27. *The Third Explosion Seismic Observations in North-Eastern Japan.*

By The Research Group for Explosion Seismology.*

(Read Oct. 21, 1953.—Received Oct. 31, 1953.)

1. Introduction.

The third explosion seismic observations in North Eastern Japan were made on July 25th, 1952 when five tons of explosives were fired at the construction site of Isibuti dam. The place of explosion was adjacent to the site of the last two explosions utilized for the same experiments. Their results had already been published.[1]

Nineteen temporary field stations were established along two profiles, as shown in Fig. 1. To the south from the shot point along the island arc of Japan, the seismological profile was extended for more than 300 kms as far as Tukuba, where a branch observatory of E. R. I. is located. Another profile, transverse to the island, was extended westward from the shot point, in the opposite direction to that in the last experiment.

Some necessary improvements had been made on the instruments, especially on those in distant stations. Special care was also taken to increase the ratio of signal to noise in picking up the weak initial motions. Consequently, in order to minimize the ground noise, the

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1) La Groupe pour Recherches de Séismologie par Explosion, Tokio, "Observation Sismique par Explosion d'Isibuti"., *Zisin* Ser. [ii], **3** (1951), 77-82. **6** (1953), 7-12. **6** (1953), 84-90.

The Research Group for Explosion Seismology, Tokyo, "Explosion Seismic Observations in North-eastern Japan", *Bull. Earthq. Res. Inst.*, **29** (1951), 97-106, **30** (1952), 279-292.

seismometers of distant stations were set up in caves or galleries, selected after the mail investigation and field inspections. However, no essential change was seen in the observational method.

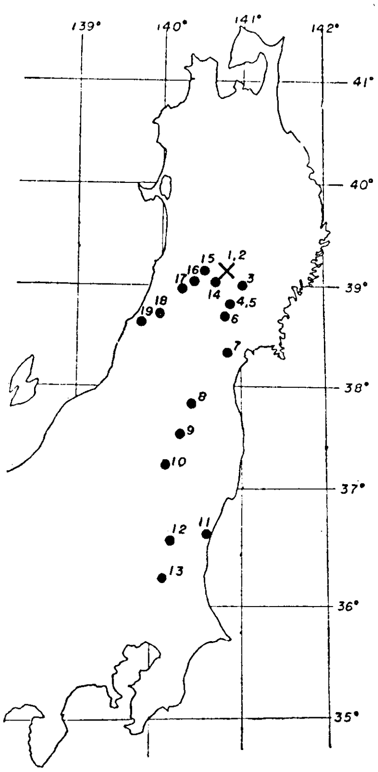

Fig. 1. Seismic observation stations for the third Isibuti explosion.

In Table I, the locations of stations and the names of observers are shown, together with some descriptions of the equipments in each station.

The communication from the shot point to each station was made available by the short wave radio network of the Tohoku District Construction Bureau and also by the civil telegram and telephone network. In addition, Nippon Hoso Kyokai (Radio Broadcasting Corporation) cooperated with the experiment in broadcasting some information about an expected time of explosion in several times before and on the very day.

The explosives were carlit as before, and the amount was 5.546 tons. They were charged in 12 chambers; three of them were inserted electric circuits fed with weak current, so that the exact time of explosion could be marked on the oscillogram by the interruption of the current. The exact time, thus registered, was 12h 04m 59.42s (Japan Standard Time). At all stations, the time marks were placed directly by the JJY short wave time signals of every second which were kept by the Tokyo Astronomical Observatory. At some stations chronometers with second contact were also employed, and some of them covered successfully the bad condition of short wave receiving.

2. Results of Observations.

In Table II, the arrival times of phases and epicentral distances are shown. The arrival times are, also, plotted in Fig. 2 and grouped in several straight lines. Travel times in the southern profile are given by

Table I. The third Isibuti explosion-seismic observations.
(1952-VII-25, 12h 04m 59.42s, $\varphi=39° 06' 22'' N$, $\lambda=140° 53' 39'' E$, h=300 m)

