

III. DEEP SEA SEDIMENTS

Eiji INOUE, Taisuke SUZUKI, Eiji MATSUMOTO
and Masato YUASA
(*G.S.J.*)

III.1 Distribution of sediments

Various types of pelagic sediments are observed in the surveyed area (Fig. 27). A glance on the figure will show that brown clay is extensively distributed on the abyssal plain of the Mariana basin, the Mariana trench and the depressions of the Magellan seamounts area. Calcareous ooze is found regionally in the Caroline islands area. on the other hand, locally around the Mariana and the South Honshu ridge area. It is also scattered in the Magellan seamount area at a depth under 4,000m. Siliceous ooze is mainly distributed in the Caroline islands area and at the limited area of the Mariana basin. Volcanic sands

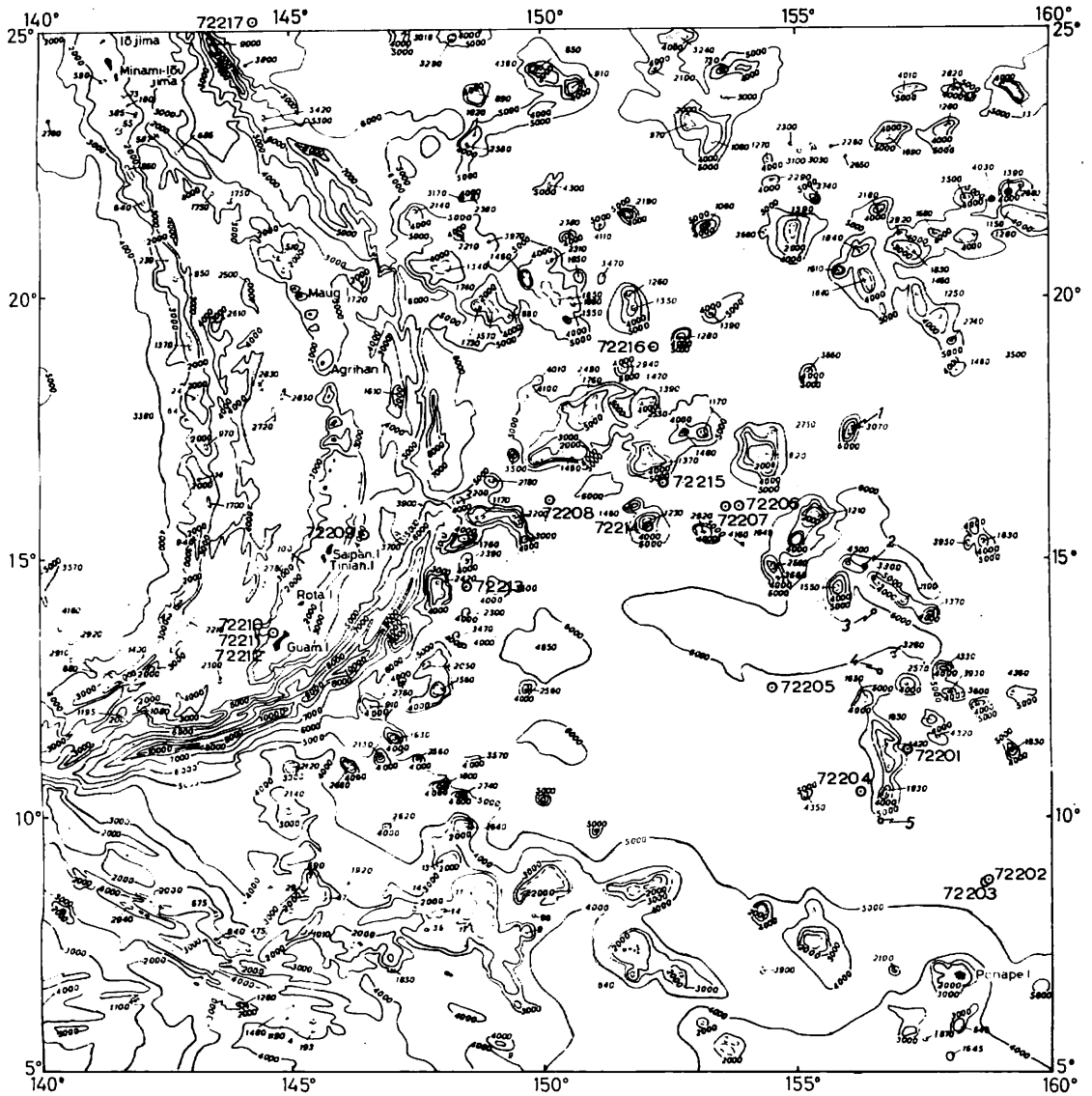
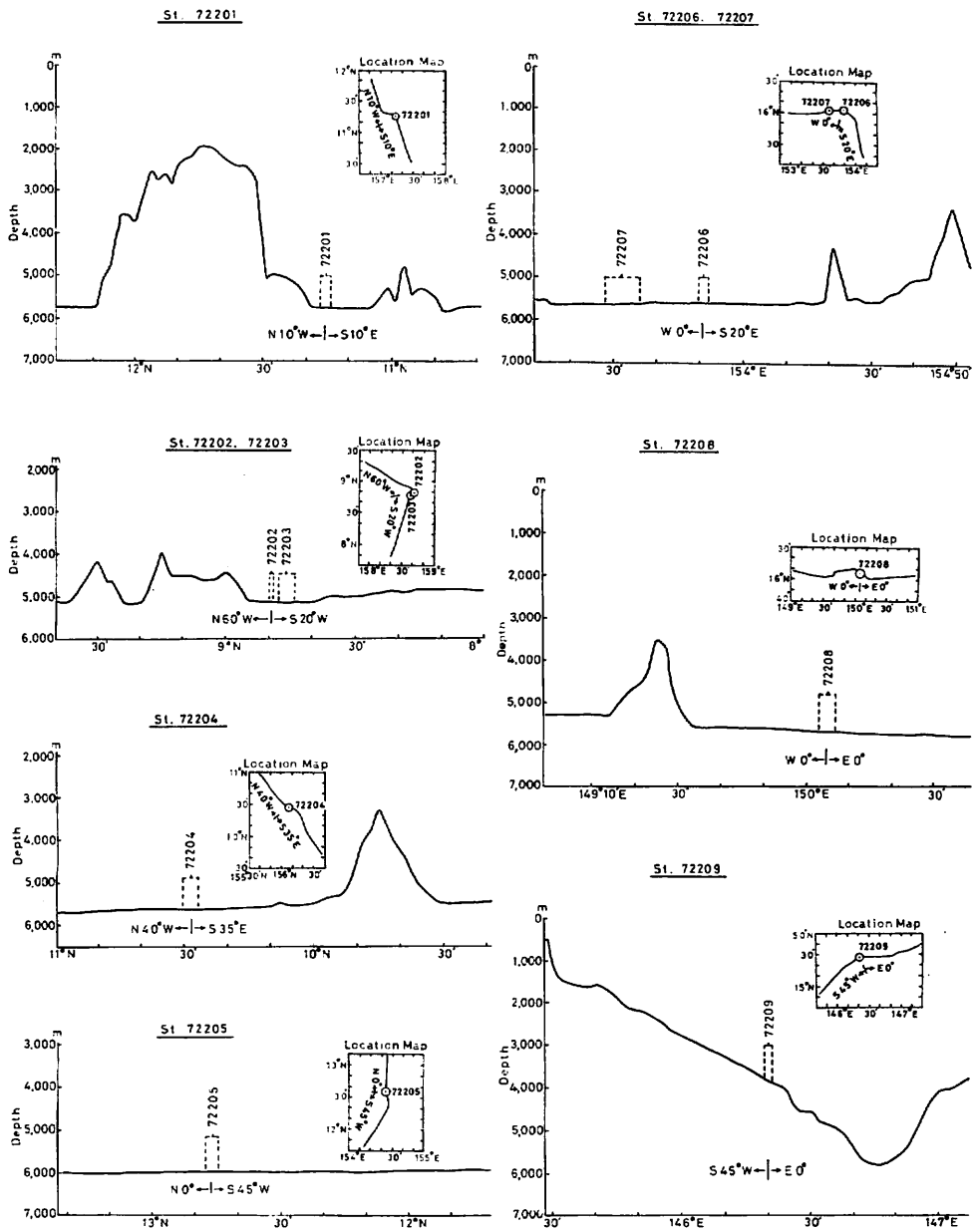
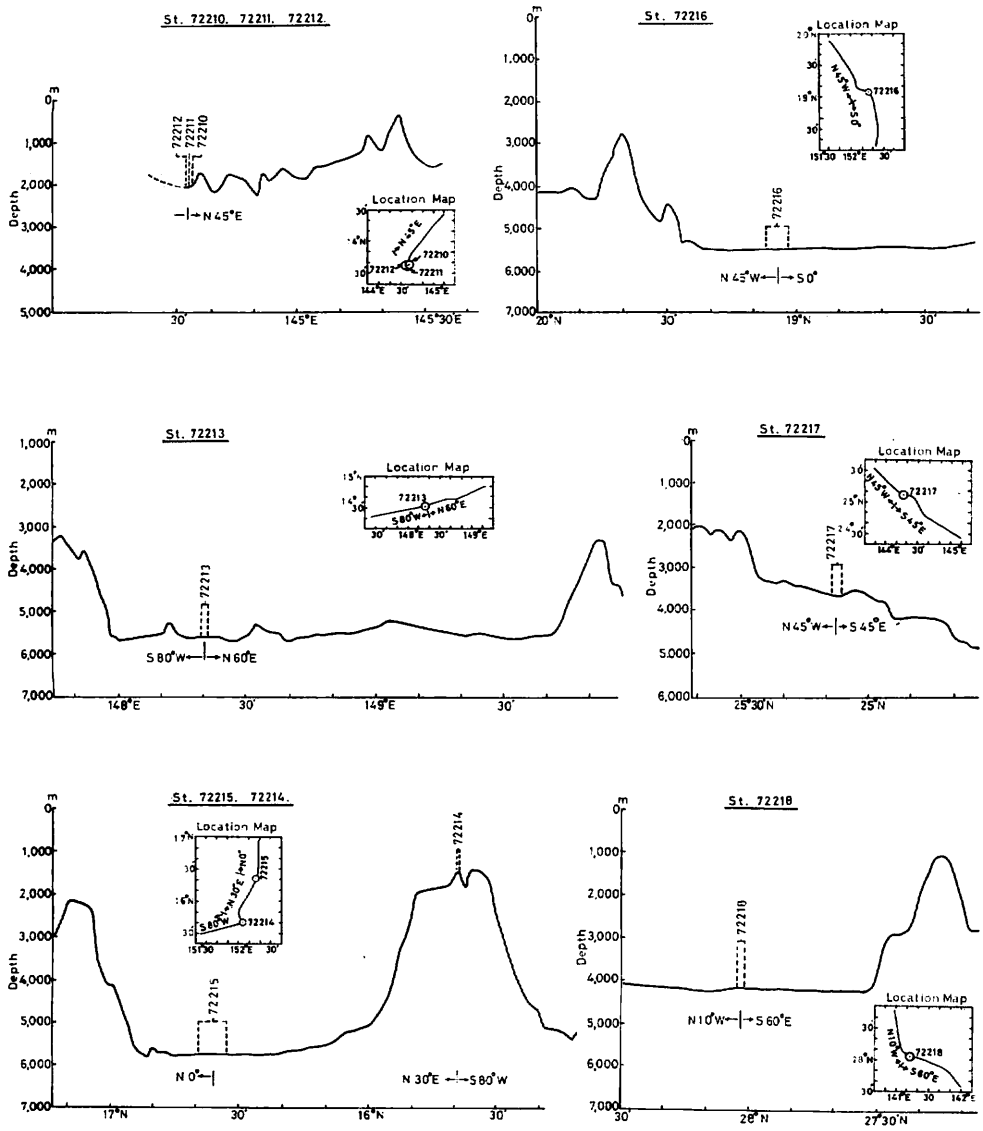


