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

(VOLUME 2)

SEA AREA OF THE REPUBLIC OF THE MARSHALL ISLANDS

March 1997

JAPAN INTERNATIONAL COOPERATION AGENCY
METAL MINING AGENCY OF JAPAN

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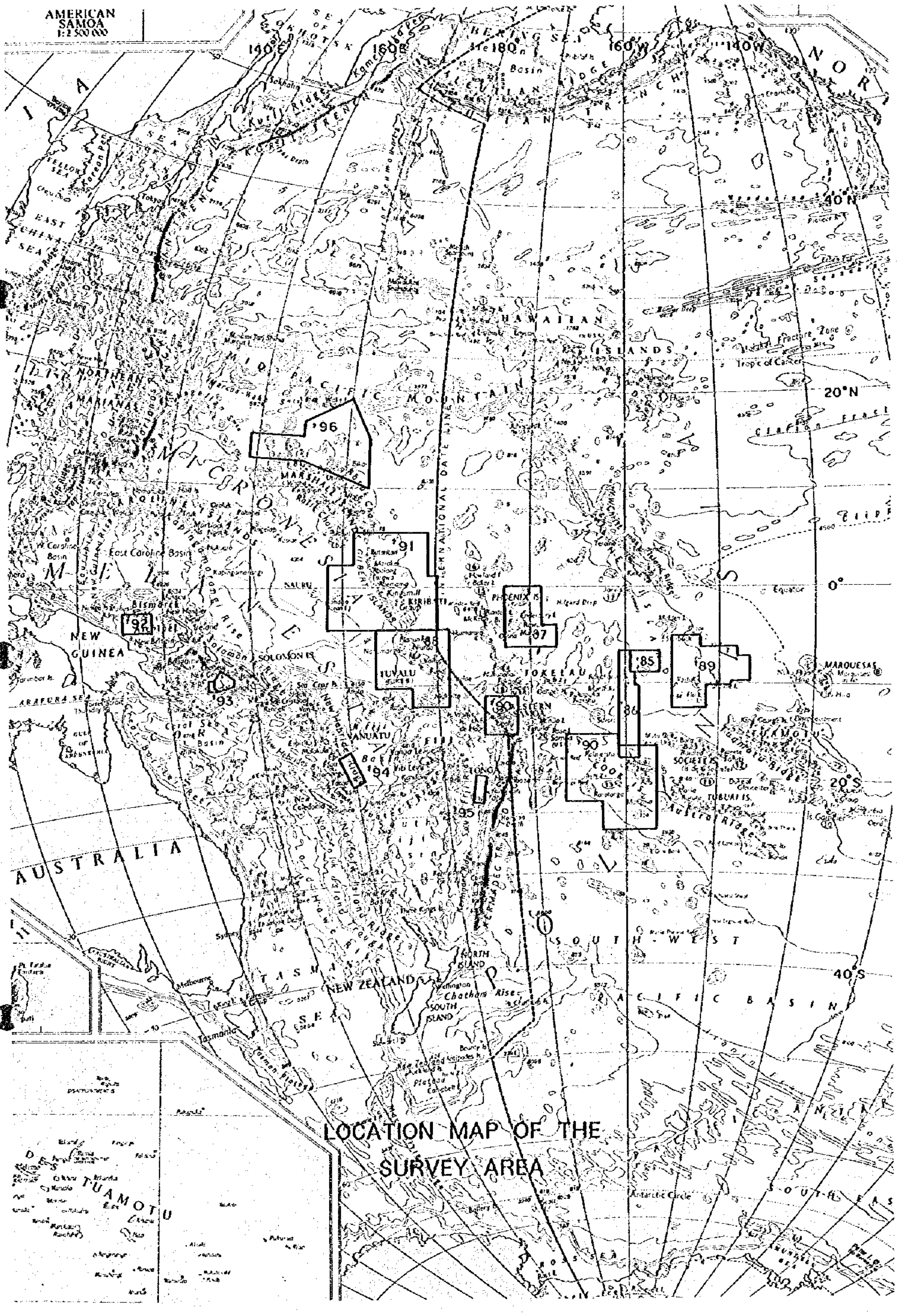

