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42. *Sea-Bottom Seismic Observation at Sagami Bay, (1) Seismic Activity.*

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1. Introduction

Using the newly built magnetic tape recorder,[1] experimental sea-bottom seismic observations have been performed at Sagami Bay in 1966 and 1967. These experiments were intended to find and solve the special problems associated with sea-bottom seismic observation and to establish the suitable method of observation system for future continuous observation of micro-earthquakes. It was also intended to obtain some information for detecting the seismic activity of micro-earthquakes in this area, which is the epicentral region of the Great Kanto Earthquake in 1923.

These experiments were performed with the cooperation of M/S TANSEI-MARU of the Ocean Research Institute of Tokyo University and M/S MEIYO of the Hydrographic Office of the Maritime Safety Agency.

2. Experimental procedure

The locations of the stations for sea-bottom seismographic observation are shown in Fig. 1. The stations B, B′, C, and D were selected along the contour of about 1 km depth. Station B is on the western side of the Sagami-bank, and station D is on the eastern side. The periods of observation are shown in Table 1. The early observations at stations A, B, C were mainly for adjusting and testing the new instrument. At stations D and B′, observation of seismic activity of micro-earthquakes was intended. At station D, the mooring of the ocean-bottom seismograph was performed for twenty days. During this mooring period, the replacement of magnetic tape was done once.

1) S. NAGUMO et al., *Bull. Earthq. Res. Inst.*, **46** (1968), 861-875.

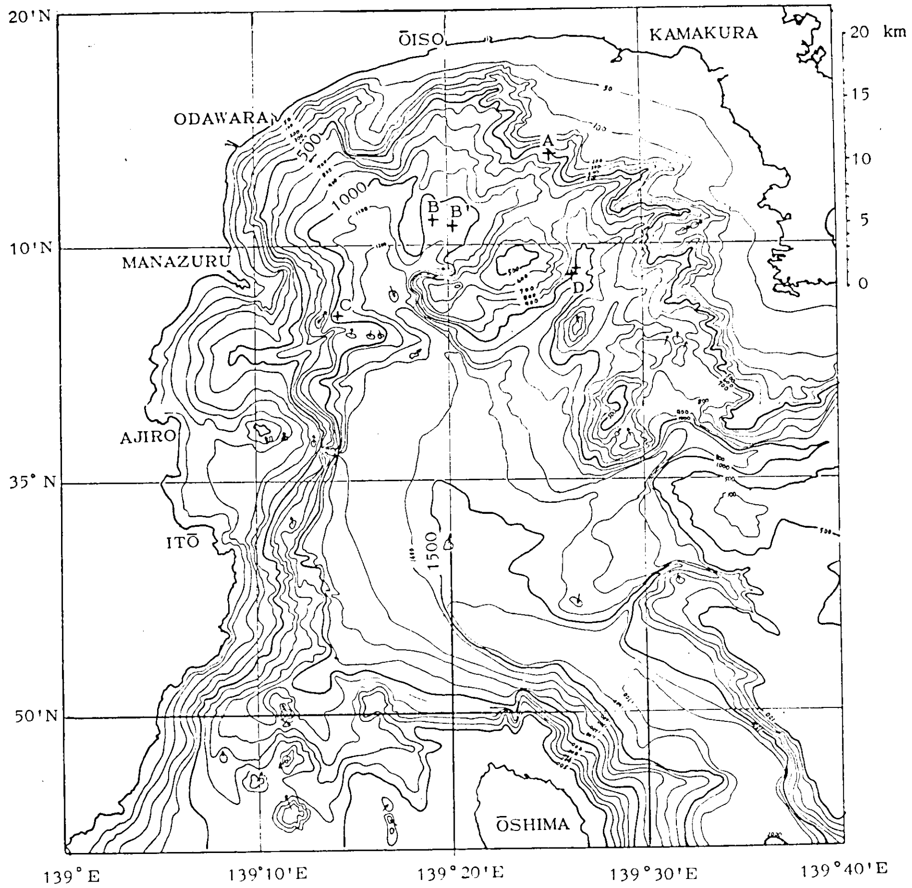

Fig. 1. Location of the stations of sea-bottom seismic observation in Sagami Bay.*)

Because of the recording life of the magnetic tape recorder, the total recording time was about 8 days.

