25. PLANT ORGANIC MATTER IN SEDIMENTS FROM HOLE 336, DSDP LEG 38

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INTRODUCTION

It was not possible to use all of the available complex methods for an exact diagnosis of the nature of all components in the organic constituents in the sediment. This was due to a very small weight of the sample combined with a relatively small amount of organic carbon (0.24%-0.96%). Thus, our study was at first confined to investigation of organic matter in bilaterally polished sections by translucent light under parallel and crossed nicols. Secondly, a luminescent-bituminological analysis was used combined with paper-chromatography (Iljina, 1975). The latter method enabled a characterization of the peculiarities of the composition of the bituminous part of organic matter. The bituminous part was isolated from the sediments through cold extraction.

Analytical Methods[1]

In preparing the chloroform extract, 1 g of ground sediment was extracted in tubes with 2.5 ml of chloroform without heating. The concentration of bituminous components in the samples was examined by visual comparison to standards of bitumens in the same solution using a luminescent lamp. The concentration of bituminous components was estimated in percent per rock. The determination of bituminosity of sediments by this method is often distorted due to the presence of pentacyclic condensed aromatic hydrocarbon-perilen ($C_{20}H_{12}$) in chloroform extracts. They cause a pronounced bright blue luminescence of the extract. Therefore, for an exact determination of the composition of organic matter of the chloroform extract, the intensity of luminescence and color characteristics were evaluated with a fluorescent photometer. The character of bituminosity was deciphered through chromatography. Chromatographic analyses were carried out on FN-3(DDR) paper. Chloroform "capillary extracts" were placed on paper bands. Chromatograms were obtained by means of "segregation" of "capillary extracts" by mixing with organic solvents: H-hexane + acetone + benzol + ethanol, the ratio being 20:3:1:1. The zones obtained "at the beginning" and "at the front" according to their luminescent characteristics made it possible to define a type of bitumen, recognize the presence of oil, as well as recognizing aromatic and polycyclic hydrocarbons.

Along with the study of chloroform extracts, alcohol-benzol extracts obtained from sediments were examined after successively being extracted by chloroform. The ratio of luminescent intensity of chloroform and alcohol-benzol extracts serves as a criteria for the determination of syngenetic or epigenetic origin bituminous substances in a sediment (Baranov et al., 1974).

The organic carbon content was determined in parallel weight by the wet combustion method. In a number of typical sediments, humic acids have been isolated by the alternative treatment of a sediment in a 0.1*N* solution of NaOH and a 0.1*N* solution of HCl during heating in a boiling water bath for 2 hours. The total amount of humic acids was estimated by the gravimetric method.

RESULTS

Organic Carbon Content in Various Types of Sediments

The amount of organic carbon (C_{org}) enables a judgment of the organic matter content in the sediments. Examination of the sediment section shows (Table 1) that, on the average, the highest content of organic carbon is associated with the upper portion including Pleistocene sediments and in the middle portion characterized by middle Eocene sediments. The organic carbon content in Pleistocene sediments (Samples 1003-1033) is not constant, ranging from 0.19% to 1.15%. The variations are due to peculiarities in the lithology of the deposits. The sediments consist of interbeds of tuffaceous clayey silts and clays with sandy silts. The latter may have been deposited by ice-rafting of terrigenous material. In some samples (1014, 1018, 1021), the higher carbon content is related to the presence of clay pebbles in sediment interbeds containing considerable amounts of brown detritus. The detritus has been brought in together with terrigenous material of the source area. Sediments of the middle part of the section (Samples 1035-1085) (late-middle Eocene) contain much less organic carbon. In some samples (1049, 1054, 1064) organic carbon was absent; in others it varied within 0.23%-0.41%, often decreasing to 0.11%. An increase in the organic carbon content (Table 1) is generally related to sediments containing a considerable admixture of coarser material (Samples 1069, 1070). The least amount (or absence) is found in thin bedded sediments enriched with siliceous tests (Samples 1035, 1037, 1040, 1042) or vitroclastic tuffs (Sample 1054). The organic carbon content in middle Eocene sediments (Samples 1089-1107) is generally constant, ranging from 0.58% to 0.88% sometimes increasing to 1.26% (Sample 1104). The sediments consist of zeolititized clays interbedded with layers enriched with sand and gravel-sized grains of weathered basalts and acid effusives. On the whole, the organic carbon content in sediments from the hole is relatively small.

