## 3-3 nSBP Survey

nSBP survey was carried out in order to clarify the distribution of the sediments under the seafloor. Records mainly of the summit (flat top) and parts of the slopes were studied. Regarding data processing, the records of each track line were classified into the types explained in (1). For T-type, the depths of the basement were determined, the total thickness of the alternation of the acoustically transparent and opaque layers were read from the record, and the result was expressed as isopach (sediment thickness) maps. Also nSBP records at the time of LC sampling and the sampling results were correlated. The frequency used was 3.5 kHz, data acquisition was done by train mode, 4 pulse and the survey was carried out simultaneously with topographic sounding and sampling.

(1) nSBP type classification

Reflection patterns of the nSBP records of the nine seamounts were divided into O-type and T-type.

a. O-type (typical example Fig. 3-3-1)

This nSBP reflection pattern consists only of opaque layers.

O-type pattern is observed for the whole seamount in pointed seamounts. On table seamounts, this is observed from top margins to the slopes. This O-type pattern generally corresponds to manganese crusts, but they may be at covered by thin unconsolidated sediments.

b. T-type (typical example Fig. 3-3-2)

This pattern consists of transparent-opaque layer alternation.

T-type is observed on tops of table seamounts and terraces. The thickness of the alternation varies from 10 ~ 200 m. This type is inferred to correspond to unconsolidated sediments.

(2) Features of the seamounts

The nSBP profile and isopach maps of the seamounts (MS01 to MS04, MS05, MS08, MS09) are shown in Figures 3-3-3 (1) ~ (7) and Figures 3-3-4 (1) ~ (7) respectively.

a. MS01

The MS01 top is covered by T-type layer. The thickness ranges from 10 to 65 m. This T-type covers the whole top along the 1,300 m water depth contour, and is most developed in the central part forming a dome-shaped structure with alternation in the upper parts. This T-type is inferred

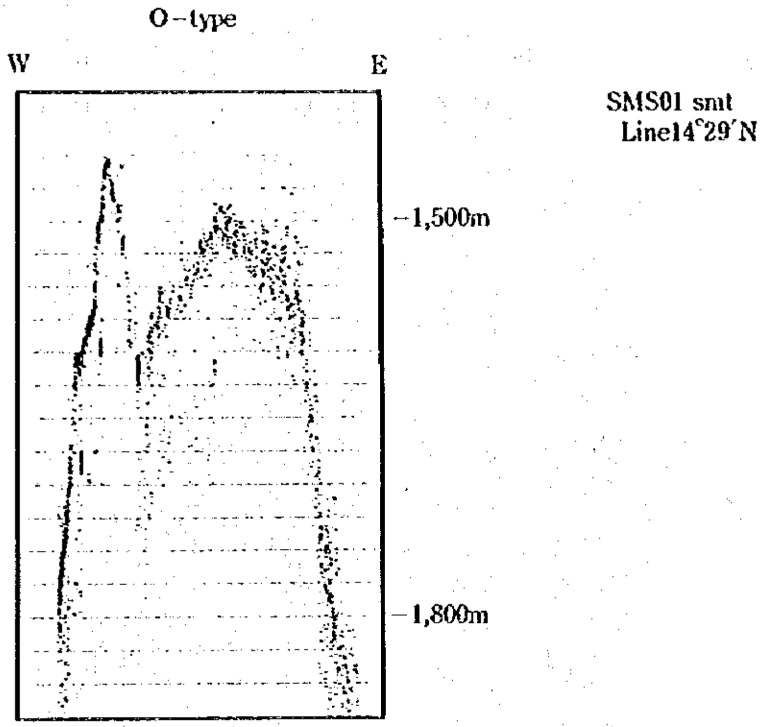



Fig. 3-3-1 Typical records of nSBP for each type (O-type)

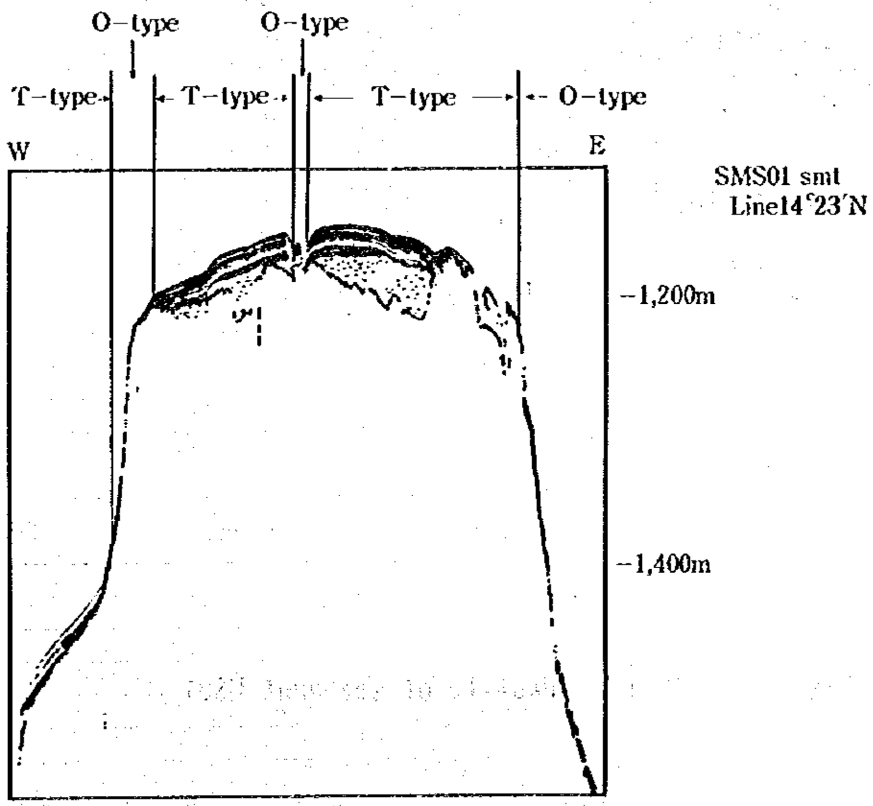



Fig. 3-3-2 Typical records of nSBP for each type (T-type)

