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18. *Crustal Structure in Northern Kwantô District by Explosion-Seismic Observations.*

Part I. Description of Explosions and Observations.

By The Research Group for Explosion Seismology.

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Since the first Nozori explosion of 14th, Nov. 1954, observation areas of our Research Group for Explosion Seismology have been shifted from Tôhoku District to Kwantô District. Since then, we have observed seismic waves due to six explosions in Kwantô District. The first and the second Nozori explosions and the first Hokota explosion were observed to obtain information about the crustal structure of the northern Kwantô District. Temporary observation stations were spread nearly in the direction N 120° E—N 60° W, i.e. on the line joining Nozori and Hokota shot points. A description of the three explosions is given.

1. Description of Explosions.

In order to get blocks of rock necessary for the construction of a rock-fill dam near Lake Nozori, in the northern part of Gunma Prefecture, explosions of dynamite were fired many times. We took advantage of two explosions of comparatively large amounts of dynamite for our study. We call them the first and the second Nozori explosions. Topographic features near these shot points are shown in Fig. 1.

The amount of charge of the first explosion was 3.70 tons and the second one was 1.55 tons. Shot times were generally registered directly on the oscillograph. But in the second Nozori explosion an instrumental disorder prevented direct registration. Fortunately we registered at the same time ground tremors and sound waves of the detonation on a magnetic tape recorder placed near the shot point. Furthermore, the air temperature at the shot time was observed. From these data, we estimated the shot time of the second Nozori explosion as 01 h 05 m 00.291 sec.

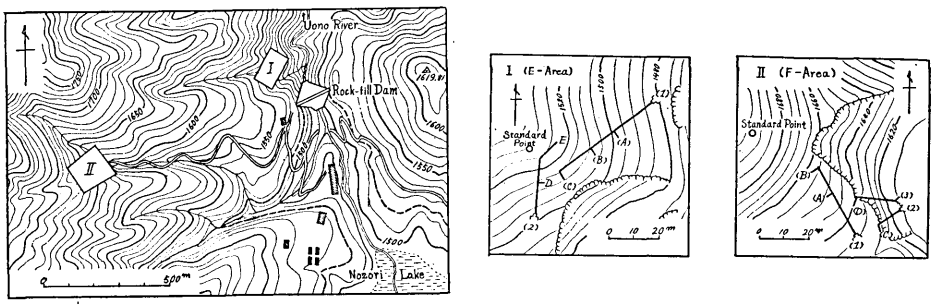

Fig. 1. Topographical map near shot points of the first and second Nozori explosions.
I, II: the first and the second shot points. ⌐¬: entrance of tunnel.
----: high water level. (A), (B), ···: charge chamber.
——: tunnel.

The first Hokota explosion was planned to obtain more precise knowledge of the crustal structure in the northern Kwantô District. This explosion forms the reverse explosion to the Nozori explosions. A shot position was selected in Taiyô-village, Ibaraki Prefecture. Six holes 70 m deep were located at five apexes and the centre of equilateral pentagon which was inscribed in a circle with 7 m radius. Holes were charged with dynamite from the bottom to 20 m below the ground level and the rest were filled with muddy water. They were blasted simultaneously. Shot time was directly registered on the oscillograph. The amount of charge was one ton in total. The latitude, longitude, height of shot points, amount of charge and shot time of the three explosions are tabulated in Table 1.

Table 1

Name of Explosion	Location of shot point			Amount of Charge	Shot Time
	λ	φ	H		
Nozori I	138°38′35.2″ E	36°42′58.2″ N	1526 m	3.70 ton	1954, Nov. 14, 01 h 05 m 00.865 s
Nozori II	138°37′59.2″	36°42′51.8″	1606	1.55	1955, Aug. 15, 01 h 05 m 00.291 s
Hokota I	140°33′39.6″	36°08′19.8″	41	1.0	1956, Dec. 5, 01 h 05 m 00.200 s

2. Description of Observations.

In total, 33 temporary observation stations were spread nearly in the N 120° E–N 60° W direction along the line joining Nozori and

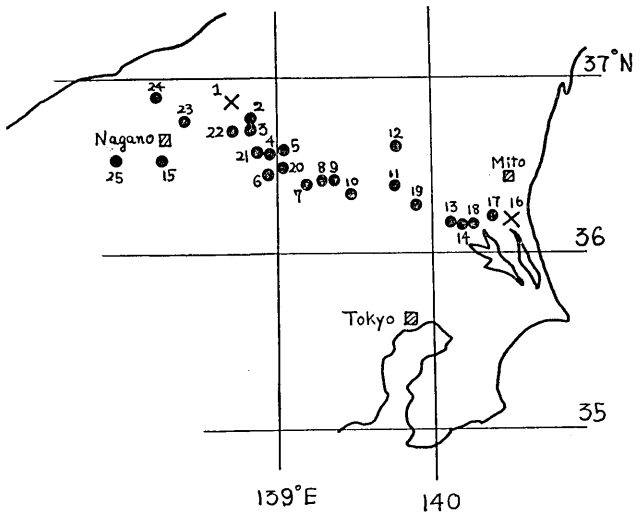

Fig. 2. Shot points and seismic observation stations for the Hokota and Nozori explosions.

×: Shot point ⊛: Observation point

Hokota shot points. They are shown in Fig. 2. The place names*, latitude, longitude, height, epicentral distance and azimuth of observation stations, type of seismometers and name of observers are tabulated in Table 2. Each station was equipped generally with electromagnetic transducers with amplifiers. But near-by stations made observations without any amplifier. The sensitivity of the transducer was 1–5 volts/kine. The output of the amplifier was connected with a galvanometer of a short proper period. By the combination of a transducer-amplifier-galvanometer, we were able to reach displacement magnification of 10^6–10^7 at 3 c/s. Satisfactory seismograms were obtained at almost all stations. They are shown in Fig. 7.

Measurements of the commencement of the first wave were made by several persons independently and a value was adopted only when satisfactory agreement was found. The running speed of the recording paper was 3 cm/sec or more and minute and second marks were registered on the oscillograph paper directly from the JJY radio time signal. Therefore, the accuracy of determination of the arrival time of first tremors is at least 0.1 sec. even in less favourable cases.

Geographical coordinates of shot and observation points were deter-

* In the romanization of place names the Japanese system is adopted instead of the Hepburn system, for example, ti for chi, tu for tsu, etc.

Table

Name of Explosion[1]	Reference Number	Observation point	λ	φ	H	Θ[2]
N 1	1	Shot point (Nozori)	138°38′35.2″E	36°42′58.2″N	1520 m	—
N 2	1′	〃			1606	N83°～113°E
N 1	2	Sima	47 44.6	37 44.6	518	124°45′E
N 2	2′	〃	47 46.4	37 50.8	516	122 28
N 1	3	Sawatariguti	47 42.5	36 22.9	446	131 53
N 2	4	Nakanozyō	51 9.8	35 17.0	358	125 31
N 1	5	Takayama	57 41.2	37 28.6	552	109 39
N 2	6	Ikaho	55 38.0	30 00.7	641	132 05
N 1	7	Ōgo	139 09 45.3	25 39.2	191	124 34
N 2	8	Ōmama	17 45.8	27 26.0	253	115 41
N 2	9	Kiryū	23 2.5	26 56.8	178	113 39
N 1	10	Asikaga	30 12.5	19 00.5	36	117 55
N 1	11	Totigi	42 36.9	21 38.2	49	112 26
N 2	12	Ōya	49 30.1	35 25.9	152	97 21
N 1	13	Tukuba	140 06 39.9	12 38.6	286	113 05
N 2	13′	〃	〃	〃	〃	112 52
N 2	14	Kakioka	11 28.1	13 45.6	32	111 05
N 1	15	Matusiro	138 12 23.6	32 22.4	383	243 21
H 1	16	Shot point (Hokota)	140 33 39.6	36 08 19.8	41	N 101 00 E 13 00 E
〃	17	Tomoegawa	29 00.1	09 20.8	17	N 74 57 W
〃	18	Tamari	20 14.3	09 34.8	22	83 27
〃	13″	Tukuba	06 39.9	12 38.6	286	78 51
〃	19	Yūki	139 52 40.6	17 32.4	33	74 30
〃	11″	Totigi	43 24.3	22 06.2	44	71 18
〃	10″	Asikaga	30 12.5	19 00.5	36	78 16
〃	7″	Ōgo	09 45.3	25 39.2	191	75 42
〃	20	Sibukawa	138 59 38.5	29 31.7	261	74 26
〃	21	Agatuma	48 55.2	33 51.6	508	73 13
〃	22	Hanasiki	38 37.4	38 44.9	852	71 54
〃	23	Yamanouti	24 17.2	45 16.8	478	70 32
〃	15″	Matusiro	12 23.6	32 22.4	383	78 07
〃	24	Sekiyama	16 47.6	54 55.2	458	67 08
〃	25	Ōmati	137 49 50.6	33 45.4	861	79 08

