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INSTITUTT FOR KONTINENTALSOKKELUNDERSØKELSER OG PETROLEUMSTEKNOLOGI AS

Håkon Magnussons gt. 1 B • P.O. Box 1883, Jarlesletta • N-7001 Trondheim, Norway
Tel.: +47 7 9206 11 • Telex: 55 434 iku n • Telefax: +47 7 9209 24 (Aut.)**REPORT**

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REPORT TITLE:

ORGANIC GEOCHEMICAL CHARACTERISATION
OF AN FMT OIL AND GAS SAMPLE FROM WELL 34/7-9

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AUTHORS:

L. Leith, M.B. Myhr, I.K. Almås

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SUMMARY: The 34/7-9 FMT oil is a moderately light, low sulphur, paraffinic-naphthenic oil of similar composition to other 34/7 oils analysed at IKU. The FMT gas shows characteristics typical of oil-associated gases. An upper Jurassic source is suggested for the FMT fluid, which is considered to be thermally mature.				

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34/7-9	Snorre Field

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1. INTRODUCTION

One oil and one gas sample from a formation test (FMT) in well 34/7-9 were characterised using organic geochemistry as requested by Saga Petroleum a.s.

The following data on the physical nature of the FMT fluids was provided by Core Lab. Norsk on the instructions of Saga Petroleum a.s.

	GAS/OIL RATIO (Sm ³ /m ³)	GAS GRAVITY (Air=1.000)	OIL DENSITY (Kg/m ³)	OILS MOLE. WT. (gm/mole)
34/7-9 FMT	121.1	0.993	832.5	202

SAMPLE DEPTH : 2585 m RKB

The FMT fluids were analysed according to the analytical programme outlined in Saga's letter of 8 October 1985. These analyses are as follows:

Gas samples:

- GC of C₁-C₈ hydrocarbons for recombination.
- δC stable isotope ratio of the C₁, C₂, C₃ and C₄ hydrocarbons.
- D/H ratio of methane.

Oil samples:

- API gravity.
- S, Ni and V content.
- GC of C₂-C₈ hydrocarbons for recombination.
- GC of whole oil.
- Evaporation of light oil compounds (<210°C).
- Chromatographic separation of oil fractions by MPLC, including asphaltene precipitation.
- GC of saturated and aromatic fractions.
- Urea adduction of saturated fraction and GC of branched/cyclic hydrocarbons.
- Combined GC-MS of saturated and aromatic fractions.
- δ¹³C ratio of saturate, aromatic, NSO and asphaltene fractions.

The fluid samples were analysed under IKU project number 22.1830 and were assigned the following IKU sample codes:

34/7-9 FMT GAS = C-4632
 OIL = C-4631

A draft copy of the final report will be sent to Saga Petroleum for approval. On approval, a further ten copies of the final report will be sent to Saga and ten copies will be retained at IKU.

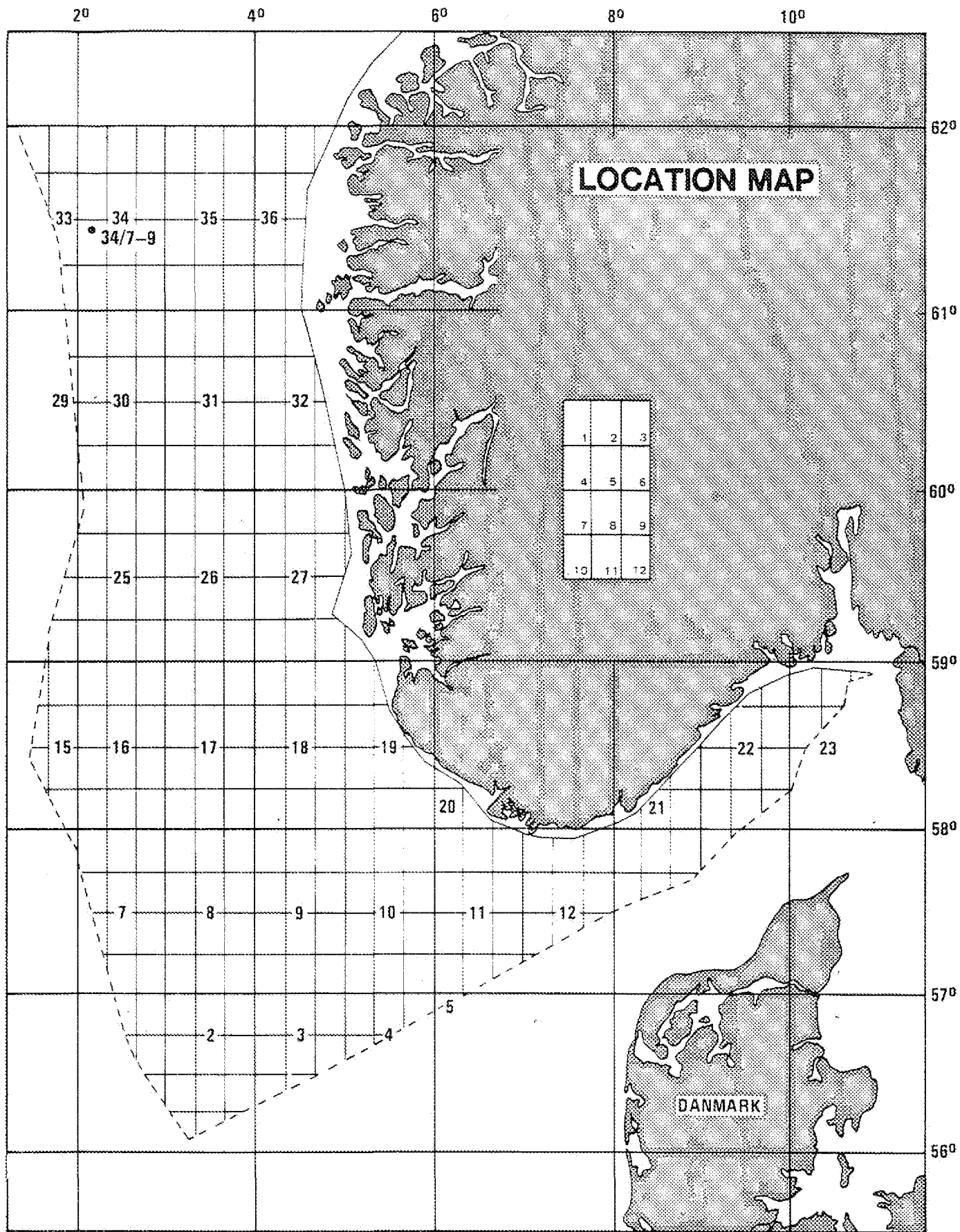


Figure 1: Location of well 34/7-9

2. DISCUSSION OF RESULTS

2.1 Recombination of FMT oil and gas (C₁-C₈ hydrocarbons)

2.1.1 Composition of FMT gas (C₁-C₈ hydrocarbons)

Methane accounts for 27.1% of the gaseous C₁-C₈ hydrocarbons in the sample. C₆₊ hydrocarbon compounds are scarce or non-existent in the gas sample (Figure 1, Table 1). The FMT gas has a high wetness value of 68.2%, which is typical of oil-associated gases. An iC₄/nC₄ ratio of 0.31 suggests that the gas is thermally mature. The 34/7-9 FMT gas is similar in composition to the 34/4-6 DST 3 gas and the 34/7-8 DST 1a and DST 2 gases.

2.1.2 Composition of DST oil (C₂-C₈ hydrocarbons)

The gas chromatogram of the C₂-C₈ hydrocarbons in figure 2 shows a series of prominent n-alkane compounds. Only a few branched/cyclic compounds, especially methylcyclohexane, are of similar prominence. This would suggest a thermally mature oil. A high paraffin index (Thompson, 1979) of 1.16 suggests that the oil is thermally mature.

2.1.3 Recombination of C₁-C₈ hydrocarbons from gas and oil

The compositions of the FMT gas and the C₂-C₈ hydrocarbon fraction of the oil were combined in order to provide some indication of the light hydrocarbon composition of the fluid sampled by the FMT. The oil and gas compositions were recombined using the gas/oil ratio provided with the samples (Table 2).

2.1.4 Stable isotope composition of the FMT gas

The isotope data for the gas sample are shown in table 3 and figure 4. The FMT gas has a relatively low δ¹³C methane value, the nearest value being obtained from DST 2 in 34/7-3. Figure 4a suggests a non-associated gas derived from liptitinic sapropel, while figure 4b suggests a gas associated with a mature oil or a condensate.

With the exception of the C₁ carbon isotope value, the carbon isotope ratios of the C₂-C₄ components are similar to those obtained from other 34/7 DST gases.

2.2 Analysis of FMT oil sample

2.2.1 API gravity

The FMT oil sample has an API gravity of 37.9⁰ (Table 4) which would suggest a thermally mature, moderately light oil. This value is similar to the gravities obtained from most of the 34/7 oil samples analysed so far.

2.2.2 Nickel, Vanadium and Sulphur content of the oil

The FMT oil has a low sulphur content of around 0.3%, which is around the average for the 34/7 DST oils and suggests a low sulphur oil (Table 5). A Ni content of around 6 mg/kg is higher than has been observed in other 34/7 oils, while a V content of around 3.2 mg/kg is about average for a 34/7 DST oil.

2.2.3 Gross composition of the crude oil samples

Low molecular weight compounds in the <210⁰C fraction of the oil account for 54.5% of the total oil (Table 6). This relatively high content of low molecular weight compounds might be expected from the API gravity of the sample.

Of the >210⁰C oil fraction, asphaltene compounds account for 0.8%, and NSO compounds account for 13.5% of the total fraction (Table 7). The asphaltene content of the 34/7-9 FMT oil is lower than is observed in most of the 34/7 oils, with the exception of the 34/7-6 and 34/7-8 oils. The NSO content of the FMT oil is similar to values observed in the 34/7-8 oils, but is higher than in the other 34/7 oils.

Problems were encountered with the >210⁰C oil fraction due to the presence of a significant amount of wax, resulting in an apparently increased saturate fraction. Due to this problem, it is difficult to say much about the relative proportions of the different chromatographic fractions.

2.2.4 Gas chromatography of the FMT oil

a) Whole oil gas chromatography

The whole oil gas chromatogram of this oil is shown in figure 5 and has a smooth unimodal n-alkane envelope decreasing in intensity from nC_6 down to around nC_{30} . The n-alkane compounds are the most prominent compounds in the gas chromatogram, branched/cyclic compounds being generally less well developed, with the exception of the methylcyclohexane peak. This peak is prominent on the whole oil gas chromatograms of all the 34/7 oils studied at IKU.

The whole oil gas chromatogram of the 34/7-9 oil is similar to those of the 34/7-8 DST oils.

b) Gas chromatography of saturated hydrocarbons

The gas chromatogram of the saturated hydrocarbons (figure 6) shows a unimodal distribution of n-alkanes reaching a maximum at nC_{22} - nC_{24} . The gas chromatogram also shows a 'hump' of unresolved compounds which may reflect the wax content previously noted. The appearance of the gas chromatogram contrasts with that of the whole oil and the rapid drop-off in peak intensity below nC_{20} may reflect problems in sample preparation due to the wax content. A pristane/phytane ratio of 0.8 (Table 9) suggests a mildly reducing source-rock depositional environment, although the relative peak heights may have been affected by the loss of the lighter components.

c) Gas chromatography of branched/cyclic compounds

The gas chromatogram of the branched/cyclic compounds (Figure 7) is dominated by a large 'hump' of unresolved compounds. The most prominent isoprenoid peaks are pristane and phytane. The iC_{18} peak is also present, but is less well developed.

d) Gas chromatography of aromatic hydrocarbons

The aromatic hydrocarbon gas chromatogram (Figure 8) is dominated by a large 'hump' of unresolved compounds, only the phenanthrene and alkyl-phenanthrene peaks showing significant development. Methyl-phenanthrene

indices of 0.94 and 0.93 (Table 8) suggest that the oil is probably mature. Other 34/7 DST oils showing significant humps of unresolved compounds in the aromatic gas chromatogram are seen in 34/7-5, 34/7-6 and 34/7-7.

2.2.5 Gas chromatography-mass spectrometry (GC-MS)

The mass chromatograms representing the terpane, sterane and aromatic biomarkers are shown in figures 9, 10 and 11. The biomarker ratios are given in tables 11, 12 and 13.

The biomarker characteristics of the 34/7-9 FMT oil are similar to those of the other 34/7 oils analysed at IKU. The maturity-dependant ratios have values which suggest thermal stability or thermal maturity.

The high relative abundance of 28,30-bisnorhopane (Z in m/z 191) may suggest a contribution from source-rocks of upper Jurassic age as this compound is encountered in samples from the Draupne/Heather formations.

The aromatic hydrocarbon (TIC) total ion chromatogram of the 34/7-9 FMT oil shows a full suite of naphthalenes and phenanthrenes which was not seen in the aromatic gas chromatogram (Figure 8). The naphthalene, phenanthrene and dibenzothiophene mass chromatograms show moderately mature to mature assemblages of compounds. The gas chromatograms of the mono- and tri-aromatic steranes show distributions which suggest an early-oil window maturity for the oil, in contrast to the other data.

2.2.6 $\delta^{13}\text{C}$ stable isotope composition of the FMT oil

The carbon isotope ratios for the saturate, aromatic, NSO and asphaltene chromatographic fractions are given in Table 14. Most of the values are comparable to the ratios obtained from other 34/7 DST oils, although the NSO fraction yielded a relatively high $\delta^{13}\text{C}$ ratio of -34.20/00. The only sample with a greater $\delta^{13}\text{C}$ NSO ratio is DST 1a from 34/7-8.

The isotope profile shown in figure 12 is similar to that observed for DST 1a from 34/7-8, and differs from the majority of the 34/7 DST oils. The cause of this difference is uncertain.

