extremely pale image is observed at the saddle in southwest indicating thick unconsolidated cover.

The small seamount to the north has similar image of the summit with pale color distributed in the flat part indicating the wide occurrence of unconsolidated sediments. Exposed bedrock is observed at the shallowest part and along the eastern periphery of the summit. This small northern seamount is more steep than MC10, dark color indicating bedrock exposure is seen to the lower slope.

3-3 SBP Survey

SBP 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 following types. For T-type, the depths of the basement were determined, the total thickness of the alternation of the acoustically transparent-opaque layers were read from the record, and the results were expressed as isopach (sediment thickness) maps. Also SBP 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 single mode and the survey was carried out simultaneously with topographic sounding and sampling.

(1) SBP type classification

Reflection patterns of the SBP records of the ten seamounts were divided into O-type and T-type as shownin Figure 3-3-1.

1) O-type)

This SBP reflection pattern consists only of opaque layers.

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

2) T-type

This pattern consists of transparent-opaque layer alternation.

T-type is observed on summits of table seamounts and terraces. The thickness of the alternation varies from 10 ~ 80 m. This type is inferred to correspond to unconsolidated sediments.

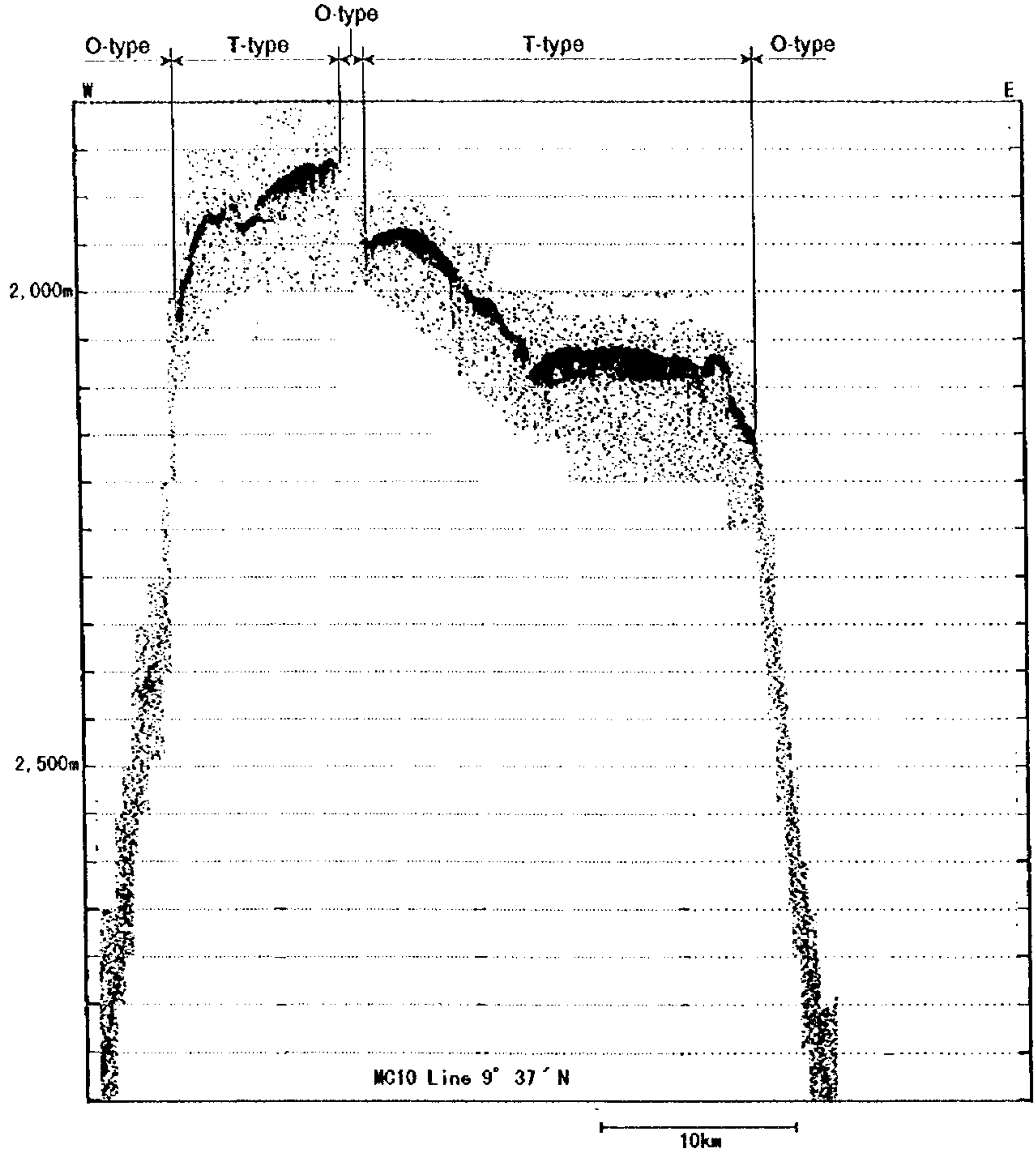


Fig. 3-3-1 Typical records of SBP for each type

(2) Distribution of unconsolidated sediments by SBP

Unconsolidated sediments were clearly confirmed by SBP records from the following four, namely MC02, MC07, MC08, and MC10. Of the above four seamounts the latter three are guyots with clear development of T-type pattern.

Then the results of sampling (LC), seafloor photography, and SBP records were correlated. The results are shown in Table 3-3-1. It is clear from this table that generally O-type pattern corresponds to exposed rocks (mainly crusts) and that T-type pattern to unconsolidated sediments. There are exceptions such as the locality with T-type SBP record showing exposed rocks in the photograph, but this is considered to be the result of different localities for the SBP and photography.

(3) Characteristic features of the seamounts

Of the ten seamounts surveyed, development of the T-type SBP reflection was observed in the following four seamounts, namely MC02, MC07, MC08 north, and MC10 south. The characteristics of these seamounts are reported below.

1) MC02

The SBP section and an isopach map of MC02 are laid out in Figures 3-3-2 (1) and 3-3-3 (1).

The whole summit is covered by T-type layer. The thickness is about 10 m. This T-type is inferred to correspond to unconsolidated sediments. Unconsolidated sediments exceeding 20 m in thickness is observed locally in the central north part, the relatively shallow parts of the summit and the maximum thickness reaches 30 m.

2) MC07

The SBP section and isopach map of MC07 are shown in Figures 3-3-2 (2) and 3-3-3 (2).

T-type layer more than 10 m thick occur in oval shape in the particularly flat area in the central part of the flat summit. O-type layer occurs outside of this oval where the relief is variable. In the T-type area, thick parts are in the southwestern side with unconsolidated sediments exceeding 20 m in thickness is probably deposited.

3) MC08 North

The SBP section and an isopach map of MC08 are shown in Figures 3-3-2 (3) and 3-3-3 (3).

The whole summit is covered by about 10 m thick T-type layer. This T-type is believed to correspond to unconsolidated sediments. The layer is relatively thin in the central part and thick

Table 3-3-1 Comparison of SBP Records and Sampling(LC)

Area	Sampling No.	Type	Observation of Seabottom	Samples (cm)	Bit deformation
MC02	LC01	—	sand	sediments (215)	none
	LC05	O	--	crust	
	LC06	O	sand, rock	crust	
	LC07	T	sand	sediments (23)	none
MC03	LC01	T	sand	sediments (260)	none
	LC14	—	—	sand block (7)	none
	LC15	0	rock	crust	
	LC16	0	rock	—	
MC04	LC01	—	sand	sediments (160)	none
	LC20	T	sand	sediments (150)	none
	LC21	--	sand	—	
MC05	LC01	T	--	sediments (280)	none
MC07	LC01	T	sand	sediments (145)	none
	LC10	0	—	--	
	LC11	0	—	sediments (200)	none
	LC12	T	sand	rock fragments	dent
	LC13	0	rock	—	
MC08	LC01	T	sand, conglomerate	crust	none
	LC16	T	rock	crust	
	LC17	T	sand, conglomerate	--	dent
MC09	LC01	—	--	sediments (40)	none
MC10	LC01	T	sand	sediments (90)	none
	LC17	T	sand	--	dent
	LC18	T	sand	sediments (30)	dent

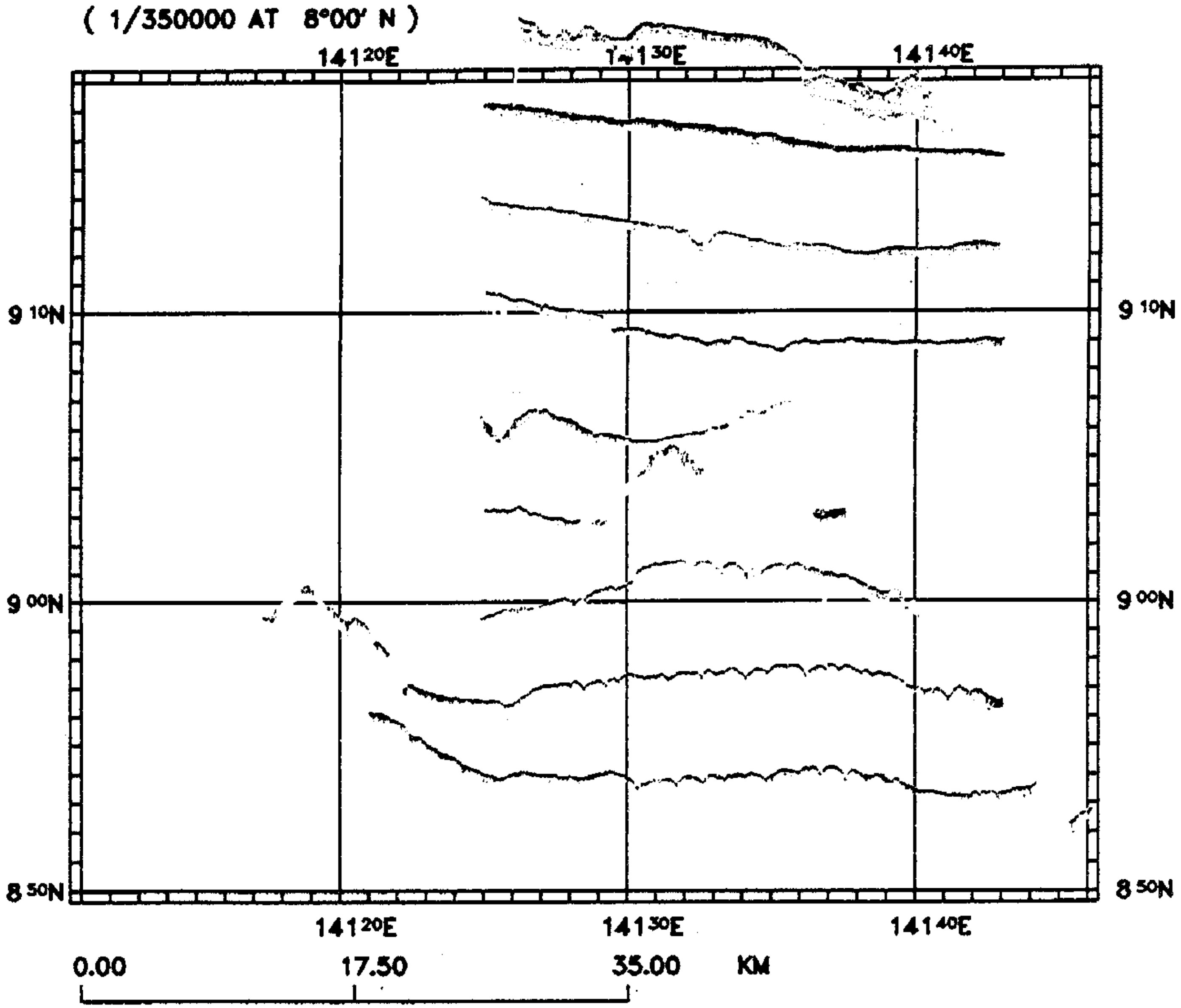


Fig. 3-3-2(1) SBP Profile of MC02 area

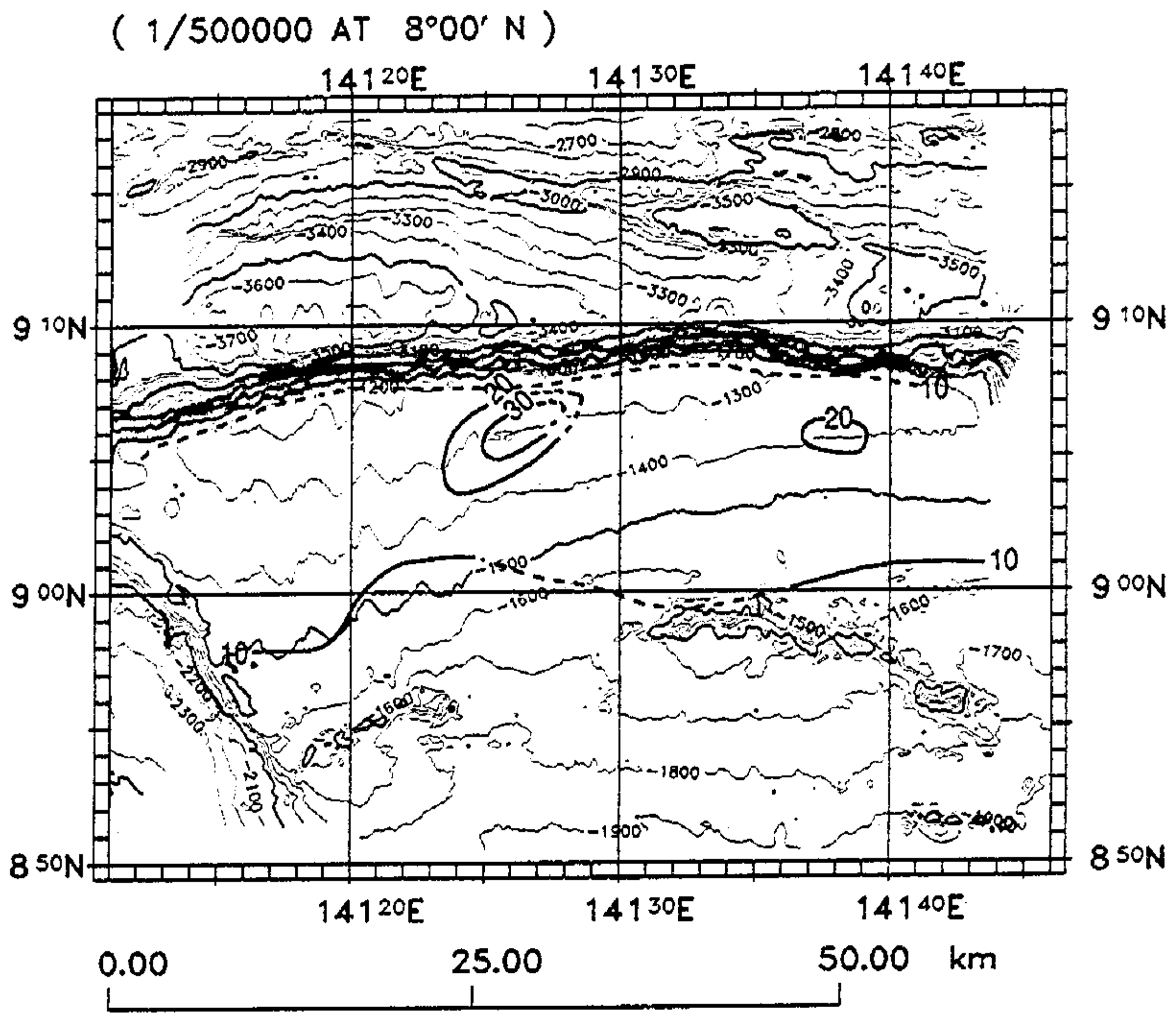


Fig. 3-3-3(1) Isopach map of MC02 area

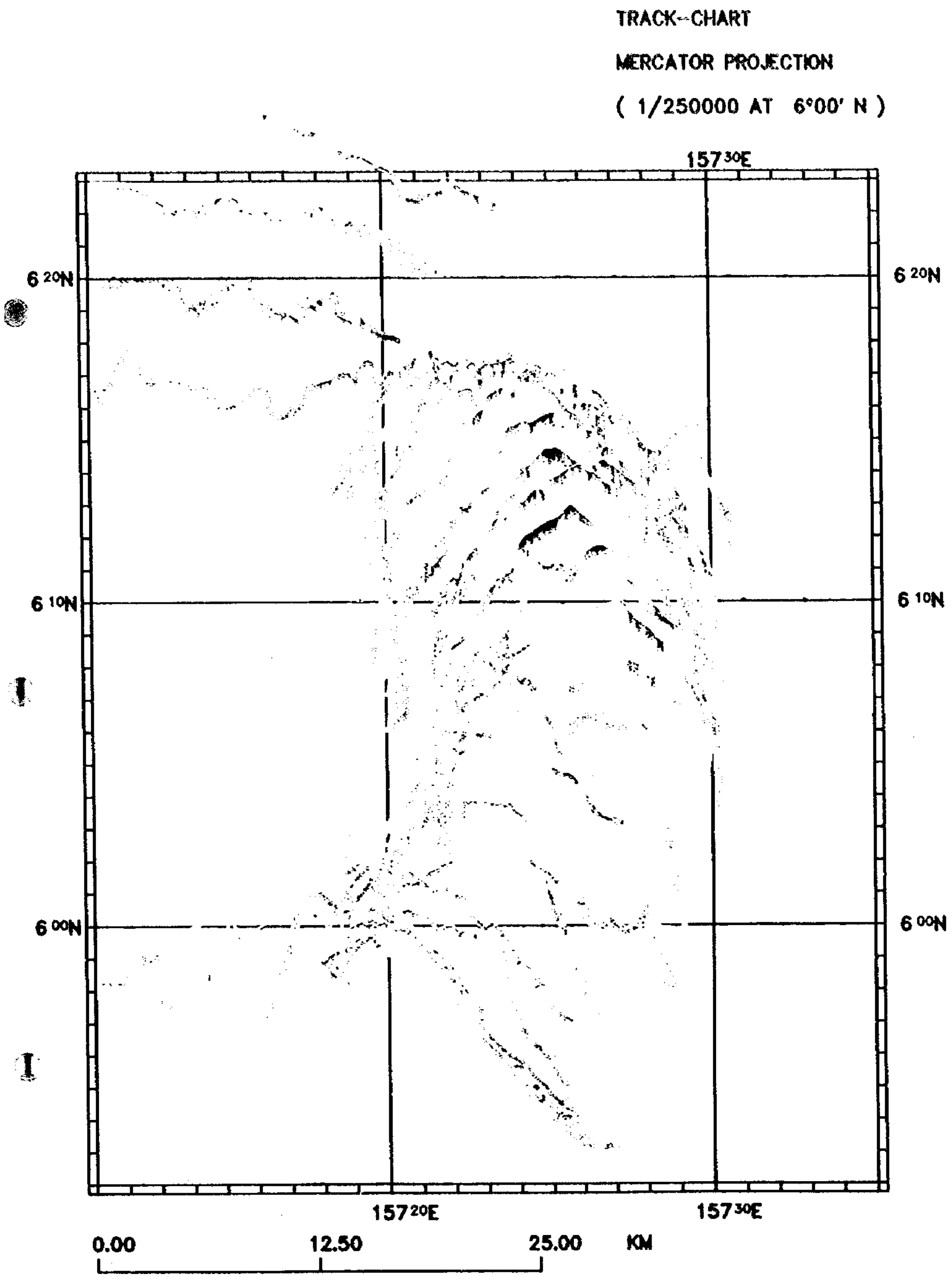


Fig. 3-3-2(2) SBP Profile of MC07 area

(1/500000 AT 6°00′ N)

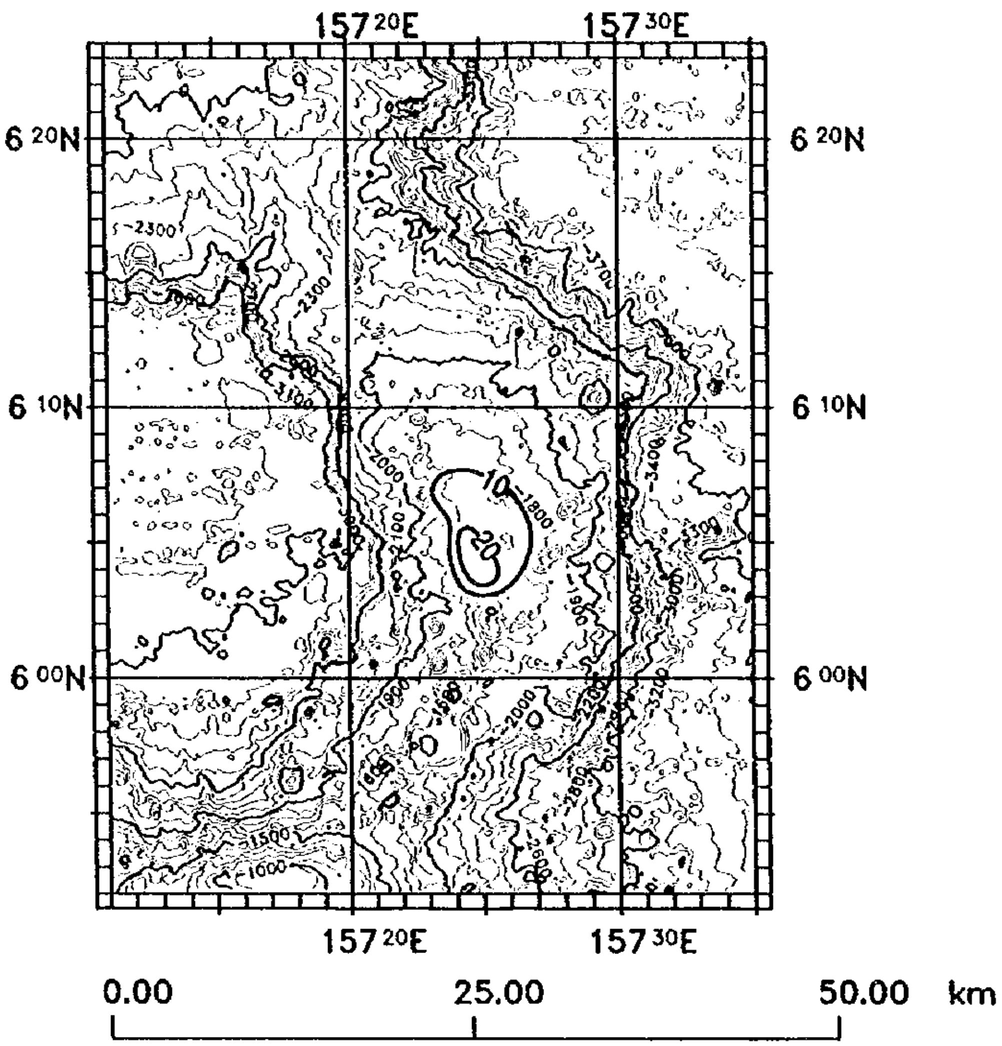


Fig. 3-3-3(2) Isopach map of MC07 area

TRACK—CHART

MERCATOR PROJECTION

(1/400000 AT 10°00' N)

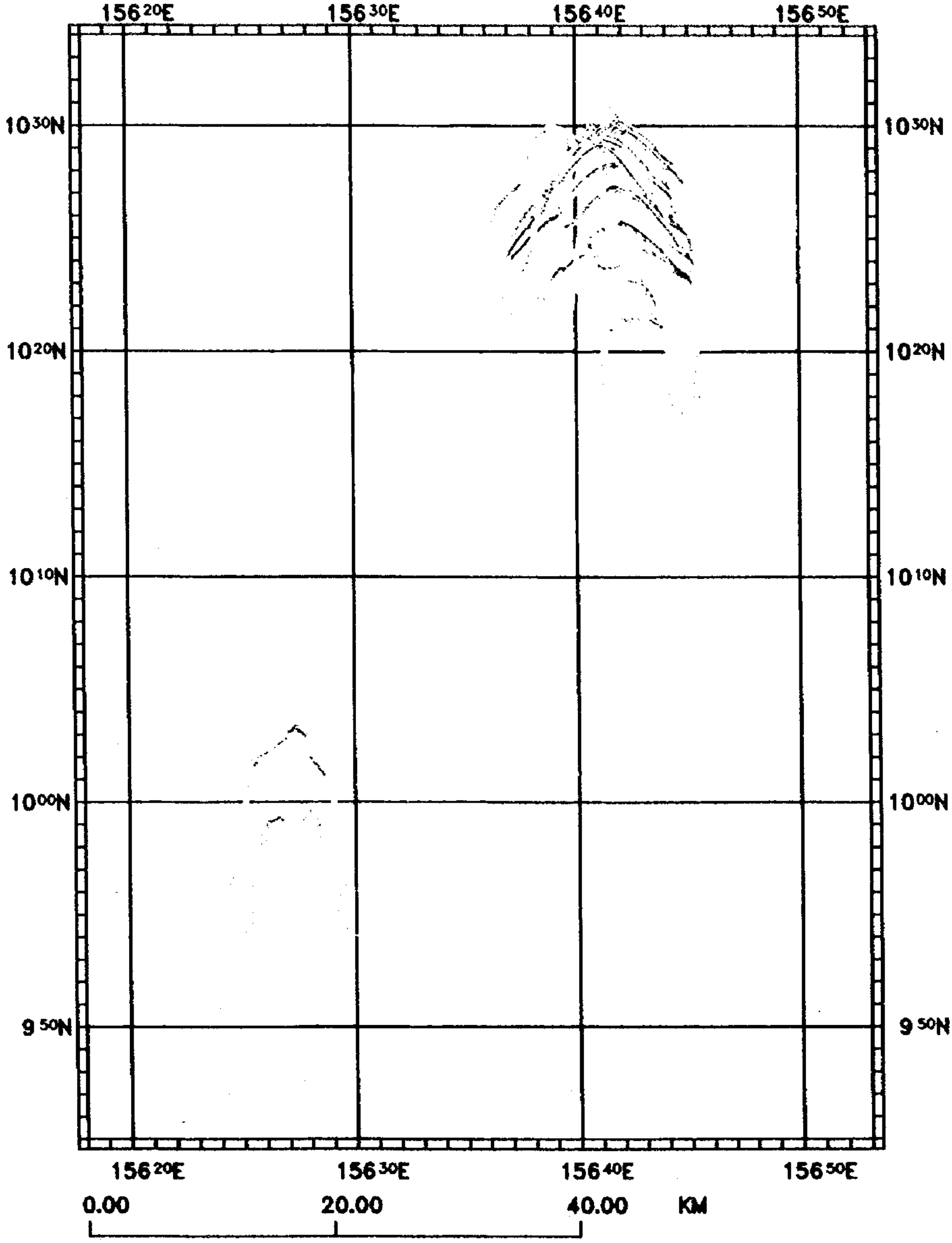


Fig. 3-3-2(3) SBP Profile of MC08 area

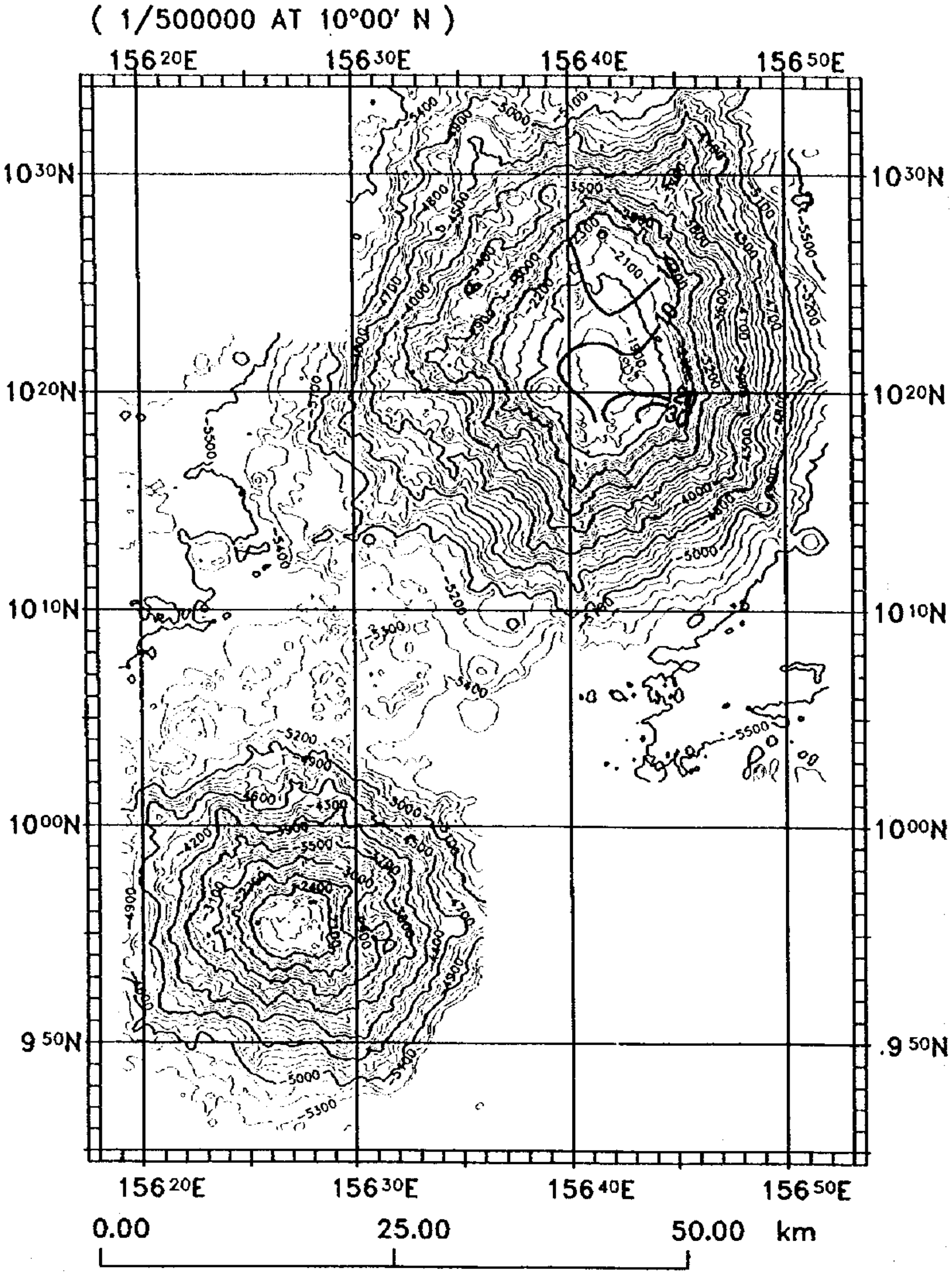


Fig. 3-3-3(3) Isopach map of MC08 area

layers are deposited in the northern and southern parts of the summit. A thick T-type layer occurs locally in the southwestern part of the summit and here it is more than 30 m thick.

