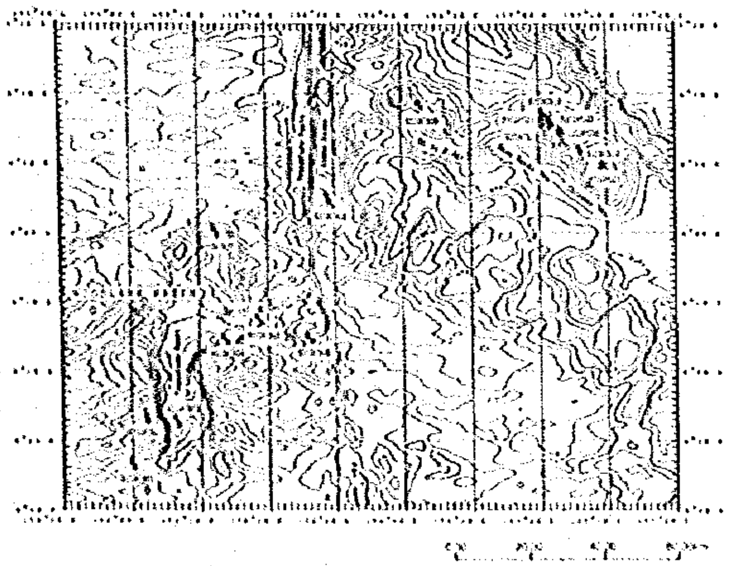
The Woodlark Basin
Solomon Islands
Detailed Survey of Hydrothermal Ore Deposits (1993)

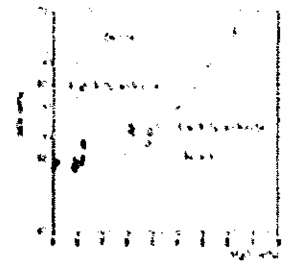


Location map of detailed survey sampling points

As for the detailed survey, FDC (Continuous Deep Sea Camera with [illegible]) observations were carried out at 9 track lines around the spreading center and the submarine volcanoes. Sampling was carried out at 16 points on places where visible [illegible] (FDC) are signs of mineralization were expected.

(Rocks)

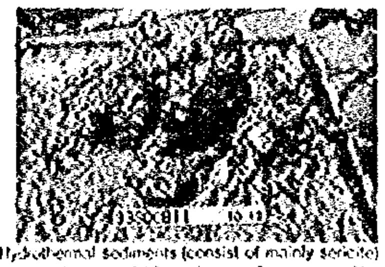
Rock samples from the seafloor spreading center, which is on the western side of the survey area, belong to the tholeiite rock series (MORB), and rock samples from the submarine volcanoes which are to the east, belong to the calcalkali rock series (Islands Arc or Back Arc).



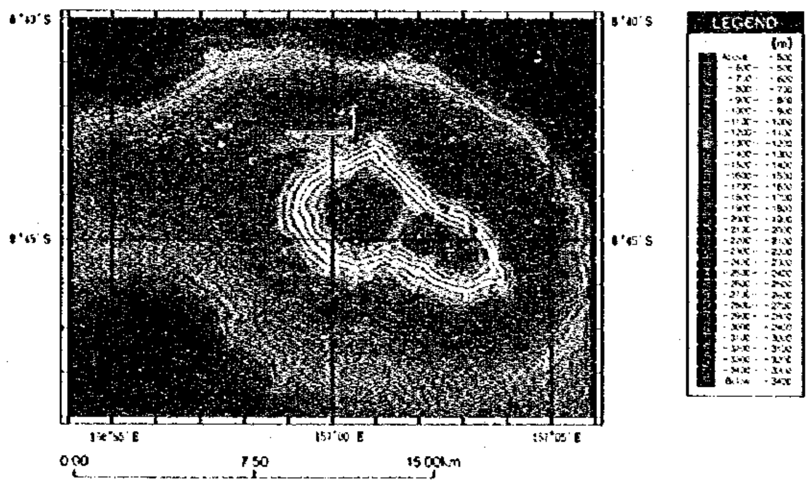
SiO_2 versus MgO for basalts

SiO_2 versus $Na_2O + K_2O$ for basalts

Hydrothermal sediments (altered clay) collected from 93SOFG02

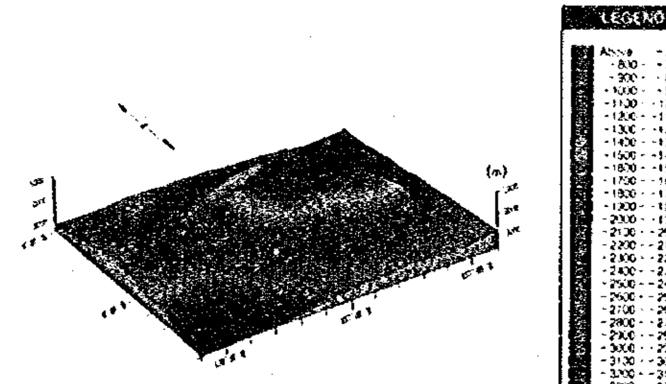


Hydrothermal sediments (consist of mainly sericite) collected from 93SOCB11 dredge



Bathymetric map (Kana Keoki Seamount)

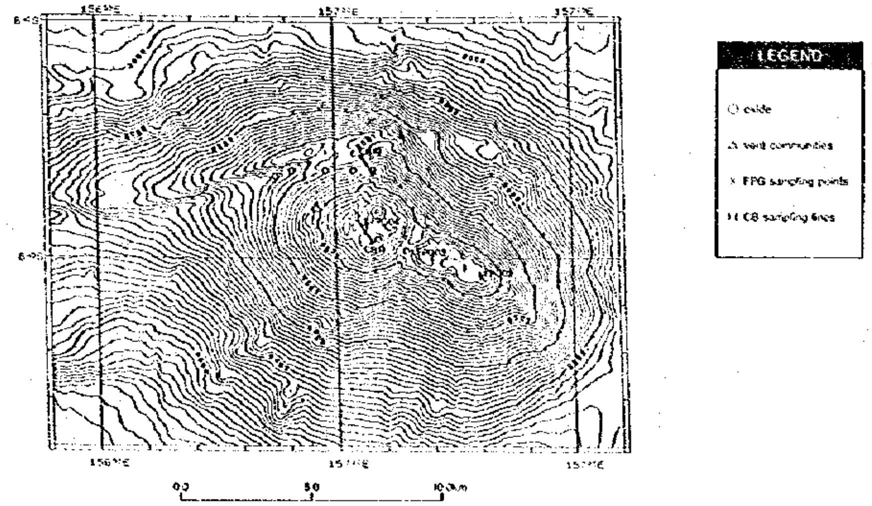
Kana Keoki Seamount is situated on the Ghizo Ridge at east side of the Simbo Ridge. It is an elliptical shape with trend NW - SE. It has oval with two peaks and there are three small peaks on the north - western summit, which assumes caldera structure. The depth of the summit is 650 meters, basal depth is 3000 meters and relief is about 2400 meters. Major axis of basal diameter is 25 kilometers, minor axis is 16 kilometers and slope is about 15 degrees. Moreover the northern flank of Kana Keoki Seamount slips ENE - WSW direction laterally.



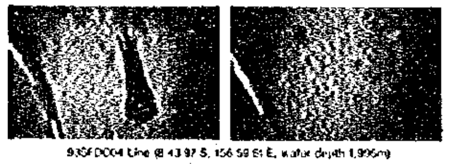
Bird's-eye view (Kana Keoki Seamount)
(S45 W direction)

(Apparent Sign of Mineralization)

Light gray clay and siliceous rocks including minor amounts of pyrite were collected from the crest of a submarine volcano (Kana Keoki Seamount). The chemical analysis, X ray diffraction and microscopic analysis were performed back on land. Assay data of one specimen was 11.5g/t Au and 72g/t Ag and microscopically chalcopyrite, tetrahedrite and sphalerite were observed. Sericite, which is commonly present in hydrothermal deposits was also detected. Furthermore, very small chimney structures which were composed of powdered galena and barite were collected.

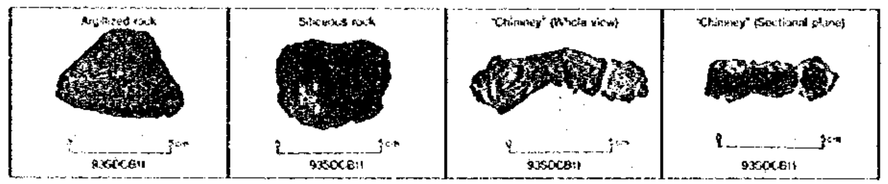


Sampling points (Kana Keoki Seamount)



Seafloor pictures photographed by FDC

Microscopic photos of ore minerals of 93SOCB11

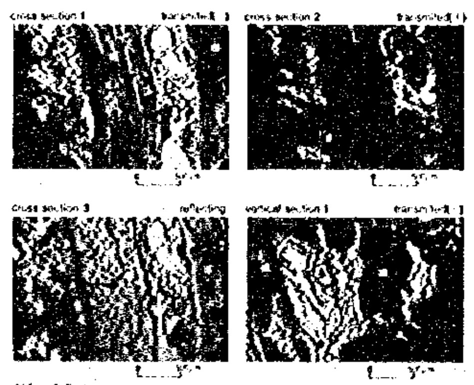


Photos of sample (rock) collected during detailed survey

Result of whole rock analysis and trace level analysis for ores

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	<5	180	>10000	190	275	250	205	270
[illegible]			0.170					
[illegible]	0.78	3.18	1.24	6.90	6.14	3.82	4.30	6.92
Cu ppm	45.0	675.0	26100	280.0	140.0	140.0	105.0	274.0
Pb ppm	1125.0	3900.0	2620	678.0	74.0	75.0	37.0	160.5
Zn ppm	575	3075	250	218	64	48	94	561
[illegible]	1375	389	475	545	30	160	65	60
[illegible]	1.36	6.76	9.53	1.38	0.94	1.84	5.95	6.52
[illegible]	0.163	2.490	3.178	1.030	0.220	2.576	6.310	7.660
[illegible]	0.1	1.0	8.2	0.3	0.3	<0.1	0.2	1.5
[illegible]	0.1	0.1	5.3	0.3	0.4	<0.1	0.2	0.5
[illegible]	25	71	12	20	18	25	16	20
[illegible]	29	39	10	15	15	19	14	14
[illegible]	1388	836.6	244.0	86.3	16.9	67.7	15.5	81.0
[illegible]	<0.1	<0.2	25.5	0.2	<0.2	<0.2	<0.2	<0.2
[illegible]	30	300	10	20	20	20	20	10
[illegible]	4150	850	85	160	80	115	85	206
[illegible]	510	770	25	67	10	11	18	13
[illegible]	1.4	51.2	5.6	16.8	3.8	6.4	6.8	9.2
[illegible]	<1	<1	<1	<1	<1	<1	<1	<1
[illegible]	1	<1	<1	1	<1	<1	3	2

