79. Matsushiro Earthquakes Observed with a Temporary Seismographic Network. Part 2.

By the Party for Seismographic Observation of Matsushiro Earthquakes and the Seismometrical Section.

Earthquake Research Institute.

(Read March 22, April 26, May 24, June 28, July 19 and September 27, 1966.—Received September 30, 1966.)

The Matsushiro earthquake swarm which commenced in August 1966 has not come to an end even at present when one year has passed since the outbreak. The activity reached a peak on November 22, 1965, the daily frequency of earthquakes felt by local residents at this period exceeding 200 a day. The daily frequency of earthquakes then decreased to some extent but remained at a constant level showing some fluctuation up to the middle of March, 1966 when the activity reached the second peak. An outline of the result of the seismographic network observation of this earthquake swarm from October 1965 to March 1966 has been reported in the previous paper¹⁾. The daily frequency of earthquakes felt in the Matsushiro area increased rapidly from the middle of March, 1966 and at the same time strong earthquakes began to occur frequently. The daily frequency of earthquakes recorded at the Matsushiro Seismological Observatory, JMA, exceeded 6,000 and residents felt more than 600 shocks on the day of April 17, 1966. The earthquakes with an intensity of 4 to 5 on the JMA intensity scale, which corresponds to the intensity of 6 to 8 on the modified Mercalli intensity scale, occurred fifteen times in April and eleven times in May, some of them causing considerable damage to the town of Matsushiro and its environs. The daily frequency of earthquakes decreased gradually from June and it was expected that the activity might come to an end in a not-too-distant future. However, a strong earthquake took place in the northern part of Kôshoku, a town

¹⁾ The Party for Seismographic Observation of Matsushiro Earthquakes and the Seismometrical Section, Earthquake Research Institute, "Matsushiro Earthquakes Observed with a Temporary Seismographic Network. Part 1," Bull. Earthq. Res. Inst., 44 (1966), 309-333.

adjacent to Matsushiro, on August 3, following which event the daily frequency of earthquakes began to increase again until the activity reached its third peak.

During the first stage of activity in 1965, the felt earthquakes occurred in a circular area with a radius of a few kilometers, the center lying in the neighbourhood of Mt. Minakami. During the second stage of activity occurring in April and May 1966, the seismic area spread northwards to Wakaho, a town adjacent to Matsushiro. The third stage of

Table 1. Constants of Seismographs.

	Comp.	Seismographs			
Station		HES 1-0.2	Acceleration seismograph		
		V max	V	S (gal/mm)	
	E	50,000	220	2.3	
Hoshina	Ñ	10,000	210	2.2	
Hosiima	$egin{array}{c} \mathbf{N} \\ \mathbf{Z} \end{array}$	10,000	$\overline{210}$	$\overline{1.9}$	
	Ц	10,000	210		
	E N Z	50,000	220	2.2	
Zozan	N	10,000	220	2.1	
Lozan	7	10,000	220	1.8	
	Ц	10,000	220		
	F.	10,000	230	2.1	
Akashiba	N	10,000	230	2.3	
Akasiiiba	E N Z	10,000	220	1.8	
	Ц	10,000	220		
	E.	10,000	200		
Mori	N	10,000	$\frac{200}{200}$		
Mori	E N Z	10,000	200		
	<i>L</i>	10,000	200		
	Е	10,000	200		
NT	N	10,000	$\frac{200}{200}$		
Nagano	N Z	10,000	200		
	<i>L</i>	10,000	200		
	E	10,000	200		
Nire	N	10,000	$\frac{200}{200}$		
Nire	N Z	10,000	200		
	<u> </u>	10,000	200		
	E		200		
Naganuma	N	ļ	$\frac{200}{200}$		
Naganuma	N Z	1 1	200		
	E		200		
Sakaki	l Ñ		200		
Danani	E N Z			,	
				1	
	E	10,000	200		
Sanada	Ñ	10,000	200		
Danada	Ž	10,000	$\frac{1}{200}$		
				<u> </u>	
	E	10,000			
Toyono	N	10,000		1	
10,0110	\mathbf{z}	10,000			
		20,000	l		

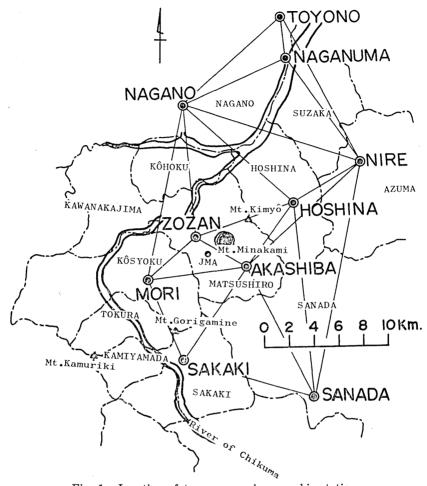


Fig. 1. Location of temporary seismographic station.

activity was felt in August and September 1966, the seismic area extended southwards to Kôshoku and Tokura and many earthquakes began to be felt in these towns.

On May 14, earthquakes of high intensity were felt several times in the neighbourhood of Ubasute, a small town 10 km southeastwards from Matsushiro, but further activity was not noticeable in this area.

The Earthquake Research Institute established more seismographic stations in this area counter-acting the spread of seismic activity since April 1966, Ten stations equipped with the HES 1-0.2 electromagnetic seismograph and the Ishimoto acceleration seismograph are now in operation as shown in Table 1 and Fig. 1.

