XII. MANGANESE DEPOSITS

By Shuji Maruyama, Masato Nohara,
Masashi Arita and Kenji Sawada

Introduction

The present cruise revealed the distribution pattern of manganese deposits on the sea floor of Eastern Central Pacific Basin. They include two types of manganese nodule and manganese crust, the former being found on the deep basin floor and the latter being found in areas of seamount or guyots.

The survey was achieved mainly by means of wire-line grab sampling by the Okean-70 grab, and subsidiarily by uses of dredges and corers. Deep sea photography and deep sea television surveys were done at some stations respectively for the purpose of observation of nodules. Data of sonic prospecting particularly of 12 KHz PDR and 3.5 KHz PDR were brought into consideration at each of the stations and along tracks between stations for estimating an extent of ore deposits, particularly with relation to topography and acoustic pattern of sediments.

Among the types of sampling apparatus particular attention was given to the Okean-70 grab. It was very effective in obtaining nearly undisturbed samples of nodules and sediments and estimation of population density of nodules at each station, as shown in another chapter (Chapter IX).

Recovered samples of manganese nodules were observed and examined particularly with regard to shape, size, wet density, internal structure and population density.

As the result of the survey, some high concentration areas of manganese nodule were preliminarily delineated in the small basin of inter-hilly area and rather wide deep sea basin immediately south of the northern seamounts chain, in consideration of properties of the surficial sediments, topography and sonic pattern of 3.5 KHz records.

Occurrence of manganese deposits

The surveyed area is mostly represented by a deep sea basin of 5,000–5,400 m. It is defined, to the north and east, by the seamounts and guyots chain of the Christmas Ridge at a depth of 1,500–2,000 m, where manganese crusts are well developed on bed rocks (Fig. XII-1). The main part of the surveyed area is areally divided into two, the eastern topographically flat deep sea basin and the median-western rolled deep sea basin with many deep sea hills and some seamounts. Manganese nodules are only very poorly developed at the eastern part, while they are generally found at the latter part, though the quantity of those at each station varies markedly. In the following, manganese nodules from the median-western part are mostly dealt with.

The manganese nodules were obtained by samplers at about 20 stations and observed by the optical method at 2 stations. The larger part of the nodules came from the nearly flat sea floor at a depth of more than 5,000 m, some of which are situated in small basin surrounded by deep sea hills and also in rather large flat basin to the south of the northern seamounts. Those at only two stations came from the sea floor at a depth of less than 5,000 m (Sts. 141 and 145).

Fig. XII-1 Occurrence of manganese crusts.
The left figure showing the fragments of manganese crusts recovered together with calcareous sand, and the right figure showing basaltic rocks coated with the crust.

Fig. XII-2 Occurrence of semi-buried manganese nodules in surficial sediments at St. 132.

The shape and size of nodules vary markedly from station to station as well as population density, and they vary even at one station. Nodules are generally semi-buried in surficial sediment, as evidenced by the nearly undisturbed samples recovered by grab and optical pictures taken by the deep sea camera and television, as shown in Figs. VII-4, 5, IX-2 and XII-2. The lower half or lower two-thirds of the nodule is buried in sediment, and has a rugged surface, while the upper part tends to have a smooth surface, as illustrated by Horn et al. (1973, Fig. 25). As already interpreted by these authors, the smooth surface above the interface between bottom water and sediment might have resulted from denudation by bottom water, and the rugged under part from growth beneath the sediment-water interface.

