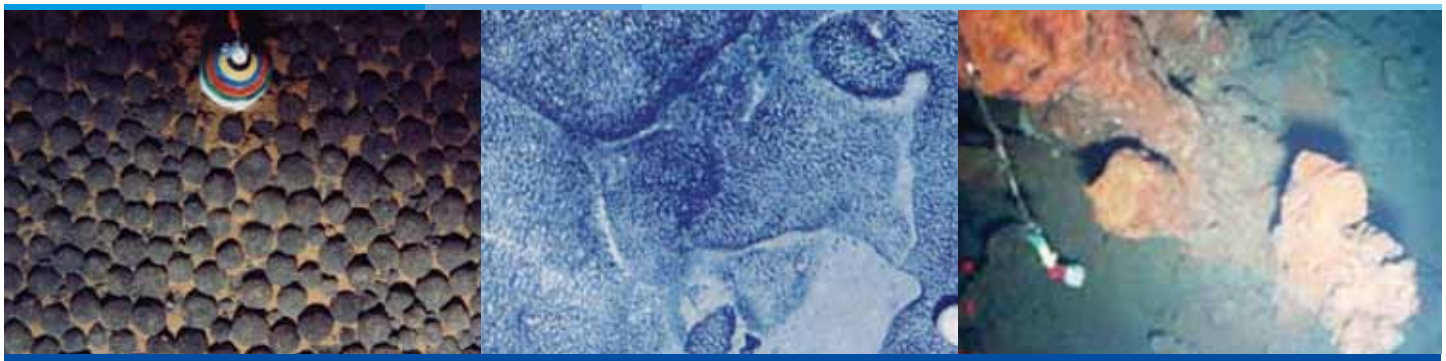
SPC
Secretariat of the Pacific Community

Applied Geoscience and Technology Division (SOPAC)

SPC-EU EDF10 Deep Sea Minerals (DSM) Project



Information Brochure 8
Samoa Deep-sea Minerals Potential

The Samoan island chain (i.e. Samoa and American Samoa) consists of high volcanic islands, atolls and submerged reef banks, and seamounts near the southwest margin of the Pacific plate (Figure 1). The chain trends in a south-eastern direction and the islands are unusually volcanically active on both the eastern and western end of the chain. This has complicated known hot spot behaviours that are consistent with the formation of intra-plate island chains such as Hawaii.

The country of Samoa is made up of the western part of the island chain including the major islands of Upolu and Savaii (Figure 1). The country's 120,000 square kilometre Exclusive Economic Zone (EEZ) is the smallest in the region due to the fact that Samoa is bordered to the North by Tokelau, American Samoa to the East and Northeast, to the South by Tonga and Wallis and Futuna to the West. The country's EEZ boundary is displayed in Figure 3.