		Observation point	Location		Distance from shot	Seismographs	Amplifier	Observers
Southern profile	1	Shot point	Near the shot point		0~2km	Haeno type-5 (12c/s)	None	Kozima, Furuya
	2	South point from shot			2~4	Haeno type-4	D-2	Mori, Uziie
	3	Hondera	140°58'.5 E	38°58'.4 N	15.3	3V-1, 3H-1 10V-1	D-3	Hori, Tuziura
	4	Hosokura (I)	140 54.6	38 38.2	32.2	H-1	Kyoto Univ.-H	Kozuki
	5	Hosokura (II)			32.2	3V-1	None	Yosiyama, Nisioka, Kawano
	6	Kawatabi	140 45.5	38 44.6	41.9	3V-2, 3H-1	D-3	Matumoto, Kobayasi, Asano,
	7	Neno-siraisi	140 48.9	38 19.0	87.8	3V-1, 3H-1	D-2	Noritomi, Takagi
	8	Daiyama	140 24.7	37 49.2	148.8	3V-1, 3H-1	H-3	Kobayasi, Hagiwara
	9	Takatama	140 17.6	37 30.6	185.0	3V-2, 3H-1 1H-1 (K)	H-3	Yamazaki, Saito, Hiraoka
	10	Hatori	140 05.5	37 15.7	216.4	3V-1, 3H-1 1H-1 (A)	H-3	Suzuki, Mine
	11	Hitati	140 36.8	36 35.5	280.2	3V-1, 1H-1 (K)	D-1	Tanaka, Nagata
	12	Motegi	140 11.3	36 32.9	290.7	3V-2, 1H-1 (A)	H-1, H-2	Den, Chujo, Sato
	13	Tukuba	140 06.7	36 12.6	327.1	3V-1, 3H-1 1H-1 (A)	H-1, H-3	Kasahara, Watanabe, Mogi
Western profile	14	Katurazawa	140 40.6	38 59.8	22.2	3V-1 3H-1	D-1, H-1	Akima, Matumoto
	15	Yuzawa	140 30.5	39 09.6	33.8	H-1	Kyoto Univ.-H	Tamaki
	16	Innai	140 21.9	39 02.8	46.0	3V-2	D-2	Sima, Sibano, Yanagisawa
	17	Mamurogawa	140 17.2	38 52.0	58.7	3V-1 1/3H-1	D-2	Utu
	18	Sinasawa	140 00.5	38 41.0	90.0	3V-1 3H-1	H-3	Honda, Asanuma
	19	Tagawa	139 41.0	38 30.0	116.1	3V-1 3H-1	D-2	Tazime

three straight lines, and their equations given by the least squares method are as follows:

$$t_3'=12^h05^m+(-0.06\pm0.06)^{sec}+(0.1673\pm0.0003)^{sec}\Delta,$$

$$t_4'=12^h05^m+(3.7\pm0.3)^{sec}+(0.139\pm0.002)^{sec}\Delta,$$

and $$t_5'=12^h05^m+(1.9\pm0.3)^{sec}+(0.279\pm0.001)^{sec}\Delta.$$

The velocities corresponding to the above travel times are

$$V_3'=5.98\pm0.01 \text{ km/sec},$$

$$V_4'=7.17\pm0.07 \text{ km/sec},$$

and $$V_5'=3.58\pm0.002 \text{ km/sec},$$ respectively.

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

Observation point			Distance from shot	Elevation	Time of phase commencement (12^h05^m+)		
					t_4	t_3	t_5
			km	m			
Southern profile	1	Shot point	0.22; 0.31	340		0.63; 0.67	
	2	South point from shot	1.50; 1.73	340		1.18; 1.27	
	3	Hondera	15.3	200		2.44	
	5	Hosokura	32.2	140		5.25	10.40
	6	Kawatabi	41.9	220		7.01	—
	7	Neno-siraisi	87.8	230		14.66	26.88
	8	Daiyama	148.8	450	24.49	—	43.70
	9	Takatama	185.0	560	—	—	—
	10	Hatori	216.4	700	34.0	36.2	—
	11	Hitati	280.2	400	—	—	80.00
	12	Motegi	290.7	150	34.92	48.5	83.39
	13	Tukuba	327.1	280	49.6	—	93.0
Western profile	14	Katurazawa	22.2	540		3.83	
	15	Yuzawa	33.8	120		5.73	10.61
	16	Innai	46.0	280		7.98	14.41
	17	Mamurogawa	58.7	100		10.16	17.77
	18	Sinasawa	90.0	200		15.46	
	19	Tagawa	116.1	560			

Suffixes indicate the order of horizontal layering from the surface, which is supposed in the region from the previous experiments, and V_i represents the characteristic longitudinal wave velocity in the layer. "′" indicates the quantities in the southern profile as in the previous publi-