The members of the Institute who participated in the field observation were: T. Hagiwara, S. Saito, I. Karakama, M. Watanabe, T. Watanabe, T. Takahashi and Y. Maeda, the members of the Institute engaged in interpretation and analysis of seismographs being: T. Hagiwara, T. Iwata, K. Makino, N. Kamata, M. Kino and Y. Miura.

Although the daily frequency of earthquakes generally has a tendency to decrease, the Matsushiro earthquakes are still active, strong shocks taking place occasionally, even at the end of September 1966, thirteen months since the original outbreak. Hence, in this paper, we shall compile the result of our observation carried out during the period from March to the end of August 1966 as the second report continuing our previous report.

1. Daily frequency of earthquakes at each station.

The daily frequency of earthquakes was counted on the seismographs at each station as shown in Fig. 2-6. Such frequencies read off from the acceleration seismograms correspond approximately to those of earthquakes felt by the residents, so that these frequencies were indicated as the daily frequency of felt earthquakes in the figures. The frequency of earthquakes recorded by the HES seismographs was indicated simply as the daily frequency of recorded earthquakes in the figures. The daily frequencies of recorded earthquakes and felt earthquakes announced from

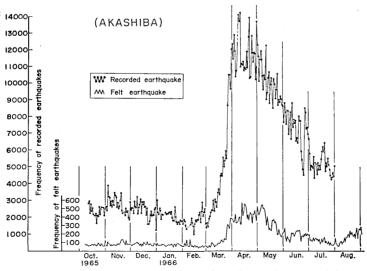


Fig. 2. Daily frequency of earthquakes observed at Akashiba.

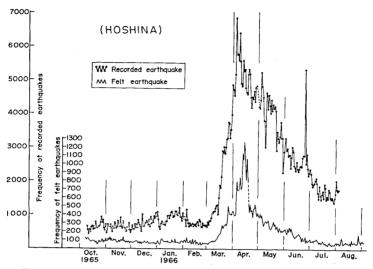


Fig. 3. Daily frequency of earthquakes observed at Hoshina.

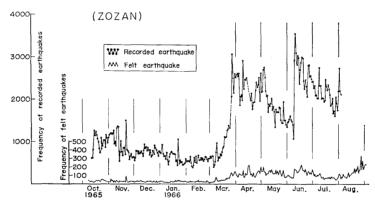


Fig. 4. Daily frequency of earthquakes observed at Zozan.

Matsushiro Seismological Observatory, JMA, are also shown in Fig. 7.

The daily frequency of earthquakes at Akashiba, Hoshina and Zozan increased remarkably from the middle of March 1966. On June 26, the daily frequency of earthquakes at Hoshina increased abruptly to 5292 while other stations did not show such an increase on that day. This phenomenon would have been caused by the local microearthquake activity in a limited area in the neighbourhood of Hoshina.

The acceleration seismograph at Hoshina was moved on April 20 to a slightly distant location. The location of the HES seismograph and the acceleration seismograph at Zozan were also relocated on June 10.

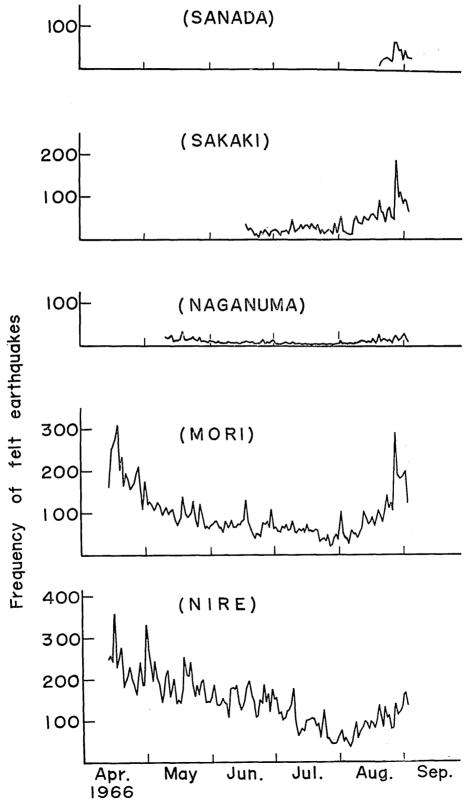


Fig. 5. Daily frequency of felt earthquakes observed at each station.

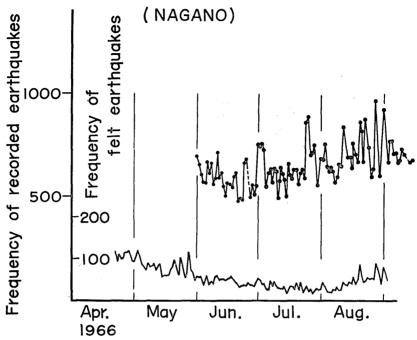


Fig. 6. Daily frequency of earthquake observed at Nagano.

The daily frequency of earthquakes at these station indicated in the figures shows a discontinuity on the day when the change of place of

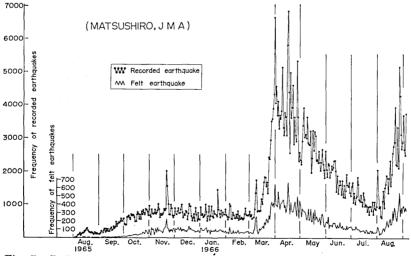


Fig. 7. Daily frequency of earthquakes observed at Matsushiro Seismological Observatory, JMA.

the instruments were made, that is to say, the daily frequency decreased greatly at Hoshina and increased greatly at Zozan after the instruments were moved. Such changes in daily frequency of earthquakes recorded on the seismographs are due to the effect of the structure of the ground on which the seismographs are placed.

