24. *The Second Explosion-Seismic Observations in North-Eastern Japan.*

By The Research Group for Explosion Seismology,*

Earthquake Research Institute, Tokyo University,
Geophysical Institute, Faculty of Science, Tokyo University,
Seismological Section, Central Meteorological Observatory,
Section of Geophysical Exploration, Geological Survey,
Geophysical Institute, Faculty of Science, Tohoku University,
Faculty of Mining, Akita University,
National Science Museum,
Geophysical Institute, Faculty of Science, Kyoto University,
International Latitude Observatory of Mizusawa.

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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 mapping earth crust structures of geologic interest. In Japan such an experiment was first made on October 25th, 1950 when a large amount of explosives was exploded for engineering purposes in Iwate-ken. In spite of the short time of preparation, the experiment went unexpectedly well as has already been reported.[1]

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* Members of the group, who participated in the project are as follows (in alphabetic order).

AKIMA T., HORI M., HAGIWARA Terukazu, HIRAGA S., KAWASUMI H., KASAHARA K., KOBAYASI Naoyosi., MATUMOTO T., MATUMOTO H., MIYAMURA S., MIYAZAKI T., OMOTE S., SAKUMA S., SAWAKURI T., SHIMA E., SHIBANO M., TUZIURA M., YAMAZAKI Y., YANAGISAWA M. (E.R.I.)

ASADA T., DEN N., HAYATU A., KOBAYASHI Naota, MATUZAWA T., MOGI K., SATO R., SHIMIZU Y. (Geophys. Inst., Tokyo Univ.)

AIHARA K., INOUYE W., ICHIKAWA M., OGAWA T., SUYEHIRO S., UTSU T. (C.M.O.)

HURUYA S., KANEKO T., KOJIMA S., TATEISHI T., UZIIE A. (Geol. Surv.)

KATO Y., MINE N., NORITOMI K., OSSAKA G., SUZUKI Z., TAKAGI A. (Geophys. Inst., Tohoku Univ.)

TAZIME K. (Akita Univ.) HONDA T., MURAUCHI S. (Nat. Sci. Mus.)

KOZÙKI A., OKANO K., TAMAKI H. (Geophys. Inst., Kyoto Univ.)

MURAKAMI G., SUKAWA T. TAKAHASI T., (Mizusawa Lat. Obs.)

1) La Groupe pour Recherches de Séismologie par Explosion, Tokio, Observation Sismique par Explosion d'Isibuti., ZISIN Ser. II, **3** (1951), 77-82.

The Research Group for Explosion Seismology, Tokyo, Explosion Seismic Observations in North-eastern Japan, Bull. E.R.I. **29** (1951), 97-106.

Table I. Second Isibuti
(1951-XII-27, $12^h 06^m$,

	Observation point	Location	Elevation	Distance from shot	Seismographs
Nearby region	2. Tunnel	Near the explosion point	m 340	km 0.22 0.32	Electromag. (20 c/s Vert.)
	1. Orose	140°52′57″E 39 04 38 N	340	1.08	Mechanical (1 c/s Hor. $V_G=400$)
	3. Isibuti	140 54 43 E 39 06 51 N	300	1.69	Mechanical (1 c/s Hor. $V_G=400$)
	4. Umadome	140 56 32 E 39 07 05 N	195	4.31 4.40	Electromag. (10 c/s Hor. Ver.)
Eastern profile	5. Atago	140 59 31 E 39 07 26 N	150	8.65	Electromag. (10 c/s Ver.)
	6. Dobasi	141 01 58 E 39 07 31 N	100	12.09	Electromag. (3 c/s Hor. Ver.)
	7. Wakayanagi	141 03 41 E 39 07 43 N	100	14.62	Electromag. (3 c/s Hor. Ver.)
	8. Mizusawa	141 08 13 E 39 07 54 N	50	21.10	Mechano-optical (1 c/s, Hor. $V_G=4000$)
	9. Ide	141 17 30 E 39 10 30 N	150	30.00	Electromag. (10 c/s Hor. Ver.)
	10. Setamai	141 32 27 E 39 08 57 N	100	55.90	Electromag. (3 c/s Hor. Ver.)
	11. Kamaisi	141 53 31 E 39 15 36 N	10	87.54	Electromag. (3 c/s Hor. Ver.)
Southern profile	12. Hondera	140 56 29 E 38 58 24 N	206	15.29	Electromag. (3 c/s Hor. Ver.)
	13. Kurikoma	140 54 35 E 38 54 13 N	200	22.52	Electromag. (3 c/s Hor. Ver.)
	14. Hosokura	140 54 33 E 38 48 13 N	140	33.03	Electromag. (5 c/s Ver.)
	15. Kawatabi	140 45 31 E 38 44 38 N	220	41.92	Electromag. (3 c/s Hor. Ver.)
	16. Nakaniida	140 51 30 E 38 34 00 N	50	60.00	Electromag. (3 c/s Hor. Ver.)
	17. Matusima	141 04 31 E 38 23 05 N	10	81.60	Electromag. (3 c/s Hor. Ver.)
	18. Sinobu	140 30 31 E 37 41 39 N	180	159.92	Electromag. (3 c/s Hor. Ver. 1c/s Hor.)

explosion-seismic observations.
$\varphi=39°06'22''$N, $\lambda=140°53'39''$E, h=300 m)

Electronic amplifier	Electro-magnetic oscillographs (type of vibrator)	Observers
None	6-elements Haeno (Haeno-type vibr.)	Kojima, Huruya, Sakuma
None	None	Ichikawa, Takahashi
None	None	Suyehiro, Kobayashi, Sukawa, Murakami
None	6-elements YEW (YEW-D-type vibr.)	Matumoto, Aihara, Hayatu
1 for H-vibr.	2-elements (YEW-H-type vibr.)	Tuziura, Mogi
2 for D-vibr.	3-elements YEW (YEW-H-type vibr.)	Noritomi, Ossaka, Takagi
3 for D-vibr.	4-elements (YEW-D-type vibr.)	Utsu, Ogawa
None	None	Miyazaki, Hiraga
1 for H-vibr. 2 for D-vibr.	4-elements (YEW-H&D-type vibr.)	Akima, Sawakuri
3 for D-vibr.	6-elements Haeno-type	Tateishi, Ujiie
3 for H-vibr.	4-elements (YEW-H-type vibr.)	Kasahara, Sato
3 for H-vibr.	7-elements (YEW-H-type vibr.)	Hori, Den, Shimizu
3 for D-vibr.	4-elements (YEW-D-type vibr.)	Murauchi, Honda
		Tamaki, Okano, Kozuki
4 for D-vibr.	7-elements (YEW-D-type vibr.)	Tazime, Kobayashi
3 for D-vibr.	5-elements (YEW-D-type vibr.)	Shima, Shibano, Yanagisawa
3 for D-vibr.	7-elements (YEW-H-type vibr.)	Yamazaki, Kobayasi, Hagiwara
3 for H-vibr.	4-elements (YEW-H-type vibr.)	Suzuki, Mine, Oowaki

After that our group awaited for the second opportunity, which came on December, 27th, 1951. In this paper, the second explosion-seismic observation will be reported.