4) MC10 South

The SBP section and an isopach map of MC10 are laid out in Figure 3-3-2 (4) and 3-3-3 (4).

Highest quality data with good continuity were acquired from this seamount during the present cruise. On the flat summit, T-type namely unconsolidated sediments are widely distributed in a shape similar to the outline of the periphery. The thickness of the T-type corresponds to the contour lines of the dome and generally increases from the periphery to the center and reaches a maximum exceeding 40 m. This is the maximum thickness encountered during this survey. Also the increase of thickness from the southern margin is gradual, but from the northern side it is abrupt.

3-4 SSS Survey

Two SSS track lines in MC02 area and one line each in MS03 and MC08 areas were carried out with the major objective of clarifying the micro topography and the distribution of exposed bedrocks.

Acoustic waves reflect strongly from hard material and weakly from soft material. In SSS records, the strong reflections are shown in dark tone and the weak ones in pale tone. Information regarding the dark and pale tones and their distribution pattern are obtained from these SSS maps. These are interpreted to reflect the hardness and shape of the surface material, and the strongly reflected parts are generally considered to indicate the existence of exposed rocks or pebbles, while the weak reflections indicate the unconsolidated material.

The SSS survey was carried out on three seamounts for confirming the distribution of exposed bedrocks and pebbles and cobbles in the vicinity of pinnacles on flat summits, conditions of rock exposures near the summit peripheries and on middle slope around 3,000 m depth. The track lines were set over the high MBES acoustic reflection intensity zones.

It is possible to clarify the variation of micro topography and bottom material in more detail by SSS images compared to the MBES acoustic reflection intensity distribution. In this survey area, rock exposure conditions on the pinnacle slopes, nodule distribution on the gentle slope at the foot of the pinnacles, rock exposure conditions on the shoulders and slopes where the gradient increases, and rock exposure conditions on the upper slope were clarified.

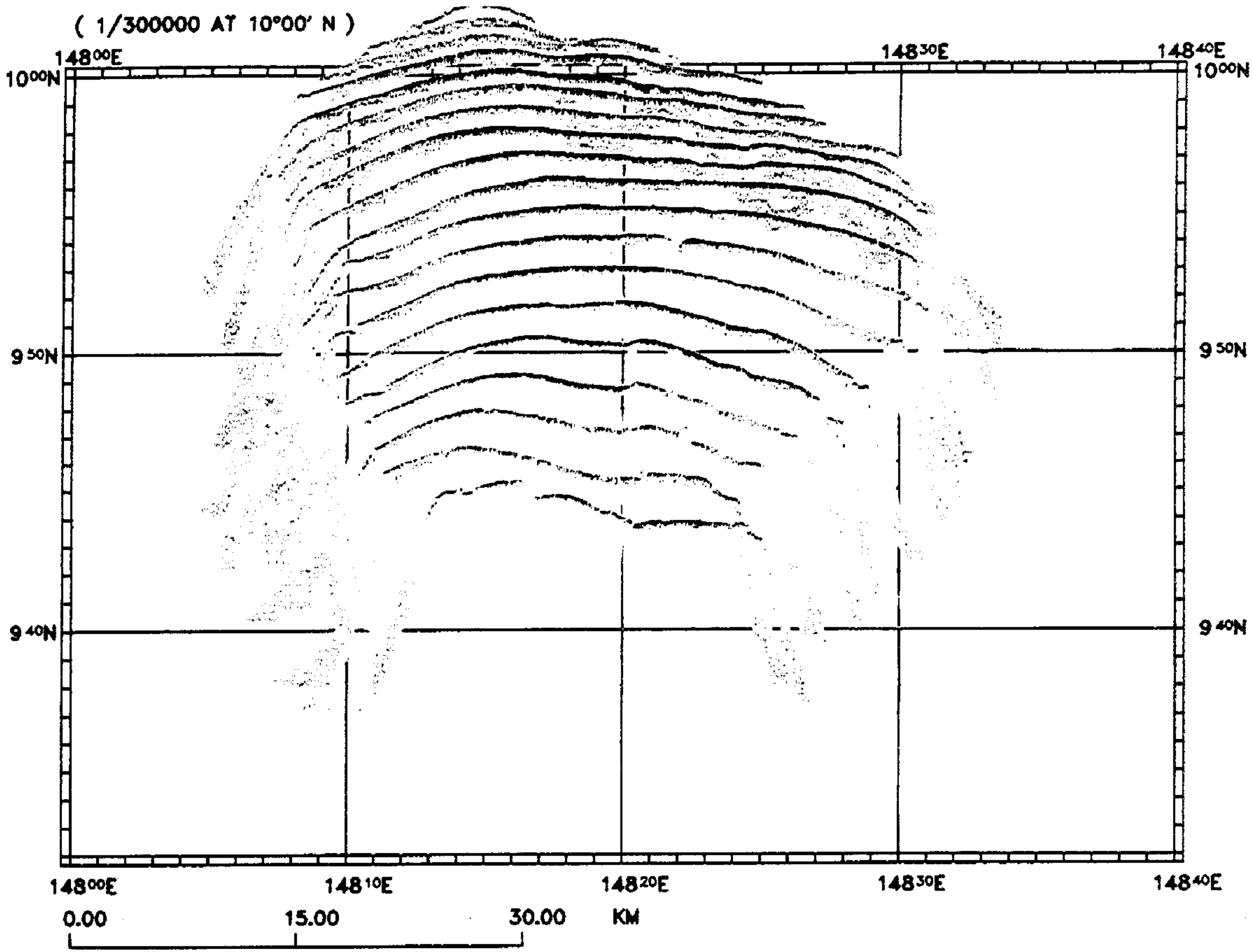


Fig. 3-3-2(4) SBP Profile of MC10 area

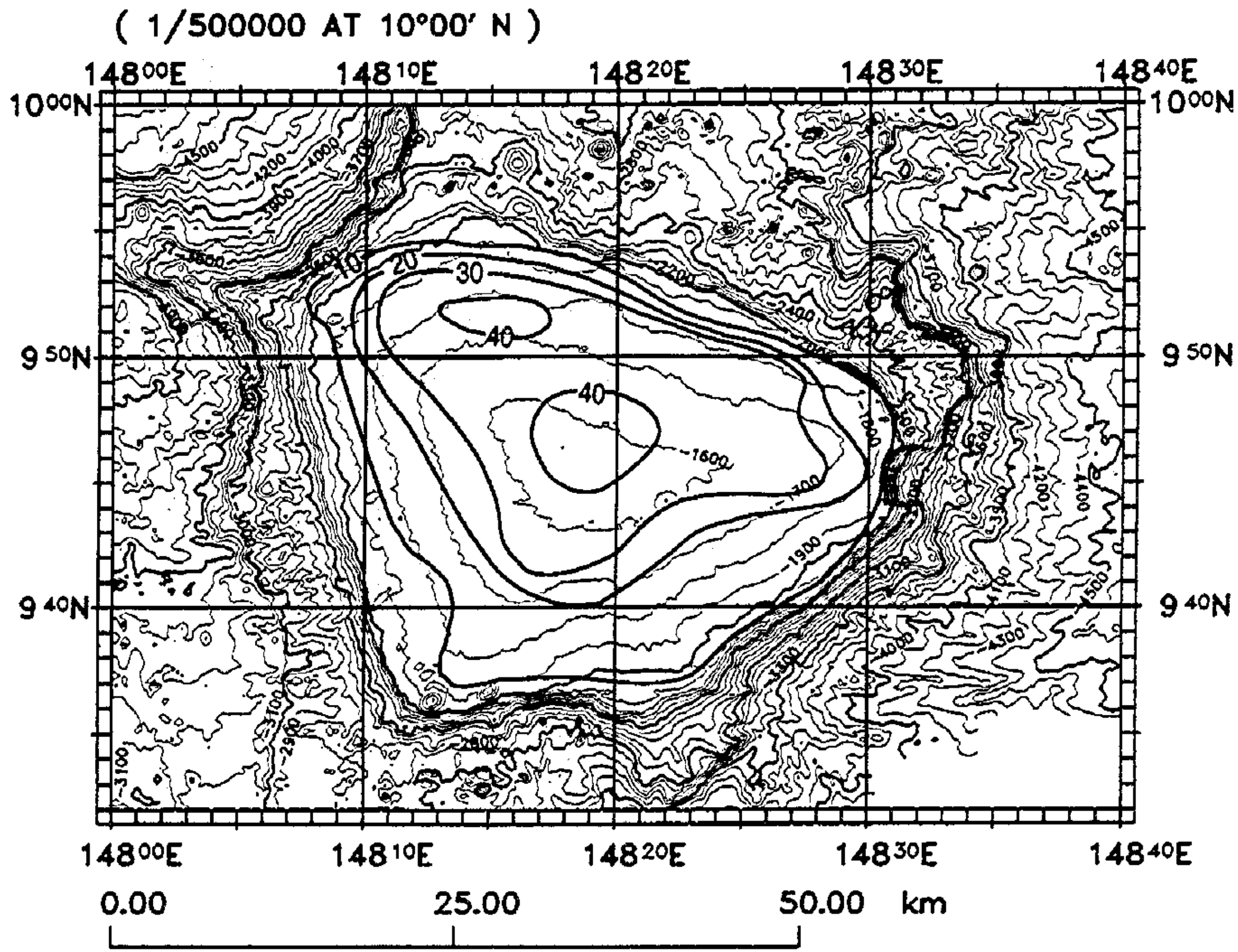


Fig. 3-3-3 (4) Isopach map of MC10 area

(1) MC02

1) Track line SSS01

Pinnacles occur in an arc at the gently sloping flat part of the summit in the southern part of MC02. These pinnacles are considered to be the result of late volcanic activity. This track line was set in order to confirm the distribution of the exposed bedrock and pebbly material.

SSS image, MBES acoustic reflection intensity map, MBES seafloor topographic map, and seafloor topographic profile of the Track line SSS01 are laid out in Figure 3-4-1.

In the flat parts, SSS image show the distribution of unconsolidated sediments. The pinnacle slopes show strong reflection and indicate exposed rocks. Pebbly materials are expected to occur at the transitional parts from the steep pinnacle slope to the flat part near the foot, but bedrocks are often exposed and the reflection intensity variation is not very clear.

2) Track line SSS02

SSS image, MBES acoustic reflection intensity map, MBES seafloor topographic map, and seafloor topographic profile of the Track line SSS02 are laid out in Figure 3-4-2.

The northern side of MC02 is a structural slope with relative height exceeding 2,000 m and continues in the east-west direction. The present MBES data processing methods cannot show the correct intensity variation where the topography slopes one way at the margin of the flat summit. Therefore, this track line was designed to confirm the micro topography of the shoulder from the flat summit to the steep slope, and the conditions regarding rock exposures and coverage of sediments.

In the SSS image, it is seen that unconsolidated sediments are distributed to the very edge of the flat summit turning to the upper slope. The border with the upper slope is clear and bedrocks are exposed on the steep slope. It is seen that there is a white part in the lower slope both in SSS image and MBES reflection intensity map, this is interpreted to be a part which cannot receive the acoustic reflection because of being in a shadow of the shoulder. The tone indicating exposed rock is shown as small valleys to the east of 141 ° 23' E., and in stepwise pattern parallel to the bathymetric contour to the west of the border, and this is in harmony with the topographic variation expressed by the bathymetric contours.

(2) MC03 (Track line SSS01)

SSS image, MBES reflection intensity map, MBES seafloor topographic map, and seafloor topographic profile of Track line SSS01 are shown in Figure 3-4-3.

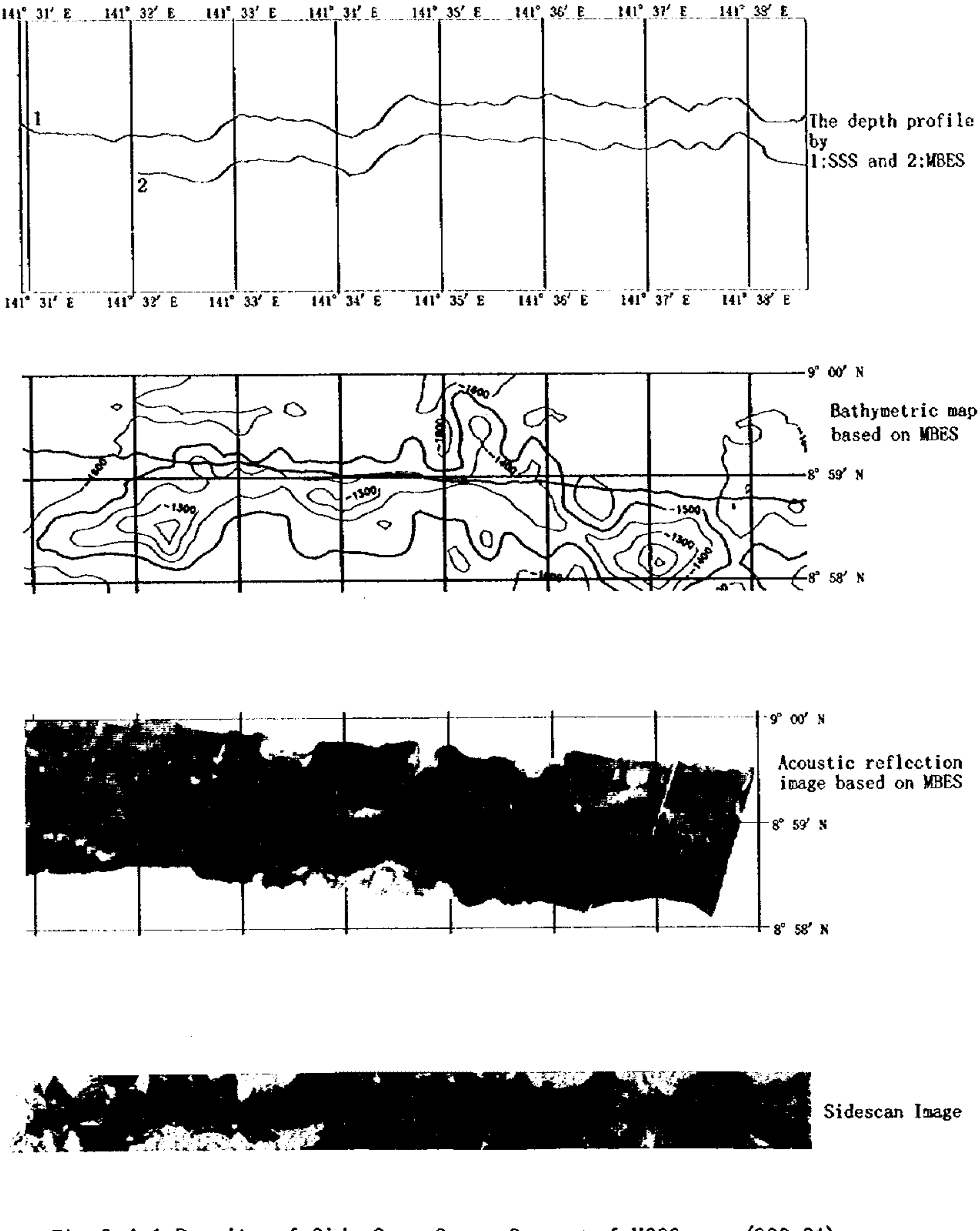


Fig. 3-4-1 Results of Side Scan Sonar Survey of MC02 area (SSS-01)

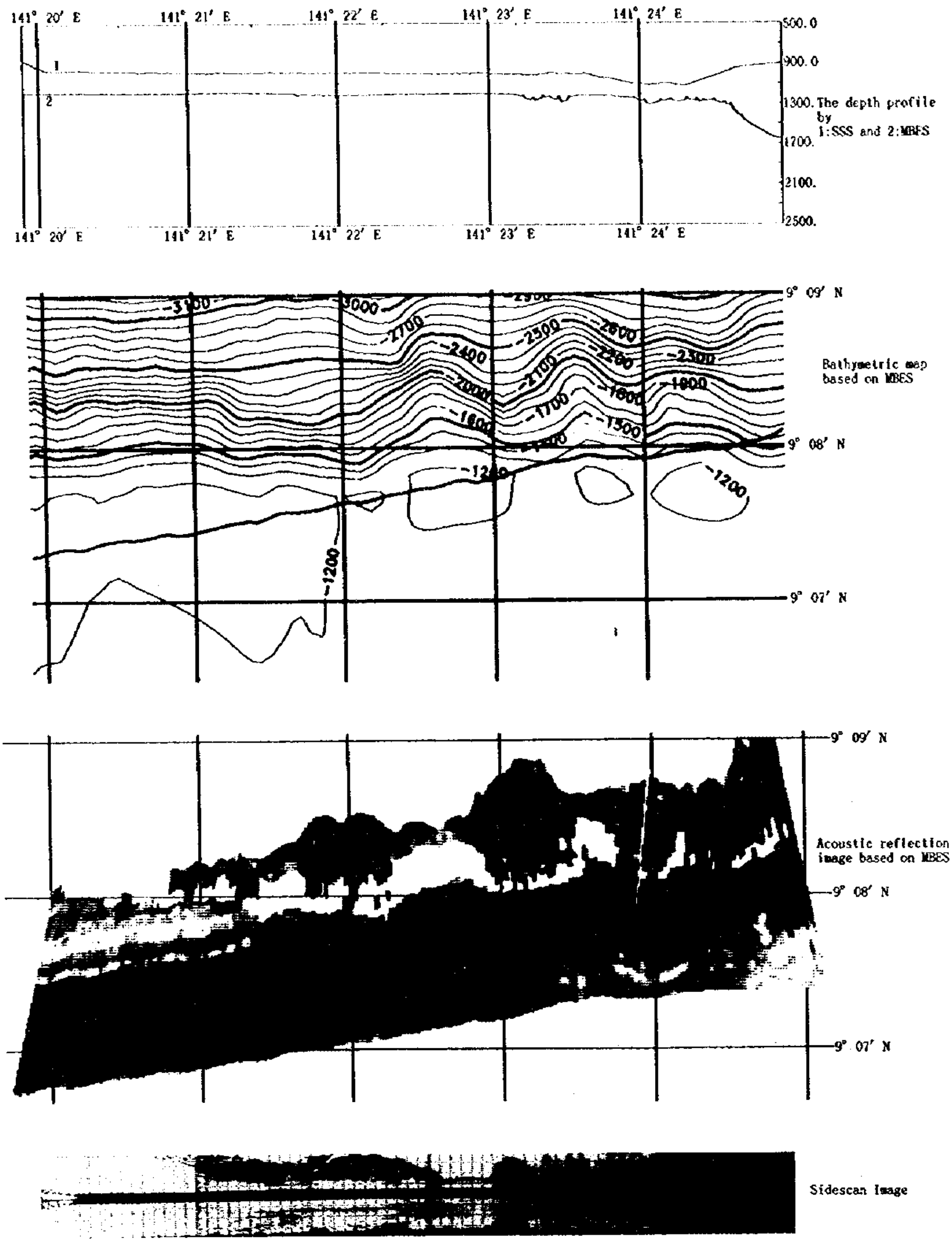


Fig. 3-4-2 Results of Side Scan Sonar Survey of MC02 area (SSS-02)

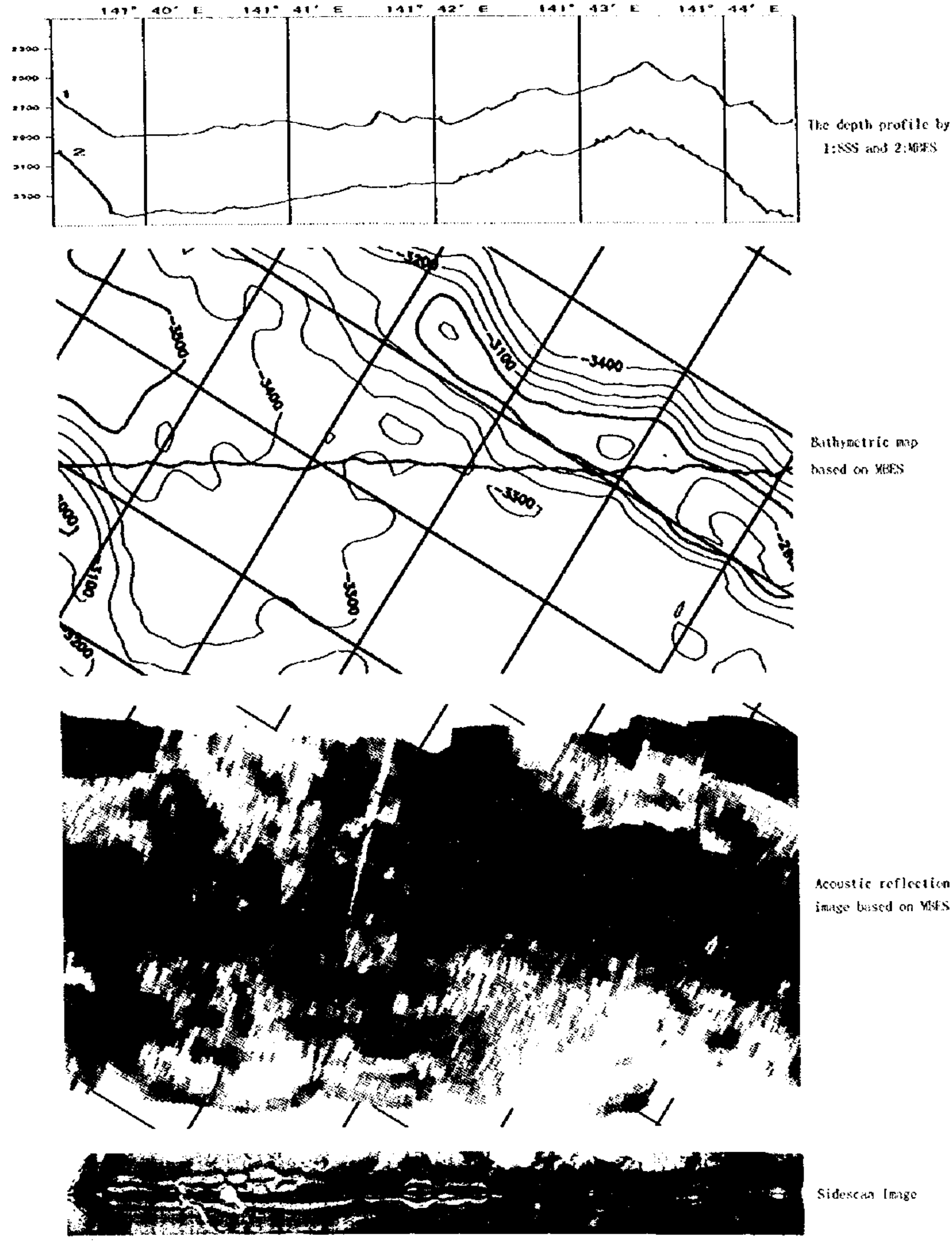


Fig. 3-4-3 Results of Side Scan Sonar Survey of MC03 area (SSS-01)

From the summit topography, it is considered that MC03 could have been formed by the difference of the movements of two plates, one to the SE and another to the NW. The effect is apparent in the topography of the 3,000 m deep (water depth) graben to the north showing a small ridge-type rise which is thought to accompany seafloor spreading. Bedrock exposure was expected from MBES reflection intensity map on this ridge-type topography and SSS survey was carried out in order to confirm the conditions.

In the SSS image, low reflectivity indicating unconsolidated sediments appears on the bottom of the graben, and relatively high reflectivity indicating exposed bedrocks covered thinly by unconsolidated sediments appears on the slope toward the ridge zone. Low reflectivity from unconsolidated sediments appears in gentle parts of the slope near the summit of the ridge and high reflectivity considered to represent exposed rocks was confirmed in the central part of the summit.

(3) MC08 (Track line SSS01)

SSS image, MBES reflection intensity map, MBES seafloor topographic map, and seafloor topographic profile of Track line SSS01 are shown in Figure 3-4-4.

For MC08, northern periphery of the summit from the pinnacles through the shoulder to the slope were observed.

MBES reflection intensity is expressed by pale color in the central part of the summit indicating the distribution of unconsolidated sediments. This also appears clearly in the SSS image and weak reflection zone extends on the central side of the pinnacles. High reflectivity with small variation appears on the pinnacle slope indicating rock exposure. High reflectivity is observed at the foot of the pinnacles and the gentle slope between pinnacles indicating the occurrence of pebbly material. The topographic gradient increases from the periphery to the shoulder, and complex pattern of the strong and weak reflection is observed at this point of the shoulder indicating the uneven surface of the exposed rock covered by thin unconsolidated sediments. Ridges and valleys are observed on the slope, and the SSS image indicate the occurrence of exposed rocks on the ridges and unconsolidated sediments on the valleys.

