BULLETIN OF THE EARTHQUAKE
RESEARCH INSTITUTE
Vol. 57 (1982), pp. 83-104

3. *A Linear Trend of Hypocenter Distribution in the Outer Slope Region of the Japan Trench Revealed by OBS Array —Preliminary Report—*

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(Received February 16, 1982)

One month OBS array observation was carried out in the Japan Trench region using seven pop-up OBS's. Preliminary determination of hypocenters was made. The hypocenter distribution shows strong seismic activities in the outer slope region. There was a linear trend of epicenter distribution, roughly along the 6,000 m bathymetric contour. The focal depths of these earthquakes were shallow, less than 10 km. The graben-like structure in this region might have a strong correlation with this seismic activity. Some earthquakes, which form a cluster, occurred near the trench axis. There was another broad distribution of epicenters in the north of 40°N. In the inner slope region a swarm activity occurred which included four $M \fallingdotseq 4$ events. The focal depths of them were shallow.

Some distinct features on wave forms of OBS records are presented. One of the most significant features is the predominancy of low frequency component for some earthquakes, which occurred in the outer slope region and were recorded at the stations on the outer slope. There may be some similarities between the low frequency earthquakes and the "slow earthquakes", if the low frequency was generated by the source itself. Another new feature is the appearance of S-S multiple reflections which occurred within the sediment layer under the station.

1. Introduction

One of the important problems of plate tectonics is to know precisely the seismicity near the trench axis closely associated with the subduction of oceanic plate. The seismicity in this region has been investigated by seismic networks on land. The network of the Tohoku University revealed the presence of a dual seismic plane (HASEGAWA *et al.*, 1978). However,

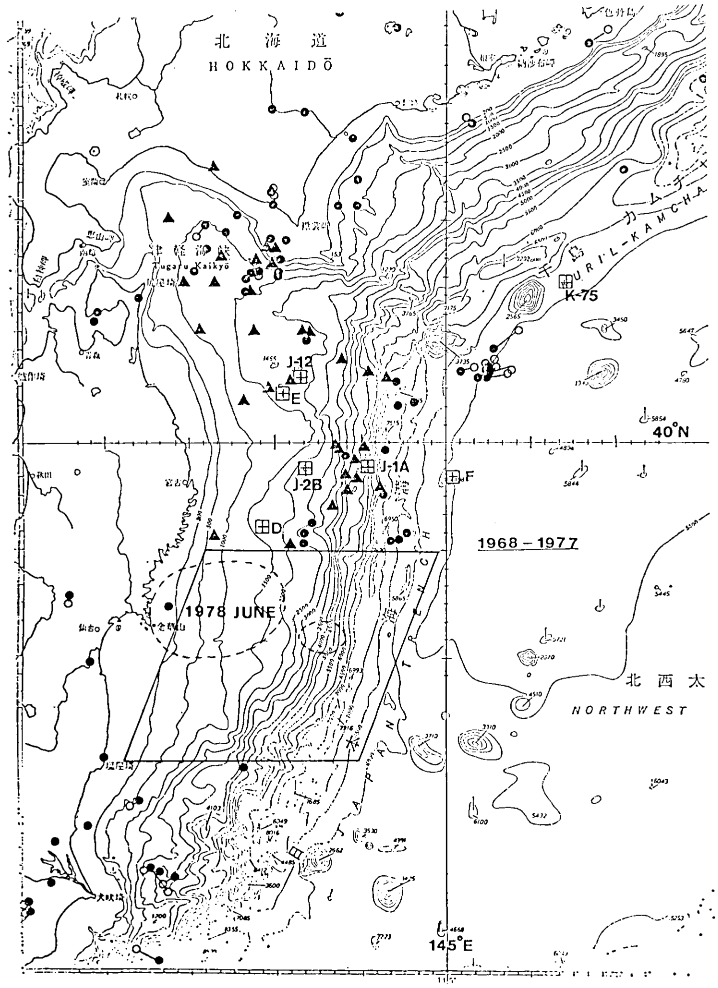


Fig. 1. Summarized epicenter distribution obtained by five independent OBS observations conducted between 1968 and 1977 (after KASAHARA *et al.*, 1978c). Each observation lasted approximately one week. Triangles: no-T phase earthquakes, closed circles: T-phase earthquakes with island-arc velocity model and open circles: T-phase with oceanic model. Stations are shown by a square with a cross inside, D, E and F in 1970. K-75 in 1975, and J-1A, J-12 and J-2B in 1977. The stations in 1968 and 1969 are not shown. A seismic gap was identified by OBS observations. The off Miyagi Earthquake in June, 1978, occurred in above gap. Outer slope seismic activity occurred at junction of Kuril and Japan Trenches (39°56′N, 145°30′E).

the hypocenter distribution just below the Japan Trench appeares to be rather scattered. The hypocenter depths reported are between 0-100 km. Such scattered distribution is a result of the poor accuracy for depth determination in this region because the hypocenters are located far from the network. The distance is almost 300 km to 500 km. Another possible cause of the poor accuracy is as suggested by several authors (e. g., ENGDAHL *et al.*, 1977) such that the ray from the event which occurred at the seaward side of the trench goes into a shadow zone. To study precise hypocenters occurring near the trench axis, it is necessary to observe earthquakes by OBS array deployed above the hypocenters.

The authors have carried out OBS observations in the Japan Trench area several times since 1968 (NAGUMO *et al.*, 1970a, 1976; KASAHARA and HARVEY, 1977; KASAHARA *et al.*, 1978c; KASAHARA *et al.*, 1979b). The hypocenters observed during 1969 to 1977 are summarized in Fig. 1 (after KASAHARA *et al.*, 1978c). Since these observations were done by a few number of OBS stations (maximum three) and the observation periods were one or two weeks, it was difficult to discuss precise depth distribution of earthquakes which occurred beneath and seawardside of the Japan Trench. However, several important features of hypocenter distribution has been obtained in these studies as given below. (1) A seismic gap seen in Fig. 1 (KASAHARA *et al.*, 1978c), (2) Strong seismic activity in the outer slope region of the Japan Trench (NAGUMO *et al.*, 1970a, 1976). (3) Earthquake swarm activity in the outer slope region near the junction of the Japan and the Kuril Trenches (NAGUMO *et al.*. 1978). And (4) high velocity in the subducting oceanic plate (NAGUMO *et al.*, 1970b; KASAHARA and HARVEY, 1977).

However, there still remains several important problems, namely, (a) precise distribution of hypocenters in the outer slope region of the Japan Trench, (b) focal depth of the earthquakes occurring just beneath the trench axis, (c) configuration of the seismic plane near the trench axis, and (d) presencce of any earthquakes in the "subducting complex" under the inner slope of the Japan Trench.

To study these problems, an OBS array observation was carried out in June and July, 1981. This array was also a part of the long range seismic array which was extended southeast from there towards Marcus island, and was used to control natural seismic sources which would be used to study the upper mantle structure.

