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11. *Matsushiro Earthquakes Observed with a Temporary Seismographic Network. Part 3.*

By the Party for Seismographic Observation
of Matsushiro Earthquakes
and
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The Matsushiro earthquake swarm commenced in August 1965, the activity reaching the first peak in November 1965, the second peak of the activity taking place in the period from March to May in 1966. Subsequently the daily frequency of earthquakes seemed to gradually decrease. However, the third peak of the activity occurred unexpectedly in the beginning of August 1966. The activity was most violent in August, the earthquakes with the intensity larger than IV on JMA scale occurring ten times in this month. Earthquakes with the intensity of IV occurred twice in the same day on 20th and 29th respectively. Earthquakes with the intensity larger than IV took place 7 times in September and 5 times in October 1966. The earthquake on 26th 03 h 04 m October was the greatest in magnitude among those which have occurred in this area since the beginning of the forementioned earthquake swarm. The magnitude of this earthquake was reported to be M=5.1 by JMA (Japan Meteorological Agency). Dwelling houses were partially damaged, cracks were created on the roads and stone-fences fell down in the villages near the epicenter. There was some damage to glass windows in the city of Nagano. In November 1966, no large earthquakes occurred and the frequency of small earthquakes also decreased.

This paper will describe the observational results of the felt earthquakes during the period from September to November 1966 as the third report, following our previous papers.[1)2)]

1) "Matsushiro Earthquakes Observed with a Temporary Seismographic Network, Part 1," *Bull. Earthq. Res. Inst.*, **44** (1966), 309-333.

2) "Matsushiro Earthquakes Observed with a Temporary Seismographic Network, Part 2," *Bull. Earthq. Res. Inst.*, **44** (1966), 1687-1741.

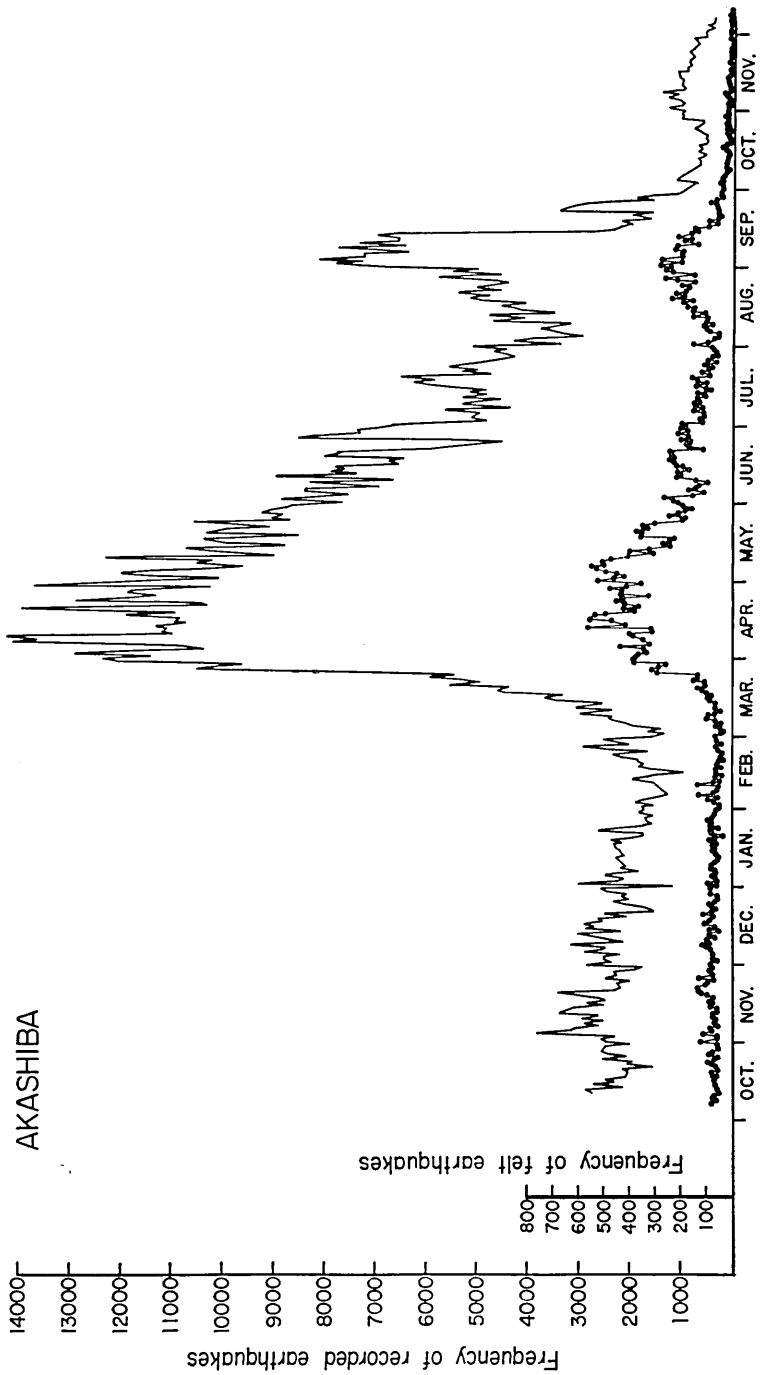

Fig. 1. Daily frequency of earthquakes observed at Akashiba.

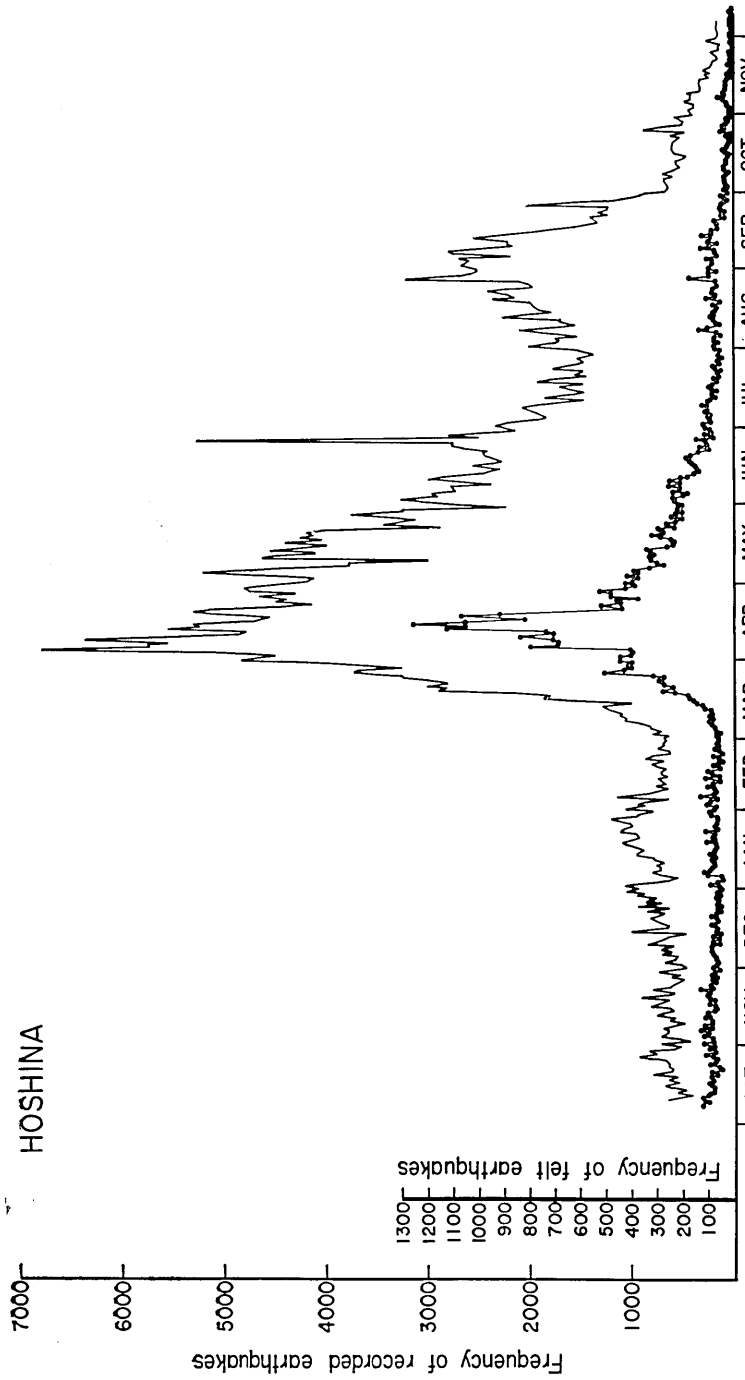

Fig. 2. Daily frequency of earthquakes observed at Hoshina.

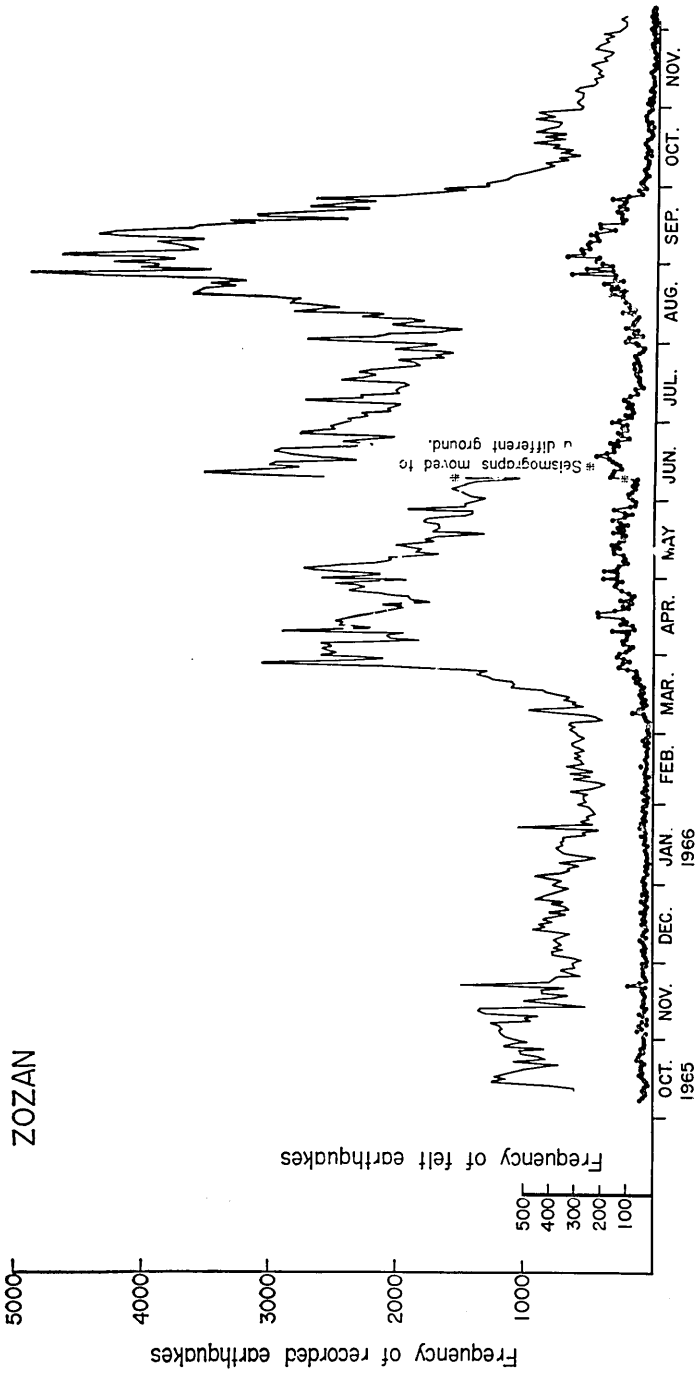

Fig. 3. Daily frequency of earthquakes observed at Zôzan.

