NO.

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 FIJI ISLANDS

MARCH 2005

JAPAN INTERNATIONAL COOPERATION AGENCY
JAPAN OIL, GAS AND METALS NATIONAL CORPORATION

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PREFACE

In response to a request by the South Pacific Applied Geosience 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 Japan Oil, Gas and Metals National Cooperation (JOGMEC) to execute the survey.

The survey will be undertaken for two terms of three years (a total 6 years) starting from the fiscal year 2000. This is the second year of the Phase 2 of Stage II, and the survey was carried out in the Exclusive Economic Zones of the Republic of the Fiji Islands. The JOGMEC dispatched the Hakurei Maru No.2, a research vessel for investigating deep sea mineral resources, to the survey area for 28 days from December 15, 2004 to January 11, 2005, completing the survey on schedule with the cooperation of the Fiji Government.

The present report sums up the results of this year survey and results of past two years in the Exclusive Economic Zones of the Republic of the Fiji Islands.

We wish to extend our sincere gratitude to all persons concerned, particularly to the staff of the SOPAC Secretariat, Government of the Republic of the Fiji Islands, as well as the Japanese Ministry of Foreign Affairs, the Ministry of Economy, Trade and Industry and the Japanese Embassy in the Republic of the Fiji Island.

February 2005

Japan International Cooperation Agency
Vice President in Charge Tadashi Izawa

Japan Oil, Gas and Metals National Cooperation
President Hidejiro Ohsawa

ABSTRACT

The joint study program for the deep sea mineral resources in the exclusive economic zone (EEZ) of the SOPAC member countries was started in 1985 and the Stage II Phase 2 Program with three years duration of this program was started in 2003. This is the second year of the Stage II Phase 2 program and the survey was conducted in the EEZ of the Republic of the Fiji Islands. In the EEZ of this country, the surveys were conducted in 1999 and 2001 and two areas, Central Hill and ERZ A, were selected to be high potential for hydrothermal mineralization in the survey of 1999. Based on the results of the survey in 1999, the survey of this year, including bathymetric survey, seafloor observation (FDC), samplings (FPG AD), was conducted in the two areas for assessing the potentiality of seafloor hydrothermal mineralization. Further, the environmental survey using RO and MC was carried out as baseline studies of the area to predict the magnitude of mining impact on the deep-sea environment.

The survey of the Central Hill resulted in finding the still active hydrothermal zone, consisting of bluish green and yellow discolored zone accompanied by organisms characterizing hydrothermal activity, distributed over the top of solid intrusive complex of ultramafic and mafic rocks. The active hydrothermal zone, north-south extension of 180m and 30m wide, occurs on west facing slop of north declining ridge. The thin coatings of ferro-oxides, possibly characterizing hydrothermal activity, were observed on the surface of rock samples, however, mounds and chimneys formed by sulfide mineralization were not found. Since temperature anomaly of seawater and distribution of hydrothermal activity related shell fragments were observed in the area surrounding the active hydrothermal zone, the zone of hydrothermal activity, in the past, might have been distributed in much wider area centering the ridge.

The ERZ A, characterized by ridges and graben topography, is overlain by basaltic lavas erupted along the north-south trending extensional relay zone of the North Fiji Fracture Zone. Although yellow and light brown discolored zone with north-south extension of approximately 250m was identified overlapped by temperature anomaly of seawater along the boundary of steep slop and flat terrace, neither organisms characterizing hydrothermal activity nor sulfide mineralization was found

The fundamental information characterizing the environmental features of the areas was obtained by the environmental survey. Some of the characteristic features identified by the survey in the areas are; the vertical temperature profiles with anomalies, the existence of calcium carbonate related to hydrothermal activity and the organisms of chemosynthetic community type.

Since hydrothermal activities of past and present found in the Central Hill and ERZ A by the survey of this year are located in still active North Fiji Fracture Zone and hydrothermal activities associated by sulfide mineralization were recognized in the Triple Junction Area of the Central Spreading Axis by the survey of previous years, further works in the future are recommended to be conducted in the Central Spreading Axis and the North Fiji Fracture Zone of the North Fiji Basin to find new areas of hydrothermal mineralization.

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Chapter 1 Outline of the Survey

1-1 Survey Title

Joint Basic Study for the Development of Mineral Resources in the Exclusive Economic Zone of the Republic of the Fiji Islands, Fiscal Year 2004

1-2 Survey Area

The survey scheme was decided in accordance with the joint study program for deep sea mineral resources in the exclusive economic zone (EEZ) of the SOPAC member countries agreed upon by the Japanese executing agency and the South Pacific Applied Geoscience Commission (SOPAC) on February 27, 2003. Based on this, the survey cruise plan for this year was decided in September, 2004. The survey area is a quadrilateral area (Approximately 2,000 sq.km) within the EEZ of the Republic of the Fiji Islands, enclosing geodesic lines concerning the following coordinates, (Figure 1-1).

	Latitude	Longitude
1	16° 00′ S	177° 15′ E
2	16° 00′ S	177° 35′ E
3	16° 30′ S	177° 35′ E
4	16° 30′ S	177° 15′ E
1	16° 00′ S	177° 15′ E

1-3 The Purpose of the Survey

The purposes of the survey are to assess the potential of seafloor hydrothermal mineralization and to understand environmental characteristics in the Central Hill and the ERZ A, located within the Exclusive Economic Zones of the Republic of the Fiji Islands.

1-4 Duration of the Survey

Survey cruise: December 15, 2004 to January 11, 2005 (28 days including moving and stopping at port, Table 1-1 and Table1-2)

Analysis and other work: April 1, 2004 to March 31, 2005

1-5 Survey Participants

Negotiators for the Agreement
Japanese Participants
Yoshitaka HOSOI (Technical Development Department, JOGMEC)
Hiroyuki YASUNO (Mineral and Natural Resources Division, Agency for Natural Resources and Energy)
Masayoshi KAMEYAMA (Technical Development Department, JOGMEC)
Norihiro YAMAJI (Mining and Industrial Development Cooperation Department, JICA)
Natsumi KAMIYA (Head of JOGMEC Canberra Office)

Consigning Participants
Kodaro GALLEN (The Federated States of Micronesia)
Tania T. TAGICAKIBAU (The Republic of the Fiji Islands)
Bhaskar RAO (The Republic of the Fiji Islands)
Meita BEIABURE (The Republic of Kiribati)
Alfred SIMPSON (Niue)
Alfred SIMPSON (SOPAC Secretariat)
Russell HOWORTH (SOPAC Secretariat)
Cristelle PRATT (SOPAC Secretariat)
Nobuyuki OKAMOTO (SOPAC Secretariat)

Inspectors at the site
Nobuyuki Okamoto (JOGMEC)
Masaaki Sasaki (Ministry of Economy, Trade and Industry)
Natsumi Kamiya (JOGMEC)

SOPAC participants
Bhaskar Rao (SOPAC)
Fijian participants
Wong Hen Loon (Mineral Resources Department of Fiji)

Participants of Field Survey

Naoaki Tomizawa	DORD, Leadr	Matsuo Imai	OED
Nadao Saito	DORD	Yoshikazu Yoshino	OED
Mutsuo Kondo	DORD	Masahiro Hamazaki	OED
Hirotsugu Noguchi	DORD	Yutaka Hashimoto	OED
Kazuyuki Kadoshima	DORD	Noboru Ichinose	OED
Akinori Uchiyama	DORD	Kenichi Ogawa	OED
Tomoki Miyamukai	DORD	Yoshihiro Hatanaka	OED

DORD: Deep Ocean Resources Development Co., Ltd.

OED: Ocean Engineering Development Co., Ltd.

In addition to them, Wong Hen Loon, Mineral Resources Department, Republic of the Fiji Islands, participated to the survey as technical trainee.

The survey cruise was conducted using the R/V No.2 Hakurei Maru, owned by JOGMEC and operated by Captain Morio Endo and other 34 cruise stuffs.

1-6 Survey Apparatus and Equipments

Major apparatus and equipments used during the survey are shown on Table 1-3 and the photographs in Figure 1-2.

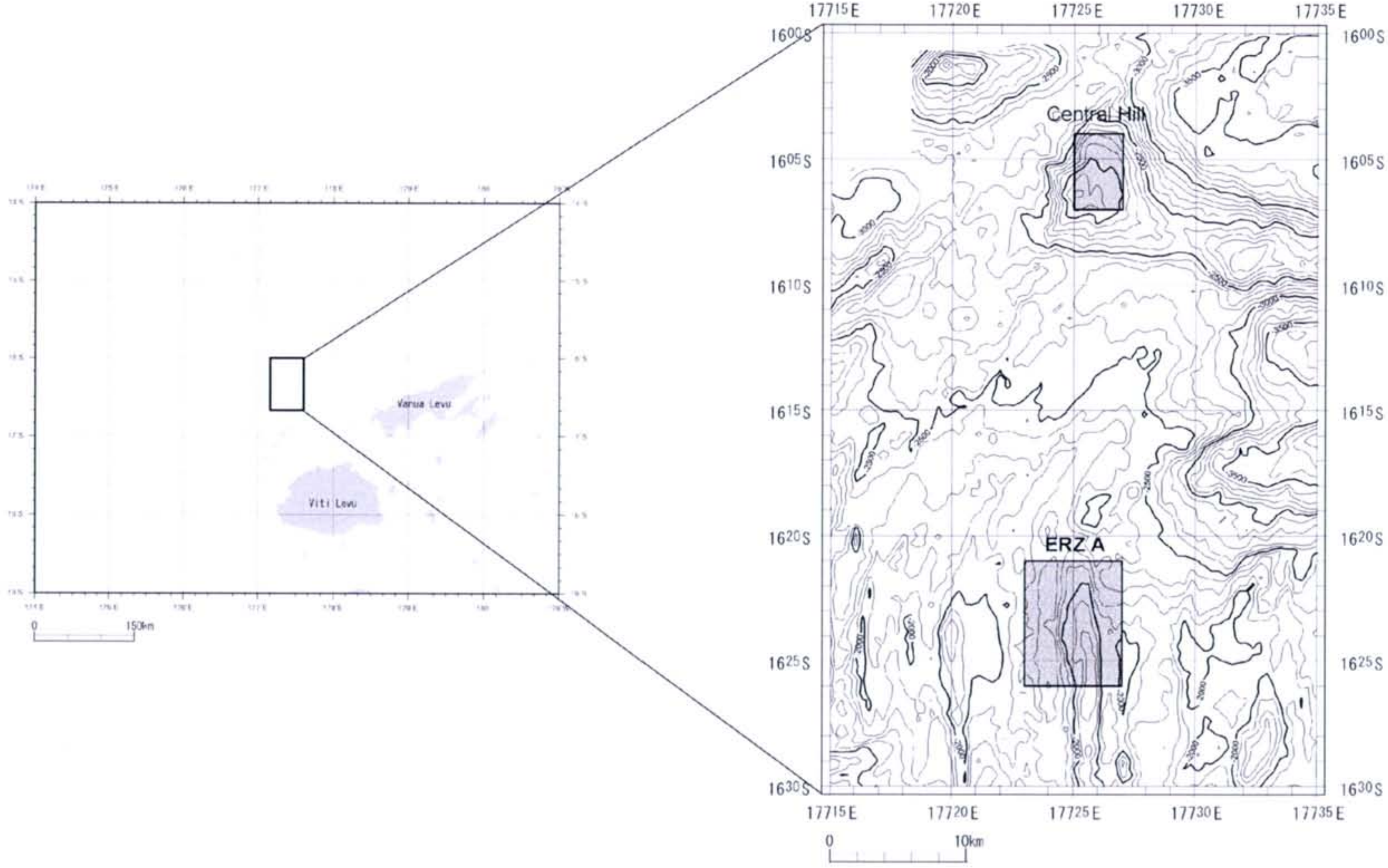


Figure1-1 Location Map of Survey Area

Table1-1 Survey Achievements

Item		Accomplishment		
Survey Schedule	Depart from Majuro	Dec. 17 2004 10:00		
	Arrive at the survey area	Dec. 22 2004 11:22		
	Start the survey	Dec. 22 2004 11:22		
	Finish the survey	Dec. 28 2004 16:40		
	Depart from the survey area	Dec. 28 2004 16:40		
	Arrive at Funabashi base	Jan. 11 2005 10:00		
	Total survey days	7 days		
Survey area		Central Hill	ERZ A (Extensional Relay Zone A)	Total
Sampling	Armed Dradge (AD) Sampling point No.	5	4	9
	Total sample weight (Kg)	406.4	1132.8	1539.2
	Rock samples (Kg)	381.4	1116.2	1497.6
	Others (Kg)	25.0	16.6	41.6
	Finder-installed Power Grab (FPG) Sampling Point No.	3	0	3
	Total sample weight (Kg)	117.9	0	117.9
	Rossette (RO) sampling point No.	1	1	2
	Multi Core (MC) ssampling poins No.	5	0	5
	Total sample weight (kg)	18.5	0.0	18.5
Seafloor obwervation	Finder-insatlled Deep-sea Camera (FDC) survey line No.	6	4	10
	Total survey line length(nM)	4.4	2.7	7.1
	No. of photos.	676	320	996
	No. of image files (Capacity)	6(12.2GB)	4(8.2GB)	10(20.4GB)
CTD	With FDC	6	4	10
	With RO	1	1	2
Batymetric Survey	MBES (15.5 KHz) n.m	470.3		470.3
Data Processing	Map Drawing	Track line map, batymetric map, acoustic pressure map, shade map		

Table1-2 Records of Survey Schedule

Days		Date	Week	Area	Survey Item	Batymetric survey Unit: n.m.
1		Dec. 15 2004	Wed		Anchorge in Majuro	
2		Dec. 16 2004	Thu		Anchorge in Majuro	
3		Dec. 17 2004	Fri		Depart from Majuro (10:00), Moving to the survey area	
4		Dec. 18 2004	Sat		Moving to the survey area, Wrecked ship guard (19:10~24:00)	
5		Dec. 19 2004	Sun		Moving to the survey area	
6		Dec. 20 2004	Mon		Moving to the survey area	
7		Dec. 21 2004	Tue		Moving to the survey area	
8	1	Dec. 22 2004	Wed	C.H.	Arrive to the survey area (C.H.) (11:22)、 Starting survey (11:22) 04SFRO06, 04SFFDC15, 04SFFDC16 RO 1point、FDC 2 survey lines	
9	2	Dec. 23 2004	Thu	C.H.	04SFFDC17, 04SFFDC18, 04SFFDC19, 04SFFDC20 ,04SFMC08 FDC 4 survey lines、MC 1 survey lines (C.H.)	88.7
10	3	Dec. 24 2004	Fri	ERZ A	04SFRO07, 04SFFDC21, 04SFFDC22 ,04SFFDC23,04SFFDC24 RO 1 point (C.H.)、FDC 3 survey lines	73.1
11	4	Dec. 25 2004	Sat	C.H.	04SFMC09,04SFMC10,04SFMC11,04SFFPG01,04SFFPG02 MC 3 points、FPG 2 points	76.9
12	5	Dec. 26 2004	Sun	C.H.	04SFFPG03,04SFMC12,04SFAD01 FPG 1 point、MC 1 point、AD 3 points	77.0
13	6	Dec. 27 2004	Mon	ERZ A	04SFAD02, 04SFAD03, 04SFAD04,04SFAD05 AD 4 points	114.2
14	7	Dec. 28 2004	Tue	C.H.	04SFAD06,04SFAD07 ,04SFAD08,04SFAD09 AD 4 points Finishing the survey (16:39)、Depart from the survey area (ERZ A) (16:40)	40.4
15		Dec. 29 2004	Wed		Moving to Funabashi base	
16		Dec. 30 2004	Thu		Moving to Funabashi base	
17		Dec. 31 2004	Fri		Moving to Funabashi base	
18		Jan. 1 2005	Sat		Moving to Funabashi base	
19		Jan. 2 2005	Sun		Moving to Funabashi base	
20		Jan. 3 2005	Mon		Moving to Funabashi base	
21		Jan. 4 2005	Tue		Moving to Funabashi base	
22		Jan. 5 2005	Wed		Moving to Funabashi base	
23		Jan. 6 2005	Thu		Moving to Funabashi base	
24		Jan. 7 2005	Fri		Moving to Funabashi base	
25		Jan. 8 2005	Sat		Moving to Funabashi base	
26		Jan. 9 2005	Sun		Moving to Funabashi base	
27		Jan. 10 2005	Mon		Moving to Funabashi base	
28		Jan. 11 2005	Tue		Arrive to Funabashi base (10:00)	

C.H.: *Central Hill*, ERZ A: *Extensional Relay Zone A*

Rmks:Date and time is in local time.

Total 470.3 n.m

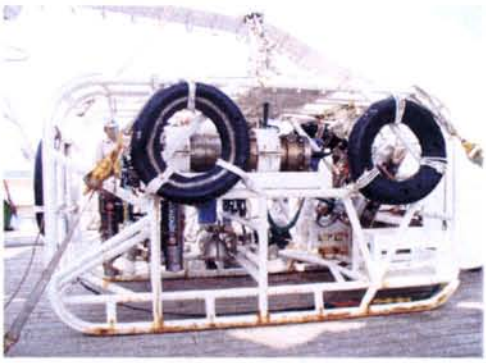
Table1-3 Survey Apparatus and Equipments

Category	Survey Method		Survey Apparatus and System	Abbreviation	Remarks
Positioning	Satellite Navigation		Global Positioning System GPS+GLONASS	GPS	
Sea Bottom Topography and Geological Survey	Acoustic Survey	Acoustic Sounding Bathymetry	Multi-narrow Beam Echo Sounder Narrow Beam Echo Sounder	MBES NBS	
		Subsurface Geological Structure	Narrow Beam Sub-Bottom Profiler	nSBP	
	Magnetic Survey		Proton Gradio Meter	PGM	Toward Type
	Seawater Survey		Conductivity, Temperature and Pressure Measuring System	CTD	
	Light Transmission Survey		Transmission meter	TR	
	Sampling		Multi Corer	MC	
			Rosette sampling	RO	
			Large Gravity Corer	LC	
			Benthic Multicoring System	BMS	Drilling Machine
Sea Floor Observation	Photograph		Deep Sea Camera		with LC or MC
Data Recording and Processing	On-line Functions		Data Processing System	DPS	
	Date Storage Functions		Sensor CPU		
	Off-Line Functions		File Server CPU		
	↓		Host CPU		
	Track Line Maps etc.,		EWSCPU		
	Data Analysis		LAN, PC, ICM		

FPG
(Finder-installed Power Grab)

AD (Arm Dredge)

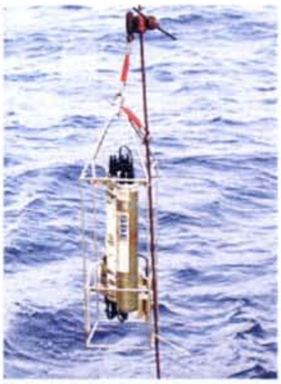
RO (Rosette Sampler)



FDC (Finder-installed Deep-sea Camera)

MC (Multi Corer)

Pinger



CTD (Conductivity Tempurature and Depth Profiling System)

Figure1-2 Photographs of Survey Equipment

Chapter 2 Survey Methods

2-1 Survey Plan

The joint study program for the deep sea mineral resources in the exclusive economic zone (EEZ) of the SOPAC member countries was started in 1985. The survey scheme of Stage II, Phase 2 of the joint study program was agreed between Japanese executing agency and SOPAC in February 2003. It is the second year of the program and according to its Scope of Work, the survey of this year (2004) was conducted in the EEZ of the Republic of Fiji Islands.