This paper reports the hypocenter distribution in the Japan Trench area. This paper also reports low frequency earthquakes which were found in the outer slope region.

2. Experimental method

2.1. Instrument description

All OBS's were of the same type (ERI P-79). A detailed description of P-79 is described in KASAHARA *et al.*, (1979a). In order to achieve one month observation, however, a modification was made. The tape speed was decreased from 1/400 to 1/900 of the standard cassette tape speed. Due to this modification, the life of recording was extended from 400 hours to 900 hours (>35 days). The over-all frequency response of recording and playback, however, changed to 1-10 Hz(−3 dB). The sensors were one vertical 2 Hz geophone, one horizontal 2 Hz geophone and one hydrophone. Amplifications for vertical, horizontal and hydrophone components were 66 dB, 48 dB and 60 dB respectively. The low amplification of horizontal component was used to identify S-phase arrivals. The fourth channel of the recorder was used for a timecode. Dual timers activated a release mechanism. Then, by dropping the ballast weights, OBS's poped up to the sea surface.

2.2. Field experiment

Seven Pop-up OBS's were deployed on both the east and the west sides of the Japan Trench (Fig. 2). The deployment and retrieving of all OBS's were done by the R/V Hakuho-maru of the Ocean Research Institute, University of Tokyo (Legs KH 81-03 and KH 81-04). The determination of the ship position was done by Loran C because of its high accuracy in this area. The observation period lasted from June 8 to July 16, in 1981. The simultaneous recordings by the all seven OBS's were obtained in the period from June 10 to July 12. The precision of Quartz clock is 5×10^{-7} over the temperature range from 0 to 40°C. Since the temperature on the

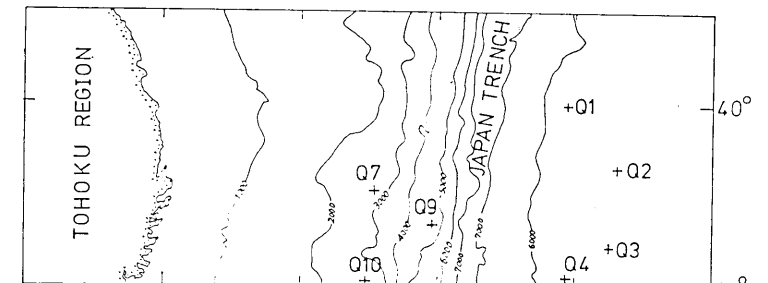


Fig. 2. OBS positions of the present survey. KHQ1 is abbrebiatied to Q1 in following figures. KHQ1, KHQ2, KHQ3 and KHQ4 are on outer slope of Japan Trench. KHQ9 is on lower half of inner slope, while KHQ7 and KHQ10 on upper half of inner slope.

Table 1. Geographic data and observed period for Japan Trench OBS Array (JTOA). Location are also shown on map (Fig. 2).

Station	Latitude	Longitude	Depth	Recording period
KHQ1	39°59.49′N	144°56.48′E	5,700 m	June 8, 19 h-July 15, 06 h
KHQ2	39°38.81	145°19.13	5,365 m	June 9, 06 h-July 15, 15 h
KHQ3	39°13.51	145°15.05	5,380 m	June 9, 17 h-July 16, 13 h
KHQ4	39°02.99	144°57.63	5,530 m	June 9, 23 h-July 14, 12 h
KHQ7	39°32.60	143°32.50	2,740 m	June 10, 10 h-July 12, 12 h
KHQ9	39°21.21	143°57.35	4,815 m	June 10, 11 h-July 13, 18 h
KHQ10	39°02.61	143°28.94	2,730 m	June 10, 23 h-July 12, 16 h

ocean bottom is nearly constant, the time drift during the observation was very small. With this small drift and also by the calibration before and after the observation by a stable master clock (1×10^{-9} accuracy) and/or JJY, an absolute time accuracy of 0.01 seconds was hold.

2.3. Data processing

The use of a newly developed playback system drastically decreased the time for data processing. The scheme for this playback system is described in KASAHARA (1981). Main features of this are (1) use of a 14 channel data recorder (Sony Magnescale A-814) which is able to change the tape speed from 1.5 cm/sec to 152 cm/sec, (2) development of a time code reader using a microcomputer (KASAHARA, 1981), and (3) use of an ink-jet recorder (Nihon-Koden RIJ-2508) which responses up to 1 kHz. The use of these instruments and technique cut down the time for data processing to one tenth or even less. Several earthquakes were digitally processed by the use of A to D conversion system and computers.

2.4. Hypocenter determination

The data of the seven OBS stations was used for hypocenter determination. The HYPO71 program (LEE and LAHR, 1975) was used. The P wave velocity model which was used in the calculation was a typical oceanic structure, that is, 2.0 km/sec (0.4 km thickness), 4.7 km/sec (1.0 km thickness), 6.6 km/sec (5.0 km thickness) and 8.2 km/sec (below 6.4 km in depth). The reason for using the oceanic structure is that many hypocenters were located in the oceanic lithosphere. The use of oceanic structure, however, seems to strongly affect hypocenters which occurred around the inner slope of the trench. In order to improve the accuracy of hypocenter determination, an introduction of ray tracing technique into the hypocenter determination program is underway, more accurate results will be reported later.

One of the significant errors in hypocenter determination is caused by the delay of S wave arrival due to low S wave velocity in the soft sediments located at the top of the oceanic crust. Since the S wave velocity in the soft sediments is approximately 200-500 m/sec (HAMILTON, 1976), the S-P time is 1-3 seconds longer than that in the case where there is no sediment. The time differences between P and PS (P to S conversion) and between SP (S to P conversion) and S were used for the soft sediment correction for the S-P time. Further discussions are given in the next section.

The F-P time was used for the magnitude determination. The coefficients for the (F-P)—M equation were determined by using the JMA magnitude scale (JMA, 1982a, b). The magnitude determined by the OBS records, M_{OBS}, is shown by

$$M_{OBS}=12.56+2.94 \log \text{(F-P)}$$

where (F-P) is given in seconds. The coefficients in this equation are a little different from those for the land stations (e. g., HORI, 1973). Hypocenters during the period from June 10 to July 13, 1981, were obtained. Although the processing time was decreased considerably, the arrival time readings for the whole records have not been completed yet. We made the complete data for seven OBS stations only for July. For the data in June, however, we selected earthquakes for readings by such criterion at the station KHQ1 that the amplitude was greater than the fix value (approximately 100 micro-kines) and the S-P time was shorter than 20 seconds. Because of this selection, the hypocenter distribution are biased to be dense around the KHQ1 station. Although the selection of earthquakes is biased, the hypocenter distribution for the earthquakes whose magnitudes are roughly greater than $M=2$ seems to be uniform in the region between latitudes 39°-40°N and longitudes 144°-145.5°E.

