Some Characteristic Features of the Vertical Profile of Organic Matter in Recent Sediment from the Bering Sea

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Abstract: Sedimentary samples were collected from a site (57°02.9'N, 176°57.4'W: 3,650 m) in the Aleutian Basin of the Bering Sea and analyzed for organic carbon, total nitrogen and various organic materials. Organic carbon and total nitrogen were measured in the range of 0.1-1.9 % and 0.01-0.2 % of the dry weight of the sediment, these values tended to decrease with depth, but considerably lower values were obtained in the volcanogenic sediment layers. Carbohydrate, amino acid and protein and lipid carbons accounted for 40 % of the total organic carbon on the surface of the sediment, and this value tended to decrease with depth to 20 % at 10 m depth from the top of the core sample. The carbon to nitrogen (C/N) ratios ranged from 6.3 to 9.0. Vertical change in the values of the ratios can be understood in terms of a higher decay rate of amino acids and proteins.

Radiocarbon age determinations on five sedimentary samples yielded sedimentation rates ranging from 37 to 90 cm/1,000 y.

1. Introduction

The Bering Sea can be divided into two areas, the shallow northern to eastern continental shelf with depths of less than 200 m and the southern basin with depths greater than 4,000 m. According to the data obtained by Russian workers (LISITSYN, 1966; 1972), sediments of the basin are derived from terrigenous, biogenic and volcanogenic materials.

Most of the terrigenous material enters the sea as a result of wave action and glacial abrasion. Storms and tidal currents may intensify coastal erosion. Run-off from the mainland may play an important role in the supply of sediment to the Bering Sea (LISITSYN, 1966). Volcanic ash is also important in the formation of the sediment in the Bering Sea, especially in the center and south of the Aleutian Basin in connection with volcanic activity in Kamchatka, the Aleutian Islands and Alaska (LISITSYN, 1966). A great deal of attention has been paid to the biogenic materials because the Bering Sea is one of the most productive areas in the world's oceans (HOOD and KELLEY, 1974).

Numerous studies of organic carbon in the surface sediments collected from the whole area of the Bering Sea were conducted by Russian workers (BORDOVSKIY, 1965a; LISITSYN, 1966), who found 2.56 % (on the average) of organic carbon in sediments consisting of mainly silt and clay. In view of sedimentary organic carbon contents reported elsewhere [1.20 % in the Sea of Japan (STRAKHOV, 1953; MASUZAWA and KITANO, 1977), 2.20 % in the Sea of Okhotsk (BEZRIKOV, 1960), 3.12 % in the Barents Sea (GORSHKOVA, 1931; 1938), 1.62 % in the Norwegian Sea (GORSHKOVA, 1960), 2.35 % in the Caspian Sea (LISITSYN, 1972) and 1.91 % in the Black Sea and 0.83 % in the Mediterranean (ERDMAN and SCHORNO, 1978)], the sediment of the Bering Sea is considered to be relatively rich in organic carbon compared to those of the marginal seas and basins of the world's seas.

Another characteristic feature of the horizontal distribution of organic carbon in the surface sediment of the Bering Sea is that the peripheral regions of the Bering Sea abyssal basin are girdled by a continuous ring of sediments with high organic carbon content. However, very little is known regarding the vertical distribution of organic matter in the bottom sediment of the Bering Sea. Organic carbon and nitrogen, humic materials and bitumen have been detected from a few of the core samples collected from the abyssal basin (BORDOVSKIY, 1965b), but any
Fig. 1. Vertical profile of lithofacies, $^{14}$C age, water content, total organic carbon and total nitrogen in the core sample collected from the Bering Sea.
information concerning biochemically interesting organic matter is still lacking. Nothing conclusive has been reported as to the age of the sediments in the Bering Sea, although extensive collections and analyses of the sedimentary samples from the continental shelves through deep basins have been conducted by Russian workers (BORDOVSKY, 1965b; LISITSYN, 1966). Due to the lack of knowledge of the age of the sediment it is difficult to calculate precisely the sedimentation rate and to understand the material balance of this oceanic area.

The aims of present work are, primarily to elucidate the general features of the sediment from the Bering Sea, such as general appearances of the sediment, the sedimentary age and the sedimentation rate, and secondly to draw vertical distribution profiles of organic carbon, nitrogen, carbohydrate, amino acid and protein and lipid.

