

REPORT

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<p>REPORT TITLE:</p> <p>ORGANIC GEOCHEMICAL CHARACTERISATION OF OIL AND GAS SAMPLES FROM WELL 34/7-12</p> <p>REPORT NO.: 22.1881.00/01/88</p>
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CLIENT:

Saga Petroleum a.s.

SUMMARY:

Organic geochemical data were used to evaluate two sets of oil and gas samples from DST's 2 and 3 in well 34/7-12.

The DST gas samples are thermally mature gases with characteristics indicating association with crude oils. The oils are thermally mature, low sulphur, paraffinic-naphthenic oils. Both sets of DST samples are nearly identical in composition and maturity. The composition and maturity of the 34/7-12 fluids lie close to those of the average Snorre oil.

The organic geochemical data suggest that the 34/7-12 DST fluids share a common source with the majority of the adjacent Snorre oils. This source is thought to lie within the upper Jurassic Kimmeridge Clay / Draupne formation of the North Sea.

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1. INTRODUCTION

Oil and gas samples from drill stem tests (DST) 2 and 3 in well 34/7-12 (Figure 1) were characterised using organic geochemical techniques as requested by Saga Petroleum A/S (Contract No.: KO-EUG-87-0033). In addition, carbon isotope data were obtained for a gas sample from DST 1 in the same well. The analysis of the DST fluids was carried out under IKU project number 22.1881.

Physical data on the DST fluids were provided by Geco on the instructions of Saga Petroleum A/S. These data are shown below, along with the IKU numbers assigned to the samples.

SAMPLE	IKU No.	GAS/OIL	OIL	OIL
		RATIO	DENSITY	MOLEC WT.
		(Sm ³ /m ³)	(Kg/m ³)	(gm/mole)
DST 2	C-7245(gas)			
	C-7246(oil)	109.2	842.7	205
DST 3	C-7247(gas)			
	C-7248(oil)	115.8	845.0	207

(Standard conditions - 20°C at 250 bar to 15°C at atmospheric)

The analytical programme used was that outlined in the contract, and was as follows:

- 1) S, Ni, V content of DST oils.
- 2) CGC of whole oil.
- 3) Topping of oil and separation of oil fractions by MPLC (including asphaltene content).
- 4) CGC of saturate and aromatic oil fractions.
- 5) GC-MS of saturate fraction (m/z 177,191,205,217,218,231,259).
- 6) $\delta^{13}\text{C}$ isotope ratio of C₁, C₂, C₃, iC₄, and nC₄ gas fractions; and $\delta^{13}\text{C}$ isotope ratio of saturate, aromatic, NSO and asphaltene oil fractions.
- 7) δH isotope ratio of C₁ gas component.
- 8) GC of C₁-C₈ hydrocarbons of DST oil and gas for recombination of reservoir fluid (GOR provided).

The two sets of fluid samples from DST's 2 and 3 were received at IKU on 4 February, 1988. The gas sample from DST 3 proved to contain air, and after discussion with Saga Petroleum A/S, only $\delta^{13}\text{C}$ isotope data are reported for this gas sample. A sample of the gas from DST 1 was not provided for GC analysis, and therefore only $\delta^{13}\text{C}$ isotope data are reported from this sample.

A draft copy of this report was sent to Saga Petroleum A/S for approval. On approval, ten copies of the final report were sent to the client and a further five copies are stored at IKU A/S.

2. DISCUSSION OF RESULTS

2.1 Recombination of Oil and Gas samples (C₁-C₈ hydrocarbons)

The C₁-C₈ gas data and the C₂-C₈ oil data are given in table 1a-c, and the gas chromatograms are shown in figures 2 and 3, respectively.

Gas chromatographic data could only be obtained for the DST 2 gas due to leakage of the DST 3 gas during transit. Methane accounts for around 60 % of the DST 2 gas, the gas wetness being only 36 %. These values differ from most of the Snorre gases in the higher methane content and lower gas wetness of this gas sample. An iC₄/nC₄ ratio of 0.39 suggests that this gas is thermally mature.

The C₂-C₈ gas chromatograms of the two DST oil samples are similar in appearance. The n-alkane peaks are amongst the most prominent on the gas chromatograms, and show a steady decrease in peak height with increasing molecular weight. The development of the n-alkane peaks, together with paraffin index values of around 1, suggest that these oils are thermally mature.

The C₁-C₈ data from the gas and oil samples was recombined using gas/oil ratios supplied by Saga Petroleum A/S in order to simulate the subsurface composition of the DST fluids.

2.2 Carbon and Hydrogen Isotope Ratios of C₁-C₄ Gas components

The δ¹³C and δD isotope data are given in table 2 and selected data have been cross-plotted after the method of Schoell (1983). These figures are shown in figure 4.

The carbon isotopic composition of the analysed gas components is very similar, with values for individual components deviating by less than 0.4 ‰ PDB. The greatest deviation in carbon isotope ratio is seen for the nC₄ component, where values vary between -31.5 and -30.0 ‰ PDB. The δD composition of the C₁ gas component also shows little variation, with values of between -202 and -199 ‰ SMOW.

The isotope ratio values obtained from the three gas samples lie close to the average values obtained from gases from the Snorre field. This is illustrated in figure 4, where it can be seen that the isotope ratios for the 34/7-12 gas samples plot in, or close to, the field containing the majority of the Snorre gas samples analysed at IKU. The diagrams indicate that the 34/7-12 gas samples show characteristics of relatively mature, oil-associated gases.

2.3 Characterisation of Crude Oil samples

2.3.1 Sulphur, Nickel and Vanadium Content

The two oil samples have rather similar sulphur contents of around 0.4 %, which is close to the mean value of 0.3 % obtained from Snorre oils (Table 3). The two 34/7-12 oil samples can be considered low-sulphur oils.

Some difference can be seen in the nickel and vanadium content of the two DST oils. The concentration of vanadium (3.02 mg/kg) in the DST 2 oil is twice that of the concentration of nickel (1.4 mg/kg) in the oil. In the DST 3 oil, the concentrations of nickel (2.22 mg/kg) and vanadium (2.64 mg/kg) are nearly equal. These concentrations are within those observed in oils from the Snorre field.

2.3.2 Gross Composition of the Crude Oil samples

Low molecular weight hydrocarbon compounds account for only 29 % to 35 % of the DST oils (Figure 5, Tables 4 and 5). This is a slightly lower percentage than is found in most of the oils from the Snorre field, where low molecular weight compounds account for, on average, 39 % of the oil.

Hydrocarbon compounds account for around 70 - 75 % of the topped oil (Tables 6 and 7). The hydrocarbon compounds are divided between saturated and aromatic compounds in a ratio of about 60:40. The percentage content in each of the 34/7-12 DST oils is close to the average saturated and aromatic hydrocarbon content of 49 % and 24 % for the Snorre oils.

The two DST oils also have similar percent asphaltene and NSO contents of around 2.4 % and 4.3 - 5.9 %, respectively (Table 8). Similar values have been reported from the majority of the Snorre oils analysed at IKU.

2.3.3 Gas Chromatography of the Whole Oil

The whole oil gas chromatograms obtained from the two DST samples are shown in figure 6, and are rather similar in appearance. Both gas chromatograms show a unimodal distribution of n-alkanes, with a smooth decrease in peak height from a maximum at nC_5 to a minimum below nC_{30} . A very slight "hump" in the n-alkane envelope can be seen around the nC_{15} peak. A similar feature has been observed in a number of Snorre oils (e.g. 34/4-7).

2.3.4 Gas Chromatography of the Saturate and Aromatic Oil Fractions

The saturated hydrocarbon gas chromatograms of the two DST samples (Figure 7) show similar unimodal distributions of n-alkane compounds, with peak heights reaching a maximum around the nC_{15} - nC_{16} peaks. These n-alkane distributions are typical of mature oils derived from marine organic matter. The thermal maturity of the oils is supported by carbon preference indices (CPI) of 1.0 (Table 9). Pristane/phytane ratio values of 1.5 for both DST oils are thought to suggest that the source organic matter for these oils was deposited under fluctuating anoxic-dysoxic conditions. These pristane/phytane ratios are similar to values obtained from most of the Snorre oils (Figure 8).

The aromatic hydrocarbon gas chromatograms of the two DST oils are also similar in appearance (Figure 9), and show a rather abbreviated development of aromatic compound peaks representing the alkyl naphthalenes, phenanthrene and the alkyl phenanthrenes. The gas chromatogram of the DST 3 oil is distinguished from that of the DST 2 oil by the presence of a "hump" of unresolved compounds in the former sample. Methyl-phenanthrene index (MPI 1) values of 0.72 and 0.68 (Table 10) suggest that the oils are thermally mature, and are similar to values reported from DST oils from wells 34/7-3, 34/7-4 and 34/4-7. The majority of the Snorre oils analysed at IKU have higher MPI 1 values of around 1.0.

2.3.5 Gas Chromatography - Mass Spectrometry of DST Oil Saturate Fractions

The saturate fraction of the two DST oils was analysed by combined GC-MS for eight ions (i.e. m/z 163, 177, 191, 205, 217, 218, 231, 259). The terpene and sterane mass fragmentograms are shown in figures 10 and 11, and ratios calculated from these mass fragmentograms are given in tables 11 and 12.

The m/z 191 terpene mass fragmentograms of the two samples show similar distributions of hopane and moretane compounds, the C_{30} hopane peak being the most prominent peak. Both mass fragmentograms show small peaks representing the tricyclic diterpane compounds. A peak thought to represent C_{28} bisnorhopane is similarly developed in both mass chromatograms, and is often associated with North Sea oils thought to have been sourced from the upper Jurassic Kimmeridge Clay formation.

The relatively low moretane peaks, represented by the high $\alpha\beta/\alpha\beta+\beta\alpha$ ratios of 0.94 and 0.95, and the prominence of the 22S isomer of the C_{31+} extended hopane compounds, represented by %22S values of around 60 %, suggest that the oils are thermally mature. Thermal maturity is also indicated by the low T_m/T_s ratios of around 0.7. Similar values for these ratios have been observed in most of the Snorre oils analysed at IKU.

The m/z 217 sterane mass fragmentograms of the two DST oils also show similar distributions of both rearranged and regular sterane compounds. The prominence of the rearranged sterane peaks, relative to those of the regular steranes, suggest that the two oil samples are thermally mature. This is reflected in the relatively high $a/a+j$ ratios of 0.79 and 0.87, which are higher than is observed in most of the Snorre oils.

The internal distribution of the C_{27} , C_{28} , and C_{29} $5\alpha 20R$ regular steranes is shown in figure 12. The distribution of the regular steranes for the two 34/7-12 DST oils is similar to that observed for most of the Snorre oils, suggesting a similar source (Figure 12).

2.3.6 Carbon Isotope Data for the DST Oil Fractions

Carbon isotope data were obtained for the saturate, aromatic, NSO and asphaltene DST oil fractions. The data are shown in figure 13 and table 13.

The $\delta^{13}\text{C}$ isotope ratio values for the analysed fractions reveal little difference between the two oil samples. The only variation occurs in the NSO fraction, where the value for the DST 3 oil is slightly higher than the value for the DST 2 oil. This indicates that the NSO fraction is isotopically lighter in the DST 3 oil. The isotopic similarity of the two oils is well-illustrated in figure 13.

In comparison with the majority of the Snorre oils, the 34/7-12 DST oils appear to be slightly isotopically heavier.

3. CONCLUSIONS

The gas and oil samples from DST's 2 and 3 in well 34/7-12 are very similar in composition. The gas samples are isotopically similar, and have characteristics of oil-associated gases similar to those described for gases from the Snorre field. The oils from these two DST's may be characterised as moderate density, low sulphur, paraffinic-naphthenic oils.

The organic geochemical composition of the two oils suggests that they are thermally mature, with characteristics lying close to the average for Snorre oils. Isoprenoid and biomarker compound data suggest that the oil samples from 34/7-12 are derived from a source similar to that which produced the previously analysed Snorre oils. This source is postulated to be the upper Jurassic Kimmeridge Clay / Draupne formation. The data suggest a more marginal development of this unit as the source of the oils, rather than a wholly marine development.

4. REFERENCES

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Previous IKU reports concerned with block 34/7 and 34/4 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.
- 22.1830.00/01/86: Organic geochemical characterisation of oil and gas samples from well 34/7-8.
- 22.1831.00/01/86: Organic geochemical characterisation of oil and gas samples from well 34/4-6.
- 22.1837.00/01/86: Asphaltene content of core extracts from 34/7-7 and 34/7-10: Data report.
- 22.1851.00/01/87: Oil-oil correlation study of DST oils from blocks 34/4 and 34/7.
- 22.1840.00/01/87: Organic geochemical characterisation of DST and FMT samples from well 34/7-10.
- 22.1859.00/01/87: Organic geochemical characterisation of oil and gas samples from well 34/4-7.

5. ANALYTICAL PROCEDURES

5.1 Gas analyses

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 silica 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 Porapak T x 4 ft steel column packed with Porapak Q, 80/100 mesh.

Temperature program: 30°C (12 min.) - 8°C/min. - 150°C (5 min.).

Standard gas samples containing methane, ethane, propane, n-butane, n-pentane, n-hexane and hydrogen, oxygen, nitrogen, carbon monoxide, carbon dioxide and methane, respectively, were used for quantification.

5.2 Evaporation of the light components in fluid samples

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

The fraction of light components was determined as the weight difference between the original sample and the residuum left after heating. The plate and transferred to a short column of DCM-washed, deactivated alumina. The fractions were eluted from the column using ca. 30 ml DCM. The solvent was reduced to a volume of ca. 1 ml using a Büchi rotary evaporator and the remaining solvent/fraction mixture was transferred to a preweighed glass vial. The remaining solvent was evaporated under nitrogen and the weight of each fraction was determined.

5.3 Medium-pressure liquid chromatography (MPLC)

The oil (>210°C) sample was diluted in DCM (1:3 mg/ μ l) and the asphaltenes were precipitated using excess n-pentane (40:1 pentane:(DCM+EOM)). The asphaltene fraction was weighed after drying at 50°C 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, then transferred to glass vials and the remaining solvent removed.

5.4 Gas chromatographic analysis

The whole oil sample from hydrous pyrolysis was analysed using an HP 5730A gas chromatograph fitted with a 15 m DB-5 fused silica column. 0.02µl of sample solution were injected in split mode (split ratio 1:10). Hydrogen with a flow rate of 2.5 ml/min. was used as a carrier gas, and the temperature programme used was -50°C (2 min.) - 4°C/min. - 280°C.

The C₂-C₈ hydrocarbon compounds were analysed 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 1.0 µm DB-1. The temperature programme used was 50°C (2 min.) - 4°C/min. - 210°C. An internal standard was used for quantification.

The saturated hydrocarbon fractions were diluted with n-hexane and analysed on a Carlo Erba Fractovap gas chromatograph equipped with a 15 m DB-1 fused silica column. Hydrogen was used as a carrier gas with a flow rate of about 1.5 ml/min. Injections were performed in split mode (split ratio 1:10). The temperature program 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 5710A gas chromatograph, fitted with a DB-5 fused silica column (15 m 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.

All the data from the GC analyses were processed on a VG Multichrom lab data system.

5.5 Gas chromatography - mass spectrometry (GC-MS)

GC-MS analyses were performed on a VG Micromass 70-70H GC-MS-DS system.

VG 70-70H system: A Varian Series 3700 GC was fitted with a fused silica DB-5 capillary column (30 m x 0.3 mm i.d.). Helium (1.5 ml/min.) was used as a carrier gas and the injections were performed in splitless mode.

The GC oven was programmed from 120°C (2 min.) to 280°C at 4°C/min. for analysis of the saturated hydrocarbons.

