# 6. *The Fourth Explosion-Seismic Observations in North-Eastern Japan.*

By The Research Group for Explosion Seismology.*

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## 1. Preface.

Seismic prospecting on a large scale, using a large amount of explosives, is highly effective in studying the propagation of seismic waves as well as in investigating the crustal structures. In Japan, the first opportunity for such experiments was afforded on October 25th, 1950 when a large amount of explosives was exploded for engineering purpose at the construction site of Isibuti dam in Iwate-ken, and our research group named "The Research Group for Explosion Seismology (R.G.E.S.)" was formed.

After that time, on December 27th, 1951 and on July 25th, 1952, explosions on a similar scale took place at the same spot, and experiments were made on each opportunity, the results of which have already been reported respectively.[1)]

On December 7th 1952, the fourth opportunity was offered when a large amount of explosives, i.e. 29.7 tons of dynamite, were exploded for the purpose of setting down the weakened deposits in the Kamaisi Mine at Sennin-tōge, about 18 km west of the city of Kamaisi, Kamiheigun, Iwate-ken.

Very fortunately the new explosion point was situated exactly on

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1) *Zisin*, [ii], **3** (1951), 77-82. **6** (1953), 7-12. **6** (1953), 84-90. *Bull. Earthq. Res. Inst.* **29** (1951), 97-106, **30** (1952), 279-292. **31** (1953), 281-288.

the eastern profile of the second Isibuti experiment, and it provided a good opportunity for us to reexamine the previous results.

## 2. Preparation for observation.

Nineteen temporary observation points (14 points on the southern and 5 points on the western profile) were established. Their locations are shown in Fig. 1. The pick-ups used were vertical or horizontal electromagnetic seismographs of 3 c/s, except in a few points, and high-gain amplifiers and oscillographs were prepared as in the previous case.

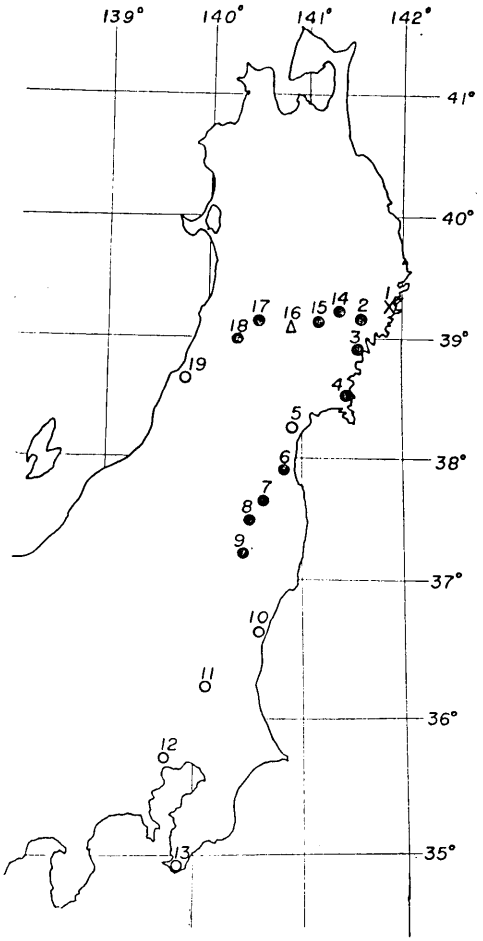


Fig. 1. Seismic stations of the first Kamaisi explosion of Dec. 7, 1952.

As for the time marking system, in addition to the time signals of J.J.Y. in 4 Mc, special cooperation was given by NHK, Nippon Broadcasting Company, who kindly received the time signal of J.J.Y. and broadcast it in its civil broadcasting frequency band of 590 Kc from JOAK, Tokyo, for 20 minutes before and after the explosion time. The special broadcasting from JOAK was also utilized for the communication between the observation points.

The shot-time was calculated as 03 h 34 m 59.91 s from the record obtained at the shot point. The explosives were fired in 7 steps with 25 milli-second delay detonators.