3. ANALYTICAL PROCEDURES

Gas analyses

Natural gas (full analysis of hydrocarbons and inert gases):

Natural gas samples were analysed on an HP 5880 gas chromatograph equipped with a capillary column and an FID for hydrocarbon analysis and two packed columns and a TCD for analysis of the inert gases (N_2 , O_2 , CO_2):

- 50 m x 0.2 mm i.d. fused silical column, coated with 0.5 μ m OV-101.
- 3 ft steel column packed with molecular sieve 13x, 80/100 mesh.
- 6 ft steel column packed with Porapack T x 4 ft steel column packed with Porapack Q, 80/100 mesh.

Temperature program: 30^oC (12 min.) - 8^oC/min. - 150^oC (5 min.).

A standard gas sample containing methane, ethane, propane, n-butane, n-pentane and n-hexane was used for quantification.

Evaporation of the light components in fluid samples

Prior to chromatographic separation, the oil/condensate samples were heated to 210^oC at atmospheric pressure until constant weight (at 210^oC) was obtained.

The fraction of light components was determined as the weight difference between the original sample and the residuum left after heating.

Medium-pressure liquid chromatography (MPLC)

The oil (>210^oC) sample was diluted in DCM (1:3 mg/ μ l) and the asphaltenes were precipitated using excess n-pentane (40:1 pentane:(DCM+oil)). The asphaltene fraction was weighed after drying at 50^oC for 12 hours.

The remaining maltenes were separated into saturated, aromatic and non-hydrocarbon fractions using an MPLC system with n-hexane as eluant (Radke et al., 1980). The various fractions were concentrated using a Büchi Rotavapor, transferred to glass vials and the remaining solvent removed.

Urea adduction

An aliquot of the saturated hydrocarbon fraction (5 mg) was diluted with n-hexane (2 ml), followed by the addition of acetone (1 ml). A saturated solution of urea in methanol (1 ml) was then added dropwise. The solvent was removed in a nitrogen stream and the adduction procedure repeated twice more. The white crystals were rinsed with hexane (3x5 ml) and the combined extract was filtered through a cotton plug covered with Al_2O_3 to produce a non-adduct containing the branched and cyclic hydrocarbons. GC analyses were performed on the non-adduct using the conditions outlined in the next section.

Gas chromatographic analysis

A whole oil sample was analysed using an HP 5730A gas chromatograph fitted with a 15 m DB-5 fused silica column. 0.02 μ m of sample solution was injected in split mode (split ratio = 1:10). Hydrogen was used as a carrier gas with a flow rate of 2.5 ml/min, and the temperature programme used was $-50^{\circ}C$ (2 min) - $4^{\circ}C/min$ - $280^{\circ}C$.

The C_2 - C_8 hydrocarbon compounds were investigated by hydrogen stripping on a Carlo Erba Fractovap gas chromatograph fitted with a 60 m x 0.32 mm (i.d.) fused silica column coated with DB-1, 1.0 μ m. The temperature programme used was $50^{\circ}C$ (2 min) - $4^{\circ}C/min$ - $210^{\circ}C$. An internal standard was used for quantification.

The saturated and the branched/cyclic hydrocarbon fractions were each diluted with n-hexane and analysed on an HP 5730A or an HP 5710 GC. Both GCs are equipped with 15 m DB-1 fused silica columns, and hydrogen is used as carrier gas with a flow rate of about 1.5 ml/min. Injections were performed in split mode (split ratio 1:10). The temperature programme used was $80^{\circ}C$ (2 min) - $4^{\circ}C/min$ - $280^{\circ}C$.

The total aromatic fractions were diluted with n-hexane and analysed on an HP 5730A gas chromatograph, fitted with a DB-5 fused silica column (15 x 0.25 mm i.d.), using a hydrogen carrier gas with a flow rate of 2.5 ml/min. The injection split ratio was 1:10.

The temperature programme used was $80^{\circ}C$ (2 min.) - $4^{\circ}C/min$ - $280^{\circ}C$.

Data processing for all the GC analyses was performed on a VG Multichrom lab data system.

Gas chromatography - mass spectrometry (GC-MS)

GC-MS analysis were performed on a VG Micromass 70-70H GC-MS-DS system. The Varian Series 3700 GC was fitted with a fused silica OV-1 capillary column (30m x 0.3 mm i.d.). Helium (1.5 ml/min) was used as carrier gas and the injections were performed in split mode (1.5 μ l, split ratio 1:15).

The GC oven was programmed from 120^oC (2 min.) to 280^oC at 4^oC/min. for analysis of the saturated hydrocarbons, and from 70^oC/min. to 280^oC at 4^oC/min. for analysis of the aromatic hydrocarbons.

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 spectrometers operated at 70eV electron energy with an ion source temperature of 200^oC. Data acquisition was performed using VG data systems.

Peaks were identified by comparison with elution patterns in certain mass chromatograms. Peak ratios were calculated from peak heights in the appropriate mass chromatograms.

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

The $\delta^{13}\text{C}$ isotope analyses were performed by mass spectrometry at the Institute for Energy Technology (IFE) in Oslo according to their method. Their reference value for the standard NBS-22 is -29.8 ‰ (PDB).

The samples were filled in a glass capillary and transferred into a combustion system filled with copper dioxide, heated to 900^oC. A stream of ultrapure helium and oxygen flushed the reaction products through silver wool (450^oC) to remove traces of halogens and sulphur.

H₂O and CO₂ were trapped in separate cooltraps. After removal of the carrier gas by high vacuum, CO₂ and H₂O were sealed off separately in

6 mm glass tubes. H₂O was reduced to H₂ by zinc at 460°C.

The ¹³C/¹²C - isotope ratio (and D/H- isotope ratio) was measured with a high precision mass spectrometer Finnigan MAT 251.

Precision of the preparation lines and the mass spectrometer was daily controlled by measurements of standard substances and by double analyses.

The isotope ratios are given as delta-values (del):

$$\text{del (\%)} = ((R \text{ sample} - R \text{ stand.}) / (R \text{ stand.})) * 1000$$

¹³C/¹²C- isotope ratios are calculated versus PDB.

D/H-isotope ratios are calculated versus SMOW.

The CV value is calculated after SOFER (1984) to differentiate between marine and terrestrial-sourced oils:

$$CV = (-2.53 * \text{del}^{13}\text{C}_{\text{sat}}) + (2.22 * \text{del}^{13}\text{C}_{\text{aro}}) - 11.65.$$

4. CONCLUSIONS

The 34/7-9 FMT oil is a moderately light, low sulphur, paraffinic-naphthenic oil of similar composition to other 34/7 oils analysed at IKU. The FMT gas shows characteristics typical of oil-associated gases. An upper Jurassic source is suggested for the FMT fluid, which is considered to be thermally mature.

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Previous IKU reports concerned with block 34/7 fluids:

05.1725.00/02/84: Fluid characterisation of well 34/7-1.

05.1728.00/02/85: Hydrocarbon characterisation of well 34/7-3.

22.1767.00/03/85: Hydrocarbon characterisation of well 34/7-4.

22.1771.00/03/85: Analysis of fluid and gas samples from well 34/7-5.

22.1779.00/03/85: Analysis of fluid and gas samples from well
34/7-6 (DST 2 and DST 3b).

22.1805.00/01/86: Analysis of fluid and gas samples from well 34/7-7.

Table 1a: Ratios obtained from C₁-C₈ oil/gas compositions.

IKU no.	Sample id.	%CH ₄	%Wetness	iC ₄ /nC ₄	P.I. 1
C-4632/C-4631	FMT	27.1	68.2	0.31	1.16

$$\% \text{Wetness} = (\Sigma C_{2-C_5} / \Sigma C_{1-C_8}) \times 100$$

$$\text{P.I. 1 (after Thompson, 1978)} = 2\text{-MeC}_6 + 3\text{-MeC}_6 / \text{diMeCyC}_5 \text{ (3 isomers)}$$

C1-C8 YIELD

WELL NO: 34/7-9
 IKU NO,GAS: C4632
 IKU NO,OIL: C4631
 GOR = 121.1 SM3/M3

Table 1b:

Recombination of FMT oil and gas (C₁-C₈ hydrocarbons).

COMPOUND	GAS MG/ML	GAS MG/121.1ML	OIL MG/ML	TOTAL HC IN MG/ML OF RESERVOIR FLUID
Methane	0.270	32.697	0.000	32.697
Ethane	0.154	18.649	0.000	18.649
Propane	0.235	28.459	0.484	28.943
i-Butane	0.044	5.328	0.511	5.839
n-Butane	0.142	17.196	2.816	20.012
i-Pentane	0.040	4.844	3.294	8.138
n-Pentane	0.049	5.934	6.234	12.168
Cyclo-C5+				
2,3-diMeC4	0.005	0.606	1.434	2.040
2-MeC5	0.012	1.453	3.516	4.969
3-MeC5	0.006	0.727	2.286	3.013
n-Hexane	0.015	1.817	7.614	9.431
MeCyC5	0.008	0.969	5.027	5.996
Benzene	0.002	0.242	1.384	1.626
CycloC6	0.006	0.727	4.956	5.683
2-MeC6	0.002	0.242	2.325	2.567
2,3-diMeC5	0.000	0.000	0.946	0.946
3-MeC6	0.002	0.242	3.634	3.876
diMeCyC5	0.002	0.242	5.277	5.520
n-Heptane	0.003	0.363	7.854	8.217
MeCyC6	0.000	0.000	10.083	10.083
EtCyC5+				
2,5-diMeC6	0.000	0.000	1.313	1.313
2,4-diMeC6	0.000	0.000	0.829	0.829
triMeCyC5	0.000	0.000	0.874	0.874
Toluene	0.000	0.000	4.502	4.502
2-MeC7+				
4-MeC7	0.000	0.000	3.956	3.956
3-MeC7	0.000	0.000	1.924	1.924
diMeCyC6	0.000	0.000	4.341	4.341
n-Octane	0.000	0.000	8.116	8.116
2,4-diMeC7+				
diMeCyC6	0.000	0.000	1.613	1.613
EtCyC6	0.000	0.000	3.366	3.366
EtBenzene	0.000	0.000	1.639	1.639
m+p-xylene	0.000	0.000	3.955	3.955
2-MeC8+				
4-MeC8	0.000	0.000	1.880	1.880
o-Xylene	0.000	0.000	1.782	1.782
SUM	0.997	120.737	109.776	230.513

Table 2:

C₂-C₈ hydrocarbon composition of FMT oil.

C 4631	area	ug	mg/ml	% of t.oil
nC3	29539	.145	.484	.057
iso-C4	31219	.153	.511	.061
nC4	171812	.844	2.816	.337
iso-C5	200971	.988	3.294	.394
nC5	380367	1.870	6.234	.746
CyC5+2,3diMeC4	87510	.430	1.434	.171
2MeC5	214536	1.054	3.516	.420
3MeC5	139509	.686	2.286	.273
nC6	464524	2.284	7.614	.911
MeCyC5	306694	1.508	5.027	.601
benzene	84446	.415	1.384	.165
CyC6	302400	1.487	4.956	.593
2MeC6	141843	.697	2.325	.278
2,3diMeC5	57761	.284	.946	.113
3MeC6	221742	1.090	3.634	.435
DiMeCyC5	321965	1.583	5.277	.631
nC7	479204	2.356	7.854	.940
MeCyC6	615198	3.025	10.083	1.207
EtCyC5+2,5diMeC6	80137	.394	1.313	.157
2,4diMeC6	50631	.248	.829	.099
triMeCyC5	53329	.262	.874	.104
toluene	274711	1.350	4.502	.539
2+4MeC7	241359	1.186	3.956	.473
3MeC7	117384	.577	1.924	.230
DiMeCyC6	264875	1.302	4.341	.519
nC8	495143	2.434	8.116	.971
2,4diMeC7+diMeCyC6	98445	.484	1.613	.193
EtCyC6	205373	1.009	3.366	.403
EtBenzene	99784	.490	1.635	.195
m,p-Xylene	241317	1.186	3.955	.473
2+4MeC8	114753	.564	1.880	.225
o-xylene	108720	.534	1.782	.213
sum		32.932	109.776	13.142

tot.oil ant ug inj.: 250.590ug

%C2-C8(tot.area)in tot.oil: 14.574%

Table 3: Stable isotope data for the FMT gas.

IKU nr.	C ₁		C ₂	C ₃	i-C ₄	n-C ₄
	$\delta^{13}\text{C}$ PDB	δD SMOW	$\delta^{13}\text{C}$ PDB	$\delta^{13}\text{C}$ PDB	$\delta^{13}\text{C}$ PDB	$\delta^{13}\text{C}$ PDB
C-4632	-38.5	-152	-31.8	-30.9	-32.6	-31.6

Project No.: 22.1830
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Table 5:

CONTENT OF SULPHUR, NICKEL AND VANADIUM IN OIL %210°C

I	:	:	:	:	:	I
I	IKU-No	CODE	S	Ni	V	I
I	:	:	:	:	:	I
I	:	:	%	(mg/kg)	(mg/kg)	I
I	:	:	:	:	:	I
I	3477-9	:	:	:	:	I
I	C-4631	FMT	0.31-0.34	6.0-5.8	3.20-3.22	I
I	:	:	:	:	:	I

Project No.: 22.183D
 Date : 22 - 7 - 86

Table 6:

FRACTION BOILING BELOW 210 °C

IKU No	CODE	Crude Oil (mg)	EOM (>210 °C) (mg)	Low Molecular Weight Compounds (mg)	(%)
34/7-9	FMT	776.9	353.5	423.4	54.5

Project no.: 22.1850
 DATE : 9 - 7 - 86

Table 7:

AMOUNT OF ASPHALTENES AND NSO'S IN OIL

IKU No	DST No	Crude Oil (mg)	Asphaltenes (mg)	(%)	NSO (mg)	(%)
34/7-9						
C-4631	FMT	776,9	6,4	0,8	105,0	13,5

Project No.: 22.1830
 Well : 34/7-9
 Date : 22 - 7 - 86

Table 8a:

CONCENTRATION OF OIL CHROMATOGRAPHIC FRACTIONS

I	:	:	Crude	:	EOM	:	:	:	Non	I						
I	IKU No	:	Oil	:	>2100	:	Sat.	:	HC	HC						
I	:	:	:	:	:	:	:	:	:	I						
I	:	:	(mg)	:	(mg)	:	(mg)	:	(mg)	(mg)						
I	:	:	:	:	:	:	:	:	:	I						
I	C 4631*	:	FMT	:	776.9	:	353.5	:	154.0	:	80.5	:	234.5	:	14.7	I
I	:	:	:	:	:	:	:	:	:	:	:	:	:	:	I	

* High wax content of oil caused problems in weighing saturate fraction.

