A Preliminary Study on Sea-bottom Seismograph Observation in Bohai Sea Area, China*

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Abstract

The present paper is a preliminary technical report of the development of ocean-bottom seismograph observation in the Bohai Sea area of China, conducted under financial support from Japan Foundation for Shipbuilding Advancement.

This report mainly includes the following contents:

(1) The seismicity and seismic risk assessment of the Bohai Sea area and its vicinity.

(2) Conditions for sea-bottom seismograph observation in the Bohai Sea area.

(3) Some results of preliminary study on instruments and techniques for ocean-bottom seismograph observation in the Bohai Sea area.

(4) The results of experimental modelling researches on the noises of ocean-bottom seismograph observation in the case of shallow sea.

The historical and present seismicity, the long-term seismic risk, and the relation between large earthquakes which occurred in North China and Japan have been studied. The problems on influences of a strong earthquake and tsunami upon the Bohai Sea navigation routes and near populated areas were discussed. Based on the result the necessity of sea-bottom seismograph observation in the Bohai Sea area was explained.

The conditions in the Bohai Sea area, introduced in this paper,

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include the sea-bottom geomorphology, strong waves and meteorological conditions, and the sea navigation and Sea work condition in this sea area.

Some problems on the instruments and techniques for sea-bottom seismograph observation in the Bohai Sea area were studied and discussed. The preliminary seismograph observation test at the platform of an oil well in the Bohai Sea area was made by the Seismological Bureau of Tianjin, Some new techniques, and successes in noise reduction and signal transmission etc. of sea-bottom seismograph observation advanced by the Meteorological Research Institute of Japan Meteorological Agency (JMA) may be applied to the sea-bottom seismograph observation in the Bohai Sea area. On the basis of these results, a preliminary project to develop the sea-bottom seismograph observation in the Bohai Sea area of China was proposed.

To study the noises of sea-bottom seismograph observation in the case of shallow sea, a new experimental modelling research has been completed. The noises caused by sea surface source and sea interior source were studied separately. Some important experimental results have been presented.

The preliminary results, obtained in this paper, may be useful to develop the sea-bottom seismograph observation in the Bohai Sea area and its vicinity.

1.INTRODUCTION

More than 10 large and moderate cities including Tianjin (天津), Dalian (大连), Yantai (烟台), Qinhuangdao (秦皇岛), Tangshan (唐山), Yingkou(营口) are located near Bohai Sea. There are three shipping lines in Bohai Sea used to sea transportation from Tianjin, Qinhuangdao and Yingkou to Japan and other countries. Obviously, the establishment of the sea-bottom seismograph observation system in the Bohai Sea area will be helpful to determining earthquake hypocenters and studying characteristics of the seismicity, seismic precursors and the earthquake prediction in the area and its vicinity which is very important for the populated cities near Bohai ea Sas well as for the sea navigation routes.

For developing the cooperative research works on earthquake and tsunami prediction between seismologists of JMA and the State Seismological Bureau of China, three seismologists of the Seismological Bureau of Tianjin Municipality under financial support from Japan Foundation for Shipbuilding Advancement have worked in the Seismo logical and Volcanological Research Division, Meteorological Research Institute of JMA for two months (January 26 — March 26, 1987). On February 27, Mr. Ryoichi Sasakawa, Chairman of the Foundation for Shipbuilding Advancement, accompanied by Mr. Hisashi Suzuki, Managing Director, and Mr. Haruo Shibazaki, Manager of International Affairs Division of this foundation met them and had cordial and friendly talks with them. The main coorperative research topic in this period was the study on the sea-bottom seismograph observation in the Bohai Sea area of China by applying some new techniques, successes and experiences of the ocean-bottom seismograph observation(OBS) developed by the Meteorological Research Institute of JMA. Under the kind help and support of the Institute of Ocean Environmental Technology of Japan Foundation for Shipbuilding Advancement, a new experimental modelling research on noises of a sea-bottom seismograph observation system in the case of shallow sea has been conducted.

This report presents the preliminary results of cooperative research work on the development of the sea-bottom seismograph observation system in the Bohai Sea area of China.

2. SEISMICITY AND SEISMIC RISK OF BOHAI SEA AREA AND ITS VICINITY

2.1 Historical and recent seismicity

The Bohai Sea area is a part of North China, seismically active region, and at the same time it belongs to the Tancheng-Lujiang seismic belt. Until 1986, there occurred 13 earthquakes of magnitude 4.0—4.9, 5 earthquakes of magnitude 5.0—5.9, 5 earthquakes of magnitude 6.0—6.9, and 4 earthquakes of magnitude 7.0—7.9 in the Bohai Sea area and its vicinity. Generally, at present in this area the small events of magnitude 1.0—1.9 are counted in hundreds per year and the events of magnitude 2.0—2.9 are counted in tens per year in average, respectively. Therefore, this area is a frequently seismically active period of North China continued until the present. In this period, fo-

Table 1 The parameters of M≧7.0 earthquakes in Bahai Sea area. (1548-1969)

No.	Date	Latitude	Longitude	Magnitude
1	1548/9/13	38.0°N	121.0°E	7.0
2	1597/10/6	38.5°N	120.0°E	7.0
3	1888/6/13	38.5°N	119.0°E	7.5
4	1969/7/18	38.3°N	119.5°E	7.4

ur large earthquakes of magnitude 7.0 and larger had occurred in the Bohai Sea area, as shown in Table 1.

Figure 1 shows the distribution of earthquake epicenters in the Bohai Sea area and its vicinity during the period from 409 to 1986. From this plot, we can see that the seismic activity in this area was actually very high.

2.2. Assessment of long-term seismic risk

According to the earthquake catalogue, the seismicity of North China region including the Bohai Sea area can be characterized by some active periods, and the duration of every active period was about 300 years. At present, the third active period belayed in more than 250 years and its end will be in forthcoming 50—100 years.

Based on the analysis of seismic activity of North China region, in general, the mean recurrence time intervals for earthquakes of various magnitudes in this region approximately are about 10 years for M = 5 earthquakes, about 30 years for earthquakes of M = 6, about 100 years for earthquakes of M = 7, and about 300—400 years for earthquakes of M = 8. The Bohai Sea area is a special seismically active area of North China region. According to incomplete statistics, there

