ACCUMULATION OF ORGANIC MATTER IN MARINE BOTTOM AND ITS OCEANOGRAPHIC ENVIRONMENT IN THE SEA TO THE SOUTHEAST OF HOKKAIDO

Kenji KATO
Faculty of Fisheries, Hokkaido University

I. Introduction

Organic substances (marine humus) in marine sediments are rather variable in accumulated amount or in chemical properties owing to change of environment of sedimentation. The organic constituents, because of thier greater susceptibility to change with varying conditions of deposition, might prove to be more sensitive indexes of the environmental conditions than the inorganic ones; however, of course, both should be used together in the interpretation of the history of the sedimentation or of the environments.

As to environmental factors relating to the characters of organic matter in sea bottom, there are to be emphasized the oceanographic conditions as well as submarine topography (Kato, 1951) of the site of deposition. So, it will be needful to examine how the properties of the water overlying the site of deposition influence the regional distribution of organic matter in the sediments. It seems difficult to analyze the dynamical complexity throughout the year concerning oceanographic conditions in a given area. On the other hand, the mass properites of the sediments are influenced sensitively by the variation of the water column overlying the site of sedimentation. A study of such mass properties of the sediments will suggest the integrated contribution of oceanographic environment to subaquatic accumulation on the bottom floor.

In this paper, the regional distribution of marine humus in the sea to the southeast of Hokkaido is discussed being based upon the results of the serial observation on the oceanographic conditions (Kotō, 1952) or the mass properties of the bottom samples as determined by mechanical analysis. The submarine topography (Ōgaki *et al*, 1953) of the area under discussion appears to be rather monotonous. The slope of the shelf is gentle and there is not any large river supplying any good amount of terrigenous debris. The oceanographic conditions, consequently, will probably be the most important factor controlling the sedimentary accumulation on the bottom. So, the area seems to be suited for the purpose of investigating the influence of oceanographic environments upon organic accumulation in sediments.

The Hokkaido Regional Fisheries Research Laboratory undertook during 1948-1952 to investigate the bottom topography and sediments of the off-shore fishing grounds at about 100-1000 meters depth all around the coast of Hokkaido.

The bottom survey of the present area was made during the 3-21st of September,

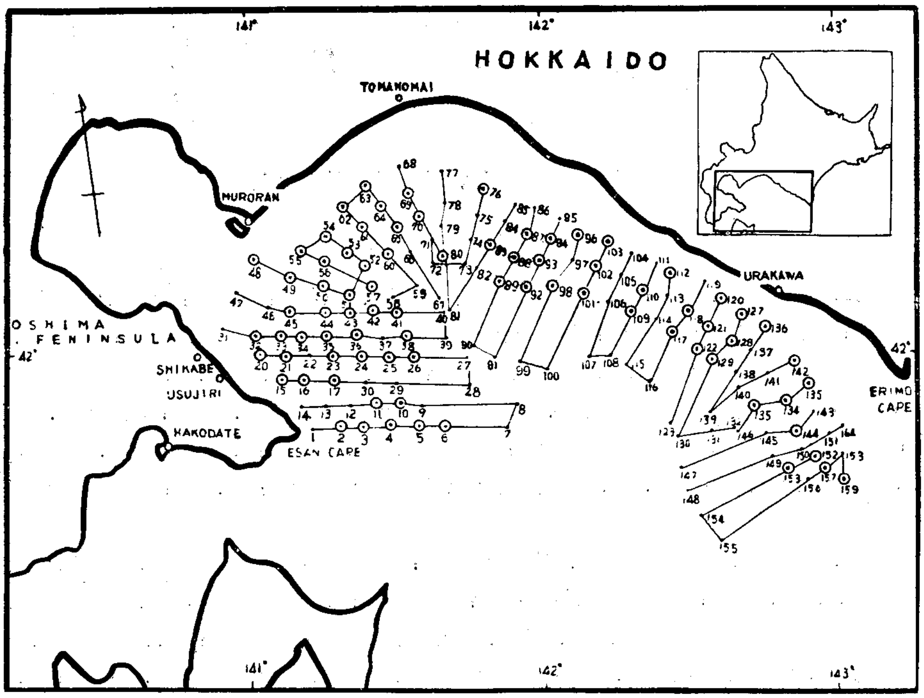


Fig 1. Stations of observation in the area to the southeast of Hokkaido (August 3 - 20, 1952)

1952, as one of the series of surveys by the Laboratory. The author undertook a chemical investigation dealing with the bottom sediments, of which bottom samples were obtained by Mr. H. Kosugi of the Laboratory and Mr. S. Tanaka, a student of the author's university, on shipboard TANKAI-MARU (68 tons), the research vessel of the Laboratory. The survey was conducted at intervals of four miles, so the bottom samples of 82 stations were observed after sampling, and 78 bottom samples from them were subjected to investigation at the laboratory of the university.

II. Methods employed

The oceanographic observation has been carried out with good position controls. For obtaining locations accurately, not only was the visible or sextant method employed, but other kinds of instrumental controls were used. Echo-sounding has played practically a very important role in performing the investigation of topography.

Bottom samples were obtained by using a small coring device or snapper. The samples obtained thus were submitted to laboratory investigation. At the same time, for preventing deterioration, the larger remains of benthos or weeds found in sediments were stored in vials containing formalin or spirit, and submitted later to biological investigation.

Of the bottom sample dried at 100–105°C, the organic carbon content was determined by using Turin's (1931) modification of Schollenberger's (1927) method: The sample was oxidized by treating with an excess of potassium dichromate, after which the remained dichromate was determined by titration with ferrous ammonium sulphate. Although the method is not absolutely accurate, it is rapid and convinient, moreover duplicate analyses of the sediments checked to within one per cent.

The content of total nitrogen in the dried sample was determined by using the common Kjeldahl method.

For obtaining as accurate as possible knowledge of dynamical processes of sedimentation in the present area, the following laboratory method on mass properties was used for the bottom samples from the area:

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

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

and the skewness coefficient as

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

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 0.06 mm mesh sieve to separate sand fraction from the silt. The settling method was used for analyzing the fraction finer than 0.06 mm in grain size. The clay fraction finer than 0.01 mm in grain size was separated from the silt fraction ranging from 0.01 mm to 0.06 mm in grain size. After a while, the sand fraction remaining in the sieve was analyzed by the common wet method of sieving.

Labratory work, next, led to microscopic observation of planktonic remains accumulated in the sediments, for ascertainment of how the organic remains had affected the accumulation of organic matter in the bottom floor.

III. General description of the area under discussion

There is at present little information available concerning the oceanographic character of this area. H. Kotō (1952), the author's colleague, has been investigating the oceanographic condition of the present area, since 1949, for clarifying the hydrographical mechanism of the water exchange in Funka Bay located to the westward of that area. One may understand the oceanographic characteristics of the investigated area after reading his following interpretation regarding the oceanographic condition observed in the mouth of Funka Bay (May 1950, Fig. 3):

The Tsugaru Current, or a branch of the Tsushima Current, has branched off northwards after passing through the Strait of Tsugaru. As the branched current develops gradually, the upper water of the Oyashio Current which had been staying ever since winter has separated into the two parts in the northwestern part of the area as illustrated in Fig. 3. The water mass separated thus may stay usually at the separated state until the influence of the Oyashio Current will increase again in autumn, although both the salinity and the temparature of the separated water will become somewhat higher owing to being mixed gradually with the water of the warm current. The characteristic equilibrium mentioned above appears fairly stable until the influence of the warm current becomes weak in autumn. The Tsugaru Current begins to regress in November. At the same time, the influence of the Oyashio Current appears to be developing gradually; the cold water presses the warm water to southward and flows into Funka Bay in winter. Then, the water exchange does occur in the bay.

After all, the area under discussion might be divided into the following subareas from the oceanographic point of view: The open sea (1) appears to be usually under the influence of the Tsugaru Current. But the area adjacent to the Oshima Peninsula (2) will be complicated in the motion of the water owing to the complicated configuration of the part, while the area off the coast of Hidaka (3) is accustomed to be under the influence of the Oyashio Current, especially in autumn and winter. Furthermore, at the western part in the vicinity of the mouth of Funka Bay (4), a part of the upper water of the Oyashio Current has been isolated hydrographically by the developing strength of the Tsushima Current in spring and summer, and there is usually found a kind of counter current against the branched current of the Tsugaru.

In texture, the sediments in the area are mostly sandy mud and become muddy with increasing water depth of the site of deposition (Fig. 4). Remarked sedimentation of volcanic materials such volcanic ashes or pumices is observed at the mouth of Funka Bay and off the eastern coast of the Oshima Peninsula. Such materials would be brought from the volcanoes, i.e., from Komagatake (1142 m), Usudake (732 m) and Tarumaisan (1026 m). It is notable that there are found distribution of gravel off Urakawa but the gravel observed was not pumice. Sand with 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 large amount of benthic animals, either living or dead, viz., sea worms, brittle stars, heart urchins, amphipods or young shells of scallop.

IV. General view of marine humus distribution in the area

The amounts of organic materials in the sediments have been summarized in Table 1. The regional distribution of organic contents in sediments have been illustrated in Figs. 5-7. These figures might indicate some correlation between the humus distribution and the environmental conditions at the site of deposition.

The abundance of organic accumulation was indicated by the contents of organic carbon and total nitrogen, which might vary with water depth at the site of deposition. The relation between the organic content and the corresponding water depth was examined statistically, and the findings were summarized in Table 2. According to it, there was found a fairly positive correlation between the two variables but the ratio of carbon to nitrogen had almost no correlation to the water depth.