In the EEZ of the Republic of the Fiji Island, surveys including bathymetric survey, magnetic survey, seafloor observation (FDC), samplings (LC, AD, BMS) were conducted for assessing the potentiality of seafloor hydrothermal mineralization in 1999. Based on the survey, two areas, Central Hill and ERZ A, were selected to be high potential for hydrothermal mineralization. Also the survey was carried out in the Tipple Junction area for known ore showings and deposit in 2001. For this reason, Japanese executing agency, SOPAC and the Mineral Resources Department of Fiji decided, on September 2004, to conduct the survey of 2004 in the Central Hill and the ERZ A for assessing the potentiality of hydrothermal mineralization and understanding the environmental impact in the area of hydrothermal activity.

2-2 Positioning of the Vessel

Since determining the precise location of the vessel and sampling site is key factor for seafloor mineral resources project, three GPSs (Global Positioning System), each of which is equipped at different site of the vessel, are installed on the R/V No.2 Hakurei-maru. For positioning of the vessel, the GPS installed on the bridge is used. While, for drawing track lines of FDC during towing, the position of the FDC was obtained based on the GPS at the stern of the vessel, calculated by Pythagorean theorem from the water depth measured by the acoustic sounding and the cable length, under the assumption that the FDC was located directly behind the vessel. The positions of the RO and MC sampling sites were obtained using the GPS installed near starboard crane at the time of the sampler reaching the see bottom and the water depth was obtained from the acoustic sounding.

The geodetic coordinates used for the positioning were WGS84. For recording various events of survey equipments, GMT was used.

2-3 Bathymetric Surveys (MBES)

Bathymetrical survey was carried out over E-W directed parallel track lines of

1nm intervals with vessel speed of 10~12 knots, and sounding by MBES was made every 8~12 seconds.

2-4 Seafloor Observations (FDC)

For the purposes of investigating geological situation and searching for mineral showings, seafloor observation was conducted towing FDC (Finder-installed Deep-sea Camera). All along the track lines, TV images were recorded by digital video recorder and stills of the seafloor were taken.

2-5 Sampling (AD, FPG)

The samplings, either by AD or FPG, were conducted by optimal way of most certain and efficient considering the weather and sea state.

2-6 Numbering of Survey Lines and Samples

Numbering system for sampling sites and track lines are as follows.

The numbers start from two digits of the year (e.g. Year 2004 is shown as 04) and SF (S and F, respectively, denote SOPAC and Fiji.) and followed by used equipments and number of sampling site or FDC track line. The sampling site and FDC track line are numbered sequentially from the previous years.

Sampling site: 04SFAD01 (AD sampling)
04SFFPG01 (FPG sampling)

FDC track line: 04SFFDC15 (The last number of the FDC line in the previous year was 14.)

Track line of Bathymetric survey: starting from 04S and followed by degree and minute of latitude of track line.

2-7 Laboratory Work

For further investigation of collected samples, various laboratory works, such as bulk chemical analyses of rock, ore assaying, chemical analyses of sediments, polish thin section studies, chemical analyses of minerals, X-ray diffraction analyses and fossil identification, were conducted (Table2-1).

2-8 Processing and Analyses of Survey Data

The processing and analysis of the acoustic survey data were carried out mainly through on-line functions and off-line functions of the data recording and processing device on board as shown in Figure 2-1. A part of the data processing and comprehensive analysis were done after the cruise.

2-9 Environmental Survey

The environmental survey, consisting of seawater sampling by RO and bottom sediments sampling by MC, was conducted as a baseline study of the area to predict the magnitude of mining impacts on the deep-sea environment.

Table2-1 The Samples of Laboratory Work

Sea Area	Sampling Poins	Water Depth (m)	Water Depth Sample Sub-No.	Geology	Sample Number: Whole rock analysis	K-Ar age	XRD	Analysis of ore elements	Organism identification	Analysis of sediments	Fossil identification	Observation of thin section	Model acounts	EPMA	Remarks
Central Hill	04SFFPG01	1,971		White vein cutting serpentinite			XRD01								
				Black colored serpentinite				CR01				2 pieces			
				Yellow colored serpentinite				CR02							
				Benthic roganism					MC01						
	04SFFPG02	1,967		Benthic roganism					MC01			1 pieces			
	04SFFPG03	1,968		Serpentinite with white aaltered veinlet				CR01				4 pieces	1 spls.	2 spls.	
				Conglomerate with reddish coating				CR02							
				Blue-gray clay on serpentinite				CR03							
				Black dolored altered part of serpentinite			XRD01								
				Black materials on serpentinite			XRD02								
				Clastic sandy clay			XRD03								
				Light blue-gray colored clay			XRD04								
				Pebble in light blue-gray colored clay			XRD05								
				Reddish brown colored sediments			XRD06								
				White niddle-like crystall in vug			XRD07								
				Benthic organism					MC01						
	04SFAD01	2,000 →1,961		Benthic organism					MC01			1 pieces			
	04SFAD07	1,910 →1,784		Dunite, wehrlite, clinopyroxenite, gabbro								47 pieces	9 spls.	20 spls.	
	04SFMC11	1,946	0.00	Black and white colored sediments			XRD01								
			0.10 ~0.18	Foraminifera sand							FS01				
			0.10 ~0.15	Foraminifera sand						CS01					
			0.15 ~0.18	Foraminifera sand			XRD02			CS02					XRD02 : black clastics
ERZ A	04SFAD02	1,956 →1,803		Greenish altered part of lava flow			XRD01								
			C3	Glassy part of basaltic lava flow surface	CA01	KR01						TS01			
			C5	Chilled margin of pillow basalt	CA02							TS02			
			C10	Altered basalt			XRD01								Marginal part of conglomerate
							XRD02								Fiber type part
							XRD03								Marginal part of rock
			C11	Alterd basalt			XRD04								Fiber type part
							XRD05								Irregular fiber part
	04SFAD03	1,954 →1,801	C5	Small pillow lava	CA01	KR01						TS01			
			C6	Surface part of lava flow	CA02							TS02			
	04SFAD04	1,941 →1,925		Benthic organism					MC01						
			C1	Fragment of hyaloclastite	CA01							TS01			
			C3	A part of pillow lava	CA02	KR01						TS02			
	04SFAD05	2,072 →1,955	C2	Fragment of hyaloclastite	CA01	KR01						TS01			
			C5	A part of pillow lava	CA02							TS02			
Total No. of Xamples					8	4	16	5	5	2	1	63	10	22	

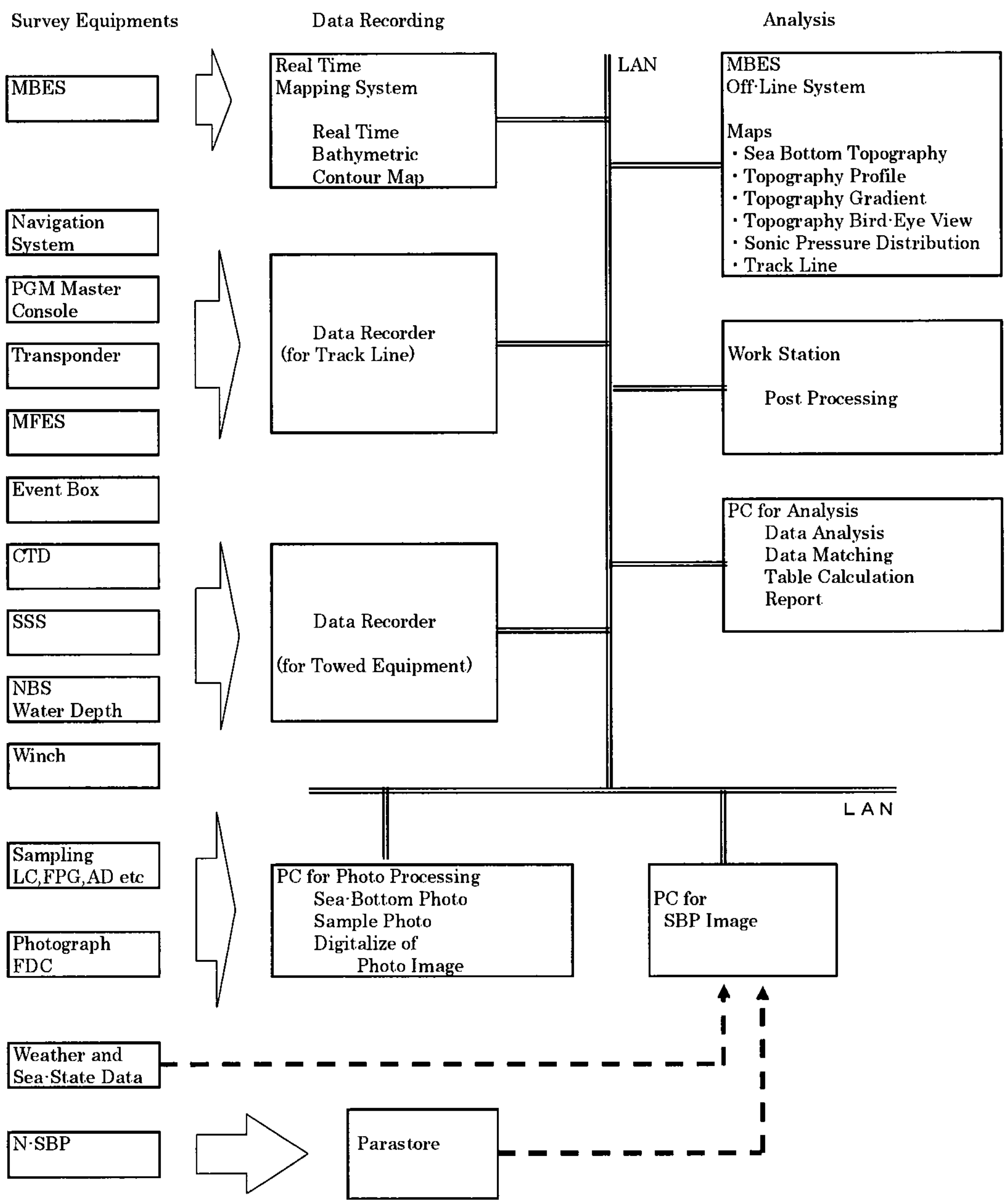


Figure2-1 Flow of Data Processing and Analysis

Chapter 3 Survey Results

3-1 Outline of the Survey Area

3-1-1 Topography

The survey area, including Central Hill and ERZ A (Extensional Relay Zone A), is located in the eastern part of the North Fiji Basin, and it shows complicated seafloor topography reflecting the geological structure. The Central Hill is a knoll with summit of 1,800m deep, located immediately north of east-west trending North Fiji Fracture Zone (NFFZ). The ERZ A, with the highest point of 1,800m deep, is north-south trending part of east-west trending NFFZ, and shows north-south trending ridge and valley topography reflecting spreading axis. The Central Hill is located at northern extension of ERZ A (Figure3-1-2).

3-1-2 Geology and Geological Structure

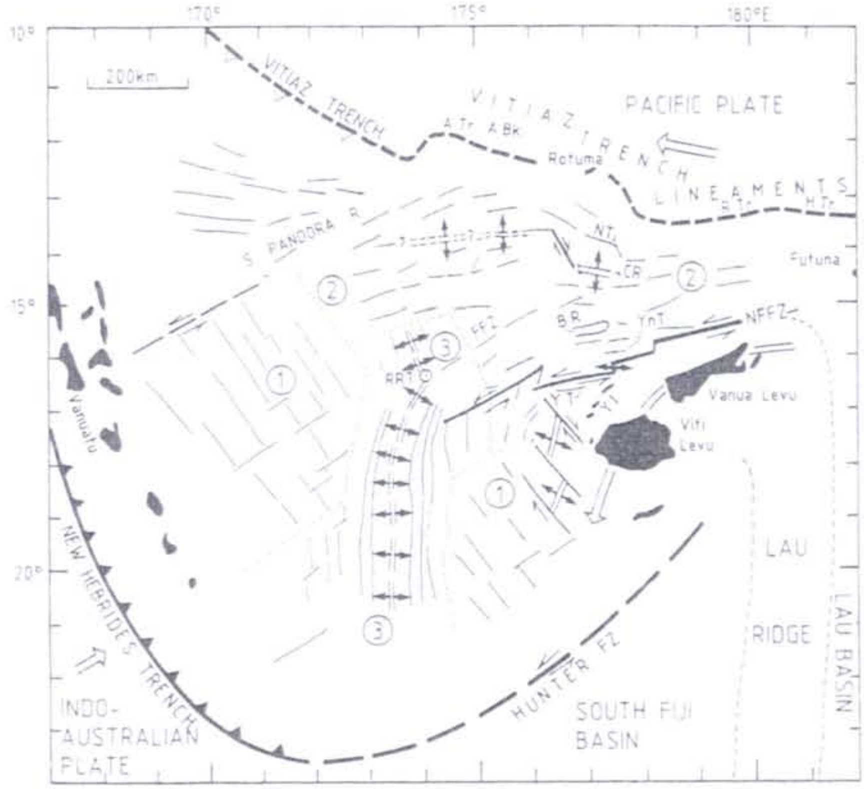
The North Fiji Basin, in where survey area is located, is back-arc basin, bounded by Vitiaz Trench to the north, Vanuatu arc to the west and Hunter Fracture Zone to the south, and it is characterized by high heat flow, relatively thin oceanic crust, shallow water depth (approximately 3,000m) and thin overlying sediments.

The rifting of the North Fiji Basin was initiated at 12Ma by the splitting of the Vitiaz-New Hebrides-Fiji-Lau-Tonga arcs. After the rifting, spreading along a NW-SE direction continued synchronous with the clockwise rotations of the New Hebrides arc and the anticlockwise rotation of the Fiji Platform. The outline of the fan-shaped North Fiji Basin was formed during this period. The NW-SE spreading axis stopped at 7Ma and was replaced by an E-W trending spreading center from the northwestern tip of the basin to the north of the Fiji Platform. Around 3Ma, a triple junction was active between the E-W axis and the newly created N-S trending spreading center. Around 1.5Ma the opening along the E-W axis was reorganized by the development of the North Fiji Fracture Zone along the Fiji Platform up to N-S spreading axis, creating the Triple Junction.

The North Fiji Fracture Zone became more active after 0.7Ma and its dislocation was estimated to be 9.5cm/a. Although it is, essentially, east-west trending, left lateral fault, it has topographic features characterized by north-south trending ridge and trough of 9 to 18km long near the latitude of 16.25S These zones are explained by "leaky transform fault or extensional relay zone" within the east-west trending North Fiji Fracture Zone and are accompanied by spreading axis with eruption of fresh N-MORB and Back Arc Basin Basalt. Minor sulfide mineralization is rarely observed in these basalts (Stackelberg and Rad, 1990).

3-1-3. Seafloor Hydrothermal Activities

Spreading axes of different ages, such as 10-3Ma and 0.7-0Ma, exist in the North Fiji Basin and extensive hydrothermal activities with sulfides mineralization are observed at the Triple Junction Area, however, within the survey area minor mineralization and alteration were observed only in ERZ A. Other than this, occurrences of manganese oxides crust of hydrothermal origin were reported on the inactive ridge. Since this crust is covered by hydrogenous manganese oxides, the formation of this hydrothermal crust seems to be not recent (Stackelberg and Rad, 1990).



After Stackelberg and Rad (1990)

Spreading center : ①=10-3 Ma, ②=3-0.7 Ma, ③=0.7-0 Ma
NFFZ : North Fiji Fracture Zone
RRT : Triple junction

Figure3-1-1 Geological Structure of the North Fiji Basin

3-1-4 Results of Previous Surveys

The surveys previously conducted in the area of this project are Sonne Cruise SO-35, Leg3 (1990) and JICA/MMAJ (1999). The Sonne Cruise SO-35 revealed topographic and geological features of the area by bathymetric survey, magnetic survey, seafloor observation by stills and dredging. The basalt with minor sulfides mineralization was obtained in the ERZ A by this cruise. While, JICA/MMAJ (1999) conducted acoustic sounding surveys including MBES and magnetic survey (PGM) over the area of 17,000 sq.km including survey area of this project, and based on geological and magnetic structures Central Hill and ERZ A were extracted as areas of high potential for hydrothermal mineralization. This was furthered convinced by subsequently conducted seafloor observation (FDC) and samplings (LC, CB and BMS).

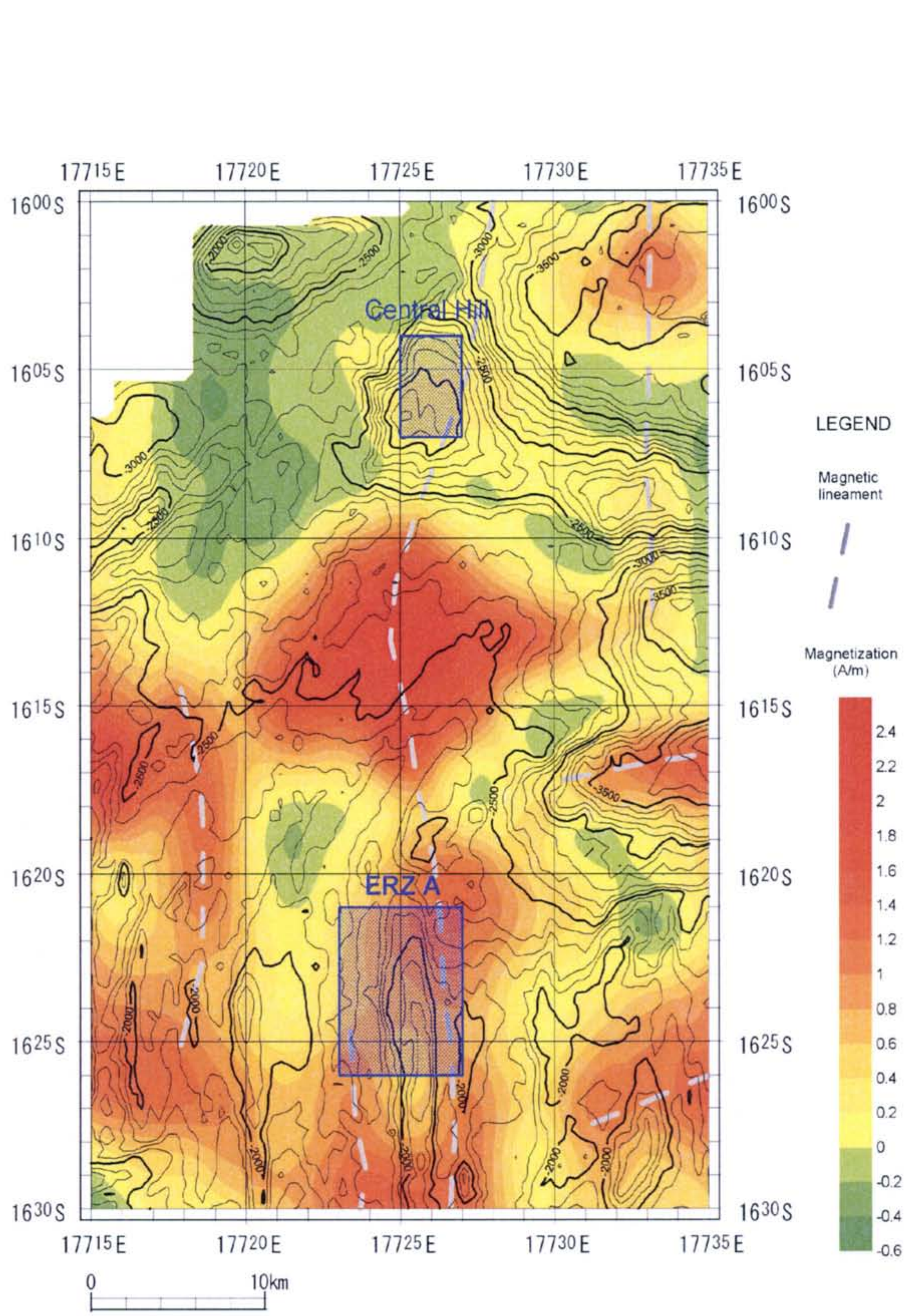


Figure3-1-2 Bathymetry and Magnetic Structure of the Survey Area

3-2 The Central Hill

3-2-1 Results of Previous Surveys

The Central Hill is a knoll with summit of 1,800m deep, located at 16-06S and 177-26E, 35km direct north from the ERZ A. From topographic feature of N-S trending crevice with occurrences of topographic high (similar appearance to hydrothermal mound) on the summit and existence of magnetic lineament extending north from ERZ A in the valley, the summit area of the Central Hill was considered to be potential area for hydrothermal mineralization and FDC, CB and LC were conducted during the JICA/MMAJ project of 1999. As the results of this survey, accumulation of white bivalve fragments over an area of 300m x 300m, discoloring of rock and sediments, a protrusion shape like chimney and water temperature anomaly were observed, and, further, sediments including pyrite were collected by BMS.