93SOCB11 chimney



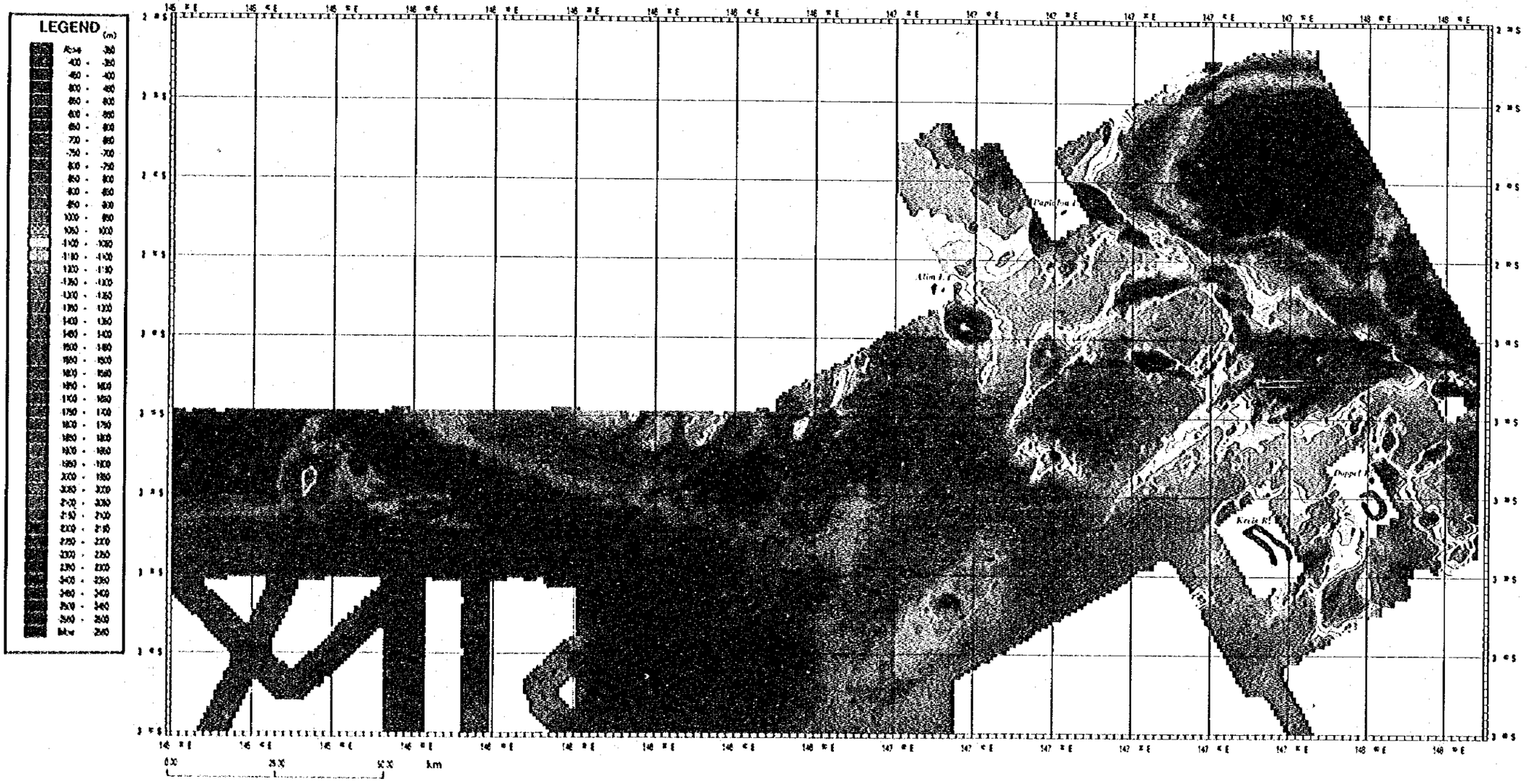
Abbreviation
Ga : Galena, Ba : Barite, Py : Pyrite, Ro : Wall rock

Microscopic photos of 93SOCB11 chimney (polished thin section)

JICA/MMAJ/SOPAC ATLAS 1995.3 Surveyed by DORD

The New Guinea Basin and the Manus Basin Papua New Guinea

The Survey of R/V Sonne Hydrothermal Vent Expedition (1992)



Color-coded bathymetric contour map based on MBES (contour interval : 50 m)

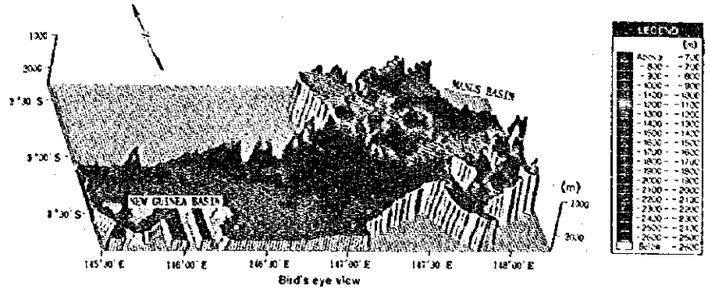
JICA/MMAJ/SOPAC ATLAS 1995. Surveyed by DORD

South Pacific Seafloor Atlas, Sheet no 14

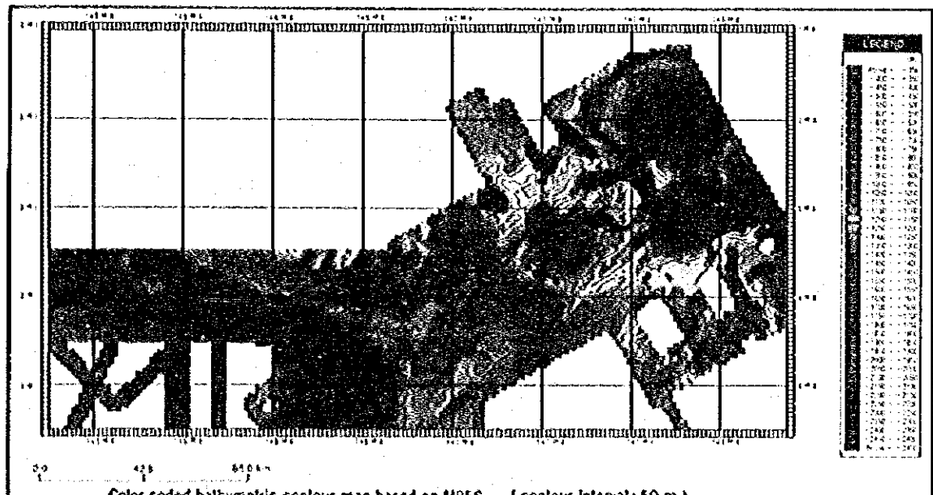
The New Guinea Basin and the Manus Basin Papua New Guinea

The Survey of Seafloor Hydrothermal Deposits (1994)

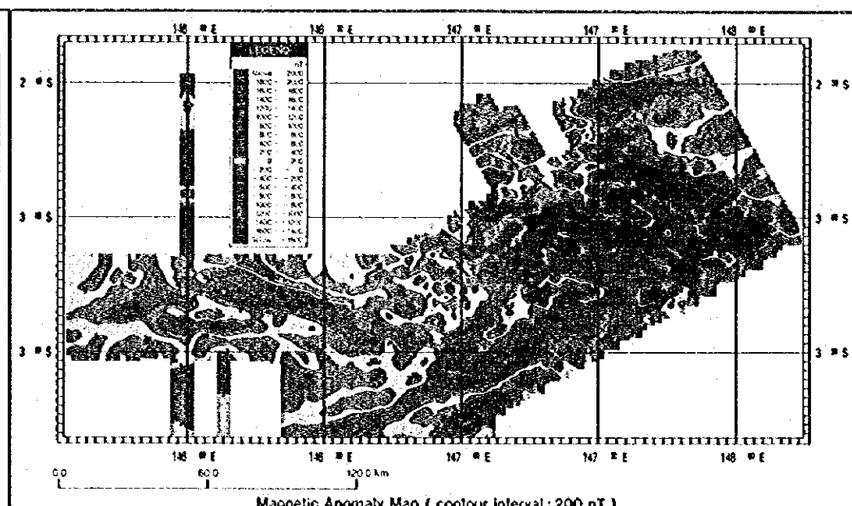
Location map of the survey area (after Bruns et al., 1989) : survey site.



Bird's eye view



Color coded bathymetric contour map based on MBES (contour interval : 50 m)



Magnetic Anomaly Map (contour interval : 200 nT)

According to Taylor (1979), the boundary between the Bismarck and Pacific plates is composed of at least four segments: two transform faults, one spreading segment, and one "leaky" transform. Specific sea floor spreading magnetic anomalies have not yet been identified in the New Guinea Basin.

The survey was done in the sea area which had this leaky transform.

Bismarck Sea are divided into two parts by the northwest trending Williamez Rise running through the eastern margin in this survey area; the Manus Basin (in the northern-most margin) and the New Guinea Basin. The Williamez Rise is 60 - 70 km wide, its crests varies in the water depth from 270 to 1500 m due to numerous large and small seamounts and magnetic basement relief show a horst like feature (cf. figure in this atlas). The western New Guinea Basin are 3,800 to 2,300 m deep and are unusually flat.

From new bathymetric and magnetic data, inferred spreading system are composed of four transform fault zones and two spreading centers as (cf. below left figure in this atlas).

A trending N72° W transform fault: is coincident with the higher magnetization location (>5A/m), which extends high magnetization along the eastern flank of the Williamez Rise.

A trending S45° W spreading center: the minimum water depth is 170 m and spreading center segment parallel short ridges and valleys are symmetrically distributed and are associated with low magnetization. Specific seafloor spreading magnetic anomaly (stripes) are not found.

A trending N50° W transform fault: located along western flank of Williamez Rise and coincide with high magnetization location (>5 A/m).

A trending S35° W spreading center: is a ridge; the water depth of its crests increase toward the west and the crest belongs to low magnetization, to high reflectivity zone, i.e. sediment free zone by the Sile scan sonar. But the magnetic pattern does not follow any of the seafloor spreading feature.

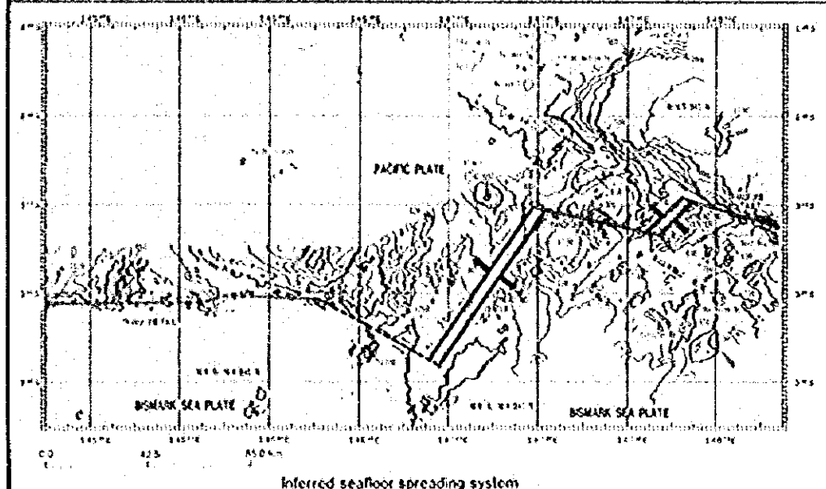
A trending N60° W transform fault: not found predominant topographic and magnetic feature.

A trending N-W transform fault: is coincident with a chain of seamounts. Magnetization is far lower than that of a trending N80° W transform fault.