Results obtained indicate that the core sample from the Aleutian basin was uniform in appearance but the uniformity was broken by volcanic ash at 31 layers throughout the 1,000 cm long core sample. The age of the sediment layers centered at a depth of 914 cm in the core sample was determined to be 20,000 y B.P. Organic carbon and total nitrogen tended to decrease with depth, while C/N value increased with depth. These findings indicate that diageneric changes in the organic matter due to chemical and biological agents evidently occur in the core sample from the Bering Sea.

2. Materials and methods

Sedimentary samples were collected from the sea bottom at 3,650 m depth at a station (57°02.9′N, 176°57.4′W) located in the Bering Sea during the cruise of the Hakubō Maru of the Ocean Research Institute, University of Tokyo in June 21-August 18, 1975. A piston corer with inner diameter of 68 mm, a wall thickness of 6 mm and length of 12 m was used for the coring operation. Within few hours after collection the colors and distinct characteristics of the surface of the 10 m long core sample were noted, and then the core sample was cut every 5 cm. The sedimentary samples were kept frozen at −20°C until analyzed.

2.1. Core description

The description of the core sample was conducted on board and is presented in Fig. 1. The core sample was greenish gray from the top to the bottom. Several greenish black streaks were found to occur perpendicularly to the axis of the core. This indicates that the corer hit the sediment-water interface vertically. Circular and elliptical mottles were found to be abundant at around the 4 m depth of the core sample. More than 10 layers of volcanic ash with brownish white and black colors were found at various depth throughout the core. It was found that volcanic glasses, including well oriented mineral crystals, were abundant in these volcanic ash samples. This fact indicates that the volcanic ash is supplied directly from the source without any significant weathering or reworking (biological or physical).

2.2. Chemical analyses

Organic carbon and total nitrogen, carbohydrate and amino acid and protein were determined by the dry combustion method (KOMIYAMA, 1972) using the CHN-Corder (Yanaco, Model MTS-2), by the anthrone method (HANDA, 1972) and by the fluorescamine method (UDENFRIEND et al., 1972; HANDA, 1973), respectively. Carbohydrate carbon was calculated on the basis of total carbohydrate multiplied by a factor of 0.40. Amino acid and protein carbon and nitrogen were obtained on the basis of total amino acid and protein multiplied by factors of 0.475 and 0.16 respectively. Lipid carbon was measured by the dichromate method.

Fig. 2. Plot of 14C age versus depths in the core sample collected from the Bering Sea.
Table 1. Radiocarbon age measurements on the core sample from the Bering Sea and rates of sedimentation.

<table>
<thead>
<tr>
<th>Laboratory No.</th>
<th>Depth below top of core (cm)</th>
<th>Midpoint (cm)</th>
<th>Apparent age (years, ±1σ)</th>
<th>Interval (cm)</th>
<th>Rate* of sedimentation (cm/1,000 y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GaK-7155</td>
<td>117-171</td>
<td>144</td>
<td>5,300±300</td>
<td>0-144</td>
<td>51.4</td>
</tr>
<tr>
<td>GaK-7156</td>
<td>270-331</td>
<td>301</td>
<td>9,550±370</td>
<td>144-301</td>
<td>36.8</td>
</tr>
<tr>
<td>GaK-7157</td>
<td>411-461</td>
<td>436</td>
<td>11,060±1,490</td>
<td>301-436</td>
<td>89.7</td>
</tr>
<tr>
<td>GaK-7158</td>
<td>539-589</td>
<td>564</td>
<td>13,910±12,630</td>
<td>436-564</td>
<td>44.9</td>
</tr>
<tr>
<td>GaK-7159</td>
<td>889-939</td>
<td>914</td>
<td>19,980±1,320</td>
<td>564-914</td>
<td>57.7</td>
</tr>
</tbody>
</table>

* Average, 56.1 cm/1,000 y.

(HANDA, 1973).

The radiocarbon age determination of the sedimentary samples was conducted by the Radiocarbon Measurement Laboratory of Gakushuin University.

3. Results

The core sample collected from the abyssal plain of the Bering Sea was fairly uniform in appearance and gray to greenish gray throughout from the surface to 1,000 cm depth. The uniformity was sometimes broken by intercalations of greenish black or dark greenish gray volcanic ash and of circular or elliptical mottles colored dark brownish gray and green at layer A (Fig. 1). The sedimentary layers B and D were dark green, while a pale brownish white layer appeared at C.