Survey

1) N1....the first Nozori explosion.
N2....the second Nozori explosion.
H1....the first Hokota explosion.
2) Azimuth of observation points measured clockwise from the north.

2

Δ	Electro-magnetic Seismometer	Observers
0.00	3V5	Murauchi, Asanuma
0~0.80	3V4	Murauchi, Asanuma, Honda, Omote, Matuzawa, Suyehiro
16.57	P-11	Yamazaki, Saitō, Daikubara
17.21	3V3	Kobayashi (K), Saitō
18.22	2V1, 2H2	Mikumo, Ōtsuka, Tanaka
24.05	3V1	Shima, Sibano
30.18	3V2	Shima, Sibano, Yanagisawa
35.39	3V3, 3H2	Suzuki, Mine
56.43	3V2	Suyehiro, Ogawa, Usami
65.75	3V2	Ogawa, Usami
73.29	3V2	Asano, Yanagisawa
88.86	3V2	Kasahara, Kobayashi (K), Komaki
103.34	N.D. 3V1, 3V2, 3H2	Matsumoto (T), Karakams
107.37	N.D. 3V1, 3V1	〃 〃
142.99	N.D. 3V1, 3V2	Santō, Shimazu, Tazima
〃	1H1, N.D. 3V1	Asada, Tazime, Akamatu
149.56	N.D. 3V1, 3V1	Hori, Matsumoto (E)
43.53	1H1, 3V1	Utsu, Hisamoto
0~1.24	7V3 (E.T.L.), 7V3	Matuzawa, Tazime, Kaneko, Kawashima, Ōtaki, Hirasawa, Asanuma, Okamura
7.24	3V1, 15V2, 2H2	Okano, Kamo
20.26	2V1, 2H2, Strain meter	Mikumo, Ōtsuka
41.26	1H1, 3V2	Akamatu, Karakama
63.73	3V1, 3V2	Tamaki, Kitamura
79.46	7V12 (E.T.L.)	Noritomi, Ueda, Shibata
97.10	3V2, 2H1	Wada, Muramatsu
129.64	N.D. 3V1, 3V1	Takagi, Nakamura
146.06	N.D. 3V1, 3V1	Utsu, Usami
163.63	N.D. 3V1, 3H1	Suzuki, Mine
180.91	N.D. 3V1, 3V1	Den, Tsunekawa
205.01	N.D. 3V1, 3V3	Asano, Yanagisawa
215.94	N.D. 3V1	Suyehiro
221.72	N.D. 3V1	Sima, Sibano
249.60		Asada, Kobayashi (T), Takeuchi
		Okada

3) For example, 3V5 means that five vertical transducers with natural frequency 3 c/s. were used.
N.D. means transducer with high senstivity (5 volts/kine).

Table 3. Arrival time of tremors at three explosions

Name of Expl.	Ref. No.	Observation points	Δ	P 0.5 m+	P.U. Number	P−shot	$P-\Delta/6$−shot
N 1	1	Nozori	96.5 m		P.U. 1	00.036 sec	
			506.2		2	0.718	
			770.6		3	0.299	
N 2	1′	〃				0.00	0.00
N 1	2	Sima					
N 2	2′	〃	17.21 km	3.43 sec		03.14	0.27 sec
N 1	3	Sawatariguti	18.22	4.20		03.33	0.29
N 2	4	Nakanozyō	24.05	4.80		04.51	0.50
N 1	5	Takayama	30.18	6.65		05.78	0.75
N 2	6	Ikaho	35.39	6.79	P.U.A	06.50	0.60
N 1	7	Ōgo	56.43	11.17		10.30	0,90
N 2	8	Ōmama	65.75	11.73		11.44	0.48
N 2	9	Kiryū	73.29	12.94		12.65	0.44
N 1	10	Asikaga	88.86	16.18		15.31	0.49
N 1	11	Totigi	103.34	18.58		17.71	0.49
N 2	12	Ōya	107.37	18.81		18.52	0.62
N 1	13	Tukuba	142.99	24.60		23.73	−0.10
N 2	13′	〃	〃				
N 2	14	Kakioka	149.56	25.13		24.84	−0.09
N 1	15	Matusiro	43.53	8.785		07.92	0.665
H 1	16	Hokota	0.0	0.20		0.00	0.00
〃	17	Tomoegawa	7.24	2.51		2.30	1.10
〃	18	Tamari	20.26	4.78		4.57	1.19
〃	13″	Tukuba	41.26	8.08		7.87	0.99
〃	19	Yūki	63.73	12.61		12.40	1.78
〃	11″	Totigi	79.46	14.57		14.36	1.13
〃	10″	Asikaga	97.10	16.97		16.76	0.58
〃	7″	Ōgo	129.64	22.43		22.22	0.62
〃	20	Sibukawa	146.06	25.00		24.80	0.45
〃	21	Agatuma	163.63	27.23		27.00	−0.27
〃	22	Hanasiki	180.91	28.86		28.65	−1.50
〃	23	Yamanouti	205.01	31.8		31.60	−2.57
〃	15″	Matusiro	215.94	34.12		33.91	−2.08
〃	24	Sekiyama	221.72				
〃	25	Ōmati	249.60	38.68		38.47	−3.13

Shot time N1: 1954, Nov. 14th, 01 h 05 m 00.865 sec.
N2: 1955, Aug. 16th, 01 h 05 m 00.291 sec.
H1: 1956, Dec. 5th, 01 h 05 m 00.208 sec.