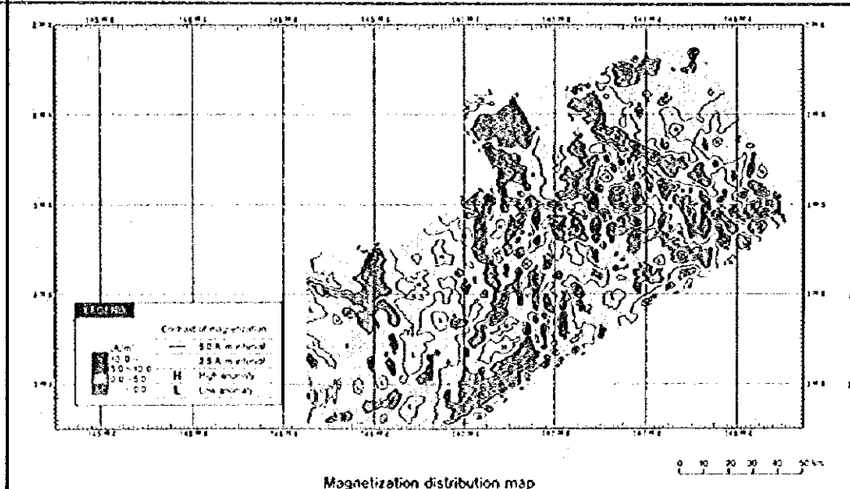
Reference

Taylor, B., 1979: Bismarck Sea: Evolution of a back arc basin. Geology 7, 171-174.

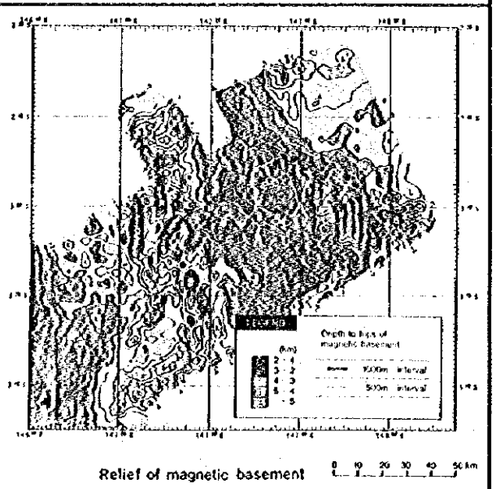
Johnson R.W., Mutter J.C., 1982: Origin of the Williamez Rise, Papua New Guinea. Earth and Planetary Science Letters 61, 247 - 260.



Inferred seafloor spreading system



Magnetization distribution map



Relief of magnetic basement

JICA/MMAJ/SOPAC ATLAS 1995. Surveyed by DORD

South Pacific Seafloor Atlas, Sheet no 15

The New Guinea Basin and the Manus Basin Papua New Guinea

Geochemical Exploration and Hydrothermal Ore Deposit Survey (1992)

The geochemical exploration consists of regional geochemical sampling and base line geochemical sampling. Bottom sediments were collected at 39 points in a 20 mile grid over total area. In the base line geochemical sampling two base lines were set across the ore indications which had been discovered during the hydrothermal ore deposit survey. Along the two lines we planned to take a total of 30 samples of bottom sediments. However, we had to abandon sampling at 3 points where hard rock made sampling impossible. Out of the samples from the 66 points, we have selected 24 samples for chemical analysis and 20 samples for X-ray defraction. Consequently, a small amount of pyrite was identified, but its genetic relation with hydrothermal ore deposits was obscure.

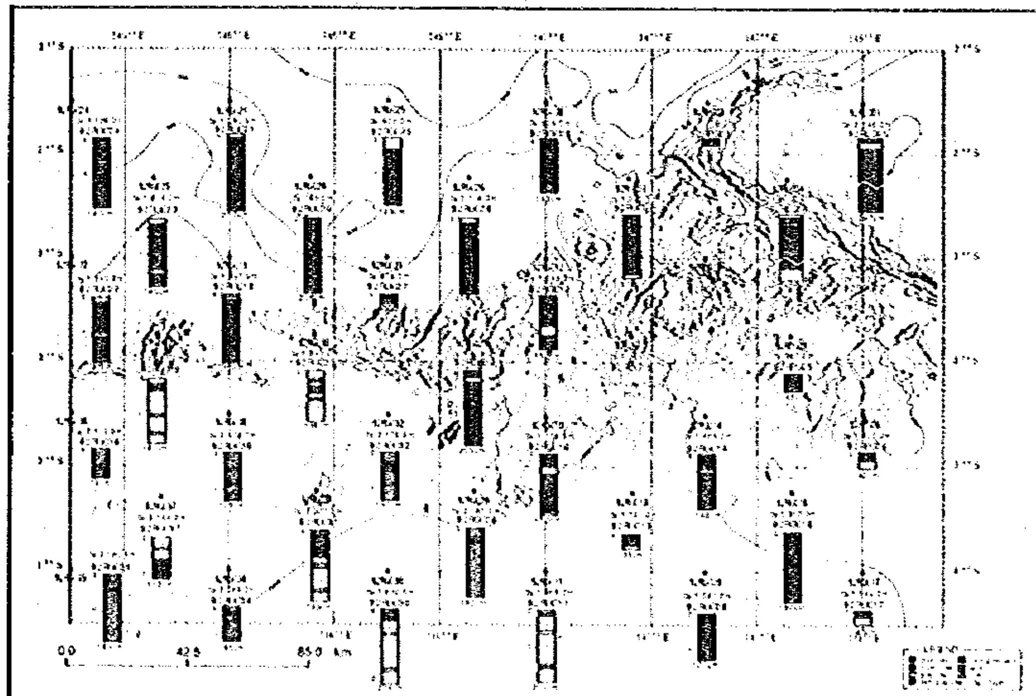
The ore deposit survey consisted of the survey by SSS, seafloor observation and sampling. The SSS was conducted on three track lines (59 miles in total) in the direction crossing diagonally with the seafloor spreading center which had been estimated through the topographic map, in order to confirm sediments free zones. And then, the seafloor observation by FDC was conducted along 6 track lines (45 miles in total), and as a result, ore signs were found at 3 places and oxidized zones at 2 places.

Neither vent animal nor smoker were observed. We conducted sampling at the five ore sign places and one oxidized zone and obtained a great amount of oxidized iron and hydroxide ore, but could not confirm any visible sulfide materials.

(1) On the result of geochemical exploration along the base line, values of Fe_2O_3 of the sediments showed the trend increasing towards the spreading center where the mineralized zone existed.

(2) On the results of Principal Component Analysis, the third component is considered to show one related to the mineralized zone which was found in this area.

(3) The surface of the mineralized zone observed in this area consists mainly of oxides accompanying trace amount of sulfide.
Geochemical method is a useful tool for exploration of hydrothermal deposit, and more geochemical data should be collected in other prospective area.



Schematic drawings of sampling results obtained from regional geochemical survey

Main factor loading

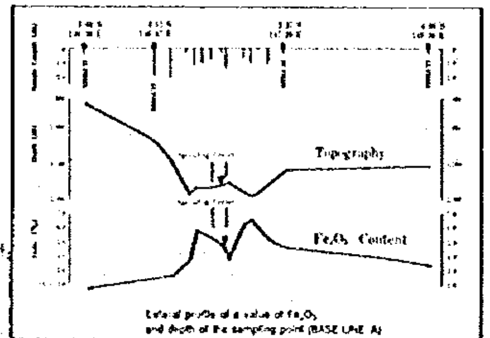
	Positive				Negative	
1st Component	Al_2O_3	(0.91)	REE	(0.69)	CaO	(−0.92)
	Ga	(0.81)	MgO	(0.65)	LOI	(−0.90)
	SiO_2	(0.80)	FeO	(0.64)	Sr	(−0.70)
	K_2O	(0.71)	TiO_2	(0.63)		
2nd Component	Zn	(0.89)	Ca	(0.51)	SiO_2	(−0.35)
	Ni	(0.87)	Hg	(0.48)	Na_2O	(−0.33)
	Co	(0.70)	S	(0.45)		
	Cu	(0.66)	MgO	(0.45)		
3rd Component	As	(0.82)	MnO	(0.16)	Ga	(−0.31)
	Fe_2O_3	(0.77)			Ag	(−0.31)
	Mo	(0.74)				
	P_2O_5	(0.57)				

Composition of the mean values of Chemical Analysis

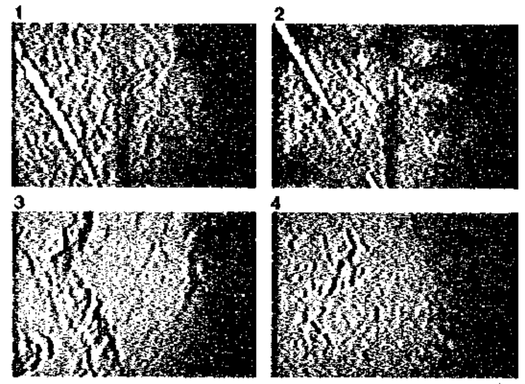
	Color Anomaly Area	Regional Area
Fe_2O_3	10.03 %	4.28 %
P_2O_5	0.53 %	0.21 %
As	28.56 ppm	10.09 ppm
Mo	13.47 ppm	1.69 ppm
P	0.23 %	0.09 %
REE	223 ppm	146 ppm
CaO	9.42 %	17.38 %
Ni	13.21 ppm	33.9 ppm

Chemical analysis of 14 samples from the color anomaly area (%)

	SiO_2	Fe	S	Mn	Cu	Ba	Cu	Pb	Zn
Max.	52.10	35.72	0.219	7.63	3.92	0.93	0.01	<0.01	<0.01
Min.	19.00	9.68	0.309	0.42	0.45	<0.01	<0.01		
Average	33.74	23.39	0.107	1.57	1.74	0.01	<0.01	<0.01	<0.01

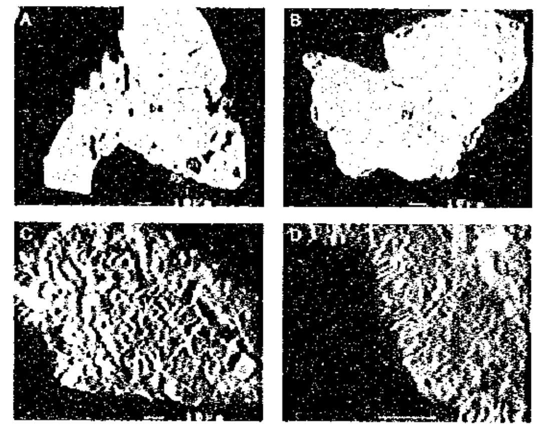


Lateral profile of a value of Fe_2O_3 and depth of the sampling point (BASE LINE A)



1 Reddish brown hydroxides
Ore indication No.4 92SFDC07/03 02.2 S, 147 51.7 E, water depth 501m
2 Yellow hydroxides. Pebbles are accumulated on the surface
Ore indication No.4 92SFDC07/03 02.2 S, 147 51.6 E, water depth 495m
3 Yellowish brown hydroxides
Ore indication No.5 92SFDC07/03 02.2 S, 147 51.6 E, water depth 873m
4 Spongy hydroxides
Ore indication No.5 92SFDC09/03 06.1 S, 147 45.1 E, water depth 975m

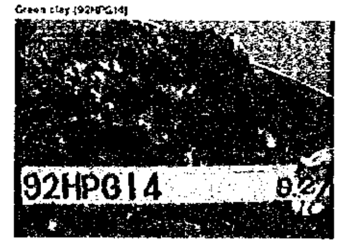
Photographs of ore indications (FDC)