The operations of deployment and retrieval of the ocean-bottom seismograph were very smooth, and it took about 1.5~2 hours for the whole operation of placement upon or retrieval from the sea-depth of about 1 km.

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*) The submarine topographic map is prepared by the courtesy of the Japan Hydrographic Office.

Table 1. Location and period of sea-bottom seismic observation at Sagami Bay.

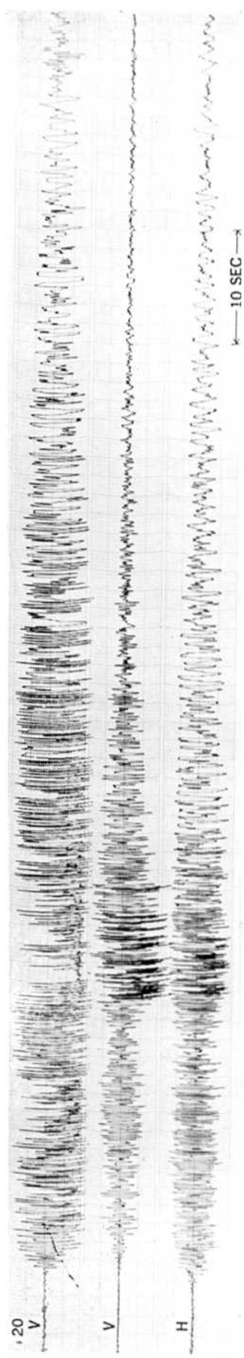
Station	Location	Depth	Recording period	Total recording time	Ship
A	139°25.3′E 35°13.7′N	485^{m}	From 1966, Oct. 29, 02 p.m. To 1966, Nov. 2, 10 a.m.	92$^{hrs.}$	TANSEI-MARU
B	139°19.7′E 35°10.9′N	1,060^{m}	From 1967, Jan. 18, 09 a.m. To 1967, Jan. 20, 08 a.m.	47$^{hrs.}$	TANSEI-MARU
C	139°14.3′E 35°07.1′N	1,010^{m}	From 1967, Jan. 20, 11 a.m. To 1967, Jan. 22, 08 a.m.	47$^{hrs.}$	TANSEI-MARU
D	139°26.8′E 35°09.0′N	1,020^{m}	From 1967, Jun. 13, 11 a.m. To 1967, Jun. 17, 09 a.m.	94$^{hrs.}$	MEIYO
	139°26.5′E 35°08.9′N	880^{m}	From 1967, Jun. 22, 01 p.m. To 1967, Jun. 26, 06 a.m.	89$^{hrs.}$	
B′	139°20.2′E 35°10.7′N	1,085^{m}	From 1967, Dec. 7, 02 p.m. To 1967, Dec. 11, 07 a.m.	89$^{hrs.}$	TANSEI-MARU

