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2. *Seismicity of the Izu Peninsula and Its Vicinity from 1901 through 1980 with Some Remarks on the Characteristics of Foreshock Activities.*

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Abstract

Spatial and temporal features of the seismicity of the Izu area, central Japan for the past 80 years have been studied on the basis of a newly prepared catalog of shallow earthquakes of $M \geqq 5.4$. This area is characterized by relatively frequent occurrence of foreshock sequences and earthquake swarms. A peculiarity of the seismicity is the occurrence of swarm-like sequences with exceedingly large main shocks. This type of sequence cannot be classified among the three types proposed by Mogi in 1963 and is called here an "earthquake sequence of type 4". The shallow earthquakes are divided into four classes according to the values of $M-M_I$, where M is the magnitude determined from the maximum amplitudes recorded by medium-period seismographs used in the JMA network and M_I is the magnitude determined from the size of the area in which it is felt. Such a classification seems to be useful in the discrimination of foreshocks from earthquake swarms.

Introduction

The Izu Peninsula of central Japan (Fig. 1) has been one of the fields of intensive studies for earthquake prediction, since a remarkable land upheaval was found in 1976 in the northeastern part of the peninsula. Prior to this upheaval, an earthquake of $M=6.9$ occurred in 1974 near the southern tip of the peninsula, killing 28 persons. After this event, the area in and around the peninsula has become very active seismically. During the last six years, several damaging earthquakes including an $M=7.0$ event took place in and off the east coast of the peninsula. At the end of 1980, it is hard to forecast how the activity will change in space and time in the future. The recent crustal activity

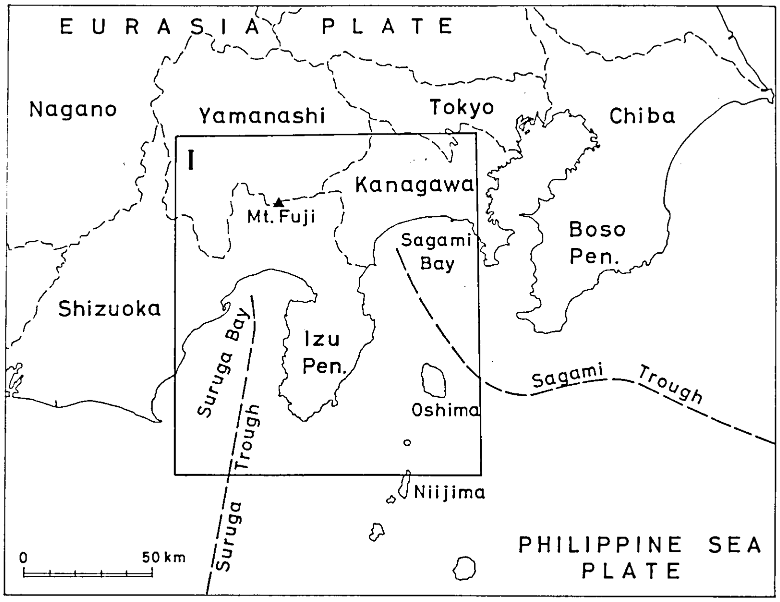


Fig. 1. Index map of the Izu Peninsula and its vicinity. Seismicity of the rectangular area I has been studied in this paper.

in the Izu area is summarized by MOGI (1979) and SATO (1980) from the viewpoint of earthquake prediction. This paper is intended to review the seismic activity during the last 80 years and search for some clues for predicting relatively large earthquakes in this area which may occur in the near future. The area in and around the Izu Peninsula is known for relatively frequent occurrence of foreshock sequences and earthquake swarms. Therefore, the discrimination of foreshock activity from earthquake swarms is of prime importance in short-term prediction of earthquakes in this area.

Seismic activity in this area after 1926 can be investigated by using the earthquake catalogs of the Japan Meteorological Agency (JMA). No reliable catalogs had been available for the period before 1926 until UTSU (1979, 1981) prepared new catalogs of earthquakes of $M \geqq 6$ in the whole region of Japan for 1885–1925 and of shallow earthquakes of $M \geqq 5.4$ in the Kanto and Chubu districts for 1904–1925. UTSU (1980) discussed the spatial and temporal distribution of so-called low-frequency earthquakes of $M \geqq 6$ in the region of Japan for the period 1904–1979. The low-frequency earthquakes classified by UTSU (1980) are those felt over relatively small areas for their instrumental magnitudes. The instrumental magunitude is determined from the maximum amplitudes on seismograms of medium-period seismographs used in the JMA network. In this paper,

Table 1. List of shallow earthquakes of $M \geqq 5.4$ in the Izu Peninsula and its vicinity from 1901 through 1980.

