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CHEMICAL INVESTIGATIONS ON MARINE HUMUS IN BOTTOM SEDIMENTS

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I. INTRODUCTION

The sea bottom is covered with sediments, which are an accumulation of solid materials of organic or inorganic origin. Bottom sediments are intimately connected with many physical, chemical and biological problems of the sea. Sedimentary matter, whether carried in suspension or supplied directly from solution, is distributed from its source by the movement of the sea water. The topography of the sea floor, the position of sea level, and tidal phenomena influence the sedimentation process, modifying the character and distribution of the sediments.

A wide variety of substances from many sources contributes to the sediments (Sverdrup, et al., 1949). Detrital materials, largely of terrigenous origin, contribute to the characteristics of littoral sediments, where there is a noticeable degree of disintegration and weathering or decomposition; that is, the degree of the former is indicated by the size of the fragments and that of the latter by the presence of products of chemical weathering. Volcanic products sometimes may contribute to the origin of the sediments. In the ocean, the principal source of the sedimentary particles is the skeletal remains of organisms, especially of planktonic life. Certain types of deposits are almost entirely composed of calcareous or siliceous detritus. The detrital organic matter in the sediments serves as food to benthic animals and bacteria (Fox, 1950); much of this material is destroyed by the activities of bacteria and bottom-living animals which transforms the constituent elements to solution in inorganic forms. The organic matter in marine sediments plays an important rôle in marine metabolism (Waksman, 1932-38). Since all petroleum is obtained from fossil marine sediments and marine humus is considered to have been the source of petroleum, areal distribution of the humus has received a great deal of attention. A series of bacteriological works by ZoBell and his collaborators (1943-1952) is the most valuable for interpretation of formation mechanism of petroleum after bacterial activities in the sediments.

The problem which has most interested the present author is that of the organic matter in the sediments. The term "organic matter" is used to designate that portion of the sediment which has arisen through organic activities and which contains carbon in any form other than carbonate. Because it is somewhat analogous to the humus fraction found in land soil it may be termed "marine humus" (Waksman, 1932). Sometimes the expression "decomposable organic matter" is used to indicate that the material may be destroyed by organisms, particularly by bacteria. In this paper, Waksman's "marine humus" as well as "organic matter" is used at the author's discretion.

Extensive studies of organic matter in marine sediments have been carried out especially by Trask and Waksman. In a series of publications beginning in 1927 Trask has contributed to the knowledge of the distribution and composition of humus

in recent marine sediments from geological points of view. Waksman treated the related problems from a microbiological point of view and further investigated the regional and stratigraphical distribution. The works of Trask and Waksman induced several petrographers to carry out similar investigations in different environments of sedimentation.

Organic substances in marine sediments are fairly variable in chemical composition in different environments of sedimentation. The organic constituents, owing to their greater susceptibility to change with varying conditions of deposition, might prove to be more sensitive indexes of the environmental conditions than the inorganic ones, though, of course, both should be used together in forming an interpretation on the origin of the sediments and of the environments.

In the seas adjacent to Japan, some investigations (Niino, 1930; Hoshino, 1952-53; Asano, 1954; Tayama, 1952) have been carried out from the viewpoint of geology. Few geochemical investigation, however, have as yet been made regarding areal distribution of organic matter in marine deposits, especially in hemipelagic ones. Only Hamaguchi (1953) has investigated the regional distribution of marine humus in the central Japan Sea and in Suruga Bay on the Pacific side.

Few available data have been published yet on the organic substances observed in sediment in relation to the environments of sedimentation. In the seas adjacent to Northern Japan, a series of investigations on distribution of marine humus by areas has been carried out by the present author since 1948 for the purpose of gaining some clues relating to the environmental conditions. The results of that series of investigations have been described in the principal part of this paper.

In the present paper, previous to dealing with marine humus, chemical characters in general have been examined of the hemipelagic sediments in the vicinity of North-western Hokkaido because they would supply information on the geochemical circumstances related to the accumulation or the chemical weathering of organic matter in bottom floor. Next, chemical examinations of marine humus in a narrow sense have been made using the littoral sediments. The seasonal difference of organic abundance was examined as being connected with nutrient metabolism in the bay. The oxygen consumption by the sediment is related intimately to bacterial activities and to redox condition in the bottom, consequently, it influences the habitation of bottom-living animals. So, the oxygen consumption is one of the problems discussed in the present paper. Sedimentary particles in the sea water may largely contribute to the accumulation of organic matter in the bottom. The actual states of flocculated materials suspended in the sea have been observed by using a kind of bathysphere, "Kuroshio", their states of aggregation have been observed under microscope, and these results have also been described in a part of this paper. Finally, there is presented in this paper a description of the distribution of marine humus in the seas neighboring Hokkaido; the distribution has been examined in relation to oceanographical and

topographical environments of the site of deposition in which work statistical examination has proven very useful.

Regrettably, on account of many disadvantages the observations and experiments performed were by no means fully satisfactory, but the main results obtained were felt to be sufficiently valuable to merit their publication.

II. ACKNOWLEDGEMENT

The author is much indebted to Prof. Hitoshi Tominaga of the Chemical Institute, Faculty of Science, Tôhoku University, at Sendai, for his untiring encouragement during the investigation. To Prof. Noboru Suzuki of the Faculty of Fisheries, Hokkaido University, at Hakodate, grateful acknowledgement is due for giving facilities for the work.

Furthermore, the author has much pleasure in thanking other people for help in his work. He is much obliged to Dr. Senji Tanita, of the Department of Fishery Cultivation, Tohoku Regional Fisheries Research Laboratory, at Shiogama, and to Prof. Tadashi Tamura of the Faculty of Fisheries, Hokkaido University, for their advice and cooperation in the working out of the biological problems.

The author wishes to express his thanks to Mr. Kohei Ôgaki, Director of Hokkaido Regional Fisheries Research Laboratory, at Yoichi, for affording facilities for making investigations in the sea skirting Hokkaido.

Thanks are also due to Messrs. Taizo Okuda, Mitsutake Nakazawa and Miki Oguro and Miss Michiko Konishi for their generous assistance carrying out observations or experiments. The author wishes to express his appreciation of patient help in field work by Messrs. Osamu Tanaka, Kazunari Horiuchi, Hiroshi Kawahara, and Mitsugu Sato.

The present work was rendered possible through the financial support of a grant-in-aid for Fundamental Scientific Research from the Ministry of Education, to which the author expresses his sincere thanks.

III. GENERAL DESCRIPTION OF THE AREAS INVESTIGATED

The sea areas adjacent to Hokkaido as reported in this paper are two: One is the Northern Japan Sea off the west coast of Hokkaido located intermediate between Cape Soya and Cape Shirakami, and the other is the Pacific area north of the line connecting Cape Esan with Cape Erimo (Fig. 1).

The topography of the Northern Japan Sea is found to be very complicated, being divisible into two subareas characterized by their topography. The subarea north of the Shakotan Peninsula has a fairly wide shelf about 70 miles wide and 180 miles long. There lie four islands, viz., Rishiri, Rebun, Teuri and Yagishiri; several bands rise of which the largest is Musashi Bank. A narrow trough called Musashi Channel

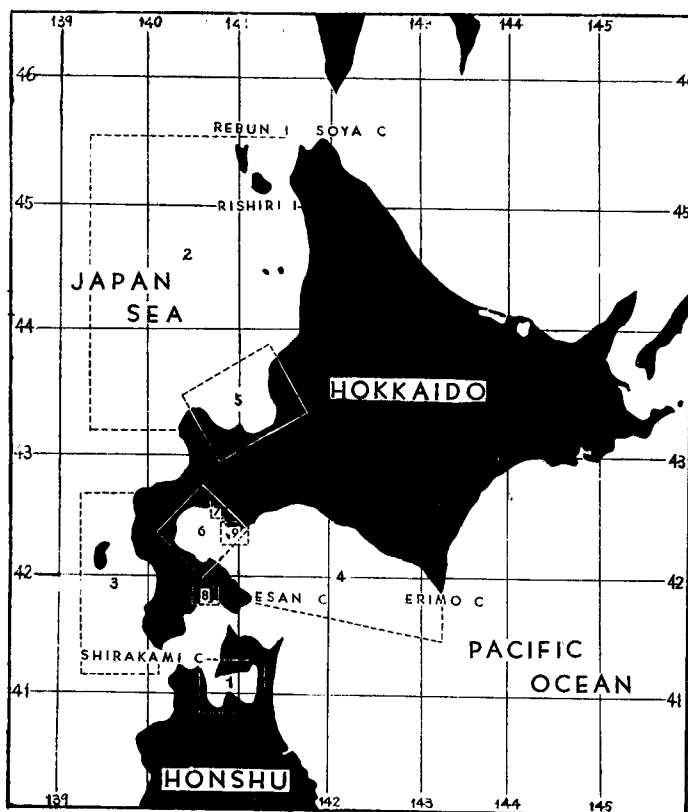


Fig. 1. Investigated areas adjacent to North Japan (1948-1953)

has water depth ranging 200-300 meters and runs intermediate between Rishiri Island and Musashi Bank. In the southern part of the subarea, a basin having water depth below 800 meters lies off the mouth of Ishikari Bay. Moreover, a steep and narrow ridge leads the Shakotan Peninsula to Musashi Bank. The deep-sea floor of the Japan Sea approaches with steep slope to the westside of Musashi Bank or/of the ridge. Consequently, the hydrographical condition appears very complicated owing to the complexity of topography; notable peculiarities are exhibited in the presence of organisms such as plankton, fishes and benthos.

As to the southern subarea, there exists only a narrow shelf 3-5 miles in width in the vicinity of Okushiri Strait. The deep-sea floor of the Japan Sea approaches to the west coast of the Oshima Peninsula, wherein several small submarine valleys develop at right angles. Okushiri Island lies alone, and is skirted by a somewhat wide but steep island shelf. Between the Island and the Oshima Peninsula, there is located Okushiri Strait which has width of 10 miles and 550 meters depth in maximum. Most of the sediments are sand or gravel.

In the northern Japan Sea area, the Tsushima Current flows northward with

modifications by the topography, at a speed of 0.3–0.8 knots in average. Coastal water lies near shore, being diluted by inlet of rivers, as Rivers of Ishikari, Teshio and so on.

In the second area surveyed, off the southern coast of Hokkaido on the Pacific side, the topography is considerably monotonous : That is, the slope next to the shelf appears fairly gentle, where the sediments being almost sandy or muddy, and somewhat complicated by contributions of volcanic material from several volcanoes such as Mts. Komagatake (1142 m), Usudake (732 m), and Tarumai (1026 m) on the west side of the area. Through the Strait of Tsugaru, a branch of the Tsushima Current, or "Tsugaru Current," flows into this area, and controls the conditions of the oceanographical circumstances. The Oyashio Current moving southward along the eastern coast of Hokkaido flows by passing Cape Erimo, and turns its course to the direction westward in winter. That influence is almost nil in summer.

Funka Bay lies in the northwestern part of this area. It has a depth near 50 meters in average, and the floor is quite even. The hydrographic behavior is very interesting because the motions of bay current seem to be induced by the outer oceanic waters. In the inner part of the bay is located Usu-Bay, which is comparatively small in area, about 2150 meters in maximum width and 5 meters in depth, but being an interesting and important field for the culture of lavers.

Mutsu Bay of Aomori Prefecture, Honshu, facing the Strait of Tsugaru is one of the areas studied in the present investigations. It is divided geographically into two parts, the Bays of Aomori and Noheji, but both of them seem to be unique in topography except the area in the vicinity of the Natsudomari Peninsula.

When investigating ecological environments of shell-fish fields, two important harbours, Hakodate and Muroran, in Hokkaido, were the objects of research.

a) Procedure of Investigations

Between May 1948 and August 1953 a series of investigations was made of the areas adjacent to Hokkaido Island, and of the submarine topography and the bottom sediments. The investigations progressed as follows :

(1) Mutsu Bay, Aomori Prefecture (May, 1948)

The investigation was carried out as a portion of a fishery research project under plans of Aomori Prefecture. The investigation was undertaken in cooperation among the Faculty of Fisheries of Hokkaido University (the then Hakodate College of Fisheries), the Hakodate Marine Observatory, and the Biological Station at Asamushi attached to the Tōhoku University. The author took charge of surveying bottom sediments in the Bay of Mutsu where 14 bottom samples were obtained on the training ship, "Oshoro-Maru" (560 ton), of the Faculty of Fisheries on May, 5–7

1948.

(2) The Japan Sea to the Northwest of Hokkaido (July, 1949)

A series of synthetic surveys in the area, $43^{\circ}19'$ to $45^{\circ}23'N$ and $139^{\circ}24'$ to $141^{\circ}18'E$, have been carried on, since 1949, for the purpose of ascertaining the relation of fishing procedures to the environmental conditions controlling the fishing ground, by the Fisheries Research Association of Northern Japan Sea. The first survey was made in summer 1949, when the author took charge of surveying bottom environments, attempting to investigate the bottom configuration and the characters of the sediments. For the period from 16 of July to 18 of August, Mr. T. Okuda, one of the author's assistants, engaged in collecting bottom samples on board the "Oshoro-Maru", one of the research vessels in the survey. The bottom survey with accompanying investigation of topography by echo-sounding device equipped in the vessel was carried out at intervals of five sea miles. Thus the bottom characters of 253 stations were observed and 96 bottom samples were subjected to chemical or microscopical investigations. Furthermore, some preliminary experiments on the absorption of water-dissolved oxygen by sediments were made on board the vessel.

(3) Area in the Vicinity of Okushiri Strait (Aug. 1952)

The Hokkaido Regional Fisheries Research Laboratory attempted during 1948-1952 to research the bottom topography and sediments of the off-shore fishing grounds ranging approximately 100-1000 meters in depth, around the coast of Hokkaido. The area in the vicinity of the Okushiri Strait, $41^{\circ}19'$ to $42^{\circ}36'N$ and $139^{\circ}28'$ to $140^{\circ}05'E$, was investigated on 23-31 of August, 1952, as one of the series of surveys. The author was responsible for a chemical investigation dealing with the sediments, of which bottom samples were collected by Mr. H. Kosugi of the Laboratory and Mr. S. Tanaka, a research student of the author's laboratory on board the "Tankai-Maru" (68 ton), the research vessel of the Laboratory. The survey was conducted at intervals of three miles, so the bottom characters were observed at 83 stations; 44 bottom samples were subjected to laboratory investigations involving chemical and microscopical analyses as well as mechanical one of grain-size grades by sieving sedimentary matter.

(4) The Sea to the Southeast of Hokkaido, the Pacific Side West of the Cape Erimo (Sept., 1952)

A bottom survey of the sea southeast of Hokkaido, located north of a direct line drawn from Cape Esan to Cape Erimo, has followed to directly after the above noted study (3), between the 3rd and 21st of September, 1952. The investigation of topography by echo-sounding and the observation of bottom characters by sampling sediments were made in this survey similarly to the above case (3). The bottom characters of 82 stations were observed after sampling at intervals of four miles, 79 bottom samples were studied in laboratory, after which the chemical properties of the

sediments were examined in reference to the sedimentological characteristics of the site of deposition.

(5) Ishikari Bay, Hokkaido (July, 1953)

In summer of 1953, oceanographical observations in Ishikari Bay, Hokkaido, were undertaken in connection with the underwater survey by the undersea observation chamber, "Kuroshio", designed by Prof. N. Inoue (1953) of the Faculty of Fisheries, Hokkaido University, and his collaborators.

The observations were conducted by the author and Prof. Suzuki, on 28-29 July, on board "Oshoro-Maru", in company with Mr. Hideto Koto, an Assistant Professor of oceanography and the author's colleague, who collaborated in conducting hydrographical observations. Eighteen stations in the bay and the mouth of the Ishikari River were observed.

The distribution of organic matter in the bottom floor was investigated with emphasis on correlation with the environmental condition in the site of deposition; use was made of the results of these oceanographical observation undertaken simultaneously.

Furthermore, decomposing action of hydrogen peroxide in sea water was examined on the water samples obtained in the observation. The action has some relation to the quantities of chemical constituents or suspended matter in the water, consequently the experimental results were extremely interesting to the author from the standpoints of oceanography as well as of marine biochemistry. But these detailed results will be reported in another paper.

(6) Funka Bay, Hokkaido (August, 1951)

Funka Bay (Volcano-Bay) in the southern part of Hokkaido was one of the best fishing grounds in the seas adjacent to Japan, but a sudden decrease of the catch out of the bay has been experienced in recent several years. Hence, some synthetic surveys have been attempted by the Hokkaido Regional Fisheries Research Laboratory to ascertain possible countermeasures against the decrease. A scientific research commission to assist in the attempt was organized by scientists of the Faculty of Fisheries, Hokkaido University. The commission investigated for five years, 1949-1953, inquiring into the causes of the decrease of the catch and for clarifying the ecological significances of environmental conditions in the bay. Prof. Tamura and the author have engaged in an ecological survey of the bay, investigating especially the relation of bottom characters to benthic animals. The survey was carried out during 15-27th of August, 1951, using the "Uchiura-Maru" (23 ton), the research vessel of the Muroran Cooperative Association of Fisheries. Topography of bottom floor was recorded by echo-sounding device equipped with the vessel, and characters of sediments were observed, after sampling at 40 stations; thirty bottom samples were subjected to investigations at the laboratory.

(7) Usu Bay, Hokkaido (January and August, 1950)

Usu Bay, a small bay facing Volcano Bay, is comparatively small in area, but one of the very important fields for the culture of lavers and oysters. The first investigation was carried out in January, 1950, and the second in August of the same year. In these investigations, the author has engaged mainly in oceanographical and chemical researches while Dr. Tanita, (collaborator and adviser in reference to biological problems), engaged in ecological research and mechanical analysis of grain size of bottom deposits. Mr. Okuda aided them in the field work or chemical investigation.

(8) The Harbours of Hakodate and Muroran, Hokkaido

In Hakodate harbour, there formerly dwelt useful shellfishes in abundance, but at present they are nearly exterminated. To clarify the causes of such a change in the output of shellfish in the harbour, was one of the main objects of the investigations. Dr. Tanita and Mr. Okuda were associated the author taking the same responsibilities respectively as in the case of the above investigation.

The field observations were made on 5-6 of July, 1949. In Muroran Harbour, there dwell abundantly such useful shellfishes as scallops. The oceanographical and ecological investigations were done, four times during 1949-1950, by the same party for examining ecological environments and influences of urban sewages or of industrial residues upon the fishery fields in the harbour.

b) Methods Employed in these Field Observations

The oceanographical observations have been carried out with good position control. For obtaining locations accurately, not only was employed the visible or sextant method, but also other kinds of instrumental control, e.g., radio acoustic ranging, radio direction and range (radar), and echo-sounding were used according to whether the situation had visible well-located points of land or was lacking them. Echo-sounding has played practically a very important rôle in making investigation of topography.

Bottom samples were collected by using snapper, dredger or small coring sampler. In the case of Ishikari Bay, there were used new dredger and small coring sampler devices, both designed by the author. Thus obtained samples were stored in ice-box or freezer in research vessel, then carried to laboratory, where they were submitted to examinations whether immediately, if possible, without treatment or with treatment of drying at room temperature or 105-110°C.

As to the methods of chemical and mechanical analysis of bottom sample in laboratory, the successive steps will be described below in this paper.

Laboratory work, next, leads to microscopic observation of remains of organisms in the sediment for the purpose of inquiring whether their origin is from plankton or benthos.

In order to prevent deterioration, the larger remains of benthos creatures or weeds found in sediments were stored in vials containing formalin solution or spirit, being held for subsection to biological determination.

Both procedures of oceanographical observation and chemical determination of water sample were conducted in accordance with customary methods used in marine observatories in Japan :

Of sea water collected by means of Nansen's sea sampler, the routine observations were made of temperature, salinity, pH, oxygen, phosphate, silicate, iron, nitrite, dissolved organic matter and decomposing activity of hydrogen peroxide. Of them, pH and oxygen as well as temperature have been determined on board ship as quickly as possible after sampling ; pH by the dye method of colorimetry, and oxygen by Winkler's method. In laboratory, chemical contents of the sampled water which was brought in cold have been determined the following routine methods : salinity by Mohr and Knudsen's method, phosphate by Deniges and Atkin's method, silicate by Dienert and Wandenbulke's method, iron by thiocyanate method, nitrite by Griess and Ilosvay's method, dissolved organic matter by alkaline oxidation method by permanganate, and decomposing activity of hydrogen peroxide has been determined by Matsudaira's method (1950) modifying iodometry.

IV. CHEMICAL COMPOSITION OF MARINE SEDIMENTS IN THE NORTHERN JAPAN SEA ADJACENT TO HOKKAIDO

As yet few investigations have been made of chemical composition of the sediments in the Japan Sea, accordingly the author attempted to determine the chemical composition of the bottom samples from Northern Japan Sea adjacent to Hokkaido.

Table 1. Bottom Samples from the Sea to the Northwest of Hokkaido (July-Aug. 1949)

Station Number	Locality		Depth of Water (m)	Character of Bottom Sample	
	Latitude (N)	Longitude (E)		Color	Structure
M 18	43°30'24"	140°22' 0"	648	dark green	mud
M 67	43°55'48"	140°34'54"	710	green	mud
M 95	44° 3'30"	139°59'24"	950	greyish green	mud
M 114	44° 8'18"	140°25'18"	430	green	mud
M 142	44°20' 0"	140°50'54"	320	green	mud
M 159	44°23'12"	139°57' 0"	920	green	mud
M 183	44°24'12"	139°28'18"	746	greyish green	muddy sand
M 189	44°34'12"	140° 6' 6"	320	dark green	muddy sand
M 196	44°34' 6"	140°55'36"	200	dark green	sandy mud
M 221	44°43'54"	140°49'24"	220	dark green	sandy mud
M 250	45° 0' 0"	140°44'18"	340	green	mud
M 285	43°13'12"	140° 9'18"	600	green	mud

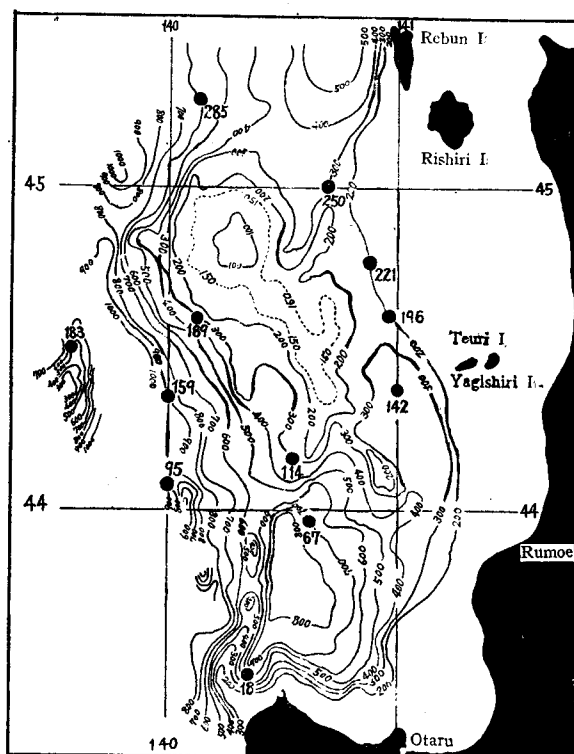


Fig. 2. Stations observed in the Northern Japan Sea to the northwest of Hokkaido (1949)

Chemical determinations were made of twelve bottom samples extracted at random from 96 samples of the area. General characters and localities of these test samples are shown in Table 1 and Fig. 2.

a) Systematic Method of Chemical Analysis for Marine Sediments

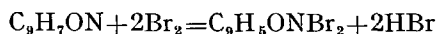
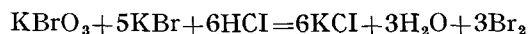
For undertaking systematic analysis on constituents of the samples, the author has employed his own below-described method modifying the two methods of Ishibashi (1940) and of Shioiri (1936) :

Previous to determination, the air-dried sample is pulverized in agate mortar, after which dried at 100–110°C for two hours. For determining the mineral composition, about 0.3–1.0 g of the dried test sample is fused with carbonate mixture in platinum crucible, thereafter being dissolved in HCl (1:1), and its silicate content is determined according to usual method. The filtrate from the silicic acid is treated with bromine water for oxidizing ferrous ion, and the excess of bromine is expelled by heating. The treated filtrate is neutralized with ammonia, adding ammonium carbonate and ammonium acetate (Mittash's method), whereupon phosphorus preci-

pitates in the forms of iron phosphate and basic acetate of iron. In the precipitate are contained all of phosphoric acid, most of iron and a part of aluminium of the sample. For separating phosphoric acid from iron and aluminium, the precipitate is dissolved with nitric acid, followed by the precipitation of the phosphorus by addition of ammonium molybdate. The precipitate is, after washing with two per cent solution of ammonium nitrate and acetone and drying at room temperature, dissolved by adding an excess of N/20 caustic soda solution. Phosphorus content is determined by titrating the remains of the soda with N/20 hydrochloric acid. For separating iron and aluminium from the filtrate after Mittash's method, to the filtrate is added ammonium chloride which is neutralized carefully with ammonia by adding a few drops of methyl red indicator. The precipitate is dissolved in hydrochloric acid and both contents of iron and aluminium can be determined by ordinary methods.

The solution free from iron, aluminium, and phosphoric acid, is treated with hydrogen sulfide at slightly alkaline state, causing precipitation of manganese sulfide.

Manganese sulfide is dissolved in hydrochloric acid, and sodium acetate and sulfurous acid are added. The solution is kept alkaline by adding ammonia, acidified again with acetic acid. In digesting the acidic solution with 2 per cent alcoholic solution of oxiquinoline at 70°C, precipitate of oxiquinolinate of manganese occurs. The oxiquinolinate is dissolved in diluted hydrochloric acid, added a slight excess of N/30 potassium bromate solution involving potassium bromide, next 1-5 cc of 20 per cent potassium iodide solution. So, the oxiquinoline dissolved from the above manganese salt in acidic solution reacts to bromine from the $\text{KBrO}_3\text{-KBr}$ reagent. The bromine in the solution oxidized potassium iodide to iodine. The content of manganese is determined by titrating the liberated iodine with N/50 sodium thiosulfate solution.



Hydrogen sulfide in the filtrate from heavy metals and from aluminium is expelled by heating with hydrochloric acid. After filtering out the liberated sulfur and adding oxalic acid, calcium oxalate precipitates by neutralizing the solution with ammonia. Calcium is determined by titrating the oxalate with N/10 acidic solution of permanganate.

For determining magnesium content, the filtrate from calcium is kept alkaline by adding ammonium, digested with two per cent alcoholic solution of oxiquinoline at 70°C. Then the oxiquinolinate of magnesium which occurred here is treated similarly to the case of manganese, and magnesium content is determined by the same volumetric method.

As to the contents of alkali-metals, determinations were attempted by usual methods without satisfactory results.

b) Relation between Chemical Composition and Water Depth of the Site of Deposition

The results determined by using the above systematic method are summarized in Table 2, while Table 3 shows the atomic ratio of these chemical constituents.

Table 2. Chemical Compositions of Bottom Samples (%)

Station Number	SiO ₂	Al ₂ O ₃	CaO	MgO	Fe ₂ O ₃	MnO	P ₂ O ₅	Ignition Loss
M 18	55.92	16.94	1.66	2.57	3.45	0.46	0.18	13.32
M 67	57.05	17.11	1.13	2.06	3.35	0.63	0.13	13.54
M 95	54.61	12.63	2.52	3.54	7.17	2.48	0.16	11.39
M 114	56.04	12.82	2.31	4.35	3.72	1.36	0.13	11.21
M 142	55.91	9.77	2.18	2.89	4.79	1.80	0.09	11.29
M 159	58.23	17.15	1.08	2.47	3.82	0.18	0.14	11.71
M 183	64.69	10.85	1.52	3.09	3.08	1.72	0.13	7.30
M 189	66.31	8.38	2.46	1.51	3.45	0.23	0.12	4.60
M 196	64.51	11.58	2.75	2.65	5.86	1.27	0.12	5.32
M 221	65.66	10.70	1.98	5.02	5.48	0.52	0.10	5.51
M 250	60.69	14.46	2.22	2.33	4.65	0.17	0.10	7.31
M 285	58.74	13.46	2.85	3.23	4.17	1.54	0.13	10.48
Average	59.86	12.99	2.14	2.98	4.42	1.03	0.13	9.42

Table 3 Atomic Ratio of Inorganic Constituents

Station Number	Si/Al	Fe/Mn	Mg/Ca
M 18	2.80	6.67	2.14
M 67	2.83	4.70	2.51
M 95	3.63	2.57	1.91
M 114	3.71	2.65	2.63
M 142	4.91	2.37	1.58
M 159	2.89	1.97	3.19
M 183	5.06	2.08	1.71
M 189	6.72	2.48	0.85
M 196	4.72	4.27	1.34
M 221	5.02	4.74	3.54
M 250	3.56	4.24	1.50
M 285	3.70	2.92	1.57
Average	3.90	3.47	2.04

These data have been used in discussing how chemical composition of the sediment would deviate under the influences of environmental factors in the site of deposition.

The deviation in quantities of chemical components is indicated in Figures 3-10 in relation to water depth of the site of deposition, and that of Si/Al or Fe/Mn in Figures 11 or 12 respectively. In Table 4, there are summarized the data of analysis gained by various investigators on the chemical composition

of different sediments. Making use of such data, one is somewhat able to compare the various sediments on the basis of the characteristics of their chemical composition.

(1) Silicate Content (Fig. 3)

It will be clear from Fig. 3 that the more abundant content of silicate is found in the comparatively shallow sites of deposition. The silicate content may be influenced by bottom weathering. With increasing water depth, the weathering appears to become gradually more noticeable. This tendency seems more remarkable than that

Table 4. Contents of Inorganic Substances in Marine Deposits (%)

Item	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	P ₂ O ₅	
1	54.48	14.94	8.66 (FeO 0.84)	1.21	3.31	1.96	0.30	Red Clay (Pacific, Atlantic)
2	52.45	16.05	8.26	1.12	3.35	2.44	0.44	Red Clay (North Pacific)
3	50.77	20.76	10.94	2.01	3.03	1.72	0.28	Red Clay (North Pacific)
4	57.05	17.22	5.07	0.12	2.17	2.04	0.21	Terrigenous mud (Blue mud, green)
5	61.77	15.37	7.00	0.82	2.32	4.03	0.30	Blue mud (Japan Deep)
6	59.86	12.99	4.42	1.03	2.98	2.14	0.13	Terrigenous Deposits (Japan Sea)
7	69.96	10.52	3.47	0.06	1.41	2.17	0.18	Mississippi silt.
8	53.58	13.86	7.28	3.32	3.66	1.40	0.67	Red Clay (Central Japan Sea)

- 1) Clark, F. W. (1924): "The Data of Geochemistry", U. S. Geol. Survey Bull; 770 P. 5Ed., Washington.
- 2) Hamaguchi, H. (1941): Jour. Chem. Soc. Japan, **63**, 1,689-1,694.
- 3) Ishibashi, M. and Y. Harada, (1932): Jour. Chem. Soc. Japan, **59**, 569
- 4) Steiger, G. (1924): quoted from 1)
- 5) Hamaguchi, H. (1941): Jour. Chem. Soc. Japan, **63**, 1,700-1,703.
- 6) Kato, K. (1951): Bull. Fac. Fish. Hokkaido Univ., **2**, 134-144.
- 7) Steiger, G. (1924): quoted from 1).
- 8) Hamaguchi, H. (1953): Jour. Chem. Soc. Japan, **74**, 761-764.

found in Thorp's data (1931) on the bottom samples from the Northwestern Atlantic or the Caribbean Sea. Thorp (1931) has emphasized that, in the deposits under 1,800 meters water depth, it would be scarcely possible to find any tendency toward decrease in silicate content with increase of water depth of the site of deposition.

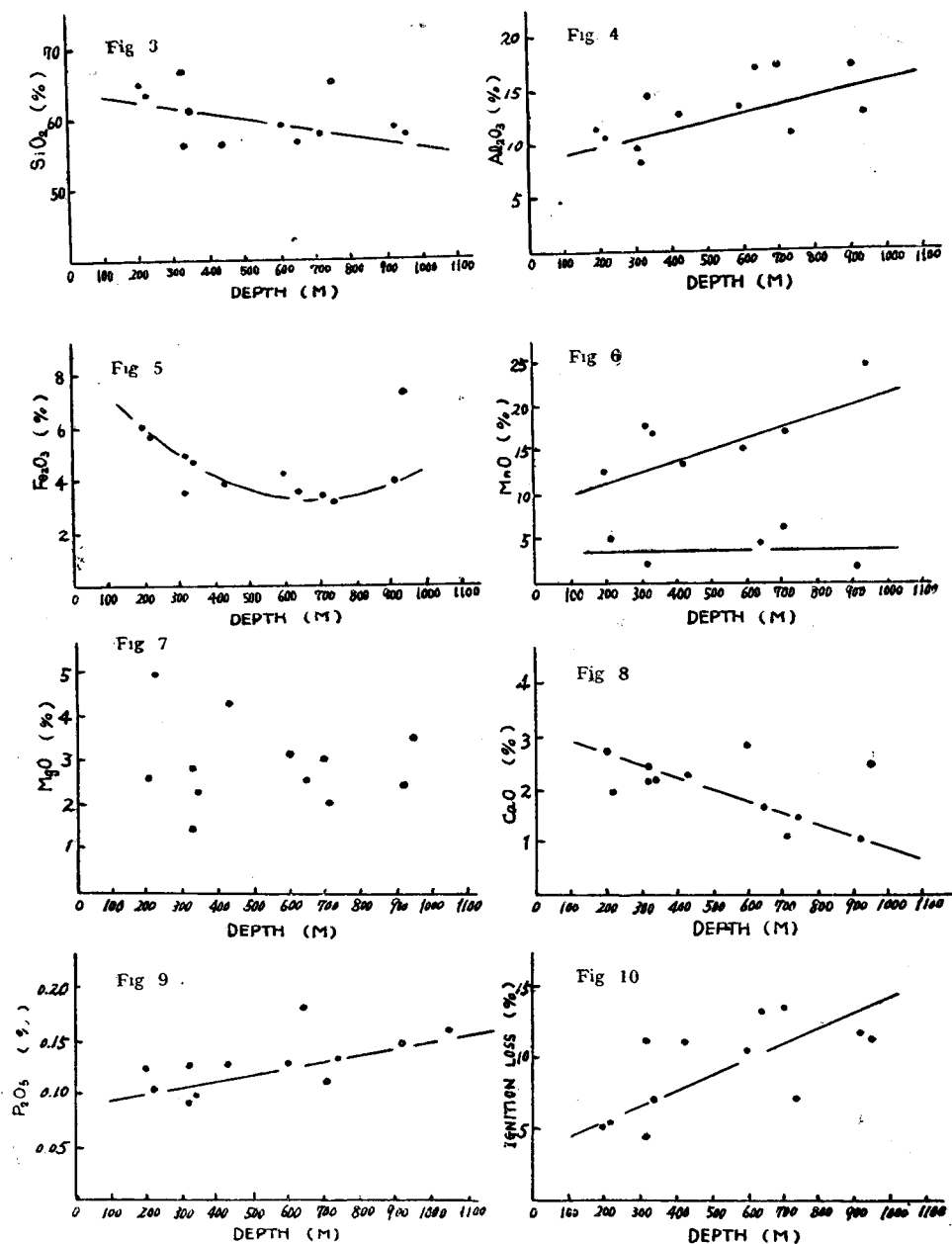
The averaged value, 59.86%, of silicic contents obtained in the present investigation appears to be entirely reasonable in comparison with various data regarding hemipelagic deposits as determined by other investigators indicated in Table 4.

(2) Aluminium Content (Fig. 4)

As characters of the sediments become rather pelagic, a gradual increase of aluminium content in sediments may be observed in the present area. Such increase may be caused either by electrochemical aggregation of colloidal aluminous debris transported from land or by the relative decrease of silicates or calcium compounds by chemical weathering.

(3) Iron Content (Fig. 5)

Figure 5 is very interesting in that a characteristic catenary is drawn by the



Figs. 3-10, showing the relations of the chemical properties of sediment to the water depth of the site of deposition (Northern Japan Sea, 1949)

Fig. 3. SiO_2 ; Fig. 4. Al_2O_3 ; Fig. 5. Fe_2O_3 ; Fig. 6. MnO ; Fig. 7. MgO ;
Fig. 8. CaO ; Fig. 9. P_2O_5 ; Fig. 10. Ignition loss

two variables as iron content and water depth ; the water depth which indicate the minimum in iron content seems to be about 700–800 meters.

The quantity of iron in deep-sea sediments appears, in general, to increase with water depth (Thorp, 1931). However, the accumulation of iron in sediments shallower than 700 meters in water depth is somewhat strange to the general ones mentioned above ; the iron content decreases with increasing water depth of the site of deposition. The characteristic decreasing of the content with depth may be affected by particular environments of deposition. With increasing water depth of the site of deposition, a certain kind of reduced circumstance may develop over the bottom owing to sedimentary accumulation of organic matter. Accordingly, the iron compounds may be reduced near or in the bottom into soluble form, and may return to the overlying water in the form of ions or colloidal particles combined with marine humus.

However, the iron which has returned into pelagic water will be oxidized, as pointed out by Rankama (1949), into oxidates. The particulated oxidates will begin to settle again in the sea water, and will ultimately accumulate in the sediments. This process of accumulation of iron seems progressive in the waters of Tsushima Current, where the quantity of iron in the sediments tends to increase. Such geochemical transition regarding areal distribution of iron accumulated in the sediments may be observed in the area ranging 700 to 800 meters in water depth, wherein may be found the minimum value of iron content of sediments. Thorp (1931) suggested too that the quantity of Fe_2O_3 in the sediments might decrease in reverse to increasing water depth in the areas ranging 100 to 1,000 meters in depth, notwithstanding the quantity tends to increase with depth in the present areas deeper than 1,000 meters.

It is of interest that the average value, 4.42%, of Fe_2O_3 contents of the sediments in the investigated area is found intermediate between that of the terrigenous deposits, 3.47%, in the Mississippi Delta (Steiger, 1924) and that of the red clay, 10.94%, in the Northern Pacific (Ishibashi and Harada, 1932).

