 km N–S.

According to the statistics prepared by the authorities of Sui-hua prefecture, main damage was limited to one town and four villages as shown in Table 4.

Houses in this area are poorly built brick houses and thatched houses. The latter are wooden-framed houses with walls of sun-dried bricks called tu-pi-tzu. Therefore, the relationship between the intensity and damage to dokaku (sun-dried

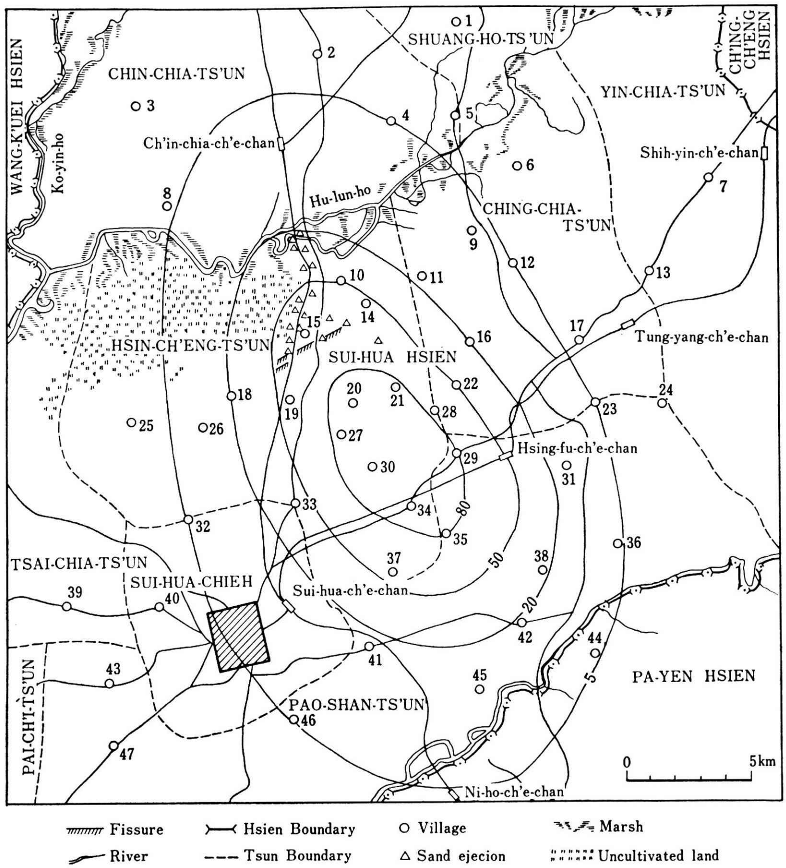

Fig. 2. Percentage of totally damaged houses in the Sui-hua area.

1 Kuo-chia-tien
2 Wang-ch'ing-shui
3 Yang-chia-yu-fang
4 San-hsing-t'un
5 Wu-ch'ang-lung-t'un
6 Chiao-wo-p'u
7 Lan-chia-wa-tzu
8 Hsiao-tung-t'un
9 Pei-chang-wo-p'u
10 Niang-niang-miao
11 Kao-chia-tien
12 Liang-hai-tzu
13 Ta-p'ing-ling
14 Chu-chia-wo-p'u
15 Ting-chia-sui-tzu
16 Hsiao-chang-wo-p'u
17 San-men-chang-t'un
18 Huang-chia
19 Erh-tao-kou
20 Hsiao-hsin-ch'eng-wo-p'u
21 Ta-hsin-ch'eng-wo-p'u
22 Ta-chang-wo-p'u
23 Chien-ching-ho
24 Hsing-chia-t'un
25 Hsi-fu-ch'un-ling
26 Ta-fang-shen
27 Tiao-yü-t'oi
28 Meng-chia-wo-p'u
29 Huang-fien-te-t'un
30 Huang-chia-kou
31 San-chia-wei-tzu
32 Hsü-chia-fen-fang
33 Lan-feng-ch'ih
34 T'ung-chia-wo-p'u
35 Hsiao-fang-shen-kou
36 Meng-chia-kao-tzu
37 Sheng-chia-wo-p'u
38 Erh-lung-shan
39 Hsi-ch'ang-fa-t'un
40 Hsi-ssu-p'ing-chieh
41 Tung-wan-fa-t'un
42 Kung-hsing-fu
43 Ying-chia-wo-p'u
44 Hou-chou-feng-lu
45 Chia-pao-t'un
46 Lang-chia-choi
47 Fan-chia-t'un

Table 4. Statistics on Damage.

