36. PRELIMINARY LIPID ANALYSIS OF SECTION 481-2-2[1]

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ABSTRACT

We investigated the solvent-extractable lipids of a Quaternary diatomaceous ooze (Section 481-2-2) from the Guaymas Basin. The section contained high concentrations of lipids, principally derived from algae. We also recognized components derived from bacterial and terrestrial sources. Major dinoflagellate blooms were indicated by the presence of dinosterol as the major component. The lipid composition was typical of that of Recent marine sediments and reflected a very early stage of lipid diagenesis.

INTRODUCTION

We investigated several classes of solvent-extractable lipids (hydrocarbons, alcohols, and acids) of a late Pleistocene diatomaceous ooze from the Guaymas Basin, Gulf of California (Section 481-2-2; 7.5 m subbottom; TOC = 1.4%). We evaluated the lipid distributions to determine their source, conditions of sediment deposition, and diagenetic alteration.

METHODOLOGY

The experimental procedure used to extract "free" lipids has been reported in our previous DSDP investigation (Brassell et al., 1980a). We performed gas chromatography (GC) on a Carlo Erba 2150 gas chromatograph equipped with a 17-meter OV-1 glass capillary column (0.25-mm i.d.); the carrier gas was helium. Mass spectra were recorded with a Finnigan 4000 gas chromatograph–mass spectrometer (GC–MS), equipped with a 20-meter OV-1 glass capillary column. Data acquisition and processing were controlled by an INCOS 2300 data system. We made compound assignments from individual mass spectra and GC retention times—with reference to literature spectra and authentic standards—where possible. Mass fragmentography (MF) was used to characterize homologous and pseudohomologous series (Wardroper et al., 1977; Brassell et al., 1980b) and to aid compound identification. Where possible, we quantitated individual compounds from their GC response or by MF. The problems associated with quantitation are discussed elsewhere (Brassell et al., 1980a).

RESULTS

The detailed compound distributions of aliphatic hydrocarbons, alcohols, and acids are reported herein. A brief description of the ketone fraction is given in Table 5. Aromatic components, although present, are not reported.

Aliphatic Hydrocarbons

Acyclic Components

The *n*-alkanes of Section 481-2-2 ranged from nC_{17} to nC_{35} with an odd/even carbon preference index (CPI) of 7.2. The absolute concentration of individual homologues (quoted in ng/g dry-sediment weight) are shown in Figure 1A. In the C_{23} to C_{35} range, the overall distribution is dominated by odd-numbered homologues in the C_{23} to C_{35} range and maximizes at nC_{29}. No *n*-alkenes or branched alkanes or alkenes were detected. The concentrations of acyclic isoprenoid alkanes, pristane, phytane, 2,6,10,15,19-pentamethyleicosane (I), squalane (II), and lycopane (III) are given in Figure 1. No unsaturated isoprenoid hydrocarbons were detected.