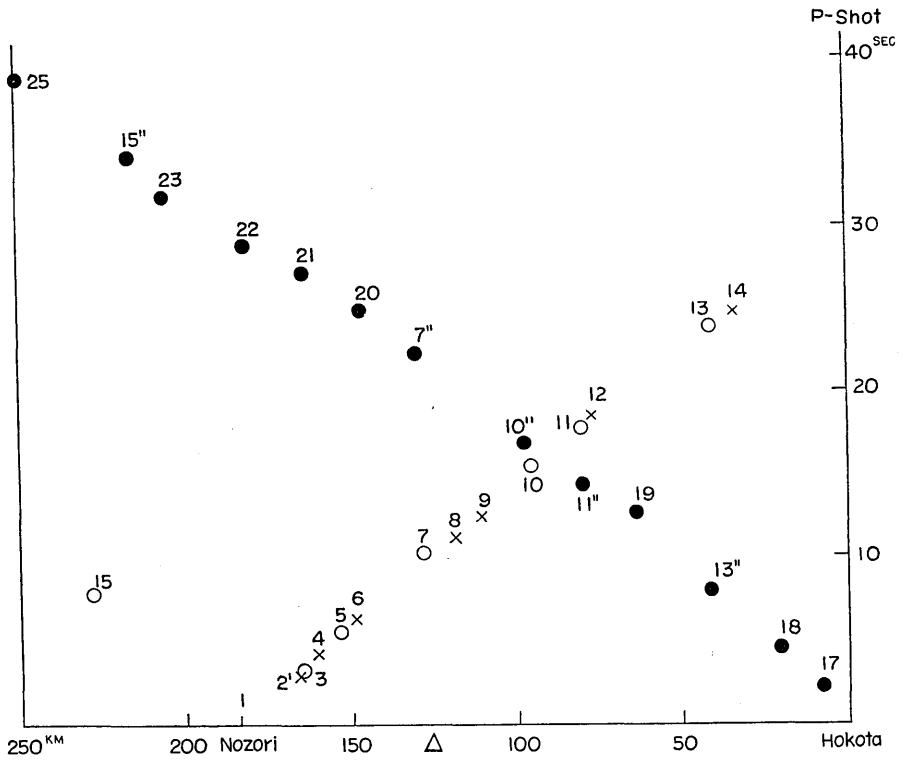

Fig. 3. Travel time graph of seismic waves from the Nozori and Hokota explosions.
○: the first Nozori explosion. ×: The second Nozori explosion.
●: the first Hokota explosion.

mined by the method based upon triangulation, by which we were able to keep errors of latitude and longitude within 0.3″. Therefore errors in epicentral distances were estimated to be less than 10 meters.

Arrival times of P waves and epicentral distances are tabulated in Table 3. They are also shown in Fig. 3, in which all data of three explosions except near-by stations are plotted. In order to visualize deviations from a general trend of travel times, $P-\Delta/6$ was taken as the ordinate, and the same data as in Fig. 3 are plotted in Fig. 4. From a slight inspection of Fig. 4, it is found that a travel time curve with an apparent velocity of 5.5 km/sec, passing through stations near the shot point of Nozori explosions and that with an apparent velocity of 7.7 km/sec., passing through distant stations of the Hokota explosion are plausibly acceptable, but as to the apparent velocity and the extension of a travel time curve which passes through stations between 70–130 km

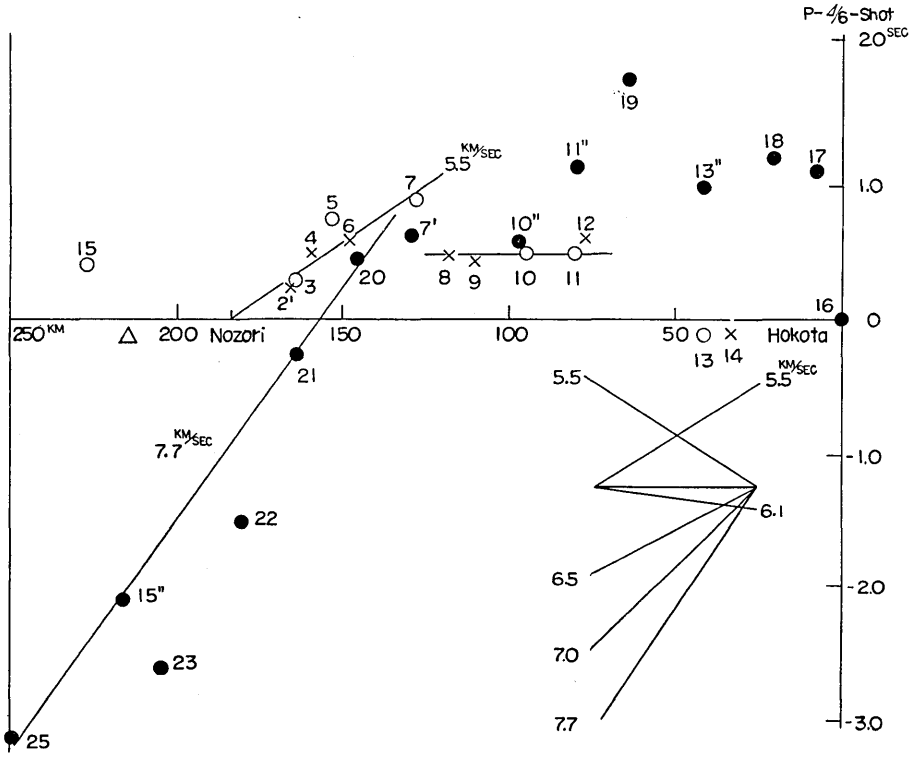

Fig. 4. Travel time curves of the waves from the Nozori and Hokota explosions.
○: the first Nozori explosion. ×: the second Nozori explosion.
●: the first Hokota explosion.

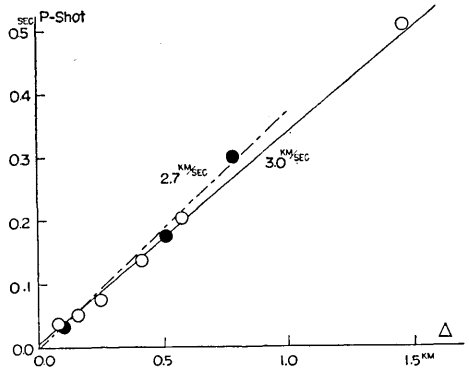

Fig. 5

●-·-·-: Travel times observed at stations near the shot point of the first Nozori explosion.

○——: Travel times from a small explosion fired several days before the day of the first Nozori explosion.

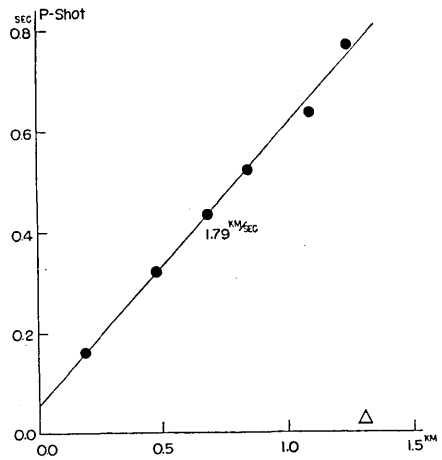

Fig. 6. Travel times observed at nearby stations for the first Hokota explosion.

from Hokota, some uncertainty is left for future investigations.

Fig. 5, 6, Table 4, 5, and 6 are the results of near-by points. Seismic waves produced by a small blast fired several days before the first Nozori explosion were observed near the shot point in order to determine the wave velocity in the layer near the surface. The velocity is obtained as 3.00 km/sec by the method of least squares using the data in Table 5. But the velocity obtained from observations of the first Nozori explosion at near-by points is 2.7 km/sec. We adopt the latter value as the velocity in the surface layer near the Nozori station.

Table 4

	P 01h 05m+	P−shot	Δ
Shot point	00.865		
Pick-up 1	.901	00.036	96.5 m
〃 2	01.044	.178	506.2
〃 3	.165	.299	770.6

Table 5*

Pick up position	P−shot	Δ
(0)	0.000 sec	0.00 m
1	.039	76.7
2	.056	155.2
3	.077	248.6
4	.138	403.9
5	.202	570.0
6	.512	1454.4

* By the method of least squares, we get
$t=0.000337\Delta$(meter)$+0.00448$ sec
$V=3.00$ km/sec.