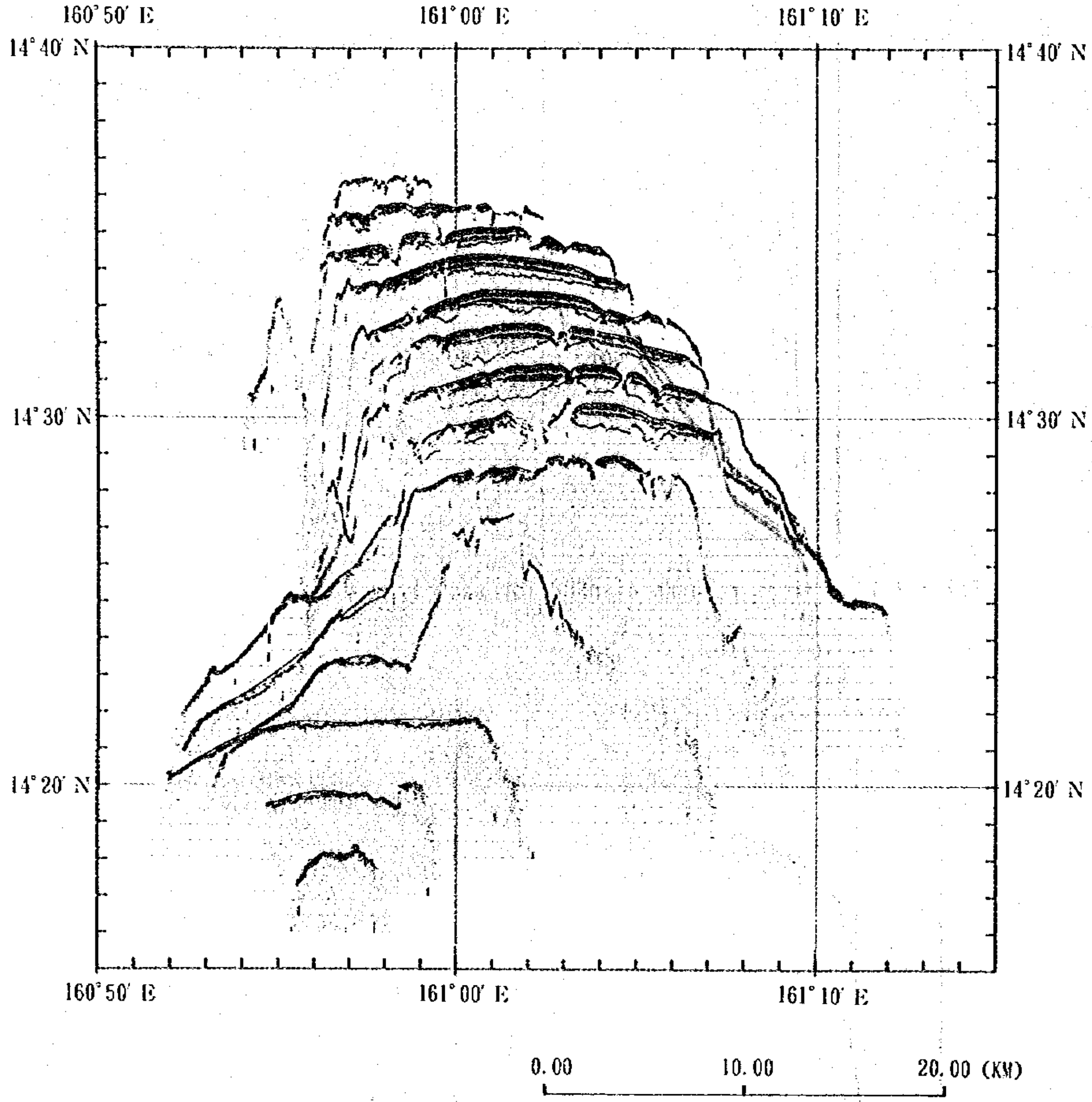



Fig. 3-3-3 (1) nSBP Profile of seamount MS01

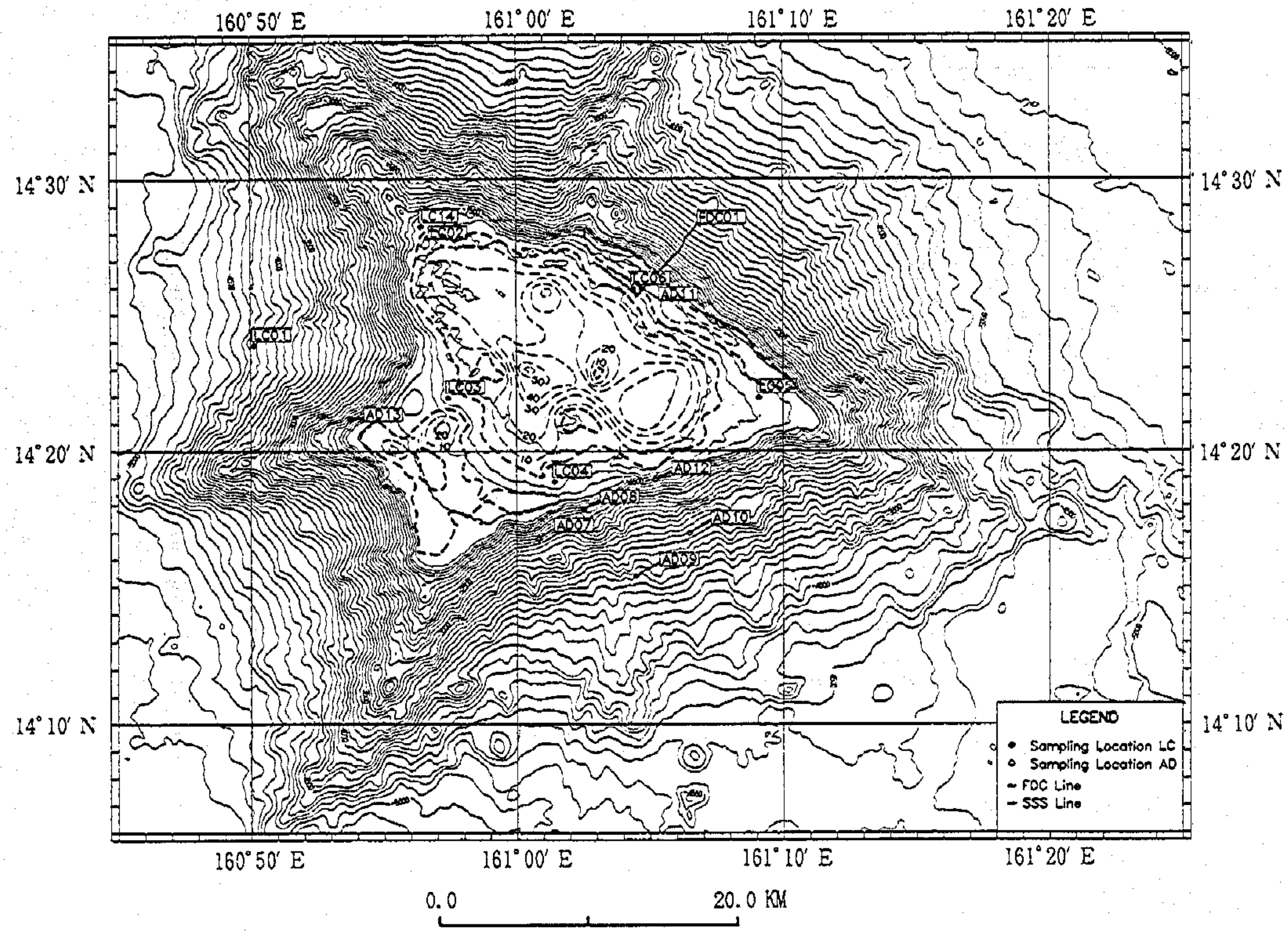



Fig. 3-3-4(1) Isopach map of seamount MS01

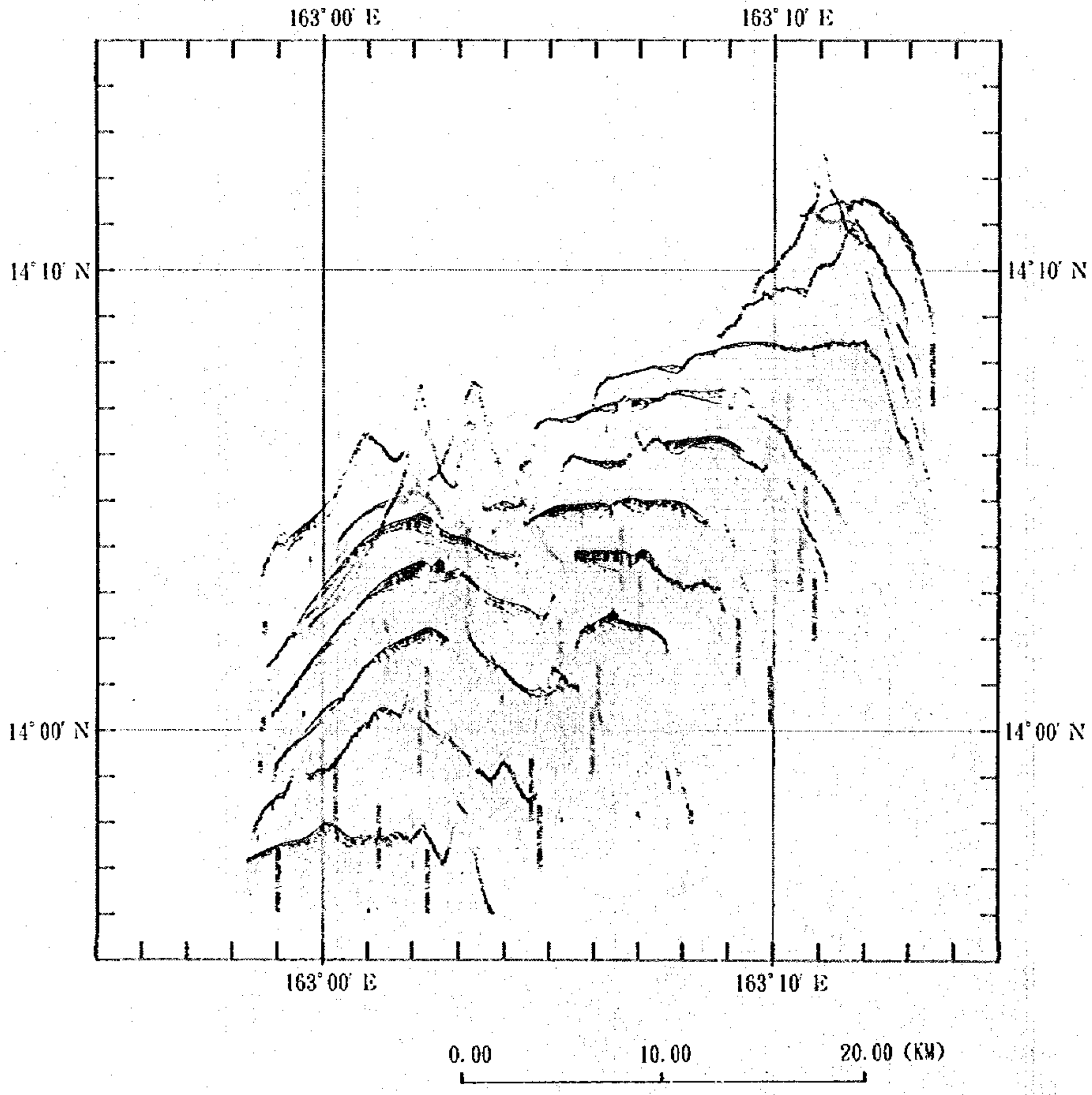



Fig. 3-3-3 (2)  nSBP Profile of seamount MS02

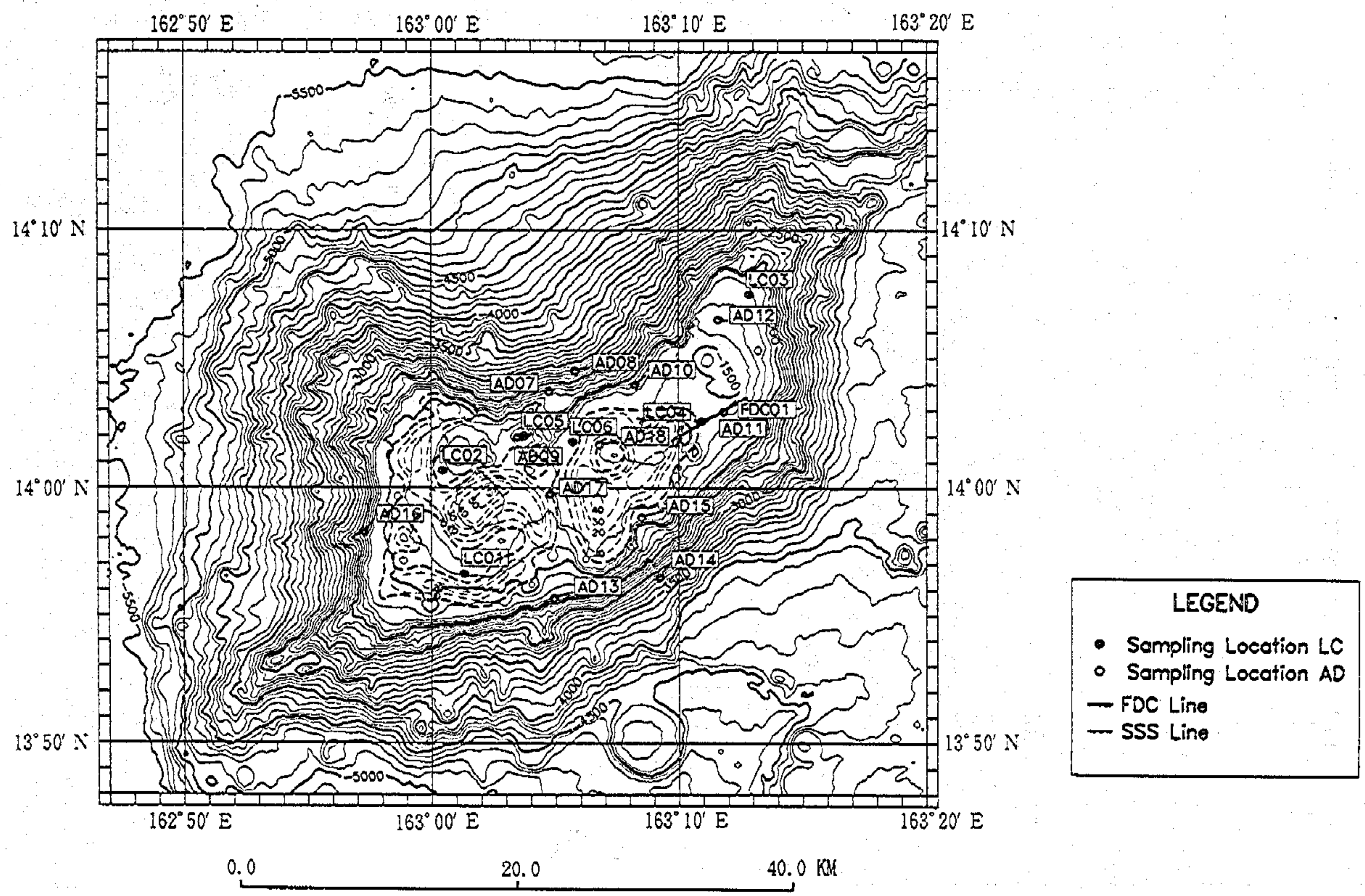



Fig. 3-3-4 (2) Isopach map of seamount MS02

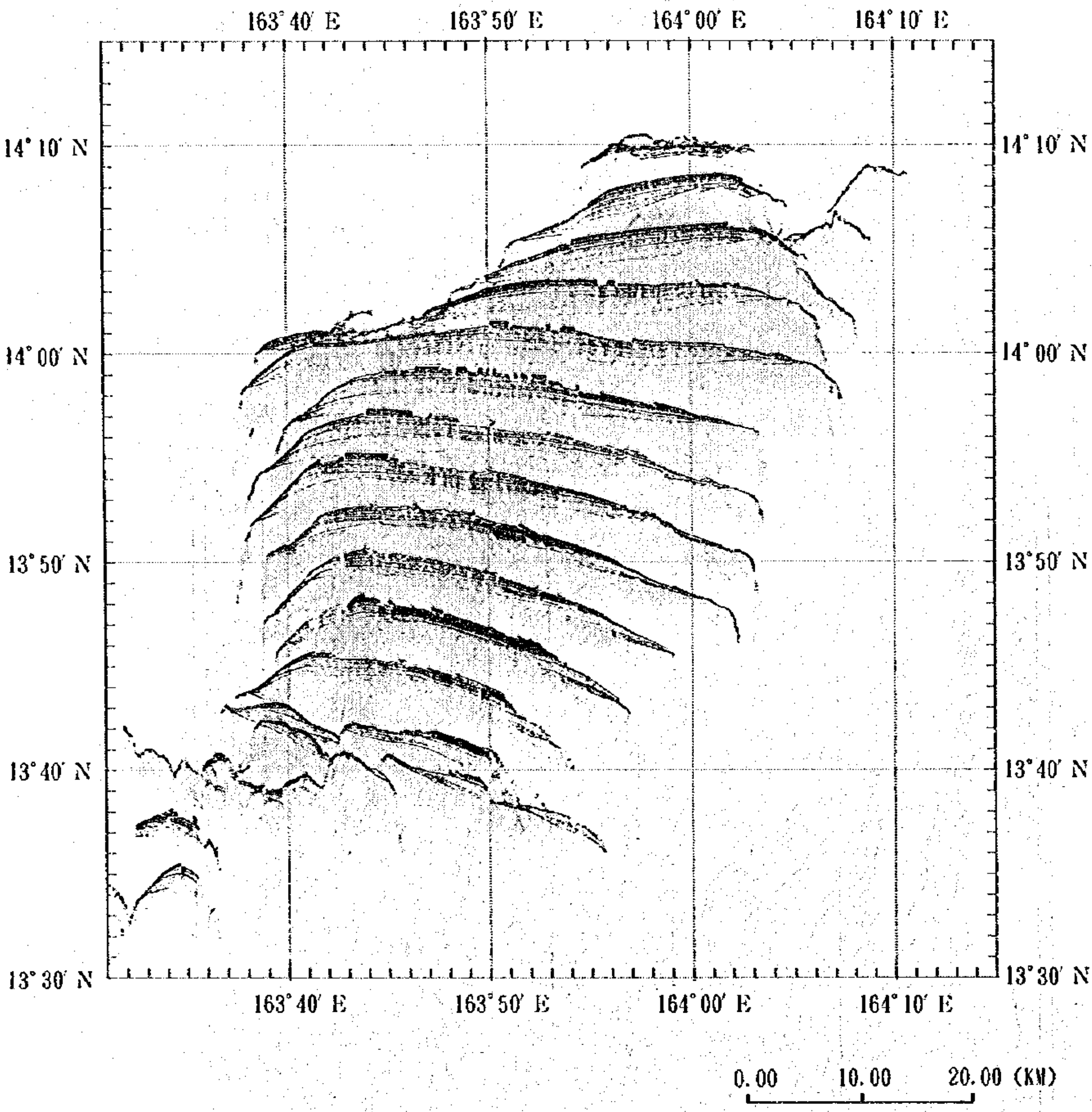



Fig. 3-3-3 (3) nSBP Profile of seamount MS03

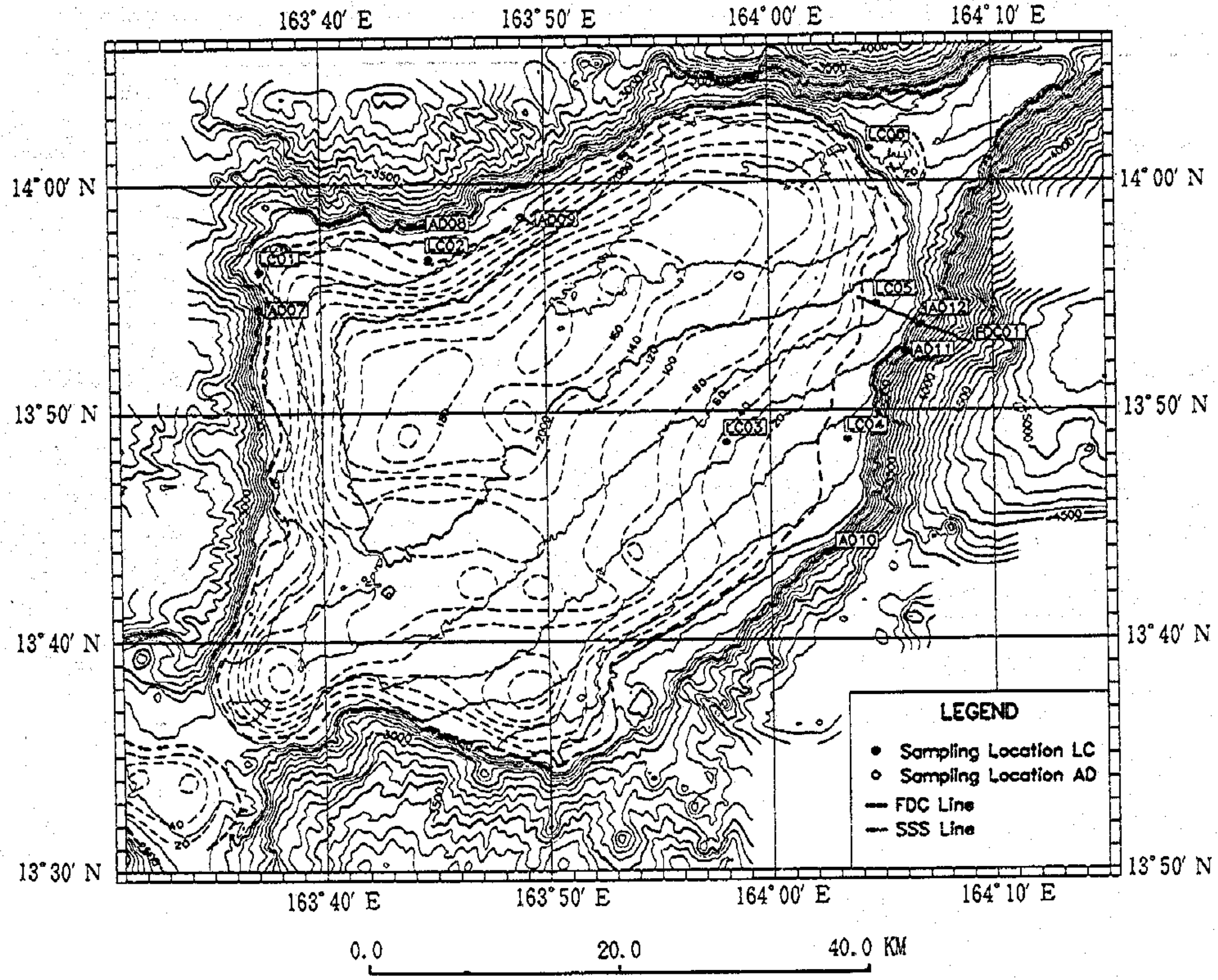



Fig. 3-3-4 (3)  Isopach map of seamount MS03

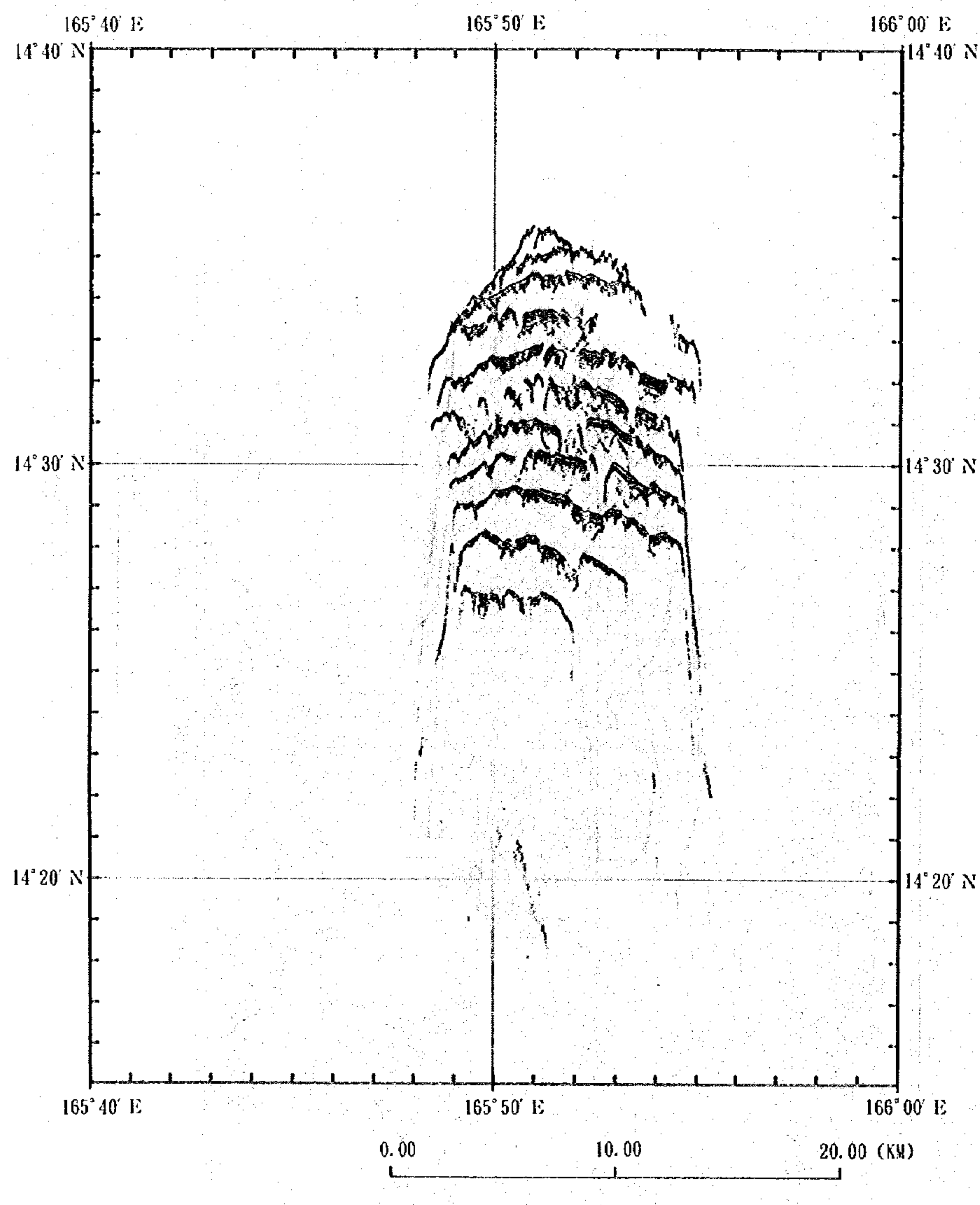



Fig. 3-3-3 (4)　nSBP Profile of seamount MS04

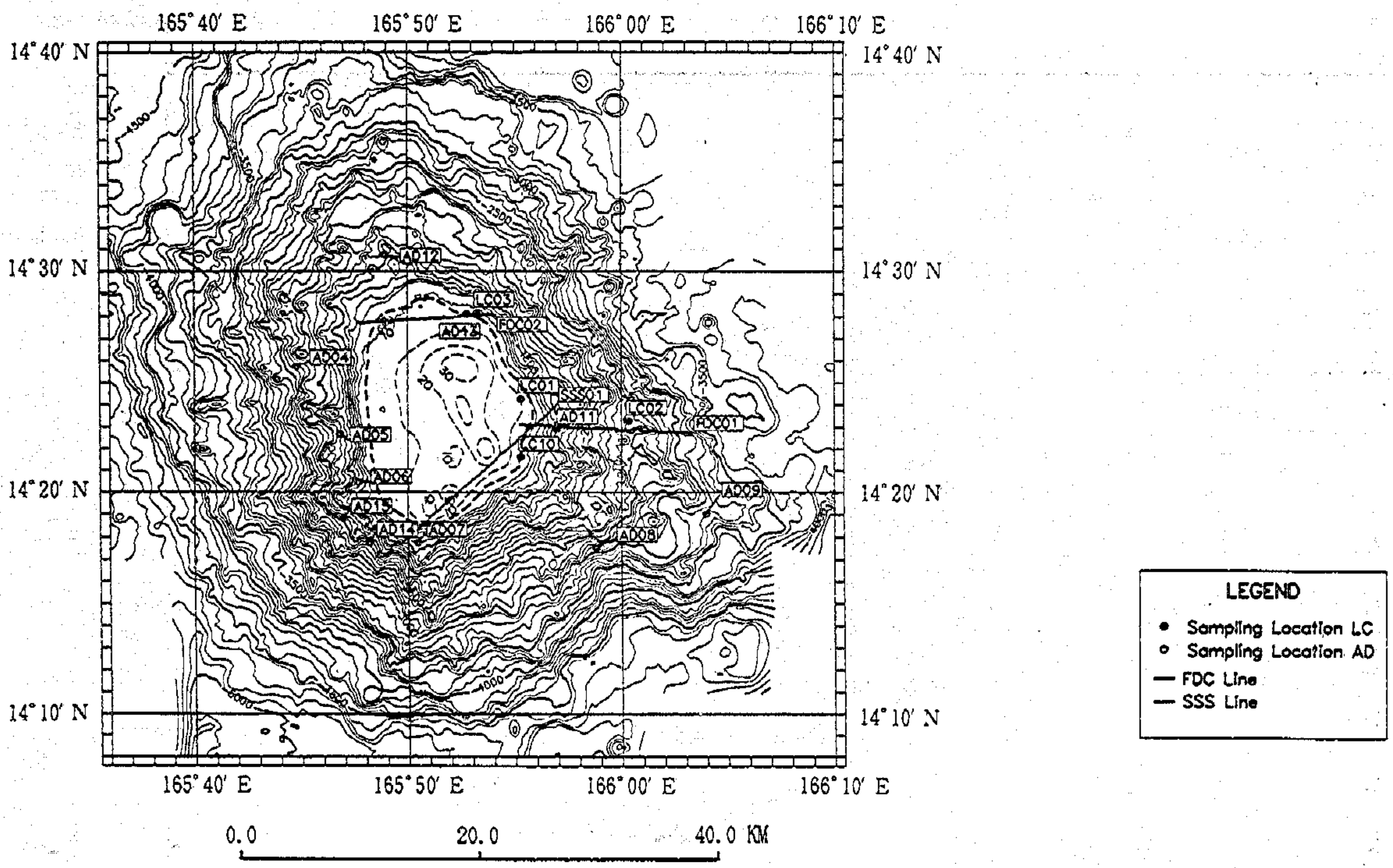



Fig. 3-3-4 (4)　Isopach map of seamount MS04

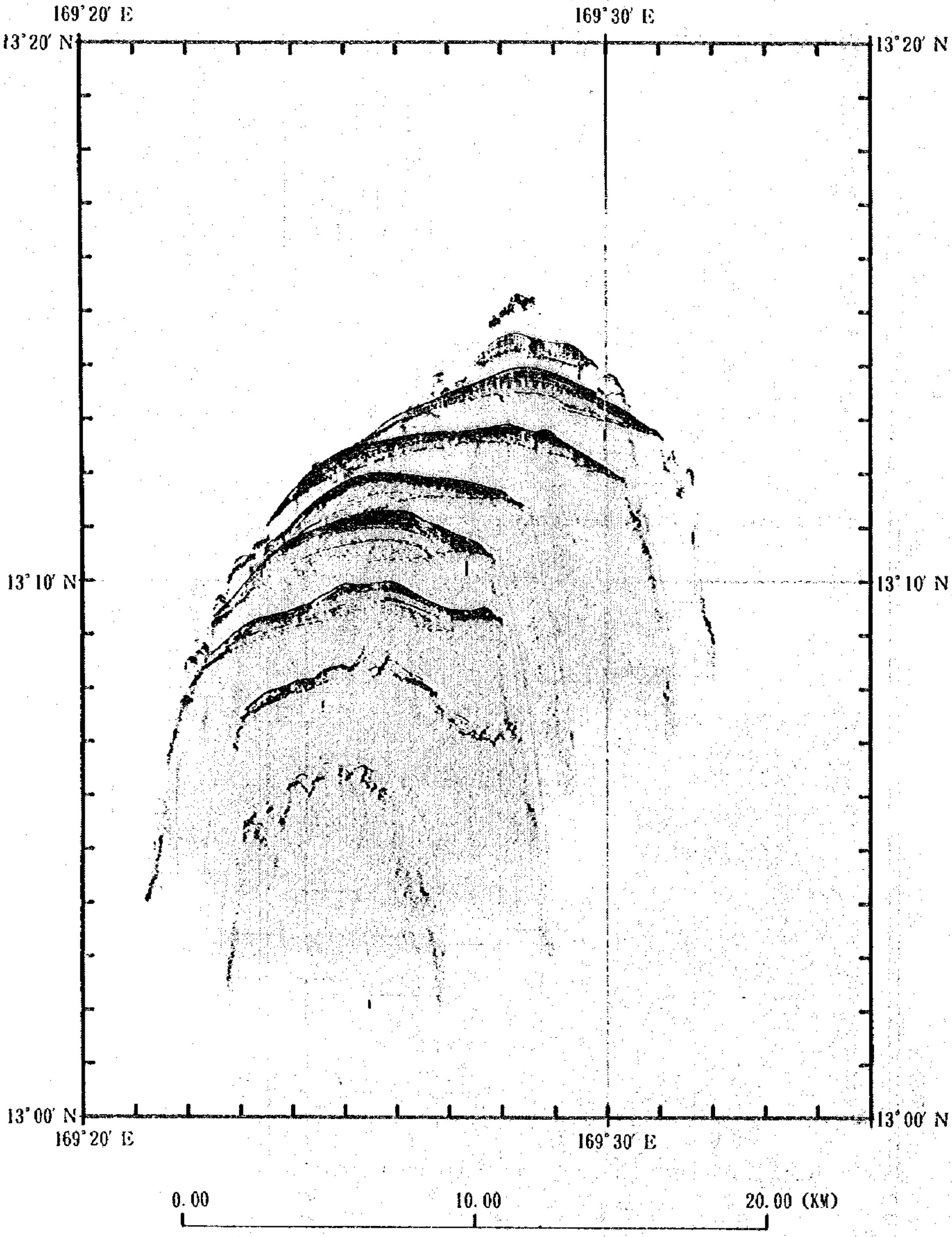



Fig. 3-3-3 (5)  nSBP Profile of seamount MS06

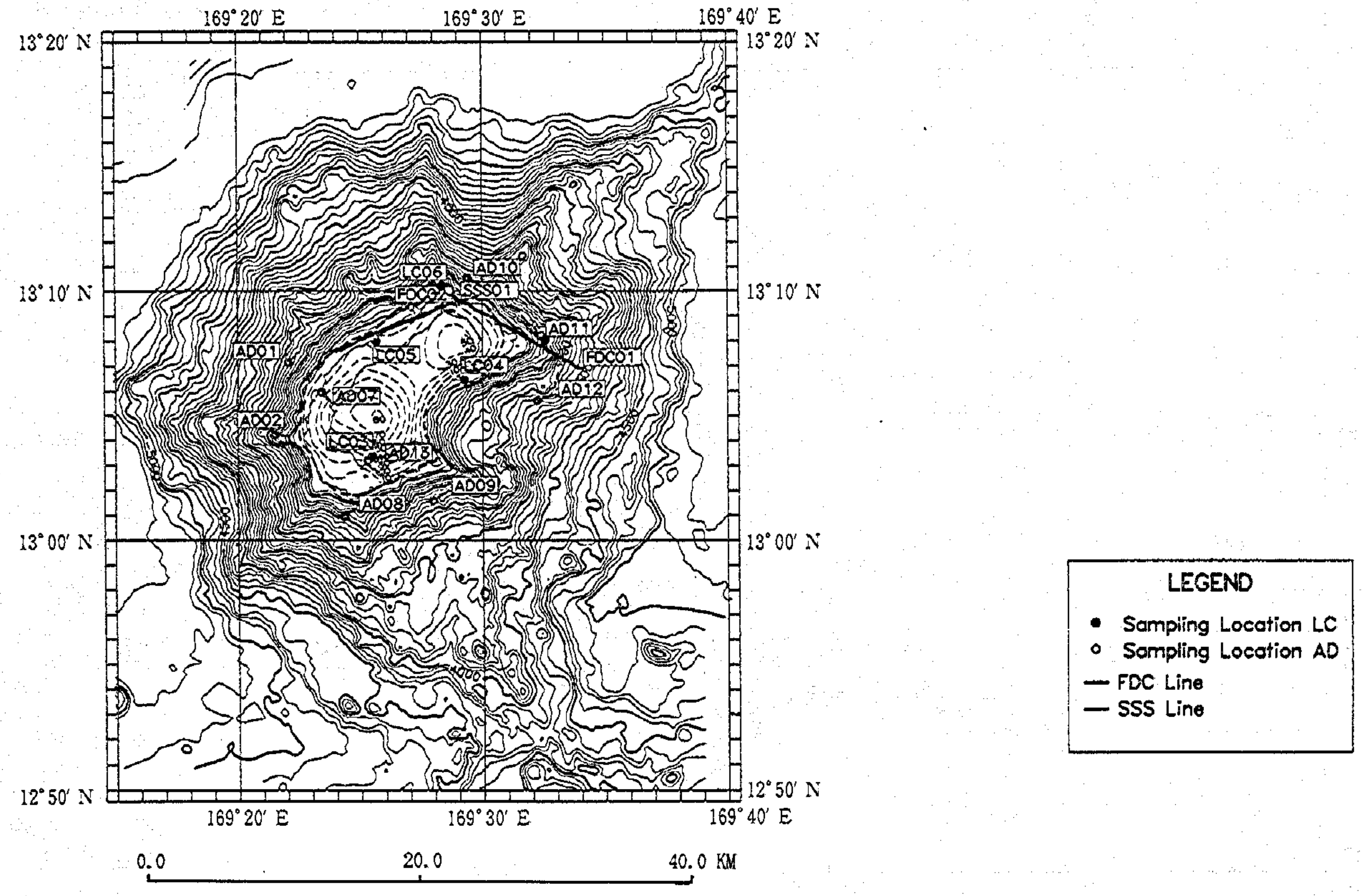



Fig. 3-3-4 (5) Isopach map of seamount MS06

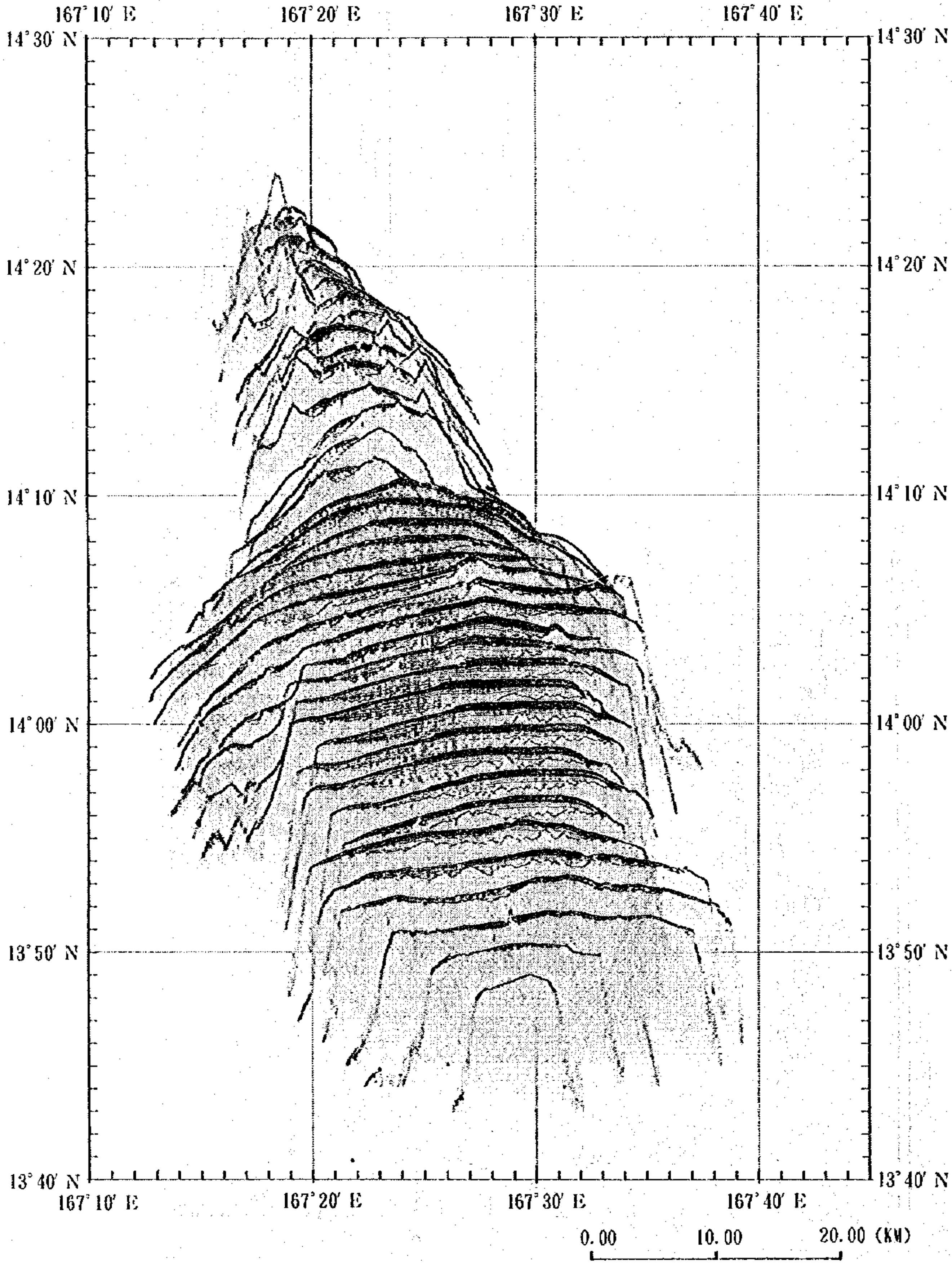



Fig. 3-3-3 (6) nSBP Profile of seamount MS08

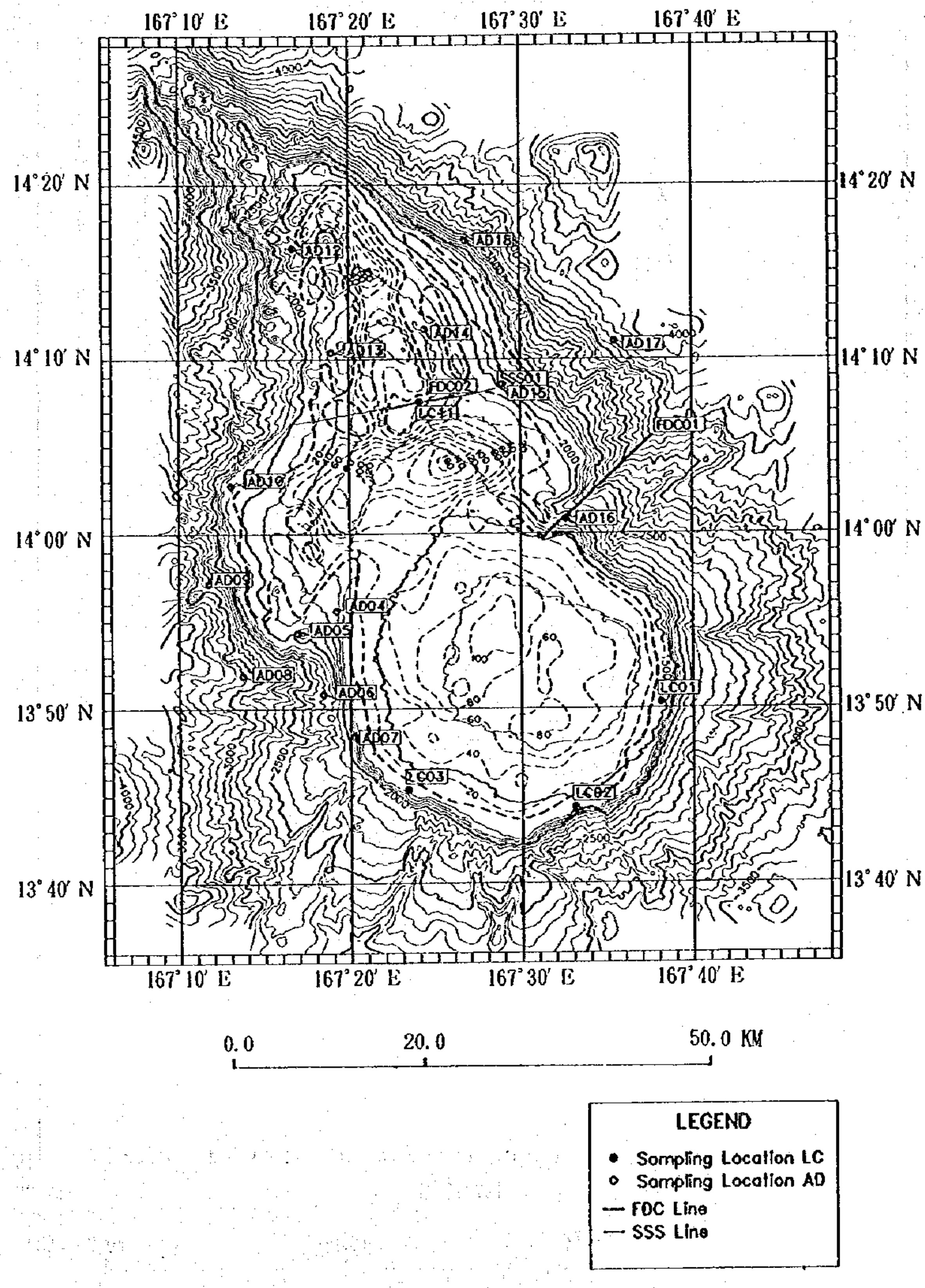



Fig. 3-3-4 (6) Isopach map of seamount MS08

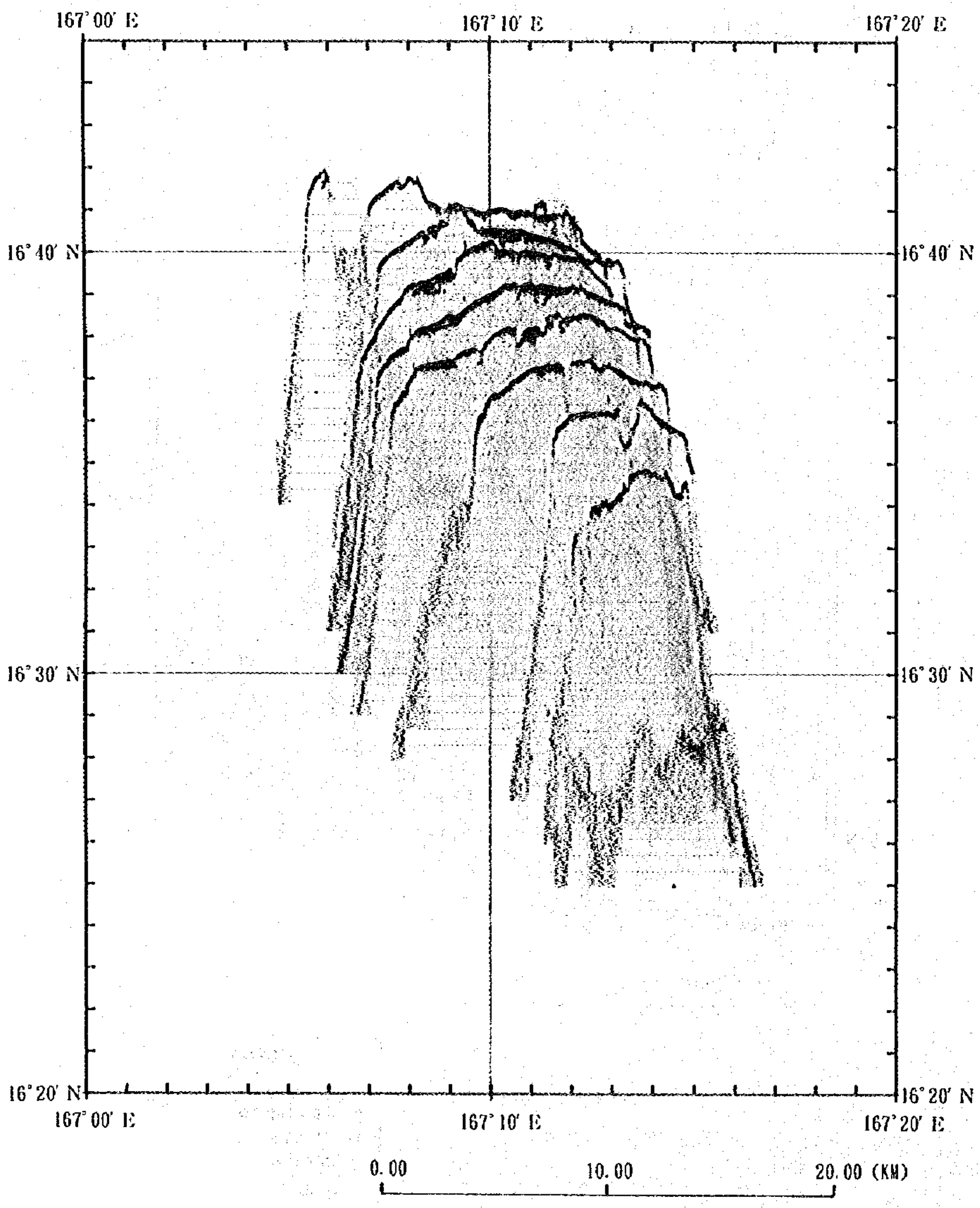



Fig. 3-3-3 (7) nSBP Profile of seamount MS09

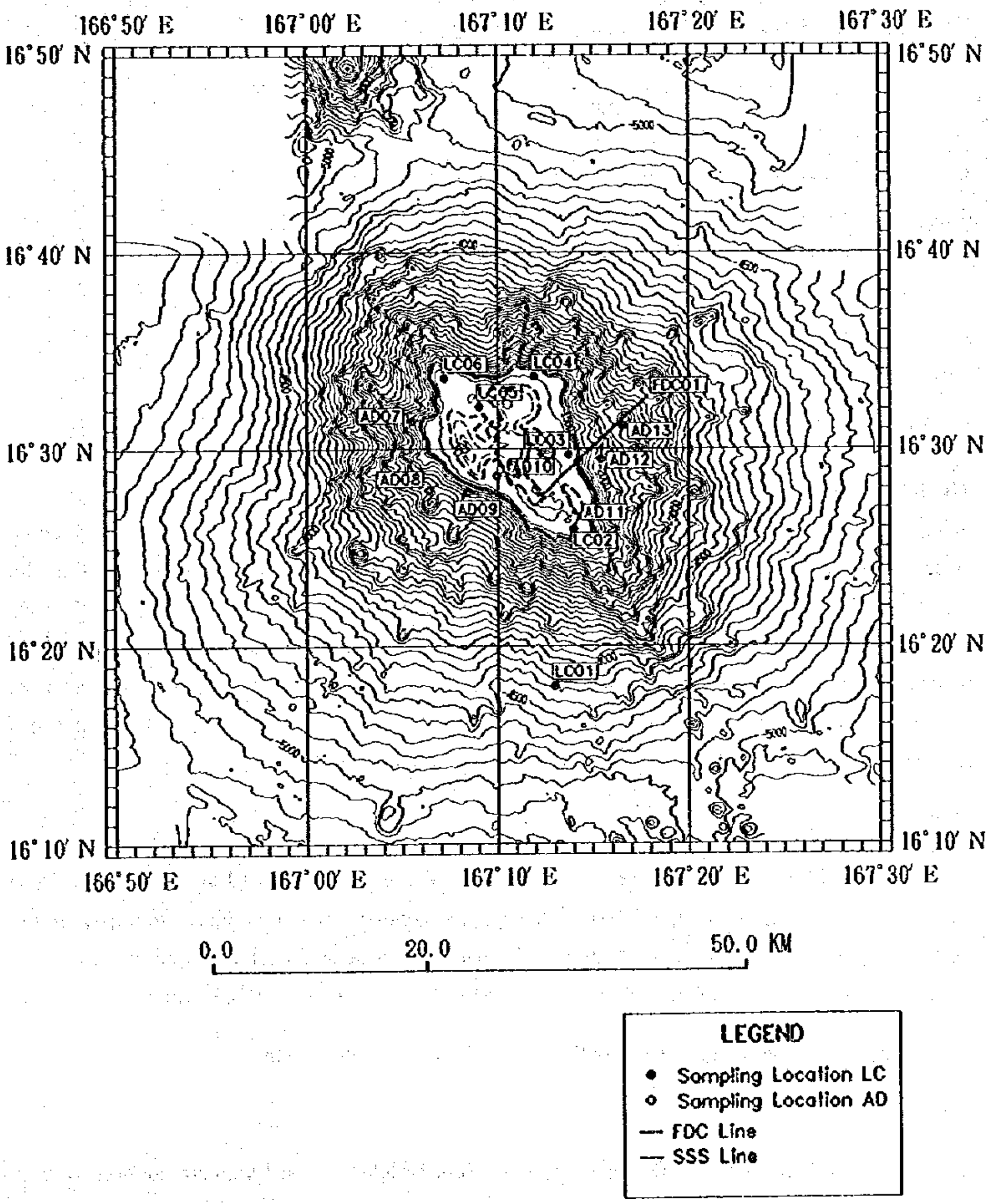



Fig. 3-3-4(7) Isopach map of seamount MS09 to correspond to unconsolidated sediments. T–type also occurs in 10 ~ 20 m thickness on the terraces of the northeastern and southwestern parts. O–type pattern occurs on the periphery of the top from 1,600 m water depth. Also there are O–type patterns corresponding to pinnacles on the top.

b. MS02

MS02 top is covered by T–type layer. Its thickness ranges from 10 to 70 m. T–type layer is divided into the eastern and western parts at 163° 05'E. It is most developed at the northwestern side of the top, and the upper layers form alternation and dome structure. On the southeastern side of the top, the thickness is about 40 m. O–type pattern occurs from 2,100m of water depth on the western side of the top and from 1,600 m depth on the eastern side. O–type also occurs sporadically corresponding to the pinnacles and topographic highs.

c. MS03

The MS03 top is covered by T–type layer. Its thickness ranges from 10 to 200 m. This T–type is most developed in the northwestern part where the upper layers form alternation and dome structure extending in the NE–SW direction. The sediment thickness of this seamount is the thickest of the nine seamounts surveyed. The isopach map shows an embayment near 13° 45'N., 163° 40'E., where the sediments appear to have been washed away. This embayment corresponds to a topographic depression. T–type layer occurs on the southwest terrace in 10 to 60 m thickness. O–type is distributed in the marginal parts of the top from 2,200 m water depth, but those corresponding to pinnacles or topographic highs on the top are not observed.

d. MS04