2. Preparation of observation.

With the experience of the first experiment as a guide, every phase of the instruments was much improved both in quality and quantity as compared with the first experiment. Vertical and horizontal electromagnetic seismographs of 3 cycles in natural frequency, high-gain electronic amplifiers and electromagnetic oscillographs were prepared in a large number. Most of them were designed on almost the same standard so as we could register seismic motions of the ground far from the explosion point and compare seismograms with sufficient accuracy. In addition to the seismographs of 3 cycles, electromagnetic

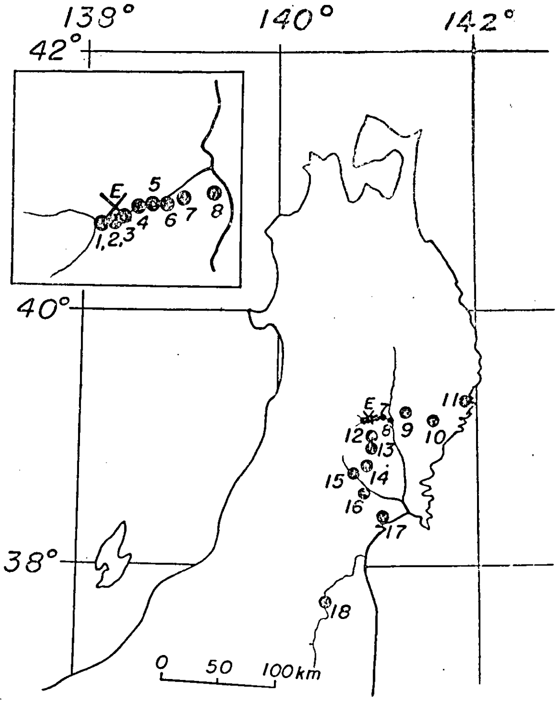

Fig. 1. Seismic observation stations for the second Isibuti explosion.
(Letter E indicates the place of shot and the numbers correspond to those in Table I.)

seismographs of 10 cycles and 1 cycle, mechanical seismographs and mechano-optical seismographs of 1 cycle were also employed.

As for the time-marking system, a similar method to that used in the previous case was adopted, whereby the time signals of the standard radio wave, JJY were received by a special receiver and put directly on the seismograms. Chronometers and other clocks were also prepared to cover unfavourable conditions of radio receiving.

Thus equipped, 18 temporary observation points were established as shown in Fig. 1 and Table I. Generally speaking, observations in only one direction are insufficient for mapping earth crust structures, and this is especially the case in the Tohoku District (North-eastern part of Honsyu) according to our geophysical knowledge. From the above point of view, the observation points were lined up in two directions, eastwards and southwards from the explosion point.

The amount of explosives used in the present explosion was one seventh of that of the first explosion, but the observation points could be extended as long as 160 km owing to the high quality of instruments.

The communication among these observation points was made by the government telephone network, the special telephone network of Tohoku Electric Company and the radio broadcast of NHK.

3. Explosion point.

7.8 tons of carlit were exploded at Isibuti (in Wakayanagi-mura, Isawa-gun, Iwate-ken) adjacent to the site of the first experiment (λ=140°53′39″E, φ=39°06′22″N) in order to loosen 36,000 cubic meters of rock for the construction of a dam (cf. Fig. 4). The explosives were charged in 9 chambers and were fired simultaneously by electric detonator and fuse (cf. Fig. 2). In one of the 9 chambers an electric circuit was put in to mark the time of explosion.

The explosion came off at 12h 06m, 27th of December, 1951.

4. Observation and results.

Unfortunately a strong wind and rain or snow due to a barometric depression which was passing over the Tohoku District from the day before and the bad condition in radio receiving affected the observation to some extent, but generally the observation went on successfully.

It would have been desirable to make an observation of three components in every observation point for the analysis of seismic waves, but it was practically impossible to make such observations. However, in order to analyse the local state of propagation of seismic waves, several seismographs were lined up some hundred meters apart at several observation points[2].

The epicentral distances were calculated through spherical trigonometry (the radius of the earth: 6367.7 km), the longitude and the latitude of the observation points being determined from the ordnance map (scale: 1/50,000). However, the epicentral distances of the observation points in the neighbourhood of the explosion point were measured horizontally on a 1/5,000 map. In this case, an epicentral distance means the distance from an observation point to the nearest explosive chamber among the nine, and the error is supposed to be less than 30 meters.

In determining the arrival time of the phases, more stress was laid on the seismograms of vertical component, and other components were referred to only when necessary. The seismograms obtained are shown in photographic copies (Figs. 5∼9), where the arrows show the commencements of the phases adopted.

As described previously, the time accuracy reaches about a hundredth of a second, favoured by the direct mark of the radio time signal. The time determination of the initial phase is comparatively easy, and its error is supposed to be less than several hundredths of a second, even when every source of error is taken into consideration. In fact, the arrival time of the initial motion was determined twice, once by the observer himself and then by another, and the personal error was only two or three hundredths of a second. On the other hand, the determination of other phases is largely affected by personal judgement, and the accuracy in this case is poorer.

In Table II. the arrival time of every phase is shown and arrival times which are supposed to belong to the same phase are shown in the same column. Numerical values written besides are deviations from the value which is computed by the least square method (cf. eqs. (1)-(5)). The travel-time curves from the data are shown in Fig. 3, where (a) is the travel-time curve consisting of the nearby points to the explosion point, while (b) consists of more distant points. In the diagram (b), it is an outstanding fact that travel times in eastern direction and those in southern direction show different features. For example, at Wakayanagi and Hondera, and at Mizusawa and Kurikoma, in each pair two points being at almost the same epicentral distance

2) At Umadome, Hondera, Kawatabi and Kamaisi were made these arrangements of seismographs.

Table II. Arrival times of the second Isibuti explosion tremors observed at the temporary stations of the group.

	Observation point	Epi-central distance	Time of phase commencement (12 h 06 m+)							
			1		2		3		4	
			Time of commence-ment	Deviation	Time of commence-ment	Deviation	Time of commence-ment	Deviation	Time of commence-ment	Deviation
Nearby region	Tunnel I	km 0.22	sec. −0.095*)	sec. +0.0020	—	—	—	—	—	—
	Tunnel II	0.32	−0.056*)	−0.0020	—	—	—	—	—	—
	Orose	1.08	0.25	+0.0001	—	—	—	—	—	—
	Isibuti	1.69	0.50	−0.0002	—	—	—	—	—	—
	Umadome I	4.31	—	—	sec. 1.18	sec. −0.0754	—	—	—	—
	Umadome II	4.40	1.56	+0.0001	—	—	—	—	sec. 1.56	sec. −0.136
Eastern profile	Atago	8.65	—	—	2.26	+0.0742	sec. 2.20	sec. +0.175	2.97	+0.015
	Dobasi	12.09	—	—	2.90	−0.0644	2.52	+0.022	3.93	−0.044
	Wakayanagi	14.62	—	—	3.53	−0.0232	3.03	−0.072	—	—
	Mizusawa	21.10	—	—	4.82	−0.0348	3.93	−0.144	6.67	+0.028
	Setamai	55.90	—	—	12.31	−0.0052	9.79	−0.012	—	—
	Kamaisi	87.54	—	—	—	—	15.04	+0.031	26.44	+0.121
Southern profile	Hondera	15.29	—	—	3.44	—	2.78	−0.040	5.08	+0.159
	Kurikoma	22.52	—	—	—	—	3.99	−0.054	7.08	+0.017
	Kawatabi	41.92	—	—	—	—	7.43	+0.102	—	—
	Matusima	81.60	—	—	—	—	14.06	+0.015	24.4	−0.160
	Sinobu	159.92	—	—	—	—	I : 26.57 II : 27.28	−0.023	46.3	—

* Shot time is calculated from the least squares as 12 h 05 m 59.84s. (cf. eq. (1)).

