25. GEOCHEMISTRY OF CARBON: DEEP SEA DRILLING PROJECT LEGS 58 AND 59

Karl S. Schorno, Phillips Petroleum Company, Bartlesville, Oklahoma

INTRODUCTION

I obtained 68 quarter sections of cores from the JOIDES Organic Geochemistry Panel for studying type, distribution, and stages of organic diagenesis of sedimentary organic matter in the West Philippine and Parece Vela basins and Mariana Trough area (Figure 1). The present chapter compares (1) 11 geochemical parameters used to determine organic source and its stage of genesis within the 9 site locations in this study area and (2) compares these 11 with the same parameters reported from Leg 56, outer trench slope of the Japan Trench, and Leg 60, Mariana Trough and Trench (Schorno, in press a, b). Even though these sediments are considered pelagic, the organic content in most of the core sections appears to be hemipelagic. The sedimentary organic matter in these cores is believed to be in an early stage of diagenesis. Both conclusions are based primarily on the *n*-alkane distribution within the organic matter. This particular parameter, I note later, has a major weakness. As Hunt (Hunt, 1979) and I (in press b) observed, marine organisms synthesize *n*-alkanes with distributions containing neither odd nor even preferences. Thus those sediments that did contain *n*-alkane distributions with $\overline{OEP}$ near 1, suggesting a late stage of catagenesis, may in actuality be immature marine sediments.

SAMPLING AND STUDY PROCEDURES

The sampling procedure used in this study is shown schematically in Figure 2. The frozen quarter sections were crushed to $\leq 150\ \mu m$ (100 mesh) and an aliquot analyzed for organic and inorganic carbon and nitrogen by oxidative-combustion and Kjeldahl procedures, respectively. The crushed core was soxhlet-extracted with methylene chloride and the solvent removed at 45°C at atmospheric pressure. Because of the paucity of extract in these organic-lean cores, the analysis of the extract is limited to a capillary gas chromatography and stable carbon isotope determinations.

RESULTS AND DISCUSSION

The organic geochemical data appear in Tables 1 and 2 and the average values for each set of data for each site in Table 3. The following sections will be broken into a discussion of each of five organic chemical properties—the organic content, *n*-alkane content, ratio of pristane to phytane, stable carbon isotopic compositions of both bitumen and kerogen fractions, and the organic nitrogen content—of these cores. Finally, the average values of 11 geochemical properties of these cores are compared with similar averaged values from sediments from the Mariana Trough and Trench recovered during Leg 60 and the outer trench slope from the Japan Trench recovered during Leg 56.

Figure 1. Location of sites from which samples were obtained for geochemical study.

Organic Content

The organic content of the 68 cores obtained for this study is low, averaging 0.12% and ranging from 0.01% to 0.33%. Variations in the values of organic carbon within each site or among sites may be significant or may reflect only the precision of this particular measurement. We can reproduce the total organic carbon (TOC) content to 0.01%. However, the values given in Table 1 are based on a single measurement. There is a possibility that the sample is slightly inhomogeneous, which could account for slight fluctuation in the TOC. Even though these values are low, there is an apparent trend in the organic carbon content in Holes 442A, 442B, 443, 444, and 444A in the Shikoku Basin, and in Hole 445, in the small basin in the Daito Ridge. The trend appears to be real in that the organic carbon content of the Pleistocene sediments at these locations is slightly higher than that of the lower units. Moreover, the organic carbon content of the remaining cores from the study area is relatively constant and near the average value for all of the sites.

The bitumen content reflects the low TOC content within each site. Because the amount of TOC is less than 3300 ppm (0.33%), the bitumen content of course cannot be greater. The bitumen content ranges from a low of 3 ppm (Sample 449-13-4) to a high of 440 ppm (Sample 450-2-5). TOC content for these two samples is 2200 ppm and 3200 ppm, respectively. Of the 68 cores studied, only 4 contain over 100 ppm bitumen. Of the remaining 64 cores, the average bitumen content is 24 ppm.

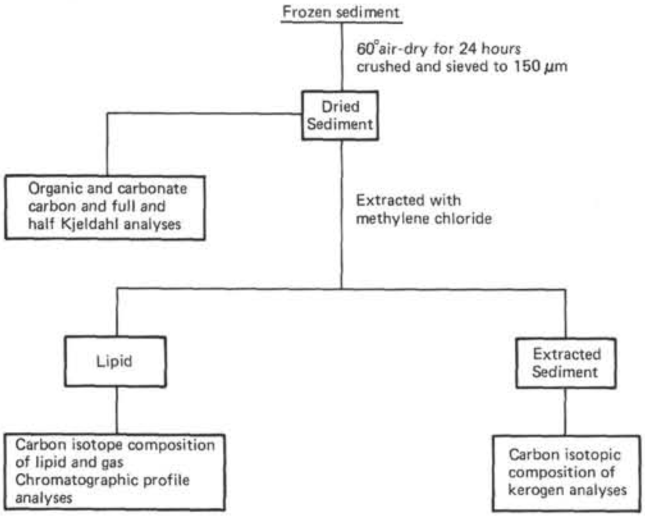

Figure 2. Flow sheet for the separation and characterization of organic matter from DSDP cores from Legs 58 and 59.

