

## **CONTINENTAL SHELF SURVEY PROJECT OF JAPAN**

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### **1. OUTLINE OF THE CONTINENTAL SHELF SURVEY PROJECT OF JAPAN**

In recent years, transportation, exploration, exploitation and other activities at sea around Japan have become very brisk. To cope with these activities and to establish a new maritime regime according to the U.N. Law of the Sea Convention, the Hydrographic Department of Japan has been conducting a survey project since 1967 to acquire the basic information of the continental shelves of Japan, which include bottom topography, seismic reflections, seismic refractions, gravity, magnetic and other geological data. At the beginning of this survey project, the continental shelf was considered to be limited within the areas up to 200 meters depth or areas with exploitable depths, in accordance with the definition in the Convention on the Continental Shelf (1958, Geneva). In the initial survey program, called 'Phase 1' here, areas with depths of up to 200 meters and adjacent continental slopes were chosen as the survey areas, where the Department conducted sounding, seismic reflection survey and geomagnetic and gravity measurements. The results of the survey program were published in the form of 'Basic Map of the Sea in Continental Shelf Areas' on a scale of 1 to 200,000. This Phase 1 of the project has already been completed (KAWAKAMI, 1970).

Discussions at the Third United Nations Conference on the Law of the Sea resulted in a drastic change in the concept of the limits of the continental shelf, reflecting the recent rapid advance of marine technology. In the new Convention on the Law of the Sea, however, the continental shelf was defined as

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the area comprising the sea bed and subsoil of the submarine areas that extend beyond the territorial sea throughout the natural prolongation of a land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance. In a case where the margin extends beyond 200 nautical miles, the outer edge of the continental margin shall be established on the basis of topographical and geological conditions. The definition of the continental shelf is set forth in Article 76 of the Convention on the Law of the Sea and the topographical and geological conditions are described in paragraph 4 as:

- 4 (a) For the purposes of this Convention, the Coastal State shall establish the outer edge of the continental margin wherever the margin extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by either:
- (i) a line delineated in accordance with paragraph 7 by reference to the outermost fixed points at each of which the thickness of sedimentary rocks is at least 1 per cent of the shortest distance from such point to the foot of the continental slope; or
  - (ii) a line delineated in accordance with paragraph 7 by reference to fixed points not more than 60 nautical miles from the foot of the continental slope.
- (b) In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base.

In paragraph 7 it is stipulated that the coastal State shall delineate the outer limits of its Continental Shelf, where that shelf extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by co-ordinates of latitude and longitude.

Of the vast continental shelves around Japan, those located to the south of Japan are thought to have possible continental margins extending beyond 200 nautical miles. To make peaceful and effective use of these southern continental shelves, it is essential to obtain meaningful scientific and technological data of them and results of these scientific and technological investigations of such limits must be submitted to the Commission on the Limits of the Continental Shelf as soon as possible, but in any case within ten years of the entry into force of this Convention for the State (Annex II of the Convention).

For this purpose, the Hydrographic Department of Japan started on a three-year program to build a new survey vessel *Takuyo* (gross tonnage: 2,600 tons) in 1981, and reshuffled its organization in 1983, thereby establishing the 'Continental Shelf Surveys Office'. Also, since 1973 the Department has been conducting a survey program to prepare the Basic Map of the Sea in Coastal Waters comprised of a basic data set for determining the baselines. The results of the survey for the Basic Map of the Sea in Coastal Waters have been published in the bathymetric and geological structure charts. Furthermore, efforts are currently being made to develop a precise geodetic network for marine geodetic control

around Japan to determine the accurate locations of Japan's main islands and off-lying isolated islands. In order to determine the relationship between the regional geodetic system of Japan (Tokyo Datum) and the World Geodetic Reference System, the Department has been carrying out satellite laser ranging to 'Lageos' since 1982. On 13 August, 1986 a Japanese geodetic satellite was launched and named 'AJISAI'. Ajisai is equipped with cube corner reflectors and solar reflectors, and is in orbit at about 1,500 km altitude. Since the altitude of the orbit is very low, Ajisai is supposed to be effective in conducting precise laser ranging from the isolated islands. Now the Department is producing a transportable laser ranging system. Precise geodetic observation by laser ranging on the isolated islands will be started in 1988.

'Phase 2' of the Continental Shelf Survey Project was started in October 1983 when the survey vessel *Takuyo* was built and the crew and engineer training program was completed. In Phase 2 of the project, waters south of Japan were given the first priority of the surrounding waters of Japan. The whole area of the Continental Shelf Survey Project was divided into  $3^\circ$  latitude  $\times$   $2.5^\circ$  longitude squares, and three of these squares are being surveyed each year. Figure 1 shows these survey areas and squares. Depth sounding, seismic reflection survey, gravity and magnetic measurement, dredging of sea bed samples, photographing of the

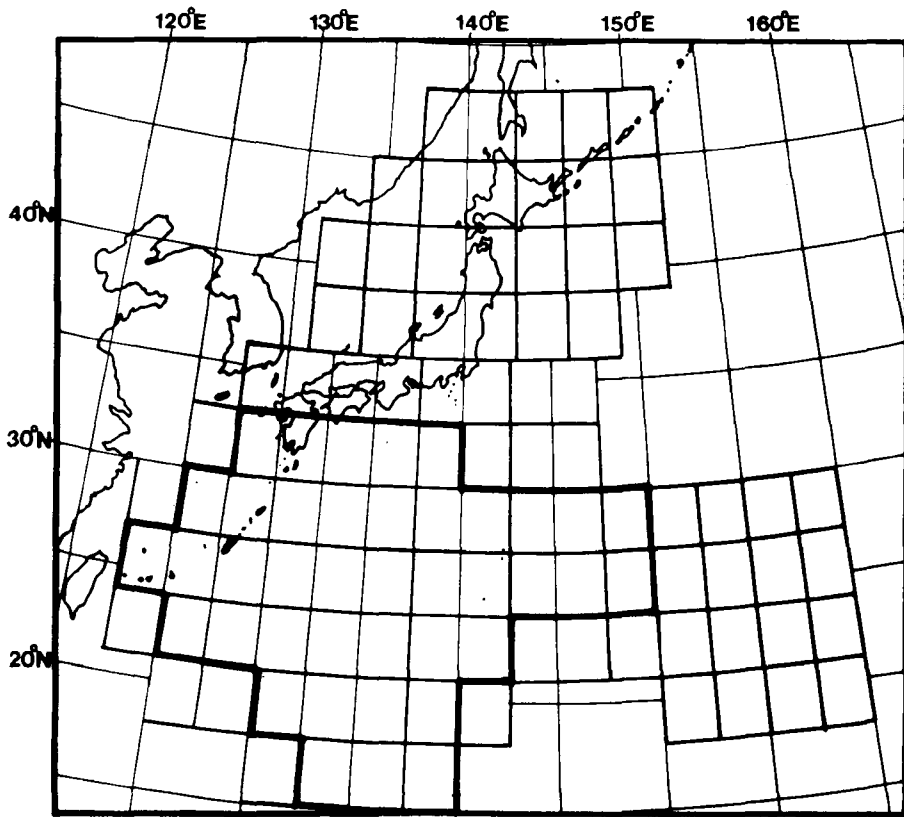


FIG. 1. — Survey areas and squares of the Continental Shelf Survey Project. Thick line is showing the area given the first priority. The Department has been surveying three squares a year.

sea bottom and observation of vertical distribution of salinity and temperature are carried out in each square of the survey area. Average spacing of the survey tracks is 5 nautical miles, whereas the special areas of interest were covered by closer tracks. Smooth sheets of the survey are compiled at a scale of 1 to 500,000.

In response to the strong demands by resource development related experts, fishery related experts and earth scientists in Japan for these continental shelf data, the Hydrographic Department of Japan has been providing them with these data through the Japan Oceanographic Data Center. Also the surveyed data have been used in nautical chart compilation whenever the surveyed areas are included in the charts concerned. Furthermore, the Department is going to publish a new series of Basic Maps of the Sea in Continental Shelf Areas at a scale of 1 to 500,000. This basic map series is expected to play an important role in future continental shelf exploitation in Japan.

