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Oil/oil Correlations, Well 6407/1-3

CLIENT/ OPPDRAGSGIVER

Statoil

RESPONSIBLE SCIENTIST/ PROSJEKTANSVARLIG

T.L. Leith

AUTHORS/ FORFATTERE

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SUMMARY/ SAMMENDRAG

A condensate, an oil and an oil from a mud sample were analysed for correlation purposes. GC, GC-MS and $\delta^{13}C$ isotope analyses suggest that the three samples may have been generated from the same or similar types of source rocks. The condensate may have been generated from a more mature stage of the source rock.

KEY WORDS/ STIKKORD

Oil/Oil Correlation	Haltenbanken
GC-MS	$\delta^{13}C$ isotopes

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1. INTRODUCTION

Three samples from well 6407/1-3 (figure 1) were analysed for correlation purposes. Of the samples one was a condensate (B-2318), one an oil (B-2317) and the third one an oil from a mud sample (B-922).

The samples were submitted to gas chromatography (GC) and combined gas chromatography - mass spectrometry (GC-MS) in addition to $\delta^{13}C$ isotope analysis.

1.1 Molecular ratios from terpane and sterane mass chromatograms applied as maturity and source characteristic parameters.

Geochemical fossils or biological marker components are characteristic of the type of organic matter present at the time the sediments were deposited. The biological isomers of these components undergo changes due to increased maturity in particular, but also to a certain degree caused by migration and weathering processes.

1.1.1 Source characteristics parameters

In the m/z 191 mass chromatograms, representing terpanes, the hopanes and moretanes are the major components in most extracts and oils. Of the hopanes the C_{27} and C_{29}-C_{35} homologs are ubiquitous, while the C_{28} bisnorhopane is believed to be typical of certain types of source rocks. The amounts of tricyclic terpanes relative to the hopanes are also believed to a certain extent to be characteristic of the source rock. This is also the case for the component, probably gammacerane, sometimes seen to coelute with the 22S isomer of the C_{31} 17α(H)-hopanes (H). In the sterane mass chromatograms, m/e 217 and m/e 218, the molecular weight distribution of the C_{27}-C_{29} regular steranes is believed to be representative of the original input of organic matter. The highest molecular weight compounds, the C_{29} steranes, represent organic matter of terrestrial origin, while the lower molecular weight analogs originate from more marine type environments.

1.1.2 Maturity parameters

The biological isomers of the hopanes, the 17β(H), 21β(H)-hopanes, undergo structural changes during the maturation process. The isomerisation

reactions are thought to produced via the 17β(H), 21α(H)-hopanes (moretanes) to the most stable 17α(H), 21β(H)-hopanes. At equilibrium 100% of the 17α(H)-hopanes are seen. The ratio αβ/αβ+βα is used to describe this reaction. In the extended hopanes ($\geq C_{31}$), the thermally stable S configurations at C-22 become increasingly more abundant as compared to the biologically preferred R configurations at increased maturity level. The equilibrium ratio is approximately 60% of the 22S configuration. Another ratio that is known to change with maturity is the Tm/Ts (Seifert et al., 1978) of the C_{27} hopanes. The maturable 18α(H)-trisnorneohopane (Tm) is reduced in intensity relative to the more stable 17α(H)-trisnorhopane (Ts), causing the Tm/Ts to decrease at increased maturity. This ratio is also believed to be source dependant, and this should be borne in mind when applying the ratio for maturity comparison. The amount of tricyclic terpanes is also to a certain extent seen to be maturity dependant.

Two isomerisation reactions taking place in the steranes are most commonly applied for maturity assignments from the m/z 217 mass chromatograms. The biologically preferred 14α(H), 17α(H)-isomers of the regular steranes is transformed to the thermally stable 14α(H), 17β(H)-steranes, the %ββ approaching 75% at equilibrium. An equilibrium concentration of 50% is seen of the stable S configuration at C-20 as opposed to the 100% of the biological 20R epimer (Mackenzie et al., 1980). The abundance of rearranged steranes increases with increasing maturity.

One of the reactions taking place at an early stage of diagenesis is the aromatisation of steranes, leading to the formation of mono- and triaromatic analogs. This process is measured as the abundance of triaromatic relative to mono-aromatic compounds (% tri/tri + mono) in the m/z 231 and 253 mass chromatograms, respectively. In addition the degree of side chain cracking, as $\%C_{20}/C_{26,\ 27}$ and $\%C_{21}/C_{28,29}$ respectively, is applied. These cracking processes are also taking place during early diagenesis, and are used for maturity assignment together with the previously mentioned ratios.

1.1.3 Migration and weathering

The effect on the geochemical fossils of migration and weathering, is less apparent than the maturity induced changes. Migration is believed to cause an increase in the relative amounts of rearranged and 14β(H),

17β(H) regular steranes (Seifert and Moldowan, 1978, 1981). Severe biological alteration leads to the formation of desmethyl-hopanes (Seifert and Moldowan, 1979).

2. EXPERIMENTAL

2.1 Chromatographic Separation

The oils were topped under reduced pressure to constant weight prior to the chromatographic separation.

The topped oils were separated into saturated fraction, aromatic fraction and non hydrocarbon fraction using a MPLC system with hexane as eluant (Radke et al., Anal. Chem., 1980). The various fractions were evaporated on a Buchi Rotavapor and transferred to glass vials and dried in stream of nitrogen.

2.2 Gas Chromatographic Analysis

The saturated hydrocarbon fractions were each diluted with n-hexane and analysed on a HP 5730A gas chromatograph, fitted with a 25m OV-101 fused silica capillary column. Hydrogen (0.7ml/min) was used as carrier gas. The total aromatic fractions were after dilution with n-hexane, analysed on a Carlo Erba Fractovap Series 2150 GC fitted with a 20mm SE-54 fused silica column.

Injections on both systems were performed in the split mode (1:20). The temperature program applied was 80°C (2 min) to 260°C at 4°C/min.

In addition the whole oils were analysed on the HP 5730 A GC, applying a temperature program of the GC oven from -50°C (2 min.) to 280°C at 4°C/min.

The data processing for all the GC analyses was performed on a VG Multichrom System.

2.3 Gas chromatography - mass spectrometry (GC-MS)

GC-MS analyses were performed on a VG Micromass 70-70H GC-MS-DS system. The Varian Series 3700 GC was fitted with a fused silica DB-1 capillary column (30m x 0.3mm i.d.). Helium (0.7kg/cm^2) was used as carrier gas and the injections were performed in split mode (1.5µl, split ratio 10:1). The GC oven was programmed from 120°C to 280°C at 4°C/min. after an initial isothermal period of 2 minutes for the saturated hydrocarbons,

while 70°C to 280°C at 5°C/min. was applied for the aromatic compounds.

The saturated hydrocarbons were analysed in multiple ion mode (MID) at a scan cycle time of approximately 2 secs. Full data collection was applied for the aromatic hydrocarbons at a scan time of 1 sec/decade. The mass spectrometer operated at 70eV electron energy and an ion source temperature of 200°C. Data acquisition was done by a VG data system.

Peak identification was performed applying knowledge of elution patterns in certain mass chromatograms. Calculation of peak ratios was done from peak height in the appropriate mass chromatograms.

3. RESULTS AND DISCUSSION

3.1 API gravity

The API gravities of the oils/condensate given in Table 1 show that sample B-922 (oil from mud) and B-2317 give similar values, while B-2318 is a much lighter condensate type sample.

3.2 GC of whole oils

All three samples seem to contain approximately the same distribution of hydrocarbons, the only difference being that the condensate (B-2318) contain hardly any n-alkanes above nC_{25} while the oil samples contain more of the high molecular weight n-alkanes. The relative distribution of n-alkanes, isoprenoids, cyclic and aromatic compounds is seen to be similar for all three samples.

3.3 Gross composition

The extraction data in Table 2 show some variations between the samples. These variations are believed mainly to be due to the experimental procedure rather than significant differences in the samples. The condensate (B-2318) seems to contain more non-hydrocarbons than the other two samples. This is probably so because the samples were topped at a too low temperature, i.e. the weights of EOM in the table are too high compared to what is left as saturated and aromatic hydrocarbons after the separation. Since the non-hydrocarbons are determined as the difference between EOM and the sum of hydrocarbons the non-hydrocarbons weights will be too high. The effect of this is most pronounced for the light condensate. The relatively low ratio of saturated to aromatic hydrocarbons and the high ARO/EOM in sample B-2317 is caused by a high weight of the aromatic fractions. Based on the similarities seen from the whole oil GC's it is believed that this high ARO value is due to some contamination of this sample.

3.4 GC-analysis of saturated hydrocarbons

A similar picture as from the whole oil GC's was seen from the saturated hydrocarbon GC's presented in figure 3. The main difference is the low abundance of high molecular weight hydrocarbons in the condensate. No

significant difference is seen in the isoprenoid/n-alkane ratios or the CPI (Table 3).

3.5 GC-analysis of aromatic hydrocarbons

In addition to the lower molecular weight naphthalene homologs showing higher relative abundance in the condensate (figure 4), the methylphenanthrene index (MPI) varies between the oils and the condensate. The higher MPI value (Table 4) for the condensate suggests higher maturity of this sample as compared to the two oils.

3.6 GC-MS analysis of saturated hydrocarbons

The three oil/condensate samples were analysed for their content of steranes and terpanes.

Only minor variations were seen in the three mass chromatograms that represent these compounds, m/z 191, 217 and 218 (Figure 5). From the molecular ratios presented in Table 5 a similar picture is seen. All the maturity ratios represent well mature hydrocarbons, and the fingerprints of the mass chromatograms suggest that the three samples probably are generated from the same or similar types of source rocks. The high relative abundance of tricyclic terpanes in sample B-2318 (DST 2) is probably due to lower absolute amounts of the hopanes (A-M), rather than a characteristic source difference.

3.7 GC-MS analysis of aromatic hydrocarbons

Mass chromatograms representing aromatic hydrocarbons are presented in Figure 6. The total ion chromatograms (TIC) resemble the ordinary gas chromatograms, and they show mainly alkylated naphthalene and phenanthrene homologs. Sample B-2318 (DST 2) seems to contain relatively less of the higher phenanthrene homologs as compared to the naphthalenes. But apart from this it is difficult to draw any firm conclusions from these complex chromatograms. The traces that represent the alkylated benzenes (m/z 92 and 106) show samples B-922 and B-2317 to be very similar, while B-2318 is seen to contain less of the higher molecular weight compounds. The distribution in the lower molecular weight range is, however, similar for all three samples. No significant variations are seen in any of the naphthalene, phenanthrene or dibenzothiophene chromatograms.

The differences seen in the aromatic sterane traces (m/z 231 and 253) suggest that sample B-2318 is slightly different to the others. The higher relative intensities of the lower molecular weight steranes in this sample, is an effect of the general molecular weight distribution in this sample. Whether this is due to higher maturity when this oil was generated or is a fractionation effect during migration is difficult to say.

3.8 $\delta^{13}C$ isotope analysis

Saturated and aromatic hydrocarbon fractions in addition to aliquots of the whole oils were analysed for their carbon isotope distributions. The results given in Table 6 suggest that the three samples are very similar, and probably originate from the same or similar types of source rock.

4. CONCLUSION

From the analyses of these three oil samples we conclude that two of the samples are nearly identical, while the third sample (B-2318) shows a higher relative abundance of the lower molecular weight range compounds. The overall distributions in all three samples suggest they are all very similar, and originate from similar source rocks. The condensate seems to be of higher maturity than the two oils, and may thus have been generated from a more mature stage of the same rock as the one that have sourced the oils.

5. REFERENCES

MACKENZIE, A.S., PATIENCE, R.L., MAXWELL, J.R., VANDENBROUCKE, M. and DURAND, B. Geochim.Cosmochim.Acta, 44 (1980) 1709-1721.

RADKE, M., WILLSCH, H. and WELTE, D.H. Anal.Chem., 52 (1980) 406-411.

SEIFERT, W.K. and MOLDOWAN, J.M. Geochim.Cosmochim.Acta, 42 (1978) 77-95.

SEIFERT, W.K. and MOLDOWAN, J.M. Geochim.Cosmochim.Acta, 43 (1979) 111-126.

SEIFERT, W.K. and MOLDOWAN, J.M. Geochim.Cosmochim.Acta, 45 (1981) 783-794.

Table 1. API gravities for oils/condensate.

IKU no.	Sample type	API gravity
B-922	oil from mud	31.0^{o}
B-2317	oil	29.9^{o}
B-2318	condensate	47.8^{o}

T A B L E : 2a.

CONCENTRATION OF EOM AND CHROMATOGRAPHIC FRACTIONS

IKU-No	OIL 6407/1-3	EOM (mg)	Sat. (mg)	Aro. (mg)	HC (mg)	Non HC (mg)
B 922		110.5	53.3	15.0	68.3	42.2
B 2317		182.5	81.3	43.7	125.0	57.5
B 2318		150.7	34.9	12.8	47.7	103.0

DATE : 15 - 3 - 84.

T A B L E : 2b.

COMPOSITION IN % OF MATERIAL EXTRACTED FROM THE ROCK

IKU-No	OIL	Sat / EOM	Aro / EOM	HC / EOM	SAT / Aro	Non HC / EOM	HC / Non HC
	6407/1-3						
B 922		48.2	13.6	61.8	355.3	38.2	161.8
B 2317		44.5	23.9	68.5	186.0	31.5	217.4
B 2318		23.2	8.5	31.7	272.7	68.3	46.3

DATE : 15 - 3 - 84.

T A B L E 3.

TABULATION OF DATA FROM THE GASCHROMATOGRAMS

IKU No.	OIL 6407/1-3	PRISTANE / n-C17	PRISTANE / PHYTANE	CPI
B 922		0.6	1.2	1.0
B 2317		0.7	1.2	1.0
B 2318		0.8	1.3	1.0

DATE : 14 - 3 - 84.

Table 4. Methyl phenanthrene indices (MPI) for oils/condensate.

IKU no.	Sample type	MPI*
B-922	Oil from mud	0.65
B-2317	Oil	0.61
B-2318	Condensate	0.94

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

Table 5. Molecular ratios calculated from peak heights in terpane (m/z 191) and sterane (m/z 217) mass chromatograms.

	m/z 191					m/z 217	
JKU no.	Q/E[1]	Tm/Ts[2]	αβ/αβ+βα[3]	%22S[4]	%ββ[5]	%20S[6]	a/a+j[7]
B-922	0.17	0.6	0.96	62	80	63	0.88
B-2317	0.17	0.5	0.94	60	78	60	0.85
B-2318	0.28	0.5	0.94	62	78	58	0.88

1) Relative abundance of tricyclic terpanes (Q/E in m/z 191).
2) B/A in m/z 191.
3) E/E+F in m/z 191.
4) % distribution between first and second eluting isomers of doublet J (m/z 191).
5) 2(r+s)/(q+t+2(r+s)) in m/z 217.
6) q/q+t in m/z 217.
7) Relative abundance of C_{27} rearranged steranes (a/a+j in m/z 217).

Table 6. $\delta^{13}C$ isotope data for oil/condensate.

IKU no.	Sample type	SAT	ARO	Whole oil
B-922	Oil from mud	-30.4	-29.1	-29.2
B-2317	Oil	-30.1	-29.1	-29.4
B-2318	Condensate	-30.5	-28.9	-29.2

Figure 1.

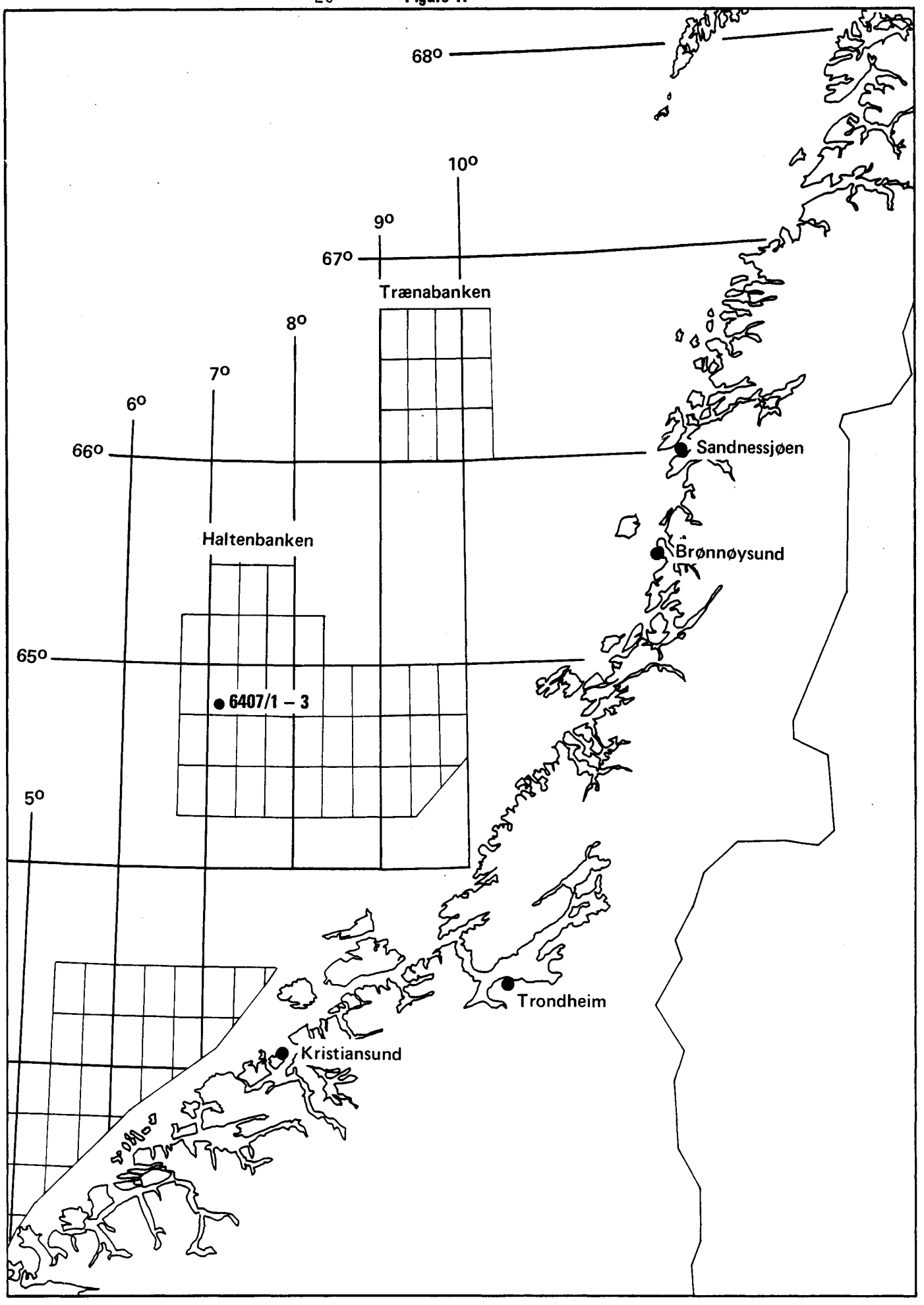
68°
10°
9°
67°
Trænabanken
8°
7°
6°
66°
Sandnessjøen
Haltenbanken
Brønnøysund
65°
6407/1 – 3
5°
Trondheim
Kristiansund