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BERING SEA
140°E
160°E
180°
160°W
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0°
20°S
40°S
HAWAIIAN ISLANDS
Tropic of Cancer
Equator
MID PACIFIC MOUNTAINS
MARSHALL ISLANDS
CAROLINE ISLANDS
East Caroline Basin
NORTHERN MARIANAS
NEW GUINEA
Bismarck
SOLOMON IS
NAURU
KIRIBATI
PHOENIX IS
TUVALU
TOKELAU
VANUATU
FIJI
TONGA
MARQUESAS
TUAMOTU
SOCIETY IS
TUBUAI IS
AUSTRALIA
Sydney
Melbourne
Tasmania
NEW ZEALAND
NORTH ISLAND
SOUTH ISLAND
Chatham Rise
Coral Sea
ARAFURA SEA
EAST CHINA SEA
YELLOW SEA
SOUTH-WEST PACIFIC BASIN
Antarctic Circle
'96
'91
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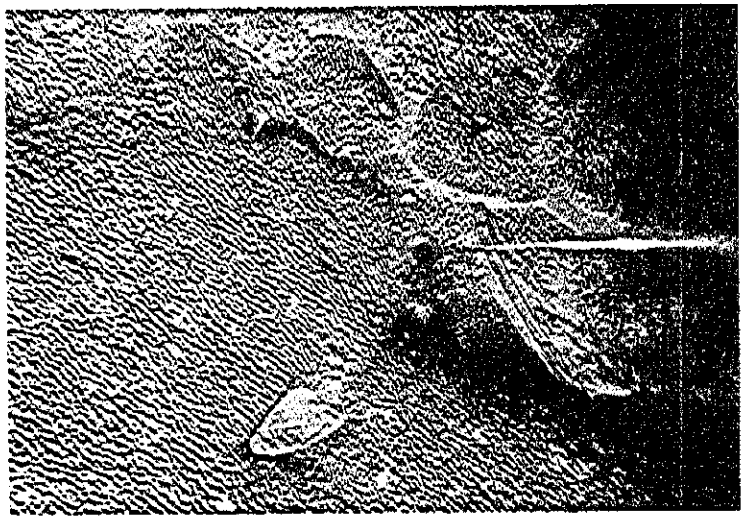
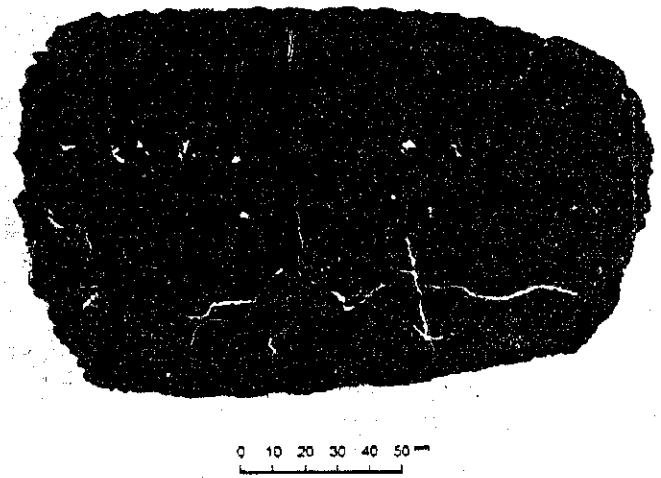
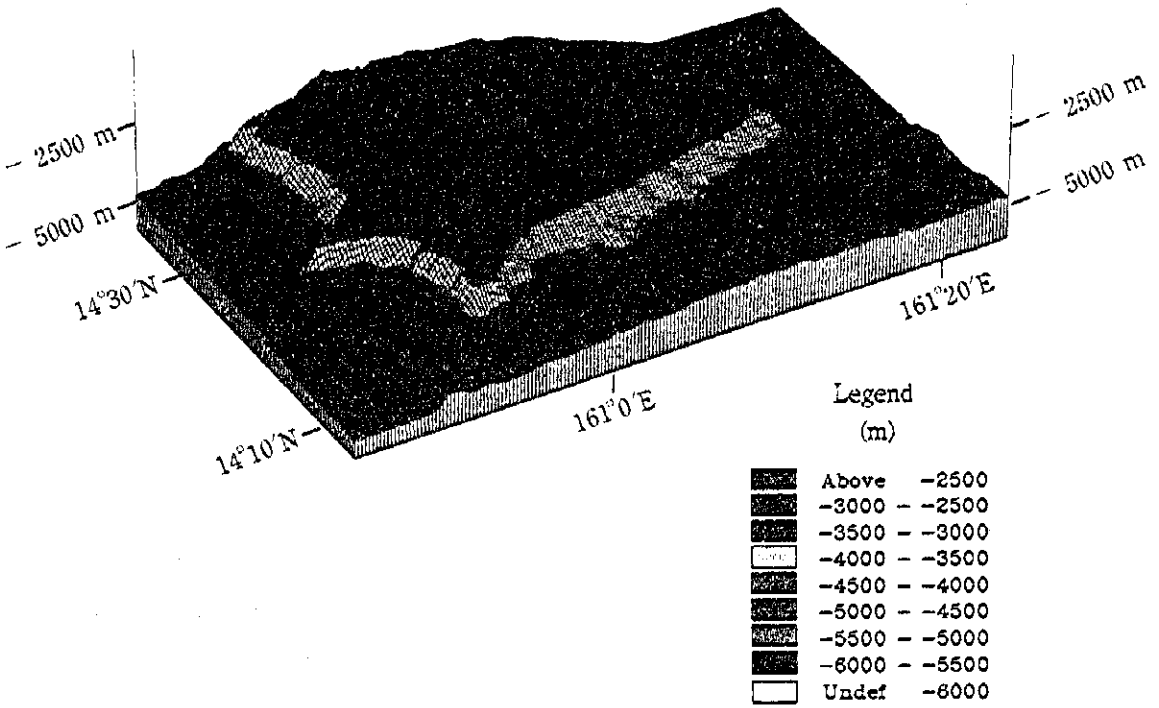
LOCATION MAP OF THE SURVEY AREA



Seafloor photograph of manganese crusts



Sectional photograph of manganese crust



Bird's eye view of bathymetry of seamount MS01

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 resource 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 second year of the project, and the target area is the exclusive economic zone of the Republic of the Marshall Islands. MMAJ dispatched the Hakurei Maru No. 2, a research vessel fitted for investigating deep sea mineral resources, to the survey area for a total of 69 days from July 1, 1996 to September 7, 1996, successfully completing the survey as planned with the cooperation of the Government of the Republic of the Marshall Islands.

The present report sums up the results of this second year survey.

It is a pleasure to record our deep gratitude to all persons concerned, particularly the staff of the SOPAC Secretariat, the 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 Fiji.

March, 1997.

Kimio FUJITA
President
Japan International Cooperation Agency

Shozaburo KIYOTAKI
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 second year. The survey for this year was carried out from July 1 to September 7, 1996 in an area of 738,000 km^2 in the exclusive economic zone of the Republic of the Marshall Islands. The duration of the survey was 69 days and the target mineral resources were seafloor manganese crust deposits.

The survey area is characterized by two seamount chains; namely the Ralik chain extending in the northwest–southeast direction on the western side of the area and the Ratak chain extending in the NNW–SSE direction on the eastern side. The surveyed seamounts largely belong to these two seamount chains. These seamounts were selected after considering, from charts and available data; the water depth of the summits (1,000~2,000 m where the crusts are best developed), the shape, size, and other relevant factors. During the first half of the survey (Leg 1), four seamounts aligned east–west along the same latitude and located to the west of long. 166° E., were studied. During Leg 2, five seamounts with varying features such as the water depth of the summits and size were surveyed. They are located in the eastern part of the survey area. These seamounts are distributed nothwestward toward the northern edge of the survey area from the vicinity of long. 171° E., lat. 11° N.

The major methods employed were bathymetric cruise for clarifying the detailed morphology of each seamount, and sampling by large corer (LC) and arm dredge (AD) for confirming the mode of crust occurrences. Also seafloor observation and photography by FDC were carried out in order to study the continuity of the deposits, the type, thickness, density, grade, exposure ratio, and other relevant features of the manganese crusts. Important samples were studied in laboratories on land by various methods including; chemical analysis, X–ray diffraction, and microscopy. These laboratory work together with the on–board analysis provided the basic data for the assessment of the deposits. nSBP survey together with MBES was carried out in order to clarify the conditions of the sediments, and for some of the seamounts, SSS survey was conducted for understanding the microtopography of the seafloor.