The portion of the TOC that is bitumen carbon varies from a high of 31.6 (Sample 444A-9-3) to a low of 0.11% (Sample 445-42-5). Only 10 out of 67 of the values given in Table 1 are greater than 10%. Of these 10, the TOC content of 9 is less than 0.05%. Because the content is so low, only a trace amount of contaminant, such as soluble sulfur, can have had a signficant effect on this value. Thus the high percentage of bitumen in these few cores may be suspect. The average percentage of bitumen in the remaining cores is 1.59, a typical value for most bitumen fractions of DSDP-IPOD cores that contain immature organic matter.

n-Alkane Content

The discussion of the *n*-alkane content is divided into two sections. The first deals with the study of the relative abundance of marine versus terrestrial organic matter within the cores as given in the *S*-value $S = (n\text{-}C_{21} + n\text{-}C_{22})/(n\text{-}C_{28} + n\text{-}C_{29})$ (Philippi, 1974). According to Philippi, the range of *S*-values for crudes and their terrigenous rocks is from 0.6 to 1.2 and for marine rocks from 1.5 to 5. The second describes the difficulty in using *n*-alkane distributions for determining maturation stages of purely marine sediments. A well-accepted maturation parameter is the ratio of odd to even *n*-alkanes in the range from $n\text{-}C_{23}$ to $n\text{-}C_{35}$. This ratio is described by a mathematical expression ($\overline{OEP}$) developed by Scalan and Smith (1970):

$$\overline{OEP} = \left[\frac{C_i + 6C_{i+2} + C_{i+4}}{4C_{i+1} + 4C_{i+3}}\right](-1)^{i+1}.$$

In this case, organic matter in the major stage of genesis, the catagenesis stage (Tissot and Welte, 1978), is described by an $\overline{OEP}$ of less than 1.3. Sedimentary organic matter containing $\overline{OEP}$ values greater than 1.3 are considered immature—that is, in the diagenetic stage. As I point out in the next section, both *S* and $\overline{OEP}$ are suspect for the particular usage outlined in the foregoing for pure marine sediments.

The amount of terrigenous organic matter within these sediments as inferred by *S* less than 1 is high in 36 of the 68 cores. Of the 68 cores, 25 contained *S* greater than 1 but less than 1.5, and 7 contained *S* values greater than 1.5. In many cases where *S* is low, the *n*-alkane distribution from $n\text{-}C_{15}$ to $n\text{-}C_{35}$ has a minimum of approximately $n\text{-}C_{22}$. In several cases the maximum at $n\text{-}C_{18}$ is larger than the second maximum at $n\text{-}C_{28}$, suggesting that the Philippi selection (1974) for the *n*-alkanes for representing marine-derived organic matter was poor.

According to the maturation interpretation placed upon $\overline{OEP}$ values, 45 of the 65 cores analyzed are in the diagenetic stage of maturation ($\overline{OEP} > 1.3$). The remaining 20 sediments are in the catagenetic to metagenetic stages of maturation ($\overline{OEP} < 1.3$). In the latter case there is some evidence of igneous intrusions in the study area that could explain the higher stages of maturation. Because these are limited to at most two of these sediments, I believe that the low values are due to the occurrence of *n*-alkanes with neither odd nor even preferences—that is, they are included in the original sedimentary organic matter. Two examples are reported in the literature of immature open marine sediments containing $\overline{OEP}$ values of near 1. These are the Cariaco Trench sediments reported by Hunt (1979) and the Mariana Trough and Trench sediments reported by me (Schorno, in press b). Presumably, marine organisms can synthesize high molecular weight *n*-alkanes that have $\overline{OEP}$-values near 1.

Pristane to Phytane Ratio (Pr/Ph)

In the past, the ratio of pristane to phytane (Pr/Ph) has been used to distinguish marine from terrigenous organic matter or, more accurately, from organic matter derived in an oxidizing versus reducing environment of deposition (Lijmbach, 1975; Powell and McKirdy, 1973). By empirical observation it was noted that marine-derived organic matter contained a predominance of phytane (Pr/Ph less than 1) and that for terrigenous-derived organic matter Pr/Ph is greater than 1.5. Of the 68 samples studied, 60 contain Pr/Ph less than 1, indicating either a predominance of marine organic matter or a reducing environment of deposition.

