REPORT
ON
THE COOPERATIVE STUDY PROJECT
ON THE DEEPSEA MINERAL RESOURCES
IN SELECTED OFFSHORE AREAS OF THE SOPAC REGION

(VOLUME 4-2)

SEA AREA OF
THE FEDERATED STATES OF MICRONESIA

March 1999

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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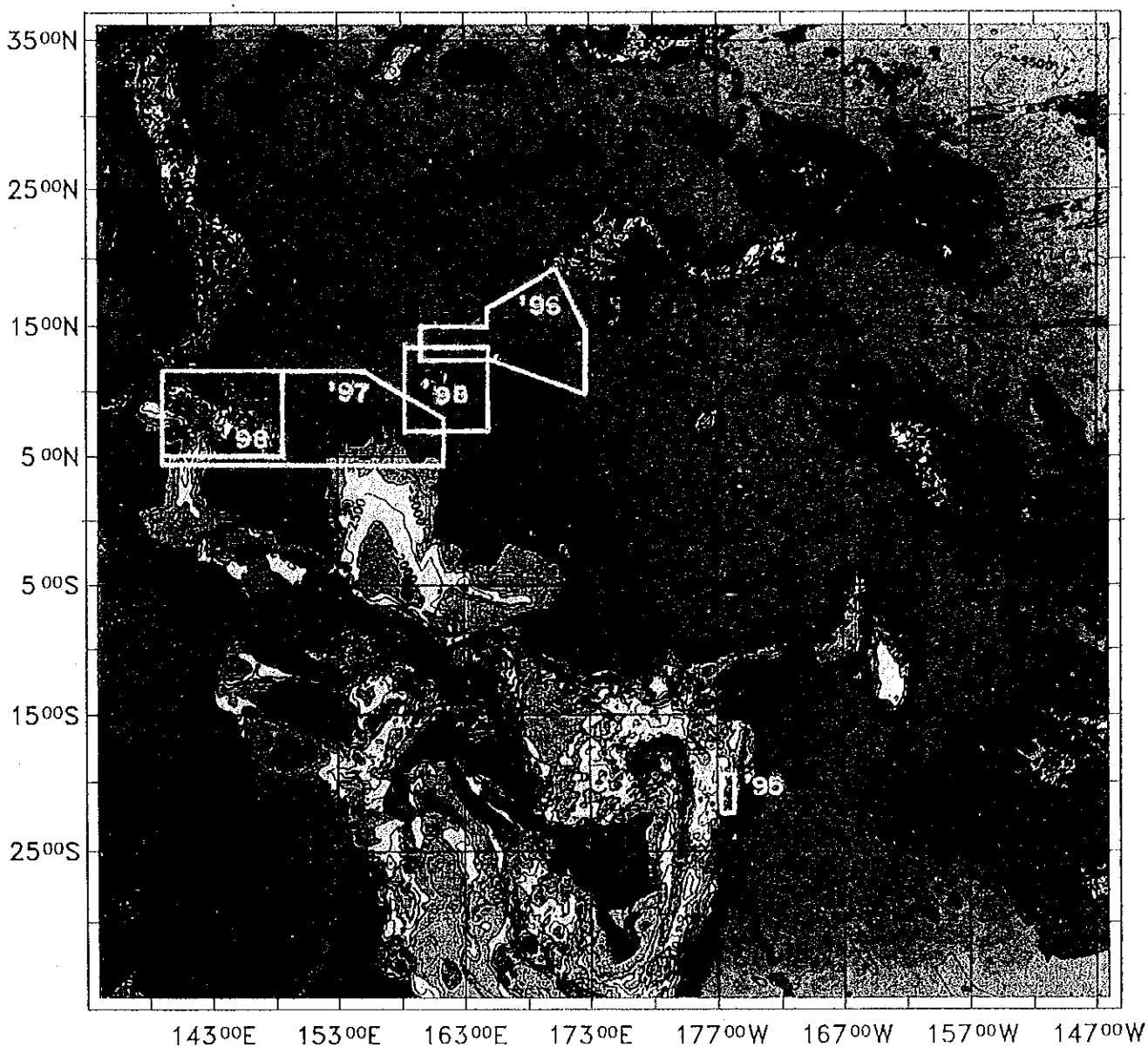
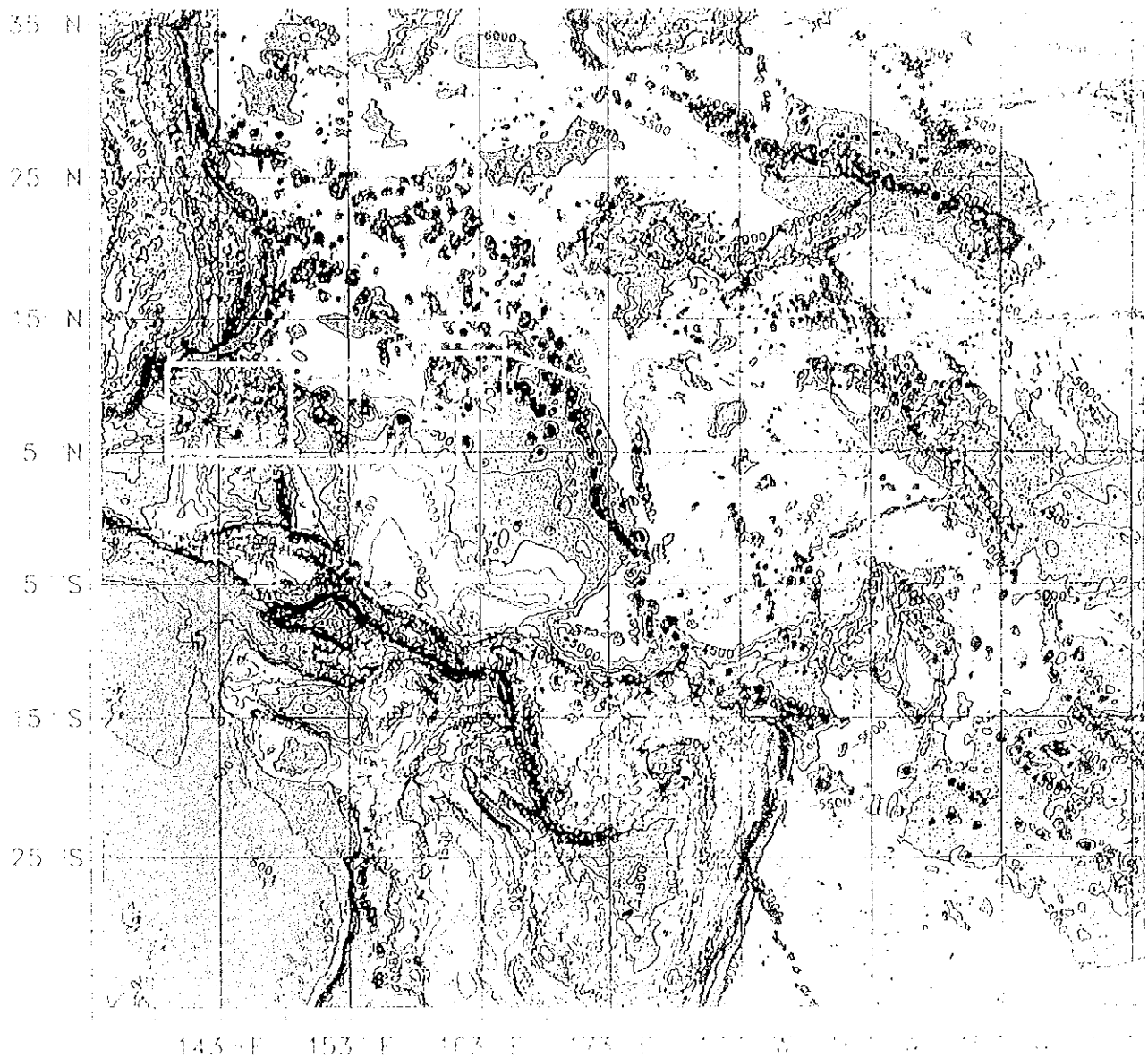


LOCATION MAP OF THE SURVEY AREA



LOCATION MAP OF THE SURVEY AREA

PREFACE

In response to a request by the South Pacific Applied Geoscience Commission (SOPAC), the Government of Japan has undertaken marine geological and other studies relating to mineral prospecting to assess the mineral resources potential of the deep sea bottom in the offshore regions of SOPAC member countries. Implementation of the survey has been consigned to the Japan International Cooperation Agency (JICA). Considering the technical nature of geological and mineral prospecting studies, JICA commissioned the Metal Mining Agency of Japan (MMAJ) to execute the survey.

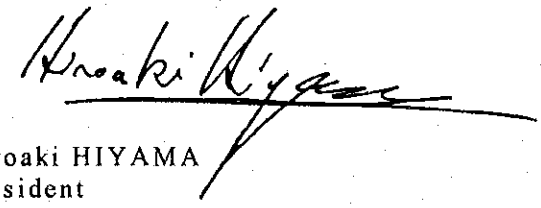
The survey is planned to be undertaken over a period of five years starting from Fiscal 1995. This is the fourth year of the project, and the target area is the exclusive economic zones of the Republic of the Marshall Islands and the Federated States of Micronesia. MMAJ dispatched the Hakurei Maru No.2, a research vessel fitted for investigating deep sea mineral resources, to the survey area from May 5, 1998 to July 17, 1998, successfully completing the survey as planned with the cooperation of both government. The survey in the Exclusive Economic Zone of the Federated States of Micronesia was carried out during the periods from May 28th, to May 30th, and from June 14th to July 2nd.

The present report sums up the results of this fourth year survey in the Exclusive Economic Zone of the Federated States of Micronesia.

It is a pleasure to record our deep gratitude to all persons concerned, particularly to the staff of the SOPAC Secretariat, Government of the Republic of the Marshall Islands, as well as the Japanese Ministry of Foreign Affairs, the Ministry of International Trade and Industry and the Japanese Embassy in the Federated States of Micronesia.