FIGURE 2

WHOLE OILS GC'S

C_5,C_6 etc. - n-alkanes
CyC_6 - cyclohexane
$MeCyC_6$ - methylcyclohexane

Created at 11:01 on 16/Mar/84
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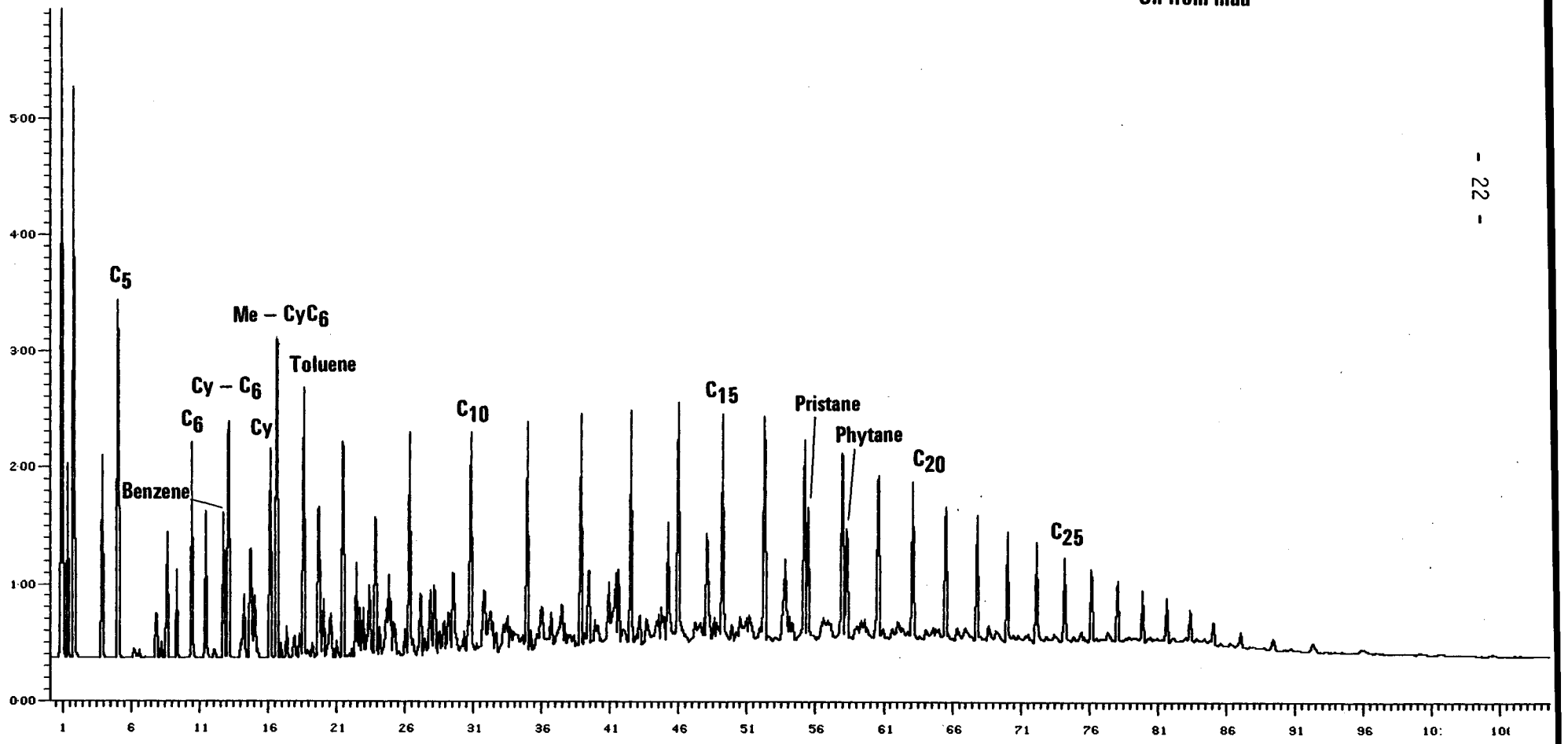
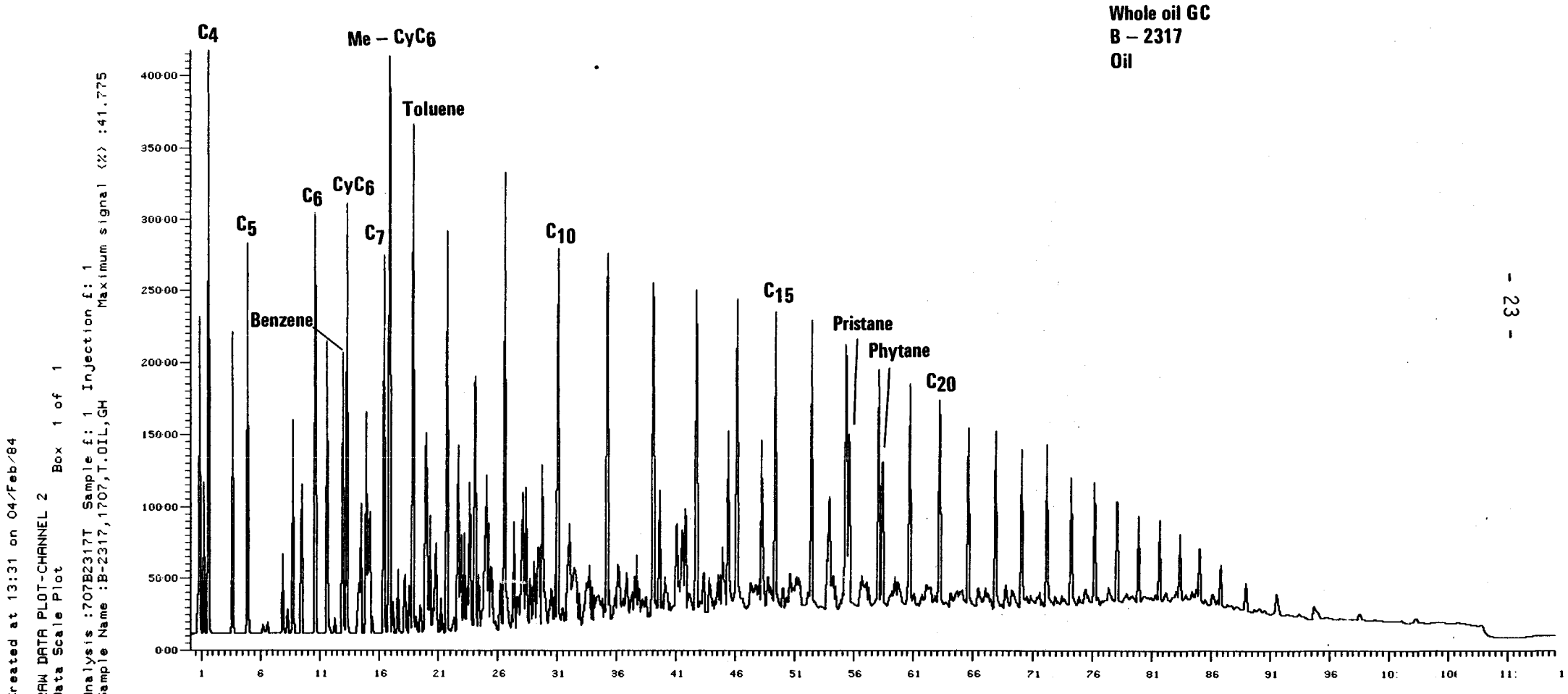
Data Scale Plot
Analysis :1703B922T Sample £: 1 Injection £: 1 Maximum signal (%) :5.943
Sample Name :B-922,TOTAL OIL,TV



Whole oil GC
B – 922
Oil from mud


Whole oil GC
B – 2317
Oil
C4
Me – CyC6
Toluene
C6
CyC6
C5
C7
C10
C15
Benzene
Pristane
Phytane
C20
400·00
350·00
300·00
250·00
200·00
150·00
100·00
50·00
0·00
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96
Created at 13:31 on 04/Feb/84
RAW DATA PLOT-CHANNEL 2
Data Scale Plot
Box 1 of 1
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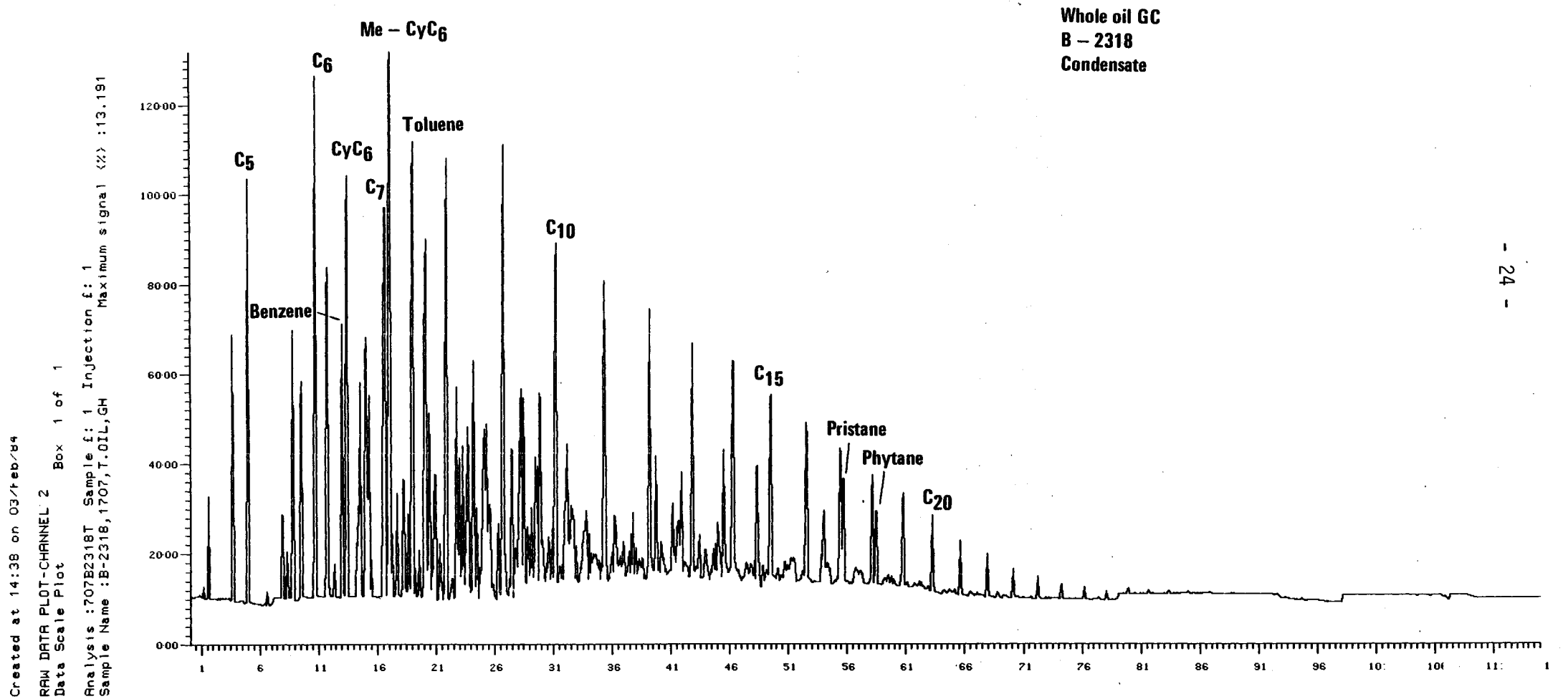
Sample Name :B-2317,1707,T.OIL,GH
Maximum signal (%) :41.775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RAW DATA PLOT-CHANNEL 2
Data Scale Plot
Box 1 of 1
Analysis :707B2318T Sample £: 1 Injection £: 1
Sample Name :B-2318,1707,T.OIL,GH
Maximum signal (%) :13.191
Whole oil GC
B – 2318
Condensate
Me – CyC6
C6
Toluene
CyC6
C5
C7
C10
Benzene
C15
Pristane
Phytane
C20
120·00
100·00
80·00
60·00
40·00
20·00
0·00
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76
81
86
91
96

FIGURE 3

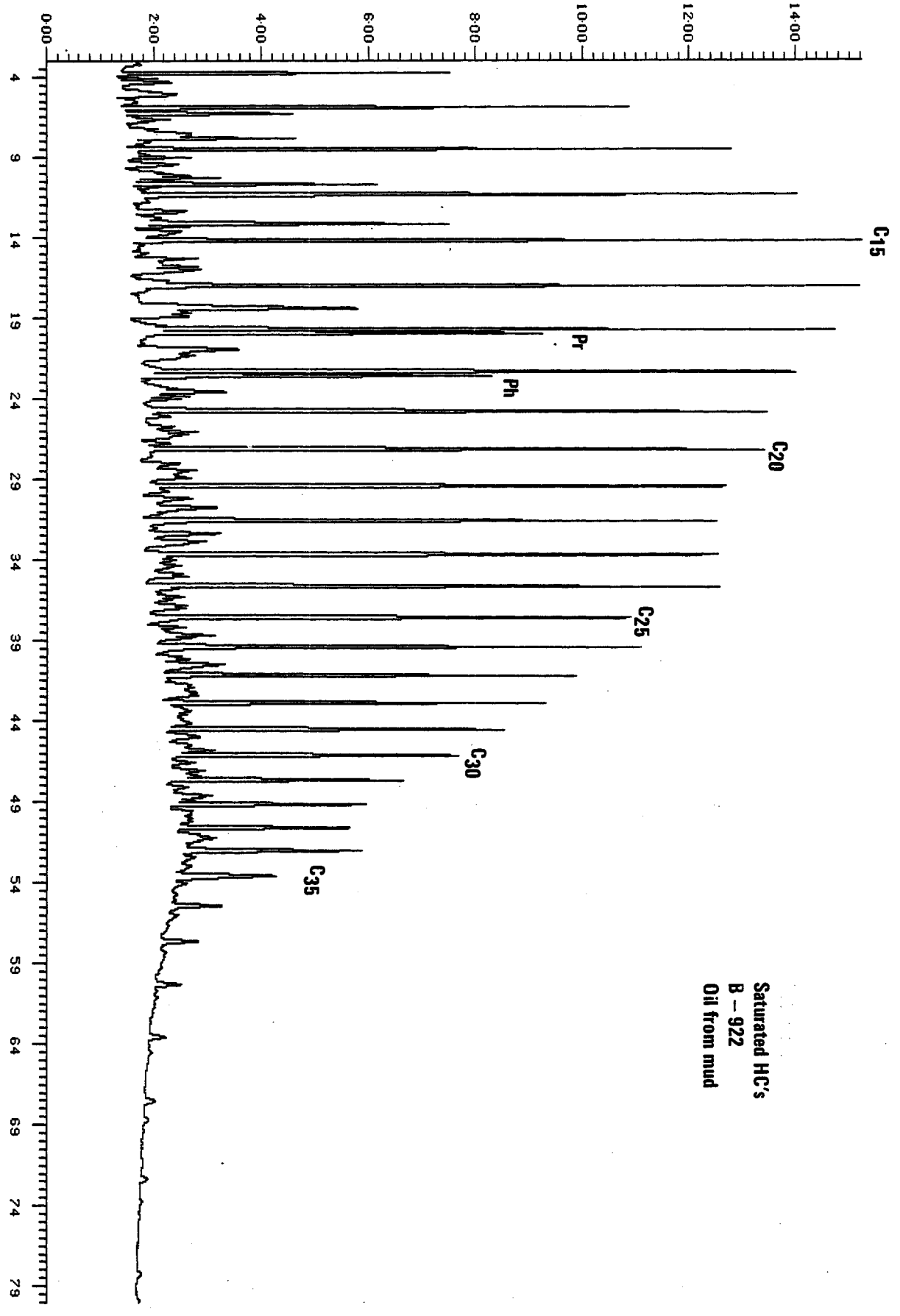
SATURATED HYDROCARBON GC'S

$C_{15,20}$ etc. - n-alkanes
Pr - pristane
Ph - phytane

Created at 15:37 on 20/Feb/84

RAW DATA PLOT-CHANNEL 3
Data Scale Plot Box 1 of 1

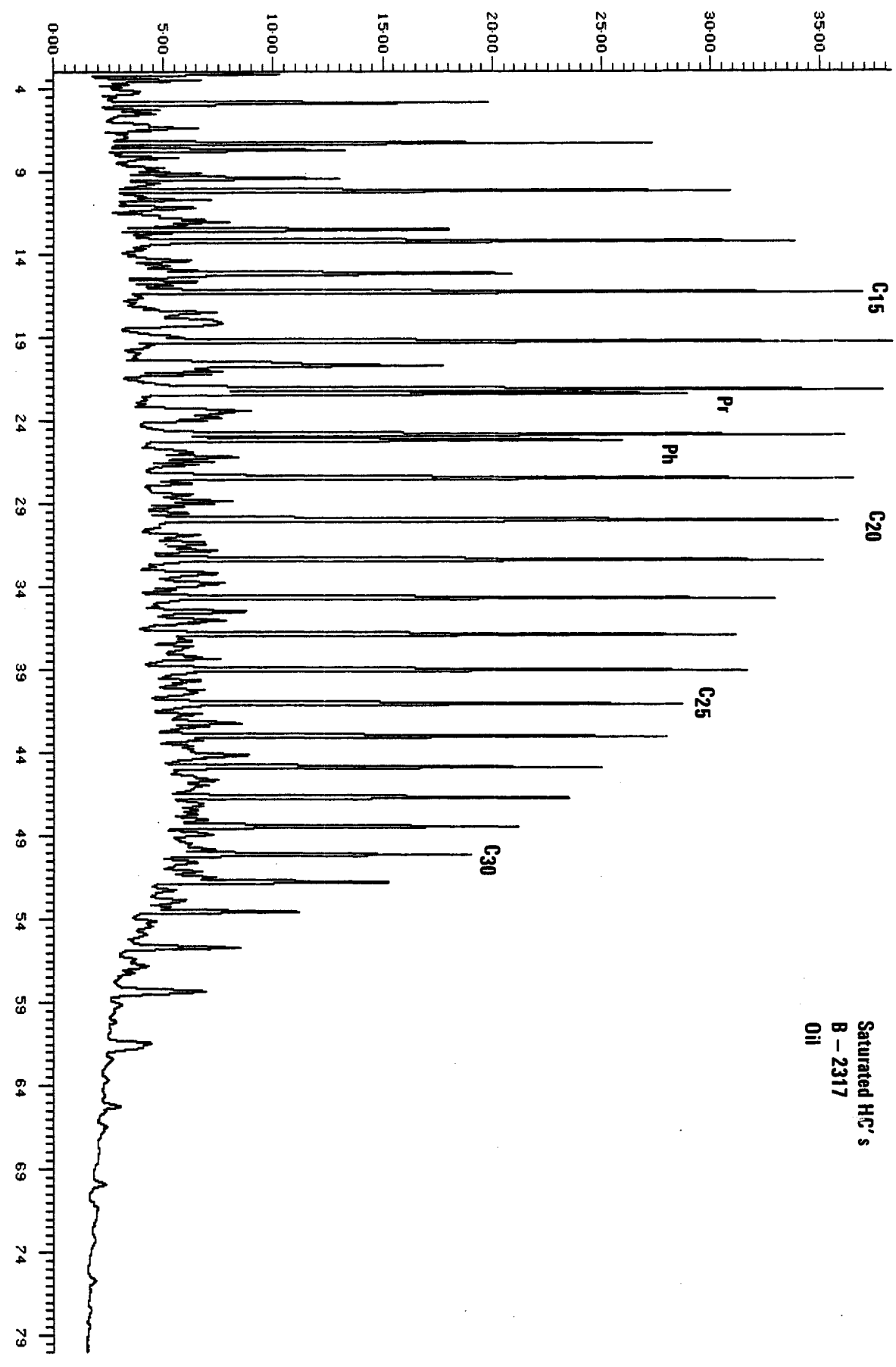
Analysis :707B922S Sample £: 1 Injection £: 1
Sample Name :B-922,SAT,1707,GH Maximum signal (%) :15.238