Carbon Isotopic Composition of the Bitumen and Kerogen Fractions[1]

The number of samples for which carbon isotopic composition determinations are reported is small for the bitumen fraction because of limited sampling, whereas all but six values are reported for the kerogen. Of the

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[1] Carbon isotopic composition is reported herein by $\delta^{13}C_{PDB}$. *PDB* is the carbonate standard from the Pee Dee Formation in North Carolina.

$$\delta^{13}C_{PDB} = \left[\frac{{}^{13}C/{}^{12}C\text{ sample} - {}^{13}C/{}^{12}C_{PDB}}{{}^{13}C/{}^{12}C_{PDB}}\right] \times 1000$$

Table 1. Geochemical data from frozen core sections from DSDP Legs 58 and 59.

					Carbonate		Organic Carbon			$\overline{OEP}$	Carbon Isotopic Composition ($\delta^{13}C_{PDB}$)			Kjeldalh Nitrogen (ppm)		Atomic Ratio
Core	Section	Interval (cm)	Chronostratigraphy	Sub-bottom Depth (m)	Carbon (wt. %)	As $CaCO_3$ (wt. %)	Total (wt. %)	Bitumen (ppm)	Bitumen / TOC (wt. %)		Bitumen	Kerogen	Diff. B − K	Ammonium Nitrogen (half)	Organic N (full-half)	Organic C / Organic N
						West-central part of the Shikoku Basin										
Leg 58																
Hole 442A, Unit I																
2	3	93–118	upper Pleistocene	13.8	0.38	3.15	0.23	28	1.73	3.1	−26.4	−23.3	−3.1	84	516	5
7	3	100–125	upper Pleistocene	61	0.63	5.2	0.30	17	0.58	2.3	—	−11.8	—	45	662	5
14	2	100–125	upper Pleistocene	127.5	0.28	2.33	0.15	34	2.25	1.7	−27.0	−23.0	−4.0	48	595	3
Hole 442A, Unit II, Sub-unit IIA																
19	2	100–125	upper Pliocene	173.5	0.32	2.68	0.03	5	1.88	3.0	—	−24.2	—	30	494	1
19	2	125–150	upper Pliocene	174.7	0.11	0.91	0.33	7	0.34	2.0	−25.8	−25.7	−0.1	26	417	9
Hole 442A, Unit III, Sub-unit IIIA																
23	2	100–125		211.8	0.25	0.04	0.06	111	19.91	—	−26.5	−25.6	−0.9	16	477	2
23	2	125–150		213	0.34	2.83	0.05	35	7.19	2.2	−26.4	−27.0	+0.6	36	478	1
28	2	100–125	middle Miocene	259	0.03	0.28	0.29	20	0.70	1.7	−30.7	−22.1	−8.6	38	541	6
28	2	125–150	middle Miocene	260.5	0.08	0.67	0.01	23	23.3	1.9	−27.5	−26.4	−1.1	23	343	<1
Hole 442B, Unit III, Sub-unit IIIB																
2	3	100–125	lower Miocene	281	0.19	1.58	0.01	13	12.8	2.1	—	−27.9	—	12	30	4
						East-central part of the Shikoku Basin										
Hole 443, Unit IV, Sub-unit IVA																
23	3	100–125	upper Miocene	210.5	0.19	1.58	0.04	24	6	1.2	−26.5	—	—	35	455	1
31	3	100–125	upper Miocene	291	0.22	1.83	0.03	23	7.73	1.8	−26.6	−25.8	−0.8	33	340	1
34	2	100–125	upper Miocene	318	1.26	10.49	0.24	—	—	—	—	−28.2	—	24	266	1
Hole 444, Unit I, Sub-unit IA																
2	4	94–119	upper Pleistocene	11.5	0.44	3.67	0.31	35	1.13	1.5	−30.7	−22.8	−7.9	65	649	6
Hole 444, Unit II																
7	5	94–119	upper Pliocene	60.5	0.22	1.83	0.01	30	30.1	3.2	−25.8	−25.8	0.0	14	187	<1
Hole 444A, Unit III, Sub-unit IIIA																
1	4	100–125	upper Miocene	87.5	0.23	1.92	0.01	10	10.3	1.5	−30.7	−27.1	−3.6	28	247	<1
Hole 444A, Unit III, Sub-unit IIIB																
6	4	71–96	upper Miocene	134.7	0.20	1.67	0.01	10	10	1.9	−26.0	−26.9	+0.9	33	390	<1
9	3	90–115	upper Miocene	162	0.70	5.83	0.01	32	31.6	1.4	−27.2	−26.3	−0.9	31	257	<1
Hole 444A, Unit IV, Sub-unit IVB																
14	3	100–125	middle Miocene	209.3	0.59	4.92	0.01	15	14.5	—	−25.7	—	—	13	155	1
Hole 444A, Unit IV, Sub-unit IVC																