The stations other than Hoshina, Akashiba, Zozan and Mori were established after April. The increase in the frequency of felt earthquakes observed at Mori and Sakaki shows evidently that the seismic area has spread to Kôshoku and Tokura.

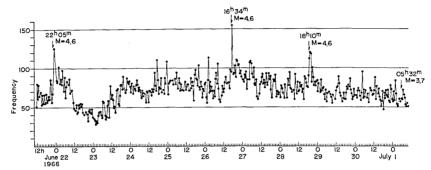


Fig. 8. Frequency of earthquakes at an interval from 0 to 10 minutes and from 30 to 40 minutes of each hour during the period from June 22 to July 1, 1966, counted on HES Seismogram of EW component at Hoshina Station.

Fig. 8 shows the change in the number of occurrences of small earthquakes before and after a large earthquake. The representation of the figure is the same as that written in our previous paper. The number of occurrences of small earthquakes has a tendency to increase to a greater or lesser extent just before the occurrence of a large earthquake. The number of occurrences of small earthquakes increases greatly following the occurrence of a large earthquake, just like ordinary aftershocks, but it decreases rapidly and returns to the average level in a few hours. This phenomenon is evident particularly in the case of an earthquake with magnitude larger than 4.0.

2. Hypocentral distribution of felt earthquakes.

The process of determination of the location of hypocenters has been described in the previous report.

Fig. 9-14 show the horizontal and vertical distributions of foci of felt earthquakes in each month. The general aspect of the earth-

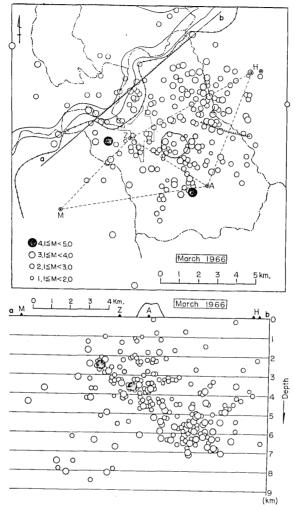


Fig. 9. Above: Epicentral distribution of the felt earthquakes.

Below: Vertical distribution of the felt earthquakes (Projected to the vertical plane a b).

quake activity after March 1966 can be outlined from these figures as in the following.

Activity in March (Fig. 9). An earthquake swarm occurred within a distance of a few kilometers from Mt. Minakami (642 m above sea level) continuing until February 1966, however, in March the activity became noticeable in and near Hoshina. The earthquakes clustered at a depth of $5\sim 6\,\mathrm{km}$ near Mt. Kimyô. (1099 m above sea level). The earthquakes

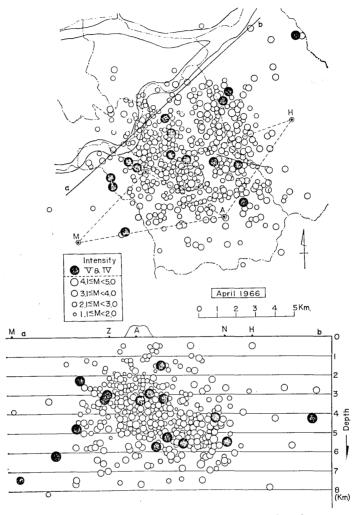


Fig. 10. Above: Epicentral distribution of the felt earthquakes.

Below: Vertical distribution of the felt earthquakes (Projected to the vertical plane a b).

that have been occurring since February in the neighbourhood of Mori in Kôshoku city at a depth of $8{\sim}9\,\mathrm{km}$ began to spread to a shallower position in March.

Activity in April (Fig. 10). The epicenters gathered in two groups near Mt. Minakami and near Mt. Kimyô. The large earthquakes (M>4.0) occurred without exception in the southern part of Mt. Minakami until March but many large earthquakes began to occur in the

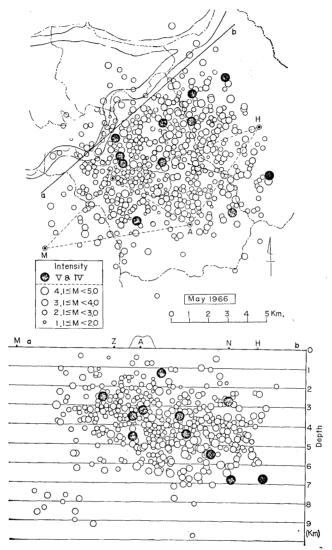


Fig. 11. Above: Epicentral distribution of the felt earthquakes.

Below: Vertical distribution of the felt earthquakes (Projected to the vertical plane a b).

northern part of Mt. Minakami in April. The earthquake which gave maximum intensity of 4 on the JMA scale occurred in the eastern part of Kôshoku for the first time during this month. Earthquakes clustered in the area where the population of Matsushiro is dense. The seismic area extended to the River of Chikuma.

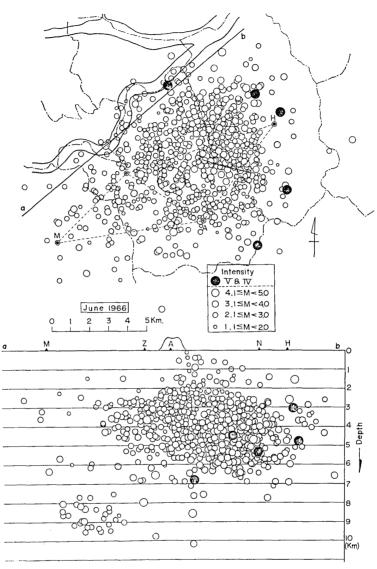


Fig. 12. Above: Epicentral distribution of the felt earthquakes.

Below: Vertical distribution of the felt earthquakes (Projected to the vertical plane a b).

