

## 34. PRELIMINARY LIPID ANALYSES OF SEDIMENTS RECOVERED DURING LEG 117<sup>1</sup>

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### ABSTRACT

The solvent-extractable organic fractions of sediment samples from six Ocean Drilling Program Leg 117 sites were investigated by gas chromatography and gas chromatography-mass spectrometry. Sediments deposited in the Indus Fan (Site 720) as well as Miocene sediments from the Owen Ridge (Sites 722 and 731) contain almost exclusively organic matter of terrigenous origin. The organic matter in sediments from the Oman Margin (Sites 723, 725, and 728) and in the Pliocene/Pleistocene sections from the Owen Ridge is mainly of a marine origin with variable admixtures of terrigenous material. In these latter samples strong variations of the lipid composition and distribution are noted. However, the interpretation of the relation to potential biological sources is hampered by a lack of information on the possible lipid composition of appropriate organisms.

### INTRODUCTION

During ODP Leg 117 numerous holes were drilled at 12 sites in the northeast Arabian Sea with the major objective of unravelling the evolution of the summer monsoon in the Indian Ocean. The driving force for the monsoonal winds, which change direction seasonally, is a cooling of the Asian continent during the northern hemisphere winter and heating during the summer which creates high pressure or low pressure, respectively, above the Tibetan Plateau (Shipboard Scientific Party, 1989a, and references cited therein). The southwestern summer monsoon induces coastal upwelling along the coast of Oman and Somalia (Fig. 1), making the surface-water masses highly fertile and supportive of concomitant high primary bioproductivity. The remineralization of sinking organic matter at depth in combination with a sluggish subsurface water circulation and the stability of the intermediate waters due to their relatively high salinity causes extremely low oxygen concentrations (<0.2 mL/L) between about 200 m and 1500 m water depth (Shipboard Scientific Party, 1989b).

As part of our current research program on the characterization of organic matter deposited in areas underlying active upwelling regimes, we have previously studied sediment samples from the upwelling areas off northwest Africa (Leg 108; ten Haven et al., 1989) and off Peru (Leg 112; ten Haven et al., 1990a). Here we report on the distribution of extractable lipids from organic-carbon-rich sediments deposited offshore Oman. In a separate paper we discuss the influence of sea surface temperatures on the distribution of long-chain alkenones during the late Quaternary offshore Oman (ten Haven and Kroon, this volume).

### SAMPLES AND EXPERIMENTAL METHODS

Samples from six ODP sites were collected on board the ship. Three of these sites (723, 725, 728) are located on the Oman Margin, two on the Owen Ridge (722, 731), and one in the Indus Fan (720; Fig. 1). Their locations are depicted in Figure 2 on an idealized transect of the continental margin off Oman. The water depths of Sites 723, 725 and 728 straddle the

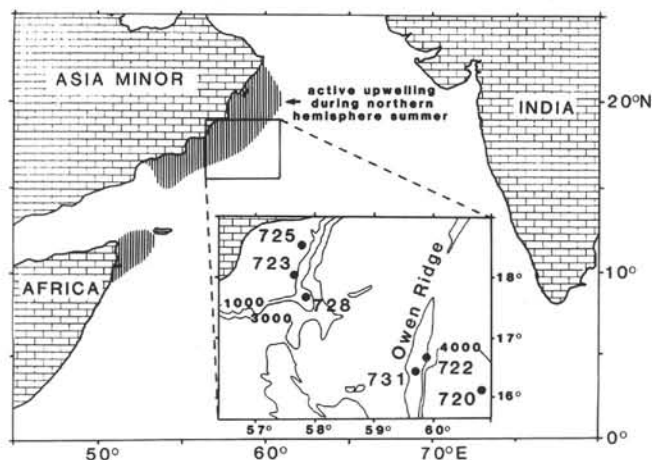


Figure 1. Location of drill sites in the Arabian sea and the area of active upwelling due to the Indian Ocean summer monsoon.

depth interval at which the pronounced oxygen-minimum zone impinges the margin (Fig. 2).

The hydrogen index (HI) and oxygen index (OI) values of the organic matter were determined using a Delsi Rock-Eval 2 apparatus. The sample preparation techniques for microscopic analyses, carbon measurements, lipid extraction, chromatographic separation, derivatization, as well as instrumental conditions used for gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) were identical to those described in the study of ODP Leg 112 samples (ten Haven et al., 1990a). Compound identifications are based on comparison of relative GC retention times and mass spectra with those reported in the literature. Coinjections with commercially available olean-12-en-3 $\beta$ -ol, urs-12-en-3 $\beta$ -ol, and friedelan-3-one (all Roth) were made to confirm the presence of these compounds in some of the samples.

The distribution of organic compounds is discussed in qualitative rather than quantitative terms. Structures of selected compounds are shown in Figure 3, and in the text these structures are referred to by Roman numerals.

### RESULTS

Depth, stratigraphic age, and the results of carbon and Rock-Eval analyses are given in Table 1. These data are consistent with those measured on board the ship (Prell, Niitsuma, et al.,

<sup>1</sup> Prell, W. L., Niitsuma, N., et al., 1991. *Proc. ODP, Sci. Results*, 117: College Station, TX (Ocean Drilling Program).

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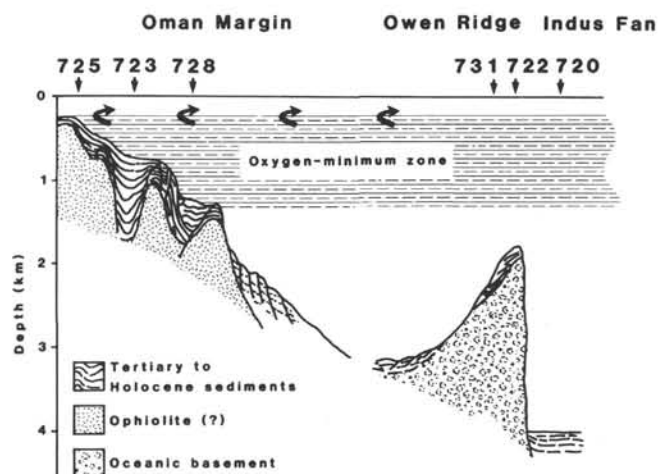


Figure 2. Idealized transect of the continental margin off Oman showing major geologic and oceanographic features and locations of sites discussed in text (vertical scale exaggerated).