Project No.: 22.1830
 Well : 34/7-9
 Date : 22 - 7 - 86

Table 8b:

COMPOSITION OF OIL

I	:	:	Sat.	:	App.	:	HC	:	Sat.	:	Non HC	:	HC	I
I	IKU No	:	CODE	:	---	:	---	:	---	:	---	:	---	I
I	:	:	EOM	:	EOM	:	EOM	:	App.	:	EOM	:	Non HC	I
I	:	:	%	:	%	:	%	:	% 100	:	%	:	% 100	I
I	:	:	:	:	:	:	:	:	:	:	:	:	:	I
I	C 4631	:	FMT	:	58.4	:	37.4	:	95.8	:	191.3	:	4.2	2304.8 I

Table 9:

TABULATION OF DATA FROM THE GASCHROMATOGRAMS

I			:	PRISTANE	PRISTANE	PHYTANE	A	n-C17		I
I	Tr. No.	CODE	:	-----	A = -----	B = -----	-----	-----	OP1	I
I			:	PHYTANE	n-C17	n-C13	B	n-C27		I
I			:							I
I	C 4631	FMT	:	0.8	0.8	0.7	1.3	0.6	1.1	I
I			:							I

DATE : 4 - 7 - 86.



Table 10:

Ratios from aromatic gas chromatograms

IKU no.	DST no.	MPI-1	MPI-2
C-4631	FMT	0.94	0.93

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

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

Table 11: Molecular ratios from sterane and terpane mass chromatograms.
Maturity ratios.

IKU code	Well no.	$\alpha\beta/\alpha\beta+\beta\alpha$ ¹⁾	%22S ²⁾	% $\beta\beta$ ³⁾	%20S ⁴⁾
C-4631	34/7-9	0.93	58.8	76.0	49.3

1) E/E+F in m/z 191

2) Average % distribution between first and second eluting isomers of extended hopanes (G-M in m/z 191)

3) $2(r+s)/(q+t+2(r+s))$ in m/z 217

4) $q/q+t$ in m/z 217

Table 12: Molecular ratios from terpane and sterane mass chromatograms.
 Maturity and source characteristic ratios.

IKU no.	Well no.	Q/E ¹⁾	T _m /T _s ²⁾	X/E ³⁾	Z/E ⁴⁾	a/a+j ⁵⁾
C-4631	34/7-9	0.05	0.69	0.10	0.36	0.70

- 1) Relative abundance of tricyclic terpanes (Q/E in m/z 191)
- 2) B/A in m/z 191
- 3) Relative abundance of unknown (X/E in m/z 191)
- 4) Relative abundance of bisnorhopane (Z/E in m/z 191)
- 5) Relative abundance of C₂₇ rearranged steranes (a/a+j in m/z 217)

Table 13: Molecular ratios from mass chromatograms of aromatic fractions.

IKU no.	Well no.	%C ₂₀ /C _{26,27} ¹⁾	%C ₂₀ /C _{28,29} ²⁾
C-4631	34/7-9	28.6	28.1

1) Relative abundance of low molecular weight triaromatic steranes (M/M+P in m/z 231).

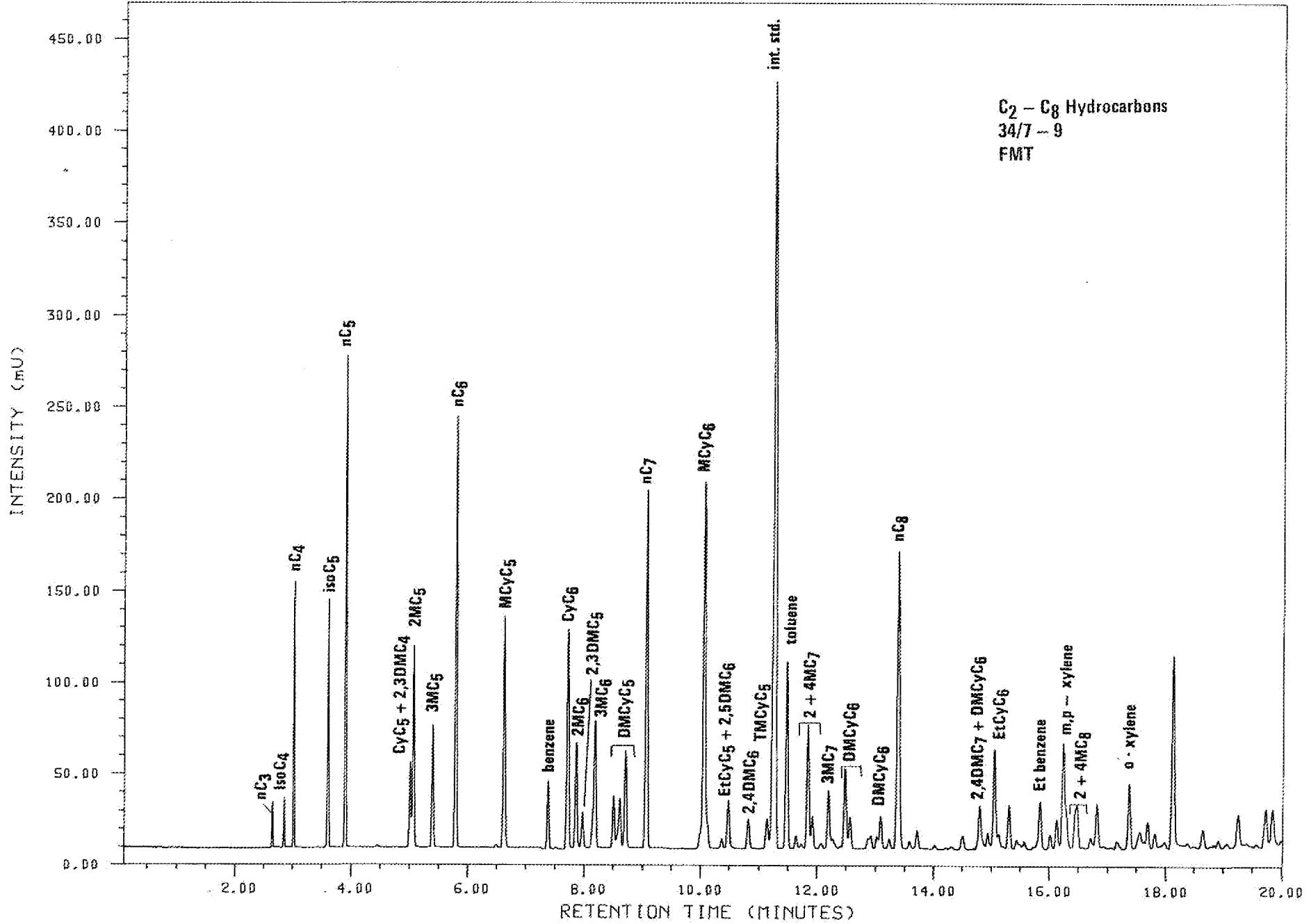
2) Relative abundance of low molecular weight monoaromatic steranes (a/a+h in m/z 253).

Table 14: $\delta^{13}\text{C}$ isotope data for FMT oil fractions.

IKU no.	DST no.	SAT	AROM	NSO	ASF
C-4631	FMT	-30.5	-30.1	-34.2	-30.0

FIGURE 3

C₂-C₈ HYDROCARBON GAS CHROMATOGRAMS



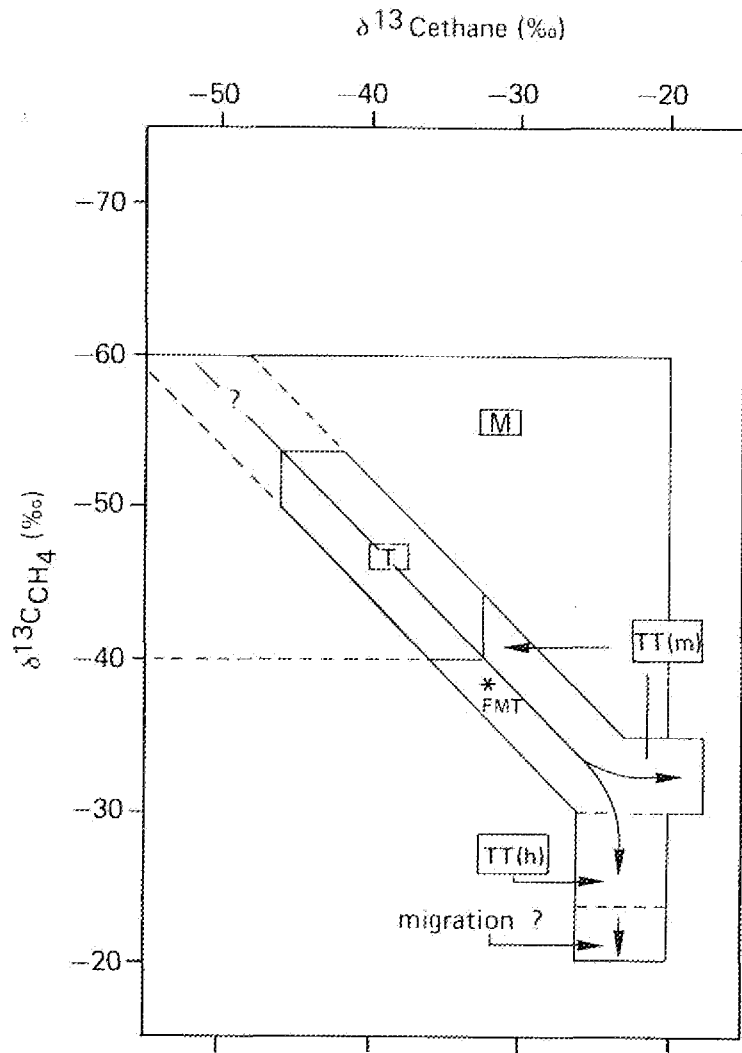


Figure 4a: The FMT sample plots within the field for nonassociated gases from sapropelic liptinitic organic matter. This is somewhat unexpected as the gas is associated with an oil. (After Schoell, 1983).

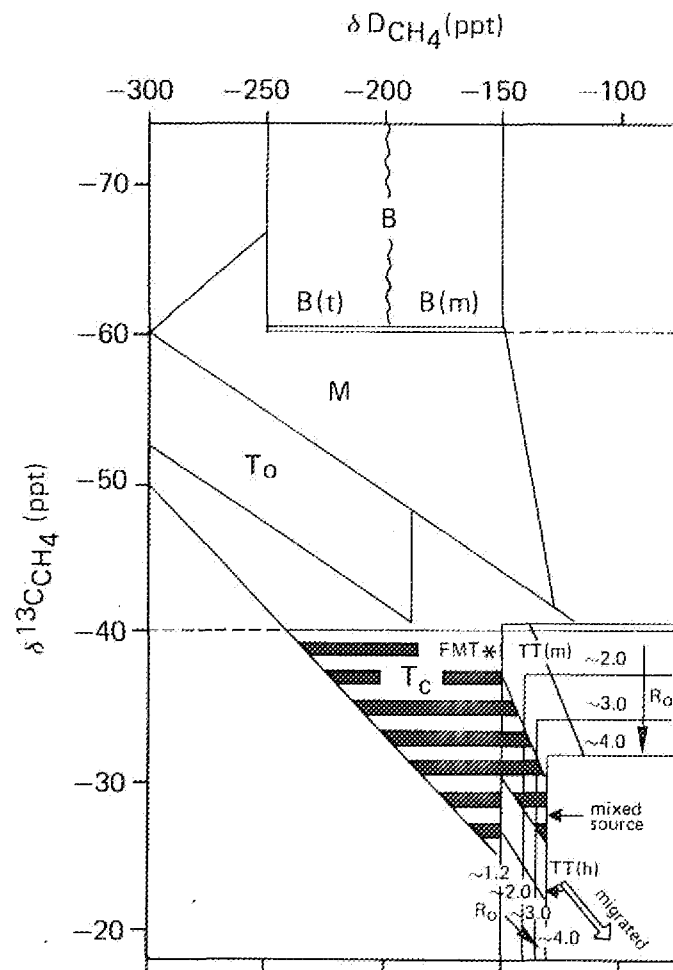


Figure 4b: The FMT sample plots in the field for condensate-associated gases. (After Schoell, 1983).

