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26. *Seismometrical Studies of Volcano Asama, Part 2.*

Anomalous Distribution of the P Arrival Times and some Information of the Velocity of the P Wave Propagating through the Volcano.

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Contents

1. Introduction

In the previous paper[1], the writers reported on the general feature of the earthquakes originating from Volcano Asama and gave an outline of the seismic activity of the volcano during the period from 1934 to 1969.

1) T. MINAKAMI, S. UTIBORI, S. HIRAGA, T. MIYAZAKI, N. GYODA and T. UTSUNOMIYA, *Bull. Earthq. Res. Inst.*, **48** (1970), 235-301.

On that occasion, they remarked that the outstandingly anomalous distributions on the volcano were found not only in the amplitude of the earthquake motions of the B quakes, but also in their seismic frequency, these anomalies being closely related with the nature of the geological formations on which the seismometrical observations were made.

It will, however, be needless to mention that the arrival times on the volcano also have a close relation not only with the altitudes of the stations but also with the geological formations of the volcano consisting of vastly different ejecta with respect to the seismic propagating velocity.

It is important to study the structure of the volcano from the view-point of velocity distribution of the seismic waves and to examine if the magma chamber exists. However, on account of a lot of difficulties, there are very few volcanoes in the world, except Volcano Kilauea in Hawaii, of which the structure has been precisely studied. D. P. Hill studied the structure of Big Island of Hawaii including Volcano Kilauea[2] which was expressed by the distribution of the seismic P wave from its earth's surface to the upper mantle, by means of a series of blasts. For the same purpose, the writers carried out a series of seismic observations with the permanent seismometrical network and the temporary ones established on and around the volcano as the first step to the study.

As described in the previous paper[3], the attenuations acting to the seismic waves passing through the volcano are extremely serious and, on the other hand, the noise levels are quite high on the loose ejecta of the volcano. For the above-mentioned reasons, the following problems have been studied on the basis of a number of seismometrical observations:

(1) the investigations of the arrival times of elastic wave caused by the blasts at the Matsushiro area,

(2) the seismometrical observations of the arrival times of the Matsushiro earthquakes,

(3) the seismic prospects by blasts on the east and west flanks of the volcano.

In this report, the writers deal with the anomalies of the P arrival times of the seismic stations on the volcano or the deviations of the P arrival times from the travel time curve of the adjacent region and with some information about the P velocity distribution inside and underneath the volcano, though the problem needs to be studied further for making clear the precise structure of Volcano Asama.

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2) D. P. HILL, *Bull. Seism. Soc. Amer.*, **59** (1969), 101-130.

3) T. MINAKAMI et al., *loc. cit.*, (1)

2. The Matsushiro (or Togura) blasts in November-December, 1967 and in November 1969

As is well-known, the Matsushiro area was visited by an earthquake swarm on an outstandingly big scale in August 1965, lasting for at least four years. S. Asano and his colleagues[4] studied the structure of the Matsushiro area on the basis of the travel time curves of the seismic waves originating from a series of blasts.

They carried out explosion seismic experiments on the Matsushiro epicentral area in the periods from November 21 to December 4, 1967, and from November 21 to 25, 1969. The result of these experiments for the former period has already been published.

On the occasion of the above experiments, the writers made a series of special seismic observations with the Asama permanent net-work and the temporary ones on and around Volcano Asama, in order to make clear the anomalous distribution of the arrival times at each station on the volcano and the velocity distribution of the seismic waves in the volcano.

As can be seen in Figs. 1 and 11, the Matsushiro epicentral area and the shot point (A-IV) of the experiments are situated 25～40 km and 35～45 km north-west of the Asama seismic net respectively. The

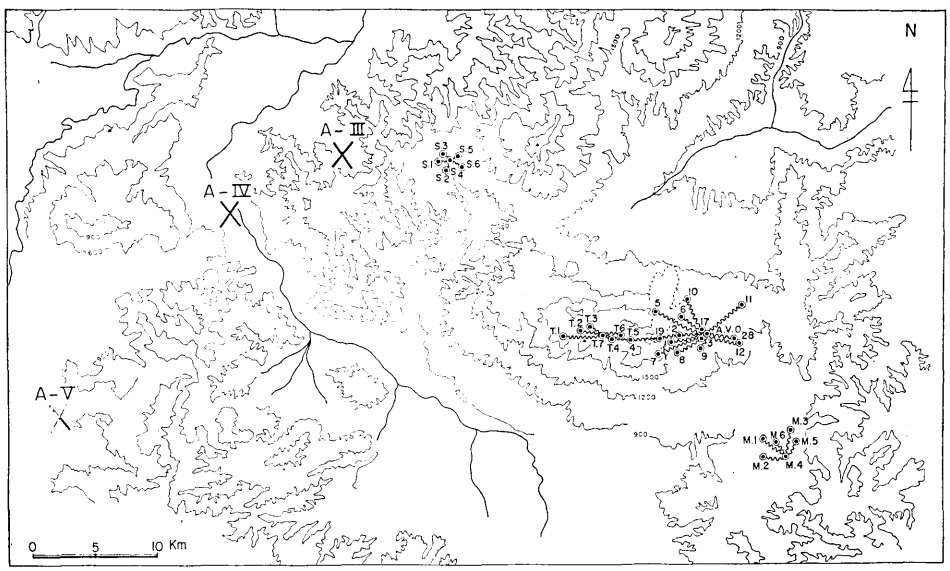

Fig. 1. The localities of the seismometrical net-works for the 1967 and 1969 blasts at the Matsushiro area.
A-III, A-IV and A-V; positions of shot points.

4) S. Asano et al., *Jour. Phys. Earth.*, **17** (1969), 77-90.

localities of the Asama permanent seismograph net-work and the temporary ones for the present purpose are shown on the map of Fig. 1 and Table 1.

Of a series of blasts at the Matsushiro area, the following two were

Table 1. The locality of the observation points.

(1) The Sugadaira net-work

Stn. No.	Place	Longitude (E)	Latitude (N)	Altitude
S1	Hokiya-dake	138°18′33″	36°31′35″	1289m
S2	Daimatu-yama	138 19 35	36 30 57	1297
S3	Kensyo-zi	138 19 43	36 31 58	1290
S4	Hoyosyo	138 20 06	36 31 24	1265
S5	Junction P.	138 20 28	36 31 46	1300
S6	Tri. P. 1294 m	138 20 57	36 30 57	1294

(2) The Takamine net-work

Stn. No.	Place	Longitude (E)	Latitude (N)	Altitude
T1	Sanpoogamine	138°26′14″	36°24′09″	2025m
T2	Takamine H. S.	138 27 14	36 24 19	1730
T3	Takamine H. S. Guti	138 27 49	36 24 26	1950
T4	Kurumazaka Tooge	138 28 53	36 24 03	2040
T5	Gippa-yama	138 29 54	36 23 40	2000
T6	Kurohu-yama	138 29 33	36 23 56	2300
T7	Takamine Hotel	138 28 19	36 24 04	1985

(3) The Asama permanent net-work

Stn. No.	Place	Longitude (E)	Latitude (N)	Altitude
4	Gippa-yama	138°29′54″	36°23′40″	2000m
5	Oniosidasi W.	138 31 17	36 25 21	1630
7	Sekison-san	138 31 17	36 23 10	1860
19	Higasi-Maekake	138 31 56	36 24 00	2350
6	Kuromamegawara U.	138 32 40	36 25 12	1560
1	Huzimizaka	138 32 22	36 23 55	2160
8	Hotokeiwa	138 32 26	36 22 29	1470
2	Sannotorii	138 33 05	36 24 02	1820
9	Okubosawa	138 33 32	36 23 15	1580
3	Nakanosawa	138 34 09	36 24 01	1380
11	Tutuzigahara	138 35 53	36 25 13	1350
28	Siraitonotaki II	138 35 16	36 24 00	1420
12	Siraitonotaki I	138 35 41	36 23 39	1365

(to be continued)

Table 1. (Continued)

(4) The Minami-Karuizawa net-work

Stn. No.	Place	Longitude (E)	Latitude (N)	Altitude
M. K. 1	Park Hotel	138°36′55″	36°19′27″	940m
M. K. 2	Airport	138 37 08	36 18′42	940
M. K. 3	Seizan Hotel	138 38 23	36 20 11	940
M. K. 4	Seibu Office	138 37 58	36 18 39	930
M. K. 5	Iriyama-tooge	138 38 43	36 19 08	960
M. K. 6	Narusawa	138 37 51	36 19 24	920

the same in shot point and, therefore, the writers will deal mainly with the results of observations in the two blasts.

Shot point 36°29′32″(N), 138°07′59″(E), $H=369$ m.

Shot time (1) 03h 05m 00.326s,
Dec. 2, 1967,
Charge 324 kg,

(2) 03h 05m 00.034s,
Nov. 22, 1969,
Charge 324 kg.

Besides the Asama permanent seismic net-work, temporary nets were set at Sugadaira, Minami-Karuizawa for the 1967 experiment and were added at Takamine for the 1969 one, as shown on the map of

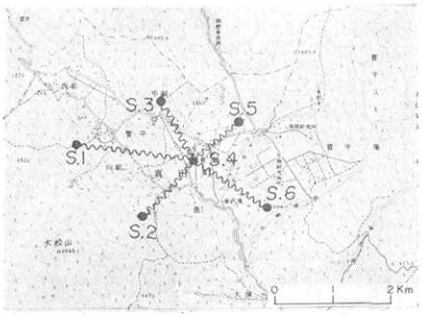

Fig. 2. The localities of the observation points belonging to the Sugadaira net.

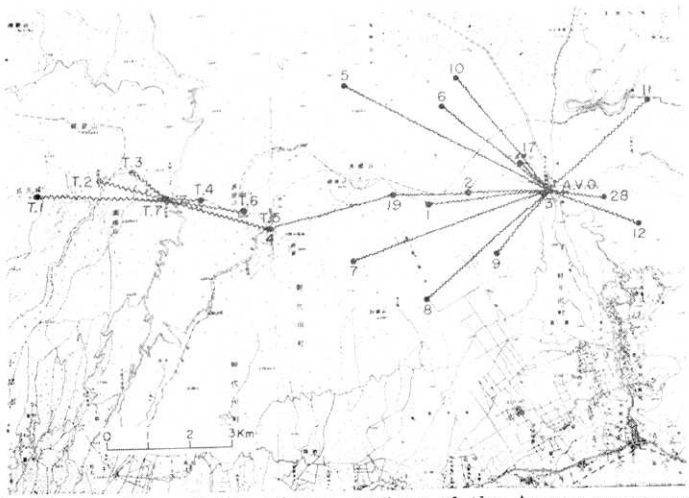

Fig. 3. The localities of the seismic stations of the Asama permanent net and the seismometric observation points at Takamine.

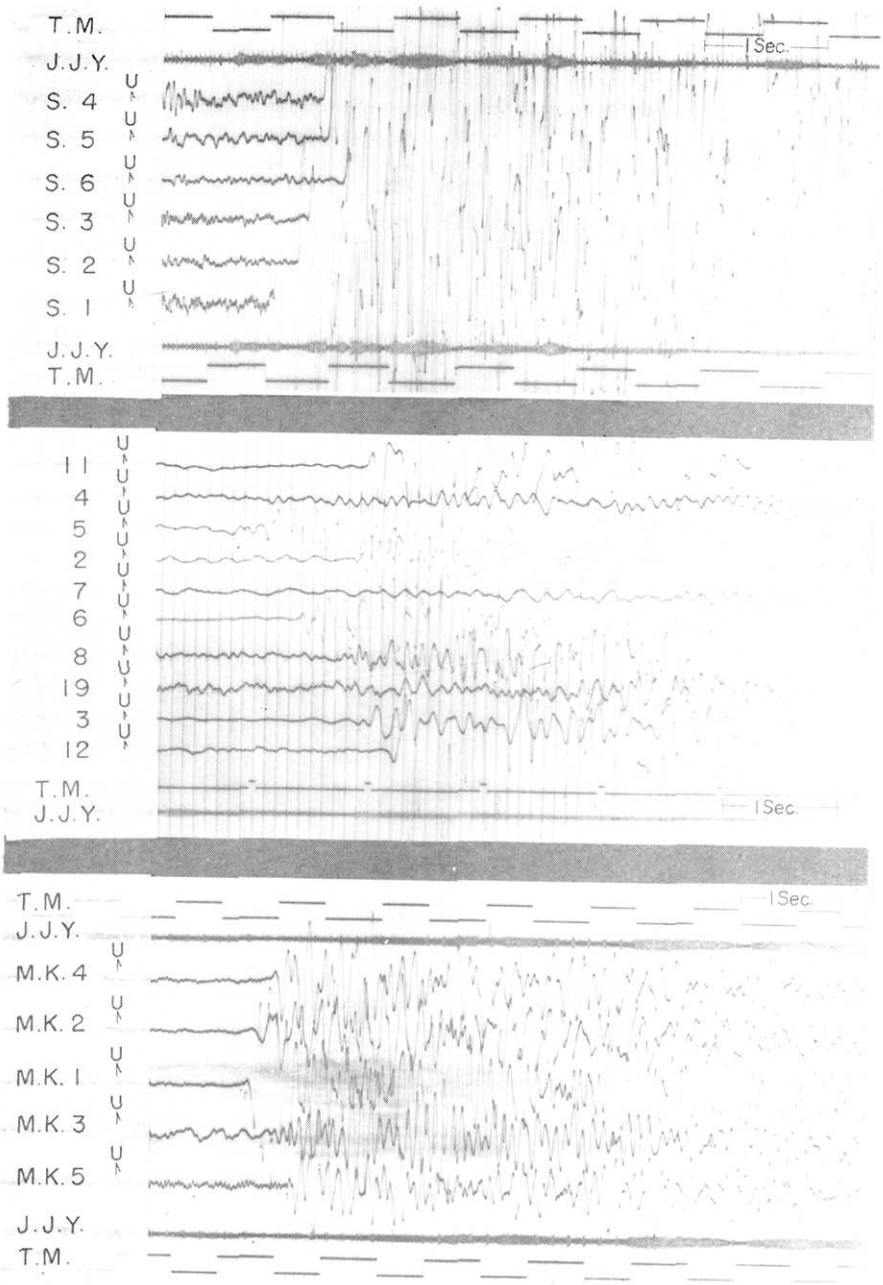

Fig. 5. The seismograms of the Sugadaira, Asama and Minami-Karuizawa net-works for the Togura blast at 03h 05m, December 2, 1967.

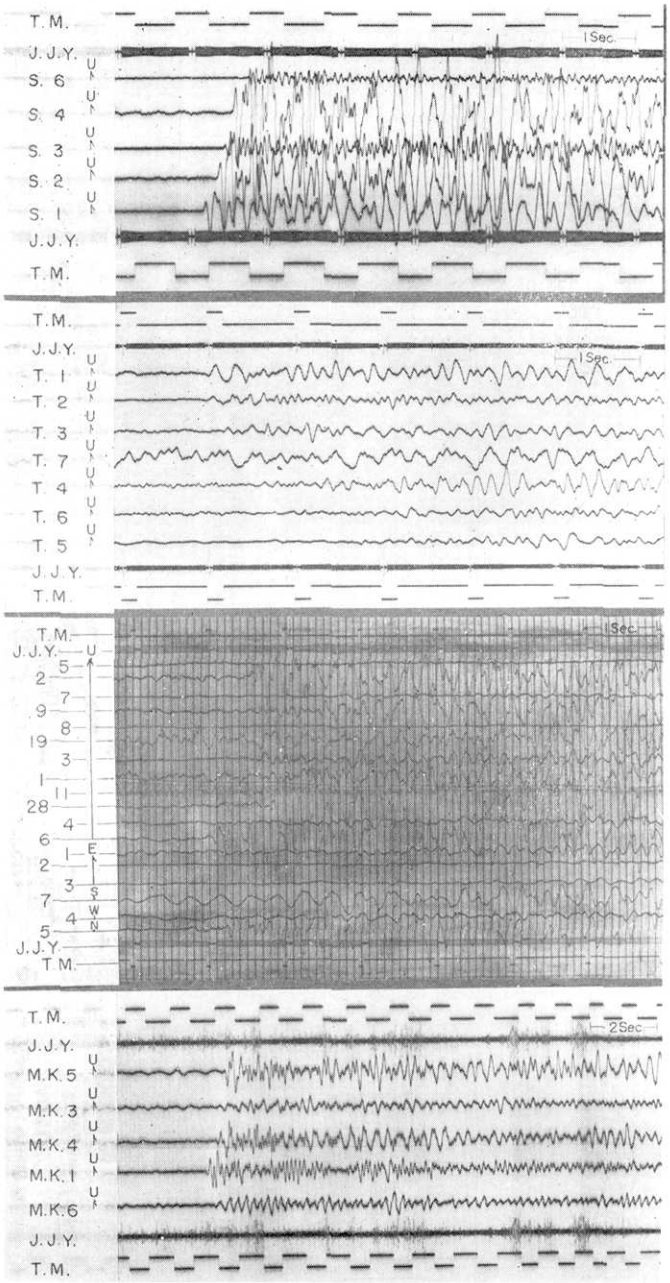

Fig. 6. The seismograms of the Sugadaira, Takamine, Asama and Minami-Karuizawa net-works for the Togura blast at 03h 05m, November 22, 1969.

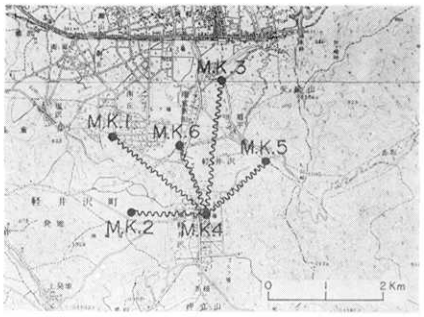

Fig. 4. The localities of the observation points belonging to the Minami-Karuizawa net.

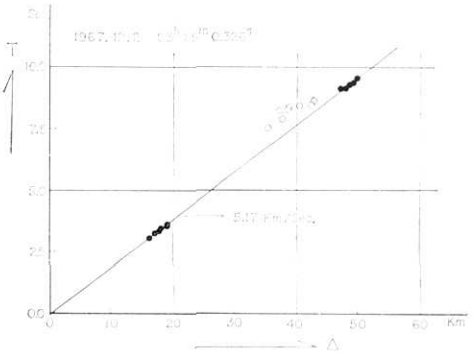

Fig. 7. The travel time curve of the December 2, 1967 blast at Togura (A–IV).
Solid circles; arrival times at the Sugadaira and Minami-Karuizawa nets,
Open circles; arrival times at the Asama net.

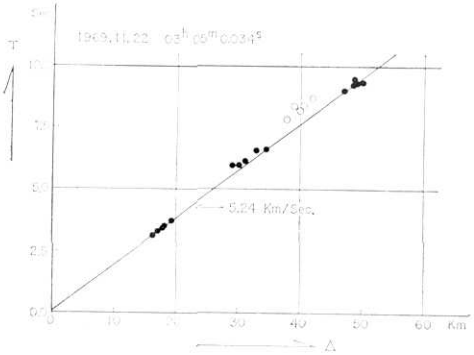

Fig. 8. The travel time curve of the seismic P wave originating from the 03h 05m 0.03s, November 22, 1969 blast at Togura (A–IV).

Fig. 3. For the seismic observations, the writers used the electromagnetic oscillographs as the recorder at the respective nets, and the crystal clock and the J.J.Y. radio for catching the absolute time.

In Tables 2 and 3 the arrival times and the distances from the shot point to each observation point are given for the abovementioned two blasts.