The saturated hydrocarbons were analysed in multiple ion mode (MID) at a scan cycle time of approximately 2 secs. The mass spectrometers operated at 70eV electron energy with an ion source temperature of 200°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.

5.6 $\delta^{13}\text{C}$ isotope analysis

The $\delta^{13}\text{C}$ isotope analysis was 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.

IKU Nr.: GAS : C-7245
 IKU Nr.: OIL : C-7246
 Well : 34/7-12
 Code : DST 2

Table 1a.

RECOMBINATION OF OIL AND GAS (C1-C8 HYDROCARBONS)

	yi % of tot gas	xi % of tot oil	z'i mol/comp	zi mol %
N2	1.4601	0	.006743369	1.27
CO2	.6366	0	.002940092	.55
C1	60.0801	0	.277475720	52.48
C2	13.6797	0	.063178733	11.95
C3	13.4675	0	.062198702	11.76
isoC4	2.088	0	.009643281	1.82
nC4	5.3092	0	.024520167	4.63
isoC5	1.1377	.38	.006821099	1.29
nC5	1.3158	.93	.009911251	1.87

Light end total	99.1747	1.31	.463432417	87.65
CyC5 + 2,3DMC4 + 2MC5	.2005	.75	.004018190	.76
3MC5	.073	.35	.001780169	.33
nC6	.1753	1.11	.005386059	1.01

Hexanes total	.4488	2.21	.011184419	2.11
MCyC5	.0753	.69	.003192587	.60
benzene	.0233	.29	.001303258	.24
CyC6	.0646	.84	.003761609	.71
2MC6	.0207	.33	.001456167	.27
2,3DMC5	.0093	.12	.000537702	.10
3MC6	.0226	.48	.002083381	.39
DMCyC5 x 3	.0333	.67	.002916154	.55
nC7	.0332	1.19	.005059614	.95

Heptanes total	.2823	4.61	.020310475	3.84
MCyC6	0	1.57	.006472995	1.22
EtCyC5 + 2,5DMC6	0	.23	.000948273	.17
2,4DMC6	0	.13	.000535980	.10
TMCyC5	0	.12	.000494751	.09
toluene	.046	1.03	.004459062	.84
2 + 4MC7	.0052	.46	.001920562	.36
3MC7	.003	.31	.001291962	.24
DMCyC6	.0027	.62	.002568684	.48
nC8	.0126	1.23	.005129392	.97

Octanes total	.0695	5.7	.023821663	4.50
2,4DMC7 + DMCyC6	0	.24	.000989502	.18
EtCyC6	0	.41	.0016904	.31
Etbenzene	0	.33	.001360565	.25
m/p-xylene	0	.8	.003298341	.62
2 + 4MC8	0	.32	.001319336	.24
o-xylene	0	.31	.001278107	.24

Nonanes total	0	2.41	.009936253	1.87

C10+ total	0	83.76	.345336351	65.31

Total sum	99.9753	100	.528685229	100
=====				

Moleculw. stock tank oil (Ms) 205
 Gas/oil ratio (GOR) 109.2 Sm³/m³
 Density stock tank oil (μs) .8452 g/cm³
 c2-c8 oil 16.24 %

Table 1b.

C2 - C8 HYDROCARBON COMPOSITION OF THE OILS

C-7246 34/7-12 DST 2	area	µg	mg/ml	% of tot
isoC3	0			
nC3	0			
isoC4	0			
nC4	0			
isoC5	142243	1.02	3.43	.38
nC5	349539	2.52	8.43	.93
CyC5 + 2,3DMC4 + 2MC5	282781	2.04	6.82	.75
3MC5	131710	.95	3.17	.35
nC6	415481	3.00	10.02	1.11
MCyC5	257014	1.86	6.20	.69
benzene	110197	.79	2.65	.29
CyC6	315386	2.28	7.60	.84
2MC6	125985	.91	3.03	.33
2,3DMC5	48189	.34	1.16	.12
3MC6	182293	1.31	4.39	.48
DMCyC5	251450	1.81	6.06	.67
nC7	444884	3.21	10.73	1.19
MCyC6	587986	4.25	14.18	1.57
EtCyC5 + 2,5DMC6	86830	.62	2.09	.23
2,4DMC6	49762	.36	1.20	.13
TMCyC5	44964	.32	1.08	.12
toluene	385745	2.79	9.30	1.03
2 + 4MC7	171455	1.24	4.13	.46
3MC7	118152	.85	2.85	.31
DMCyC6	232822	1.68	5.61	.62
nC8	457949	3.31	11.04	1.23
2,4DMC7 + DMCyC6	90763	.65	2.18	.24
EtCyC6	153078	1.10	3.69	.41
Etbenzene	123536	.89	2.98	.33
m/p-xylene	299715	2.16	7.23	.80
2 + 4MC8	119187	.86	2.87	.32
o-xylene	115431	.83	2.78	.31
sum		44.10	147.02	16.37

total oil (µg inj): 269.34

%C2-C8 (tot.area) in tot.oil: 19.98

Table 1b.

C2 - C8 HYDROCARBON COMPOSITION OF THE OILS

C-7248 34/7-12 DST 3	area	µg	mg/ml	% of tot
isoC3	0			
nC3	0			
isoC4	0			
nC4	0			
isoC5	115336	.84	2.83	.33
nC5	324311	2.38	7.96	.93
CyC5 + 2,3DMC4 + 2MC5	281704	2.07	6.91	.81
3MC5	125906	.92	3.09	.36
nC6	410668	3.02	10.08	1.18
MCyC5	253962	1.87	6.23	.73
benzene	116470	.85	2.85	.33
CyC6	302280	2.22	7.42	.87
2MC6	126344	.93	3.10	.36
2,3DMC5	48291	.35	1.18	.13
3MC6	181954	1.34	4.46	.52
DMCyC5	235854	1.73	5.79	.68
nC7	426732	3.14	10.47	1.23
MCyC6	548843	4.04	13.47	1.58
EtCyC5 + 2,5DMC6	73797	.54	1.81	.21
2,4DMC6	43879	.32	1.07	.12
TMCyC5	40974	.30	1.00	.11
toluene	406893	2.99	9.98	1.17
2 + 4MC7	164321	1.21	4.03	.47
3MC7	111107	.81	2.72	.32
DMCyC6	216483	1.59	5.31	.62
nC8	434897	3.20	10.67	1.25
2,4DMC7 + DMCyC6	86718	.63	2.12	.25
EtCyC6	149974	1.10	3.68	.43
Etbenzene	121843	.89	2.99	.35
m/p-xylene	310111	2.28	7.61	.89
2 + 4MC8	116476	.85	2.85	.33
o-xylene	122992	.90	3.01	.35
sum		43.44	144.83	17.06

total oil (µg inj): 254.64

%C2-C8 (tot.area) in tot.oil: 21.51

Table 1c. Ratios Calculated From C₁-C₈ Hydrocarbon Data

	DST-1	DST-2	DST-3
% Methane	na ⁺	61.4	na
% Gas Wetness	na ⁺	36.0	na
iC ₄ /nC ₄ Ratio	0.37*	0.39	0.47*
Paraffin Index 1	na	1.22	1.31

$$\% \text{ Gas Wetness} = (E \text{ C}_2\text{-C}_5) / (E \text{ C}_1\text{-C}_5)$$

$$\text{Paraffin Index 1 (after Thompson, 1978)} = \frac{2\text{-MeC}_6 + 3\text{-MeC}_6}{\text{diMeCyC}_5} \text{ (3 isomers)}$$

* From IFE data

+ The IFE calculated values have been calculated by a different method to that used at IKU, and are therefore not comparable.

Table 1d. C₁-C₄ gas composition (normalized) of gas samples from well 34/7-12.*

IKU no.	Sample	C ₁ %	C ₂ %	C ₃ %	iC ₄ %	nC ₄ %	CO ₂ o/oo	ΣC ₁ -C ₄
-	DST no. 1	89.1	5.5	1.6	0.09	0.24	3.6	96.4
C-7247	DST no. 3	80.6	11.9	5.0	0.51	1.08	0.96	99.0

* Data provided by IFE.

Table 2. Carbon and hydrogen isotope ratios for the DST gases.

IKU No.	DST No.	C ₁		C ₂	C ₃	iC ₄	nC ₄
		$\delta^{13}\text{C}$	δD	$\delta^{13}\text{C}$	$\delta^{13}\text{C}$	$\delta^{13}\text{C}$	$\delta^{13}\text{C}$
	1	-46.3	-202	-32.0	-29.8	-30.0	-31.5
C-7245	2	-46.5	-200	-32.1	-30.0	-30.0	-30.0
C-7247	3	-46.4	-199	-31.6	-29.7	-29.8	-31.2

Project no.: 22.1881.00
 Well ident.: 34/7-12
 DATE : 7 - 3 - 88.

Table 3.

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

IKU-No.	CODE	S	Ni	V
		%	(mg/kg)	(mg/kg)
C 7246	DST 2	0.40	1.40	3.02
C 7248	DST 3	0.38	2.22	2.64

TABLE 4: SUMMARY OF GEOCHEMICAL PROPERTIES OF SNORRE OILS

	MEAN	MIN	MAX	MEAN 34/7-12
API Gravity	36.7	33.9	39.4	-
% Sulphur	0.3	0.2	0.5	0.4
Gas/Oil ratio	88.9	54.9	163.7	112.5
% <210°C Fraction	36.0	17.1	64.6	32.4
% Asphaltenes (*)	2.5	0.4	16.3	2.4
% Saturates (*)	48.0	27.2	79.4	45.6
Saturate/Aromatic	2.7	0.8	9.9	1.6
Pristane/nC-17 (+)	0.7	0.5	0.9	0.8
Pristane/Phytane (+)	1.5	1.3	1.7	1.5
% 20S C-29 Steranes	47.2	34.0	59.0	42.0
% 22S Hopanes	60.3	54.8	65.3	61.2
% $\beta\beta$ C-29 Steranes	75.4	61.7	79.8	78.7
δ 13C-SAT	-30.3	-30.7	-29.6	-29.9

(* = Percent topped oil)

(+ = Unreliable data excluded)

Project no.: 22.1881.00
 Well ident.: 34/7-12
 DATE : 23 - 2 - 88.

Table 5.

FRACTION BOILING BELOW 210 C

IKU-No.	CODE	Crude oil (mg)	EOM >210C (mg)	Low molecular weight compounds (mg)	(%)
C 7246	DST 2	187.7	121.1	66.6	35.5
C 7248	DST 3	157.1	111.1	46.0	29.3

Table 6.

WEIGHT OF EOM AND CHROMATOGRAPHIC FRACTIONS

IKU-No	CODE	Crude oil (mg)	EOM >210C (mg)	Sat. (mg)	Aro. (mg)	HC (mg)	Non HC (mg)
C 7246	DST 2	187.7	121.1	55.9	32.2	88.1	33.0
C 7248	DST 3	157.1	111.1	49.9	33.0	82.9	28.2

Project no.: 22.1881.00
 Well ident.: 34/7-12
 DATE : 23 - 2 - 88.

Table 7.

COMPOSITION OF TOPPED OILS

IKU-No	CODE	Sat	Aro	HC	SAT	Non HC	HC
		EOM	EOM	EOM	Aro	EOM	Non HC
		%	%	%	x 100	%	x 100
C 7246	DST 2	46.2	26.6	72.7	173.6	27.3	267.0
G 7248	DST 3	44.9	29.7	74.6	151.2	25.4	294.0

Table 8.

AMOUNT OF ASPHALTENES AND NSO'S IN OIL

IKU-No.	CODE	Crude oil (mg)	Asphaltenes (mg)	(%)	NSO (mg)	(%)
C 7246	DST 2	187.7	4.7	2.5	11.0	5.9
C 7248	DST 3	157.1	3.6	2.3	7.5	4.8

Project no.: 22.1881.00
 Well ident.: 34/7-12
 DATE : 23 - 2 - 88.

Table 9.

TABULATION OF DATA FROM THE GASCHROMATOGRAMS

I	I	I	I	I	I	I	I	I	I	I		
I	IKU No.	CODE	:	PRISTANE	A=	PRISTANE	B=	PHYTANE	A	n-C17	CPI	CPI
I			:	PHYTANE		n-C17		n-C18	B	n-C27	1	2
I	C 7246	DST 2	:	1.5		0.8		0.6	1.4	4.7	1.0	0.9
I	C 7248	DST 3	:	1.5		0.8		0.6	1.4	4.5	1.0	0.9

DATE : 1 - 3 - 88.

Table 10. Ratios calculated from aromatic gas chromatograms.

IKU no.	DST no.	MPI-1	MPI-2
C-7246	2	0.72	0.48
C-7248	3	0.68	0.47

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

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

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

IKU code		$\alpha\beta/\alpha\beta+\beta\alpha^1)$	%22S ²⁾	%20S ³⁾	% $\beta\beta^4)$
C-7246	DST 2	0.95	61.20	41.67	79.31
C-7248	DST 3	0.94	61.29	42.34	78.11

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

2) % distribution between first and second eluting isomers of doublet G and H (m/z 191).

3) $2(r+s)/(q+t2(r+s))$ 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.		Q/E ¹⁾	Tm/Ts ²⁾	X/E ³⁾	Z/E ⁴⁾	a/a+j ⁵⁾
C-7246	DST 2	0.09	0.69	0.05	0.23	0.87
C-7248	DST 3	0.07	0.73	0.05	0.24	0.79

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. Carbon Isotope Ratios From Oil Fractions

IKU No.	DST No.	SAT	$\delta^{13}\text{C}$ o/oo _{PDB}		
			ARO	NSO	ASPH
C-7246	2	-29.9	-28.9	-29.3	-28.8
C-7248	3	-29.8	-28.9	-28.8	-28.8

(IFE's value for NBS-22 = -29.77 ± 0.06 o/ooPDB).

