Bulletin of the Earthquake
Research Institute
Vol. 41 (1963), pp. 659-680

39. *Foreshocks, Aftershocks and an Earthquake Swarm Detected by the Micro-earthquake Observation.*

By Takahiro HAGIWARA and Ikuo KARAKAMA,

Earthquake Research Institute,

and

Ichiro KAYANO and Katsutada KAMINUMA,

Graduate School, University of Tokyo.

(Read April 23, 1963.—Received June 30, 1963.)

On February 9, 1963, a small earthquake was felt in the mountainous region of the central part of Japan, which is underlain by Cretaceous granites which intrude into the Nōhi rhyolites (Cretaceous) and the Paleozoic sediments.* Volcanoes Yakedake and Tateyama lie 20 kilometres away from the epicentral region, but it seems that the seismic activities discussed in this paper have no relation to the activities of those volcanoes. Small earthquakes occur occasionally, but no large earthquake has been experienced in this region.

A few aftershocks were felt after the earthquake above mentioned. At that time we were carrying out micro-earthquake observation with the "HES 1-0.2" seismograph at the Kurobe IV Dam (36°34′ N, 137°40′ E, 1394 m above sea level), Kwansai Electric Power Company, about 20 kilometres away from the epicentres and fortunately we were able to record several micro-foreshocks which preceded the main shock, a great number of aftershocks and a small earthquake swarm which occurred in the neighbourhood about twenty days after the earthquake mentioned.

Our micro-earthquake observation at this station started at the beginning of November, 1962. The number of earthquakes with p-s intervals shorter than 15 seconds which were observed at this station from November 1962 to January 1963 were as small as shown in Table 1 (a). (See the end of this paper)

In this table, disturbances of which p-s intervals were shorter than 1.0 second are omitted because such earthquakes were very difficult to be distinguished from artificial noises generated by the construction of the

* 1/500,000 Geologic Map, "KANAZAWA", Geological Survey of Japan (1958).

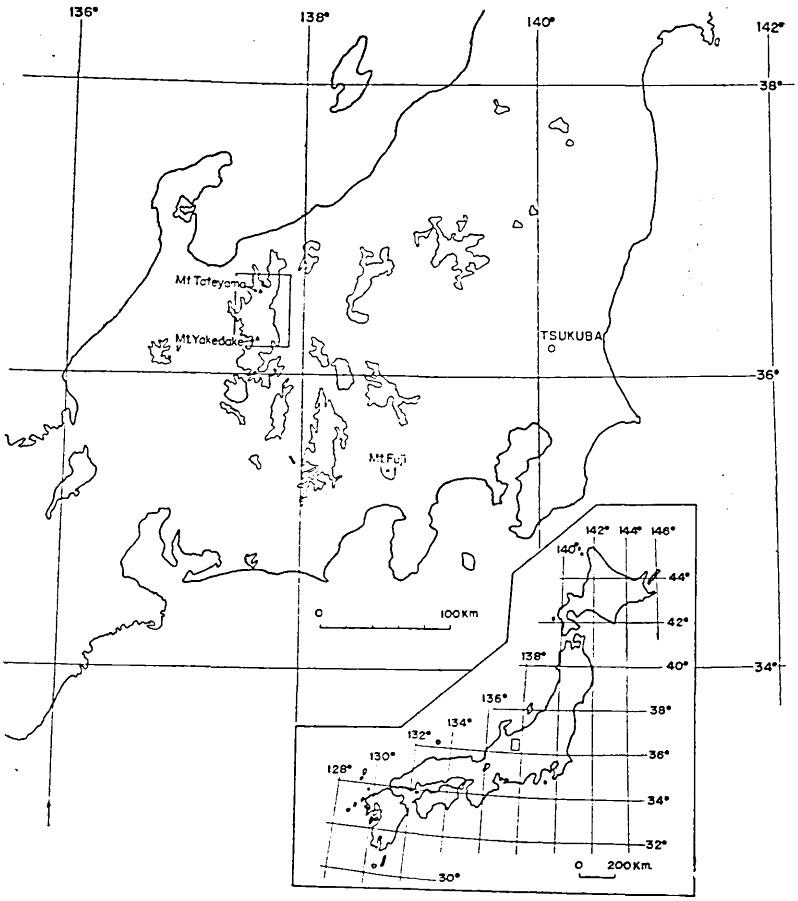


Fig. 1. The block in the figure indicates the area of Figs. 8 and 9. The 1500m contour lines were drawn in the upper figure in order to show mountainous regions.

dam. On and after February 5, 1963, several minor shocks having p-s intervals of about 3 seconds were recorded and on February 9 a felt earthquake occurred which seemed to be the main shock of this activity. After that a great many aftershocks were recorded as shown in Table 1(b) and Fig. 3.

We may sefely say that the six shocks with an asterisk in Table 1(b) were foreshocks. If our micro-earthquake observation had not been carried out there, such micro-foreshocks would have escaped our notice.

After the main shock, the number of aftershocks was fairly fluctuating, but on average it decreased according to the hyperbolic formula.

On February 21, twenty days after the main shock, the aftershock activity was apparently stopped. But toward the end of that month seismic activity was activated again in the same region. Earthquakes increased rapidly in number and that activity reached its peak on March 1, when the largest earthquake of the second period of activity occurred. It seemed that the second period of activity stopped in the middle of March, but in April and May some ten earthquakes occurrd with p-s intervals between 2.0 and 4.0 seconds. In this paper the investigation is confined to earthquakes which occurred by the middle of March, but this limitation does not affect the value of the paper.

For convenience' sake, we

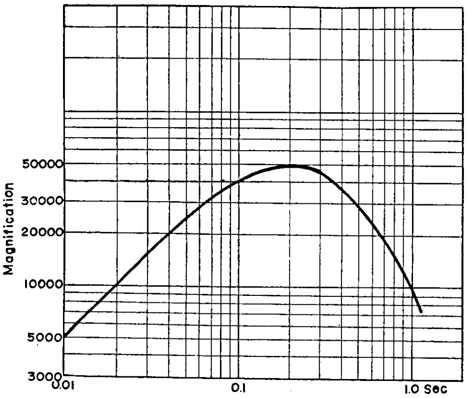


Fig. 2. Magnification vs. period curves of the "HES 1—0.2" seimograph at the Kurobe IV Dam. Seismograph constants are as follows:

Component	V_{max}	T_1	T_2	h_1	h_2	σ
E-W	50000	1.00	0.20	1.0	1.0	0.14
N-S	50000	1.00	0.19	1.0	1.0	0.13
U-D	50000	1.00	0.17	1.0	1.0	0.09

V_{max}: Maximum magnification on the film reader (×8)
T_1 : Period of pendulum
T_2 : Period of Galvanometer
h_1 : Damping constant of pendulum when the galvanometer is clamped.
h_2 : Damping constant of galvanometer when the pendulum is clamped.
σ : Coupling factor.

