U-579 .3

STATOIL

SECTOR FOR PETROLEUM TECHNOLOGY

Geological laboratories

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Title		
GEOCHEMICAL DATA REPORT: DST-1 AND DST-2 FROM 6506/12-8 WELL		
Requested by T. G. Gloppen, LET-K	**Project** WELL 6506/12-8, GEOCHEMISTRY	
Date 12.12.88	**No. of pages**	**No. of enclosures**

Key words

Abstract

The present report is in accordance with Statoil's requirements for analytical work and reporting within organic geochemistry.

Prepared by

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Text operator

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Prepared for

STATOIL

GEOCHEMICAL DATA REPORT

DST-1 AND DST-2 FROM
6506/12-8 WELL
CONTRACT T6192 NO. 40

November 1988

GEOCHEM

CONTENTS

INTRODUCTION

This report presents the results of geochemical analyses performed upon two DST fluids from Statoil's 6506/12-8 well.

The project was authorised by T. Meyer, Statoil Stavanger, under Contract T6192 No. 40.

ANALYTICAL

Samples of DST-2 (3915-3923 metres and 3934-3955 metres RKB) and DST-1 (4205-4221 metres and 4237-4277 metres RKB) were assigned the Geochem job number 1863.

The samples were analysed in accordance with a telexed specification (15.8.88). Analyses are as follows:

ANALYSIS	NUMBER
API Gravity	2
Whole Oil Chromatogram	2
C_2-C_8 Hydrocarbons	2
C_{15+} Chromatography	2
C_{15+} Saturates Chromatograms	2
C_{15+} Aromatics Chromatograms	2
Mass Fragmentogram (6 ion)	2
Carbon Isotope Ratios (5 fractions)	2

The results of these analyses are tested in tables 1 to 7 and presented graphically in figures 1 to 8.

A brief description of the analytical methods is enclosed at the back of this report.

GENERAL

Ten copies of this report and a magnetic tape of the numerical data have been forwarded to T. Meyer, Statoil, Stavanger. An additional copy of the data has been retained by Geochem for future consultation with authorised Statoil personnel.

The results of this study are proprietary to Statoil.

GEOCHEM

TABLE 1

BULK OIL PROPERTIES

Geochem Sample Number	1863-001	1863-002
Identification	DST-2	DST-1
Depth (MRKB)	3915-23+	4205-21+
	3934-55	4237-77
API Gravity (API)	39.4	42.3
210 C + Fraction (%)	79.6	70.6

GEOCHEM

TABLE 2a
DETAILED GASOLINE RANGE (C_4 - C_7) COMPOSITION

GEOCHEM SAMPLE NUMBER	1863-001	1863-002
DEPTH	3915-23 & 3934-55	4205-21 & 4237-77
SAMPLE TYPE	DST-2	DST-1
Ethane	0.04	0.02
Propane	0.29	0.51
isobutane	0.45	0.53
n-butane	2.34	3.29
isopentane	2.99	3.60
n-pentane	4.89	4.86
2,2-dimeth1B	1.04	0.15
cyclopentane	0.73	0.99
2,3-dimethy1B	0.21	0.00
2-methy1P	3.61	4.31
3-methy1P	2.26	2.46
n-hexane	6.86	6.07
methy1CP	4.22	4.75
2,2-dimethy1P	0.39	0.52
2,4-dimethy1P	0.00	0.00
2,2,3-trimethy1B	0.00	0.00
benzene	1.93	1.98
cyclohexane	7.17	7.11
3,3-dimethy1P	0.00	0.00
1,1-dimethy1CP	0.00	0.00
2-MH	3.61	2.73
2,3-dimethy1P	0.00	0.60
3-MH	2.70	2.60
1,c,3-DMCP	0.93	0.93
1,t.3-DMCP	0.62	0.52
1,t,2-DMCP	2.23	2.09
3-ethy1P	0.00	0.00
n-heptane(nC7)	8.04	7.70
methy1CH	11.70	12.25
1,c,2DMCP	0.00	0.00
toluene	7.09	7.06
C7	0.70	0.00
ethy1CP	0.70	1.33
C8	0.20	0.00
C8	0.42	0.00
Trimethyl CP	0.69	0.66
Trimethyl CP	0.57	0.52
C8	0.08	0.07
C8	0.39	0.00
C8	0.80	1.05
2 Methyl	4.54	3.94
3 Methyl Hp	3.29	5.03
C7	0.41	0.34
C8	0.19	0.17
Dimethyl CH	1.09	0.77
Dimethyl CH	1.24	1.16
C8	0.45	0.00
n-octane (n8)	7.88	7.35

DMCP *dimethylcyclopentane* **MH** *methylhexane* **B** *butane* **CH** *cyclohexane* **CP** *cyclopentane* **H** *hexane* **P** *pentane*

TABLE 2b
DETAILED GASOLINE (C_4–C_7) ANALYSIS

GEOCHEM SAMPLE NUMBER	001	002
DEPTH	3915-23 & 3934-55	4205-21 & 4237-77
isobutane	0.59	0.69
n-butane	3.08	4.26
isopentane	3.94	4.67
n-pentane	6.45	6.31
2,2-dimethylB	1.36	0.19
cyclopentane(CP)	0.96	1.28
2,3-dimethylB	0.25	0.00
2-methylP	4.75	5.59
3-methylP	2.94	3.19
n-hexane	8.97	7.88
methylCP(MCP)	5.54	6.16
2,2-dimethylP	0.48	0.67
2,4-dimethylP	0.00	0.00
2,2,3-trimethylB	0.00	0.00
benzene	2.54	2.56
cyclohexane(CH)	9.46	9.22
3,3-dimethylP	0.00	0.00
1,1-dimethylCP	0.00	0.00
2-methylH	4.76	3.54
2,3-dimethylP	0.00	0.78
3-methylH	3.56	3.38
1,c,3-dimethylCP	1.23	1.20
1,t,3-dimethylCP	0.82	0.67
1,t,2-dimethylCP	2.91	2.71
3-ethylP	0.00	0.00
n-heptane	10.59	9.99
methylCH(MCH)	15.44	15.90
1,c,2-dimethylCP	0.00	0.00
toluene	9.36	9.16
ABUNDANCE		
nC7/C7nap x100	51.91	48.78
MCP/Bz	2.18	2.41
MH/DMCP	1.68	1.51
nC6/MCP	1.62	1.28
%n-PARAFFINS	29.09	28.44
%iso-PARAFFINS	22.63	22.70
% NAPHTHENES	36.36	37.14
% AROMATICS	11.90	11.72

TABLE 3
COMPOSITION (NORMALISED %) OF C_{15+} MATERIAL

JOB			HYDROCARBONS		NON HYDROCARBONS		
GEOCHEM SAMPLE NUMBER	LITHO	DEPTH	Saturates	Aromatics	Preciptd. Asphaltenes	Eluted NSO's	Non eluted NSO's
1863-001	3915-55 DST-2		83.51	9.12	0.81	6.34	0.21
1863-002	4205-77 DST-1		85.58	8.43	0.72	5.06	0.21

S – shale, SS – sandstone, L – limestone, D – dolomite, M – mixed, see Table 1.

TABLE 4

COMPOSITION (NORMALISED %) OF C_{15+} SATURATE (PARAFFIN – NAPHTHENE) HYDROCARBONS

GEOCHEM SAMPLE NUMBER	001	002
DEPTH	3915-23 + 3934-55	4205-21 + 4237-77
SAMPLE TYPE	DST-2	DST-1
nC15	10.99	10.74
nC16	10.11	10.06
nC17	10.82	9.08
nC18	8.80	8.20
nC19	8.00	7.71
nC20	7.21	7.32
nC21	6.60	6.74
nC22	6.77	6.25
nC23	5.72	5.76
nC24	4.75	5.66
nC25	4.13	4.79
nC26	3.43	4.10
nC27	2.81	3.42
nC28	2.73	2.73
nC29	2.20	2.34
nC30	1.50	1.66
nC31	1.14	1.17
nC32	0.79	0.78
nC33	0.62	0.59
nC34	0.62	0.59
nC35	0.26	0.29
Paraffin	53.48	53.78
Isoprenoid	7.01	7.35
Naphthene	39.51	38.87
CPI 1 Index	0.98	1.00
CPI 2 Index	1.02	1.05
CPI 3 Index	0.91	1.00
Prist/Phytane	1.29	1.30
Prist/nC17	0.68	0.85
Phytane/nC18	0.65	0.73

C.P.I. 1 = $\frac{1}{2}\left(\frac{C21+C23+C25+C27}{C20+C22+C24+C26} + \frac{C21+C23+C25+C27}{C22+C24+C26+C28}\right)$

C.P.I. 2 = $\frac{1}{2}\left(\frac{C25+C27+C29+C31}{C24+C26+C28+C30} + \frac{C25+C27+C29+C31}{C26+C28+C30+C32}\right)$

C.P.I. 3 = $\frac{2x\ (C27)}{C26+C28}$

Job Number : 1863

CT – ditch cuttings **CO**– core **SWC** – sidewall core

TABLE 5
METHYLPHENANTHRENE INDICES (MPI)

GEOCHEM SAMPLE NUMBER	DEPTH	SAMPLE TYPE	MPI 1		MPI 2	
			AREA	HEIGHT	AREA	HEIGHT
WELL: 6506/12-8						
1863-001	3915- 3955m	DST-2	1.10	0.98	1.32	1.11
1863-002	4205- 4277m	DST-1	1.14	1.30	1.31	1.40

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

CT - ditch cuttings CO - core SWC - sidewall core

Table 6a

BIOMARKER PEAK HEIGHTS (SIR)

STERANES M/Z 217

SAMPLES	DEPTH	29E	29F	29G	29H
1863-001R	3915-55	29.5	44.0	36.0	24.5
1863-002R	4205-77	40.0	61.0	55.0	34.0

JB15

Table 6b

BIOMARKER PEAK HEIGHTS (SIR)

STERANES M/Z 218

SAMPLES	DEPTH	27F	27G	28F	28G	29F	29G
1863-001R	3915-55	106.5	89.5	104.5	108.0	117.0	105.0
1863-002R	4205-77	98.0	85.0	103.0	100.0	109.5	118.0

Table 6c

BIOMARKER PEAK HEIGHTS

TRIPERPANES M/Z 191

SAMPLES	DEPTH	Q	27A	27B	28A	29A	29B	X	30A	30B	31A	31B
1863-001R	3915-55		50.0	27.0	8.0	69.5	7.0	27.0	113.0	12.0	48.0	41.0
1863-002R	4205-77		38.5	25.0	21.0	62.0	6.0	22.5	119.0	10.0	53.0	37.0

SAMPLES	DEPTH	32A	32B	33A	33B	34A	34B
1863-001R	3915-55	36.5	22.0	29.0	21.0	18.0	11.5
1863-002R	4205-77	43.0	28.0	31.5	23.0	19.0	14.0

JB15

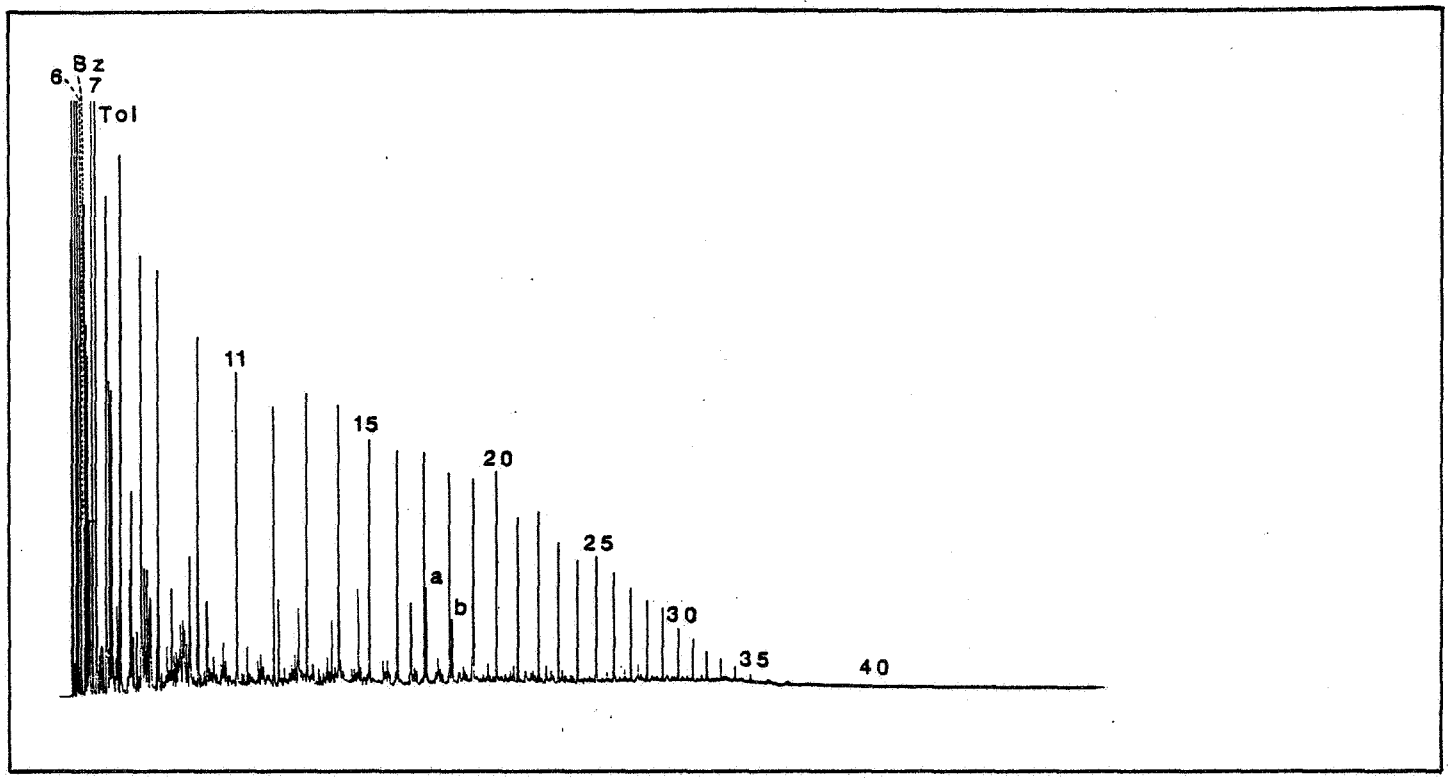
TABLE 7

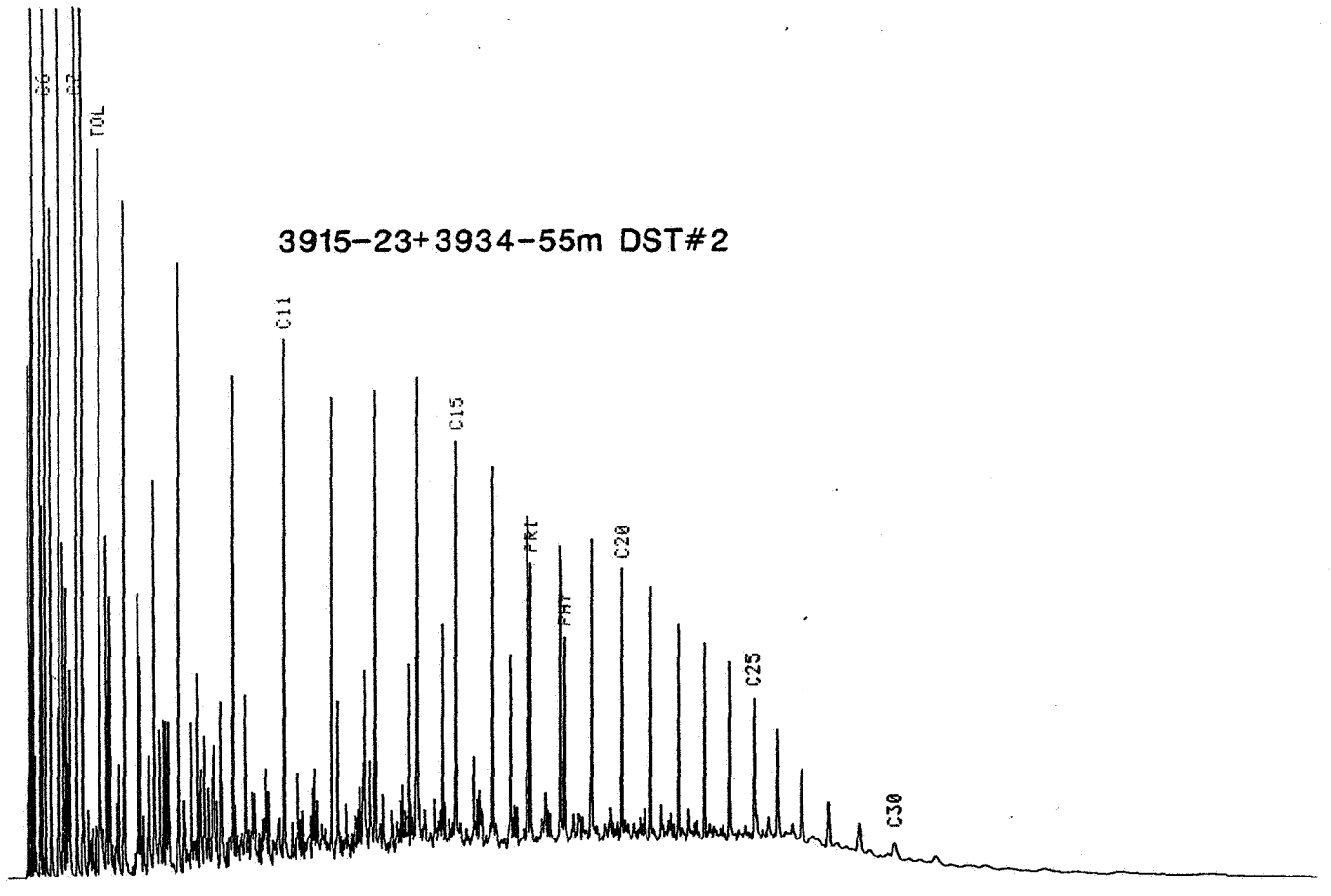
CARBON ISOTOPE COMPOSITIONS (‰,PDB)

GEOCHEM SAMPLE NUMBER	DEPTH	TOTAL EXTRACT WHOLE OIL	SATURATES	AROMATICS	NSO	ASPHALTENES	KEROGEN	PYROLYSATE (S2)
WELL: 6506/12-8								
1863-001	3915-55	-29.15	-29.40	-27.96	-28.47	-29.18		
1863-002	4205-77	-29.24	-29.52	-27.98	-28.58	-29.27		