(4) *Manganese Content* (Fig. 6)

Remarkable accumulation of manganese in the sediments is observed in the present area, the average content being 1.03%, the maximum 2.43%. That may be one of the characteristics of the sediments in the Northern Japan Sea adjacent to Hokkaido. Hamaguchi (1953) also observed an abundant accumulation of manganese in the sediments from the central area of the Japan Sea. In general, a tendency of increasing manganese content with water depth has been observed in various marine sediments by many investigators as mentioned by Clark (1924).

As to accumulation of manganese in the sediments in this area, there may be two kinds of characteristic regions according to degree of the content ; that is, one being ordinary region, 0.5% or so, and the others concentrated one, 1% or over. In the ordinary region, the contents may not always deviate according to change of

water depth of the site of deposition. While, they may increase with water depth in the concentrated region. The distribution of the sediments classified into the concentrated region seems of much interest in comparison with that of pyrolusite in the west side of Hokkaido, where many manganese mines, viz., Ishizaki, Shimamaki, Okushiri and Meppu, are found. The Meppu Mine is of sedimentary pyrolusites, in which have been often discovered fossil remains of teeth of shark or those of otoliths of whale.

As the mechanism of this remarkable accumulation of manganese will not be clear enough, a discussion of condensation mechanism of manganese, by Hamaguchi (1938), in deep-sea sediments of the Southern Pacific might be very noteworthy. His point is that manganese acts an important role in the condensation of radioactive elements such as radium in deep sea bottom. So, chemical investigations on these radioactive elements in the sediments of the northern Japan Sea will be very interesting in relation to the distribution of heavy metals as well as of manganese.

(5) *Magnesium Content* (Fig. 7)

There may be shown, in general, an increase of magnesium content in the sediment with water depth of the site of deposition, but it is scarcely possible to observe a general increase with depth in the present investigation, as shown in Fig. 7.

(6) *Calcium Content* (Fig. 8)

The deep-sea deposits in the Japan Trench off Cape Inubo have indicated an enormous content of calcium, 4.03%, in Table 4. However, the calcium contents observed in the present area were 2 per cent or so. These contents may be nearly analogous to those of ordinary bathyal sediments.

The distribution of calcium carbonate in pelagic deposits has already been observed, in detail, by Trask (1937). He indicated in a map, which being based on his data has been revised to take into account more recent data, an enormous accumulation over 30 per cent of calcium carbonate in deep-sea bottom floor. However, Steiger (1924) has observed about 2 per cent content of CaO averaged in terrigenous deposits. As to the CaO content in the samples under discussion, there may be found a slight tendency to decrease with water depth of the site of deposition, although that is not very obvious.

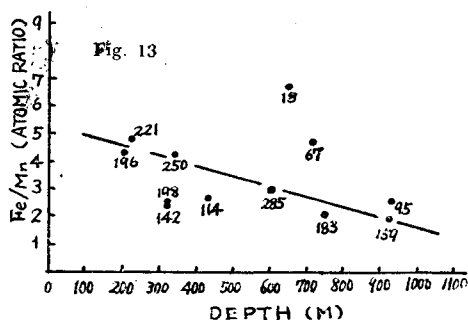
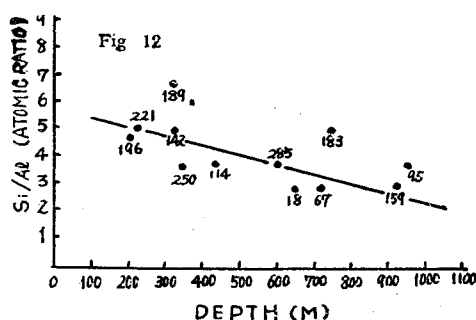
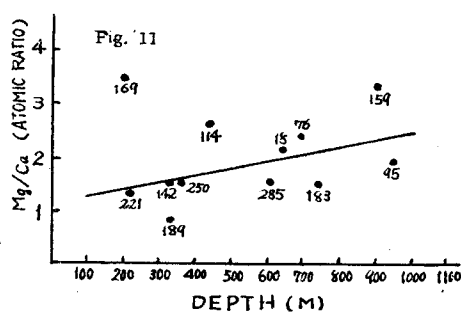
(7) *Phosphate Content* (Fig. 9)

The quantity of phosphate in the samples is 0.13% in average, which appears somewhat lower than that determined by other investigators. The cause of the difference is not clear yet. The deviation of the contents owing to water depth seems nearly proportional to the depth as other investigators similarly have pointed out. Hamaguchi (1953) has suggested that the phosphate content in the pelagic sediments in the Japan Sea may indicate rather higher in the Cold Current Area than in the

Warm Current Area in the vicinity of Japan.

(8) *Ignition Loss* (Fig. 10)

The weight loss by ignition of the sample may be contributed to not only by the amount of organic matter but also by that of other decomposable matter lost by heating. Colloidal substances also may contribute to the loss owing to their bound water. In this investigation it will be observed that the loss on ignition will become greater with increase in the water depth, but a detailed inspection on the relation will be attempted in a later chapter.



Figs. 11-13, showing the relation of atomic ratio in sediment to the water depth

Fig. 11. Mg/Ca; Fig. 12. Si/Al;

Fig. 13. Fe/Mn

(9) *Ratio of Magnesium to Calcium* (Fig. 11)

The ratio of magnesium to calcium in the sample appears, as shown in Fig. 11, to increase with water depth at the site of deposition. The terrigenous deposits may show rather lower values in Mg/Ca than the pelagic ones do. Regarding the chemical weathering of mineral substances in sea bottom, Goldich (1949) pointed out that CaO might be rather more unstable than MgO. Accordingly, the increasing tendency of the ratio as observed in the present investigation may indicate that the weathering of calcium will become more advanced with increase in the water depth at the site of deposition.

(10) *Ratio of Silicon to Aluminium* (Fig. 12)

The ratio, Si/Al, in the sample may decrease in reverse proportion to increasing water depth. This tendency will show that the sediments off the coast must probably subject to weathering, and that they are decomposing progressively into clay or claylike substances.

(11) *Ratio of Iron to Manganese* (Fig. 13)

The ratio of iron to manganese in the sample seems to vary in reverse with water depth similarly to the case of Si/Al. That may be attributed either to a decrease of iron or to an increase of manganese with increasing water depth until the ratio retains a certain definite value in deep-sea floor, where an equilibrium between resolution and accumulation of these elements may be maintained according to the corresponding redox condition of the environments.

According to the discussions briefly offered above, it may be clear that the sediments in this area can be characterized as hemipelagic ones. Then, three variables, as Al, Ca plus Mg, and Fe plus Mn, were plotted in the triangular coordinates, as illustrated in Fig. 14, for examining the mineral compositions or the progress of bottom weathering in the sediments.

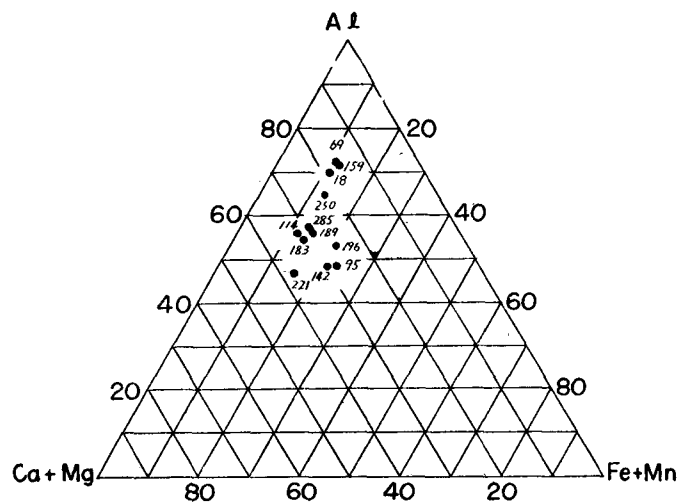


Fig. 14. Mineral composition of bottom sediment (Northern Japan Sea)

Figure 14 shows that the bottom samples from the area will show composition nearly analogous to the hemipelagic sediments and that bottom weathering is fairly progressive in the present area.

V. GENERAL CHARACTERS OF MARINE HUMUS IN THE SEDIMENTS

The term "Marine Humus" may be understood in two senses, that is to say, one

in the broad sense is analogous to total "Organic Matter" in the sediments used in the sense of organic compounds other than mineral carbonates; the other is interpreted in narrow sense as "Humic Substances", as well as soil humus, affected by bacterial or chemical activities.

In order to determine the organic content of sediments, it is customary to determine some property, such as the content of carbon or nitrogen, that has a fairly constant relation to the organic contents, and then multiply it by some approximate factor. As carbon forms about 50 or 60 per cent of the organic matter, it is an almost reliable index of the organic content. However, as the quantity of carbon in the organic matter varies somewhat, the organic content cannot be determined with absolute accuracy by means of the carbon content. As to the determination of organic carbon, there seems not any simple and rapid method with sufficient accuracy as yet, in spite of the enormous exertion by many investigators. In the present investigations, the carbon was determined by the use of Tiurin's modification (1931) of Schollenberger's method (1927), because of its simplicity and rapidity notwithstanding its unsatisfactory accuracy. The carbon content obtained thus is fairly good as a measure for organic factor of the environment in bottom floor, in particular, controls an ecological condition in the fishing ground and is influenced by hydrographical or topographical conditions. The nitrogen determinations were made by the usual Kjeldahl method. In some cases, the loss on ignition was also determined using the common procedure of igniting the oven-dried material to constant weight.

a) Chemical Constituents of Marine Humus in Littoral Sediments

Marine humus contributes to the chemical, physical or ecological conditions of the sediments in respect to the abundance or nature. Inasmuch as few investigations regarding chemical nature of marine humus have yet been made in Japan, the author attempted some investigations dealing with that of littoral sediments in Usu Bay, Hokkaido. (Fig. 15)

Previous to the investigations, the chemical and physical characters of the bottom samples were examined by usual methods, and these results were summarized in Table 5.

For making clear the composition of main organic constituents in the bottom sample, a systematic organic analysis was made by a modification of Waksman's method (1932).

Twenty-five-gram portions of the dry sample were extracted for 24 hours with ether in a Soxhlet apparatus. The ether soluble portion was determined by evaporating the ether and drying the residue in a weighing bottle. The residual mud was then treated with boiling 95 per cent ethanol for 10 hours; the ethanol extract was evaporated on water bath, and the residue was dried, and weighed. This was followed

Table 5. Characters of Bottom Samples from Usu-Bay, Hokkaido, (Aug. 1950)

	U5	U7
Location	Mouth of the bay	Inner part of the bay
Water depth (m)	5.0	1.2
Texture of sample	Mud	Mud
Organic carbon (%)	2.05	0.83
Total nitrogen (%)	0.17	0.07
NH ₃ -N (%)	0.002	0.001
NO ₃ -N (%)	0.001	0.010
Ignition loss (%)	8.83	4.60
Water (%)	6.26	4.04

by extraction with 2 per cent hot HCl solution for 5 hours. The residue left after the treatment was washed, dried, and weighed. The filtrate was mixed with the washed solution to a definite volume, after which aliquot portions were used for determining reducing sugar, ammonia-N and total nitrogen. Thus determined values contributed to estimating the organic contents, respectively, reducing sugar to that of hemicellulose, NH₃-N to that of amide. In the treatment with hydrochloric acid, a good amount of iron or aluminium was dissolved, after which was rejected by precipitation through neutralization previous to determining sugar, because these metals might inhibit the determination. The residue after hydrochloric acid treatment was dried, of which 10 grams was used for treatment with 10 cc of 80 per cent sulfuric acid solution in cold for 2.5 hours, and by dilution with 15 volumes (about 150 cc) of water and boiled for 3 hours; the residue was washed, dried, weighed, and analyzed for total carbon and nitrogen. The filtrate mixing with the washed liquor was used for determining reducing sugar and total nitrogen, of which the reducing sugar content aided in estimating cellulose content. The organic material in the residue of the sulfuric acid treatment might be called "Marine Humus" in a restricted sense, showing a hard resistance against bacterial attack or chemical weathering. Waksman (1932) suggested that the marine humus might be composed of lignin or its derivatives and that it contains 62 per cent of organic carbon.

Table 6 indicates the organic composition, in milligrams, of 100 grams of dry sample obtained by the process described above.

Between the sediments of Station U5 (the deeper position near the mouth of Usu Bay) and that of Station U7 (the shallower position in inner part of the bay), there may be observed not so great difference in the content of fat-like substances soluble in ether or ethanol as in that of cellulose or hemicellulose having hard resistance against external attacks. The quantity of the resistant humus occupies about one-third of total organic content in U7, while, a half of that in U5. The above quantities may indicate that not only the accumulation but also the huminization of the organic substances in the deposits may take place more actively in the mouth of Usu Bay than in the inner part.

Table 6. Organic Composition of Bottom Samples of Usu-Bay
(mg per 100g sample)

	U5	U7
Ether soluble matter	140	155
Alcohol soluble matter	680	573
Hemicellulose	124	9
Cellulose	199	20
Cold 80% H ₂ SO ₄ soluble	517	236
N-compound		
Lignin-humus complex	1,563	468
{ Insoluble crude		
protein	(99)	(18)
{ Lignin-complex	(1,464)	(450)
Total	3,223	1,461

b) Fractional Separation of Marine Humus

It is clear in the results obtained by the above examination that about a half or a third of the total organic substances in the bottom sample may be humus-like in nature. Next, a fractional separation was attempted by means of Waksman's method (1932).

One-hundred-gram portions of the dry sample were extracted with 100 cc portions of a 2.5 per cent NaOH solution, for 1 hour, at 15 pounds pressure. The extracts were filtered through glass filter and the residue again extracted with additional quantities of 50 cc of the same alkaline solution for 30 minutes at 15 pounds pressure, again filtered. The residues after the second extraction were neutralized in the cold with a hydrochloric acid solution (1:1). An excess of the acid, equivalent to about one-half of the amount used for neutralization, was then added. A heavy, dark-colored

Table 7. An Example of Humus Separation (mg per 100g of air-dried deposit)
(Bottom Samples of Usu-Bay)

	U5	U7
α -Fraction	836	205
β_1 -Fraction	9,818	5,302
β_2 -Fraction	235	494
γ -Fraction	664	215

precipitate was produced; it was removed by filtration through glass filter, washed with distilled water until free from acid, and dried. The precipitate was called the α -fraction of marine humus. The acid filtrate from the α -fraction was now neutralized to litmus with 40 per cent NaOH solution, to a pH value of about 4.8. A heavy precipitate was again formed, which was filtered off, washed, and dried; this fraction formed a light colored powder and was designated as β_1 -fraction. The filtrate from the fraction was now treated with saturated CaCl₂ solution, which resulted in another

heavy precipitate. This fraction was also removed by filtration, washed, and designated as the β_2 . It was also very light in color. The filtrate from the β_2 -fraction was treated with two volumes of 95 per cent ethyl alcohol. A heavy precipitate was formed, which was allowed to settle and removed by centrifuging. It was washed with 95 per cent alcohol and acetone and dried over sulfuric acid. A light-brown colored preparation was thus obtained, which was designated as the γ -fraction of the marine humus.

Some information regarding yields of the four fractions prepared from 100 gram of dry sample is given in Table 7, and those of the total nitrogen and carbon balanced and ash are given in Table 8.

Table 8. Chemical Compositions of Humus Fractions

	Fraction	Organic-C (%)	Total-N(%)	C/N	Ash (%)
U5	α	60.29	3.963	15.7	5.01
	β_1	3.70	0.312	11.9	90.71
	β_2	14.52	0.946	15.4	71.36
	γ	15.82	1.242	12.7	64.05
U7	α	63.31	3.971	15.7	4.83
	β_1	2.10	0.182	11.5	86.02
	β_2	3.24	0.201	16.2	88.72
	γ	3.72	0.675	12.9	76.03

c) Chemical Composition of Marine Humus Fractions

Table 7 shows that the respective fractions of β_1 and β_2 contain comparatively small amounts of organic materials because their major parts were mineral substances. Consequently they will be left out of further consideration.

The greater portion of the humic substances which have been extracted with diluted soda solution may be mostly the fractions of α and γ rather than of β_1 and β_2 . It is of much interest that the ratios C/N in the respective fractions of α and γ appear nearly analogous in the two bottom samples which differ from each other in the points of their depositional environments. This fact will show that these fractions obtained through the same treatments are nearly the same in chemical composition. Approximate examinations, accordingly, were conducted for ascertaining the actual compositions of the humic substances by using the predominant fractions, α and γ , mentioned above.

On the basis of the quantities of the major elements such as organic carbon, total nitrogen or mineral substances, contained in the two humus-fractions, α and γ , some presumptions were made concerning chemical constituents of the fractions. The process of such presumptions was shown in Table 9.

By subtracting the ash from the total dried materials of the α -fraction and assuming that all of the nitrogen is in the form of protein, with 16 per cent nitrogen

Table 9. Presumption of Chemical Constituents of Humus Fractions

(1) α -Fraction

	Organic Constituent	Content in the Fraction (%)	Organic-C in the Fraction (%)	Carbon in the Constituent (%)
U5	Crude Protein	24.77 (A)	12.39 (B)	50 (C)
	Non-N-Compound	70.23 (D)	47.90 (E)	68 (F)
U7	Crude Protein	24.82	12.14	50
	Non-N-Compound	70.93	49.90	71

So, the α -fraction may be mainly the Ligno-Protein Complex.

(2) γ -Fraction

	Organic Constituent	Content in the Fraction (%)	Organic-C in the Fraction (%)	Carbon in the Constituent (%)
U5	Crude Protein	7.76	3.88	50
	Non-N-Compound	64.05	11.94	42
U7	Crude Protein	4.22	2.11	50
	Non-N-Compound	80.03	6.61	41

So, the γ -fraction may be mainly the Carbohydrate-Protein Complex.

NOTE: (A) = (total-N) \times 6.25; (B) = (A) \times (C); (D) = 100 - (A) - (ash);
(E) = (organic-C) - (B); (F) = (E)/(D)

and 50 per cent carbon. The organic matter of the fraction can be divided into two complexes; namely, the protein complex, which makes up about 25 per cent, of the total fraction, and another complex, making up the remaining 75 per cent of the fraction, which is non-nitrogenous and contains 68-71 per cent carbon; this high carbon content is characteristic of lignin-complexes.

One can conclude, therefore, that the α -fraction is largely a ligno-protein complex in cases of both U5 and U7.

The organic composition of the γ -fraction can be presumed in the same way as the α -fraction. It is found that the non-nitrogenous part of the organic matter of the γ -fraction in U5 contains 42 per cent carbon and that in U7, 41 per cent. Such a constitution would place this fraction among the carbohydrates. It is very noticeable that these examinations on humus fraction lead to results almost identical to Waksman's report (1932) on the bottom samples off the eastern coast of America. On treating some of the dry γ -fraction with a hot diluted mineral acid, a considerable amount of reducing substances resulted, so the carbohydrates of the γ -fraction may consist largely of the uronic polymers as pointed out by Waksman (1932, 1933), but they were not identified.

d) Amino-Acids Detected in Marine Humus Fractions

No experiments have yet been made which allow one to identify the amino acids in marine sediments. A paper partition chromatographic method which was proposed by Davidson et al (1951) was employed to detect amino acids in marine humus fractions separated in the above experiments.

Each humus fraction was hydrolyzed with 6 N HCl in the ratio of 1:20 under reflux for 24 hours. The acid hydrolyzate was brought to dryness three times in vacuo to remove most of the HCl and then was neutralized with $\text{Ca}(\text{OH})_2$. The ammonia was distilled off, the suspension centrifuged and washed, and the combined supernatant liquid and washings made up to volume.

The amino acids in the solution were detected by a two-dimensional chromatogram where 90 per cent phenol-water solution and water-saturated solution of lutidine were chosen as solvents and the 0.1 per cent ninhydrin butanol solution was sprayed after the paper was dried. The amino acids were identified by their R_f values (Consden et al, 1944).

Table 10. Amino Acids Detected in Humus Fractions

Amino-Acid	α	β_1	β_2	γ
Glutamic Acid	+	+	+	+
Aspartic Acid	+	+	+	+
Glycine	-	+	-	-
Tyrosine	+	-	-	-
Alanine	+	+	+	+
Valine	+	+	+	+
Leucine	+	+	+	+
Iso-Leucine	+	-	-	-
Cystine	+	+	+	+

Chromatographic identifications on the humus fractions, similarly to the land soil humus, have resulted in the detecting of many amino acids, viz., glutamic acid, aspartic acid, glycine, tyrosine, alanine, leucine, iso-leucine, cystine and some unidentified acids.

VI. SEASONAL DIFFERENCE OF MARINE HUMUS CONTENT IN THE SEDIMENTS, IN CONNECTION WITH NUTRIENT METABOLISM IN THE BAY

The abundance or chemical properties of marine humus in the sediments may influence not only the ecological conditions for bottom-living animals but also the nutrition value of the sea water particularly in the bays. Those factors may also affect the cycle of nutrient metabolism found among the overlying water, organic life and sediments.

For examining how marine humus acts in metabolic cycle of nutritious substances in a restricted bay, two oceanographical and chemico-ecological investigations were made of Usu Bay, Hokkaido. The first investigation was carried out in January, 1950, and the second in August of the same year (Fig. 15).

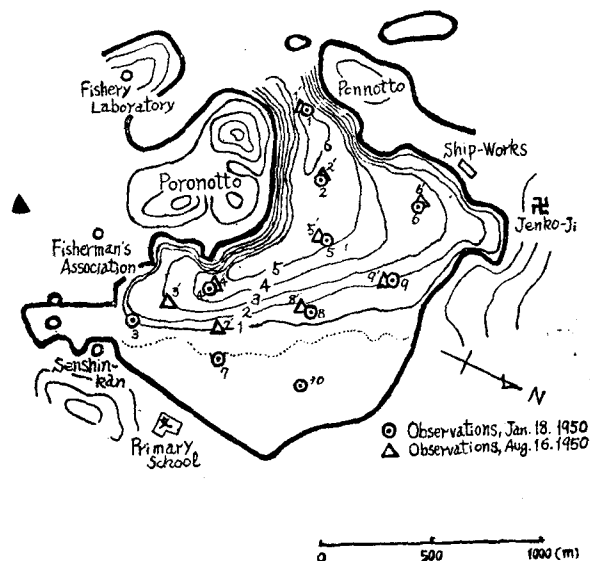


Fig. 15. Stations observed in Usu Bay, Hokkaido (1950)

Usu Bay as noted above is located in the inner part of Funka Bay, Hokkaido. It is stomach-like in shape (Igarashi, 1943). The entrance of the bay has 140 meters width and it opens out facing the Funka Bay. The long axis extends from southeast to northwest about 2150 meters, the short axis about 900 meters, accordingly, the area measures only about 37 hectares. Thus the bay is comparatively small in area, but is one of the very important and interesting fields for culture of lavers and oysters. Kinoshita (1941, 1949) continued his investigations on the life cycle of SUSABI-NORI, *Porphyra yezoensis* Ueda, in this bay, and the culture of the lavers under his guidance has been attempted with a successful outcome. Moreover, ear-shells are cultured successfully, in the reef in front of the mouth of the bay, while the culture of oysters is now being attempted in the inner part.

a) Oceanographical Character of the Bay Investigated

Of these investigations, the first was made at high tide, and was successful in investigating the entire bay. The second investigation was done at low tide and the exposed parts were out of the investigation. In both investigations, use was

made of Kitahara's B-type sea-sampler or a Tamura's syphon sea-sampler (1942) for collecting water. The latter was especially useful for collecting water near the bottom. A Tanita coring sampler (1950) and an Ekmann-Birge bottom sampler were used to obtain bottom samples. The chemical examinations were carried out by the ordinary methods.

The results obtained by these oceanographical investigations are summarized in Tables 11, 12 and 13. According to these results, the oceanographical characteristics in the bay may be stated briefly as follows :

Table 11. Results of Oceanographical Observations in Usu-Bay
(Jan. 8, 1950) —No. 1

Station Number	Depth of Layer Obs. (m)	Water Temp. (°C)	Cl (%)	Salinity (‰)	O ₂ (cc/L)	Soluble Org. Matter (mg/L)	P ₂ O ₅ (mg/m ³)	SiO ₂ (mg/L)
U 1 s	0	2.8	17.52	31.65	8.50	1.11	187	1.06
U 1 b	6.0	3.8	18.00	32.52	8.17	0.63	182	1.15
U 2 s	0	3.2	17.61	31.82	—	0.59	207	0.52
U 2 b	5.5	4.0	18.14	32.76	7.71	3.50	134	0.54
U 3 s	0	6.5	14.88	26.89	10.53	3.61	197	8.55
U 4 s	0	4.6	16.22	29.31	—	0.81	163	6.08
U 4 b	4.5	4.3	17.97	32.46	8.04	0.79	131	1.01
U 5 s	0	3.6	17.12	30.93	8.09	3.44	170	1.97
U 5 b	5.0	4.3	18.12	32.74	7.98	1.63	201	1.28
U 6 s	0	3.2	17.88	32.30	—	3.48	183	1.21
U 6 b	3.0	4.2	18.69	33.77	8.71	1.88	185	1.27
U 7 s	0	6.2	16.17	29.21	9.34	2.78	188	4.78
U 8 s	0	5.4	14.98	27.06	8.16	0.83	197	7.37
U 9 s	0	4.8	12.00	23.49	8.43	0.47	223	15.92
U 10 s	0	6.2	16.70	30.32	8.34	0.47	175	3.55

Table 12. Results of Oceanographical Observations in Usu-Bay
(Aug. 16, 1950)—No. 2

Station Number	Depth of Layer Obs. (m)	Water Temp. (°C)	Cl (%)	Salinity (‰)	O ₂ (cc/L)	Sol. Org. Matter (mg/L)	P ₂ O ₅ (mg/m ³)	SiO ₂ (mg/L)	H ₂ S (cc/L)	NO ₂ (mg/m ²)
U 1' s	0	26.7	16.77	30.30	5.08	4.45	29.3	3.65	—	2.30
U 1' b	6.0	23.4	17.81	32.18	4.12	6.24	34.3	1.31	0.52	0.93
U 2' s	0	26.8	16.25	29.36	5.44	5.18	22.2	4.63	—	0.00
U 2' b	5.5	23.6	17.84	32.23	3.81	4.88	19.1	7.20	0.50	2.03
U 3' s	0	20.9	15.23	27.52	4.65	2.73	117.5	27.35	—	2.42
U 4' s	0	25.2	14.74	26.64	4.66	4.07	65.9	11.25	—	3.00
U 4' b	3.5	24.2	17.71	32.00	3.47	5.20	55.3	1.62	0.64	0.73
U 5' s	0	26.5	15.97	28.86	4.81	6.17	32.2	4.13	—	1.16
U 5' b	4.5	23.9	17.75	32.07	3.87	4.15	93.5	1.67	0.42	0.98
U 6' s	0	25.7	15.90	28.73	4.46	5.29	66.5	5.59	—	4.76
U 6' b	2.7	25.0	17.64	31.87	3.87	5.08	50.0	1.81	0.45	0.00
U 7' s	0	23.0	15.54	28.08	4.97	4.60	137.0	20.90	—	4.50
U 8' s	0	25.6	15.56	28.12	4.80	4.02	104.8	19.05	—	4.80
U 8' b	1.0	25.5	16.62	30.03	4.07	4.36	71.3	5.30	0.35	2.50
U 9' s	0	26.8	12.55	22.68	4.92	3.20	103.2	16.90	—	3.31
U 9' b	1.5	26.7	16.55	29.90	4.60	3.79	50.0	4.55	0.30	0.43

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Table 13. Chemical Properties of Bottom Samples in Usu-Bay

A) In Winter (Jan. 18, 1950)

Station Number	Depth (m)	Texture	Loss on Ignition (%)	Org.-Carbon (%)	Total-Nitrogen (%)
U 1	6.0	M	7.10	2.69	0.19
U 2	5.5	M s	5.56	1.34	0.10
U 3	1.2	M s	4.05	0.91	0.02
U 4	4.5	M	5.93	1.35	0.13
U 5	5.0	M	6.60	2.06	0.41
U 6	3.0	M	9.51	2.19	0.16
U 7	1.0	M s	3.91	0.74	0.13
U 8	1.5	S	3.74	0.77	0.06
U 9	2.0	S, G r	2.70	0.61	0.06
U10	1.0	M s	3.50	0.70	0.20

B) In Sumner (Aug. 16, 1950)

Station Number	Depth (m)	Texture	Loss on Ignition (%)	Org.-Carbon (%)	Total-Nitrogen (%)
U 1'	6.0	M	12.07	2.72	0.19
U 2'	5.5	M	11.53	3.00	0.25
U 3'	0.4	M s	3.62	0.58	0.08
U 4'	3.5	M	7.66	1.74	0.15
U 5'	4.5	M	8.83	2.05	0.17
U 6'	2.7	M	8.72	2.06	0.17
U 7'	0.5	M	4.69	0.83	0.07
U 8'	1.0	S, G r	3.84	0.69	0.12
U 9'	1.5	M	5.78	1.22	0.12

1) As the entrance of the bay is very narrow, the open water has little influence upon the oceanographical conditions of the bay. The water in the bay is exchanged mostly by tidal currents.

2) From the southeastern corner of the bay near SENSŌIN-KAN, a fairly good amount of fresh water flows into the bay, and serves to dilute the bay water or to supply mineral nutrients such as silicates and phosphates.

3) There are found four masses of water controlling the properties of the water in the bay; (1) the open water flows through PORONOTTO, (2) water which is low in salinity but enriched in nutrients remains stagnant at the southeastern corner of the bay, (3) the water at the northwestern part has higher salinity and abundant dissolved organic matter and (4) another body of stagnant water at the northwestern part separated from the less saline waters at the southeastern corner.

4) There is a good population of animals and plants, viz., lavers, eelgrass, benthos and plankton, and the metabolic circulation of nutrients may progress actively between the bottom and overlying water, when the above population may act as a medium.

b) Discussion on Seasonal Differences of Nutrients and Marine Humus

Seasonal differences between winter and summer in respect to chemical properties of water and of sediments are of much interest in suggesting the development of metabolism in the bay. The metabolism may be somewhat influenced by the topography too.

For examining the metabolism in the bay, the seasonal differences of nutrients in water or in deposits were observed. For this purpose the bay was divided into two regions according to topography: One of the regions, A-region, is located near the entrance of the bay and has water depth over three meters. The other region called B-region is in the inner part of the bay and has water depth under three meters. The former comprises stations U1,2,4,5, and 6 and has muddy deposits, and the latter comprises stations U3,7,8,9, and 10 and has sandy mud sediments. The seasonal differences of nutritious matter in water or in deposits are indicated in connection with topography in Tables 14 and 15 respectively, where properties of water shallower than 0.5 meters were computed, in summer, in common between the two regions.

Table 14. Seasonal Difference of Nutritious Matter of Sea Water in Usu-Bay (1950)

Item			Sol. Org. Matter (mg/L)	P ₂ O ₅ (mg/m ³)	SiO ₂ (mg/L)
Jan.	A-Region	Surface Water (a)	1.89	182	2.17
		Bottom Water (b)	1.69	167	1.05
	(Average) (c)		(1.79)	(175)	(1.61)
	B-Region	Surface Water (d)	1.62	196	8.03
	Average on the Whole Bay (A)		(1.71)	(188)	(4.82)
Ratio of A to B (c)/(d)			1.10	1/1.12	1/5.00
Aug.	A-Region	Surface Water (e)	5.03	43.2	1.85
		Bottom Water (f)	5.11	50.4	2.72
		(Average) (g)		(5.07)	(46.8)
	B-Region	Surface Water (h)	3.64	115.1	21.05
		Bottom Water (i)	3.88	94.7	14.52
		(Average) (j)		(3.76)	(104.9)
	Average on the Whole Bay (B)		(4.49)	(72.6)	(8.40)
	Ratio of A to B (g)/(j)		1.35	1/2.24	1/7.76
Seasonal Difference on the Whole (B)/(A)			2.63	1/2.61	1.74

Note: "A-region", having water depth over 3 meters Stations of U1, 2,4,5, and 6.
 "B-region", having water depth under 3 meters Stations of U3,7,8,9, and 10.

(1) *Properties of the Water*

i) Soluble Organic Matter

The distribution of soluble organic matter in the bay water has not indicated, in winter, any very remarkable deviation owing to topography : The greatest amount (1.89 mg/L) was found in the surface layer of A-region, a moderate amount (1.69 mg/L) in the bottom layer of the same region and the least (1.62 mg/L) in B-region. Thus the greatest amounted to only 1.1 times the least. On the other hand, in summer, a considerable accumulation of organic matter was observed in the bottom layer of A-region (5.11 mg/L). The organic contents of the water in A-region appeared more abundant, being 1.35 times that of B-region. In general, a remarkable accumulation was observed in summer, and the average quantity in the whole in summer (4.49 mg/L) was 2.63 times that in winter (1.71 mg/L). When comparing the upper water with the bottom, the larger content of organic matter was found, in winter, in the upper water, while that in summer was found in the bottom layers. Throughout one year, the water of A-region appeared more abundant in organic matter content than that of the B-region. The regional difference in the accumulation of water-soluble organic matter between these regions might however be more remarked in summer, and especially more distinguished in the water in A-region.

ii) Phosphate

In winter, the upper water was richer in phosphates than the bottom water was. The most abundance in the bay was found in the water of the inner part (196 mg/m³) which is usually under the influence of fresh water near SENSINKAN, a moderate amount was found in the upper water of A-region (182 mg/m³), and the comparatively poor amount in the bottom water of the same region (167 mg/m³) which was scarcely diluted by the fresh water. The amount of phosphates in the whole bay appeared less remarkable in winter, comparing with that in summer. There was found, however, more abundant distribution in B-region than in A-region.

In summer as well as winter, the water of B-region was found richer in phosphate than that of A-region : The former content (115 mg/m³) was 2.24 times as large as that of the latter one (47 mg/m³). The most abundance in phosphate content was found in the upper water (115 mg/m³) of B-region, next in the bottom water of the same region (95 mg/m³). Of A-region, the content appeared larger in the bottom water (50 mg/m³) than in the upper (43 mg/m³).

The quantity of phosphate in the whole bay has reduced in summer (72.6 mg/m³) to 1/2.6 of that in winter (188 mg/m³). The larger content was found, in winter, in the upper water, but that in summer found in the bottom water. Throughout the year, the phosphate content was larger in the upper water than in the bottom, that tendency being rather marked in summer.

iii) Silicate

The amount of silicates in the bay water may be largely contributed by the inflow of fresh water. So, the shallow water in the inner part of the bay was enriched in silicate, so that the content in winter (8.0 mg/L) was about five times that in the outer A-region. There was found a remarkable deviation on silicate distribution between these two regions. Even in A-region, silicate content in the upper water which was diluted with fresh water was about two or more times as large as that in the bottom water.

In summer, silicate in B-region was more concentrated (7.7 times) than that in A-region. Silicate in the upper water of B-region indicated remarkable concentration (21 mg/L), and even in the bottom layers, seven times that in A-region. However, the silicate content in A-region was larger in the bottom water than in the upper water, resembling the case of phosphate content.

The amount of silicate in the bay water appeared, in general, more marked in summer (8.40 mg/L, average in whole bay) than that in winter (4.82 mg/L, average in whole bay). Thus concentration in summer might show some predominant influences of the fresh water flowing into the bay. Such influences, accordingly, were more remarkable in the upper water (21.05 mg/L). On the other hand, the silicate distribution in A-region was different in feature from that in B-region. The concentrated layer was found rather alternating by season, namely, the greater quantity in summer being found in the upper layers but that in winter found in the bottom.

The seasonal differences in nutritious materials in the water of Usu Bay may be summarized as follows:

1) The distribution of silicate or of phosphate in the bay may be influenced by fresh water flowing into the bay. The terrigenous supplies of these salts seem contributed not only by dilution with the fresh water from a spring near the eastern corner but also by the water which oozes from the coastal bank and dissolves probably a fairly amount of mineral substances.

2) Both contents of dissolved organic matter and silicate appeared remarkably plentiful in summer. A different feature was shown in the comparatively deep area such as A-region where terrigenous influences was not so predominant as in a shallow area such as B-region. That is to say, in the deep place of the bay, these contents may reduce for the period from spring to summer owing to biochemical consumption which may be resulted from remarkable developments of phytoplankton or other organisms. This reduction seems rather remarkable in the upper water, but it may be less remarkable in the shallow place, because a fairly good amount of these mineral nutrients is customarily supplied in the shallow place near the beach.

3) The pronounced development of phytoplankton in spring may contribute to a noticeable reduction of phosphate which has been accumulated during winter. This reduction of phosphate content may become further remarkable owing to an

insufficient supply from land.

In summer, the amount of phosphate in the whole bay seems to become 40 per cent of that in winter. Especially this tendency appears very remarkable in the deep place where the contents have decreased to one-quarter for the summer period. Further, the amount of phosphate in summer even in the shallow place has decreased to a half of that in winter.

(2) Organic Content in Sediments

The organic content in the sediment has been indicated by respective measures of the weight loss by ignition the organic content, or the total nitrogen. The content appeared in general to be abundant rather in the deep place than in the shallow one.

Ignition loss of the sediment appeared more abundant in summer (7.59%) in the whole of Usu Bay, being 1.44 times that in winter (5.27%). That might be remarked rather in the deep bottom, where remains of plankton or plants would be accumulated progressively.

Table 15. Seasonal Difference of Organic Matter of Bottom Deposits in Usu-Bay (1950)

Item		Ignition Loss (%)	Org. Carbon (%)	Total Nitrogen (%)	C/N
Jan.	A-Region (a)	6.94	1.93	0.20	9.65
	B-Region (b)	3.60	0.75	0.09	7.79
	Average on the Whole Bay (c)	(5.27)	(1.34)	(0.15)	(8.81)
	Ratio of A to B (a)/(b)	1.93	2.57	2.22	1.21
Aug.	A-Region (d)	9.76	2.31	0.19	12.15
	B-Region (e)	4.48	0.82	0.09	9.10
	Average on the Whole Bay (f)	(7.50)	(1.65)	(0.15)	(10.76)
	Ratio of A to B (d)/(e)	2.18	2.81	2.11	1.34
Seasonal Difference on the Whole Bay (f)/(c)		1.44	1.23	1.00	1.21
On A-Region (d)/(a)		1.41	1.19	0.95	1.25
On B-Region (e)/(b)		1.24	1.09	0.95	1.13

Cf. "A-Region", having water depth over 3 meters, Stations of U 1, 2, 4, 5, 6;
 "B-Region", having water depth under 3 meters, Stations of U 3, 7, 8, 9, 10.

