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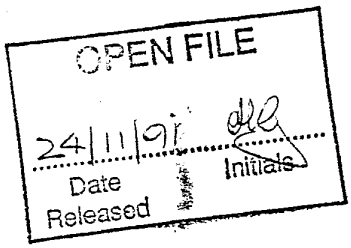

TOTAL ORGANIC CARBON AND ROCK-EVAL PYROLYSIS DATA FOR SAMPLES FROM 11 WELLS, ONSHORE SOUTH AUSTRALIA

Prepared for :

SHELL DEVELOPMENT (AUSTRALIA) PTY LTD

AUGUST 1984

By

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10 April 1989

The Director General
South Australian Department of Mines
& Energy
PO Box 151
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Attention: C.G. Gatehouse

REPORT F7224/89

YOUR REFERENCE:	EX-758, Project 12/07
TITLE:	Biomarker geochemistry of oil shows in the Late Precambrian Murnaroo Formation, Lake Maurice West-1, Officer Basin, S.A.
MATERIAL:	Oil-stained core (3 samples)
LOCALITY:	Lake Maurice West-1 (Aquitaine SMD 5001)
WORK REQUIRED:	TOC and Rock-Eval pyrolysis. Solvent extraction. Liquid chromatography. GC of saturates. Isolation (by urea adduction) and GC-MS analysis of naphthenes. Isolation (by TLC) and GC-MS of aromatics. Interpretation.
DATE RECEIVED:	10 May 1988
Investigation and Report by:	Dr David M. McKirdy and Brian L. Watson
Manager, Petroleum Services:	Dr Brian G. Steveson

Brian G Steveson.

for Dr William G. Spencer
General Manager
Applied Sciences Group

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1. INTRODUCTION

Three core samples of sandstone from the Murnaroo Formation in Aquitaine drillhole SMD (SADME Lake Maurice West -1: Gatehouse et al, 1986) were submitted for organic geochemical analysis. Examination of thin sections of core from the interval 534-576 metres depth in Lake Maurice West -1 had revealed a "pale brown stain" in intergranular porosity of fine to coarse-grained quartz sandstone (C.G. Gatehouse, pers. comm.). If the stain could be demonstrated to be residual oil, then this would represent the stratigraphically oldest occurrence of hydrocarbons in the eastern Officer Basin. The host Murnaroo Formation is now considered to be of Adelaidean age (Brewer et al, 1987). Oil shows previously have been recorded in the immediately overlying Rodda Beds (Adelaidean) at Ungoolya -1 (G. Weste, pers. comm.); in the Relief Sandstone (Early Cambrian) at Observatory Hill -1 (Gatehouse and McKirdy, 1989); in the Ouldburra Formation (Early Cambrian) at Duvall KD-2A (McKirdy, 1986), Marla -9 (McKirdy and O'Leary, 1986) and Wilkinson -1 (McKirdy et al., 1984); and in the Observatory Hill Formation (Middle Cambrian) at Byilkaoora -1,3 (McKirdy et al., 1983, 1984; Weste et al., 1984).

The aims of the present study were twofold:

1) to confirm the presence of residual oil in sandstones of the Murnaroo Formation at Lake Maurice West -1; and

2) to compare its biomarker geochemistry, and aromatic maturity, with that of other oil shows elsewhere in the Officer Basin.

2. RESULTS

Analytical data are summarised and presented herein as follows:

	Table	Figure
TOC, Rock-Eval pyrolysis	1	-
C_{15+} extract yield and composition	2	1-3
GC-MS of naphthenes	3	4-12
GC-MS of aromatics	4	13,14

Preliminary geochemical data on the Observatory Hill -1 (Relief Sandstone) oil show are included in Tables 3 and 4 for comparison.

3. PETROLEUM GEOCHEMISTRY

3.1 CONCENTRATION AND BULK COMPOSITION

The low total organic carbon contents (TOC = 0.06 - 0.08%) of the three sandstone samples reflect their non-source character. The only organic matter in these sandstones is present as free hydrocarbons (S_1 = 0.06 - 0.07 kg/tonne); there is no pyrolysable kerogen (S_2 = zero) (Table 1). The Rock-Eval S_1 values are broadly consistent with the yields of C_{15-} reservoir bitumen obtained by extraction with dichloromethane/methanol (36-103 ppm : Table 2).

The residual oils recovered from the cores have an aromatic C_{15-} composition (Table 2), thus:

534.14 m	aromatic-intermediate
540.83 m	aromatic-asphaltic
576.07 m	aromatic-naphthenic

NOTE: the three cores probably contain the same type of oil; the apparent range in composition can be attributed to the experimental error inherent in working with very small aliquots of sample (4-13 mg of total extract).

Oils of similar composition are present in the Relief Sandstone, Ouldburra Formation and Observatory Hill Formation.

3.2 SOURCE AFFINITY

The low pristane/phytane and C_{29}/C_{27} sterane ratios of the three oil shows (pr/ph = 1.0 - 1.8; C_{29}/C_{27} ster = 0.89 - 1.1: Table 3) indicate that they were derived from organic matter rich in the remains of photosynthetic eukaryotic algae which were deposited in a highly reducing aquatic environment.

The C_{15+} n-alkane profiles of the oils from 540.83 m and 576.07 m depth (range C_{15} - C_{29}, maximum at C_{18} or C_{20}) are characterised by a slight predominance of the C_{18} and C_{20} homologues. This feature, although not common, has been reported from anoxic carbonate-evaporite palaeoenvironments (Tissot and Welte, 1984).

A high input of bacterial (relative to algal) lipids is evident from the oils' high hopane/sterane ratio (C_{30} hop/C_{29} ster = 3.4 - 4.9: Table 3). The same ratio is somewhat lower (2.4) in the Observatory Hill -1 (Relief) crude. Nevertheless, the C_{27} - C_{29} sterane distributions ($27 \geq 29 > 28$) and C_{23} tricyclic/C_{24} tetracyclic terpane ratios of the Lake Maurice West -1 (Murnaroo) oils are very similar to those of the Observatory Hill -1 oil show (Table 3). Moreover, all these oils are markedly different from those of oil shows associated with younger evaporitic source beds in the Ouldburra and Observatory Hill Formations (C_{28} sterane dominant; C_{21} - C_{25} and C_{30} extended acyclic isoprenoid alkanes prominent: McKirdy et al, 1983, 1984, 1986). The low diasterane/sterane ratios of the Lake Maurice West -1 and Observatory Hill -1 oils (C_{29} dia/ster = 0.29 - 0.52: Table 3) suggest that they may be derived from non-argillaceous (i.e. carbonate) source rocks.

3.3 MATURITY

Maturity measurments based on sterane and triterpane isomeric ratios (biomarker parameters, 4, 6, 9, 10, 11 and 12: Table 3), for the most part, concur in demonstrating that the Lake Maurice West -1 (Murnaroo) oils are very mature. One exception is the C_{29} sterane 20S/20R ratio (parameter 4) for which the measured values (20S/20R = 0.73 - 0.86) are considerably lower than the equilibrium value attained by mature oils and source rocks (20S/20R = 1.0 - 1.2). However, there is evidence that the 20S isomer may be preferentially destroyed at high maturation levels (R. Alexander, pers. comm) as appears to have happened in this case. Another indication of elevated maturity is the high abundance of C_{29} 17α(H)-30-norhopane relative to C_{30} hopane (C_{29} norhop/C_{30} hop $\geq$ 1: Table 3).

Confirmation of the advanced maturity of the Lake Maurice West-1 oil shows is provided by their triaromatic hydrocarbon distributions (MPI = 1.03-1.40; VR_{calc} = 0.94-1.20%: Table 4). If the calculated vitrinite reflectance values do in fact represent source bed maturity at the time of primary migration, then these hydrocarbons probably are inspissated residues of originally light, condensate-like crude oils. It is worth noting that the Observatory Hill-1 (Relief) oil has a similarly high maturity (Table 4).

4. CONCLUSIONS

1. Detailed organic geochemical analysis of three sandstone core samples from 534-576 metres depth in Lake Maurice West-1 confirms the presence of low concentrations (36-103 ppm) of residual oil.

2. The host reservoir is the Adelaidean (Late Precambrian) Murnaroo Formation which this study demonstrates to be the oldest hydrocarbon-bearing unit in the eastern Officer Basin.

3. The hydrocarbons (reservoir bitumen) comprise very mature aromatic crude oil (VR_{calc} = 0.94-1.20%) of algal/bacterial origin. The inferred source rocks are carbonates which were deposited in an anoxic marine(?) environment.

4. The oil is of similar composition, source affinity and maturity to residual hydrocarbons present in the basal Cambrian Relief Sandstone at Observatory Hill-1. However, it differs from evaporite-associated oils in the younger Ouldburra and Observatory Hill Formations.

5. REFERENCES

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TABLE 1

ROCK-EVAL PYROLYSIS

CLIENT: SADME

LOCATION: LAKE MAURICE WEST -1

DEPTH	T Max	S1	S2	S3	S1+S2	PI	S2/S3	PC	TOC	HI	OI
534.14	256	0.06	0.00	0.12	0.06	1.00	0.00	0.00	0.07	0	171
540.83	276	0.07	0.00	0.29	0.07	1.00	0.00	0.00	0.08	0	362
576.07	252	0.06	0.00	0.07	0.06	1.00	0.00	0.00	0.06	0	116

KEY TO ROCK-EVAL PYROLYSIS DATA SHEET

PARAMETER		SPECIFICITY
T max	position of S_2 peak in temperature program (°C)	Maturity/Kerogen type
S_1	kg hydrocarbons (extractable)/tonne rock	Kerogen type/Maturity/Migrated oil
S_2	kg hydrocarbons (kerogen pyrolysate)/tonne rock	Kerogen type/Maturity
S_3	kg CO_2 (organic)/tonne rock	Kerogen type/Maturity *
$S_1 + S_2$	Potential Yield	Organic richness/Kerogen type
PI	Production Index ($S_1/S_1 + S_2$)	Maturity/Migrated Oil
PC	Pyrolysable Carbon (wt. percent)	Organic richness/Kerogen type/Maturity
TOC	Total Organic Carbon (wt. percent)	Organic richness
HI	Hydrogen Index (mg h'c (S_2)/g TOC)	Kerogen type/Maturity
OI	Oxygen Index (mg $CO_2(S_3)$/g TOC)	Kerogen type/Maturity *

* Also subject to interference by CO_2 from decomposition of carbonate minerals.

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TABLE 2

ROCK EXTRACT DATA, MURNAROO FORMATION, LAKE MAURICE WEST-1

Depth m	TOC %	Wt Sample Extracted g	Wt EOM mg	EOM Yield		EOM Composition				Alkane Ratios				
				ppm	mg/g TOC	N+Iso %	Naph %	Arom %	Res+Asph %	TMTD/Pr	Np/Pr	Pr/Ph	Pr/n-C_{17}	Ph/n-C_{18}
534.14	0.07	142.54	6.1	43	431	13.6	20.3	3.2	62.9	-	0.18	1.19	0.91	0.40
540.83	0.08	126.73	13.0	103	1016	9.7	31.1	1.5	57.7	-	0.36	1.79	0.83	0.40
576.07	0.06	118.03	4.2	36	508	9.5	11.9	---78.6---		-	0.17	1.01	0.83	0.45

N+iso = normal + iso-alkanes
Naph = naphthenes
Arom = aromatic hydrocarbons
Res = resins
Asph = asphaltenes

TMTD = 2,6,10-trimethyltridecane
Np = norpristane
Pr = pristane
Ph = phytane
n-C_{17} = n-heptadecane
n-C_{18} = n-octadecane

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TABLE 2

ROCK EXTRACT DATA, MURNAROO FORMATION, LAKE MAURICE WEST-1

Depth m	TOC %	Wt Sample Extracted g	Wt EOM mg	EOM Yield		EOM Composition				Alkane Ratios				
				ppm	mg/g TOC	N+Iso %	Naph %	Arom %	Res+Asph %	TMTD/Pr	Np/Pr	Pr/Ph	Pr/n-C_{17}	Ph/n-C_{18}
534.14	0.07	142.54	6.1	43	431	13.6	20.3	3.2	62.9	-	0.18	1.19	0.91	0.40
540.83	0.08	126.73	13.0	103	1016	9.7	31.1	1.5	57.7	-	0.36	1.79	0.83	0.40
576.07	0.06	118.03	4.2	36	508	9.5	-----	~~20.5~~ 78.6	------	-	0.17	1.01	0.83	0.45

N+iso = normal + iso-alkanes
Naph = naphthenes
Arom = aromatic hydrocarbons
Res = resins
Asph = asphaltenes

TMTD = 2,6,10-trimethyltridecane
Np = norpristane
Pr = pristane
Ph = phytane
n-C_{17} = n-heptadecane
n-C_{18} = n-octadecane

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TABLE 3A

BIOMARKER PARAMETERS OF SOURCE, MATURITY, MIGRATION AND BIODEGRADATION IN RESIDUAL OIL FROM LAKE MAURICE WEST-1 AND OBSERVATORY HILL-1

Formation	Depth (m)	Steranes							Terpanes						Acyclic Alkanes			
	Parameter*	1**	2	3	4	5	6	7	8	9	19	11	12	13	14	15	16	17
Lake Maurice West-1																		
Murnaroo	534.14	42:21:37	0.89	0.81	0.86	1.96	1.34	0.39	-	0.89	0.56	1.36	0.08	0.05	1.19	-	0.91	0.40
	540.83	42:22:36	0.84	0.57	0.78	1.63	1.16	0.52	-	0.92	0.47	1.51	0.13	0.12	1.79	-	0.83	0.40
	576.07	37:23:40	1.09	0.78	0.73	1.48	1.16	0.40	-	0.92	0.42	1.48	0.10	0.10	1.01	-	0.83	0.45
Observatory Hill-1																		
Relief	155.20 -155.50	36:25:39	1.08	0.74	0.88	1.40	1.30	0.29	-	0.86	0.29	1.57	0.11	0.08	2.22	-	0.64	0.18

* See key (next page) for derivation and specificity of each parameter. The derivation of several parameters has been modified as follows:

parameters 1 & 2 are based on C_{27}-C_{29} $\alpha\beta\beta$ 20R steranes (m/z 218)
parameter 11 is based on C_{31} homohopane isomers (m/z 191)

** All three cores from Lake Maurice West-1 appear to be contaminated with immature cholestane (C_{27} $\alpha\beta\beta$ 20R and 20S isomers only: peaks 8 and 5, Figure 9).