Date and Time (JST)					Location	Epicenter		M	M_I	Class
1902	May	25	20 h	29 m	E Yamanashi Pref.	139.0°E	35.6°N	5.4	5.1	N
	June	23	07	42	E Kanagawa Pref.	139.6	35.5	5.7	5.1	L1
1905	June	7	14	39	Near Izu-Oshima	139.3	34.8	5.8	5.1	L2
1908	Dec.	28	17	08	E Yamanashi Pref.	138.7	35.6	5.8	5.4	L1
1909	Jan.	16	16	57	Near Izu-Oshima	139.6	34.8	5.7	4.5	VL
1912	Oct.	18	20	02	SE Yamanashi Pref.	138.9	35.5	5.9	5.7	N
1915	June	20	01	01	〃	139.0	35.5	5.9	5.1	L2
	July	2	22	37	E Yamanashi Pref.	138.8	35.6	5.9	5.7	N
1918	June	26	22	46	W Kanagawa Pref.	139.1	35.4	6.3	6.2	N
1920	Dec.	27	18	21	SW Kanagawa Pref.	139.0	35.2	5.7	<4.5	VL
1921	Feb.	14	12	00	E Yamanashi Pref.	138.7	35.6	5.8	5.1	L2
1923	Sep.	1	11 h 59 m—13 h 29 m: The Kanto earthquake (M=7.9) and more than 10 aftershocks occurred in the Sagami Bay area during this 1.5-hour interval.							
			13	30	SW Kanagawa Pref.	139.0	35.2	6.3	5.8	L1
			13	36	Sagaminada	139½	35	5.7	5.2	L1
			13	38	〃	〃		5.4	4.9	L1
			13	45	SE Yamanashi Pref.	139	35½	5.5	5.0	L1
			14	23	W Kanagawa Pref.	139.0	35.4	6.7	6.0	L2
			14	53	〃	139.1	35.5	5.4	4.9	L1
			15	14	S Yamanashi Pref.	138½	35½	5.5	4.6	L2
			15	43	NE off Niijima	139½	34½	5.7	5.2	L1
			16	38	SE Yamanashi Pref.	138.9	35.5	6.6	5.7	L2
	Sep.	2	09	05	Sagami Bay	139.5	35.2	5.3*	<4.5	VL
			22	09	SW Kanagawa Pref.	139.1	35.3	6.5	5.7	L2
			23	16	〃	〃		6.2	5.1	VL
	Sep.	3	23	30	〃	139.0	35.3	5.7	5.1	L1
	Sep.	8	18	09	〃	〃		5.9	5.6	N
	Sep.	10	02	11	Near Izu-Oshima	139.2	34.8	5.9	5.4	L1
	Sep.	26	17	24	〃	139.4	34.8	6.7	6.1	L1
	Sep.	29	12	01	C Kanagawa Pref.	139.3	35.5	5.4	5.0	L1
	Oct.	4	00	54	W Kanagawa Pref.	139.1	35.4	6.4	5.9	L1
	Oct.	5	22	05	〃	〃		6.1	5.7	L1
	Oct.	17	03	04	E Yamanashi Pref.	139.1	35.6	5.8	5.6	N
	Oct.	23	04	46	SE Yamanashi Pref.	138.9	35.5	5.4	5.1	N
	Nov.	23	11	32	E Kanagawa Pref.	139.5	35.4	6.2	6.3	N
	Dec.	24	12	39	SW Kanagawa Pref.	139.2	35.3	5.8	4.9	L2
	Dec.	31	14	51	E off Niijima	139.5	34.4	5.5	5.2	N
1924	Jan.	15	05	50	W Kanagawa Pref.	139.2	35.5	7.3	>7.5	N
1929	July	27	07	48	〃	139.1	35.5	6.1	5.8	N
1930	Feb.	21	08	37	E off Izu Peninsula	139.2	35.0	5.4	5.1	N
	Mar.	22	17	50	〃	〃		5.8	5.3	L1

1930	May	17	05 h	14 m	E off Izu Peninsula	139.2°E	34.9°N	5.8	5.4	L1
	Nov.	26	04	02	E Shizuoka Pref.	139.0	35.1	7.3	6.7	L1
1931	Mar.	7	01	53	〃	138.9	35.2	5.4	4.6	L2
	June	11	15	16	SE Yamanashi Pref.	138.9	35.4	6.0	5.8	N
	Sep.	16	21	43	〃	138.9	35.5	6.5	5.9	L1
1934	Mar.	21	12	39	C Izu Peninsula	138.9	34.8	5.5	<4.5	VL
1935	July	11	17	24	C Shizuoka Pref.	138.4	35.0	6.3	5.9	L1
1936	Nov.	19	22	57	W Kanagawa Pref.	139.1	35.5	5.4	5.1	N
	Dec.	27	09	14	Near Niijima	139.2	34.5	6.3	5.6	L2
	Dec.	29	02	20	〃	139.2	34.4	5.6	5.4	N
1939	Jan.	10	21	09	S off Izu Peninsula	138.9	34.5	5.5	5.2	N
1944	Dec.	8	05	57	E off Niijima	139.5	34.4	5.7	5.5	N
	Dec.	8	06	23	N off Niijima	139.3	34.5	5.5	<4.5	VL
1947	Mar.	11	14	16	Suruga Bay	138.4	34.9	5.9	5.9	N
1964	Nov.	3	20	09	S Izu Peninsula	138.80	34.63	5.4	5.1	N
	Dec.	9	02	49	S off Izu Peninsula	139.30	34.58	5.8	5.0	L2
	Dec.	26	02	01	〃	139.28	34.67	5.5	<4.5	VL
1965	Apr.	20	08	42	C Shizuoka Pref.	138.30	34.88	6.1	5.9	N
1972	Oct.	6	20	31	SW off Izu Peninsula	138.52	34.40	5.5	5.4	N
1974	May	9	08	33	S off Izu Peninsula	138.80	34.57	6.9	6.2	L2
1976	June	16	07	36	SE Yamanashi Pref.	139.00	35.50	5.5	5.3	N
	Aug.	18	02	19	E Izu Peninsula	138.95	34.78	5.4	4.7	L2
1978	Jan.	14	12	24	Near Izu-Oshima	139.25	34.77	7.0	6.9	N
	Jan.	15	07	31	C Izu Peninsula	138.88	34.83	5.8	5.5	N
	Jan.	15	07	36	〃	138.83	34.80	5.4	5.1	N
	Dec.	3	22	15	E off Izu Peninsula	139.18	34.88	5.4	5.2	N
1980	June	29	16	20	〃	139.32	34.92	6.7	6.0	L2

* $M_s \doteqdot 6.0$.

a similar classification is applied to shallow earthquakes in the Izu area. This classification seems to be useful in discriminationg foreshock sequences from earthquake swarms in this particular area.