Fig. 25. Submarine topographic map. (Compiled map of pre-existing data)



Lat : Long = 1:18

Fig. 26-a. Profiles of submarine topography at sampling stations.



Lat : Long = 1 : 18

Fig. 26-b.

Table 2. List of sea-bottom topography, sediments and manganese nodules at each station.

No. of Station	Station		Depth of Water (m)	Sea-bottom topography	Sediments	Ferromanganese nodules
	Latitude	Longitude				
72201	11°16.0'	157°10.0'	5,790			None sampled (winch trouble)
72202	8°48.9'	158°41.9'	5,160	Flat surface of abyssal plane, weakly dipping to north, in the east of the Mariana basin.	Brown clay with manganese nodules and pumice.	Earthy black and pale black, small oblate and large slab shape. Total weight 6 kg.
	8°46.5'	158°39.1'	5,150			
72203	8°46.5'	158°40.5'	5,140	ditto		None sampled (Used Deep-sea camera)
	8°45.8'	158°39.0'				
72204	10°29.0'	156°10.0'	5,700	Foot of seamount, southeast of the Mariana basin.	Brown clay with few manganese nodules and pumice.	Small coating type.
	10°28.3'	156°06.5'	5,690			
72205	12°48.0'	154°22.5'	5,950	Eastern part of the Mariana basin, weakly dipping to north.	Brown clay Temperature of mud, 5°C	None
	12°51.5'	154°22.0'				
72206	16°02.0'	153°51.3'	5,580	Depression with gentle undulation in the Magellan seamounts.	Brown clay with many manganese nodules. Temperature of mud 2°C	Earthy black and spherical shape, 4-5 cm in diameter Total weight of nodules 44 kg.
	16°00.8'	153°50.5'	5,600			
72207	16°01.0'	153°34.0'	5,635	Ditto	Brown clay with many manganese nodules. Large pieces of shark teeth. Temperature of mud 1°C	Earthy black, and spherical and semispherical in shape. Largest oblate one has 14 cm in longest dimension. Total weight of nodules 80 kg.
	16°02.0'	153°31.0'	5,645			
72208	16°05.0'	150°06.5'	5,710	Flat plane of depression in the Magellan seamounts	Brown clay Temperature of mud 2°C	None
	16°08.0'	150°04.0'	5,700			
72209	15°28.0'	146°22.2'	3,930	Archipelagic apron near the Mariana islands.	Brown clay	None
	15°27.9'	146°20.2'	3,820			
72210	13°37.7'	144°37.4'	1,770	Slope of the west side of the Guam island.	Foraminifera ooze	None
72211	13°37.2'	144°36.5'	2,010	ditto		(Used deep-sea camera)
	13°37.15'	144°36.35'				
72212	13°36.1'	144°35.9'	2,040	ditto	Foraminifera ooze with basaltic rock fragments. Temperature of mud 3°C	None
	13°36.6'	144°35.5'	2,080			
72213	14°31.0'	148°19.5'	5,690	Depression between seamounts, at the east of the Magellan seamounts.	Brown clay with rock fragments coated with manganese.	Small nodules less than 1 cm in diameter. Some large nodules with slab shape are mixed. Total weight of nodules 9 kg.
	14°31.0'	148°17.9'	5,685			
72214	15°31.0'	152°06.0'	1,470	Top of a guyot in the Magellan seamounts.	Foraminifera ooze with manganese nodules and rock fragments.	None
	15°40.0'	152°05.0'	1,485			
72215	16°23.8'	152°18.0'	5,820	Depression between seamounts in the Magellan seamounts.	Brown clay with many manganese nodules. Temperature of mud 1°C	Nodules are uniform in shape and size, semi-octahedral in shape and 3.5 cm in diameter. Total weight of nodules 80 kg.
	16°29.8'	152°16.2'				
72216	19°02.0'	152°19.2'	5,520	Plane with gentle undulation in the Magellan seamounts.	Brown clay with manganese nodules. Temperature of mud 2°C	Nodules are predominant in coalescent and knob types. Large oblate ones are found. Total weight of nodules 5 kg.
	19°05.0'	152°15.1'	5,525			
72217	25°07.5'	144°19.3'	3,810	Foot of the Bonin ridge.	Radiolaria ooze with pumice and rock. Temp. of mud 2°C	None
	25°07.5'	144°18.3'	3,680			
72218	28°01.7'	141°14.2'	4,145	Small trough at the west of the Bonin ridge.	Terrigenous sandy silt with volcanic matters.	None
	28°02.5'	141°12.6'	4,140			