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KEY TO BIOMARKER PARAMETERS OF SOURCE, MATURITY, MIGRATION AND BIODEGRADATION

Parameter		
1	C_{27} : C_{28} : C_{29} 5α(H)14α(H)17α(H) 20R steranes	Source
2	C_{29} 5α(H)14α(H)17α(H) 20R sterane / C_{27} 5α(H)14α(H)17α(H) 20R sterane	Source
3	C_{29} 13β(H)17α(H) 20R diasterane / C_{27} 13β(H)17α(H) 20R diasterane	Source
4	C_{29} 5α(H)14α(H)17α(H) 20S sterane / C_{29} 5α(H)14α(H)17α(H) 20R sterane	Maturity, Biodegradation
5	C_{27} 13β(H)17α(H) 20S diasterane / C_{27} 13β(H)17α(H) 20R diasterane	Maturity
6	C_{29} 5α(H)14β(H)17β(H) 20R sterane / C_{29} 5α(H)14α(H)17α(H) 20R sterane	Maturity, Migration
7	C_{29} 13β(H)17α(H) 20R+20S diasteranes / C_{29} 5α(H) steranes	Maturity, Source
8	C_{30} pentacyclic terpane/C_{30} 17α(H)21β(H) hopane	Source
9	C_{27} 17α(H)-22,29,30-trisnorhopane / C_{27} 18α(H)-22,29,30-trisnorhopane (T_m/T_s)	Maturity, Source
10	T_s / C_{30} 17α(H)21β(H) hopane	Maturity
11	C_{32} 17α(H)21β(H) 22S homohopane / C_{32} 17α(H)21β(H) 22R homohopane	Maturity
12	C_{30} 17β(H)21α(H) moretane / C_{30} 17α(H)21β(H) hopane	Maturity
13	C_{29} 17α(H)-25-norhopane / C_{29} 17α(H)-30-norhopane	Biodegradation
14	pristane / phytane	Source
15	2,6,10-trimethyltridecane / pristane	Maturity
16	pristane / n-heptadecane	Source, Biodegradation, Maturity
17	phytane / n-octadecane	Source, Biodegradation, Maturity

* Ratios calculated from peak areas as follows:

Parameters 1-6 m/z = 217 mass fragmentogram
Parameter 7 m/z = 217, 259 mass fragmentograms
Parameters 8-13 m/z = 191 mass fragmentogram
Parameters 14-17 capillary gas chromatogram of alkanes of whole oil/extract

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TABLE 3B

SUPPLEMENTARY BIOMARKER PARAMETERS OF SOURCE AND MATURITY
IN RESIDUAL OILS FROM LAKE MAURICE-1
AND OBSERVATORY HILL-1

Well/Depth (m)	C_{23} Tricyclic / C_{24} Tetracyclic	C_{29} Norhopane / C_{30} Hopane	C_{30} Hopane / C_{29} Steranes
Lake Maurice West -1			
534.14	2.24	1.36	3.5
540.83	1.56	1.03	4.9
576.07	1.62	1.23	3.4
Observatory Hill-1			
155.20 - 155.50	1.31	1.03	2.4
Derivation	m/z 191	m/z 191	m/z 191, 217
Specificity	Source	Maturity	Source

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TABLE 4

OIL MATURITY BASED ON TRIAROMATIC HYDROCARBON DISTRIBUTIONS*,
LAKE MAURICE WEST-1 AND OBSERVATORY HILL-1

Well	Formation	Depth m	MPI	VR_{calc} (e) %
Lake Maurice West-1	Murnaroo	534.14	1.03	0.94
		540.83	1.40	1.20
		576.07	nd	nd
Observatory Hill-1	Relief	155.20 -155.50	1.32	1.15

* See key next page

NOTE: n.d. = not determined

KEY TO AROMATIC MATURITY INDICATORS

Methylphenanthrene index (MPI), methylphenanthrene ratio (MPR), dimethylnaphthalene ratio (DNR) and calculated vitrinite reflectance (VR_{calc}) are derived from the following equations (after Radke and Welte, 1983; Radke *et al.*, 1984):

$$MPI = \frac{1.5\ (2\text{-MP} + 3\text{-MP})}{P + 1\text{-MP} + 9\text{-MP}}$$

$$VR_{calc}\ (a) = 0.6\ MPI + 0.4 \quad (\text{for } VR < 1.35\%)$$

$$VR_{calc}\ (b) = -0.6\ MPI + 2.3 \quad (\text{for } VR > 1.35\%)$$

$$MPR = \frac{2\text{-MP}}{1\text{-MP}}$$

$$VR_{calc}\ (c) = 0.99 \log_{10} MPR + 0.94 \quad (VR = 0.5\text{-}1.7\%)$$

$$DNR = \frac{2,6\text{-DMN} + 2,7\text{-DMN}}{1,5\text{-DMN}}$$

$$VR_{calc}\ (d) = 0.046\ DNR + 0.89 \quad (\text{for } VR = 0.9\text{-}1.5\%)$$

Where

P	=	phenanthrene
1-MP	=	1-methylphenanthrene
2-MP	=	2-methylphenanthrene
3-MP	=	3-methylphenanthrene
9-MP	=	9-methylphenanthrene
1,5-DMN	=	1,5-dimethylnaphthalene
2,6-DMN	=	2,6-dimethylnaphthalene
2,7-DMN	=	2,7-dimethylnaphthalene

Peak areas measured from m/z 156 (dimethylnaphthalene), m/z 178 (phenanthrene) and m/z 192 (methylphenanthrene) mass fragmentograms of diaromatic and triaromatic hydrocarbon fraction isolated by thin layer chromatography.

Recalibration of the methylphanthrene index using data from a suite of Australian coals has given rise to another equation for calculated vitrinite reflectance (after Boreham *et al.*, 1988):

$$VR_{calc}\ (e) = 0.7\ MPI + 0.22 \quad (\text{for } VR < 1.7\%)$$

The methylphenanthrene distribution ratio (MPDF) and calculated vitrinite reflectance VR_{calc} (f) is derived from the following equation (after Kvalheim *et al.*, 1987):

$$MPDF = \frac{(2\text{-MP} + 3\text{-MP})}{(2\text{-MP} + 3\text{-MP} + 1\text{-MP} + 9\text{-MP})}$$

