

Abstract

Results of soundings carried out during five Japanese Antarctic Research Expeditions are summarized. The bottom sediments collected by the 5th Expedition were analyzed concerning the grain size distribution, chemical composition, gravel composition, heavy mineral association, clay mineral composition and organic matters.

The area studied is divisible into at least four sedimentary petrographic sub-provinces on the basis of gravel composition, heavy mineral association and clay mineral composition. It is probable that these sediments were transported to the present sites from different sources without much sorting effects. The occurrence of trioctahedral illite in clay fraction may be the result of weak chemical weathering in the Antarctic region.

1. INTRODUCTION

Many soundings had been carried out during five Japanese Antarctic Research Expeditions from 1956 to 1961. The data taken by the UMITAKA-MARU and SOYA's first expedition have been reported by KUMAGORI et al (1958) and SHOJI and SATO (1959), respectively. Concerning the bottom sediments, NIINO (1958) reported on the samples dredged by the UMITAKA-MARU, and SHOJI and SATO (1959) on those by SOYA's second expedition. In the present paper, the authors will describe the compiled soundings of the second to fifth SOYA's expeditions and the bottom sediments collected by the fifth SOYA's expedition. The analyses and analyzers are as follows:

Topography	SATO
Grain size	SATO
CaCO ₃ and H ₂ O	IJIMA
Clastics	IJIMA
Chemical analysis	SATO
Clay minerals	OINUMA and KOBAYASHI
Organic matters	IWABUCHI

Sounding data treated in this report were arranged by the members of the Japanese Hydrographic Office. The bottom samples were obtained by Mr. S. HORI, member of the JARE-V. The manuscript was critically reviewed by Prof. T. TATSUMI of the Geological Institute of the University of Tokyo. The authors express hearty thanks to these gentlemen.

II. SUBMARINE TOPOGRAPHY

1. Africa to Antarctica

Soundings were presented in the form of tracks and topographic profiles (Figs. 1 and 2). Original sounding data are preserved in the Japanese Maritime Safety Board.

Continental shelf off Cape Town, southern end of Africa, ranges from 80 to 240 km in width, with 250 to 300 m edge depth. The foot of the continental slope is about 5100-5200 m deep. The apparent gradient of the slope is about (14-24)/1000 on the topographic profiles, so the true gradient of slope is more than 80/1000. A height of 600 to 1000 m is seen at a depth of 3000 m on the slope.

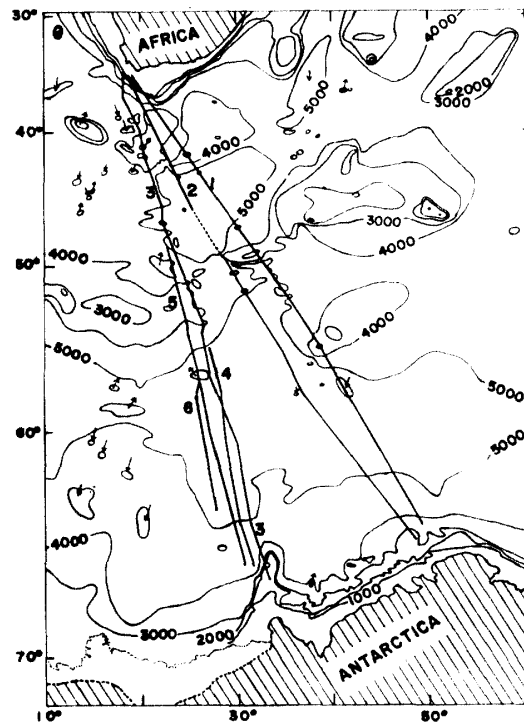


Fig. 1. Sounding tracks between Africa and Antarctica.

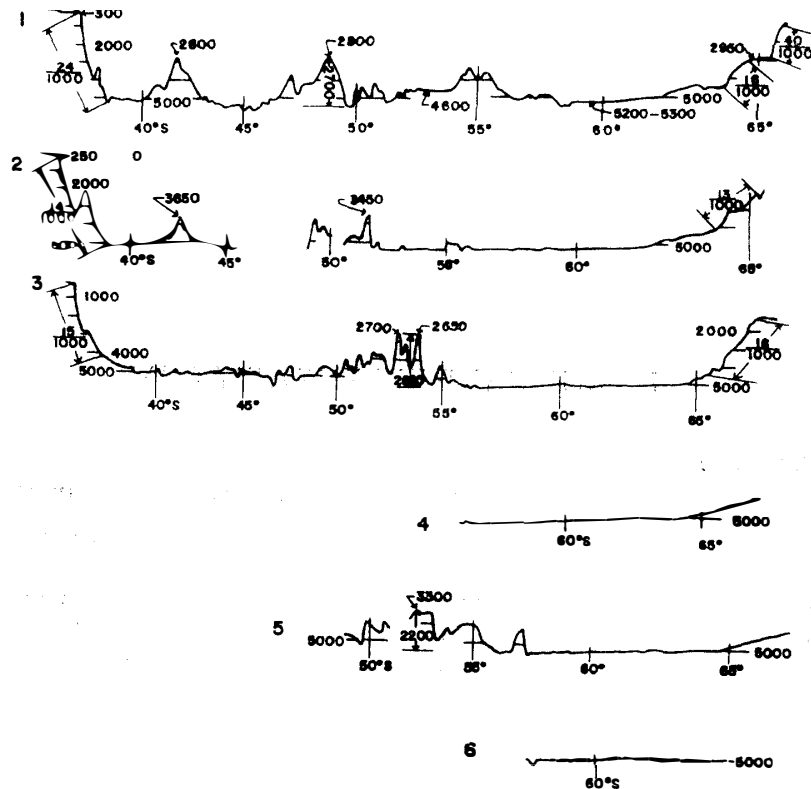


Fig. 2. Topographic profiles.

The ocean floor between Africa and Antarctica is divided into two provinces by a large submarine ridge trending WSW, as seen at the south mountain in profiles 1 and 2, and at that in profiles 3 and 5. These mountains are 2000-2800 m high and the shallowest peak is located at a depth about 2700 m. They are the continuation of Mid-Atlantic Ridge, as EWING and HEEZEN (1956) suggested that the Mid-Atlantic Ridge stretches to the Pacific and Indian Oceans via south of Africa.

The ridge divides the ocean floor into northern and southern provinces. The southern province is a very flat floor 5200-5300 m deep, as seen in profiles 1 to 6. The northern province has also a flat part of 5000-5200 m deep, but shows a fairly rugged relief; profiles 1 and 2 show mountains of 1600-2700 m high.

The continental slope on the Antarctica side also has a gradient similar to the African side.

2. Submarine topography of Antarctica side

a. Off Enderby Land

The continental slope decreases its gradient at depth more than 3000 m, becoming gentler with depth. The relief of the slopes shallower than 3000 m suggest the existence of submarine canyons.

b. Off Prince Olav Coast

Longitudinal profiles of the continental slope show a moderate relief down to the depth of 4000 m or more. Transverse profiles show a smooth slope probably lacking submarine canyons.

c. Lützow-Holm Bay

The continental slope extends to the depth more than 4000 m. Transverse profiles show that the base of the slope is a flat floor of 4500 m deep, and the slope has a moderate relief.

d. Continental shelf

The depth of the shelf edge is 300-400 m off the eastern part of Lützow-Holm Bay and 500-600 m on the Gunnerus Bank, north of Cape Cook. The width of the shelf is 60 km off the Prince Olav Coast and more than 70 km off Lützow-Holm Bay.

III. GENERAL ASPECTS OF BOTTOM SEDIMENTS

1. Grain size

a. Method

The samples were dried in air, weighed about 30 g each, and dispersed into distilled water. One liter of dispersed solution was shaken vigorously so that grains are uniformly distributed. No peptizer was used. The density of solution was measured by hydrometer at 1, 2, 5, 15, 30, 60, 240, and 1440 minutes after, respectively. The hydrometer is the one designated by "Japanese Industrial Standards", which can measure the specific gravity from 1.000 to 1.050. The diameter of the glass cylinder used for suspension is about 6 cm, by which A (cm^2), cross-section of the cylinder, was calculated. So, the depth (L) where hydrometer measures the specific gravity of suspension, is defined as follows (Fig. 3):

$$L = L_1 + 1/2 \cdot (L_2 - V_b / A)$$

where V_b (cm^3) is the volume of the main part of the hydrometer,

L_1 (cm) is the distance from the water level to the top of the main part of the hydrometer, and

L_2 (cm) is the length of the main part of the hydrometer.

Thus, the depth L can be calculated for each reading the scale of the hydrometer. According to Stoke's Law, the largest diameter (d , mm) of mud grains is calculated from the following equation ;

$$d = \sqrt{\frac{30 n L}{930 (G - G_1) t}}$$

where d is the largest diameter of grains (mm),

n is the drag coefficient of water (p),

G is the specific gravity of mud grains, and

G_1 is the specific gravity of water.

On the other hand, the weight percentage (P) of suspended grains in 1 cc at each depth L is calculated from the following equation ;

$$P = \frac{100}{w} \cdot \frac{G}{G - G_1} (r' + F)$$

where w is the weight of sample in 1 cc of initial dispersion (g),

r' is the decimal fraction of the scale of hydrometer (meniscus error corrected), and

F is the correction of hydrometer scale for temperature. Thus, using d and P , the distribution of grain size can be plotted. Of course, d is changed to ϕ scale by the equation $\phi = -\frac{\log d}{\log 2}$.

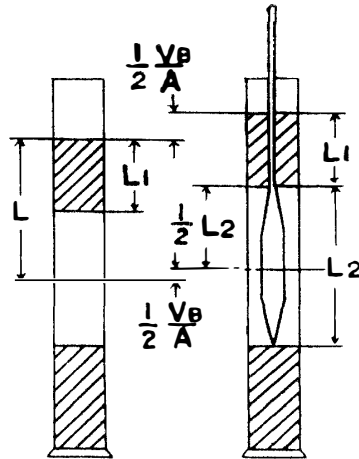


Fig. 3. Depth L and hydrometer.

b. Result

During the fifth cruise of the SOYA, 18 samples have been taken at 11 stations, which are shown in Fig. 4 and listed in Table 1.

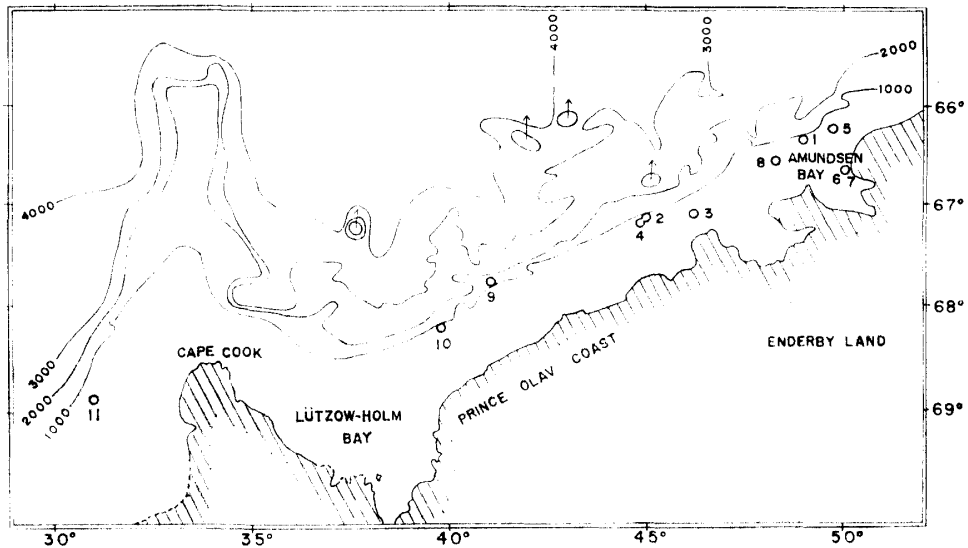


Fig. 4. Bathymetric chart and sampling stations around Antarctica.

St. 1 is situated at the upper part of the continental slope north of Amundsen Bay and Enderby Land. It is composed of coarse materials and much gravels. Sts. 2 and 3 are situated at the shelf edge off the eastern part of the Prince Olav Coast. They contain also angular gravels. St. 4 is situated at a slightly deeper

Table 1. Records of bottom sediments.