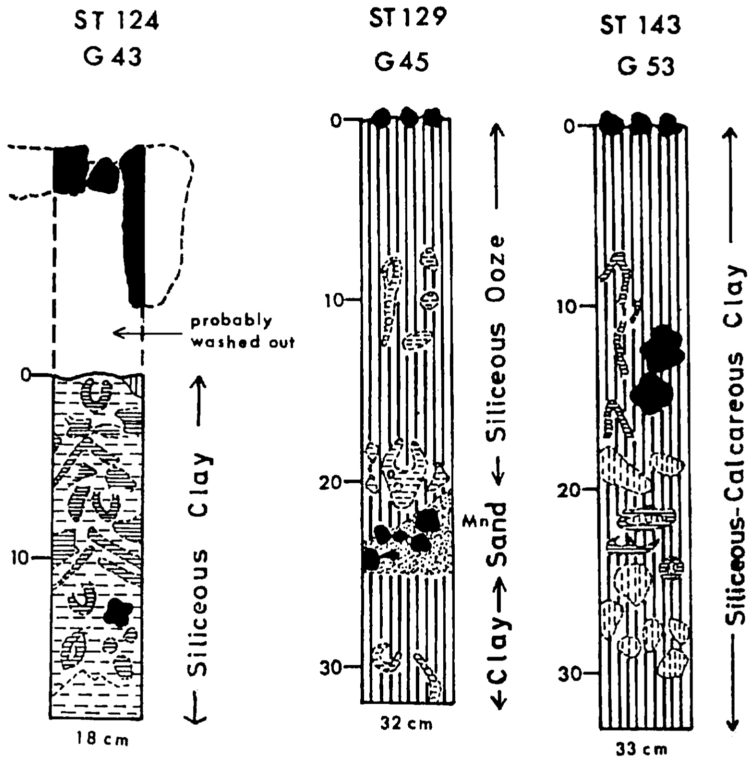


Fig. XII-3 Occurrence of manganese nodules in the lower portion of surficial sediments.
Cited from Fig. X-2, to which the legend is referable.

Nodules occur at the surface of sea floor in general. While, in some stations of Sts. 124, 129, 138 and 143, they are also contained in lower horizons, although this is rare, as shown in Fig. XII-3. It is highly probable that the nodules in the lower horizon of St. 129 have been buried after migration to the present place, judging from their occurrence in a sandy layer.

Abundance, property and related matters of nodules at each of the stations are summarized in Table XII-1, and stations and tracks are shown in Fig. XII-4.

Characteristics of manganese nodules

Shape, size and colour

Nodules are variously shaped, i.e., spheroidal, subspheroidal, polylobate, botryoidal, discoidal, subangular or slab-like (Fig. XII-5), and some kinds of type were generally found together at one station, although at stations, 121, 122, 126, 132, 139 and 143, where nodules are rather highly concentrated, polylobate and/or subangular types tend to predominant.

Nodules are also variously sized from less than 1 cm to about fifteen centimetres in diameter, but those with dimensions of 4–2 cm and/or 2–1 cm dia. are predominant. They are dark bluish black or black in colour and are lustrous in a wet state.

The details of shape and size of nodules at each station are referable in Table XII-1.

Table XII-1 Manganese deposits in

St.	Sample No.	Depth	Sediment	Popul. density	Morphology and surface
111	D50	1,340	Ca-ooze	—	Crust coating basalt, very smooth, botryoidal
112	D51	2,900	Ca-ooze	(4 kg)	Crust coating basalt, botryoidal
113	D52	1,660	Ca-ooze	—	Crust coating basalt
120	TV2	5,803		—	
121	G42	5,450	Si-ooze/-clay	19 kg/m²	angular-polylobate, smooth, botryoidal
122	D53	5,635	Si-clay	(9 kg)	irregularly polylobate, subspheroidal
124	G43	5,200	Si-clay	8.5 kg/m²	subspheroidal, tabulate, botryoidal, smooth
125	D54	5,170	Si-ooze	(11 kg)	subspheroidal, polylobate, botryoidal, rough
126	G44	5,010	Si-Ca-clay	15 kg/m²	Tabulate, polylobate, botryoidal, smooth
128	D55	2,880	Ca-ooze	(1 kg)	Crust coating basalt, smooth, botryoidal
129	G45	5,259	Si-ooze	12 kg/m²	spheroidal, rough, strawverry-like
130	G46	5,270	Si-ooze	(0.1 kg)	spheroidal, rough, strawverry-like
131	G47	5,228	Si-clay/Si-clay	trace	—
132	G48	5,164	Si-Ca-ooze	14 kg/m²	angular, mushroom, smooth
133	G49	5,277	Si-ooze/Si-clay	(1 kg)	spheroidal-discoidal, polylobate, granulated, rough
134	G50	5,524	Si-clay/Si-ooze	trace	subspheroidal, irregular, strawberry-like, granulated
135	D56	5,554	—	(2 kg)	spheroidal-discoidal, strawberry-like, granulated, very rough
136	G51	5,338	Si-ooze/Si-clay	trace	spheroidal, discoidal, strawberry-like
137	C3	5,450	—	—	
138	P14	5,480	Si-ooze/Clay	trace	—
139	D57	5,530	—	(43 kg)	angular, discoidal, slab-like, botryoidal, rough and smooth
141	D58	4,800	—	(9 kg)	spheroidal-discoidal, botryoidal, smooth
142	G52	5,150	Si-clay	1 kg/m²	spheroidal-subsheroidal
143	G53	5,152	Si-Ca-ooze	26 kg/m²	spheroidal-subspheroidal, platy, polylobate, smooth
144	G54	5,300	Si-clay/Clay	7 kg/m²	spheroidal-subspheroidal, botryoidal, smooth
145	G55	4,930	Si-Ca-ooze/ Ca-clay	1 kg/m²	spheroidal, angularly tabulate
146	G56	5,610	Si-clay/Clay	5 kg/m²	discoidal-platy