The shot point at the above blasts at Togura (shot point A–IV) was located at the south side of the epicentral region of the 1965–1968 Matsushiro earthquakes or almost 40 km west of the Asama permanent net. On account of the

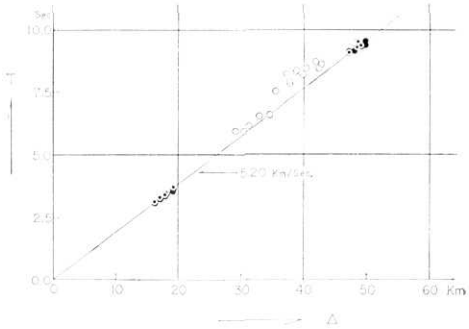

Fig. 9. The superposed travel time curve of the seismic P waves originating from the 1967 and 1969 Togura blasts of which the shot points are exactly the same, (A–IV).
Solid circle; the 1967 blast at the Sugadaira and Minami-Karuizawa nets,
Double circle; the 1969 blast at the Sugadaira and Minami-Karuizawa nets.
Open circle; the 1967 and 1969 blasts at the Asama and Takamine nets.
(The velocity of the seismic P waves is given by the 1967 and 1969 observations at the Sugadaira and Minami-Karuizawa nets.)

above reason, the seismic waves from the Togura blasts propagated to the Minami-Karuizawa net without passing through the root of Volcano Asama as being seen in Fig. 1.

On the other hand, the Sugadaira net was located at 17 km northeast of the Togura shot point and the Minami-Karuizawa net located at 48 km east slightly south of the above shot point. Therefore, the seismic waves observed at the above two nets were those that passed on the different route.

Table 2. The arrival times and epicentral distances of the blast at Togura (A-IV) at 03h 05m 0.326s, December 2, 1967.

Δ; distance from the origin,
T; arrival time, T'; origin time,
t; $T-T'$, travel time,
$t-t_c$; anomaly of the arrival time,

$$t_c=0.033^{(S)}+\frac{\Delta(\mathrm{km})}{5.17\ (\mathrm{km/sec})}\ .$$

(1) The Sugadaira net

Stn. No.	Δ	T	t	t_c	$t-t_c$
S1	16.23km	3.420sec	3.094sec	3.061sec	0.033sec
S2	17.12	3.607	3.281	3.233	0.048
S3	17.89	3.696	3.370	3.382	−0.012
S4	18.14	3.803	3.477	3.430	0.047
S5	19.08	3.877	3.551	3.612	−0.061
S6	19.25	3.968	3.642	3.645	−0.003

(2) The Asama permanent net

Stn. No.	Δ	T	t	t_c	$t-t_c$
5	35.37km	7.857sec	7.531sec	6.763sec	0.768sec
19	37.22	8.571	8.245	7.120	1.125
6	37.74	8.236	7.910	7.221	0.689
8	38.67	8.638	8.312	7.401	0.911
2	38.85	8.707	8.381	7.436	0.945
3	40.40	8.788	8.462	7.735	0.727
11	42.44	8.802	8.476	8.130	0.346
12	42.80	8.953	8.627	8.200	0.427

(to be continued)

Table 2. (Continued)

(3) The Minami-Karuizawa net

Stn. No.	Δ	T	t	t_c	$t-t_c$
M. K. 1	47.10km	9.463sec	9.137sec	9.031sec	0.106sec
M. K. 2	47.96	9.492	9.166	9.197	−0.031
M. K. 3	48.62	9.610	9.284	9.325	−0.041
M. K. 4	49.13	9.656	9.330	9.424	−0.094
M. K. 5	49.81	9.891	9.565	9.555	0.010

Table 3. The arrival times and epicentral distances of the blast Togura (A-IV) at 03h 05m 0.034s, November 22, 1969.

Δ; distance from the origin,
T; arrival time, T'; origin time,
t; $T-T'$; travel time,
$t-t_c$; anomaly of the arrival time,

$$t_c=0.034^{(S)}+\frac{\Delta(\mathrm{km})}{5.24(\mathrm{km/sec})}\ .$$

(1) The Sugadaira net

Stn. No.	Δ	T	t	t_c	$t-t_c$
S1	16.23km	3.158sec	3.124sec	3.125sec	−0.001sec
S2	17.12	3.336	3.302	3.295	0.007
S3	17.89	3.437	3.403	3.442	−0.039
S4	18.14	3.544	3.510	3.490	0.020
S6	19.25	3.738	3.704	3.702	0.002

(2) The Takamine net

Stn. No.	Δ	T	t	t_c	$t-t_c$
T1	29.09km	6.006sec	5.972sec	5.580sec	0.392sec
T2	30.40	5.997	5.963	5.830	0.133
T3	31.17	6.182	6.148	5.977	0.171
T4	32.90	6.594	6.560	6.308	0.252
T5	34.50	6.643 6.681	6.609 6.647	6.613 〃	−0.004 0.034

(to be continued)

Table 3. (Continued)

(3) The Asama permanent net

Stn. No.	Δ	T	t	t_c	$t-t_c$
6	37.74km	7.868sec	7.834sec	7.232sec	0.602sec
2	38.85	8.386	8.352	7.443	0.909
9	39.91	8.258	8.224	7.646	0.578
3	40.40	8.470	8.436	7.739	0.697
28	41.89	8.766	8.732	8.024	0.708

(4) The Minami-Karuizawa net

Stn. No.	Δ	T	t	t_c	$t-t_c$
M. K. 1	47.10km	9.100sec	9.066sec	9.018sec	0.048sec
M. K. 6	48.53	9.330	9.296	9.291	0.005
M. K. 3	48.62	9.550	9.516	9.309	0.207
M. K. 4	49.13	9.370	9.336	9.406	−0.070
M. K. 5	50.01	9.430	9.396	9.574	−0.178

However, the arrival times at the observation points of the Sugadaira and Minami-Karuizawa nets are almost exactly on the same travel time curve which passes the origin time and shows the velocity of 5.20 km/sec in the blasts both in 1967 and 1969. As mentioned already, the two blasts at Togura were carried out at exactly the same place as their shot point.

In the 1969 blasts, the Takamine net was added to the other three nets located closely at the west side of the Asama permanent net, in order to obtain information of the arrival times just before those at the Asama net.

In order to make clear the delay or anomaly of the arrival times on Asama, it was defined by the deviation or difference of the arrival time at each station on the volcano from the travel time given with a series of the arrival times at the Sugadaira and Minami-Karuizawa nets. As a matter of convenience those anomalies in the Matsushiro blasts are referred to the first anomaly to distinguish from the second one dealt in the Matsushiro earthquakes. The anomalous values thus defined are shown in Tables 2, 3 and 4, with other observed data.

As a result, remarkable delays of arrival times were found mainly on the east and south-east sides of Asama, ranging from 1.13 sec to 0.35 sec, these being quite large values.

Table 4. Average anomalies of the arrival times on Volcano Asama and its vicinity given from the 1967 and 1969 Matsushiro (Togura A–IV) blasts.

(1) The Sugadaira net

Stn. No.	Place	H(Altitude)	Average anomaly
S1	Hokiya-dake	1289m	0.02sec
S2	Daimatsu-yama	1297	0.03
S3	Kensyo-zi	1290	−0.03
S4	Hoyosyo	1265	0.03
S5	Junction P.	1300	0.06*
S6	Tri. P. 1294m	1294	0.00

(2) The Asama permanent net

Stn. No.	Place	H(Altitude)	Average anomaly
4	Gippa-yama	2000m	0.03sec
5	Onisidasi W.	1630	—
7	Sekison-san	1860	—
19	Higasi-Maekake	2350	1.13*
6	Kuromame. U.	1560	0.65
8	Hotokeiwa	1470	0.91*
2	Sannotorii	1820	0.93
3	Nakanosawa	1380	0.71
11	Tutuzigahara	1350	0.35*
12	Siraitonotaki I	1365	0.43*
28	Siraitonotaki II	1420	0.71*

(3) The Minami-Karuizawa net

Stn. No.	Place	H(Altitude)	Average anomaly
M. K. 1	Park Hotel	940m	0.08sec
M. K. 2	Airport	940	−0.03*
M. K. 3	Seizan Hotel	940	0.08
M. K. 4	Seibu Office	930	−0.08
M. K. 5	Iriyama-tooge	960	−0.08
M. K. 6	Narusawa	920	0.01*

*; Anomaly of the arrival times is given by the 1967 blast or the 1969 one. (cf. Tables 2 and 3)

3. The seismic observations of the 1966 Matsushiro earthquakes with the Asama permanent and temporary net-works on and around the Volcano

In order to indicate the development of the 1965–1968 Matsushiro earthquakes, their daily frequencies observed at three seismic stations on Asama are shown in Fig. 10 together with those of the B earthquakes originating from the summit crater and its vicinity. We have a lot of examples in which a series of strong earthquakes near active volcanoes gave influences to these volcanoes and, as a result, they showed abnormal features in their seismic and volcanic activities as in the cases of the 1968 Tokati-dake activity[5] soon after the Tokati-oki earthquake and the 1961 Kakuto caldera one[6] just after the Hyuganada earthquake.

However, in the period before, during and after the Matsushiro earthquakes, we did not find any change in the seismicity and volcanic phenomena of Volcano Asama.

It was indeed fortunate to have had the opportunity for carrying out seismic observations of the Matsushiro earthquakes on and around Volcano Asama in order to obtain various information about the arrival times on the volcano and to study the structure of the volcano from seismological view-points.

For this purpose, the writers established temporarily the seismometric nets at Sugadaira and Minami-Karuizawa in 1966, the localities of the observation points of which were the same as those for the 1967 and 1969 Matsushiro blasts. The other temporary nets were established in the same year at the Ookuwa area and the Oodo one in the north-eastern foot of the volcano, and at the Hosina area, north-east of the Matsushiro epicentral area. The localities of the observation points for the latter three nets are shown in Table 5.

The temporary seismic observations for the Matsushiro earthquakes were made with the above six nets including the Asama permanent one during June and October 1966. However, on account of the lack of instruments and operators, all of the above six nets were never operated at the same time. The observations were made in the following four combinations of the nets;

(1) Sugadaira-Asama-Minami·Karuizawa ·····the first group net,
(2) Sugadaira-Asama-Ookuwa ·····the second group net,
(3) Sugadaira-Asama-Oodo ·····the third group net,
(4) Hosina-Sugadaira-Asama ·····the fourth group net.

5) Japan Meteorological Agency, *Volcano. Bull.*, 8, II (1969), 55-66.
6) T. MINAKAMI, D. SHIMOZURU et al., *Bull. Earthq. Res. Inst.*, **46** (1968), 965-992.

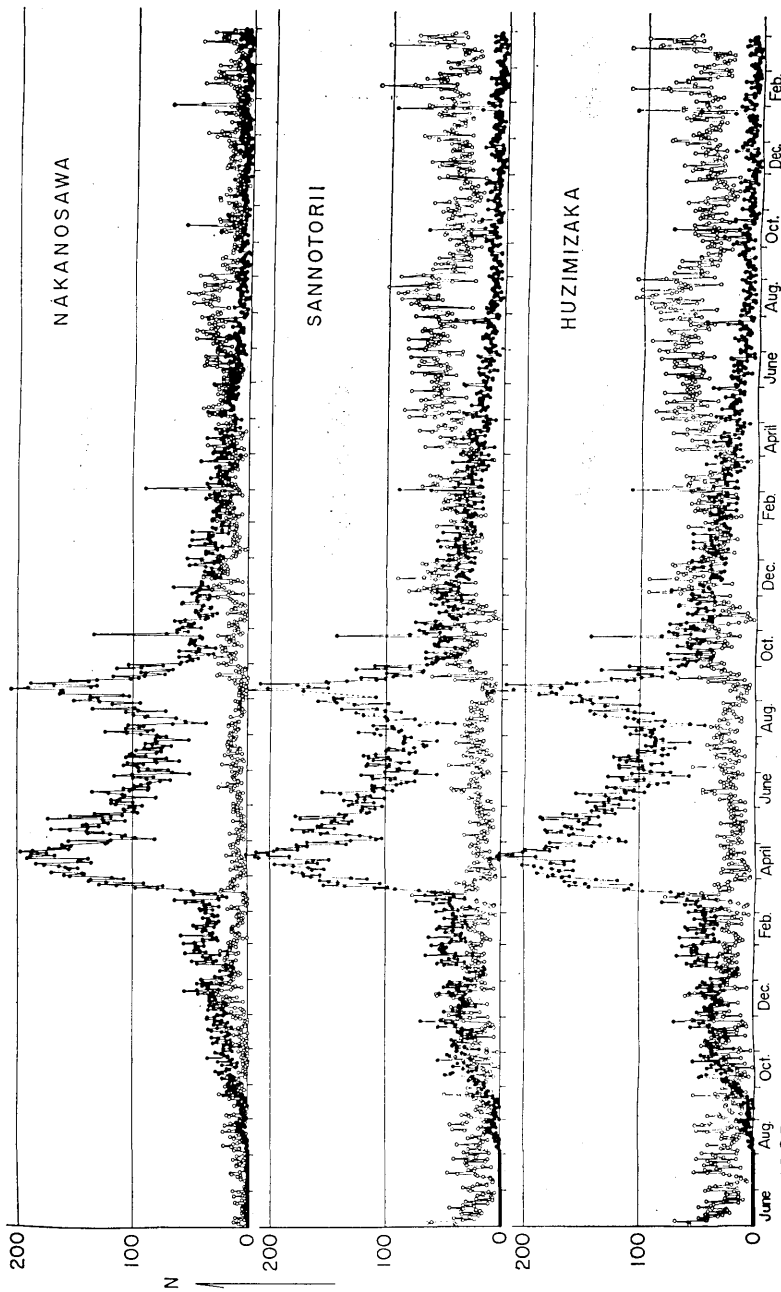

Fig. 10. Daily frequencies of the Matsushiro earthquakes and those of the Asama B earthquakes observed at three seismic stations on Asama.
Solid circle: Matsushiro quakes
Open circle; Asama B quakes

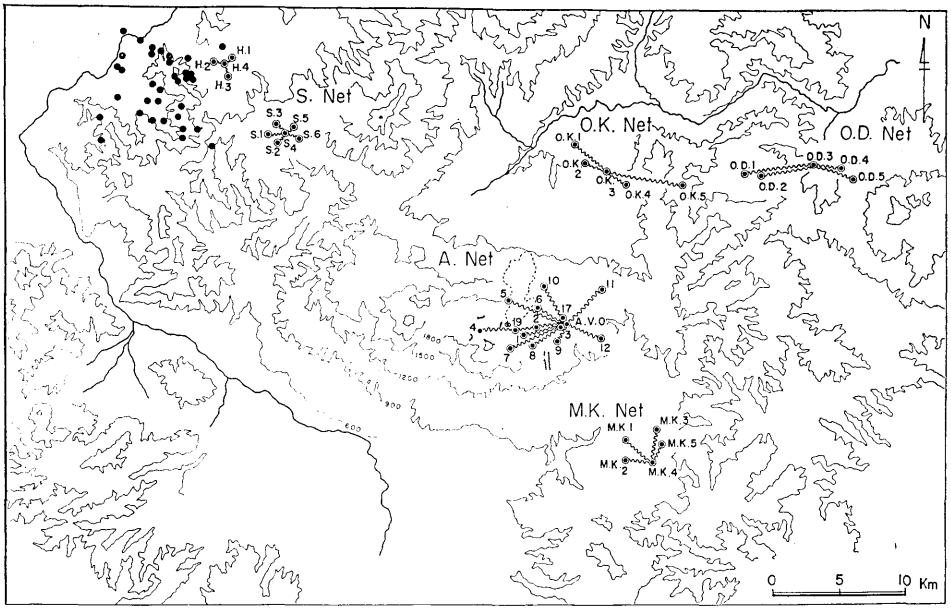

Fig. 11. The localities of the seismometrical net-works on and around Volcano Asama for the seismometrical observations for the 1966 Matsushiro earthquakes.
Solid circle; epicentral positions of the Matsushiro earthquakes observed with the above nets.

Table 5. The location of the observation points in the 1966 Matsushiro earthquakes.

(1) The Ookuwa net-work

Stn. No.	Place	Longitude (E)	Latitude (N)	Altitude
O. K. 1	Kozyuku	138°34′22″	36°31′37″	860m
O. K. 2	Kosiro	138 35 13	36 30 51	930
O. K. 3	Ookuwa	138 36 02	36 30 25	960
O. K. 4	Kariyado	138 36 49	36 29 50	950
O. K. 5	Hatonoyu	138 39 59	36 29 28	900

(2) The Oodo net-work

Stn. No.	Place	Longitude (E)	Latitude (N)	Altitude
O. D. 1	Take	138°42′57″	36°30′28″	680m
O. D. 2	Hommaru	138 44 04	36 30 27	640
O. D. 3	Oodo	138 46 36	36 30 37	500
O. D. 4	Tekomaru	138 47 22	36 30 30	610
O. D. 5	Kogara-yama	138 48 22	36 30 14	720

(3) The Hosina net-work

Stn. No.	Place	Longitude (E)	Latitude (N)	Altitude
H1	Takaoka	138°16′24″	36°34′42″	600m
H2	Kazoo	138 16 40	36 34 36	600
H3	Zisya	138 17 16	36 34 06	600
H4	Hosina	138 17 08	36 34 24	600

For making clear the relation between the arrival times and the epicentral distances, the result of the seismic observations with the above four-group nets are represented in Tables 6～9, as an example, with respect to five of the earthquakes originating from the Matsushiro area.

The epicentral distances in Tables 6～9 are given on the basis of the epicentral positions which were studied by T. Hagiwara and his associates[7] with the temporary seismograph net at the Matsushiro area during the period.

The seismograms obtained with the four-group net-works are shown in Figs. 12, 15 and 16. In order to determine the precise arrival times at each net-work, the writers recorded not only the second signals of the crystal clock, but also those from J. J. Y. on the seismograms.

4. The travel time curves on and around Volcano Asama, based on the seismometrical observations of the 1966 Matsushiro earthquakes.

In order to give an outline of the anomalous distribution of the arrival times on the volcano, the travel time curves are illustrated in Figs. 13, 17, 20, 21 and 23, which correspond to the first, second, third and fourth groups of the seismometrical net-works respectively.

(1) *The travel-time curve along the first group of the nets.*

The first group of the nets, or the Sugadaira, Asama and Minami-Karuizawa ones, are located on a straight narrow belt running from the Matsushiro epicentral area to the south-east direction. The Asama net is situated mid-way of the other two nets and, therefore, it can be said that the seismic waves observed at the Minami-Karuizawa net propagated under the root of Volcano Asama. The Minami-Karuizawa net is located on and near the Usue formation, or the Tertiary geological

7) K. HAMADA and T. HAGIWARA, *Bull. Earthq. Res. Inst.*, **44** (1966), 351-361; **44** (1966), 1213-1238; **44** (1966), 1239-1268; **44** (1966), 1665-1687; **45** (1967), 159-196.
Party for Seismographic Observation of Matsushiro Earthquakes, *Bull. Earthq. Res. Inst.*, **44** (1966), 309-333; **44** (1966), 1689-1714; **45** (1967), 197-223; **45** (1967), 887-917.