Station	Date	Lat. S	Long. E	Depth	Sampler
1	Jan. 7	66-22.0	49-09.5	945m	dredger
2	Feb. 9	67-10.5	45-01.5	385	"
3	9	67-07.0	46-15.0	280	"
4	11	67-13.0	44-50.5	560	"
5	15	66-33.5	49.38.5	330	"
6	16	66-41.0	50-02.0	980	"
7	16	66-41.0	50-03.0	1020	corer
8	17	66-33.5	48-21.0	275	dredger
9	21	67-47.0	41-01.0	1750	corer
10	22	68-12.0	39-43.5	380	dredger
11	Mar. 1	68-53.0	30-56.0	190	"

part than the shelf edge in the same area. It is muddy without coarse materials. St. 5 is situated on the continental shelf off Amundsen Bay. Sts. 6 and 7 are situated off Mt. Larsen in Amundsen Bay. Here it is about 400 m deep on average, but Sts. 6 and 7 are at about 1000 m depth which may suggest the presence of a submarine canyon. They do not contain gravels. St. 8 is on the continental shelf off Amundsen Bay. It contains angular gravels. St. 9 is the deepest station recorded by this cruise, and is situated on the continental slope off the Prince Olav Coast. St. 10 is on the continental shelf off the Prince Olav Coast, and is sand and angular gravels. St. 11 is situated at the southwestern shallow on the Gunnerus Bank. It contains coarse materials and many fragments of organic remains.

The samples usually contain muddy and sandy fractions, sometimes gravels. The grain size of muddy fraction was analyzed by hydrometer method and sandy fraction by Emery's Tube method. The gravels were measured and are presented only by their maximum diameters. The result of grain size analysis of muddy

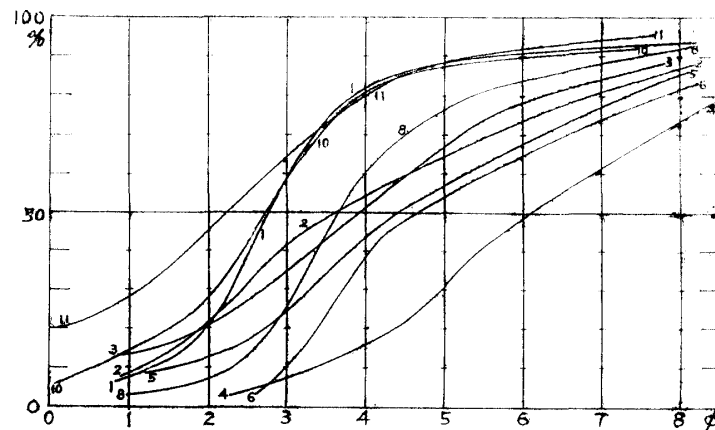


Fig. 5. Cumulative curves of the grain size distribution.

Table 2. Results of grain-size analysis.

Station	ϕ 16	ϕ 25	ϕ 50	ϕ 75	ϕ 84	Gravel
						Maximum diameter
1	1.8	2.1	2.7	3.6	4.1	4 cm
2	1.6	2.2	3.5	6.2	7.5	4.5
3	1.4	2.4	3.9	5.6	6.9	3
4	3.9	4.7	6.1	8.1	—	—
5	2.4	3.1	4.5	6.8	7.7	2
6	3.3	3.5	4.6	7.2	8.2	—
8	2.6	3.0	3.6	4.9	6.0	4
10	1.2	1.9	2.7	3.6	4.2	4
11	—	0.7	2.2	3.6	4.3	3.5

and sandy fractions excluding gravels is shown in Table 2. Fig. 5 gives cumulative curves of the grain size distribution.

The samples on the continental shelf, such as Sts. 2, 3, 5, 8, 10 and 11, are fairly sandy, containing gravels. The organic remains on the Gunnerus Bank have been ascertained in the second expedition. The samples on the continental slope, such as Sts. 1, 4, 6, 7 and 9, are muddy, in which St. 1 is abnormal sediments containing sand and gravels, seemingly a results of iceberg transportation.

Gravels range from 4 to 4.5 cm of maximum diameter. All gravels are very angular and chiefly composed of granite or gneiss.

2. Chemical analysis

The sediments were sampled by a small gravity corer at Sts. 4, 7 and 9. Chemical analyses were made on them. Table 3 shows the location of the samples. These three samples are the muds on the continental slope, Sts. 4 and 7 representing the bottom deposits near the continental shelf and in the environs of submarine canyon, and St. 9 a hemipelagic sediment. Results of chemical analyses are shown in Table 4.

Fe_2O_3 : Total iron is presented in the form of ferric oxide. In general, the contents of iron and manganese are higher in pelagic deposits than in the terrigenous ones. The samples are poor in iron and manganese, probably due to dilution by detritus.

SiO_2 : The samples show a high content of silica, but St. 9 which is the deepest sample, has a relatively low content.

Table 3. Depth of samples used for chemical analysis.

Station	Depth below bottom
4	— 7 to 16 cm
7	—15 to 21
9	—24 to 31

Table 4. Recalculated chemical compositions excluding CaCO_3 , water and residual salts.

	St. 4	St. 7	St. 9
SiO_2	69.85 wt. %	73.01 wt. %	63.89 wt. %
Al_2O_3	12.93	11.80	16.22
Fe_2O_3	5.12	4.88	5.22
TiO_2	0.61	0.57	0.76
P_2O_5	0.19	0.08	0.29
MnO	0.14	0.06	0.11
CaO	3.71	3.22	4.98
MgO	2.61	2.40	2.33
Na_2O	2.78	2.11	4.50
K_2O	2.05	1.88	1.72
Total	100.00	100.00	100.00

Al_2O_3 : Generally, the alumina content is rich in clayey sediments. All three have low values of Al_2O_3 , which suggests abundance of detritus, but St.9 has a relatively high content of Al_2O_3 .

P_2O_5 : Considerably poor in all of them.

The results of chemical analysis indicate that these three samples are terrigenous sediments abounding in detritus transported from land. But, the deepest sample at St. 9 shows a somewhat hemipelagic character.

3. Water content of bottom sediments

The water content was measured for the sediments which had been collected by a gravity core sampler from the bottom of 550 m in depth at St. 4, lat. $67^\circ 12.5' \text{S}$ and long. $44^\circ 49.0' \text{E}$. The core sample is 41 cm in length and 5 cm in diameter.

As soon as the core was raised up onto the deck of the research vessel, its both ends were tightly plugged with rubber stoppers, and the core was placed in a refrigerator. Arriving at Tokyo, the core was taken out of the refrigerator, and was cut into nine pieces at the Hydrographic Office, Maritime Safety Board. Each cutting face of the pieces was tightly covered with a vinyl sheet immediately.

The piece samples were weighed immediately after they had been taken out of the tube. Then, they were heated at 110°C until the weight became constant. The ignition loss is regarded as the water content of sediments.

The water content of the Antarctic bottom sediments is shown in Table 5 and Fig. 6. It is remarkable that the top and bottom of the core sample contain less water than the other parts. This may be ascribed to dehydration during storage in the refrigerator of the vessel, due to incomplete plugging of both ends of the core tube. In the superficial part of the Eastern Antarctic bottom sediments, the water content is 60-70 weight percent, according to LISITZIN (1960). In general, it decreases with the increase of the depth of burial by compaction; it is

Table 5. Water and carbonate contents and modal distribution of the core samples of the Antarctic bottom sediments at Station 4.

Depth below the bottom floor	Water content	Carbonate content	Very coarse sand and gravel	Sand	Silt and clay
0- 1 cm	18.5 wt. %	5.6 wt. %	— wt. %	14.4 wt. %	85.6 wt. %
1- 6	39.8	4.7	0.1	13.8	86.1
6-11	39.9	4.9	1.1	25.5	73.4
11-16	42.2	4.5	0.5	26.6	72.9
16-21	43.0	4.3	0.3	15.3	84.4
21-26	40.8	4.4	1.8	18.2	80.0
26-31	43.2	10.7	1.0	13.9	85.1
31-36	35.5	4.6	2.0	27.1	70.9
36-41	21.8	2.8	4.3	42.5	53.2

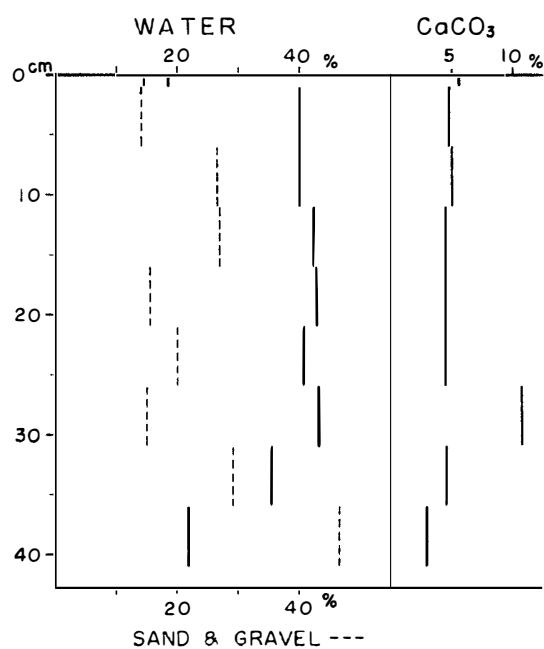


Fig. 6. Water, carbonate, and sand and gravel contents of the Antarctic bottom sediments at Station 4.

about 40 weight percent at the depth between 90 and 400 cm—data are not available at the depth between 5 and 90 cm—, and keeps nearly constant below 700 cm from the bottom surface, being about 20 weight percent. In the recently investigated bottom sediments, the water content is 36-43 weight percent at the depth between 1 and 36 cm. These values are not incompatible with the LISITZIN's. The water content seems not to be greatly affected by the content of sand and gravel in argillaceous sediments (Fig. 6).

4. Carbonate content of bottom sediments

The bottom samples were dried at 110°C and weighed. They were treated

with dilute hydrochloric acid and washed in distilled water; then, they were dried and weighed. The soluble material is composed exclusively of such calcareous organic remains as mollusca, echinodermata, foraminifera and bryozoa. The inorganic solubles exist but their amount is negligible.

a. Carbonate content of core samples

The carbonate content was measured for two cores at Sts. 4 and 9. The length of the core is 41 cm and 31 cm, respectively. The result of analyses is given in Tables 5 and 6. At St. 4, with a depth of 550 m, the carbonate content is relatively constant, being about 5 percent, except for 10.7 percent between 26 and 31 cm below the bottom surface (Fig. 6). At St. 9, with a depth of 1750 m, the content amounts to 33.3 percent between 10 and 15 cm below the surface, although it is usually much less than 5 percent (Fig. 7). It is unknown whether or not the above two high carbonate horizons are correlative to each other.

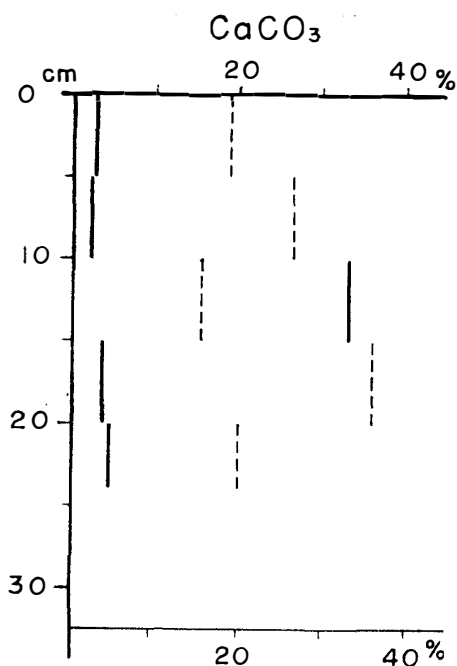


Fig. 7. Carbonate (solid line) and sand and gravel (dashed line) contents of the Antarctic bottom sediments at Station 9.

Table 6. Carbonate content and modal distribution of the core samples of the Antarctic bottom sediments at Station 9.

Depth below the bottom floor	Carbonate content	Very coarse sand and gravel	Sand	Silt and clay
0-5 cm	2.8 wt. %	0.1 wt. %	19.1 wt. %	80.8 wt. %
5-10	2.2	tr	26.4	73.6
10-15	33.3	0.1	15.6	84.3
15-20	3.7	0.1	35.9	64.0
20-24	4.6	—	20.1	79.9

b. Regional aspect of carbonate content

The carbonate content of the East Antarctic bottom sediments is usually much less than 10 weight percent, as shown in Table 7 and Fig. 8 in which SUGIMURA and NOGUCHI's data (1961) are added. The content agrees well with LISITZIN's result (1958).

It will be seen on the diagram of Fig. 9 that the carbonate content does not have any direct relationship with the sand and gravel content of argillaceous sediments. It is also difficult to look for some significant connection between the carbonate content and the bottom configuration on the chart in Fig. 8. On the

Table 7. Carbonate and organic silica contents of the Antarctic bottom sediments.