Activity in May (Fig. 11). The two groups of the epicenters which were recognized in April disappeared and the epicenters distributed uniformly from Matsushiro to Wakaho. Many earthquakes occurred in the northern part of Mt. Minakami. The large earthquakes had a



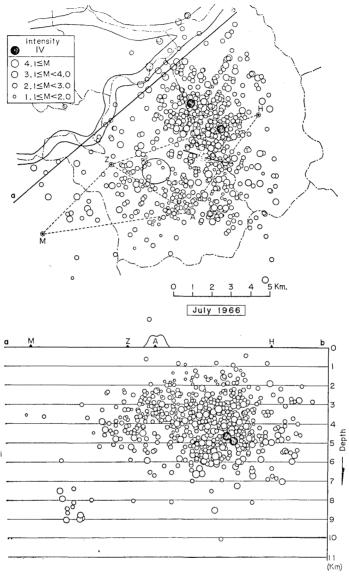


Fig. 13. Above: Epicentral distribution of the felt earthquakes. Below: Vertical distribution of the felt earthquakes (Projected to the vertical plane a b).

tendency to take place near the border of the cluster of smaller earthquakes.

Many earthquakes began to occur in the southwest part of Matsushiro

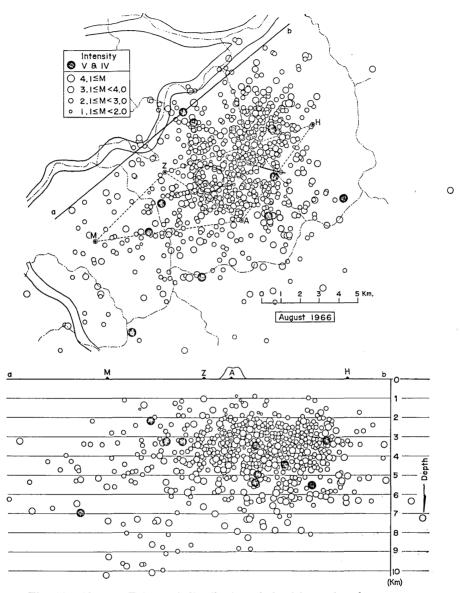


Fig. 14. Above: Epicentral distribution of the felt earthquakes.

Below: Vertical distribution of the felt earthquakes (Projected to the vertical plane a b).

and in the eastern part of Kôshoku. Seven shocks with considerable intensity occurred near Mt. Kamuriki 10 km from Matsushiro in the interval from 19^h on 14th to 06^h on 15th May. The shock which occur-

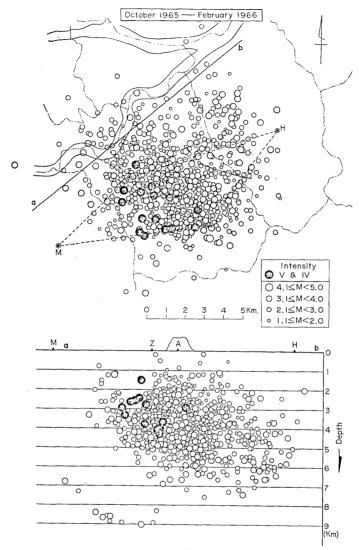


Fig. 15. Above: Epicentral distribution of the felt earthquakes during the period from October 1965 to February 1966.

Below: Vertical distribution of the felt earthquakes during the

period from October 1965 to February 1966 (Projected to the vertical plane a b).

red at $20^{\rm h}32^{\rm m}$ on 14th was the strongest, its magnitude being estimated at 4.2.

Activity in June (Fig. 12). The earthquakes which have been crowding

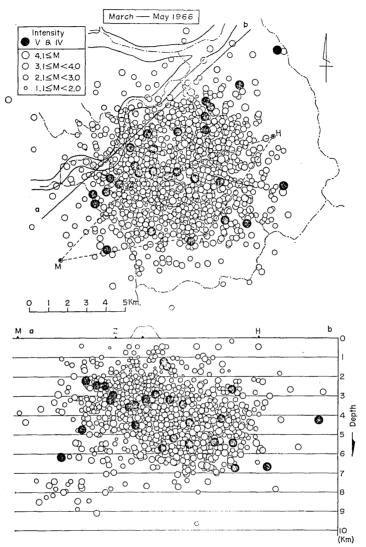


Fig. 16. Above: Epicentral distribution of the felt earthquakes during the period from March to May 1966.

Below: Vertical distribution of the felt earthquakes during the period from March to May 1966 (Projected to the vertical plane a b).

near Mt. Minakami since the outbreak began to decrease in number and in contrast many earthquakes began to cluster near Mt. Kimyô. On the other hand, the earthquakes at a depth of $8 \sim 9 \,\mathrm{km}$ near Kôshoku became noticeable. The large earthquakes occurred at the border of the

earthquake cluster near Mt. Kimyô. The seismic area spread slightly.

Activity in July (Fig. 13). The earthquakes mostly clustered at Mt. Kimyô and Akashiba. The earthquakes in the dense population area of Matsushiro decreased in number.

Activity in August (Fig. 14). Many earthquakes occurred near Mt. Minakami. The seismic activity spread to Kôshoku, Tokura and Sanada. The area where many felt earthquakes occurred was of elliptical form with a major axis lying in a northeastward direction, the large earthquakes occurring near the border.

Fig. 15 shows the epicentral distribution of noticeable felt earth-quakes that occurred during the period from October 1965 to February 1966. Fig. 16 shows the epicentral distribution of the same kind for the period from March to May 1966. Comparing these two figures, it is noticed that the seismic active area spread with an elapse of time and the location where the large earthquakes occurred moved from place to place.