March, 1999

Kimio FUJITA
President
Japan International Cooperation Agency



Hiroaki HIYAMA
President
Metal Mining Agency of Japan

Abstract

The third phase of the cooperative survey for the development of resources of the SOPAC member countries is being scheduled for implementation during a period of five years starting from 1995, and this is the fourth year. The survey for this year was carried out from May 5 to July 17, 1998 in an area of 1,265,000km^2 in the exclusive economic zones of the Republic of the Marshall Islands and the Federated States of Micronesia. The duration of the survey was 49 days and the target mineral resources were cobalt-rich manganese crust deposits.

The occurrence of cobalt-rich crusts in the exclusive economic zone of the Republic of Marshall Islands was surveyed in Fiscal 1996, and those in the exclusive economic zone of the Federated States of Micronesia in Fiscal 1997. This year, based on the results obtained by the earlier surveys, similar work was carried out in the unexplored parts of the EEZ of the two countries with the purpose of acquiring further information and data on these resources. Also investigation on hydrothermal activities was carried out in the area where the possibility of such activity was indicated during the 1997 survey.

The survey area consisted of two marine areas, namely the eastern sea area centered around the oceanic plateau with Anewetak Atoll and Ujelang Atoll of the Republic of Marshall Islands, and the western sea area in the vicinity of the Caroline Islands of Yap Province of the Federated States of Micronesia. The seamounts for the survey were selected referring to "Measured and Estimation from gravity data derived from satellite altimetry and ship board depth soundings: W.H.F.Smith and D.T.Sandwell (1997)" considering; the water depth of the summit (targeting 1,000~2,000m water depth where crusts are considered to be well developed), morphology, and size, and other relevant factors as necessary. A total of seven seamounts were selected; namely for Leg 1 in the first half of the cruise, five seamounts in the eastern sea mainly in the EEZ of the Marshall Islands, and for Leg 2 in the latter half, two seamounts in the western sea of the Micronesia EEZ were planned to be surveyed.

As for hydrothermal activities, a larger part of the MC02 area in the Caroline Ridge in the western sea of Micronesia was surveyed in detail.

This paper reports the results of the cobalt-rich crust exploration carried out this year in the EEZ of the Federated States of Micronesia.

The survey cruise for cobalt-rich crust investigation consisted mainly of; MBES survey (topographic cruise) for clarifying the detailed topography of each area, seafloor observation by FDC and photography for

confirming the continuity of the ore deposits, and sampling by chain bag dredge (CB), arm dredge (AD), and large corer (LC) for understanding the mode of occurrence of the crusts such as type, thickness, and grade. Parts of the collected samples were assayed, rocks studied by thin section microscopy, and fossils were identified on land. These results, together with the results of the onboard work, were used for integrated analysis and interpretation of the cobalt-rich crust occurrences in the survey area. Also parallel with MBES, SBP survey was carried out in order to clarify the distribution of unconsolidated sediments, and SSS survey was conducted in some seamounts for the study of microtopography of the seafloor and nodule and pebble distribution.

Topographic survey was carried out in five areas, confirming four seamounts in four areas by clarifying the detailed seafloor topography, and expanded the survey in one area surveyd in 1997. The survey revealed that the seamounts in the two areas of the eastern sea were both guyots, while the seamounts in the two areas of the western sea were an ocean ridge type and an oceanic plateau type.

The acoustic pressure maps prepared on the basis of MBES acoustic reflection intensity were very effective in understanding the lateral areal extent of exposed bedrock. These maps clarified the conditions of bedrocks exposures at protrusions such as pinnacles, summit peripheries, and steep slopes. Also the SSS survey, by applying more detailed acoustic pressure distribution, clarified the microtopography and the distribution of rock exposures, cobbly material and other relevant matters.

From seafloor observation by FDC, the mode of occurrence of cobalt-rich crusts of each seamount was confirmed. Particularly, the continuity of distribution, type, and shape of crusts, and the distribution of unconsolidated sediments and talus, and their relation to microtopography were clarified. The FDC observation clarified that cobalt-rich crusts are attached to the exposed rocks on the pinnacles, from the summit peripheries to the upper slopes of the seamounts.

Sampling was carried out at, 6~15 sites for each area, a total of 49 sites in four areas. Rocks with crusts attached, surface crusts, and bottom sediments such as foraminiferal sands were collected. The collected cobalt-rich crusts samples were described as to their weight, type, and thickness. These were assayed, fossils in limestones and foraminiferal sands identified, basalts were chemically analyzed and age determined on land.

The occurrence of the cobalt-rich crusts in the survey area, as understood by the above work together with the results of the 1997 survey, are summarized as follows.

Guyots including oceanic plateau-type, occur centered in the northern part of the sea area, and are harmonious with the SBP transparent layer distribution and the low reflectivity parts of the MBES acoustic

pressure distribution map. On the other hand, seamounts with oceanic ridge shape, pointed summit, and rugged summit occur in the southwestern・eastern parts and are harmonious with the SBP opaque layers and high reflectivity parts of the acoustic pressure distribution.

Sampling results and seafloor observation revealed that crusts with thickness exceeding 10cm occur at water depth of 1,000~3,500m. Cobalt-rich crusts occur as crusts, cobbles, and nodules, and their thickness varies mainly with area, topography, and substrate.

Thus the mode of occurrence of cobalt-rich crusts vary widely by area in the present survey area. In the north, guyots of; MC02, MC08, MC10, MC11, MC13 areas and oceanic ridge-type and rugged seamount in MC12 and MS13 areas have crusts with average thickness exceeding 20mm, and those over 100mm have been collected from four seamounts. On the other hand in southern parts, the crust exposure is good, but the average thickness is very thin at one to several millimeters.

The relation between the crust occurrence and topography・geology is summarized as follows.

- Crusts are developed and thick on seamounts older than Paleogene (MC08, MC10, MC11, MC12, MC13, MS13
  areas), while the crusts are thin in younger seamounts (MC04, MC05, MC06, MC07, MC09 areas).
- The crust thickness of the seamounts younger than Paleogene is affected more by topography and geology than by age.
- Crusts are very thin on seamounts with pointed summit and in very shallow water depth (MC04, MC05 areas).

There are differences in average metal grade by area. Crusts in MC02, MC08, and MC10 areas, Cu content is higher and Co and Mn contents are lower than crusts in other areas. Average cobalt content is high at 0.5~0.61% in the area adjacent to the EEZ of Marshall Islands, but it decreases to 0.35~0.41% in the northern part to the west, and in the southern part it is 0.38~0.48%.

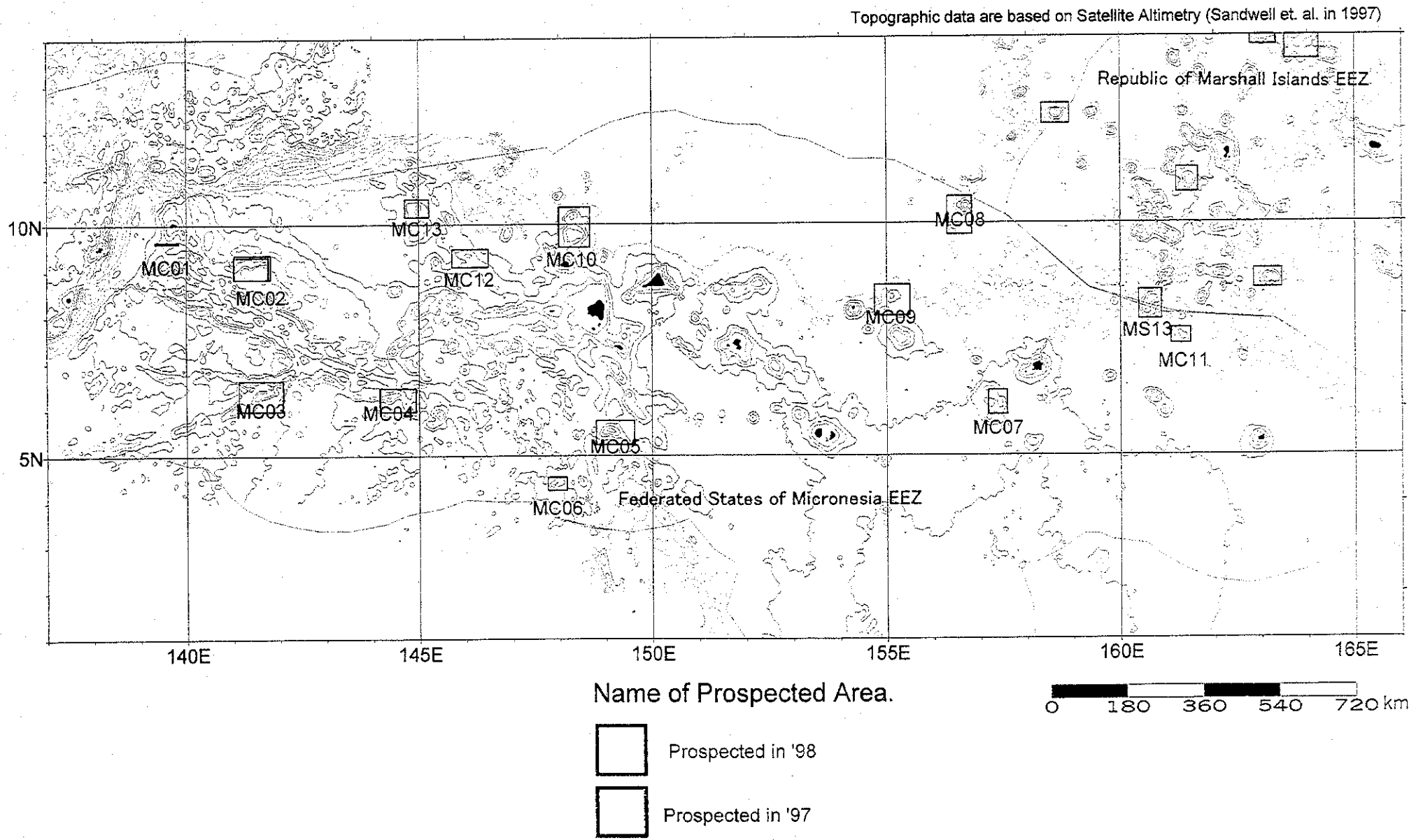
Assessing the areas on the basis of crust occurrences, the most promising part of this year's survey area is that adjacent to the EEZ of the Marshall Islands, namely MC11 and MS13 areas. This part is followed by MC12 and MC13 areas to the north of the Caroline Ridge. As a whole, the old seamounts in the northern