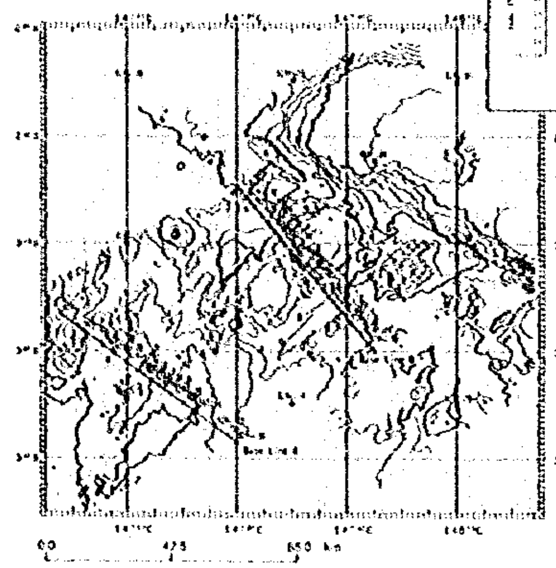
Back scattered electron images of heavy minerals from oxidized zones of the New Guinea Basin. (A) aggregate (HOG11); barite (ba) and pyrite (py) (B) aggregate (HPG27); pyrite and chalcopyrite (cp) and (C) and (D) fibrous aggregates of hydrothermal todorokite (HGC9 2 and HPG4) by GSJ

Brown deposits (92HPG07)

Green clay (92HPG14)



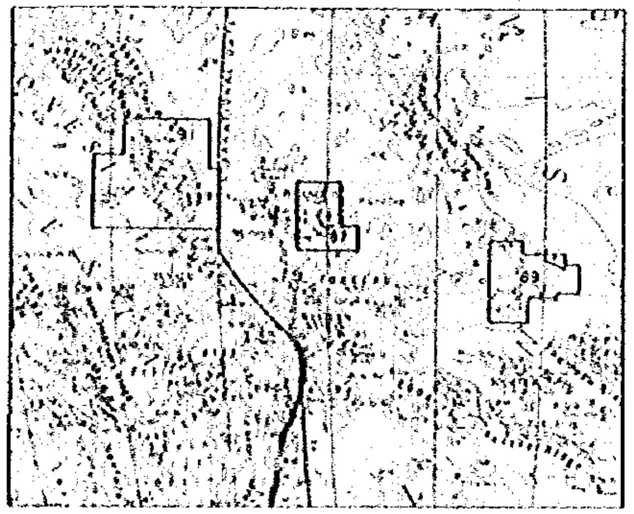
Photos of samples collected during ore deposit investigation



Location map of base line geochemical sampling points

Republic of Kiribati

The Survey of Manganese Nodules (1987,1989,1991)



Location map of the survey area

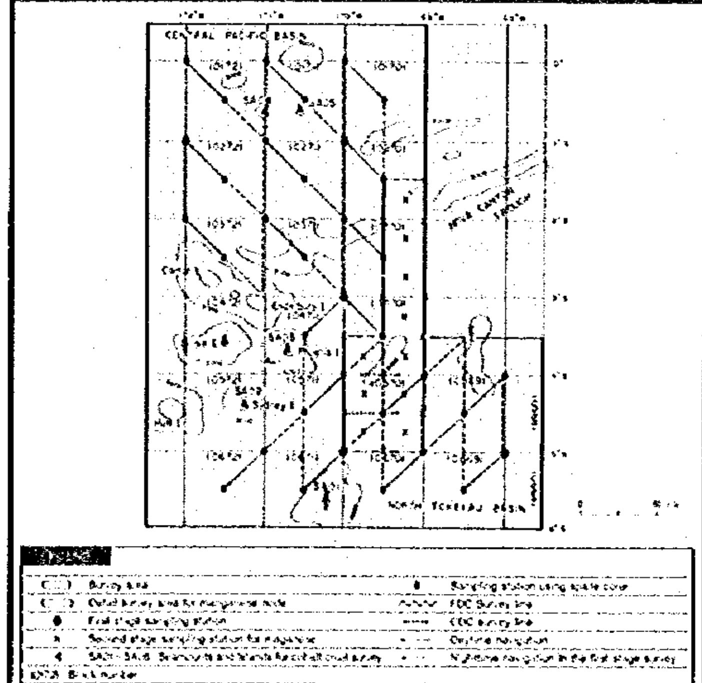
[illegible]

	Ni rich type	Co rich type
Mn/Fe	>2.5	<2.5
Abundance	Low [illegible]	High [illegible]
Morphology	Spheroidal-ellipsoidal	Pebble-massive-plate
Ni grade	[illegible]	[illegible]
Cu grade	[illegible]	[illegible]
Co grade	[illegible]	[illegible]
Water depth	[illegible]	[illegible]
Sediment	Pelagic clay	Calcareous sediment
Topography	Abyssal plain	Abyssal hill

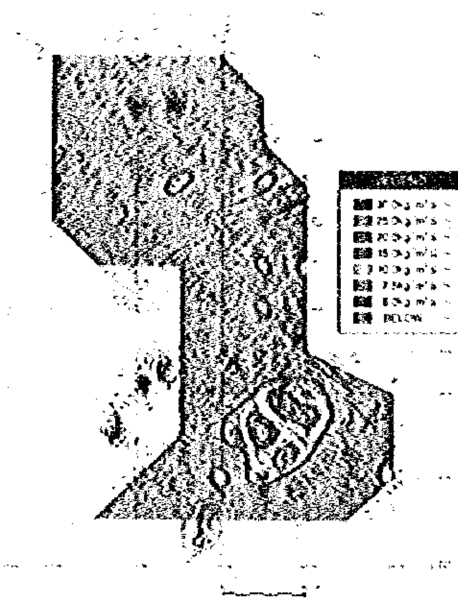
[illegible]

[illegible]

1987

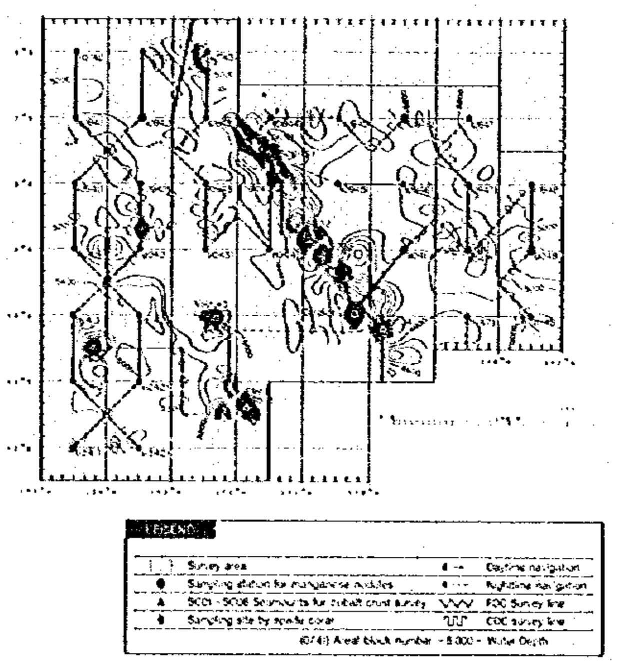


Location map of survey stations, seamounts and others

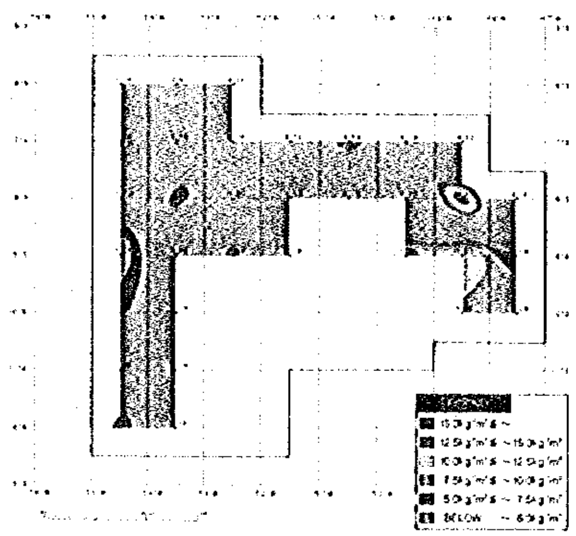


Abundance map of manganese nodules

1989

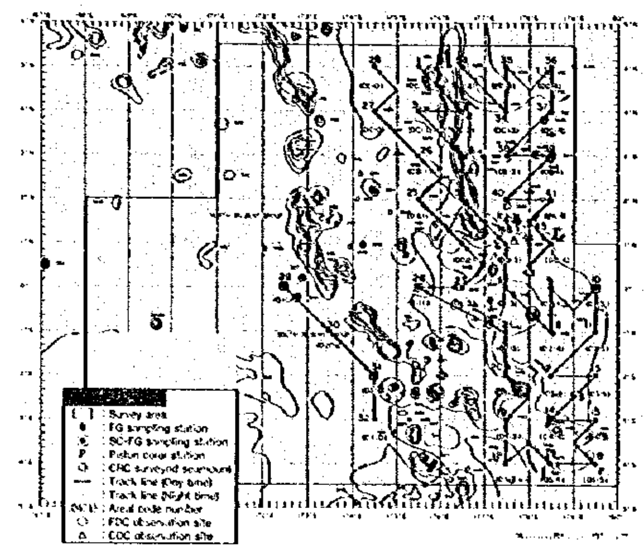


Location map of survey stations and seamounts

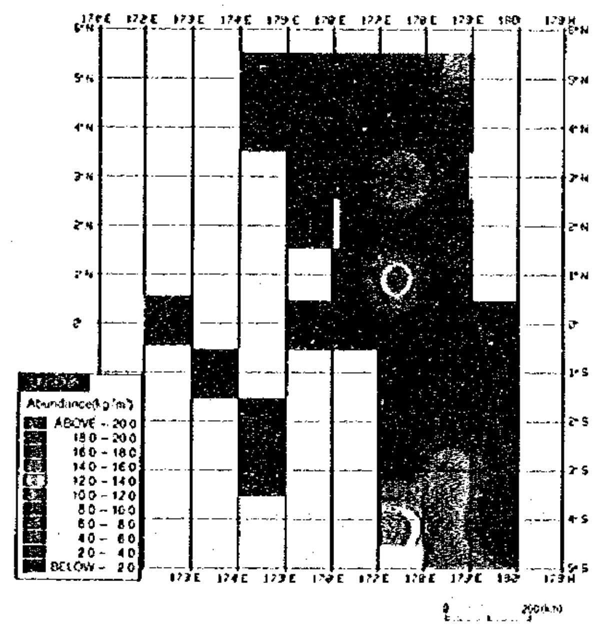


Abundance map of manganese nodules

1991



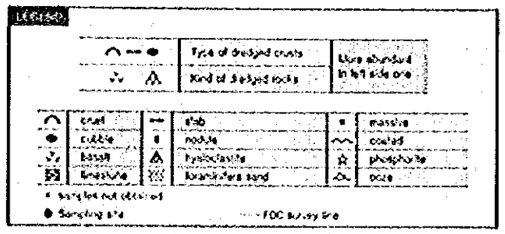
Location map of survey stations, track lines, seamounts and others