1989). Hereafter, we will discuss these results together with those obtained from GC and GC-MS analyses of the "total lipid" fractions (i.e., total extracts not chromatographically separated but treated with diazomethane and a silylating reagent to derivatize carboxylic acids and alcohols) in three sections corresponding to the major geological features of the northwestern Arabian Sea, viz., the Indus Fan, the Owen Ridge, and the Oman margin. A few samples were studied in more detail by separating the "total lipid" fraction into aliphatic and aromatic hydrocarbons, ketones plus esters, alcohols, acids and a highly polar neutral subfraction, and subsequent GC-MS analyses.

### Indus Fan

The deposition of Indus Fan sediments is thought to have started during Oligocene/early Miocene times. Site 720 is located on the westernmost part of the fan, and the sediments recovered are characteristic of turbiditic deposition with small intercalations of mainly pelagic beds.

The Rock-Eval results for one sample with an elevated organic carbon content (1.43%, Table 1) as well as results obtained from shipboard analyses indicate that the organic matter deposited in the Indus Fan is mainly of terrigenous origin. Although the sink for fluvial-transported terrigenous organic matter normally lies in nearshore sediments, the major river systems

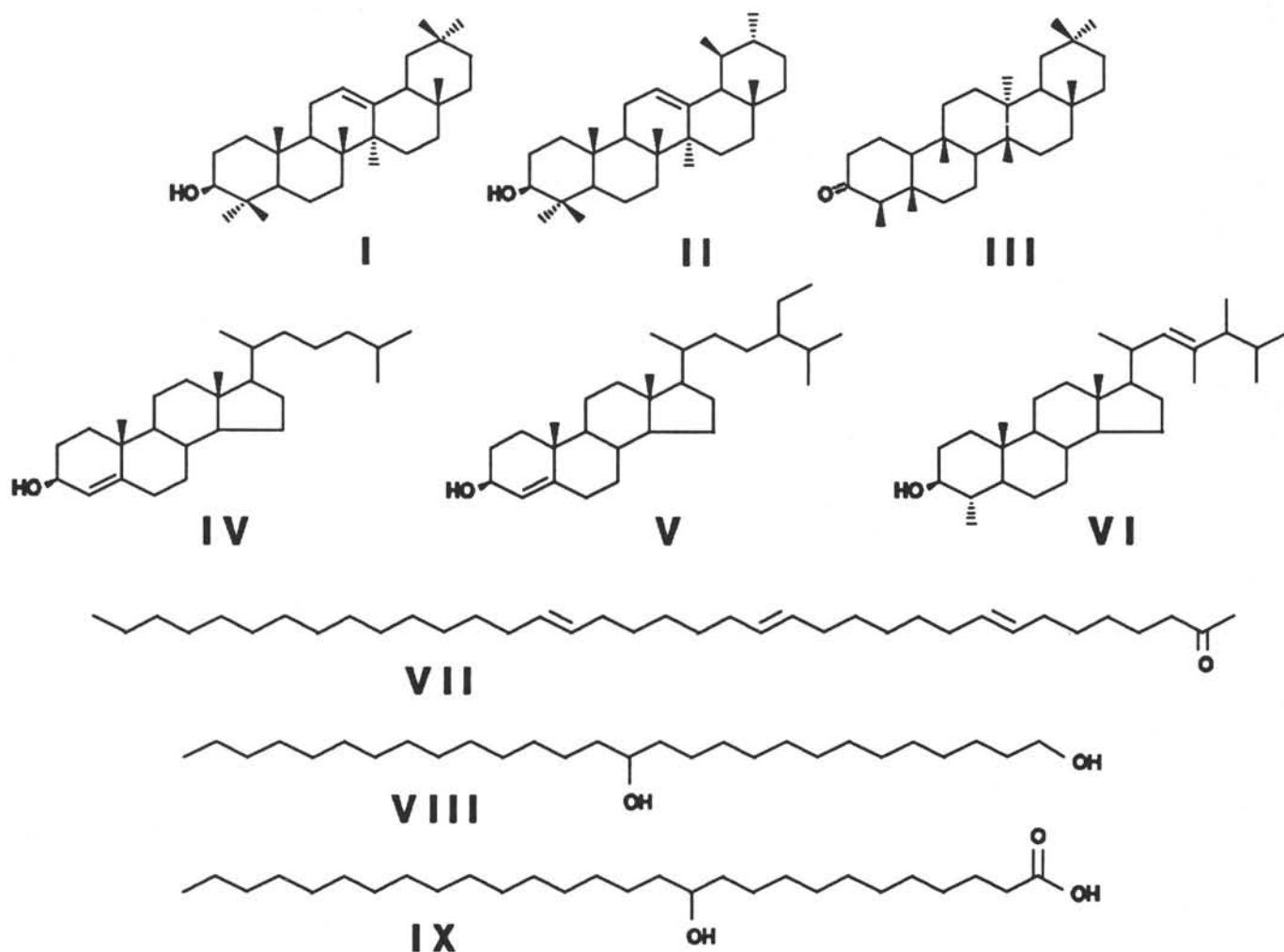


Figure 3. Structures of selected organic compounds identified.