3. Results

3.1. A linear trend of hypocenter distribution in the outer slope region

Epicenters are shown for two cases, namely, for the case without soft sediment correction (NPSC) and with soft sediment correction (PSC), in Figs. 3 and 4 respectively. The vertical distribution for the case of PSC is shown in Fig. 5. Although NPSC epicenters are rather scattered, the major pattern in the outer slope region is the same for the two figures (Figs. 3 and 4). The main features are:

(1) a strong seismic activity in the outer slope region, (2) a linear trend of seismic activity along the 6,000 m bathymetric contour in the outer slope region, (3) a scattered seismic activity toward the abyssal plane in the region of 40°-41°N, and (4) a cluster of earthquakes near the trench axis at 39°20′N.

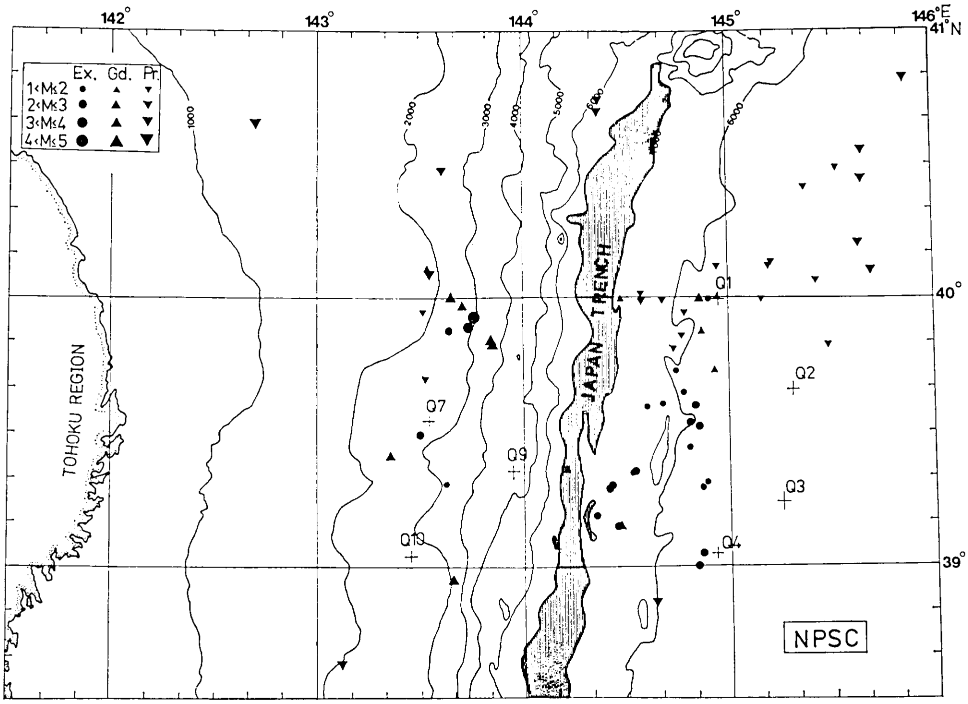


Fig. 3. Epicenter distribution determined by JTOA (Japan Trench OBS Array) in June-July, 1981, without P-S correction (PSC).

Among these features, the strong seismic activity in the outer slope region is the same as those found in 1970 (NAGUMO *et al.*, 1976) and in 1977 (KASAHARA *et al.*, 1978c). In those observations, however, because of a few number of stations (maximum three) across the Japan Trench, the detailed hypocenter distributions were not revealed. It is the array observation of this time which used seven OBS's that revealed the detailed picture of the hypocenter distribution in the outer slope region.

The similar feature of the linear trend of hypocenter distribution was also found in other cases, for example in the short term OBS observation off Boso Peninsula south of Tokyo (KASAHARA *et al.*, 1978a) and in the aftershock observations on land (e.g., WATANABE and KUROISO, 1969; RESEARCH GROUP FOR AFTERSHOCKS, 1975; KASAHARA *et al.*, 1978b; TSUMURA *et al.*, 1978). The depths of the earthquakes which form the linear trend are shallow, less than 10 km (Fig. 5). The hypocenters which are fixed at the depth 5 km during the calculation are not included in Fig. 5.

The stations of KHQ1 and KHQ4 were located on the graben-like topography which was clearly appeared on the 3.5 kHz sub-bottom profiler record (Fig. 6, by the courtesy of Dr. Nasu). Considering the shallow

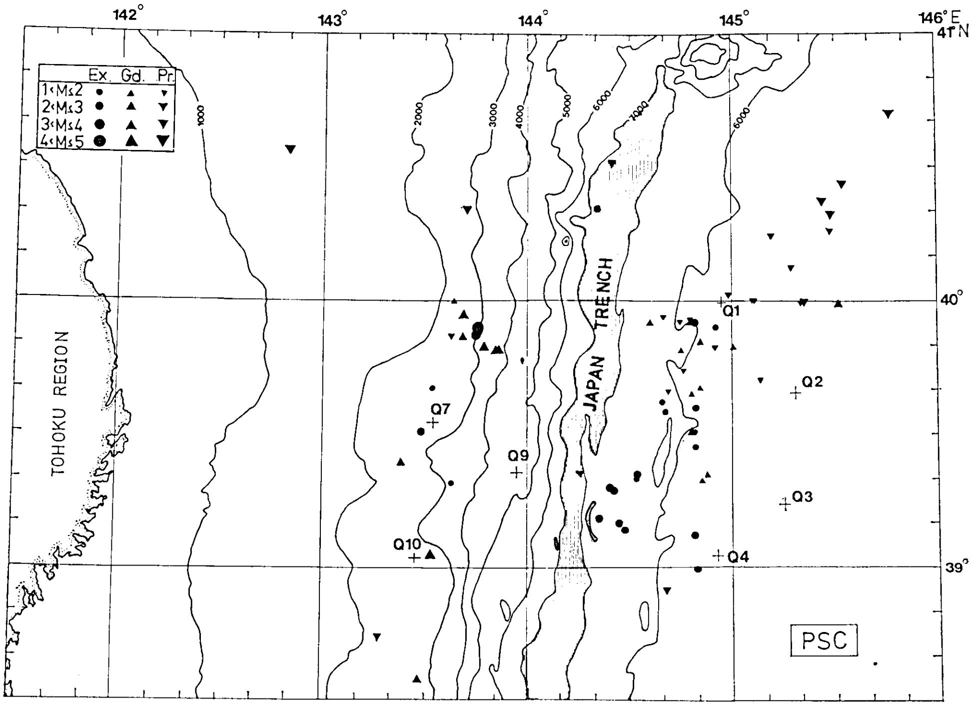


Fig. 4. Epicenter distribution determined by JTOA, with PSC. Linear trend activity is evident along 6,000 m contour on the outer slope region of the Japan Trench.