It is remarkable that organic accumulation in the sediments appears developing with increase in the water depth and that the humus distribution somewhat resembles the sedimentary map of planktonic remains (Fig. 8).

In the open sea below 700 meter depth, a pretty good amount of organic matter, 1.8-2.4% C or 0.18-0.23% N, may be accumulated in the sediment. On the other hand, in the nearshore or comparatively shallow bottom, organic accumulation will be not so remarkable as in the case of the deeper sites; especially, an accumulation under 0.1 per cent in nitrogen content is observed on the continental shelf or at the offing east of Cape Esan. Further it is very remarkable that a strange accumulation of marine humus is observed in the western part of the area, where a part of the water of the Oyashio is customarily isolated from the water of the Tsugaru as emphasized in the previous section. At the center of that part, a comparatively abundant accumulation of organic matter in sediment is observed in contrast with a poor accumulation at the bottom neighboring the above center. Such characteristic humus distribution may be due to some influence of a kind of up-welling that usually occurs in this part.

A strip of poor accumulation of organic carbon in sediment pushes out off the coast to the northwest of the present area; that strip may be caused by some sort of erosion as induced by the water of Tsugaru Current approaching the coast. For a while, not only the abundance but also the character of organic materials in the sediments appears farily complicated in the area to the northeast of Cape Esan; that will be due to the complexity of oceanographic conditions in this part.

The local variation of the ratio, C/N, seems to be very interesting in reference to either terrigenous supplies or oceanographic character in the area. A belt possessing a ratio comparatively large in value runs along the continental slope, as shown in Fig. 7, where the major water of Tsushima Current is used probably to contact with the other waters near the coast. The noticeable portion of the belt lying in the northern part of the present area appears to be contributed largely by remarkable decomposition of nitrogenous substances in comparatively fresh terrigenous debris, judging from the remarkable reduction of nitrogen content. The organic detritus has perhaps been supplied from land by rivers on the coast and transported by the water of Tsugaru Current flowing to southeast. Another large ratios are also found at the central part of the northwestern area and off Usujiri on the Oshima Peninsula coast. At both of these areas, the existence of eddies has been suggested in the preceding section. It is very notable further that some singular stations having extremely small ratio are located nearby the area indicating an extremely large ratio.

After all, comparatively large ratios, 10 or over, will be found in the sediments of certain characteristic areas which will usually be found to be under the influence of current rip in broad sense. In such sediments, nitrogenous substances of fresh organic matter will be decomposed more actively by bacteria in comparison with non-nitrogenous substances because of supplying a fairly good amount of oxygen for the bacterial decomposition. Waksman (1938) has shown that fresh organic matter attacked by bacteria will first lose nitrogen than carbon until a more or less definite equilibrium ratio is attained.

Preliminary examination of organic remains shows that the abundance of skeletal residues of diatom accumulated in the sediment appears nearly analogous to that of the nitrogen content. Organic remains might consequently contribute effectively to sedimentary accumulation of nitrogenous substances in the bottom floor. It is also one of the characteriatics of the area under discussion that the fragments of sponge spicule were observed in almost all of the bottom samples from this area.

V. Sedimentological inspection on organic accumulation in sediments

The median diameter and Trask's coefficients of sorting and skewness of the sample were investigated to see if these sedimentological indexes after mechanical analysis of the sample would show any relationship not only to the various topographic or oceanographic environments but to the regional distribution of organic matter in sediments.

Figure 9 shows a bottom sediment map of the area under discussion, but that will not always be satisfactory for representing the dynamical process of sedimentation occuring therein. So, a contour map of median size based upon the cumulative distribution curve on grain size of sediment is shown in Fig. 9, which was made for the fraction of the bottom sample finer than two milimeters in grain size. The median map illustrates that a remarkable accumulation of grains finer than 0.025mm is observed in the northwestern part of that area although these finer sediments are usually found in the offing deeper than 500 meters. Moreover, off the coast between Urakawa and Cape Erimo, it is remarked, the sediments have the finest grains, 0.001 mm or less in median diameter. It appears that these characteristic regions as emphasized above are located in the areas where there may usually occur some eddy current by contact of different masses of water.

Viewing the relationship of sedimentological indexes, as Md, S_o and Sk, of the bottom sample to the water depth at the site of deposition, one can scarcely find any distinguished correlation between them as a whole.

The bottom samples from the investigated area were classified into several groups, as shown in Fig. 10 and Table 3, on the basis of the shape of cumulative curve on grain size of sample. The area under discussion is divided as illustrated in Fig. 11 into several regions with reference to sediment type as well as to oceanographic environments. Such partition of the area will be useful in examining the correlation between organic accumulation in sediment and dynamical process of sedimentation taking place in the site of deposition. Examination of the sedimentary process appears very useful for investigating the oceanographic environment. These regions divided thus may be described as follows:

1) A – Region:

This region is the relatively pelagic part of the investigated area, in which water depths range from 500 meters to 840 meters, thus appearing to be under the influence of the Tsugaru Current. The region possesses sediments with fairly fine median diameter's, 0.010–0.045 mm, being so poor-sorted as to indicate 12.3 in S_o averaged. These sedimentological characters indicate that the sedimentation occurring in this region appears remarkable rather in deposition process than in erosion or transportation ones. Relatively poor sorting in A_2– region seems to indicate the conceivable presence of a kind of current rip which usually results from contact between the water of the Tsugaru and the coastal water.

In short, an inspection of the sedimentological characters shows that A-region should be characterized as pelagic or hemipelagic.

Sedimentary accumulation of organic matter seems relatively abundant, that is to say, the average content of organic carbon in the sediments ranges from 1.21% to 1.66% and that of total nitrogen from 0.143% to 0.182%. Decomposition of organic matter in sediment appears fairly active and the ratio of carbon to nitrogen is given as the average ratio near 8.6. The sediments which have been comparatively poorly sorted in A_2-region appear to be rather less abundant in organic matter (ignition loss) than those of the other parts, as A_1 or A_3.

2) B – Region:

The major part of this region is the shelf adjacent to the Oshima Peninsula; the movement of water is complicated owing to the geographical configuration. The sedimentological characters in this region indicated that the median diameter of sediment is of coarse or medium-sand and well-sorted as indicated usually by 2 - 3 in S_o. Especially, the sediments in B_1-region are better sorted. The sediments in the B region, however, seem somewhat poorly sorted in the fine fraction. This tendency is more remarked in B_1- or B_3- region. It is otherwise very noticeable that the sediments in the vicinity (B_4-region) of Station 16 are extremely poorly sorted, 32.7 in S_o, especially of their fine fractions, and 0.03 in Sk. These coefficients regarding B_4-region will indicate that there will usually be found a characteristic deposition of sedimentary particles in this region. This noticeable deposition may be due to a small eddy which is usually found near the coast and influenced by configuration of the coast.

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 approximately 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 are found to predominate in this region, although somewhat divergent values are observed in B_1-region. These facts show that there will be found not only poor accumulation of terrigenous organic matter owing to better sorting but also to complicated condition of oceanographic environment.

3) C - Region:

The continental shelf off the coast (Hidaka) west of Cape Erimo belongs to this region. This region may be divided into two parts which are characterized on the basis of sediment type of bottom samples as well as their oceanographic environment. One of these two parts is the area consisting of C_1 and C_2, lying intermediate between Urakawa and Cape Erimo. The sediments of the above area are mostly clay or silt; their poor assortment is remarkable, the median diameters are finer than 0.01 mm and sorting coefficient 9 or over. These sedimentological characters in C_1-region show that there must occur a characteristic sedimentation in which the deposition process will be rather more important than the other process such as erosion or transportation in this region; then there is the possibility of the occurrence of a kind of eddy or a counter current. Such an eddy current will be induced from the contact of the two currents of the Tsugaru and the Oyashio, of which the latter flows bypassing Cape Erimo. It is moreover noticeable that the sediment type in the C_1-region is nearly analogous to that in A_1-region or D-region. Organic accumulation, however, in C-region is not as abundant as that in the analogous region in sediment type mentioned above. Also the qualities of organic materials accumulated in the sediments of the C_1-region appear rather terrigenous judging from the high ratio of carbon to nitrogen.

The other part suggested above occupies most of the C-region comprising C_3, C_4, C_5 and C_6. The flows of both the Tsugaru Current (in spring and summer) and the Oyashio Current (in autumn and winter) seems to be fairly influenced by the change of the corresponding season. The sediments, consequently, are well sorted as indicating the S_o ranging 1.4 - 4.6 or mostly near 2, but the finer fraction appears rather less sorted than the ccarser ones.. The sediments in C_3-region, moreover, have median diameter near 0.05 mm and appear rather less sorted, 0.31 - 0.37 in Sk, than those in the other parts of the C region do. These sedimentological features of the C_3-region may look similar to thsoe in A_3-region; there will usually be suggested the existence of a current rip in this region and a fairly good amount of organic matter is accumulated in the bottom sediments.

In C_4-region occupying the major portion of the C-region, the sediments have 0.06-0.15 mm median diameter, being well sorted and indicating somewhat symmetrical size distribution, where the best sorted sediments have median diameter near 0.13 mm.

As the sediments in the regions of C_{3-6} have been well sorted by flows of currents, the organic materials in these regions will be comparatively lacking in the sedimentary accumulation but rather terrigenous in character. Such terrigenous characters of organic materials in the sediments will indicate some contribution of organic debris supplied by rivers on the coast to the north of the investigated area.

4) D - Region:

D-region is the northern part of the area under discussion. It is complicated in oceanographic environments as emphasized in the previous section; then the sediment type of the bottom samples should be very changeful.

