

21. PRELIMINARY LIPID ANALYSES OF TWO QUATERNARY SEDIMENTS FROM THE MIDDLE AMERICA TRENCH, SOUTHERN MEXICO TRANSECT, DEEP SEA DRILLING PROJECT LEG 66¹

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ABSTRACT

We investigated the solvent-extractable hydrocarbons, ketones, alcohols, and carboxylic acids of two Quaternary sediments from the Middle America Trench (Sections 487-2-3 and 491-1-5). These lipids are derived from a mixed input of autochthonous and allochthonous materials, with minor contributions from thermally mature sources. Their compositions are typical of those of immature Quaternary marine sediments, and their lipid distributions show many similarities to those of Japan Trench sediments.

INTRODUCTION

The solvent-extractable lipids of two Quaternary sediments (Sections 487-2-3 and 491-1-5) from the oceanic plate and central slope of the Middle America Trench were investigated by gas chromatography and computerized gas chromatography-mass spectrometry. The sections were chosen to permit the comparison of environments on either side of the trench. This preliminary report describes the lipid compositions of these two samples and interprets them in terms of their input sources, conditions of deposition, and extent of diagenesis. We also make a brief comparison of their lipid distributions with those of Quaternary sediments from the Japan Trench.

Table 1 summarizes the lithological characteristics of the samples and includes their weights. Organic carbon determinations were not made for these samples, but the values of adjacent sections are given (site chapters, this volume).

EXPERIMENTAL

The experimental procedures for Leg 66 samples generally follow those of our earlier DSDP investigations (Barnes et al., 1979; Brassell et al., 1980a, 1980b). Gas chromatographic (GC) analyses were performed on a 20m OV-1 WCOT capillary column fitted in a Carlo Erba 2150 instrument. Computerized gas chromatography-mass spectrometry (C-GC-MS) was used to achieve compound identification. The Finnigan 4000 system with INCOS 2300 data system has been described elsewhere (Brassell et al., 1980d), but for these analyses a 20-m fused silica column coated with methyl silicone fluid led through to the ion source was used. Compound assignments were made from individual mass spectra and GC retention times, with reference to literature spectra and authentic standards, where possible. Mass fragmentation (MF) was used extensively to characterize homologous and pseudohomologous series and to aid in compound identification. Individual components were quantitated from their GC response, where possible, from their C-GC-MS response or by MF. For particular compound classes either the small quantities or problems with component coelution prevented absolute quantitation. In such instances, a semiquantitative estimate of their relative abundances is given.

RESULTS

The distributions of aliphatic hydrocarbons, ketones, alcohols, and carboxylic acids and of aromatic hydrocarbons are reported herein. In addition, other suites of components such as α , ω -dicarboxylic acids and numerous minor or unrecognized compounds were detected, but are not included.

Aliphatic Hydrocarbons

Acyclic Components

The *n*-alkanes of Sections 487-2-3 and 491-1-5 both ranged from C₁₄ to C₃₅ with *n*-C₂₉ dominant. The concentrations of individual homologues are shown in Figure 1A and the CPI values in Table 2. Both distributions are dominated by the odd-numbered *n*-alkanes in the C₂₅ to C₃₅ range, but in Section 491-1-5 the C₁₇ to C₂₂ homologues are also prominent. No *n*-alkenes were detected in either sample. *Iso*- and *anteiso*-alkanes in the C₁₇ to C₂₃ range were recognized as minor components (<0.5 ng/g) of Sections 487-2-3 and 491-1-5. No other simple branched alkanes or alkenes were found in either sediment.

Seven isoprenoid alkanes were found in both samples; the concentrations of five of them, 2,6,10-trimethylpentadecane, pristane (2,6,10,14-tetramethylpentadecane), phytane (2,6,10,14-tetramethylhexadecane), 2,6,10,15,19-pentamethyleicosane (I), and squalane (2,6,10,15,19,23-hexamethyltetracosane, II), recognized by comparison with literature spectra (e.g., Holzer et al., 1979), are shown in Figure 1A. For Section 487-2-3 the identification of 2,6,10,15,19-pentamethyleicosane is tentative; the mass spectrum suggested a contribution to the GC peak from another acyclic isoprenoid alkane, perhaps 2,6,10,14,18-pentamethyleicosane (III, Holzer et al., 1979). The presence of the two other acyclic isoprenoid alkanes was suggested by the enhanced response of the *m/z* 183 MF (Albaiges, 1980) for the *n*-C₃₄ and *n*-C₃₅ peaks in GC-MS. From these mass spectral data the acyclic isoprenoid alkanes coeluting with these *n*-alkanes are probably 2,6,10,14,17,21,25,29-octamethyl-

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Table 1. Sample descriptions and lithological characteristics.

Site Location	Sample (interval in cm)	Sub-bottom Depth (m)	Age	Lithology	Organic Carbon (%)	Weight (g)	
						Wet ^a	Dry ^b
oceanic plate	487-2-3, 135-150	5.2	middle-late Pleistocene	mud	1.7 ^c	83	47
central trench slope	491-1-5, 110-135	7.2	Quaternary	muddy silt	1.9 ^d	162	108

^a Weight prior to extraction.^b All lipid concentrations are quoted in ng/g dry weight of sediment.^c Value for Section 487-2-2, 40.^d Value for Section 491-1-5, 101.

hentriacontane (IV) and lycopane (2,6,10,14,19,23,27,31-octamethyldotriacontane, V), since both possess prominent m/z 183 ions (Moldowan and Seifert, 1979; Kimble et al., 1974) and appropriate retention times. Trace concentrations (<0.7 ng/g) of two phytene isomers with mass spectra similar to that of phyt-2-ene (3,7,11,15-tetramethylhexadec-2-ene, VI; Urbach and Stark, 1975) were found in Section 491-1-5.

Cyclic Components

A series of cyclohexylalkanes ranging from C_{16} to C_{26} was recognized by MF (m/z 83 and 82) in Section 491-1-5. The concentration of the major homologue, cyclohexyldodecane (VII), was approximately 0.8 ng/g. These components were not detected in Section 487-2-3.

Fichtelite (VIII) was detected as a minor component (approx. 0.3 ng/g) of Section 487-2-3 but was not present in Section 491-1-5. Section 487-2-3 also contained compounds with mass spectra similar to published spectra of a $C_{25}H_{44}$ bicyclic alkadiene (M^+ 344, Farrington et al., 1977; Boehm and Quinn, 1978) and a $C_{30}H_{52}$ bicyclic alkatriene (M^+ 412, I2558 of Prah et al., 1980). Of the three major fragment ions in the spectra, two (m/z 231 and m/z 259) are common to both components, whereas the third occurs at 68 amu higher (m/z 315 rather than m/z 247) in the spectrum of the C_{30} compound, suggesting that the two hydrocarbons share a common bicyclic skeleton and differ by one isoprene (C_5H_8) unit. The mass spectral data do not, however, permit unambiguous assignment of the structure of these C_{25} and C_{30} compounds, which are present in concentrations of 6.5 ng/g and 4.6 ng/g, respectively.

Steranes (IX) and diasteranes (X) were recognized by MF (m/z 217) as minor components of both samples. The distributions of these compounds in the two sediments were similar, but their low concentrations (<0.5 ng/g and <0.3 ng/g for Sections 487-2-3 and 491-1-5, respectively) prevented component identification from individual mass spectra. Hence, an accurate assessment of the maturity of the steranes from specific stereoisomeric ratios (Mackenzie et al., 1980) was not possible, although the apparent proportions of 20S- and 14 β (H)-steranes and diasteranes, as seen from MF, were comparable in both samples with those in petroleum and mature sediments (Seifert and Moldowan, 1979; Mackenzie et al., 1980). Sterenes were significant components of both sections, but the complexity of the polycyclic region of the hydrocarbon fractions prevented their absolute quantitation. In addition, the mass spectral differences between sterenes, steradienes, and stera-

trienes preclude their quantitation from a single MF. Hence, Table 3 gives only approximate concentration values derived from the total ion intensities of individual sterene mass spectra. Ster-2-enes (XII) and stera-3,5-dienes (XIII) were recognized by comparison with standard spectra; the nuclear positions of unsaturation of the other components are uncertain. Three of the sterenes with nuclear triunsaturation are thought to possess aromatic A or B rings (XIV or XV); Spyckerelle, 1975; Rullkötter et al., in press). Their mass spectral similarities to D ring aromatic hopanes (Greiner et al., 1977) suggest that B ring aromaticity (XV) is the more probable. The distributions and approximate concentrations of sterenes in Sections 487-2-3 and 491-1-5 are generally similar. Section 487-2-3 appears to contain greater relative amounts of nuclear triunsaturated sterenes, whereas Section 491-1-5 possesses higher abundances of stera-3,5-dienes.

A wide range of triterpenoid hydrocarbons was found in both samples, although as with the sterenes, their absolute quantitation was not possible. The abundances given in Table 4 are therefore approximate values calculated from the total ion signal of individual mass spectra. The intensities for each component's m/z 191 response, relative to that of the major triterpenoid, are also given. The majority of compounds were recognized from their mass spectra by comparison with those of standards or by MF. Two components with mass spectra and GC retention times similar to those of two of the three unknown triterpenoid hydrocarbons—those assigned as C_{30} triterpenes in Table 4—were previously found in Section 481-2-2 (Thomson et al., in press b); their structures have not been characterized. The relative abundances of hop-22(29)-ene (diploptene, XVIII) and homohop-29(31)-ene (XVIIIi) are markedly higher in Section 487-2-3 than in Section 491-1-5, whereas the latter sample contains a greater abundance of ferenes and $\alpha\beta$ -hopanes, notably the C_{31} to C_{35} homologues. In other respects the distributions and approximate concentrations of triterpenoid hydrocarbons in the two sediments are generally similar. Neither triterpanes nor triterpenes with 6-membered E rings, such as gammacerane (XXVI) and olean-18-ene (XXVII), were detected in the samples. Both sections, however, contained a suite of eight C_{24} components that were tentatively assigned as tetracyclic degradation products of 3-oxytriterpenoids (Fig. 2). The mass spectrum of component D is the same as that of a compound originally found in the Messel shale (Kimble, 1972), which has been characterized as a tetracyclic alkane (XXVIII) related to

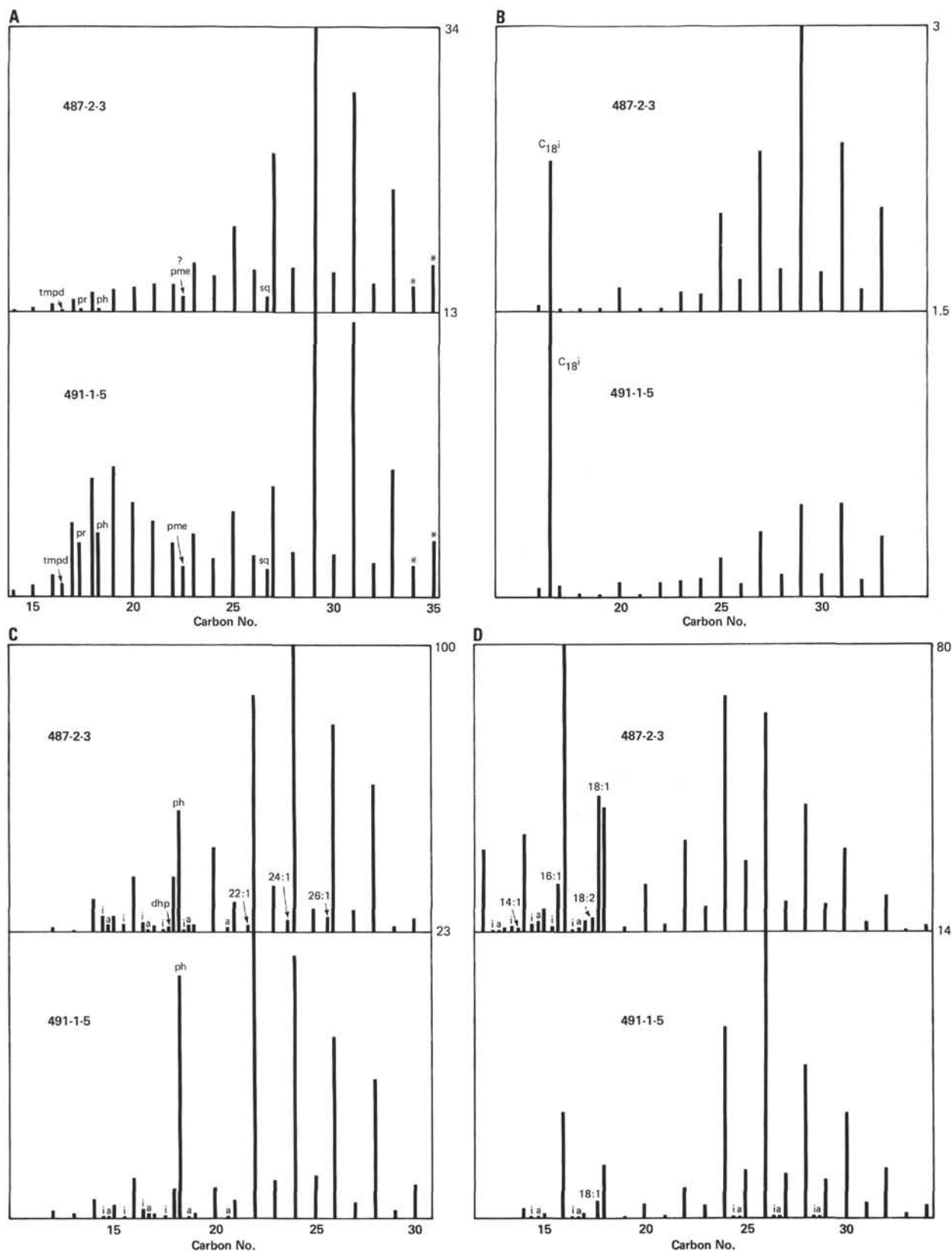


Figure 1. Concentrations (ng/g dry sediment) of acyclic hydrocarbons, ketones, alcohols, and acids in Sections 487-2-3 and 491-1-5. A. *n*-alkanes. (tmpd = 2,6,10-trimethylpentadecane; pr = pristane; ph = phytane; pme = 2,6,10,15,19-pentamethyleicosane; sq = squalane; * = *n*-alkane peaks enhanced by coelution of acyclic isoprenoid alkanes [see text].) B. *n*-alkan-2-ones. (C_{18}^i = 6,10,14-trimethylpentadecan-2-one.) C. *n*-alkanols. (i = *iso*-alkanols; a = *anteiso*-alkanols; dhp = dihydrophytol; ph = phytol; 22:1, 24:1, 26:1 = alkenols.) D. *n*-alkanoic acids. (i = *iso*-alkanoic acids; a = *anteiso*-alkanoic acids; 14:1, 16:1, 18:1, 18:2 = alkenoic acids.)

