11. SOURCE QUALITY AND RICHNESS OF DEEP SEA DRILLING PROJECT SITE 535 SEDIMENTS, SOUTHEASTERN GULF OF MEXICO[1]

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ABSTRACT

There are substantial differences in the character of organic matter contained in the Pleistocene and Cretaceous sedimentary sequences of DSDP Site 535. The argillaceous Pleistocene section contains type III, gas-prone organic matter whereas the calcareous Cretaceous section is dominated by type II, oil-prone organic matter. A more detailed investigation of the Cretaceous section reveals that the finely laminated limestones of Valanginian to Barremian age are of good to excellent source quality. The indigenous organic matter contained within this organically rich section is thermally immature, not having undergone sufficient thermal diagenesis for the generation and expulsion of hydrocarbons. Within this stratigraphic section, however, staining by mature hydrocarbons was detected. These stains are associated with a fractured interval. These fractures may in turn represent potential migration pathways.

INTRODUCTION

Site 535, drilled in the southeastern Gulf of Mexico, penetrated 714 m of sediment. The hole terminated in sediment of Berriasian age. The recovered sediments offered several interesting avenues for organic geochemical research including: a comparison of the generation potential of the argillaceous Pleistocene and calcareous Cretaceous strata; an examination of the hydrocarbon source potential of the deep-water Cretaceous section in the Gulf of Mexico; and an examination of the geochemical character of the "hydrocarbon" staining observed within a deep-water, fine-grained, fractured limestone sequence. The primary aim of this paper is to provide a general overview of the organic geochemical character of the sediments upon which subsequent studies may be based. Eighty-six samples were selected for this study. Their stratigraphic distribution is summarized in Figure 1. The analytical program was designed to provide general information on organic richness, organic character, and hydrocarbon source potential. The analytical scheme included organic carbon analysis, Rock-Eval pyrolysis, bitumen analysis, and elemental analysis of isolated kerogen.

ANALYTICAL METHODOLOGY

Upon receipt, each sample was oven-dried at 60°C and ground to approximately 325 mesh (44 μm). The organic carbon content (C_{org}) was determined on each sample using a LECO combustion system after decarbonating. The remainder of the analytical program was dependent upon both the level of organic enrichment and availability of sample material. All samples containing ≥ 0.5 wt.% organic carbon were subjected to pyrolytic assay using a Rock-Eval system as described by Espitalié et al. (1977). If sufficient sample material was available, kerogen was isolated and bitumen extracted. Isolated kerogen underwent elemental analysis (C, H, O, and N). Samples were soxhlet-extracted using an azeotropic mixture of methanol, acetone, and chloroform. The extracts were deasphaltened with pentane and fractionated using liquid column chromatography. Capillary gas chromatography was performed on the nonaromatic hydrocarbon fraction if its concentration was ≥ 100 ppm by weight of the rock.

Sample 535-59-2, 89-95 cm, which contained several "tar-filled" fractures, was not dried or ground. Fracture coatings were dissolved using the methanol, acetone, and chloroform mixture, then treated as an extract with respect to fractionation and chromatography.

ANALYTICAL RESULTS

Organic Carbon

The organic carbon contents were highly variable within the stratigraphic column, ranging from <0.10 to >11.00 wt.%. These results are summarized in Table 1 and Figure 1.

All of the Holocene/late Pleistocene samples analyzed contain above-average quantities of organic carbon (>0.3 wt.%) relative to deep-sea sediments (McIver, 1975). Within the Cretaceous, the richest samples were associated with finely laminated limestones of Valanginian to Aptian age. These samples typically contained between 1 and 2 wt.% carbon. The Cenomanian and Berriasian/ lower Valanginian strata, which were light colored and bioturbated, were organically lean, generally containing less than 0.3 wt.% organic carbon.

Rock-Eval Pyrolysis

Pyrolytic assay provides information on generation potential, expected hydrocarbon product (gas and/or oil), and thermal maturity. Pyrolysis results are also summarized in Table 1 and Figure 1.

The total generation potentials ($S_1 + S_2$: free distillable hydrocarbons + generatable hydrocarbons) in the analyzed Holocene/late Pleistocene samples were all less than 1 mg HC/g rock. A good source rock yields ≥ 6 mg HC/g rock (Tissot and Welte, 1978, p. 447). The total generation potentials for the analyzed Cretaceous samples ranged from 1.21 to 70.36 mg HC/g rocks. Those samples of good source-rock quality are of Hauterivian, Barremian, and Valanginian age.