3-2-2 Results of Year 2004 Survey

This survey was conducted in the area covering the distributions of bivalve accumulation, discoloring of rocks and sediments, water temperature anomaly found in 1999 for the purpose of assessing the potential of hydrothermal mineralization and understanding the environmental impact in the area of hydrothermal activities. At first, FDC was conducted to know geological situation and to find the area of hydrothermal mineralization, then, samplings by FPG and AD were conducted to specify the area of hydrothermal mineralization and to characterize the mineralization. Further, seawater and bottom sediments were collected by RO and MC for baseline studies of the area to predict the magnitude of mining impact on the deep-sea environment (Figure 3-2-1).

(1) FDC Survey (Fugure3-2-2, Appendices 2-4)

1) 04SF FDC15

The track line of the FDC was planed to confirm the eastern extension of the area of bivalve distribution and anomaly of seawater temperature found in 1999, however, actual track line was sifted toward south and, consequently, the track line passed through southern extension of the area. Although fragments of bivalve were observed on this track line, discolored area indicating hydrothermal mineralization was not observed.

2) 04SF FDC16

The track line was set approximately 350m north of and parallel to FDC15 to confirm northern extension of bivalve distribution and seawater temperature anomaly found in 1999. Although fragments of bivalve were observed on this track line, discolored area indicating hydrothermal mineralization was not observed.

The results of FDC15 and 16 suggest that the area of hydrothermal mineralization does not exceed northward and southward beyond these lines and it is distributed in the limited area between these lines. Therefore, line of FDC17 was set in the middle of FDC15 and FDC16.

3) 04SF FDC17

North-south trending discolored zone (including distribution of discolored seabed to bluish green and yellow, fragments of bivalve and protrusions with adhesions) was observed mainly in bedrock exposed area on the west-facing slope, and, then, it disappeared in the flat top area covered by unconsolidated sediments. The discolored zone seems to be distributed covering the seabed from the valley to the top of slop.

Base on the results of FDC17, the track line of FDC18 was set to confirm northern extension of the discolored zone.

4) 04SFFDC18

Same as FDC17, discolored zone with discolored seabed and fragments of bivalve was observed covering the seabed from the foot of the slop to flat area of the top..

Since the distribution and discoloring of the discolored zone on FDC18 were less compared with these on FDC17, the more intensive discolored zone seemed to be not expected in the area further north beyond FDC18. In addition to this, only fragments of bivalve were observed on track line FDC16 located further north. From these evidences, the discolored zone was considered to be diminishing toward north from FDC18. The track line FDC19 was set between FDC17 and FDC18 to find predominant discolored zone.

5) 04SF FDC19

Same as FDC17, discolored zone with discolored seabed and fragments of bivalve was observed covering the seabed from the valley, passing through foot of the slop, to flat area of the top. Furthermore on the track line FDC19, the habitation of biocommunities characterizing hydrothermal activities, such as deep-sea mussel *(Bathymodiolus)* and *Galatheidae* were observed in the discolored zone and protrusions covered by adhesions were found on the most upper part of the slop.

Discolored zones including fragments of bivalve, discolored seabed and biocommunities characterizing hydrothermal activity were observed on three FDC lines of FDC17, 18 and 19. Among them, the most intensive discolored zone with habitation of deep-sea mussel and *Galatheidae* was observed on track line FDC19, suggesting the most active zone of hydrothermal activity. The hydrothermal activity is, possibly, still on-going in the area. Since, from these FDC lines, it was clarified that the discolored zone was distributed on north-south trend, FDC20 line was set to traverse the discolored zone in north-south direction.

6) 04SF FDC20

Going up from north to south, the FDC passed immediate west of the north-south trending discolored zone, and, then, as the FDC proceed to south, it gradually approached to the discolored zone. After passing through the discolored zone with discolored seabed and fragments of bivalve along the slops of ups and downs, it reached to flat area of unconsolidated sediments.

7) Summary of FDC Survey

As the results of 6 track lines (a total of 4.4nm) of FDC survey, the distribution and characteristic of the discolored zone found in the 1999 survey were clarified, and the locations of samplings were decided.

It is clarified that the discolored zone of the Central Hill was distributed over the area on slops of the north-south trending small ridge. The discolored zone was observed starting from the foot of the slop, all through the slop and to the top of the hill. The north-south extension of the discolored zone is estimated to be approximately 180m assuming possible extensions beyond the FDC17 and FDC19 interval of 95m. The east-west extension of the discolored zone was estimated to be approximately 30m from FDC17, 18 and19. Further, fragments of bivalve were distributed on unconsolidated sediments and exposed rock in the surrounding area of the discolored zone, and temperature anomalies of seawater were extensively observed along the FDC lines.

(2) Sampling by FPG and AD

Based on the results of seafloor observation, FPG sampling at 3 sites and AD sampling at 2 sites were conducted to collect typical samples of the discolored zone. In addition to them, AD sampling at 2 sites were conducted to collect the basements rock to understand the geological nature of the Central Hill (Figure 3-2-1 and Appendices 2 and 3).

FPG sampling

1) 04SF FPG01

The target of the FGP01 was set at the point where most intensive discoloring was observed, possibly most active point, within the discolored zone along the FDC19 line, and the sampling was conducted after searching for the point where sampling was possible. The sampling site was located on the middle slop of the discolored zone where bedrock was discolored to yellow and brown, and inhabitants of bivalves and shrimps were commonly observed. The collected samples, a total of 85.2kg, mainly consist of deep-sea mussel and serpentinized ultramafic rocks with abundant cracks. The surface of ultramafic rocks is black and partly yellowish brown. White veins were observed, but sulfides were not identified by naked eye.

2) 04SF FPG02

Sampling was conducted at the site showing similar appearance to FGP01 site, located in the south part of the discolored zone on FDC19 line. Collected samples, a total of 232.7kg, consist of mainly rocks samples with minor amount of organism such as shells. The rock samples are dark gray, serpentinized ultramafic rocks with milky white thin veins. No visible sulfide was found in the rock samples.

3) 04SF FPG03

The areas with smooth surface covered by adhesions and protrusions with smooth surface covered by adhesions are observed on the rise near the top of the ridge on the FDC19 line. The sampling of FPG03 was conducted targeting these areas. Collected samples, a total of 800kg, mainly consist of ultarmafic rocks and chimney-like protrusion. Black manganese oxides and reddish brown iron oxides materials of approximately 1mm thick coat the ultramafic rocks, and inside of the coating they are yellowish brown and sepentinized. The chimney-like protrusion was identified to be columnar shaped outcrop consists of ultramafic rocks with columnar joint and the surface of it showed smooth appearance because of thin coverage by iron oxides and black materials. No visible sulfide was found in the ultramafic rocks.

AD Sampling

1) 04SF AD01

The dredging was conducted from northwest to southeast to cut north-south trending discolored zone obliquely. The collected samples, a total of 24.4kg, mainly consist of pebble size fragments of gabbro.

2) 04SF AD06

The dredging was conducted beneath the ridge of the western part of the discolored zone to collect the basement rocks to understand the geological nature of the Central Hill. A total of 113.4kg rock samples, consisting of gabbro and basalt, were collected.

3) 04SF AD07

The dredge of AD7 was conducted on the same ridge slightly above AD06 to collect the basement rocks of the Central Hill. A total of 232.4kg rock samples consisting of gabbro and serpentinite was collected.

4) 04SF AD08

The dredging was conducted around northern end of the discolored zone. Conglomerate, partly coated by manganese oxides, was collected. Total weight of sample was 26.9kg.

5) 04SF AD09

The dredge AD09 was conducted around southern end of the discolored zone. Green schist and pumice with black coating, a total of 6.8kg, were collected.

(3) Summary on FPG and AD Sampling

Since it is possible to conduct sampling simultaneously observing seafloor by TV monitor, the sampling by FPG was efficiently conducted and target samples were collected. While, AD sampling was suitable for hard bedrock and rock fragments, however, it seemed to be not suitable for collecting products of hydrothermal activities in the discolored zone.

3-2-3 Results of Laboratory Work

For the purposes of characterizing the basement rocks and hydrothermal mineralization, laboratory works, such as microscopic observation of thin sections, chemical analyses of minerals, mode counting, x-ray diffraction analyses, ore analyses and identification of biocommunities etc., were conducted (Table 2-1, Appendices 5 and 6).

The results of petrologic studies, including microscopic observation of 55 thin sections, mineral chemistry of 22 analyses, mode counting for 10 sections, showed that the basement rock collected in the Central Hill were strongly serpentinized ultramafic rocks and mafic rocks essentially consisting of olivine and clinopyroxene with minor chromspinel, namely dunite-wehrlite–clinopyroxenite-gabbro. The layer structures observed in the hand specimens and thin sections of the ultramafic rocks suggest that these samples once formed certain part of a layered complex. While, homogeneous dunites, showing slightly different characteristics from these samples, were, also, included in the samples of ultramafic rocks. The gabbros, in many cases, show occurrences of network veins injected into the ultramafic rocks. The mineral chemistries, particularly Cr/(Cr+Al) atomic ratio, imply that basement rocks forming the Central Hill were originated from island arc setting, not from mid-oceanic ridge setting.

The X-ray diffraction analyses carried out for 10 samples of altered part occurring on the surface of and in the cracks of the basement rocks show clay minerals mainly consists of serpentine and carbonates, and pyrite was found in one sample.

The results of ore analyses conducted for 5 samples of the basement rocks show Ni and Cr contents of nearly 0.15% and approximately 0.4%, respectively. Other than these, Pt7-24ppb, Co less than 0.01%, and Au less than detection limit were obtained. Cu, Pb and Zn are less than 0.01%. The unconsolidated sediments collected near the discolored zone by MC have few ppb of Pt and Co, below detection limit of Au and few tens of ppm of Ni, Cr, Cu, Pb and Zn. The organisms found in the discolored zone were identified to be type of chemosynthetic community.