The average content of organic carbon in summer was 1.65% which is 1.23 times that in winter (1.34%). That accumulative ratio between summer and winter, however, seemed not so remarkable as the ratio of ignition loss. In this case, the seasonal difference in the deep place, or A-region, appeared as remarkable as in the case of ignition loss.

As to total nitrogen, it would be hard to find any variation owing to season. Alike to ignition loss or organic carbon, the quantity of total nitrogen would be remarkable rather in the deep place (0.20%) which is double of that in the shallow place (0.09%).

According to the results observed above the seasonal difference of organic matter in the sediment may be emphasized as follows :

For the period from spring to summer, the activities of life will be very marked, and organic production will progress actively. The organic remains, accordingly, will be accumulated gradually on the bottom floor and this accumulation will be rather remarkable on the lower bottom levels. After the remarkable accumulation on the bottom floor, however, the seasonal variation of nitrogenous substances in the deposits will be rather less remarkable in comparison with that of such non-nitrogenous materials as carbohydrates and it appears nearly constant for the whole year. The major part of nitrogenous substances accumulated in the deposits may convert into humic substances after bacterial activities, or a part of them may enter into the bodies of such bottom-living organisms as bacteria. Therefore, the difference of organic content between winter and summer, as shown by organic carbon content or by ignition loss, might suggest the relative amount of energy necessary for organic activities in the bay. Judging from the noticeable seasonal variation of phosphate content in the bay water, the amount of phosphate seems to be the major limiting factor controlling the organic production in Usu Bay.

The ratio of carbon to nitrogen in sediment, as indicating the progress of biochemical metabolism in sediments, indicated, in the whole bay, 8.8 in winter or 10.8 in summer. This fact shows that organic metabolism in bottom floor has been going on under rather favourable condition. In summer, the ratio has grown larger in value than that in winter, owing to the increase in quantities of carbohydrates which have been generated by photosynthesis of plants.

It may become clear after these examinations that the abundance and the nature of organic materials in sediment will relate not only to organic sources supplied but to organic activities occurring in Usu Bay.

VII. CONSUMPTION OF WATER-DISSOLVED OXYGEN BY SEDIMENTS, AS AFFECTING REDOX CONDITION OF BOTTOM FLOOR

Oxygen content of sea water has long been studied extensively by innumerable investigators, and the results of their works have revealed various important and interesting facts in biology as well as in oceanography, chemistry or other sciences. Surface water in general is nearly saturated with or rich in oxygen, but the distribution of oxygen at different depths in the water varies greatly according to circumstances. The oxygen dissolved in sea water then controls the animal life dwelling there. In

the open ocean, it is rarely found, excepting near deep sea bottom, that the livings are impossible to be alive owing to lack of oxygen. But, in a restricted bay such as the Norwegian fjord or in stagnant bottom of a depressed basin where may be accumulated an enormous amount of reductive material such as remains of organisms, there is often reported the existence of a water layer containing practically no oxygen at all. Without oxygen, the products of decomposition would be very different from those formed in the presence of oxygen, and the chemical nature not only of the water but also of the sea bottom should be materially altered. In short, a respiratory system is as essential for ocean life as it is for an animal. Here one meets with the problem of oxidation-reduction in waters or in bottom sediments. As to the intensity of the oxidation-reduction in bottom materials, ZoBell (1937) pointed out that some marine deposits had remarkable reducing intensities, and Nomura (1941) emphasized that the oxidation-reduction potential should be studied as an important ecological factor of environmental conditions. The lowering of the redox potential in bottom materials may be caused largely by the lack of oxygen owing to various causes.

The lack of oxygen available in bottom may be attributed to the insufficient supply of oxygen from the overlying water, or to the less production of oxygen by plant metabolism than that in the upper water. Moreover, the lack of oxygen may be greatly attributed to the consumption of oxygen by the sediments. As to the causes which seem to have exert some influence upon the oxygen consumption by the sediments, one may emphasize various factors such as bacteriological or chemical.

Ecological investigations dealing with the oxygen consumption by subaquatic sediments have been carried out in Japan by many investigators; namely, Miyaji (1934) and Yamamoto (1942) on the lake deposits, Motoda (1934) on the silts of coral reef, Kawamura (1940), and Kato, T. (1940, 1949) on bay deposits, Kurashige and Ohta (1942) on mud in tideland, but most of them respectively have studied from the standpoint of biology.

Therefore, the present author and his collaborators have undertaken some biochemical investigations concerning the oxygen consumption by marine sediments. Hemipelagic sediments from the northwestern sea of Hokkaido, 100-1,000 meters in water depth, and littoral sediments from the Bays of Shiogama and Onagawa, Miyagi Prefecture, were respectively employed as experimental materials on these investigations.

a) Descriptions of Bottom Samples and Methods Employed

As to the activities of oxygen consumption by the sediments in situ, field experiments were made on ship board at 20 stations, ranging from 90 to 950 meters in water depth, of the oceanographical investigation in summer of 1949, in the Northern

Japan Sea, northwest of Hokkaido. The general characters of bottom samples were shown in Table 16.

On the other hand, the bottom samples obtained from Shiogama Harbour, Miyagi Prefecture, were employed for examining the relations of the oxygen consumption to the bottom characters. The harbour is located in the inner part of Matsushima Bay. It is almost restricted, and comparatively shallow in depth, becoming gradually shallower owing to the settling of debris. Consequently, dredging of the bottom is

Table 16. Organic Character and Oxygen Consumption of Bottom Samples of the Sea to the North-West of Hokkaido Island

St. No.	Location		Depth (m)	Texture of Deposit	Organic Carbon (%)	Total Nitrogen (%)	Oxygen Consumption (cc/100cc mud)
	Lat. N	Long. E					
M 17	43°30'30"	140°29'48"	680	M	2.61	0.34	8.1
M 21	43°30'30"	139°59'12"	616	M s, G r	1.22	0.12	5.3
M 24	43°37'18"	140°15'30"	760	M	2.18	0.49	3.3
M 30	43°34'30"	140°55'30"	145	G r, S	0.64	0.49	5.4
M 31	43°39'30"	140°56' 0"	450	M	2.53	0.07	6.1
M 51	43°50'12"	140°16' 0"	147	MS	1.97	0.27	17.3
M 54	43°39'36"	140°57'24"	395	M	2.46	0.15	10.1
M 95	44° 3'30"	139°59'24"	950	M	2.04	0.25	3.1
M 97	44° 4'12"	140°12' 6"	690	M	2.36	0.63	6.4
M 138	44°14'42"	141°17' 0"	90	MS	1.32	0.25	11.5
M 141	44°19'54"	141° 5'36"	340	M	2.11	0.09	13.2
M 184	44°33'42"	139°31'18"	590	MS	1.25	0.31	7.2
M 189	44°34'12"	140° 6' 6"	320	MS	0.49	0.15	5.2
M 195	44°34'18"	140°51'30"	230	MS	0.72	0.06	11.0
M 245	44°52'54"	140°34'30"	360	MS	2.02	0.09	15.0
M 248	44°53'24"	140°53' 6"	140	S	0.98	0.27	12.0
M 264	45° 4'24"	140° 1'30"	512	MS	1.41	0.17	8.0
M 269	45° 3'42"	140°36' 6"	365	M	1.89	0.21	10.5
M 298	45°19'30"	140°37' 6"	468	M	2.32	0.21	6.4
M 306	45°24'18"	140°18'42"	450	M	2.17	0.18	12.6

necessary. The water is comparatively stagnant with little disturbance by wind; it is contaminated by accumulation of sewages, and the bottom appears almost muddy. Figure 16 indicates the stations of observations in Shiogama Harbour. Table 17 shows the tabulated data of bottom samples of the harbour.

Furthermore, experiments concerning the relations between the consumption and the temperature were carried out in the Marine Laboratory at Onagawa, attached to the Tohoku University, by kindness of Prof. Takeo Imai. The mud samples obtained off the Laboratory contained 2.75 per cent of organic carbon on dry basis.

The activities of these bottom samples were determined respectively by employing the following methods:

(1) Since the shipboard experiments, in the investigations of the Northern Japan Sea, were attempted preliminarily, they might be rather more unsatisfactory than those in laboratory for accurately determining the activities. It might however be somewhat possible to observe the approximate intensities of the consumption of oxygen by bathyal sediments.

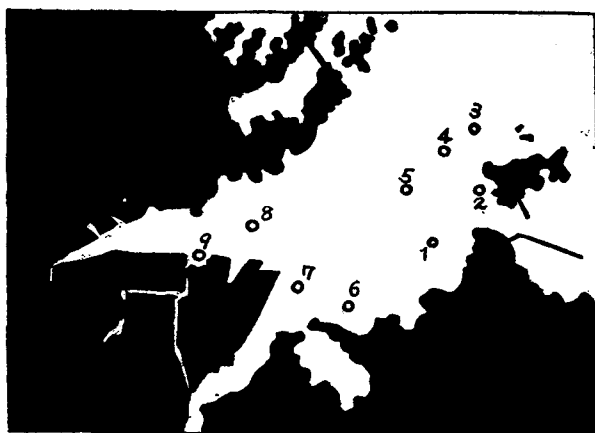


Fig. 16. Stations observed in Shiogama Harbour, Miyagi Prefecture (1951)

Table 17. Characters of Bottom Samples from Shiogama Harbour.

St. No.	Depth (m)	Fine Mud ($<10\mu$) (%)	Organic Carbon (%)	Total Sulfide (%)
S 1	1.5	67.4	2.60	0.055
S 2	1.8	79.1	2.92	0.127
S 3	2.0	47.3	1.95	0.001
S 4	1.5	73.5	2.92	0.115
S 5	1.0	62.4	2.79	0.109
S 6	1.2	78.4	3.42	0.163
S 7	7.0	89.5	3.21	0.284
S 8	4.5	88.2	3.08	0.668
S 9	3.0	40.3	4.15	1.174

At each station, four grams of bottom sample were taken up immediately with measuring spoon from the bottom sampler, put into a bottle of 250 cc capacity and water added until the bottle was sufficiently filled without air bubbles. The bottle was allowed to stand for 12 hours after shaking 50 times by hand. A portion of the supernatant fluid was transferred with syphon to Winkler's oxygen bottle, the oxygen in water being determined by using Winkler's method. The quantity of oxygen consumed by the bottom sample was computed on the basis of 100 grams of wet sample from the reduction of the quantity of oxygen in sea water after consumption by sediments.

(2) As to the bottom samples from Shiogama Harbour, the treatment as described above was adapted for field observation, but the consumption was allowed to continue for 24 hours after shaking for two minutes. The supernatant fluid was treated in the same manner as mentioned above. The quantity of consumed oxygen, however, was given per 100 grams of dried sample left after treatment of consumption.

(3) The bottom samples from Onagawa Bay were brought, keeping without

contact with air, to laboratory, and used for experiments. In experiments, 6 cc of mud sample was used, and the mud which remained after experiment was transferred on filter paper, washed and dried in the same manner as above. The amount of consumed oxygen was given per 100 grams of dried mud.

b) Relation of Oxygen Consumption to Experimental Procedures

Previous to experiments regarding the consumption of oxygen by marine sediments, it may first be necessary to inquire into the method which is to be employed for inspecting the factors controlling the consumption. So, some preliminary experiments were done on the experimental procedures for determining the activity of the action, wherein bottom samples from Shiogama Harbour were mostly employed but samples from Onagawa Bay were used in part for examining the relation of the activity to the experimental temperature.

(1) *Amount of Oxygen Consumed and Amount of Test Sample*

The amount of test sample used for experiment may affect the activity of consumption, hence some experiments were carried out for examining this relation. Table 18 as illustrating this relation shows that the larger the amount of the sample employed the greater was the amount of oxygen consumed. However, the differential

Table 18. Oxygen Consumption and Quantity of Sample

Dried Sample (g)	0.53	0.93	2.13	3.79	9.98
Decreased-O ₂ (cc/L)	2.02	2.13	2.81	3.84	4.94
O ₂ -Consumption (cc/g × 100)	81.0	48.7	27.2	20.3	10.0

Temperature 8.8°C

consumption per gram of test sample may be rather declining, which might be due to reduction of relative surface of sample settled on the bottom of the experimental vessel. For comparison between the activities of oxygen consumption by different bottom samples, it appears necessary to use a definite amount of mud for the experiments.

(2) *Amount of Oxygen Consumed and Duration of Standing previous to Experiment*

The bottom samples taken from the anaerobic environments may be probably sensible to external oxidation previous to experiments. The influence of the length of time, for which the mud sample is allowed to stand previous to experiments, upon the activities of oxygen consumption should perhaps be examined. After having been obtained from bottom, the samples were exposed to air during different hours, viz., 0, 6, 22.5 or 48 hours, previous to experiments. The results are shown in Table 19.

Table 19. Oxygen Consumption and Expored Duration after Sampling

Time (hrs.)	0	6	22	30	48
Decreased-O ₂ (cc/L)	2.59	3.80	3.89	4.02	4.03
O ₂ -Consumption (cc/g×100)	24.8	30.1	31.7	33.3	32.5

Temperature 10.0°C

These results show that the exposure of deposits appears to excite the activity of consumption of sediment. That is to say, the sample exposed for six hours has indicated rather more remarked consumption than that without exposure. By further exposure, however, the bottom sample does not consume so much more oxygen than occurred upon exposure for 6 hours. This fact may suggest that a suitable exposure may activate any agents of oxygen consumption in sediments.

(3) *Amount of Oxygen Consumed and Shaking Time of Experimental Vessel*

As pointed out by Kawamura (1940) or by Kurashige and Ohta (1942), the consumption of oxygen by sediments seems to advance greatly within comparatively short times. The influences of shaking the experimental vessel with mud and base water were next examined. The results were shown in Table 20. There may be observed that the more the vessel was shaken the more oxygen consumed.

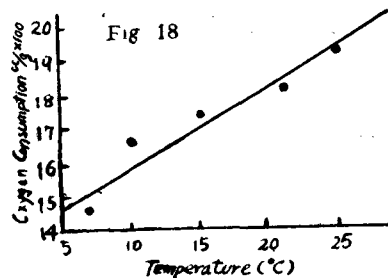
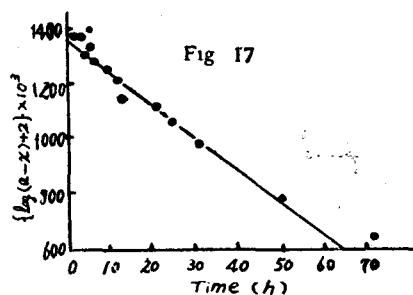
Table 20. Oxygen Consumption and Shaking Duration.

Time (min.)	2	4	6	10	20
Decreased-O ₂ (cc/L)	2.77	3.05	3.00	3.35	3.31
O ₂ -Consumption (cc/g×100)	32.0	35.0	36.1	38.1	42.6

Temperature 8.8°C

(4) *Amount of Oxygen Consumed and Reaction Period*

The rate of oxygen consumption by the sediment was examined by the following



Figs. 17-18, showing the relations of oxygen consumption by sediment to the experimental conditions

Fig. 17. Duration of consumption; Fig. 18. Consumption temperature

experiments. Using sea water kept at $10 \pm 0.1^\circ\text{C}$ as the base water, the deviation in oxygen consumption was examined at the same temperature but for different duration of reaction. The results are shown in Table 21 and Fig. 17, where the ordinates are the logarithms of the consumed amount of oxygen and the abscissae are the corresponding reaction periods. It is obvious that a nearly linear relationship is found between these two variables; therefore the consumption velocity will change adapting to the first reaction formula.

(5) *Amount of Oxygen Consumed and Reaction Temperature*

In general, elevation of reaction temperature has a marked effect upon the velocity of chemical reaction. The relation between the reaction temperature and the corresponding oxygen consumption was examined using bottom samples from Onagawa Bay. At different temperatures, viz., 6, 8, 10, 15, 21 and 25°C , oxygen in filtered sea water was consumed by the bottom sample for 24 hours. The results obtained are shown in Table 21 and Fig. 18. An approximately linear relationship is found, similarly to that shown in Fig. 18, between these two variables. Moreover, statistical

Table 21. Oxygen Consumption and Reaction Temperature

Temp. ($^\circ\text{C}$)	Sample (g)	Initial- O_2 ($\text{O}_2\text{cc/L}$)	Decrease ($\text{O}_2\text{cc/L}$)	Consumption ($\text{cc/g} \times 100$)
6.8	4.81	5.45	3.36	14.6
10.0	4.20	5.36	3.33	16.6
15.0	4.28	5.30	3.60	17.4
21.0	4.42	5.18	4.14	18.2
25.0	4.19	4.86	4.06	19.3

Table 22. Correlation of Oxygen Consumption to Experimental Conditions

(1) Relation between Oxygen Consumption and Consuming Duration (Samples of Shioyama Harbour)

Factor	Variation	Degree of Freedom	Mean Square	F
Regression	707.99	1	707.80	475.7
Residual	19.34	13	1.49	
Total	727.13	14		

(2) Relation between Oxygen Consumption and Experimental Temperature (Samples of Onagawa Harbour)

Factor	Variation	Degree of Freedom	Mean Square	F
Regression	11.5	1	11.5	31.1
Residual	1.1	3	0.37	
Total	12.6	4		

test showed a linear regression between them at 95% level of confidence ($F=31.1 > F'_{13}(0.05)$).

From all of the base water used in these preliminary experiments, suspended materials such as the remains of organisms had been removed by filtering. Some blank tests were made for examining the oxygen consumption by bacteria in the base waters. Such examination showed that the bacterial consumption of oxygen is not very remarkable, but, in fact, rather negligible in the present experiments.

c) Examination of Factors Controlling the Oxygen Consumption

There are emphasized mainly two factors controlling the oxygen consumption by sediments: One of these factors is a biological one exerted by bacteria in the bottom, while the other is a chemical one exerted by reductive organic matter as well as reduced heavy metals in the sediments.

As to the factors concerning oxygen consumption, Kato, T. (1949) emphasized a decay of mud, and Kawamura (1940) pointed out that the finer part of the sediment was related to oxygen consumption by sediment. Kurashige (1942) suggested that the oxygen consumption was contributed to by abiotic factors such as organic matter, iron compounds or other sulfides, rather than by biotic ones such as bacterial activities or enzymes of organisms. On the other hand, Miyadi (1934) indicated, as to oxygen consumption by lake deposits, that a certain relationship existed between the consumption and the trophic type of lake. Yamamoto (1942) said that the consumption in eutrophic lake was related closely to loss on ignition of the sediments, but that was not related to the microorganisms in the bottom.

So the author undertook to examine the relation between the bottom characters and the factors exerting influence upon the consumption. Nine bottom samples from Shiogama Harbour were employed as test materials. Statistical tests were made of correlations between the activity of oxygen consumption and the bottom characters. The results are summarized in the two Tables, 23-24.

For grasping the elementary factors controlling the oxygen consumption, the activities of consumption were determined of the bottom samples which had been treated by various methods as follows:

(1) *Examinations on Oxygen Consumption Due to Biotic Elements*

For inquiring into the influences of biotic factors such as bacteria or enzymes, the bottom samples were treated as follows:

(a) Measured on ship-board without any treatment just after collection from bottom Consumption due to all factors.

(b) Measured on ship-board after inhibiting bacterial activities by adding drops of toluene. Most of bacterial activities may be inhibited, accordingly,

the activity of consumption ought to become weak owing to reduction of bacterial activities.

(c) Measured after treatment for inhibiting activities of both the bacteria and the enzymes. That is, the sample bottle previous to measurement was allowed to stand in boiling water for 30 minutes. The treatment causes the consumption to be reduced owing to inhibition of the activities of both bacteria and enzymes.

(a)–(b)=Consumption owing to bacterial activities

(b)–(c)=Consumption owing to enzymes

(c)=Consumption owing to abiotic elements

Table 23 shows that the oxygen consumption appears largely controlled by abiotic elements rather than biotic ones such as bacteria or enzymes.

Table 23. Examination on Causes of Oxygen Consumption
(Samples of Shiogama Harbour)

St. No.	A	B	C	A-B	B-C
1	39.7	34.1	23.4	5.6	10.7
2	31.9	31.8	23.5	0.1	8.3
3	28.9	22.7	16.0	6.2	6.7
4	32.9	31.7	23.2	1.2	8.5
5	42.1	34.0	23.2	8.1	10.8
6	41.5	38.9	30.2	2.6	8.7
7	37.8	36.4	22.0	1.4	14.4
8	40.2	39.2	28.5	1.0	10.7
9	33.5	32.4	20.6	1.1	11.8

A : Measured on ship board, just after sampling (Consumption by all factors).

B : Measured, after the sample was added a few drops of toluol (for restraining bacterial activities of the sample)

C : Measured, after the sample was placed in boiling water for half an hour, for restraining both activities of bacteria and enzymes in the sample. (Consumption by abiotic factors)

A-B : Consumption by bacterial activity

B-C : Consumption by enzymes

(2) Examination of oxygen consumption owing to abiotic elements

The oxygen consumption owing to abiotic elements was examined in connection with characters of bottom sample as respective amounts of sulfides, organic matter or mud in the sediments.

1) Oxygen Consumption and Sulfide Content in Sediment

The sulfides in bottom samples were determined by means of Tomiyama-Kanzaki's method (1942). The raw sample was allowed to distill, after adding 2cc of 10 per cent HCl solution, for 5–8 minutes. The distillate was caught in 5cc of saturated solution of zinc acetate. Zinc sulfide formed here was oxidized by adding iodine solution and 2cc of 10 per cent HCl solution; the sulfide could be determined by titrating the remaining iodine with N/20 solution of $\text{Na}_2\text{S}_2\text{O}_3$. The sulfide content

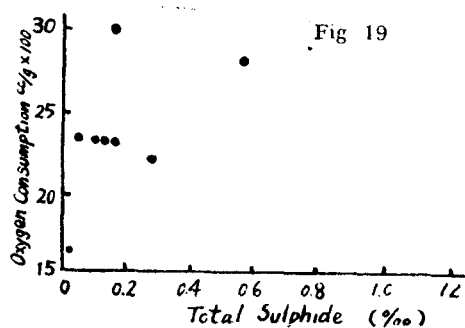


Fig. 19. Oxygen consumption and total sulfide content

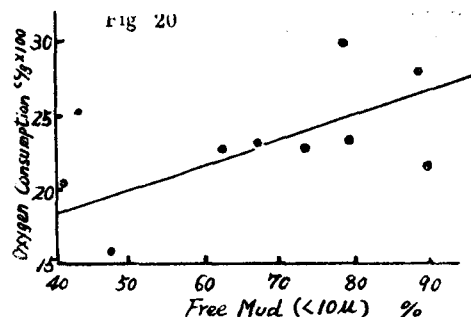


Fig. 20. Oxygen consumption and fine mud content

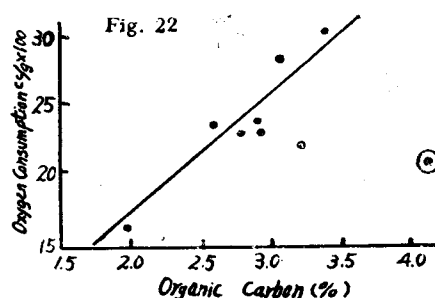
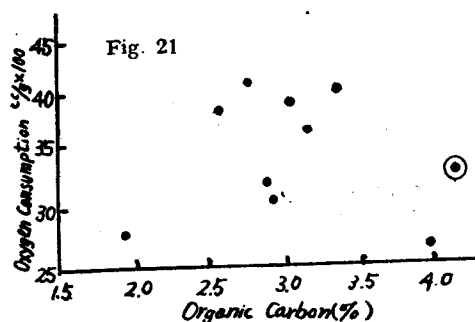
was indicated as grams per 1,000 grams of dried sample. It may be scarcely possible to observe in Fig. 19 any certain relationship between the oxygen consumption and sulfide content in sediments.

2) Oxygen Consumption and Amount of Mud in Sediment

By using the A.S.K. apparatus (Ōsugi, 1988) for mechanical analysis, the grain size grades of sediments were investigated, whereby the amounts of fine mud were measured. There was observed a certain correlation, as shown in Fig. 20, between the amount of fine mud and the oxygen consumption. The correlation was ascertained at a 95% level of confidence. ($F_0=5.89 > F'_0 (0.05)$).

3) Oxygen Consumption and Organic Content in Sediment

No correlation could be observed, as indicated in Fig. 21, between the content of organic carbon and the oxygen consumption which was measured without pretreatment just after obtaining the sample. The statistical test on the linear regression between the two variables also led to the same result ($F_0=1.61 < F'_0 (0.05)$). Bottom sample of St.S9 was obtained from bottom near a wharf, and having a good amount of organic matter which was decomposed insufficiently yet. That seemed rather extraordinary in comparison with other bottom samples. Another inspection on the relationship in question was consequently attempted excepting the bottom sample of St.S9. But that test resulted unsatisfactorily too, that is to say, there was not always observed any relationship between them ($F_0=3.47 < F'_0 (0.05)$). So it may be hardly possible to assert any definite relationship between these variables. Regarding this relation, further inspection was made as follows (Fig. 22): A statistical examination was carried out concerning the correlation between the organic content and the oxygen consumption of bottom sample pretreated in boiling water, of which result could be scarcely satisfactory for proving the linearity. So, the data of St. S9 were examined statistically to determine whether they could be accepted or not.



Figs. 21-22, showing the relation between the oxygen consumption and organic carbon content of near-shore sediment (Shiogama)

Fig. 21. By sediment untreated

Fig. 22. By sediment treated in boiling water

The examination showed that the data would be abandoned at 99% level of confidence. As to 8 bottom samples excepting St.S9 sample, statistical examinations were made for ascertaining the relationship between the organic contents and the oxygen consumption by the abiotic factors, whereby it was ascertained that there might be found a linear relation between these variables ($F_0=13.75 > F'_8 (0.01)$).

After all, there could scarcely be found any relationship between the organic content and the entire oxygen consumption as measured on shipboard just after obtaining the sample. Accordingly, it might be found that the entire consumption was not always affected by the organic matter in the sediments, nevertheless the restricted consumption by abiotic elements appeared to be affected by the organic matter in the sediment. Concerning the bottom samples from the Northern Japan Sea (Fig. 24), there did not exist any relationship between the consumption and the organic content.

4) Amount of Fine Mud and Organic Carbon Content in Sediment

Figure 23 illustrates the relation between the amounts of fine mud less than 10μ in grain diameter and the organic contents in bottom samples, whereby it could

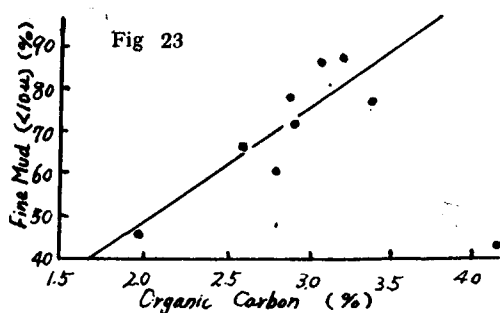


Fig. 23. Fine mud and organic carbon content

hardly be possible to discover any correlation between them ($F_0=205 < F'_8 (0.05)$). So a Thompson's abandonment test was attempted on the data of St.S9 which pointed out the abnormality in characters in the previous section. The result of test showed that the data of St.S9 might be abandoned from other data at higher level, 99%, of confidence ($(F_0=34.05 > F'_8 = (0.01))$. Consequently, regarding the

bottom samples excepting that of St. S9, an examination for correlationship between these variables has shown that a linear regression between them ($F_0 = 17.17 > F'_8$ (0.01)) was found with a high degree of reliability.

According to the above examinations, the manner of oxygen consumption owing to abiotic elements, in particular to organic matter, might be summarized as follows: The principal factor controlling the oxygen consumption is the abiotic elements, especially organic matter, rather than biotic ones such as the activities of bacteria or enzymes. Inspection on oxygen consumption as mentioned above might suggest that all of organic materials did not always exert influence upon the oxygen consumption, but one of the factors affecting the consumption would be the organic material which were progressively accumulated in bottom floor and called "colloid humus".

Table 24. Relations of Oxygen Consumption to Chemical Properties of Bottom Sediment (Shiogama Harbour)

A-Consumption: Consumption by all factors

C-Consumption: Consumption by abiotic factors

A) *In the case of employing all of 9 bottom samples*

(1) A-consumption and organic carbon content

	Variation	Degree of Freedom	Mean Square	F
Regression	14.9	1	14.9	
Residual	168.0	7	24.0	1.61
Total	182.9	8		

(2) C-consumption and organic carbon content

	Variation	Degree of Freedom	Mean Square	F
Regression	23.2	1	23.2	
Residual	113.7	7	16.2	1.42
Total	136.9	8		

(3) C-consumption and fine mud content

	Variation	Degree of Freedom	Mean Square	F
Regression	62.4	1	62.4	
Residual	74.5	7	10.6	5.89
Total	136.9	8		

(4) Organic carbon content and fine mud content

	Variation	Degree of Freedom	Mean Square	F
Regression	1.6	1	1.6	
Residual	2293.8	7	327.7	204.8
Total	2295.4	8		

B) *In the case of employing all samples except abnormal one of St. S 9*

(5) A-consumption and organic carbon content

	Variation	Degree of Freedom	Mean Square	F
Regression	62.2	1	62.2	
Residual	107.6	6	17.9	3.47
Total	169.8	7		

(6) C-consumption and organic carbon content

	Variation	Degree of Freedom	Mean Square	F
Regression	89.9	1	89.9	
Residual	38.9	6	6.48	13.75
Total	128.0	7		

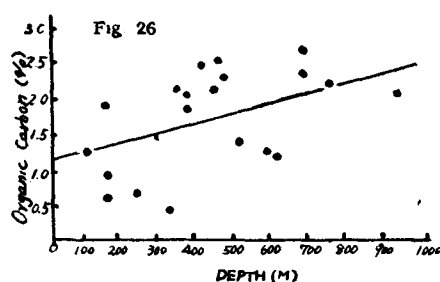
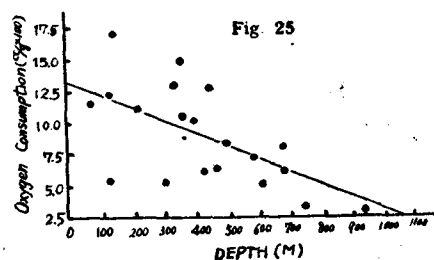
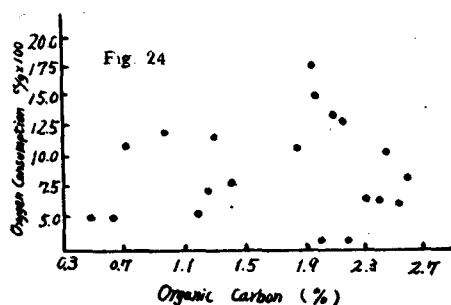
(7) Organic carbon content and fine mud content

	Variation	Degree of Freedom	Mean Square	F
Regression	1049.1	1	1049.1	
Residual	354.4	6	59.1	17.75
Total	1403.5	7		

d) **Relation of Oxygen Consumption by Hemipelagic Sediments to Water Depth at the Site of Deposition**

As the hemipelagic sediments in the Northern Japan Sea, the oxygen consumption has been examined in relation to the water depth at the site of deposition. The results were summarized in Table 25.

A rather negative correlationship would be observed between these variables; namely, the consumption seems rather to decrease with reduction in the water depth ($F_0=11.27 > F'(0.01)$). On the other hand, a definite correlationship was observed between the organic content and the water depth; that is, organic matter might be accumulated progressively with increasing water depth at the site of deposition. Such relation of the consumption to organic content might appear somewhat strange in comparison with the case of the littoral sediments as mentioned in the previous section, but it may be rather characteristic of oxygen consumption by bathyal sediments. Waksman (1938) pointed out that the oxidizing decomposition process of organic matter would be somewhat different between shallow-water deposits and deep-sea ones: Most of the organic matter in deep-sea deposits would have been rather progressively huminized and would have become fairly stable against oxidizing decomposition. So, nothing more oxygen would be necessary for decomposing organic matter. Further-



Figs. 24-26, showing the characteristics of oxygen consumption by pelagic sediment (Northern Japan Sea)

Fig. 24. Consumption and organic carbon content ;

Fig. 25. Consumption and water depth ;

Fig. 26. Organic carbon content and water depth

more, the independence between the consumption and the water depth has been observed of the sediments in Shiogama Harbour, where the bottom floor appears rather even and the water depth is so shallow that no influence of topography will be found upon the oxygen consumption.

Table 25. Relation of Oxygen Consumption to Topographic Factor
(Samples of the sea to the northwest of Hokkaido Island)

(1) Oxygen consumption and depth of water in the site of deposition

Factor	Variation	Degree of Freedom	Mean Square	F
Regression	110.9	1	110.9	
Residual	177.1	18	9.84	11.27
Total	288.0	19		

(2) Organic carbon content and depth of water in the site of deposition

Factor	Variation	Degree of Freedom	Mean Square	F
Regression	1.83	1	1.83	4.65
Residual	7.09	18	0.39	
Total	8.92	19		

After all the factors controlling the oxygen consumption seem not always simple, but complicated so much that they are difficult to unravel. The major part of the oxygen consumption seems probably to be due to abiotic elements, especially to

organic substances, in the sediment rather than to biotic ones such as bacterial activities or to enzymes. However, the effect of these abiotic elements on the oxygen consumption should be influenced not only by the bottom conditions either oceanographical or topographical but also by activities of organisms as bacteria or by enzymes in the sediment because the factors are not independent of each other but exert influence by turns.

VIII. SUSPENDED MATERIALS IN THE SEA, IN RELATION TO ORGANIC ACCUMULATION IN MARINE SEDIMENTS

Suspended materials in the sea act an important rôle in accumulating organic matter in the sediments as emphasized by Trask (1939). Carson (1951) thought of the existence of the suspended materials as "a stupendous snowfall in the sea". Now, innumerable flake-like substances in sea water were actually observed in the underwater survey by the undersea observation chamber, "Kuroshio", designed by Prof. N. Inoue of Hokkaido University and his collaborators (1953). The flake-like substances observed might be just the same as Carson's 'snowfalling' particles. As yet only few investigations on the particles suspended have been made and none has clarified their true characters in detail.

Jerlov (1951) made an interesting investigation on the distribution of the suspended particles, of which the biological characters were not understandable. Fox and his collaborators (1952) investigated on colloiddally or finely particulate organic and inorganic detritus suspended in natural bodies of water and measured their chemical composition and relative quantities.

The author (1953) has observed suspension of the particles in sea water through the window of "Kuroshio" at several different stations, viz., Tsugaru Strait, Mutsu Bay and Kagoshima Bay, around Japan, and preliminary examinations of the particles were done under microscope.

As shown in the photographs appended, it is clear that the suspended materials are chiefly aggregates of planktonic remains which are sinking in some stages of disintegration by bacteria. The main component of suspended materials may be the skeletal residues of diatoms which are fairly stable against attacks of bacteria. While there may be no essential difference as regards the biological components among materials obtained from the different stations, the species of organisms composing the aggregates show rather distinct characteristics as the locality of observation differs.

From the appearance of the suspended materials the author and Prof. N. Suzuki have proposed to give the name "*marine snow*" to them. The *marine snow* seems identical to the *marine leptopel* named by Fox and his collaborators (1953). But it is necessary to ascertain the identification between them, because actual undersea observation and microscopic detection of the *marine leptopel* have not been done.