## 2. SURVEY VESSEL AND EQUIPMENTS

The survey vessel *Takuyo*, which is primarily designed for use in the Continental Shelf Survey Project, was built at Nippon Kokan K.K. Tsurumi Works, Yokohama, Japan and commissioned in August 1983.

The principal particulars of the *Takuyo* are as follows:

Type of ship	.....	Flush deck with forecastle
Length overall	.....	96.00 meters
Breadth moulded	...	14.20 meters
Depth moulded	.....	7.30 meters
Gross tonnage	.....	2,600 tons
Cruising speed	.....	16 knots
Cruising range	.....	12,000 miles
Complement	.....	38 officers and crew members (additionally 23 scientists and/or technicians can be accommodated, if necessary).

The major equipment for hydrographic and geological surveys are:

- 1 Magnavox integrated navigation system, model 200, composed of 2 satellite receivers (for Transit and Navstar), 1 Omega receiver, 2 Loran-C receivers, 1 cesium oscillator and 1 computer;
- 1 data acquisition and processing system Hewlett-Packard 2197A (1 MB) with a plotter TDM/912LHB manufactured by Tokyo Denki Co. Ltd.;
- 1 Sea Beam precision bathymetric system manufactured by General Instrument Corporation;
- 1 precision echo sounder, 12/34 kHz, manufactured by Raytheon Ocean Systems Company;
- 1 digital marine seismic profiling system (12-24 channels) manufactured by Texas Instruments Incorporated, with an air gun Bolt PAR 1500C of 466/1,000 cubic inches;

- 1 3.5 kHz sub-bottom profiler with correlation echo sounder processor (CESP);
- 1 proton magnetometer manufactured by Barringer Research GM/123;
- 1 onboard gravimeter system GBBH KSS/30 manufactured by Bodenseewerk Geosystems;
- 1 CTD/O system mark 3B manufactured by Neil Brown Instrument Systems;
- 1 Batfish model 8801 with CTD system manufactured by Guildeline Instrument, Ltd.

The installation of the Sea Beam system enabled the rapid acquisition of precise bathymetric data (GLENN, 1970) which was incorporated for the purpose of precisely defining the 2,500 m contour line, the exact location of the foot of the continental slope. The 12/24-channel digital marine seismic profiling system was installed aboard the vessel to investigate the structure and thickness of sedimentary layers. The proton magnetometer and the onboard gravimeter system are instrumental in investigating the other physical features of the sea bed. The gravimeter room is located in the center of the vessel where the motion by rolling and pitching is expected to be minimum. The room was designed free from various kinds of mechanical oscillation of the vessel. Furthermore, an observation platform of aseismic structure is installed in the room in which the gravimeter sensor is placed.

### 3. DATA PROCESSING

#### 3-1 Field Processing

The *Takuyo* has an off-line field data processing system. This system consists of a Hewlett-Packard 2179A with 1.5 megabyte memory, one 132 megabyte + two 10 megabyte disk drives, two magnetic tape units and a pen plotter (841 mm × 1,200 mm).

The flow chart for field data processing is shown in Figure 2. The major routines of field data processing are:

- Correcting ship's position and compiling the complete position data files.
- Merging position data and Sea Beam data into a single file, and compiling preliminary Sea Beam bathymetric chart.
- Compiling and plotting geophysical data files.

Corrections of ship's position are done both on a real-time basis and non real-time basis. When anomalous discrepancies between the successive positioning data are found on board by monitoring the track of the ship displayed on the CRT, the surveyor quickly changes the fix to recover a reasonable position by using a stronger fix among the satellite fixing data, Loran C data, Doppler sonar data and others. This real-time correction, however, leaves erroneous positioning

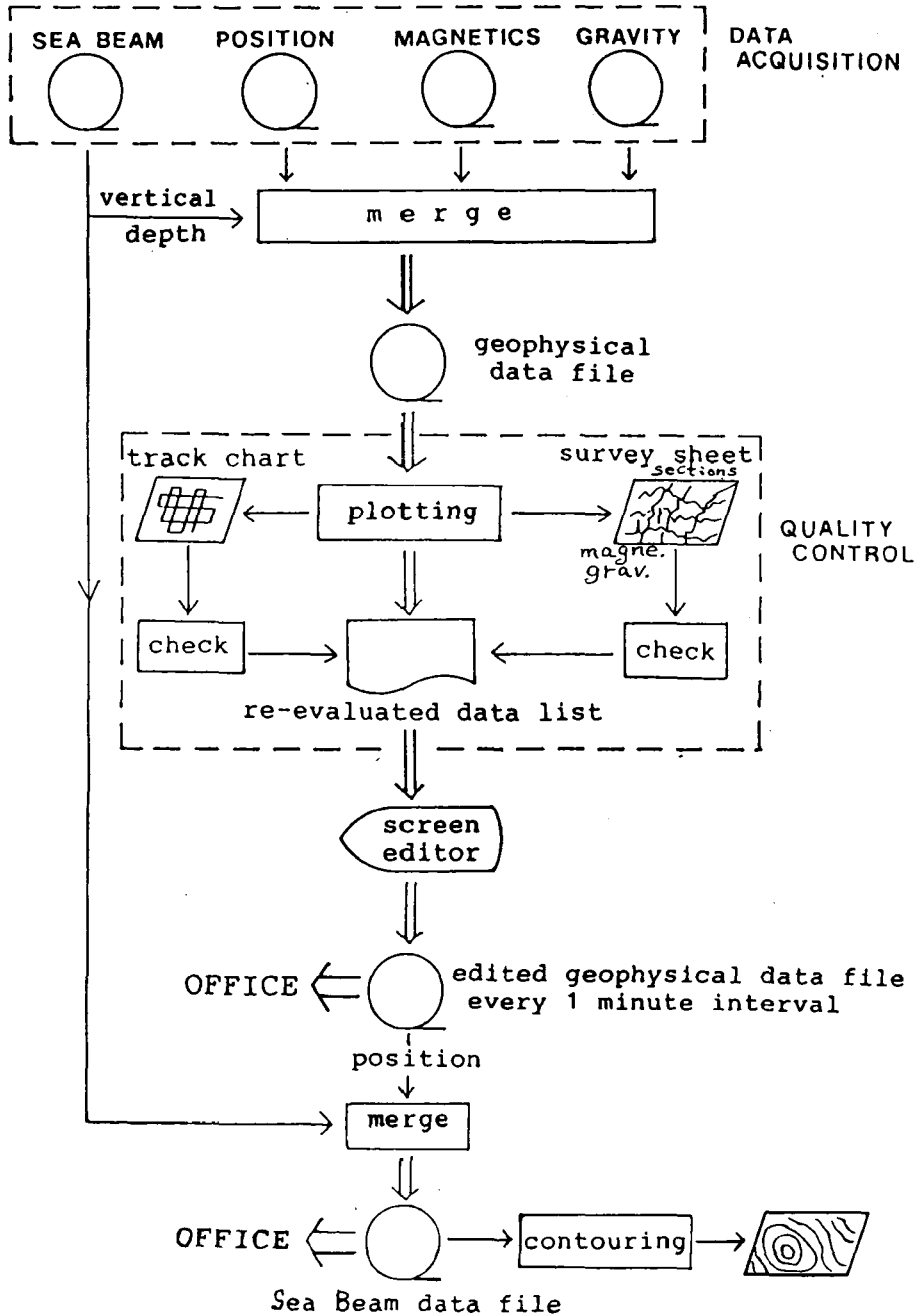


FIG. 2. — Flow chart for office data processing.

data on magnetic tapes prior to the recovery of fixed position. The surveyor must, if necessary, refine the previous ship's position using all available navigational aid information to give the best position and replace erroneous data with revised data. All the changes of fix calculations are done on board, so that

the complete positioning data files are compiled before returning to port.

The positioning data files are checked by plotting the ship's track. After satisfactory plotting, positioning data are merged with Sea Beam data into a single file which is used in compiling a preliminary Sea Beam bathymetric chart on board.

For the convenience of plotting survey data, geophysical data files composed of even 1 minute interval positioning, depth, geomagnetic and gravity data are compiled. Sea Beam data files and geophysical data files are forwarded to the office for further processing.

### 3-2 Office Processing

The system used consists of a Hewlett Packard PA-5248A with two 1 megabyte memories, one 132 megabyte disk memory, 2 magnetic tape units, a color graphics terminal, a color plotter, and digitizing tablet.