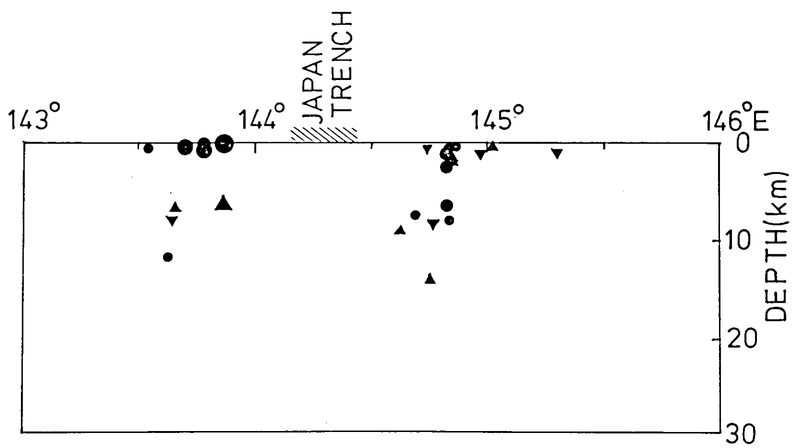


Fig. 5. Focal depth distribution for PSC hypocenters between 39°N and 40°N. Fix depth (5 km) hypocenters are not shown. Simbols are the same as legend in Fig. 4. Activities near 145°E correspond to those in outer slope region.

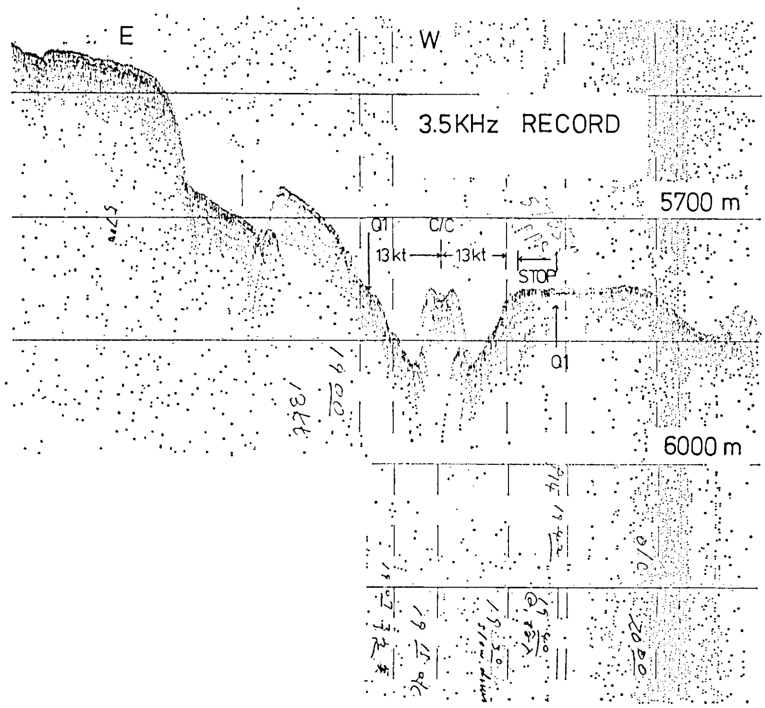


Fig. 6. A 3.5 kHz sub-bottom profiler record during KHQ1 deployment (by the courtesy of Dr. Nasu). Time axis from left (E) to rignt (W). Ship acrossed proposed site from E (left) to W (right). Ship passed Q1, changed her course 180° at middle of figure (c/c) and returned to Q1 station. At Q1 (middle-right), she stopped and deployed OBS Q1. A graben seen in left on outer slope, with 200 m-500 m height gap. Absolute depth value shown in figure is not correct due to no-base line correction, but it is relatively correct.

focal depth of the earthquakes which form the linear trend, we think that these earthquakes occurred in association with a graben forming movement.

Hypocenters which are located north of 40°N, in the outer slope region, are poorly determined due to their greater distance from the network.

3.2. Seismic activity in the inner slope region

The following seismic activities were observed in the inner slope region (Figs. 3, 4 and 5):

(1) a swarm activity which included four $M \doteqdot 4$ events in the region of the upper half (from 2 to 4 km water depth) of the inner slope where the IPOD drilling sites (holes 435 and 440) exist, (2) besides the above, weak seismic activities scattered over the inner slope region, and (3) no detectable earthquakes in the region of the lower half (from 4 km water depth to the trench axis) of the inner slope where a large amount of

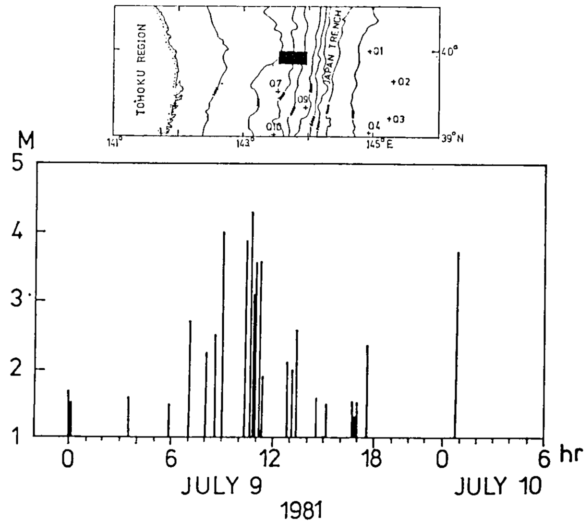


Fig. 7. Time-magnitude relation for swarm activity in zone shown in upper figure. Detailed hypoceters are shown Figs. 3, 4 and 5.

subduction complex exists (VON HUENE *et al.*, 1980).

The time sequence of the swam activity is illustrated in Fig. 7. Magnitude of each earthquake plotted as a function of time. Although the whole activity occurred in a day, most of earthquakes were concentrated during two hours in July 9. All of hypocenters of the swarm were determined to be shallower than 10 km from the sea bottom. However, the accuracy of the depth of the earthquakes whose magnitudes are larger than 3 is poor because S wave arrival times could not be read due to saturation. Small earthquakes whose magnitudes are less than 3 give very shallow focal depths. JMA (1982a, b) also reports 0 km depth for the swarm earthquakes whose magnitudes are greater than or nearly equal four. Although there is some errors in the focal depth, it will be almost certain that the swarm occurred in the continental block which overrided the subducting oceanic plate.