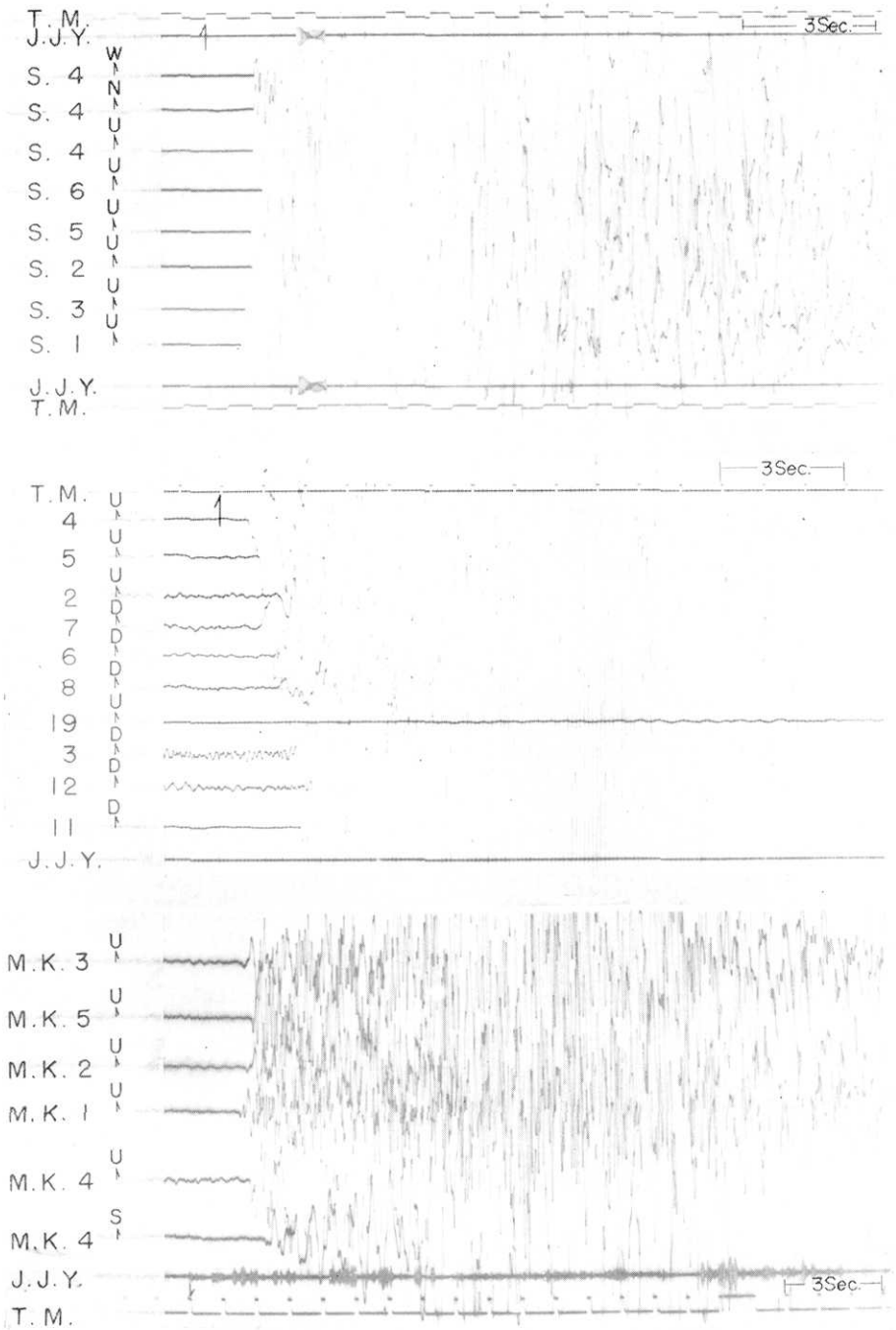

Fig. 12. The seismograms of the 21h 15m, June 17, 1966 Matsushiro earthquake observed by the oscillographs in the Sugadaira, Asama and Minami-Karuizawa net-works.

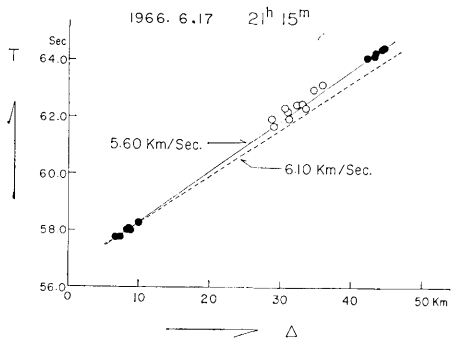

Fig. 13. The travel time curve of the 21h 15m, June 17, 1966 Matsushiro earthquake. The velocity (5.6 km/sec) of the seismic P wave is given with the Sugadaira and Minami-Karuizawa nets.
Solid circle; arrival times of the Sugadaira and Minami-Karuizawa nets,
Open circle; arrival times of the Asama net.

formation, and the observation point of the same net, M. K. 5 (Iriyama-tooge), is located on the formation. On the other hand, the Sugadaira net is located on the flat topography of the small plateau which is intruded by quartz diorite, according to the geological survey by R. Ota and M. Katada[8].

As seen in the travel time curve in Fig. 13, the travel times of the Sugadaira and the Minami-Karuizawa nets are almost on a line which indicates a propagating velocity of 5.6 km/sec, though those of the Asama net are much deviated from the line. As described already, the same phenomenon was seen in the case of the 1967

Table 6. The arrival times, their anomalies and the epicentral distances of the Matsushiro earthquake at 21h 15m, June 17, 1966 (Hypocentral depth = 4.9 km).

Δ; epicentral distance,
T; arrival time,
T^*; arrival time expected from the travel-time curve given by the Sugadaira-Ookuwa-Oodo seismometrical observation,
T'; arrival time expected from the Sugadaira-Minami Karuizawa observation.

(1) The Sugadaira net

Stn. No.	Δ	T	T^*	$T-T^*$	T'	$T-T'$
S1	6.65km	57.78sec	57.75sec	0.03sec	57.74sec	0.04sec
S3	7.35	57.89	57.87	0.02	57.86	0.03
S2	8.33	58.04	58.03	0.01	58.04	0.00
S4	8.45	58.07	58.05	0.02	58.06	0.01
S5	8.75	58.03	58.10	−0.07	58.11	−0.08
S6	9.88	58.29	58.28	0.01	58.31	−0.02

(to be continued)

8) R. OTA and M. KATADA, Geological map and explanatory text "Suzaka", Geological Survey of Japan (1955).

Table 6. (Continued)

(2) The Asama permanent net

Stn. No.	Δ	T	T^*	$T-T^*$	T'	$T-T'$
5	28.63km	61.95sec	61.37sec	0.58sec	61.66sec	0.29sec
4	28.93	61.69	61.42	0.27	61.72	−0.03
6	30.43	62.34	61.68	0.66	61.98	0.36
19	30.83	62.20	61.73	0.47	62.06	0.14
7	31.08	61.97	61.77	0.20	62.10	−0.13
2	32.15	62.46	61.95	0.51	62.29	0.17
8	32.88	62.47	62.07	0.40	62.42	0.05
3	33.45	62.35	62.16	0.19	62.72	−0.35
11	34.55	62.98	62.34	0.64	62.72	0.26
12	35.78	63.17	62.54	0.63	62.94	0.23

(3) The Minami-Karuizawa net

Stn. No.	Δ	T	T^*	$T-T^*$	T'	$T-T'$
M. K. 1	42.08km	64.10sec	63.58sec	0.52sec	64.07sec	0.03sec
M. K. 3	43.03	64.18	63.74	0.44	64.24	−0.06
M. K. 2	43.25	64.29	63.77	0.52	64.27	0.02
M. K. 4	44.18	64.44	63.92	0.52	64.44	0.00
M. K. 5	44.45	64.49	63.97	0.52	64.49	0.00

and 1969 Matsushiro blasts. It will not be unreasonable to define the anomalies of the arrival times of the Asama volcano with the deviations from the travel curve of 6.1 km/sec, which will be given later as in the case of the Matsushiro blasts.

In order to compare the anomalies of the Asama arrival times given in various seismic observations, the above anomalies are also represented in Table 6 as the second anomalies of Asama.

(2) *The travel time curve along the second group of the nets.*

In the second group of the nets, the Ookuwa one is located at the north-eastern foot of Volcano Asama and the observation points of the net are at distances from 30 km

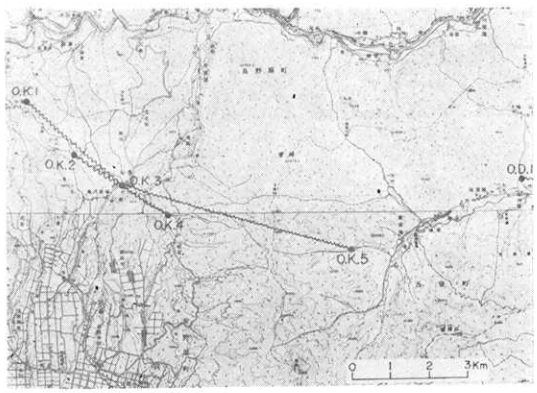

Fig. 14. The localities of the observation points belonging to the Ookuwa net.

to 40 km from the Matsushiro epicentral area and at altitudes from 860 m to 960 m. Naturally, the volcanic ejecta from Asama at these stations of the Ookuwa net are estimated to be quite thin and, therefore, the arrival times on the net will not seriously be affected by the accumulation of the recent Asama ejecta, notwithstanding the fact that the net is located quite near the volcano.

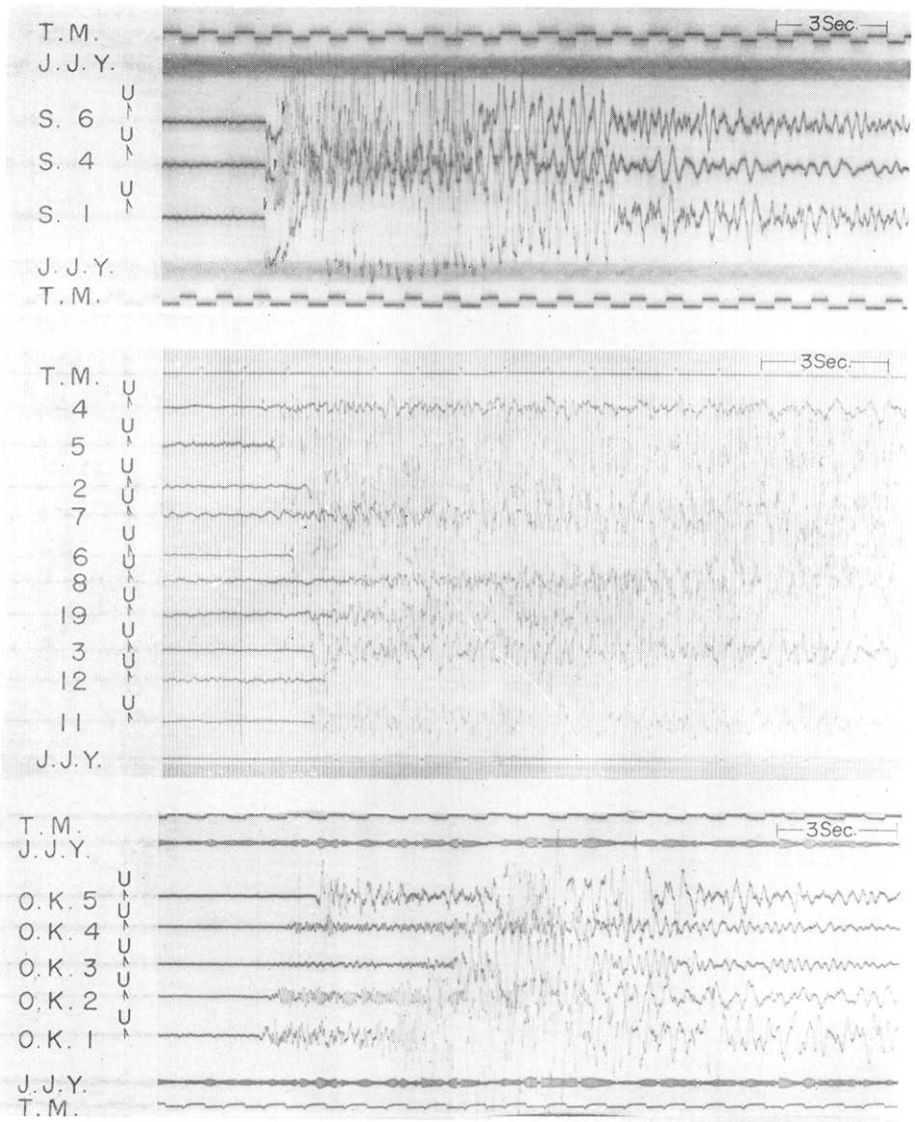

Fig. 15. The seismograms of the 00h 04m, October 1, 1966 Matsushiro earthquake observed at the Sugadaira, Asama and Ookuwa net-works, recorded with the oscillographs.

As an example, the arrival times and the epicentral distances of the second group of the nets are shown in Table 7 for one of the Matsushiro earthquakes on October 1, 1966, the relation between the arrival times and the epicentral distances being illustrated in Fig. 17. At a glance of Fig. 17, it will be remarked that the arrival times on the volcano are essentially different from those on the Ookuwa net, though the epicentral distances of the two nets are almost the same.

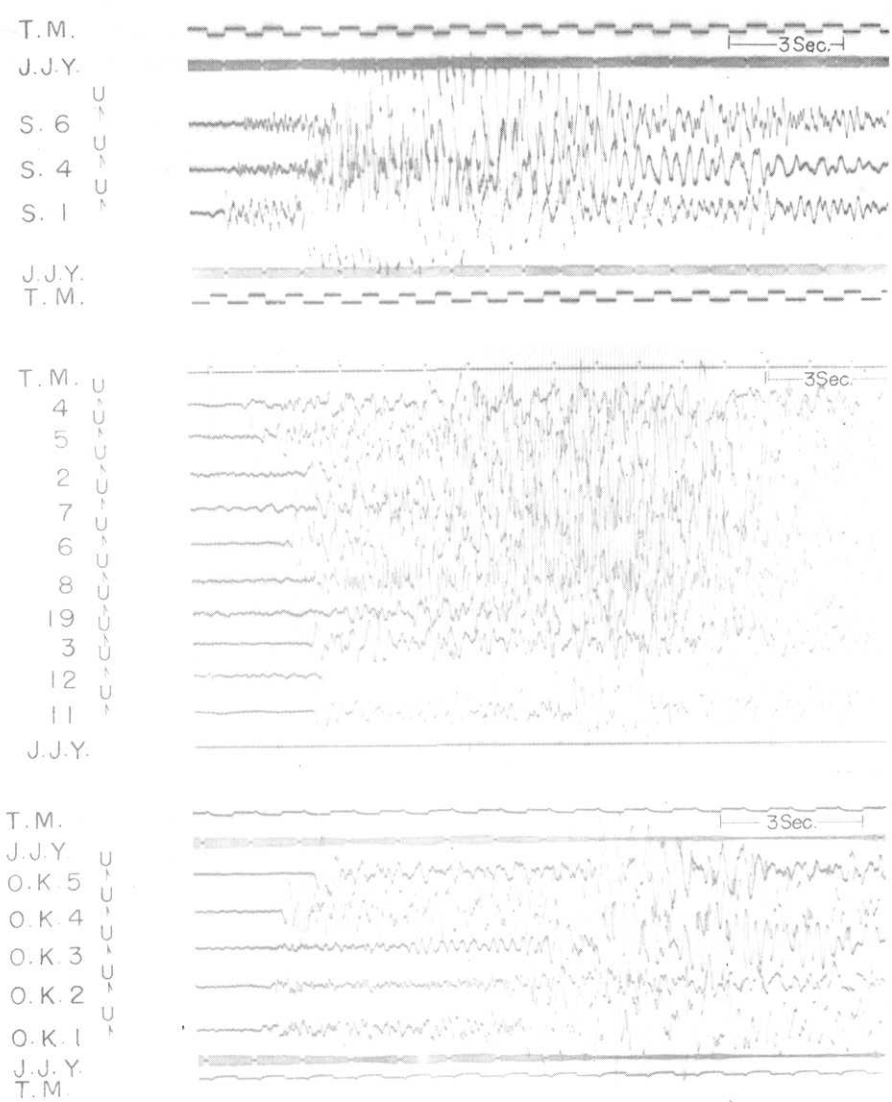

Fig. 16. The seismograms of the 22h 29m, October 1, 1966 Matsushiro earthquake observed by the Sugadaira, Asama and Ookuwa net-works, recorded with the oscillographs.

Table 7. The arrival times, their anomalies and the epicentral distances of the Matsushiro earthquake at 00h 04m, October 1, 1966 (Hypocentral depth = 3.8 km).

Δ; epicentral distance,
T; arrival time,
T^*; arrival time expected from the travel time curve given from Sugadaira-Ookuwa nets,
$T-T^*$; anomaly of arrival time.

(1) The Sugadaira net

Stn. No.	Δ	T	T^*	$T-T^*$
S1	8.83km	29.51sec	29.49sec	0.02sec
S4	10.45	29.74	29.76	−0.02
S6	11.95	29.96	30.01	−0.05

(2) The Asama permanent net

Stn. No.	Δ	T	T^*	$T-T^*$
5	30.50km	33.51sec	33.09sec	0.42sec
4	30.88	33.25	33.15	0.10
6	32.33	33.93	33.39	0.54
3	35.34	34.44	33.89	0.55
11	36.35	34.48	34.06	0.42
12	37.57	34.75	34.26	0.49

(3) The Ookuwa net

Stn. No.	Δ	T	T^*	$T-T^*$
O. K. 1	29.73km	33.05sec	32.96sec	0.09sec
O. K. 2	31.28	33.26	33.22	0.04
O. K. 3	32.68	33.44	33.45	−0.01
O. K. 4	34.02	33.67	33.67	0.00
O. K. 5	38.80	34.40	34.47	−0.07

From the results of the observations at the Sugadaira and the Ookuwa nets, the travel time curve is given in Fig. 17.

The second anomalies of the arrival times on the volcano are defined by the deviations from the above travel-time curve and listed in Table 7 for a comparison of those given from other nets.

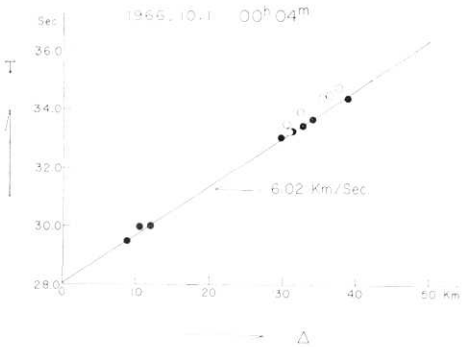

Fig. 17. The travel time curve of the 00h 04m, October 1, 1966 Matsushiro earthquake. The velocity of the P wave is given with the Sugadaira and Ookuwa nets.
Solid circle; arrival times at the Sugadaira and Ookuwa nets,
Open circle; arrival times at the Asama net.

(3) *The travel time curve along the third group of the nets.*

In the third group of the nets, the Oodo net was set at the most distant place from the volcano and the observation points of the net

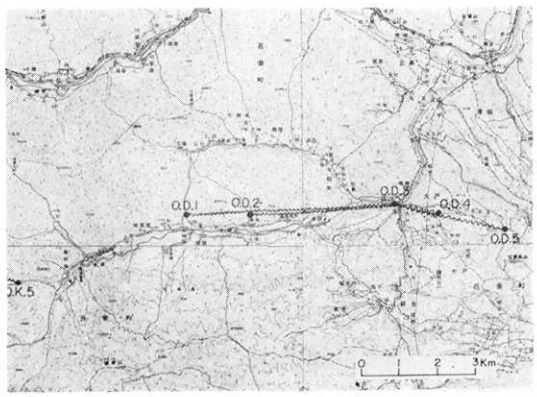

Fig. 18. The localities of the observation *points belonging to the Oodo net.*

were established along the Agatuma river. The two observation points at the east side in the net were located on the western foot of Volcano Haruna. The geological formation of the area consists of hard rocks independent of the Asama formation.