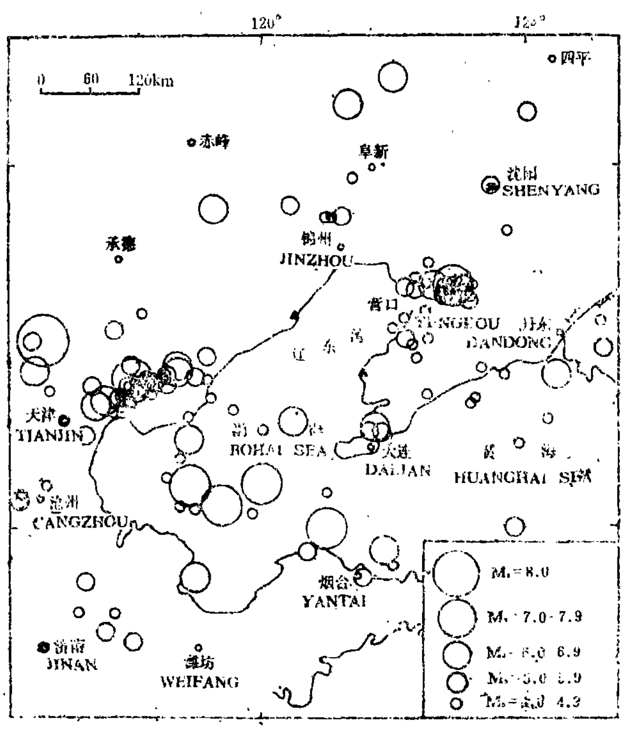


Fig. 1 The distribution of earthquake epicenters in Bohai Sea area
(408—1960, $M_S \geq 4.7$, 1961—1986, $M_S \geq 4.0$)

occurred 3 earthquakes of magnitude larger than 7 and 5 earthquakes of magnitude larger than 6 since 1597, respectively. This indicates that the recurrence time intervals of the earthquakes in Bohai Sea area are shorter than the mean time intervals for North China region.

Moreover, after 1969 the Bohai Sea area has become relatively quiet region in seismicity, and has appeared to be a seismic gap region (see Fig.2). Therefore, the seismic risk of M≧7.0, even M≧7.5 earthquakes must be considered in the forthcoming 100 years.

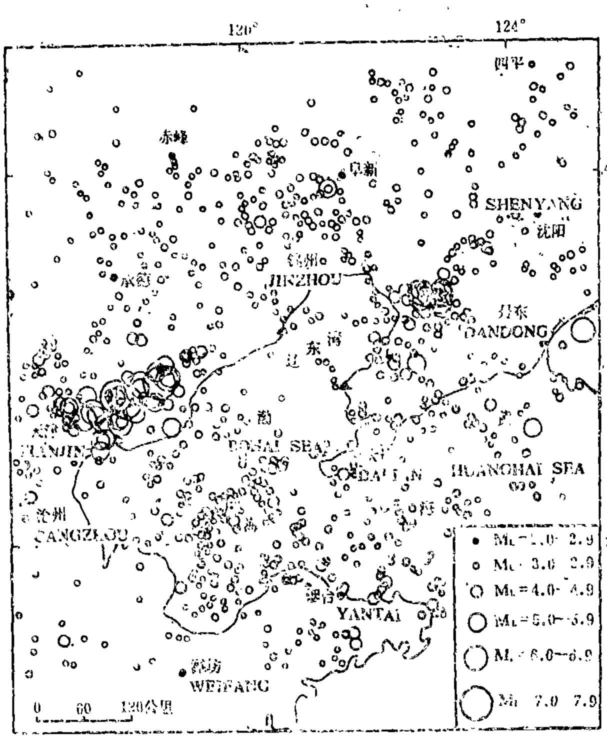


Fig. 2 The distribution of earthquake epicenters in Bohai Sea area and its vicinity (1972—1983)

2.3. The relation between large earthquakes of North China and Japan

Based on the analysis of earthquake catalogues, it can be seen that there is a remarkable correlation between the large earthquakes which occurred in North China and in Japanese oceanic trench and in the west part of the Japan Sea. Generally, we can elucidate the approximately similar seismic circles: firstly, a M=7—8 great earthquake occurred in the Japanese oceanic trench, then, a large deep earthquake occurred in the west part of the Japan Sea or Heilongjiang region of East-North China, and finally, the earthquake of M≧6.0 occurred in North China. Since 1918 the such seismic circles can be noted more remarkably, as shown in Table 2(10).

Table 2 The seismic circles of earthquakes in North China. Japan Oceanic Trench. and West part of Japan Sea.

Period of circle	Date	Latitude	Longitude	Focal deoth(km)	District	The depthe of oceanic trench near epicenter	Magnitude
1018-1922	1918/11/8	44.1°N	148.9°E	520	择捉岛	4.0KM	7.3
	1920/5/6	43.0°N	131.5°E		Boundary bertween China.USSR and Korea		6 1/4
	1922/9/28	39.2°N	120.5°E		Bohai sea		6 1/2
1930-1932	1931/3/9	41.2°N	142.5°E	350	青森县东方冲	1.5KM	7.6
	1931/2/20	44.5°N	135.7°E		North part of lapan Sea		7.4(MG)
	1932/8/22	36.1°N	121.6°E		East of Qingdao		6 1/4
1943-1946	1945/2/10	40.9°N	142.1°E		青森县东方冲	1.0KM	7.3
	1946/1/11	45.0°N	131.0°E		Muling		7.2(MG)
	1944/12/19	39.7°N	124.3°E		South of Dandong		6 3/4
1947-1950	1947/11/14	41.7°N	145.7°E	600	茂咲半岛南方冲	6.0KM	6.7
	1949/4/5	42.0°N	131.0°E		Boundary between China. USSR and Korea		6.7(MG)
	1948/5/23	37.7°N	121.9°E		West north of Weihai		6.0
1968-1972	1968/5/16	40.7°N	143.6°E	420	Off Sanriku	2.0KM	7.9
	1969/8/31	38.6°N	134.6°E		The middle part of lapan Sea		6.8
	1969/7/18	38.2°N	119.4°E		Bohai Sea		7.4

2.4. Strong sea waves and tsunami in the Bohai Sea area and its vicinity

According to historical materials, strong sea waves which occurred in the Bohai Sea area can be caused only by the combinational action of astronomical factors (the large tides in full moon, waning moon in spring and autumn equinoxes) and meteorological factors (strong east cold wave, near east heavy wind, typhoon and storm). From the historical data on strong sea waves in 1895, 1938 and 1965, we can obtain this conclusion, because in the recent 100 years only these events of strong sea waves occurred in the given sea area. At the same time, the historical data on large earthquakes in the Bohai Bay and Laizhou Bay show that only any tsunami caused by earthquakes had not occurred in these two sea areas.

For example, the large earthquake of M=7.4 which occurred in the Bohai Sea area did not cause any tsunami, and even some people of the Tanggu land region went to ships on the Bohai Sea to take shelter from the earthquake.

2.5. Influence of Bohai Sea earthquakes on navigation

Generally, because the Bohai Sea earthquakes can not cause tsunamis, their direct influences on navigation may be enough weak. For example, on June 1888, when the largest earthquake (M = 7.5) occurred in Bohai Sea, several ships navigating on the sea were only vibrated, but not damaged. Of course, the direct factors caused by earthquakes, such as damage of port, evacuation of population, land and sea disaster relief and the others may influence the navigation strongly.

2.6. The necessity of sea-bottom seismograph observation system in the Bohai Sea area

At first, in order to predict the large earthquakes occurring just in the Bohai Sea area, we must develop the sea-bottom seismograph observation system in this area. In fact, the earthquakes of Bohai Sea area might be predicted by using seismic precursors. For example, after G. Wei (10), the Bohai earthquake (M=7.4) occurred on July 18, 1969 was an event of main-aftershock type, and some precursory anomalous variation in regional seismicity, such as b-value decrease and belt-shaped distribution of earthquakes (see Fig.3) and the others had occurred before this large earthquake. The seismological observations on sea-bottom are very useful to study the seismic patterns and seismic precursors before the forthcoming large Bohai Sea earthquakes for predicting them.