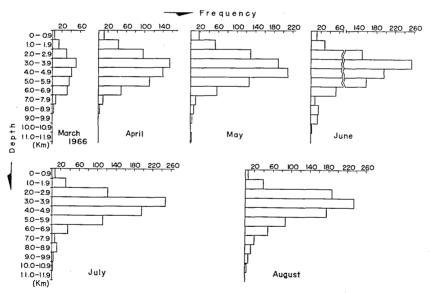
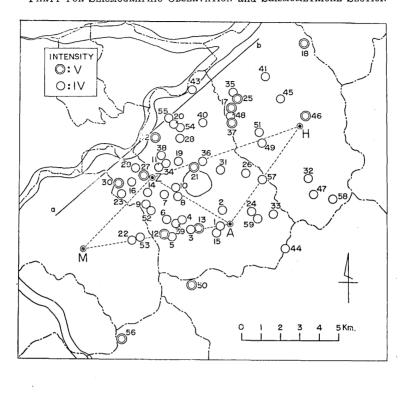


Fig. 17. Frequency distribution of the depth of felt earthquakes.

Fig. 17 shows the depth distribution of the felt earthquakes in each month. The depth from 3.0 to 5.9 km was most frequent.

3. Hypocenters of the large earthquakes.

The horizontal and vertical distribution of the large earthquakes



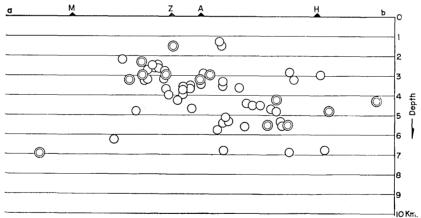


Fig. 18. Above: Epicentral distribution of the Matsushiro earthquakes that gave maximum intensity larger than IV during the period from November 1965 to August 1966.

Below: Vertical distribution of the Matsushiro earthquakes that gave maximum intensity larger than IV during the period from November 1965 to August 1966 (Projected to the vertical plane a b).

Table 2. Remarkable shocks among the Matsushiro earthquakes.

Damage		第一報参照		石がき約 3m くずれる (岩穂, 山笋田地区) 土蔵の壁くずれる (松代, 西条地区)家居の一部破損約 100 戸 (岩穂)一人負傷, 豊栄小学校壽堂の壁が大きくき裂 (松代)千田川堤防約 300m にわたりき裂 (松代, 西寺尾地区)	家屋破損,電線,、電話線切断,道路き勢,水道管破裂など79件(松代,篠ノ井,更埴) 壁落下,ガラス窓破損(更級郡, 更北村真島, 青木島) 屋根の頂上が落ちる. 被害3件(松代) 落石による重傷一人 また窓 - 344年98件 - 124年12年12年12年12年12年12年12年12年12年12年12年12年12年	型, 足成ハンハ宿18日) 217件 (更道) 33件など11件 (篠ノ井) 1被害 9件 (岩穂)
М				4.5.1. 4.5.5.	444.5 5.0 0.0	4444 7.44662
Depth				4.2 4.3 1.5 1.5	6.64 6.65 6.65 6.65 6.65 6.65 6.65 6.65	0.000000 0.000000
Maximum Intensity	N N N N N N N N N N N N N N N N N N N	22222	N > > N	200	>5 N N N N N N N N N N N N N N N N N N N	N>NN
Hour	344 30 30 30 30	57 113 43 59	2005 28 28 28 28	222223	28238	2862482
H	22333 _b	242 133 133 133 133 133 133 133 133 133 13	22242	05 17 04 04	08 08 12 10 10	22222
Date	1965 Nov. 04 13 21 22	23 24 Dec. 09 1966 Jan. 03	08 23 Feb. 07 Mar. 08	10 Apr. 01 05	14 16 17	
No.	H000410	6 8 9 10	1122 123 144 151	16 17 18 19 20	22 23 22 23 25 25 25 25 25 25 25 25 25 25 25 25 25	22 22 30 30 30

Remarkable shocks among the Matsushiro earthquakes. (continued) Table 2.

Damage	棚から物が落ち, 時計がとまる程度(松代) 石がきの崩壊屋根ガワラの落下など(若穂)	【負傷者3人,家屋一部破損14件,非住家被害7件,山くずれ5件,へいの倒壊 【4件,堤防被害2件,石がき前壊1件(長野) 石がき高さ5m 幅 5m 崩れる(保科)	石がきの崩壊,民家の壁の崩れなど (松代) 材木の倒れにより1人負傷,がけ崩れなど 42 件 (松代) 石がきの崩壊,国民宿舎の窓の破損など 9 件 (保科)	水道管の破裂, 屋根ガワラの落下, 石がきの崩壊(岩組) 壁, 石がきの崩壊4件(松代, 岩組, 更植) 家屋全壊1件(更進) 約180件の被害届(松代)	5がきの崩壊など 22 件 (保科) 5がき 7 個落下,松代署会議室の壁,農家,土蔵 (代) 皮損など (松代)	医セグン、医セガソラの加燥、ガラスの破損、物質の倒壊、石がきの崩れなど (更植 246 件、戸倉町 1,227 件、上山田町 15 件、松代 41 件) 壁の落下 (岩穂) 壁の落下、道路のき裂など (松代)
M	4444 7.5.7.7.6.6	44444	4444 6.64 6.64 7.64 7.64	3.4 3.7 5.0 5.0	4444	4.6 4.3 5.8
Depth	10 00 00 00 00 00 00 00 00 00 00 00 00 0	1.3 2.7.4 4.5 4.5	86.4.88 8.5.7.80	477448 8.6.7-8.6	35.1.25 3.1.1.25	7.0 3.5 5.4 5.4
Maximum Intensity	NNNN	Z>ZZ	NN	> 7	77 77 7	7777
Hour	44 0 44 0 45 0 45 0 48 9 08	1 51 28 30 25 57 52 03 57 57	12 28 14 21 12 05 09 43 22 05	6 34 5 32 5 44 3 48	09 37 04 05 18 42 19 50 19 50	13 09 00 36 10 37 13 37
	28 14 02 00 04 10 06 19	19 21 22 22 17 25 05 27 22 22 22 22 22 22 22		26 16 28 18 01 05 10 15 03 03	08 14 16 16 16 16 16 16 16 16 16 16 16 16 16	28 13 29 00 31 13
Date	1966 Apr. 2 May C	r-1 64 64 64 64	28 June 11 12 21	July (Aug. (3.04
No.	32 33 35 35	36 33 39 40	42524	44 48 50	52 53 54 55	56 58 59