## 3. Observation and results.

At several distant ones of the nineteen observation points, it

Table I.

| | Station | $\lambda$ | $\varphi$ | h | $\Delta$ | Seismometre | Observers |
|---|---|---|---|---|---|---|---|
| Southern profile | Shot point | 141°41′49″ E | 39°17′37″ N | 500 m | 0 km | 20V12 | Kaneko, Huruya |
| | Setamai | 32′46″ | 09′08″ | 180 | 20.4 | 10V1, 10H1 | Asano, Sato |
| | Kesennuma | 34′26″ | 38°53′55″ | 35 | 45.5 | 10V1, 10H1 | Matumoto (T), Hayatu |
| | Onagawa | 27′27″ | 26′15″ | 20 | 97.3 | 3V1, 3H1 | Noritomi, Takagi, Ossaka |
| | Mukaiyama | 140°49′07″ | 14′36″ | 130 | 140.0 | 3V1, 3H1 | Yoshiyama, Sima (T), Nakamura |
| | Kanayama | 47′51″ | 37°53′43″ | 80 | 173.7 | 3V2, 3H1 | Murauchi, Honda, Asanuma |
| | Kawamata | 36′47″ | 40′49″ | 260 | 202.3 | 3V2, 3H1 | Kobayashi (Naoyosi), Hagihara |
| | Siroiwa | 28′52″ | 29′30″ | 340 | 226.5 | 3V1, 3H2 | Suzuki (Z), Mine |
| | Nogizawa | 25′18″ | 10′98″ | 180 | 261.1 | 3V2, 3H1 | Yamazaki, Kobayashi (Naota) |
| | Hitati | 36′06″ | 36°37′33″ | 374 | 311.6 | 3V1 | Tanaka, Suzuki (T) |
| | Tukuba | 06′40″ | 12′36″ | 280 | 369.9 | 3V1 | Kasahara, Chujo |
| | Tokyo | 36′53″ | 35°36′11″ | 6 | 445.0 | 3V1 | Tateishi, Suzuki |
| | Kanbe | 139°50′37″ | 34°56′25″ | 20 | 510.0 | 3V2, 1H1 | Den, Mogi, Haseba |
| Western profile | Ide | 141°17′48″ E | 39°10′27″ N | 140m | 36.9 km | 3V1, 3H1 | Akima, Tsujiura |
| | Mizusawa | 08′11″ | 07′57″ | 61 | 51.4 | 10V1, 1H1 | Sakai, Sugawa, Usami |
| | Isibuti | 140°54′28″ | 06′44″ | 300 | 70.8 | 3V1, 3H1 | Utsu, Ogawa |
| | Yuzawa | 30′30″ | 09′36″ | 120 | 103.3 | 15V6, 2H3 | Tamaki, Okano |
| | Mamurogawa | 17′13″ | 38°51′58″ | 100 | 130.5 | 3V2 | Sima (E), Sibano, Yanagisawa |
| | Tagawa | 139°38′36″ | 39′00″ | 40 | 195.0 | 3V1, 3H1 | Yamashita, Tazime |

N.B. 3V2 means two vertical seismometers of 3 c/s natural frequency.

failed to record the seismic waves generated by the explosion. This regrettable result may have been caused from the fact that the explosion at this time was not effective enough to produce strong seismic waves on account of the following reasons: the first is that the explosion of 29.7 tons of dynamite was performed by delayed blasting: the second is that fairly large amount of blasting energy was probably released into free air due to the condition of blasting chamber. For such reasons, records of only 8 stations in southern and of 3 stations in western profiles were used for the present analysis.