Table 6**

Pick up position	P 01h 05m+	P−shot	Δ
Shot	0.205 sec		0 m
1			0
2	.365	0.160	188
3	.523	.318	471
4	.637	.432	676
5	.724	.519	840
6	.839	.634	1090
7	.972	.767	1240

** By the method of least squares, we have

$$t=0.258+\frac{\Delta}{1.79}.$$

From the observations at near-by stations of the Hokota explosion, the velocity in the surface layer was found to be 1.79 km/sec by the method of least squares using the data in Table 6. From these results, we consider that a surface layer with the P-wave velocity of 1.79 km/sec and one with the P-wave velocity of 2.7 km/sec lie respectively near the Hokota and the Nozori shot points.

Crustal structures inferred from data in Part I will be given in the second part of this paper.

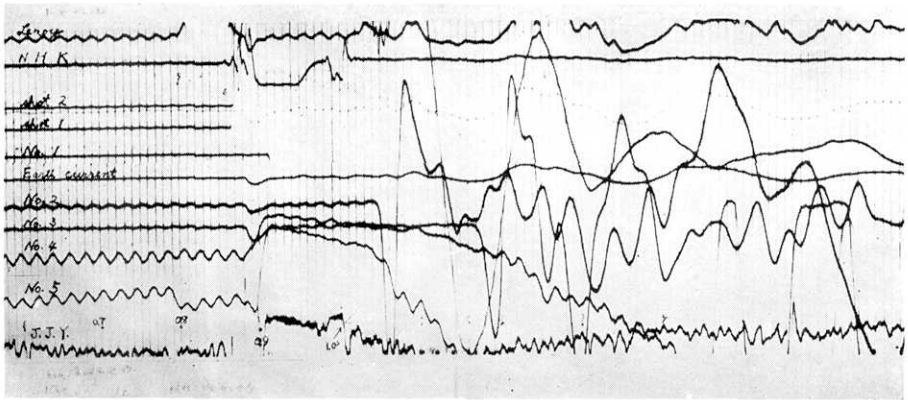

Fig. 7. (1) Seismogram obtained at Nozori in the first Nozori explosion.

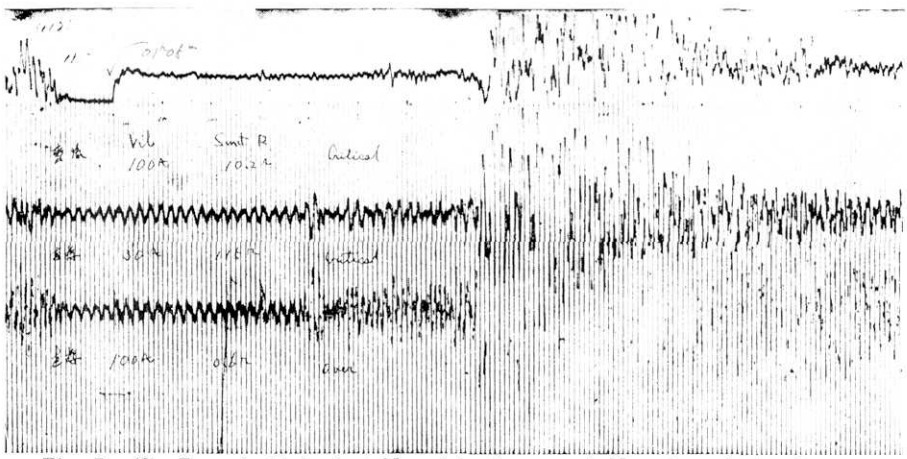

Fig. 7. (2) Record obtained at Nozori in the second Nozori explosion by magnetic tape recorder.

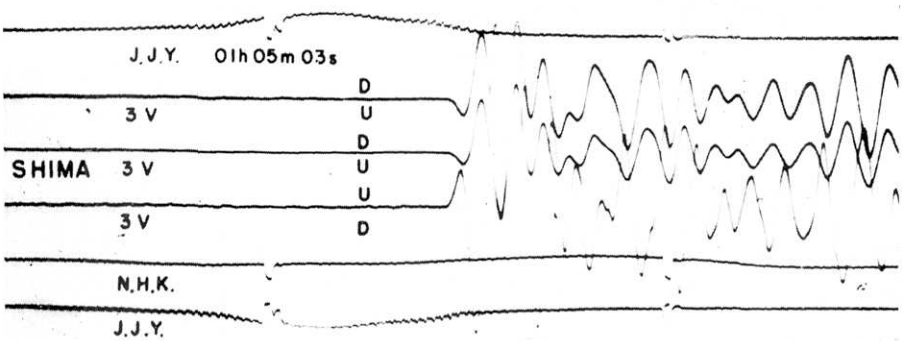

Fig. 7. (3) Seismogram obtained at Sima in the second Nozori explosion.

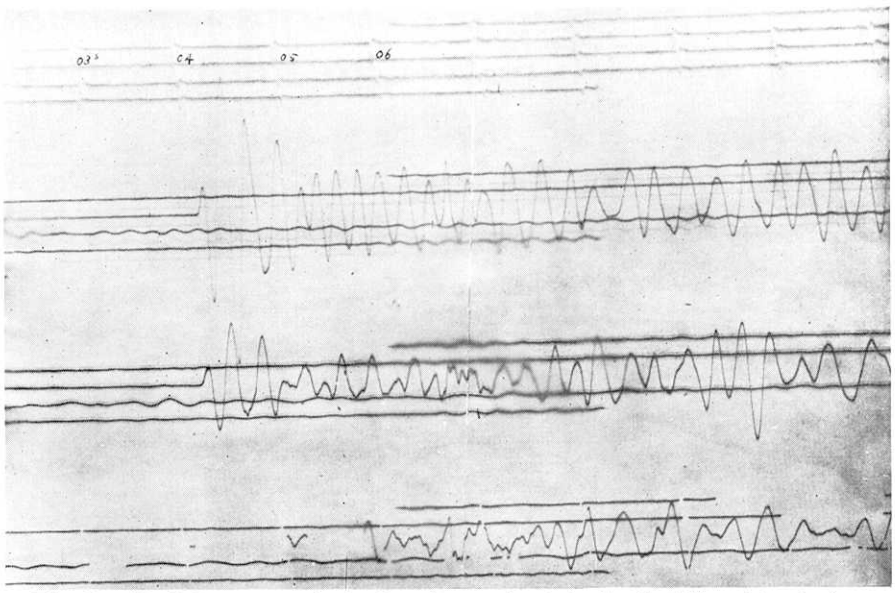

Fig. 7. (4) Seismogram obtained at Sawatariguti in the first Nozori explosion.

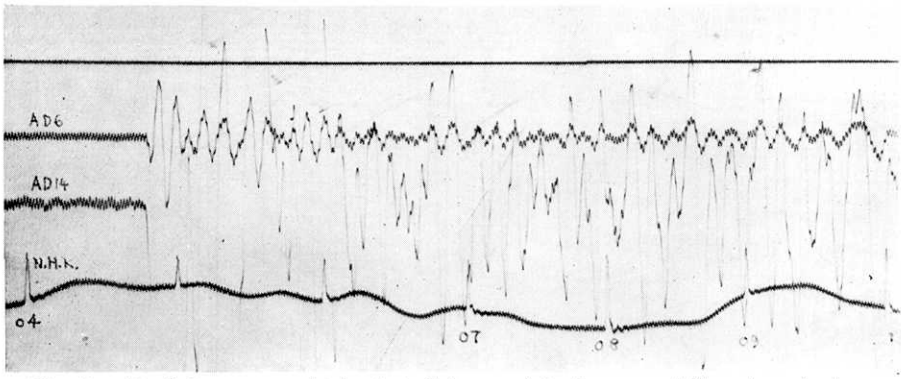

Fig. 7. (5) Seismogram obtained at Nakanozyô in the second Nozori explosion.

