XIV. PRELIMINARY CONCLUSION ON SEDIMENTOLOGY AND MANGANESE DEPOSITS

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Geology and sedimentology

Continuous seismic reflection profiling survey revealed that the eastern half topographically flat area is characterized by thick turbidite layer of about 0.5 sec. thickness, which is partly covered by a thinner transparent layer that overlies a densely stratified layer. The western boundary of turbidite layer is found in the hilly central part of the surveyed area, where the turbidite covers the crests and slopes of deep sea hills, showing evidence of post-depositional erosion and deformation.

In the western half area, where deep sea hills are distributed here and there, showing gently rolled topography as a whole, the acoustic layers can be divided into four parts; in descending order, upper transparent-, densely stratified- and lower transparent layers and acoustic basement.

The first layer is developed widely and becomes thicker in the southwestern area, and the second layer which is the counter part of the densely stratified layer in the eastern area is also widely developed. The acoustic basement, probably being represented by basalt is mostly concealed beneath the subsea layers as well as in the eastern area. In some places, however, it is uplifted to born a horst-like structure. This is particularly apparent in the vicinity of deep sea hills and seamounts.

Also, the records show the basement rocks cropping out on the flanks of the seamounts and guyots, although for the most part the summit areas of such topographic highs are covered by sedimentary materials. At least, some of the deep sea hills seem to have been formed by a faulting in recent times, as evidenced by the air-gun records.

Unfortunately we do not have the data concerning the geological interpretation of acoustic stratigraphy. However, some data are available from the contribution by DSDP Leg 17 (Winterer, Ewing et al., 1973). And we can roughly correlate our acoustic data with the geologic formations at Sites 165 and 166 of the Leg as follows.

Eastern area	*Site 165*
Transparent layer	Quaternary-upper Miocene deposits
Turbidite layer	Miocene-middle Eocene turbidite
Densely stratified layer	Early Eocene-upper Cretaceous chert, limestone and volcanogenic turbidite
Acoustic basement	basement basalt

Western area	*Site 166*
Upper transparent layer	Quaternary-middle Eocene radiolarian ooze
Densely stratified layer	chert, radiolarian ooze and volcaniclastics of lower horizon

The 3.5 KHz profiling records show a rough discrimination of transparent and underly-

ing stratified and/or opaque layers. The transparent layer corresponds at some places, and does not correspond at another places to the transparent layer by the air-gun record. Generally speaking, the transparent layer, widely developed in the surveyed area, often changes its thickness, and the distribution pattern of its thickness is rather irregular, but it tends to be thicker towards southwestern area (about 200 m in maximum) and rather thinner to the north (about several metres or traceable). An abrupt change of thickness is also recognized even within a very limited area. The transparent layer may consist of Quaternary and upper Tertiary deposits.

The bottom sediments can be divided into several types of facies. *Calcareous ooze* is found only in the area of the seamounts and guyots chain bordering the northern and eastern peripheries of the area. In the deep sea basin, *siliceous ooze/clay* is widely distributed in the central-western district, while *siliceous-calcareous ooze/clay* tends to be developed in the boundary area between the siliceous ooze-clay and calcareous ooze, particularly showing a rather wide distribution over the flat eastern half area, and tounging into the siliceous ooze zone in a part of the central-western area. The *deep sea clay* is confined to the central-northern areas, immediately south of the northern calcareous ooze zone.

The uppermost 30 cm columns of sediments are characterized by a remarkable change of color tone, showing a more or less mottled structure, which is caused by *lebensspurren*. Vigorous benthic animal activity are evidenced in the sea floor pictures taken by deep sea photography.