The basic requirements of the data processing system in the office are:

- Compatible with the on board computer so that there is no need to change the code of data compiled on board. Software developed in the office can be used on board with only a slight modification, and vice versa.
- Capable of editing data rapidly with an interactive color graphics terminal, a digitizing tablet and a large disk memory.

Digital multi-channel seismic data are processed and analyzed by private companies under contract.

The flow chart of data processing in the office is shown in Figure 3. Major routines of data processing in the office are:

- Correcting geomagnetic daily and short period variations and instrumental drift of gravimeter.
- Editing and checking the data files to correct error, to add or delete data.
- Compiling the final Sea Beam data files.
- Compiling the final geophysical and geological data files.
- Compiling bathymetric map, total intensity anomaly map and free-air gravity anomaly map.

Geomagnetic variations are observed at a selected point on the sea bed in the survey area by an Ocean Bottom Magnetometer (OBM) during the survey period. The effect of geomagnetic daily and short period variations is removed by geomagnetic filtering techniques with the OBM data. Corrections for instrumental drift of the gravimeter are measured at the quay of the Hydrographic Department at Tokyo Port. Eötvös corrections are re-evaluated where ship's position data show anomalous discrepancy and Eötvös corrections applied on board seem to be insufficient.

Two kinds of data files are compiled and preserved as final processed files,

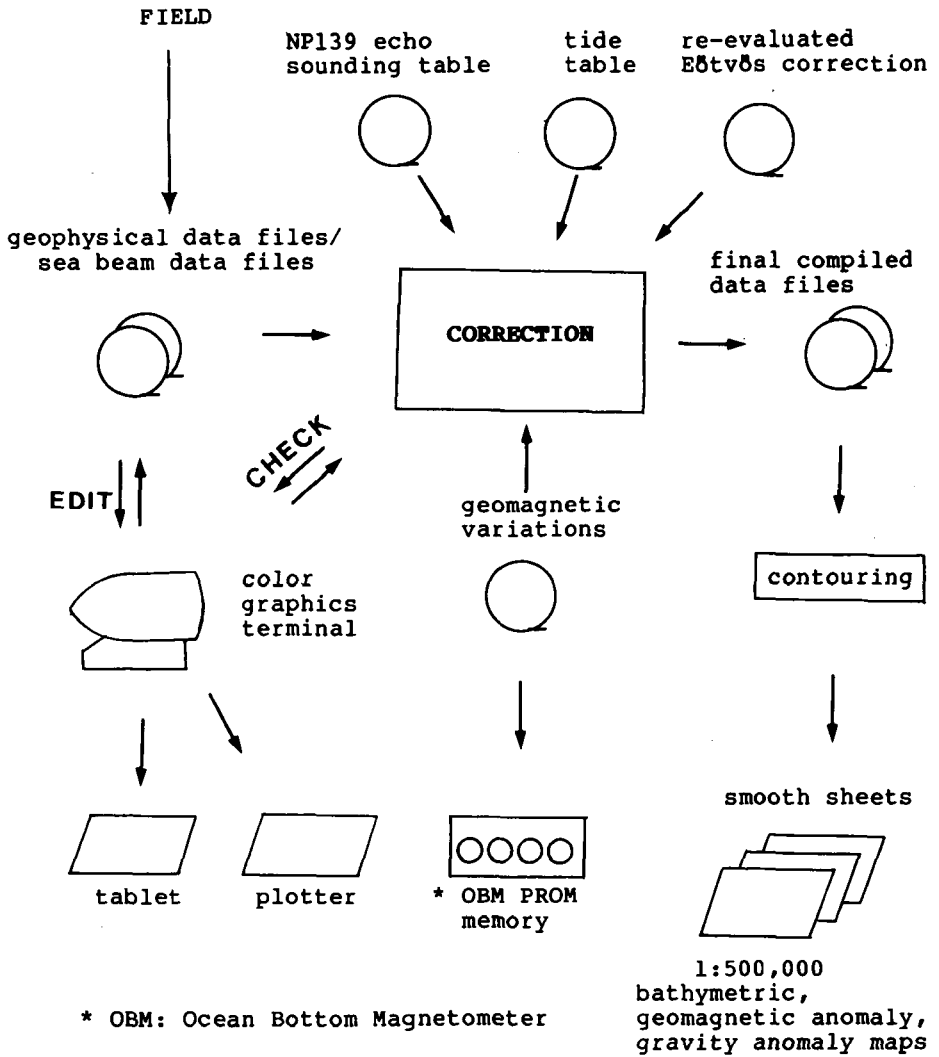


FIG. 3. — Flow chart for office data processing.

that is Sea Beam data files and geophysical data files composed of even 1 minute interval positioning, depth, geomagnetic total intensity and free-air anomaly data. These data are plotted on the graphic charts for careful checking.

Finally, bathymetric and geophysical data are compiled into smooth sheets.

#### 4. DIFFICULTY IN ESTABLISHING THE LIMITS OF THE CONTINENTAL SHELF IN THE PACIFIC RIM

The Convention on the Law of the Sea stipulates that the limits of the continental shelf shall be determined from topographical, geological and geophy-



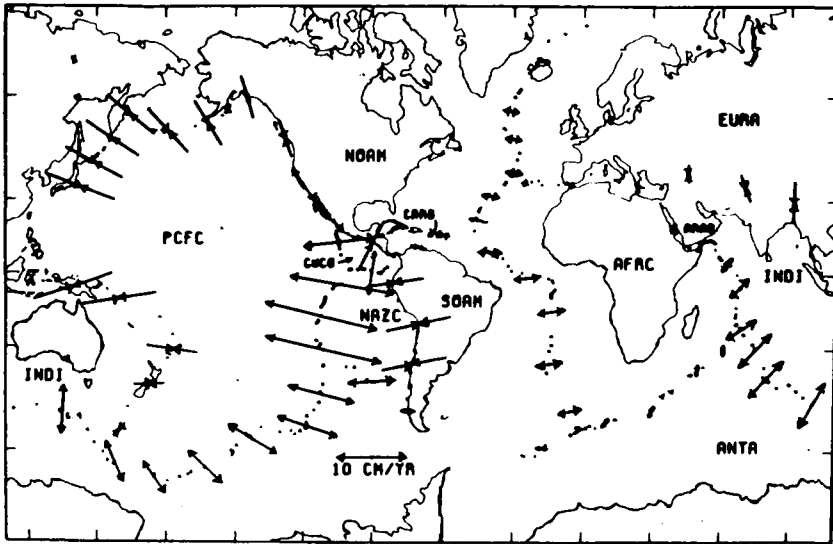


FIG. 4. — Relative velocities between major plates at selected points along plate boundaries (MINSTER and JORDAN, 1980).

EURA — Eurasian plate	NOAM — North American plate
INDI — Indian plate	SOAM — South American plate
ARAB — Arabian plate	CARB — Caribbean plate
ANTA — Antarctic plate	COCO — Cocos plate
AFRC — African plate	NAZC — Nazca plate
	PCFC — Pacific plate

sical parameters. It is necessary, therefore, to review the characteristics of the continental margins.