Created at 13:54 on 08/Feb/84

RAW DATA PLOT-CHANNEL 2
Data Scale Plot Box 1 of 1

Analysis :707B2317S Sample £: 1 Injection £: 1
Sample Name :B-2317,SAT,1707,GH Maximum signal (%) :38.253



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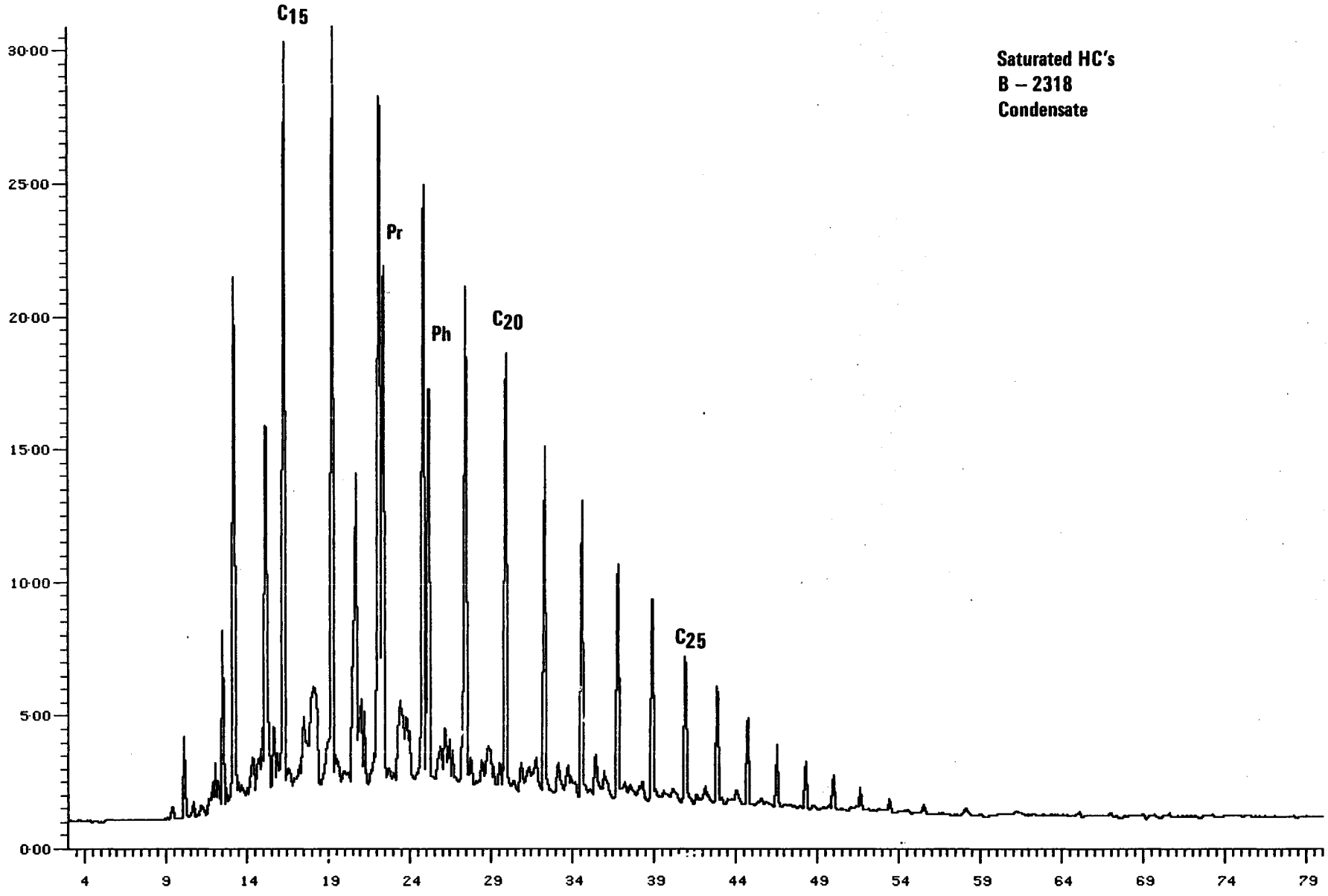
Sample Name :B-2318,SAT,1707,GH Maximum signal (%) :30.904



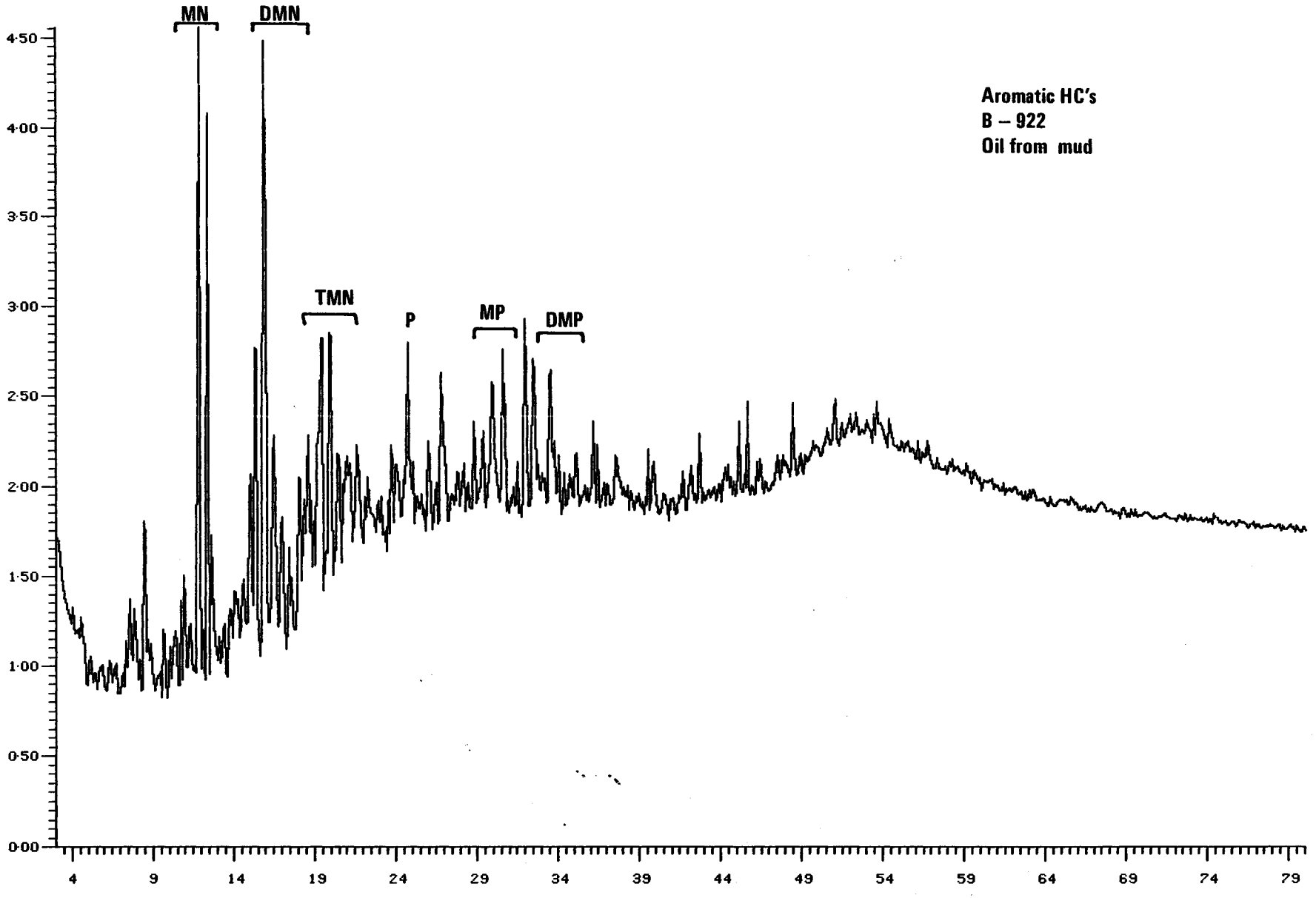
Saturated HC's
B – 2318
Condensate

FIGURE 4

AROMATIC HYDROCARBON GS'S

MN - C_1-naphthalenes
DMN - C_2-naphthalenes
TMN - C_3-naphthalenes
P - phenanthrene
MP - C_1-phenanthrenes
DMP - C_2 phenanthrenes

Created at 12:17 on 15/Feb/84
RAW DATA PLOT-CHANNEL 4 Box 1 of 1
Data Scale Plot
Analysis :707B922A Sample £: 1 Injection £: 1
Sample Name :B-922,ARO,1707,GH Maximum signal (%) :4.561

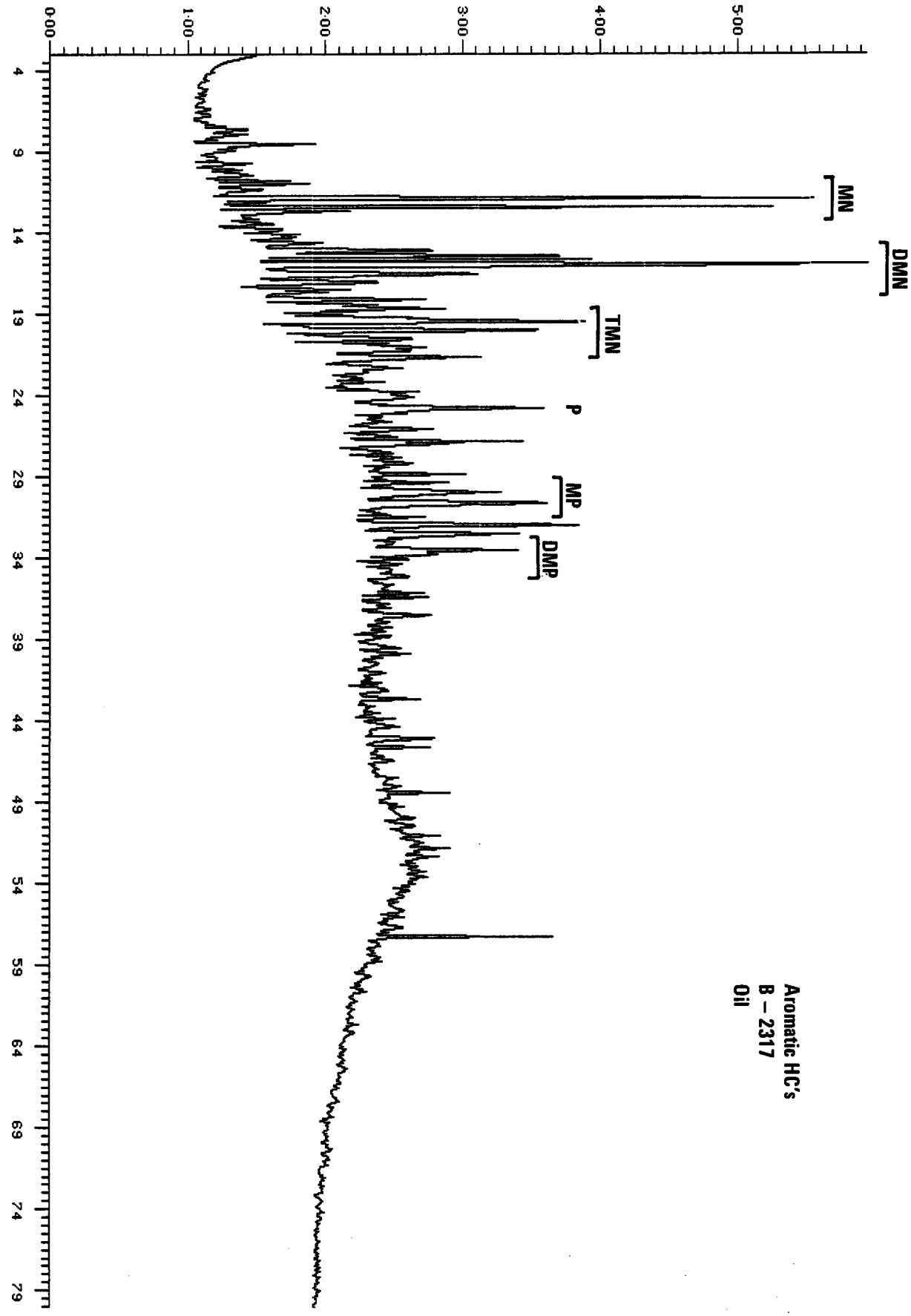


Aromatic HC's
B – 922
Oil from mud

Created at 08:45 on 15/Feb/84

RAW DATA PLOT-CHANNEL 4
Data Scale Plot Box 1 of 1

Analysis :707B2317A Sample £: 1 Injection £: 1
Sample Name :B-2317,ARO,1707,GH Maximum signal (%) :5.939



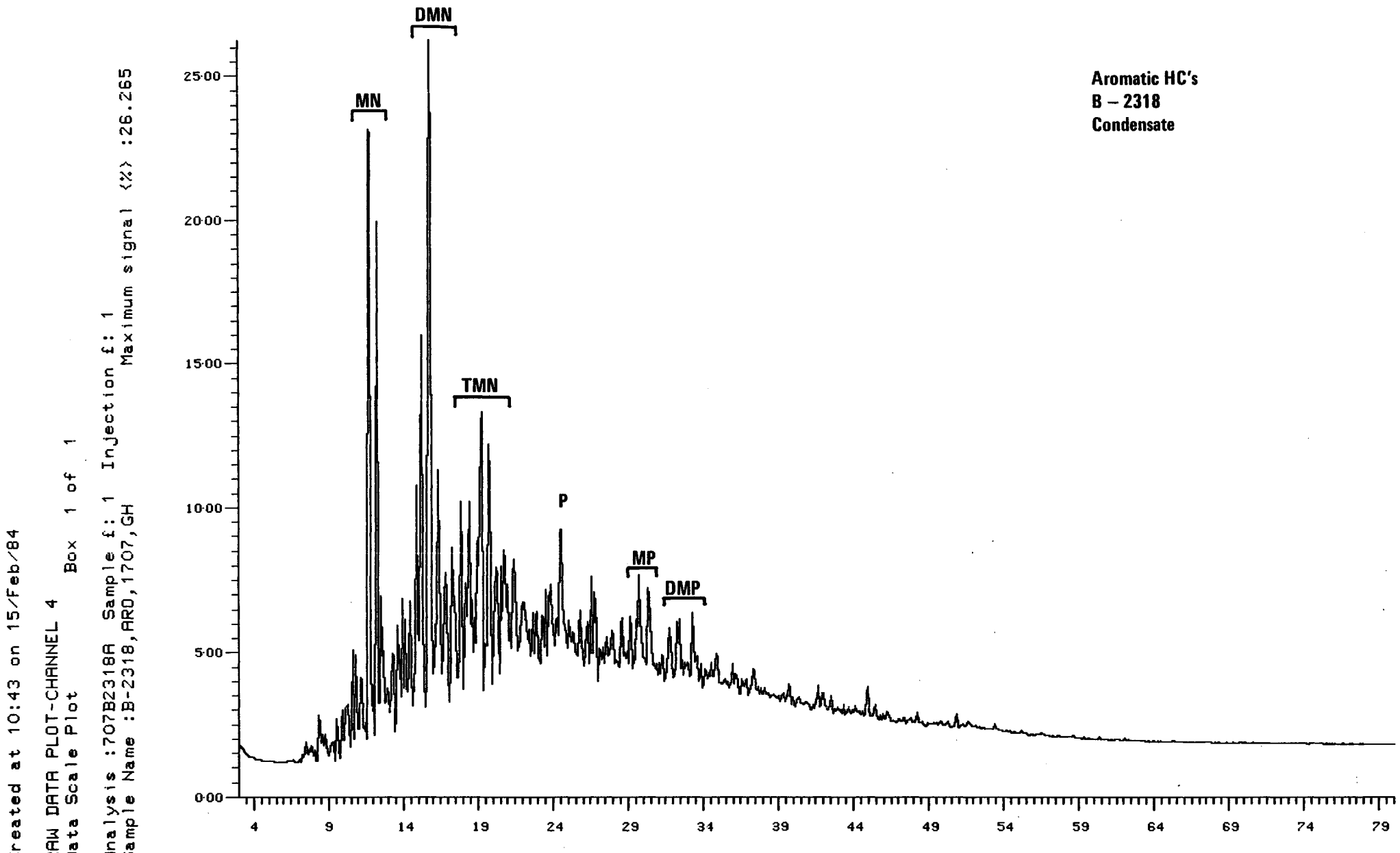
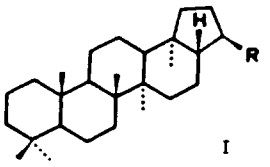

Created at 10:43 on 15/Feb/84
RAW DATA PLOT-CHANNEL 4
Data Scale Plot
Box 1 of 1
Analysis :707B2318A Sample £: 1 Injection £: 1
Sample Name :B-2318,ARO,1707,GH
Maximum signal (%) :26.265
Aromatic HC's
B – 2318
Condensate
MN
DMN
TMN
P
MP
DMP
25·00
20·00
15·00
10·00
5·00
0·00
4
9
14
19
24
29
34
39
44
49
54
59
64
69
74
79

Figure 5a.