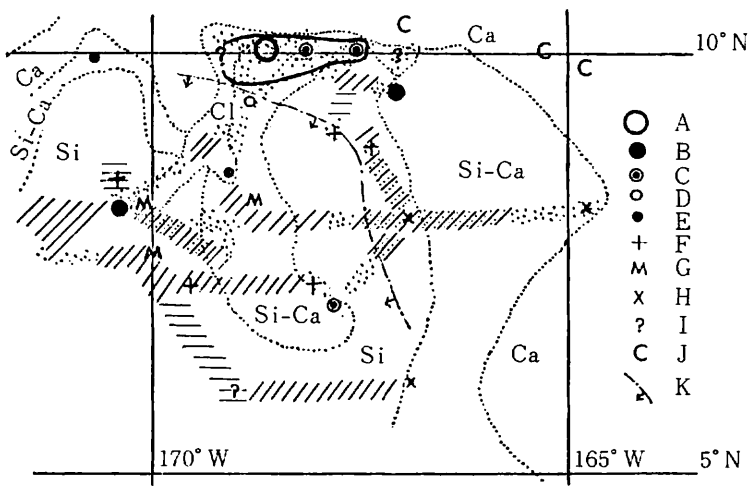

Fig. XIV-1 Integrated distribution map of the surveyed area.
Population density of nodules (kg/m²)
A: more than 20, B: 15–20, C: 10–15, D: 5–10, E: less than 5, F: trace, G: density unknown, H: nodule not found, J: manganese crust.
Sedimentary facies
Ca: calcareous ooze, Si: siliceous ooze/clay, Si-Ca: siliceous-calcareous ooze/clay, Cl: deep sea clay.
Thickness of transparent layer by 3.5 KHz PDR (m)
horizontally hatched: 100–200, obliquely hatched: 60–100, obliquely hatched and dotted: 30–60, dotted: less than 30.
K showing deep sea hills region and the closed dense curved line showing the quantitatively most promising field of manganese nodules.

According to the data of the piston core, the column in the eastern part of the deep sea basin yields some graded beds and parallel laminations derived from turbidity currents.

Manganese nodule deposits, and conclusions

The general tendency of nodule distribution in the surveyed area is summarized as follows (Fig. XIV-1): 1) nodules are rarely found on the sea-floor of the eastern half area, where the thick turbidite layer is predominant beneath surficial siliceous-calcareous sediments; 2) they are generally developed in the western half area, though their abundance varies areally; 3) in the hilly areas occupying the larger part of the western half, nodules are rather poorly developed as a whole, and even in some abundantly distributed areas, their horizontal extent is limited to a very narrow area; 4) the most remarkable area of nodule distribution is found in the rather flat deep sea basin, just south of the northern seamounts chain, and also in narrow basins surrounded by deep sea hills in the

Table XIV-1 Population density of manganese nodules and characteristics of transparent layer by 3.5 KHz PDR.

St.	Water depth (m)	Popul. density*	Characteristics of transparent layer**	Sedimentary facies
111†	1,340	—	Opaque	Ca-ooze
112†	2,900	—	Opaque	Ca-ooze
113†	1,660	—	Opaque	Ca-ooze
114	5,000	x	Tr 0/stratified	Si-Ca-ooze
115	5,190	x	Tr 45/stratified	Si-ooze/Si-Ca-ooze
116	5,150	x	Tr 45/stratified	Si-ooze(?)
117	4,950	x	Tr 45/stratified	Si-Ca-ooze
118	4,930	x	Tr 45/stratified	Si-Ca-ooze
120	5,830	?	Tr 12/stratified-opaque	—
121	5,450	19 kg/m²	Tr 12/stratified-opaque	Si-ooze/Si-clay
122	5,635	(9 kg)	Tr 12/stratified-opaque	Si-clay
124	5,200	8.5 kg/m²	Tr trace/stratified 30/Tr 30/opaque	Si-clay
125	5,170	(11 kg)	Tr trace/stratified 30/Tr 30/opaque	Si-ooze
126	5,010	15 kg/m²	Tr 4/opaque	Si-Ca-ooze
127	5,230	?	Tr 4.5/opaque	Deep sea clay
128†	2,880	—	Opaque	Ca-ooze
129	5,259	12 kg/m²	Tr 10/stratified	Si-ooze
130	5,270	(0.1 kg)	Tr trace/stratified	Si-ooze
131	5,228	trace	Tr 30/stratified	Si-clay/Si-ooze
132	5,164	14 kg/m²	Tr trace/stratified	Si-Ca-ooze
133	5,277	2 kg/m²	Tr 30/stratified	Si-ooze/Si-clay
134	5,524	trace	Tr 70/stratified	Si-clay/Si-ooze
135	5,554	(2 kg)	Tr 60/stratified	—
136	5,338	trace	Tr 120/stratified	Si-ooze/Si-clay
137	5,450	?	Tr 10/stratified-opaque	—
138	5,480	trace	Tr 20/opaque	Si-ooze/Clay
139	5,530	(43 kg)	Tr 10/opaque	—
141	4,800	(9 kg)	Tr 0/stratified	—
142	5,150	1 kg/m²	Tr 30/stratified	Si-clay
143	5,152	26 kg/m²	Tr 17/opaque	Si-Ca-ooze
144	5,300	7 kg/m²	Tr 0/opaque	Si-clay/Clay
145	4,930	1 kg/m²	Tr trace/opaque	Si-Ca-ooze/Ca-clay
146	5,610	5 kg/m²	Tr 15/opaque	Si-clay/Clay

*X Nodule not found.
**Tr Thickness of transparent layer(in *m*). / showing downward succession of acoustic layers.
† Manganese crust.