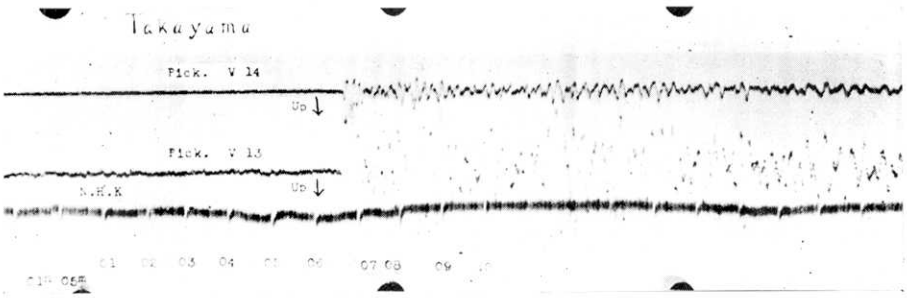

Fig. 7. (6). Seismogam obtained at Takayama in the first Nozori explosion.

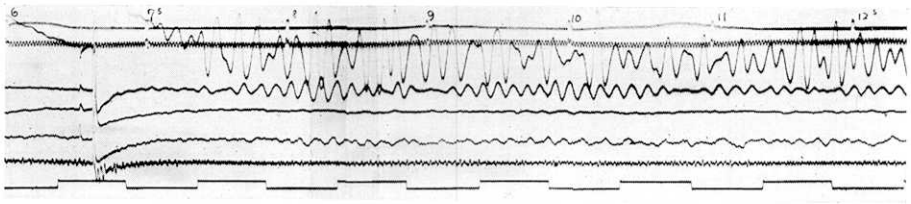

Fig. 7. (7) Seismogram obtained at Ikaho in the second Nozori explosion.

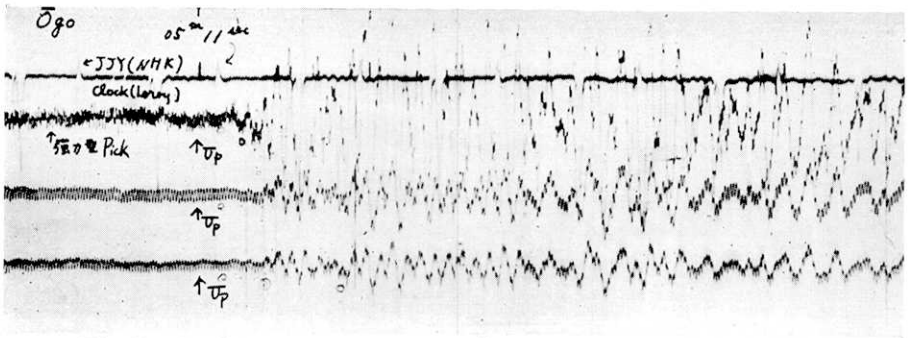

Fig. 7. (8) Seismogram obtained at Ôgo in the first Nozori explosion.

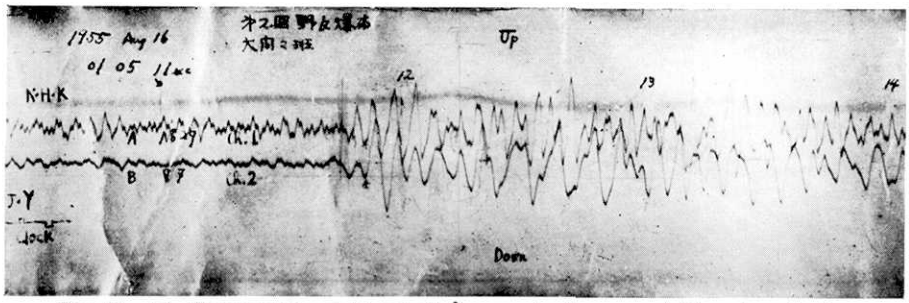

Fig. 7. (9) Seismogram obtained at Ômama in the second Nozori explosion.

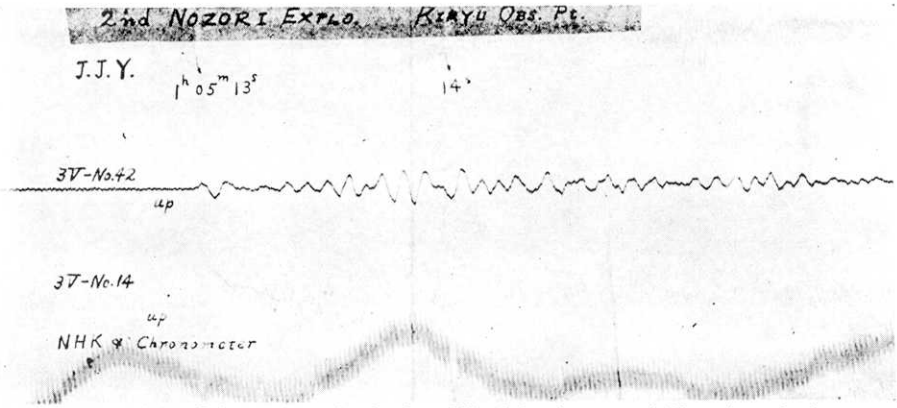

Fig. 7. (10) Seismogram obtained at Kiryû in the second Nozori explosion.

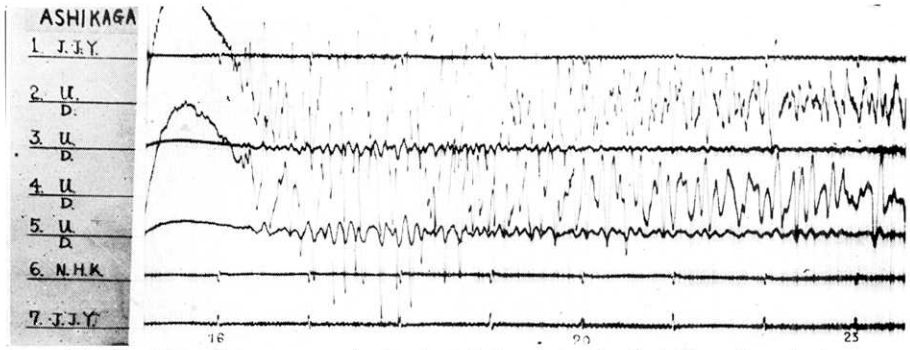

Fig. 7. (11) Seismogram obtained at Asikaga in the first Nozori explosion.

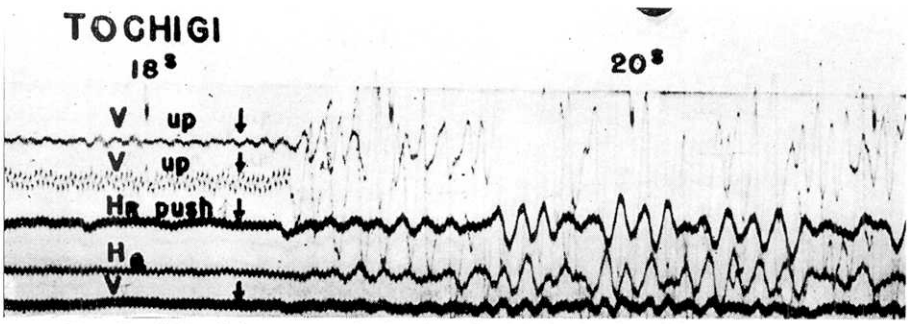

Fig. 7. (12) Seismogram obtained at Totigi in the first Nozori explosion.