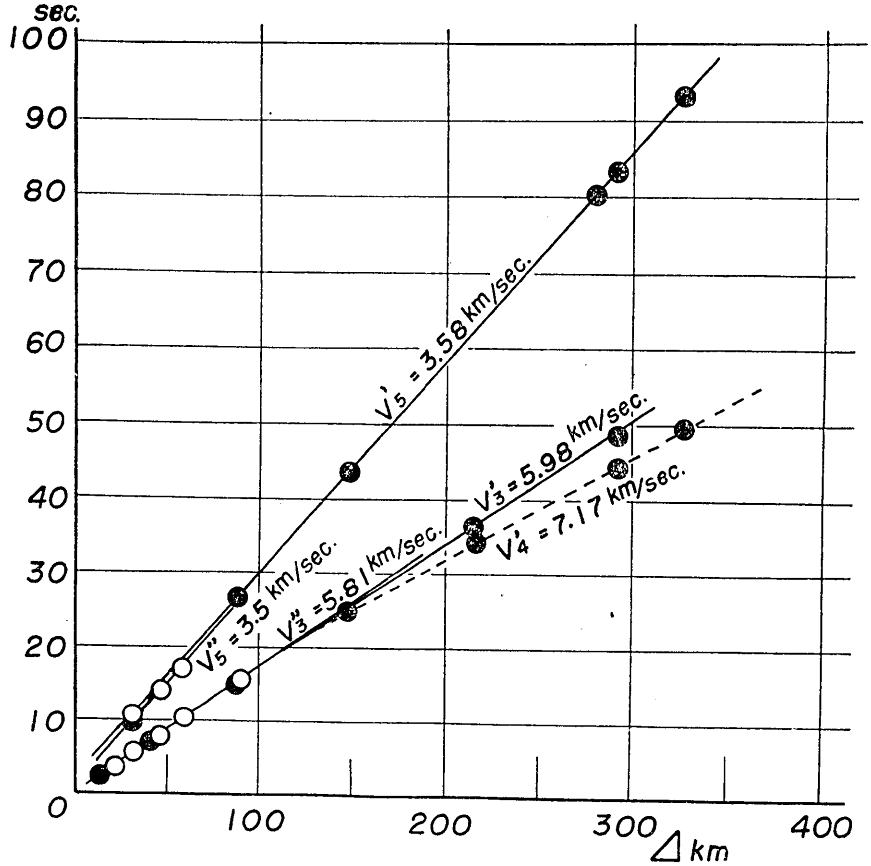

Fig. 2. Travel time curves from the third Isibuti explosion. V' represent velocities from the southern profile and V'' represent velocities from the western profile.

cation, and " $''$ ", those in the western profile, while letters with no mark represent the quantities in the eastern profile in the last experiment.

The travel time equations in the western profile are calculated as follows:

$$t_3''=12^h05^m+(0.00\pm0.05)^{sec}+(0.172\pm0.001)^{sec}\Delta,$$

$$t_5''=12^h05^m+(1.03\pm0.4)^{sec}+(0.287\pm0.009)^{sec}\Delta.$$

The corresponding velocities are

$$V_3''=5.81\pm0.03 \text{ km/sec},$$

and $$V_5''=3.5\pm0.2 \text{ km/sec}, \quad \text{respectively.}$$

3. Discussions.

3–1 Crustal Structure along the Southern Profile.

In the eastern profile (including all nearby stations) of the second Isibuti experiment, double surface layering had been interpreted, and the characteristic P-wave velocities of the layers were 2.56 km/sec and 4.67 km/sec. They overlay the granitic layer of 6.08 km/sec, P-wave velocity. The depths of the interfaces between those layers were calculated to be 750 m and 1590 m respectively. On the contrary, no effect of the second surface layer was found in the southern profile in the last experiment, and the velocity in the granitic layer along this line was 5.91 km/sec. No data for the first layer along the southern profile were obtained. However, the thickness of the first layer was calculated to be 550 m, on the assumption that the second layer is lacking along the southern profile, and the first surface layer of 2.56 km/sec directly overlays the granitic layer.

A travel time curve of the nearby region could not be drawn, which would have represented a characteristic P-wave velocity of the first surface layer. For, the present way of distribution of stations was aimed at decisive data for the depth of the crust. As for the thickness of the second layer, the characteristic P-wave velocity is assumed to be 4.67 km/sec. An intercept time of the travel time curve in the third (granitic) layer, τ_3' is

$$\tau_3'=2\frac{d_1'\sqrt{V_3'^2-V_1'^2}}{V_1'\ V_3'}+2\frac{d_2'\sqrt{V_3'^2-V_2'^2}}{V_2'\ V_3'}$$

In this equation V_3' and τ_3' are given by the hodograph obtained in the present experiment; d_1', V_1' and V_2' are assumed to be 750 m, 2.56 km/sec and 4.67 km/sec respectively. Thus, the thickness of the second layer, d_2' is

$$d_2'=\frac{V_2'\ V_3'}{2\sqrt{V_3'^2-V_2'^2}}\left\{\tau_3-\frac{2d_1'\sqrt{V_3'^2-V_1'^2}}{V'_1\ V_3'}\right\}=0.04\ \text{km}$$

and this value seems to be almost negligible as a thickness of the layer. In neglecting d_2' and assuming d_1' be unknown, the relation

$$\tau_3'=\frac{2d_1'\sqrt{V_3'^2-V_1'^2}}{V_1'\ V_3'}$$

is given. From this equation, the thickness of the first layer, d_1', which directly overlays the granitic layer, is 0.74 ± 0.01 km. This value is very close to that of $d_1=750$ m in the eastern profile in the last experiment.

A puzzling nature of the second layer of the last experiment, namely whether it exists or not in both profiles, could not be solved completely; however, the above calculation indicates the reality of the assumption, and probably a very narrow horizontal zonal distribution of the second layer may be assumed, extending in east-west under Isibuti.

The characteristic velocity of the third layer along the southern profile in the present experiment was obtained to be 5.98 km/sec, and in considering the probable errors, it differs from the values of 6.13 km/sec and 5.91 km/sec in the last two experiments.

As the initial on-sets at the distant stations were very weak, it is premature to deduce the thickness of the granitic layer. However, if a velocity of the fourth layer be 7.17 km/sec and its thickness is calculated only from the present travel time data,

$$d_3' = (20 \pm 4)\,\text{km}$$

is given. Although it might be changed by the future experiments, this can be accepted as an adequate value of the thickness of the granitic layer for the present.