Sedimentary samples from 31 layers of volcanic ash were examined microscopically and it was found that these sedimentary samples consisted of a considerable amount of volcanic glasses, and orthopyroxene, clinopyroxene and hornblende, which will be reported elsewhere.

Radiocarbon age determinations of the total organic carbon were conducted at five depths in the core sample (Fig. 1) and tended to increase linearly with depth below the top of the core sample (Fig. 2). The radiocarbon age of the surface sediment can be determined to be 2,500 y B.P. by upward extrapolation of the line (Fig. 2). This value of radiocarbon age occurs within the range determined in the core samples taken from basins off southern California (1,400-4,400 y B.P.; EMERY and BRAY, 1962). Almost identical values of radiocarbon age of the surface sediment were obtained by NOZAKI et al. (1977) in the region of the Mid-Atlantic Ridge west of the Azores and in the Indian Ocean by BERGER and JOHNSON (1978).

The sedimentation rate of the core sample was found to be within the range of 27.4 to 89.7 cm/1,000 y as shown in Table 1. These data clearly indicate that the environmental conditions for sedimentation have not been uniform in the Bering Sea for at least the last 20,000 y. The figures for the sedimentation rate are almost twice as much as those obtained by BORDOVSKY (1965a) in the northwest peripheral region of the Aleutian Basin, however these values are almost comparable with the values ranging from 5 to 180 cm/1,000 y in the

Fig. 3. Vertical profile of C/N value in the core sample collected from the Bering Sea.
basins off southern California (EMERY and BRAY, 1962) and in the Gulf of Mexico (EMILIANI et al., 1978).

Water content of the sediment was measured in the range of 24.3 to 75.7 % from the top through the bottom of the core sample (Fig. 1). The values tended to decrease with depth with a certain amount of fluctuation. Low values of less than 30 % of water content were measured in the volcanic ash layers 2, 7, 8, 9, 11, 24 and 28, however those values tended to decrease with the increase in content of volcanic ash. This indicates that the water content of the sediment tends to decrease with depth due to the increase in compaction of the sediment. The lithology, in particular volcanic ash content, is another factor that determines the water content of the sediment.

Vertical profiles of organic carbon and total nitrogen in the core sample are very similar to that of the water content as shown in Fig. 1. These compounds were found to range from 1.06 to 18.8 milligram carbon per gram of dry sediment and from 0.14 to 2.16 milligram nitrogen per gram of dry sediment for the organic carbon and total nitrogen respectively, and tended to decrease with depth with considerable fluctuations. Low values of organic carbon, less than 2.69 mgC g⁻¹ dry sediment, and of total nitrogen, less than 0.32 mgN g⁻¹ dry sediment, were obtained in 7 volcanic ash layers irrespective of their depth, while much higher values of organic carbon and total nitrogen were obtained in the terrigenous and biogenic sediments, although these values also tended to decrease with depth. These facts indicate that volcanic ash may tend to dilute the concentration of organic carbon in the sediment.

Higher values of organic carbon and total nitrogen were measured in the layer between 376 and 486 cm depth, especially at the levels of 376-381 and 461-466 cm depth. The radiocarbon ages of the sediments in these layers can be calculated to be 10,000–12,200 y B.P., by

Fig. 4. Vertical profiles of carbohydrate, amino acid and protein and lipid in the core sample collected from the Bering Sea.
referring to the relationship between core depth and radiocarbon age shown in Fig. 2.

C/N value of the sediment was calculated to be in the range of 6.31 to 9.03 throughout the sample (Fig. 3). The values tended to increase with depth to about 8.5 at a depth of 400 cm but no further significant change in the value of the ratio was observed below 400 cm depth, although fluctuation of its value was evident to a certain extent. No systematic trend in the C/N value was observed in the samples from either the organic poor (volcanic ash) or the rich (376-486 cm depths) layers. These facts suggest that organic matter bearing almost identical composition may be incorporated not only into the terrigenous and biogenic sediments but also into the volcanogenic sediments. The vertical increase in C/N value in the layers between the surface to 400 cm depth indicates that diagenetic change in the organic matter obviously takes place in the sediments of these layers due to a preferential decay of nitrogenous organic compounds.