Town and village	Population before earthquake		Damaged houses	Casualties
	Houses	People		Killed
Sui-hua town	9,711	57,546	353	32
Hsin-cheng village	1,569	10,619	269	63
Yen-lin village	1,408	10,386	103	15
Chin-ho village	1,714	12,190	109	9
Chin-chia village	1,708	11,054	24	1
Total	16,110	101,795	858	120

Town and village	Casualties		Houses	
	Severaly injured	Slightly injured	Totally demolished	Partially demolished
Sui-hua town	6	16	Pangtsu 71	Pangtsu 3,337
Hsin-cheng village	33	45	1,067	18
Yen-lin village	12	28	483	439
Chin-lin village	20	30	310	349
Chin-chia village	3	10	19	35
Total	74	129	1,950	4,178

brick) houses in Taiwan, as investigated by Ryūtarō TAKAHASHI, can be applied to this case.

According to MONONOBE, 50 percent of Japanese modern houses are totally demolished when the acceleration of earthquake motion reaches 450 gals. According to TAKAHASHI, 50 percent of dokaku (sun-dried brick) houses are totally destroyed by the acceleration of 300 gals.

There are very few data from which the acceleration of earthquake motion in the meizoseismic area can be known, but the results of KAWASUMI's field observations are as follows:

Based on the damage to an iron bridge on the Hu-lan River north of Sui-hua, the fissures produced in the railway banking, the sinuous buckling of rails, and quantities of sand forced up through the cracks in the alluvial land, KAWASUMI estimated the acceleration of earthquake motion in the vicinity to have been about 300 gals. Glass bottles, tableware, and other vessels fell from shelves in the town of Sui-hua. An iron incense-burner in the courtyard of the mausoleum of Emperor Sheng-tsung rotated, at the same time it was displaced 4 cm to the northeast and the lid fell to the northeast. Moreover, the upper part of the double granite pedestal of the incense-burner was displaced to the east by about one cm.

The ratio of the acceleration that causes these movements to gravity is almost equal to the friction coefficient. So the acceleration in the town of Sui-hua is estimated to have been about 250 gals.

Not only the hypocenter of this earthquake was shallow but in the case of the above-mentioned poorly-built houses damage of quite a different type is produced from a slight difference in intensity. It has been considered that the damage from this earthquake was limited to a small area for these reasons.

(e) Topographic Changes and Ground Water

It seems that there was no topographic change directly related to the mechanism of occurrence of the earthquake. Fissures were produced in the skirt of a hill situated on the boundary between the tablelands of Hsiang-chia-wei-tzu and Wan-ho-fu and the marshy land on the Hu-lan River, and great quantities of sand and water were ejected at several places from the fissures. Moreover, sand was ejected here and there on both sides about 30 m from the railway track south of the iron bridge on the Hu-lan River, and sand ejection occurred as far as the vicinity of the hill.

(f) Mechanism of Occurrence of the Earthquake

The distribution of "Push" and "Pull" of the initial motion instrumentally observed is of great use in clarifying the mechanism of occurrence of an earthquake. In the case of this earthquake the initial motion was observed in Nagano and Kobe, both which are situated southeast of the epicenter, and the intitial motion was "Pull" in both places. These data are insufficient for the clarification of the mechanism of earthquake occurrence. But it is not illogical to consider that the hypocenter was subjected to pressure from the northwest and southeast and tension to the northeast and southwest. The epicenter of this earthquake corresponds approximately with the center of a circle including the arc of the Japanese Islands, so the epicentral distance of the station in Japan is almost equal, i.e., 1,200 to 1,600 km. If it is admitted that of the maximum motion observed at each station, the seismic motion of short duration was caused by the S-wave and that of long duration by the surface wave, the S-wave was large in Nagasaki, Fukuoka, and Kumamoto all of which are situated south of the epicenter, and in Aomori and Mizusawa which are east of the epicenter. But in Osaka, which is southeast of the epicenter, the S-wave was small. On the contrary, the surface wave was largest in Toyama southeast of the epicenter.