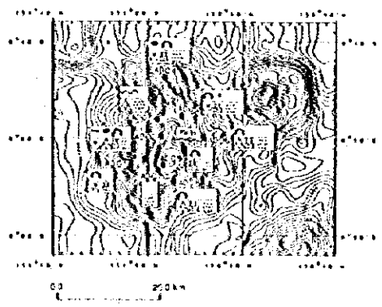
Abundance map of manganese nodules

Republic of Kiribati

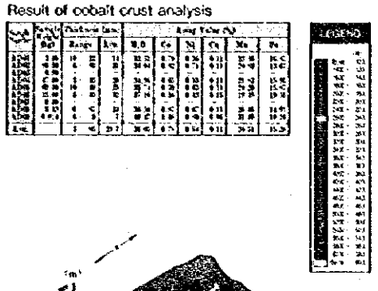
The Survey of Cobalt Rich Crust (1987, 1989,1991)

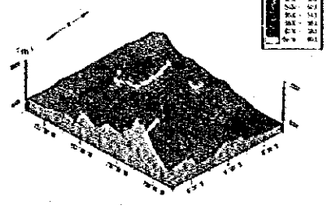


SC02 (1989)



Result of cobalt crust analysis

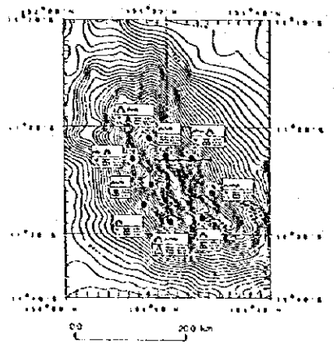




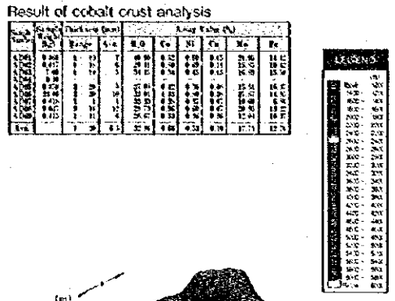
Distribution of cobalt crust in SC02 Seamount (1989)

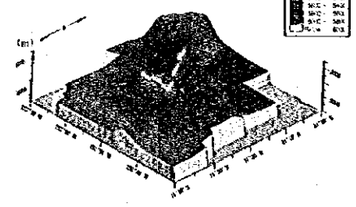
Bird's eye view of SC02 Seamount

SC05 (1989)



Result of cobalt crust analysis

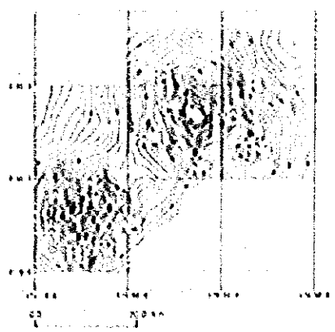




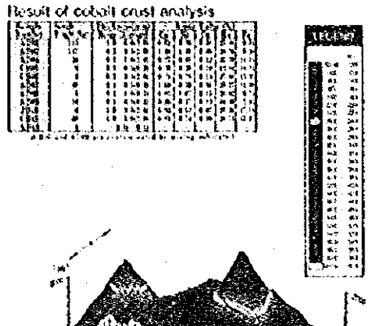
Distribution of cobalt crust in SC05 Seamount (1989)

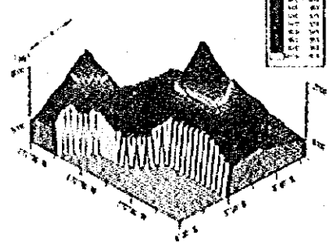
Bird's-eye view of SC05 Seamount

SA03 (1987)



Result of cobalt crust analysis

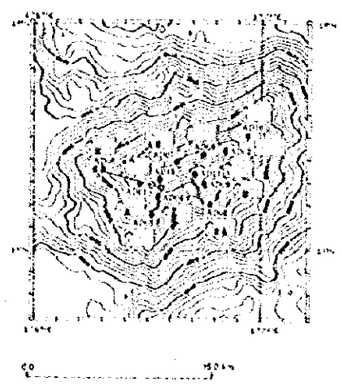




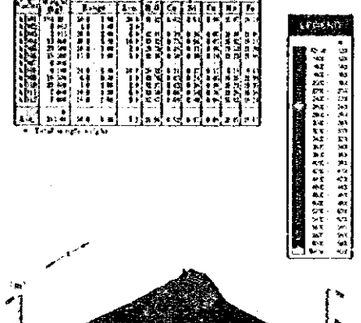
Distribution of cobalt crust in SA03 Seamount (1987)

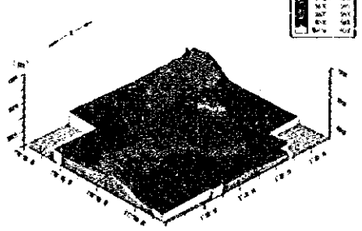
Bird's eye view of SA03 Seamount

SE04 (1991)



Result of cobalt crust analysis

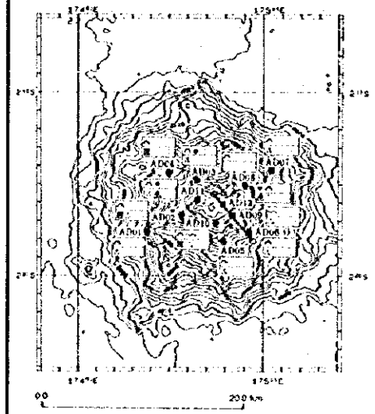




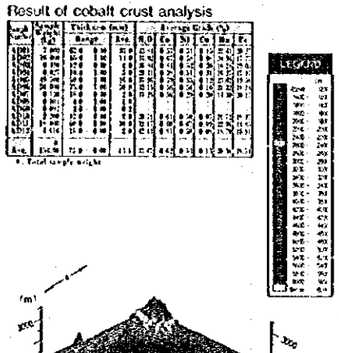
Distribution of cobalt crust in SE04 Seamount (1991)

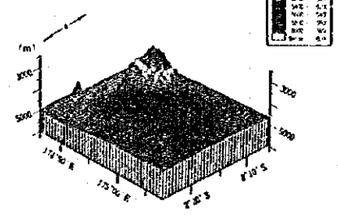
Bird's eye view of SE04 Seamount

SE05 (1991)



Result of cobalt crust analysis





Distribution of cobalt crust in SE05 Seamount (1991)

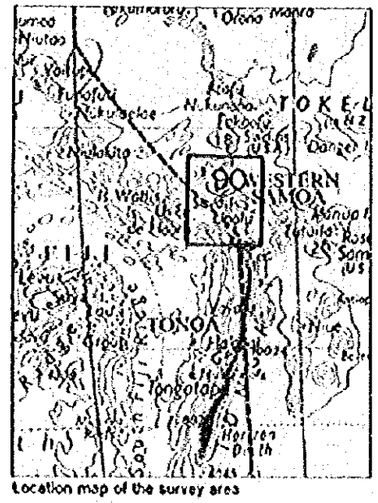
Bird's-eye view of SE05 Seamount

JICA/MMAJ/SOPAC ATLAS 1995. Surveyed by DORD

South Pacific Seafloor Atlas, Sheet no 18

Western Samoa

The Survey of Cobalt Rich Crust (1990)



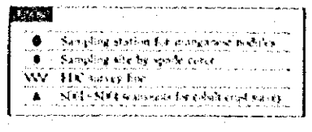
Location map of the survey area

The purpose of the survey is to evaluate the potential mineral resources, especially that of manganese nodules and cobalt rich crust.

Sampling of manganese nodules was done only in 4 stations (30 mile grid), and a few nodule samples were collected.

Occurrence of cobalt rich crust in the four seamounts can be summarized as follows.

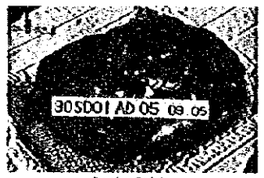
- Average crusts thickness : 3.4 mm
- Average major five metal grade : 0.41% Co, 0.21% Ni, 0.68% Cu, 17.96% Mn and 20.02% Fe
- The thin concentration (max 13 mm) with mono layer structure may indicate that the age of cobalt crust is not so very old.
- The Mn, Ni and Cu contents are positively correlated and the Fe content is positively correlated with Co content.
- A tendency of higher Co grade with decreasing water depth is clearly observed.
- The Ni - Cu - Co ternary diagram reveals that the all plots are concentrated at high Co, Ni zone.



Location map of survey stations, seamounts and others

Crust Type Cobalt Crust
Crust Coverage: 95 %
Water Depth: 1,972 m
S002 Seamount, F0003 Track line

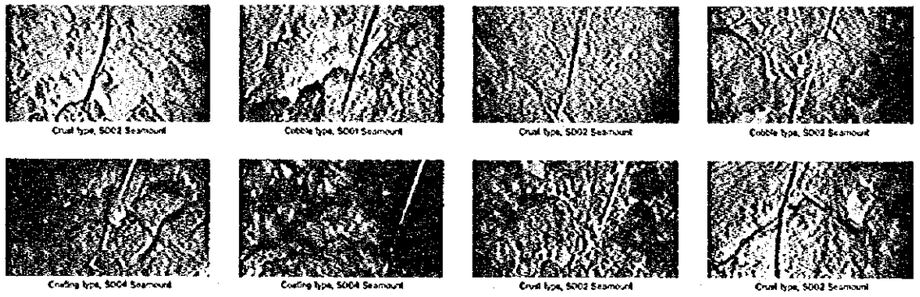
Seafloor



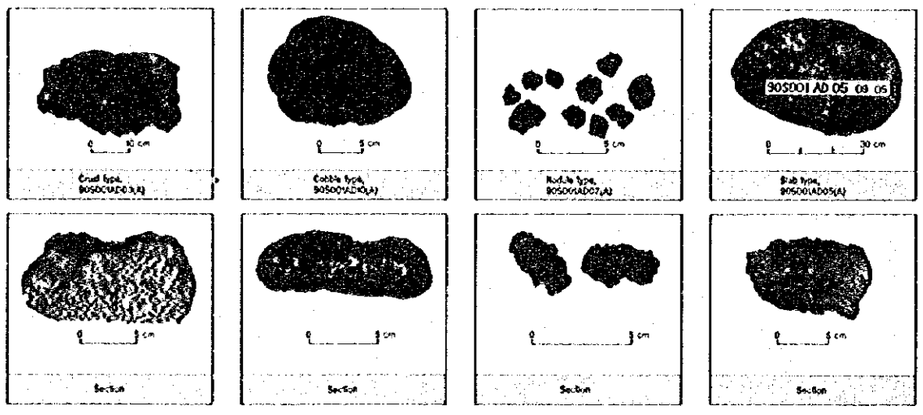
Slab Type Cobalt Crust
(Sample No. 90SD01AD05)
Dredged Amount: 33.5 kg
Water Depth: 1,973 m
SD01 Seamount

Sample collected

Representative occurrence of cobalt crust



Occurrence of cobalt crust (FDC photographs)



Morphology of cobalt crust

JICA/MMAJ/SOPAC ATLAS 1995. Surveyed by DORD

South Pacific Seafloor Atlas, Sheet no 19

Western Samoa

The Survey of Cobalt Rich Crust (1990)