3.3. General features of wave forms on OBS records

The earthquake records obtained by OBS's have several different features from those obtained on land stations. For example, T-phase, P to S converted phase, the delay of the first motion on the horizontal component from the P arrival on the vertical component, and reflection from the sea surface, are some of these features. In addition to these features, the observation of this time gives several new findings which is also characteristics of the inherent to the OBS observation. The new findings

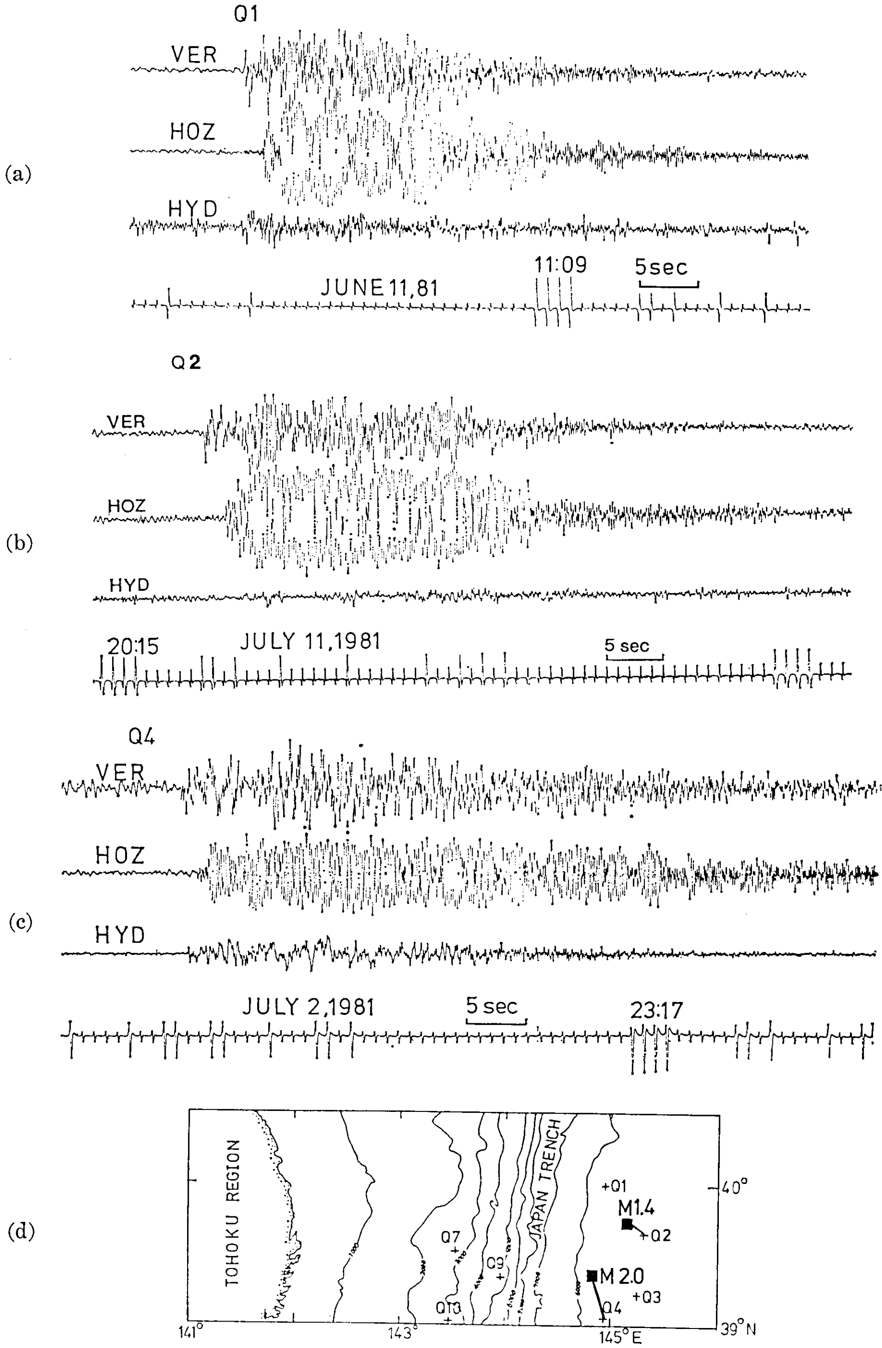


Fig. 8. Low frequency earthquakes observed by KHQ1 (8a), KHQ2 (8b) and KHQ4 (8c). All earthquakes occurred in outer slope region. Hypocenter of 8a was not determined, but obviously it was in the outer slope region. Combination of epicenter and station is shown by line in 8d.

are (1) low frequency characteristics, (2) multiple reflection of S to P converted phase within the water layer, and (3) multiple reflection of S-wave within the soft sediment layer. These features will be described in detail in the following sections.

3.4. Low frequency earthquakes

Low frequency earthquakes were observed by the present OBS's in the outer slope region of the Japan Trench. Fig. 8 shows typical exam-