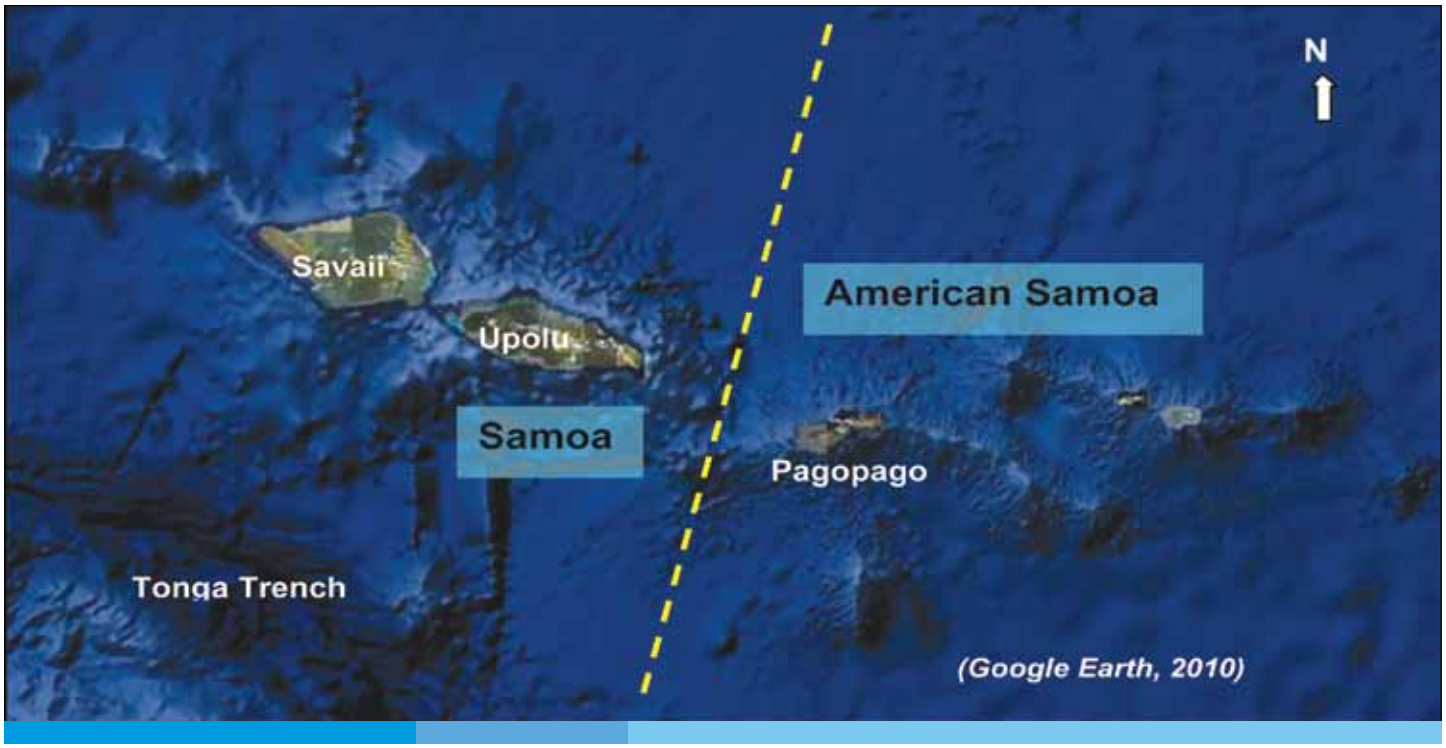


Figure 1. The 2010 Google Earth satellite image of the Samoa island chain showing islands and seamounts. The yellow dotted line roughly indicates the boundary separating Samoa (West) and American Samoa (East).

Seafloor topography of the Samoa EEZ is divided into abyssal plain, mountainous zone, and the Tonga Trench (Figure 2). The mountainous zone is composed of topographic high of the Samoa Islands including Savaii and Upolu Islands and the seamounts that occur to the western end of the island chain (Figure 2). The islands and seamounts are surrounded by abyssal plains.

This information brochure highlights the early marine mineral surveys and the 1990 Japan-SOPAC study results within the EEZ of Samoa.