Table 8 shows the arrival times and the epicentral distances at each station belonging to the third group of the nets for two of the Matsushiro earthquakes on October 8, 1966. As can be seen in Figs. 20 and 21 which illustrate the epicentral distances and the arrival times

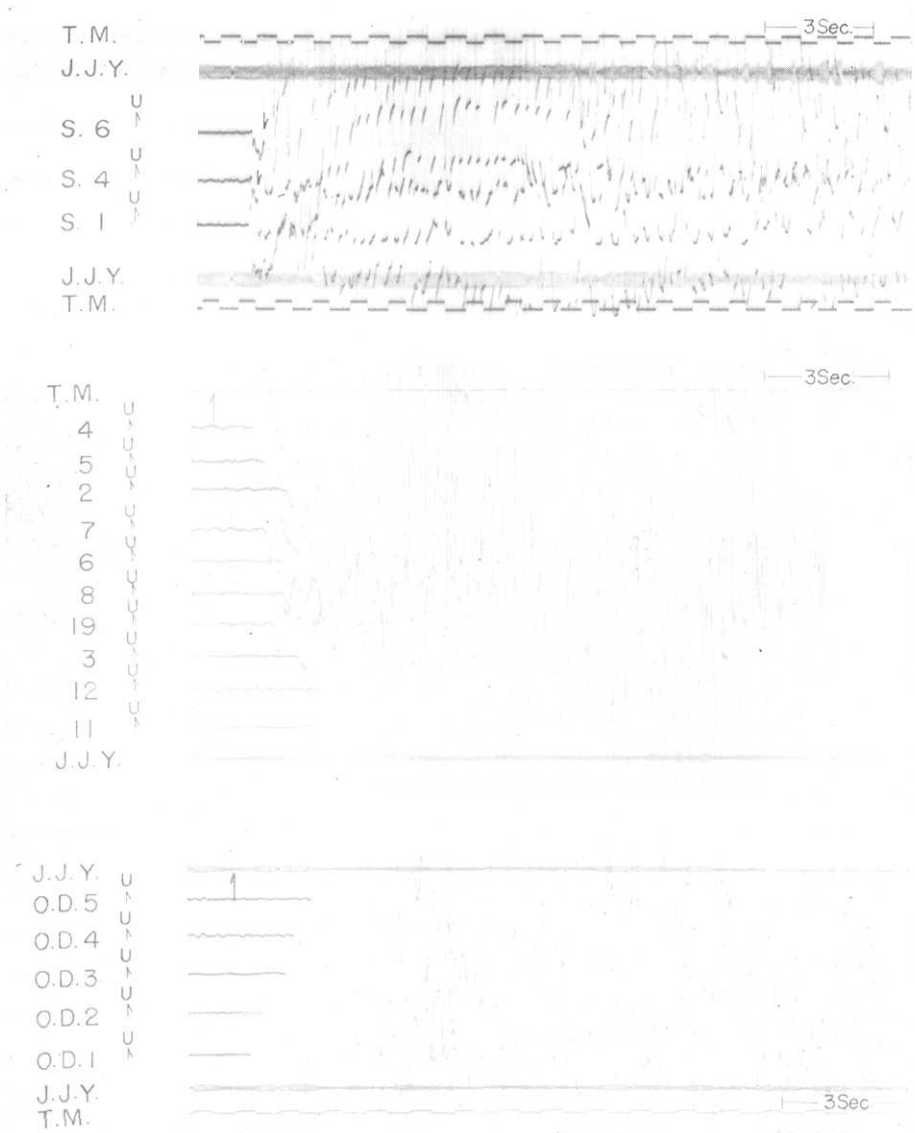

Fig. 19. The seismograms of the 23h 08m, October 8, 1966 Matsushiro earthquake observed by the Sugadaira, Asama and Oodo net-works, recorded with the oscillographs.

of the above earthquakes, the arrival times on Asama do not harmonize with the travel time curve given on the basis of the observations with the Sugadaira and Oodo nets as well as with the second group of the nets.

Table 8(1). The arrival times, their anomalies, epicentral distances and initial motions of the Matsushiro earthquake at 23h 08m, October 8, 1966 (Hypocentral depth = 5.3 km).

Δ; epicentral distance,
T; arrival time,
T^*; arrival time expected from the travel time curve given from Sugadaira-Ookuwa nets,
$T-T^*$; anomaly of arrival time.

(1) The Sugadaira net

Stn. No.	Δ	T	T^*	$T-T^*$	Init. mot.
S1	5.53km	18.49sec	18.44sec	0.05sec	Up
S4	7.58	18.75	18.78	−0.03	Up
S6	9.00	18.96	19.02	−0.06	Up

(2) The Asama permanent net

Stn. No.	Δ	T	T^*	$T-T^*$	Init. mot.
4	27.20km	22.22sec	22.02sec	0.20sec	Down
5	27.33	22.50	22.04	0.46	Down
19	29.20	22.73	22.35	0.38	Down
6	29.27	22.89	22.37	0.52	Down
7	29.42	22.51	22.39	0.12	Down
2	30.77	23.01	22.61	0.40	Down
8	31.13	22.97	22.67	0.30	Down
3	32.20	23.26	22.85	0.41	Down
11	33.62	23.61	23.08	0.53	Down
12	34.57	23.85	23.24	0.61	Down

(3) The Oodo net

Stn. No.	Δ	T	T^*	$T-T^*$	Init. mot.
O. D. 1	41.42km	24.37sec	24.37sec	0.00sec	Down
O. D. 2	43.10	24.67	24.65	0.02	Down
O. D. 3	46.30	25.19	25.18	0.01	Down
O. D. 4	47.97	25.37	25.45	−0.08	Down
O. D. 5	49.50	25.77	25.71	0.06	Down

Table 8(2). The arrival times, their anomalies, and epicentral distances of the Matsushiro earthquake at 23h 59m, October 8, 1966 (Hypocentral depth = 5.1 km).

Δ; epicentral distance,
T; arrival time,
T^*; arrival time expected from the travel time curve given from Sugadaira-Oodo nets,
$T-T^*$; anomaly of arrival time.

(1) The Asama permanent net

Stn. No.	Δ	T	T^*	$T-T^*$
4	26.42km	41.01sec	40.93sec	0.08sec
5	26.58	41.26	40.96	0.30
19	28.45	41.47	41.26	0.21
6	28.53	41.66	41.27	0.39
7	28.63	41.30	41.29	0.01
2	30.02	41.80	41.52	0.28
8	30.35	41.69	41.57	0.12
3	31.47	42.01	41.75	0.26
11	32.90	42.50	41.99	0.51
12	33.83	42.62	42.14	0.48

(2) The Oodo net

Stn. No.	Δ	T	T^*	$T-T^*$
O. D. 1	40.90km	43.30sec	43.29sec	0.01sec
O. D. 2	42.55	43.59	43.56	0.03
O. D. 3	46.30	44.10	44.17	−0.07
O. D. 4	47.42	44.32	44.35	−0.03
O. D. 5	48.93	44.67	44.60	0.07

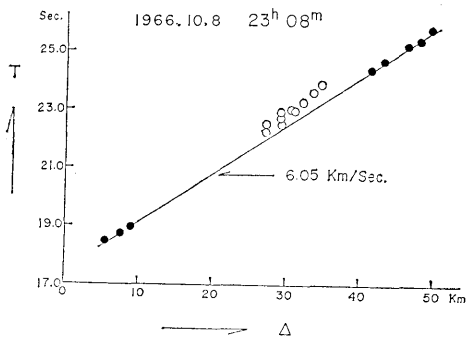

Fig. 20. The travel time curve of the 23h 08m, October 8, 1966 Matsushiro earthquake.
Solid circle; arrival times at the Sugadaira and Oodo nets,
Open circle; arrival times at the Asama net.

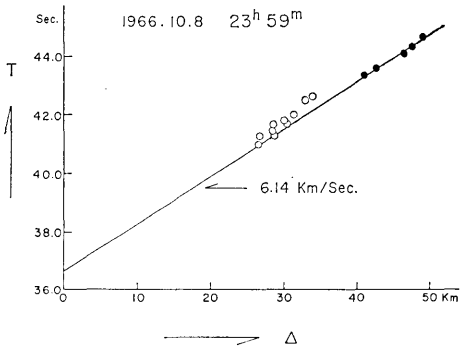

Fig. 21. The travel time curve of the 23h 59m, October 8, 1966 Matsushiro earthquake. The velocity is given by the observation of the Oodo net only.
Solid circle; arrival times at the Oodo net,
Open circle; arrival times at the Asama net.

(4) *The travel time curve along the fourth group of the nets*

The fourth group of seismic nets, or the Hosina, Sugadaira and Asama ones, is located within a narrow straight belt from the epicentral area to Volcano Asama. As will be seen on the map of Fig. 22, the Hosina net was placed extremely near the epicenters of the Matsushiro earthquakes. Therefore, the seismic observations with this group of nets were not always made for the above mentioned purpose of the present investigation, but for a study of the natures of the Matsushiro earthquakes. At the beginning of 1966, we had a lot of questions about the mechanism of occurrences of the Matsushiro earthquakes if the solidified lava had been intruded toward the Matsushiro area as well as the 1943–45 seismic and volcanic activities of Volcano Usu. Based on the above seismic observation, it was made clear that the B type earthquake did not appear in the Matsushiro area and, therefore, the natures of the Matsushiro earthquakes were very different from the seismic and volcanic phenomena of Usu in 1943–1945.

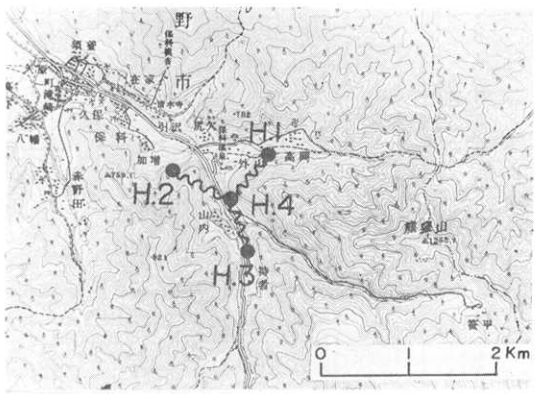

Fig. 22. The localities of the observation points belonging to the Hosina net.

Table 9. The arrival times, their anomalies and the epicentral distances of the Matsushiro earthquake at 21h 19m, June 6, 1966 (Hypocentral depth = 4.5 km).

Δ; epicentral distance,
T; arrival time,
T^*; arrival time expected from the travel time curve given from Sugadaira net,
$T-T^*$; anomaly of arrival time.

(1) The Sugadaira net

Stn. No.	Δ	T	T^*	$T-T^*$
S1	8.30km	14.98sec	14.94sec	0.04sec
S3	9.00	15.05	15.05	0.00
S2	10.03	15.26	15.22	0.04
S4	10.10	15.28	15.23	0.05
S5	10.38	15.22	15.28	−0.06
S6	11.60	15.43	15.48	−0.05

(to be continued)

Table 9. (Continued)

(2) The Asama permanent net

Stn. No.	Δ	T	T^*	$T-T^*$
5	30.18km	19.06sec	18.52sec	0.54sec
4	30.50	18.80	18.58	0.22
6	31.80	19.52	18.79	0.73
19	32.38	19.51	18.89	0.62
7	32.65	19.10	18.93	0.17
2	33.70	19.59	19.10	0.49
8	34.43	19.58	19.22	0.36
3	35.00	19.84	19.31	0.53
11	36.15	20.08	19.50	0.58
12	37.30	20.35	19.69	0.66

(3) The Hosina net

Stn. No.	Δ	T	T^*	$T-T^*$
H2	2.88km	14.37sec	—	—
H4	3.58	14.36	—	—
H3	3.90	14.40	—	—
H1	4.08	14.42	—	—

On the other hand, the travel time curves of the P arrival times along the above three nets were investigated for the present main purpose. In order to compare the anomalies of the arrival times on Asama with the results given from the observations in the other groups of the nets, the travel time curve observed with the Hosina-Sugadaira-Asama nets is illustrated in Fig. 23 for the Matsushiro earthquake at 21 h 19 m, June 6, 1966. The travel time curve in Fig. 23, is drawn by a line passing through the arrival times at the Sugadaira net, indicating a velocity of 6.1 km/sec.

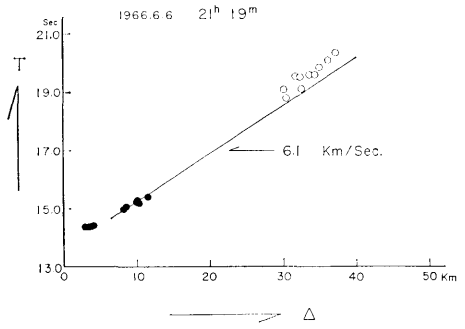

Fig. 23. The travel time curve of the 21h 19m, June 6, 1966 Matsushiro earthquake.
Solid circle; arrival times at the Hosina and Sugadaira nets,
Open circle; arrival times at the Asama net.

The anomalous values of the arrival times on Asama, which are obtained by the above procedure, harmonize well with those

given by the observations with the other groups of nets.

5. The relative anomalies of the arrival times on Asama

As described above, it was made clear from seismic observations

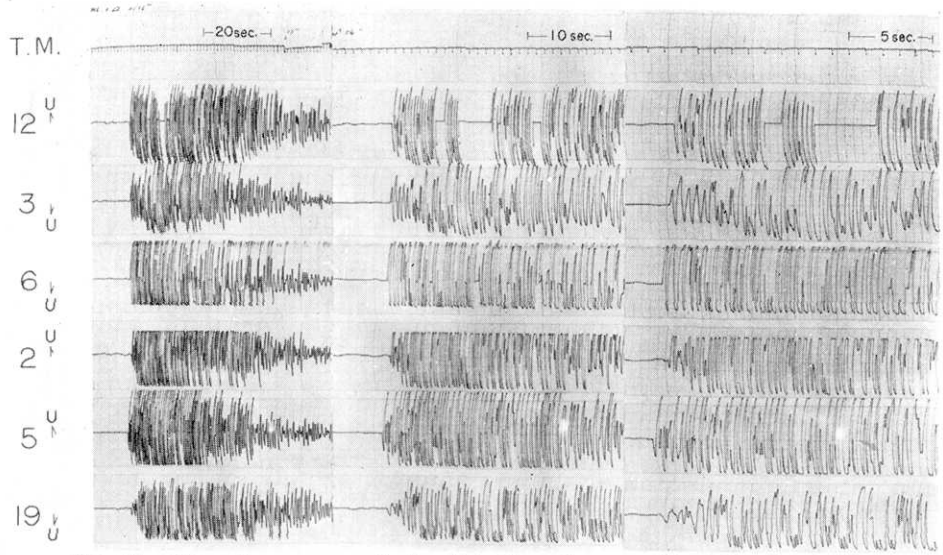

Fig. 24. The seismograms of the 01h 56m, January 22, 1966 Matsushiro earthquake observed Stn. Nos. 12, 3, 6, 2, 5 and 19 of the Asama permanent net recorded with the seven channelled tape recorder.

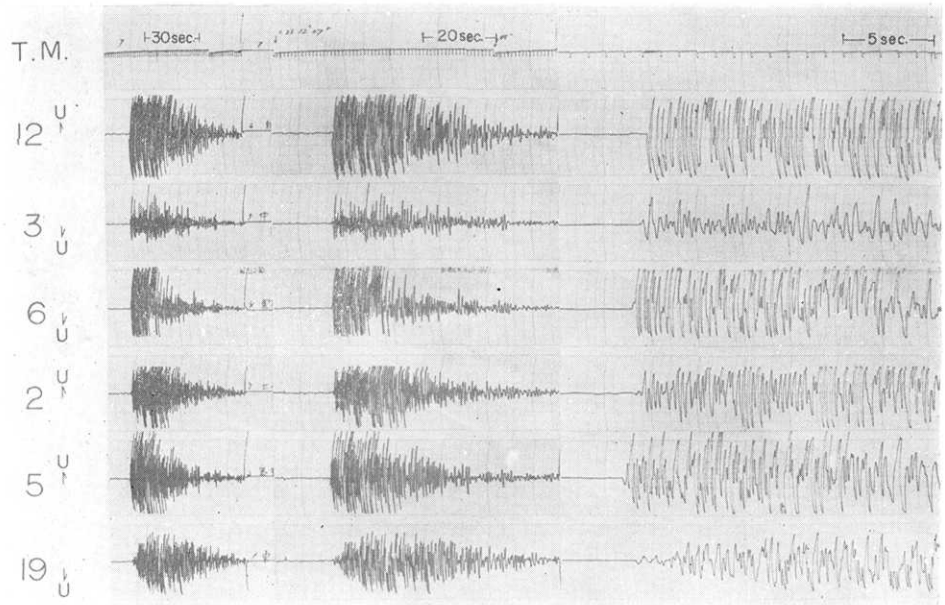

Fig. 25. The seismograms of the 12h 07m, January 23, 1966 Matsushiro earthquake observed at Stn. Nos. 12, 3, 6, 2, 5 and 19 of the Asama permanent net, recorded with the seven-channelled tape recorder.

with the Sugadaira, Ookuwa and Oodo nets that the *P* wave or the initial wave of the Matsushiro earthquakes propagated along the 6.1 km/sec layer just before its arrival underneath the volcano. However, it must be added that only ten or so Matsushiro earthquakes were observed with the Ookuwa, Oodo or Minami-Karuizawa nets together

Table 10(a). The dates, times and hypocentral depths of the Matsushiro earthquakes which the report deals with. (A group)

Eqk. No.	Date	Time	Hypocentral depth
	1965	h m	km
1	Nov. 7	01 41	5.3
	1966		
2	Apr. 19	20 10	4.6
3	Apr. 3	23 48	4.6
4	Apr. 4	02 24	6.7
5	Apr. 4	22 11	4.0
6	Apr. 5	23 52	4.4
7	May 13	18 00	1.3
8	June 6	21 19	4.5
9	June 6	21 29	4.6
10	June 17	21 16	4.9
11	Aug. 2	23 17	6.2
12	Aug. 5	22 29	3.9
13	Aug. 5	22 40	2.5

Table 10(b). (B group)

Eqk. No.	Date	Time	Hypocentral depth
	1966	h m	km
14	Jan. 20	23 59	5.6
15	Jan. 22	01 56	4.0
16	Jan. 22	12 42	3.3
17	Jan. 23	12 07	4.1
18	Mar. 20	23 56	5.2
19	Mar. 22	08 00	5.9
20	Mar. 25	22 36	6.3
21	May 26	16 12	4.5
22	May 26	16 25	3.8
23	May 28	02 33	4.8
24	July 10	02 40	6.0
25	July 12	14 09	2.1

with the Asama and Sugadaira ones. Since the above observations were insufficient to study precisely the arrival times on various parts of the volcano, a series of the Matsushiro earthquakes were studied not only with the Asama permanent net, but also with the temporary seismic stations on Asama.

As soon as the Matsushiro earthquakes began to take place on August 3, 1965, the writers made a plan to study the natures of their

earthquake motions which passed inside and underneath Volcano Asama. Especially, they paid attention to the initial motions and arrival times observed at a series of seismic stations on the volcano. For that purpose, a great number of the Matsushiro earthquakes were observed with the seven-channelled tape-recorder and the twelve-element oscillograph.

In Tables 11 and 12, the arrival times and epicentral distances at each station on the volcano are shown in the form of the differences from those of Stn. 4, Gippa-yama, for the A group of the earthquakes, and from those of Stn. 5, Oniosidasi W., for the B group of earthquakes.

Since the anomalies of the arrival times at Gippa-yama and Oniosidasi W. were made clear on the basis of the 6.1 km/sec travel-time curve given with the other nets, the relative anomalies of the arrival times in Tables 11 (A) and (B) were corrected to those referred to the above

Table 11(a). Anomalies of the arrival times on Volcano Asama for the Matsushiro earthquakes (A group).

$$T_n - T_4 = t_n, \qquad \Delta_n - \Delta_4 = \delta\Delta_n ,$$

$$t_n - \delta\Delta/6.1_{(\mathrm{km/sec})} = \delta t_n ,$$

where T_n; arrival times at Stn. n on Asama,
T_4; arrival times at Stn. 4, Gippa-yama,
Δ_n; epicentral distance at Stn. n on Asama,
Δ_4; epicentral distance at Stn. 4, Gippa-yama,
t_n; anomaly of the arrival time at Stn. n,
$\delta\Delta_n$; difference between epicentral distances at Stn. 4 and Stn. n.

Eqk. No.	Stn. 4	Stn. 5	Stn. 2	Stn. 7	Stn. 6	Stn. 9	Stn. 19	Stn. 1	Stn. 12	Stn. 17	Stn. 8	Stn. 3	Stn. 11
	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec
1	0.00	−0.03	—	—	0.29	—	0.31	—	—	—	0.63	0.77	—
2	0.00	−0.04	0.54	—	0.28	—	—	—	—	—	0.63	—	0.98
3	0.00	−0.01	0.56	—	0.31	—	—	—	—	—	0.63	—	0.70
4	0.00	−0.09	0.50	—	0.22	—	—	—	—	—	—	—	0.81
5	0.00	0.03	0.59	—	0.36	—	—	—	—	—	0.63	—	1.10
6	0.00	−0.03	0.54	—	0.28	—	—	—	—	—	0.63	—	0.98
7	0.00	−0.03	0.55	—	0.29	—	0.32	—	1.17	—	0.63	0.77	0.99
8	0.00	−0.05	0.52	0.35	0.21	—	0.31	—	1.11	—	0.64	0.74	0.93
9	0.00	0.00	0.57	0.35	0.29	—	0.33	—	1.18	—	0.65	0.79	1.01
10	0.00	−0.05	0.53	0.35	0.25	—	—	—	1.12	—	0.65	0.74	0.92
11	0.00	−0.14	0.44	0.31	0.15	0.67	0.25	0.35	1.01	0.53	—	—	—
12	0.00	−0.08	—	—	—	0.72	0.29	0.39	1.10	0.61	0.62	0.72	0.90
13	0.00	−0.11	—	—	—	0.70	0.27	0.38	1.06	0.58	0.62	0.69	0.85
Mean	0.00	−0.05	0.54	0.34	0.27	0.70	0.30	0.38	1.11	0.57	0.63	0.75	0.95
$\pm\sqrt{\frac{\Sigma}{n}}$	0.00	0.04	0.03	0.03	0.05	0.01	0.02	0.01	0.04	0.02	0.01	0.02	0.10

6.1 km/sec travel time curve. The result is illustrated in Fig. 26.