		Weather and sea conditions							
Date	Time	Weather	Temperature		Wind			Wave & Current	
			Air	Water	Direction	Force	Wave	Direction	Speed
1972									
11.18	1014 ~ 1437	fine and cloud	29.0°	29.7°	NNE	4	2	166°	kt
11.19	0611 ~ 1106	cloud	27.5°	30.2°	W	2	0.5 ~ 1.0		
11.19	1315 ~ 1647	fine	28.8°	31.9°			<0.5		
11.23	1219 ~ 1700	cloud	28.0°	30.0°	NE	5	1.0 ~ 2.5	228°	
11.24	0724 ~ 1145	fine	28.0°	29.6°	NE	4	3.0 ~ 5.0	201°	0.5 ~ 1.0
11.25	0524 ~ 0952	fine and cloud	29.5°	27.9°	NE	4	2.0 ~ 2.5	188°	
11.25	1220 ~ 1716	cloud	25.2°	29.4°	E	4	1.0 ~ 2.0	188°	1.5
11.26	0908 ~ 1421	fine and cloud	28.7°	29.3°	E	4	1.0	75°	0.5 ~ 1.0
11.27	0918 ~ 1225	fine and cloud	27.3°	29.2°	ENE	2	1.0 ~ 2.0	190°	
11.28	0601 ~ 0656	fine and cloud	28.0°	29.5°	NE	3	1.0		
11.28	0707 ~ 0825	cloud	27.8°	29.4°	E	3	1.0		
11.28	0825 ~ 1000	cloud	27.8°	29.4°	E	3	1.0		
12.2	0815 ~ 1153	fine and cloud	29.0°	29.3°	E	3	1.0 ~ 2.0	200°	1.0
12.3	0759 ~ 0908	fine	27.5°	29.4°	ENE	3	1.0	221°	
12.3	1311 ~ 1811	fine	28.8°	29.4°	ENE	3	2.0	285°	
12.4	0810 ~ 1238	fine and cloud	27.7°	28.9°	ENE	3	2.0 ~ 3.0	185°	
12.6	1322 ~ 1509	cloud	25.0°	28.0°	E	2 ~ 3	2.0	175°	0.36
12.8	1340 ~ 1716	cloud	24.8°	24.7°	S	5	1.5	118°	0.25

Table 3. Localities of different depths from pre-existing data.

Loc. No.	Locality of different depths				Pre-existing data
	N-Lat.	E-Long.	Depth	Submarine topography	
1	17°30'	156°15'	5,780m	Abyssal plane	Depth 3,070m Slope of seamount
2	14°45'	156°20'	6,020m	ditto	Depth 4,020m Slope of seamount
3	14°10'	156°32'	1,860m	Seamount	Depth 6,000m Abyssal plane
4	12°52'	156°40'	1,970m	ditto	Depth 6,000m Basin
5	9°53'	156°32'	3,970m	Ridge	Depth 6,000m Basin