**Table 1. Depth intervals and bulk characteristics of samples.**

Core, section, interval (cm)	Depth (mbsf)	Age	CaCO <sub>3</sub> (%)	C <sub>org</sub> (%)	HI	OI
<b>Indus Fan</b>						
117-720A-						
12X-2, 21-26*	107.71	Pleist.	13.33	1.43	45	91
32X-1, 75-80*	299.75	Pleist.	11.66	0.24		
<b>Owen Ridge</b>						
117-722A-						
2H-6, 72-78	18.02	Pleist.	71.22	1.22	270	255
3H-4, 91-96	24.81	Pleist.	64.56	0.98		
4H-2, 80-86*	31.30	Pleist.	66.72	1.41	302	227
5H-7, 25-31	47.85	Pleist.	70.47	0.95	251	269
7H-4, 15-21	62.15	Plioc.	53.23	2.26	305	179
10X-5, 54-60*	93.04	Plioc.	63.97	3.27	401	150
14X-1, 128-135	126.58	Plioc.	65.14	0.90		
19X-2, 74-80*	175.84	l. Mioc.	46.23	2.57	370	142
27X-4, 10-16	255.60	l. Mioc.	26.91	1.34	258	190
117-722B-						
29X-2, 122-127	268.62	l. Mioc.	28.65	2.14	376	158
29X-3, 78-81	269.68	l. Mioc.	33.49	1.07	241	228
31X-1, 36-39	285.66	l. Mioc.	25.74	2.17	335	118
32X-5, 16-18*	301.16	l. Mioc.	11.99	3.09	310	93
48X-1, 44-45*	450.24	e. Mioc.	7.83	1.37	26	126
51X-CC, 1-2	479.40	e. Mioc.	11.66	46.40	74	64
117-731A-						
1H-2, 71-74*	2.23	Pleist.	64.72	0.84		
1H-3, 132-135*	4.32	Pleist.	61.64	0.71		
40X-4, 126-128	376.15	Miocene	10.41	2.35	66	104
<b>Oman margin</b>						
117-723B-						
17X-1, 69-75*	149.59	Pleist.	46.56	2.75	368	99
25X-2, 49-52*	228.19	Pleist.	59.48	4.36	381	91
33X-2, 70-76*	315.20	Plioc.	31.74	4.49	423	86
40X-3, 97-103*	375.27	Plioc.	38.65	3.91	398	87
41X-2, 50-53*	383.00	Plioc.	15.91	8.24	459	64
117-725C-						
1H-1, 47-50	0.47	Pleist.	28.24	3.51		
1H-1, 111-114	1.11	Pleist.	50.98	0.30		
1H-2, 60-63	2.10	Pleist.	51.98	0.38		
1H-2, 105-108*	2.55	Pleist.	55.14	0.62		
1H-3, 52-55	3.52	Pleist.	53.31	0.35		
1H-3, 107-110	4.07	Pleist.	53.14	0.49		
1H-4, 60-63	5.10	Pleist.	55.14	0.46		
1H-4, 105-108	5.55	Pleist.	55.89	0.51		
1H-5, 53-56	6.53	Pleist.	53.31	0.47		
1H-5, 110-113	7.10	Pleist.	53.98	0.35		
1H-6, 60-63	8.10	Pleist.	54.64	0.31		
2H-1, 52-55	9.52	Pleist.	55.23	0.39		
2H-1, 110-113	10.10	Pleist.	55.98	0.50		
2H-2, 40-43	10.90	Pleist.	55.06	0.56		
2H-2, 100-103	11.50	Pleist.	50.31	0.30		
2H-3, 53-56	12.53	Pleist.	49.81	0.36		
2H-3, 110-113	13.10	Pleist.	51.06	0.57		
2H-4, 40-43	13.90	Pleist.	49.98	0.63		
2H-4, 100-103	14.50	Pleist.	50.15	0.33		
2H-5, 53-56	15.53	Pleist.	51.90	0.67		
2H-5, 110-113	16.10	Pleist.	55.39	0.55		
2H-6, 40-43	16.90	Pleist.	54.98	0.32		
2H-6, 100-103	17.50	Pleist.	54.06	0.28		
6X-1, 80-83	48.30	Pleist.	55.14	0.37		
6X-3, 80-83	51.30	Pleist.	58.48	0.71		
11X-1, 70-73	96.00	Pleist.	45.90	1.20	298	94
14X-1, 70-73	124.80	Pleist.	43.48	3.17	379	63
117-728B-						
1H-1, 14-17*	0.14	Pleist.	68.89	1.80		
2H-6, 35-38*	9.05	Pleist.	51.98	0.85		
5H-7, 53-58*	39.13	Pleist.	46.06	2.21	309	115
10X-4, 74-80*	82.54	Plioc.	43.07	5.23	447	68
15X-1, 75-80*	126.25	Plioc.	48.65	3.17	384	91
20X-3, 80-86	177.60	Plioc.	42.32	2.48	331	94
25X-2, 125-130	224.95	Plioc.	41.82	2.43	356	86
30X-3, 72-78	280.20	Mioc.	51.73	1.67	304	126
35X-4, 80-86	328.50	Mioc.	36.82	2.22	343	92

\* Sample extracted and extract analyzed by GC and GC-MS.

of southeast Asia, such as the Indus, have depositional centers extending several thousand kilometers offshore (Kolla et al., 1981). Microscopic analyses revealed the presence of abundant vitrinites, inertinites, cutinites, and subordinate amounts of sporinites. Extremely large particles, up to 300  $\mu\text{m}$  in diameter, were observed.

A partial gas chromatogram of the total lipid extract of Sample 117-720A-12X-2, 21-26 cm, is shown in Figure 4. The compounds identified are listed in Table 2. N-Alkanols with a distinct maximum at C<sub>22</sub> (peak 4) dominate the extract. Long-chain alkanols are usually ascribed to a contribution of epicuticular waxes (e.g., Eglinton and Hamilton, 1967; Simoneit, 1978), but in those cases their distribution usually maximizes at C<sub>26</sub> or C<sub>28</sub>. Epicuticular waxes also contain long-chain alkanes with a strong odd-over-even carbon number predominance and long-chain fatty acids with a strong even-over-odd carbon number predominance, but these latter compounds were virtually absent in the Indus Fan sediments. However, a contribution of terrigenous organic matter is evident from the high relative abundance of functionalized terrigenous triterpenoids (e.g., Brassell and Eglinton, 1983), like olean-12-en-3 $\beta$ -ol (peak 19; I), urs-12-en-3 $\beta$ -ol (20; II) and friedelan-3-one (22, III). These latter compounds are important constituents of higher plants (e.g., Pant and Rastogi, 1979). Also the abundance of 24-ethylcholest-5-en-3 $\beta$ -ol (16; V) can here be ascribed to terrigenous sources (Huang and Meinschein, 1976).