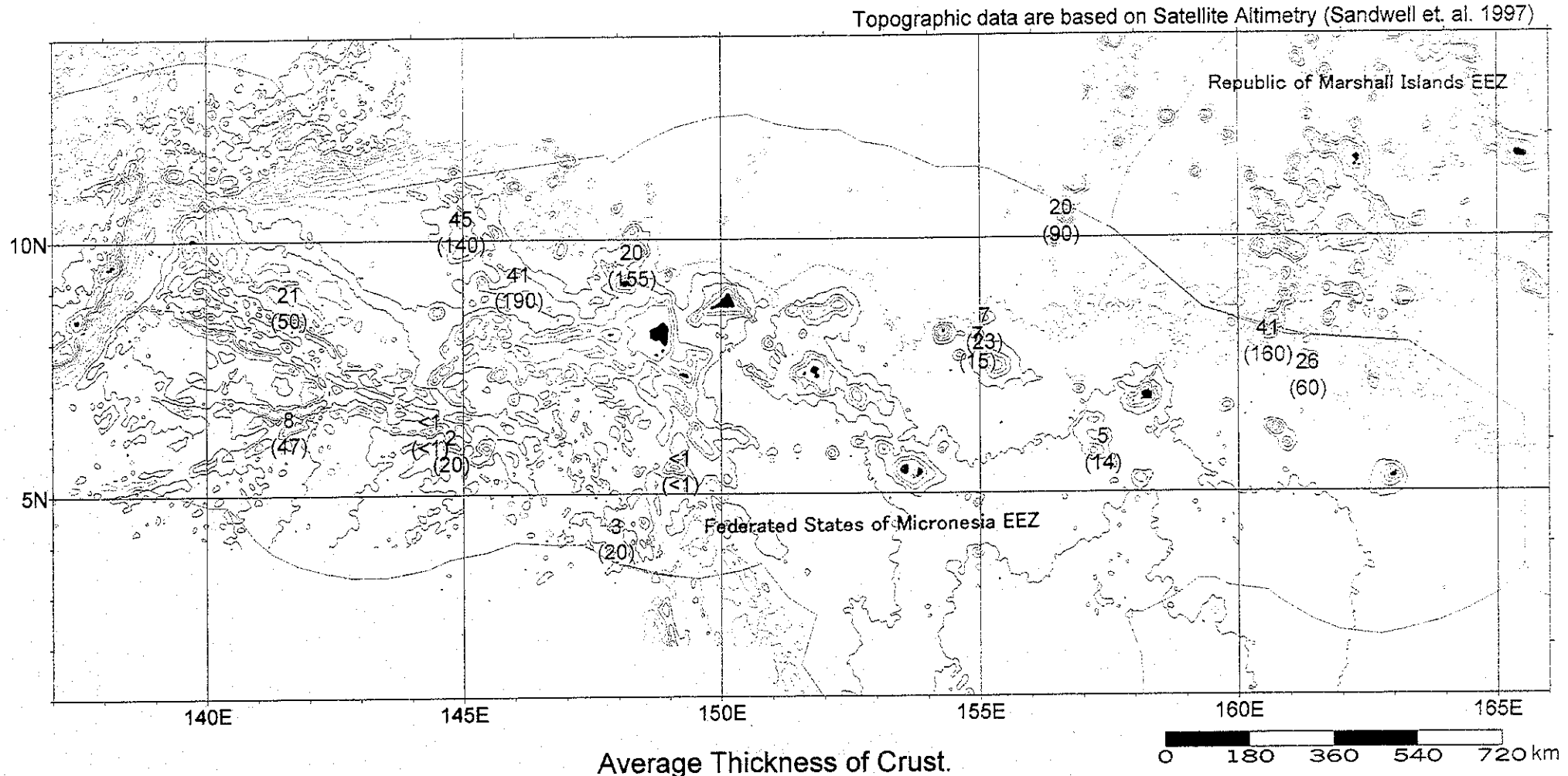
side of the survey area are promising. But although these seamount have high potential for thick cobalt-rich crust occurrence, the effect of volcanism and tectonic movement after the formation of the seamounts on the cobalt-rich crusts are observed. The most promising MC11 and MS13 areas also have negative factors such

as great water depth and large amount of unconsolidated sediments. Thus more detailed investigation is necessary.

The existence of hydrothermal activity was indicated in the MC02 area during the 1997 survey cruise. Survey was carried out in the area during the present survey in order to ascertain the activities. It was shown as a result that, aside from the foot of the steep northern slope of the seamount where pyrite disseminated rock samples were collected in 1997, there are indications of hydrothermal activities in the small depression on the northern side of the seamount, but it is covered by sediments and mineral showings could not be found.

Important and relevant data and information regarding the cobalt-rich crust occurrences and the possibility of hydrothermal activity in the EEZ of Micronesia were acquired by the present survey. The data acquired, however, are not sufficient and the present knowledge regarding the tectonic development and ore deposits of this area is very limited. Further acquisition of data on geology and geologic structure of this area is desirable for understanding the details of the above problems.

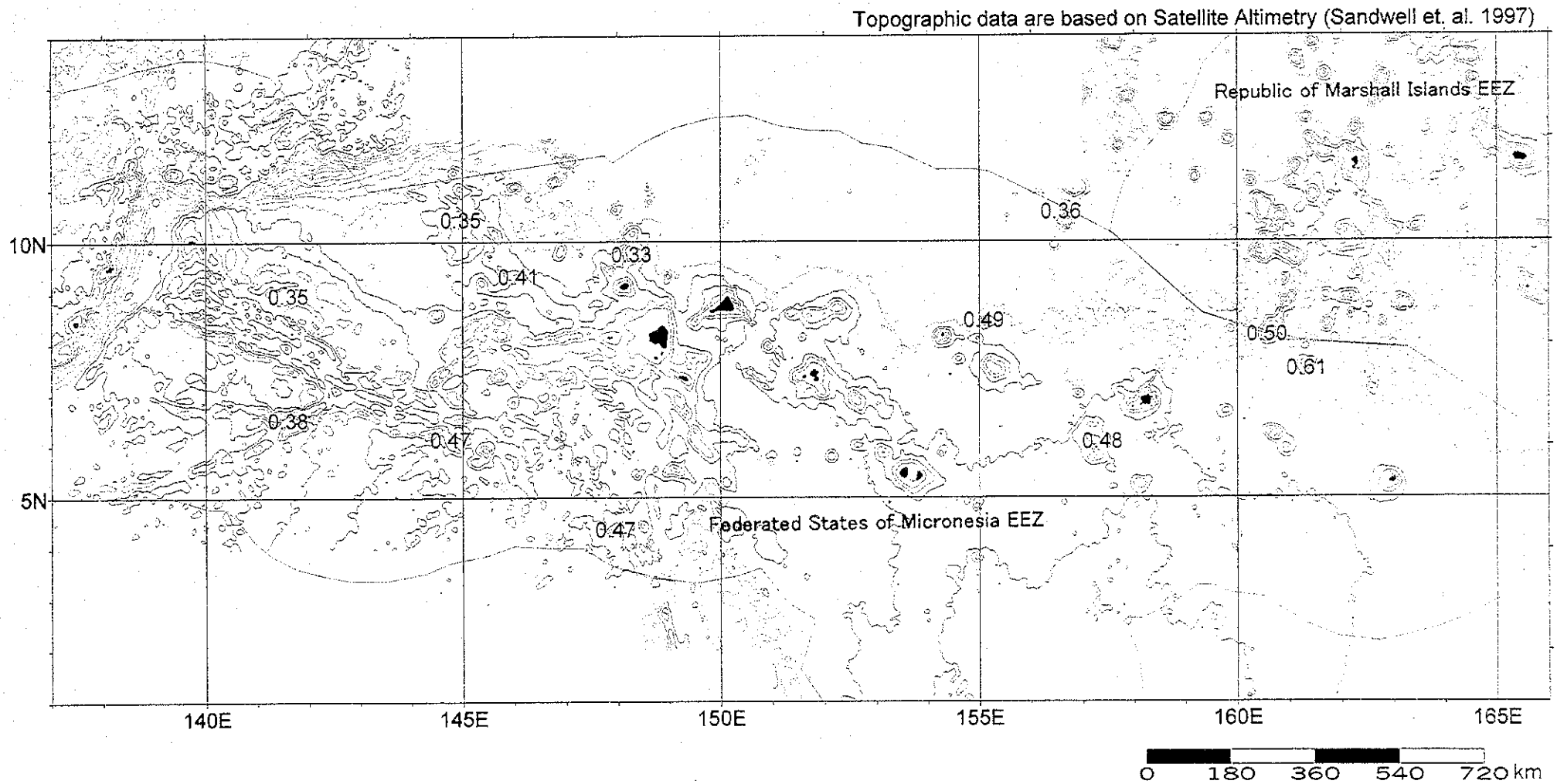

Topographic data are based on Satellite Altimetry (Sandwell et. al. in 1997)
Republic of Marshall Islands EEZ
Federated States of Micronesia EEZ
10N
5N
140E
145E
150E
155E
160E
165E
MC01
MC02
MC03
MC04
MC05
MC06
MC07
MC08
MC09
MC10
MC11
MC12
MC13
MS13
Name of Prospected Area.
Prospected in '98
Prospected in '97
0
180
360
540
720 km



Average Thickness of Crust.