3-2 Crustal Structure along the Western Profile.

As stated above, in the second Isibuti experiment two different characteristic P-wave velocities in the third (probably granitic) layer along the eastern and southern profiles were derived, namely 6.08 km/sec in the former and 5.91 km/sec in the latter. To conclude this problem in the present experiment, the stations were distributed in the western direction from Isibuti, and the travel times obtained along this profile gave 5.81 km/sec as a characteristic velocity of the third layer. It will be a consistent interpretation for the above result, that the thickness of the surface layer or layers overlaying the granitic layer is thinner in the eastern profile than in the western profile. If the structure shown in Fig. 3 is assumed, which lacks the second layer of 4.67 km/sec velocity,

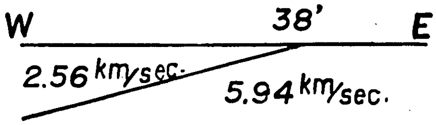

Fig. 3. An assumed seismic structure of the E-W profile in the N-E Japan.

the slope of the interface between the surface and granitic layers becomes 38′, and the true velocity in the granitic layer becomes 5.94 km/sec, which is very close to the value of 5.98 km/sec for the southern profile obtained in the present experiment. If a value, 740m as a thickness of the surface layer at Isibuti is employed, this sloping interface comes up to the surface of the ground about 70 km to the east of Isibuti.

Geologic map of the district in large scale shows that from about 20–30 km to the east of Isibuti, extends the palaeozoic mass of Kitakami mountains which are intruded by granite mass at places, and no low-velocity surface layer is seen in that region. Western part of the island arc in N–E Japan are deposited by thick tertiary formations, and in the central part volcanic rocks of newer stages are found. Base of these canozoic rocks is the so-called green-tuff which is found widely over the N–E Japan.

The geologic fact stated above is very illustrative to explain the results obtained. Nevertheless, discussion on the problem will rather be postponed to the future.

4. Acknowledgements.

Many thanks go to the agencies and persons under whose helpful cooperation and patronage this experiment was successfully made. They were Tohoku District Construction Bureau of Ministry of Construction, Nisimatu-Construction Co., Tohoku Electric Co., Tokyo Electric Co., Sendai Broadcasting Station of NHK, Broadcasting Station of Standard Wave JJY, Mizusawa Forestry Bureau, Prefectural Authorities and Police Authorities of Iwate, Miyagi, Hukusima, Akita, Yamagata, Ibaraki and Totigi. Much help was also given by the Geophysical Committee of the National Council, Central Meteorological Observatory, Earthquake Research Institute and all other organizations to which the members of the group belong.

The present study received encouragement and guidance from Prof. T. Matuzawa.

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27. 東北日本における第3回爆破地震動観測

爆破地震動研究グループ

岩手県胆沢郡若柳村石淵における石塊堰堤工事採石の大爆破はすでに1950年10月,1951年12月の2回にわたり爆破地震学の目的のために利用された．1952年7月25日この工事としては最後の大爆破が行われ，われわれもふたたびその地震動観測を実施した．