Bathymetric survey was carried out for all nine seamounts and detailed morphology was clarified. Of the nine seamounts, seven are flat topped, and two are pointed seamounts.

Acoustic reflection image maps prepared from MBES acoustic pressure measurements are highly effective for understanding the areal extent and the distribution of crust exposures on the seamount surfaces. With SSS survey, more detailed acoustic pressure distribution is available, and confirmation of more detailed topography became possible. These data formed the basis of planning the track lines for seafloor observation and sampling locations.

The mode of occurrence of the manganese crusts of each seamount was confirmed by FDC observation and seafloor photography. Of particular importance was the clarification of the type and distribution of crusts, conditions of sediments, the relation between the microtopography and crust distribution, shape of the crusts, and other significant information.

Sampling was done at an average of 15 points per seamount by LC and AD. At all seamounts, crusts with substrates, surface crusts, and foraminifera sand were collected. The type, thickness, density, grade, and other relevant features of the collected samples were measured onboard, and it was clarified that manganese crust deposits exist throughout the survey area. FDC survey showed that manganese crusts are particularly developed from the marginal parts of the summit to the slope. Similar results were obtained from topographic maps and acoustic image maps. Also in almost all seamounts, clear relations could not be confirmed among; characteristics of the crusts, thickness of the crusts, water depth, and the location of the sampling points.

The average chemical composition of the crust samples collected at the nine seamounts is; Co 0.73, Ni 0.58, Cu 0.11, Mn 23.08, Fe 13.89%. The average thickness is 21 mm with a maximum of 105 mm. The largest systematic difference of chemical composition is between the stratigraphic horizons of the crusts (outer and inner layers). And location of the seamounts, topography, difference of the substrates do not affect the composition systematically.

On the reserves of manganese crusts of each seamount, the dry tonnage of the ores of typical seamounts (60 x 60 km) amount to 15 to 20 million tons. Also comprehensive assessment of each seamount including the metal content indicate that MS01, MS02, are the most promising seamounts for future development.

Regarding survey methods, the strength and limitations of various survey methods have been clarified, and the importance of applying the optimum combination of these methods is recognized. As it is expected from the results of the present survey that manganese crusts exist in all seamounts with summits shallower than 2,000 m of the survey area, it is desirable to carry out surveys for clarifying the areal extent of the crusts distribution with high accuracy in the future.

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Chapter 1 Outline of the Survey

1-1 Survey Title

The Cooperative Study Project on the Deepsea Mineral Resources in the Sea Area of the Republic of the 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 Zone of the Republic of the Marshall Islands, a member of SOPAC, through submarine topographical survey, sampling and other surveys.

1-3 Survey Area

The survey area for this study is the area within the polygon obtained by joining the following coordinates (738,000 km ^{2}, Figs. 1-3-1 and 2-1-1). This area was selected in accordance with the cooperative 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.

The area within 200 nm radius of Kwajalein Island and waters outside of the exclusive economic zone of the Republic of the Marshall Islands are excluded from the present survey area.

No.	Latitude	Longitude
1.	15 ° 00'N.,	159 ° 00'E.
2.	15 ° 00'N.,	165 ° 00'E.
3.	16 ° 30'N.,	165 ° 00'E.
4.	19 ° 00'N.,	170 ° 00'E.
5.	15 ° 00'N.,	172 ° 30'E.
6.	10 ° 00'N.,	172 ° 30'E.
7.	12 ° 30'N.,	165 ° 00'E.
8.	12 ° 30'N.,	159 ° 00'E.

