86-6211-BA   U-497

IKU
SINTEF-GRUPPEN

INSTITUTT FOR KONTINENTALSOKKELUNDERSØKELSER OG PETROLEUMSTEKNOLOGI AS

Håkon Magnussons gt. 1 B • P.O. Box 1883, Jarlesletta • N-7001 Trondheim, Norway
Tel.: +47 7 92.06 11 • Telex: 55 434 iku n • Telefax: +47 7 92.09.24 (Aut.)

REPORT

REG. NO.:	ACCESSIBILITY:
86.141	Confidential

REPORT TITLE:

ORGANIC GEOCHEMICAL CHARACTERISATION OF OIL AND GAS SAMPLES FROM WELL 34/4-6

REPORT NO.: 22.1831.00/01/86

AUTHORS:

L. Leith, M.B. Myhr, I.K. Almås

DATE:	NO. OF PAGES:	NO. OF APPENDICES:	PROJECT MANAGER:	SIGN.:
23 Oct. 1986	62	-	Leslie Leith	

CLIENT:

Saga Petroleum a.s., v/ E.S. Mo

SUMMARY:

An oil and a gas sample from DST 3 in well 34/4-6 were characterised using organic geochemistry. The gas has a fairly high wetness of 69% as might be expected from an oil-associated gas. An iC_4/nC_4 ratio of 0.36 suggests that the gas is thermally mature.

The oil is moderately light, low sulphur oil which is thermally mature. The 34/4-6 oil is similar in composition to a number of DST oils analysed from block 34/7, and is thought to be derived from a similar Upper Jurassic source rock.

KEY WORDS:	
Organic Geochemistry	Well 34/4-6
DST oil and gas	

161/E/anl/1

CONTENTS

CONTENTS continued

FIGURES

1. INTRODUCTION

One gas and one oil sample from DST 3 in well 34/4-6 were characterised by organic geochemistry at the request of Saga Petroleum a.s. The samples were received from GECO Petroleum Laboratory as a stock tank oil sample and a separator gas sample. The following data concerning the DST fluid were also received from GECO:

Flash of reservoir fluid to Stock Tank Conditions.

Flash Conditions:	200 barg, 100.0°C to atmosphere and 15°C.
Gas/Oil Ratio:	107.3 Sm^3/m^3.
Bo at 200 barg:	1.419 m^3/m^3.
Bo at bubble point:	1.483 m^3/m^3.
Density of oil at 15°C:	834.3 kg/m^3.
Molecular weight of oil:	186.
Standard Conditions:	For gas volumes = 15°C and 1 bar.
	For oil volumes = 15°C and atmospheric pressure.

The DST fluid was analysed according to the analytical plan outlined by Saga Petroleum in their letter of 8 October 1985. These analyses are as follows:

Gas sample:

- Gas chromatography of C_1-C_8 hydrocarbons.
- $\delta^{13}C$ stable isotope ratios of C_1, C_2, C_3 and C_4 components.
- D/H isotope ratio of C_1.

Oil sample:

- API gravity.
- Sulphur, nickel and vanadium content.
- Gas chromatography of C_2-C_8 hydrocarbons for recombination.
- Gas chromatography of whole oil.
- Liquid chromatography (MPLC) with asphaltene precipitation.
- Urea adduction of saturated hydrocarbons.
- Gas chromatography of saturated, branched/cyclic and aromatic hydrocarbons.

- GC-MS of saturated hydrocarbons (m/z 191, 217, 218).
- GC-MS of aromatic hydrocarbons.
- δ^{13}C stable isotope ratio for saturates, aromatics, NSO and asphaltenes.

The DST fluids were analysed and reported under IKU project number 22.1831. The samples were assigned the following IKU code numbers:

DST 3 gas: C-4606
       oil: C-4607

One copy of a draft report is sent to Saga Petroleum a.s. for approval. On approval, ten copies of a final report are sent to Saga and ten copies are retained at IKU.
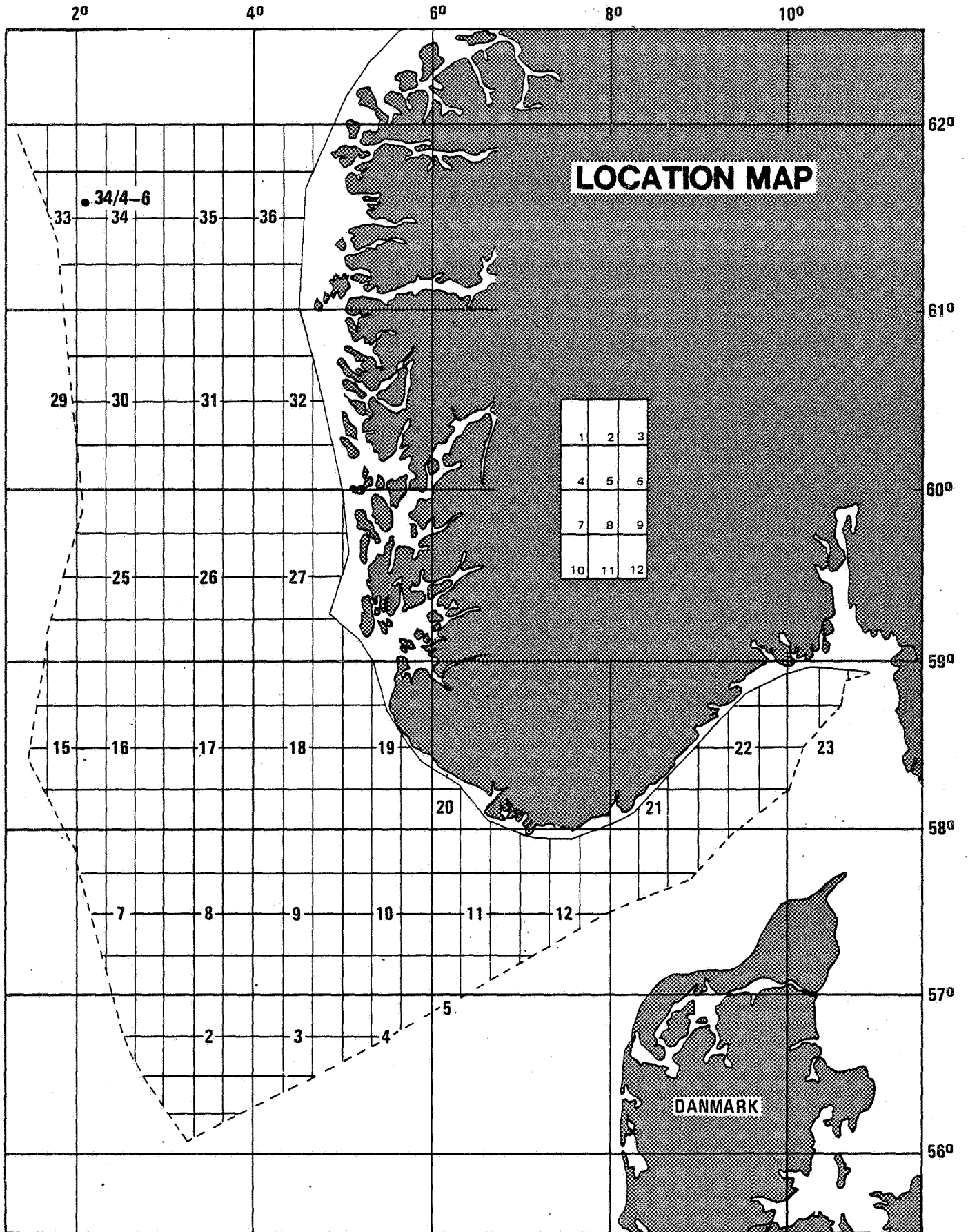
Figure 1: Location of well 34/4—6

2. DISCUSSION OF RESULTS

2.1 Recombination of DST oil and gas (C_1-C_8 hydrocarbons)

2.1.1 Gas chromatography of C_1-C_8 hydrocarbons

Methane accounts for 28.1% of the C_1-C_8 hydrocarbons analysed from the DST gas (Tables 1 and 2). The gas has a high wetness of 69.2% which is typical of oil-associated gas. An iC_4/nC_4 ratio of 0.36 suggests that the gas is thermally mature. C_{5+} hydrocarbon components are almost absent from this DST gas.

2.1.2 Gas chromatography of C_2-C_8 hydrocarbons (oil sample)

The C_2-C_8 hydrocarbon composition of the DST oil is shown in figure 2 and table 3. The gas chromatogram suggests that the composition of the oil is dominated by n-alkanes, with the exception of occasional branched/cyclic compounds such as methylcyclohexane. The C_2-C_8 fraction accounts for 19.8% of the whole oil sample. A high paraffinicity index (after Thompson, 1979) of 1.41 suggests that the oil sample is thermally mature.

2.1.3 Combination of C_1-C_8 hydrocarbons for DST gas and oil

This recombination of the C_1-C_8 gas composition and the C_2-C_8 oil composition was carried out in an attempt to reconstruct the original C_1-C_8 composition of the DST fluid. This recombination was carried out using the gas/oil ratio supplied by GECO from this DST (Table 1b).

2.1.4 Stable isotope data for the DST 3 gas sample

The carbon and deuterium ratios for the C_1-C_4 gas components are shown in figure 4 and table 3. The carbon isotope ratios of the C_1-C_4 components are similar to the values obtained from other 34/7 DST gases, especially 34/7-3, 34/7-6, 34/7-7 and 34/7-8. The deuterium ratio of -21 lo/oo is about average for the 34/7 gases.

Figures 4a and 4b suggest that the isotopic composition of the gas is fairly typical of gases associated with oils, as might be expected, although in figure 4a, the sample plots slightly into the mixed biogenic/

161/F/anl/6

catagenic gas field. This is similar to the situation observed in wells
34/7-7 and 34/7-8.

2.2 Crude oil characterisation

2.2.1 API gravity

The DST oil has a relatively high API gravity of 39.4^0 (Table 3), sug-
gesting a thermally mature, moderately light oil. This API gravity is
slightly higher than the values obtained from the 34/7 block oils. The
highest API gravity for the 34/7 oils is 37.9^0, obtained from the 34/7-9
FMT oil.

2.2.2 Sulphur, nickel and vanadium content

The 34/4-6 DST oil may be considered a low sulphur oil on the basis of
a sulphur content of 0.27% (Table 4). The sample has a nickel content
of about 8 mg/kg and a vanadium content of about 2.4 mg/kg. The sulphur
content of the 34/4-6 DST sample is similar to that for the majority of
the 34/7 oils. The nickel content of this oil is higher than is usually
seen in the 34/7 oils, whereas the vanadium content is slightly below
the average for the 34/7 oils.

2.2.3 Gross composition of the DST crude oil sample

Low molecular weight compounds in the $<210^0C$ oil fraction account for
50.3% of the oil (Table 5). This high percentage might be expected from
the relatively high API gravity of this oil.

Asphaltene compounds account for 1.1% of the oil and NSO compounds ac-
count for 9.5% of the oil (Table 6). The asphaltene content of the 34/4-6
DST oil is below the average for the 34/7 oils (34/7 average = 2.0%) as
is the NSO content (34/7 average = 10.2%).

Saturated hydrocarbons account for 56.7% of the $>210^0C$ fraction of the
oil, and aromatic hydrocarbons account for 30.0% (Table 7). The hydro-
carbon content of the $>210^0C$ fraction of the 34/4-6 DST oil appears to
be higher than is observed in most of the 34/7 oils analysed at IKU.
This might be expected from the higher API gravity of this sample.

2.2.4 Gas chromatography of the DST oil

a) Whole oil gas chromatography

The whole oil gas chromatogram of this oil is shown in figure 3 and shows
a unimodal n-alkane distribution with a maximum at nC_5, decreasing smoothly
to a minimum at about nC_{30}. The appearance of the gas chromatogram is
similar to those for the 34/7-8 and 34/7-9 oils.

b) Gas chromatography of saturated hydrocarbons

The saturated hydrocarbon gas chromatogram of the DST oil is shown in
figure 4 and is similar in appearance to that described from 34/7-9.
The n-alkanes have a smooth unimodal distribution reaching a maximum at
about nC_{20}. The rapid drop-off in peak intensity below nC_{20} may be due
to evaporation during sample preparation.

A pristane/phytane ratio of 1.6 (Table 6) suggests a mildly oxidising
source-rock depositional environment, although the value may have been
slightly altered during maturation. The carbon preference index value
of 1.1 and pristane/nC_{17} ratio of 0.8 suggest that the sample is ther-
mally mature.

c) Gas chromatography of branched/cyclic hydrocarbons.

The gas chromatogram of the branched/cyclic hydrocarbons (figure 5) shows
a fairly restricted development of isoprenoid hydrocarbons consisting
of pristane, phytane and the iC_{16} and iC_{18} isoprenoids. The gas chromato-
gram also shows a 'hump' of unresolved compounds and is generally similar
in appearance to gas chromatograms from 34/7-7 and 34/7-8 DST samples.

d) Gas chromatography of aromatic hydrocarbons

The aromatic hydrocarbon gas chromatogram (figure 6) is dominated by a
large 'hump' of unresolved compounds. Nevertheless, there is a good deve-
lopment of the naphthalene and phenanthrene compounds, both groups of
compounds showing nearly equal development. Methyl-phenanthrene indices
of 0.96 and 0.91 (table 9) agree with other previously discussed matu-
ration indicators and suggest that the oil is thermally mature.