An understanding of organic character, and thus hydrocarbon product, can be obtained from the hydrogen (mg S_2 HC/g C_{org}) and oxygen (mg CO_2/g C_{org}) indexes.
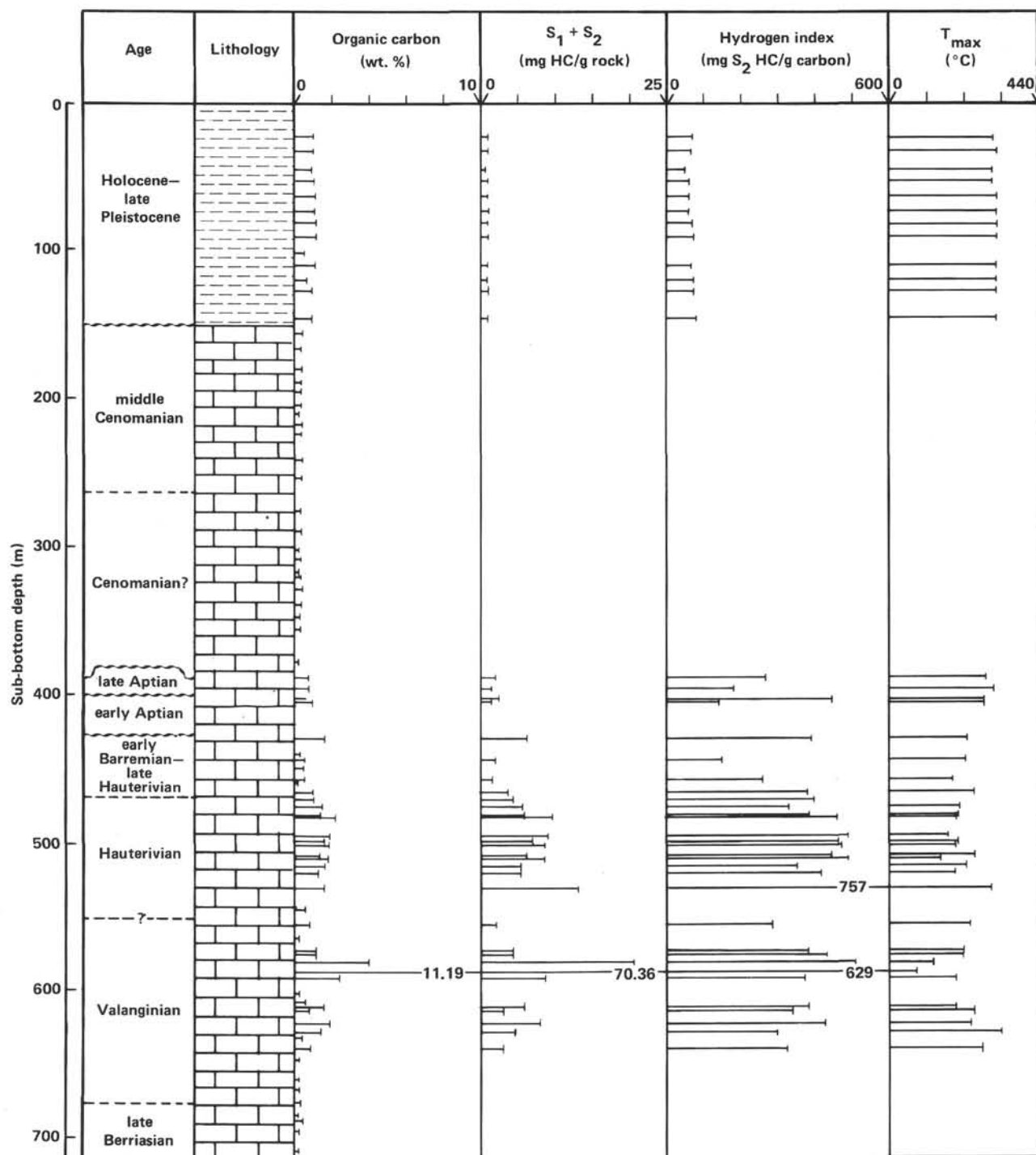
Figure 1. Stratigraphic summary, sample positions, organic carbon, and Rock-Eval pyrolysis data, Site 535.

These ratios provide information similar to the atomic H/C and O/C ratios (Espitalié et al., 1977). These data are presented in Table 1 and Figure 2.

The lowest hydrogen and highest oxygen indexes are associated with the Holocene/late Pleistocene samples (Fig. 2). These values are typical of samples containing either terrestrial organic matter (type III) or marine organic matter that has been severely oxidized. The Cretaceous samples yielded higher hydrogen indexes and lower oxygen indexes. These data plot between the type II reference curve, representative of marine organic matter deposited and preserved under anaerobic conditions, and the type III reference curve (Fig. 2). Both the oxygen and hydrogen indexes are influenced by factors in addition to organic matter composition. These factors include the level of organic enrichment and the mineral matrix (Katz, 1981). It is believed that the elevated oxygen index values (>100 mg CO_2/g C_{org}) of the Creta-

Table 1. Summary of organic carbon and pyrolysis data, Hole 535.