the eastern Central Pacific Basin.

Size in dia. (cm)	Manganese oxide layer (cm)	Nucleus	Bulk wet density (g/cm³)
8.8–4.7	1.2–0.5	—	—
18.5 × 14.0	4.8-film	—	—
14 (Max)	4.8–1.2	—	—
(Monitoring by DTV, details unknown)			
4–2 predominant, more than 8 (max)	zonal	altered volcanic material	1.93–2.00
4–2 predominant	3–1	altered volcanic material	1.72–2.07
4–2 and 2–1 predominant, more than 16 (max)	0.9–0.4	altered volcanic material	2.00
4–2 predominant, 8 (max)	zonal, 1.5 material 2–1 mm	altered volcanic material 2–1 mm dia.	1.98–2.00
4–2 predominant,	—	altered volcanic material, 1–2 mm dia.	1.99–2.00
13.2 × 8.3	3.8–1.8	—	—
2–1 predominant, 4 (max)	5.2–less than 1	very poor	1.75 (surface) 1.96 (subsurface)
—	—	—	—
4–2	—	—	—
4–2	1.5–1.0	altered volcanic material, 1–0.4 cm dia.	1.89
5–2	0.9–0.5	clayey material, 2 mm dia.	1.89–1.83
3.0–0.5	film	pumice	—
2–1 predominant, 8 (max)	massive	usually not found, with exceptions of shark's teeth and some animal bones	1.92–2.08
—	film	pumice, 1.7 cm dia.	—
(Monitoring by deep sea camera; details unknown)			
—	—	—	—
16–2	3–2	phosphorite and altere bolcanic material	—
8–1	zonal, 8–1	shark's teeth and altered volcanic material	1.94–2.06
2–1 and less than 1 extremely predominant	—	very small, 2–1 mm dia.	1.79–1.88
less than 8, 4–2 predominant	thick	hard black material, 4–3 mm dia.	1.95–1.97
less than 4	5.5–4.0 mm	altered volcanic rock	1.94
1–0.5 predominant	5 mm-film	pumice	—
4–2 and 2–1 predominant	rather thick	pumice and volcanic rock, 12–1 mm dia.	—

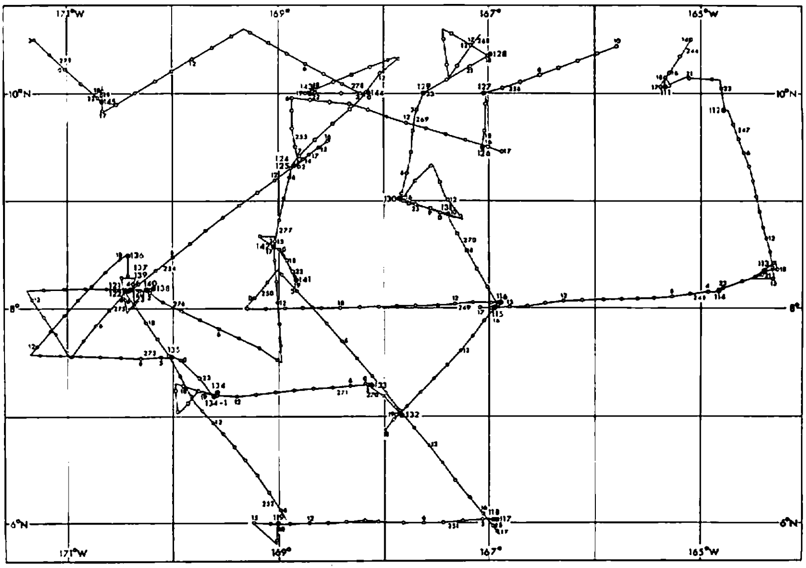


Fig. XII-4 Stations and tracks in the surveyed area, cited from Fig. I-5.