Table 2. Carbon preference indices of normal components in the samples.

Compound Class	C No. Range	Section		Odd/Even or Even/Odd ^a
		487-2-3	491-1-5	
<i>n</i> -alkanes	14-33	3.5	2.5	o/e
	14-21	1.2	1.2	o/e
	22-33	4.1	3.7	o/e
<i>n</i> -alkan-2-ones	16-33	4.5	2.8	o/e
<i>n</i> -alkanols	11-30	5.7	7.4	e/o
	12-34	6.3	5.5 ^b	e/o
<i>n</i> -alkanoic acids	12-21	11.7	12.2 ^c	e/o
	22-34	4.7	4.9	e/o

^a Odd/even predominance o/e; even/odd predominance e/o^b CPI for C₁₄₋₃₄ range.^c CPI for C₁₄₋₂₁ range.

Table 3. Abundance of sterenes in Sections 487-2-3 and 491-1-5.

Assignment	Structure	Abundance in Section	
		487-2-3	491-1-5
cholesta-n,24-diene ^a	XIb	+	+
cholest-2-ene	XIIa	++	++
cholesta-3,5-diene	XIIIa	++	++
24-methylenecholestene	XId	+++	++
24-methylenecholest-2-ene	XIIc	++	+
24-methylenecholestene	XId	+++	+++
24-ethylcholesta-n,22-diene ^a	XIe	+++	+++
24-methylcholestatatriene	XIc	+	++
24-methylcholesta-3,5-diene	XIIIc	n.d.	++
24-methylcholestatatriene	XIc	++	+
23,24-dimethylcholest-2-ene	XIIIf	+	++
24-ethylcholest-2-ene	XIIg	++	++
cholestatatriene	XIVa or XVa	+	n.d.
24-ethylidenecholestene	XIh	+++	+++
24-ethylcholesta-3,5-diene	XIIIe	+	++
24-ethylidenecholestatadiene	XIh	+++	++
24-methylcholestatetriene	XIVd or XVd	+	+
24-ethylcholestatatriene	XIVg or XVg	+	n.d.

Note: Section 487-2-3: +++ = approx. 3 ng/g; ++ = approx. 1.5 ng/g; + = approx. <0.5 ng/g. Section 491-1-5: +++ = approx. 3 ng/g; ++ = 1 ng/g; + = <0.3 ng/g. n.d. = not detected.

^a n designates nuclear double bond in an uncertain position.

lupane (XXIX, Corbet et al., 1980). The identities of the other components cannot be unambiguously assigned from their mass spectra. The distributions of these compounds in the two samples are similar, but they are present in rather greater concentrations in Section 487-2-3 than in Section 491-1-5.

Aromatic Hydrocarbons

Aromatic hydrocarbons were minor components of both samples (approx. ≤ 1 ng/g), with the exception of perylene (XXXIX) in Section 491-1-5. The small amounts of these compounds prevented their accurate quantitation; hence, Table 5 gives approximate values for their concentrations, estimated from the total ion signal of their mass spectra or from MF of their molecular ions. Simonellite (XXX), retene (XXXI), and perylene (XXXIX) were identified from C-GC-MS by comparison with standard spectra, whereas the tri- and di-

Table 4. Abundance of triterpenoid hydrocarbons in Sections 487-2-3 and 491-1-5.

Assignment	Structure	Abundance in Section ^a	
		487-2-3	491-1-5
18 α H-22,29,30-trisnorhopane	XVI	n.d.	+
17 α H-22,29,30-trisnorhopane	XVIIa	+	(5)
17 β H-22,29,30-trisnorhopane	XVIIIa	++	(25)
C ₃₀ triterpene	? ^b	+++	(58)
$\alpha\beta$ -30-norhopane	XVIIb	+++	(72)
hop-17(21)-ene	XIX	+++	(15)
unknown	?	++	(19)
$\alpha\beta$ -hopane	XVIIc	+++	(65)
fern-8-ene	XX	n.d.	+
neohop-13(18)-ene	XXI	+++	(20)
$\beta\beta$ -30-norhopane	XVIIIb	+++	(49)
fern-9(11)-ene	XXII	++	(-)
C ₃₀ triterpene	? ^c	n.d.	+
neohop-12-ene	XXIII	++	(8)
fern-7-ene	XXIV	++	(-)
22S $\alpha\beta$ -homohopane	XVIIId	+	(16)
22R $\alpha\beta$ -homohopane	XVIIe	+	(15)
$\beta\beta$ -hopane	XVIIIc	+++	(57)
hop-22(29)-ene	XVIIIIf	+++	(100)
hop-21-ene	XXV	++	(26)
22S $\alpha\beta$ -bishomohopane	XVIIg	+	(6)
22R $\alpha\beta$ -bishomohopane	XVIIh	+	(6)
homohop-29(31)-ene	XVIIIf	+	(9)
$\beta\beta$ -homohopane	XVIIIe	+++	(50)
22S $\alpha\beta$ -trishomohopane	XVIIj	n.d.	+
22R $\alpha\beta$ -trishomohopane	XVIIk	n.d.	+
$\beta\beta$ -bishomohopane	XVIIIh	n.d.	+
22S $\alpha\beta$ -tetrakishomohopane	XVIIIf	n.d.	+
22R $\alpha\beta$ -tetrakishomohopane	XVIIIm	n.d.	+
22S $\alpha\beta$ -pentakishomohopane	XVIIIn	n.d.	+
22R $\alpha\beta$ -pentakishomohopane	XVIIIo	n.d.	+

Note: Section 487-2-3: +++ = approx. 5 ng/g; ++ = approx. 2 ng/g; + = approx. <1 ng/g. Section 491-1-5: +++ = approx. 4 ng/g; ++ = approx. 1 ng/g; + = <0.5 ng/g. n.d. = not detected.

^a Values in parentheses are the m/z 191 intensities relative to the major component of that MF. The variability in the intensity of m/z 191 fragmentation for the different triterpenoids (e.g., Barnes et al., 1979) restricts the use of these values for quantitation purposes.^b C₃₀ triterpene also found in Section 481-2-2 (component D of Thomson et al., in press b).^c C₃₀ triterpene also found in Section 481-2-2 (component J of Thomson et al., in press b).^d m/z 191 is an insignificant ion in fernene mass spectra.

aromatic tetracyclic components (XXXIV to XXXVIII) were recognized by comparison with literature spectra (Spyckerelle, 1975; Spyckerelle et al., 1977a, 1977b; Laflamme and Hites, 1979; Wakeham et al., 1980a, 1980b). Assignments of the monoaromatic tetracyclic components (XXXII and XXXIII) were made by comparison with a literature spectrum (Spyckerelle, 1975) and by spectral interpretation. In addition to the aromatic hydrocarbons listed in Table 5 and the monoaromatic steroids just discussed, series of ring C aromatic steroids (XL, Schaeffle et al., 1978) were found as trace components (<0.1 ng/g) of both samples. The major difference between the two distributions of aromatic hydrocarbons, which were present at similar concentrations in both sections, is the greater abundance of the aromatic diterpenoids simonellite and retene in Section 491-1-5.

Ketones

Acyclic Components

In both samples the *n*-alkan-2-ones are dominated by odd-numbered components as seen in their CPI values

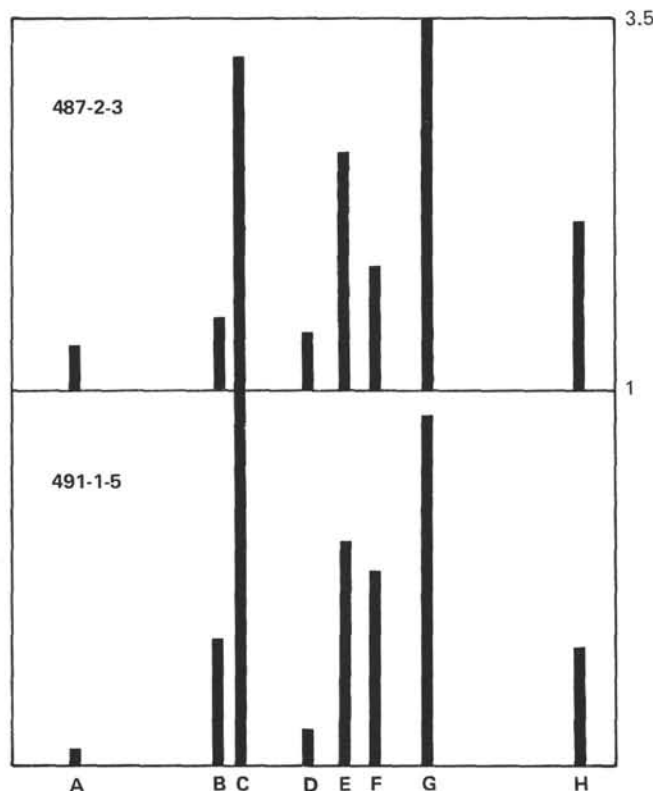


Figure 2. Concentrations (ng/g dry sediment) of C_{24} tetracyclic alkenes/alkanes, assigned as ring A degraded triterpenoids, in Sections 487-2-3 and 491-1-5. (Formulae: A, B, C, E, F, and H = $C_{24}H_{28}$ ($M^+ 326$); D = $C_{24}H_{32}$ ($M^+ 330$, XXVIII); G = $C_{24}H_{30}$ ($M^+ 328$)).

(Table 2). The concentrations of individual members of the homologous series, which range from C_{16} to C_{33} , are illustrated in Figure 1B. The C_{29} and C_{31} components are the dominant homologues of Sections 487-2-3 and 491-1-5, respectively. The two samples contain similar distributions of long-chain unsaturated ketones (Fig. 3) but not the full suite of C_{37} to C_{39} compounds found elsewhere (Brassell et al., 1980b; de Leeuw et al., 1980; Volkman et al., 1980a, 1980b). These limited ranges of alkadienones and alkatrienones are dominated by the $C_{37:2}$ methyl ketone (heptatriaconta-15,22-diene-2-one, XLIIa), which is the major ketone in these sediments. No other alkenones or simple branched acyclic ketones were

recognized in either sample. 6,10,14-trimethylpentadecan-2-one was present as a prominent component of both sections (Fig. 1B); indeed, in Section 491-1-5 it is more abundant than the n -alkanones. No other acyclic isoprenoid ketone was found in the sections.

Cyclic Components

The minor components of both samples included steroidal ketones that were identified from standard or literature spectra (Gagosian and Smith, 1979; Withers et al., 1978), by spectral interpretation or from their GC retention times using MF. 5α - and 5β -cholestan-3-one (XLIIa and XLIVa), 24-ethyl- 5α -cholestan-3-one (XLIIb), dinosterone (4 α ,23,24-trimethyl- 5α -cholestan-22-en-3-one, XLVc), dinostanone (4 α ,23,24-trimethyl- 5α -cholestan-3-one, XLVd), and an isomer of dinostanone, probably differing in its side chain methylation (perhaps 4 α ,22,24-trimethyl, XLVe or 4 α ,22,23-trimethyl, XLVf), were identified in the samples. Dinosterone was the dominant component of both distributions, found in minor amounts (<0.1 ng/g) and approximately 1 ng/g in Sections 487-2-3 and 491-1-5, respectively. None of the other steroidal ketones was present in more than trace concentrations (≤ 0.1 ng/g).

Both samples contain hopanoid and nonhopanoid triterpenes, but their distributions differ significantly (Table 6). 22,29,30-trisnorhopan-21-one (XLVI) and 30-norhopan-22-one (L) were assigned by comparison with literature spectra (Dastillung et al., 1980a); recognition of the other triterpenes was made by comparison with standard spectra and from their GC retention times. 22,29,30-trisnorhopan-21-one (XLVI) is the major triterpene of Section 491-1-5 but was not detected in Section 487-2-3, whereas friedelan-3-one (LIII) was a major component of both sections. Apart from these two compounds, none of the other triterpenes was present at concentrations >0.2 ng/g. Hence, Table 6 provides estimates of their concentrations calculated from their total ion intensities or from MF.

Alcohols

Acyclic Components

The n -alkanols of Sections 487-2-3 and 491-1-5 range from C_{12} to C_{30} , with the even-numbered components dominant. Their concentrations are shown in Figure 1C,

Table 5. Abundance of aromatic hydrocarbons in Sections 487-2-3 and 491-1-5.