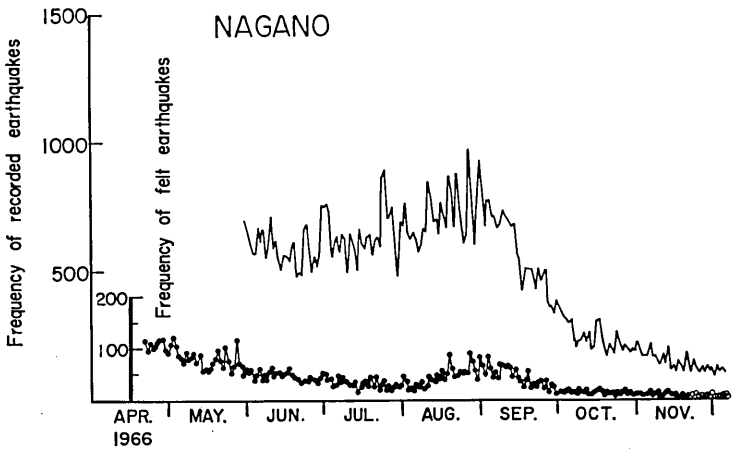

Fig. 4. Daily frequency of earthquakes observed at Nagano.

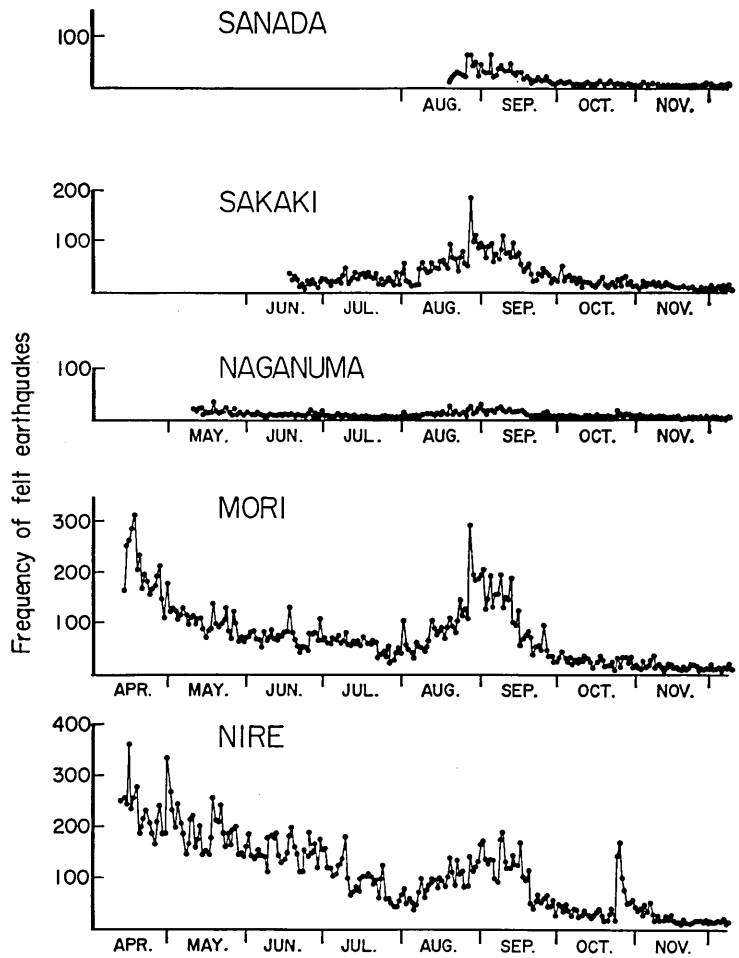

Fig. 5. Daily frequency of the felt earthquakes observed at each station.

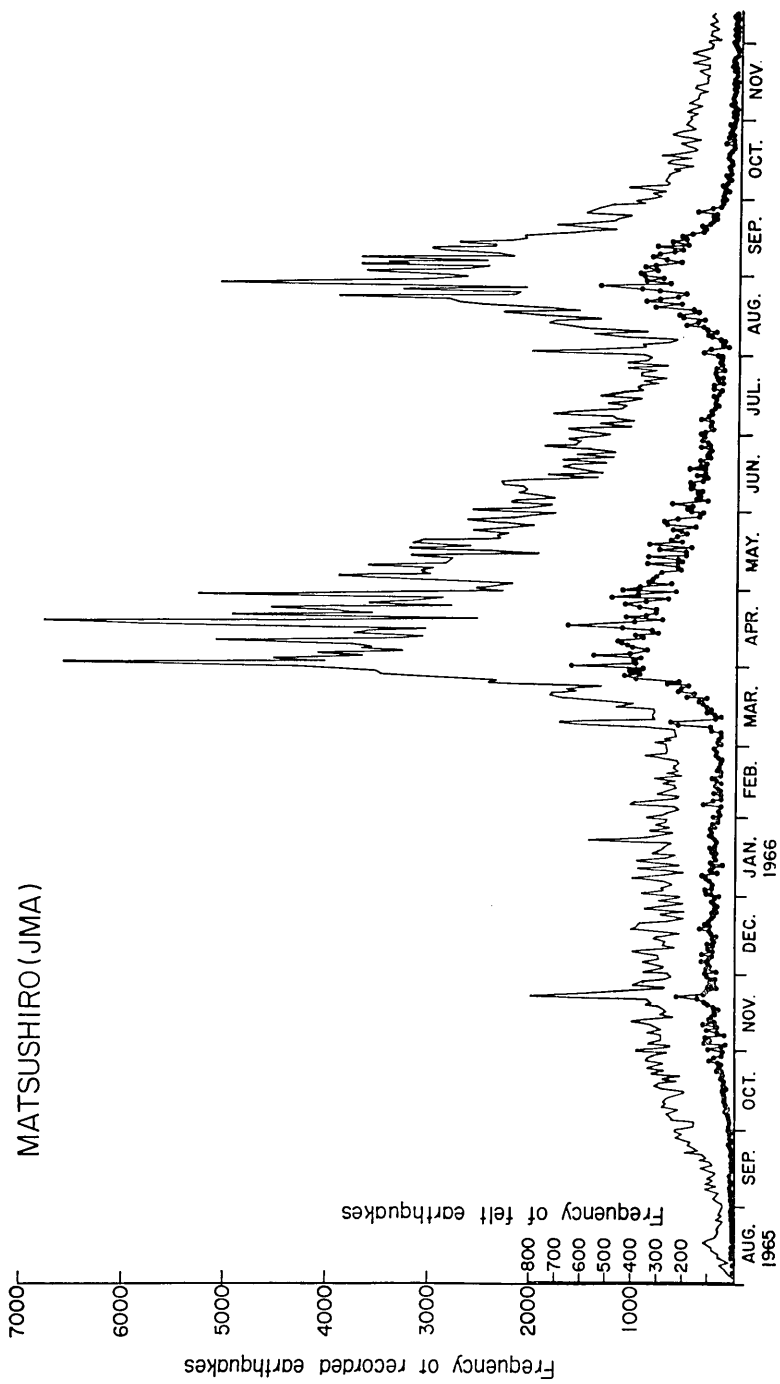

Fig. 6. Daily frequency of earthquakes observed at Matsushiro (JMA).