FIGURE 1a **WHOLE OIL CHROMATOGRAMS**

WELL 6506/12-8





a = PRISTANE
b = PHYTANE

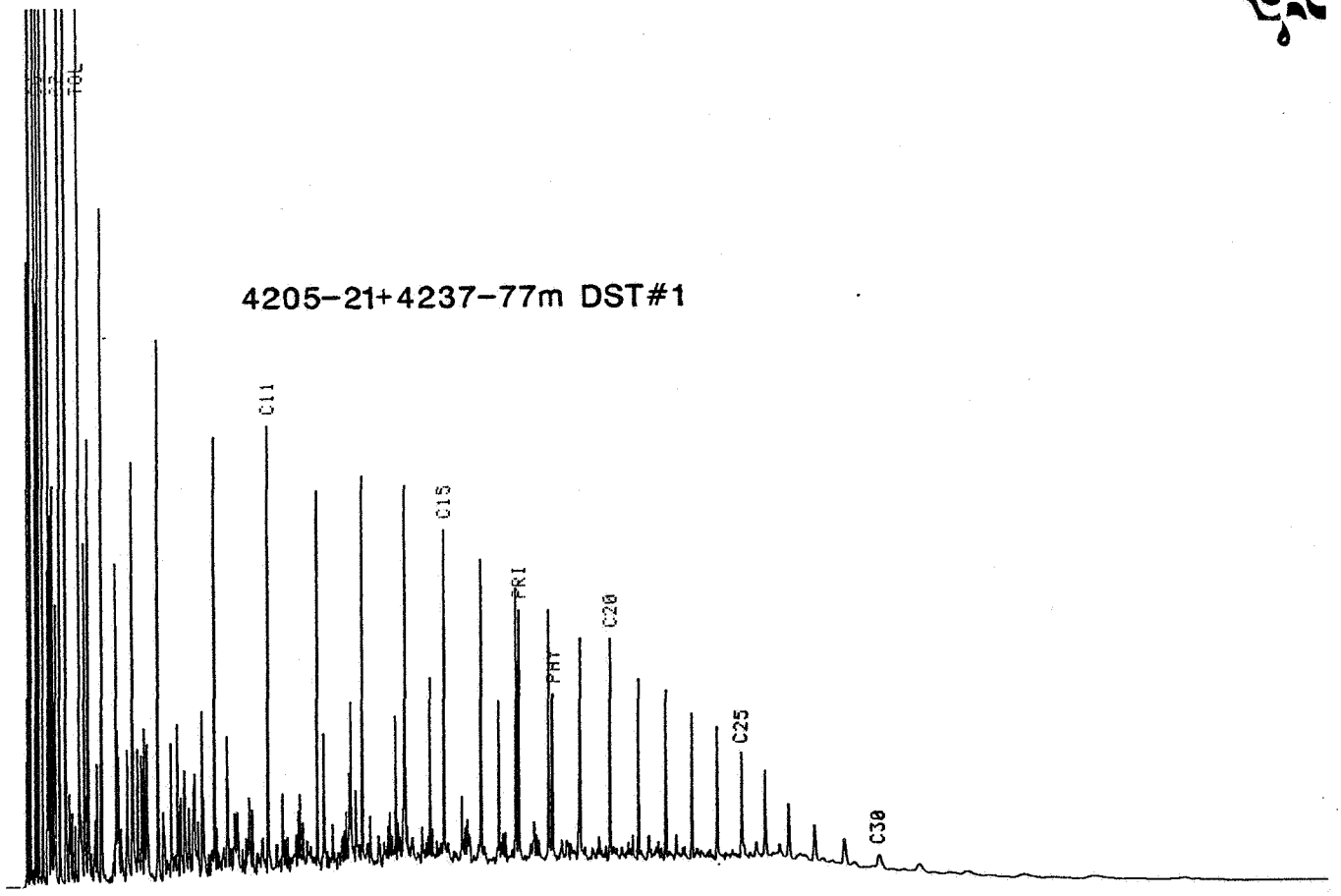
Bz = BENZENE
To = TOLUENE

NORMAL PARAFFINS IDENTIFIED BY CARBON NUMBERS

FIGURE 1b

WHOLE OIL CHROMATOGRAMS

WELL 6506/12-8



a = PRISTANE
b = PHYTANE

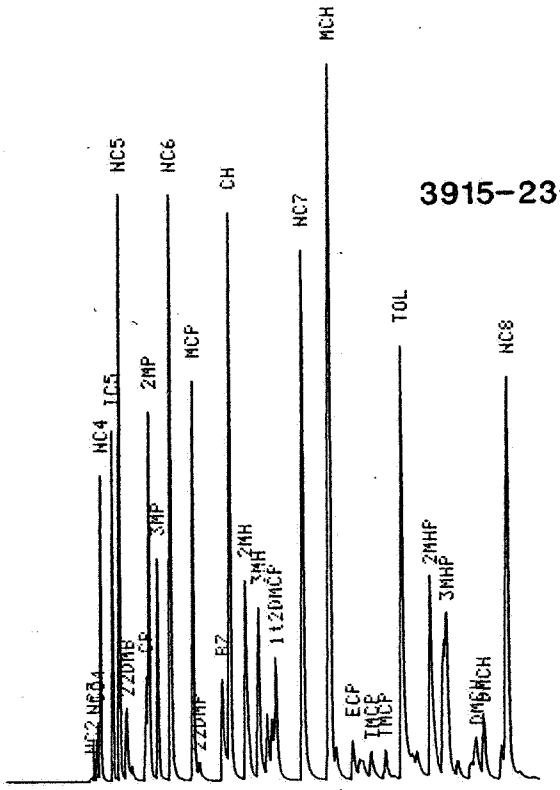
Bz = BENZENE
To = TOLUENE

NORMAL PARAFFINS IDENTIFIED BY CARBON NUMBERS

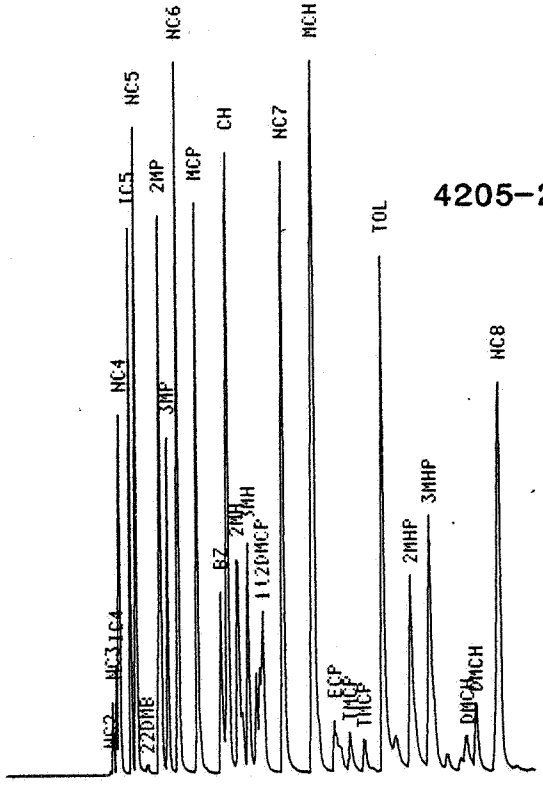
FIGURE 2

C_2-C_8 CHROMATOGRAMS

WELL 6506/12-8



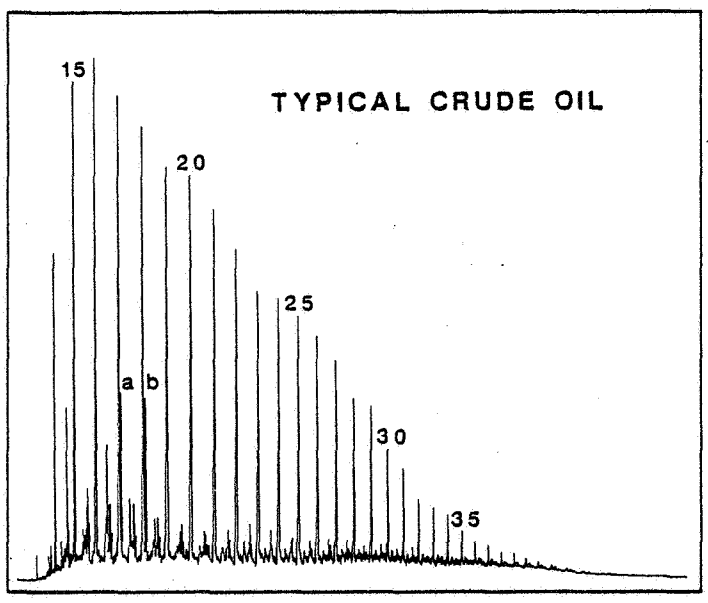
3915-23+3934-55m DST#2

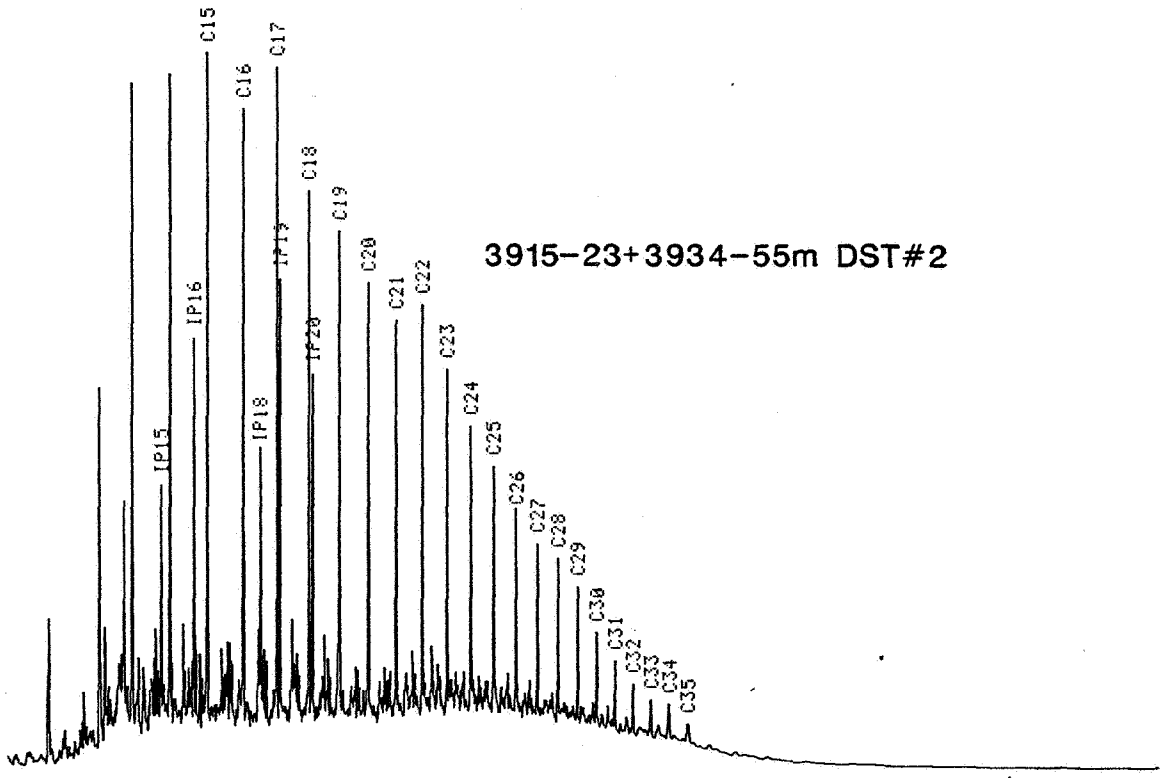


4205-21+4237-77m DST#1

FIGURE 3a C_{15+} SATURATES CHROMATOGRAMS

WELL 6506/12-8





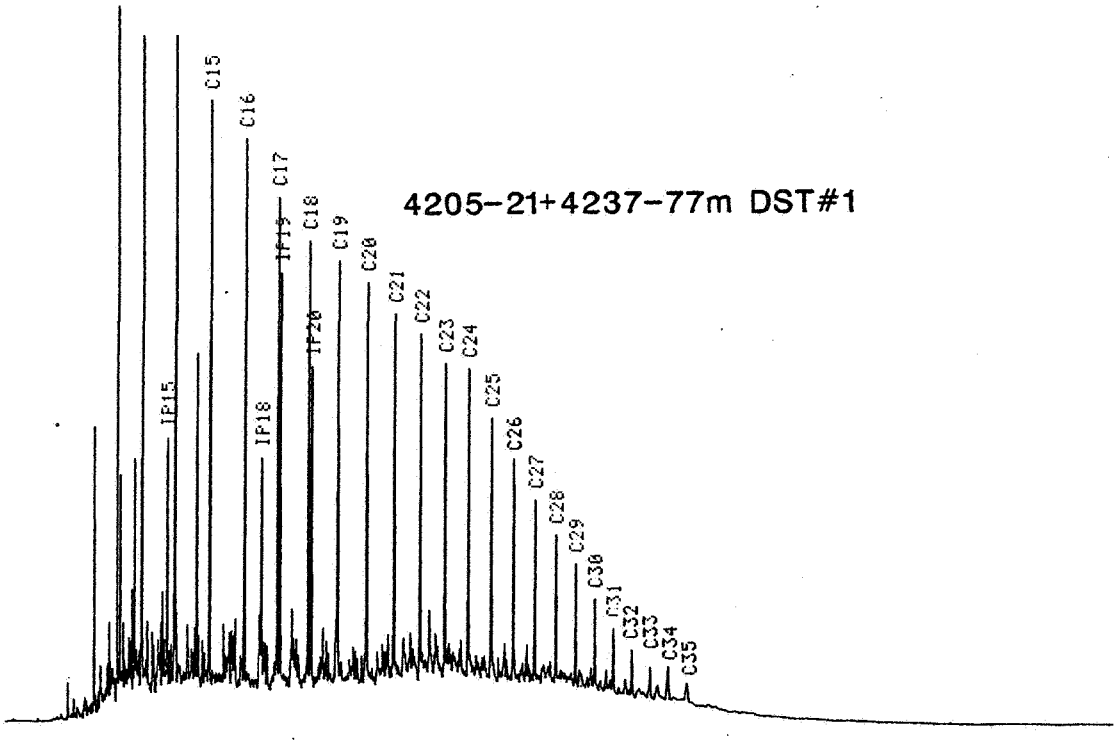
a = PRISTANE

b = PHYTANE

CARBON NUMBERS OF NORMAL PARAFFINS INDICATED ($20-nC_{20}$)

FIGURE 3b C_{15+} SATURATES CHROMATOGRAMS

WELL 6506/12-8



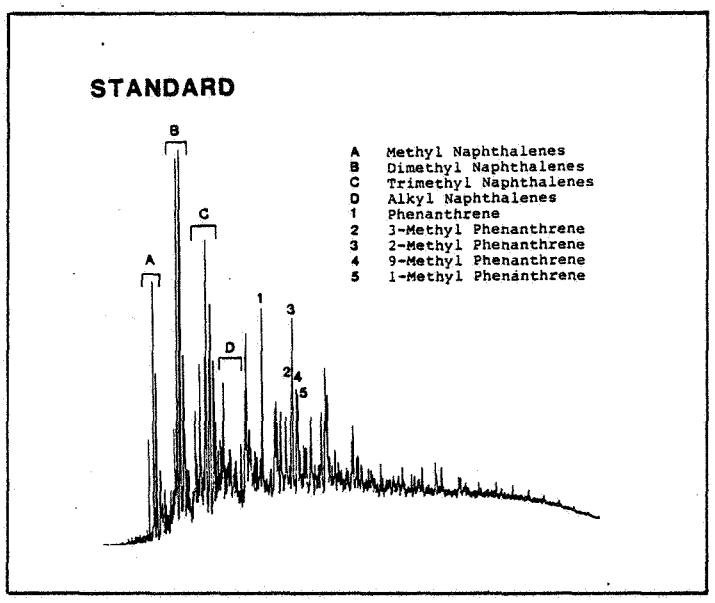
a = PRISTANE

b = PHYTANE

CARBON NUMBERS OF NORMAL PARAFFINS INDICATED (20 - nC_{20})

FIGURE 4a C_{15+} AROMATIC CHROMATOGRAMS

WELL 6506/12-8



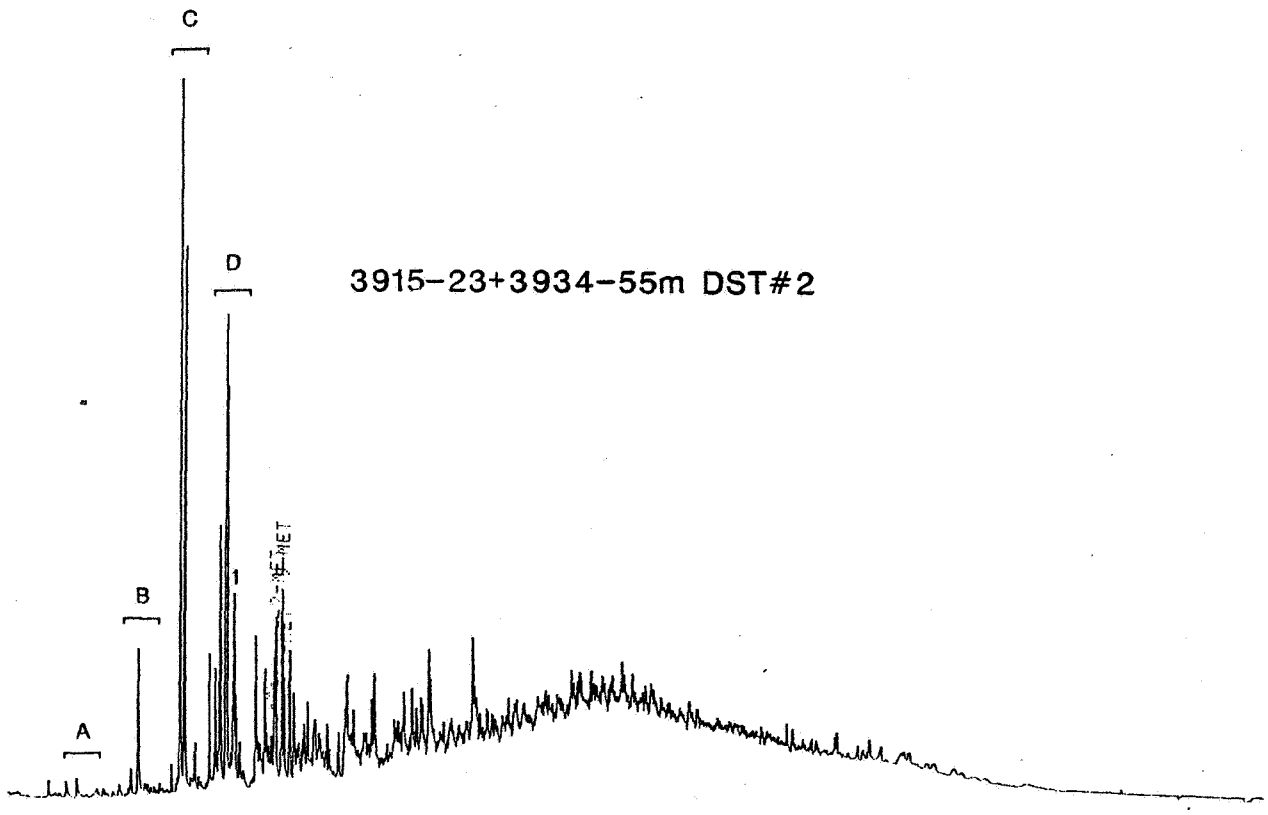
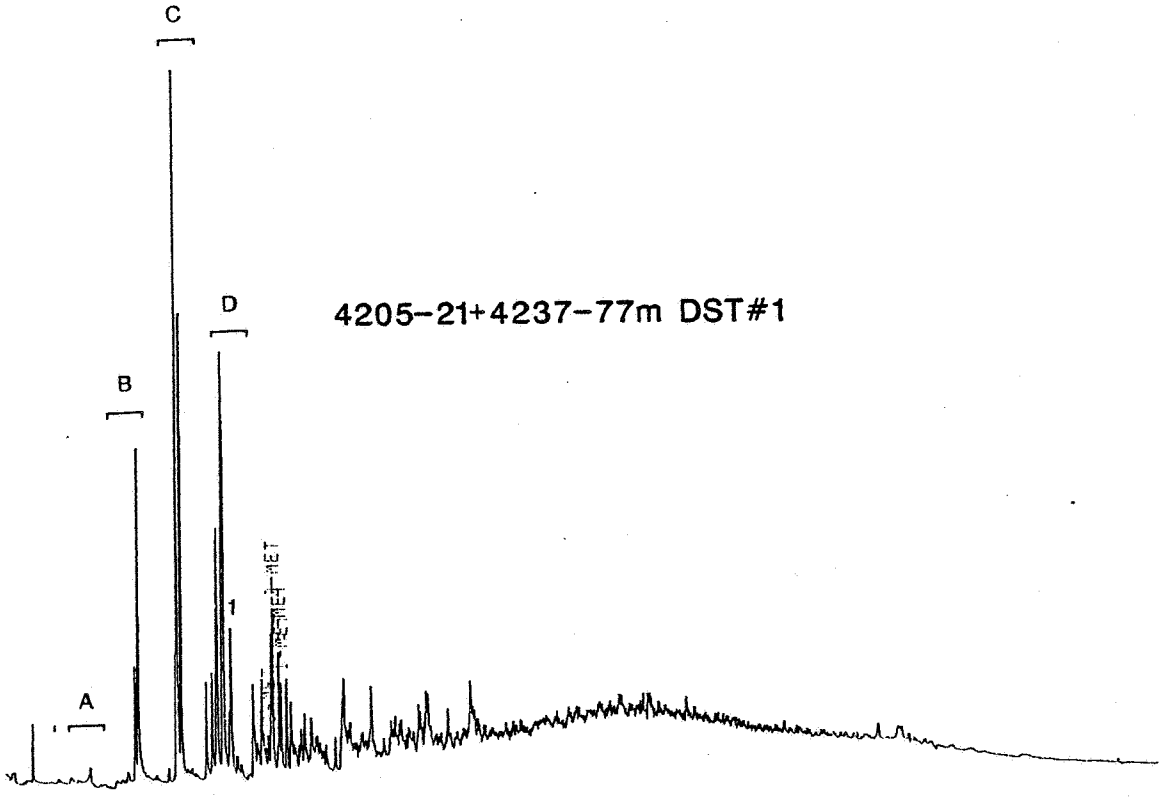