FIGURE 5

WHOLE OIL GAS CHROMATOGRAMS

C ₁₀ etc.	-	n-alkanes
Cy-C ₆	-	cyclohexane
MeCy-C ₆	-	methylcyclohexane
Pr	-	pristane
Ph	-	phytane

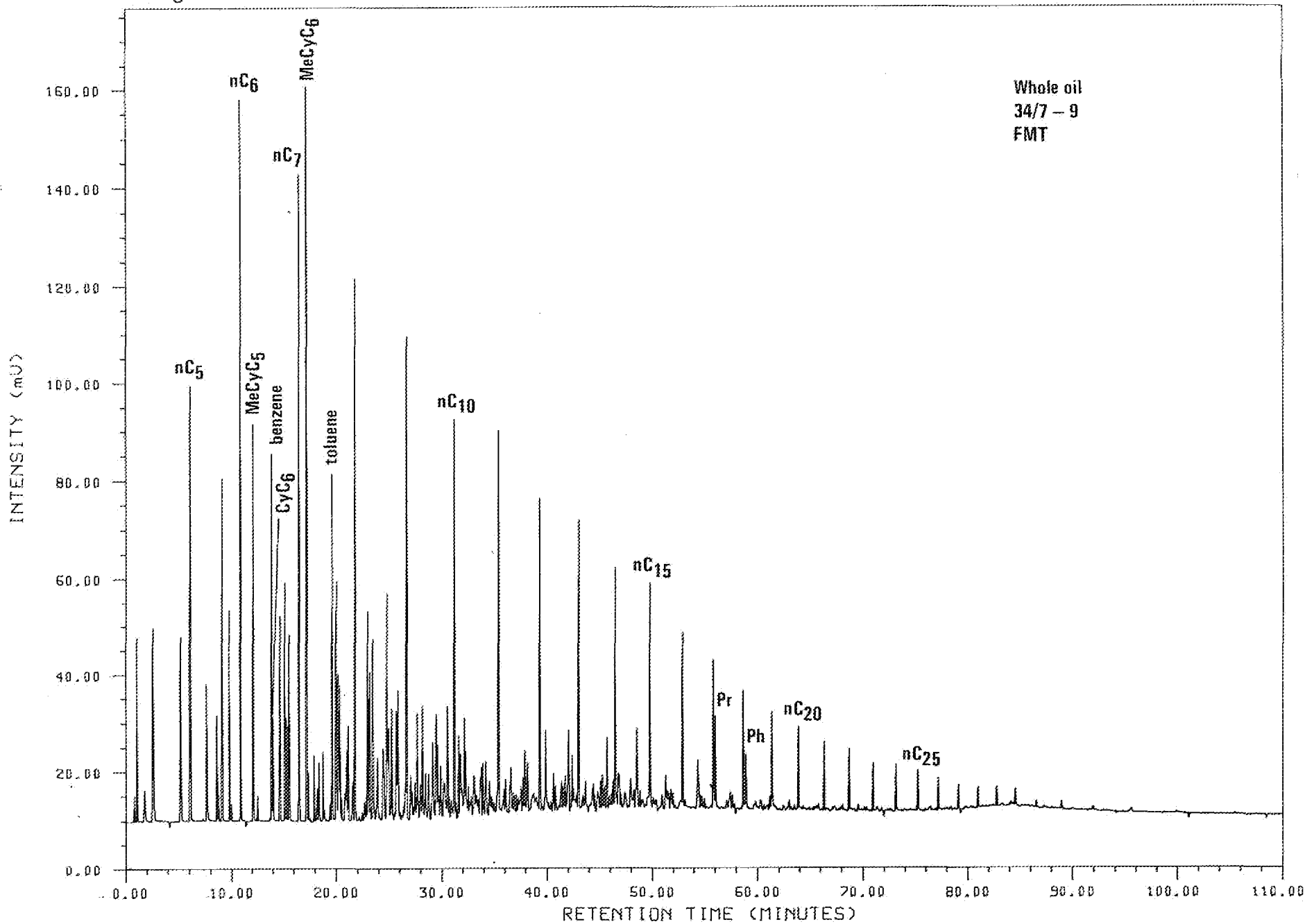


FIGURE 6

SATURATED HYDROCARBON GAS CHROMATOGRAMS

n-C₁₅ etc. - n-alkanes
Pr - pristane
Ph - phytane
* - other acyclic
isoprenoids

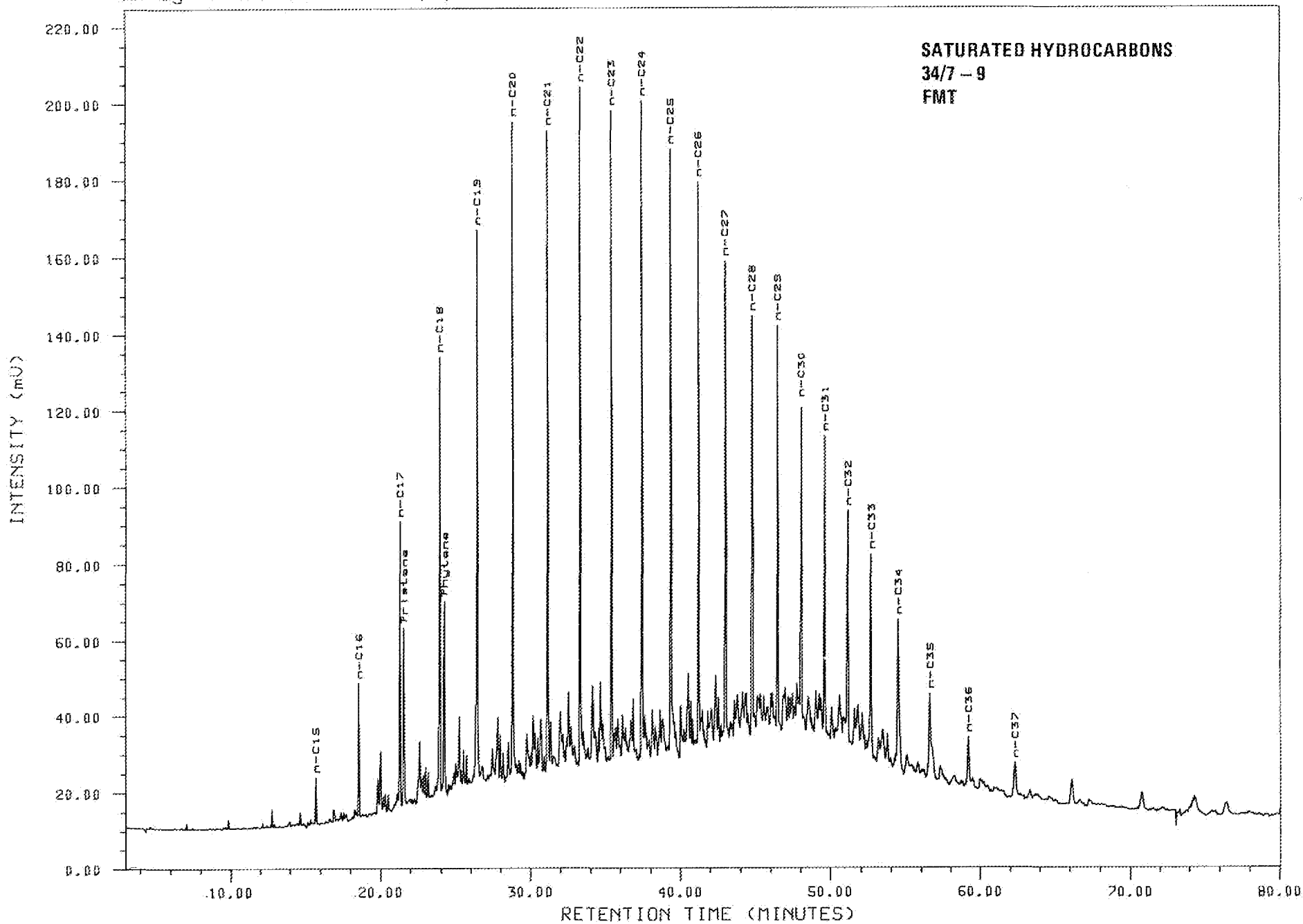


FIGURE 7

BRANCHED/CYCLIC HYDROCARBON GAS CHROMATOGRAMS

Pr	- pristane
Ph	- phytane
isopr.C ₁₈ etc.	- isoprenoids
*	- n-alkanes remaining after adduction

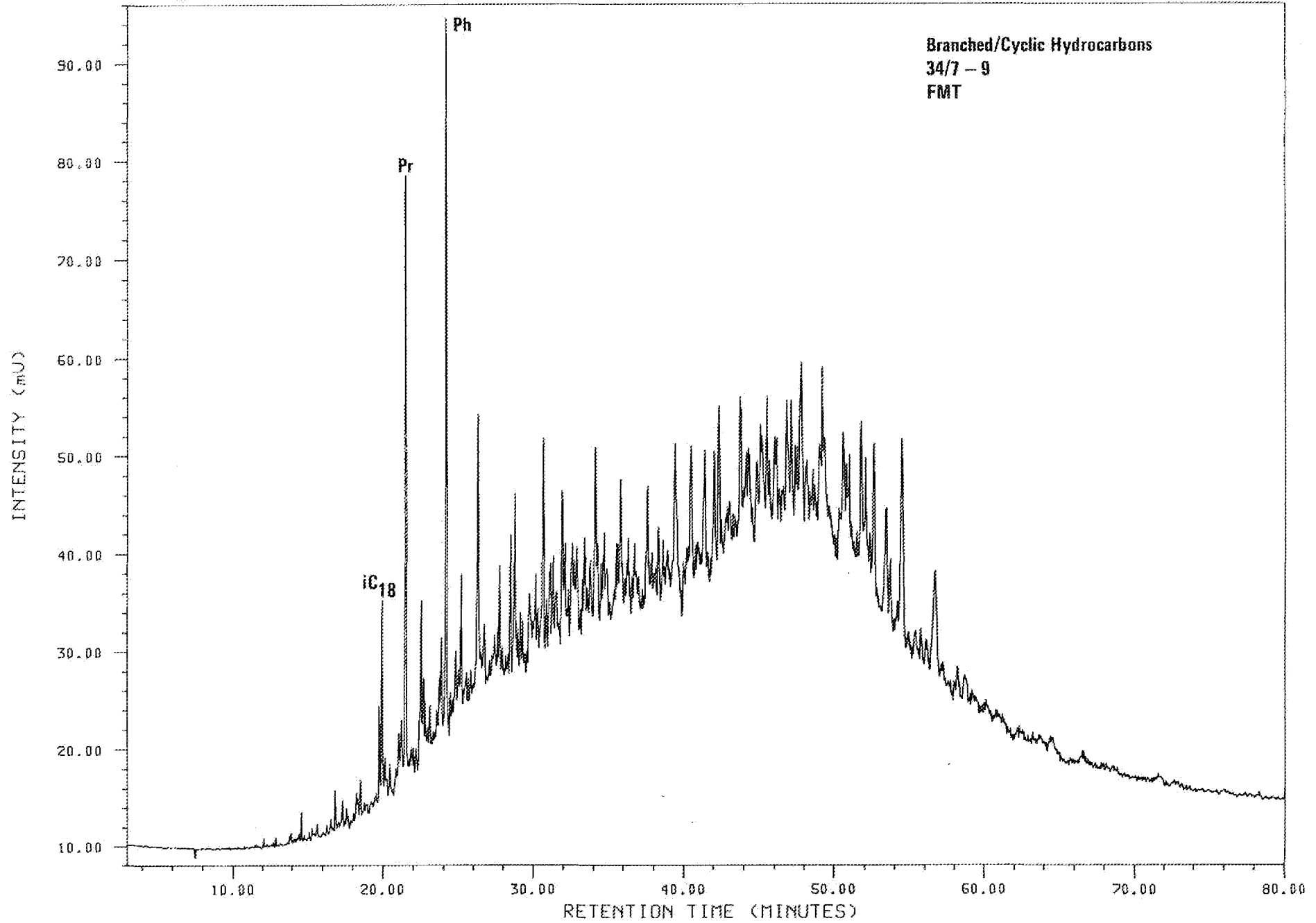


FIGURE 8

AROMATIC HYDROCARBON GAS CHROMATOGRAMS
FID DETECTION

N,MN,DMN,TMN - naphthalene and alkylated homologs
P,MP,DMP - phenanthrene and alkylated homologs

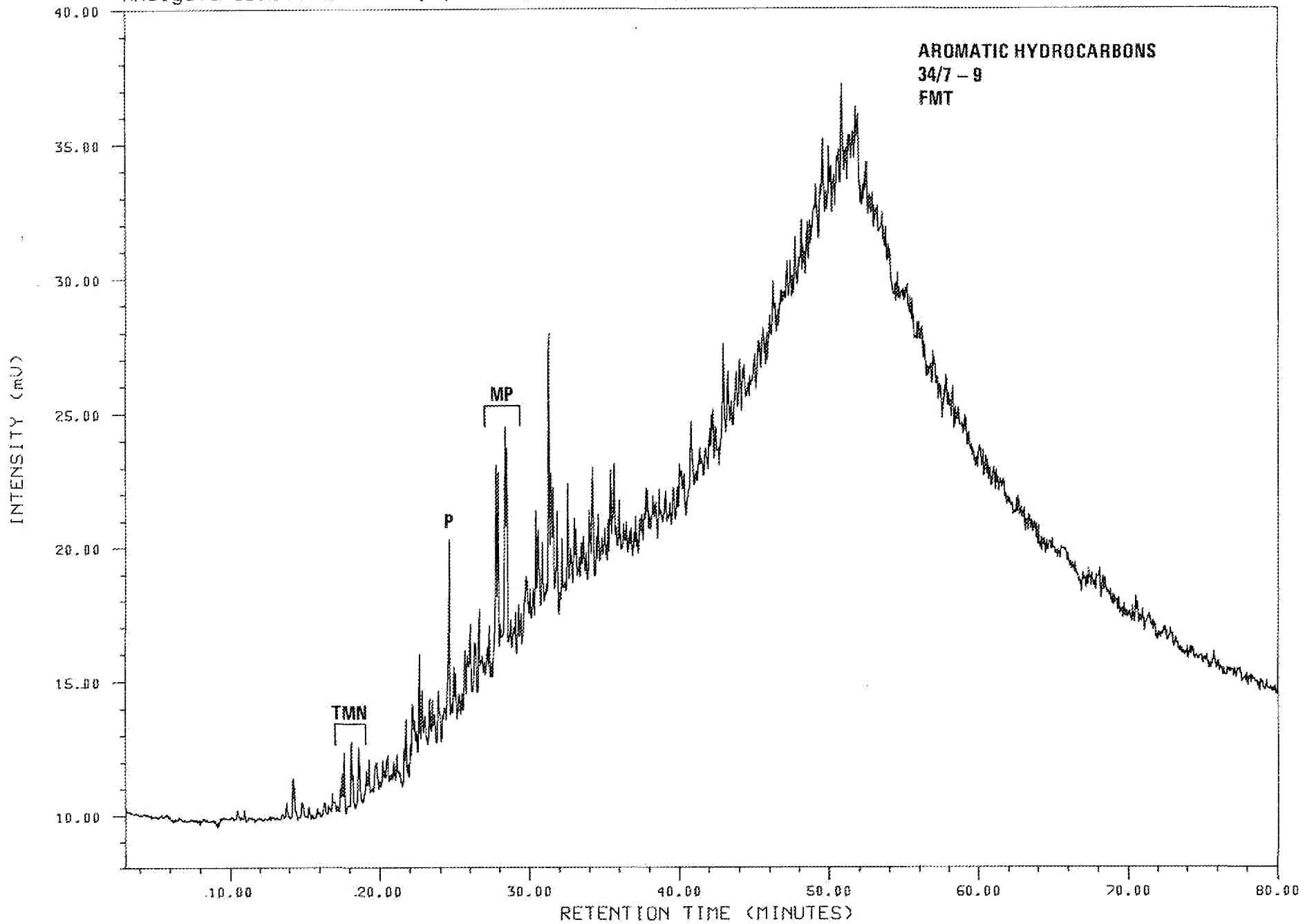
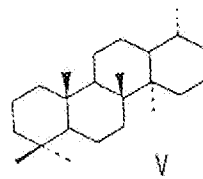
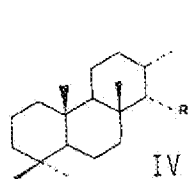
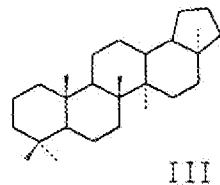
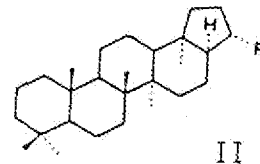
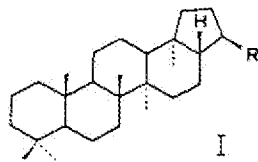


