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DISTRIBUTION OF SOME BIOCHEMICAL COMPOUNDS IN THE SEDIMENTS OF THE BAY OF BENGAL

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Abstract

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Surficial sediment samples collected from the continental shelf and slope of the Bay of Bengal were studied for the distribution of organic carbon and its constituent fractions such as carbohydrates, proteins, amino acids and lipids. Organic carbon, carbohydrates, proteins, amino acids and lipids content of the slope sediments were higher than those of the shelf sediments. A positive correlation was observed between the organic carbon and the concentrations of the individual constituents. Carbohydrates constituted 30-50% of organic matter as compared with proteins (10-24%) and lipids (1.91-4.28%). The group composition of carbohydrates, amino acids and lipids shows that residual carbohydrates, combined amino acids and polar compounds, respectively, were the major components. No relationship was observed between the concentrations of these compounds and the depth of the overlying water column. The total caloric content of the sediments calculated from the above data varied from 11.33-68.46 cal./g dry sediment. Carbon-normalized total carbohydrate yields indicate the presence of terrestrially derived carbohydrates.

1. Introduction

Organic matter in marine sediments is derived from terrestrial and marine sources (Premuzic et al., 1982; Gagosian and Peltzer, 1986). Since aquatic organisms like algae are more abundant in the marine environment, primary productivity is probably an important factor controlling the distribution of organic molecules in sediments (Deuser and Ross, 1980; Betzer et al., 1984). Moreover, rivers can discharge large quantities of terrestrially derived organic matter to the sea sediments (Degens and Ittekkot, 1985; Ittekkot et al., 1985; Ittekkot and Arain, 1986). Atmospheric transport of land-derived natural compounds to the sea sed-

iment can also take place (Gagosian and Peltzer, 1986). Organic matter exists in particulate and dissolved forms within the water column. Initial input of this organic matter consists of all major classes of naturally occurring organic compounds such as carbohydrates, proteins, amino acids, pigments, phenolic substances, lipids and other constituents of living organisms (Premuzic et al., 1982). During sedimentation only a small portion of this initial input in the form of large particles such as fecal pellets or "marine snow" reaches the sea floor (Deuser and Ross, 1980; Honjo, 1982; Wakeham and Canuel, 1986; Asper, 1987). Numerous recent studies on elemental ratios (Brewer et al., 1980; Honjo, 1980; Wefer et al.,

1982), lipids (Wakeham et al., 1983; Wakeham and Canuel, 1986); amino acids and sugars (Ittekkot et al., 1984; Lee and Cronin, 1984; Müller et al., 1986), all indicate that biochemical decomposition and transformation processes act on rapidly sinking particles throughout the water column. These reactions, however, are more dominant in relatively shallow depths (Suess, 1980; Liebezeit, 1985). The survival of individual organic constituents during sedimentation depends on a number of factors including their chemical stability, biochemical usefulness, oxygen concentration and their interaction with clay minerals (Premuzic et al., 1982; Degens and Ittekkot, 1984; Stein et al., 1986). This vertical transport of organic matter in the water column on or in particulate material is an important source of carbon to surface sediment (Ittekkot et al., 1984; Gagosian and Peltzer, 1986). After arriving at the sediment, significant alteration of organic matter takes place due to activities of benthic organisms. Thus, the knowledge of the amount and relative distribution of organic carbon and its constituent fractions such as carbohydrates, amino acids, proteins and lipids in recent marine sediments may provide useful information on the origin, nature and fate of these compounds during early stages of diagenetic reactions. Further, this may offer the possibility to obtain information on the starting structures of the insoluble organic material in ancient sediments, the so-called kerogen.

Although the composition of organic matter in marine sediments has been a subject of study for several decades there are only isolated instances of detailed analysis (Degens et al., 1964; Bordovskiy, 1965; Hatcher et al., 1982; Klok et al., 1984a).