FIGURE 4b C_{15+} AROMATIC CHROMATOGRAMS

WELL 6506/12-8



PEAK IDENTIFICATION ON FIRST SHEET

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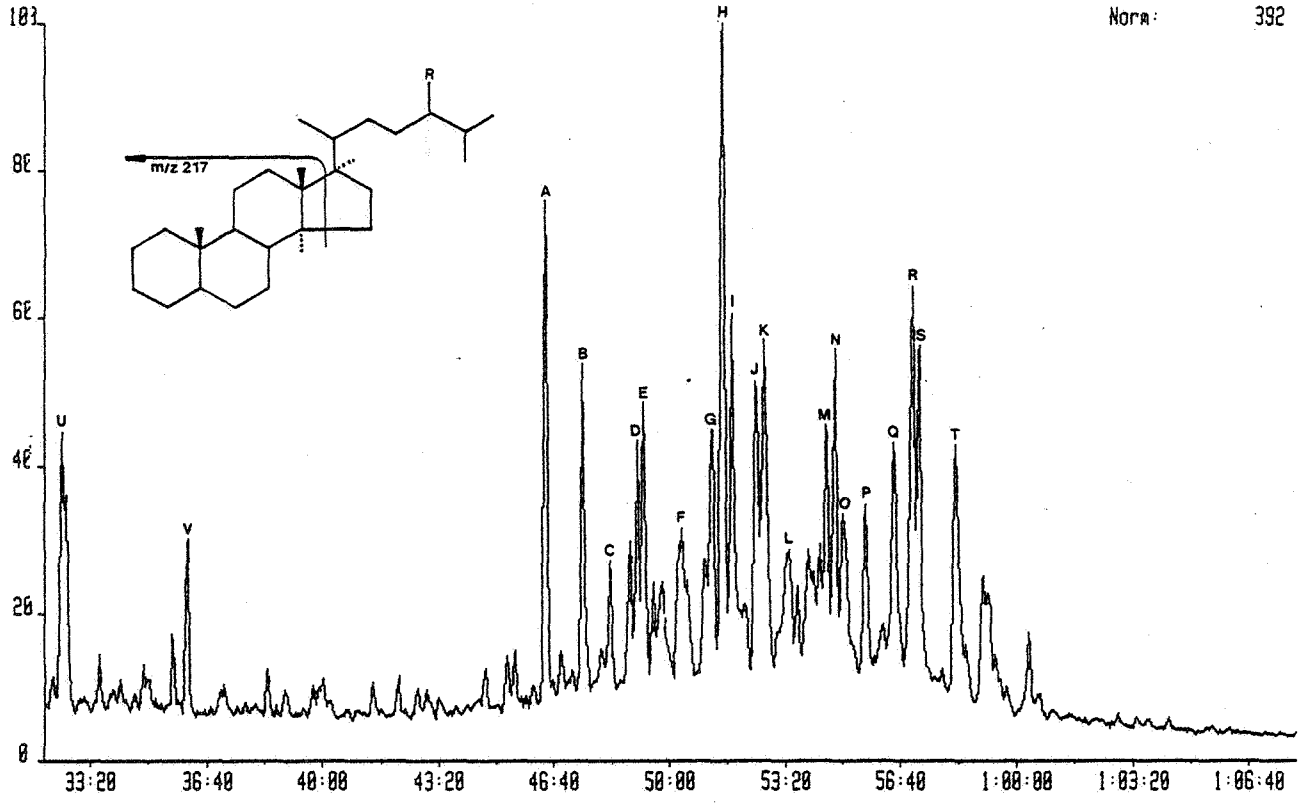
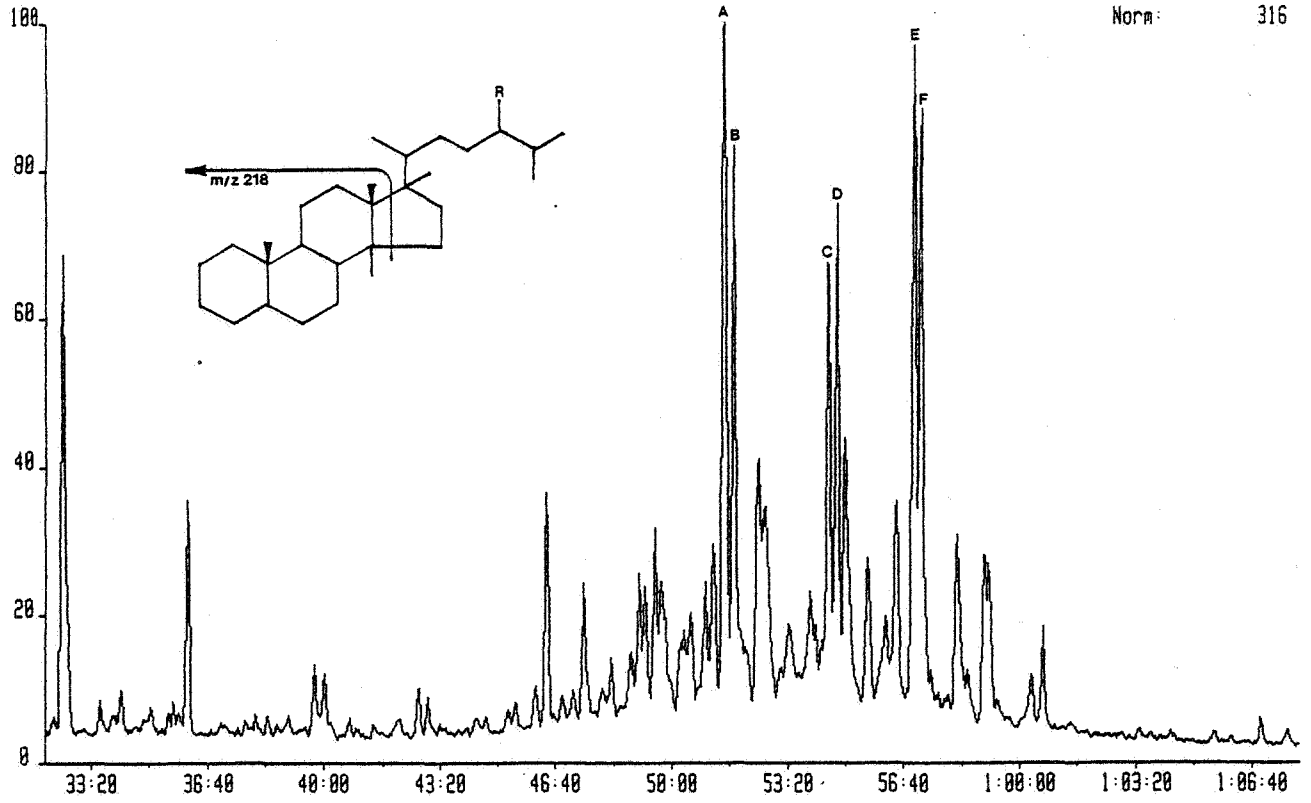
Sample 1 Injection 1 Group 1 Mass 217.1956
Text:BIOMARKER TEST RUN



STERANE IDENTIFICATION
(m/z 217 FRAGMENTOGRAM)

	COMPOUND	ELEMENTAL COMPOSITION
A	13β, 17α -diacholestane (20S)	$C_{27}H_{48}$
B	13β, 17α -diacholestane (20R)	$C_{27}H_{48}$
C	13α, 17β -diacholestane (20S)	$C_{27}H_{48}$
D	13α, 17β -diacholestane (20R)	$C_{27}H_{48}$
E	24-methyl - 13β, 17α -diacholestane (20S)	$C_{28}H_{50}$
F	24-methyl - 13β, 17α -diacholestane (20R)	$C_{28}H_{50}$
G	24-methyl - 13β, 17α -diacholestane (20S)	$C_{28}H_{50}$
+	14α, 17α -cholestane (20S)	$C_{27}H_{48}$
H	24-ethyl - 13β, 17α -diacholestane (20S)	$C_{29}H_{52}$
+	14β, 17β -cholestane (20R)	$C_{27}H_{48}$
I	14β, 17β -cholestane (20S)	$C_{27}H_{48}$
+	24-methyl - 13α, 17β -diacholestane (20R)	$C_{28}H_{50}$
J	14α, 17α -cholestane (20R)	$C_{27}H_{48}$
K	24-ethyl -13β, 17α-diacholestane (20R)	$C_{29}H_{52}$
L	24-ethyl -14α, 17α-diacholestane (20S)	$C_{29}H_{52}$
M	24-methyl -13β, 17β-cholestane (20S)	$C_{28}H_{50}$
N	24-ethyl -13β, 17β-diacholestane (20R)	$C_{29}H_{52}$
+	24-methyl -14α, 17β-cholestane (20R)	$C_{28}H_{50}$
O	24-methyl -14α, 17α-cholestane (20S)	$C_{28}H_{50}$
P	24-methyl -14α, 17α-cholestane (20R)	$C_{28}H_{50}$
Q	24-ethyl -14α, 17α-cholestane (20S)	$C_{29}H_{52}$
R	24-ethyl -14β, 17β-cholestane (20R)	$C_{29}H_{52}$
+	UNKNOWN STERANE	
S	24-ethyl -14β, 17β-cholestane (20S)	$C_{29}H_{52}$
T	24-ethyl -14α, 17α-cholestane (20R)	$C_{29}H_{52}$
U	5α(H)-pregnane	$C_{21}H_{36}$
V	5α(H)-bisnorcholane	$C_{22}H_{38}$

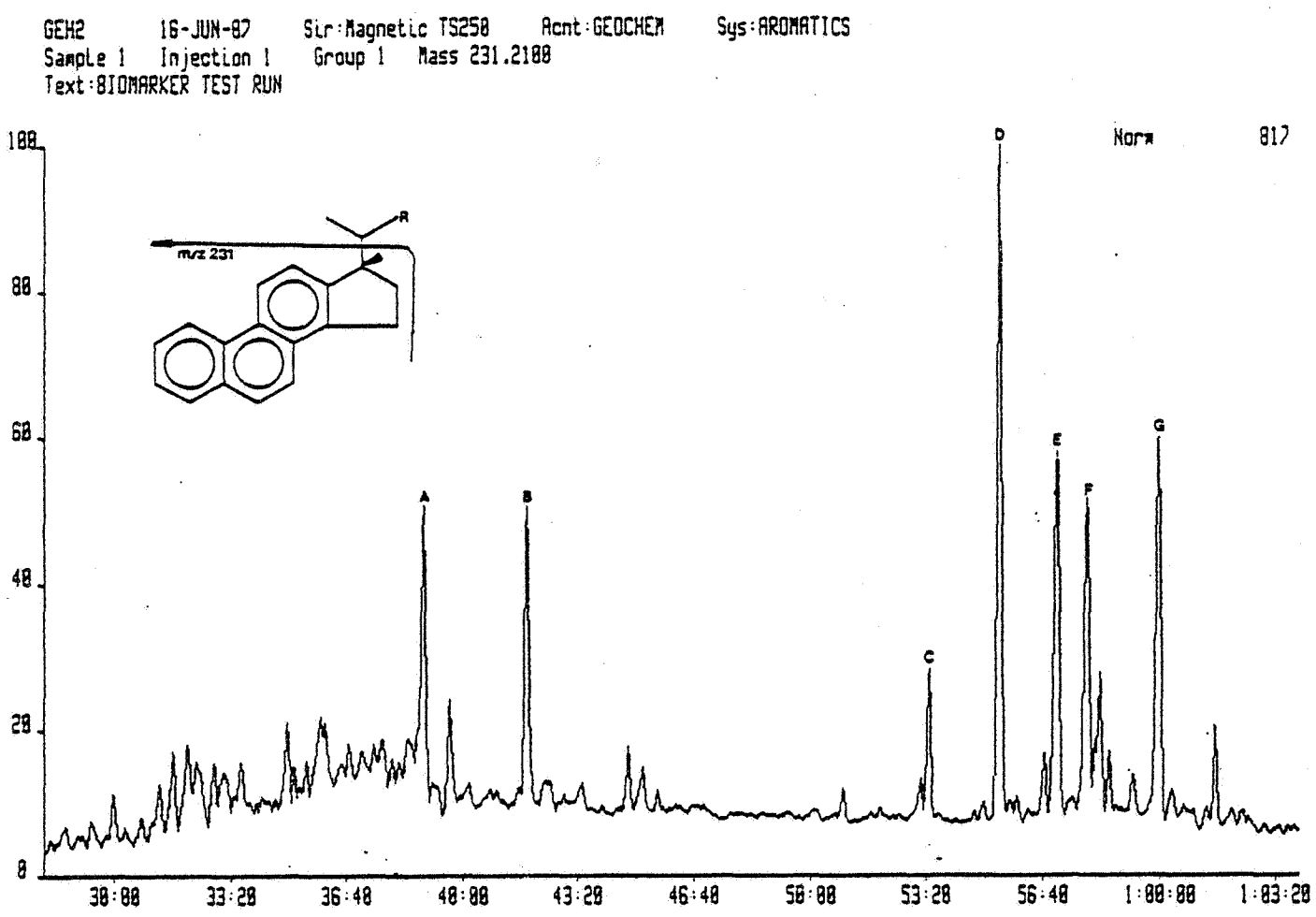
GEH1 16-JUN-87 Sir:Magnetic TS250 Acnt:GEOCHEM Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 218.2034
Text:BIOMARKER TEST RUN



STERANE IDENTIFICATION

(M/Z 218 FRAGMENTOGRAM)

	COMPOUND	ELEMENTAL COMPOSITION
A	14β,17β-cholestane (20R)	$C_{27}H_{48}$
B	14β,17β-cholestane (20S)	$C_{27}H_{48}$
C	24-methyl-14β,17β-cholestane (20R)	$C_{28}H_{50}$
D	24-methyl-14β,17β-cholestane (20S)	$C_{28}H_{50}$
E	24-ethyl-14β,17β-cholestane (20R)	$C_{29}H_{52}$
F	24-ethyl-14β,17β-cholestane (20S)	$C_{29}H_{52}$



PEAK IDENTIFICATION FOR TRIAROMATIC STERANES (M/Z 231)

A 20 Carbon Triaromatic Sterane
B 21 Carbon Triaromatic Sterane
C 26 Carbon (20S) Triaromatic Sterane
D 26 (20R) + 27(20S) Carbon Triaromatic Steranes
E 28 (20S) Triaromatic Sterane
F 27 (20R) Triaromatic Sterane
G 28 (20R) Triaromatic Sterane

GEH2 16-JUN-87 Sir:Magnetic TS250 Acnt:GEOCHEM Sys:AROMATICS
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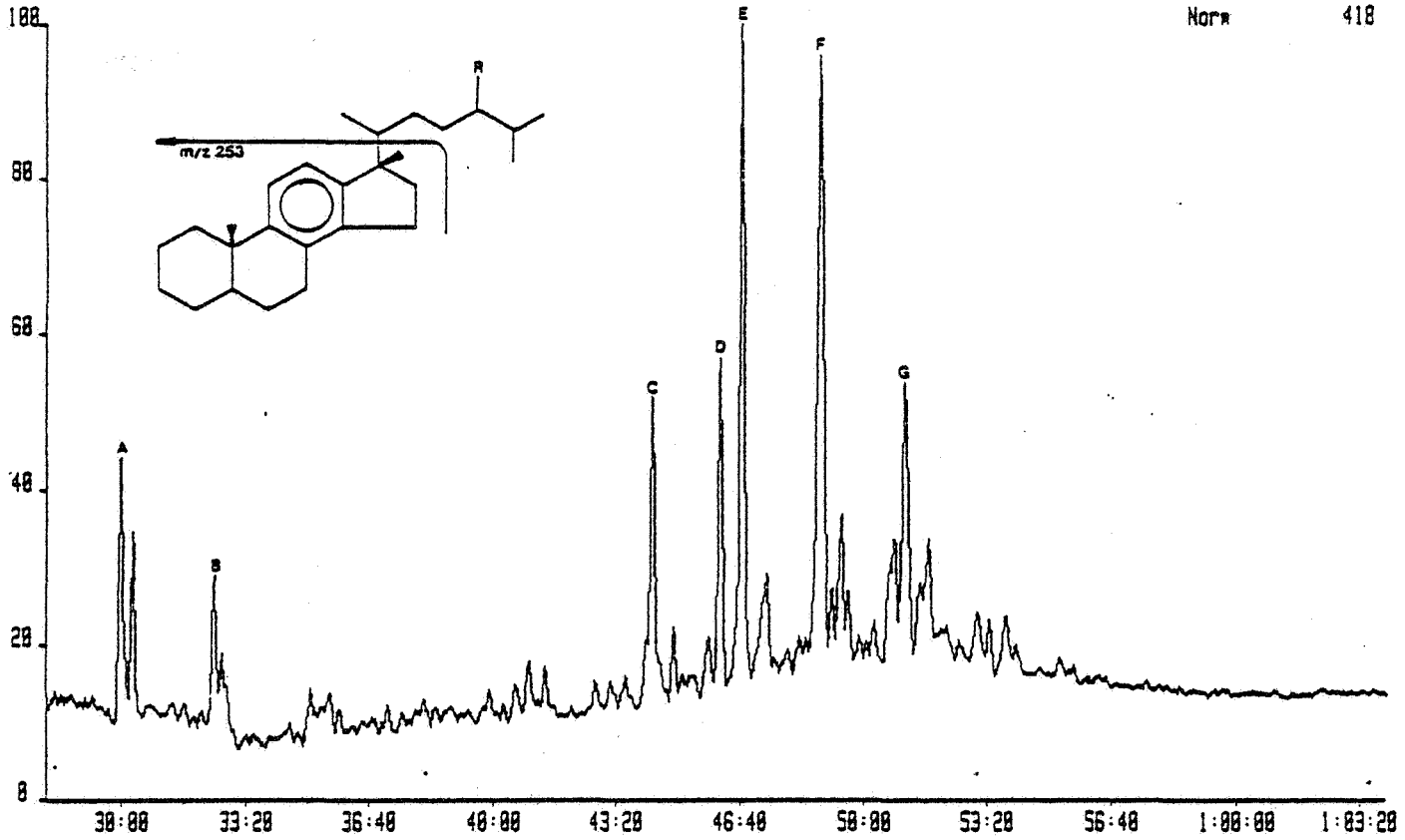

PEAK IDENTIFICATION FOR MONOAROMATIC STERANES (M/Z 253)

A 21 Carbon Monoaromatic Sterane
B 22 Carbon Monoaromatic Sterane
C 27 Carbon Monoaromatic Sterane
D 27 Carbon Monoaromatic Steranes
E 27 + 28 Carbon (20R) Monoaromatic Steranes
F 28 + 29 Carbon Monoaromatic Sterane
G 29 (20R) Carbon Monoaromatic Sterane