The large unresolved 'hump' is seen in many of the 34/7 oils, especially in the DST's from 34/7-5, 34/7-7, 34/7-8 and 34/7-9.

2.2.5 Gas chromatography - mass spectrometry (GC-MS

Saturated hydrocarbons

The terpane and sterane mass chromatograms are presented in figures 9 and 10 and the molecular ratios calculated from these are given in tables 11 and 12.

The data routinely used for maturity estimation suggest a mature assemblage of hydrocarbons. Most parameters calculated from the triterpane mass chromatogram (m/z 191) have values indicative of thermal maturity. The calculated sterane parameters, however, are close to, but have not reached, final maturity values. This may suggest a more moderate thermal maturity.

A relatively high abundance of 28,30-bisnorhopane (Z in m/z 191) may indicate an Upper Jurassic source rock for this sample. This compound is common in samples from the Draupne and Heather formations.

Aromatic hydrocarbons

The aromatic hydrocarbon mass chromatograms are presented in figure 11 and some molecular ratios calculated from these are given in table 13.

The distribution of methylphenanthrenes and methyldibenzothiophenes, in the m/z 192 and m/z 198 mass chromatograms respectively, indicate a moderately mature hydrocarbon assemblage. The relative content of low molecular weight tri- and mono-aromatic steranes suggest an early oil window maturity of this sample, which contrasts with previously discussed maturity data for the oil sample.

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

The carbon isotope ratios for the saturate, aromatic, NSO and asphaltene fractions of the DST 3 oil are given in figure 12 and table 14. The isotopic ratios for the four fractions have similar values of -28.5o/oo to -30.6o/oo. These are similar to the values obtained from most of the 34/7 DST oils (excluding 34/7-8 (DST 1a) and 34/7-9).

The isotope ratio profile in figure 12 is similar to the profiles obtained from the DST 2 and DST 3 oils of well 34/7-8.

IKU
SINTEF-GRUPPEN

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 μm 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/μl) 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.

161/0/anl/1

IKU
SINTEF-GRUPPEN

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 μm 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°C (2·min) - 4°C/min - 280°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 μm. The temperature programme used was 50°C (2 min) - 4°C/min - 210°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°C (2 min) - 4°C/min - 280°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°C (2 min.) - 4°C/min - 280°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 µl, split ratio 1:15).

The GC oven was programmed from $120^{o}C$ (2 min.) to $280^{o}C$ at $4^{o}C/min.$ for analysis of the saturated hydrocarbons, and from $70^{o}C/min.$ to $280^{o}C$ at $4^{o}C/min.$ 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 $200^{o}C$. 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.

$\delta^{13}C$ isotope analysis

The $\delta^{13}C$ 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 $^{o}/oo$ (PDB).

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

H_2O and CO_2 were trapped in separate cooltraps. After removal of the carrier gas by high vacuum, CO_2 and H_2O were sealed off separately in

6 mm glass tubes. H_2O was reduced to H_2 by zinc at 460^oC.

The $^{13}C/^{12}C$ - 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):

del (%) = ((R sample - R stand.) / (R 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:

$$CV = (-2.53 * del^{13}C_{sat}) + (2.22 * del^{13}C_{aro}) - 11.65.$$

4. CONCLUSION

An oil and a gas sample from DST 3 in well 34/4-6 were characterised using organic geochemistry. The gas has a fairly high wetness of 69% as might be expected from an oil-associated gas. An iC_4/nC_4 ratio of 0.36 suggests that the gas is thermally mature.

The oil is a moderately light, thermally mature, low sulphur oil. The 34/4-6 oil is similar in composition to a number of DST oils analysed from block 34/7, and is thought to be derived from a similar Upper Jurassic source rock.

161/F/anl/10

5. REFERENCES

RADKE, M., WILLSCH, H., WELTE, D.H. 1980: Preparative hydrocarbon group type determination by automated medium pressure liquid chromatography. Anal. Chem., 52, pp.406-411.

SCHOELL, M., 1983: Genetic characterisation of natural gases. Amer. Assoc. Petrol. Geol. Bull., 67, pp.2225-2238.

SOFER, Z., 1984: Stable carbon isotope compositions of crude oils. Application to source depositional environments and petroleum alteration. AAPG Bull. 68, pp.31-49.

STAHL, W.J., 1977: Carbon and nitrogen isotopes in hydrocarbon research and exploration. Chem. Geol., 20, pp.121-149.

THOMPSON, K.F.M., 1978: Light hydrocarbons in subsurface sediments. Geochim. Cosmochim. Acta. 93, pp.657-672.

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.

IKU
SINTEF-GRUPPEN

Table 1a: Ratios obtained from C_1-C_8 gas/oil compositions.

IKU no.	DST no.	%CH$_4$	%Wetness	iC$_4$/nC$_4$	P.I. 1
C-4606/4607	3	28.1	69.2	0.36	1.38

%Wetness = $(\Sigma C_2$-$C_5/\Sigma C_1$-$C_5) \times 100$

P.I. 1 (after Thompson, 1978) = $2MeC_6+3MeC_6/diMeCyC_5$ (3 isomers).

IKU
SINTEF-GRUPPEN

C1-C8 YIELD
WELL NO: 34/4-6
IKU NO,GAS:C4606
IKU NO,OIL:C4607
GOR = 107.3 SM3/M3

Table 1b:

Recombination of DST gas and oil (C_1-C_8 hydrocarbons): DST 3.

COMPOUND	GAS MG/ML	GAS MG/107.3ML	OIL MG/ML	TOTAL HC IN MG/ML OF RESERVOIR FLUID
Methane	0.262	28.113	0.000	28.113
Ethane	0.176	18.885	0.000	18.885
Propane	0.250	26.825	0.000	21.825
i-Butane	0.047	5.043	0.000	5.043
n-Butane	0.131	14.056	1.812	15.868
i-Pentane	0.031	3.326	5.087	8.413
n-Pentane	0.031	3.326	9.452	12.778
Cyclo-C5+				
2,3-diMeC4	0.002	0.210	1.900	2.110
2-MeC5	0.001	0.107	5.371	5.478
3-MeC5	0.000	0.000	3.392	3.392
n-Hexane	0.000	0.000	11.101	11.101
MeCyC5	0.000	0.000	6.526	6.526
Benzene	0.000	0.000	1.881	1.881
CycloC6	0.000	0.000	6.982	6.982
2-MeC6	0.000	0.000	3.244	3.244
2,3-diMeC5	0.000	0.000	1.127	1.127
3-MeC6	0.000	0.000	4.831	4.831
diMeCyC5	0.000	0.000	6.125	6.125
n-Heptane	0.000	0.000	11.126	11.126
MeCyC6	0.000	0.000	14.111	14.111
EtCyC5+				
2,5-diMeC6	0.000	0.000	1.671	1.671
2,4-diMeC6	0.000	0.000	1.104	1.104
triMeCyC5	0.000	0.000	1.045	1.045
Toluene	0.000	0.000	6.507	6.507
2-MeC7+				
4-MeC7	0.000	0.000	5.416	5.416
3-MeC7	0.000	0.000	2.687	2.687
diMeCyC6	0.000	0.000	5.329	5.329
n-Octane	0.000	0.000	11.003	11.003
2,4-diMeC7+				
diMeCyC6	0.000	0.000	2.064	2.064
EtCyC6	0.000	0.000	4.479	4.479
EtBenzene	0.000	0.000	1.987	1.987
m+p-xylene	0.000	0.000	5.671	5.671
2-MeC8+				
4-MeC8	0.000	0.000	2.704	2.704
O-Xylene	0.000	0.000	2.297	2.297
SUM	0.931	99.891	148.192	248.083

IKU
SINTEF-GRUPPEN

Table 2:

C_2-C_8 hydrocarbon composition of DST 3 oil.

C 4607	area	ug	mg/ml	% of t.oil
nC3	0	.000	.000	.000
iso-C4	0	.000	.000	.000
nC4	84085	.543	1.812	.218
iso-C5	236012	1.526	5.087	.614
nC5	438511	2.835	9.452	1.141
CyC5+2,3diMeC4	88163	.570	1.900	.229
2MeC5	249202	1.611	5.371	.648
3MeC5	157384	1.017	3.392	.409
nC6	515024	3.330	11.101	1.340
MeCyC5	302762	1.957	6.526	.788
benzene	87269	.564	1.881	.227
CyC6	323942	2.094	6.982	.843
2MeC6	150522	.973	3.244	.391
2,3diMeC5	52329	.338	1.127	.136
3MeC6	224150	1.449	4.831	.583
DiMeCyC5	284183	1.837	6.125	.739
nC7	516171	3.337	11.126	1.343
MeCyC6	654699	4.233	14.111	1.704
EtCyC5+2,5diMeC6	77564	.501	1.671	.201
'2,4diMeC6	51236	.331	1.104	.133
triMeCyC5	48523	.313	1.045	.126
toluene	301915	1.952	6.507	.785
2+4MeC7	251273	1.624	5.416	.654
3MeC7	124667	.806	2.687	.324
DiMeCyC6	247266	1.598	5.329	.643
nC8	510471	3.300	11.003	1.328
2,4diMeC7+diMeCyC6	95766	.619	2.064	.249
EtCyC6	207823	1.343	4.479	.540
EtBenzene	92215	.596	1.987	.240
m,p-Xylene	263141	1.701	5.671	.684
2+4MeC8	125477	.811	2.704	.326
o-xylene	106590	.689	2.297	.277
sum		44.413	148.046	17.877

tot.oil ant ug inj.:   248.430ug

%C2-C8(tot.area)in tot.oil: 19.773%

IKU
SINTEF-GRUPPEN

Table 3: Stable isotope data for DST 3 gas.

IKU nr.	C_1		C_2	C_3	$i\text{-}C_4$	$n\text{-}C_4$
	$\delta^{13}C$ PDB	δD SMOW	$\delta^{13}C$ PDB	$\delta^{13}C$ PDB	$\delta^{13}C$ PDB	$\delta^{13}C$ PDB
C-4606	-49.7	-211	-34.5	-31.8	-32.8	-30.7

162/gg/anl/14

IKU
SINTEF-GRUPPEN

Project No.: 22.1831
        Date : 27-6-86

Table 4:

API GRAVITY OF OIL SAMPLE

IKU-No	CODE	API GRAVITY (DENSITY)	
		Crude oil	>210'C
34/4-6 C-4607	DST 3	39.4 (0.8281)	24.7 (0.9057)

Project No.: 22.1831
Date : 27-6-86

Table 5:

CONTENT OF SULPHUR, NICKEL AND VANADIUM IN OIL >210'C

IKU-No	CODE	S %	Ni (mg/kg)	V (mg/kg)
34/4-6 C-4607	DST 3	0.27	8.21-7.72	2.46-2.22

IKU
SINTEF-GRUPPEN

Project No.: 22.1831
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)	(%)
34/4-6 C 4607	DST 3	709.9	352.8	357.1	50.3

IKU
SINTEF-GRUPPEN

Project no.: 22.1831
DATE : 9 - 7 - 86

Table 7:

AMOUNT OF ASPHALTENES AND NSO'S IN OIL

IKU No	DST No	Crude Oil (mg)	Asphaltenes (mg)	Asphaltenes (%)	NSO (mg)	NSO (%)
34/4-6 C-4607	3	709.9	7.5	1.1	67.2	9.5

Project No.: 22.1831
Well : 34/4-6
Date : 22 - 7 - 86

Table 8a:

CONCENTRATION OF OIL CHROMATOGRAPHIC FRACTIONS

IKU No	CODE	Crude Oil (mg)	EOM >210C (mg)	Sat. (mg)	Aro. (mg)	HC (mg)	Non HC (mg)
C 4607	DST 3	709.9	352.8	154.0	80.5	234.5	47.1

Project No.: 22.1831
Well : 34/4-6
Date : 22 - 7 - 86

Table 8b:

COMPOSITION OF OIL

IKU No	CODE	Sat. EOM %	Aro. EOM %	HC EOM %	Sat. Aro. x 100	Non HC EOM %	HC Non HC x 100
C 4607	DST 3	56.7	30.0	86.7	191.3	13.4	649.0

IKU
SINTEF-GRUPPEN

Table 9:

TABULATION OF DATA FROM THE GASCHROMATOGRAMS

IKU No.	CODE	:	PRISTANE / PHYTANE	A = PRISTANE / n-C17	B = PHYTANE / n-C18	A / B	n-C17 / n-C27	CPI
C 4607	DST 3	:	1.6	0.8	0.5	1.7	1.7	1.1

DATE :   4 - 7 - 86.

Table 10:

Ratios from aromatic gas chromatograms.

IKU no.	DST no.	MPI-1	MPI-2
C-4607	3	0.96	0.91

MPI-1 = 1.5(2-MP+3-MP)/P+1-MP+9-MP

MPI-2 = 3(2-MP)/P+1-MP+9-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-4607	34/4-6	0.93	59.7	76.1	50.8

[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]	Tm/Ts [2]	X/E [3]	Z/E [4]	$a/a+j$ [5]
C-4607	34/4-6	0.08	0.50	0.12	0.40	0.75

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 C_{27} 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]	$\%C_{21}/C_{28,29}$ [2]
C-4607	34/4-6	35.4	32.5
	Stock tank oil no.3		

[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: $\delta^{13}C$ isotope data for DST oil fractions.