Earthquake Catalog and Epicenter Map

Table 1 lists shallow earthquakes of $M \geqq 5.4$ which occurred in the area 138.3°-139.6°E longitude, 34.4°-35.6°N latitude. The magnitude denoted by M in this paper is the JMA magnitude (1926-1980) or its equivalent (1901-1925) assigned by the author. The magnitude M_I given in Table 1 is determined from the maximum range of perceptibility R by the use of a standard M_I vs R relation shown in Table 2 (UTSU, 1980). The range R is obtained from the isoseismal map of each earthquake constructed on the basis of seismic intensities observed at JMA stations.

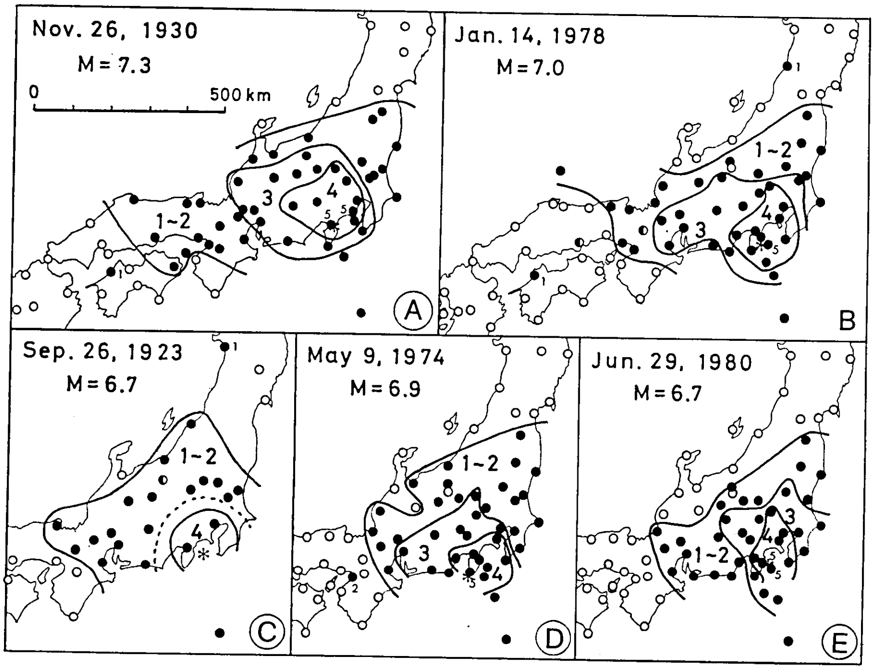
Table 2. M_I vs R relation.

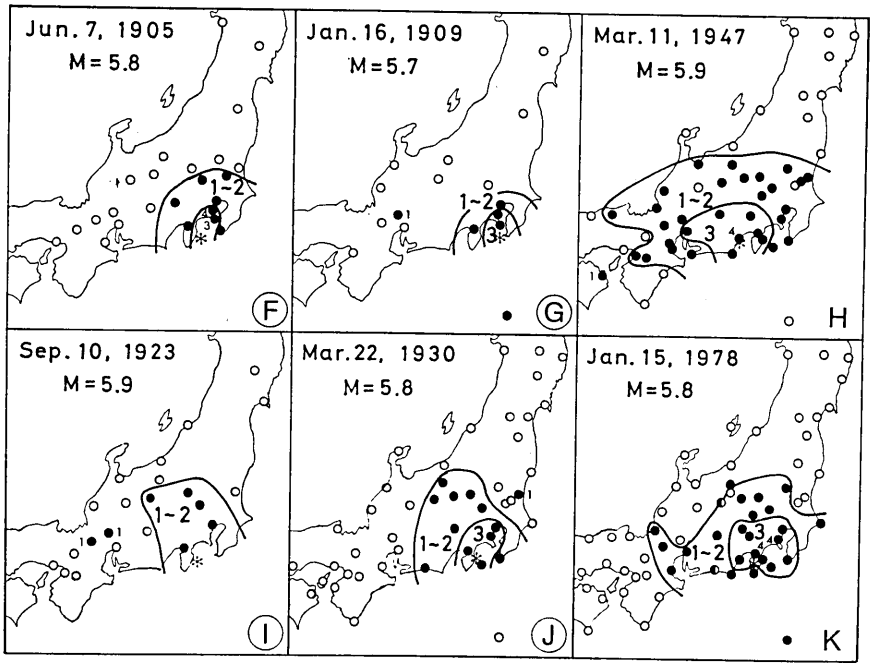
M_I	R(km)	M_I	R(km)	M_I	R(km)	M_I	R(km)
4.5	100	5.3	210	6.1	369	6.9	574
4.6	112	5.4	227	6.2	393	7.0	601
4.7	125	5.5	245	6.3	418	7.1	628
4.8	137	5.6	264	6.4	444	7.2	655
4.9	150	5.7	283	6.5	470	7.3	687
5.0	164	5.8	303	6.6	496	7.4	712
5.1	179	5.9	324	6.7	522	7.5	741
5.2	194	6.0	346	6.8	548	7.6	770