Station	Depth	Total carbonate content	Carbonate content in mud fraction	Carbonate content in sand fraction	Organic silica in sand fraction
1	945m	2.48 wt. %	5.08 wt. %	1.42 wt. %	2.7 wt. %
5	330	4.11	3.89	4.57	3.5
6	980	1.83	2.06	1.29	2.5
8	275	6.37	10.02	1.05	1.2
2	385	3.56	3.35	4.06	3.3
3	280	3.53	4.75	3.88	3.5
4	560	1.29	1.26	2.16	5.4
10	380	2.13	4.40	1.50	1.7
11	190	7.39	15.96	4.82	0.6

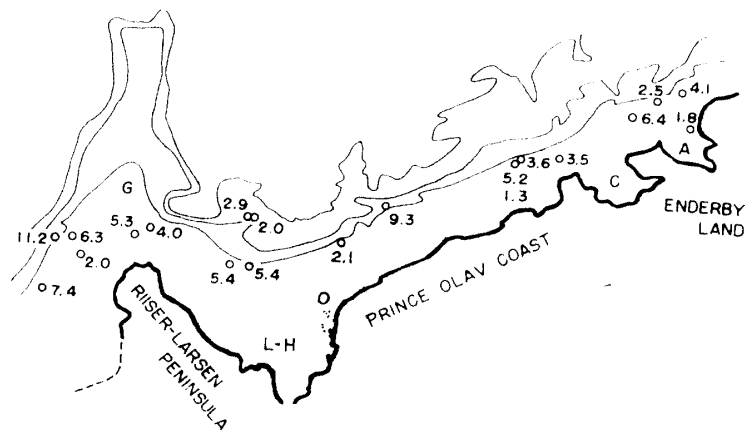


Fig. 8. Regional aspect of carbonate content of the East Antarctic bottom sediments. Interval of the isobaths is 1000 m. A: Amundsen Bay. C: Casey Bay. L-H: Lützow-Holm Bay. O: Ongul Islands. G: Gunnerus Bank.

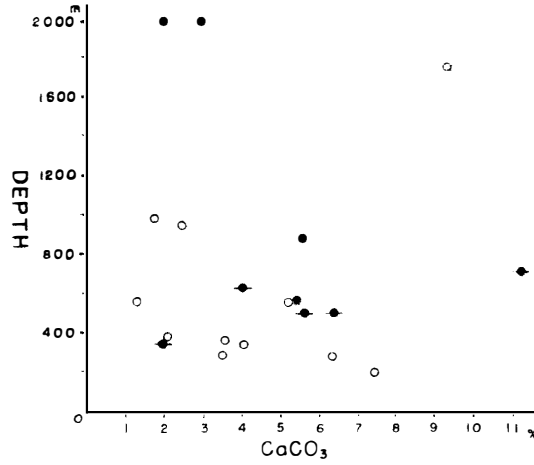


Fig. 9. Carbonate content - water depth diagram of the East Antarctic bottom sediments.

- : recently investigated.
- : SUGIMURA and NOGUCHI's.
- : on the Gunnerus Bank.

Gunnerus Bank the content is not exceedingly higher than the surrounding area. The regional aspect of the carbonate content is not related to the sedimentary petrographic sub-provinces which reflect the geology of the source area as will be stated in the next chapter.

IV. CLASTIC MATERIALS

The Antarctic iceberg sediments generally contain a large quantity of gravels and sands originating from adjacent land. One of the most characteristic features is that the coarse clastic grains are usually very angular and fresh.

1. Gravels of bottom sediments

Seventy-three gravels were separated from seven dredge samples—Sts. 1, 2, 3, 5, 8, 10 and 11. The dimensions and roundness of the gravels were measured, and the outline has been reported in the previous paper (SATO, 1964). The thin sections were petrographically observed under the polarized microscope.*

a. Modal analyses

The combined modal distribution of all gravels is given in Table 8 and Fig. 10. The largest diameter is used as a parameter. The diameter of the gravels ranges from 10 cm to 45 cm and the highest frequency is recorded in the range of 15-19 cm. It will be seen in Fig. 10 that any specific kind of gravels does not

Table 8. Relationship between the modal distribution and the rock type of gravels.

The largest diameter (in cm)	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49
Granitic gneiss & granite	5	6	4	1	1	—	2	1
Granodioritic gneiss & granodiorite	1	5	3	2	1	3	—	—
Dioritic gneiss & diorite	7	7	2	1	—	1	—	—
Basic metamorphic rock	—	2	1	—	1	—	—	—
Sillimanite-garnet gneiss	1	—	—	—	—	—	—	—
Hybrid gneiss	—	1	—	2	—	—	—	—
Hornfels	1	1	1	—	1	—	—	—
Marble	—	1	—	—	—	—	—	—
Dolerite	—	2	1	—	2	1	—	—
Total amount	15	25	12	6	6	5	2	1
Percentage	20.8	34.8	16.7	8.3	8.3	6.9	2.8	1.4

* Thanks are due to Prof. T. TATSUMI and Dr. S. BANNO of the Geological Institute, the University of Tokyo, for their help and advice in identification.

Fig. 10. Combined modal distribution of gravels of the East Antarctic bottom sediments. 1: dolerite. 2: marble. 3: hornfels. 4: sillimanite-garnet gneiss. 5: hybrid gneiss. 6: basic metamorphic rock. 7: dioritic gneiss and diorite. 8: granodioritic gneiss and granodiorite. 9: granitic gneiss and granite.

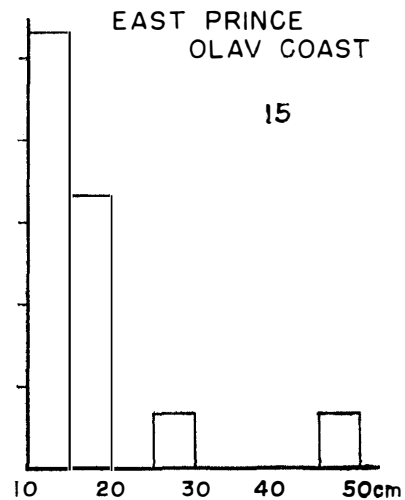
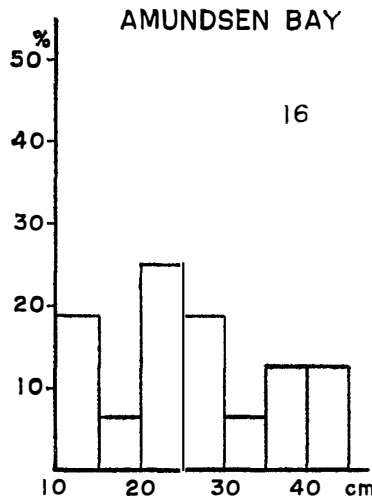
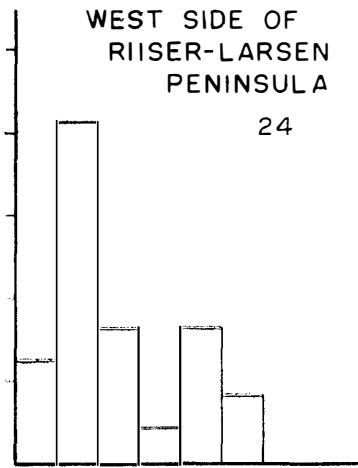
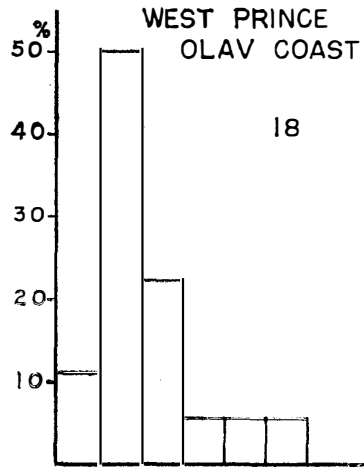
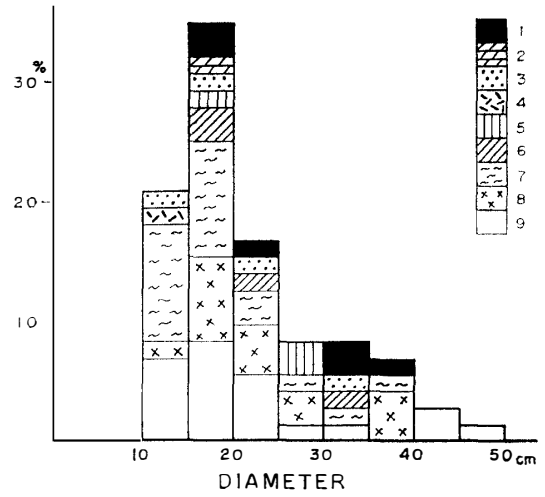


Fig. 11. Modal distribution of gravels in each sedimentary petrographic sub-province. The number indicates the total measured gravels.

appear at a specific range of the diameter. The investigated sea area is divided into four sedimentary petrographic sub-provinces as will be discussed later. Each sub-province has a slightly different modal distribution of gravels (Fig. 11). The Amundsen Bay sub-province shows a relatively flat modal distribution, while its western neighbor, the East Prince Olav Coast sub-province, is characterized by an asymmetrical one deviating to the finer fraction. In the West Prince Olav Coast and west side of Riiser-Larsen Peninsula sub-provinces, the modal distribution resembles each other; the highest frequency appears in the 15-20 cm range.

It will be recognized in Fig. 12 that there is no critical relationship between the roundness and the diameter of gravels.

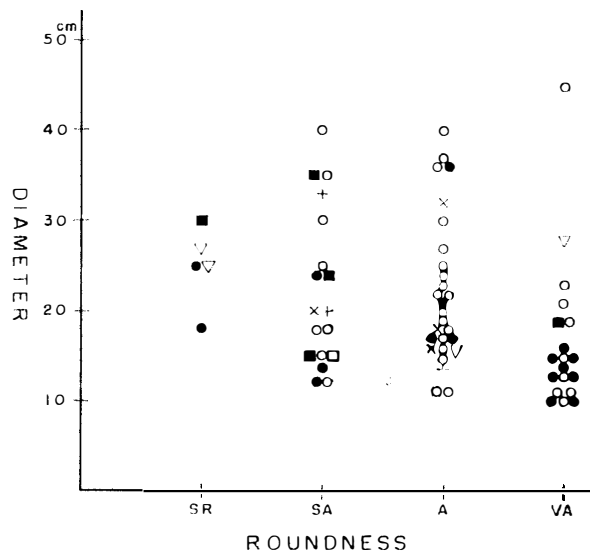


Fig. 12. Roundness-diameter diagram of the East Antarctic bottom sediments.

○: granitic and granodioritic gneiss, granite and granodiorite. ●: dioritic gneiss and diorite. ×: basic metamorphic rock. ▽: hybrid gneiss and sillimanite-garnet gneiss. □: marble. +: hornfels. ■: dolerite.

b. Petrography

The gravels are composed exclusively of igneous and metamorphic rocks. Soft sedimentary rocks, as reported by NIINO (1961) from the sea bottom in the offing of Cape Cook, were not found.

GRANITIC GNEISS and GRANITE are common, and are counted 20 of 73 total gravels. The dominant feldspar is kalifeldspar (orthoclase, microcline or perthite), which is occasionally porphyritic. Plagioclase and quartz are also the common constituent minerals. The common ferromagnesian minerals include biotite and/or green hornblende. Hypersthene is characteristic in a few granitic rocks which belong to the so-called acidic charnockite. Zircon, apatite and iron opaques usually occur as accessories. Sphene and epidote are sometimes found in the hornblende granitic gneiss and granite.

GRANODIORITIC GNEISS and GRANODIORITE are also common, being

15 of 73 total gravels. Plagioclase is the dominant constituent and often occurs in the form of porphyritic crystal. Quartz follows plagioclase. Kalifeldspar exists persistently but not abundant. Green hornblende and biotite, occasionally associated with white mica, are present as the common ferromagnesian minerals. Garnet is abundant in some granodioritic gneiss. Monoclinic pyroxene is also found. Zircon, apatite and iron opaques occur usually as accessories. Sphene and epidote are sometimes present.

DIORITIC GNEISS and **DIORITE** are the dominant rock types. They resemble the so-called intermediate charnockite in mineral composition and texture. Plagioclase is generally the most predominant mineral and is often porphyritic. Kalifeldspar is absent or rare. Quartz is rather common. Green hornblende, monoclinic and rhombic pyroxenes, biotite and sometimes white mica occur in variable amount as ferromagnesian minerals. Garnet is occasionally abundant, especially in the garnetiferous gneiss at St. 3. Apatite and iron opaques always appear as accessories. Zircon is often present. Sphene is sometimes found in the pyroxene-free diorite and dioritic gneiss at Sts. 1 and 11. Epidote rarely appears.

BASIC METAMORPHIC ROCKS are not common. Amphibolite, consisting of green hornblende, monoclinic pyroxene and plagioclase, was collected from St. 10. The other three gravels are made up of the so-called basic charnockite. The dominant ferromagnesian minerals are green hornblende, biotite, and monoclinic and rhombic pyroxenes. A small amount of mosaic quartz is often present. Plagioclase is the dominant feldspar, whereas kalifeldspar rarely occurs. As accessories, apatite and iron opaques are always found. Zircon and sphene are found in the green hornblende-biotite gneiss at St. 11.

HYBRID GNEISS is uncommon. Owing to the composite nature, it varies in mineral composition. Either orthoclase or plagioclase is the dominant feldspar, and the ferromagnesian minerals include biotite, garnet, green hornblende, and monoclinic pyroxene. Epidote is occasionally present.