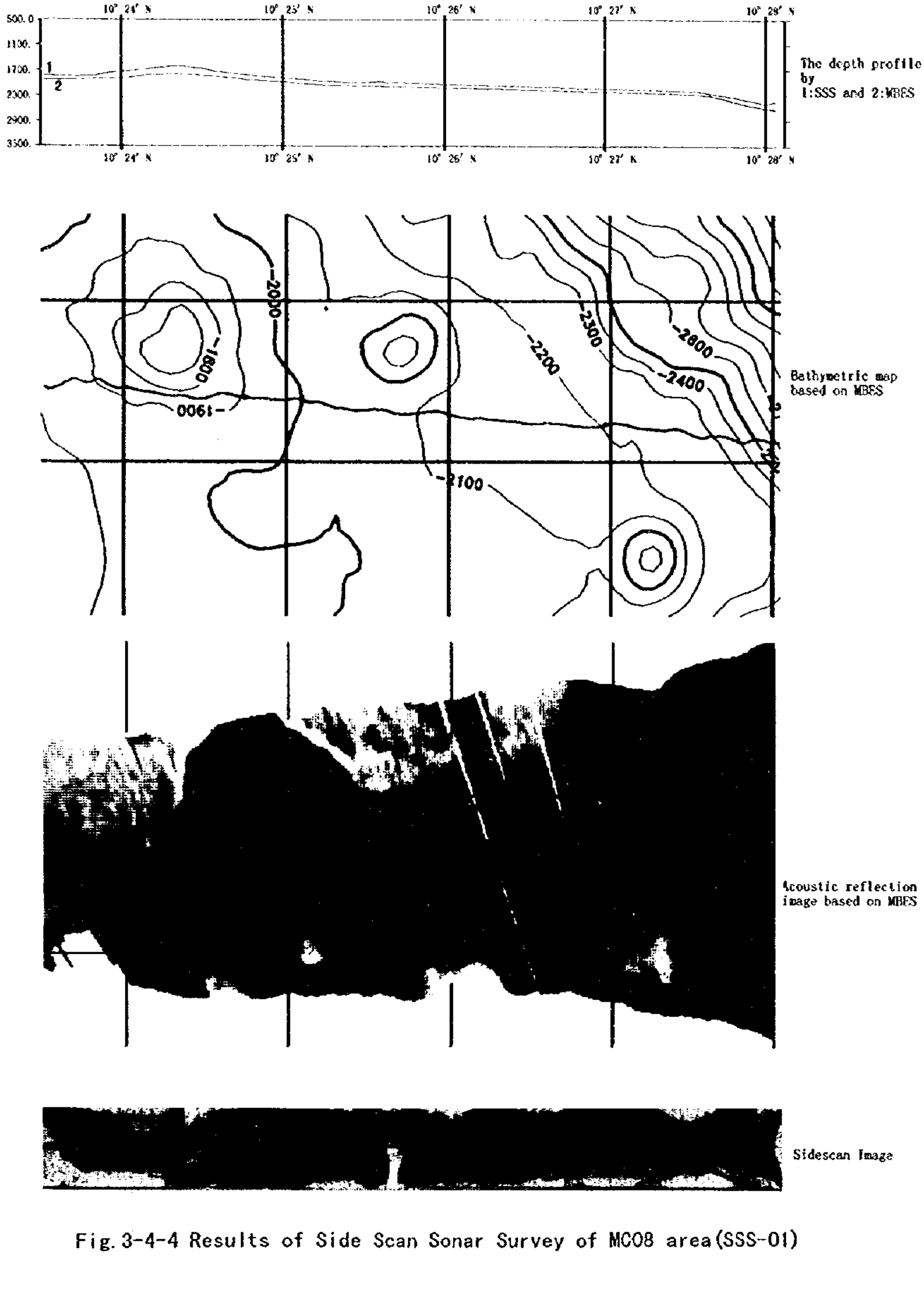


Fig.3-4-4 Results of Side Scan Sonar Survey of MC08 area(SSS-01)

Chapter 4 Geology

4-1 General Geology

The volcanic rocks which form the seamounts have different characteristics from the oceanic ridge basalt (MORB) and are called the oceanic island basalt (OIB). The geologic structure of the surveyed seamounts and their morphology vary considerably and thus the age of the seamounts and the chemistry of the basalts differ significantly, this will be mentioned later.

The seamounts of the ten areas surveyed are formed by basalt and basaltic clastics with occasional association of limestone and sediments. The exposed bedrocks on the seafloor, with some exceptions in the shallow zones, are always covered by iron and manganese oxides, and these are called manganese crusts. The summits of the guyots, with the exception of the peripheries, small hills, and slopes, are covered by thick unconsolidated foraminifera sand. On the slopes of these seamounts, secondary sediments are considered to be predominant due to denudation and water flow, while foraminifera sand are deposited on terraces and gentle slopes.

The target of the survey is the manganese crusts exposed on the seafloor. These crusts are ferromanganese oxides similar in nature to the manganese nodules which occur on the deep ocean floor. The significant characteristics of the manganese crusts are that they contain 0.5 ~ 1.5 wt% of cobalt which is considerably higher than the average 0.2 wt% content of the nodules. Thus they are sometimes called cobalt-rich manganese crusts. Also the relatively high content of platinum (0.1 ~ 0.3 ppm) is also a notable feature of these crusts. The thickness of these crusts varies significantly by the topography, geology, water depth, morphology and location of the seamounts, and other factors. Their average thickness in the western Pacific is about 2 cm with a maximum exceeding 10 cm. The results of the investigation on the geology, petrology and manganese crusts will be presented in the appropriate sections of this report.

4-2 Sampling Results

Chain back dredge (CB), arm dredge (AD) and large gravity corer (LC) were used for sampling manganese crust and other bottom materials on the seamounts. The sampling sites amount to 128 in the nine areas MC02 ~ MC10, of which 104 were by dredges and 24 by corer.

In this section, rocks recovered by dredges and corer and unconsolidated sediments recovered by corer will be described and the outline of the samples will be reported for each seamount. Sampling sites are shown in Figures 4-2-1 (1) ~ (9), the outline of the geology of each seamount in Tables 4-2-1 (1) ~ (3), and the summary of the collected samples in Appendix Tables 2 (1) ~ (7).

MC02

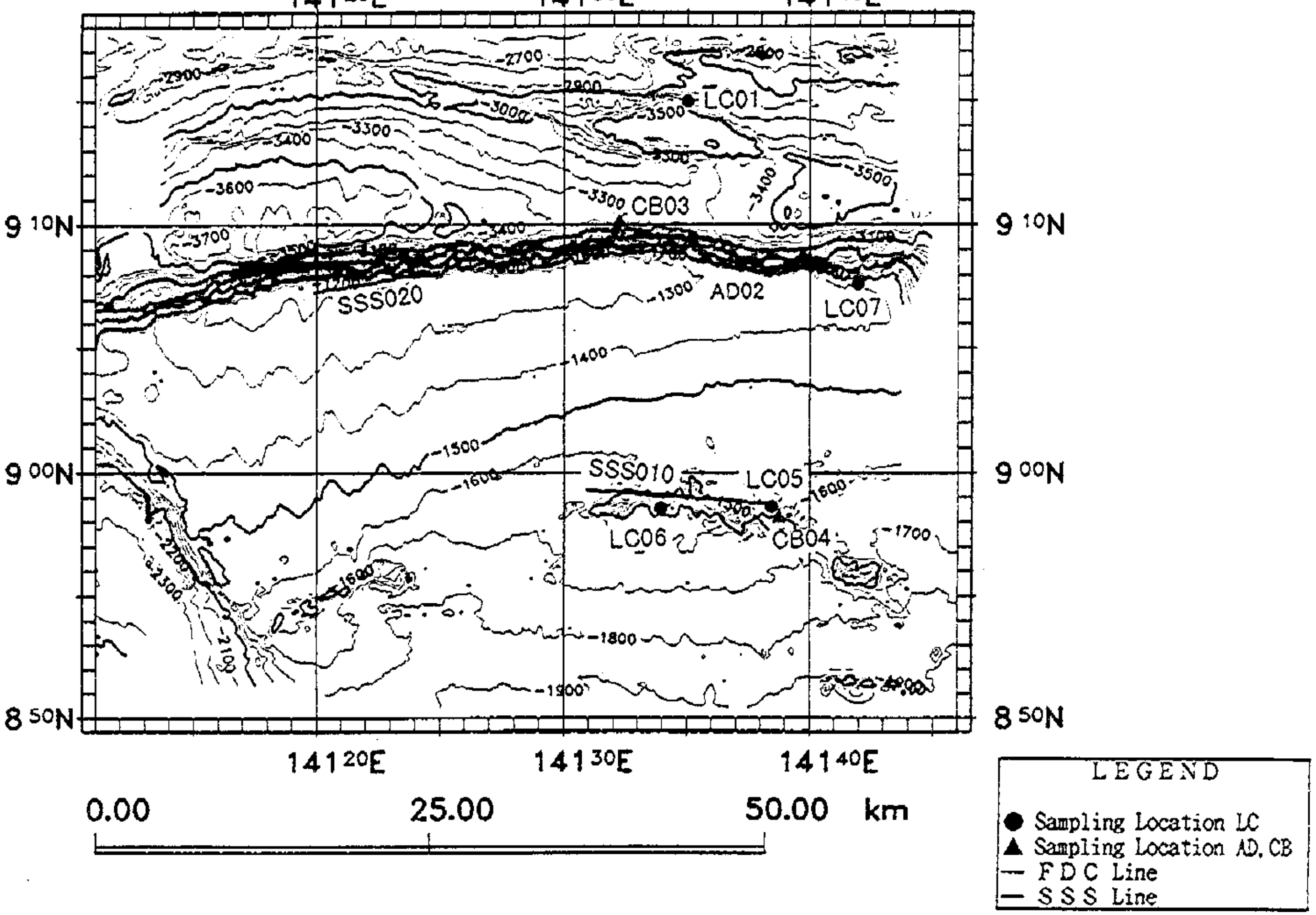


Fig. 4-2-1 (1) Location map of sampling sites (MC02 area)

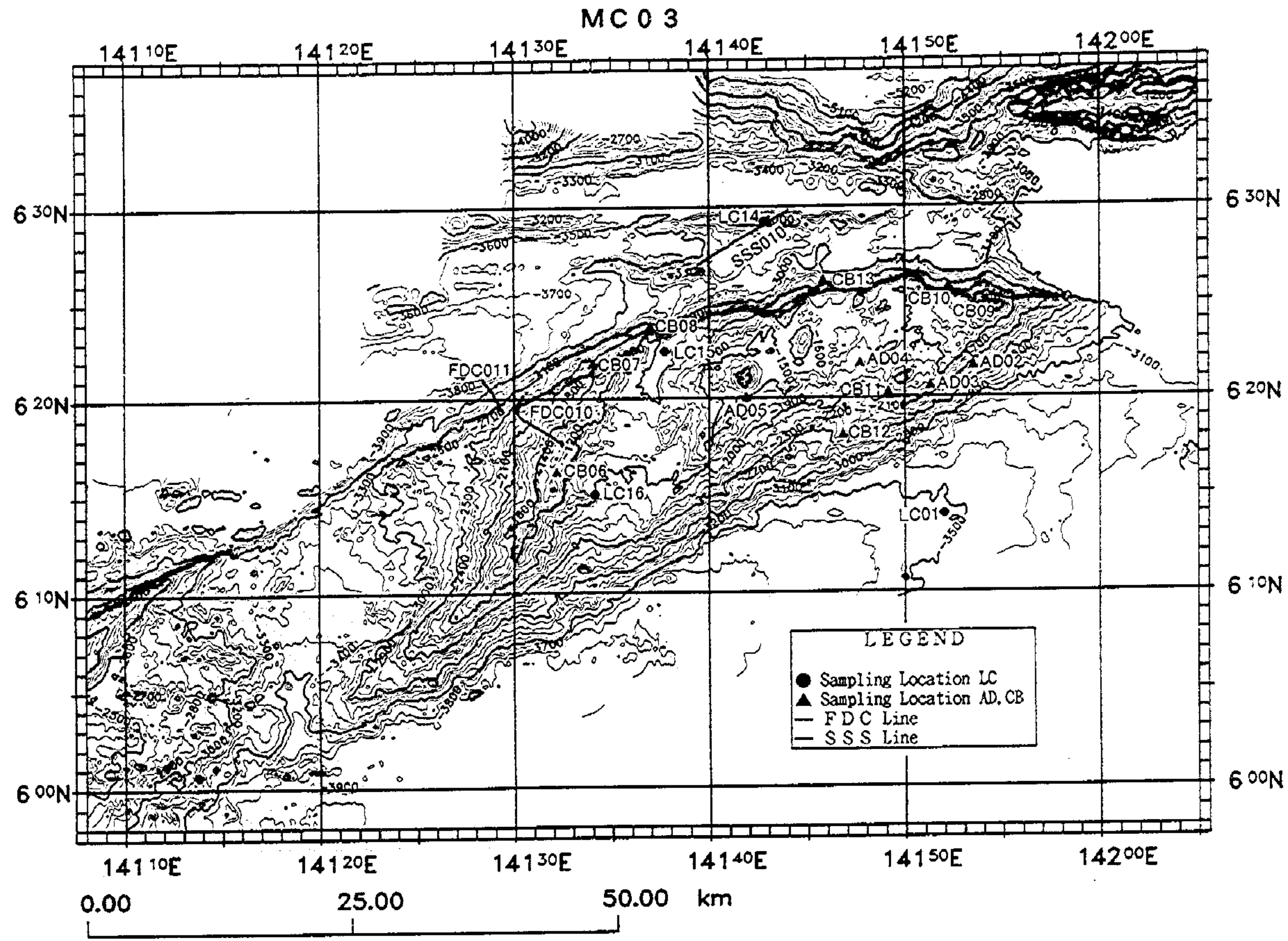


Fig. 4-2-1 (2) Location map of sampling sites (MC03 area)

MC04

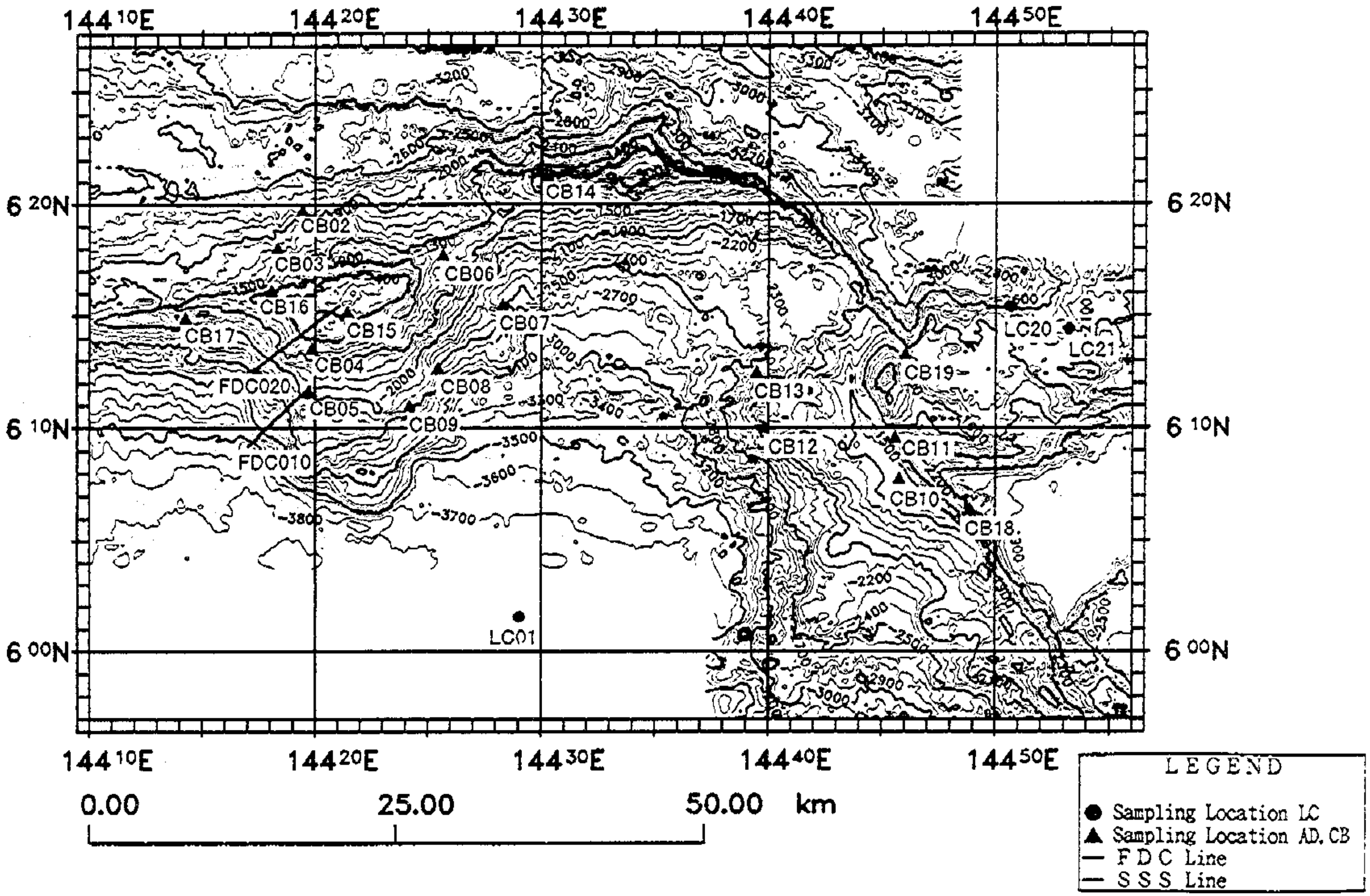


Fig. 4-2-1 (3) Location map of sampling sites (MC04 area)

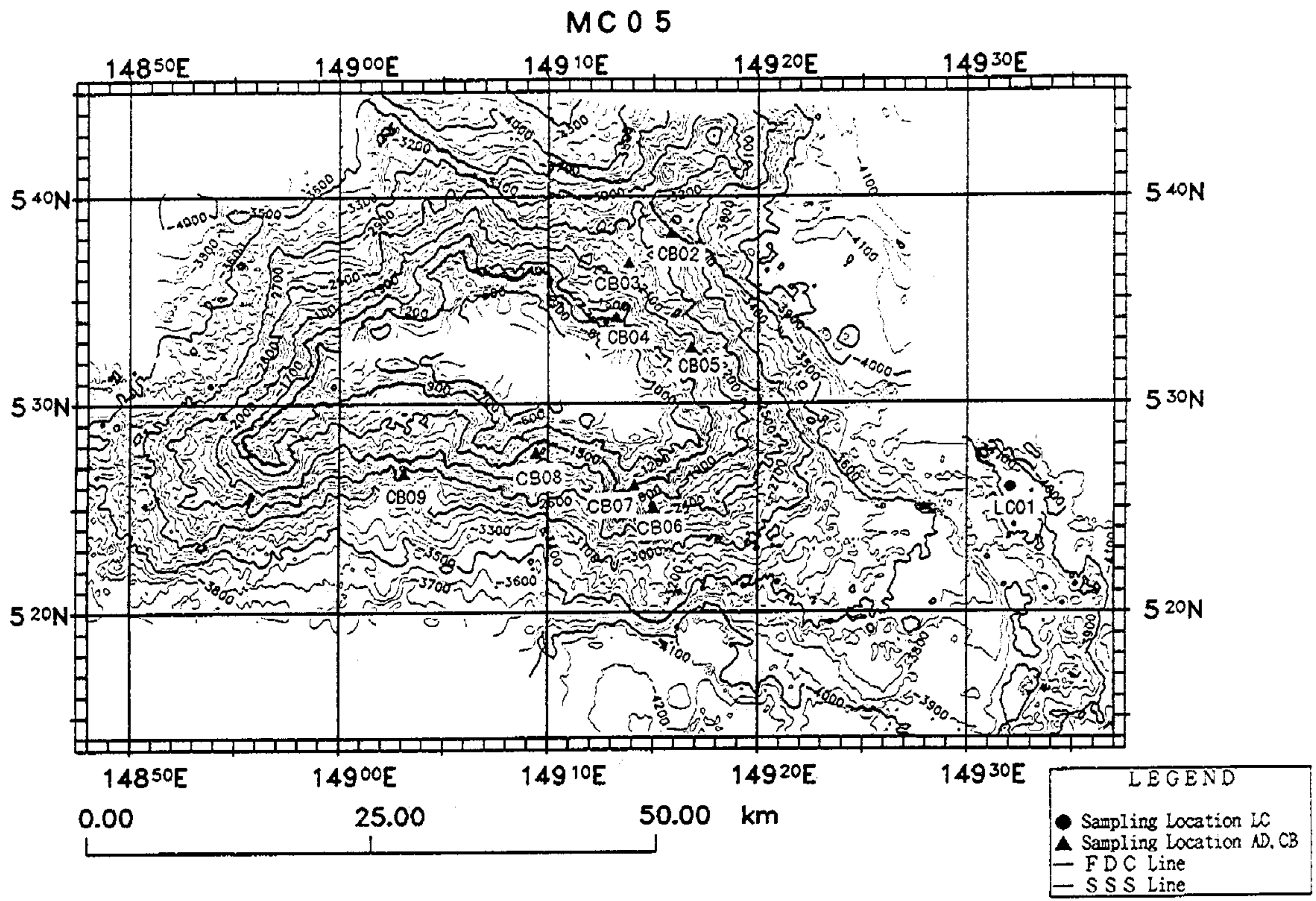


Fig. 4-2-1 (4) Location map of sampling sites (MC05 area)

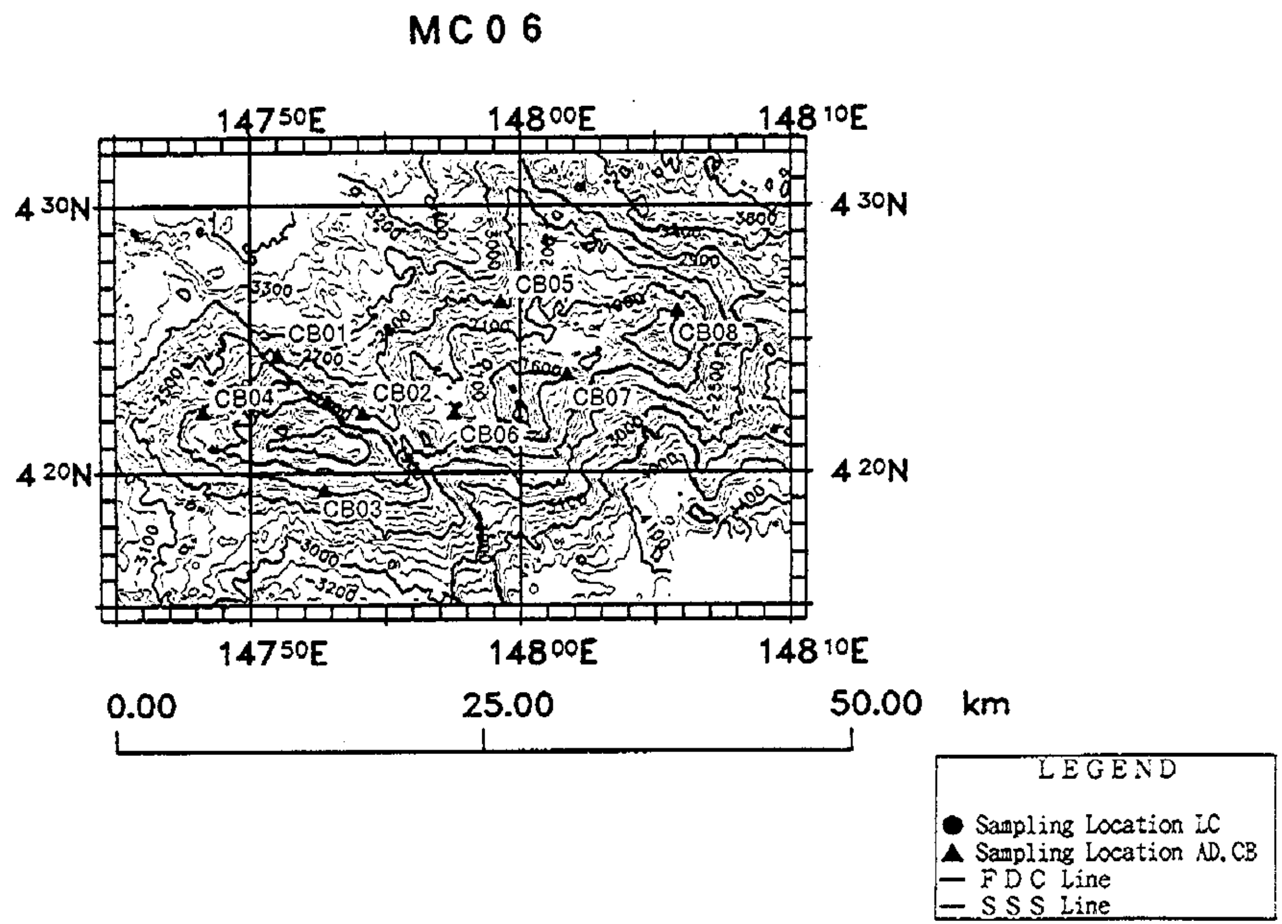


Fig. 4-2-1 (5) Location map of sampling sites (MC06 area)

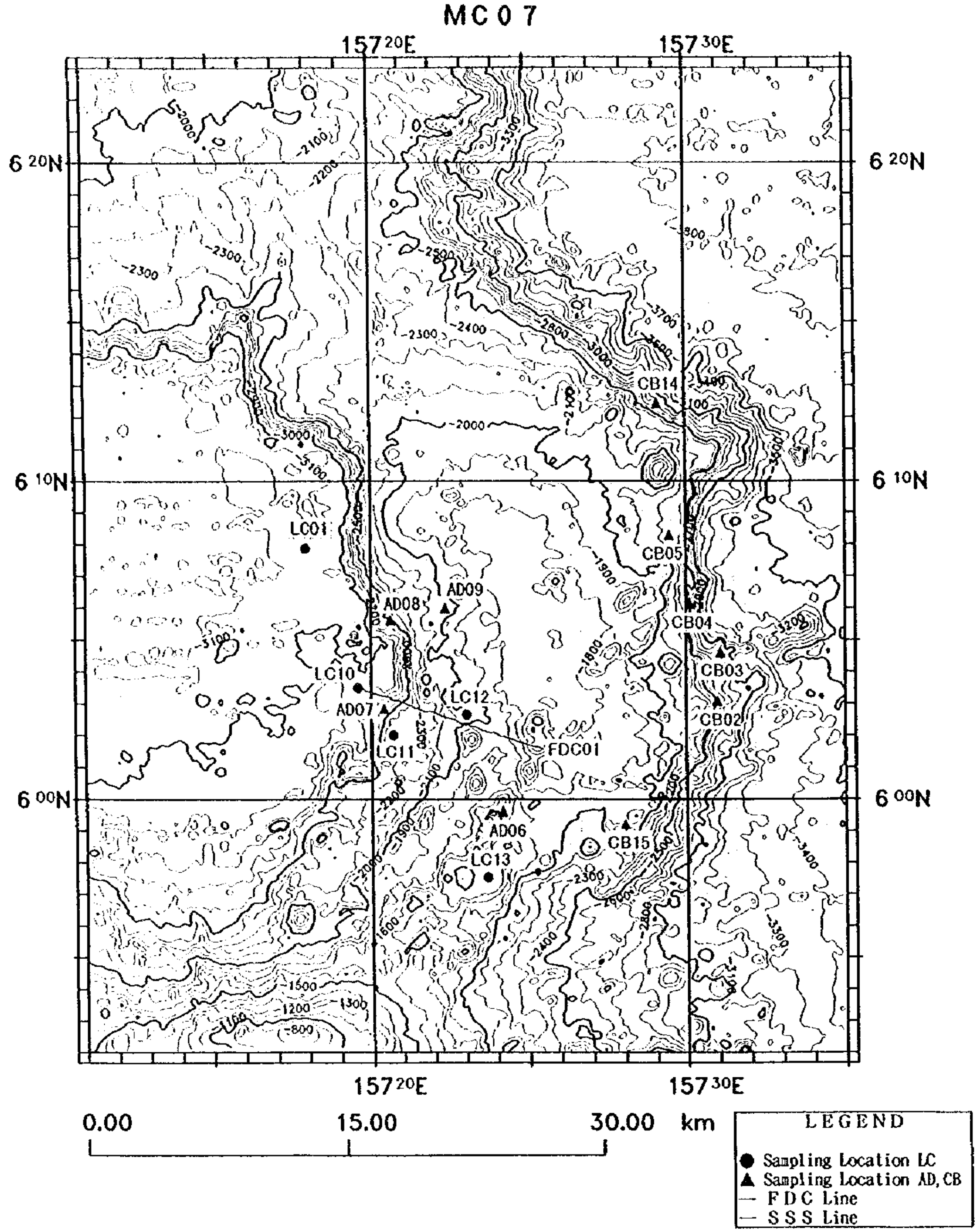


Fig. 4-2-1 (6) Location map of sampling sites (MC07 area)