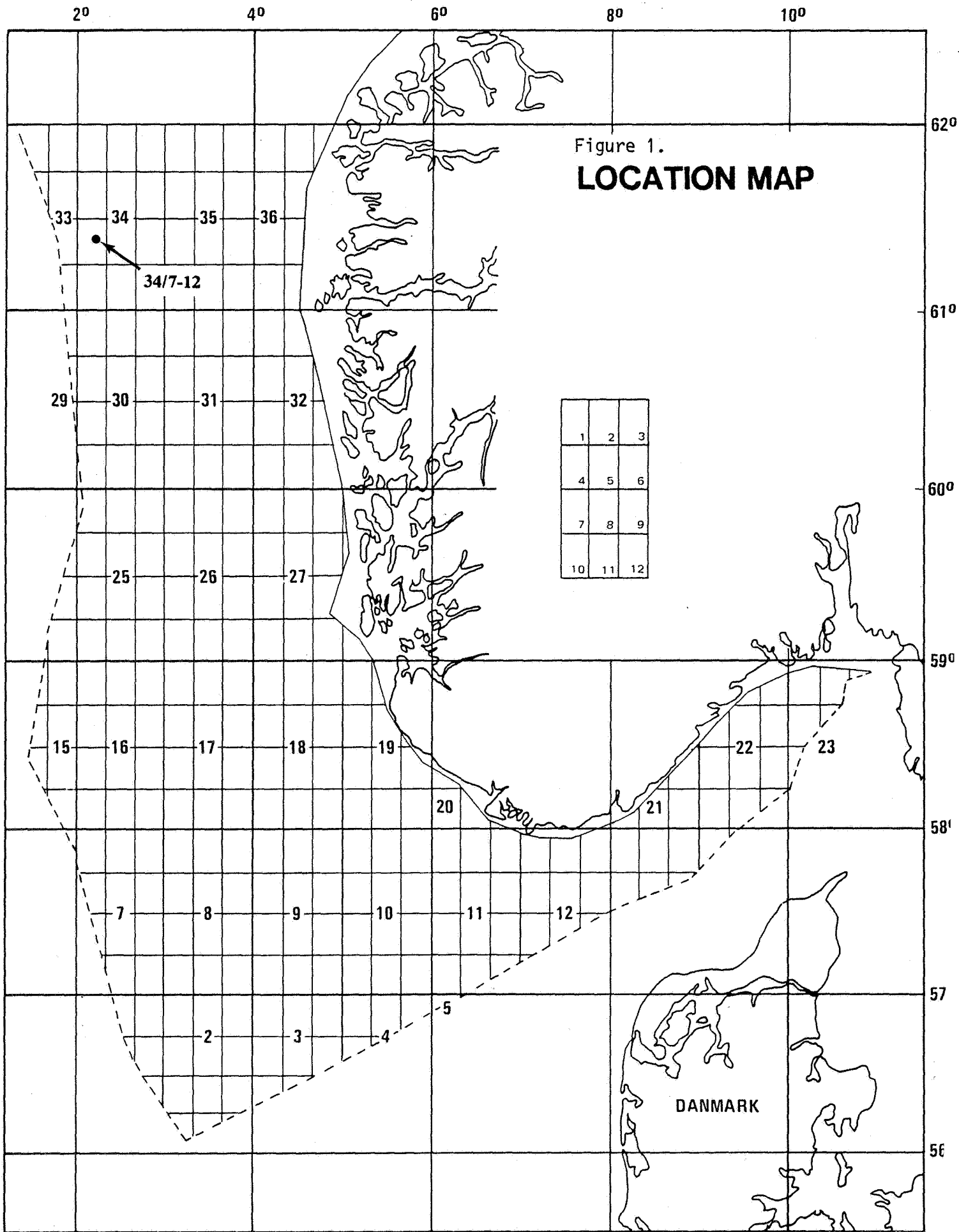
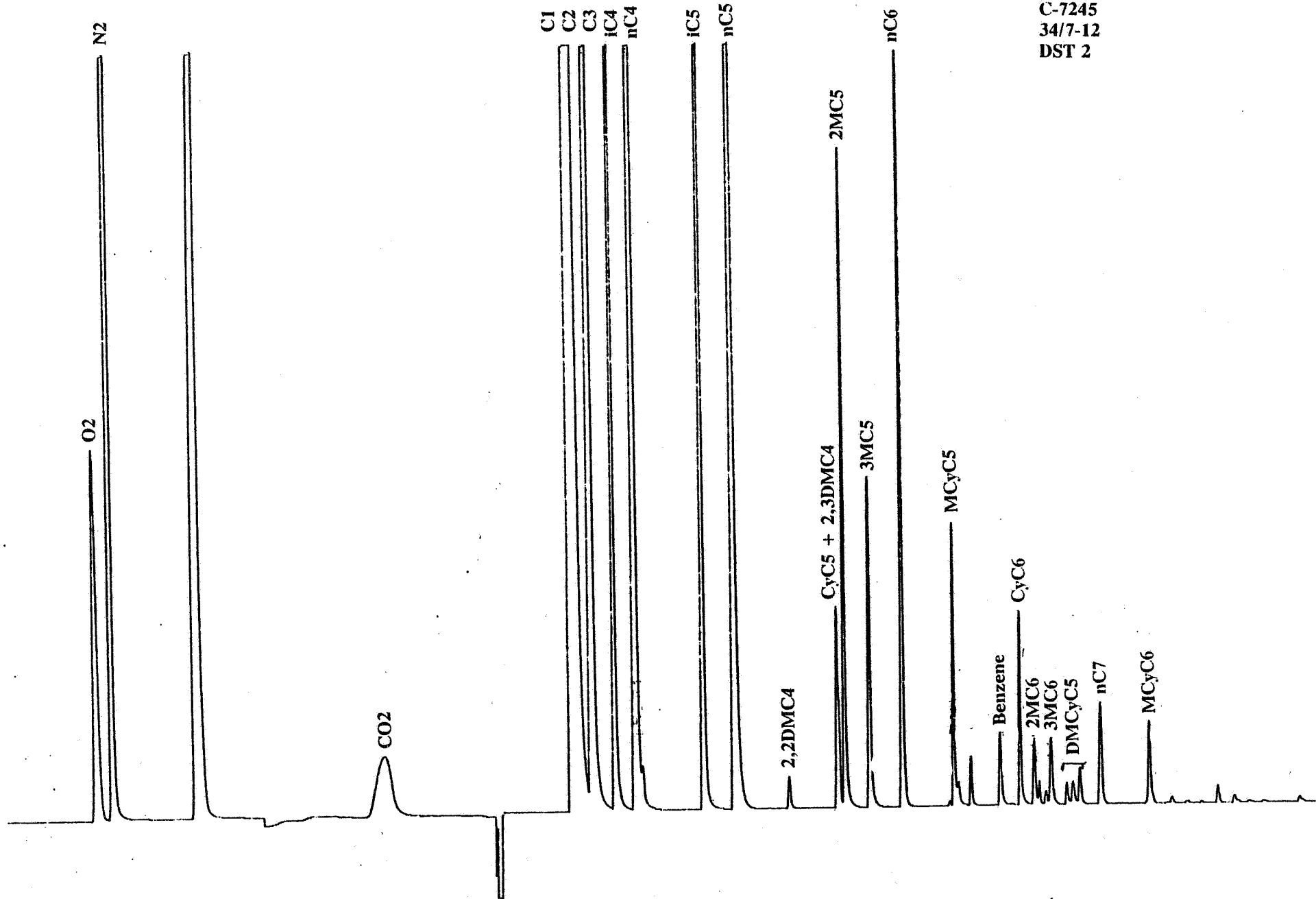


Figure 1.
LOCATION MAP

1	2	3
4	5	6
7	8	9
10	11	12

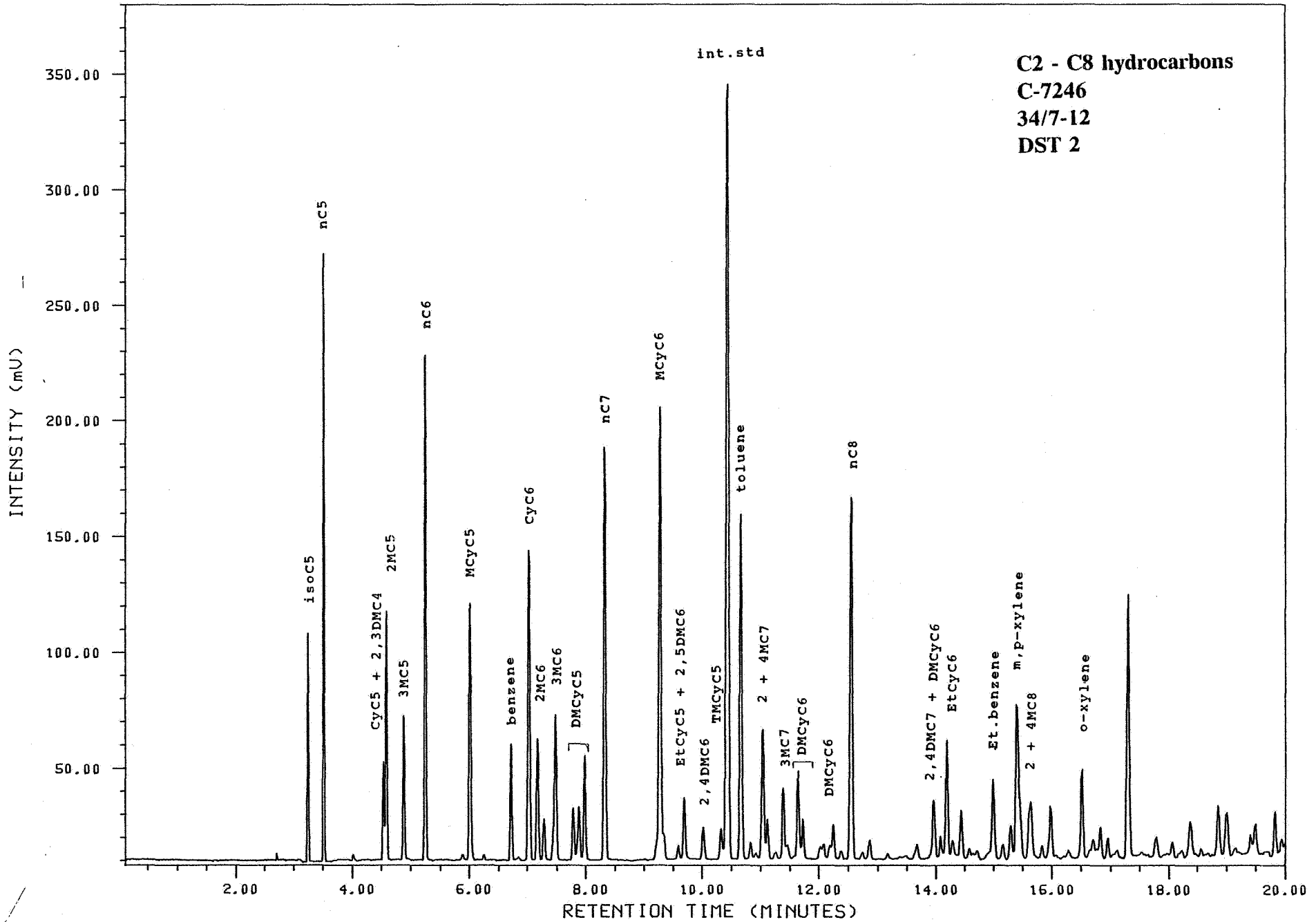
Figure 2.
Gas Chromatograms of C_1 - C_8 Hydrocarbons (DST gas).

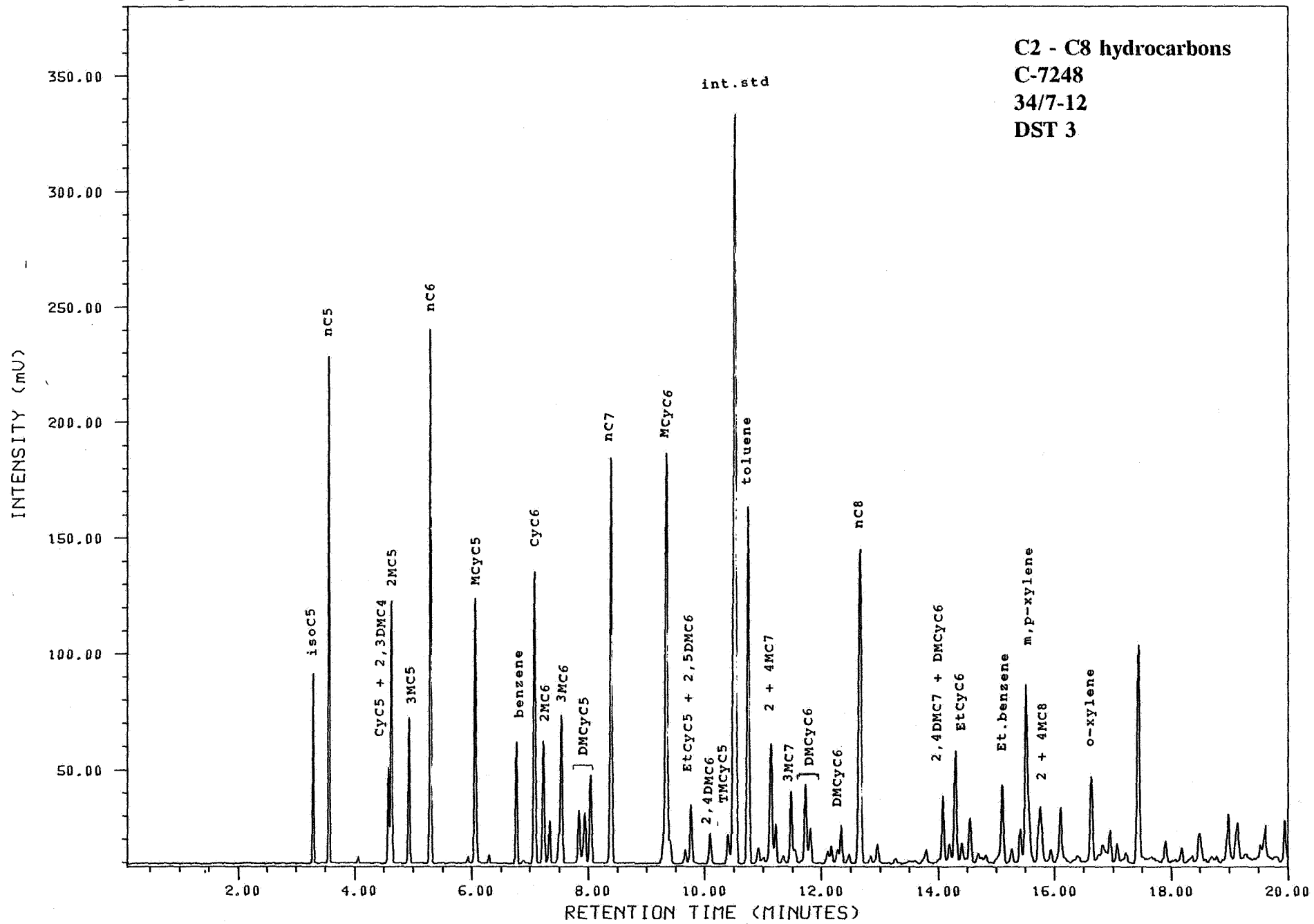


C1 - C8 hydrocarbons
 C-7245
 34/7-12
 DST 2

Figure 3.

Gas Chromatograms of C₂-C₈ Hydrocarbons (DST oil).





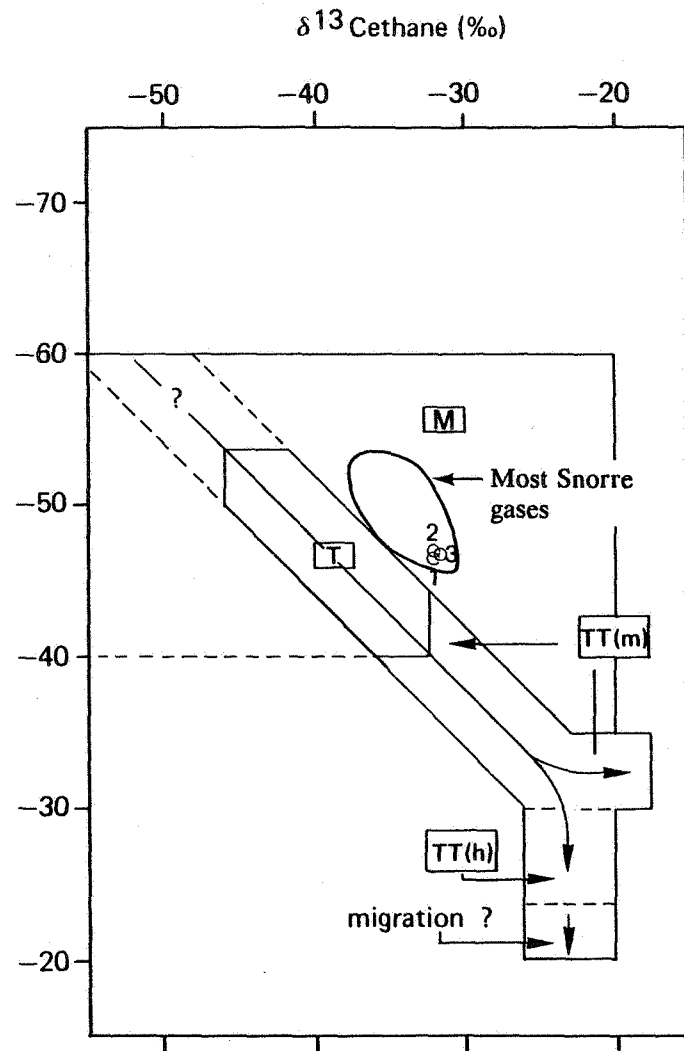


Figure 4a. The two DST gases plot in the area associated with thermogenic gas, close to the field containing most of the previously-analysed Snorre gases (after Schoell, 1983).