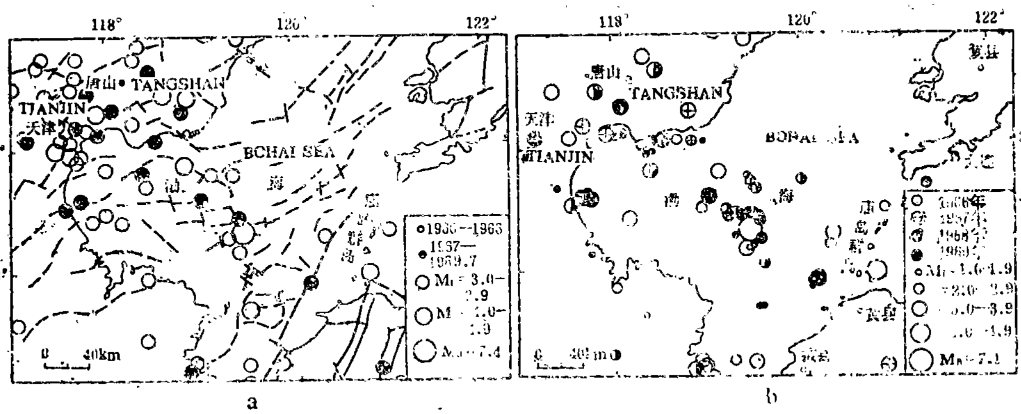


Fig. 3 The distribution of earthquake epicenters in Bohai Sea area and its vicinity before 1969 Bohai earthquake of M=7.4
a. 1960—July, 1969 b. Jan., 1966—July, 1969

Secondly, the Bohai sea-bottom seismograph observations can be used to seismological researches and earthquake prediction in its adjacent land regions, especially in the most important and seismically enough riskful Beijing—Tangshan region, because in this region the State Seismological Bureau of China has established enough dense land seismological network, excepting the Bohai Bay area which is a free region without seismic stations.

3.THE CONDITIONS FOR SEA-BOTTOM SEISMOGRAPH OBSERVATION SYSTEM IN THE BOHAI SEA AREA

3.1.The main characteristics of sea-bottom geological structure and crustal structure in the Bohai Sea area

The Bohai Sea is a subsidence basin of the mesozonic—Neozonic era. It consists of the depression of the Liaodong Bay, depression of central Bohai and the fault zone of Yingkou—Weifang. The area of Huanghe River mouth and area Bohai Bay belong to the Jiyang basin and Huanghua basin, separately. Figure 4 is a rough sketch of the structures of the Bohai Sea area and its vicinity(7). The fault zone of Yingkou—Weifang northwards through Laizhou Bay enters the sea, then, crosses Miaoxi, Bodong, Liaodong Bay, and at Yingkou disembarks. The north-westward directed Zhangjiakou—Penlai deep fault zone crosses the Jiyunhe cannal. The Haihe river, stretches along the north side of interior swell of the Bohai Sea, then intersects Yingkou—Weifang fault zone and approaches to the Shandong peninsula. The Bohai earthquake of 1969(M=7.4) just occurred in the intersecting area of these two fault zones.

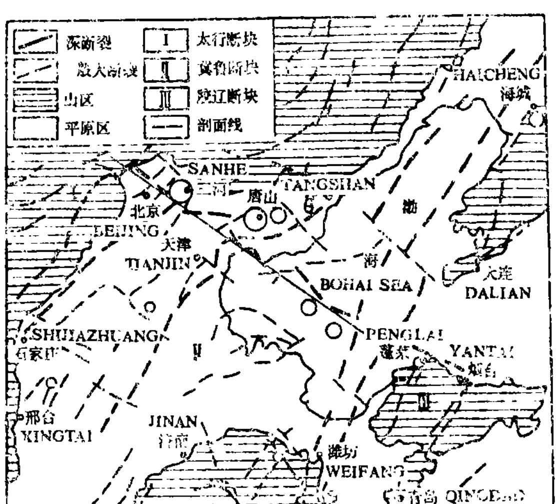
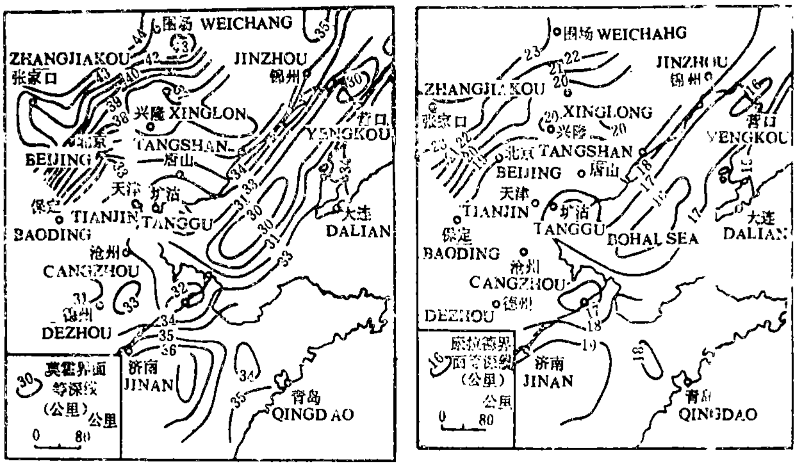


Fig. 4　The structure sketch of Bohai Sea area and its vicinity

Figure 5 shows the features of the earth's crust structure in the Bohai Sea area(6). From this plot we can find an earth's mantle swell zone directed south—westwards from the Liaohe river depression.

The highest point of this mantle swell zone is located in the central Bohai depression. The depth of the Moho discontinuity in this point is 29.4 km. A series of depression of tertiary period are distributed on the above-mentioned mantle swell zone. Moreover, the other two mantle swell zones, directed approximately east—westwards and south—northwards, respectively, were discovered in this area. Therefore, we have 3 mantle swell zones intersected each others in the highest point of the earth's mantle under the central Bohai depressio. Corresponding to them, there are 3 depression zones intersected each other in the central Bohai depression. The thickness of the deposit of tertiary period in the central Bohai depression is very large, about 8 km.



a b

Fig. 5 The crust structure in Bohai Sea area and vicinity
a.Depth of Moho discontinuity b.Depth of Canrad discontinuity

Figure 6 shows the sketch of Tancheng—Lujiang fault zone, called Tan-Lu fault zone for simplicity(8). This is a deep, complicated, and large scale fault. It is more than 2500 km long from Suihua in the north to Susong in the south. The Tan-Lu fault zone at present is an active fault zone, and become to be an important seismically active belt in the east part of China. The largest historical large earthquake of North China, that is Linyi great earthquake (M = 8.5) in 1668, just had occurred on this seismic belt. The Bohai Sea area is located on the middle part of Tan-Lu fault zone. In the interior part of the Bohai Sea, the Tan-Lu fault is wide and also complicated. Since the tertiary period, this fault zone has become intense depression and crossed by north—western Zhangjiakou—Penglai fault zone. But, the Yingkou—Weifang fault zone has stable north-north-east direction continuously. It can be divided remarkably into two parts by the central Bohai depression as a boundary. The northern part of the Yingkou—Weifang fault is characterized by length in 300 km and extent in 5—20 km. In this part enough more stratums of the mesozonic era distributed, and the fault may control the stratums of cenozonic era. The length and extent of the southern part of Yingkou—Weifang fault are 200 km and 40—50 km, respectively. The thickness of deposit of cenozonic era in the central Bohai depression may be closed to 9500 km, and in the Liaohe river depression it is 6000—7000 m.