Internal structure

Nodules generally comprise one or several nuclei. They may measure up to 8 cm in diameter, but is generally less than 1 cm. They consist of various materials, eg., fragments of basalt, weathered rock, clayey material or pumice grains. Nodules with a nucleus of pumice tend to have a thin (less than several millimetre) coating of ferromanganese material which was only poorly grown. Nodules with a nucleus of weathered rock or clayey material are often disseminated by ferromanganese materials (Figs. XII-6, 7).

Ferromanganese materials which grew around nucleus have a bluish-black or black colour, typically showing a striking striped structure. Their thickness is generally about 1 cm, but may range up to a maximum of 3.8 cm.

Wet density

The wet bulk density of nodules was measured immediately after recovery on board about 5–10 samples of every size grade. The results are shown in detail in Table XII-1. Summarizing the results, the wet bulk density has a range of 1.72–2.20 g/cm^3, and 1.95 g/cm^3 in average.

Metal content

For the purpose of detailed research, some of manganese nodules were chemically analysed preliminarily by the Tokyo Institute of Coals and Minerals. According to the analytical results, the content of Mn, Ni, Cu and Co in the nodules tend to show the following distribution, roughly speaking.

Mn ranges from 14 to 24%, mostly concentrated around 16–17%. Ni ranges from 0.5 to 0.8% in crusts, but from 0.5 to 1.3% in nodules and in the latter a content of 0.6–0.8% is rather predominant. Cu has a similar range as Ni, while Co is strikingly rich in crusts, ranging from 0.8 to 1.6%, and rather poor in nodules, ranging from 0.1 to 0.3%.

The chemistry of the nodules will be described elsewhere in near future.

Population density and cover-ratio

Population density of manganese nodules was calculated at each of the stations on the basis of total weight of nodules on the surface of the sediment in the Okean-70 grab, which has an area of about 0.5 m^2 (70 cm × 70 cm). The population density varies markedly in the surveyed area, ranging from less than 1 kg/m^2 to 26 kg/m^2 (Fig. XII-8). It tends to change abruptly over short distance; for example, at the stations in the western extremity of the area, the population density at St. 121 was measured to be 19 kg/m^2,