Carbohydrate, amino acid and protein and lipid were determined to lie in the ranges of 0.02 to 0.42, 0.06 to 1.84 and 0.17 to 2.14 mg C g⁻¹ dry sediment in the core sample from the surface through 10 m depth, respectively. These values tended to decrease with depth (Fig. 4). Minimum values of less than 0.05, 0.03 and 0.2 mg C g⁻¹ dry sediment for carbohydrate, amino acid and protein and lipid respectively were found in the samples from volcanogenic sediments, in which organic carbon and total nitrogen also reached their minimum values. These facts suggest that low concentrations of organic matter may be caused by dilution of the terrigenous and biogenic materials with volcanic ash from the surrounding continental shelves and islands.

Fig. 5. Vertical profile of cumulative percent of organic matter in the core sample collected from the Bering Sea.
High concentrations of carbohydrate, amino acid and protein were found in the layers between 376 and 466 cm depth, where organic carbon and total nitrogen are also high, as stated previously.

Vertical variability of the organic composition obviously occurs. Carbohydrate, amino acid and protein and lipid carbons were calculated to be in the ranges from 0.51 to 4.37, from 4.83 to 17.1 and from 5.10 to 22.4% of organic carbon content of the sediment, respectively. These values tended to decrease with depth with a certain amount of fluctuation, especially for lipids. However, no tendency of change in organic composition in the volcanogenic layers was observed throughout the core sample. These facts do not conflict with the results of C/N value and indicate that the sources of organic matter in the volcanogenic sediments may not be different from those in the biogenic and terrigenous sediments. Also no distinctive change in organic composition was observed in the organic rich layers of 376-466 cm depths.

The cumulative values of carbon percents of carbohydrate, amino acid and protein and lipid were calculated in the range of 14.1 to 40.2%. These values tended to decrease with depth from 40% at the top of the core sample to less than 20% at 10 m depth although the values fluctuated to a certain extent (Fig. 5). These facts indicate that these organic materials are more susceptible to chemical and biochemical agents during burial and that the decay of these organic materials tends to leave residual organic materials in the sediment.

4. Discussion

A core sample of the sediment was collected from the abyssal plain of the Aleutian Basin of the Bering Sea and analyzed for organic carbon, total nitrogen and various organic materials. The radiocarbon age of the sedimentary core sample was determined at 5 depths.

The following characteristic features were observed in the Aleutian Basin sediments: 1) high rates of sedimentation, 2) high contents of organic carbon, total nitrogen and various organic materials, and 3) high C/N values relative to values reported for pelagic sediments so far.

4.1. Sedimentation rate

It is conceivable that river run-off and abrasion of the coastal terraces control the influx of sedimentary materials into the Bering Sea. Fast ice formed near the shores also plays an important role in the transportation of the coarse to fine littoral materials to off-shore. According to Russian workers, annual influxes of materials into the Bering Sea were calculated to be 120 and 200-400 million tons due to run-off and abrasion of the terraces respectively, which were calculated on the basis of the erosion of sedimentary materials from the catchment area determined from the rates of mechanical and chemical denudation (Strakhov, 1962). The supply of materials to the bottom sediments by ice was calculated to be 20-40 million tons in the total area of the Bering Sea (Lisitsyn, 1966). Assuming that the total area of the Bering Sea is \(2.3 \times 10^6\) km\(^2\), the annual influx of materials to the Bering Sea are 50, 90-180 and 9-17 g m\(^{-2}\) y\(^{-1}\) for river run-off, abrasion of the coastal terraces and ice formation, respectively.

Primary production of phytoplankton may be another factor determining the supply of materials to the sediment of the Bering Sea. The primary production of phytoplankton in the Aleutian Basin area was measured on the basis of the diurnal variation of dissolved oxygen (Vinberg, 1960; Ivanenko, 1961) and nutrients (Smetsin, 1956). Ivanenko (1961) found the primary production of phytoplankton to be 1,070 g m\(^{-2}\) y\(^{-1}\).

These data mentioned above indicate that the annual influx of materials to the water column in the Aleutian Basin area are calculated to be 1,219-1,317 g m\(^{-2}\) y\(^{-1}\) (on the average). Taking the water content to be 71.3% and the density to be 2.5 for the bottom sediment from the surface to 144 cm depth, the sedimentation rate of the terrigenous and biogenic materials to the bottom sediment is estimated to be 176 cm/1,000 y, which is approximately three times as high as the sedimentation rates obtained in the core sample used in this study.