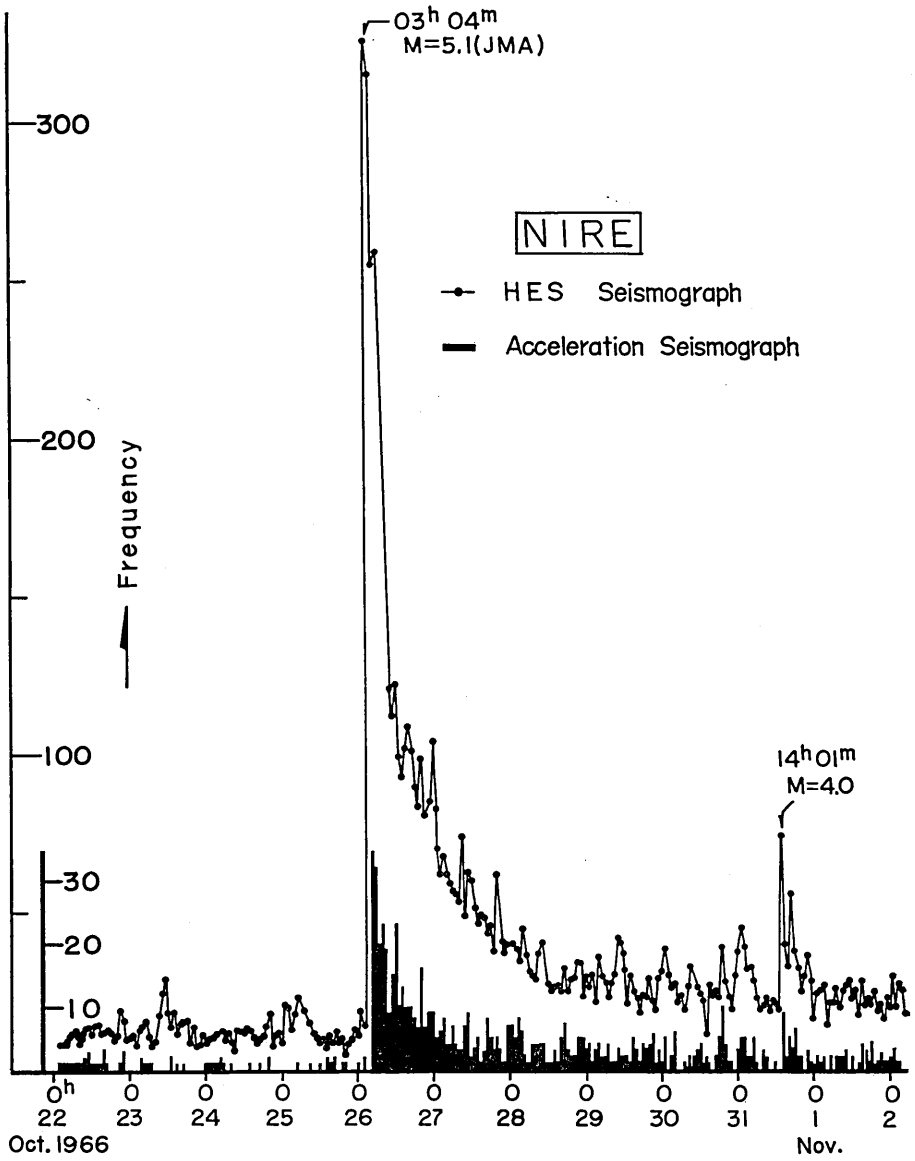

Fig. 7. Hourly frequency of earthquakes with P-S interval less than 1.2 sec recorded by the acceleration seismograph and HES seismograph at Nire before and after the strong earthquake.

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 the interpretation and analysis of seismograms being:

T. Hagiwara, T. Iwata, K. Makino, N. Kamata, M. Kino and Y. Miura.

1. Daily frequency of earthquakes at each observation point.

The daily frequency of felt earthquakes was determined from the acceleration seismograms. The daily frequency of earthquakes including very small ones was counted on the seismograms of NS component of the HES 1-0.2 seismographs ($T_1=1$ sec, $T_2=0.2$ sec, $V_{max}=10{,}000$) at each point.

These frequencies are shown in Figs. 1～5. The daily frequency of earthquakes reported by the Matsushiro Seismological Observatory of JMA is also indicated in Fig. 6. Although the frequency of earthquakes differs very much at each observation point, the tendency of increase and decrease was quite similar.

The daily frequency of felt earthquakes observed at Nire shows an abrupt increase on 26th October. This is due to the small aftershocks following a strong earthquake which occurred at 03 h 04 m in the same day with magnitude of 5.1 giving the intensity V on JMA scale to the village of Azuma-mura.

Fig. 7 shows the hourly frequency of earthquakes with P-S interval less than 1.2 sec recorded by the acceleration seismograph and the HES seismograph at Nire before and after the strong earthquake. At a glance over the figure, we find that there was no evident increase of small earthquakes called foreshocks just before this strong earthquake.

2. Hypocentral distribution of felt earthquakes.

The horizontal and vertical distribution of main felt shocks during the period from September to November 1966 are shown in Figs. 8～10. The earthquakes with intensity larger than IV on JMA scale which corresponds to IV on the modified Mercalli scale are listed in Table 1. The number was given to the large earthquakes in the order of occurrence and it is common to the figures and the table. Earthquakes with

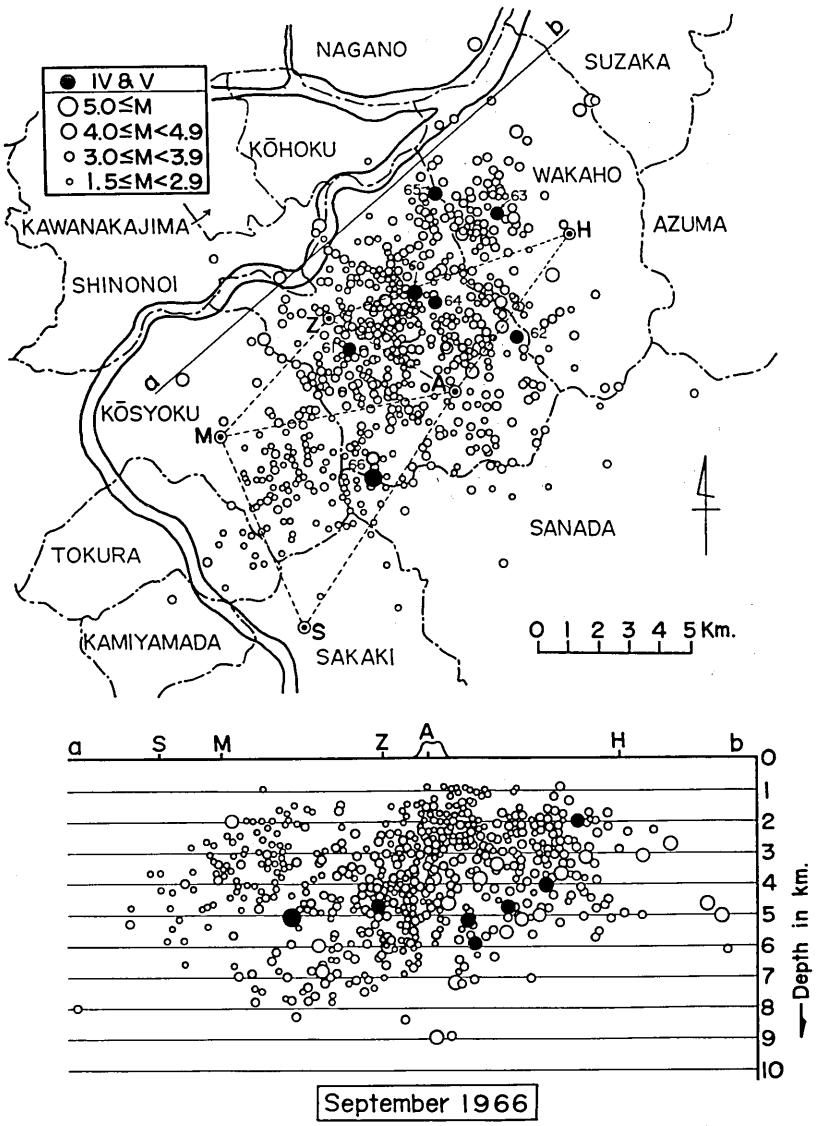

Fig. 8. Above: Epicentral distribution of the felt earthquakes.
Below: Vertical distribution of the felt earthquakes.
a-b: Plane of projection, H: Hoshina, Z: Zôzan, M: Mori,
A: Akashiba, S: Sakaki.

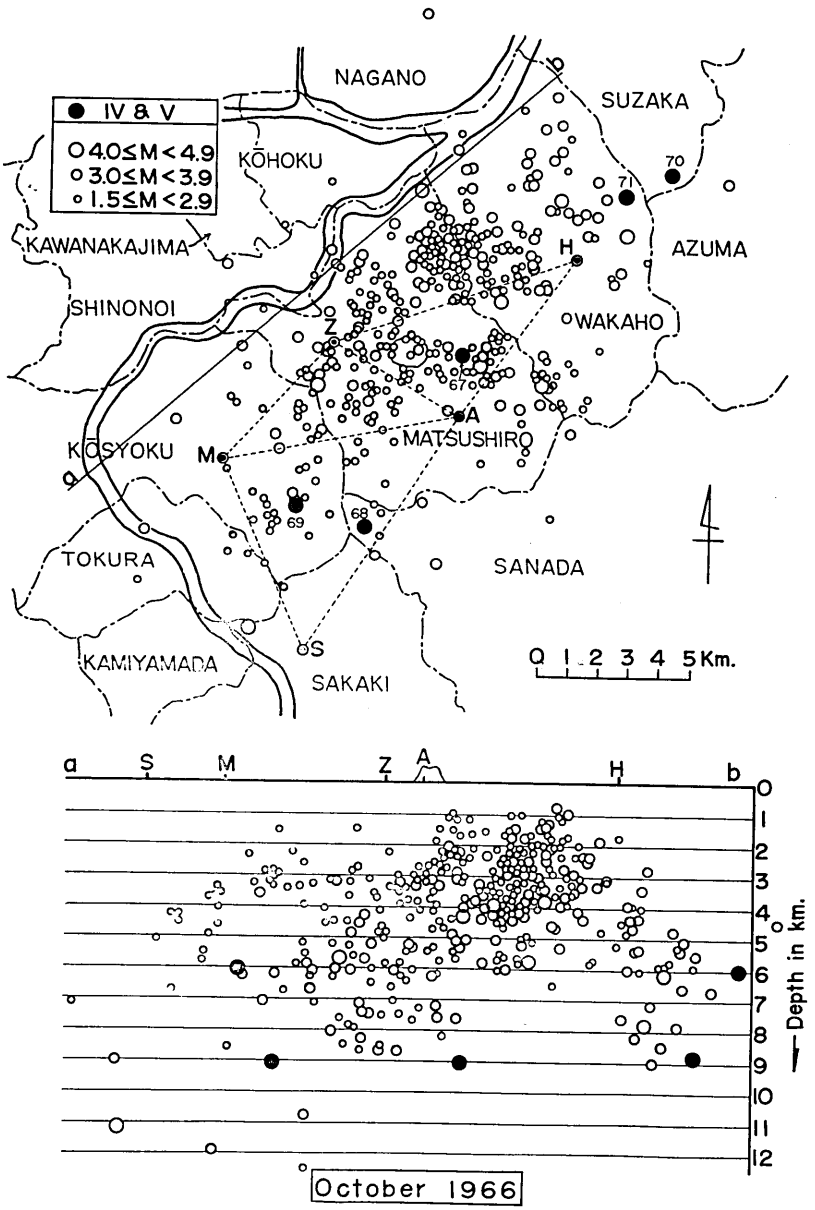

Fig. 9. Above: Epicentral distribution of the felt earthquakes.
Below: Vertical distribution of the felt earthquakes.
a-b: Plane of projection, H: Hoshina, Z: Zôzan, M: Mori,
A: Akashiba, S: Sakaki.