PLATE

Plate I

(A) Aggregation state of flakes of marine snow
(Mutsu Bay) $\times 80$

(1)

(2)

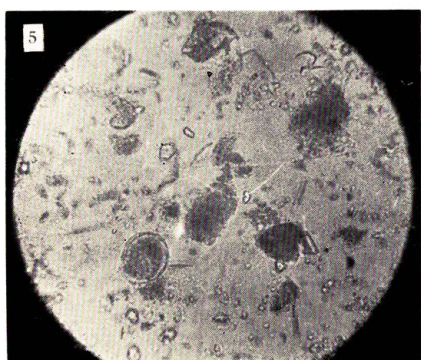
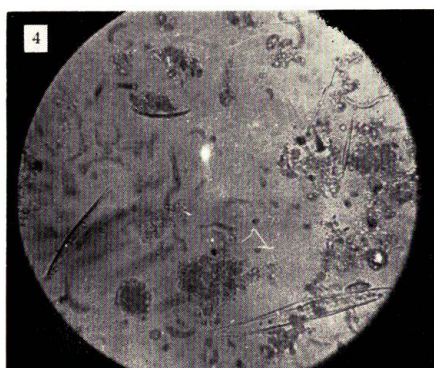
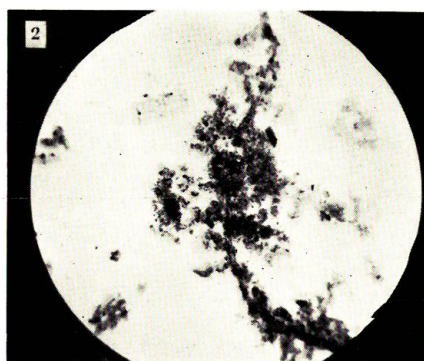
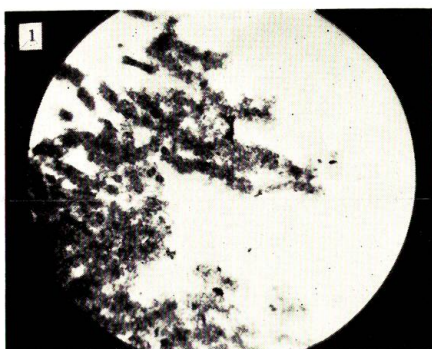
(B) Some stages in disintegration processes of
diatom, *Coscinodiscus* sp.
(Mutsu Bay) $\times 360$

(3)

(4)

(5)

(6)



K. Kato : Chemical Investigations on Marine Humus

Plate II

(C) Biological constituents of marine snow
(Kagoshima Bay) $\times 360$

(7)

(8)

(9)

(10)

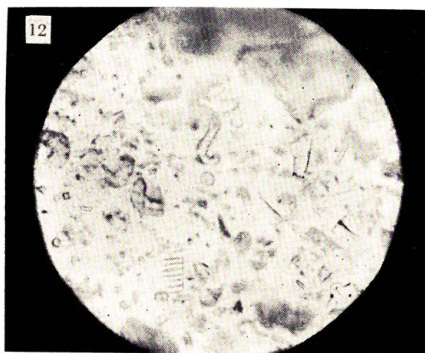
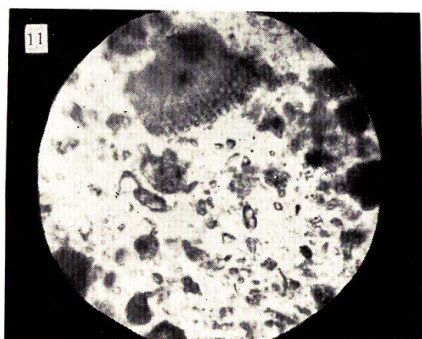
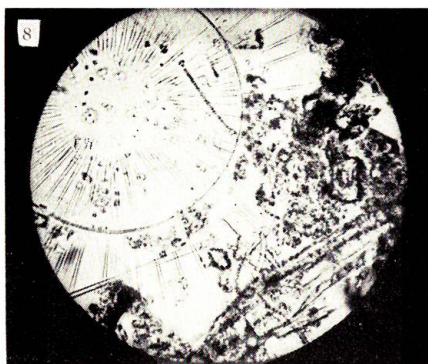
(D) Bottom deposits $\times 360$

(11)

(12)

Mutsu Bay

Kagoshima Bay



K. Kato : Chemical Investigations on Marine Humus

a) Undersea Observation of Suspended Materials "Marine Snow"

The underwater photograph (Fig. 27) shows an enormous amount of *marine snow*, ranging from sharply defined points, vague clusters and strings of dots, to elongated streaks. According to actual observation of *marine snow* suspended in natural bodies of water, the flake-like substance in Tsugaru Strait appeared luminously scattering

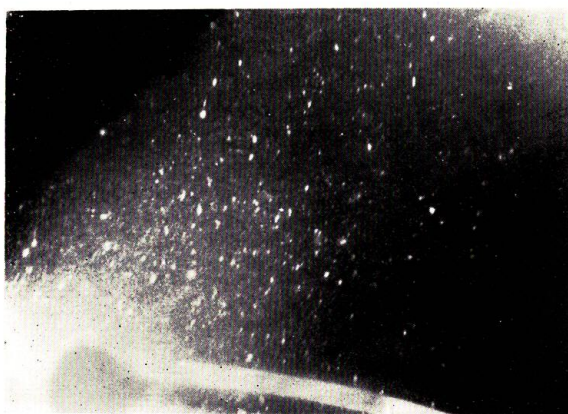


Fig. 27. Appearance of *marine snow* falling in water, Tsugaru Strait (50 m water depth) (photographed by S. Sugimoto)

light and rather more compact than that in the other areas observed. The distribution of the marine snow with increasing water depth showed a gradual reduction and also the particles became smaller in size. In a calm bay such as the bays of Mutsu and Kagoshima, the flakes of the suspended materials appeared to be in flocculent clusters containing a pretty large amount of water. The distribution of *marine snow* in Kagoshima Bay in southern Japan appeared rather thinner than in northern Japan, e.g., in Tsugaru Strait or in Mutsu Bay.

b) Sources of "Marine Snow" as Observed under Microscope

Characteristic aggregation states of *marine snow* are indicated in Plates I and II. The cellular substances of plankton which were destroyed by bacteria have aggregated around the larger materials suspended in water. It appears that the remains of organisms or debris carried from land may play the chief rôle as nuclei in this aggregation process. Moreover the similarity of microscopic appearance between the *marine snow* and the bottom sediment (plate II, 11 and 12) may indicate that the detritus on the bottom floor is formed of the sedimentary accumulation of the falling flakes of the *snow*.

Furthermore, it is very noticeable that the suspended materials, *marine snow*,

obtained from sea water in the vicinity of the Aleutian Islands (Suzuki, Kato and Oguro, 1954) have been composed mostly of terrestrial inorganic debris and epidermis fragments of land plants rather than of aggregates of planktonic remains. This fact may suggest that both the inorganic debris and the epidermis fragments may be brought by drift ice or icebergs migrating from the coast facing the Bering Sea. The tracing of the characteristic *marine snow*, consequently, might give some clues regarding the oceanographical migration of the water from the Bering Sea or the Arctic Ocean. Further investigations are needed for clarifying this problem.

IX. MARINE HUMUS DISTRIBUTION IN THE NORTHERN JAPAN SEA TO THE NORTHWEST OF HOKKAIDO, AS INFLUENCED BY BOTTOM CONFIGURATION

General characters of bottom samples from the Japan Sea northwest of Hokkaido as determined in the course of the investigation in summer of 1949 have been tabulated in Table 26.

The bottom configuration of the Northern Japan Sea appears very complicated (Niino, 1936). So the oceanographic condition, it is probable, will be found to have been influenced by the complicated configuration of the bottom floor. The submarine topography as well as the oceanographic environment may be the most important factor for controlling the distribution of marine humus in the present area.

a) General Description of Bottom Characters in the Area

The sediment just after collecting has sometimes looked rainnet green, and over green or olive green because the locality of deposition differed. These colors were respectively represented as (G) or green, (GG) or greyish green, (DG) or dark green in Table 26. In general, the sediments, either sand or sandy mud, of the continental shelf looked rather dark green, but those of the banks looked comparatively light colored. The color of the mud appeared lighter with the farther distance off the coast, that is to say, shallow water sediments appeared rainnet green but deep sea deposits over green. The surface of the sediment, however, was mostly oxidized and rust-colored.

In the littoral deposits, there were usually found some of the bottom-living animals e.g., polychaetae, shellfishes, sea stars and sponges.

Observation of the bottom samples from 252 stations show that muddy sediments were found in 119 stations or 47 per cent of all, sandy mud in 55 stations or 21 per cent, rock in 50 stations or 20 per cent, and sand or gravel in the remaining stations amounting to 12 per cent.

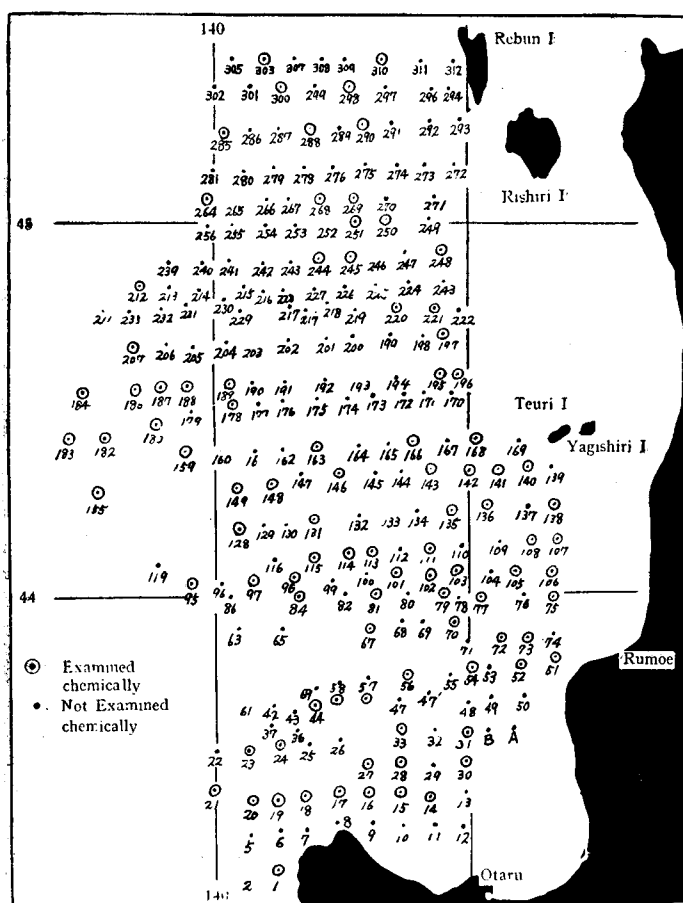


Fig. 28. Stations observed in the Northern Japan Sea to the northwest of Hokkaido (July-August, 1949)

b) General View of Marine Humus Distribution in the Area

Contents of organic matter in the bottom samples are indicated in Table 26. Figure 33 illustrates the regional distribution of marine humus as indicated in loss on ignition.

Humus distribution in this area, owing to the complexity in environmental conditions of sedimentation, appears to be very complicated. The accumulation of organic matter in sediment seems to be more remarked with increasing water depth of the site of deposition. That is to say, sandy sediments in the continental shelf had rather small amount, 6 per cent or so, of organic matter (ignition loss) but mud in the deeper depression had a pretty good amount, 12 per cent or over.

However, it is very noteworthy that there is found the following characteristic distribution closely influenced by the environmental conditions of sedimentation :
A notable distribution of the less accumulation below 6 per cent of organic matter



Fig. 29. Bottom topography of the Northern Japan Sea to the northwest of Hokkaido

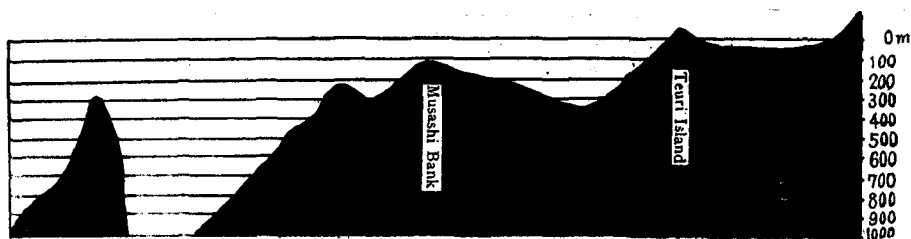


Fig. 30. Vertical section on 44°25'-N



Fig. 31. Vertical section on 140°20'-E

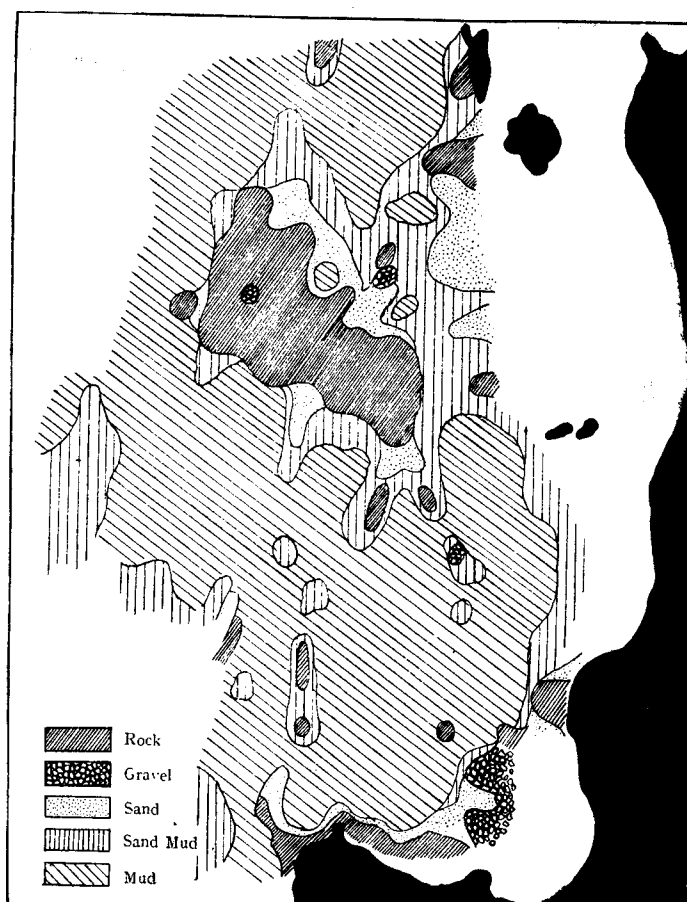


Fig. 32. Bottom character in the Northern Japan Sea to the northwest of Hokkaido

was found on the southwestern slope of Musashi Bank, corresponding to the tongue like shape. However, in sharp contrast to the above area, an abundant accumulation, 10 per cent or over, was found on the northeastern slope of the same bank. Thus the characteristic contrast in humus distribution may be attributed largely to the development of the overlying water and to the bottom configuration of the site of deposition.

Table 26. General Properties of Bottom Samples from
(July 17-Aug.

St. No.	Date	Location		Water Depth (m)	Character of Deposits		
		Lat. N	Long. E		Color	Gr.	S. M.
M 1	17, July	43°18.6'	140°13.2'	430	DG		A
M 13	17, July	43°28.7'	140°55.5'	110	G		A C
M 14	17, July	43°28.6'	140°47.8'	530	G		A
M 15	19, July	43°29.2'	140°41.5'	660	G		C A
M 16	19, July	43°29.1'	140°35.3'	750	G		C A
M 17	19, July	43°30.5'	140°29.8'	680	G		C C
M 18	19, July	43°30.4'	140°22.0'	648	DG		A
M 19	19, July	43°28.7'	140°13.1'	270	DG		A
M 20	19, July	43°28.7'	140° 7.8'	907	DG		R A
M 21	19, July	43°30.5'	139°59.2'	616	G	R	A C
M 23	21, July	43°36.5'	140° 7.5'	790	G		A
M 24	21, July	42°37.3'	140°15.5'	760	G		A
M 27	21, July	43°34.3'	140°36.2'	800	G		R A
M 28	21, July	43°34.5'	140°42.5'	720	G		A
M 30	21, July	43°34.5'	140°55.5'	145	G	A	C R
M 31	21, July	43°39.5'	140°56.0'	450	G		A
M 33	21, July	43°39.5'	140°48.7'	770	G		A
M 44	24, July	43°44.4'	140°27.8'	828	GG		C A
M 45	24, July	43°43.0'	140°36.9'	796	G		A
M 46	24, July	43°43.5'	140°42.2'	770	G		A
M 51	26, July	43°50.2'	141°16.0'	147	DG		C A
M 52	26, July	43°49.5'	141° 9.7'	255	G		A R
M 54	26, July	43°39.5'	140°57.4'	395	G		C A
M 56	4, Aug.	43°48.4'	140°52.3'	570	G		R A
M 67	17, Aug.	43°55.8'	140°34.9'	710	G		A
M 70	3, Aug.	43°56.8'	140°54.7'	370	GG		C A
M 72	26, July	43°54.5'	141° 4.0'	338	G		R A
M 73	26, July	43°54.0'	141°10.4'	269	G		A R
M 75	27, July	44° 0.2'	141°17.6'	140	G		C R
M 77	27, July	44° 0.2'	141° 1.3'	418	G		R A
M 79	3, Aug.	44° 1.0'	140°51.5'	390	G		A
M 81	3, Aug.	44° 1.0'	140°37.8'	645	G		R A
M 84	3, Aug.	44° 1.0'	140°22.4'	565	G		C R
M 95	30, July	44° 3.5'	139°59.4'	950	G		R A
M 97	30, July	44° 4.2'	140°12.1'	690	G		R A
M 98	30, July	44° 4.5'	140°20.0'	590	DG		R A
M 101	30, July	44° 4.0'	141°41.9'	555	DG		C A
M 102	30, July	44° 4.4'	140°47.9'	428	DG		R A
M 103	30, July	44° 4.5'	140°53.8'	170	DG		A C
M 105	30, July	44° 4.2'	141° 8.6'	340	G		C R
M 106	30, July	44° 4.8'	141°14.2'	210	G		C C
M 107	31, July	44°10.1'	141°17.2'	120	G		C R
M 108	31, July	44° 9.5'	141°10.2'	306	G		R A
M 111	31, July	44° 9.0'	140°47.9'	400	G		R A
M 113	31, July	44° 8.6'	140°32.5'	310	G		A R
M 114	31, July	44° 8.3'	140°25.3'	430	G		R A
M 115	31, July	44° 8.2'	140°16.9'	585	DG		R A
M 128	31, July	44°11.9'	140° 7.2'	734	DG		C A
M 131	31, July	44°12.9'	140°26.2'	380	G		R A
M 135	31, July	44°14.4'	140°55.8'	316	G		C R
M 136	31, July	44°14.5'	141° 2.9'	333	G		C C
M 138	31, July	44°14.7'	141°17.0'	90	G		C R

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the Japan Sea Northwest of Hokkaido
16, 1949)

Marine Humus Content of Dried Deposits				Color after Ignition	Diatom Residues	Spore Spicules
Organic Carbon (%)	Total Nitrogen (%)	C/M	Ignition Loss (%)			
2.23	0.809	2.76	8.92	VC	C	C
0.64	0.065	9.89	9.72	dCP	R	
2.90	0.218	13.30	12.60	dSP	C	C
2.59	0.268	9.66	12.00	SP	C	
2.37	0.240	9.89	11.62	SP	C	
2.61	0.243	7.62	10.66	SP	C	C
2.88	0.234	12.29	13.32	pG(Pumice)	A	
0.52	0.052	10.06	4.53	HB	R	AA
2.25	0.208	10.80	11.03	lSP	A	
1.22	0.118	10.35	5.76	dSP	C	
2.02	0.188	10.75	9.90	OS	C	C
2.18	0.492	4.44	10.49	SP	C	C
2.16	0.246	10.36	10.95	dSP	A	
3.04	0.244	12.45	12.65	SP	A	
0.64	0.065	9.88	5.14	M	R	
2.53	0.267	9.48	10.35	SP	R	C
2.72	0.278	9.80	11.37	SP	A	
2.75	0.654	4.21	13.62	SP	AA	C
2.48	0.272	9.12	12.08	SP	AA	
2.57	0.376	6.84	10.50	lSP	R	
1.97	0.154	12.81	7.64	RC	R	
2.51	0.114	21.99	5.55	dVC	R	
2.46	0.253	9.71	9.46	SP	C	
2.89	0.319	9.07	11.12	dSP	C	
2.28	0.291	7.85	13.54	pCP	A	
1.52	0.796	1.91	6.66	RC	R	R
2.22	0.239	9.27	9.30	OS	C	
1.52	0.156	9.76	7.73	VC	R	
1.90	0.220	8.59	8.16	dVC	RR	
1.15	0.205	7.26	11.81	pCP	R	
2.55	0.258	9.89	11.57	dSP	A	
2.98	0.279	10.69	12.59	SP	C	
1.87	0.147	12.75	10.03	pG(Pumice)	R	
2.04	0.633	3.23	11.88	pG	R	
2.36	0.253	9.32	12.17	SP	AA	
2.27	0.291	7.71	11.14	lCP	A	
2.90	0.289	10.04	12.76	dSP	RR	
2.79	0.266	10.48	10.78	dSP	A	C
2.98	0.355	8.40	14.86	lSP	C	C
2.26	0.254	8.89	10.19	VC	R	
2.17	0.177	12.28	8.62	dVC	R	
1.52	0.254	5.99	7.26	pRU	R	
1.88	0.185	10.14	7.87	dVC	R	
1.10	0.313	3.51	11.40	dSP	C	
1.69	0.134	12.62	7.57	VC	R	A
2.32	0.294	7.88	11.21	dSC	C	
2.15	0.218	9.84	13.93	pG(Pumice)	A	
1.37	0.102	13.42	8.71	A	
2.13	0.230	9.27	13.01	dE	C	
2.40	0.125	19.19	12.29	dSP	A	
2.59	0.256	10.11	11.47	dSP	R	
1.32	0.086	15.36	6.51	dVC	R	

St. No.	Date	Location		Water Depth (m)	Character of Deposits			
		Lat. N	Long. E		Color	Gr.	S.	M.
M 140	1, Aug.	44°19.5'	141°10.5'	254	G		C	R
M 141	1, Aug.	44°19.9'	141° 5.6'	340	DG		C	A
M 142	1, Aug.	44°20.0'	140°58.9'	320	G		R	A
M 143	1, Aug.	44°20.0'	140°52.4'	260	G		R	A
M 146	1, Aug.	44°20.0'	140°30.7'	330	G			A
M 148	1, Aug.	44°17.5'	140°14.7'	490	G		C	R
M 149	1, Aug.	44°17.1'	140° 8.1'	870	G		R	A
M 155	2, Aug.	44°18.5'	139°34.1'	650	G		C	C
M 159	1, Aug.	44°23.2'	140°57.0'	920	G			A
M 163	1, Aug.	44°23.7'	140°26.0'	300	G		R	C
M 166	1, Aug.	44°23.9'	140°48.0'	240	G		C	C
M 168	1, Aug.	44°24.0'	141° 2.4'	304	DG			A
M 178	2, Aug.	44°31.3'	140° 5.4'	474	G		R	A
M 180	2, Aug.	44°30.3'	140° 5.4'	1200	DG		R	A
M 182	2, Aug.	44°24.2'	139°76.0'	1115	DG		C	C
M 183	2, Aug.	44°33.7'	139°28.3'	745	DG		C	A
M 184	3, Aug.	44°33.7'	139°31.3'	590	G		C	A
M 186	3, Aug.	44°33.7'	139°45.5'	1050	GG			A
M 187	3, Aug.	44°34.0'	139°50.8'	720	G			A
M 188	3, Aug.	44°34.0'	139°57.8'	470	G		C	A
M 189	3, Aug.	44°34.2'	140° 6.1'	320	DG		A	C
M 195	2, Aug.	44°34.3'	140°51.5'	230	DG		A	R
M 196	2, Aug.	44°34.1'	140°55.6'	200	DG		A	R
M 197	9, Aug.	44°40.4'	140°54.4'	162	DG		A	
M 207	10, Aug.	44°40.9'	140°45.1'	750	G		C	A
M 212	10, Aug.	44°47.6'	139°47.9'	370	G		C	C
M 220	10, Aug.	44°44.3'	140°42.0'	214	DG		C	A
M 221	10, Aug.	44°43.9'	140°49.4'	215	DG		A	R
M 222	10, Aug.	44°43.6'	140°56.9'	150	DG		A	
M 244	16, Aug.	44°53.0'	140°28.0'	180	G	R	A	R
M 245	16, Aug.	44°53.9'	140°34.5'	360	G		R	A
M 248	16, Aug.	44°53.4'	140°53.1'	140	DG		A	
M 250	16, Aug.	45° 0.0'	140°44.3'	340	G		R	A
M 251	16, Aug.	45° 0.0'	140°36.9'	350	G		R	A
M 264	15, Aug.	45°4 .4'	140° 1.5'	512	G		C	C
M 268	15, Aug.	45° 3.9'	140°29.2'	320	G		R	A
M 269	15, Aug.	45° 3.7'	140°36.1'	365	G			A
M 285	15, Aug.	45°13.2'	140° 9.3'	600	G			A
M 288	15, Aug.	45°13.5'	140°27.5'	420	G		R	A
M 298	15, Aug.	45°13.7'	140°39.5'	444	G			A
M 298	14, Aug.	45°19.5'	140°37.1'	468	G		C	A
M 300	14, Aug.	45°20.0'	140°21.5'	400	G			A
M 366	14, Aug.	45°24.3'	140°13.7'	450	G		C	A
M 310	14, Aug.	45°23.9'	140°43.9'	566	G			A

Note: 1) Color of deposits; G-green, D. G.-dark green, G. G.-greyish

2) Colors of ignited bottom samples are largely based upon Sanzo Wada (1935).

C-Cinnamon; VC-Vinaceous Cinnamon; RC-Rufous

E-Ecru; G-Grey; HB-Harzel Brown; SB-Sudan

3) Abundance of organic remains in sample:

A-abundant; C-common, or frequent; R-rare; RR-

The major current of the Tsushima flowing to north strikes against the continental slope of the Musashi Bank, where a remarked sorting of sediment may be caused to

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Marine Humus Content of Dried Deposit				Color after Ignition	Diatom Residues	Sponge Spicules
Organic Carbon (%)	Total Nitrogen (%)	C/N	Ignition Loss (%)			
1.36	0.112	12.14	8.98	d V C	RR	
2.11	0.307	6.86	10.89	d E	C	
2.37	0.303	7.81	11.29	V C	RR	
1.82	0.172	10.56	8.31	d V C	C	
1.96	0.183	10.73	10.44	V C	AA	
1.02	0.094	10.83	5.95	d V C	R	
1.95	0.236	8.24	12.59	p C P	R	
0.75	0.182	4.12	7.37	l S P	A	
1.83	0.269	6.79	11.71	l S P	AA	
1.25	0.157	7.99	8.08	d S P	RR	
1.32	0.122	10.80	7.42	d V C	R	
2.07	0.256	8.07	9.34	l V C		
2.21	0.281	7.87	11.26	AA	
1.68	0.139	12.17	11.47	S P	A	
1.25	0.165	7.55	7.86	V C	C	
0.96	0.076	12.67	7.29	S P	C	
1.25	0.150	8.35	8.46	l V C	C	
2.07	0.222	8.31	10.98	S P	A	
1.97	0.229	8.56	10.08	S P	AA	
2.12	0.205	10.35	11.29	G	A	
0.49	0.060	8.15	4.60	d E	C	A
0.72	0.092	7.82	4.15	S B	RR	
1.12	0.150	7.49	5.32	S B	RR	
0.78	0.152	5.10	5.30	S B	RR	
1.75	0.315	6.56	10.74	d S P	A	
2.17	0.250	8.69	12.56	d S P	A	
1.24	0.142	8.73	5.22	V C	R	
1.23	0.136	9.05	5.51	d V C	R	C
0.67	0.160	4.16	9.54	S B	RR	
0.82	0.125	6.55	12.13	E	R	A
2.02	0.265	7.61	10.21	S P	R	A
0.98	0.173	5.69	4.36	MB	RR	
2.46	0.292	8.41	7.31	O S	C	A
1.91	0.282	6.76	8.36	d S P	C	C
1.42	0.205	6.90	9.05	S P	A	C
1.34	0.161	8.29	7.31	V C	A	C
1.89	0.213	8.89	9.52	d S P	R	C
1.98	0.344	5.76	10.48	l V C	A	
1.62	0.125	12.98	8.76	d S P	C	
1.62	0.167	9.68	8.94	d S P	C	
2.32	0.238	9.74	11.32	V C	A	
1.81	0.253	7.12	9.26	d S P	A	
2.17	0.179	12.13	11.95	p C P	C	
2.28	0.183	12.46	10.89	d S P	AA	

green.

Directory on "STANDARD COLOR CARD" (SHIKIMEI-SOKAN) edited by

Cinnamon; SP—Seashell Pink; OS—Ochraceous Salmon; RU—Raw Umber; M—Marple;
Brown; MB—Mars Brown; d—dark; l—light; p—pale.

very rare

take place and accordingly organic accumulation will become less active. The current is obliged to turn its course along the western slope. While a branch of the current

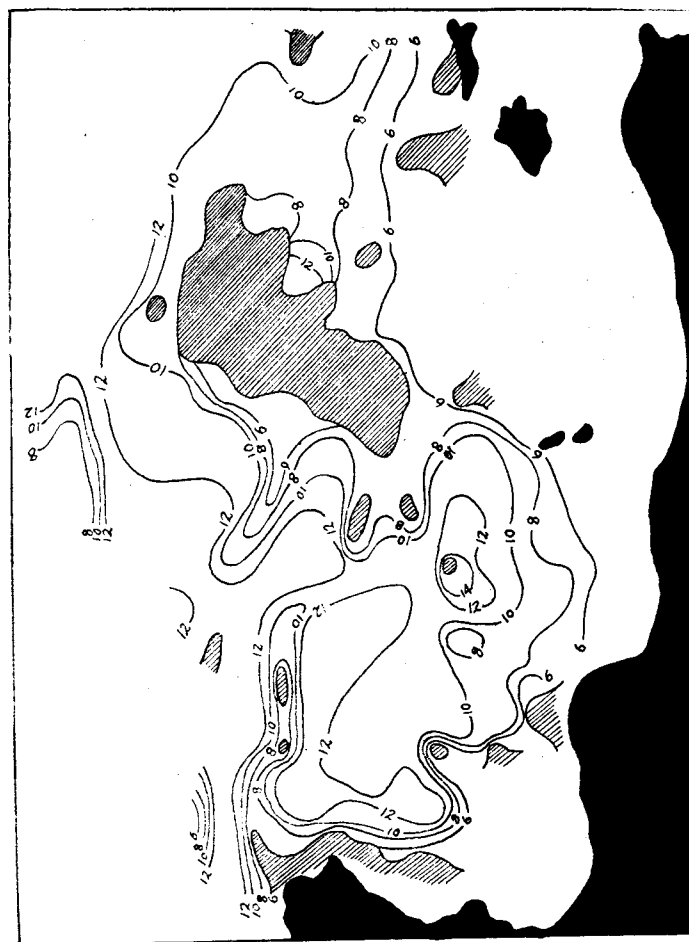


Fig. 33. Distribution of organic content (ignition loss, %) in bottom sediment (Northern Japan Sea)

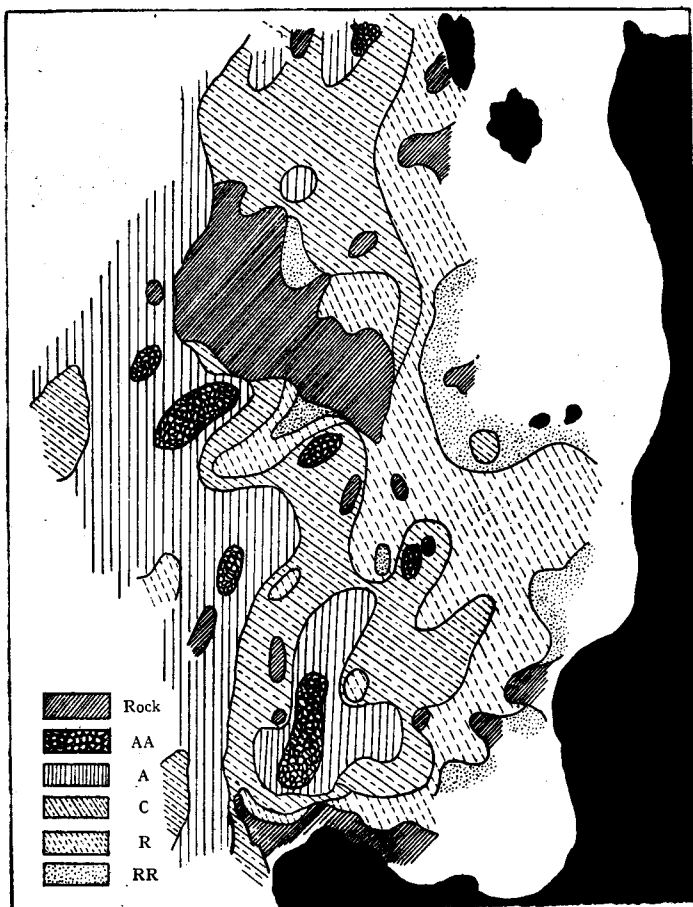


Fig. 34. Distribution of diatom residues accumulated on bottom floor (Northern Japan Sea)

after striking the bank flows along its eastern slope. Both of these branch currents meet together on the back side of the bank, where detrital materials suspended in the overlying water will begin to settle down on the bottom floor and organic materials will probably be accumulated in abundance.

c) Relation between Humus Distribution and Water Depth of the Site of Sedimentation

For deducing how humus distribution may be influenced by the condition such as water depth or topography in the site of deposition, some statistical examinations were made employing the data on organic content, which were represented by respective amounts of organic carbon, total nitrogen, or ignition loss. The examinations were made on the assumption that these data would indicate a normal distribution

Table 27. Means and Standard Deviations of Organic Content
in Bottom Sample

	Number of Individuals	Mean in Sample	Standard Deviation	Confidence Limit of Population Mean ($\alpha=0.05$)
Ignition loss	96	9.68	2.383	9.20 - 10.16
Organic Carbon Content	96	1.87	0.635	1.74 - 2.00
Total Nitrogen Content	96	0.21	0.086	0.186 - 0.234
C/N	96	9.44	2.634	8.90 - 9.98

in frequency. The coefficient of correlation between the above quantity representing humus content and water depth of the site of deposition has been examined after

Table 28. Correlation Table for the Relation between Ignition Loss of Bottom
Sample and the Depth of the Site of Deposition

Water Depth (m)	Loss of Ignition (%)											Total
	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	
50			1									1
150	2	2		2	1	2			1		1	11
250	2	3		2	4							11
350	1		1	4	1	4	4	4	2	1		22
450		1			3	1	2	6				13
550					1	1	3	2	2	1		10
650		1		1			1	1	2	1		7
750				1	1	1	5	2	2	1		13
850									1	1		2
950								3				3
1050							1					1
1150				1				1				2
Total	5	7	2	11	11	9	16	19	10	5	1	96

γ loss (Correlation coefficient in sample) = 0.463

Table 29. Correlation Table for the Relation between Organic Carbon Content of Bottom Sample and the Depth of the Site of Deposition

Water Depth (m)	Organic Carbon Content														Total
	0.5	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	
50					1										1
125		4	2	1		1		2					1		11
250	1	1			5	1		1	1		1				11
350	1			1	1	1	1	4	6	3	4				22
450				2			2	1	2	4		1			13
550					1	1		2	1	2			3		10
650		1			1				1	1	1	1	2		7
750			1		1		1	1	3	2		1		1	13
850								1				1			2
950								1	1	1					3
1050									1						1
1150					1		1								2
Total	2	6	3	4	11	4	5	13	15	13	9	4	6	1	96

 γ (Correlation coefficient in sample)=0.344

Table 30. Correlation Table for the Relation between Total Nitrogen Content of Bottom Sample and the Depth of the Site of Deposition

Water Depth (m)	Total Nitrogen Content (%)							Total
	0.075	0.125	0.175	0.225	0.275	0.325	0.375	
50	1		4					1
150	2	2	4	1	1		1	11
250	2	5	3					11
350	1	2	2	4	8	3		21
450	1	1	1	3	5			12
550		2	1	3	2	2		10
650		1	1	1	3	1		7
750	1	1		4	3	1	1	12
850				1				1
950				1	1			2
1050				1				1
1150		1	1					2
Total	8	15	17	19	23	7	2	91

 γ_N (Correlation coefficient)=0.150* Values abandoned by Thompson's test ($\alpha=0.05$)

St. M 1 (440 m depth).....0.809%N

St. M 24 (760 ").....0.492%N

St. M 44 (830 ").....0.650%N

St. M 70 (370 ").....0.790%N

St. M 95 (950 ").....0.633%N

some of the abnormal data had been abandoned according to Thompson's test ($\alpha=0.05$). These correlation tables are presented in Tables 28-31, and the corresponding coefficients of correlation are summarized in Table 32. Further, the confidence of these population coefficients (S) has been inspected statistically by examining whether the null hypothesis as might be $\delta=0$ should be abandoned or not. This

Table 31. Correlation Table for the Relation between C/N of Bottom Sample and the Depth of the Site of Deposition

Water Depth (m)	C/N								Total
	2	4	6	8	10	12	14	16	
50								1	1
150		1	4	3	2	1			11
250				3	5	1		1	10
350	1	1	2	9	1	1			21
450	1			4	6	2			13
550			2	2	3	2	1		10
650		1		1	4	1			7
750		1	2	2	5	2	1		13
850		1		1					2
950		1	1		1				3
1050					1				1
1150				1		1			2
Total	2	6	11	26	34	11	2	2	94

$\gamma_{C/N}$ (Correlation coefficient) = -0.011

* Values abandoned by Thompson's test ($\alpha=0.05$)

St. M 52 (255 m depth).....21.99

St. M 135 (320 ").....19.19

statistical checking was done using "t-distribution table", on the level, 95 or 99%, of confidence. That checking shows that both ignition loss and organic carbon content in the sediment become larger with increasing the water depth ($\gamma_{\text{loss}}=0.463$ and $\gamma_C=0.344$). The correlation coefficient on total nitrogen content, however, was estimated as having a comparatively small value, $\gamma_N=0.195$. A statistical deduction may be hardly possible for stating positively any definite relationship between nitrogen content and water depth at the site of deposition. As regards the ratio of carbon to nitrogen, C/N, which will illustrate the state of decomposition equilibrium of organic substances, it seems impossible to find any relationship to water depth judging from the correlation coefficient $\gamma_N=-0.011$.

Table 32. Correlation Coefficients between Organic Contents and Water Depth, and Statistical Examination for the Correlationship

	Number of Individuals	Correlation Coefficient in Sample (γ)	$(t)=\gamma(n-1)^{1/2}$	$t^\circ(\alpha=0.01)$ [$t^\circ(\alpha=0.05)$]	Correlation Coefficients in Population (ρ)
Ignition Loss	96	0.463	4.513	2.628 [1.985]	$\rho \neq 0$
Organic Carbon Content	96	0.344	3.353	2.628 [1.985]	$\rho \neq 0$
Total Nitrogen Content	91	0.195	1.848	2.632 [1.987]	$\rho = 0$
C/N	94	-0.011	0.106	2.629 [1.986]	$\rho = 0$

Another pronounced accumulation of organic matter was found on the bottom floor in the vicinity of Otaru Bank, where the existence of an anticlockwise eddy current has been pointed out by Fukutomi (1950).

Next, the distribution of marine humus was examined statistically in relation to the topography of the site of deposition. Both population means and standard deviations respecting organic content are summarized in Table 27.

Few data have hitherto been made available concerning areal distribution of marine humus in the sediments of the sea adjacent to Japan. Hamaguchi (1953) has indicated 0.54 per cent as average content of organic carbon in the bottom samples from Suruga Bay. He has also pointed out that only a small amount of organic matter has been found in the deep-sea deposits, as globigerina ooze or red clay, in the Pacific. Consequently, the average content of organic matter, 1.74–2.00% C, in the area under discussion seems somewhat strange comparing with Hamaguchi's data mentioned above. Recent data by Hamaguchi (1953), however, showed a remarkable abundance of organic accumulation such as 0.5–2.0% C in average had been observed in the bottom samples from the Japan Sea. This abundant accumulation of organic matter, as Hamaguchi has emphasized too, will be one of the characteristics of the deposits in the Japan Sea.