IKU no.	DST no.	SAT	AROM	NSO	ASF
C-4607	3	-30.6	-28.5	-28.5	-30.2

RT: VALVE 2 → ON

OV: START PRGM RATE 1

Figure 2.
$C_1 - C_8$ Hydrocarbons
DST 3
C - 4606

3.09 nC_1
nC_2
3.90 nC_3

5.18 $isoC_4$

6.18 nC_4
6.52 neo-C_5

8.59 $isoC_5$

9.54 nC_5

10.16

10.74 2,2DMC$_4$

2,3DMC$_4$

CyC$_5$
13.36 2MC$_5$
13.49 3MC$_5$

12.97

13.18 nC_6

14.00 MCyC$_5$

14.29 2,4DMC$_5$

14.82 2MC$_6$

15.13 CyC$_6$

3MC$_6$

DMCyC$_5$

nC_7

17.19 MCyC$_6$
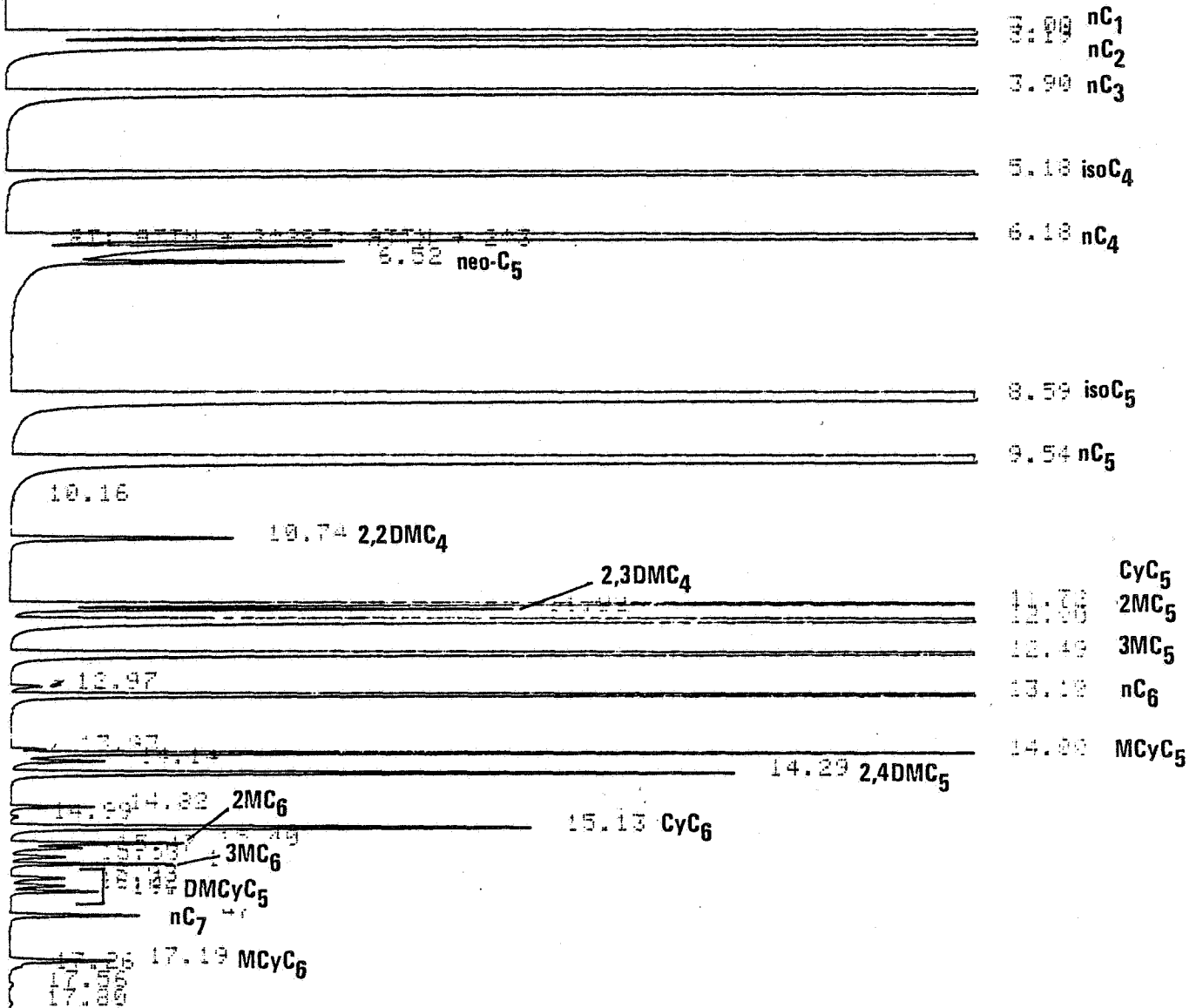
OV: START FINAL TIME 1

IKU
SINTEF-GRUPPEN

FIGURE 3

C_2-C_8 HYDROCARBON GAS CHROMATOGRAMS

Analysis 831C4607   5,1,1   SAGA 34/4-6 #3

C₂ – C₈ Hydrocarbons
34/4 – 6
DST 3
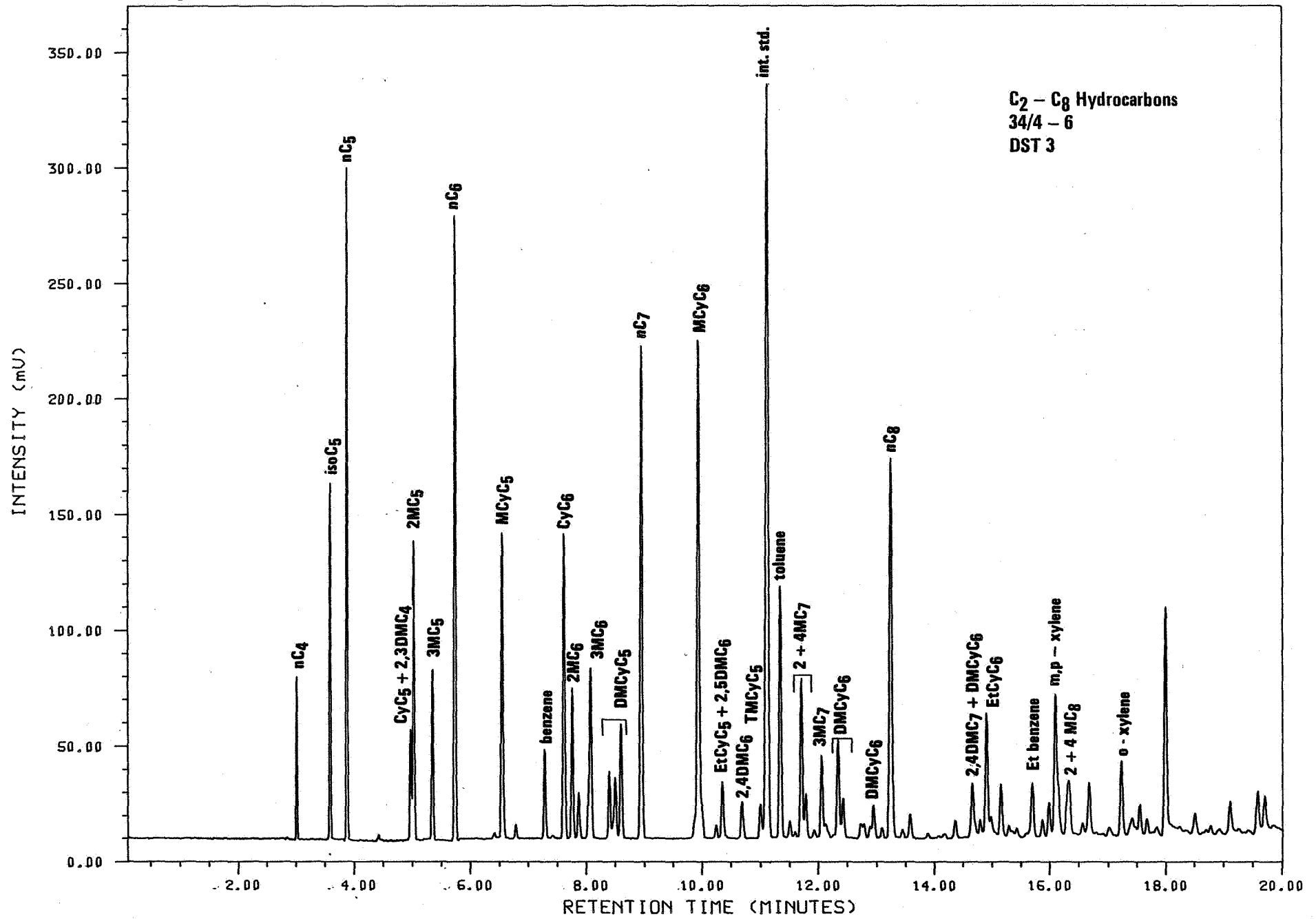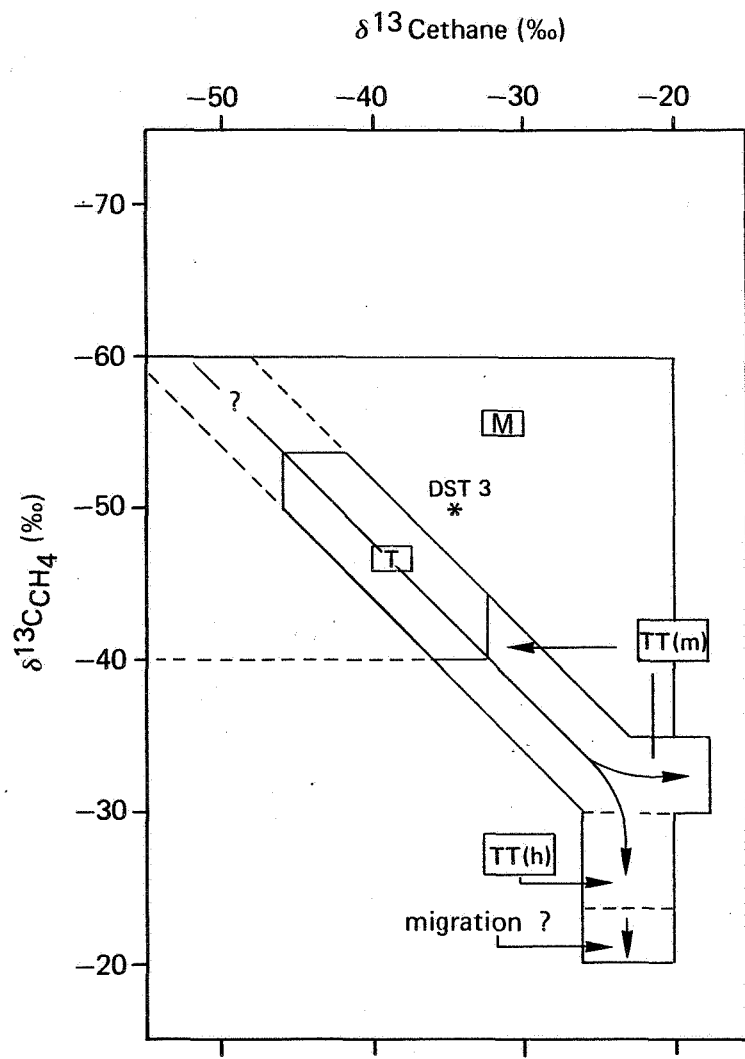
Figure 4a: The DST gas sample has a $\delta^{13}C$ isotope value which plots close to the zone of gases associated with oils condensates, but lying just inside the zone normally associated with mixed catagenic/biogenic gases. (After Schoell 1983).
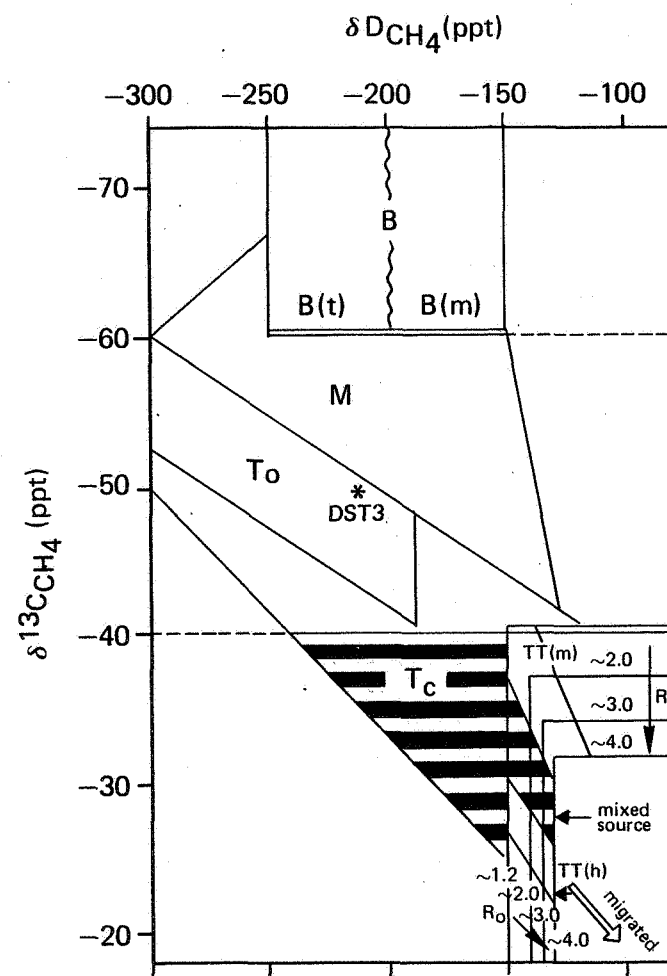
Figure 4b: The DST 3 gas plots within the field for oil-associated gases as might be expected. (After Schoell, 1983).