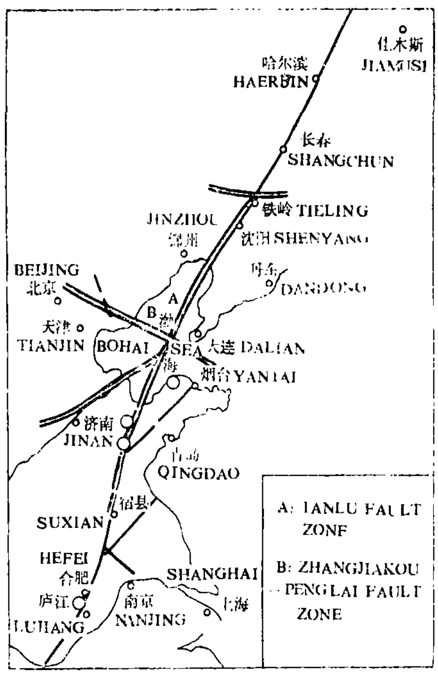


Fig. 6　The sketch of Tancheng—Lujiang Fault Zone

3.2 Brief review of sea-bottom geomorphologic conditions in the Bohai Sea area

The Bohai Sea is basically confined by land, only opened by the Bohai Sea channel in the east. It is a nearly closed sea basin on the continental structure. Its length from east-north to west-south is about 300 sea miles, and its extent in east-west direction is about 187 miles. The extent of the Bohai channel in north-south direction is 57 sea miles. In general, the area of the Bohai Sea is about 77000 km^2, and its average depth is 18 m. Because the Yellow river, Haihe river, Luanhe river, Liaohe river flow into the Bohai Sea and carry a lot of silt there, the Bohai Sea in general is shallow, excepting its deeper central part and channel part (see Fig.7). The slope of the Bohai bottom is small, and its surface has been covered by the recent sediment. All three main bays of the Bohai Sea, namely, the Bohai Bay, Liaodong Bay, and Laizhou Bay have ooze-type coasts.

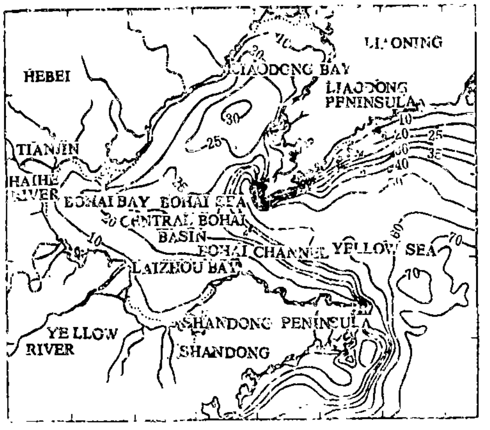


Fig. 7 The sketch of isobathes of Bohai Sea

The Bohai Bay is an arc-shape shallow bay concave westward. In the aspect of tectonic structtre this bay and its coast area belong to the same depression with a east-western tectonic line. The thickness of sedimentary layer of cenozoic era in the whole Bohai Sea is more than 3 km. At present, this bay continuously subsides. The sea-bottom relief is smooth and dull. Its isobathes are parallel to east, and water depth in generally more than 20 m. The sea water is yellow and contains a lot of silt. The sediment mainly consists of powder sand and ooze.

The Liaodong Bay is located in the north of the Bohai Sea. The sea-bottom relief is characterized by smooth slope from the bay top and both east and west side to the central part. The east side of this bay is deeper than the west side. The central part of the bay mouth is the deepest, and its water depth is 32 m. The tectonic structure of the Liaodong Bay is a graben-type depression located between two great faults. The top of this bay links up with the plain of lower reaches of the Liaohe river. The sediment is silt carried by the river. In the bay top, it is covered by ooze, and in the sides it is covered by powder sand.

The Laizhou Bay also can be characterized by smooth shape to central basin. In the most of the bay, water depth is no more than 10 m. The deepest part is located in the west of the bay, and its depth is 18 m. The structure of Laizhou Bay belongs to depression region. The thickness of its sediment of cenozonic era is 8 km. The Tan-Lu fault zone crosses the east of the Laizhou Bay. The surface sediment mainly is powder sand.

The central basin of the Bohai Sea is located between the above-mentioned three bays and the Bohai channel. Its northern part is narrow, but the southern part is broad. So, the shape ia an approximately triangle. The water depth there is 20—25 m. The central part of this basin is low-lying, and the northeastern part is relatively high in sea-bottom relief. The tectonic structure is also a graben-type depression between the two great faults belonging to the Tan-Lu fault zone. The thickness of sediment of the cenozoic era is 5 km. The surface sediment is sand and powder sand.

The Bohai channel is 57 sea miles in south—north width. The Miaodao archipelago consisting of more than 40 islands of different scales is located in the channel mouth and forms 8 main water ways. In general, the water ways in the north are wide and deep, but those in the south are narrow and shallow. The Laootiesan water way is a main passage way where the water from the Yellow sea enters into the Bohai Sea with a large speed. The largest depth of the Bohai channel is 78 m. This is the limited depth of the Bohai Sea, too.

The sea bottom under the water ways is covered by gravel, in some places we can find the bedrock outcropping.

3.3. Stormy waves and meteorological conditions in the Bohai Sea area

The Bohai Sea is a sea area of strong tidal current. The sea current in the Bohai Sea is weak, and its speed is often equivalent to about 1/10 of largest tidal current. The most strong stormy waves appear in winter. They are often of 3 or 4 grade, but the cold waves may approach 6 grade. The heights of stormy waves are different in different seasons. For example, the mean height of stormy waves in January, April, July and October are 11—17, 1.0—1.3, <0.9 and 1.2—1.4 m, respectively. In the period from summer to autumn, the strong stormy waves of grade 6 may sometimes occur under influence of a typhoon. The highest stromy waves often appear in the north of Miaodao archipelago and the central Bohai Sea, and the lowest stormy waves are in the Liaodong Bay and Bohai Bay.

The annual mean atmospheric temperature is 12° C, the highest and lowest atmospheric temperatures in many years are 39.9℃ and -18.3℃, respectively.

The annual mean wind speed is 4.5 m/sec, and the largest is 26.5 m/sec. The winds are usually from west—north in winter and east—south in summer.

3.4.Conditions of navigation and sea work in the Bohai Sea area

The sea lines in Bohai are enough busy. More than :0 ships navigate in the Bohai Sea every day. The Bohai Sea oil field has been developing and constructing. The fishers usually go fishing in the sea, especially in the fishing season.