If estimates are made of the amount of marine humus from carbon content by means of Trask's factor, $C \times 1.72$, the humus contents in bottom samples will respectively be 1.0–1.5% for the Northern Pacific, 1.3–1.5% for the Atlantic, but 3.21% for the Japan Sea as estimated in the present investigation. The ratio, C/N, was however found to have an average value of 9–10 within the confidence limit, 95%, in population. The above ratio appears almost similar to Trask's ratio, 8–12 or about 10, notwithstanding the remarkable accumulation of organic matter in the area. Organic accumulation in sediment, in general, may rather decrease with the transformation of bottom character to the more pelagic. This decreasing tendency has also been observed of the sediments in the deep bottom floor of the Japan Sea by Hamaguchi (1953). So, it may be somewhat strange to report again the observation of a positive correlationship between the organic content and the corresponding water depth as mentioned concerning the bottom samples under discussion. The progressing of organic accumulation, if observed in detail, appears not always even, but rather susceptible to the conditions of environment of the sedimentation. A wide variety of organic accumulation may be found in littoral sediment owing respectively to supply of terrigenous debris, bottom configuration or to the sorting of sediment by water movement. Organic substances which have been accumulated in the sediment will convert into humic substances in part owing to bacterial activities or to chemical weathering. The predominant supplies, either terrigenous or pelagic, which are usually found in the littoral region, will lead to an increase in the amount of organic matter accumulated on the bottom floor. This characteristic accumulation of organic matter may develop

actively with increasing water depth of deposition until the influence of supplies, especially terrigenous, or of the other factors, becomes comparatively ineffective. The change of organic accumulation in the sediment will be observed on the bottom of the continental slope. Farther off the slope, the organic accumulation process will necessarily decrease under pelagic circumstances; thus the sedimentary accumulation of organic matter in the sediment will reach the minimum in the deep bottom floor of the Japan Sea. It may consequently be reasonable that the sedimentary accumulation of organic matter in the present area becomes larger with increasing water depth of deposition, if one may bring to his mind that the investigation has been carried out mainly in the continental shelf or slope ranging from 100 meters to 1,000 meters in water depth. The regression of organic accumulation with water depth would consequently be graphed as a convex curve having the minimum accumulation in 700-800 meters in water depth.

Yet, as to the distribution of nitrogen content in this area, it was hardly possible to state positively any linear relationship to water depth of deposition, although a definite relationship between them has been observed in other areas as will be discussed in the successive chapters. The deviation of nitrogenous distribution may be attributed not only to topographical environments but also to such biological or biochemical factors as planktonic or benthic organisms or their decomposed substances. Next attention may be directed to characteristic distribution of the ratio, C/N, in the sediment. The correlation coefficient of the ratio to water depth has indicated nearly zero. That ratio, accordingly, will be scarcely influenced by the topographic factor. A nearly definite ratio, 9-10, will be given as a whole in despite of the greater complexity in topography or in water movement. This may point to the fact that there would be developing a definite equilibrium of organic decomposition owing to bacterial activities as a whole even if various organic materials have been decomposed by various kinds of bacteria into various decompositionates. Consequently, if there would be observed an abnormal value of the ratio in a given location, one should be inclined to question whether the equilibrium of organic decomposition has been developing in the usual manner or not.

d) Influences of Submarine Topography upon Humus Distribution

Since bottom configuration in this area to the northwest of Hokkaido appears one of the most important factors controlling the organic accumulation, the areal distribution of marine humus will be examined from the topographical point of view.

For that purpose, the area has been divided into the following six subareas according to characteristics of submarine configuration (Fig. 35) :

- (1) Subarea I: Continental shelf, ranging from 100 meters to 250 meters in depth; the deposits are mostly sandy.



Fig. 35. Subareas divided owing to bottom configuration
(Northern Japan Sea)

- (2) Subarea II: Trough, running from north to south, having water depth ranging 300–500 meters, intermediate between the shelf and Musashi Bank; the sediments are mud or sandy mud.
- (3) Subarea III: Basin, 400–800 meters in water depth, northeast of Shakotan Peninsula; the sediments are mud.
- (4) Subarea IV: Steep ridge, 300–600 meters in water depth, north of Shakotan Peninsula; the sediments are sandy mud or mud.
- (5) Subarea V: Continental slope, 300–1,000 meters in depth, developing toward the deep bottom floor; most of the sediments are mud or partly sand.
- (6) Subarea VI: Some banks, discovered in this investigation, 600–700 meters

in water depth, rising in the deep bottom floor farther off the coast; the sediments are sandy mud.

For inspecting the influences of bottom configuration upon humus accumulation, examination was made within the confidence limits, 95%, of population means or variances, concerning organic distribution in each subarea. The results of examination may be summarized by stating that the most abundance of organic matter has been found in the basin (III) or the ridge (IV), next in the trough (II) or the continental

Table 33. Relation between Marine Humus Distribution and Topography of Sea Bottom (cf. Fig. 35)

		Subarea Devided in Reference to Topography					
Item		I (Conti- nental Shelf)	II (Trough)	III (Basin)	IV (Ridge)	V (Conti- nental Slope)	VI (Bank)
Number of Individuals		16	18	16	8	27	4
Range of water depth (m)		90-254	300-468	416-800	430-828	300-1200	590-750
Mean Water Depth (m)		175±28	356±40	601±82	722±117	592±101	651±110
Ignition Loss (%)	\bar{X}_{loss}	6.67	9.55	11.60	11.20	10.22	7.22
	S_{loss}	1.92	1.47	1.06	1.61	2.22	1.11
	M_{loss}	5.74-	8.98-	11.04-	9.89-	9.35-	5.47-
		7.78	10.17	12.16	12.51	11.09	8.97
Organic Carbon Content (%)	\bar{X}_C	1.23	1.97	2.56	2.41	1.81	1.05
	S_C	0.49	0.42	0.45	0.30	0.44	0.24
	M_C	0.97-	1.76-	2.32-	2.16-	1.64-	0.67-
		1.49	2.18	2.80	2.66	1.98	1.43
Total Nitrogen content (%)	\bar{X}_N	0.142	0.233	0.271	0.396	0.207	0.135
	S_N	0.052	0.057	0.039	0.232	0.072	0.045
	M_N	0.115-	0.210-	0.250-	0.207-	0.179-	0.050-
		0.171	0.256	0.292	0.585	0.235	0.204
C/N	$\bar{X}_{C/N}$	9.27	8.77	9.94	7.85	9.28	7.74
	$S_{C/N}$	3.33	1.96	1.88	1.56	2.66	3.59
	$M_{C/N}$	7.51-	7.80-	8.94-	6.58-	8.25-	3.11-
		11.0	9.74	10.94	9.12	10.33	12.37

\bar{X} : Mean in sample

S: Standard deviation

M: Population mean (Confidence limit ($\alpha=0.05$) of)

slope (V), and the least in the continental shelf (I) or the banks (VI) farther off the coast.

As to the population mean on organic content of the sediment in the above subareas, the confidence limit ($\alpha=0.05$) was estimated for examining whether the significance was recognized or not within the confidence limits ($\alpha=0.05$) of the data

on these subareas. These examinations indicated the occurrence of a fairly good significance of organic accumulation among these subareas. The organic accumulation, that is to say, will be greatly controlled by the corresponding submarine topography. The general tendency is that the organic accumulation becomes more remarkable with increasing water depth of the site of deposition, but that the subareas having nearly same water depth would not always indicate the same degree of organic accumulation. There exist two subareas forming a striking contrast to each other, disregarding the nearly same average water depth. One of them is the banks (VI) farther offshore where is found the less abundant accumulation, while the other is the ridge (IV) connected to the Shakotan Peninsula where is found a remarkable accumulation. The less accumulation of organic matter in the former subarea may be attributed to the comparatively poor supply of organic substances probably from land. While the notable accumulation in the latter subarea may be attributed to biological elements, particularly the remains of benthic animals rather than to the topographic factors—judging from the enormous accumulation as well as the greater variation as indicated by the unbiased estimate concerning nitrogenous substances.

Further examinations were attempted for inquiring into the influences of bottom configuration upon humus distribution, by using the data of two characteristic subareas as the continental slope and the basin: These subareas have different bottom configurations from each other although both of them indicate nearly the same average depth, about 600 meters. First, as to ignition loss of the bottom sample, the confidence limits ($\alpha=0.50$) of population mean were respectively estimated as 9.35–11.9% in the continental slope (V) and as 11.04–12.16% in the basin (III). Tests of the significance between these limits resulted the recognition of a high significance. Similarly to the above, a high significance was recognized from the result of statistical test on the organic carbon content, 1.64–1.98% (V) and 2.32–2.80% (III), as well as on the total nitrogen content, 0.179–0.235% (V) and 0.250–0.292% (III). These results may be useful enough for illustrating the influences of bottom configuration on the distribution of marine humus.

On the other hand, judging from the confidence limits of these respective populations, it was hardly possible to observe any significance in the ratio, C/N, between these six subareas characterized according to topography. Accordingly, bottom configuration of the site of sedimentation, at least in the hemipelagic region, appears to have almost no influence upon the decomposition equilibrium of organic matter accumulated in the sediment. It is not clear in respect to the sediments in the banks farther off the coast why the ratios have deviated largely according to their localities.

e) Some Discussion of Abnormal Data on Humus Content beyond the Population in Normal Distribution

Previous to statistical examination for estimating the relations of humus distribution to the environmental factors, the Thomposon abandonment test was usually available for examining whether abnormal data were to be abandoned from the population or not. Available data reported by other researchers as oceanographers or biologists in this investigation might be very profitable for discussing these abandoned data.

No data which should be abandoned at the level, 95%, of confidence was found in regard to either ignition loss or organic carbon. In Table 30, five abandoned data on nitrogen content, of the respective stations of M1, 24, 44, 70, and 95, would have need of discussion.

Of these five stations yielding the abandoned data, both M24 and M44 are located on the steep ridge connected to the Shakotan Peninsula, and M1 is on the steep slope off Cape Kawashira of the same peninsula. These two stations, consequently, appear analogous to each other from the viewpoint of topography. At these stations, a fairly good amount of sponge spicules was observed in each bottom sample under microscope, which might suggest that there have been dwelling a good number of animals in the bottom. Thus the remarked accumulation of nitrogenous substances in these two stations seems to be contributed to by the remains of benthic animals.

The other remarkable accumulation was observed at M95 on one of the banks (VI). The characteristic accumulation seems rather to be contributed to the remains of planktonic organisms judging from the fact that there were observed some concentrated populations of *Calmus plumchrus* in the water in the vicinity of the station (Motoda, 1950).

It seems somewhat difficult to deduce any cause which would account for the strange organic accumulation in M70 in the vicinity of Otaru Bank. Because there were scarcely any large amount of organic remains, as diatom residues or spicules of sponge, in the sediment, the strange accumulation of organic matter might be built up largely by abnormal condensation of small molecular nitrogenous compounds which would reach abnormal equilibrium of organic decomposition owing to a peculiar activity of bacteria. That might, however, be attributed partly to planktonic origin judging from a pronounced population of *Parathemisto oblivia* observed at M79 near the station under consideration.

Next, examinations on the ratio, C/N, will be made. Data from two station, M25 and M135, were abandoned as shown in Table 31. Five stations, M1, M70, M95, M111 and M138, will be added to the above, if brought to the test at the level, 99%, of confidence. These seven abandoned stations may be divided into two groups :

One of them indicates remarkably large value in C/N beyond the popular mean, about 9-10, and the other does rather small value beyond the above mean. The former comprises stations M52, M135 and M138, and the latter of stations of M1, M70, M95 and M111. Among the four stations indicating smaller C/N beyond the means, stations M1, M70 and M95 might have sediments which were contributed by remarked accumulation of nitrogenous substances from organic remains as emphasized above. Moreover, in the case of M11, the abnormal value of C/N seems also to be mainly attributed to the remains of benthic animals judging from a pretty good amount of sponge spicules observed under microscope.

On the other hand, remarkably large values of C/N in the sediments may be observed from stations where organic accumulations would be greatly controlled by non-nitrogenous substances such as carbohydrates rather than by nitrogenous substances as protein. These stations are located on or near the continental shelf. In the vicinity of stations M135 or M136 intermediate between Teuri Island and Otaru Bank, an anticlockwise eddy was observed in the oceanographical investigation simultaneously undertaken. The eddy may occur owing to the contact of two water masses, i.e., a branch of the Tsushima Current flowing to the eastward and the coast current with the water of Ishikari River flowing to the north. There might consequently be found a pronounced sedimentation of terrigenous organic debris carried from the River. Thus, oceanographical inspection on this specific location will show that abnormally large values of C/N found in these stations might be due to terrestrial organic matter enriched in carbohydrates. Another characteristic station, M25, off Cape Ofuyu seemed also to be influenced by terrestrial supplies from the Ishikari River.

Waksman's illustration (1933) on bacterial decomposition of organic remains seems to suggest some clues to the causes inducing the irregular equilibrium of organic decomposition: Some of the nitrogenous substances would be necessary for forming cellular substances of bacteria. So, the propagation of bacteria, without an adequate amount of nitrogenous substances would be restrained even if foods for bacteria were sufficiently enriched in carbonous substances. Accordingly, a fairly good amount of these carbon sources would stay in undecomposed condition.

So, in these stations characterized by abnormally large ratio, terrigenous organic materials, which were carried actively from the Ishikari River and allowed to settle, seem to be insufficiently decomposed by bacteria owing to poor supply of nitrogenous substances and then a part of terrigenous organic matter might be accumulated in somewhat undecomposed condition.

f) A New Environmental Coefficient on Marine Humus Distribution

For indicating the degree of variation in a given population, the variance (V) or

standard deviation (S) is generally used when statistical studies are undertaken; that is,

$$S = \sqrt{\bar{V}} \sqrt{\frac{1}{N} \sum_{i=1}^k f_i (x - \bar{x})^2}$$

where, N represents number of samples, f_i frequency, \bar{x} unbiased estimate or population mean, and x datum observed.

Table 33 indicates the standard deviations in population of organic contents in sediment of the six subareas which were divided as above by their topographic characters. When examining a dynamical complexity of organic accumulation in bottom, the author has a doubt whether it would be adequate or not to employ only the corresponding standard deviation in disregard of the remarkable difference in topography among these areas.

If discussing as to which of the two subareas, the continental shelf (I) and the continental slope (V), is relatively variable in distribution of nitrogen content of sediment, one may notice that the standard deviation, 0.0072%, of nitrogen content is higher on the continental slope rather than 0.0052% on the continental shelf. Are these standard deviations adequate to indicate the degree of dynamical variation in sedimentary accumulation of nitrogenous substances in these two subareas? Because these areas are remarkably different in bottom configuration as well as in dynamical process of sedimentation occurring on them. The continental slope has a large range of water depth, 300–1,200 meters and the standard deviation of the depth 257 meters, while the continental shelf has a water depth range 90–250 meters and a standard deviation of the depth 53 meters. Accordingly these two subareas are not always similar in the degree of complexity of bottom configuration.

Here, a measure in consideration of topographic effect will become necessary to express the variability of organic accumulation in a given area. So, the author proposes to indicate a measure concerning variability of the organic sedimentary accumulation as considering the corresponding topographic factor.

The author's measure (Vr) is represented by the following ratio between the standard deviations on the two variables, i.e., organic content in sediment and water depth at the site of deposition:

$$Vr = Sx/Sy = \beta/\gamma$$

where Sx and Sy represent respective standard deviations in organic content and in water depth, β and γ , coefficients of regression and correlation. Then, the above measure will be called "Environmental Coefficient of Marine Humus Distribution" or "Relative Variation in Marine Humus Distribution". The coefficients on the sediments in the six subareas are summarized in Table 34, in which large coefficients are found rather in the case of the continental shelf than in that of the other subareas. Such measures may well responsible for illustrating the following fact:

Table 34. Environmental Coefficients, V_r , on Marine Humus Distribution
in Six Subareas Characterized by Topography
(The Northern Japan Sea northwest of Hokkaido, 1949)

Subarea Devided owing to Topography	Ignition Loss (%) ($\times 10^{-2}$)	Organic Carbon (%) ($\times 10^{-3}$)	Total Nitrogen (%) ($\times 10^{-4}$)	C/N (%) ($\times 10^{-2}$)
I Continental Shelf	3.6	9.2	9.8	6.3
II Trough	1.8	5.2	7.2	2.4
III Basin	0.7	2.9	2.5	1.2
IV Ridge	1.1	2.1	16.1	1.1
V Continental Slope	0.8	1.5	2.8	1.0
VI Bank	1.6	3.5	6.5	5.2

Note: $V_R = S_x/S_y$, Where S_x or S_y is respectively standard deviation in reference to humus content or to water depth in the site of sedimentation.

The continental shelf, called "*Belt of Variables*" in geology, looks much complicated in conditions of sedimentation, accordingly, where there may be observed a more variable accumulation of organic substances not only in quantity but in quality comparing with the cases of the other subareas. However, it appears that the farther off coast the sediments are the less the influence of terrigenous factors becomes, that is to say, the pelagic factors become more influential. Now, the environmental coefficients, V_r , are observed gradually decreasing with increasing distance off coast, as ranging from shelf to slope, until they become approximately constant in pelagic area. This appears to reflect well the increase of pelagic influences.

A large coefficient on nitrogen content observed in the underwater ridge (IV) extending from the Shakotan Peninsula appears to suggest the active accumulation of benthic remains. Further, the respective coefficients of carbon content, nitrogen content and C/N are observed comparatively large in the banks (VI) west off the coast. In the above banks, there may be found a comparatively active accumulation of remains of planktonic or benthic organisms, but a less abundance in bacteria which decompose these remains. This point was emphasized in the preceding chapter concerning oxygen absorption by sediments. The organic decomposition may accordingly be arrested, so that the above deviation of the coefficients may be brought. But the consideration on these causes may be not entirely correct because of poverty in number of samples employed.

The environmental coefficient of marine humus distribution employed herein will be very useful, as pointed out above, to indicate the variability in humus distribution in a given area, especially in consideration of geographical factors influencing sedimentation.

X. MARINE HUMUS DISTRIBUTION IN THE SEA TO THE SOUTHEAST
OF HOKKAIDO, IN RELATION TO OCEANOGRAPHICAL ENVIRONMENT
AS DEDUCED FROM SEDIMENTOLOGICAL EXAMINATION
OF THE SEDIMENTS

As to environmental factors relating to the characters of marine humus, there are emphasized oceanographical conditions of the water column as well as submarine topography of the site of deposition. So an examination was undertaken as to how the properties of the water overlying the site of deposition may influence the regional distribution of organic materials in the sediments. As yet it seems difficult to indicate the dynamical complexity throughout a year concerning the oceanographical conditions in a given area, but the mass properties of sediment are induced by the variation of environments of the water column overlying the site of deposition and they suggest the integral contribution of oceanographical environments to subaquatic accumulation.

In the present chapter, the regional distribution of marine humus in the sea to the southeast of Hokkaido was discussed with reference to the data of a series of oceanographical observations (Koto, 1952) or to the mass properties of the bottom samples as determined by mechanical analysis. Moreover the area under discussion seems the most suitable to investigate the influences of oceanographical environments on humus distribution. The submarine topography appears rather even and the slope next to the shelf is gentle. There is not any large river supplying a good amount of terrigenous debris. Accordingly it seems that there are scarcely to be found any pronounced effects of topography or/of terrigenous supplies from any large river for influencing accumulation of organic matter on the bottom. The oceanographical conditions, then, appear to be the most important factor in organic accumulation on bottom floor (Fig. 37).

General characters of bottom samples taken from the sea to the southeast of Hokkaido (the Pacific west of Cape Erimo) were tabulated in Table 35.

For obtaining as accurate as possible knowledge of dynamical processes of sedimentation in the area, the following laboratory method (Inman, 1950) on particle size distribution was applied to the mechanical analysis of bottom samples from this area:

After drying, each sample was subjected to a preliminary examination under microscope previous to chemical or mechanical analyses.

From the mechanical analysis data, a cumulative curve was drawn for each sample on logarithmic probability paper. The median diameter and the first and third quartile measures were obtained from the curve. From these measures Tarsk's (1932) coefficients of sorting and skewness were computed. The sorting coefficient is determined as

$$S_0 = \sqrt{\frac{Q_1}{Q_3}}$$

Table 35. General Properties of Bottom Samples from the Area to the Southeast of Hokkaido (3-20, September, 1949)

St. No.	Date (Sept. 1949)	Location		Water Depth (m)	Texture of Sediment	Organic Carbon(%)	Total Nitrogen(%)	C/N	Ignition Loss (%)	Diatom Residues	Silicious Sponge
		Lat. N	Long. E								
H 2	3	41°48.7'	141°18.7'	249	SM	0.18	0.066	2.73	0.48	RR	C
H 3	3	41°48.5'	141°23.6'	299	SM	0.53	0.044	12.05	1.38	R	A
H 4	3	41°48.5'	141°29.3'	274	SM	0.58	0.046	12.83	3.37	RR	C
H 5	3	41°48.7'	141°34.8'	521	G SM	0.66	0.085	7.77	1.69	C	C
H 6	3	41°48.7'	141°40.0'	830	G SM	0.70	0.097	7.22	4.05	R	C
H 10	3	41°52.2'	141°31.1'	527	SM	0.74	0.107	6.92	3.92	C	C
H 11	3	41°51.8'	141°26.0'	297	SM	0.79	0.072	10.97	3.67	C	C
H 15	4	41°55.8'	141°7.0'	102	SM	0.47	0.041	11.46	5.07	C	C
H 16	4	41°55.8'	141°11.7'	198	G SM	0.09	0.043	2.09	0.85	RR	C
H 17	4	41°55.5'	141°18.3'	288	G SM	0.82	0.122	6.72	3.59	C	C
H 20	8	41°59.5'	141°2.5'	97	G SM	0.34	0.036	9.45	5.88	R	C
H 21	8	41°59.5'	141°7.8'	123	G SM	0.13	0.060	2.17	7.32	C	C
H 23	8	41°59.4'	141°18.3'	290	SM	0.28	0.055	5.09	1.99	C	C
H 24	8	41°59.5'	141°23.8'	255	SM	0.55	0.118	4.66	3.23	A	A
H 25	8	41°59.0'	141°29.7'	459	SM	0.52	0.102	5.10	4.43	A	C
H 26	8	41°59.0'	141°34.2'	797	M	1.24	0.120	10.33	—	C	C
H 32	9	42°2.9'	141°1.6'	98	G SM	0.30	0.045	6.67	5.16	C	C
H 33	9	42°2.8'	141°6.7'	116	G SM	0.62	0.126	4.62	4.23	C	C
H 34	9	42°2.5'	141°11.5'	133	G SM	0.56	0.041	13.66	3.80	C	C
H 35	9	42°2.7'	141°17.0'	252	G SM	0.49	0.101	4.92	3.65	A	C
H 36	9	42°2.8'	141°22.4'	352	SM	0.84	0.126	6.67	5.89	A	C
H 38	9	42°6.5'	141°33.0'	604	M	1.57	0.148	10.61	9.07	A	C
H 41	9	42°6.6'	141°31.0'	541	M	1.39	0.140	9.93	8.45	C	C
H 42	9	42°6.6'	141°26.0'	420	M	1.18	0.136	8.68	6.82	C	C
H 43	9	42°6.4'	141°21.5'	355	M	1.21	0.176	6.88	8.94	A	C
H 44	9	42°6.0'	141°16.4'	256	SM	0.62	0.091	6.81	4.04	R	C
H 45	9	42°6.0'	141°9.3'	121	SM	0.46	0.057	8.07	—	R	C
H 48	10	42°14.4'	141°1.2'	75	GM	0.90	0.079	11.39	5.77	C	C
H 49	10	42°11.9'	141°8.9'	98	SM	0.65	0.052	12.50	4.82	C	C
H 50	10	42°10.2'	141°15.2'	193	SM	0.72	0.088	8.18	0.62	C	C
H 51	10	42°8.7'	141°20.8'	376	M	1.13	0.131	8.63	6.31	C	C
H 52	10	42°14.0'	141°25.0'	430	M	1.11	0.087	12.76	6.91	C	C
H 53	10	42°15.4'	141°20.4'	289	G SM	1.02	0.113	9.03	6.38	C	C
H 54	10	42°18.1'	141°16.5'	139	G SM	0.47	0.067	7.02	3.26	R	C
H 55	10	42°15.7'	141°11.8'	100	SM	0.66	0.101	6.54	5.93	C	C
H 56	10	42°13.2'	141°15.6'	258	M	1.04	0.192	5.42	8.11	C	C
H 57	10	42°10.5'	141°25.5'	460	M	1.13	0.195	5.80	8.04	A	C
H 60	10	42°15.0'	141°29.0'	453	M	0.95	0.202	4.70	6.92	A	C
H 61	10	42°18.7'	141°23.8'	402	MG	1.28	0.209	6.12	9.83	C	C
H 62	10	42°22.2'	141°20.0'	93	G SM	0.63	0.070	9.00	4.22	C	C
H 63	10	42°25.2'	141°24.5'	88	G SM	0.36	0.074	4.87	3.01	R	C
H 64	10	42°22.0'	141°27.6'	338	M	1.40	0.142	9.86	9.96	AA	C
H 65	10	42°19.1'	141°29.5'	449	MS	1.11	0.146	7.60	5.32	A	C
H 69	13	42°24.5'	141°33.5'	285	M	1.39	0.170	8.18	7.34	A	C
H 70	13	42°20.8'	141°34.4'	399	M	1.01	0.183	5.52	7.52	A	C
H 76	13	42°25.0'	141°48.1'	79	SM	0.64	0.036	17.78	5.77	R	C
H 80	14	42°14.6'	141°41.4'	648	M	1.87	0.187	10.00	11.18	A	C
H 83	14	42°16.1'	141°49.4'	530	M	1.85	0.201	9.20	10.91	A	A
H 87	15	42°18.4'	141°57.2'	160	SM	0.79	0.032	24.69	3.30	RR	C
H 88	15	42°14.8'	141°54.5'	630	M	1.71	0.184	9.29	—	C	C
H 89	15	42°11.2'	141°51.6'	785	M	2.01	0.186	10.81	12.63	C	C
H 92	15	42°10.2'	141°58.7'	785	M	0.85	0.162	5.25	12.13	AA	C
H 93	15	42°14.3'	142°0.2'	565	M	0.74	0.136	5.44	4.67	R	A

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St. No.	Date (Sept. 1949)	Location		Water Depth (m)	Texture of Sediment	Organic Carbon (%)	Total Nitrogen (%)	C/N	Ignition Loss (%)	Diatom Residues	Silicious Sponge
		Lat. N	Long. E								
H 94	15	42° 17.4'	142° 2.1'	120	C S	0.56	0.071	7.89	3.05	RR	C
H 96	16	42° 17.7'	142° 9.0'	95	S M	0.59	0.044	13.41	3.67	RR	C
H 98	16	42° 10.3'	142° 4.0'	820	M	1.21	0.208	—	—	C	C
H 101	16	42° 9.5'	142° 9.2'	840	M	1.11	0.178	6.80	12.14	C	A
H 102	16	42° 13.3'	142° 11.7'	500	M	1.70	0.121	9.17	10.23	R	C
H 109	16	42° 6.4'	142° 18.8'	715	M	1.66	0.101	16.83	10.91	AA	C
H 110	16	42° 9.5'	142° 21.0'	465	M	0.26	0.103	16.12	8.42	C	C
H 112	17	42° 12.2'	142° 28.0'	85	S M	—	0.043	6.05	3.87	RR	C
H 117	17	42° 2.6'	142° 28.1'	780	M	1.21	0.143	8.46	9.74	A	C
H 118	17	42° 6.4'	142° 30.0'	370	M	1.52	0.132	11.52	8.26	C	C
H 120	17	42° 8.5'	142° 37.2'	100	S M	0.41	0.084	4.88	3.43	RR	C
H 121	17	42° 4.0'	142° 33.7'	540	M	1.05	0.136	7.72	12.92	A	A
H 122	17	42° 0.8'	142° 31.7'	780	M	2.39	0.215	11.12	15.56	A	C
H 125	18	42° 6.0'	142° 41.1'	245	M	0.77	0.100	7.70	3.73	R	A
H 127	18	42° 6.0'	142° 41.1'	95	S	0.70	0.065	10.77	4.24	RR	C
H 128	18	42° 1.9'	142° 38.9'	320	M S	1.36	0.097	14.02	7.30	C	C
H 129	18	41° 58.7'	142° 35.7'	705	M	1.74	0.188	9.26	9.32	C	C
H 133	18	41° 51.0'	142° 43.6'	320	G S M	0.68	0.112	6.07	3.94	A	C
H 134	18	41° 52.0'	142° 49.7'	115	S M	0.18	0.063	18.73	4.59	R	C
H 135	18	41° 55.1'	142° 54.2'	90	S	0.81	0.048	16.88	6.23	C	C
H 136	19	42° 3.8'	142° 46.4'	85	G S	0.53	0.042	12.62	4.86	R	C
H 142	19	41° 58.6'	142° 51.7'	90	S	1.00	0.053	18.87	5.43	C	C
H 144	19	41° 48.0'	142° 52.4'	125	S M	0.67	0.060	11.17	4.08	C	C
H 152	20	41° 44.5'	142° 55.2'	210	S M	0.72	0.053	13.59	2.97	C	C
H 153	20	41° 42.5'	142° 50.4'	465	S M	0.73	0.092	7.94	4.60	A	C
H 157	20	41° 42.2'	142° 57.9'	200	G S	0.76	0.062	12.67	2.52	—	—
H 159	20	41° 41.5'	143° 1.4'	426	M	1.03	0.123	8.37	8.78	R	C

and the skewness coefficient as

$$Sk = \frac{Q_1 Q_3}{Md^2}$$

where Q_1 , and Q_3 ($Q_1 > Q_3$) are the quartile measures and Md is the geometric median diameter. Detailed description of the mechanical analysis is given as follows:

Each sample was air-dried, then crushed with rubber pestle, and ten grams of the crushed test sample was used for mechanical analysis.

Test sample was soaked for two or three hours in hot water adding a few drops of ammonia, then wet-sieved through 0.06mm mesh sieve to separate sand fraction from the silt. The settling method was used for analysing the fraction finer than 0.06mm in diameter of particle. The clay fraction finer than 0.01mm in grain size was separated from the silt fraction ranging from 0.01mm to 0.06mm in size. The sand fraction remaining in the sieves was analysed by common wet method of sieving.

a) General Description of the Area

Occasional observations in the area have hitherto been carried out by the Hakodate Marine Observatory. Koto (1952), the author's colleague, has investigated the

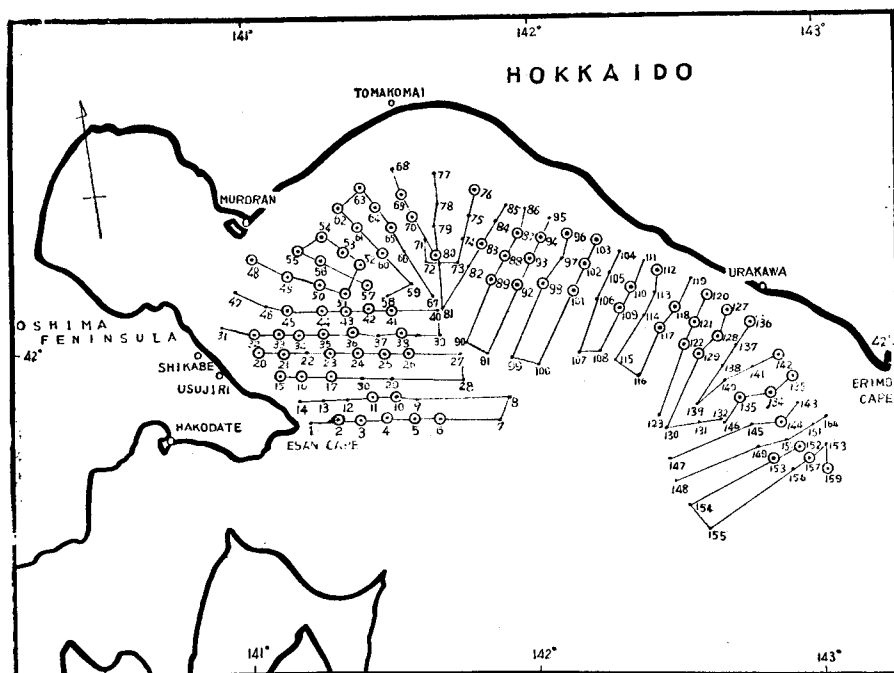


Fig. 36. Stations observed in the area to the southeast of Hokkaido (August 3-20, 1952)

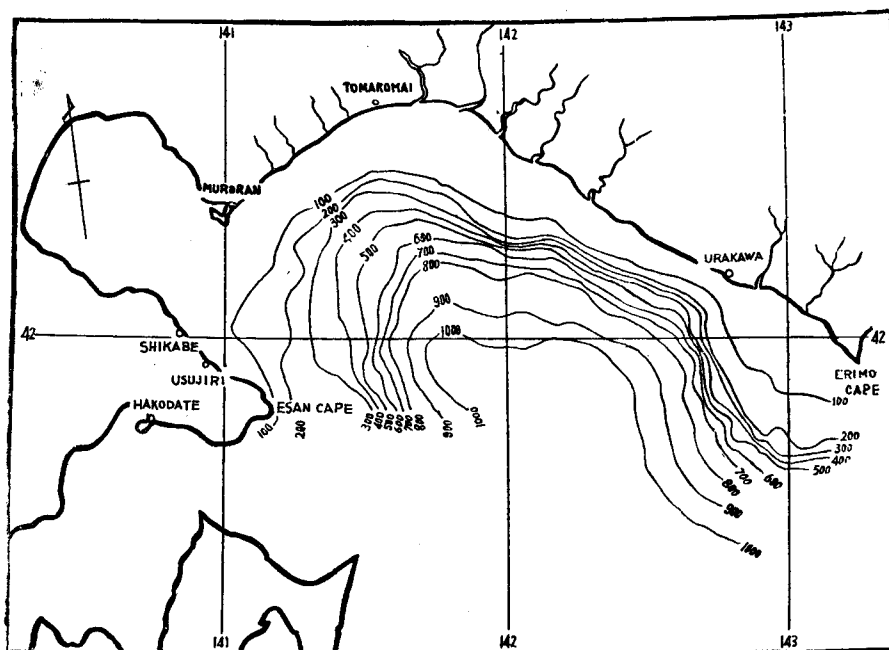
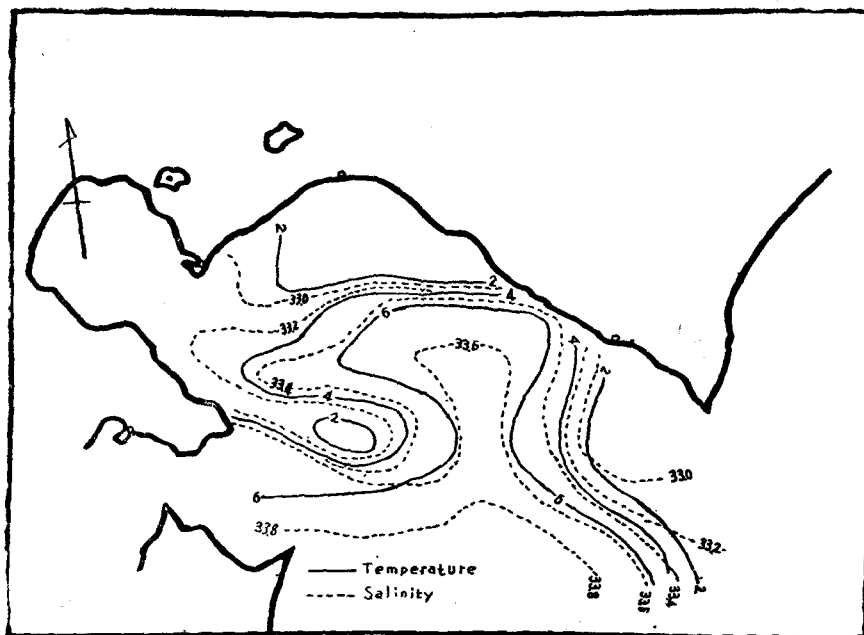


Fig. 37. Submarine topography in the area to the southeast of Hokkaido (meter)

oceanographical conditions, since 1949, for clarifying the hydrographical mechanism of the water exchange in Funka Bay located in the western part of the area under discussion. One may understand the oceanographical characteristics of the area after reading his following interpretation regarding the oceanographical condition observed in the mouth of the bay (May 1950, Fig. 38):

A branch of Tsushima Current as called 'Tsugaru Current', after passing through the Strait of Tsugaru, has branched off northwards. As the branched current develops gradually, the upper water of Oyashio Cold Current which had been staying ever since winter has separated into two parts in the area intermediate between Tomakomai and Urakawa (Fig. 38). The western water separated thus will stay at the state of a separated water-mass as well as the water of Funka Bay do and will become mixed gradually with the water of the warm current, and then both salinity and tem-



from the oceanographical point of view : The open sea (1) appears to be usually under the predominant influence of the Tsugaru Current. But the area adjacent to the Peninsula of Oshima (2) will be complicated in the movement of the water owing to the geographical configuration, while the area off the coast of Hidaka (3) is usually under the influence of Oyashio Current, especially in autumn and winter. Furthermore, in the western area in the vicinity of the mouth of Funka Bay (4), a part of the upper water of Oyashio Current has been remained hydrographically owing to the increasing of the influence of Tsushima Current in spring and summer, and moves as a counter current against the Tsugaru Current.

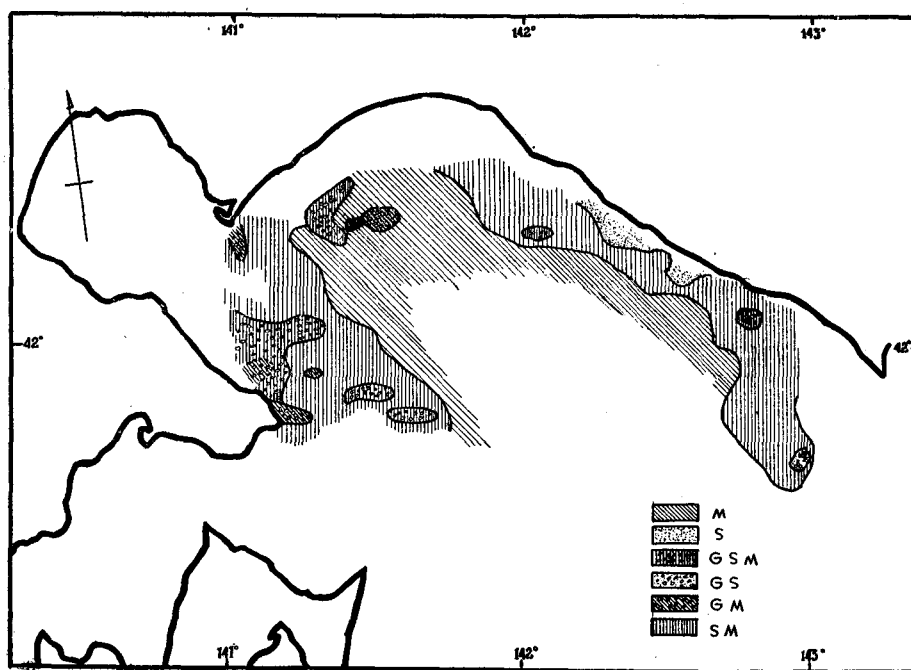


Fig. 39. Bottom character in the area to the southeast of Hokkaido

The textures of sediments in the area appear mostly as sandy mud and become muddy with increasing water depth of the site of deposition (Fig. 39). Remarkable sedimentation of volcanic materials such as volcanic ashes or pumices is observed at the mouth of the bay and off the eastern coast of the Oshima Peninsula. They appear to be brought from the volcanoes, as Komagatake and Tarumaisan. It is notable that there is found a distribution of gravels off Urakawa ; these gravels observed are not pumices. Sand and shell fragments are found on the bottom floor lying between Tomakomai and Mitsuishi. In the sediments enriched in sand or gravel, there was found a pretty good amount of benthic animals, either living or dead, e.g., sea worms, brittle stars, heart urchins, amphipods, or young shells of scallop.

b) General View of Marine Humus Distribution in the Area

The amounts of organic materials in the sediments were summarized in Table 35. The regional distribution of organic contents in the sediments were illustrated in Figs. 40, 41 and 42. These figures might indicate some correlations between the humus distribution and the environmental conditions at the site of deposition.