22	5	100–125	lower-middle Miocene	269.3	0.23	1.92	0.01	25	25.4	0.9	−27.2	−27.5	+0.3	22	192	<1
						Small Basin in the Daito Ridge										
Hole 445, Unit I, Sub-unit IA																
1	4	94–119	upper Pleistocene	4.0	5.32	44.37	0.23	119	5.25		−27.3	−21.9	−5.4	27	361	7
1	4	119–144	upper Pleistocene	5.5	5.94	49.50	0.29	111	3.89	1.5	—	−27.5	—	24	294	12
6	5	94–119	upper Pliocene	53.5	5.44	45.33	0.05	19	3.76	1.7	—	−25.0	—	33	240	2
Hole 445, Unit I, Sub-unit IB																
11	2	100–125	upper Pliocene	96.5	0.19	1.58	0.01	17	0.17	1.6	−27.0	−24.7	−2.3	22	173	<1
Hole 445, Unit II, Sub-unit IIA																
17	1	90–115	upper Miocene	152	0.19	1.58	0.01	21	20.6	4.2	−27.0	−23.8	−3.2	11	160	<1
23	4	0– 25	upper Miocene	212.5	0.96	8.00	0.01	17	0.17	4.5	−26.9	−24.8	−2.1	15	193	<1
27	4	94–119	upper Miocene	251.5	6.63	55.25	0.01	22	0.22	2.2	−25.3	−25.9	+0.6	23	252	<1
Hole 445, Unit II, Sub-unit IIB																
32	2	90–115	lower-middle Miocene	296	12.00	100.00	0.02	11	5.60		−24.7	−27.3	+2.4	15	105	2
Hole 445, Unit II, Sub-unit IIC																
37	4	90–115	upper Miocene	346	9.43	78.55	0.15	1	0.07	1.3	—	−27.7	—	21	178	10
42	5	100–125	upper Oligocene	395	10.24	85.33	0.01	11	0.11	1.2	−26.2	−26.1	−0.1	10	110	1
47	4	100–125	upper Oligocene	441.5	4.63	38.58	0.01	13	0.13	1.0	−26.0	−25.3	−0.7	10	70	2
52	4	100–125	upper Pleistocene	489	10.21	85.08	0.01	7	0.07	1.4	—	−26.8	—	23	40	3
Hole 445, Unit III																
60	3	100–125	upper Eocene	563.5	5.15	42.93	0.12	8	0.69	1.8	−26.0	−27.2	+1.2	36	7	200
Hole 445, Unit IV																
65	2	100–125	upper Eocene	610	0.14	1.16	0.17	11	0.81	1.5	−25.3	−27.1	+1.8	81	2	992
65	2	125–150	upper Eocene	611	0.33	2.73	0.14	4	0.26	1.9	—	−27.0	—	7	34	48
Hole 445, Unit V																
75	4	100–123	middle Eocene	706	2.49	20.72	0.05	3	0.59	2.6	—	−28.3	—	38	45	13
75	4	123–145	middle Eocene	708	2.74	22.86	0.06	2	0.33	1.5	—	−29.9	—	14	97	7
80	4	100–125	middle Eocene	753	1.37	11.43	0.19	2	0.10	2.2	—	−25.6	—	0	41	54
80	4	125–150	middle Eocene	754.5	1.72	14.31	0.12	2	0.16	1.6	—	−27.0	—	10	61	23
83	3	100–125	middle Eocene	781	0.82	6.83	0.23	10	0.44	1.4	−26.6	−26.2	−0.4	32	6	447
83	3	125–150	middle Eocene	782.5	0.69	5.76	0.18	3	0.16	1.0	—	−27.5	—	31	52	40
						Daito Basin south of the Daito Ridge										
Hole 446, Unit II																
3	5	90–115	Miocene	15	0.21	1.75	0.21	4	0.19	3.0	—	—	—	32	467	5
9	4	100–125	upper-lower Miocene	73.5	0.06	0.50	0.13	10	0.79	2.0	−25.5	−26.9	+1.4	17	238	6
14	4	94–119	middle Oligocene	121	0.01	0.08	0.24	19	0.80	1.1	−26.6	−27.6	+1.0		138	
Hole 446, Unit III, Sub-unit IIIA																
24	2	100–125	middle Eocene	213	0.08	0.67	0.13	9	1.08	1.3	−26.3	−28.6	+2.3	32	6	245
30	5	90–115	lower-middle Eocene	273	0.12	1.00	0.13	11	0.89	1.1	−26.3	−29.8	+3.5	18	11	138
34	5	90–115	lower-middle Eocene	312	0.07	0.58	0.15	11	1.57	1.2	−26.2	−28.9	+2.7	25	3	583
Hole 446, Unit IV																
41	2	90–115	lower-middle Eocene	273	0.81	6.75	0.14	5	0.35	1.7	—	−29.8	—	24	2	817
Hole 446A, Unit IV																
10	2	100–125	upper-lower Eocene	489	0.07	0.55	0.11	5	0.42	1.1	—	—	—	24	19	68
						Eastern side of the West Philippine Basin										
Leg 59																
Hole 447A, Unit III																
6	3	100–125	early-upper Oligocene	50.5	0.30	2.53	0.27	17	0.64	1.0	−26.4	−28.6	+2.2	19	43	73
6	3	125–150	early-upper Oligocene	51.5	0.37	3.06	0.17	6	0.32	1.0	—	−28.7	—	24	25	79

Table 1. (Continued).