FIGURE 5

WHOLE OIL GAS CHROMATOGRAMS

C_{10} etc.   -   n-alkanes

Cy-C_6 -   cyclohexane

MeCy-C_6 -   methylcyclohexane

Pr   -   pristane

Ph   -   phytane

Analysis 831C4607T   2,1,1   SAGA 34/4-6

Whole oil
34/4 — 6
DST 3
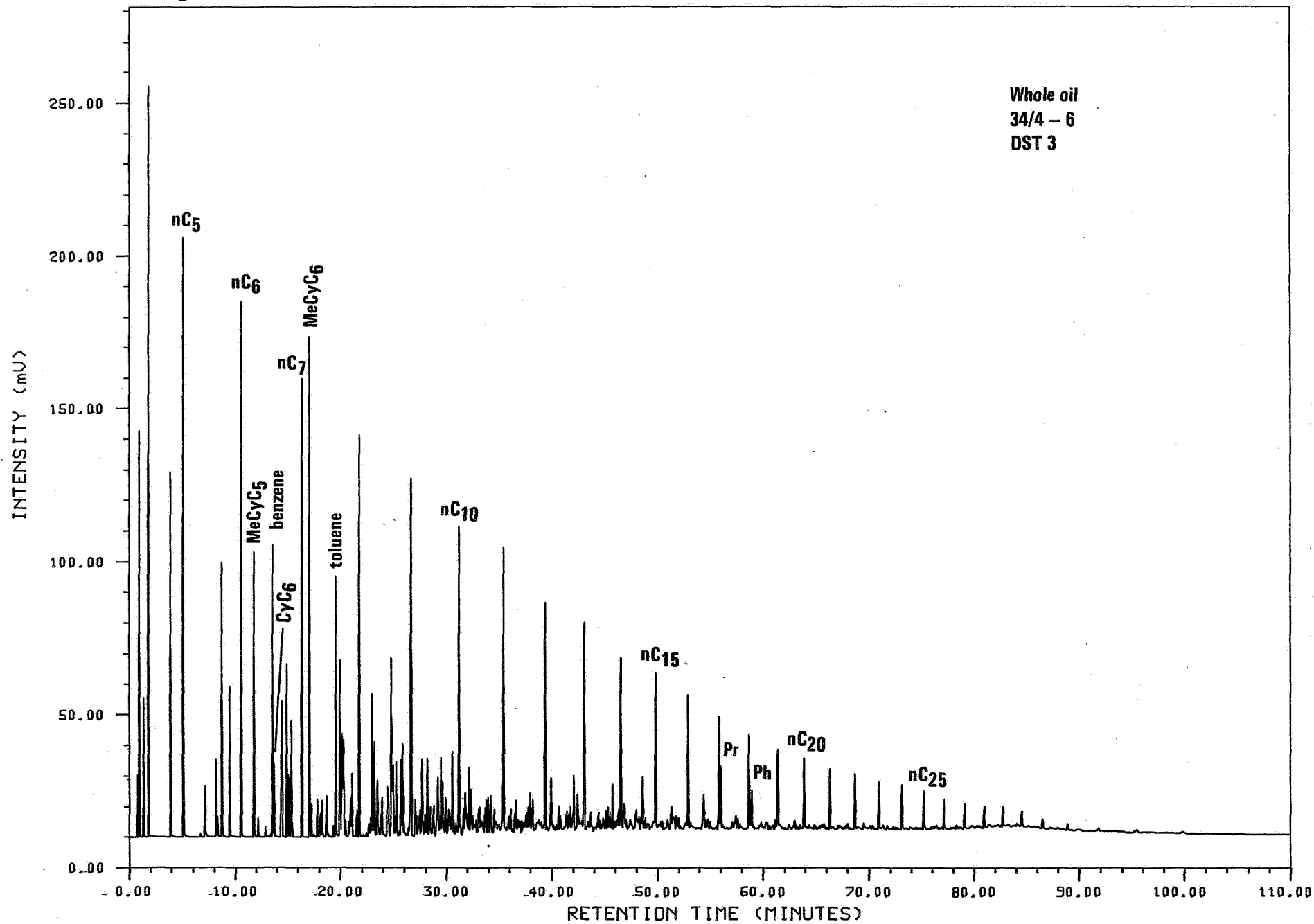
FIGURE 6

SATURATED HYDROCARBON GAS CHROMATOGRAMS

$n-C_{15}$ etc. - n-alkanes

Pr   - pristane

Ph   - phytane

*   - other acyclic
              isoprenoids

Analysis 831C4607S   3,1,1   SAGA 34/4-6 SAT

**SATURATED HYDROCARBONS
34/4 — 6
DST 3**

INTENSITY (mU)

RETENTION TIME (MINUTES)

IKU
SINTEF-GRUPPEN
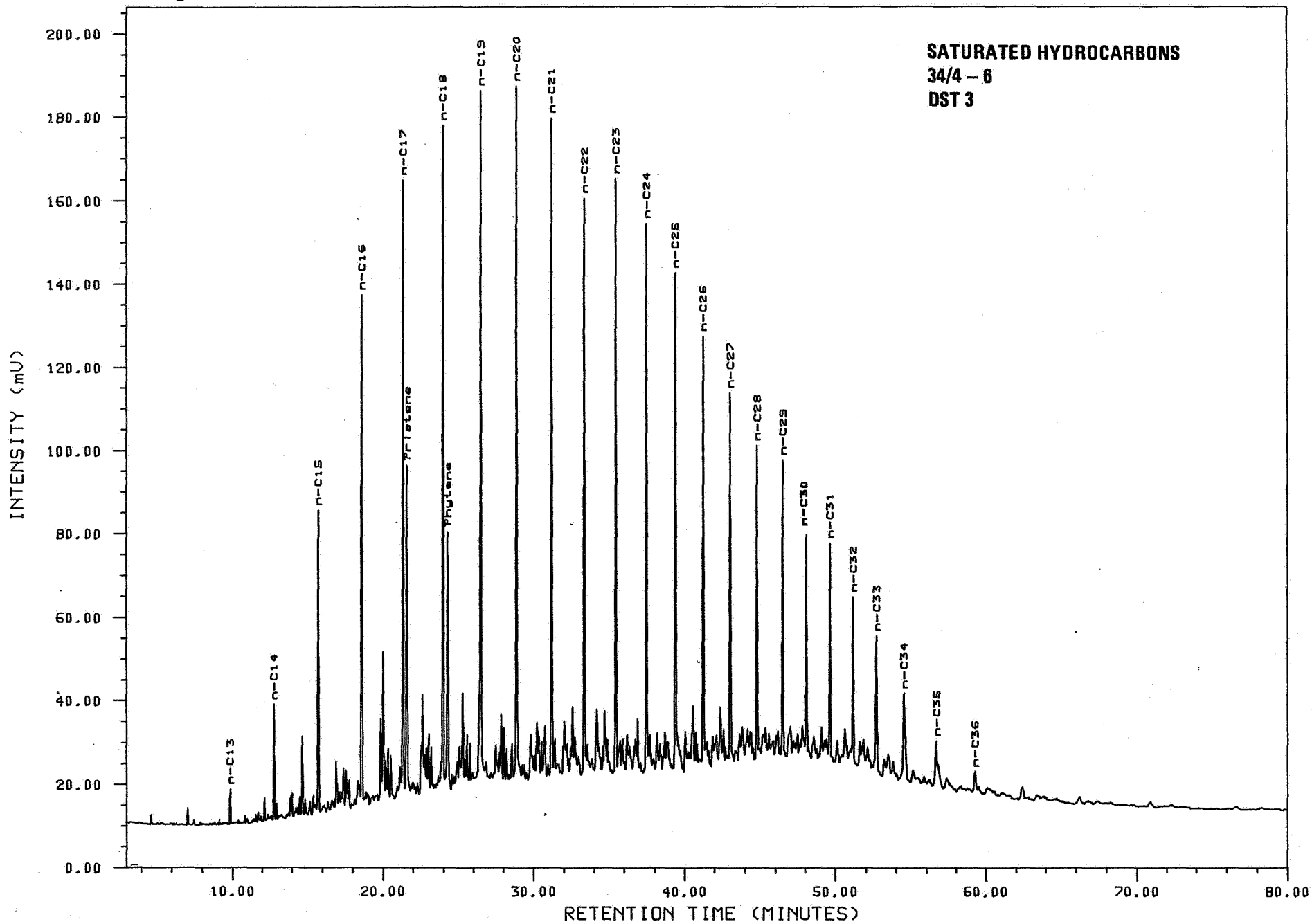
FIGURE 7

BRANCHED/CYCLIC HYDROCARBON GAS CHROMATOGRAMS

Pr   - pristane
Ph   °   - phytane
isopr.C_{18} etc. - isoprenoids
*   - n-alkanes remaining after
                  adduction

Analysis 830C4607B   3,1,1   SAGA **34/4 − 6** B/C

Branched/Cyclic Hydrocarbons
34/4 − 6
DST 3

INTENSITY (mU)

120.00

100.00

80.00

60.00

40.00

20.00

0.00

Pr

Ph

iC₁₈

iC₁₆

.10.00   20.00   .30.00   .40.00   .50.00   .60.00   70.00   80.00

RETENTION TIME (MINUTES)
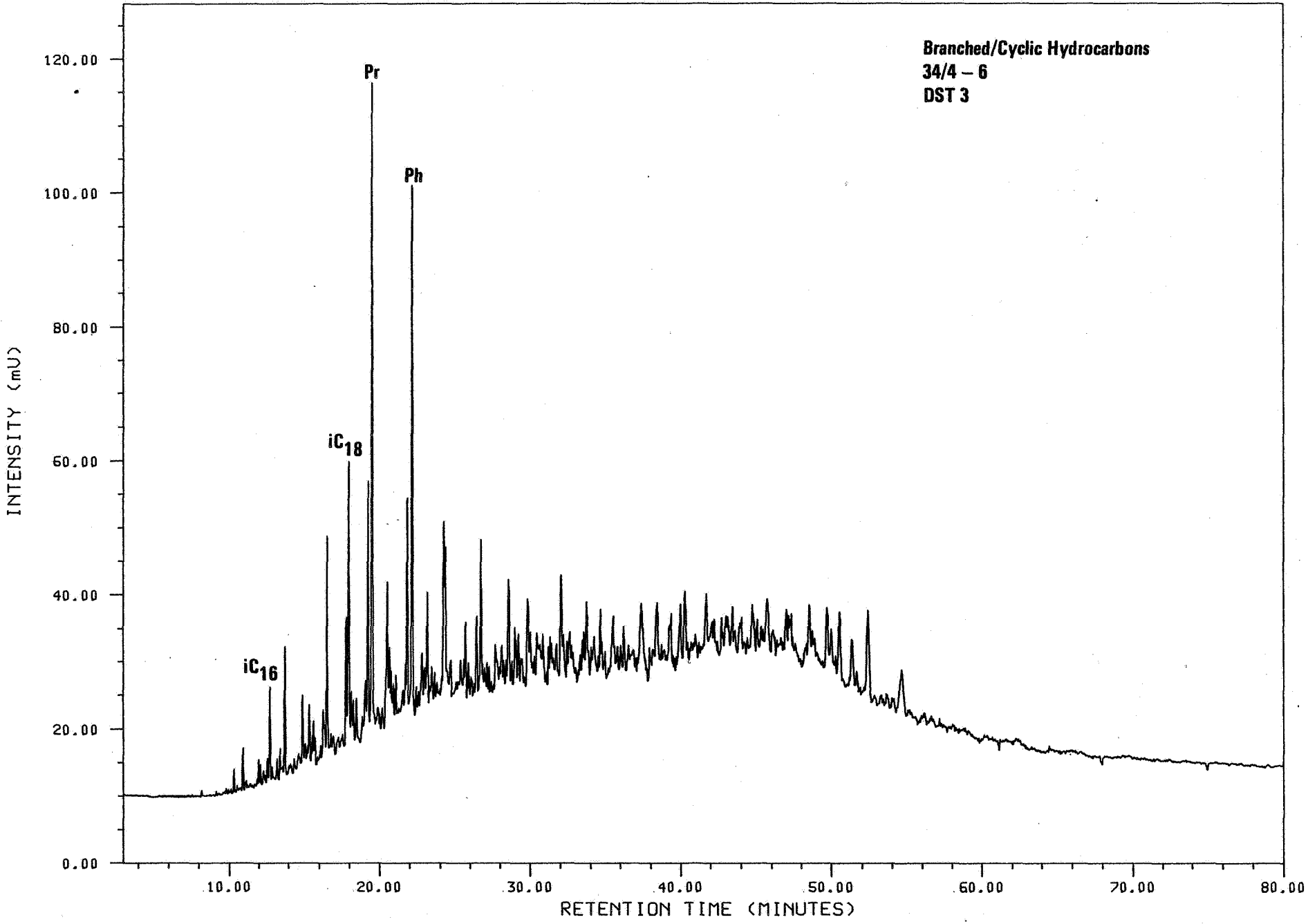
FIGURE 8

AROMATIC HYDROCARBON GAS CHROMATOGRAMS
FID DETECTION

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

Analysis 831C4607A   2,1,1   SAGA. 34/4-6

AROMATIC HYDROCARBONS
34/4 – 6
DST 3

INTENSITY (mV)

RETENTION TIME (MINUTES)

MN
DMN
TMN
P
MP

Figure 9.