GEH1 16-JUN-87 Sir:Magnetic TS250 Acnt:GEOCHEM Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 259.2427
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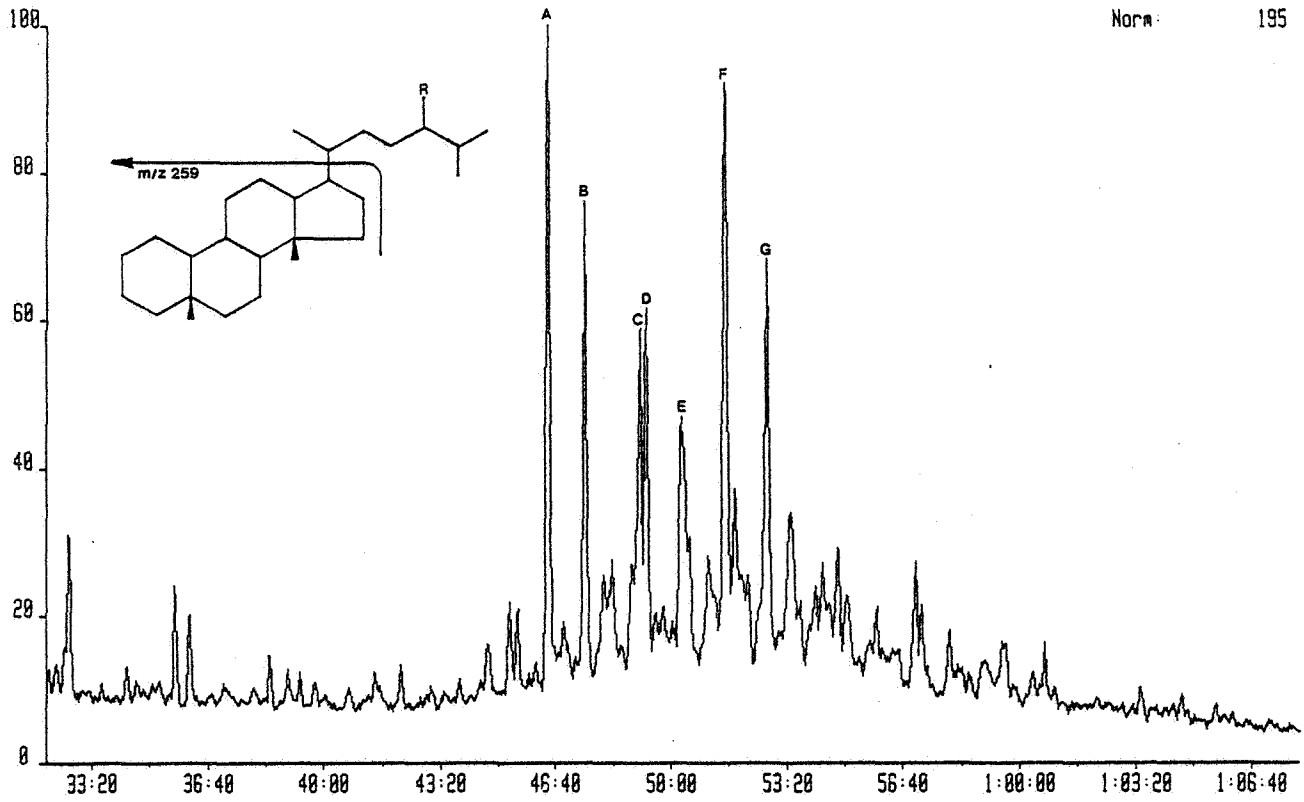


STERANE IDENTIFICATION

(M/Z 259 FRAGMENTOGRAM)

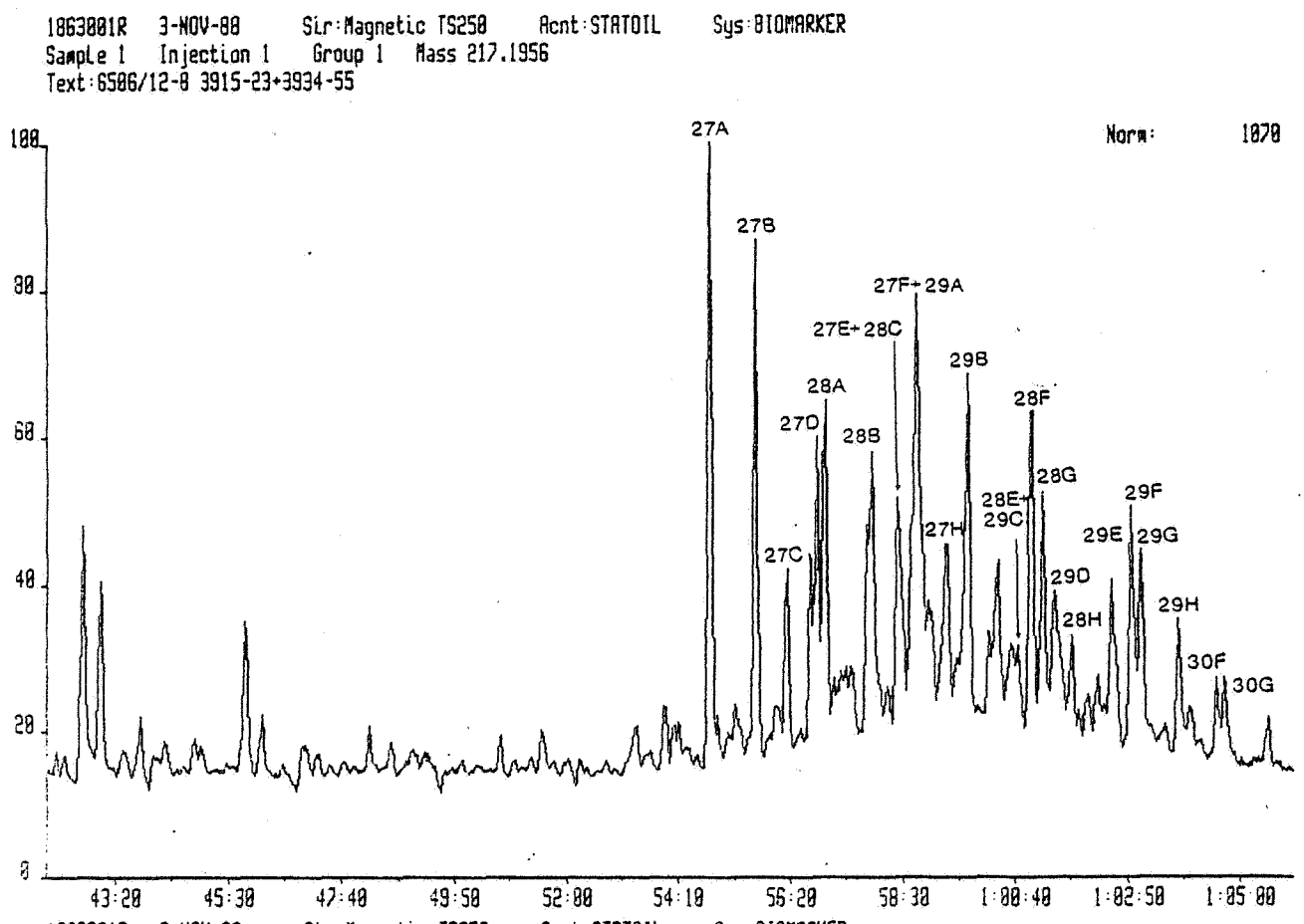
	COMPOUND	ELEMENTAL COMPOSITION
A	13β,17α-diacholestane (20S)	$C_{27}H_{48}$
B	13β,17α-diacholestane (20R)	$C_{27}H_{48}$
C	13α,17β-diacholestane (20R)	$C_{27}H_{48}$
D	24,-methyl-13β,17α-diacholestane (20S)	$C_{28}H_{50}$
E	24,-methyl-13β,17α-diacholestane (20R)	$C_{28}H_{50}$
F	24,-ethyl-13β,17α-diacholestane (20S)	$C_{29}H_{52}$
G	24,-ethyl-13β,17α-diacholestane (20R)	$C_{29}H_{52}$

FIGURE 5a

MASS FRAGMENTOGRAMS

WELL 6506/12-8

STERANES



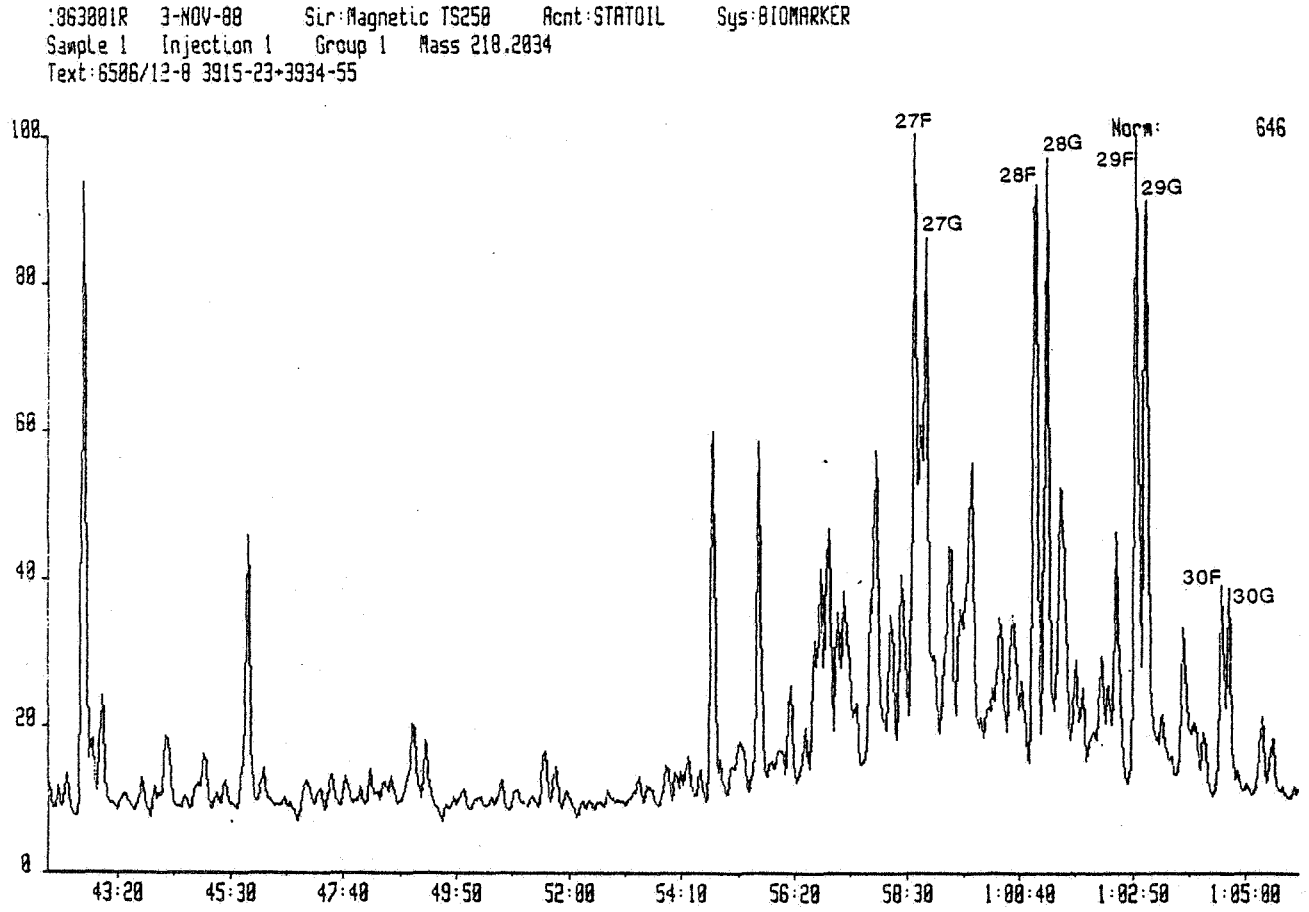


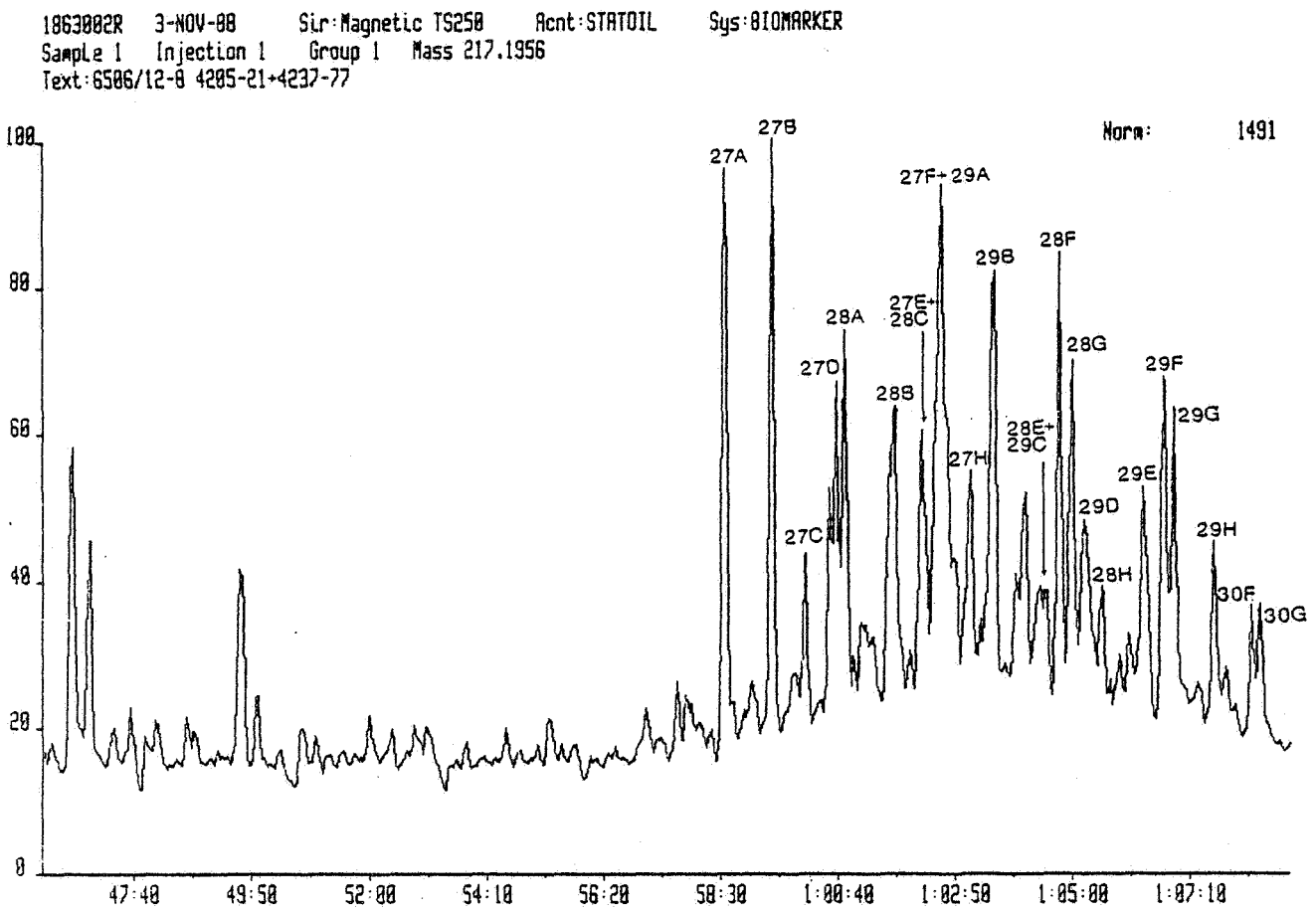
FIGURE 5b

MASS FRAGMENTOGRAMS

WELL 6506/12-8

STERANES

GEOCHEM



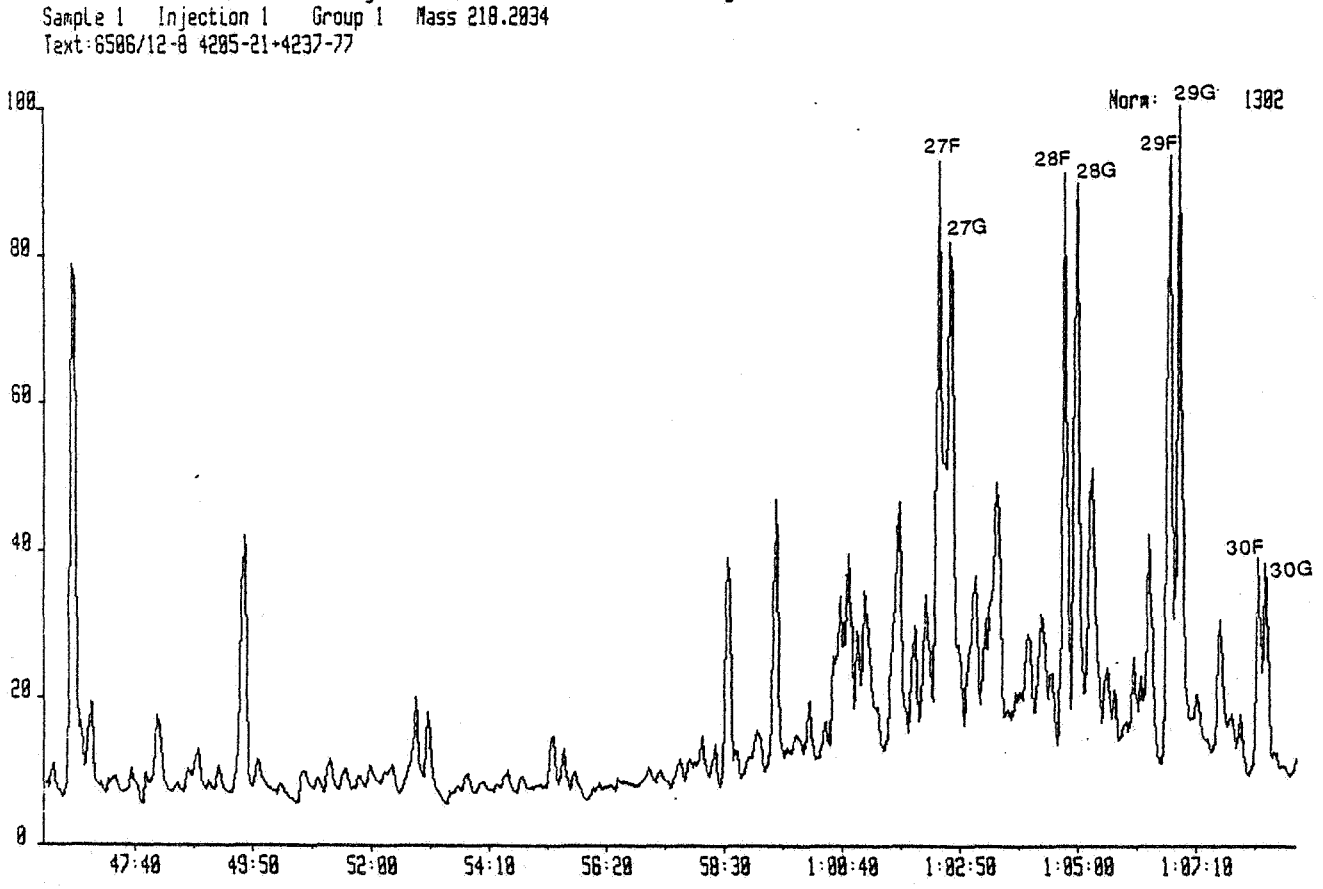


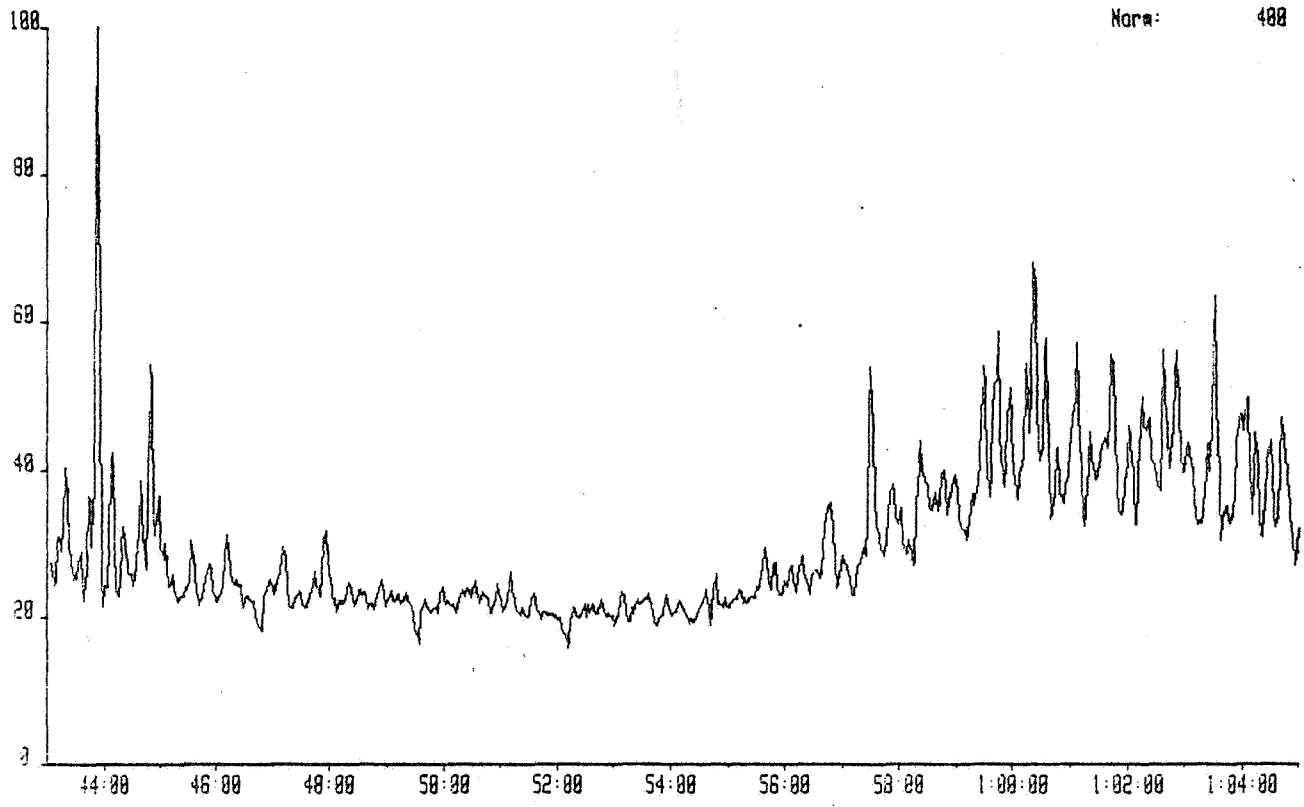
FIGURE 6a

MASS FRAGMENTOGRAMS

WELL 6506/12-8

STERANES

1863001R 3-NOV-88 Sir:Magnetic TS250 Acnt:STATOIL Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 231.2100
Text:6506/12-8 3915-23+3934-55