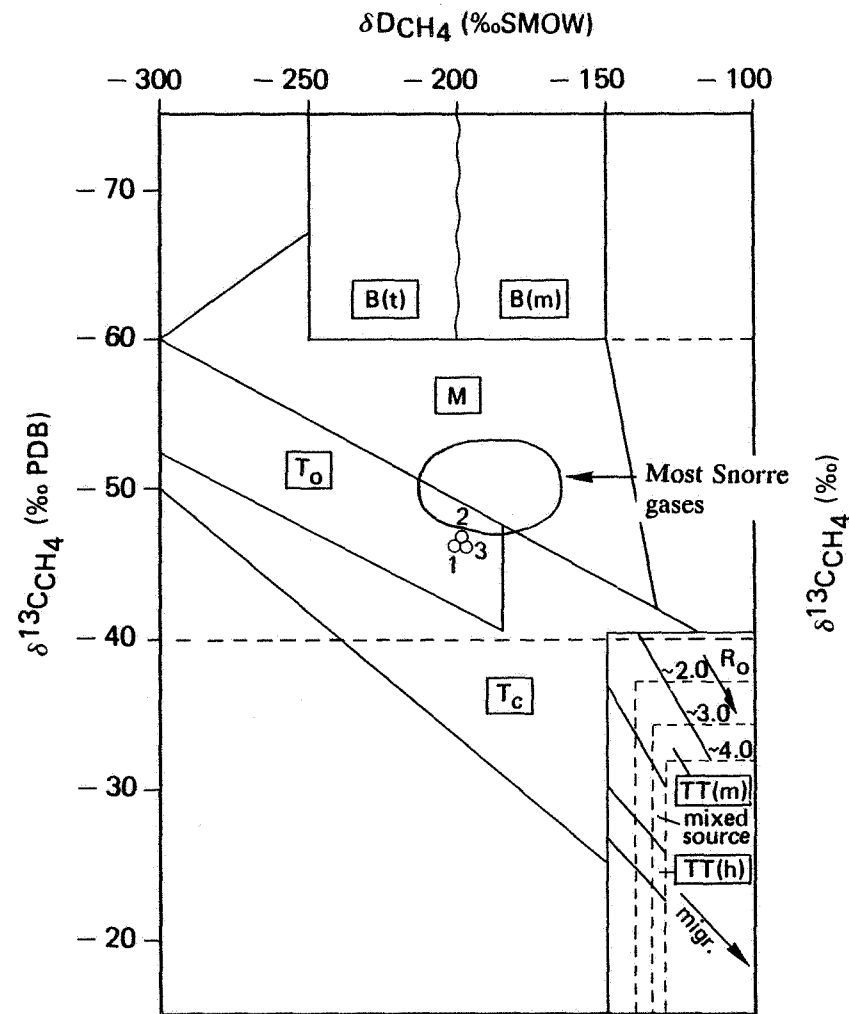
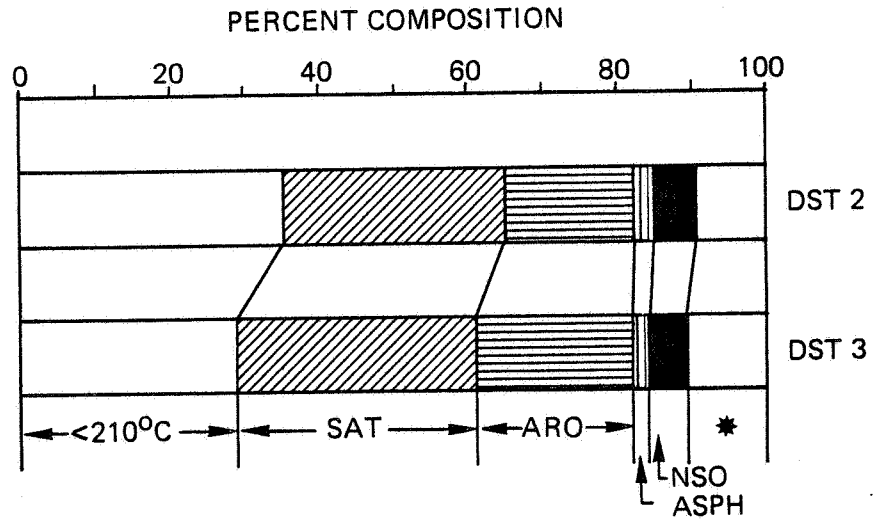


Figure 4b. The two DST gases plot close to the maturity of the previously-analysed Snorre gases (after Schoell, 1983).



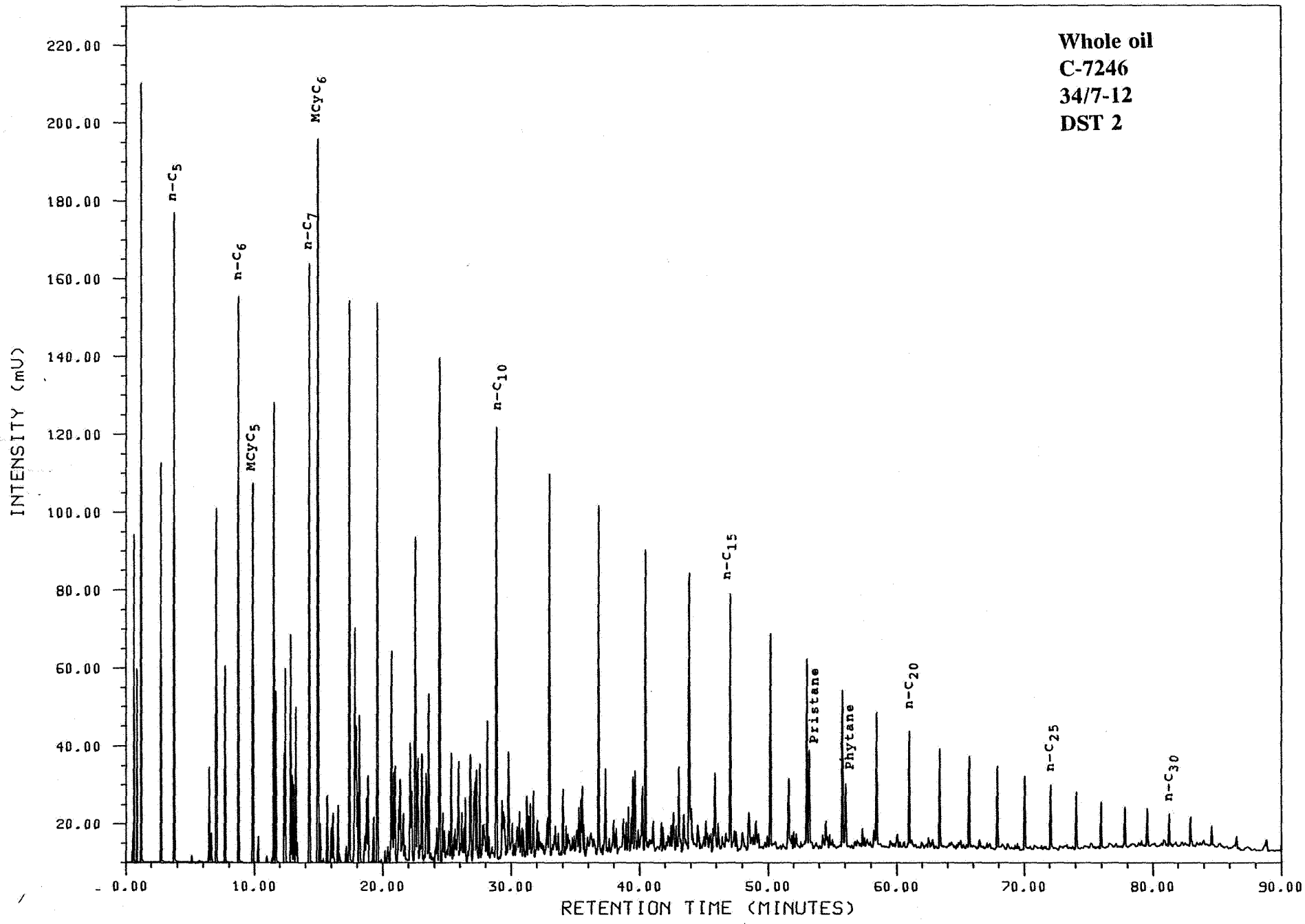
* = Amount of material lost during analytic procedure.

Figure 5. Gross composition of the 34/7-12 DST oils.

Figure 6.

Gas Chromatograms of Whole Oil.

C_{10} etc.	- n-alkanes
Cy- C_6	- cyclohexane
MeCy- C_6	- methylcyclohexane
Pr	- pristane
Ph	- phytane



Whole oil
C-7246
34/7-12
DST 2

Analysis 881C7248T

2,1,1

SAGA 34/7-12, DST 3

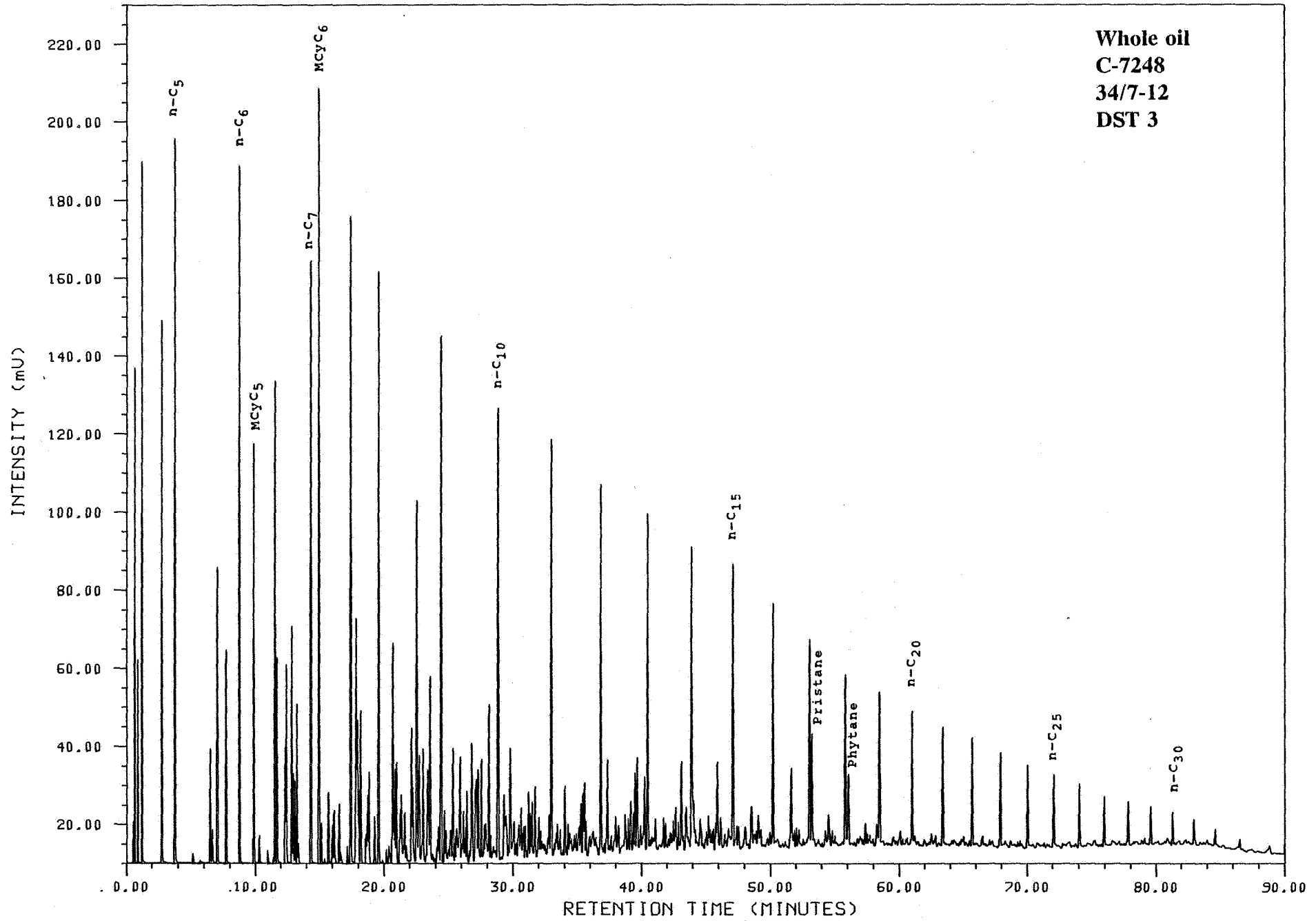
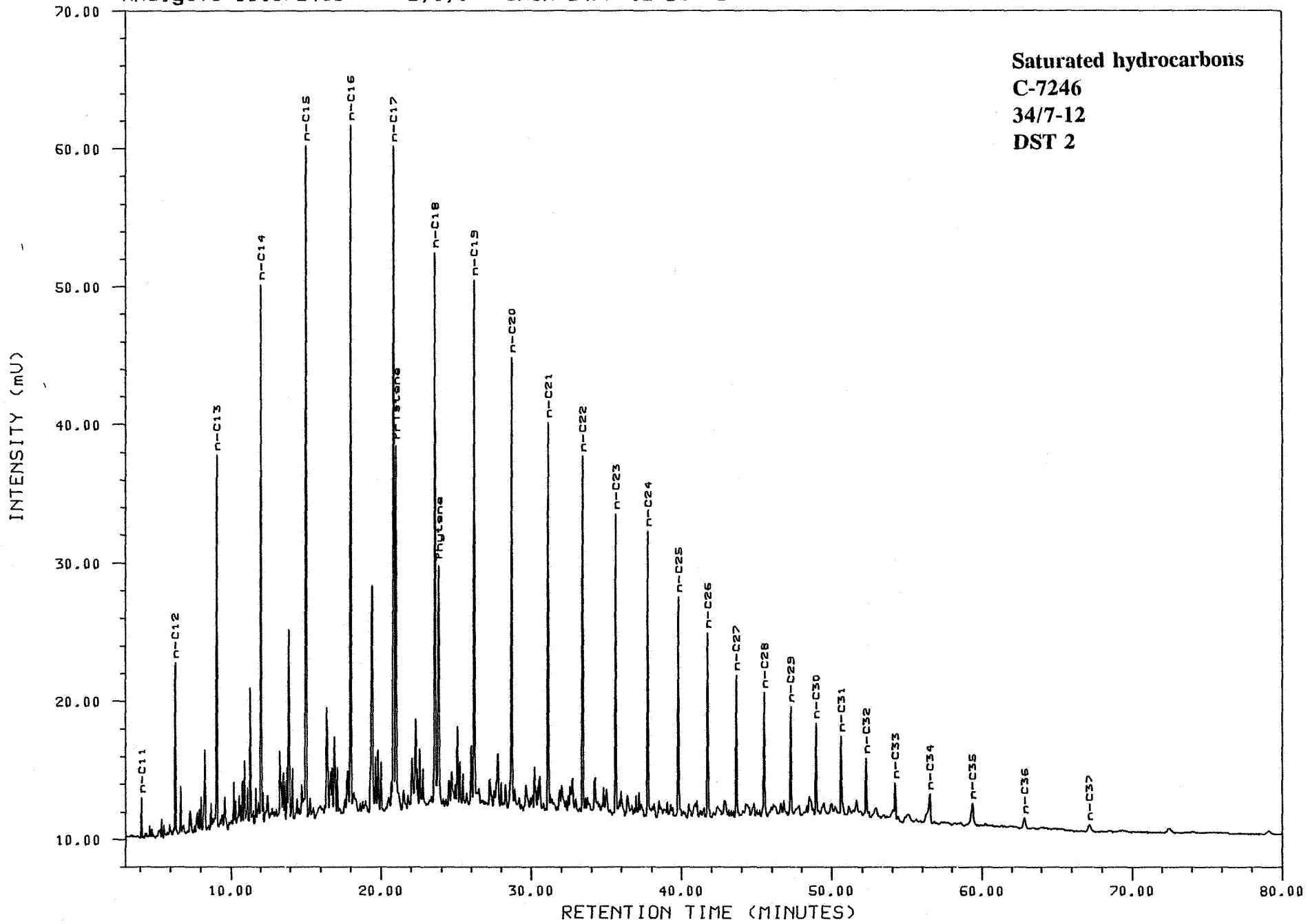
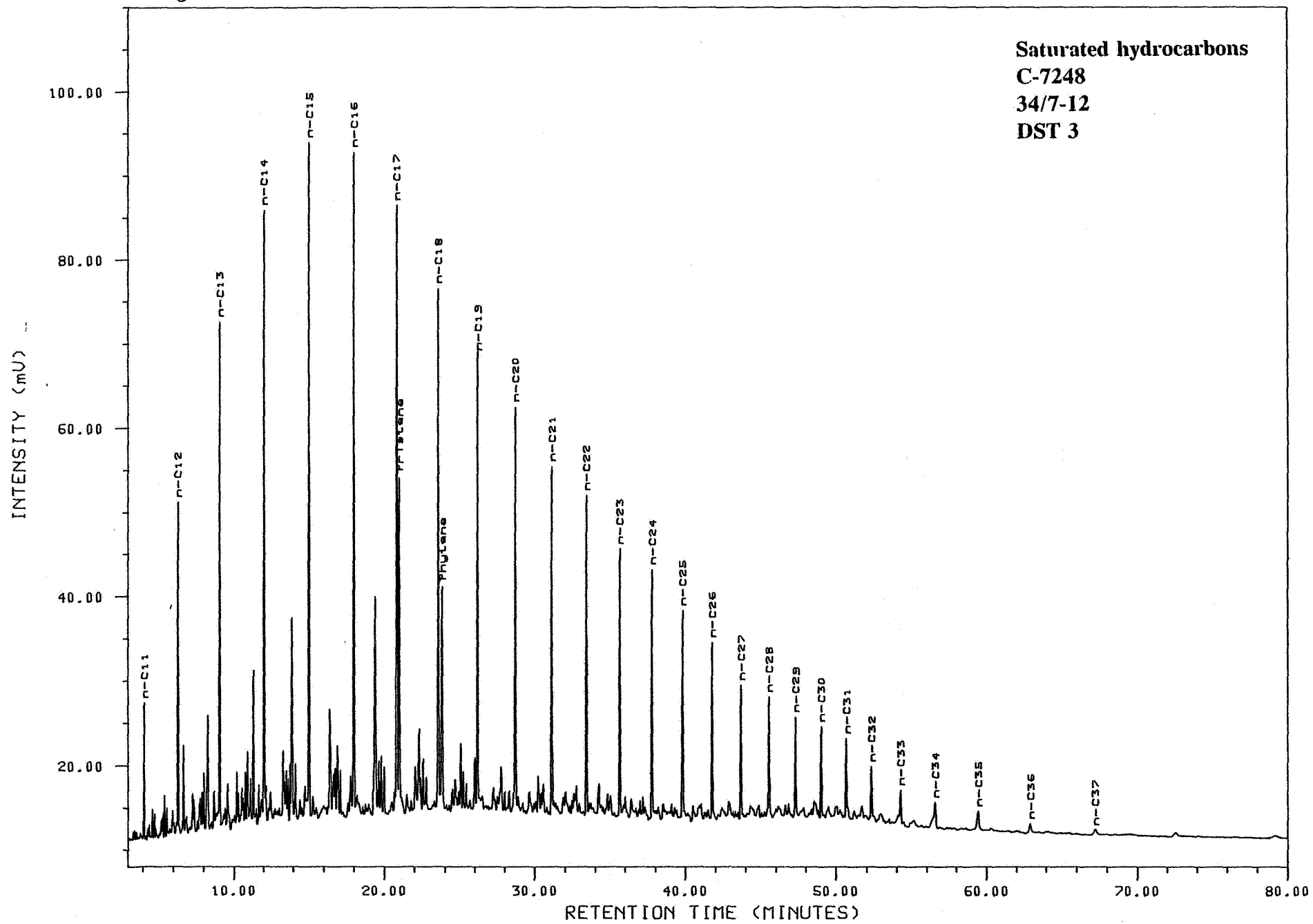