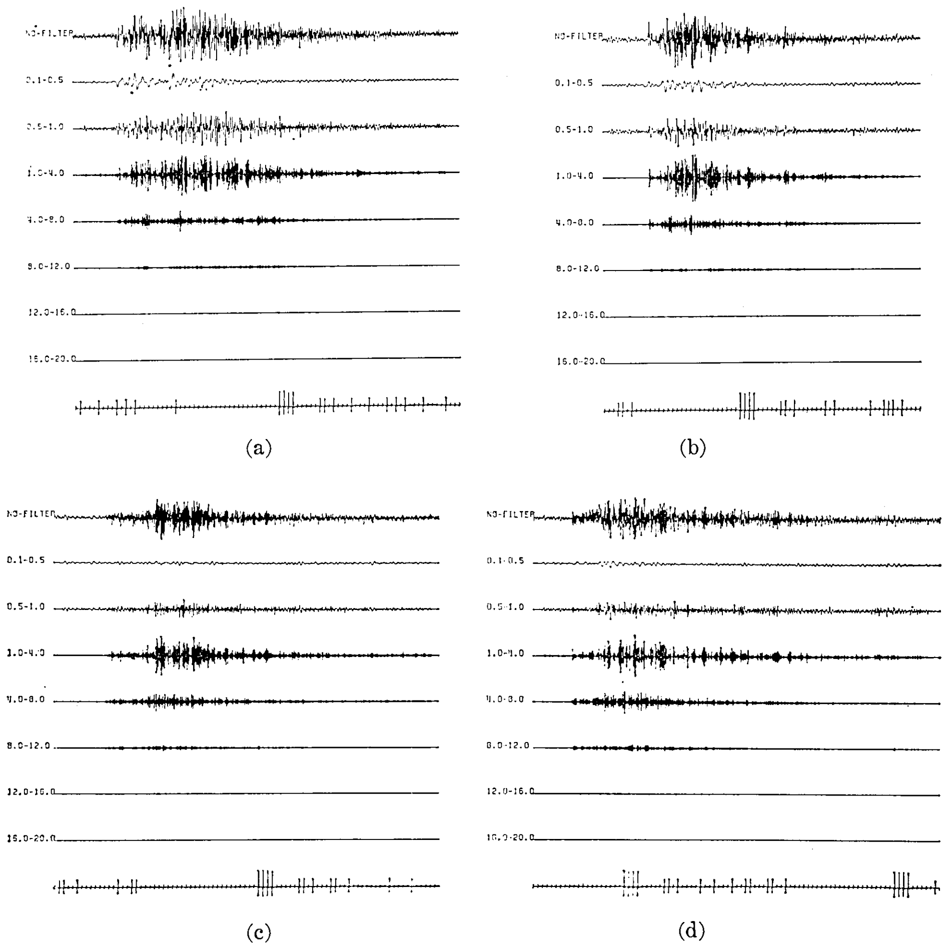


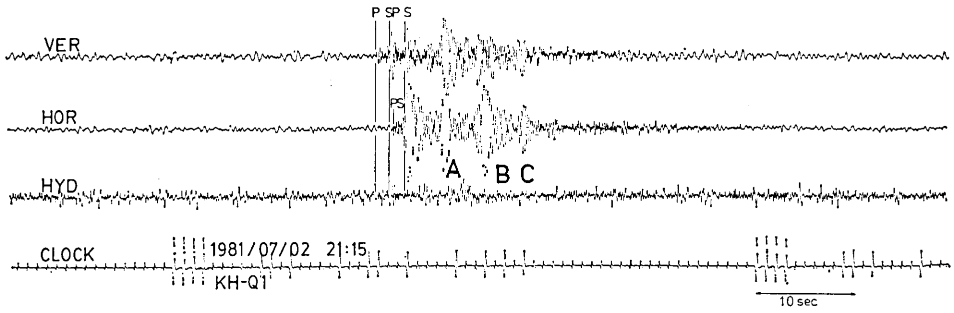
Fig. 9. Chebychev digital band-pass filtering for earthquakes observed at KHQ1. (a) and (b) are low frequency rich. (c) and (d) are less low frequency (0.1-0.5 Hz band). Numbers show frequency in Hz. Comparing 0.1-0.5 and 8-12 Hz, (c) and (d) are high frequency rich, though magnitudes of (a) and (b) are slightly higher than (c) and (d). Bottom trace in each figure shows time code. A tick is one second.

ples of low frequency earthquakes which occurred in the outer slope region and were observed at the outer slope stations. Fig. 9 shows examples of the band-pass filtered records. The filter is the Chebyshev digital band-pass-filter. The signal is the vertical component obtained at the KHQ1 station. Figs. 9a and 9b are examples of low frequency earthquakes and 9c and 9d are those of normal earthquakes. These low frequency earthquakes occurred in the outer slope region. The frequency content from 0.1 to 0.5 Hz are large for earthquakes shown in Figs. 9a and 9b and small for the earthquakes shown in Figs. 9c and 9d. The higher frequency contents are nearly the same in these earthquakes. There are not much differences in their magnitudes and epicenter distances. Since the frequency responces of the sensor and the recording system are very low in the frequency range of 0.1–0.5 Hz, the true amplitude of the signal in this frequency range is very large, more than ten times of the filtered record. Since the magnitude of these earthquakes are very small, about $M=1.5$ or less, the presense of such low frequency content in the range from 0.1 to 0.5 Hz is quite surprising. The earthquake which shows low frequency feature at one or two stations near the source does not always show the same low frequency feature at more distant stations. This suggests that the low frequency component rapidly decreases with distance.

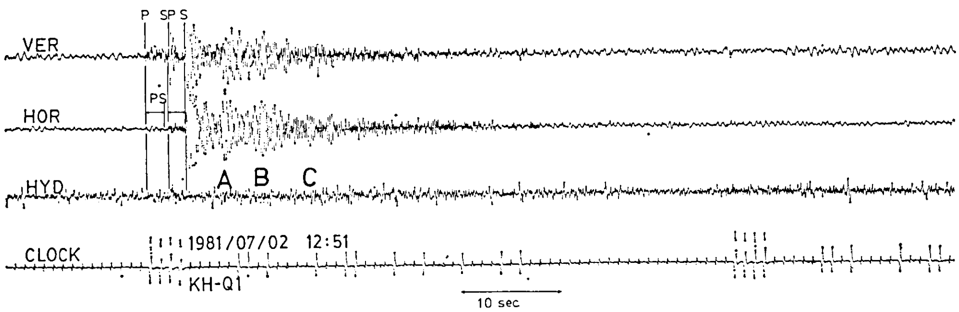
The low frequency feature is caused neither by instrument responses nor by the resonance of soft sediment which underlies the OBS. If the instrumental system produces such low frequency feature, all stations and all earthquakes should show similar feature. At other stations, particularly, at the stations KHQ7, KHQ9 and KHQ10 they did not show such feature. If it is caused by the resonance of the soft sediment, all the records taken on the outer slope region should show the similar low frequency feature, but obviously they did not. Two alternate causes could be thought, the one is such that the source itself contained low frequency, and the other is such that the low frequency component was generated during the propagation. We do not know yet which is the true cause.

3.5. P to S and S to P conversion

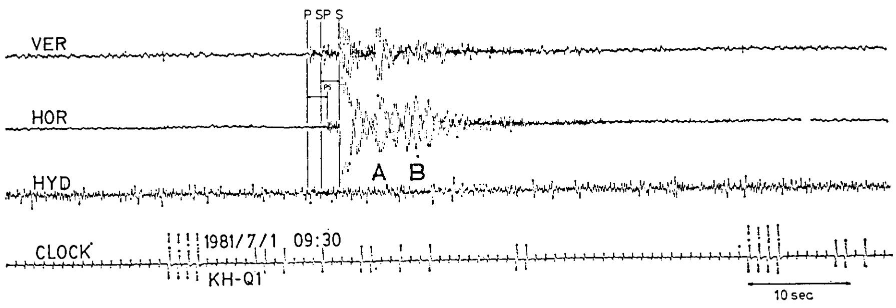
The P to S (PS) and S to P (SP) converted phases in the OBS records have been reported by many authours (e. g., AULD *et al.*, 1969; HASEGAWA and NAGUMO, 1970; SUTTON *et al.*, 1977; KASAHARA and HARVEY, 1977; LEWIS and MCCLAIN, 1977; NAGUMO *et al.*, 1980). The time differences between P and PS, and between SP and S gives the S wave velocity in the soft sediment at the observed site. As seen in Fig. 10, the first arrival of the horizontal component is approximately 1.8 seconds behind the P arrival of the vertical component. This time difference is written as T_{ps}. On the vertical component, there is a large phase (SP) before the S arrival, which is clearly identified on the hydrophone component.



(a)



(b)



(c)

Fig. 10. Examples of P to S (shown as PS) and S to P (shown as SP) conversions, and phases A, B and C behind S arrival. P to S conversion arrival is earlier than S to P in (b), but not in (a) and (c). P-PS and SP-S intervals are almost same in each example. S-A and A-B intervals are slightly less than twice of P-PS and/or SP-S interval and B-C interval is slightly longer than twice of P-PS interval. Wave forms after S arrivals are quite similar among examples, suggesting S-S reflection in soft sediment.