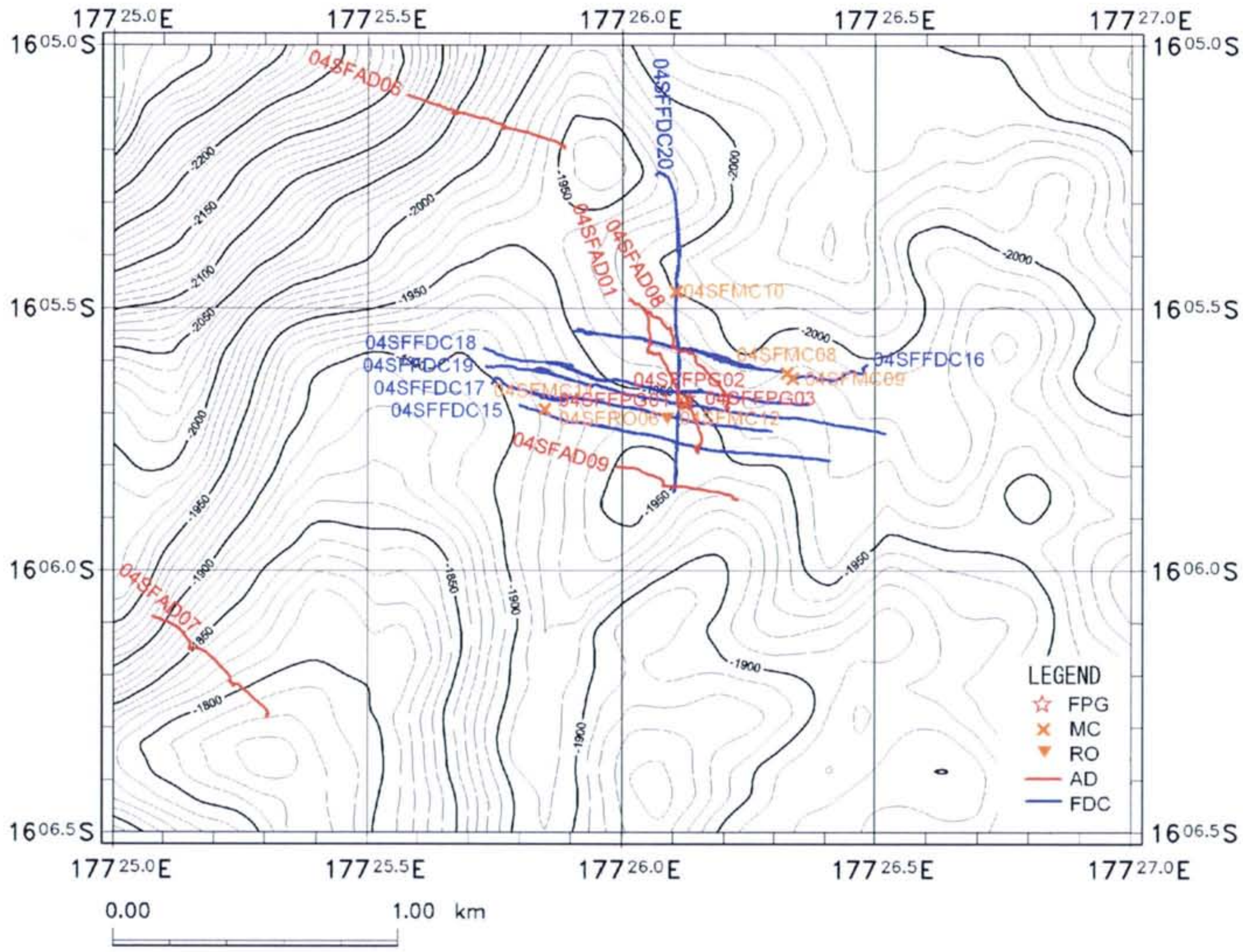


Figure3-2-1 Bathymetric Map and Locations of Sampling and Survey of Central Hill

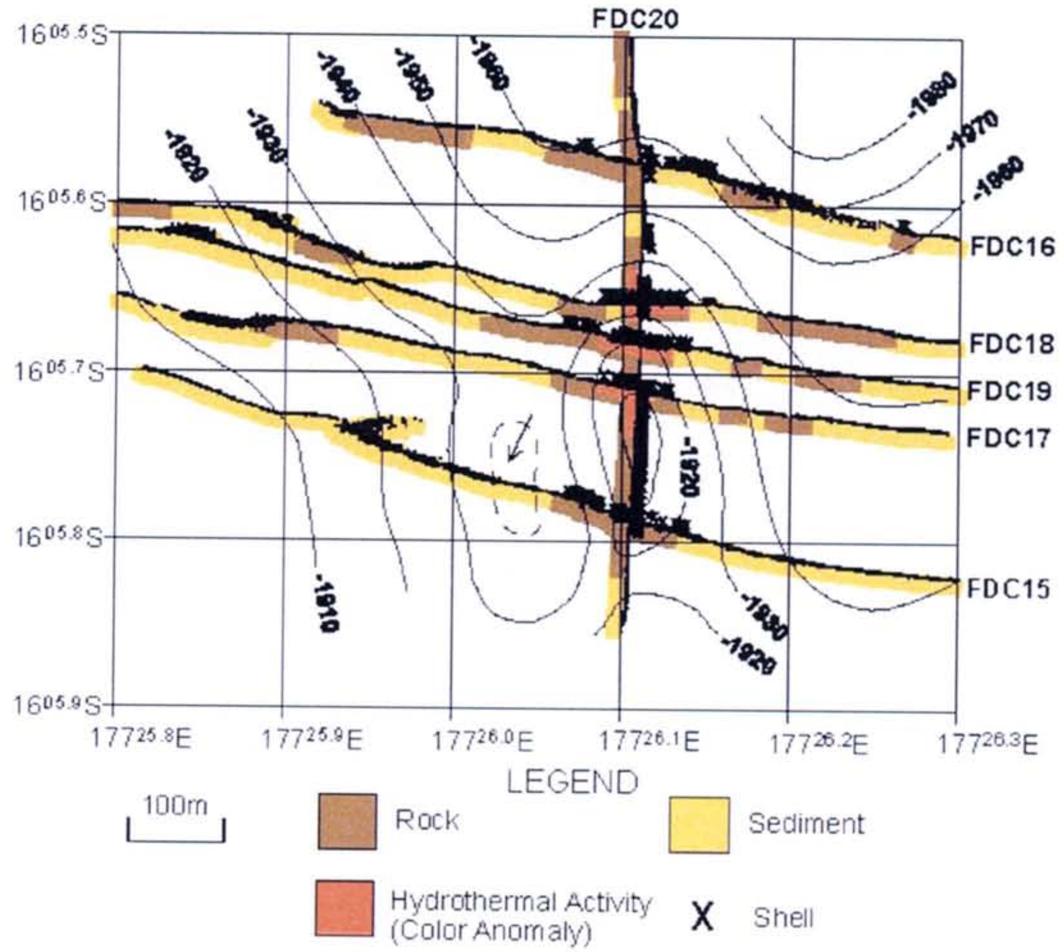


Figure3-2-2 The Results of Seafloor Observation by FDC in Central Hill

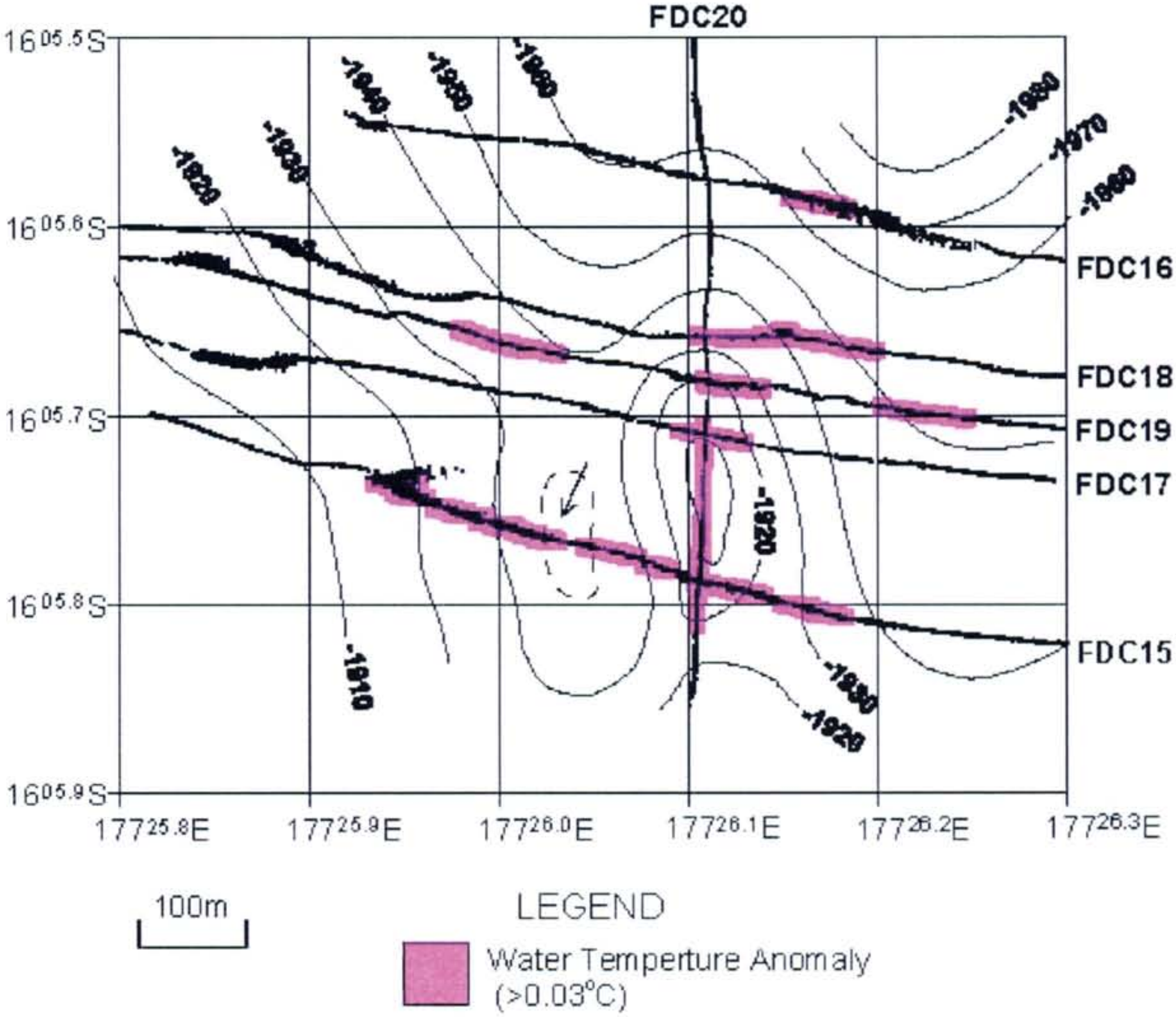


Figure3-2-3 Temperature Anomaly Map of the Central Hill

3-2-4 Considerations

The Central Hill is a knoll with summit depth of 1,800m, located at 16-06S and 177-26E, 35km direct north from the ERZ A. From topographic features of N-S trending crevice with occurrences of topographic high (similar appearance to hydrothermal mound) on the summit and existence of magnetic lineament extending north from ERZ A in the valley, the summit area of the Central Hill was considered to be potential area for hydrothermal mineralization and FDC, CB and LC were conducted in JAPAN/SOPAC project of 1999. The results of this survey revealed the occurrences of accumulated white bivalve fragments over an area of 300m x 300m, discoloring of rock and sediments and sediments including pyrite on the summit area of the Central Hill. Based on the results of 1999 survey, 2004 survey was conducted over the above-mentioned area by FDC, FPG and AD for the purposes of assessing the potential of hydrothermal mineralization. In addition to this, environmental survey was conducted as a baseline survey of the area to predict the magnitude of mining impacts of the deep-sea environment.

At first, FDC survey was conducted to confirm the north-south extension of the area of accumulated white bivalve found by 1999 survey, then inside of the area was examined by FDC. The results of the seafloor observation by FDC, a total of 6 track lines (4.4nm), revealed that north-south trending discolored zone (including distribution of discolored seabed, fragments of bivalve and protrusions with adhesions) occurred with extension of 180m in north-south trend and width of 30m over the area of west facing slop of small ridge. Further, surrounding the discolored zone, fragments of shells were distributed over unconsolidated sediments and exposed rock, and temperature anomalies of seawater were observed over the FDC track lines.

The area of hydrothermal activity (the discolored zone) is smaller compared to the area of the distribution of shell fragments and seawater temperature anomalies. The possible reason for this is that hydrothermal activity occurred in much larger area in the past and it is waning stage of hydrothermal activity. The sulfide mineralization associated to the hydrothermal activity was not observed by naked eye (Figure 3-2-4).

The rock samples collected in and around the discolored zone by FPG and AD are ultramafic and mafic rocks. The ultramafic rocks mainly consist of olivine and clinopyroxene with minor cromspinel and they are classified into dunite, wehrlite, olivine clinopyroxenite and clinopyroxenite. The mafic rocks are mostly gabbro with clinopyroxene, orthpyroxene and plagioclase. The ultramafic rocks are injected by network veins of gabbro. These rocks are altered/metamorphosed to serpentinite and greenshcist. These ultramafic and mafic rocks form solid intrusive bodies, possibly related to the tectonics of the North Fiji Fracture Zone and their origins are deduced to be island arc setting from mineral chemistry, especially that of spinel.

The hydrothermal activities in the Central Hill now seem to be waning stage, however, in the past hydrothermal activity of certain degree might have been existed. One of the possible candidates responsible for heat source of the hydrothermal activities in the Central Hill, consisting of solid intrusion of ultramafic and mafic rocks, is the heat of reaction generated by serpentinization of these rocks. The other candidate is elucidated from the magnetic lineament running, continuously from the ERZ A, over the Central Hill, that is, the igneous activity of the north-south trending spreading axis of EAZ A is considered to be another candidate of heat source of the hydrothermal activities in the Central Hill. The biocommunities found in the discolored zone have odor of hydrogen sulfide, and they were identified to be chemosynthetic communities. Hydrogen sulfide has been, possibly, generated in the area by the reduction of carbonates in the seawater by the heat.

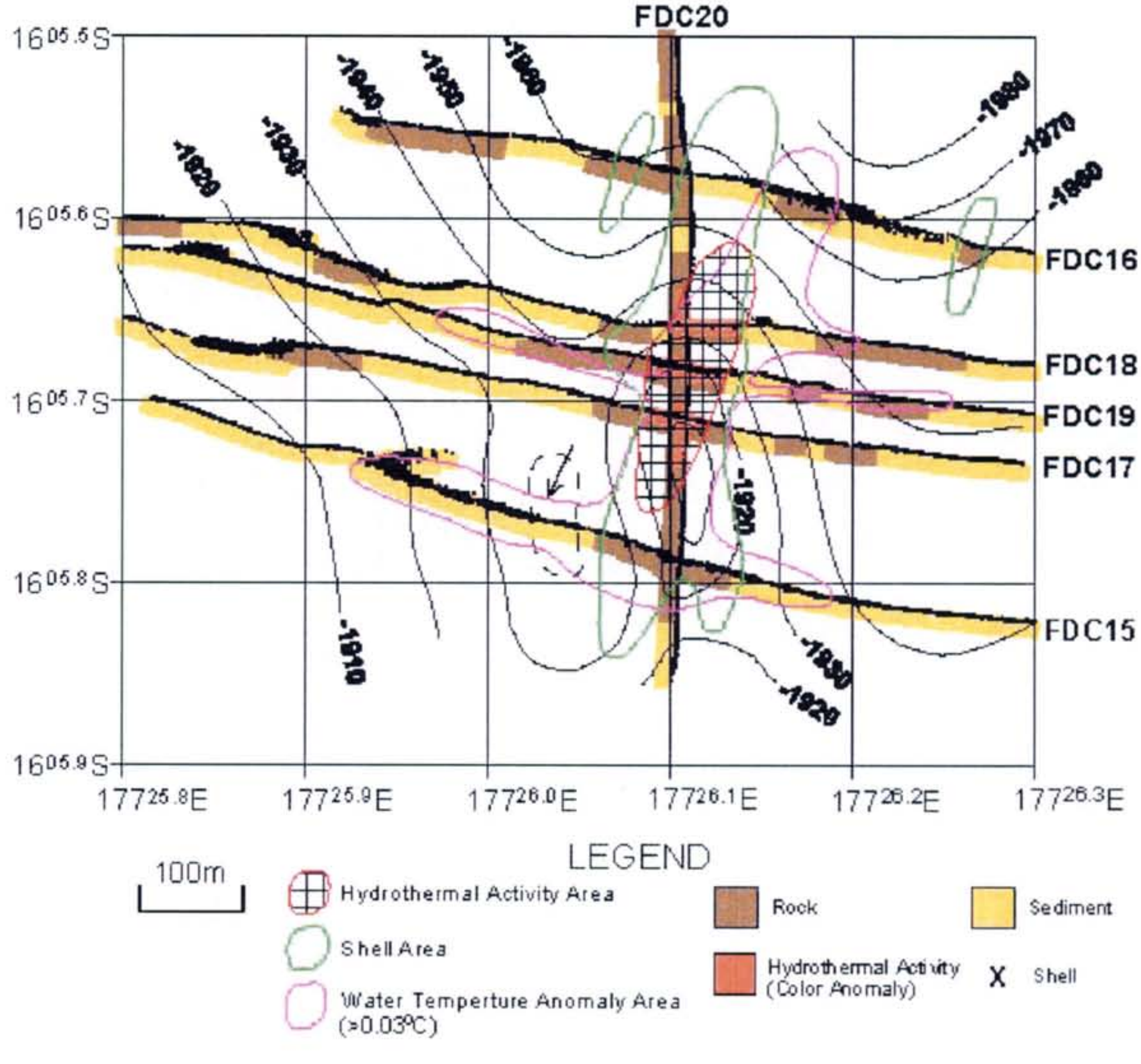


Figure3-2-4 Compilation of Survey Results of the Central Hill

3-3 The ERZ A

3-3-1 Results of Previous Survey

The ERZ A is north-south trending ERZ (Extensional Relay Zone) formed in East-West trending North Fiji Fracture Zone and it consists of north-south trending valley with ridges in both side of it. The discolored zone and temperature anomalies were found on middle slope of the eastern ridge, at the boundary between terrace and slopes by FDC seafloor observation in the previous survey of JAPAN/SOPAC in 1999. Among the samples collected by AD and BMS, a basalt sample with pyrite was collected. The results of the survey suggested the existence of possible hydrothermal activity that caused discolored zone at the boundary between terrace and slope, that is, boundaries between terraces and slopes are faults which acted as conduits for the hydrothermal fluids.

3-3-2 Results of Year 2004 Survey

For assessing the potentiality of hydrothermal mineralization, FDC and AD were conducted over the area of the discolored zone found in 1999 as an indication of hydrothermal mineralization (Figure 3-3-1 and Appendices 2-3).

(1) Seafloor Observation by FDC

The track line of FDC21 was set along the base of the north-south trending cliff to confirm the discolored zone and temperature anomaly of seawater found during the JAPAN/SOPAC 1999 survey, and then, two FDC lines (FDC22, FDC23) were set to intersect the FDC21 line obliquely. Further, FDC24 was conducted over the discolored zone found in 1999 at the western end of the terrace.

1) 04SF FDC21

The track line was set along the base of the cliff to confirm the north-south extension of the discolored zone occurring along the base of north-south trending cliff. The results of the seafloor observation revealed that the yellow, partly light brown, discolored zone was distributed for approximately 250m over the surface of fractured volcanic rocks and pillow lavas.

2) 04SF FDC22

The track line was set to intersect the FDC21 line for confirmation of east-west extension of the discolored zone observed on the FDC21 track line. The discolored zone with same appearance to that of FDC21 was found over the surface of pillow lava occurring widely on the base of the cliff to fractured volcanic rocks occurring slightly upper side of the cliff.

3) 04SF FDC23

The track line of FDC23 was set along 200m north of FDC22 line to investigate the northern extension of the discolored zone found on FDC21 line. The discolored zone with same appearance to that of FDC22 line was observed.

4) 04SF FDC24

The FDC24 line was set to investigate the discolored zone distributed on the top of the west-facing slop of terrace–like ridge. The discolored zone was found over fractured volcanic rocks, however, it consists of scattered distribution of small discolored zones.

5) **Summary of FDC Survey**

As the results of 4 track lines (a total of 2.7nm) of FDC survey, the distribution and characteristic of the discolored zone found in the 1999 survey were clarified, and the locations of samplings were decided.

From the three FDC lines, the discolored zone at the base of north-south trending cliff was confirmed over the area of approximately 250m in north-south direction with maximum width of 30m. The temperature anomalies, overlapping the discolored zone and at two other locations on the cliff were found. Confirmed only by one FDC line, though, the discolored zone of the western part of the terrace seemed to consist of scattered distribution of small discolored zones.

The discolored zones of ERZ A are characterized by discoloring over the exposed rocks and temperature anomalies of seawater overlapping and surrounding the discolored zone, but neither organisms characterizing hydrothermal activities nor fragments of shells was observed.

(2) **AD Sampling**

Based on the distribution of discolored zone confirmed by the FDC seafloor observation, AD sampling at four sites was conducted for understanding the nature and origin of the discolored zone.

1) 04SF AD02

The dredging was conducted to intersect the temperature anomaly of FDC21 line from the terrace to the slop. A total of 180.2 kg sample consisting of dark gray, altered, chloritizesd basalt with vitric surface and limonite was collected.

2) 04SF AD03

The dredging was conducted parallel to FDC23 line to intersect the discolored zone and temperature anomaly of seawater from the terrace to the slop. A total of 116.4kg sample consisting of dark gray basalt with vitric surface was collected.

3) 04SF AD04

The dredging was conducted parallel to FDC22 line, intersecting the discolored zone and temperature anomaly of seawater from the terrace to the slop. Massive, weakly vesicular, dark gray basalt was collected at a total weight of 19.4kg.

4) 04SF AD05

The dredging was conducted close to FDC24 line for intersecting the discolored zone and temperature anomaly of seawater from the terrace to the slop. The collected samples are brecciated basalt of 816kg.

5) Summary of AD Sampling

AD sampling seems to be very efficient for fractured hard rocks, collecting large quantity of fractured volcanic rock by all of four dredgings.

3-3-3 Results of Laboratory Work

For the purposes of characterizing the basement rocks and hydrothermal mineralization, laboratory works, such as microscopic observation of thin sections, chemical analyses of rocks, x-ray diffraction analyses, K-Ar dating, identification of biocommunities and etc., were conducted (Table 2-1, Appendices 5 and 6).

The results of microscopic observation (8 samples), chemical analyses (8 samples) and X-ray diffraction analyses (6 samples) show that the ridges of ERZ A is constituted by basalt with a small amount of plagioclase phenocrysts and aphyric basalt. The former basalt mainly composed of clinopyroxene, plagioclase and olivine. A small amount of alteration minerals such as smectite and goethite were identified by X-ray diffraction analyses.

A wide range of ages, 3.1+/-1.6Ma to 144.3+/-6.8Ma, were obtained from K-Ar dating of 4 basaltic lava samples, probably because analyzed samples are pillow lavas consisting of inhomogeneous material including vitric parts and obtained ages were affected by excess ^{40}Ar.

The organisms collected by AD were identified to be of chemosynthetic community type.

3-3-4 Considerations

The ERZ A is located at 16-24S and 177-25E, 35km south of the Central Hill, and it shows topographic feature of north-south trending ridges of approximately 1,800m deep with a valley in the middle of the ridges. Because of characteristic topography of spreading axis with overlapping magnetic lineament, FDC, CB and BMS were conducted in the JAPAN/SOPAC surve of 1999. The results of this survey revealed that the discolored zone with temperature anomaly of seawater was distributed over the boundary area between west facing slop beneath the ridge and flat terrace, and the basalt sample with pyrite was collected.

Based on the results of 1999 survey, the survey of this year (2004) was conducted over the area of the discolored zone by FDC and AD for the purposes of assessing the potential of hydrothermal mineralization. In addition to this, environmental survey was conducted as a baseline survey of the area to predict the magnitude of mining impacts of the deep-sea environment.

As the results of 4 track lines (a total of 2.7nm) of FDC survey, the discolored zone at the base of north-south trending cliff was confirmed over the area of approximately 250m in north-south direction with maximum width of 30m, and temperature anomalies overlapping the discolored zone were found. The bedrocks collected by AD dredged over the area of the discolored zone are basaltic lava with vitric surface, and neither alteration materials nor adhesions were found in the basalt. The results of seafloor observation and dredging suggests an existence of hydrothermal activity in the ERZ A, however, the organisms characterizing the hydrothermal activity and sulfide mineralization were not observed in the ERZ A (Figure 3-3-4).

A small scale, local distribution of the discolored zones was formed by volcanic activities related to the spreading of north-south trending axis in the North Fiji Fracture Zones.