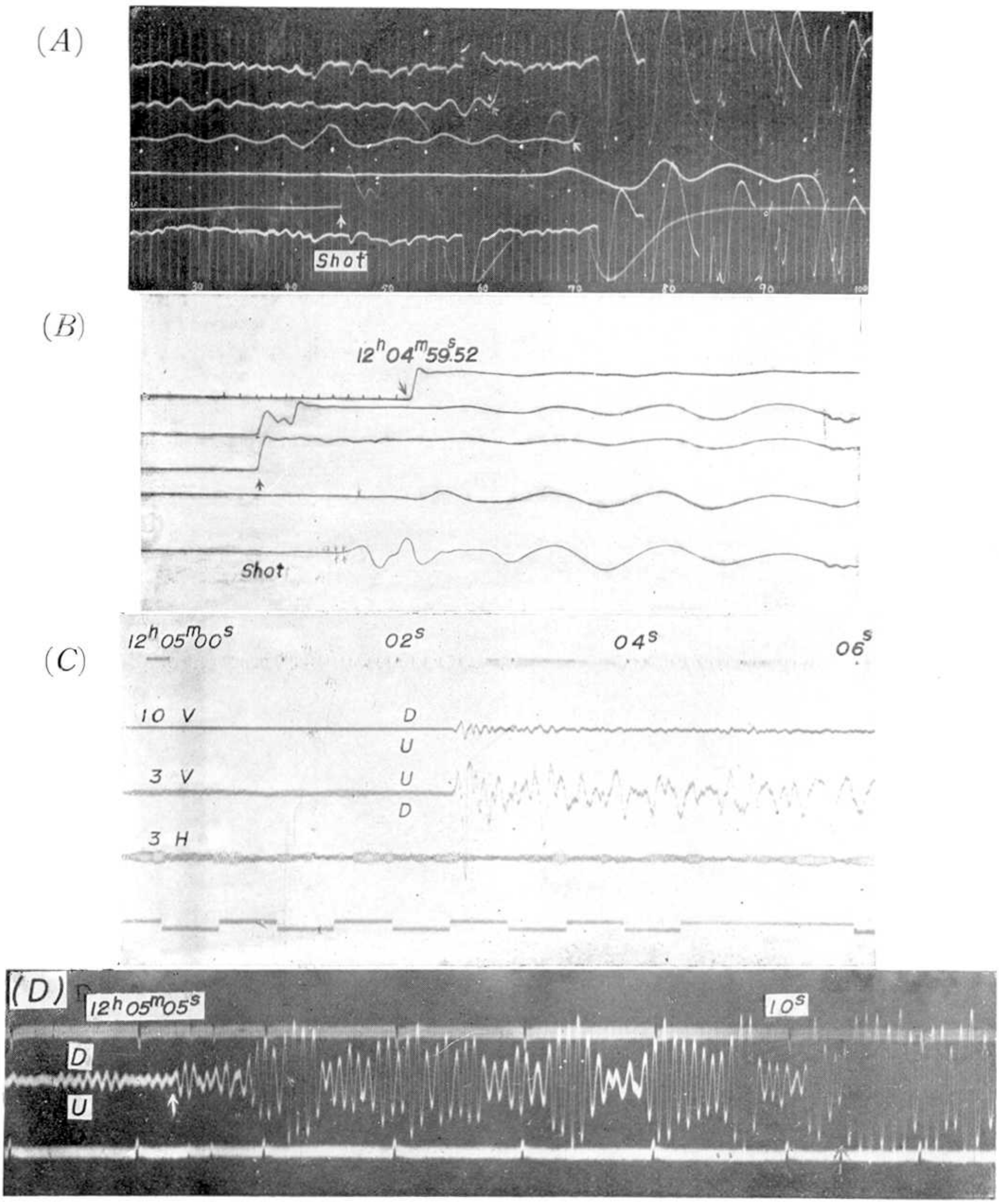

Fig. 4. Seismograms obtained at the third Isibuti explosion of 1952 on the southern profile at Isibuti (*A* and *B*), Hondera (*C*) and Hosokura (*D*).

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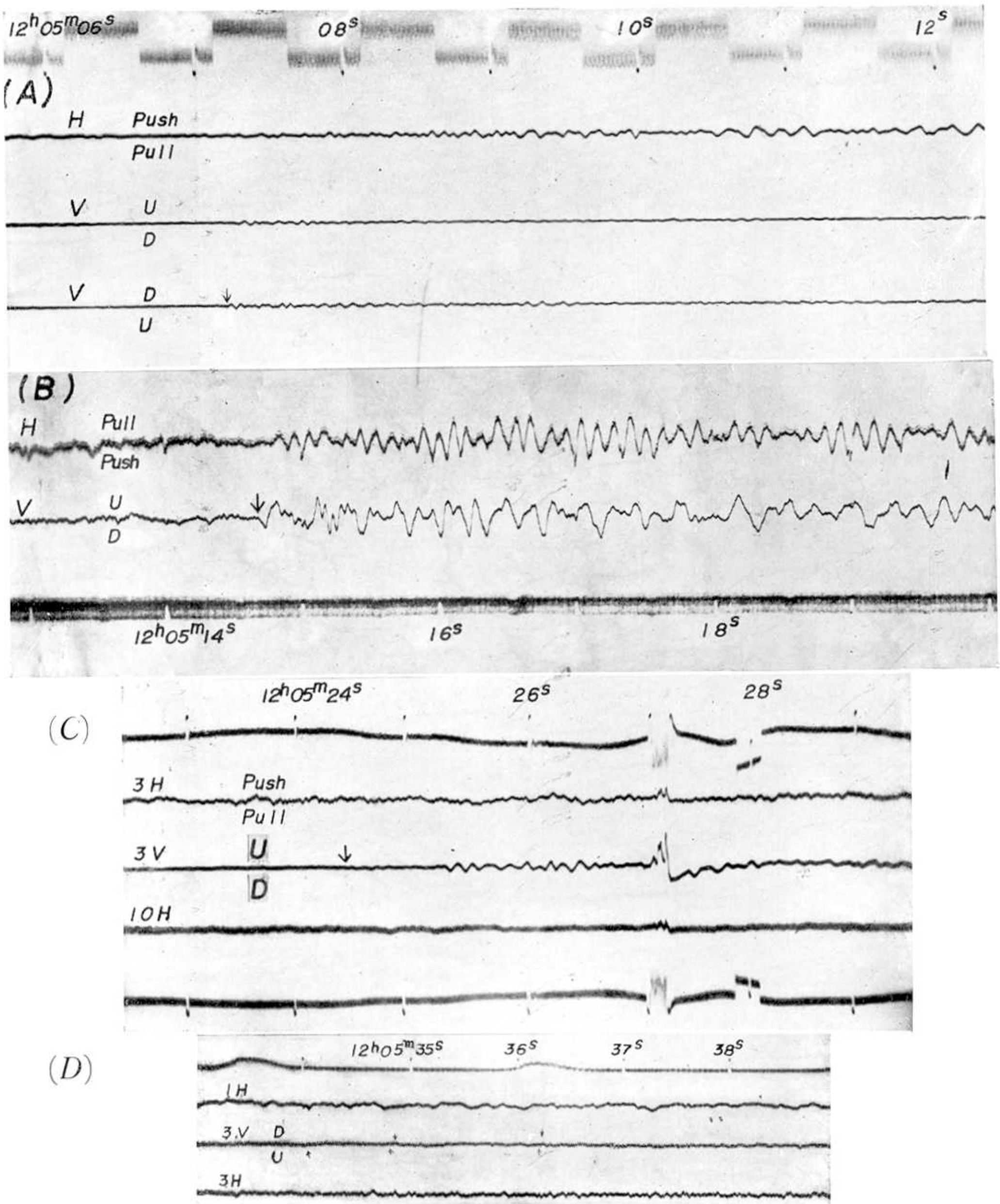