Core-Section (interval in cm)	Depth (m)	Organic carbon (wt.%)	S_1 (mg/g rock)	S_2 (mg/g rock)	HI[a]	OI[b]	T_{max} (°C)	TR[c]
4-2, 50–52	23.50	0.99	0.04	0.64	65	262	428	0.06
5-2, 50–52	33.00	1.05	0.05	0.69	65	247	429	0.07
6-4, 53–55	45.53	0.97	0.05	0.54	56	295	428	0.08
7-2, 50–52	52.00	1.00	0.04	0.59	59	260	428	0.06
8-4, 50–52	64.50	1.02	0.05	0.61	60	270	429	0.08
9-3, 50–52	72.50	1.15	0.05	0.69	60	219	428	0.07
10-3, 52–54	82.02	1.08	0.04	0.72	67	243	428	0.05
11-3, 50–52	91.50	1.14	0.04	0.74	64	228	428	0.05
12-4, 50–52	102.50	0.49						
13-3, 52–54	110.52	1.06	0.04	0.64	61	245	429	0.06
14-2, 50–52	118.50	0.61	0.06	0.44	72	472	429	0.12
15-2, 53–55	128.03	0.87	0.05	0.62	72	314	429	0.07
17-1, 100–102	146.00	0.88	0.05	0.67	80	318	429	0.07
18-2, 51–56	156.51	0.33						
19-3, 55–66	167.55	0.29						
20-5, 50–55	180.00	0.34						
21-4, 50–55	188.00	0.34						
22-2, 52–59	194.52	0.31						
23-2, 98–103	204.48	0.25						
23-5, 100–105	209.00	0.16						
24-3, 57–62	215.07	0.33						
25-2, 50–55	223.00	0.33						
27-1, 100–105	241.00	0.37						
28-3, 50–53	253.00	0.31						
30-5, 50–55	275.00	0.19						
31-1, 50–55	278.50	0.20						
31-4, 50–55	283.00	0.24						
32-2, 50–55	289.50	0.34						
33-3, 50–55	300.50	0.13						
34-2, 50–55	308.50	0.21						
35-2, 50–55	318.00	0.09						
35-4, 77–82	321.27	0.22						
36-5, 19–24	331.69	0.36						
37-3, 60–85	338.60	0.38						
38-3, 70–76	348.20	0.13						
39-2, 50–55	356.00	0.32						
41-4, 90–95	378.40	0.15						
42-4, 90–95	387.90	0.65	0.03	1.69	261	242	426	0.02
43-2, 51–56	394.01	0.65	0.05	1.16	179	255	428	0.04
44-1, 31–39	401.31	0.56	0.06	2.49	444	206	426	0.02
44-2, 35–42	402.85	0.94	0.07	1.31	140	248	424	0.05
46-1,100–105	420.00	0.02						
47-1, 86–96	428.86	1.53	0.07	6.06	396	95	421	0.01
48-2, 90–95	439.40	0.22						
48,CC	443.80	0.59	0.06	1.98	336	141	421	0.03
49-2, 100–105	448.50	0.43						
50-2, 85–90	457.35	0.50	0.03	1.32	264	210	418	0.02
50-3, 100–105	458.00	0.12						
51-2, 20–25	465.70	0.93	0.05	3.61	388	125	423	0.01
51-4, 100–105	469.50	1.02	0.04	4.05	401	140	418	0.01
52-1, 86–91	473.86	1.57	0.06	5.17	330	118	419	0.01
53-3, 32–37	480.82	1.46	0.06	5.58	382	116	419	0.01
53-3, 117–122	481.86	2.16	0.07	9.64	447	96	418	0.01
54-6, 73–78	495.23	1.89	0.06	9.22	488	84	416	0.01
55-2, 5–10	498.05	1.60	0.05	6.94	463	120	418	0.01
55-4, 43–50	501.43	1.81	0.06	8.49	469	93	418	0.01
56-2, 130–135	508.80	1.33	0.05	5.93	446	123	423	0.01
56-5, 62–72	512.62	1.69	0.05	8.14	482	91	413	0.01
57-3, 6–11	518.56	1.51	0.03	5.19	344	90	420	0.01
57-4, 45–53	520.45	1.23	0.05	5.11	416	101	418	0.01
58-4, 8–15	529.58	1.47	1.67	11.12	757	59	427	0.13
60-3, 50–55	546.50	0.33						
61-3, 50–55	555.50	0.58	0.05	1.68	289	227	422	0.03
62-3, 50–55	564.50	0.10						
63-2, 55–60	572.05	1.08	0.05	4.16	385	117	420	0.01
63-4, 92–97	575.42	0.98	0.05	4.20	425	132	420	0.01
64-2, 119–124	581.69	3.94	0.10	20.06	509	46	412	0.00
64-6, 50–55	587.00	11.19	0.00	70.36	629	27	407	0.00
65-3, 0–5	591.00	2.32	0.07	8.52	367	84	418	0.01
66-3, 50–55	600.60	0.18						
67-2, 25–30	607.75	0.49						
67-4, 75–80	611.25	1.49	0.05	5.73	384	110	418	0.01
68-2, 65–70	612.65	0.75	0.04	3.27	436	133	423	0.01
69-3, 20–25	622.70	1.90	0.06	8.08	425	82	422	0.01
69-6, 90–95	627.90	1.43	0.04	4.22	295	111	430	0.01
70-3, 15–20	631.65	0.29						
71-1, 62–65	638.12	0.93	0.06	2.98	321	149	425	0.02
72-1, 50–55	647.00	0.20						
73-3, 70–75	659.20	0.01						
74-2, 50–55	666.50	0.17						
75-1, 100–105	674.50	0.23						
76-1, 141–146	683.91	0.11						
76-3, 43–48	685.93	0.44						
77-2, 50–55	693.50	0.19						
79-2, 86–91	707.36	0.01						