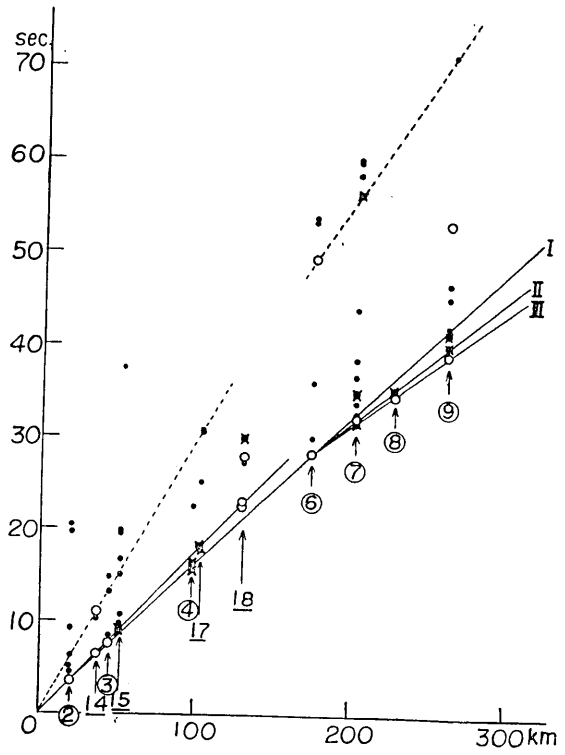


Fig. 2. Time-distance curves in the southern profile of the first Kamaisi explosion seismic observations.

In order to avoid personal error, the arrival times of phases in each record were measured by three members independently of one another. From the data of these results, the travel-time curves are drawn as shown in Fig. 2 and 3, for southern and western profiles respectively. In Fig. 2, the points marked ○, ✕, and ● correspond to the phases

which were recognized by all 3, by 2 and by only one of the 3 persons respectively.

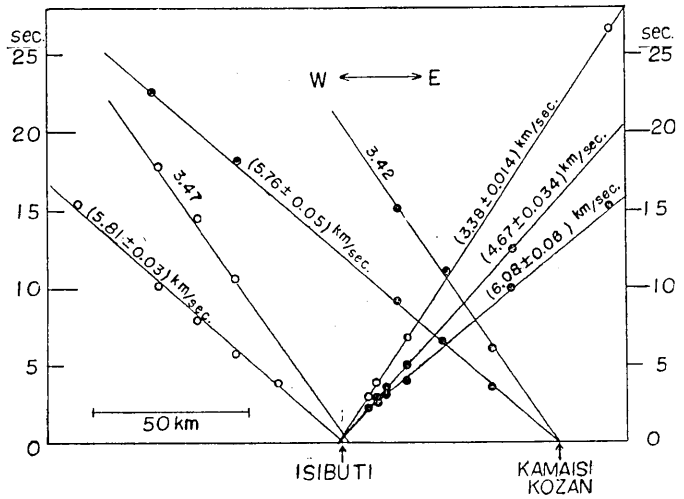


Fig. 3. Time-distance curves of the E-W profile of the first Kamaisi explosion seismic observations.

## 4. The travel-time curves in southern profile.

Based upon the data concerning the arrival times of identified phases in each record, three travel-time curves are drawn, which are shown by solid straight lines in Fig. 2. By reducing the equations of these lines by the least squares, they are expressed as follows:

$$\text{I} \qquad t=0.21\pm0.07+\frac{\Delta}{6.19\pm0.02}$$

$$\text{II} \qquad t=4.18\pm0.29+\frac{\Delta}{7.37\pm0.06}$$

$$\text{III} \qquad t=7.06\pm0.40+\frac{\Delta}{8.20\pm0.10}$$

The data used for reducing these equations are in Table II.

Equation I means the existence of a layer in which the $P$-wave travels at an apparent velocity of 6.19 km/sec. This layer seems to correspond to the 3rd layer found in the last three experiments at Isibuti, and the apparent values of $P$ wave velocities obtained in the

layer were $(6.13 \pm 0.02)$ km/sec, $(5.91 \pm 0.02)$ km/sec and $(5.98 \pm 0.01)$ km/sec respectively.

The value of $V_p = (6.19 \pm 0.02)$ km/sec calculated in the present case is significantly larger than the previous ones just given above. This fact deserves investigation in the near future. Anyhow, it cannot be considered as observational errors and we must reexamine our whole process of inferences, taking geographical distributions and geological informations of the profiles into consideration.