1863001R 3-NOV-88 Sir:Magnetic TS250 Acnt:STATOIL Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 259.2427
Text:6506/12-8 3915-23+3934-55

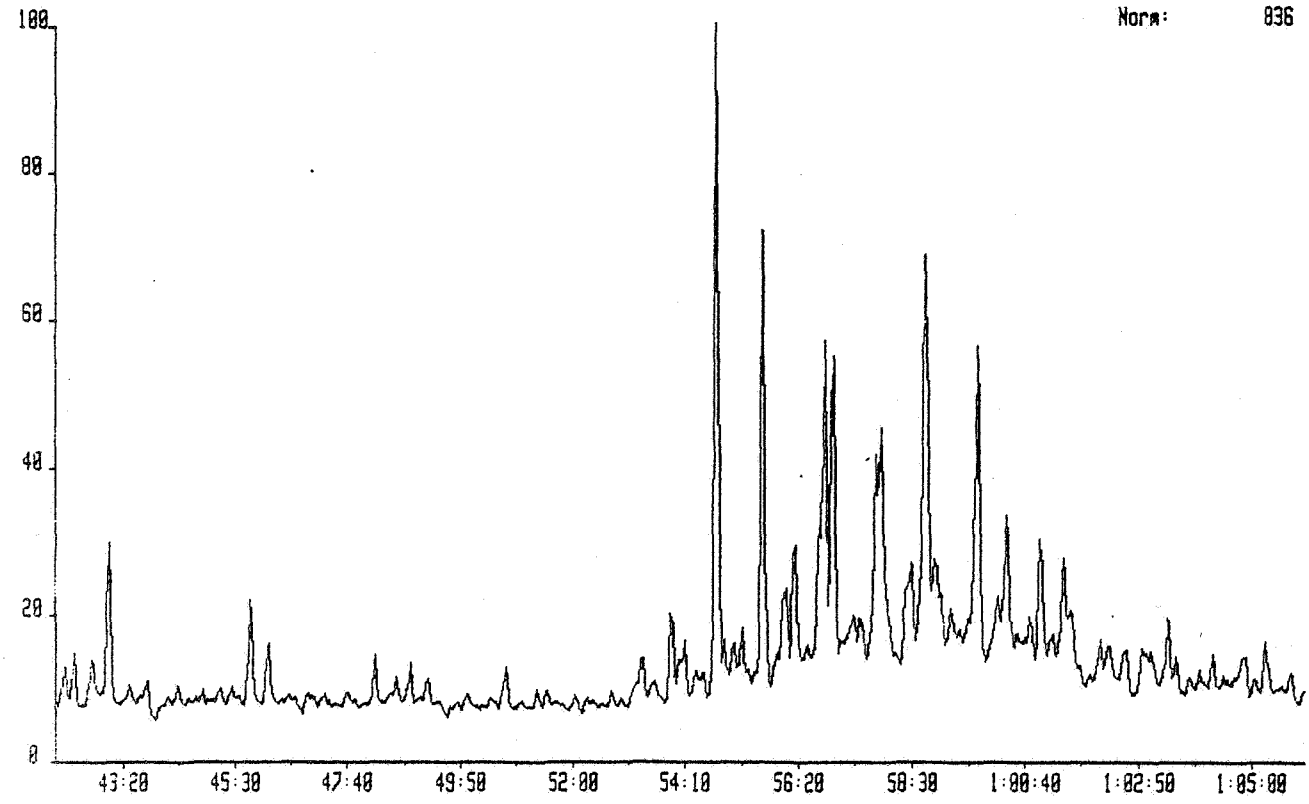
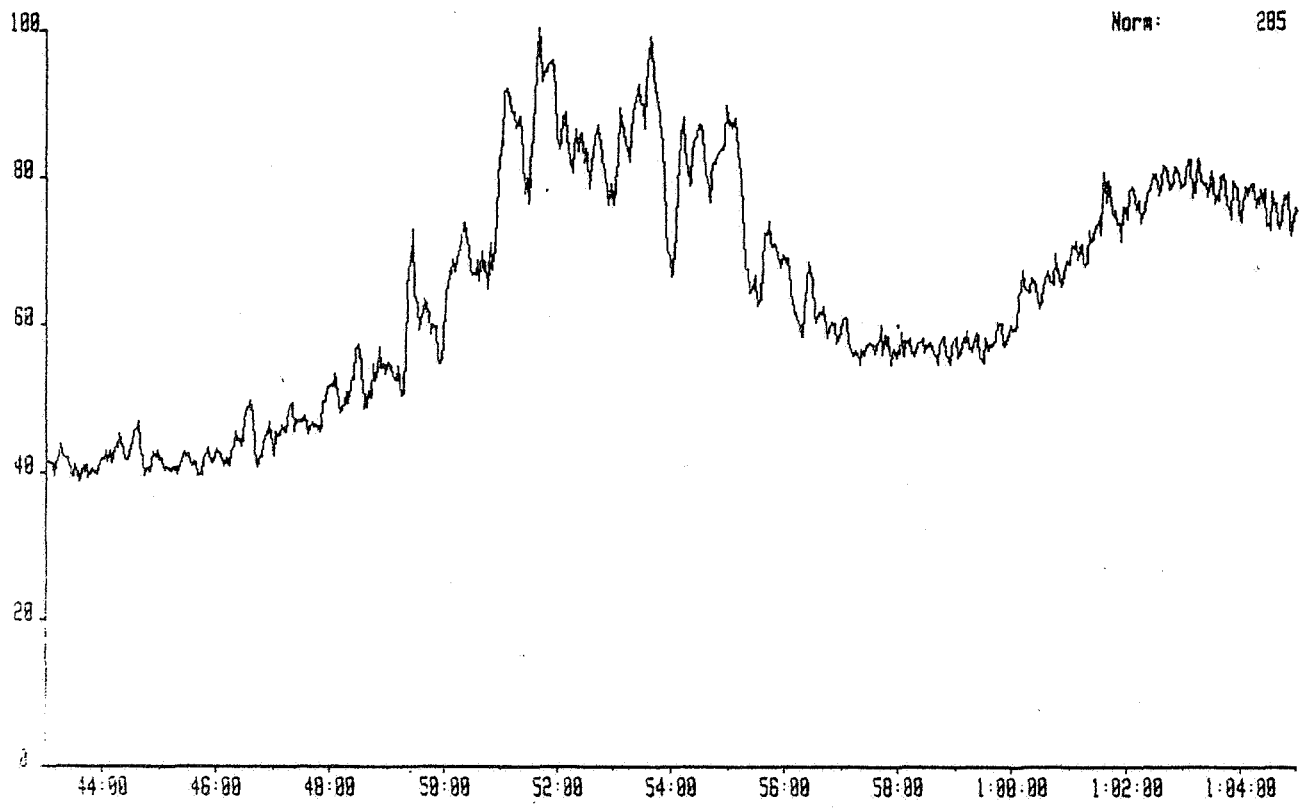


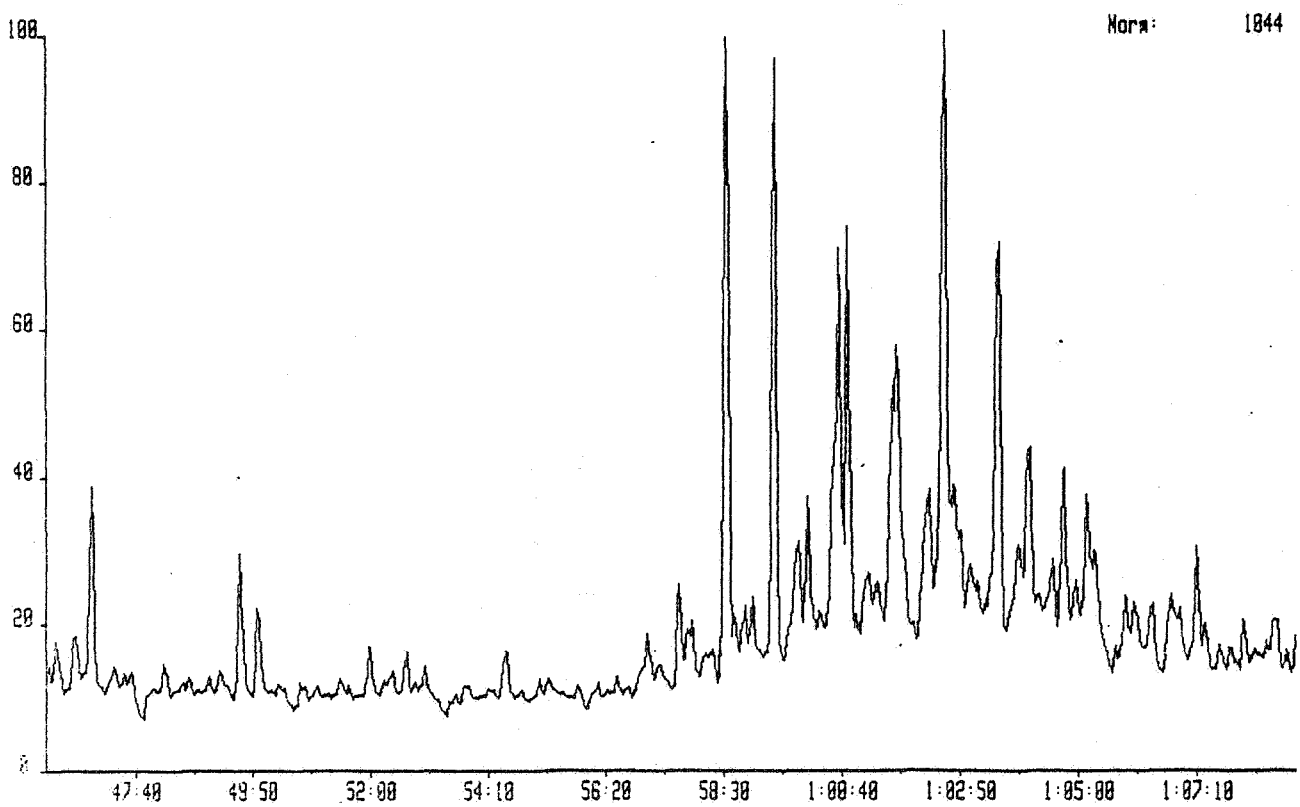
FIGURE 6b

MASS FRAGMENTOGRAMS

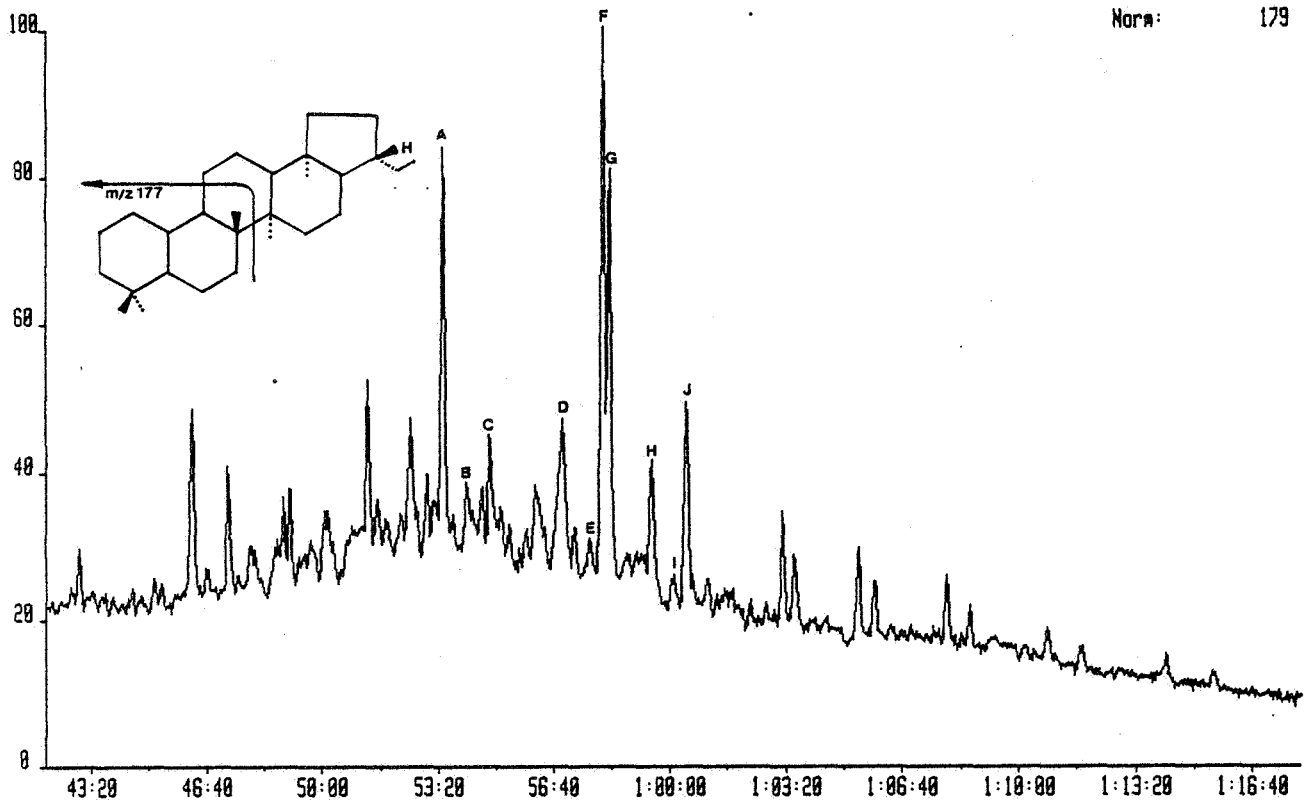
WELL 6506/12-8

STERANES





GEH1A 30-JUN-87 Sir:Magnetic TS250 Acnt:GEOCHEM Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 177.1642
Text:STANDARD BIOMARKER

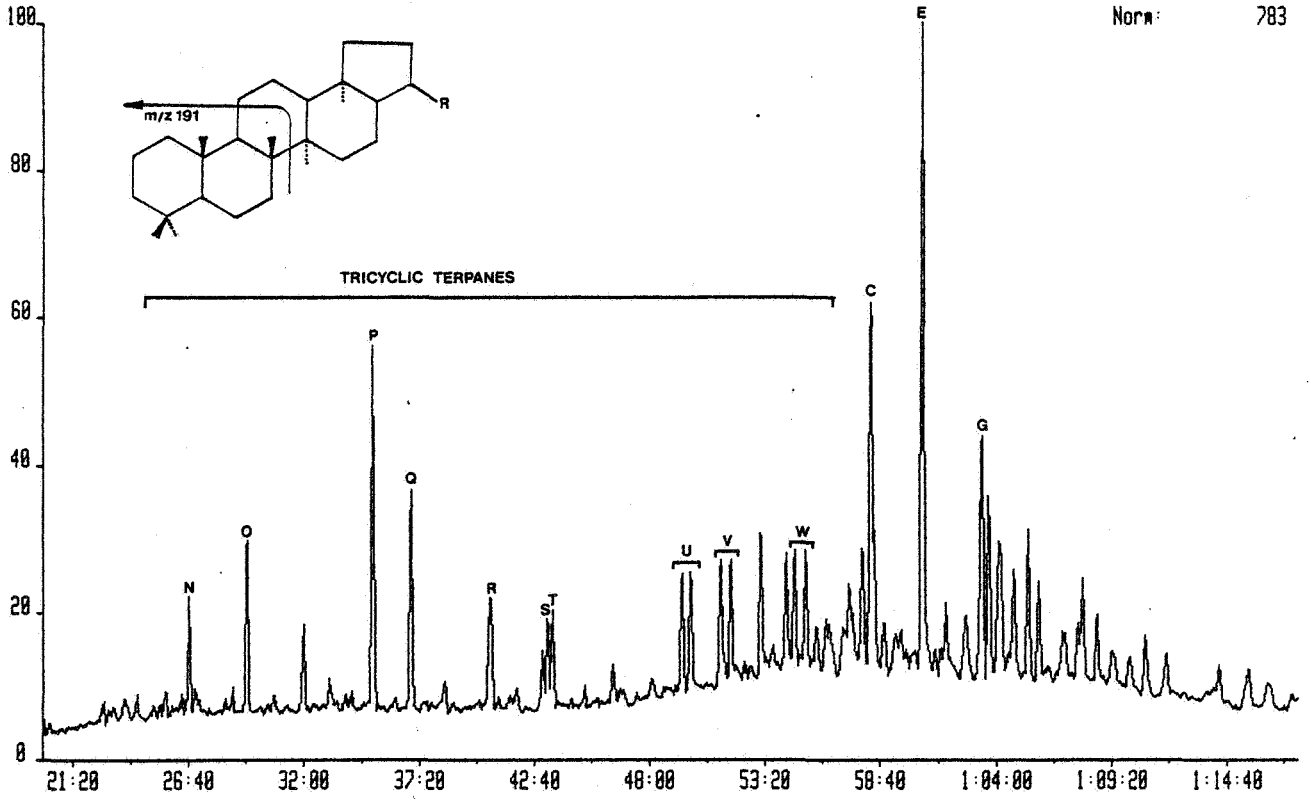


DEMETHYLATED HOPANES

(m/z 177 FRAGMENTOGRAM)