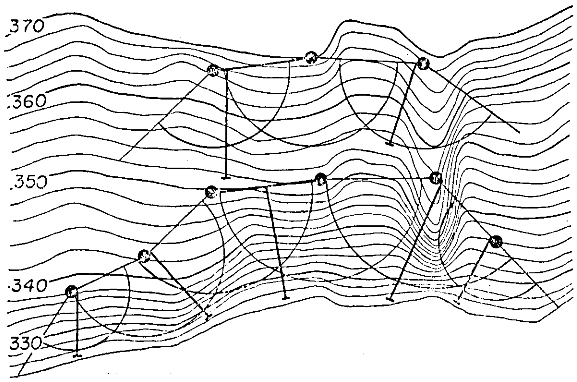

Fig. 2. Location plan of the explosive chambers and the area to be loosened by each chamber charge.

but not the same in direction, a difference is obviously greater than an error seen in the arrival time of the initial motion. From this fact, it is reasonable to discuss the results of the two directions separately.

Observation points, "Inside of tunnel", Orose, Isibuti, and Umadome are located in different directions from the explosion point. Therefore, the results from the observations at these points are treated separately from those of the above two profiles. As seen in Fig. 3 (a), the travel-time of these points are on a straight line, and by the method of the least squares, the line is given by the following equation, (Δ being measured in kilometers.)

$$t_1 = 12\text{h}06\text{m} + (-0.1617 \pm 0.0022)\text{s} + (0.3910 \pm 0.0008)\Delta.\text{s} \quad \ldots(1)$$

Consequently, the velocity corresponding to the equation (1) is

$$V_1 = (2.56 \pm 0.005)\ \text{km/sec}.$$

As shown in Fig. 3 (b), the travel-time curve of the initial motion in the eastern direction consists of a combination of two straight lines of different tangents showing different velocities. If number 2 is put to the line of lower velocity and 3 to the line of higher velocity, line 2 and line 3 are expressed by the following equations respectively,

$$t_2 = 12\text{h}06\text{m} + (0.331 \pm 0.040)\text{s} + (0.2144 \pm 0.0016)\Delta.\text{s}, \quad \ldots\ldots.(2)$$

$$t_3 = 12\text{h}06\text{m} + (0.602 \pm 0.076)\text{s} + (0.1646 \pm 0.0017)\Delta.\text{s}. \quad \ldots\ldots.(3)$$

Then the velocities are

$$V_2 = (4.67 \pm 0.034)\ \text{km/sec}, \qquad V_3 = (6.08 \pm 0.063)\ \text{km/sec}.$$

In the seismograms in the southern direction no phase corrosponding to phase (2) can be found, therefore the initial motion may be

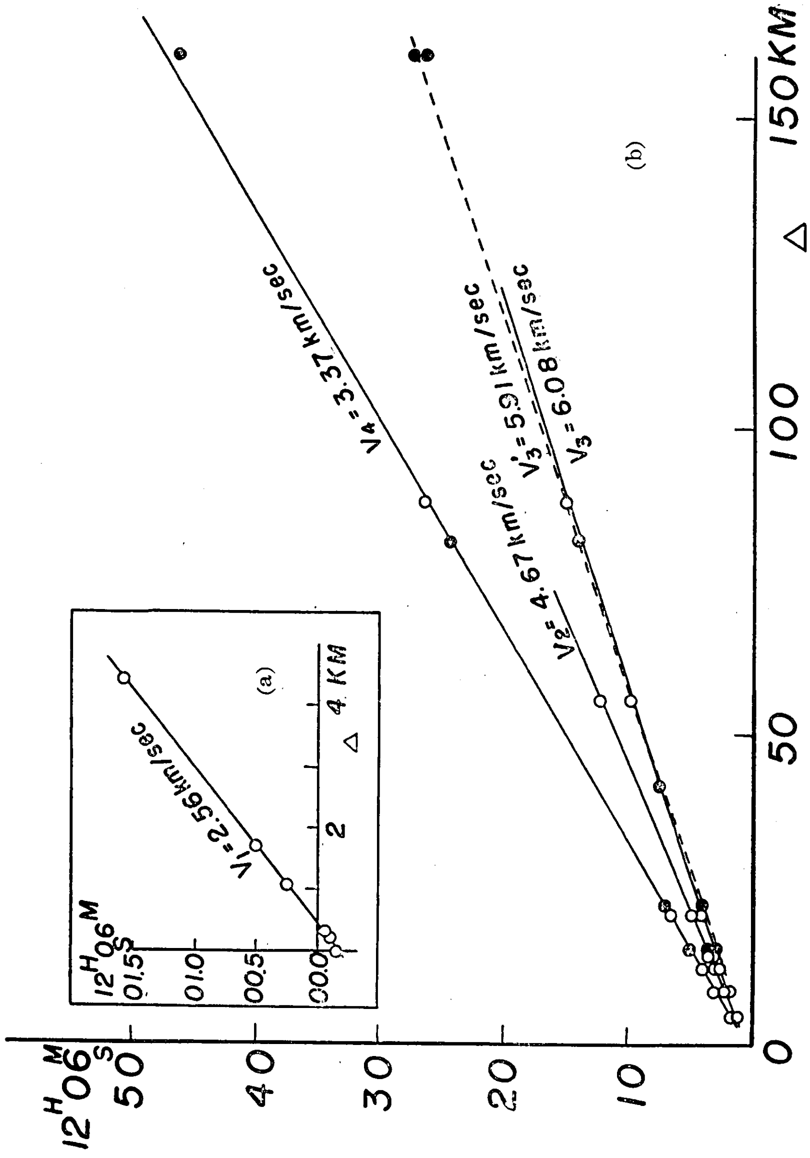

Fig. 3. Travel-time curves from the second Isibuti explosion data.

considered to correspond to phase (3). If this phase is on a straight line (let this be called 3'.), the line shows a larger tangent than that in the eastern direction. On the other hand, in the seismogram Sinobu, two phases can be seen in a similar way one after another (I and II in the photographic copy of the seismogram). Which phase belongs to 3' is a very interesting problem as shall be treated later. The equation in each case is obtained as follows,

$$t_3'(\mathrm{I})=12\mathrm{h}06\mathrm{m}+(0.400\pm0.142)\mathrm{s}+(0.1645\pm0.0017)\Delta.\mathrm{s}\ , \quad \ldots.(4)$$

$$t_3'(\mathrm{II})=12\mathrm{h}06\mathrm{m}+(0.232\pm0.051)\mathrm{s}+(0.1693\pm0.0006)\Delta.\mathrm{s}\ . \quad \ldots.(5)$$

Of these two, by reason of the smaller mean error of each coefficent, the latter equation is preferable.

The correspoding velocity is

$$V_3'=(5.91\pm0.021)\ \mathrm{km/sec.}$$

The later phase (4) shows the same feature in both directions (Fig. 3 (b)), and the corresponding velocity seems to be

$$V_4=(3.37\pm0.014)\ \mathrm{km/sec.}$$

5. Discussions.

How can the earth crust structures be interpreted from the results of the above observation? Now let us assume, for the sake of simplicity, that the underground structure of the Tohoku District consists of a series of uniform horizontal layers. If phases (1), (2), and (3) in the nearby region and eastern direction correspond to the direct and refracted longitudinal waves, the thickness of each layer can be computed as follows from the intersections between travel time curves.

$$Z_1=0.75\pm0.06\ \mathrm{km},$$

$$Z_2=1.59\pm0.33\ \mathrm{km}.$$

Here, Z_1 means the depth from the surface of the ground to the bottom of the first layer and Z_2 to the bottom of the second layer. From the observation of the first explosion at Isibuti, the existence of two layers with the boundary (1.3±1.27) km under the surface was inferred as the mean structure of the Tohoku District, the velocity being (5.26±0.007) km/sec in the upper layer and (6.13±0.017) km/sec in the lower. Z_2, V_2 and V_3 seem to correspond to the above values, respectively. Z_2 and V_3 coincide well with the values in the previous case, while V_2 does not. Further discussion will be necessary on this difference.