Figure 4 shows relative velocities between major plates along plate boundaries (MINSTER and JORDAN, 1980). In modern earth science the geological phenomena of the earth are explained well by the plate tectonics theory. The theory maintains that the earth's surface is covered with more than twenty plate-like lithospheres and that such geological phenomena as earthquakes and volcanic activity are caused by the spreading or collision of these lithospheres. The oceanic plate, produced on the mid-oceanic ridge, moves across the ocean and subsides beneath the trench. The continent is composed of several plates which are different from the oceanic plate. Figure 4 shows that along the coast of Europe, the west coast of Africa and the east coasts of North and South America, the continental plates move in accordance with the motion of the oceanic plates. So there is no significant interaction between the oceanic and the continental plates. The boundaries between the ocean and the continent in these regions are called 'passive margins'. These passive margins are characterized by relatively small geological, bathymetric and geophysical changes from the land toward the deep ocean floor. The definition of the continental margin in passive margins, as defined in the Convention on the Law of the Sea, is shown in Figure 5. The continental margin comprises the shelf, the slope and the rise. In determining the limits of the continental shelf as such, it is essential to determine the position of the foot of the continental slope. In the Convention on the Law of the Sea the foot of the continental slope is defined as the point of maximum change in the gradient at its base. In passive margins with relatively monotonous configurations

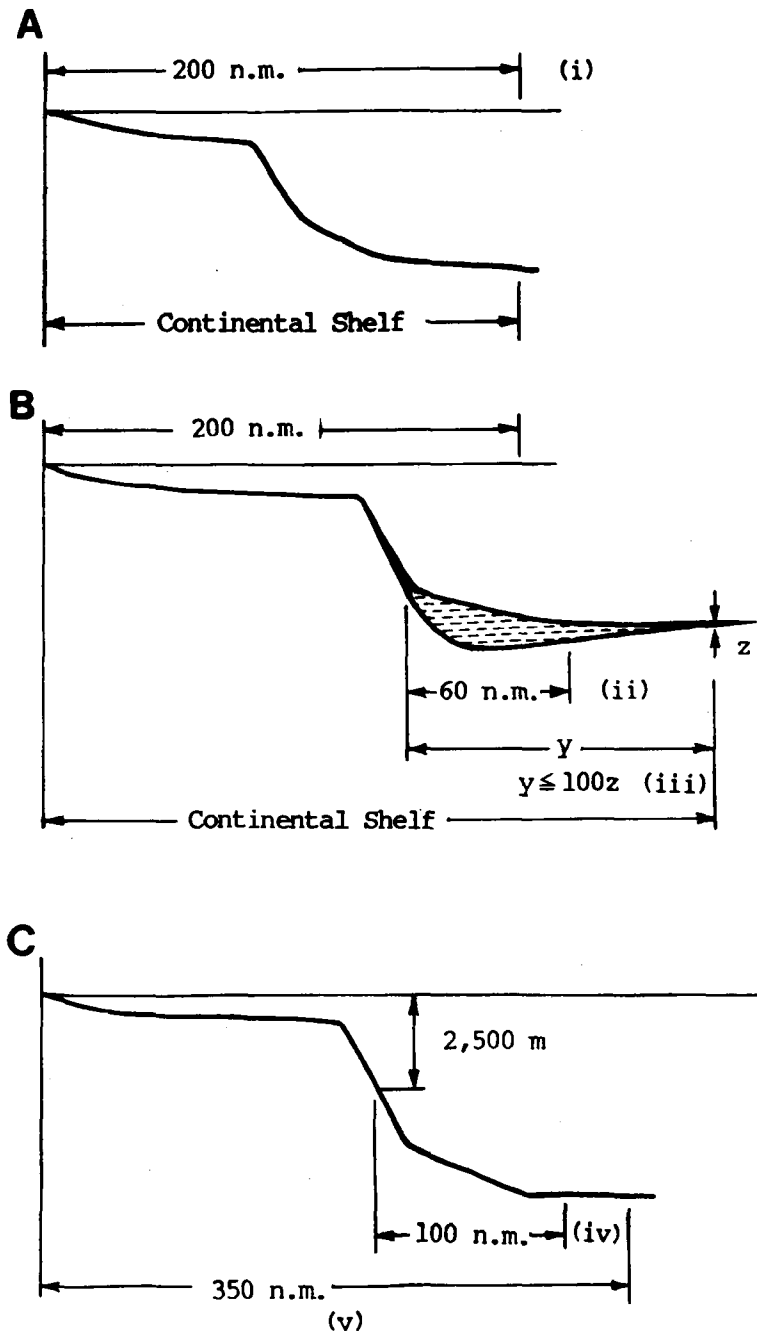


FIG. 5. — Definition of the continental margin defined in the Convention on the Law of the Sea.  
 A: Where the outer edge of the continental margin does not extend up to 200 n.m. from the baseline, (i) Continental Shelf extends to a distance of 200 n.m. from the baselines. B: Wherever the continental margin extends beyond 200 n.m., the coastal State shall establish the outer edge of the continental margin by either: (ii) 60 n.m. from the foot of the continental slope or, (iii) Outermost fixed points at each of which the thickness of sedimentary rocks is at least 1% of the shortest distance from the foot of the continental slope. C: Either shall not exceed, (iv) 100 n.m. from the 2,500 m isobath or, (v) 350 n.m. from the baselines. On submarine ridges, the outer limit of the continental shelf shall not exceed 350 n.m. from the baseline. This does not apply to submarine elevations that are natural components of the continental margin, such as its plateaux, rises, caps, banks and spurs.

it will be relatively easy to determine the position of the foot of the continental slope.

On the other hand, in the Pacific Rim, which includes Japan, relative velocity between the oceanic and the continental plates ranges about 10 cm a year, as can be seen on Figure 4. The boundaries between the ocean and the continent where an apparent mutual interaction is observed are called 'active margins'. In the most active margins, trenches are formed along the plate boundary, where the oceanic plates are subducting under the continental or another oceanic plates. In other words the oceanic plates are consumed along the trenches.

Where a trench is formed, therefore, the boundary between the oceanic crust and the continental crust is the trench axis. So it is relatively easy to determine the plate boundary.

In active margins, however, frictional heat between the subsided oceanic plate and the lower part of the continental plate generate magmatic activity along the deeper part of the thrust plane, forming enormous masses of igneous melted materials, which travel up through the continental crust, erupt as lava and ashes, and build up the narrow chain of volcanic islands along the inner side of the trench. In case when the oceanic plate continues to subduct along the trench, oceanic sediments and seamounts, originally situated on the oceanic plate, are accreted to the continental plate, resulting in composite formations of the island arc.

In some cases there are several rows of ridges, which are thought to be paleo-island arcs. In these areas behind island arcs, tectonic activities in the active margins make the sea bottom configuration very complicated.

There are roughly three types of difficulties in establishing the outer edge of the continental margin at sea behind the island arcs.

First, it is very difficult to determine the position of the foot of the continental slope due to the complicated bottom topography.

Second, it is very difficult to objectively determine the thickness of sedimentary rocks.

Third, it is very difficult to objectively discriminate the deep ocean floor with its oceanic ridges from other parts of the sea bed.

#### **4-1 Steps to cope with the Difficulty in determining the Limits of the Continental Shelf — Case Studies at Sea around Japan**

As mentioned earlier, the sea bottom configuration is very complicated in active margins. In a bathymetric survey conducted in active margins, it is necessary to have a clear grasp of the detailed ocean floor configuration in the survey area, in order to determine the position of the foot of the continental slope — the point of maximum change in the gradient at its base.

The results of the bathymetric survey conducted by the Hydrographic Department of Japan in the Daito Ridge and its vicinity are shown in Figure 6. Depth sounding was done by means of the Sea Beam system along the track lines at an average of 5 nautical miles interval.