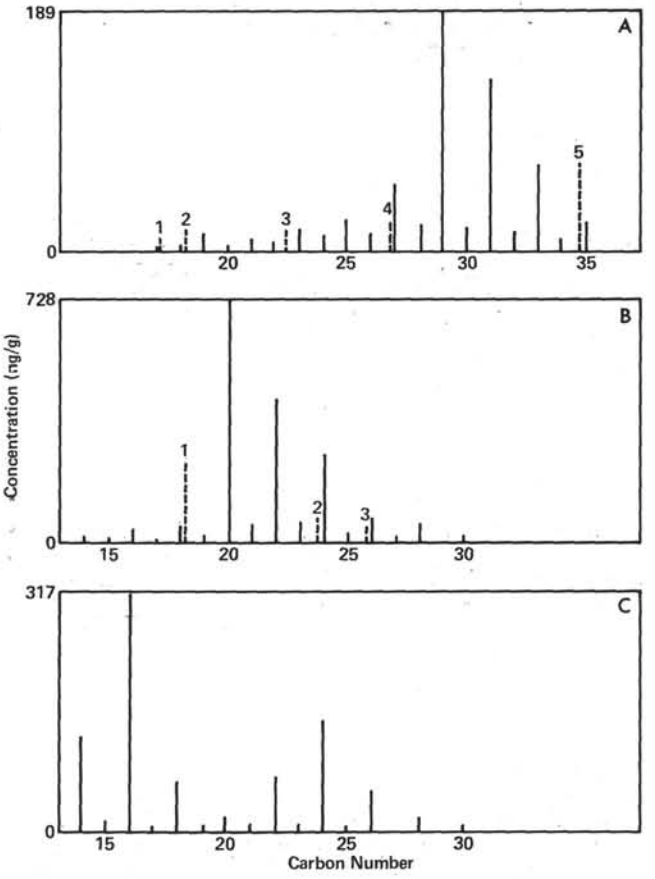

Figure 1. Lipid concentrations in Section 481-2-2. A. Principal acyclic alkanes (solid lines = *n*-alkanes; dashed lines = acyclic isoprenoids in GC-elution positions. Bar numbers correspond as follows: 1. pristane, 2. phytane; 3. 2,6,10,15,19-pentamethyleicosane, 4. squalane, 5. lycopane). B. Acyclic alcohols (solid lines = *n*-alkanols; dashed lines = 1. phytol, 2. $C_{24:1}$ *n*-alken-1-ol, 3. $C_{26:1}$ *n*-alken-1-ol. C. *n*-alkanoic acids.

[1] Curray, J. R., Moore, D. G., et al., *Init. Repts. DSDP*, 64: Washington (U.S. Govt. Printing Office).

Cyclic Components

No diterpenoid alkanes, alkenes, tetracyclic alkanes, or alkenes derived from 3-oxytriterpenoids (Corbet et al., 1980) were detected.

Steranes were recognized as trace components, but the low intensity of diagnostic ions in MF and individual mass spectra precluded compound assignment. No 4-methylsteranes, diasteranes, or 4-methyldiasteranes were detected by MF. A complex mixture of mono-, di-, tri-, and tetra-unsaturated sterenes (C_{27}–C_{29}) occurs in Section 481-2-2; Table 1 shows the concentrations of the major components. We recognized C_{27} to C_{29} ster-2-enes and stera-3,5-dienes from their characteristic mass spectra and GC-retention times (Wardroper, 1979); the C_{27} compounds predominate. Lack of standard spectra prevented the assignment of nuclear double-bond positions in steradienes (except stera-3,5-dienes), steratrienes, and steratetrenes, but several components have been tentatively assigned as monoaromatic steroids by comparison with literature spectra (Spyckerelle, 1975; Schaeffle et al., 1978). In general, the C_{27} sterenes are the most abundant ($C_{27} > C_{28} > C_{29}$), and the C_{28} sterenes show the greatest diversity of individual components. No 4-methylsterenes, diacholestenes, or 4-methyldiacholestenes were detected.

The major triterpanes and triterpenes of Section 481-2-2 are listed in Table 2 and are shown in a partial MF of m/z 191 (Fig. 2). Their distribution is limited to C_{27}, C_{30}, and C_{31} carbon numbers, and hop-22(29)-ene is the most abundant. We recognized several triterpenes (Components D, E, I, J, L and M) and a triterpadiene (Component G) of unknown structure but with spectra similar to those of hop-22(29)-ene and hop-21-ene. No $\alpha\beta$- or $\beta\alpha$-hopanes were detected, and three fernenes (Δ^7, Δ^8, and $\Delta^{9(11)}$) occur in the section.

Table 1. Concentrations of sterenes in Section 481-2-2.