Up to here, the velocity of waves has been assumed to be uniform in each layer. However, the fact must be taken into consideration that near the surface, the velocity changes with depth. For the sake of simplicity, the velocity is assumed to increase with depth as expressed by the following equation,

$$V=V_0(1+\alpha z) \qquad \text{.........(6)}$$

where, V_0 is the velocity at the surface and z the depth. When the equation of the travel-time is expanded with Δ and smaller terms than Δ^5 are neglected,

$$T=\frac{1}{V_0}\left(\Delta-\frac{\alpha^2}{24}\Delta^3\right)+\cdots \qquad \text{.........(7)}$$

is given. On the other hand, if the phases expressed by the two lines (1) and (2) should be formulated by a third degree equation with Δ,

$$t=12\text{h}06\text{m}+0.128\text{s}+0.2296\Delta.\text{s}-3.776\times10^{-6}\Delta^3.\text{s} \qquad \text{......(8)}$$

is given, and thus V_0 and α in the eq. (6) can be obtained. According to these values, the waves which give the initial motion at the epicentral distance of 55 km, show the velocity of 5.15 km/sec at the deepest point of the seismic ray, and its depth is about 9 km. On the other hand, from the intersection between equations (3) and (8), the boundary of the two layers is seated only 4 km from the surface of the ground. This value of 4 km obviously contradicts with the above value. Consequently, it is inadequate to interpret the travel-time curves (1) and (2) en bloc by the assumption that the velocity varies with depth in the upper layer.

In the southern direction, as described previously, the features are different from those in the eastern direction. For instance, phase (2) which is identified in the eastern direction is not clearly seen in the southern direction.

This is a fascinating problem, though it is premature to infer the lack of the second layer in the southern direction simply from this fact. Phase (3′) shows similar features to those of (3) in the eastern direction, while considerable differences are seen between times at the origin and velocities. So far as uniform and horizontal layers are assumed, the heterogeneity of seismic velocity in the third layer seems to be beyond dispute. However, owing to some uncertainty in the assumption, no decisive conclusion can be obtained in this stage. If the travel times of the nearby region and in the southern direction are considered en bloc, the thickness of the first layer turns to be (0.55 ± 0.08) km. But this value is the result of mere assumption.

From the standpoint of lessening the mean error in the travel-time equation, phase II of Sinobu was considered to belong to phase (3′). If this be true, initial motion I of Sinobu must be given by the waves which are propagated through a layer beneath the third layer with a higher velocity. The velocity of phase (3) or (3′) coincides with that of the so-called P^*, and therefore it gives rise to a possibility of correspondence between initial motion I at Sinobu and so-called P_n. Then, if this assumption is reasonable and if the velocity of P_n be 7.5 km/sec (which has been obtained from the observations of natural earthquakes in Japan), the depth of the layer of P_n is computed at about 24 km, and this value does not seem to be unreasonable. However, this conclusion is too premature, and further investigations, such as observations in the coming third large explosion, are desirable to give us a definite answer to this problem.

The phase with the velocity of $V_4=3.37$ km/sec observed in both directions is the same phase as was observed in the previous experiment and temporarily called S_1. Though little is known about this phase, it may be a kind of surface waves. Anyhow, further investigations are also requested in this matter. In the previous experiment, the peculiar phenomenon was seen that phase S_2 showing the same velocity as that of S_1 appeared 1 second after S_1. But this phenomenon was not seen in the present case. If such a phenomenon depends on the way the explosives are charged and exploded as was alluded to in the previous reports, the lack of the phenomenon in the present case may be understandable, because the conditions of explosion were different from those in the previous case. (cf. Figs. 4, 5 of the previous paper and Fig. 4 of the present paper.)

6. Conclusions.

More facts about the propagation of seismic waves in Tohoku District have been revealed by the seismic observations of the present explosion. The most outstanding fact is that the propagation of seismic waves in the eastern direction differs from that in the southern direction. In the eastern direction, at least three layers are expected on the assumption that the underground structure consists of uniform and horizontal layers. The depths from the surface to the two boundaries are 0.75 km and 1.59 km and the velocities of the seismic waves which give the initial motion are 2.56, 4.67 and 6.08 km/sec, respectively. Different features are seen in the southern direction, that is, no effect of the second layer can be recognized, and the velocity in the lower layer is about 5.91 km/sec. At the observation point where the epicentral distance is 160 km, a phase is seen, which may correspond to the so-called P_n. Also, a phase with the velocity of 3.37 km/sec is seen in both directions. Though it corresponds to the phase which was supposed to be S wave in the previous experiment, no phase of the same velocity is found this time about 1 sec before or after.

After all, the present results have clarified that the phenomenon which we observed and tried to interpret by means of experiment is not so simple. Further development covering this complicacy and giving a clear interpretation about the earth crust structures of Tohoku District calls for a third explosion seismic observation in the same area.

7. Acknowledgements.

Finally, many thanks go to the agencies and persons under whose helpful cooperation this experiment has been successfully done. They are Tohoku District Construction Bureau of Ministry of Construction, Nisimatu-gumi Construction Company, Tohoku Electric Company, Sendai Broadcasting Station of Nippon Hoso Kyokai (NHK), Broadcasting Station of Standard Wave JJY, Prefectural Authorities of Iwate, Miyagi and Hukusima-ken and Mizusawa Forestry Bureau.

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24. 東北日本における第2回爆破地震動観測

爆破地震動研究グループ

東大地震研究所， 東大地球物理学教室， 中央気象臺地震課，
地質調査所物理探鉱部， 東北大地球物理学教室， 秋田大学，
科 学 博 物 館， 京大地球物理学教室， 水沢緯度観測所.

1950 年 10 月 25 日岩手縣膽澤郡若柳村石淵 (水澤西方約 20 km) で東北地方建設局が堰堤工事のために行つた 57 トンの大爆破による地震動を観測した結果はすでに報告した. 1951 年 12 月 27 日ふたゝび同所において 7.8 トンの工事用爆破が行われることになつたので，われわれは前回にくらべ相当向上した装備と組織とをもつてその地震動観測をおこない，東北地方の地殻構造についての

よりすゝんだ知見をうることができた．

今回は第 I 表および第 1 図にしめすように爆破点近傍，東方測線，南方測線にわけて合計 18 点の観測点をもうけ，その大部分はあらたに準備された電磁型地震計をもちい，またおゝむね増巾器を使用した． 爆破方法は前回と大差なく，第 2 図にしめすような薬室配置で一斉爆破をおこなつた．今回は特に發破時刻を記錄するため，薬室に導線をひきいれたが，別の故障のためこの發火記錄は解析には利用できなかつた．

低氣壓通過のため当日は風雨，風雪のところがおゝく，電波天候もわるく無線分秒報時 (JJY) の受信も困難であつたが，2〜3 の点をのぞいて観測に成功した．圖版 II〜VI は各点の記錄寫眞である．

初動および若干の位相についてのよみとりは第 II 表に示すとおりであり，これを圖示した走時圖は第 3 圖である．東方測線と南方測線とは別々にとりあつかう方が適当であることは疑をいれない．結果を簡單にまとめればつぎのとおりになる．すなわち，各測線別の走時を最小自乗法によりもとめると，$\varDelta$ を km でとつて，

爆破点附近： $t_1=12^h06^m+(-0.^s1617\pm0.^s0022)+(0.3910\pm0.0008)\varDelta^s$,

$V_1=2.56\pm0.005$ km/s.