HORNFELS is largely encountered at St. 10. Biotite, white mica, garnet and epidote are the dominant ferromagnesian minerals. Calc-silicate rock, consisting of green amphibole, diopside, scapolite, kalifeldspar and calcite, was collected at St. 2.

BASIC DYKE ROCKS are relatively common, and most of them appear at St. 11. Two types of dolerite are found; ilmenite-titanaugite and coarse-grained augite dolerites.

TATSUMI and **KIKUCHI** (1959, 1961) reported the geology of the region around Syowa Station, the Ongul Islands, Lützow-Holm Bay. They distinguished the following seven rock types, on the basis of petrology and field occurrence: (1) hornblende-pyroxene dioritic gneiss (the so-called intermediate charnockite), (2) marble and quartzite, (3) basic metamorphic rocks (the so-called basic charnockite), (4) pyralspite-biotite granodioritic gneiss, (5) biotite granitic gneiss and granite, (6) pegmatite, and (7) glacial morainic deposits and erratic boulders. About one half of the gravels have the same or very similar appearance to one of the above rock types. According to the recent report on the geology of the "Yamato Mountains" [Dronning Fabiolafjella] by **TATSUMI**, **KIKUCHI** and **KI-**

Table 9. Gravels of the East Antarctic bottom

Sedimentary petrographic sub-province	Amundsen Bay			East Prince Olav Coast		West Pr Olav C
	1	5	8	2	3	10
GRANITIC GNEISS and GRANITE	2	1	2	2	1	3
Biotite-(muscovite) granite						
Green hornblende granite		1				
Green hornblende-biotite granite						2
Altered hypersthene granite			1			
Biotite mylonitized granite						
Biotite granitic gneiss			1	2		
Green hornblende-(muscovite)-biotitegranitic gneiss					1	1
Hypersthene granitic gneiss	1					
Green hornblende-biotite porphyritic granitic gneiss	1					
GRANODIORITIC GNEISS and GRANODIORITE	1	0	0	0	1	6
Muscovite-biotite porphyritic granodiorite						2
Green hornblende-biotite porphyritic granodiorite						2
Muscovite-biotite porphyritic granodioritic gneiss						1
Green hornblende-(muscovite)-biotite porphyritic granodioritic gneiss						
Garnet-monoclinic pyroxene-green hornblende-biotite porphyritic granodioritic gneiss					1	
Garnet-muscovite-biotite granodioritic gneiss	1					
Garnet-biotite granodioritic gneiss						1
DIORITIC GNEISS and DIORITE	3	0	2	0	8	3
Biotite-green hornblende porphyritic quartz diorite	1					1
Green hornblende-(muscovite)-biotite porphyritic quartz diorite						
Biotite-green hornblende-monoclinic and rhombic pyroxenes porphyritic dioritic gneiss					1	
Monoclinic pyroxene-green hornblende porphyritic dioritic gneiss					1	
Garnet-stilpnomelane ?-green hornblende porphyritic quartz dioritic gneiss	1					
Garnet-(biotite)-monoclinic and rhombic pyroxenes-green hornblende porphyritic quartz dioritic gneiss					6	
Garnet-(muscovite)-biotite-green hornblende porphyritic quartz dioritic gneiss						1
Biotite-rhombic pyroxene quartz dioritic gneiss	1					
Biotite-monoclinic and rhombic pyroxenes quartz dioritic gneiss			1			
Monoclinic and rhombic pyroxenes quartz dioritic gneiss			1			
Green hornblende-biotite-monoclinic pyroxene quartz dioritic gneiss						1
BASIC METAMORPHIC ROCK	1	0	0	0	0	2
Green hornblende-biotite-monoclinic and rhombic pyroxene gneiss	1					1
Green hornblende-biotite gneiss						
Monoclinic pyroxene amphibolite						1
HYBRID GNEISS	1	0	0	0	2	0
Epidote-green hornblende-quartz plagioclase gneiss	1					
Epidote-green hornblende-perthite-quartz-plagioclase gneiss					1	
Garnet-monoclinic pyroxene-green hornblende-biotite-plagioclase-quartz gneiss					1	
SILLIMANITE-GARNET GNEISS	0	0	1	0	0	0
Garnet-sillimanite-plagioclase-quartz gneiss			1			
HORNFELS	0	1	0	0	0	3

s of the East Antarctic bottom sediments.

East Prince Olav Coast		West Prince Olav Coast	West side of Riiser-Larsen Peninsula	Known locality of the similar rock type.
2	3	10	11	
2	1	3	9	
			5	Around Syowa Station, Ongul Islands.
		2	2	Around Syowa Station.
			2	Around Syowa Station.
			1	
2			1	Around Syowa Station.
	1	1	1	Around Syowa Station.
				Around Syowa Station and Proclamation Island. Very widespread in the western part of Australian Antarctic Territory.
0	1	6	7	
		2		
		2		
		1		
	1		7	
				Around Syowa Station.
		1		Around Syowa Station.
0	8	3	2	
		1		
	1		1	
	1			
	6			
		1	1	
				Around Syowa Station.
				Around Syowa Station.
		1		Around Syowa Station.
				Around Syowa Station.
0	0	2	1	
		1		Around Syowa Station.
			1	Around Syowa Station.
		1		Erratic boulder around Syowa Station.
0	2	0	0	
	1			Very widespread throughout the western part of Australian Antarctic Territory.
	1			
0	0	0	0	
				Erratic boulder around Syowa Station and at Proclamation Island.
0	0	3	0	

Green hornblende (muscovite)-biotite-granitic gneiss	1					
Hypersthene granitic gneiss	1					
Green hornblende-biotite porphyritic granitic gneiss	1					
GRANODIORITIC GNEISS and GRANODIORITE	1	0	0	0	1	6
Muscovite-biotite porphyritic granodiorite						2
Green hornblende-biotite porphyritic granodiorite						2
Muscovite-biotite porphyritic granodioritic gneiss						1
Green hornblende-(muscovite)-biotite porphyritic granodioritic gneiss						
Garnet-monoclinic pyroxene-green hornblende-biotite porphyritic granodioritic gneiss					1	
Garnet-muscovite-biotite granodioritic gneiss	1					
Garnet-biotite granodioritic gneiss						1
DIORITIC GNEISS and DIORITE	3	0	2	0	8	3
Biotite-green hornblende porphyritic quartz diorite	1					1
Green hornblende-(muscovite)-biotite porphyritic quartz diorite						
Biotite-green hornblende-monoclinic and rhombic pyroxenes porphyritic dioritic gneiss					1	
Monoclinic pyroxene-green hornblende porphyritic dioritic gneiss					1	
Garnet-stilpnomelane?-green hornblende porphyritic quartz dioritic gneiss	1					
Garnet-(biotite)-monoclinic and rhombic pyroxenes-green hornblende porphyritic quartz dioritic gneiss					6	
Garnet-(muscovite)-biotite-green hornblende porphyritic quartz dioritic gneiss						1
Biotite-rhombic pyroxene quartz dioritic gneiss	1					
Biotite-monoclinic and rhombic pyroxenes quartz dioritic gneiss			1			
Monoclinic and rhombic pyroxenes quartz dioritic gneiss			1			
Green hornblende-biotite-monoclinic pyroxene quartz dioritic gneiss						1
BASIC METAMORPHIC ROCK	1	0	0	0	0	2
Green hornblende-biotite-monoclinic and rhombic pyroxene gneiss	1					1
Green hornblende-biotite gneiss						
Monoclinic pyroxene amphibolite						1
HYBRID GNEISS	1	0	0	0	2	0
Epidote-green hornblende-quartz plagioclase gneiss	1					
Epidote-green hornblende-perthite-quartz-plagioclase gneiss					1	
Garnet-monoclinic pyroxene-green hornblende-biotite-plagioclase-quartz gneiss					1	
SILLIMANITE-GARNET GNEISS	0	0	1	0	0	0
Garnet-sillimanite-plagioclase-quartz gneiss			1			
HORNFELS	0	1	0	0	0	3
Garnet-biotite-plagioclase-quartz hornfels		1				
Biotite-plagioclase-quartz hornfels						1
Muscovite-biotite-plagioclase-quartz hornfels						1
Epidote-biotite-plagioclase-quartz hornfels						1
MARBLE	0	0	0	1	0	0
Green hornblende-diopside-scapolite-kalifeldspr marble				1		
BASIC DYKE ROCK	1	0	0	0	0	0
Ilmenite-titanaugite dolerite	1					
Augite coarse-grained dolerite						
Total Amount (72)	9	2	5	3	12	17

Around Syowa Station and Proclamation Island. Very widespread in the western part of Australian Antarctic Territory.

0	1	6 2 2 1	7 7	Around Syowa Station. Around Syowa Station.
0	8	3 1	2 1	
	1			
	1			
	6			
		1	1	Around Syowa Station. Around Syowa Station. Around Syowa Station. Around Syowa Station.
0	0	2 1	1 1	Around Syowa Station. Around Syowa Station. Erratic boulder around Syowa Station.
0	2	0	0	Very widespread throughout the western part of Australian Antarctic Territory.
	1			
	1			
0	0	0	0	Erratic boulder around Syowa Station and at Proclamation Island.
0	0	3 1 1 1	0	Erratic boulder around Syowa Station.
1	0	0	0	Around Syowa Station, and in the Prince Charles Mountains. Erratic boulder in the Masson Range and at Cape Bruce.
	1			
0	0	0	5 3 2	Erratic boulder around Syowa Station, in the Amundsen Bay Area, and at Proclamation Island, Dronning Maud Land.
3	12	17	24	

Table II. Heavy-mineral association of the core samples of the Antarctic bottom sediments.

Station	Station 4					Station 9		
	0-1	1-6	11-16	21-26	31-36	0-5	10-15	20-24
Depth below the bottom floor (cm)								
Heavy residue content (in wt. %)	7.1	12.0	8.6	11.0	10.3	8.4	9.0	8.1
Biotite	9.0%	4.0%	4.0%	3.5%	3.5%	8.5%	2.0%	9.0%
Chlorite	—	—	—	—	—	1.5	0.5	0.5
Green hornblende	27.0	33.5	33.5	45.5	51.5	67.5	75.5	71.5
Brown hornblende	1.0	—	1.0	1.0	2.5	2.0	2.5	1.5
Rhombic pyroxene	19.5	18.0	17.0	17.0	12.5	1.5	0.5	1.0
Monoclinic pyroxene	20.0	18.0	20.0	15.0	13.5	6.5	4.5	3.5
Garnet	12.5	17.5	16.0	9.5	7.5	3.5	2.0	2.5
Epidote	3.0	1.5	2.5	1.0	1.0	1.5	2.0	3.0
Zircon	—	0.5	—	—	0.5	2.0	4.5	1.5
Sphene	0.5	0.5	—	1.0	1.0	1.0	3.5	3.0
Magnetite and ilmenite	6.5	6.0	5.0	5.5	5.5	4.5	2.5	3.0
Indetermined grains	1.0	0.5	1.0	1.0	1.0	—	—	—
Total amount	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

a. Content of heavy residue

The content of heavy residue in the Antarctic bottom sediments ranges from 8.5 to 20.6 weight percent, except for 5.6 percent at St. 11, to the west of the Riiser-Larsen Peninsula. In the raised beach sand of East Ongul Island, Lützow-Holm Bay, the content is 15.1-22.3 weight percent. These values are considerably higher than in the ordinary sedimentary rocks which usually contain much less than 5 weight percent of heavy residue.

There is an interesting fact that the core samples include less heavy minerals than the adjacent dredge samples. At St. 4, the gravity core samples contain 7.1-12.0 (mean 9.8) weight percent of heavy minerals, which is lower than 13.3 percent in the sample dredged at the same station. The content of heavy residue is 8.1-9.0 (mean 8.5) weight percent in the core samples at St. 9, while it is 15.2 percent in the dredge sample at St. 10. The above fact is possibly explained by considering that slight concentration of heavy minerals might have occurred during dredging of the bottom sediments, on account of wash-out of some lighter grains. In fact, the average content of micas is considerably higher in the core samples, 5 and 9 percent of the total counted grains at Sts. 4 and 9, respectively, than in the adjacent dredged samples, 1 and 2 percent at Sts. 4 and 10, respectively.

It is impossible to introduce any direct relationship between the content of heavy minerals and the water depth or the distance from shoreline.

b. Heavy-mineral Association

The main constituents of the heavy-mineral association of the Antarctic

bottom sediments are amphiboles, monoclinic and rhombic pyroxenes, garnet, biotite and iron opaques. The adjacent land, including Enderby Land, Prince Olav Coast, Prince Harald Coast, and the Riiser-Larsen Peninsula, is composed of Older Paleozoic and Precambrian metamorphic and plutonic rocks—500 and 900 million years, respectively (SAITO et al, 1961). Most of heavy minerals of the bottom sediments are undoubtedly derived from bedrocks of the adjacent land, for they can be referred to the rock-forming minerals of the gravels which are mostly identical with the bedrocks (Table 9).