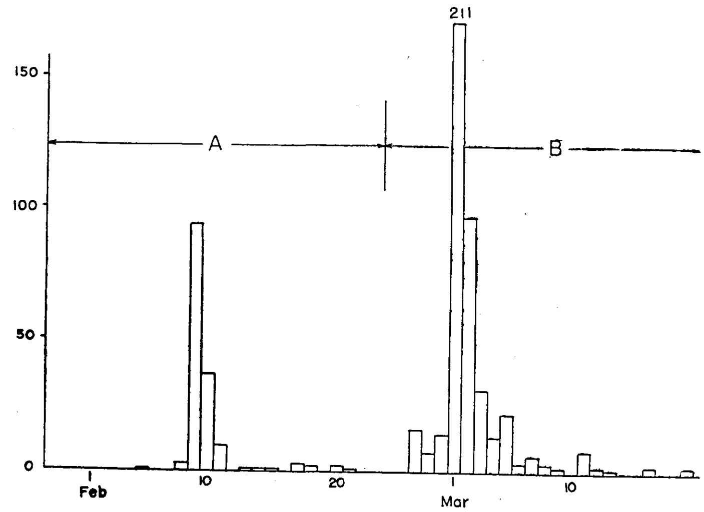


Fig. 3. Daily frequencies of earthquakes recorded at the Kurobe IV Dam with p-s intervals between 2.0 and 4.0 seconds. February 1 to March 20, 1963.

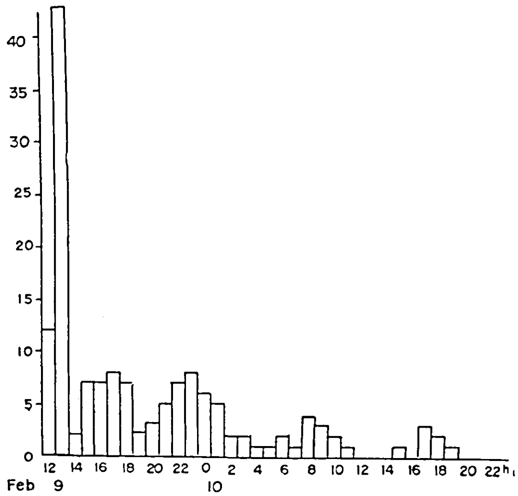


Fig. 4. Hourly frequencies of earthquakes recorded at the Kurobe IV Dam with p-s intervals between 2.0 and 4.0 seconds. Main part of the sequence "A".

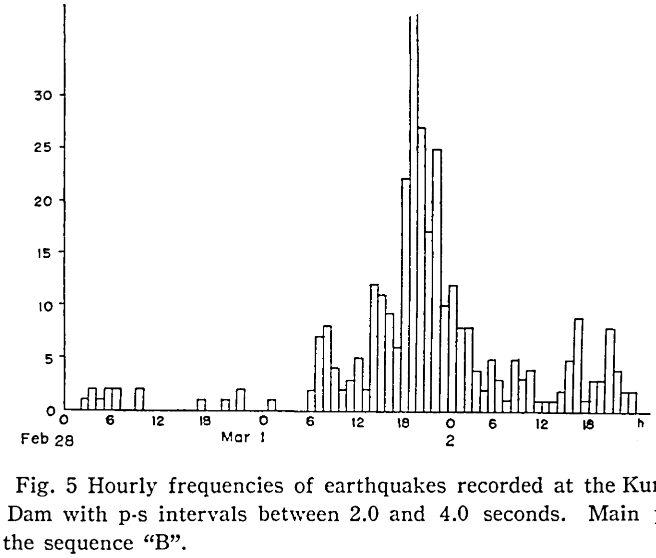


Fig. 5 Hourly frequencies of earthquakes recorded at the Kurobe IV Dam with p-s intervals between 2.0 and 4.0 seconds. Main part of the sequence "B".

call the seismic activity from the beginning to the 25th of February the sequence " A " and the other one after the end of February to the middle of March the sequence " B ".

The p-s intervals of all shocks in the sequences " A " and " B " range from 2.0 to 3.7 seconds and are concentrated around 3.0 seconds. No significant difference is found between the p-s interval distribution of the sequence " A " and that of " B ".

Some fifty shocks belonging to the sequence " A " and some one hundred belonging to " B " were recorded at Matsushiro Seismological Station, JMA, 50 kilometres distant from the epicentral region.

When we want to know the epicentral distribution of these shocks, only two values of p-s intervals observed at two stations are not sufficient. So assuming that the focal depths of all shocks are 5 kilometres, epicentral distribution was determined according to the p-s time table calculated by Sagisaka and Takehana. Even if the foci of some shocks are a little deeper or shallower than 5 kilometres, the errors of epicentral determinations will be within few kilometres and it has only a slight effect on the epicentral distribution as a whole.

The epicentre of one of the foreshocks was determined and shown in Fig. 8 with a double circle.

Fig. 10 shows the relation between the maximum trace amplitude and the frequencies of earthquakes with the corresponding maximum trace amplitudes. The inclination of the line in this figure gives $m=2.2$, which is rather large[1] to the numerical constant in the Ishimoto-Iida's relation: $n(a)\delta a=-ka^{-m}\delta a$, where a is the maximum trace amplitude and $n(a)\delta a$ the frequency of the shocks of which the maximum trace amplitudes lie between a and $a+\delta a$.

The Anderson-Wood seismograph at Mt. Tsukuba Station,

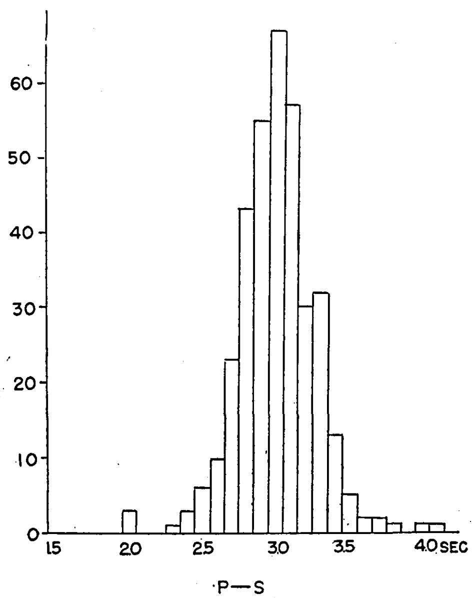


Fig. 6. Frequency distribution of p-s intervals of earthquakes belonging to the sequences "A" and "B".