Examples of isoseismal maps are reproduced in Fig. 2. Filled and open circles in these maps indicate the JMA stations where the shock was felt or unfelt by the station staff, respectively. Half-filled circles indicate the stations where the shock was unfelt by the staff but felt by some people in the same city. There are noticeable differences in the size of felt areas between two shallow earthquakes of nearly equal instrumental magnitudes occurring at nearly the same place (compare for example, F and K, L and O, or P and Q in Fig. 2). All earthquakes in Table 1 are divided into four classes, N ($M-M_I<0.4$), L1 ($0.4 \leqq M-M_I<0.7$), L2 ($0.7\leqq M-M_I<1.0$), and VL ($1.0\leqq M-M_I$). N, L1 and L2, and VL approximately correspond to normal, low-frequency, and very low-frequency earthquakes classified by UTSU (1980), respectively. Letters not circled between A and W in Fig. 2 indicate normal (N) classes.

The epicenter location and magnitude of the first two earthquakes in Table 1 have been determined by the author. No other shallow earthquakes of $M\geqq5.4$ were found in the area concerned during 1901–1903. For the earthquake of April 23, 1901, 03h 20m JST, the catalog of the Central Meteorological Observatory (CMO) published in 1952 gives the epicenter at Sagaminada with a magnitude of 6.5. Reexamination indicates that the hypocenter cannot be determined accurately, but it was located at around $139\,{}^1/_2$°E. $35\,{}^1/_2$°N with a focal depth of 100 to 150 km. The magnitude was about 6.0. This event is not listed in Table 1 because it was rather deep, but it should be added to UTSU's catalog (1979).

The earthquakes for 1904–1925 in Table 1 have been selected from UTSU's catalog (1981). Several earthquakes of $M\geqq6$ were found in the CMO catalog of 1952, but they are not listed in Table 1, because their redetermined magnitudes fall below 5.4. For example, the central Izu earthquake of August 31, 1906, 11h 20m JST has a magnitude 6.2 in the CMO catalog, but the redetermination yields $M=5.1$ with an epicenter at


Nov. 26, 1930
M = 7.3
0
500 km
A
Jan. 14, 1978
M = 7.0
B
Sep. 26, 1923
M = 6.7
C
May 9, 1974
M = 6.9
D
Jun. 29, 1980
M = 6.7
E


Jun. 7, 1905
M = 5.8
F
Jan. 16, 1909
M = 5.7
G
Mar. 11, 1947
M = 5.9
H
Sep. 10, 1923
M = 5.9
I
Mar. 22, 1930
M = 5.8
J
Jan. 15, 1978
M = 5.8
K