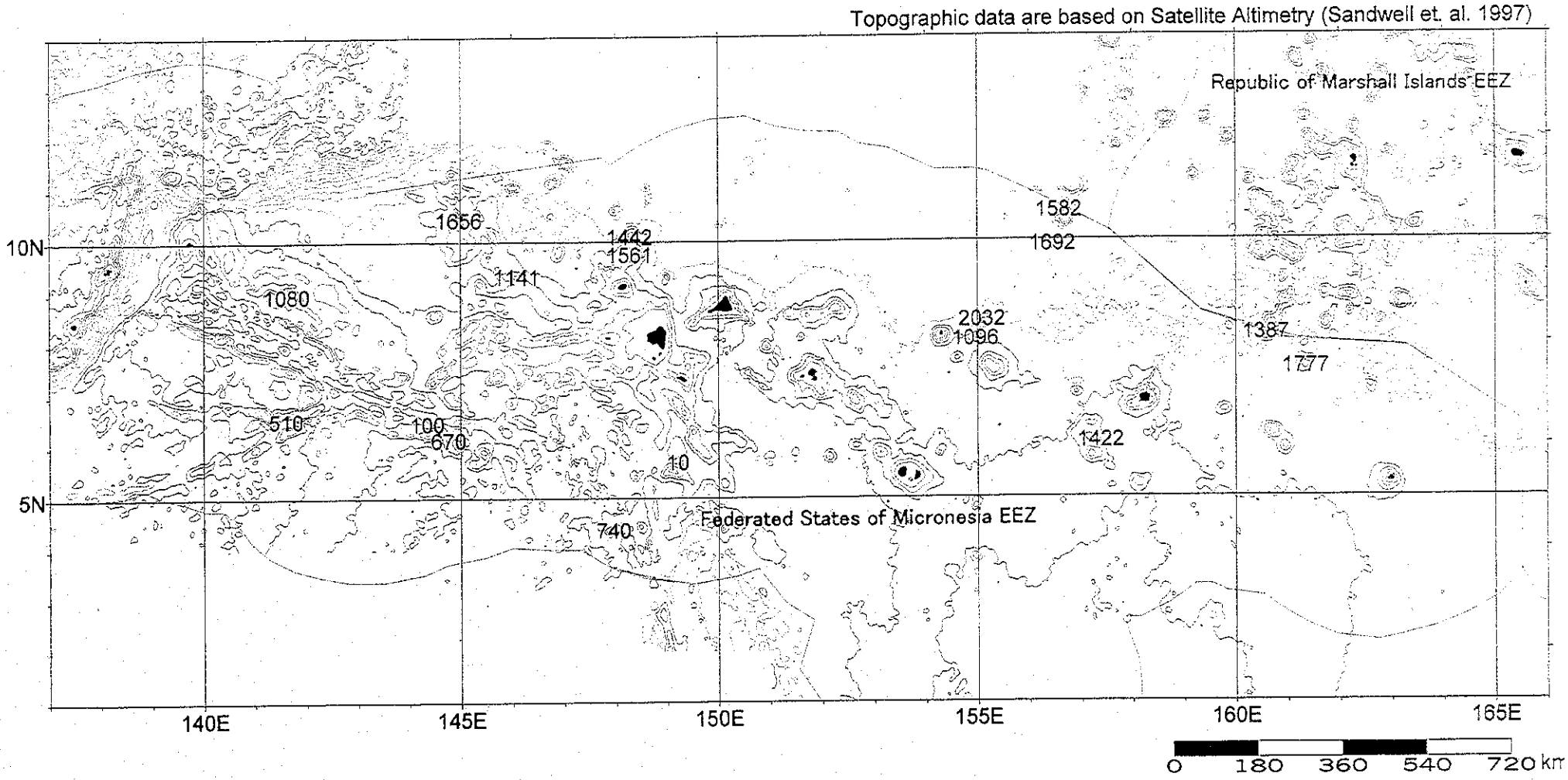
Average

(Maximum)



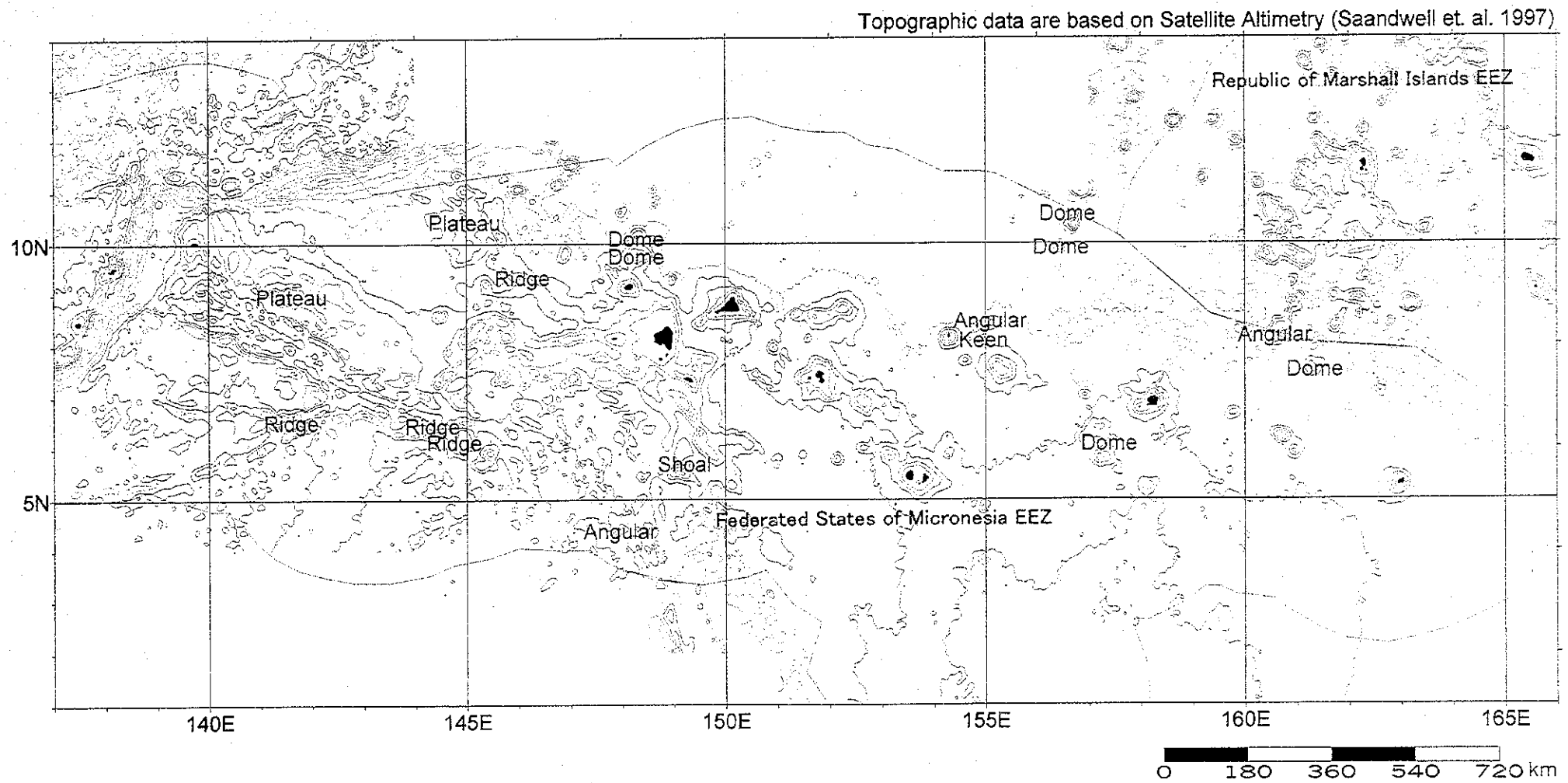
Average Co. Contents.

(%)