The MS04 top is covered by T–type layers. Their thickness ranges from 10 to 20 m. The T–type covers the entire top along the 1,100 m topographic contour. And it is most developed in the northeastern part, the upper layers forming alternation. The sediments tend to occur widely and thinly in the northern and western margin compared to the eastern and southern parts.

O–type occurs on the marginal parts of the top from 1,100 m water depth.

e. MS05

This is a pointed seamount and O–type is well developed while T–type layers are not observed.

This O–type is believed to represent manganese crust.

f. MS06

T–type layers occur on the top. Its thickness ranges from 10 to 80 m. The T–type layers cover the entire top and is most developed in the southern part where the upper layers form alternation and dome structure. Its thickness in the northeastern part is around 50 m. O–type occur in the marginal parts of the top from water depth of 1,800 m. High reflection acoustic intensity is observed within the marginal parts and is believed to be the edge by MBES acoustic image. But nSBP records show them as T–type.

g. MS07

This is a pointed seamount with well developed O–type layers and T–type layers are not observed. This O–type layer is believed to be manganese crust.

h. MS08

T–type layers occur on the top. Its thickness ranges from 10 to 160 m. These layers are divided into northern, middle, and southern groups. Those on the eastern side of the middle group is most developed and its upper layers form alternation and dome structure which extends east–northeastward. Isopach map shows an embayment near 14° 40'N., 167° 25'E. The sediments appears to have been washed away in this embayment. This corresponds to a topographic valley. The nSBP section records show what appears to be an eroded section in the south. The thickness of the sediments of this locality is similar to that of the eastern and western parts. This seemingly eroded part corresponds to the low reflection acoustic intensity zone in the MBES image indicating the existence of sediments. The slope is more gentle in the western side compared to the east. O–type occurs in the marginal parts of the top from about 2,200 m of water depth. Also in the central part, there are O–type patterns corresponding to pinnacles and topographic highs.

i. MS09

T–type layers occur on the top at water depth shallower than 1,300 m. Its thickness ranges from 10 to 20 m and the upper layers form alternation. O–type occurs on the top from around 1,300 m of water depth.

(3) Summary of nSBP survey

Nine seamounts were surveyed, and seven of which were table seamounts. Of these table seamounts, T–type layers are most developed on MS03 with maximum thickness of 200 m and they occur over the top to the marginal zone. There are no significant relations between the thickness of the sediments and the size of seamounts and water depth of the table seamounts.