The sorting of sediments in this region appears not only extremely poor but also widely variable. Moreover the cumulative curve on grain size of the bottom sample appears somewhat singular in shape which finding may suggest some influence of mass movement of unconsolidated sediments in the form of mud flows. The transportation effect suggested above appears to be more remarked in the respective stations, marked E in Fig. 10, of 42,65 and 76 judging from the abnormal shapes of grain-size cumulative curves obtained from samples of the three stations. A characteristic sedimentation is clearly found at the central part, D_1, of the D-region; the sediment type of the sample from D_1-region indicates median diameter near 0.015 mm and sorting coefficient near 7. This seems somewhat analogous to the type of such a pelagic region as A_1, although the size-distribution of the sample from D_1-region is skewed towards the coarser size. These feature of D_1-region may be somewhat peculiar in effects from eddy or rip current. Both inspections on the regional distribution of granule (Fig. 4) and on the skewness towards the coarser size found in grain-size distribution curve may indicate that a ccast line in geological age would be found in the vicinity of the D_1-region. The above geographical suggestion regarding the characteristic mass properties of the bottom sample, however, will need more investigations in future. A fairly abundant accumulation of organic matter, 0.14 – 0.21%N is observed in D_1–region, while D_6–region neighboring the D_1 has some strange stations, as 49 or 52, which indicate fairly high ratio of carbon to nitrogen near 12.5. This fact will suggest not only complexity in water diffusion towards vertical or holizontal direction but transportation of unconsolidated sediments.

Sedimentological inspection of the ratio C/N shows that rather higher ratio may be observed in the sediment which has been relatively poorly sorted and which shows a strange curve of grain-size distribution with connection to transportation process over the bottom floor.

VI. Relationship between sedimentological indexes and accumulation of organic matter in sediment

The sedimentological indexes, as median diameter or coefficients of sorting and skewness, of the bottom sample were examined to see whether they would indicate a relationship to the character or abundance of organic materials accumulated in the sediment. These relations are illustrated in a series of Figures 13 – 15.

Although organic accumulation appears rather correlative to median diameter (Fig. 13), it will be hard in general to see any definite correlationship to the coefficients of sorting and of skewness. Further inspection in detail leads to an approximate estimation on a relationship between the organic accumulation and these indexes.

It appears that the finer the sediment is in diameter the more abundant in organic accumulation. As to the sediment finer than 0.01 mm in median diameter, however, there will be found something of a tendency for a reduction in organic content to accompay a reduction in diameter of grain size.

Plots of the organic content against the sorting for the relatively well sorted sediments, as indicating S_o below 5, fall in some reasonable mass. While the plots on the poorly sorted sediments seems almost to be dispersed. With the progress of the sorting, the well sorted sediments appear to be reduced in organic contents, particularly more remarkably in nitrogen content. In the others, the plots regarding the poorly sorted sediments will scarcely show as a whole any definite relationship to the degree of sorting because of their random deviations, but further detailed examination may suggest some relation between sorting degree and organic accumulation of the poorly sorted sediment. The quantity of organic carbon in sediment will decrease with reduction in the degree of sorting; otherwise, that of nitrogen will show some increase with reduction of sorting, until a more or less definite ratio of carbon to nitrogen will be attained. Further it is noticeable that the constancy of the carbon nitrogen ratio appears rather more reliable in the well sorted sediments than in the poorly sorted ones. This fact will show that the better sorting leads to settling of fresh terrigenous debris comparatively large in shape as well as to the removal of colloidal detritus of organic matter which has been humi-nized progressively. The progress of sorting appears moreover to render the material more profitable for the inhabitation of benthic animals because of the presence of a pretty good supply of oxygen or foods.

Plots of organic content against the skewness on the well sorted sediments in B-region show that the considerable deviation of skewness appears not to exert much influence in controlling organic accumulation in the bottom. This fact will suggest that the abundance of organic matter accumulated in the well sorted sediments will be more largely contributed by large organic debris or remains than fine detrital materials. The most sediments of C region, as C_3, C_4, C_5 and C_6, have rather coarser median diameter in comparison with those of B region, but the sediments of the C have been sorted simi-larly to those of the B-region. Now, it appears that the abundance of organic matter decrease with approach of the skewness to unity.

Plots on the poorly sorted sediments such as those of A_1- or D-region are dispersed on the diagram; it is scarcely possible to see any relationship between the organic content and the skewness coefficient of sediment. These examinations show that the organic ac-cumulation in poorly sorted sediments were probably contributed by detrital organic matter.

VII. Conclusion

Regional distribution of marine humus (organic matter in sediment) in the sea to the southeast of Hokkaido was investigated with reference to the oceanographic environment of the site of deposition. As the oceanographic character of the site of deposition will contribute to the mass properties of the bottom sediment, sedimentological examination of the mass properties was attempted as described in the present paper for discussing the relation of organic accumulation in bottom to the oceanographic environment.

Statistical examinations on the relation of the organic accumulation to such a topo-graphic factor as water depth at the site of deposition indicated that there is a fairly positive correlationship between the organic content and the water depth, but that the ratio of carbon to nitrogen showed scarcely any correlation to the water depth.

It is true that sedimentary accumulation of organic matter will be susceptible to the influence of oceanographic surroundings, but the local variation of the carbon nitrogen ratio of the sediment seems very interesting in relation to either terrigenous supply or oceanographic condition in a given area. It was remarked in the area under discussion that a comparatively large ratio above 10 was almost always observed in the sediment which was customarily under the influence of rip current in broad sense.

The abundance of organic remains, particularly of skeletal residues of diatom, in the sediment appeared nearly analogous to that of the nitrogen content. Consequently organic remains might fairly influence the sedimentary accumulation of nitrogenous substances on the bottom floor.

Sedimentological indexes, e. g., median diameter and Trask's coefficients of sorting and skewness, of the bottom samples were investigated, after mechanical analysis, for discussing the relation of them to the regional distribution of marine humus as well as to the influences of topographic or oceanographic environments.

Here, the samples were classified into several types of sedimentation on the basis of the shape of cumulative frequency curve on grain size. Further, the area under discussion was divided into several regions with reference to the sediment type of the bottom samples as well as to the oceanographic characters. Such partition of the area would be reasonable for clarifying any correlation between the organic accumulation and dynamical process of sedimentation going on at the site. Examination of the sedimentary process appeared of much use for investigating the oceanographic environments in the area.

Although organic accumulation in bottom appeared rather correlative to median diameter, it would be hard in general to observe any definite correlation to the Trask's coefficients. The abundance of organic matter in poorly sorted sediment seemed to be rather more variable according to its location. Otherwise, the well sorted sediment seemed to be decreasing in respect to organic content with the progress in the sorting; that would be even more remarkable in the case of their nitrogen contents.

In the poorly sorted sediments, the amount of organic carbon decreased while that of nitrogen rather increased with reduction in the degree of sorting process, until a more or less definite ratio of carbon to nitrogen tended to be attained.

Of the well sorted sediments, a considerable deviation of skewness appeared not to have much influence upon organic accumulation in bottom. The abundance of organic matter, however, decreased with approach of the skewness to unity. Of the poorly sorted sediments, it is scarcely possible to observe any relation between the organic content and the skewness.

The author is much indebted to Professor Noboru Suzuki for his untiring encouragement, and to Mr. Kohei Ōgaki, Director of the Hokkaido Regional Fisheries Research Laboratory, for giving many facilities for this work. He also is much obligated to Professor Tadashi Tamura for helping him in the working out of the biological problems. Thanks due to Messrs. H. Kosugi and S. Tanaka for obtaining bottom samples in field works. 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.

References

1) Kato, K. (1951). Chemical studies on marine deposits. Part 3. On the distribution of marine humus contents in the sea to the northwest of Hokkaido Island. *Bull. Fac. Fish., Hokkaido Univ.* 2 (1),

10–30. (in Japanese appended English abstract).

2) Kotō, H. (1952). Oceanographic observation of Funka-Wan. ***Funkawan-Gyogyō-Keiei-Antei-Kisochosa*** (Interim Reports). No. 2, 1–17. (in Japanese).

3) Ōgaki, K., Kosugi, H. & Tomabechi, Y. (1953). Submarine topography and distribution of bottom sediment on deep sea fishing ground of Hokkaido. ***Bull. Hokkaido Reg. Fish. Lab.*** (9), 1–16. (in Japanese appended English abstract).

4) Schollenberger, C. J. (1927). A rapid approximate method for determining soil organic matter. ***Soil Sci.*** **24**, 63–68.

5) Tiurin, I. V. (1931). A new modification of the volumetric method of determining soil organic matter by means of chromic acid. ***Pedology*** **26**, 36–47.

6) Trask, P. D. (1932). ***Origin and environment of source sediments of petroleum.*** A. P. I., 323 p. Gulf Publ. Co.

7) Waksman, S. A. (1938). On the oxidation of organic matter in marine sediments by bacteria. ***Jour. Mar. Res.*** **1**, 101–118.