which gave a maximum intensity larger than 4 on the JMA scale are shown in Fig. 18. The numerals indicated in the circles in the figure are the numbers given to the earthquakes in the order of occurrence and correspond to the numbers in Table 2. As seen in the figure the focal depth of the large earthquakes was in the range from 1.3 km to 7.0 km, most of them being around 3 km.

4. Release of energy.

The cumulative sum of energy released by the Matsushiro earthquakes since the beginning was 1.21×10^{21} ergs through August 31, 1966 (Fig. 19). This value is equal to the energy released by a single earthquake of magnitude 6.2.

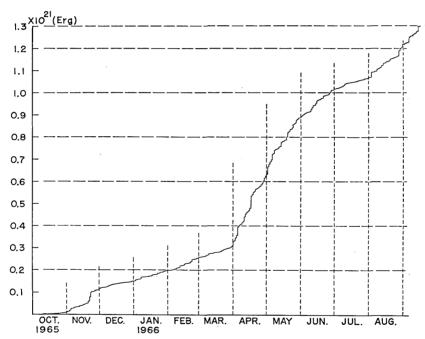


Fig. 19. Cumulative sum of energy released by the Matsushiro earthquakes.

Variation of m and b.

We examined the values of m and b in each month. m is the coefficient in the statistical formula called Ishimoto-Iida's relation which gives the relation between the number of occurrences and maximum trace amplitude. b is the coefficient of the statistical formula given by Richter and Gutenberg for the relation between the number of occurrences and the magnitude M. Fig. 20 shows the variation of the values

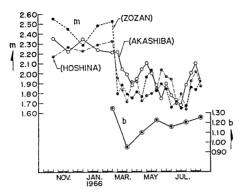


Fig. 20. Time variation of the values m and b.

of m and b obtained from the acceleration seismograms at Akashiba, Hoshina and Zozan. The process of obtaining these values has been explained in our previous report. As seen in the figure, the values of m were larger than 2.1 at each station up till February 1966 but apparently decreased after March. The values of b showed the same tendency.

6. Push-pull distribution of initial motions.

The push-pull distribution of initial motions of the Matsushiro earth-quakes of large magnitude as determined from the ordinary wide seismological network under JMA has been reported by JMA²). According to this report, the distribution is of the quadrant type, the nodal lines inclining by 45° from the meridian.

We examined the same matter with respect to smaller earthquakes observed at our temporary stations, Hoshina, Akashiba and Zozan. For this purpose we used the acceleration seismograms obtained at these stations during the period from May 1 to June 10, 1966. The push-pull distributions of different earthquakes were superimposed together, the epicenters put at a common point. If the mechanism of earthquakes is the same for all earthquakes, the distribution obtained by such a method may give a certain configuration. Fig. 21 shows push-pull distribution obtained by this method with respect to earthquakes deeper than

²⁾ Report of Matsushiro Earthquake published by Tokyo Meteorological Observatory and Nagano Local Meteorological Observatory (in Japanese), January, 1966.

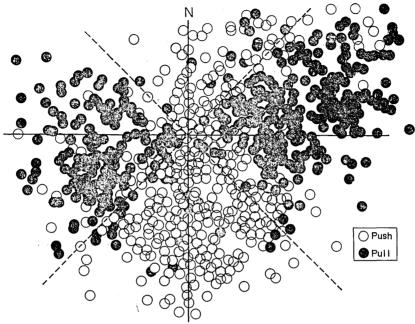


Fig. 21. Push-pull distribution of the initial motions of the Matsushiro earthquakes.

3 km. As seen from the figure, we may regard the push-pull distribution of smaller earthquakes as being of the same type as that of large earthquakes determined by the JMA network. The same result has been obtained with respect to the small earthquakes that occurred during the period from October 1965 to January 1966, this having been mentioned in our previous report.

Hence, we may conclude that, so far as the push-pull distribution is concerned, the mechanism of the Matsushiro earthquakes did not alter throughout the whole period.

Résumé 7.

- 1) The area where the felt earthquakes occurred was situated at Matsushiro and Wakaho up till April 1966. The area spread to Kôshoku from May 1966.
- 2) The area spread out southwestward and many felt earthquakes took place at Sakaki, Tokura and Kamiyamada. An earthquake of magnitude 5.0 took place near Mt. Gorigamine on August 28, 1966. This was the furthest south among large ones of the Matsushiro earthquakes.