In the case of the quadrant-type distribution of initial motion it is theoretically expected that the S-wave is large in places which correspond with the nodal line, while the surface wave is large in places which correspond with the loop. In the case of the Sui-hua earthquake the mechanism of occurrence can be explained as follows: first, the E–W and N–S nodal lines of initial motion at the epicenter are drawn. In the four quadrants thus obtained, the initial motion was "Pull" in the NW and SE quadrants, and "Push" in the NE and SW quadrants.

In this case, if the hypocenter was subjected to horizontal shearing force, either of the E–W and N–S nodal lines must be a fault line. If fracture occurred at the

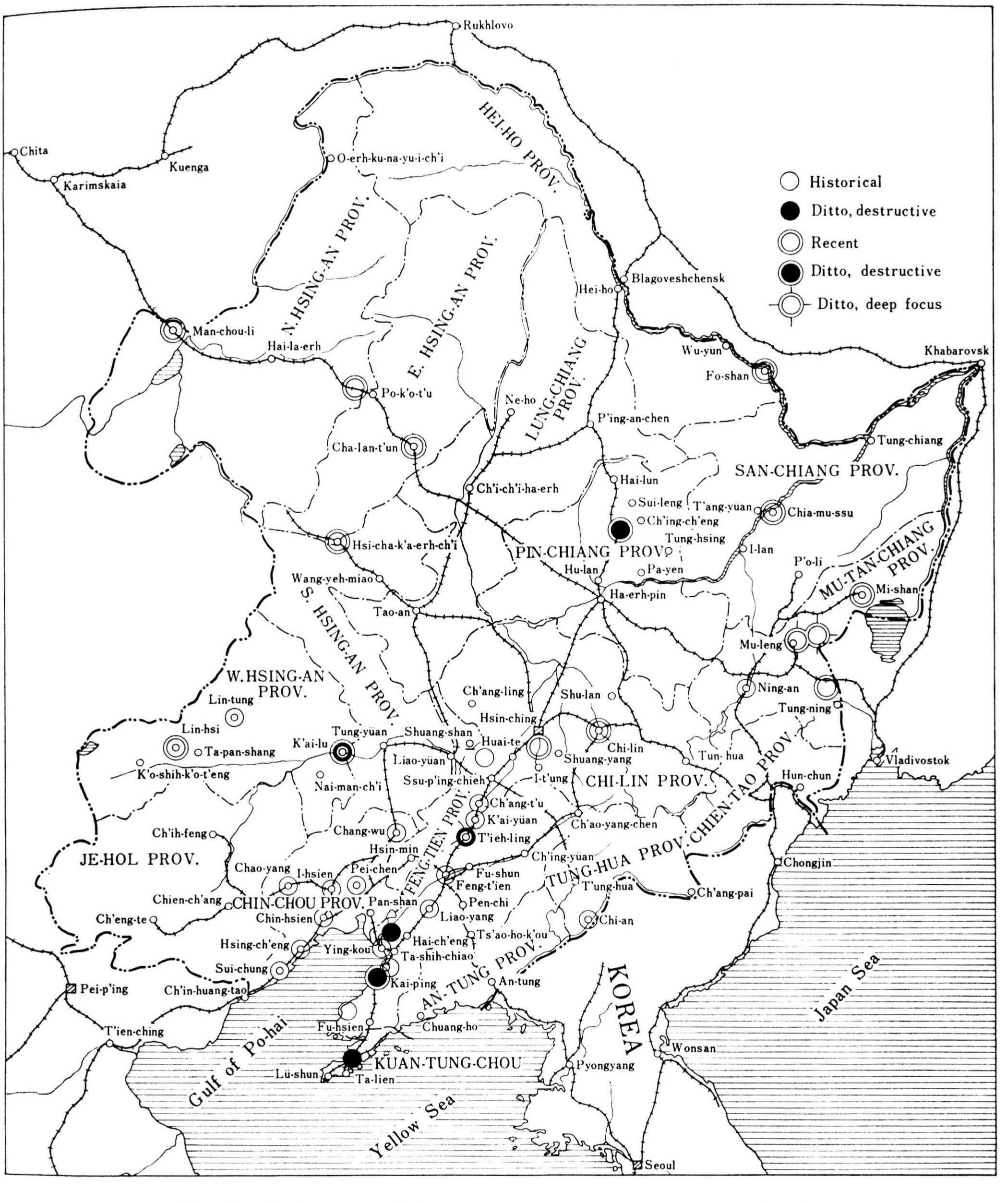

Fig. 3. Epicenters of the earthquakes occurred in Manchuria.

hypocenter as a result of tension, the direction of the fault line must be northwest or southeast; and it is also probable that magma intruded through the fault line.