Assignment[a]	Formula	Structure[b]	Concentration[c] (ng/g)
C28 $3\Delta^n$ (aromatic), Δ^{scd}	$C_{28}H_{42}$	IV	<1.0
C28 $3\Delta^n$ (aromatic), Δ^{scd}	$C_{28}H_{42}$	IV	<1.0
C28 $3\Delta^n$ (aromatic)[d]	$C_{28}H_{44}$	IV	<1.0
C27 Δ^n, Δ^{22}	$C_{27}H_{44}$	IV	16.6
C27 Δ^n, Δ^{24}	$C_{27}H_{44}$	IV	11.5
C27 Δ^2	$C_{27}H_{46}$	IV $R_1 = R_2 = H$	60.5
C27 $2\Delta^n$, Δ^{sc}	$C_{27}H_{42}$	IV	12.8
C28 Δ^n, Δ^{22}	$C_{28}H_{46}$	IV	9.4
C27 $\Delta^{3,5}$	$C_{27}H_{44}$	IV $R_1 = R_2 = H$	74.6
C28 $2\Delta^n$, Δ^{24}	$C_{28}H_{44}$	IV	16.6
C28 Δ^n, Δ^{24}	$C_{28}H_{46}$	IV	18.1
C28 Δ^n, Δ^{24}	$C_{28}H_{46}$	IV	1.8
C28 Δ^2	$C_{28}H_{48}$	IV $R_1 = H, R_2 = CH_3$	15.3
C28 Δ^n, Δ^{24}	$C_{28}H_{46}$	IV	13.4
C29 Δ^n, Δ^{22}	$C_{29}H_{48}$	IV	3.2
C28 $2\Delta^n$, Δ^{24}	$C_{28}H_{44}$	IV	20.4
C28 $\Delta^{3,5}$	$C_{28}H_{46}$	IV $R_1 = H, R_2 = CH_3$	10.4
C28 $2\Delta^n$, Δ^{24}	$C_{28}H_{44}$	IV	11.2
C29 Δ^2	$C_{29}H_{50}$	IV $R_1 = R_2 = CH_3$	7.3
C29 3Δ	$C_{29}H_{46}$	IV	14.3
C29 Δ^2	$C_{29}H_{50}$	IV $R_1 = H, R_2 = C_2H_5$	28.2
C27 $3\Delta^n$ (aromatic)[e]	$C_{27}H_{42}$	IV	16.1
C27 $3\Delta^n$ (aromatic)[e]	$C_{27}H_{42}$	IV	3.2
C29 Δ^n, Δ^{24}	$C_{29}H_{48}$	IV	5.4
C29 $\Delta^{3,5}$	$C_{29}H_{48}$	IV $R_1 = H, R_2 = C_2H_5$	21.0
C28 $3\Delta^n$ (aromatic), Δ^{sce}	$C_{28}H_{42}$	IV	2.8
C28 $2\Delta^n$, Δ^{24}	$C_{28}H_{44}$	IV	2.3
C27 4Δ (aromatic)[e]	$C_{27}H_{40}$	IV	<1.0
C29 4Δ	$C_{29}H_{44}$	IV	<1.0
C29 $3\Delta^n$ (aromatic)[e]	$C_{29}H_{46}$	IV	1.7

[a] Nomenclature: double bond positions assigned where possible; otherwise, Δ^n and Δ^{sc} indicate double bonds in nucleus or side chain, respectively.
[b] See Appendix for general structure not showing double-bond positions.
[c] Dry-weight sediment (quantitated from GC response and MF of diagnostic ions).
[d] C-ring aromatic.
[e] A- or B-ring aromatic.

Table 2. Concentrations of triterpenoid hydrocarbons in Section 481-2-2.

Component[a]	Assignment[b]	Structure[c]	Concentration (ng/g)[d]
A	22,29,30-trisnorneohop-13(18)-ene	V	4.9
B	22,29,30-trisnorhop-17(21)-ene	VI	13.0
C	17β-22,29,30-trisnorhopane	VII	8.8
D	C_{30}-triterpene	—	42.8
E	C_{30}-triterpene	—	17.6
F	hop-17(21)-ene	VIII	31.0
G	C_{30}-triteradiene	—	38.9
—	fern-8-ene	IX	1.4
H	neohop-13(18)-ene	X	30.7
I	C_{30}-triterpene	—	14.8
—	fern-9(11)-ene	IX	1.2
J	C_{30}-triterpene	—	47.4
K	neohop-12-ene	XI	13.8
—	fern-7-ene	IX	9.9
L	C_{30}-triterpene	—	6.7
M	C_{30}-triterpene	—	15.2
N	hop-22(29)-ene	XII	100.0
O	$\beta\beta$-homohopane	XIII	29.3

[a] See Figure 2; fernenes do not exhibit intense m/z 191 in their mass spectra.
[b] Assignments made by mass spectral interpretation, mass fragmentography, and GC-retention times.
[c] See Appendix.
[d] Dry-weight sediment.

Alcohols

Acyclic Components

The relative abundance of individual *n*-alkanols and their absolute concentrations are shown in Figure 1B. The *n*-alkanols range from C_{14} to C_{30} with the even-numbered members predominant and maximizing at nC_{20}. No simple-branched alcohols were detected. Two unsaturated *n*-alkenols ($C_{24:1}$ and $C_{26:1}$) and a single isoprenoid (phytol) were recognized. Their concentrations are shown in Figure 1B.

Cyclic Components

The concentrations of the major stenols and stanols in Section 481-2-2 are given in Table 3. They are the most abundant extractable lipids in the section. Series of Δ^5 and $\Delta^{5,22}$ stenols and their corresponding 5α-stanols were detected. Dinosterol (4,23,24-trimethyl-5α-cholest-22-en-3β-ol, XVIf) is the major component and occurs in approximately four times the concentration of any other sterol. No C_{26} sterols or short side-chain sterols (C_{19}–C_{25}) were detected. Two extended hopanoid alcohols, $\beta\beta$-homohopan-31-ol (XVIIIa) and $\beta\beta$-bishomohopan-32-ol (XVIIIb), occur in concentrations of 94 and 180 ng/g dry-sediment weight, respectively.