Mass chromatograms representing terpanes (m/z 191)

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

IKU
SINTEF-GRUPPEN
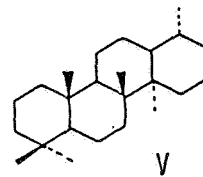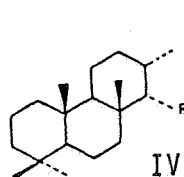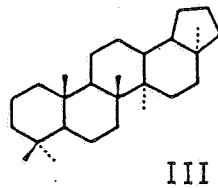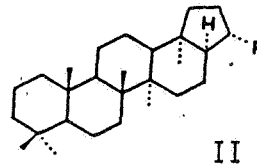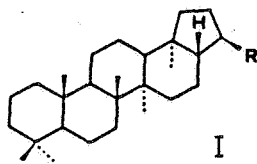
C4607SAT   30-JUN-86   Sir:Voltage 12-250   Acnt:IKU   System:QUAMID
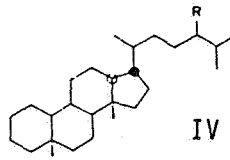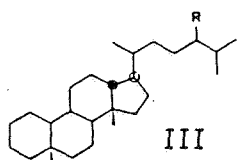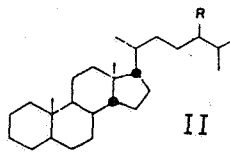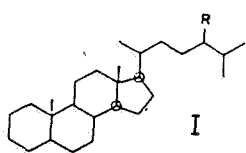Sample 1   Injection 1   Group 1   Mass 191.1000
Text:
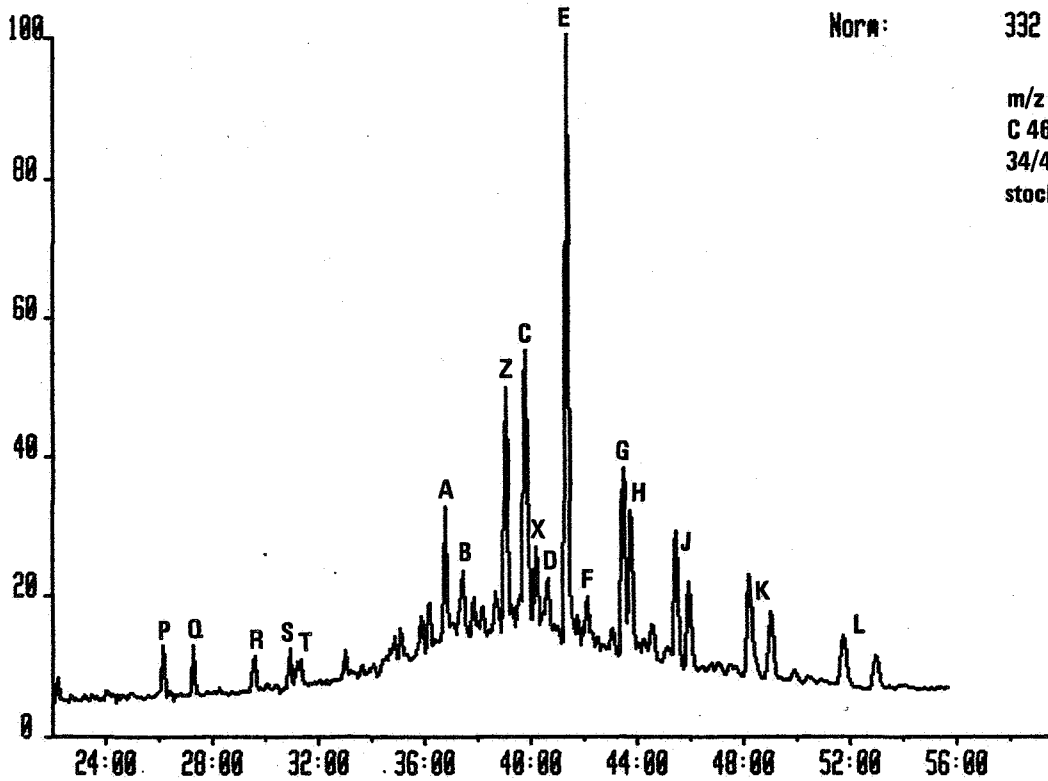
Norm: 332

m/z 191
C 4607
34/4 — 6
stock tank oil no. 3

Figure 10.

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

a	13β(H),17α(H)-diasterane (20S)	$C_{27}H_{48}$	(III,R=H)
b	13β(H),17α(H)-diasterane (20R)	$C_{27}H_{48}$	(III,R=H)
c	13α(H),17β(H)-diasterane (20S)	$C_{27}H_{48}$	(IV,R=H)
d	13α(H),17β(H)-diasterane (20R)	$C_{27}H_{48}$	(IV,R=H)
e	13β(H),17α(H)-diasterane (20S)	$C_{28}H_{50}$	(III,R=CH$_3$)
f	13β(H),17α(H)-diasterane (20R)	$C_{28}H_{50}$	(III,R=CH$_3$)
g	13α(H),17β(H)-diasterane (20S)	$C_{28}H_{50}$	(IV,R=CH$_3$)
	+ 14α(H),17α(H)-sterane (20S)	$C_{27}H_{48}$	(I,R=H)
h	13β(H),17α(H)-diasterane (20S)	$C_{29}H_{52}$	(III,R=C$_2$H$_5$)
	+ 14β(H),17β(H)-sterane (20R)	$C_{27}H_{48}$	(II,R=H)
i	14β(H),17β(H)-sterane (20S)	$C_{27}H_{48}$	(II,R=H)
	+ 13α(H),17β(H)-diasterane (20R)	$C_{28}H_{50}$	(IV,R=CH$_3$)
j	14α(H),17α(H)-sterane (20R)	$C_{27}H_{48}$	(I,R=H)
k	13β(H),17α(H)-diasterane (20R)	$C_{29}H_{52}$	(III,R=C$_2$H$_5$)
l	13α(H),17β(H)-diasterane (20S)	$C_{29}H_{52}$	(III,R=C$_2$H$_5$)
m	14α(H),17α(H)-sterane (20S)	$C_{28}H_{50}$	(I,R=CH$_3$)
n	13α(H),17β(H)-diasterane (20R)	$C_{29}H_{52}$	(III,R=C$_2$H$_5$)
	+ 14β(H),17β(H)-sterane (20R)	$C_{28}H_{50}$	(II,R=CH$_3$)
o	14β(H),17β(H)-sterane (20S)	$C_{28}H_{50}$	(II,R=CH$_3$)
p	14α(H),17α(H)-sterane (20R)	$C_{28}H_{50}$	(I,R=CH$_3$)
q	14α(H),17α(H)-sterane (20S)	$C_{29}H_{52}$	(I,R=C$_2$H$_5$)
r	14β(H),17β(H)-sterane (20R)	$C_{29}H_{52}$	(II,R=C$_2$H$_5$)
	+ unknown sterane		
s	14β(H),17β(H)-sterane (20S)	$C_{29}H_{52}$	(II,R=C$_2$H$_5$)
t	14α(H),17α(H)-sterane (20R)	$C_{29}H_{52}$	(I,R=C$_2$H$_5$)
u	5α(H)-sterane	$C_{21}H_{36}$	(V,R=C$_2$H$_5$)
v	5α(H)-sterane	$C_{22}H_{38}$	(IV,R=C$_3$H$_7$)
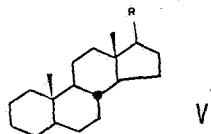
IKU
SINTEF-GRUPPEN

C4607SAT   30-JUN-86   Sir:Voltage 12-250   Acnt:IKU   System:QUANID
Sample 1   Injection 1   Group 1   Mass 217.1000
Text:

Norm: 177

m/z 217
C 4607
34/4 — 6
stock tank oil no. 3
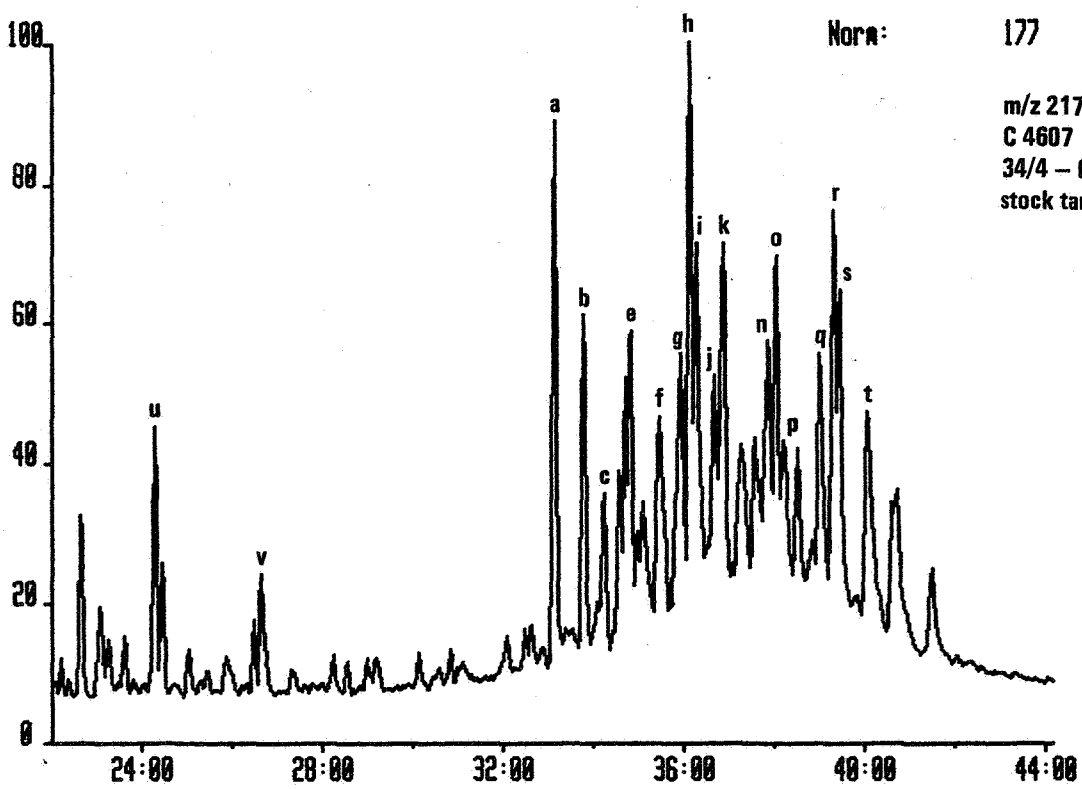
C4607SAT   30-JUN-86   Sir:Voltage 12-250   Acnt:IKU   System:QUANID
Sample 1   Injection 1   Group 1   Mass 218.1000
Text:

Norm: 149

m/z 218

IKU
SINTEF-GRUPPEN
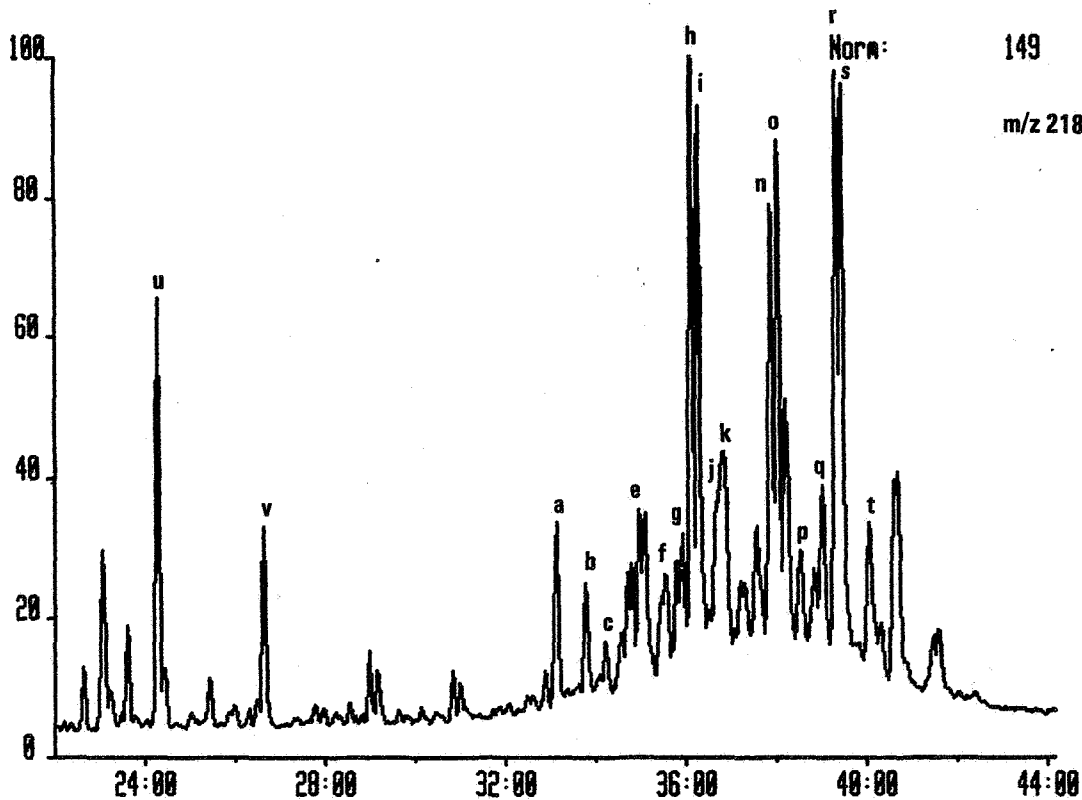
FIGURE 11

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 alkyldibenzo-
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 - C_{21} monoaromatic sterane