Almost all garnet grains are isotropic. They are pink or red to the naked eye, and are colorless, pale pink or brownish red under the microscope. Some garnet grains were separated by hand-picking from the heavy residue of Sts. 2, 8, 10 and 11, and were X-rayed. The result is shown in Table 12, with the data of pyralspite garnet from East Ongul Island (MINAMI et al, 1961). The diffraction lines of four garnet samples of the bottom samples agree well with those of pyralspite from East Ongul Island. Most of garnet grains in the bottom sediments are probably derived from granodioritic gneiss and basic charnockite.

Table 12. X-ray diffraction data of the garnet of the Antarctic bottom sediments.

Station 8		Station 2		Station 10		Station 11		East Ongul Island (MINAMI et al, 1961)		
d _{obs}	I	d _{obs}	I	d _{obs}	I	d _{obs}	I	dÅ	I	hkl
2.885	9	2.889	14	2.885	12	2.889	14	2.89	19	400
2.578	24	2.581	36	2.580	28	2.578	34	2.58	44	420
2.461	2	2.462	5	2.462	3	2.462	4	2.46	5	
2.356	4	2.356	7	2.359	6	2.356	7	2.36	7	422
2.259	3	2.270	4	2.265	4	2.262	8	2.26	8	431
2.106	3	2.108	5	2.108	5	2.107	6	2.11	8	215
								2.04	3	
1.871	4	1.873	6	1.872	7	1.871	10	1.88	9	253
1.664	2	1.664	4	1.664	5	1.667	5	1.67	5	444
1.599	3	1.601	6	1.600	6	1.601	9	1.60	13	640
1.542	5	1.543	9	1.542	7	1.542	13	1.54	18	642
1.442	1	1.443	4	1.443	3	1.443	3	1.44	3	800
1.290	2	1.290	3	1.290	1	1.290	2	1.29	4	840
1.259	5	1.258	2	1.259	3	1.260	3	1.26	8	842
a ₀ =11.54 Å		a ₀ =11.55 Å		a ₀ =11.54 Å		a ₀ =11.54 Å		a ₀ =11.530 Å		
								Al _{47.64} Py _{35.49} Sp _{2.18}		
								An _{4.59} Gr _{10.10}		

Norelco, CuK α , Proportional counter, 8-1-4, 1°/min. Used silicon as internal standard.

3. Sedimentary petrographic province

The sedimentary petrographic province is defined as a sedimentary area in which clastic materials originate in the same geologic unit, that is to say, a depositional area with the same provenance. The area investigated is a part of the East Antarctic sedimentary petrographic province which has the provenance of

the East Antarctic Older Paleozoic and Precambrian crystalline basement rocks. Most gravels and heavy minerals in the bottom sediments are derived from the neighboring land consisting of crystalline rocks, as stated in the foregoing paragraphs.

The investigated area is, furthermore, subdivided into four sub-provinces, on the basis of heavy-mineral association and gravel composition analyses:

- a. Amundsen Bay sub-province,
- b. East Prince Olav Coast sub-province,
- c. West Prince Olav Coast sub-province, and
- d. West Side of Riiser-Larsen Peninsula sub-province.

The Lützow-Holm Bay area cannot be subdivided, because of lack of data.

- a. Amundsen Bay sub-province

The Amundsen Bay sub-province includes Sts. 1, 5, 6 and 8, and occupies Amundsen Bay and its near open sea. As to heavy-mineral association, the sub-province is characterized by the small ratios of both amphiboles to pyroxenes (0.1-0.8) and monoclinic pyroxene to rhombic one (0.7-1.0). Garnet is abundant, being 22-33 percent of the total counted grains, so that the garnet/iron opaques ratio is considerably high (4.0-8.3). Epidote usually occurs in a relatively large amount, whereas sphene is seldom found.

Acidic to intermediate charnockite and granite are the dominant rock types of gravels, being about 60 percent of 16 gravels. 11 of the 16 gravels resemble the rock types which are found around Syowa Station, Ongul Islands.

- b. East Prince Olav Coast sub-province

The East Prince Olav Coast sub-province includes Sts. 2, 3 and 4. It is characteristic in the relatively small ratios of both amphiboles to pyroxenes (0.6-1.1) and monoclinic pyroxene to rhombic one (0.9-1.4), as in the Amundsen Bay sub-province. However, the garnet/iron opaques ratio decreases to 2.2-4.0. Epidote and sphene are rarely present; zircon occurs in a small amount.

Porphyritic dioritic gneiss, especially garnet-bearing gneiss, is dominant in the gravels at St. 3. Hybrid gneiss and granitic gneiss are also relatively common. Only 3 of 15 gravels are identical with the rock types around the Ongul Islands.

The East Prince Olav Coast and Amundsen Bay sub-provinces bear a resemblance to each other in heavy-mineral association and gravel composition. The peninsula which separates Amundsen Bay from Casey Bay is composed only of low ice plateau (CROHN, 1959).

- c. West Prince Olav Coast sub-province

Sts. 9 and 10 belong to the West Prince Olav Coast sub-province. On account of insufficiency of data, the accurate boundary of the East Prince Olav Coast sub-province cannot be drawn.

Amphiboles are the dominant heavy minerals, so that the amphiboles/pyroxenes ratio is very large, being 5.3-12.3. Monoclinic pyroxene surpasses rhombic one, and their ratio becomes 5.0 which is about five times of that of the above two sub-provinces. On the contrary, garnet is not much, and the garnet/iron opaques ratio falls to 0.8-1.0. Epidote, zircon and especially sphene appear persistently, though not common.

The gravel composition of St. 10 is characterized by large contents of granodiorite and granodioritic gneiss of mostly porphyritic texture which is never seen around the Ongul Islands, eastern Lützow-Holm Bay. Hornfels, biotite-granite and granitic gneiss, dioritic gneiss and basic metamorphic rocks are not uncommon.

To be compared with the West Prince Olav Coast sub-province, the heavy-mineral assemblage of the raised beach sand of East Ongul Island* was analyzed (Table 13). It is somewhat similar to that of the sub-province in the small ratio of garnet to iron opaques.

Table 13. Heavy-mineral association of the raised beach sand at East Ongul Island, Lützow-Holm Bay, Antarctica.

	Kitamihama		Kainohama	
	Upper	Lower	Upper	Lower
Heavy residue content (in wt. %)	15.9	15.1	22.3	18.8
Biotite	5.0%	15.0%	8.0%	9.0%
Green hornblende	36.5	30.5	22.0	33.0
Brown hornblende	3.5	5.5	12.5	5.0
Rhombic pyroxene	9.5	16.0	2.0	10.5
Monoclinic pyroxene	20.5	16.0	43.0	27.0
Garnet	8.5	5.0	1.0	4.0
Epidote	1.0	—	0.5	1.0
Zircon	1.5	2.0	—	0.5
Sphene	1.0	0.5	2.0	0.5
Anatase	—	0.5	—	—
Apatite	4.0	2.0	3.0	2.0
Magnetite and ilmenite	9.0	7.0	6.0	7.5
Total amount	100.0	100.0	100.0	100.0
Upper terrace at Kitamihama Beach (12 m A.S.L.) grey silt to fine sand with shell fragments				
Lower terrace at Kitamihama Beach (7-8 m A.S.L.) grey silt to fine sand with shell fragments				
Upper terrace at Kainohama (9-10 m A.S.L.) brown coarse sand with shell fragments				
Lower terrace at Kainohama (3-4 m A.S.L.) grey fine sand with pebbles and shell fragments				

However, the both ratios of amphiboles to pyroxenes and monoclinic pyroxene to rhombic one are considerably small at East Ongul Island. Only 7 of 18 gravels were, moreover, correlated to the rock types around the island.

d. West side of Riiser-Larsen Peninsula sub-province

The west side of Riiser-Larsen Peninsula sub-province includes St. 11 only. The dominant heavy mineral is amphiboles, so that the amphiboles/pyroxenes

* The sample were organized by Dr. T. УснЮ at the Oil Mining Institute, University of Tokyo. Thanks are due to Dr. УснЮ.

ratio is 2.2. Monoclinic pyroxene surpasses rhombic one and their ratio is 5.0. Garnet is common. The garnet/iron opaques ratio is 2.2. Epidote, sphene and zircon show relatively high frequency.

Biotite granite that is very similar to that near the Ongul Islands is one of the dominant rock types of gravels. Porphyritic granodioritic gneiss is another dominant rock type, which has not been found around Syowa Station. Dolerite is also common. One half of the 24 gravels resemble the rock types found around the Ongul Islands.

The characteristic features of the foregoing four sub-provinces are summarized in Table 14 and Fig. 13.

The amphiboles/pyroxenes ratio is sometimes affected by sorting during the transportation of sediments, because of the difference in specific gravity and crystallography of both minerals. The ratio of monoclinic pyroxene to rhombic ratio, on the other hand, is not significantly influenced by sorting. The garnet/iron opaques ratio should increase with the increase of the amphiboles/pyroxenes ratio, since both garnet and amphiboles are more easily transported by water currents than iron opaques and pyroxenes. It is, therefore, impossible to interpret that the high ratio of amphiboles to pyroxenes and monoclinic pyroxene to rhombic one and the small ratio of garnet to iron opaques in the West Prince Olav Coast sub-province may have resulted from sorting during the transportation of the sediments of the East Prince Olav Coast sub-province which have the small ratio of amphiboles to pyroxenes and monoclinic pyroxene to rhombic one and the high garnet/iron opaques ratio, due to east wind drift current along the Prince Olav Coast (ONO, 1960; KUMAGORI, 1963). Furthermore, the difference of the gravel composition of each sub-province is not explained by sorting. The distribution pattern of heavy-mineral association and gravel composition is easily interpreted by assuming that each of the sub-provinces had its own provenance.

Table 14. Characteristic features of each sedimentary petrographic sub-province.

Sedimentary petrographic sub-province	West side of Riiser-Larsen Peninsula	West Prince Olav Coast	East Prince Olav Coast	Amundsen Bay
Amphiboles/pyroxenes	2.2	5.3—12.3	0.6—1.1	0.1—0.8
Monoclinic / rhombic pyroxene / pyroxene	5.0	5.0	0.9—1.4	0.7—1.0
Garnet/iron opaques	2.2	0.8—1.0	2.2—4.0	4.0—8.3
Epidote	3%	1—2%	tr—1%	1—13%
Sphene	2%	3%	0—tr%	0—tr%
Zircon	2%	1—3%	tr—2%	tr%
Characteristic rock type of gravels	Biotite granite, porphyritic dioritic gneiss, and dolerite	Porphyritic granodiorite and gneiss, hornfels, and basic metamorphic rock	Garnet-bearing porphyritic dioritic gneiss, and hybrid gneiss	Granite, granitic gneiss, and granodioritic gneiss

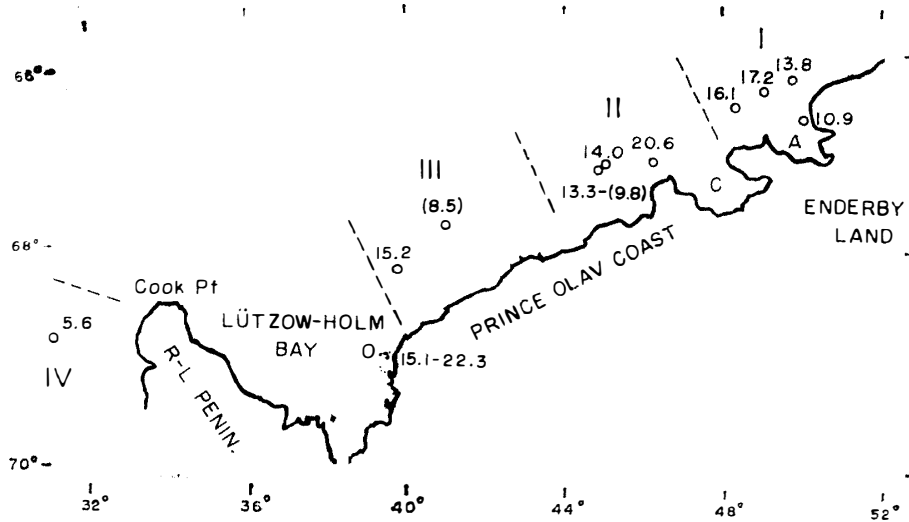


Fig. 13. Heavy residue content and the sedimentary petrographic sub-provinces of the East Antarctic bottom sediments.

I: Amundsen Bay sub-province. II: East Prince Olav Coast sub-province. III: West Prince Olav Coast sub-province. IV: West side of Riiser Larsen Peninsula sub-province. A: Amundsen Bay. C: Casey Bay. O: Ongul Islands. R-L: Riiser-Larsen Peninsula.