	COMPOUND
A	17α(H), 18α(H), 21β(H) 25, 28, 30 - trisnorhopane
B	17β(H), 18α(H), 21α(H) 25, 28, 30 - trisnormoretane
C	17α(H) -25, 30 - bisnorhopane
D	17α(H), 18α(H), 21β(H) -28, 30 bisnorhopane
E	17α(H),-25 - norhopane
F	17α(H) -30 - norhopane
G	X
H	17α(H) -30 - normoretane
I	(22S) -17α(H) -25 - norhomohopane
J	(22R) -17α(H) -25 - norhomohopane

1560007 1-JUL-87 Sir:Magnetic TS250 Acnt:GEOCHEM Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 191.1798
Text:0

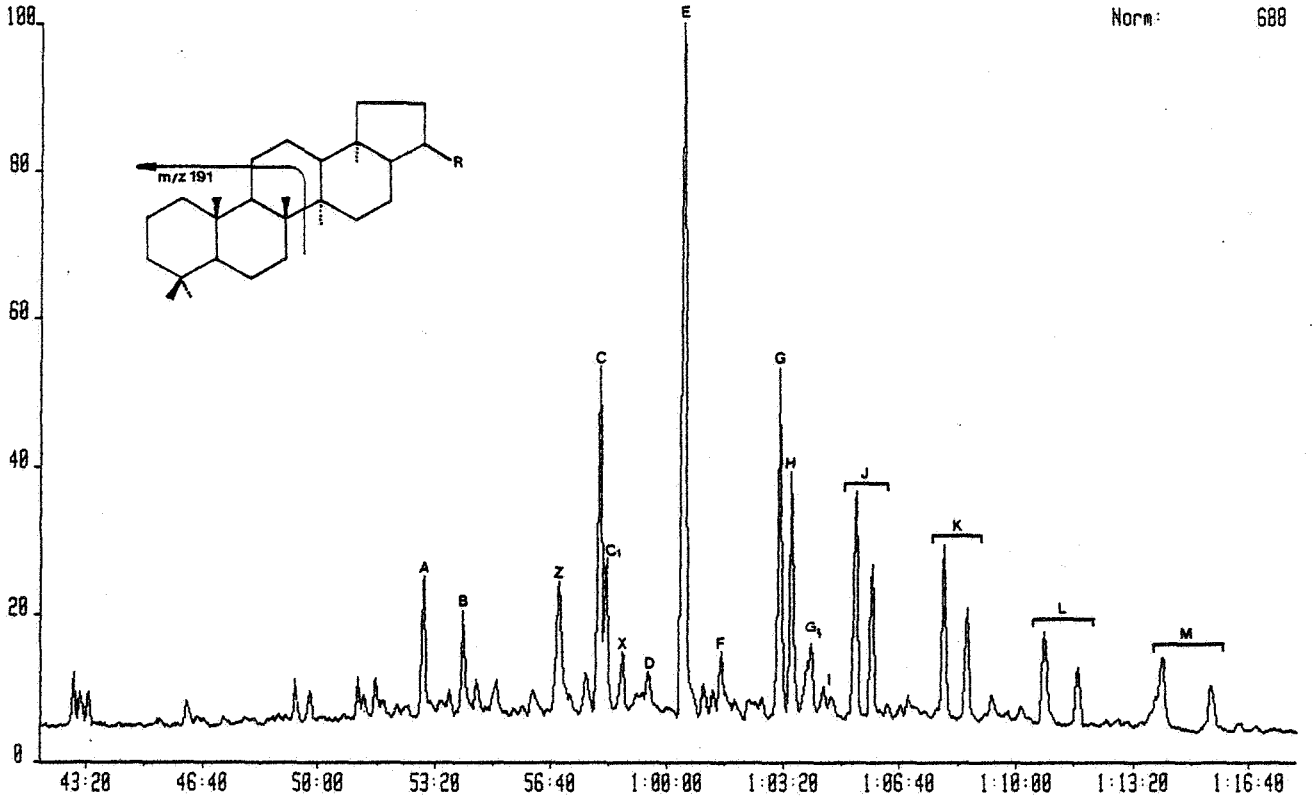


PEAK IDENTIFICATION FOR TRITERPANES (m/z 191)

A 18 α (H), 21 β (H) -22,29,30- trisnorhopane (Ts)
B 17 α (H), 21 β (H) -22,29,30- trisnorhopane Tm)
Z 17 α (H), 18 α (H) 21 (H) -28,30 bisnorhopane
C 17 α (H), 21 β (H) - norhopane
C_1 C_{29} pentacyclic triterpenoid (unidentified)
X C_{30} pentacyclic triterpenoid (unidentified)
D 17 β (H), 21 α (H) -30 - normoretane
E 17 α (H), 21 β (H) - hopane
F 17 β (H), 21 α (H) - moretane
G 17 α (H), 21 β (H) - homohopane (22S)
H 17 α (H), 21 β (H) - homohopane (22R)
G_1 Gammacerane
I 17 β (H), 21 α (H) - homomoretane
J 17 α (H), 21 β (H) - bisnorhopane (22S and 22R)
K 17 α (H), 21 β (H) - trisnorhopane (22S and 22R)
L 17 α (H), 21 β (H) - tetrakishomohopane (22S and 22R)
M 17 α (H), 21 β (H) - pentakishomohopane (22S and 22R)

N C_{20} Tricyclic Terpane
O C_{21} Tricyclic Terpane
P C_{23} Tricyclic Terpane
Q C_{24} Tricyclic Terpane
R C_{25} Tricyclic Terpane
S C_{26} Tricyclic Terpane
T C_{24} Tetracyclic Terpane
U C_{28} Tricyclic Terpane
V C_{29} Tricyclic Terpane
W C_{30} Tricyclic Terpane

GEMIA 30-JUN-87 Sir:Magnetic TS250 Acnt:GEOCHEM Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 191.1798
Text:STANDARD BIOMARKER



PEAK IDENTIFICATION FOR TRITERPANES (m/z 191)

A	18 α (H), 21 β (H) -22,29,30- trisnorhopane (Ts)
B	17 α (H), 21 β (H) -22,29,30- trisnorhopane Tm)
Z	17 α (H), 18 α (H) 21 (H) -28,30 bisnorhopane
C	17 α (H), 21 β (H) - norhopane
C_1	C_{29} pentacyclic triterpenoid (unidentified)
X	C_{30} pentacyclic triterpenoid (unidentified)
D	17 β (H), 21 α (H) -30 - normoretane
E	17 α (H), 21 β (H) - hopane
F	17 β (H), 21 α (H) - moretane
G	17 α (H), 21 β (H) - homohopane (22S)
H	17 α (H), 21 β (H) - homohopane (22R)
G_1	Gammacerane
I	17 β (H), 21 α (H) - homomoretane
J	17 α (H), 21 β (H) - bisnorhopane (22S and 22R)
K	17 α (H), 21 β (H) - trisnorhopane (22S and 22R)
L	17 α (H), 21 β (H) - tetrakishomohopane (22S and 22R)
M	17 α (H), 21 β (H) - pentakishomohopane (22S and 22R)

N	C_{20} Tricyclic Terpane
O	C_{21} Tricyclic Terpane
P	C_{23} Tricyclic Terpane
Q	C_{24} Tricyclic Terpane
R	C_{25} Tricyclic Terpane
S	C_{26} Tricyclic Terpane
T	C_{24} Tetracyclic Terpane
U	C_{28} Tricyclic Terpane
V	C_{29} Tricyclic Terpane
W	C_{30} Tricyclic Terpane

FIGURE 7a

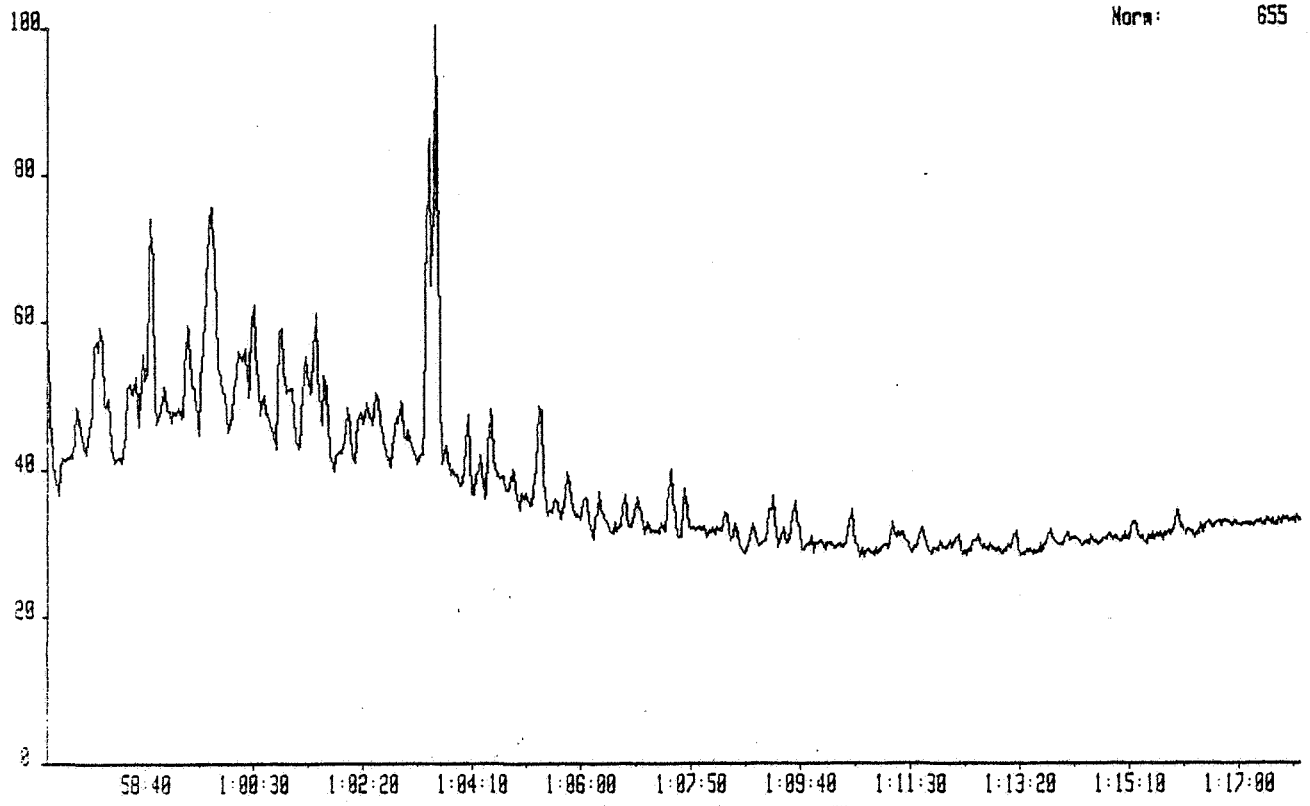
MASS FRAGMENTOGRAMS

WELL 6506/12-8

TERPANES

GEOCHEM

1863001R 3-NOV-88 Sir:Magnetic TS250 Acnt:STATOIL Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 177.1642
Text:6506/12-8 3915-23+3934-55



18S3001R 3-NOV-88 Sir:Magnetic TS250 Acnt:STATOIL Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 191.1798
Text:6506/12-8 3915-23+3934-55

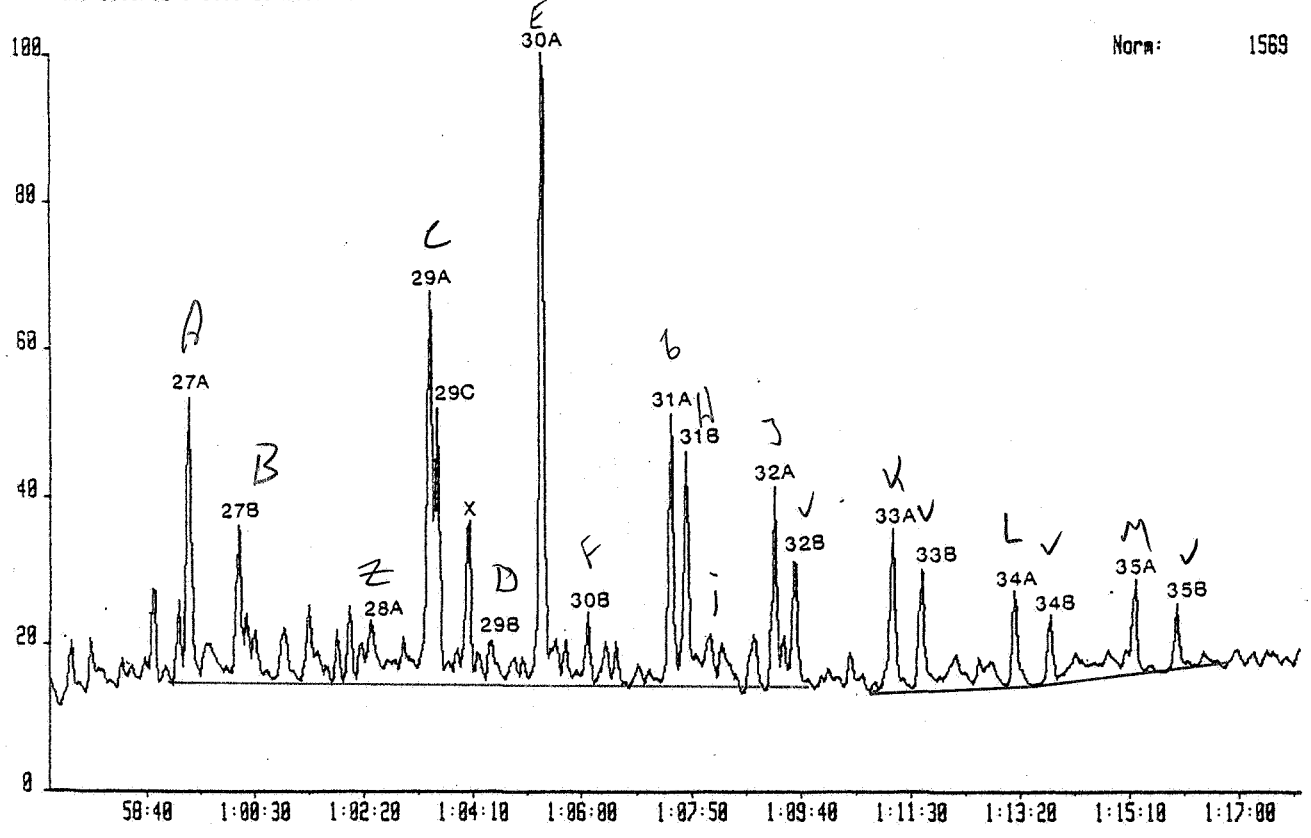
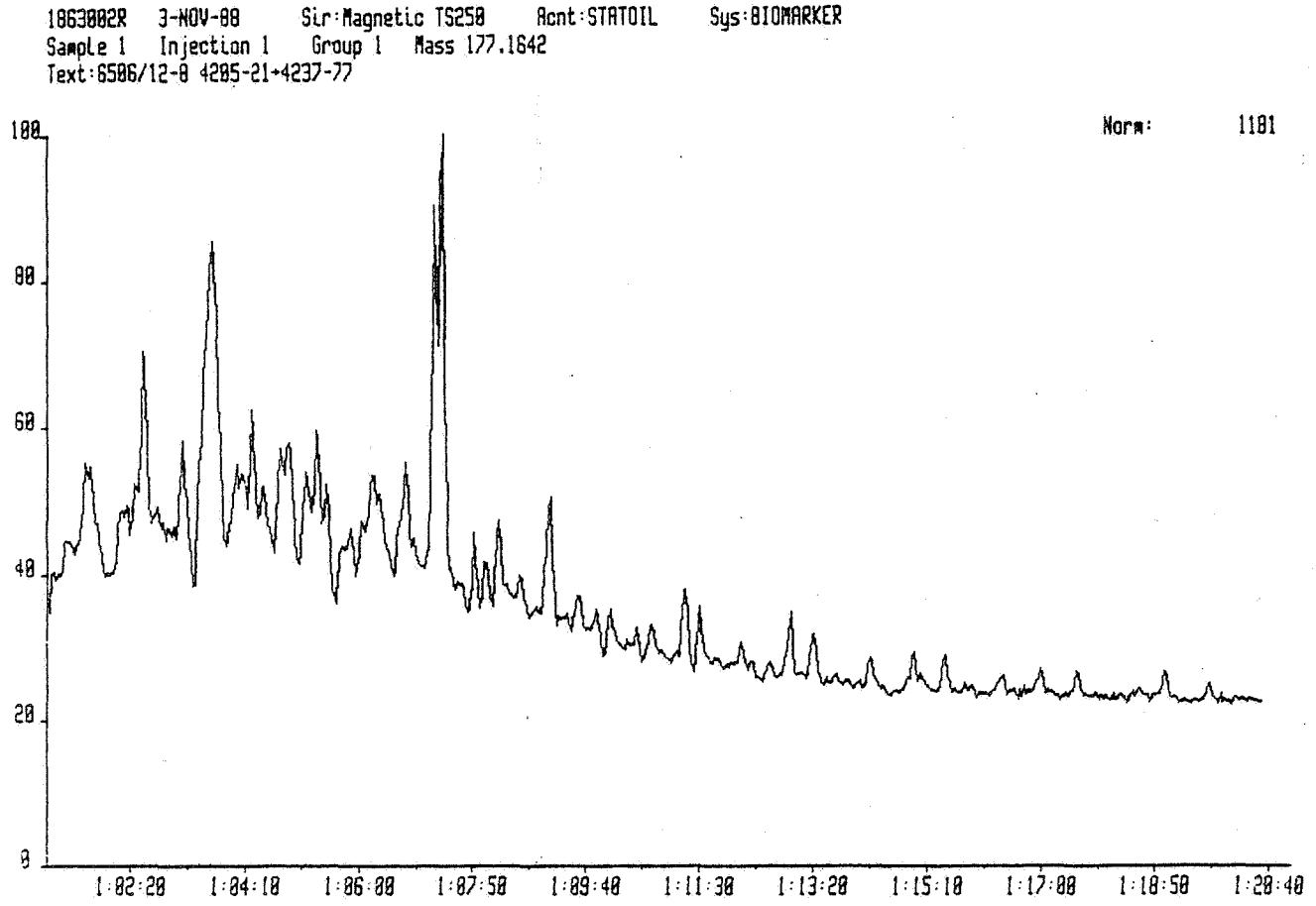