$$VR_{calc}\ (f) = -0.166 + 2.242\ MPDF$$

FIGURES 1-3

GAS CHROMATOGRAMS OF SATURATES IN ROCK EXTRACTS,
LAKE MAURICE WEST-1

Figure 1: Sandstone, 534.14 m

Figure 2: Sandstone, 540.83 m

Figure 3: Sandstone, 576.07 m

FIGURE 1

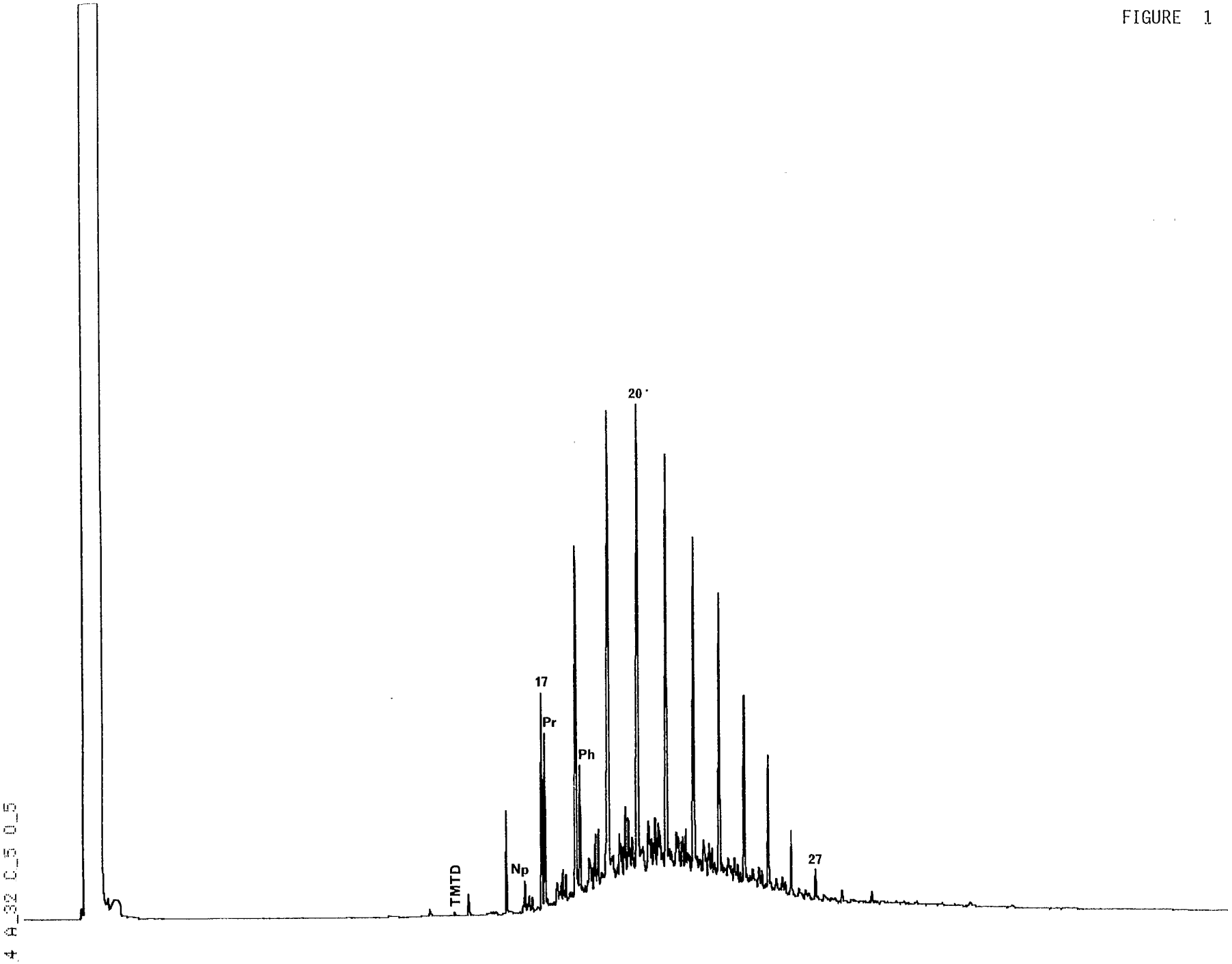

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FIGURE 2

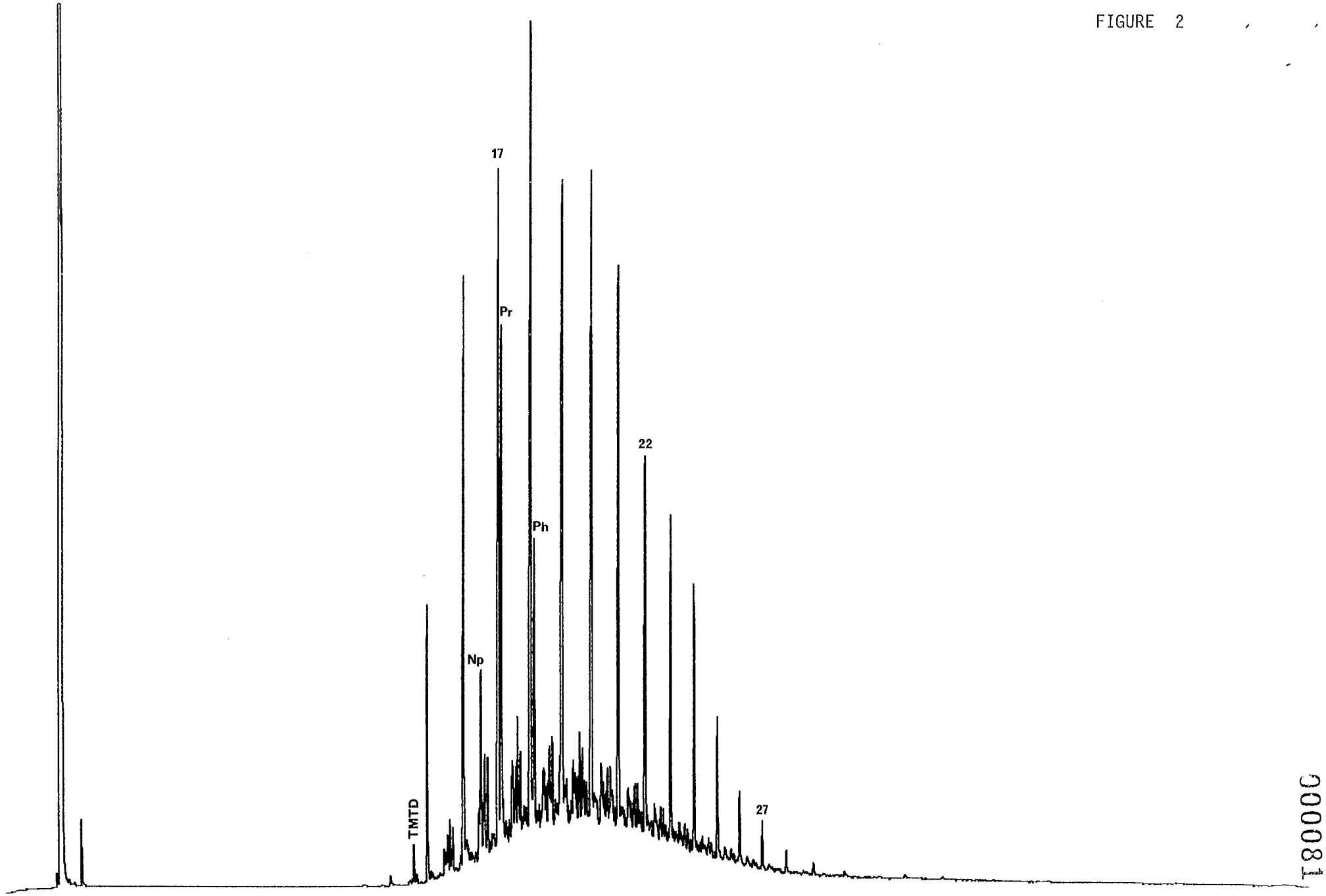
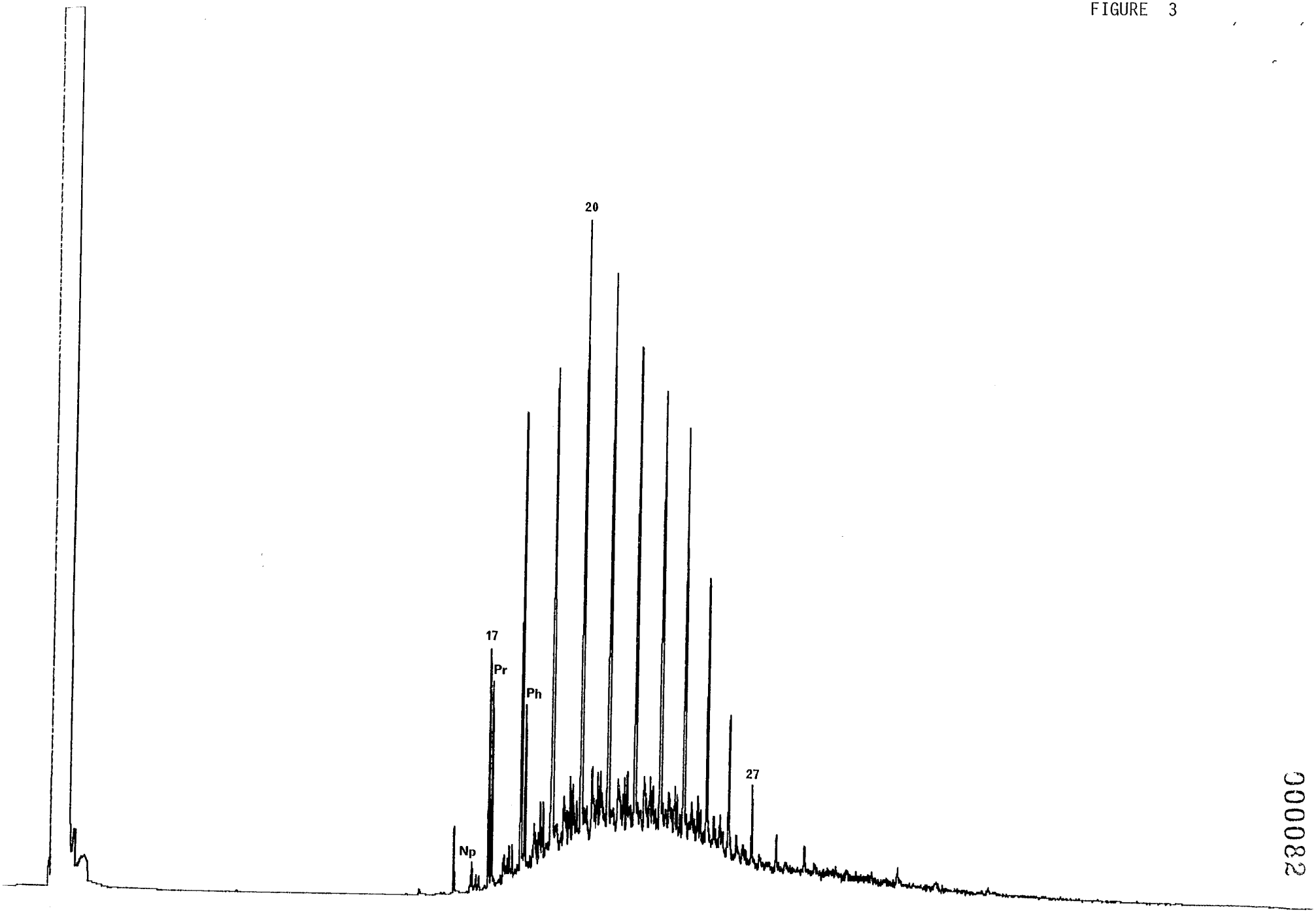


FIGURE 3



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FIGURES 4-12

MASS FRAGMENTOGRAMS OF NAPHTHENES IN ROCK EXTRACTS,
LAKE MAURICE WEST-1

TOP:	SANDSTONE, 534.14 m
MIDDLE:	SANDSTONE, 540.83 m
BOTTOM:	SANDSTONE, 576.07 m

Figure 4: m/z 183 acyclic alkanes (isoprenoids)

Figure 5: m/z 191 tricyclic and tetracyclic terpanes

Figure 6: m/z 191 triterpanes (incl. hopanes, moretanes)

Figure 7: m/z 177 demethylated triterpanes

Figure 8: m/z 205 methyl triterpanes

Figure 9: m/z 217 steranes

Figure 10: m/z 218 steranes

Figure 11: m/z 231 methyl steranes

Figure 12: m/z 259 diasteranes

KEY TO MASS FRAGMENTOGRAMS

m/z 123, 259 (diterpanes)

1	C_{19}	isopimarane
2	C_{20}	ent-beyerane
3	C_{20}	isopimarane
4	C_{20}	16β(H)-phyllocladane
5	C_{20}	ent-16β(H)-kaurane
6	C_{20}	16α(H)-phyllocladane
7	C_{20}	ent-16α(H)-kaurane

m/z 183 (acyclic isoprenoid alkanes)

15-40	numbers indicate number of carbon atoms in compound
*	irregular (head-to-head)

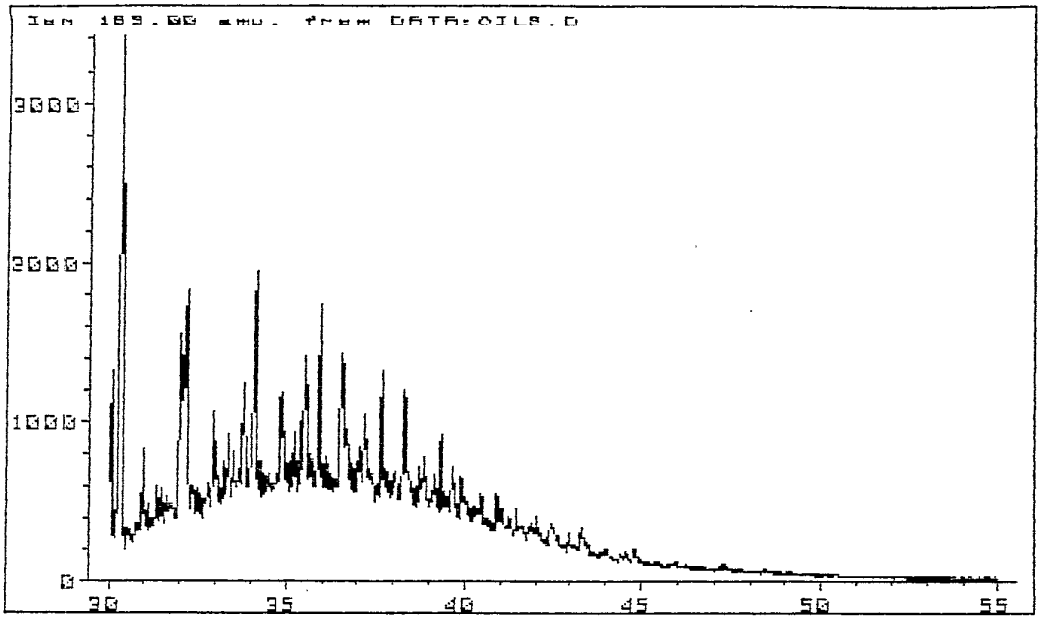
m/z 191 (terpanes)

1-6	C_{20}-C_{25}	tricyclic terpanes
7	C_{24}	tetracyclic terpane
8	C_{26}	tricyclic terpane
9	C_{27}	18α(H)-22,29,30-trisnorhopane (Ts)
10	C_{27}	17α(H)-22,29,30-trisnorhopane (Tm)
11	C_{28}	17α(H)-28,30-bisnorhopane
12	C_{29}	17α(H)-25-norhopane
13	C_{29}	17α(H)21β(H) norhopane
14	C_{30}	pentacyclic terpane
15	C_{29}	17β(H)21α(H) moretane
16	C_{30}	17α(H)21β(H) hopane
17	C_{30}	17β(H)21α(H) moretane
18-22	C_{31}-C_{35}	17α(H)21β(H) 22S (left) and 22R (right) homohopanes

m/z 217, 218, 259 (steranes, diasteranes)

1	C_{21}	sterane
2	C_{22}	sterane
3&4	C_{27}	20S and 20R diasteranes
5&8	C_{27}	5α(H)14α(H)17α(H) 20S and 20R steranes
6	C_{27}	5α(H)14β(H)17β(H) 20R sterane
7	C_{27}	5α(H)14β(H)17β(H) 20S sterane + C_{29} 20S diasterane
9	C_{29}	20R diasterane
10&13	C_{28}	5α(H)14α(H)17α(H) 20S and 20R steranes
11&12	C_{28}	5α(H)14β(H)17β(H) 20R and 20S steranes
14&17	C_{29}	5α(H)14α(H)17α(H) 20S and 20R steranes
15&16	C_{29}	5α(H)14β(H)17β(H) 20R and 20S steranes

FIGURE 4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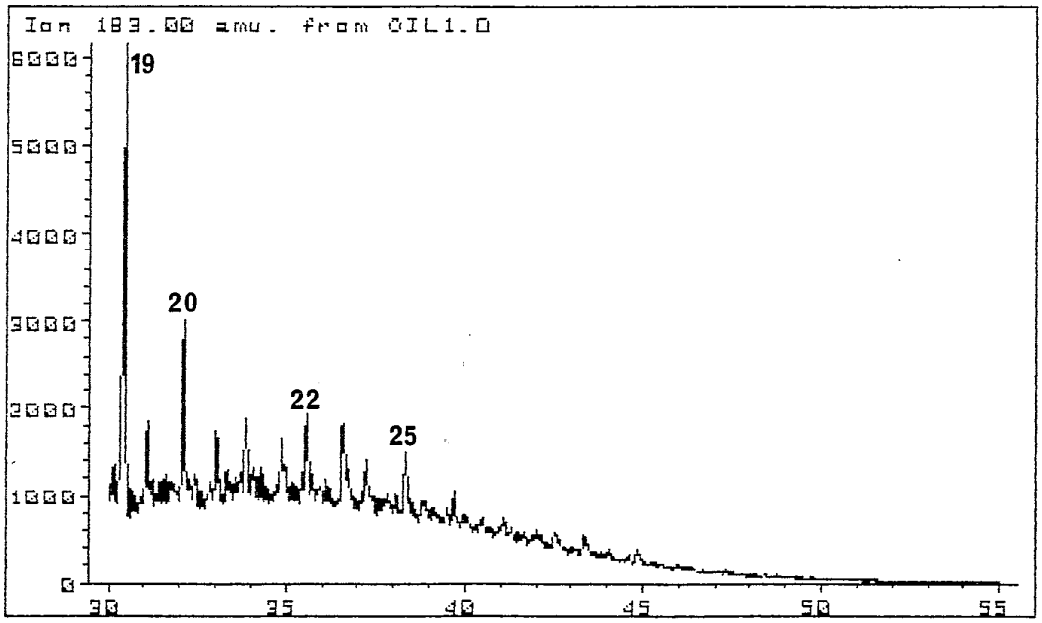
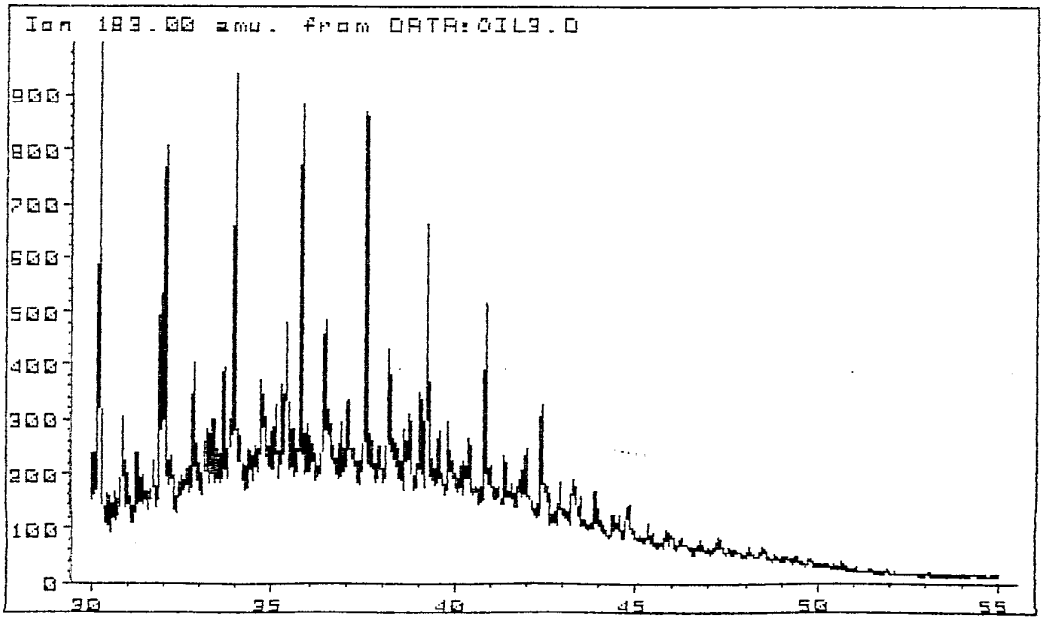
2000
1000
0
30
35
40
45
50
55