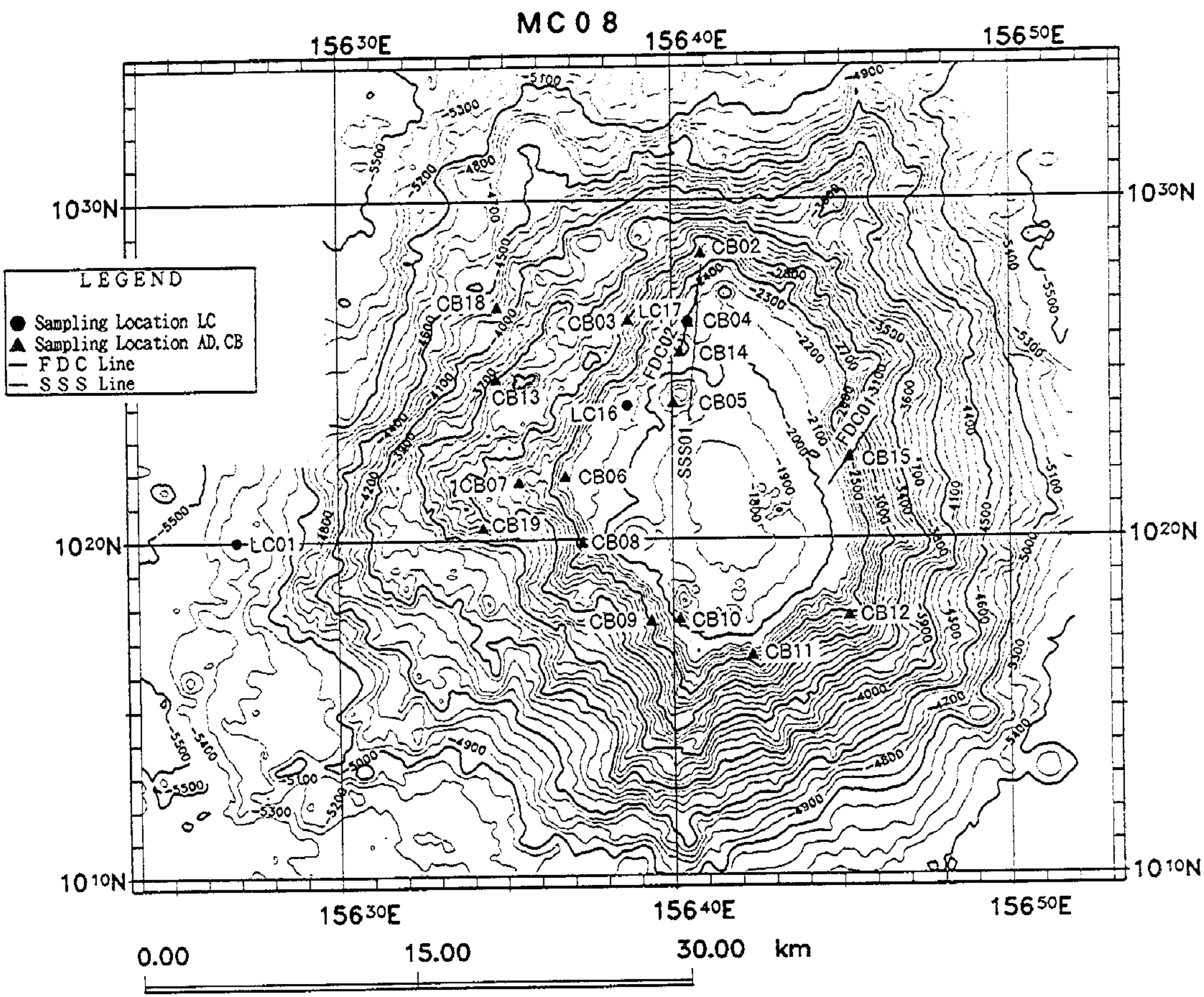


Fig. 4-2-1 (7) Location map of sampling sites (MC08 area)

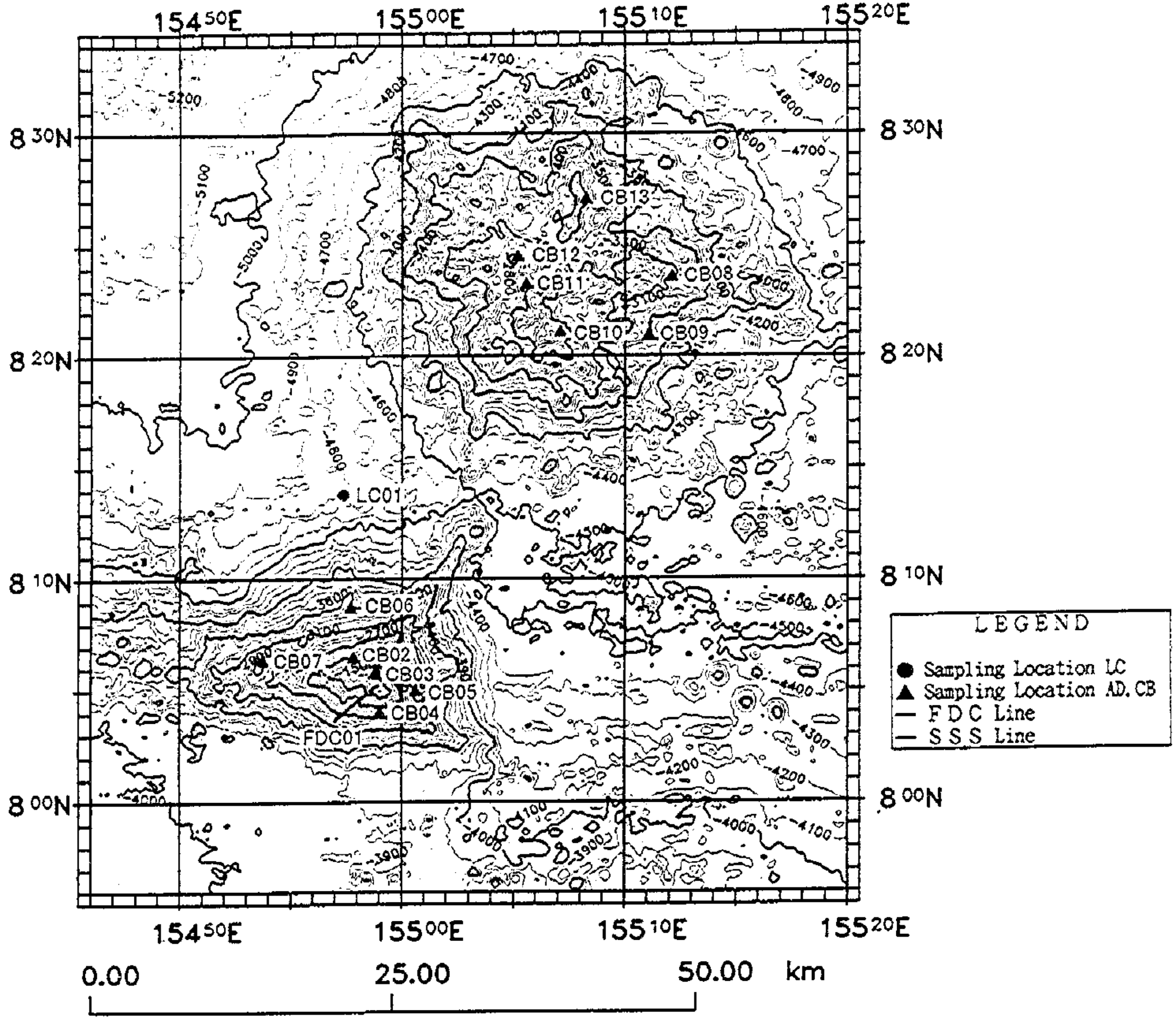


Fig. 4-2-1 (8) Location map of sampling sites (MC09 area)

MC10

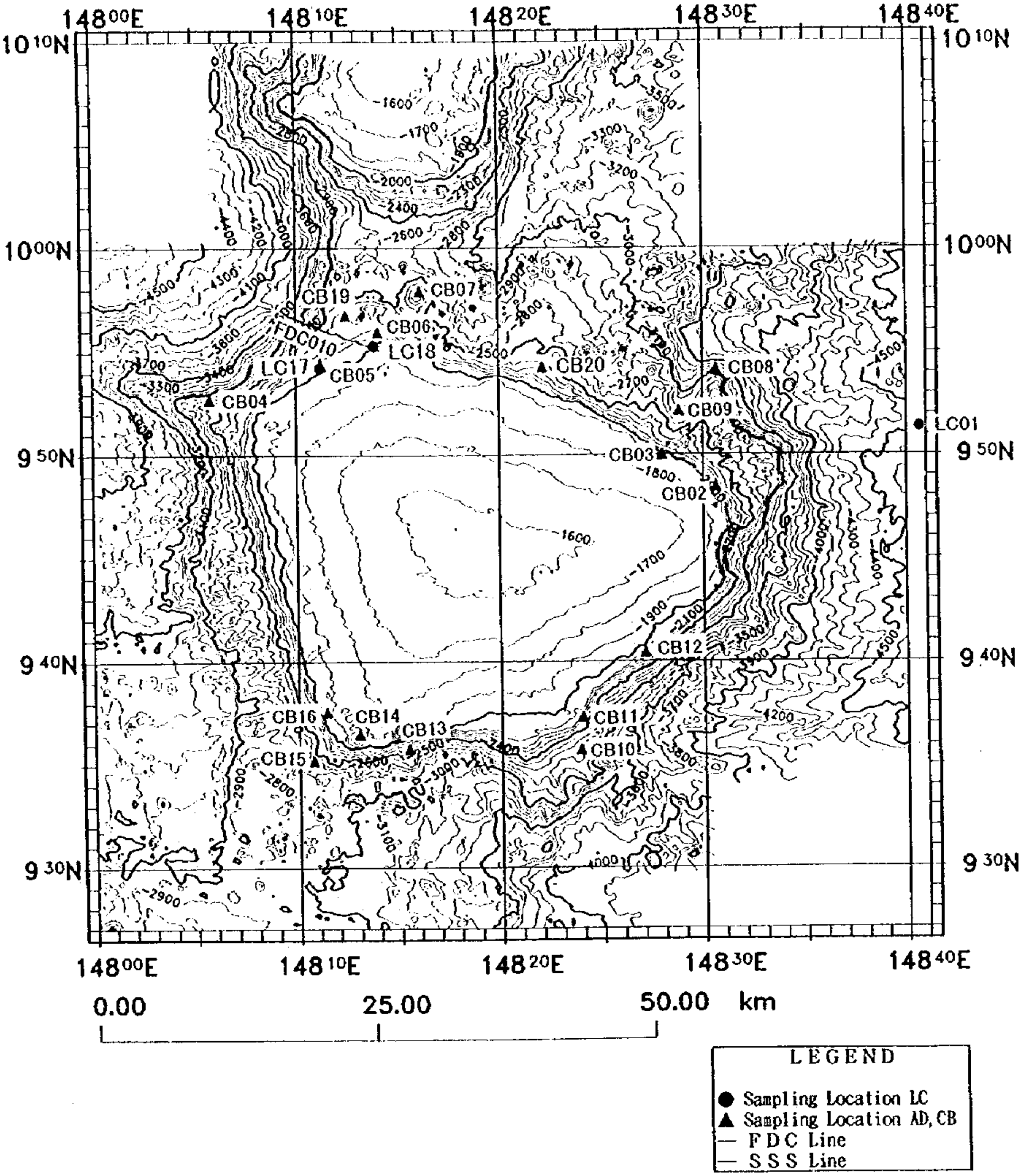


Fig. 4-2-1 (9) Location map of sampling sites (MC10 area)

Table 4-2-1 (1) Regional summary of geology

District	Seamount Form (depth data)	Division	Geology	Basalt	Limestone	Sediments	Crust (thick)
MC02							
	guyot (part of plateau) The summit extends east-west. (peak: 1,080m) (flat summit: 1,200~1,600m)	flat summit	Substrate rocks do not exposed.	not exposed	not exposed	deposited wholly and thickly	not exist
		pinnacles in the summit	Basalt and limestone are distributed in the ridges on the south flat summit.	porphyritic	reefal Ls, foraminiferal Ss, phosphatized ooze	poor	botryoidal (22~33mm)
		lower flank	Linear and steep north flank is supposed to reflect a large tectonic zone and altered basalt is distributed.	pillow lava, altered, pyrite disseminated	not recovered	poor in the north steep flank	stain (<1mm)
MC03							
	part of ridge Flat area lies at about 1,500m in depth. The body extends ENE-WSW. (eastern peak: 510m) (western peak: 950m)	shallower parts than the flat part	Reefal limestone is dominant. Limestone is widely distributed in the western summit. Basalt and hyaloclastite are only distributed in a eastern pinnacle.	vesicular porphyritic	reefal Ls, conglomeratic, foraminiferal Ss	distributed wholly except in the summit and pinnacles.	coating~ botryoidal (<1~10mm)
		upper flank	Basalt is dominant but limestone partly	vesicular porphyritic ~ aphyric	gravel bearing foraminiferal Ss	abundant in the south to west gentle flank and the terrace.	coating~ botryoidal (<1~21mm)
		lower flank	North flank is linear and steep. Basalt is distributed.	porphyritic, vesicular porphyritic	not recovered	distributed abundantly except in the north steep flank.	granular (4~14mm)
MC04							
West	part of ridge The body extends ENE-WSW. Flat area lies at 400m and 900m in depth. (peak: 100m)	summit	Limestone is wholly distributed.	not recovered	reefal Ls	poor	uncoated~stain
		upper flank	Limestone is widely distributed in the depth shallower than around 1,800m. Basalt is distributed in the ridge extending east-west.	vesicular glassy	reefal Ls, foraminiferal Ls	abundant in the gentle flanks and terrace part.	mainly coating (<1~10mm)
		lower flank	Basalt and limestone are distributed. Limestone is secondary deposits supplied from shallow part.	pillow lava, vesicular porphyritic	reefal Ls	abundant except in the steep flanks.	coating (<1mm)
East	part of ridge The ridge extends NW-SE and the northeast flank is steep. The summit at the depth of 1,400~1,500m is flat. (peak: 1,300m)	summit	Limestone is widely distributed in the summit and flat part shallower than 1,500m.	not recovered	reefal Ls	poor	botryoidal~ coating (3mm)
		upper flank	Limestone is widely distributed. Roumded gravels of mudstone is distributed in the valley of east flank.	not recovered	reefal Ls	abundant in the west gentle flank.	mainly coating (<1~1mm)
		lower flank	Basalt, hyaloclastite and foraminiferal sandstone are distributed. Reefal limestone on the east steep flank is float.	vesicular, porphyritic, vesicular aphyric	reefal Ls, foraminiferal Ss	abundant in the west gentle flank.	botryoidal~ coating (<1~8mm)

Table 4-2-1 (2) Regional summary of geology

District	Seamount Form (depth data)	Division	Geology	Basalt	Limestone	Sediments	Crust (thick)
MC05							
	peaked seamount	summit	Limestone is wholly distributed.	not recovered	reefal Ls	poor	stain
	The body has a triangular shape standing out to the north.	upper flank	Limestone is wholly distributed.	not recovered	reefal Ls	abundant except in the steep flanks.	stain ~ coating (<1mm)
	The summit part forms an arc.	middle flank	Basalt and hyaloclastite are dominant. Conglomerate, limestone and sandstone are also distributed.	vesicular porphyritic, aphyric	reefal Ls	abundant except in the steep flanks.	stain ~ coating (<1mm)
	(peak: 190m)	lower flank	Basalt is distributed. Limestone is float. Northeast flank is linear, steep and tectonic.	pillow lava, vesicular	porous recrystallized	abundant except in the steep flanks.	stain
MC06							
	peaked seamount Three bodies extending NW-SE range east and west.	upper flank	Limestone is dominant. Hyaloclastite and conglomerate are also distributed in the flat area.	vesicular porphyritic	reefal Ls	generally poor, distributed in the gentle flank and terrace.	botryoidal~ coating (<1~13mm)
	Flat area lies at around 1,900m in depth. (peak: 740m)	middle flank	Only limestone is distributed in some area and only hyaloclastite in other area.	vesicular porphyritic, aphyric	foraminiferal Ss ~Ls	distributed abundantly except in the steep flank and ridges.	botryoidal~ coating (<1~20mm)
		lower flank	Basalt, hyaloclastite and limestone are distributed.	porphyritic, vesicular porphyritic	reefal Ls, foraminiferal Ss ~Ls	distributed abundantly except in the steep flank and ridges.	granular, stain (<1~3mm)
MC07							
	guyot east part of ringed body The southern part continues to	flat summit	Basalt and hyaloclastite are dominantly distributed. Limestone is distributed only in the pinnacle on the shallowest part.	vesicular porphyritic, vesicular aphyric	reefal Ls	distributed widely except in the pinnacles and south ridge.	botryoidal~ smooth (<1~10mm)
	the south peaked seamount. (peak: 1,420m) (flat summit: shallower than	upper flank	Hyaloclastite is dominant with basalt, sandstone and mudstone. The boundary between upper flank and flat summit is unclear.	vesicular	not recovered	abundant except in the steep flank. flank.	botryoidal~ granular (<1~12mm)
	2,000m)	middle flank	Basalt is dominant with basaltic tuff breccia and calcareous sandstone.	pillow lava, vesicular porphyritic ~aphyric	not recovered	generally poor except in the gentle flank.	botryoidal~ coating (<1~14mm)

Table 4-2-1 (3) Regional summary of geology

District	Seamount Form (depth data)	Division	Geology	Basalt	Limestone	Sediments	Crust (thick)
MC08							
	guyot The body has an oval shape extending north and south. Pinnacles are scattered on the northeast and southwest parts of flat summit. (peak: 1,580m) (flat summit: shallower than 2,200m)	flat summit	Hyaloclastite and mudstone are dominant with basalt.	vesicular porphyritic	phosphatized ooze	deposited thickly except in the pinnacles and summit margin.	botryoidal–smooth (<1–70mm)
		pinnacles in the summit	Basalt and hyaloclastite are distributed.	vesicular aphyric	not recovered	poor	botryoidal–smooth (<1–90mm)
		upper flank	Basalt, conglomerate, hyaloclastite and mudstone are distributed. The uppermost flank is steep.	vesicular aphyric, porphyritic, glassy	porous phosphatized ooze	generally poor	botryoidal–granular (<1–83mm)
		middle flank	Basalt and hyaloclastite are distributed.	spherulitic, aphyric	massive phosphatized ooze	abundant except in the ridges and steep flank.	botryoidal–smooth (<1–11mm)
		lower flank	Basalt is dominant with hyaloclastite and mudstone.	spherulitic, aphyric, vesicular porphyritic	porous phosphatized ooze	abundant except in the steep flank.	botryoidal–coating (<1–27mm)
MC09							
North	peaked seamount The body has a circular shape. The summit has a lot of pinnacles. (peak: 2,030m)	summit	Only basalt is distributed. The summit consists of many peaks.	vesicular porphyritic	not recovered	abundant except in the ridges and steep flank.	botryoidal–granular (1–15mm)
		upper flank	Conglomerate and basalt are distributed.	vesicular aphyric	not recovered	abundant except in the steep flank.	granular (<1–11mm)
South	peaked seamount The body extends east-west and has an isosceles triangular shape whose base is east side. (peak: 1,090m)	summit	Basalt and basaltic volcanic breccia are distributed.	vesicular aphyric	not recovered	poor	botryoidal (1–12mm)
		upper flank	Basalt and conglomerate are distributed.	vesicular porphyritic, vesicular aphyric	not recovered	poor	granular (5–12mm)
		middle flank	Basalt, basaltic tuff breccia and hyaloclastite are distributed.	vesicular aphyric	not recovered	abundant except in the ridges and steep flank.	granular (<1–14mm)
		lower flank	Basalt, hyaloclastite and conglomerate are distributed.	vesicular porphyritic, vesicular aphyric	not recovered	abundant except in the ridges.	granular–smooth (1–23mm)
MC10							
	guyot The body has a reverse trapezoid extending rather WNW-ESE. (peak: 1,560m) (flat summit: shallower than 2,100m)	flat summit	Mudstone is dominant with basalt and conglomerate. Pinnacles are dotted on the southwest margin.	vesicular porphyritic, porphyritic	not recovered	deposited thickly except in a part of summit margin.	botryoidal–granular (<1–24mm)
		upper flank	Basalt, hyaloclastite and conglomerate are dominant with mudstone and phosphorite. The north flank continues to the northern next guyot.	porphyritic – aphyric, vesicular porphyritic, vesicular aphyric	not recovered	poor	botryoidal–granular (<1–155mm)
		middle flank	Basalt and hyaloclastite are dominant with conglomerate, mudstone and phosphorite.	porphyritic, vesicular porphyritic	not recovered	abundant except in the ridges and steep flank.	botryoidal–granular (<1–120mm)

(1) Rocks

The collected rocks are; volcanic rocks; basalt, basaltic pyroclastic rocks (volcanic breccia, tuff breccia, hyaloclastite), and pumice; sedimentary rocks; 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), Photos A ~ F)

Fresh surface is dark gray, but most of them are brownish gray by weathering. Most have porphyritic and porous texture and aphyric basalt is rare. Phenocrysts are 0.5-5 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 olivine. Fresh prismatic plagioclase is observed. The matrix is porous with vesicles, and is rarely compact. Spherical to ellipsoidal pores with 1 mm ~ 1 cm major axes are filled with clay minerals, zeolite, calcite, phosphorite, or soft mud in some cases. Pillow lava ~ breccia were collected from some seamounts.

Compact pillow lava was collected at MC02CB03 (Fig. 4-2-2 (1), Photo A). The diameter of the pillow lobe is about 20 cm, and 1 cm chilled margin is brown to black. These compact pillow lavas tend to be collected in zones deeper than 3,000 m of water. Photo D of the above figure shows porous basalt with most of the vesicles filled with ooze, and it has vesicles of differing size forming banded structure. Vitric basalt rich in 2 ~ 13 mm spherulites were collected from MC08CB07 and MC08CB18 (Fig. 4-2-2 (1), Photo F).

2) Basaltic pyroclastic rocks (Fig. 4-2-2 (1), Photos G, H)

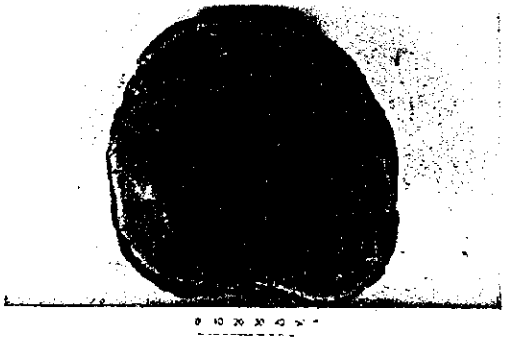
These rocks are subdivided into hyaloclastite and volcanic breccia ~ tuff breccia. Hyaloclastite was collected at more localities than the breccia..

The matrix of the former rock consists of similar material as the subangular to subrounded pebbles of the argillized greenish yellow gray to brown porous basaltic lapilli. The latter rock consists of grayish brown basaltic lapilli and matrix of argillized fine-grained clastics. Both are poorly sorted and the amount of pebbles vary greatly. The matrix sometimes contain phosphorites, carbonates, manganese oxides, foraminifera, and other material.

3) Volcanic conglomerate (Fig. 4-2-2 (2), Photos A-C)

This consists of weathered brown ~ brownish gray basalt cobbles to granules. They are mostly subangular to subrounded pebbles, poorly sorted, with many voids between the pebbles. The matrix consists of argillized green ~ brownish green fine-grained basalt clastics, phosphatized calcareous ooze, and phosphorites. Phosphorites and calcite sometimes fill the voids and form veins.

A

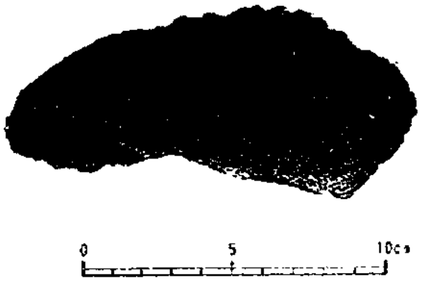


Basalt pillow lava:
black rim part is chilled margin (MC02CB03)

B

Basalt: black band is chilled margin (MC05CB02)

C



Basalt: vesicular, aphyric (MC07AD06)

D

Basalt: vesicular, banded (MC09CB07)

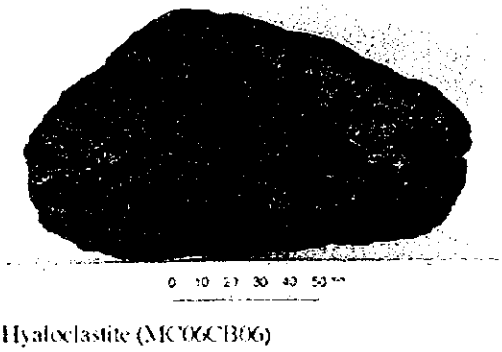
E

Basalt: reddish brown, porphyritic,
zeolite in vesicles (MC03CB09)

F

Basalt: spherulitic (brown part) (MC08CB07)

G



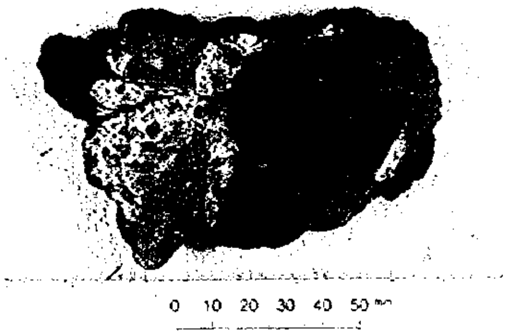
Hyaloclastite (MC06CB06)

H

Hyaloclastite (MC08CB07)

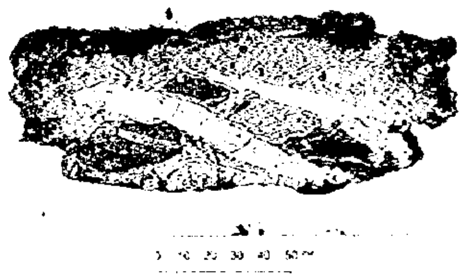
Fig. 4-2-2 (1) Photographs of rocks

A



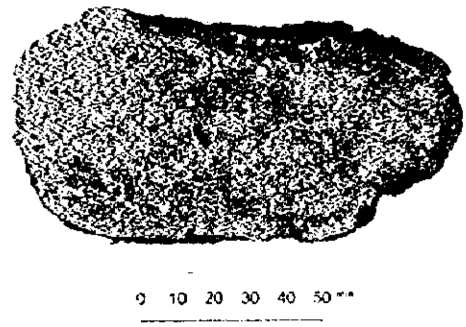
Pebble conglomerate: basalt pebble and phosphorite matrix (MC03CB10)

B



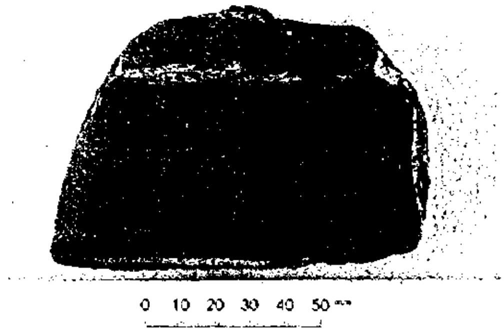
Pebble conglomerate: white phosphorite vein (MC08CB06)

C



Granule conglomerate: matrix is phosphatized ooze (MC10CB20)

D



Mudstone: stratified (MC05CB03)

E

Reefal limestone (MC02CB04)

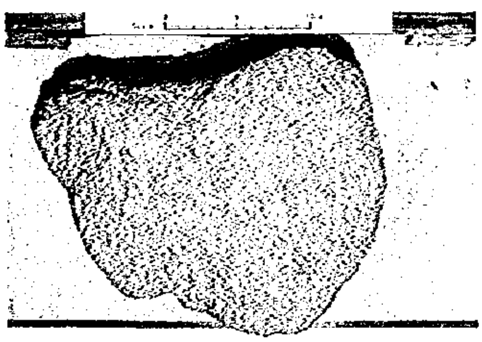
F

Reefal limestone: composed of coral (MC08CB08)

G

Reefal limestone: phosphatized (MC03CB06)

H



Foraminiferal sandstone (weekly consolidated sand) (MC03CB11)

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

Photo A (Fig.4-2-2 (2)) shows a typical pebbly conglomerate with phosphoric matrix. Photo B shows basalt conglomerate transected by thick a phosphorite vein.