Exploration History

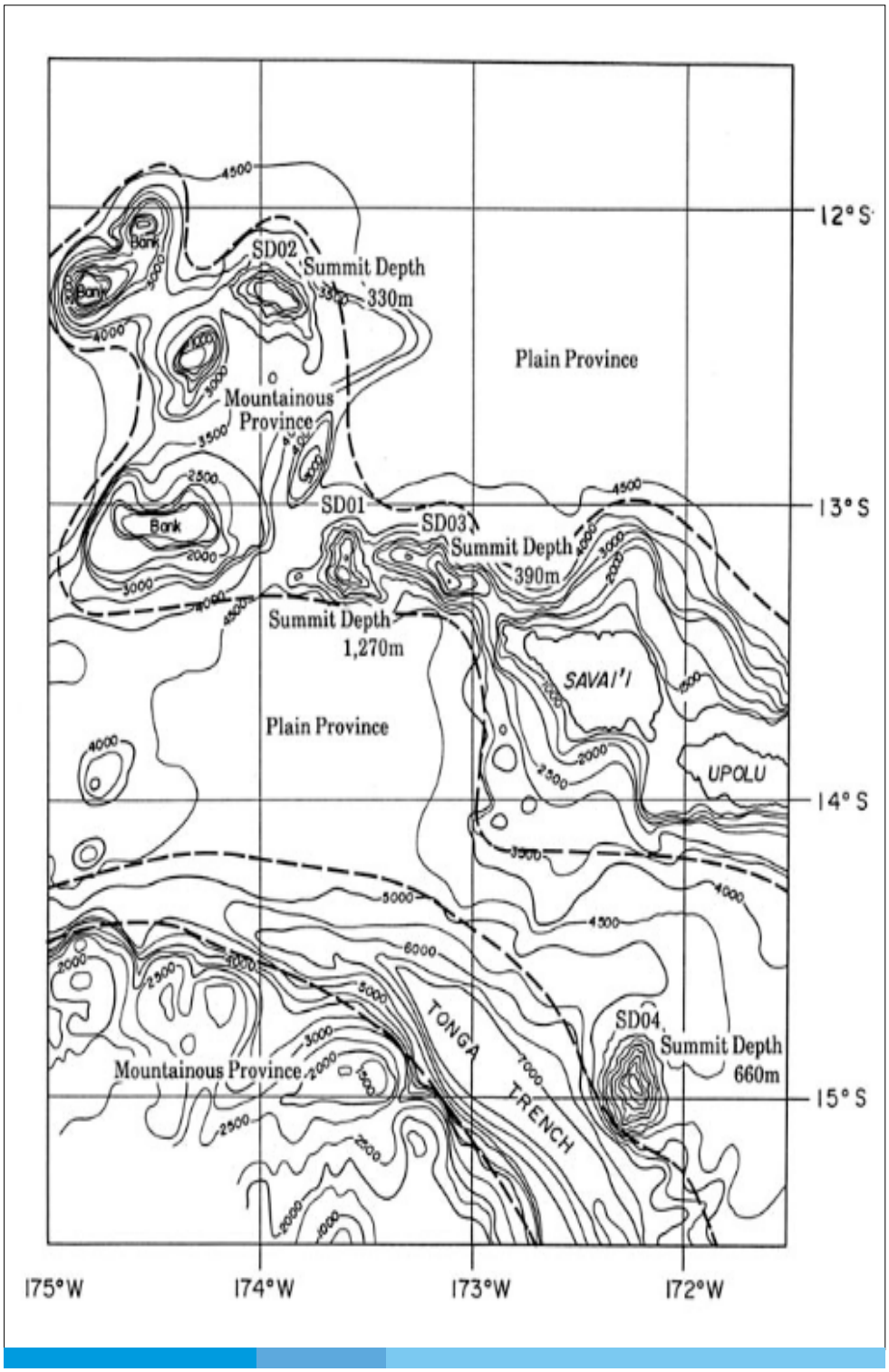


Figure 2. Seafloor topographic map of Samoa showing the locality of major topographic features.

Deep sea minerals investigation in Samoa started in the late 1970s assessing the potential for Manganese Nodules, Phosphate, Precious Coral and Cobalt-rich Crusts (CRC).

1990 Cobalt-rich Crusts Survey

During the 1990 Japan-SOPAC survey in Samoa, sampling of Manganese Nodules and seafloor photography were carried out as well as CRC investigation on four seamounts. Three of the surveyed seamounts (i.e. SD01, SD02 and SD03) belong to the Samoan island line, while the Machias Seamount (SD04) is located at the point where the Tonga Trench bends from N-S direction to E-W. The FDC, SBP and SSS survey methods were used for the crusts survey. The location of each of the four surveyed seamounts is shown in Figure 2.

1990 Manganese Nodule Survey

Manganese Nodules survey was also conducted during the 1990 Japan-SOPAC survey in Samoa. Four Manganese Nodules sampling stations were selected in the survey area (Figure 3). Three sampling points were identified in each of the four stations where samples were collected.