Figure 9.

Mass chromatograms representing terpanes (m/z 191)

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



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Sample 1 Injection 1 Group 1 Mass 191.1000
Text:

System:QUANID

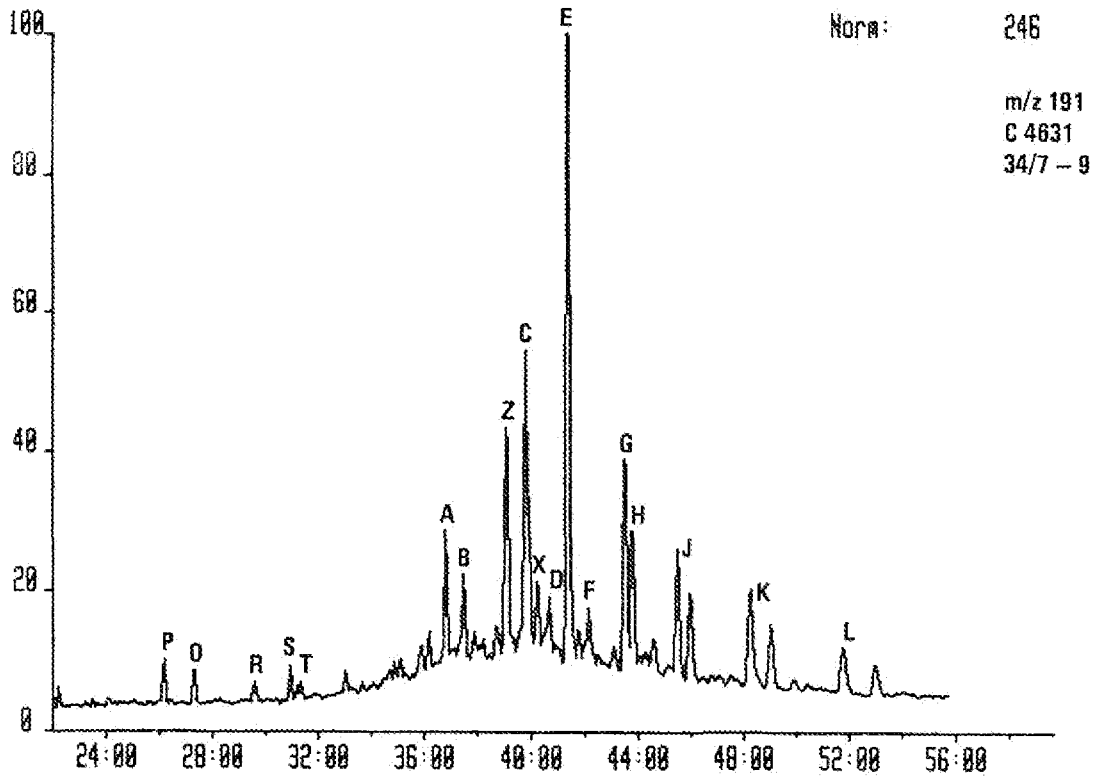
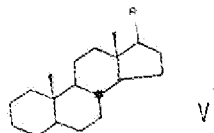
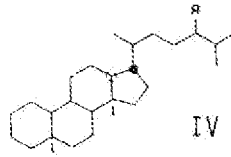
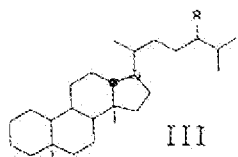
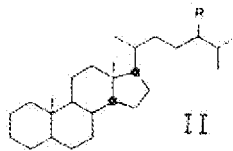
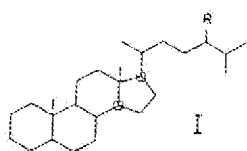


Figure 10.

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

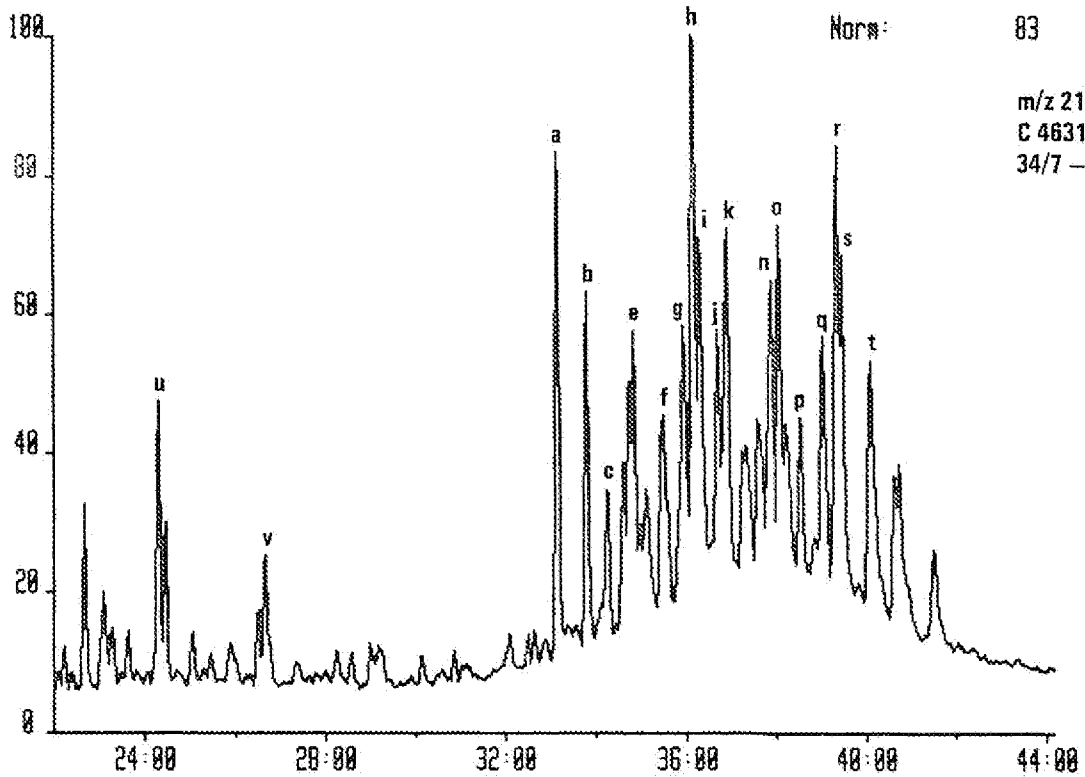
a	13 β (H),17 α (H)-diasterane (20S)	C ₂₇ H ₄₈	(III,R=H)
b	13 β (H),17 α (H)-diasterane (20R)	C ₂₇ H ₄₈	(III,R=H)
c	13 α (H),17 β (H)-diasterane (20S)	C ₂₇ H ₄₈	(IV,R=H)
d	13 α (H),17 β (H)-diasterane (20R)	C ₂₇ H ₄₈	(IV,R=H)
e	13 β (H),17 α (H)-diasterane (20S)	C ₂₈ H ₅₀	(III,R=CH ₃)
f	13 β (H),17 α (H)-diasterane (20R)	C ₂₈ H ₅₀	(III,R=CH ₃)
g	13 α (H),17 β (H)-diasterane (20S)	C ₂₈ H ₅₀	(IV,R=CH ₃)
	+ 14 α (H),17 α (H)-sterane (20S)	C ₂₇ H ₄₈	(I,R=H)
h	13 β (H),17 α (H)-diasterane (20S)	C ₂₉ H ₅₂	(III,R=C ₂ H ₅)
	+ 14 β (H),17 β (H)-sterane (20R)	C ₂₇ H ₄₈	(II,R=H)
i	14 β (H),17 β (H)-sterane (20S)	C ₂₇ H ₄₈	(II,R=H)
	+ 13 α (H),17 β (H)-diasterane (20R)	C ₂₈ H ₅₀	(IV,R=CH ₃)
j	14 α (H),17 α (H)-sterane (20R)	C ₂₇ H ₄₈	(I,R=H)
k	13 β (H),17 α (H)-diasterane (20R)	C ₂₉ H ₅₂	(III,R=C ₂ H ₅)
l	13 α (H),17 β (H)-diasterane (20S)	C ₂₉ H ₅₂	(III,R=C ₂ H ₅)
m	14 α (H),17 α (H)-sterane (20S)	C ₂₈ H ₅₀	(I,R=CH ₃)
n	13 α (H),17 β (H)-diasterane (20R)	C ₂₉ H ₅₂	(III,R=C ₂ H ₅)
	+ 14 β (H),17 β (H)-sterane (20R)	C ₂₈ H ₅₀	(II,R=CH ₃)
o	14 β (H),17 β (H)-sterane (20S)	C ₂₈ H ₅₀	(II,R=CH ₃)
p	14 α (H),17 α (H)-sterane (20R)	C ₂₈ H ₅₀	(I,R=CH ₃)
q	14 α (H),17 α (H)-sterane (20S)	C ₂₉ H ₅₂	(I,R=C ₂ H ₅)
r	14 β (H),17 β (H)-sterane (20R)	C ₂₉ H ₅₂	(II,R=C ₂ H ₅)
	+ unknown sterane		
s	14 β (H),17 β (H)-sterane (20S)	C ₂₉ H ₅₂	(II,R=C ₂ H ₅)
t	14 α (H),17 α (H)-sterane (20R)	C ₂₉ H ₅₂	(I,R=C ₂ H ₅)
u	5 α (H)-sterane	C ₂₁ H ₃₆	(V,R=C ₂ H ₅)
v	5 α (H)-sterane	C ₂₂ H ₃₈	(IV,R=C ₃ H ₇)





C4631SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU
Sample 1 Injection 1 Group 1 Mass 217.1000
Text:

System:QUAMID



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Sample 1 Injection 1 Group 1 Mass 218.1000
Text:

System:QUAMID

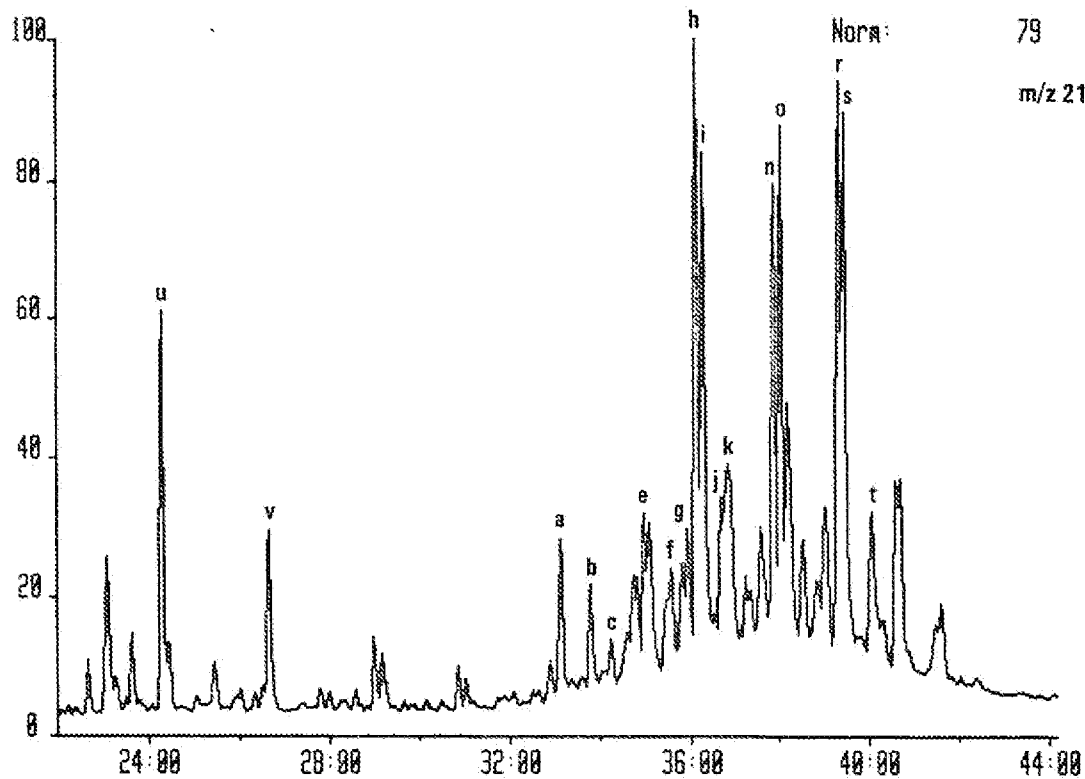


FIGURE 11

MASS CHROMATOGRAMS REPRESENTING AROMATIC HYDROCARBONS

TIC	- total ion current chromatogram
m/z 92,106	- alkylbenzenes
m/z 142,156,170	- alkylnaphthalenes
m/z 178,192,206	- phenanthrene and alkylphenanthrenes
m/z 184,198,212	- dibenzothiophene and alkyl-dibenzo- thiophenes
m/z 231	- triaromatic steranes
m/z 253	- monoaromatic steranes