4) Sandstones

Sandstones are relatively rare in the survey area, and their lithology differs by locality as follows. Gray, coarse, bedded sandstone comprised mainly of foraminifera containing basalt granules. Grayish brown, fine, hyaloclastic sandstone containing foraminifera. Dark brown, fine, pelitic sandstone containing pumice. Solidification of these sandstones are lower than that of mudstones.

Also pale brownish gray ~ white coarse sandstone (sand lumps) samples were collected from some seamounts. These are weakly solidified foraminifera sand (Fig. 4-2-2 (2), Photo E). These are clearly younger than other rocks.

5) Mudstone (Fig. 4-2-2 (2), Photo D)

Mudstone in this area is pale brown ~ brown and some are bedded. Most were collected as pebbles and many are platy. Many were collected in MC08 and MC10.

6) Limestone (Fig. 4-2-2 (2), Photo F ~ H)

Limestone in this area is reef limestone consisting of corals, shells, and foraminifera. It is pale brown ~ white and its nature varies from hard and compact to soft and porous. Some have been recrystallized and phosphatized. Many were collected in the shallow parts of MC02 ~ MC06.

7) Phosphorite

This is mainly composed of phosphatized calcareous ooze and occurs as; matrix of conglomerates and pyroclastic rocks (Fig. 4-2-2 (2), Photo A), at the boundary of bedrocks and manganese oxides (Fig. 4-2-2 (2), Photo G), and in the voids of rocks and manganese oxides (Fig. 4-2-2 (1), Photo D). Also it occurs as veins (Fig. 4-2-2 (2), Photo B), phosphatized limestone, and pebbles of these rocks.

8) Pumice

Pumice in this area is pale gray ~ white, highly foamed, and thus is very porous. Many are subrounded and the long axes are 1 ~ 6 cm. This is believed to be transported by the ocean current and not autochthonous. Samples were collected from almost all areas.

(2) Seafloor Sediments

LC sampling was carried out at 24 points in eight seamounts excluding MC06. Seafloor Sediments were collected at 13 points, rock or manganese crust samples at five points, and none from six points.

Of the 13 localities, where seafloor sediments were collected, eight (one point on each seamount) were from the foot of the seamounts at 3,000 ~ 5-200 m water depth. Of this eight points, at one point the seafloor sediments surface was covered by crust, and at another point crust and nodules are intercalated in a horizon lower than the seafloor sediments. A typical photograph of the seafloor sediments and the seafloor is shown in Figure 4-2-3.

The collected seafloor sediments consisted mainly of unconsolidated foraminifera sand and ooze with rare inclusion of pebbles. Most of the seafloor sediments were of pale gray tone (10YR6/3: pale brown ~ 10YR7/3: very pale brown ~ 10YR8/2: white, by MUNSELL SOIL COLOR CHARTS. These charts were used throughout this work). The diameter of the foraminifera fossils are 0.3 ~ 2 mm and is identifiable by unaided eyes. The nature of the collected samples is as follows.

1) 97SMC02LC01

The recovered core is 215 cm long. It consists entirely of clay ~ soft mud containing foraminifera and the viscosity is generally high. Pale brown (10YR6/4) clay is dominant with intercalation of beds or spots of white (10YR8/2) ooze. The boundary of the clay and mud is relatively clear and is somewhat irregular. White mud is dominant at 20 ~ 55 cm and 135 ~ 150 cm depth. The percentage of foraminifera fossil content is 10 to several tens.

2) 97SMC02LC07 (Fig. 4-2-3, Photo B)

The recovered core is 23 cm long. It is inferred from the conditions of the sampling that the unconsolidated part near the seafloor was lost during the sampling and only the weakly solidified part in the deeper zones were recovered. Core is generally white (5YR8/1), and is weakly solidified foraminifera sand.

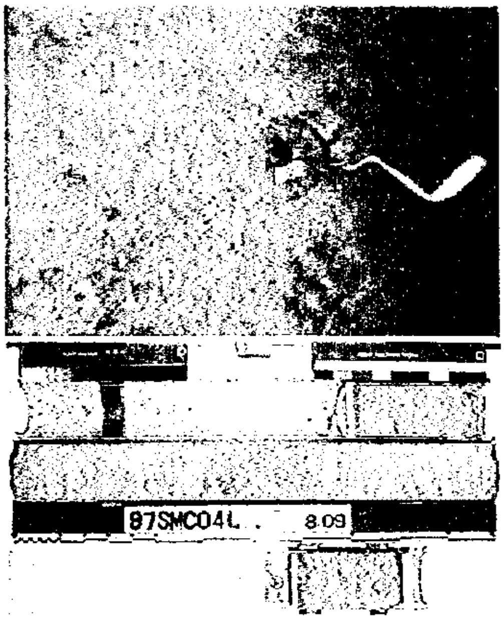
3) 97SMC03LC01

The recovered core is 260 cm long. It consists of ooze, silt, and sand. The boundaries are relatively clear and the rock is partly weakly bedded.

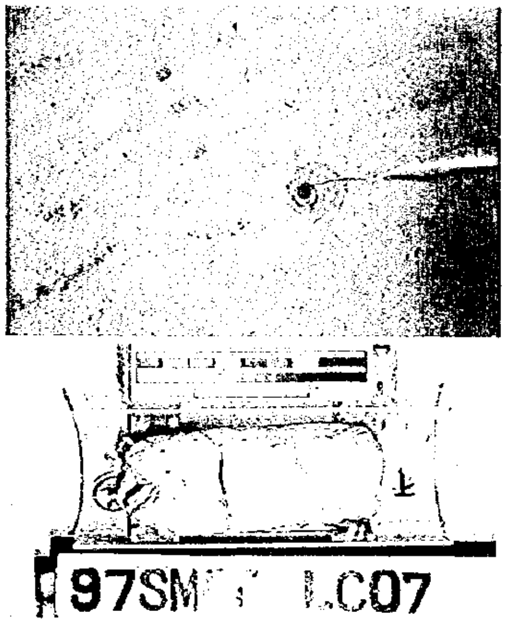
The sediment consists of pale brown ooze from the surface to 15 cm depth and from 27 to 45 cm. Intervals 15 ~ 27 cm and 86 ~ 120 cm depth consists of white foraminifera. Thin beds (0.5 ~ 2 cm thick) of grayish green (5Y5/3) tuffaceous silt are intercalated at 58 ~ 80 cm depth. Below 120 cm, white (10YR8/1), foraminifera-rich and partly bedded ooze is dominant. The compaction of the core improves below 170 cm because of the decrease of the water content.

4) 97SMC03LC14

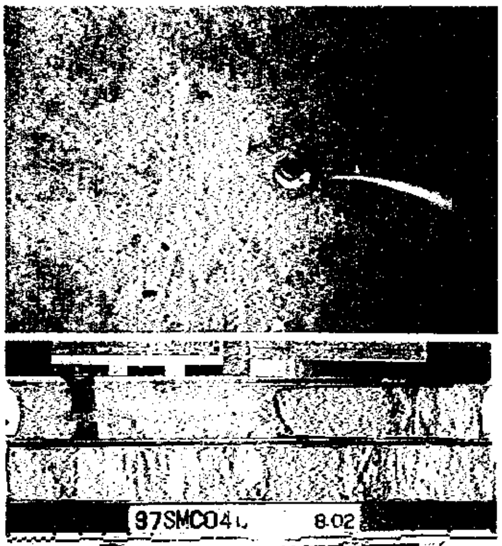
The recovered core is 7 cm long. Similar to 97SMC02LC07, it is believed that the unconsolidated material was washed away during the sampling with recovery of only the weakly solidified material.



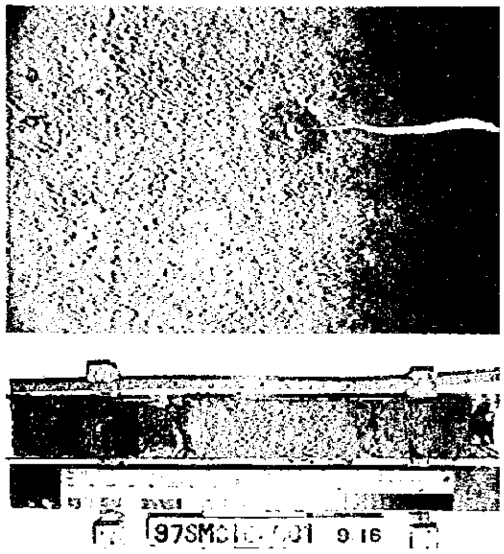
MC04LC20 core length: 150cm
pale brown foraminiferal sand.
white spotted parts are scattered.



MC02LC07 core length: 23cm
ripple marks on the seafloor sediments.
white massiv foraminiferal sand.



MC04LC01 core length: 160cm
pale brown ooze, turbidite, white ooze.
angular gravels of limestone in 90 cm depth



MC10LC01 core length: 90cm
brown mud, granule, crust, brown pelagic clay.
crust (2~3 mm thick) and nodules (<1 cm diameter) in 25 cm depth.

Note: The upper photo of each site shows seafloor and the lower sediments core.
In the core photo, the upper-left side is the top and lower-right the bottom.

Fig. 4-2-3 Photographs of seafloor and unconsolidated sediments

Core is, on the whole, white consisting of weakly solidified foraminifera sand.

5) 97SMC04LC01 (Fig. 4-2-3, Photo C)

The recovered core is 160 cm long. It consists of ooze with intercalation of turbidite.

Intervals 20 ~ 30 cm, 85 ~ 93 cm, 110 ~ 120 cm, and 150 ~ 160 cm depths are believed to consist of turbidites from the existence of limestone pebbles. There are many 0.5 ~ 1 cm angular pebble of reef limestone at 90 ~ 93 cm depth, and similar pebbles of 2.5 cm in diameter occur at the bottom of the hole.

Seafloor surface to 30 cm depth and 93 ~ 120 cm depth consist of pale brown ooze containing foraminifera. Intervals 30 ~ 93 cm and 120 ~ 160 cm depths consist of irregular alternation of white foraminifera ooze and pale brown layers.

6) 97SMC04LC20 (Fig. 4-2-3, Photo A)

The recovered core is 150 cm long. It is generally homogeneous, pale brownish gray foraminifera sand without bedding and contains small amount of manganese oxide fragments which are smaller than 1 mm. There are white spots below 30 cm.

7) 97SMC05LC01

The recovered core is 280 cm long. The whole core consists of ooze containing foraminifera and clay. The boundary between the mud and clay is generally clear.

The core is divided into the following six units. Surface ~ 27 cm depth: Soft part immediately below the seafloor. 27 ~ 70 cm depth: ooze with intercalation of thin jelly-like layers. 70 ~ 160 cm depth: upper part ooze, lower part clay. 160 ~ 170 cm depth: upper part clay, lower part ooze. 170 ~ 240 cm depth: upper part clay, lower part ooze. 240 cm ~ bottom: clay. The boundary between the 160 cm and 240 cm beds is very clear. The water content below 70 cm depth is small and the compaction is high.

The surface to 27 cm interval consists of ooze and brown and white patches are mixed in this part of the core. 27 ~ 135 cm interval consists of pale gray ~ white foraminifera ooze and gray ~ brownish gray patches are intercalated irregularly. 27 ~ 70 cm interval consists of ooze with intercalation of five layers of thin (1 ~ 16 mm thick) greenish gray and very soft jelly-like material. Intervals; 135 ~ 160 sm, 170 ~ 228 cm, and 240 ~ bottom consist of pale brown ~ pale grayish brown clay. 228 ~ 240 cm interval consists of white medium ~ fine grained foraminifera sand with grading.

8) 97SMC07LC01

The recovered core is 145 cm long. The surface to 35 cm depth consists of foraminifera ooze with bedding in the lower part. Compaction is fair, and the material is viscous. Interval 35 ~ 145 cm consists of pale yellow ~ white foraminifera sand without bedding. This layer is low in mud content compared to the overlying mud and compaction and viscosity are low. The average diameter of the foraminifera is less than 1 mm.

9) 97SMC07LC11

The recovered core is 200 cm long. The whole core consists of pale brown ~ white foraminifera sand.

The surface to 35 cm depth consists of irregular mixture of sands with different color. The interval 35 cm to the bottom is homogeneous and massive without bedding, but it is generally graded. Small amount of 2 ~ 4 mm basalt fragments occur below 90 cm depth.

10) 97SMC08LC01

The recovered core is 20 cm long. The surface is covered by 6 ~ 15 mm thick manganese crust.

The interval 1 ~ 9 cm depth consists of weakly bedded fine calcareous sand containing foraminifera fossils and micronodules of manganese oxides. The upper part is solidified (lithified) and the lower part is weakly solidified. Interval 9 ~ 16 cm consists of calcareous ooze, and is a mixture of brown and dark brown patches. From 16 cm to the bottom consists of dark brown (10YR3/4) clay with many minute grains of manganese oxides.

The surface of the crust is flat and smooth with small irregularity and the average thickness of the crust is 10 mm. The seafloor photographs show that the crusts with small irregular surface covers the whole summit which is thinly covered by unconsolidated sediments.

11) 97SMC09LC01

The recovered core is 40 cm long. The surface is coated by manganese oxides.

The surface to 7 cm depth consists of dark brown solidified (phosphatized?) mud and is disseminated with manganese oxides. The interval 7 ~ 20 cm depth consists of dark brown fairly well compacted mud. The interval 20 ~ 40 cm consists of pale brown somewhat solidified ooze containing manganese oxide micronodules of less than 1 mm in diameter. Phosphatized 1 ~ 2 cm thick fine-grained sandstone beds are intercalated between 20 cm to 35 cm depth.

12) 97SMC10LC01 (Fig. 4-2-3, Photo D)

The recovered core is 90 cm long. It generally consists of brown mud with intercalation of turbidites, nodules, and crust between 15 to 25 cm.

The surface to 15 cm depth consists of dark brown mud containing foraminifera and micronodules of manganese oxides. The interval 15 ~ 25 cm consists of turbidite consisting of granules. These granules are fragments of basalt, phosphorites, manganese crusts, and nodules. Matrix is rare and consists of mud containing foraminifera. Crusts with 2～3 mm thickness are intercalated at 25 cm depth. From 25 cm to the bottom consists of brown massive mud containing many micronodules.

The surface of these intercalated crusts is botryoidal and flat nodules with long axis less than 1 cm occur immediately above them. Also some nodules with 1～2 cm long axis occur at 20～25 cm depth.

13) 97SMC10LC18

The recovered core is 30 cm long. It consists of pale brown to white foraminifera sand. The core is very loosely solidified.

(3) Samples from individual areas

Basalt and basaltic pyroclastic rocks were collected from all seamounts and they constitute the largest portion of the sampled material. They are the major substrate material of the manganese crust. The appearance of these rocks is very similar and there is no apparent difference among those of different seamounts. Those with characteristic lithology are; pillow lava (Fig. 4-2-2 (1), Photo A), vesicular banded structure (Fig. *ib.*, Photo B); and examples of unique lithology are; reddish brown basalt from MC03 (Fig. *ib.*, Photo E), and granular texture from MC08 (Fig. *ib.*, Photo F). The appearance of sedimentary rocks such as sandstones, mudstones, and limestones vary by the area and the sampling sites. Pumice of unknown origin was collected throughout the survey area, they are rounded and are not covered by manganese crust and thus are believed to be the products of relatively young effusion transported by sea current. The nature of the rocks collected at each seamount are as follows.

1) MC02 area

Large amount of pillow basalt and reef limestone were collected, together with basaltic pyroclastic rocks, metabasalt, and foraminifera sand mass. Basalt pillow lava, pyroclastic rocks, and metabasalt occur in the northern slope while limestone is predominant on the small hill of the summit. Metabasalt is greenish dark gray and is generally chloritized and carbonatized. Thin (less than 1 mm thick) quartz-calcite veinlets occur in some samples with weak pyrite dissemination along the veins. The matrix of the pyroclastic rocks is argillized and accompanied by carbonatization and pyrite dissemination. USGS-KORDI (1992) reports similar pillow basalt alteration and pyrite-chalcopyrite dissemination in the vicinity.

The seamount in this area forms a part of an east-west trending oceanic plateau and the northern slope is linear in the east-west direction and is very steep. There is a parallel graben to the north. The northern slope is a fault scarp formed together with the graben and it is believed that the alteration occurred simultaneously. Thus the alteration is inferred to be not very young.

2) MC03 area

Basalt and reef limestone were collected in large amount together with conglomerate, sandstone, and hyaloclastite. Limestone occurs in the shallower part than the flat area (about 1,600 m water depth) in the eastern part of the seamount. Basalt occurs in the deeper slopes.

In 97SMC03LC16 on the saddle near the center of the seamount, the hydrothermal organism "*Munidopsis*" sp., was confirmed by seafloor photography. Although the existence of "*Munidopsis*" sp., alone does not immediately indicate hydrothermal activity, it is noteworthy because this seamount is a part of a oceanic ridge with large scale geologic structures in the vicinity.

3) MC04 area

Two seamounts--eastern and western--were surveyed in this area. Reef limestone was collected from both seamounts and basalt, basaltic pyroclastic rocks, and mudstone were also collected in small amounts. In the western seamount, limestone is distributed at 2,000 m depth or above, while basalt pillow lava occur in deeper zones. Similar occurrence is also observed in the eastern seamount and also mudstone is distributed in the upper slope and pyroclastic rocks and hyaloclastite in the lower slope.

In the western seamount, manganese crusts occur only thinly on the reef limestone with thickness less than 1 mm. At 97SMC04LC01 on the southeastern foot of this seamount located 3,870 m depth, turbidite containing angular fragments of reef limestone is intercalated at core depth of 90 cm and 160 cm. The limestone on the surface of the present slope is relatively young and is believed to have been supplied from the shallower part by events such as slope failure.

4) MC05 area

Basalt and reef limestone were mainly collected and basaltic pyroclastic rocks, conglomerate, and sandstone were also collected in some places. Basalt and clastic rocks occur only below 2,000 m water depth, and limestone is predominant above this depth.

The seamount in this area has the shallowest summit within the nine areas surveyed, and only a very minor amount of manganese crusts occur here. Thus the age of this seamount is inferred to be fairly young.

5) MC06 area

Basalt, hyaloclastite, and reef limestone were mainly collected with minor amount of conglomerate in some places. There is a flat part at 1,900 m depth, and basalt and hyaloclastite occur below this depth and limestone above.

6) MC07 area

Very vesicular basalt, hyaloclastite were abundantly collected, together with sandstone, mudstone, and limestone in some localities. The water depth of the flat summit is about 1,800 ~ 2,000 m, and the border with the gentle upper slope is not clear. Basalt is predominant in the steep middle slope, hyaloclastite is predominant in the upper slope together with sandstone and mudstone. Basalt and hyaloclastite are predominant around the summit periphery. Basalt and granules of limestone were collected at the small hill in the central part of the summit and this was the only locality in this area where limestone was collected.

7) MC08 area

Basalt and hyaloclastite were mainly collected with fair amount of mudstone, conglomerate, limestone, and phosphorite. The seamount here is a guyot and the geology of the base matches the topography as follows.

The small hills scattered on the northwestern and southwestern parts of the flat summit consist of vesicular, aphyric basalt and hyaloclastite, and mudstone and hyaloclastite are distributed near the periphery of the summit. The upper slope consists of porphyritic to vesicular aphyric basalt, conglomerate, hyaloclastite, and mudstone, while the middle to lower slope consists of spherulitic and vesicular porphyritic basalt, hyaloclastite, and mudstone. Spherulitic basalt is a characteristic volcanic rock collected only below 2,500 m depth in this area. Spherulites does not necessarily occur throughout the rock and the matrix is very vitreous and is generally argillized and pale brown. Fresh part is dark gray and is very rare, the strongly argillized parts are greenish yellow.

8) MC09 area

Two seamounts—northern and southern—were surveyed in this area. In both seamounts, vesicular basalt is predominant and basaltic pyroclastic rocks and conglomerate were also collected. The northern seamount has several peaks and has different topography from the independent pointed seamount in the south. The summits consists only of basalt, and the upper slope consists dominantly of basalt with conglomerate in some places. In the southern seamount, basalt, basaltic pyroclastic rocks, and conglomerate occur throughout the mountain. The basaltic pyroclastic material is composed of volcanic breccia, tuff breccia, and hyaloclastite. Conglomerate consists of granule to pebble and matrix of phosphatized calcareous ooze.

Limestone was not collected from either seamount. The shallowest part of the northern seamount is deep at 2,030 m, while that of the southern one is shallow at 1,090 m. At MC03-MC—06 areas where limestone was collected abundantly, it occurs predominantly at 1,600 ~ 2,000 m depth. In MC08 and MC10 areas where limestone was not collected, the summit of the seamounts ranged in depth from 2,000 m to 2,200 m. From these facts, it would seem that limestone should occur in the southern seamount. The reason for the lack of limestone in this seamount could be; the summit was above the sea at one time but for some reason the conditions were unfavorable for limestone formation, or the seamount is so young that the summit was never above water.

9) MC10 area

Basalt is predominant and hyaloclastite, conglomerate, and mudstone were also collected in fair amount. The periphery of the summit is dominantly mudstone, and vesicular basalt and conglomerate occur in the small hills in the southwestern margin. Porphyritic to aphyric or vesicular basalt and conglomerate are predominant on the upper slope, and hyaloclastite and mudstone also occur on the gentle slope on the northern side. On the middle slope, porphyritic to vesicular basalt and hyaloclastite are predominant with conglomerate, mudstone, and phosphorites. Limestone was not collected.

4-3 Description of Rocks

(1) Microscopic observation of thin section

The dredged samples were prepared into thin sections and studied microscopically. The major part of the collected samples were basalt and basaltic pyroclastic rocks, and thus the major part of the studied samples were also these rocks. Number of samples studied was 52, and 30 of these samples were examined by X-ray diffractometry and the results will be reported in later sections. The results of microscopic studies are shown in Tables 4-3-1 (1), (2), and representative microphotographs are laid out in Figures 4-3-1 (1), (2).

It is seen by the unaided eyes that almost all basalt samples are weathered with many vesicles which are sometimes filled by secondary minerals. The matrix of the pyroclastic rocks are strongly argillized and many of the pebbles also are altered. Basalt and pyroclastics are magnetic. Limestone is recrystallized and hard.

The following rocks were identified and studied microscopically. Volcanic rocks; basalt, dolerite, hyaloclastite, and harzburgite; sedimentary rocks; conglomerate, sandstone, mudstone, and limestone. Basalt is largely grouped into, in order of abundance; vesicular porphyritic basalt, compact porphyritic basalt and vesicular aphyric basalt.

The major rocks of the seamounts are described below.