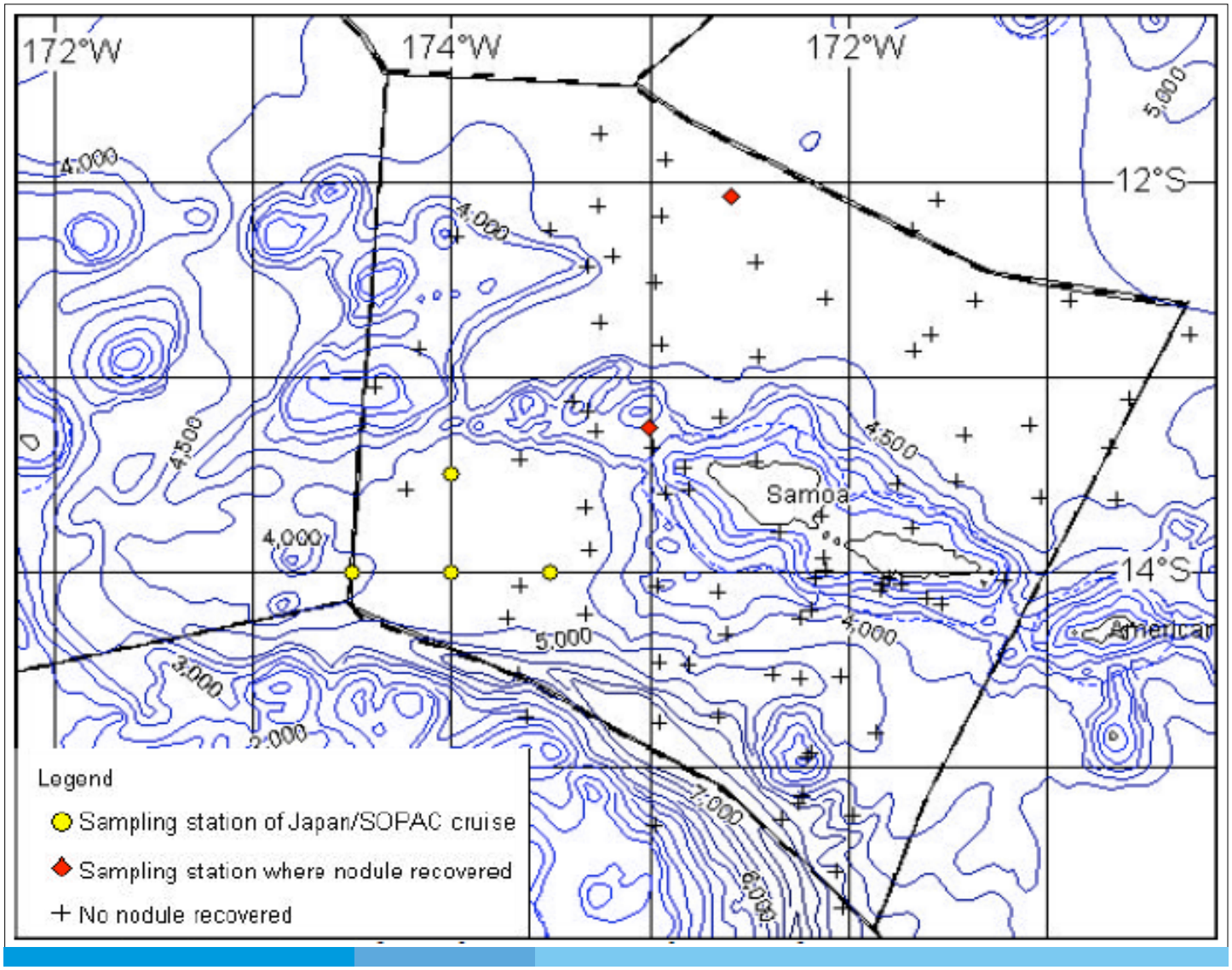


Figure 3. Location map of sampling stations in the EEZ of Samoa.

Summary of Exploration in Samoa

Previous seabed mineral investigations in Samoa are given in Table 1 below.

Table 1. Summary of previous offshore minerals exploration in Samoa.

Research Vessel and Year of Survey	Survey Area	Surveyed Commodity
RV Coriolis (1977)	Samoa's EEZ	Manganese Nodules
R. V. Machias (1979)	Pasco Bank West of Savaii, and shallow bank northeast of Pasco Bank	Precious coral, Phosphate
R. V. Machias (1979)	Assau and Salelologa Harbours	Nearshore sediment deposits for construction and landfill
R. V. Machias (1979)	South (to the Tonga Trench) and west of Upolu and Savaii	Precious Coral, Manganese Nodules/crust, Phosphate
R. V. Machias (1980)	Deeper flanks of the Samoa Island slope	Precious coral
R. V. Moana Wave (1987)	Machias Seamount, southern coast and western tip of Savaii;	Cobalt-rich Crusts, metalliferous sediments, hydrothermal vents
R. V. Hakurei Maru 2 (1990)	Sea area of Upolu and Savaii Islands	Manganese Nodules, Cobalt-rich Crusts

Exploration Results

The EEZ of Samoa is reported to have moderate potential for CRC but is poor in Manganese Nodules. According to Lonsdale (1975), the greater part of the Samoa waters is presumed to have had its sedimentation of turbidite and slumping sediments ever since its formation 5 Million years ago (Ma).

Exon (1983) and Cronan (1984, 1986) further revealed that the principal environmental conditions for the formation of high abundant zones of Manganese Nodules in the southwestern Pacific Ocean including the EEZ of Samoa, are the following three points:

(i) Biological productivity should be more than 50g/cm^2/year.

(ii) Water depth should be at around or deeper than the Carbonate Compensation Depth (CCD).

(iii) Turbidite sediments, which are supplied by islands and seamounts with high sedimentation speed, should not exist on the seafloor.

Within and around the EEZ of Samoa, only two out of 90 sampling stations have been registered in the SOPAC Deep-sea Mineral Resources database show the existence of Manganese Nodules (Figure 3). The grade of Manganese Nodules is presumed to be low due to the EEZ of Samoa being outside of the high biological production zone of the equatorial region. Furthermore, even if the upwelling from the bottom current were formed by the existence of the Samoan Islands, the effect of plankton generation by the upwelling is insignificant due to the younger formation age of the Samoan Islands (i.e. 5Ma – present). The water depth within Samoa's EEZ is about 4,600 – 4,800 m which is relatively shallow as the area is situated not far from the Samoan Islands.