Petrographic Composition of Plant Organic Matter

Thin section studies of the organic matter in the sediments from the hole enabled recognition of the

[1]All sample numbers referred to herein are GIN numbers, Academy of Sciences, USSR.

TABLE 1
Amount of Organic Carbon (C_{org}) and Characteristics of Plant Organic Matter

Age	Depth (m)	Sample (Interval in cm)	Sample GIN Acad. Sci. USSR	CO_2 (% for Dry Weight)	C_{org} Absolute	Lithology	Microscopic Characteristics of Plant Organic Matter
Pliocene to Plio-Pleistocene	5.52	336-1-4, 100-102	1003	1.15	0.24	Unsorted sandy silt with clayey cement	No plant remains
	11.32	336-2-2, 80-82	1006	1.18	0.19	Silty clay with an admixture of sandy material	As above
	14.62	336-2-4, 110-102	1007	2.80	0.85	Clayey silt with an arenaceous admixture	Brown detrital matter
	36.73	336-5-1, 120-123	1011	1.65	0.91	Silty clay with sand and pebbles.	Brown detrital matter Clay pebbles enriched with detritus
	41.05	336-5-4, 103-105	1014	1.52	0.96	Silty, sandy, clayey	Brown detrital matter
	45.86	336-6-1, 84-86	1017	0.96	0.32	Tuffaceous silt with glass fragments and siliceous tests	Brown detrital matter Clay pebbles enriched with detritus
	48.64	336-6-3, 62-64	1018	1.82	0.64	As above	As above
	53.10	336-6-6, 58-60	1021	1.88	1.15	Silty clay with sand	No plant remains
	69.42	336-8-4, 90-92	1025	Absent	0.23	Tuffaceous clayey silt	Brown detrital matter
	80.39	336-9-5, 87-89	1029	4.82	0.60	As Above	No plant remains
	115.20	336-11-4, 68-70	1033	Absent	0.26	Silty clay with siliceous tests	Sporadic brown detrital matter
	132.10	336-12-2, 58-60	1035	Absent	0.23	Silty clay with abundant silicic tests, with pyroclastic material (glass)	
Oligocene or Eocene, L. Oligocene	179.25	336-16-1, 119-125	1037	Absent	0.21	As above (?)	As above
	193.60	336-18-4, 100-110	1040	Absent	0.11	Colloform clay overfilled with sponges and diatom; many fragments of glass and basalts	No plant remains
	216.82	336-20-1, 80-82	1042	Absent	0.24	Slightly silty clay with abundant sponges	Sporadic brown detrital matter
	219.77	336-20-3, 75-77	1044	Absent	0.29	Clay with zeolites without siliceous test	Sporadic brown detrital matter
	224.27	336-20-6, 75-77	1047	0.54	0.37	As above	As above
	228.77	336-21-2, 75-77	1049	Absent	Absent	Pelitomorphic clay with fragments of basalts and quartz grains	No plant remains
	235.66	336-22-1, 64-66	1054	Absent	Absent	Vitroclastic tuff, zeolitized	As above
	240.48	336-22-5, 96-98	1058	Absent	0.36	Homogeneous clay without admixture of sandy silty material	Sporadic brown detrital matter and fragments of gelefied tissues
Late Eocene	246.31	336-23-2, 79-80	1061	0.77	2.71?	Clay with grains of silt	As above
	256.31	336-24-2, 79-81	1064	Absent	Absent	Clay with grains of quartz and extrusives	Sporadic brown detrital matter
	267.11	336-25-3, 109-111	1069	Absent	0.41	Silty clay, strongly arenaceous	Brown detrital matter
	272.61	336-25-6, 109-111	1070	Absent	0.41	As above	Sporadic fragments of gelefied tissues and detritus
	285.29	336-27-2, 27 29	1075	Absent	0.22	Clay with inclusion of oval and irregularly shaped grains of montmorillonite clays	Brown detrital matter
	292.90	336-28-1, 86-90	1077	Absent	0.18	Clay with fragments of basalt	Brown detrital matter
	331.21	336-30-1, 120-122	1081	Absent	0.39	Silty clay with fragments of weathered basalts, zeolites	Brown detrital matter Sporadic fragments of
	338.61	336-30-6, 109-111	1085	Absent	0.27	Clay with fragments of weathered basalts and zeolites	tissues and detrital matter
Middle or late Eocene	369.22	336-32-1, 120-122	1089	Absent	0.58	Clay saturated with zeolites	Brown detritus, gelefied structureless matter
	393.75	336-33-5, 77-75	1094	Absent	0.36	Clay with fragments of altered basalts; saturated with zeolites	Brown detrital matter
	427.38	336-35-2, 96-88	1097	Absent	0.70	As above	Rare small fragments of gelefied tissues, gelefied structureless matter
	435.88	336-36-1, 136-138	1101	Absent	0.59	Zeolitized tuff	Sporadic brown detrital matter
	440.24	336-36-3, 52-53	1103	Absent	0.85	Silty clay, zeolitized	Brown detrital matter, small fragments of gelefied
	440.86	336-36-4, 122-124	1104	Absent	1.26	As above	tissues, gelefied structure-
	442.40	336-36-5, 34-36	1105	Absent	0.88	As above	less matter