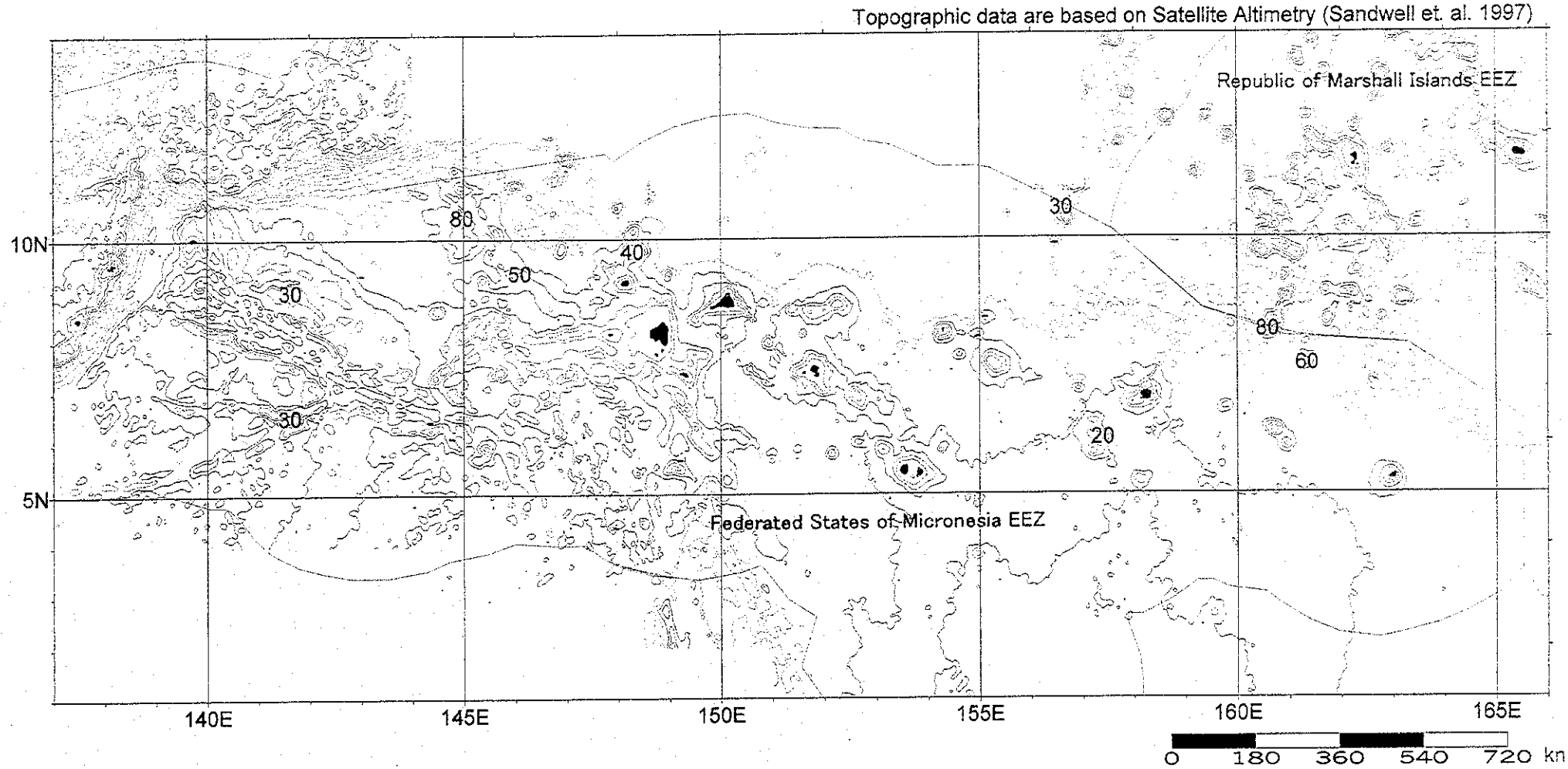


Shallowest Depth

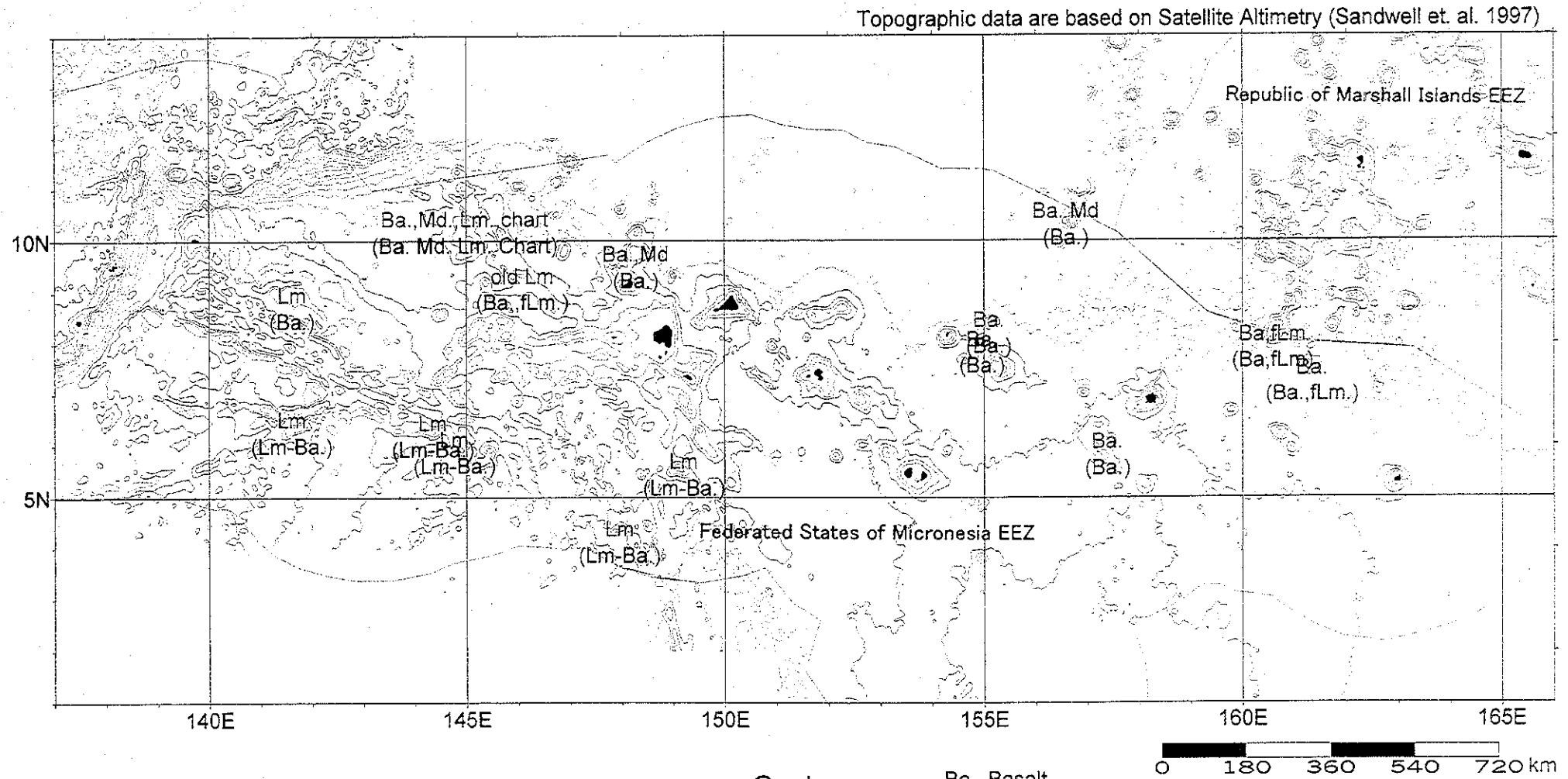
(unit m)



Shape of Summit



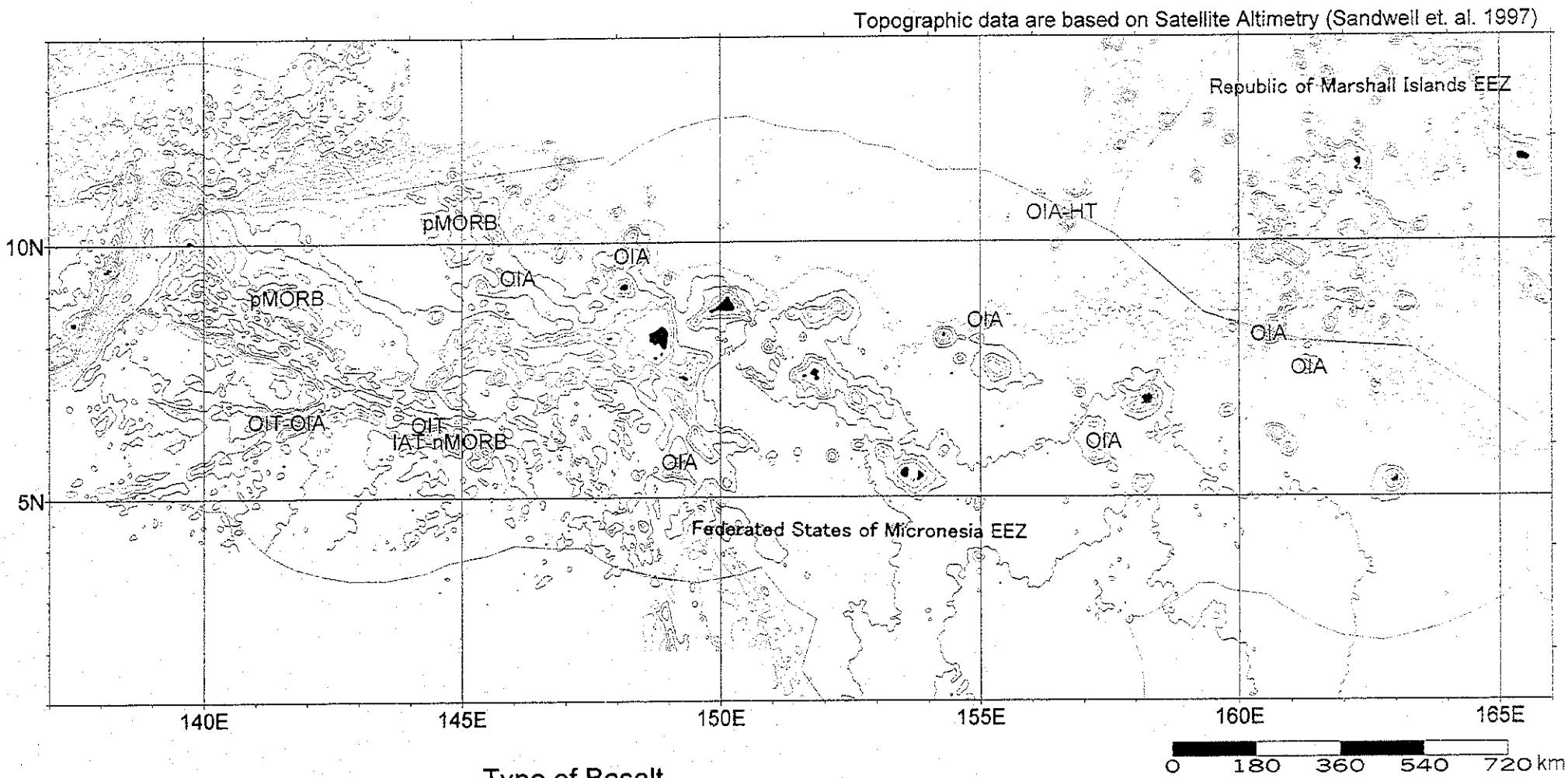
Thickness of SBP Transparency Layer. (m)



Geology

Summit
(Slope)

Ba Basalt.
Md Mudstone.
Lm Limestone.
fLm forminifera Limestone
rLm reefal Limestone
Ch Chart.



Type of Basalt

OIA Ocean Island Alkali-Basalt.