Mass chromatograms representing monoaromatic (m/z 239 and 253) and triaromatic (m/z 231) steranes.

m/z 253

- a - C₂₁ monoaromatic sterane
- b - C₂₂ monoaromatic sterane
- c - unidentified
- d - C₂₇ monoaromatic sterane
- e - C₂₇ monoaromatic sterane
- f - C₂₈ monoaromatic sterane
- g - C₂₇ monoaromatic sterane
- h - C₂₈ + C₂₉ monoaromatic sterane
- i - C₂₉ monoaromatic sterane
- j - C₂₉ monoaromatic sterane
- k - unidentified
- l - unidentified

m/z 231

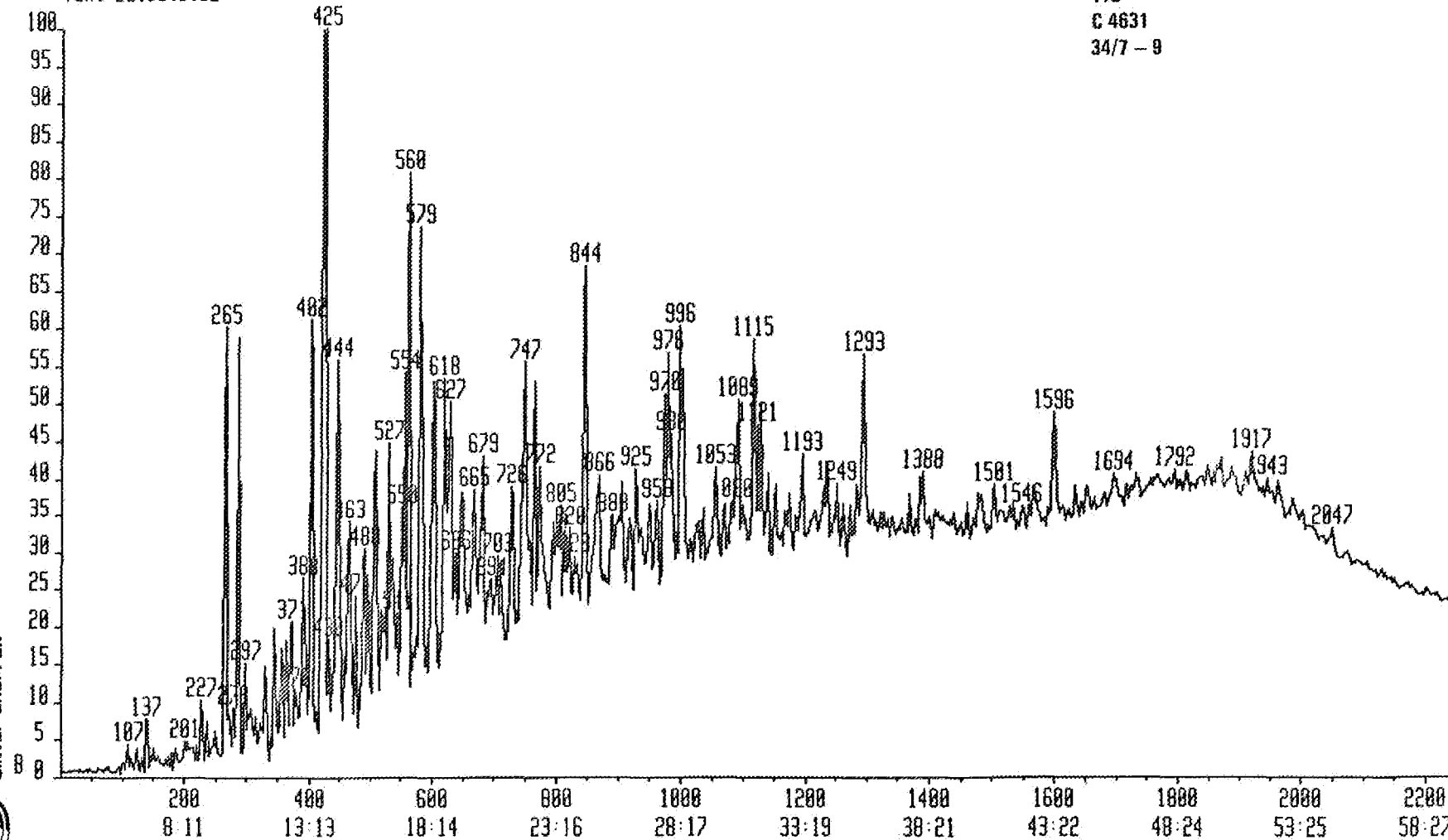
- M - C₂₀ triaromatic sterane
- N - C₂₁ triaromatic sterane
- O - C₂₆ triaromatic sterane
- P - C₂₆ + C₂₇ triaromatic sterane
- Q - C₂₈ triaromatic sterane
- R - C₂₇ triaromatic sterane
- S - C₂₈ triaromatic sterane

C4605ARO #1-2250 1-JUL-86 14:41 12250 acnt:IKU
Chromatogram Identifiers: B1-TIC
Text:22.8843.82

System: AROMATICS

Aromatic hc's
TIC
C 4631
34/7 - 9

IHP
B: 16444000



IKU
SINTEP-GRUPPEN

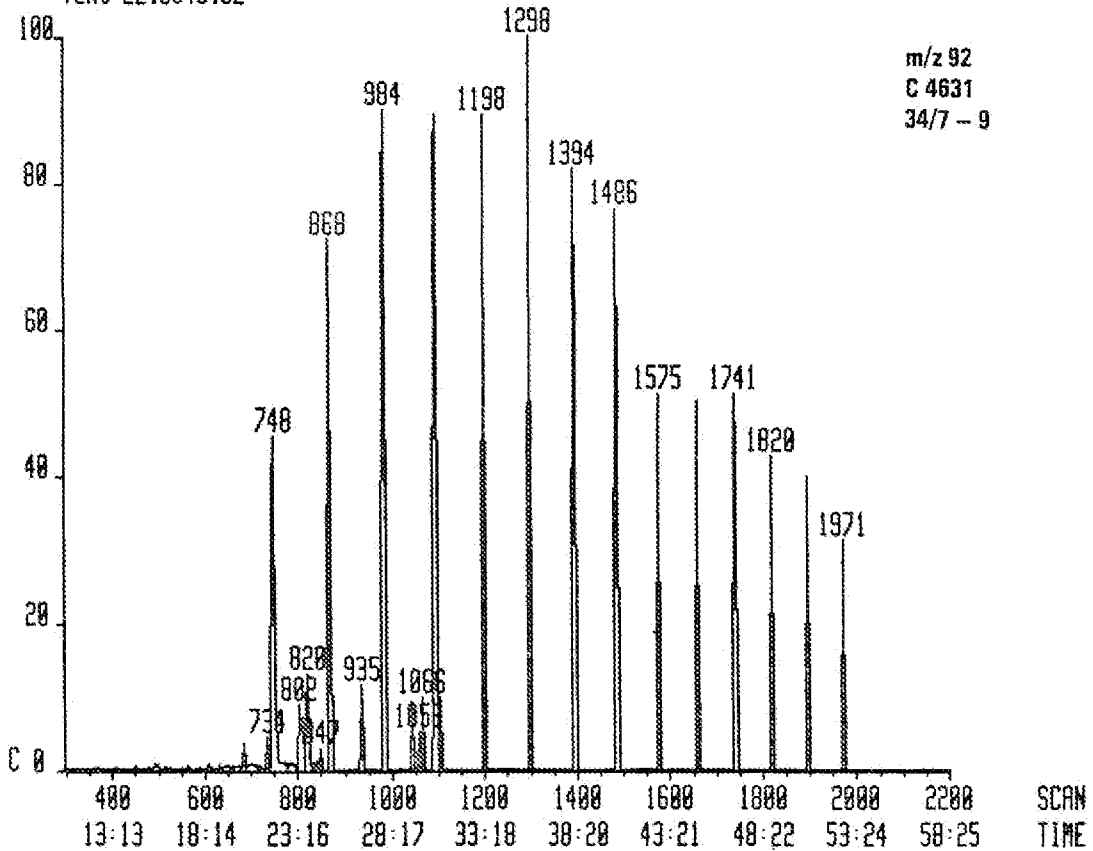


SCAN
TIME



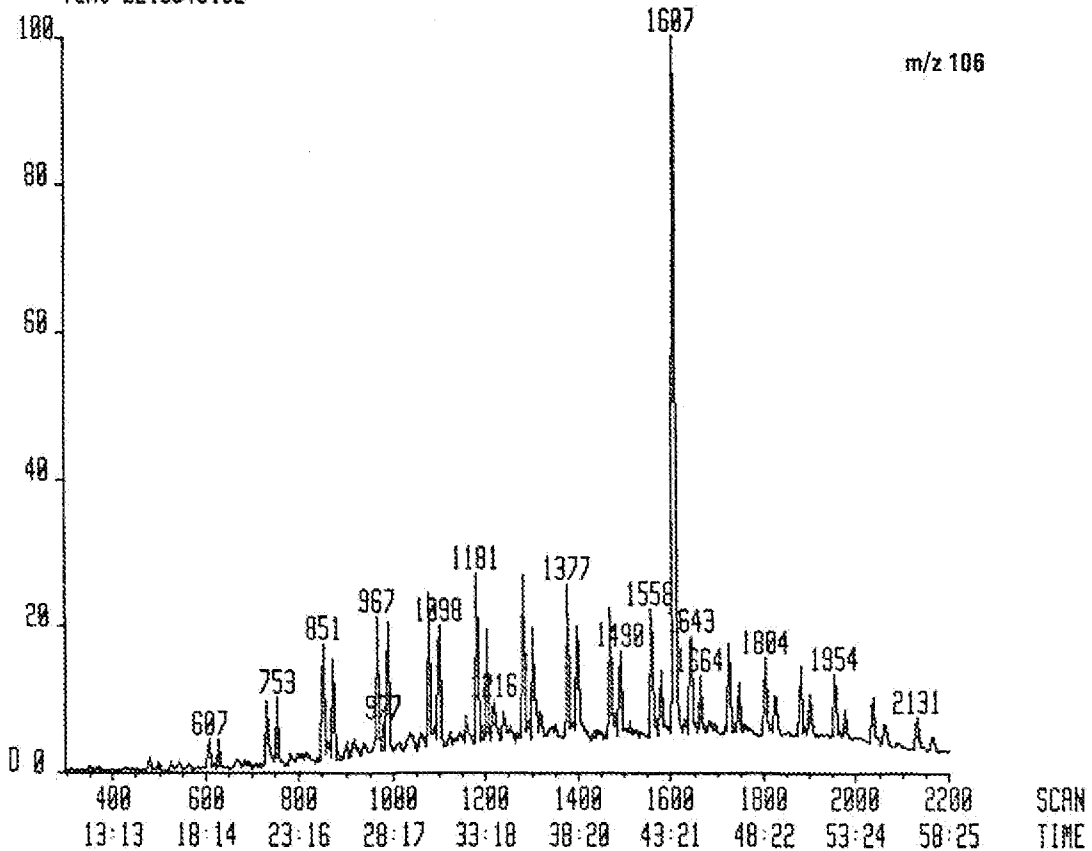
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Chromatogram Identifiers : C1:92
Text:22.8043.02

System:PAROMATICS
C: 942000



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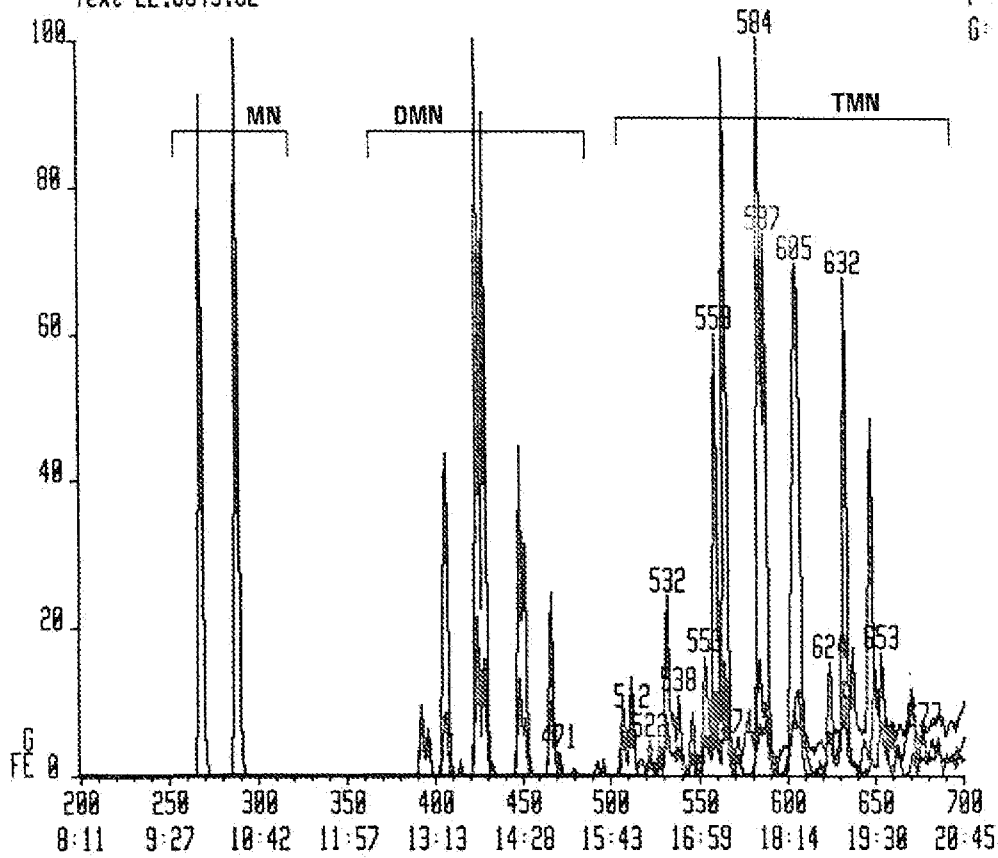
System:PAROMATICS
D: 3183000