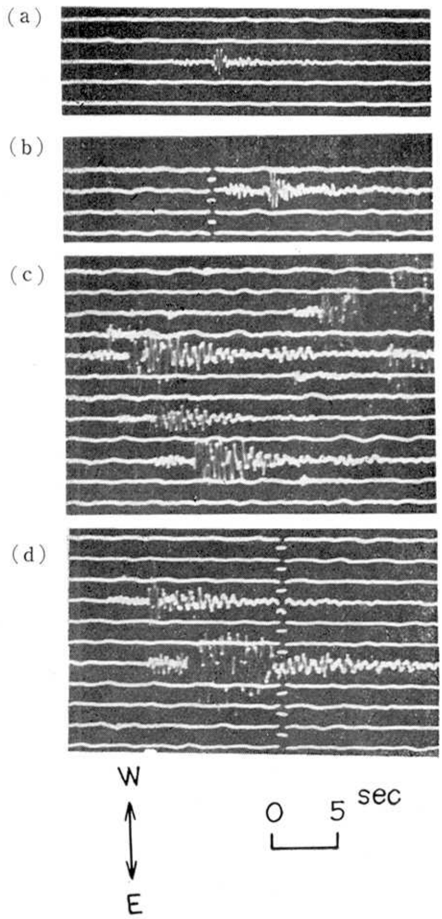


Fig. 7. Typical "HES 1-0.2" seismograms recorded at the Kurobe IV Dam.

a) Foreshock: Feb. 8d 20h 15m JST $M=1.9$
b) Aftershock: 9 13 07 $M=2.0$
c) Earthquake swarm: Four comparatively large shocks are recognized. Up to down
Mar. 1d 20h 10m $M=2.7$
19 10 $M=2.1$
17 40 $M=1.8$
16 40 $M=2.5$
In addition to them four other smaller shocks can be recognized.
d) Eathquake swarm: Up to down
Mar. 2d 06h 10m $M=2.2$
04 10 $M=2.5$

Earthquake Research Institute, (36°13′ N, 140°07′ E, of which the epicentral distance was about 210 kilometres) recorded only the main shock. The magnitude of that shock was determined to be 4.8. This value is much smaller than that determined by JMA. We think the value 5.8 determined by JMA may be a little too large, but the cause of this discrepancy will be investigated in another opportunity.

Several larger shocks were recorded with the "HES 1-1" seismograph at Mt. Tsukuba Station. We have a set of formulae[2] for magnitude determination with an "HES 1-1" seismogram at Mt. Tsukuba station. In order to determine the magnitudes of the earthquakes observed at the Kurobe IV Dam station, we used a formula of the following type:

$$M=\log A_{max}+\alpha \log \Delta+\beta$$

where M is magnitude, A_{max} maximum trace amplitude, Δ epicentral distance, α and β numerical coefficients. The p-s interval multiplied by a constant was substituted in place of the epicentral distance Δ in this formula. For the coefficient α, 3 was adopted, and the value -0.13 of β is derived from the relation between magnitudes determined at Mt. Tsukuba station and maximum

1) Ishimoto, M. and K. Iida, *B. E. R. I. Tokyo Univ.*, **17** (1939), 443.
Iida, K. *B. E. R. I. Tokyo Univ.*, **17** (1939), 741, **18** (1940), 532.
Suzuki, Z. *Sci. Rep. Tohoku Univ., Geophys.*, **5** (1953), 177, **6** (1955), 105, **10** (1958), 15, **11** (1959) 10.

2) Kayano, I., in preparation.

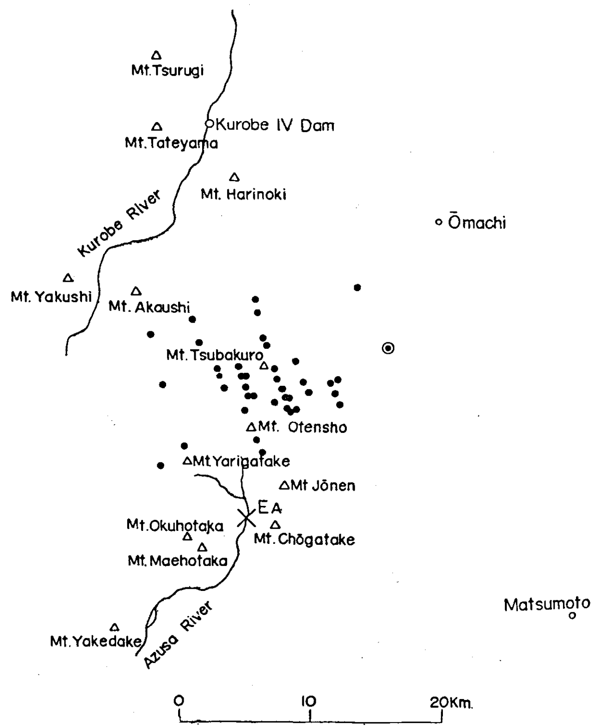


Fig. 8. Epicentral distribution of the earthquakes belonging to the sequence "A". E_A is the epicentre of the main shock determined by JMA. Double circle shows the epicentre of a foreshock.

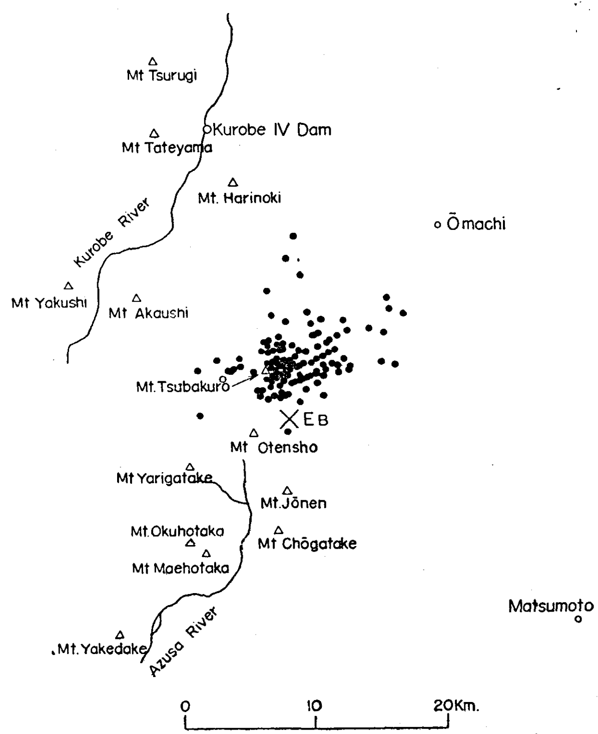


Fig. 9. Epicentral distribution of the earthquakes belonging to the sequence "B". E_B is the epicentre of the largest shock in this sequence determined according to observations by JMA.