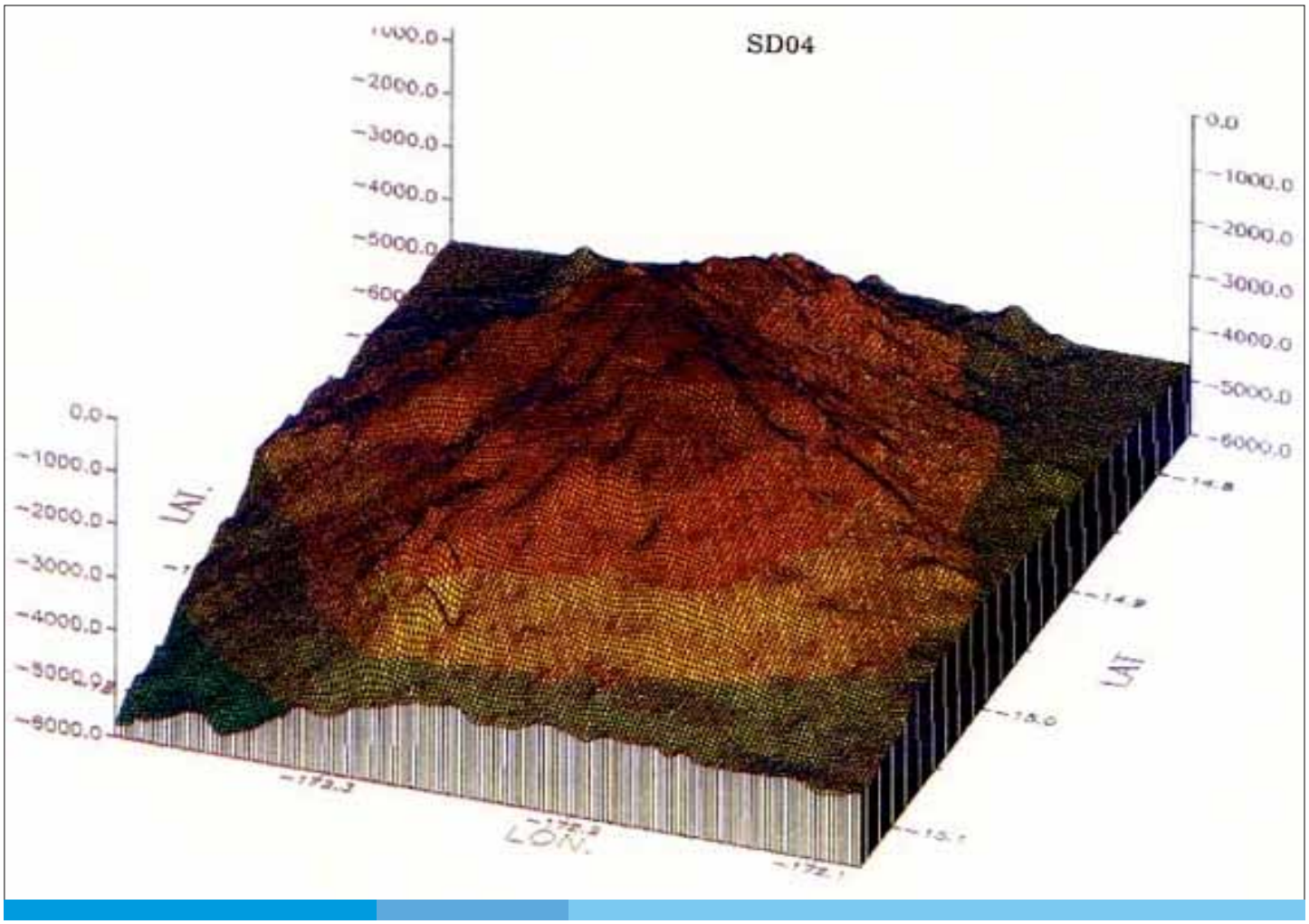


Figure 4. Three dimensional view of the Machias Seamount (SD04).

1979 Survey

- The 1979 sampling results conclude that there is little potential for the discovery of manganese nodule deposits of any significance within the waters of Samoa.
- In the deep water areas, the rate of terrigenous sediment deposition from the Samoan Islands is probably too great to allow nodule formation.

1986 Survey

- The 1986 survey of the Machias Seamount (Figure 4) concluded that the mineral potential of this guyot is limited by tectonic dismemberment. The entire trench-facing slope of the seamount has been remobilized and reworked down-slope and the east-side is characterised by several large slides. This down-slope reworking of sediment and rock inhibits growth of crusts on rock exposures.
- This survey also suggests that the island of Savaii is probably too young and the surrounding sea-floor too unstable for thick CRC to have formed. Additionally, the submarine volcanic cones located are too small to have produced even moderate quantities of hydrothermal mineral deposits.
- Further, sediment samples dredged from seamounts for phosphorite investigation recorded well below ore grade, and the precious coral sampling work produced negative results.