For the present study of the structure of Volcana Asama, the writers dealt with the initial waves of the Matsushiro earthquakes and the blasts at the Matsushiro area and on Asama. Therefore, it will be necessary to mention with respect to the initial motions of the Matsushiro earthquakes which were applied to the present investigation.

According to the geographical distribution of the initial motions of the Matsushiro earthquakes studied by T. Hagiwara[9], K. Hamada and others, one of the nodal lines of the Matsushiro earthquakes passed in most cases toward the south-east direction of the respective epicenters at the Matsushiro area. Therefore, the nodal line sometimes passed in the midst of the Asama net and in other cases at the northern and southern sides of the nets according to the geographical positions of

Table 11(b). Anomalies of the arrival times on Volcano Asama for the Matsushiro earthquakes (B group).

$$T_n - T_5 = t_n\ , \qquad \Delta_n - \Delta_5 = \delta\Delta_n\ ,$$
$$T_n - \delta\Delta_n/6.1_{(\mathrm{km/sec})} = \delta t_n\ ,$$

T_n; arrival times at Stn. n on Asama,
T_5; arrival time at Stn. 5, Oniosidasi W,
Δ_n; epicentral distance at Stn. n on Asama,
Δ_5; epicentral distance at Stn. 5, Oniosidasi W,
δt_n; anomaly of arrival times at Stn. n,
$\delta\Delta_n$; difference between epicentral distances at Stn. n and Stn. 5.

Eqk. No.	Stn. 4	Stn. 5	Stn. 2	Stn. 7	Stn. 6	Stn. 9	Stn. 19	Stn. 1	Stn. 12	Stn. 17	Stn. 8	Stn. 3	Stn. 11
		sec	sec	sec	sec		sec		sec	sec	sec	sec	sec
14	—	0.00	0.59	—	0.31	—	0.37	—	1.18	—	—	0.80	—
15	—	0.00	0.58	—	0.31	—	0.37	—	1.19	—	—	0.80	—
16	—	0.00	0.57	—	0.33	—	0.33	—	1.20	—	—	0.80	—
17	—	0.00	0.57	—	0.33	—	0.33	—	1.20	—	—	0.80	—
18	—	0.00	0.58	0.34	0.32	—	—	—	—	—	0.65	—	1.03
19	—	0.00	0.57	0.34	0.32	—	—	—	—	—	0.64	—	1.04
20	—	0.00	0.58	0.39	0.31	—	—	—	—	—	0.69	—	1.00
21	—	0.00	0.57	0.33	0.33	—	0.34	—	—	—	—	—	1.05
22	—	0.00	0.55	0.26	0.33	—	0.30	—	—	—	—	—	1.08
23	—	0.00	0.58	0.39	—	—	0.36	—	—	—	—	—	1.00
24	—	0.00	0.59	0.40	0.31	—	0.37	—	—	—	0.70	—	—
25	—	0.00	0.59	0.40	0.31	—	0.37	—	—	—	0.70	—	—
Mean	—	0.00	0.58	0.36	0.32	—	0.35	—	1.19	—	0.68	0.80	1.03
$\pm\sqrt{\frac{\Sigma}{n}}$	—	0.00	0.01	0.04	0.01	—	0.02	—	0.00	0.02	—	0.00	0.02

9) K. HAMADA and T. HAGIWARA, *loc. cit.*, (7).

Table 12(a). The differences (t_n) of the arrival times (T_n) at the stations on Asama to those (T_4) at Stn. Gippa-yama for the Matsushiro quakes listed in Table 10(a).

$$t_n = T_n - T_4$$

Eqk. No.	Stn. 4	Stn. 5	Stn. 2	Stn. 7	Stn. 6	Stn. 9	Stn. 19	Stn. 1	Stn. 12	Stn. 17	Stn. 8	Stn. 3	Stn. 11
	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec
1	0.00	0.31	—	—	0.73	—	0.64	—	—	—	0.75	1.22	—
2	0.00	0.28	0.87	—	0.75	—	—	—	—	—	0.76	—	1.47
3	0.00	0.25	0.84	—	0.75	—	—	—	—	—	0.82	—	1.46
4	0.00	0.21	0.73	—	0.63	—	—	—	—	—	—	—	1.14
5	0.00	0.31	0.70	—	0.69	—	—	—	—	—	0.72	—	1.43
6	0.00	0.18	0.67	—	0.60	—	—	—	—	—	0.87	—	1.19
7	0.00	0.37	0.80	—	0.75	—	0.53	—	1.69	—	0.79	1.18	1.46
8	0.00	0.26	0.80	0.30	0.72	—	0.72	—	1.56	—	0.78	1.02	1.28
9	0.00	0.27	0.79	0.33	0.72	—	0.70	—	1.69	—	0.80	1.04	1.50
10	0.00	0.26	0.77	0.28	0.65	—	—	—	1.48	—	0.78	1.16	1.29
11	0.00	0.26	0.75	0.32	0.65	0.80	0.50	0.61	1.40	1.11	—	—	—
12	0.00	0.29	—	—	—	1.09	0.47	0.72	1.52	1.17	0.55	1.09	1.16
13	0.00	0.29	—	—	—	1.05	0.51	0.65	1.55	1.10	0.74	1.05	1.26
Mean	0.00	0.27	0.77	0.31	0.69	0.98	0.65	0.66	1.56	1.13	0.76	1.11	1.33

Table 12(b). The differences (t_n) of the arrival times (T_n) at the stations on Asama to those (T_5) at Stn. Oniosidasi W. for the Matsushiro quakes listed in Table 10(b).

$$t_n = T_n - T_5$$

Eqk. No.	Stn. 4	Stn. 5	Stn. 2	Stn. 7	Stn. 6	Stn. 9	Stn. 19	Stn. 1	Stn. 12	Stn. 17	Stn. 8	Stn. 3	Stn. 11
	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec	sec
14	—	0.00	0.50	—	0.43	—	0.16	—	1.26	—	—	0.76	—
15	—	0.00	0.51	—	0.38	—	0.18	—	1.20	—	—	0.82	—
16	—	0.00	0.52	—	0.44	—	0.23	—	1.39	—	—	0.86	—
17	—	0.00	0.54	—	0.46	—	0.22	—	1.34	—	—	0.84	—
18	—	0.00	0.55	0.08	0.42	—	—	—	—	—	0.52	—	1.10
19	—	0.00	0.58	0.14	0.41	—	—	—	—	—	0.62	—	1.08
20	—	0.00	0.50	0.08	0.41	—	—	—	—	—	0.45	—	1.00
21	—	0.00	0.50	0.02	0.40	—	0.16	—	—	—	—	—	1.08
22	—	0.00	0.48	0.08	0.49	—	0.19	—	—	—	—	—	1.19
23	—	0.00	0.48	0.11	—	—	0.24	—	—	—	—	—	0.95
24	—	0.00	0.44	0.01	0.37	—	0.18	—	—	—	0.43	—	—
25	—	0.00	0.51	0.20	0.39	—	0.31	—	—	—	0.46	—	—
Mean	—	0.00	0.51	0.09	0.42	—	0.21	—	1.29	—	0.50	0.82	1.07

Table 13(a). The differences ($\delta\Delta_n$) of the epicentral distances (Δ_n) at the stations on Asama to those (Δ_4) at Stn. Gippa-yama for the Matsushiro quakes listed in Table 10, (a).

$$\delta\Delta_n = \Delta_n - \Delta_4$$

Eqk. No.	Stn. 4	Stn. 5	Stn. 2	Stn. 7	Stn. 6	Stn. 9	Stn. 19	Stn. 1	Stn. 12	Stn. 17	Stn. 8	Stn. 3	Stn. 11
	km	km	km	km	km	km	km	km	km	km	km	km	km
1	0.00	−0.21	—	—	1.74	—	1.92	—	—	—	3.84	4.70	—
2	0.00	−0.22	3.30	—	1.72	—	—	—	—	—	3.84	—	5.99
3	0.00	−0.06	3.43	—	1.91	—	—	—	—	—	3.85	—	6.27
4	0.00	−0.52	3.05	—	1.36	—	—	—	—	—	—	—	4.94
5	0.00	0.20	3.62	—	2.21	—	—	—	—	—	3.85	—	6.69
6	0.00	−0.21	3.32	—	1.73	—	—	—	—	—	3.83	—	5.99
7	0.00	−0.19	3.33	—	1.75	—	1.94	—	7.13	—	3.84	4.72	6.04
8	0.00	−0.32	3.20	2.15	1.30	—	1.88	—	6.80	—	3.93	4.50	5.65
9	0.00	0.00	3.47	2.12	1.77	—	2.02	—	7.20	—	3.97	4.85	6.17
10	0.00	−0.30	3.22	2.15	1.50	—	—	—	6.85	—	3.95	4.52	5.62
11	0.00	−0.87	2.71	1.92	0.92	4.10	1.52	2.16	6.14	3.25	—	—	—
12	0.00	−0.51	—	—	—	4.37	1.75	2.41	6.71	3.71	3.79	4.39	5.50
13	0.00	−0.65	—	—	—	4.27	1.66	2.32	6.50	3.53	3.76	4.23	5.21
Mean	0.00	−0.30	3.27	2.09	1.63	4.25	1.81	2.29	6.76	3.49	3.86	4.56	5.82

Table 13(b). The differences ($\delta\Delta_n$) of the epicentral distances (Δ_n) at the stations on Asama to those (Δ_5) at Stn. Oniosidasi W. for the Matsushiro quakes listed in Table 10(b).

$$\delta\Delta_n = \Delta_n - \Delta_5$$

Eqk. No.	Stn. 4	Stn. 5	Stn. 2	Stn. 7	Stn. 6	Stn. 9	Stn. 19	Stn. 1	Stn. 12	Stn. 17	Stn. 8	Stn. 3	Stn. 11
	km	km	km	km	km	km	km	km	km	km	km	km	km
14	—	0.00	3.61	—	1.89	—	2.27	—	7.22	—	—	4.91	—
15	—	0.00	3.56	—	1.89	—	2.23	—	7.24	—	—	4.90	—
16	—	0.00	3.47	—	1.99	—	2.01	—	7.34	—	—	4.89	—
17	—	0.00	3.48	—	1.99	—	2.03	—	7.35	—	—	4.90	—
18	—	0.00	3.51	2.10	1.96	—	—	—	—	—	3.96	—	6.30
19	—	0.00	3.50	2.08	1.96	—	—	—	—	—	3.93	—	6.34
20	—	0.00	3.56	2.37	1.90	—	—	—	—	—	4.21	—	6.09
21	—	0.00	3.49	2.03	1.99	—	2.05	—	—	—	—	—	6.39
22	—	0.00	3.38	1.61	2.03	—	1.85	—	—	—	—	—	6.59
23	—	0.00	3.56	2.36	—	—	2.22	—	—	—	—	—	6.11
24	—	0.00	3.58	2.45	1.90	—	2.26	—	—	—	4.29	—	—
25	—	0.00	3.58	2.42	1.87	—	2.24	—	—	—	4.26	—	—
Mean	—	0.00	3.52	2.18	1.94	—	2.13	—	7.29	—	4.13	4.90	6.30

respective epicenters.

In Tables 14 (a) and (b), the directions of the initial motions at a series of seismic stations on Asama were listed up for the Matsushiro earthquakes which were used for the present study. It will be somewhat needless to affirm that the travel times and the anomalous distribution of the arrival times on the volcano etc., as already mentioned, were independent of the sense of the initial motions of the Matsushiro earthquakes.

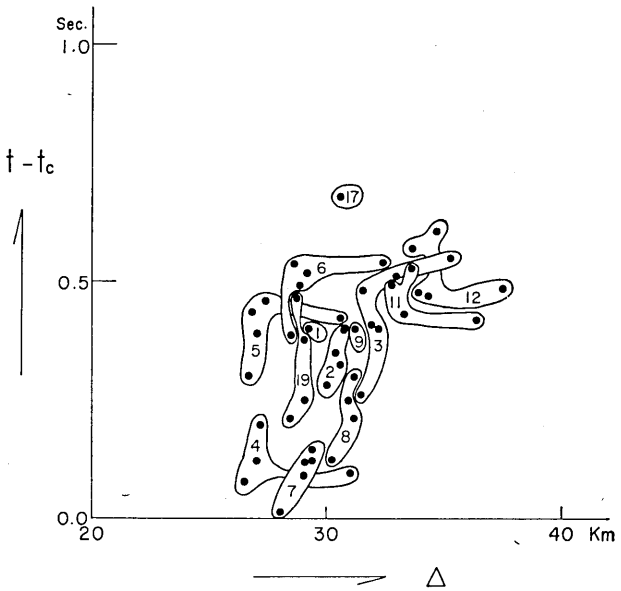

Fig. 26. The delays of the P arrival times at the stations on Asama as compared with the travel time curve of 6.1 km/sec, for the Matsushiro earthquakes.
Numerals; Stn. Nos.,
t=arrival times on Asama,
t_c=arrival times along the Sugadaira-Ookuwa and Oodo nets.

Table 14(a). The initial motions on Asama of the Matsushiro earthquakes which are listed in Table 10(a).
D; Downward motion,
U; Upward motion.

Eqk. No.	Stn. 4	Stn. 6	Stn. 2	Stn. 7	Stn. 6	Stn. 9	Stn. 19	Stn. 1	Stn. 12	Stn. 17	Stn. 8	Stn. 3	Stn. 11
1	D	D	—	—	D	—	D	—	—	—	D	D	—
2	D	D	D	—	D	—	—	—	—	—	D	—	D
3	D	D	D	—	D	—	—	—	—	—	D	—	D
4	D	D	D	—	D	—	—	—	—	—	—	—	D
5	D	D	D	—	D	—	—	—	—	—	D	—	D
6	D	D	D	—	D	—	—	—	—	—	D	—	D
7	D	D	D	?	U	—	D	—	D	—	U	U	D
8	D	D	D	?	U	—	U	—	D	—	U	D	D
9	D	D	D	U	U	—	U	—	D	—	D	U	D
10	D	D	D	D	D	—	?	—	D	D	D	D	D
11	D	D	D	U	D	D	D	D	D	D	—	—	—
12	U	U	—	—	—	U	U	U	U	U	U	U	U
13	U	U	—	—	—	U	U	U	U	U	U	U	U

Table 14(b). The initial motions on Asama for the Matsushiro earthquakes which are listed in Table 10(b).
D; Downward motion,
U; Upward motion.

Eqk. No.	Stn. 4	Stn. 5	Stn. 2	Stn. 7	Stn. 6	Stn. 9	Stn. 19	Stn. 1	Stn. 12	Stn. 17	Stn. 8	Stn. 3	Stn. 11
14	—	D	D	—	D	—	D	—	D	—	—	D	—
15	—	D	D	—	D	—	D	—	D	—	—	D	—
16	—	D	D	—	D	—	D	—	D	—	—	D	—
17	—	D	D	—	D	—	D	—	D	—	—	D	—
18	—	D	D	D	D	—	D	—	—	—	D	—	—
19	U	U	U	D	U	—	D	—	—	—	U	—	D
20	D	D	D	U	D	—	—	—	—	—	D	D	D
21	D	D	D	D	D	D	—	—	—	—	—	—	D
22	D	D	D	D	D	—	D	—	—	—	—	—	D
23	U	U	U	U	U	—	U	—	—	—	—	—	U
24	D	D	D	D	D	—	D	—	—	—	D	—	—
25	D	D	D	D	D	—	D	—	—	—	D	—	—

6. The anomalous distributions on Volcano Asama in the arrival times of the seismic waves by the blasts and the Matsushiro earthquakes

On the basis of seismometrical observations, the writers made clear the two kinds of anomalies of arrival times of the seismic P wave on Volcano Asama, of which the one, the first anomaly, was based on seismometrical experiments of the 1967 and 1969 blasts at Togura near the Matsushiro epicentral area, and the other second anomaly, based on the seismometrical observations of the 1955 and 1966 Matsushiro earthquakes by means of the same net-works on and around the volcano.

As mentioned already, the former anomalies on Asama by the two blasts are defined by the deviations from the travel time curve obtained from the observations by the Sugadaira and Minami-Karuizawa net-works. The anomalous values at the observation points of the Asama and Takamine nets are illustrated on the topographical map of Fig. 27. At a glance of the map, it will be clear that the anomalies of the arrival times on the volcano are outstandingly remarkable, moreover, they distribute systematically and concentrate on the east and north-east flanks of the volcano.

In order to find the origins of the above anomalies on Asama, the writers examined the relation with the altitudes of the observation points for the reason that they distribute from about 900 m to 2350 m above sea-level, as can be seen in Figs. 38 and 39, and Tables 4～9. It must be remarked that the arrival times at each observation point on the Sugadaira and Minami-Karuizawa nets are almost exactly on the

travel time curve of 5.20 km/sec and therefore, the anomalies on these points are extremely small except for 2 to 3 points on the Minami-Karuizawa nets. It will be necessary to add also that the altitudes of the observation points adhering to the above Sugadaira and Minami-Karuizawa nets are in the ranges from 1265 m to 1300 m for the former net and from 920 m to 960 m for the latter. Therefore, the Sugadaira net was located at about 300 m higher than the latter, though the heights of the observation points belonging to the same net are quite similar respectively.

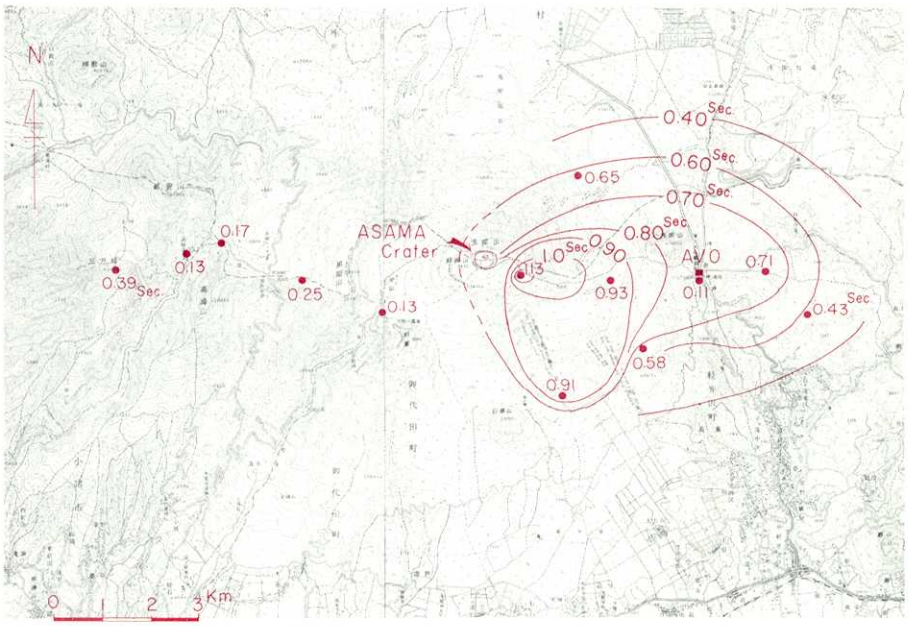

Fig. 27. Anomalous distribution of the arrival times or the delayed times of the P waves on Volcano Asama, given from the seismometrical observations of the Matsushiro (Togura) blasts.

On the other hand, the Takamine net was located on an altitude from 1730 m to 2300 m, but the observation points, on which the 1969 Matsushiro blasts were recorded, were in the range from 1730 m to 2040 m in their height above sea-level. Therefore, it can be said that the Takamine-net was situated at the highest place among the other nets.