3. Example of earthquake record

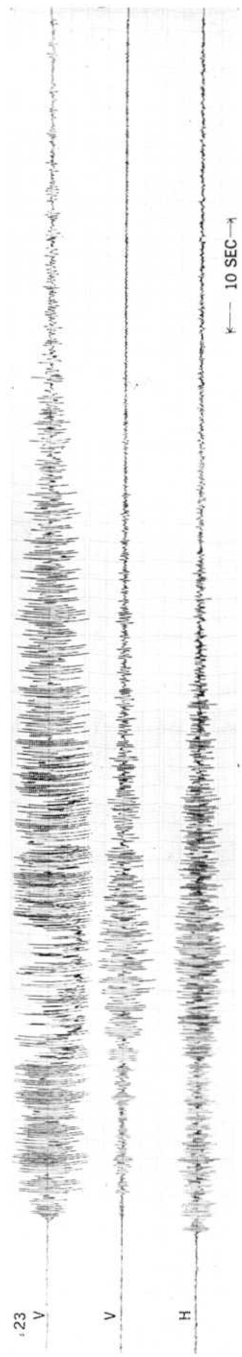
During the experimental seismic observations, many earthquakes ranging from micro-earthquakes to moderate earthquakes were recorded by the ocean-bottom seismograph. Some examples of the earthquake records are shown in Fig. 2(a)$\sim$(g), which were reproduced from magnetic tape. In Fig. 2(a) and (b) are shown earthquakes which have characteristics of ringing type. Most of those earthquakes in Fig. 2(a) are the ones which are registered by JMA and their magnitudes range from 3.9 to 4.9.

In Fig. 2(c) are shown earthquakes which have characteristics of repetition of pulse train. The magnitude and epicenter which were determined by JMA are described for each record. In Fig. 2(d) are shown examples of earthquakes which have characteristics of repetition of ringing wave packets. In Fig. 2(e) are shown examples of earthquakes of which P-wave part is larger than S-wave part. In Fig. 2(f) are shown earthquakes of which $S-P$ time is small, less than several seconds.

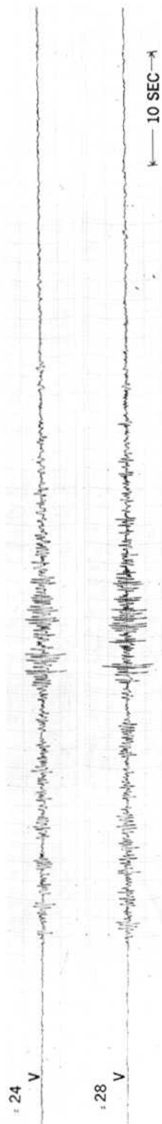
As seen in these examples, the apparent features of oscillation of earthquake motion recorded at sea-bottom by the ocean-bottom seismo-



(a) St. D, No. 20, Near Matsushiro, $M=4.9$, $H=0.0$ km, 1966 Jun 24.

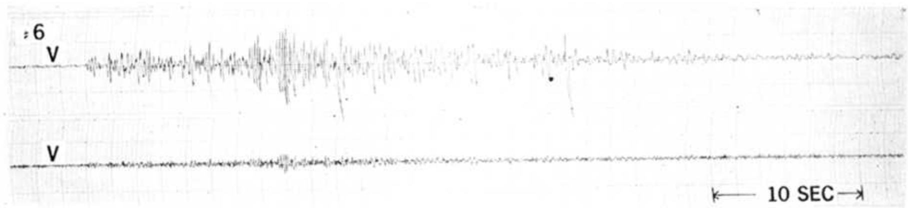


(b) St. D, No. 23, Ibaragi Prefecture, $H=70$ km, 1966 Jun 25.