Correlation between sampling (LC), seafloor photography (25 photographs), and nSBP records was attempted and the results are reported below.

Of the 25 seafloor photographs taken simultaneously with LC sampling, 14 show exposed manganese crust. Although the remaining 11 photographs show sediments, there were 6 samples which either contained manganese crusts or corer bits were deformed during sampling most probably by crust or exposed rocks. The remaining 5 samples were sediments and the maximum collected was 310 cm. Thus, 20 from 25 points were confirmed to contain manganese crust. This is a strong indication that localities of nSBP O−type correlates very well with the MBES acoustic reflection intensity data and is a very effective tool for determining the sampling localities. In the present case, sites with high MBES reflection acoustic pressure and nSBP O−type were selected for manganese crust sampling.

There were, however, localities where nSBP records show the existence of T−type layers and even its thickness could be inferred, but manganese crust exposures were confirmed by seafloor photography and sampling. Therefore, nSBP record alone is insufficient for determining the distribution of the sediments. High MBES acoustic zone often occur in such cases and it is important to consider both MBES acoustic pressure and SSS data together with nSBP records. Integrated study of all types of data is necessary particularly in determining the sampling points.

## 3−4 SSS Survey

SSS survey was carried out over the marginal areas of seamount summits where manganese crusts predominate. The major objective was to clarify the microtopography and the sediment distribution. In determining the location of the track lines, high MBES acoustic intensity zones (manganese crust exposures expected) were considered. Three seamounts, namely MS04, MS06, MS08 were surveyed.

Result of Side Scan Sonar Survey of seamounts MS04, 06, 08 are shown in Figures 3−4−1 ~ 3.

(1) Results of the survey

a. MS04

Seafloor topographic maps and MBES acoustic images show that unconsolidated sediments occur extensively on the top and that topographic highs which appear to be edges occur sporadically in the marginal parts. Also high acoustic intensity zones occur sporadically indicating small pinnacles or topographic highs.

For this seamount, intention of the survey was to clarify the conditions of the flat summit and the southeastern slope which have high MBES acoustic reflection intensity image. Small parts covered by sediments were found in the southern slope. The MBES acoustic reflection images and SSS images are harmonious on the flat top. Relatively strong MBES acoustic reflection occurs near 14° 23'N., 165° 55.5'E., on the southeastern slope, but SSS image indicates the existence of sediments with low reflection pressure. It was confirmed by FDC observation that sediments cover this locality.