Mass chromatograms representing terpanes (m/z 191)

A	T_s, 18α(H)-trisnorneohopane	$C_{27}H_{46}$	(III)
B	T_m, 17α(H)-trisnorhopane	$C_{27}H_{46}$	(I,R=H)
C	17α(H)-norhopane	$C_{29}H_{50}$	(I,R=C_2H_5)
D	17β(H)-normoretane	$C_{29}H_{50}$	(II,R=C_2H_5)
E	17α(H)-hopane	$C_{30}H_{52}$	(I,R=C_3H_7)
F	17β(H)-moretane	$C_{30}H_{52}$	(II,R=C_3H_7)
G	17α(H)-homohopane (22S)	$C_{31}H_{54}$	(I,R=C_4H_9)
H	17α(H)-homohopane (22R) + unknown triterpane (gammacerane?)	$C_{31}H_{54}$	(I,R=C_4H_9)
I	17β(H)-homomoretane	$C_{31}H_{54}$	(II,R=C_4H_9)
J	17α(H)-bishomohopane (22S,22R)	$C_{32}H_{56}$	(I,R=C_5H_{11})
K	17α(H)-trishomohopane (22S,22R)	$C_{33}H_{58}$	(I,R=C_6H_{13})
L	17α(H)-tetrakishomohopane (22S,22R)	$C_{34}H_{60}$	(I,R,=C_7H_{15})
M	17α(H)-pentakishomohopane (22S,22R)	$C_{35}H_{62}$	(I,R=C_8H_{17})
Z	bisnorhopane	$C_{28}H_{48}$	
X	unknown triterpane	$C_{30}H_{52}$	
P	tricyclic terpane	$C_{23}H_{42}$	(IV,R=C_4H_9)
Q	tricyclic terpane	$C_{24}H_{44}$	(IV,R=C_5H_{11})
R	tricyclic terpane (17R,17S)	$C_{25}H_{46}$	(IV,R=C_6H_{13})
S	tetracyclic terpane	$C_{24}H_{42}$	(V)
T	tricyclic terpane (17R,17S)	$C_{26}H_{48}$	(IV,R=C_7H_{15})



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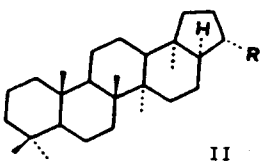

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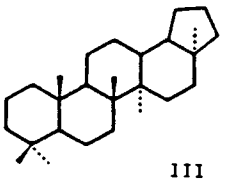

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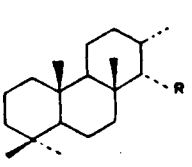
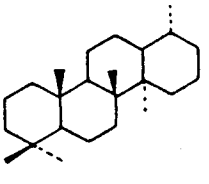
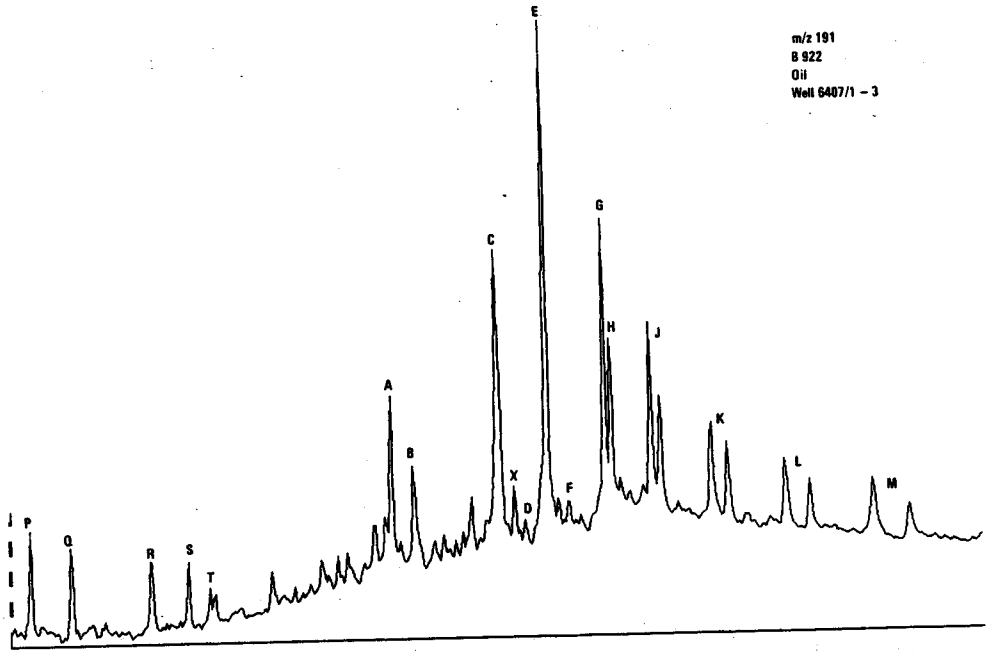
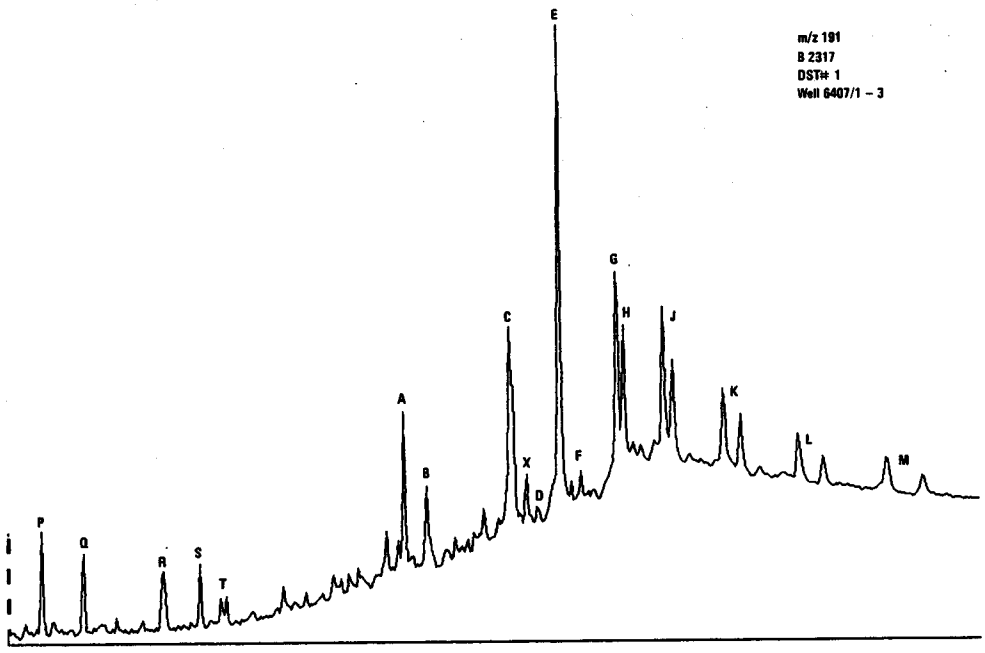
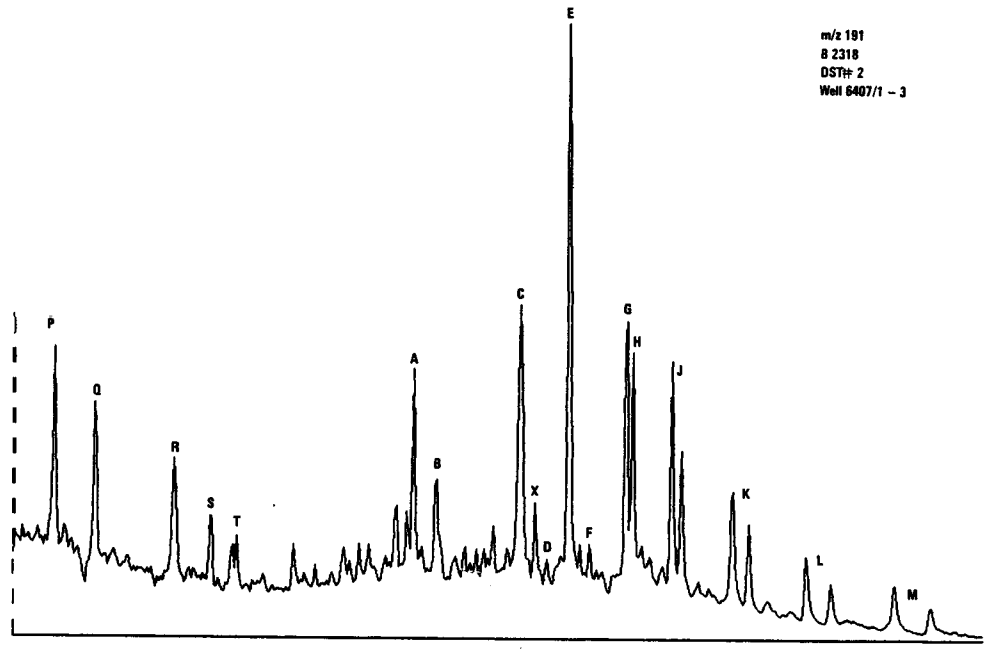





m/z 191
B 922
Oil
Well 6407/1 – 3
P
Q
R
S
T
A
B
C
X
D
E
F
G
H
J
K
L
M


m/z 191
B 2317
DST# 1
Well 6407/1 – 3
P
Q
R
S
T
A
B
C
X
D
E
F
G
H
J
K
L
M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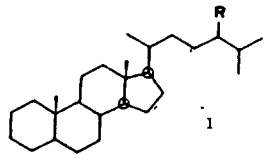
B 2318
DST# 2
Well 6407/1 – 3
P
Q
R
S
T
A
B
C
X
D
E
F
G
H
J
K
L
M

Figure 5b.

Mass chromatograms representing steranes (m/z 217 and 218)

a	13β(H),17α(H)-diasterane (20S)	$C_{27}H_{48}$	(III,R=H)
b	13β(H),17α(H)-diasterane (20R)	$C_{27}H_{48}$	(III,R=H)
c	13α(H),17β(H)-diasterane (20S)	$C_{27}H_{48}$	(IV,R=H)
d	13α(H),17β(H)-diasterane (20R)	$C_{27}H_{48}$	(IV,R=H)
e	13β(H),17α(H)-diasterane (20S)	$C_{28}H_{50}$	(III,R=CH_3)
f	13β(H),17α(H)-diasterane (20R)	$C_{28}H_{50}$	(III,R=CH_3)
g	13α(H),17β(H)-diasterane (20S)	$C_{28}H_{50}$	(IV,R=CH_3)
	+ 14α(H),17α(H)-sterane (20S)	$C_{27}H_{48}$	(I,R=H)
h	13β(H),17α(H)-diasterane (20S)	$C_{29}H_{52}$	(III,R=C_2H_5)
	+ 14α(H),17α(H)-sterane (20R)	$C_{27}H_{48}$	(II,R=H)
i	14β(H),17β(H)-sterane (20S)	$C_{27}H_{48}$	(II,R=H)
	+ 13α(H),17β(H)-diasterane (20R)	$C_{28}H_{50}$	(IV,R=CH_3)
j	14α(H),17α(H)-sterane (20R)	$C_{27}H_{48}$	(I,R=H)
k	13β(H),17α(H)-diasterane (20R)	$C_{29}H_{52}$	(III,R=C_2H_5)
l	13α(H),17β(H)-diasterane (20S)	$C_{29}H_{52}$	(III,R=C_2H_5)
m	14α(H),17α(H)-sterane (20S)	$C_{28}H_{50}$	(I,R=CH_3)
n	13α(H),17β(H)-diasterane (20R)	$C_{29}H_{52}$	(III,R=C_2H_5)
	+ 14β (H),17β (H)-sterane (20R)	$C_{28}H_{50}$	(II,R=CH_3)
o	14β(H),17β(H)-sterane (20S)	$C_{28}H_{50}$	(II,R=CH_3)
p	14α(H),17α(H)-sterane (20R)	$C_{28}H_{50}$	(I,R=CH_3)
q	14α(H),17α(H)-sterane (20S)	$C_{29}H_{52}$	(I,R=C_2H_5)
r	14β(H),17β(H)-sterane (20R)	$C_{29}H_{52}$	(II,R=C_2H_5)
	+ unknown sterane		
s	14β(H),17β(H)-sterane (20S)	$C_{29}H_{52}$	(II,R=C_2H_5)
t	14α(H),17β(H)-sterane (20R)	$C_{29}H_{52}$	(I,R=C_2H_5)
u	5α(H)-sterane	$C_{21}H_{36}$	(V,R=C_2H_5)
v	5α(H)-sterane	$C_{22}H_{38}$	(IV,R=C_3H_7)



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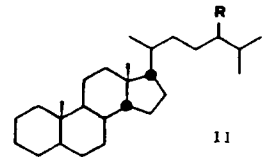

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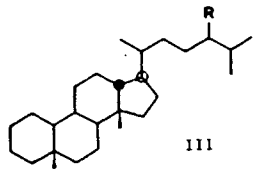

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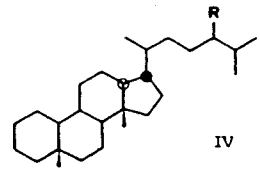

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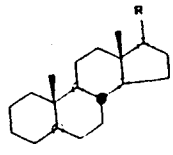
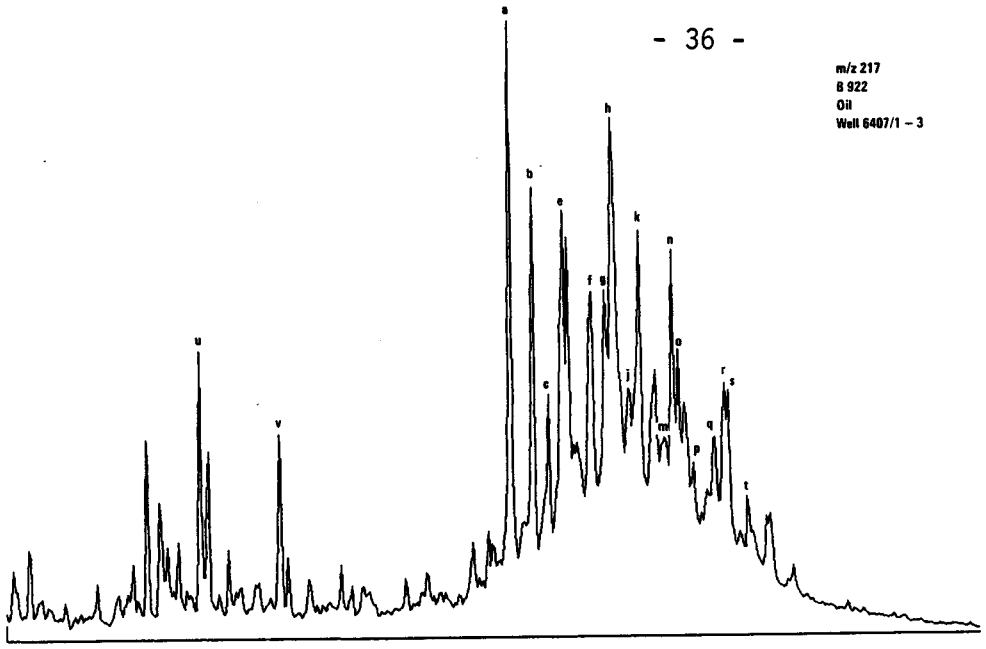
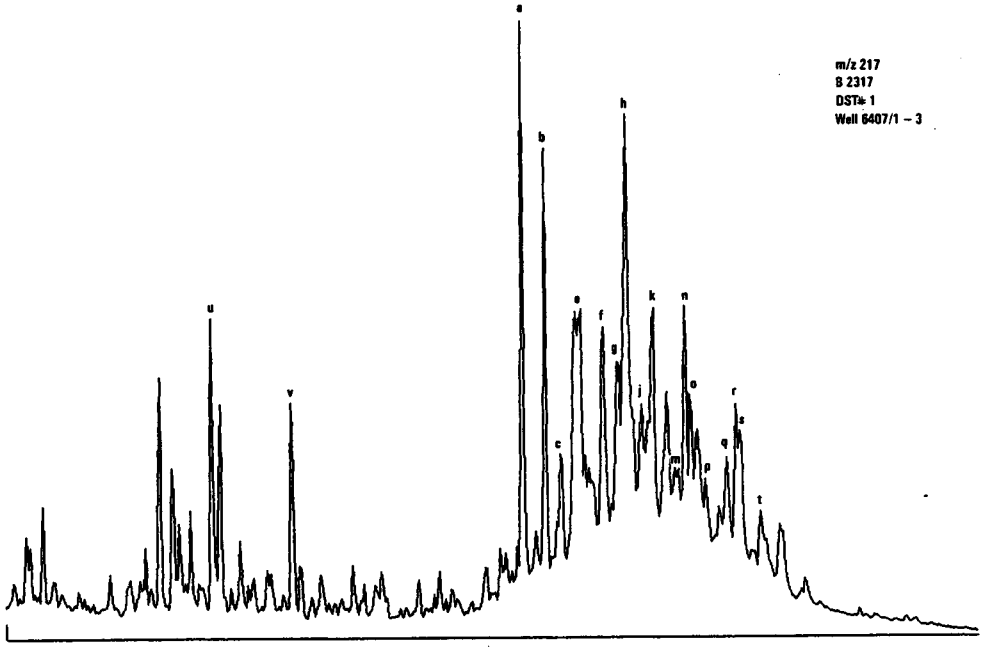
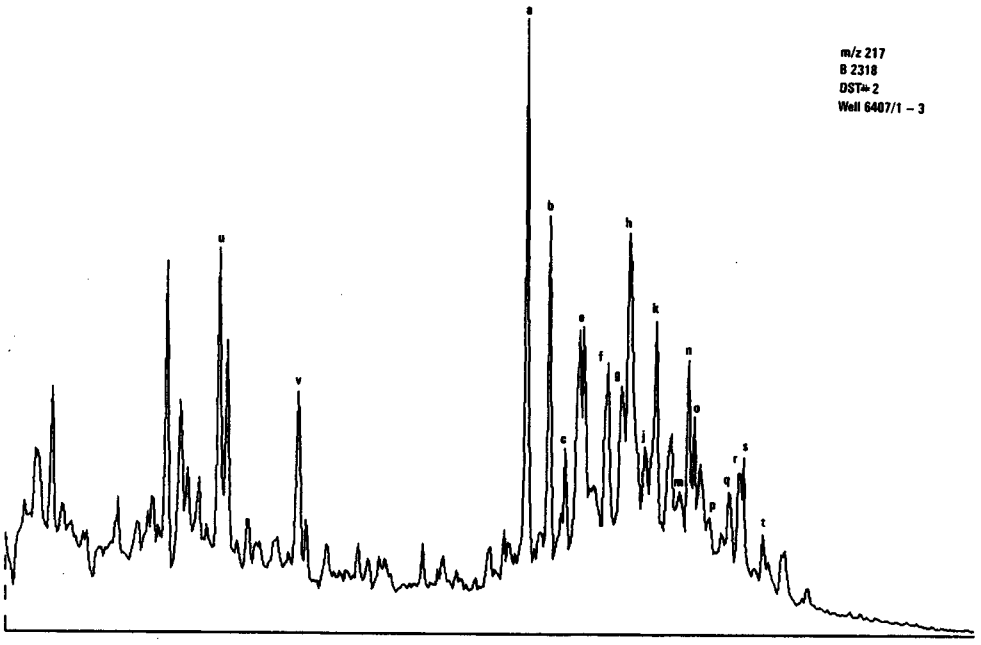
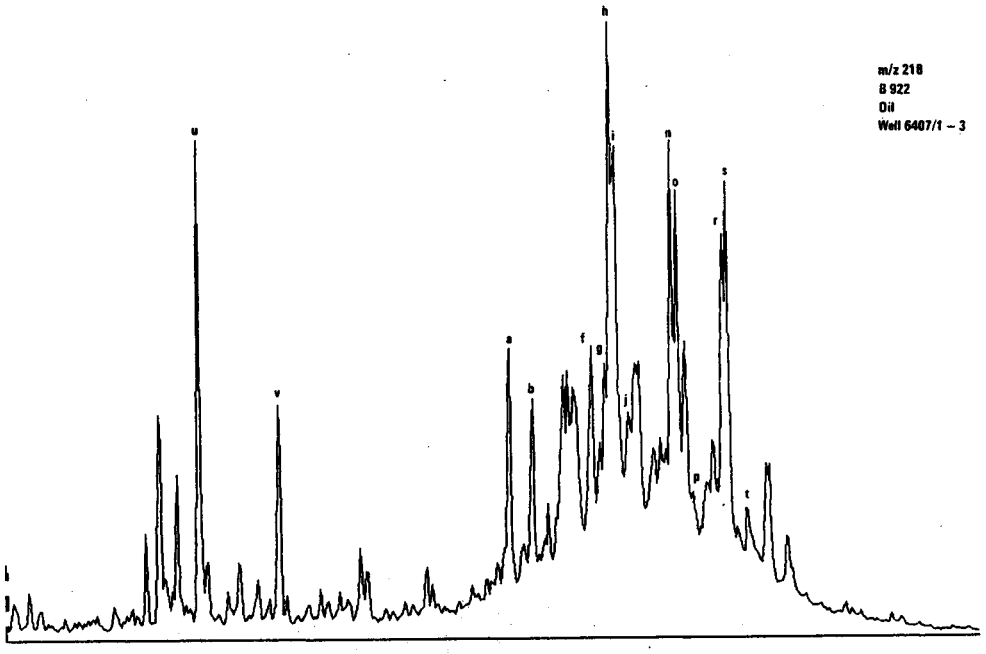
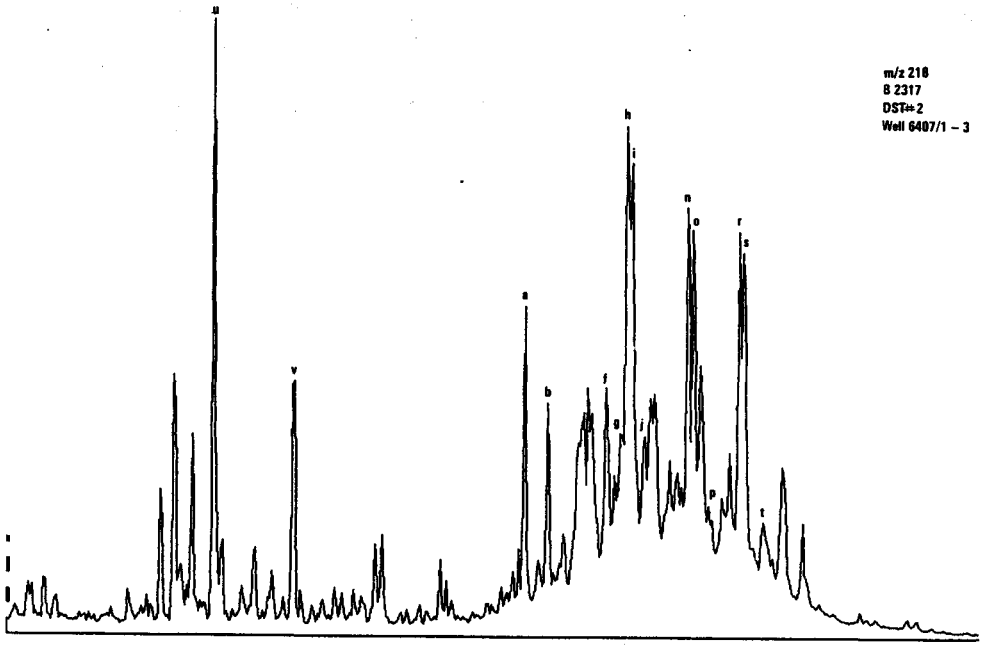