The abundance of organic matter indicated by the content of organic carbon or total nitrogen might vary with water depth of the site of deposition. These relations between them were examined statistically, and the results were summarized in Table 36, according to which there is found a fairly positive correlation between organic content and water depth. But the ratio of organic carbon to total nitrogen does not have any correlation to the water depth.

Table 36. Organic Contents of the Sediments and Their Relation to the Water Depth of the Site of Deposition ($\alpha=0.05$)
(The Sea to the Southeast of Hokkaido, Sept. 3-20, 1952)

Number of Individuals	Population Mean ($\alpha=0.05$)(\bar{x})	Standard Deviation (S)	Correl Coeff. (γ)	Test of Null Hypothesis	Equation of Regression
Organic-C 79	0.82 - 1.06	0.50	0.689	$\delta \neq 0$	$C = 0.00149 d + 0.339$
Total-N 80	0.091 - 0.118	0.058	0.552	$\delta \neq 0$	$N = 0.000162d + 0.0490$
C/N 77	7.2 - 8.9	3.7	- 0.092	$\delta = 0$	—

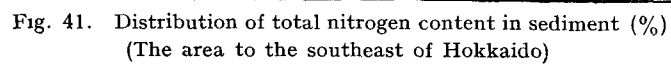
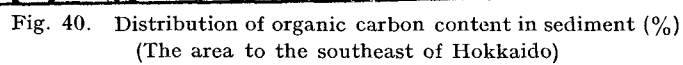
C: Carbon Content (%)

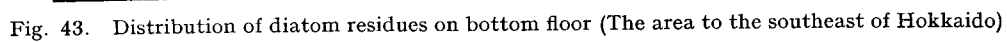
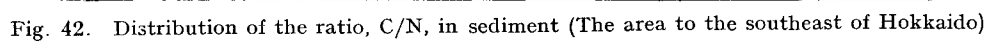
N: Nitrogen Content (%)

d: Water Depth of the Site of Deposition (m)

It is remarkable that organic accumulation in the sediments shows an increase with water depth and resembles the sedimentation map of planktonic remains (Fig. 43) in distribution.

In the open sea deeper than 700 meters in depth, a good amount of marine humus, 1.8-2.4% C or 0.18-0.23%N, may be accumulated in the sediments. While, in the nearshore or comparatively shallow bottom organic accumulation is not so remarkable as that in the deeper ones; that is, accumulation under 0.1 per cent in nitrogen content is found in the continental shelf or at the offing east of Cape Esan. Further it is very remarkable that characteristic accumulation of marine humus is found in the western area, of which water is customarily isolated from the water of Tsushima Current. At the center of this area, there occurs an upwelling and a comparatively abundant accumulation of organic matter is observed in the sediments notwithstanding poor accumulation at the bottom neighbouring to the above center. Further a strip of poor accumulation in organic carbon which pushes out offshore the northeastern coast may be due to erosion induced by the water of Tsugaru Current approaching the coast. In the area to the northeast of Cape Esan, not only the amount but character of





organic materials in the sediment appear remarkably complicated, both of which fact may be due to the oceanographical complexity found there.

The local variation of the ratio, C/N, seems very interesting in reference to either terrigenous supplies or oceanographical characteristics in the area: A belt of ratio comparatively large in value runs along the continental slope, as shown in Fig. 42, where the major water of Tsugaru Current has, probably and usually, come into contact with the other waters near the coast. The noticeable portion of the belt lying off the northeastern coast appears to be contributed by a remarkable decomposition of nitrogenous substances in comparatively fresh terrigenous detritus, judging from the poverty of nitrogen content. The organic detritus has perhaps been supplied from land by rivers in the northern coast and transported by the water of Tsugaru Current flowing to southeast. Other ratios as large as the above are also found at the central part of the northwestern area as well as at the offing of Usujiri, the Oshima Peninsula. At both of them, the existence of eddies is suggested in the preceding part of this chapter. Further it is very notable that some singular stations having extremely small ratio are located nearby a station showing an extremely large ratio.

After all, comparatively large ratio, 10 or over, will be found in the sediment of the characteristic place which will be usually under the influence of rip current in broad sense. In the above sediments, nitrogenous substances of fresh organic matter will be decomposed more actively by bacteria than non-nitrogenous substances because there will be supplied a fairly good amount of oxygen to promote the bacterial decomposition. Waksman (1933) has shown that fresh organic matter attacked by bacteria will first lose more nitrogen than carbon until a more or less definite equilibrium ratio is attained.

According to the preliminary examination under microscope, the abundance of organic remains, especially skeletal residues of diatom, in the sediment appears nearly analogous to that of the nitrogen content. Consequently the organic remains might contribute effectively to sedimentary accumulation of nitrogenous substances on the bottom floor. It will be also one of the characteristics of the sediments in the area under discussion that the fragments of sponge spicule were observed in almost all of the sediments.

c) Sedimentological Examination of Marine Humus Distribution

The median diameters and Trask's coefficients of sorting and skewness of the sample were investigated to see if these indexes after mechanical analysis of the sample would show any relationship not only to the various topographic or oceanographic environments but also to the regional distribution of marine humus.

Figure 39 shows a bottom sediment map of the whole area, but that will be not

always satisfactory for representing dynamical process of sedimentation occurring therein. So, a contour map of median diameter from cumulative size-distribution curve is shown in Fig. 44, which was drawn in reference to the fraction of the bottom sample finer than two millimeters in grain size. The median map shows that a

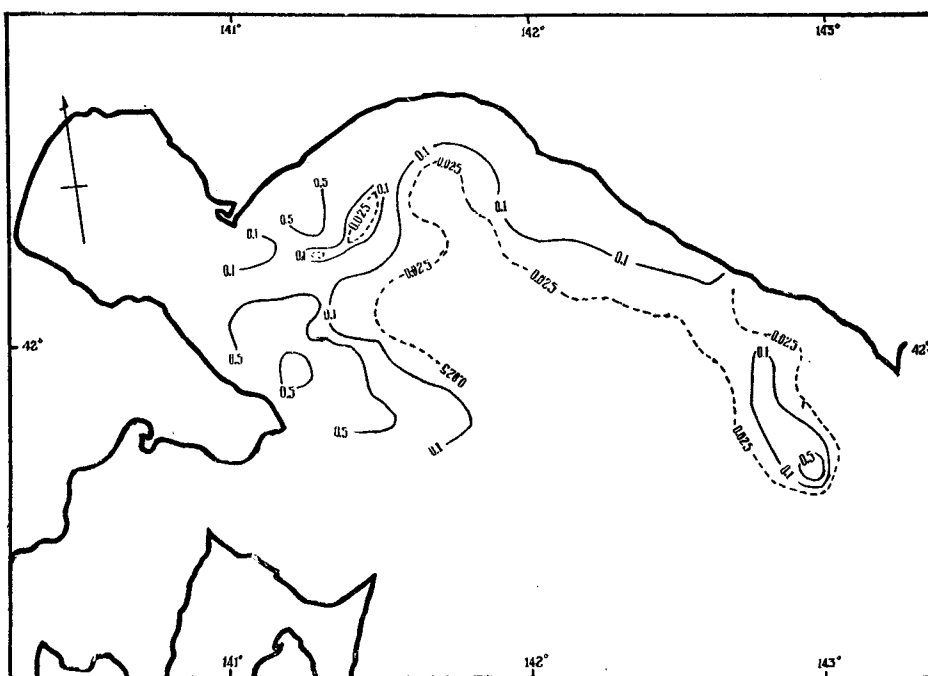


Fig. 44. Median map of the area to the southeast of Hokkaido (mm)

remarkable accumulation of grains finer than 0.025 mm is found in the north-western part of the area although these finer sediments are usually found in the offing deeper than 500mm meters. Further, off the coast between Urakawa and Cape Erimo, it is remarked that the sediments have the fine grains of 0.001 mm or less in median diameter. It appears that these characteristic regions emphasized above are located in the areas where there will usually occur some eddy currents induced by contact of different masses of water.

The inspection on relationship between sedimentological indexes, i.e., Md, So, Sk, in the sediment and water depth of the site of deposition shows that it is hardly possible to find any correlation between them as a whole.

The samples from the area were classified into several groups, as shown in Fig. 46 or Table 37, on the basis of the shape of cumulative frequency curve on grain size (Fig. 45). The area under discussion is divided as illustrated in Fig. 44 into several regions with reference to sediment type as well as to oceanographical environment. Such partition of the area will be reasonable for clarifying a correlation between the

Table 37-1. Relations of Organic Accumulation to Mass Properties of Bottom Sample

(1) A-Region :

	St.	Depth (m)	Md (mm)	Sk	So (%)	Ignition Loss (%)	C (%)	N (%)	C/N
A 1	83	530	0.013	0.899	6.164	10.91	1.85	0.201	9.20
	89	785	0.016	1.019	6.633	12.63	2.01	0.187	10.81
	92	785	0.018	0.906	5.506	12.31	0.85	0.162	5.25
	117	780	0.018	1.000	5.679	9.74	1.21	0.145	8.46
	122	780	0.013	1.041	6.633	15.56	2.39	0.215	11.12
A 2	38	604	0.023	0.962	12.47	9.07	1.57	0.148	10.61
	41	541	0.022	1.113	10.10	8.45	1.39	0.140	9.93
	70	399	0.023	0.516	16.88	7.52	1.01	0.183	5.52
	125	245	0.010	0.879	9.747	5.73	0.77	0.100	7.70
A 3	80	648	0.045	0.691	7.616	11.18	1.87	0.187	10.11
	88	630	0.035	0.713	6.566	—	1.71	0.184	9.29
	101	840	0.042	0.756	6.297	10.14	1.21	0.178	6.80
	102	500	0.043	0.823	4.484	10.23	1.11	0.128	9.17
	121	540	0.042	0.756	6.290	12.92	1.05	0.136	7.72

Table 37-2.

(2) B-Region :

	St.	Depth (m)	Md (mm)	Sk	So (%)	Ignition Loss (%)	C (%)	N (%)	C/N
B 1	4	274	0.593	0.734	1.539	3.38	0.58	0.046	12.83
	5	521	0.480	0.880	1.490	1.69	0.66	0.085	7.77
	6	830	0.398	0.680	1.774	4.05	0.70	0.097	7.22
	11	297	0.578	0.456	2.038	3.66	0.79	0.072	10.97
	15	102	0.843	0.799	1.513	5.07	0.47	0.041	11.46
	21	123	0.878	0.865	1.408	7.32	0.13	0.060	2.17
	23	290	0.650	0.452	1.883	1.99	0.28	0.055	5.09
	34	133	0.542	0.395	2.817	3.80	0.56	0.041	13.66
	54	139	0.637	0.587	2.017	3.26	0.47	0.067	7.02
B 2	10	527	0.380	0.311	2.828	3.91	0.74	0.107	6.62
	17	288	0.582	0.195	3.025	3.59	0.82	0.122	6.72
	24	255	0.518	0.179	3.317	3.23	0.55	0.118	4.66
	25	459	0.264	0.220	4.858	4.43	0.52	0.102	5.10
	33	116	0.590	0.131	4.861	4.23	0.62	0.126	4.92
	44	256	0.540	0.193	3.614	4.04	0.62	0.091	6.81
B 3	20	97	0.508	0.364	3.066	5.88	0.34	0.036	9.45
	32	98	0.535	0.374	3.204	5.16	0.30	0.045	6.67
	35	252	0.280	0.560	3.435	3.65	0.49	0.101	4.85
B 4	16	198	0.186	0.032	32.71	0.85	0.09	0.043	2.09

Table 37-3.

(3) C-Region

	St.	Depth (m)	Md (mm)	Sk	So (%)	Ignition Loss (%)	C (%)	N (%)	C/N
C 1	135	90	<0.001	—	—	6.22	0.81	0.048	16.88
	136	90	<0.001	—	—	4.86	0.53	0.042	12.62
	159	426	<0.001	—	—	8.78	1.03	0.123	8.37
C 2	129	705	0.025	0.326	9.165	9.32	1.74	0.188	9.26

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C 3	110	465	0.046	0.308	4.615	8.42	1.66	0.103	16.12
	118	370	0.047	0.367	3.162	8.26	1.52	0.132	11.52
	120	100	0.094	0.349	2.775	3.43	0.41	0.084	4.88
	128	320	0.046	0.372	3.114	7.30	1.36	0.097	14.02
C 4	96	95	0.154	1.017	1.706	3.67	0.59	0.044	13.41
	112	85	0.135	0.995	1.374	3.87	0.26	0.043	6.05
	133	320	0.097	0.710	2.018	3.94	0.68	0.112	6.07
	134	115	0.082	0.851	1.739	4.59	0.18	0.063	11.73
	142	90	0.061	0.436	2.442	5.43	1.00	0.053	18.87
	144	125	0.125	1.005	1.740	4.08	0.67	0.060	11.17
	152	210	0.117	0.788	1.732	2.97	0.72	0.053	13.59
	153	465	0.104	0.919	1.955	4.60	0.73	0.092	7.94
C 5	87	160	0.332	0.703	2.280	3.30	0.79	0.032	24.69
	94	120	0.245	0.839	2.123	3.05	0.56	0.071	7.89
C 6	157	200	0.650	0.929	1.791	2.51	0.76	0.062	12.67

Table 37-4.

(4) D-Region and E-Region:

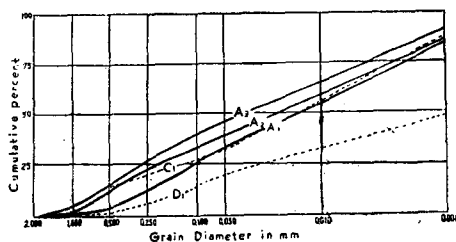
	St.	Depth (m)	Md (mm)	Sk	So ¹ (%)	Ignition Loss (%)	C (%)	N (%)	C/N
D 1	56	258	0.015	1.029	13.42	8.11	1.04	0.129	5.42
	61	402	0.015	1.143	7.746	9.83	1.28	0.209	6.14
	64	348	0.016	1.371	7.206	9.96	1.40	0.142	9.86
D 2	55	100	0.135	0.427	6.787	5.93	0.66	0.101	6.54
	69	265	0.094	0.215	9.684	7.34	1.39	0.170	8.18
D 3	62	93	0.306	0.263	4.239	4.22	0.63	0.070	9.00
	63	88	0.375	0.374	3.141	3.01	0.36	0.074	4.87
D 4	36	352	0.083	0.686	8.595	5.89	0.84	0.126	6.67
	48	75	0.076	1.391	7.274	5.77	0.90	0.079	11.39
D 5	51	376	0.091	0.323	11.24	6.31	1.13	0.131	8.63
	57	460	0.072	0.655	8.324	8.04	1.13	0.195	5.80
D 6	49	98	0.321	0.090	7.390	4.92	0.65	0.052	12.50
	50	193	0.391	0.323	11.24	6.16	0.72	0.088	8.18
	52	415	0.347	0.054	8.07	6.91	1.11	0.087	12.76
	53	289	0.431	0.064	8.07	6.38	1.02	0.113	9.03
	60	453	0.295	0.067	8.51	6.92	0.95	0.202	4.70
E	42	541	0.055	0.088	14.83	6.82	1.18	0.136	9.68
	65	449	0.295	0.311	4.221	5.32	1.11	0.146	7.60
	76	79	0.072	0.119	12.41	5.77	0.64	0.036	17.78

organic accumulation in the sediment and the dynamical process of sedimentation occurring in the site of deposition. Examination of the sedimentary process appears highly useful for investigating the oceanographical environment. These regions divided thus will be illustrated as follows:

(1) A-Region

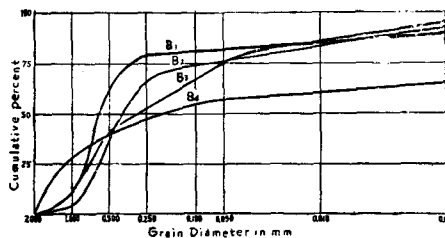
The region is the relatively pelagic part in the area investigated, whose water depth ranges from 500 meters to 840 meters, then seeming to be under influence of

A-Region :



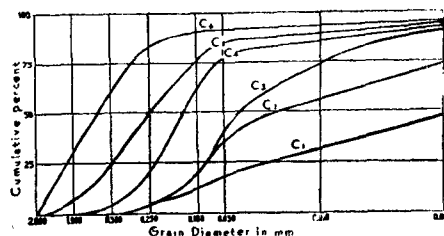
A_1 : H 89, A_2 : H 4, A_3 : H 80,
 C_1 : H 159, D_1 : H 64

B-Region :



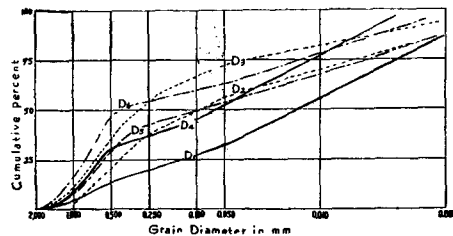
B_1 : H 4, B_2 : H 10, B_3 : H 35, B_4 : H 16

C-Region :



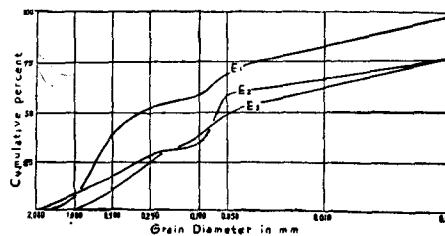
C_1 : H 159, C_2 : H 129, C_3 : H 118,
 C_4 : H 144, C_5 : H 94, C_6 : H 157

D-Region :



D_1 : H 64, D_2 : H 69, D_3 : H 62, D_4 : H 48,
 D_5 : 51, D_6 : H 50

E-Region :



E_1 : H 65, E_2 : H 76, E_3 : H 42

Fig. 45. Graphs of cumulative curves showing sediment types

the Tsugaru Current. Examination shows that the sediments have fairly fine median diameters 0.010–0.045 mm, and that they are poorly sorted indicating 12.3 in S_0 averaged. These sedimentological characters show that the sedimentation occurs in this region remarkably rather in deposition process than in erosion or transportation. Relatively poor sorting in A_3 -region seems to suggest the presence of a kind of current rip which may usually result from contact between the water of Tsugaru and the coastal water as emphasized in the previous sections of this chapter.

In short, an examination of sedimentological characters shows that the region may be characterized as the pelagic or hemipelagic.

Sedimentary accumulation of organic matter seems relatively abundant, that is to say, average content of organic carbon in the sediments ranges from 1.21% to

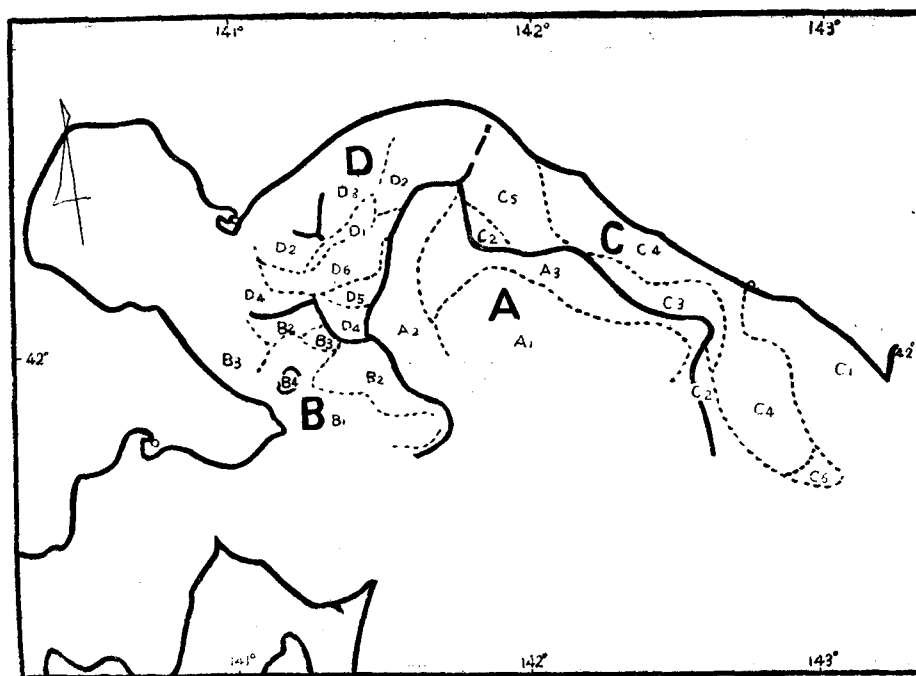


Fig. 46. Geographical regions divided owing to sedimentological character of sediment (The area to the southeast of Hokkaido)

1.66% and that of total nitrogen from 0.143% to 0.182%. Decomposition equilibrium of organic matter in the sediments appears fairly well attained and the ratio of organic carbon to nitrogen will average near 8.6. The sediments in A_2 -region which indicate comparatively poor sorting seem to be rather less abundant in organic matter (ignition loss) than the other parts, A_1 or A_3 of this region do.

(2) B-Region

The major part of the region is the shelf adjacent to the Oshima Peninsula, where the water movement is complicated owing to the geographical configuration. The sedimentological characters in this region show that the median diameter is of coarse or medium sand, and that S_0 of the sediments usually ranges 2-3. Especially, the sediments in B_2 -region are comparatively well sorted. The sediments in B-region, however, seem somewhat poorly sorted in the finer fraction. This tendency is comparatively more remarkable in B_2 or B_3 region. It is very noticeable that the sediments in

the vicinity (B_4 -region) of Station H16 are extremely poorly sorted, 32.7 in S_0 especially in finer fraction of them, 0.03 in Sk. These coefficients regarding B_4 -region indicate that there will usually be found a characteristic deposition of sedimentary particles in the region. The noticeable deposition may be due to a small eddy which is usually found near the coast and influenced by the coastal configuration.

In the B-region, organic accumulation in the bottom appears not so remarkable as that in A-region; that is, the sediments have organic carbon contents ranging nearly from 0.3% to 0.8% or nitrogen contents from 0.04% to 0.12%. Comparatively small values, 5-7, in the ratio, C/N, will predominate in this region, although somewhat strange values are found in B_1 -region. These facts will show that there will be found not only poor accumulation of terrigenous organic matter owing to better sorting but also complex variation of oceanographical environments.

(3) C-Region

The continental shelf off the coast from Cape Esan to Tomakomai belongs to this region. It is divisible into two parts which are characterized on the basis of sediment type of the bottom samples as well as their oceanographical environments. One of them are the areas, C_1 and C_2 , lying intermediate between Urakawa and Cape Esan, where the sediments are mostly of clay or silt and remarkably poorly sorted, namely, their median diameters are finer than 0.01 mm and sorting coefficient 9 or over. These sedimentological characters in C_2 -region show that there occurs a characteristic sedimentation in which deposition process will be rather more active than any other process such as erosion or transportation in the region, and that a kind of eddy or a counter current will be suggested to the observer. Such an eddy current will be induced from the contact of the two currents of the Tsugaru and the Oyashio, of which the latter current flows bypassing Cape Esan. Moreover, it is notable that the sediment type in the C_1 -region is nearly analogous to that in A_1 - or D-region. Organic accumulation, however, in C-region is not so abundant as that in the analogous regions in sediment type mentioned above, and also the qualities of organic materials accumulated appear rather terrigenous judging from the high ratio of carbon to nitrogen.

Another part divided thus occupies most of the C-region and is composed of regions C_3 , C_4 , C_5 and C_6 . The flow of either Tsugaru Current (in spring and summer) or Oyashio Current (in autumn and winter) seems fairly influential. Consequently the sediments are well sorted indicating S_0 ranging 1.4-4.6 or mostly near 2, but the finer fraction appears rather less sorted than the coarser ones. The sediments in C_3 -region, moreover, have median diameter near 0.05 mm and appear relatively rather less sorted, 2.8-4.6 in S_0 , than sediments in the other parts of the C-region do. Such sedimentological features may indicate similarity between C_3 - and A_3 -regions; that is, there will usually be found some rip currents in C_3 -region and resulting the accumulation of a fairly good amount of organic matter in the bottom sediments. In C_4 -region

occupying the major portion of C-region, the sediment particles have 0.06–0.15 mm median diameter, being well-sorted and having somewhat symmetrical size-distribution, where the best sorted sediments have median diameter near 0.13 mm.

As the sediments in the regions C_{3-6} have been well sorted by flows of currents, the organic materials in them will be not only less abundant in sedimentary accumulation but also rather terrigenous in character. Such terrigenous characters of organic materials in the sediments will indicate some influence of organic debris supplied from rivers in the northern coast.

(4) *D-Region* :

D-region is the eastern part of the area under discussion, and complicated in oceanographical environments as emphasized in the previous article, then the sediment type of the bottom samples should likewise be quite complex.

The sorting of sediments in this region appears not only extremely poor but also widely variable. Moreover, the cumulative curve on grain size of sediment appears somewhat singular in shape and suggests some influences of mass movement of unconsolidated sediments as mud flows. The transportation effect mentioned above appears more remarkable in the stations as marked E, or H42, H65 and H76, from the irregular shapes of their cumulative curves. It is so noticeable that there is found a characteristic sedimentation in the central part, D_1 , of the region; the sediment type indicates median diameter near 0.015 mm or sorting coefficient near 7 and appears somewhat analogous to that of the pelagic region as A_1 in sediment type, although the size distribution is skewed towards the coarser sizes. These features of D_1 -region may be somewhat peculiar as effects of eddy or rip current. Moreover, both inspections on the regional distribution of granule (Fig. 39) and on the skewness towards the coarser sizes in grain size distribution of the sediment may indicate that a coast line in geological ages may have existed in D_1 -region. The above geological explanation regarding the sedimentological characteristics, however, will need for confirmations more investigation in future. Further there is found a fairly abundant accumulation of organic matter, 0.14–0.21% N, in D_1 -region, while the neighboring D_6 -region has some characteristic stations such as H49 or H52 indicating fairly high ratio near 12.5 of carbon to nitrogen. This fact will suggest not only complexities in water diffusion towards vertical or horizontal direction but transportation of unconsolidated sediment.

Sedimentological examination of the carbon-nitrogen ratio shows that rather higher ratio may be found in the sediment which has been relatively poorly sorted and indicate characteristic distribution curve with respect to transportation process along the bottom floor.

d) Relationship between Sedimentological Indexes and Organic Accumulation in the Sediment

The sedimentological indexes, as median diameter or coefficients of sorting and skewness, of the bottom samples were examined to see if they might indicate a relationship to the character or abundance of organic materials accumulated in the sediments.

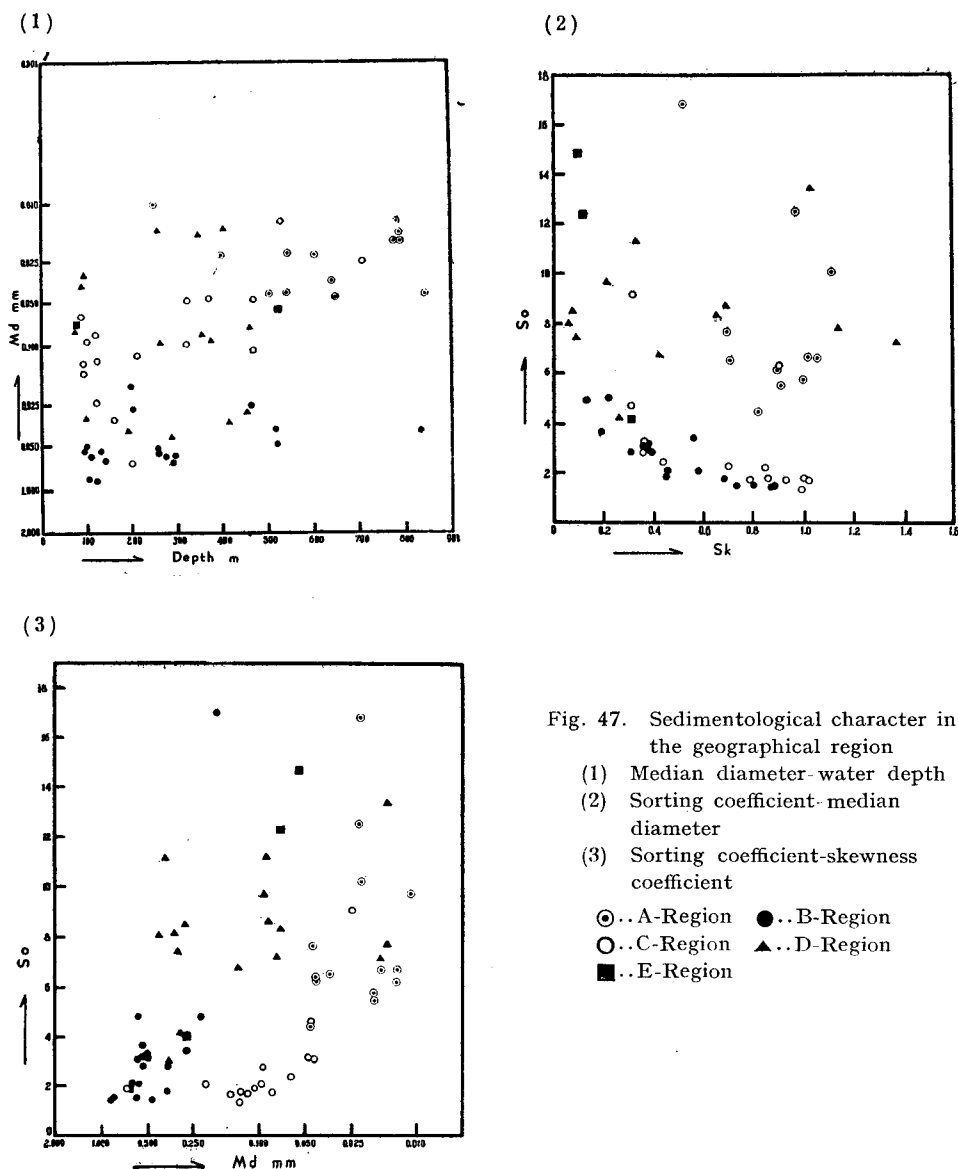


Fig. 47. Sedimentological character in the geographical region

- (1) Median diameter-water depth
- (2) Sorting coefficient-median diameter
- (3) Sorting coefficient-skewness coefficient

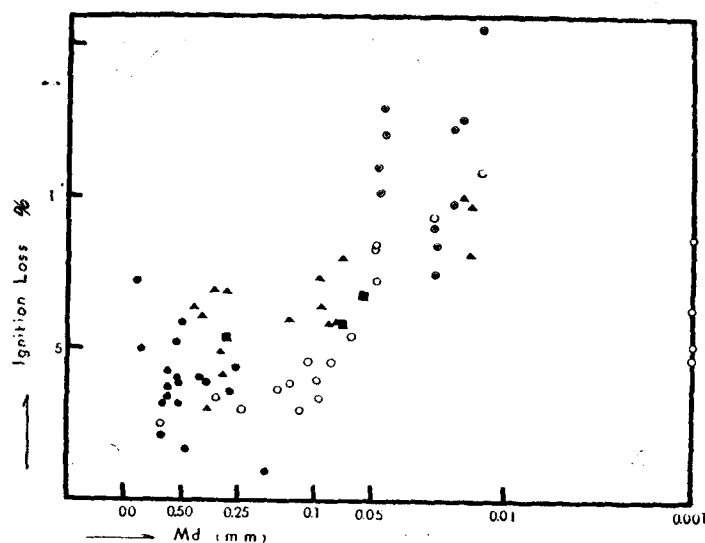
○...A-Region ●...B-Region
 ○...C-Region ▲...D-Region
 ■...E-Region

Results of these examinations are illustrated in the series of Figures 47-50.

Although organic accumulation appears rather correlative to median diameter (Fig. 48), it will be hard in general to see any definite relationship to the coefficients of sorting and skewness. Further inspection in detail leads to approximate estimations on a relationship between the organic accumulation and these indexes.

It appears that the finer in median diameter the more abundant is the organic

(1)



(2)

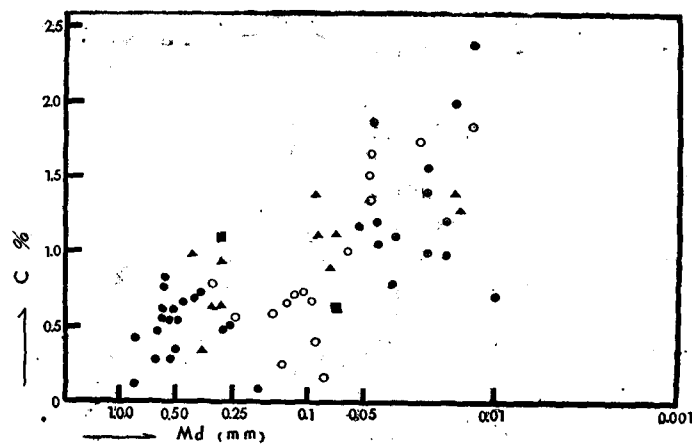


Fig. 48. Relation of median diameter to organic content in sediment

(1) To ignition loss

(2) To organic carbon content

○...A-Region ●...B-Region ○...C-Region ▲...D-Region ■...E-Region

accumulation. As to the sediment finer than 0.01 mm in median diameter, however, there will be found rather a tendency toward reduction of organic content with reduction in the diameter.

Plots of the organic content against the sorting (Fig. 49) for the relatively well sorted sediments as indicating S_0 below 5, fall in some reasonable mass. While, the plots on the poorly sorted sediments seem almost at random. With developing the sorting process the former well sorted sediments appear to reduce their organic contents, particularly more remarkable in respect to nitrogen content. On the other hand, plots regarding the latter sediments poorly sorted will scarcely show any relationship because of their random deviations. However, it seems probable that some definite tendency can be found. The abundance of carbon content will decrease with reducing the degree of sorting while that of nitrogen content will tend to increase with reduction of sorting, until a more or less definite ratio of carbon to nitrogen will

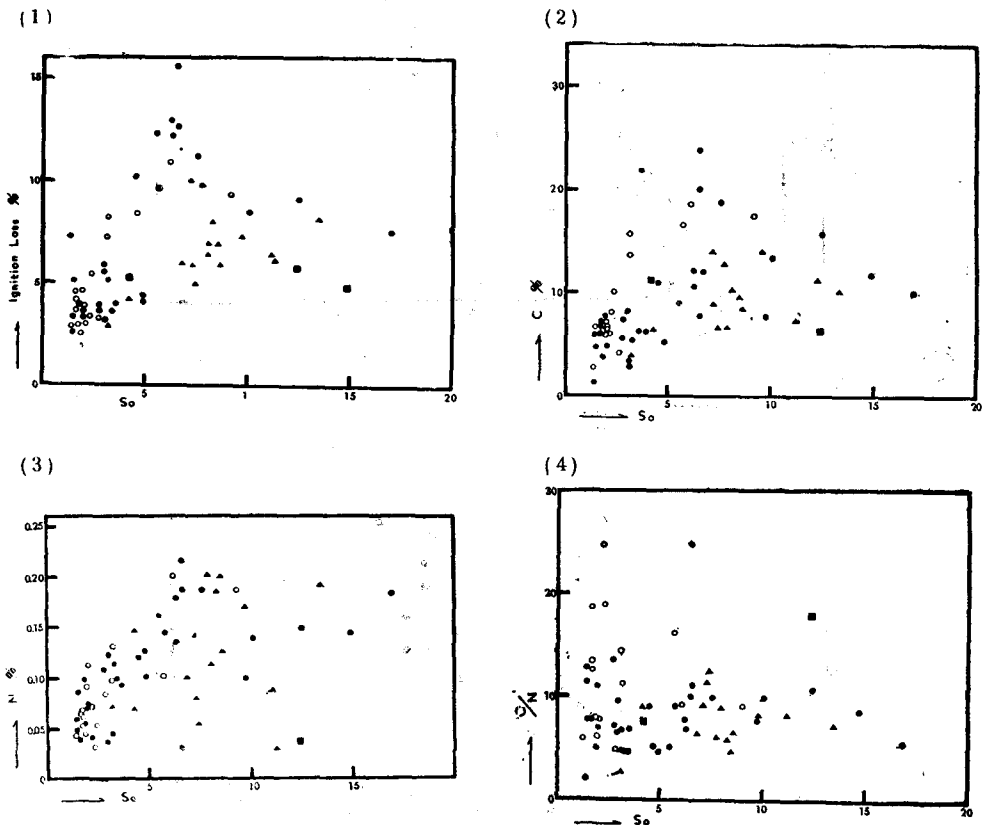


Fig. 49. Relation of sorting coefficient to organic carbon content in sediment

(1) To ignition loss (2) To organic carbon content

(3) To total nitrogen content (4) To the ratio of carbon to nitrogen

○...A-Region ●...B-Region ○...C-Region ▲...D-Region ■...E-Region

be attained. Further it is noticeable that the constancy of carbon nitrogen ratio appears rather less reliable in the sediments relatively well sorted than in the poorly sorted sediments. The fact will show that the better sorting leads to settling of fresh terrigenous debris comparatively larger in size as well as to removal of colloid detrital organic matter, which has been fairly huminized and appears suitable for the inhabiting of benthic animals because of pretty good supplies of oxygen or food material.