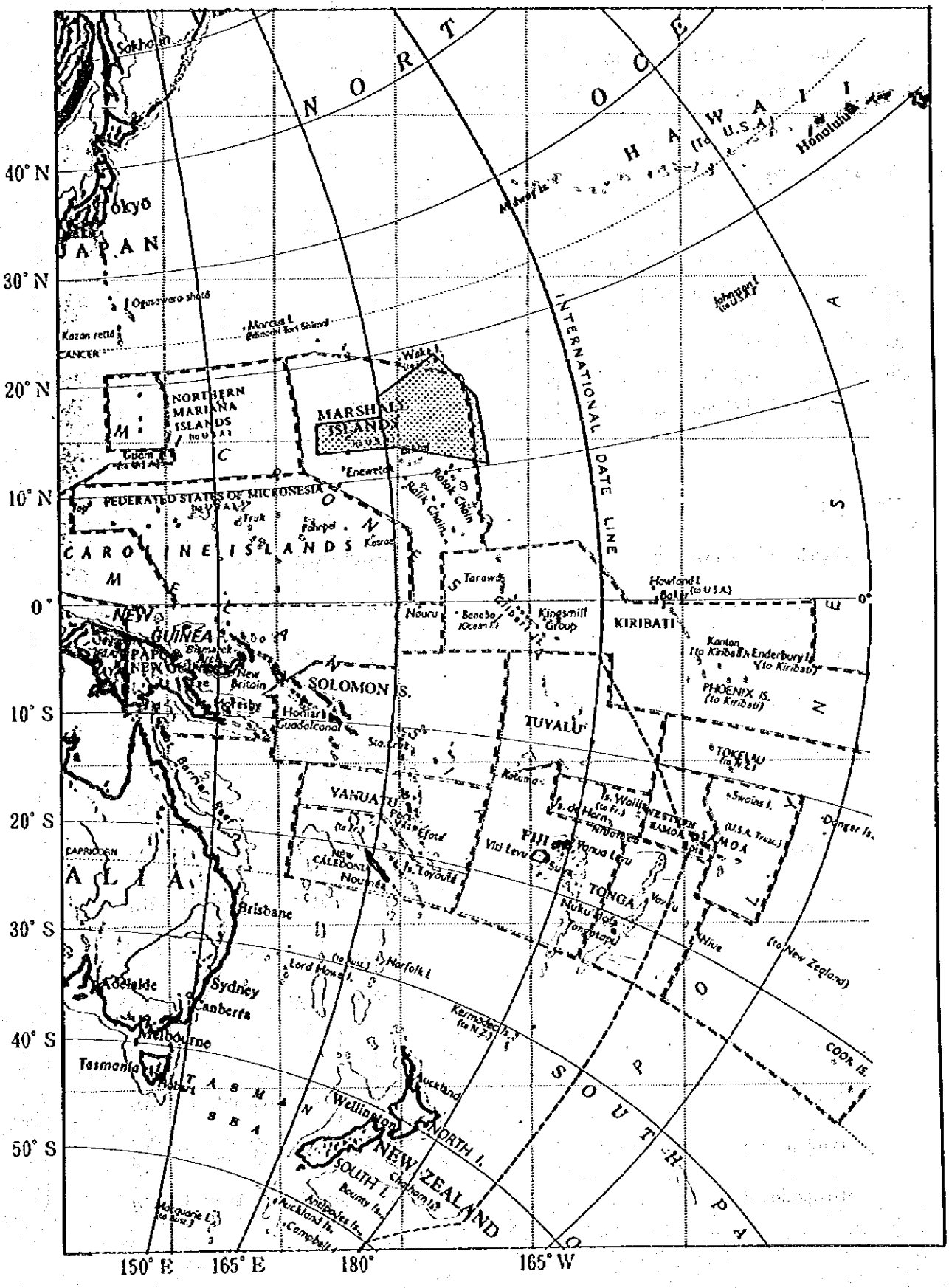


Fig. 1-3-1 Location map of the survey area

1–4 Duration of the Survey

Survey cruise: July 1 to September 7, 1996 (69 days)
Analysis and other work: April 1 to March 31, 1997

1–5 Survey Participants

The staff who participated in the survey cruise were delegated by DORD (Deep Ocean Resources Development Co., Ltd.) and OEDC (Ocean Engineering and Development Co., Ltd.).

Japanese participants
Supervisor at survey sites:

Akira USUI (Geological Survey of Japan)	July 1 to 31	

Members:

Leader & Chief Geophysicist	Kiyoshi KAWASAKI	(DORD)
Chief Geologist	Kazunori MATSUI	(DORD)
Geologist	Takumi ONUMA	(DORD)
Geologist	Kenjiro KAWADA	(DORD)
Geologist	Kazuo IKEDA	(DORD)
Geologist	Yutaka MATSUURA	(DORD)
Geologist	Osamu ODA	(DORD)
Geologist	Akio HAMANO	(DORD)
Geologist	Shinichiro YAMASAKI	(OECD)
Geophysicist	Masahiro TAKEDA	(DORD)
Geophysicist	Takao SEO	(DORD)
Geophysicist	Kazuhiko KASHIWASE	(DORD)
Geophysicist	Seiji HASHIMOTO	(DORD)
Geophysicist	Kazuyoshi FURUYA	(DORD)

Geophysicist	Michiharu OONO	(DORD)
Geophysicist	Akihiro MIYAWAKI	(DORD)
Geophysicist	Shinichi KUSAKA	(OEDC)
Geophysicist	Hisashi SUZUKI	(OEDC)
Geophysicist	Keiji SHIKAMA	(OEDC)

Consigned Participants

Trainees

Mr. Clyde James (Republic of Marshall Islands)	July 1 to August 1
Mr. Andrike Albert (Republic of Marshall Islands)	August 2 to September 7

1–6 Apparatus and Equipment for the Survey

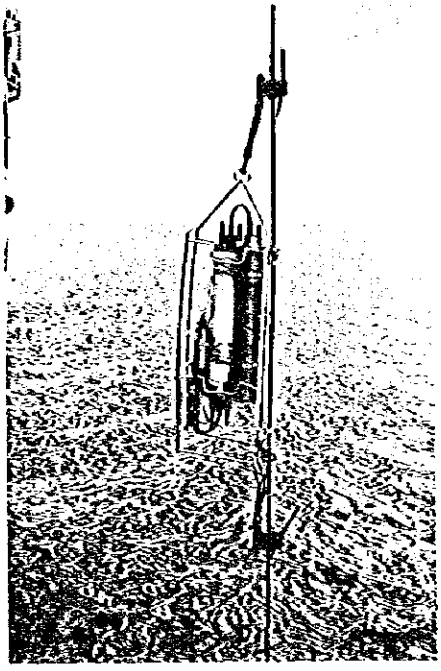
Major apparatus and equipment used during the survey are shown in Table 1–6–1 and Figure 1–6–1.

1–7 Survey Achievements

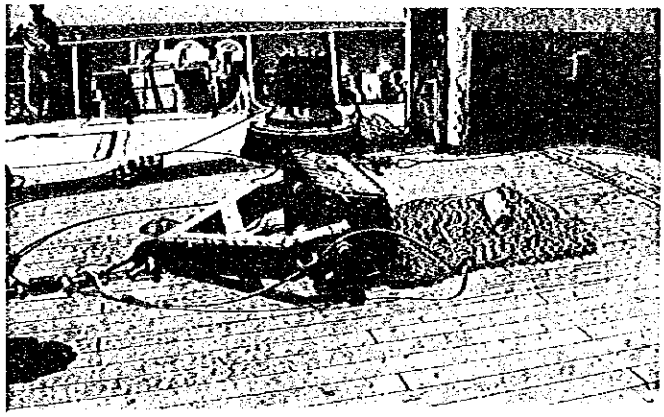
Survey operations were accomplished as shown in Tables 1–7–1 and 1–7–2 (1), (2).