Three components recently recognized in Black Sea sediment and assigned as a series of straight-chain C_{30}, C_{31}, and C_{32} hydroxyalkanones ("keto-ols"; de Leeuw et al., personal communication), were identified (Table 4).

Carboxylic Acids

The carboxylic acids of Section 481-2-2 (Fig. 1C) are predominantly straight-chain components, ranging from nC_{14} to nC_{30}. The distribution is bimodal, max-

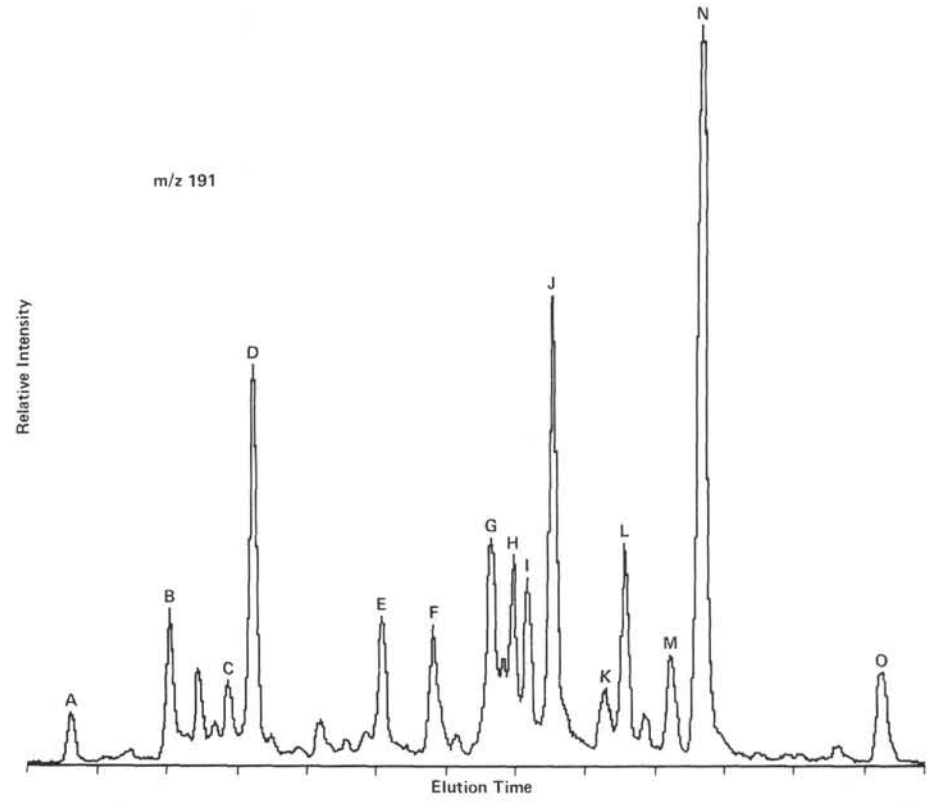

Figure 2. Total alkanes of Section 481-2-2. Gas chromatographic–mass spectrometric analysis: partial mass fragmentogram for m/z 191 diagnostic for triterpenoid hydrocarbons (Table 2).

Table 3. Concentrations of sterols in Section 481-2-2.[a]

Assignment[b]	Structure[c]	Concentration (ng/g)[d]
cholesta-5,22-dien-3β-ol	XIVa	84
5α-cholest-22-en-3β-ol	XVa	47
cholest-5-en-3β-ol	XIVb	201
5α-cholestan-3β-ol	XVb	104
24-methylcholesta-5,22-dien-3β-ol	XIVc	275
24-methyl-5α-cholest-22-en-3β-ol	XVc	78
C_{28} stanol	—	42
24-methylenecholest-5-en-3β-ol	XIVd	97
C_{28} stanol	—	18
24-methylene-5α-cholestan-3β-ol / 24-methylcholest-5-en-3β-ol	XVd / XIVe	115
24-methyl-5α-cholestan-3β-ol	XVe	42
23,24-dimethylcholesta-5,22-dien-3β-ol	XIVf	69
23,24-dimethyl-5α-cholest-22-en-3β-ol	XVf	135
24-ethylcholesta-5,22-dien-3β-ol	XIVg	224
24-ethyl-5α-cholest-22-en-3β-ol	XVg	95
23,24-dimethylcholest-5-en-3β-ol	XIVh	127
23,24-dimethyl-5α-cholestan-3β-ol	XVh	83
24-ethylcholest-5-en-3β-ol	XIVi	331
24-ethyl-5α-cholestan-3β-ol[e]	XVi	633
4,23,24-trimethyl-5α-cholest-22-en-3β-ol	XVIf	1933
C_{30} 4-methylsterol	—	81
C_{30} 4-methylsterol	—	54
C_{30} 4-methylstanol	—	95
4,23,24-trimethyl-5α-cholestan-3β-ol	XVIh	309