The organic matter data base for the Bay of Bengal is very meager. There are a few studies dealing with the bulk organic carbon distribution (S. Rao, 1960; Bezrukov, 1964). This paper presents preliminary results of a study on the shelf and slope sediments of the Bay of

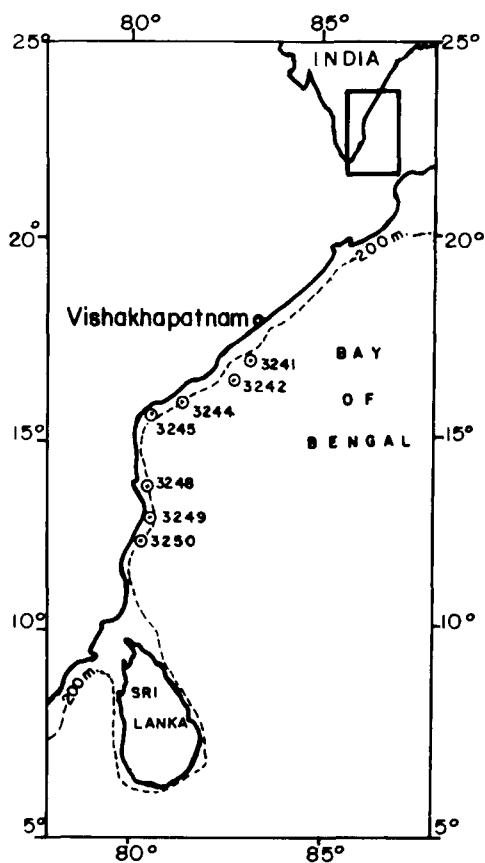


Fig. 1. Location of sampling sites in the Bay of Bengal.

Bengal for the detailed nature of organic matter present in them.

2. Materials and methods

2.1. Description of study area

The Bay of Bengal is an embayment of the Indian Ocean, bounded by the Indian Peninsula and Sri Lanka on the west and by the Andaman–Nicobar Islands and Burma on the east. The uniqueness of the bay is that six major rivers flowing through the various geological formations of the Indian subcontinent introduce into it $\sim 2.0 \cdot 10^{15}$ g of suspended particulate matter annually, i.e. $\sim 15\%$ of the contemporaneous global discharge of fluvial sediments into the world oceans (Ch.M. Rao, 1985).

The 200-m isobath represents roughly the

outer limit of the eastern continental shelf of India (Fig. 1). The inner shelf and the continental slope are covered by clastic sediments and the outer shelf by calcareous relict sediments whereas off the river mouths the shelf is covered by fine-grained terrigenous sediments (S. Rao, 1964).

The shelf at the mouths of the rivers receives a large part of its sediment supplies from the rivers Ganges, Brahmaputra and Mahanadi in the north, Godavari and Krishna in the central region and comparably smaller rivers such as the Pennar and Cauvery in the south. The average annual discharges are very high for the Ganges–Brahmaputra and very low for the Pennar and Cauvery (Ch.M. Rao, 1985).

2.2. Collection of the samples

Seven surface sediment samples, i.e. four from the continental shelf and three from the slope, were collected using a Van Veen® grab sampler during the 143rd cruise of R.V. "Gaveshani" in the Bay of Bengal from October 30 to November 7, 1984. The samples, essentially representing the top 10–15 cm of deposit were immediately stored at -20°C . Before analysis samples were thawed, oven dried at 50°C and ground to a fine powder.

2.3. Organic carbon and organic matter

Organic carbon was determined by wet oxidation with chromic acid according to El Wakel and Riley (1957). A known quantity of sediment was digested with 10 ml chromic acid for 15 min. Samples were cooled and diluted to 200 ml and titrated with 0.2 N ferrous ammonium sulphate using ferrous–phenanthroline as indicator. Organic carbon content was calculated as follows:

$$1 \text{ ml of } 0.2 \text{ N ferrous ammonium sulphate} = 1.15 \times 0.6 \text{ mg of carbon}$$

The amount of organic matter was obtained by

multiplying the organic carbon values with 1.724.

2.4. Carbohydrates

Total carbohydrates were analyzed by the phenol–sulphuric acid method (Dubois et al., 1956). To a known amount of sediment sample 1 ml of distilled water, 2 ml of phenol (5% w/v in distilled water) and 5 ml of concentrated H_2SO_4 were added. Samples were cooled and absorption was measured at 490 nm. Glucose was used as standard. The carbohydrate-carbon was calculated from the carbohydrate value by multiplying with 0.40.

Carbohydrate fractions were obtained following the method of Hitchcock (1977). A known amount of sediment sample was first extracted twice with 2 ml 0.1 N H_2SO_4 to get acid-soluble carbohydrates. This was followed by double extraction with 2 ml of 0.1 N NaOH to get alkali-soluble carbohydrates. One ml aliquot from each fraction was analyzed for carbohydrate as above. The residual carbohydrate concentration was then calculated by subtracting the sum of acid- and alkali-soluble fractions from the total carbohydrate concentration.