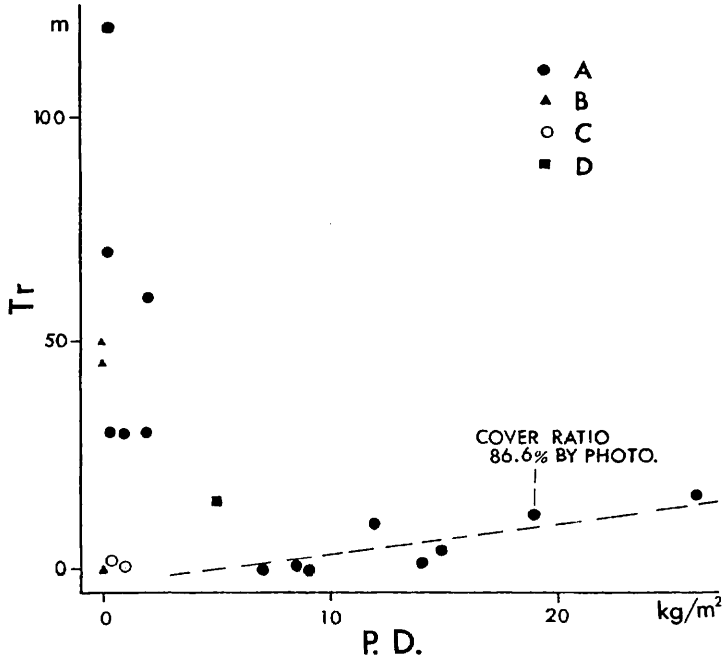

Fig. XIV-2 Relationship between population density (P.D.) and transparent layer of 3.5 KHz PDR (Tr).
A: stations of normal pattern of record, B: those of thick turbidite by air-gun, C: those of eroded transparent layer, D: station at northwest to the surveyed area.

western area; 5) the nodules are mostly confined to the interface between water and sediment with very rare exceptions; and 6) nodules tend to be abundant in the zone of siliceous-calcareous ooze/clay.

The nodules are typically dark bluish-black or black in colour and are variously shaped, i.e., spheroidal, subspheroidal, polylobate, botryoidal, discoidal, subangular or slab-like, and the some kinds of type are generally found together in one locality. The nodules have a maximum diameter of more than 10 cm, but they are commonly 4–2 cm and/or 2–1 cm in diameter. The average wet bulk density is 1.95 g/cm^3. The nodule nuclei consist of fragments of basalt, clayey material or pumice, all of which commonly measure less than 1 cm in size.

The population density of nodules varies horizontally in the distribution area, ranging from less than 1 kg/m^2 to a maximum of 26 kg/m^2. Nodule distribution is irregular and the density abruptly changes even over a short distance, but areas with a density of more than 5 kg/m^2 seem to be rather widely developed particularly in the environs of the northern area. Such a pattern of nodule distribution is likely to be closely related with the type of sedimentary facies, topography and thickness of the transparent layer by 3.5 KHz PDR profiling.

Table XIV-1 and Fig. XIV-2 show the relationship between the population density, thickness of transparent layer and sedimentary facies. In the following, a particular comment will be given to the relationship between the population density (P.D.) and thickness of transparent layer by 3.5 KHz PDR (Tr.), the latter of which is figured in Fig. XIV-