Assignment	Formula	Structure	Abundance in Section	
			487-2-3	491-1-5
1,1-dimethyl-7-isopropyl-1,2,3,4-tetrahydrophenanthrene (simonellite)	$C_{19}H_{24}$	XXX	n.d.	+++
1-methyl-7-isopropylphenanthrene (retene)	$C_{18}H_{20}$	XXXI	+	++
3,4,7,10b,12a-pentamethyl-1,2,3,4,4a,4b,5,6,10b,11,12,12a-dodecahydrochrysene ^a	$C_{23}H_{34}$	XXXII	+	+
3,3,7,10a,12a-pentamethyl-1,2,3,4,4a,4b,5,6,10b,11,12,12a-dodecahydrochrysene	$C_{23}H_{34}$	XXXIII	+	+
2,8-dimethyl-5'-isopropyl-1,2-cyclopentano-1,2,3,4-tetrahydrophenanthrene	$C_{22}H_{30}$	XXXIV	+++	+++
3,4,7,12a-tetramethyl-1,2,3,4,4a,11,12,12a-octahydrochrysene	$C_{22}H_{30}$	XXXV	+++	+++
3,3,7,12a-tetramethyl-1,2,3,4,4a,11,12,12a-octahydrochrysene	$C_{22}H_{30}$	XXXVI	++	++
3,4,7-trimethyl-1,2,3,4-tetrahydrochrysene	$C_{21}H_{26}$	XXXVII	+	+
3,3,7-trimethyl-1,2,3,4-tetrahydrochrysene	$C_{21}H_{26}$	XXXVIII	+	++
perylene	$C_{20}H_{12}$	XXXIX	+	7 ng/g

Note: Sections 487-2-3 and 491-1-5: +++ = approx. 1 ng/g; ++ = approx. 0.2 ng/g; + = <0.1 ng/g. n.d. = not detected.

^a Tentative assignment based on spectral interpretation.

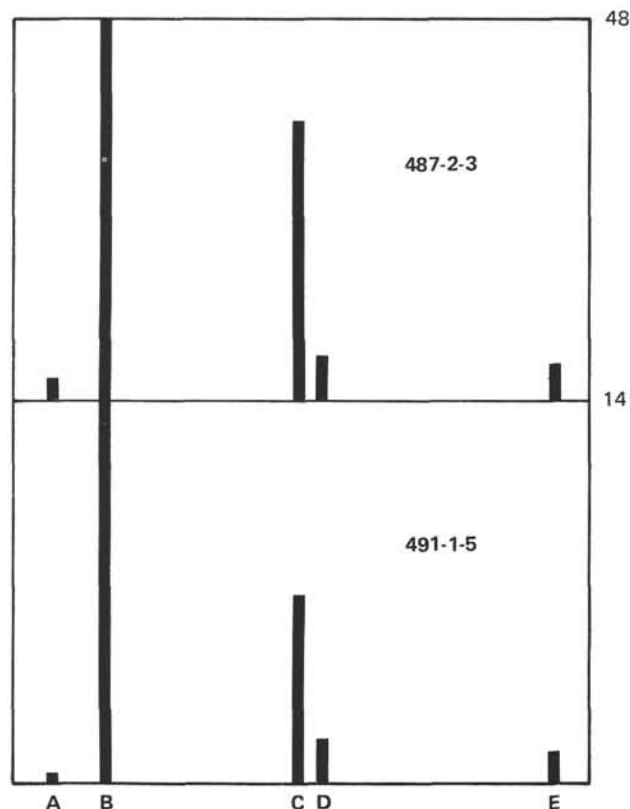


Figure 3. Concentrations (ng/g dry sediment) of alkadienones and alkatrienones in Sections 487-2-3 and 491-1-5. (A = heptatriaconta-8,15-22-trien-2-one (XLa); B = heptatriaconta-15,22-dien-2-one (XLIIa); C = octatriaconta-16,23-dien-3-one (XLIIb); D = octatriaconta-16,23-dien-2-one (XLIIc); E = nonatriaconta-17,24-dien-3-one (XLId).)

Table 6. Abundance of triterpenoid ketones in Sections 487-2-3 and 491-1-5.

Assignment	Structure	Abundance in Section	
		487-2-3	491-1-5
22,29-30-trisnorhopan-21-one ^a	XLVI	n.d.	8 ng/g
taraxer-14-en-3-one	XLVII	+	+
olean-12-en-3-one	XLVIII	+	+
urs-12-en-3-one	XLIX	+	+
30-norhopan-22-one ^b	L	+	+
$\beta\beta$ -hopan-3-one	LI	n.d.	+
glut-5-en-3-one	LII	++	n.d.
friedelan-3-one	LIII	3 ng/g	3 ng/g

Note: Sections 487-2-3 and 491-1-5: ++ = 0.2 ng/g; + = <0.1 ng/g. n.d. = not detected.

^a Stereochemistry of C-17 uncertain (cf. Dastillung et al., 1980a).

^b Stereochemistry of C-17 and C-21 uncertain but may be $\beta\alpha$ (cf. Dastillung et al., 1980a).

and Table 2 gives their CPI values. The two distributions are broadly similar, but Section 487-2-3 contains higher relative amounts of short-chain (C_{14} to C_{20}) members and is dominated by the C_{24} rather than the C_{22} alkanol. Section 487-2-3 contained three *n*-alkenols (Fig. 1C), but none was detected in Section 491-1-5. *Iso*-

and *anteiso*-alkanols ranging from C_{15} to C_{21} were found in both samples (Fig. 1C), but no *n*-alkan-2-ols (cf. Cranwell, 1980) were detected. Phytol (3,7,11,15-tetramethylhexadec-2-enol) was a prominent component of both samples (Fig. 1C) but dihydrophytol (3,7,11,15-tetramethylhexadecanol) was only found in Section 487-2-3.

Cyclic Components

Sterols were major components of both sections; the concentrations of the 35 compounds characterized (Table 7) are shown in Fig. 4. Standard and literature spectra (Gaskell and Eglinton, 1976; Wardroper et al., 1978; Lee et al., 1979; Wardroper, 1979; Boon et al., 1979; Brassell and Eglinton, 1981; Brassell, 1980 and references therein) and GC retention times were used for most sterol identifications; other assignments are based on spectral interpretation (Table 7).

Dinosterol [$4\alpha,23,24$ -trimethyl- 5α -cholest-22(E)-en- 3β -ol, LVIj] was the dominant sterol of both sections, which possessed similar distributions, except for the greater prominence of 5α -stanols and $C_{29}\Delta^{22}$ components in Section 491-1-5. No sterols with short side chains ($<C_{26}$) were detected (cf. Brassell et al., 1980b; Brassell, 1980).

Both hopanoid and nonhopanoid triterpenols were recognized in the sediments (Table 8), although their distributions (Fig. 5) are somewhat dissimilar. Most

Table 7. Sterols identified in Sections 487-2-3 and 491-1-5.

Peak (Fig. 4)	Assignment	Structure
A	24-norcholesta-5,22(E)-dien- 3β -ol	LIVa
B	24-nor- 5α -cholestan- 3β -ol	LVb
C	5 β -cholestan- 3β -ol	LXVI
D	27-nor-24-methyl-5 β -cholestan- 3β -ol ^a	LXVII
E	5 β -cholestan- 3α -ol	LXVIII
F	27-nor-24-methylcholesta-5,22(E)-dien- 3β -ol	LIVe
G	27-nor-24-methyl-5 α -cholest-22(E)-en- 3β -ol	LVe
H	cholesta-5,22(E)-dien- 3β -ol	LIVf
I	5 α -cholest-22(E)-en- 3β -ol	LVf
J	cholest-5-en- 3β -ol	LIVc
K	5 α -cholestan- 3β -ol	LVc
L	27-nor-24-methyl-5 α -cholestan- 3β -ol	LVd
M	24-methylcholesta-5,22(E)-dien- 3β -ol	LIVg
N	24-methyl-5 α -cholest-22(E)-en- 3β -ol	LVg
O	24-methylencholest-5-en- 3β -ol	LIVh
P	24-methylene-5 α -cholestan- 3β -ol	LVh
Q	24-methylcholest-5-en- 3β -ol	LIVi
R	24-methyl-5 α -cholestan- 3β -ol	LVi
S	23,24-dimethylcholesta-5,22(E)-dien- 3β -ol	LIVj
T	23,24-dimethyl-5 α -cholest-22(E)-en- 3β -ol	LVj
U	24-ethylcholesta-5,22(E)-dien- 3β -ol	LIVk
V	24-ethyl-5 α -cholest-22(E)-en- 3β -ol	LVk
W	4 $\alpha,24$ -dimethyl-5 α -cholest-22(E)-en- 3β -ol	LVIg
X	24(Z)-ethylidenecholest-5-en- 3β -ol	LVf
Y	23,24-dimethyl-5 α -cholestan- 3β -ol	LIVm
Z	24-ethylcholest-5-en- 3β -ol	LVI
AA	24-ethyl-5 α -cholestan- 3β -ol	LVI
AB	4 $\alpha,24$ -dimethyl-5 α -cholestan- 3β -ol	LVIh
AC	24(Z)-ethylidenecholest-5-en- 3β -ol	LIVn
AD	4 $\alpha,23,24$ -trimethyl-5 α -cholest-22(E)-en- 3β -ol	LVIj
	unknown C_{30} 5 α -stanol (M ⁺ of TMS ether 500) ^c	?
	24(Z)-propylidenecholest-5-en- 3β -ol	LIVo
	4 α -methyl-24-ethyl-5 α -cholest-7-en- 3β -ol ^a	LVIIm
	4 $\alpha,22,23$ - or 4 $\alpha,22,24$ -trimethyl-5 α -cholestan- 3β -ol	LVIp or LVIq
	4 $\alpha,23,24$ -trimethyl-5 α -cholestan- 3β -ol ^b	LVIe
	22,23-methylene-4 $\alpha,24$ -dimethyl-5 α -cholestan- 3β -ol ^a	LVIr

^a Tentative assignment based on spectra interpretation.

^b Compound identified by J. K. Volkman (personal communication).

^c Unsaturation is in side chain.

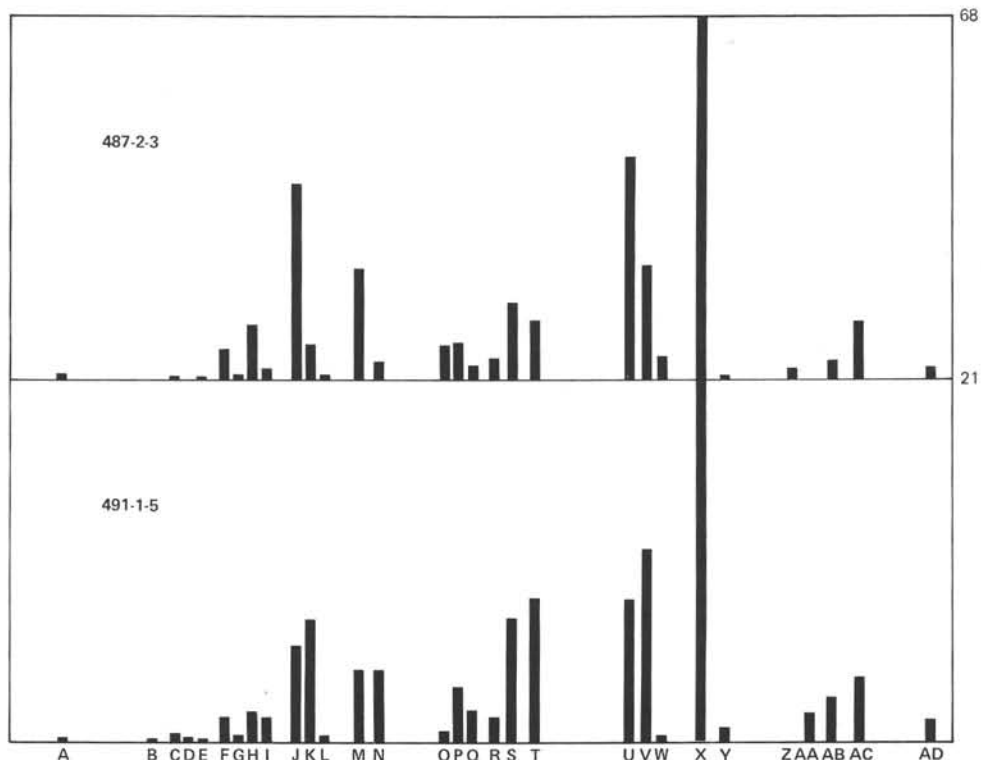


Figure 4. Concentrations (ng/g dry sediment) of sterols in Sections 487-2-3 and 491-1-5. (Assignments are given in Table 7.)