The area where houses were severely damaged in the direction of northwest and southeast, and the result of magnetic survey carried out by the writer in the vicinity of the epicenter after the earthquake revealed that an axis of large vertical magnetic force ran in the above-mentioned direction. From these facts it is reasonable to assume the presence of a NW–SE fault line rather than a fault line running E–W or N–S.

The result of magnetic survey carried out by the writer in the disturbed area from June 5th to the 8th is shown in Table 5 as a reference. The datum point was established near a monument in the square in front the Sui-hua Station, and a comparative survey was made at this point before and after the survey.

Table 5. Anomaly of the Vertical Magnetic Force.

Locality	Observation value	Distance from the datum point		Anomaly
		To N	To E	
	γ			γ
Sui-ha	0	0 km	0 km	0
San-ho-tun	+ 31	2.2	0.2	+ 13
Tung-chia-wo-pu	+119	3.5	3.5	+102
Hsi-fang-shen-kou	+202	5.05	5.1	+177
Tien-chia-wo-pu	+242	6.25	7.2	+214
Tung-chin-i	+220	10.7	13.6	+176
Shih-in-i	+197	17.4	19.8	+118
Lan-feng-chih	+ 72	4.3	0.05	+ 37
Pi-chia-fen-fang	+150	7.65	0.55	+ 90
Wan-ho-fu	+212	10.7	0.95	+128

IV. Geographical Distribution of the Epicenters in Manchuria

In Manchuria few earthquakes occurred of which the epicenters were known. Figure 3 shows rough locations of the epicenters. Recent earthquakes are shown on the map by symbols different from those of historical earthquakes. The epicenters of historical earthquakes, with the exception of Tu-chi-an in Kao-kou-li, Tu-ning-an in Chin, and Lin-tung in Je-ho Province, are distributed in a row, i.e., Chin-chou, Fu-chou, Kai-ping, Nie-chuang, Liao-yang, Mukden, Tien-ling, Kai-yuan, Chang-tu, and Li-shu. There is another row of epicenters, i.e., Sui-chung, Hsing-cheng, Chin-chou, Pei-chen, I-chou, and Chang-wu.

Earthquakes that occurred in recent years have been distributed extensively in North Manchuria, so it is difficult to establish seismic zones. But, in the past, the Chin-chou earthquake and the Nie-chuang earthquake occurred in the zone extending from Chin-chou to Hsin-ching, and the Hsing-yo-cheng earthquake recently originated from that zone which seems to be a relatively active seismic zone.

In the vicinity of Mu-ling, Mu-tan-chiang Province, a very deep-focus earthquake takes place from time to time. From the distribution of "Push" and "Pull" of the initial motion of the deep-focus earthquakes on July 10, 1940, and on

January 11, 1946, it is inferred that the hypocenter was subjected to pressure on the NW–SE side and tension on the NE–SW side.

V. Conclusion

It is unfortunate that a thorough study on the earthquakes in Manchuria is impossible due to the deficiency of historical materials and incomplete instrumental observation.

A felt earthquake occurs only several times a year in Manchuria, and a destructive earthquake very rarely occurs. The number of earthquake occurrences in Manchuria is less than one percent of those in Japan.

The magnitudes of the destructive earthquakes which recently occurred in Manchuria were determined by using TSUBOI's formula as follows:

Kai-lu Tung-liao earthquake of January 19, 1940, M=5.9
Hsiung-yo-chen earthquake of August 5, 1940, M=6.3
Sui-hua earthquake of May 6, 1941, M=6.7

There are almost no data concerning the force which worked on the hypocenter. It has been inferred, however, that pressure worked on the NW–SE side and tension worked on the NE–SW side in the cases of the Sui-hua earthquake and the deep-focus earthquake which originated from the vicinity of Mu-ling.

The determined velocity of seismic waves based on scanty data is as follows: in the upper layer the velocity of the P-wave is 5.5 km/sec, and that of the S-wave 3.2 km/sec. In the lower layer the former is 7.8 km/sec and the latter 4.3 km/sec.

The historical information on the earthquakes in Manchuria has appeared in other publications, so only the earthquakes which occurred recently in Manchuria are tabulated below.