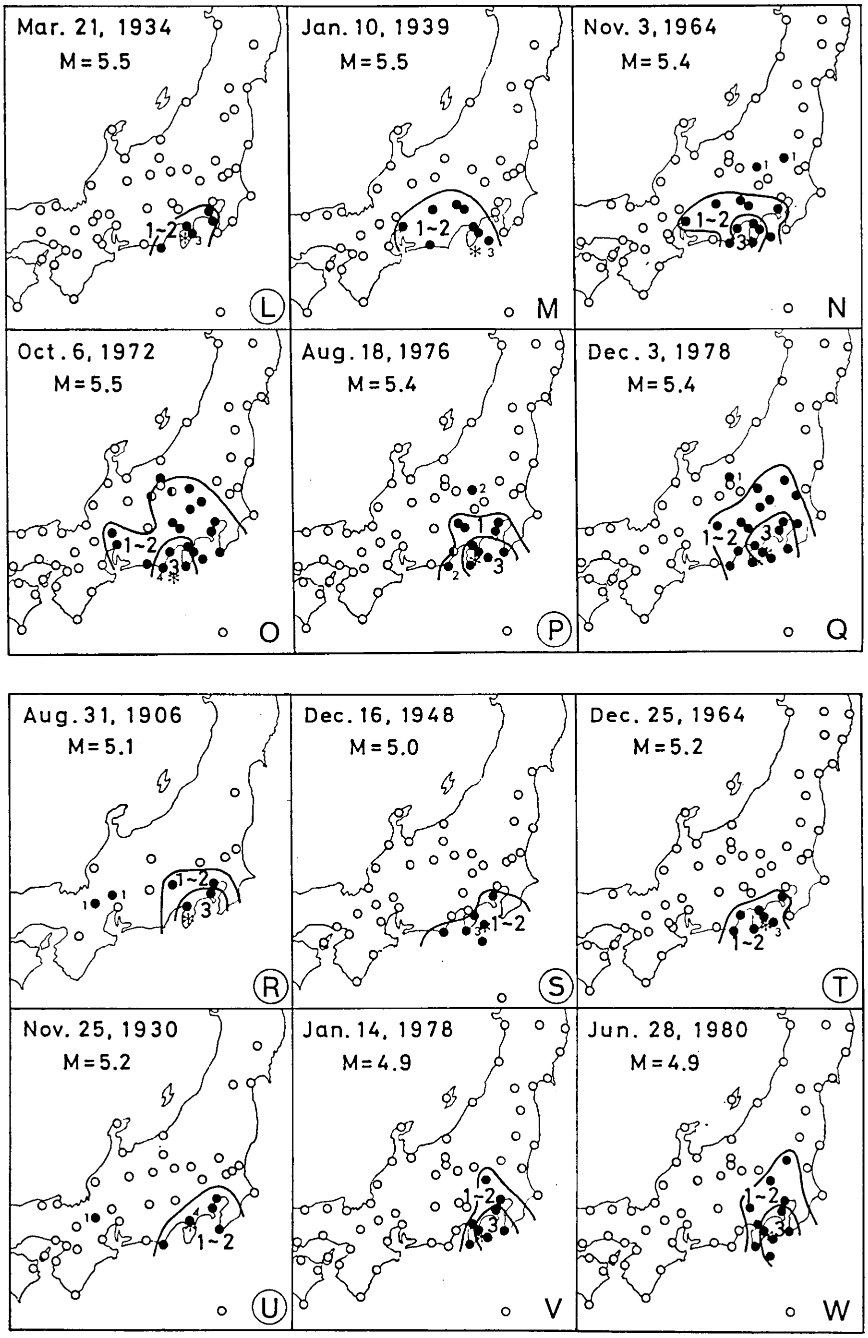


Fig. 2. Distributions of seismic intensities on the JMA scale.

138.9°E, 34.8°N. The earthquake of $M=5.3$ in Sagami Bay on September 2, 1923 was included in Table 1, because this event was recorded at teleseismic distances and its surface-wave magnitude was estimated at about 6. The area in which it was felt was quite small ($M_I<4.5$), so this was a remarkable low-frequency event.

The area considered here includes part of the source region of the Kanto earthquake of September 1, 1923 ($M=7.9$). During the 1.5 hour interval immediately after this great earthquake, many aftershocks of $M\geqq 5.4$ took place in and near Sagami Bay. The location and magnitude of these earthquakes cannot be determined accurately, because of insufficient data due to confusion of seismograms and disorder of seismographs at near-by stations. Therefore, events in this 1.5 hour interval are not listed in Table 1.

The earthquakes from 1926 through 1980 have been selected from the Seismological Bulletin of JMA and its supplementaly volumes Nos. 1 and 2. The magnitudes of three events, May 17, 1930, November 26, 1930, and December 26, 1936 were revised by the author. The epicenters of February 21 and March 22 events in 1930 were slightly corrected.

Focal depths of shallow earthquakes in the Izu Peninsula and nearby sea areas are in general less than about 10 km, except the events occurring near the Suruga trough or on the west side of it, where the focal depth may reach about 30 km. The earthquakes occurring north of the peninsula, western Kanagawa, southeastern Yamanashi, and eastern Shizuoka Prefectures have focal depths around 20 km, though the accurate depths cannot be determined for earlier events. Earthquakes having a focal depth between 40 and 80 km are rare in the area concerned.

Epicenters of the earthquakes listed in Table 1 are plotted in Fig. 3. Large, medium, and small circles indicate $M\geqq 7.0$, $7.0>M\geqq 6.0$, and $6.0>M\geqq 5.4$, respectively. Filled, half-filled, barred, and open circles denote the classes N, L1, L2, and VL, respectively. Numerals attached to the epicenter symbols represent the year of occurrence. The Kanto earthquake of 1923 and its immediate aftershocks are not shown. Most of them occurred in the area indicated by a dotted line in the upper right map.

Seismicity Pattern

Some interesting features of the seismicity in this area can be seen from Fig. 3 and Table 1.

The activity was highest between September, 1923 and January, 1924. This is due to the effect of the great Kanto earthquake. On the other