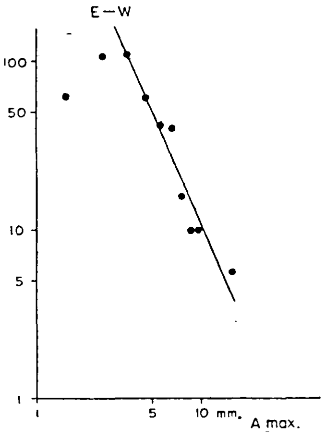


Fig. 10. Frequency distribution of Maximum trace amplitudes. $m=2.2$

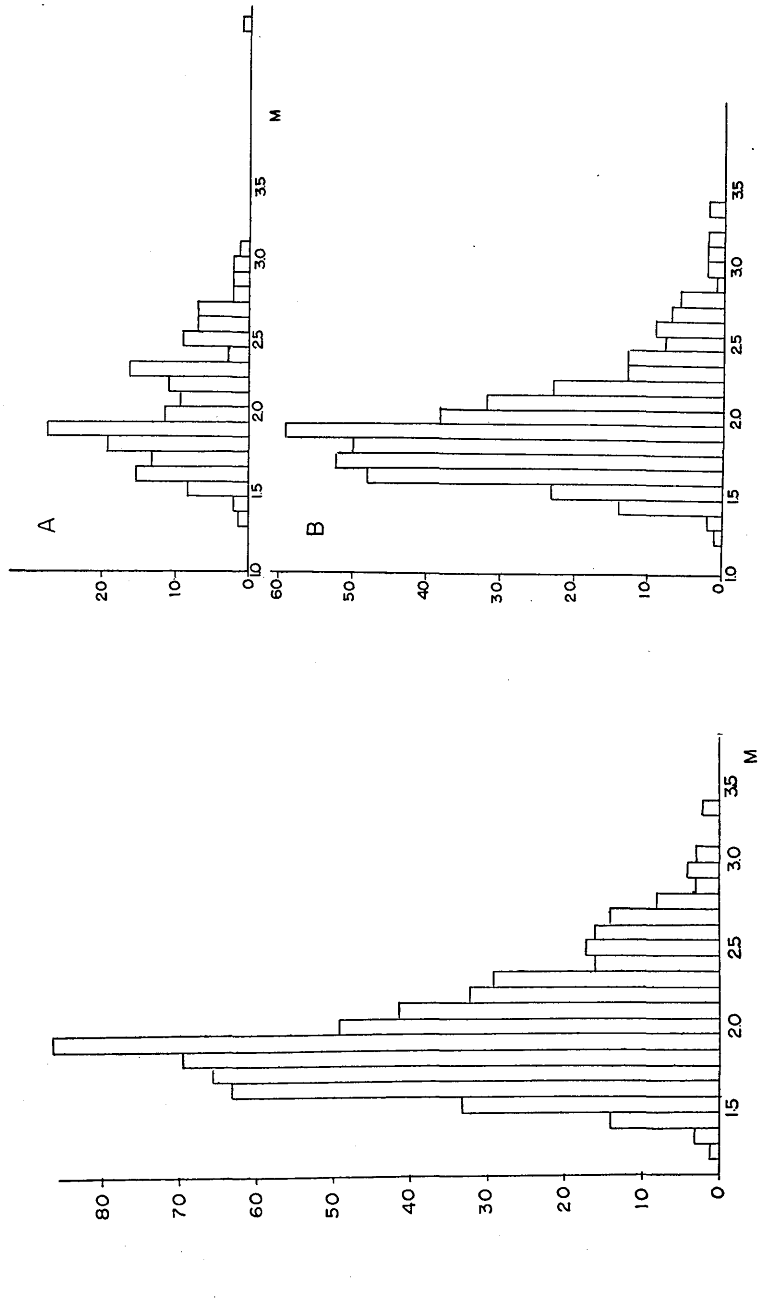
trace amplitudes on the "HES 1–0.2" seismogram at the Kurobe IV Dam. The value used for the coefficient α is the same as the coefficient in the formula for the Anderson-Wood seismograph. We adopted this value because it seemed that both seismographs gave maximum trace amplitudes at the period range below 0.3 seconds. For the shocks of which p-s intervals were not read off clearly, 3 seconds assumed as their p-s intervals. By this way, the magnitude of almost all shocks were determined and their results are listed in Table 1(b). Fig. 11 (a) shows magnitude distribution. Note especially the difference between the magnitude distributions of the sequence "A" and "B" shown in Fig. 11(b).

In the sequence "A", the largest shock (the main shock) is much larger than any other shocks. Between the largest shock ($M=4.8$ or more) and the next largest one, there is a big gap. On the other hand, in the sequence "B", magnitudes of all shocks distribute continuously.

Investigation concerning the time of occurrence of shocks tells us of characteristic differences between the sequences "A" and "B". In "A", before the largest shock only a few very small shocks occurred, after that a great many small shocks occurred in succession, and then the frequency of shocks decreased rapidly. In "B", on the contrary, many shocks including rather large ones occurred increasing gradually in number until the occurrence of the largest one, and after that the frequency decreased gradually. Figs. 4 and 5 show clearly this difference. From the above mentioned two points we may say that the sequence "A" is of a foreshock-mainshock-aftershock type and "B" is of an earthquake swarm type.

Since there are several cases[3] where, preceding or following a sequence of the foreshock-mainshock-aftershock type, an earthquake swarm is known to have occured, it has to be clarified in future what kind of intrinsic relation exists between them. An example of the former case is the Ito earthquake swarm from March to May, 1930, and the North Izu earthquake on November 26, 1930. (See Table 2).

3) Mogi, K., *B. E. R. I. Tokyo Univ.*, **41** (1963), 615-658.



a) The sequences "A" and "B" altogether.

b) The sequence "A" (up) and "B" (down) separately.

Fig. 11. Frequency distribution of magnitudes of earthquakes.