products of transformation of superior plant tissues. These products develop through the process of gelefication and can be attributed to the class of humites as judged by their petrographic composition. They are represented by small fragments of gelefied tissues, fine and coarse detritus, as well as gelefied homogeneous structureless matter. Sporadic grains of pollen of superior plants and resinous bodies were observed among leiptinite components.

Fragments of gelefied tissues have a brown color and are characterized by a more or less preserved cellular structure. According to their structure, they can belong

to xylain or xylovitrain, i.e., to the components from the gelinite-telinitic group (Internationales Lexicon für Kohlenpetrologie, System GIN, Academy of Science of the USSR, Paris, 1963; Timofeev, Yablokov, et al., 1962; Timofeev, Bogolyubova, 1965).

The coarse and fine detritus, as well as tissue remains, is brown. Its separate inclusions are structureless, but have outlines and are attributed to vitrain. The small size of the inclusions indicates they belong to the group of gelinite-posttelinitic components.

The gelefied homogeneous structure is structureless, brown, sometimes grayish-brown. It is a final transformation product of plant matter through the process of gelefication. It may originate by coagulation of humic acids. Based on its structural peculiarities, it belongs to components of the gelinite-collinitic group.

Organic matter of the sapropelic series was not found as form elements under microscope, i.e., preserved algae. It appears to be present as a collomorf form, and is absorbed by a clayey constituent of a sediment forming organo-mineral complexes. If it is not masked by a humic matter, it causes the sediments to have a dirty yellowish tint.

The above petrographic components of the organic matter of sediments from the hole are quantitatively but unevenly distributed throughout the section. Middle Eocene sediments generally consisting of silty clays (Samples 1089-1107) are greatly enriched with all three petrographic groups of components of the humic series. All groups are characterized by a relatively higher amount of structureless gelefied matter that is absorbed by clay material of a sediment and is a part of the complex of ferrum hydroxides. A higher number of tissue fragments were observed in the form of xylain and xylovitrain. They are often pyritized. A rather large amount of brown detritus of different sizes was dispersed in the sediment. Peculiar "microaggregates," generally of an oval shape, of varying sizes, and with a higher content of ferrous hydroxides were occasionally observed. They are separated by fissures from the rest of the sediment. The distribution of tissue fragments and detritus is without orientation. Some areas of discolored clay matter were observed, as are found in hydromorphous soils. Relative enrichment of these sediments with gelefied plant material corresponds to a higher carbon content in this part of the section, as well as an outflow of humic substances (Tables 1, 2). Sediments of the upper part of the section of Pleistocene age (Samples 1003-1033), as well as those of the middle Eocene, are characterized by a higher content of humic series components. Small tissue fragments are also frequently observed, as well as coarse and fine detritus. This detritus often is associated with clay pebbles. However, gelefied structureless matter is nearly absent.