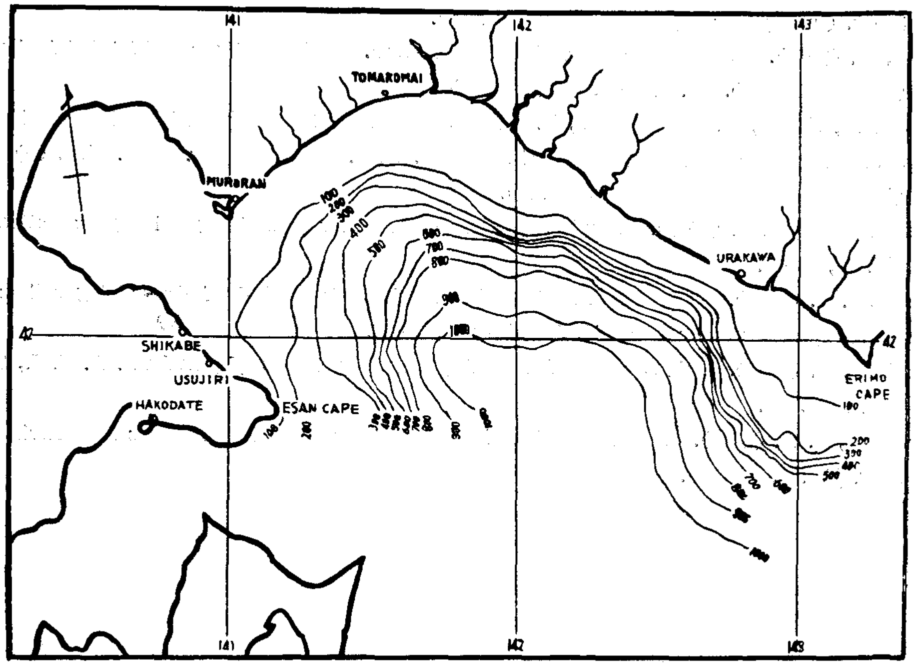


Fig. 2. Submarine topography of the area to the southeast of Hokkaido

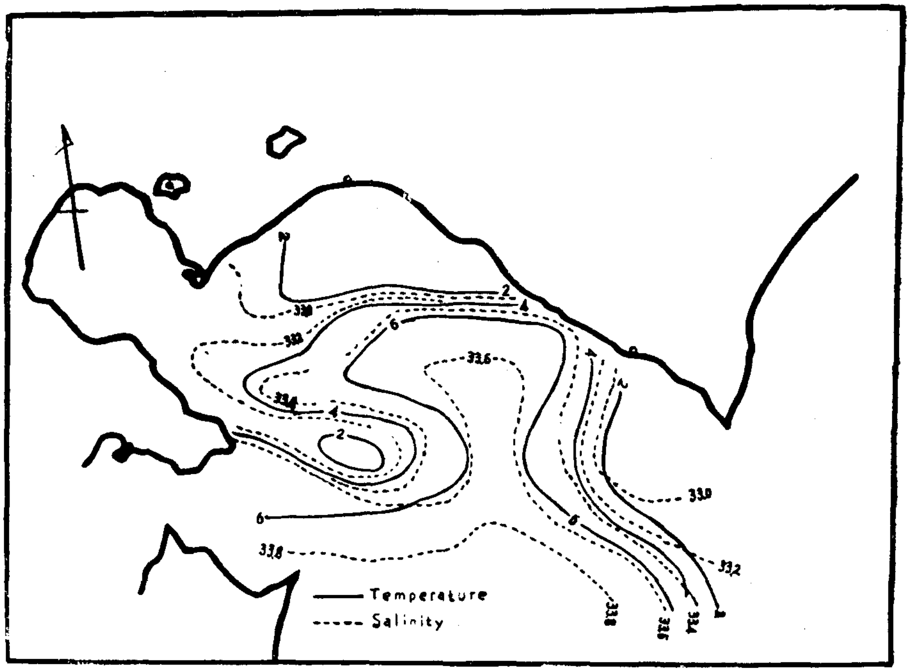


Fig. 3. Oceanographical view of the area to the Southeast of Hokkaido (50 meters layer, observed by H. Kotō; May 1950)

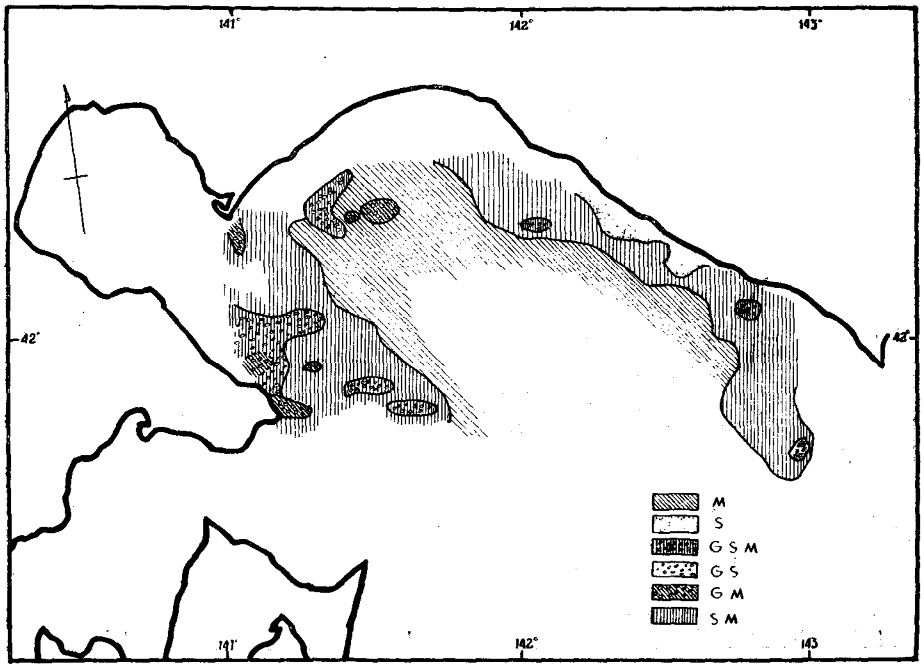


Fig. 4. Bottom character in the area to the southeast of Hokkaido

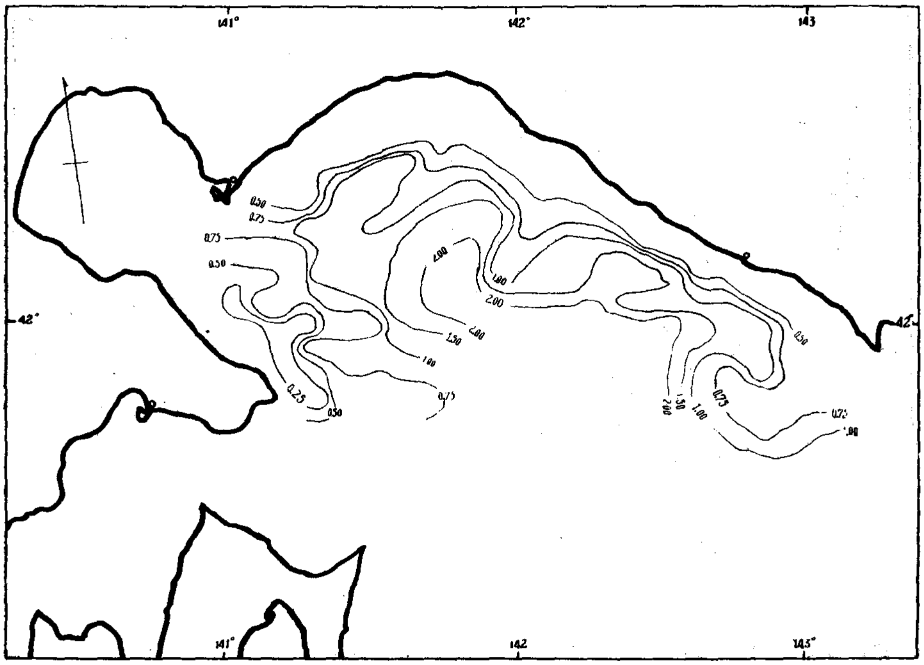


Fig. 5. Distribution of organic carbon content in sediments (The area to the southeast of Hokkaido)

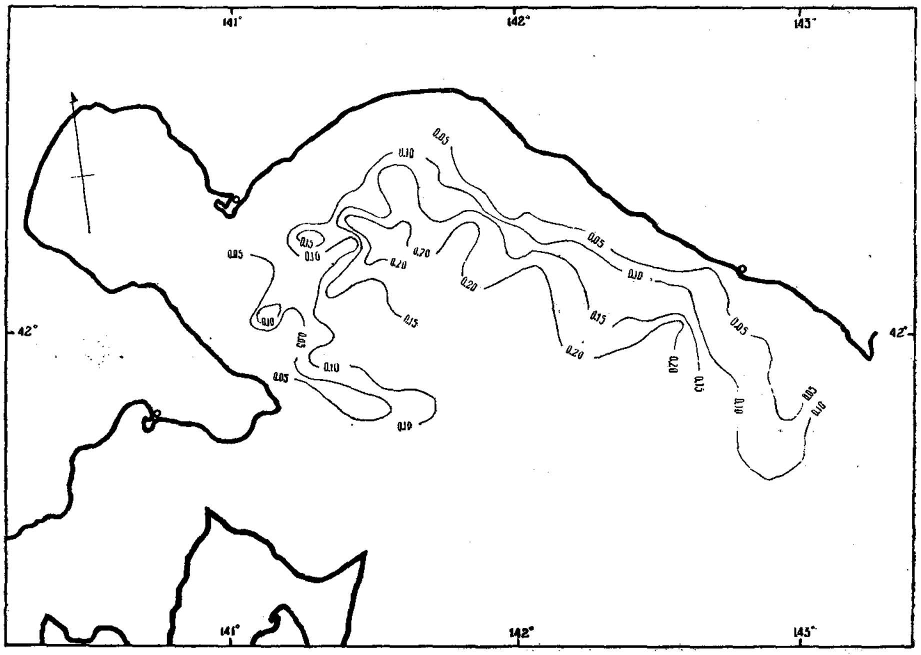


Fig. 6. Distribution of total nitrogen content in sediments (The area to the southeast of Hokkaido)