m/z 217
B 922
Oil
Well 6407/1 – 3


m/z 217
B 2317
DST# 1
Well 6407/1 – 3


m/z 217
B 2318
DST# 2
Well 6407/1 – 3


m/z 218
B 922
Oil
Well 6407/1 – 3


m/z 218
B 2317
DST#2
Well 6407/1 – 3

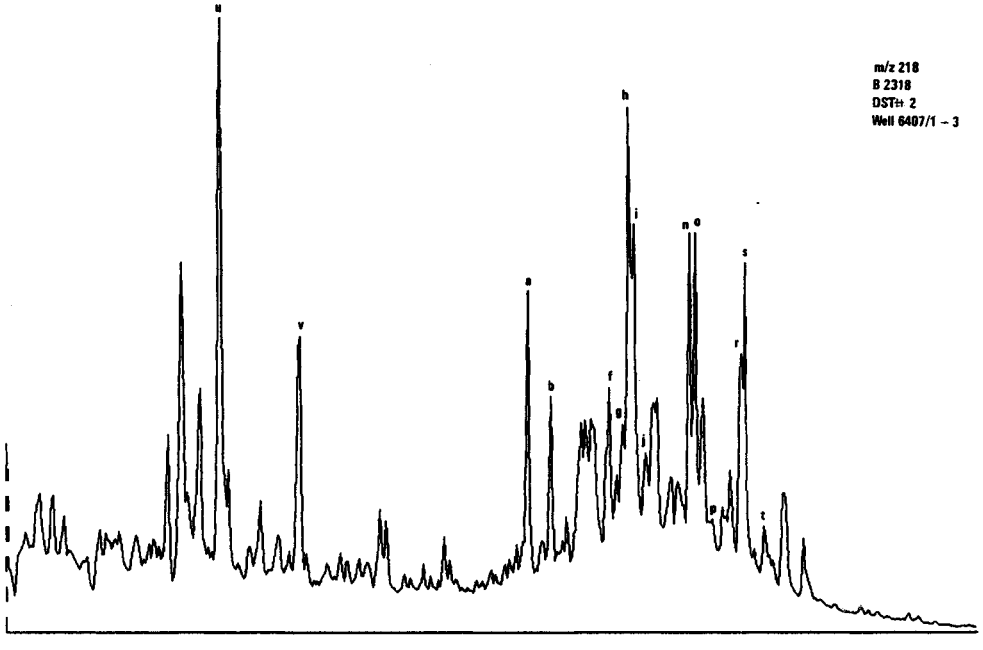
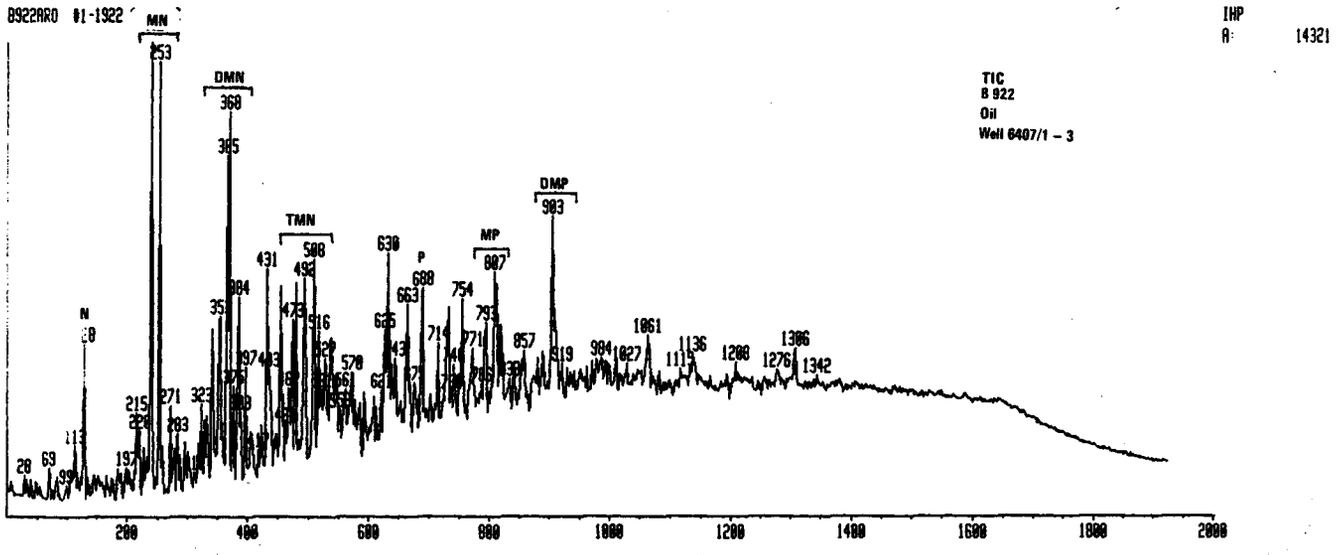
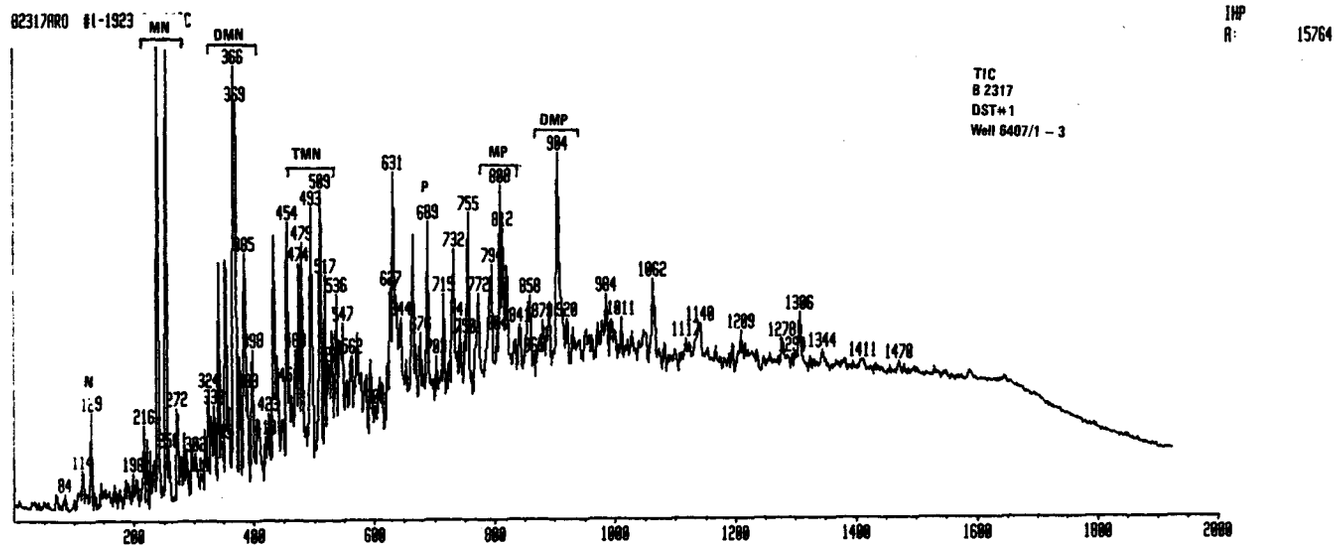

m/z 218
B 2318
DST# 2
Well 6407/1 – 3

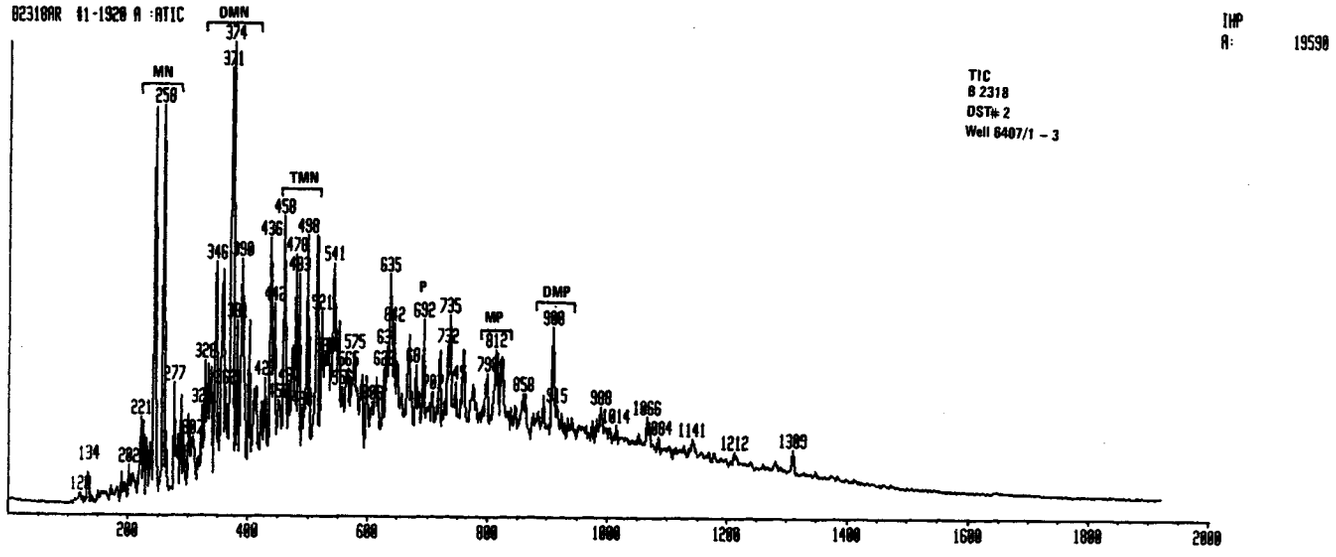
FIGURE 6

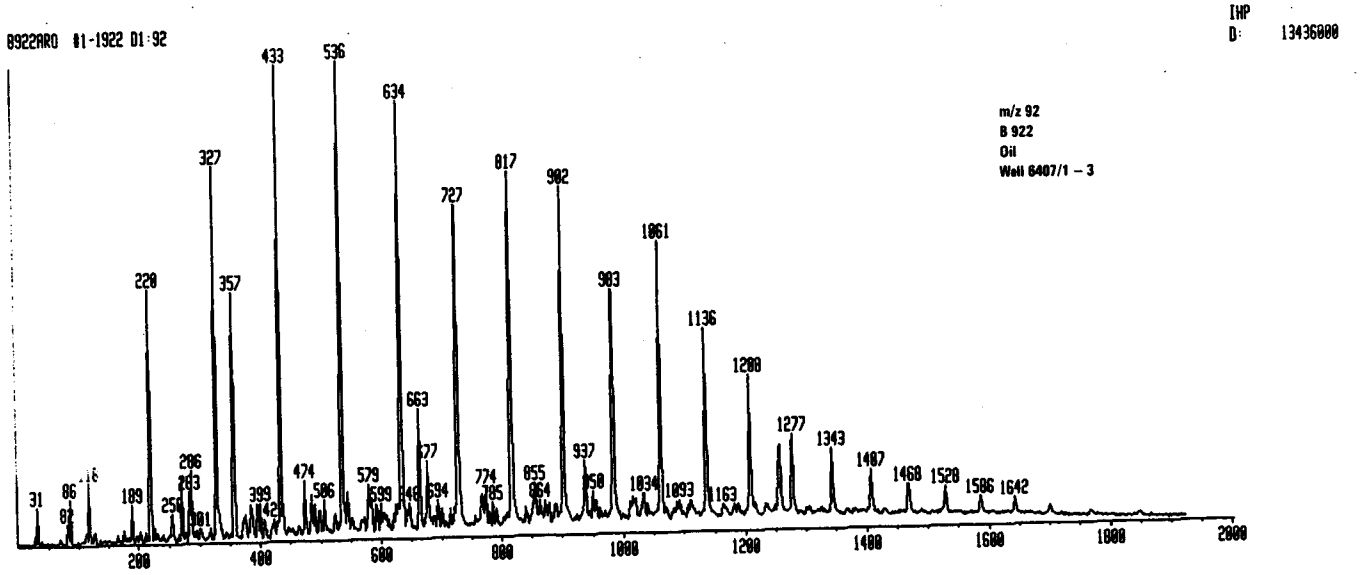
GC-MS CHROMATOGRAMS OF AROMATIC HYDROCARBONS

TIC	- total ion chromatograms
m/z 92,106	- alkylated monoaromatic hydrocarbons
m/z 142,156,170	- alkylated naphthalenes
m/z 178,192,206	- alkylated phenanthrenes
m/z 184,198,212	- alkylated dibenzothiophenes
m/z 231	- triaromatic steranes
m/z 253	- monoaromatic steranes