Note: Blanks in the pyrolysis columns indicate no analysis because organic carbon content was less than 0.5 wt.%.
[a] Hydrogen index = mg S_2 hydrocarbons/g organic carbon.
[b] Oxygen index = mg CO_2/g organic carbon.
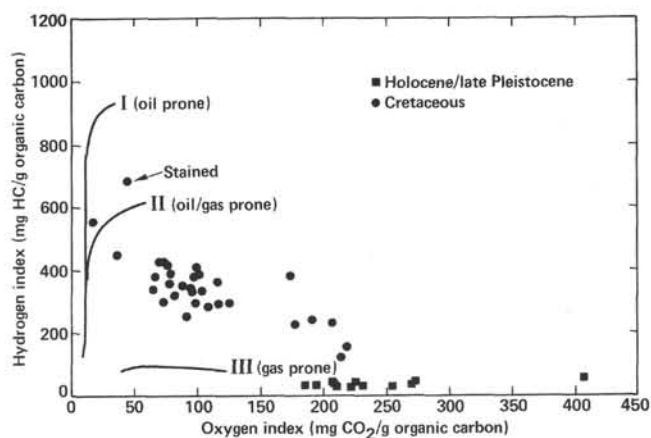[c] Transformation ratio = $S_1/(S_1 + S_2)$.

Figure 2. Modified Rock-Eval Van Krevelen-type diagram, Site 535.

ceous samples have resulted from matrix interference. Interference from these factors is not a problem with organic matter characterizations made from elemental analyses as will be pointed out later.

Pyrolysis also provides two measures of thermal maturity: the transformation ratio $[S_1/(S_1 + S_2)]$ and T_{max}, the temperature at which maximum hydrocarbon generation occurs. The T_{max} values, which are all less than 435°C (Table 1 and Fig. 1), and the transformation ratios (Table 1), which are generally less than 0.10, indicate that the organic matter, including that contained within the Lower Cretaceous strata, is thermally immature and has not entered the main stage of hydrocarbon generation and expulsion.

Bitumen Characterization

Soxhlet extraction yielded total bitumens ranging between 402 and 18,555 ppm by weight (Table 2). Yields of

Table 2. Summary of extraction and liquid chromatographic data, Hole 535.