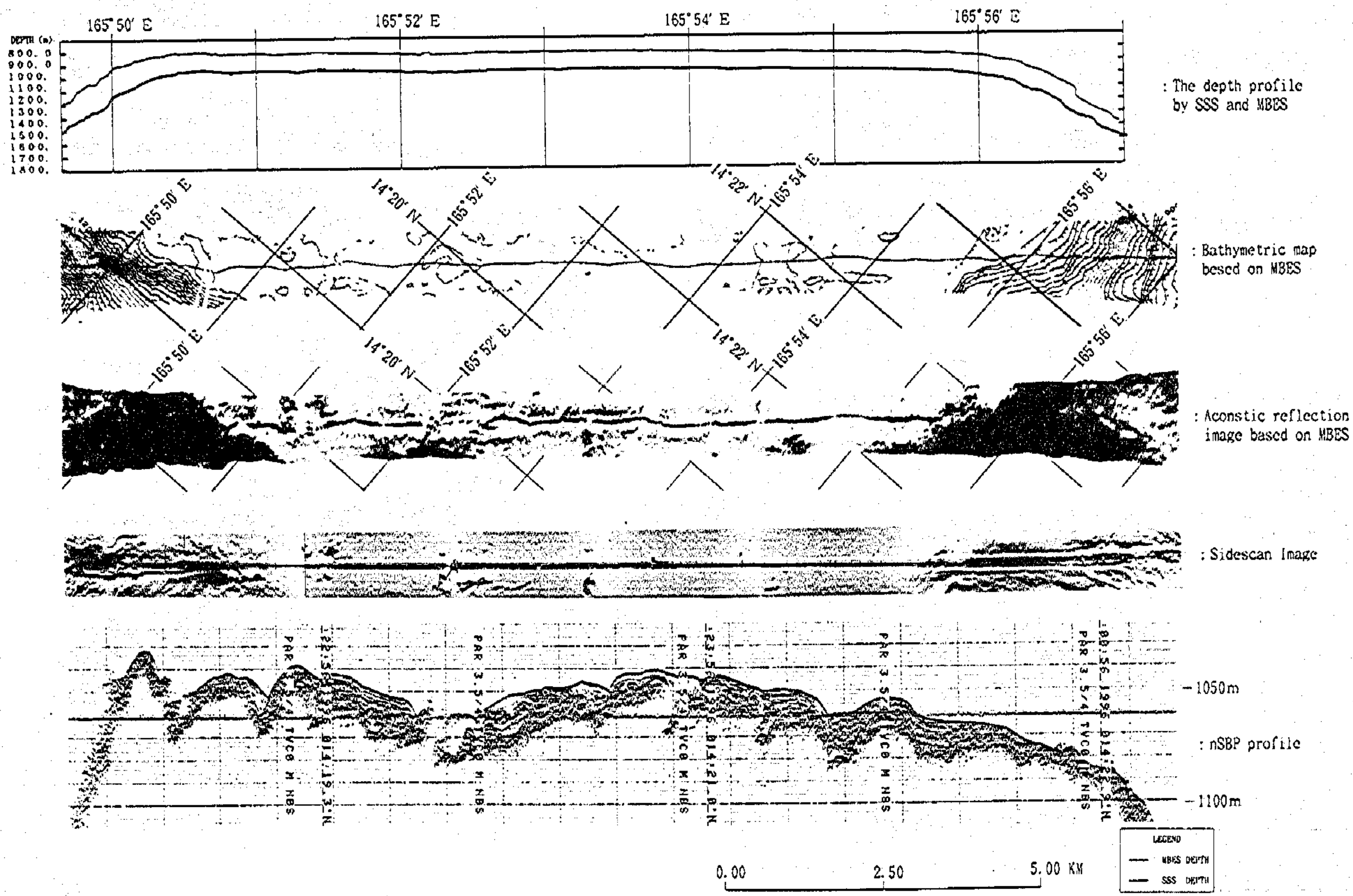



Fig. 3-4-1 Results of Side Scan Sonar Survey of seamount MS04

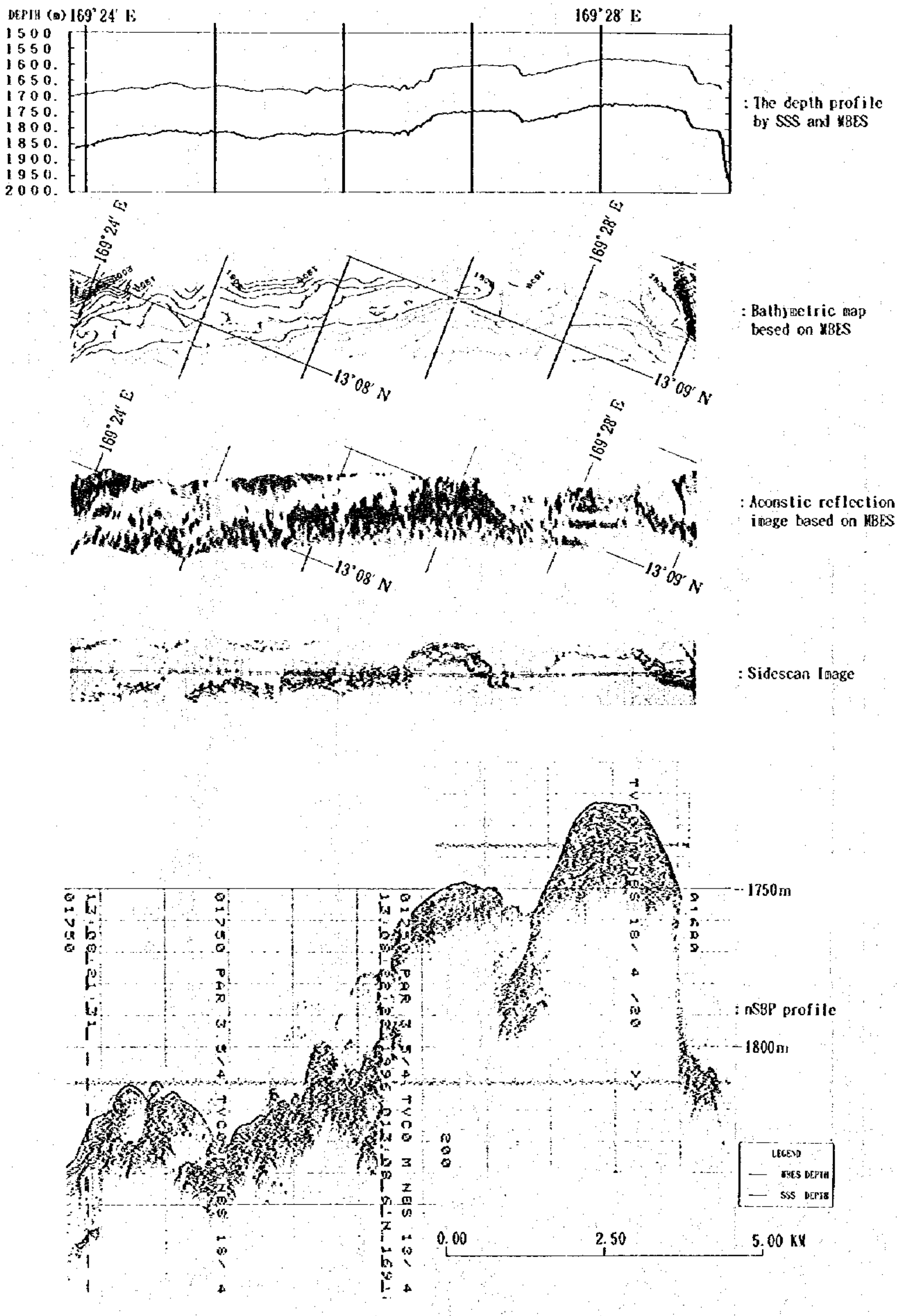



Fig. 3-4-2 Results of Side Scan Sonar Survey of seamount MS06

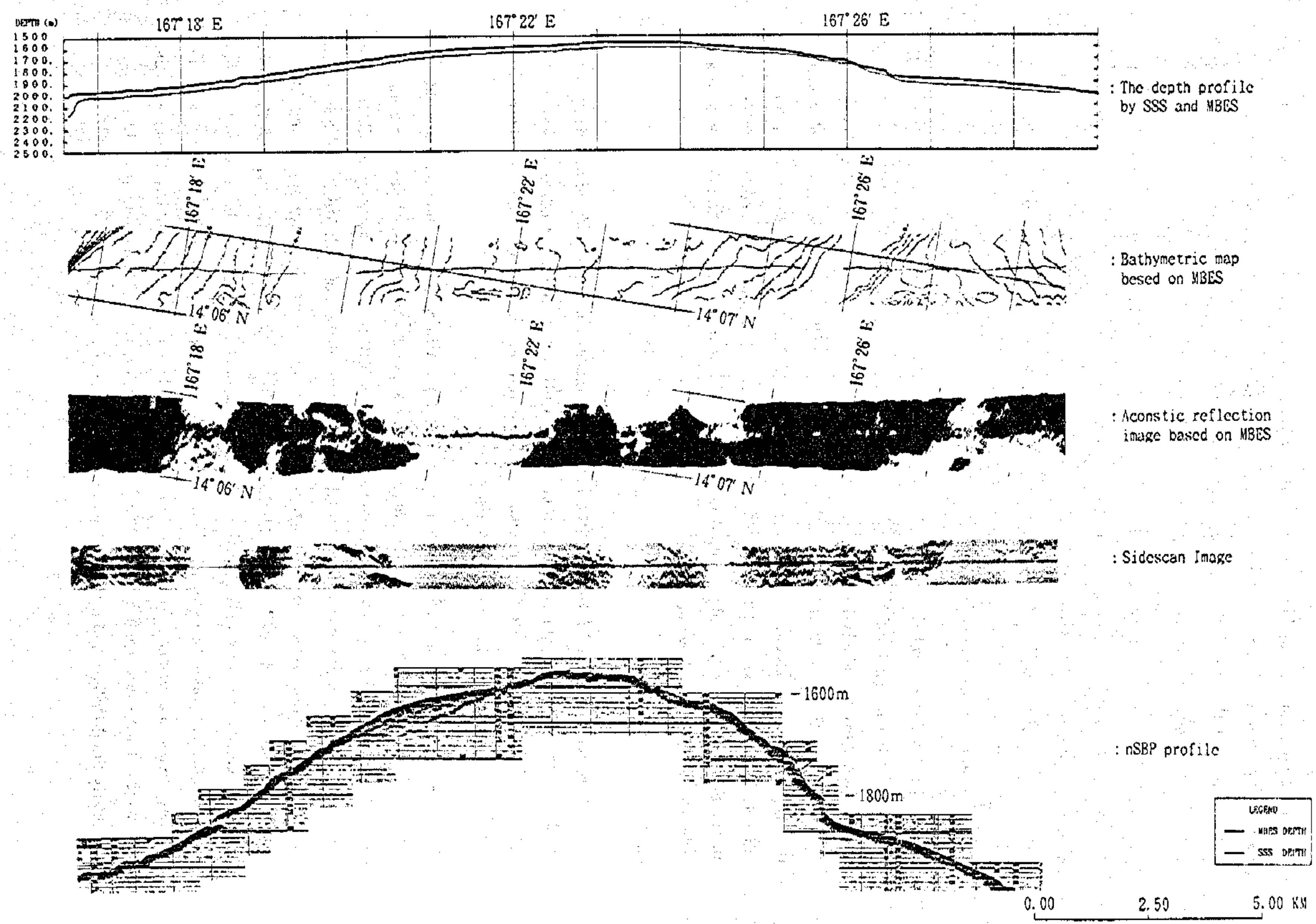



Fig. 3-4-3 Results of Side Scan Sonar Survey of seamount MS08

b. MS06

It is inferred from topographic map and MBES acoustic reflection image, that the top is widely covered by unconsolidated sediments and high acoustic reflection intensity zones believed to be edges appear at the marginal parts. Also high reflection acoustic intensity zone corresponding to pinnacles and topographic highs appear on the western and southern sides.

The track line was set northeastward from 13° 07'N., 169° 22.4'E., on the northern slope. This survey was carried out in order to clarify the conditions of the MBES high acoustic reflection intensity zones indicating edges at the top margins together with the high zones which occur between the top margins and the edges. The MBES acoustic images and the SSS images are harmonious on the northern slope. The high acoustic intensity zones on the northern slope are correlated to the distribution of the manganese crust.

The SSS images at the relatively high MBES acoustic intensity zone near 13° 08'N., 169° 25'E., between the top margins and the reef edge is correlated to manganese crust. FDC observation of this locality, however, showed sediments. This is believed to be caused by the FDC being towed over sediments between the margin and the edge. Although only strong reflection was observed in the MBES acoustic reflection image of the edge near 13° 09'N., 169° 27'E., low acoustic reflection intensity indicating the existence of sediments was confirmed within the edge by SSS. FDC observation line across this edge showed manganese crust at the high acoustic intensity zone and sediments at parts with low intensity.

c. MS08

From topographic maps and MBES acoustic images, it is seen that unconsolidated sediments occur widely on the top and high reflection acoustic intensity zones reflecting edges appear in the margins. High acoustic reflection intensity is observed in the western and southern parts corresponding to pinnacles or topographic rises.

SSS track lines were designed to pass through the high MBES acoustic pressure zone at the northern side of the southern part of the image. It extends in the east–northeast direction from 14° 06'N., 167° 14.8'E. The objective was to correlate the low MBES acoustic intensity distribution and the seafloor conditions observed. The acoustic intensity distribution of both MBES and SSS agree well along the entire track line. Although relatively strong acoustic intensity appears on MBES acoustic image near 14° 07'N., 167° 20'E., and the slope near 14° 08'N., 167° 26.5'E., low reflection acoustic intensity indicating the existence of sediments appear on the SSS image within the high reflection zone. Also seafloor observation showed that sediments occur in low SSS acoustic pressure zones and manganese crust is observed in high intensity zones nearly throughout the survey area. Thus it was confirmed that SSS images accurately reflect the conditions of the seafloor, particularly the distribution of the sediments and manganese crusts.

(2) Summary of SSS survey

The present SSS survey showed that its reflections generally agree well with the MBES acoustic reflection images and FDC observation. It is noted that SSS high acoustic intensity zones correspond to exposed manganese crusts. Also SSS method is extremely useful for studying locally low reflection acoustic intensity zones, slopes covered by thin sediments and microtopographic features which are difficult to investigate by MBES alone. Thus SSS plays an extremely important role in determining the sampling points.

As SSS images are capable of providing more detailed information regarding the distribution of sediments and manganese crust than MBES acoustic reflection images, SSS is an effective method for obtaining basic information for planning FDC track lines and for understanding the detailed conditions of the seafloor. In terms of obtaining information on seafloor conditions rapidly and for covering large areas in the reconnaissance stage, however, SSS would take second place, but for comparative study between MBES acoustic reflection image and seafloor observation, and for verification, this is an important tool.

# Chapter 4 Geology

## 4–1 Geological Setting

Marshall Islands are located in the northwestern part of the Central Pacific and are aligned in the north–northwest to south–southeast direction. Gilbert Islands are located in the southern extension of the island chain.

In the survey area, there are some oceanic islands and atolls, and many seamounts and guyots. These seamounts occur largely in two seamount chains. The western chain is called Ralik Seamount Chain extending northwest–southeastward and includes the Kwajalein and the Bikini Atolls. The former is the largest atoll in the Marshall Islands. The eastern chain is called the Ratak Seamount Chain extending north–northwest to south–southeastward and comprises the Majuro Atoll.

The three seamounts MS01 to MS03 are in the western Ralik Seamount Chain and the six seamounts MS04 to MS09 in the eastern Ratak Seamount Chain.

The seamounts and oceanic islands in the survey area were formed by hot spot activity which was the result of magma rising to the surface. As the oceanic plate moves, the old volcanoes stop their activity while the stationary hot spot forms a new volcano immediately above it. With the repetition of this activity, the islands and seamounts align to form chains. The Pacific Plate is presently moving eastward, but the alignment of the islands indicates that the plate had moved north–northwestward at the time of the formation of the seamounts in the survey area. Thus the age of the seamounts increases northward.

Submarine volcanic activity in the Central Pacific near the equator began during 105 to 85 Ma, and islands and atolls were formed and shallow sea volcanism was probably active during 85 to 80 Ma (Hein et al., 1988). The volcanic rocks forming these islands are different from the oceanic ridge basalt which forms the ocean floor, and are called oceanic island basalt (OIB).

The seamounts surveyed consist of basalt and its clastic material accompanied by limestone and sedimentary rocks. Rocks exposed on the seafloor are usually covered to varying degrees by iron–manganese oxides and these are called manganese crusts. The flat summits of the guyots, with the exception of the marginal zones, small hills, and flanks, are covered by thick unconsolidated foraminifera sand. The flanks of the seamounts are believed to be covered mainly by secondary sediments through erosion and mass movement, and foraminifera sands cover the low angle zones of the flanks.

The target of this survey is the exposed manganese crusts which cover rocks on the seafloor. Manganese crusts are mainly composed of iron–manganese oxides, which are similar to manganese nodules occurring on the deep ocean seafloor. The characteristic feature of the manganese crusts is the relatively high cobalt content of 0.5 to 1.5 wt% which is significantly higher than the 0.2 wt% average of manganese nodules. Thus it is called cobalt–rich manganese crusts. The relatively high content of platinum, 0.3 to 1.0 ppm, is also noteworthy. The thickness of the manganese crusts varies significantly under the influence of the topographic factors, geology, water depth, shape and location of seamounts. The average crust thickness in the survey area is generally around 2 cm, and the maximum value often exceeds 10cm. The results of geology, rocks, and manganese crusts studies are described in the following chapters.

## 4−2 Sampling Results

Arm dredge (AD) and large gravity corer (LC) were used for sampling manganese crusts and seafloor sediments on the seamounts. The rocks collected by AD and seafloor sediments and rocks collected by LC are described, and the outline of the samples of each seamount is reported in this section. Sampling sites are shown in Figures 4−2−1(1) to (9), and the collected samples (including manganese crusts) are listed semi−quantitatively in Tables 4−2−1(1),(2).

### (1) Rocks

The collected rocks are volcanic rocks; basalt, basaltic pyroclastic rocks, basalt breccia, tuff, and pumice, and sedimentary rocks; volcanic conglomerate, sandstone, mudstone, limestone, and phosphorite. Photographs of the typical rock samples are laid out in Figures 4−2−2 (1), (2). These rocks are described below.

1) Basalt (Fig. 4−2−2(1), Photo Nos. 1 to 5)

Fresh parts are dark gray, but most of them are brownish gray by weathering. Most have a porphyritic texture and aphyric basalt is rare. Phenocrysts are 0.5 to 7 mm, but those exceeding 4 mm are rare. Almost all phenocrysts are altered to brown color and these are probably mafic minerals such as pyroxene, and some show a glomeroporphyritic texture. Fresh prismatic plagioclases are often observed. The matrix is porous with vesicles, and is rarely compact. Spherical to ellipsoidal pores with 0.1 to 6 mm major axes are filled with silica minerals, clay, and phosphorite in some cases. Some samples have greenish−brown gray color by weak alteration. Pillow lava was collected at 96MS04AD09. (Fig. 4−2−2 (1), Photos 1,2). The diameter of the pillow lobe is 15 to 20 cm, and the chilled margin about 1cm thick is brown to grayish brown.

This category basically consists of various types of lava flow and includes volcanic breccia and floats.

2) Basaltic pyroclastic rocks (Fig. 4−2−2(2), Photo Nos. 9 to 12)

Argillized greenish yellow gray basaltic lapilli is the major constituent with brown basaltic pebbles and granules. The lapillis are subangular to subrounded and are porous with many vesicles. The sorting is poor and the compaction is somewhat low. The amount of lapillis varies from very large to almost nil and some with the low lapilli content are hyaloclastic with a weak stratification. The matrix consists mainly of fine-grained clastics argillized to greenish yellow clay. In some cases it contains phosphorite, carbonate minerals, manganese oxides, and foraminifera fossils.

This category means pyroclastic rocks in a wide sense, and includes hyaloclastite and secondary deposits.

3) Basalt breccia (Fig. 4-2-2 (1), Photo Nos. 6 to 8)

Weathered basalt boulders and pebbles are the main constituents. They are subangular to subrounded and are poorly sorted with cavities between the breccias. The matrix is small in amount and is composed of green argillized basaltic pyroclastics, phosphorite, carbonate minerals, and manganese oxides.

This category includes volcanic breccia and brecciated lava.

4) Volcanic conglomerate

This consists mainly of dark gray to brown basalt granules accompanied by pebbles. The matrix consists of basaltic-grained coarse sandstone and is carbonatized and phosphatized. Pebbles are subrounded to rounded. The sorting is moderate and the solidification is fair. The alternation of this conglomerate and pebble bearing sandstone is observed in some cases.

5) Sandstone (Fig. 4-2-2 (2), Photo No. 13)

Sandstone in this area are composed of pebble bearing coarse grained gray wacke, reddish brown low-compacted fine to coarse grained volcanic sandstone, brownish gray fine to medium-grained calcic sandstone, pale brown foraminifera-rich fine grained sandstone, and greenish brown gray tuffaceous coarse grained sandstone. Some are stratified.

6) Mudstone (Fig. 4-2-2 (2), Photo No. 14)

This comprises gray to dark gray mudstone with weak bedding, brownish gray mudstone with thin bedding, and pale brown argillaceous mudstone with thin bedding.

7) Limestone (Fig. 4-2-2 (2), Photo No. 15)

Limestone in this area consists of shells, corals, and foraminifera. It is generally porous, but it becomes compact upon phosphatization. Some have bedding. This category includes low-compacted foraminifera limestone (sandstone).

8) Phosphorite (Fig. 4-2-2 (2), Photo No. 16)

Phosphorite occur as precipitate in cavities, phosphatized limestone, phosphatized matrix of pyroclastic rocks and conglomerates, and gravels derived therefrom.