Sediments from the middle part of the section (Samples 1035-1089) (late-middle Eocene and Oligocene) are characterized by a very small amount of humic components. Tissue fragments in the form of xylain and xylovitran are sporadic, being found mainly at the base of this part of the section (Samples 1085, 1070, 1058). Detritus is present in very small amounts, and its content gradually decreases upwards to single inclusions, where clay sediments are strongly enriched with siliceous tests (Samples 1042, 1040, 1037, 1035). In this part of the section, the pollen of superior plants is observed, with sporadic resinous grains also being found.

Luminescent-bituminological and Chromotographic Study

Figure 1 presents a comparison of luminescent characteristics of chloroform and alcohol-benzol extracts of the sediments from Hole 366. Colored characteristics of luminescence are plotted on the X-axis Ic/Io (Table 2), and intensity of luminescence measured with the help of a fluorescent photometer through a blue light filter are plotted on the Y-axis. The arrangement of points of the graph corresponding to chloroform extracts enables a subdivision of the samples into four groups. The first group includes Samples 1049, 1054, 1058, 1059, 1064, 1069, 1081, and 1101. They are characterized by a weak bituminosity of the chloroform extract ($Ic<1$). This coincides with the value of bituminosity previously determined according to a standard (Table 2). The content of humic acids varies from 0.01% to 0.1%. All samples, excluding 1101, belong to the middle part of the section of middle-late Eocene and Oligocene age.

The second group consists of Samples 1002, 1006, 1033, 1048b, 1060, 1061, and 1103. They are characterized by a somewhat greater bituminosity. This is pronounced by an intensification of blue luminescence determined both visually and with the help of a fluorescent photometer. The humic acid content varies from traces to 0.08%. Samples of this group are associated to the uppermost part of the section, in the Oligocene and middle Eocene.

The third group contains Samples 1003, 1007, 1011, 1014, 1017, 1017b, 1021, and 1025. They have the bright blue luminescence of the chloroform extract and a relatively high index (Ic). This usually corresponds to bituminous components with an admixture of five-membered aromatic hydrocarbon, perilen. This is often present in the organic matter of recent sediments containing components of the humic series. On the chromatograms the presence of perilen in these samples is fixed by a zone near the front with greenish and blue luminescence. The above samples are peculiar to sediments of the upper part of the section (Pleistocene). They are characterized, contrary to other samples, by a relatively intense luminescence of alcohol-benzol extracts (Table 2) with prevailing values of Io from 6.0 to 13.6. The humic acid content in the organic matter for these samples varies from 0.02% to 0.1%.

The fourth group of samples—1089, 1104, 1105—is characterized by weak bituminosity of the chloroform extract, but has a higher color ratio ($Ic/Io = 8.3$). This testifies to the presence of components of humic series in the organic matter. The presence of these components can be seen also in the higher content of humic acids in a mononormal alkaline solution. This sample group is found at the base of the middle Eocene section consisting of silty clays overlying the basalt layer.

In all samples (Table 2) a considerably strong luminescence of alcohol-benzol extracts was recorded, as compared to luminescence of chloroform extracts,