LEGEND

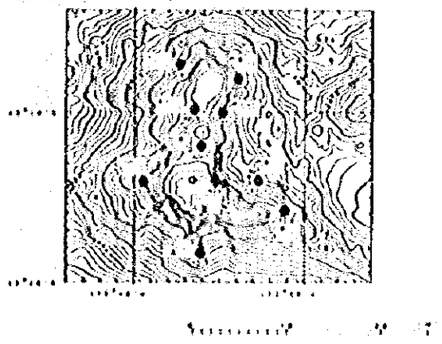
Type of dredged crust (More abundant in left side one)

Kind of dredged rocks (Older in left side one)

crust		slab		massive	
cobble		nodule		coated	
basalt		hyaloclastite		paleo-sediments	
limestone		foraminifera sand and ooze			

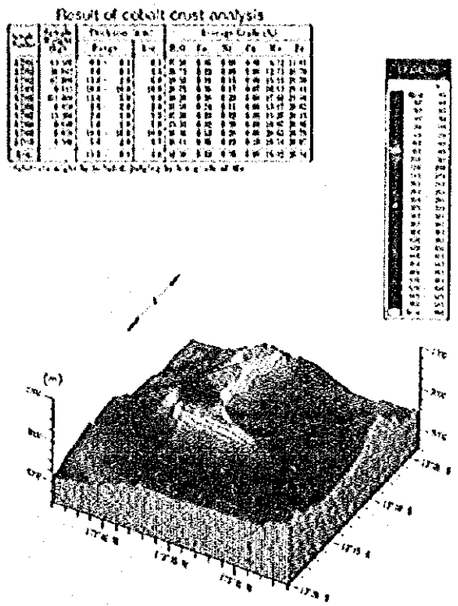
Sampling point (ADs) FDC survey line

SD01 Seamount



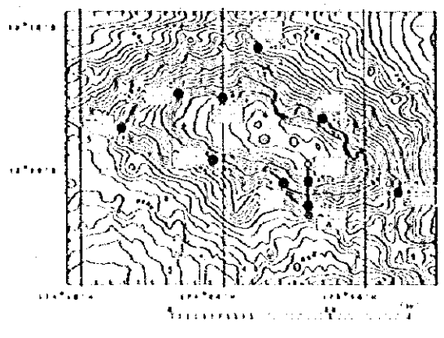
Distribution of cobalt crust in SD01 Seamount

Result of cobalt crust analysis



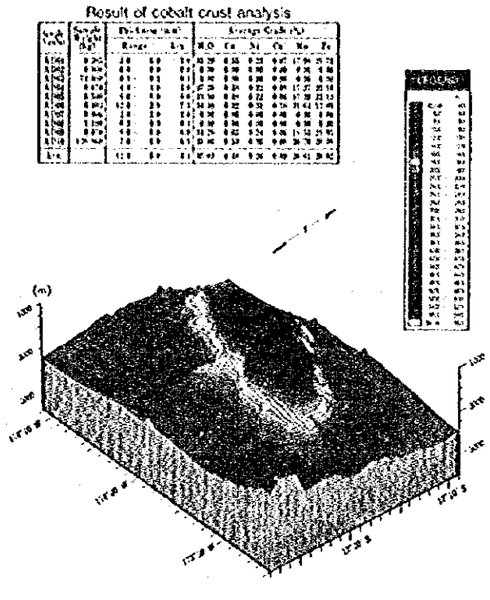
Bird's eye view of SD01 Seamount

SD02 Seamount



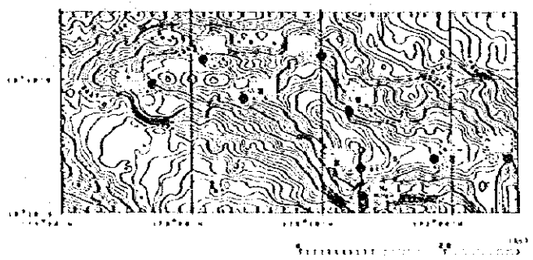
Distribution of cobalt crust in SD02 Seamount

Result of cobalt crust analysis



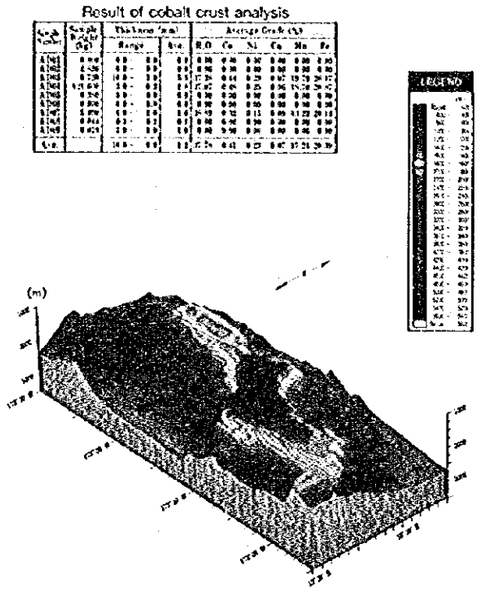
Bird's-eye view of SD02 Seamount

SD03 Seamount



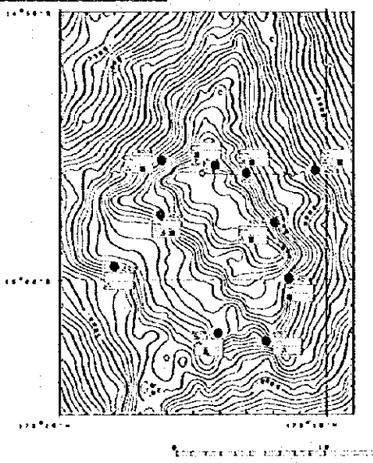
Distribution of cobalt crust in SD03 Seamount

Result of cobalt crust analysis



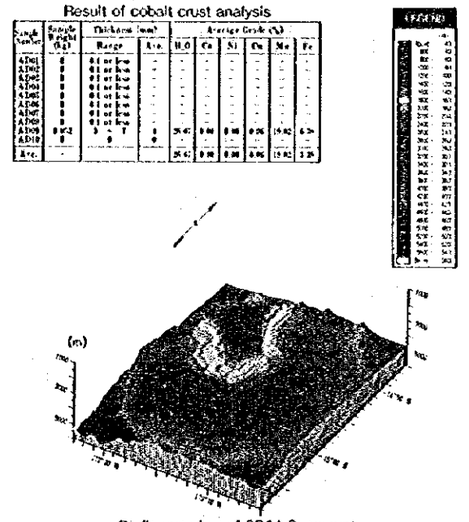
Bird's-eye view of SD03 Seamount

SD04 Seamount



Distribution of cobalt crust in SD04 Seamount

Result of cobalt crust analysis



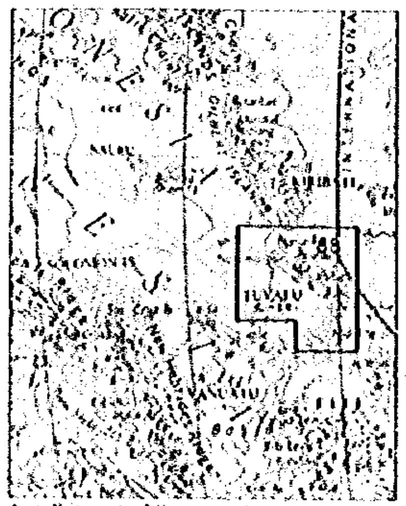
Bird's-eye view of SD04 Seamount

JICA/MMAJ/SOPAC ATLAS 1995. Surveyed by DORD

South Pacific Seafloor Atlas, Sheet no 20

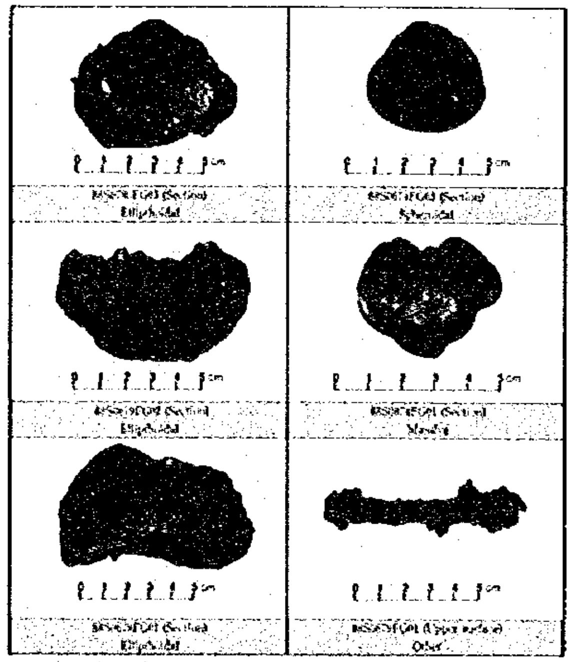
Tuvalu

The Survey of Manganese Nodules (1988)