2.5. Proteins

Proteins were analyzed following the method of Herbert et al. (1971). A weighed amount of sediment sample was homogenized in 4 ml of 1 N NaOH. The samples were then heated for 30 min. at 80°C to dissolve the proteins. After cooling, aliquots of 1 ml were transferred to clean test tubes to which 2.5 ml carbonate–tartrate–copper solution were added and mixed, followed after 10 min. by 0.5 ml of Folin–Ciocalteu reagent. Appropriate blank and standards (bovine serum albumin) were similarly treated. The protein carbon of the sediment was calculated from the protein value by multiplying with 0.475.

2.6. Amino acids

Free, combined and total amino acids were separated as suggested by Müller (1984) and analyzed by Fluorescamine® (Udenfriend et al., 1972).

In order to analyze total amino acids a portion of sediment sample was transferred to heavy-walled glass ampoules. To these 1 ml of 6.3 *N* HCl was added and the ampoules were flushed with purified nitrogen, sealed and hydrolyzed at 110°C for 22 hr. Samples were neutralized with 6 *N* KOH, centrifuged and diluted to 20 ml. To a known volume (2 ml) of sample 3 ml of sodium borate buffer (pH 9.6) and 1 ml of Fluorescamine® were added. Fluorescence emission of the samples was measured at 480 nm with excitation at 390 nm. Glycine was used as standard. The amino acid carbon was calculated from the amino acid value by multiplying with 0.32.

For the estimation of free amino acids a known amount of sediment sample was extracted with 2 ml of cold (~4°C) 2 *N* HCl and centrifuged. An aliquot of 1 ml was neutralized with 1 ml of 2 *N* KOH and free amino acids were estimated as above.

Bound amino acids were calculated by difference from total and free concentrations.

2.7. Lipids

Lipids were extracted according to the method of Bligh and Dyer (1959). A known amount of sample was extracted with 25 ml of chloroform-methanol mixture (1:2 v/v). Extraction was repeated four times. The extracts were pooled together and again extracted with chloroform-water (1:1). The chloroform layer was separated, dried over anhydrous sodium sulphate. The chloroform was removed at 40°C under reduced pressure and the residue weighed. The lipid carbon was calculated from the lipid value by multiplying with 0.5.

Extracts were dissolved in hexane and fractionated on silica-alumina columns (Bhosle et

al., 1983). Three fractions were collected: aliphatic (hexane, 10 ml), aromatic (benzene, 10 ml) and polar (methanol, 10 ml). Each fraction was concentrated and weighed.

2.8. Caloric content

Using appropriate calorific equivalents of 5.65 for proteins, 4.15 for carbohydrates and 9.40 for lipids on dry-weight basis, the calorific values of sediments in terms of each fraction and total energy were calculated (Qasim and Sankaranarayanan, 1972).

3. Results

3.1. Organic carbon

Table I shows the results of organic carbon and organic matter analyses. Organic carbon and organic matter are in the range of 2.35–13.17 and 4.04–22.07 mg/g dry sediment, respectively. These values are lower than those reported for other areas (Bordovskiy, 1965; Kolla et al., 1981) but are similar to the ones reported by S. Rao (1960) for the Bay of Bengal.

3.2. Carbohydrates

Carbohydrate concentrations varied from station to station, the maximum and minimum being 9.67 and 2.03 mg/g dry sediment, respectively (Table II). These values are in the same range as those reported from other environments (Romankevich, 1984). However, these concentrations are higher than those reported for the sediments from the San Diego Trough (0.9 mg g⁻¹), Baltic Sea (0.05–3.5 mg g⁻¹) and Santa Barbara Basin, California (2.2 mg g⁻¹) by Degens et al. (1963), Naik and Pautanen (1984) and Prashnowsky et al. (1961), respectively.