This is the S to P converted phase. The time difference between SP and S, which we write it as T_{sp}, are nearly the same as T_{ps} in each earthquake. If the P wave velocity, V_p, and the thickness, H, of the soft sediment are given, the S wave velocity, V_s, is calculated by T_{ps} or T_{sp} from the following equation,

$$T_{ps}=T_{sp}=H(1/V_s-1/V_p)=T_s-T_p$$

where T_s and T_p are the travel times of P and S waves in the soft sediment, respectively. The thickness and P wave velocity is given by the multi-channel survey. In the case of the Japan Trench, we can use the data of IPOD site survey (NASU *et al.*, 1979) for KHQ1. If we use $H=0.6$ km and $V_p=2.0$ km/sec, we obtain $V_s=0.29$ km/sec. This velocity is consistent with the values obtained by HAMILTON (1976).

3.6. Multiple reflection of S-wave within the soft sediment layer

Another interesting phases are seen behind the S wave arrival shown as A, B and C in Fig. 10. The main feature is the repetition of the packets of the wave trains such as A, B and C. These phases appeared on both vertical and horizontal components. The time intervals between succeeding phases, that is between S and the first phase (A), and between the

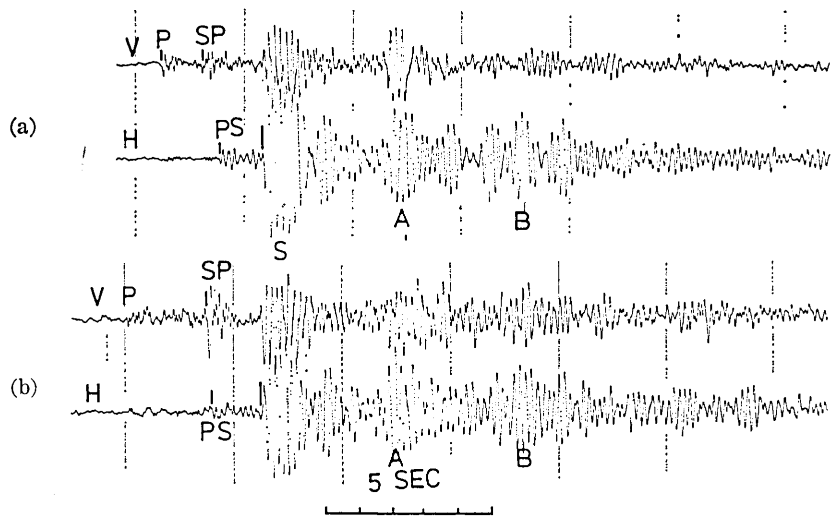


Fig. 11. Expansion records for two earthuakes (a) and (b) which correspond to records (c) and (b) shown in Fig. 10, respectively. When two seismograms (a) and (b) are superposed at first breaks of S-wave, peakes and troughs of phases A and B in (a) are well matched those in (b) each other. Note that initial motios of S-waves on horizontal components are different between two seismograms.

first phase (A) and the second phase (B), are slightly shorter than twice of T_{sp} or T_{ps}. The time difference between the second phase (B) and the third phase (C) is greater than twice of T_{ps}.

Another distinct feature is that the wave forms among three earthquakes are almost the same although S–P times are different. Two expanded seismograms of them are shown in Fig. 11. When two seismograms of different earthquakes are superposed at the first break of S wave, peaks and troughs of correspondig phases of two earthquake are well matched each other. The above fact strongly suggests that these phases were generated by multiple reflection occurring near the station, and were not generated by the source itself. The first and the second phases probably correspond to the multiple reflection of S waves within the soft sediment layer (Fig. 12).

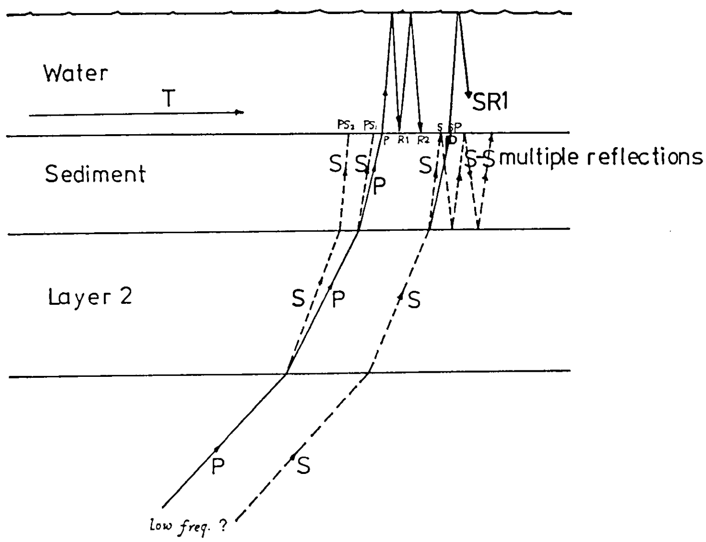


Fig. 12. Interpretations for conversions and reflections observed by OBS.

3.7. Multiple reflections between sea surface and ocean bottom

Multiple reflections between the sea surface and the ocean bottom are clearly seen on the hydrophone channel (Fig. 13). The arrival times of R1, R2 and R3 are exactly the same as those expected by two-way time for the water depth. Usually, the reflection of P phase is clearly seen on the deep-sea OBS's records. After S arrival, similar phases were observed correspoding to reflections of S to P converted phase (SP) between the sea surface and the ocean bottom, that is, SR1, SR2 and SR3. The reflection of SP phase within water layer was first identified by the present study.

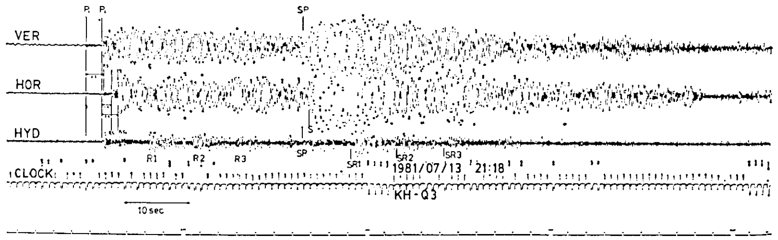


Fig. 13. An example of surface-bottom reflection at KHQ3. R1, R2 and R3 are multiple reflections within water layer, seen on hydrophone channel. SR1, SR2 and SR3 are reflections for SP phases. Interval times of P–R1, R1–R2 and R2–R3 are matched to two-way travel time for the depth travelling with water wave velocity. A tiny earthquake preceded by the earthquake which generated phases above.