b - C_{22} monoaromatic sterane

c - unidentified

d - C_{27} monoaromatic sterane

e - C_{27} monoaromatic sterane

f - C_{28} monoaromatic sterane

g - C_{27} monoaromatic sterane

h - C_{28} + C_{29} monoaromatic sterane

i - C_{29} monoaromatic sterane

j - C_{29} monoaromatic sterane

k - unidentified

l - unidentified

m/z 231

M - C_{20} triaromatic sterane

N - C_{21} triaromatic sterane

O - C_{26} triaromatic sterane

P - C_{26} + C_{27} triaromatic sterane

Q - C_{28} triaromatic sterane

R - C_{27} triaromatic sterane

S - C_{28} triaromatic sterane

C4604ARO #1-2250   1-JUL-86 10:52 12250   acnt:IKU   System:AROMATICS

Chromatogram Identifiers :   . B1:TIC

Text:22.0043.02

Aromatic hc's
TIC
C 4607
34/4 — 6
stock tank oil no. 3
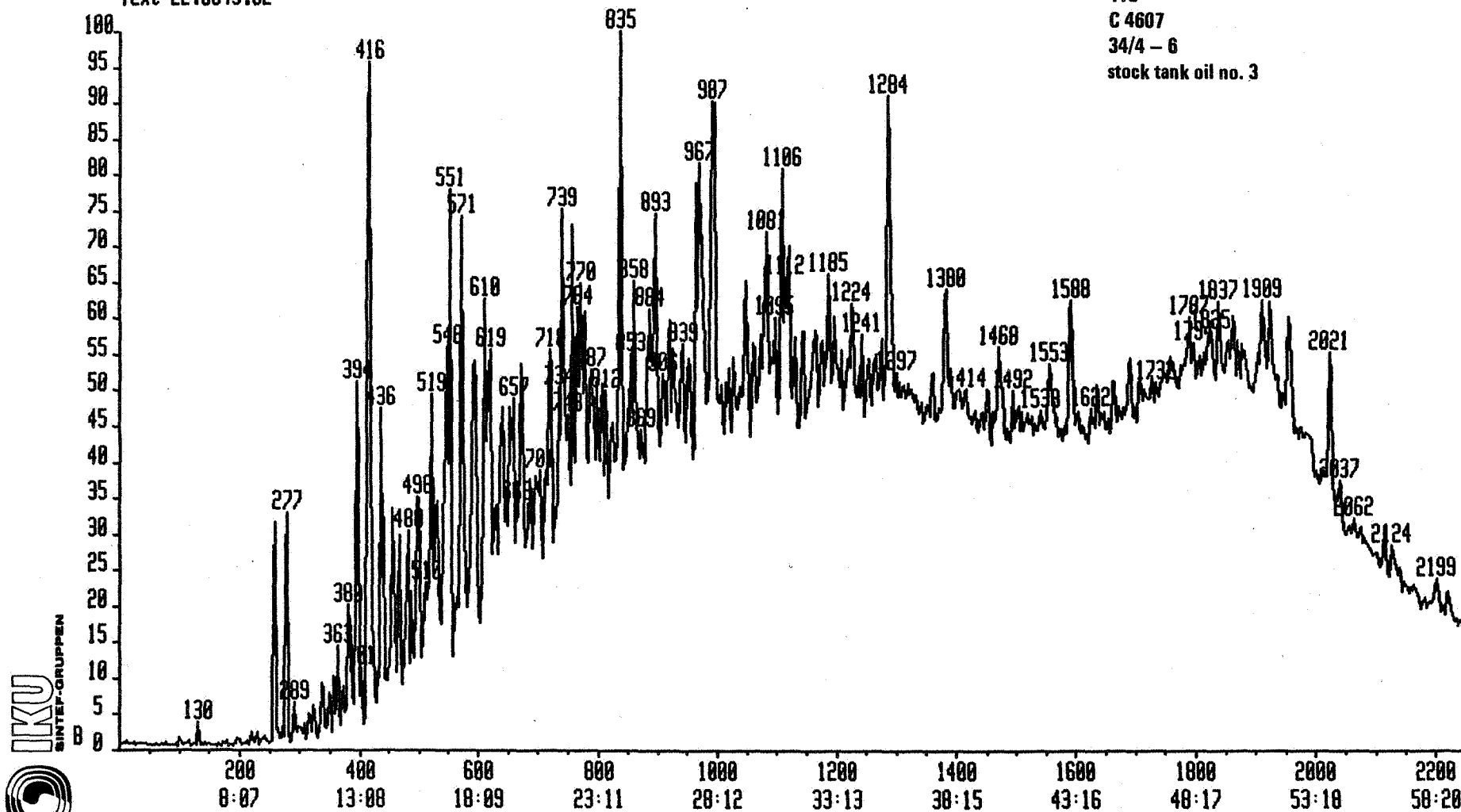
IHP
B: 3379000

- 52 -

C4607ARO #300-2200   1-JUL-86   16:10 12250   acnt:IKU   System PAROMATICS
Chromatogram Identifiers :   C1:92   C: 121000
Text:22.8043.02

m/z 92
C 4607
34/4 — 6,
stock tank oil no. 3
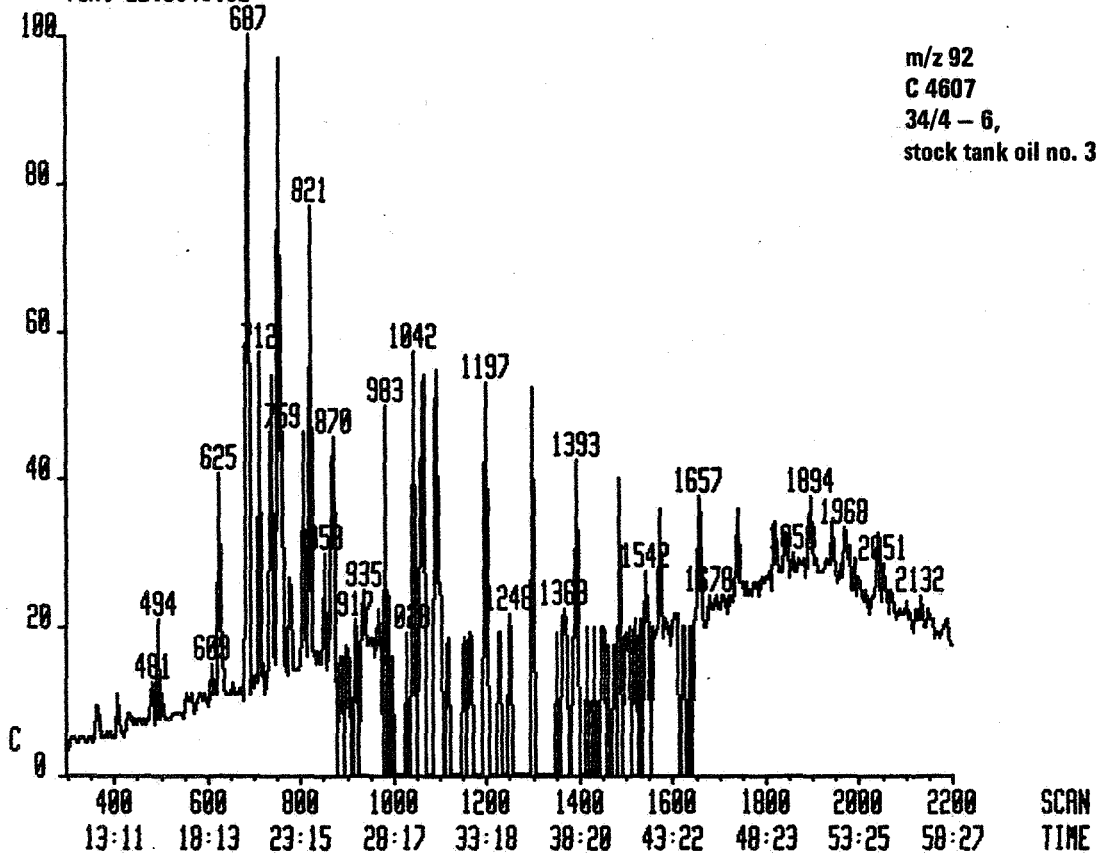
C4607ARO #300-2200   1-JUL-86   16:10 12250   acnt:IKU   System PAROMATICS
Chromatogram Identifiers :   D1:106   D: 1372000
Text:22.8043.02