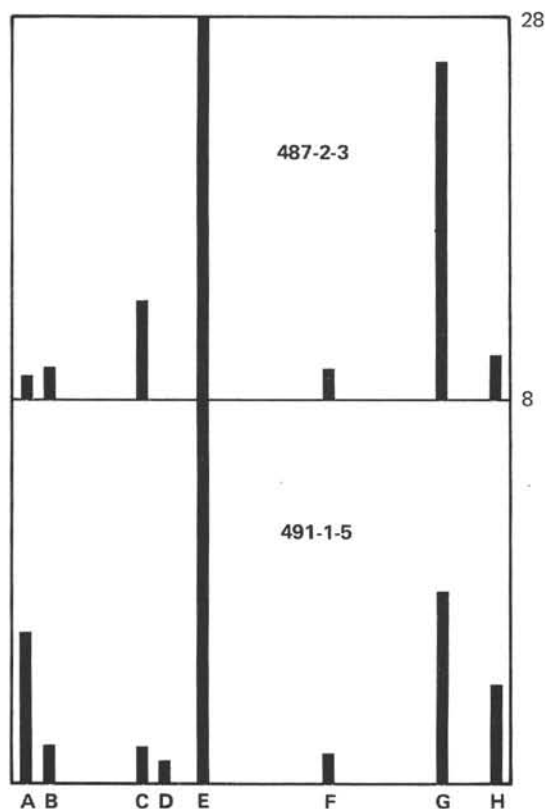


Figure 5. Concentrations (ng/g dry sediment) of triterpenols and hydroxyalkanones in Sections 487-2-3 and 491-1-5. (Assignments are given in Table 8.)

components were identified from their mass spectra by comparison with reference standards or literature spectra (Dastillung et al., 1980b) or from MF. The exceptions were taraxer-14-en-3-ol and component D (Table 8). Diplopterol ($\beta\beta$ -hopan-22-ol, XVIIIq) was not detected in either sample (cf. Rohmer et al., 1980).

Hydroxyalkanones

Both samples contained C_{30} and C_{32} hydroxyalkanones (LXIIIa and b; Table 8), compounds recently characterized by de Leeuw et al. (personal communication); their concentrations are shown in Fig. 5.

Carboxylic Acids

Acyclic Components

The concentrations of *n*-alkanoic acids in Sections 487-2-3 and 491-1-5 are shown in Figure 1D; C_{16} and C_{26} are the major homologues of the respective distributions, which are both dominated by even-numbered components, although they differ markedly in the relative amounts of their short-chain (C_{12} - C_{20}) to long-chain (C_{20} - C_{34}) members. In addition to the compounds shown in Figure 1D, Section 487-2-3 contained trace amounts of C_{35} and C_{36} *n*-alkanoic acids. *n*-Alkenoic acids were recognized in both samples (Fig. 1D), but a rather greater range of these compounds was present in Section 487-2-3. *Iso*- and *anteiso*-alkanoic acids were also found in both samples, but the carbon number ranges varied (Fig. 1D). In particular, C_{25} , C_{27} , and C_{29} components were detected only in Section 491-1-5.

Cyclic and Aromatic Components

Dehydroabiatic acid (LXIV) was detected only in Section 487-2-3 (approx. 0.5 ng/g); no other diterpenoid acids and no steroidal acids were found in either sample. $\beta\beta$ -bishomohopanoic acid (XVIIIu) was recognized in Sections 487-2-3 and 491-1-5 at concentrations of approximately 1.6 ng/g and <0.2 ng/g, respectively. Section 491-1-5 also contained traces of $\beta\beta$ -homohopanoic acid (XVIIIv). Nonhopanoid triterpenoid acids, possibly related to amyrin or friedelane skeletons (cf. Corbet et al., 1980), were present in minor amounts in Section 487-2-3, but lack of standard mass spectra precluded their identification.

DISCUSSION

Lipid Yields

Although the total lipid yields of Sections 487-2-3 and 491-1-5 have not been determined, the concentrations of individual lipids provide a measure of their total lipid content. The abundances of the compound classes evaluated in the two samples are considerably lower than those of other Quaternary marine sediments analyzed in our laboratory (e.g., Walvis Bay, Wardroper, 1979; Japan Trench, Brassell et al., 1980b, 1980c; California continental borderland, McEvoy et al., in press; Guaymas Basin, Thomson et al., in press b). Such sediments, however, show greater variability in their concentrations of components of marine origin (e.g., sterols and alkenones) than of terrestrial origin (e.g., *n*-alkanes in all the samples except Walvis Bay). The lower abundances of marine components relative to terrestrial components in the Middle America trench samples compared with the other sediments may therefore, in part, reflect less intensive water column productivity, although other environmental conditions are undoubtedly also important.

Paleoenvironmental Assessment: Lipid Indicators

Straight-Chain Components

The distributions of saturated straight-chain components (*n*-alkanes, *n*-alkan-2-ones, *n*-alkanols, and *n*-alkanoic acids) are consistent with a mixed input from autochthonous and allochthonous sources. The *n*-alkane distributions maximizing at *n*-C₂₉ (Fig. 1A), with a prominent odd/even preference in the C₂₂ to C₃₃ range (Table 2), are similar to those of higher plant waxes (e.g., Eglinton et al., 1962) and suggest that the *n*-alkanes reflect terrigenous input (e.g., Simoneit, 1978; Brassell et al., 1978). Evidence of major autochthonous input is not reflected by the lower *n*-alkanes, especially *n*-C₁₇. The mediety of *n*-C₁₇ may, however, be due to its preferential biodegradation relative to higher *n*-alkanes (e.g., Johnson and Calder, 1973; Brassell et al., 1978) in both water column and sediment rather than to a low level of algal productivity in the euphotic zone. In addition, that higher plants possess greater concentrations of *n*-alkanes in their surface waxes than do algae makes *n*-alkanes more sensitive indicators of terrestrial than of

phytoplankton inputs. The short-chain *n*-alkanes of both samples possess similar low CPI values (Table 2), but these compounds are present in greater concentrations in Section 491-1-5 than Section 487-2-3, in contrast to the overall abundance of *n*-alkanes in the two samples. In view of the evidence for thermally mature inputs to the samples (see the following) it seems probable that the short-chain *n*-alkanes of Section 491-1-5 are, at least in part, derived from such a source.

The *n*-alkan-2-one distributions resemble those of the *n*-alkanes, especially in Section 487-2-3 (cf. Fig. 1A and B). Such similarity suggests that the *n*-alkan-2-ones originate from alkane oxidation rather than from β -oxidation of alkanic acids (Brassell et al., 1980c and references therein), but it is unclear whether such oxidation occurs at a pre- or postdepositional stage. In Section 491-1-5 the low relative abundance of short-chain *n*-alkan-2-ones, in contrast to the *n*-alkane distributions, suggests predepositional alkane oxidation.

Two possible sources of the *n*-alkanols and *n*-alkenols in marine sediments are input from the wax esters of marine organisms or lipid contributions from terrigenous higher plants. In higher plant waxes hexacosanol is the dominant homologue (Eglinton and Hamilton, 1967), whereas zooplankton wax esters contain C₁₆ to C₂₂ alkanol moieties (Benson and Lee, 1975), although their composition varies with growth conditions (Lee et al., 1971). The distributions of *n*-alkanols in Sections 487-2-3 and 491-1-5 do not therefore correspond well with an origin from either source. Indeed, similar distributions have been interpreted as both wax ester (Ikan et al., 1975) and terrestrial input (Aizenshtat et al., 1973; Brassell et al., 1980c). The presence of C₂₂ to C₂₆ *n*-alkenols in Section 487-2-3 further confuses the issue in that C_{20:1} and C_{22:1} are the major alkenoid moieties of calanoid copepods (Nevenzel, 1970) and higher plants are not known to contain these compounds. These discrepancies between the biological and sedimentary distributions of *n*-alkanols and *n*-alkenols precludes the unambiguous assignment of their biological origin.

The distributions of *n*-alkanoic and *n*-alkenoic acids suggest input from both autochthonous and allochthonous sources. The prominence of C₂₂ to C₃₄ *n*-alkanoic acids with even/odd predominance (Table 2) is consistent with input from terrigenous plants (e.g., Simoneit, 1978). The widespread occurrence of C₁₆ and C₁₈ *n*-alkanoic acids in biota makes them nondiagnostic source indicators, whereas the relative abundance of C₁₂ and C₁₄ *n*-alkanoic acids in Section 487-2-3 suggests autochthonous lipid inputs. It is not possible, however, to differentiate between algal and bacterial autochthonous input of carboxylic acids without information regarding the geometrical isomerism of the *n*-alkenoic acids (Volkman and Johns, 1977). The shorter-chain *n*-alkanoic and *n*-alkenoic acids might also originate from marine wax esters (Boon and de Leeuw, 1979).

The only organism in which the C₃₇ to C₃₉ alkenones (XLI, XLII) have been recognized is *Emiliania huxleyi* (Volkman et al., 1980a, 1980b). Hence, these ketones have been ascribed to coccolithophore input to sediments, even where deposition below the CCD has de-

stroyed any skeletal evidence of such organisms (Brassell et al., 1980b, 1980c; Volkman et al., 1980a). A major difference between the distribution of alkenones in Sections 487-2-3 and 491-1-5 and in *E. huxleyi* is the ratio of di- to triunsaturated homologues. In *E. huxleyi* the alkatrienones are dominant, although analysis at the motile, sessile, and coccolith stages of growth shows that the ratio of alkadienones to alkatrienones varies throughout the growth cycle (Volkman et al., 1980a). In contrast, the alkenone distributions of sediments are generally dominated by the alkadienones (di/tri ratios range from 0.7 to 4; Volkman et al., 1980a; Brassell et al., 1980b), but Sections 487-2-3 and 491-1-5 possess alkadienones/alkatrienones ratios an order of magnitude higher (33 and 57, respectively). This dissimilarity in the alkenone ratios may reflect sediment contributions from *E. huxleyi* that has grown under different environmental conditions or an input from an organism that biosynthesises these alkenones with a different alkadienone/alkatrienone ratio. Alternatively, the alkatrienones may be more easily degraded relative to the alkadienones in the Middle America Trench than in other sediments.

Although the biological source of the hydroxyalkanoes (LXIII) is uncertain because they have yet to be recognized in organisms, they are probably of marine origin in view of their geological occurrence (de Leeuw, personal communication; Thomson et al., in press, b). The absence of the C₃₁ hydroxyalkanone is not unexpected, since this component is present in markedly lower concentrations than the C₃₀ and C₃₂ homologues in other sediments (de Leeuw et al., personal communication; Thomson et al., in press b).

Branched-Chain Components

Short-chain *iso*- and *anteiso*-alkanoic acids are constituents of bacteria (e.g., Parker et al., 1967; Cranwell, 1973), hence the occurrence of such C₁₃ to C₁₇ components (Fig. 1D) in Sections 487-2-3 and 491-1-5 may be attributed to input from bacteria (e.g., Simoneit, 1978; Brassell et al., 1980c). By analogy, the *iso*- and *anteiso*-alkanols (C₁₅-C₂₁, Fig. 1C) are also of bacterial origin (Brassell et al., 1980c). In contrast, the C₂₅, C₂₇, and C₂₉ *iso*- and *anteiso*-alkanoic acids are probably derived from terrestrial sources in view of their relationship to the long-chain 2- and 3-methylalkanes found in higher plant waxes (Eglinton et al., 1962). The *iso*- and *anteiso*-alkanes recognized in Sections 487-2-3 and 491-1-5 are short-chain homologues, however, which may be of direct bacterial origin (e.g., from methanogens; Holzer et al., 1979). Alternatively, the widespread occurrence of such compounds in ancient sediments and petroleum (e.g., Tissot and Welte, 1978) suggests that they could be contributed by an input of thermally mature lipids—e.g., from an oil seep or other reworked source. The uniformity of the carbon number distributions of the branched alkanes in Sections 487-2-3 and 491-1-5 differs from the limited range found in bacteria (Holzer et al., 1979) and in sediments thought to reflect

bacterial inputs (Brassell et al., 1981) but is consistent with a thermally mature source, which therefore seems the most probable origin of these compounds.

Acyclic Isoprenoid Components

Despite the nonspecificity of its biological occurrence, the lability of phytol means that its abundance in Sections 487-2-3 and 491-1-5 probably reflects autochthonous marine inputs (Brassell et al., 1980c). In contrast, 6,10,14-trimethylpentadecan-2-one is less readily degraded and may derive from allochthonous sources and/or be generated from phytol within the water column or sediment. There are two possible biological sources for 2,6,10-trimethylpentadecane, pristane, phytane, the phytenes, and dihydrophytol: they may be degradation products of plant phytol and/or inputs from methanogenic sources (e.g., Holzer et al., 1979). In the absence of stereochemical analyses (e.g., Patience et al., 1978) the three alkanes might alternatively originate from mature allochthonous sources (see the following). The recognition of 2,6,10,15,19-pentamethyleicosane (I) and squalane (II) in the samples provides evidence for methanogenic biological activity (Brassell et al., 1980c, 1981). Methanogens may also be the source of lycopane (V), although this compound has yet to be recognized among their lipids (Brassell et al., 1980c, 1981). Similarly, the acyclic isoprenoids coeluting with 2,6,10,15,19-pentamethyleicosane and *n*-C₃₄, tentatively assigned as 2,6,10,14,18-pentamethyleicosane (III) and 2,6,10,14,17,21,25,29-octamethylhentriacontane (IV), respectively, are probably of methanogenic origin.

Nonisoprenoidal Cyclic Components

Alkylcyclohexanes have yet to be found in organisms, although ω -cyclohexylalkanoic acids (LXV) have been recognized as lipid constituents of thermoacidophilic bacteria (e.g., De Rosa et al., 1972). Their occurrence in ancient sediments and petroleum (Johns et al., 1966; Speers and Whitehead, 1969) and their formation in simulated maturation experiments (Ishiwatari and Fukushima, 1979; Rubinstein and Strausz, 1979) suggest that their presence in Section 491-1-5 reflects input from thermally mature sources.

Cyclic Diterpenoid Components

The four cyclic diterpenoids (fichtelite, simonellite, retene, and dehydroabietic acid; VIII, XXX, XXXI and LXIV) recognized in the sediments are all believed to be diagenetic products of abietic acid (Maxwell et al., 1971; Laflamme and Hites, 1978) and markers for terrigenous input of resinous plants (Simoneit, 1977).