TABLE 2
Characteristics of the Organic Matter, Hole 33

Depth (m)	Sample (Interval in cm)	Sample from GIN Acad. Sci. USSR	C_{org} (% for Dry Weight)	Lithology	Microscopic Characteristics of Plant Organic Matter	Bituminosity for Rock Chloroformal Extract[a]	Luminescent Characteristic of Extracts				Luminescent Chromatographic Characteristic of Bituminous Components of Chloroformal Extract
							Chloroformal Extract		Alcohol-Benzol Extract		
							I_c[b]	I_c/Io[c]	Ic	Ic/Io	
3.82	336-1-3, 80-82	1002	Not determined	Unsorted sandy silt with clay cement	No plant remains	0.0012	0.83	3.8	3.4	3.8	Very faint chromatogram with bluish luminescence near the front
5.53	336-1-4, 100-102	1003	0.24	As above	As above	0.04	3.6	5.5	13.6	3.9	At the beginning: faint extended zone and bluish luminescence (not of the oil row). At the front: faint, dull zone with transition from brownish to greenish and blue luminescence
11.32	336-22, 80-82	1006	0.19	Silty clay with an admixture of sandy material	As above	0.005	0.67	3.04	2.34	3.3	At the beginning: nothing At the front: feeble, slightly emulsive zone with bluish luminescence
14.62	336-2-4, 110-102	1007	0.85	Clayey silt, with a sandy admixture	Brown detritus	0.02	2.7	5.6	6.0	3.5	See Sample 1003
36.73	336-5-1, 120-123	1011	0.91	Silty clay, with sand and pebbles	As above	0.04	6.6	6.8	8.6	4.5	Not examined
41.05	336-5-4, 103-105	1014	0.96	Sandy, clayey silt	Brown detritus, clay pebbles enriched with detritus	0.08	9.6	5.4	17.4	3.35	See Sample 1003, but much better pronounced
45.86	336-6-1, 84-86	1017	0.32	Tuffaceous silt, with siliceous tests	Brown detritus	0.005	1.95	4.9	6.0	2.8	See Sample 1003, but poorly pronounced
47.38	336-6-2, 85-88	1017b	Not determined	As above	As above	0.08	6.2	5.2	13.6	3.9	See Sample 1003, but much better pronounced
53.10	336-6-6, 58-60	1021	1.15	Silty clay, with sand	Clay pebbles enriched with detritus	0.04	4.5	4.6	9.0	4.2	See Sample 1003
69.42	336-8-4, 90-92	1025	0.23	Tuffaceous clayey silt	No plant remains	0.005	1.95	4.9	3.1	2.35	At the beginning: large white-bluish, not bright zone. At the front: concentrated, not extended, slightly emulsive zone, with bluish luminescence
115.20	336-11-4, 68-70	1033	0.26	Silty clay with siliceous tests	No plant remains	0.005	1.0	3.7	2.34	3.5	See Sample 1006, but a little better pronounced
226.20	336-21-2, 75-77	1048b	Absent	Pelitomorphic clay with quartz grains and zeolite	Brown detritus	0.0012	1.0	4.5	<0.1	Gray-bluish	At the beginning: faint bluish luminescence. At the front: a very weak zone, with bluish luminescence
228.77	336-21-1, 75-77	1049	Absent	Pelitomorphic clay with basalt fragments and quartz grains	No plant remains	0.0003	<0.1	Slightly bluish-gray	1.36	2.3	Not examined
235.66	336-22-1, 64-66	1054	Absent	Vitroclastic tuff, zeolitized	As above	0.0003	<0.1	Slightly bluish-gray	2.3	3.3	At the beginning: faint whitish narrow zone. At the front: faint bluish extended dull zone
240.48	336-22-5, 96-96	1058	0.36	Homogeneous tuff	Sporadic brown detritus and fragments of gelefied tissues	0.0006	<0.1	Slightly bluish-gray	3.4	3.8	See Sample 1048b, but slightly poorer pronounced
243.38	336-22-6, 86-88	1059	Not determined	As above	As above	0.0003	<0.1	Slightly bluish-gray	2.3	3.3	See Sample 1048b, but a poorer pronounced