m/z 106
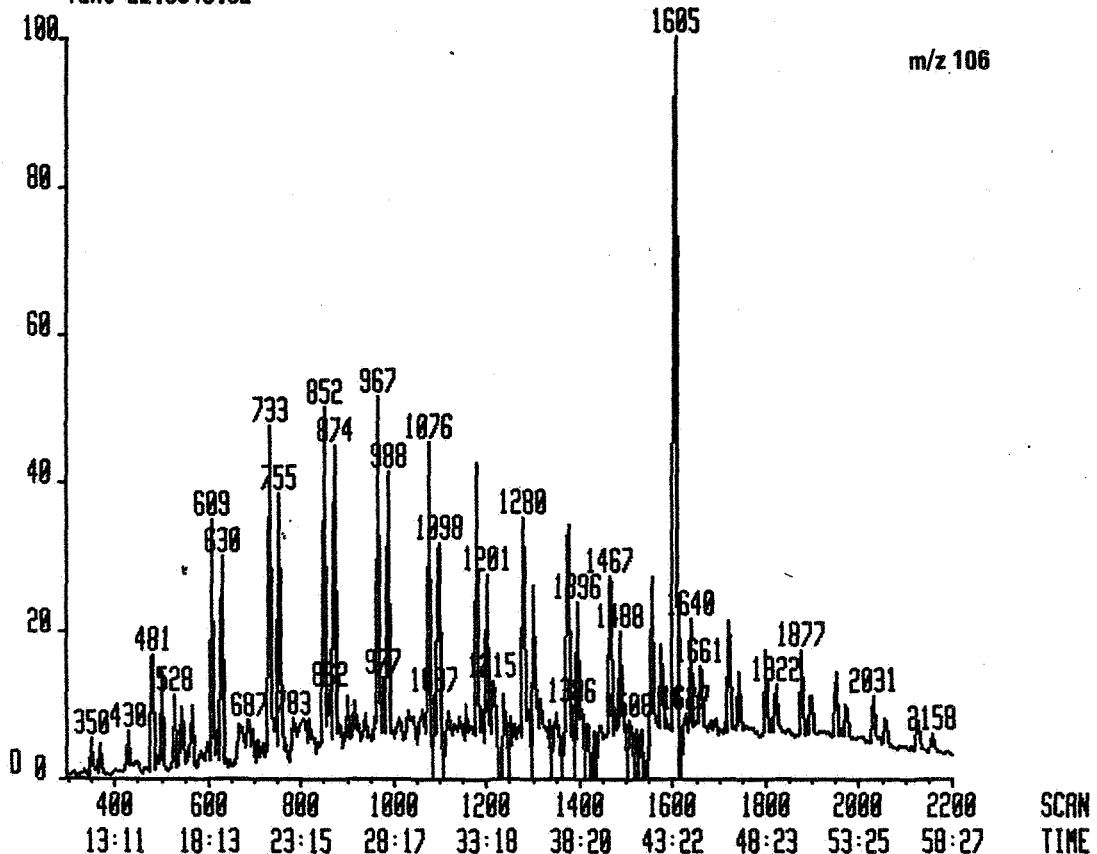
C4607ARO #200-700   1-JUL-86 16:10 12250   acnt:IKU   System NPAROMATICS
Chromatogram Identifiers :   E1:142 F1:156 G1:170   E: 653000
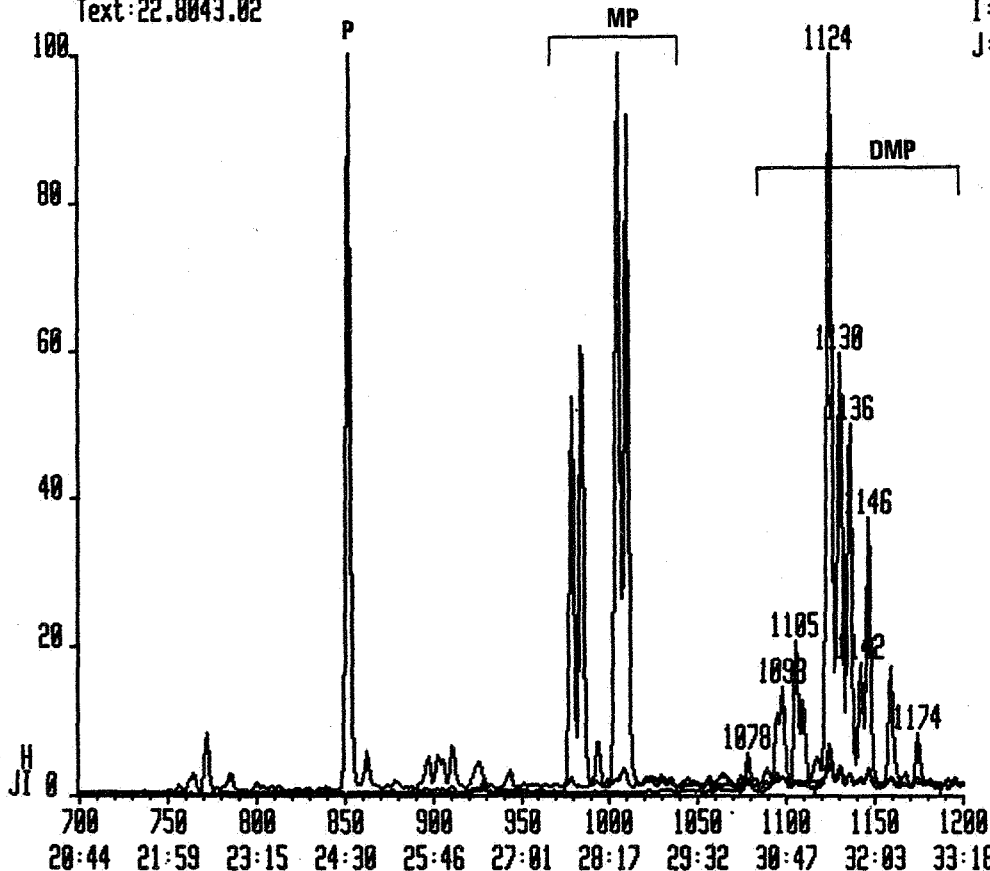Text:22.8043.02   F: 1722000
                                                               G: 1650000
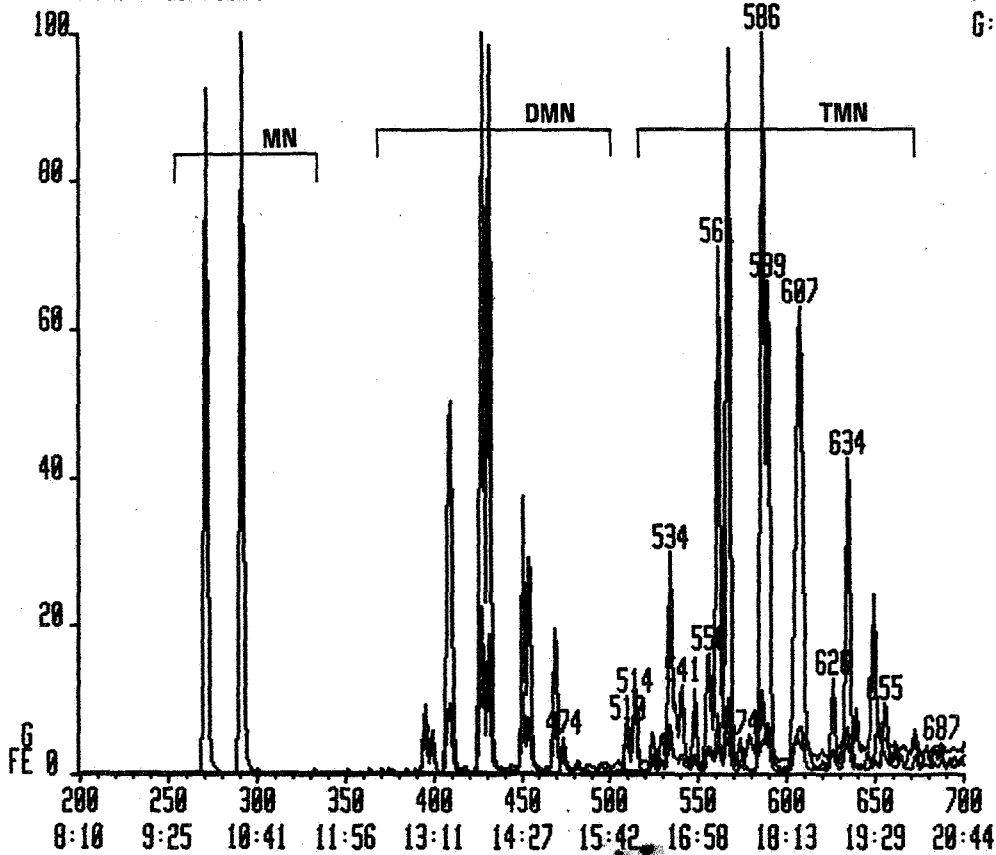
m/z 142, 156, 170
C 4607
34/4 – 6
stock tank oil no. 3

IKU
SINTEF-GRUPPEN

C4607ARO #700-1200   1-JUL-86 16:10 12250   acnt:IKU   System:NPAROMATICS
Chromatogram Identifiers :   H1:178 I1:192 J1:206   H: 3347000
Text:22.8043.02   I: 2217000
                                                                    J: 1783000
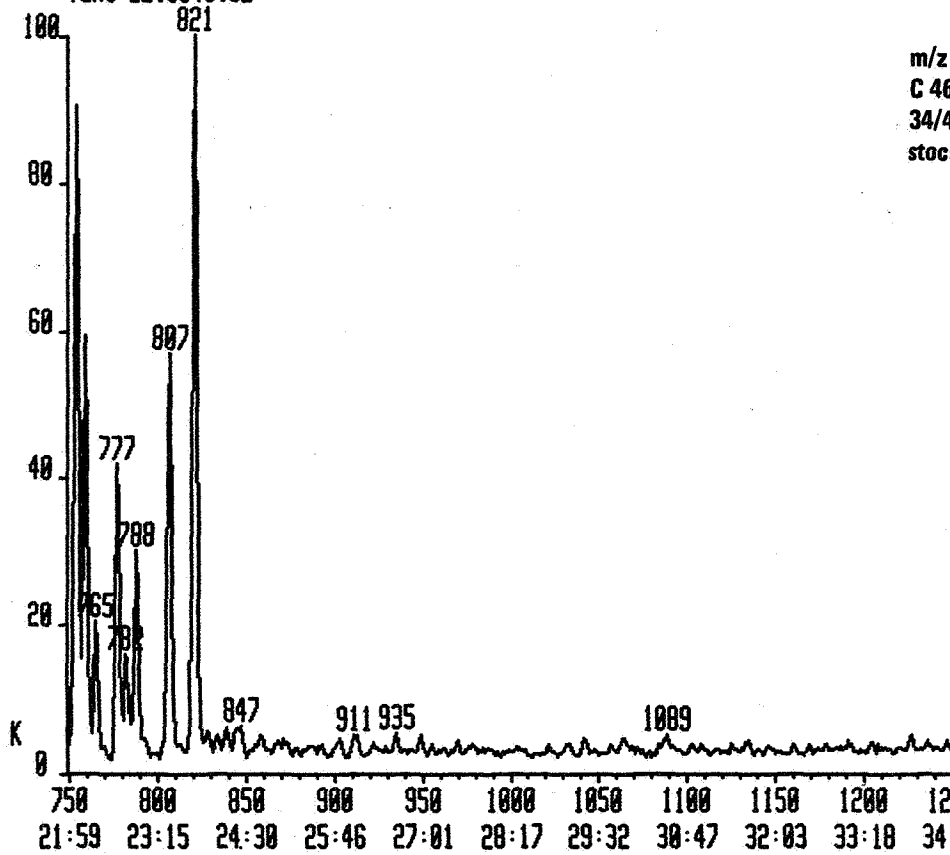
m/z 178, 192, 206
C 4607
34/4 – 6,
stock tank oil no. 3

IKU
SINTEF-GRUPPEN

C4607ARO #750-1250   1-JUL-86 16:10 12250   acnt:IKU   System:NPAROMATICS
Chromatogram Identifiers :   K1:184   K: 551000
Text:22.8043.02

m/z 184
C 4607
34/4 — 6,
stock tank oil no. 3

C4607ARO #750-1250   1-JUL-86 16:10 12250   acnt:IKU   System:NPAROMATICS
Chromatogram Identifiers :   L1:198   L: 812000
Text:22.8043.02

m/z 198

IKU
SINTEF-GRUPPEN

C4607ARO #750-1250   1-JUL-86   16:10 12250   acnt:IKU   System:WPAROMATICS
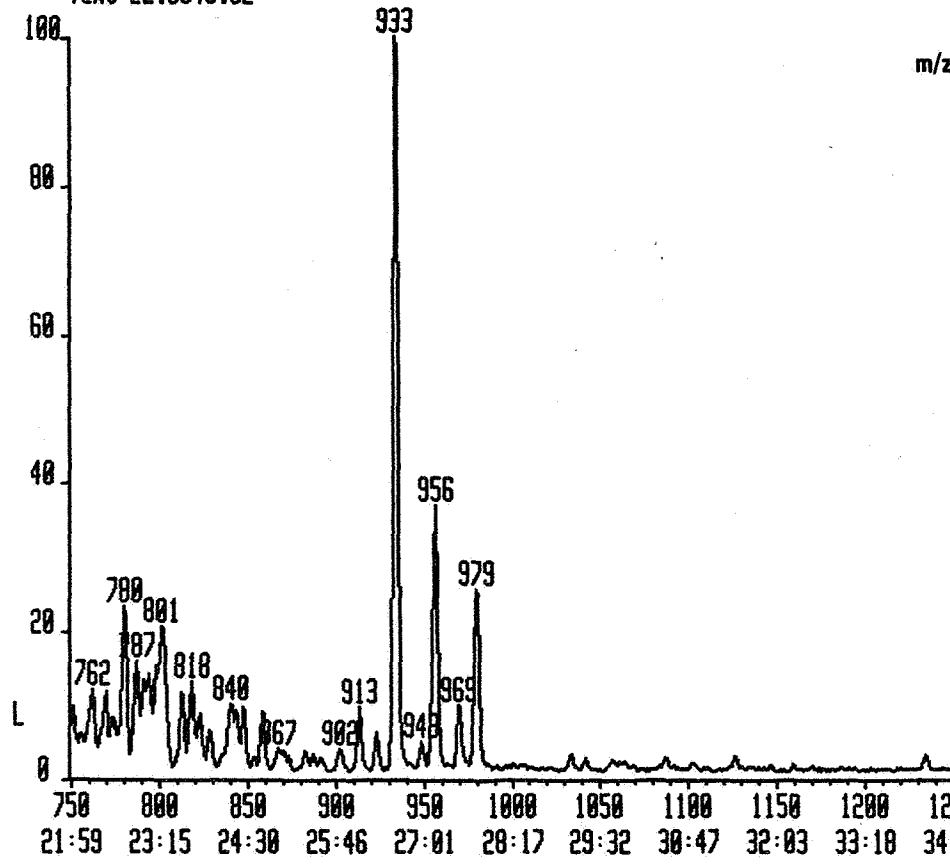Chromatogram Identifiers :   M1:212   M: 384000
Text:22.8043.02

m/z 212
C.4607
34/4 – 6,
stock tank oil no. 3

100

80

60

40

20

M 0

1042
1064
1088
1057
1103
1033
1107
843
922
855 879 901 935
834 940
782 804
997
120
1160 1191 1220

SCAN   750   800   850   900   950   1000   1050   1100   1150   1200   1250
TIME   21:59 23:15 24:30 25:46 27:01 28:17 29:32 30:47 32:03 33:18 34:34
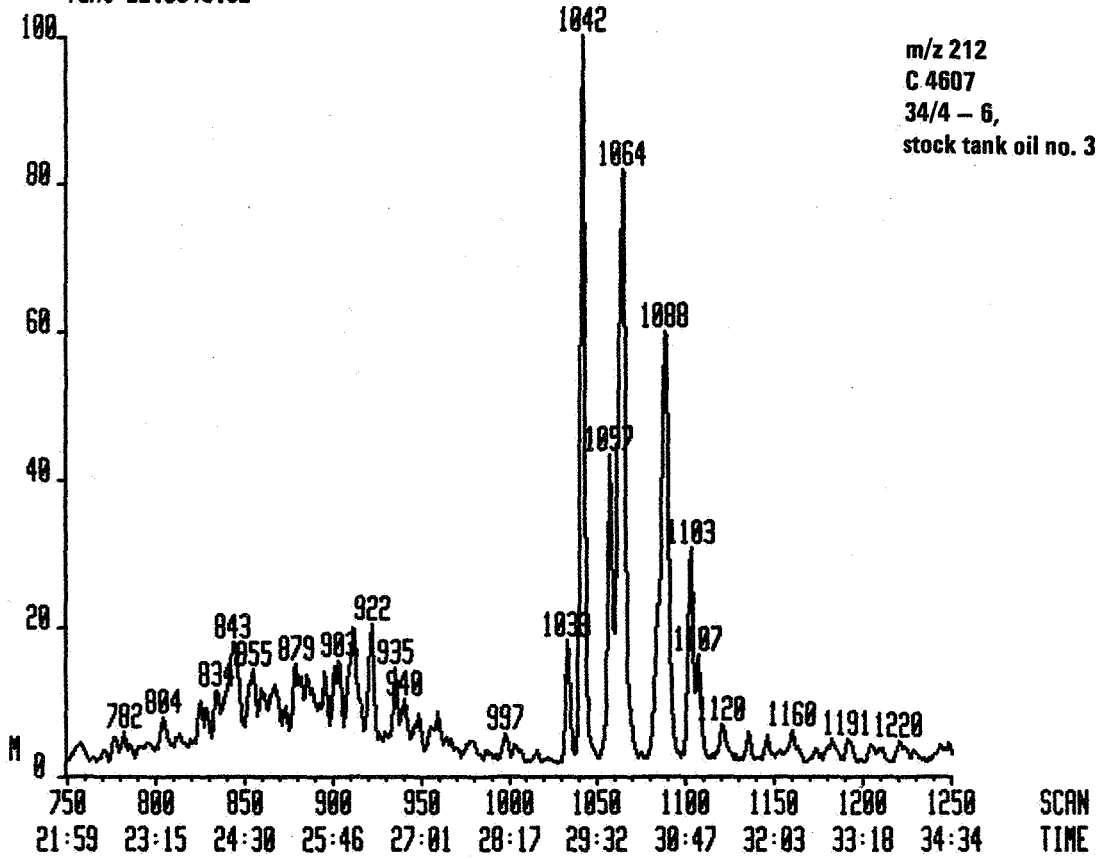
C4607ARO #1000-2200 1-JUL-86 16:10 12250   acnt:IKU   System PAROMATICS
Chromatogram Identifiers :   N1:231   N: 274000
Text:22.8043.02