東 方 測 線： $t_2=12^h06^m+(0.^s331\pm0.^s040)+(0.2144\pm0.0016)\varDelta^s$,

$t_3=12^h06^m+(0.^s602\pm0.^s076)+(0.1646\pm0.0017)\varDelta^s$,

$V_2=4.67\pm0.034$ km/s, $V_3=6.08\pm0.063$ km/s.

南 方 測 線： $t_3'(\mathrm{II})=12^h06^m+(0.^s232\pm0.^s051)+(0.1693\pm0.0006)\varDelta^s$,

$V_3'=5.91\pm0.021$ km/s.

($t_3'(\mathrm{I})=12^h06^m+(0.^s400\pm0.^s142)+(0.1645\pm0.0017)\varDelta^s$ は南方最遠点信夫の初動をとつた場合で，第 2 動をとつた $t_3'(\mathrm{II})$ にくらべ誤差が大きいのですてた．初動はより深い層に對應する屈折波と考えられるからである．)

これより，東北地方のこの部分の水平成層構造は，東方測線ではつぎのとおりになる．

第 1 層 (P 波速度 2.56 km/s)

境界面の深さ $Z_1=0.75\pm0.06$ km

第 2 層 (P 波速度 4.67 km/s)

境界面の深さ $Z_2=1.59\pm0.33$ km

第 3 層 (P 波速度 6.08 km/s)

南方測線では第 2 層に對應する走時がえられてないが，適当な震央距離に観測点がないので，第 2 層が南方でかけているということはできない．たゞ $t_3'(\mathrm{II})$ の震央時刻 τ (intercept time) は t_3 のそれとかなりちがつており，むしろ t_2 のものに近い．そこで一應第 2 層をなしと考えれば爆破点附近の走時と組合わせて，

第 1 層 (P 波速度 2.56 km/s)

境界面の深さ 0.55±0.08 km

第 3 層 (P 波速度 5.91 km/s)

なる構造がえられる．

信夫の第 1 動 I をより深い層 (第 4 層) からの屈折波と考えるとき，かりにそれを自然地震の P_n にあたるとし，速度を 7.5 km/s と假定すれば，この層までの深さは約 24 km になる．

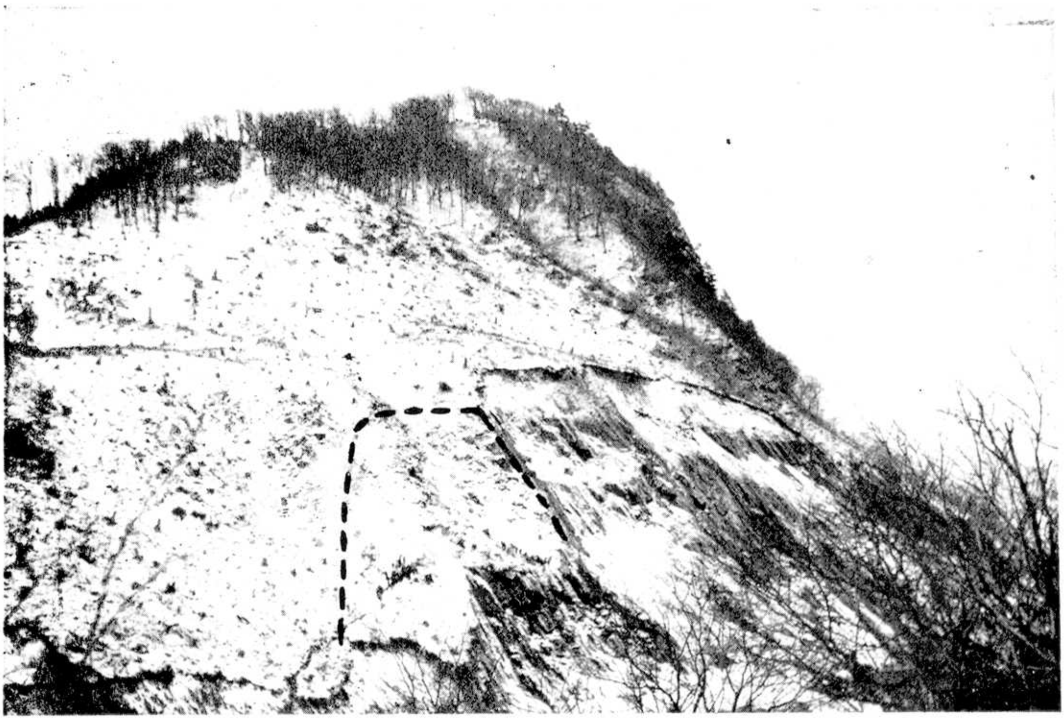
第 1 回の石淵爆破の結果では観測点が震央に近い方は東方，遠い方ほど南方になつていて，えられた平均的構造に疑問がのこつたが，その点は今回でやゝ明確になつたと考えてよい．第 1 回の結果では，平均として地表から 1.3±1.27 km まで第 1 層で 5.26±0.007 km/s の速度の層があり，その下第 2 層の速度は 6.13±0.017 km/s であつた．

なお，東方，南方兩測線とも $V_4=3.37$ km/s の波がえられ，これは前回一應 S_1 波となづけたものに對應している．これが S 波かどうかは疑問もあるが，速度は前回の S_1 と全く同じ値である．なお前回は S_1 に約 1 秒おくれ S_1 と同じ速度でつたわる S_2 が大きく記錄されたが，今回はこのような位相はみられなかつた．爆破條件のちがいによるのかも知れない．

最後に今回の觀測について，多大の後援をあたえられた東北地方建設局，西松組，東北電力株式會社，日本放送協會仙臺放送局，電波廳標準電波發射所，水沢營林署，岩手・宮城・福島各縣警察当局，各觀測点所在官民各機關及び各観測班所屬機關關係者各位にあつく御禮申し上げる次第である．