					Carbonate		Organic Carbon				Carbon Isotopic Composition ($\delta^{13}C_{PDB}$)			Kjeldalh Nitrogen (ppm)		Atomic Ratio
Core	Section	Interval (cm)	Chronostratigraphy	Sub-bottom Depth (m)	Carbon (wt. %)	As $CaCO_3$ (wt. %)	Total (wt. %)	Bitumen (ppm)	$\frac{\text{Bitumen}}{\text{TOC}}$ (wt. %)	$\overline{OEP}$	Bitumen	Kerogen	Diff. B − K	Ammonium Nitrogen (half)	Organic N (full-half)	$\frac{\text{Organic C}}{\text{Organic N}}$
						Western edge of the Palau-Kyushu Ridge										
Hole 448, Unit I																
2	5	100-125	lower Miocene	12	8.70	72.49	0.14	19	1.37	1.3	−24.2	−27.0	+2.8	28	39	42
8	2	100-125	lower Miocene	64.5	9.84	82.00	0.12	10	0.88	1.1	−23.6	−26.5	+2.9	23	19	74
Hole 448, Unit II																
13	5	100-125	upper Oligocene	116.5	10.14	84.53	0.08	8	0.99	1.8	−25.4	−27.5	+2.1	25	9	104
19	2	100-125	upper Oligocene	169	5.31	44.24	0.10	10	1	1.5	−30.7	−27.4	−3.3	27	59	20
						Western side of the Parece Vela Basin										
Hole 449, Unit I																
2	3	100-125		4	0.16	1.33	0.24	10	0.42	0.9	−28.4	−25.7	2.7	42	66	42
Hole 449, Unit IV																
8	2	100-125		59.5	0.28	2.34	0.09	15	1.60	1.9	—	−28.6	—	36	29	36
Hole 449, Unit V																
13	4	100-125	lower Miocene	110	7.22	60.15	0.22	3	0.13	1.1	—	−27.0	—	27	34	76
						Eastern Side of the Parece Vela Basin										
Hole 450, Unit I, Sub-unit IA																
2	5	100-125	Pliocene	14.5	0.01	0.05	0.32	440	13.88	1.2	—	—	—	38	25	149
Hole 450, Unit II, Sub-unit IIA																
14	4	100-125	middle Miocene	126	0.28	2.36	0.08	14	1.69	1.5	—	−28.0	—	34	8	117
14	4	125-150	middle Miocene	127	0.58	4.82	0.001	9	0.90	1.1	−26.1	—	—	15	26	<1
19	5	100-125	middle Miocene	175	0.70	5.86	0.13	5	0.36	1.9	—	−28.1	—	13	57	27
19	5	125-150	middle Miocene	176	0.66	5.50	0.18	9	0.13	1.3	—	−28.1	—	21	33	64
30	3	100-125	middle Miocene	276	0.71	5.88	0.02	11	5.58	1.2	—	−28.0	—	36	35	7
30	3	125-150	middle Miocene	277	6.15	51.27	0.09	35	4.07	1.7	−27.9	−28.2	+0.3	18	81	13
						Eastern edge of the West Mariana Ridge										
Hole 451, Unit I																
2	5	100-125	Quaternary	12	0.21	1.75	0.27	15	0.55	1.6	—	−27.4	—	20	110	29
Hole 451, Unit II																
6	3	100-125	upper Miocene	46	1.09	9.08	0.11	11	1.00	1.6	—	−27.7	—	19	—	—
6	3	125-150	upper Miocene	47.3	2.63	21.91	0.03	4	1.06	1.4	—	−27.6	—	—	—	—

samples for which a bitumen value is reported, the averages of the $\delta^{13}C_{PDB}$ values for both the bitumen and kerogen are similar, −26.7 and −26.6, respectively. In the past, $\delta^{13}C_{PDB}$ values for the bitumen fraction have been used to characterize organic source. The common interpretation of these $\delta^{13}C_{PDB}$ values, at least for deltaic environments, is that terrestrial, brackish, and marine-derived organic matter falls into the following ranges: less than −30, −29 to −30, and greater than −29, respectively. In open marine environments the classification scheme breaks down. Nevertheless, very light δ-values (< -29) are indicative of primarily terrigenous organic matter. Based on this designation, the four samples, 442A-28-2, 444-2-4, 444A-1-4, and 448-19-2, contain primarily terrigenously derived organic matter ($\delta^{13}C_{PDB} = -30.7$, respectively).

The $\delta^{13}C_{PDB}$ values of the 62 kerogen fractions averaged −26.6 with a range from −21.8 to −29.9. Ten cores within this range contained kerogens with $\delta^{13}C_{PDB}$ values less than −25. All 10 are from the Shikoku Basin and the small basin in the Daito Ridge.