Dilute acid- and alkali-extractable carbohydrates varied from 8.89% to 27.50% and from 2.95% to 28.80% of total carbohydrate, respectively, and the residual carbohydrates between

TABLE I

Organic matter, organic carbon in the surface sediments

Station	Date of sampling	Location		Depth (m)	Organic matter (mg g ⁻¹)	Organic carbon (mg g ⁻¹)
		lat. (°N)	long. (°E)			
3241	30/11/84	17 00.0	82 59.5	352	22.70	13.17 ± 0.15
3242	30/10/84	16 30.0	82 29.7	700	14.38	8.35 ± 0.06
3244	31/10/84	15 39.1	81 06.4	660	10.47	6.08 ± 0.02
3245	31/10/84	14 54.2	80 20.2	90	13.08	7.59 ± 0.02
3248	01/11/84	13 29.4	80 31.2	125	12.72	7.38 ± 0.09
3249	01/11/84	13 08.1	80 32.5	120	7.85	4.55 ± 0.02
3250	01/11/84	12 30.0	80 19.0	50	4.04	2.35 ± 0.02

TABLE II

Concentrations of some biochemical compounds in the sediments

Station	Carbohydrates			Proteins			Lipids*		
	A	B	C	A	B	C	A	B	C
3241	9.67 ± 0.44	42.60	29.36	3.40 ± 0.27	14.97	12.26	0.97	4.28	3.69
3242	4.41 ± 0.28	30.66	21.13	2.35 ± 0.19	16.34	13.37	0.52	3.59	3.09
3244	4.00 ± 0.17	38.18	26.31	2.05 ± 0.12	19.57	16.02	0.20	1.91	1.65
3245	4.48 ± 0.86	34.26	23.61	3.25 ± 0.02	24.85	20.34	0.53	4.05	3.49
3248	4.61 ± 0.02	36.21	24.98	1.35 ± 0.19	10.61	8.69	0.46	3.60	3.10
3249	2.77 ± 0.03	35.33	24.35	0.85 ± 0.05	10.83	8.87	0.26	3.31	2.85
3250	2.03 ± 0.36	50.22	34.55	0.25 ± 0.06	6.19	5.05	0.16	3.88	3.55

A = mg/g dry sediment; B = percent of organic matter; C = contribution of carbohydrate-carbon, protein-carbon and lipid-carbon as percent of organic carbon.

*Single analysis.

TABLE III

Carbohydrates in the sediments

Station	Total carbohydrates	Acid soluble		Alkali soluble		Residual	
		A	B	A	B	A	B
3241	9.67	0.86	8.89	1.47	15.20	7.34	75.91
3242	4.41	0.86	19.50	1.27	28.80	2.28	51.70
3244	4.00	1.10	27.50	0.94	23.50	1.96	49.00
3245	4.48	1.15	25.67	1.11	24.78	2.22	49.55
3248	4.61	0.46	9.99	0.17	3.69	3.98	86.32
3249	2.77	0.46	16.61	0.11	3.97	2.20	79.42
3250	2.03	0.39	19.21	0.06	2.95	1.58	77.84

A = mg/g dry sediment; B = percent of total carbohydrate.

49% and 86% (Table III). This suggests that acid- and alkali-soluble carbohydrates are either utilized preferentially in the water column during sedimentation (terrestrial or marine) or by benthic organisms. Acid- and alkali-soluble carbohydrates of particulate matter generally decrease with water depth (Hitchcock, 1977). Selective removal of these carbohydrates leaves the particulate matter enriched in residual carbohydrates. As a result of this, pelagic sediments have a higher proportion of residual carbohydrates as compared with near-shore sediments (Romankevich, 1984). From the particulate matter (terrestrial or marine) reaching the pelagic sediments most of the biodegradable carbohydrates are removed before settling to the sea floor because of the longer residence times within the water column as compared with the near-shore environment. The residual carbohydrates will get tightly bound to mineral particles within the water column or the upper few centimeters of sediments, making them resistant to mineralization. These carbohydrates further survive early diagenesis relatively unchanged (Degens et al., 1964), resulting in the selective enrichment of residual carbohydrates in the sediments which in turn enhances their potential to become part of the insoluble organic matter in the sediments.

3.3. *Proteins and amino acids*

The concentrations of proteins varied from 0.25 to 3.40 mg/g dry sediment, and accounted for 5.05–20.34% carbon of the total organic carbon (Table II), and followed a pattern similar to that of organic carbon. As compared with amino acids, these protein values are high probably due to interference from humic acids.