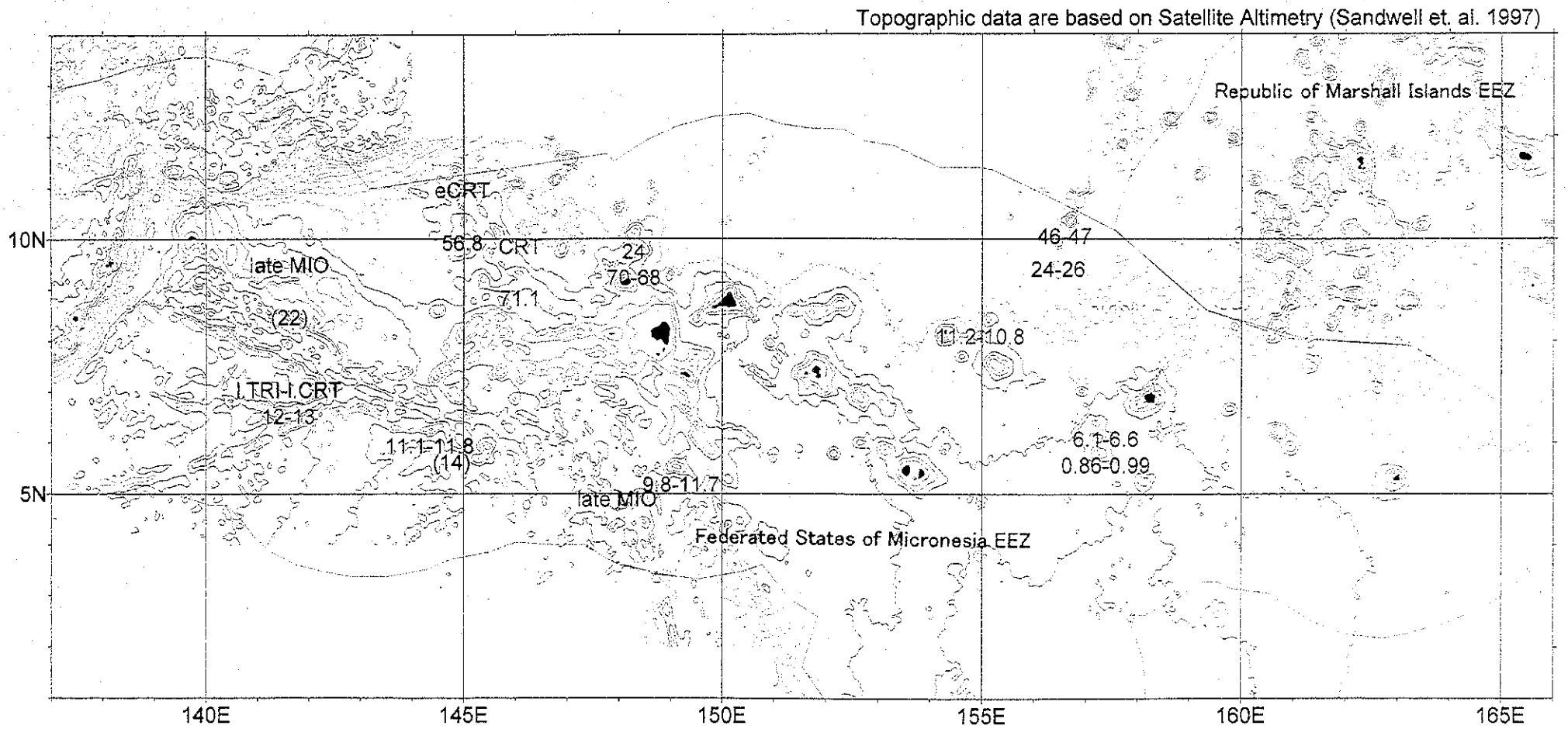
OIT Ocean Island Tholeiite.

IAT Island-arc Tholeiite.

HT High Alkali Tholeiite.

pMORB plume-type Mid-Ocean Ridge Basalt.

nMOPB normal-type Mid-Ocean Ridge Basalt.



Age of Fossils.
Age of Basalt (summit).
Age of Basalt (slope).

(unit Ma)

CONTENTS

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Chapter 1 Outline of the Survey

1 - 1 Survey Title

The Cooperative Study Project on the Deepsea Mineral Resources in Selected Offshore Areas of the SOPAC Region, 1998

— Sea Area of the Federated States of Micronesia and the Republic of Marshall Islands —

1 - 2 Purpose of the Survey

The purpose of the survey is to assess the potential of submarine mineral resources within the Exclusive Economic Zones of the Republic of the Marshall Islands and the Federated States of Micronesia, members of SOPAC, through submarine topographical survey, sampling and other surveys.

1 - 3 Survey Area

The survey areas for this study are the areas within the polygons obtained by joining the following coordinates (approximately 551,793km^2 in the eastern sea area, and 712,683km^2 in the western sea area, Figs.1-3-1. These areas were selected in accordance with the joint study program for marine mineral resources in the exclusive economic waters of the SOPAC member countries agreed upon by Japanese executing agency and South Pacific Applied Geoscience Commission (SOPAC) on 13 March 1995.

Eastern Area			Western Area		
No.	Latitude	Longitude	No.	Latitude	Longitude
A.	13° 30' N,	158° 00' E	A.	11° 30' N,	139° 00' E
B.	13° 30' N,	165° 00' E	B.	11° 30' N,	148° 00' E
C.	7° 00' N,	165° 00' E	C.	5° 00' N,	148° 00' E
D.	7° 00' N,	158° 00' E	D.	5° 00' N,	139° 00' E
A.	13° 00' N,	158° 00' E	A.	11° 30' N,	139° 00' E

1 - 4 Duration of the Survey

Survey cruise: May 3 to July 18, 1998

Analysis and other work: April 1, 1998 to March 31, 1999

1 - 5 Survey Participants

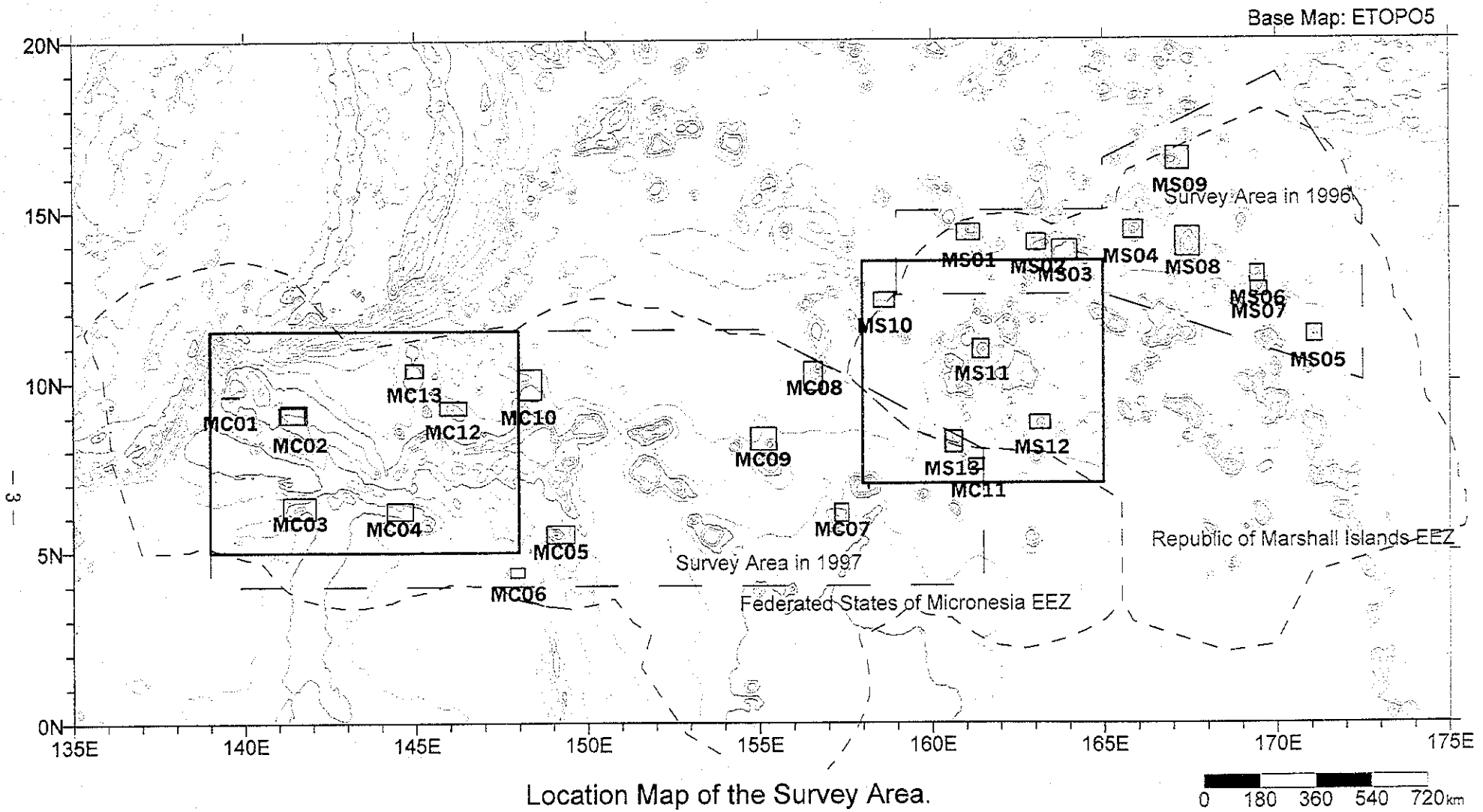
			(period)
Japanese participants			
Field supervisor :	Akira USUI	(Geological Survey of Japan)	(5/3～6/9)
Members:			
Leader	Kohei MAEDA	(Deep Ocean Resources Development Co., Ltd. : DORD)	(5/3～7/18)
	Kiyoshi TONO	"	(5/3～7/18)
	Nadao SAITO	"	(5/3～7/19)
	Nobuyuki MURAYAMA	"	(5/3～7/20)
	Masatsugu OKAZAKI	"	(5/3～7/21)
	Kazunori MATSUI	"	(5/3～7/22)
	Takayoshi KODAMA	"	(5/3～7/23)
	Junzo YOSHIWAKA	"	(5/3～7/24)
	Hiroyuki II	"	(5/3～7/25)
	Takehiro BUTO	"	(5/3～7/26)
	Tadashi SATO	(Ocean Engineering & Development Co., Ltd. : OED)	(5/3～7/18)
	Takao SAITO	"	(5/3～6/9)
	Iori ONIZUKA	"	(6/18～7/18)
	Yutaka HASHIMOTO	"	(5/3～6/9)
	Shinji MARUYAMA	"	(5/3～7/18)
	Nobuhiro YAMAMOTO	"	(6/10～7/18)
	Masashige OKADA	"	(5/3～7/18)
	Yoshihiro HATANAKA	"	(6/10～7/18)
	Kou ITO	"	(5/3～7/18)
	Yukari SHIMIZU	"	(5/3～6/9)
Consigned Participants			
Trainee:	Mr. Andrike Albert	(Republic of the Marshall Islands)	(5/5 ~ 6/8)

1 - 6 Survey Apparatus and Equipment

Major apparatus and equipment used during the survey are shown in Table 1-6-1 and Figure 1-6-1.