As can be clearly seen in Fig. 27, the deviations of the arrival times from the 5.20 km/sec travel time curve on the Takamine net-work for the 1969 Matsushiro blasts were in the range from 0.13 to 0.39 sec, showing a markedly smaller value than those on Asama. Judging from the altitudes of the Takamine observation points, it will be reasonable to assume that the arrival times at the above points are on the 5.2

km/sec travel time curve if the correction for the altitudes will be made for the Takamine net which was located at 650 m higher in average than the Sugadaira one, and 1000 m higher than the Minami-Karuizawa one respectively.

Therefore, it will not be unreasonable to infer that the P wave from the shot point A-IV at the Togura blasts propagated with a velocity of 5.2 km/sec to the Takamine net, located at the west side of Asama

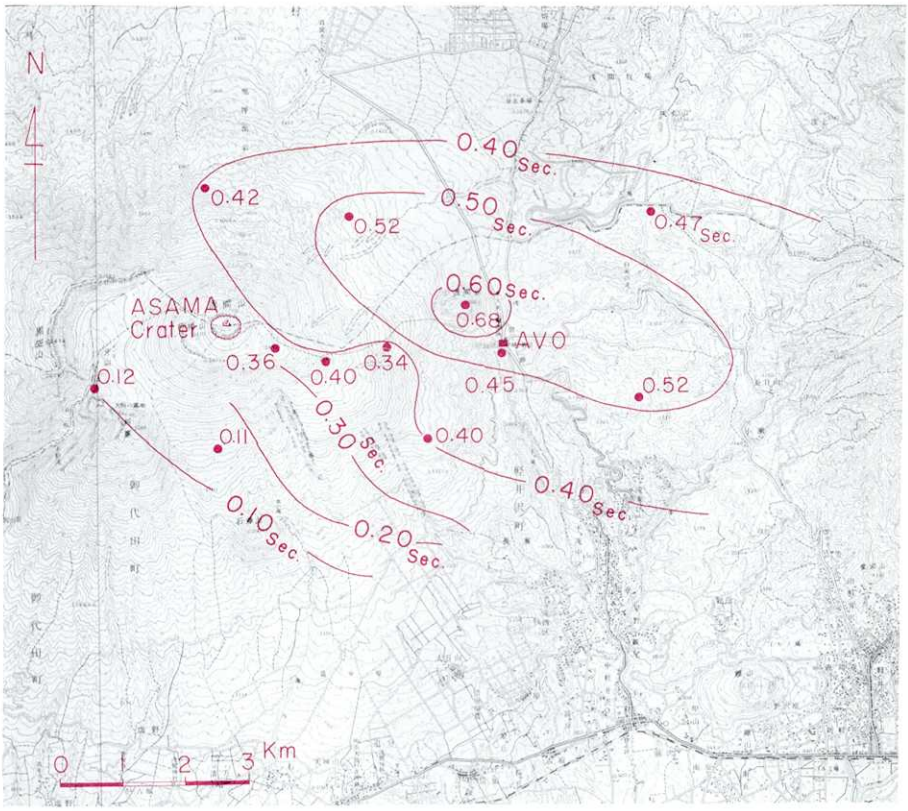

Fig. 28. Anomalous distribution of the arrival times or the delayed times of the P waves on Asama given from the seismometrical observations of a series of the 1966 Matsushiro earthquakes.

or at a nearer place to the short point than to the Asama one, as will be seen in Fig. 1. Therefore, it will also be reasonable to suppose that the anomalies of the Asama observation points defined by the deviations from the 5.20 km/sec travel time curve are originating from the surface, the inside and the root of Volcano Asama.

As already described, delays of arrival times of the P wave on Asama were investigated on the basis of seismic observations of a series of the 1965-1966 Matsushiro earthquakes, the delayed times of the arrival

times on Asama being defined by deviations from the 6.10 km/sec travel time curve given by seismic observations with the Sugadaira, Ookuwa and Oodo net-works.

Although the values of the delayed time on Asama in Fig. 28 are less than those given by the 1967 and 1969 blasts, the pattern of geographical distribution of the delay of arrival times is almost similar to each other.

From the relationships between the delayed times and altitude of observation points, it can be said that their main origins are not derived from the differences in altitude but from the root of the volcano which shows the different or the lower velocity distribution as compared with that of the surrounding region. The problem will be discussed again later in this paper.

7. The seismometrical experiments by blasts on the eastern and western flanks of Volcano Asama

In order to make clear the structure of the volcano, the writers carried out a series of seismometrical experiments by small blasts on the eastern middle flank near Stn. Sannotorii and on the western flank of Kurohu-yama, the oldest formation of Asama.

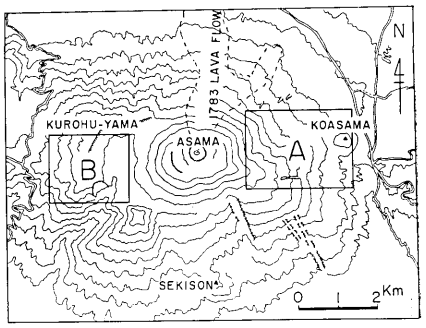

Fig. 29. The localities of the seismometrical experiments of the blasts on the eastern and western sides of Asama.

Of the above two places, the former place consists of a series of layers of pumice, ash, gravel and other fine ejecta, of which the propagating velocities of the seismic wave were expected to be markedly low. On the contrary, the latter place consists of a series of lava flows originating from Kurohu-yama in which the propagating velocities of the seismic wave were expected to be highest on the surface part of the volcano. For the above reasons, the writers chose the above extreme places as the first step of the investigation.

(1) *The seismometrical experiments on the middle eastern flank of Asama on May 28, 1969*

Based on experiments of the effects of the powder in the blast on the same place as made in December 1967, the observation line and the situation of the transducers were established near Stn. Sannotorii as shown on the map of Figs. 30 and 33 and in Table 15.

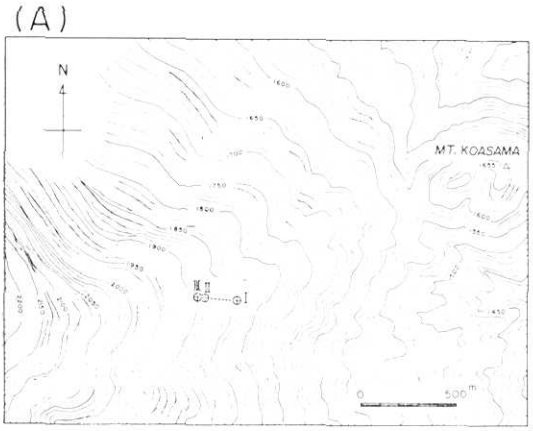

Fig. 30. The locality of the May 28, 1969blasts near Sannotorii, I, II & III; Shot point

For the purpose of the experiments, 2 kg of powder was used for each blast and the travel time curves were obtained as illustrated in Fig. 33. According to the analysis of these travel time curves, the propagating velocity of the P wave was in a range from 350 m/sec to 500 m/sec, the thickness of the surface layers being about 30 m at the west side of the observation line

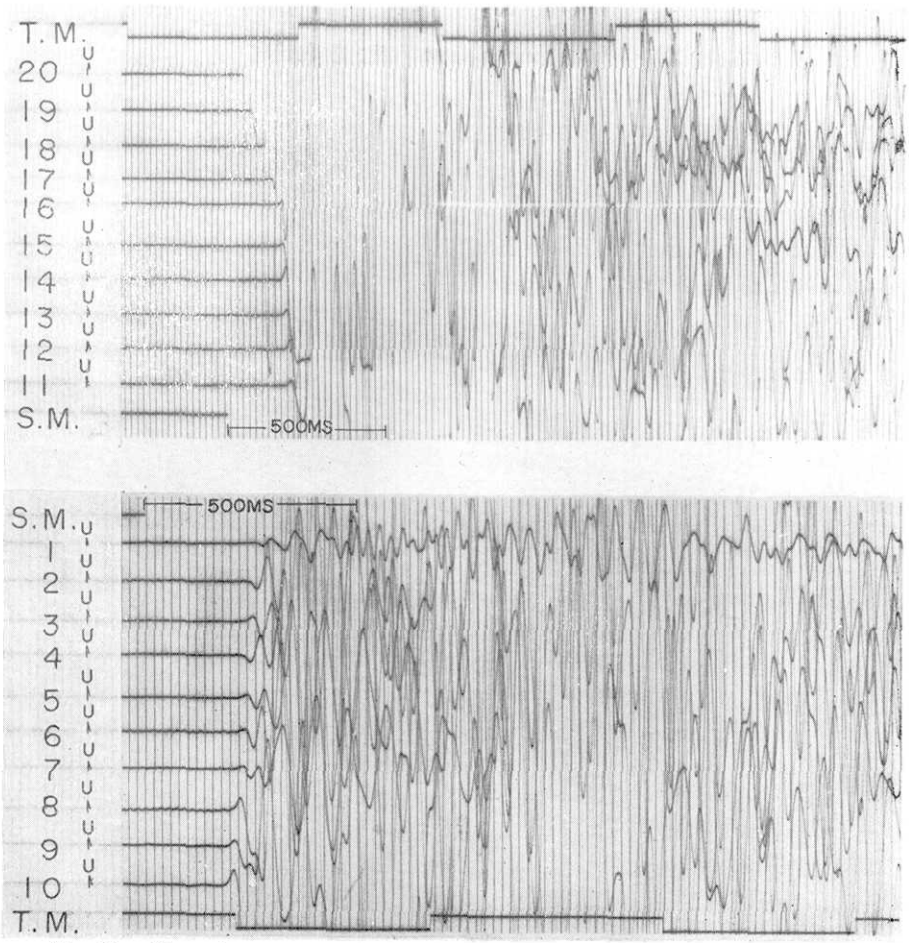

Fig. 31. The seismograms of the Asama blast on May 28, 1969, at the eastern middle flank of the volcano.

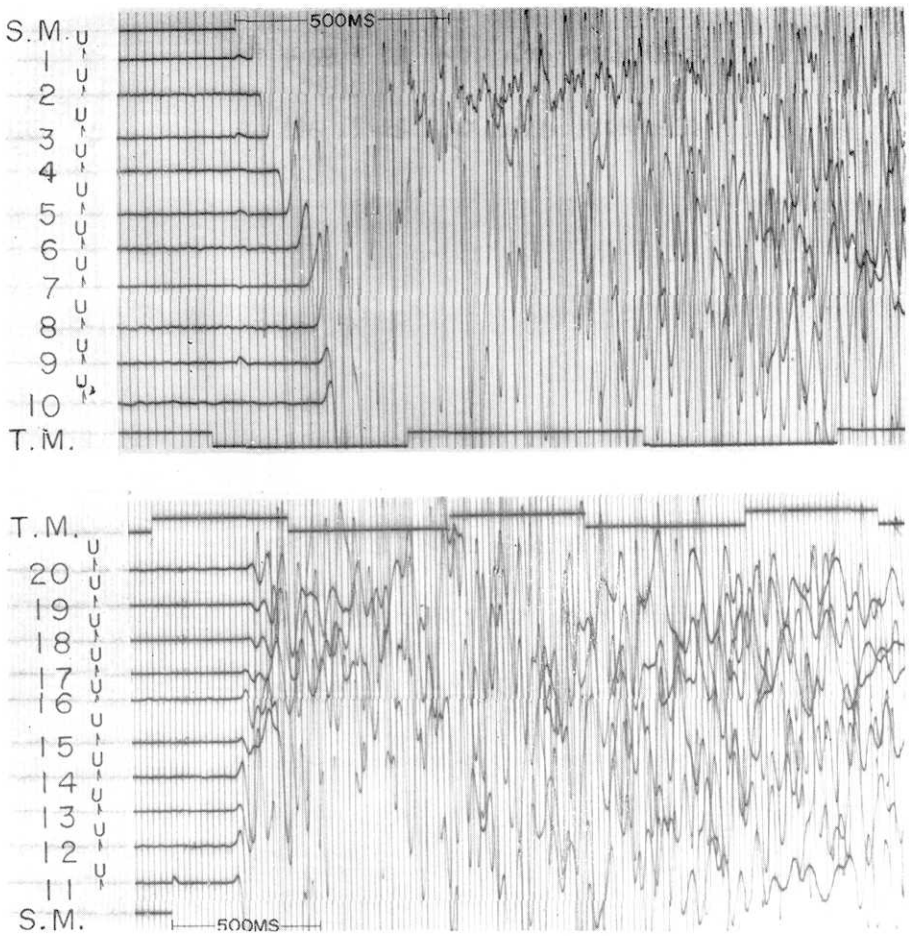

Fig. 32. The seismograms of the Asama blast on May 28, 1969, at the eastern middle flank of the volcano.

and nearly 20 m at the other side, though the earth's surface on the observation line is covered by a thin layer of about 1–2 m with 260 m/sec as its propagating velocity.

From the same travel time curves, it was made clear that the second layer has a velocity of 1.9 km/sec and contacts with the surface one, making a conspicuous boundary as seen clearly in Fig. 33. It will be certain that the second layer will correspond to Hotokeiwa lavas, the old formation of Asama volcano, which is covered by ejecta originating from Maekake-yama and the present central cone, according to geological investigations by S. Aramaki[10]. However, it was impossible to find the third layer under the second one on account of the short observation line.

10) S. ARAMAKI, *Jour. Fac. Sci. Univ. Tokyo*, Sec. II, **14** (1963) 229–443.

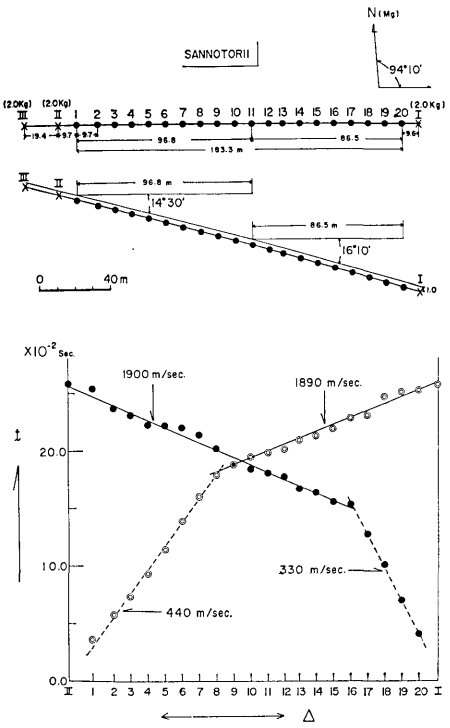

Fig. 33. The travel time curves of the seismic waves originating from the blasts on the eastern flank near Sannotorii.

Table 15. The May 28, 1969 blast on the eastern middle flank, near Sannotorii (A), of Volcano Asama.

Δ: horizontal distance,
t: arrival time,
S. P.: shot point.

Table 15(a)-1.

Direction of the observation line (counterclockwise)	Slope angle	
Pick Nos. 1-20	Pick Nos. 1-11	Pick Nos. 11-20
85° 50′-265°50′	−14°30′	−16°10′

Table 15(a)-2, Charge (set 1 m under ground)

Shot No. I(A)	Shot No. II(A)	Shot No. III(A)
2 kg	2 kg	2 kg

Table 15(b).

Pick No.	No. I(A)		No. II(A)			No. III(A)		
	Δ	t		Δ	t		Δ	t
			S. P.	0.0 m	0.0×10^{-2} sec	S. P.	0.0 m	0.0×10^{-2} sec
1	200.0 m	25.4×10^{-2} sec		10.0	3.6		30.0	7.4
2	190.0	23.7		20.0	5.7		40.0	9.1
3	180.0	23.1		30.0	7.3		50.0	11.0
4	170.0	22.2		40.0	9.3		60.0	13.1
5	160.0	22.2		50.0	11.4		70.0	15.1
6	150.0	22.0		60.0	13.9		80.0	17.5
7	140.0	21.4		70.0	16.0		90.0	18.9
8	130.0	20.2		80.0	17.9		100.0	19.9
9	120.0	19.1		90.0	18.9		110.0	20.5
10	110.0	18.4		100.0	19.5		120.0	20.7
11	100.0	17.7		110.0	19.9		130.0	21.4
12	90.0	17.4		120.0	20.2		140.0	21.9
13	80.0	16.7		130.0	20.9		150.0	22.4
14	70.0	16.4		140.0	21.2		160.0	22.6
15	60.0	15.6		150.0	21.9		170.0	23.2
16	50.0	15.4		160.0	22.9		180.0	23.8
17	40.0	12.8		170.0	23.1		190.0	24.6
18	30.0	10.1		180.0	24.7		200.0	26.1
19	20.0	7.0		190.0	25.2		210.0	26.4
20	10.0	4.1		200.0	25.3		220.0	27.1
S. P.	0.0	0.0						

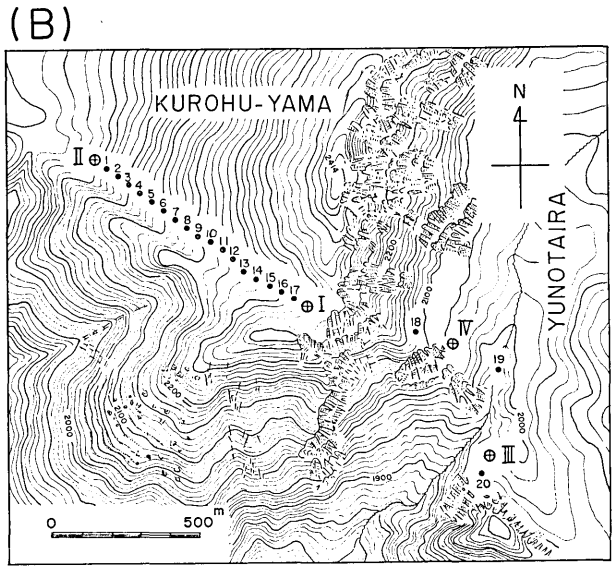

Fig. 34. The localities of the observation points for the seismometrical experiments of the blasts on Kurohu-yama on the western side of Asama.

(2) *The seismometrical experiments on the Kurohu-yama on June 9 and 10, 1969*

In order to investigate the velocity distribution of the Kurohu-yama formation, seismometrical experiments by blasts were carried out on Kurohu-yama, the oldest formation of Asama, on June 9 and 10, 1969.

The localities of the observation line and a series of transducers are shown on the map of Fig. 34, and for the purpose, 10 kg of powder was used in each blast.

In Table 16, the arrival times, distances from the shot points and other necessary elements are listed, and in Fig. 37 the travel time curves are illustrated.

After the analyses of these travel time curves, the following formation was given with respect to the velocity distribution of the

Locality	P Velocity	Thickness
Surface	480–600 m/sec	5– 8 m
1st layer	900 m/sec	10–15 m
2nd layer	2500–2800 m/sec	

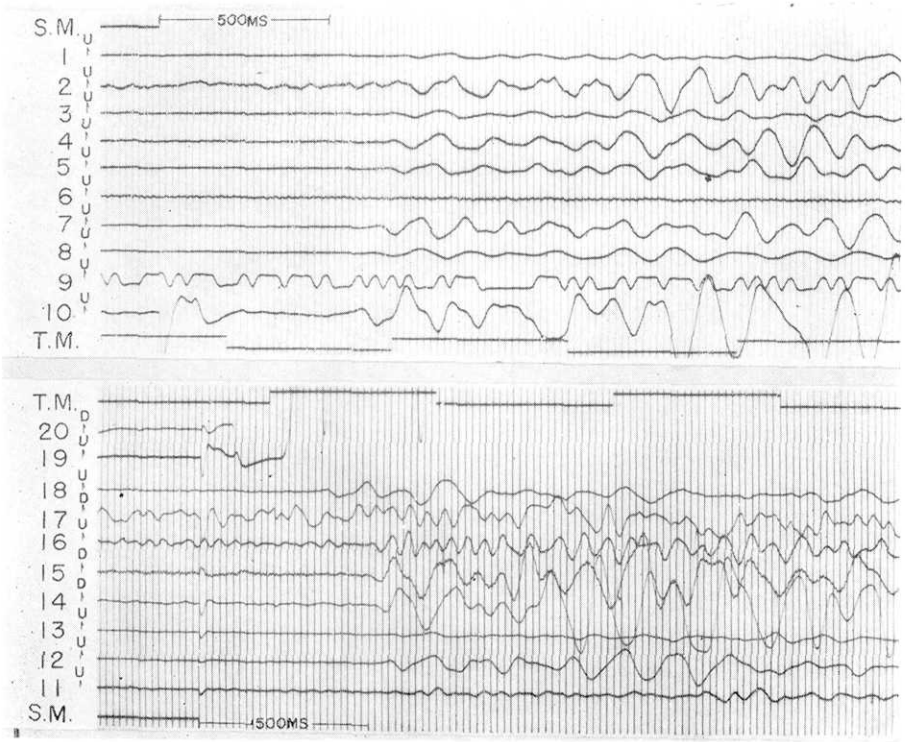

Fig. 35. The seismograms of the Asama blast on June 10, 1969, on Kurohu-yama, old Asama formation.