8922ARO #1-1922
MN
DMN
TMN
MP
DMP
P
N
TIC
B 922
Oil
Well 6407/1 - 3
IHP
A: 14321


82317ARO #1-1923
MN
DMN
TMN
MP
DMP
P
N
TIC
B 2317
DST#1
Well 6407/1 - 3
IHP
A: 15764


82318AR #1-1920 A :ATIC
MN
DMN
TMN
MP
DMP
P
TIC
B 2318
DST# 2
Well 6407/1 - 3
IHP
A: 19598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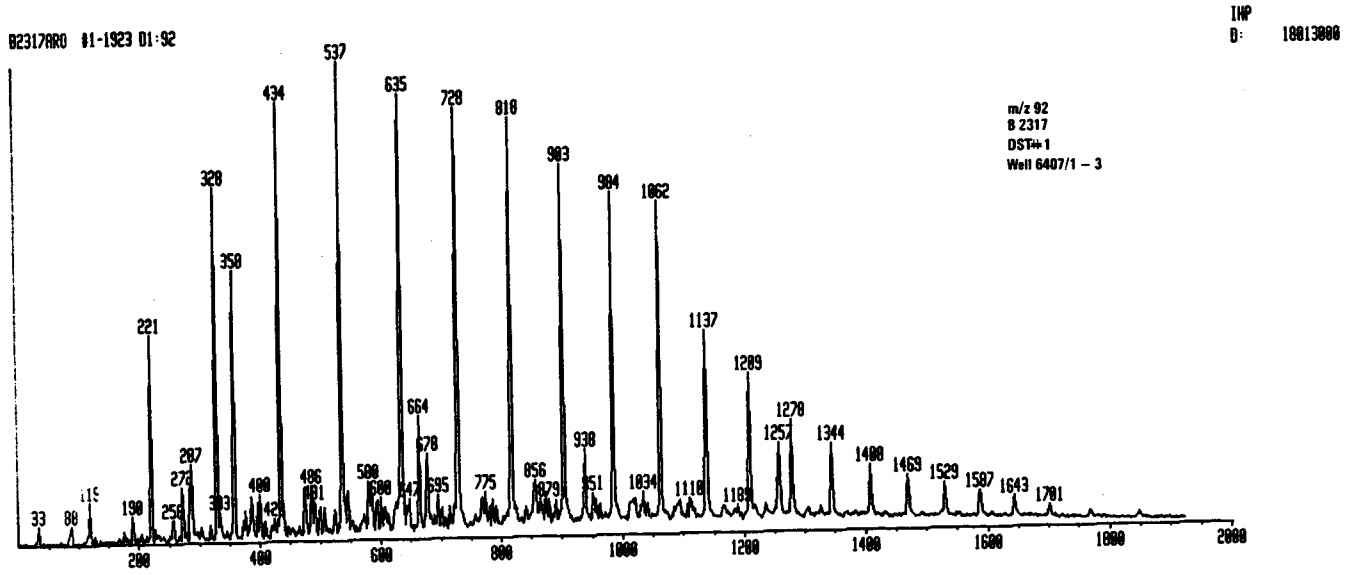
IHP
D: 13436000
m/z 92
B 922
Oil
Well 6407/1 - 3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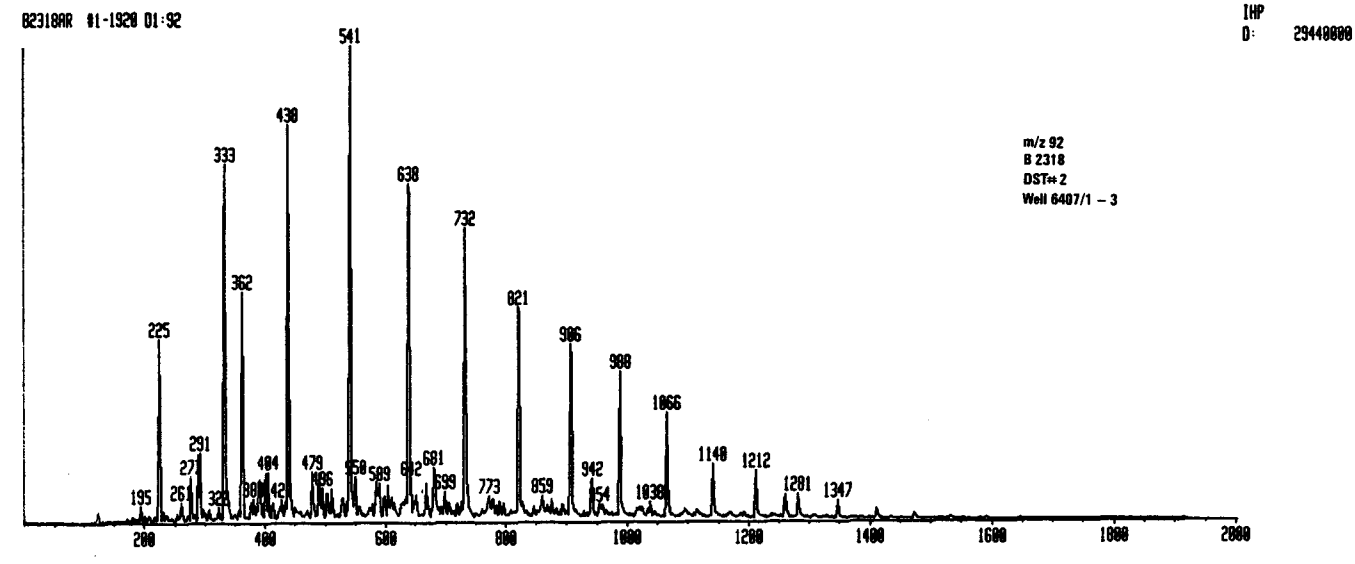
IHP
D: 10013000
m/z 92
B 2317
DST#1
Well 6407/1 - 3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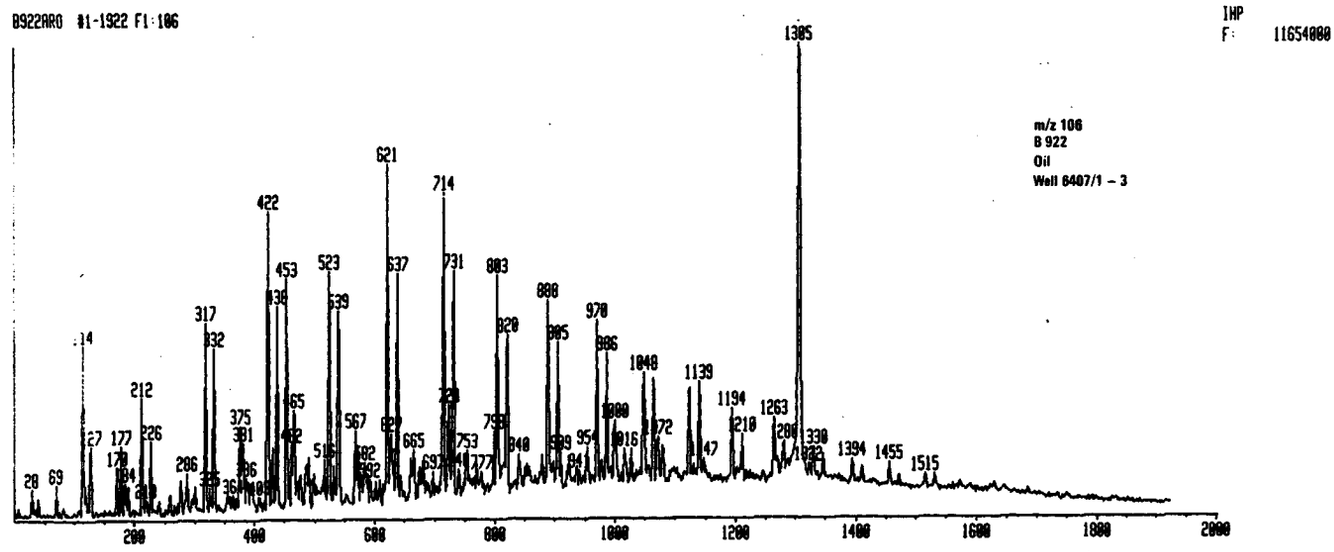
IHP
D: 29440000
m/z 92
B 2318
DST#2
Well 6407/1 - 3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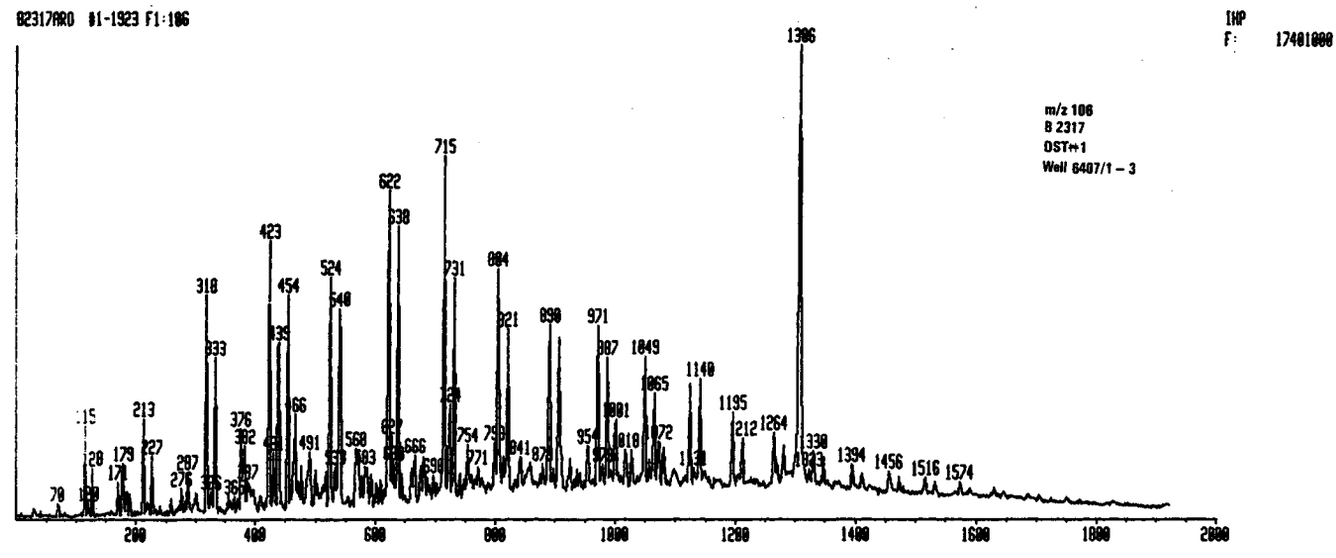
IHP
F: 11654000
m/z 106
B 922
Oil
Well 6407/1 – 3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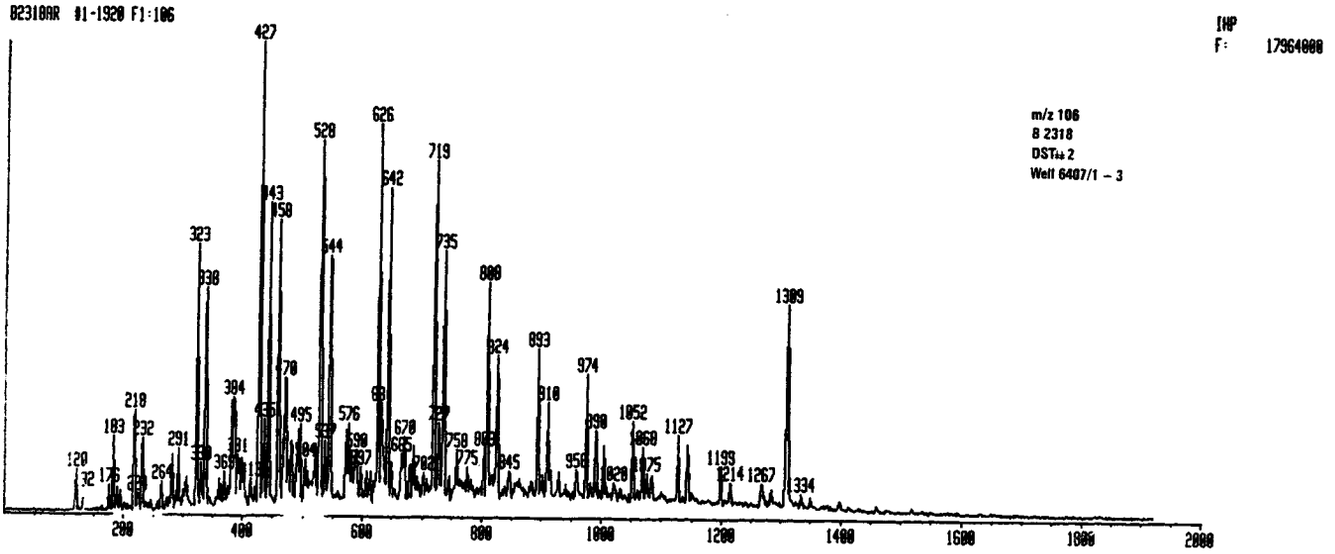
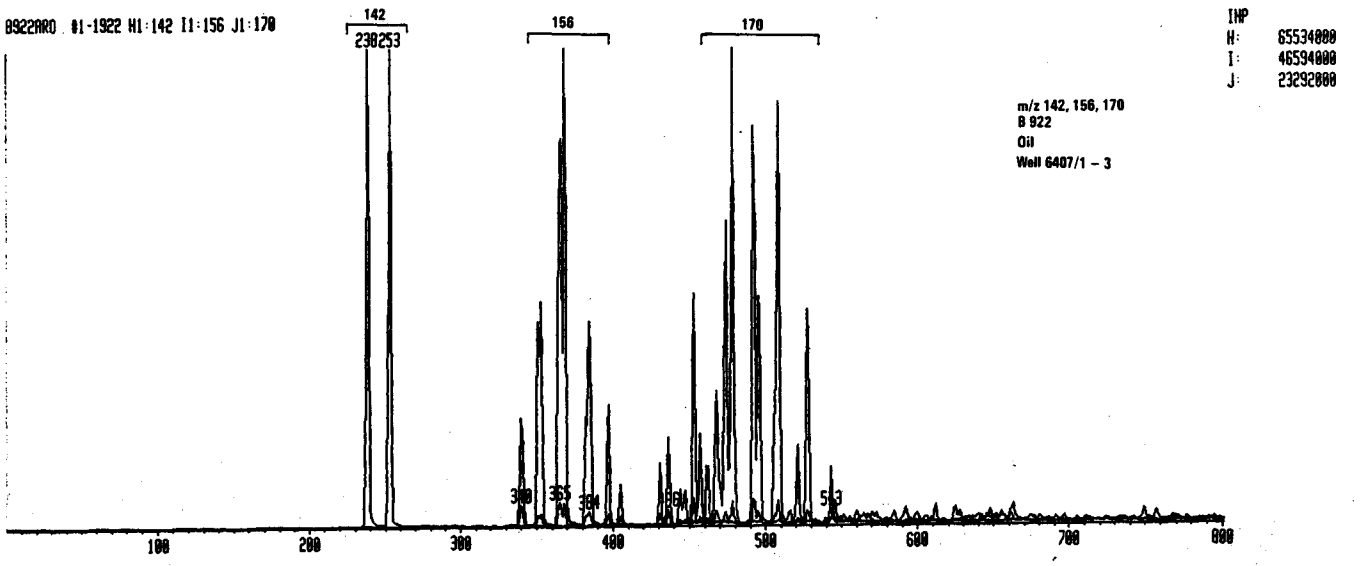
IHP
F: 17481000
m/z 106
B 2317
DST#1
Well 6407/1 – 3


B2318AR #1-1920 F1:106
IHP
F: 17964000
m/z 106
B 2318
DST# 2
Well 6407/1 – 3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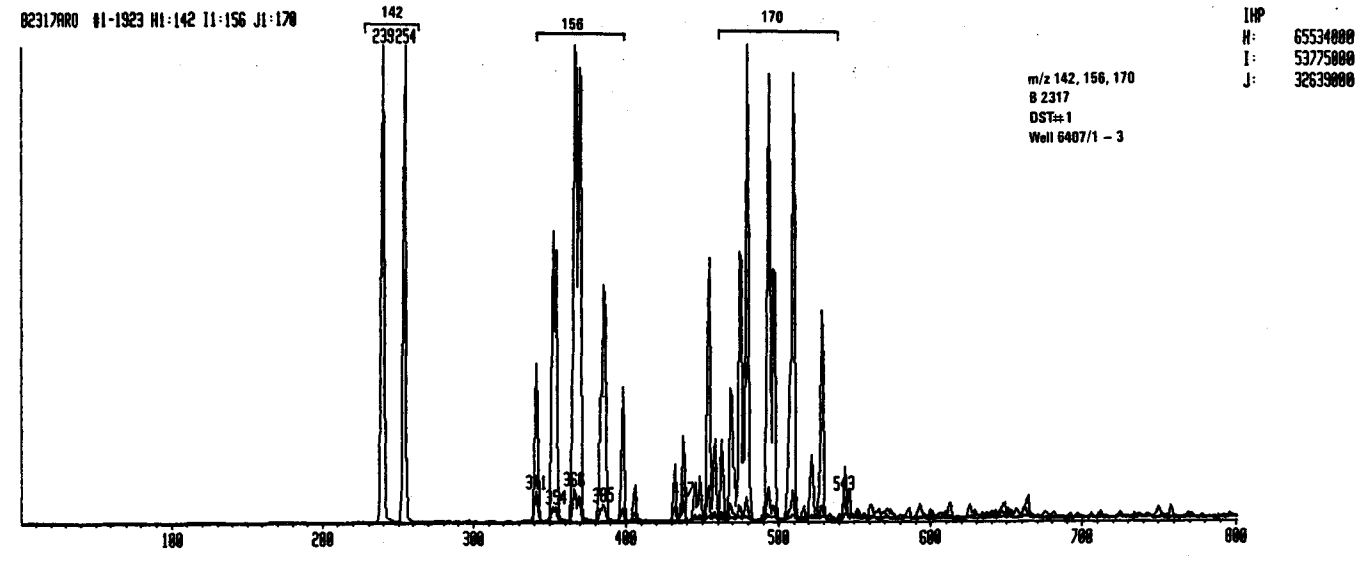
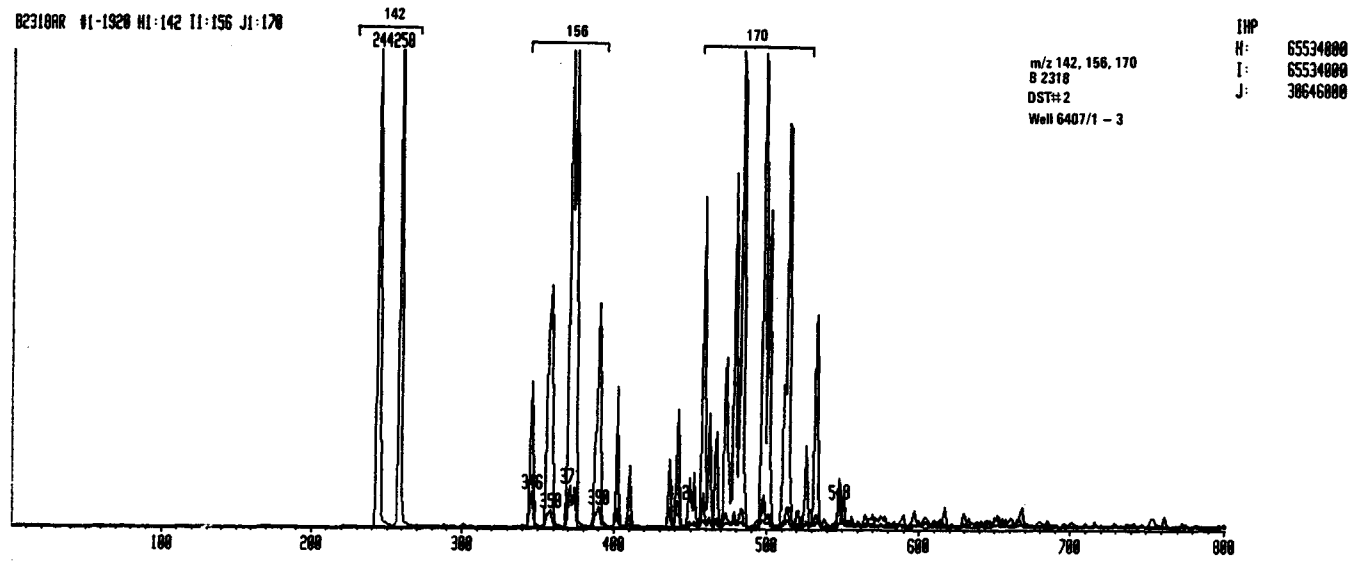
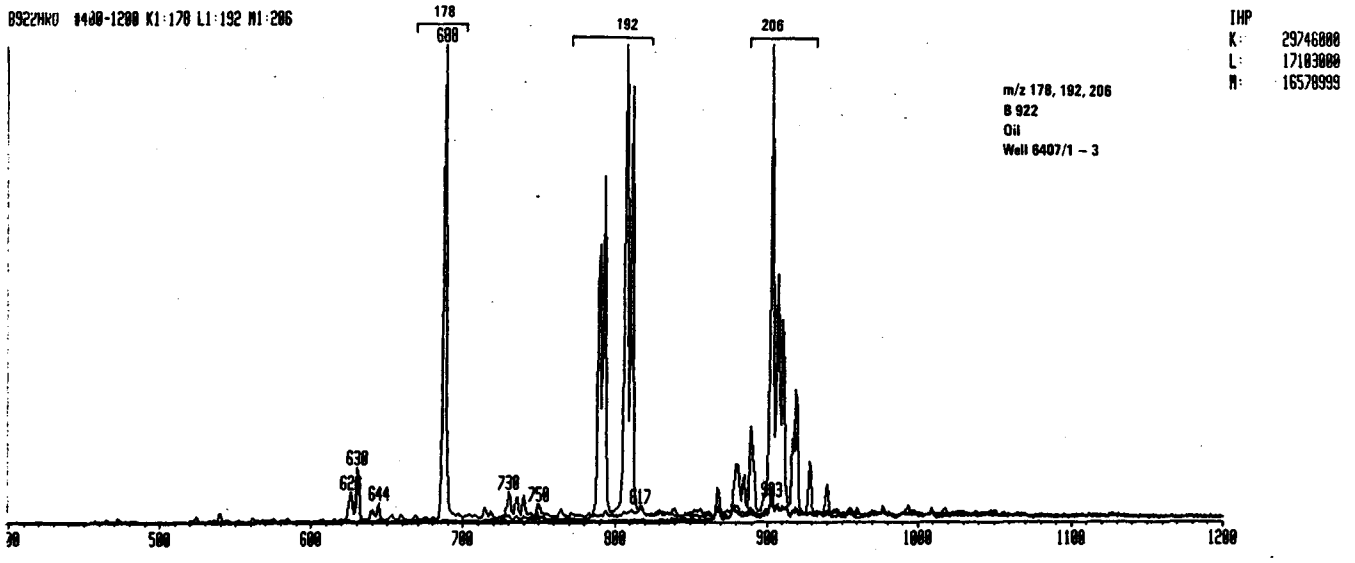
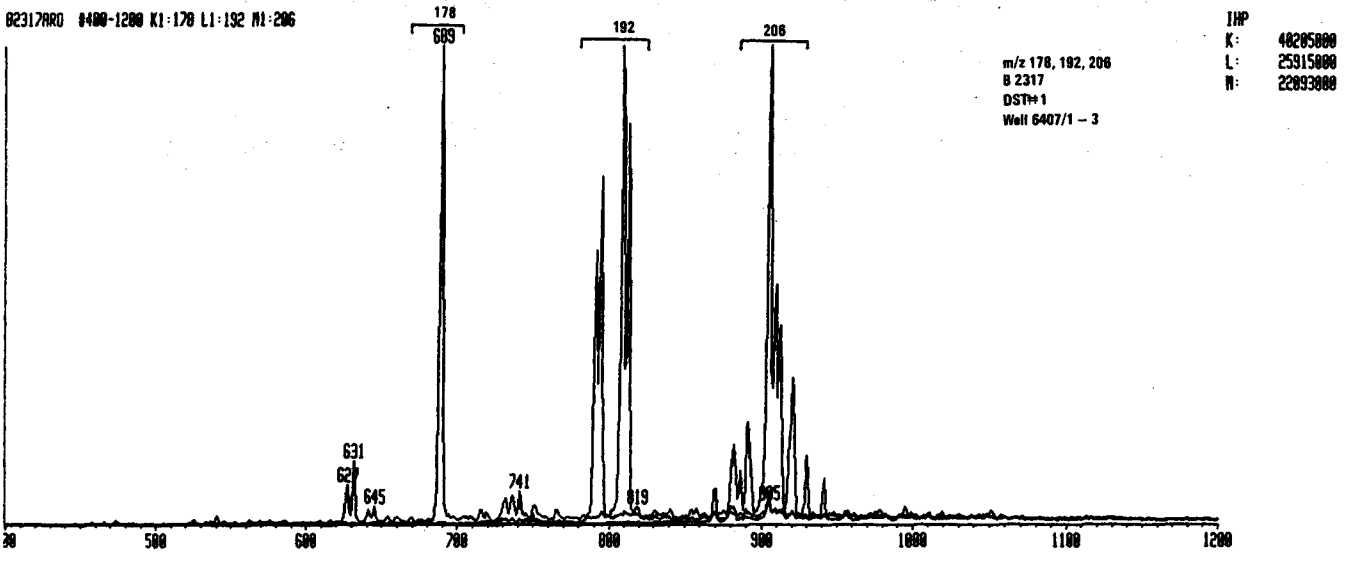
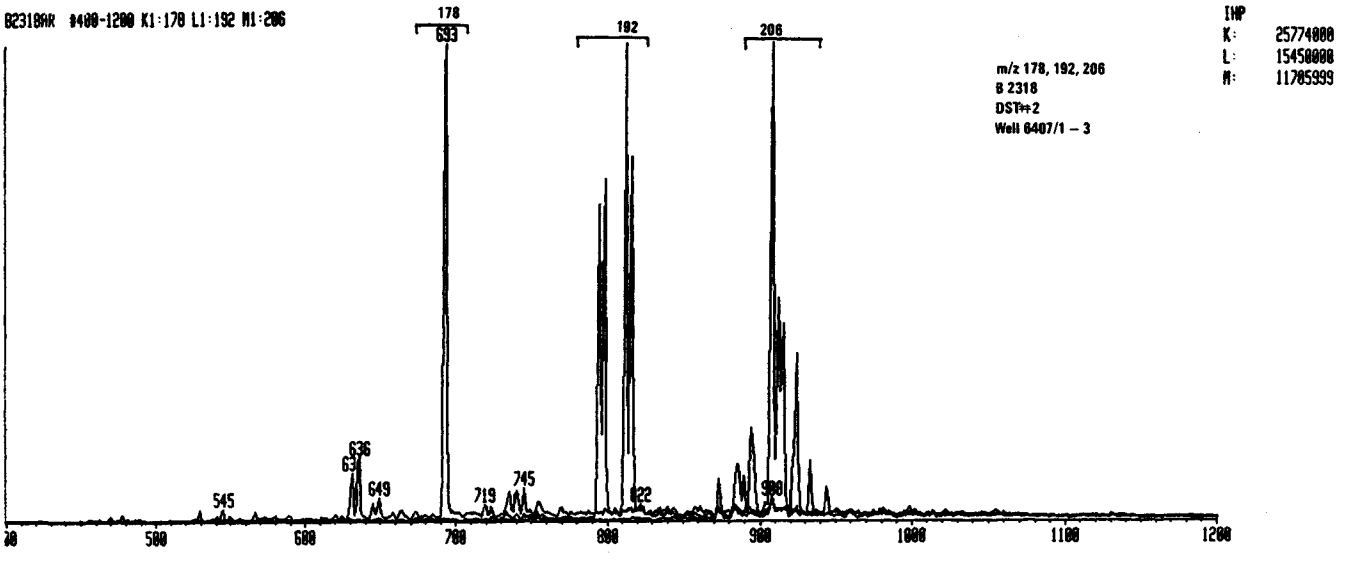
142
238253
156
170
IHP
H: 65534000
I: 46594000
J: 23292000
m/z 142, 156, 170
B 922
Oil
Well 6407/1 - 3
100
200
300
400
500
600
700
800