Ion 183.00 amu. from OIL1.D
6000
5000
4000
3000
2000
1000
0
19
20
22
25
30
35
40
45
50
55


Ion 183.00 amu. from DATA:OIL9.D
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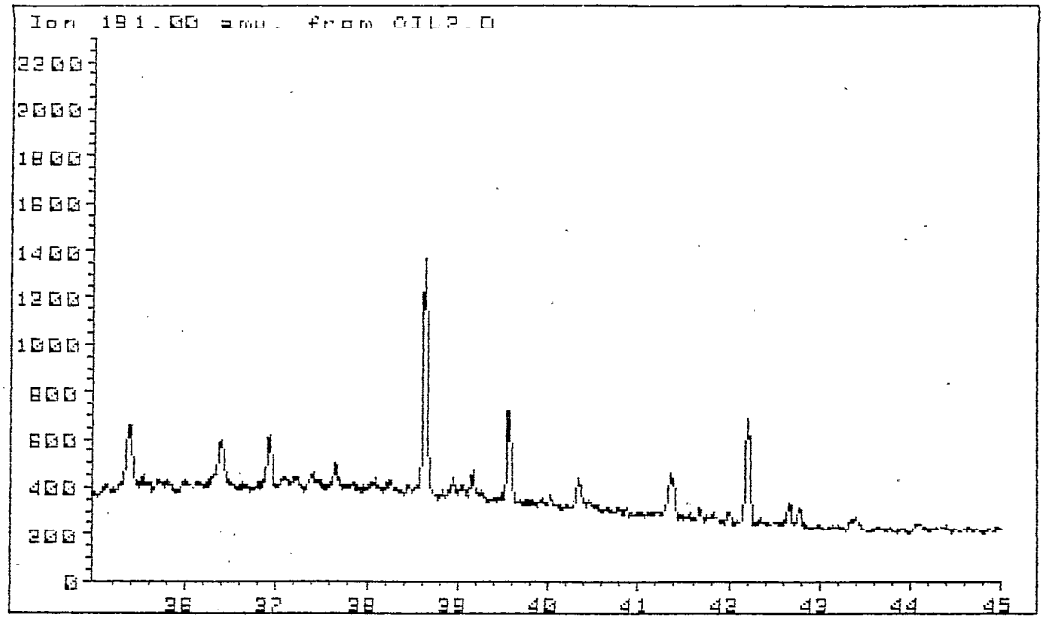
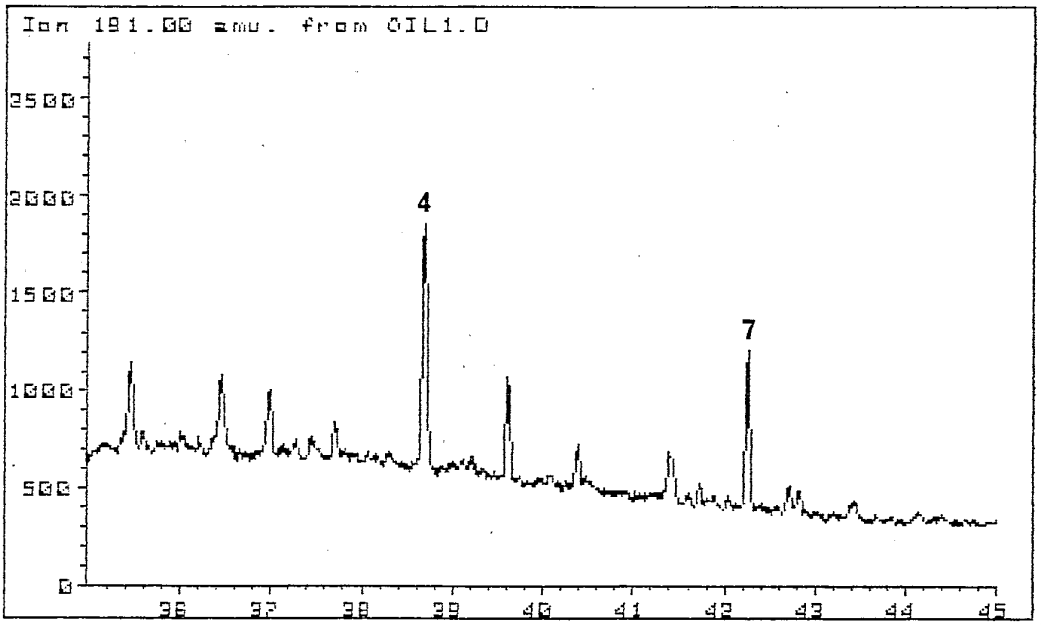
800
700
600
500
400
300
200
100
0
30
35
40
45
50
55

FIGURE 5


Ion 191.00 amu. from OIL2.D
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
36
37
38
39
40
41
42
43
44
45


Ion 191.00 amu. from OIL1.D
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2000
1500
1000
500
0
4
7
36
37
38
39
40
41
42
43
44
45

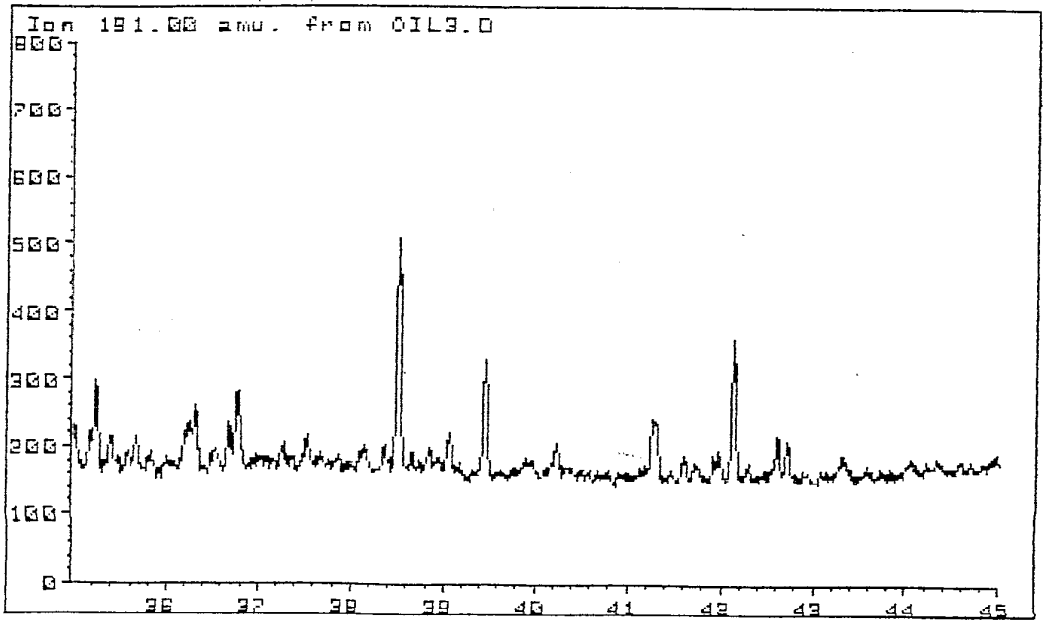
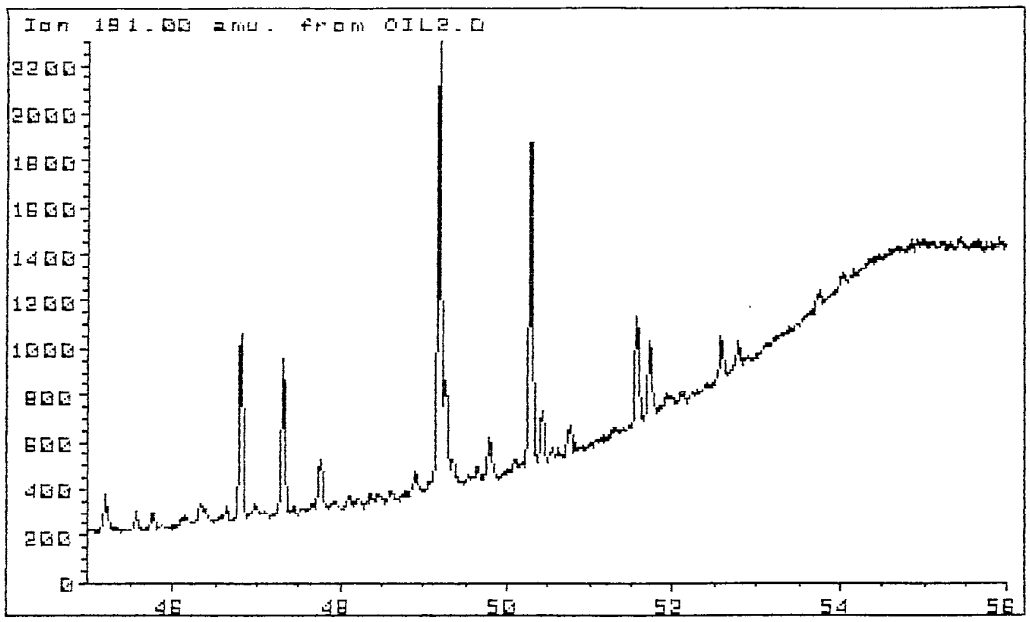

Ion 191.00 amu. from OIL3.D
800
700
600
500
400
300
200
100
0
36
37
38
39
40
41
42
43
44
45

FIGURE 6


Ion 191.00 amu. from OIL2.D
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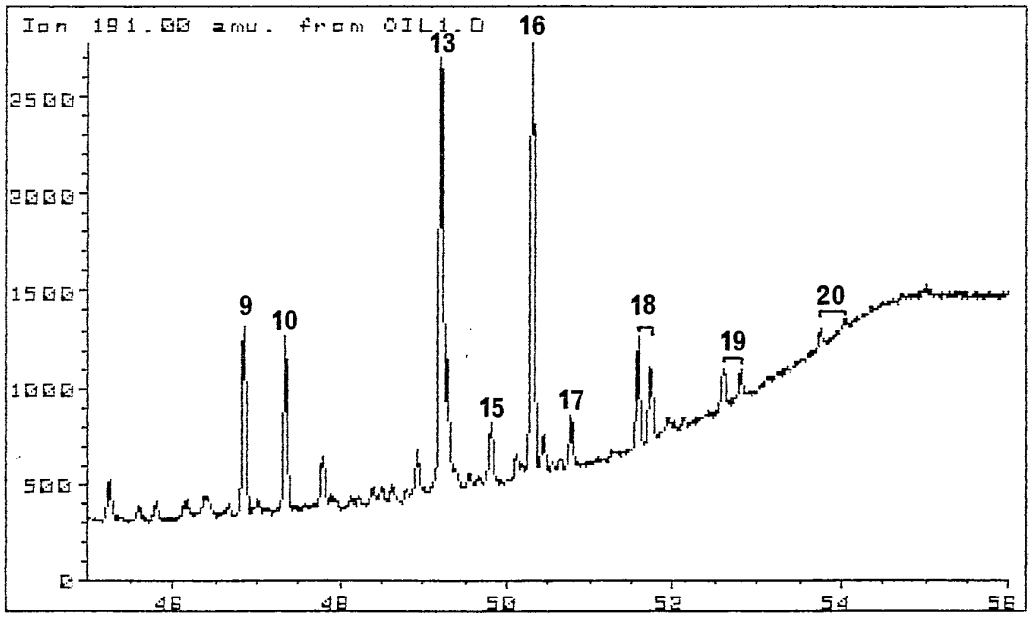
2000
1800
1600
1400
1200
1000
800
600
400
200
0
46
48
50
52
54
56


Ion 191.00 amu. from OIL1.D
13
16
9
10
15
17
18
19
20
2500
2000
1500
1000
500
0
46
48
50
52
54
56