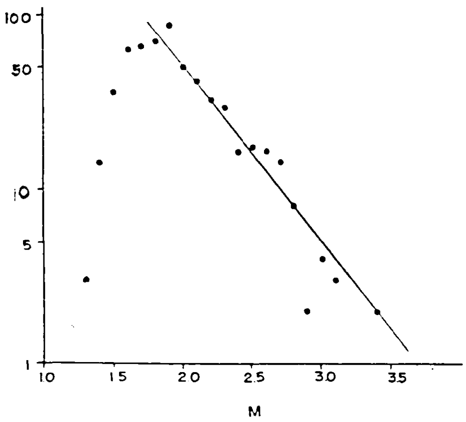


Fig. 12. Frequency distribution of magnitudes of earthquakes belonging to the sequences "A" and "B". $b=1.0$

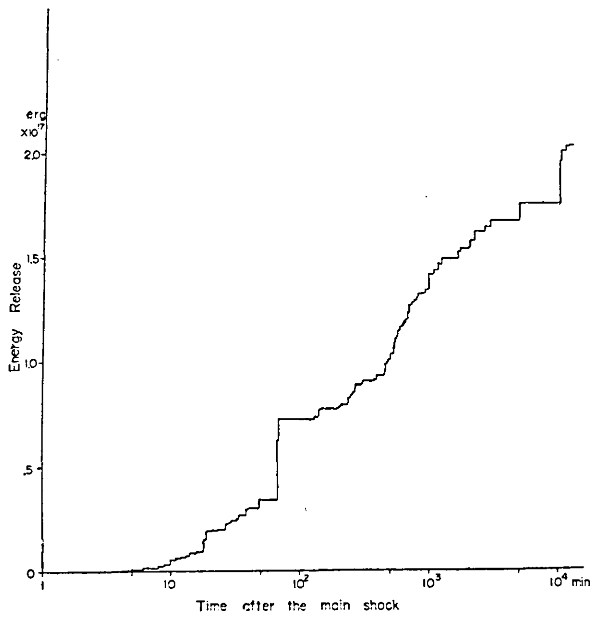


Fig. 13. Cumulative sum of energy released by aftershocks (the sequence "A").

Fig. 13 shows the cumulative sum of the energy release calculated by Gutenberg-Richter's formula: $\log E = 11.8 + 1.5M$,[4] for aftershocks of the sequence "A". This figure tells the cumulative sum of the energy released by the aftershocks increased logarithmically.

The aftershocks and the earthquake swarm discussed in this paper show close similarities of behaviors when compared with the observations that have been made hitherto with respect to earthquakes of ordinary magnitude, laying aside the disparity of scale. We believe, however, that if such micro-earthquake observations were carried out in many other places, the foreshocks of earthquakes too small for the ordinary routine observations hitherto to be noticed would be detected and this could lead to valuable information for the work of earthquake prediction.

The authors wish to express their hearty thanks to the members of staff of the Kwansai Electric Power Company for co-operation in seismological observation and to the members of staff of Japan Meteorological Agency for offer of observational data obtained at its stations.

---

4) Gutenberg, B. and C. F. Richter, *B. S. S. A.*, **46** (1956), 105-143.

Table 1. Earthquakes of p-s intervals between 1.0 and 15.0 seconds.
(a) November 1, 1962—January 31, 1963

Date	Time h	Time m	p-s (sec)	Date	Time h	Time m	p-s (sec)
1962 Nov. 6	13	51	4.8	18	17	26	1.1
9	15	14	7.8	24	05	25	1.5
10	00	15	1.7	27	06	41	1.1
14	16	57	11.8	31	20	02	2.0
15	23	19	10.0			03	2.0
19	15	03	5.8	1963 Jan. 1	04	29	1.8
		08	5.7		13	19	1.9
Dec. 1	14	23	1.3		15	09	2.2
7	03	42	8.7	4	10	29	4.3
14	16	57	5.8	6	23	59	1.4
16	03	42	4.2	9	00	15	10.
	15	15	5.1	11	15	06	2.6
	16	29	1.0	13	08	19	4.7
18	12	01	1.7	17	10	42	5.0
	14	31	2.5		15	07	1.0
	17	26	1.0				

(b) February 1, 1963—May 20, 1963

Date	Time h	Time m	p-s interval Kurobe (sec)	p-s interval Matsu-sniro (sec)	*M*	Date	Time h	Time m	p-s interval Kurobe (sec)	p-s interval Matsu-shiro (sec)	*M*
Beginning of the sequence "A"						9	12	58			1.6
Feb. 5	12	54*	2.8		1.7			59			1.7
8	11	56*	3.3	5.	2.4			〃	3.4		2.1
	13	53*	2.8		1.7		13	00	3.0		1.7
	20	15*	3.1		1.9			01	3.2	6.	2.2
9	10	59*	3.2		2.0			〃			1.9
	12	52*	3.1		1.5			〃			1.9
		53†		6.1	4.8			02	2.8		1.9
		55			2.3			03	3.0		2.3
		〃	3.3		1.9			〃			1.9
		56	2.6		2.3			〃			1.8
		57			2.6			04	3.0	6.	2.5
		〃	2.8		1.5			05			1.8
		58			1.6			〃			1.8
		〃	2.9		1.9			〃			1.6

* Foreshocks. † the main shock. (to be continued)

(continued)

Date	Time		p-s internal		M
	h	m	Kurobe (sec)	Matsu-shiro (sec)	
Feb. 9	13	06			2.0
		07	3.3		2.0
		〃	2.7		1.6
		〃		6.	1.9
		〃			2.0
		10	3.1		1.6
		11			1.9
		〃	3.4	6.	2.6
		〃	3.0		1.8
		12	3.1		2.5
		〃			1.9
		14	2.7		1.4
		〃			1.6
		〃			1.7
		15			1.5
					1.5
		16			1.7
		17			1.5
		20	2.8	7.	2.5
		21	3.3		2.0
		22	3.2		2.0
		23	2.8		1.9
		26	3.3	6.	2.7
		27	3.1	6.	2.3
		32	3.0	7.	2.7
		33	3.2		1.9
		〃			1.9
		38	2.9		1.6
		40	3.3		1.8
		41			1.8
		42	3.3	6.	2.6
	14	02		7.	3.1
		04		6.	2.8