Table II.

| | Station | $P_1$ | $P_2$ | $P_3$ | S (?) |
|---|---|---|---|---|---|
| Southern profile | 1 | Shot time: $03^h 34^m 59^s.91$ | | | |
| | 2 | $35^m 03^s.51$ | | | $06^s.08$ |
| | 3 | 07.63 | | | |
| | 4 | 15.77 | | | |
| | 6 | 28.32 | $28^s.32$ | $28^s.32$ | 49.45 |
| | 7 | | 32.21 | 31.75 | 50.40 |
| | 8 | | 35.64 | 34.52 | |
| | 9 | | 40.13 | 39.00 | 71.38 |
| Western profile | 14 | $06^s.30$ | | | $10^s.9$ |
| | 15 | 09.00 | | | 15.0 |
| | 17 | 18.00 | | | 30.79 |
| | 18 | 22.57 | | | |

Equation III means the existence of a layer in which $P$-wave travels at an apparent velocity of 8.20 km/sec. Such a value of velocity has never been observed in Japan, though similar values have been found in other countries. On the other hand, the value of $V_p = 7.37$ km/sec expressed by equation II cannot be disregarded in considering the result of observations in the 3rd Isibuti explosion and values of $V_p$ found in natural earthquakes in Tohoku district.

It remains unsolved which of these two travel-time curves expressed by II and III, is more probable, or whether we may not admit the existence of two layers corresponding to II and III. At present, however, upon the present observations, we will admit the existence of the 2 layers corresponding to I and III, and as to the existence of the layer corresponding to II, we will make sure of it on the next opportunity.

On an assumption that thicknesses of the layers remain the same southward along the profile, they are calculated from the above equations I–II, II–III and I–III as follows:

$$d_{12}=(27.2\pm3.0)\text{ km},$$
$$d_{23}=(\ 5.1\pm3.3)\text{ km},$$
and
$$d_{13}=(32.3\pm1.3)\text{ km}.$$

In these expressions, $d_{12}$, for instance, means the thickness of the layer corresponding to I overlaying the layer corresponding to II.

As no observation points were spread, at this time, near the shot point, the travel-time curve corresponding to the layer which may probably exist over the layer of $V_p=6.19$ km/sec could not be found. But, considering the intercept time of $(0.21\pm0.07)$ sec in equation I, it seems to exist.

A dotted line in Fig. 2 shows the velocity of waves 4.1 km/sec, which seems to be slightly larger than that of *S*-waves.

## 5. The travel-time curves of the western profile.

Fig. 3 shows the travel-time curves of the western profile. By the least square method, the equation of this line becomes as follows:

$$t=(-0.02\pm0.01)^s+\frac{\Delta}{5.76\pm0.05}$$

which shows an apparent *P*-wave velocity of 5.76 km/sec. This value is almost the same as what was found in the same western profile in the last Isibuti experiment (5.78 km/sec), and will confirm our estimation on the crustal structure of the east-west profile of these regions which we have obtained previously.

The dotted line in Fig. 2 shows a velocity of approximately 3.4 km/sec, which seems to correspond to the velocity of *S*-waves.

## 6. Conclusion.

It is regrettable that sufficient number of records of seismic waves generated by the explosions could not be obtained and that few points remain unsolved. But we may say that the following points in the present investigations are of special interest. (1°) The velocity of the *P*-wave in the 3rd layer in Isibuti case was found to be significantly larger than that in previous cases. (2°) The layer having the value of

8 km/sec was found at a depth of approximately 30 km. (3°) The crustal structure of the east-west profile of these regions estimated in the last Isibuti experiments was confirmed.

## 7. Acknowledgement.

Finally, we wish to express mach thanks to the agencies and persons to whose helpful cooperation the success of this experiment is due. They are Nittetsu Mining Company, Tohoku District Construction Bureau of Ministry of Construction, Tohoku Electric Company, Japan Government Railway, Technical Department of Nippon Hoso Kyokai (NHK), Telephone Office of Morioka and Kamaisi, Post Office of Kassi, Prefectural and Police Authorities of Morioka.