The terrigenous materials once they enter the ocean may settle out according to grain size and only finer particles can reach the off-shore areas. In addition, the decay of organic matter of the diatoms during the course of sinking may give rise to a decrease in the influx of diato-
maceous cell materials to the bottom sediment. These facts are regarded as the main reasons causing the decrease in the sedimentation rates from 176 cm/1,000 yr to 37-90 cm/1,000 yr observed in the core sample, although a lack of data with respect to the transportation processes of particulate matter from the coast to the offshore and from the euphotic zone to the deep waters make it difficult to estimate the sedimentation rate.

It can be tentatively concluded that greater annual influxes of terrigenous and biogenic materials may cause the higher rates of sedimentation in the Aleutian Basin relative to pelagic areas. The annual influxes of biogenic materials to the water column were suggested to be so large that the primary productivity must be one of the most important factors controlling the vertical variability of the sedimentation rates. Volcanic ashes are regarded as another factor giving an increment of the sedimentation rate of the Aleutian Basin, because the total thickness of the volcanic ash layers is 70 cm, which is 7% of the total length of the core sample.

4.2. Source of sedimentary organic carbon

Terrigenous materials ranging from 149 to 247 g m⁻² yr⁻¹ are transported into the Bering Sea through river run-off, abrasion of the coastal terraces and ice formation as stated before. According to several workers (BORDOVSKY, 1965b; LITSYNSK, 1966; SHARMA, 1974), the organic carbon content of the terrigenous materials is estimated to be 1% on the average, although these particles have a certain range of values for the organic carbon due to the presence of different granulometric types (SHARMA, 1974). Thus, annual supplies of organic carbon to the Bering Sea through those agents are calculated to be 1.5-2.5 gC m⁻² yr⁻¹ (on the average).

IVANENKOV (1961) found the primary production of organic matter to be 206 gC m⁻² yr⁻¹. Thus, the influx of organic carbon become a total of 208 gC m⁻² yr⁻¹ in the Aleutian Basin area.

The sedimentation rate of organic carbon is estimated to be 4 gC m⁻² yr⁻¹ in the sediments from the surface to 144 cm depth if we take the water content to be 71.3%, the density to be 2.5 and the sedimentation rate to be 51.4 cm/1,000 yr. This fact obviously indicates that the influx of organic carbon to the water column far exceeds the sedimentation rate of organic carbon in the bottom sediments of the Aleutian Basin. Only 2% of the annual influx of organic carbon to the water column is calculated to be preserved in the sediments.

It has been mentioned that the organic materials of phytoplankton are highly susceptible to the decomposition processes of microorganisms in the marine environment (HANDA, 1969; OTSUKI and HANYA, 1972a, b). Many attempts have been made to estimate the decomposition rate of organic matter in the marine environments. Applying the diffusion-advection model to analyze the vertical profile of dissolved oxygen in the various oceans, the decay rates of organic materials in deep water from 1 km depth to the bottom water were estimated to lie within the range of 8 to 93 mgC d⁻¹ in the water column, with a cross-sectional area of 1 m² (MUNK, 1966; TSUNOGAI, 1972; KROOPNICK, 1974). HANDA (1977a, b) also applied this model to the analysis of the vertical profile of dissolved oxygen at a station in the North West Pacific Ocean (44°09'N, 154°02'E) and found a consumption of 420 ml O₂ d⁻¹ of dissolved oxygen in the water layers from 50 m to the bottom of the bottom of the ocean (5,000 m depth). Taking 0.76 as the CO₂/O₂ value (KROOPNICK, 1974), it can be seen that the value of the dissolved oxygen consumption can be converted to 171 mgC m⁻² d⁻¹, which is comparable to the value of 0.3 gC m⁻² d⁻¹ for the primary production of phytoplankton found by ICHIMURA and SAIJO (1960) and KOBLENZ-MISIKE et al. (1970).