なお本研究の經費の一部は文部省科學研究費によるものである．附記して謝意を表する．

A



B

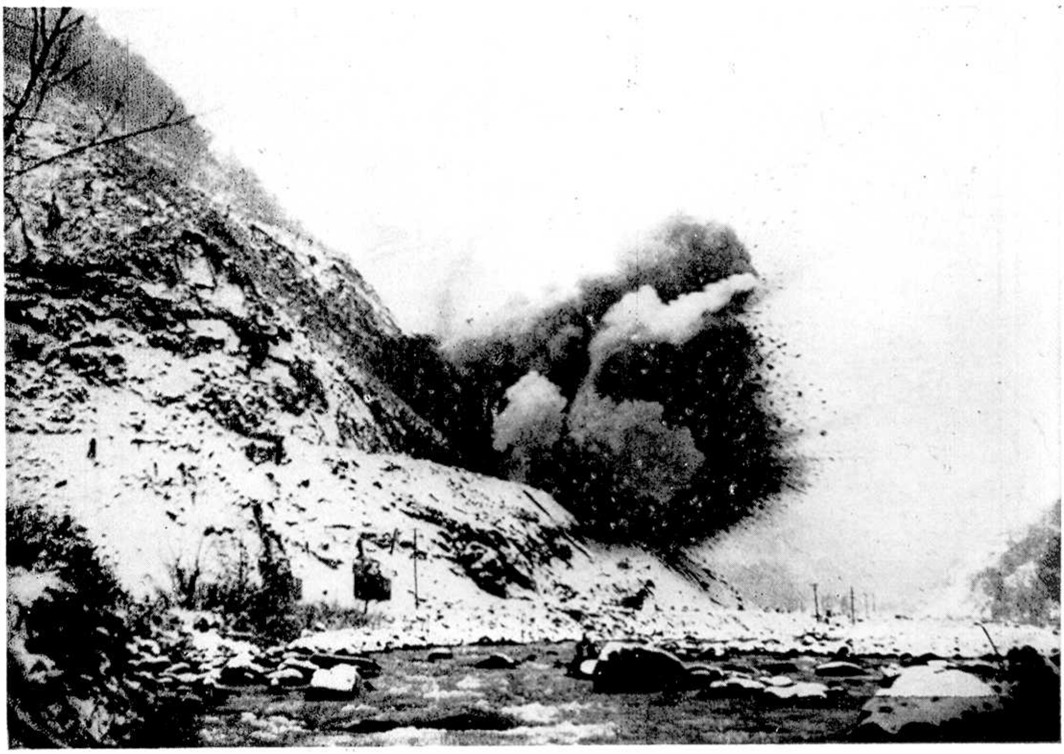
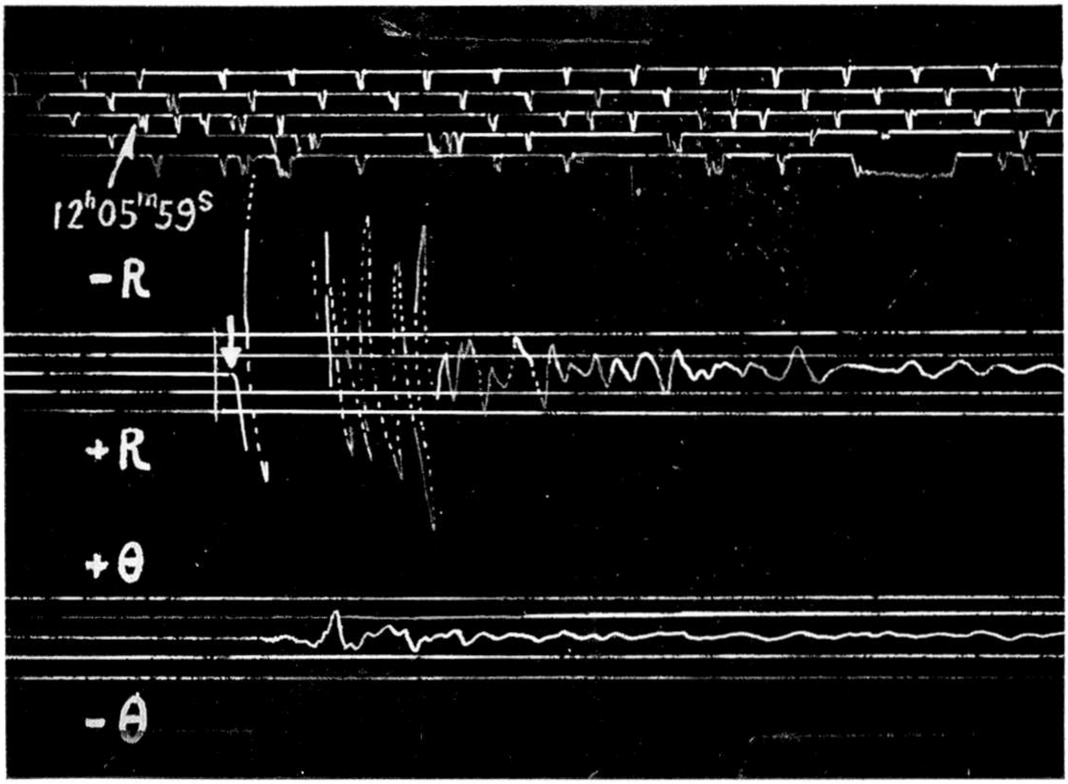


Fig. 4. The second large explosion at Isibuti, Iwate-ken, on December 27th, 1951.
A. Broken line indicates the area to be loosened.
B. Instant of explosion.

A



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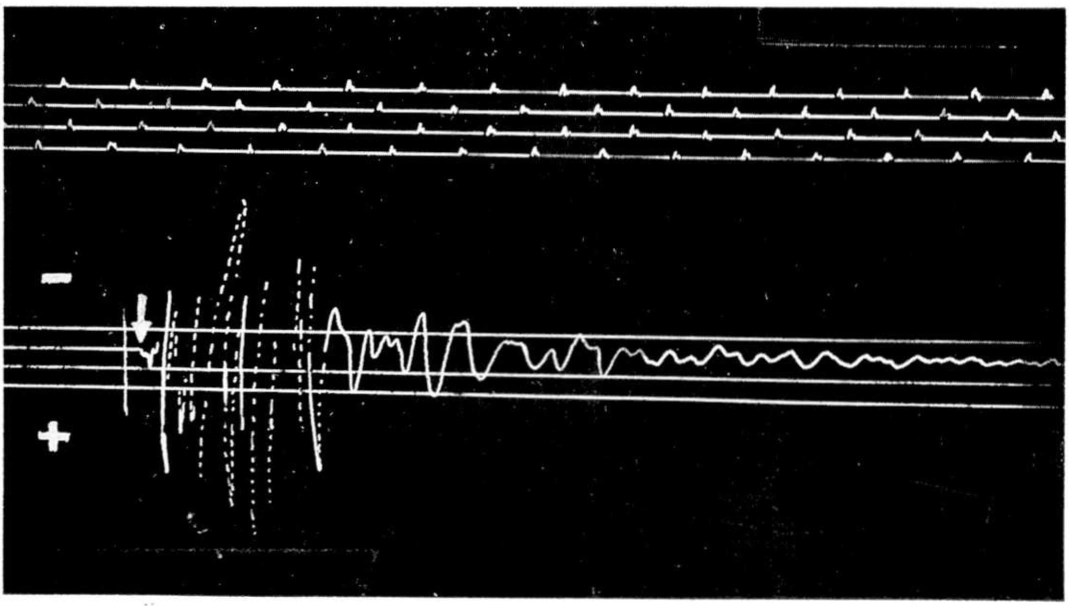

Fig. 5. Seismograms obtained at the second Isibuti explosion of 1951 at Isibuti (A) and Orose (B).