Table 4-3-1 (1) Results of microscopic observation for rock thin sections

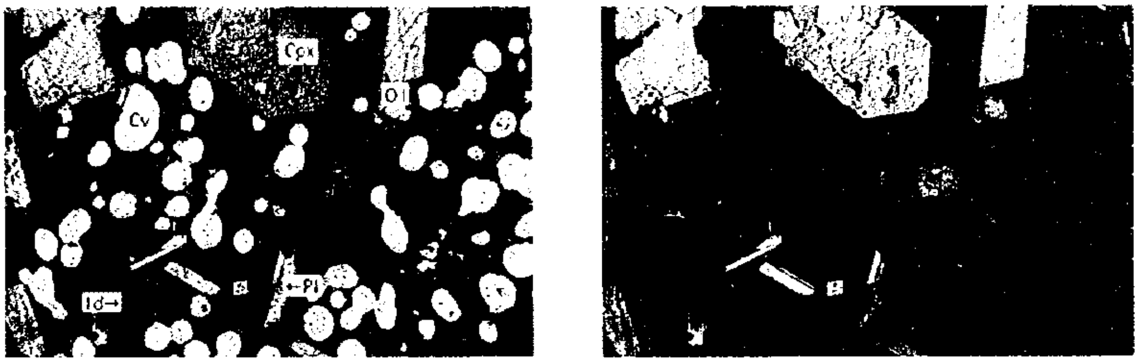
Sampling site No.	code	Rock name	Texture	Phenocryst	Vesicle	Alteration	Phenocryst						Groundmass					Alteration minerals				Remarks
							Plagioclase	Olivine	Orthopyroxene	Clinopyroxene	Opaque mineral	Spinell	Plagioclase	Olivine	Clinopyroxene	Opaque mineral	Glass	Smectite	Iddingsite	Calcite	Zeolite	
97SMC02CB03	T1	Aphyric basalt	Intersertal	R	R	W	•	△					◎		◎	○	△	△				
97SMC02CB03	T2	Augite dolerite	Intergranular	A	N	M	◎			◎	○						△	○				
97SMC03CB07	T1	Plagioclase-porphyritic basalt	Porphyritic	M	A	F	○						◎		◎	△	△	•				
97SMC03CB09	T1	Olivine basalt	Intersertal	M	A	M		○					◎	△	○	○	△	△		○		
97SMC03CB10	T1	Olivine dolerite	Dolerite	A	L	W	◎	○	◎		○							○				
97SMC03CB10	T2	Olivine basalt	Porphyritic	M	L	M	?	?					◎	?	○	○	?	◎		○	○	Olivine is pseudomorph
97SMC04CB07	T1	Olivine basalt	Porphyritic, glassy	M	L	F	△	△					△			○	◎	•				Non-altered glass of chilled facies exists
97SMC04CB08	T1	Olivine basalt	Intersertal, microporphyritic	L	A	M		○					△	?	?		○	◎		○		
97SMC04CB18	T1	Augite olivine basalt	Intersertal, porphyritic	L	A	M		○		△	•		◎	◎	○	○	△	◎				
97SMC04CB18	T2	Aphyric basalt	Intersertal, variolitic	R	M	M	•	•					○			○	○	◎			○	Chilled facies texture is notable
97SMC05CB02	T1	Olivine basalt	Glassy, microporphyritic	M	M	W	◎	○									◎	△	△		△	
97SMC05CB02	T2	Glassy basalt (chilled margin)	Glassy, microporphyritic	M	A	W	◎	△		△							◎	○				Chilled margin glass part
97SMC05CB03	T1	Augite basalt	Intersertal	A	M	F	◎			○			◎		△		△	△		○		
97SMC06CB02	T1	Basalt	Porphyritic	M	M	W	◎	?		?			◎				◎	△			○	
97SMC06CB06	T1	Olivine basalt	Porphyritic	L	A	W		○					○				○	△	△			
97SMC06CB06	T2	Harzburgite	Mylonite	M	N	F		◎	◎			△										Pyroxene and olivine are porphyroclast
97SMC07AD06	T1	Augite basalt	Porphyritic	M	A	F				○			○			△	○	△				
97SMC07AD07	T1	Augite olivine basalt	Porphyritic	L	L	M	△	◎		△			○		○		○	◎				
97SMC07CB14	T1	Augite basalt	Microporphyritic	L	R	M	○			△			◎			○	○	◎	△			
97SMC07CB14	T2	Basalt	Microporphyritic, flow	L	N	M	○			?			◎			○	○	◎				
97SMC07CB15	T1	Olivine augite basalt	Porphyritic, glassy	M	A	W		△		◎			?				◎	△	△			
97SMC08CB03	T1	Augite olivine basalt	Porphyritic	M	N	W	○	△		△			◎	△	△		○					
97SMC08CB07	T1	Altered basalt	Porphyritic?, variolitic	?	L	S		?		?							○	◎				Original texture is unknown
97SMC08CB07	T2	Altered basalt	Glassy ?	?	M	S											?	◎				Original texture is unknown
97SMC08CB07	T3	Spherulitic basalt	Spherulitic	?	A	S											◎	◎			△	Spherulite is secondarily formed ?
97SMC08CB09	T1	Aphyric basalt	Radial ~ spherulitic	R	A	M		△					◎			○	△	○				Olivine is pseudomorph
97SMC08CB12	T1	Augite olivine basalt	Porphyritic	L	L	F	◎	△		△			◎		◎		○	△			△	
97SMC08CB13	T1	Augite olivine basalt	Intersertal	M	N	W		◎		△					◎		△	△			△	
97SMC09CB03	T1	Aphyric basalt	Intersertal	N	A	N							◎	?	?		○					
97SMC09CB06	T1	Augite olivine basalt	Porphyritic, glassy	A	A	F	○	○		○			◎	△	△		◎	•				
97SMC09CB07	T1	Aphyric basalt	Hyaloophitic	R	A	W							△	△	△		◎	△			△	
97SMC09CB08	T1	Augite olivine basalt	Intersertal	A	A	F		◎		◎			△	△	◎		△	△			△	
97SMC10CB02	T1	Augite olivine basalt	Porphyritic	L	N	W		○		○				△	◎	△	○	△		◎	○	
97SMC10CB11	T1	Augite olivine basalt	Porphyritic	M	N	F	○	△		◎			◎		△	△	○	△			△	
97SMC10CB20	T1	Aphyric basalt	Hyaloophitic	R	A	W							◎	△	△		○	△		△	○	

Legend A : Abundant M : Moderate L : A little R : Rare N : None, S : Strong M : Moderate W : weak F : faint N : None
◎ : Abundant ○ : Moderate △ : A little • : Rare ? : Uncertain

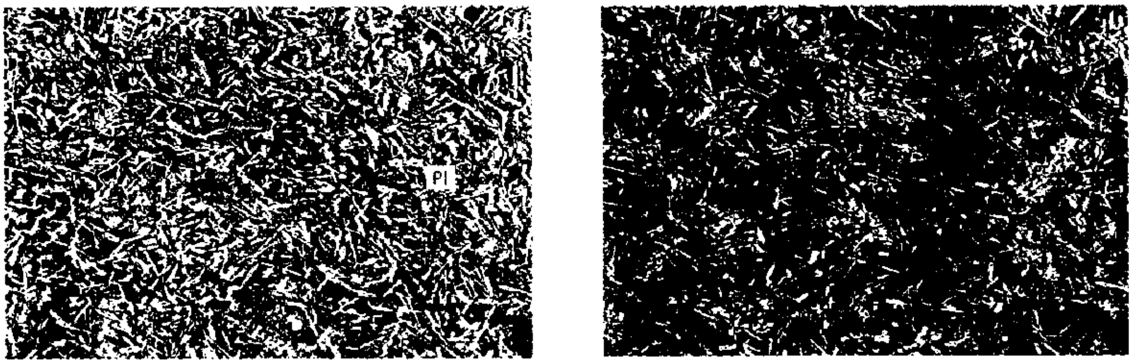
Table 4-3-1 (2) Results of microscopic observation for rock thin sections

Sampling site No.	code	Rock name	Gravel or material composed	Grain size (mm)	Roundness	Sorting	Clastic material														Matrix	Alteration mineral			Remarks
							Rock fragment										Mineral fragment							
									Phenocryst				Groundmass											
							Phenocryst	Vesicle	Plagioclase	Olivine	Clinopyroxene	Spinell	Plagioclase	Clinopyroxene	Opaque mineral	Glass	Plagioclase	Olivine	Clinopyroxene		Smectite	Calcite	Zeolite	
97SMC02CB03	T3	Hyaloclastite	Basalt ?	1~10	B	B	L	L			△		?	·		?			·	Foraminifera is included.	◎	△	◎	Original texture is unknown.
97SMC03AD05	T1	Limestone	Shell, foraminifera	0.2~2	B	B														Recrystallized calcite		◎		Vesicular
97SMC03CB09	T2	Hyaloclastite	Aphyric basalt	2~5	B	M	N	M					◎	△	○	◎				Secondary minerals are filled with.	◎		◎	Fine-grained materials in matrix lack.
97SMC04CB11	T1	Tuffaceous mudstone	Volcanic glass ?													?	·			Fine-grained alteration clay	◎	△		Coarse grains are porous.
97SMC04CB16	T1	Limestone	Foraminifera	0.2~1	B	B														Recrystallized calcite		◎		Calcareous mud is intercalated.
97SMC04CB18	T3	Hyaloclastite	Aphyric basalt	1~5	B	B	N	M								◎				Zeolite is filled with.	◎		◎	Rock fragments have chilled margin.
97SMC04CB18	T4	Hyaloclastite	Olivine basalt	1~4	B	B	L	A	△	△			○			◎				Secondary minerals are filled with.	◎	◎	△	Rock fragments have many vesicles.
97SMC05CB03	T2	Hyaloclastite	Olivine basalt	1~5	B	B	A	L	◎	○	△	△				○				Vesicles are abundant.	◎		△	Groundmass of basalt is wholly altered.
97SMC05CB03	T3	Volcanic sandstone	Volcanic glass ?	<1		G											△		△	Many microfossils are included.	◎		?	Bedded
97SMC05CB04	T1	Limestone	Fossil fragments	0.2~1	B	B														Recrystallized calcite		◎	△	Zeolite occurs in pores.
97SMC05CB05	T1	Conglomerate	Basalt	1~30	B	B	L	L	◎		△					○				Fossils are included.	◎			Matrix is limestone.
97SMC06CB02	T2	Pyroclastic rock	Olivine basalt	1~20	B	B	L	L	△	△	△					◎	△	△	△	Fine-grained altered volcanic glass	◎	△	△	Free phenocrysts are included.
97SMC06CB07	T1	Limestone	Fossil fragments	0.2~2	B	B														Recrystallized calcite		◎	△	Thin bedded
97SMC08CB03	T2	Conglomerate	Olivine basalt	1~10	B	B	M	N	○	○	△		◎		○	◎	△			Secondary minerals replace.	◎		○	Origin of matrix is mud ?
97SMC08CB04	T1	Hyaloclastite	Unknown					L												Completely altered	◎			Original texture is unknown.
97SMC08CB04	T2	Mudstone	Clay minerals	<1																No coarse-grained materials exist.	◎		○	Weakly bedded
97SMC10CB10	T1	Conglomerate	Olivine basalt	1~10	B	B	M	N	○	○	○					◎	△			Volcanic sand to mud	○			

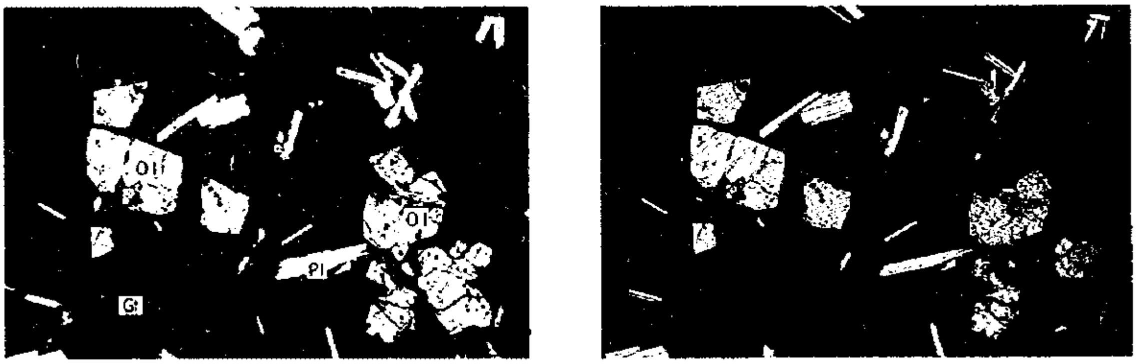
Legend B : Bad M : Moderate G : Good, A : Abundant M : Moderate L : A little N : None
◎ : Abundant, ○ : Moderate, △ : A little, · : Rare, ? : Uncertain



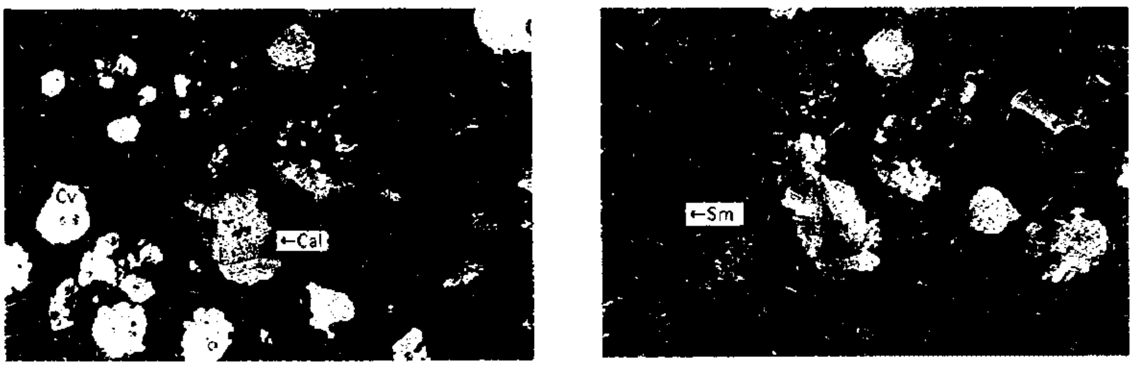
A : 97SMC09CB06-T1   Augite olivine basalt (porphyritic,glassy)



B : 97SMC02CB03-T1   Aphyric basalt (intersertal)



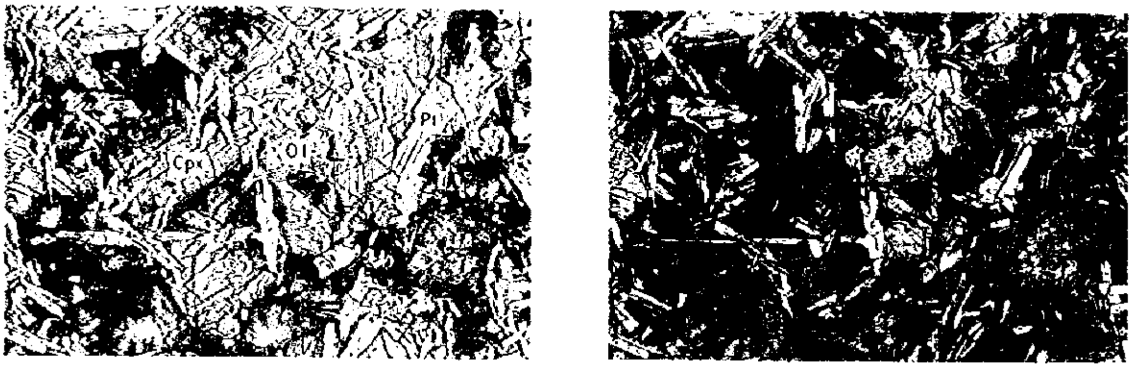
C : 97SMC04CB07-T1   Olivine basalt (porphyritic,glassy)



D : 97SMC06CB02-T1   Basalt (calcite fill the cavities)

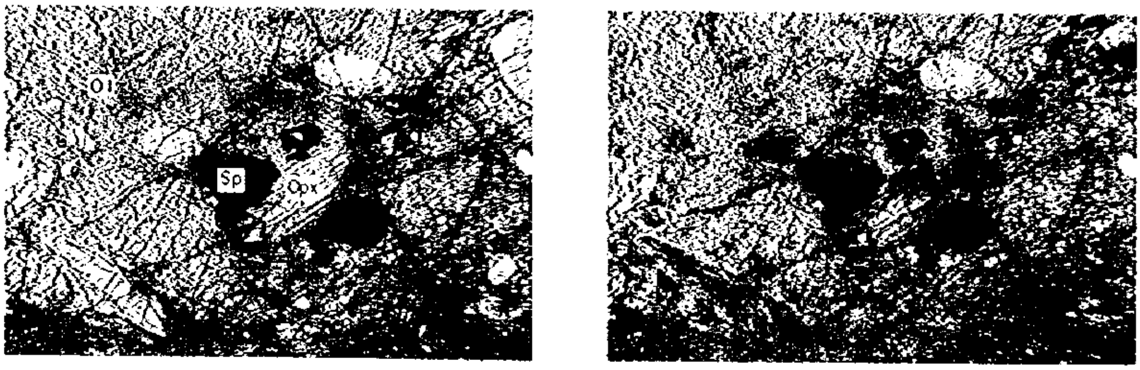
Legend Ol:Olivine, Cpx:Clinopyroxene, Pl:Plagioclase, Sp:Spinel,
Id:Iddingsite, Sm:Smectite, Ze:Zeolite, Cal:Calcite, Gl:Glass, Cv:Cavity

Fig. 4-3-1 (1) Photographs of microscopic observation of rock thin sections



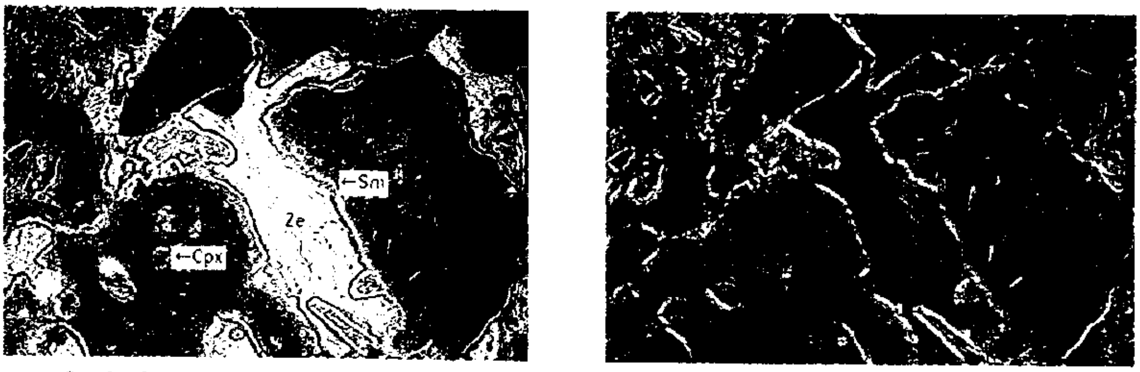
E : 97SMC03CB10-T1 Olivine dolerite

1mm



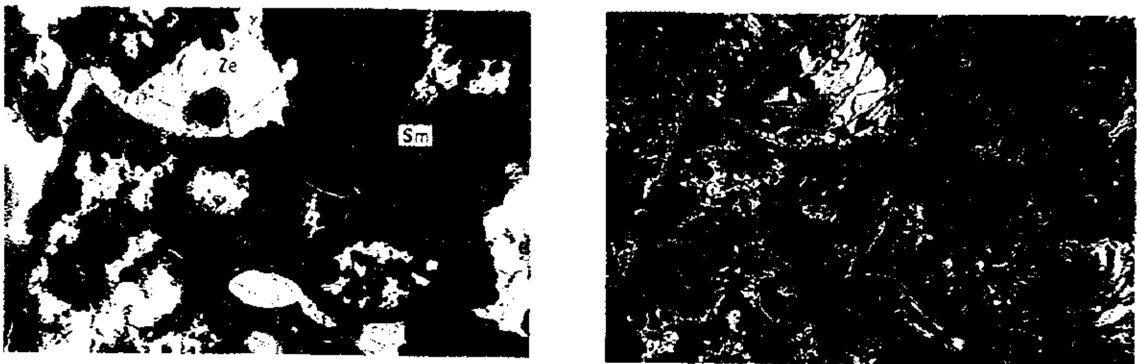
F : 97SMC06CB06-T2 Harzburgite (mylonite)

1mm



G : 97SMC03CB09-T2 Hyaloclastite

1mm



H : 97SMC04CB18-T3 Hyaloclastite (strong alteration)

1mm

Legend Ol:Olivine, Cpx:Clinopyroxene, Pl:Plagioclase, Sp:Spinel,
Id:Iddingsite, Sm:Smectite, Ze:Zeolite, Cal:Calcite, Gl:Glass, Cv:Cavity

Fig. 4-3-1 (2) Photographs of microscopic observation of rock thin sections

1) Basalt

① Vesicular porphyritic basalt (augite–olivine–basalt)

This basalt is most common and has porphyritic and intersertal texture and contain vesicles of 0.1 ~ several millimeter in diameter (Fig. 4–3–1 (1), Photo A). The wall of the vesicles are often covered by thin colloform to amygdaloidal smectite, and are at times filled by zeolites and calcite (Fig. 4–3–1 (1), Photo D).

The phenocrysts are olivine, augite, and plagioclase. The phenocrysts are mostly around 1 mm in size with a maximum of 5 mm. Olivine is prismatic to granular and generally is altered to clay minerals or iddingsite, but there are many fresh grains. Clinopyroxene is prismatic and is relatively fresh. Plagioclase is prismatic to tabular and is unaltered. Olivine and pyroxene phenocrysts do not occur in 97SMC03CB07–T1 and this sample is characterized by 2 ~ 5 mm long prismatic phenocrysts of plagioclase.

The matrix has intersertal texture and comprises minute prismatic to granular microcrystals of altered olivine and clinopyroxene, and tabular to acicular plagioclase under 0.6 mm and glass. The matrix has been devitrified to smectite, but the quenched phase glass of 97SMC04CB07–T1 and 97SMC05CB02–T2 is fresh (Fig. 4–3–1 (1), Photo C).

② Compact porphyritic basalt (clinopyroxene–olivine basalt)

This basalt has porphyritic and intersertal texture with very few vesicles. 97SMC07CB14–T1 and 97SMC10CB11–T1 are examples of this type.

With the exception of the lack of the vesicles, the lithology of this basalt is essentially the same as the basalt ① . 97SMC07CB14–T2 has few mafic minerals and has flow texture.

③ Aphyric basalt

There is very small amount of phenocrysts in this basalt, and is generally vesicular (97SMC09CB03–T1, 97SMC09CB07–T1), but also there is non–vesicular type (97SMC02CB03–T1: Fig. 4–3–1 (1), Photo B)). The occurrence of the alteration minerals in the vesicles is the same as that reported for the vesicular basalts. 97SMC09CB03–T1 is unaltered. 97SMC08CB09–T1 has characteristic reddish brown color.

Phenocrysts are either totally non–existent or minute phenocrysts of olivine and augite occur in very minor amount. The matrix has intersertal to hyalopilitic texture, and consists of platy to acicular plagioclase under 0.6 mm, granular augite under 0.4 mm, minute opaque minerals and glass. Almost all of the mafic phenocrysts and the matrix are replaced by smectite, and the glass is also smectized.

The wall of the vesicles are thinly coated by smectite and clay minerals and zeolite are formed inside.

④ Others (metabasalt)

This basalt is pale brown to yellowish brown and is strongly argillized. The examples are the three samples; 97SMC08CB07–T1, T2, T3. The latter two T2 and T3 are from the same rock body.

In 97SMC08CB07–T1, the phenocrysts have been completely argillized and only traces can be observed. The matrix is also strongly altered and variolitic texture is observed in places. In sample T2, phenocrysts are not observed, and the matrix has been completely replaced by smectite and zeolite. In sample T3, many spherulites of secondary minerals are contained, do not contain phenocrysts, and the matrix is completely replaced by smectite and zeolite. It is inferred that these rocks were susceptible to alteration because of their large content of primary glass.

2) Dolerite

Two samples of dolerite were recovered, namely 97SMC02CB03–T2 and 97SMC03CB10–T1. The former sample has intergranular texture and consists of 0.5～1 mm augite and plagioclase. This rock was altered with pyrite dissemination, but microscopically the alteration is not very strong. The latter sample is almost totally holocrystalline and the phenocrysts are prismatic to granular olivine, prismatic augite, and tabular plagioclase. The diameter of the grains is 1～2 mm (Fig. 4–3–1 (2), Photo E).

3) Hyaloclastite

The constituent pebbles are aphyric basalt and augite–olivine basalt. The textures of the basalts are the same as those reported above and these pebbles are generally strongly altered.

The matrix consists of small basalt fragments and glass, and in rare cases mineral fragments and foraminifera fossils are included. The glass is replaced by smectite and zeolite, and irregularly shaped voids are filled by zeolite and calcite (Fig. 4–3–1 (2), Photo H). Thin layers of colloform to amygdaloidal smectite and zeolite are formed on the outer side of the pebbles and along the inside wall of the voids (Fig. 4–3–1 (2), Photo G).

Sample 97SMC02CB03–T3 consists of sediment filling the pebbles of basalt pillow lava.

4) Harzburgite (Fig. 4–3–1 (2), Photo F)

One harzburgite sample was recovered, 97SMC06CB06–T2. It is mylonitized, and deformed clinopyroxene and granular olivine form porphyloclasts whose surroundings are filled by finely crushed olivine. The direction of the elongation of the crystals and the arrangement of the minerals is the same indicating the direction of the deformation. Small amount of irregularly shaped spinel under 1 mm in size occur in this harzburgite.

5) Conglomerate

Three samples of conglomerate were collected. The constituent pebbles are basalt, and the matrix is mudstone to sandstone or limestone.

The basalt contains olivine, augite, and plagioclase phenocrysts and is altered. In 97SMC08CB03-T2, the matrix is pinkish pale brown and is replaced by smectite and zeolite. In 97SMC05CB03-T1, matrix is milky white and is fossiliferous limestone.

6) Sandstone

One sandstone sample, 97SMC05CB03-T3, was recovered. The clastic material consists of plagioclase crystal fragments of under 0.5 mm and many microfossils, and the sorting is good. The fine-grained matrix is believed to be volcanic glass and is smectized. Many irregular voids occur and the inside walls are covered thinly by zeolite.

7) Mudstone

Two mudstone samples, 97SMC04CB11-T1 and 97SMC08CB04-T1, were collected. Clastic materials are not included and the matrix considered to have been derived from volcanic glass is replaced by smectite, calcite, and zeolite.

8) Limestone

Four limestone samples were collected. They are milky white to white and hard, consisting of fossil fragments such as foraminifera, shells, and corals. They are recrystallized.

(2) X-ray diffraction analysis

X-ray diffraction analysis were carried out for dredged samples with the purpose of mainly identifying alteration products and confirming the degree of alteration. Non-oriented powder, elutriated, and ethylene-glycol treated samples were studied. The number of samples amounted to 30 and all were studied microscopically. The results are shown in Table 4-3-2.

Identified alteration minerals are; montmorillonite, chlorite/montmorillonite mixed-layer mineral, sericite/montmorillonite mixed-layer mineral, chlorite, sericite, phillipsite, analcite, laumontite, calcite, and siderite. Major constituents are; montmorillonite, mixed-layer clay minerals, phillipsite, and calcite. Alteration minerals were not identified in 97SMC07AD07-X1

Table 4-3-2 Results of X-ray diffraction analysis for rocks

Samling site No.	Code	Rock name	Mon	M/C	M/S	Chl	Ser	Phi	Ana	Lau	Pl	Am	Px	Ol	Cal	Sid	Mag
97SMC02CB03	X1	Aphyric basalt	△	·							◎						
97SMC02CB03	X2	Augite dolerite	·		·						◎		·				
97SMC02CB03	X3	Hyaloclastite	△	△					△	○					○	?	
97SMC03CB09	X1	Olivine basalt	·	·							◎		·		◎		
97SMC03CB10	X1	Olivine dolerite	△	△							◎		·				
97SMC03CB10	X2	Olivine basalt	△	△	·					?	◎		·		○	?	
97SMC04CB08	X1	Olivine basalt	△			+					◎		?		○		
97SMC04CB11	X1	Tuffaceous mudstone	△					△				·			△		
97SMC04CB18	X1	Augite olivine basalt	·								◎		△			△	
97SMC04CB18	X2	Aphyric basalt	○								○						
97SMC04CB18	X3	Hyaloclastite	△					△				?					?
97SMC04CB18	X4	Hyaloclastite	·	·	·			△			△	·			◎		
97SMC05CB02	X1	Olivine basalt	·	·	·						◎						?
97SMC05CB03	X1	Glassy basalt (chilled margine)	·								◎	?			○		
97SMC05CB03	X2	Hyaloclastite	·		·			△			○	·					
97SMC06CB02	X1	Basalt	△	·							◎				○		
97SMC06CB02	X2	Pyroclastic rock	·	·				△			◎						
97SMC07AD06	X1	Augite basalt				·	·				○	?	△				
97SMC07AD07	X1	Augite olivine basalt									◎	·	△				
97SMC07CB15	X1	Olivine augite basalt	+			·		△				·	△	△			
97SMC08CB03	X1	Augite olivine basalt	·	·							◎					·	
97SMC08CB04	X1	Hyaloclastite	○														
97SMC08CB07	X1	Altered basalt	·	·	·						◎					·	
97SMC08CB07	X2	Altered basalt	○	·	·			△									
97SMC08CB13	X1	Augite olivine basalt	+	·			○	·			△		◎			?	
97SMC09CB03	X1	Aphyric basalt									◎		·				△
97SMC09CB07	X1	Aphyric basalt	+				△	△			·		△			·	·
97SMC09CB08	X1	Augite olivine basalt			·								△	△			
97SMC10CB02	X1	Augite olivine basalt					·						△		△		
97SMC10CB11	X1	Augite olivine basalt	+						△		◎		◎				

Legend Amount ◎: Abundant ○: Moderate △: A few · : Rare +: Detected only in the スイヒ specimen

Mineral name Mon: Montmorillonite, M/C: Montmorillonite-Chlorite mixed layer mineral, M/S: Montmorillonite-Sericite mixed layer mineral, Chl: Chlorite, Ser: Sericite, Phi: Phillipsite, Ana: Analcime, Lau: Laumontite, Pl: Plagioclase, Am: Amphibole, Px: Pyroxene, Ol: Olivine, Cal: Calcite, Sid: Siderite, Mag: Magnesite

Montmorillonite occurs in almost all samples, and chlorite/montmorillonite mixed-layer mineral was identified in nearly half of the samples studied. Also sericite/montmorillonite mixed-layer mineral, chlorite, and sericite were identified in several samples. These clay minerals occur paragenetically, and argillization occur in all substrates such as basalt and clastic rocks. Microscopy shows that the clay minerals have replaced the mafic minerals and glass matrix of basalts, and occur abundantly in vesicles and matrix of basalt, and in matrix of clastic rocks.

Phillipsite occur in nine samples, mostly in hyaloclastite and also in basalt, and tuff. It occurs with montmorillonite and other clay minerals, but not with other zeolites. Analcite was identified in one greenish gray hyaloclastite and one basalt sample and occurs together with montmorillonite. Laumontite was identified in one hyaloclastite sample with analcite and occurs together with calcite. Microscopy indicates that zeolite minerals occur filling the voids in the clastic rock matrix and basalt vesicles, and also as veinlets.

Calcite was identified in nine samples, and occurs together with clay minerals , but not with siderite. In 97SMC03CB09-X1 where abundant calcite occur, it is the white mineral which fills the vesicles of basalt, while in 97SMC04CB18 it is the white mineral which replaces the matrix of hyaloclastite. Siderite was identified in four basalt samples.

4-4 Chemical Composition of Rocks

Relatively fresh 18 basalt samples and one hyaloclastite sample, a total of 19 dredged samples were analyzed chemically. The analytical results are shown in Table 4-4-1.