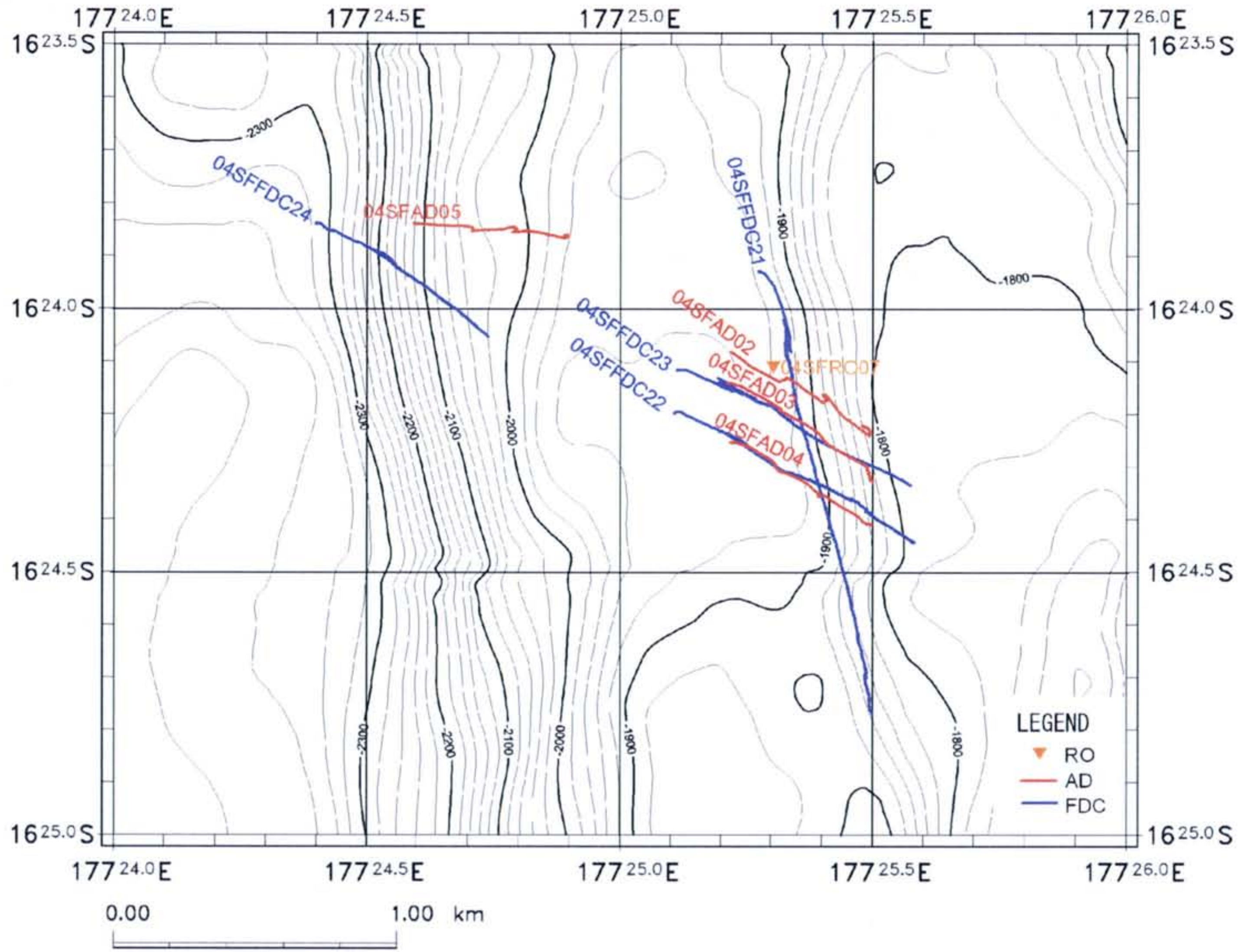


Figure3-3-1 Bathymetric Map and Location of Sampling and Survey of the ERZ A

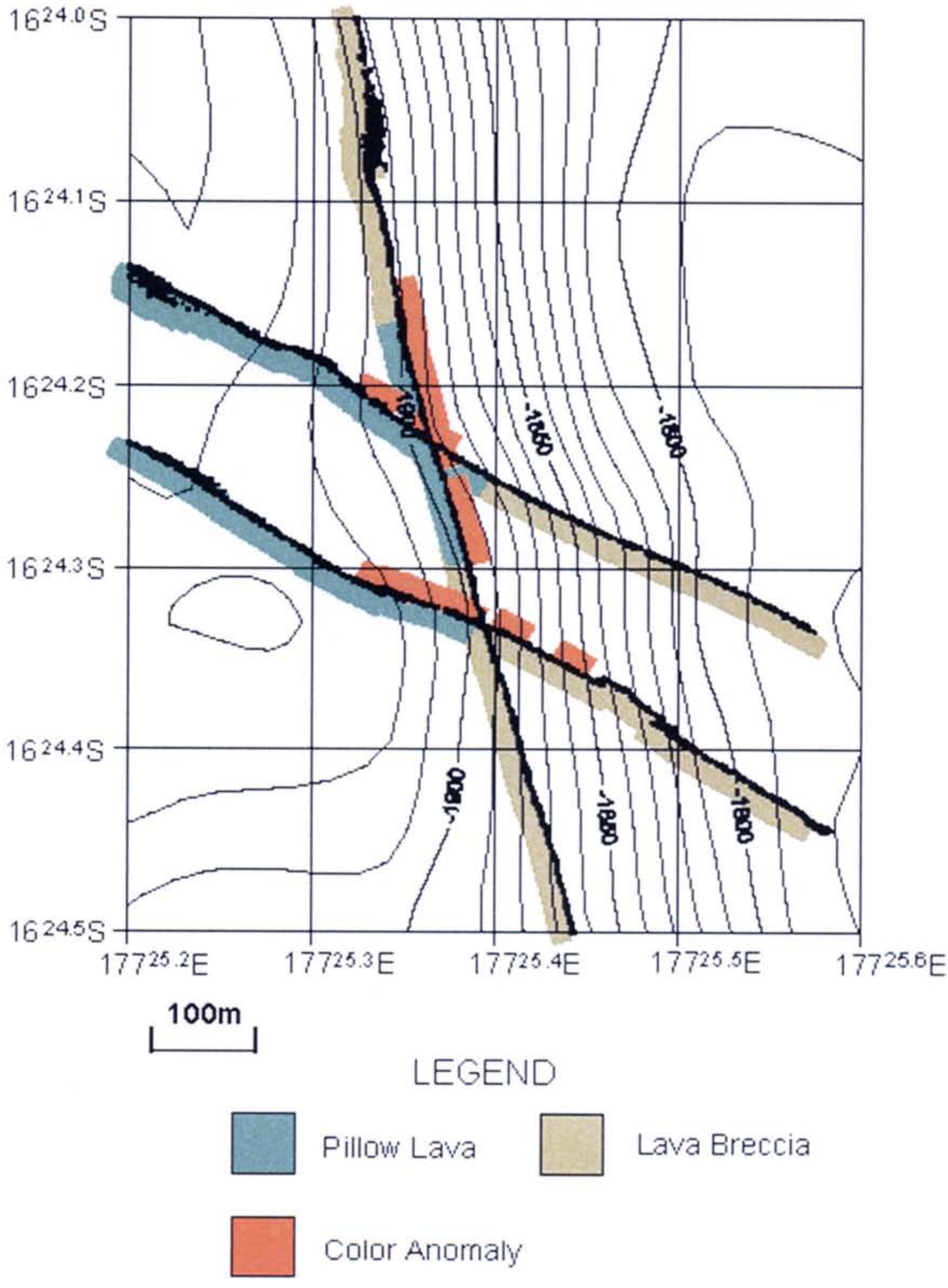


Figure3-3-2 The Result of Seafloor Observation by FDC in the ERZ A

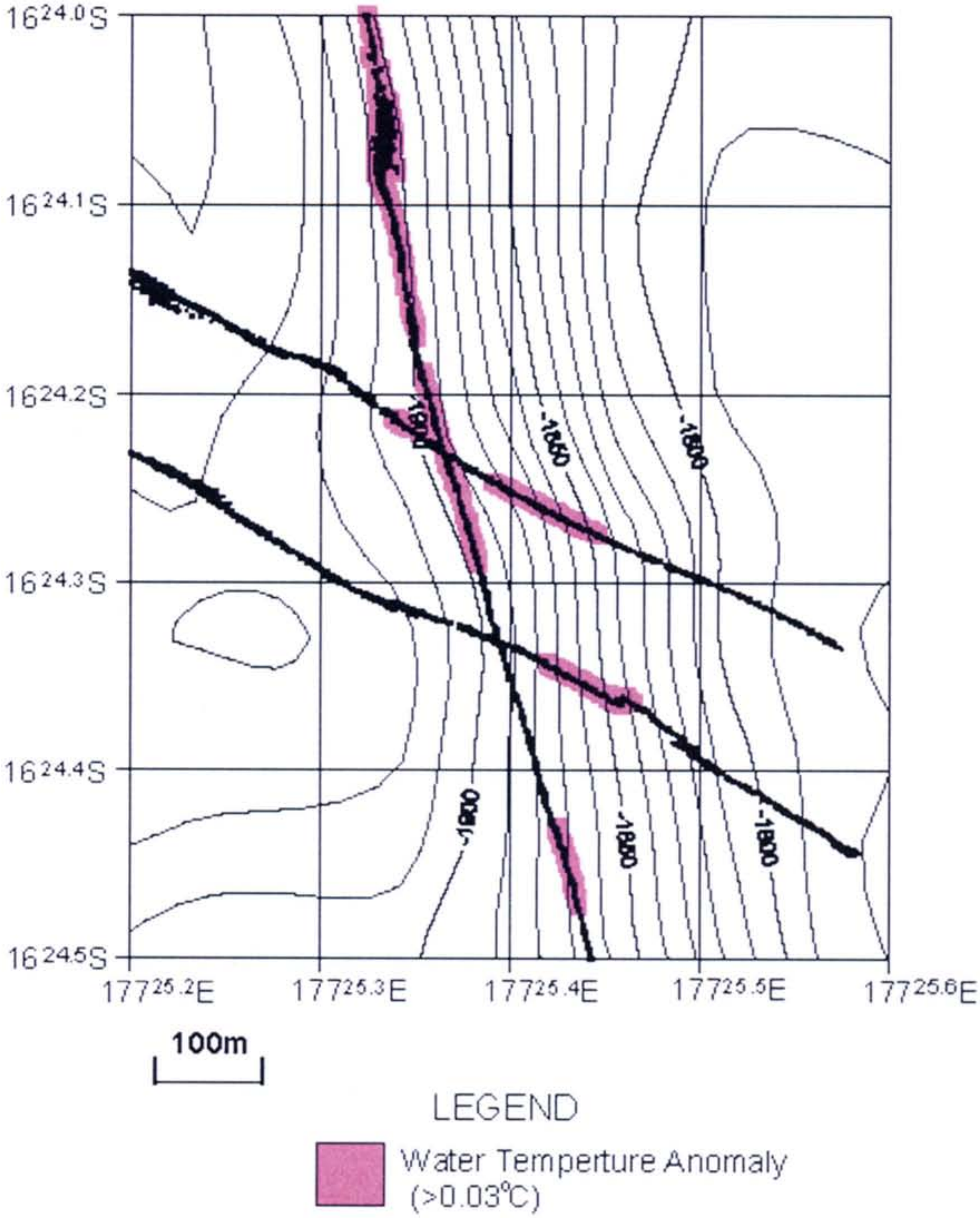


Figure3-3-3 Temperature Anomaly Map of the ERZ A

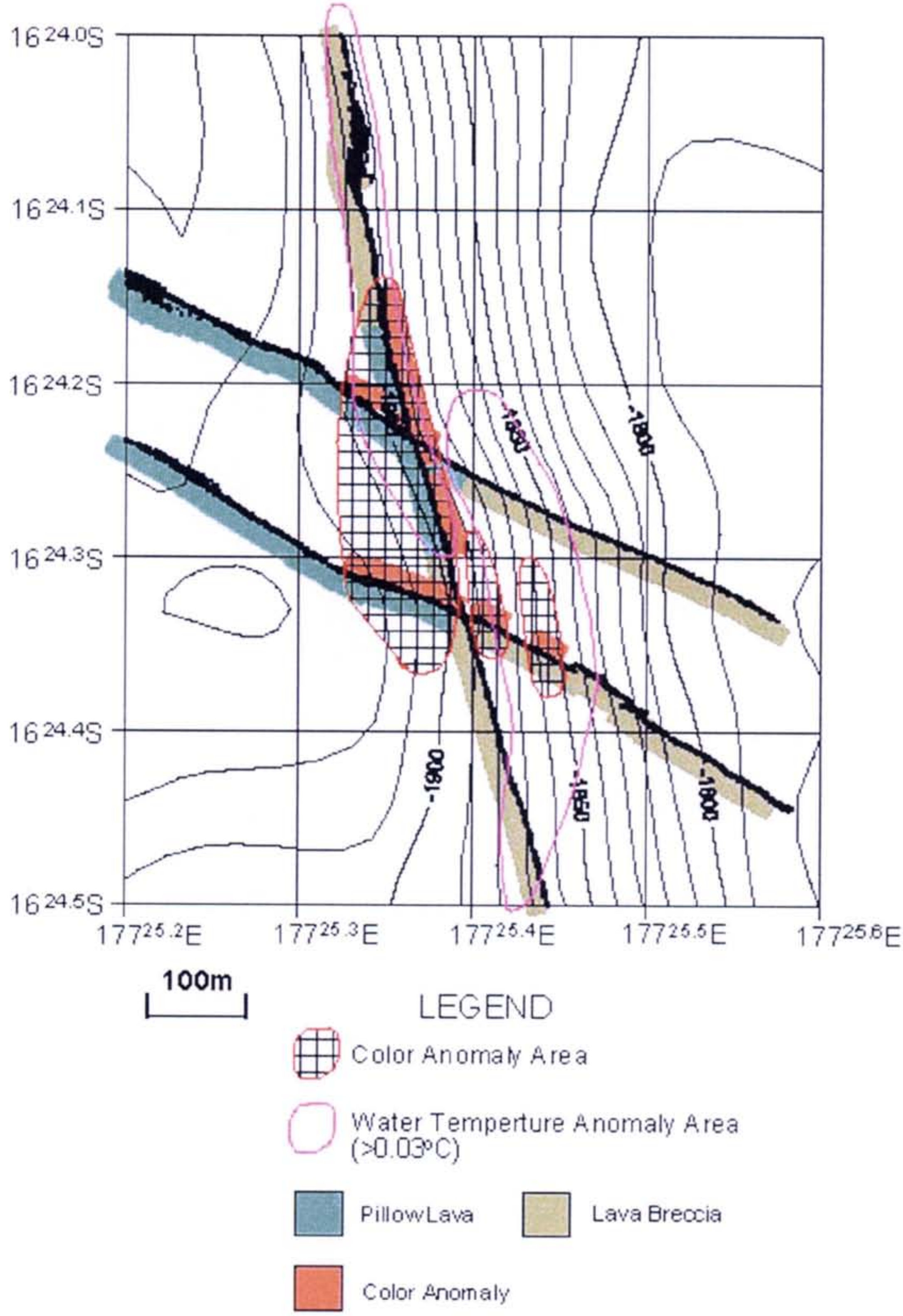


Figure3-3-4 Compilation of Survey Results of the ERZ A

3-4 Environmental Survey

3-4-1 Results

In the "water quality survey", regression lines were drawn from the profiles of water temperature and salinity in water depths of 1,400 m to 1, 600 m and T-S diagrams of depths greater than 1,400 m in both sites. These regression equations were used to predict the existence of hydrothermal plumes in the areas. Both sites were characterized by low temperature and high saline conditions as shown by a shift to higher values in these parameters toward the seafloor. The large difference between the actual water temperature and the estimated value from the regression line, showed the existence of water mass with anomalous temperature in depths greater than 1,600 m. In addition, it was observed that the abundance of bacterioplankton was increased in depths exhibiting anomalous temperature.

Sediment properties were compared between the sampling sites. The vertical distribution of water content, calcium carbonate, organic carbon, total nitrogen and specific gravity in 04SFMC09 and 04SFMC10 were analogous. However, vertical distributions of these parameters differed in 04SFMC11. In particular, the concentrations of calcium carbonate were highest in the 5 to 6 cm layer compared with the other two stations. The abundances of sedimentary bacteria and meiobenthos were also much higher in 04SFMC11 than 04SFMC09 or 04SFMC10. Analysis of the macrobenthos revealed a number of chemotrophic organisms, such as tube-dwelling worms (Vestimentifera) and bivalves (*Calyptogena* sp.) in 04SFFPG01 and 04SFFPG03. Better correlations between the abundances of meiobenthos and the concentrations organic carbon or total nitrogen were observed.

3-4-2 Discussion

Results of the water quality and bacterioplankton survey may prove the existence of hydrothermal plumes in the surrounding area of the sampling sites. The observation of an anomalous temperature toward the sea floor may be a result of the release of thermal water from these plumes, leading to an increase in the abundance of bacteria that utilize the chemical component of the plumes as an energy source.

It may be inferred from the difference in the sediment properties (especially the higher values for calcium carbonate in the 5 to 6 cm layer) observed in 04SFMC11 than that in 04SFMC09 and 04SFMC10 that hydrothermal plumes exist in the area. Calcium carbonate is deposited in the sediment as ejection of thermal water from the plumes progresses. The higher calcium carbonate content in the sediments of 04SFMC11 suggests hydrothermal deposits in this area. The results of macrobenthos survey cannot be compared with the results from the sediment properties obtained from the sedimentary bacteria and the meiobenthos survey; the collection method and survey stations for the macrobenthos survey were different from those of the other subjects. However, the presence of some chemotrophic organisms in the macrobenthos community at 04SFFPG01 and 04SFFPG03 suggests the existence of hydrothermal deposits in these sampling sites.

Comparing the correlations between the abundance of meiobenthos and each sediment properties, better correlation was observed with the organic carbon. This result could probably imply that the meiobenthos are utilizing organic carbon in the bottom sediment as food.

Chapter 4 Conclusions

4-1 Survey Area

4-1-1 Geology and Tectonics

The survey areas of both Central Hill and ERZ A are located in the North Fiji Fracture Zone, which is still active from 0.7Ma, east-west trending left-lateral fault in the North Fiji Basin, however, their geology and tectonics are quite different from each other. The Central Hill is a huge body of solid intrusion consisting of strongly serpentinized ultramafic rocks and gabbro, intruded into the North Fiji Fracture zone, and mineral chemistries, particularly that of spinel, suggest island arc setting for their origin. The ERZ A, on the other hand, consisting of north-south trending ridges and trough of 9-18 km long, is a spreading axis known as "leaky transform fault" or "extensional relay zone" formed in the east-west trending North Fiji Fracture Zone, and it is still spreading with eruption of hyaloclastite and pillow lava.

Although the geology and tectonics of the Central Hill and the ERZ A are different, nearly north-south trending magnetic lineament, suggesting existence of high magnetic body, runs connecting two areas of 35km apart (Figure 3-1-2).

4-1-2 Hydrothermal Activities

The hydrothermal activity of the Central Hill is observed in north-south trending zone within the solid intrusive body, consisting of ultramafic rocks and gabbro and it is still active. While, in the ERZ A, the hydrothermal activity is observed along the boundary between terrace and slop of the north-south trending ridge consisting of volcanic rocks in the North Fiji Fracture Zone.

The heat source of the hydrothermal activity in the ERZ A can be related to the magmatic activity of north-south trending extensional relay zone formed in the North Fiji Fracture Zone. While, in the Central Hill, the heat source of the hydrothermal activities can be sought to the heat of reaction generated by serpentinization of the solid intrusive complex of ultramafic and mafic rocks. Considering from the magnetic lineament running, continuously from the ERZ A, over the Central Hill, the magmatic activity of the north-south trending extensional relay zone of EAZ A can be another candidate for the heat source in the Central Hill.

4-1-3 Considerations

By JAPAN/SOPAC survey of 1999, the Central Hill and the ERZ A were selected as areas of high potential for hydrothermal mineralization. The survey of this year further investigated hydrothermal activity of the two areas to understand and characterize zones of the hydrothermal activity.

The two areas were selected by the survey of JAPAN/SOPAC (1999) from the large sea area of 17,000 sq.km based on geologic and magnetic structures obtained by acoustic sounding survey (MBES) and magnetic survey (PGM), and a high potentiality for hydrothermal mineralization was recognized for two areas by subsequently conducted FDC seafloor observation and samplings by LC, CB and BMS.

The survey of this year was focused on understanding geology and characterizing hydrothermal activity of the areas by efficiently conducting FDC seafloor observation, sampling in hydrothermal activity zones by FPG and AD and laboratory works of samples.