C₂₅ and C₃₀ Unknown Alkenes

The biological origins of the C₂₅H₄₄ bicyclic alkadiene and the C₃₀H₅₂ bicyclic alkatriene are uncertain. The mass spectral, and hence structural, similarities of the two compounds imply that they derive from a common source, which appears to be marine rather than ter-

restrial. Indeed, a planktonic source for the C_{30} component has been suggested (Prahl et al., 1980) but has yet to be confirmed by its isolation from such an organism.

Steroidal Components

The majority of the stenols of Sections 487-2-3 and 491-1-5—namely $C_{26}\Delta^{5,22}$ and C_{27} - $C_{29}\Delta^5$, $\Delta^{5,22}$, and $\Delta^{5,24(28)}$ components (A, F, H, J, M, O, P₂, R, S₂, U₂, and W in Table 7)—may be attributed to phytoplankton inputs (e.g., Boutry and Jacques, 1970; Boutry and Barbier, 1974; Orcutt and Patterson, 1975; Ballantine et al., 1979; Volkman et al., 1980c), although they are not uniquely biosynthesized by these organisms. For example, all of these Δ^5 -sterols occur in tunicata (Ballantine et al., 1977), but previous investigations of sedimentary sterol distributions (e.g., Lee et al., 1977, 1979; Wardroper et al., 1978; Wardroper, 1979; Brassell, 1980) have ascribed them to phytoplankton or terrestrial higher plant contributions (Huang and Meinschein, 1976).

In Sections 487-2-3 and 491-1-5, as in Japan Trench sediments (Brassell, 1980; Brassell and Eglinton, 1981), the inconsistency of the Δ^5 -sterol/ 5α -stanol ratios and the occurrence of only C_{27} 5β -stanols argue against diagenetic reduction of Δ^5 -sterols (Gaskell and Eglinton, 1975) as a major source of 5α -stanols. Hence, the 5α -stanols probably originate from direct biological inputs to the sediment. 5α -Stanols are minor constituents of various organisms, including phytoplankton, zooplankton, and higher plants (e.g., Nishimura and Koyama, 1976, 1977); echinoderms (Goad et al., 1972); coelenterates (Kanazawa et al., 1977); and sponges (Nes and McKean, 1977), which all might contribute lipids to the sediments. These Leg 66 sediments, like most others (cf. Wardroper et al., 1978), contain larger amounts of 5α -stanols relative to Δ^5 -sterols than do organisms, a fact which may largely reflect a bias in the analyses of biological sterols. In particular, stanols can be more prevalent at stationary growth phases than at exponential growth stages (Ballantine et al., 1979). The relative abundance of sedimentary stanols compared with sterols may therefore reflect direct lipid contributions from phytoplankton at their stationary rather than exponential growth stages. Alternatively, Δ^5 -sterols may be preferentially degraded relative to 5α -stanols in the water column, but evidence for the Black Sea shows that this is not the case there (Gagosian et al., 1979).

The overall distribution of 4-desmethyl sterols and stanols suggests that they are largely of phytoplanktonic origin, with the exception of components U₂ and V₁ (24-ethylcholest-5-en-3 β -ol, LIVm and 24-ethyl-5 α -cholestan-3 β -ol, LVm; Table 7 and Fig. 4), which may derive from allochthonous inputs of higher plants (Huang and Meinschein, 1976). The absence of C_{21} to C_{25} stanols and other characteristic sponge and coelenterate sterols (e.g., gorgosterol, LIVs; Wardroper et al., 1978) argues against major lipid inputs from such organisms (cf. Brassell, 1980; Brassell and Eglinton, 1981).

The dominant sterol of both samples is dinosterol (component X in Table 7 and Fig. 4, LVIj), which is the principal sterol of dinoflagellates (Shimizu et al., 1976)

and a marker for dinoflagellate blooms (Boon et al., 1979). Other sedimentary 4-methylstanols may also derive from dinoflagellates (e.g., Withers et al., 1978, 1979), although methanotrophic bacteria contain such compounds and have been suggested as their source (Dastillung et al., 1980b). On present evidence, however, sediment inputs from these two types of organism cannot be distinguished, except that the abundance of dinosterol in sediment traps in the equatorial Atlantic Ocean (Wakeham et al., 1980c) indicates that it can originate from a pelagic source.

The stanones appear to represent direct biological inputs to the sediment, although they are not widely reported as constituents of organisms, with the exception of dinosterone (4 α , 23,24-trimethyl-5 α -cholest-22-en-3-one, XLVc), a known component of dinoflagellates (Withers et al., 1978). The other 4 α -methylstanones appear to be the 3-oxy equivalents of sterols AB and dinostanol (AC, LVI ℓ), and may therefore be derived from the same unknown sources. The overall dissimilarity of the sterol and sterone distributions seems to preclude a diagenetic origin for the latter (cf. Gagosian and Smith, 1979; Edmunds et al., 1980).

Sterenes have not been detected among the lipids of any organisms and are regarded as microbial degradation products of sterols (e.g., Dastillung and Albrecht, 1977; Gagosian and Farrington, 1978). In Sections 487-2-3 and 491-1-5 the distribution and relative abundances of the sterenes do not parallel those of their presumed precursor sterols, suggesting that their formation is selective, affecting only specific individual sterols or sources of sterols. In particular, the prominence of Δ^{24} -sterenes is disproportionate to the relative abundance of Δ^{24} -sterols and stanols, suggesting that Δ^{24} -sterols may be more susceptible to microbial dehydration than other sterols, such as Δ^{22} components. Indeed the abundance and range of Δ^{22} -sterols in the sediments (Table 7 and Fig. 4) are markedly greater than those of Δ^{22} -sterenes (Table 3). Among the nuclear unsaturated sterenes, Δ^2 -sterenes (XII) and $\Delta^{3,5}$ -steradienes (XIII) may originate from dehydration of stanols and Δ^5 -sterols, respectively (e.g., Dastillung and Albrecht, 1977; Gagosian and Farrington, 1978). The recognition of such sterenes in particle traps illustrates their relatively fast formation associated with sinking particles (Wakeham et al., 1980c) and attests to their pelagic origin. The source of the stratienes, thought to be monoaromatic steroids (XIV or XV), is uncertain, but they are probably microbial degradation products of sterols (Gagosian and Farrington, 1978), perhaps stera-5,7-dienols (LXIX) which are rarely found intact in sediments (Brassell, 1980; Edmunds et al., 1980).

The absence of 4-methylsterenes in Sections 487-2-3 and 491-1-5, despite the abundance of 4-methylstanols, is consistent with results for other Quaternary marine sediments (Wardroper, 1979; Brassell, 1980; Gagosian et al., 1980; Thomson et al., in press b). It appears, therefore, that defunctionalization of 4-methylstan-3 β -ols may be inhibited by the steric hindrance of a 4-methyl substituent. Such discrepancy in the occurrence of sterenes and 4-methylsterenes compared to 4-des-

methyl- and 4-methylsterols suggests that microorganisms effect sterol to sterene conversions, since a geochemical transformation would be expected to be less dependent on sterol C-4 substitution (Thomson et al., in press b; Gagosian et al., 1980).

The steranes (IX) and diasteranes (X) of Sections 487-2-3 and 491-1-5 do not represent direct biological input but derive from an allochthonous thermally mature source (see the following).

Triterpenoidal Components

Hopanoids

The majority of hopanoids in the two samples are either direct bacterial inputs or diagenetic derivatives of bacterial lipids such as polyhydroxybacteriohopanes (XVIIIw or x, De Rosa et al., 1971; Ourisson et al., 1979; Dastillung et al., 1980a, 1980b; Rohmer et al., 1980). In particular, extended hopanols and hopanoic acids have not been found in organisms; their occurrence in sediments is attributed to oxidation of polyhydroxybacteriohopanes, which are the only extended hopanoids found in biota (Ourisson et al., 1979). Hop-17(21)-ene (XIX) and neohop-13(18)-ene (XXI) have been assigned as isomerization products of hop-22(29)-ene (XVIIIf) in the Paris Basin (Ensminger, 1977) and as direct terrigenous inputs from ferns in immature sediments from the Japan Trench (Brassell et al., 1980c). The recent recognition of hop-17(21)-ene and neohop-18(18)-ene in an anaerobic photosynthetic bacterium (Howard, 1980) suggests that these compounds may represent direct sediment inputs of bacterial lipids (Brassell et al., 1981). By analogy, neohop-12-ene (XXIII) may also be derived from bacteria (Brassell et al., 1981) rather than from ferns (Brassell et al., 1980c and references therein). The C₂₇ and C₂₉ hopanoid ketones (XLVI and L), like *n*-alkan-2-ones, may be products of microbial oxidation of the corresponding hydrocarbons (Dastillung et al., 1980a), further illustrating the importance of bacteria in influencing sedimentary lipid compositions.

Nonhopanoids

Until recently the occurrence of ferenes (XX, XXII, XXIV) in a sediment was thought to reflect terrestrial inputs, since these triterpenes had only been recognized in ferns (Wardroper, 1979; Brassell et al., 1980c). The discovery of ferenes in a bacterium (Howard, 1980), however, casts doubt on this interpretation and suggests that they may be of microbial origin (Brassell et al., 1981). The other nonhopanoid triterpenones (Table 6) and triterpenols (Table 8) are all components of higher plants (e.g., Devon and Scott, 1972) and may therefore represent terrigenous inputs to the samples (Brassell et al., 1980c). Similarly, the tetracyclic aliphatic and aromatic hydrocarbons recognized in Sections 487-2-3 and 491-1-5 (Fig. 2 and Table 5) are of allochthonous, terrigenous origin because they appear to be photochemical or microbially induced photomimetic products of higher plant triterpenoids (Corbet et al., 1980).

The unknown triterpenes found in Sections 487-2-3 and 491-1-5 are of uncertain origin, but a bacterial

Table 8. Triterpenols and hydroxyalkanones identified in Sections 487-2-3 and 491-1-5.

Peak (Fig. 5)	Assignment	Structure
A	taraxer-14-en-3-ol ^a	LVIII
B	olean-12-en-3-ol (β -amyryn)	LIX
— ^b	urs-12-en-3-ol (α -amyryn)	LX
C	$\beta\beta$ -hopan-29-ol	XVIIIp
D	hopan-3 β -ol or hopan-6 α -ol? ^c	LXI or LXII?
E	hydroxytriacontan-15-one	LXIIIa
F	$\beta\beta$ -homohop-31-ol	XVIIIr
G	hydroxydotriacontan-15-one	LXIIIb
H	$\beta\beta$ -bishomohop-32-ol	XVIIIs
— ^b	$\beta\beta$ -trishomohop-33-ol	XVIIIt

^a Assignment based on spectral interpretation by comparison with spectrum of taraxer-14-en-3-one (XLVII).

^b Compounds present in minor amounts (< 1 ng/g for Section 487-2-3, < 0.3 ng/g for Section 491-1-5).

^c Tentative assignments suggested by mass spectral comparison with standard and literature spectra (Rohmer, 1975), respectively.

source appears probable in view of the fact that the other triterpenes are all attributed to bacterial lipid inputs.

Perylene

The origin of perylene is uncertain (Wakeham et al., 1979, 1980a), but it appears to be an early-stage diagenetic product formed *in situ* from unknown precursors. The source of such precursors, i.e. whether marine or terrestrial, is also unclear (Wakeham et al., 1979, 1980a).

Summary

The lipid markers in the sediments provide evidence for inputs of organic matter from both autochthonous and allochthonous sources (Table 9). The autochthonous indicators include components characteristic of algae and bacteria and of bacterial reworking within the water column or sediment. The lipids of allochthonous origin include compounds derived from higher plants and inputs from a thermally mature source. The lack of full quantitative data for all compounds complicates the assessment of the relative size of autochthonous and allochthonous lipid inputs. On balance, however, the dominance of higher straight-chain compounds derived from terrestrial sources suggests that the major lipid input to both samples is of terrigenous origin, assuming that the C₂₂ to C₂₆ *n*-alkanols are derived from higher plants. The lipid contributions from algae are of a similar order of magnitude, greatly outweighing the bacterial and thermally mature allochthonous inputs. There are, however, significant differences between Sections 487-2-3 and 491-1-5 in the relative sizes of their four major sources of lipids (Table 9).

Diagenetic Assessment

The dominant lipids of both sediments are functionalized compounds, namely alcohols, ketones, and carboxylic acids; for example, sterols are markedly more abundant than other steroidal lipids. Such dis-

Table 9. Lipid markers in Sections 487-2-3 and 491-1-5 indicative of autochthonous and allochthonous sources of organic matter.

Compound Structural Class	Autochthonous		Allochthonous	
	Marine (nonbacterial)	Bacterial ^a	Terrestrial (higher plant)	Rederived (thermally mature)
(i) straight-chain	<i>n</i> -alkanols? <i>n</i> -alkenones: hydroxyalkanones	<i>n</i> -alkenoic acids (<i>n</i> -alkan-2-ones)	<i>n</i> -alkanes; <i>n</i> -alkan-2-ones; <i>n</i> -alkanols? <i>n</i> -alkanoic acids	<i>n</i> -alkanes
(ii) branched-chain		<i>iso</i> - and <i>anteiso</i> - alkanols and alkanolic acids		<i>iso</i> - and <i>anteiso</i> - alkanes
(iii) acyclic isoprenoids	phytol	2,6,10,15,19-pentamethyleicosane and squalane		
(iv) nonisoprenoidal cyclics (v) cyclic diterpenoids			fichtelite, simonellite, retene, and dehydro abietic acid	alkylcyclohexanes
(vi) unknown alkenes (vii) steroids	C ₂₅ H ₄₄ and C ₃₀ H ₅₂ components (sterenes) many sterols and 4-methylstanols; stanones and 4-methylstanones		24-ethylcholesteroids	steranes and diasteranes
(viii) triterpenoids a) hopanoids b) nonhopanoids		extended hopanoids and hopanes farnenes? (tetracyclic aliphatic and aromatic hydrocarbons)	farnenes? triterpenones and triterpenols; tetracyclic aliphatic and aromatic hydrocarbons ?	$\alpha\beta$ -hopanes (in part)
(ix) perylene	?	?	?	