Core-Section (interval in cm)	Depth (m)	Total yield (ppm)	Asphaltenes (%)	NSOs (%)	Nonaromatics (%)	Aromatics (%)
42-4, 90–95	387.90	558	23.8	27.0	27.0	22.2
43-2, 51–56	394.01	493	39.5	21.0	18.4	21.1
44-1, 31–39	401.31	552	44.3	21.6	14.8	19.3
44-2, 35–42	402.85	594	37.7	23.3	13.0	26.0
47-1, 86–96	428.86	899	61.3	20.8	5.8	12.1
48,CC	443.80	507	40.5	29.7	10.7	19.1
50-2, 85–90	457.35	402	42.4	13.7	29.3	14.6
51-2, 20–25	465.70	793	51.9	35.8	3.8	8.5
51-4, 100–105	469.50	770	57.5	24.0	6.4	12.1
52-1, 86–91	473.86	1147	59.7	25.0	3.9	11.7
53-3, 32–37	480.82	1176	57.5	30.5	5.4	6.6
53-3, 117–122	481.67	1623	64.6	26.9	4.5	4.0
54-6, 73–78	495.23	1746	62.6	33.5	3.9	6.0
55-2, 5–10	498.05	1305	55.6	34.1	2.8	7.8
55-4, 43–50	501.43	1544	64.3	25.0	4.1	6.6
56-2, 130–135	508.80	1065	59.0	28.0	3.6	9.4
56-5, 62–72	512.62	1385	66.7	25.0	3.9	5.3
57-3, 6–11	518.56	1069	54.5	34.9	3.2	7.4
57-4, 45–53	520.45	1115	64.9	27.6	2.7	4.8
58-4, 8–15	529.58	18555	55.5	17.2	3.9	23.4
61-3, 50–55	555.50	442	46.8	36.1	4.3	12.8
63-4, 92–97	575.42	674	49.6	34.5	5.0	10.9
64-2, 119–124	581.69	3158	64.1	17.7	6.8	11.4
64-6, 50–55	587.00	10837	77.7	12.3	2.0	8.0
65-3, 0–5	591.00	2158	73.3	15.2	3.6	7.9
67-4, 75–80	611.25	902	53.9	30.7	3.9	11.5
68-2, 65–70	612.65	784	49.1	26.8	6.5	17.6
69-3, 20–25	622.70	1191	53.7	28.8	5.3	12.2
69-6, 90–95	627.90	876	50.7	34.6	4.7	10.0

>1000 ppm are indicative of potential source facies (Geo-Chem Laboratories, Inc., 1980) and are restricted to the Hauterivian and Valanginian strata. The bitumens are dominated by nonhydrocarbon compounds (precipitated asphaltenes and soluble NSOs). The predominance of nonhydrocarbon compounds, the low (commonly less than 1.0) nonaromatic-to-aromatic ratios, and the low percentage of nonaromatic hydrocarbons (commonly less than 10%; Table 2) are characteristic of thermally immature sediments (Héroux et al., 1979).

The anomalously high extractable yield of Sample 535-58-4, 8–15 cm (18,555 ppm; Hauterivian) relative to its organic carbon content (1.47 wt.%) indicates that this sample has been stained and/or contaminated. Sample 535-58-4, 8–15 cm exhibits an unusually high S_1 hydrocarbon yield that is also suggestive of the presence of nonindigenous soluble material. The nonaromatic fraction gas chromatogram (Fig. 3A) is characterized by the absence of n-paraffins, the presence of a slight "naphthene hump," and an enrichment of steranes and triterpanes. This chromatographic pattern is not typical of immature bitumens obtained elsewhere in the section (Fig. 3B), although there are similarities in the higher carbon-number range. The typical immature pattern is bimodal, dominated by the isoprenoids pristane and phytane, and steranes and triterpanes in the C_{27} to C_{33} range.

Samples 535-64-2, 119–124 cm (Valanginian) and 535-64-6, 50–55 cm (Valanginian) also exhibit high total extractable yields (3158 and 10,837 ppm, respectively) relative to their organic carbon contents (3.94 and 11.19 wt.%, respectively). These relative yields are also suggestive of staining and/or contamination. Additionally, the nonaromatic-fraction chromatogram of Sample 535-64-2, 119–124 cm (Fig. 3C) is atypical of immature bitumens. The pattern is more characteristic of a thermally mature crude oil, exhibiting a harmonic decrease in n-paraffins from C_{17} to C_{32} with only minor amounts of isoprenoids, steranes, and triterpanes present.

Seventy-one milligrams of the "tarry" fracture-filling material was obtained from Sample 535-59-2, 89–95 cm (Hauterivian; 536.39 m). The gross composition of this material shows only a slight enrichment in hydrocarbons (nonaromatics 6.8%; aromatics 27.6%) compared to the extracted bitumens of the other samples studied. However, the tar is dominated also by nonhydrocarbon components (asphaltenes 45.5%; NSO's 20.1%). The gas chromatogram (Fig. 3D) is bimodal. Unlike the immature bitumen (Fig. 3B), pristane and phytane do not dominate the n-paraffins, and there is a marked increase in the abundance and number of steranes and triterpanes as well as an increase in the size of the "naphthene hump." A genetic relationship between this "tarry" material and the "mature" material (Sample 535-64-2, 119–124 cm) is suggested by the similarity of their normalized n-paraffin distributions (Fig. 4).