FIGURE 7b

MASS FRAGMENTOGRAMS

WELL 6506/12-8

TERPANES



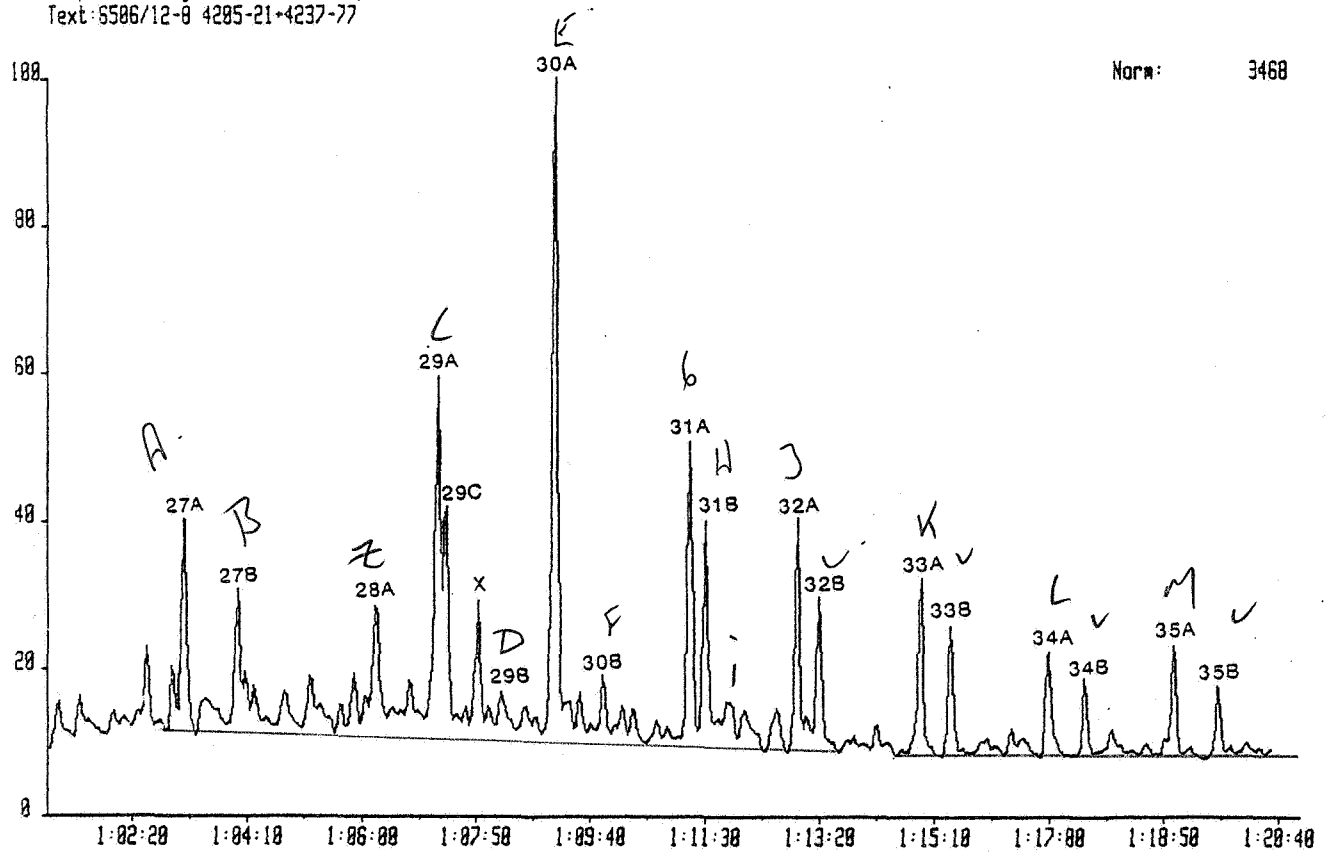


FIGURE 8a

MASS FRAGMENTOGRAMS

WELL 6506/12-8

TERPANES

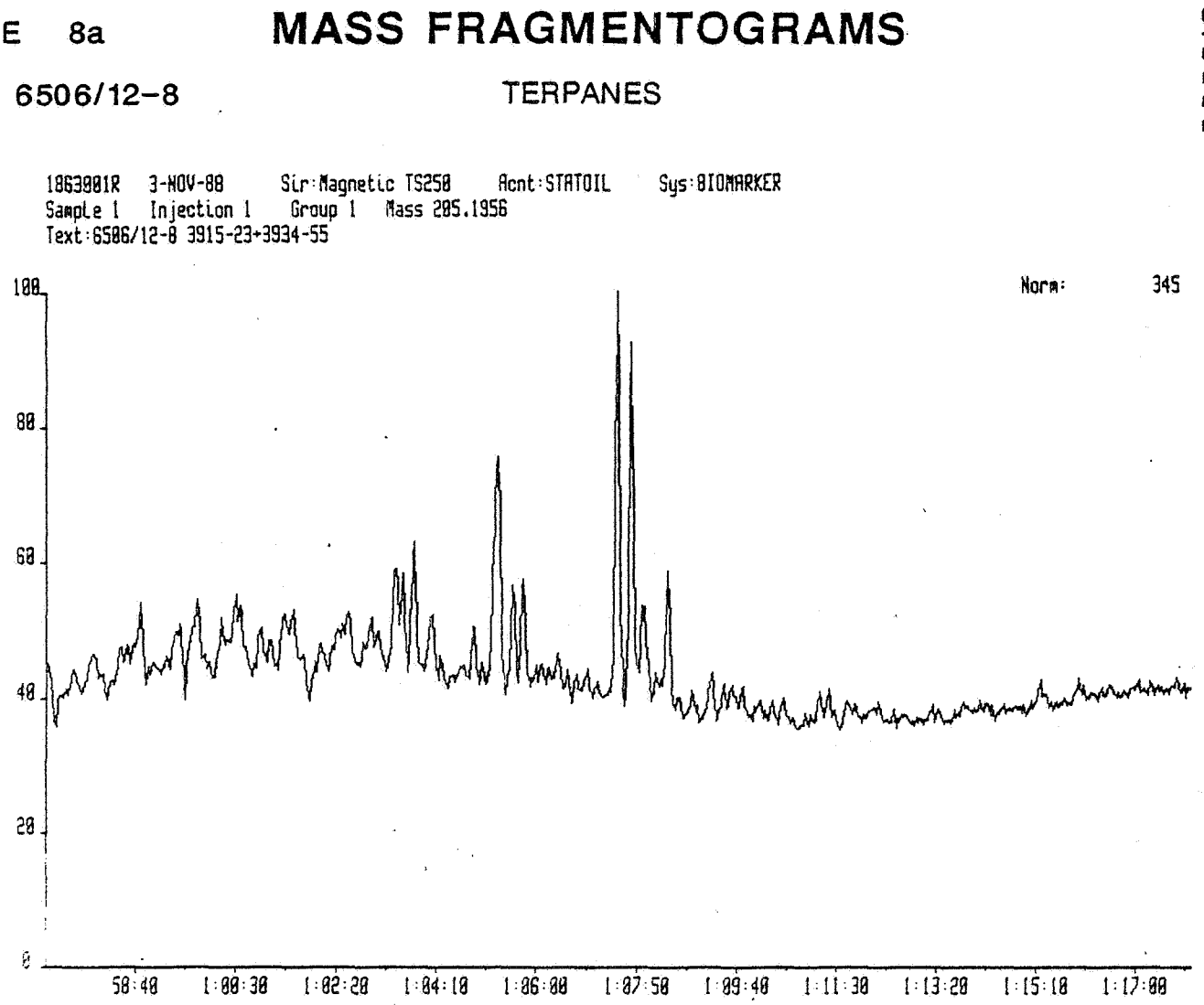


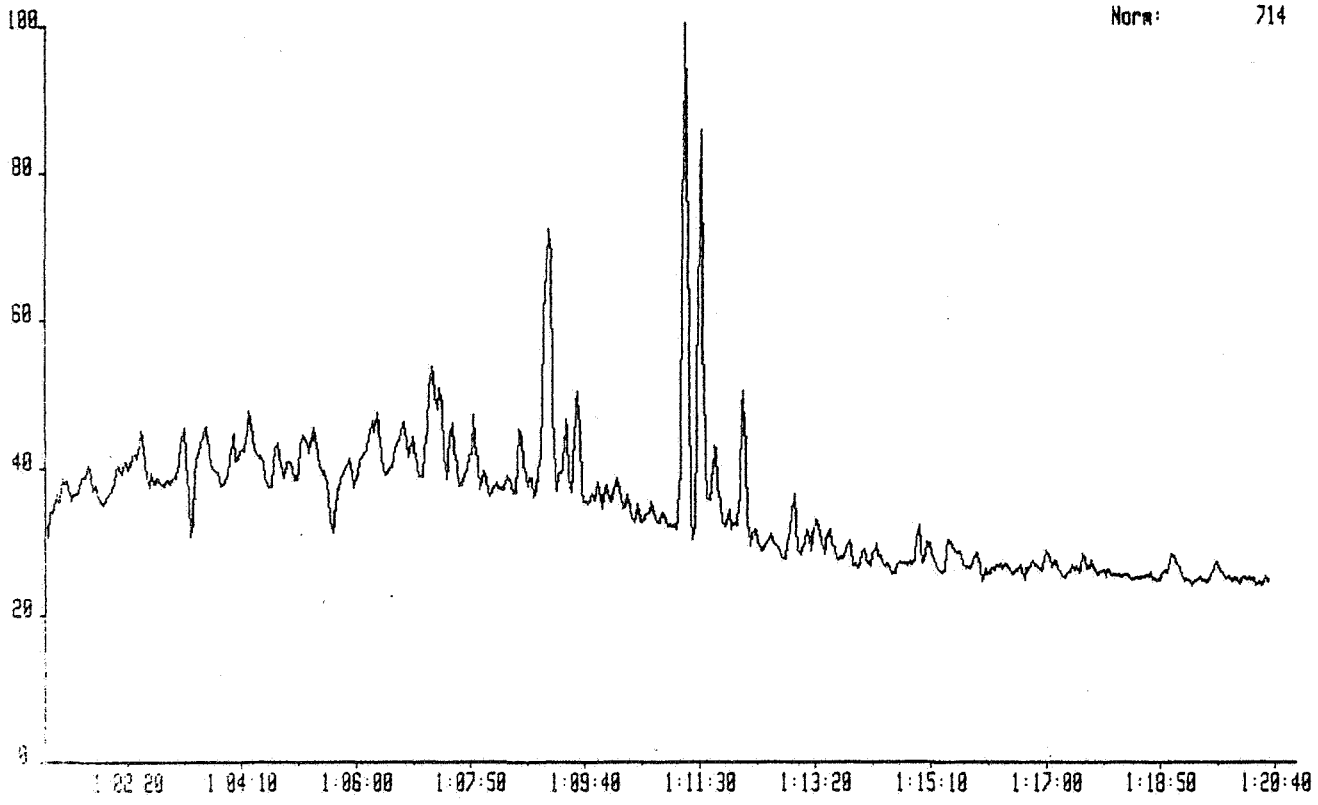
FIGURE 8b

MASS FRAGMENTOGRAMS

WELL 6506/12-8

TERPANES

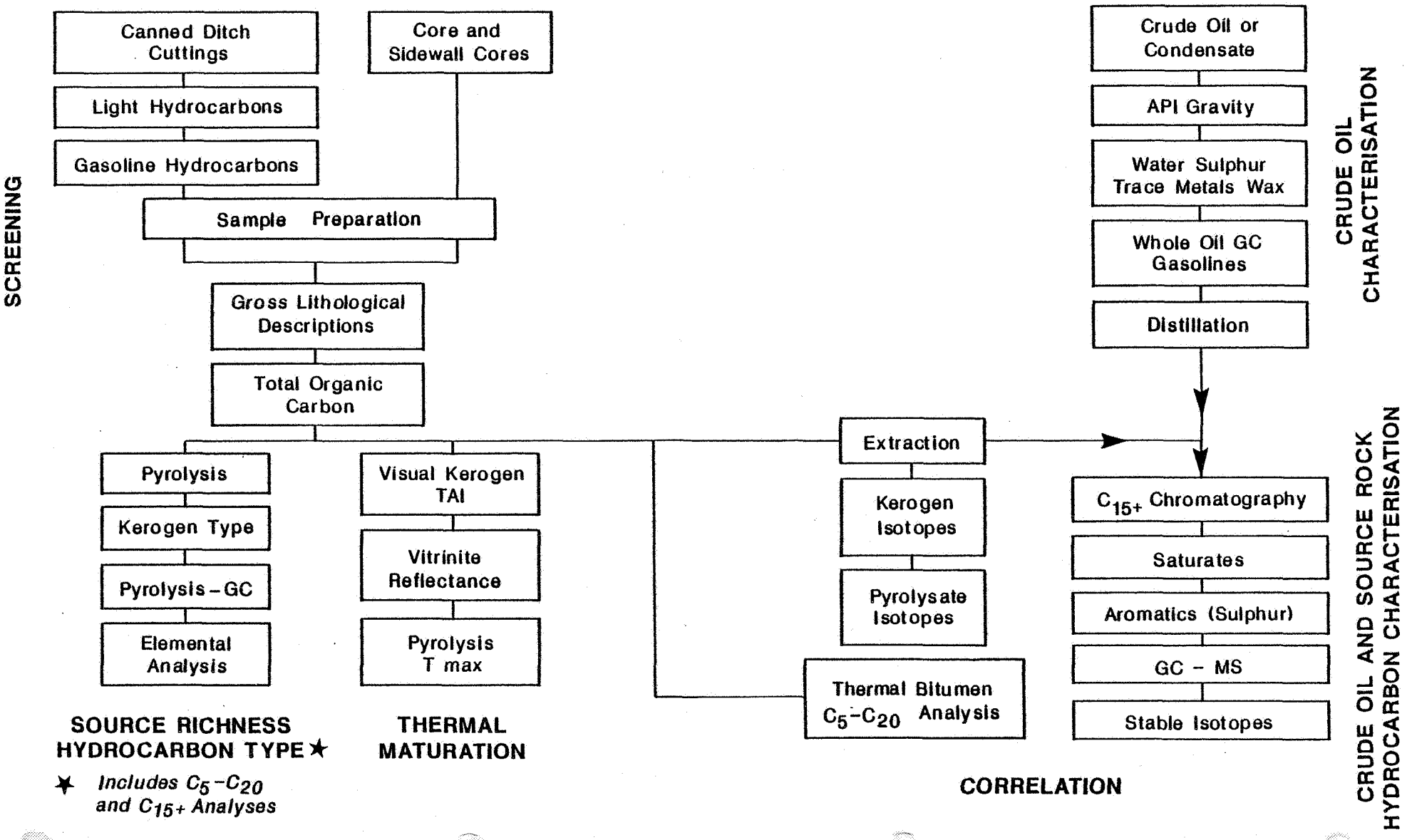
1963002R 3-NOV-88 Sir:Magnetic TS250 Acnt:STATOIL Sys:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 205.1956
Text:6506/12-8 4205-21-4237-77



BRIEF DESCRIPTION

OF ANALYSES

GEOCHEM ANALYSIS SCHEME



BRIEF DESCRIPTION OF ANALYSES PERFORMED BY GEOCHEM

Analyses described in this section include industry standard methods and techniques resulting from more than thirteen years of development by Geochem Laboratories. Analytical methodology arising from collaboration with individual clients or groups of clients (e.g. the Norwegian oil companies) is not necessarily included in these descriptions.

The flowchart illustrates a typical sequence of analyses and their functional relationships.

These analyses may be grouped as follows :

A source rock screening
B source richness and hydrocarbon type
C source rock thermal maturity
D source rock hydrocarbon characterisation
E crude oil characterisation
F gas characterisation
G correlation

A. SOURCE ROCK SCREENING

A-1 C_1-C_7 LIGHT HYDROCARBONS ANALYSIS

The abundance and composition of the C_1-C_7 hydrocarbons in sediments reflects their source richness, maturity and the character of the hydrocarbons they can yield. Most importantly, it is extremely sensitive to the presence of migrated hydrocarbons and is an excellent method for their detection. As it provides the information on most of the critical parameters and is also economical, this analysis is recommended for screening samples to decide which of them merit further analysis.

During the time which elapses between the collection of the sample at the wellsite and its analysis in the laboratory, a variable fraction of the total gas passes from the rock to the air space at the top of the can. For this reason, both the air space and the cuttings are analysed. To minimise loss of air space gases, cans fitted with pressfit lids are stored in the inverted position.

A sample of the headspace gases is withdrawn from the can using a syringe and then analysed by gas chromatography. The can is opened and the head space volume measured. A small portion of the cuttings is homogenised in a sealed blender and the released cuttings gases are analysed by the method used for the headspace gases.

Concentrations of the individual C_1-C_4 gases, plus the total C_{5+} hydrocarbons for both headspace and cuttings gases, are determined by means of a gas chromatograph equipped with flame detector and calibrated with a standard gas mixture. These data are reported in ppm by volume or in µl/Kg(dry) rock - for the headspace and cuttings gas and for the combined headspace and cuttings gas.

A-2 DETAILED GASOLINE RANGE (C_4-C_7) HYDROCARBONS ANALYSIS

The abundance and composition of the C_4-C_7 hydrocarbons in sediments reflects their source quality, level of thermal maturity and kerogen type or, if they are reservoir facies, the strength and nature of hydrocarbon shows. This analysis is particularly useful in evaluating the reservoir history of crude oils and in oil to oil correlation studies.

Selected lithologies are heated and crushed in a sealed blender in order to liberate the C_4-C_7 hydrocarbons from the rock matrix. A sample of these hydrocarbons is withdrawn by syringe and analysed by capillary gas chromatography to identify the individual hydrocarbons. With crude oils, a sample of the oil is injected directly into the chromatograph.

The gross composition, selected ratios and normalised composition of the individual C_4-C_7 hydrocarbons (including toluene) are tabulated and plotted against depth.

A-3 SAMPLE PREPARATION

All of the analyses described in subsequent sections are run on washed and hand picked samples.

Cuttings are washed to remove the drilling mud, care being taken not to remove soft clays and fine sand during the washing procedure. The lithology of each facies is then described and the presence of caved material noted. Sidewall core material is liberated from any associated drilling mud and then

described. Using the C_1-C_7 hydrocarbon and the organic carbon profiles of the well, electric logs (if supplied) and the lithology and appearance of the cuttings, sidewall cores and cores under the binocular microscope, samples are selected to represent the lithological and geochemical zones penetrated by the well. These samples are then carefully hand picked and it is these samples which are submitted for further analysis.

Sample material remaining after analysis is retained for six months. Unless instructions are received to the contrary, Geochem Laboratories may then destroy the samples.

Our reports incorporate a gross lithological description of all the samples which have been analysed and litho percentage logs. As screen analyses are recommended at narrow intervals, a complete lithological profile is obtained.

A-4 ORGANIC CARBON ANALYSIS

The organic carbon content of a rock is a measure of its total organic richness. Combined with the visual kerogen, C_1-C_7, C_4-C_7, pyrolysis and C_{15+} analyses, the organic carbon content is used to evaluate the potential (not necessarily actual) hydrocarbon source richness of the sediment. This analysis is an integral part of any evaluation and is also used as an economical screen analysis for dry samples (when the C_1-C_7 analysis cannot be employed).

Hand picked samples are dried, crushed and then acidised to remove the inorganic calcium and magnesium carbonates. The actual analysis involves combustion in a Leco CS244 carbon/sulphur analyser. Blanks, standards and duplicates are run routinely for purposes of quality control at no extra cost to the client. Sulphur contents are also measured but are not reported routinely.

The organic carbon data are tabulated and presented diagramatically in our reports in a manner which facilitates comparison with the gross lithology of the samples.

B. SOURCE RICHNESS AND HYDROCARBON TYPE

B-1 PYROLYSIS

The thermal maturation process is simulated in the laboratory by the pyrolysis analysis. This involves heating the source rock under controlled conditions to produce firstly, a distillate (thermal bitumen) and secondly, a pyrolysate (from the breakdown of the kerogen). The thermal bitumen (S1) content is related to the present potential of a source rock (plus any non-indigenous hydrocarbons) whilst the pyrolysate yield (S2) is a measure of ultimate source potential.

Industry standard machines made by Leco (Thermolytic Hydrocarbons Analyser, THA) and by Delsi (Rockeval II) are used to automatically measure S1 and S2 and to ascertain the temperature, Tmax, at which maximum S2 evolution occurs. In addition, the Rockeval machine measures S3 - the proportion of oxygen containing species in the kerogen. This latter value is used to calculate the oxygen index (S3/TOC) which, together with the hydrogen index (S2/TOC), is used to identify kerogen types on the van Krevelen diagram. Care must be used in the interpretation of S3 data since they are influenced by inorganic carbonates.

S1, S2 and where applicable S3, values (in mg/g rock) are reported, with production indices [S1/(S1 + S2)], hydrogen indices, oxygen indices and Tmax values for all prospective source units. The pyrolysate yield (S2) is preferred to organic carbon contents as an unambiguous measure of potential source richness.

B-2 KEROGEN TYPE

Kerogen is the insoluble organic matter in rocks. Visual examination of the kerogen ("Visual Kerogen" analysis) directly assesses the composition of the organic matter (organic facies) and indicates the source quality of the sediment - which is confirmed using the pyrolysis, pyrolysis-GC and C_{15+} analyses. Thermal maturity is also evaluated from the colour of the spore-pollen material (see below).