Total amino acids ranged from 88 to 682 $\mu\text{g/g}$ dry sediment, and the amino acid carbon formed 1.2–2.02% of the total organic carbon (Table IV). These values are similar to those reported from other areas (Nissenbaum et al., 1972; Gonzalez et al., 1983). Free and combined amino acids varied from 3.55 to 27.13 and 81 to

672 $\mu\text{g/g}$ dry sediment, respectively (Table IV). Presence of free amino acids probably suggests decomposition by microbial activity, hydrolysis because of the redox conditions in the sediments, or their adsorption to the sediments (Henrichs and Farrington, 1987). The extremely low concentrations of free amino acids and high concentrations of combined amino acids suggest that even in the early stages of deposition nitrogenous organic matter is present as intact proteins or peptides (Kemp and Mudrochova, 1973; Gonzalez et al., 1983).

Although amino acids in surface sediments, depending on the physico-chemical conditions and heterotrophic organisms, are subjected to intensive decomposition, presence of significant amounts of these compounds suggests that they are trapped in sediment. During diagenetic processes, N-compounds are adsorbed by clay minerals and incorporated into humic matter through various humification pathways. Both of the above-mentioned processes explain, at least in part, the ability of N-compounds to survive over long periods of geological time. It has been shown that amino compounds either bound to clay minerals or associated with geopolymers are particularly resistant to chemical and biological breakdown (Gonzalez et al., 1983; Kemp and Mudrochova, 1973; Belluomini et al., 1986).

3.4. *Lipids*

Total lipids varied from 0.16 to 0.97 mg/g dry sediment and the lipid carbon accounted for 1.65–3.69% of total organic carbon (Table II). These values are in the same range as reported for marine sediments from other areas (Romankevich, 1984).

Silica-alumina column chromatography of lipids suggests that polar lipids accounted for the major part of total lipids followed by aliphatic and aromatic lipids (Table V). The concentrations of these compounds are lower in comparison with those reported from other

TABLE IV

Amino acids in the sediments*

Station	Total amino acids		Free amino acids			Combined amino acids		
	A	C	A	B	C	A	B	C
3241	682.10	1.66	9.33	1.37	0.02	672.77	98.63	1.64
3242	444.10	1.70	3.55	0.80	0.01	440.55	99.20	1.69
3244	292.98	1.54	18.75	6.40	0.09	274.23	93.60	1.45
3245	402.34	1.69	27.13	6.74	0.11	375.21	93.26	1.58
3248	454.82	1.97	12.33	2.71	0.05	442.49	97.29	1.92
3249	287.50	2.02	16.33	5.68	0.11	271.17	94.32	1.91
3250	88.06	1.20	6.47	7.35	0.09	81.59	92.65	1.11

A = $\mu\text{g/g}$ dry sediment; B = percent of total amino acids; C = amino acid-carbon as percent of organic carbon.

*Mean of duplicate analysis.

TABLE V

Lipids content in the sediments

Station	Lipids		Free lipids*			Aliphatic fraction			Aromatic fraction			Polar fraction		
	A	A	C	A	B	C	A	B	C	A	B	C		
3241	972.55	490.40	1.85	107.15	21.85	0.41	94.78	19.33	0.36	234.90	47.90	0.89		
3242	516.57	276.67	1.65	76.67	27.71	0.46	36.67	13.25	0.22	153.33	55.42	0.92		
3244	200.00	100.00	0.82	26.67	26.67	0.21	13.33	13.33	0.11	53.33	53.33	0.44		
3245	530.00	288.00	1.90	62.00	21.53	0.41	38.00	13.19	0.25	180.00	62.50	1.19		
3248	457.78	415.56	2.81	122.22	29.41	0.83	77.78	18.72	0.52	197.78	47.60	1.33		
3249	260.00	233.33	2.56	66.67	28.57	0.73	40.00	17.14	0.44	120.00	51.43	1.32		
3250	157.50	132.50	2.82	40.00	30.19	0.85	27.50	20.75	0.57	60.00	45.28	1.26		

A = $\mu\text{g/g}$ of dry sediment; B = percent of free lipids; C = lipid-carbon as percent of organic carbon.

*Asphaltenes free hexane-soluble lipids.

areas (Barrick et al., 1980; Venkatesan et al., 1980).

3.5. Caloric content

Caloric content of the sediments is shown in Table VI. The slope sediment has more caloric content than the shelf sediment. Overlying water depth did not have any influence on the caloric content of these sediments.