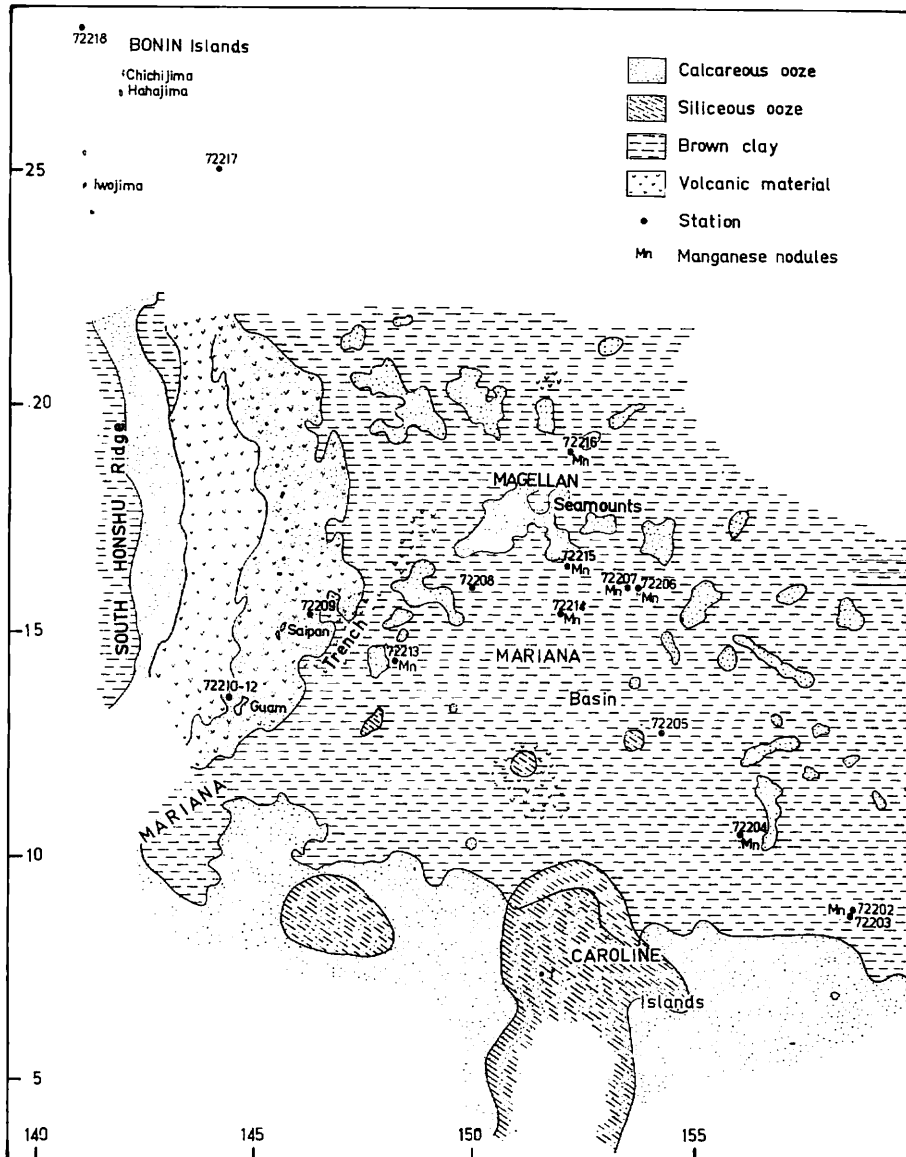


Fig. 27. Distribution of the various types of sediments and sampling stations in the surveyed area. (Slightly simplified after Geologic Data Center, Scrips Institution of Oceanography, 1972)

have wide distribution between the Mariana basin and the South Honshu ridges.

III.2 Relations among depth range, submarine topography and pelagic sediments

Depth and submarine topography constitute important factors controlling the distribution of different types of marine sediments. Relations between the types of sediments and the depths are represented in Fig. 28. based on the results of sampling at 44 stations during three times of research cruise in 1971 and 1972. As illustrated in Fig. 28, most of calcareous oozes occur between 1,300 m and 3,500 m in depth, on the other hand, brown clays are mainly found at depths over 4,500m. Therefore, the mode of distribution of pelagic sediments could be divided into three zones according to the different depths; that is, calcareous ooze is from 1,300m to 3,500m, and brown clay zone at depth over 4,500m. Between both

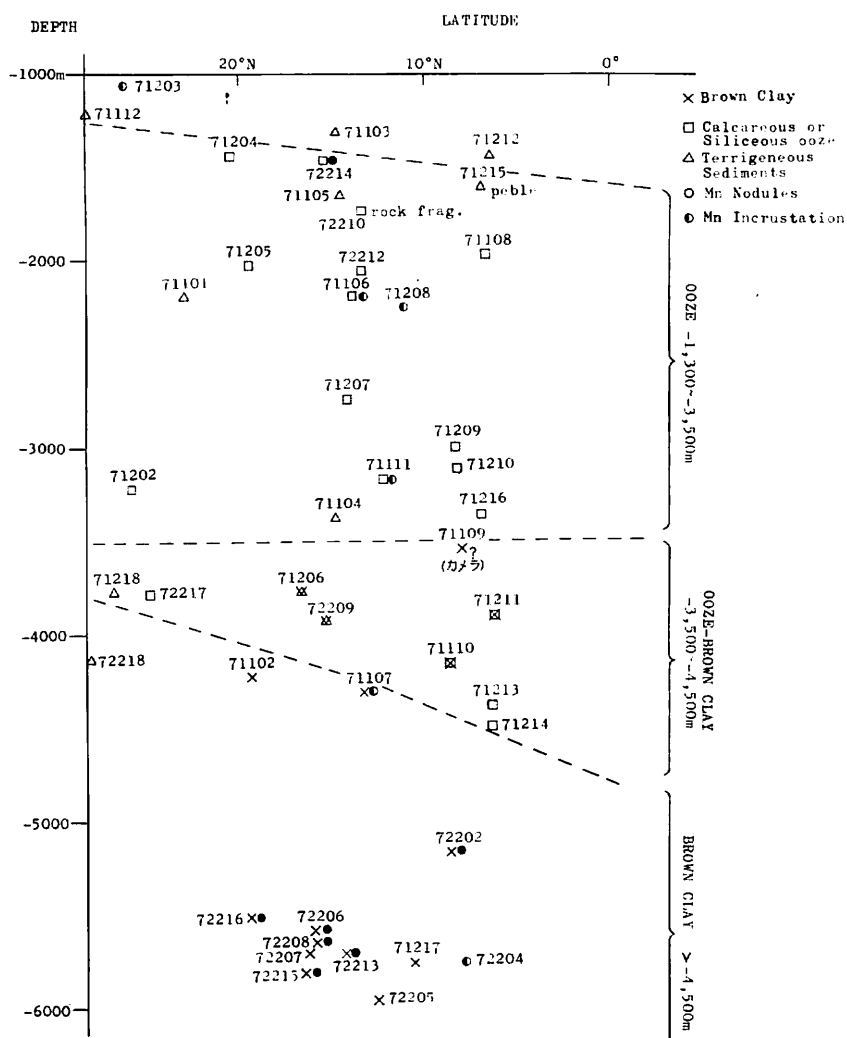


Fig. 28. Relation among sediments, depths and latitudes.