In addition, two major compounds occur (peaks 14 and 15) whose mass spectra are shown in Figure 5. Chromatographic separation of the "total lipids" of this sample revealed the presence of these two compounds in the alcohol fraction. Although their exact structures are unknown at present, we believe that peak 14 is a triterpenoid alcohol (M<sup>+</sup> = m/z 500) and peak 15 is a nortriterpenoid alcohol (both silylated for GC-MS analysis), both of terrigenous origin. GC-MS analysis of the isolated aliphatic hydrocarbon fraction indicated the presence of numerous ring-A degraded triterpenoids (saturated and unsaturated, many of them in very low concentrations) with the des-A-lupane (peak 1 in Fig. 4) as the most abundant compound (cf. Corbet et al., 1980).

The gas chromatogram of the total lipid extract of Sample 117-720A-32X-1, 75-80 cm, showed a similar lipid distribution, but with compounds 14 and 15 present in much lower relative abundance.

### Owen Ridge

The lithologic sequence of sediments recovered on the Owen Ridge consists of turbidites (Unit IV; late Oligocene/early Miocene), nannofossil chalk (Unit III; early/middle Miocene), siliceous nannofossil chalk (Unit II; late Miocene), and alternating light and dark layers of foraminifer-bearing to foraminifer-nannofossil ooze (Unit I; late Miocene/Holocene). The increase of pelagic deposits with the younger sediments of Unit IV is thought to relate to the uplift of the Owen Ridge.

The Rock-Eval results indicate that organic matter in samples from lithologic unit IV is mainly of terrigenous origin, whereas in units II and I the organic matter is of a marine origin with variable admixtures of terrigenous material (Table 1; no samples of unit III were investigated). An organic petrographical investigation of the Miocene Samples 117-722B-51X-CC, 1-2 cm, and -731A-40X-4, 126-128 cm, both with a high organic carbon content, revealed that the former resembles a piece of well-preserved, non-carbonized wood with extremely high amounts of pyrite and that the latter sample exclusively contains terrigenous organic particles with a dominance of vitrinite macerals. Mean vitrinite reflectance of both samples is 0.17% (Fig. 6), attesting to the immature character of the organic matter. The distributions of the vitrinite reflectance values (Fig. 6) are extremely narrow, indicating the absence of reworked material

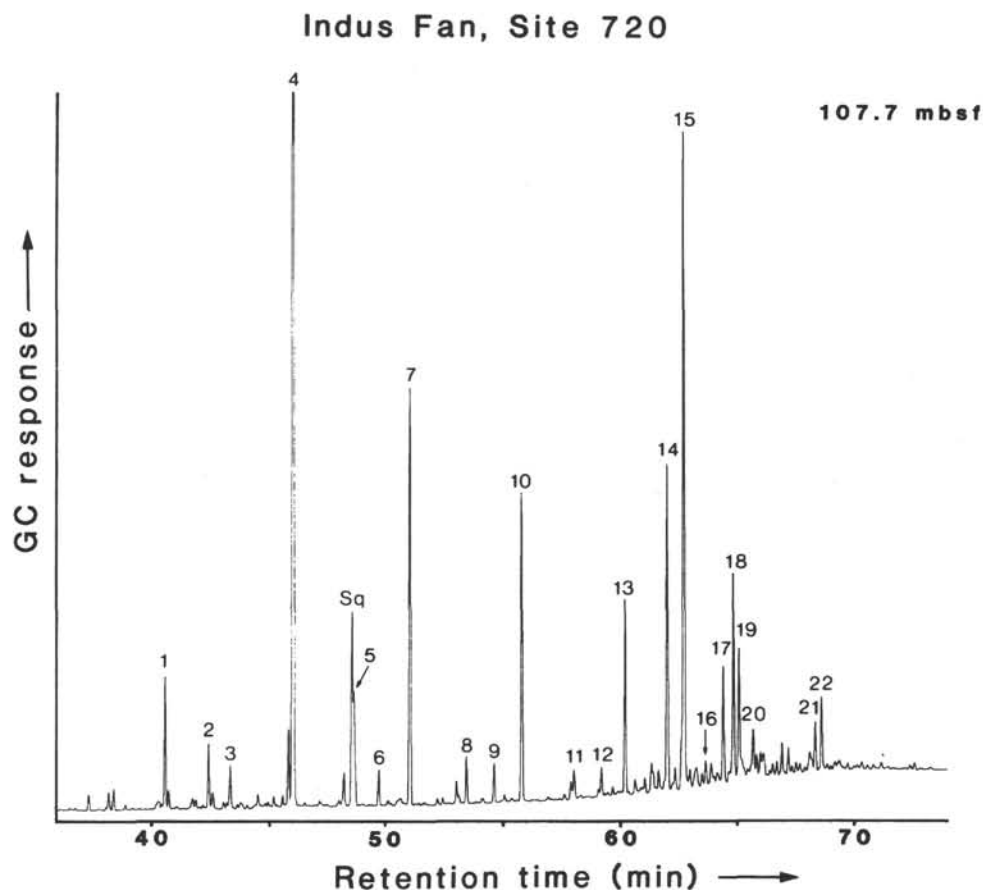


Figure 4. Partial gas chromatogram of "total lipid" extract of Sample 117-720A-12X-2, 21-26 cm, from the Indus Fan. Identities of numbered compounds are given in Table 2. Sq = squalane (internal standard).