List of the Recent Earthquakes in Manchuria
(Japanese standard time)

(1) The earthquake which originated in the Hsing-an-ling Mountains on Dec. 4, 1936 at about 11^h 49^m.

The intensity was III in Hsing-an. Though the earthquake was rather brisk, no damage was produced.

(2) The earthquake in Kuo-chia-tun south of Chang-chun of Feb. 18, 1937 at about 19^h 43^m.

The earthquake was felt in Chang-chun. The time of occurrence in Pyong-yang, Seoul, and Tae-gu was 19^h 44^m 50.2^s, 19^h 45^m 37.6^s, and 19^h 46^m 41.1^s, respectively.

(3) The earthquake north of Chi-lin on June 11, 1937 at about 1^h 55^m. A felt earthquake occurred in the drainage basin of the Sungari River north of Chi-lin. The intensity in Chang-chun and Harbin was I. The epicenter was located at a point in the drainage basin of the Second Sungari River (T.N.; the Sungari above Harbin) north of Chi-lin. This earthquake was followed by two small ones which

originated from the same point. The earthquake which occurred at 3 o'clock was not felt, and the intensity of the earthquake which took place at 6 o'clock was I at Chang-chun.

The result of seismological observation in Chang-chun is as follows:

Locality	Time of occurrence	Maximum amplitude			Period			Duration of preliminary tremors	Initial motion
		N	E	Z	N	E	Z		
Chang-chung	$01^h\ 56^m\ 10^s$	430	430	140	0.6^s	0.6^s	—	12.9^s	ENE, Down
〃	03 36 09	—	10	—	—	—	—	—	—
〃	06 00 33	—	90	—	—	0.5	—	—	ENE

The time of occurrence of this earthquake in Pyong-yang, Seoul, and In-chon was $1^h\ 57^m\ 30.6^s$, and $1^h\ 58^m\ 56.9^s$, respectively. The duration of preliminary tremors in Pyong-yang and Seoul was $1^m\ 60^s$ and $1^m\ 29.7^s$, respectively. From these results of observation the time of occurrence at the hypocenter was determined as $1^h\ 55^m\ 52^s$. The magnitude of this earthquake determined from the maximum amplitude in Chang-chun by using TSUBOI's formula is 5.75.

(4) The earthquake in Mi-shan on July 6, 1937.

(5) The earthquake in Lin-hsi on March 7, 1938 at about $21^h\ 57^m$. At first slight shocks were felt in Lin-hsi, then a subterranean noise which resembled the sound of a passing truck was heard, and after that sliding doors and others began to rattle with the vibration.

(6) The earthquake in Tung-ning and Sui-fen-ho on April 21, 1938 at about $20^h\ 20^m$.

The intensity of this earthquake was II in Sui-fen-ho and I in Tung-ning. In Sui-fen-ho and its vicinity a subterranean noise was heard, simultaneous with the shock, from the direction of southwest or west.

(7) On May 3, 1938, it seems that a local but considerably severe earthquake occurred in Fo-shan and its vicinity, Hei-ho Province. Details are unknown, however.

(8) At about $4^h\ 24^m$ on June 29, 1938, an earthquake occurred which was strong enough to vibrate houses in the Chia-mu-ssu district. But we have no details.

(9) An earthquake was instrumentally recorded in Chang-chun at $3^h\ 18^m$ on June 30, 1938. This earthquake seems to have been felt in some districts.

(10) An earthquake with an intensity of II was felt in So-lun at $20^h\ 48^m$ on January 24, 1939. Vibrations continued for about 20 seconds, and the oscilation of water in vessels was observed.

(11) The earthquake in Chan-lan-tun on Feb. 6, 1939 at about 14^h. An earthquake with an intensity of I was felt in Cha-lan-tun. According to the seismological observation in Chang-chun, the time of occurrence was $14^h\ 28^m\ 59.2^s$, and the duration of preliminary tremors was 58 seconds. Therefore, the distance

between Chang-chun and the epicenter must be 500 km, i.e., the epicenter is Cha-lan-tun.

(12) The earthquake in Manchouli on April 18, 1939.

(13) The earthquake in the drainage basin of the Liao-ho between Kai-lu and Tung-liao on January 19, 1940, at about $14^h\ 23^m$.