We also acknowledge the encouragement and instruction given by Prof. T. Matuzawa throughout our study.

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## 6. 東北日本における第4回爆破地震動観測

爆破地震動研究グループ

三回にわたる石淵での大爆破による地震動の観測が終了して間もなく，我々は 1952 年 12 月 7 日に，場所も同じ東北地方の，しかも石淵の場合の観測の東西測線上に丁度のる，釜石市から 15 km 程西によつた釜石鉱山における約 30 トンの火薬による大爆破の地震動を観測する機会にめぐまれた．

19 の臨時観測点のすべてがきれいな記録をうることに成功したと云う訳でないので，1，2 その決論を次回にゆづる点を残す結果となつたが，少くとも今度の観測で認められた注意すべき点は，

1. 石淵の場合に見出された第三層に相当すると思われる層の中の P 波の速度が，観測誤差の範囲をかなり外れて大きく出たということ．

2. 今迄日本では見出されなかつた 8 km/sec 程度の P 波の速度をもつ層が，約 30 km 位の深さで見出されたこと．

3. 東方測線による結果は，石淵の場合の東西測線からえられた結果とよく一致し，この辺の東西方向に関する地殻構造は，これでかなりの確実性をおびるに至つたことである．

尚，今回の観測に当つて多大の便宜を与えられた日鉄鉱業釜石鉱山，建設省，国鉄盛岡管理局，NHK技術部，盛岡県庁，東北電力，その他各方面の関係者に対してはここに厚くお礼を申し上げたい．

なお，本研究は，文部省科学研究費によつてなされたものであることを附記して謝意を表する．

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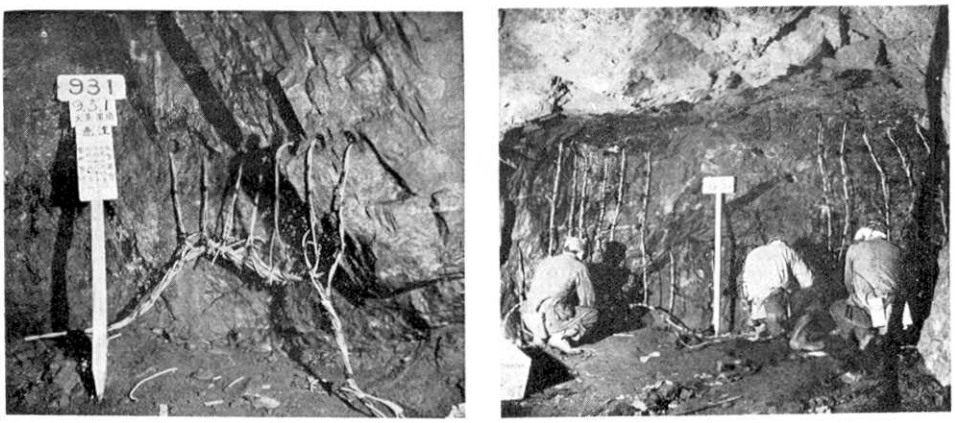
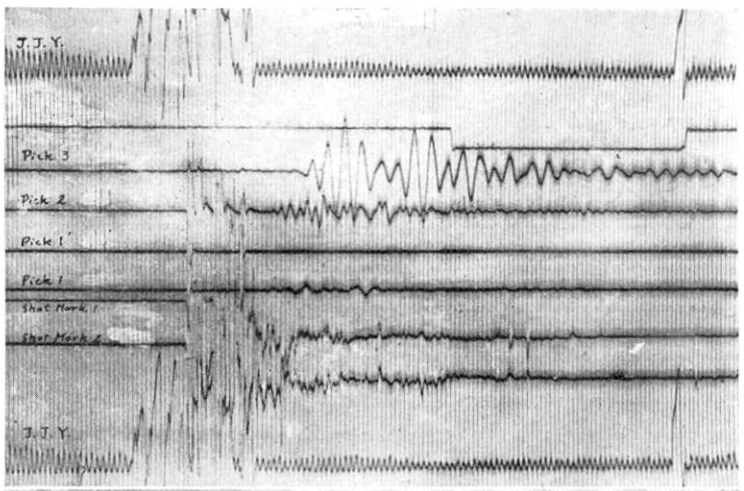
(A)