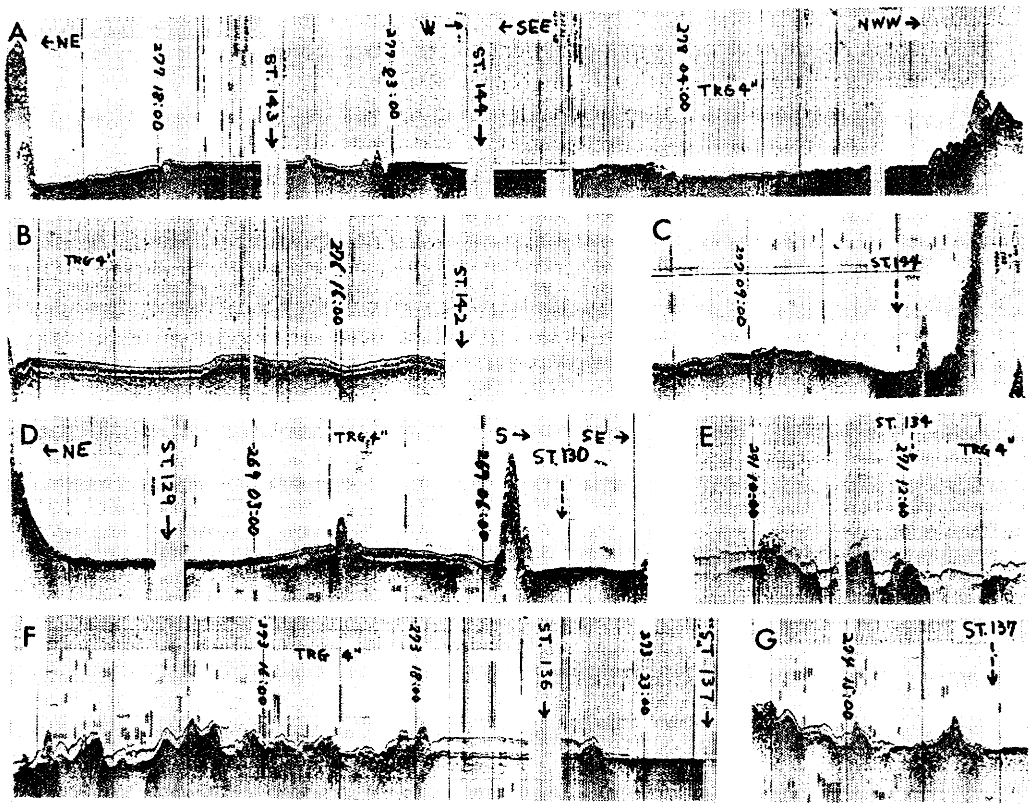

Fig. XIV-3 Records of 3.5 KHz profiling, showing acoustic pattern at some stations and their environs.

3, of some representative stations and their environs.

In summarizing the detailed examinations, the following conclusion can be made.

1) The population density depends on the thickness of transparent layer with some rare exceptions; 2) the transparent layer with thickness more than about 30 m yields only very poor nodules with a density less than about 2 kg/m^2; 3) the P.D. more than about 5 kg/m^2 is related to the Tr less than about 20 m; 4) moreover, in the latter case, a rough relationship is recognized, P.D. more than 20 kg/m^2 being restricted to the distribution area of the Tr of 10–20 m; and 5) angular slab-like nodules tend to be associated with the transparent layer with a thickness of less than about 10 m.

Whether or not such a relation generally holds true in the environs of the surveyed area remains as a problem to be solved in future studies as well as the reason for the relationship. If such a relation is true over large areas, the 3.5 KHz PDR profiling survey will play an effective role at least in a quantitative survey of nodule deposits, particularly in the early stage of prospecting. It may be significant to study in detail those problems for clarifying the geneses of nodule deposits in relation to geology and sedimentology in that the formation of abundant nodules might be controlled by the sedimentary rate of siliceous-calcareous clay, and also for prospecting the deposits in that a continuous survey with higher speed will serve as a rapid and effective quantitative prospecting of the deposits.

Unfortunately we have only preliminary data on the metal content of nodules obtained as yet. However, they show rather high content of nickel (0.6–1.2%) and copper (0.3–1.1%), which is coincident with previous data summarized by Horn et al. (1973).

In conclusion, from the above discussions, the most promising area for nodule deposits in the surveyed area may be expected in the rather flat deep sea basin floor immediately south of the northern seamounts chain, where the promising ore deposits are probably developed in a rather narrow belt running in a W-E direction roughly along the 10°N line. Also, another rather dense concentration of nodules with higher contents of metals is found in the small flat basin surrounded by deep sea hills at the western extremity of the surveyed area. A further detailed survey will be necessary to delineate the exact extension of the deposits in these areas.