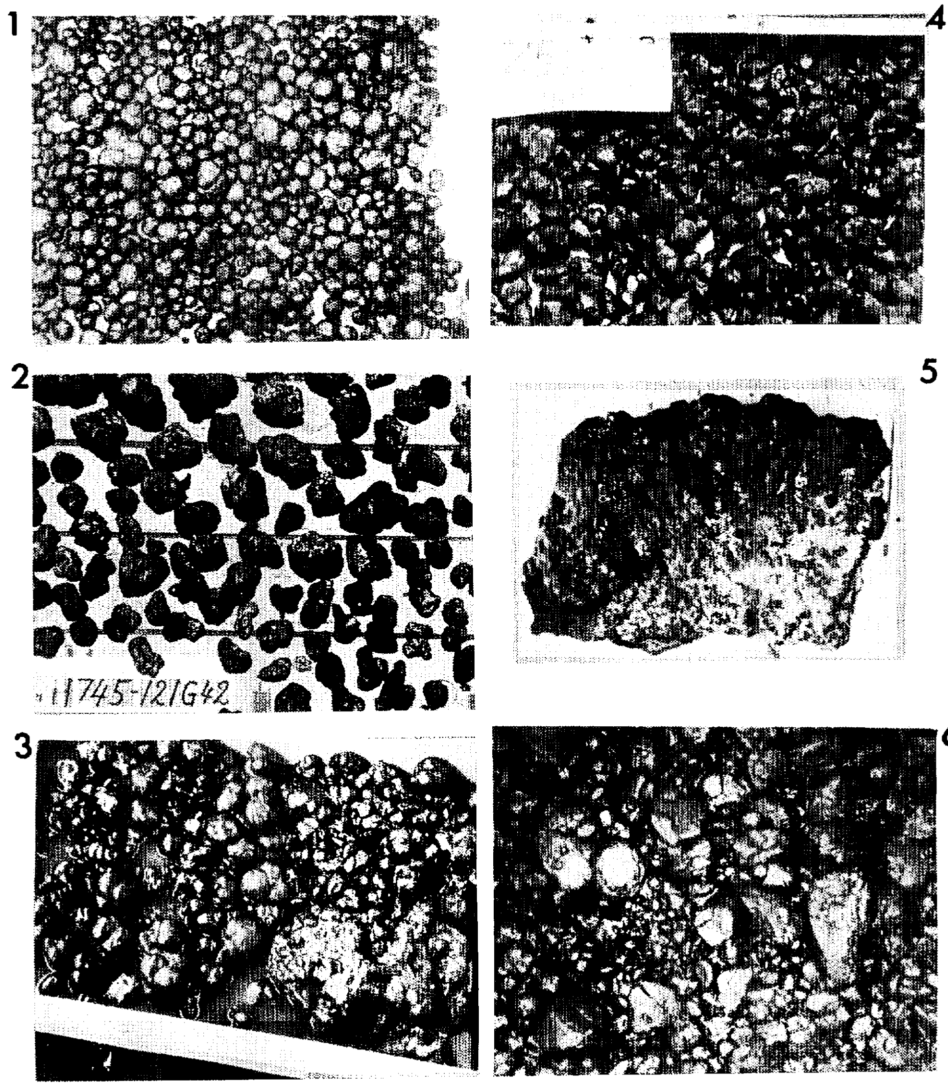


Fig. XII-5 Various types of manganese nodules.
1: spheroidal, at St. 129, 2: subangular and polylobate, at St. 121, 3: subspheroidal and botryoidal, at St. 124, 4: polylobate, at St. 132, 5: slab-like, at St. 139, 6: subangular, at St. 139.