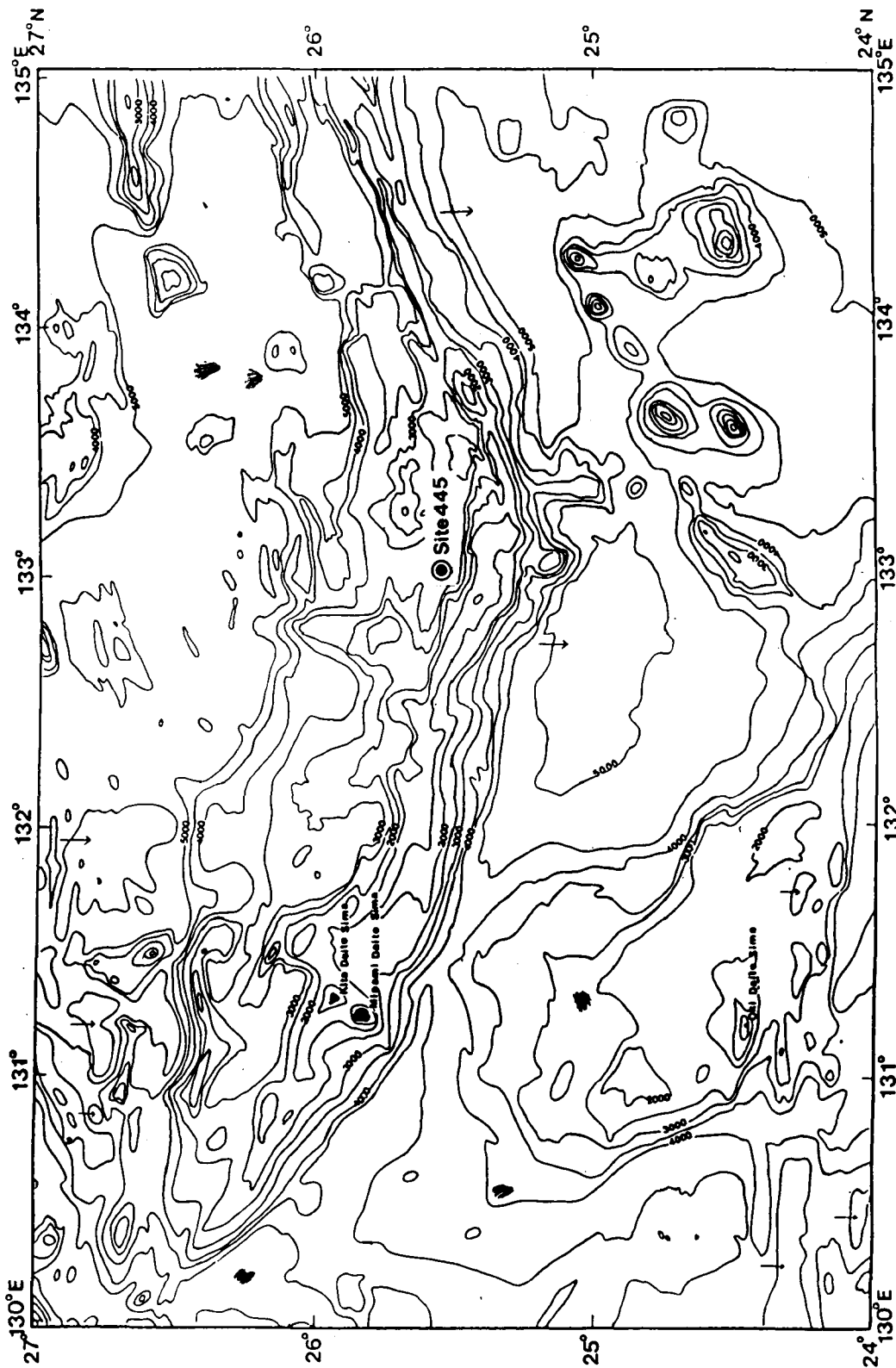


FIG. 6. — Bathymetric map in the Daito Ridge and its vicinity — result of Continental Shelf Survey. Contour interval 500m.

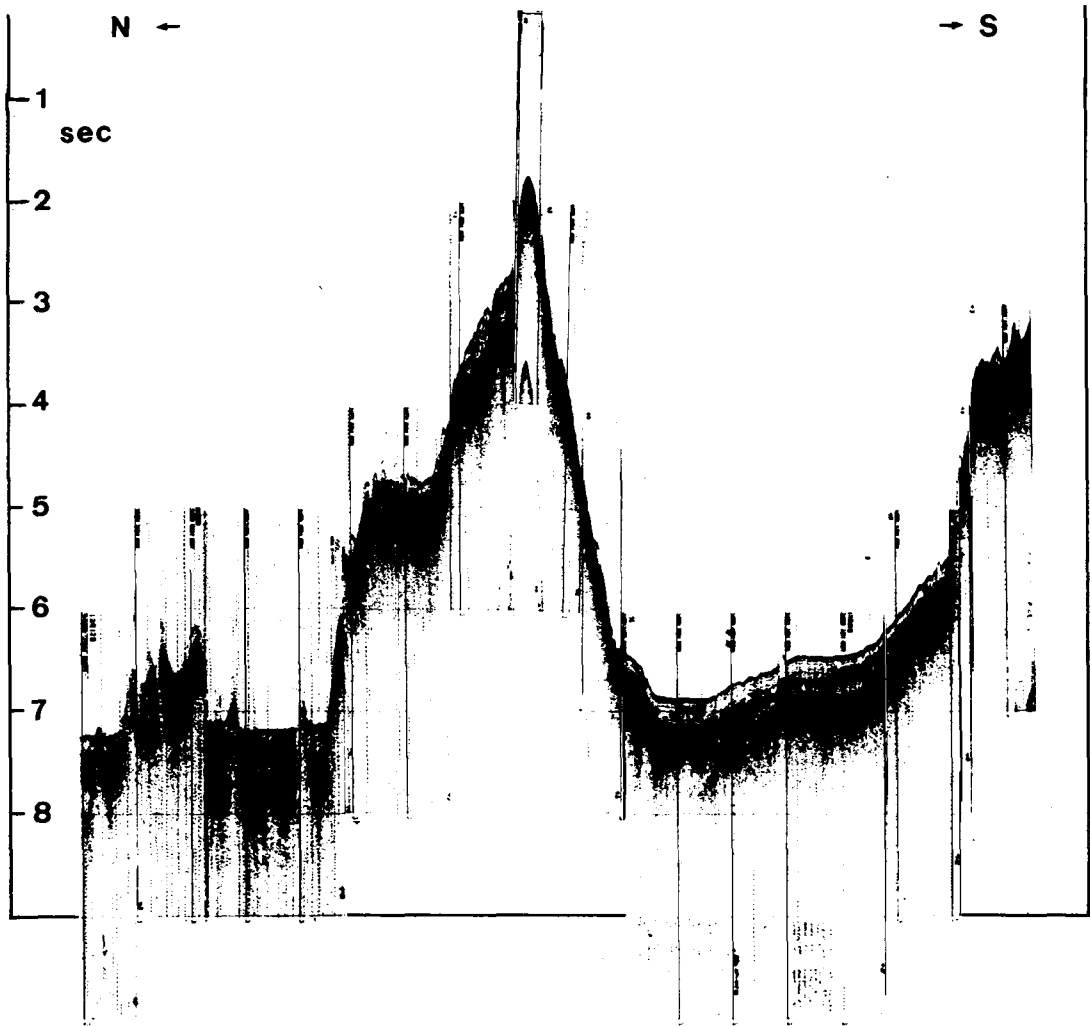


FIG. 7. — North to south seismic reflection profile of the Daito Ridge showing topography and sub-bottom geological structure.

In Figure 6 the Daito Ridge is shown as a long and narrow uplift extending east and west in the northern part of the figure. To the west of the ridge are Kita-Daito Sima and Minami-Daito Sima. The two islands' major industries are sugar cane farming and fishing.

These two islands satisfy the requirements for having a continental shelf. It is therefore necessary to determine the accurate position of the foot of the continental slope surrounding the Daito Ridge. For example, where should we set the foot of the continental slope on the northern side of the ridge? Figure 7 shows the north to south seismic reflection profile of the ridge. The northern flank of the ridge is a terraced slope, which meets the flat ocean floor at a depth of about 5,000 meters. To determine the position of the foot of the continental slope of such a configuration, it is necessary to prepare a very detailed bathymetric

contour map. For this purpose, the Hydrographic Department of Japan is utilizing the Sea Beam system in conducting bathymetric surveys. Since the average interval of the track lines is 5 nautical miles, the sounding coverage is about 30%. But in this system contour lines are drawn for the long and narrow area of a few thousand meter width along the track, which makes this system vital. We prepared a contour map at a scale of 1 to 500,000 using only the vertical sounding data and compared it with a contour map prepared by using all the Sea Beam data. As a result, we found that there were considerable differences between the two maps, particularly in areas of complicated configuration. Our conclusion is that, while it is necessary to do as precise a depth sounding as possible, it is advisable to choose a multi-beam swath system when a wide interval of the track is arranged to reduce the length of the survey period.

#### **4-2 Steps to cope with the Difficulty of determining the Thickness of Sedimentary Rocks**

In the Convention on the Law of the Sea the thickness of sedimentary rocks is considered a very important factor in determining the limits of the continental shelf. How, then, should we determine the correct and accurate thickness of sedimentary rocks?