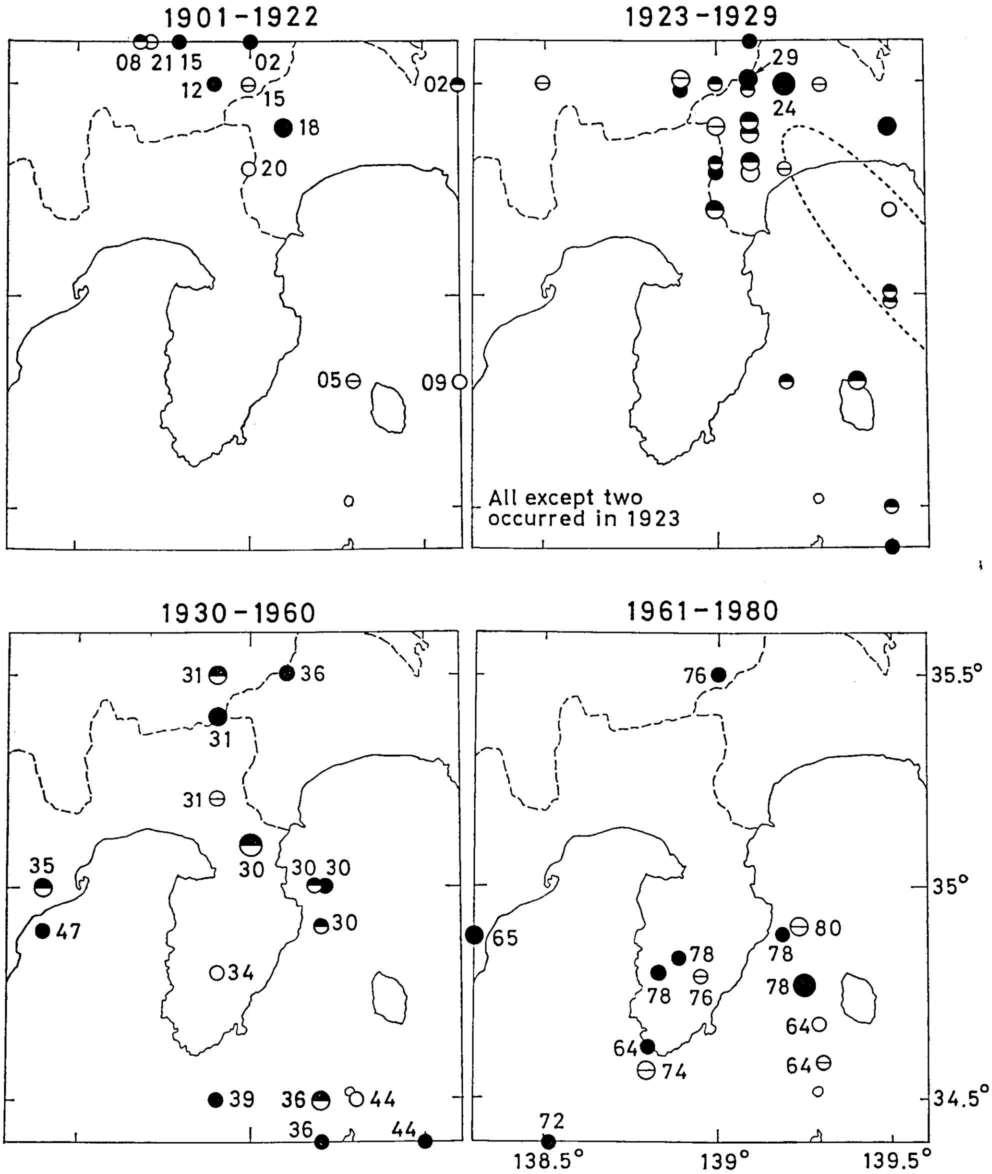


Fig. 3. Epicenters of shallow earthquakes ($h \lesssim 35$ km). Large, medium, and small circles indicate $M \geqq 7$, $7 > M \geqq 6$, and $6 > M \geqq 5.4$, respectively. Filled, half-filled, barred, and open circles represent N, L1, L2, and VL events defined in text, respectively.

hand, during the 16-year interval from 1948 through 1963, no events with $M \geqq 5.4$ occorred.

A zone north of the Izu Peninsula, including southeastern Yamanashi and western Kanagawa Prefectures was most active after the Kanto earthquake of 1923, but the activity decreased after 1936. Activity was fairly high for more than 20 years before the Kanto earthquake. This might be a long-term precursor to the Kanto earthquake. The activity in this zone has usually been considered in connection with the collision of the Philippine Sea plate with the the Eurasia plate. No surface faulting was observed in these earthquakes including an $M=7.3$ quake on January 15, 1924.

Surface fault displacements were found in three earthquakes of magnitude around 7 near the margin of the peninsula. They are the Kita-Izu earthquake of 1930, the Izu-Hanto-oki earthquake of 1974, and the Izu-Oshima-kinkai earthquake of 1978. In the central part of the peninsula, only four quakes of $M \geqq 5.4$ occurred during the 80-year interval. The next largest quake was the $M=5.1$ shock on August 31, 1906.

Most of the earthquakes off the east coast of the Izu Peninsula are generated in the form of swarms. The 1905 quake had a magnitude 7.0 in the CMO catalog (also in *Rika-Nenpyo*) which is as large as the 1978 Izu-Oshima-kinkai earthquake. However, it was reduced to $M=5.8$ by the redetermination (compare B and F in Fig. 2). This shock was the largest one in a swarm-like activity, but the other quakes in the same activity had a magnitude 4.8 or less.

From February to May of 1930, a remarkable swarm occurred accompanying a land upheaval near the northeastern coast of the peninsula. The number of shocks felt at Ito exceeded 3,500. In June and July of 1980, a swarm-like activity occurred a little east of the site of the 1930 swarm. The number of felt shocks in this activity were far smaller than that of the 1930 swarm, but the magnitude of the largest quake ($M=6.7$) was about one unit larger than that of the 1930 swarm.

The earthquakes near Niijima in December, 1936 ($M=6.3$) and November, 1957 ($M=6.3$) were accompanied by marked foreshock activity. The later event is not included in Table 1, because it is located 0.1° south of the border of the area considered. Activity around Niijima and the southern Izu Peninsula increased considerably after the great Tonankai earthquake of December 7, 1944 ($M=8.0$). This activity was apparently triggerred by the great earthquake. The two shocks of $M=5.7$ and 5.5 on December 8 are treated here as members of a swarm, but this is not an ordinary swarm in which many shocks originate from a small region.

Two cases of the seismic migration are found out in the Izu area. One is the northward migration starting with the 1930 Kita-Izu earthquake and reaching the Nishi-Saitama earthquake of September 21, 1931 (M=7.0) located about 50 km north of the area in consideration. Another is the migration northeast from the 1972 quake in the Suruga trough. The last event to date is the 1980 M=6.7 quake off the east coast of the peninsula.

Foreshocks and Earthquake Swarms

The proportion of earthquakes preceded by foreshocks is comparatively high in the Izu area, where the earthquake swarms are also fairly frequent (MOGI, 1963). An earthquake swarm is usually defined as a series of earthquakes which includes no exceedingly large event, i. e., the difference in magnitude between the largest and the second largest events in a swarm is small, say, less than about 0.5. MOGI (1963) classified earthquake sequences into the following three types. Type 1 : main shock—aftershock sequence, type 2 : foreshock sequence—main shock—aftershock sequence, and type 3 : earthquake swarm. If an earthquake sequence includes an exceedingly large quake (the main shock), the sequence is classified as type 2 or 1 according to whether or not it is preceded by foreshocks.