In the Central Hill, six track lines (a total of 4.4 nm) of FDC seafloor observation, conducted in the summit area of the knoll consisting of solid intrusive complex of ultaramafic and mafic rocks, revealed still active hydrothermal zone with bluish green and yellow discolored seabed accompanied by organisms characterizing hydrothermal activity. The zone, north-south extension of 180m and 30m wide, occurs on west facing slop of north declining ridge. The thin coatings of ferro-oxides, possibly characterizing hydrothermal activity, were observed on the surface of rock samples, however, mounds and chimneys formed by sulfide mineralization were not found. Since temperature anomaly of seawater and distribution of shell fragments were observed in many localities in the area surrounding the active hydrothermal zone, the zone of hydrothermal activity, in the past, might have been distributed in much wider area centering the ridge, but, now, no sight of hydrothermal activity was discovered in this surrounding area. In the Central Hill, the country rocks of hydrothermal activity were identified to be altered and metamorphosed (serpentinite and green schist) solid intrusive complex of ultramafic and magic rocks (Figure3-2-4).

The ERZ A, characterized by ridges and graben topography, is overlain by basaltic lavas erupted along the north-south trending spreading axis of the North Fiji Fracture Zone. Although yellow and light brown discolored zone with north-south extension of approximately 250m was identified, being overlapped by temperature anomaly of seawater, along the boundary of steep slop and flat terrace, neither organisms characterizing hydrothermal activity nor sulfide mineralization was found (Figure 3-3-4).

The heat source of the hydrothermal activity in the ERZ A can be related to the magmatic activity of north-south trending spreading axis formed in the North Fiji Fracture Zone. While, in the Central Hill, the heat source of the hydrothermal activities can be sought to the heat of reaction generated by serpentinization of the solid intrusive complex of ultramafic and mafic rocks. Considering from the magnetic lineament running continuously from the ERZ A over the Central Hill, the magmatic activity of the north-south trending spreading axis of EAZ A can be another candidate for the heat source in the Central Hill.

4-2 Future Works in The Area of Fijian EEZ

Following the various surveys such as STARMER (1987-1992), Sonne SO-35 (1990) and SO-134 (1998), JAPAN/SOPAC projects in the EEZ of the Republic of the Fiji Islands were conducted in 1999, 2001 and 2005 (Table4-1, Table4-2). As the results of these surveys, a weak but on-going hydrothermal activity was identified in the Central Hill, however sulfide mineralization was not observed. Since hydrothermal activities of past and present found in the Central Hill and ERZ A by the survey of this year are located in still active North Fiji Fracture Zone and the hydrothermal activities associated by sulfide mineralization were recognized in the Triple Junction Area of the Central Spreading Axis by the survey of previous years (Figure 3-1-1), further works in the future are recommended to be conducted in the Central Spreading Axis and the North Fiji Fracture Zone of the North Fiji Basin to find new areas of hydrothermal mineralization. The future survey must be conducted systematically step by step, starting from compilation of existing data, regional survey to detail survey for successfully finding the mineralized zone (Figure 4-1).

4-3 Environmental Survey

Results of the water quality and sedimentary bacteria survey, confirm the existence of an abnormal distribution of water temperature and bacteria in water depths greater than 1,600 m. This finding supports the possibility that hydrothermal plumes were present in these areas. In the sediment properties and benthic organism survey, higher concentrations of calcium carbonate at 04SFMC11 than at 04SFMC09 and 04SFMC10 suggests that 04SFMC11 is affected by the hydrothermal deposits accumulated from the activity of thermal water. The presence of hydrothermal deposits is further supported by the observation of a number of chemotrophic macrobenthos, such as tube-dwelling worms (Vestimentifera) and bivalves (*Calyptogena* sp.etc.) at 04SFFPG01 and 04SFFPG03. The environmental survey leads to obtain the basic environmental information on the sea area.

Table4-1 Compilation of Survey Amount in the Sea Area of Fiji

Suevey	Method	Unit	1999			2001	2004			Total
			Area 1	Area 2	Sub-total		Central Hill	ERZ A	Sub-total	
Bathymetric Suevey	NBS(30.0kHZ)	nm	305.0	3,224.4	3,528.4	420.6	-	-	-	3949.0
	PDR(12.0kHZ)	nm	-	-	-	420.6	-	-	-	420.6
	SBP(3.5kHZ)	nm	305.0	3,224.4	3,528.4	420.6	-	-	-	3949.0
	MBES(15.5kHZ)	nm	305.0	3,224.4	3,528.4	-	470.3		470.3	3998.7
	SSS(59.0kHZ)	nm	9.9	19.4	29.3	-	-	-		29.3
Magnetic survey	PGM	nm	-	1,100.0	1,100.0	420.6	-	-		1520.6
Conductivity, Temp, Depth	CTD	Point	1	1	2	-	1	1	2	4
Seafloor observation	FDC	line No., nm	7, 5.4	7, 13.0	14, 18.4	-	6, 4.4	4, 2.7	10, 7.1	27, 25.5
Sampling	LC	Point	2	1	3	20	-	-	-	23
	CB	Point	-	3	3	-	-	-	-	3
	AD	Point	-	-	-	-	5	4	9	9
	FPG	Point	-	-	-	-	3	-	3	3
	BMS	Hole No., m	-	5, 9.1	5, 9.1	22, 50.06	-	-	-	27, 59.16
Environment assessment	RO	Point	-	-	-	5	1	1	2	7
	MC	Point	-	-	-	7	5	-	5	12
Heat flow	HF	Point	-	-	-	13	-	-	-	13
	Observation of thin section	No. of Spls	1	-	1	25	-	-	-	26
	Observation of thin section of ore	No. of Spls	1	19	20	15	10	8	18	53
	Sulfur isotope determination	No. of Spls	1	-	1	-	-	-	-	1
	X-ray diffraction analysis	No. of Spls	5	16	21	23	10	6	16	60
	Whole rock analysis	No. of Spls	-	2	2	9	-	8	8	19
	Chemical analysis of ore	No. of Spls	-	1	1	21	5	-	5	27
	Geochemical analysis	No. of Spls	1	6	7	41	2	-	2	50
	Ar-Ar age determination	No. of Spls	-	2	2	-	-	-	-	2
	K-Ar age determination	No. of Spls	-	-	-	-	-	4	4	4
	Smear slide observation	No. of Spls	-	4	4	-	-	-	-	4
	Fossil determination	No. of Spls	-	-	-	-	1	-	1	1
	Micro fossil detemination	No. of Spls	-	3	3	-	-	-	-	3
	Shell fossil determination	No. of Spls	-	1	1	-	-	-	-	1
	Fossil determination in unconsolidated material	No. of Spls	-	-	-	-	1	-	1	1
	Living being determination	No. of Spls	-	-	-	-	4	1	5	5
	C14 age determination	No. of Spls	-	1	1	-	-	-	-	1
	Mode analysis	No. of Spls	-	-	-	-	10	-	10	10
	EPMA	No. of Spls	-	-	-	-	20	-	20	20

Table4-2 Results of SOPAC Survey in the EEZ of Fiji

	1999		2001	2004	
Survey Area	Area 1	Area 2	Triple Junction Area	Central Hill	ERZ A
JAPAN/SOPAC Project	Bathymetry 、FDC、LC	Bathymetry 、Magnetic Survey、LC、CB、BMS	Bathymetry、Magnetic Survey、FDC、LC、BMS	Bathymetry、FDC、FPG、AD	Bathymetry 、FDC、AD
Other Projects	STARMER(1987-1992), Sonne SO-35(1990) and SO-134(1998)	Sonne SO-35(1990)	Sonne SO-35(1990) and SO-134(1998)	Sonne SO-35(1990)、Volcanic rocks were collected by AD	Sonne SO-35(1990)、a sign of hydrothermal activity was found
Location and Area	area of approximately 470㎢ including Triple Junction Area (16-54S、173-56E) at the center	area of approximately 36,000㎢ including North Fiji Fracture Zone	Triple Junction Area	16-05.7 S 177-26.1 E	16-24.5 S 177-25.5 E
Topography	valleys of approximately 2,500m deep trending in south, northwest and northeast and ridges of less than 2,000m deep	complicate topography reflecting E-W and N-S trending geological structure, 1,000 to 4,500m deep	N-S trending graben of approximately 2,000m deep and ridges (minimum depth of 1,860m) on both sides of it	a knoll with summit depth of approximately 1,800m deep in E-W trending North Fiji Fracture Zone	N-S trending ridges (approximately 1,900m deep) and valley in the North Fiji Fracture Zone
Magnetic Characteristics	magnetic structure controlled by geological structure (SO-35)	magnetic lineament occur along the N-S trending ERZ A and it extend toward north to the Central Hill	magnetic structure reflecting the grabens structure of Triple Junction	northern extension of N-S trending magnetic lineament of ERZ A	N-S trending magnetic lineament overlapping the ERZ A
Geology	volcanic rocks, mainly basalt, related to the activity of spreading axis	volcanic rocks, mainly basalt, related to the North Fiji Fracture Zone	volcanic rocks, mainly basalt, related to the activity of spreading axis	solid intrusion of ultramafic rocks related to North Fiji Fracture Zone	volcanic rocks such as pillow lavas related to the spreading of ERZ
Mound, Discolored Zone, Alteration Zone	many mounds with chimney-like protrusions and discoloration	discolored zone and distribution of shell fragments	mounds of 5 to 10m high with chimney on top of them	bluish green and yellow discolored zone with organisms related to hydrothermal activity such as deep-sea mussel	yellow and brown discolored zone on pillow lava
Chimney	found on nine mounds	not observed	chimneys of 3-5m high area observed on mound	not found	not found
Temperature Anomaly and Hydrothermal Activities	temperature changes (max. 0.077 deg. C) were found at 22 sites	temperature changes of more than 0.02 deg. C were observed over the area of discolored zone	heat flows of 0.1-0.6 deg. C were obtained but hydrothermal activity was not directly observed	temperature changes of >0.03 deg. C were observed in and around the discolored zone with organisms characterizing hydrothermal activity	temperature changes of >0.03 deg. C were observed over the discolored zone
Mineralization	mainly pyrite and marcasite with minor chalcopyrite and sphalerite	not found	sulfides mineralization of Zn, Cu, Au and Ag	coating of ferro-manganese oxides	coating of ferro-manganese oxides
Distribution of mineralization/ discolored zone	concentrated in two area of east (750 X 450m) and west (600X100m), each one has extension of more or less 100m	Central Hill: distribution of shell fragments over the area of 300x300m, ERZ A: discolored zone was found	East Area: 22 sites, West Area: 11 sites, each mineralized zone has maximum extension of approximately 100m	area of hydrothermal activities is 350m long in N-S direction and 35m wide	discolored zone of approximately 350m long in N-S direction
Location of mineralization/ discolored zone	Triple Junction area	along N-S trending magnetic lineament running over ERZ A	concentrated in east and west of north-south trending graben at the vicinity of Triple Junction	western slop of the north-south trending rise	along the boundary zone between terrace and slop of the ridge
Stage and Intensity of Hydrothermal Activity	waning stage, abundant chimneys with sulfide mineralization	sign of hydrothermal mineralization with temperature change	Waning stage, abundant chimneys with sulfide mineralization	waning stage, the area of hydrothermal activity was larger in the past	weak hydrothermal activity
Remarks	distribution of known hydrothermal mineralization in the Triple Junction Area	Central Hill and ERZ A were extracted as area of high potential	already known mineralization, widespread distribution of hydrothermal mineralization	sighs of hydrothermal mineralization were found, weak sulfide mineralization	signs of hydrothermal mineralization were found, weak sulfide mineralization

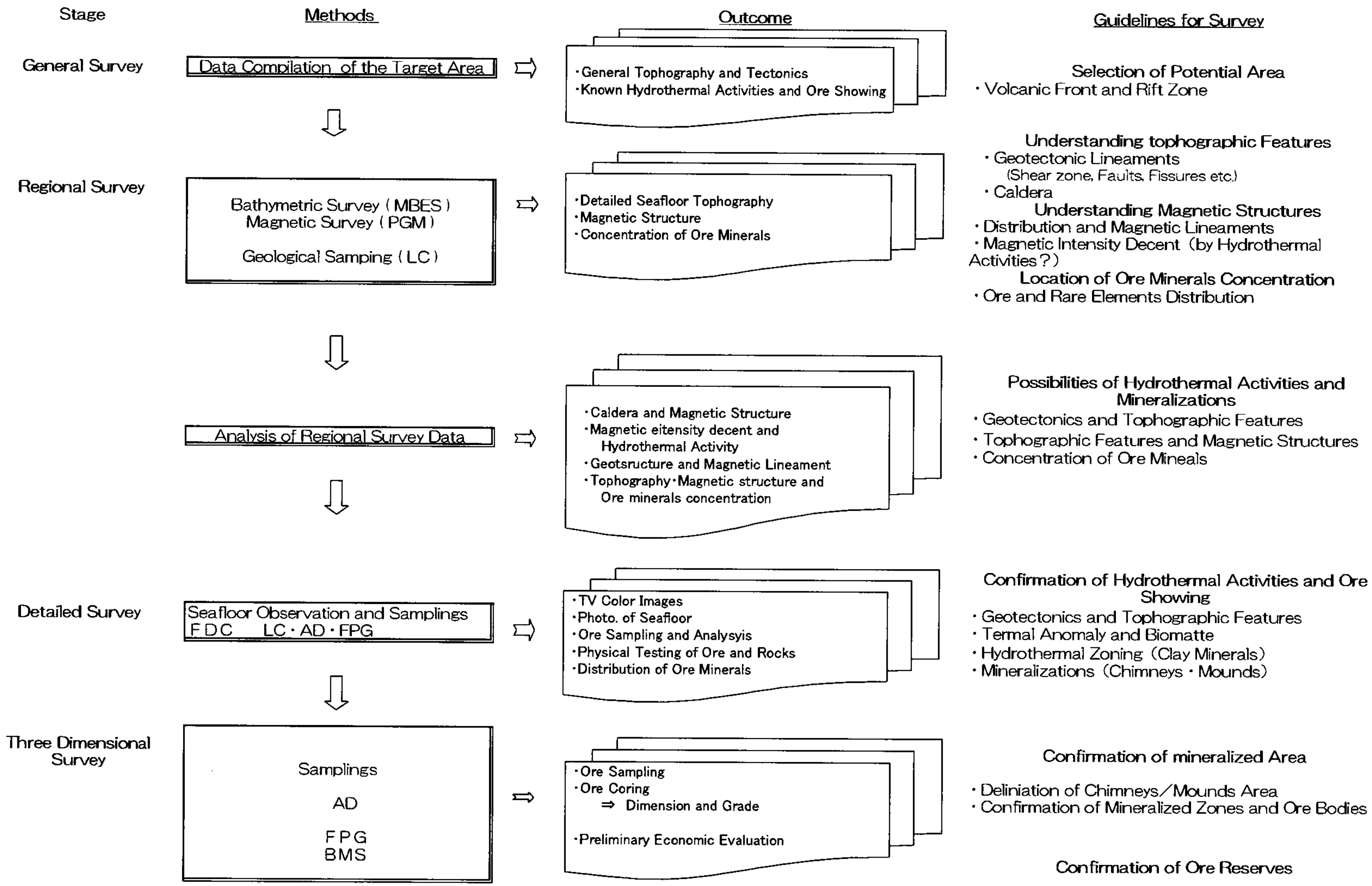


Figure4-1 Exploration Flow of the Seafloor Hydrothermal Mineralization

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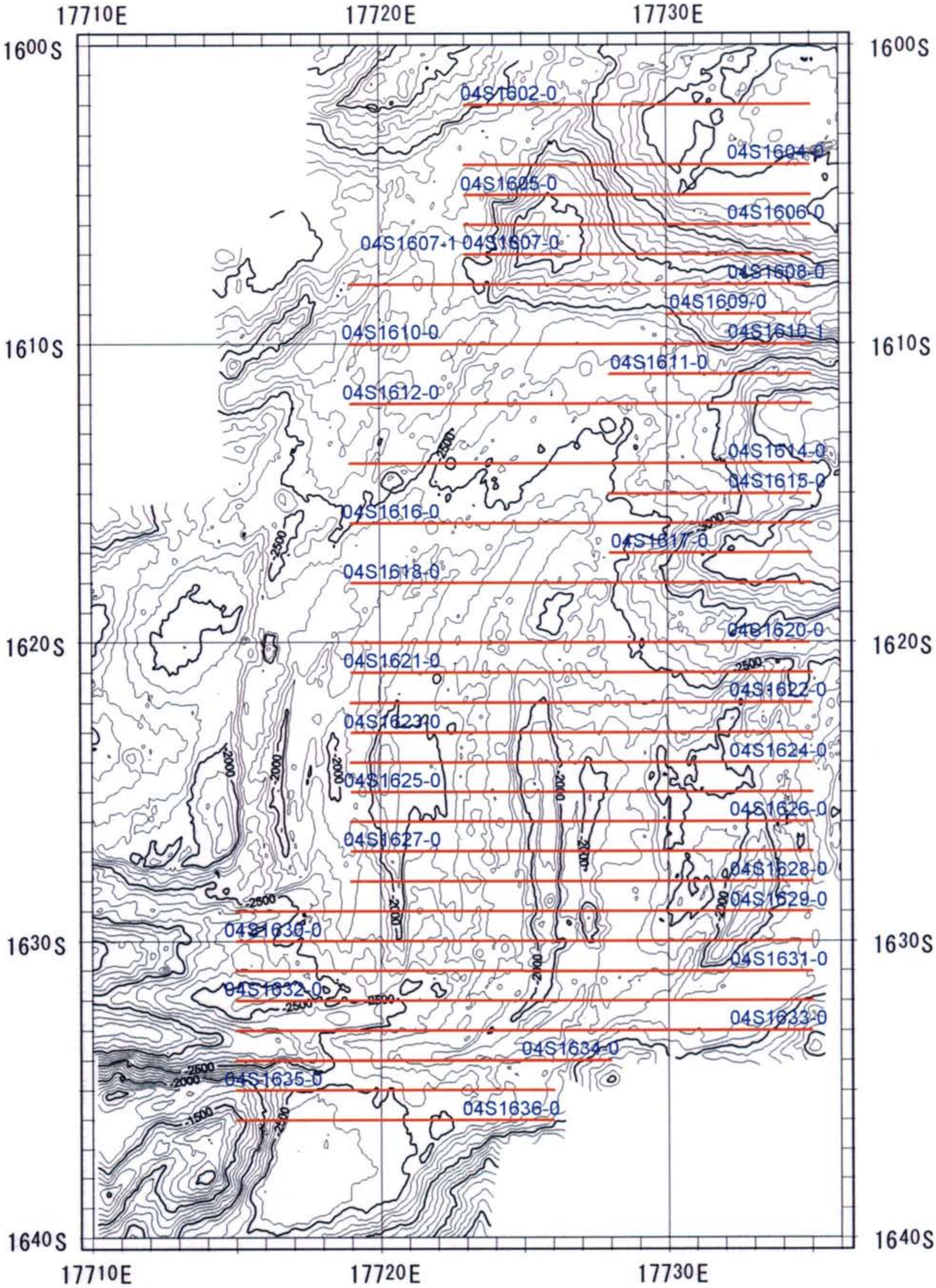
Appendix 1

Track Line Map
Relation of Sound-Velocity
  and water Depth
Weather and Sea-State Data