3.5.Conclusion on the conditions for sea-bottom seismograph observation system in Bohai

The Bohai Sea is an interior sea where the stormy waves are weak, and the mean water depth is only 18 m. There are some installations on the sea which can be used to seismic observations. They are: the platforms of oil wells, navigation marks, light houses, meteorological buoys, and the others. All these conditions are helpful to developing the sea-bottom seismograph observation in the Bohai Sea area.

However, the Bohai is a shallow sea with thick sediment. This condition may cause some difficulties to seismograph observation. The navigation, fishing, and sea work of oil field also may cause some influences which must be considered in the observation.

4.PRELIMINARY INVESTIGATION OF INSTRUNENTS AND TECHNIQUES FOR SEA—BOTTOM SEISMOGRAPH OBSERVATION SYSTEM IN THE BOHAI SEA AREA

4.1.Seismograph observation test on platform of oil well in the Bohai Sea

The ocean seiemograph observation system was advanced since 30 years of recent centenary. The development of sea oil field, monitoring of underground nuclear test and study of sea and ocean seismicity have given a great motivity to develop the ocean-bottom seismograph observation. Many important observation and research works were completed by American and Japanese scientists and scientists of some countries.

In recent years, several organizations of China started to develop sea seismograph observation system. One of them is the Seismological Bureau of Tianjin. This bureau has begun a sea-bottom seismograph observation test on platform of oil well in the Bohai Sea since 1985.

At first, some sea-bottom observations in the oil wells at platforms Nos. 7 and 8 under the Bohai Sea and directly on its sea bottom were completed by using deep well seismometers. Figure 8 shows the locations of the platforms of oil well in the Bohai Sea used to the seismograph observation. The water depths in the areas of platforms

Nos. 7 and 8 are 7 m and 26 m, respectively. The depths of oil well of platforms Nos. 7 and 8 are about 160m and 260m, respectively. The deep well seismometer of JDS—2 type was put into the well bottom. Then, the seismic signal recorded by the deep well seismometer was transmitted by cable to the platform and recorded there by seismograph recorder of DJ—1 type. The deep well seismometer of JDS—2 type is a seismometer of electromagnetic type, and its natural period is 0.8 sec. The amplification of recorder system is about 10000—30000. In the test period, the near and distant earthquakes had recorded very clearly.

Secondly, the test on transmission of seismic signal from the platform No. 7 to the center of observation in Tianjin was made. The seismic signals recorded on the sea were transmitted by "768" radio seismograph telemetering transmitter through FM—FM way to the Dongtai station on the land. After demodulation, these were converted into original seismic signals, then these signals were input into "PTY—8" seismograph telemetering transmitter and transmitted to the observation center in Tianjin via telephone line (see Fig.8).

The result of test on the platform No. 8 indicates that the background noise is larger than that on the platform No. 7.

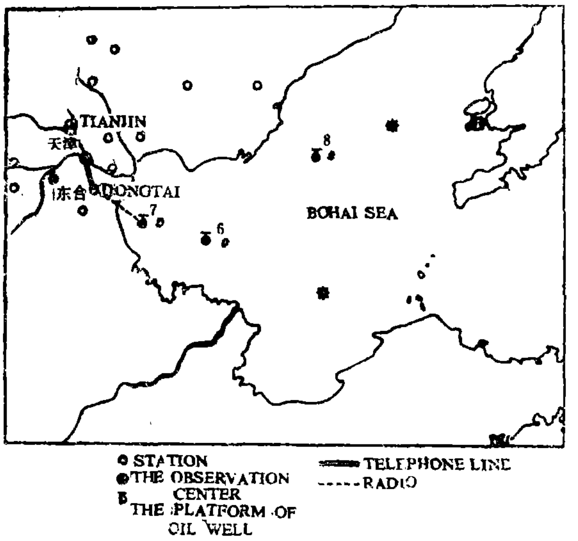


Fig. 8 The locations of oil platforms used to seismograph observation test in Bohai Sea and the transmission ways of seismic signals on the sea

4.2. Sea-ocean noises and seismograph observation

Studies of seismic noises and microseisms are very important for seismological observations. There are many specialists and scientists in the world, who conducted the ocean noises. A series of successful results were obtained. Based on the data, observed at some standard observational points in 1963, the analyses of absolute and relative power density spectra of ocean noises and the researches of worldwide microseismic activity were conducted by G. D. Hair and J. H. Funk in 1964. From power density spectra of noises, it was noted that a uniform worldwide pattern of slopes was observed between 1 cps and 2 cps. The same change in the slope was observed by Vinnik and Pruchkina in 1964(3). Figure 9 shows that the number of stations whose spectral slope (frequency 1.0 cps or greater) falls within each slope increment of 10 dB/octave. It was noted that 84.1 percent of the slope's values fall within the range of 10—40 dB/octave and that of these 48.8 percent fall within the range of 20—30 dB/octave. Iyer has suggested that the earth itself is filled with noise(2). The other causes of noises, from cultural noise to sea storms, have been investigated, too. The problem lends itself for further study. G. D. Hair and J. H. Funk considered that two separate sources generating microseisms above and below 1 cps respectively can be suggested, and that the spectra above 1 cps are independent of storms, fronts, etc. The spectra for frequencies less than 1.0 cps show greater seasonal variations. These variations were concluded to be mostly meteorological in origin. Monthly contour maps of average noise show that noise is seasonally variable and that it is attenuated at continental structures.

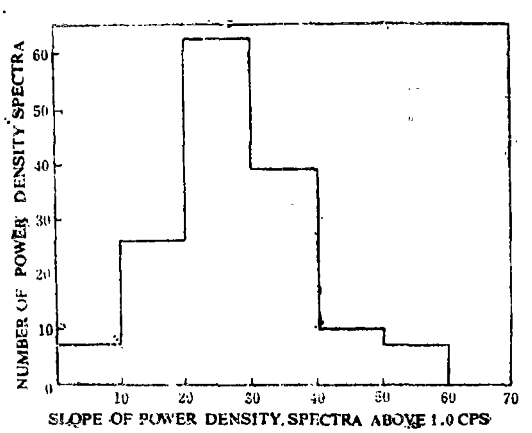


Fig.9 Comparison of spectral slopes at frequency of 1.0 cps or greater

During the period of development of a cable-type ocean-bottom seismograph (OBS) observation system, the relation between ocean microseisms and environmental conditions were studied by the Meteorological Research Institute(MRI) of JMA(5). The results show that the amplitudes of ocean-bottom microseismic noises are relevant to stormy waves on the ocean surface. Figure 10 compares the amplitudes of three kinds of stormy phenomena (wind, wave and swell) observed at the Omaezaki Weather Station of JMA and corresponding microseismic noises.