Fig. 5. Seismograms obtained at the third Isibuti explosion of 1952 on the southern profile at Kawatabi (*A*), Nenosiraisi (*B*), Daiyama (*C*) and Hatori (*D*).

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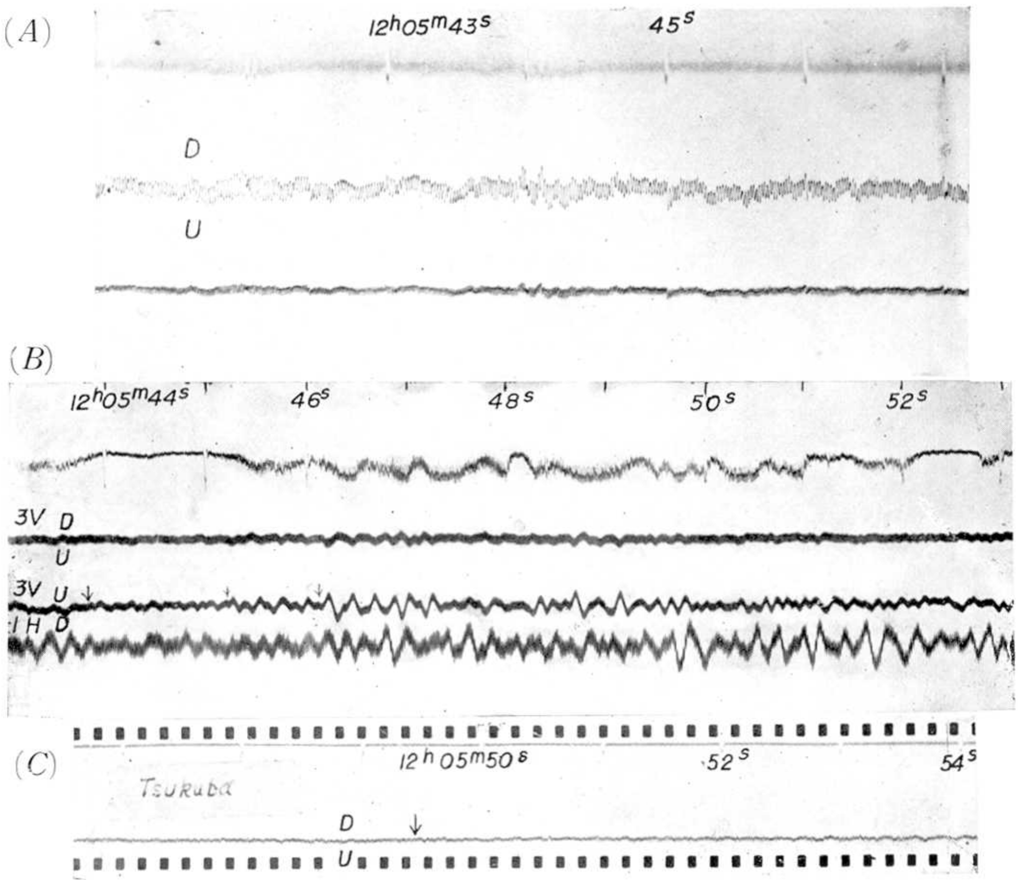

Fig. 6. Seismograms obtained at the third Isibuti explosion of 1952 on the southern profile at Hitati (A), Motegi (B) and Tukuba (C).