**Table 2. Compounds identified in the total lipid fraction of Sample 117-720A-12X-2, 21-26 cm (Fig. 4).**

1. Eicosanol	13. Octacosanol
2. Des-A-lupane	14. Unknown (see Fig. 5A)
3. Heneicosanol	15. Unknown (see Fig. 5B)
4. Docosanol	16. 24-Ethylcholesta-5,22-dien-3 $\beta$ -ol
5. Tricosanol	17. Tricosanol
6. Heptacosane	18. 24-Ethylcholest-5-en-3 $\beta$ -ol
7. Tetracosanol	19. 24-Ethyl-5 $\alpha$ (H)-cholestan-3 $\beta$ -ol + olean-12-en-3 $\beta$ -ol
8. Pentacosanol	20. Urs-12-en-3 $\beta$ -ol
9. Nonacosane	21. Dotricosanol
10. Hexacosanol	22. Friedelan-3-one
11. Heptacosanol	
12. Henetricosane	

Note: Alcohols have been measured as trimethylsilylether derivatives.

and the lack of oxidation during transport (probably short transport distance).

The mineralogical composition suggests that the provenance of the turbiditic sediments on the Owen Ridge, prior to its uplift, was probably the same as for the Indus Fan sediments (Shipboard Scientific Party, 1989c). GC and GC-MS analyses of the extract of Sample 117-722B-48X-1, 44-45 cm, showed that the terrigenous triterpenoid friedelan-3-one was one of the most abundant compounds, in accordance with the suggestion above. Friedelane had been obtained previously as a major component

during hydrogenolysis of humic substances, e.g., lignite (Michaelis et al., 1989), while friedelan-3-one was found in Messel oil shale (Robinson et al., 1989) and was attributed to the terrigenous component in the organic matter.

Microscopical analyses of the organic matter from Units I and II mainly showed an abundance of dark-brown fluorescing material with an extremely small particle size ( $< 10 \mu\text{m}$ ) indicating long-distance transport with oxidation (Littke et al. 1991). Alginites and minor amounts of terrigenous macerals could be identified. Similar results were obtained from our study of samples from the Peruvian upwelling area (Leg 112; ten Haven et al., 1990a).

Partial gas chromatograms of the total lipid fraction of Samples 117-722A-4H-2, 80-86 cm (Unit I) and 117-722B-32X-5, 44-45 cm (Unit II) are shown in Figure 7. Generally, the same organic compounds (Table 3) were found in all samples from (Unit I and II, but their relative abundances differ markedly. In some samples, the long-chain alkenones (peaks 17, 18, e.g., VII) are the most abundant constituents, whereas in others alkanediols (peaks 12, 15) dominate (Fig. 7). The former compounds are thought to reflect a contribution of Prymnesiophyte algae (Marlowe et al., 1984), and the latter have been ascribed to planktonic cyanobacteria (Morris and Brassell, 1988). However, no  $\text{C}_{28}$  alkanediols (peak 12, VIII) were reported in these organisms. Other important classes of compounds are straight-chain alcohols, fatty acids, and alkanes, indicative of the terrigenous contribution to the organic matter (Eglinton and Hamil-

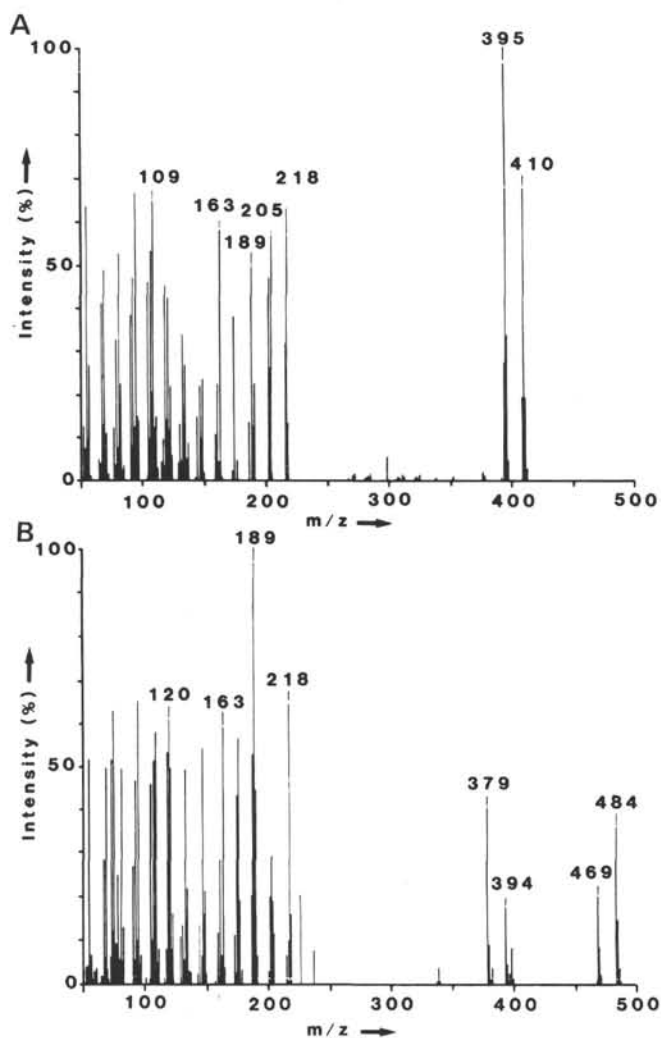


Figure 5. Mass spectra of major unknown compounds of the "total lipid" fraction of Sample 117-720A-12X-2, 21–26 cm. **A.** Compound 14 of Figure 4. **B.** Compound 15 of Figure 4.

ton, 1967; Simoneit, 1978), and numerous sterols with various degrees of unsaturation and with and without C-4 alkylation, characteristic of marine contribution (e.g., Volkman, 1986).

Noteworthy is the presence of 2-tricosylthiophene in Sample 117-722A-19X-2, 74–80 cm (Table 4). GC analysis of the isolated aromatic hydrocarbon fraction with dual flame ionization and flame photometric detection showed that this fraction consisted almost entirely of 2-tricosylthiophene whereas in Sample 117-722B-32X-5, 16–18 cm, the same applies to the lower homolog, i.e., 2-heneicosylthiophene (peak 3, Fig. 7). A similar relatively high abundance and patchy occurrence of these two alkylthiophenes has been observed previously in other marine sediments (ten Haven et al., 1990b), but their significance remains unclear. These compounds most likely arise from the incorporation of inorganic sulfur species into labile functionalized lipids during early diagenesis (e.g., Brassell et al., 1986; Sinnighe Damsté et al., 1989).