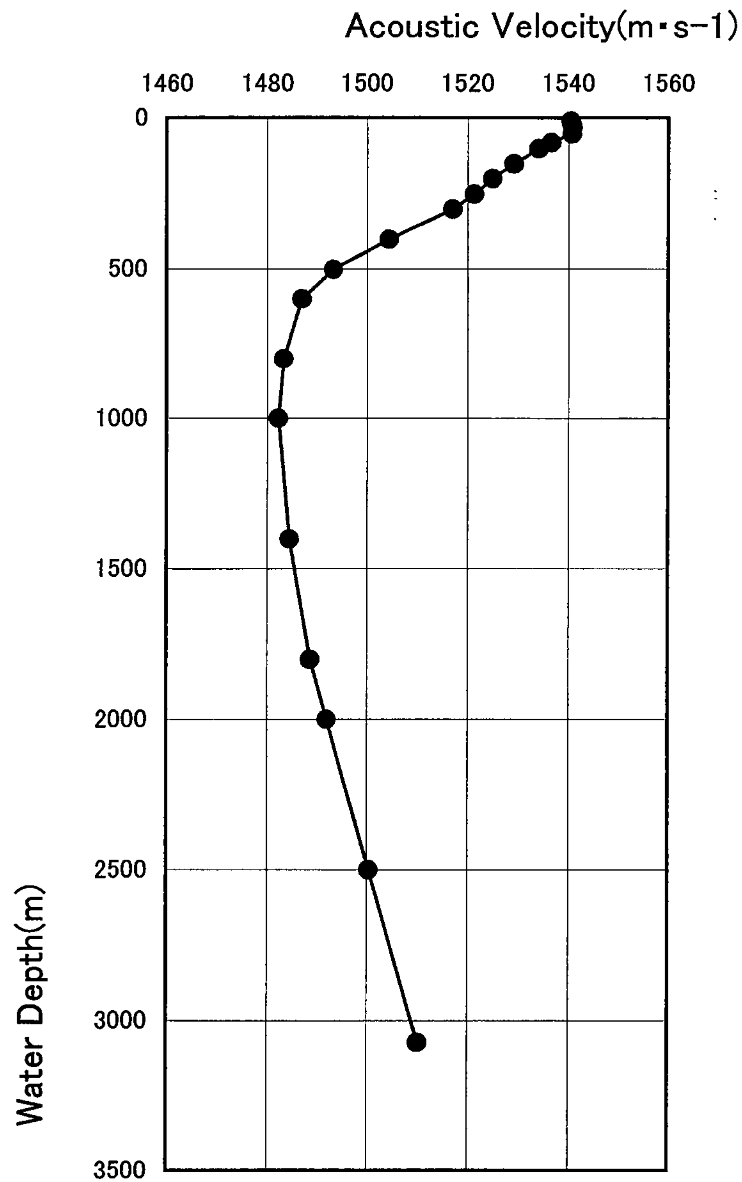
(1/350000 AT 16°00' S)



Track Line Map

Relation of Sound-velocity and Water Depth

	測定位置 Lat. / Long.	17° 14.600'S / 173° 59.811'E
	Water Depth(m)	Acoustic Velocity(m・s^{-1})
1	10	1,540.4
2	20	1,540.6
3	30	1,540.8
4	51	1,540.7
5	81	1,536.6
6	101	1,534.1
7	151	1,529.2
8	200	1,524.9
9	251	1,521.3
10	301	1,517.1
11	401	1,504.4
12	502	1,493.2
13	600	1,486.9
14	801	1,483.3
15	1,000	1,482.2
16	1,401	1,484.4
17	1,801	1,488.6
18	2,000	1,491.9
19	2,500	1,500.3
20	3,072	1,510.2
	Mean acoustic Velocity	1,496.5



Weather and Sea-state Data(December)

Table-2 Monthly Distribution of Wind Direction(W.D)

W.D	CALM	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	un known	Total
F.Q	0	0	0	2	14	18	86	34	3	0	0	0	0	0	0	0	0	0	157
%	0.00	0.00	0.00	1.27	8.92	11.46	54.78	21.66	1.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

Table-2 Monthly Distribution of Wind Velocity(W.V) (W.V: m/sec)

W.V	CALM	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20-	Total
F.Q	0	0	0	2	3	15	25	31	23	22	20	6	10	0	0	0	0	0	0	0	0	0	157
%	0.00	0.00	0.00	1.27	1.91	9.55	15.92	19.75	14.65	14.01	12.74	3.82	6.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

*) CALM:0.0m/sec
W.V =0 : 0.1m/sec～1.0m/sec
W.V=3 : 3.0m/sec～4.0m/sec
W.V=20- : 20.0m/sec <

Table-3 Monthly Distribution of Weather

Weather	fine	cloudy	rain	un known	Total	light day
F.Q	5	3	0		8	3
%	62.50	37.50	0.00	0.00	100.00	37.50

*) rain:r、d、p、q > 5times in a day
fine:other than rain day and b、bc >half day
cloudy:other fine & rain day and r,d,p,q,c,o > half
light day:fine or cloudy and r,d,p,q day

*) Weather Mark
b: fine(clear and sunny)
bc: half fine(fine)
c: cloudy
o: all cloudy(cloudy)
r: rain
d: light rain
p: showery rain
q: squall
f: fog
m: mist

Table-4 Monthly Frequency Distribution of Atmospheric (A.P)

A.P	-980	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996
F.Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A.P	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014
F.Q	0	0	0	0	0	0	0	1	6	19	39	41	30	17	2	2	0	0
%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	3.82	12.10	24.84	26.11	19.11	10.83	1.27	1.27	0.00	0.00
A.P	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030-	kno	Total
F.Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	157
%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

*)A.P1000 : 1000.0～1001.0mb
A.P-980 : <980mb
A.P1030- : 1030.0mb<

Table-5 Monthly Frequency Distribution of Swell 2 Direction (S.D)

S.D	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	un known	Total
F.Q	0	0	32	20	25	1	5	0	0	0	0	0	0	0	0	0	74	157
%	0.00	0.00	20.38	12.74	15.92	0.64	3.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.13	100.00

Table-6 Monthly Frequency Distribution of Swell 2 Cycle (S.C) (S.C: Sec)

S.C	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	un known	Total
F.Q	0	0	0	0	0	0	83	0	0	0	0	0	0	0	0	0	74	157
%	0.00	0.00	0.00	0.00	0.00	0.00	52.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.13	100.00

Table-7 Monthly Frequency Distribution of Swell 2 Height (S.H) (S.H: m)

S.H	0	1	2	3	4	5	6	7	8	9	10	un known	Total
F.Q	0	31	40	12	0	0	0	0	0	0	0	74	157
%	0.00	19.75	25.48	7.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.13	100.00

Table-8 Monthly Frequency Distribution of Degree of Cloudiness (D.C)

D.C	0	1	2	3	4	5	6	7	8	9	10	un known	Total
F.Q	0	0	7	18	27	30	46	20	9	0	0	0	157
%	0.00	0.00	4.46	11.46	17.20	19.11	29.30	12.74	5.73	0.00	0.00	0.00	100.00

Table-9 Monthly Frequency Distribution of Swell 3 Direction (S.D)

S.D	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	un known	Total
F.Q	1	0	0	5	4	9	19	0	0	0	7	4	0	0	0	0	108	157
%	0.64	0.00	0.00	3.18	2.55	5.73	12.10	0.00	0.00	0.00	4.46	2.55	0.00	0.00	0.00	0.00	68.79	100.00

Table-10 Monthly Frequency Distribution of Swell 3 Cycle (S.C) (S.C: Sec)

S.C	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	un known	Total
F.Q	0	0	0	0	0	1	43	4	1	0	0	0	0	0	0	0	108	157
%	0.00	0.00	0.00	0.00	0.00	0.64	27.39	2.55	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	68.79	100.00

Table-11 Monthly Frequency Distribution of Swell 3 Height (S.H) (S.H: m)

S.H	0	1	2	3	4	5	6	7	8	9	10	un known	Total
F.Q	0	8	41	0	0	0	0	0	0	0	0	108	157
%	0.00	5.10	26.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	68.79	100.00

Appendix 2

Amount of Survey, FDC, FPG and AD

Amount of FDC Survey

Area	Survey line	Work	Survey Date・Time (GMT)		Coodinates LAT・LNG	Direction	Depth (m)	Distance (n.m.)	Line setting	Seafloor observation
C.H.	04SF FDC15	Start	Dec. 22	03:23:36	177°25.8939′ E 16°05.7113′ S	NNW-ESE	1,895	0.7	Confirmation of southern extension of shell colonies finded in 1999	Shell remains is distributed on basement partly covered by Unconsolicated
		End	Dec. 22	04:11:31	177°26.6591′ E 16°05.8369′ S		1,953			
C.H.	04SF FDC16	Start	Dec. 22	05:17:00	177°26.3997′ E 16°05.6354′ S	NNW-ESE	1,981	0.6	Confirmation of northen extension of shell colonies finded in 1999	Shell remains is distributed on basement partly covered by Unconsolicated
		End	Dec. 22	05:58:54	177°25.7857′ E 16°05.5280′ S		1,941			
C.H.	04SF FDC17	Start	Dec. 22	20:40:03	177°25.8222′ E 16°05.6488′ S	NNW-ESE	1,893	0.7	Confirmation of chimny-like mound fined in 1999	Live shell and color anomaly in a western slope of small ridge
		End	Dec. 22	21:24:09	177°26.5178′ E 16°05.7805′ S		1,954			
C.H.	04SF FDC18	Start	Dec. 22	23:09:17	177°25.8345′ E 16°05.5988′ S	NNW-ESE	1,903	0.8	Confirmation of north extension of color anomaly finded by FDC17	Live shell and color anomaly in a western slope of small ridge
		End	Dec. 22	23:58:31	177°26.6284′ E 16°05.7231′ S		1,925			
C.H.	04SF FDC19	Start	Dec. 23	02:05:04	177°25.8329′ E 16°05.6264′ S	NW-SE	1,894	0.9	Confirmation of color anomaly nature finded between FDC17 and FDC18	Live shell and living being, color anomaly, basement with mound-like part
		End	Dec. 23	03:00:30	177°26.7973′ E 16°05.7813′ S		1,955			
C.H.	04SF FDC20	Start	Dec. 23	04:50:41	177°26.1016′ E 16°05.3038′ S	N-S	1,950	0.7	Confirmation of N-S continuity of color anomaly finded by FDC17, 18 and 19	Live shell and color anomaly
		End	Dec. 23	05:38:44	177°26.1139′ E 16°05.9964′ S		1,933			
ERZ A	04SF FDC21	Start	Dec. 23	22:33:51	177°25.3098′ E 16°23.9893′ S	NNW-SSE	1,927	1.0	Confirmation of N-S directed color anomaly finded in 1999	Pillow lova and hyaloclastite with color anomaly for about 250m long
		End	Dec. 23	23:37:19	177°25.5622′ E 16°24.9666′ S		1,814			
ERZ A	04SF FDC22	Start	Dec. 24	01:23:28	177°25.1801′ E 16°24.2381′ S	NW-SE	1,911	0.6	Confirmation of color anomaly width confirmed by FD21	Pillow lova and hyaloclastite with color anomaly
		End	Dec. 24	02:06:24	177°25.7753′ E 16°24.5455′ S		1,750			
ERZ A	04SF FDC23	Start	Dec. 24	04:04:19	177°25.1840′ E 16°24.1421′ S	NW-SE	1,907	0.6	Confirmation of color anomaly width confirmed by FD21	Pillow lova and hyaloclastite with color anomaly
		End	Dec. 24	04:40:19	177°25.7249′ E 16°24.4078′ S		1,752			
ERZ A	04SF FDC24	Start	Dec. 24	06:29:47	177°24.4907′ E 16°23.8955′ S	NW-SE	2,241	0.5	Confirmation of extension of color anomaly finded in 1999	Limited color anomaly on rised portion of hyaloclastite
		End	Dec. 24	07:02:24	177°24.9233′ E 16°24.1729′ S		1,981			
							Total	7.1		

Amount of AD and FPG Surveys (Central Hill)

No.	Survey Line	Work	Survey Date・Time (GMT)		Coordinates LAT・LNG	Direc-tion	Water Depth (m)	Distance (n.m.)	Samples and its weight (kg)	Setting	Samples
1	04SFAD01	Start	Dec. 26	01:51:16	177°26.049′ E 16°05.491′ S	NW-SE	2,000	0.3	Rocks(19.5) Others(5.3) Total(24.8)	Crossing color anomaly area	Cgl. of gabbro, pumice etc.
		End	Dec. 26	02:36:11	177°26.182′ E 16°05.766′ S		1,961				
2	04SFAD06	Start	Dec. 27	20:39:03	177°25.603′ E 16°05.098′ S	NW-SE	2,125	0.3	Rocks(108.4) Others(5.4) Total(113.8)	Confirmation of basement in color anomaly area	Ssampled cgl. of alteded gabbro etc.
		End	Dec. 27	21:14:33	177°25.915′ E 16°05.202′ S		1,947				
3	04SFAD07	Start	Dec. 27	23:05:39	177°25.097′ E 16°06.106′ S	NW-SE	1,910	0.3	Rocks(229.7) Others(4.4) Total(234.1)	Confirmation of basement in color anomaly area	Ssampled cgl. of serpentinite, gbbro etc.
		End	Dec. 27	23:37:38	177°25.332′ E 16°06.292′ S		1,784				
4	04SFAD08	Start	Dec. 28	1:27:22	177°26.072′ E 16°05.505′ S	NW-SE	2,002	0.2	Rocks(21.5) Others(5.4) Total(26.9)	Confirmation of northern part of color anomaly	Ssampled Mn oxide coarted green rock cgl.
		End	Dec. 28	1:47:34	177°26.246′ E 16°05.691′ S		1,988				
5	04SFAD09	Start	Dec. 28	3:32: 9	177°26.017′ E 16°05.800′ S	NW-SE	1,967	0.2	Rocks(2.3) Others(4.5) Total(6.8)	Confirmation of southern part of color anomaly	Ssampled coarted green rock and pumice cgl.
		End	Dec. 28	3:54:19	177°26.253′ E 16°05.864′ S		1,947				
6	04SFFPG01	Hit	Dec. 25	3:50:38	177°26.120 ′E 16° 5.675′ S	−	1,971	−	Rocks(82.9) Others(2.3) Total(85.2)	Most impressive color anomaly area near FDC19	Sampled serpentinite and living beings
7	04SFFPG02	Hit	Dec. 25	6: 0:25	177°26.131′ E 16° 5.670′ S	−	1,967	−	Rocks(231.9) Others(0.8) Total(232.7)	Most impressive color anomaly area near FDC19	Sampled altered fabbro-dolerite and living being
8	04SFFPG03	Hit	Dec. 25	21:03:16	177°26.126′ E 16° 5.682′S	−	1,968	−	Rocks(約800) Others(2.4) (800.0)	Most impressive color anomaly area with mound-like part near FDC19 cut	Sampled altered fabbro-dolerite and living being
9	04SFMC08	Hit	Dec. 23	7:29:10	177°26.323′ E 16° 5.623′ S	−	1,990	−	−	Sampling seafloor sediments at east of color anomaly area	Not Sampled
10	04SFMC09	Hit	Dec. 24	20:37:10	177°26.335′ E 16° 5.634′ S	−	1,980	−	Foraminirera sand(8.9)	Same point of MC08	Sampled in 4 tubes
11	04SFMC10	Hit	Dec. 24	22:36:59	177°26.104′ E 16° 5.468′ S	−	2,006	−	Foraminefera sand(7.6)	Sampling seafloor sediments at west of color anomaly area	Sampled in 4 tubes
12	04SFMC11	Hit	Dec. 25	0:36:33	177°25.847′ E 16° 5.692′ S	−	1,946	−	Mn oxide coated foraminifera sand(2.0)	Sampling seafloor sediments at north of color	Sampled in 3 tubes
13	04SFMC12	Hit	Dec. 25	23:05:15	177°26.121 ′E 16° 5.682′ S	−	1,974	−	−	Sampling seafloor sediments near color anomaly	Not Sampled
							Total	1.3	1,542.8		

Amount of ＡＤ survey (ERZ A)

No.	Survey Line	Work	Survey Date・Time (GMT)		Coordinates LAT・LNG	Direc -tion	Water Depth (m)	Distance (n. m.)	Samples and its weight (kg)	Setting / Samples
1	04SFAD02	Start	12月26日	20:38:47	177°25.240′ E 16°24.094′ S	NW-SE	1,956	0.3	Rocks (175.8) Others (4.4) Total (180.2)	Sampling of basement with color anomaly confirmed by FDC21
		End	12月26日	21:39:07	177°25.502′ E 16°24.2376′ S		1,803			Partly altered basaltic rocks
2	04SFAD03	Start	12月26日	23:25:22	177°25.236′ E 16°24.162′ S	NW-SE	1,954	0.3	Rocks (111.4) Others (5.4) Total (116.8)	Sampling of basement with color anomaly confirmed by FDC21 and FDC23
		End	12月27日	00:17:33	177°25.525′ E 16°24.340′ S		1,801			Mainly basaltic rocks
3	04SFAD04	Start	12月27日	02:07:10	177°25.253′ E 16°24.258′ S	NW-SE	1,944	0.3	Rocks (15.5) Others (3.9) Total (19.4)	Sampling of basement with color anomaly confirmed by FDC21 and FDC23
		End	12月27日	02:47:44	177°25.530′ E 16°24.415′ S		1,802			Partly altered basaltic rocks
4	04SFAD05	Start	12月27日	04:46:08	177°24.615′ E 16°23.842′ S	W-E	2,072	0.3	Rocks (813.5) Others (2.9) Total (816.4)	Sampling of basement rocks with color anomaly finded by FDC24
		End	12月27日	05:29:26	177°24.927′ E 16°23.860′ S		1,955			Mainly basaltic rocks with glassy surface
Total								1.2	1,132.80	

Appendix 3

Photographs of FDC, FPG and AD

04SF FDC19

Photo No.060

2004/12/23 2:36:10, Temp2.298℃
16° 05.680′ S, 177° 26.093′ E Depth 1922m
Blue-green color anomaly

Photo No.061

2004/12/23 2:36:16, Temp2.301℃
16° 05.680′ S, 177° 26.095′ E Depth 1922r
White color anomaly and shell remains

Photo No.064

2004/12/23 2:36:32, Temp2.296℃
16° 05.680′ S, 177° 26.102′ E Depth 1921m
Living beings in hydrothermal activity

Photo No.066

2004/12/23 2:36:44, Temp2.303℃
16° 05.682′ S, 177° 26.102′ E Depth 1918r
Living beings in hydrothermal activity and hydrothermal coating on rocks

Photo No.069

2004/12/23 2:37:02, Temp2.306℃
16° 05.681′ S, 177° 26.109′ E Depth 1919m
Shell remains colony

Photo No.073

2004/12/23 2:37:30, Temp2.327℃
16° 05.683′ S, 177° 26.109′ E Depth 1922r
Unconsolidated sediments and shell remain

04SF FDC21

Photo No.035

2004/12/23 22:56:55, Temp2.360°C
16° 24.158′ S, 177° 25.346′ E Depth 1889m
Pillow lavas with color anomaly

Photo No.052

2004/12/23 23:00:08, Temp2.371°C
16° 24.193′ S, 177° 25.354′ E Depth 1894r
Subaqueous volcanic rocks with color anomaly