Table 4. Relation between various types of sediments and submarine topography.

Submarine topography	Sediments	Brown clay	Calcareous ooze	Terrigenous sediments	Manganese nodules	Coating type of manganese nodules
Top of seamount or guyot		0	10	1	1	4
Slope of seamount or island		2	3	4	0	0
Foot of seamount		0	3	1	0	0
Depression between seamounts		7	0	2	4	2
Abyssal plain		4	4	0	1	0

zones the transitional zone is from 3,500m to 4,500m.

On the contrary, the terrigenous sediments are found at various depths from 1,200m to 4,000m. It seems that the transported distance may be more important factor than the depth in controlling their distribution.

Ferromanganese nodules were dredged at various depths from 1,075m to 5,820m. However, the characteristics of the nodules are different with depth; the nodules at depths over 4,000m form spheroid and are thickly concreted with iron-manganese oxides, while the nodules at shallower water are thinly coated with iron-manganese oxides and have irregular shape.

The mode of the distribution of the sediments is closely related to the submarine topography as shown in Table 4.

In view of the above results, the following points can be deduced in the surveyed area.

- (1) Most of the brown clays occur on the abyssal plain of basins at depths over 4,500m.
- (2) The calcareous oozes are predominant at the top, slope and foot of seamounts and guyots.
- (3) The terrigenous sediments are distributed near islands.
- (4) The spherical and concreted nodules are associated with brown clays at depths over 4,500m, but coated type is mainly found in shallow water.

III.3 Sediments dredged at each station

During the research cruise in November-December of 1972, various sea floor sediments, such as brown clay, foraminiferal and radiolarian oozes and terrigenous volcanic sediments, were obtained at 15 stations, and also ferromanganese nodules were dredged at 8 stations. The characteristics of the sediments at each station are summarized in Table 2. St. 72202 (Depth 5,150-5,160m)

At the station, dredged sediments are composed mainly of brown clay, associated with ferromanganese nodules and rock fragments. The clay is moderate brown in color, and has clay grade in size fraction. A few organic remains are also found in the clay. The ferromanganese nodules of 3.7 kg, contained in the brown clays, were dredged with two cylindrical type buckets. Most nodules have oblate form, and are less than 3 cm in longer dimension. Several large nodules, with irregular slab shape and 15 cm in largest dimension, are also obtained. In general, the nodules are earthy black in color, and contain nucleus of altered volcanic rocks.

St. 72204 (Depth 5,690–5,700m)

Sediments dredged at the station consist mainly of brown clay with a few ferromanganese nodules and rock fragments. The clay has moderate brown color and silt-clay grade in size fraction. The nodules are small, ranging 0.5–1.0 cm in dimension, and coated type of subangular pumice fragments.

St. 72205 (Depth 5,950m)

Brown clay was dredged at the station. It is pale brown in color and clay grade in size fraction. It contained a few radiolarian remains, but no ferromanganese nodules.

St. 72206 (Depth 5,580–5,600m)

At the station sediments are composed of brown clay with many ferro manganese nodules. The clay is also moderate brown in color and consists of silt and clay grade. The nodules of 44 kg in total weight were obtained with two cylindrical type buckets. They are earthy black in color, and most of them are really spherical with less than 5 cm in diameter. The surface of the nodules is not so smooth. Some nodules, formed oblate with 9 cm in longest dimension, are mingled. The remains of large shark teeth, coated with iron-manganese oxides, are also found, and the interior of the teeth is often cemented with the oxides.

St. 72207 (Depth 5,635–5,645m)

Sediments at the station are also brown clay, associated with a great number of the ferromanganese nodules and a few fragments of pumice. The clay is moderate brown in color and consists mainly of silt grade in size fraction. A total weight of ferromanganese nodules, dredged with the box type bucket and cylindrical type one, is about 80 kg. Most of the nodules are spherical or semi-spherical, but some of them are oblate, coalescent, or triangular in shape. The nuclei of triangular shape are shark teeth. The size of the nodules is larger than those of the former station, for instance, the largest one has a dimension of 13.5 × 9.0 × 6.0 centimeters. The largest shark tooth is 10.1 cm in height and 10.5 cm in width. According to the identification by M. Goro (Tokyo Medical and Dental University), larger shark teeth belong to *Carcharodon megalodon*, of Miocene to Pliocene, and smaller ones are *Isurus hastalis*, of Miocene to Pliocene (Fig. 29).

St. 72208 (Depth 5,700–5,710m)

Dredged sediments are mainly brown clay, composed of silt, clay and very fine sand grade. The clay is moderate brown in color and rather ill-sorted.

St. 72209 (Depth 3,820–3,930m)

A small amount of brown clay was obtained only.

St. 72210 (Depth 1,770m)

Sediments, sampled with a Shipek type grab sampler, are a small amount of foraminiferal ooze with yellowish brown color and fine to coarse sand in grain size. Some photographs of the sea floor at the depth of 2,010m (St. 72211), situated nearly same as St. 72210, were taken by the deep sea camera of Riken type. In the photographs (Figs. 21~24), light colored sediments, which may be calcareous ooze, thinly cover the rocks at bottom surface.