- 3) The epicentral area where felt earthquakes occurred is of elliptical form with a major axis lying in the direction from northeast to southwest and is 20 km long with a minor axis 12 km long lying in the direction from northwest to southeast through August 1966.
- 4) The earthquakes in the neighbourhood of Mori occurred at a depth from 8 to 10 km in May, June and July 1966 but a group of shallower earthquakes appeared at the depth $4.0\sim6.0$ km in August 1966.
- 5) The cumulative sum of energy released by the Matsushiro earth-quakes in thirteen months since the outbreak up to August 1966 is 1.21×10^{21} ergs, which corresponds to the energy released by a single earthquake of magnitude 6.2.
- 6) The push-pull distribution of initial motions of the Matsushiro earthquakes was of quadrant type and did not change its character throughout the whole period.

79. 臨時地震観測網による松代地震群の調査結果 (第二報)

地震研究所 地震 観測 班地震 計測部

1965 年 8 月 3 日に始まる松代町附近の群発地震は、 その年の 11 月下旬に第 1 期のピークと称される地震活動の一つの山があり、その後、1966 年 3 月中旬までは震度 IV 級の地震が月に $2\sim3$ 回程度発生したが、毎日の地震回数は概ね横ばい状態を示した。

しかし、3月中旬以降再び地震活動は活潑となり、第2期の活動に入つたのである。

ことに、4 月と5 月の活動は激しく、4 月には震度 IV と V の地震が、あわせて15 回発生し、引続いて5 月には同級の地震が11 回起り、これに伴ない毎日の地震回数は最高頂に達し、これら大きな地震による被害も、松代町のほか、若穂町をはじめとして周辺の市町村にまで及んだ。

6月以降,地震回数は暫時減少傾向をみせて,このまま終局に向うもののように思われたが,8月3日の震度Vの地震を契機に再び地震活動は活潑となり,第3期の活動とみられるに至つた.

有感地震の起る区域は、前年の第1活動期の頃は、皆神山を中心に半径数 km 程度であつたが、第2活動期に至り松代町北方の若穂町方面にも拡大した。さらに、第3活動期には松代町南方の更埴市方面にも多数の有感地震が発生するようになつた。

また,5月14日には更級郡冠着山(姨捨山)附近に震央を有する有感地震が多発したが,その後の 統発はみられなかつた.

地震研究所では、1966 年 4 月以降の震域拡大に伴ない、それまでの観測点(松代町象山、同町赤柴、若穂町保科および更埴市森)に加えて、東村仁礼、長野市平柴、同市長沼、上水内郡豊野町、埴科郡坂城町および小県郡真田町にそれぞれ、HES 1-0.2 型地震計や加速度地震計を設置した(詳しくは Table 1 と Fig. 1 を参照).

また、地震気象の読取、解析を迅速化するために、長野県上田市内に臨時地震計測分室を設け、これは4月20日から6月25日まで続けた。

今回の地震観測に参加した者は次の通りである.

萩原尊礼, 斎藤貞夫, 唐鎌郁夫, 渡辺政雄, 渡辺唯夫, 高橋辰利, 前田良弘.

また, 地震記象の読取, 解析には次の者が当つた.

萩原尊礼,岩田孝行,牧野和子,鎌田憲子,木野みさ子,三浦義治.

松代群発地震が始つて以来, 気象庁の報告によれば, 8月31日までに至る約13ヶ月間に, 松代町 西条の気象庁地震観測所で観測された地震総回数は 472,756 回, 有感地震総回数は 50,371 回である.

9月上旬に入り、地震回数は徐々に減少しつつあるが、ときどき震度 Ⅳ または V の地震が発生し、 皆神山附近の土地変動量も大きく、9月末現在地震活動は、なお当分続きそうな状態である。

今回は,第 1 報(1965 年 10 月~1966 年 2 月)—地震研究所彙報第 44 号第 1 冊 309 頁~333 頁- に 続いて、1966年3月から8月31日までの調査結果を第2報として報告することとした。

1. 各観測点における地震问数

有感地震回数は加速度地震計記象から、それより小さい地震 (無感級) は HES 1-0.2 型地震計 (NS 成分, V_{max}.=10,000) 記象から集計した.

これらの地震回数を Fig. 2~6 に, また,参考資料として, 気象庁松代地震観測所の標準地震計 (Vmax.=100,000) による地震回数を Fig. 7 に示す.

赤奘、保科および象山における地震回数は、いずれも、3月中旬から著しい増加を示している。こ れは4月の地震活動の前駆といえよう。また、6月26日に保科のみ地震回数が急激に増し5,292回と いう大きな値を示したが、これは保科近辺で極めて局地的な微小地震活動が起つたことによるものと 思われる.

図中の点線による接続個所は欠測の部分である。

また,保科の加速度計は4月20日に,象山の HES型と加速度計は6月10日にそれぞれ現地の事情 により移転を行なつた。この時を境にして保科では地震回数が減少し、象山では逆に地震回数が増加 しているが、これは地盤の軟弱の影響によるものである.

保科,赤柴および象山以外の測点は、いずれも4月以降に設置した。これらの測点のうち、森およ び坂城における有感地震回数の増加は、更埴市から戸倉町方面に震源が拡大したことによる影響を顕 著に示している.

Fig. 8 は大きな地震の前後における地震回数の変化であるが、第1報に報告したときと全く同様 な方法で表示してある. すなわち, 大きな地震の前に多少の増加がみられ, また, 大きな地震の直後 に余震に相当する回数増加もみられるが、急速に元の値に近い回数にもどる。このことは、 M=4.0以上の地震の場合に明瞭に現われる。

2. 有感地震の震源分布

震源決定の方法については、すでに第1報に述べているので省略する.