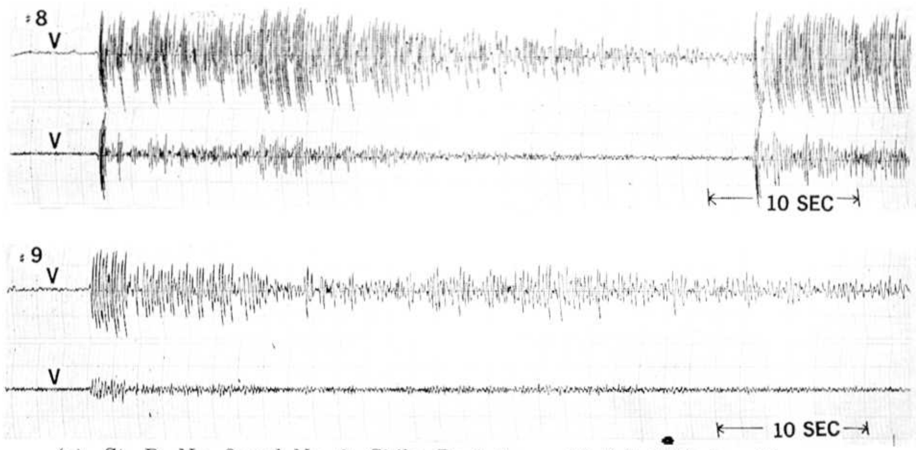


(c) St. D, No. 24, and No. 28, Near Matsushiro, 1966 Jun 25.

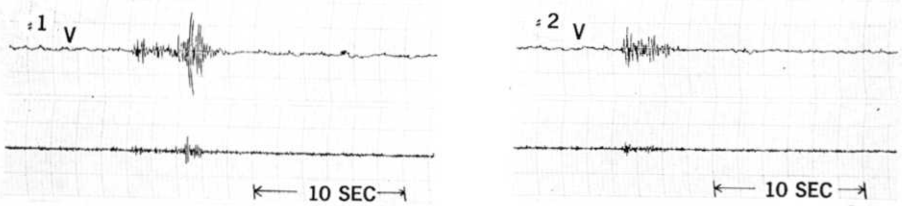
Fig. 2. Examples of earthquake record obtained by ocean-bottom seismograph.



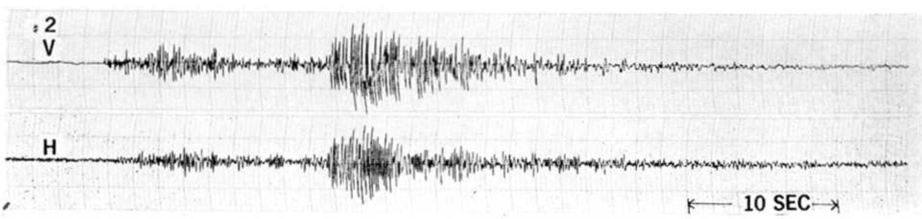
(d) St. D, No. 6, 1966 Jun 15.



(e) St. D, No. 8 and No. 9, Chiba Prefecture, $M=3.9$, 1966 Jun 15.



(f) St. D, No. 1 and No. 2, 1966 Jun 13 and 14.



(g) St. B, No. 2, 1966 Dec 7.

Fig. 2. Examples of earthquake record obtained by ocean-bottom seismograph. (continued)

graph are different for different earthquakes. This will evidently mean that, as far as wave forms are concerned, the ground coupling of the seismograph to the ocean-floor was good, and that the effect of natural vibration of the soft sedimentary layer at the sea-bottom did not seriously effect the observing of the characteristics of each earthquake. The examinations of the effect of soft layer which may appear in the spectrum analysis of earthquake motion will be reported in another paper.

4. Disturbance due to bottom current

When any earthquake observation is planned for revealing seismic activity in a certain area, it is always required that the registration of the earthquake should be homogeneous with respect to time and space. In other words, every earthquake which is larger than a certain specified level should be registered, if it occurs, without omission. The ocean-bottom has been thought as a suitable place for such observation because of its being far from land, where most of the artificial ground vibration is generated. However it was found through the experimental observation of this time that bottom current is another serious source of noise which disturbs the homogeneous registrations of seismic activity.

During the observation period at stations D and B, the records had been disturbed by noises from time to time. The disturbances appear with small amplitude at the beginning and increase their amplitudes gradually, continue for several hours, and then die out gradually. The disturbances are characterized by a train of damped sinusoidal oscillation of short duration. From the mode of such appearance and characteristics of their damping oscillation, it is inferred that these disturbances were caused by sea-bottom current through polyethylene rope and pressure vessel which stands up-right on the sea-floor.

The period of repetition of its appearance was not so clear as is seen in Fig. 3, where the time of the appearance of such disturbance during the observation time is represented by hatched mark. About a quarter of the whole observation period was disturbed by such noise.