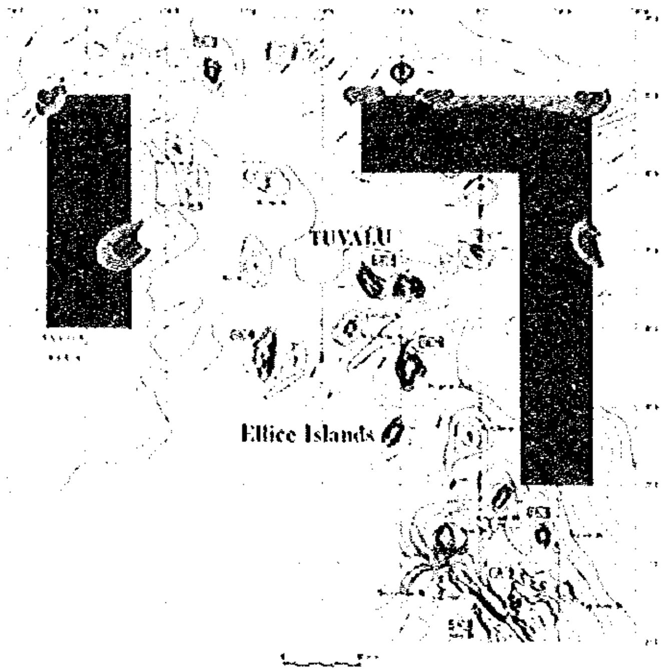


Location map of the survey area

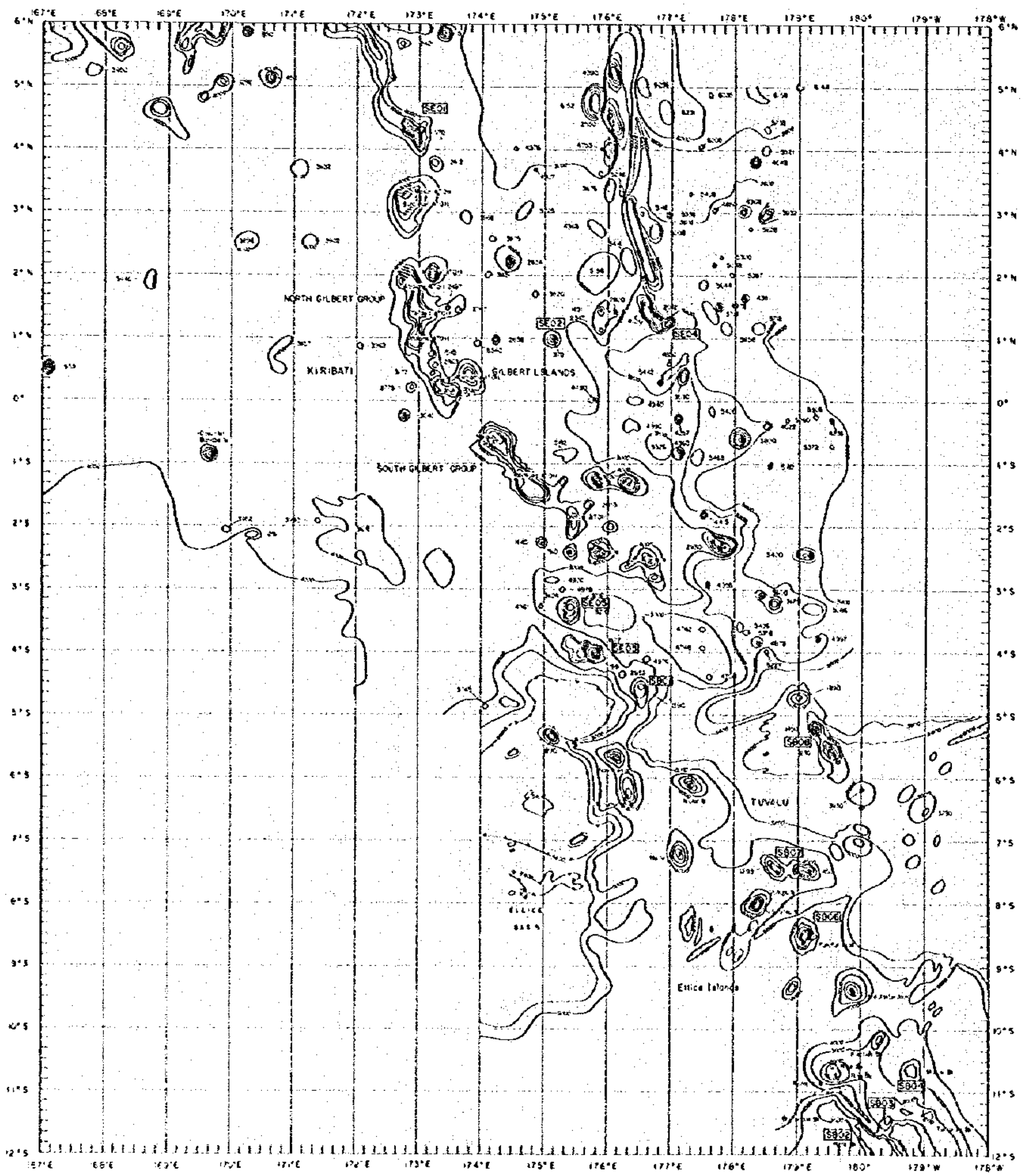
[illegible]



Morphology of Manganese Nodules



Abundance Map of Manganese Nodules



Bathymetric contour map

[illegible]

JICA/MMAJ/SOPAC ATLAS 1995. Surveyed by DORD

Tuvalu

The Survey of Cobalt Rich Crust(1988)

Overview of cobalt rich crust can be summarized as follows.

- Morphology of the crusts : crust, slab, block, cobble and nodule type
- The crusts have various inner structure such as single layer, double layer and triple layer. The crusts of triple layer become progressively compact toward the substrate
- Major constituent mineral : δ-MnO₂
- Substrate : Basalt, limestone and phosphorite
- Average crusts thickness : [illegible] cm, maximum [illegible] cm
- Average crusts grade : [illegible]% Cu, [illegible]% Ni, [illegible]% Co, [illegible]% Mn, [illegible]% Fe
- Mn/Fe ratio : [illegible]
- Age dating of [illegible] basalt : [illegible] and [illegible] Ma

LEGEND

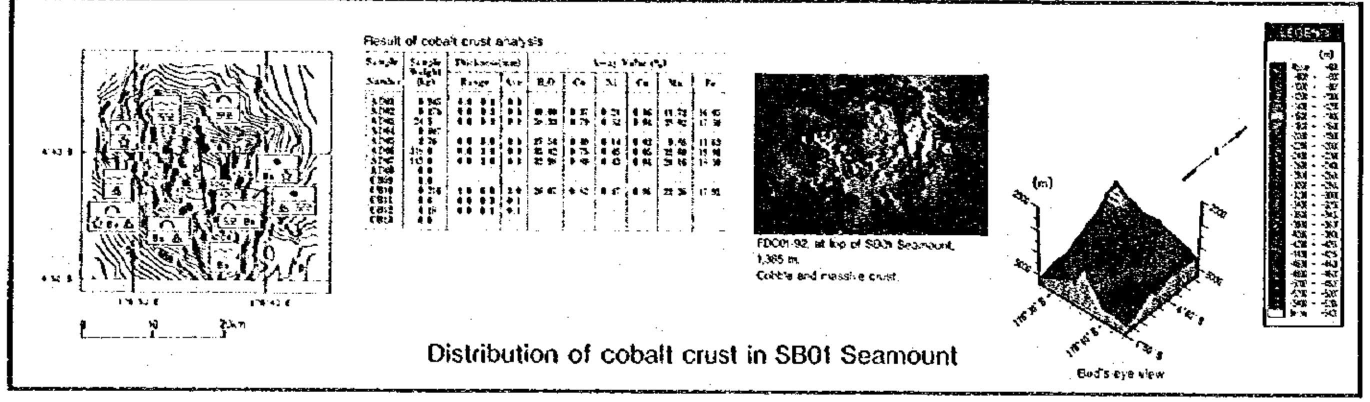
Symbol	Meaning	
∩ — ●	Type of dredged crusts	More abundant in left side one
Bs ⚠	Kind of dredged rocks	

Symbol	Meaning	Symbol	Meaning	Symbol	Meaning
∩	crust	—	slab	■	massive
●	cobble	•	nodule	～	coated
Bs	basalt	⚠	hyaloclastite	☆	phosphorite
⊞	limestone	⁘	foraminifera sand	∾	ooze

* samples not obtained

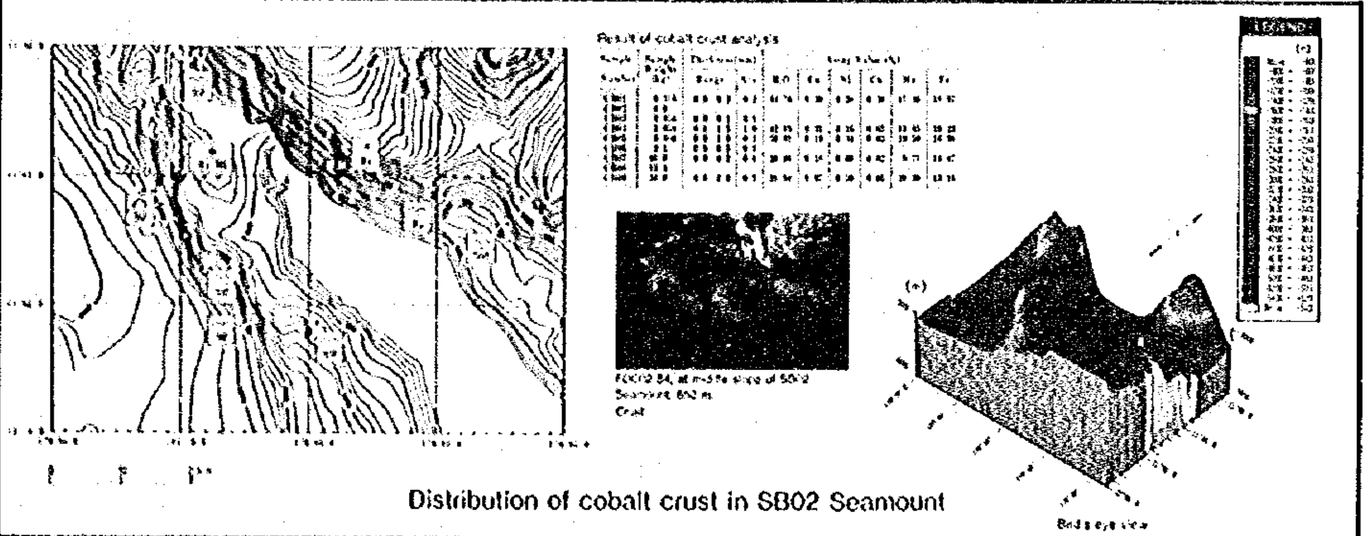
◆ Sampling site ——— FDC survey line

SB01 SEAMOUNT



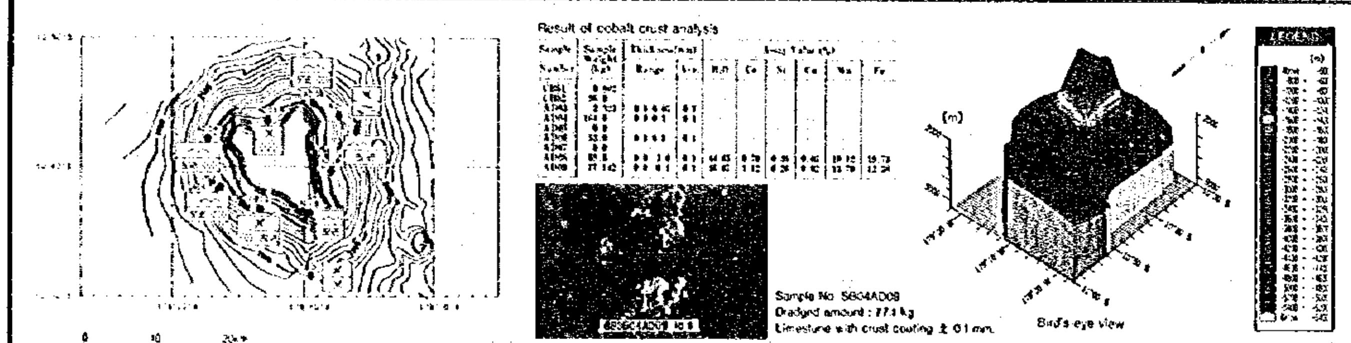
Distribution of cobalt crust in SB01 Seamount

SB02 SEAMOUNT (BAYONNAISE BK)



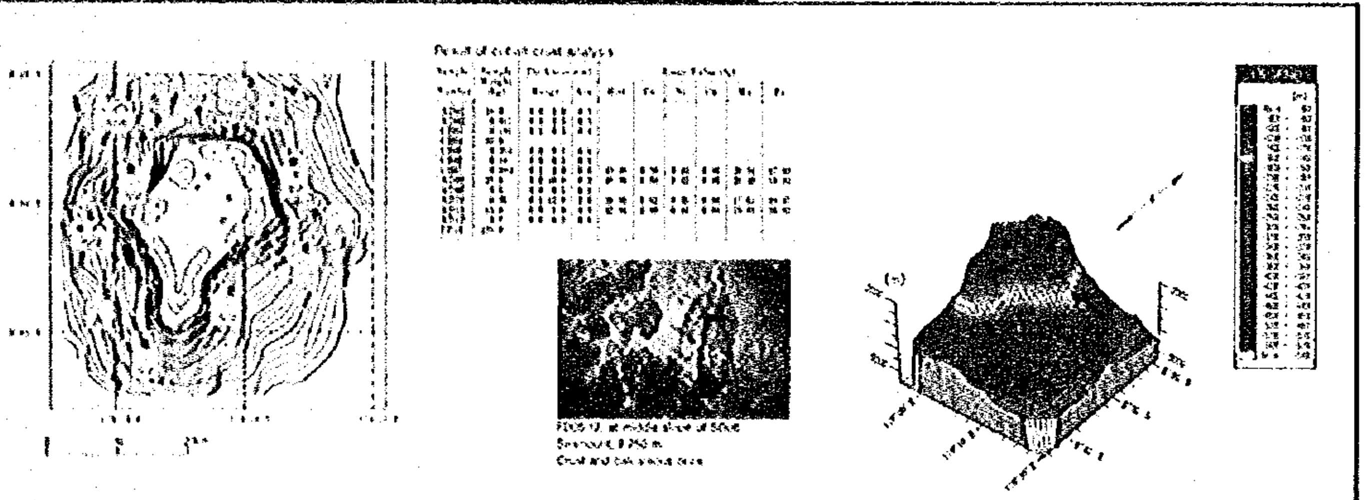
Distribution of cobalt crust in SB02 Seamount