(1) Analytical methods

Analytical methods used and elements analyzed are as follows. Before the analysis, samples were washed, dried until constant weight was confirmed, and then prepared.

- ICP emission spectroscopy: SiO_2, TiO_2, Al_2O_3, MnO, MgO, CaO, NA_2O, K_2O, P_2O_5
- ICP mass spectroscopy: Rb, Sr, Ba, Zr, V, Nb, Y, La, Ce, Pr, Nd, Sm, Eu, Gd, Dy, Ho, Er, Tm, Yb, Lu .
- Neutralization titration: FeO
- Combustion and infrared absorption spectroscopy (LECO): CO_2
- Gravimetry: H_2O+ , H_2O- , LOI

Table 4-4-1 Results of chemical analysis for rocks

Sampling site No.	Code	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3 %	FeO %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	P_2O_5 %	CO_2 %	H_2O^+ %	H_2O^- %	LOI %	Total %	FeO* %	Mg# %
97SMC02CB03	CA1	47.11	1.74	14.57	4.68	6.74	0.21	6.96	12.11	2.79	0.13	0.17	0.01	2.40	1.04	2.97	100.17	10.95	0.445
97SMC02CB03	CA2	46.56	1.68	13.12	2.72	8.58	0.20	8.74	9.71	3.03	0.55	0.17	0.04	1.70	2.56	4.32	99.38	11.03	0.441
97SMC03CB09	CA1	44.82	1.39	16.48	7.85	1.29	0.22	8.16	10.20	2.52	1.03	0.52	0.35	3.00	1.37	6.14	100.62	8.36	0.831
97SMC03CB10	CA1	46.26	1.50	15.04	5.17	3.44	0.14	11.48	9.16	2.32	0.77	0.23	0.04	1.82	1.71	5.08	100.58	8.09	0.721
97SMC04CB08	CA1	44.34	1.81	14.88	< 0.01	9.78	0.11	6.85	10.79	3.07	0.60	0.26	0.59	3.88	0.97	7.11	99.13	9.77	0.352
97SMC04CB18	CA1	45.84	0.81	15.78	4.50	5.14	0.14	11.45	10.05	2.12	0.19	0.08	< 0.01	1.36	0.83	3.72	99.81	9.19	0.633
97SMC04CB18	CA2	38.90	0.90	14.40	7.96	1.56	0.12	11.74	0.44	2.51	1.49	0.06	< 0.01	8.90	5.80	19.33	99.41	8.72	0.854
97SMC05CB02	CA1	43.79	3.85	15.23	9.25	3.97	0.21	3.22	8.74	3.51	0.86	1.45	< 0.01	4.29	1.23	6.05	100.13	12.30	0.386
97SMC05CB03	CA1	41.88	2.78	16.39	7.76	3.68	0.15	3.36	12.17	2.84	0.53	0.62	0.41	3.66	0.79	6.73	98.88	10.66	0.415
97SMC07AD06	CA1	40.84	3.64	15.02	5.88	6.98	0.19	5.45	10.35	3.48	1.38	1.07	< 0.01	3.31	1.00	4.96	99.25	12.27	0.377
97SMC07AD07	CA1	46.64	1.74	14.88	4.38	7.35	0.18	7.25	11.10	3.37	0.84	0.57	0.11	0.58	1.11	1.50	99.80	11.29	0.434
97SMC08CB03	CA1	43.68	3.10	17.12	11.33	< 0.1	0.15	1.27	8.52	3.63	1.43	2.90	< 0.01	2.47	1.29	6.89	100.01	10.10	1.113
97SMC08CB07	CA1	47.26	0.81	18.04	9.23	0.44	0.01	1.18	9.90	3.30	2.04	2.69	0.03	2.62	1.08	5.46	100.36	8.75	0.675
97SMC08CB09	CA1	35.56	1.73	13.80	7.50	1.54	0.12	0.98	18.07	3.11	0.94	9.21	0.06	1.39	1.69	6.65	99.20	8.29	0.331
97SMC08CB13	CA1	39.03	3.19	12.24	10.30	6.54	0.15	5.13	9.46	2.60	2.84	1.52	< 0.01	3.79	2.26	9.58	99.57	15.81	0.378
97SMC09CB03	CA1	46.55	4.26	15.08	3.72	5.88	0.16	3.53	11.83	3.87	1.57	2.29	0.04	0.33	0.23	0.94	99.67	9.23	0.318
97SMC09CB08	CA1	41.52	3.35	9.79	4.92	7.72	0.18	14.64	10.52	2.32	1.65	0.61	< 0.01	0.81	1.60	2.05	99.26	12.15	0.595
97SMC10CB02	CA1	36.39	4.94	14.18	7.56	6.41	0.16	5.98	12.97	1.25	0.64	0.90	0.17	4.51	1.70	7.48	98.85	13.21	0.420
97SMC10CB11	CA1	46.01	3.23	15.96	5.39	3.43	0.18	5.55	9.76	3.95	1.91	0.85	0.16	1.10	1.30	3.38	99.59	8.28	0.557

Sampling site No.	Code	Rb ppm	Sr ppm	Ba ppm	Zr ppm	V ppm	Nb ppm	Y ppm	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm
97SMC02CB03	CA1	< 1	199	24	102	372	5	29	6.46	17.30	2.54	12.60	4.01	1.41	4.89	0.93	5.37	1.13	3.24	0.49	3.08	0.44
97SMC02CB03	CA2	4	229	71	92	374	4.2	26	5.43	14.80	2.19	10.90	3.48	1.23	4.34	0.83	4.85	1.02	2.87	0.44	2.75	0.39
97SMC03CB09	CA1	10	274	234	94	238	17	23	14.50	28.10	3.37	14.50	3.56	1.17	3.74	0.68	3.81	0.79	2.27	0.34	2.10	0.30
97SMC03CB10	CA1	14	255	224	96	242	15	20	12.70	25.30	3.07	13.80	3.33	1.16	3.60	0.63	3.68	0.73	2.04	0.32	1.89	0.27
97SMC04CB08	CA1	11	261	105	120	314	11	31	10.70	24.30	3.32	15.10	4.28	1.51	4.80	0.92	5.49	1.09	3.25	0.48	3.04	0.45
97SMC04CB18	CA1	3	110	29	46	249	1.1	23	1.28	4.28	0.75	4.50	1.87	0.76	2.92	0.60	3.93	0.86	2.55	0.43	2.64	0.39
97SMC04CB18	CA2	19	45.3	31	46	148	1.2	19	1.44	4.97	0.80	4.59	1.77	0.72	2.69	0.58	3.97	0.83	2.49	0.42	2.45	0.37
97SMC05CB02	CA1	13	562	226	264	282	29	39	29.80	64.40	8.53	40.00	9.28	3.17	9.25	1.44	8.07	1.40	3.71	0.53	2.95	0.43
97SMC05CB03	CA1	8	543	185	140	292	19	24	21.70	45.00	5.95	27.20	6.41	2.52	6.19	0.98	5.20	0.88	2.42	0.31	1.72	0.25
97SMC07AD06	CA1	24	888	507	285	306	54	39	55.00	110.00	13.38	57.60	11.50	3.77	10.30	1.57	8.24	1.35	3.60	0.46	2.45	0.37
97SMC07AD07	CA1	15	601	355	120	210	25	24	39.00	73.70	8.72	34.10	6.97	2.23	5.82	0.97	5.03	0.87	2.42	0.30	1.75	0.25
97SMC08CB03	CA1	27	749	832	238	181	18	39	28.30	53.50	7.85	38.50	9.52	3.37	9.53	1.41	7.42	1.29	3.36	0.44	2.43	0.36
97SMC08CB07	CA1	35	287	41	48	132	4	14	5.37	8.96	1.38	6.63	2.11	1.27	2.48	0.44	2.49	0.45	1.26	0.17	1.04	0.15
97SMC08CB09	CA1	27	641	172	115	161	18	55	43.40	34.70	8.18	38.00	8.22	3.25	9.44	1.34	7.37	1.39	3.59	0.47	2.50	0.38
97SMC08CB13	CA1	63	733	1432	226	212	83	37	77.60	132.00	15.23	59.50	12.30	4.00	9.70	1.51	7.16	1.15	3.02	0.32	1.71	0.24
97SMC09CB03	CA1	20	940	294	374	313	40	51	51.00	125.00	16.40	72.50	16.90	4.98	14.50	2.25	11.00	1.89	4.75	0.56	3.17	0.42
97SMC09CB08	CA1	22	628	377	222	297	43	22	42.40	86.10	9.68	40.00	7.92	2.47	6.74	0.98	4.97	0.83	2.08	0.26	1.36	0.18
97SMC10CB02	CA1	9	775	390	280	484	46	34	43.40	92.60	11.87	53.30	11.00	3.48	9.58	1.42	7.56	1.25	3.24	0.41	2.16	0.31
97SMC10CB11	CA1	21	1129	1040	352	234	70	37	61.60	125.00	14.80	61.50	11.70	3.65	9.92	1.47	7.84	1.34	3.54	0.46	2.47	0.37

(2) Analytical results

The major contents vary considerably by sample. This is believed to be caused by the diverse texture, alteration, age, geologic structure of the locality of the basalts in this area. Sample 97SMC04CB18-CA2 is the only pyroclastic rock analyzed, and has a chemical tendency different from other basalt samples. The characteristics of the major elements analyzed are as follows.

- SiO_2 : SiO_2 content is generally low at 35.56 ~ 47.26 %. It is particularly low, less than 40 %, in the three samples; 97SMC08CB09-CA1, 97SMC08CB13-CA1, and 97SMC10CB02-CA1. CaO, P_2O_5 , LOI, and total Fe tend to be high in these three samples.

- TiO_2 : TiO_2 content is generally high at 0.81 ~ 4.94 %. It is particularly high, exceeding 2.7 %, in all six samples from the three areas of MC05, MC09, and MC10. It is also very high in three samples of the six from MC07 and MC08 areas. P_2O_5 content is also high in these samples.

- Al_2O_3 : With the exception of one sample, Al_2O_3 content is relatively constant between 13 to 18 %. The exception is SMC09CB08-CA1 and the Al_2O_3 content is the lowest at 9.79 %, MgO is highest at 14.64 %, and SiO_2 content is low at 41.52 %. This is due to the fact that this sample is rich in olivine and augite and the alteration is weak.

- MgO: MgO content of the samples vary significantly from 0.98 ~ 14.64. The MgO content is believed to reflect the amount of mafic minerals (the primary content and the degree of alteration). 97SMC09CB08-CA1 which has the largest MgO content at 16.64 % is rich in olivine and augite phenocrysts, and these minerals have been only weakly altered. On the other hand, 97SMC08CB 07-CA1 is most strongly altered and the mafic minerals exist only as relicts.

- $Na_2O + K_2O$: $Na_2 + K_2O$ content of the samples also vary. But area-wise, the analytical values do not vary within each area, for example the samples from MC02, MC03, and MC04 areas contain 3 ~ 4 %, MC07 area 4 ~ 5 %, and MC08 are 4 % ~ 5.5 %. All samples analyzed are classified into alkaline rock from the $Na_2O + K_2O$ values.

- P_2O_5 : The maximum P_2O_5 value analyzed is 9.21 % and is very large compared to others. The content of other samples is in the range of 0.06 ~ 2.69 % and the variation among the samples is quite significant. The sample with the highest P_2O_5 value is 97SMC08CB09-CA1 and its CaO content is also very high at 18.07 %. Oceanic alkali basalt characteristically high P_2O_5 content (Fig. 4-4-2), it is possible that this sample had vesicles filled with carbonate and phosphate minerals. MgO content is low in the four samples with P_2O_5 content exceeding 2 %.

(3) Classification of basalts

The following diagrams were prepared from the major and minor element contents and the basalts were classified.

1) MFA diagram (Fig. 4-4-1)

Largely, many samples are plotted near the border of calk-alkaline basalt and tholeiite, but the plots are generally scattered. With the exception of MC09 and MC10 areas, samples from each area are plotted in a group. Samples from MC03 are plotted closest to MgO, while those from MC08 closest to $Na_2O + K_2O$. Six samples from MC05 and MC08, and 97SMC10CB02-CA1 are classified in calc-akaline series.

2) $MnO-TiO_2-P_2O_5$ diagram (Fig. 4-4-2)

Two samples from MC02 are grouped in mid-oceanic ridge basalt (MORB), two from 97SMC04CB 18 in island-arc tholeiite (IAT), 97SMC03CB09-CA1 in island-arc calc-alkaline basalt (CAB). With the exception of the above five samples, other 14 are ocean island alkali basalt (OIA).

MC02 are correspond to a part of an oceanic plateau, and MC03 and MC04 areas to a part of an oceanic ridge, and these seamounts are in a different geologic environment from other seamounts surveyed. Thus the five samples from MC02 ~ MC04 are plotted in areas other than OIA.

3) Spider diagram of incompatible elements (Figs. 4-4-3 and 4-4-4)

The basalts of the samples collected during this survey were comparatively studied and also with other basalts by using spider diagram of Sr, K, Rb, Ba, of large ion lithophile elements (LIL) and Nb, P, Zr, Ti, Y of high field strength elements (HFS) normalized by N-MORB (normal MORB). Normalized patterns of all 19 samples are shown in Figure 4-4-3, and those of several characteristic basalts in Figure 4-4-4. N-MORB of Bevins et al., (1984) was used for normalization.

Many samples show chevron pattern with peak at Ba (Fig. 4-4-4), this agrees with those of OIT ~ OIA (Fig. 4-4-4). Samples with other characteristic pattern are the following seven samples of the three series.

- Two samples from MC02 area: Pattern of 97SMC02CB03-CA2 is close to that of back-arc basin basalt (BAB). That of 97SMC02CB03-CA1 has valley at Rb and K and is similar to plume type MORB (P-MORB).

- Two samples from 97SMC04CB18: Patterns of these two samples have peaks at Rb, and HFS is lower and more flat than N-MORB. That of 97SMC04CB18-CA1 has relatively low LIL, but the two samples show patterns similar to low alkali tholeiite (LT).

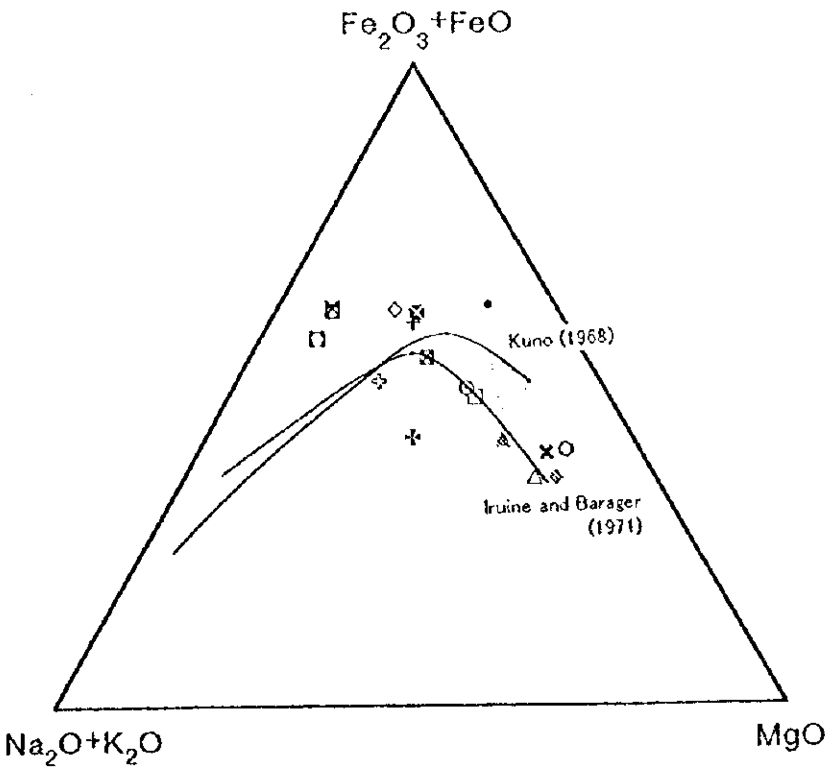


Fig. 4-4-1 MFA diagram

凡例 （4－4章共通）

97SMC02CB03-CA1	97SMC07AD06-CA1
97SMC02CB03-CA2	97SMC07AD07-CA1
97SMC03CB09-CA1	97SMC08CB03-CA1
97SMC03CB10-CA1	97SMC08CB07-CA1
97SMC04CB08-CA1	97SMC08CB09-CA1
97SMC04CB18-CA1	97SMC08CB13-CA1
97SMC04CB18-CA2	97SMC09CB03-CA1
97SMC05CB02-CA1	97SMC09CB08-CA1
97SMC05CB03-CA1	97SMC10CB02-CA1
	97SMC10CB11-CA1

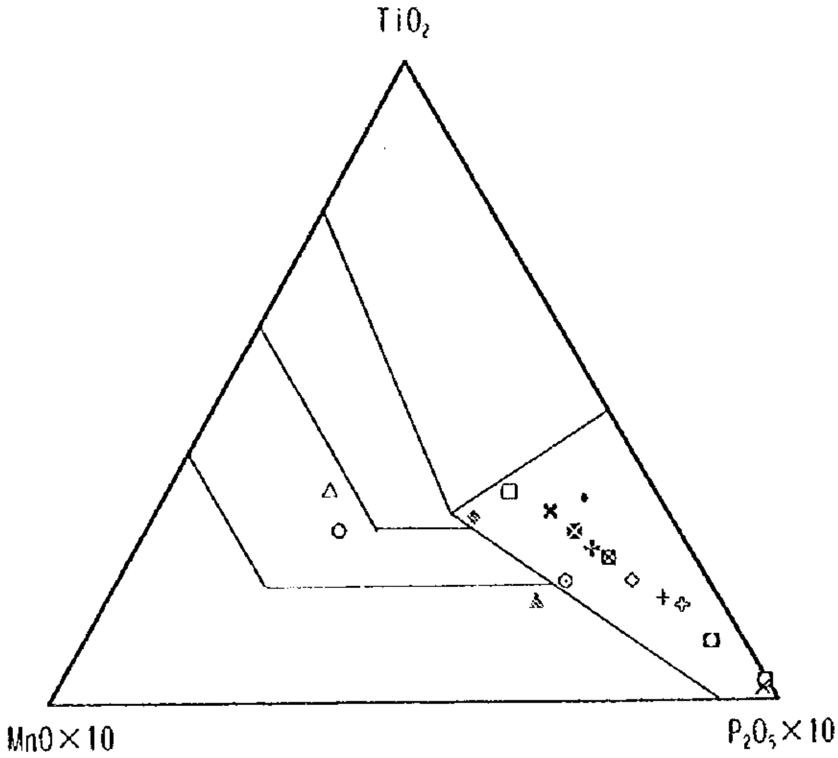
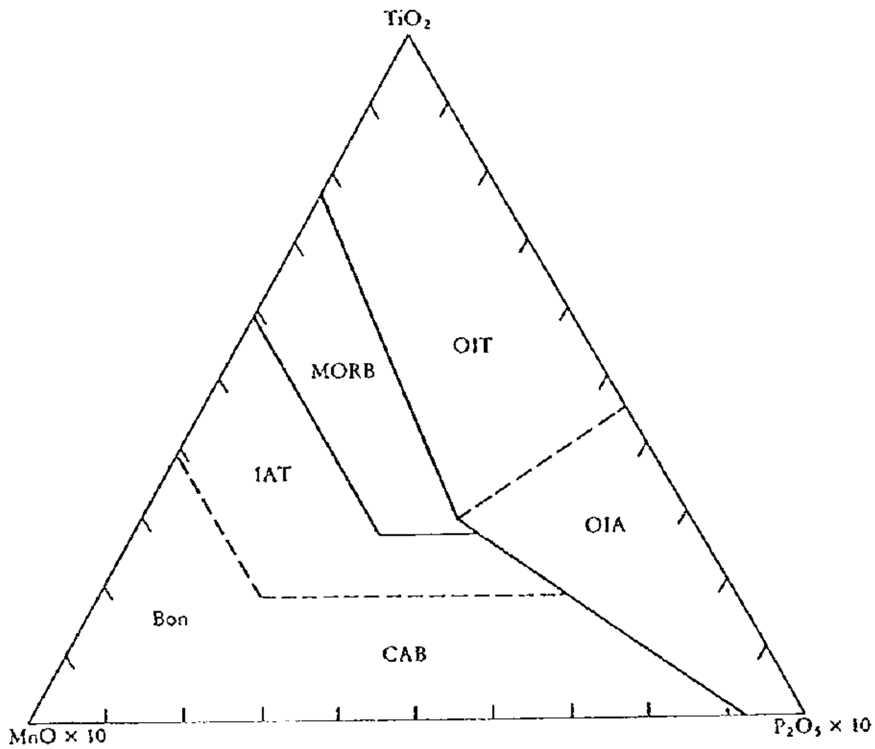


Fig. 4-4-2 Mn-TiO$_2$-P$_2$O$_5$ diagram



The MnO-TiO$_2$-P$_2$O$_5$ discrimination diagram for basalts and basaltic andesites (45–54 wt % SiO$_2$) (after Mullen, 1983). The fields are MORB; OIT — ocean-island tholeiite or seamount tholeiite; OIA — ocean-island alkali basalt or seamount alkali basalt; CAB — island-arc calc-alkaline basalt; IAT — island-arc tholeiite; Bon — boninite. The boninite field occupies the MnO-rich sector of the CAB field.

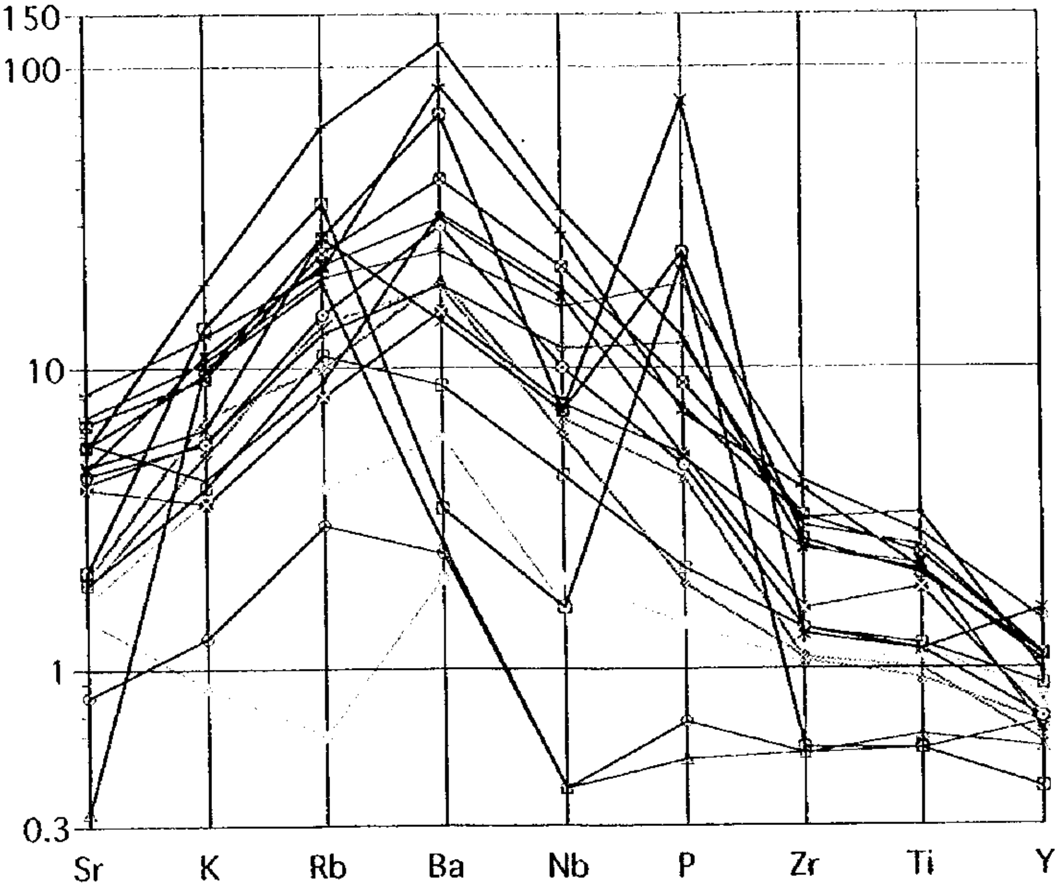


Fig. 4-4-3 Spidergram of incompatible elements

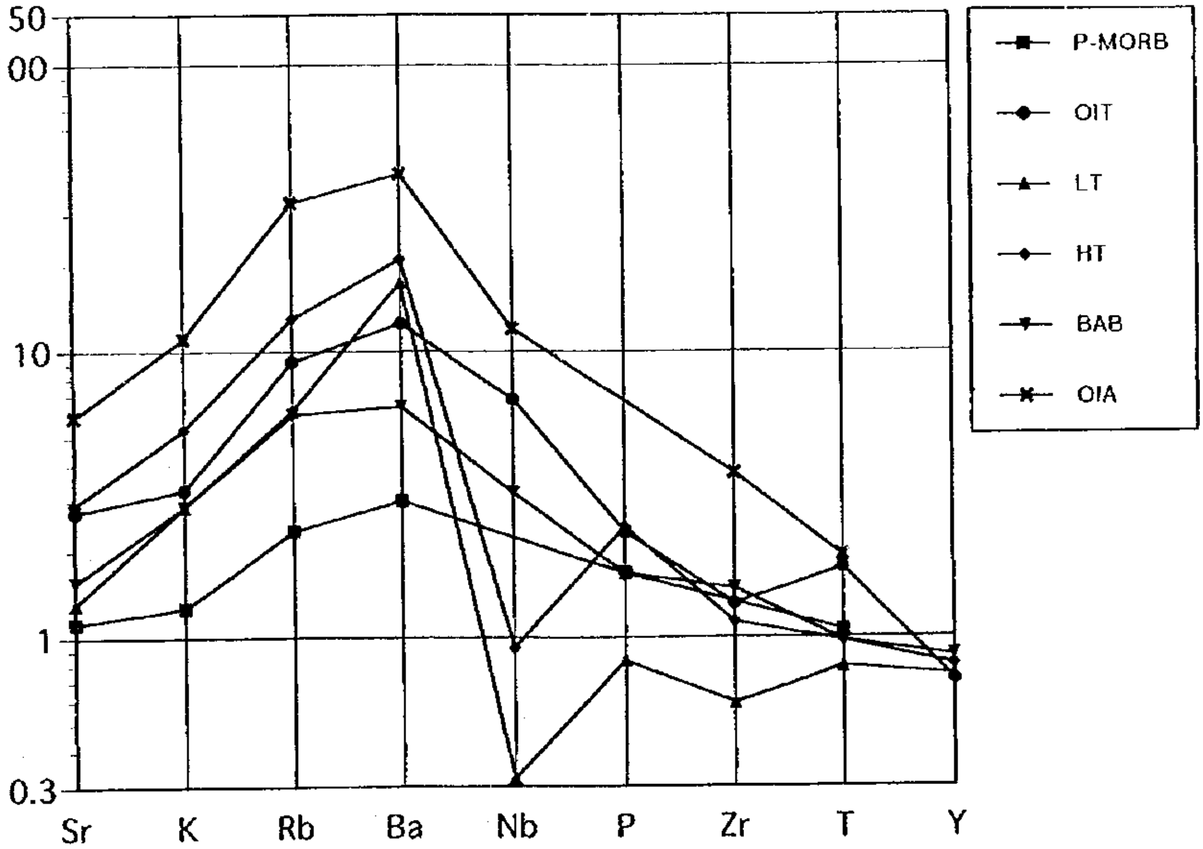


Fig. 4-4-4 Spidergram of incompatible elements (examples of representative basalt)

- Three samples, CB03, CB07, CB09 of MC08 area: The patterns of the three samples are close to that of OIT ~ OIA, but they have characteristically large peak at P. The value of P differs significantly, but the patterns are similar to that of high alkali tholeiite (HT).

Area-wise, the patterns of individual area are relatively similar. The areas relatively poor in incompatible elements are as follows in decreasing order.