### Oman Margin

The Miocene to Holocene sediments recovered on the Oman margin are dominantly green to olive calcareous oozes to clayey silts, rich in organic carbon. Some of these contain laminated diatom-bearing intervals. The laminae were observed in upper

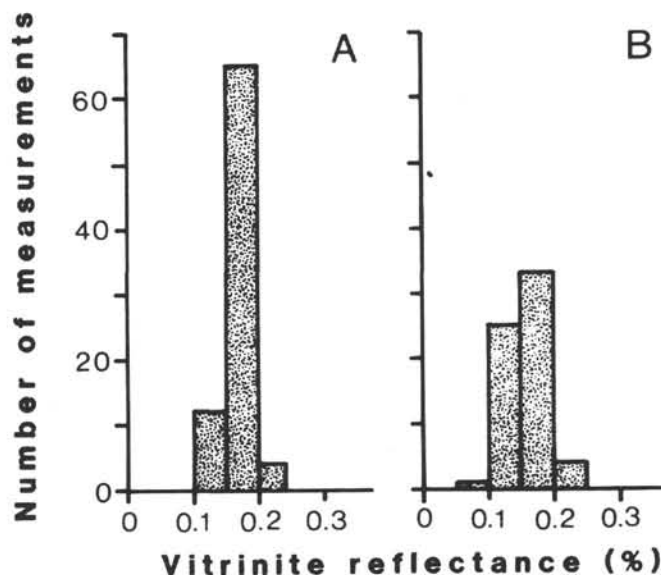


Figure 6. Vitrinite reflectance histograms. **A.** Sample 117-722B-51X-CC, 1–2 cm. **B.** Sample 117-731A-40X-4, 126–128 cm.

Pliocene/lower Pleistocene sections of the four most landward sites (726, 725, 724, 723) and are characterized by elevated organic carbon contents (Table 1). This is attributed to a strong oxygen depletion in the oxygen minimum zone.

The hydrogen indices from Rock-Eval pyrolysis, on average, are slightly higher than those measured for Owen Ridge samples (Table 1) indicating better preservation of the organic matter. However, microscopic kerogen inspection also revealed the presence of abundant dark-brown fluorescing material similar to that observed in samples from the Owen Ridge and probably of a more distal origin.

Partial gas chromatograms of the "total lipid" fractions of two samples from Site 723 and two samples from Site 728 are shown in Figures 8 and 9, respectively. These examples show that there is a great variability in lipid composition of these samples. Long-chain alkenones (peaks 17, 18) are important constituents in all samples, sometimes accompanied by abundant sterols, in others by abundant alkanediols. This indicates variable contribution of planktonic cyanobacteria (alkanediols) and higher planktonic organisms (sterols) over a strong background of lipids from Prymnesiophyte algae (long-chain alkenones). An influence of a variance in preservation of these compound classes due to fluctuations in the extension of the oxygen minimum zone cannot be excluded, however.

The mass spectrum of peak 12 in the "total lipid" fraction of Sample 117-723B-41X-2, 50–53 (Fig. 8, bottom) is shown in Figure 10. It indicates the presence of at least two isomers, viz., octadecane-1,14-diol (VIII) and octadecane-1,12-diol. The 1,14-alkanediol is always the dominant compound of the  $C_{28}$  alkanediols, whereas in the case of the  $C_{30}$  components, either the 1,15- or the 1,14-alkanediol is the most abundant isomer. This is in contrast to previous observations, obtained from a variety of marine sediments, in which the 1,15-diol isomer is always the most abundant one (e.g., de Leeuw et al., 1981; Nichols and Johns, 1986; Poynter et al., 1989; ten Haven et al., 1987, 1990a).

As in the Owen Ridge samples, a wide variety of sterols, with various degrees of unsaturation and with and without C-4 alkylation, were identified. Of these, cholest-5-en-3 $\beta$ -ol (IV), 5 $\alpha$ (H)-cholestan-3 $\beta$ -ol, 24-ethylcholest-5-en-3 $\beta$ -ol (V), 24-ethyl-5 $\alpha$ (H)-cholestan-3 $\beta$ -ol, and 4 $\alpha$ ,23,24-trimethylcholest-22-en-3 $\beta$ -ol (VI) are always dominant sterols. The last compound is thought to