[a] Sterols analyzed as TMS ethers.
[b] Based on mass spectral interpretation, comparison with literature spectra, and GC-retention times.
[c] See Appendix.
[d] Dry-weight of sediment.
[e] Concentration of this component greatly enhanced by coelution with an unknown C_{29} 4-methylsterol.

Table 4. Concentrations of long-chain hydroxy ketones ("15-keto-1-ols") in Section 481-2-2.

Assignment[a]	Formula	Structure[b]	Concentration (ng/g)[c]
1-hydroxytriacontan-15-one	$C_{30}H_{60}O_2$	XVII, $n = 14$	1070
1-hydroxyhentriacontan-15-one	$C_{31}H_{62}O_2$	XVII, $n = 15$	30
1-hydroxydotriacontan-15-one	$C_{32}H_{64}O_2$	XVII, $n = 16$	520

[a] Based on comparison with compounds assigned by de Leeuw et al. (personal communication) from comparison with synthetic homologues.
[b] See Appendix.
[c] Dry-weight sediment.

imizing at nC$_{16}$ and nC$_{24}$, with an even over odd preference of 4.3. Minor amounts of unsaturated ($C_{16:1}$ and $C_{18:1}$) and branched (*iso*- and *anteiso*-C_{15} and C_{17}) components were also detected. ββ-bishomohopanoic acid (XVIIIc) also occurs as a minor component.

DISCUSSION

The high amount of extractable lipids in Section 481-2-2 is similar to that obtained from anoxic bottom sediments in areas of high productivity, such as Walvis Bay (Wardroper, 1979).

Paleoenvironment

Acyclic Components

The distributions of straight-chain components (*n*-alkanes, *n*-alkanols, and *n*-alkanoic acids) suggest allochthonous and autochthonous contributions to the sedi-

ment. The *n*-alkane maximum at nC_{29} and the prominent odd/even preference in the C_{22} to C_{35} range suggest that the origins of the *n*-alkanes are predominantly terrestrial (Simoneit, 1975). The absence of major concentrations of short-chain components—particularly nC_{17}, a major alkane of phytoplankton (Oro et al., 1967; Gelpi et al., 1970; Blumer et al., 1971; Brassell et al., 1978)—may reflect preferential degradation of these components in the water column or sediment rather than low productivity (Johnson and Calder, 1973).

The origin of *n*-alkanols in marine sediments is not well understood. Their distribution in the Guaymas Basin (Fig. 1B) differs from that of the Japan Trench—where the predominant source of *n*-alkanols (maximizing at nC_{24}) has been assigned as terrestrial (Brassell et al., 1980a; Brassell, 1980)—and Walvis Bay, where phytoplankton have been suggested as the source of the *n*-alkanols (maximizing at nC_{16}) (Wardroper, 1979). Zooplankton wax esters may be the source of the *n*-alkanols of the Guaymas Basin, as indicated by the predominance of nC_{20} and nC_{22}, which are major fatty-alcohol moieties of wax esters (Sargent et al., 1976; Boon and de Leeuw, 1979). But the minor concentrations of nC_{16} and nC_{18} in the sediment argue against a wax-ester origin for the *n*-alkanols, as they are major alcohol components of these compounds (Boon and de Leeuw, 1979).

The bimodal distribution of the *n*-alkanoic acids (Fig. 1C) provides evidence of a mixed contribution from terrestrial and bacterial/algal sources (Simoneit, 1978; Brassell et al., 1980a, 1980b). It is also possible that the shorter-chain compounds may originate from saponified wax esters. We found trace amounts of *iso*- and *anteiso*-C_{15} and C_{17} acids, whose origins are probably bacterial (Simoneit, 1975, 1978; Brassell et al., 1980a, 1980b).