Generally, the seismic reflection survey and the seismic refraction survey are very effective in determining the structure of the oceanic crust. If we use the seismic reflection survey, we can record the structure of the oceanic crust as deep as several hundreds meters below the ocean floor. If the multi-channel seismic reflection systems are used, it is possible to analyze the structure of the deeper portions of the sedimentary layers. Figure 7 shows the results of the single channel seismic profiling conducted by the Hydrographic Department of Japan near the Daito Ridge. The single channel seismic profiling was conducted on the survey vessel running at a speed of approximately 10 knots. When single channel seismic profiling is conducted on a vessel running at a speed less than 8 knots, the signal to noise ratio becomes high, and good quality records come out. If it is done on a vessel running at more than 10 knots, however, the quality of the records is poor. Thus the maximum practical speed of the survey vessel is about 10 knots. It is only the seismic profiling that imposes serious restrictions on a ship's speed of continental shelf survey. Depth sounding and geomagnetic and gravity measurements can be conducted on a survey vessel running at more than 10 knots.

The multi-channel seismic profiler is very effective in profiling the deeper part of the sedimentary layer. But this device is very expensive and it is very difficult to operate it efficiently. Furthermore, it is necessary to use the multi-channel seismic profiler on a survey vessel running at less than 5 knots, and much more labor and cost are required to analyze the data obtained through this device. So it is advisable to use this device only for particularly important survey lines.

The seismic refraction survey is effective in determining physical properties, seismic velocity in particular, of the deeper part of the oceanic crust. If the distribution of seismic velocities within the oceanic crust is determined, it is

possible to analyze precisely the results of the multi-channel seismic profiling. Furthermore, the seismic wave itself will be useful in determining the type of rocks forming the oceanic crust.

The decisive solution to this problem is collecting samples through boring. Since the boring method costs a great deal, however, it is impossible to use this method as part of a continental shelf survey. In the Ocean Drilling Project (ODP), which took over the Deep Sea Drilling Project (DSDP), now being implemented under the leadership of the U.S. and participated in by Japan and other countries, core samples of the length of several hundred meters have been collected from ocean depths and are now being analyzed. In the Daito Ridge area, drilling was done in the sedimentary basin on its northern slope (DSDP Site 445). Figures 6 and 8 show the location of DSDP Site 445 and the results of the seismic profiling conducted with the multi-channel seismic profiler passing the DSDP Site 445. The drill reached 892 meters deep and conglomerates were obtained from that depth. Figure 9 shows the lithology and seismic P-wave velocity of the core samples and the record of the multi-channel seismic profiler at the same position. In the seismic profiler the depth of about 850 meters is set as the acoustic basement, where there exist conglomerates. This is the point of maximum change of seismic velocity and is where the acoustic basement is recorded. It is obvious that the Daito Ridge's basement exists far below the acoustic basement, but this fact is not shown in the seismic profiling record. It is often difficult to identify the basement of a sedimentary layer in the seismic profiling record.

In the light of the above fact, it should be permitted to think the vertical distance from the ocean floor to the acoustic basement as an index for the thickness of sedimentary rocks as stipulated in the Convention on the Law of the Sea, Article 76, paragraph 4(a) (i).

The Hydrographic Department of Japan is conducting single-channel seismic profiling along all the tracks and multi-channel seismic profiling for a very limited number of important tracks in the Continental Shelf Survey Project. It also started seismic refraction measurement in 1986. Moreover, it is collecting rock samples by dredging in places where the basement is exposed and taking photos of the ocean floor. After these surveys, it is conducting an analysis of the data obtained as well as chemical, mineralogical and palaeontological analyses of the samples collected. The Department intends to incorporate other significant scientific data such as DSDP data included in the area of current Continental Shelf Survey Project. Such an approach will be of practical value in determining the thickness of sedimentary rocks.

#### 4-3 Difficulty in Discrimination of the Deep Ocean Floor with its Oceanic Ridges

Discrimination of the deep ocean floor with its oceanic ridges from other sea bed is equivalent to determining whether the ocean floor surveyed belongs to the oceanic crust or to the continental crust. To determine whether the crust is oceanic or continental, it is necessary to investigate geomagnetic anomaly distribution and gravity anomaly distribution in addition to the above mentioned bathymetric and seismic surveys.

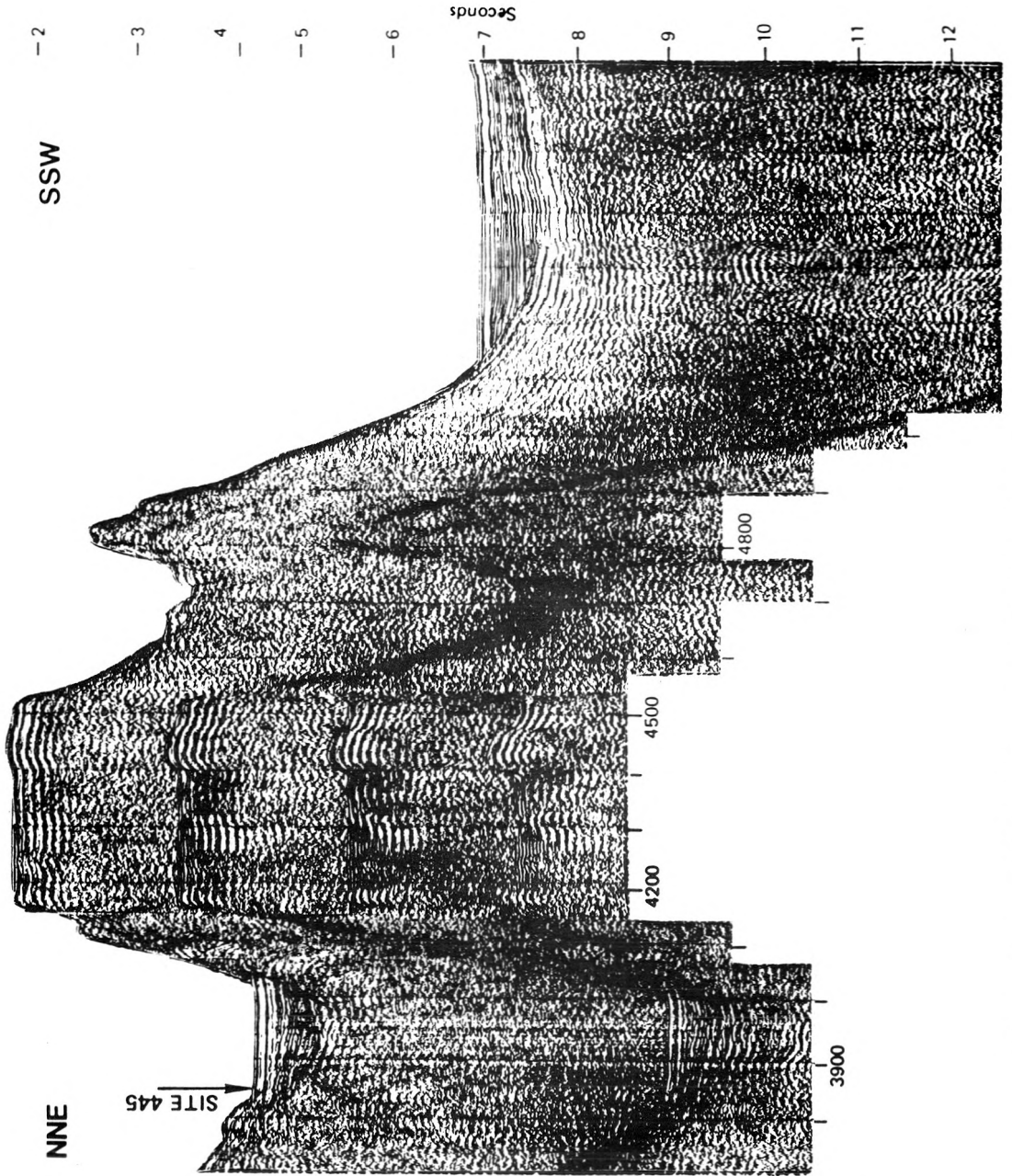


FIG. 8. — Location of DSDP Site 445 on a multi-channel seismic profiler record (from IPOD-Japan (1977) and KLEIN, KOBAYASHI *et al.* (1980)).