244.81	336-23-1, 109-111	1060	Not determined	As above	Brown detritus	0.0006	0.98	2.94	1.7	1.3	See Sample 1048b
246.31	336-23-2, 79-81	1061	2.71?	Clay with silt	Brown detritus and tissue fragments	0.0012	0.83	3.8	3.1	2.4	See Sample 1003
256.31	336-24-2, 79-81	1064	Absent	Clay with grains of quartz and extrusives	Brown detritus	0.0003	<0.1	Slightly bluish-gray	<0.1	Gray-bluish	See Sample 1048b, but poorer pronounced
267.11	336-25-3, 109-111	1069	0.41	Clay, silty, strongly arenaceous	As above	0.0003	<0.1	Gray-bluish	<0.1	Gray-bluish	See Sample 1054
272.61	336-25-6, 109-111	1070	0.41	As above	Brown detritus and sporadic fragments of gelefied tissues	0.0006	1.0	4.0	<0.1	Gray-bluish	See Sample 1048b
331.21	336-30-1, 120-122	1081	0.39	Silty clay with fragments of weathered basalts	Brown detritus	0.0003	<0.1	Slightly bluish-gray	1.7	1.3	See Sample 1054
369.22	336-32-1, 120-122	1089	0.58	Clay saturated with zeolites	Brown detritus, gelefied structureless matter	0.0006	0.83	8.3	1.4	2.3	See Sample 1054, but stronger pronounced
435.88	336-36-1, 136-138	1101	0.59	Zeolitized tuff	Sporadic brown detritus	0.0003	<0.1	Slightly bluish-gray	1.36	2.5	See Sample 1002, but poorer pronounced
440.24	336-36-3, 52-53	1103	0.85	Silty, zeolizited clay	Brown detritus, small fragments of gelefied tissues, gelefied structureless matter	0.0012	1.0	4.5	2.63	2.35	See Sample 1002, but stronger pronounced
440.86	336-36-4, 122-124	1104	1.26	As above		0.006	0.83	8.3	2.68	2.8	See Sample 1054, but stronger pronounced
442.40	336-36-5, 34-36	1105	0.88	As above		0.006	0.83	8.3	3.4	3.4	See Sample 1054, but stronger pronounced

[a]Bituminosity, % for rock. Colorimetrical (visual) determinations.

[b]Intensity of blue luminescence – I_c.

[c]Color characteristic – $\frac{Ic}{Io}$.