1 - 7 Survey Achievements

Survey operations were accomplished as shown in Tables 1-7-1 and 1-7-2.



Location Map of the Survey Area.

Survey Area in 1998.

Map Area

Map in past year.

Fig. 1-3-1 Location map of the survey area

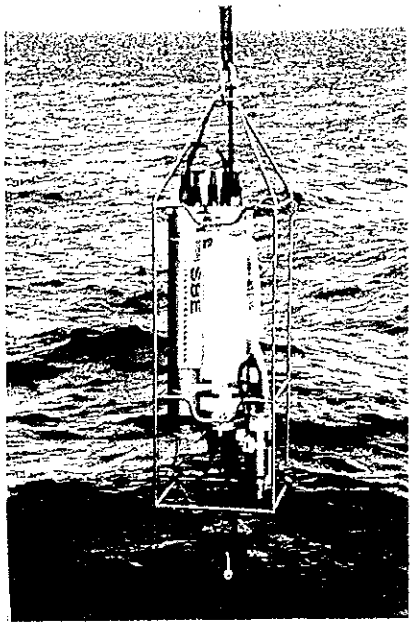
Table 1-6-1 Survey apparatus and equipment

	Survey Method	Survey Apparatus and System	Abbre-viation	Remarks
Positioning	Satellite navigation	Global Positioning System	GPS	
Sea Bottom Topography and Geological Survey	Acoustic Sounding Bathymetry	Multi-narrow Beam Echo Sounder	MBES	
		Narrow Beam Echo Sounder	NBS	
	Subsurface Geological Structure	Narrow Beam Sub-Bottom Profiler	nSBP	
		Side Scan Sonar	SSS	Towed Type
	Seawater Survey	Conductivity, Temperature and Pressure measuring System	CTD &TD	Vertical type and Towed type
	Sampling	Chain Back Dredge	CB	
		Arm Dredge	AD	
		Large Gravity Corer	LC	
Seafloor Observation	Photograph and TV	Continuous Deep Sea Camera With Finder	FDC	with CTD Towed Type
	Photograph	Deep Sea Camera		with LC
Data Recording and Processing	On-Line Functions Data Storage Functions Off-Line Functions ↓ Track Line Maps Various Plan Maps Cross Sections Data Analysis	Data Processing System Sensor CPU・File Server CPU Host CPU Engineering Work Station (EWS) Local Area Network (LAN) Personal Computer (PC) Intelligent Color Monitor (ICM)		

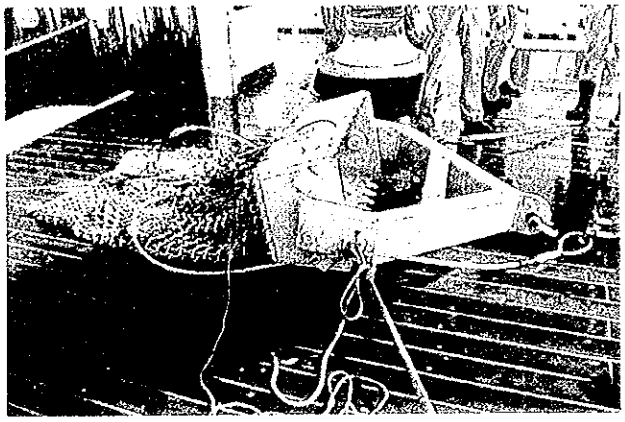
Table 1-7-1 Survey achievements

Survey Schedule		
Departure from Guam	5/5	16:00
Start of SOPAC survey	5/8	23:00
Finish of SOPAC survey	6/6	21:19
Arrival at Pohnpei	6/8	9:00
Departure from Pohnpei	6/12	8:00
Start of SOPAC survey	6/14	20:00
Finish of SOPAC survey	7/2	20:00
Arrival at Guam	7/17	9:00
Total days of survey	49 days	(MC area 22days)

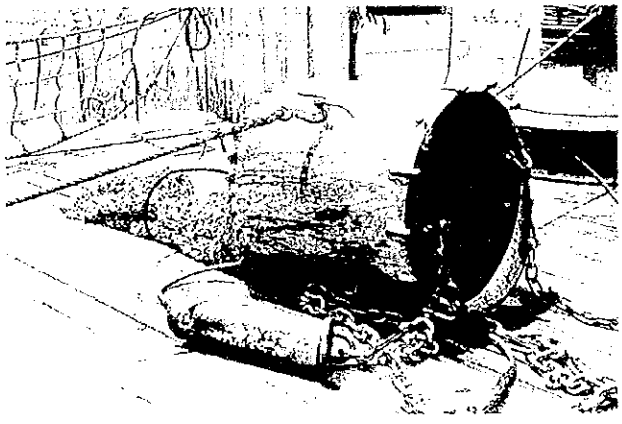
Survey districts	5 districts	MC02	MC11	MC12	MC13	MS13
Number of sampling sites	57 sites	8	6	14	14	15
Kind of sampler AD	44 sites	3	5	13	11	12
CB	1 sites	1	–	–	–	–
LC	12 sites	4	1	1	3	3
Amount of sampling	3045 kg	244	22	961	994	824
Crusts	817 kg	0	6	379	23	409
Cobble crusts	872 kg	0	0	199	473	200
Nodules	333 kg	0	0	19	290	24
Rocks	713 kg	63	4	337	154	155
Sediments	310 kg	181	12	27	54	36
Seafloor observation						
FDC Number of track line	8 lines	3	1	1	1	2
Length of track lone	12.9 nm	2.3	2.1	2.4	2.2	3.9
Number of photos	954 sheets	287	111	182	182	192
Number of tapes	13 reels	3	2	2	2	4
Acoustic survey						
Length of track lines MBES·NBS	3174.4 nm	490.7	310.6	827.0	701.1	845.0
Length of track lines SSS	22.8 nm	12.7	–	–	4.7	5.4



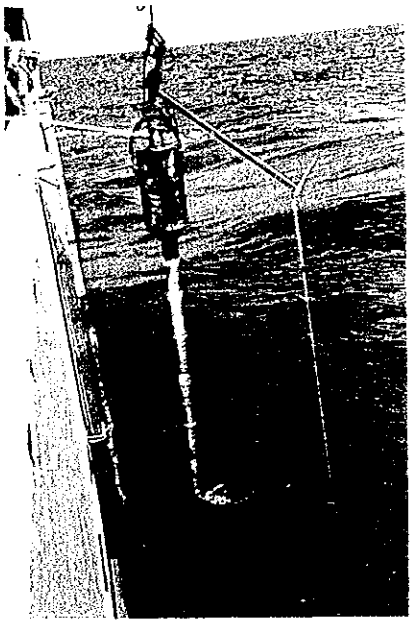
Conductiuity,Temperature and Depth Measurement System



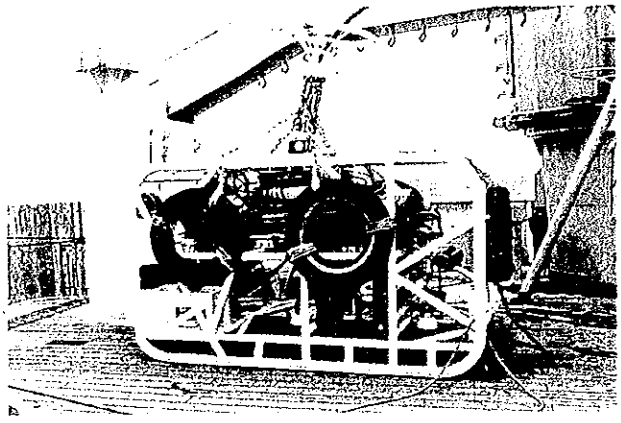
Arm Dredge



Chain-back Dredge



Large Gravity Corer



Deep Sea Towed Camera

Fig. 1-6-1 Photographs of main survey equipments

Table 1-7-2 Records of survey schedule

	Month/Day		Survey Item	Bathymetric survey	Area	Remark
1	5/28	Tu	ctdLC01	172.3	MC11	01:00 Start
2	5/29	Fr	AD02,03,04	80.7	MC11	
3	5/30	Sa	AD05,06 FDC01	89.4	MC11	18:00 Finish
	6/12	Tu	Departure from Pohnei			
	6/13	Fr				
4	6/14	Sa		123.4		20:00 Start
5	6/15	Mo	ctdLC01,AD02	166.7	MC12	
6	6/16	Tu	AD03,04,05	118.7	MC12	
7	6/17	We	AD06,07,08	136.9	MC12	
8	6/18	Tu	FDC01,AD09	128.9	MC12	
9	6/19	Tu	AD10,11,12	109.5	MC12	
10	6/20	Fr	AD13,14	82.3		14:30 Moving to Mc13
11	6/21	Sa	ctdLC01	190.1	MC13	03:30 Start
12	6/22	Mo	AD02,03,04,05	118.5	MC13	
13	6/23	Tu	AD06,07,08	124.8	MC13	
14	6/24	We	LC09,10	117.7	MC13	
15	6/25	Tu	FDC01,AD11	110.6	MC13	
16	6/26	Fr	AD12,13,14		MC13	15:50 Moving to MC02
17	6/27	Sa	ctd08	176.2		07:10 Start
18	6/28	Su	SSS03,04	47.6	MC02	
19	6/29	Mo	SSS03-1,FDC01	85.5	MC02	
20	6/30	Tu	FDC02,03,LC09	77.9	MC02	
21	7/1	We	AD10,11,12	87.3	MC02	
22	7/2	Tu	LC13,14,15	16.2	MC02	20:00 Finish
	7/17	Fr	Arrival in Guam			
	7/18	Sa				

Chapter 2 Survey Methods

In 1998, the fourth fiscal year of the Third Phase of the five year SOPAC Program, topographical survey and other surveys relevant to submarine mineral resources exploration were carried out, as planned, within the exclusive economic zones of the Republic of the Marshall Islands (27 day cruise from the 8th to 27th of May and from the 31st of May to 6th of June), and of the Federated States of Micronesia (22 day cruise from the 28th to 30th of May and from the 14th of June to 2nd of July). The target of the survey was cobalt-rich manganese crust deposits (henceforth cobalt-rich crust deposits).