Figure 7.
Gas Chromatograms of Oil Saturate Fractions



Saturated hydrocarbons
C-7246
34/7-12
DST 2



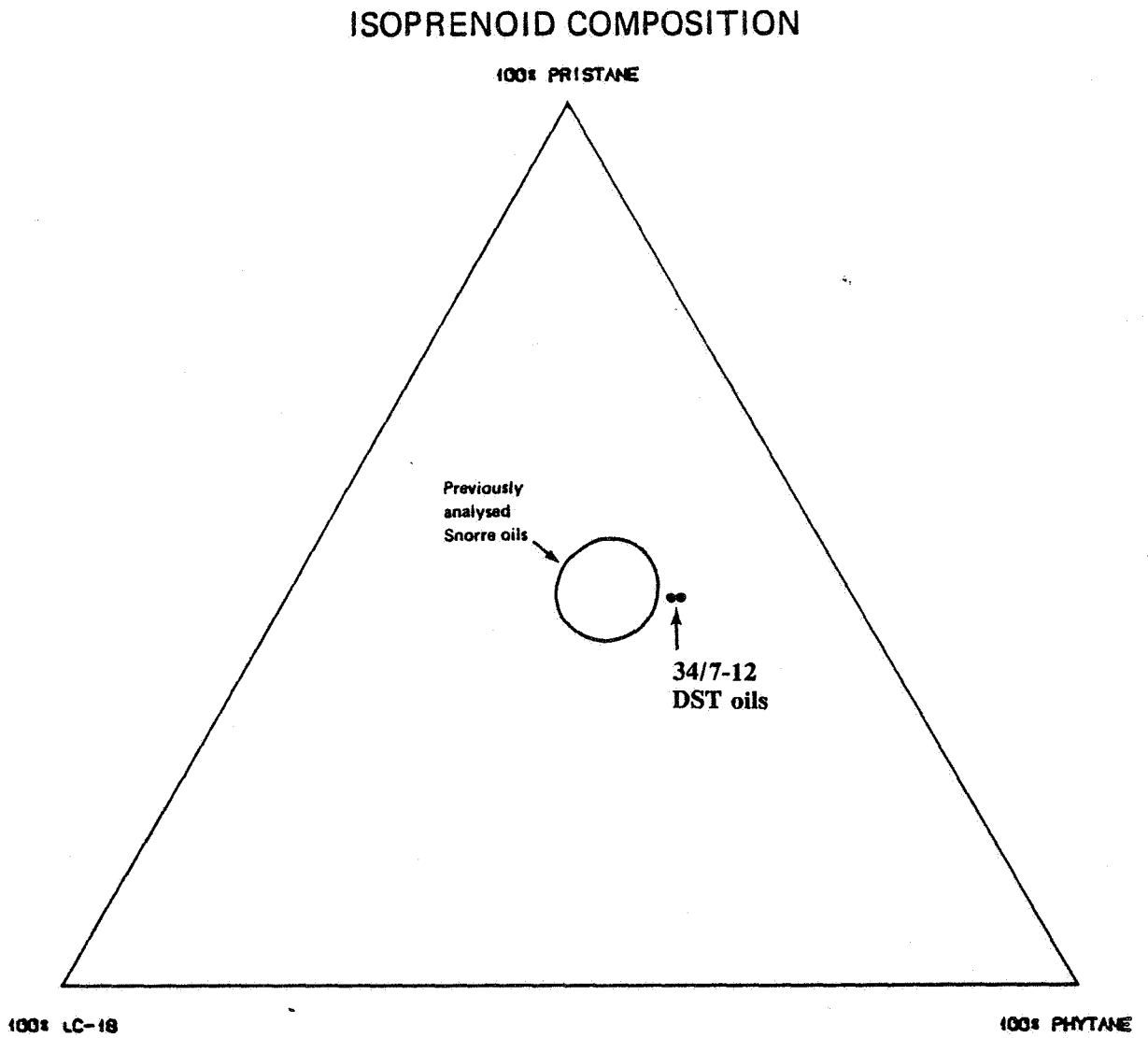
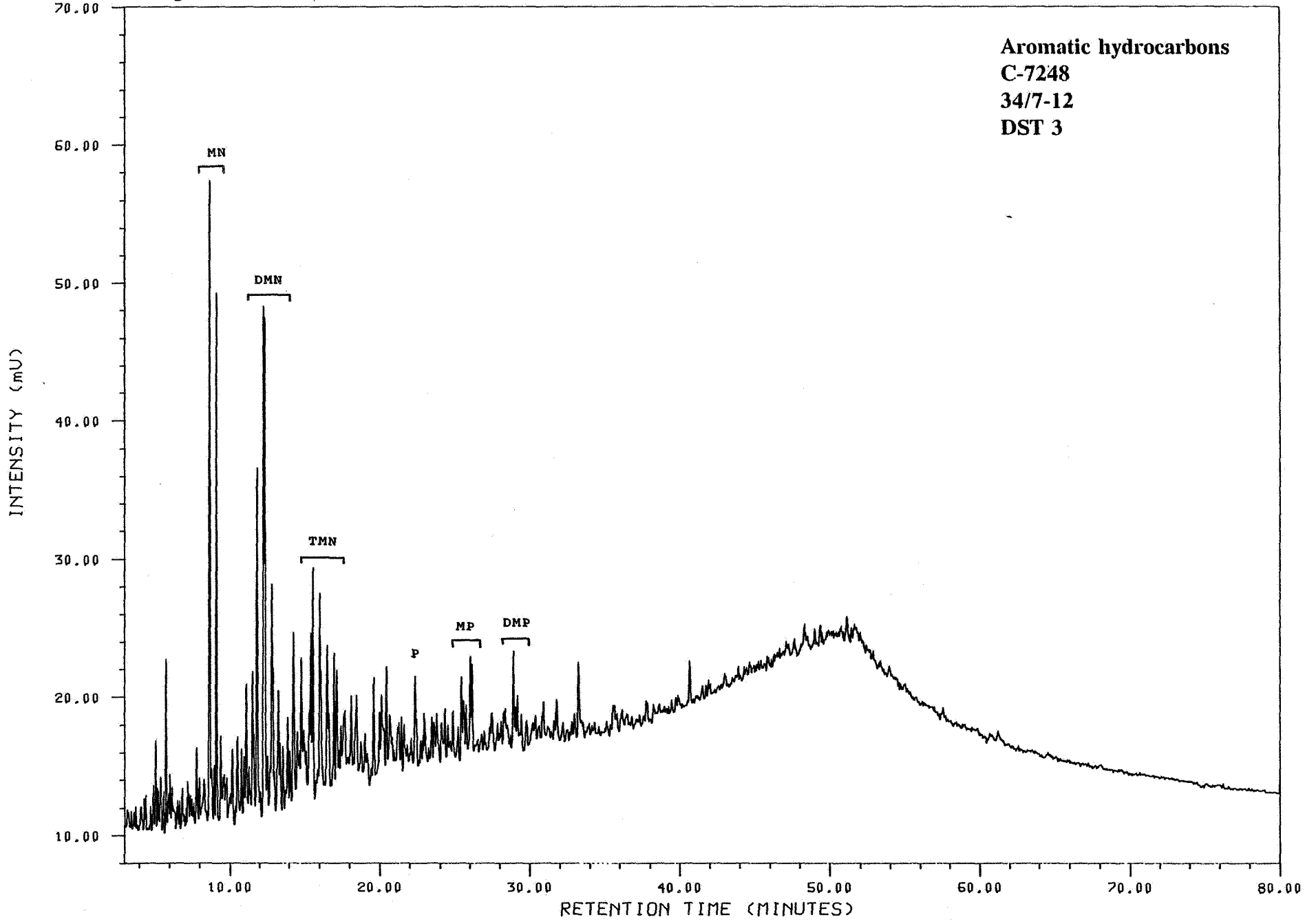


Figure 8. Isoprenoid Composition of DST Oils.

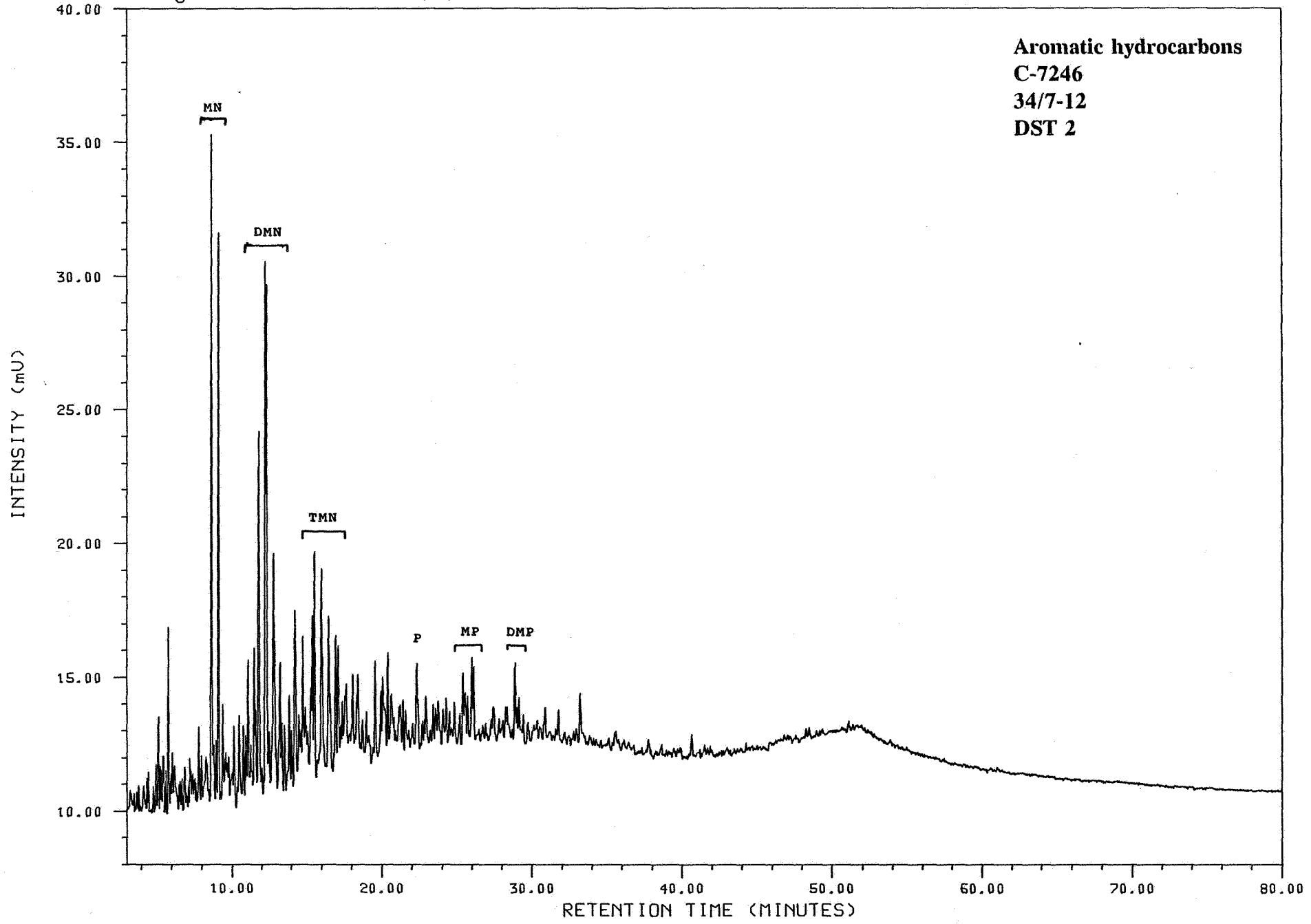
Figure 9.