Table 1-6-1 Survey apparatus and equipment

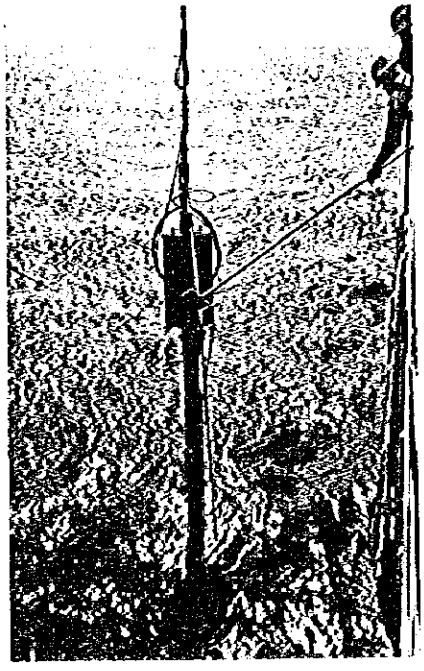
	Survey Method	Survey Apparatus and System	Abbre-viation	Remarks
Positioning	Satellite naviga-tion	Global Positioning System	GPS	
Sea Bottom Topography and Geological Survey	Acoustic Sounding Bathymetry	Multi-narrow Beam Echo Sounder	MBES	
		Narrow Beam Echo Sounder	NBS	
	Subsurface Geolo-gical Structure	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	Large Gravity Corer	LC	
		Arm Dredge	AD	
	Analysis	Sample Treatment Equipment (Drier and Crusher)	XRF	
Seafloor Observation	Photograph and TV	Continuous Deep Sea Camera With Finder		with CTD Towed Type
	Photograph	Deep sea Camera		with LC
Data Recording and Prpcessing	On-Line Functions Data Storage Func-tions 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 Areal Network (LAN) Personal Computer (PC) Intelligent Color Monitor (ICM)	DPS	



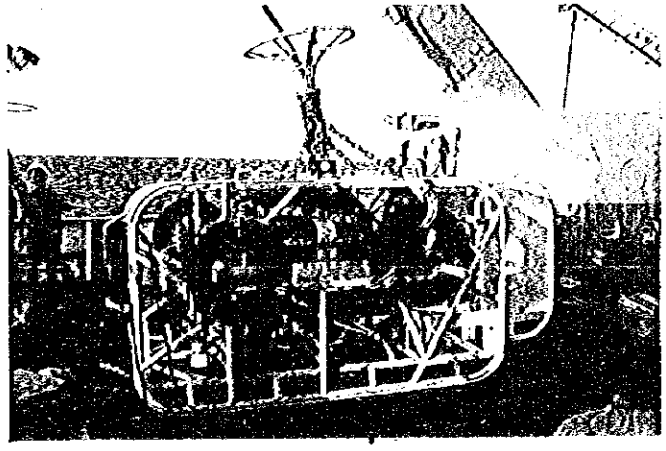
Conductivity, Temperature and Depth
Measurement System



Arm Dredge



Large Gravity Corer



Deep Sea Towed Camera

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

Table 1-7-1 Survey achievements

Survey Schedule

Depart Guam	Jul. 01 16:00	Depart Majuro	Aug. 03 16:00
Arrive Survey Area	Jul. 05	Arrive Survey Area	Aug. 04
Start the Survey		& Start the Survey	
Finish the Survey	Jul. 28	Finish the Survey	Aug. 31
& Sailing		Sailing	Sep. 01 13:25
Arrive Majuro	Jul. 31 09:00	Arrive Honolulu	Sep. 07 09:00

Number of Seamount

9 Seamount: MS01. MS02. MS03. MS04. MS05. MS06. MS07. MS08. MS09

Amount of samples

Seamount	AD	LC	Samplingpoint
MS01	7	7	14
MS02	12	6	18
MS03	6	6	12
MS04	11	4	15
MS05	9	4	13
MS06	9	4	13
MS07	3	–	3
MS08	14	4	18
MS09	7	6	13
Total	78	41	119

Sampler
AD:Arm Dredge
LC:Large Gravity Corer

Amount of samples

seamount	Crust	pebbly crust	nodule	Rock	Sediments
MS01	62.74	241.10	2.34	15.49	52.24
MS02	67.11	22.75	0.82	28.98	12.43
MS03	31.98	1.10	0.02	2.20	70.21
MS04	244.49	477.70	41.91	203.57	45.58
MS05	28.97	332.72	90.57	120.47	29.41
MS06	63.73	66.71	147.00	0.50	18.09
MS07	3.27	2.93	58.10	2.18	1.84
MS08	547.09	234.20	91.59	20.17	9.92
MS09	33.38	88.45	92.77	64.95	11.74
Total	1,082.76	1,467.66	525.12	458.51	251.46

Number of track line
Length of track line
Number of photos

seamount	No. of lines	Acquired photographs	VTR Tapes	Total line miles
MS01	1	310	3	5.3
MS02	1	175	2	3.4
MS03	1	340	3	5.3
MS04	2	756	7	14.2
MS05	2	55	4	8.1
MS06	2	593	6	11.9
MS07	–	–	–	–
MS08	2	689	6	12.8
MS09	1	435	4	5.5
Total	12	3,353	35	66.5

Number of analyzed samples	Total: 311 (MS01:41, MS02:46, MS03:18, MS04:43 MS05:30, MS06:31, MS07:17, MS08:52, MS09:33)
Analyzed elements	Ni, Co, Cu, Mn, Fe
Total number of analyses	1,555 (311 samples×5 elements)

Table 1-7-2 (1) Records of survey schedule (Leg 1)