(B)




(C)

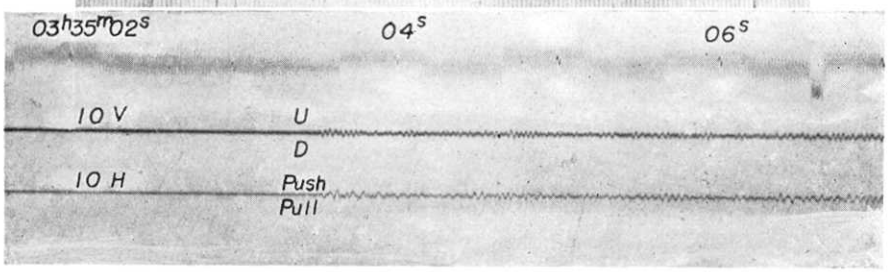



Fig. 4. The first explosion at Kamaisi, Iwate-ken, on December 7th 1952.
Charged walls along the gallery in the mine (*A*). Seismograms on the eastern profile at Shot point (*B*) and Setamai (*C*).

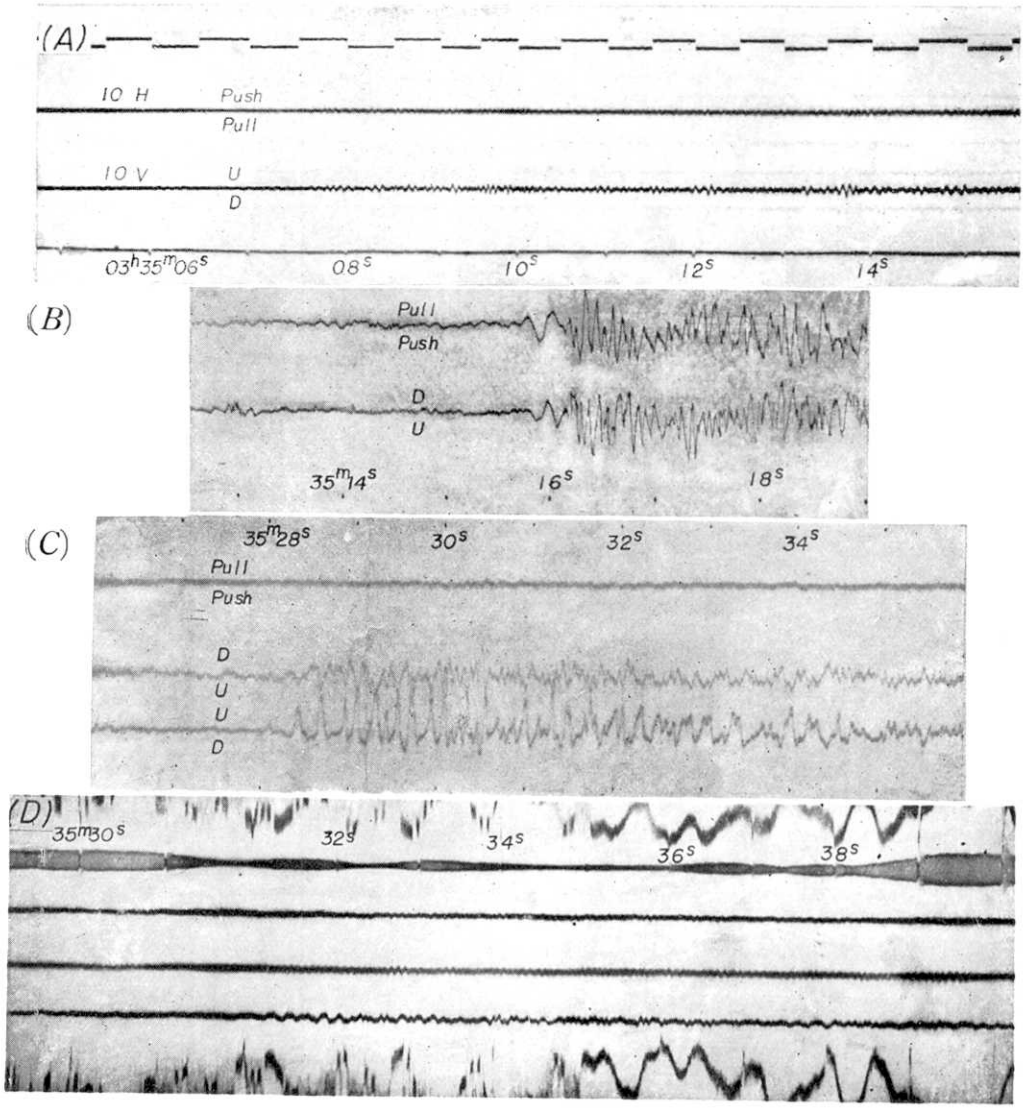