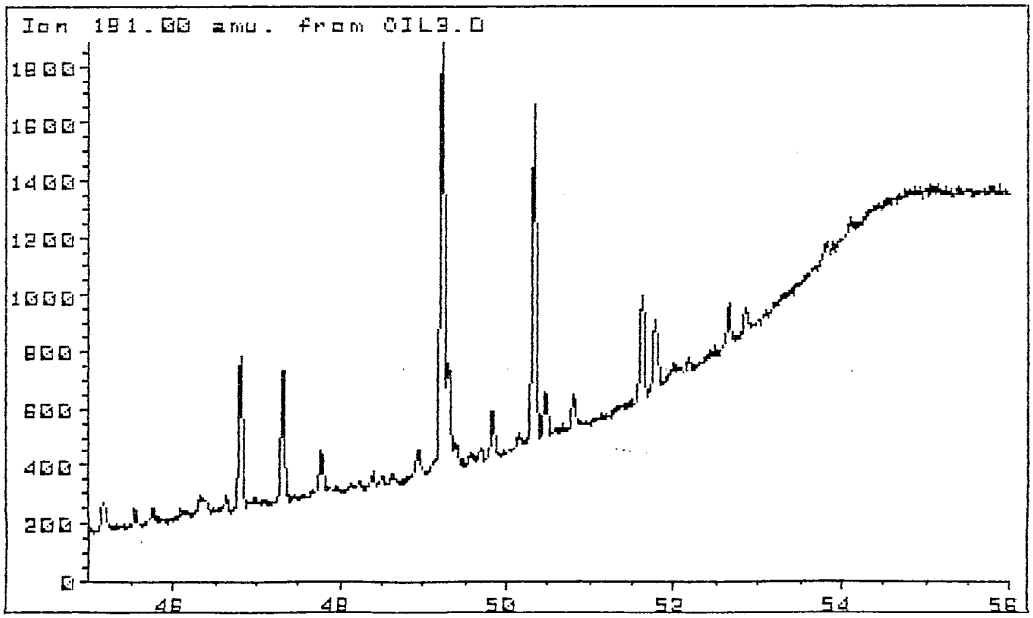
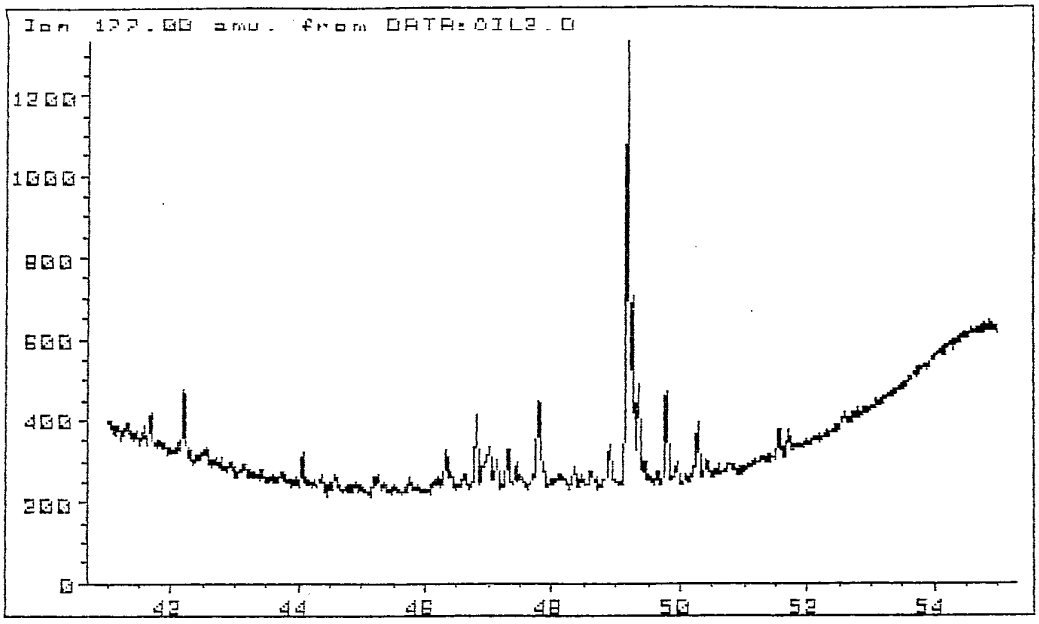
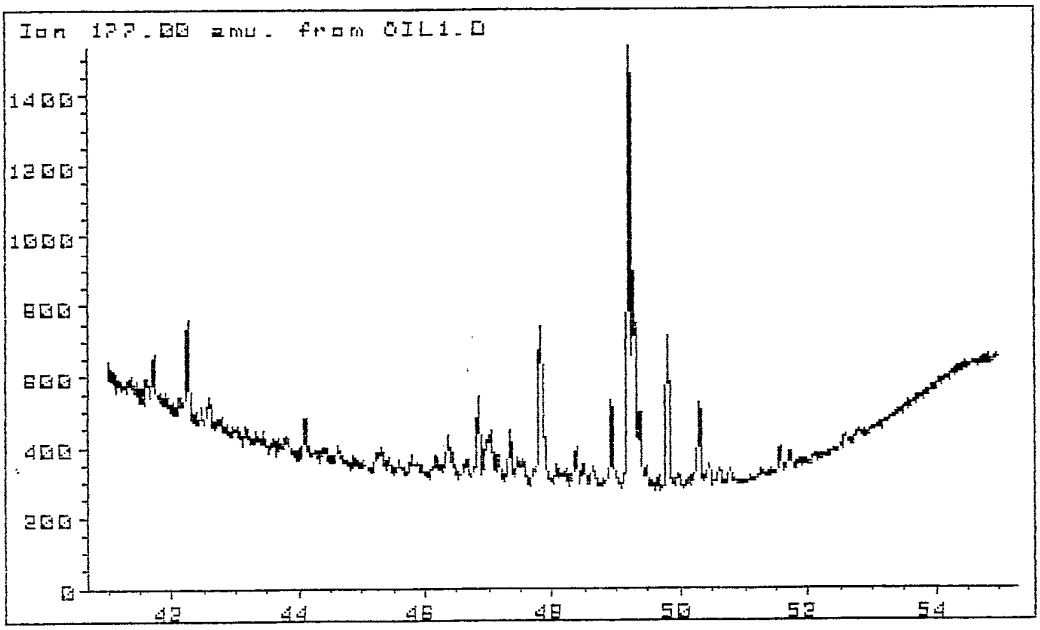

Ion 191.00 amu. from OIL3.D
1800
1600
1400
1200
1000
800
600
400
200
0
46
48
50
52
54
56

FIGURE 7

000088





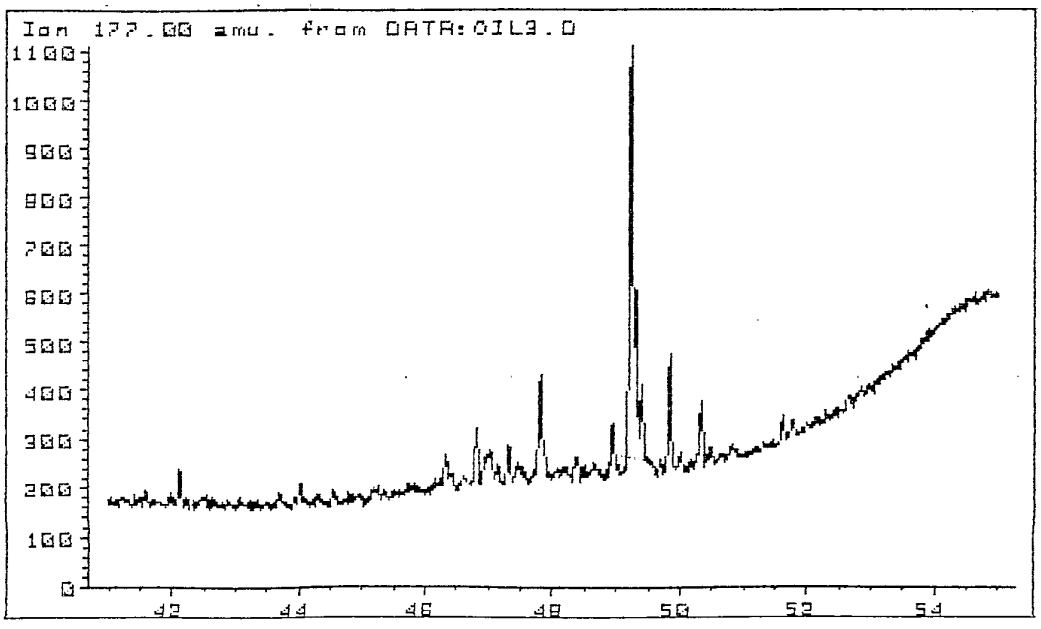
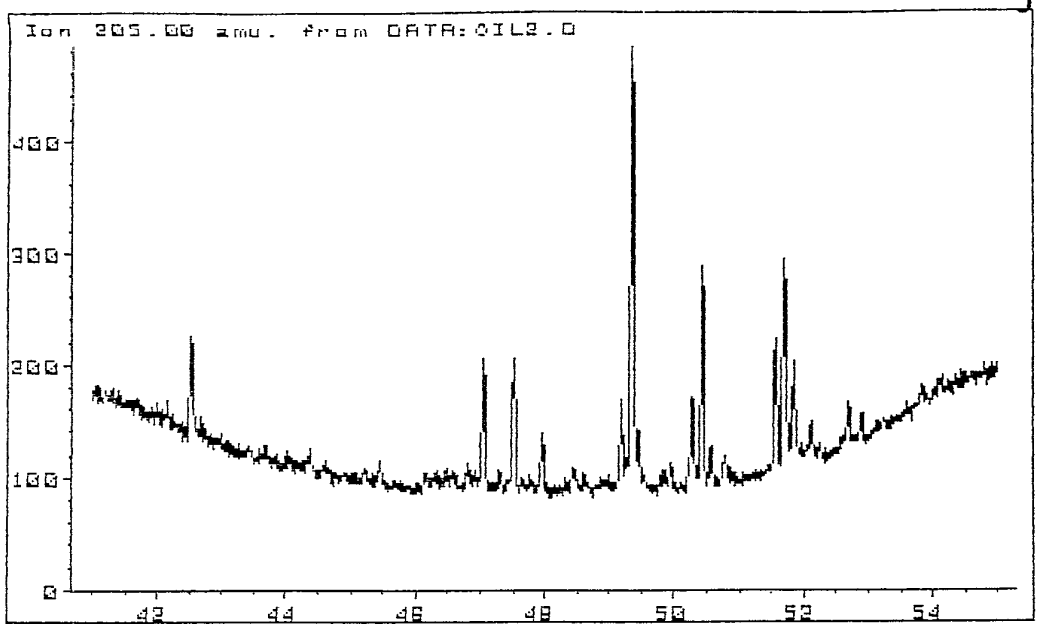
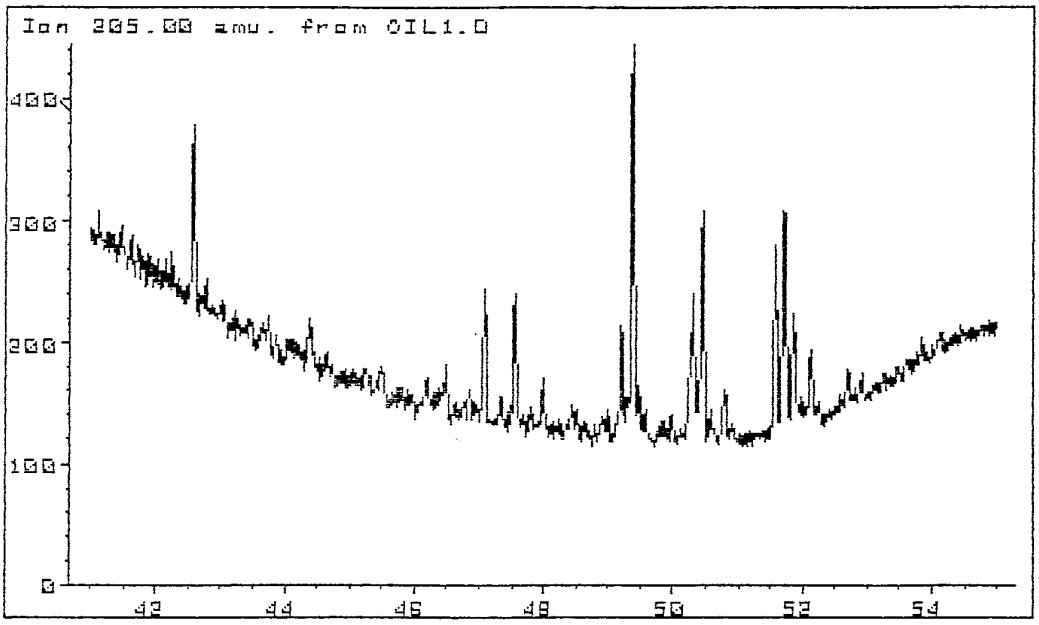