The isotopic composition of both the bitumen and kerogen is similar, which is unusual if we assume that the bitumen derived primarily from the kerogen. The breakdown of kerogen during maturation involves the splitting of various chemical bonds. The results of empirical observation of kerogen degradation have been that the carbon of bitumen is isotopically lighter than the carbon of the associated kerogen by 1 to 4 δ units (Tissot and Welte, 1978). The difference between the bitumen and kerogen (B-K) δ-values is either small (less than −1) or positive for most of the cores. These small differences can be explained by the late stage of genesis (the catagenesis to metagenesis stage), a mixture of organic source material that is immature admixed with mature organic matter (in this case the immature organic matter is isotopically lighter than the mature), or by the fact that bitumen is derived from isotopically similar organic matter in which case isotopic fractionation did not occur during bitumen formation.

Organic Nitrogen

The organic nitrogen content determined by the Full minus Half Kjeldahl varies greatly within the samples. Generally, the organic nitrogen content is greater than 100 ppm for Samples 442A, 442B, 443, 444, 444A, and 445. The nitrogen content in Hole 445 is less than 100 ppm below 441.5 meters to depth and for the remaining 36 cores, with the exception of the Miocene to Oligocene units in Hole 446.

The atomic ratio of organic carbon to organic nitrogen (C/N) is used herein to reflect the organic nitrogen content of the sedimentary organic matter. Because the organic nitrogen is an approximation of the true value, the organic nitrogen values reported in Table 1 are only relative and are used here only to provide approximations of the organic nitrogen content. Values of C/N near 1 are not realistic but do indicate a rather high concentration of nitrogen. C/N of the sedimentary organic matter for the Shikoku Basin Holes 442A, 442B, 443, 444, and 444A and the Daito Ridge Basin Hole 445 down to the upper Oligocene at 489 meters is less than 11. Low values for this ratio are indicative of marine organic matter—that is, a high organic nitrogen content (C/N < 20) is associated with marine-derived organic matter. Conversely, a high ratio (>20) is in-

Table 2. A compilation of the ratio of pristane to phytane and the marine versus terrestrial *n*-alkane as given by the ratio $(n\text{-}C_{21} + n\text{-}C_{22})/(n\text{-}C_{28} + n\text{-}C_{29})$.

Table 2. (Continued).