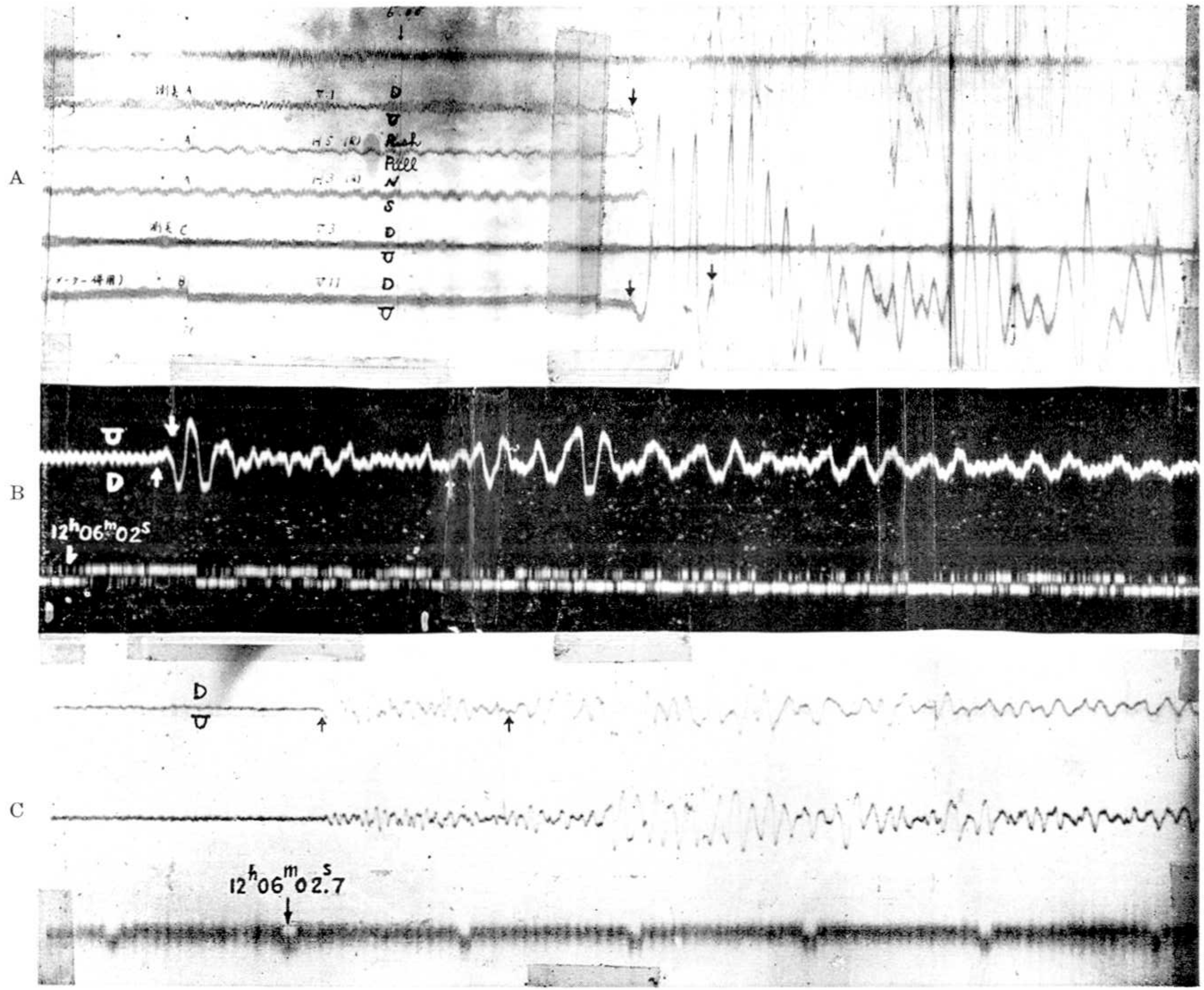

Fig. 6. Seismograms obtained at the second Isibuti explosion of 1951 on the eastern profile at Umadome (A), Atago (B) and Dobasi (C).

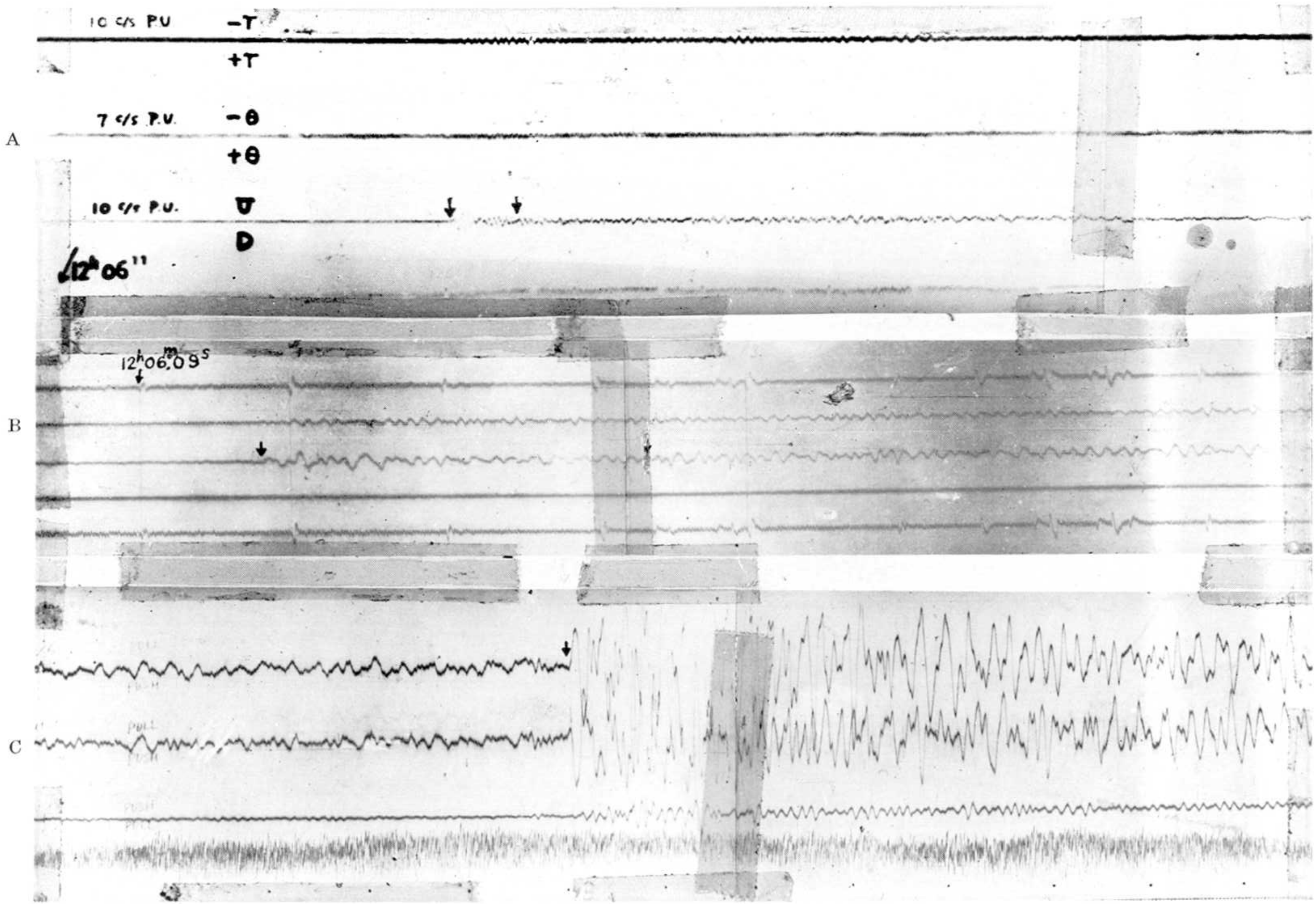

Fig. 7. Seismogrms obtained at the second Isibuti explosion of 1951 on the eastern profile at Wakayanagi (A) Setamai (B) and Kamaisi (C).