FIGURE 8


Ion 205.00 amu. from DATA:OIL2.D
400
300
200
100
0
42
44
46
48
50
52
54


Ion 205.00 amu. from OIL1.D
400
300
200
100
0
42
44
46
48
50
52
54

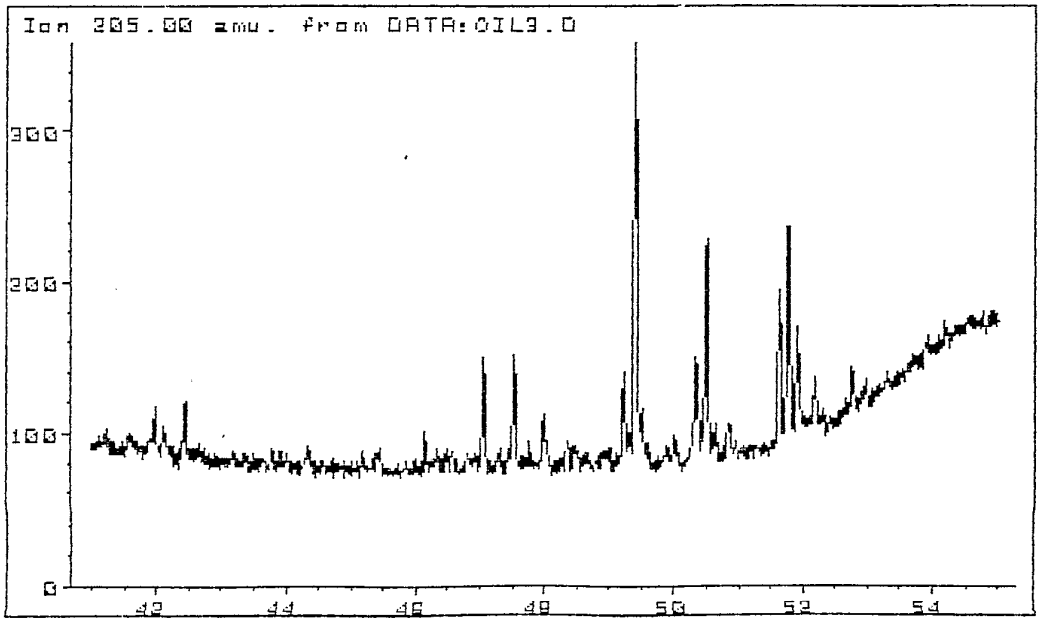
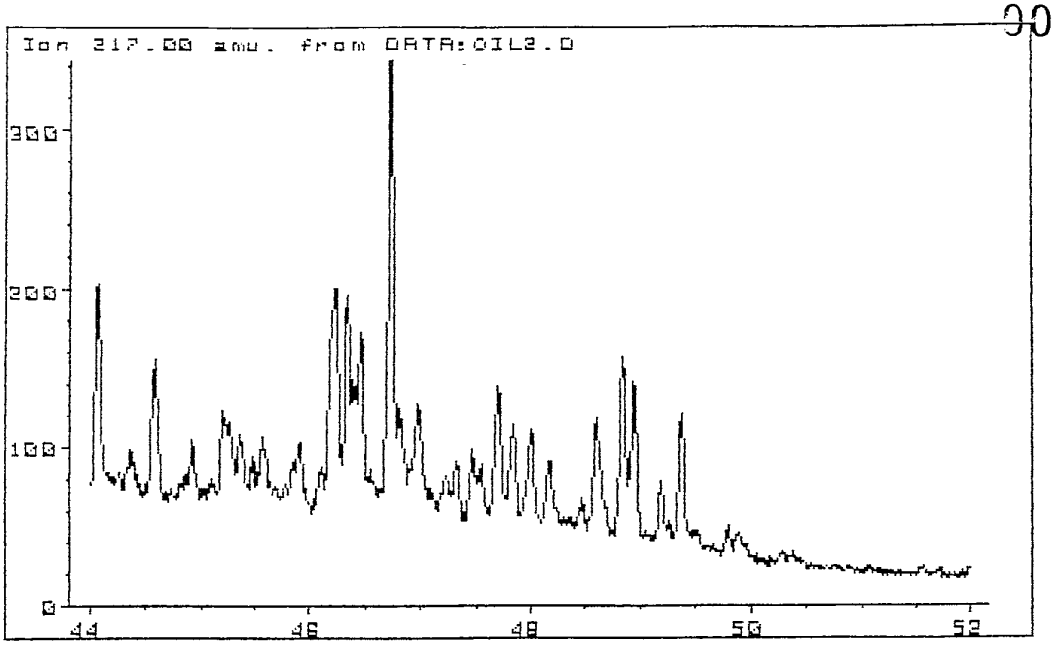
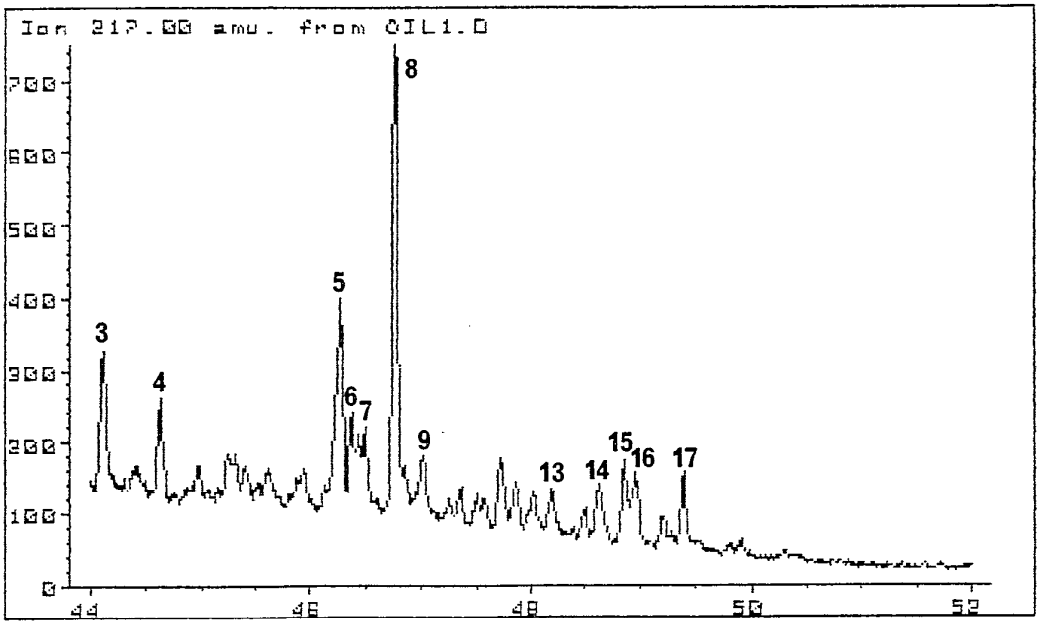

Ion 205.00 amu. from DATA:OIL3.D
300
200
100
0
42
44
46
48
50
52
54

FIGURE 9

000090





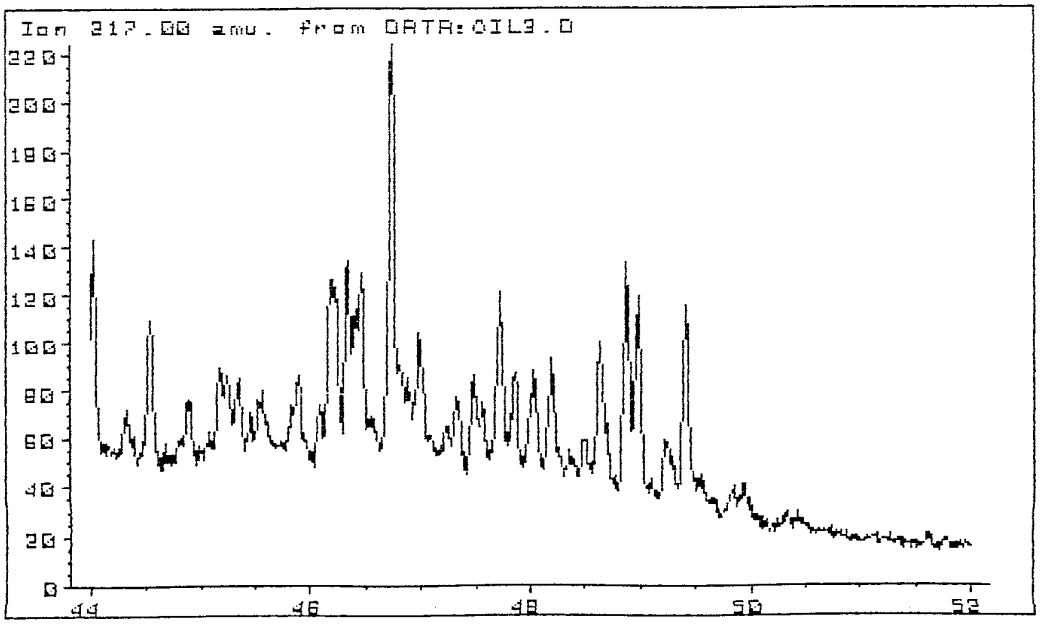
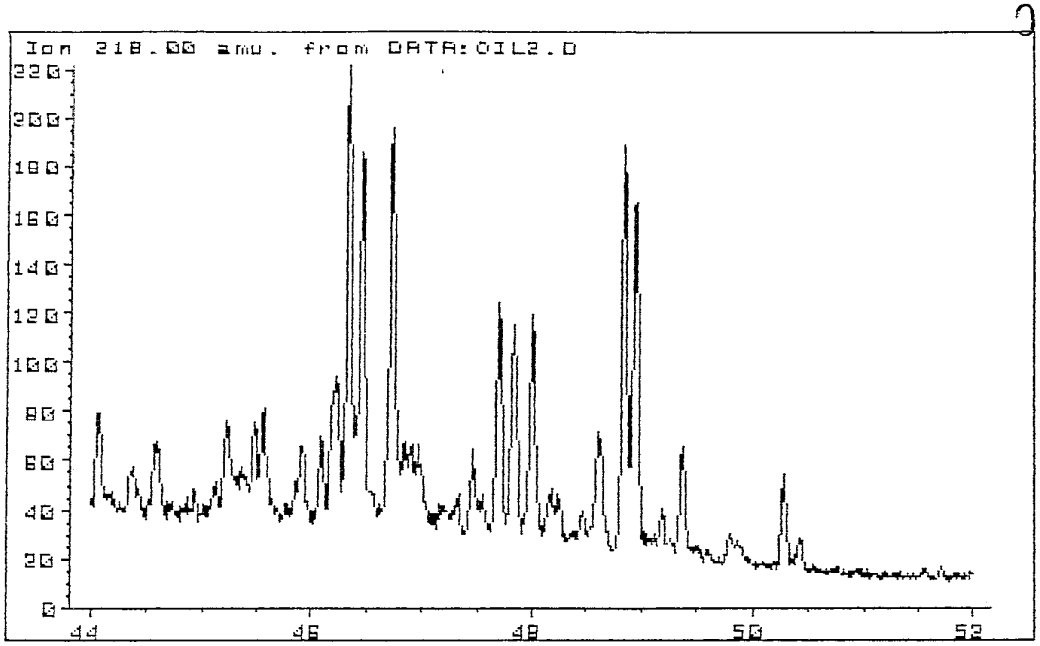
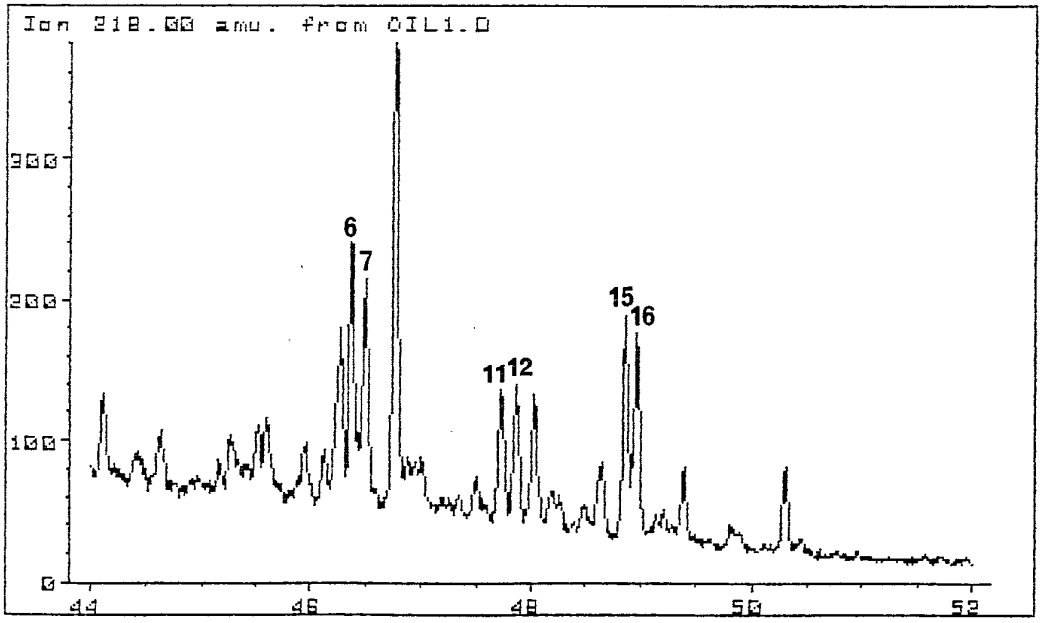


FIGURE 10


Ion 218.00 amu. from DATA:OIL2.D
220
200
180
160
140
120
100
80
60
40
20
0
44
46
48
50
52