Photo No.064

2004/12/23 23:02:19, Temp2.386°C
16° 24.226′ S, 177° 25.363′ E Depth 1895m
Subaqueous volcanic rocks with color anomaly

Photo No.066

2004/12/23 23:02:31, Temp2.382°C
16° 24.222′ S, 177° 25.362′ E Depth 1894r
Subaqueous volcanic rocks with strong color anomaly

Photo No.072

2004/12/23 23:04:01, Temp2.378°C
16° 24.245′ S, 177° 25.369′ E Depth 1894m
Huge pillow lava

Photo No.098

2004/12/23 23:15:32, Temp2.380°C
16° 24.407′ S, 177° 25.416′ E Depth 1876r
Hyaloclastite

04SF FPG01

Date: 2004/12/25, 3:50:38

Lon: 16° 05.675' S

Lat: 177° 26.120 'E

Depth 1971m

Weight: 85.2kg

Contents:
Partly altered serpentinite Living beings in hydrothermal activity

04SF FPG02

Date: 2004/12/25, 6:00:25

Lon: 16° 05.670' S

Lat: 177° 26.131' E

Depth 1967m

Weight: 232.7kg

Contents:

Altered doloerite～gabrro Living beings in hydrothermal activity

04SF FPG03

Date: 2004/12/25, 21:03:16

Lon: 16° 05.682'S

Lat: 177° 26.126' E

Depth 1968m

Weight: 800kg

Contents:

Altered serpentinite and doloerite～gabrro Living beings in hydrothermal activity

04SF AD01

Date: 2005/12/26, 01:51:16 - 02:36:11

Lon: 16° 05.491' S - 16° 05.766' S

Lat: 177° 26.049 'E - 177° 26.182 'E

Depth 2000m - 1961m

Weight: 24.8kg

Contents:
gabrro pyroxenite pumice

04SF AD02

Date: 2005/12/26, 20:38:47 – 21:39:07

Lon: 16° 24.094' S – 16° 24.238' S

Lat: 177° 25.240 'E – 177° 25.502 'E

Depth 1956m – 1803m

Weight: 180.2kg

Contents:
Basalts altered

04SF AD03

Date: 2005/12/26, 23:25:22 - 00:17:33

Lon: 16° 24.162' S - 16° 24.340' S

Lat: 177° 25.236 'E - 177° 25.525 'E

Depth 1954m - 1801m

Weight: 116.8kg

Contents:

Basalts

04SF AD04

2005/12/27, 02:07:10 – 02:47:44

16° 24.258' S – 16° 24.415' S

177° 25.253 'E – 177° 25.530 'E

1944m – 1802m

19.4kg

Basalts partly altered

04SF AD05

Date: 2005/12/27, 04:46:08 – 05:29:26

Lon: 16° 24.615' S – 16° 24.927' S

Lat: 177° 24.615 'E – 177° 24.927 'E

Depth 2072m – 1955m

Weight: 816.4kg

Contents:

Basalts glassy surface

04SF AD06

Date: 2005/12/27, 20:39:03 - 21:14:33

Lon: 16° 05.098' S - 16° 05.202' S

Lat: 177° 25.603 'E - 177° 25.915 'E

Depth 2125m - 1947m

Weight: 113.8kg

Contents:
Altered gabbro dolerite basalt

04SF AD07

Date: 2005/12/27, 23:05:39 – 23:37:38

Lon: 16° 06.106' S – 16° 06.292' S

Lat: 177° 25.097 'E – 177° 25.332 'E

Depth 1910m – 1784m

Weight: 234.1kg

Contents:
Gabbro serpentinite pyroxinite

04SF AD08

Date: 2005/12/28, 01:27:22 - 01:47:34

Lon: 16° 05.505' S - 16° 05.691' S

Lat: 177° 26.072 'E - 177° 26.246 'E

Depth 2002m - 1988m

Weight: 26.9kg

Contents:

Conglomerate of green rock etc. with manganese crust

04SF AD09

Date: 2005/12/28, 03:32:09 – 03:54:19

Lon: 16° 05.800' S – 16° 05.864' S

Lat: 177° 26.017 'E – 177° 26.253 'E

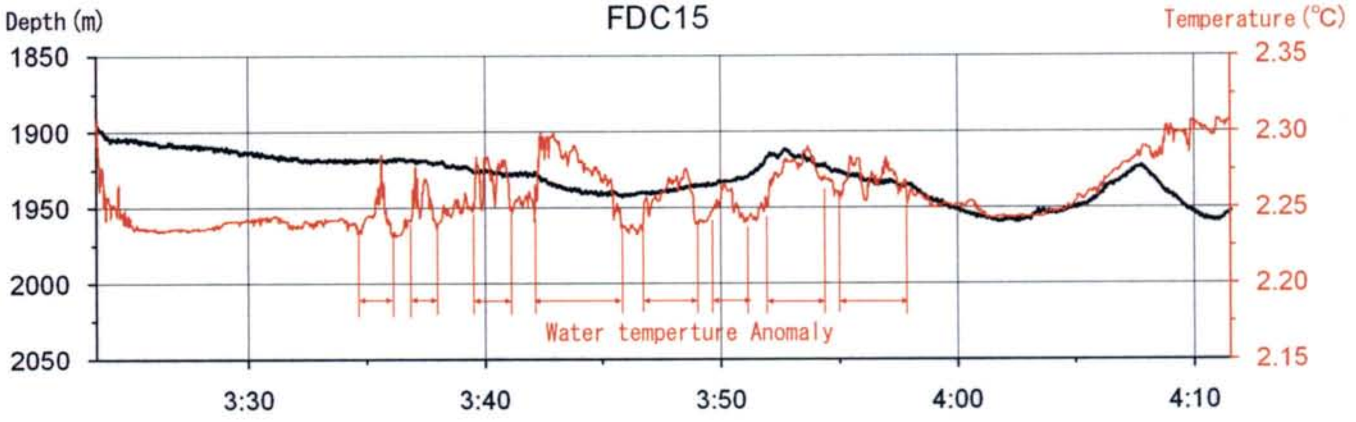
Depth 1967m – 1947m

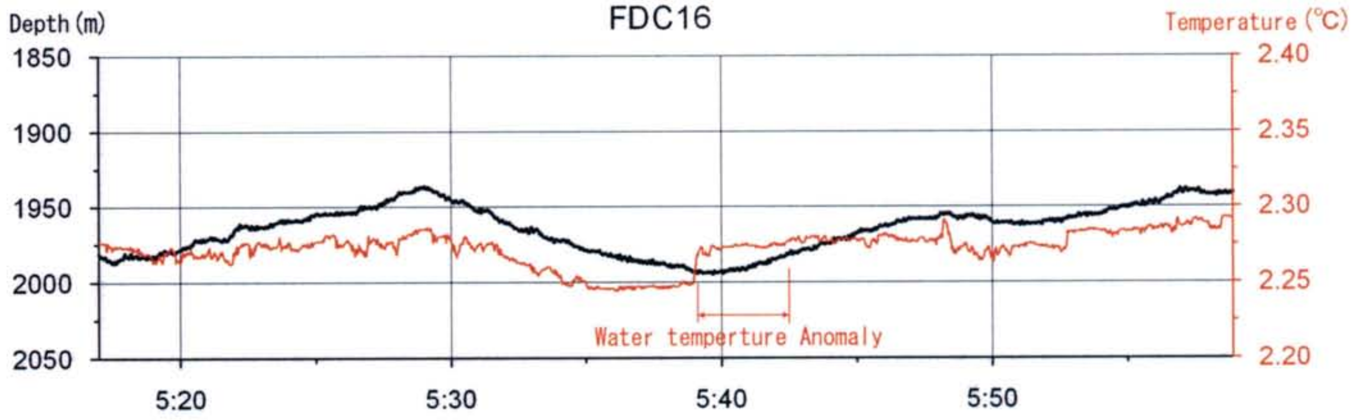
Weight: 6.8kg

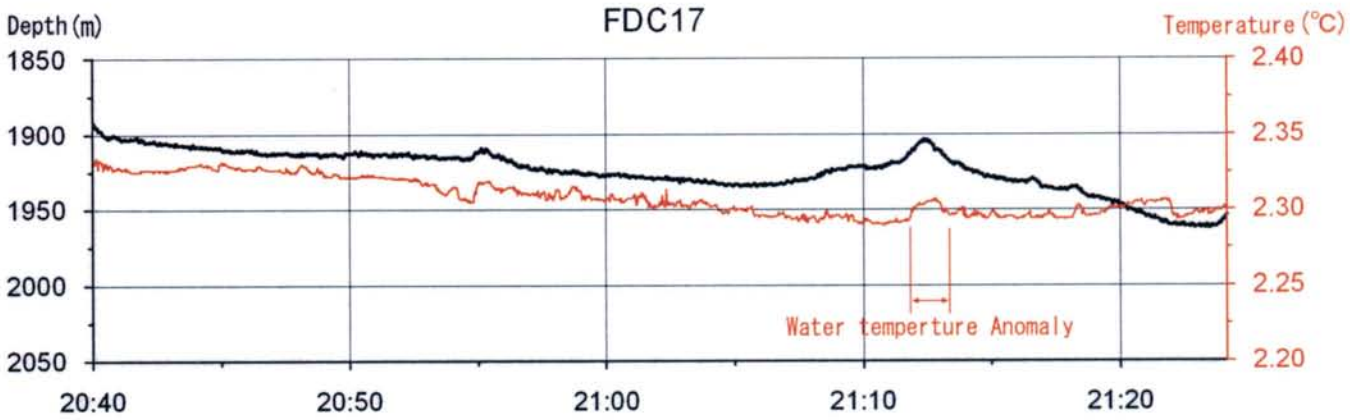
Contents:
Green rock pebble and pumice

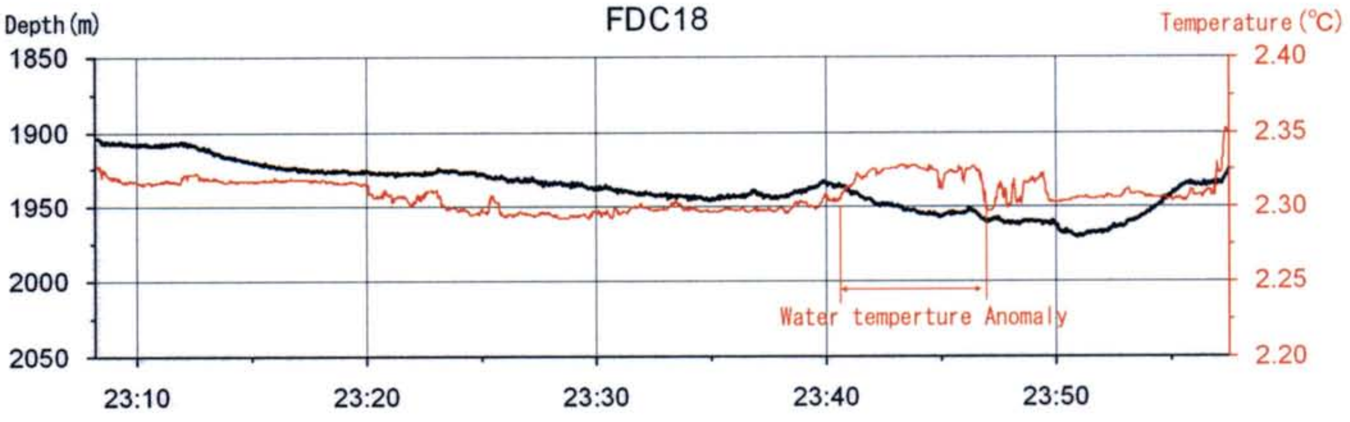
Appendix 4

Topographic Profile and Temperature of Sea Water (FDC)

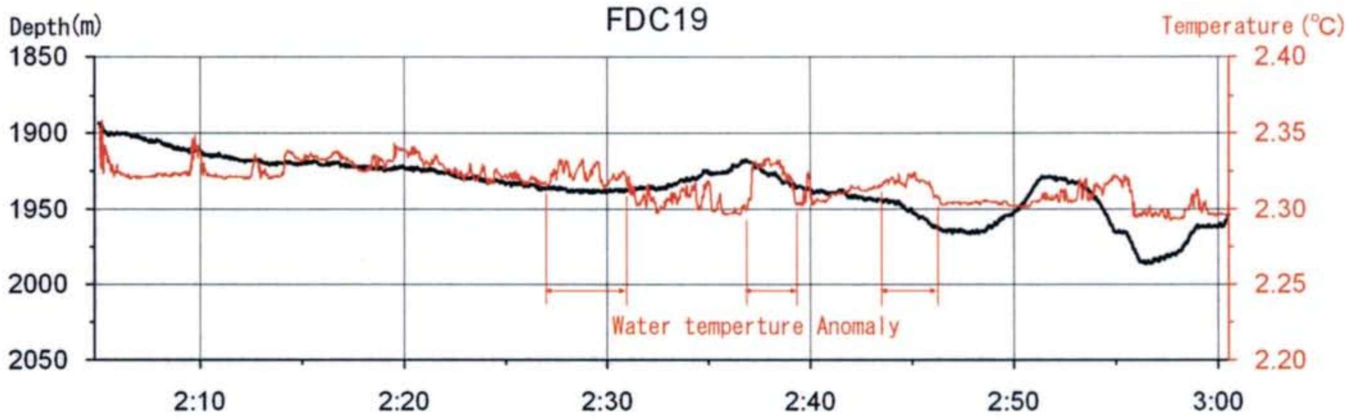


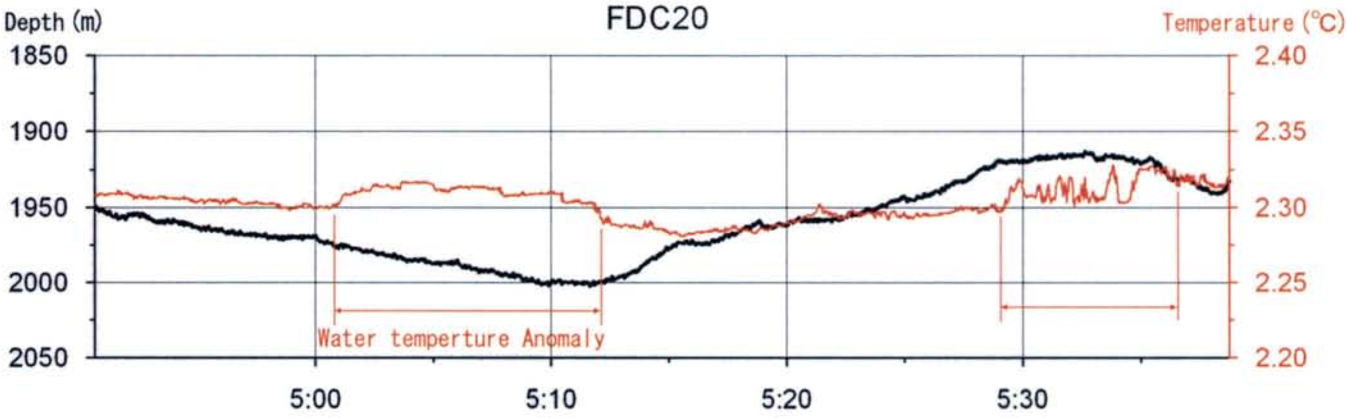




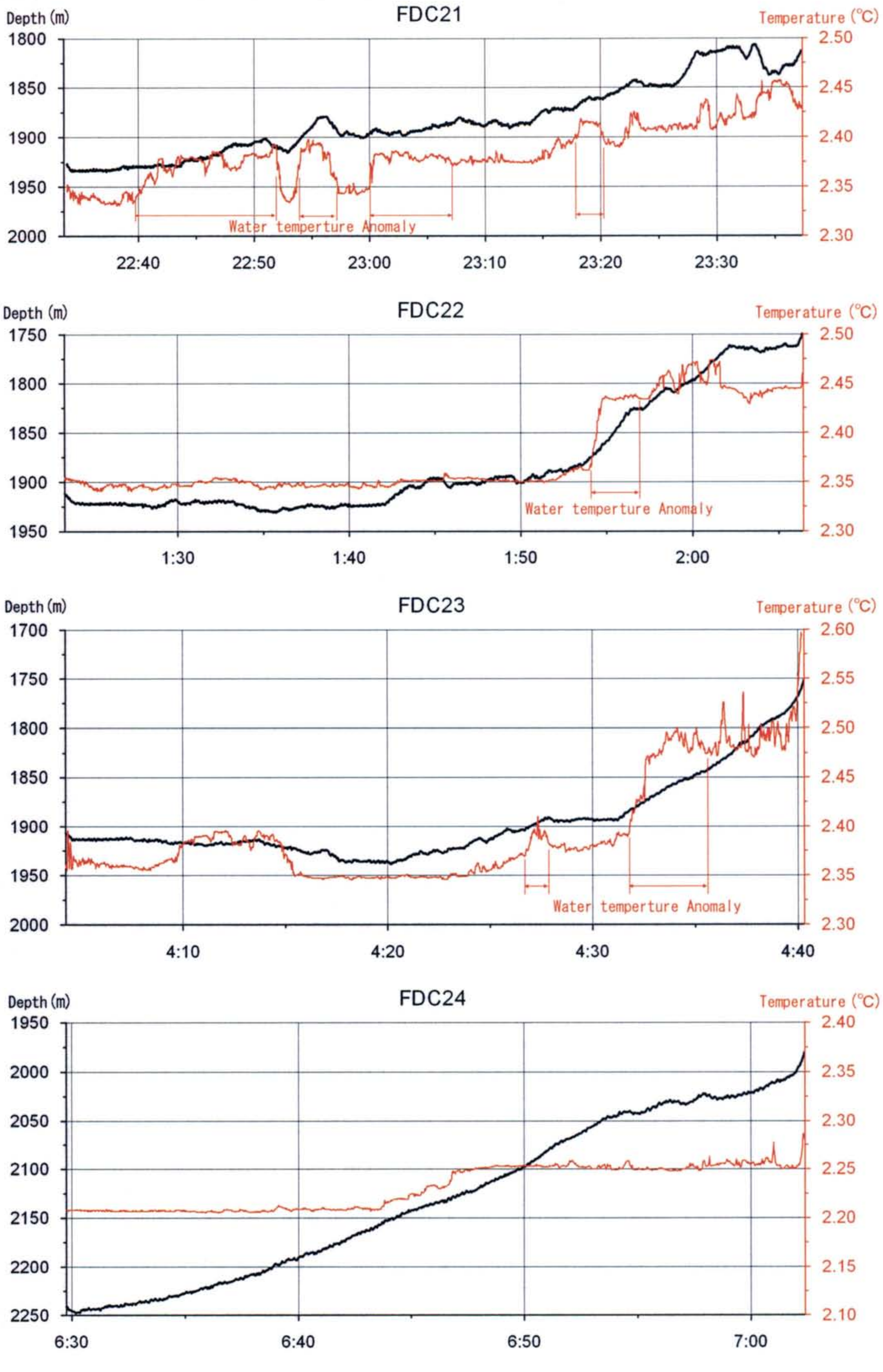


Topographic Profile and Temperature of Sea Water, Central hill(1)





Topographic Profile and Temperature of Sea Water, Central hill(2)



Topographic Profile and Temperature of Sea Water, ERZ A