The investigated bottom sediments of the Antarctic sea were transported undoubtedly by sea currents along with icebergs from the adjacent land. Most of coarse clastic materials which were captured by ice may have dropped rapidly onto the sea floor shortly after they were released from ice. Along the Prince Olav Coast flows the east wind drift current from ENE to WSW with a velocity of 0.2 to 0.3 knot (KUMAGORI, 1963). Therefore, the heavy-mineral assemblage and the gravel composition, as a rule, reflect the geology of the source area which is located not far in the east.

V. MINERALOGICAL STUDY OF CLAY FRACTIONS

1. Sample preparation

About 10 g of the raw sample was placed in a 1000 ml graduated cylinder and was added with distilled water so to make the volume 1000 ml. The sample was well dispersed. The suspension containing $<2\mu$ fraction was siphoned off after a predetermined settling time. The suspending particles were collected by centrifugal sedimentation. The cylinder was refilled with distilled water. This procedure was repeated until a clear supernatant liquid was obtained. This fraction was used in the following experiments.

2. Experimental methods

X-ray diffraction analysis was the principal technique of investigation for this study. Clay mineral species were identified on the basis of differences in X-ray diffraction effects after various treatments.

The procedure for identification of clay minerals is as follows.

a. X-ray analysis

i) Well-oriented aggregates

Well-oriented aggregates were made by gently pouring a suspension of the specimen over a glass slide, and settling it and drying it up at room temperature.

Heat treatment: A silica glass slide was used in heat treatment. As the first step, X-ray powder diffraction effects were recorded at room temperature. Next, oriented aggregates on this silica glass slide were heated stepwise at the temperatures of 300°C, 450°C, 600°C and 750°C for 45 minutes, air quenched, and X-ray diffraction effects were examined immediately after each step of heating.

Treatment with ethylene glycol: The specimen was saturated with drops of ethylene glycol on a glass slide, and the resultant wet film was radiated by X-ray. This treatment was used for detection of expanding lattice.

Treatment with ammonium nitrate solution: Oriented aggregates were made with the specimen boiled for 10 minutes in 1 N solution and washed with distilled water. This treatment was used for detection of Mg-vermiculite (WALKER, 1949).

Treatment with hydrochloric acid: The specimen was heated at 95°C in 6 N hydrochloric acid for 30 minutes and washed with distilled water (KOBAYASHI and OINUMA, 1961). In this treatment Mg-Fe chlorite, vermiculite and biotite

Table 15. X-ray diffraction data of well-oriented aggregates of clay fractions.

No. 1		No. 2		No. 3		No. 4		No. 5		No. 6		No. 7		No. 8		No. 9		No.
d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)
15.2	12	15.2	25	15.2	17	15.2	15	15.8	27	15.8	10	15.2	15	15.0	13	15.0	8	14.7
10.3	12	10.3	61	10.0	44	10.2	33	10.4	14	10.3	8	10.3	12	10.3	12	10.3	102	10.1
8.6	3	8.5	13	8.5	10	8.5	9	8.5	8	8.6	5	8.6	7	8.5	6	8.6	18	8.5
7.2	10	7.3	22	7.2	15	7.1	10	7.2	22	7.3	8	7.3	14	7.1	15	7.3	15	7.3
		5.7	3							5.9	3			6.5	4	6.5	4	
5.3	3	5.3	3											5.6	4	5.8	4	
4.9	2					5.0	2							5.0	3			
		4.8	4	4.7	4			4.7	5					4.7	5	4.7	5	
4.53	4					4.53	4							4.52	4			
4.29	4	4.27	8	4.23	10	4.25	6	4.27	10	4.27	4	4.27	6	4.27	9	4.27	5	4.27
4.08	3	4.08	8	4.04	8	4.04	6	4.07	7	4.05	5	4.07	5	4.05	5	4.07	7	4.07
		3.99	3	3.93	3					3.90	3							
				3.87	4			3.88	3									
3.79	3	3.79	10	3.77	7	3.77	5	3.80	7	3.78	4	3.80	5	3.76	6	3.80	8	3.76
		3.68	8	3.65	6											3.67	5	3.67
3.58	5	3.59	12	3.56	7	3.56	6	3.59	10			3.56	6	3.56	7	3.57	7	3.56
3.48	4	3.48	4	3.48	3	3.48	3					3.49	4	3.47	4	3.50	4	3.47
3.37	13	3.36	60	3.35	50	3.35	40	3.37	38	3.37	9	3.36	27	3.35	32	3.37	20	3.36
		3.26	5	3.23	5					3.25	6							3.25
3.20	7	3.21	30	3.20	25	3.20	20	3.20	20	3.20	9	3.20	14	3.20	19	3.20	30	3.20
		3.14	12	3.14	13	3.14	12	3.15	9			3.14	6	3.14	6	3.15	18	3.14
								3.05	5									
		3.01	4	3.00	5	3.00	3	3.01	6	3.01	3							
		2.95	5	2.94	4	2.94	6	2.95	5	2.95	3	2.95	3			2.95	6	2.95
				2.84	3			2.86	5			2.85	3	2.84	4	2.84	5	
				2.71	4	2.73	4											
		2.63	3	2.64	2	2.62	2			2.63	3					2.63	3	
		2.61	7															
				2.52	6	2.52	4	2.54	5	2.86	4			2.53	3	2.53	13	2.53
				2.46	3	2.44	3							2.45	3			
		2.39	4	2.39	3	2.39	3	2.40	4					2.40	3	2.40	3	
														2.34	3	2.34	3	2.34
						2.30	2	2.29	4					2.29	3	2.28	2	2.28

M: montmorillonite. C: chlorite. I: trioctahedral illite. K: kaolinite. X: clay minerals. Q: quartz. F: feldspar. Ca

Table 15. X-ray diffraction data of well-oriented aggregates of clay fractions.

3	No. 4		No. 5		No. 6		No. 7		No. 8		No. 9		No. 10		No. 11		
	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	
17	15.2	15	15.8	27	15.8	10	15.2	15	15.0	13	15.0	8	14.7	10	14.7	10	M, C
44	10.2	33	10.4	14	10.3	8	10.3	12	10.3	12	10.3	102	10.1	66	10.1	84	I
10	8.5	9	8.5	8	8.6	5	8.6	7	8.5	6	8.6	18	8.5	12	8.5	7	A
15	7.1	10	7.2	22	7.3	8	7.3	14	7.1	15	7.3	15	7.3	11	7.1	13	C, K
									6.5	4	6.5	4					F
					5.9	3			5.6	4	5.8	4					F
	5.0	2							5.0	3							I
4			4.7	5					4.7	5	4.7	5					C
	4.53	4							4.52	4					4.55	5	X
10	4.25	6	4.27	10	4.27	4	4.27	6	4.27	9	4.27	5	4.27	8	4.27	7	Q
8	4.04	6	4.07	7	4.05	5	4.07	5	4.05	5	4.07	7	4.04	6	4.05	7	F
3					3.90	3											F
4			3.88	3													F
7	3.77	5	3.80	7	3.78	4	3.80	5	3.76	6	3.80	8	3.76	7	3.76	8	F
6											3.67	5	3.67	6	3.66	6	F
7	3.56	6	3.59	10			3.56	6	3.56	7	3.57	7	3.56	4	3.56	7	C, K
3	3.48	3					3.49	4	3.47	4	3.50	4	3.47	5	3.49	5	F
50	3.35	40	3.37	38	3.37	9	3.36	27	3.35	32	3.37	20	3.36	56	3.36	68	Q, I
5					3.25	6							3.23	10			F
25	3.20	20	3.20	20	3.20	9	3.20	14	3.20	19	3.20	30	3.20	19	3.20	23	F
13	3.14	12	3.15	9			3.14	6	3.14	6	3.15	18	3.14	10	3.14	10	F
			3.05	5											3.03	19	Ca
5	3.00	3	3.01	6	3.01	3											F
4	2.94	6	2.95	5	2.95	3	2.95	3			2.95	6	2.94	6	2.94	4	F
3			2.86	5			2.85	3	2.84	4	2.84	5			2.84	4	F
4	2.73	4															
2	2.62	2			2.63	3					2.63	3			2.62	4	F
6	2.52	4	2.54	5	2.86	4			2.53	3	2.53	13	2.52	7	2.52	9	F
3	2.44	3							2.45	3					2.49	8	Q
3	2.39	3	2.40	4					2.40	3	2.40	3					
									2.34	3	2.34	3	2.34	4			
	2.30	2	2.29	4					2.29	3	2.28	2	2.28	4	2.28	5	Q

te. I: trioctahedral illite. K: kaolinite. X: clay minerals. Q: quartz. F: feldspar. Ca: calcite. A: amphibole.

are easily decomposed, whereas kaolinite and illite remain behind.

ii) Randomly oriented powder

The sample powder was packed in an aluminium holder, to observe the (060) reflections of clay minerals. For mica groups the spacing of this reflection is used to differentiate dioctahedral and trioctahedral forms; minerals having (060) reflection in the region of 1.49-1.52 Å are usually dioctahedral and those with (060) reflection in the range 1.525-1.535 Å are usually trioctahedral.

b. Infrared spectra analysis

The infrared spectrophotometer used in this study was Japan Spectroscopic DS 401G Grating Spectrometer. The spectra of OH region were obtained by the paste method using Nujol as the base.

3. Mineral identification

a. Non-clay minerals

X-ray diffraction patterns and data of the clay fractions less than $2\ \mu$ are shown in Figs. 14 and 15 and Table 15. Non-clay minerals were identified on the basis of their X-ray reflections. Reflections at 4.27 and 3.35 Å correspond respectively to the (100) and (101) peaks of quartz. Feldspar was identified by

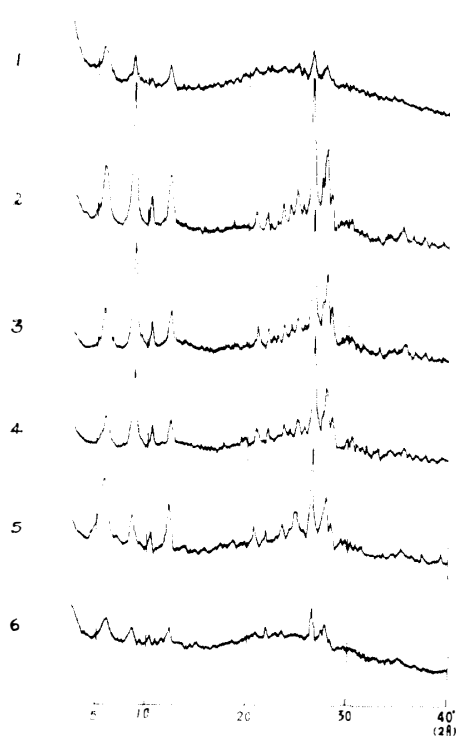


Fig. 14. X-ray diffraction patterns of well-oriented powders of clay fractions (1). Numbers refer to sample No.

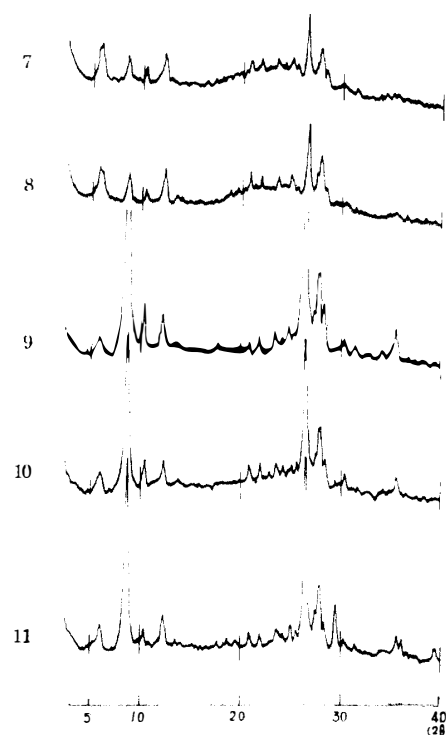


Fig. 15. X-ray diffraction patterns of well-oriented powders of clay fractions (2). Numbers refer to sample No.

strong reflections at 3.20 and 3.14 Å and weak ones at 4.0, 3.7-3.9, 3.65, 2.94, 2.63 and 2.52 Å. Reflection at 8.5 Å shows the presence of amphibole. Thus, it is clear that all specimens contain quartz, feldspar and amphibole. In the case of sample No. 11, the peak at 3.03 Å due to calcite is confirmed.

b. Clay minerals

Reflections at 15-14, 10, 7, 5-4.7, 4.5, 3.5-3.3 Å are due to clay minerals, but identification of each mineral component from the above data is difficult. For the purpose of identification of clay minerals, the writers investigated the effects of the above-mentioned treatments upon X-ray diffraction data.

Three examples of identification are given below.