Core	Section	Interval (cm)	Sub-bottom Depth (m)	$\frac{\text{Pristane}}{\text{Phytane}}$	$\frac{n\text{-}C_{21} + n\text{-}C_{22}}{n\text{-}C_{28} + n\text{-}C_{29}}$	$\frac{\text{Pristane}}{\text{C-17}}$	$\frac{\text{Phytane}}{\text{C-18}}$
Hole 442A, Unit I							
2	3	93–118	13.8	0.7	0.5	0.4	0.5
7	3	100–125	61.0	2.1	1.0	0.5	0.2
14	2	100–125	127.5	1.8	1.0	0.4	0.2
Hole 442A, Unit II, Sub-unit IIA							
19	2	100–125	173.5	0.2	0.1	0.9	1.3
19	2	125–150	174.7	0.5	0.5	0.8	1.3
Hole 442A, Unit III, Sub-unit IIIA							
23	2	100–125	211.6	0.9	1.7	0.2	0.2
23	2	125–150	213.0	1.2	1.4	0.4	0.1
28	2	100–125	259.0	0.7	0.7	1.2	0.4
28	2	125–150	260.5	0.9	0.7	0.3	0.3
Hole 442B, Unit III, Sub-unit IIIB							
2	3	100–125	281	0.7	1.0	0.5	0.6
Hole 443, Unit IV, Sub-unit IVA							
23	3	100–125	210.5	0.4	0.4	0.3	0.5
31	3	100–125	291	0.9	0.6	0.5	0.5
34	2	100–125	318	—	—	—	—
Hole 444, Unit I, Sub-unit IA							
2	4	94–119	11.5	1.1	1.2	0.6	0.4
Hole 444, Unit II							
7	5	94–119	60.5	0.9	0.4	0.4	0.4
Hole 444A, Unit III, Sub-unit IIIA							
1	4	100–125	87.5	0.7	0.4	0.3	0.4
Hole 444A, Unit III, Sub-unit IIIB							
6	4	71–96	134.7	0.9	0.5	0.3	0.3
9	3	90–115	162	0.6	0.9	0.6	0.5
Hole 444A, Unit IV, Sub-unit IVB							
14	3	100–125	209.3	0.3	1.1	0.4	1.0
Hole 444A, Unit IV, Sub-unit IVC							
22	5	100–125	269.3	0.6	1.0	0.5	0.6
Hole 445, Unit I, Sub-unit IA							
1	4	94–119	4.0	0.7	0.8	0.7	0.6
1	4	119–144	5.5	0.6	1.0	0.6	0.6
6	5	94–119	53.5	0.3	0.2	0.5	1.5
Hole 445, Unit I, Sub-unit IB							
11	2	100–125	96.5	2.8	0.6	1.7	1.0
Hole 445, Unit II, Sub-unit IIA							
17	1	90–115	152	0.2	0.2	0.5	3.7
23	4	0–25	212.5	0.2	0.4	0.4	2.3
27	4	94–119	251.5	0.1	0.7	0.4	4.4
Hole 445, Unit II, Sub-unit IIB							
32	2	90–115	296	1.5	0.3	0.4	0.3
Hole 445, Unit II, Sub-unit IIC							
37	4	90–115	346	0.6	0.4	1.6	5.9
42	5	100–125	395	0.2	1.3	0.4	2.0
47	4	100–125	441.5	0.1	1.2	0.3	3.1
52	4	100–125	489	0.3	1.4	0.3	2.3
Hole 445, Unit III							
60	3	100–125	563.5	0.2	0.6	0.6	1.6
Hole 445, Unit IV							
65	2	100–125	610	0.6	0.4	0.5	0.8
65	2	125–150	611	0.2	0.3	0.6	1.9
Hole 445, Unit V							
75	4	100–123	706	0.5	0.8	0.5	2.0
75	4	123–145	708	0.5	0.7	1.0	0.7
80	4	100–125	753	0.3	0.4	0.3	1.0
80	4	125–150	754.5	0.6	0.9	1.0	1.4
83	3	100–125	781	0.9	0.5	0.4	0.6
83	3	125–150	782.5	0.8	0.6	0.4	0.6
Hole 446, Unit II							
3	5	90–115	15	0.3	0.3	0.5	1.3
3	4	100–125	73.5	0.2	1.4	0.3	1.3
14	4	94–119	121	0.5	0.9	0.4	0.6
Hole 446, Unit III, Sub-unit IIIA							
24	2	100–125	213	0.6	5.3	0.4	0.4
30	5	90–115	273	1.1	1.0	0.2	0.4
34	5	90–115	312	1.0	0.5	0.4	0.4
Hole 446, Unit IV							
41	2	90–115	273	0.3	1.6	0.6	1.9
Hole 446A, Unit I							
10	2	100–125	489	0.2	0.8	0.5	2.3
Hole 447A, Unit III							
6	3	100–125	50.5	0.7	3.4	0.5	0.7
6	3	125–150	51.5	0.4	0.6	0.5	1.4
Hole 448, Unit I							
2	5	100–125	12	0.4	0.6	1.0	0.8
8	2	100–125	64.5	0.8	1.3	0.6	0.4
Hole 448, Unit II							
13	5	100–125	116.5	0.5	1.0	0.5	0.7
19	2	100–125	169	0.9	1.9	0.4	0.4
Hole 449, Unit I							
2	3	100–125	4	0.6	2.4	2.6	2.3
Hole 449, Unit IV							
8	2	100–125	59.5	0.4	0.8	0.4	0.9
Hole 449, Unit V							
13	4	100–125	110	0.1	0.8	0.3	2.1
Hole 450, Unit I, Sub-unit IA							
2	5	100–125	14.5	0.8	1.3	0.7	0.5
Hole 450, Unit II, Sub-unit IIA							
14	4	100–125	126	0.9	4.3	0.5	0.5
14	4	125–150	127	0.4	0.6	0.5	1.1
19	5	100–125	175	0.6	0.7	0.6	0.8
19	5	125–150	176	0.3	0.8	0.4	1.0
30	3	100–125	276	0.3	0.6	0.4	1.4
30	3	125–150	277	0.3	1.2	0.5	1.6
Hole 451, Unit I							
2	5	100–125	12	0.5	1.2	0.5	0.9
Hole 451, Unit II							
6	3	100–125	46	0.4	1.5	0.4	0.8
6	3	125–150	47.3	0.5	1.0	0.5	1.0

dicative of terrigenous organic matter. C/N is highest in Hole 445 at 610 meters (C/N = 992). Generally C/N is greater than 20 for the remaining cores. These high values reflect a higher terrigenous input into these sediments than is seen in other sediments in the area that we studied.

Average Values for Organic Chemical Properties of Open Marine Sediments

The averaged values of 11 chemical properties of open marine sediments are given in Table 3. These sediments are from Site 436 on the outer trench slope of the Japan Trench (Schorno, in press a), each site reported herein, and seven sites from the Mariana Trough and Trench (Schorno, in press b). The closest agreement among the selected chemical properties of these open marine sediments among sites is noted in the ratio of pristane to phytane (Pr/Ph = 0.6 S.D. = 0.12), the percentage of organic carbon (TOC = 0.14 S.D. = 0.04), the carbon isotopic composition of the bitumen ($\delta^{13}C_{PDB}$ = −26.6 S.D. = 1.0), and the kerogen ($\delta^{13}C_{PDB}$ = −26.6 S.D. = 1.8) fractions.