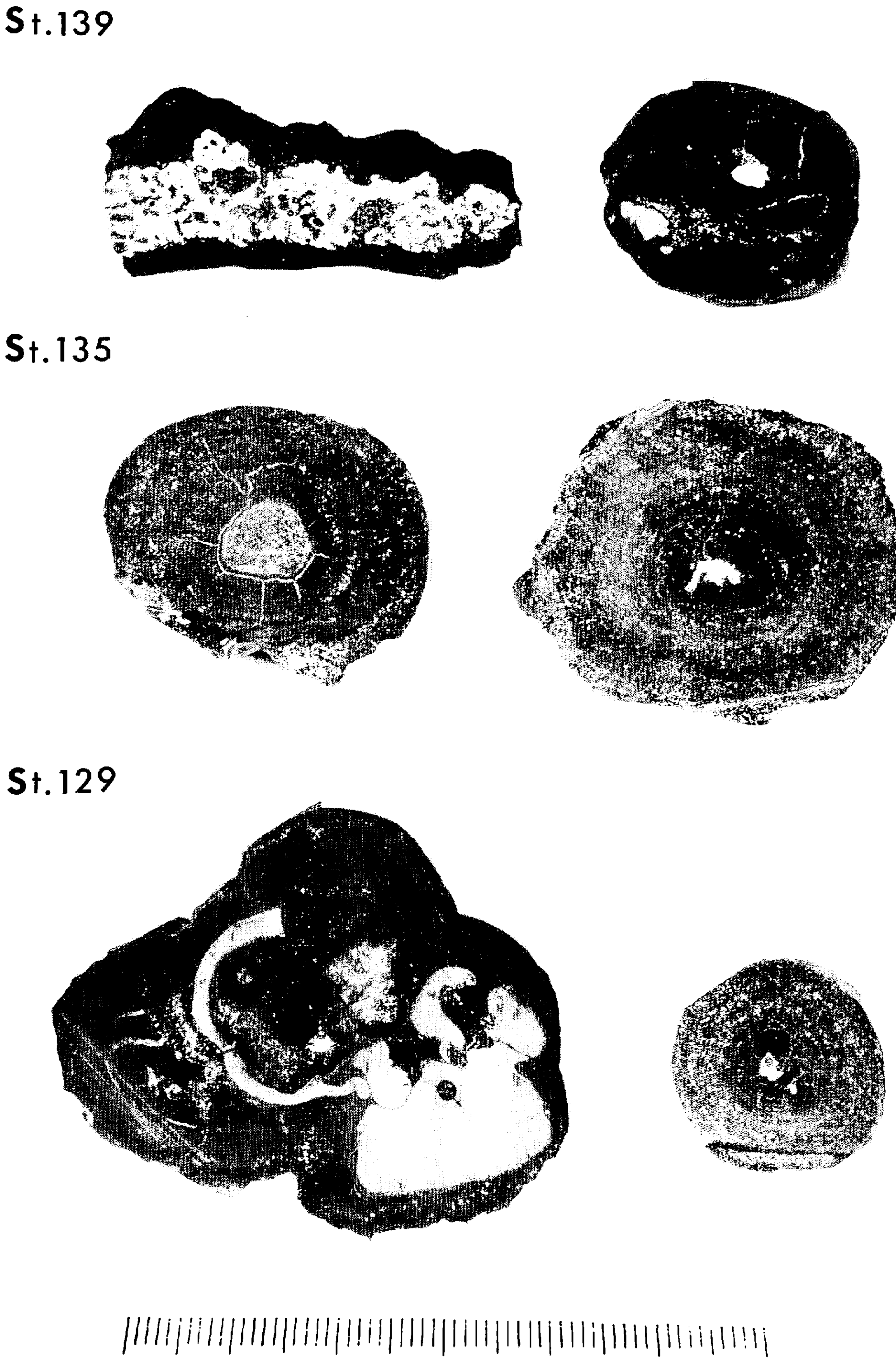
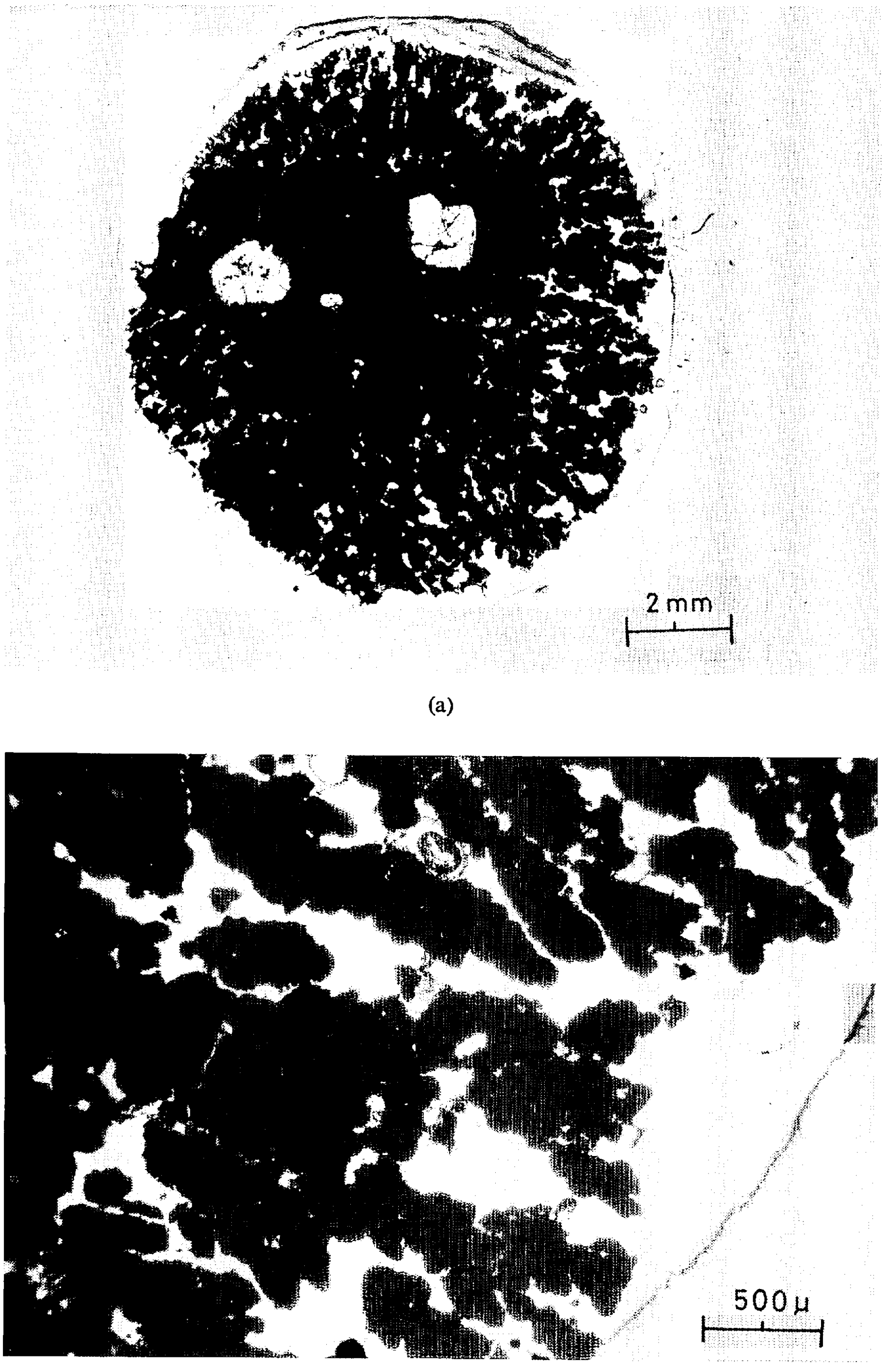