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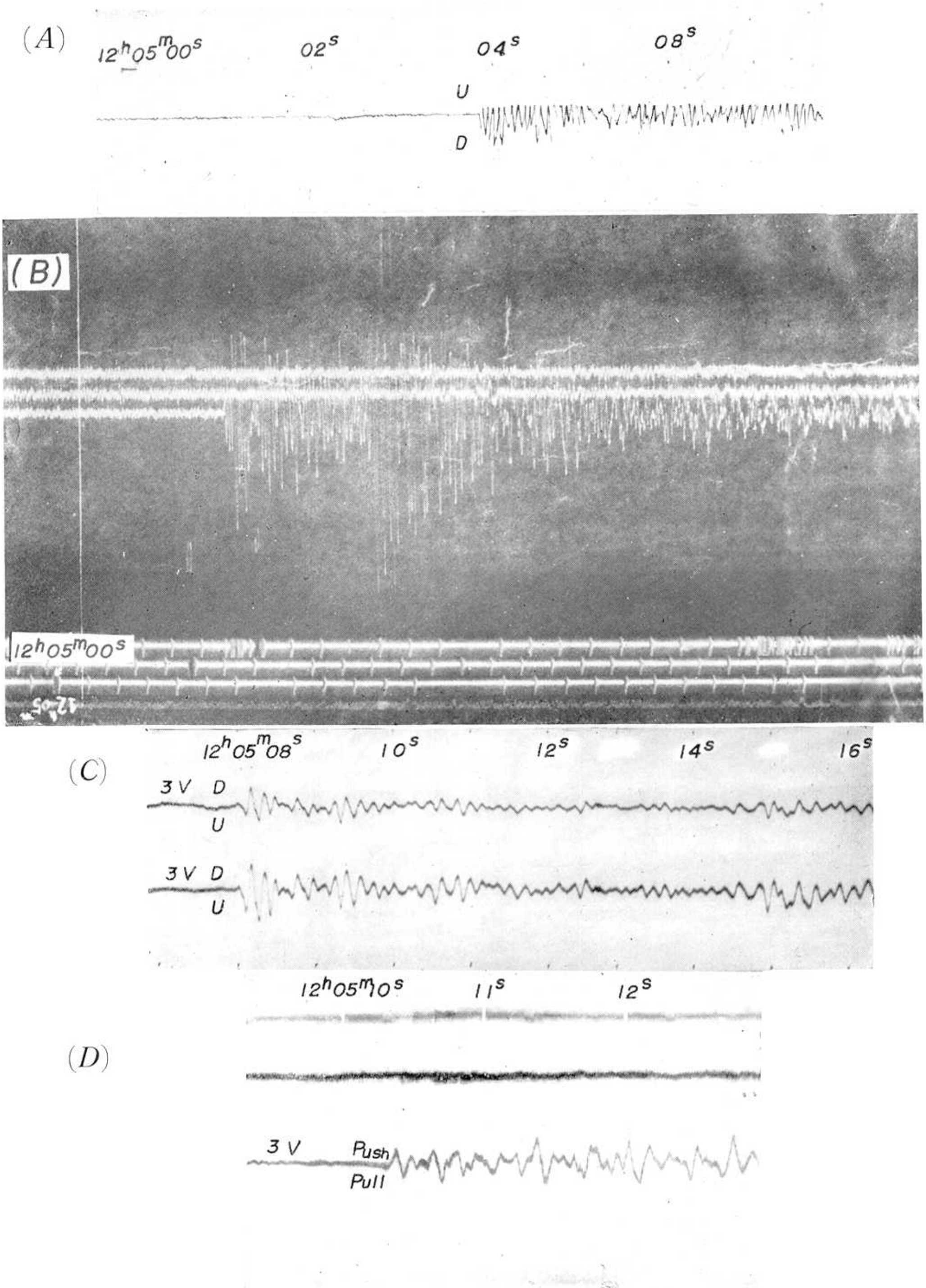

Fig. 7. Seismograms obtained at the third Isibuti explosion of 1952 on the western profile at Katurazawa (*A*), Yuzawa (*B*), Innai (*C*) and Mamurogawa (*D*).

(A)

(B)

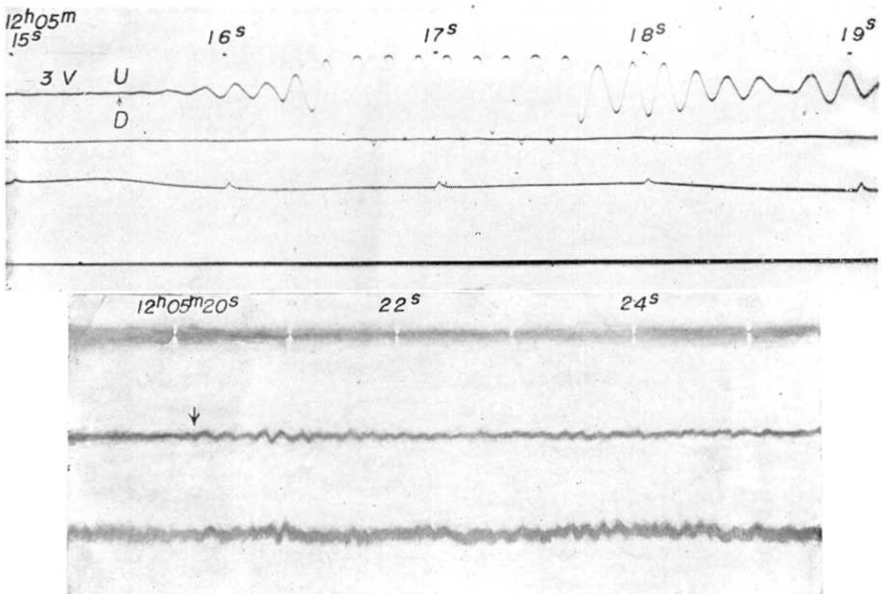

Fig 8. Seismograms obtained at the third Isibuti explosion of 1952 on the western profile at Sinazawa (*A*) and Tagawa (*B*).