## MS01

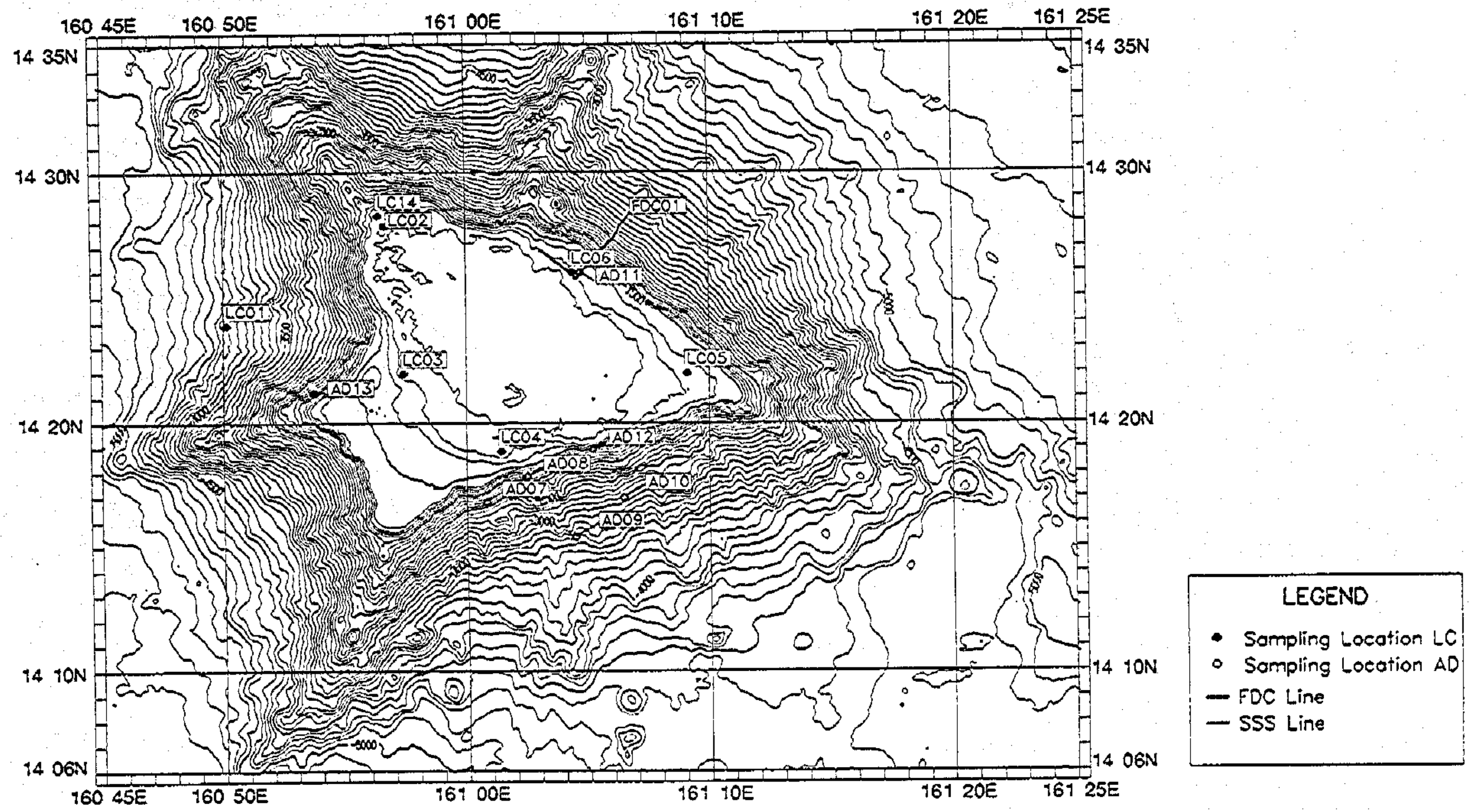



Fig. 4-2-1(1) Location map of sampling site (seamount MS01)

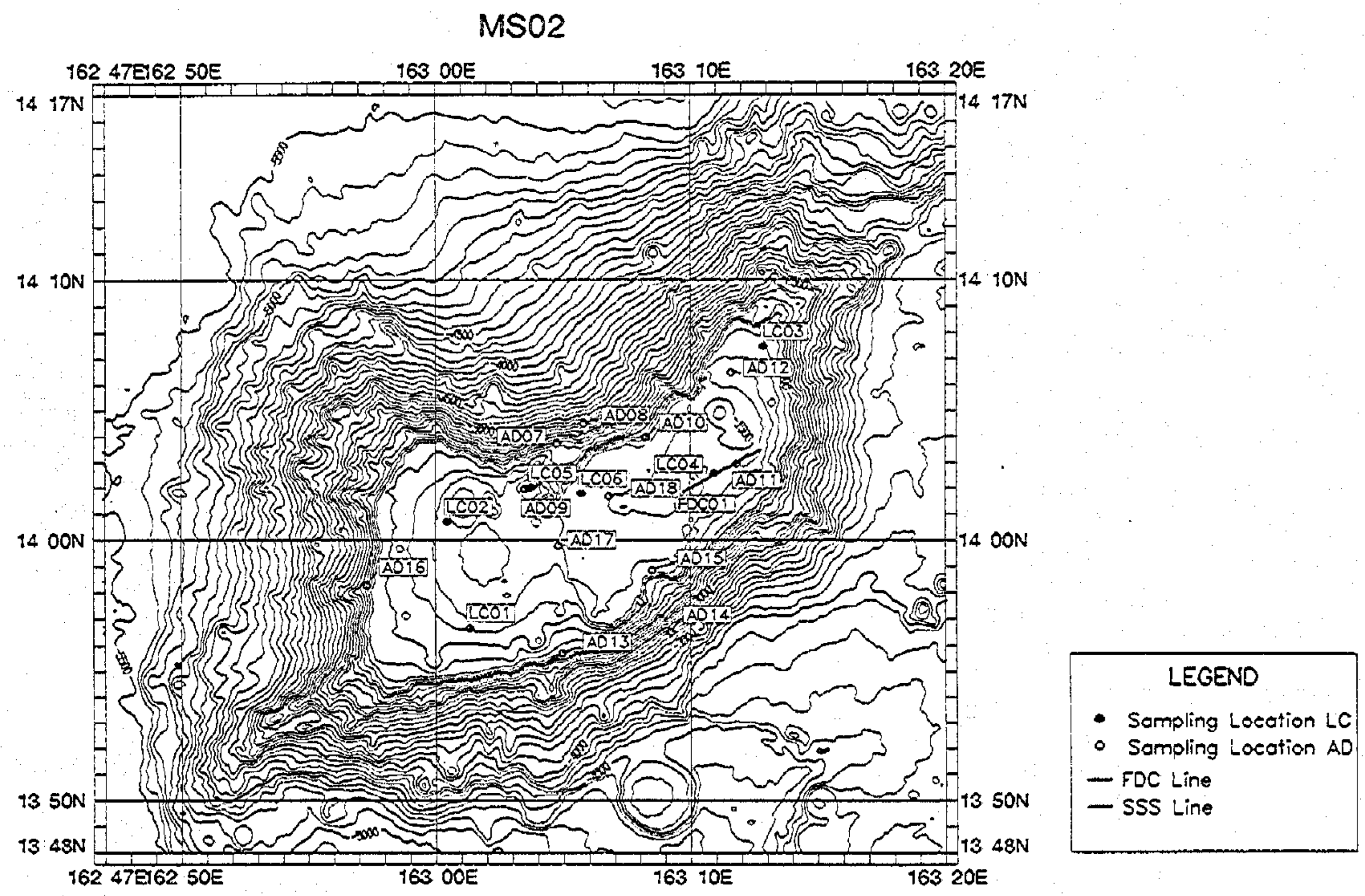



Fig. 4-2-1(2) Location map of sampling site (seamount MS02)

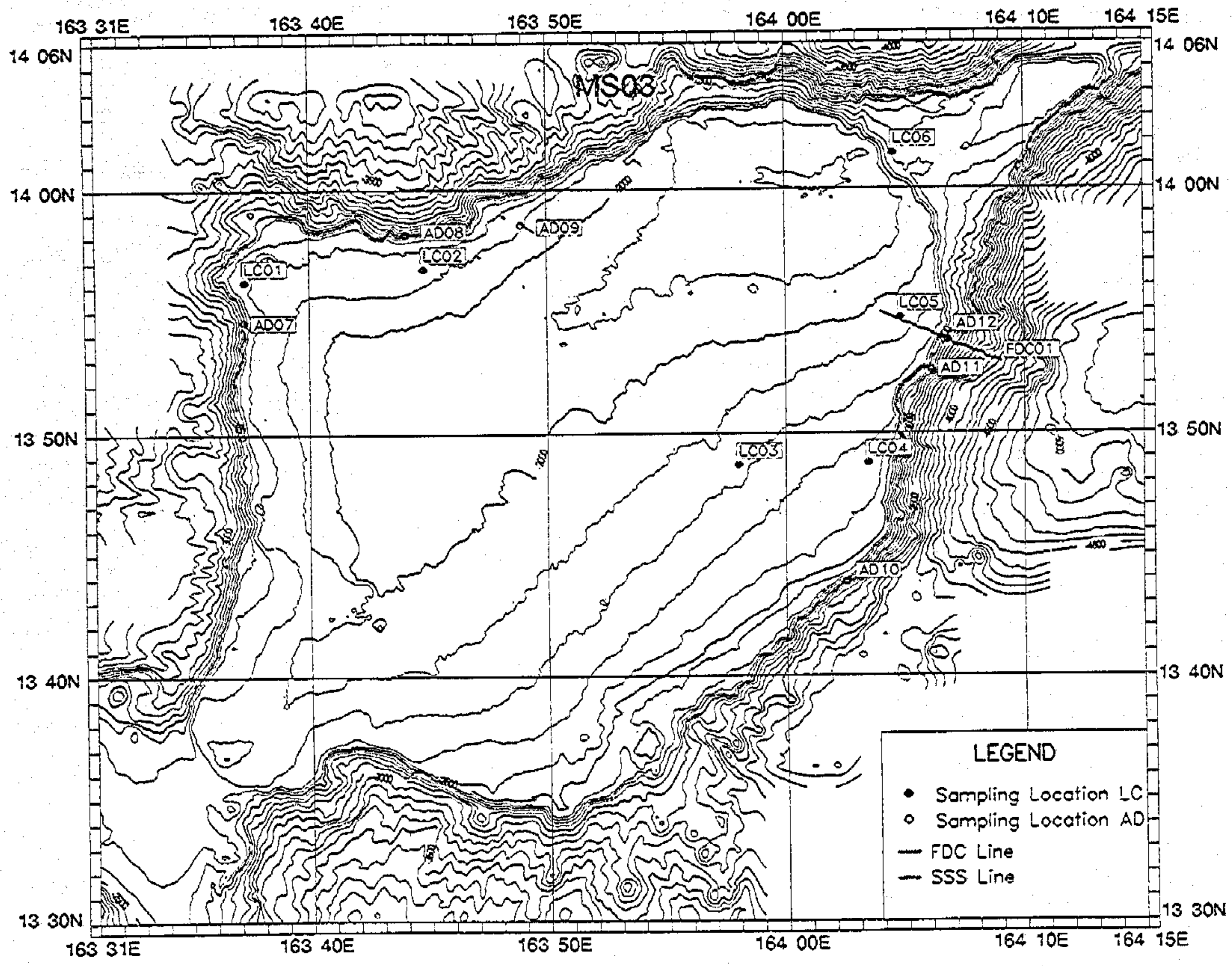



Fig. 4-2-1(3) Location map of sampling site (seamount MS03)

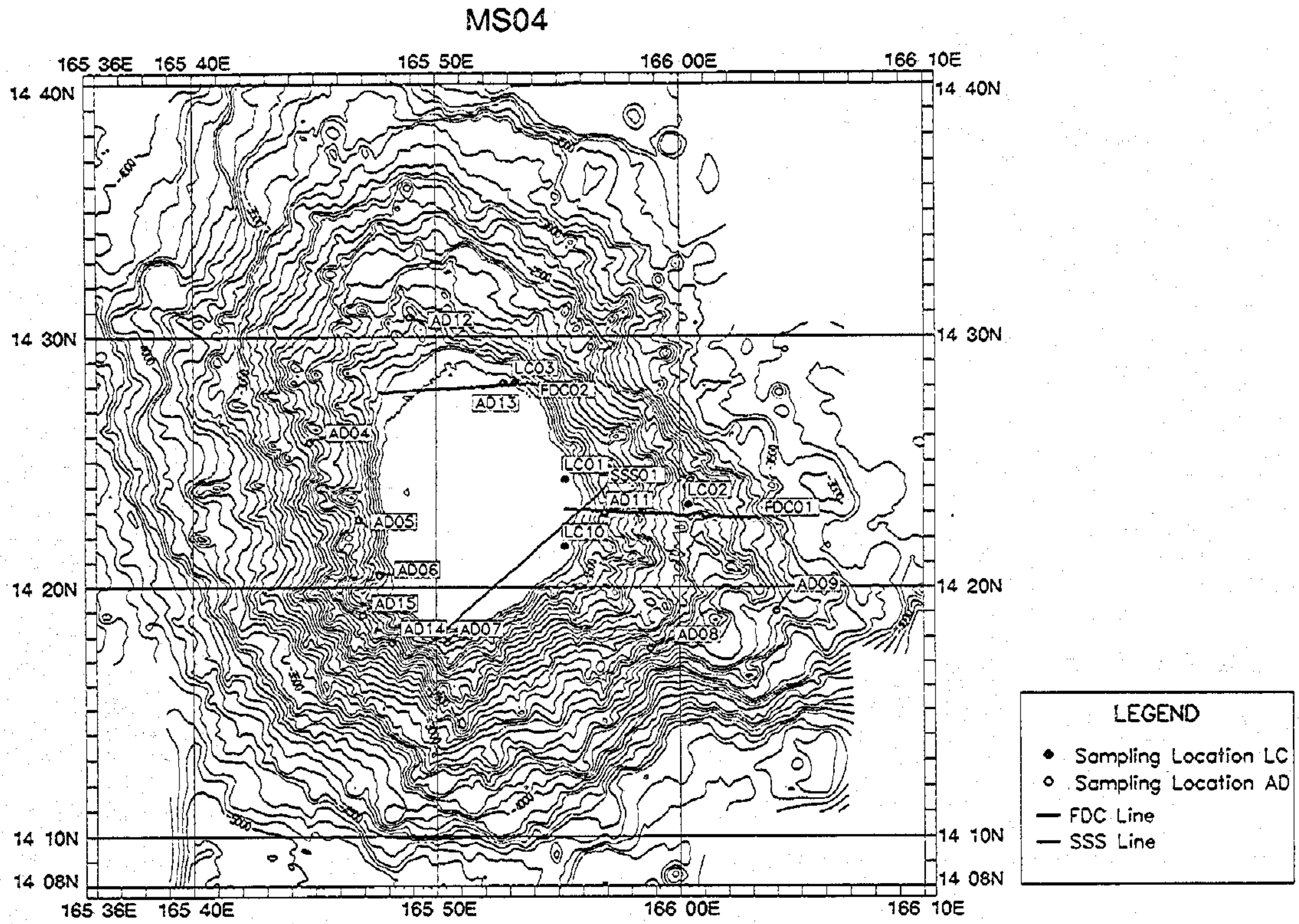



Fig. 4-2-1(4) Location map of sampling site (seamount MS04)

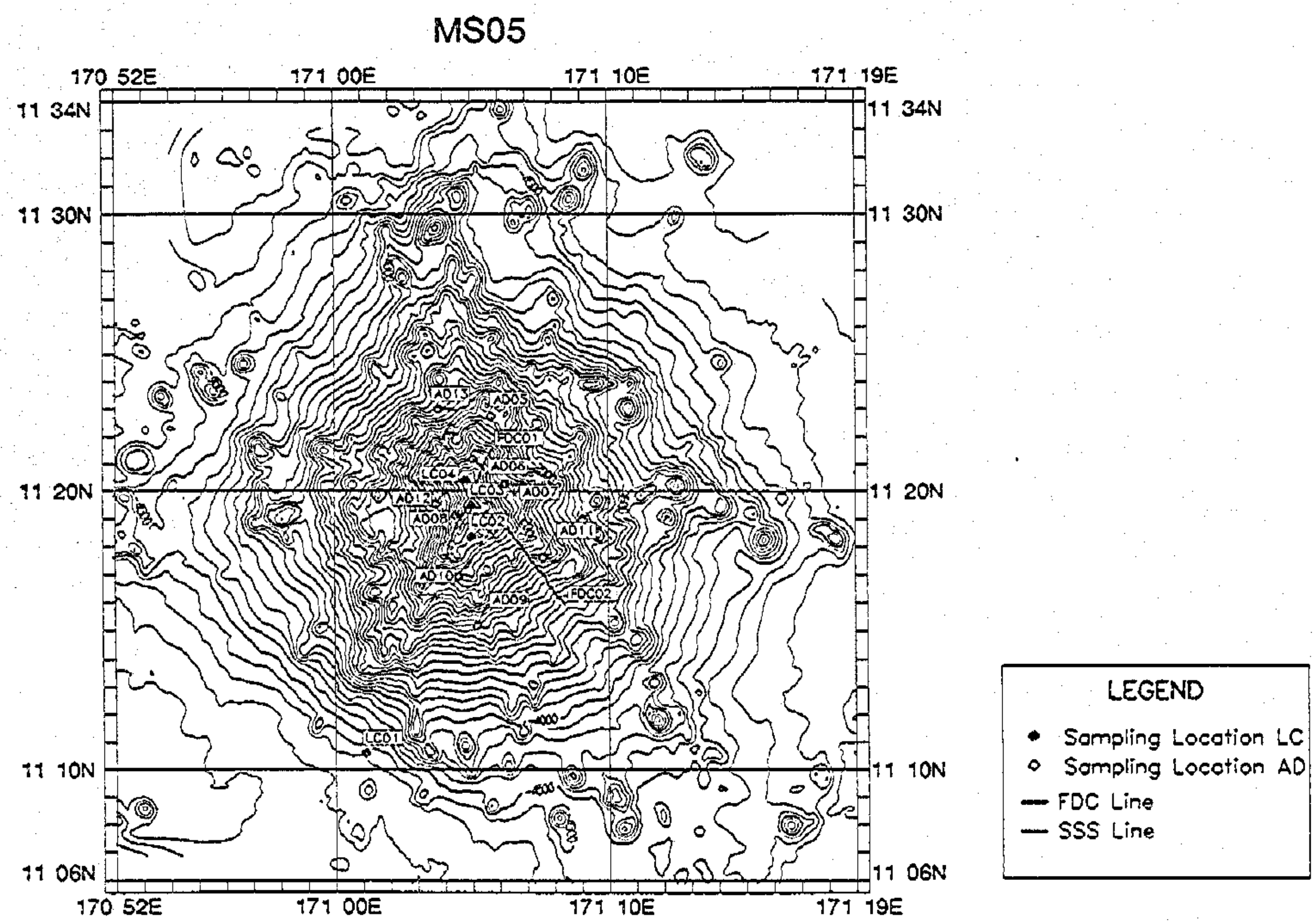



Fig. 4-2-1(5) Location map of sampling site (seamount MS05)