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Text:22.8843.82

System:PAROMATICS
E: 212000
F: 427000
G: 482000



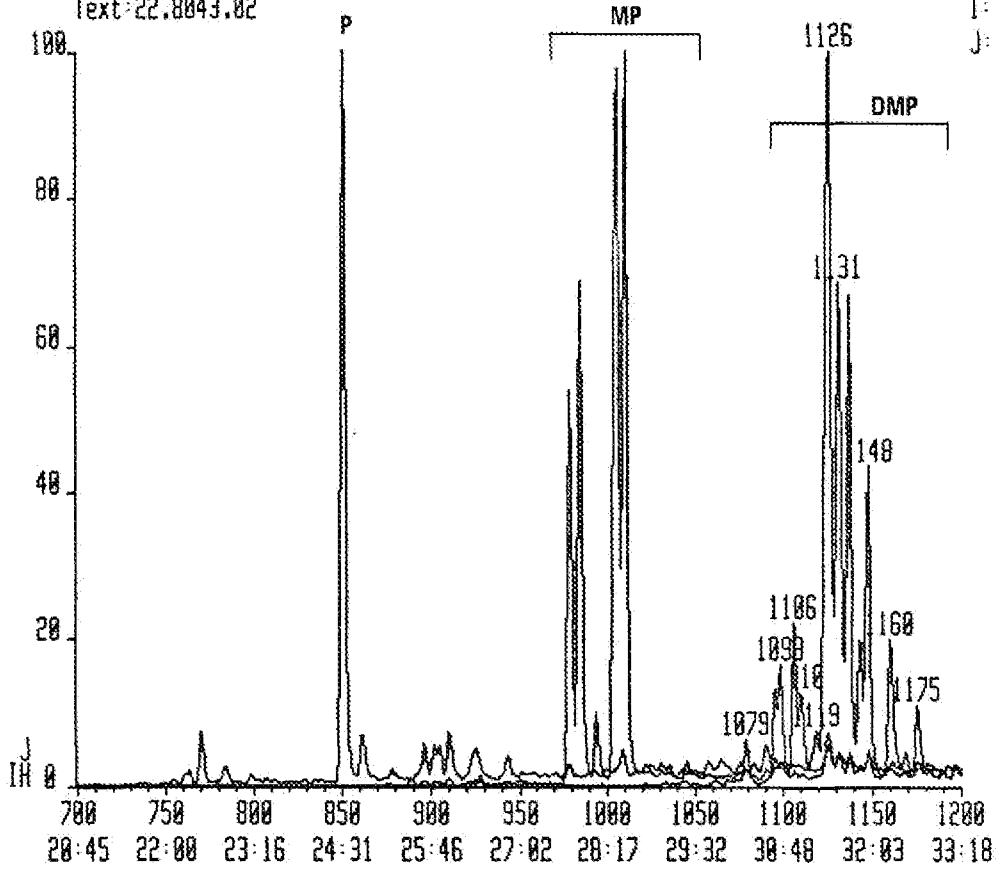
m/z 142, 156, 170
C 4631
34/7 - 9

SCAN
TIME



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Chromatogram Identifiers : H1:178 I1:192 J1:206
Text:22.8843.82

System:PAROMATICS
H: 2392000
I: 1843000
J: 1421000



m/z 178, 192, 206
C 4631
34/7 - 9

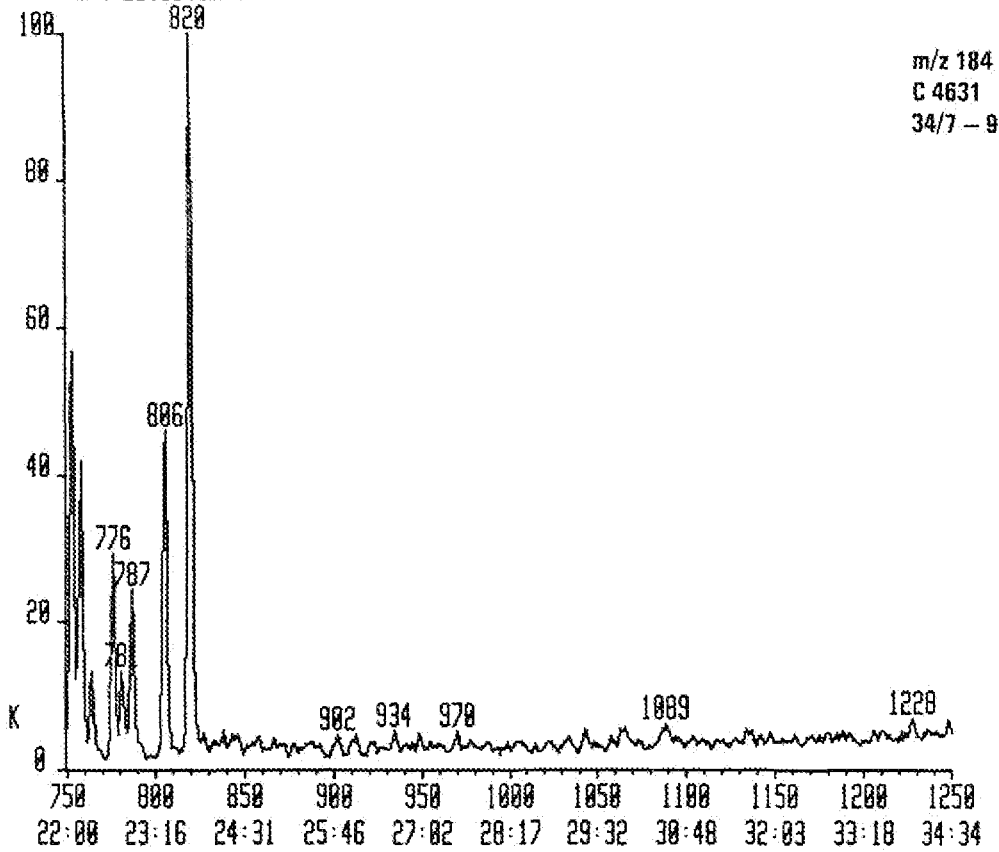
SCAN
TIME



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Chromatogram Identifiers : K1:184
Text:22.8843.02

acnt:IKU

System:PAROMATICS
K: 447808

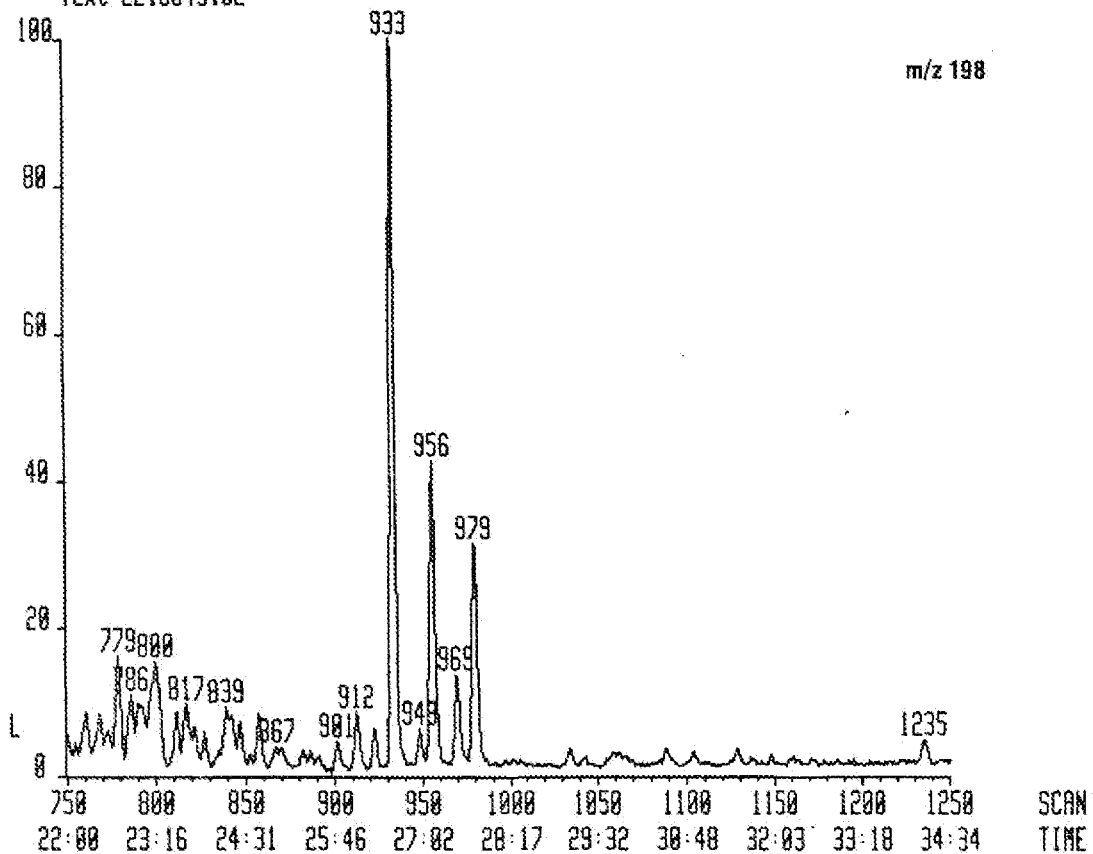


m/z 184
C 4631
34/7 - 9

C4631AR0 #750-1250 2-JUL-86 11:13 12250
Chromatogram Identifiers : L1:198
Text:22.8843.02

acnt:IKU

System:PAROMATICS
L: 627808



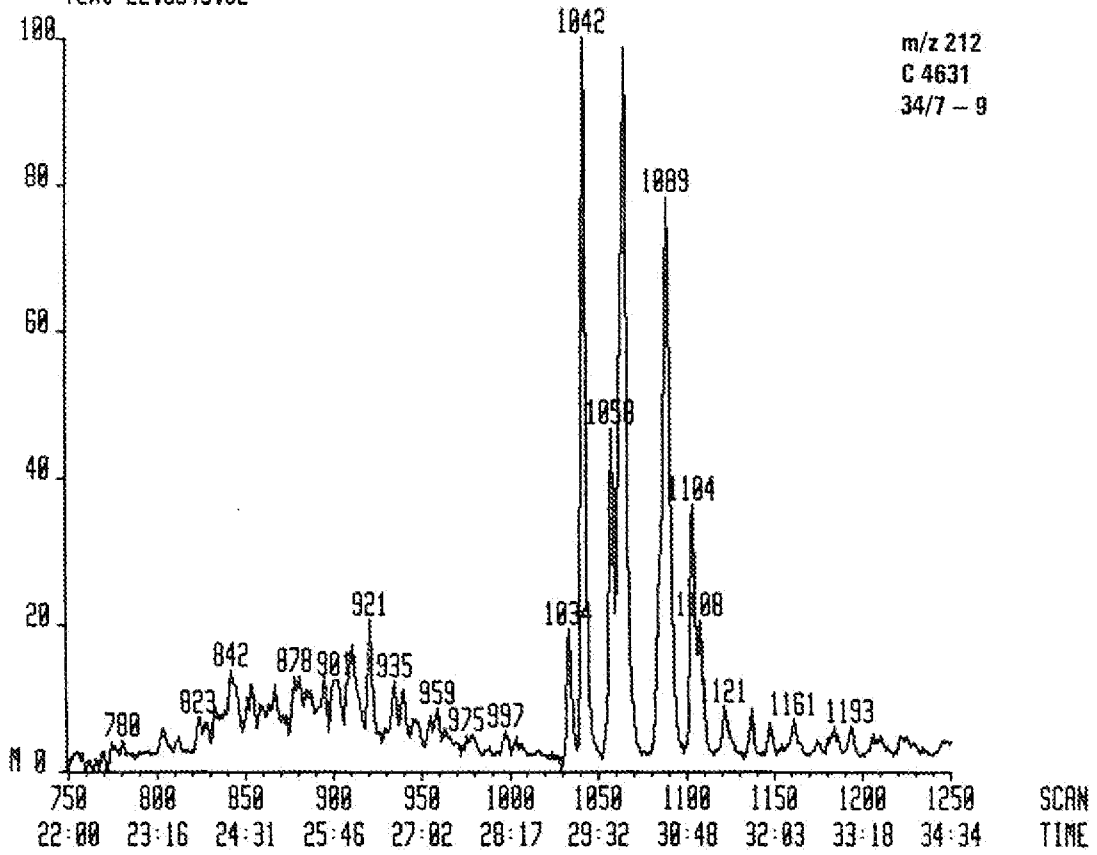
m/z 198



C4631ARO #758-1258 2-JUL-86 11:13 12250
Chromatogram Identifiers : M1:212
Text:22.8843.82