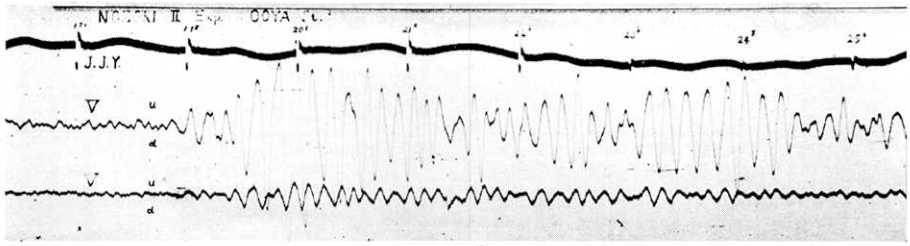

Fig. 7. (13) Seismogram obtained at Ôya in the second Nozori explosion

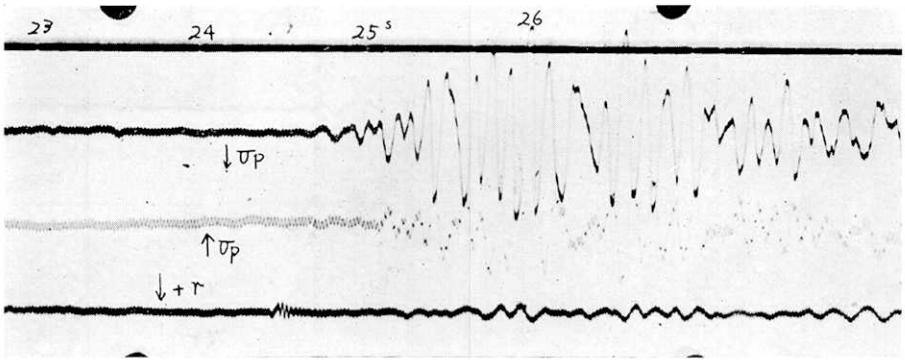

Fig. 7. (14) Seismogram obtained at Tukuba in the first Nozori explosion.

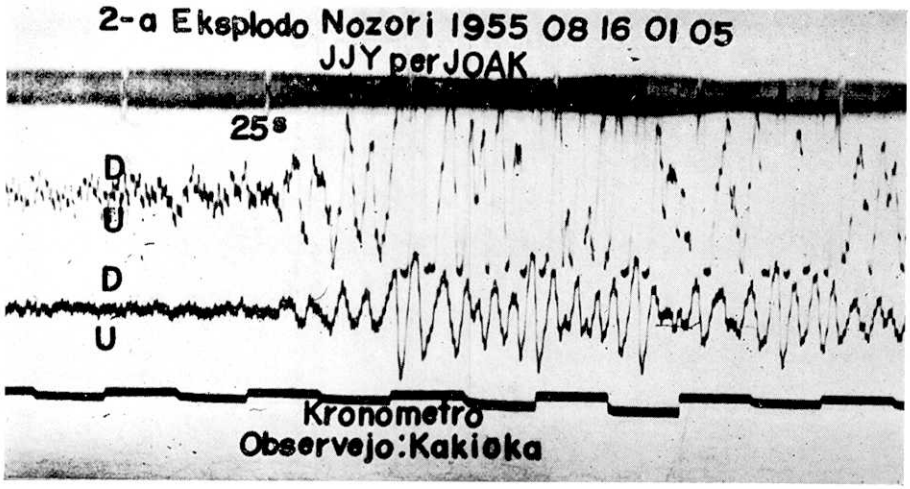

Fig. 7. (15) Seismogram obtained at Kakioka in the second Nozori explosion.

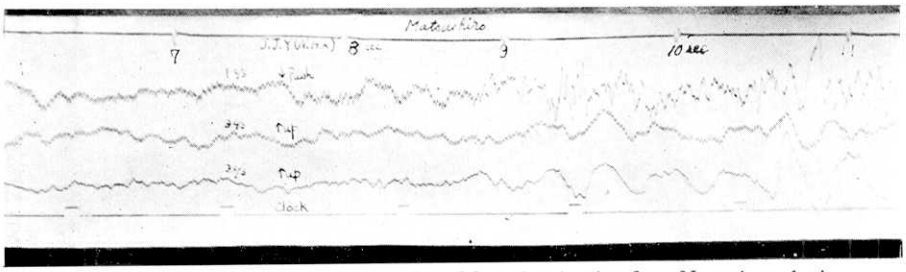

Fig. 7. (16) Seismogram obtained at Matusiro in the first Nozori explosion.

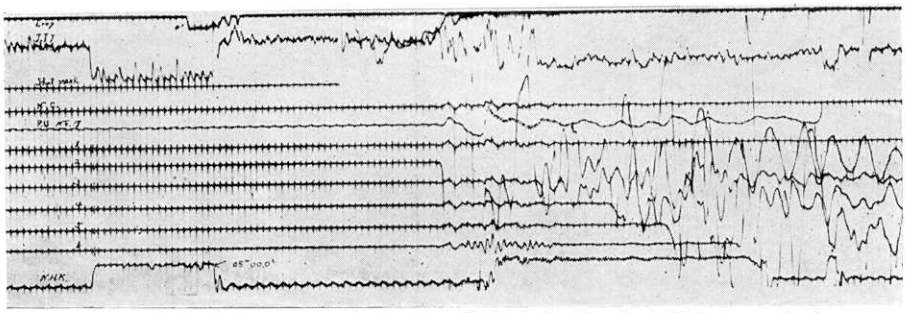

Fig. 7. (17) Seismogram obtained at Hokota in the first Hokota explosion.

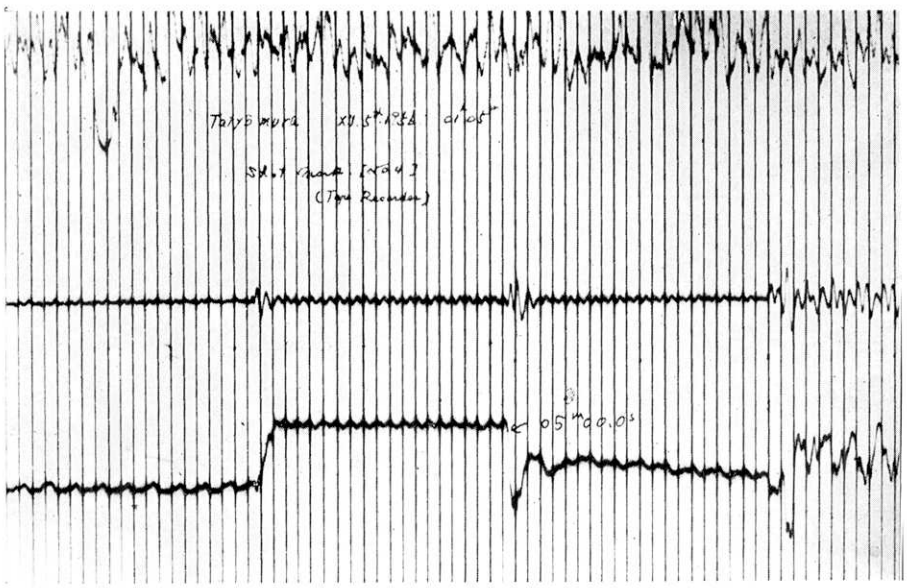

Fig. 7. (18) Record obtained at Hokota in the first Hokota explosion by magnetic tape recorder.