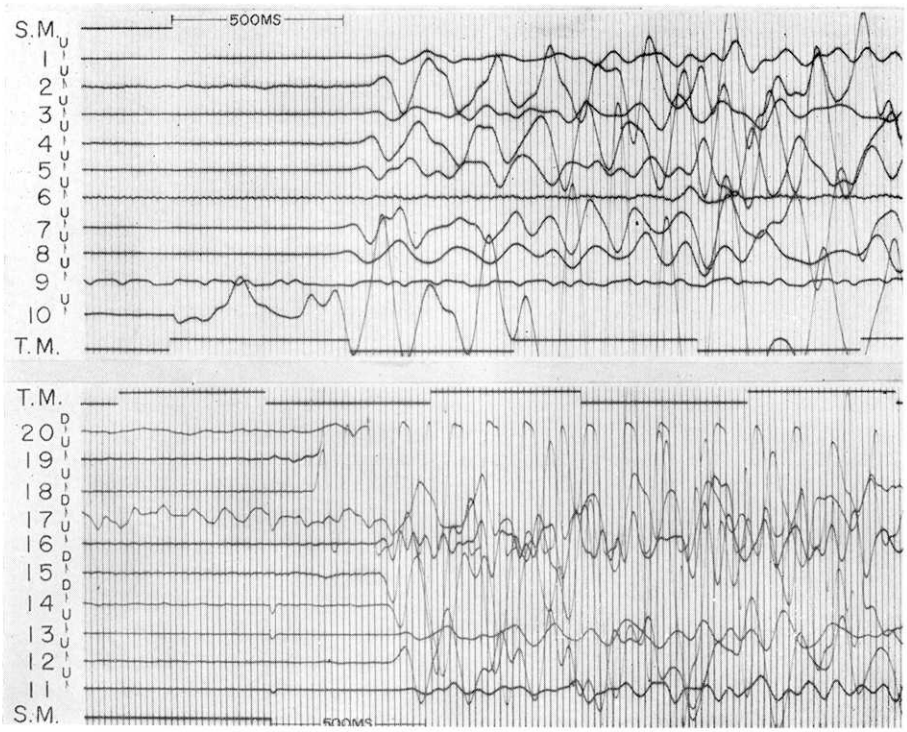

Fig. 36. The seismograms of the Asama blast on June 10, 1969, on Kurohu-yama, old Asama formation.

Table 16. The June 1969 blasts at Kurohu-yama (B).

Δ; epicentral distance,
h; difference between the altitudes of the shot point and respective transducers,
t; arrival time,
H; altitude of the shot point (above the sea level),
S. P.; shot point.

Table 16(a). Charge (set 1 m under ground)

Shot No. I(B)	Shot No. II(B)	Shot No. III(B)	Shot No. IV(B)
10 kg	10 kg	10 kg	10 kg

Table 16(b)-1. Shot No. I, blast at 18h 25m, June 9 (H=2273.1 m).

Pick No.	Δ	h	t
	S. P. 0 m	0.0 m	0.0×10^{-2} sec
1	824	−178.6	47.2
2	774	−164.0	45.5
3	730	−150.5	44.8
4	680	−144.2	42.4
5	632	−136.7	40.9
6	581	−129.2	39.3
7	533	−120.0	37.0
8	485	−108.4	35.9
9	436	− 96.7	33.4
10	390	− 81.0	30.5
11	343	− 64.9	26.9
12	299	− 54.8	25.6
13	244	− 49.3	24.6
14	195	− 45.8	22.3
15	145	− 35.9	18.5
16	97	− 24.6	15.8
17	49	− 10.8	10.4
18	380	−163.6	37.9
19	684	−285.5	40.6
20	826	−241.8	45.1

Table 16(b)-2. Shot No. II, blast at 19h 40m, June 9 (H=2075.5 m).

Pick No.	Δ	h	t
	S. P. 0 m	0.0 m	0.0×10^{-2} sec
1	46	+ 19.5	10.3
2	100	+ 34.1	15.9
3	142	+ 47.6	20.2
4	190	+ 53.9	22.5
5	239	+ 61.4	25.0
6	283	+ 68.9	27.4
7	338	+ 78.1	30.0
8	386	+ 89.7	31.9
9	434	+101.4	34.8
10	480	+117.1	—
11	527	+133.2	34.9?
12	573	+143.3	36.4
13	628	+148.8	—
14	677	+153.3	41.6
15	726	+162.2	42.9
16	774	+173.5	43.8
17	821	+187.3	46.7?
18	1233	+ 34.5	—
19	1540	− 87.4	65.5
20	1691	− 43.7	66.3

Table 16(b)-3. Shot No. III, blast at 17h 30m, June 10 (H=2007.2 m).

Pick No.	Δ	h	t
	S. P. 0 m	0.0 m	0.0×10^{-2} sec
1	1623	+ 87.3	69.1
2	1575	+101.9	—
3	1527	+115.4	65.4
4	1479	+121.7	63.8
5	1430	+129.2	62.9
6	1381	+136.7	—
7	1331	+145.9	60.5
8	1283	+157.5	59.0
9	1235	+169.2	—
10	1189	+184.4	57.8
11	1143	+201.0	—
12	1097	+211.1	53.1
13	1041	+216.6	—
14	992	+221.1	50.5
15	943	+230.0	49.3
16	896	+241.3	—
17	849	+255.1	—
18	488	+102.3	32.8
19	294	− 19.6	24.8
20	68	+ 24.1	8.8

Table 16(b)-4. Shot No. IV, blast at 18h 30m, June 10 (H=2047.5 m).

Pick No.	Δ	h	t
	S. P. 0 m	0.0 m	0.0×10^{-2} sec
1	1318	+ 47.0	58.7
2	1271	+ 61.6	57.4
3	1225	+ 75.1	55.8
4	1176	+ 81.4	54.3
5	1127	+ 88.9	52.3
6	1080	+ 96.4	—
7	1033	+105.6	47.2
8	985	+117.2	46.5
9	930	+128.9	—
10	890	+144.6	42.1
11	843	+160.7	39.1
12	801	+170.8	37.6
13	753	+176.3	40.0
14	704	+180.8	37.2
15	656	+189.7	34.6
16	607	+201.0	—
17	561	+214.8	—
18	134	+ 62.0	11.8
19	177	− 59.9	14.0
20	457	− 16.2	31.6

Table 17. The result of the June 9, 1969 blast experiment at Kurohu-yama (B).
Δ'; distance from the shot point,
δt; travel time.

Obs. P. No.	No. I(B)		Obs. P. No.	No. II(B)	
	Δ'	δt		Δ'	δt
	m	10^{-2} sec		m	10^{-2} sec
14	0.0	0.0	3	0.0	0.0
13	49.5	2.3	4	49.2	2.3
12	103.0	3.3	5	98.5	4.8
11	149.0	4.6	6	148.2	7.2
10	198.3	8.2	7	197.5	9.8
9	247.1	11.1	8	247.4	11.7
8	296.9	13.6	9	297.3	14.6
7	346.5	14.7	10	395.2	14.7
6	396.9	17.0	11	441.4	16.2
5	445.4	18.6	12	545.2	21.4
4	495.2	20.1	14	595.0	22.7
3	544.8	22.5	15	643.5	23.6
2	593.9	23.2	16	693.9	26.5
1	643.6	24.9	17		

$\Delta(m) = -0.709\times10^{-2}+2455\delta t(\text{sec})\cdots$No. I(B),
$\Delta(m) = -34.987\times10^{-2}+2739\delta t(\text{sec})\cdots$No. II(B).

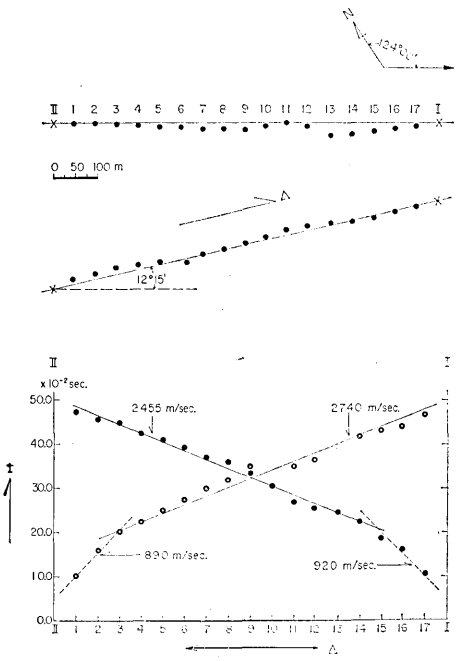

Fig. 37. The travel time curves of the blasts on the Kurohu-yama, old Asama formation.

seismic wave in the Kurohu-yama formation.

In the comparison with the velocity distribution of the eastern side of the volcano, the velocity of the second layer at the Kurohu-yama formation is remarkably higher than that at the eastern side or the Hotokeiwa formation.

On the other hand, as already mentioned, the delays in arrival times on the western side of the volcano including Stn. 4, Gippa-yama, and Stn. 7, Sekison-san, are considerably smaller than those on the eastern side. However, the delayed time originating from the surface formation at the eastern side will not exceed 0.2–0.3 sec, as compared with that at the western side. Whereas, the delayed times on the eastern side of Asama, given by the seismometrical ex-

periments of the Matsushiro blasts, are in the range from 1.13 sec to 0.35 sec, notwithstanding the fact that those on the western side including the Takamine formation are only in a range from 0.39 sec to 0.13 sec.

Considering from the various points of view, it will be reasonable to look for the causes or origins of the delays of arrival times of the *P* wave on Asama in its deeper part and the root of the volcano.

8. Where should we look for the origins of the delays of the arrival times on Volcano Asama?

As described above, the anomalous distributions of the arrival times on Volcano Asama were studied on the basis of the seismometrical observations from various sides. In other words, the first and second anomalies of the *P* arrival times on the volcano, the anomaly given from

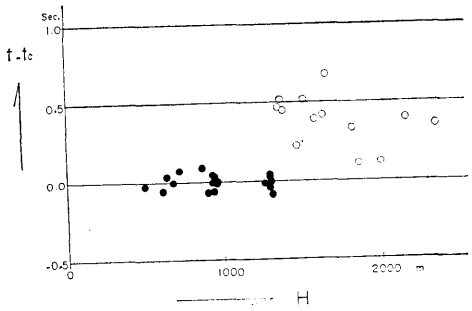

Fig. 38. The deviations of the arrival times of the Matsushiro earthquakes as compared with the 6.1 km/sec travel time curve and the altitudes of the observation points of the four networks.
Solid circle; Sugadaira, Ookuwa and Oodo nets,
Open circle; Asama net.

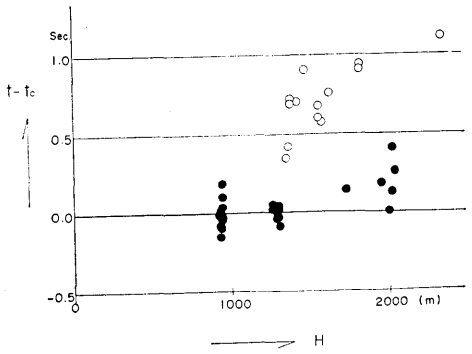

Fig. 39. The deviations of the arrival times of the Togura blasts as compared with the 5.2 km/sec travel time curve, and the altitudes of the observation points of the four nets.
Solid circle; Sugadaira, Minami-Karuizawa and Takamine nets,
Open circle; Asama net.

a comparison with the travel time of the upper crust of 5.2 km/sec, and the other given from a comparison with that of the middle crust of 6.1 km/sec, respectively, indicate a remarkable delay of arrival time of the *P* seismic wave on Asama, especially on the eastern side of the volcano. It will indeed be interesting and important problem to make clear the sources of these anomalous distributions of arrival times on Volcano Asama.

It is necessary to study the delays of arrival time on Asama in relation with the altitudes of observation points. The seismic stations on which

the present seismic observations of the Matsushiro earthquakes and blasts were made, distribute on various altitudes above sea-level as shown in Tables 4~5. Therefore, it will be necessary to investigate the relationship between the arrival times and the heights of the observation points.

For that purpose, the above relation is illustrated in Figs. 38 and 39 with respect to the Matsushiro earthquakes and the Togura blasts separately.

Since the altitudes of the Asama net were situated at the highest position for the observations of the Matsushiro earthquakes in which the Sugadaira, Ookuwa, Oodo and Minami-Karuizawa nets besides the Asama one were operated, it seems apparently that the above relation or the large values of the delay times on Asama are closely related with the altitudes of the observation points (Fig. 38).

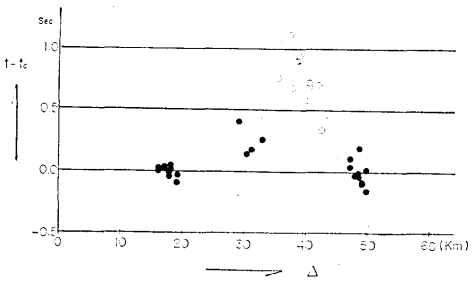

Fig. 40. The anomalous distribution of the arrival times of the seismic P waves originating from the 1967 and 1969 Togura blasts at the Matsushiro area.
Solid circle; Sugadaira, Takamine and Minami-Karuizawa nets,
Open circle; Asama net.

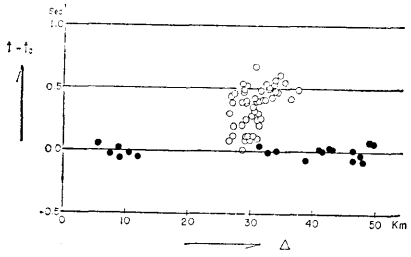

Fig. 41. The anomalous distribution of the arrival times of the seismic P waves on Asama for the Matsushiro earthquakes as compared with the 6.1 km/sec travel time curve.
Solid circle; Sugadaira, Ookuwa, Oodo and Minami-Karuizawa nets.
Open circle; Asama net.

However, the observations of the blasts were carried out not only at the above three places, but also at the Takamine area which has a higher altitude than the other places. In Fig. 39, the relationship between the arrival times and the altitudes of the observation points is illustrated in the form of delays of arrival times as compared with the 5.2 km/sec travel time curve. From the relation shown in Figs. 38 and 39, it will be clear that the great amount of delayed times on Asama originate not from the altitudes of the stations, but from other sources, inside and underneath Volcano Asama.

The values of the first anomaly of the *P* arrival time are represented in Figs. 39 and 40 in connection with the epicentral distance of the

respective observation points of the five net-works. From the illustration in Figs. 40 and 41, it is clear that the delayed times or the positive anomalies of the P arrival time on Asama are outstandingly larger than those of the other four nets, and the relation to the altitude of each observation point is not the essential factor for the anomalous distribution of the P arrival time.

After all, it is reasonable to look for the origin of the anomalies of the arrival time on Asama in the anomalous velocity distribution of the inside of and beneath the volcano.

Judging from the fact that the first anomaly is not so different from the other anomaly, it will be natural to expect that the main origin of the anomaly lies near the upper crust of the 5.2 km/sec~6.1 km/sec layers.

The geographical distributions of the above two anomalies of the arrival times on Asama shown in Fig. 27 and Fig. 28 indicate an almost similar pattern in their forms of the iso-anomaly lines of arrival times at each station on the volcano, though the values of the delayed times at most of the stations are larger in the first anomaly than those in the other.

The above phenomenon will be related with the differences in the pass of the seismic waves and in the vibration period of the P wave or the wave length of the P wave, for the reason that the period of the P wave originated from the blasts is quite shorter than those of the Matsushiro earthquakes.

The very characteristic differences between the first anomaly and second one is, however, that the center of the second anomaly shifts geographically to the east by 2-3 km as compared with that of the first one. This shift has a close relation to the depth and dimension of the origin causing the delay of arrival times.

9. The seismic observations at Asama for the August-September 1969 Kamikooti earthquakes

The earthquakes began to occur in a form of swarm at the foot of Volcano Yake-dake, Kamikooti, on August 31, 1969, and lasted for about one month. The epicentral region is located at 80 km west slightly south of Volcano Asama. D. Shimozuru and M. Sawada[11] established a temporary seismic net at Kamikooti for investigating the nature of these earthquakes and their hypocentral positions. According to the result of their investigations, the epicenters were found at 6-7 km east

11) D. Shimozuru, M. Sawada and N. Osada, *Bull. Volcanol. Soc. Japan*, **15** (1970), 22-32.

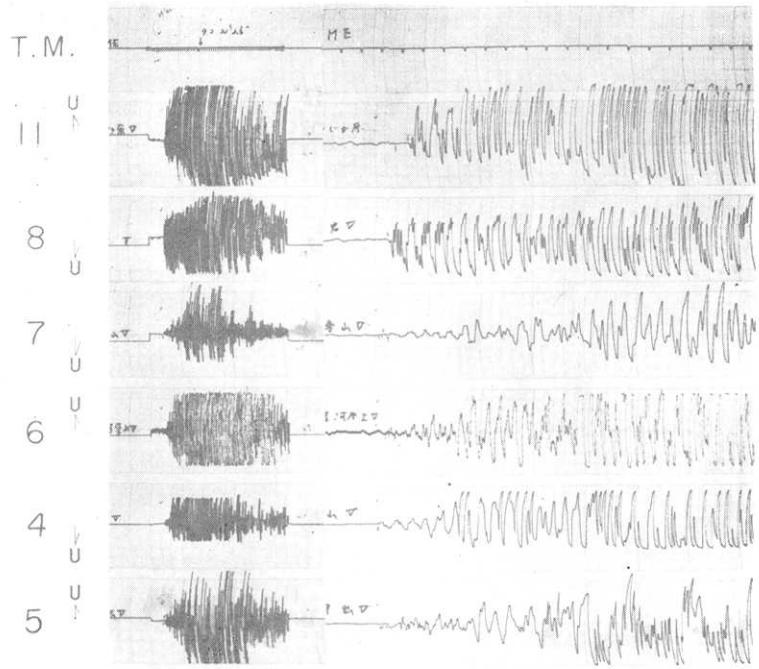

Fig. 42. The seismograms of the Kamikooti earthquake at 21h 26m, September 2, 1969, observed at six stations on Volcano Asama.
Numerals; Stn. No.

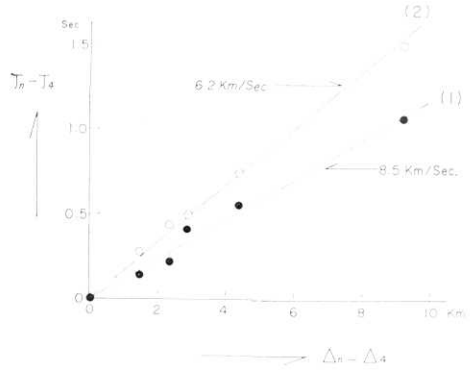

Fig. 43. The travel time curves of the Kamikooti earthquakes on September 1 (1) and 2 (2), 1969, observed on Volcano Asama.
T_n=arrival time at Stn. No. n,
T_4=arrival time at Stn. No. 4;
Δ_n=epicentral distance at Stn. No. n,
Δ_4=epicentral distances at Stn. No. 4.

of the summit of Yakedake and the hypocentral depths distributed from 1 km to 10 km for the earthquakes during September 6～26.