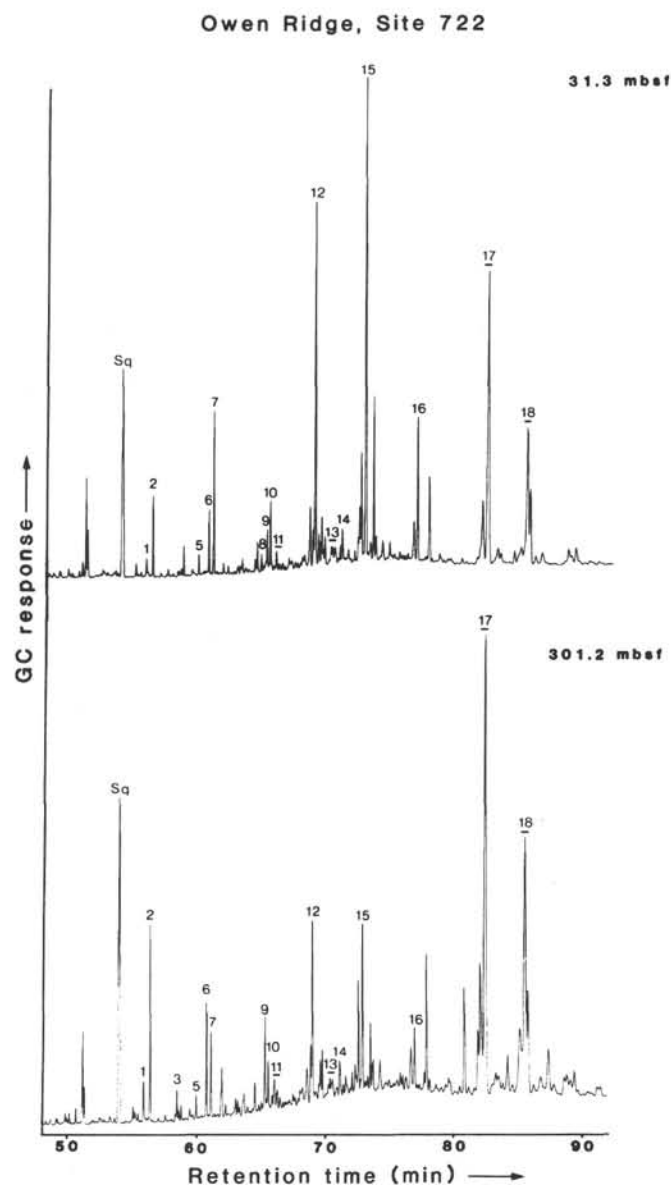


Figure 7. Partial gas chromatogram of "total lipid" extract of Samples 117-722A-4H-2, 80-86 cm (top) and 722B-32X-5, 44-45 cm (bottom) from the Owen Ridge. Identities of numbered compounds are given in Table 3. Sq = squalane (internal standard).

Table 3. Selected compounds identified in the total lipid fraction of samples from the Owen Ridge (Fig. 7) and Oman Margin (Figs. 8, 9).

1. Tetracosanoic acid	12. Octacosane-1,14- and 1,12-diols
2. Tetracosanol	13. 24-Ethylcholest-5-en-3 $\beta$ -ol + 24-ethyl-5 $\alpha$ (H)-cholestan-3 $\beta$ -ol
3. 2-Heneicosylthiophene	14. 4 $\alpha$ ,23,24-trimethylcholest-22-en-3 $\beta$ -ol
4. Perylene	15. Triacontane-1,14- and 1,15-diols
5. Nonacosane	16. Dotriacontane-1,12- and 1,15 diols
6. Hexacosanoic acid	17. Heptatriaconta-8,15,22-trien-2-one heptatriaconta-15,22-dien-2-one
7. Hexacosanol	18. Octatriaconta-9,16,13-trien-3-one + octatriaconta-9,16,23-trien-2-one + octatriaconta-16,23-trien-3-one + octatriaconta-16,23-dien-2-one
8. 1,12-Dihydroxyhexacosane	
9. Octacosanoic acid	
10. Octacosanol	
11. Cholest-5-en-3 $\beta$ -ol + 5 $\alpha$ (H)-cholestan-3 $\beta$ -ol	

Note: Fatty acids and alcohols have been measured as methyl esters and trimethylsilyl ether derivatives, respectively.

indicate a contribution from dinoflagellates (Boon et al., 1979). In a few samples a compound tentatively identified as 12-hydroxy octacosanoic acid (IX) predominates. This has previously been reported to occur in Mediterranean sapropels (ten Haven et al., 1987), but its origin is still unclear.

GC and GC-MS analyses of isolated aromatic hydrocarbon fractions revealed the presence of two isoprenoid thiophenes (3-methyl-2-(3,7,11-trimethyldodecyl)- and 3-(4,8,12-trimethyltridecyl) thiophene) and two 2-alkylthiophenes as the most abundant extractable free organic sulfur compounds (Table 4). The former two compounds are present in all Oman Margin samples, whereas the latter ones show a similarly patchy occurrence as observed for the Owen Ridge samples. Analysis of Sample 723B-41X-2, 50-53 cm, which had a high-temperature GC, indicated the presence of C<sub>36</sub>-C<sub>54</sub> 3,4-dialkylthiophenes, whose origin is still unknown (Kohnen et al. 1990).

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**Table 4: Occurrence and arbitrary relative abundance of organic sulfur compounds in ODP Leg 117 samples.**

Core, section, interval (cm)	Sample concentrations of organic sulfur compounds			
	3-methyl-2-(3,7,11-trimethyl) dodecylthiophene	3-(4,8,12-trimethyl) tridecylthiophene	2-heneicosyl- thiopene	2-tricosyl- thiophene
	m/z 111, 308	m/z 98, 308	m/z 97, 378	m/z 97, 406
<i>Owen Ridge</i>				
722A-4H-2, 80-86	—	—	++	++
722A-10X-5, 54-60	++	++	+++	+++
722A-19X-2, 74-80	+	+	+++++	—
722B-32X-5, 16-18	—	—	+++++	—
722B-48X-1, 44-45	+	—	+	—
<i>Oman Margin</i>				
723B-17X-1, 69-75	++	+	+	+
723B-25X-2, 49-52	++	+	++	—
723B-33X-2, 70-76	+++	++	—	—
723B-40X-3, 97-103	+++	++	+	++
723B-41X-2, 50-53	++	++	+	+
728B-10X-4, 74-80	++	++	+	—
728B-35X-4, 80-86	++	++	++	—

Note: Numbers below compound names are important mass spectral peaks. — = not detected.