The effect of sea-bottom water current upon the vibration of pressure vessel and ropes will be understood as similar to the effect of wind to obstacles upon the earth's surface. As is well known, when wind blows, the ground noise increases and the obstacles which stand

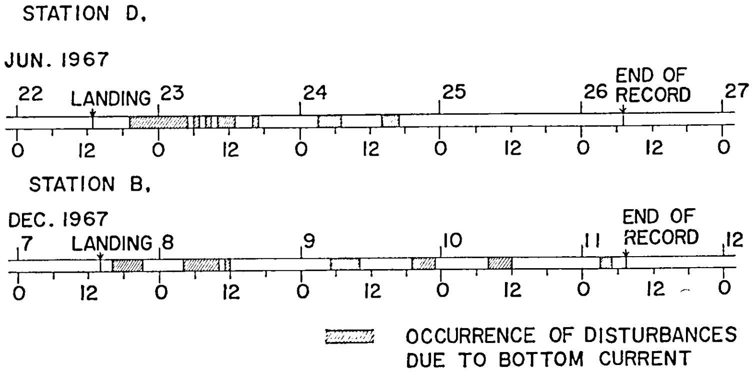


Fig. 3. Occurrence of disturbances due to bottom water current.

upon the earth's surface are forced to vibrate. A similar effect may be supposed to occur on the sea-floor. Since the kinetic energy of moving fluid, wind or bottom current, is expressed by $(1/2)\rho v^2$, where ρ and v are the density and speed of fluid respectively, the speed of bottom current which has the same kinetic energy as wind is given by

$$v_l = (\sqrt{\rho_{air}/\rho_l})\, v_{air}$$

where v_l, v_{air}, ρ_l, ρ_{air} are the speed and density of water and air respectively. Since $\rho_{air} \fallingdotseq 1.23 \times 10^{-3}$ g/cm^3, and $\rho_l \fallingdotseq 1.0$ g/cm^3, the wind speed $v_{air} = 5$ m/sec corresponds to $v_l \fallingdotseq 17$ cm/sec. Even though the actual measurement of sea-bottom current has not been performed yet, it will not be unplausible that such an amount of bottom current may take place from time to time upon the deep sea-floor.

As seen in these considerations, if one wants to accomplish homogenous earthquake registration, it is necessary to reduce the resistance of the pressure vessel to bottom current as much as possible. Some modifications have been undertaken for this purpose.

5. Seismic activity

Since Sagami Bay was the epicentral region of the great Kanto Earthquake of 1923, it will be very interesting to investigate the present state of seismic activity in this region.

The identification and reading of earthquakes which were observed by the sea-bottom seismograph were performed on pen writing paper records which were produced by a procedure described in the previous paper. The paper speed was selected as 5 mm/sec in recording time. The earthquakes of which velocity amplitudes are larger than 60 μkine were picked up, and readings were made for the first arrival time, $S-P$ time, maximum double amplitude, and total duration time. When there were doubts in identifying the events as micro-earthquakes or as cable shocks, further examinations were made for wave forms and P and S phases by making another paper record with faster paper speed. Many events of which total duration time is less than a few seconds were thus identified as cable shocks.

At station D, 80 earthquakes were thus registered in 180 hrs recording time. Among them, the number of earthquakes of which $S-P$ time is identified was 51. At station B, 25 earthquakes were registered in 90 hrs recording time. The number of earthquakes of which $S-P$ time is identified was 16. The frequency distributions $S-P$ time for station D and B are shown in Fig. 4. It will be seen in these figures