MC02<MC04<MC03<MC05<MC07, MC09<MC08, MC10

4) Spider diagram of REE (Fig. 4-4-5)

Chondrite normalized rare earth elements (REE) spider diagram is shown in Figure 4-4-5. The REE values used for the normalization are those of C1 chondrite values of Evensen et al., (1978).

Thirteen samples exceeding La 50 show left-high linear pattern rich in light REE and this is the same as the pattern for OIA. The light REE content varies more than that of the heavy REE and the gradient of the line differs from sample to sample. The gradient is the largest for 97SMC09CB08-CA1 and the smallest are 97SMC03CB09-CA1 and 97SMC03CB10-CA1. The samples with characteristic patterns other than the above are the following six in four series.

- 97SMC04CB08-CA1: Pattern is left-high gentle gradient linear, and is close to those of OIR or BAB.
- Two samples from MC02 area: The pattern of the two samples are more or less flat and is sloe to that of P-MORB.
- 97SMC08CB07-CA1: The REE content is generally low and the pattern is left-high gentle gradient with positive anomaly at Eu. There are no basalt with REE patterns similar to sample. In the triangular and spider diagrams reported in the earlier, this sample is plotted in areas in close proximity to those of three other samples of MC08 area, and it shows a very different characteristics only in the REE spider diagram. The reason for this is not clear, but it is a fact that this sample is much more strongly altered compared to other samples.

5) Summary

The samples are chemically classified by areas as follows.

Oceanic island alkali basalt: MC05, MC07, MC09, MC10 areas
Oceanic island alkali basalt ~ tholeiite: MC08 area
Oceanic island tholeiite ~ oceanic island alkali basalt: MC03 area
Island arc ~ normal mid-oceanic ridge basalt: MC04 area
Plume mid-oceanic ridge basalt: MC02 area

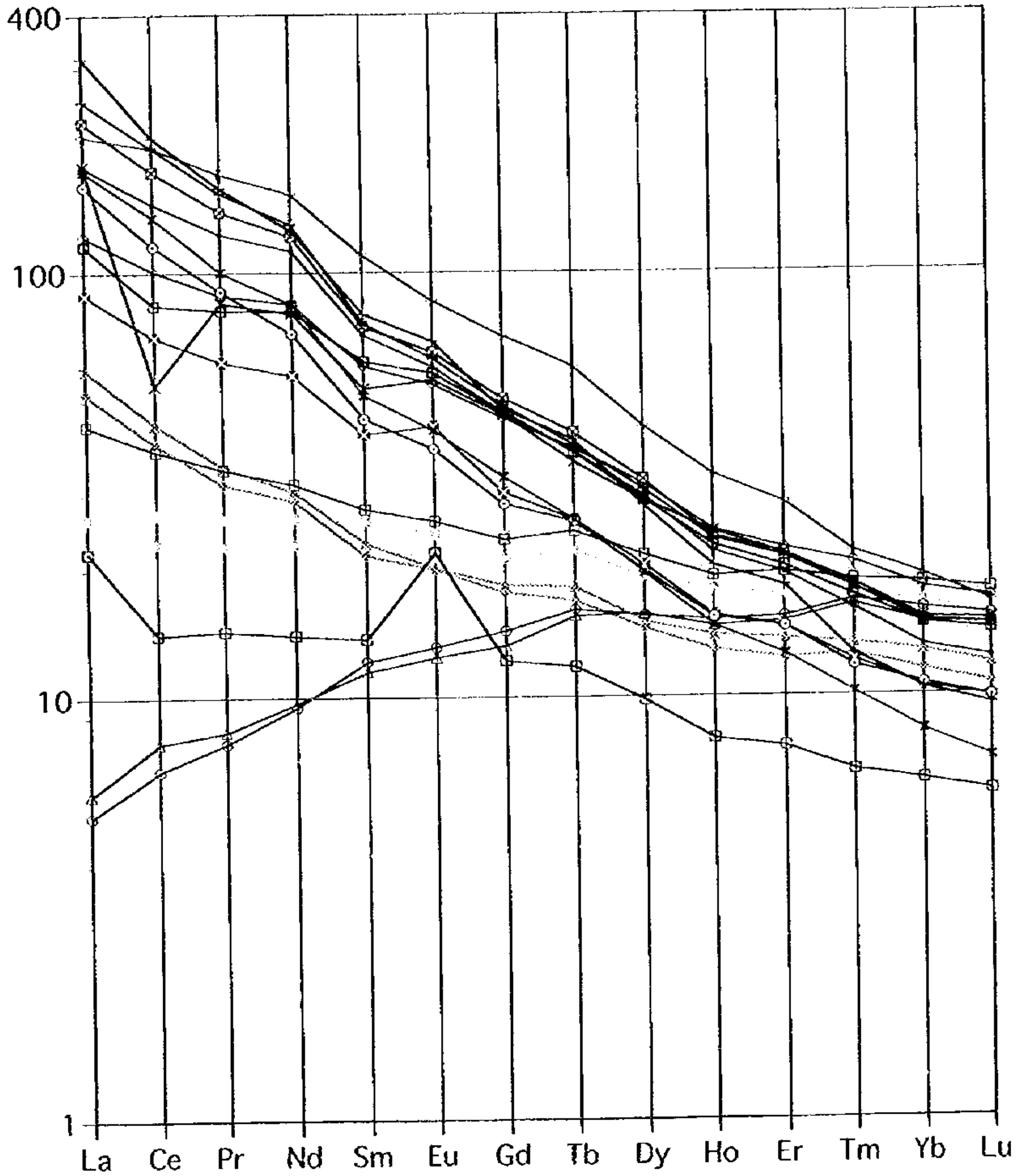


Fig. 4-4-5 Spidergram of REE

It is now clear that the basalt of the three areas MC02, MC03, and MC04 areas have chemical composition different from other areas. These three areas are located in the western part of the whole survey area where the geologic structure is complex, and the shape of the seamounts differ from other general seamounts. The fact that the basalt in the MC02 area have MORB composition in the two spider diagrams is important in considering the geologic structure of the vicinity.

4-5 Age of the Rocks

Age of 13 dredged basalt samples were determined by K-Ar method. All of these 13 samples have been studied by chemical analysis, thin section microscopy, and X-ray diffractometry. The results are shown in Table 4-5-1.

Potassium was quantified by flame spectroscopy and argon isotope ratio by rare gas mass spectroscopy. Steiger and Jagers (1977) radioactive disintegration constant was used.

Regarding the age of the guyots in MC08 and MC10 areas in the northern part of FSM area, figures 69 Ma, 46.5 Ma, 25 Ma, and 24 Ma were obtained. This is harmonious with those of the basalt of the Marshal Islands adjacent to the east (JICA-MMAJ, 1997). On the other hand, measurement of the age of samples from a guyot in the MC07 area in the southeast showed, 6.3 Ma and 0.92 Ma. The last figure is the youngest of the 13 samples measured and is a unique value. Those of the MC02 area show 22 Ma and is conformable with the results reported from nearby seamounts by USGS-KORDA (1992). Similar ages of 10 ~ 14 Ma were obtained for the seamounts in the MC03, C04, MC05, and MC09 areas. One sample each from the MC02 and MC04 areas contained very low amount of potassium and the reliability of the results is somewhat low. The ages of the seamounts are summarized as follows.

The seamounts in the MC08 and MC10 areas in the northern part of the survey area were formed during Cretaceous to Paleogene and the volcanism continued to Oligocene. These are the oldest seamounts in the FSM EEZ, and their age is distinctly different from the seamounts of other areas.

The seamounts in the MC02 area in the northwestern part were formed in early Miocene. Western Caroline Ridge where the MC02 is located is considered to have formed during late Oligocene to early Miocene.

The seamounts in the MC03, MC04, and MC05 in the southwestern part, and the southern seamount in MC09 in the central eastern part were formed din middle Miocene. The northern seamount of MC09 and the pinnacles on the flat summit of the seamount in MC07 in the southeastern part were formed in late Miocene. Although Pleistocene age was obtained from samples on the seamount slope of the MC07 area, it is inferred that the seamount itself was formed also in middle Miocene from age of the summit

Table 4-5-1 Results of dating rocks

Sampling point No.	Code	K %wt	40Ar (radiogenic) nl/g	40Ar (radiogenic) % total	Age Ma	Alteration grade
97SMC02CB03	K1	0.12	0.1026	6	22	weak
		0.11				
97SMC03CB10	K1	0.64	0.3308	13	13 ± 1	weak
		0.63	0.2907	10	12 ± 1	
97SMC04CB08	K1	0.49	0.2128	6	11.1 ± 0.3	moderate
		0.49	0.2258	3	11.8 ± 0.4	
97SMC04CB18	K1	0.17	0.0940	3	14	moderate
		0.16				
97SMC05CB02	K1	0.71	0.3226	12	11.7 ± 0.6	weak
		0.71	0.2724	10	9.8 ± 0.5	
97SMC07AD06	K1	1.20	0.3094	12	6.6 ± 0.4	slight
		1.18	0.2787	18	6.1 ± 0.3	
97SMC07AD07	K1	0.70	0.0230	1.4	0.85 ± 0.07	moderate
		0.69	0.0265	1.1	0.99 ± 0.08	
97SMC08CB03	K1	1.39	2.5568	49	47 ± 1	weak
		1.38	2.4677	50	46 ± 1	
97SMC08CB13	K1	2.61	2.6991	30	26 ± 1	weak
		2.59	2.4738	40	24 ± 1	
97SMC09CB03	K1	1.33	0.5784	18	11.2 ± 0.2	none
		1.32	0.5561	30	10.8 ± 0.2	
97SMC09CB08	K1	1.48	0.3115	21	5.4 ± 0.2	slight
		1.46	0.2881	33	5.1 ± 0.2	
97SMC10CB02	K1	0.57	0.5292	23	24 ± 1	weak
		0.57	0.5342	38	24 ± 1	
97SMC10CB11	K1	1.57	4.3352	71	70 ± 1	slight
		1.56	4.2190	94	68 ± 1	

40K decay constants $\lambda\beta = 0.4962 \times 10^{-9}$/year, $\lambda e = 0.581 \times 10^{-10}$/year

Isotopic abundance 40K/K = 0.01167 atomic%

Note : Because of very low Kalium content in samples 97SMC02CB03 and 97SMC04CB18, the reliability of their age are low.

pinnacles and the age of the fossils which will be mentioned later.

The age of basalt volcanism is largely divided into pre-46 Ma, 26 ~ 22 Ma, 14 ~ 10 Ma, and 7 ~ 4 Ma from the age of the samples from 13 points in the eight areas. The periods of volcanic activities are clearly related to areas. With the exception of the seamounts in the northern part formed before Paleogene, the age of the seamounts and ridges extending in the east-west direction in the FSM EEZ, tend to become younger from northwestern part, southwestern part, through the central part to the eastern part.

4-6 Fossils in Rocks and Seafloor sediments

Foraminifera, nanno fossils, and coral fossils in limestone, sandstone, mudstone, sands and soft mud collected by dredge and corer were determined. The results are shown in Table 4-6-1 and typical photomicrograph of foraminifera is shown in Figure 4-6-1.

(1) Foraminifera

Foraminiferas of 11 dredged limestone samples, 30 unconsolidated samples collected by corer, and 13 other sedimentary rock samples, namely a total of 54 samples were studied for foraminifera. Foraminifera was not found in five limestone samples, three unconsolidated sediment samples, and two mudstone samples. Also in three samples, only benthic foraminifera were identified and no planktonic type was found.

1) Limestone

97SMC02CBD04-F2 and 97SMC03AD05-F3 are correlated to Pleistocene, and 97SMC06CB04-F1 to late Miocene. In other three samples, either foraminifera is scarce or the preservation is poor and the ages could not be determined.

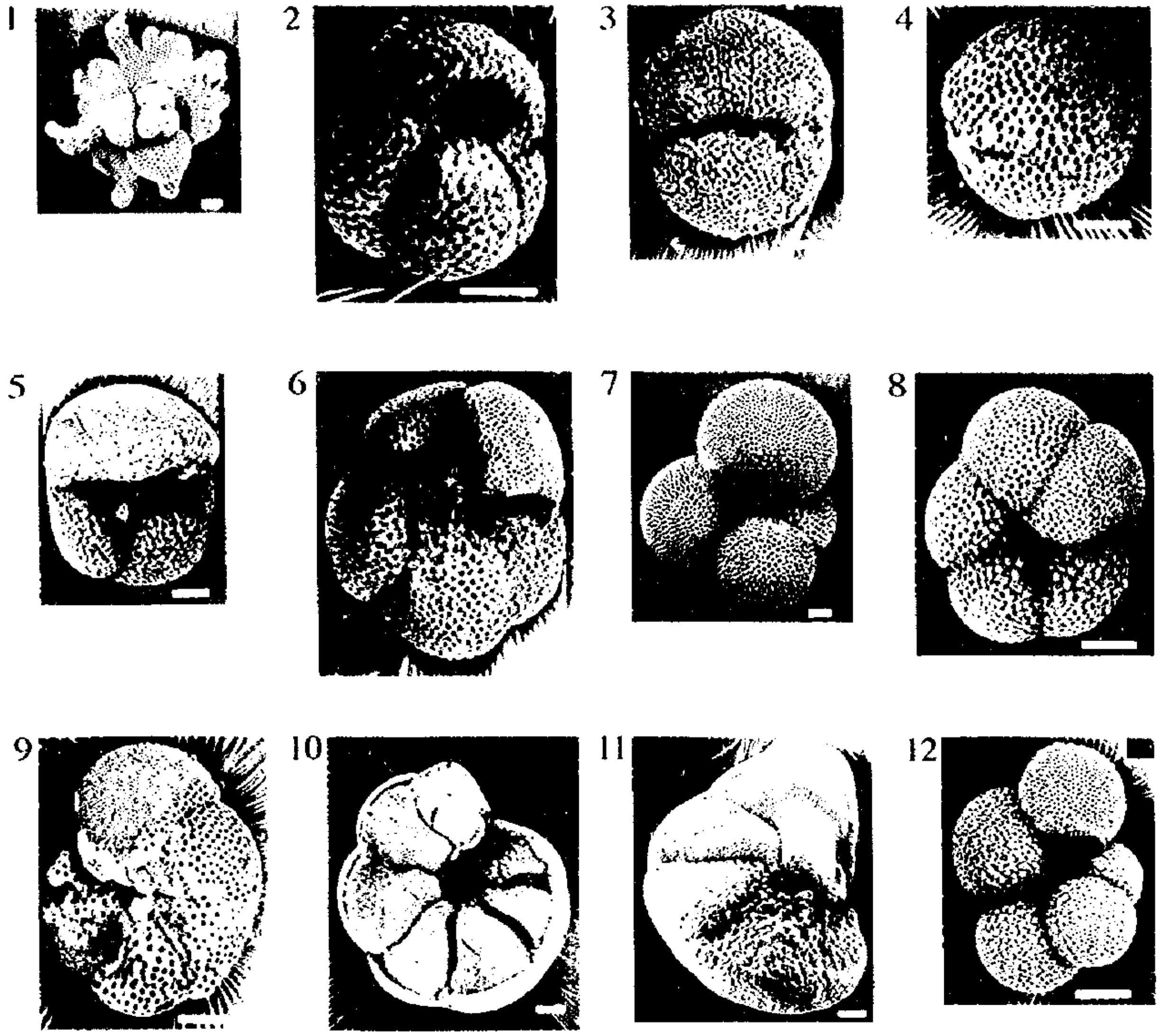
2) Unconsolidated sediments (core column samples)

Large amounts of foraminifera occur in almost all of the 30 core samples studied (soft mud and sand). These fossils are correlated to Pliocene or Pleistocene Epoch and the sampling points and the age correlation are as follows. The number indicate the depth of the core from the seafloor.

97SMC02LC01: Pleistocene, 145 cm (F2) ~ bottom 215 cm (F4)
97SMC03LC01: Late Pliocene, 50 cm (F1) ~ 210 cm (F4)
Early-late Pliocene, bottom 260 cm (F5)
97SMC04LC01: Pleistocene, 55 cm (F1) ~ 155 cm bottom (F3)
97SMC04LC20: Pleistocene, 85 cm (F1), late Pliocene bottom 150 cm (F2)

Table 4-6-1 Results of fossil observation for rocks and seafloor sediments

Sampling site No.	Code	Water depth (m)	Sample	Core depth (cm)	Foraminifera					Coral	Other fossils	Relative age	Absolute age (Ma)
					Planktonic		Benthonic						
					Amount	Condition	Amount	Condition	Solution				
97SMC02LC01	F1	3,256	ooze	85-90	abundant	moderate	a little	moderate	abundant			Recent ?	
	F2		ooze	140-145	abundant	moderate	abundant	moderate	abundant			Pleistocene	< 0.12
	F3		ooze	180-185	abundant	good	abundant	moderate				Pleistocene	< 0.12
	F4		ooze	210-215	abundant	moderate	abundant	moderate	abundant			Pleistocene	< 0.12
97SMC02CB04	F1	1,558	limestone		none		none					–	–
	F2		limestone		a little	moderate	rare	moderate				Pleistocene	0.65~1.6
	F3		limestone		none		none			fragment		–	–
97SMC02LC06	F1	1,482	limestone		a little	bad	rare	bad	distinct			unknown	–
97SMC02LC07	F1	1,412	sand		abundant	moderate	rare	moderate	abundant			Late Miocene	5.7~8.3
97SMC03LC01	F1	3,508	ooze	50-55	abundant	bad	a little	moderate	abundant		radiolaria	Late Pliocene	1.77~2.0
	F2		ooze	115-120	abundant	good	rare	moderate				Late Pliocene	3.09~3.33
	F3		ooze	150-155	abundant	good	rare	moderate				Late Pliocene	< 3.12
	F4		ooze	205-210	abundant	good	none					Late Pliocene	3.25 <
	F5		ooze	255-260	abundant	moderate	rare	moderate	abundant			E~L Pliocene	4.18 <
97SMC03AD05	F1	1,542	sand		moderate	moderate	none					Pleistocene	2.0 <
	F2		limestone							not exist	sponges	Late Triassic ~ Cretaceous	
	F3		limestone		a little	bad	a little	moderate	abundant			Pleistocene	0.65 <
97SMC03CB06	F1	1,177	limestone								sponges	Late Triassic ~ Cretaceous	
	F2		limestone		none		none					–	–
97SMC03CB11	F1	1,832	sand		abundant	good	rare	moderate				Pleistocene	1.6~1.77
97SMC03LC14	F1	2,904	sand		abundant	moderate	none		abundant			Middle Miocene	15.1~16.4
97SMC04LC01	F1	3,876	ooze		abundant	moderate	rare	moderate			radiolaria	Pleistocene	0.22 <
	F2		ooze		abundant	good	none					Pleistocene	0.22 <
	F3		ooze		abundant	good	none					Pleistocene	0.22 <
97SMC04CB04	F1	1,305	limestone		none		none					–	–
97SMC04CB05	F1	1,944	coral							Hexacorallia	shellfish	Cretaceous ~ Recent	
97SMC04CB10	F1	1,454	limestone		a little	bad	rare	moderate				unknown	–
	F2		coral							Hexacorallia		Cretaceous ~ Recent	
97SMC04CB11	F1	1,928	mudstone		none		none				no nannofossil	–	–
97SMC04CB15	F1	485	limestone							Hexacorallia	shellfish	Cretaceous ~ Recent	
97SMC04LC19	F1	1,699	limestone							Hexacorallia		Cretaceous ~ Recent	
97SMC04LC20	F1	2,408	sand	85-90	abundant	good	none					Pleistocene	< 0.22
	F2		sand	145-150	abundant	good	none					Late Pliocene	1.6~3.25
97SMC05LC01	F1	4,060	ooze	73-78	abundant	moderate	none		abundant			Pleistocene	< 0.22
	F2		ooze	152-157	abundant	moderate	a little	moderate	abundant			Pleistocene	0.22 <
	F3		ooze	200-205	abundant	moderate	a little	moderate	abundant			Pleistocene	0.22 <
	F4		sand	233-238	abundant	moderate	rare	moderate	abundant			Pleistocene	0.65 <
	F5		ooze	243-248	moderate	bad	moderate	moderate	distinct		radiolaria	Pleistocene	0.65 <
	F6		ooze	275-280	abundant	good	rare	moderate				Pleistocene	2.0 <
97SMC05CB04	F1	1,417	limestone							Hexacorallia		Jurassic ~ Recent	
	F2		limestone							Hexacorallia		Cretaceous ~ Recent	
97SMC05CB07	F1	1,500	limestone		none		rare	bad	abundant		shellfish	unknown	–
	F2		limestone							not exist	shellfish	unknown	–
97SMC06CB04	F1	1,969	limestone		abundant	good	rare	moderate				Late Miocene	5.7~8.3
97SMC06CB06	F1	1,937	ooze		abundant	good	none					Pleistocene	1.77~2.0
	F2		limestone		none		none					–	–
97SMC06CB08	F1	1,625	limestone		The rock is changed into chert							unknown	–
97SMC07LC01	F1	3,079	sand	45-50	abundant	good	a little	moderate	abundant		sponge spicule	Pleistocene	1.6~2.0
	F2		sand	120-125	abundant	good	none					Pleistocene	1.6~2.0
97SMC07AD05	F1	2,256	sand		abundant	good	none					Late Pliocene ~	3.25 <
97SMC07LC11	F1	2,372	sand	80-85	abundant	good	none					Pleistocene	1.6~2.0
	F2		sand	195-200	abundant	good	none					Pleistocene	1.6~2.0
97SMC08LC01	F1	5,208	sand	6-9	none		none				fish tooth	–	–
	F2		sand	16-20	none		none					–	–
97SMC08CB04	F1	2,177	mudstone		rare	bad	rare	moderate			no nannofossil	unknown	–
97SMC08CB12	F1	2,598	phosphorite		a little	moderate	rare	moderate				Late Pliocene ~	3.25 <
97SMC09LC01	F1	4,758	mud		none		none					–	
97SMC09CB02	F1	2,253	conglomerate		abundant	bad	a little	moderate				Middle Miocene	12.1~12.5
97SMC10LC01	F1	4,366	mud	10-14	a little	bad	moderate	moderate	abundant		radiolaria	Late Pliocene ~	3.25 <
	F2		mud	35-40	rare	bad	rare	moderate				unknown	–
	F3		mud	80-85	rare	good	rare	moderate	abundant		fish tooth	Late Pliocene ~	3.25 <
97SMC10CB04	F1	2,587	sandstone		rare	moderate	rare	moderate				unknown	–
97SMC10CB07	F1	2,262	phosphorite		rare	bad			distinct		shellfish	unknown	–
97SMC10CB12	F1	2,152	mudstone		none		none				no nannofossil	–	–



Scale bars : 100μm

1. *Globigerinoides fistulosus* (Schubert). Spiral view, Sample from MC03LC01-F2.
2. *Globigerinoides obliquus* Bolli. Umbilical view, Sample from MC06CB04-F1.
3. *Pareorbulina sicanus* (de Stefani). Umbilical view, Sample from MC03LC14-F1.
4. *Pareorbulina glomerosa* Blow. Umbilical view, Sample from MC03LC14-F1.
5. *Globorotalia dehiscens* (Chapman, Parr and Collins). Umbilical view, Sample from MC06CB04-F1.
6. *Globorotalia altispira* Cushman and Jarvis. Umbilical view, Sample from MC06CB04-F1.
7. *Globorotalia pseudofoliata* (Parker). Umbilical view, Sample from MC07LC01-F1.
8. *Neogloboquadrina acostaensis* (Blow). Umbilical view, Sample from MC06CB04-F1.
9. *Globorotalia periperoronda* Blow and Banner. Umbilical view, Sample from MC03LC14-F1.
10. *Globorotalia multicamerata* Cushman and Jarvis. Umbilical view, Sample from MC06CB04-F1.
11. *Globorotalia tumida* (Brady). Umbilical view, Sample from MC03LC01-F2.
12. *Bolliella calida* (Parker). Umbilical view, Sample from MC05LC01-F1.

Fig. 4-6-1 Photographs of microfossils

97SMC05LC01: Pleistocene, 73 cm (F1) ~ bottom 280 cm (F6)

97SMC07LC01: Pleistocene, 45 cm (F1) ~ 120 cm (F2)

97SMC07LC11: Pleistocene, 80 cm (F1) ~ bottom 200 cm (F2)

97SMC08LC01: No foraminifera occurrence, 6 cm(F1) ~ bottom 20 cm (F2)

97SMC09LC01: No foraminifera occurrence at bottom 35 cm(F1)

97SMC10LC01: Late Pliocene, 10 cm (F1) ~ bottom 85 cm(F3)

The above nine points excluding 97SMC04LC20 and 97SMC07LC11 are all located from the lower slope to the foot of the seamounts, ranging in water depth from 3,000 m to 5,200 m. The following samples show dissolution of the carbonate surfaces indicating that they were deposited near the calcium carbonate compensation depth (CCD, around 4,000 m water depth); 97SMC02LC01 (3,256 m), 97SMC03LC01 (3,508 m), 97SMC04LC01 (3,876 m), 97SMC05LC01 (4,060 m). Also the surface of carbonates of 97SMC10LC01 show notable dissolution indicating deposition at deeper zones. In samples 97SMC08LC10 (5,208 m) and 97SMC09LC01 (4,758 m), foraminifera fossils do not occur, but they contain many minute grains of manganese oxides indicating that they were deposited below CCD. Thus the results of the fossil studies and the present water depth are harmonious and it is believed that the deposition occurred at depth close to the present seafloor.

In samples 97SMC03LC01 and 97SMC10LC01, Pleistocene sediments are very thin and Pliocene sediments occur from the very shallow parts of the cores. On the other hand, Pleistocene sediments constitute the core to the 125 ~ 280 cm bottom and Pliocene sediments are distributed below these depths in samples 97SMC02LC01, 97SMC04LC01, 97SMC05LC01, and 97SMC07LC01. It is believed that Pleistocene sediments are very thin in 97SMC10LC01 because it is presently located below the CCD. It is, however, inferred that the location was shallower than CCD during Pliocene or that CCD was deeper at that time.

3) Sandstone, mudstone

Two weakly consolidated foraminifera sand samples collected by corer (97SMC02LC07−F1, 97SMC 03LC14−F1) are correlated to late Miocene and middle Miocene respectively. On the other hand, three samples of similar lithology which were dredged (97SMC03AD05−F1, 97SMC03CB11−F1, 97SMC07CB05−F1) are all correlated to Pleistocene. This is believed to be the result of dredging relatively shallow surface (younger) sediments, while corer recovered deeper (older) sediments.

As 97SMC02LC07 is located at the periphery of flat summit, the summits of the seamounts in the MC02 area were submerged to the seafloor during late Miocene.

The fossil community of Pleistocene show the characteristics of tropic community and is considered to have deposited at latitude similar to the present (tropical geographic zone). Also the Miocene fossil community is basically similar to that of Pleistocene and was probably deposited in similar tropic to subtropic zone. Therefore, the locality of the survey area probably has not changed latitudinally since Miocene.

(2) Nanno fossils

Three dredged mudstone samples were studied for nanno fossils. All three samples do not contain nanno fossils and since foraminifera is also lacking, it is not possible to determine the age of these samples.

(3) Coral fossils, others

Eleven dredged limestone samples were studied for coral fossils.

Colonies and solitary hexacollaria fossils were identified in six samples from MC04 and MC05 areas, and these are all show reef environment of deposition. It was not possible to determine the species of these corals and thus only a broad range of age from Cretaceous to Recent or Jurassic to Recent could be determined.

Late Triassic to Late Cretaceous porifera was identified in 97SMC03AD05-F1 and 97SMC03AD06-F1. Both show depositional environment constituting reef bodies and the latter is biolithite.

97SMC02CB04-F3 is fine-grained bedded limestone, and it is believed to have deposited on quiet and flat seafloor. 97SMC05CB07-F2 is a sparse biomicrite and indicate deposition in atoll lake. 97SMC06CB08-F1 has been altered to chert, and the details are not clear.