St. 72212 (Depth 2,040–2,080m)

Sediments are foraminiferal ooze containing basaltic rock fragments. The ooze with yellowish brown color is composed of silt and sand.

St. 72213 (Depth 5,685–5,690m)

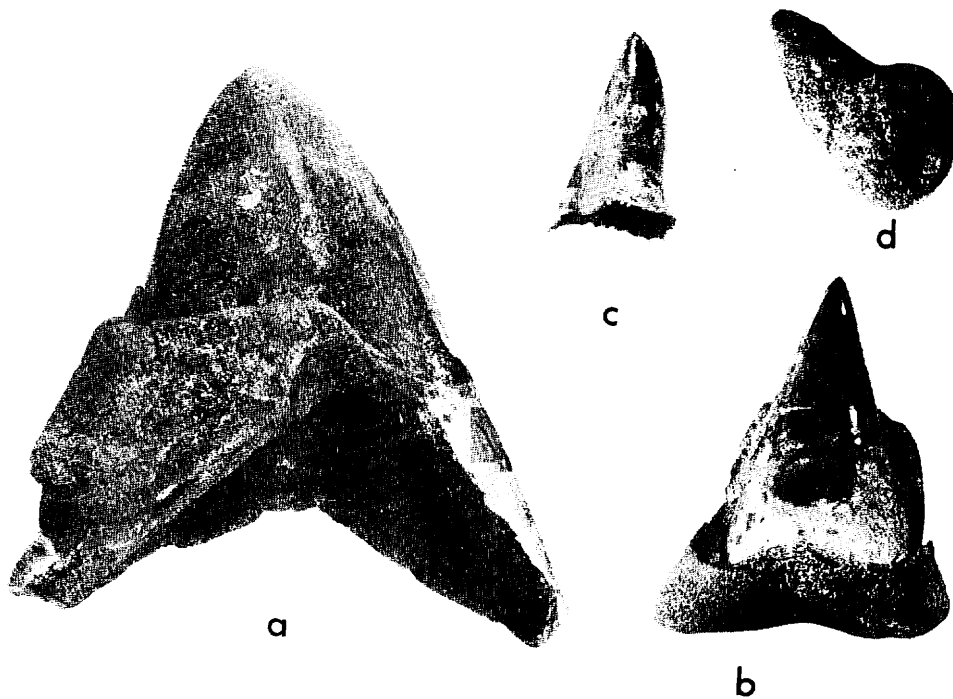


Fig. 29. Shark teeth obtained in the Magellan seamounts area.
 a: *Carcharodon megalodon* $\times 1.0$, b and c: *Isurus hastalis* $\times 1.7$, and d: a
 tooth coated with iron manganese oxide $\times 1.5$

Sediments at the station are composed mainly of brown clay, associated with a few ferromanganese nodules and rock fragments. The clay has pale brown color and silt and sand grade in size fraction. The nodules of 9 kg in total weight were dredged with two cylindrical type buckets. They are small and less than 1 cm in diameter. However, some large nodules with irregular slab shape, 10 cm in largest dimension and 2 cm in thickness, are mixed.

St. 72214 (Depth 1,470–1,485m)

Sediments are foraminiferal ooze with milky yellowish brown color, associated with a few ferromanganese nodules and rock fragments. The nodules are less than 1.5 cm in diameter, and spherical and subangular in shape. The subangular nodules are coating type of altered rock fragments.

St. 72215 (Depth 5,820m)

Sediments, dredged with three cylindrical type buckets, consist mainly of brown clay and ferromanganese nodules. The clay is pale brown in color and has clay grade in size fraction. A total weight of nodules is about 80 kg under wet condition. It is very interesting that the shape and size of them are quite uniform; semi-octahedral in shape and 3.5 cm in average diameter.

St. 72216 (Depth 5,520–5,525m)

Sediments are brown clay with a few ferromanganese nodules. The clay is moderate brown in color. The nodules are predominantly of coalescent type of small nodules with

2–3 cm in diameter and also knob type. Some large nodules with oblate form are also found.

St. 72217 (Depth 3,810–3,680m)

Radiolarian ooze with small fragments of pumice was dredged at this station. The ooze is dark yellowish brown in color and consists mainly of fine sand and silt grade with a small amount of clay.

St. 72218 (Depth 4,140–4,145m)

Dredged sediments are terrigenous and contain much volcanic matter. The sediments are composed of sandy silt with ill-sorted grains and dark yellowish brown color.

III.4 Brief description of the sediments

The sediments obtained through this cruise have been examined by physical and chemical methods. The results of the preliminary studies are described respectively as follows:

1) Brown clay

The brown clay consists of silt and clay in size fraction, and is associated with a very small amount of fine sand. In general, it is moderate brown (5 YR 3/4 in the color chart of U.S.G.S.) in color under wet condition. The volume ratio between clay and silt in it varies from place to place: silt is dominant at St. 72206, 72207 and 72208, on the other hand, clay rich at St. 72202, 72205, 72215 and 72216.

The constituent minerals of very fine sand in 74–104 micron size fraction are quartz, feldspar, olivine and volcanic glass, associated with rock fragments. Organic remains of planktonic Foraminifera, Radiolaria, diatoms and Sponge needles, are found in very fine sand to silt fraction of the brown clay. For example, the proportion of the constituents of the brown clay in the same fraction as mentioned above at St. 72207 is as follows: quartz – 68%, rock fragments – 10%, volcanic glass – 9%, feldspar, olivine and other minerals – 2% and organic remains – 3%.