Table 1. Remarkable shocks among the Matsushiro earthquakes.

No.	Date	Hour	M	Depth (km.)	JMA Intensity	Damage
60	1966 Sep. 06	03 37	4.9	5.2	IV	
61	07	15 18	4.1	4.8	IV	Slight damage at Matsushiro
62	09	16 14	4.2	4.8	IV	
63	14	06 26	4.5	2.0	IV	
64	14	10 14	4.9	6.0	IV	
65	24	19 29	4.1	4.1	IV	Slight damage at Wakaho.
66	27	04 03	5.0	5.1	V	Slight damage at Kôsyoku.
67	Oct. 13	06 01	4.9	9.0	IV	Slight damage at Wakaho.
68	19	00 04	4.8	9.0	IV	
69	23	11 14	4.5	6.0	IV	
70	26	03 04	5.0	6.0	V	Slight damage at Azumamura.
71	31	14 01	4.0	8.8	IV	
72	Dec. 01	19 36	4.2	3.9	IV	

number smaller than 59 were reported in our previous paper.

The hypocentral distribution in each month are as follows.

September 1966 (Fig. 8) The earthquakes around Mt. Kimyô decreased in number compared to those in August but many earthquakes still occurred around Mt. Minakami.

October 1966 (Fig. 9) Many earthquakes occurred in the north of Mt. Kimyô while the earthquakes around Mt. Minakami became inactive.

It is worthy of special mention that the earthquakes seldom occurred in the zone northeast of Mt. Minakami, where long craks developed on the ground surface in echelon.

These cracks began to appear on the northeast side of Mt. Minakami when the seismic activity reached the third peak in August 1966, the crack distribution suggesting that a hidden earthquake fault, running from southeast to northwest, was created on the base rock in that area.

The existence of this fault was confirmed later by the resurvey of the triangulation points in the Matsushiro area.

November 1966 (Fig. 10) The hypocentral distribution pattern was almost the same as that in October.

The hypocenters were dense in the neighbourhood of Mt. Kimyô, and the activity in the south of Wakaho was also remerkable.

The activity area extended northward to Nire and Suzaka.

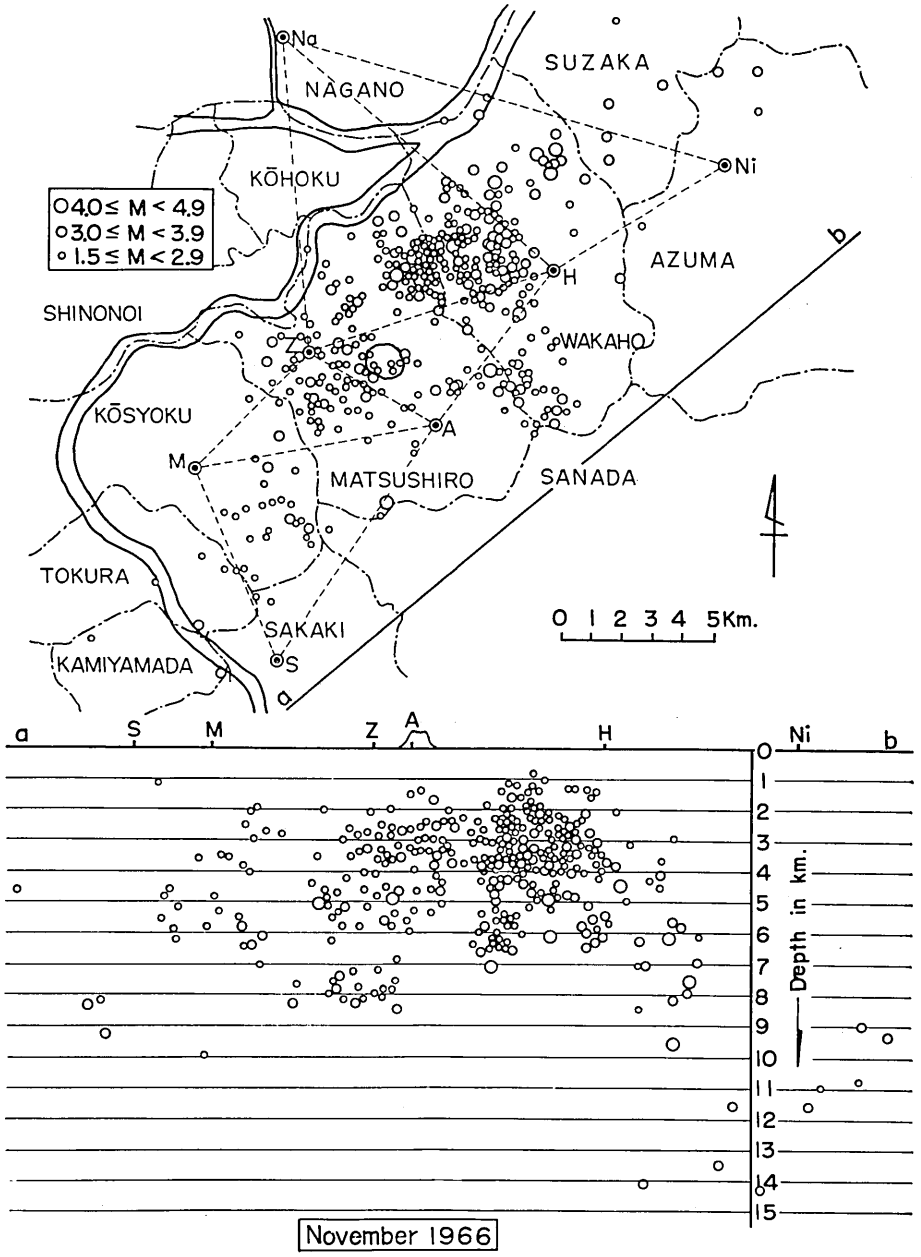

Fig. 10. Above: Epicentral distribution of the felt earthquakes.
Below: Vertical distribution of the felt earthquakes.
a-b: Plane of projection, H: Hoshina, Z: Zôzan, M: Mori, Ni: Nire, A: Akashiba, S: Sakaki, Na: Nagano.

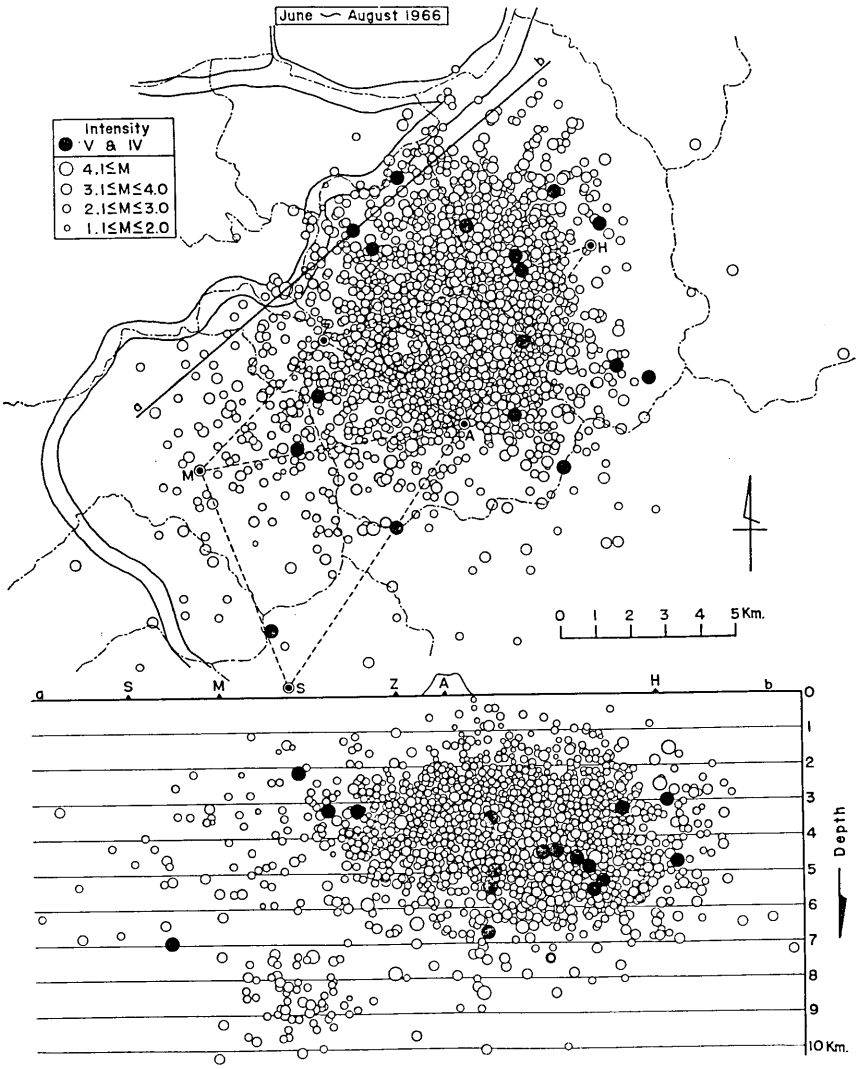

Fig. 11. Above: Epicentral distribution of the felt earthquakes during the period from June to August 1966.
Below: Vertical distribution of the felt earthquakes during the period from June to August 1966.
a-b: Plane of projection, H: Hoshina, Z: Zôzan, M: Mori, S: Sakaki, A: Akashiba.