Two major sources for the production of the isoprenoids pristane and phytane have been suggested: They may result from the degradation of plant phytol (also recognized in this sample) or they may be direct contributions from methanogenic bacteria (Holzer et al., 1979). But the recognition of 2,6,10,15,19-pentamethyleicosane (I) and squalane (II) in Section 481-2-2 (which are constituents of archaebacteria [Holzer et al., 1979]) and other evidence for methanogenic bacterial activity in this hole (Oremland et al., this volume) suggest that methanogens are a source of these lipids. The origin of lycopane (III) in sediments is unclear, but a direct bacterial origin from methanogens (Brassell et al., 1981) seems more likely than diagenetic hydrogenation of lycopene, a constituent of marine algae.

The source of the 1-hydroxyalkan-15-ones is unknown. They are probably of direct biological origin but have not yet been recognized as constituents of organisms. A marine source of these components in Section 481-2-2 seems likely because of their occurrence in other Quaternary and Neogene marine sediments from the Black Sea (de Leeuw et al., personal communication), the Cariaco and Japan trenches, and the Californian continental borderland (University of Bristol [England], Organic Geochemistry Unit, unpublished).

Cyclic Components

The wide range of sterols and stanols in Section 481-2-2 is typical of areas of high productivity such as Walvis Bay and the Japan Trench (Wardroper et al., 1977; Brassell et al., 1980a).

Although C_{27} to C_{29}, Δ^5, $\Delta^{5,22}$, and Δ^{22} sterols are widespread in organisms, their source probably is phytoplankton (Boutry and Jacques, 1970; Boutry and Barbier, 1974; Orcutt and Patterson, 1975; Ballantine et al., 1979; Volkman et al., 1980). Certainly 23,24-dimethyl sterols have been recognized only in marine sediments (Wardroper, 1979; Brassell et al., 1980b). Dinosterol (XVIf) is the predominant sterol in this section. It is the principal sterol of dinoflagellates (Shimizu et al., 1976) and a marker for major dinoflagellate blooms (Boon et al., 1979). Other 4-methylsterols may also derive from dinoflagellates (Withers et al., 1978) or, perhaps, from methanotrophic bacteria (Bird et al., 1971).

The hopanoids are probably an original bacterial contribution to the sediment (De Rosa et al., 1971; Rohmer, 1975). Hop-17(21)-ene (VIII) and neohop-13(18)-ene (X) are probably isomerization products of hop-22 (29)-ene (Ensminger, 1977). But the absence in Section 481-2-2 of hop-21-ene, the proposed intermediate of this isomerization, suggests that these hopanoids also may have a primary origin from bacteria. The recent report of the presence of several hopenes and fernenes in a photosynthetic anaerobic bacterium (Howard, 1980) supports this view and suggests that, in the marine environment, fernenes, as well as hopenes, may originate from bacteria as well as from terrigenous sources (e.g., from ferns; Berti and Bottari, 1968). Since no isomerization of hopenes has occurred, the unknown triterpenoid hydrocarbons in Section 481-2-2 are probably derived directly from bacteria, rather than from the diagenetic alteration of other triterpenes.

Diagenesis

The study of a single section precludes the evaluation of major diagenetic trends in Hole 481. But the lipid data for Section 481-2-2 can be related to proposed diagenetic pathways, which enables us to assess the maturity of the sediment. The odd/even preference of the *n*-alkanes, although an insensitive indicator, and the presence of *n*-alkanols and *n*-alkanoic acids as major components are characteristic of immature Deep Sea Drilling Project (DSDP) sediments (Simoneit, 1978; Brassell et al., 1980a, 1980b). The predominance of sterols over their defunctionalized counterparts also attests to the immaturity of the section. The wide range of sterenes, including Δ^2-sterenes, $\Delta^{3,5}$-steradienes, and partially characterized Δ^{22}- and Δ^{24}-steradienes and Δ^{24}-steratrienes, is similar to that of other Quaternary DSDP sediments from the Japan Trench (Brassell, 1980; Brassell et al., 1980a) and the California continental borderland (McEvoy et al., in press). The absence of Δ^4-and Δ^5- sterenes, thought to be acid-clay catalyzed diagenetic products of Δ^2-sterenes (Rubinstein et al., 1975) is characteristic of immature sterene distributions,

although they do occur in immature Quaternary sediment elsewhere (Simoneit, 1975; Brassell, 1980; Dastillung and Albrecht, 1977). This observation may reflect the high alkalinity in Hole 481 (see site chapter, this volume) when compared with other environments. Or these other sediments may receive rederived material.