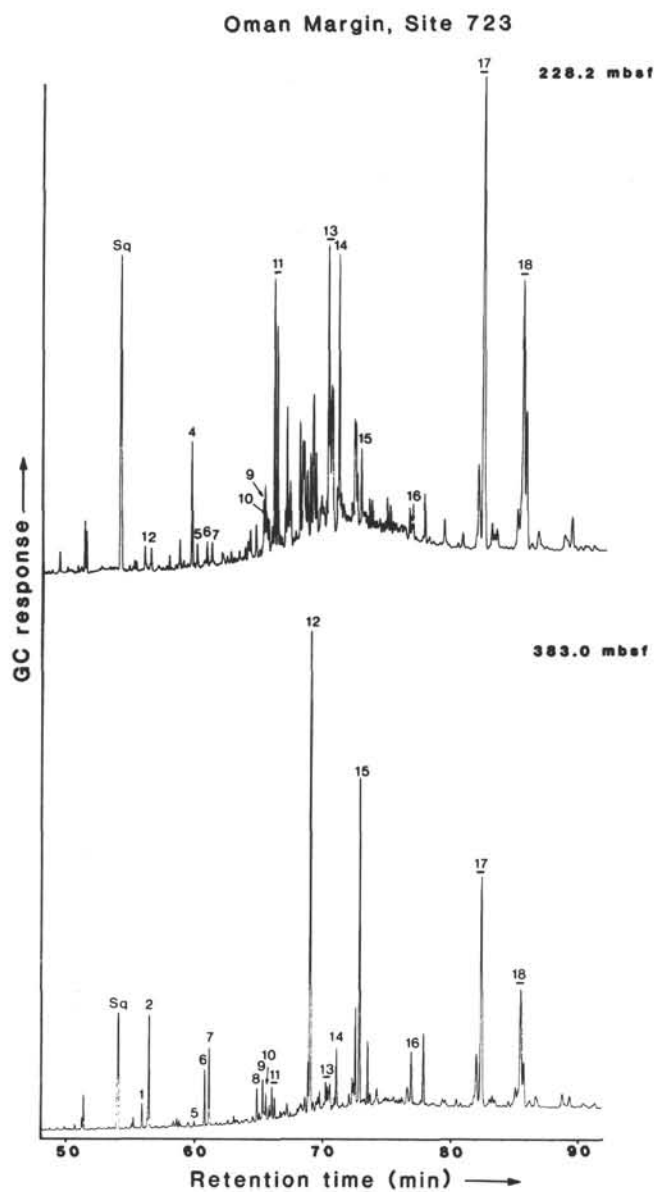


Figure 8. Partial gas chromatogram of "total lipid" extract of Samples 117-723B-25X-2, 49-52 cm (top), and 723B-41X-2, 50-53 cm (bottom), from the Oman Margin. Identities of numbered compounds are given in Table 3. Sq = squalane (internal standard).

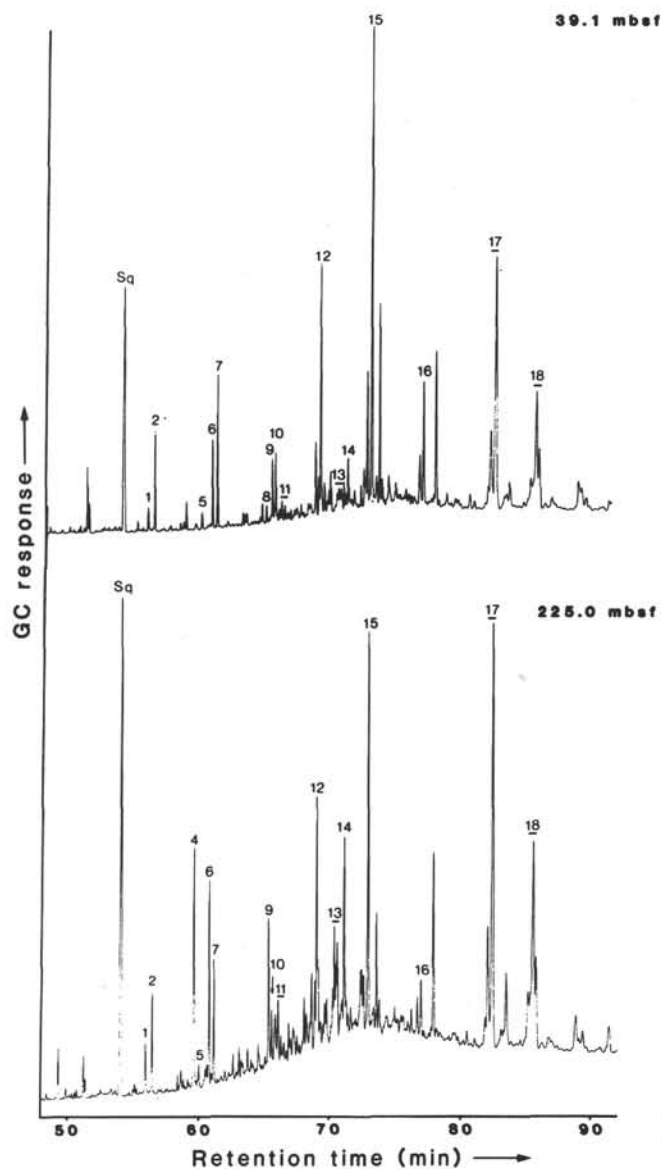


Figure 9. Partial gas chromatogram of "total lipid" extract of Samples 117-728B-5H-7, 53-58 cm (top), and 728B-25X-2, 125-130 cm (bottom), from the Oman Margin. Identities of numbered compounds are given in Table 3. Sq = squalane (internal standard).



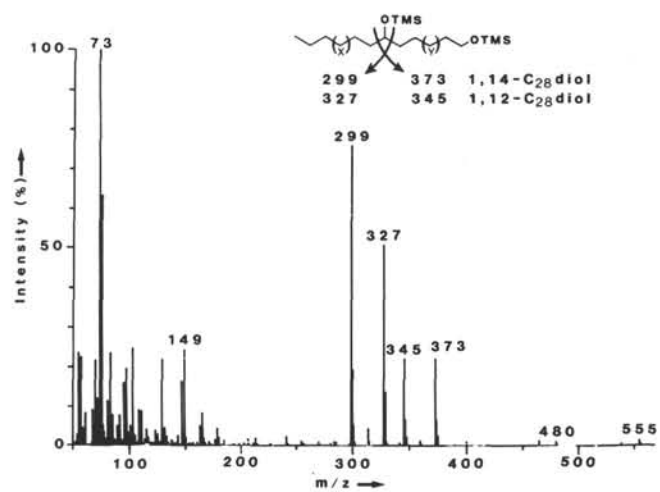


Figure 10. Mass spectrum of compound 12 of Sample 117-723B-41X-2, 50-53 cm (see Fig. 6, bottom), tentatively identified as a mixture of 1,14- and 1,12-dihydroxyoctacontane. A trace of 1,13-dihydroxyoctacontane is also possibly present.