From these facts, it can be concluded that most of the organic materials supplied by the primary production of phytoplankton to the abyssal area of the Bering Sea may have decayed by the time they reach the bottom sediment. Only a portion of the biogenic organic materials, which escape from biological attack in overlaying water layers, can enter the bottom sediment. On the other hand, the terrigenous organic materials which constitute only 1% of the biogenic materials introduced into the water column in the euphotic zone must accumulate in the bottom sediment without significant modification or degradation become the main components of the sedimentary organic matter, be-
cause they mainly consist of biologically stable organic matter such as humic materials (Bordovskiy, 1965; Lisitsyn, 1966; Schnitzer and Khan, 1972).

4.3. C/N value

Total nitrogen of the Aleutian Basin sediments was determined to be in the range of 0.1–2.0 mgN g⁻¹ dry sediment which is almost identical to the values (0.3–1.5 mgN g⁻¹ dry sediment) determined in the sedimentary samples taken off Guadalupe Island, Mexico during the experimental Mohole drillings (Rittenberg et al., 1963; Stevenson and Tiloo, 1966), in the Pacific Ocean (Arrhenius, 1950; Müller, 1977) and in the Indian Ocean (Marching, 1972).

The C/N value of the sedimentary samples from the Aleutian Basin was determined to be 6 at the surface and this value tended to increase with depth to 9 at a depth of 400 cm. Apart from the Aleutian Basin sediments, some surface sediments of the North Pacific Ocean (Arrhenius, 1950; Müller, 1977) showed C/N values close to 2. Several attempts have been made to interpret such low values of C/N in deepsea areas. Arrhenius (1950) supposed that the low C/N values of the deep-sea sediments might be due to substantial amounts of ammonium ion being adsorbed by clay minerals.

The presence of considerable amounts of ammonium in soils, sediments and rocks has been confirmed by numerous authors (Stevenson and Cheng, 1972; Müller, 1977; Handa and Tanaka, 1978). Scheffer and Schachtschabel (1970) concluded that ammonium ions fixed in those geological samples were dependent on the content of illite.

According to Griffin et al. (1968) who studied the distribution profiles of clay minerals in the world ocean, the most remarkable feature of illite in the Pacific Ocean is the wide band of high concentration of this clay mineral (50–60 %) stretching across the North Pacific (20–40°N). The concentration tends to decrease toward the north to less than 20 %. On the contrary, high values of montmorillonite are found along the continental edges of the North Pacific Ocean and the Bering Sea (Windom, 1977). These facts strongly suggest that low C/N values of sediments as observed in the offshore of the North Pacific Ocean can be interpreted as being due to high contents of ammonium fixed on the sedimentary clay minerals, mainly illites, while relatively high C/N values observed in the Aleutian Basin sediments must be due to the high content of montmorillonites which have less ability to adsorb ammonium produced by the decomposition of the sedimentary nitrogenous organic compounds.

4.4. Radiocarbon age of surface sediment

The radiocarbon age of the surface sediments can be determined by the upward extrapolation of the points of age determination along the lengths of the core sample. The age of 2,500 y B.P. was obtained for the surface sediment.

The vertical mixing of surface sediment with deeper sediment of older age due to mechanical and biological reworking has been proposed to explain such an ancient radiocarbon age of the surface sediment for many years (Hulsemann and Emery, 1961; Nozaki et al., 1977). Such a reworking may have been occurred during the course of sedimentation because circular and elliptical mottles are observed in the core sample. The presence of the volcanic ash layers, however, show vertical mixing to occur to a much less extent.

Dissolved organic carbon of which radiocarbon age determined to be 3,400 y B.P. (Williams et al., 1969) may interact with clay minerals such as montmorillonite by sorption on the external clay surface without regard to pH, and in the interlayer space at a pH of 4.5 as mentioned by Kodama and Schnitzer (1968). This process gives the surface sediment an ancient age.

There are many estimates of the radiocarbon ages of soil organic matter with the range of 750–37,000 y B.P. (Emery and Bray, 1962) and with the range of 50–15,000 y B.P. (Delibrias et al., 1966; Goh and Stout, 1973). If these terrigenous materials were transferred to the Bering Sea and redeposited onto the abyssal plain, the surface sediment would reflect their ancient radiocarbon age.

Thus, these facts strongly suggest that the sorption of dissolved organic materials onto the particulate matter and the erosion and redeposition of land outcrops are most likely the reasons for the ancient radiocarbon age of the surface sediment of the Aleutian Basin.