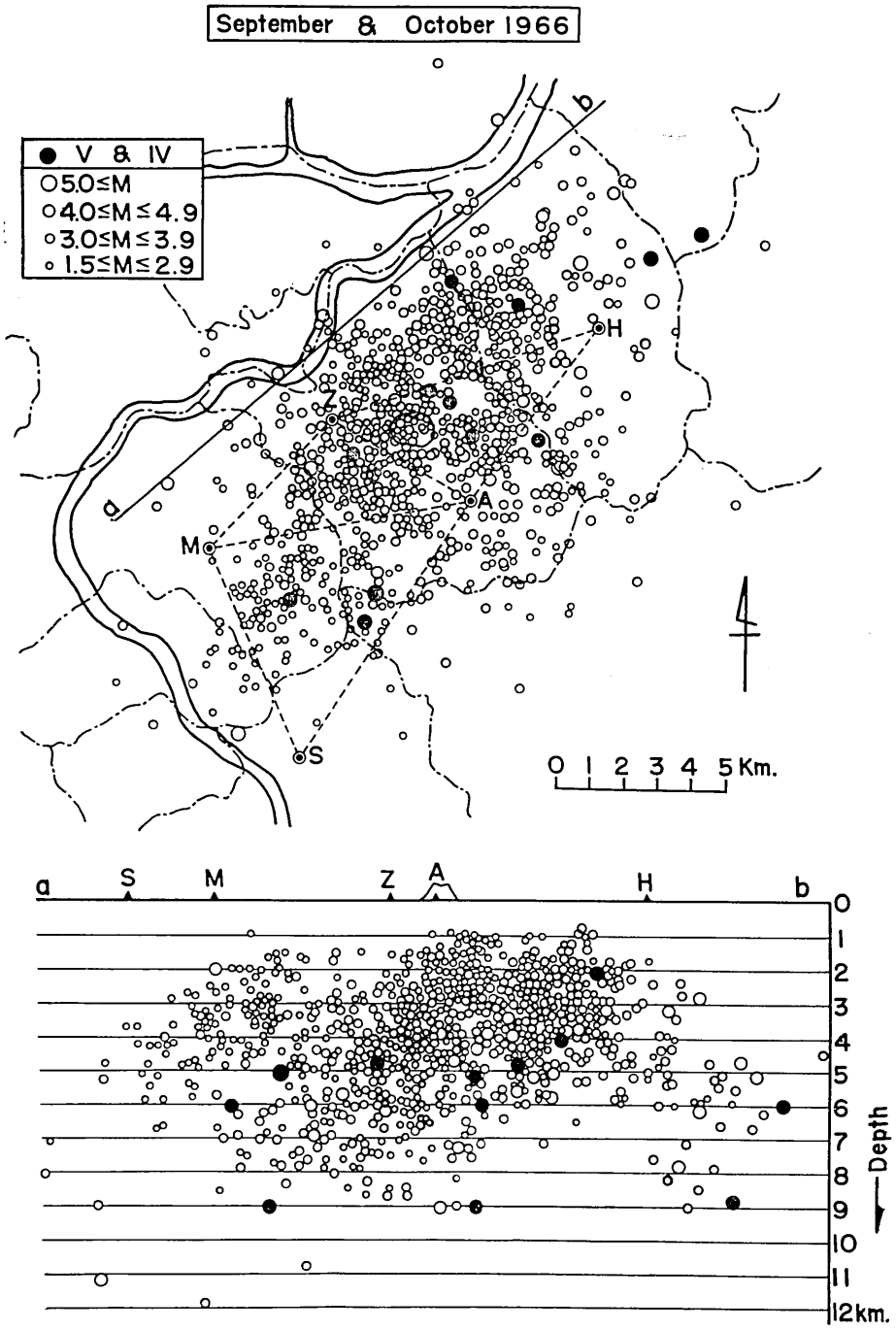

Fig. 12. Above: Epicentral distribution of the felt earthquakes during the period from September and October 1966.
Below: Vertical distribution of the felt earthquakes during the period from September and October 1966.
a-b: Plane of projection, H: Hoshina, Z: Zôzan, M: Mori, S: Sakaki, A: Akashiba.

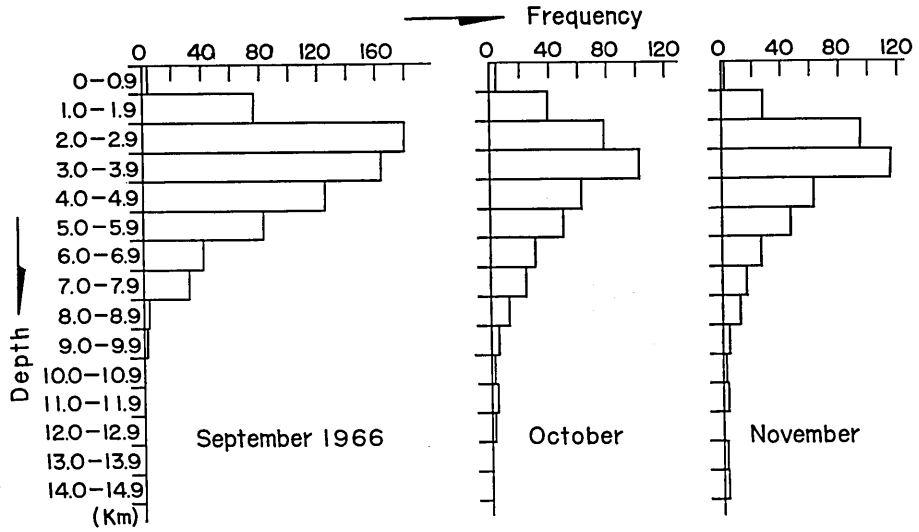

Fig. 13. Frequency distribution of depth of the felt earthquakes.

The earthquakes with intensity larger than IV on JMA scale were not reported in this month but those with intensity of nearly IV occurred at Wakaho.

The hypocentral distributions of earthquakes during the periods from June to August and from September to October are shown in Fig. 11 and 12 respectively.

The seismic activity in the period from June to August was concentrated in a circular area with radius of 5 km having its center at Mt. Kimyô.

Fig. 13 shows the frequency distribution of felt earthquakes for each month with respect to depth.

The depth 2.0～5.9 km is most predominant throughout the whole period while depths deeper than 10 km appeared in October with further deep ones, 13.0～14.9 km, occurring in November.

3. P-S time distribution

The monthly P-S time distribution was investigated from the acceleration seismograms and the HES 1-0.2 seismograms at each observation point as shown in Figs. 14～19. Since the residents of the village, where the Nire observation point was set up, began to feel earthquakes more frequently from the end of October, the daily P-S time distribution was

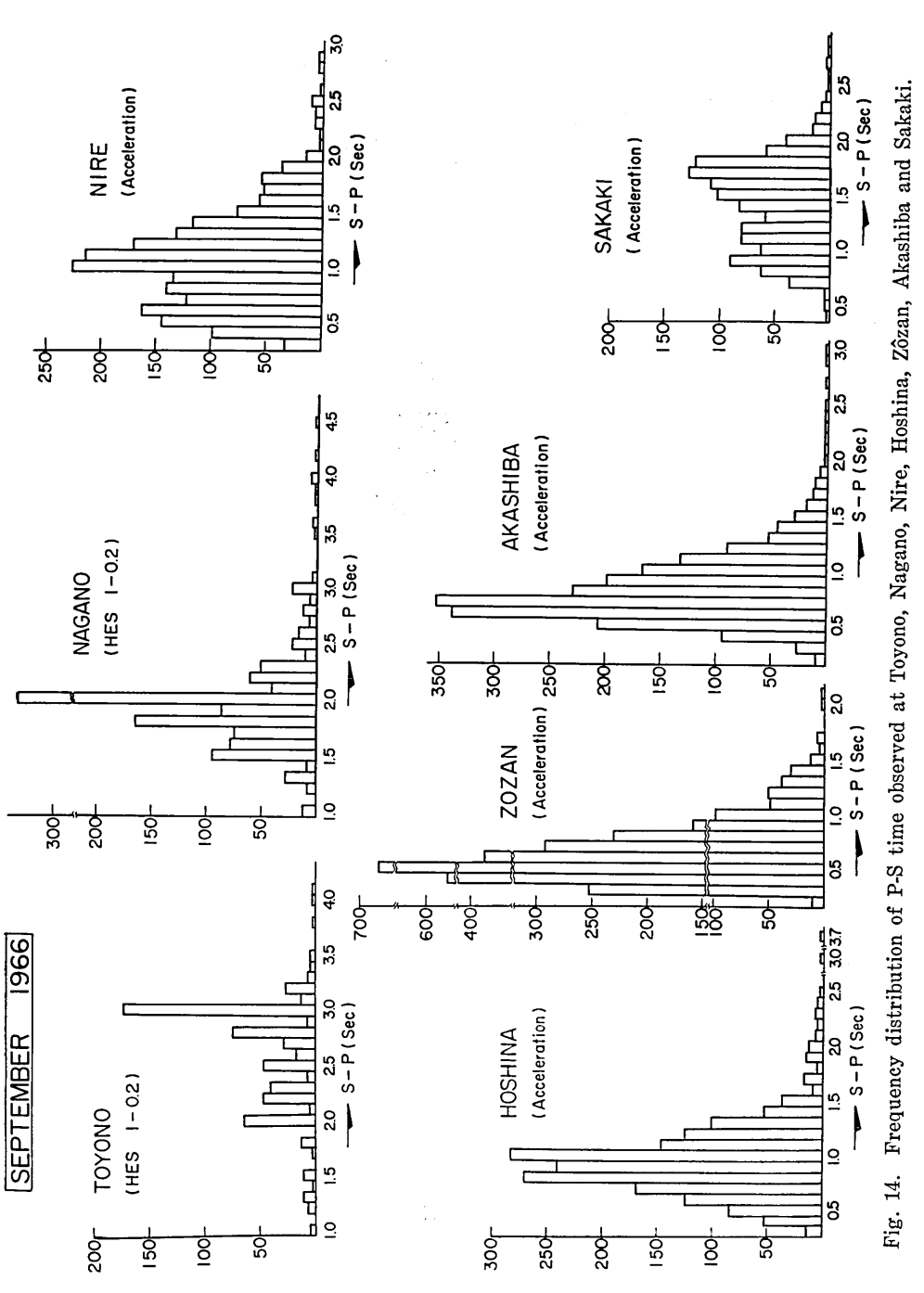

Fig. 14. Frequency distribution of P-S time observed at Toyono, Nagano, Nire, Hoshina, Zôzan, Akashiba and Sakaki.