^a Components in parentheses are assigned as products of bacterial reworking rather than direct input of bacterial lipids.

tributions are characteristic of immature sediments in which diagenetic processes, other than microbial degradation, have not occurred to a marked extent. The lipid analysis of two shallow samples from different sites precludes an evaluation of diagenetic trends in the Middle America Trench, but the extent of microbial degradation of lipids and other early-stage transformations can be assessed.

The presence of diunsaturated carboxylic acids in Section 487-2-3 is an indication of sample immaturity, as such compounds usually undergo rapid microbial breakdown in sediments (e.g., Matsuda and Koyama, 1977). The occurrence of alkenes varies among compound classes: several sterenes derived from sterol precursors were present in both samples, whereas phytenes formed from dehydration of phytol or contributed as direct input from methanogens (Tornabene et al., 1979; Holzer et al., 1979) were only recognized as trace components in Section 491-1-5. No *n*-alkenes were detected. These differences in the occurrence of alkenes suggest that alcohol dehydration is a microbially mediated process rather than a physicochemical reaction in this instance. Sedimentary ketones can come from direct contributions of biological lipids (e.g., sterones) or be derived from the oxidation of input of alkanes, acids, or alcohols (e.g., hopanones). In some instances (e.g., *n*-alkan-2-ones) these two different modes of origin cannot be distinguished on the basis of compound distributions. Overall, the ketones recognized in Sections 487-2-3 and 491-1-5 suggests that their *in situ* formation by microbial degradation is not a significant process, as illustrated by the disparity of hopanone and other hopanoid distributions.

Hop-22(29)-ene (XVIII_f) originates from a direct autochthonous input and undergoes diagenetic isomerization to hop-21-ene (XXV) and thence to hop-17(21)-ene (XIX; Ensminger, 1977; Brassell et al., 1980c). The presence of hop-22(29)-ene and hop-21-ene in the samples is an indication of their immaturity, since these compounds disappear at an early stage of diagenesis (Brassell et al., 1980c). On the basis of their hop-22(29)-ene/hop-21-ene ratios, Section 491-1-5 appears to be more mature than Section 487-2-3, but differences in the clay content of the sediment or other lithological characteristics may also influence their rates of isomerization. In addition, the recent recognition of hop-17(21)-ene and neohop-13(18)-ene (XXI) in a bacterium (Howard, 1980) means that hop-21-ene may in fact originate as both a direct biological input and an isomerization product of hop-22(29)-ene. Although both samples contained ster-2-enes (XII), no Δ^4 - or Δ^5 -sterenes nor diasterenes were detected, indicating that no isomerization of sterenes has yet occurred (cf. Rubinstein et al., 1975; Wardroper, 1979; Brassell, 1980).

Aromatization, presumably microbial, of diterpenoids, steroids, and triterpenoids can occur at an early stage of diagenesis or, especially for compounds derived from allochthonous sources, prior to sediment deposition. Whether the aromatic diterpenoids (simonellite, XXX and retene, XXXI) and the aromatic tetracyclic components derived from nonhopanoid triterpenoids (XXXII-XXXVIII) are formed *in situ* or predepositionally cannot be resolved from the analysis of an individual shallow sediment. The aromatization of such compounds may be a continuing process in the sediments, however, in view of the presence of incompletely aro-

matized components (e.g., dehydroabiatic acid, LXIV). The presumed precursor of one of the major tetracyclic aromatic components (XXXIV) and the $C_{24}H_{32}$ alkane (XXVIII), lupan-3-one (LXVI), was not detected in either sample, suggesting that the microbial degradation of its A ring and subsequent saturation or aromatization (Corbet et al., 1980) is well advanced. In contrast, the minor amounts of steratrienes with aromatic A or B rings (XIV or XV) found in the samples (Table 3) suggest that their formation by microbial dehydrogenation or dehydroxylation (e.g., Gagosian and Farrington, 1978) may not be favored in these sediments or that it has not yet proceeded far. The aromatic hopanoids thought to be products of microbial action on other hopanoids (Greiner et al., 1977; Ourisson et al., 1979) were not detected in the samples, although they have been recognized in other marine sediments (e.g., Tissier and Dastillung, 1978). These results may reflect differences in sedimentary microbial populations or overall sample immaturity, since few of the microbial degradation products of lipids are present in any abundance.

The majority of lipids in the sections therefore represent direct biological inputs or microbial degradation products of such inputs (e.g., steranes). The exceptions are those compounds (steranes, $\alpha\beta$ -hopanes, etc.) derived from thermally mature sources whose recognition in shallow, immature DSDP sediments necessitates an evaluation of the possibility of shipboard core contamination from drilling lubricants, principally pipe dope (Brassell and Eglinton, 1980; Thomson et al., in press a). There are, however, significant differences between the thermally mature components of Sections 487-2-3 and 491-1-5 and the hydrocarbons of pipe dope sampled during Leg 59 (Brassell and Eglinton, 1980). These dissimilarities include the distributions of *n*-alkanes, alkylcyclohexanes, extended diterpanes (which are absent in Leg 66 samples), and steranes and the C_{max} unresolved complex mixture of hydrocarbons. They suggest that pipe dope is not the source of the thermally mature lipids in Sections 487-2-3 and 491-1-5, although the uniformity of its composition cannot be guaranteed. Hence these allochthonous lipids appear to represent a natural, rather than contaminant, input of reworked material, perhaps derived from oil seeps. On the evidence of the distribution of *n*-alkanes assigned as a thermally mature input in Section 491-1-5 it appears that the input is of relatively unbiodegraded material.

Sample Comparisons

A summary of the qualitative differences and similarities between the lipid compositions of Sections 487-2-3 and 491-1-5 is given in Table 10. In quantitative terms, the lipid content of Section 487-2-3 is generally higher than that of Section 491-1-5 (Table 11); a difference that is probably a function of sediment inputs or of lipid preservation, as seen in Table 10. The larger amounts of autochthonous lipids in Section 487-2-3 may reflect the magnitude of such input and/or their better preservation. The discrepancy in the apparent size of input of bacterial lipids (e.g., branched alkanolic acids) to the

samples suggests that their microbial populations may differ, although it may also simply reflect lipid preservation. The few compounds present in greater amounts in Section 491-1-5 than in Section 487-2-3 include those components that are derived largely from thermally mature sources (e.g., *n*-heptadecane in 491-1-5) and certain aromatic components (e.g., retene) and several ketones (e.g., 22,29,30-trisnorhopan-21-one) thought to derive from allochthonous sources. The greater relative proportion of lipids derived from thermally mature sources in Section 491-1-5 may reflect its proximity to such sources. Similarly, consideration of the geographical location of the two sites suggests that the trench slope sample (Section 491-1-5) should possess a higher proportion of lipids of terrestrial origin, which it does in terms of their relative abundance, although their absolute concentration is often lower in Section 491-1-5 than in Section 487-2-3.

The lithological characteristics of the samples may also bear on the relative size of their lipid input from autochthonous and allochthonous sources, since higher plant material may be concentrated in coarser-grained sediment fractions (Thompson and Eglinton, 1978).

Comparison with Japan Trench Samples

Although a detailed comparison of the lipids of Sections 487-2-3 and 491-1-5 with those of Pleistocene sediment from the Japan Trench (Brassell et al., 1980b, 1980c; Brassell, 1980) is not presented here, the considerable similarity that exists between some of their lipid distributions is illustrated in Figure 6. In addition, Table 12 provides a general comparison between these sediments in terms of the distributions of specific lipid classes. Both suites of samples contain similar series of lipids derived from autochthonous (algal and bacterial) and allochthonous (higher plant) sources, although inevitably there are minor differences in their distributions (Table 12). The more significant discrepancies between the lipid distributions appear to reflect the variety of biological input represented (e.g., sterol distributions are more complex in Japan Trench sediments), the extent of diagenesis (e.g., diasterenes occur only in Japan Trench sediments), the presence or absence of hydrocarbons from thermally mature sources (e.g., branched alkanes in the Middle America Trench sediments), and, possibly, environmental conditions (e.g., alkenone distributions). It is significant, however, that the differences in lipid composition between Sections 487-2-3 and 491-1-5 are as great (or as small) as those between Leg 66 and 56/57 samples.

The resemblance between the lipid distributions of the Middle America and Japan Trench sediments probably reflects a general similarity in their autochthonous and allochthonous lipid input; their conditions of deposition (especially their microbial populations), and their diagenetic processes. The greater relative size of the autochthonous inputs in the Japan Trench sediment (Brassell et al., 1980b, 1980c) is probably a function of water column productivity.

Table 10. Qualitative differences and similarities between the lipid compositions of Section 487-2-3 and 491-1-5.

Lipid Class	Comparison between Sections 487-2-3 and 491-1-5	Comments
Straight-Chain		
<i>n</i> -alkanes	The proportion of short-chain components is greater in 491-1-5 (Fig. 1A)	difference arises from thermally mature inputs in 491-1-5
<i>n</i> -alkan-2-ones	similar (Fig. 1B)	—
<i>n</i> -alkanols	similar (Fig. 1C)	—
<i>n</i> -alkanoic acids	short-chain components are more prominent in 487-2-3 (Fig. 1D)	larger autochthonous inputs in 487-2-3
alkenones	similar (Fig. 3)	—
alkenols	detected only in 487-2-3 (Fig. 1C)	better lipid preservation in 487-2-3?
alkenoic acids	greater range present and more abundant in 487-2-3 (Fig. 1D)	autochthonous input larger and better preserved in 487-2-3?
hydroxyalkanones	similar (Fig. 5)	—
Branched-Chain		
alkanes	more prominent in 491-1-5 than 487-2-3	occurrence reflects thermally mature inputs
alkanols	similar (Fig. 1C)	—
alkanoic acids	short-chain homologues are more abundant in 487-2-3, higher homologues were found only in 491-1-5	differences reflect greater autochthonous and terrigenous inputs, respectively
Acyclic Isoprenoids		
alkanes	similar, except for the coeluting C ₂₅ component in 487-2-3 (Fig. 1A)	differences may reflect variations in methanogen populations
ketone	6,10,14-trimethylpentadecan-2-one is relatively more abundant in 491-1-5 (Fig. 1B)	greater allochthonous input to or poor lipid preservation in 491-1-5?
alcohols	similar, except that dihydrophytol was recognized only in 487-2-3 (Fig. 1C)	autochthonous inputs may differ
Nonisoprenoid Cyclics		
alkylcyclohexanes	detected only in 491-1-5	components originate from thermally mature input
Cyclic Diterpenoids		
alkane	fichtelite was detected only in 487-2-3	feature of differences in allochthonous lipid input or lipid preservation?
aromatic hydrocarbons	simonellite and retene are more abundant in 491-1-5	greater allochthonous input in 491-1-5
acid	dehydroabietic acid was recognized only in 487-2-3	better preservation of unaltered lipids in 487-2-3
Unknown Cyclics		
alkenes	C ₂₅ H ₄₄ and C ₃₀ H ₅₂ components were observed only in 487-2-3	autochthonous inputs more prominent in 487-2-3
Steroids		
alkanes	distributions differ in the relative size of their C ₂₉ components and diasteranes	components derive from separate input of thermally mature lipids to each sample
alkenes	similar distributions except steratrienes and stera-3,5-dienes are more abundant in 487-2-3 and 491-1-5, respectively (Table 3)	sterenes may originate from different sources or reflect variability in diagenesis.
ketones	similar	—
alcohols	similar, but 5 α -stanols and C ₂₉ Δ^{22} components are more prominent in 491-1-5 (Fig. 4)	sources of sterols differ, in part
Hopanoid Triterpenoids		
alkanes	491-1-5 contains a higher abundance of $\alpha\beta$ -hopanes, distributions are otherwise similar (Table 4)	thermally mature inputs are greater in 491-1-5
alkenes	similar, except for the prominence of hop-22(29)-ene in 487-2-3 (Table 4)	autochthonous input or bacterial populations differ, or lipids of 491-1-5 are diagenetically more mature
ketones	dissimilar; 22,29,30-trisnorhop-21-one, the major component of 491-1-5 was not detected in 487-2-3 (Table 6)	greater allochthonous input to, or poorer lipid preservation in, 491-1-5?
alcohols	similar, except for the absence of component D in 487-2-3 (Fig. 5)	minor differences in autochthonous inputs
acids	similar	—
Nonhopanoid Triterpenoids and Derivatives		
alkanes/alkenes	ferrenes are more prominent in 491-1-5 tetracyclic alkanes and alkenes are similar (Fig. 2)	greater allochthonous inputs to 491-1-5, or different bacterial populations
aromatic hydrocarbons	similar (Table 5)	—
ketones	similar, except for the presence of glutenone in 487-2-3 (Table 6)	reflects differences in lipid inputs or preservation?
alcohols	taraxerol is more prominent in 491-1-5 (Fig. 5)	reflects differences in lipid inputs or preservation?
Other		
perylene	perylene is much more abundant in 491-1-5	In 491-1-5 perylene precursors are more abundant or depositional conditions are more favorable for perylene formation

Table 11. Quantitative comparisons of lipid compositions of Sections 487-2-3 and 491-1-5.