This earthquake was felt throughout the western part of South Manchuria, and it seems that there was some damage in the epicentral area. The intensity was V in Kai-lu, III in Chin-feng and Pai-cheng, II in Chin-chou and I in Chang-chun and Mukden. The results of seismological observations in Mukden and Chang-chun were as follows:

Locality	Time of occurrence	Maximum amplitude			Period			Duration of preliminary tremors
		N	E	Z	N	E	Z	
Mukden	$14^h\ 23^m\ 55.3^s$	—	204	—	$—^s$	$—^s$	$—^s$	36.7^s
Chang-chun	$14^h\ 24^m\ 29.7^s$	227	269	152	1.1	1.1	0.9	56.2^s

The epicenter was located at a point 121°E, 43.5°N. The magnitude of this earthquake was determined from the maximum amplitude in Mukden and Chang-chun and by using TSUBOI's formula. The result is M=5.9.

(14) An earthquake with an intensity of I was felt in Cha-lan-tun at about $14^h\ 30^m$ on February 6, 1940.

(15) The unfelt earthquake in the vicinity of Chang-chun at about $14^h\ 4^m$ on March 24, 1940.

(16) An earthquake which had an intensity of I was felt in Lin-hsi at $5^h\ 34^m$ on May 27, 1940.

(17) The deep-focus earthquake in the vicinity of Mu-leng, Mu-tan-chiang Province on July 10, 1940, at about $14^h\ 51^m$.

The epicenter was situated in 130.6°E, 44.8°N, i.e., in the vicinity of Mu-leng. At many weather stations in Japan the ScS wave was observed. From the ScS-wave, the depth of the hypocenter was estimated at 560 km. The intensity was I in Chang-chun, and II in Chong-jin and Na-nam, Chōsen. A zone of abnormal seismic intensity was observed in Japan proper. The intensity II was reported from Hakodate, Urakawa, and Hachinohe, and I from Wajima, Aomori, Obihiro, Miyako, Kushiro, Utsunomiya, Onahama, and Yokohama. The initial motion was "Pull" at all weather stations in Japan where this earthquake was observed, i.e., in Sapporo, Aomori, Sendai, Nagano, Kyoto, Fukuoka, In-chon, and Dairen, except for the "Push" motion in Nemuro and Shikuka. From the distribution of the "Pull" and "Push" of the initial motion it is inferred that the stress at the hypocenter was pressure on the NW–SE side and tension on the NE–SW side.

(18) The earthquake in Hsiung-yo-cheng on August 5, 1940 at about 18^h 55^m.

The epicenter of this earthquake lay at a point about 10 km southwest of Hsiung-yo-cheng, i.e., 122.1°E, 40.1°N. The time of occurrence at the hypocenter was $18^h\ 55^m\ 06^s$. According to the investigation by the Kai-ping Prefectural Office, two persons were killed, five were injured, and about 1,000 houses were totally demolished.

The intensity was III in Ying-kou and Pi-tsu-wo, II in Chin-chou, Lien-shan-kuan, Hsin-i-chou, and Dairen, and I in Chin-feng, Mukden, Chang-chun, and Pyong-yang. The magnitude of this earthquake was M=6.3.

(19) The earthquake in the Sui-hua district, North Manchuria, on May 6, 1941 at about $0^h\ 18^m$.

According to the investigation by the Sui-hua Prefectural Office, 122 persons were killed, 74 were severely injured, 129 were slightly injured, 1952 fang-tsu (T.N.: houses) were totally destroyed, and 4178 fang-tsu were partially destroyed. The magnitude of this earthquake was M=6.7, and the earthquake was of the same magnitude as the Nsihi-Saitama earthquake of Sept. 21, 1931.

(20) The deep-focus earthquake in the vicinity of Sui-fen-ho on Jan. 11, 1946, at about $10^h\ 35^m$.

The epicenter was assigned to a point 131°E, 45°N, and the focal depth was estimated at 600 km. Whether or not this earthquake was felt in the vicinity of the epicenter is unknown, but an earthquake with an intensity of I was abnormally felt in Hachinohe, Tokyo, Shizuoka, and Kashiwara. The initial motion was "Pull" at more than ten weather stations from Mori in Hokkaidō to Fukuoka in Kyūshū. Therefore, it is inferred that this earthquake was caused by the same stress that caused the deep-focus earthquake on July 10, 1940.

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