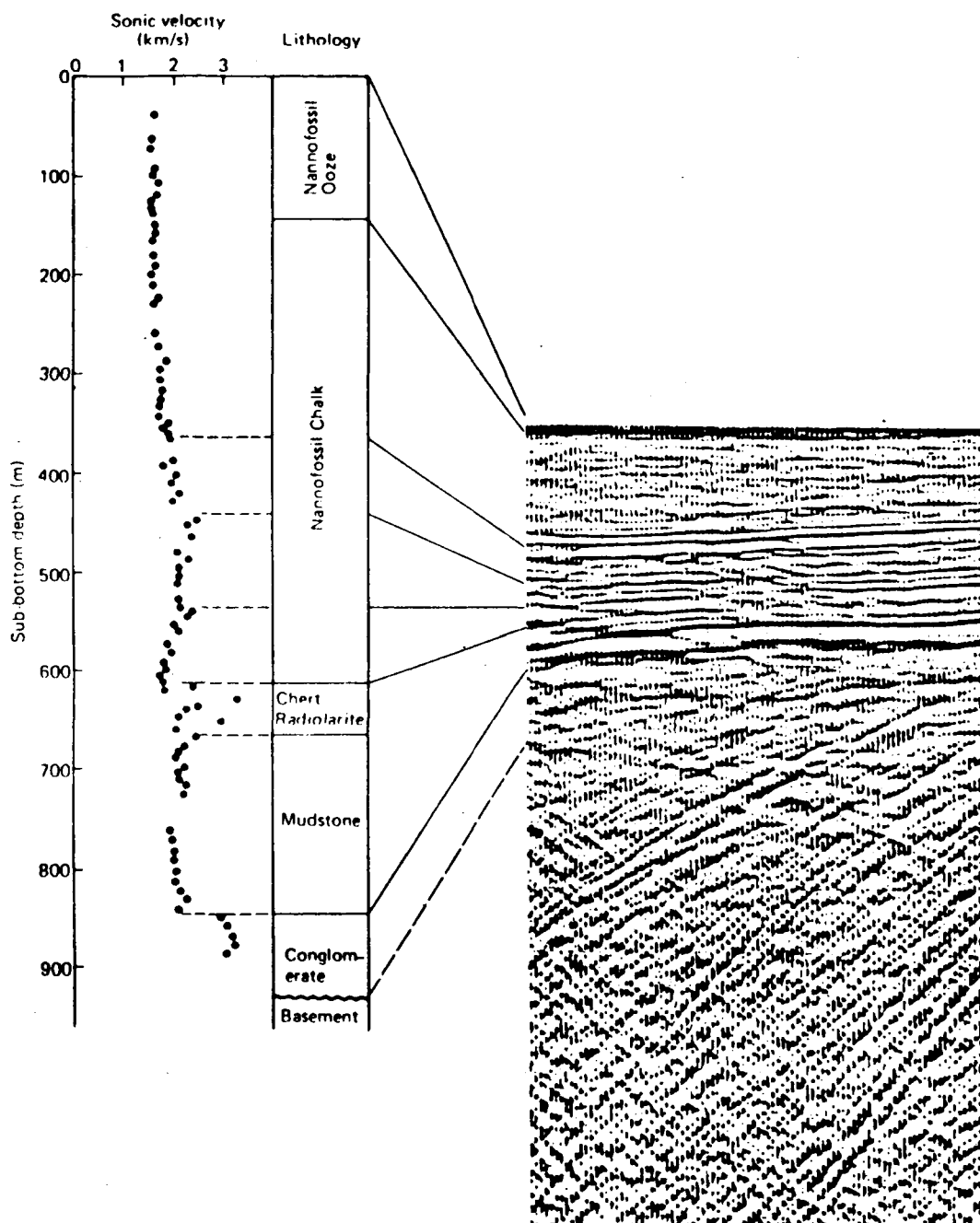


FIG. 9. — Lithology and sonic velocity of the core samples and the record of the multi-channel seismic profiler record at the same depth (from IPOD-Japan (1977) and KLEIN, KOBAYASHI *et al.* (1980)).

A classic example of schematic cross-section of the continental and oceanic crust is shown in Figure 10. The granitic layer in the continental crust has a thickness of 30 to 50 km, a density of 2.7 to 2.8 g/cc and a seismic P-wave

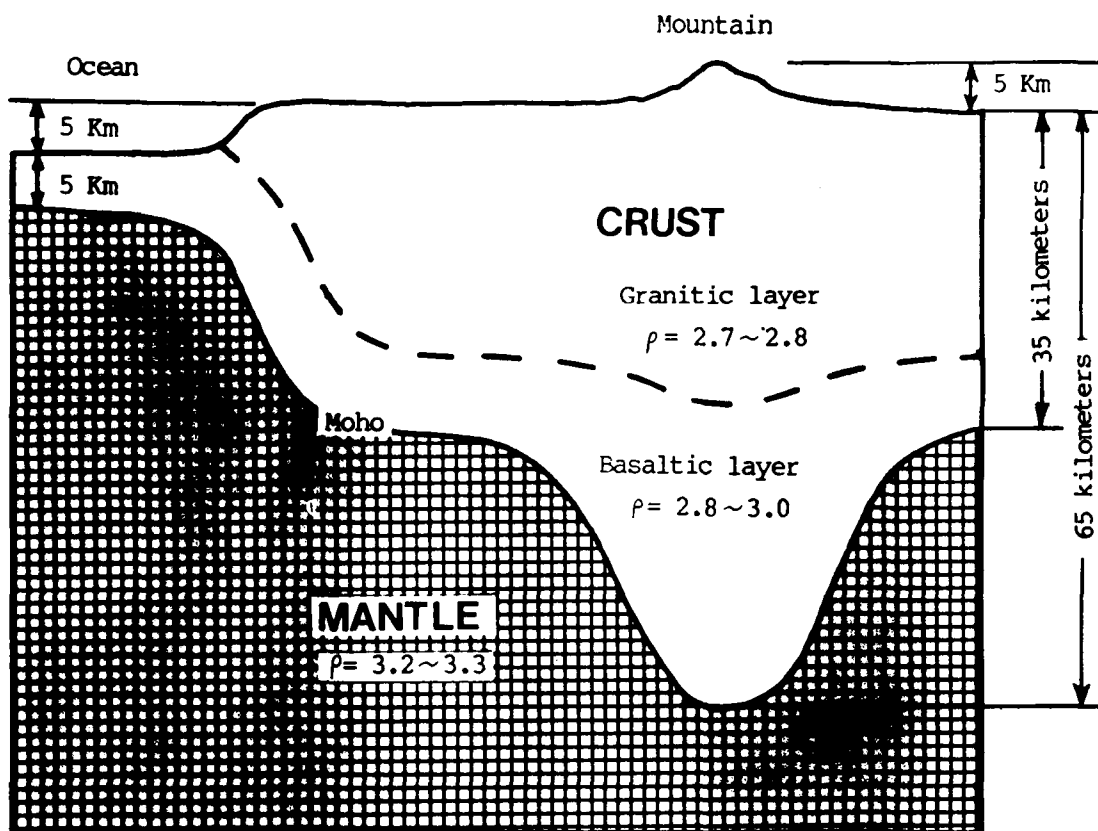


FIG. 10. — Typical oceanic crust and continental crust (from UYEDA (1978), partly modified).

velocity of about 6.0 km/sec. The oceanic crust consists of a basaltic layer, which has a thickness of less than 10 km, a density of 2.8 to 3.0 g/cc and a P-wave velocity of about 6.7 km/sec. While the degree of granite's magnetization is approximately  $1 \times 10^{-3}$  emu/cc (1 A/m) or less, the degree of basalt's magnetization is  $1 \times 10^{-2}$  emu/cc (10 A/m). In passive margins, it will be relatively easy to determine the boundary between the oceanic and the continental crust based on the values for density, seismic P-wave velocity and degree of magnetization.

In active margins, however, it is impossible to determine whether the crust is oceanic or continental on the basis of the type of rocks alone. In case of the island arcs, it is known that sediments and seamounts of oceanic origin are accreted to the island arc. Actually, older accreted oceanic materials of the Japan Arc are found coexisting with younger formations on land.

It will be possible to distinguish to some extent the deep ocean floor and the oceanic ridge as mentioned in the Convention on the Law of the Sea, Article 76, paragraph 3, on the basis of the characteristics of geomagnetic anomaly distribution. For example, typical deep ocean floor shows magnetic lineations originated from alternations of normal and reverse magnetization of the basaltic layer, of which distributions are symmetrical about oceanic ridges (spreading center).