acnt:IKU

System:PAROMATICS
N: 322888

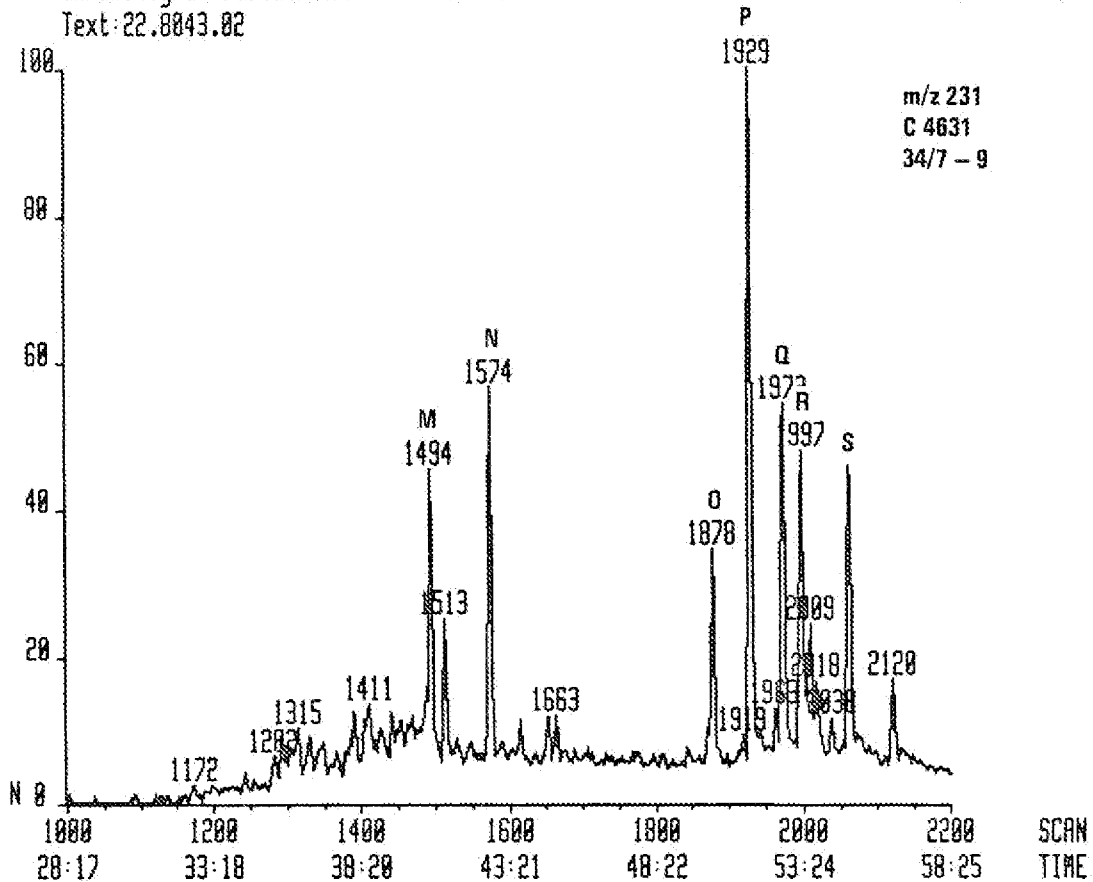




C4631AR0 #1000-2200 2-JUL-86 11:13 12250
Chromatogram Identifiers : N1:231
Text:22.8043.02

acnt:IKU

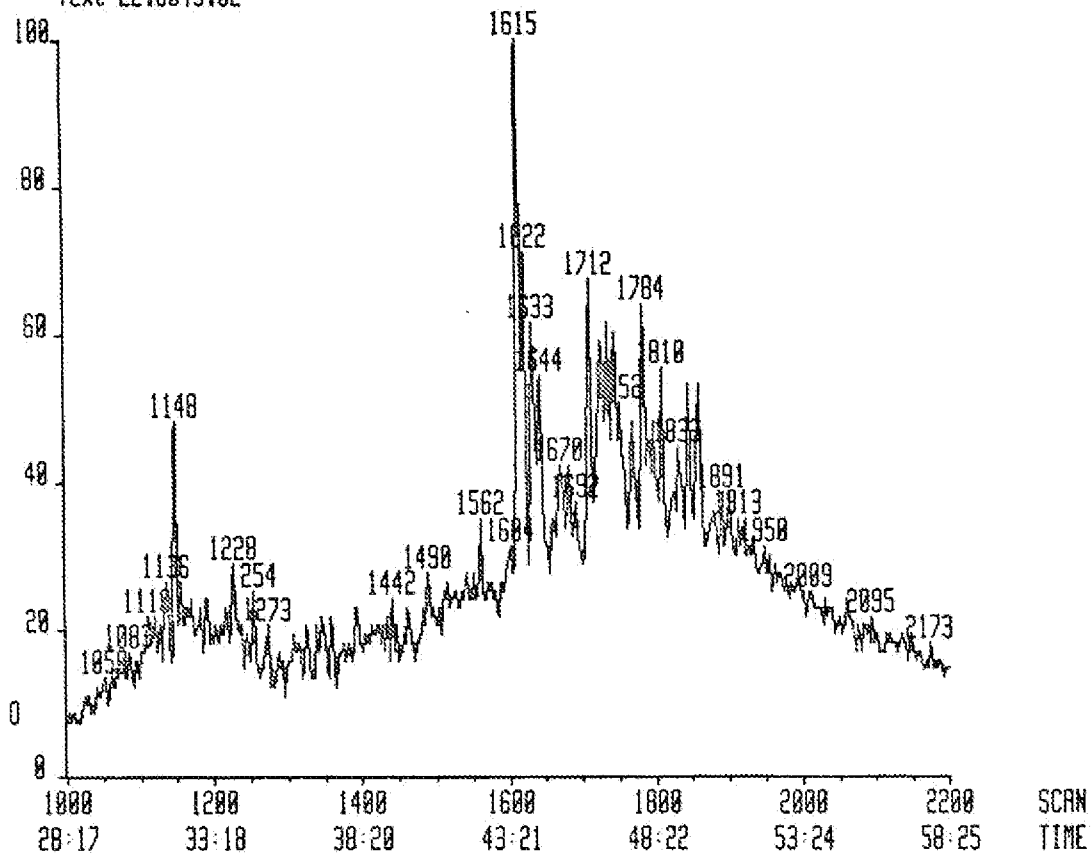
Syst#PAROMATICS
N: 397000



C4631AR0 #1000-2200 2-JUL-86 11:13 12250
Chromatogram Identifiers : 01:239
Text:22.8043.02

acnt:IKU

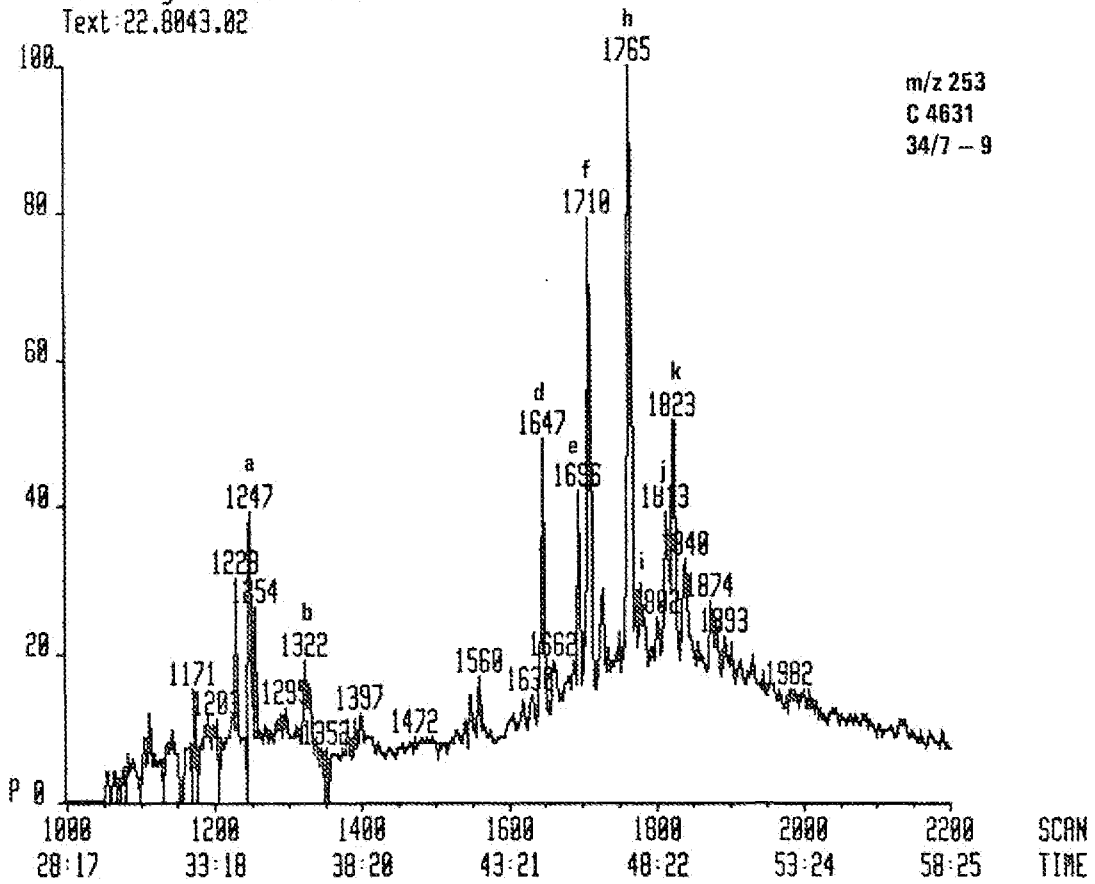
Syst#PAROMATICS
0: 03000

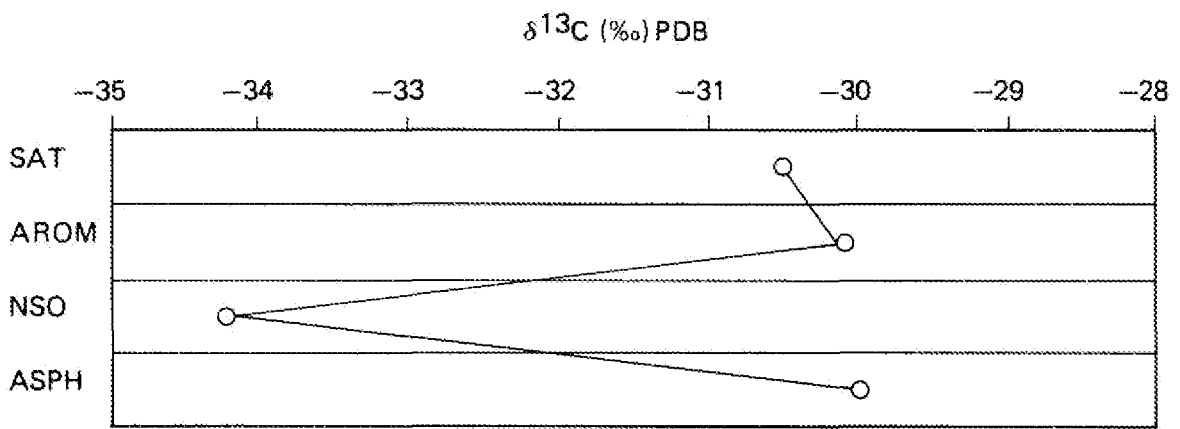




C4631ARD #1000-2200 2-JUL-86 11:13 12250 acct:IKU
Chromatogram Identifiers : P1:253
Text:22.8043.02

System:PAROMATICS
P: 126000





Well: SAGA 34/7-9
Sample: FMT

Figure 12: Plot of $\delta^{13}\text{C}$ values for various oil fractions. (After Stahl, 1977).

rations with increased maturity. The ratio of the 22S:22R isomers stabilises at about 60:40 at thermal maturity. The Tm/Ts C₂₇ hopane ratio (Seifert et al, 1978) also varies with thermal maturity such that, with increasing maturity, 17 α (H)-trisorhopane (Tm) is reduced in intensity relative to the more stable 18 α (H)-trisorhopane (Ts), causing the Tm/Ts ratio to decrease. However, this ratio is also thought to be source-dependent, and this should be allowed for when using the ratio as a maturation indicator. The tricyclic terpanes vary in abundance with maturity (Schou et al., 1984a), as does 28,30-bisorhopane (Cornford et al., 1983; Schou et al., 1984b).

Two sterane isomerisation reactions are commonly used for maturity determination based on data from the m/z 217 mass chromatogram. The biologically preferred 14 α (H),17 α (H) regular sterane isomers are gradually replaced by the more thermally stable 14 β (H),17 β (H)-sterane isomers. At thermal maturity, $\beta\beta$ isomers may account for 75-85% of the $\alpha\alpha/\beta\beta$ mixture. Mackenzie et al (1980) have observed a change from a dominance of the biological sterane epimer in recent sediments to the more stable S-configuration at C₂₀, such that this configuration accounts for 50% of the epimers at thermal maturity. The abundance of rearranged steranes relative to regular steranes has also been reported to increase with thermal 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 by the abundance of triaromatic compounds relative to mono-aromatic compounds (% tri/tri+mono) from the m/z 231 and 253 mass chromatograms, respectively. Cracking processes also take place during early diagenesis, and may be used for maturity determination together with the %tri/tri+mono ratio (Mackenzie et al., 1980; 1981; 1982).

The effect of migration and weathering on the distribution of biological markers is less well understood than maturity-induced changes. Migration may be observed to cause an increase in the relative amounts of rearranged and 14 β (H),17 β (H) regular steranes (Seifert and Moldowan, 1978). Severe biological alteration leads to the formation of desmethyl-hopanes (Seifert and Moldowan, 1979).