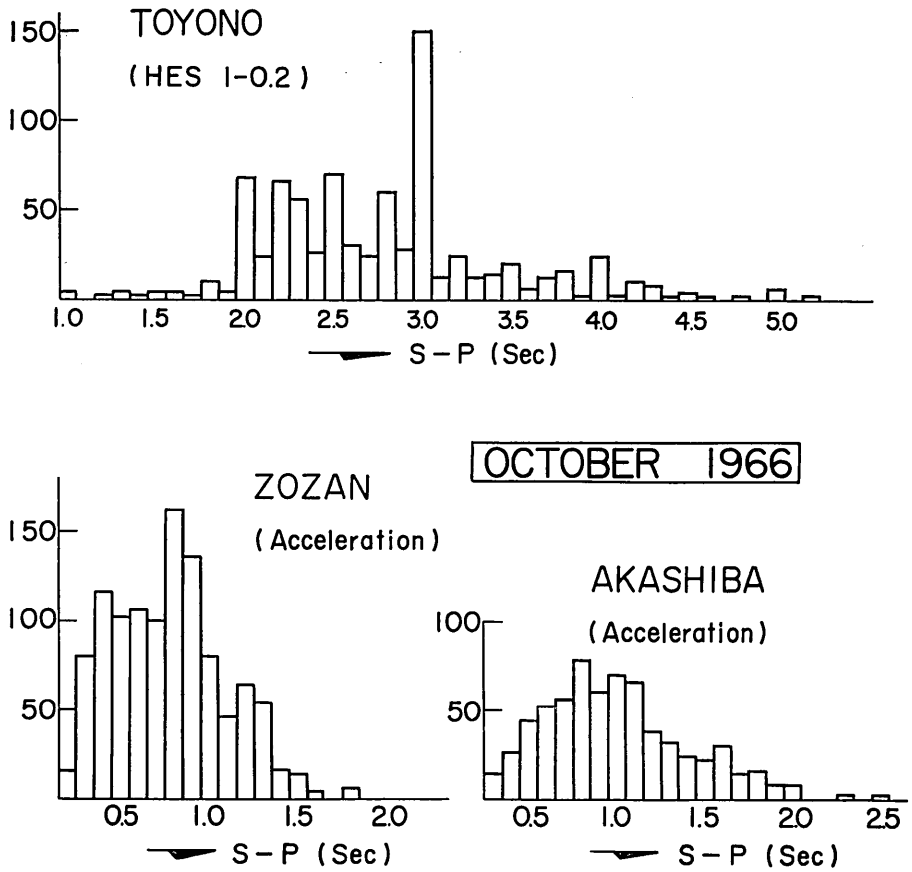

Fig. 15. Frequency distribution of P-S time observed at Toyono, Zôzan and Akashiba.

investigated particularly for the Nire observation point (Fig. 20).

The characteristics of the P-S time distribution at various points will be described in the following.

1) **Toyono** (HES 1-0.2)

The P-S time distributed mostly in the range 2.0~3.0 sec and had the maximum frequency at 3.0 sec throughout the whole period from September to November. This means that all the earthquakes observed at Toyono were originated in the area around Mt. Minakami and Mt. Kimyô, there being no seismic activity near this observation point.

2) **Nire** (the acceleration seismograph)

The maximum frequency of P-S time was around 1.0 sec in September, around 0.5 sec in October and at 0.5 sec and 1.0 sec in November.

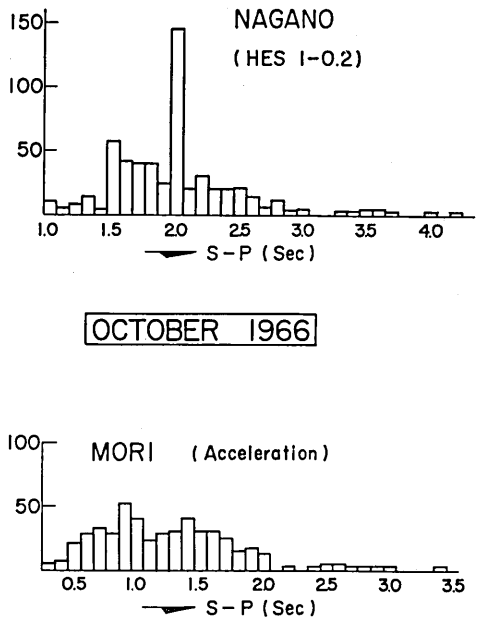

Fig. 16. Frequency distribution of P-S time observed at Nagano and Mori.

The earthquakes with P-S time around 1.0 sec seem to have originated north of Mt. Kimyô and in the north part of Wakaho. The earthquakes with P-S time around 0.5 sec show the seismic activity in the neighbourhood of this observation point. The number of earthquakes with P-S time around 0.5 sec increased very much in November due to the aftershocks of the strong earthquake which occurred on 26th October.

3) Zôzan (the acceleration seismograph)

The maximum frequency of the P-S time was at 0.5 sec in September, at 0.8 sec in October and November. Such a change in maximum frequency is due to the fact that the most active area was located near Mt. Minakami in September and it moved to the north of Mt. Kimyô in October and November.

4) Mori (the acceleration seismograph)

The distribution of P-S time was the same in October and November. Shorter P-S times at this observation point indicate that there was seismic activity near the observation point, i.e., in the east part of Kôshoku. This fact is also endorsed by the P-S time observed at Sakaki.

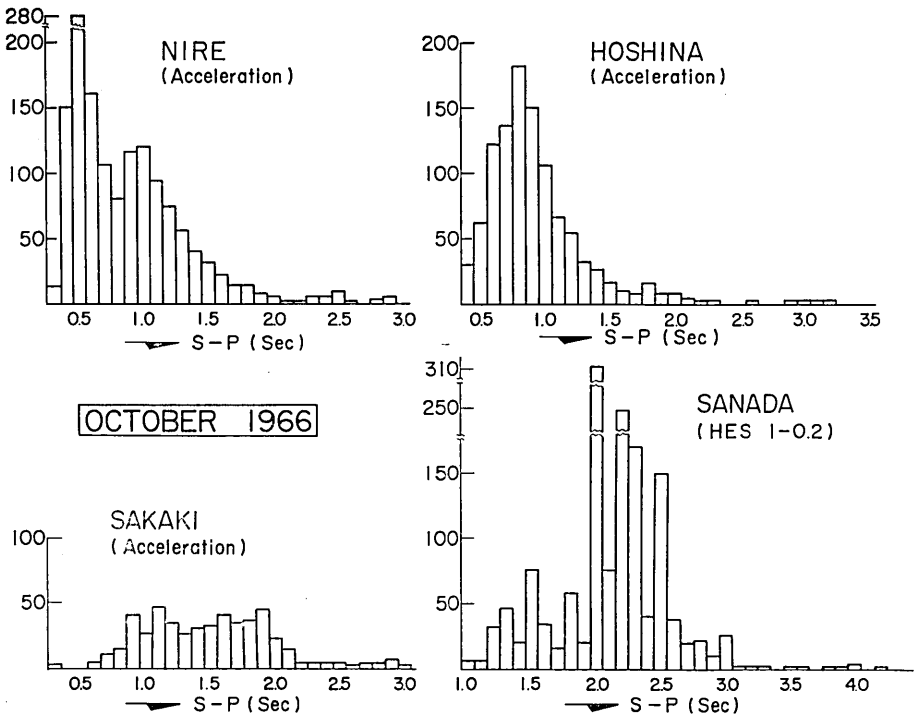

Fig. 17. Frequency distribution of P-S time observed at Nire, Hoshina, Sakaki and Sanada.

4. Energy released by earthquakes.

The cumulative sum of energy released by the Matsushiro earthquakes reached 1.43×10^{21} ergs through 30th November 1966. This value corresponds to the energy released by a single earthquake with magnitude of 6.2 (Fig. 21).

5. Fluctuation of m and b.

Fig. 22 shows the values of m and b in each month obtained from the acceleration seismograms at Akashiba, Zôzan and Hoshina, where m is the coefficient in Ishimoto-Iida's formula expressing the relation between the maximum trace amplitudes and the number of occurrence and b is the constant in the Gutenberg-Richter's formula expressing the relation between M and the number of occurrence of earthquakes in a

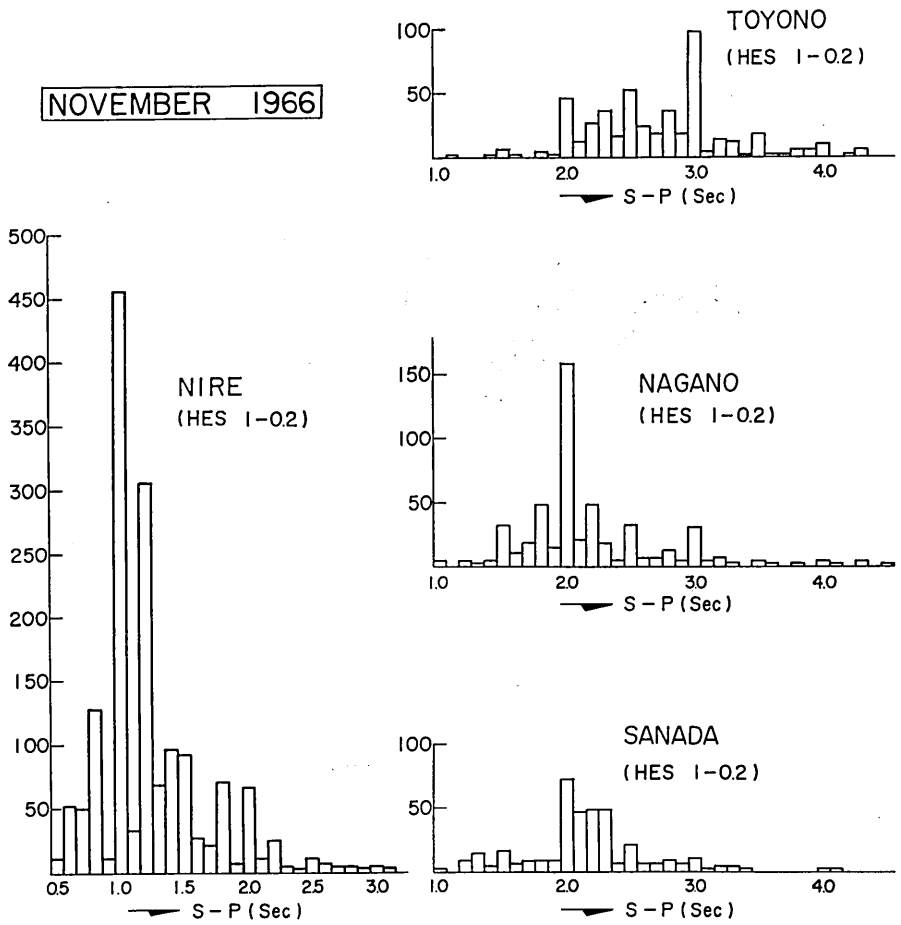

Fig. 18. Frequency distribution of P-S time observed at Nire, Toyono, Nagano and Sanada.

region. Some fluctuations were seen in the value of m, i.e., m was smaller than 2.1 in the period from March to September 1966, increased from the end of September and decreased again in the middle of November. The discussion on this fluctuation of the value of m will be postponed to the next report.