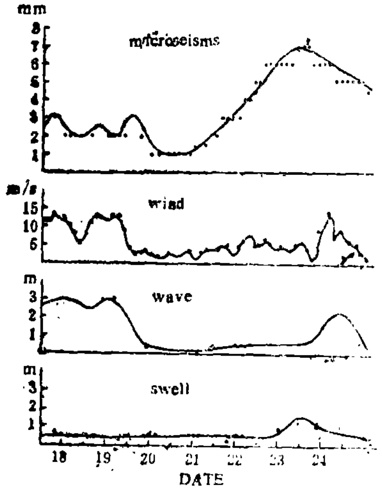


Fig.10Comparison of three kinds of phenomena observed at Omaezaki weather station and the corresponding microseisms

A. William Prothero, Jr. considers the noises caused by sources of geophysical fields include the background microseismic noises and the noises induced by ocean current. In the shallow sea and the sea area where geophysical prospecting is developed, the noises from activities of living things and humankind may play important roles. Moreover, the soft sediment on the ocean or sea bottom may amplify the microseismic noises.

The problem on the influences of noises from sea surface to sea-bottom seismograph observation is very important to shallow sea, such as the Bohai Sea of China. In order to study this problem, we have completed some modelling experiments by using a water channel. The results obtained will be described in the next section of this reprot.

The studies of ocean and sea noises can be used to calculate the theoretical limits of perceptibility for a given station and determine the countermeasures against the seasonal variations of noise levels. Moreover, the analyses of noise spectra are useful to choose the frequency band of seismograph. H. Brander gave an example for comparison of spectra power density of deep sea-bottom noises with that of land noises, as shown in Fig. 11. From this plot, we can see that the spectra power density of deep sea-bottom noises in high frequency domain is obviously smaller than that in its low frequency domain. Figure 12 shows the seismic noise spectrum observed by using OBS. This result was obtained by H. Matsumoto and M. Takahashi(4). For comparison, some noise spectra observed on the land by Brune and Oliver (1959, MAX, AVE, MIN) and by Peterson and Orsini (1976, P&O) are shown in Fig. 4,5, too. From these plots, we can see that the amplitudes of ocean-bottom noises with period in 2—3 second are in 10 times larger than that of land noises with the same period. But, in the frequency range of the short period small earthquakes, the difference between them becomes unremarkable.

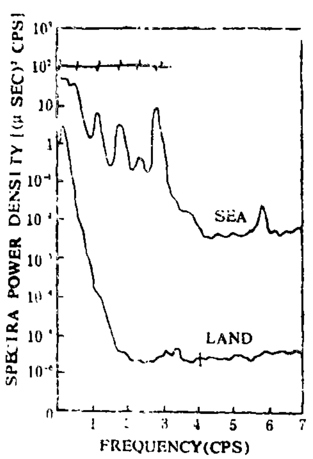


Fig.11 Comparison of spectral power densities observed on the sea bottom and on the land

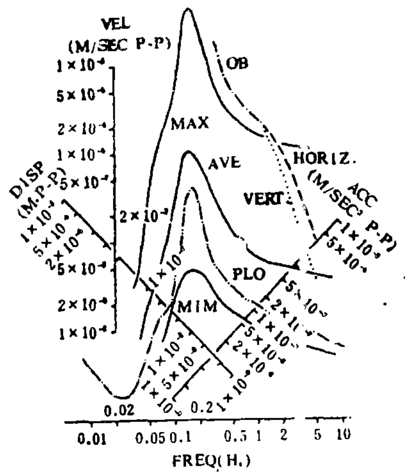


Fig.12 Comparison of noise spectra on the sea observed by OBS and on the land

Finally, the noise from ship navigating on the sea is an another type noise. This noise is often characterized by high frequency, higher than 10 cps. Moreover, when the ship is navigating at the distance, more than 5 km from seismometer, its influence may be enough weak.

From the above-mentioned results, it can be seen that the 0.2—2 cps band is most noisy frequency band on the sea bottom for seismic observation.

4.3. Preliminary project for development of sea-bottom seismograph observation system in the Bohai Sea area.

The ocean-bottom seismograph systems, prepared by seismologists in different countries, in aspect of their locations can be classified into three kinds. The first kind OBS systems include the anchored buoy type OBS, pop-up OBS, cable type OBS, etc. The seismometers of such kind OBS systems are put down directly into the ocean bottom. The OBS systems of second kind are so-called hydrophone systems characterized by hanging the sensors in the water. The OBS systems of the third kind are characterized by using holes or wells directly into the ocean or sea bottom and putting the sensors in holes or wells. according to the present conditions, we can consider that the OBS systems of the third kind may be more suitable to sea-bottom seismograph observation in the Bohai Sea area.

Based on the results obtained in this report for development of the sea-bottom seismograph observation in the Bohai Sea area can be proposed.

1. Establishing the sea-bottom seismograph observation system in the Bohai Sea on the sea footing of oil platforms.

According to the geological and geophysical conditions, and considering the fact that some oil platforms may be used, we can suggest to establish the sea-bottom seismograph observation system in the Bohai Sea area directly on the sea footings of oil platforms. The oil platforms in the Bohai Sea can be used as centers of seismological observation or relay stations. The seismometers can be put in the oil wells on platforms or put down on the sea bottom. The sea-bottom seismograph observation by using oil wells on platform at present also has good prospect. To be alike to the case of deep well observation on the land, we can expect to get enough high signal to noise ratio, if the used well is enough deep. Of course, the parameters of deep well seismometer used to oil well on the sea platform must be determined according to the features of sea-bottom microseismic noises.

It is important to find a footing on the sea. For example, in order to monitor the activity of earthquakes in nests east off Fukushima Prefecture, northern Japan, the Center of Earthquake Prediction Observation of Tohoku University has established an OIP seismological observation point on the Pacific ocean by using of the SSO company as a footing in the sea. A hydrophone hanging on the wellstand in the water was used as a sensor. The seismic signal detected by the hydrophone was transmitted to the platform by cable, and then transmitted to a land station by radio communication of 400 Mcps.

At the same time, it is necessary to develop the sea-bottom seismograph observation system of the first kind in which the seismometers are put on the sea bottom directly.

2. On design of the sea-bottom seismograph.

The key problem for the sea-bottom seismograph observation in shallow sea is how to enhance the signal to noise ratio. From the above-mentioned discussion on sea-bottom microseismic noises, we can obtain that the most noisy frequency band on the sea bottom is the band in 0.2—2 cps. Therefore, to avoid the noisy band of sea bottom noises, the natural frequency of seismometers must be taken as about 4.5 cps for recording the near earthquakes. In the other cases, we can cut the lower frequency signal from the sensor by using an electric filter. Moreover, the developing low-noise pre-amplifier and putting it into the cylinder sealed container together with seismometer is useful to enhance the signal to noise ratio.

In order to the coupling between seismometer and sea bottom, we can apply the method of water work to free the seismometer sensor into sea-bottom silt. In this case in the seismometer design, we must consider its performance.

3.The means of record, transmition, and power supply.

The seismic signal, detected by seismometer, can be recorded by slow speed tape recorder or by using visual record way. The seismic signal detected in the Bohai Sea also can be transmitted to the land relay station by 400 Mcps radio communication installation through FM-FM way or PCM way. Then, the signal will be transmitted to the observation center. Considering the effect of curvature of the earth's surface, the communication distance d and antenna height h in 400 Mcps communication must satisfy the following relation:

$$d = \sqrt{2kah(m)} \qquad (km),$$

where the constant $k = 4/3$.