Sample No. 3: X-ray diffraction data are shown in Fig. 16 and Table 16. The X-ray diffraction pattern of untreated sample shows reflections at 15.8, 10.3, 7.3, 3.58 and 3.36 Å due to clay minerals. The treatment with ethylene glycol causes the 15.8 Å reflection to be replaced by the 16.9 Å reflection. From this the presence of montmorillonite can be suggested. After heating at 300°C, the 15.8 Å reflection disappears and the weak reflection at 14.0 Å remains, whereas the 10 Å reflection becomes slightly stronger. This fact suggests the presence of

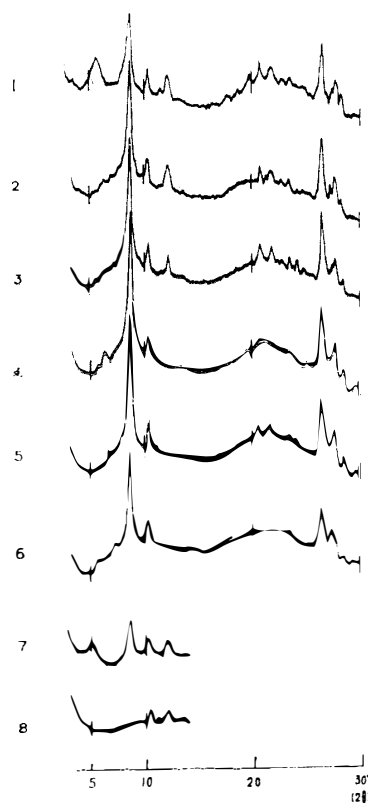


Fig. 16. X-ray diffraction patterns of sample No. 3 after various treatments.

1: untreated. 2: heated at 300°C. 3: heated at 450°C. 4: heated at 600°C. 5: heated at 750°C. 6: heated at 900°C. 7: treated with ethylene glycol. 8: treated with hydrochloric acid.

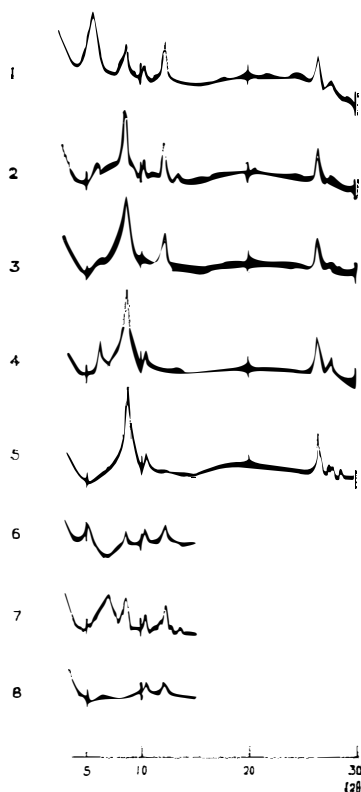


Fig. 17. X-ray diffraction patterns of sample No. 5 after various treatments.

1: untreated. 2: heated at 300°C. 3: heated at 450°C.
 4: heated at 600°C. 5: heated at 750°C. 6: treated with ethylene glycol. 7: treated with ammonium nitrate.
 8: treated with hydrochloric acid.

montmorillonite, which dehydrates to the 9-10 Å lattice. After heating at 600°C, the 14.0 Å reflection decreases to 13.8 Å, and the 7.3 Å reflection becomes barely visible. These facts clearly show the presence of chlorite. The weak reflection at 7.3 Å remains after treatment with hydrochloric acid. From this the presence of kaolinite can be suggested. The presence of a small amount of kaolinite can be confirmed also by infrared spectra analysis. The 10 Å reflection is unchanged in its spacing after heating and treatment with ethylene glycol. This indicates that the 10 Å reflection is due to mica clay mineral. Mica clay mineral in this sample may be trioctahedral illite, because this mineral is easily decomposed by acid treatment, has no diffraction line at 5.0 Å which usually appears in diffraction pattern of dioctahedral illite, and is the same as mica mineral in sample No. 11.

Conclusively, the clay mineral compositions of this specimen can be represented by montmorillonite, chlorite, trioctahedral illite and kaolinite.

Sample No. 5: X-ray diffraction data are shown in Fig. 17 and Table 17.

Treatment with ethylene glycol: The 15.5 Å reflection is replaced by the 17.3 Å reflection. From this the presence of montmorillonite is suggested.

Treatment with ammonium nitrate solution: The 15.5 Å reflection shifts to 12.8 Å. Usually it has been reported that, by this treatment, vermiculite contracts

to the 10 Å-lattice, whereas montmorillonite shows a partial contraction to about 12 Å-lattice. Hence, the result obtained suggests that the presence of Mg-vermiculite is not expected. Thus, the expanding lattice and the contractable lattice noticed above can be considered as attributable to montmorillonite.

Hydrochloric acid treatment: The weak 7.2 Å reflection remains after this treatment. This fact suggests the presence of kaolinite.

Heat treatment: The 10.3 Å reflection is unchanged after heat treatment. This indicates the presence of a mica clay mineral. In view of the facts that this mineral has no diffraction line at 5.0 Å and is easily decomposed by acid, it can be suggested that this mineral is trioctahedral illite.

Infrared absorption spectra in the OH region (Fig. 18): A band at 3700 cm^{-1} is characteristic to kaolin minerals and is useful in distinguishing them from other clay minerals (KODAMA and OINUMA, 1963). As will be seen in Fig. 18, this specimen shows clearly a band at 3700 cm^{-1} . This fact supports the presence of kaolinite.

The results are the same as those of sample No. 3, and show that the clay minerals in the specimen are defined as montmorillonite, chlorite, trioctahedral

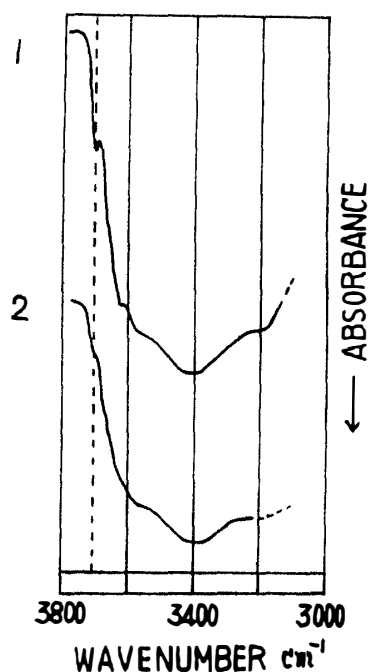


Fig. 18. Infrared absorption spectra in the OH region of sample No. 5 and sample No. 10.

1: sample No. 5. 2: sample No. 10.

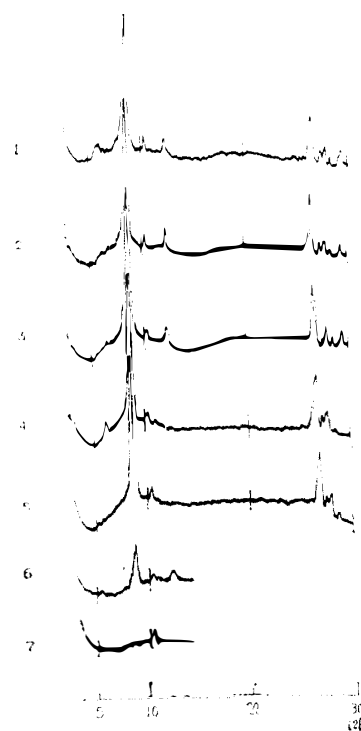


Fig. 19. X-ray diffraction patterns of sample No. 11 after various treatments.

1: untreated. 2: heated at 300°C. 3: heated at 450°C. 4: heated at 600°C. 5: heated at 750°C. 6: treated with ethylene glycol. 7: treated with hydrochloric acid.

illite and kaolinite.

Sample No. 11 (Fig. 19 and Table 18): The reflections at 14.7 Å and 7.1 Å are very weak and the 10.3 Å reflection is strong. The 14.7 Å and 7.1 Å reflections suggest the presence of montmorillonite and chlorite. Infrared analysis shows the presence of a very small amount of kaolinite. The 10.3 Å reflection due to a mica clay mineral does not accompany the reflection at 5.0 Å, remains unchanged after treatment with ethylene glycol, and disappears after hydrochloric acid treatment. These facts suggest that this mineral has a trioctahedral nature rather than a dioctahedral nature. On the other hand, X-ray diffraction pattern obtained from randomly oriented powder indicates the spacing of its (060) reflection to be 1.53 Å. From this, it is concluded that this mineral is trioctahedral mica. Such clay mineral was first described and referred as trioctahedral clay mica or simply "clay biotite" by WALKER (1950). BROWN (1951) gave a name "trioctahedral illite" to trioctahedral clay mica. The Nomenclature Sub-Committee of the Clay Minerals Group (1955) proposed a name "ledikite" for such mineral. In this report, this mineral is described in the name "trioctahedral illite".

Conclusively, the clay minerals in this specimen can be enumerated as trioctahedral illite, montmorillonite, chlorite and kaolinite.

Table 18. X-ray diffraction data of sample No. 11 after various treatments.

Untreated		300°C		450°C		600°C		750°C		Ethylene glycol		Hydrochloric acid	
d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I	d(Å)	I
14.7	6												
10.3	58	10.0	64+	10.0	63	10.2	61+	10.0	60+	10.3	17		
8.5	7	8.5	6	8.5	4	8.5	4	8.0	5	8.1	4	8.5	4
7.1	8	7.1	10	7.1	8								
3.36	18	3.36	26	3.35	25	3.34	24	3.33	23				
3.25	7	3.25	8			3.24	8	3.25	6				
3.20	9	3.20	9	3.19	10	3.20	11	3.20	9				
		3.14	4	3.13	4	3.12	3	3.12	3				
3.05	7	3.03	8	3.03	7								

4. Mineral compositions of clay fractions

From the results of mineral identification and comparison of X-ray reflection intensities of constituent minerals, mineral compositions of the specimens used in this study are deduced, and are shown in Table 19. The clay fractions of all samples contain quartz, feldspar, amphibole, montmorillonite, chlorite, trioctahedral illite, and a small amount of kaolinite. Trioctahedral illite is not often found in Recent marine sediments, so the presence of such mineral is a characteristic of the specimens. Trioctahedral illite may be formed from biotite which is contained commonly in granitic gneiss and biotite granite distributed in continents. In general, when biotite becomes fine-grained through weathering, it changes to vermiculite or its structure decomposes. Therefore, formation of trioctahedral illite and its stability are related to its environment, such as the low-temperature

Antarctic region. In Antarctica, chemical weathering is weak, so biotite is decomposed mainly by mechanical weathering and trioctahedral illite may result from it. As will be seen in Table 19, the samples are different in their mineral compositions. According to their clay mineral compositions, especially the amount of trioctahedral illite, the samples may be classified into three groups; that is, (1) samples Nos. 1, 5, 6, 7 and 8 containing a small amount of trioctahedral illite, (2) samples Nos. 2, 3 and 4 in which trioctahedral illite is abundant, and (3) samples Nos. 9, 10 and 11 in which trioctahedral illite is more abundant than in the other samples. The samples in each group are located near each other. These results of the present study apparently indicate that, in the area studied, clay mineral compositions, especially the amount of trioctahedral illite, tend to vary with locality.

Table 19. Mineral compositions of clay fractions.

Sample No.	1	2	3	4	5	6	7	8	9	10	11
Montmorillonite	+	++	++	+	++	+	++	+	+	+	+
Chlorite	+	++	++	+	++	+	+	+	+	+	+
Trioctahedral illite	+	###	###	++	+	+	+	+	###	###	###
Kaolinite
Quartz	+	++	++	+	++	+	+	++	+	+	+
Feldspar	.	++	++	++	++	.	+	+	++	++	++
Amphibole	.	+	+	+	+	.	+	.	+	+	+
Calcite	-	-	-	-	-	-	-	-	-	-	+

much
 ## ↑
 ++ ↑↓
 + ↓
 . little
 - absent

VI. ORGANIC MATTERS

Distribution of organic matters and components of their fractions have been studied in connection with sedimentary environments. The results obtained are shown in Table 20 and Figs. 20-23.

1. Method

Extraction of bitumen in the sediment samples was carried out in the Soxhlet apparatus with a mixture of benzen and ethanol (1:1) for nine hours. Organic carbon of bitumen was estimated at 70 per cent of the extracted bitumen weight.

The sum of fulvic acid and humic acid in the sediments free of bitumen was extracted at first with 1/10 N sodium hydroxide after reaction of one day, and was extracted again and again with 1/50 N sodium hydroxide after reaction of several hours until the centrifugal extract solution became transparent.