From 13h to 15h, observation at Kurobe interrupted

	15	09	3.2	6.	2.0
		14			1.6

Date	Time		p-s inteaval		M
	h	m	Kurobe (sec)	Matsu-shiro (sec)	
9	15	20	3.6		2.5
		23	3.5		1.8
		24	3.1		1.9
		44	3.0		1.8
		59			1.6
	16	07	2.9		1.5
		16	2.8		1.7
		23			1.6
		24			1.5
		54	2.7		1.7
		55	3.7		3.0
		57	3.3		2.3
	17	07	3.4		2.1
		〃	3.0		1.9
		12	2.8		1.7
		15	5.9		
		16	3.3		2.1
		27	3.5		2.3
		29	3.3		1.7
		59	2.8		1.3
	18	01	3.0		2.7
		05	2.9	1.5	
		10	3.3	6.0	2.4
		12	3.1		2.1
		〃	3.3		1.7
		〃	3.2		1.9
		38	3.2		2.0
	19	22	3.1		2.0
		35	3.2		2.3
	20	48	3.0		1.8
		52	2.7	5.1	2.3
		53	2.9	6.	2.7
	21	04	3.3		1.8
		06	3.4		2.1
		14	3.2		1.1
		27	2.8		1.4
		41	3.2	5.8	2.6

(to be continued)

(continued)

Date	Time h	Time m	p-s interval Kurobe (sec)	p-s interval Matsu-shiro (sec)	M	Date	Time h	Time m	p-s interval Kurobe (sec)	p-s interval Matsu-shiro (sec)	M
Feb. 9	22	06	3.0		1.9	10	08	26	3.3		1.8
		14	3.3	6.4	2.2			36	3.0		2.3
		16	3.2		2.1			46	3.2	6.0	1.9
		19	3.3	5.5	2.3		09	15	3.3		1.9
		21	2.7	6.6	2.2			21	3.0	6.7	2.3
		24	3.1		1.8			34			1.5
		50	2.9	5.8	2.3		10	30	2.7		1.9
	23	04	3.1	6.3	2.2			52	3.3		1.8
		〃			2.1		11	14	3.1	5.7	2.5
		14	3.0	5.8	2.1		15	24			
		23	2.6	6.4	1.6		17	11			1.8
		34	3.2		2.3			34	3.3		1.6
		〃			2.0			41	3.1	5.9	2.0
		37			1.5		18	16	3.1	6.2	1.6
		58	3.1		1.9			55	3.0	6.3	2.3
10	00	05	3.1		1.8		19	04	3.5	5.6	2.2
		14	3.4	6.1	2.2	11	00	18	3.1		1.6
		17	3.4		1.8		01	02	2.5	6.6	1.9
		26	3.3		1.9			43	3.4	6.3	2.5
		27			1.5			52	3.3	6.1	2.0
		54		5.5	2.7		04	50	2.9	7.3	2.5
	01	05	2.9	6.3	1.8		07	08	2.9		1.9
		〃			1.8		14	01	3.3	6.0	2.1
		06	3.0	6.1	1.9			02	3.3	5.6	2.2
		18	3.1		1.8		19	09	2.8	6.3	2.5
		59	3.1	6.0	2.6	13	18	07	3.2	6.2	2.7
	02	01			1.9	14	07	51	3.8	7.3	2.8
		21	3.2	6.3	2.0	15	23	48	3.1		1.7
	03	05	3.3		2.2	17	08	16	3.0	6.3	2.9
		15	3.2	6.3	2.3			19	3.1	6.5	2.6
	04	13	3.4		1.7		09	44	3.4		2.2
	05	26	2.9	6.5	2.6		23	24	3.3	5.8	2.4
	06	17			1.6	18	04	31	3.2		1.9
		33	3.0	6.6	2.9		09	39	3.6	7.0	2.4
	07	22	3.0		1.7	20	06	39		6.6	1.9
	08	06	3.3	6.4	1.4		11	50	3.4	6.0	2.5
		19	2.7	6.0	2.3	21	21	50	3.0		1.7
						End of the sequence "A"					

(to be continued)

(continued)

Date	Time h	Time m	p-s interval Kurobe (sec)	p-s interval Matsu-shiro (sec)	*M*
Beginning of the sequence "B"					
Feb. 26	05	00		6.	1.9
		01			1.6
		03			1.8
		11	2.9	2.7?	2.3
		43			1.9
	06	05	3.1	5.6	2.1
		59	2.3	5.6	1.9
	07	11	3.1	5.8	1.9
		34	3.0	5.8	1.9
	08	10	3.2	5.4	1.9
	09	22	3.3	5.1	2.4
		49		5.5	
	10	41	3.3	6.8	2.0
	11	09	3.1	5.8	2.1
	12	47	3.3	5.7	2.2
	13	37	2.9	5.8	2.1
27	04	15	3.1	5.8	2.1
		17	3.0	6.	1.9
	11	52	3.0	5.9	2.6
	13	25		6.1	2.4
		32	3.2	6.	2.0
	14	38	3.3	5.9	2.3
	15	50	3.2		2.2
28	02	56	3.0	6.5	2.9
	03	35	2.8		1.7
		54			1.7
	04	44	2.7	5.5	1.8
	05	00	3.0	5.7	1.9
		06	2.0		1.5
	06	08			1.8
		53	2.8		2.0
	09	11	2.7	6.	1.9
		12		6.	1.5
	17	07	3.2		1.9
	20	04	2.9	5.3	2.0
	22	28	3.1	5.7	2.2
28	22	42	3.0	6.	2.6
Mar. 1	01	47	3.1	6.2	2.0
	06	32	3.1	6.2	2.8
		33			1.8
	07	15	3.0		1.9
		20	3.4	5.5	2.1
		37	3.0	6.0	1.9
		43	3.0	5.8	1.9
		52	3.1	5.0	2.2
		〃	2.7		1.8
		53	3.1	5.9	2.5
	08	00	3.0	6.0	2.4
		01			1.6
		02			1.6
		03	2.9	5.5	2.3
	09	12	2.8	6.3	2.6
		18	3.3		2.0
		22	2.9	6.4	1.8
		46	2.8	5.3	1.9
	10	54	2.7	5.6	1.5
		55	2.8		1.9
	11	17	3.1	6.1	2.5
		31	2.8		2.2
		38	3.0		2.1
	12	01	2.9		2.2
		14	3.1		2.0
		34	2.4		1.6
		36	3.1	6.0	2.3
		50	3.1	6.2	2.2
	13	25	3.1	5.9	1.9
		51			1.9
	14	01	2.7		1.8
		14	3.4	5.0	1.9
		22	3.1	4.8	2.6
		24			1.9
		26	2.6		1.8
		〃			1.8

(to be continued)

(continued)