6. Push-pull distribution of initial motions.

Fig. 23 shows the push-pull distribution of initial motions of the

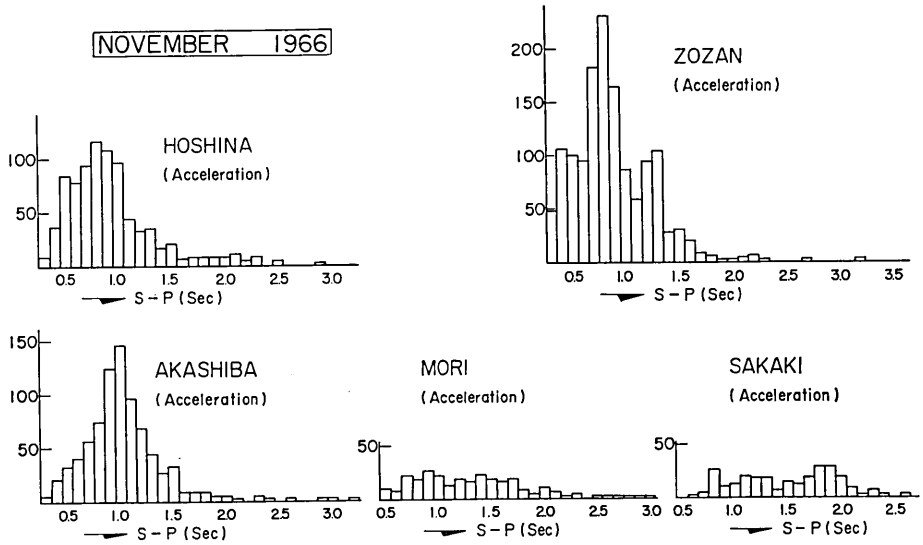

Fig. 19. Frequency distribution of P-S time observed at Hoshina, Akashiba, Zôzan, Mori and Sakaki.

felt earthquakes which occurred in the depth deeper than 3.0 km during the period from 15th September to 30th November 1966. The push-pull distribution of different earthquakes were superimposed together, putting the epicenters to the common point as was done in the first and second reports. At a glance over the figure, we may regard the distribution as being of the quadrant type as a whole, the nordal line inclining by 45° from meridian. We can say that the type of distribution did not change through the whole period since the beginning of the Matsushiro earthquakes.

7. Résumé

1) The Matsushiro earthquakes reached the third peak of the activity in August 1966. In September the number of occurrence decreased rapidly but comparatively large shocks still occurred. In November there were no earthquakes with intensity larger then IV on JMA scale.

2) The daily frequency of felt earthquakes at Matsushiro was 10 to 20 through the end of November 1966.

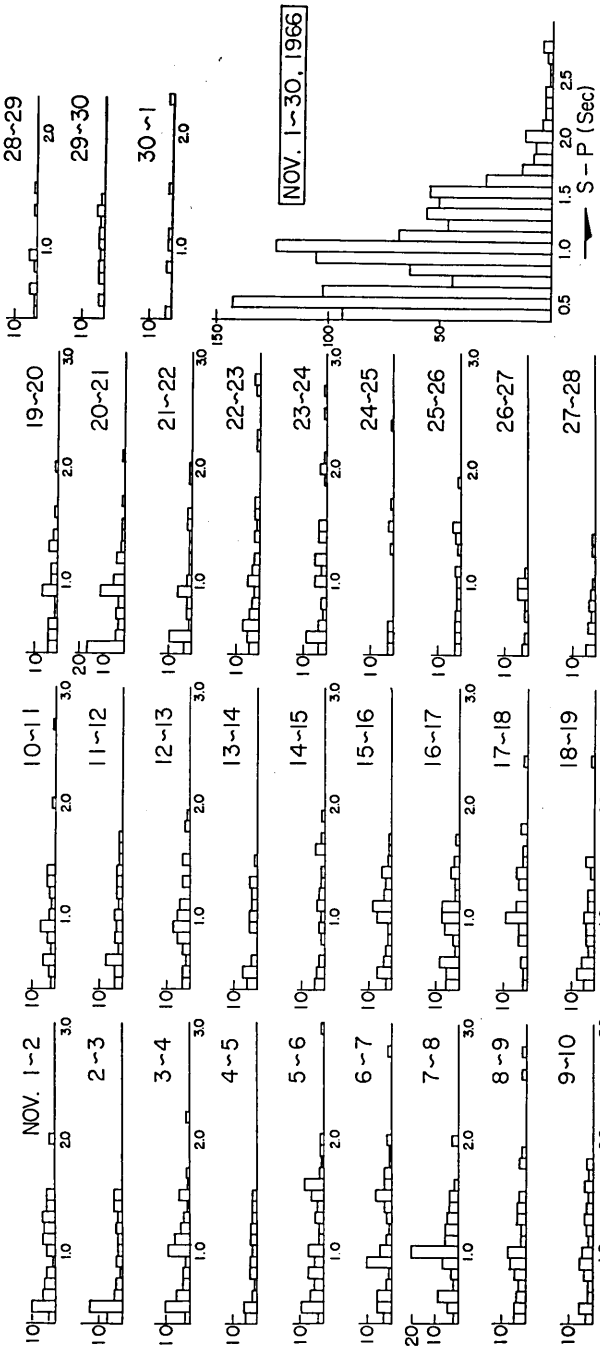

Fig. 20. Daily frequency distribution of P-S time observed at Nire.

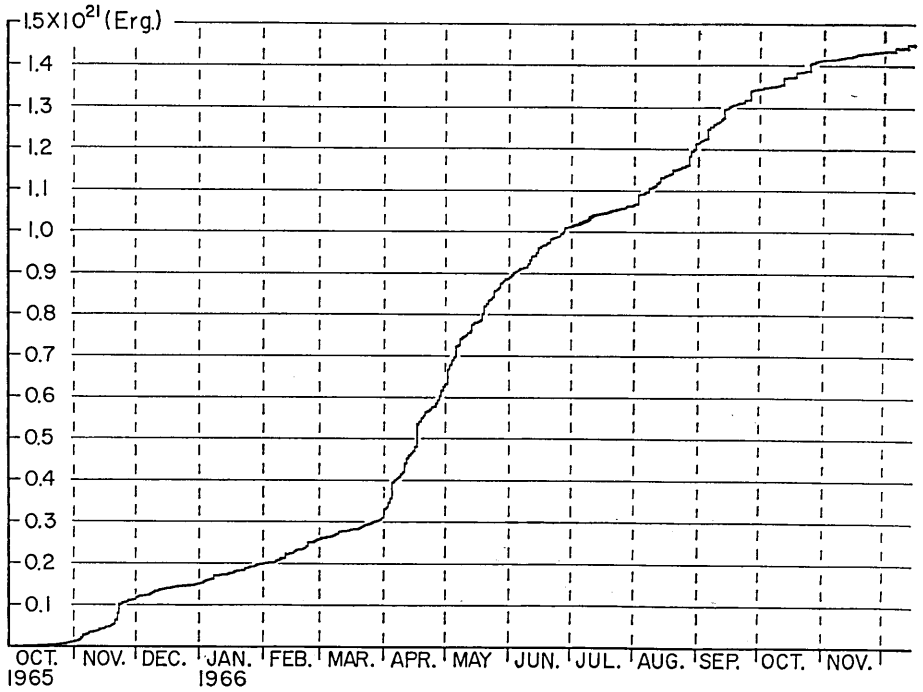

Fig. 21. Cumulative sum of energy released by Matsushiro earthquakes.

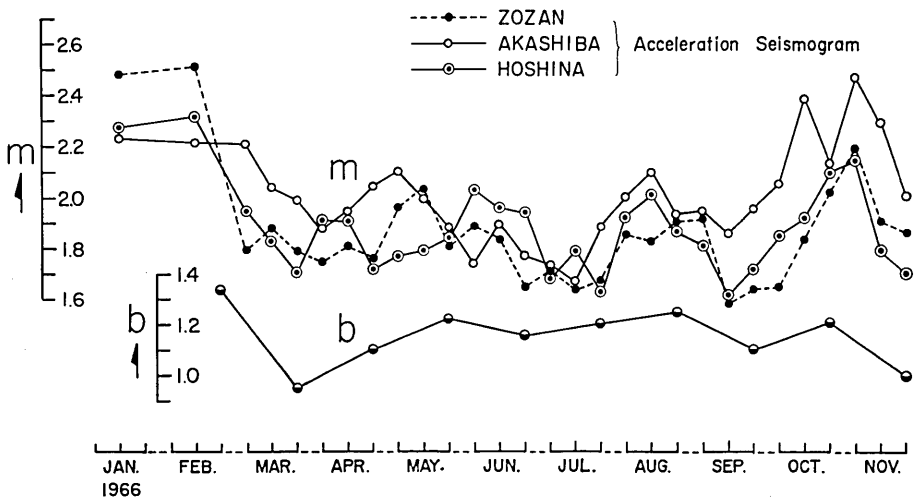

Fig. 22. Values of m and b in each month obtained from the acceleration seismograms at Akashiba, Zôzan and Hoshina.