The frequency of aftershocks in types 1 and 2 sequences decays regularly with time, following the Omori formula or its modified form (UTSU,

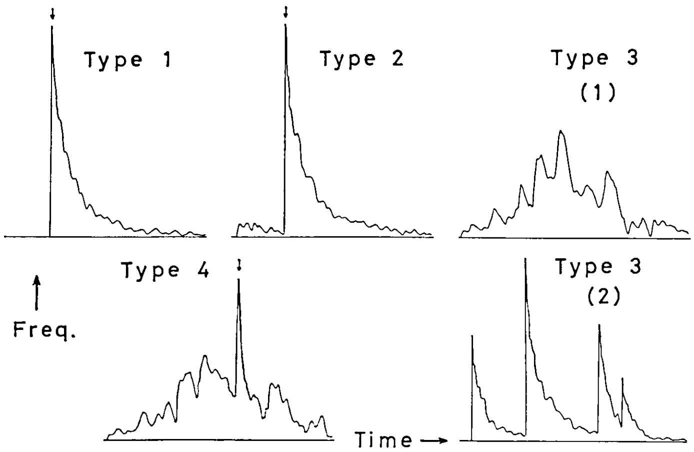


Fig. 4. Schematic graphs of the variation of earthquake frequency with time for various types of earthquake sequences. The main shocks are indicated by arrows.

1961) as shown schematically in Fig. 4. On the other hand, the temporal change in the rate of occurrence of shocks after the largest quake in a swarm is irregular and does not fit the Omori formula (Fig. 4, type 3-(1)). UTSU (1970) noticed a type of earthquake swarm which can be regarded as a successive occurrence of types 1 or 2 sequences of comparable size (Fig. 4, type 3-(2)). UTSU (1970) called this type of swarm "earthquake swarm of the second kind".

In the Izu area, a different type of sequence is sometimes observed. In a sequence of this type, the character of the occurrence of shocks in time is very similar to the ordinary swarm (type 3-(1)). The largest shock does not occur at the beginning but often in a later stage of the sequence. However, the largest shock is exceedingly greater than the other shocks in the same sequence. It has a magnitude of about one unit larger than the next largest one, but the frequency of shocks following the largest shock varies irregularly in time, not obeying the Omori formula. A typical example is the series of earthquakes occurring in November and December, 1930 including the Kita-Izu earthquake of $M=7.3$. The daily frequencies of shocks in this series felt at JMA stations are shown in Fig. 5. The occurrence times of several large quakes are indicated by arrows. This type of sequence can be interpreted as the superposition of a type 3-(1) sequence and a type 1 or 2 sequence. We shall call this type "type 4" (swarm-like sequence with an exceed-

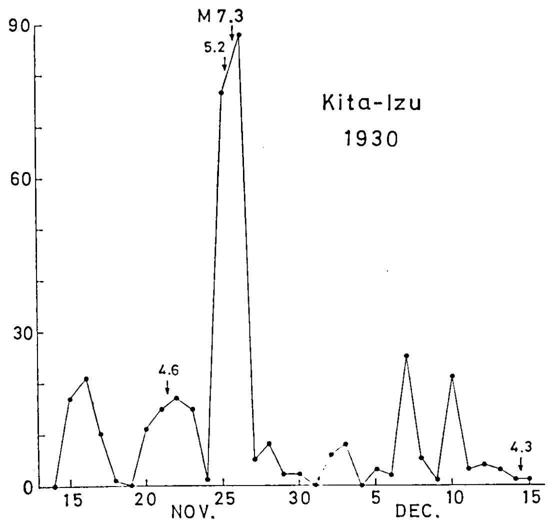


Fig. 5. Variation of the daily frequency of felt shocks in the Kita-Izu sequence of 1930. Large shocks are indicated by arrows.

ingly large main shock).

Earthquake sequences of this type are also found outside the Izu area. An example is the earthquakes near Sakurajima volcano in southern Kyushu in January, 1914. The temporal distribution of shocks was similar to the ordinary swarm, but the largest shock had a magnitude of 7.1 (UTSU, 1979) or 7.0 (ABE, 1980) and caused extensive damage near the epicenter. The magnitude of the second largest shock was 5.2 (ABE, 1980).

Among the earthquakes listed in Table 1, six events were preceded by foreshocks of magnitude about 5 or more. Table 3 lists these events together with their largest foreshocks and aftershocks. Some of these quakes belong to type 4 sequences as indicated in the column headed by "Type".

Table 3. List of earthquakes preceded by foreshocks. F: the largest foreshock, M: the main shock, A: the largest aftershock.

Date and Time (JST)						Location	M	Class	Type
F	1905	June	6	02 h	05 m	Near Izu-Oshima	4.8	N	4
M		June	7	14	39		5.8	L2	
A		June	7	22	05		4.9	L1	
F	1930	Nov.	25	16	05	North Izu Pen.	5.2	L2	4
M		Nov.	26	04	02		7.3	L1	
A	1931	Mar.	7	01	53		5.4	L2	
F	1936	Dec.	27	09	12	Near Niijima	4.8	N	2
M		Dec.	27	09	14		6.3	L1	
A		Dec.	29	02	20		5.6	N	
F	1978	Jan.	14	09	45	Near Izu-Oshima	4.9	N	2
F		Jan.	14	09	47		4.9	N	
M		Jan.	14	12	24		7.0	N	
A		Jan.	15	07	31		5.8	N	
F	1980	June	27	06	06	E off Izu Pen.	4.9	N	4
F		June	28	12	05		4.9	N	
M		June	29	16	20		6.7	L2	
A		June	30	02	23		4.9	N	

During the years 1901-1980, five earthquake swarms satisfying the following conditions are found in the area concerned. The conditions are $M_1 \geqq 5.0$ and $M_1 - M_2 \leqq 0.5$, where M_1 and M_2 are the magnitudes of the first and second largest shocks in a sequence, respectively. The two largest shocks in each swarm are listed in Table 4.