The type of hydrocarbons (oil or gas) generated by a source rock is a function of its level of thermal maturation and of the composition of its organic

matter. Both of these parameters are measured directly by this visual kerogen method. Kerogen is separated from the inorganic rock matrix by acid digestion and flotation methods which avoid oxidation of the organic matter. It is then mounted on a glass slide and examined at high and low magnifications with a Leitz microscope. Chemical methods measure the total kerogen population but, with this technique, individual particles can be selected for examination and spurious material identified and avoided. This is particularly valuable in reworked, contaminated and turbodrilled sediments.

The following data are generated: the types of the organic matter present and their relative abundances, an estimate of the proportion of reworked material, the preservation state and the thermal maturity (see below, C-1) of the non-reworked organic matter using the spore colouration technique.

A total of fourteen types of organic matter are sought based upon the major categories of algal, amorphous, herbaceous (spore, pollen, cuticle), wood, inertinite and resin. This detail is essential for a proper understanding of hydrocarbon source potential as the different sub-groups within each category have different properties.

Upon completion of the study, the kerogen slides are sent to the client.

B-3 PYROLYSIS-GC

The nature of potential hydrocarbon products is deduced from gas chromatograms of the pyrolysate material (S2, see above). These 'pyrograms' resemble the hydrocarbons generated by the source rock at peak maturity. Thus, for oil prone sediments the chromatograms display a methane peak followed by a series of alkene-alkane double peaks which extend out to C_{25}-C_{30}, whereas these doublets are absent in gas-prone source rocks. The gas-oil index (% C_1-C_5/total pyrolysate) provides a digital representation of the pyrogram and predicts the hydrocarbon product : oil prone sediments have values of less than 20%, 20-35% corresponds to a potential for oil and gas, 35-50% to condensate and values greater than 50% to gas.

Small (1-2 mg) samples of solvent-extracted rock powder are heated by one of two methods to produce a pyrolysate (S2) which is subsequently analysed by capillary gas chromatography. The two methods differ only in the pyrolysate generation mode. In the first 'instantaneous' method a pyroprobe rapidly (10

seconds) generates the pyrolysis products whereas in the second, the pyrolysate is generated over a period of several minutes by programmed pyrolysis. These two methods are referred to as flash and programmed pyrolysis-GC respectively. The actual pyrolysis temperature range is comparable in each case and both methods give similar results, although the light ends are relatively enhanced by flash pyrolysis-GC.

B-4 ELEMENTAL ANALYSIS OF KEROGEN

Kerogen isolated from prospective source rocks is analysed in a Carlo Erba 1106 Elemental Analyser. Carbon, hydrogen, nitrogen, oxygen and sulphur are measured directly by this machine. Hydrogen : carbon ratios have been traditionally used by the oil industry to assess the oil potential of organic matter in source rocks and, in conjunction with the oxygen : carbon ratio permit the use of the Van Krevelen diagram. This assigns the gross organic matter population to Types I, II or III and gives an indication of its ability to generate oil or gas. It is employed in association with the visual kerogen, pyrolysis and pyrolysis-GC analyses.

C. SOURCE ROCK THERMAL MATURITY

C-1 SPORE COLOURATION THERMAL ALTERATION INDEX (TAI)

Organic matter darkens with increasing thermal maturity. The increasing colouration of the spore and pollen material, as observed microscopically using kerogen concentrates, accurately reflects the hydrocarbon generation process and is used to assess thermal maturity. As with the vitrinite reflectance analysis, core and sidewall core material is preferred for this "Visual Kerogen" analysis when available.

Our maturation scale has been developed to digitise small but recognisable changes in organic matter colouration resulting from increasing maturity and to place particular emphasis upon the immature to mature transition. In the absence of a universal colouration scale, the most significant points on our scale have been calibrated against equivalent vitrinite reflectance values.

The top of the condensate zone corresponds to the base of the oil window.

C-2 VITRINITE REFLECTANCE

Vitrinite reflectance is an alternative/confirmatory method for evaluating thermal maturation which is used in conjunction with the visual kerogen analysis. The reflectivity of vitrinite macerals increases in response to thermal alteration and is used to define maturation levels and, by projection, to predict maturity at depth or the thicknesses of section removed by erosion.

Measurements are made upon carefully polished blocks either of kerogen concentrates or of whole rocks depending upon the organic richness of the samples and the preference of the client. In general, this analysis is performed upon the same samples as the visual kerogen analysis, thus facilitating a direct comparison of the two sets of results.

If possible, forty to fifty measurements are taken per sample, although this may not be possible if the sediments are organically lean or vitrinite is sparse. The data are processed using an interactive computer program which allows the operator to select, calculate and plot populations and mean reflectances. Indigenous vitrinite is thus distinguished from possible

reworked or caved material. Comments upon exinite fluorescence (if relevant) and upon the character of the phytoclasts are noted on the histograms. The reports contain the tabulated data, histograms and the reflectivities plotted against depth.

The vitrinite and visual kerogen techniques provide mutually complementary information upon maturity, organic matter type and diagenesis.

C-3 PYROLYSIS TMAX

This is an empirical parameter which can produce a depth related maturity trend. Tmax is also affected by gross kerogen composition, the amount of reworked material etc and must therefore, be used with caution in the assessment of thermal maturity.

The measurement of Tmax has been described under the 'Pyrolysis' analysis (B-1).

D. SOURCE ROCK HYDROCARBON CHARACTERISATION

C_2+ hydrocarbons in source rocks reflect in situ generation, diffusion of migrated hydrocarbons (via microfractures or sand bodies) or contamination from the mud-system. It is important, therefore to identify these hydrocarbons because their abundance is diagnostic of source richness, maturity or, if migrated species, of show strength. Any hydrocarbons detected in reservoir facies merit further investigation. The gasoline range analysis has been discussed above (A-2).

D-1 C_{15+} HYDROCARBON EXTRACTION, DEASPHALTENING AND CHROMATOGRAPHIC SEPARATION

Hand picked rock samples are ground and then extracted in a Soxtec machine - a modern version of the soxhlet extractor - employing solvents such as dichloro methane and methanol. Pre-extracted cellulose extraction thimbles are used in conjunction with selected pure solvents to minimise the introduction of extraneous material by the extraction process. The procedures have been designed to avoid loss of the lighter hydrocarbons and to ensure quantitative recovery of the heavy ends.

Asphaltenes are precipitated from the total extract using standard methods (e.g. IP143) and the soluble material is then separated into fractions by liquid chromatography. These fractions comprise the saturated hydrocarbons (paraffin-naphthenes), aromatic hydrocarbons, eluted NSO's (nitrogen, sulphur and oxygen species) and non-eluted NSO's.

Traditional column chromatographic methods, for the separation of source rock extract and crude oil components, have largely been replaced by high performance liquid chromatography (HPLC). This technique gives an optimal separation of the saturated and aromatic hydrocarbon fractions which is important for subsequent GC-MS analyses.

Quantification of the C_{15+} hydrocarbons and non-hydrocarbons is achieved by means of the Iatrascan equipment, in which rods coated with silica are used to separate the fractions by thin layer liquid chromatography. The resolved hydrocarbons are measured by passing the rods through a flame ionisation detector.

Analyses of the C_{15+} fractions are reported either in parts per million (ppm) by weight of rock or as mg/g TOC, as normalised % composition of the C_{15+} fraction and as selected diagnostic ratios. These data are also plotted to facilitate the evaluation of depth-related trends.

Oils and condensates are distilled or 'topped' to give a C_{15+} (210°C+) fraction which is then analysed in the same way as the total soluble extract from source rocks.

D-2 ANALYSIS OF C_{15+} SATURATED HYDROCARBONS

The distribution of C_{15+} saturated hydrocarbons - n-alkanes, iso-alkanes (including the principal acyclic isoprenoids) and cyclo alkanes (naphthenes) - is affected by changes in organic facies, maturity and source rock geochemistry, and by the presence of shows. Of most value are the n-alkane configuration which defines crude oil type (waxiness, maturity, gravity etc), the ratios of the odd to even carbon number n-alkanes (CPI) - which approach unity with increasing maturity - and the ratios of the isoprenoids (e.g. pristane and phytane) to the adjacent alkanes, which are affected by source depositional environment.

Saturated hydrocarbons, isolated from the source rock extracts or from crude oils by C_{15+} liquid chromatography, are injected into a high resolution gas chromatograph. The individual hydrocarbons separated by the capillary column in this instrument are detected by a flame ionisation detector and quantified (by reference to standard hydrocarbons) using a computerised laboratory data processor. Care is taken to ensure that all of the alkanes including those heavier than C_{30} are quantitatively recorded. Concentrations of each n-alkane in the C_{15} - C_{35} range are reported as normalised percentage of total alkanes or in parts per million of total extract. The principal C_{15} - C_{20} isoprenoids plus the total n-alkanes, isoprenoids and naphthenes are also tabulated.

Ratios reported include:

$$\text{CPI (1)} = 1/2\left[\frac{(C_{21} + C_{23} + C_{25} + C_{27})}{(C_{20} + C_{22} + C_{24} + C_{26})} + \frac{(C_{21} + C_{23} + C_{25} + C_{27})}{(C_{22} + C_{24} + C_{26} + C_{28})}\right]$$

$$\text{CPI (2)} = 1/2\left[\frac{(C_{25} + C_{27} + C_{29} + C_{31})}{(C_{24} + C_{26} + C_{28} + C_{30})} + \frac{(C_{25} + C_{27} + C_{29} + C_{31})}{(C_{26} + C_{28} + C_{30} + C_{32})}\right]$$

$$\text{CPI (3)} = \frac{2 \times C_{27}}{\left(\frac{C_{26} + C_{28}}{}\right)}$$

Pristane : Phytane Pristane : nC_{17}

Phytane : nC_{18}

D-3 ANALYSIS OF C_{15+} AROMATIC HYDROCARBONS

The C_{15+} aromatic hydrocarbons are relatively more resistant to alteration in the reservoir by biodegradation than the corresponding saturates. They are, therefore, of value in correlation studies. Furthermore, ratios of selected methyl-phenanthrenes and of phenanthrene (MPI) are used to ascertain the maturation levels of (inferred) hydrocarbon source rocks.

C_{15+} aromatic hydrocarbons are analysed by methods analagous to those used for the saturated hydrocarbons. The gas chromatogram displays the naphthalenes, methyl substituted naphthalenes, phenanthrene, the methyl phenanthrenes and the heavier aromatics. Methyl phenanthrene indices are calculated and included in the reports:

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

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

P = phenanthrene MP = methyl phenanthrene

Note : Calculated mean reflectance (Rc)

$Rc = 0.6\ MPI\ (1) + 0.40$ (Ro <1.35%)
$Rc = -0.6\ MPI\ (1) + 2.30$ (Ro > 1.35%)

(M. Radke & D.H. Welte, 1981)

Under certain conditions dibenzothiophenes co-elute with the methyl phenanthrenes (for example 3-MP coelutes with methyldibenzothiophene) and hence GC-MS data are preferred, although the MPI(2) ratio calculated from the gas chromatograms is reliable.

D-4 ANALYSIS OF C_{15+} SULPHUR AROMATIC HYDROCARBONS

These compounds are present in the C_{15+} aromatic hydrocarbons fraction and, by substituting a flame photometric detector for the more normal flame ionisation detector in the GC, are detected and measured in the same way as the aromatic hydrocarbons. The sulphur aromatic hydrocarbons produce a characteristic chromatogram which is principally used in correlation studies.

D-5 NORMAL AND BRANCHED/CYCLIC SATURATES CHROMATOGRAMS

By using clathrating agents, such as urea or molecular sieves, the C_{15+} saturates fraction is separated into normal (straight chain) and branched/cyclic alkane fractions. These fractions are then analysed by the same techniques as those used for the total saturates fractions.

D-6 THERMAL BITUMEN (C_5-C_{20}) ANALYSIS

Powdered rock samples are heated in a thermal desorption cold trap injector and the evolved hydrocarbons are analysed by gas-chromatography. This technique enables us to examine the C_{15-} hydrocarbons which are normally lost and requires only milligram quantities of rock. The resulting chromatogram for the sediment is comparable to the whole oil trace.

A small quantity of powdered rock is heated to approximately 350°C in a helium gas stream and the desorbed hydrocarbons are collected on-column in a cold trap at -130°C. After a pre-determined time interval the furnace is cooled, the cold trap heated and the liberated hydrocarbons are analysed by capillary column gas-chromatography in the usual manner. The high resolution chromatogram displays a full range of hydrocarbons and non-hydrocarbons from C_4 to C_{25+} but is not quantitative beyond C_{20}. This analysis is invaluable for the evaluation of source rocks, for show detection, for correlation purposes and for volumetric yield calculations. Total abundances are reported together with the normalised distribution of the C_5-C_{20} n-alkanes.

D-7 ANALYSIS OF SATURATED AND AROMATIC HYDROCARBON BIOMARKERS BY GC-MS

Hydrocarbons representing the skeletal remains of the original biolipids in plant and animal debris survive to advanced levels of thermal maturity and are not seriously affected by normal biodegradation. These 'biomarker' hydrocarbons are therefore invaluable in correlation studies because they are diagnostic of the facies, depositional environment and maturity of the source.

C_{15+} saturated and aromatic hydrocarbons from crude oils or source rock extracts are separated on a Hewlett Packard 5890 capillary gas chromatograph. The molecular fragments associated with specific biomarkers are monitored as they emerge from the capillary column by a V.G. TS250 double focussing mass spectrometer, coupled to a V.G. 11250 data system. In conjunction with the associated mass-spectra library, this system permits the quantitative identification of all biomarkers. Mass fragmentograms of the steranes (at m/z 217, 218, 231 and 259) and of triterpanes (at m/z 177, 191 and 205) are routinely reported with eleven biomarker ratios plus, if required, peak area data. Similarly, for the aromatic hydrocarbons, the mono- and tri-aromatic steranes (at m/z 253 and m/z 231 respectively) together with the phenanthrene series (m/z 178, 192 and 206) and dibenzothiophenes (m/z 184, 198 and 212) fragmentograms are reproduced in the report. Other fragment ions can be monitored at the client's request. Peak area data from the aromatic steranes and phenanthrenes are used to evaluate thermal maturity and for correlation purposes. The saturates are employed for correlation, maturity and source facies evaluations.

Considerable enhancements in sensitivity and selectivity in biomarker analysis can now be provided by the selective metastable ion monitoring (SMIM) mass spectroscopic technique. This new technique (also known as metastable reaction monitoring, MRM) produces less complex fragmentograms, avoids co-elution problems and permits the detailed investigation of the C_{30} steranes.

D-8 CARBON ISOTOPE RATIOS

The ratio of the stable ^{13}C and ^{12}C atoms in living organic matter is controlled by biosynthetic pathways and by environment. Thus, plants and animals which develop in fresh-water have different isotopic ratios to similar species growing in seawater. The geothermal history of the sedimentary organic matter has a secondary influence on the isotope values. The principal application of stable carbon isotopic ratios is therefore, in oil-oil and oil-source rock correlation studies, since the generated hydrocarbons retain the isotopic signature of the source kerogen.

Carbon isotope ratios are measured on hydrocarbons and non-hydrocarbons isolated from crude oils and source rocks, from source rock kerogens and from kerogen pyrolysates. The hydrocarbon fraction or kerogen is combusted under controlled conditions (to avoid isotopic fractionation) and the resulting carbon dioxide is analysed by a mass spectrometer. This is a specialised spectrometer (a modified VG 602) fitted with dual collector and micro processor controlled ratio measurement device.

^{13}C is approximately 1% of the total carbon in organic matter and the changes in composition are, therefore, only a few parts per million. For this reason the absolute ratios are compared to those of an international standard (the Peedee belemnite, PDB). In practice, a secondary standard (NBS 22 oil) is used in routine measurements and the results expressed as a deviation (δ) in parts per thousand from the PDB standard.

$$^{13}C = \left[\frac{^{13}C/^{12}C)\ \text{sample}}{^{13}C/^{12}C)\ \text{standard}} - 1 \right] \times 1000$$

The δ values for hydrocarbons, non-hydrocarbons, pyrolysates and kerogens are tabulated and plotted as X-Y or Galimov plots.

Oil to source rock correlation studies should involve the analysis of the whole oil, each of the four C_{15+} fractions and of the kerogen and kerogen pyrolysate material. Carbon isotopes are essential in correlation studies involving gases, when each hydrocarbon which is sufficiently abundant is separated for individual analysis.

E. CRUDE OIL CHARACTERISATION

Crude oils and condensates are, if necessary, dehydrated before measuring their bulk properties. Typical analyses by industry standard methods (ASTM, IP) include API gravity, viscosity, sulphur content, wax content, trace metal content, nitrogen content, pour point, flash point, water, sediment and salt contents, total acid content and total base number.

Large liquid samples are distilled, generally to give a 210°C+ fraction, whilst small samples are topped by evaporating under controlled conditions, to give a comparable fraction.

Capillary gas chromatographic analyses of the whole oil and of the gasoline fraction (A-2) provide detailed fingerprints and quantitative data for correlation studies. Crude oils and condensates are further characterised by analyses which are analagous to those performed on source rock extracts (D-1 through D-5, D-7, D-8).

F. HYDROCARBON GAS ANALYSIS

Hydrocarbons and non-hydrocarbons are measured by gas chromatography. Methane and, if possible, the individual C_2-C_4 hydrocarbons are separated by gas chromatography prior to determining their carbon isotope ratios. These data are used to evaluate the nature of the hydrocarbon source rock and its thermal maturity.

G. CORRELATION

Analyses (referred to above) of the gasolines, whole oil, C_{15+} saturates and aromatics by GC and by GC-MS, and of the carbon isotope ratios of the C_{15+} fractions, are performed upon crude oils/condensates and source rock extracts. Correlations between oils and between oils and source rocks are investigated by comparing the two sets of data.

See A-2, D-1 through D-8.

G-1 STABLE LIGHT ISOTOPES ANALYSES

Stable isotope ratio measurements not only of carbon but also of oxygen, sulphur, nitrogen and hydrogen (deuterium) are used in correlation studies. Carbon and sulphur isotope ratios are applied to the study of kerogen diagenesis whereas oxygen and carbon isotope data are used to investigate carbonate diagenesis. Hydrogen : deuterium and carbon isotope ratios of methane and the heavier gaseous hydrocarbons are sensitive to changes in source type and maturity and are therefore, used in hydrocarbon migration studies. Biosynthetic processes are often accompanied by isotopic fractionation and isotope ratio techniques have therefore a wide application in the field of environmental analysis.

Preparative techniques, determined by the nature of the sample and by the element under investigation, are designed to avoid fractionation. Combustion techniques are generally used for carbon and sulphur whilst chemical methods of isolation are employed for oxygen and hydrogen/deuterium. Measurement of isotopic ratios of these elements is by means of a Sigma 7X mass spectrometer. This fully computer controlled machine uses automatic freeze down for small samples, dual collectors for hydrogen and deuterium and triple collectors for the heavier elements such as carbon, oxygen, sulphur and nitrogen.

Results are reported as delta values by reference to the appropriate international standard.

H-1 INTERPRETATION

Interpretation of the geochemical data obtained from the analytical specification agreed with the client is undertaken by a team of experienced geochemists. In addition to an extensive knowledge of petroleum geochemistry the members of this team are also specialists in areas such as organic petrography, mass spectrometry or data processing and statistical analysis. When required, data from related disciplines such as biostratigraphy are incorporated into the interpretation. Reports are specifically designed to aid the explorationist in prospect evaluation and to solve any particular problems raised by the client. They contain detailed evaluations of the lithological succession, source facies and hydrocarbon potential and source rock maturity in addition to show detection and the characterisation of the shows. Integration of these topics gives the source rock and show character of each formation/interval. The report also contains a concise executive summary for the benefit of senior management.

I-1 COMPUTER DATA FILES

Tabulated geochemical data can be supplied on one of several standard magnetic media, including ½ inch 9 track tapes at 1600 BPI, 5.1/4" IBM compatible diskettes or on TK50 DEC tapes. The content and file structure is usually agreed between the client and Geochem.