P
1926

m/z 231
C 4607
34/4 – 6,
stock tank oil no. 3

Q
1969

N
1571

M
1491

S
R 2056

O
1874

2005

1400

1510

2014

2115

1291

1347

1649

1887

2115

1241

N

100

80

60

40

20

0

1000   1200   1400   1600   1800   2000   2200   SCAN
20:17   33:18   38:20   43:22   48:23   53:25   58:27 TIME

C4607ARO #1000-2200 1-JUL-86 16:10 12250   acnt:IKU   System PAROMATICS
Chromatogram Identifiers :   O1:239   O: 96000
Text:22.8043.02

1610

1618
1628

1732
1738

1843

1147

1749 1829

1897

1560

1811

1156
1228

1392

168

2118

1679

100

80

60

40

20

0
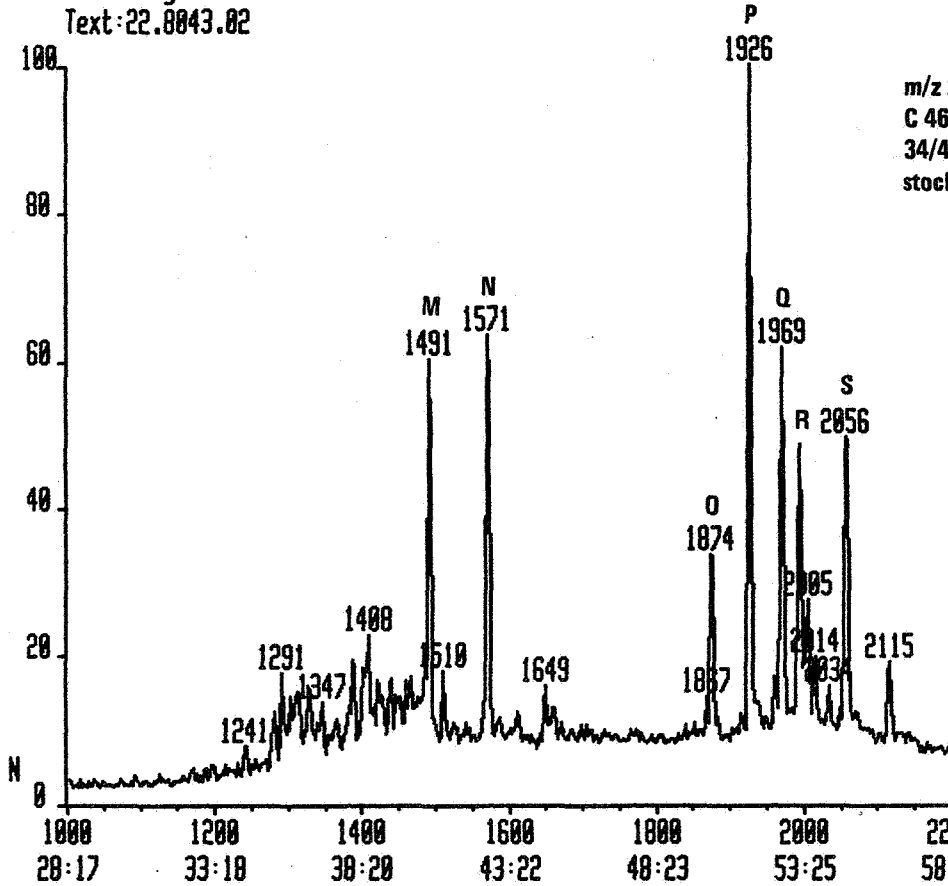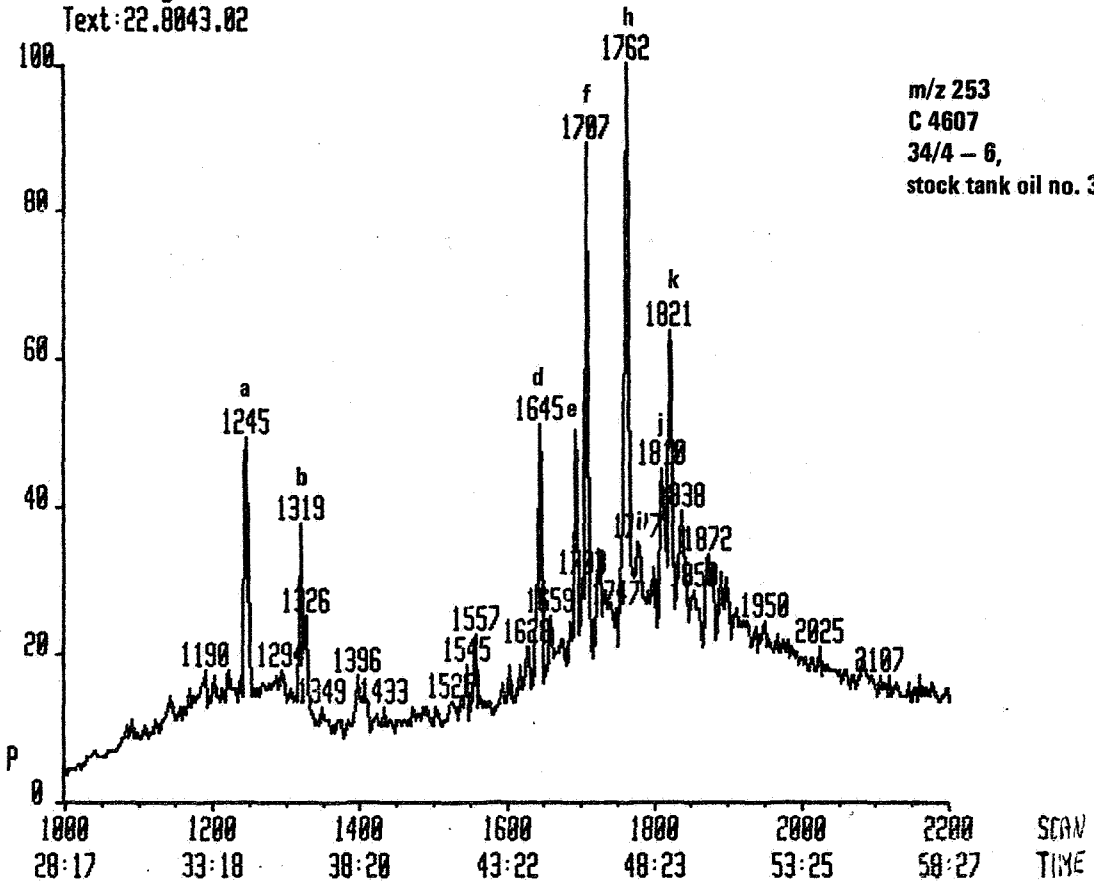
1000   1200   1400   1600   1800   2000   2200   SCAN
20:17   33:18   38:20   43:22   48:23   53:25   58:27 TIME

C4607ARO #1000-2200 1-JUL-86 16:10 12250 acnt:IKU System APROMATICS
Chromatogram Identifiers : P1:253 P: 120000
Text:22.8043.02

m/z 253
C 4607
34/4 — 6,
stock tank oil no. 3

δ^{13}C (‰) PDB
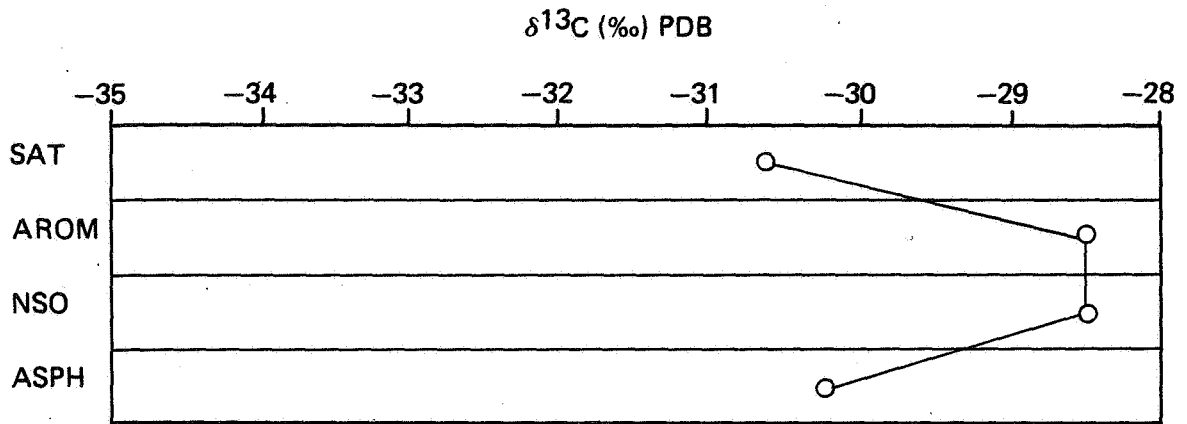
Well: SAGA 34/4—6
Sample: DST 3

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

IKU
SINTEF-GRUPPEN

APPENDIX 1.

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

Geochemical fossil/biological marker compounds are characteristic of
the type of organic matter present at the time the sediments were depo-
sited. The biological isomers of these compounds are converted to the
geochemical isomers with increasing maturity until a stable mixture of
the isomers is attained. Migration and weathering processes also alter
the distribution of biomarker compounds in a sample.

Hopanes, moretanes and tricyclic terpanes are the most common compounds
in the m/z 191 mass chromatograms of most extracts and oils. Of the hopa-
nes, the C_{27} and C_{29}-C_{35} homologs are ubiquitous, while 28,30-bisnorhopane
is believed to be typical of certain types of source rocks. This is also
thought to be true for a component, probably gammacerane, which sometimes
coelutes with the 22S isomer of the C_{31} 17α(H)-hopanes. The relative
distribution of the C_{27} trisnorhopanes is thought to be both source-
and maturity-dependant.

In the m/z 217 and 218 sterane mass chromatograms, the molecular weight
distribution of the C_{27}-C_{30} regular steranes is thought to be represen-
tative of the original organic matter input. The C_{29} steranes are gene-
rally indicative of input from higher land plants, but, more recently,
similar compounds have been reported from marine micro-organisms.
Moldowan (1984) has also recently published data on C_{30} steranes that
are thought to be characteristic of input from marine organisms. This
is one of the few marine markers reported, and previously the indica-
tion of marine origin for mature geolipids was assessed on the basis of
absence of nonmarine marker compounds.

The biological hopane isomers, the 17β(H),21β(H)-hopanes, undergo struc-
tural changes during maturation. These isomerisation reactions are be-
lieved to proceed through the 17β(H),21α(H)-hopane structure (moretanes)
to the stable 17α(H),21$\beta\alpha$(H)-hopane structure. With thermal maturity,
17α(H)-hopanes account for 90-100% of the hopanes present. The ratio
$\alpha\beta/\alpha\beta+\beta\alpha$ is used to describe this reaction. In the extended hopanes
($\geq C_{31}$), the thermally stable S configurations at C-22 become increas-
ingly more abundant compared to the biologically preferred R configu-

ORG/a/34

rations with increased maturity. The ratio of the 22S:22R isomers stabilises at about 60:40 at thermal maturity. The Tm/Ts C_{27} hopane ratio (Seifert et al, 1978) also varies with thermal maturity such that, with increasing maturity, $17\alpha(H)$-trisnorhopane (Tm) is reduced in intensity relative to the more stable $18\alpha(H)$-trisnorhopane (Ts), causing the Tm/Ts ratio to decrease. However, this ratio is also thought to be source-dependant, and this should be allowed for when using the ratio as a maturation indicator. The tricylic terpanes vary in abundance with maturity (Schou et al., 1984a), as does 28,30-bisnorhopane (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 $14\alpha(H),17\alpha(H)$ regular sterane isomers are gradually replaced by the more thermally stable $14\beta(H),17\beta(H)$-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 C_{20}, 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 $14\beta(H),17\beta(H)$ regular steranes (Seifert and Moldowan, 1978). Severe biological alteration leads to the formation of desmethyl-hopanes (Seifert and Moldowan, 1979).