Table 4. List of earthquake swarms. M_1: the largest shock, M_2: the second largest shock.

	Date and Time (JST)					Location	*M*	Class
M_2	1906	Aug.	16	15 h	38 m	Central Izu Pen.	4.9	L1
M_1		Aug.	31	11	20		5.1	L1
M_1	1930	Mar.	22	17	50	E off Izu Pen.	5.8	L1
M_1		May	17	05	14		5.8	L1
M_1	1944	Dec.	8	05	57	Near Niijima	5.7	N
M_2		Dec.	8	06	23		5.5	VL
M_1	1948	Dec.	16	14	09	Near Izu-Oshima	5.0	L1
M_2		Dec.	27	20	05		4.6	L1?
M_1	1964	Dec.	9	02	49	Near Izu-Oshima	5.8	L2
M_2		Dec.	26	02	01		5.5	VL

It is worthy of note that the largest foreshocks listed in Table 3 are normal (N) events with the single exception of the November 25, 1930 shock. On the other hand, in four cases out of five, the largest events in the swarms listed in Table 4 are low-frequency (L1, L2, or VL) quakes. The only exception is the December 8, 1944 event which may not be a member of an ordinary swarm as explained before.

An ordinary significance test (test of independence in contigency tables) indicates that the difference between foreshock sequences and earthquake swarms in respect to the proportion of low-frequency events for the largest shocks is significant at the 4% level, if the December 8, 1944 event is excluded. If it is included, the significance level must be 11%.

The normal (high-frequency) nature of the largest foreshocks and the low-frequency nature of the largest shocks in swarms may be useful in discriminating foreshock activity from earthquake swarms in this particular area for the purpose of earthquake prediction. Although the cause of low-frequency earthquakes is not yet completely understood, it is possible that many low-frequency earthquakes are generated under relatively low average stress. Prior to the occurrence of a large earthquake, the crust around its focus is in a state of relatively high stress, which tends to generate high-frequency earthquakes of small magnitude.

It is very likely that the characteristics of shocks preceding the largest event in a type 4 sequence are similar to those of a type 3-(1) swarm rather than those of foreshocks in a type 2 sequence. Therefore, some techniques suggested so far for discriminating foreshocks from earthquake swarms of type 3-(1) may not be applicable to the prediction of the occurrence of the main shock of a type 4 sequence. For example, the *b*-value for foreshocks of the Kita-Izu earthqauke of 1930 (the main shock of a type 4 sequence) is not as small as the values reported for some foreshock sequences (SAMC, 1976). The analysis of the similarity in waveforms of events in a series of earthquakes is a promising technique for the identification of an earthquake swarm (TSUJIURA, 1979a). However two type 4 sequences off the east coast of the Izu Peninsula in June, 1980 (M_1=6.7, M_2=4.9) and in December, 1978 (M_1=5.4, M_2=4.1) contain groups of shocks with very similar waveforms (TSUJIURA, 1979b, 1981). The classification of earthquakes into normal and low-frequency ones seems to be effective in the discrimination between foreshocks in both type 2 and 4 sequences and the ordinary earthquake swarm, though the examples presented here are not enough to evaluate the probability of successful prediction by this procedure.

Conclusion

Seismicity of the Izu Peninsula and its vicinity for the past 80 years has been studied by the use of a newly prepared catalog of shallow earthquakes of $M \geqq 5.4$. The seismicity for the years 1901-1925 was not well known due to the lack of reliable earthquake catalogs. The new catalog reveals that during 1901-1925 the seismic activity in the peninsula and nearby sea areas was comparatively low, but the activity was fairly high in a region north of the peninsula. Other notable features of the seismicity pattern in the 80 years have been described. The Izu area is characterized by relatively frequent occurrence of foreshock sequences and earthquake swarms. A peculiar trait of the seismicity of this area is the occurrence of type 4 sequences defined in this paper. For a type 4 sequence, some techniques for the prediction of its main shock on the basis of the characteristics of the ordinary foreshock sequences may not be applicable, because the shocks preceding the main shock have the characteristics similar to the swarm of type 3-(1). The classification of earthquakes into normal and low-frequency events seems to be effective in the prediction of the main shocks of both type 2 and 4 sequences. More data must be accumulated to evaluate the reliablity of this technique.

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2. 伊豆半島とその周辺の地震活動 (1901年～1980年) と前震の性質について

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最近80年間における伊豆半島とその周辺地域の浅い地震の活動状況を調べた．震源要素は，1901～25年については筆者による再調査，1926～80年については気象庁地震月報による．この地域では，前震も群発地震も比較的多いが，とくに1930年北伊豆地震とその前後の活動のように，活動の様式は群発地震的であるが，一つだけ極立って大きい本震を含むようなタイプ（type 4）がみられる．M と最大有感距離の関係によって，地震を普通の地震と低周波地震（M の割に有感域が狭い地震）に分けると，一連の活動が群発地震か前震（type 4 の本震の前の地震を含む）かを判断する参考になりそうである．