Gas Chromatograms of Oil Aromatic Fractions.

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



Aromatic hydrocarbons
C-7248
34/7-12
DST 3



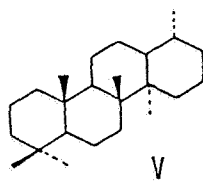
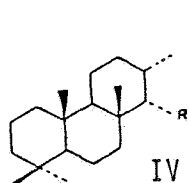
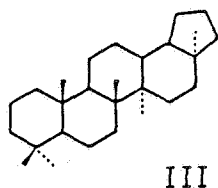
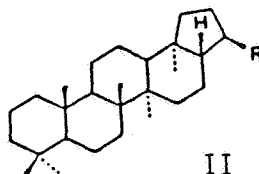
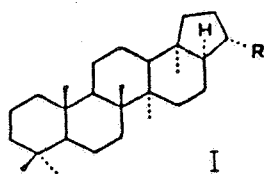
Aromatic hydrocarbons
C-7246
34/7-12
DST 2

Figure 10.

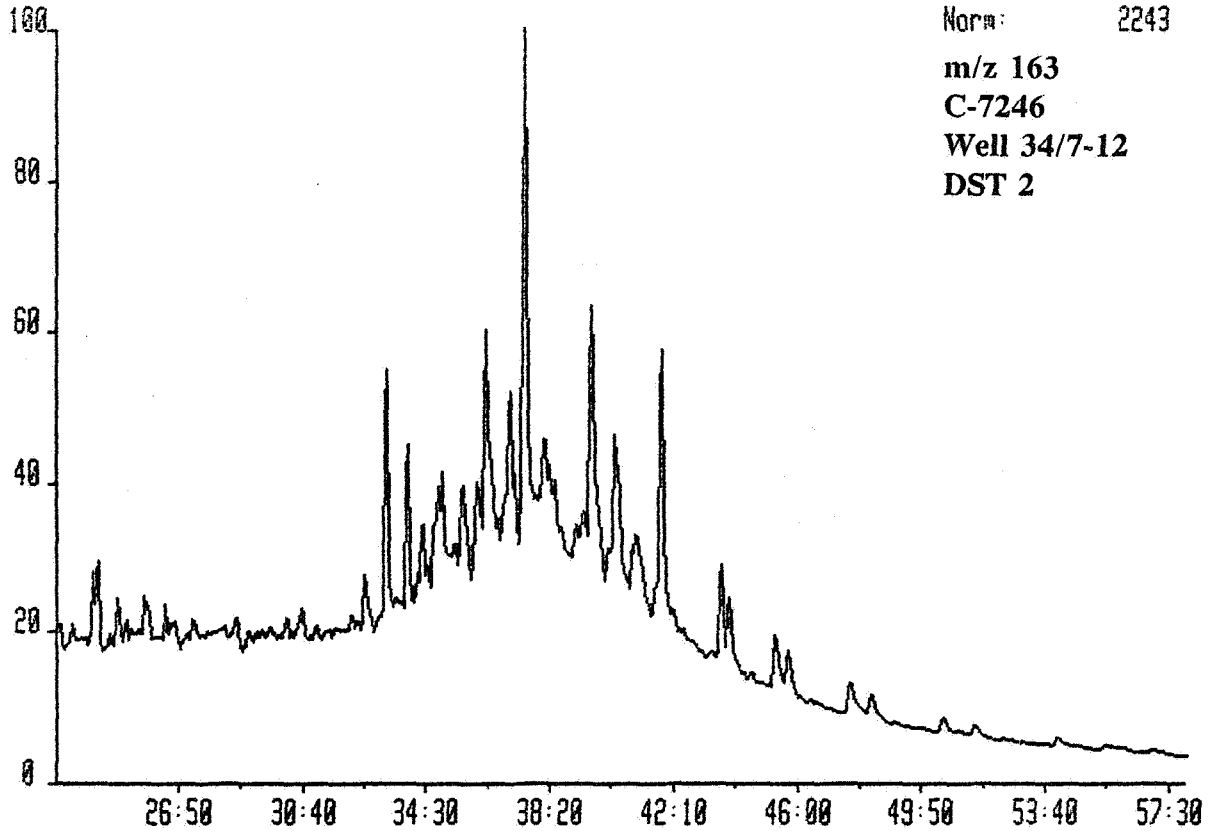
Mass Fragmentograms of Terpanes (m/z 163, 177, 191, 205)

Mass chromatograms representing terpanes

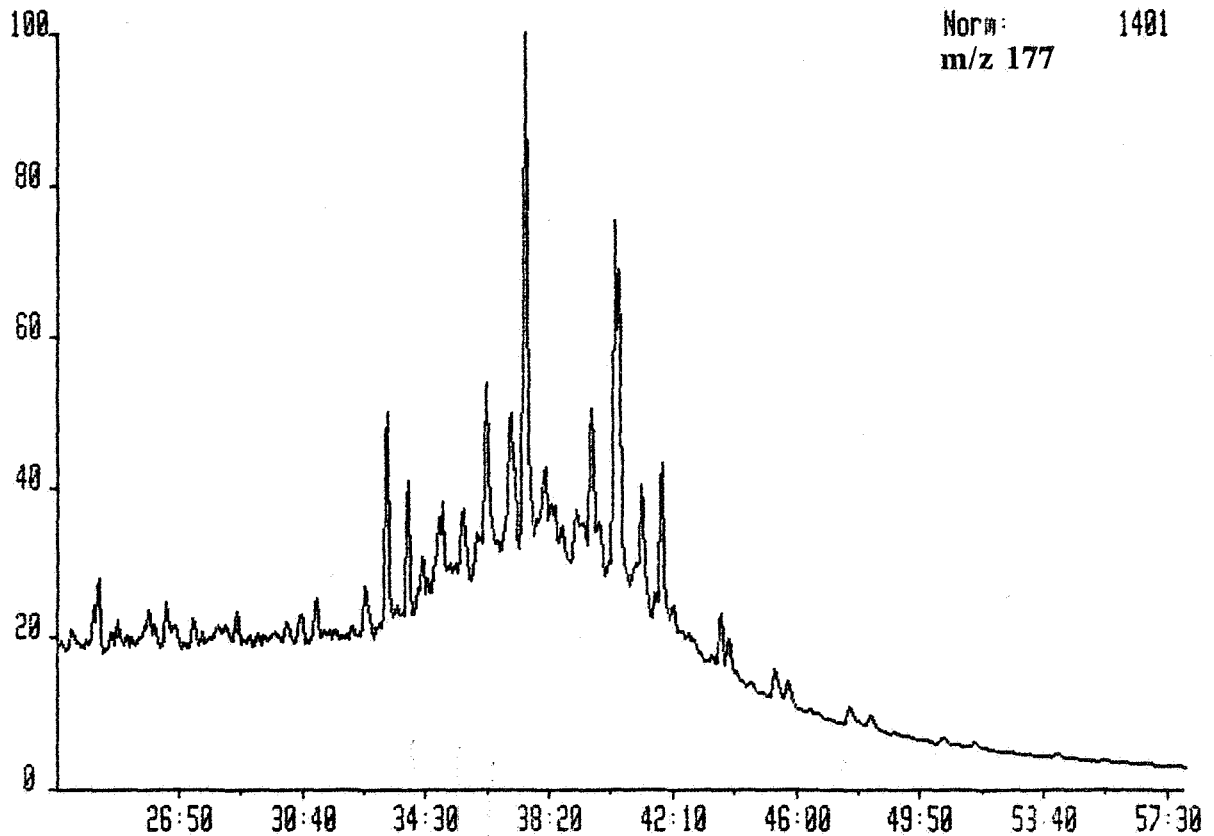
P	tricyclic terpene	$C_{23}H_{42}$	(IV, R=C ₄ H ₉)
Q	tricyclic terpene	$C_{24}H_{44}$	(IV, R=C ₅ H ₁₁)
R	tricyclic terpene (17R,17S)	$C_{25}H_{46}$	(IV, R=C ₆ H ₁₃)
S	tetracyclic terpene	$C_{24}H_{42}$	(V)
T	tricyclic terpene (17R,17S)	$C_{26}H_{48}$	(IV, R=C ₇ H ₁₅)
A	T _S , 18α(H)-trisnorneohopane	$C_{27}H_{46}$	(III)
B	T _m , 17α(H)-trisnorhopane	$C_{27}H_{46}$	(I, R=H)
Z	bisnorhopane	$C_{28}H_{48}$	
C	17α(H)-norhopane	$C_{29}H_{50}$	(I, R=C ₂ H ₅)
X	unknown triterpene	$C_{30}H_{52}$	
D	17β(H)-normoretane	$C_{29}H_{50}$	(II, R=C ₂ H ₅)
E	17α(H)-hopane	$C_{30}H_{52}$	(I, R=C ₃ H ₇)
F	17β(H)-moretane	$C_{30}H_{52}$	(II, R=C ₃ H ₇)
G	17α(H)-homohopane (22S)	$C_{31}H_{54}$	(I, R=C ₄ H ₉)
H	17α(H)-homohopane (22R)	$C_{31}H_{54}$	(I, R=C ₄ H ₉)
	+ unknown triterpene (gammacerane?)		
I	17β(H)-homomoretane	$C_{31}H_{54}$	(II, R=C ₄ H ₉)
J	17α(H)-bishomohopane (22S,22R)	$C_{32}H_{56}$	(I, R=C ₅ H ₁₁)
K	17α(H)-trishomohopane (22S,22R)	$C_{33}H_{58}$	(I, R=C ₆ H ₁₃)
L	17α(H)-tetrakishomohopane (22S,22R)	$C_{34}H_{60}$	(I, R=C ₇ H ₁₅)
M	17α(H)-pentakishomohopane (22S,22R)	$C_{35}H_{62}$	(I, R=C ₈ H ₁₇)



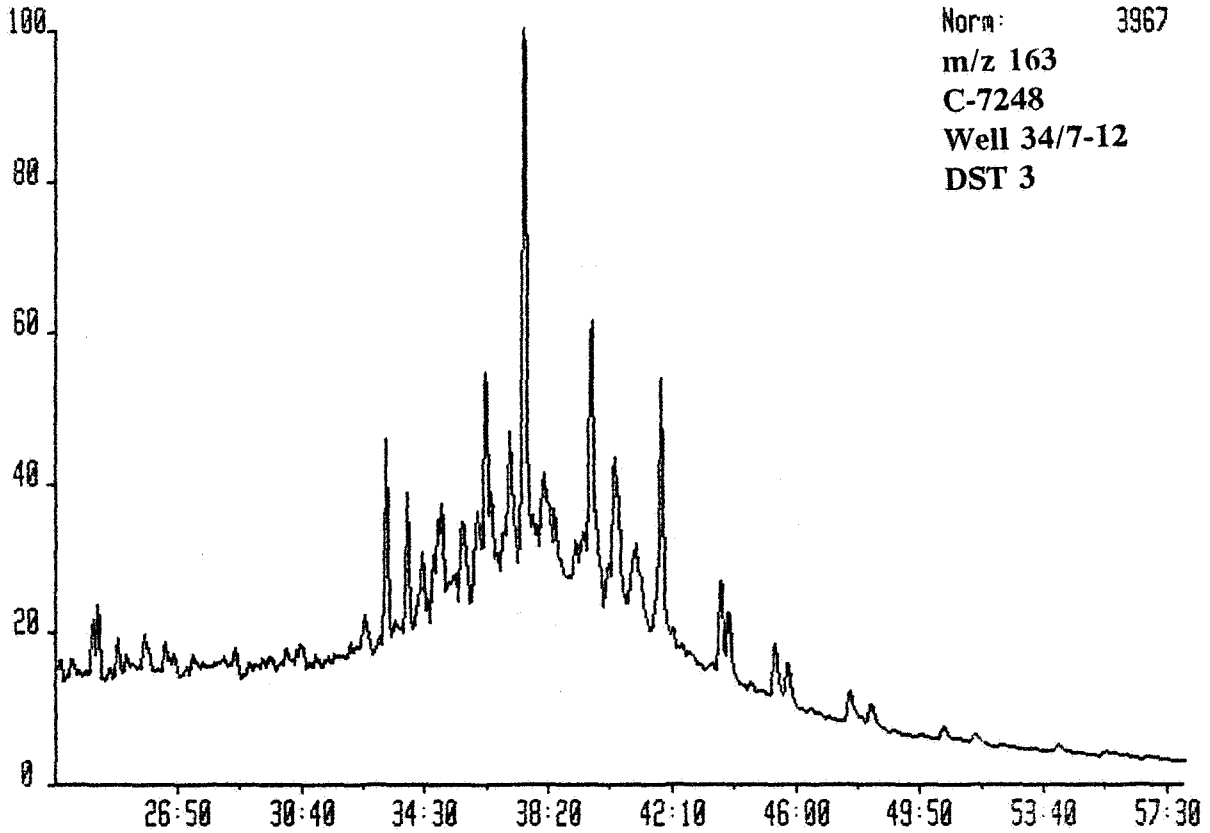
C7246SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
Sample 1 Injection 1 Group 1 Mass 163.1000
Text:22.1881 SAGA 34/7-12 C7246SAT