4. Discussions and conclusions

A linear trend of the hypocenter distribution was found along 6,000 m bathymetric contour in the outer slope region of the Japan Trench by the OBS array measurement. The focal depths of these earthquakes are very shallow, less than 10 km. We think that these linear trend earthquakes occurred in association with graben forming movement in the subducting Pacific plate. An example of the graben structures is seen in the 3.5 kHz record (Fig. 6). The distribution of the graben structures on the outer slope in the region from 38° to 40°N are also reported by IWABUCHI (1979). According to Iwabuchi, the height contrast is almost 200–400 m, the length of cotinuation is up to 50 km and the lineations run almost parallel to the trench axis. These features are in agreement with that of the linear trend of the hypocenter distribution. The graben structure suggests the normal faulting focal mechanism. KANAMORI (1971) concluded that the 1933 Sanriku earthquake (M=8.3), which occurred in the outer slope region, was caused by a normal faulting mechanism. In the Alutian Trench, FROHLICH *et al.* (1982) claimed a normal faulting mechanism for the earthquakes occurring in the outer slope region. However, the present data are rather complex, and the determination of the focal mechanism still remains for the further study.

The detection capability of the land station for the seismic activity occurring in the outer slope region of the Japan Trench is very poor. There might be several causes. The one is the shadow zone. FROHLICH *et al.* (1982) gave an explanation such that the land stations are in the shadow zone of the seismic rays which originate from the earthquakes occurring in the outer slope region. KASAHARA (1980), however, calculated the seismic rays using the ray tracing method for the velocity model which was obtained by the explosion experiment (OKADA *et al.*, 1979), and showed that the rays could reach to the land stations, and explained the arrival times of the explosion experiment by the model. The different conclusions might be due to different models used for their calculations. The other possible causes are the small magnitude of earthquakes occurring in the outer slope region, unknown attenuation zone in the course of the ray paths, and the method of the hypocenter determination itself.

Earthquakes occurring in the outer slope region had low frequency component. Since the sensors were of the velocity type and the low frequency responses of the recording system was very low as mentioned in the previous section, the recording of the low frequency content means that the displacement of earthquake motion in the range from 0.1 to 0.5 is extremely large.

As regards the cause of low frequency feature, however, it is not clear whether it is generated by the source or through the path. KANAMORI and STEWART (1979) proposed a term of "slow earthquake", for an explanation of the efficient tsunami wave generation from the shallow focus earthquakes in spite of its relatively small body wave magnitude. The "slow earthquake" shows anomalously low frequency component of seismic wave. The 1933 Sanriku earthquake, which generated huge tsunamis up to 28.2 m (IIDA *et al.*, 1967), occurred in the outer slope region and might be "slow earthquake". If the low frequency feature appearing in the present OBS observation was generated by source itself, there may be some similarities between the low frequency earthquakes and the "slow earthquakes".

FUKAO and KANJO (1980) reported that the low frequency earthquakes occurred mostly in the region of the lower half of the inner slope of the Japan Trench, not in the region of the outer slope. The observation this time showed that the occurrence of low frequency earthquakes is not limited in this region which they identified.

In conclusion, the following measurements were obtained over one month observation at seven OBS stations in the Japan Trench region:

(1) Seismic activity was very active in the outer slope region of the Japan Trench.

(2) In the region of 39°-40°N, hypocenter distribution formed a linear trend along the 6,000 m bathymetric contour on the outer slope. The focal depths of these earthquakes were less than 10 km. This shallow linear trend seismicity probably relates to the graben structures which exist in this region. And both might be related to the subduction movement of the Pacific plate. The direction of the linear trend of the seismic activity and the graben structures are nearly the same.

(3) North of 40°N, there was a broad scattered seismic activity in the outer slope region. However, the scattered distribution may be a result of poor accuracy of the hypocenter determination in this region

which is far distance from the network.

(4) There was a cluster of earthquakes near the trench axis under the outer slope. There was a few seismic activity just beneath the trench axis, but not intensive.

(5) An earthquake swarm activity occurred in the region of the upper half of the inner slope. The swarm included four $M \doteqdot 4$ events, and its intensive activity continued for about two hours.

(6) No seismic activity was found during the one month observation period in the region of the lower half (between 4 km depth and the trench axis) of the inner slope.

(7) Low frequency earthquakes occurred in the outer slope region and were observed at the station on the outer slope. The low frequency feature was not caused by the instrument responses. If this low caused by source itself, there may be some similarities between the low frequency earthquakes and the "slow earthquakes".

(8) Phases which appear behind the S arrival are almost identical among many earthquakes. The phases might be generated by multiple reflections of S wave within the soft sediment layer which underlies the station.

(9) The reflections between the sea surface and the ocean bottom were also observed for S to P converted phase (SP).

Acknowledgements

The present authors express thanks to the Ministry of Education of Japan, for the present study was performed by its Scientific Research Fund for the 1981 academic year. The authors also express great thanks to chief scientists, Professors N. Nasu in leg KH 81-3 and M. Horikoshi in leg KH 81-4, both of whom are in Ocean Research Institute, University of Tokyo. We also thank Captain I. Tadama and the crew of the R/V Hakuho-maru, Ocean Research Institute, University of Tokyo.

Miss M. Baba (Chiba University), Mr. C. Igarashi and Mr. H. Otobe (both in Ocean Research Institute, University of Tokyo) are to be thanked for their help in the construction and deployment of OBS on the shipboard of R/V Hakuho-maru. Also to be thanked are the people in the Seismological Division of JMA which kindly gave us their preliminary results of hypocenter determination in June and July, 1981.

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3. OBS アレー観測によって見つかった日本海溝外側斜面地域における帯状震央分布—序報—

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7台の浮上式海底地震計を用いて1981年6月10日から7月13日まで，日本海溝を横断する約1ヵ月のアレー観測を行った．震源決定を行い以下のことがわかった．海溝軸外側の太平洋側斜面下に活発な地震活動があった．これらのうちのある地震群は，6,000 m の等水深線にそってほぼ帯状に分布し，震源の深さは 10 km 以浅と浅かった．この地域は地溝状の構造が有り，地震活動との強い相関が推定される．他の，海溝軸外側の活動は，海溝軸付近の塊状分布，40°N 以北の幅広い分布，が存在した．海溝軸内側斜面上部には，4個の $M \geqq 4$ の地震を含む浅い群発活動が起った．

海底地震計の記録波形に，いくつかの特徴が見られ，これらのうちいくつかは新しい結果であった．もっとも重要な新しい特徴は，海溝軸外側斜面に起った地震のうちいくつかは外側斜面上の観測点で低周波に富んだ波形を示した，ことである．この低周波地震は，もしそれが震源自身で生成したのであれば，"低速地震"とこの地震の間にある類似性が有るであろう．S 波の後に 2～3 の新しい相が見つかった．これらの相は観測点直下における S-S 反射によって生成されたのであろう．