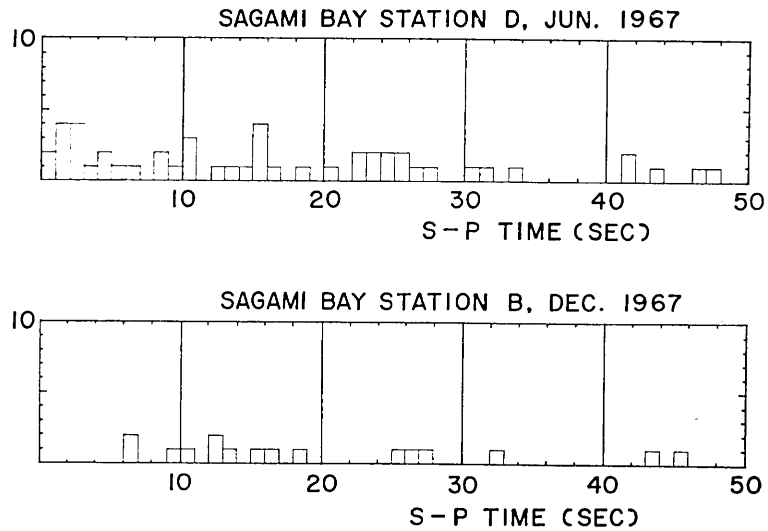


Fig. 4. Frequency distribution of $S-P$ time.

that there are several earthquakes of which $S-P$ time is less than 10 seconds, these earthquakes are the ones which take place in and near Sagami Bay.

In order to represent seismic activity in a certain area, the frequency of earthquake occurrence may be expressed in terms of the frequency of earthquake registration at a station. At station D, the number of earthquakes of which $S-P$ time is less than 10 seconds and of which amplitude is larger than 60 μkine was 18 during a total 180 hrs. At station B, it was 3 earthquakes during a total 90 hrs (Table 2). Therefore, the average number of earthquakes which were

Table 2. Seismic activity. The number and frequency of occurrence of earthquakes registered by ocean-bottom seismograph at the sea-bottom of Sagami-Bay.

Station	Total observation time	Total number of earthquakes (frequency of occurrence per day)	Number of earthquakes of which $S-P$ time is less than 10 sec. (frequency of occurrence per day)
D	180 hrs.	80 (10.5/day)	18 (2.4/day)
B	90 hrs.	25 (6.6/day)	3 (0.8/day)

registered for every 24 hours was 2.4 earthquakes at station D, and 0.8 earthquakes at station B respectively. From these results, it will be said that the average number of earthquakes which were registered for every 24 hours, and of which $S-P$ time is less than 10 seconds and velocity amplitude is larger than 60 μkine, was about 1~2 earthquakes per day at the sea-bottom station in Sagami Bay in June and December of 1967.

In order to get some idea about the seismic activity in this area, let us compare these values with other observational data.

Asada[2,3] has reported that, at Tsukuba in 1957, the average number of earthquakes of which amplitude is larger than 4.15 μkine (0.83 μkine/mm $\times$ 5 mm) was about 200 for every 24 hrs, and at station Matsushiro in 1958, the number of earthquakes of which amplitude is larger than 0.86 μkine (0.86 μkine/mm $\times$ 1 mm) was about 24 for every 24 hrs. If these data are converted to the number of earthquakes of which amplitude is larger than 60 μkine by assuming that Ishimoto-Iida's relation holds and the coefficient is $m=2$, the number of earthquakes become

$$200\times\left(\frac{4.15}{60}\right)^2=1.0 \qquad \text{(earthquake/24 hours)} \qquad \text{at Tsukuba}$$

2) T. ASADA, *J. Phys. Earth*, **5** (1957), 83-113.
3) T. ASADA et al., *J. Phys. Earth*, **6** (1958), 23-33.

$$24 \times \left(\frac{0.96}{60}\right)^2 = 0.005 \qquad \text{(earthquake/24 hours)} \qquad \text{at Matsushiro.}$$

It will be interesting to examine how many earthquakes were registered simultaneously at sea-bottom seismic station and land stations. During the period of observation at station D, simultaneous seismic observations were performed at several land stations. Statistics of of simultaneous registration of earthquakes is shown in Table 3.