Fig. XII-6 Internal structure of some manganese nodules.



(a)

(b)

Fig. XII-7 Dendritic texture of nodule at St. 132.
Showing outward growth of nodule by replacement of clayey materials (white parts) by ferromanganese oxides (dark parts).

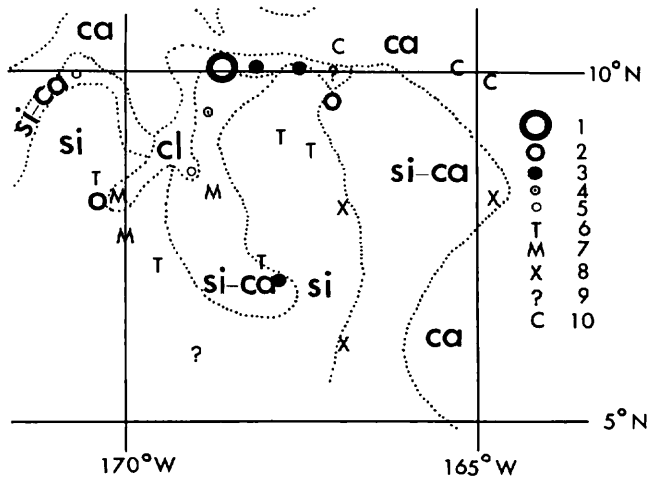


Fig. XII-8 Distribution of population density (kg/m²), in relation to type of sedimentary facies.
1: more than 20, 2: 15–20, 3: 10–15, 4: 5–10, 5: less than 5, 6: trace, 7: population density unknown, 8: nodule not found, 9: existence of nodule unknown, 10: occurrence of crust, Si: siliceous ooze/clay, Si-Ca: siliceous-calcareous ooze/clay, Ca: calcareous ooze, Cl: deep sea clay.

while it decreases to trace (less than 1 kg/m^2) at Sts. 136 and 138, which are situated about 17–18n.m. from St. 121. The area with a density of more than 5 kg/m^2, however, seems to be rather widely developed particularly in the environs of St. 143 where the maximum density of 26 kg/m^2 was measured, i.e., in the northern peripheral part of the surveyed area, the density of 15 kg/m^2 (St. 126), 12 kg/m^2 (St. 129) and 7 kg/m^2 (St. 144) was found, besides that of St. 143. Another station of a higher concentration of nodule is represented by St. 132, where a density of 14 kg/m^2 was found, but its prolongation seems to be very poor.

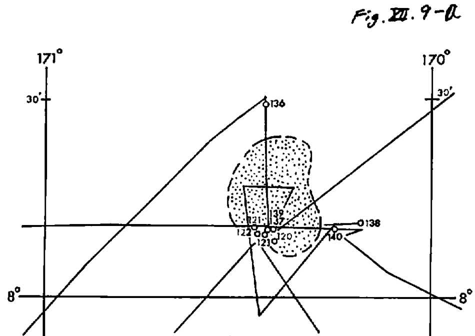
The cover-ratio was measured only at one station. According to some pictures by deep sea photography at St. 137 which is very closely situated to St. 121 cited above, the cover-ratio attains up to 86.6%, being measured by means of a density slicing measurement (ref. Chapter VII). A deep sea television survey also clarified the similar cover-ratio at St. 120, very near to St. 121.