4. Discussion

Even though the samples are too few and not closely enough spaced, from the limited data on

TABLE VI

Energy values for the sediments (results expressed in calories/g dry sediment)

Station	Carbohydrate	Protein	Lipid	Total
3241	40.13	19.21	9.12	68.46
3242	18.30	13.28	4.89	36.47
3244	16.60	11.58	1.88	30.06
3245	18.59	18.36	4.98	41.93
3248	19.13	7.63	4.32	31.08
3249	11.50	4.80	2.44	18.74
3250	8.42	1.41	1.50	11.33

hand, the following generalization can be made with respect to the distribution of the studied biochemical compounds in the sediments.

Amongst the various constituents of the organic matter studied, carbohydrates were the most abundant, comprising 30–50% of organic matter as compared with proteins (10–24%) and lipids (1.91–4.28%). These differences can be attributed to the quality of organic matter settling towards the sea floor and its subsequent transformation by benthic organisms. Together these compounds comprise ~49–63% of organic matter and thus constitute a large part of the organic matter input into the sediment. They represent an important food source for heterotrophic organisms and are rapidly recycled (Gagosian and Lee, 1981; Ittekkot et al., 1984). Data on carbohydrates, proteins and lipids suggest that the latter compounds are more rapidly recycled than the former.

It has been suggested that the decrease in the relative contribution of carbohydrates to organic carbon may reflect the nature of carbohydrates in sediments (Klok et al., 1984b, c). Occurrence of consistently higher values of carbohydrates either indicates their non-availability for biological utilization and/or inert nature. This is probably because of high content of residual carbohydrates. These carbohydrates generally include structural elements such as chitin, pectin and cellulose which are considered to be more stable in the marine environment.

In general the average concentrations of organic carbon, carbohydrates, proteins, amino acids and lipids in slope sediments were higher by about a factor of 2 than those obtained for shelf sediments. Higher concentrations of organic matter from continental slope sediments have also been reported from other areas (Nino and Emery, 1969; Closs et al., 1974; Bhosle et al., 1978; Kolla et al., 1981; Premuzic et al., 1982). Such high values of these compounds could be due to high biogenic productivities in the surface waters (Radhakrishna et al., 1978), transport of organic matter (marine and/or

terrestrial) from the shelf to the slope (Premuzic et al., 1982; Stein et al., 1986), high rate of sedimentation and subsequent preservation due to low oxygen supply to the waters of the sea floor (Kolla et al., 1981; Premuzic et al., 1982; Stein et al., 1986).

The observed irregularity in the levels of organic carbon, carbohydrates, proteins, amino acids and lipids with increasing depth confirms earlier findings (Stevenson and Cheng, 1972; Bhosle et al., 1978; Kolla et al., 1981). However, our results are in contrast with those reported for sediments from other areas where organic matter has been found to decrease uniformly with water depth. For example, Bordovskiy (1965) found that the organic carbon content of sediments from the Bering Sea decreased progressively with water depth. In addition, Degens (1970) suggested that water depth plays a decisive role in the alteration of amino acids in such a way that absolute concentrations are higher in the near-shore zone, but decrease with increasing depths (Siezen and Mague, 1978; Henrichs and Farrington, 1979).

Grain size of the sediments seems to play a significant role in controlling the distribution of these compounds. For example, sandy sediments obtained at station 3250 showed minimum concentrations of all compounds as compared with finer-grained sediments sampled at the other stations. This association of organic matter with smaller grain size is a well-known phenomenon (Erlenkeuser et al., 1981; Jocteur-Monrozier et al., 1983; Liebezeit, 1986). The reason for this is most probably the high surface area and hence high adsorptive capacity of the finer-grained sediments (Hunt, 1963; Suess, 1973).

4.1. Relationships among organic carbon, carbohydrates, proteins, amino acids and lipids

There is a direct correlation between organic carbon and major biochemical compounds as carbohydrates, proteins, amino acids and lipids as shown in Fig. 2. Similarity in the distribution