In active margins, marginal seas are often situated landward of island arcs. The features of topography and geological structure of marginal seas are very complicated. Submarine ridges, seamounts and basins are randomly distributed in the marginal seas. Of these, it has to be determined whether the basins are part of deep ocean floors or not. A basin should be classified as deep ocean floor only when it has a thin crust of basaltic (and the other mafic) rocks, in other words, only when it has an oceanic crust. Even though a basin has an oceanic crust, it is not considered to be a deep ocean floor if it shows characteristics of the land mass prolongation as stipulated in the Convention on the Law of the Sea, Article 76, paragraph 4 (a).

Even in the field of earth science the process of formation of a marginal sea is still not clarified. There are some hypotheses, but none of them is yet generally accepted. At the present time, therefore, it is most important to conduct detailed bathymetric, geological and geophysical research and surveys to cope with this matter.

Incidentally, the submarine ridges mentioned in the Convention on the Law of the Sea, Article 76, paragraph 6, refers to ridges other than the oceanic ridges, and most of those submarine ridges are thought to be paleo-island arcs or fragmental blocks of continent in the adjacent marginal seas of Japan. These submarine ridges are composed of intermediate or acidic rocks such as andesites, granites or rhyolites in addition to basaltic rocks. Generally, the amplitude range of the geomagnetic anomaly of these submarine ridges is lower than that of oceanic ridges, but there is no distinct simple criterion with which to discriminate clearly the continental crust from the oceanic crust in active margins. So it is necessary to discriminate between the two, based on comprehensive geological and geophysical investigation.

Figure 11 shows the results of a geomagnetic survey at sea near the Daito Ridge. Weak negative anomalies are distributed on the northern side of the ridge and positive anomalies are distributed on the southern side of the ridge. The amplitude of geomagnetic anomaly is low in some parts of the ridge. This fact and the remarkable lineated feature of the topography show that there exist intermediate to acidic rocks as the basement. In fact, such intermediate or acidic rocks as andesite, diorite and granodiorite were dredged from some parts of the ridge (SHIKI *et al.*, 1985).

Figure 12 shows the free-air gravity anomaly distribution. The general trend of the figure is similar to that of the topography. Positive gravity anomaly of +80 to +100 mgal, partly +140 mgal, is distributed along the ridge. In the basin on the northern side of the Daito Ridge, negative free-air gravity anomaly of about -50 mgal is distributed. As a result of an analysis of this anomaly distribution, the conclusion was reached that there exists a layer of 2.7 g/cc or less at a depth shallower than about 15 km and a layer of 2.9 g/cc at the depth of about 15 to 20 km below the Daito Ridge. Since the depth of the surface of the upper mantle of 3.3 g/cc density is 12 km or more in the basins around the ridge, it is assumed that the crust of the Daito Ridge has a thickness about two times that of the basins.

The Daito Ridge was considered as a paleo-island arc from the results of the previous scientific researches up to the present, which coincide with the results of the Continental Shelf Survey mentioned above.

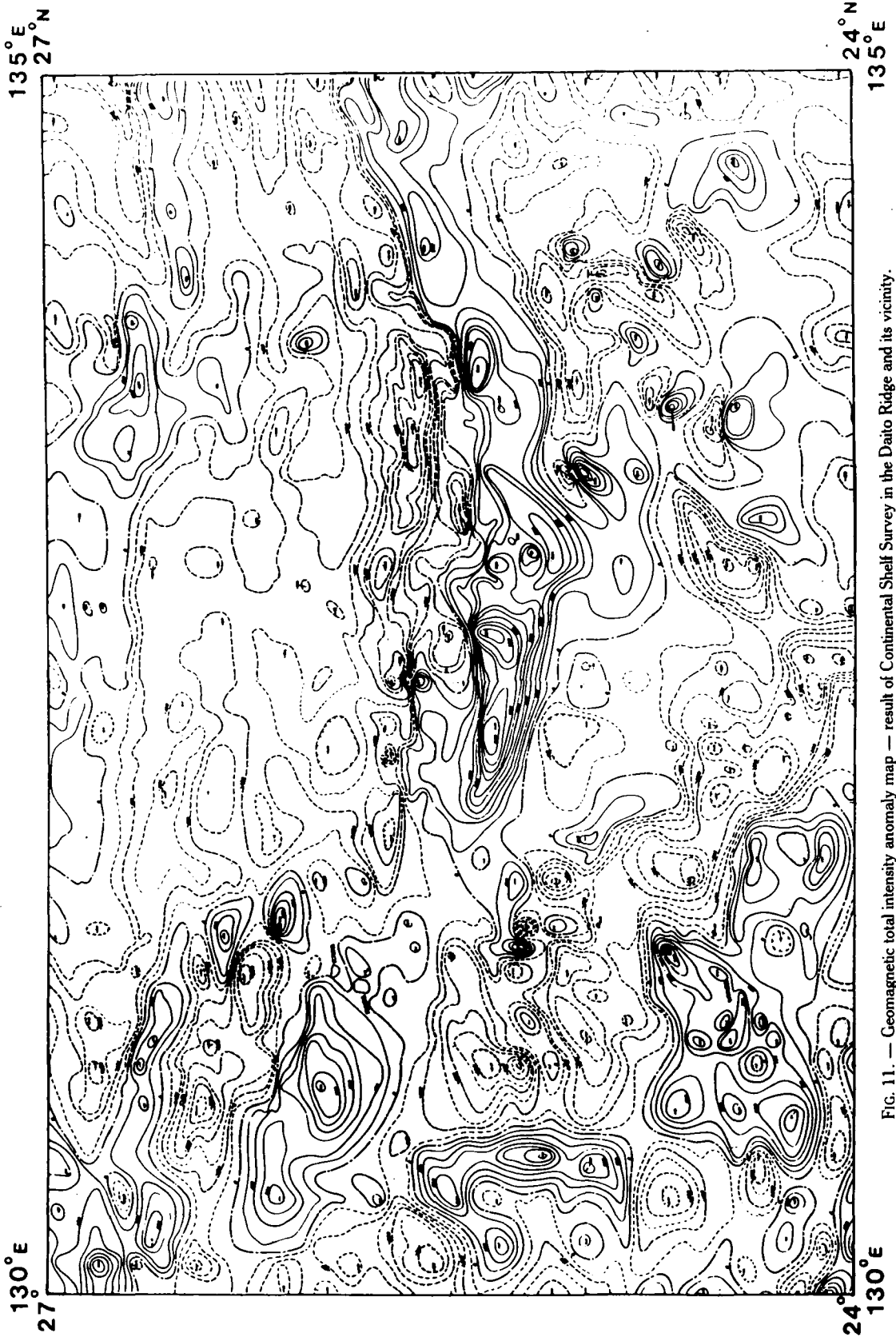


FIG. 11. — Geomagnetic total intensity anomaly map — result of Continental Shelf Survey in the Daito Ridge and its vicinity.



FIG. 12. — Free-air gravity anomaly map — result of Continental Shelf Survey in the Daito Ridge and its vicinity.

## 5. CONCLUSION

In active margins like the Pacific Rim, including Japan, the outer limits of the continental shelf should be determined based on the detailed bathymetric, geological and geophysical surveys, controlled by very precise positioning.

It is very difficult to have a clear grasp of complicated topographic features of the active margins solely on the basis of ordinary single-beam echo sounder, so that it is advisable to use a narrow multi-beam system to enable efficient high resolution of bathymetry. Since the 2,500 meter contour lines have an important meaning, it is also advisable to do precise depth sounding at the same time, even if a side scan sonar would be used to cover the topography of the survey area.

Single and multi-channel seismic, magnetic and gravity measurements and dredging are effective as geophysical and geological methods. In active margins like the Pacific Rim where the tectonic structure is very complicated, it is desirable to conduct very detailed geological and geophysical surveys to determine the outer edge of the continental shelf.

Generally the single-channel seismic profiler's records can reveal the structure of sedimentary layers. Since multi-channel seismic profiling must be done on a survey vessel running at less than 5 knots and analysis of the collected data costs a great deal, it is impossible to use this method in a vast sea area. For this reason, it should be permitted to use the depth of the acoustic basement on the single channel seismic profiler's record as an index for measurement of the thickness of sedimentary rocks as stipulated in the Convention on the Law of the Sea, Article 76, paragraph 4. It will also be necessary to prepare information on the continental shelf with supporting scientific and technological data in which such previous scientific results as DSDP results are incorporated.

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