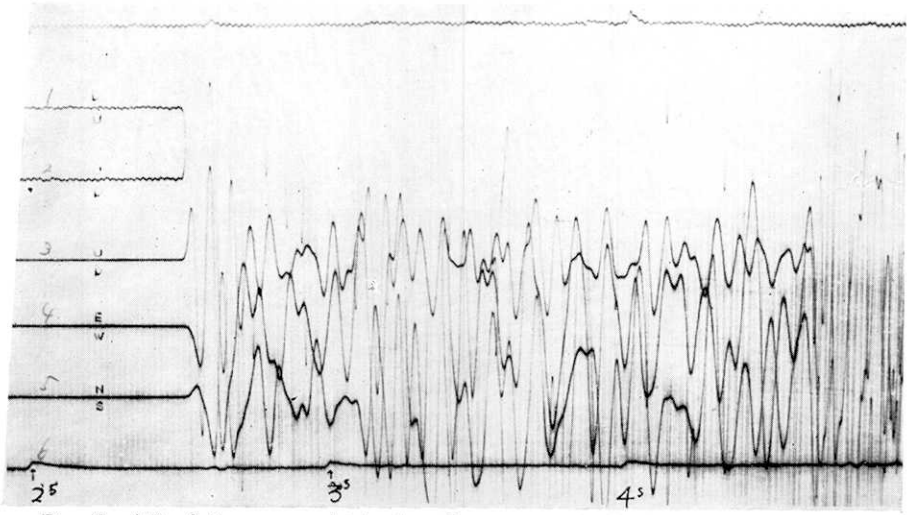

Fig. 7. (19) Seismogram obtained at Tomoegawa in the first Hokota explosion.

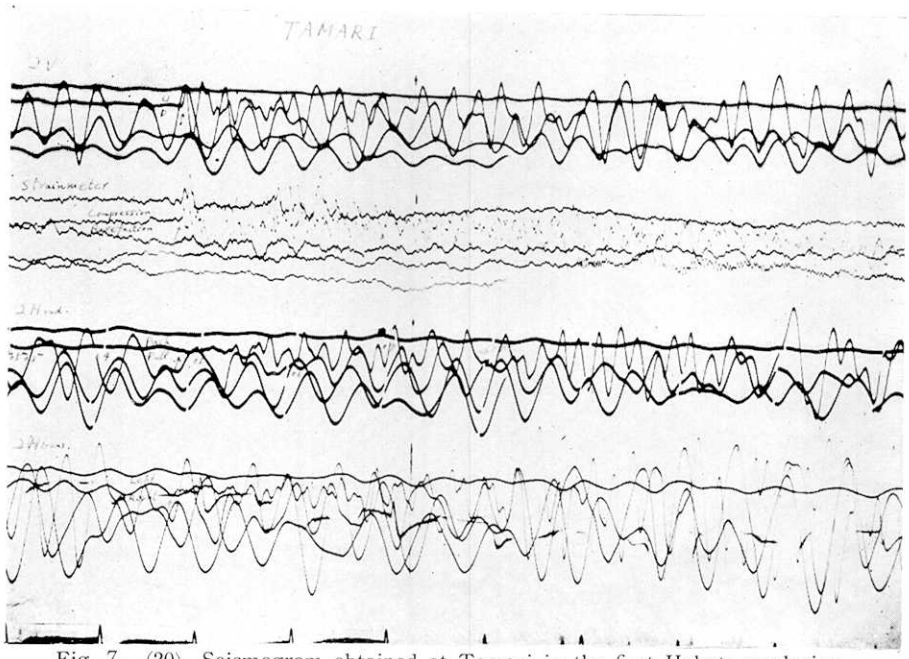

Fig. 7. (20) Seismogram obtained at Tamari in the first Hokota explosion.

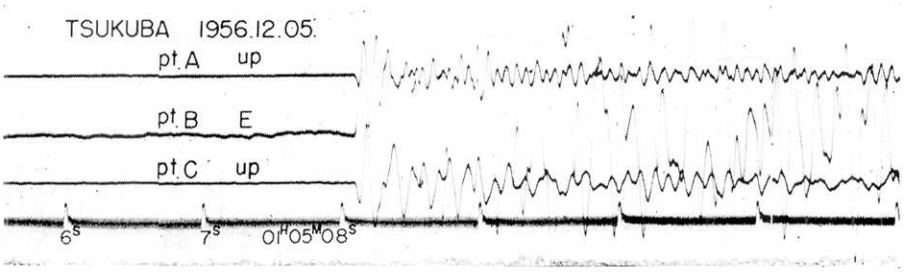

Fig. 7. (21) Seismogram obtained at Tukuba in the first Hokota explosion.

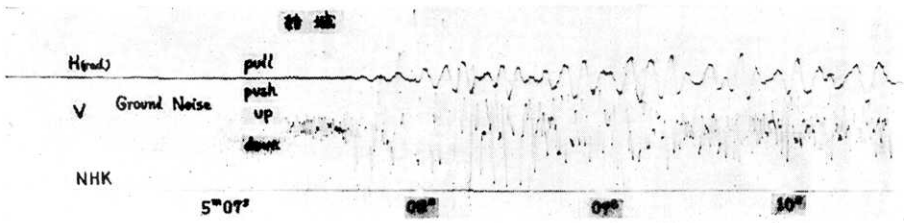

Fig. 7. (22) Seismogram obtained at Yûki in the first Hokota explosion.

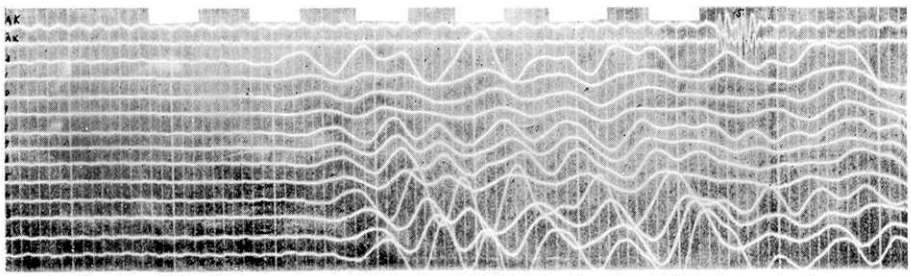

Fig. 7. (23) Seismogram obtained at Totigi in the first Hokota explosion.

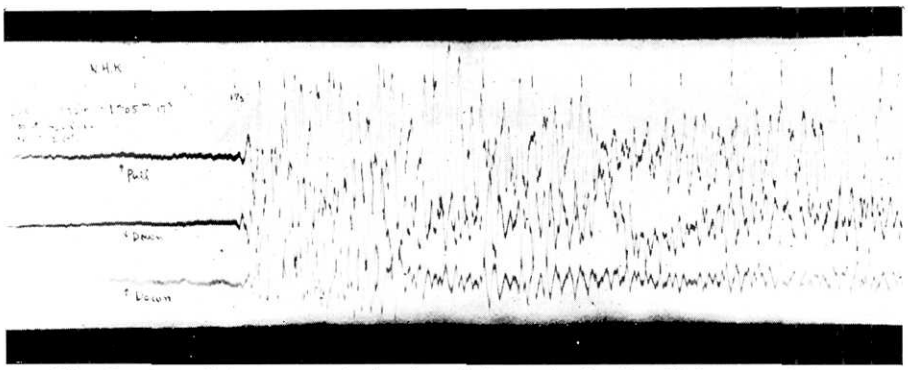

Fig. 7. (24) Seismogram obtained at Asikaga in the first Hokota explosion.

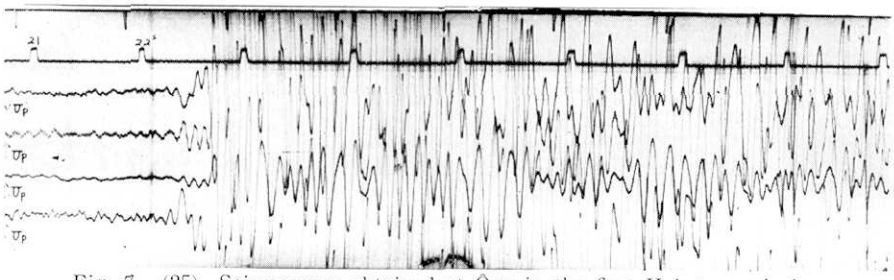

Fig. 7. (25) Seismogram obtained at Ogo in the first Hokota explosion

Fig. 7. (26) Seismogram obtained at Sibukawa in the first Hokota explosion.