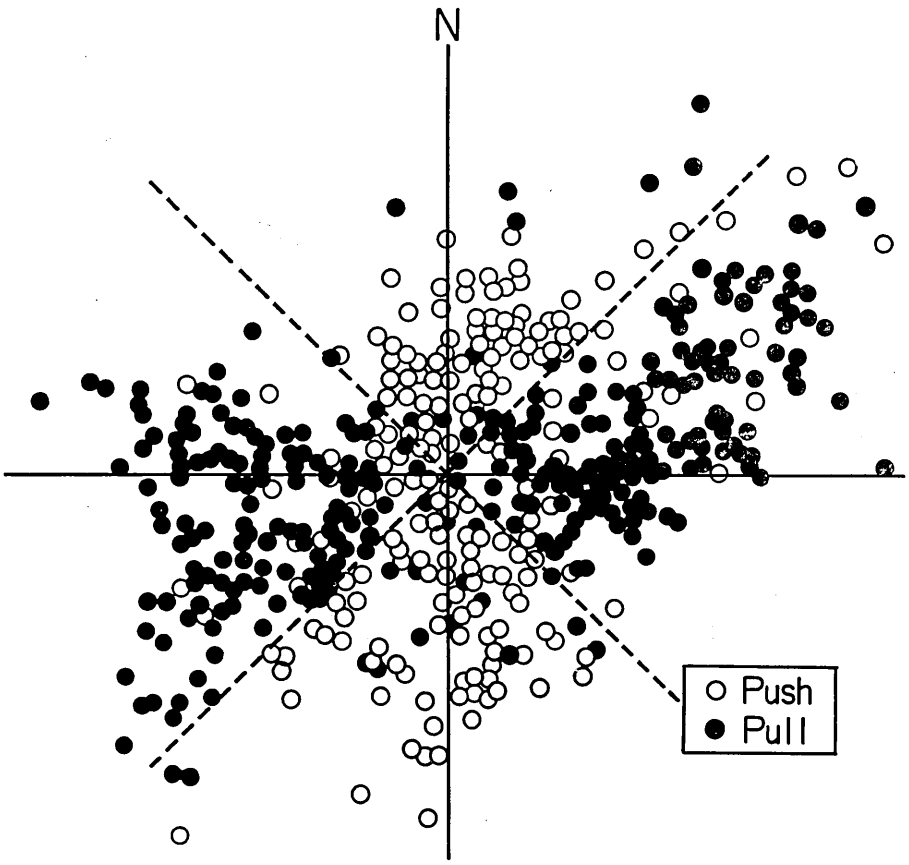

Fig. 23. Push-Pull distribution of initial motions of Matsushiro earthquakes.

3) The seismic active area still maintained its dimension through November 1966.

4) Since the end of September 1966, the earthquakes seldom occurred in a narrow zone northeast of Mt. Minakami where a newly created earthquake fault was estimated to exist.

5) The cumulative sum of energy released by the Matsushiro earthquakes reached 1.43×10^{21} ergs on 30th November 1966.

6) The push-pull distribution of main felt earthquakes was of the quadrant type in the period from September to November 1966, as was so previously.

11. 臨時地震観測網による松代地震群の調査結果（第三報）

地震研究所 {地震観測班 / 地震計測部}

1965 年 8 月に始った松代町附近の群発地震は，その年の 11 月に第 1 期とみられる地震活動があり，1966 年 3 月から 5 月には第 2 期の活動をむかえ，この期間が最もはげしく，その後，次第に減少するように見受けられたが，8 月に至って第 3 期の活動をむかえた．

第 3 期活動の中心は 8 月で，震度 IV 以上の地震が 10 回起っている．20 日と 29 日には震度 IV の地震が一日のうちに 2 回も発生した．

震度 IV 以上の地震は 9 月には 7 回，10 月には 5 回となお相当な活動が続いた．10 月 26 日 03時 04 分の地震は，これまでに発生している松代群発地震の中でも最もマグニチュードの大きな地震であり，気象庁によると M=5.1 と報告されている．震源に近い上高井郡東村では住家の一部破損，道路の地割れ，石垣のくずれ等があり，長野市内ではガラス窓の破損した家があった．

11 月に入ると M の大きい地震の発生は無くなったが，震度 IV 程度の地震は数回発生している．

地震回数については各観測点ともに 11 月に至って極端に減少した．

今回は第 2 報（1966 年 3 月～8 月）［地震研究所彙報］第 44 号第 4 冊 1687 頁～1741 頁に続いて，1966 年 9 月から 11 月に至る有感地震についての調査結果を第 3 報として報告する．

今期間に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，地震記象の読取り，解析には次の者が当った．

萩原尊礼，岩田孝行，牧野和子，鎌田恵子，木野みさ子，三浦義治．

1. 各観測点における地震回数

有感地震の回数は加速度地震計記象から，これより小さい地震（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. 1～5 に示す．また，気象庁地震観測所の標準地震計による地震回数を Fig. 6 に示してある．

第 3 期（1966 年 8 月～9 月）の地震活動が起ってからの各観測点における地震回数は，いずれも同じ傾向で増減してはいるが，回数そのものにはかなり大きな違いがみられる．これは小さな区域について見ると活動の状態がそれぞれ異っていることを示すと言えよう．

仁礼における有感地震回数が 10 月 26 日に大幅な増加を示しているが，これは同日 03 時 04 分の地震（東村：V，M=5.1）の余震に相当するものが含まれているためである．Fig. 7 は，この地震の前後における仁礼の加速度計と HES 1-0.2 型地震計 (NS 成分，V_{max}=10,000) に記録された P-S 1.2 秒以内の地震について毎時間の回数を調べたものである．図からわかるように，この地震の前には前震らしいものは見られない．

2. 有感地震の震源分布

1966 年 9 月から 11 月の主な有感地震の震源の水平分布と鉛直分布を Fig. 8～10 に示し，震度 IV 以上の地震のリストを Table 1 に示す．大きな地震には発生順に番号を附してあり，これはリストの番号と対応している．なお，59 番までは第 2 報を参照されたい．

まず，月別に有感地震の震源分布についての特徴を次に述べる．

9 月の活動 (Fig. 8)　1966 年 8 月の分布に比較すると奇妙山附近の活動が減っているが，皆神山周辺での活動は 8 月に引続いて活発である．

10 月の活動 (Fig. 9)　奇妙山の北側，すなわち，松代町と若穂町の境界附近に多発する傾向が見られ，皆神山および他の地域では顕著に減少している．さらに特筆すべきことは，皆神山北東部の地割れ地帯の附近に地震がほとんど起っていないことである．この地割れ群は基盤に生じた地震断層を示すものと解釈されているが，この断層線に沿って地震が起らなくなったことは興味あることである．

11 月の活動 (Fig. 10)　10 月と同様な分布を示しているが，特に奇妙山附近の活動が盛んである．また，若穂町南部の活動もやや盛んで，須坂，仁礼方面にも若干の地震が起っている．この月には気象庁からは震度 IV 以上の地震は全く発表されていないが，これに匹敵する程度の地震は若穂町に数回起きている．

Fig. 11 は 1966 年 6 月から 8 月まで，Fig. 12 は 9 月から 10 月までの期間の震源分布を示している．6 月～8 月については奇妙山を中心に半径 5 km の範囲に地震活動が集中していることがわかる．

Fig. 13 は有感地震の深さ別頻度分布を月ごとに示したものである．深さ 2.0～5.9 km のものが最も多く，さらに，10 月になると 10 km 以上のやや深いものがあり，11 月には 13.0～14.9 km とさらに深い地震が現われている．

3. P～S 分布

各観測点における加速度計，または，HES 1-0.2 型地震計の記録から P～S 頻度分布を調べた．この結果を Fig. 14～19 に示す．また，仁礼の観測点附近では 1966 年 10 月下旬頃から住民が地震を多く感じるようになったと言うので，特に日別の P～S 頻度を調べた (Fig. 20)．

主な観測点について P～S 分布の特徴を記すと，

1) **豊野** (HES 1-0.2)　9 月から 11 月を通じて 3.0 秒にピークがある．これは皆神山北部から奇妙山附近の地震である．大体 2.0～3.0 秒の範囲が最も多い．

2) **仁礼** (加速度計)　9 月では 1.0 秒附近に，10 月では 0.5 秒前後，11 月には 0.5 秒と 1.0 秒にそれぞれ頻度のピークがあるが，P～S 1.0 秒附近の地震は奇妙山北部から若穂町北部にかけての地震活動であらう．11 月に 0.5 秒が多数あるのは，10 月 26 日震度 V の地震の余震の影響である．

3) **象山** (加速度計)　9 月には 0.5 秒，10 月，11 月では 0.8 秒附近とピークに変化がみえる．これの理由は，9 月には皆神山周辺で，10 月，11 月には奇妙山北部で活動が盛んであったことによるものである．

4) **森** (加速度計)　10 月，11 月ともに同様な分布であり，更埴東部でも有感地震が若干起っていることが見られる．このことは坂城における分布をみても明らかである．

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 11 月 30 日現在で 1.43×10^{21} erg. となる．この量は，ほぼ，M=6.2 の地震を上まわる地震 1 発分に相当する (Fig.

5. m と b の推移

Fig. 22 は赤柴，保科および象山の加速度計記象から旬別に求めた m と b の値である．1966 年 3 月以降 9 月中旬までは m=2.1 より小さい値を示し，9 月下旬から大きくなり，11 月中旬から再び小さくなる傾向を示している．この結果の解釈は今後の研究にゆずる．

6. 押し引き分布

Fig. 23 は 1966 年 9 月 15 日から 11 月 30 日までの期間に起った深さ 3.0 km 以上の有感地震の資料から求めた押し引き分布である．第 1 回の資料 (1965 年 10 月～1966 年 1 月)，第 2 回の資料 (1966 年 5 月～7 月) から得られた押し引き分布と同様で，象限型の分布を示している．

7. 総　　括

1) 松代群発地震は 8 月に第 3 の活動ピークに達したが，9 月以降発生回数の上では急速に衰退の傾向をみせた．なお，比較的大きな地震がときどき発生した．ただし，11 月には震度 IV 以上の地震は報告されていない．

2) 11 月末現在松代における有感地震は 1 日 10～20 回程度である．

3) 地震活動域としては 11 月の震央分布からみても今までより縮小されたとは思えない．妙徳山附近，若穂町奇妙山附近，若穂町南部，皆神山南西部および更埴市東部の地域で若干の活動が今後も続くものと思われる．

4) 皆神山北東部の地割れ地帯に沿って 9 月下旬頃から地震が起らない地域があり，この傾向は 10 月になるとさらに明瞭である．

5) 11 月 30 日までの放出エネルギーの積算値は 1.43×10^{21} erg. となる．

6) 主な有感地震の押し引き分布は 4 象限型で，これまでと変化していない．