4.5. Composition of organic materials and their vertical changes
Chemical analyses of the surface sediments from the Aleutian Basin indicate that carbohydrate, amino acid and protein and lipid carbons have been reported to account for 15-30%, 30-50% and 10-15% of the particulate organic carbon (STRICKLAND, 1965; HANADA et al., 1972). This fact strongly suggests that the particulate organic matter must be modified to a large extent during the course of sinking from the surface to the bottom of the ocean floor and/or early diagenetic processes taking place after the settlement of the particulate matter on the surface of the sediment.

PALACAS et al. (1966) reported that the contents of lipid and humic materials accounted for only 0.7-2.8 and 1.4-4.0% of the total organic carbon of sedimentary samples from the deep-sea floors of the North Pacific Ocean, respectively. These facts indicate that a characteristic feature

Fig. 6. Changes in the concentrations of $\sum$ organic carbon and residual organic carbon with depth in the core sample collected from the Bering Sea.
of the Aleutian Basin sediment is the abundance of lipid and humic materials, however practically no difference was found in the contents of carbohydrates and amino acid and protein between sediments from the North Pacific Ocean and the Aleutian Basin.

It is noteworthy that humic materials account for a relatively high proportion (33\%) of the sedimentary organic matter in the samples from the Aleutian Trench (PALACAS et al., 1966), where woody plant fragments have been observed by SMITH (1963). These facts strongly suggest that the humic materials of the Aleutian Basin are derived from the nearby land.

BORDOVSKY (1965b) analyzed for lipid which was extracted with benzene-methanol from a wide variety of the surface samples of the bottom sediment from the Bering Sea and found that lipid carbon accounted for 3-32\% of the sedimentary organic carbon. This value is almost identical with that obtained in this study. ORR and EMMER (1956) made extensive studies of lipid materials from various basins off southern California and concluded that an anoxic environment and high sedimentation rate were the determinative factors giving rise to a high content of lipid in the sediments. This conclusion can be applied to interpret the high content of lipid materials in the sedimentary samples of the Aleutian Basin, because of the high sedimentation rate which causes organic debris to be buried more rapidly into the anoxic sediment.

Vertical changes in organic carbon (consisting of carbohydrates, amino acids and proteins and lipids) and residual organic carbon are shown in Fig. 6. The regression equations relating organic carbon and residual organic carbon to depth in cm (Z) are:

\[
\ln \text{C}_Z \text{ organic carbon} = -8.25 \times 10^{-4}Z + 1.11
\]

\[
\ln \text{C}_Z \text{ residual organic carbon} = -4.62 \times 10^{-4}Z + 2.13
\]

where the values of \( Z \) organic carbon and residual organic carbon in the volcanic ash layers are excluded. The calculations indicate that the decay rate of organic carbon is about twice as high as that of residual organic carbon. Such a difference in the decay rates can be concluded to give rise to the vertical change in the organic composition of the sediment as shown in Figs. 4 and 5, and preferential preservation of residual organic matter consisting of kerogen and humic materials.

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Vertical Profile of Organic Matter in the Bering Sea Sediment


ベーリング海の現世海底堆積物における有機物の
鉛直分布に関する二、三の特徴

田上英一郎* 半田鶴彦*

要旨: ベーリング海のアリューシャン海盆の観測点
(57°02.9’N, 176°57.4’W: 3,650 m) から堆積物試料を
採集し、有機炭素、全窒素および種々の有機物を分析し
た。有機炭素および全窒素は堆積物の乾重量に対してそ
れぞれ 0.1-1.9% および 0.01-0.2% の範囲で測定さ
れ、深さとともに減少した。また、火山灰層ではきわめ
て低い有機炭素および全窒素濃度が測定された。

炭水化物、アミノ酸およびタンパク質および有機炭素
は堆積物の表層試料では有機炭素の 40% に相当してい
たが、深さとともに減少し、10 m 層では 20% であっ
た。

堆積物の C/N 値は 6.3 から 9.0 の範囲で算定され
その値は深さとともに増加していた。このことは堆積過
程におけるアミノ酸およびタンパク質の分解が他の有機
物に比して速いことを示した。

柱状試料のうち 5 つの層からの試料について放射性炭
素同位体による年代測定を行ない、アリューシャン海盆
における堆積速度が 1,000 年当り 37-90 cm であること
を認めた。

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