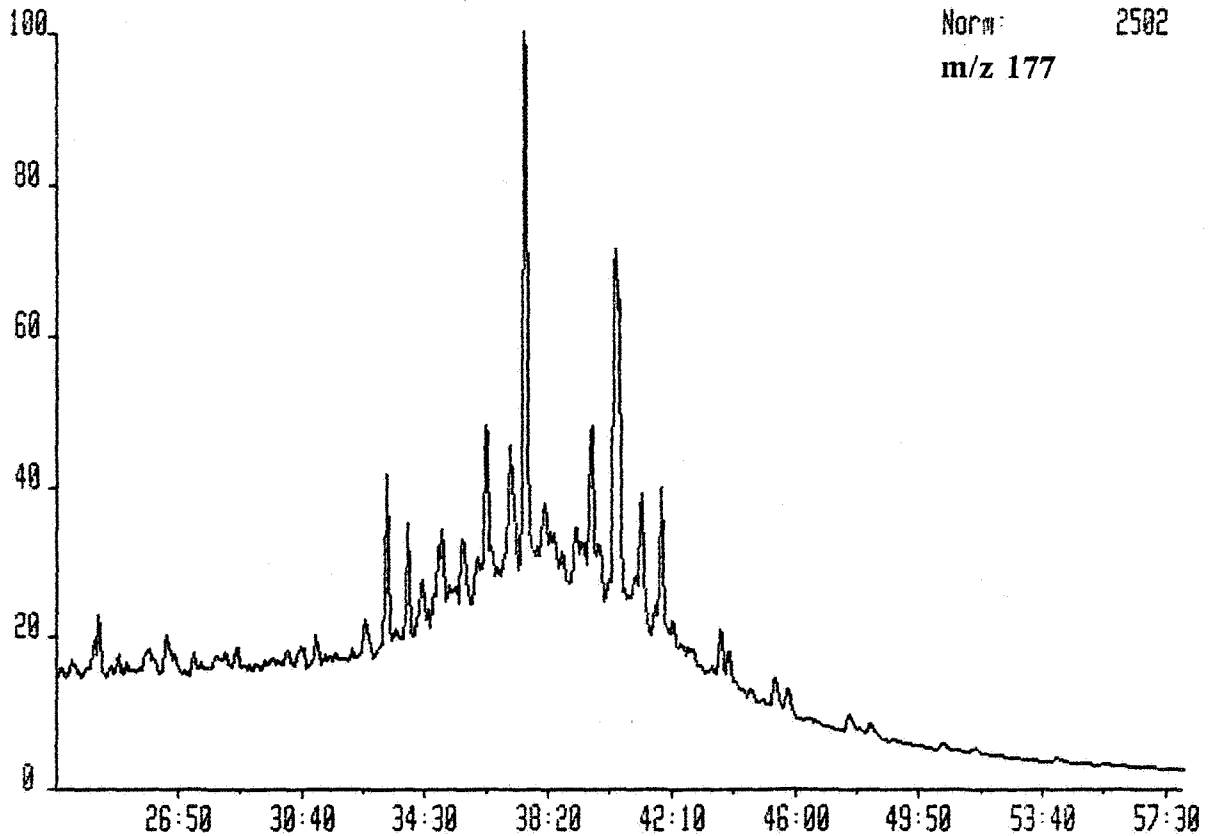
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Sample 1 Injection 1 Group 1 Mass 177.1000
Text:22.1881 SAGA 34/7-12 C7246SAT



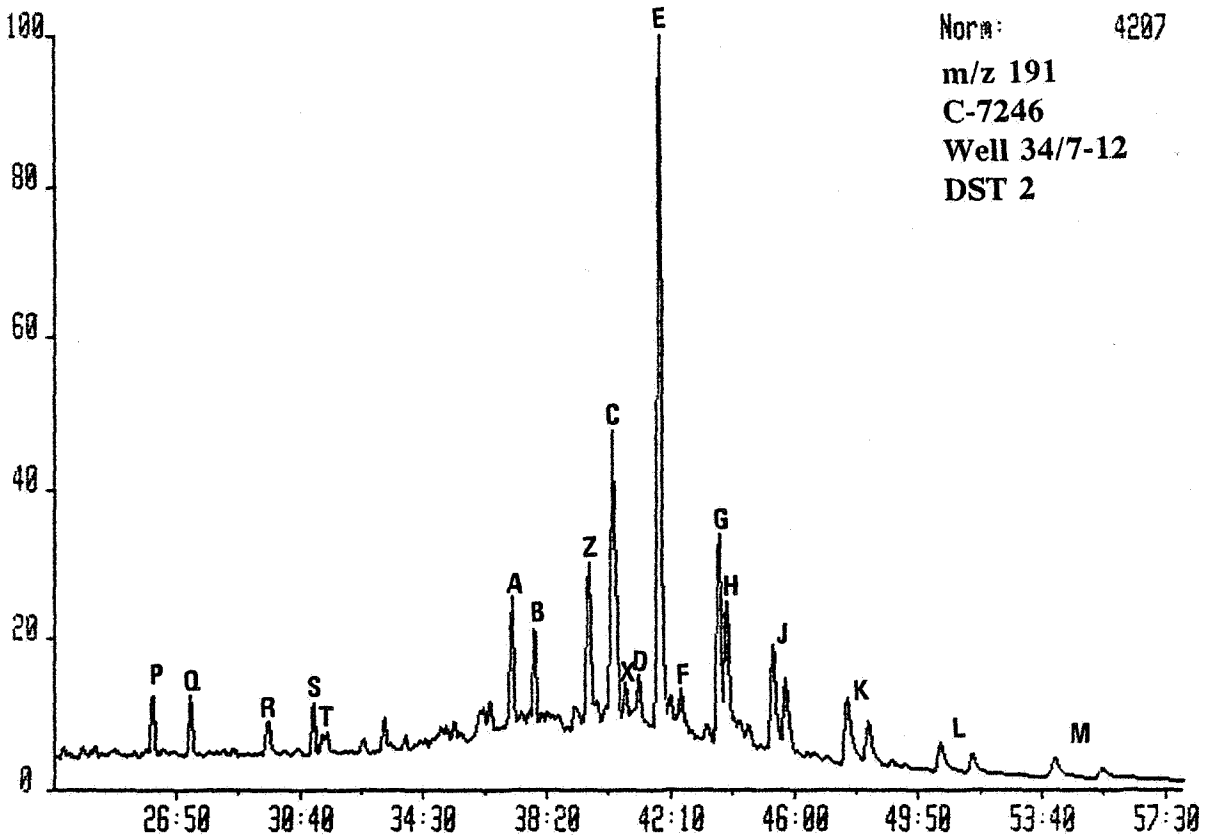
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Text:22.1881 SAGA 34/7-12 C7248SAT



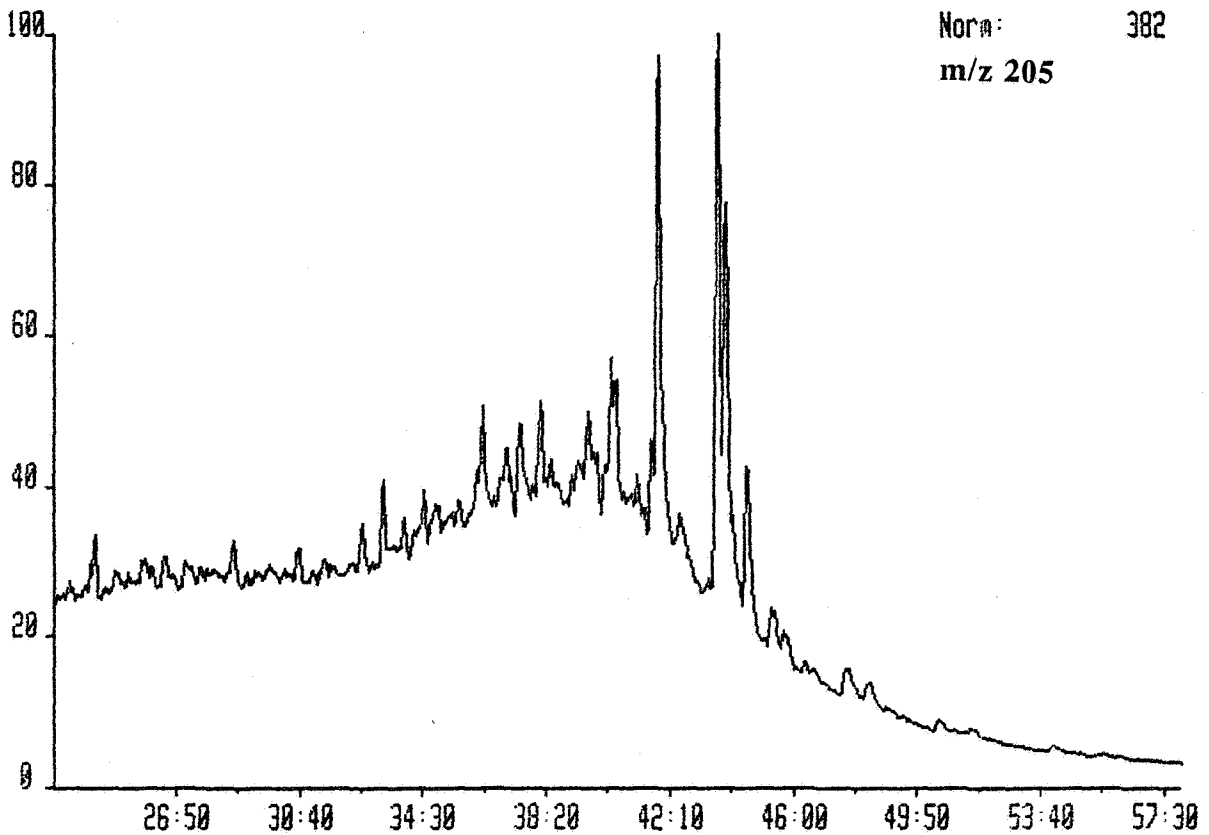
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Sample 1 Injection 1 Group 1 Mass 177.1000
Text:22.1881 SAGA 34/7-12 C7248SAT



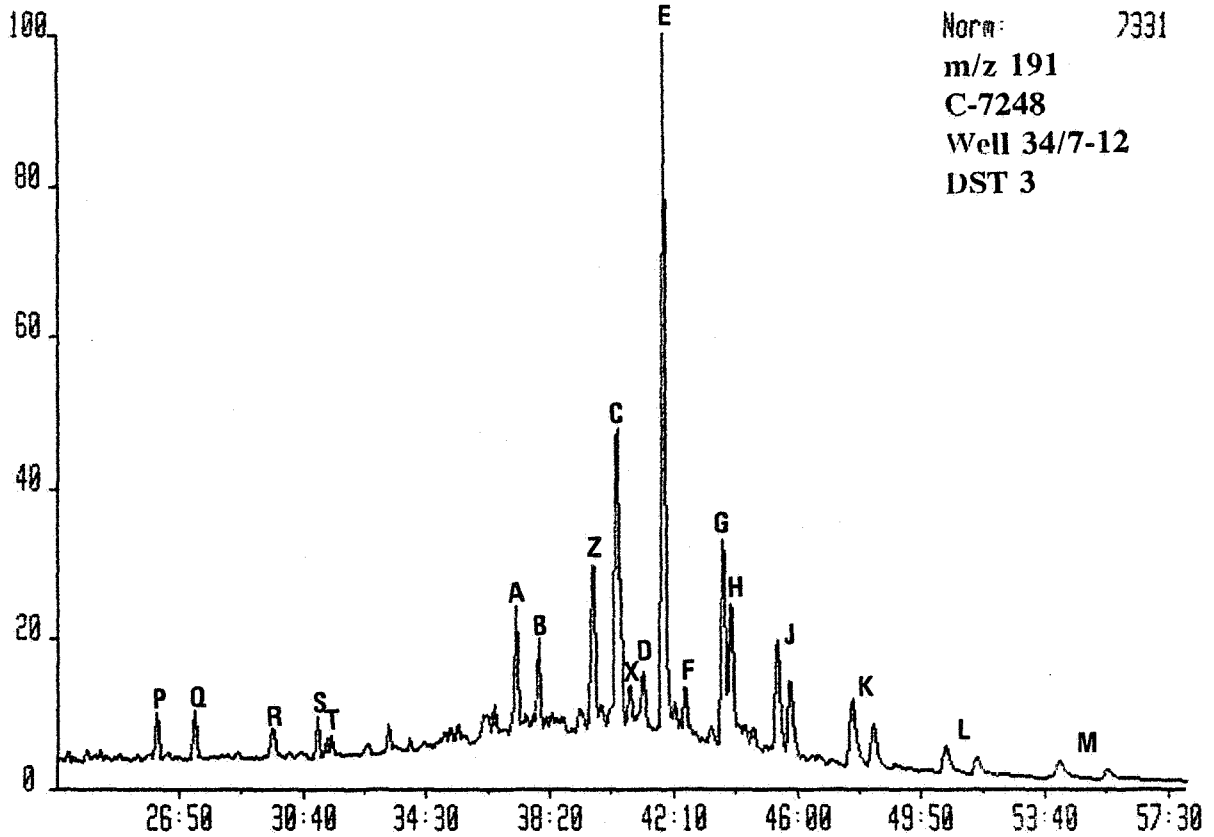
C7246SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
Sample 1 Injection 1 Group 1 Mass 191.1000
Text:22.1881 SAGA 34/7-12 C7246SAT



C7246SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
Sample 1 Injection 1 Group 1 Mass 205.1000
Text:22.1881 SAGA 34/7-12 C7246SAT



C7248SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
Sample 1 Injection 1 Group 1 Mass 191.1000
Text:22.1881 SAGA 34/7-12 C7248SAT



C7248SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
Sample 1 Injection 1 Group 1 Mass 205.1000
Text:22.1881 SAGA 34/7-12 C7248SAT

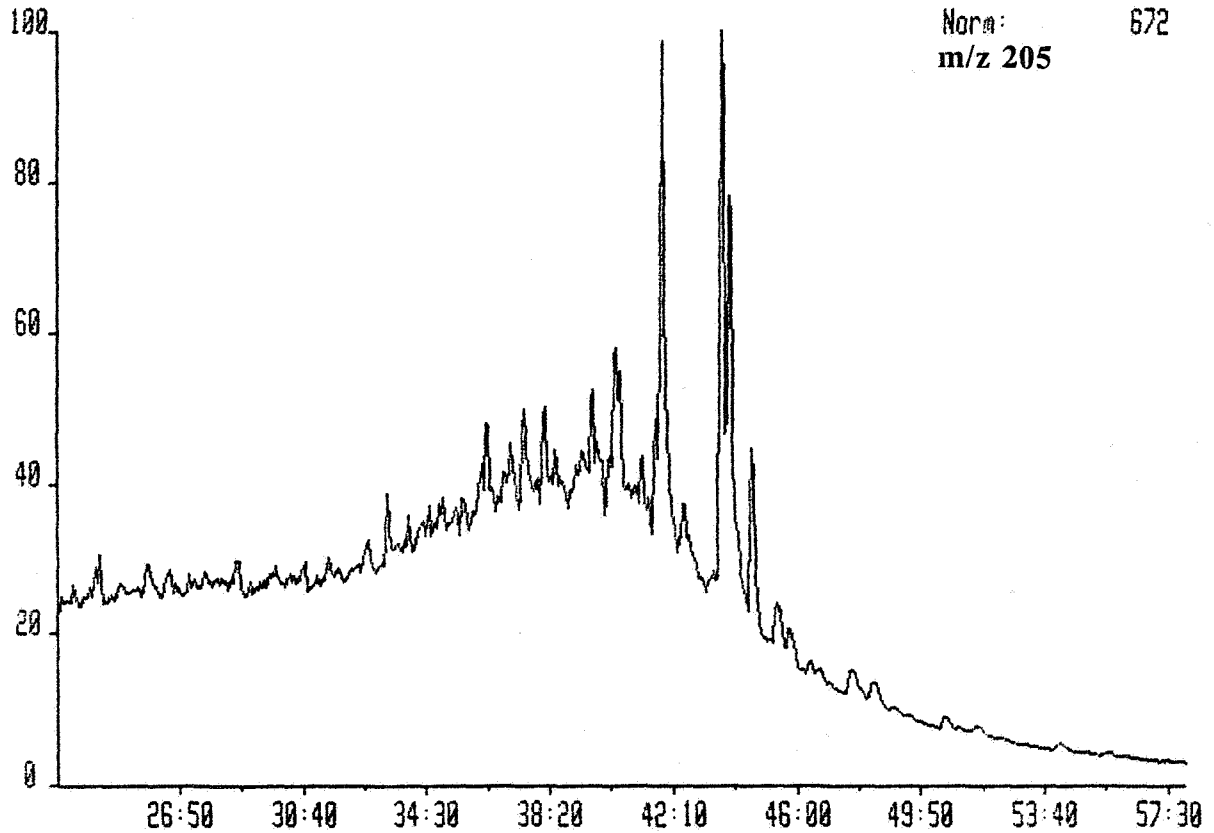
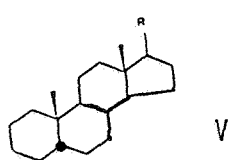
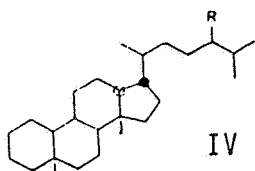
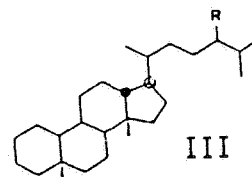
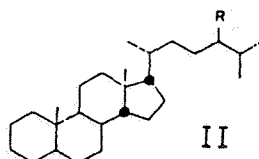
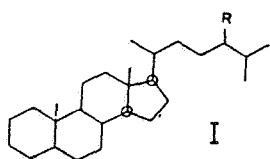


Figure 11.