		Month/Day		Survey Items
01		07/01	Mo	16:00 Departure from Guam
02		07/02	Tu	Sailing (1,020nm from Guam to the survey area)
03		07/03	We	--ditto--
04		07/04	Th	--ditto--
05	01	07/05	Fr	[MS01] Arrival in the survey area Sampling (LC01, CTD)
06	02	07/06	Sa	Bathymetric survey
07	03	07/07	Su	Sampling (LC02, 03, 04, 05, 06) Bathymetric survey
08	04	07/08	Mo	Sampling (AD07, 08, 09, 10) 〃
09	05	07/09	Tu	Sampling (AD11, 12, 13, LC14) 〃
10	06	07/10	We	FDC survey, Moving to MS02
11	07	07/11	Th	[MS02] Sampling (LC01, 02) Bathymetric suevey
12	08	07/12	Fr	FDC survey, Sampling (LC03, 04) 〃
13	09	07/13	Sa	Sampling (LC05, 06, AD07, 08) 〃
14	10	07/14	Su	Sampling (AD09, 10, 11, 12) 〃
15	11	07/15	Mo	Sampling (AD13, 14, 15) 〃
16	12	07/16	Tu	Sampling (AD16, 17, 18), Moving to MS03
17	13	07/17	We	[MS03] Sampling (LC01, 02) Bathymetric Survey
18	14	07/18	Th	Sampling (LC03, 04, 05, 06) 〃
19	15	07/19	Fr	FDC Survey 〃
20	16	07/20	Sa	Sampling (AD07, 08, 09) 〃
21	17	07/21	Su	Sampling (AD10, 11, 12), Moving to MS04
22	18	07/22	Mo	[MS04] Sampling (LC01, 02) Bathymetric Survey
23	19	07/23	Tu	SSS Survey, Sampling (LC03) 〃
24	20	07/24	We	Sampling (AD04, 05, 06, 07) 〃
25	21	07/25	Th	Sampling (AD08, 09, LC10) 〃
26	22	07/26	Fr	FDC Survey (01) 〃
27	23	07/27	Sa	FDC Survey (02), Sampling (AD11)
28	24	07/28	Su	Sampling (AD12, 13, 14, 15) Departure from the survey area
29		07/29	Mo	--- Sailing to Majuro --- (609nm from MS04 to Majuro)
30		07/30	Tu	------- ditto -------
31		07/31	We	09:00 Arrival in Majuro
32		08/01	Th	in Majuro

Date and Time are shown in Local Time.

Table 1-7-2(2) Records of survey schedule (Leg 2)

		Month/Day		Survey Items
33		08/02	Fr	In Majuro
34		08/03	Mo	16:00 Departure from Mjuro
35	25	08/04	Su	[MS05] Arrival in the survey area Sampling (LC01, CTD)
36	26	08/05	Mo	Sampling (LC02, 03, 04) Bathymetric survey
37	27	08/06	Tu	FDC Survey (01) 〃
38	28	08/07	We	Sampling (AD05, 06, 07, 08) 〃
39	29	08/08	Th	Sampling (AD09, 10, 11) 〃
40	30	08/09	Fr	Sampling (AD12, 13), Moving to MS05 〃
41	31	08/10	Sa	[MS06] Sampling (AD01, 02, 03) Bathymetric survey
42	32	08/11	Su	Sampling (LC03, 04, 05, 06) 〃
43	33	08/12	Mo	FDC Survey (01) 〃
44	34	08/13	Tu	Sampling (AD07, 08, 09) 〃
45	35	08/14	We	SSS Survey 〃
46	36	08/15	Th	Sampling (AD10, 11, 12) 〃
47	37	08/16	Fr	FDC survey (02), Sampling (AD13), Moving to MS07
48	38	08/17	Sa	Sampling (AD01, 02, 03)
49	39	08/18	Su	[MS08] Bathymetric Survey
50	40	08/19	Mo	Sampling (LC01, 02, 03) Bathymetric Survey
51	41	08/20	Tu	Sampling (AD04, 05, 06, 07) 〃
52	42	08/21	We	Sampling (AD08, 09, 10) 〃
53	43	08/22	Th	SSS Survey, Sampling (LC11) 〃
54	44	08/23	Fr	Sampling (AD12, 13, 14, 15) 〃
55	45	08/24	Sa	Sampling (AD16, 17, 18) 〃
56	46	08/25	Su	FDC survey (01) 〃
57	47	08/26	Mo	FDC survey (02), Moving to MS09
58	48	08/27	Tu	[MS09] Sampling (LC01, CTD) Bathymetric Survey
59	49	08/28	We	Sampling (LC02, 03, 04, 05, 06) 〃
60	50	08/29	Th	FDC Survey (01) 〃
61	51	08/30	Fr	Sampling (AD07, 08, 09, 10) 〃
62	52	08/31	Sa	Sampling (AD11, 12, 13) Departure from the survey area
63		09/01	Su	-- Sailing to Honolulu -- (2014nm from MS09 to Honolulu)
64		09/02	Mo	------- ditto -------
65		09/03	Tu	------- ditto -------
66		09/04	We	------- ditto -------
67		09/05	Th	------- ditto -------
68		09/06	Fr	------- ditto -------
69		09/07	Sa	09:00 Arrival in Honolulu

Chapter 2 Survey Methods

In 1996, the second fiscal year of the Third Phase of the five year SOPAC Program, submarine topographical survey and other surveys relevant to the study of submarine mineral resources exploration were carried out, as planned, within the exclusive economic zone of the Republic of Marshall I Islands (Fig. 2-1-1).

The survey was carried out in two segments, the first and the second half with a call at Majuro in between. The first half will be called Leg 1 and the second half Leg 2. The target of the survey was cobalt-rich manganese crusts.

2-1 Selection of Seamounts

In considering the seamounts, for the survey, we referred to the Bathymetric Map of Marshall Islands-EEZ, 1995, SOPAC and various charts, and more than a dozen seamounts were first listed. The most important criteria for consideration were the depth (manganese crust is believed to be best developed on seamounts with summits at water depth of 1,000 to 2,000 m), and shape and size of the seamounts. From this long list, selection was made considering the location and the cruise plan including the port of call (Guam-survey area-Majuro-survey area-Honolulu) so that the survey can be carried out effectively. For Leg 1, four seamounts located to the west of long 166 ° E., were selected. These are aligned E-W along the same latitude. For Leg 2, five seamounts with varying characteristics were selected from those in the eastern part of the survey area. The selected five include somewhat large seamounts and those with deep summit. These seamounts occur northwestward from 171 ° E., 11 ° N. toward the northern periphery of the survey area.

The nine selected seamounts were numbered from MS01 to MS09 as the survey progressed.

2-2 Survey Methods

The survey of each seamount consisted mainly of the following work; namely, bathymetric survey for clarifying the detailed seafloor topography, sampling by large corer or arm dredge (AD) 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 nSBP survey was carried out parallel with the bathymetric cruise for clarifying the conditions of the sediments and the structure of the shallow zones below the seafloor. And SSS survey was done for some seamounts in order to understand the micro-topography and the sediments of the seafloor.