Plots of organic content against the skewness on the well sorted sediments in B-region show that a considerable deviation of skewness does not appear to result in much control of organic accumulation (Fig. 50). This fact will suggest that the organic matter accumulated in the well sorted sediment will be built up rather effectively by larger organic debris or remains than by finer detrital materials. The sediments in most of C-region, as in C₃, C₄, C₅ and C₆, have rather coarser median diameter than in B-region, but they are sorted similarly to those in the latter region. Now, it appears that the abundance of organic matter decreases with approach of the skewness to unity. Plots on the poorly sorted sediments such as in A₁-or D-region are widely separated on the diagram, that is to say, it will be scarcely possible to see any relationship between the organic content and the skewness. These examinations show that organic accumulation in the poorly sorted sediments will be fairly contributed to by detrital organic matter.

XI. MARINE HUMUS DISTRIBUTION OF THE WESTERN COAST OF HOKKAIDO

Marine humus distribution off the northern part of the western coast of Hokkaido has been discussed in Chapter IX. Herein, humus distribution off another part of that coast farther south is the subject of discussion. This investigation on humus distribution has been done in the vicinity of Okushiri Strait and next in Ishikari Bay.

A. HUMUS DISTRIBUTION IN THE VICINITY OF OKUSHIRI STRAIT

a) General Description of the Area

The area under discussion is located between Cape Motta (42°36' N) and Koshima Island (41°19' N) at the western entrance of Tsugaru Strait. The Tsugaru Current flows northward through the area and branches off at the Island of Okushiri (Fig. 51).

The characteristics of submarine topography in the area may be emphasized as follows: The continental shelf is narrow and about one to five miles wide; it goes down in a steep slope to the deep bottom of the Japan Sea. The Okushiri Channel between Okushiri Island and the Oshima Peninsula is comparatively shallow. In the midportion of the channel runs a narrow trough having 400-500 meters of water

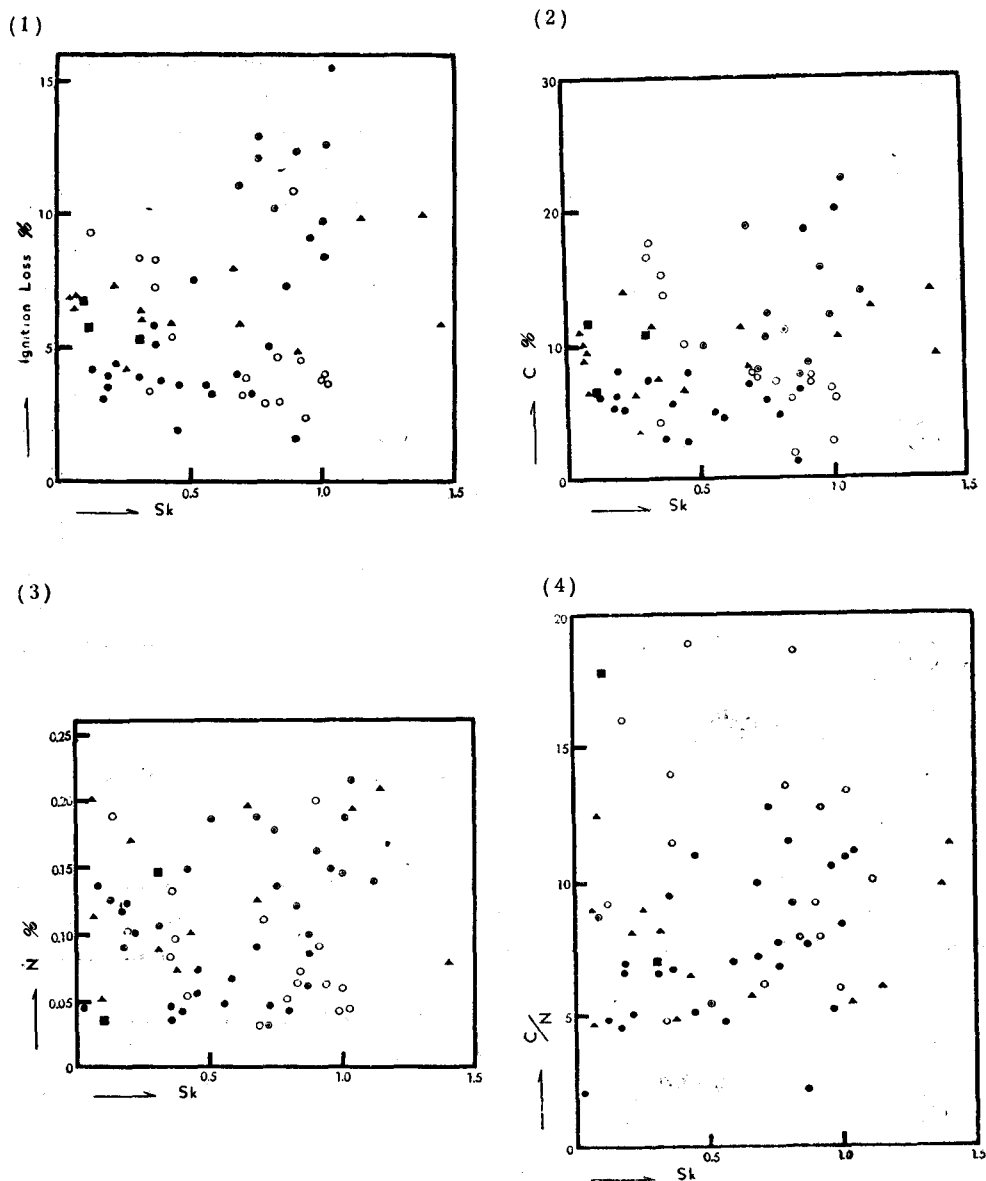


Fig. 50. Relation of skewness coefficient to organic content in sediment

- (1) To ignition loss
- (2) To organic carbon content
- (3) To total nitrogen content
- (4) To the ratio of carbon to nitrogen

○...A Region ●...B-Region ○...C-Region ▲...D-Region ■...E-Region

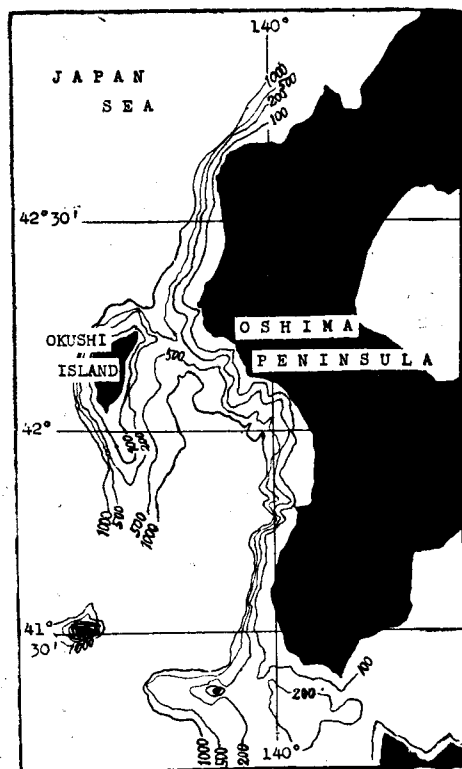


Fig. 52. Submarine topography in the vicinity of Okushiri Strait

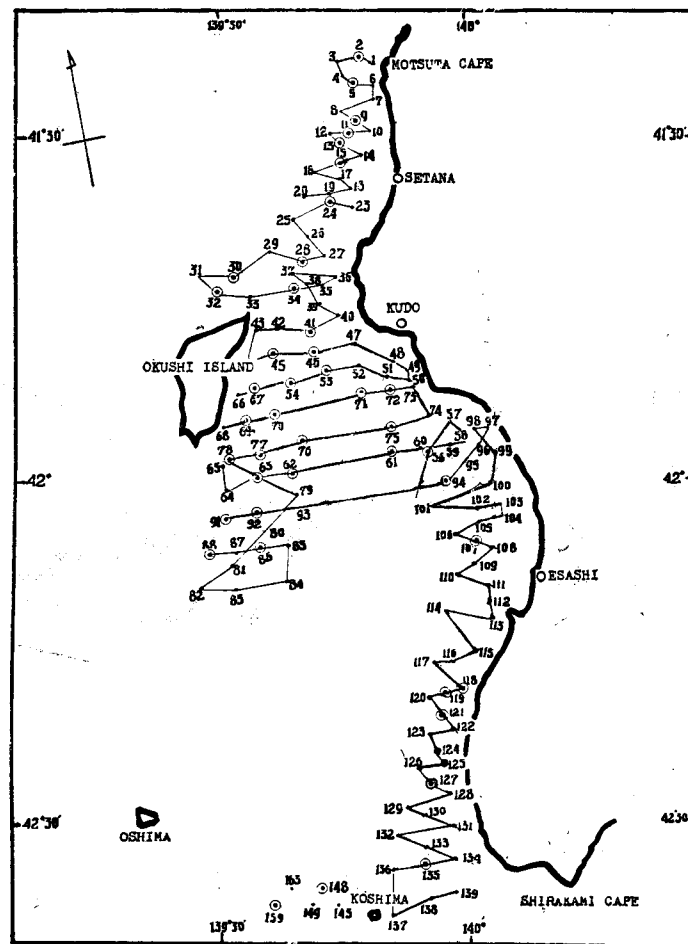


Fig. 51. Stations observed in the vicinity of Okushiri Strait (August 23-31, 1952)

depth. A shelf lies between Cape Shirakami and Koshima Island. Another characteristic is that a number of small submarine canyons traverse the continental shelf of the peninsula (Fig. 52).

Bottom characters of the shelf and of the slope skirting the peninsula or the islands are rocky, sandy or gravelly, and that of the deep slope is muddy, as illustrated in Fig. 53.

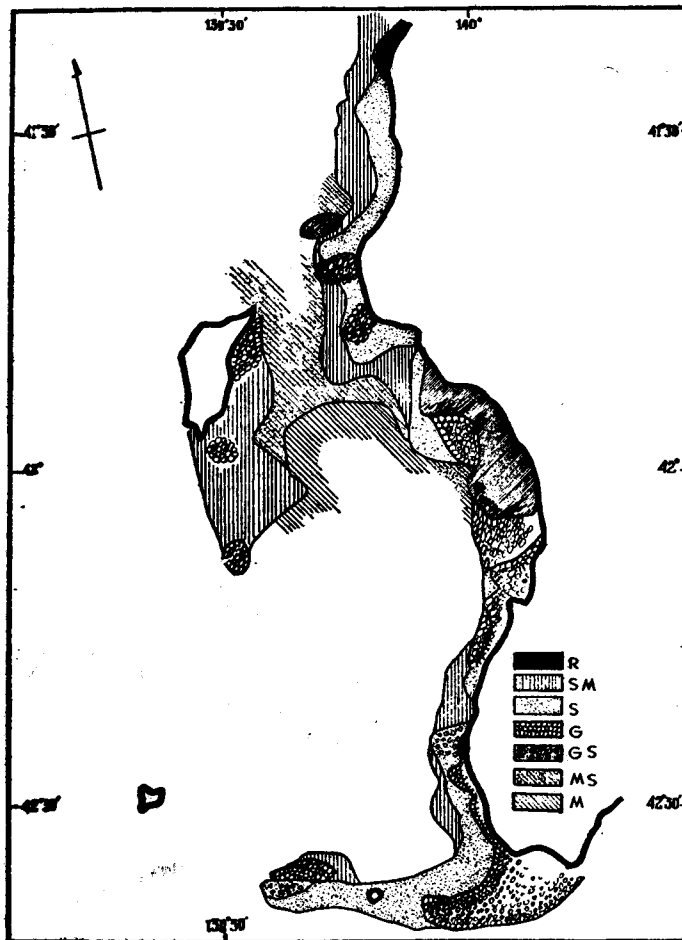


Fig. 53. Bottom character in the vicinity of Okushiri Strait

b) Regional Distribution of Marine Humus

The organic contents of the sediments have been summarized in Table 38 and illustrated in Figs. 54-56.

The abundance of marine humus in the area is considerably variable with varying

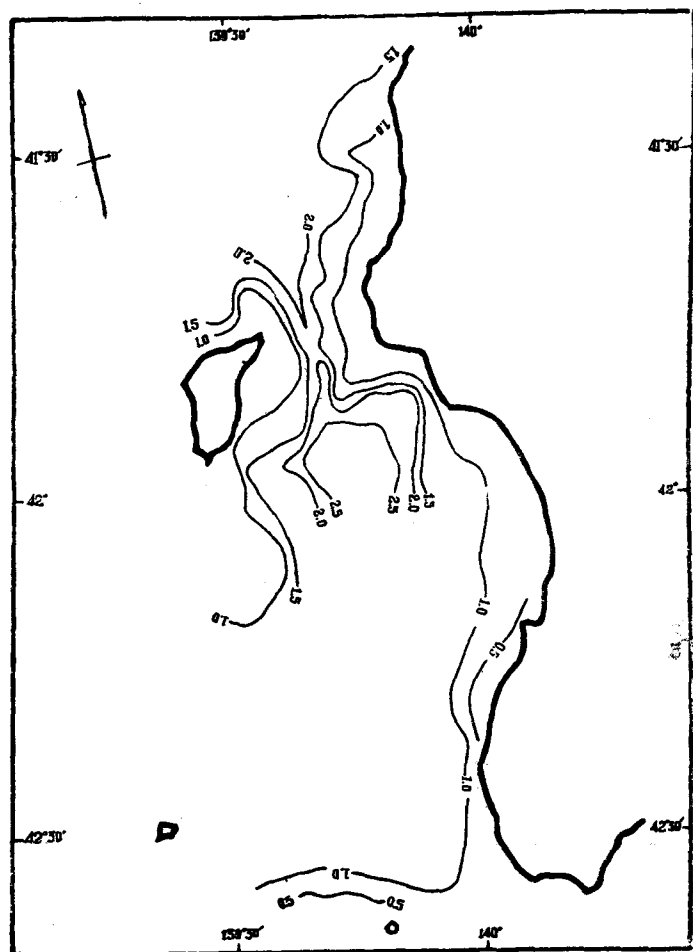


Fig. 54. Distribution of organic carbon content in sediment (%)
(The area in the vicinity of Okushiri Strait)

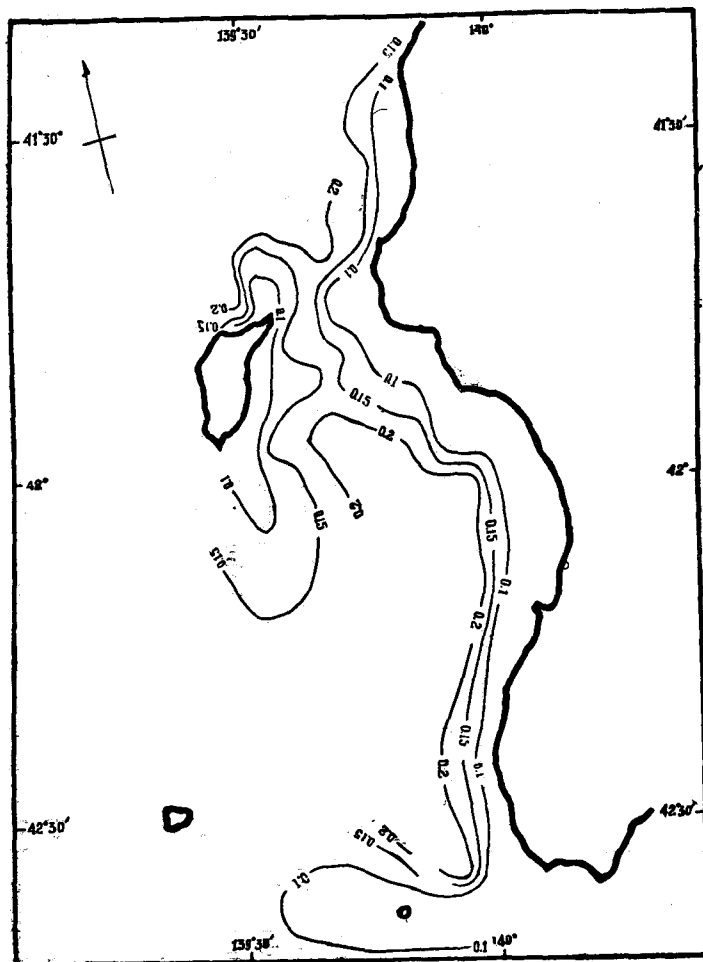


Fig. 55. Distribution of total nitrogen content in sediment (%)
(The area in the vicinity of Okushiri Strait)

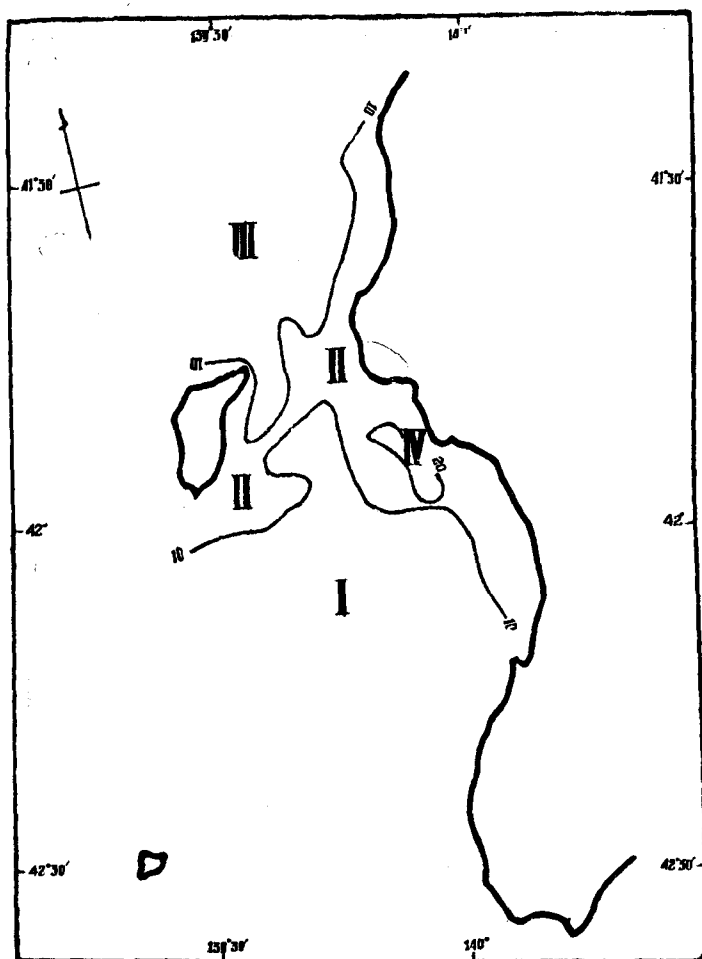


Fig. 56. Distribution of the ratio, C/N, in sediment
(The area in the vicinity of Okushiri Strait)

water depth at the site of deposition. The contour of organic contents of the sediments seems to be parallel to the submarine contour. Statistical tests were tried regarding the correlations between the organic contents of the sediments and the water depth at the site of deposition, and the results are summarized in Table 39.

According to Table 39, it is clear that some positive correlation is to be found between water depth and the amount of organic constituent such as organic carbon or nitrogen, nevertheless no correlation is to be found between water depth and the ratio of carbon to nitrogen.

Although it is difficult to find any relation of the ratio to water depth, the regional distribution of the ratio, as illustrated in Fig. 56, appears very reasonable: Values

Table 38. General Properties of Bottom Samples from the Northern Japan Sea in the Vicinity of Okushiri Strait (August 23-31, 1952)

Station No.	Location		Water Depth (m)	Mass Properties of Sample				Marine Humus Content				Diatom Residues	Silicious Sponge
	Lat. N	Long. E		Sight	Md	So	Sk	Org.-C (%)	Total-N (%)	C/N	Ignition Loss (%)		
N 2	42°36.5'	139°48.2'	540	MS	0.075	3.542	0.270	1.73	0.193	8.91	—	A	
N 5	42°37.2'	139°47.2'	550	MS	—	—	—	1.27	0.128	9.91	—	R	
N 9	42°31.6'	139°46.4'	400	sm	0.096	1.594	0.960	1.16	0.093	12.4 6	5.16	RR	C
N 11	42°30.5'	139°45.4'	500	MS	—	—	—	0.97	0.112	8.66	6.15	A	C
N 13	42°29.4'	139°44.8'	400	MS	—	—	—	1.08	0.113	9.55	—	R	A
N 15	42°27.8'	139°44.9'	620	MS	—	—	—	1.54	0.175	8.80	—	C	C
N 24	42°24.2'	139°43.0'	550	M	—	—	—	1.66	0.168	7.88	7.22	A	A
N 28	42°19.2'	139°39.8'	660	MS	—	—	—	1.64	0.213	7.69	9.15	C	C
N 30	42°16.4'	139°31.6'	700	MS	—	—	—	0.86	0.102	8.43	—	R	
N 32	42°16.4'	139°30.0'	550	MS	—	—	—	1.56	0.071	9.62	—	A	
N 34	42°16.8'	139°39.6'	480	MS	0.114	1.718	0.845	1.35	0.095	14.20	6.28	C	C
N 37	42°17.9'	139°39.1'	520	M	—	—	—	1.95	0.168	12.60	8.85	C	C
N 41	42°13.2'	139°40.6'	540	MS	—	—	—	1.50	0.102	14.70	6.44	R	C
N 45	42°10.9'	139°36.9'	550	MS	—	—	—	0.86	0.168	5.17	5.32	C (R)	
N 46	42°11.3'	139°41.2'	580	M	—	—	—	2.07	0.158	13.10	—	A	C
N 53	42° 9.5'	139°42.4'	380	M	—	—	—	1.13	0.131	8.62	4.72	R	C
N 53	42° 9.5'	139°42.4'	380	M	—	—	—	0.87	0.045	19.33	—	(R) C	C
N 54	42° 8.2'	139°38.5'	600	MS	0.078	3.685	0.321	1.41	0.126	11.19	5.97	AA	C
N 56	42° 2.2'	139°57.2'	330	sm	—	—	—	1.23	0.052	23.57	4.75	R	A
N 58	42° 2.2'	139° 0.2'	160	sm	—	—	—	0.97	0.080	12.1 2	—		
N 61	42° 2.5'	139°50.4'	820	M	0.051	6.582	0.150	2.46	0.193	12.1 6	9.27	R (C)	A
N 62	42° 0.9'	139°38.2'	680	M	—	—	—	1.53	0.161	9.50	7.77	R	
N 63	43° 0.4'	139°34.8'	610	MS	0.096	4.438	0.214	1.53	0.141	10.85	6.34	C	C
N 67	42° 7.9'	139°34.4'	450	MS	—	—	—	1.04	0.118	8.81	—	C	A
N 69	42° 5.2'	139°33.4'	460	MS	—	—	—	1.31	0.109	11.90	5.11	C (A)	C
N 70	42° 5.8'	139°37.0'	660	M	—	—	—	1.33	0.184	7.23	5.28	C	C
N 71	42° 7.5'	139°47.0'	640	M	0.002	8.944	20.00	2.25	0.116	19.31	7.56	C (R)	C
N 72	42° 7.8'	139°50.8'	330	MS	—	—	—	2.14	0.106	20.17	—	C (R)	A
N 75	42° 4.8'	139°50.0'	700	M	—	—	—	2.03	0.187	10.52	8.52	C (A)	C
N 76	42° 3.5'	139°39.9'	770	MS	—	—	—	2.87	0.230	12.46	—	C (A)	A
N 77	42° 2.6'	139°34.6'	620	MS	—	—	—	1.87	0.168	11.18	—	C (A)	C
N 86	41°54.1'	139°35.3'	480	MS	—	—	—	0.85	0.112	7.72	—	C (A)	
N 88	41°53.4'	139°28.7'	580	M	—	—	—	0.73	0.132	5.60	9.00	C (R)	C
N 91	41°56.5'	139°30.0'	70	SM	—	—	—	0.87	0.114	7.25	—	C	A
N 92	41°57.0'	139°34.5'	400	SM	—	—	—	1.06	0.114	8.41	—	R	A
N 94	42° 0.3'	139°56.6'	730	M	—	—	—	1.26	0.212	5.94	8.57	R	A
N 107	41°54.5'	140° 0.8'	300	GMS	—	—	—	0.94	0.101	9.30	—		
N 118	41°41.6'	139°59.0'	90	S	0.582	1.507	0.876	0.21	0.034	6.17	3.04	RR	
N 119	41°41.4'	139°57.3'	410	sm	0.219	2.236	0.704	0.61	0.105	5.80	3.53	R	C
N 121	41°39.3'	139°56.7'	470	sm	0.250	3.030	0.547	1.14	0.126	9.04	5.40		
N 127	41°33.4'	139°54.9'	600	M	0.083	8.031	0.150	1.39	0.180	7.72	7.96	C (R)	C
N 135	41°25.8'	139°54.5'	520	M	0.072	9.083	0.092	1.09	0.229	4.75	8.48	(R)	C
N 148	41°22.5'	139°40.0'	400	GSM	—	—	—	0.46	0.075	6.13	1.39	R (R)	C
N 159	41°19.8'	139°37.5'	300	GSM	—	—	—	0.32	0.058	5.51	—	RR	

higher than 10 are probably found in the vicinity of Okushiri Strait (II and IV), while the comparatively low values in the open areas (I and III). One may particularly notice that some irregularly large values in the ratio are found in the sediments

Table 39. Organic Contents of the Sediments and Their Relation to the Water
Depth of the Site of Deposition
(Northern Japan Sea in the Vicinity of Okushiri Strait, Aug. 22, 1952)

	Number of Samples	Population Mean (\bar{x}) ($n=0.05$)	Standard Deviation (s)	Correl. Coef. (r)	Test of Null Hypothesis ($\alpha=0.05$)	Equation of Regression
Organic-C	44	1.143-1.303	0.260	0.569	$\rho \neq 0$	$C = 0.0020 \text{ ld} - 0.296$
Total-N	44	0.132-0.140	0.016	0.663	$\rho \neq 0$	$N = 0.00020 \text{ ld} - 0.0634$
C/N	44	7.89-10.75	4.644	0.014	$\rho = 0$	—

C: Carbon content (%) N: Nitrogen content (%)

d: Water depth of the site of deposition (m)

at the eastern side of the Strait (IV), where there is to be found an eddy induced by the north-flowing current judging from the coastal shape; further, the remains of plants which have grown thick along the neighboring coast are used to be accumulated owing to the eddy.

B. HUMUS DISTRIBUTION IN ISHIKARI BAY

a) General Description of the Area

An even shelf is the principal bottom characteristic of Ishikari Bay under discussion. The bottom characters will be influenced by sedimentation of terrigenous debris from the Ishikari River or by sorting of the sediments owing to the hydrographical movement of the bay water.

The sedimentological examination on the bottom samples, as illustrated in Fig. 58 shows as follows: Most of the sediments are found ranging from 25 meters to 200 meters in water depth, pretty well sorted as indicated by the sorting coefficients 1.2-1.6 and have median diameters over 0.05 mm. Muddy sediments poorly sorted are found in the eastern inner part of the bay; they are contributed by detrital mud from the river. Another muddy bottom is found in the depression, 650 meters or over in depth, off the mouth of the bay. It is very interesting that there is found a belt of granule distribution connecting stations P7-P5-P13. Judging not only from the granule distribution but from the Trask coefficients, a bed of Ishikari River in geological age would have run on the bottom of the above belt, though more evidence will need for a full explanation.

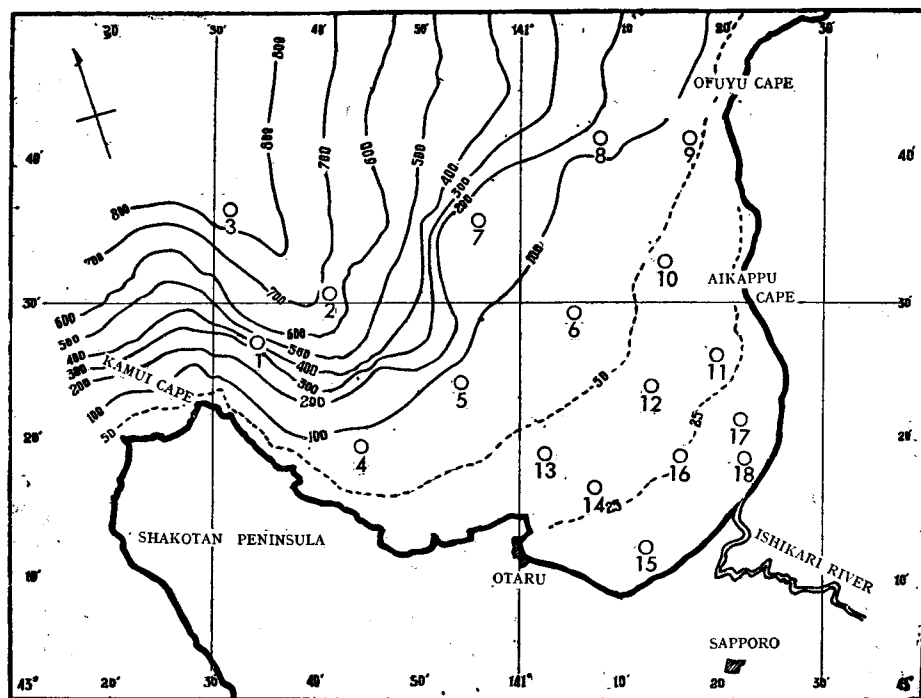


Fig. 57. Stations observed and submarine topography in Ishikari Bay, Hokkaido (July 28-29, 1953)

Table. 40. General Properties of Bottom Samples from Ishikari Bay (July 28-29, 1953)

Station No.	Location		Water Depth (m)	Texture of Sample				Marine Humus Content			
	Lat. N	Long. E		Sight	Md(mm)	So	SK	Org.-C (%)	Total-N (%)	C/N	Ignition Loss (%)
P 1	43°26.0'	140°34.3'	345	f S	0.081	1.32	1.002	0.93	0.404	2.31	4.52
P 2	43°29.7'	140°42.0'	660	M	0.001?	—	—	2.79	0.244	11.46	1.49
P 3	43°35.6'	140°36.9'	840	M	0.002?	—	—	2.28	0.283	8.05	9.19
P 4	43°19.1'	140°45.0'	85	S	0.283	1.26	0.843	0.250	0.086	2.90	1.63
P 5	43°23.0'	140°54.0'	84	Gr. S	0.055	1.62	1.060	0.739	0.068	10.84	2.32
P 6	43°28.6'	141°05.0'	80	f S	0.218	1.64	0.992	0.324	0.176	1.84	3.17
P 7	43°35.4'	140°55.5'	140	Gr. M	0.122	3.62	0.366	1.29	0.052	24.91	5.94
P 8	43°41.0'	141°00.0'	162	f S	0.178	1.28	1.065	0.289	0.051	5.58	3.21
P 9	43°41.1'	141°17.5'	59	M	0.093	—	—	—	—	—	—
P 10	43°23.1'	141°14.0'	49	S	0.194	2.13	0.960	0.111	0.035	3.20	3.16
P 11	43°25.6'	141°19.4'	28	M	0.077	—	—	0.988	0.068	12.98	14.81
P 12	43°23.1'	141°12.0'	41	S	0.312	1.52	1.072	0.042	0.035	1.23	2.51
P 13	43°18.3'	140°01.8'	42	MS	0.298	2.03	0.867	0.503	0.069	7.33	3.38
P 14	43°16.0'	141°00.7'	25	MS	0.103	1.75	1.056	0.449	0.099	4.53	4.06
P 15	43°11.6'	141°12.6'	18	MS	0.107	1.91	1.096	0.394	0.087	4.54	3.68
P 16	43°18.4'	141°16.2'	25	MS	0.084	1.51	0.795	0.601	0.096	6.27	3.79
P 17	43°21.2'	141°22.4'	22	MS	0.072	—	—	2.13	0.107	19.93	6.86
P 18	43°21.2'	141°22.4'	16	M	0.001?	—	—	3.58	0.193	18.58	9.49

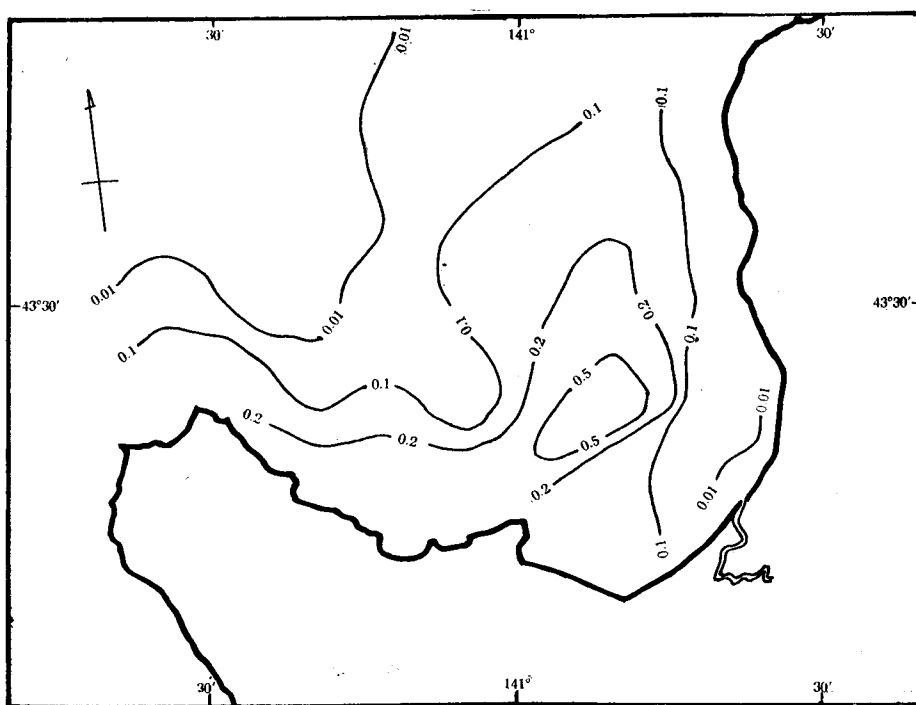


Fig. 58. Median map of Ishikari Bay (mm)

b) Regional Distribution of Marine Humus

The organic contents and mass properties of the bottom samples are summarized in Table 40 and the organic distribution were illustrated in Figs. 59, 60 and 61.

Inspection of organic distribution relating to sediment type leads to partition of the area into the three following parts (Fig. 62) : A fairly good amount of organic matter is accumulated in the inner part (F) as well as in the depression off the mouth of the bay (E). In both parts, the sediments are poorly sorted and muddy in texture. In the central part (A, B) of the bay, sedimentary accumulation of organic matter is found less abundant owing to active sorting of the sediments ; the organic materials accumulated are contributed rather by benthic animals or their remains than by fine debris of terrigenous organic materials.

The contours of organic carbon accumulation appear somewhat to deviate from the contours of total nitrogen accumulation. This deviation may give some clues on the sources of organic materials accumulated at a given station. A belt of concentrated accumulation of organic carbon runs out from the mouth of the Ishikari River to north. This concentrated belt seems to be contributed by sedimentation of terrigenous organic debris judging from the higher carbon nitrogen ratio in the sediment.