CONCLUSIONS

As noted herein, the standard techniques used to determine both organic source and degree of maturation must be re-evaluated when considering purely open marine sediments. The interpretations of the commonly used parameters S and $\overline{OEP}$ are suspect for this particular type organic source. More specific source and maturation indicators are needed for these sediments. It is hoped that bio-markers can fill this void. Open marine sediments appear to have several chemical properties in common, but additional research is needed to substantiate this.

REFERENCES

Hunt, J. M., 1979. The source rock. *Petroleum Geochemistry and Geology:* San Francisco (W. H. Freeman), pp. 302–303.

Lijmbach, G. M., 1975. On the origin of petroleum. *9th World Petroleum Congress, Proc.* (Vol. 2): London (Applied Science Publishers), 357–369.

Philippi, G. T., 1974. The influence of marine and terrestrial source material on the composition of petroleum. *Geochim. Cosmochim. Acta*, 36(6):947–966.

Schorno, K. S., in press a. Geochemistry of carbon: Legs 56 and 57, Deep Sea Drilling Project. *In* Scientific Party, *Init. Repts. DSDP*, 56, 57, Pt. 2: Washington (U.S. Govt. Printing Office).

________, in press b. Geochemistry of carbon: International Phase of Ocean Drilling Project Leg 60. *In* Hussong, D., Uyeda, S., et al., *Init. Repts. DSDP*, 60: Washington (U.S. Govt. Printing Office).

Powell, T. G., and McKirdy, D. M., 1973. The effect of source material, rock type and diagenesis on the *n*-alkane content of sediments. *Geochim. Cosmochim. Acta*, 37:623–633.

Scalan, R. S., and Smith, J. E., 1976. An improved measure of the odd-even predominance of the normal alkanes of sediment extracts and petroleum. *Geochim. Cosmochim. Acta*, 34:611–620.

Tissot, B. P., and Welte, D. H., 1978. *Petroleum Formation and Occurrence:* New York (Springer Verlag).

Table 3. A compilation of average values of 11 organic chemical properties of cores from Legs 56, 58, 59, and 60.

Location of Sampling	Mariana Trench Area	Seaward Side Japan Trench	West-Central Shikoku Basin	East-Central Shikoku Basin	Basin in Daito Ridge	Daito Basin	West Philippine Basin	Western Edge Palau-Kyushu Ridge	Western Side Parece Vela Basin	Eastern Side Parece Vela Basin	Eastern Side West Mariana Ridge	Average Value of All Sites
Leg	60	56	58	58	58	58	59	59	59	59	59	
Holes	452, 453, 454A 455, 459B, 460	436	442A 442B	443, 444	445	446	447A	448	449	450	451	
No. cores sampled	11	6	10	10	21	8	2	4	3	7	3	
Age range	Pleistocene–Miocene	Pleistocene–Miocene	Pleistocene–Miocene	Miocene	Pleistocene–Eocene	Miocene–Eocene	Oligocene	Miocene–Oligocene	Miocene	Pliocene–Miocene	Pleistocene–Miocene	
$CaCO_3$ (wt. %)	0.1	2	2	4	34	1.5	2.8	75	21	11	11	14.6
Organic carbon (wt. %)	0.18	0.15	0.15	0.07	0.1	0.16	0.20	0.12	0.18	0.12	0.14	0.14
Organic nitrogen (ppm)	160	293	455	314	120	111	34	28	43	38	110	155
Organic carbon/nitrogen	18	5	4	3	89	235	76	60	51	54	29	57
Bitumen (ppm)	36	51	29	23	20	9	12	12	3	77 (14)[b]	10	26
Bitumen/total organic carbon ×100	2.4	3.8	7.0 (2.0)[a]	15.0	2.1	0.8	0.5	1.1	0.7	4.9	0.9	3.6
$\overline{OEP}$	1.3	2.4	2.1	1.7	1.7	1.5	1.0	1.4	1.3	1.5	1.5	1.6
$\delta^{13}C_{PDB}$ Bitumen	—	−24.9	−27.2	−27.3	−26.2	−26.2	−26.4	−25.9	−28.4	−27.0	—	−26.6
$\delta^{13}C_{PDB}$ Kerogen	−26.0	−22.4	−24.7	−26.3	−26.3	−28.6	−28.7	−27.1	−27.1	−28.1	−27.6	−26.6
S	1.9	0.6	0.9	0.7	1.5	2.0		1.2	1.3	1.4	1.2	1.2
Pr/Ph	0.7	—	0.8	0.7	0.6	0.5	0.6	0.7	0.4	0.5	0.5	0.6

[a] Number in parentheses is the average of those samples less than 10% (3).

[b] Number in parentheses is the average of all but Sample 450-205; bitumen content for this sample is 440 ppm.