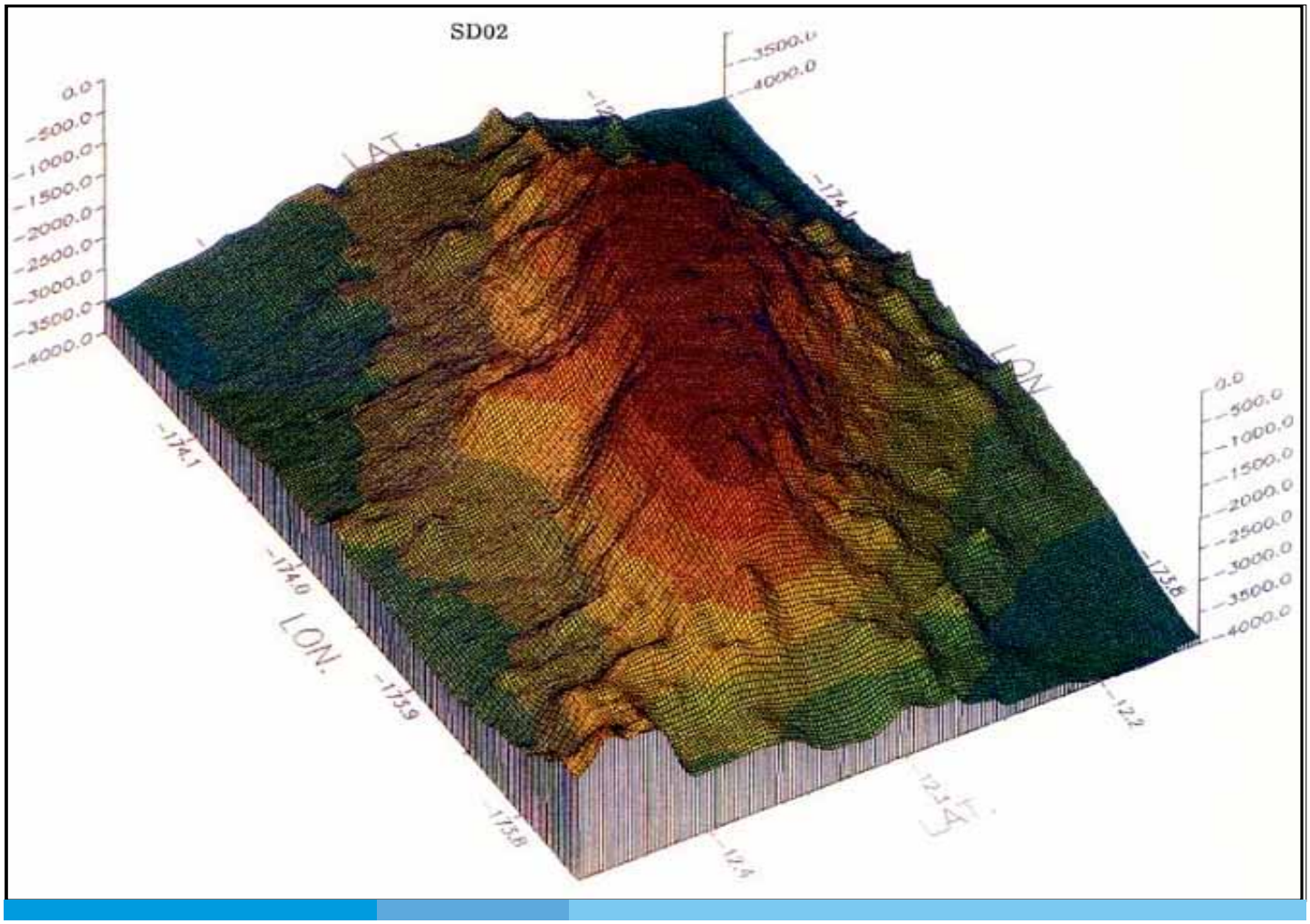


Figure 5. Three dimensional view of the SD02 Seamount.

1990 Cobalt-rich Crusts Survey

The occurrence of CRC in the four seamounts can be generally summarized as follows:

- The average grades of the four seamounts are: Co 0.41%, Ni 0.23%, Cu 0.08%, Mn 17.96%, Fe 20.42%.
- Crust type is prominent, followed by Cobble type and Nodule type and they are prominently distributed around the upper part and middle part of the slopes.
- The relationship between substrata and grade shows that siltstone has the highest grade, followed by hyaloclastite and basalt.
- The SD02 seamount (Figure 5) is the best of the four seamounts in terms of coverage (Figure 6a) and grade.
- Comparing SD02 seamount with other crust bearing seamounts in the region the thickness, grade and coverage of SD02 seamount are not promising.
- Crusts accumulate over time hence they are expected to develop thinly on relatively young substrata. The age determined through seamount basalt is 1-4 Ma, which is quite young.
- Crusts are thin (maximum of 13mm) and mono-layered, which is consistent with the young age of the substrata.
- Similar correlations to those of Manganese Nodules are recognized in grades, i.e. among Mn-Ni-Cu and between Fe-Co in positive relations respectively.
- A positive correlation between Ni and Co is also observed, which is inconsistent with the property of Manganese Nodules.
- Co exhibits a tendency to become higher in shallow areas.
- Analyzed grade spotted on the Ni-Co-Cu ternary diagram reveals that Co/Ni is concentrated on elevated spots.
- The average Co, Ni and Cu grades of surveyed seamounts are low and have a tendency of Fe > Mn. These properties differ from ordinary CRC.