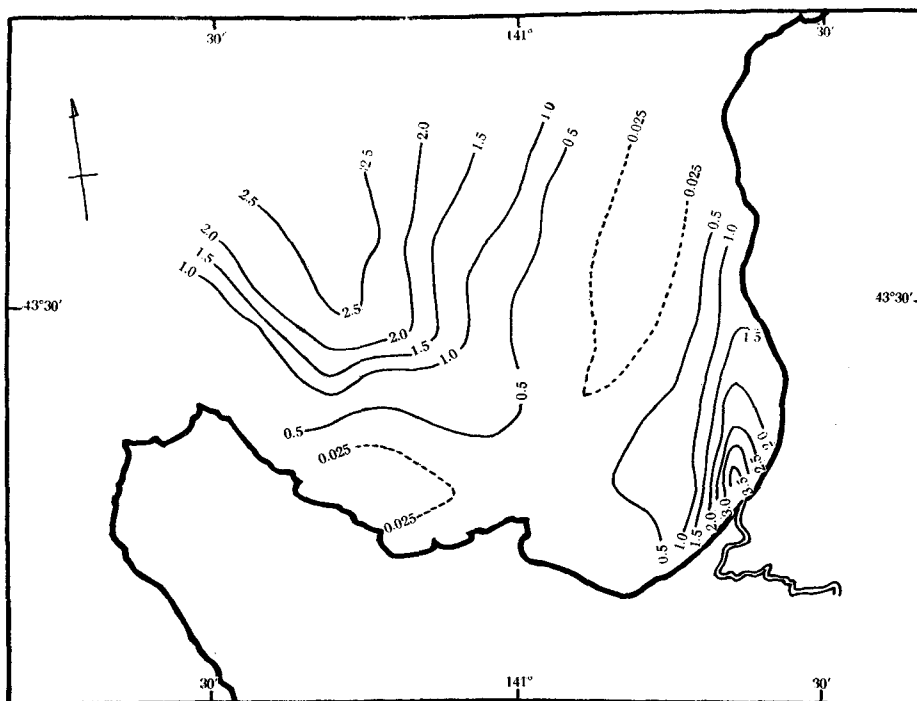


Fig. 59. Distribution of organic carbon content in sediment (%) (Ishikari Bay)

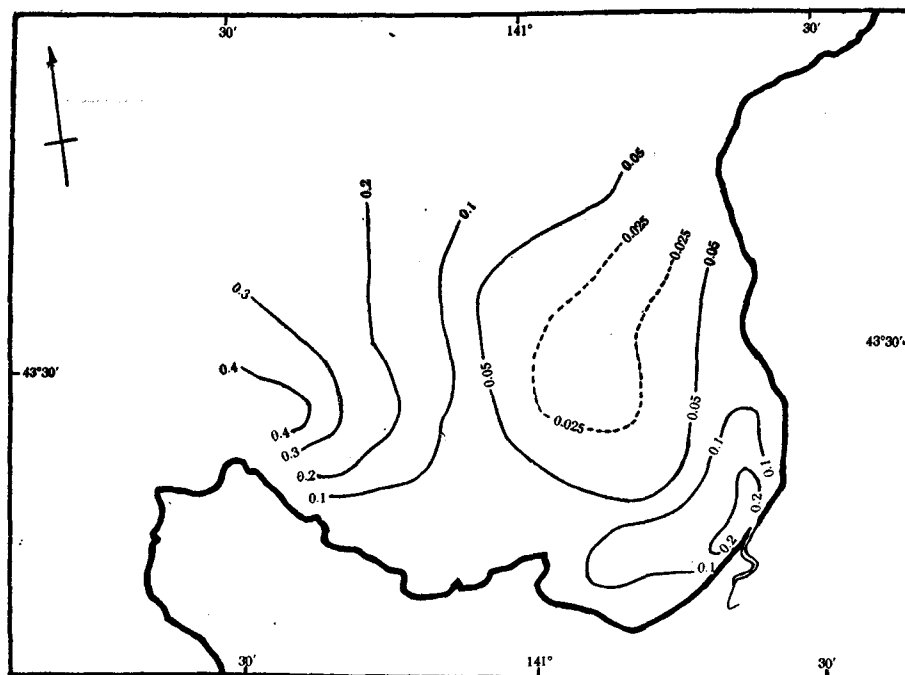


Fig. 60. Distribution of total nitrogen content in sediment (%) (Ishikari Bay)

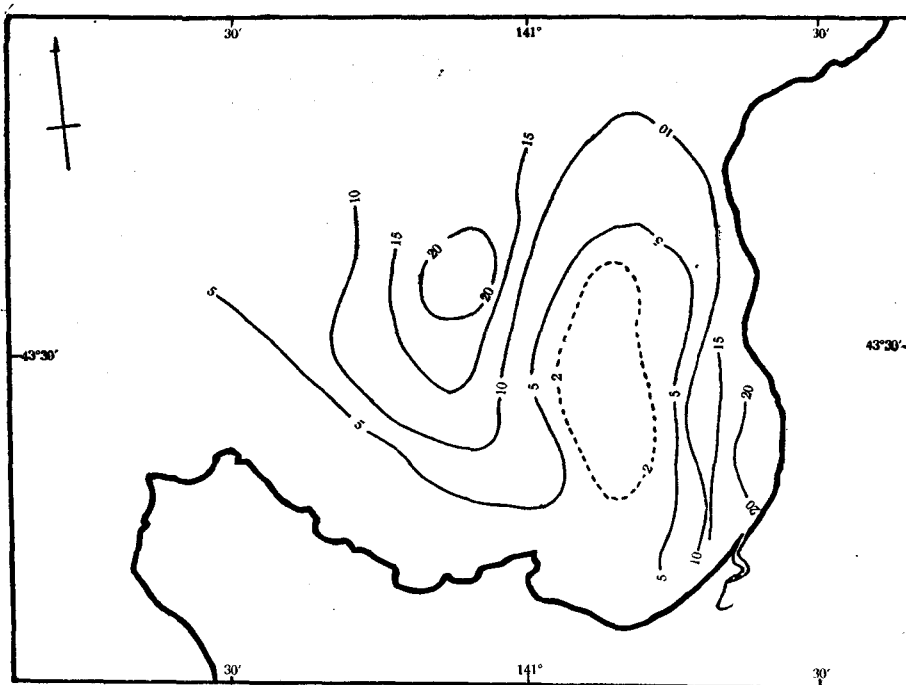


Fig. 61. Distribution of the ratio, C/N, in sediment (Ishikari Bay)

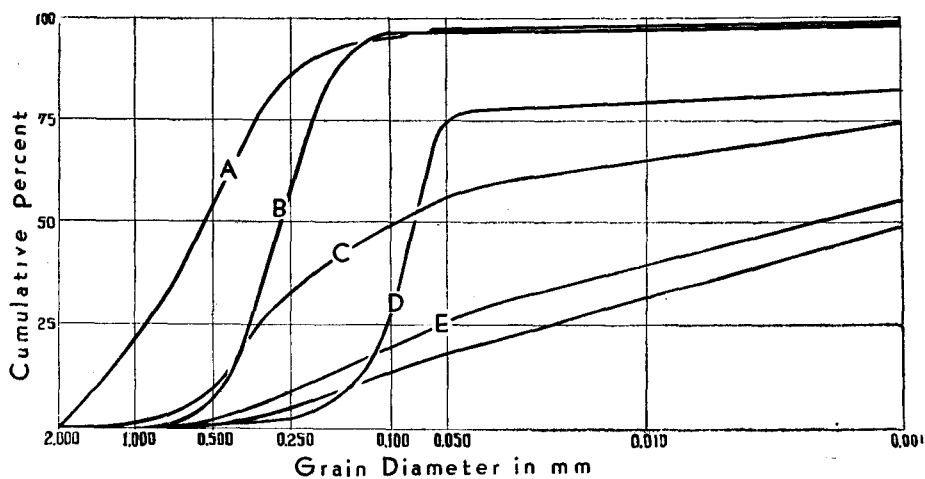


Fig. 62. Graphs of cumulative curves showing sediment types (Ishikari Bay)

A remarkable nitrogenous accumulation is found on the steep slope adjacent to the Shakotan Peninsula. That will be contributed by bottom-living animals or their remains. This explanation is based on the lower ratio of carbon to nitrogen.

Additionally, it is noticeable that there is found a characteristic ratio C/N which indicates a peculiarly large value on the edge of the continental shelf (P5) but its causes are not clear yet.

XII. CHARACTERS OF MARINE SEDIMENTS IN RESPECT TO ECOLOGICAL ENVIRONMENTS OF MARINE ORGANISMS

As to environmental factors affecting the dwelling of marine organisms, the characters of the sediments as well as the submarine topography are of the most significance. As yet few investigations have been made of the ecological significance of chemical properties of the sediments. Faser (1932-33) investigated the relation of bottom fauna to their foods as well as bottom characters at the site of dwelling. Fox (1950) has done a remarkable investigation regarding comparative metabolism of organic detritus by inshore animals. Miyadi and his collaborators (1941) have made a number of ecological investigations as to the benthic communities in reference to texture of the sediments and to the motion of the overlying water. ZoBell (1937) and Nomura (1941) have respectively measured the redox potentials of bottom materials, and Nomura (1941) has emphasized that the potential should be studied as an important ecological factor of environmental conditions.

The author and his collaborators (1949-52) have hitherto carried out a number of investigations on the ecological significances of chemical properties, especially that of the character or amount of marine humus in the sediment.

a) Distribution of Marine Humus in the Shellfish Fields

(1) *Mutsu Bay* (Fig. 63-65)

The author has investigated areal distribution of marine humus in Mutsu Bay, Aomori Prefecture, then discussed whether or not there was any correlation of the distribution to the dwelling of the common Japanese scallop. Nishioka and Yamamoto (1943) have carried out a number of ecological investigations on scallop dwelling in the Mutsu Bay and emphasized that the productivity of the shell might have some connection with the texture of the bottom materials. But formerly the shell used to live even in the area with 100% mud. So he suggested that some other bottom conditions, besides the nature of substratum, should be investigated for the explanation of the distribution of the shells. According to the author's investigation, it seems that there may be found a certain connection between the content of marine humus in the sediment and the productivity of the shell. It is remarkable that the sediments at the shellfish fields off Kurosaki or along the coast of Noheji Bay, have indicated humus contents less than about four per cent in dry basis while there were scarcely found any shell in the area where more abundant quantities of humus are found than

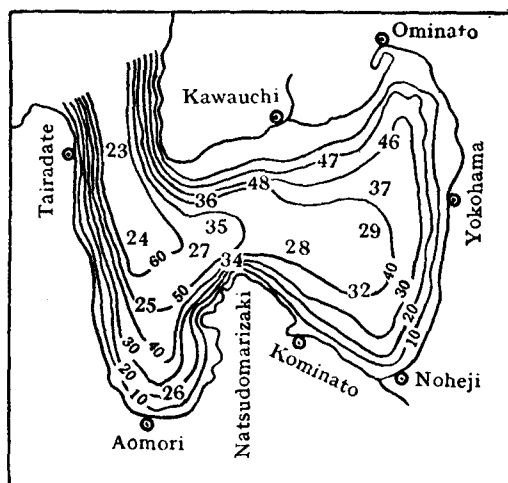


Fig. 63. Stations observed in Mutsu Bay, Aomori Prefecture (May, 1948)

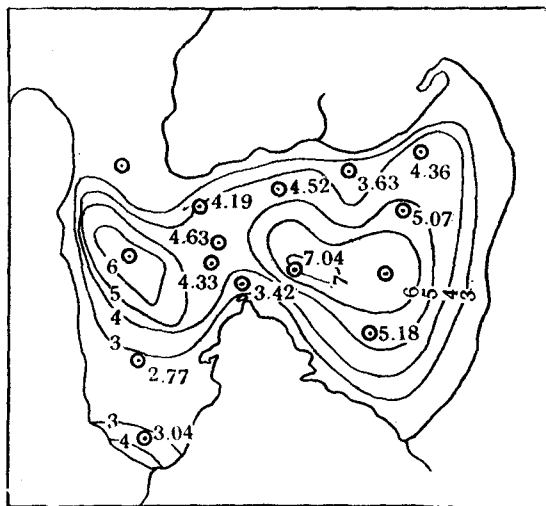


Fig. 64. Humus distribution in Mutsu Bay (%)

the above percentage. It is true that the shell may prefer a more stable substratum with gravel or sand, but it may probably be that the shell could dwell in muddy bottom because the shell has lived formerly even in finely muddy bottom in the central area of Noheji Bay judging from the shell fragments found there. The extermination of the shell in the finely muddy bottom might be attributed to a reducing condition of the bottom floor. The development of the reducing condition in bottom floor might be induced by both a remarkable sedimentary accumulation of organic remains and

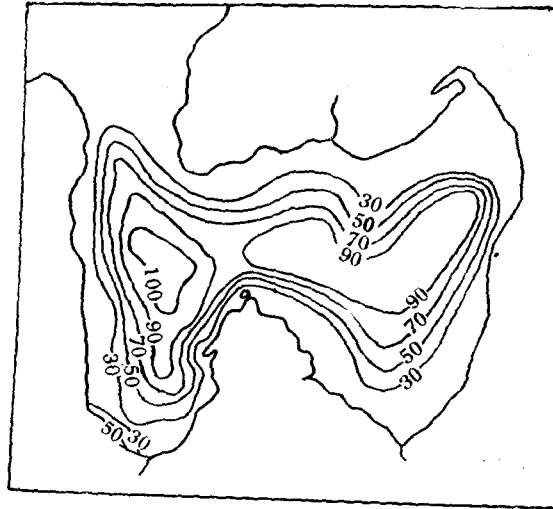


Fig. 65. Mud distribution in bottom floor of Mutsu Bay
(after Nishioka and Yamamoto, 1943)

an anaerobic decomposition of organic materials accumulated in the sediments. Either a decrease of the influence of bay current or an abundant supply of terrigenous organic debris would promote the occurring of the reducing environments.

Although an adequate quantity of organic matter in the sediment will be desirable for detritus feeders, an enormous accumulation of organic matter will make life impossible, because the development of organic accumulation will induce colloidal peptidization of consolidated sediment to make suspension of colloiddally fine particles and will widen the unfavorable reducing belt over the bottom.

(2) *Hakodate Harbour* (Fig. 66)

In Hakodate harbour, there formerly dwelt useful shellfishes in abundance, but at present they are nearly exterminated. The author and Tanita (1950) undertook to carry out an investigation to ascertain the causes of the above change in the output of the shellfishes in the harbour. For the analysis of the environmental condition, both properties of water and sediment in the harbour were investigated from ecological and oceanographical standpoints. The authors have concluded as follows from the results of investigation: The northern part of the harbour where the cockles formerly used to dwell seems to have become unfit for this species from remarkable settling of fine mud as a result of building new breakwaters. If an accumulation of organic matter greater than four per cent would be undesirable for habitation of the cockle or other shells as well as the scallop in the case of Mutsu Bay, the environmental condition of bottom floor in Hakodate harbour might be somewhat undesirable for

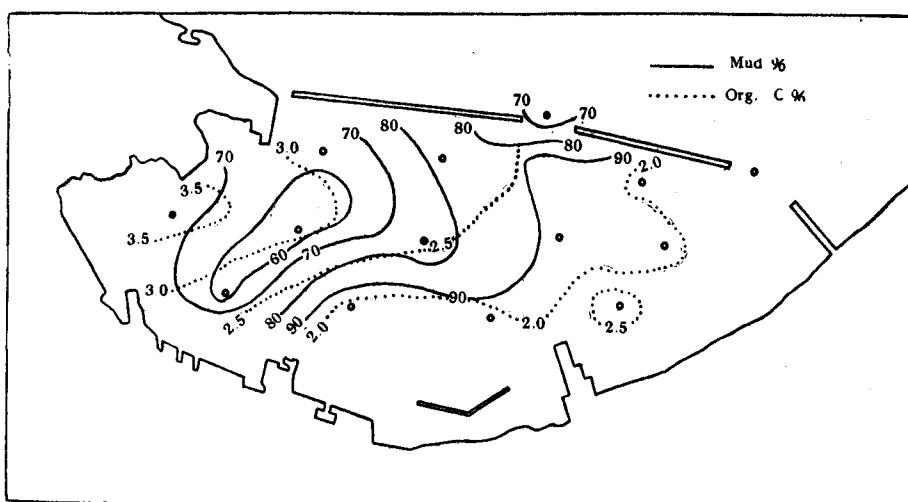


Fig. 66. Distribution of mud and organic carbon content in bottom sediment at Hakodata Harbour (1949)

the useful shellfishes because of the dense distribution of organic matter which would be supplied from sewage. The abundant content over six per cent of organic matter were found in the sediments in the inner southern parts of the harbour; the content decreased gradually towards the harbour center, reaching its minimum in the eastern part. Another characteristic accumulation over five per cent humus was found in the northern part. *Anadaras* used to dwell in the eastern part where a poor accumulation of organic matter was found as pointed out above; consequently, it is hardly possible to find any remarkable change for worse in the environments. Therefore the investigation under discussion appears insufficient for clarifying the causes of the extermination of the shellfishes.

(3) *Muroran Harbour* (Fig. 67, 68)

In Muroran Harbour, where useful shellfishes dwell abundantly, four investigations during 1949–1950 were carried out to gain evidence on the environmental conditions pertaining to the shellfish field in the harbour. In these investigations, the influences of sewage brought from the city or from iron works were mainly studied, because a reddish violet water, called “AKAMIZU (red water)” or “DOKUMIZU (poisonous water)”, used to stay in the vicinity of the iron works and has sometimes caused great damage to the shellfishes. In the area where scallops actually dwell in abundance, the water, especially the bottom water, was scarcely spoilt by the incoming sewage and the sediments did not contain enough organic matter to damage the shellfishes judging from the case of Mutsu Bay. Yet the inhabitation of shellfishes appeared hardly possible in the inner parts of the harbour (in the vicinity of the iron works or of the municipal wharf) because the dirty water has been settling on the bot-

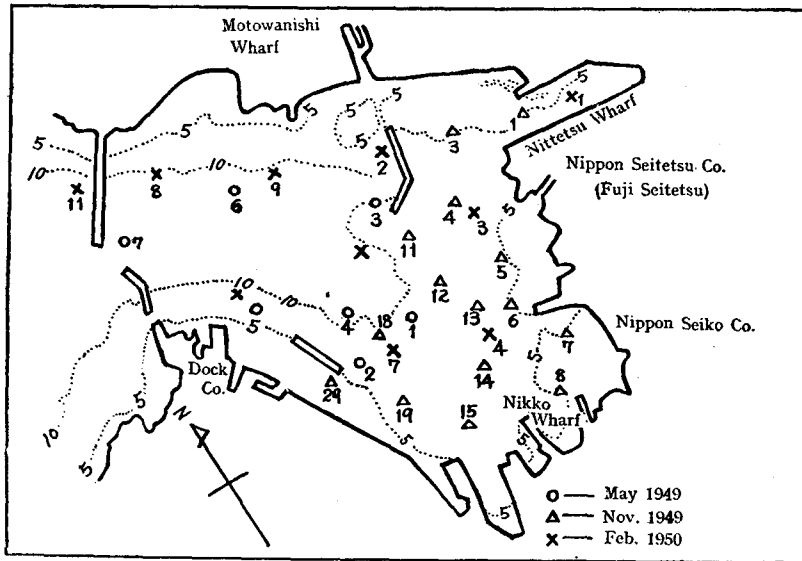


Fig. 67. Stations observed at Muroran Harbour (1949-1950)

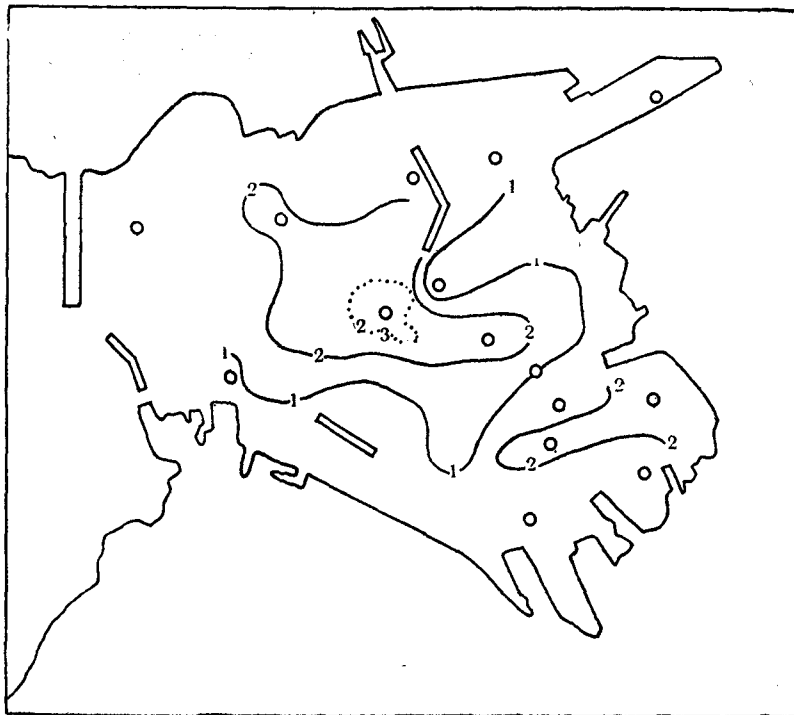


Fig. 68. Distribution of organic carbon content in sediment (Muroran Harbour, 1949)

tom and muddy sediments are abundant in humus. Every investigation on the sediments has yielded nearly the same results, although the properties of the sediments were somewhat changeable owing to the quantity of mineral or coal waste thrown out of the iron works or ships in port.

b) Benthic Animals and Characters of the Sediments

Tamura and the present author (1952) have undertaken an ecological investigation in Funka Bay for ascertaining the relation between inhabitation of benthic animals and characters of the sediments. Then the results of that investigation were tabulated in Table 41. It seems hardly possible to find any relation between the animals and the organic content in the sediment although there was found a certain relation as to the texture of the sediment. Only as to sea worm (polychaeta) or

Table 41. Relation of Benthic Animals to Bottom Characters
in Funka Bay (Aug. 1951)

Station	Water Depth (m)	Texture of Deposit	Nitrogen Content (%)	Fish (Sand Lance)	Star Fish	Echiocardium cordatum	Sea Urchin	Sea Cucumber	Ophiuroidea	Gastropod	Bivalve Mollusca	Shrimps	Crabs	Amphipoda	Polychaeta	Nemertini	Actiniaria	(Sea Weeds)	Number of Species	Total Weight of Benthos
F 1	18	S, Sh	0.093	3	5	4	2	2	1	3	6	1	1	2	6	—	1	—	16	720
F 2	62	S m	0.151	—	3	1	—	—	10	—	—	2	—	—	10	—	1	—	6	460
F 3	70	M, p	0.202	—	—	—	—	—	1	1	—	—	—	—	10	—	1	—	4	58
F 5	60	M G	0.041	—	—	—	—	1	—	—	—	—	—	—	8	—	—	—	2	75
F 6	16	M, p	0.017	—	1	3	—	—	—	—	—	—	2	—	5	—	—	—	4	75
F 7	20	S, p	0.016	—	—	—	1	—	—	1	—	—	—	—	5	—	—	1	4	15
F 8	75	M, p	0.042	—	—	—	—	—	5	1	1	—	—	—	4	—	—	—	4	30
F 9	84	M, p	0.028	—	—	—	—	—	2	—	—	—	—	—	3	—	—	—	2	3
F 11	22	S	0.017	—	8	—	—	—	10	1	—	1	—	—	6	—	—	1	6	465
F 12	30	S	0.031	—	1	—	—	—	—	—	—	—	—	1	—	—	—	1	6	27
F 13	65	M	0.018	—	4	—	—	—	—	—	—	1	—	—	3	—	—	—	3	49
F 16	72	M, p	0.082	—	—	3	—	—	6	—	—	—	—	—	6	—	—	—	3	21
F 17	60	M	0.072	—	—	—	—	—	15	—	—	—	—	—	5	—	—	—	2	19
F 18	34	M	0.087	—	1	—	—	—	6	—	—	—	—	—	10	—	—	—	3	11
F 19	45	M, p	0.043	—	—	—	—	—	2	—	—	—	—	—	5	—	—	—	2	3
F 22	72	M	0.054	1	—	—	—	—	8	—	—	—	—	—	—	—	—	—	2	9
F 23	60	M	0.039	—	—	—	—	—	3	—	—	—	—	—	7	—	—	—	2	5
F 24	34	M, Sh	0.043	—	—	—	—	—	1	—	—	—	—	—	3	1	—	—	3	20
F 26	66	M, Sh	0.075	—	1	—	—	—	2	5	—	1	—	—	10	—	—	—	6	37
F 27	80	M	0.089	—	—	—	—	—	—	—	1	—	—	—	3	—	—	—	2	10
F 28	92	M	0.071	—	—	8	—	—	—	—	—	—	—	—	8	—	—	—	2	122
F 30	50	M, p	0.053	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	2	10
F 32	47	M	0.063	—	—	1	—	—	—	—	—	—	—	—	3	—	—	—	2	18
F 36	61	M	0.067	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	1	2
F 38	42	M, p	0.036	—	—	—	—	—	—	10	—	—	—	—	3	—	—	—	2	50
Individuals of Animals				4	24	22	3	3	72	22	8	6	4	3	128	1	3	2		
Stations Observed				2	8	6	2	2	14	8	3	5	3	2	23	1	3	2		

detritus-feeder, a somewhat reasonable relation might be found as indicated in Table 41; that is, the more abundant humus content was the more worms there were.

On the other hand, humus distribution in fishing ground, especially of bottom fishes, will relate to the amount of foods for detritus-feeders as well as to the oceanographical environments controlling the fishing ground. For one example, an abundant catch of bottom-fishes has been gained from a characteristic area in the vicinity of Otaru Bank, Northern Japan Sea. There is found a remarkable accumulation of humus and abnormal ratio of carbon to nitrogen in the sediments because of a characteristic eddy current as pointed out in the previous chapter. Detailed consideration of the significance of humus distribution to fishery will be presented in a future paper.

XIII. GENERAL SUMMARY

(1) Of the bottom samples from the Northern Japan Sea to the northwest of Hokkaido, the general chemical properties were examined by means of the author's systematic method of chemical analysis because they would indicate characteristics on geochemical environments relating to the accumulation or decomposition of organic materials deposited on the bottom floor.

The general characters of chemical components of the above samples have been summarized as follows.

a) Mean contents determined of the chemical components were obtained as follows:

SiO ₂	56.86%,	Al ₂ O ₃	12.99%,	CaO	2.14%,
MgO	2.98%,	Fe ₂ O ₃	4.42%,	MnO	1.03%,
P ₂ O ₅	0.13%,	Ignition loss	9.42%.		

b) The abundant content of manganese observed above is particularly noteworthy.

c) For each component, the relation of the content to the water depth of the site of deposition was examined for inquiring into the stage of bottom weathering.

i) The content of silica or calcium appeared to decrease with increasing water depth, while that of aluminium, manganese or phosphate became larger.

ii) The diagram of Fe₂O₃ content to water depth has showed a characteristic catenary with the minimum at about 700–800 meters. The characteristic curve might suggest that the quantity of iron in sediment would be somewhat influenced by the abundance as well as by the nature of organic materials accumulated in the bottom: With increasing water depth of the site of deposition, there might occur a belt of chemical reduction over or in the bottom floor because of progressive accumulation of organic matter. The iron compounds accumulated might be reduced near or in the bottom into soluble forms, which return into the overlying water in forms of ions or colloidal particles combined with marine humus. At the same time, the iron

which has returned into water would be oxidized into oxides and settling down again in the sea water. This accumulation process of iron seemed fairly active in the water of the Tsushima Current, in the vicinity of which the accumulated amount of iron in sediment tended to increase. The above geochemical transition of iron accumulation in sediment may be found in the areas ranging 700 meters to 800 meters in water depth, wherein the minimum value of iron content in sediment may be observed.

iii) Geochemical examinations of chemical components in the samples have indicated that the sediments under discussion should be characterized as hemipelagic ones.

(2) Marine humus contributes to the chemical, physical or ecological conditions of the sediments in respect to its abundance or to its nature. As few investigations on the chemical nature of marine humus have been made in Japan, the author attempted to make some investigations dealing with humus of littoral sediments in Usu Bay, Hokkaido.

a) An approximate analysis of organic materials in the bottom sample was carried out using Waksman's method. The results of the analyses showed that the stable humic substances made up the principal portion of organic materials in the sediment, as much as $1/2$ to $1/3$.

b) The humic substances were extracted from the samples by 2.5% NaOH solution, and then were separated chemically into four fractions, as α -, β_1 -, β_2 - and γ -humus.

c) The respective contents of organic carbon, total nitrogen and of ash were determined on each fraction. It was found that α -fraction as well as γ -fraction comprised the major portion of the humic substances, and their constituents might be inferred from the chemical examinations ;

α -fraction ligno-protein complex,

γ -fraction carbohydrate-protein complex.

These inductions were identical to Waksman's data (1932) on the deposits of the eastern coast of America.

d) The paper chromatographical detection of amino acids in each humus fraction was done, and the presence was found of several amino-acids, viz., glutamic acid, aspartic acid, glycine, alanine, valine, tyrosine, leucine, iso-leucine, cystine, nearly like kinds to those in land soil humus.

(3) For examining how organic matter in sediments acts in nutrient metabolism in a restricted bay, oceanographical and chemical investigations were made on the properties of water and bottom materials in Usu Bay.

The bay is comparatively small in area, but is one of the very important and interesting fields for culture of lavers and oysters.

a) The characteristics of the oceanographical conditions of the bay may be summarized as follows : Though the entrance of the bay is very narrow, it has a

sack-like shape and extends well back into the land. As the open sea water has little influence on the oceanographical state of the bay, the water exchange is effected only by tidal current. From the southeastern corner of the bay, a fairly good amount of fresh water flows into the bay, and dilutes the salinity of the bay water or supplies the soluble nutritious salts. As the bay is narrow, the circulation of nutrients between the bottom and the overlying water in the bay seems to be very active. The bottom samples were comparatively uniform in color and in texture, containing some sediments of putrified sea weeds. The bottom was nearly muddy and contained a moderate amount of humus.

b) The amounts of soluble organic matter and of silicate in surface water, in summer, were 2.5–3.0 times those in winter, but, on the other hand, the phosphate contents decreased to $1/3$.

c) In summer, the percentages of the ignition loss and organic carbon contents of the bottom sediments perceptively increased over values in winter, while the average nitrogen contents remained almost invariable.

d) Such a difference of organic content between winter and summer might suggest the relative amount of energy necessary for organic activities in the bay. Moreover, the ratio of carbon to nitrogen, as relating to the progress on biochemical metabolism in sediments, has indicated, in the whole bay, 8.8 in winter or 10.8 in summer. This fact shows that organic metabolism in bottom floor has been going on under a rather favourable condition. In summer, the ratio has grown larger in value than that in winter owing to increase of quantities of non-nitrogenous substances such as carbohydrates which have been generated by photosynthesis of plants.

e) Judging from the distinguished seasonal deviation of phosphate content in the bay water, the abundance of phosphate seems to be the major limiting factor controlling production of organic matter in the bay.

f) It may become clear after these examinations that abundance as well as nature of organic materials in sediments will relate not only to supplies from organic sources but to organic activities in progress in the bay.

(4) A respiratory system, as relating to condition of oxidation-reduction in water or sea bottom, is essential for ocean creatures as it is for land animals.

The lack of oxygen available near or in bottom may be caused by the insufficient supply of oxygen from the overlying water, or by the less production of oxygen by plant metabolism than that in the upper water, moreover, it may be attributed to the consumption of oxygen by the sediments. For inspecting the factors controlling the oxygen consumption by sediments, various bottom samples from different areas, viz., from the northern Japan Sea northwest of Hokkaido, and from the Bays of Shiogama and Onagawa in Miyagi Prefecture, were employed as experimental materials in the investigation.

a) Previous to the investigation, the effects of the experimental procedures

upon the oxygen consumption were examined individually with each experimental measure.

From these examinations the following results were obtained:

i) The consumption velocity changes adapting to the first reaction formula; elevation of temperature promoted the consumptive action.

ii) An adequate exposure of deposits may excite the activity of the consumption owing probably to activation of the agents of the consumption although further exposure does not very much promote the action.

iii) The more the consumption bottle was shaken the more oxygen was consumed until the maximum was attained.

b) The characters of bottom sample might influence greatly the oxygen consumption, so the relation of the consumption to properties of the deposits were investigated with mud of Shiogama Harbour:

i) The major part of the oxygen consumption appeared to be not brought about by the biotic factors themselves such as bacteria and enzymes, but by the reductive abiotic elements caused by the former factors.

ii) The oxygen consumption by these abiotic factors seemed to be somewhat related to the carbon content of humus colloid or to the amount of mud ($<10\mu$), but it was hardly possible to discover any correlationship to the sulfide content in mud.

c) As to the hemipelagic sediments of the Northern Japan Sea, it seemed that the oxygen consumption had a negative correlation to the water depth at the site of deposition. Further it was difficult in the above area to detect any correlation between the consumption and the carbon content of the deposit. This feature of oxygen consumption appeared somewhat strange, but might be interpreted as follows: Most of the organic matter in deep-sea deposits would have been rather progressively huminized and fairly stabilized against oxidizing decomposition. Consequently, much oxygen would not always be necessary for decomposing organic materials because of poverty of aerobic bacteria.

After all the factors controlling the oxygen consumption seem not always simple, but very complicated, and the different factors will not be independent but influenced each other.

(5) Suspended materials in the sea act an important rôle in accumulating organic matter in the sediments. The author has observed actually the suspension of the particles in the sea water through the window of 'KUROSHIO', a kind of bathysphere. From the appearance of the suspended materials the author and his collaborator (1953) have proposed to give the name "*Marine Snow*" to them.

a) Underwater observation showed that the *marine snow* scattered light luminously and had various shapes.

b) Microscopic observation of aggreation state of *marine snow* showed that the cellular substances of plankton which were destroyed by bacteria have aggregated

around the larger materials suspended in the water.

c) Similarity of microscopic appearance between the *marine snow* and the bottom sediment may indicate that the detritus on the bottom floor is derived from sedimentary accumulation of the falling flakes of the *snow*.

(6) As few investigations have been made of organic accumulation in sea bottom in the vicinity of Japan, the author attempted to investigate the areal distribution of marine humus in areas adjacent to Hokkaido. The distribution of marine humus has been examined in connection with the environmental factors, and statistical examination was fairly useful for inspecting these relations. The following areas have investigated:

a) *The Northern Japan Sea:*

i) *The area to the northwest of Hokkaido:*

As the bottom configuration of the area is very complicated, the distribution of marine humus has been inspected particularly in relation to submarine topography.

ii) *Ishikari Bay:*

The Ishikari River flows into the bay and contributes greatly to the accumulation of organic matter on the bottom floor.

iii) *The area in the vicinity of Okushiri Strait:*

A narrow and steep slope and a shelf of Okushiri Island occupy the major part of the area.

b) *The area to the south of Hokkaido (the Pacific side):*

The area has a relatively even configuration of bottom, and the influence of rivers on bottom characters seems not very remarked. Accordingly the oceanographical environment appears to be the predominant one controlling organic accumulation. Sedimentological examinations have been used as the basis for discussing the influences on the oceanographical condition in this area.

(7) Of the Northern Japan Sea to the northwest of Hokkaido, the oceanographical environments and the bottom configuration are both very complicated. Many banks such as the Musashi Bank and a steep ridge extending out northward from the Shakotan Peninsula rise in the continental talus, while there exists a depression off the mouth of Ishikari Bay. Thus oceanographical conditions in this area are very complicated owing to the complexity of topography.

a) Some statistical examinations were made in regard to the relation of the marine humus distribution to the geographical factors which were indicated as the water depth at the site of deposition or as the bottom configuration. The results of these examinations may be summarized as follows:

i) Sedimentary accumulation of organic matter appeared to become larger with increasing in the water depth of the site of deposition, but that of nitrogenous substances indicated a more or less different feature, and did not always vary in relation to the water depth in that area.

ii) The ratio of carbon to nitrogen in the sediment seemed to have no correlation to the water depth judging from the correlation coefficient, $\gamma_{C/N} = -0.01$.

b) Averages of data having respects to marine humus are given as follows ;

$$\overline{C}=1.87\%, \overline{N}=0.21\%, \overline{C/N}=9.44; \overline{\text{Ignition loss}}=9.68\%.$$

c) The area under discussion might be divided into several subareas according to characteristics of bottom configuration. The influence of the bottom configuration upon the distribution of marine humus contents was discussed with the confidence limit, 95%, of population mean in each subarea. These discussions led to the conclusion that the more complicated the configuration of bottom floor the more accumulated humus there was. This tendency might be more remarked of the accumulation of nitrogenous substances. However, it seemed that C/N was little influenced by the topography.

d) Irregular data on marine humus as abandoned after application of the Thompson test were discussed in reference to the data derived from other oceanographical or biological investigations carried out simultaneously. An extreme excess of total nitrogen content was to be found on the banks rising in the deep sea and that might depend upon the accumulation of planktonic remains. On the steep ridge extending from the Shakotan Peninsula, the remarked content of nitrogenous substances might be rather contributed by the remains of benthic animals. Further, it is very interesting that an anticlockwise eddy current was observed in the same area neighboring Otaru Bank where an extremely large value of C/N was observed.

e) A measure indicating the degree of variation of humus accumulation in a given area has been proposed. The measure (Vr) will be indicated as follows :

$$Vr = Sx/Sy$$

where Sx and Sy represent respectively standard deviations on humus content and on water depth. Then the author proposes to call the measure "Environmental Coefficient on Marine Humus Distribution" or "Relative Variation on Marine Humus Distribution."

This coefficient may be very convenient for the comparison of regional deviation in organic accumulation among areas different in geographical conditions.

(8) Marine humus distribution in the sea to the southeast of Hokkaido (the Pacific side to the west of Cape Erimo) were investigated with reference to the data provided by oceanographical observations (Koto, 1952) or to the mass properties of the bottom samples as determined by mechanical analysis :

a) Statistical examination showed that there was found a fairly positive correlation between organic content and water depth but the ratio of carbon to nitrogen did not indicate any correlation to the depth.

b) Regional distribution of marine humus would be susceptible to the influences of oceanographical environments. In particular, the local variation of the ratio,

C/N, seemed of much interest in reference to either terrigenous supplies or oceanographical characteristics in a given area. It was remarked that comparatively large ratio 10 would be found in the sediments which are customarily under the influence of rip current in broad sense.

c) The abundance of organic remains, especially skeletal residues of diatom, in the sediments appeared nearly correspondent to that of the nitrogen content. Consequently, organic remains might perhaps contribute effectively to sedimentary accumulation of nitrogenous substances on the bottom floor.

(9) The matter of mass properties of the bottom sample was investigated to see if these properties would reveal any relationship not only to the topographical or oceanographical environments but to the regional distribution of marine humus.

a) The samples were classified into several groups on the basis of the shape of cumulative frequency curve on grain size. So, the area under discussion was divided into several regions with reference to sediment type as well as to oceanographical environment. Such partition of the area would be reasonable for clarifying any possible correlation between organic accumulation in the sediment and dynamical process of sedimentation occurring at the site of sedimentation. Examination of the sedimentation process appeared very useful for investigating the oceanographical environments in the area.

b) The sedimentological indexes, as median diameter of particles or Trask's coefficients of sorting and skewness, of the bottom sample indicated the following relations to the character or abundance of organic materials accumulated in the sediment.

i) Although organic accumulation appeared rather correlative to median diameter, it would be hard in general to see any definite relationship with Trask's coefficients.

ii) The amount of organic matter in poorly sorted sediments seemed to be rather variable according to their localities of deposition.

iii) With the progress of the sorting, the well sorted sediments appeared to have a reduced content of organic matter, but this tendency seemed more remarkable in the case of nitrogen content.

iv) In the poorly sorted sediments, the amount of carbon content would decrease with reducing the degree of sorting, while that of nitrogen content would rather increase with reduction of sorting, until a more or less definite ratio of carbon to nitrogen would be attained.

v) In the well sorted sediment, a considerable deviation of skewness appeared not to much effect in regard to accumulation of organic matter. However, the abundance of organic matter would decrease with approach of the skewness to unity.

vi) In the poorly sorted sediment, it was scarcely possible to observe any relationship between the organic content and the skewness.

(10) The marine humus distribution in the vicinity of Okushiri Strait might follow closely the lines of the topographic map. There was clearly found some positive correlation between water depth and organic accumulation, but no correlation between water depth and the ratio, C/N.

(11) Organic accumulation in Ishikari Bay would be remarkably contributed by supply of terrigenous materials from the Ishikari River. But in the central part of the bay, sedimentary accumulation of organic matter was comparatively less active owing to progressive sorting of the sediments, and the organic materials accumulated appeared to be contributed rather by benthic animals or their remains than by terrigenous organic debris.

(12) Furthermore, some investigations were carried out for examining the ecological significance of chemical properties, especially of the nature or abundance of marine humus in the sediments.

a) Marine humus content have been investigated of the sediments in shellfish fields for the purpose of examining whether there could be found any correlation of the distribution to the ecological conditions of the fields. Although an adequate amount of organic matter in sediment is desirable for the dwelling of shellfishes, an enormous accumulation of organic matter appeared to make such life impossible because of developing the reduction state on the bottom floor.

b) An ecological investigation has been undertaken in Funka Bay for taking into consideration the relation of bottom characters to inhabitation of benthic animals. Although sea worms (*Polychaetae*) indicated somewhat reasonable relation to the amount of marine humus, it seemed hardly possible to find any relationship between the other animals and the organic content in sediments.

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