Elemental Analysis

Elemental compositions of the kerogen isolates from the Cretaceous strata are presented in Table 3 and Figure 5. The H/C and O/C atomic ratios are typical of type II
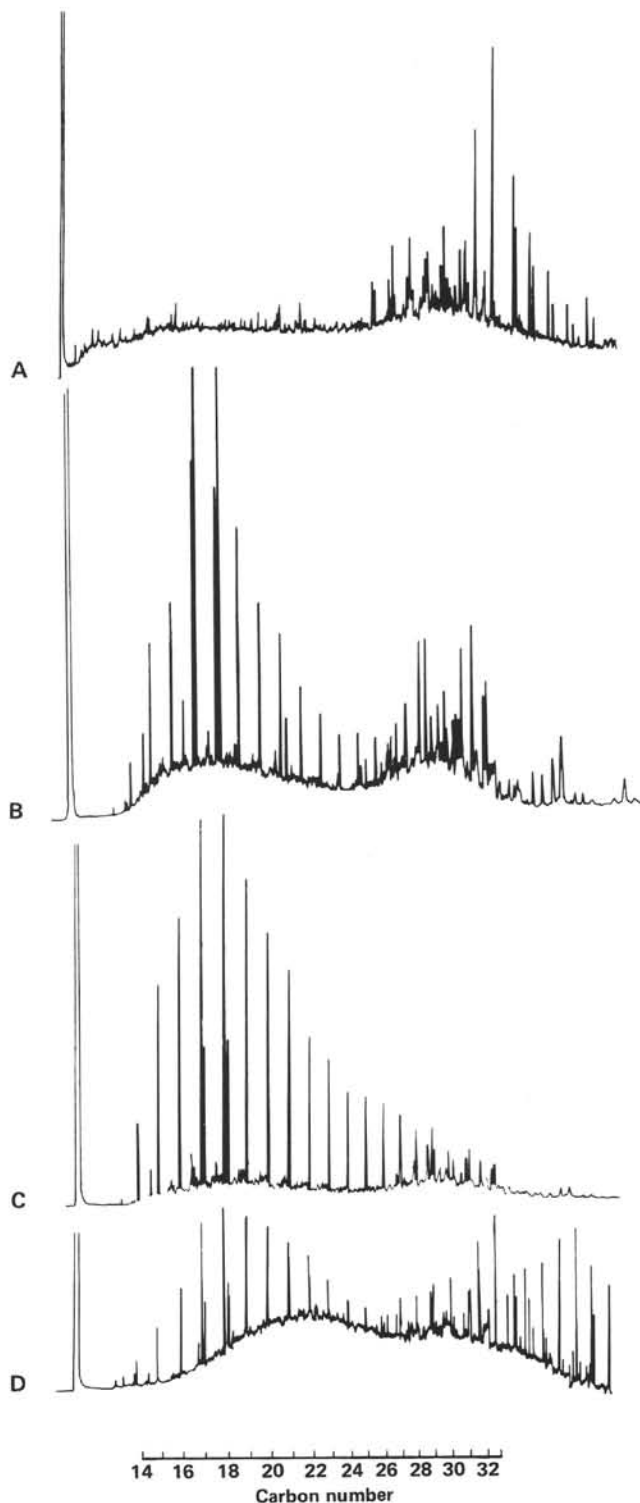

Figure 3. $C_{15}+$ nonaromatic hydrocarbon fraction chromatograms. A. Sample 535-58-4, 8–15 cm (529.58 m) from within the fractured interval. B. Sample 535-67-1, 25–30 cm (607.75 m) represents typical pattern obtained outside the fractured interval. C. Sample 535-64-2, 119–124 cm (581.69 m) pattern is similar to that of a thermally mature crude oil. D. Sample 535-59-2, 89–95 cm (536.39 m) represents extracted "tar" from the fractured interval.
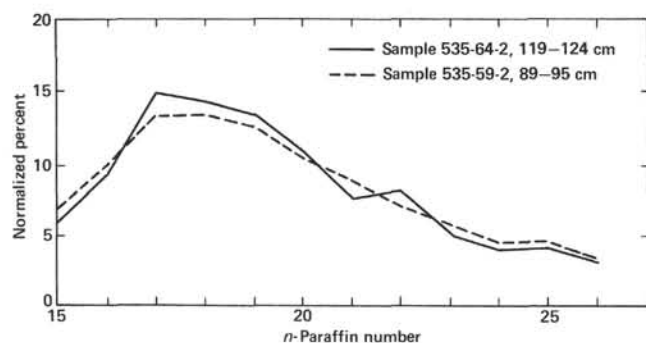
Figure 4. Normalized *n*-paraffin distribution.

Table 3. Elemental composition of kerogen isolates, Hole 535.