Seamounts for study were selected from previous data, during the cruise the existence of these seamounts was first confirmed and then topographic, acoustic, seafloor observation, sampling and other surveys were carried out. On land, samples were identified and analyzed, data were analyzed and interpreted, and the results were integrated into a report.

The following is a report of the survey in the exclusive economic waters of the Federated States of Micronesia.

The present work comprised mineral resources exploration in the waters of the Micronesia which was not surveyed during the cruise of Fiscal 1997 (ref. gravures).

2 - 1 Selection of Seamounts

During the Fiscal 1997 survey in the waters of Micronesia, the distribution of cobalt-rich crusts were confirmed on the seamounts in the vicinity of the Caroline Ridge in the relatively shallow waters in the central part of the economic waters of the country.

It was decided that unexplored areas would be surveyed during the present fiscal year, and thus the eastern marine area of the Micronesia adjacent to the western waters of the Marshall Islands and the area north of the Caroline Ridge in the western part of Micronesia waters were surveyed.

In selecting the seamounts for the survey, we first prepared seafloor topographic maps of the area by referring to the ETOP05 Topographic Grid Data prepared by NOAA (USA) and to the "Global Seafloor Topography from Satellite Altimetry and Ship Depth soundings (W.H.F. Smith and D.T. Sandwell, submitted to *Science*, April 7, 1997)". Seamounts were thus extracted and one area in the eastern seas and two areas in the western seas were selected for survey referring to the results of the past surveys and also considering the

cruise schedule.

The surveyed seamounts were numbered as areal codes by serial numbers from the previous survey as MC11~MC13. The survey results of MS13 area which straddles both Micronesian and Marshall Island waters are also included in this report. Therefore, the eastern waters include two areas namely MC11 and MS13, and the western waters include two areas of MC12 and MC13. In addition, MC02 area was surveyed in order to clarify the hydrothermal activity which was discovered during the previous survey. The results of the survey in areas MC11~MC13, and MS13 are reported in chapters 3~5 and the results of MC02 area in "Chapter 6 Hydrothermal Survey".

2 - 2 Survey Methods

Survey of each seamount consisted mainly of the following work; topographic survey for clarifying the detailed seafloor topography, sampling by arm dredge (AD) or chain bag dredge (CB), and large corer (LC) for assessing the occurrence of the ores, and sea bottom observation by FDC for clarifying the continuity of the ore deposits and the conditions of the seafloor. Also SBP survey was carried out parallel with the topographic cruise for clarifying the conditions of the sediments and the structure of the shallow zones below the seafloor. And SSS survey was done in order to understand the micro-topography and the details of the seafloor sediments.

The duration of the survey for each seamount was decided to be six to seven days after considering the size of the seamount, the water depth of the summit, and the time necessary for sufficient accuracy.

2 - 3 Numbering

The numbering system used is as follows.

For sampling points: Year - S - Area No. - Method used - Sample No.

S denotes SOPAC, areas numbered sequentially from the previous survey for each country from MS10 to MS13, samples numbered sequentially regardless of the method used.

Examples: 98SMS10CB01 (CB survey)
98SMS10AD03 (AD survey)
98SMS10LC02 (LC survey)

For SSS survey: Year - Area No. - SSS - Sample No.

Samples numbered sequentially from 01 for each area.

Example: 98MS10SSSS01

For FDC survey: Year - Area No. - FDC - Sample No.

Example: 98MS10FDC01

2 - 4 Position Locating

The position of the survey ship was determined by GPS.

The position of the towed vehicles (FDC, SSS etc.) was calculated on the formula of Pythagoras from the water depth measured by the depth sensor on the vehicle and the cable length, under the assumption that the vehicles were located directly behind the ship. And the coordinates used for the measurement was WGS84.

The water depths of the sampling points of dredges (AD, CB) and large corer (LC) were calculated on the basis of the TD sensor data attached to the tow line.

2 - 5 Acoustic Survey

The seafloor topographic survey was carried out by MBES and the main track line interval was basically 2.0 miles. Auxiliary lines were set between the main lines for shallow (under 2,000m) zones (appended fig.(1) ~ (5)).

The ship speed was basically 10 knots with MBES sounding every 5~10 seconds and NBS sounding every 8 seconds.

SBP data were obtained parallel with the topographic survey for all seamounts.

One or two SSS survey lines were set for three seamounts. Tow speed was 2~3 knots, the vehicle was towed 100m above the seafloor and the data were obtained for a width of approximately 1km including both sides of the towed line.

2 - 6 Seafloor Observation and Photography

Seafloor was observed by FDC equipment with TV and still cameras, and CTD towed immediately on the seafloor. Real time color TV observation was done at about 1 knot tow speed and interesting and distinctive features were photographed by the still camera.

The observation lines were set mostly from the peripheries downward to the slopes (ridges, valleys) of seamounts navigating against the current and wind.

2 - 7 Sampling

CB, AD, and LC were used for sampling. The sampling sites were determined considering the water depth and the direction of the slope referring to topographic maps, MBES acoustic reflection intensity maps, and SBP data. Also the distribution of the sampling sites was designed to represent the geology and the cobalt-rich crust occurrence of the total seamount.

2 - 8 CTD Measurements

Vertical CTD measurement was carried out for each area before the topographic cruise in order to determine the sonic velocity necessary for MBES. The deep-zone LC sampling was done simultaneously with this CTD measurement.

2 - 9 Processing and Analysis of Survey Data

The processing and analysis of obtained data were carried out as shown in the flow sheet of Figure 2-9-1. Basic data were processed and analyzed onboard and summarized as cruise report. Subsequently various laboratory tests and research work were carried out on land, and the present report was prepared incorporating the results of all the above work.

The collected cobalt-rich crust samples were assayed, studied by EPMA and other methods in order to determine the grade, chemical composition, and texture. The rock and sediment samples were observed microscopically, chemically analyzed, and microfossils identified. Thus, geological information necessary for ore-deposit investigation was obtained.

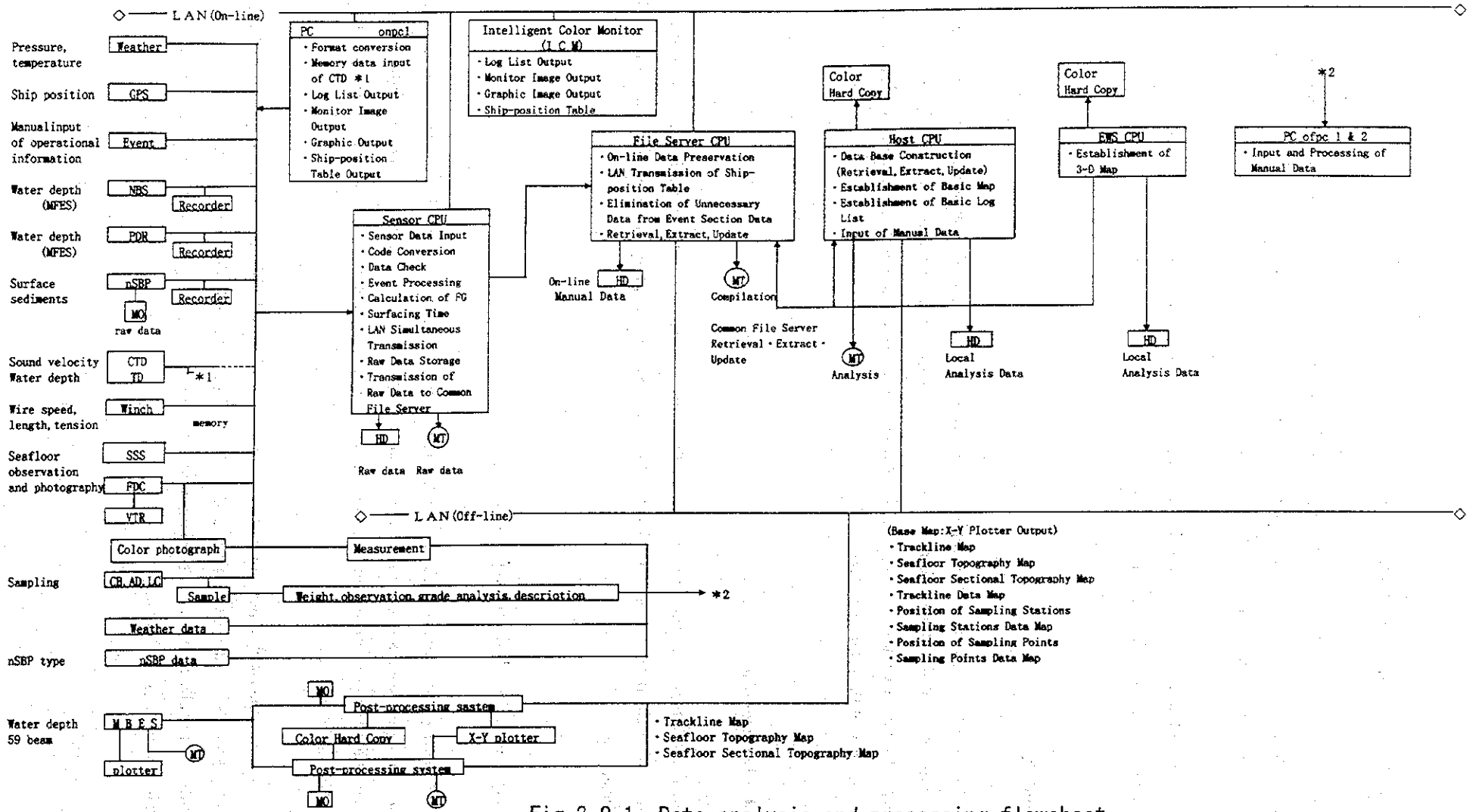


Fig. 2-9-1 Data analysis and processing flowsheet