The absence of 4-methylsterenes is surprising in view of the presence of 4-methylsterols, particularly of 4,23, 24-trimethyl-5α-cholest-22-en-3β-ol (dinosterol; XVIf). This concurs with data from other marine sediments and suggests steric hindrance by 4-methyl substitution in the defunctionalization of 4-methylsterols and 4-methylstanols. Thus, it appears that microorganisms effect sterol-to-sterene conversion, since a geochemical pathway would not be expected to exhibit such selectivity between 4-methyl- and 4-desmethyl-sterols.

In Section 481-2-2, the presence (in minor concentrations) of steranes, which are of anomalous maturity for Recent sediments, suggests a contribution of rederived material or, perhaps, minor core contamination from "pipe-dope" (drilling lubricant) (Brassell and Eglinton, 1981; Thomson et al., in press).

The distribution of hopanoids is characteristic of Recent aquatic sediment. The hopanoid alcohols, $\beta\beta$-homohopan-31-ol (XVIIIa), $\beta\beta$-bishomohopan-32-ol (XVIIIb), and $\beta\beta$-bishomohopanoic acid (XVIIIC), are probably early-stage diagenetic products of polyhydroxybacteriohopanes (Rohmer, 1975) and are widespread in immature marine sediments. Hop-22(29)-ene (XII) is often the major triterpene of contemporary sediments (Brooks, 1974). In Section 481-2-2, its isomerization has not yet occurred to any significant extent. The absence of $\beta\alpha$- and $\alpha\beta$-hopanes is consistent with the section's immaturity and precludes major pipe-dope contamination of cores and contributions from thermally mature reworked material.

CONCLUSIONS

Table 5 summarizes the results and discussion of the lipid classes and gives the concentration of the major component of each class. We draw the following conclusions:

1) 4,23,24-trimethylcholest-22-en-3β-ol (XVIIf) is the single most-abundant lipid, and its concentration is approximately four times that of any other sterol. Hence, dinoflagellate blooms may have been important contributors to the sedimentary biomass.

2) The activity of methanogenic bacteria is indicated by the presence of particular acyclic isoprenoid hydrocarbons.

3) Hydroxyalkanones are major components, which, although as yet unrecognized in organisms, are probably of marine origin.

4) Contributions from terrestrial, algal, and bacterial sources are indicated by marker lipids; the algal contribution predominates.

5) The lipid data are typical of those sediments underlying highly productive water columns.

6) Lipid distributions are characteristic of Recent marine sediments, and typify a very early diagenesis stage.

Thus, the lipid composition of older sediment in Hole 481 will determine the constancy of paleoenvironmental conditions of deposition in the Guaymas Basin. It will especially enable us to evaluate the sources of the sedimentary organic matter, the activity of methanogenic bacteria, and the history of water column productivity, especially dinoflagellate blooms. The changes in the lipid distributions with depth will also enable us to assess diagenetic trends and processes in an environment of rapid sedimentation.