Fig. 5. Seismograms obtained at the first Kamaisi explosion of 1952 on the southern profile at Kesennuma (*A*), Onagawa (*B*), Kanayama (*C*) and Kawamata (*D*).

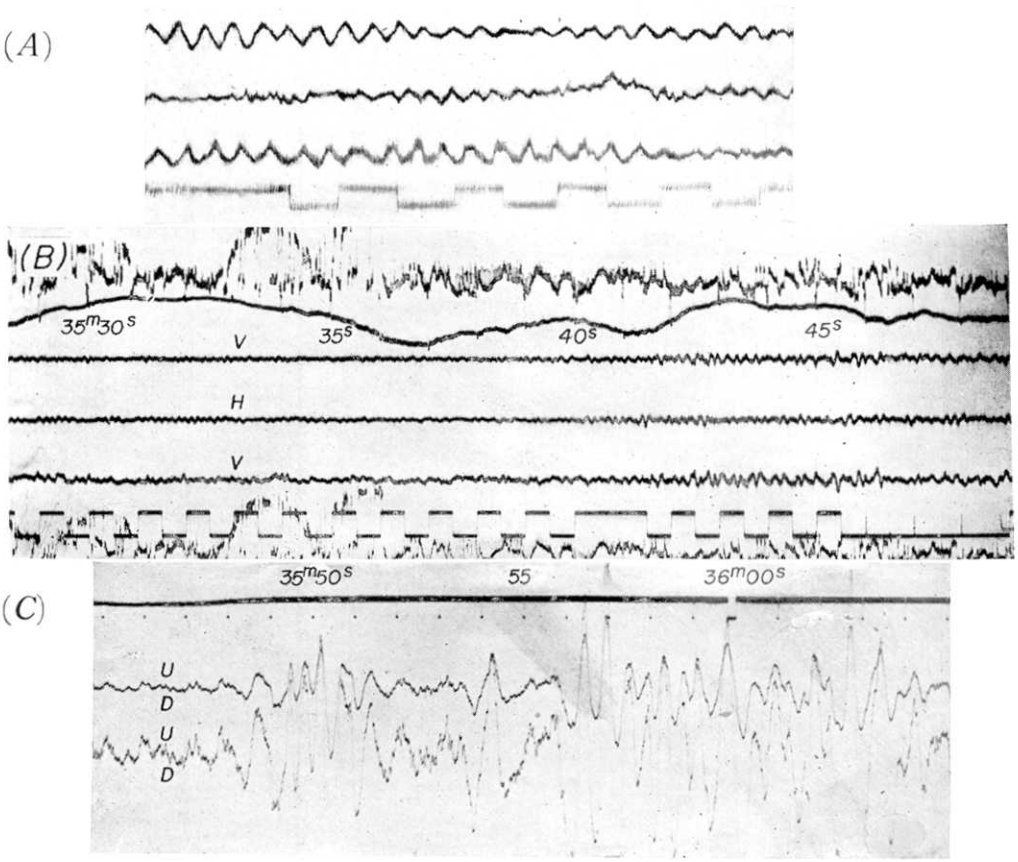



Fig. 6. Seismograms obtained at the first Kamaisi explosion of 1952 on the southern profile at Siroiwa (*A*), Nogizawa (*B*) and Hitati (*C*).