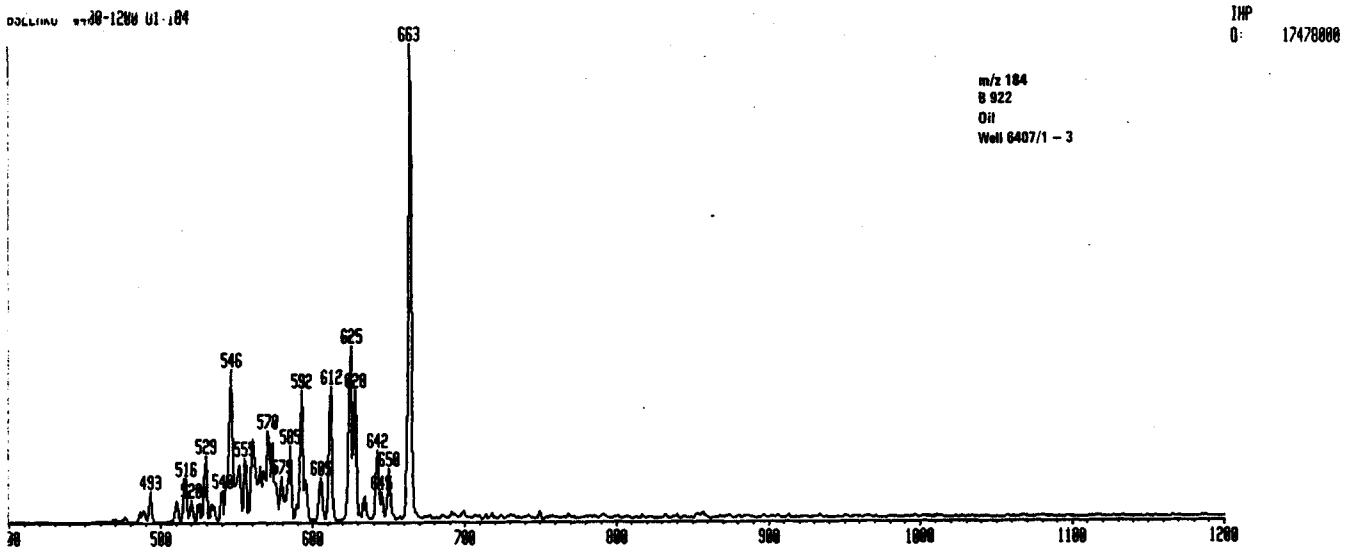

B2317AR0 #1-1923 H1:142 I1:156 J1:170
142
239254
156
170
IHP
H: 65534000
I: 53775000
J: 32639000
m/z 142, 156, 170
B 2317
DST#1
Well 6407/1 - 3
100
200
300
400
500
600
700
800

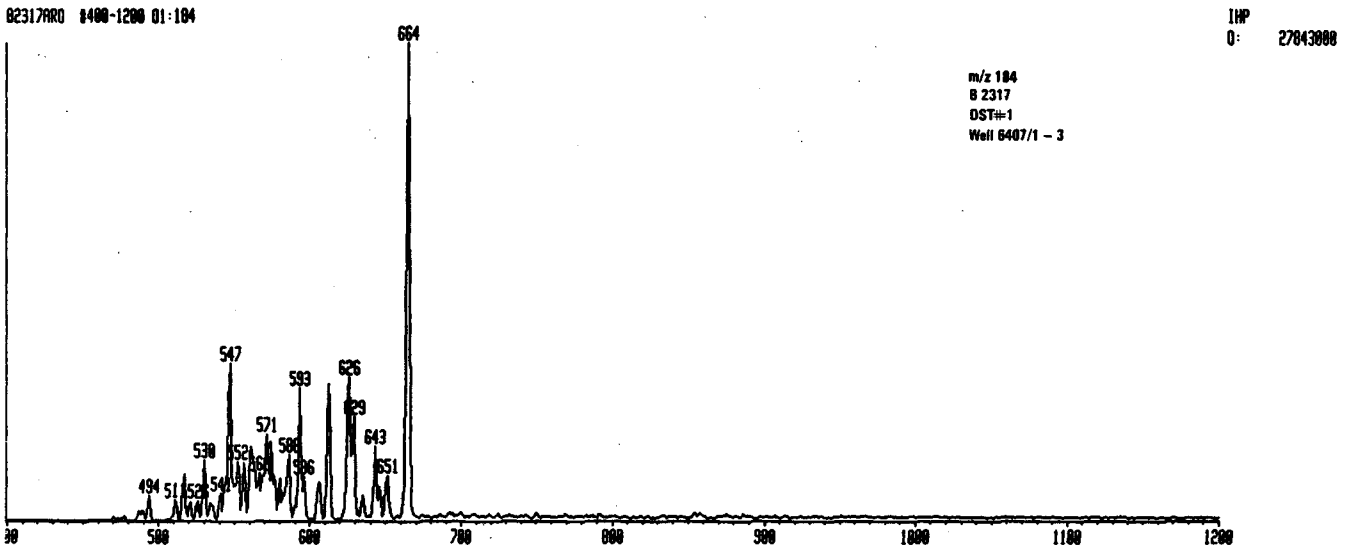

B2318AR #1-1920 H1:142 I1:156 J1:170
142
244250
156
170
IHP
H: 65534000
I: 65534000
J: 38646000
m/z 142, 156, 170
B 2318
DST#2
Well 6407/1 - 3
100
200
300
400
500
600
700
800

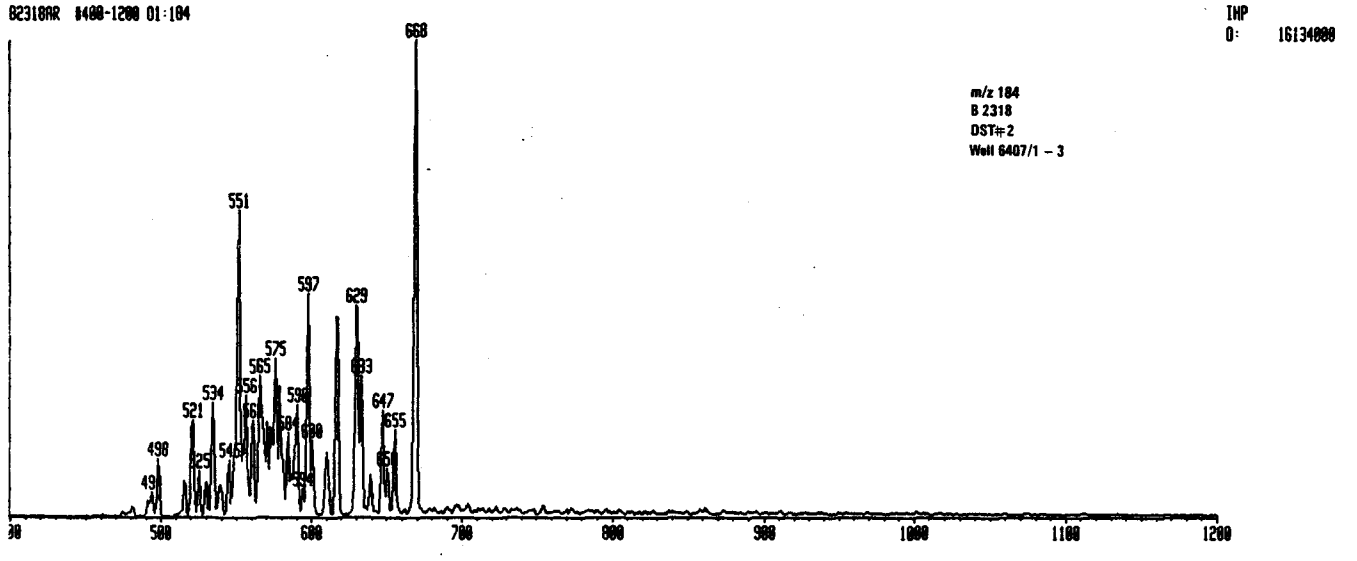

B922ARO #400-1200 K1:178 L1:192 M1:206
178
688
192
206
IHP
K: 29746000
L: 17103000
M: 16578999
m/z 178, 192, 206
B 922
Oil
Well 6407/1 – 3
630
644
730
750
617
500
600
700
800
900
1000
1100
1200

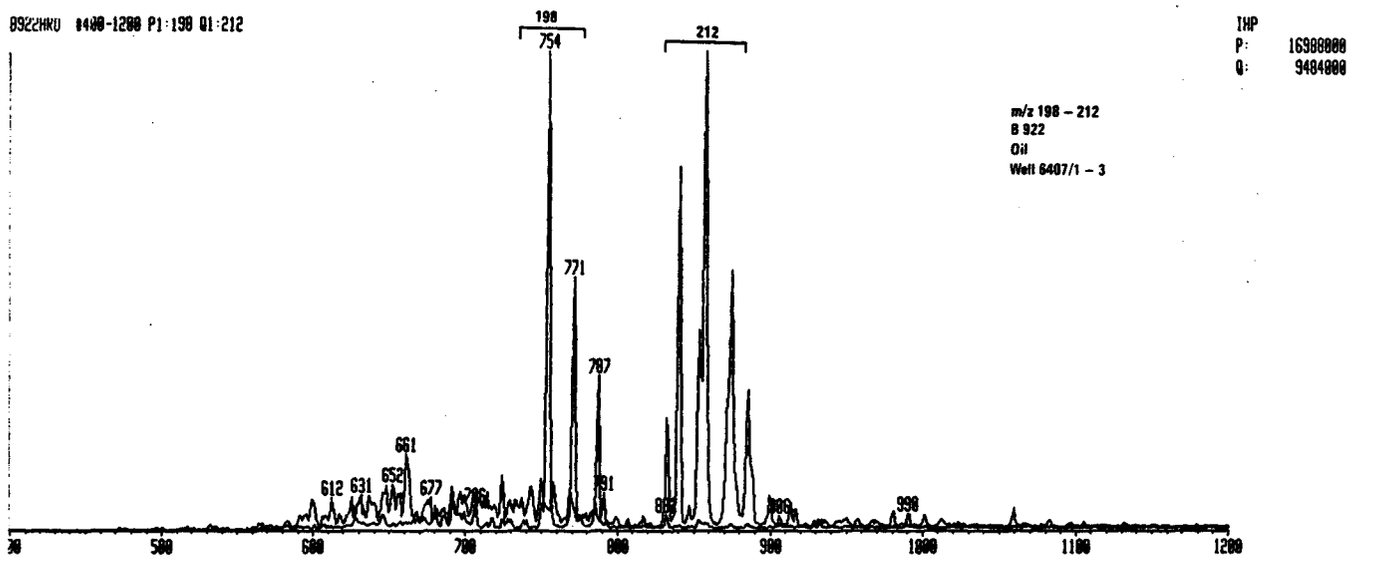

B2317ARO #400-1200 K1:178 L1:192 M1:206
178
689
192
206
IHP
K: 40205000
L: 25915000
M: 22093000
m/z 178, 192, 206
B 2317
DST#1
Well 6407/1 – 3
631
645
741
819
500
600
700
800
900
1000
1100
1200

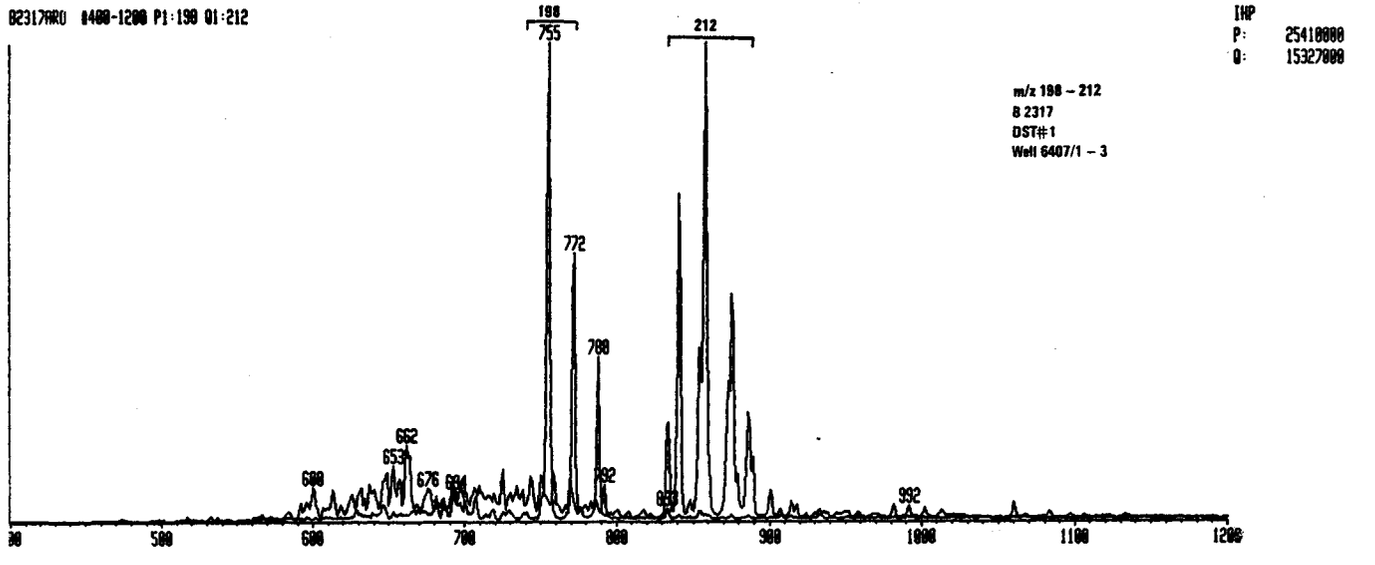

B2318AR #400-1200 K1:178 L1:192 M1:206
178
693
192
206
IHP
K: 25774000
L: 15450000
M: 11705999
m/z 178, 192, 206
B 2318
DST#2
Well 6407/1 – 3
636
649
545
719
745
822
500
600
700
800
900
1000
1100
1200