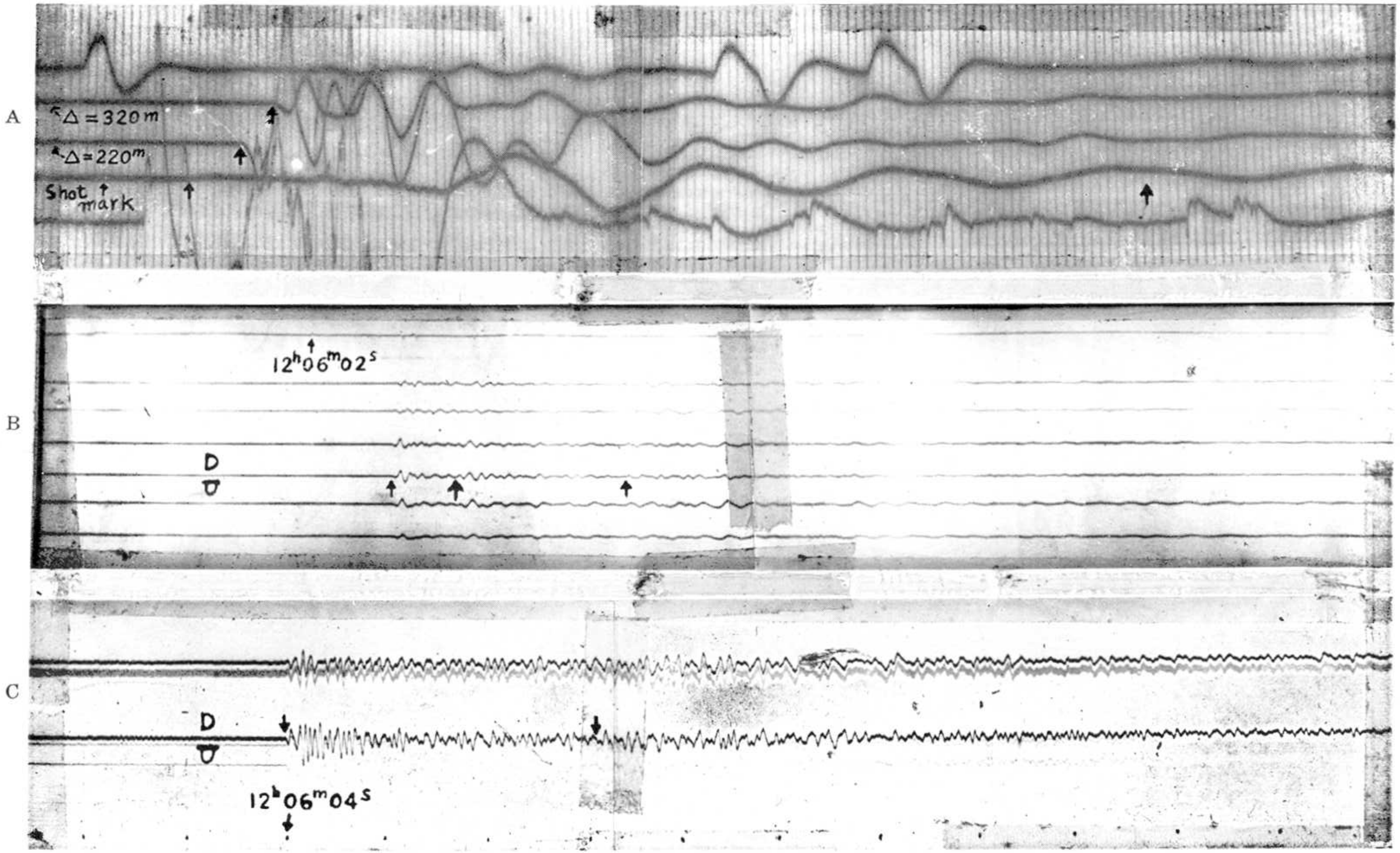

Fig. 8. Seismograms obtained at the second Isibuti explosion of 1951 on the southern profile near the explosion point (A) and at Hondera (B) and Kurikoma (C)

A

B

C

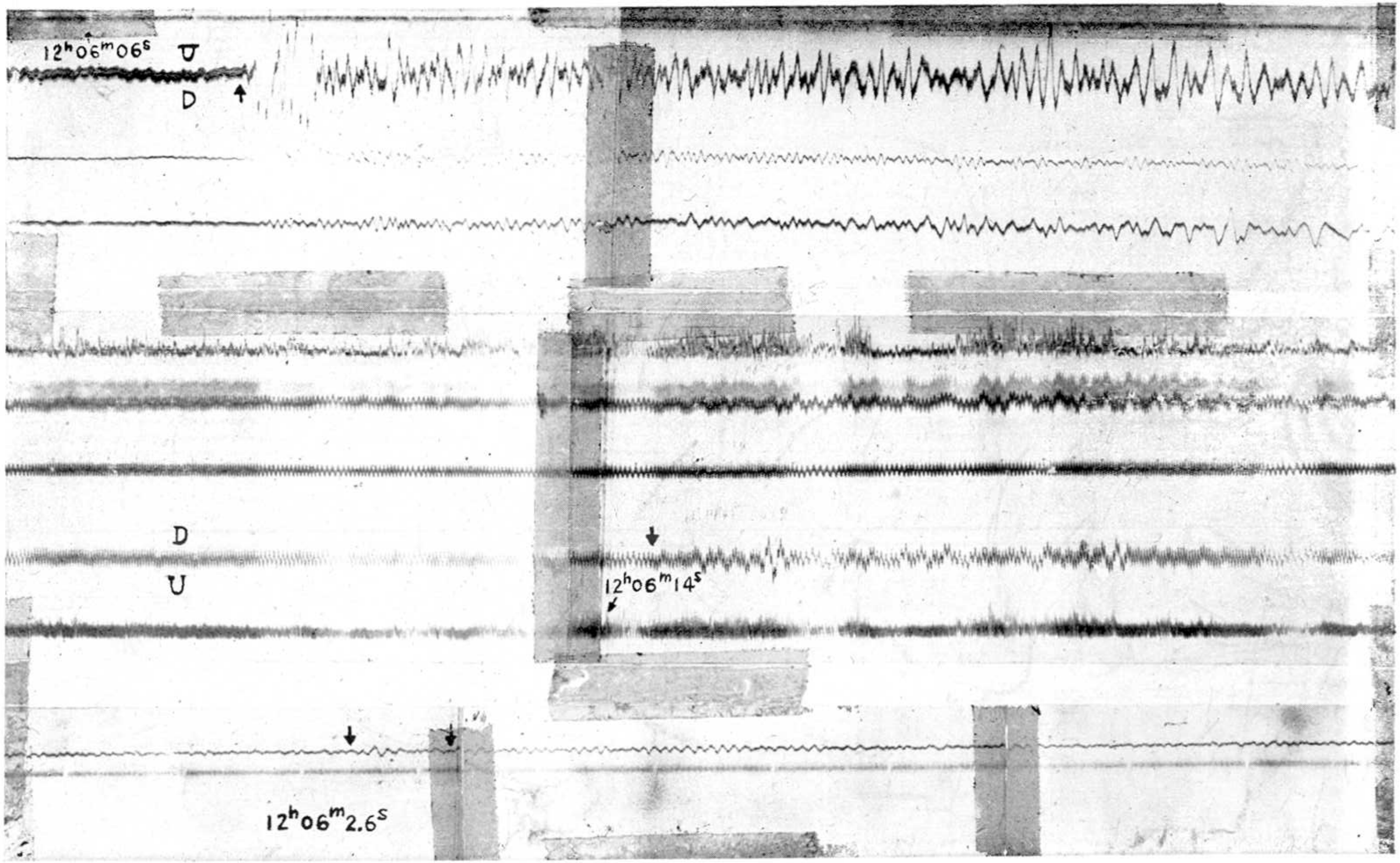

Fig. 9. Seismograms obtained at the second Isibuti explosion of 1951 on the southern profile at Kawatabi (A), Matusima (B) and Sinobu (C).