As already shown in Fig. X-3, the concentration of nodules seems to be closely related with certain kinds of sedimentary facies. Nodules tend to be densely concentrated in siliceous-calcareous clay with foraminiferal remains less than 5%, and very poorly or scanty in siliceous ooze or clay, in general.

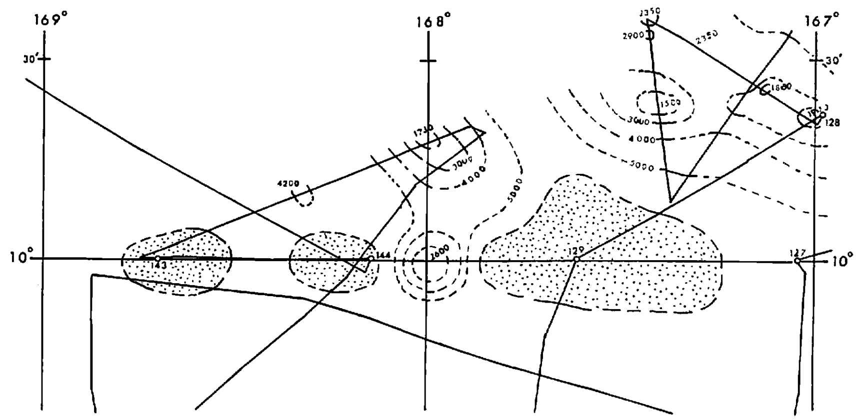
High concentration area of manganese nodules

On the basis of population density, shape and size of nodules and their relationship to surficial sedimentary facies and its acoustic pattern by 3.5 KHz PDR, expected high concentration areas may be preliminarily deduced. They are divided into some districts as follows (Fig. XII-9).

District around 10°N, including Sts. 143, 144 and 129. Immediately south of the northern seamount chain, the nearly flat deep sea basin contains at least three promising areas



(a)



(b)

Fig. XII-9 Preliminary delineation of high concentration areas of manganese nodules. Both the figures showing the probable areas of high concentration of nodules, indicated by dotted parts surrounded by broken lines. The areas were deduced from topography and acoustic pattern just beneath sea floor by 3.5 KHz PDR.

of nodule concentration. They have extents of 15n.m. × 20n.m. (St. 143), 15n.m. × 10n.m. (St. 144) and 35n.m. × 15n.m., respectively, with population density ranging from 26 to 7 kg/m^2.

District of St. 126. Southeast of St. 129, there is a rather densely populated area, with an extent of 25n.m. × 20n.m.

District of western extremity, including Sts. 120–123, 137 and 139. In a rather narrow area, an integrated survey method, including grab sampling, large box dredge sampling, core sampling, deep sea photography and deep sea television monitoring, and also grid survey by means of 3.5 KHz PDR were done. The survey indicated that the high concentration area was limited to an extent of about 18n.m. × 15n.m., and surrounded by hilly areas.

District of Sts. 124 and 125. Situated to the south of the district of St. 143, a narrow, promising area was found, It extends to extent of about 10n.m. × 10n.m., with the population density of 8.5 kg/m^2.

There was found another area of high concentration in a very small, flat basin, surrounded by deep sea hills, in the median part of the surveyed area (St. 132). It seems to have an area of only few nautical miles square, with the population density of 9 kg/m^2, and owing to small quantity of nodules, it seems to be unpromising.

In summary, although several high concentration areas of manganese nodules can be recognized by our survey, their exact delineation remains as yet a problem to be solved by more detailed investigation of every area. Moreover, the metal concentration in the nodules is not known as yet about every area. The areas of high manganese nodule concentration tend to be confined to the area of flat deep sea basins, of varying dimensions, surrounded by deep sea hills or seamounts, and to be closely related with the sedimentary facies of siliceous-calcareous clay.

Reference

Horn, D. R., Horn, B. M. and Delach, M. N. (1973): Ocean Manganese Nodules. Metal values and Mining Sites. *Tech. Rept.* no. 4, NSF-GX 33616, IDOE, NSF. (Unpublished Manuscript).