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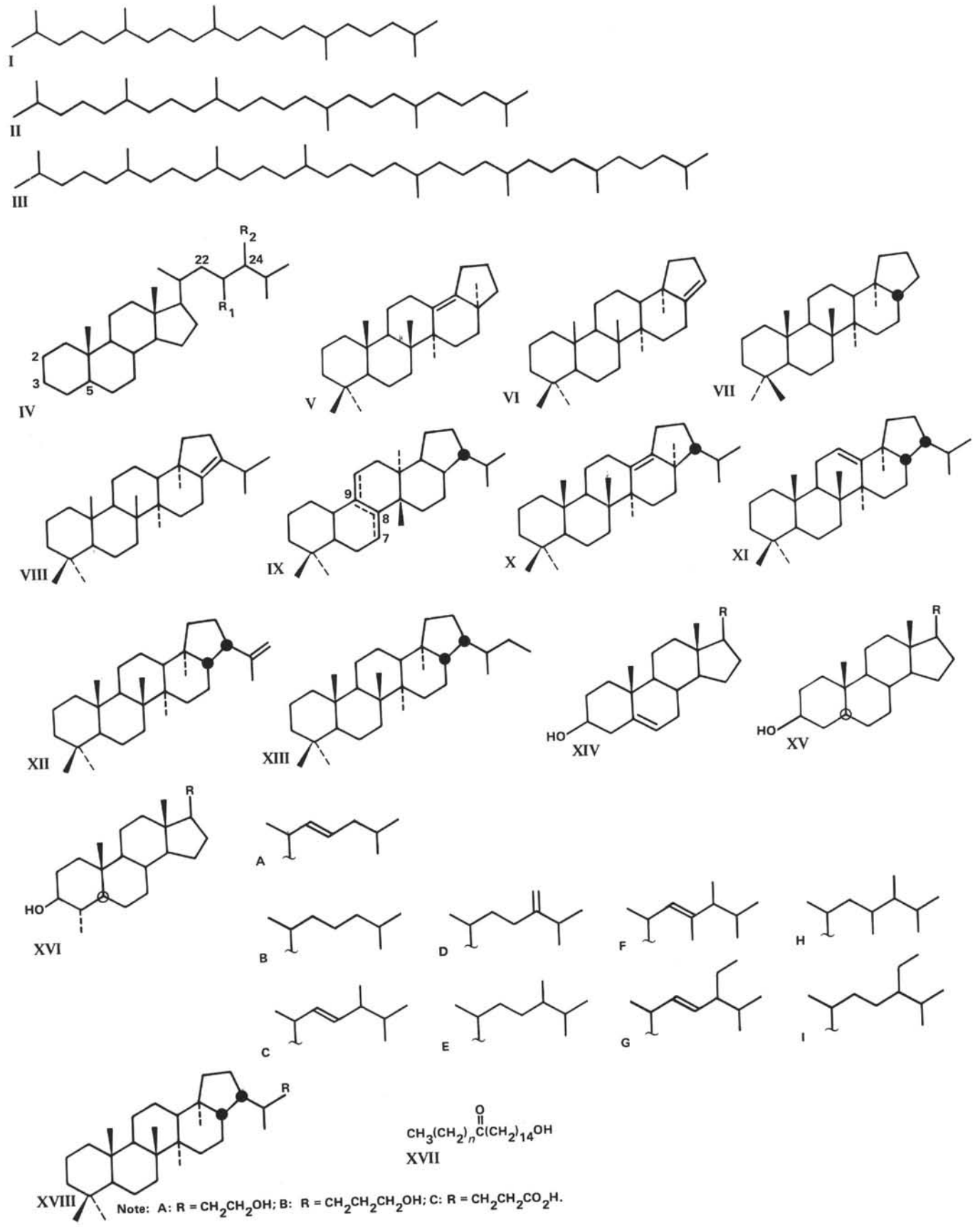
Table 5. Summary of lipids from Section 481-2-2 (7.5 m sub-bottom; late Pleistocene diatomaceous ooze).

Lipid Class	Results	Comments
n-alkanes	Long-chain components predominant; C_{29} major (189 ng/g); high CPI	Terrestrial origin; immature
n-alkanols	C_{20}–C_{24} predominant; C_{20} major (728 ng/g); high CPI	Marine(?) origin; immature
n-acids	Bimodal distribution; C_{16} and C_{24} major (317 and 155 ng/g); high CPI	Terrestrial and marine origin; immature
hydroxyalkanones	Major components; C_{30} predominant (1030 ng/g)	Unknown origin but probably marine
acyclic isoprenoid hydrocarbons	Lycopane major (68 ng/g)	Methanogenic bacterial origin
steranes	Very minor components (compound < 1.0 ng/g)	Rederived material or minor pipe-dope contamination
steroidal alkenes	Minor components: wide range; C_{27} $\Delta^{3,5}$ predominant (74.6 ng/g); sterenes all Δ^2	Typical of Recent sediment; immature; no monosterene isomerization
sterols	Major components; wide range; 4,23,24-trimethyl-5α-cholest-22-en-3β-ol predominant (1933 ng/g)	Typical of highly productive marine environments and dinoflagellate blooms
triterpanes	Minor components; only ββ-homohopane (29 ng/g) and β-trisnorhopane detected; no αβ-hopanes	Bacterial origin; immature; argues against pipe-dope contamination
triterpenes	Minor components; hop-22(29)-ene major (100 ng/g); several unidentified components	Bacterial origin; no apparent hopene isomerization; immature
hopanols	Minor components; ββ-bishomohopanol major (180 ng/g)	Characteristic of Recent sediments; bacterial contribution; immature
hopanoic acid	Minor component; ββ-homohopanoic acid	
ketones	Complex mixture of steroidal and triterpenoidal ketones; no major amounts of long-chain unsaturated ketones; minor components dinosterone and C_{18} isoprenoid ketone	Fraction not examined in detail

APPENDIX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Note: A: R = CH2CH2OH; B: R = CH2CH2CH2OH; C: R = CH2CH2CO2H.