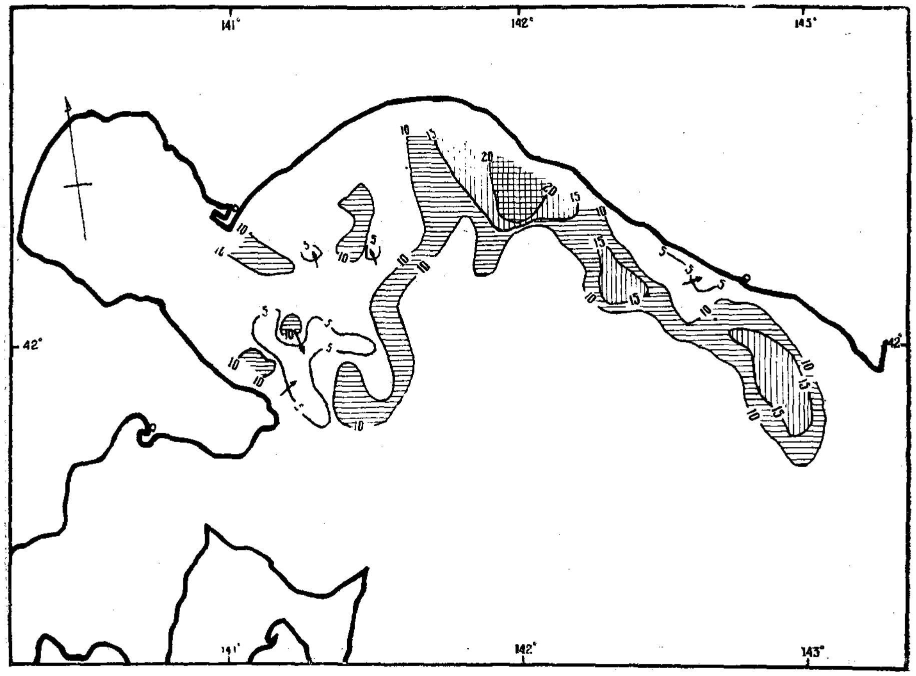


Fig. 7. Distribution of the ratio, C/N, in sediments (The area to the southeast of Hokkaido)

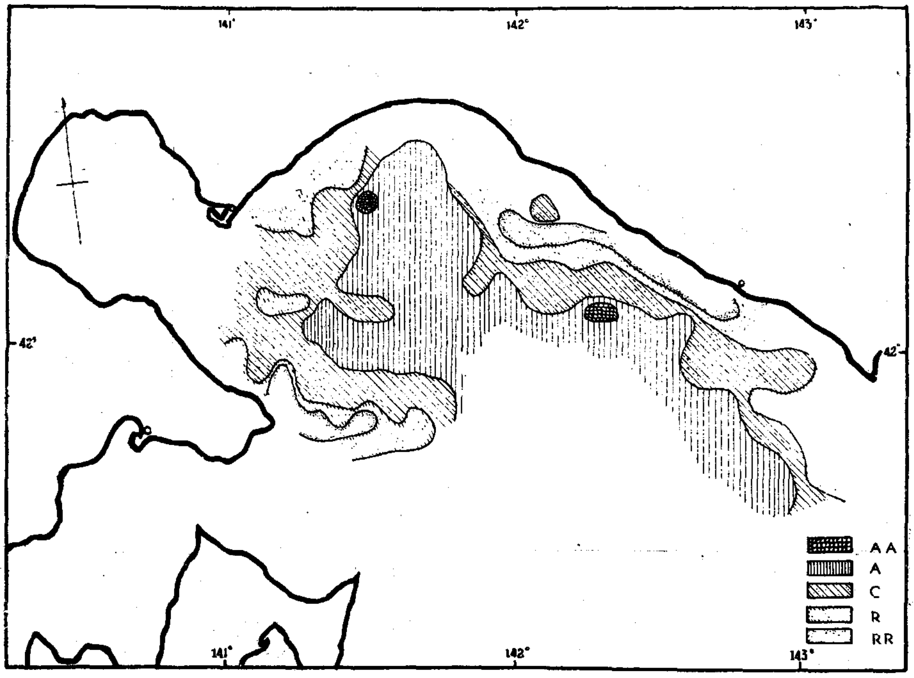


Fig. 8. Distribution of diatom residues accumulated on bottom floor (The area to the southeast of Hokkaido)

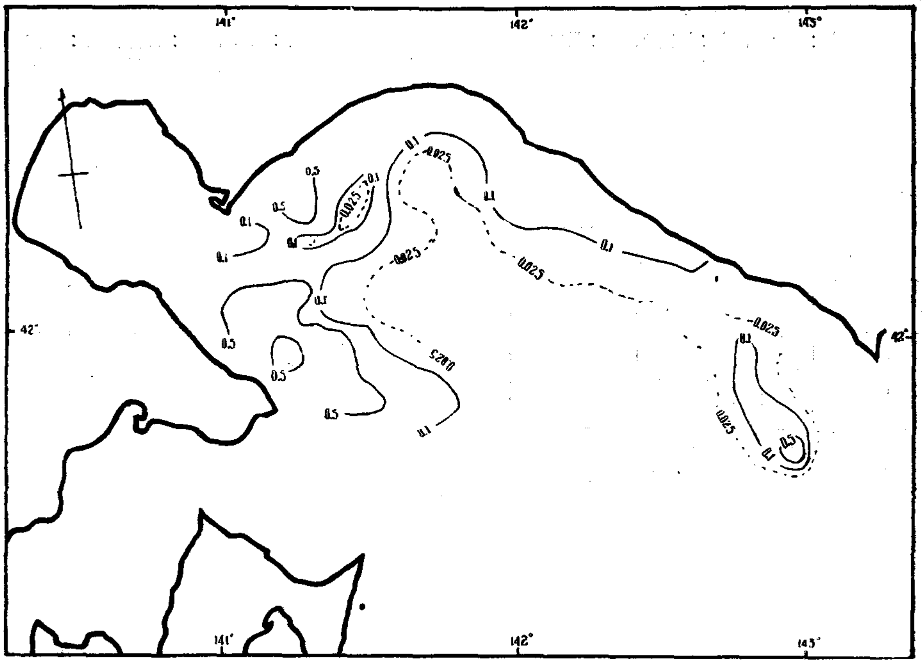
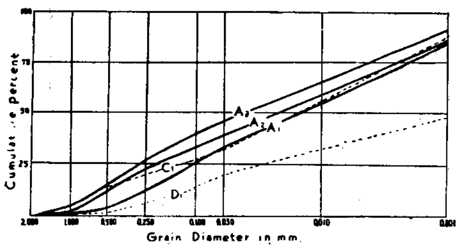


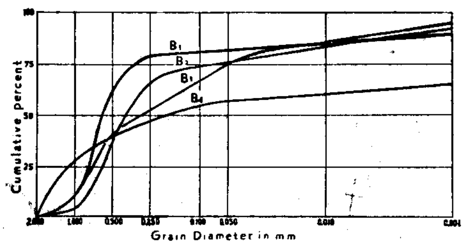
Fig. 9. Median map in the area to the southeast of Hokkaido (mm)

A - Region :



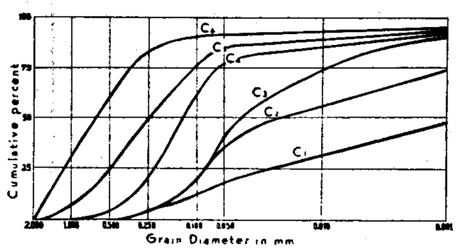
A_1 : H89, A_2 : H41,
A_3 : H80; C_1 : H159, D_1 : H61

B - Region :



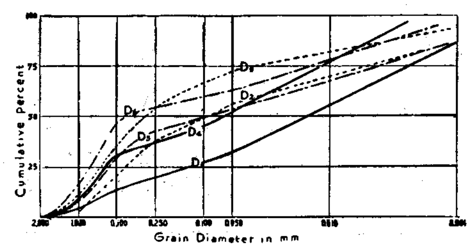
B_1 : H4, B_2 : H10, B_3 : H35,
B_4 : H16

C - Region :



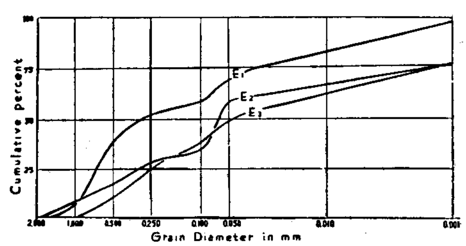
C_1 : H159, C_2 : H129, C_3 : H118,
C_4 : H144, C_5 :H94, C_6 : H157

D - Region :



D_1 : H64, D_2 : H69, D_3 : H62,
D_4 : H48, D_5 : H51, D_6 : H50

E - Region :