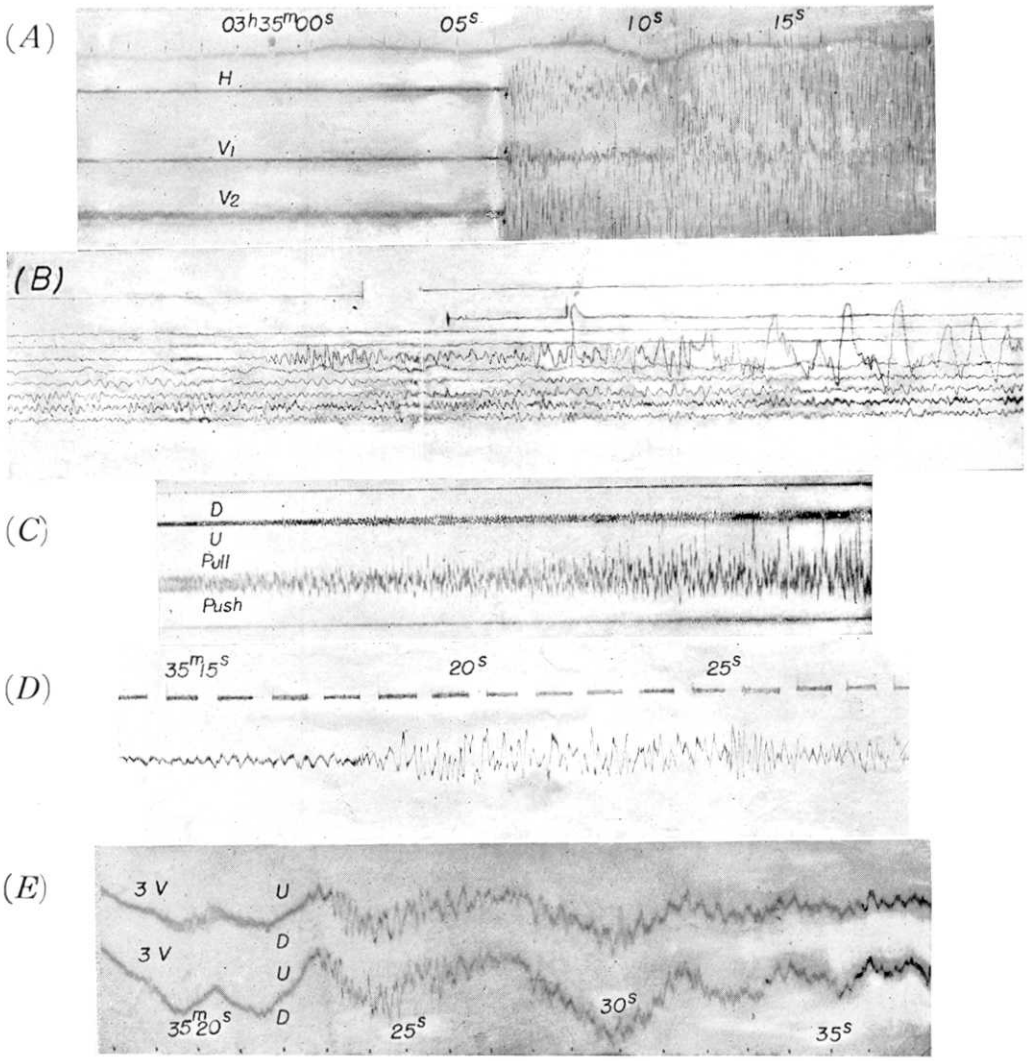



Fig. 7. Seismograms obtained at the first Kamaisi explosion of 1952 on the western profile at Ide (*A*), Mizusawa (*B*), Isibuti (*C*), Yuzawa (*D*) and Mamurogawa (*E*).