Compound (structure)	Concentrations (ng/g) ^a		487-2-3/491-1-5 Ratio
	487-2-3	491-1-5	
n-heptadecane	1.5	3	0.5
n-nonacosane	3.4	13	2.6
n-nonacosanoic acid	3	0.5	6
n-tetradecanol	100	21	4.8
n-hexadecanoic acid	80	5.2	15
n-hexacosanoic acid	61	14	4.4
heptatriacontanoic acid (XLIIa)	48	14	3.4
hydroxytriacontanoic acid (LXIIIa)	28	8	3.5
13-methyltetradecanoic acid (iso-C ₁₅)	5	>0.2	>25
phytane	0.5	3	0.1
6,10,14-trimethylpentadecanoic acid	1.5	1.5	1
phytol	43	20	2.2
retene (XXXI)	approx. 0.2	approx. 1	approx. 0.2
cholest-2-ene (XIIa)	1.5	1	approx. 1.5
cholest-5-en-3 β -ol (LIVc)	37	5.6	6.6
5 α -cholestan-3 β -ol (LVc)	7.0	7.0	1
4 α ,23,24-trimethyl-5 α -cholest-22(E)-en-3-one (dinosterone, XLVc)	<0.1	approx. 1	<0.1
4 α ,23,24-trimethyl-5 α -cholest-22(E)-en-3 β -ol (dinosterol, LVIj)	68	21	3.2
$\alpha\beta$ -hopane (XVIIc)	approx. 5	approx. 4	approx. 1.2
$\beta\beta$ -homohopane (XVIIIe)	approx. 5	approx. 4	approx. 1.2
hop-22(29)-ene (XVIIIIf)	approx. 5	<0.5	>10
22,29,30-trisnorhopane-21-one (XLVI)	n.d.	8	0
$\beta\beta$ -bishomohopane-32-ol (XVIIIIs)	3.4	2	1.7
$\beta\beta$ -bishomohopanoic acid (XVIIIIsu)	approx. 1.6	<0.2	>8
fern-7-ene (XXIV)	approx. 2	approx. 1	approx. 2
olean-12-en-3-one (XLVIII)	<0.1	<0.1	approx. 1
olean-12-en-3-ol (β -amyrin, LIX)	2.2	0.8	2.7
perylene (XXXIX)	<0.1	7	<0.02

Note: n.d. = not detected.
^a ng/g dry sediment.

CONCLUSIONS

The features of two Quaternary Middle America Trench sediment sections (487-2-3 and 491-1-5) shown by lipid analysis can be summarized as follows:

- 1) Both sections contain lipids derived from autochthonous and allochthonous sources.
- 2) Inputs of hydrocarbons from thermally mature sources, such as oil seeps, are evident in both samples.
- 3) The lipid distributions attest to the immaturity of the sediment.
- 4) The differences in the lipid compositions of the two samples can be interpreted as functions of their various inputs (autochthonous vs. allochthonous vs. thermally mature sources), the quality of their lipid preservation, their microbial populations, and their lithology.
- 5) There is considerable similarity between the lipid distributions of this sediment and those of samples from the Japan Trench.

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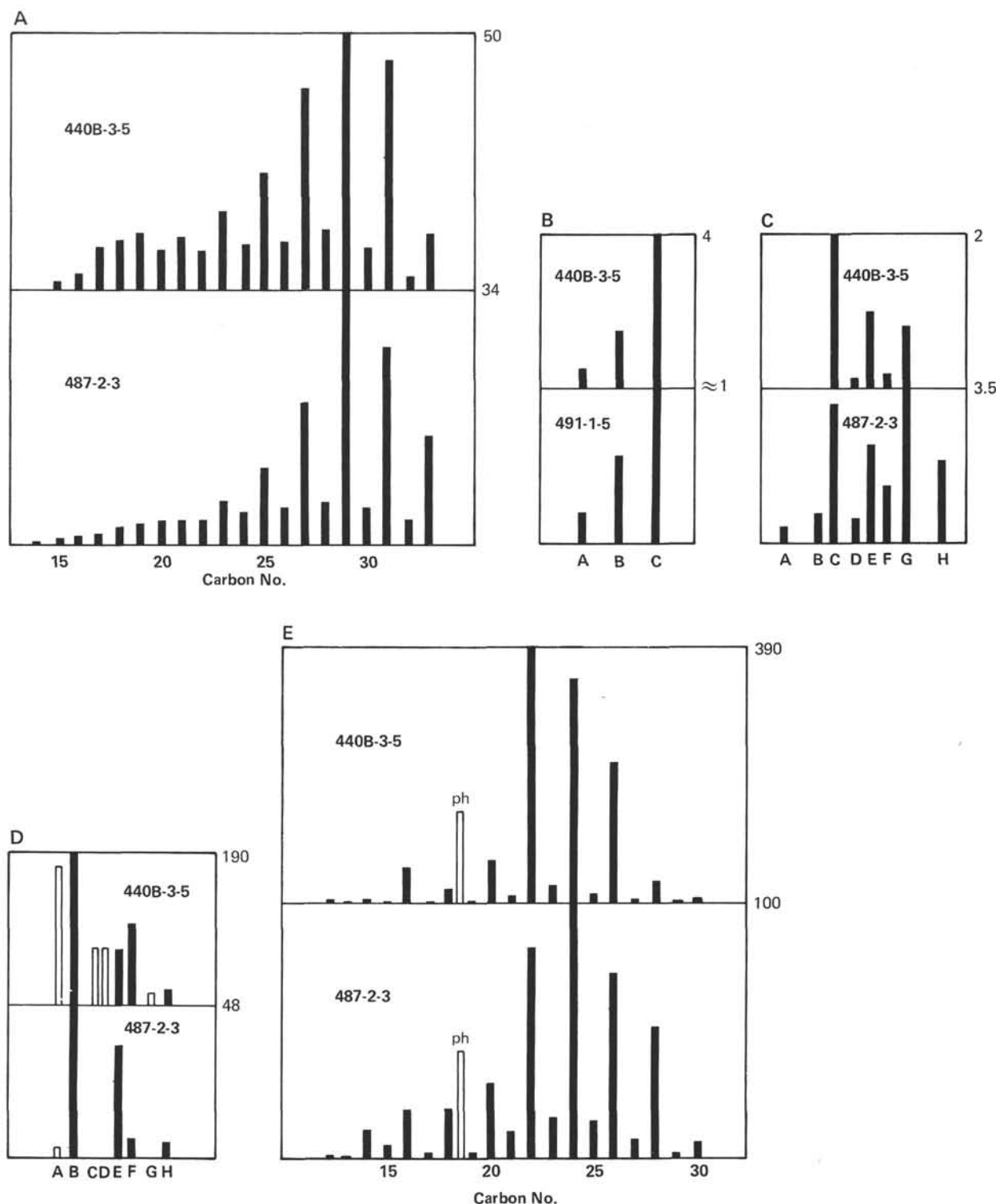


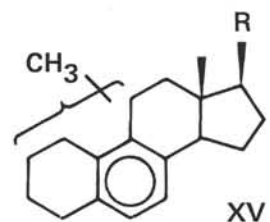
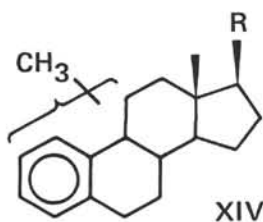
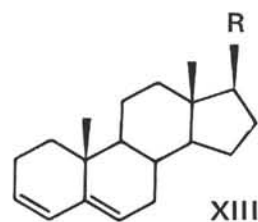
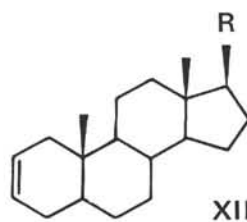
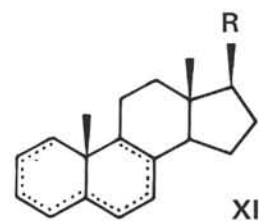
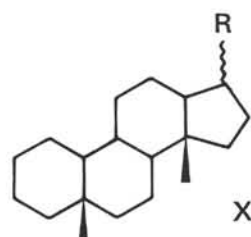
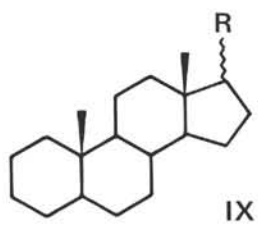
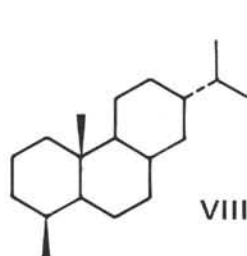
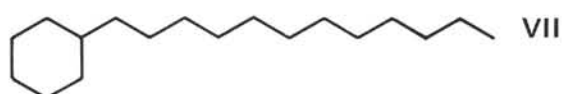
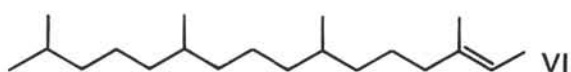
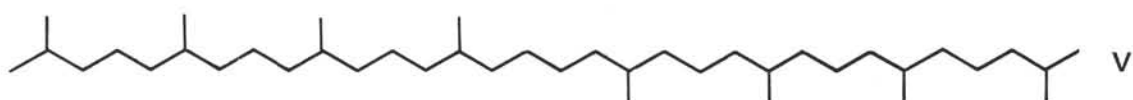
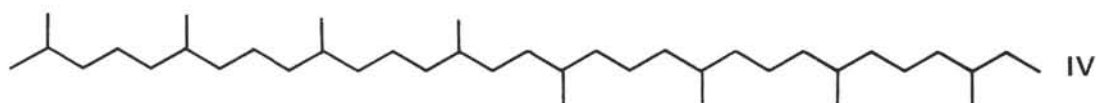
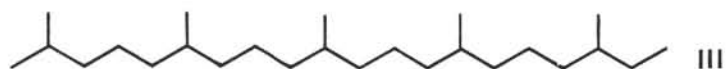
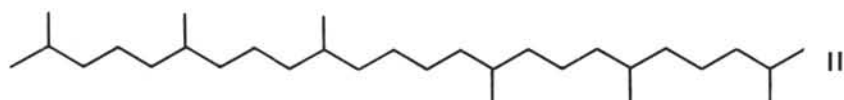
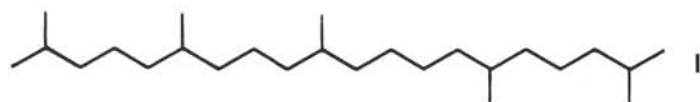
Figure 6. Comparison of lipid distributions of Quaternary Middle America and Japan Trench sediments. A. Concentrations (ng/g dry sediment) of *n*-alkanes in Sections 440B-3-5 and 487-2-3. B. Concentrations (ng/g dry sediment) of ferenes in Sections 440B-3-5 and 491-1-5. (A = fern-8-ene (XX); B = fern-9(11)-ene (XXII); C = fern-7-ene (XXIV).) C. Concentrations (ng/g dry sediment) of C_{24} tetracyclic alkanes/alkenes, assigned as ring A degraded triterpenoids in Sections 440B-3-5 and 487-2-3. Formulae as in Figure 2. D. Concentrations (ng/g dry sediment) of alkadienones (open bars) and alkatrienones (solid bars) in Sections 440B-3-5 and 487-2-3. (A = heptatriaconta-8,15,22-trien-2-one (XLa); B = heptatriaconta-15,22-dien-2-one (XLIIa); C = octatriaconta-9,16,23-trien-3-one (XLb); D = octatriaconta-9,16,23-trien-2-one (XLc); E = octatriaconta-16,23-dien-3-one (XLIIb); F = octatriaconta-16,23-dien-2-one (XLIIc); G = nonatriaconta-10,17,24-trien-3-one (XLd); H = nonatriaconta-17,24-dien-3-one (XLId). The peak lettering differs from that of Fig. 3. E. Concentrations (ng/g dry sediment) of *n*-alkanols and phytol in Sections 440B-3-5 and 487-2-3. (ph = phytol [open bar].)

Table 12. Qualitative differences and similarities between selected lipid distributions of Japan and Middle America Trench sediments.