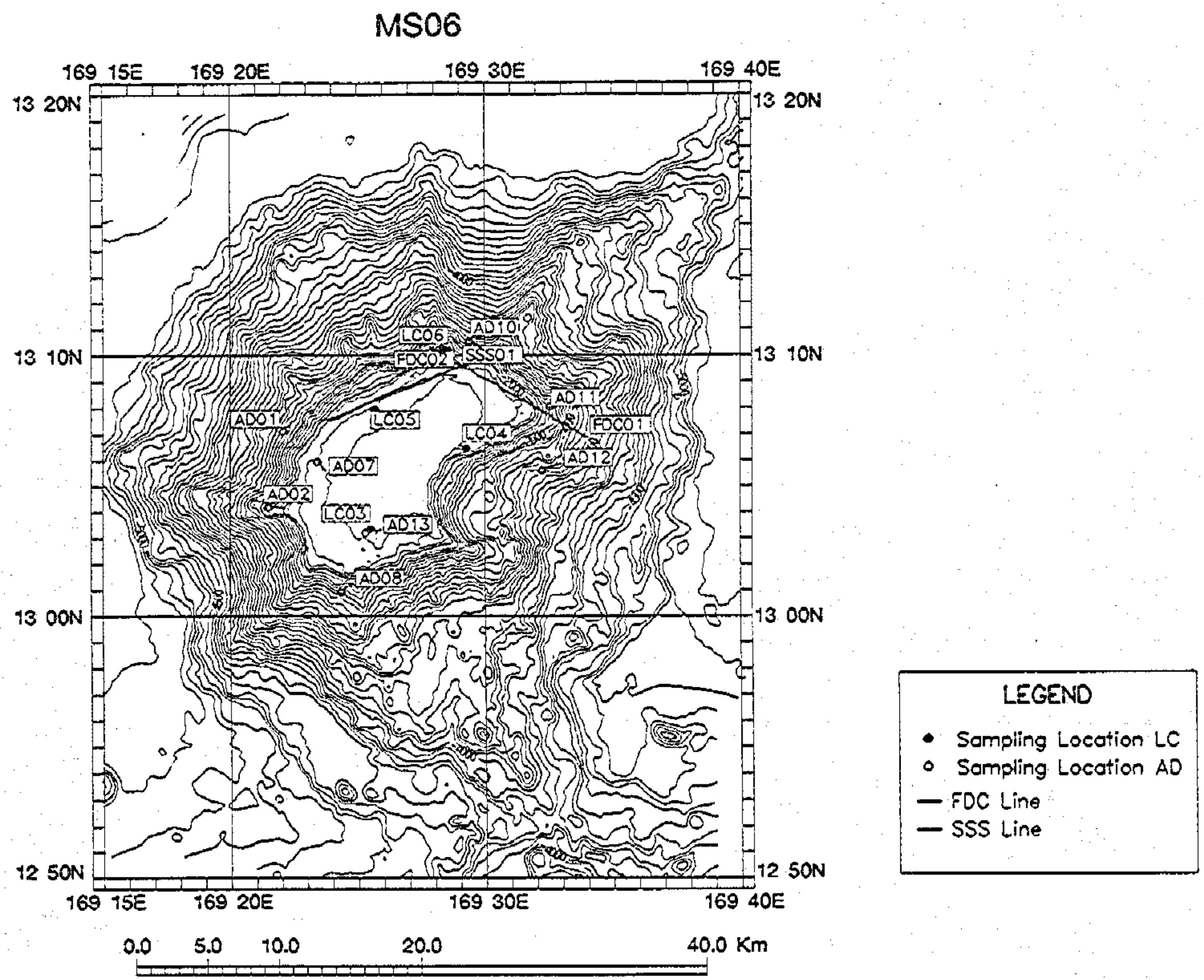



Fig. 4-2-1(6) Location map of sampling site (seamount MS06)

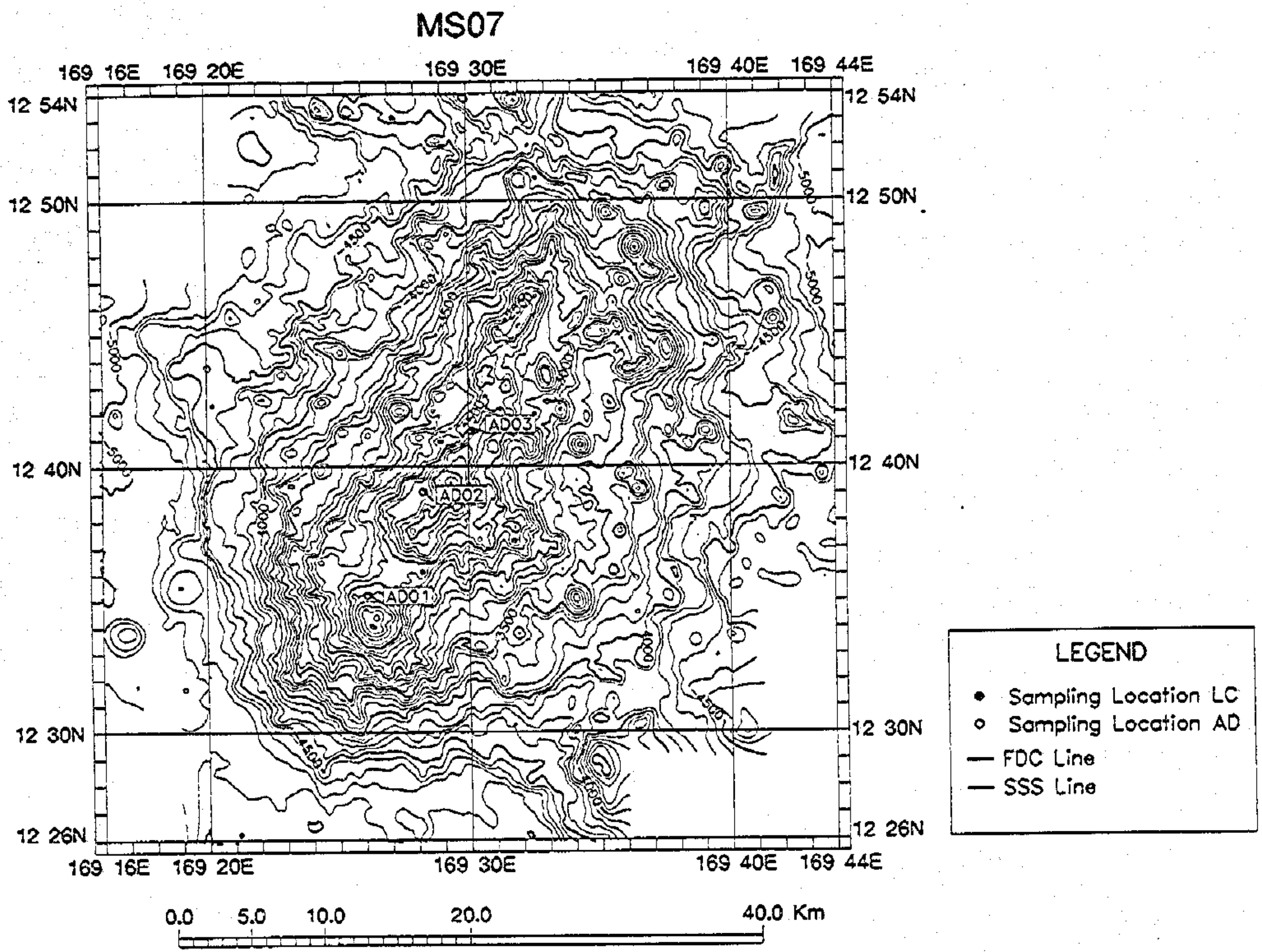



Fig. 4-2-1(7) Location map of sampling site (seamount MS07)

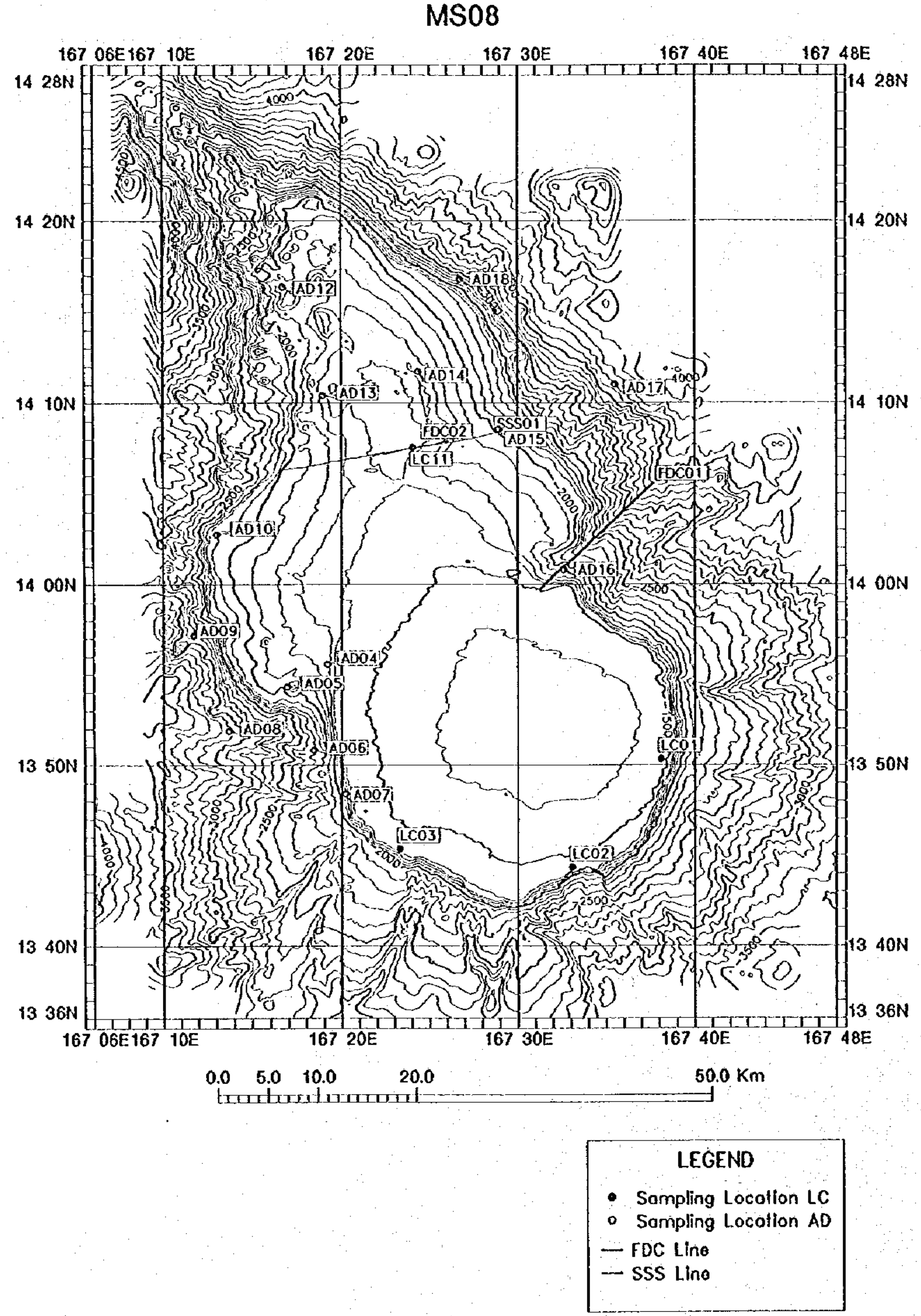



Fig. 4-2-1(8) Location map of sampling site (seamount MS08)

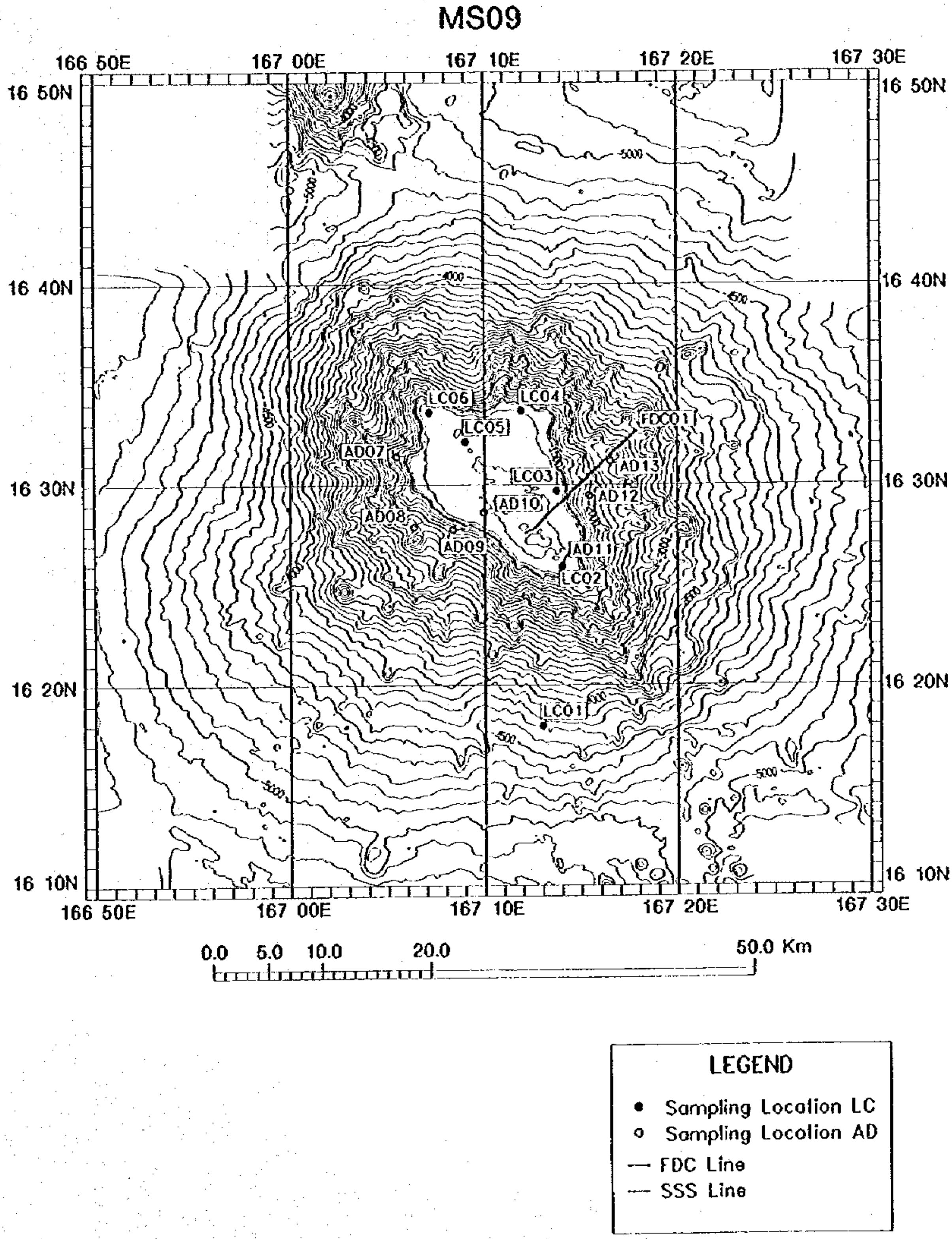



Fig. 4-2-1(9) Location map of sampling site (seamount MS09)

## Table 4-2-1(1) List of collected materials

| SMT | SSN | Cr | Cr-C | Nd | Ba | Py | Br | Cg | Ss | Ms | Ls | Ph | Pm | Fs | Others | Geology | Thick |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MS01 | LC01 | | | | | | | | | | | | | 230cm | | | |
| | LC02 | | | | | | | | | | | | | 95cm | | | |
| | LC03 | 8cm | | | | | | | | | | | | | | | 50 |
| | LC04 | 8cm | | | | | | | | | | | | | | | 75 |
| | LC05 | 9cm | | | | | | | | | | | | | | | 30 |
| | LC06 | | | | | | | | | | | | | | NS | Crust | |
| | AD07 | △ | | | △/C | | △/C | | | | | | | | | | 20 |
| | AD08 | △ | | | △/C | | | | | | + | | | | | | 30 |
| | AD09 | | ○ | △ | | ○ | | | | △ | | | | | ○/mud | | 20 |
| | AD10 | ○ | | + | | △ | ○ | | | | | | | | | | 40 |
| | AD11 | ○ | | + | ○ | | △ | | | | | | | | | | 40 |
| | AD12 | | ◎ | | | △ | ◎ | | | | | | | | | | 40 |
| | AD13 | + | | | + | | | | | | | | | | | | 20 |
| | LC14 | 4cm | | | | | | | | | | | | | | | 30 |
| MS02 | LC01 | 4cm | | | | | | | | | | | | | | | 40 |
| | LC02 | 5cm | | | | | | | | | | | | | | | 25 |
| | LC03 | | | | | | | | | | | | | | NS | Crust | |
| | LC04 | 10cm | | | | | | | | | | | | | | | 50 |
| | LC05 | + | | | | | | | | | | | | | | | |
| | LC06 | 4cm | | | | | | | | | | | | | | | 30 |
| | AD07 | ○ | | | | | | | | | ○ | | | | | | 40 |
| | AD08 | △ | | | △ | | | | | + | | | | | | | 20 |
| | AD09 | | | | | | | | | | | | | | NS | Crust | |
| | AD10 | + | | | + | | | | | | | | | | | | 10 |
| | AD11 | | | + | | | | | + | | | | | | | | 10 |
| | AD12 | + | | | | | | | | | | | | | | | 20 |
| | AD13 | | △ | + | + | △ | | | | | ○ | | | | | | 15 |
| | AD14 | ○ | | | ○ | △ | | | | | + | | | | | | 20 |
| | AD15 | + | | | | | | | | | | | | | | | 7 |
| | AD16 | ○ | | + | △ | | ○ | | + | | | | | | | | 50 |
| | AD17 | + | | | | | | | | | | | | | | | 5 |
| | AD18 | + | ○ | + | △ | | ○ | | | | | | | | | | 40 |
| MS03 | LC01 | 7.5cm | | | | | | | | | | | | | | | 75 |
| | LC02 | | | | | | | | | | | | | 105cm | | | |
| | LC03 | | | | | | | | | | | | | 310cm | | | |
| | LC04 | | | | | | | | | | | | | | NS | Sand+Crust | |
| | LC05 | 2cm | | | | | | | | | | | | | | | 20 |
| | LC06 | | | | | | | | | | | | | | NS | Sand | |
| | AD07 | + | + | | | | + | | | | | | | | | | 15 |
| | AD08 | | +/C | | +/C | | + | | | | + | | | | | | 1 |
| | AD09 | ○ | | + | | | | | ○ | | ○ | | | | | | 65 |
| | AD10 | ○ | | | ○ | | | | | | | | | | | | 20 |
| | AD11 | + | | | + | | | | | | | | | | | | 15 |
| | AD12 | + | | | +/C | + | | | | | | | | | | | 8 |
| MS04 | LC01 | | | | | | | | | | | | | | NS | Crust | |
| | LC02 | 8cm | | | | | | | | | | | | | | | 56 |
| | LC03 | + | | | | | | | | | | | | | | | |
| | AD04 | ◎ | + | + | +/C | ◎ | | | | | | | | | | | 75 |
| | AD05 | + | + | + | + | + | | | △/C | | | | | | | | 6 |
| | AD06 | ○ | ◎ | ○ | ◎/C | | ○ | | | | | | | | | | 5 |
| | AD07 | △ | | | + | | | | + | | △ | | | | | | 20 |
| | AD08 | + | | + | +/C | | | | | | | +/C | | | | | 15 |
| | AD09 | | ◎ | ○ | ◎ | ○ | | | △ | | △ | | | | | | 7 |
| | LC10 | | | | | | | | | | | | | 220cm | | | |
| | AD11 | ◎ | ○ | △ | ◎ | ○ | | | | | | △ | | | | | 7 |
| | AD12 | | ◎ | + | △ | ○ | ◎ | | | | | | | | | | 20 |
| | AD13 | + | | + | +/C | | | | | | | | | | | | 7 |
| | AD14 | △ | | | △ | △ | | | | | | | | | | | 15 |
| | AD15 | ○ | | | | | ○ | | | | | | | | | | 8 |
| MS05 | LC01 | | | | | | | | | | | | | | NS | Nodule | |
| | LC02 | | | | | | | | | | | | | 100cm | | | |
| | LC03 | | | | | | | | | | | | | | NS | Sand+Crust | |
| | LC04 | | | | | | | | | | | | | | NS | Crust | |
| | AD05 | + | | ○ | △ | + | | | | | + | | + | | | | 6 |