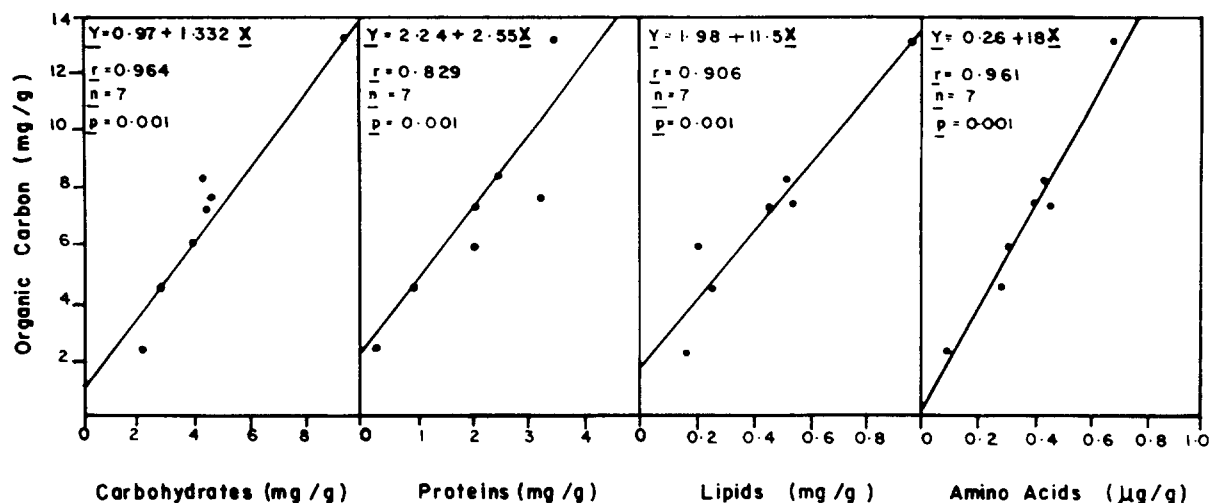


Fig. 2. Relationship between organic carbon and carbohydrates, proteins, lipids, amino acids of the sediments.

of organic carbon and these compounds in the sediments supports a genetic relationship of these constituents with the starting organic material. This is also due to the influence of initial material rich in these compounds. For example, biochemical content of diatom, algae and phytobenthos affect the concentrations of these compounds in the sediment (Romankevich, 1984).

4.2. Origin of organic carbon

All our sediment samples showed very high concentrations of carbohydrate. This information was used to locate the origin of organic carbon in these sediments. Although carbohydrates are ubiquitously present in organisms contributing to the organic matter of marine sediments and hence do not appear to be useful as markers for organic carbon origin, a number of studies have been undertaken to link sedimentary carbohydrates with possible sources. For example, ratios such as mannose/xylose, glucose/ribose and glucose/galactose have been used to distinguish between terrestrial and marine sources (Mopper, 1973; Cowie and Hedges, 1984; Ittekkot and Arain, 1986; Liebezeit, 1986). Cowie and Hedges (1984) suggested a further possible means for distinguishing these geographic

sources through total carbohydrate yields. The rationale behind this approach is that terrestrial vascular plant tissues yield significantly more (>20%) carbohydrate (normalized to organic carbon content) than either plankton or bacteria. Care must be taken, however, in using low carbohydrate yields as a marine source indicator for mixed field samples because carbon-normalized yield can be lowered through dilution by carbohydrate-poor terrigenous carbon from charcoal, soil or sedimentary rock.

Carbon-normalized total carbohydrate yields for the surface sediment samples varied from 52.81 to 86.38 mg total carbohydrate/100 mg organic carbon, and thus indicate the presence of terrestrially derived vascular plant remains in the sediments. This inference is straightforward because vascular land plants are the only important source to have carbon-normalized total carbohydrate yields >20% (Cowie and Hedges, 1984) and because diagenesis of this, or any other organic material, should result only in less yields.

5. Conclusions

Data on the distribution of organic carbon and its constituent fractions such as those employed here provide useful information about

the amount, nature and the source of organic matter in the sediments.

Lower values of energy-rich (lipids) and easily hydrolyzable (proteins) compounds suggest their preferential utilization.

Higher concentrations of residual carbohydrates and combined amino acids indicate their association with mineral particles and/or inert nature. Because of this, these compounds are resistant to biological and chemical degradation. This has a direct geochemical implication as it enhances the changes of burial of these compounds in the sediments. Together they contribute ~12–28% carbon to total organic carbon. This carbon fraction of these compounds has a good chance to become buried in the marine sediments.

Accumulation of organic carbon and the studied biochemicals in the continental slope sediments suggests that the slope may be a major sink for these compounds. This further indicates the importance of slope organic matter and its role in the global carbon cycle.

The above-mentioned conclusions are based on the distribution of major organic compounds such as those analyzed here. However, in order to obtain a more precise answer to the question about the origin and processes affecting organic matter distribution in marine sediments, further more detailed studies including individual amino acids, amino sugars, sugars and lipid biomarker compounds are needed.

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