The above expression can be written as:

$$d = 4.12\sqrt{h(m)} \qquad (km).$$

When $d = 83$km, we can find $h \approx 400$m.

The location of land receive station must be chosen according to the relief features of the Bohai coast region by using natural height difference for reduction of the spending.

Finally, to supply the power, we can use a solar cell system which is more suitable to seismological observation on the sea. In this case, the sea-bottom seismograph observation system must be designed on the basis of maximum decrease of power. The application of seismic signal transmission system of detonation by contract may be effective for power decrease.

5.AN EXPERIMENT FOR ASSESSMENT OF THE SEISMIC NOISE UNDER THE BOHAI SEA AREA

In order to study the relation between roughness of sea surface and seismic noise, a modelling experiment was carried out using a water channel. A feasibility study was conducted for testing an applicability of hydrophone as a sensor of the sea-bottom seismograph observation system in the Bohai Sea area, too.

5.1.Modelling experiment

An experiment was carried out at the Institute of Ocean Environmental Technology of Japan Fundation of Shipbuilding Advancement on March 4 and 5, 1987. The characteristics and performance of the water channel used in the present experiment is given in Table 3.

The hydrophone was set at the middle part of the water channel, and the position of the hydrophone was manually changed in accorda-

Table 3 Characteristics and Performance of the channel

Equipment	Characteristics and performance	Remarks
Tank (Horizontal circulating type)	Length of measuring part 60m Width of measuring part 3.8m Depth of measuring part 5.1m Standard water depth 4.3m	Measuring part… Reinforced concret construction with steel plate linings inside Tunnel part… Steel plate construction
Wave Generator (Flap type hydroelectric system)	Max. wave height 0.6m Max. wave length 10m Regular, irregular and transient waves	
Current Generator (Axial flow pump with variable pitch impeller)	Current velocity at measuring part 0.1-1.5m/sec Current direction reversible	
Air Blower	Size of duct 3.6×0.4m Wind velocity 5-20m/sec	Installed on a carriage*
Surface Cerrent Generator (Water jet type)	Max. velocity at outlet 0.5m/sec	Installed on a common-use carriage*
Oil Dispersing Device	Rate of dispersion max. 1.5m^3/min	
Measuring Carriage*	Length 4.0m Width 4.85m	Steel box girder structure
Mono-rail Hoist	Capacity×No. of unit 2.8t×3 units	Two on the north and one on the south of measuring part
House	Length 80m Width 12m Eaves height 12.4m Floor area Total 2,426m^2	3-storied, steel framed construction covering measuring part and the following rooms: 1st flor… power room, machinerg room 2nd floor… working platform, oil supply tank 3rd floor… control room, chemical laboratory

*All the carriages are set on rails which are laid on the side walls of the measuring part of the channel, and can be moved and fixed at any position by man power.

nce with the measurement conditions, in order to determine the vertical distribution of pressure intensity. The experiment was conducted by changing wave types, too. The three different type waves were produced at the following ways:

1) Propagating wave

We produced propagating waves by a wave generetor. The generator is stop the operation when a head wave reaches just above the hydrophone in order to avoid uncontrolled signals which will be induced by interferance of generated original waves.

2) Wind wave

Wind waves were produced by an air blower.

3) Dummy seismic waves

Some waves similar to seismic waves were generated by dropping an iron block on the iron bridge on the water channel. The hydrophone was hanged from the bridge. Figure 13 shows the schematic diagram of the measuring equipment, and in Table 4 are given characteristics of the hydrophone use in the experiment.

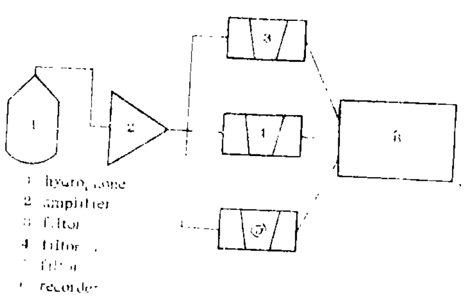


Fig.13 Schematic diagram of the measuring system

Table 4 Specification of Hydrophone

Item	specification
Natural frequency	8Hz
Sensitivity	7.5V/bar
Response	±1(11)8≈800Hz
Impedance	250Ω
DC resistance	140Ω
Maximum working depth	75m
Destruction depth	150m
Operating temperature	035℃
Case dimensions	Diameter 5cm
	Length 12cm
	Weight 230g

5.2 Results obtained from the experiment

Figure 14 shows the composite record of the hydrophone obtained by the present experiment. From these records, we can find directly some features of the pressure intensity distribution in the water.

In the records of the propagating wave experiments, we can find that the amplitude is decreasing when the position of the hydrophone becomes deeper. However, we can not find significant change in amplitude by depth in case of records obtained by the wind wave experiment.

Moreover, the records by the dummy signal show almostly same amplitude, irrespective of the depth of hydrophone.

5.3. Evaluation of the experiment

The water pressure distribution in the water induced from the propagating surface wave can be calculated by a hydrostatic theory. More concretely, relative intensity can be calculated by the following abriged formula:

$$Pw = 1/\cosh(kh),$$

where Pw is relative pressure in the water by surface wave, k the wave number and h depth.

By using of the formula, we can estimate the distributions of pressure and relative intensity in the water channel. The result of the calculation for some cases is given in Table 5. Meanwhile, the records in Fig. 14a are obtained when the wave generator sent wave train whose wave length and wave height are 3m and 30cm, respectively.

Table 5 Result of the calculation for the relative Pressure distribulion

Depth	Relative pressure
1	1/1.05
2	1/1.18
3	1/1.43
4	1/1.81
5	1/2.35
1000	1/00

The records show that the amplitude distribution as a function of the depth of the hydrophone harmonizes with that calculated by the above formula. On the contrary, the records in Fig. 14b and 14b differ from that in Fig. 14a. This means that the features of the signals shown in Figs. 14b and 14b may differ from those of the signals shown in Fig. 14a.

Many records for P waves reflected at the sea surface, which were obtained by the Tokai OBS, proved that the amplitude attenuation of compressional waves is very small. This evidence seems to suggest that both the signals generated by the air blower and iron block may be compressional waves.