Ion 218.00 amu. from OIL1.D
300
200
100
0
6
7
11
12
15
16
44
46
48
50
52

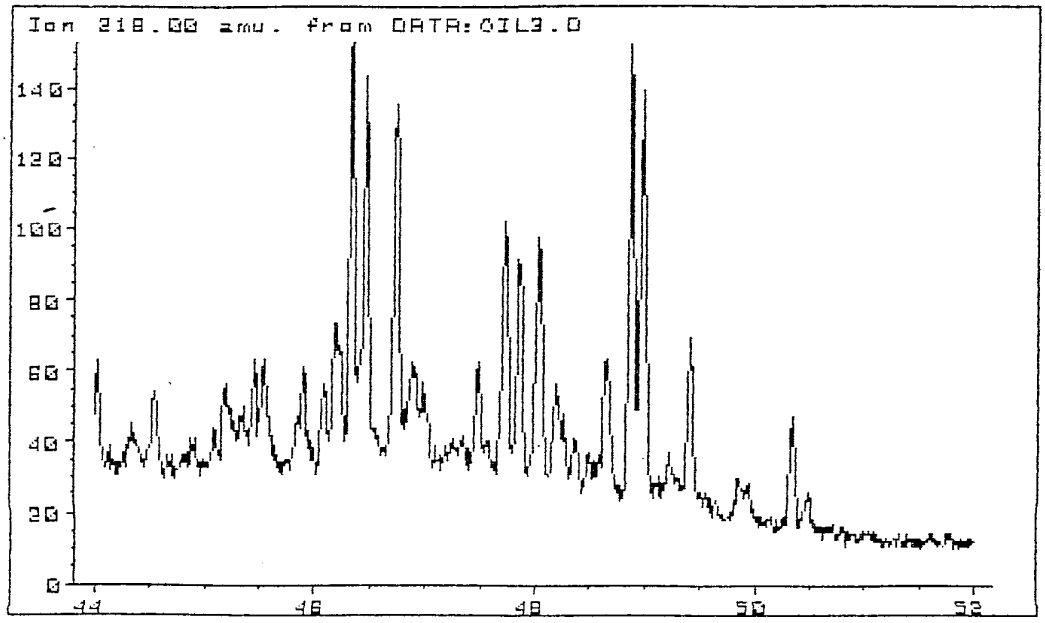
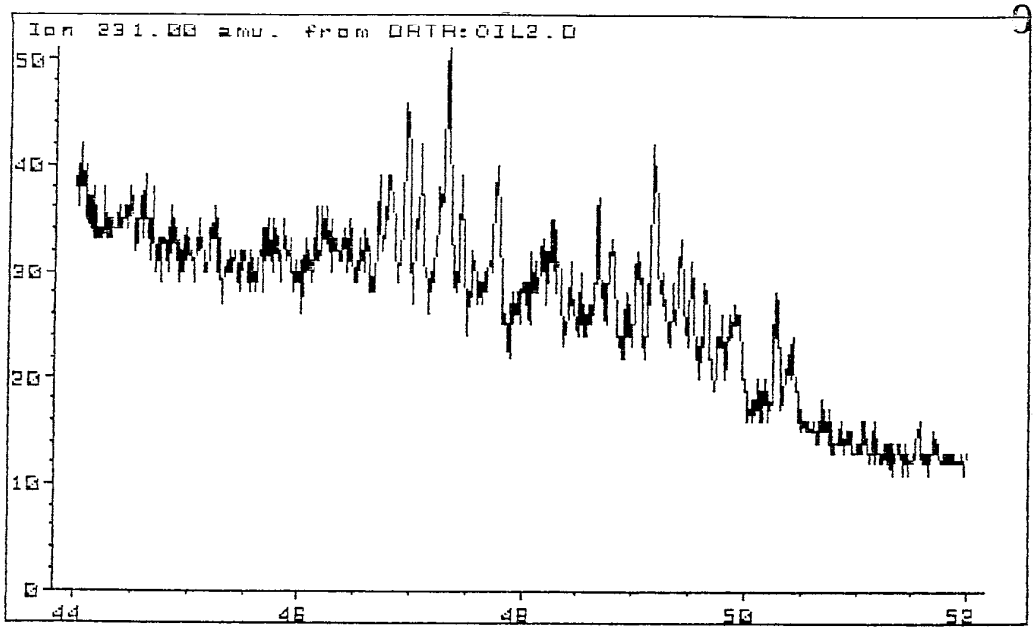
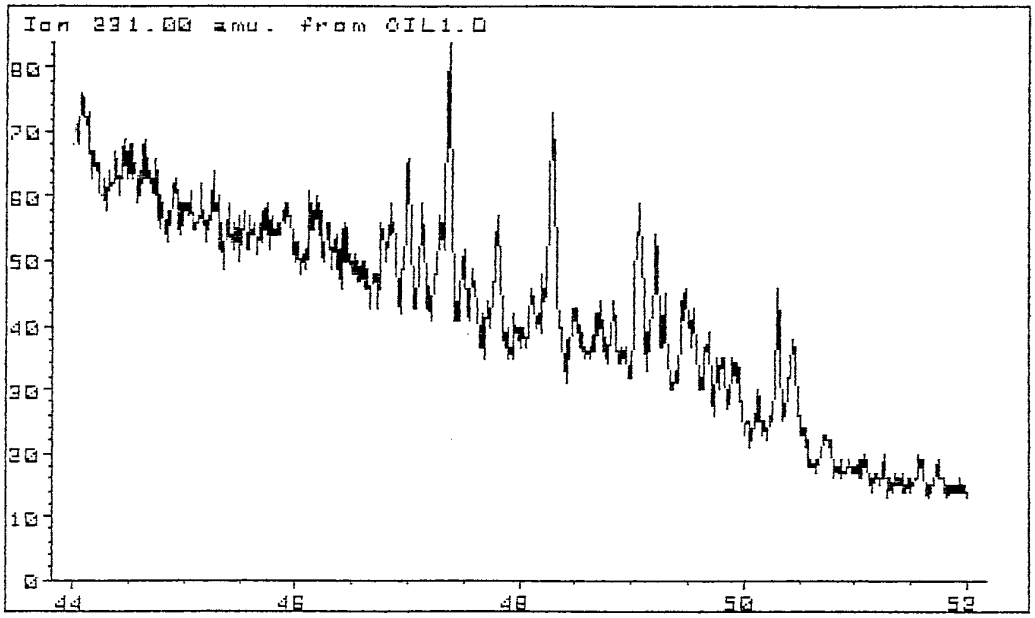

Ion 218.00 amu. from DATA:OIL3.D
140
120
100
80
60
40
20
0
44
46
48
50
52

FIGURE 11

900092





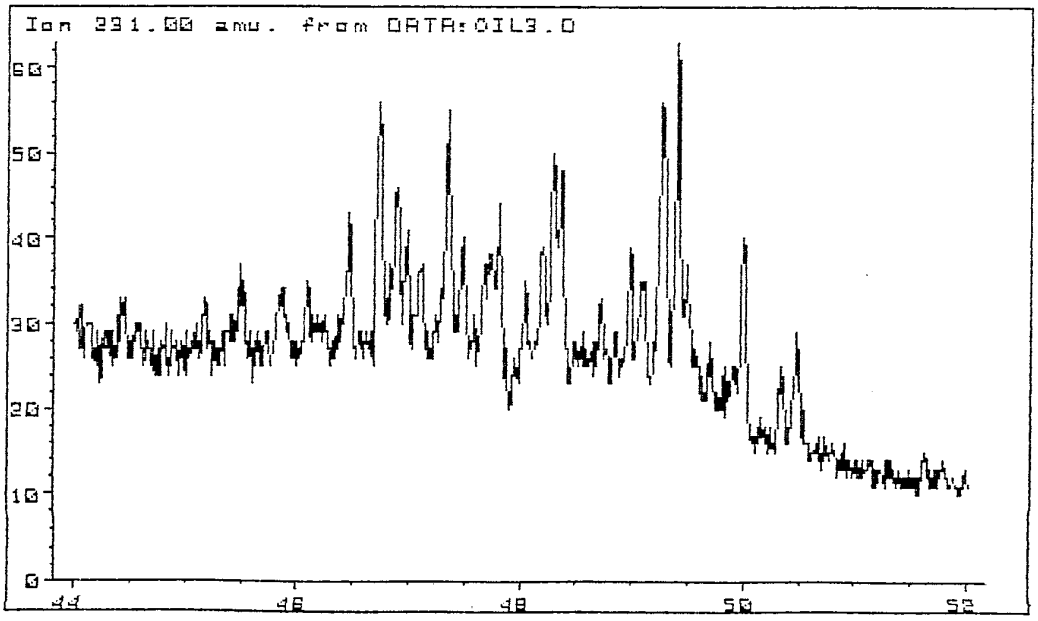
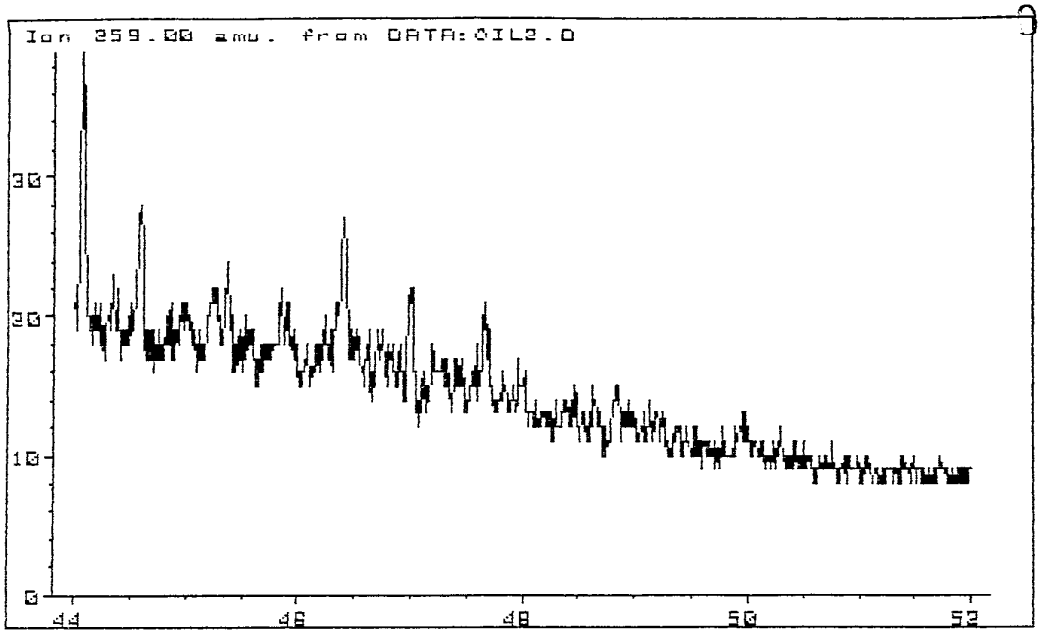
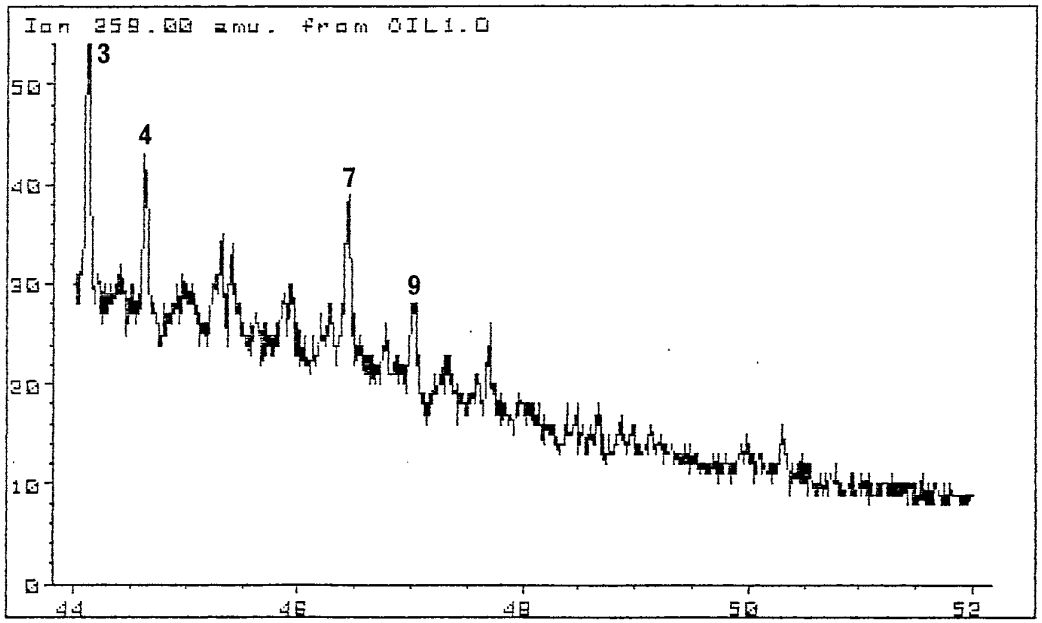
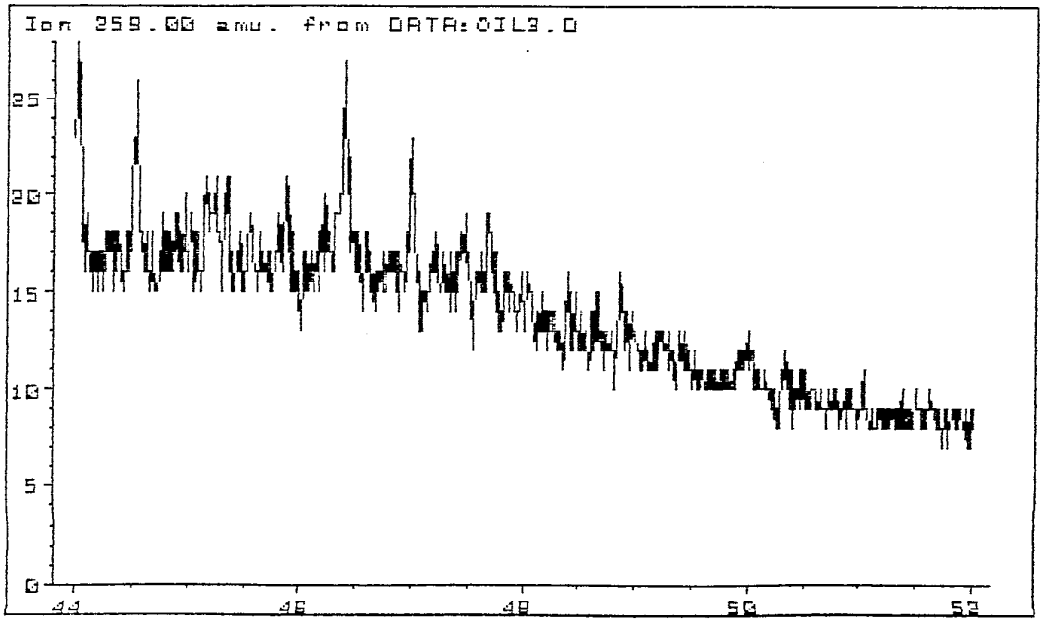