SB04 SEAMOUNT (MACAW BK)



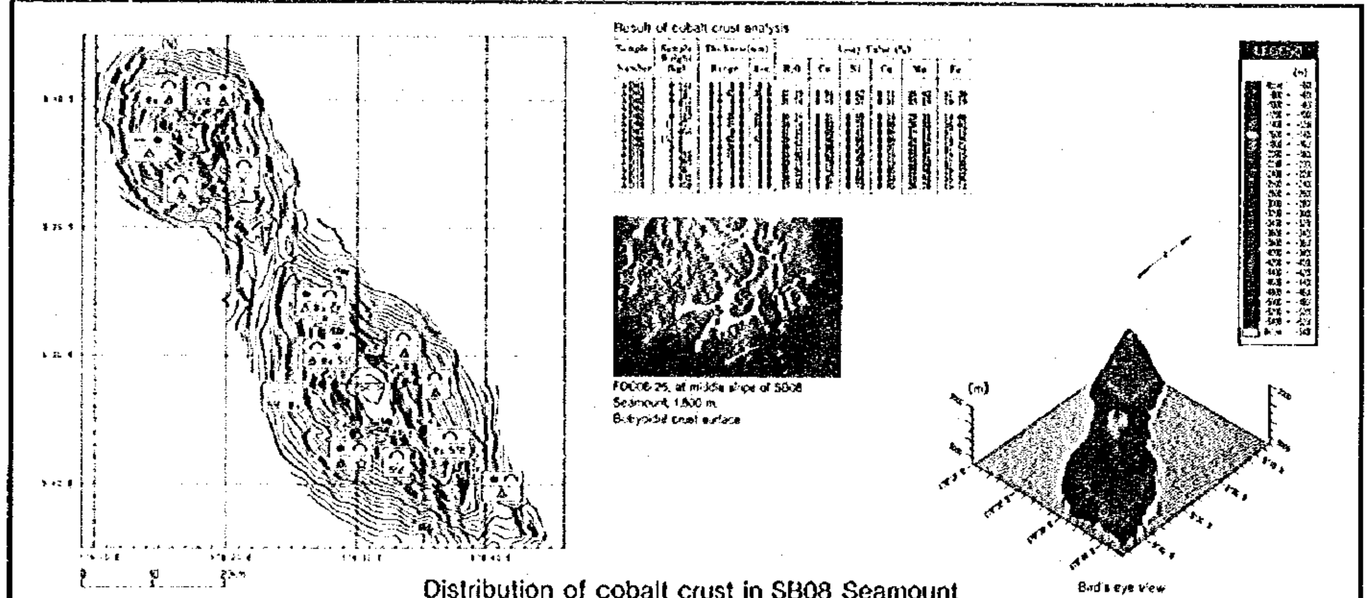
Distribution of cobalt crust in SB04 Seamount

SB06 SEAMOUNT (FUNAFUTI ATOLL)



Distribution of cobalt crust in SB06 Seamount

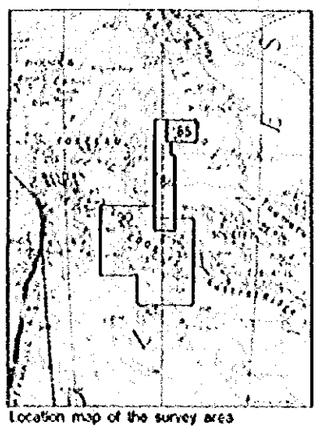
SB08 SEAMOUNT



Distribution of cobalt crust in SB08 Seamount

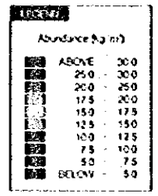
Cook Islands

The Survey of Manganese Nodules (1985,1986,1990)

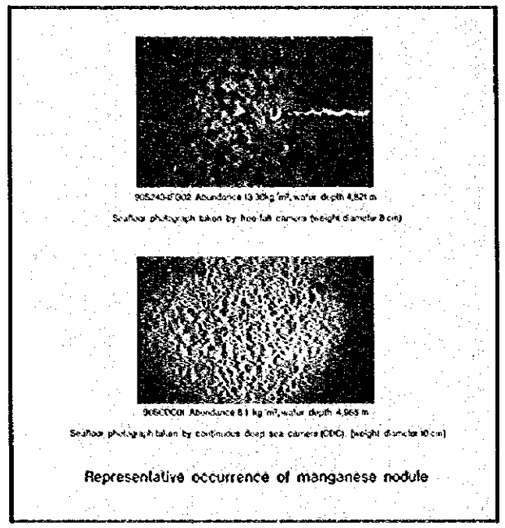


Location map of the survey area

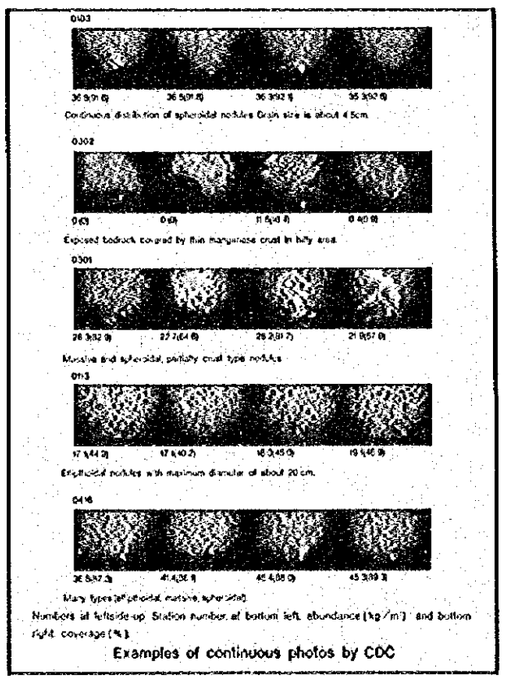
Bathymetric map



Abundance map of manganese nodules



Representative occurrence of manganese nodule



Examples of continuous photos by CDC

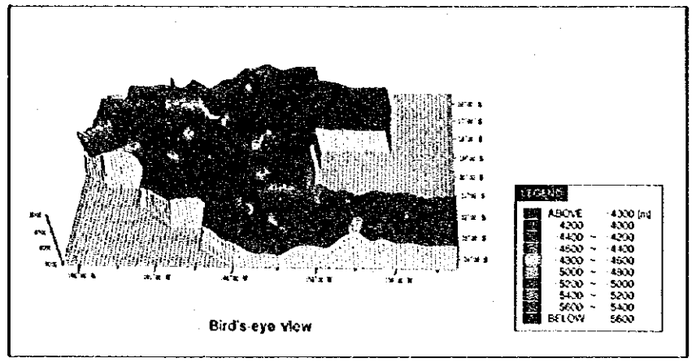
JICA/MMAJ/SOPAC ATLAS 1995. Surveyed by DORD

South Pacific Seafloor Atlas, Sheet no.23

Cook Islands

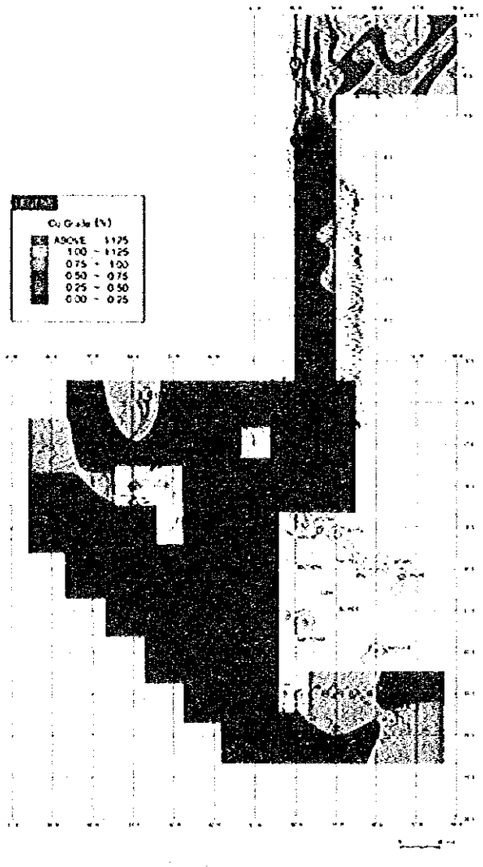
The Survey of Manganese Nodules (1985, 1986, 1990)

- The chemical composition of manganese nodules in this area is mostly low in Ni and Cu and high in Co.
- Average major five metal grade : 0.32% Ni, 0.26% Cu, 0.19% Co, 15.02% Mn and 15.47 % Fe.
- These five principal elements show the existence of high positive correlations within (1) the Ni, Cu and Mn, and (2) Co and Fe respectively, and high negative correlation between (1) and (2).
- Small size nodules are rich in Ni, Cu and Mn, and large size nodules are rich in Co and Fe. Also, there are tendencies that the manganese nodules have high Ni, Cu and Mn contents in the low abundance area and high Co and Fe in the high abundance area.

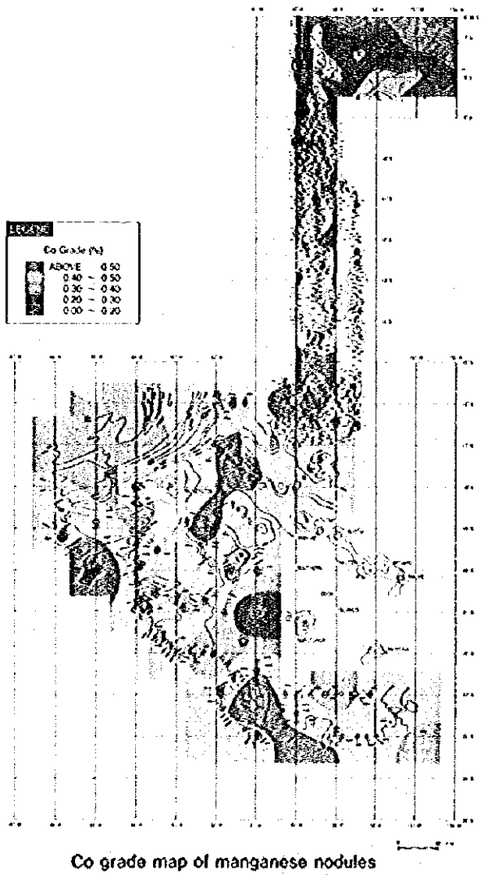


Bird's-eye view

Ni grade map of manganese nodules



Cu grade map of manganese nodules



Co grade map of manganese nodules

JICA/MMAJ/SOPAC ATLAS 1995. Surveyed by DORD

South Pacific Seafloor Atlas, Sheet no 24