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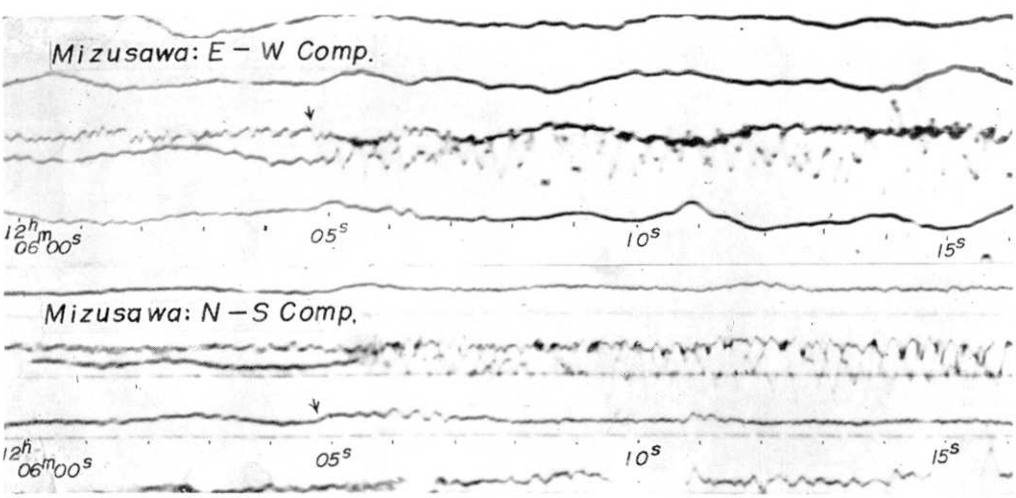

Fig. 9. Seismograms obtained in the case of the *second* Isibuti explosion of *1951* at Mizusawa stations, which were to be placed in our preceding paper. (Bull. E. R. I. **30**, 1952, 279-292).

装薬はカーリット 5.546 トンで 12 個の薬室にわけられ，前回までと同様の方法で爆破された．爆破点は前回より約 20 m 南，爆破時刻は薬室に挿入した導線切断のオツシログラムを標準電波 JJY の分秒報時と比較して $12h\,04m\,59.42s$ ともとめられた．

地震動観測班は南方，西方計 19 点で，使用計器は前回と大体おなじである．(第 I 表，第 1 図)

えられたおもな位相のよみは第 II 表に示すとおりで，これを震源距離に対してとつたのが第 2 図にしめす走時図である．これらの走時を直線として南方，西方各測線別に最小自乗法によりきめた走時式およびその対応する速度はつぎのとおりである．

南方測線： $t_3'=12h\,05m+(-0.06\pm0.06)s+(0.1673\pm0.0003)\Delta.s,$

$t_4'=12h\,05m+(3.7\pm0.3)s+(0.139\pm0.002)\Delta.s,$

$t_5'=12h\,05m+(1.9\pm0.3)s+(0.279\pm0.001)\Delta.s,$

$V_3'=5.98\pm0.01\,km/s,\quad V_4'=7.17\pm0.07\,km/s,\quad V_5'=3.58\pm0.002\,km/s.$

西方測線： $t_3''=12h\,05m+(0.00\pm0.05)s+(0.172\pm0.001)\Delta.s,$

$t_5''=12h\,05m+(1.03\pm0.4)s+(0.287\pm0.009)\Delta.s,$

$V_3''=5.81\pm0.03\,km/s,\quad V_5''=3.5\pm0.2\,km/s.$

地殻構造の推定については，南方測線では今回は震源近くに観測点がすくないため，地表層 (前回の第 1，第 2 層) の走時はえられてないので，前回の結果を用い第 1 層第 2 層の速度を 2.56 km/s, 4.67 km/s とし第 1 層のあつさ $d_1=750\,m$ ととり，今回の第 3 層の走時をつかつて，第 2 層のあつさを出すと $d_2'=0.04\,km$ となり，無視できる．そこで第 1 層の下に直接第 3 層がくるとして計算すると $d_1=0.74\pm0.01\,km$ となる．第 3 層の速度は第 1 回 6.13 km/s，第 2 回 5.91 km/s，今回が 5.98 km/s で誤差範囲をこえて相違しているが，測線がちがうので確かなことはいえない．第 4 層の走時はなお決定的とはいえないが，これをもちい第 3 層のあつさを出すと $d_3'=20\pm4\,km$ となる．

西方測線では第 3 層の速度が 5.81 km/s となつて，前回東方測線の第 3 層の 6.08 km/s と大変ちがう．しかしこれは第 3 図のような構造を考えると一応了解できることがわかつた．しかし，この傾きの値などの数値については確定的なものとは考えられない．ただ傾向としては，地質学的事実とも矛盾しないように思われるので，一応このよに考えられるというだけである．

今回の実験についても前回同様建設省，西松建設，東北電力，東京電力，電波庁，水沢營林署，NHK，県庁，警察其他各方面関係者の甚大なる後援をえた．あつく御礼申し上げたい．

なお本研究経費の一部は文部省科学研究費によるものである．記して謝意を表する．