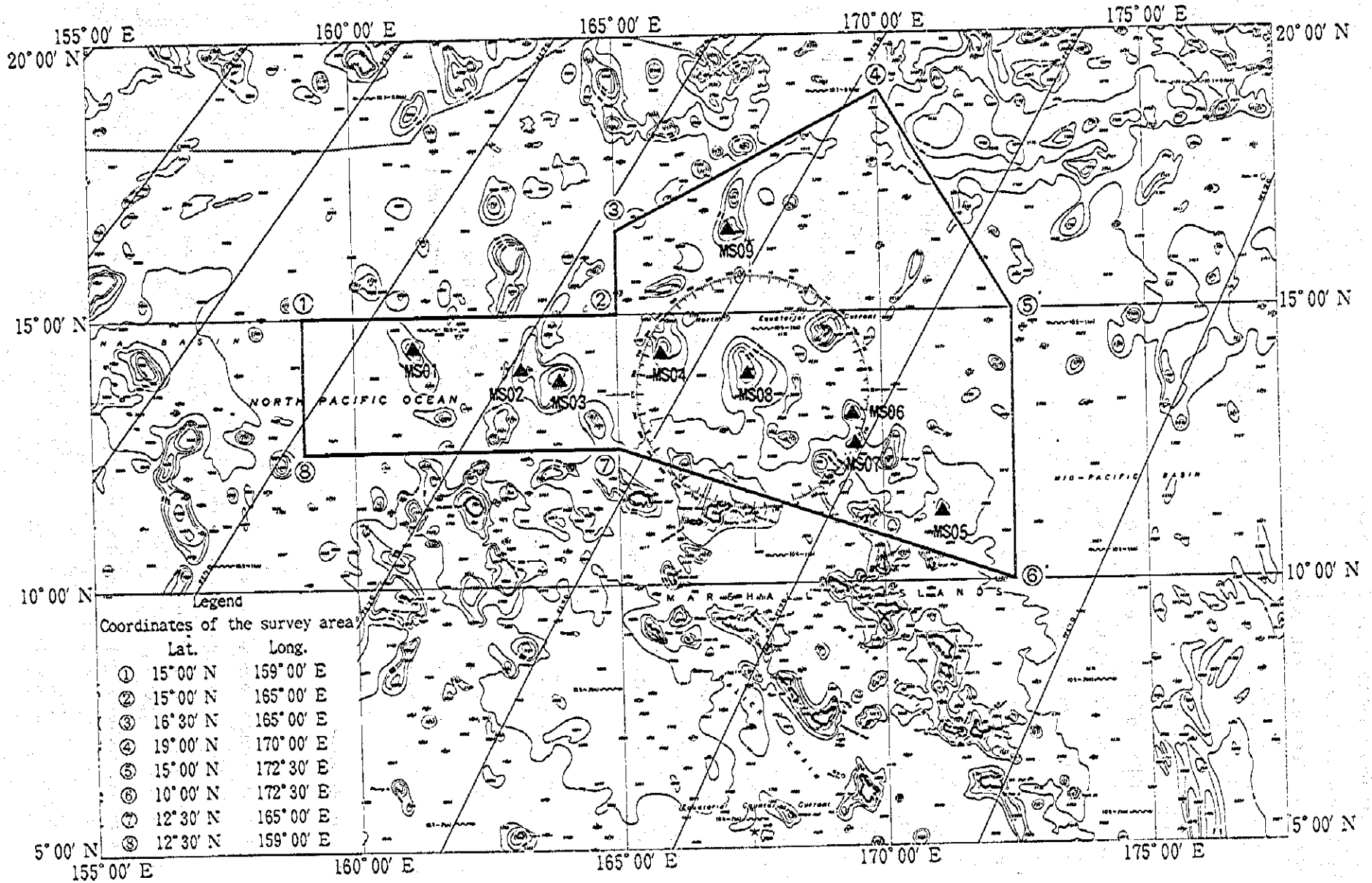


Fig. 2-1-1 Survey planning map

The duration of the survey for each seamount was five to nine days. The operation was planned so that the degree of detail would be approximately the same for all seamounts. Thus the length of the survey was dependent on the size of the seamount and the water depth of the summit.

The details and the amount of the work carried out are as follows.

a. Acoustic sounding

GPS and MBES were used with cruise speed of approximately 10 knots. Line interval of two miles was generally used, but auxiliary lines of one mile interval were used in shallows areas around the seamount summits. Total length of the bathymetric survey line was 5133.8 miles.

b. Sampling

LC and AD were used. LC was used for sampling sediments, confirmation of the manganese crust thickness, and the occurrence of the crust under sediments; while AD was used mainly for confirming the existence of the crust within certain range and for sampling rocks. LC sampling was carried out at four to seven localities mainly on the summit of each seamount, while AD sampling was done mainly on the seamount slopes and partly on the summit. The total number of sampled localities was 41 for LC and 79 for AD.

c. FDC survey

Seafloor observation was carried out over one or two lines on each seamount. A total of 12 lines and 66.5 miles were observed over all seamounts. The FDC lines were designed to mainly observe the flat summit toward the slope.

d. SSS survey

SSS lines were established after considering the results of the bathymetric survey, MBES acoustic intensity map, and the nSBP survey. The objective of this work was to correlate the above data and to clarify the details of the exposed rocks. Also parts of these lines were designed to coincide with the FDC lines to study the zone in detail. Three lines were established with a total length 49 miles over three seamounts.

2–3 Numbering

The numbering system used is as follows.

For sampling points: Year–S–Seamount No.–method–sample No.

Examples: 96SMS01LC01 LC survey

96SMS01AD01 AD survey

S denotes SOPAC, samples numbered sequentially

For SSS survey: Year–S–SSS–No.

Example: 96SSSS01

S denotes SOPAC, lines numbered sequentially

For FDC survey: Year–S–seamount No.–FDC–sample No.

Example: 96SMS01FDC01

S denotes SOPAC, lines numbered sequentially

For acoustic survey: No.–division–a ~ i

Example: 16–0–a

The number denotes that of the main acoustic lines and are numbered consecutively from the north with 2.0 mile interval. Division denotes the number (sequential from 0) of the auxiliary lines where the main survey lines are split. The notation at the end corresponds to the seamount number 01 ~ 09.

2–4 Position Locating

The position of the survey ship was determined by GPS, and that of the towed vehicles was calculated from the water depth measured by the CTD sensor on the vehicle and the cable length.