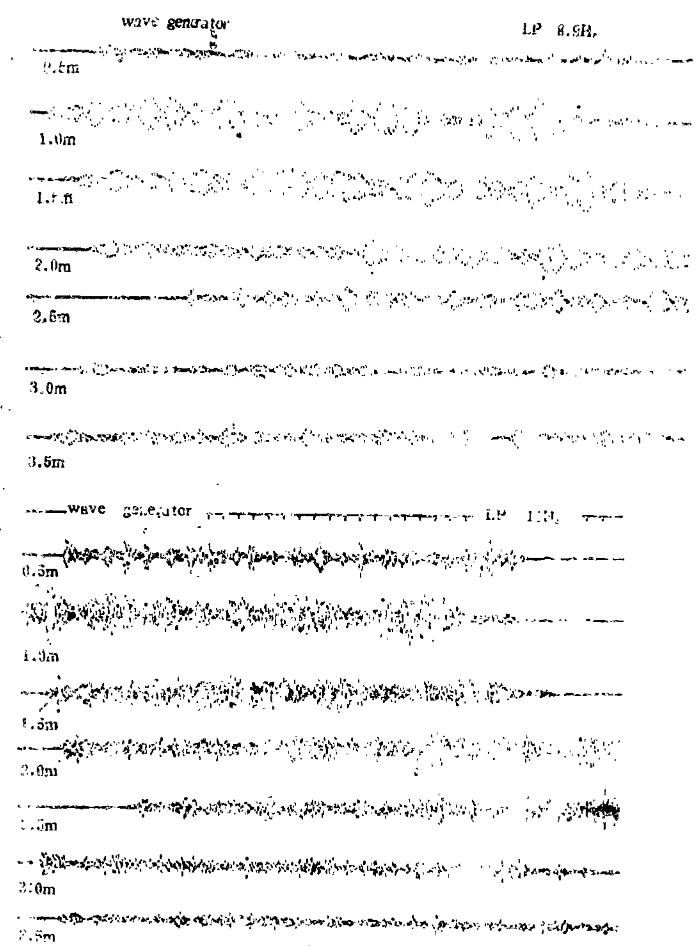
5.4. Application to the sea-bottom seismograph observation system in the Bohai Sea area

The seismic noise level of the Bohai Sea area can be estimated from the result stated above. The mean sea depth of the Bohai Sea area is nearly 18m. Therefore, the relative pressure at the sea bottom caused by the surface sea wave will reduce to 1/4 of the surface pressure, but signals recorded by the sea-bottom seismograph will be contaminated by this pressure due to roughness of the sea surface.

Because the mean sea depth of the JMA OBS sites exceeds 1000m, seismic noise due to the surface roughness of the sea can not exist near the OBS. However, the compressional waves produced by the wind will contaminate signals obtained by both the system either of the Tokai OBS or the sea-bottom of the Bohai Sea.

5.5. Comment to the design for the sea-bottom seismograph system in the Bohai Sea

Needless to say, it is indispensable to evaluate environmental noises, before fixing of the specification of the total system. Through the present experiment, we evaluated the difference in the features of noises produced by different types of noise sources. And, at same time, the present experiment proved the usefullness and convenience of a hydrophone for the seismological observations.



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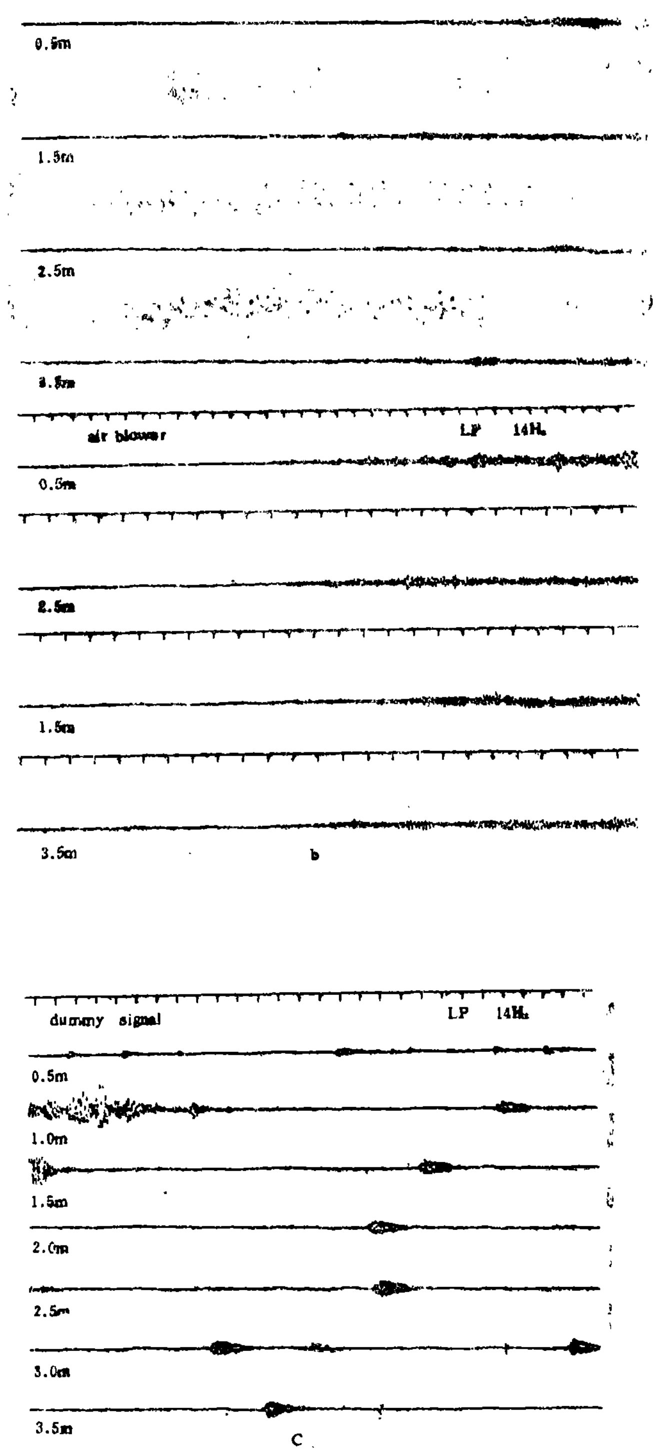

Fig.14 Examples of the record registered by the experiment
a. wave generator　b. air blower　c. dummy signal

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中国渤海地区海底地震观测的初步研究*

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摘　　要

本文是在日本造船振兴财团的经费赞助下在中国渤海地区发展海底地震观测的初步技术报告。

本报告主要包括以下内容：

（1）渤海及其邻近地区的地震活动性与地震危险性估计；

（2）渤海地区海底地震观测的条件；

（3）渤海地区海底地震观测仪器与技术的某些初步研究结果；

（4）浅海情况下海底地震观测噪声的模拟实验研究结果。

文中研究了该地区的历史与现代地震活动性、长期地震危险性以及发生在华北与日本的大地震之间的关系。还讨论了渤海强震和海啸对渤海及其邻近海域航海的影响问题。在这些研究结果的基础上对在渤海地区开展海底地震观测的必要性进行了解释。

本文探讨了在渤海地区进行海底地震观测的某些仪器和技术问题。天津市地震局曾在渤海地区石油平台的油井中作过初步地震观测试验。日本气象厅气象研究所发展的海底地震观测中有关降低噪声与信号传输等方面的新技术与经验可用于渤海地区的海底地震观测。在这些研究的基础上，提出了一个在中国渤海地区发展渤海地震观测的初步设想。指出渤海海底地震观测试验应从观测和研究渤海海底海洋噪声谱开始。

为了研究浅海情况下海底地震观测的噪声，本文完成了一项新的模拟试验工作。分别对海面源及海内源产生的噪声进行了实验研究。文中给出了一些重要实验结果。

本文所得的初步结果，对发展渤海及邻近地区海底地震观测有一定的参考价值。

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1）中国国家地震局天津市地震局
2）日本气象厅气象研究所