Fig. 9~14 は月別の震央分布と震源の鉛直分布である。 各月別について, その特徴を述べると, 3月の活動 (Fig. 9) 1966 年 2 月頃までは皆神山の周辺数 km の範囲で多発していたが, 3 月以降 は保科方面の活動が目立ち、奇妙山の直下、5~6km に一群となつて集中している。また、2月頃か ら更埴市森附近の深さ 8~9 km の所で起つていた地震が、やや浅い所でも起る傾向をみせた.

- 4月の活動 (Fig. 10) 震央分布は若穂町保科群と皆神山群の二つに分れていることがはつきり見え る。3 月以前には大きな有感地震 (M=4.0 以上) は,すべて皆神山南部に発生したが,4 月になると 大きな地震の発生域は皆神山北部が圧倒的に多くなる. また, 更埴市東部の山中で震度 IV の地震が 初めて起き、松代町附近から千曲川沿岸に多数の地震が発生した.
- 5月の活動 (Fig. 11) 4月にみられた二つの地震グループはなくなり、松代町一帯から奇妙山にか けて一様に分布するようになつた。大きな地震は相変らず皆神山北部に多く、小さい地震の発生地域 の周辺に発生する傾向がある。この月には地震は松代町南西部から更埴市東部にも多発するようにな

また, 14 日 19h00m から 15 日 06h00m までの間に, 冠着山 (姨捨山) 附近に震源を有する有感地 震が7回発生し,このうち,14日 $20^{
m h32^m}$ の地震は $M{=}4.2$ 程度で,国鉄篠井線の冠着駅では震度 Ⅳ 位の体感があり、棚から物が落ちたといわれる.

6月の活動 (Fig. 12) 皆神山附近の地震が減少し、奇妙山附近に多く発生する一方、更埴市方面の 深い地震 (8~9 km) が目立つて多くなつた. 大きな地震は奇妙山附近の地震多発区域の外側に発生 し, 震央分布の範囲がやや拡大した.

7月の活動 (Fig. 13) 地震は奇妙山附近と赤柴附近に大部分が集中し、松代町市街地附近では極めて少なくなつた。

8月の活動 (Fig. 14) 皆神山周辺の活動が活潑で, 更埴市, 戸倉町および真田町へと震源の拡がりが目立つ.

いずれも大きな地震は、震源域の外側で発生し、有感地震の発生域は、北東一南西の方向に長軸を 持つ楕円型となる.

Fig. 15 は 1965 年 10 月から 1966 年 2 月まで,Fig. 16 は 1966 年 3 月から同年 5 月までの期間に起った主な有感地震の震央分布である.両図を比較して明らかにわかることは,震源域の拡がったことと、大きな地震の発生する場所がちがったことである.

Fig. 17 は有感地震の深さの月別頻度分布であるが、 $3.0\sim5.9\,\mathrm{km}$ のものが最も多い.

3. 大きな地震の震源

今年 8 月 31 日までに発生した震度 IV 以上の地震の分布を示したものが Fig. 18 である。数字は発生の順を示す番号であり、この番号は Table 2 の番号に対応する。なお、欠測のため震源を求められなかつた地震については報告してない。

大きな地震の震源の深さは $1.3\sim7.0\,\mathrm{km}$ の範囲にあるが、 $3\,\mathrm{km}$ 前後のものが最も多い.

4. 放出エネルギー

地震波として放出されたエネルギーの積算値は、1966 年 8 月 31 日現在で 1.21×10^{21} erg となる。この量は、ほぼ、M=6.2 の地震 1 発分に相当する (Fig. 19). また、震源位置を求めてない小さい地震 (震度 I 以下) については、 $P\sim S$ と振幅を読取り、これよりエネルギーを推定した。

5. 石本・飯田の係数 m と b の推移

m と b の定義については第1報に述べてあるので省略する。 Fig. 20 は赤柴,保科および象山における加速度計記象から m と b を求め,これらの推移を示したものである。

m については、3 地点の値ともに m=2.1 より大きな値が 2 月まで続き、3 月以降はそれより小さい値となる。

m と b の推移は同じ傾向である. なお, b については M=2.5 以上の地震を対象とした.

6. 押し一引き分布

Fig. 21 は,5月1日から6月10日までの赤柴,保科および象山の加速度計記象について,第1報に述べたと同じ方法により,押し一引き分布を調べたものであるが,深さ3km より浅い地震は除いてある。第1報の調査のときは,保科側の地震を除いてあつたが,今回はこれも含めてある。

得られた結果は、前回に得た分布と全く同様の象限の分布を示している。したがつて、保科附近の 地震についても発震機構は同様であることが判明した。

7. 総括

以上述べたことを総括すると,

- 1) 有感地震の震央分布は,1966年4月までは松代町と若穂町にあつたが,5月以降は松代町,若穂町のほかに, 更埴市方面に拡大した.
- 2) 8月にはさらに南西方向にのび、坂城町、戸倉町および上山田町にも分布し、8月28日には、五里ヶ峰附近に震度 V(M=5.0) が発生した。大きな地震では、これが最南部である。
- 3) 8月現在の有感地震の震央域は、皆神山を中心に北東一南西の方向に約 20 km, 北西一南東の方向に約 12 km の長楕円形である。
- 4) 5 月, 6 月, 7 月には森附近の地震は、深さが $8.0\sim10$ km であつたが、8 月になると深さ $4.0\sim6.0$ km と、 $8.0\sim10$ km の二つの群になる。
- 5) 8月31日までに地震波として放出されたエネルギーの積算値は、 1.21×10^{21} erg となる。この量は M=6.2 の地震1発分に相当する。
- 6) 松代地震群の押し一引き分布は、象限型であり、これまでの期間を通じてその型は変化していない。