E_1 : H65, E_2 : H76, E_3 : H42

Fig. 10. Graphs of cumulative curves showing sediment types

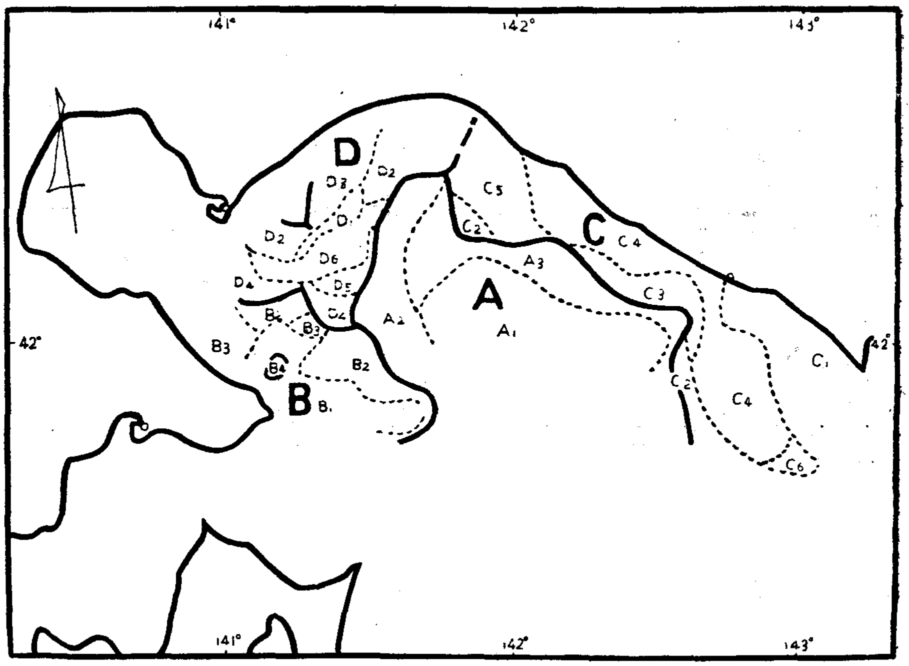


Fig. 11. Regions divided owing to sedimentological characters
(The area to the southeast of Hokkaido)

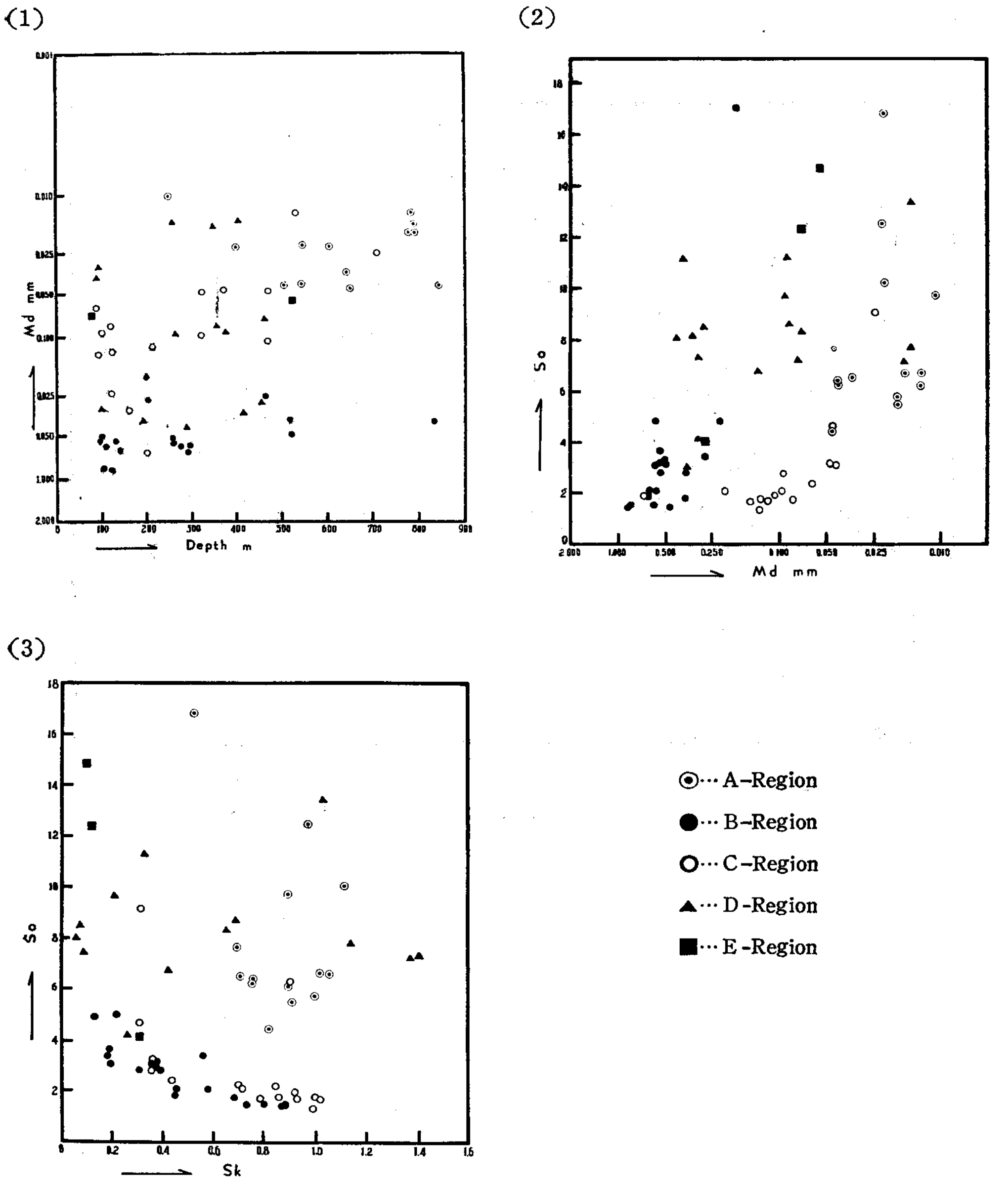


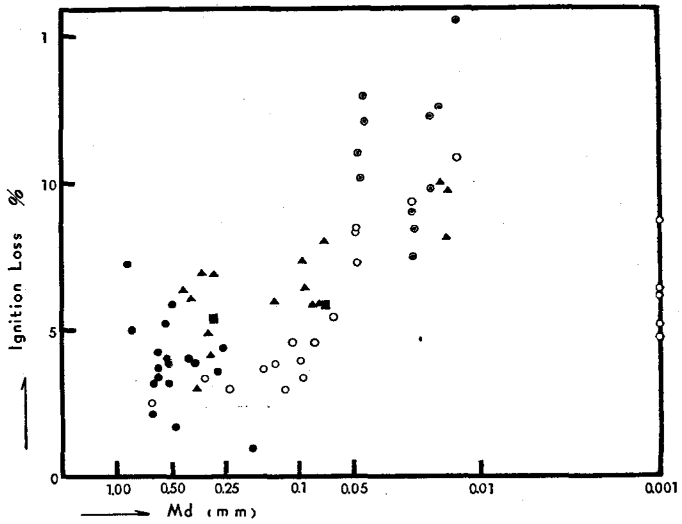
Fig. 12. Relation of the geographic region to sediment type

(1) Median diameter plotted against water depth

(2) Sorting coefficient plotted against median diameter

(3) Sorting coefficient plotted against skewness coefficient

(1)



(2)