Table 3. Simultaneous registration of earthquakes at sea-bottom station D and land stations Okuno, Izu peninsula, DDR (Dodaira) network, JMA (Japan Meteorological Agency) network.

$S-P$ time	Total number of earthquakes registered at OBS station D	Number of earthquakes registered simultaneously at Okuno (percentage)		Number of earthquakes registered simultaneously at	
				DDR	JMA
≤10 sec.	18	6	(33%)	3	0
>10	33	26	(77%)	26	9

Of 18 earthquakes which were registered at the sea-bottom station D and of which $S-P$ time is less than 10 seconds and velocity amplitude is larger than 60 μkine, only 6 earthquakes were registered simultaneously at Okuno temporary station,*) near Ito-shi, Izu peninsula. The percentage of simultaneous registration both at sea-bottom station and at land station at Okuno, which is about 40 km away, was only 33%. These earthquakes were registered neither by the network of the Dodaira Micro-earthquake Observatory nor by the network of Japan Meteorological Agency. On the other hand, about 77% of the earthquakes of which $S-P$ time is larger than 10 seconds were registered simultaneously both by sea-bottom station and land station at Okuno. These results will mean that, if one wants to monitor the micro-earthquake activity in Sagami Bay which is the epicentral region of the Kanto Great Earthquake in 1923, sea-bottom seismic observations are necessary.

6. Summary and conclusion

Experimental sea-bottom seismic observations have been performed at Sagami Bay several times in 1967. More than a hundred earthquakes,

*) This was organized by Professor S. Miyamura.

ranging from micro-earthquakes to moderate ones, have been registered during the total 270 hours recording time.

1) The activity of micro-earthquakes in and near Sagami Bay in June and December in 1967 was such that, when it is expressed by the number of earthquakes registered at a station for every 24 hours, and of which velocity amplitude is larger than 60 μkine at the station and $S-P$ time is less than 10 seconds, the frequency of earthquake registration was in average about 1～2 earthquakes for every 24 hours.

2) Simultaneous registration of these micro-earthquakes, of which $S-P$ time is less than 10 seconds, both at the sea-bottom station and at a land station which were about 40 km apart was only about 33%.

3) The homogeneity of micro-earthquake registration with respect to time was disturbed by the noises caused probably by the intermittent occurrenae of sea-bottom current.

Acknowledgements

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42. 相模湾における海底地震観測
(1) 地震活動

地震研究所 南雲昭三郎 小林平八郎 是沢定之

新しく開発された磁気テープレコーダ方式を用いて，相模湾において 1966 年から 1967 年にわたり数回海底地震観測を行なつた．これらの観測実験は計器の試験および海底地震観測上の諸問題を調べると共に，1923 年の関東大地震の震源域である相模湾における微小地震の活動を調べることを目的とした．実験は東京大学海洋研究所研究船淡青丸，および海上保安庁水路部測量船明洋の協力によつて行なわれた．

観測地点，期間は第一図第一表に示す通りである．合計 270 時間の記録が得られた．地震記録の例は第 2 図に示されているように，いろいろの顔付をもつたものが得られた．

1967 年 6 月および 12 月の相模湾およびその周辺の地震活動は，観測点で 24 時間に観測される 60 μkine 以上の速度振幅をもち，S−P 時間が 10 秒以内の地震の数で表わすと，平均 1〜2 ヶ/day という値が得られた．海底地震計で観測された S−P 時間 10 秒以内の地震の中で，海底地震計 D 点（第 1 図）と約 40 km 離れた陸上の観測点（伊豆半島奥野）との両者で同時に観測された地震の数は約 33% であつた．

微小地震に対する時間的に均質な観測が時々乱された．これは恐らく底層流の間歇(けつ)的な発生によつて雑振動が誘起されたためと思われる．この結果に基づき底層流の影響を逃げるように目下改良中である．