The coordinate for the measurement was WGS84, the ship time by 180° W local time (UTC+12 hours).

2–5 Bathymetric Survey

The bathymetric survey was designed to clarify the shape of the flat summit and the shallowest parts of the seamounts. The main track line interval was set at 2.0 miles. Auxiliary lines were set between the main lines for shallow (under 2,000 m) zones. It was planned to exclude extremely shallow zones from the survey, but such zones did not exist in the survey area.

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

nSBP data were obtained parallel with the bathymetric survey and a SSS survey line was set for three seamounts. Tow speed was 2 ~ 3 knots, vehicle was towed 100 m above the seafloor and the data were obtained for a width of 1km including both sides.

2-6 Seafloor Observation and Photography

Seafloor was observed by FDC equipment with still and TV cameras, and CTD. The observation lines were set mostly at the peripheries and along the slopes (ridges, valleys) of seamounts. Real time color TV observation was done at about 1 knot tow speed and interesting and distinctive features were photographed in color. The seafloor images were recorded in video tapes. The length of observation lines ranged from 0.7 ~ 6.3 miles, and the tow direction was decided considering the wind and current directions .

2-7 Sampling

LC and AD were used for sampling. The sampling sites were determined mainly on the basis of bathymetry, MBES acoustic reflection intensity map and nSBP results. Also sampling was designed to represent the total seamount by dispersing the sites as well as considering the water depth, slope direction and other relevant factors.

2-8 Sea Water Survey (CTD measurements)

MBES, requires water depth vs. sonic velocity data and thus vertical CTD measurement was carried out at three points. This was done simultaneously with LC sampling. The survey area was largely divided into three latitudinal zones and the measured values at one point in each zone represented the water vs. sonic velocity of that zone.

Water depth was calculated from CTD values on the FDC for positioning the towed vehicle.

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. DPS and personal computers were used. Basic data were processed and analyzed onboard and cruise report was prepared.

Later the present report was prepared on land incorporating the results of various laboratory tests and research work carried out on land. Collected manganese oxides samples were analyzed chemically, by x-ray diffractometry and their mineral composition was determined.

Rock samples were chemically analyzed, studied optically and the mineral composition as well as the textures were determined.

Microfossils were identified for the sediment samples.

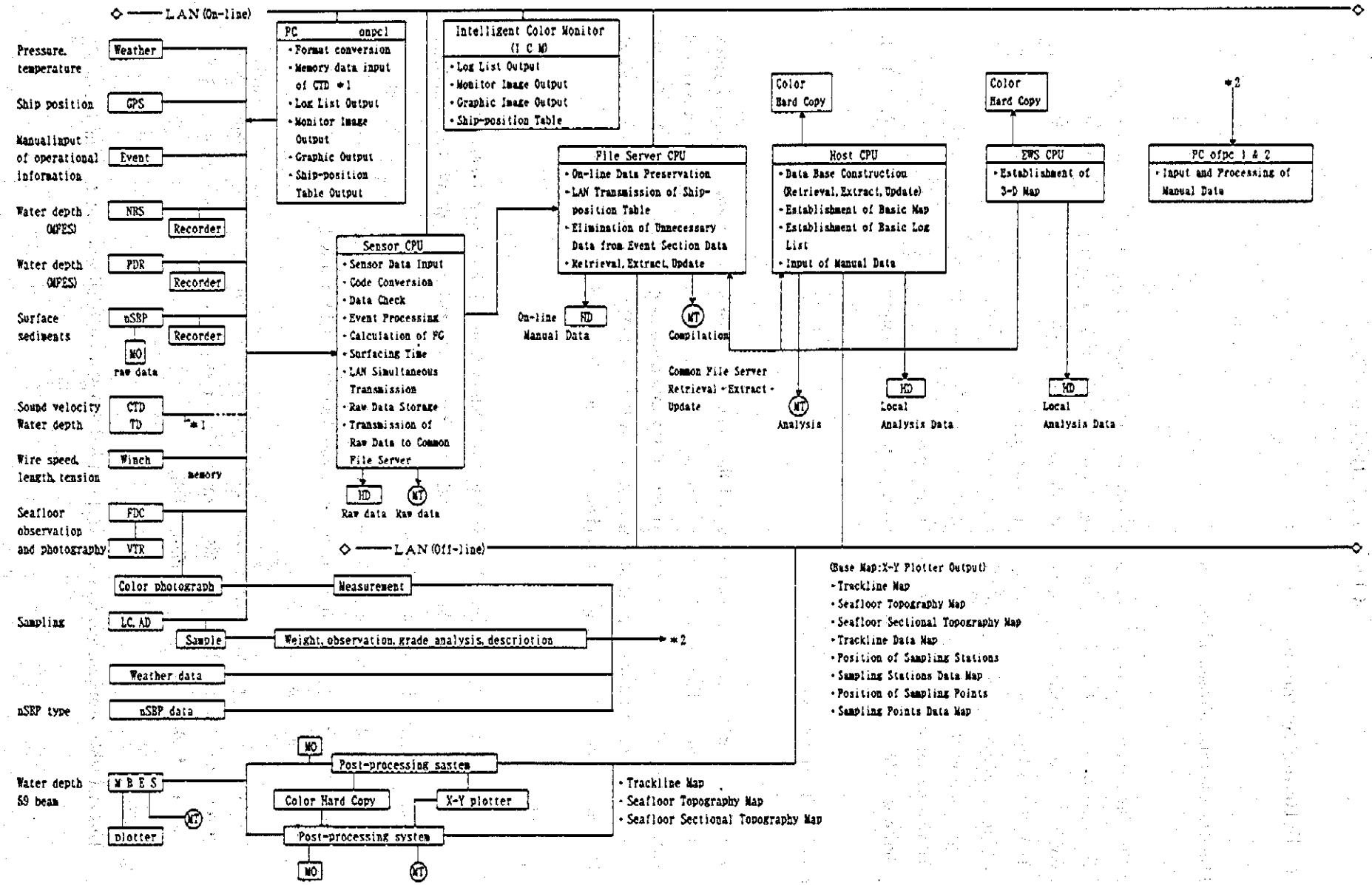


Fig. 2-9-1 Data analysis and processing flowsheet