The bulk analyses of the brown clays from St. 72207, 72215 and 72216 by X-ray diffraction method show that the main constituent minerals are quartz, illite, chlorite and plagioclase. The results of the heavy mineral analyses of 60–500 microns size fraction at St. 72202, 72204, 72208, 72210 and 72215 are shown in Table 5. They are composed mainly of augite and hypersthene with a small amount of hornblende and olivine. It seems that the mafic minerals were supplied from submarine volcanoes or volcanic islands in the surveyed area.

2) Foraminiferal ooze

The foraminiferal oozes at St. 72212 and 72214 are yellowish brown (YR 5/4 in the color chart of U.S.G.S.) under wet condition. Compared with the foraminiferal oozes obtained from the Caroline islands area during the previous cruise in 1971, the oozes in the surveyed area have darker tone. It appears that the organic contents of the Caroline oozes are higher than those of Guam.

The present oozes consist of very fine sand and silt, and the constituents in 74–104 microns size fraction are abundant in organic remains with a few of quartz grains, volcanic glass and rock fragments.

Table 5. Heavy minerals analyses of sediments.

Station numbers	Heavy minerals Samples	Olivine	Hornblende	Oxyhornblende	Hypersthene	Augite	Epidote	Zoisite	Rutile	Titanite	Grain size in mm				
											1.0 ~ 0.5	0.5 ~ 0.25	0.25 ~ 0.12	0.12 ~ 0.06	
72202	Brown clay		7		19	74						c	a		
72202	Rock fragment		3		69	24				4		r	a		
72208	Brown clay		2	+	52	42	3		1			r	r	a	
72208	Rock fragment		3		72	25					c	a	c		
72210	Brown clay	5	2	1	8	83			1				r	a	
72212	Foraminiferal ooze	2	5	4	26	63	+		+			r	r	a	
72214	ditto		4	2	17	77			+			r	r	a	
72215	Brown clay	2	3		65	27	3	+	+			r	r	a	
72216	ditto		4	--	29	63	4						r	a	
72217	Radiolaria ooze	20	1	+	9	70						r	a		
72217	Rock fragment	1	1		6	92						c	a		
72218	Sandy silt	17	3		10	70						r	c	a	

+: <1%, r: rare, c: common, a: abundant
analyst: T. SUZUKI

The organic remains are composed mostly of planktonic Foraminifera, associated with a small quantity of Radiolaria, Sponge needle and diatom. Tests of Foraminifera are perfectly preserved.

It the sample at St. 72212, eight species of planktonic Foraminifera were recognized as follows:

<i>Globorotalia</i> cfr. <i>cultrata cultrata</i> (D'ORBIGNY)c
<i>G.</i> cfr. <i>tumida tumida</i> (BRADY)c
<i>G.</i> aff. <i>ungulata</i> BERMUDEZf
<i>Globigerinoides</i> cfr. <i>conglobatus</i> (BRADY)f
<i>G. quadri-sacculifa</i> (BRADY)c
<i>Pulleniatina</i> aff. <i>obliqueloarata finalis</i>f
<i>Sphaeroidinella</i> cfr. <i>dehiscens</i> (PARKER & JONES)a
<i>Orbulina universa</i> D'ORBIGNYf

The X-ray diffraction analysis of this sample merely shows the reflection peaks of calcite. Main heavy minerals in 60–500 microns size fraction of the same sample are augite and hypersthene, accompanied by a small amount of hornblende, oxyhornblende and olivine, which are similar to those of the brown clays.

3) Radiolarian ooze

The radiolarian ooze at St. 72217 is dark yellowish brown (10 YR 4/2 in the color chart of U.S.G.S.) under wet condition, and is very fine sand to silt in grain size fraction and rather ill-sorted.

Very fine sand of the ooze is composed of 30–40% of radiolarian remains, 10% of diatoms, 5–15% of planktonic Foraminifera and 20% of volcanic glass fragments, and others are quartz grains and rock fragments. By the X-ray diffraction analysis the reflections of calcite are prominent, but those of quartz, illite and chlorite are not so clear. The proportion of mafic minerals in the ooze is as follows: 70% of augite, 10% of hypersthene,

20% of olivine and a very small quantity of hornblende. The volume ratio of augite to hypersthene is higher than that of the brown clays and the foraminiferal oozes.

4) Terrigenous sediments

The terrigenous sediments obtained at St. 72218 are dark yellowish brown (10 YR 2/2 in the color chart of U.S.G.S.) under wet condition. They correspond to silt and fine sand in size fraction, and are ill-sorted. The constituent minerals of the sample in fine sand fraction are quartz, mafic minerals and volcanic fragments, associated with little amount of organic remains.

The transparent heavy minerals in 60–500 microns size fraction are augite (70%), olivine (17%), hypersthene (10%) and hornblende (3%). This proportion of the constituents is similar to that of the radiolarian ooze at St. 72217. The mafic minerals might have been transported from the Ogasawara (Bonin) and the Iwojima islands and also peripheral submarine volcanoes, because the main rocks of the Chichijima and the Hahajima of the Ogasawara islands are Paleogene two- pyroxene andesite, and those of the Iwojima islands are olivine-augite trachyandesite and augite-olivine basalt.