Core-Section (interval in cm)	Depth (m)	H (wt.%)	C (wt.%)	O (wt.%)	N (wt.%)	Ash (wt.%)	Atomic ratios H/C	O/C
18-2, 51–56	156.51	7.1	65.3	15.0	2.2	1.5	1.31	0.173
20-5, 50–55	180.00	7.1	62.3	12.7	2.2	4.6	1.38	0.153
21-4, 50–55	188.00	7.2	62.1	12.9	1.9	7.7	1.39	0.156
22-2, 52–59	194.52	8.1	66.3	10.8	1.7	4.9	1.47	0.122
24-3, 57–62	215.07	7.7	65.7	11.4	1.9	4.8	1.40	0.130
25-2, 50–55	223.00	7.3	65.3	12.9	2.0	4.0	1.34	0.148
27-1, 100–105	241.00	7.5	66.2	11.8	2.2	24.3	1.35	0.133
28-3, 50–55	253.00	7.6	66.9	10.7	2.2	4.0	1.36	0.119
32-3, 50–55	229.50	ND	ND	ND	ND	50.41	ND	ND
36-5, 19–24	331.69	7.1	66.2	13.2	1.9	0.7	1.29	0.150
37-3, 60–85	338.60	7.4	66.6	11.7	1.8	2.6	1.34	0.132
39-2, 50–55	356.00	5.6	55.9	13.2	1.9	9.8	1.21	0.177
42-4, 90–95	387.90	6.7	65.9	10.8	1.9	4.4	1.21	0.123
43-2, 51–56	394.01	6.2	58.3	10.2	1.7	4.2	1.28	0.131
44-1, 31–39	401.31	6.3	65.2	11.8	3.7	1.2	1.17	0.136
44-2, 35–42	402.85	ND	ND	ND	ND	39.9	ND	ND
47-1, 86–96	428.86	6.6	66.3	10.4	3.0	0.0	1.19	0.118
48,CC	443.80	6.6	63.4	IS	2.7	15.0	1.24	IS
49-2, 100–105	448.50	7.6	67.8	9.8	2.1	1.3	1.34	0.109
50-2, 85–90	457.35	5.4	54.1	9.9	2.0	9.2	1.19	0.137
51-2, 20–25	465.70	6.6	64.0	11.3	2.6	3.9	1.24	0.133
51-4, 100–105	469.50	6.2	57.9	9.9	3.9	8.0	1.28	0.128
52-1, 86–91	473.86	5.2	50.2	9.4	2.5	17.7	1.25	0.140
53-3, 32–37	480.82	ND	ND	ND	ND	35.8	ND	ND
53-3, 117–122	481.86	6.2	58.8	9.7	2.2	4.3	1.26	0.124
54-6, 73–78	495.23	6.6	62.4	10.5	2.3	0.0	1.27	0.126
55-2, 5–10	498.05	6.1	56.8	10.8	2.0	8.1	1.29	0.142
55-4, 43–50	501.43	6.7	62.7	9.6	2.4	2.2	1.29	0.115
56-2, 130–135	508.80	5.8	54.8	9.4	2.0	11.1	1.28	0.128
57-3, 6–11	518.56	7.7	43.0	7.5	1.5	18.4	1.30	0.131
57-4, 45–53	520.45	6.6	60.8	10.5	2.2	6.3	1.31	0.129
58-4, 8–15	529.58	5.2	48.1	8.5	1.5	7.1	1.28	0.130
60-3, 50–55	546.50	6.9	61.2	11.3	1.9	7.2	1.33	0.137
61-3, 50–55	555.50	5.9	54.1	9.6	1.9	9.6	1.29	0.134
63-2, 55–60	572.05	6.9	62.4	10.9	2.2	0.5	1.31	0.131
63-4, 92–97	575.42	6.6	60.5	10.2	2.1	7.8	1.30	0.126
64-2, 119–124	581.69	7.3	64.5	10.4	2.2	0.7	1.35	0.121
64-6, 50–55	587.00	7.3	65.0	10.3	2.2	0.0	1.36	0.119
65-3, 0–5	591.00	6.5	60.9	11.1	2.2	7.9	1.27	0.136
67-2, 25–30	607.75	5.9	54.7	9.7	2.0	13.5	1.30	0.133
67-4, 75–80	611.25	6.5	58.6	10.2	2.0	9.6	1.32	0.131
68-2, 65–70	612.65	5.4	49.2	9.9	1.7	5.9	1.31	0.151
69-3, 20–25	622.70	7.3	68.5	10.0	2.7	2.9	1.28	0.109
69-6, 90–95	627.90	5.6	51.3	9.0	2.3	12.2	1.31	0.132
71-1, 62–65	638.12	6.5	60.7	10.7	2.4	5.1	1.29	0.132

Note: ND = ash content too high for reliable elemental determination; IS = insufficient sample for oxygen determination.

kerogens, clustering about the reference curve on the Van Krevelen diagram. These data are indicative of marine material deposited and preserved under anoxic conditions.