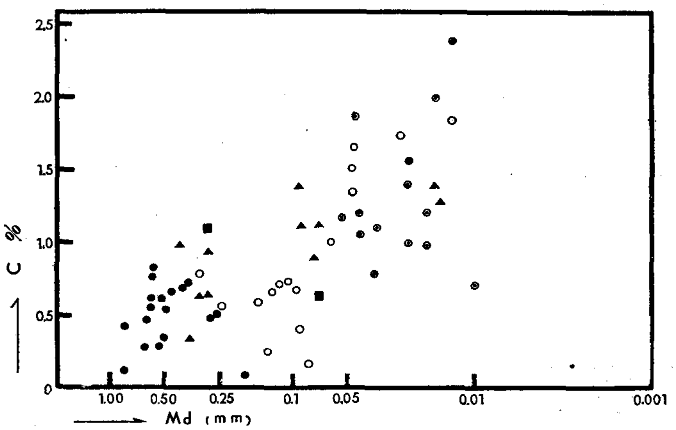


Fig. 13. Relation of median diameter to organic content in sediment

(1) Ignition loss plotted against median diameter

(2) Organic carbon content plotted against median diameter

⊙… A-Region ●… B-Region ○… C-Region ▲… D-Region ■… E-Region

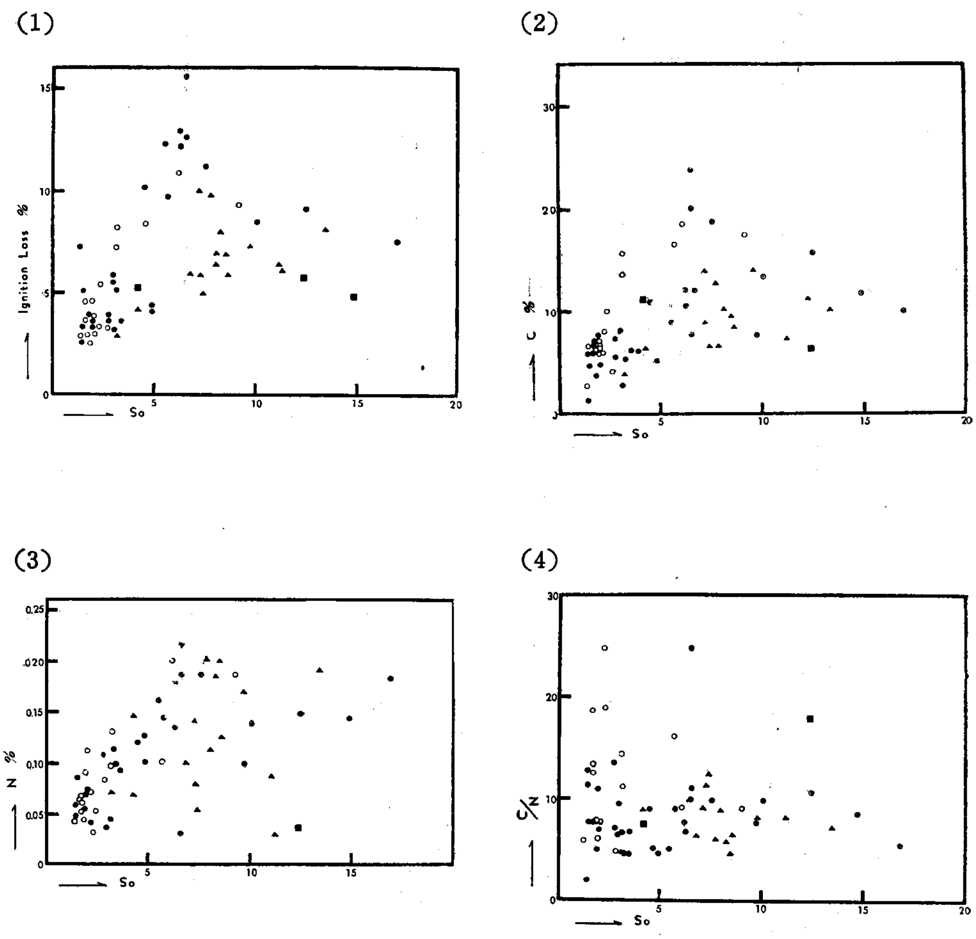


Fig. 14. Relation of sorting coefficient to organic content in sediment

(1) Ignition loss plotted against sorting coefficient
(2) Organic carbon content plotted against sorting coefficient
(3) Total nitrogen content plotted against sorting coefficient
(4) The ratio, C/N, plotted against sorting coefficient

⊙··· A-Region ●··· B-Region ○··· C-Region ▲··· D-Region ■··· E-Region

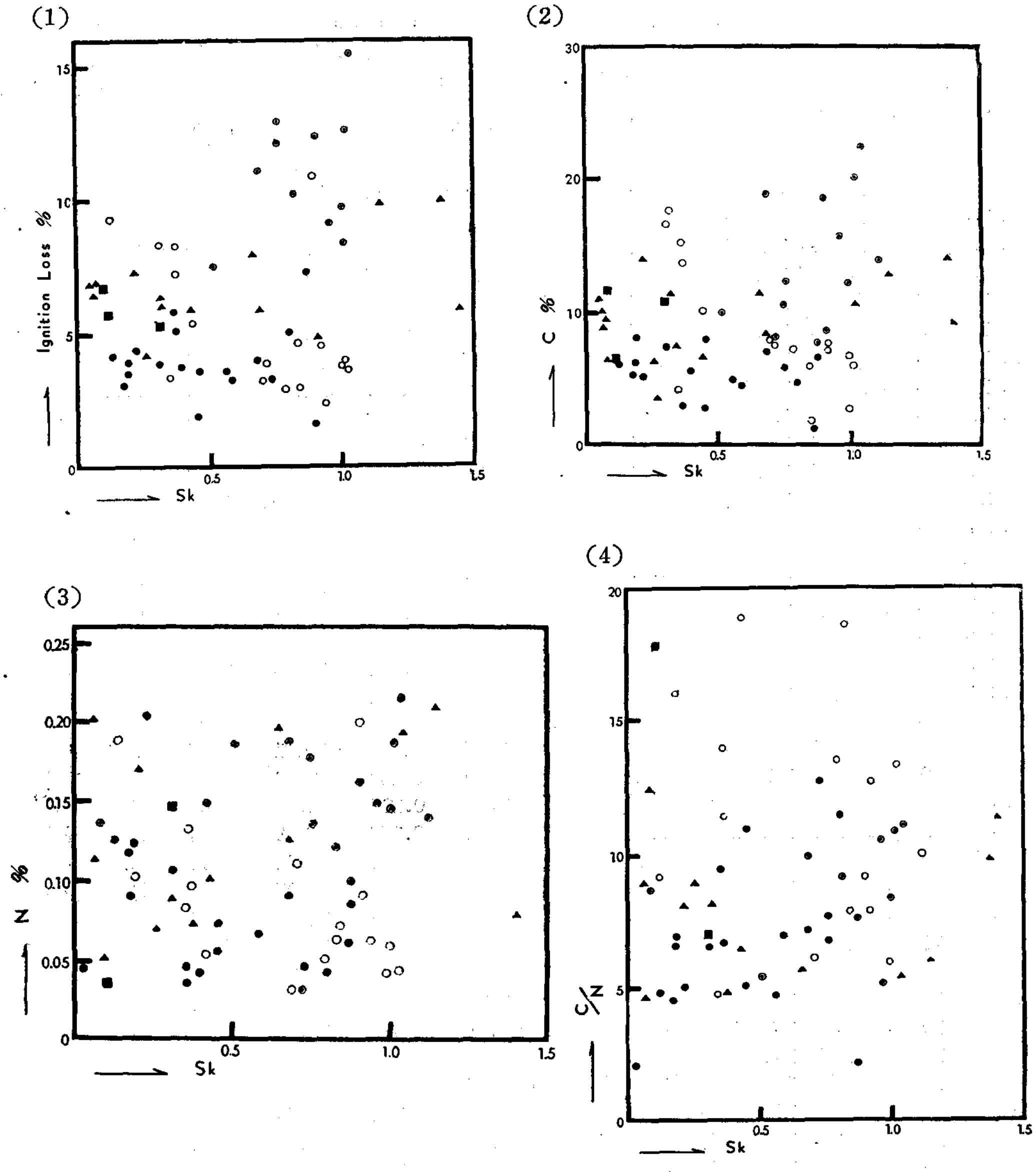


Fig. 15. Relation of skewness coefficient to organic content in sediment

(1) Ignition loss plotted against skewness coefficient
(2) Organic carbon content plotted against skewness coefficient
(3) Total nitrogen content plotted against skewness coefficient
(4) The ratio, C/N, plotted against skewness coefficient

⊙… A-Region ●… B-Region ○… C-Region ▲… D-Region ■… E-Region

Table 1. General properties of bottom samples from the area to the southeast of Hokkaido (3–20, September, 1949)

St. No.	Date (Sept. 1949)	Location Lat. N	Long. E	Water depth (m)	Texture of sediment	Organic carbon (%)	Total nitrogen (%)	C/N	Ignition loss (%)	Diatom residues	Silicious sponge
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	GSM	0.66	0.085	7.77	1.69	C	C
H 6	3	41°48′7	141°40′0	830	GSM	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	GM	0.47	0.041	11.46	5.07	C	
H 16	4	41°55′8	141°11′7	198	GSM	0.09	0.043	2.09	0.85	RR	
H 17	4	41°55′5	141°18′3	288	GM	0.82	0.122	6.72	3.59	C	
H 20	8	41°59′5	141° 2′5	97	GSM	0.34	0.036	9.45	5.88	R	
H 21	8	41°59′5	141° 7′8	123	GSM	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	GSM	0.30	0.045	6.67	5.16	C	
H 33	9	42° 2′8	141° 6′7	116	GSM	0.62	0.126	4.92	4.23		C
H 34	9	42° 2′5	141°11′5	133	GSM	0.56	0.041	13.66	3.80	C	C
H 35	9	42° 2′7	141°17′0	252	GSM	0.49	0.101	4.85	3.65	A	
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	
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	
H 50	10	42°10′2	141°15′2	193	SM	0.72	0.088	8.18	0.62	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	GSM	1.02	0.113	9.03	6.38	C	
H 54	10	42°18′1	141°16′5	139	GS(M)	0.47	0.067	7.02	3.26	R	
H 55	10	42°15′7	141°11′8	100	SM	0.66	0.101	6.54	5.93	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	
H 62	10	42°22′2	141°20′0	93	GSM	0.63	0.070	9.00	4.22	C	C
H 63	10	42°25′2	141°24′5	88	GSM	0.36	0.074	4.87	3.01	R	
H 64	10	42°22′0	141°27′6	348	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

(Table 1 continued)