## Table 4-2-1(2) List of collected materials

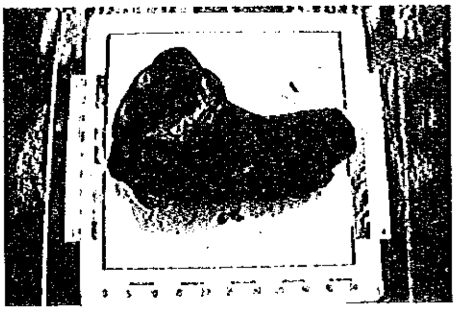
| SMT | SSN | Cr | Cr-C | Nd | Ba | Py | Br | Cg | Ss | Ms | Ls | Ph | Pm | Fs | Others | Geology | Thick |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MS05 | AD06 | | ◎ | | ◎ | △ | | | | | | | + | | | | 20 |
| | AD07 | | ○/C | + | ○ | △ | △ | | | | | | + | | | | 1 |
| | AD08 | | △ | | △ | + | | | | | | | + | | | | 25 |
| | AD09 | △ | | + | + | | | | + | | | + | + | | | | 20 |
| | AD10 | + | | + | | | | | | | | | | | | | 4 |
| | AD11 | ○ | △ | ◎ | ○ | | | | | | ○ | | | | | | 25 |
| | AD12 | + | | | + | + | | | | | + | | | | | | 8 |
| | AD13 | | +/C | + | + | + | | | | | | △ | | | | | 1 |
| MS06 | AD01 | △ | | | + | | | | | | △ | | | | | | 1 |
| | AD02 | △ | | | | | △ | | | | | | | | | | 60 |
| | LC03 | | | | | | | | | | | | | | NS | Crust | |
| | LC04 | | | | | | | | | | | | | | NS | Sand+Crust | |
| | LC05 | | | | | | | | | + | | | | 65cm | | Sand+Ms | |
| | LC06 | + | | | | | | | | | | | | | | | |
| | AD07 | | | ◎ | ◎ | ○ | | | | | | | | | | | 6 |
| | AD08 | | +/C | | + | | | | | | | + | | | | | 1 |
| | AD09 | △ | | | | △(hy) | | | | | | | | | | | 25 |
| | AD10 | △ | | | + | | | | | | △ | | | | | | 3 |
| | AD11 | + | | | | | | | | | | | | | | | 20 |
| | AD12 | ○ | | | | ○ | | | | | | | | | | | 35 |
| | AD13 | | ◎ | ○ | +/C | ◎/C | | | | | | | | | | | 20 |
| | FD01 | ○ | | | | | | | | | ○ | | | | | | 60 |
| MS07 | AD01 | | | ◎ | | | | | | | | ○ | △ | | | | 15 |
| | AD02 | △ | | | | + (hy) | | | | | | | | | | | 45 |
| | AD03 | + | △ | △ | △ | △ | | | | | | + | | | | | 15 |
| MS08 | LC01 | 4cm | | | | | | | | | | | | | | | 25 |
| | LC02 | 8cm | | | | | | | | | | | | | | | 40 |
| | LC03 | 5cm | | | | | | | | | | | | | | | 30 |
| | AD04 | | ○ | | ○/C | ○ | + | | + | | + | | | | +/tf | | 1 |
| | AD05 | | ○ | | | ○ | | | | | | | | | | | 30 |
| | AD06 | +/C | | | △ | + | | | | | + | + | | | | | 1 |
| | AD07 | + | | △ | + | | △/C | | | | | | | | | | 2 |
| | AD08 | | | + | | + | | + | + | | + | | | | | | 3 |
| | AD09 | △ | | | + | + | | | | | | | | | | | 3 |
| | AD10 | + | | + | | | | | | | + | + | | | | | 2 |
| | LC11 | 8cm | | | | | | | | | | | | | | | 45 |
| | AD12 | ◎ | ◎ | △ | | ◎ | ◎ | ◎ | | | | | | | | | 50 |
| | AD13 | | △ | ◎ | ◎ | ○ | | | | | | + | | | +/tf | | 10 |
| | AD14 | | ◎ | + | | ◎ | | | | | | | | | | | 45 |
| | AD15 | ○/C | | +/C | ○ | | | | + | | + | | | | | | 1 |
| | AD16 | ○ | △ | △ | | | | | ○ | | | | | | | | 25 |
| | AD17 | + | | | ○ | | | △ | | | + | | | | | | 1 |
| | AD18 | △ | | | | | | | △ | | | | | | | | 5 |
| MS09 | LC01 | + | | | | + | | | | | | | | 15cm | | Sand+Cr+Py | |
| | LC02 | + | | | | | | | | | | | | | | | |
| | LC03 | | | | | | | | | | | | | | NS | Crust | |
| | LC04 | 5cm | | | | | | | | | | | | | | | 25 |
| | LC05 | 10cm | | | | | | | | | | | | 50cm | | Sand+Crust | 40 |
| | LC06 | 6.5cm | | | | | | | | | | | | | | | 55 |
| | AD07 | △ | △ | ◎ | ◎ | ○ | △ | | | | | △ | | | | | 25 |
| | AD08 | △ | | | | ○(hy) | | | | | △ | △ | | | | | 10 |
| | AD09 | | △ | △ | △ | | | | | | ○/C | | | | | | 2 |
| | AD10 | | | + | △/C | | | | | | | | | | | | 8 |
| | AD11 | △ | ◎ | △ | ○ | △ | ○ | | | | | + | | | | | 45 |
| | AD12 | ○ | △ | ○ | | △ | | | | | ○/C | △ | | | | | 4 |
| | AD13 | + | + | + | | + | | | | + | | + | | | | | 10 |

Legend — SMT: Name of seamount, SSN: Sampling site No., Cr: Crust, Cr-C: Encrusted cobble, Nd: Nodule, Ba: Basalt, Py: Basalt pyroclastic rock, Br: Basalt breccia, Cg: Volcanic conglomerate, Ss: Sandstone, Ms: Mudstone, Ls: Limestone, Ph: Phosphorite, Pm: Pumice, Fs: Foraminifera sand, Geology: Seafloor geology by core and photo, Thick: Average thickness of crust (mm), hy: Hyaloclastite, mud: Mud block, tf: Tuff, NS: No sample

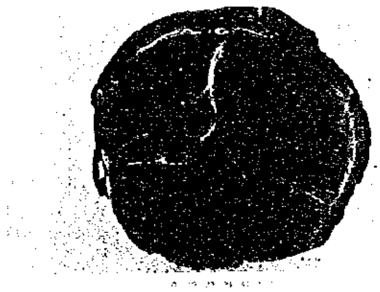
Amount — ◎: abundant, ○: moderate, △: a little, +: little

Note — Figures in the lines of Cr and Fs mean the maximum length of core sample.
"/C" after the amount sign means coating crust (very thin).

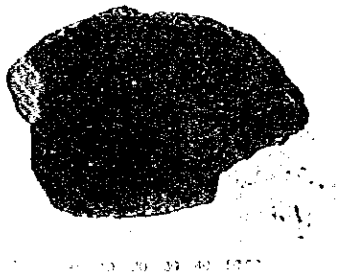
[Basalt]

1


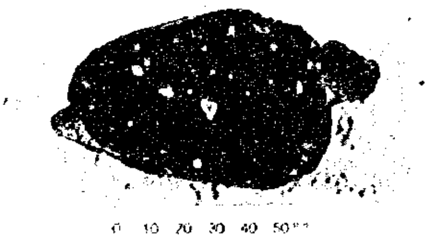
Pillow lava (MS04AD09)

2


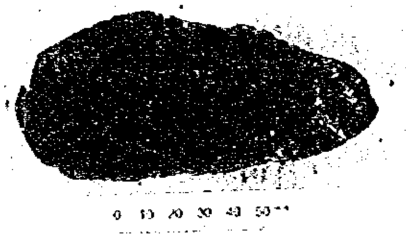
Ditto section

3


Non-porphyritic (MS08AD04)

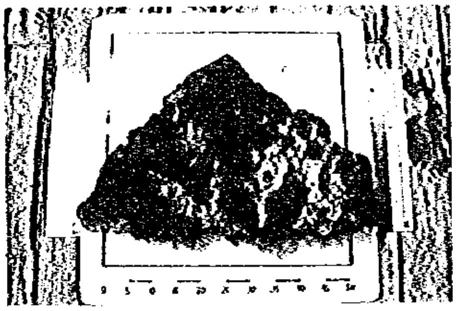
4


Porphyritic (MS08AD04)

5


Porous (MS05AD07)

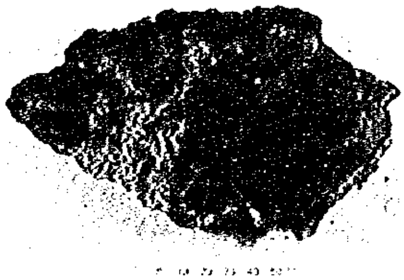
[Basalt breccia]

6


Reverse side of crust (MS04AD06)

7


Muddy matrix (MS08AD04)

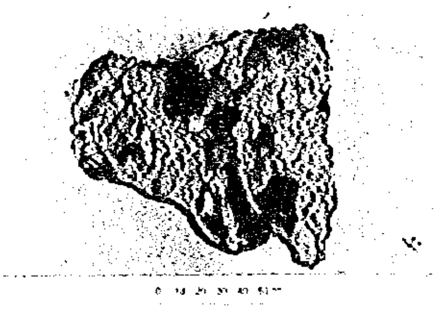
8


Alterd basalt pebble (MS04AD15)

Fig. 4-2-2(1) Photographs of rocks (AD sampling)

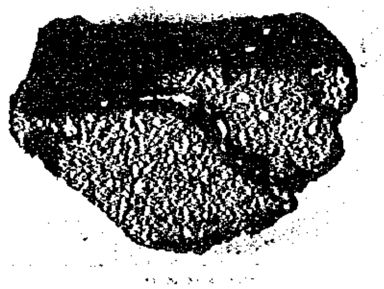
[Basalt pyroclastics]

9



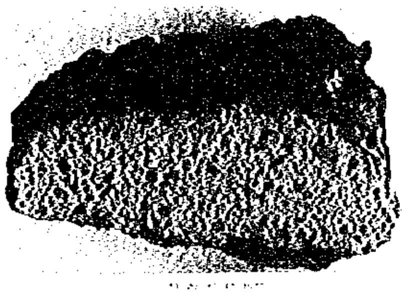
Argillized (MS01AD09)

10



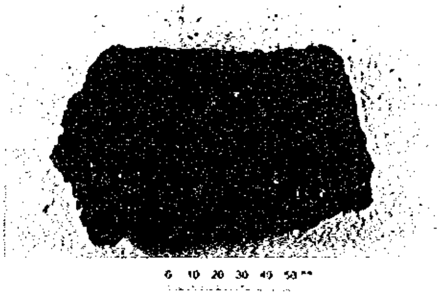
Subrounded lapilli (MS08AD05)

11



Brown lapilli (MS06AD13)

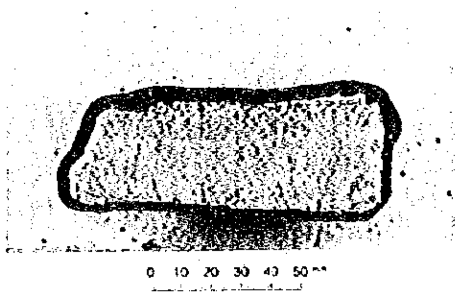
12



Hyaloclastite (MS09AD08)

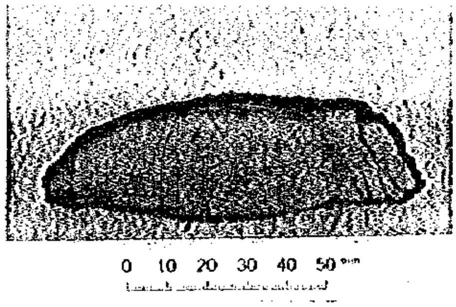
[Sedimentary rocks]

13



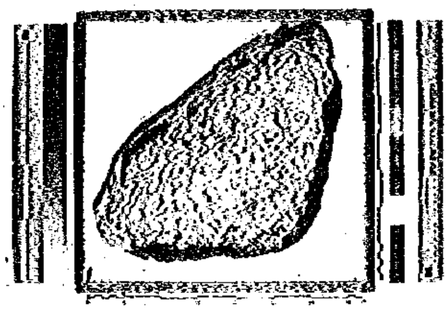
Calcic sandstone (MS04AD09)

14



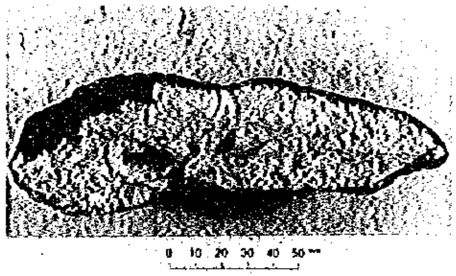

Mudstone (MS09AD13)

15



Limestone (MS02AD13)

16



Phosphorite (MS09AD08)

Fig. 4-2-2(2) Photographs of rocks (AD sampling)

9) Pumice

Pumice in this area is pale gray and rounded. It foams well and is very porous. They were collected only at the seamounts of MS05 and MS07.

10) Tuff

Tuff in this area consists of greenish gray magnetite bearing fine grained tuff and greenish gray brown basalt granule–containing coarse grained sandy tuff with weak bedding.

(2) Seafloor sediments

LC sampling was carried out at 41 points in eight seamounts excluding MS07. The objective of the sampling was recovery of manganese crust samples and thus sea seafloor sediments were recovered at nine points. Of these nine localities, six were from marginal parts of the flat summit of guyots, two from lower flank, and one from the summit of a peaked seamount. Samples collected by LC (including manganese crusts) and the contents of the photographs are listed in Table 4–2–2, photographs of typical seafloor sediments and of the seafloor are laid out in Figure 4–2–3, and the results of the LC sampling are shown in Appendix Table 3 (1), (2), and the geologic column of the nine points sampled sediments in Appendix Figures 6 (1) to (3).

The collected seafloor sediments consist mostly of unconsolidated foraminifera sand accompanied by ooze and rarely contains gravels. The color of the foraminifera sand ranges from pale brown (10YR7/3: very pale brown, to 10YR6/3: pale brown; by Munsell soil color chart) to pale yellow (2.5Y7/4: pale yellow). The foraminifera fossils are 0.3 to 1 mm in diameter and can be identified with the unaided eyes. Cores of foraminifera sand are generally firm and the water content is high. Parts of the seafloor surface consist of ooze which is, in some cases, intercalated in the foraminifera sand layer. The ooze is brown and the water content is higher than that of the foraminifera sand.

At five sampling points, only seafloor sediments were collected, and at four points, rocks and manganese crusts underlying the seafloor sediments were collected.

At the five localities where only the seafloor sediments were collected, the cores are 100 to 300 cm long with some intercalation of ooze. With the exception of 96SMS03LC03, where the longest core was recovered, the objective was the recovery of manganese crusts at the four remaining sampling points. However, only seafloor sediments were recovered. Photographs of the five localities, each covering 5 $m^2$, show only sediments on the seafloor.

The core from the four sampling points where rocks and manganese crusts were recovered under the seafloor sediments average 60 cm and are shorter than those from other five localities. Thus the lower bedrock was recovered because the overlying sediments were thinner than in the other localities. Since 96SMS01LC01 and 96SMS09LC01 are located approximately 4,300 m under water on the lower