FIGURE 12


Ion 259.00 amu. from DATA:OIL2.D
30
20
10
0
44
46
48
50
52


Ion 259.00 amu. from OIL1.D
3
4
7
9
50
40
30
20
10
0
44
46
48
50
52


Ion 259.00 amu. from DATA:OIL3.D
25
20
15
10
5
0
44
46
48
50
52

FIGURES 13 AND 14

MASS FRAGMENTOGRAMS OF TRIAROMATIC HYDROCARBONS IN ROCK EXTRACTS, LAKE MAURICE WEST -1

m/z 178 phenanthrene

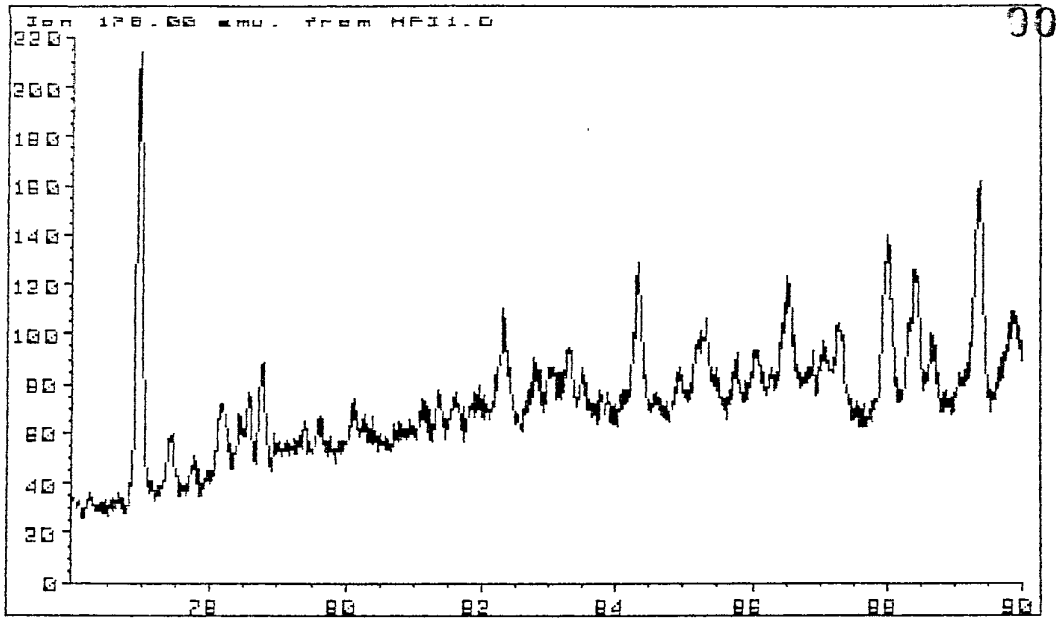
m/z 191 + 192 methylphenanthrenes

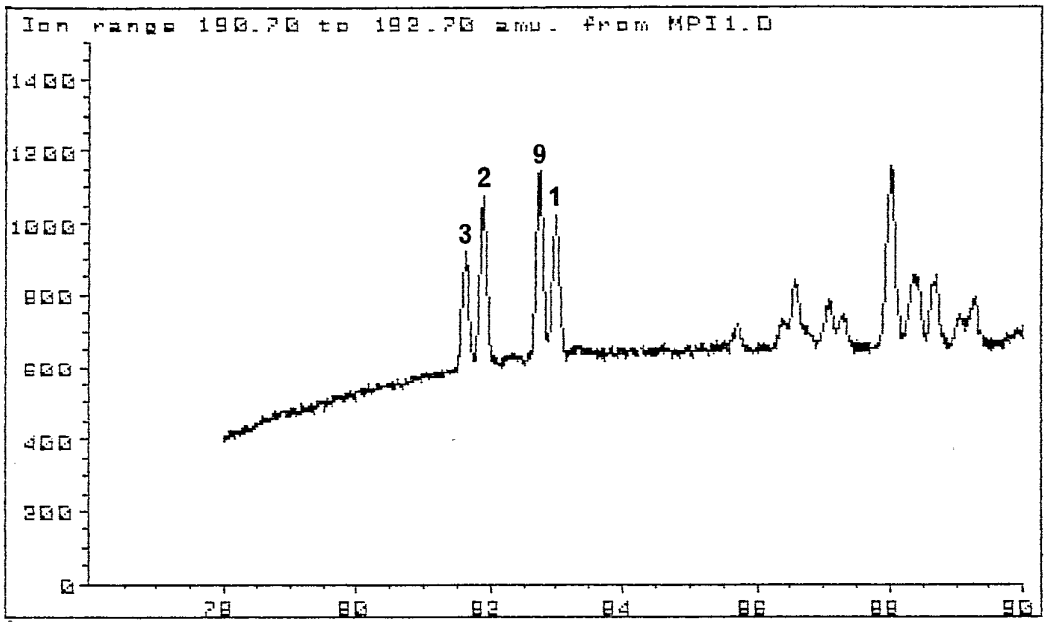
m/z 205 + 206 dimethylphenanthrenes

Figure 13: Sandstone, 534.14 m

Figure 14: Sandstone, 540.83 m

FIGURE 13


Ion 178.60 amu. from MPI1.D
220
200
180
160
140
120
100
80
60
40
20
0
78
80
82
84
86
88
90


Ion range 190.70 to 192.70 amu. from MPI1.D
14000
12000
10000
8000
6000
4000
2000
0
3
2
9
1
78
80
82
84
86
88
90

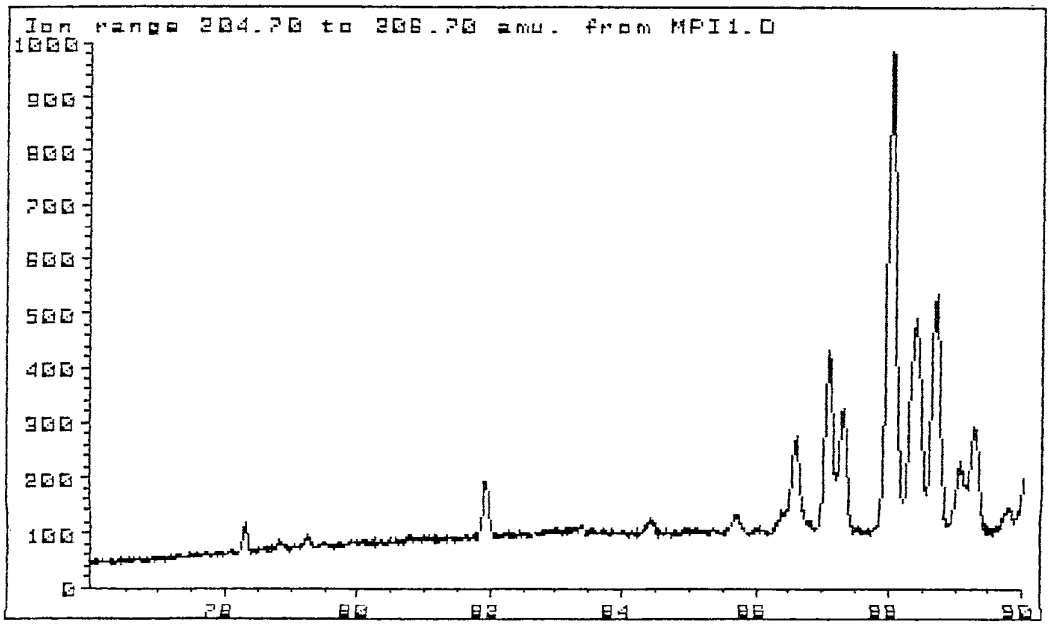
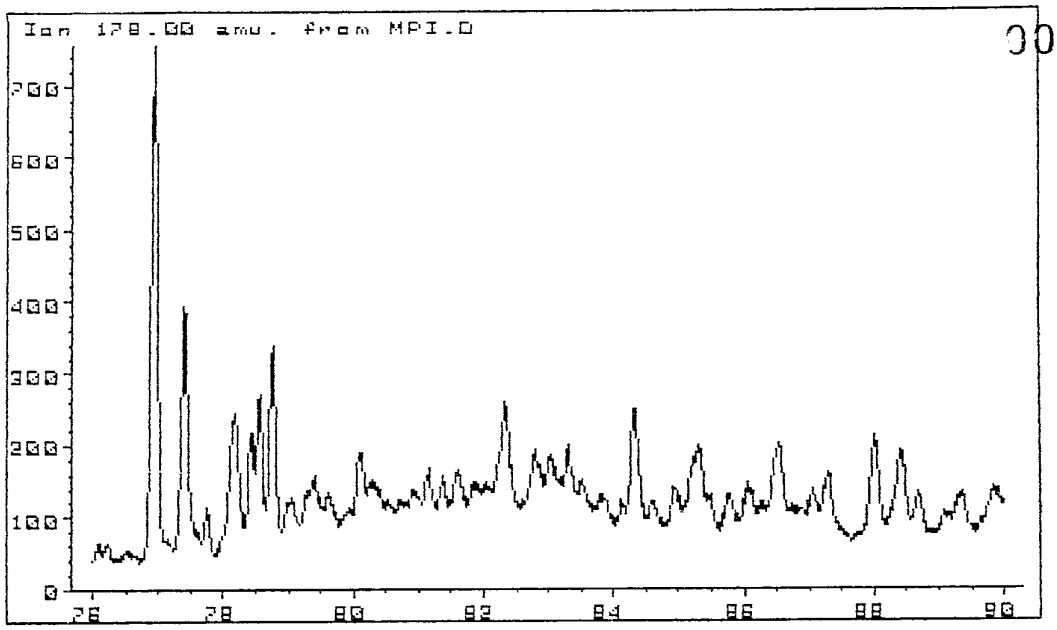
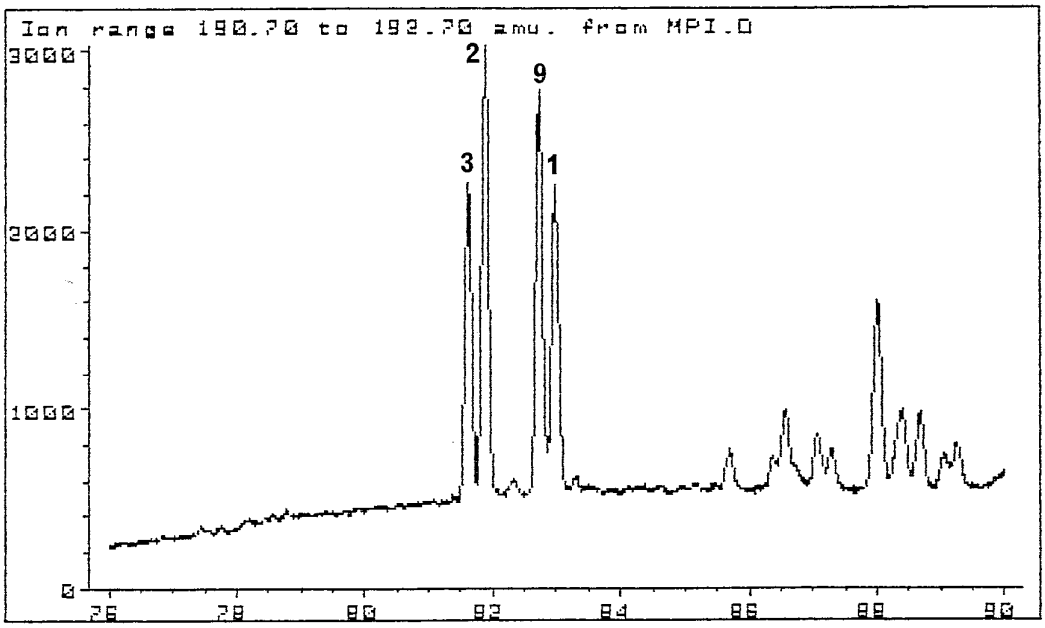
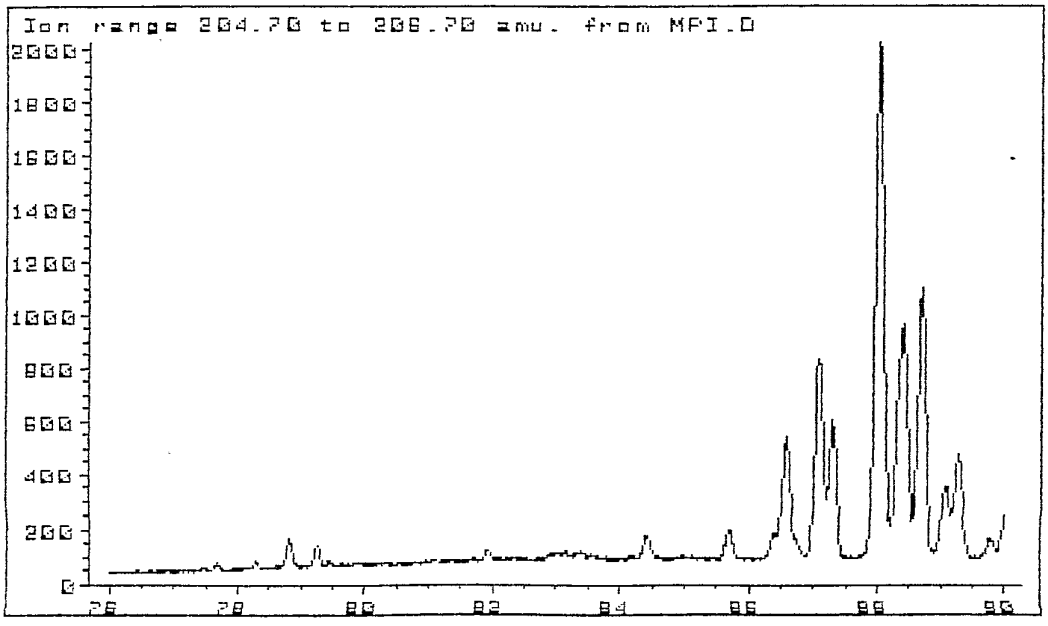

Ion range 204.70 to 206.70 amu. from MPI1.D
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
78
80
82
84
86
88
90

FIGURE 14


Ion 178.00 amu. from MPI.D
700
600
500
400
300
200
100
0
76
78
80
82
84
86
88
90


Ion range 190.70 to 192.70 amu. from MPI.D
3000
2000
1000
0
2
9
3
1
76
78
80
82
84
86
88
90


Ion range 204.70 to 206.70 amu. from MPI.D
2000
1800
1600
1400
1200
1000
800
600
400
200
0
76
78
80
82
84
86
88
90