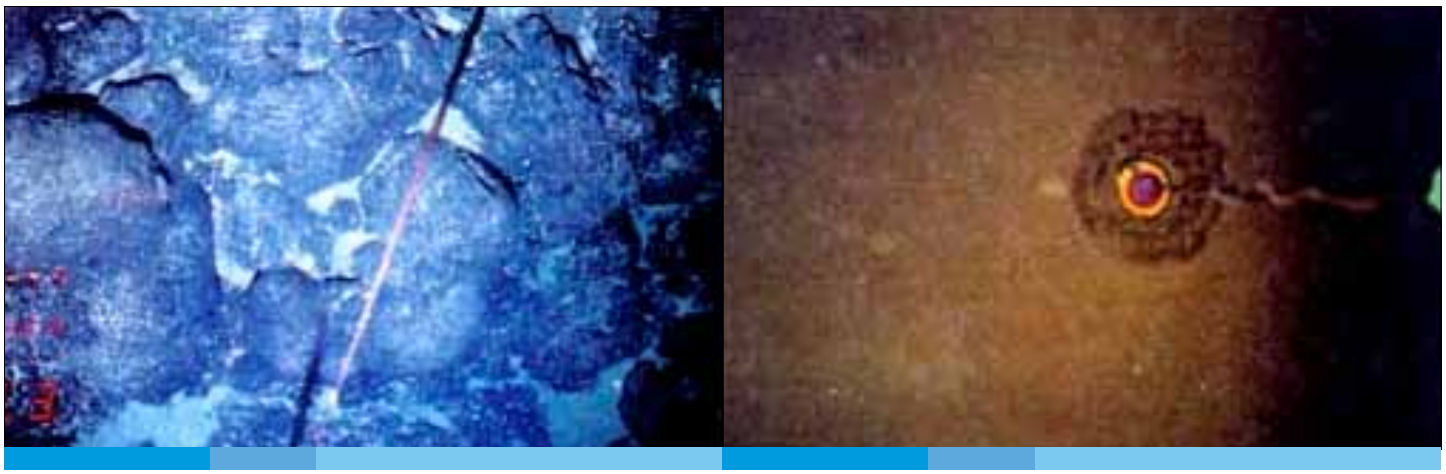


Figure 6. Photos of seafloor by Free Fall Camera: (a) crust exposure at seamount SD02, (b) brown clay appears throughout the Manganese Nodules survey area.

1990 Manganese Nodule Survey

- No Manganese Nodules were collected through the 12 attempts.
- No Manganese Nodules were recognized in the 11 photos taken by the deep-sea camera mounted on the samplers as brown clay appears throughout the survey area (Figure 6b).
- It was therefore inferred that no Manganese Nodules occur in the vicinity of the four stations.

- The non-recovery of Manganese Nodules during this survey can be attributed to the fact that the sea area of Samoa is covered with turbidite sediments and slumping sediments and has a series of archipelagic aprons.
- The existence of the Antarctic bottom current is clarified during this survey, but the potential for Manganese Nodules occurrence within the EEZ of Samoa is extremely low.

CRC Coverage and Metal Concentration

The survey suggested that crusts are widely distributed on the upper slopes and the marginal parts of the summits. The crust coverage estimated by FDC observations and other seamount characteristics are summarised in Table 2.

Crusts that occur on the four seamounts vary in thickness from a patina to 13 mm. The substrates are mainly sandstone, limestone, basalt and hyaloclastite. The average crust thickness at each seamount, calculated from the samples collected, is shown in Table 2.

Figure 7 displays the crust thickness and the major metal contents of each seamount.