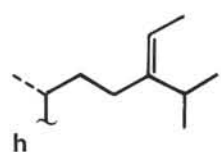
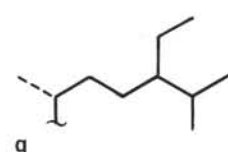
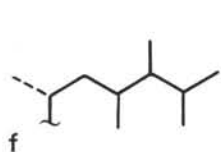
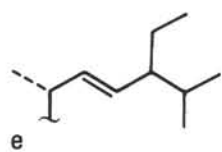
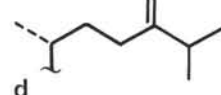
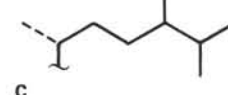
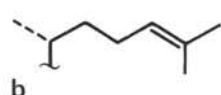
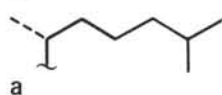
Lipid Structural Class	Comparison between Middle America (Leg 66) and Japan (Legs 56/57) Trench Sediments ^a	Comments on Differences
straight-chain	distributions of alkanes, alkan-2-ones, alkanols, alkanolic acids, alkenols and alkenolic acids generally similar (Fig. 6); alkadienone/alkatrienone ratios much higher in Leg 66 (Fig. 6)	alkenones may differ because of environmental conditions or diagenetic effects
branched-chain	distributions of alkanols and alkanolic acids similar; range of alkanes greater in Leg 66	alkanes of Legs 56/57 are direct biological inputs; those of Leg 66 come from a thermally mature source
acyclic isoprenoid	distributions of alkanes, alkanones, and alcohols similar; phytanes more abundant in Legs 56/57	phytol diagenesis may be more advanced in Legs 56/57 or phytanes may reflect lipid inputs from methanogens
cyclic diterpenoid	distributions of acids similar; range of alkanes and aromatic diterpenoids greater in Legs 56/57	inputs may be similar, but the extent of diagenetic alteration varies
steroids	range of sterols and sterenes greater in Legs 56/57, although relative abundance of common components are similar; diasterenes only present in Legs 56/57; sterane distributions differ	a greater diversity of marine organisms (e.g., diatoms) may contribute sterols and thence their diagenetic products to Legs 56/57, which are also diagenetically more mature, except in comparison to the thermally mature steranes of Leg 66
triterpenoids-hopanoid	alkane, alkene, alkanol, and alkanolic acid distributions generally similar; range of alkanones greater in Legs 56/57	minor differences reflect diagenetic discrepancies
nonhopanoid	fernene distributions similar (Fig. 6), as are ranges of higher plant triterpenes, triterpenols, and their tetracyclic alkane, alkene, and aromatic derivatives (Fig. 6)	minor differences reflect variations in sediment inputs and/or diagenetic processes

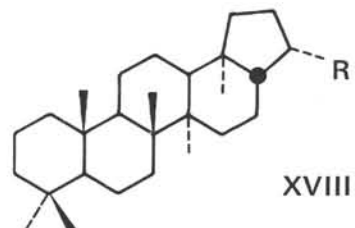
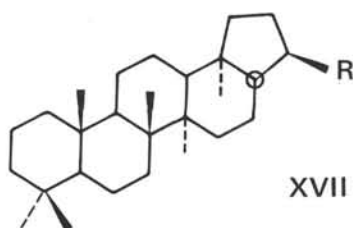
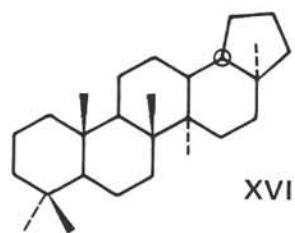
^a Sections 487-2-3 and 491-1-5 of Middle America Trench (this chapter), Sections 440-5-6, 440A-7-6, 440B-3-5, and 440B-8-4 of Japan Trench (Brassell et al., 1980b, 1980c; Brassell, 1980; Brassell et al., 1981).

APPENDIX
Compound Structures

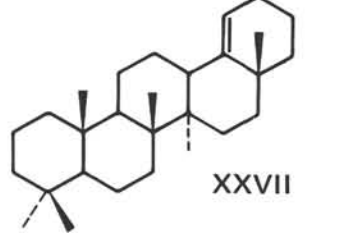
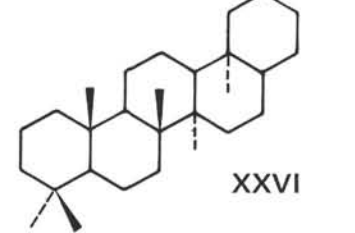
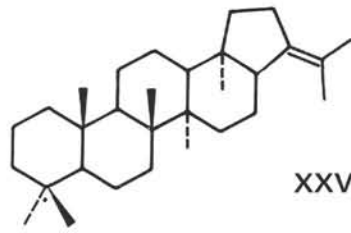
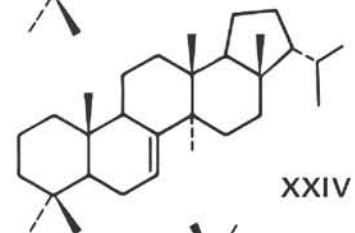
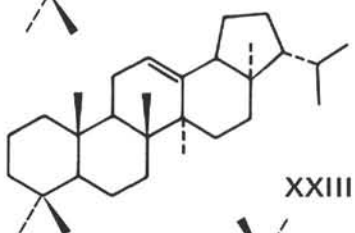
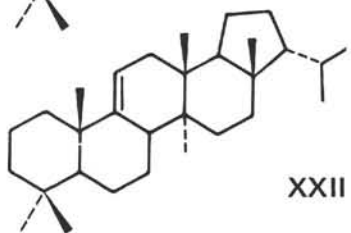
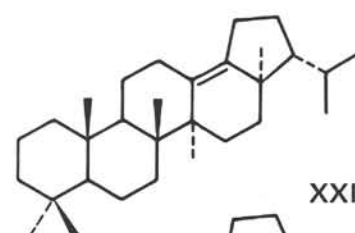
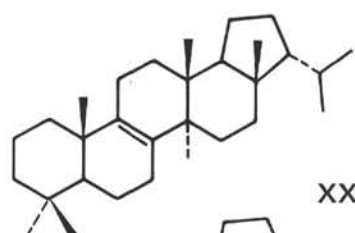
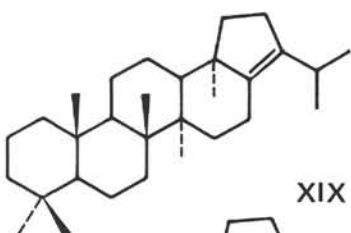
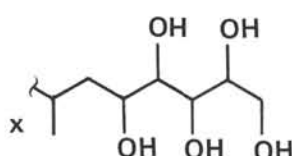
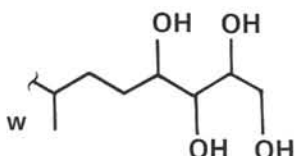
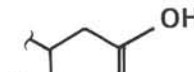
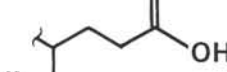
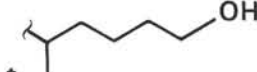
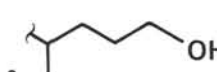
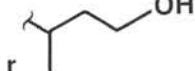
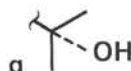
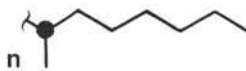
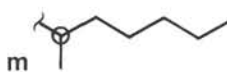
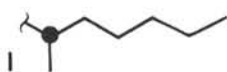
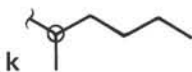
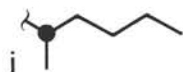
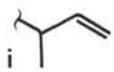


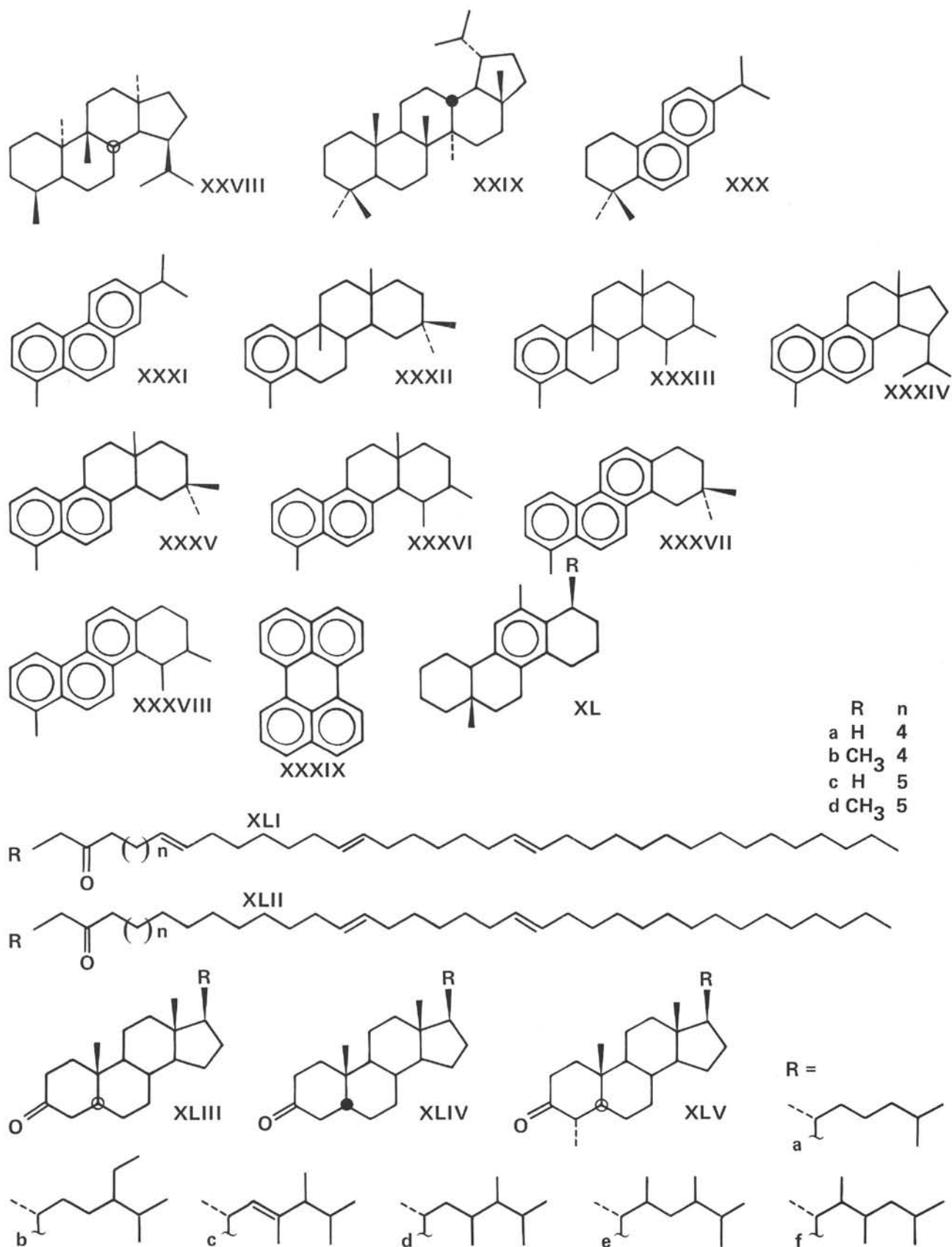
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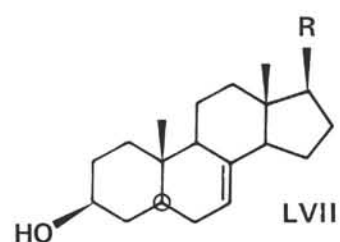
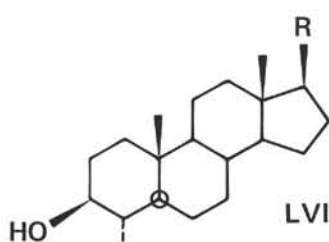
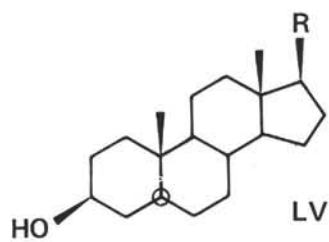
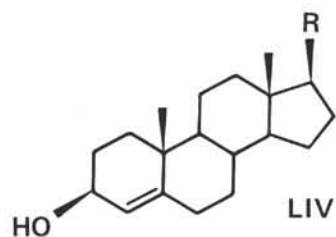
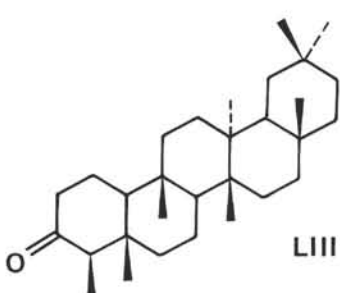
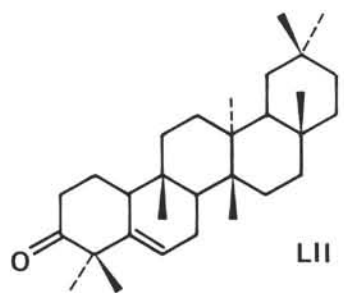
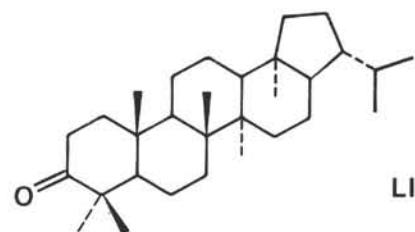
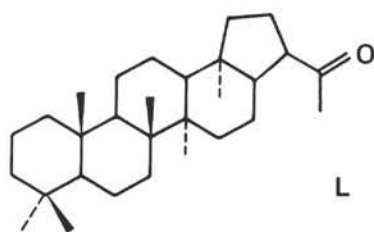
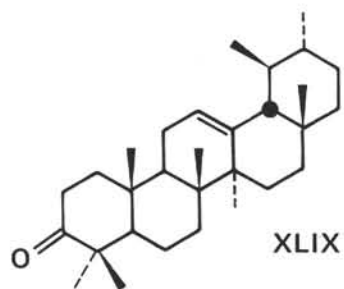
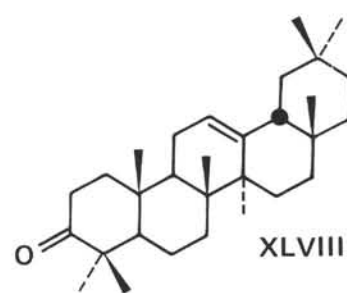
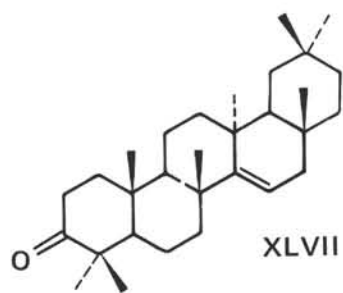
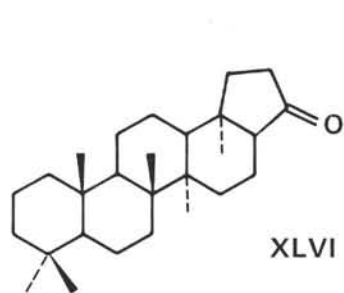




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