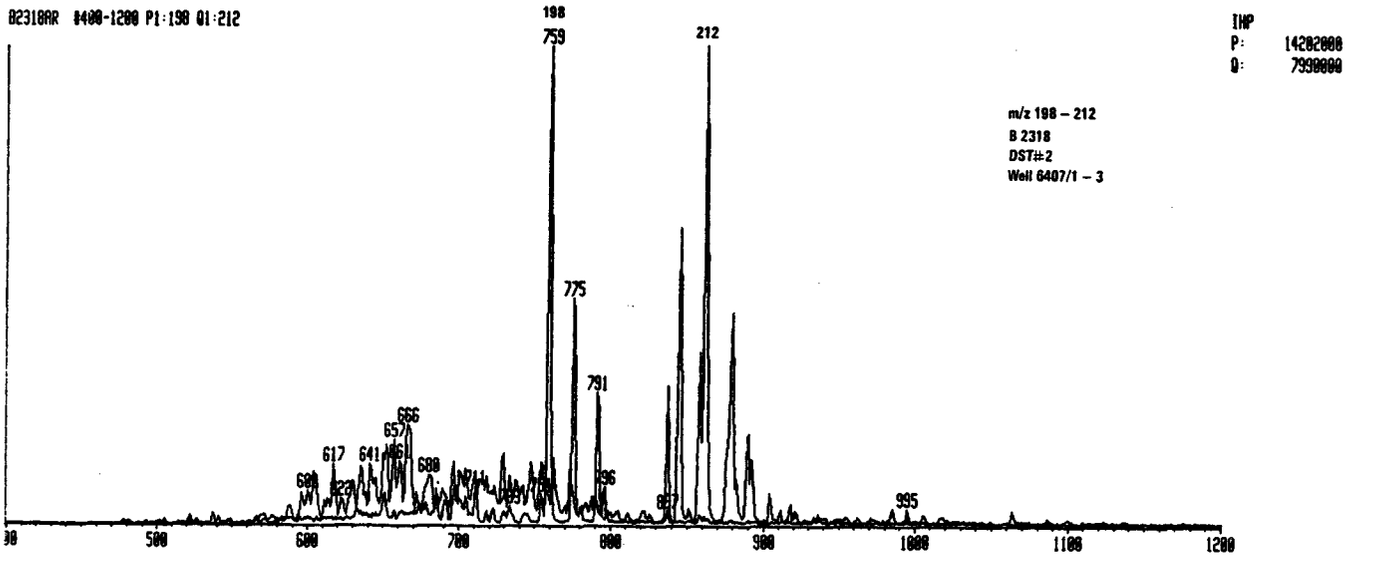

IHP
0: 17478000
663
m/z 184
B 922
Oil
Well 6407/1 - 3
625
546
592
612
628
570
529
642
516
493
500
600
700
800
900
1000
1100
1200

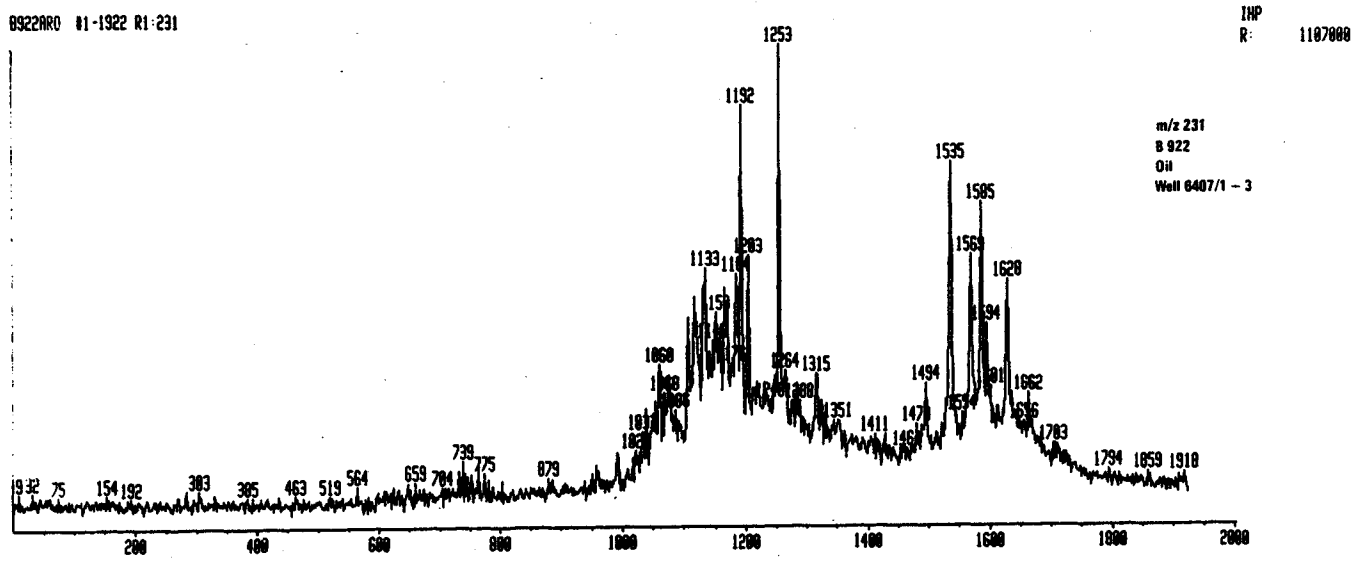

B2317RRO 8400-1200 01:184
IHP
0: 27843000
664
m/z 184
B 2317
DST#1
Well 6407/1 - 3
547
593
626
571
530
643
494
500
600
700
800
900
1000
1100
1200

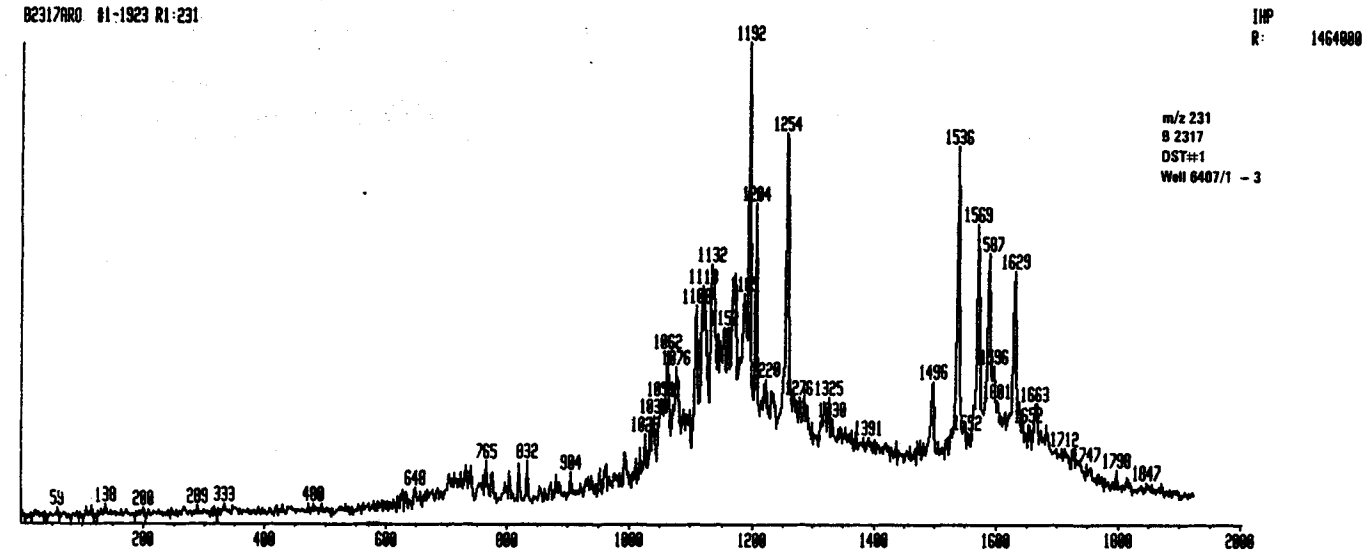

B2318RR 8400-1200 01:184
IHP
0: 16134000
668
m/z 184
B 2318
DST#2
Well 6407/1 - 3
551
597
629
575
565
534
521
647
498
500
600
700
800
900
1000
1100
1200

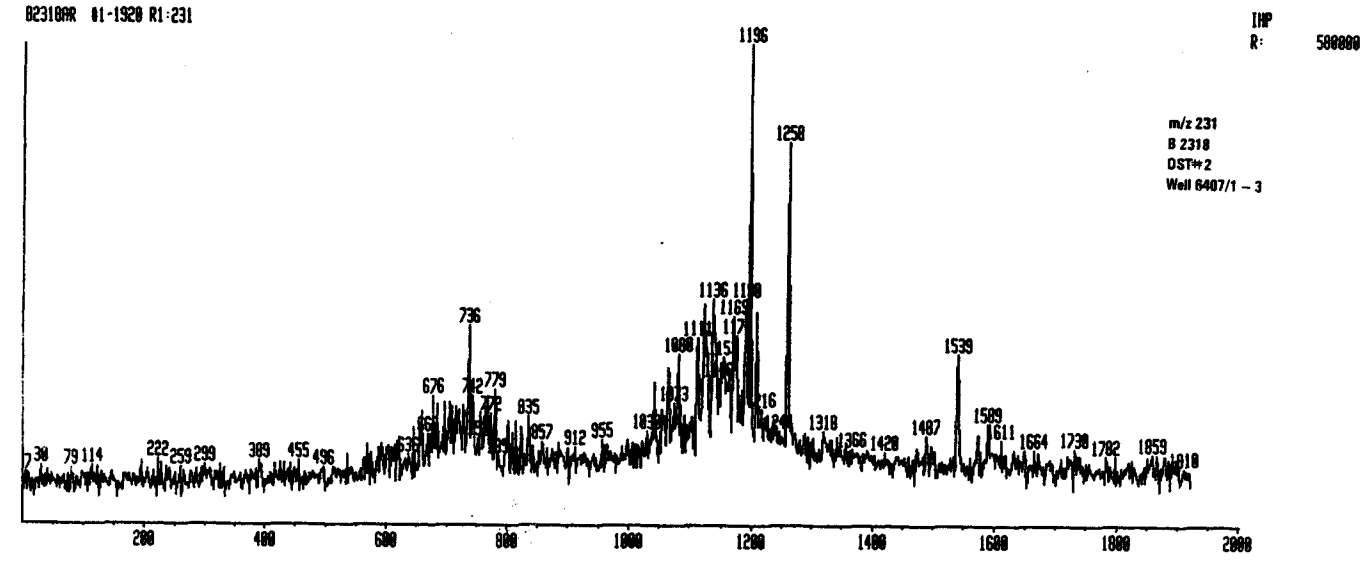

B922HKU 8400-1200 P1:198 Q1:212
198
754
212
IHP
P: 16988000
Q: 9484000
m/z 198 – 212
B 922
Oil
Well 6407/1 – 3
771
797
661
652
612
631
677
791
998
500
600
700
800
900
1000
1100
1200

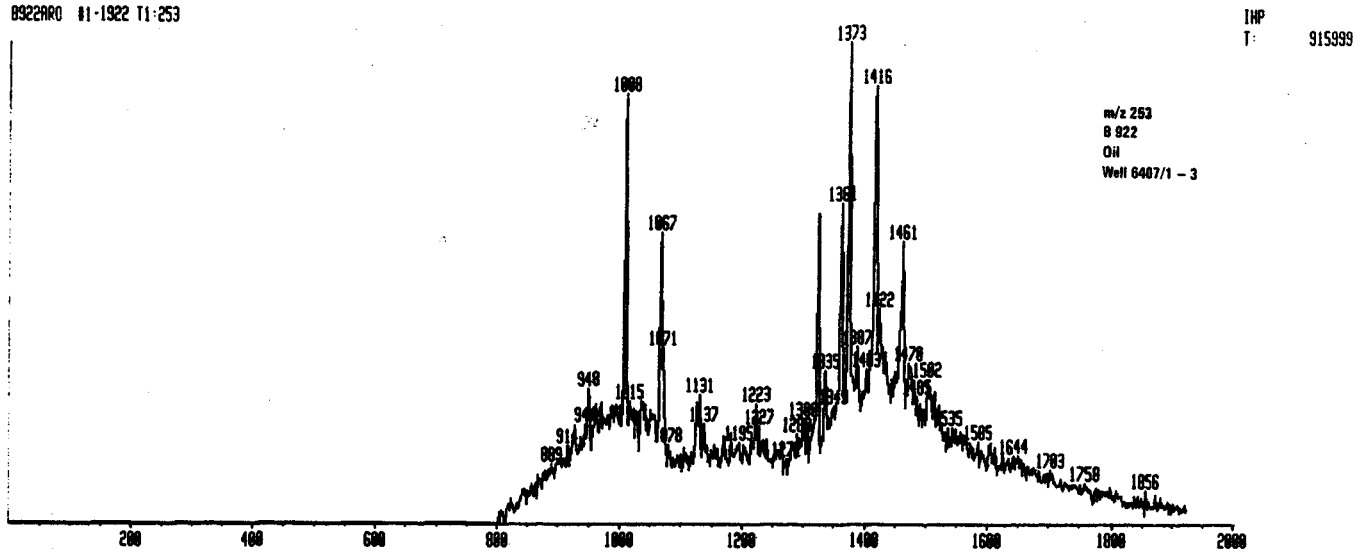

B2317HRU 8400-1200 P1:198 Q1:212
198
755
212
IHP
P: 25410000
Q: 15327000
m/z 198 – 212
B 2317
DST#1
Well 6407/1 – 3
772
788
662
653
676
792
992
500
600
700
800
900
1000
1100
1200

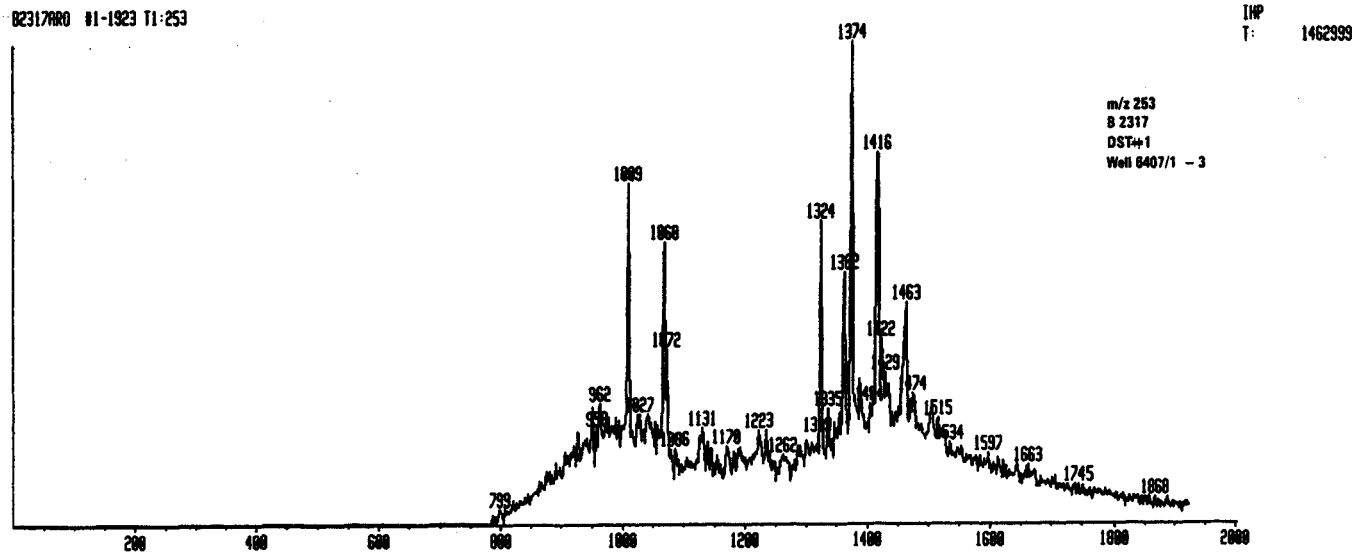

B2318HR 8400-1200 P1:198 Q1:212
198
759
212
IHP
P: 14282000
Q: 7990000
m/z 198 – 212
B 2318
DST#2
Well 6407/1 – 3
775
791
666
657
617
641
688
995
500
600
700
800
900
1000
1100
1200

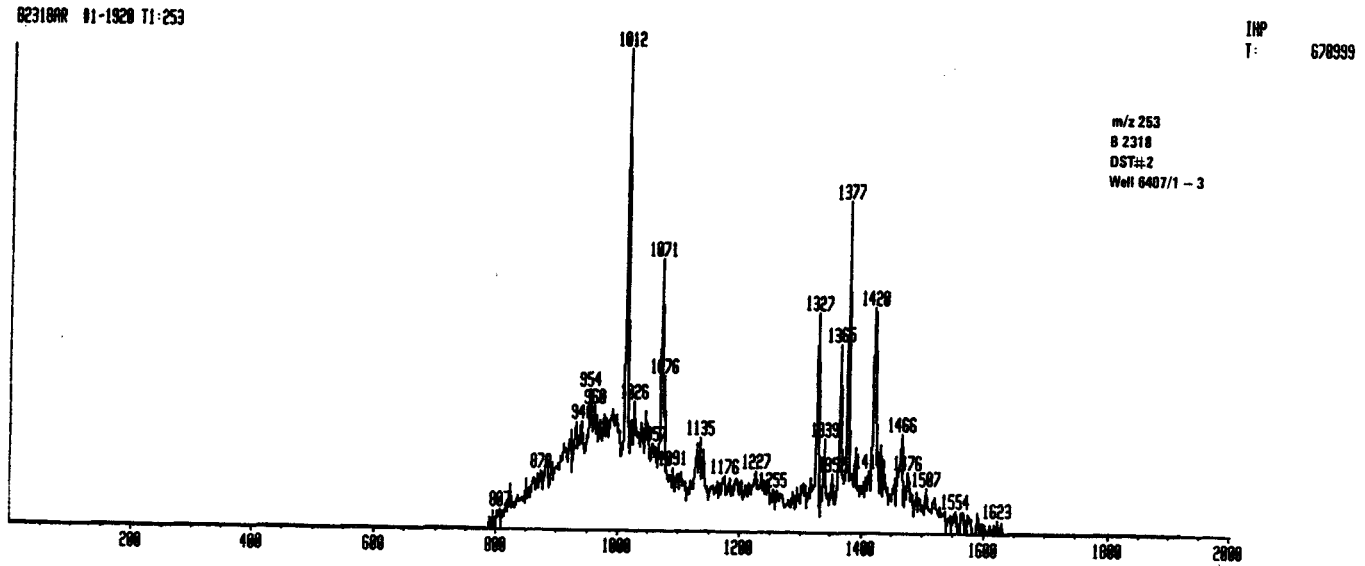

B922ARO #1-1922 R1:231
IHP
R: 1107000
m/z 231
B 922
Oil
Well 6407/1 - 3


B2317ARO #1-1923 R1:231
IHP
R: 1464000
m/z 231
B 2317
DST#1
Well 6407/1 - 3


B2318AR #1-1920 R1:231
IHP
R: 500000
m/z 231
B 2318
DST#2
Well 6407/1 - 3


B922ARO #1-1922 T1:253
IHP
T: 915999
m/z 253
B 922
Oil
Well 6407/1 - 3
1373
1416
1008
1067
1461
1071
1131
1223
948
1415
1078
1644
1703
1758
1856
200
400
600
800
1000
1200
1400
1600
1800
2000


B2317ARO #1-1923 T1:253
IHP
T: 1462999
m/z 253
B 2317
DST#1
Well 6407/1 - 3
1374
1416
1009
1068
1324
1463
1072
1131
1223
1262
1597
1663
1745
1868
799
200
400
600
800
1000
1200
1400
1600
1800
2000


B2318AR #1-1920 T1:253
IHP
T: 678999
m/z 253
B 2318
DST#2
Well 6407/1 - 3
1012
1377
1071
1327
1420
1076
954
1135
1466
1176
1227
1255
1507
1554
1623
200
400
600
800
1000
1200
1400
1600
1800
2000