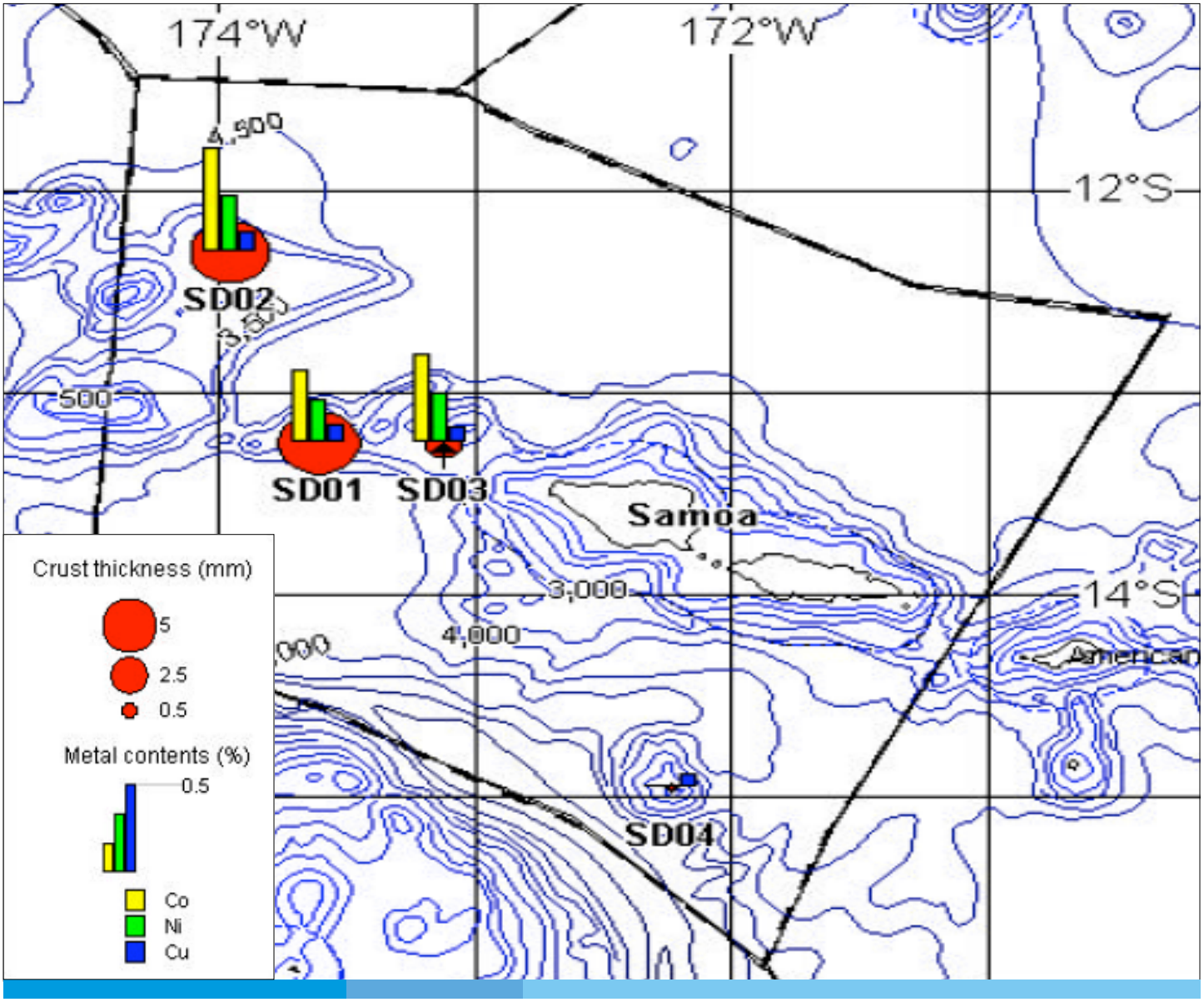


Figure 7. Thickness and metal contents of cobalt-rich crusts at each surveyed seamount in Samoa.

Summary of Results

The summary of the Japan-SOPAC survey results in Samoa are tabulated in Table 2 below.

Table 2. Summary results of the Cobalt-rich Crusts survey within the EEZ of Samoa.

Seamount		SD01	SD02	SD03	SD04
Type of Seamount		Guyot	Guyot	Peaked	Guyot
Seamount size (km x km)		10 x 18	30 x 16	55 x 12.5	2 x 4.5
Seamount height (m)		3,400	3,700	4,000	4,300
Depth to Summit (m)		1,270	330	390	660
Crust type *		C with minor B, N & S	C with minor B, N & S	C with minor B, N & S	C with minor B
Crust Coverage (%)		12	25	15	18
Average Thickness (mm)		4.6	4.4	1.2	4.0
Average Grade (%)	Co	0.33	0.48	0.41	0.00
	Ni	0.20	0.26	0.23	0.00
	Cu	0.08	0.09	0.07	0.06
Grade variation trend		The positive correlation in the Mn-Cu series is distinctive. The relationship of Mn-Ni, Fe-Co and Ni-Co series is a positive correlation.			

Crust Type: C – crust; B – Cobble; P – Pebble; M – Massive; N – Nodule; S – Slab; F sand – Foraminifera sand.

Resource Estimation

Cobalt-rich Crust

A total of 2 million tonnes of inferred crust resources is estimated to have occurred within the EEZ of Samoa. Cobalt, nickel and copper resources were estimated to be 8,100 tonnes, 4,600 tonnes and 1,700 tonnes respectively. The details are shown in Table 3 below.

Table 3. Estimation of crust and metal resources within the EEZ of Samoa.

Seamounts	Inferred Resources (tonnes)	Metal Resources (tonnes)		
		Co	Ni	Cu
SD01	881,000	2,909	1,763	705
SD02	914,000	4,387	2,376	822
SD03	211,000	864	484	147
SD04	14,000	-	-	9
Total	**2,020,000**	**8,160**	**4,623**	**1,683**

Conclusion

Both the Antarctic bottom current and the depth (deeper than the CCD) that are supposed to be necessary conditions for the growth of Manganese Nodules are recognized within the EEZ of Samoa. However, the significant occurrence of young turbidite sediments derived from the young Samoan volcanoes is believed to inhibit Manganese Nodules formation. The results of prospecting to date have failed to discover any promising nodule deposits and confirmed that the EEZ of Samoa is nodule poor. Given the geologically younger age of the seamounts in the Samoan chain, the development of crusts is expected to be relatively thin. It takes a long time for crusts to accumulate on substrates and form thicker layers. The majority of the crusts are thin and mono-layered, which may be due to the young age of the substrates. The SD02 seamount was the best of the four seamounts surveyed in Samoa. The crust coverage of this seamount is promising but, considering thickness and grade, the potential of this seamount is inferior compared to the more promising seamounts of a number of countries in the region.