Date	Time		p-s interval		M	Date	Time		p-s interval		M
	h	m	Kurobe (sec)	Matsu-shiro (sec)			h	m	Kurobe (sec)	Matsu-shiro (sec)	
Mar. 1	14	28	2.9	6.4	2.0	1	18	24	3.1	6.2	2.1
		31	2.8	5.8	3.0			25		5.9	1.9
		34	2.8	5.9	2.4			27			1.5
		35			1.8			〃			1.7
		43			1.6			29	2.8	5.6	1.8
		52	3.3		2.2			〃			1.6
	15	18	2.8		1.7			〃			2.0
		21	3.1	5.4	2.7			30	2.9		1.9
		23	3.5		2.0			38	3.1	5.7	2.2
		26	3.0	5.9	2.0			40			1.6
		45	2.9	5.6	1.7			42	2.7		1.7
		46	3.0	5.1	2.1			44			1.9
		49	2.9		1.9			52	2.9	6.4	2.1
		53			2.0			〃	2.4		1.7
		56	3.0	4.1	2.3			56	2.8		2.8
		57			1.8			57			2.1
		58			1.8			59			1.7
	16	06			1.6		19	02			2.1
		21	3.1		1.7			03	3.1	5.7	2.2
		30			1.6			05			2.0
		40	3.1	5.7	2.5			〃	2.9	5.8	2.7
		47	3.0	5.8	2.2			10	3.0	6.0	2.1
		49	2.9		1.4			〃			1.6
		50	2.8		1.6			11			1.7
		52			1.7			〃			1.7
		53	3.0		1.8			13	2.9	5.7	2.2
	17	24	2.9		1.7			〃			1.9
		34	3.0	6.0	2.8			17	2.7	5.9	
		40	2.8	5.6	1.8			20			1.6
		51	2.7		1.4			〃			1.4
		52		4.9	1.9			21			1.6
		56	2.9		1.9			〃	2.8		1.7
	18	06	2.9	5.9	2.1			23			1.7
		07			1.9			〃	2.7	5.9	2.7
		12			1.8			25	2.9	4.9	2.0
		18	2.8		1.5			28			1.5
		21	2.9		1.8			29	2.6	5.6	2.1

(to be continued)

(continued)

Date	Time		p-s interval		*M*	Date	Time		p-s interval		*M*
	h	m	Kurobe (sec)	Matsu-shiro (sec)			h	m	Kurobe (sec)	Matsu-shiro (sec)	
Mar. 1	19	32			1.4	1	20	51			1.8
		〃			1.7			52	3.1	6.	2.4
		33			1.6			53			1.6
		34			1.7			54	3.2	6.	2.1
		〃	2.7	6.	1.8			〃			1.9
		36			1.8			55		6.	1.8
		37			1.6			58			1.5
		〃			1.7			〃	2.8		1.8
		40			1.8		21	02			1.9
		44		6.	2.0			03			1.5
		〃			2.1			08			1.7
		47	3.2	5.8	2.7			15	2.9	5.4	2.8
		51	2.8	5.6	2.2			27	2.8		1.7
		52			1.6			30			1.3
		53			1.6			34	2.5	5.9	1.7
		54			1.9			45		5.6	1.7
		57	2.8	6.5	1.8			〃			1.9
		58	3.9		2.0			47			1.9
	20	09	2.9	6.7	2.0			48			2.0
		10			2.4			51	3.1	3.6	2.2
		〃	2.7	5.7	2.7			52			1.8
		16			1.9			53		5.3	3.4
		17			1.7			55			1.9
		22	2.5		1.9			57			1.6
		26	2.6	5.8	2.1			58			1.7
		〃			1.6		22	00			1.7
		27			1.6			〃			1.7
		〃	3.4		2.1			01	2.7		1.7
		33			1.6			02	3.0	5.9	2.5
		34			1.9			03			1.8
		〃		5.4	3.4			05			1.6
		37	2.8	5.9	2.4			08			1.5
		41	3.5	6.1	2.1			12			1.7
		〃			1.9			13			1.7
		42			1.4			16		6.0	2.0
		44			1.6			19			1.7
		47			1.6			20			1.6

(to be continued)

(continued)

Date	Time		p-s interval		M	Date	Time		p-s interval		M
	h	m	Kurobe (sec)	Matsushiro (sec)			h	m	Kurobe (sec)	Matsushiro (sec)	
Mar. 1	22	21			1.6	2	01	09	2.9		2.1
		25	3.1		1.8			11			1.6
		27			1.5			18	3.0	6.0	2.5
		30			1.7			27			2.0
		32			1.7			29	3.1	5.8	2.4
		37			1.6			32			1.7
		39	3.0	6.0	2.7		02	04	2.9	5.8	2.2
		40	2.7	5.6	2.0			06	2.9	5.9	2.1
		43	2.8		1.8			08	2.9		2.1
		50	3.2	6.0	2.2			12			1.5
		54		6.1	2.3			15	3.2	6.1	2.5
		56			1.6			38			1.8
		57			1.6			39			1.7
	23	02			1.6			57			1.5
		05		6.	1.6		03	05	3.0	6.0	2.1
		11			1.6			26			1.8
		14	2.8	5.9	2.0			27			1.7
		16			1.9			47	2.5	7.	1.9
		20		6.	1.9		04	22	2.6		1.8
		36			1.6			40	2.9	5.5	2.5
		37			1.6		05	07			1.8
		43			1.9			17	3.1	5.5	3.0
		49			1.6			24			1.8
2	00	02			1.6			38			1.8
		04	3.2	5.	2.0			52	2.8	6.	1.9
		〃			1.9		06	07	2.8	6.	2.0
		〃			1.8			10	3.0	5.9	2.2
		07			1.7			22	3.2	6.1	1.9
		〃			2.1		07	50			1.9
		18	3.2	5.4	2.2		08	09	3.0		2.0
		21			1.7			12	2.5		1.4
		24	3.1	.6	2.2			41	2.6		1.9
		28	2.9		1.9			47			1.8
		37			1.9			52	2.7		2.0
		39			1.4		09	28	3.3		2.1
	01	02	2.9	5.6	2.4			〃	3.1		
		03			1.6			36	2.8	5.8	2.3

(to be continued)

(continued)