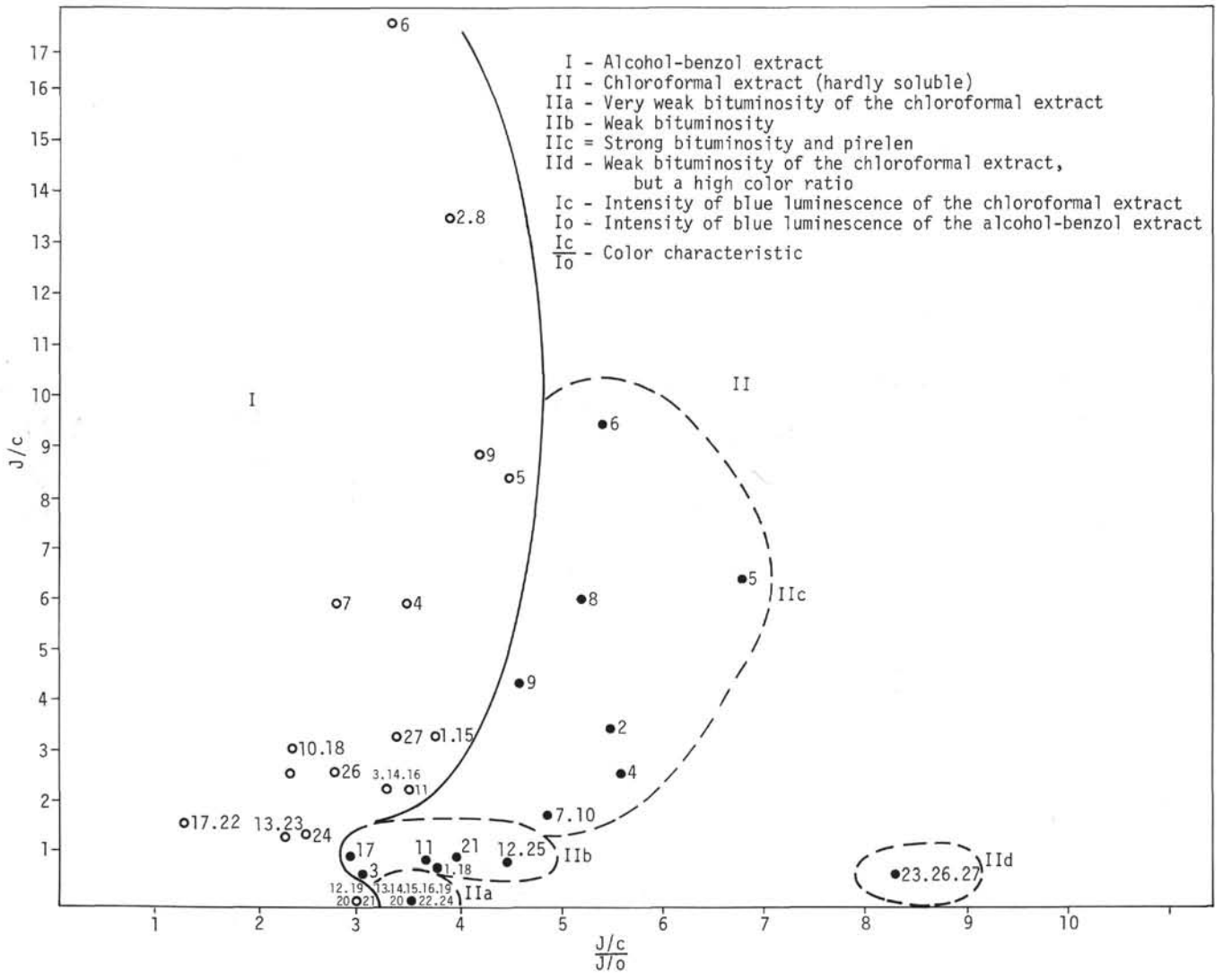

Figure 1. *Luminescent characteristics of chloroformal and alcohol-benzol extracts of sediments, Hole 336.*

i.e., Ic chloroform < Ic alcohol-benzol. In this relation, the points on the graph (Figure 1) characterizing bituminosity of alcohol-benzol extracts are located in the left side of the area relative to the points of chloroform extracts. This indicates a syngenetic character for the bituminous components of the sediments from Hole 336. For an epigenetic character of bituminous components, the Ic chloroform would be greater than the Ic alcohol-benzol.

In all samples (Table 2) the data of luminescent-chromatographic characteristics of chloroform extracts do not show the zones representative of components of the oil type, i.e., there are no indications of the presence of oil.

CONCLUSIONS

1. The distribution of organic carbon in sediments of the hole is variable. Roughly, a higher amount is found in Pleistocene sediments (the upper part of the hole) and in middle Eocene sediments (the lower part of the hole).

2. A higher C_{org} content is observed in sediments with a larger grain size (related to ice-rafting of terrigenous material [Pleistocene]), and in clay sediments of the middle Eocene which indicate a closer location of the source of supply. A lower C_{org} content is present in thin sediments enriched with siliceous [microfossils] and frequently in vitroclastic tuffs (Oligocene).

3. Bituminous components and perilen extracted by organic solvents (chloroform and alcohol-benzol), as well as humic acids extracted by alkali, have been found in the composition of organic matter.

4. Bituminous components of the organic matter are syngenetic, so the intensity of luminescence of the alcohol-benzol extract proves to be considerably higher than that of the chloroform extract.

5. The material-petrographic composition of humic components, their form, and distribution in the upper and middle parts of the section of the hole (Pleistocene, Oligocene, late-middle Eocene) testify to their allochthonous origin. The material composition of humic components, their form, and distribution of

clays in sediments of the lower part of the section (middle Eocene) indicate their more or less autochthonous origin. Conversely their allochthonous character may not be related to a distant transfer of plant material.

6. The brown color of the humic matter components and its solving in mononormal alkali point to a low rank of the organic matter corresponding to the limits of brown coal.

7. Components of an oil series have not been recognized during the investigation of the chloroform extract by means of paper chromatography.

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