St. No.	Date (Sept. 1949)	Location Lat. N	Long. E	Water depth (m)	Texture of sediment	Organic carbon (%)	Total nitrogen (%)	C/N	Ignition loss (%)	Diatom residues	Silicious sponge
H 76	13	42°25′0	141°48′1	79	S M	0.64	0.036	17.78	5.77	R	
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	S M	0.79	0.032	24.69	3.30	R R	
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	
H 92	15	42°10′2	141°58′7	785	M	0.85	0.162	5.25	12.13	A A	C
H 93	15	42°14′3	142° 0′2	565	M	0.74	0.136	5.44	4.67	R	A
H 94	15	42°17′4	142° 2′1	120	G S	0.56	0.071	7.89	3.05	R R	C
H 96	16	42°17′7	142° 9′0	95	S M	0.59	0.044	13.41	3.67	R R	C
H 98	16	42°10′3	142° 4′0	820	M	……	0.208	……	……	C	C
H101	16	42° 9′5	142° 9′2	840	M	1.21	0.178	6.80	12.14	C	A
H102	16	42°13′3	142°11′7	500	M	1.11	0.121	9.17	10.23	R	C
H109	16	42° 6′4	142°18′8	715	M	1.70	0.101	16.83	10.91	A A	C
H110	16	42° 9′5	142°21′0	465	M	1.66	0.103	16.12	8.42	C	C
H112	17	42°12′2	142°28′0	85	S M	0.26	0.043	6.05	3.87	R R	C
H117	17	42° 2′6	142°28′1	780	M	1.21	0.143	8.46	9.74	A	C
H118	17	42° 6′4	142°30′0	370	M	1.52	0.132	11.52	8.26	C	C
H120	17	42° 8′5	142°37′2	100	Sh S M	0.41	0.084	4.88	3.43	R R	C
H121	17	42° 4′0	142°33′7	540	M	1.05	0.136	7.72	12.92	A	A
H122	17	42° 0′8	142°31′7	780	M	2.39	0.215	11.12	15.56	A	C
H125	18	42° 6′0	142°41′1	245	M	0.77	0.100	7.70	3.73	R	A
H127	18	42° 6′0	142°41′1	95	S	0.70	0.065	10.77	4.24	R R	
H128	18	42° 1′9	142°38′9	320	M s	1.36	0.097	14.02	7.30	C	C
H129	18	41°58′7	142°35′7	705	M	1.74	0.188	9.26	9.32	C	C
H133	18	41°51′0	142°43′6	320	G S M	0.68	0.112	6.07	3.94	A	C
H134	18	41°52′0	142°49′7	115	S M	0.18	0.063	18.73	4.59	R	C
H135	18	41°55′1	142°54′2	90	S	0.81	0.048	16.88	6.23	C	C
H136	19	42° 3′8	142°46′4	85	G S	0.53	0.042	12.62	4.86	R	C
H142	19	41°58′6	142°51′7	90	S	1.00	0.053	18.87	5.43	C	C
H144	19	41°48′0	142°52′4	125	S M	0.67	0.060	11.17	4.08	C	C
H152	20	41°44′5	142°55′2	210	S M	0.72	0.053	13.59	2.97	C	C
H153	20	41°42′5	142°50′4	465	S M	0.73	0.092	7.94	4.60	A	C
H157	20	41°42′2	142°57′9	200	G S	0.76	0.062	12.67	2.52		
H159	20	41°41′5	143° 1′4	426	M	1.03	0.123	8.37	8.78	R	C

Table 2. Organic contents of the sediments and their relation to the water depth of the site of deposition (Sea, southeast of Hokkaido, Sept. 3-20, 1952)

	Number of individuals	Population mean (a=0.05)	Standard deviation (s)	Correl. coeff. (r)	Test of null hypothesis	Equation of regression
Organic-C	79	0.823 —1.057	0.500	0.689	S ≑ 0	C = 0.00149 d + 0.339
Total-N	80	0.0911—0.1175	0.0578	0.552	S ≑ 0	N = 0.000162 d + 0.0490
C/N	77	7.18 —8.86	3.70	−0.092	S ≑ 0	…………………………

C : Carbon content(%) N : Nitrogen content(%) d : Water depth of the site of deposition (m)

Table 3. Relations of organic accumulation to mass properties of bottom sample

Table 3-1. A - Region

	St. No.	Depth (m)	Md (mm)	Sk	S_o	Ignition loss(%)	C(%)	N(%)	C/N
A_1	H 83	530	0.013	0.899	6.164	10.91	1.85	0.201	9.20
	H 89	785	0.016	1.019	6.633	12.63	2.01	0.187	10.81
	H 92	785	0.018	0.906	5.506	12.31	0.85	0.162	5.25
	H117	780	0.018	1.000	5.679	9.74	1.21	0.145	8.46
	H122	780	0.013	1.041	6.633	15.56	2.39	0.215	11.12
A_2	H 38	604	0.023	0.962	12.47	9.07	1.57	0.148	10.61
	H 41	541	0.022	1.113	10.10	8.45	1.39	0.140	9.93
	H 70	399	0.023	0.516	16.88	7.52	1.01	0.183	5.52
	H125	245	0.010	0.879	9.747	5.73	0.77	0.100	7.70
A_3	H 80	648	0.045	0.691	7.616	11.18	1.87	0.187	10.11
	H 88	630	0.035	0.713	6.566	……	1.71	0.184	9.29
	H101	840	0.042	0.756	6.297	12.14	1.21	0.178	6.80
	H102	500	0.043	0.823	4.484	10.23	1.11	0.128	9.17
	H121	540	0.042	0.756	6.290	12.92	1.05	0.136	7.72

Table 3-2. B-Region

	St. No.	Depth (m)	Md (mm)	Sk	S_o	Ignition loss(%)	C(%)	N(%)	C/N
B_1	H 4	274	0.593	0.734	1.539	3.38	0.58	0.046	12.83
	H 5	521	0.480	0.880	1.490	1.69	0.66	0.085	7.77
	H 6	830	0.398	0.680	1.774	4.05	0.70	0.097	7.22
	H 11	297	0.578	0.456	2.038	3.66	0.79	0.072	10.97
	H 15	102	0.843	0.799	1.513	5.07	0.47	0.041	11.46
	H 21	123	0.878	0.865	1.408	7.32	0.13	0.060	2.17
	H 23	290	0.650	0.452	1.883	1.99	0.28	0.055	5.09
	H 34	133	0.542	0.395	2.817	3.80	0.56	0.041	13.66
	H 54	139	0.637	0.587	2.017	3.26	0.47	0.067	7.02
B_2	H 10	527	0.380	0.311	2.828	3.91	0.74	0.107	6.62
	H 17	288	0.582	0.195	3.025	3.59	0.82	0.122	6.72
	H 24	255	0.518	0.179	3.317	3.23	0.55	0.118	4.66
	H 25	459	0.264	0.220	4.858	4.43	0.52	0.102	5.10
	H 33	116	0.590	0.131	4.861	4.23	0.62	0.126	4.92
	H 44	256	0.540	0.193	3.614	4.04	0.62	0.091	6.81
B_3	H 20	97	0.508	0.364	3.066	5.88	0.34	0.036	9.45
	H 32	98	0.535	0.374	3.204	5.16	0.30	0.045	6.67
	H 35	252	0.280	0.560	3.435	3.65	0.49	0.101	4.85
B_4	H 16	198	0.186	0.032	32.71	0.85	0.09	0.043	2.09

Table 3-3. C-Region

	St. No.	Depth (m)	Md (mm)	Sk	S_o	Ignition loss(%)	C(%)	N(%)	C/N
C_1	H135	90	0.001	……	……	6.22	0.81	0.048	16.88
	H136	90	0.001	……	……	4.86	0.53	0.042	12.62
	H159	426	0.001	……	……	8.78	1.03	0.123	8.37
C_2	H129	705	0.025	0.326	9.165	9.32	1.74	0.188	9.26
C_3	H110	465	0.046	0.308	4.615	8.42	1.66	0.103	16.12
	H118	370	0.047	0.367	3.162	8.26	1.52	0.132	11.52
	H120	100	0.094	0.349	2.775	3.43	0.41	0.084	4.88
	H128	320	0.046	0.372	3.114	7.30	1.36	0.097	14.02
C_4	H 96	95	0.154	1.017	1.706	3.67	0.59	0.044	13.41
	H112	85	0.135	0.995	1.374	3.87	0.26	0.043	6.05
	H133	320	0.097	0.710	2.018	3.94	0.68	0.112	6.07
	H134	115	0.082	0.851	1.739	4.59	0.18	0.063	11.73
	H142	90	0.061	0.436	2.442	5.43	1.00	0.053	18.87
	H144	125	0.125	1.005	1.740	4.08	0.67	0.060	11.17
	H152	210	0.117	0.788	1.732	2.97	0.72	0.053	13.59
	H153	465	0.104	0.919	1.955	4.60	0.73	0.092	7.94
C_5	H 87	160	0.332	0.703	2.280	3.30	0.79	0.032	24.69
	H 94	120	0.245	0.839	2.123	3.05	0.56	0.071	7.89
C_6	H157	200	0.650	0.929	1.791	2.51	0.76	0.062	12.67

Table 3-4. D-Region and E-Region

	St. No.	Depth (m)	Md (mm)	Sk	S_o	Ignition loss(%)	C(%)	N(%)	C/N
D_1	H 56	258	0.015	1.029	13.42	8.11	1.04	0.129	5.42
	H 61	402	0.015	1.143	7.746	9.83	1.28	0.209	6.14
	H 64	348	0.016	1.371	7.206	9.96	1.40	0.142	9.86
D_2	H 55	100	0.135	0.427	6.787	5.93	0.66	0.101	6.54
	H 69	265	0.094	0.215	9.684	7.34	1.39	0.170	8.18
D_3	H 62	93	0.306	0.263	4.239	4.22	0.63	0.070	9.00
	H 63	88	0.375	0.374	3.141	3.01	0.36	0.074	4.87
D_4	H 36	352	0.083	0.686	8.595	5.89	0.84	0.126	6.67
	H 48	75	0.076	1.391	7.274	5.77	0.90	0.079	11.39
D_5	H 51	376	0.091	0.323	11.24	6.31	1.13	0.131	8.63
	H 57	460	0.072	0.655	8.324	8.04	1.13	0.195	5.80
D_6	H 49	98	0.321	0.090	7.390	4.92	0.65	0.052	12.50
	H 50	193	0.391	0.323	11.24	6.16	0.72	0.088	8.18
	H 52	415	0.347	0.054	8.07	6.91	1.11	0.087	12.76
	H 53	289	0.431	0.064	8.07	6.38	1.02	0.113	9.03
	H 60	453	0.295	0.067	8.51	6.92	0.95	0.202	4.70
E	H 42	541	0.055	0.088	14.83	6.82	1.18	0.136	8.68
	H 65	449	0.295	0.311	4.221	5.32	1.11	0.146	7.60
	H 76	79	0.072	0.119	12.41	5.77	0.64	0.036	17.78