Date	Time		p-s interval		*M*
	h	m	Kurobe (sec)	Matsu-shiro (sec)	
Mar. 2	10	28	2.8	5.9	2.3
		〃	2.7		1.8
		32		6.6	2.0
		39			1.6
	11	19	2.8	6.0	2.5
	12	38	3.1	5.5	2.4
	13	21			1.9
	14	06	4.1		
		07	2.0	5.6	2.2
	15	26	3.0	5.9	2.6
		27	3.0	5.9	2.6
		52		5.5	3.1
		58			1.9
		59		7.4	1.9
	16	05	2.0		1.4
		11	2.8		1.8
		13	2.9		2.0
		15			2.0
		16			1.5
		27	2.8		1.7
		31	3.7		2.0
		45			1.8
		59			1.8
	17	12	3.0	5.5	2.3
	18	19			1.8
		46			1.7
		49	3.0	6.5	2.0
	19	14	3.1	5.8	2.4
		29			1.5
		36	2.9		1.7
	20	01	3.0	5.8	2.6
		49	3.1	6.	2.2
		〃	3.1		2.7
		〃	3.0		2.6
		50	2.7		1.7
		55			1.7
		56			1.6
	20	57	2.8		2.0
	21	10	2.9		1.7
		33	3.0	5.6	2.3
		37	2.9		1.8
		48	3.2		1.8
	22	30	2.8		2.1
		45			1.5
	23	00	3.1	5.6	2.1
		23			1.7
3	00	17	3.0		1.7
		46	3.0		1.4
	03	02	2.6	5.8	1.8
		06	3.1		1.5
		35	3.0	4.9	2.6
		36	3.0		1.9
		57		5.5	3.1
		59			1.6
	04	00			1.8
		46	3.0	6.0	2.2
	05	29		6.0	1.6
		34	2.9		1.7
		48	3.2	5.7	2.8
	07	37	2.9		2.0
		59	3.1		1.9
	08	11	3.0	6.2	2.3
		23	2.8	6.2	1.8
	10	46	3.6		2.1
	11	56	3.0	6.0	1.9
	12	28			1.4
	13	26	2.9	6.3	2.1
	16	35			1.6
	17	10			1.7
		25			1.4
	18	13			1.7
	19	29	3.2	5.5	2.1
	20	02			1.6
	21	12	3.0	6.0	2.3

(to be continued)

(continued)

Date	Time h	Time m	p-s interval Kurobe (sec)	p-s interval Matsushiro (sec)	M	Date	Time h	Time m	p-s interval Kurobe (sec)	p-s interval Matsushiro (sec)	M
Mar. 3	21	44		4.0	1.7		23	20			1.5
	23	08			1.8	6	04	07	3.0		2.0
		42			1.6		09	26	3.0		1.7
4	02	04	3.0		1.8		12	17			2.8
	07	39			1.5	7	07	56	3.0		
	08	43			1.6		18	28	2.9		
	09	17			1.9			31	2.7		
		29	2.6		1.5		19	40			
	10	46	3.0	6.6	2.3		22	19	3.0		
	12	53	3.0	5.6				50			
	16	08		1.9		8	09	13			
		27		5.6			11	12			
		29			1.9		16	16			
	17	06			1.9	9	10	28			
	18	01	3.6		1.7		18	54			
		57	2.9		1.5	11	04	22			
5	01	42	3.0		1.7		09	12			
		52	3.0	5.6	2.1		13	23			
	02	34	3.0	5.5	2.1			〃			
		36	2.5		1.4		16	15			
	03	27	3.0	6.	2.2			29			
		57			1.6		17	00			
	04	13	3.0				21	47			
		22	2.9		1.3	12	03	25			
		27	2.9		1.5		10	25			
		28	2.4		1.6	13	19	05			
		34	2.9		1.9	16	02	02			
		37	3.1		1.7			15			
		45	2.9		1.4	End of the sequence "B"					
		52			1.4	18	17	39	5.9		
	08	04	2.6		1.2		18	51			
	09	03	2.9		1.8	26	07	32			1.7
		08			2.0	28	00	14			
	11	45			2.0	Apr. 1	20	15	14.0		
	13	20			1.8	3	22	57	4.1		
	16	08			1.5	4	05	42	4.4		
	20	34			1.5		06	04	4.3		

(to be continued)

(continued)

Date	Time		p-s interval		*M*	Date	Time		p-s interval		*M*
	h	m	Kurobe (sec)	Matsu-shiro (sec)			h	m	Kurobe (sec)	Matsu-shiro (sec)	
Apr. 4	07	03	4.2			27	17	30	2.9		
	08	31	4.3			28	20	54	3.3		2.0
	12	13	4.3				21	48	1.8		
	14	43	3.3				22	27	8.0		
5	11	12	2.8			May 1	06	31	5.6		
12	03	56	3.3		2.6	3	01	26	3.3		2.0
	22	11	3.2		2.0	5	20	05	11.8		
13	23	39	14.0			6	04	25	1.7		
24	04	01	3.1			8	12	02	9.4		
	19	18	3.0		1.6	14	21	55	3.1		2.1
27	07	25	2.8		1.5	17	16	02	3.2		
	15	17	1.9								

Table 2. Larger earthquakes among the earthquake swarm which occured near Ito, North Izu district, and the North Izu earthquake and its larger fore- and after-shocks.

Date	Time		*M*	Date	Time		*M*
	h	m			h	m	
1930 Feb. 21	08	37	5.4	31	05	09	5.0
Mar. 3	21	14	4.5	Apr. 1	23	04	5.0
44	05	11	5.0	May 14	08	56	4.7
5	00	08	4.5	15	15	58	4.5
9	04	39	(4.7)	17	05	14	5.4
15	18	32	(5.1)				
19	10	16	4.7	Nov. 21	21	17	4.6
22	17	03	4.3	25	16	05	5.2
		50	5.8	26	40	03	7.0
26	14	22	5.1	The North Izu Earthquake			
27	01	41	5.2	Dec. 14	17	46	4.3
30	00	06	4.7	1931 Mar. 7	01	53	5.4

39. 微小地震観測によつて見出された前震，余震および群発地震

地震研究所 萩原尊礼，唐鎌郁夫
東京大学大学院地球物理専門課程 茅野一郎，神沼克伊

昭和38年2月9日，上高地付近に小区域地震（気象庁発行の地震速報によれば $M=5.8$）が起こつた．たまたま震央より約20 km の距離にある黒部第四ダムにおいて，HES 1-0.2（最高倍率50,000倍）による観測が行なわれていたので，6個の前震，多数の余震が観測された．余震は20日頃，一応おさまつたかに見えたが，2月末から同じ地域に再び微小地震が頻発しはじめ，3月1日には1日間の発生回数が211以上に達した．マグニチュードは，本震を除いて，すべて3.5以下で典型的な微小地震群である．これらの地震群について調査を行なつたが，従来知られている，もっと大きな余震群や群発地震と比べて，ただ大きさを異にするだけで，ほぼ同じ発生様式を示していることが判つた．