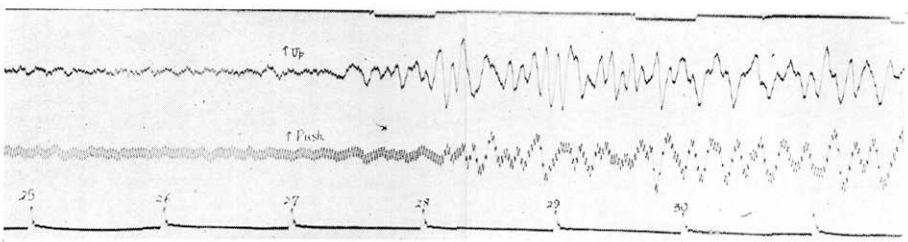

Fig. 7. (27) Seismogram obtained at Agatuma in the first Hokota explosion.

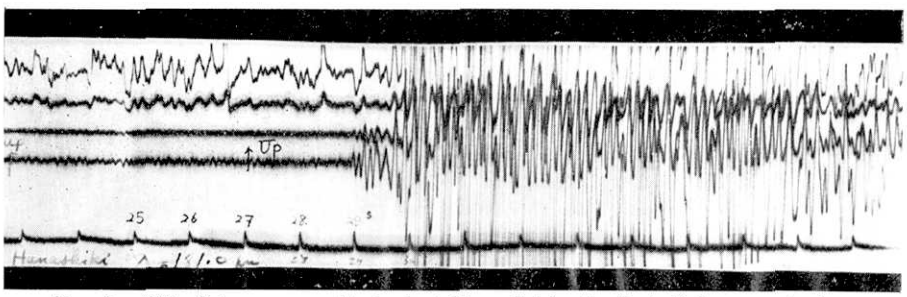

Fig. 7. (28) Seismogram obtained at Hanasiki in the first Hokota explosion.

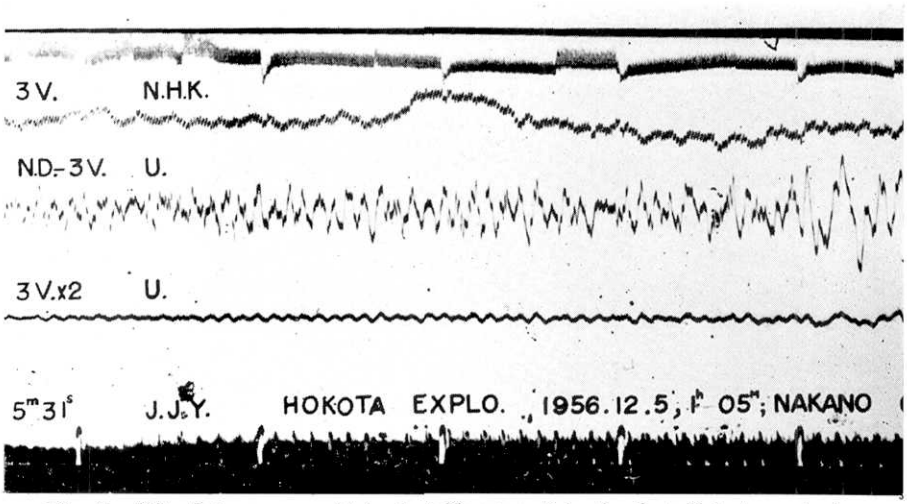

Fig. 7. (29) Seismogram obtained at Yamanouti in the first Hokota explosion.

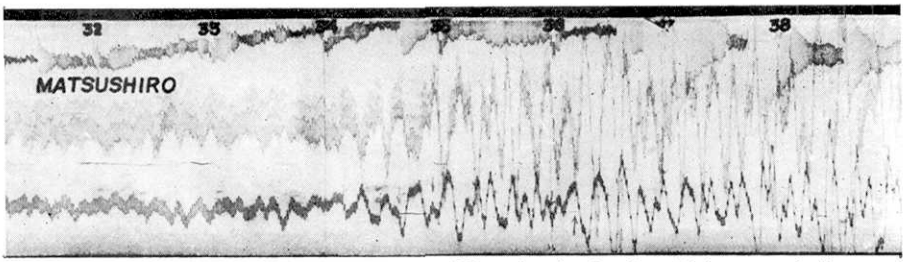

Fig. 7. (30) Seismogram obtained at Matusiro in the first Hokota explosion.

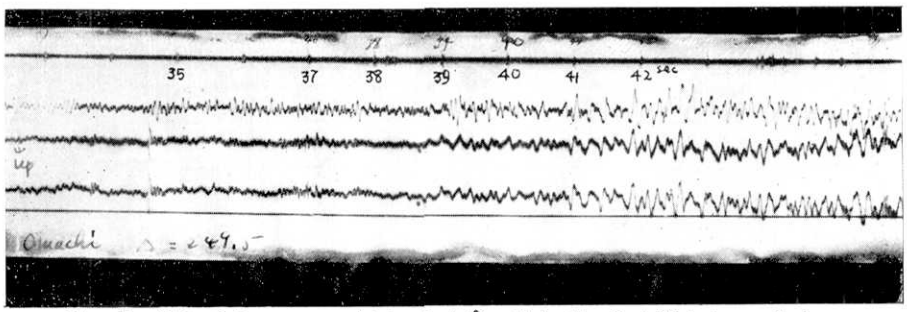

Fig. 7. (31) Seismogram obtained at Ômati in the first Hokota explosion.

3. Acknowledgement.

Our sincere thanks go to the following organizations for their kind cooperation, without which successful results could not have been obtained: Tôkyô Central Station of Nihon Hôsô Kyôkai (NHK): Japan National Railway; Tôkyô Electric Power Company; Chûbu Electric Power Company; Administration offices and Police Headquarters of some prefectures; and village or town offices and police stations where our observation stations were put. The Radio Time Signal Committee and the Broadcast Station of Standard Frequency gave us important help in these experiments.

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18. 大爆破による北関東地方の地殻構造について
其の 1 観 測 報 告

爆破地震動研究グループ

1954 年 11 月 14 日 午前 1 時 05 分に 3.7 トン，1955 年 8 月 15 日 1 時 05 分に 1.55 トンの火薬による大爆破が群馬県吾妻郡六合村野反池北方で行われた．これは同地に作るダム建設用の石を採る為に行われたが，われわれは，それを利用して，地震動の観測を行つた．合計 18 の観測点は野反と筑波を結ぶ線上に配置された．この観測だけでは地下構造を決めることはできないので 1956 年 12 月 5 日 1 時 05 分に野反・筑波を結ぶ測線の延長上にある茨城県鹿島郡鉾田町の近くの大洋村に爆破点を設けて 1 トンの火薬を爆破させた．測線は爆破点から野反の方向に向つてとり，前 2 回の野反爆破と合せて，正逆両測線による観測を行つた．後者を便宜上鉾田爆破という．観測点は14 である．同爆破点に径 5″ の火薬孔を 70 m の深さに 6 本堀り，これに火薬を50 m の長さに埋めた．

地震計は 3 c/s 又は 10 c/s の動コイル型換振器が多く，増巾器を通じて短周期のガルバノメーターにつないだ．倍率は 3 c/s で最高約 1000 万倍である．

記録のよみとりは，数人の整理委員が行い，一致したものをとつた．その精度は 0.1 sec 以上で，震央距離は 10 m 以下の誤差しかない．

第 1 回野反爆破は地震研究所特殊研究費，第 2 回野反および第 1 回鉾田爆破は地震研究所特別事業費より大部分の費用を出していただきました．心から感謝します．