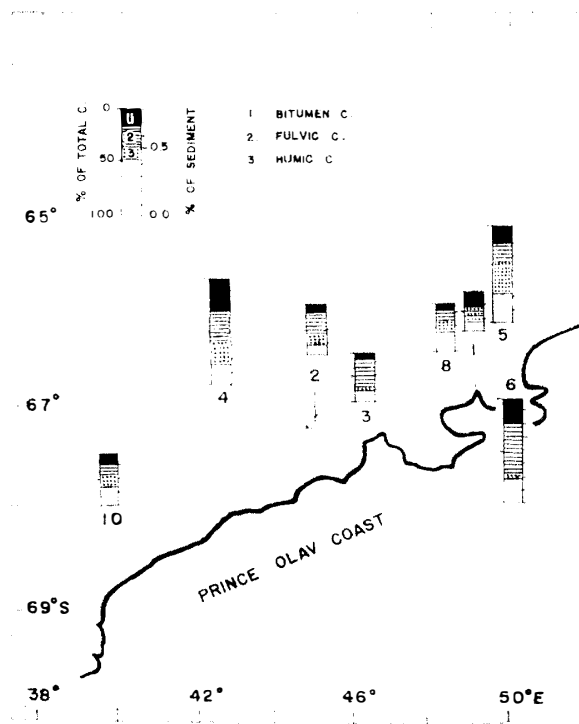


Fig. 20. Components of organic matter.

Table 20. Components of organic matters in the bottom sediments.

Station number	Depth (m)	Organic matter % of sediment	Total carbon		Bitumen		Fulvic acid		Humic acid		Humic acid Fulvic acid	Mdφ
			% of Sediment	% of Total C.	% of Sediment	% of Total C.	% of Sediment	% of Total C.	% of Sediment	% of Total C.		
1	945	0.51	0.30	100	0.10	33.3	—	—	—	—	—	2.7
2	385	0.68	0.40	100	0.05	12.5	0.14	35.0	0.12	30.0	0.86	3.5
3	280	0.58	0.34	100	0.04	11.8	0.21	61.7	0.02	5.9	0.10	3.9
4	560	1.34	0.79	100	0.23	29.1	0.23	29.1	0.16	20.1	0.70	6.1
5	330	1.22	0.72	100	0.11	15.3	0.13	18.0	0.24	33.3	1.84	4.5
6	980	1.31	0.77	100	0.14	18.2	0.41	53.3	0.03	3.9	0.07	4.6
8	275	0.60	0.35	100	0.04	11.4	0.06	17.1	0.10	28.6	1.67	3.6
10	380	0.66	0.39	100	0.07	17.9	0.07	17.9	0.09	23.1	1.29	2.7

Organic matters

The total carbon contents of fulvic acid and humic acid were determined by TYURIN's method. Humic acid was separated from sodium hydroxide extracts by means of neutralizing with sulfuric acid, and the carbon content of humic acid was determined. The carbon content of fulvic acid was determined as the difference between two determinations mentioned above.

2. Results and discussion

Organic matters and their fractions were determined from eight samples off the Prince Olav Coast. The results are shown in Table 20 and Fig. 20.

Accumulation of organic matter is remarkable in muddy sediments as represented by Sts. 4, 5 and 6. High content of organic matter in finer-grained sediments than in coarse-grained sediments is also recognized in the sediments of the continental shelf and slope off Noto and San'in, Japan Sea. However, the content of organic matter in the sediments off the Prince Olav Coast is one half or one third of that near Japan (Fig. 21).

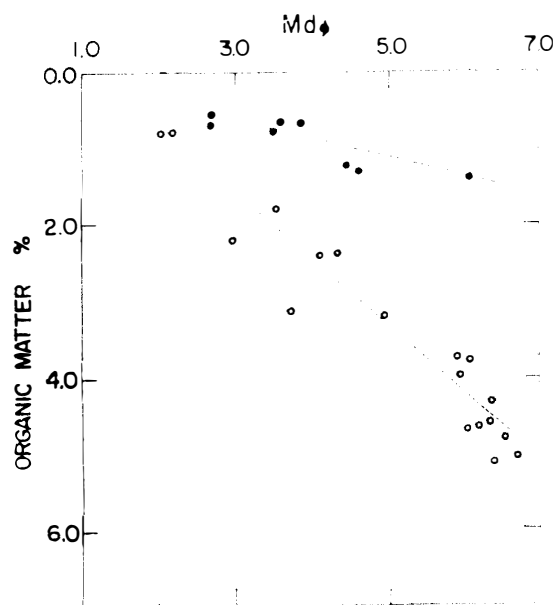


Fig. 21. Relationship between organic matter and grain size.

● Off Prince Olav Coast.

○ Off Noto and San'in (Japan Sea).

Bitumen is 0.04-0.14% (0.08% as average) carbon by dry weight of sediment, except for the maximum value of 0.23%, and its content shows an approximately same order as is found in the sediments on the continental shelf and slope around Japan. Since accumulation of bitumen is generally larger in fine-grained sediments, the maximum content, 0.23% carbon, was recorded in the muddy sediment at St. 4.

Generally speaking, organic matters which are extracted with sodium hydroxide increase with the decrease of grain size of sediment, as is the case with bitumen. Nevertheless, each carbon content of fulvic acid and humic acid is

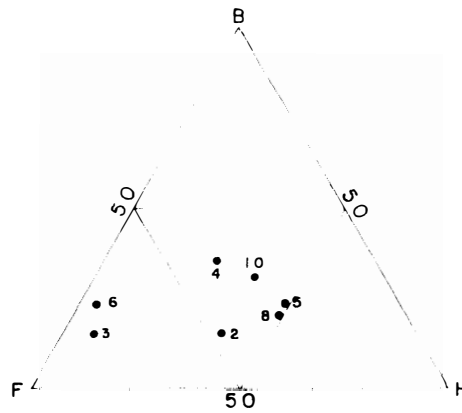


Fig. 22. Triangular diagram of bitumen - fulvic acid - humic acid components.

variable in the region, averaging 0.18% and 0.11%, respectively. The maximum content of fulvic acid is 0.41% carbon in the muddy sediment in the canyon, and its minimum content is 0.06% carbon in the coarse sediment on the continental shelf. The content of humic acid is 0.24% carbon in maximum, recorded in the silty sand, and 0.02% carbon in minimum, recorded in the fine sand on the continental shelf.

Humic acid/fulvic acid ratio is comparatively variable, ranging from 0.07 to

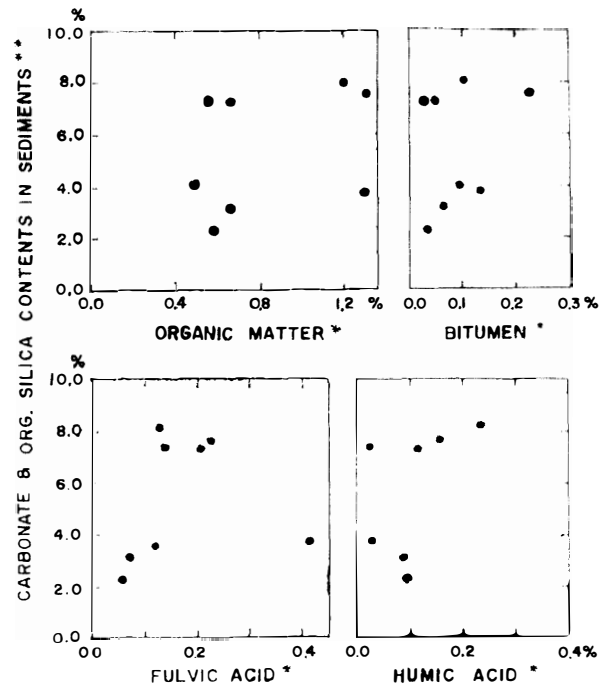


Fig. 23. Relationship between organic matter and organic debris.

* % of dry sediment.

** refer to Table 7.

1.84. But, the ratio tends to increase with distance from the land. Fig. 22 is a triangular diagram of bitumen, fulvic acid and humic acid. As shown in this figure, organic matters in the sediments are divided into two groups. One abounds in the relative carbon content of fulvic acid, but is poor in that of humic acid, i.e., the bitumen content ranges from 11.8 to 18.2%, fulvic acid from 53.3 to 61.7 %, and humic acid from 3.9 to 5.9%. The other has nearly equivalent values of relative carbon content in fulvic acid and humic acid, i.e., the bitumen content ranges from 12.5 to 29.1%, fulvic acid from 18.0 to 35.0%, and humic acid from 20.1 to 33.3%. The first group of sediments is located near the land so that the difference in the sedimentary environment may affect the components of organic matters.

As the accumulation of organic matter in the sediment more or less depends on the supply of organic debris, it is inferred that organic matter has some relation to organic debris. Fig. 23 shows the relationship between organic matter and organic debris. Organic debris in this figure does not precisely represent all the deposits, because of the sum weight content of carbonate and organic silica in the sand-size sediment, but it will be of use for comparison. As seen in the figure, there is no straight interrelation between organic matter and organic debris, but sediment containing much organic debris seems to abound in organic matter. This relation is comparatively clear in the case of fulvic acid.

In the present investigation, the sedimentary provinces that were taken from both clay mineral and clastic minerals did not coincide with that of organic matter. If we could examine many more sediment samples in a wider area, we might be able to find some interprovincial relations.

VII. SUMMARY AND CONCLUSION

The continental slope off Antarctica between Enderby Land and Lützow-Holm Bay extends down to the depth more than 4000 m. The relief of the surface of the slope sometimes suggests existence of submarine canyons. The continental shelf has the shelf edge which is 300-400 m in depth and 60-70 km in width.

Along the coast of the studied sea, the pre-Cambrian and Palaeozoic crystalline basement rocks are extensively distributed.

By depths, the samples are divided into the following two groups; one on the continental shelf and the other on the upper part of the continental slope. The samples of the first group are mud containing fairly large amount of sand and gravels. The samples of the second group are generally mud, but St. 1 off Amundsen Bay contains much sand and gravels which are assumed to have been transported by iceberg. The chemical analyses of muddy samples indicate that they are terrigenous sediments rich in detritus from land; the muds of the first group are poor in iron, manganese and alumina, and rich in silica. However, the mud of the second group relatively rich in alumina and poor in silica is of a somewhat hemipelagic character. The water content of the samples is usually about 40 weight percent, and does not have any direct relationship with the sand and gravel content of argillaceous sediments. Off the Prince Olav Coast, two stations, 550 m and 1750 m deep, show very high carbonate contents in the horizons of 26-31 cm and 10-15 cm below the sea bottom, respectively.

The investigated area is subdivided into four sedimentary petrographic sub-provinces, on the basis of heavy mineral association and gravel composition analyses. In the Amundsen Bay sub-province, there are abundant pyroxenes and garnet, and relatively common epidote. The dominant rock types of gravels are "charnockite" and granite. In the East Prince Olav Coast sub-province, pyroxenes are abundant, and garnet is relatively abundant. Gravels are dominantly porphyritic diorite gneiss, especially garnet-bearing gneiss. In the West Prince Olav Coast sub-province, amphiboles are dominant heavy minerals, and pyroxenes and garnet are not much. Gravels are granodiorite and granodioritic gneiss in abundance. In the west side of Riiser-Larsen Peninsula sub-province, amphiboles are dominant, and epidote, sphene and zircon appear persistently, though not common. Biotite granite, porphyritic granodioritic gneiss and dolerite occur in gravels as the characteristic rock types. On the basis of heavy mineral analysis,

the sediments are reasonably considered to have been transported into the present sites from different provinces without any appreciable sorting effects. About one half of the investigated gravels have the same or very similar appearance to the crystalline bedrock and erratic boulders around the region of the Ongul Islands. Porphyritic gneiss and granite are reported from the "Yamato Mountains" and the Australian East Antarctic Territory.

The clay fractions of all samples contain quartz, feldspar, amphiboles, montmorillonite, chlorite, trioctahedral illite and a small amount of kaolinite. Trioctahedral illite is not often found in Recent marine sediments. It may be formed from biotite. In general, when biotite becomes fine-grained through weathering, it changes to vermiculite or its structure decomposes. Therefore, formation of trioctahedral illite and its stability are related to the depositional environment, such as the low-temperature Antarctic region. In Antarctica where chemical weathering is weak, biotite is decomposed mainly by mechanical breakdown and trioctahedral illite may result from it. In the region studied, the clay mineral is scarce in the Amundsen Bay sub-province, common in the East Prince Olav Coast sub-province and abundant in the West Prince Olav Coast to the West side of Riiser-Larsen Peninsula sub-provinces. The grouping of samples by clay mineral composition corresponds to that determined by heavy mineral association in coarse fraction. Considering the correspondence and the origin of trioctahedral illite, it is probable that the kind of terrigenous sediments strongly controls the submarine sediments because diagenesis (chemical alteration) is not active on the Antarctic sea floor.

Accumulation of organic matter in the sediments ranges from 0.51 to 1.34 percent, and is abundant in muddy sediments. Their fractions are as follows; bitumen content is 0.04-0.23 percent, fulvic acid 0.06-0.41 percent, and humic acid 0.02-0.24 percent. Based upon the humic acid/fulvic acid ratio, the sediments are grouped into two types: (a) abundant in the relative carbon content of fulvic acid, and (b) nearly the same relative carbon content. Sediments of the first group are situated near the land, whereas the latter are far from the land. However, this grouping does not coincide with that by heavy mineral and clay mineral analyses.

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