On the other hand, the above Kamikooti earthquakes were observed with the Asama seismic network and recorded by the seven-chanelled tape recorder. However, the Kamikooti earthquakes, which were observed at Asama with the tape recorder, were only a few big ones that took place on September 1 and 2. In Fig. 43, the travel time curves are shown on the basis of arrival times on the Asama permanent net for the Kamikooti earthquakes at 04 h 14 m, September 1 and at 21 h

25 m, September 2, 1969. Judging from the above travel time curves showing 8.5 and 6.2 km/sec in the P velocity, it is sure that the seismic P waves or the initial wave arrived at the Asama net by propagating along the Moho boundary for the former quake and along the inside of the crust for the latter one.

Since the Kamikooti earthquakes were not observed with the Sugadaira, Oodo and Minami-Karuizawa nets, it is insufficient to study the problem more precisely, though it seems that the above value of the Moho velocity is slightly too large.

However, the Kamikooti area or the present epicentral area is situated at the central part of the main island of Japan and on the highest altitude in Japan. Therefore, the earth's crust of the region is thickest in the central part of Japan and consequently the Moho boundary may incline from the Asama area toward Kamikooti.

On the other hand, the above velocity was given by the observation at the stations on Asama, which has the complex structure for the propagation of the seismic waves, as described already. Judging from these reasons, it is obviously required to make a more precise study of the problem.

In examining the seismograms of the Kamikooti earthquakes on September 1 and 2, 1969, the velocities of the P waves given from the arrival times indicate nearly 8.5 km/sec for the former quake and 6.2 km/sec for the latter, as shown in Fig. 43. Since quite a big anomaly in the arrival times exists on the volcano as already described, the above velocities do not always represent exactly those of the lower crust and the Moho layer. As mentioned above, it will, however, not be so unreasonable to assume that the initial wave for the former quake propagated along the Moho boundary and, on the other hand, that for the latter one passed through the lower crust.

In general, the anomaly of the arrival times on the volcano will be markedly reduced in the seismic waves propagated from the deep part like the mantle on account of the diffraction of the seismic wave and the long wave-length, even though the anomalous body like the magma chamber were under the volcano.

10. The root of Volcano Asama seen from the propagation of the seismic P wave

The following facts were made clear with respect to the arrival times of the seismic P wave on Asama, based on the seismometrical observation of a series of the Matsushiro earthquakes and on seismometrical experiments of the 1967 and 1969 Matsushiro blasts and the

1969 Asama blasts.

(1) According to the travel time curves of the P wave for a series of Matsushiro earthquakes observed with the Ookuwa and Oodo networks, a propagating velocity indicates 6.0–6.2 km/sec or 6.1 km/sec in average. Therefore, the above result harmonizes well with the crustal structure along River Agatuma studied by the Research Group of Explosion Seismology[12] based on the 1954 and 1955 Nozori and 1956 Hokota blasts. According to their investigations, the 6.1–6.2 km/sec layer exists almost horizontally at a depth from 4 km to 5 km in the region along the upper stream of Agatuma, the north-eastern foot of Asama, its thickness being estimated to be about 20 km. Therefore, it will be reasonable to conclude that the above velocity given by the observations of the Matsushiro earthquakes indicates that of the layer.

(2) On the other hand, the arrival times of a series of Matsushiro earthquakes at the seismic stations on the volcano were compared with those at the Sugadaira and Minami-Karuizawa seismic nets. As in the former case, the travel time curves were given by the results of seismic observations in the Sugadaira and Minami-Karuizawa nets, excluding the Asama one. As a result, the arrival times at the above two places were on the travel time curve indicating 5.6 km/sec in the velocity of the P wave for a series of Matsushiro earthquakes, 0.5 km/sec lower than the former case.

It is necessary to remark that the seismic waves observed at the Minami-Karuizawa net propagated through the root of Asama and under the Sugadaira net from the hypocenters in the Matsushiro area, judging from their geographical positions. If the root of Asama shows any different characters in seismic velocity from those of its surrounding part, it is natural to expect that the arrival times at the Minami-Karuizawa net will be affected by the root of the volcano.

On the other hand, it must be mentioned that the arrival times on Asama for the Matsushiro earthquakes are not so much delayed from the 5.60 km/sec travel time curve described above.

(3) According to the results of seismometrical observations of the 1967 and 1969 blasts at Togura near Matsushiro, the arrival times at the five observation points of the Sugadaira net indicated 5.2 km/sec in the P velocity for both of the 1967 and 1969 blasts. The travel time curves given in the Minami-Karuizawa net showed also 5.20 km/sec in the P velocity, though the passes of the seismic waves from the shot points to Sugadaira are very different from those to Minami-Karuizawa.

12) Research Group for Explosion Seismology, *Zisin*, [ii], **11** (1958), 102–113.
Research Group for Explosion Seismology, *Bull. Earthq. Res. Inst.*, **37** (1959), 495–508.
T. USAMI, T. MIKUMO, E. SHIMA, I. TAMAKI, S. ASANO, T. ASADA and T. MATSUZAWA, *Bull. Earthq. Res. Inst.*, **36** (1958), 349–357.

Moreover, even though the arrival times at the Sugadaira and Minami-Karuizawa nets and the origin times at the shot point were used, the travel time curves and the velocity of the P wave do not change.

The arrival times at the Takamine net, located at a little shorter distance to the shot points than to the Asama one, were delayed by 0.2–0.3 sec as compared with the travel times expected from the 5.20 km/sec travel time curve. However, judging from the fact that the observation points of the Takamine net are located on a high altitude, 2000 m above sea level on average, 0.2–0.3 sec delay in their arrival times are reasonably expected. Therefore, it is natural to conclude that the seismic P wave propagated from the short points to the Takamine net with a velocity of 5.20 km/sec as well as that to the Sugadaira and Minami-Karuizawa nets. However, it is extremely remarkable that the arrival times on the stations of Volcano Asama only were delayed within a large range from 1.1 sec to 0.4 sec at its east side, notwithstanding the fact that their average altitudes are lower than those of the Takamine net and almost similar to those of the Sugadaira net.

(4) Since it is the usual way to interpret the anomalous distribution of arrival times by means of seismometrical experiments of the blasts near seismic stations, the writers carried out these on the eastern and western sides of the volcano as the first step, though the scale of the experiments was not so large. From the results of the experiments, it was made clear that the velocity distributions of the present Asama formation and its old formations including Hotokeiwa and Kurohu formations are not sufficient to explain the large amount of delay in arrival times on the volcano.

(5) Judging from the results of the observations described above, it will be natural to assume that the root of Asama situated under the old Asama formations extends about 4–10 km deep and to estimate the radius to be 5–7 km in its horizontal size, though further studies and seismometrical experiments by blasts on and around the volcano will be necessary for drawing any definite conclusion of the problem.

(6) The present seismic observations on Asama were made for the Matsushiro earthquakes and the Togura blasts, of which both epicenters and shot points were located at the western and north-western directions of the volcano. As mentioned often, the anomalous distribution of the arrival times of the volcano for the Matsushiro earthquakes was compared with the travel time curve 6.1 km/sec and the other one for the blasts compared with the travel curve of 5.2 km/sec. It will also be natural that the seismic waves of the Matsushiro earthquakes propagated in a deeper part of the upper crust from their hypocenters to the Asama net than these from the shot points to the same net. If this

is true, the former geographical distribution of the anomaly of arrival times must appear at a much more eastern side of the volcano than that given by the blasts.

As can be clearly seen in Fig. 27 and Fig. 28, the above check harmonizes well with the direction of the shift of the above two geographical distributions.

As a consequence, the writers are compelled to draw the conclusion that the Volcano Asama has a root extending from its base to about 10 km at least in which the seismic waves may show the lower propagating velocity by several hundreds of meters than that of its surrounding part.

Naturally, the above conclusion is conducted on the basis of seismic observations of the Matsushiro earthquakes and the Togura blasts.

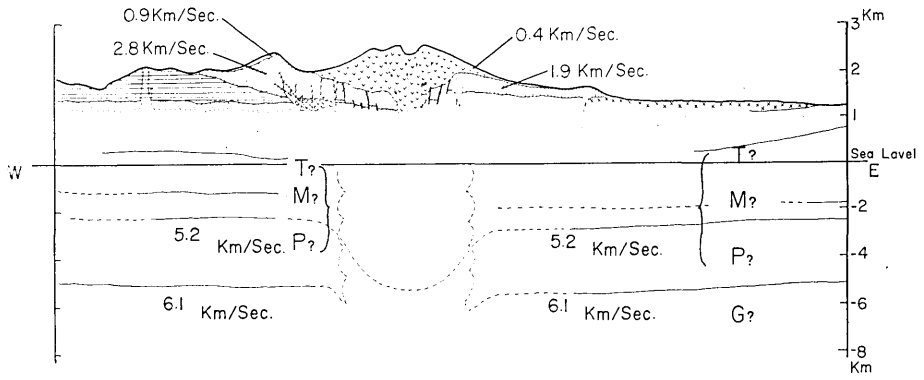

Fig. 44. The velocity distribution of the seismic P waves of the surface part and beneath of Volcano Asama.
(Compiled on the basis of the geological map of Asama made by S. Aramaki)

Since these earthquakes and blasts were all located toward the north west of Volcano Asama, another series of blasts must be made not only in the south east of Asama, but also in all directions of the volcano. It will further be necessary to investigate how the geographical distribution of the anomalies of arrival times on Asama will shift according to the direction of the wave fronts of the P and S waves.

It must be added here that the writers studied the travel time curves along the Kirisima volcanoes, based on seismometrical observations of the 1968 Ebino earthquakes.[13] According to the result of that, it was made clear that the 6.1 km/sec layer exists horizontally about 5 km beneath the volcanoes, but, no remarkable anomaly of the arrival times of the P waves being found in a lot of seismic stations on a series of

13) T. MINAKAMI et al., *Bull. Earthq. Res. Inst.*, **47** (1969), 745-767.
T. MINAKAMI, S. HIRAGA and T. MIYAZAKI, *Bull. Earthq. Res. Inst.*, **47** (1969), 769-781.

extinct cones of the Kirisima volcanoes—very different from Volcano Asama.

11. Resumé

The writers observed the 1965-1968 Matsushiro earthquakes with seismic net-works on and around Volcano Asama in order to study the nature of seismic waves passing through the volcano and the delays of arrival times of the *P* waves on the volcano, if any.

Resulting from the seismic observations, the two geographical distributions of the delay of arrival times on the volcano were made clear, one being given by the Matsushiro earthquakes and the other by the Togura blasts. On the other hand, the writers made a series of seismometrical experiments of seismic waves from the blasts on the volcano, in order to explain the above anomolous distributions of arrival times on the volcano.

However, the results of the above experiments suggest that it is impossible to explain the large delays of arrival times on Asama with the small velocities of the layers of ejecta located only near its surface.

Judging from a number of results of the observations and experiments, it will be natural to assume that the root of the volcano is located underneath Asama and shows a smaller velocity than that of its surrounding part, though a further study and experiment of the problem will be necessary.

In conclusion, the writers wish to express their thanks to Prof. T. Hagiwara and his colleagues who kindly gave them the information relative to the hypocentral positions of a large number of Matsushiro earthquakes.

The writer's thanks are also due to Dr. S. Asano, Mr. M. Ohtake and their colleagues for their kind information necessary for carrying out the seismometrical experiments of the blasts at the Matsushiro area. The writers' thanks must be extended to Mr. N. Gyoda, Mr. T. Takeda, Mr. F. Masutani and Mrs. T. Kinoshita for their assistance in the seismometrical observations and for the preparation of the manuscript.

26. 浅間火山の地震計測学的研究

その 2 浅間山の発震時異常と同火山下部の速度分布に関する情報

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1. 浅間火山の内部及び下部，マントル上部に至る状態を地震学的方法によつて考究することが本研究の第1の目的である．また近年日本の地震観測の精度，少なくとも発震時の精度が向上したが，浅間山の観測所で観測された他の地域の地震についてその発震時が同火山の特殊な構造から生ずる遅れ，すすみを明らかにし，地震観測結果を基礎とする研究の進展に役立たせるのが第2の目的である．

2. 以上の目的を以つて北関東地域に於いて爆破地震動研究グループが実施した大爆破実験の際に浅間火山の観測網を使用し，オシログラフ，テープレコーダー等によつて観測を行つたが，浅間火山の地表は極めてノイズレベルが高いことや，地震波の吸収の著しい等のために，またある時期では同火山の活動時と一致して B 型地震の震動や他地方に発生した地震（例えば 1962 年 9 月の大爆破は三宅島の地震活動と合致）等のため，充分に目的を果たすことができなかつた．

3. 然るに 1955 年 8 月より 3 年有余に亘つて，浅間火山の西北西の松代地域，震央距離にして 25～40 km に亘つて極めて顕著な地震群が発生したが，上記火山に於いて多数の震度 II, I の有感地震も含まれていた．これらの地震は12成分のオシログラフ，7 チャンネルのテープレコーダーで充分に観測され，多数の松代地震についてその発震時を明らかにすることができた．他方これらの地震の震源位置は萩原教授を中心として長期に亘る松代地震観測班によつて定められた．筆者等は上記の震源位置を使用して，浅間山の観測網に属する各観測点に対する震央距離を得ることができた．

4. 浅間火山の常時観測網の外，保科，菅平，応桑，大戸及び南軽井沢に 5 点乃至 6 点よりなる地震観測網を臨時に設置し，浅間山の観測網によると同様の方法を用いて観測を行つた．

つまり，菅平—浅間山—応桑 (1)
菅平—浅間山—大戸 (2)
菅平—浅間山—南軽井沢 (3)
保科—菅　平—浅間山 (4)

上記 4 種の観測網の組合わせによつて，それぞれ数ケの松代地震に対して走時曲線を得た．

上記の (1) 及び (2) の組合わせで，菅平—応桑 及び菅平—大戸の観測網の約 10 測点で定められた P 波の走時曲線は 6.1 km/sec を示した．他方曾つて大爆破研究グループは鋒田，野ぞりの大爆破実験から浅間山北東麓から北関東の地殻構造を研究した，それによると浅間山北部から伊香保に至る地下構造は海面下約 5 km の深さに 6.1 km/sec のほぼ水平の層が存在し，その厚さ約 20 km なる結果を得ている．今回の筆者等の観測から得た浅間山麓の P 波の速度 6.1 km/sec はそれに相当するものであつて，その層の速度が観測されたものと考えることが至当であろう．

5. 上記菅平—応桑—大戸観測網で定められた 6.1 km/sec の走時曲線との比較から，浅間山の発震時の異常を定義した．その結果，浅間山の東側の測定点は何れも 0.4～1.1 sec のおくれを，西側山体でも 0.1～0.3 sec 程度のおくれが見出された．

6. 他の観測網の組合わせ (3) について 菅平—南軽井沢観測網の観測からの走時曲線は，P 波の速度として 5.6 km/sec を示し，上記より 0.5 km だけ P 波の速度が小さく観測された．南軽井沢観測網の発震時は前記に比べて 0.4～0.5 sec おくれる結果となつた．松代地震群中の比較的北部に発生した地震を南軽井沢の観測網で捕えた地震波は方向からみて浅間山の下部を伝わつてきたことになる．この事を，考慮するとき，約 0.5 km/sec だけ P 波の速度が小さく観測されたことは浅間火山の下部に速度の異常を示す部分が存在するのではないか注目すべき事が判つた．

7. 1967 年 12 月及び 1969 年 11 月に松代地震発生地域の地殻構造の研究 のため浅野博士その他によつて同地域で爆破実験が行なわれた．この機会に筆者等は，松代地震の観測を行なつたと

きと同様に，67 年の爆破の際は菅平，浅間，南軽井沢の観測網で，69 年には上記 3 ヶ所の外，浅間山の西に隣接して爆破点に近い高峰に観測網を設けた．

爆破点の戸倉 (A-IV) よりの地震波と菅平，南軽井沢の観測網で観測される地震波は共に浅間山の下部を通過しない．その P 波の速度は常に 5.2 km/sec を示した．この走時を基準として浅間山の測点の発震時の異常を求めた．この結果異常値は前記松代地震で求めた値より，やや大きいが異常の地理的分布の傾向は類似し，等異常曲線はやや西方に，つまり火山の山頂寄りに移行した．

8．浅間山上の発震時に遅れを生ずる Origin を究明するための 第 1 歩として浅間山上で小規模な爆破実験を行なつた．まず火山の地表を構成する噴出物の堆積の中で最も伝播速度が小さいと推定される新しい軽石等の堆積層から成る東側中腹と，最も速度が大きいと推定される浅間山体の中で最も古い構造である黒斑山に於いて実施した．

その結果，東側中腹の 1783 年の軽石層を含む噴出物の地表層は約 0.4km/sec の速度，その厚さは 3 の鳥居附近で約 30 m それより東方つまり山麓へ向かつて 100 m の位置では厚さが約 20 m であること，その小さい速度を示す層の下部は荒牧重雄博士によれば仏岩火山体に対応するが，それは 1.9 km/sec の速度を持つことが明らかとなつた．

また黒斑山の上層部は 0.9 km/sec，厚さ 10～20 m，その下部は 2.7 km/sec の速度を示した．

今後爆破実験を繰返し，火山の上表部より次第に下部の速度分布を明らかにするために研究の進展をはからねばならない．しかし現在の僅かな知識をもつてしても，上述した大きい発震時の遅れは浅間火山上部だけの構造で説明されないことは明らかである．

9．浅間山上の著しい発震時の異常は火山体の内部，下部少なくとも約 10 km の深さに及び，火山の周辺に較べてかなり大きい構造の部分に速度の異常つまり速度の小さい部分の存在が推定される．また，爆破研究グループが求めた浅間火山北部の構造の中，海面下約 5 km の深さにある 6.1 km/sec の厚い層の存在は浅間火山の南麓もほぼ同じであろうと考えても無理ではあるまい．その 6.1 km/sec 層の上部に爆破実験からの 5.2 km/sec 層が浅間火山の北部及び南部に存在することはほぼ確実であろう．

また爆破実験からの同火山の発震時の等異常線と，松代地震から定めた等異常線との位置の相異に注目すると，後者は前者に較べ西方へ約 3 km 移行している．このことを考慮すると，5.2 km/sec 層が下部の層に平行していると仮定するとその厚さ約 2 km～3 km となる．5.2 km/sec 層と浅間山の下部を構成する黒斑山及び仏岩山体の下部との間にいかなる種類のいかなる速度を示す層が存在するかは今後の究明すべき課題であろう．

10．以上浅間山の発震時のおくれが意味する点について現在まで得られた情報について記述したが，今後実施すべき多くの実験，観測の作業を残している．

浅間山下部とその周辺との比較によつて，問題を解決することが最も実際的であると信ずるが，特に火山の各方向より来る地震波によつて同火山上の発震時の遅れの分布状況，つまり等異常分布曲線が地理的に移行する状況は，発震時のおくれを生じさせる原因の深さを明らかにする重要な要素である．若し，上記の異常分布が火山東方より伝播する地震波に対しても不動であるか，または著しく西方に移行しないならば，異常が生ずる原因は下部の比較的浅い所に求められなくてはならないことになるし，西方に著しく移動すればやや深所にその原因を求めなくてはならない．

11．松代地震観測より求めた浅間火山の異常分布が戸倉爆破による地震波の発震時のおくれの現われる位置より移動したばかりでなく，おくれの量は前者の方が各測点共に小さい．上記の異常は，火山の周辺の 6.1 km/sec 又び 5.2 km/sec の走時に対するものである．つまり浅間山の下部を伝播する地震波の径路が異なるが，それぞれの波の径路に於ける異常を示していることに外ならない．しかし，観測した P 波の波長にも若干関係している．つまり松代地震の初動は 0.2～0.4 sec 程度であるが爆破のそれは 0.1～0.2 sec 程度であり，火山体のごとき地震波の伝播に関し複雑な構造に対しては，波長が関係することも配慮する必要があろう。

12．以上浅間火山内部及び下部の地震波の速度分布より火山の構造を究明しようとする筆者等の試みであるが，むしろ本研究目的に対する本文は緒言に過ぎない．

終わりに，長期に亘り松代地震群の震源位置を定められ，その結果を与えられた萩原教授，岩田孝行氏他，関係の方々に対し，また松代爆破実験に際して筆者等が観測を実施し得るように必要な通報，その他に配慮いただいた浅野博士，大竹氏他，関係の方々に対し厚く謝意を表したい．