A comparison of the relative position of these data (Fig. 5) with Rock-Eval data (Fig. 2) on their respective Van Krevelen diagrams demonstrates the problems noted earlier. The Rock-Eval data appear less hydrogen-enriched and more variable with respect to oxygen enrichment than indicated by the elemental data upon which the characterization scheme was developed.
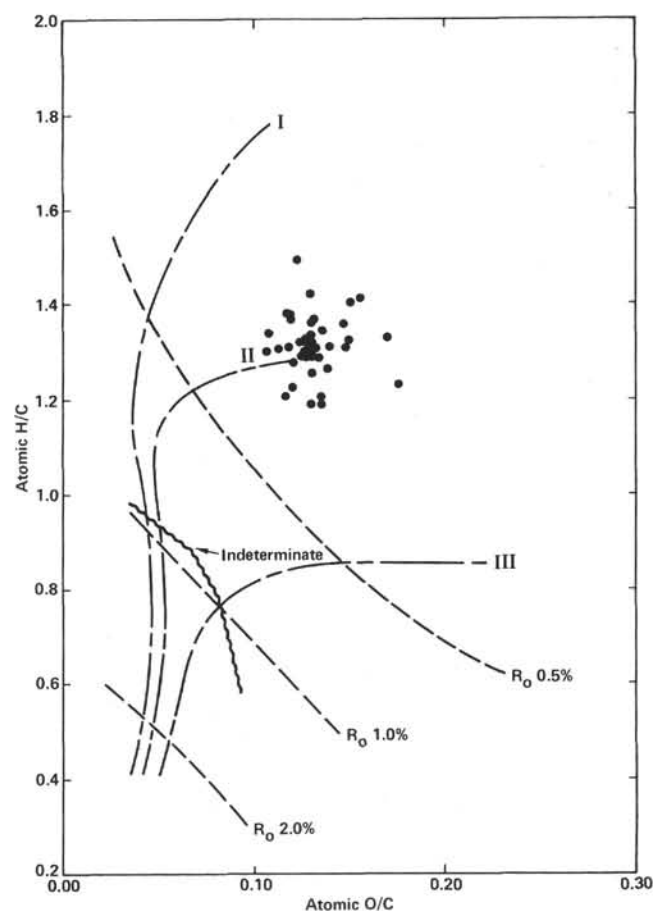
Figure 5. Elemental Van Krevelen diagram, Site 535, with approximate iso-values of vitrinite reflectance (R_o).

DISCUSSION

The analytical data obtained from the Holocene/late Pleistocene and Cretaceous sediments reflect differences in both the type of preserved organic matter and the hydrocarbon-generating potential of the sediments. The capability to generate hydrocarbons is minimal in the Holocene/late Pleistocene section because of the organic character and mineral matrix. The Holocene/late Pleistocene organic matter of Site 535, similar to the sedimentary organic matter of the Tertiary section in the Gulf of Mexico basin, is hydrogen-depleted. This depletion has resulted from both deposition in an oxygenated environment (i.e., poor preservation) and a large influx of terrestrially derived material. The high surface activity of the clay matrix tends to inhibit the expulsion of heavy hydrocarbons (Espitalié et al., 1980). Thus, the amount of hydrocarbons available for pooling is reduced, and the measured generation potentials are low.

In contrast, the properties of the Cretaceous section tend to maximize its capability to generate hydrocarbons. The preserved organic matter is hydrogen enriched. This enrichment is a consequence of better preservation and the lack of significant dilution by hydrogen-poor, terrestrially derived organic matter. The low specific surface activity of the calcium-carbonate matrix permits the retention of only small quantities of heavy hydrocarbons

(Espitalié et al., 1980). Thus, the measured generation potentials are high, and significant quantities of hydrocarbons could become available for pooling. The Cretaceous section, however, is thermally immature and has not reached sufficient levels of thermal maturity for the generation and expulsion of hydrocarbons.

The source quality of the Valanginian to Barremian section is further enhanced by the heterogeneity of the rock, manifested as dark laminae, rich in organic matter and light laminae, poor in organic matter. The concentration of organic matter in such a fashion improves the efficiency of the hydrocarbon generation process by providing an efficient expulsion system (Momper, 1978).

CONCLUSIONS

1. The finely laminated limestones of Valanginian to Barremian age represent potential oil-prone source facies of good to excellent quality.

2. At Site 535, these organic-matter-rich units have not undergone sufficient organic diagenesis for the generation and expulsion of oil to have occurred.

3. Mature hydrocarbon staining was detected within a fractured interval of Hauterivian and Valanginian age.

4. These hydrocarbon stains represent migration from thermally mature source facies.

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