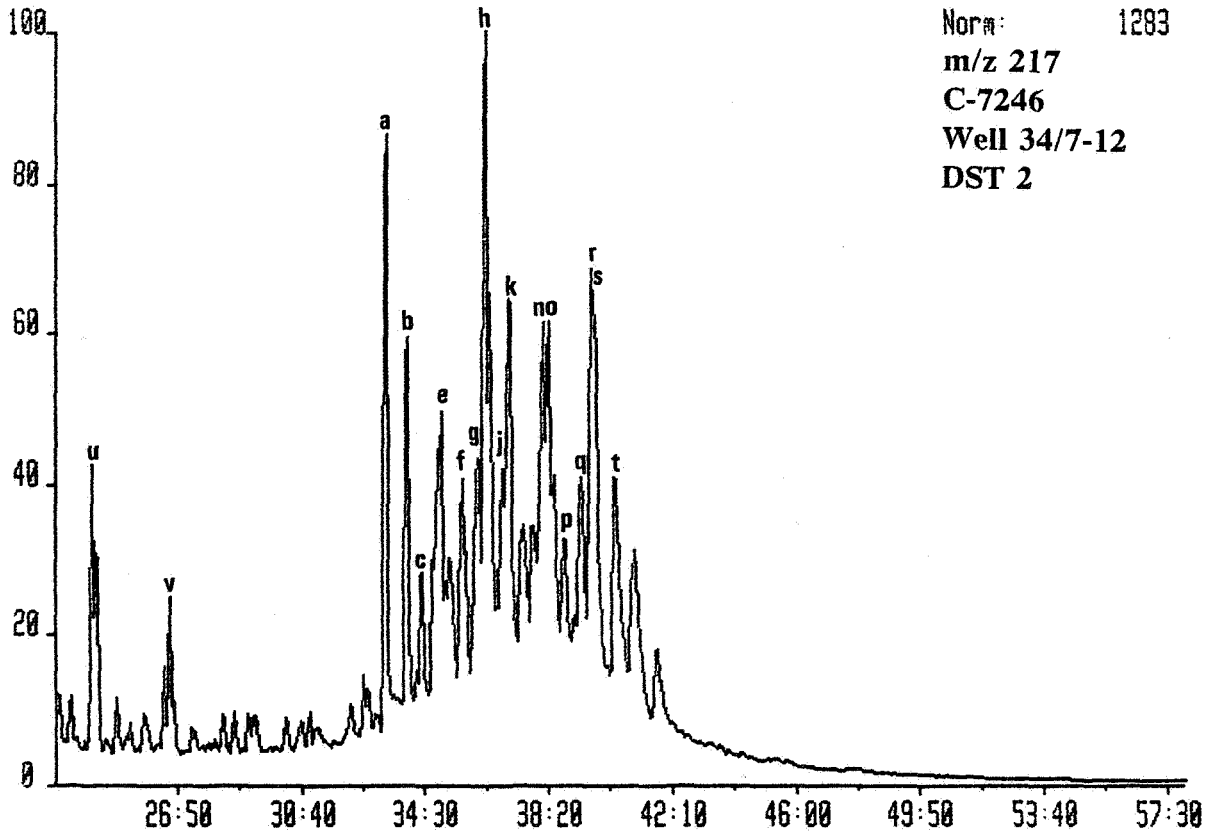
Mass Fragmentograms of Steranes (m/z 217, 218, 231, 259).

Mass chromatograms representing steranes

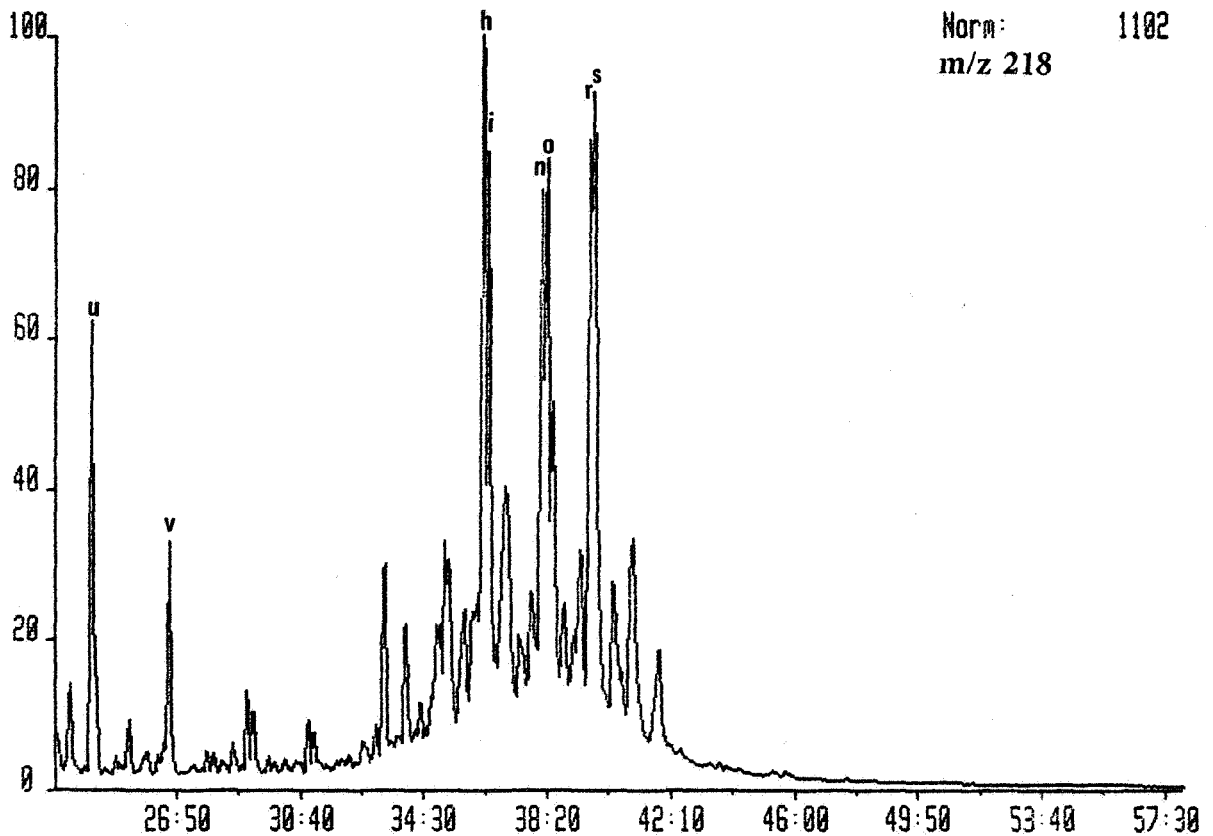
u	5 α (H)-sterane	C ₂₁ H ₃₆	(V, R=C ₂ H ₅)
v	5 α (H)-sterane	C ₂₂ H ₃₈	(V, R=C ₃ H ₇)
a	13 β (H), 17 α (H)-diasterane (20S)	C ₂₇ H ₄₈	(III, R=H)
b	13 β (H), 17 α (H)-diasterane (20R)	C ₂₇ H ₄₈	(III, R=H)
c	13 α (H), 17 β (H)-diasterane (20S)	C ₂₇ H ₄₈	(IV, R=H)
d	13 α (H), 17 β (H)-diasterane (20R)	C 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) + 14 α (H), 17 α (H)-sterane (20S)	C ₂₈ H ₅₀ C ₂₇ H ₄₈	(IV, R=CH ₃) (I, R=H)
h	13 β (H), 17 α (H)-diasterane (20S) + 14 β (H), 17 β (H)-sterane (20R)	C ₂₉ H ₅₂ C ₂₇ H ₄₈	(III, R=C ₂ H ₅) (II, R=H)
i	14 β (H), 17 β (H)-sterane (20S) + 13 α (H), 17 β (H)-diasterane (20R)	C ₂₇ H ₄₈ C ₂₈ H ₅₀	(II, R=H) (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	(IV, 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) + 14 β (H), 17 β (H)-sterane (20R)	C ₂₉ H ₅₂ C ₂₈ H ₅₀	(IV, R=C ₂ H ₅) (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) + unknown sterane	C ₂₉ H ₅₂	(II, R=C ₂ H ₅)
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)



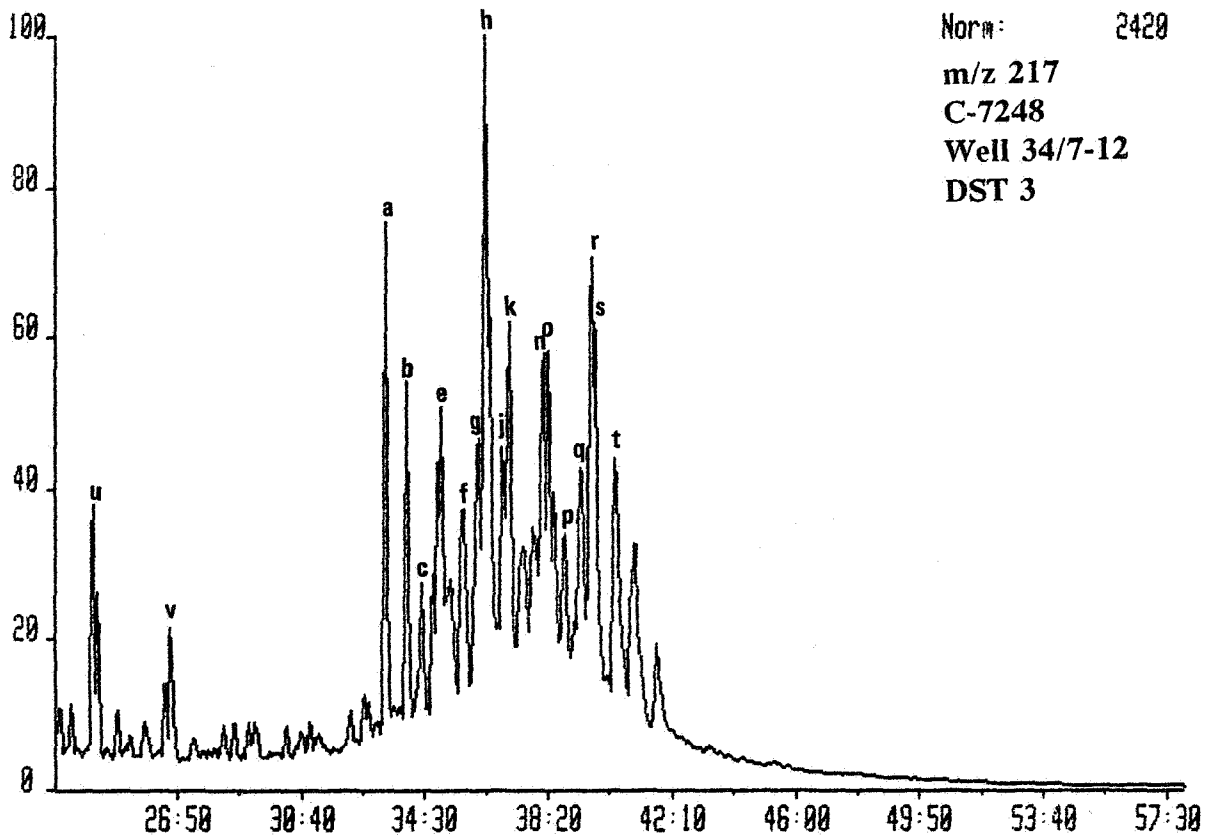
C7246SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
 Sample 1 Injection 1 Group 1 Mass 217.1000
 Text:22.1881 SAGA 34/7-12 C7246SAT



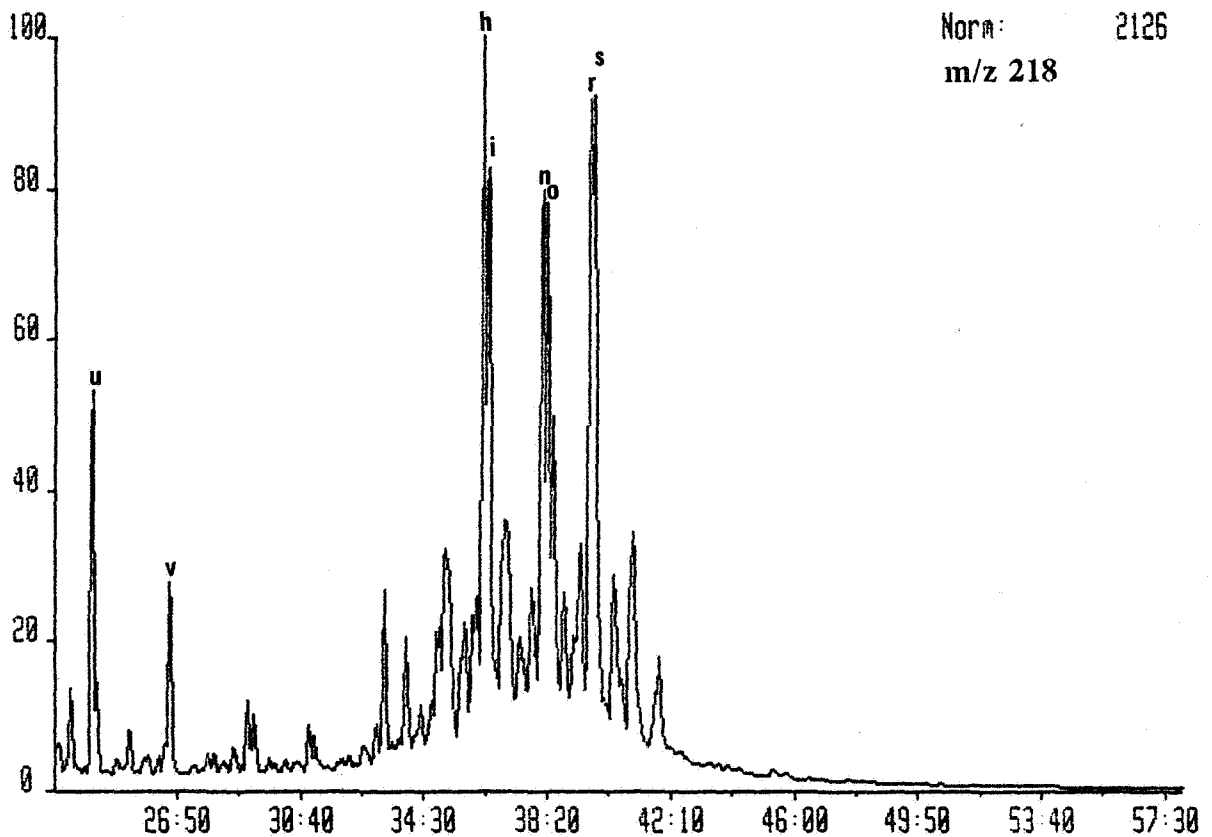
C7246SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
 Sample 1 Injection 1 Group 1 Mass 218.1000
 Text:22.1881 SAGA 34/7-12 C7246SAT



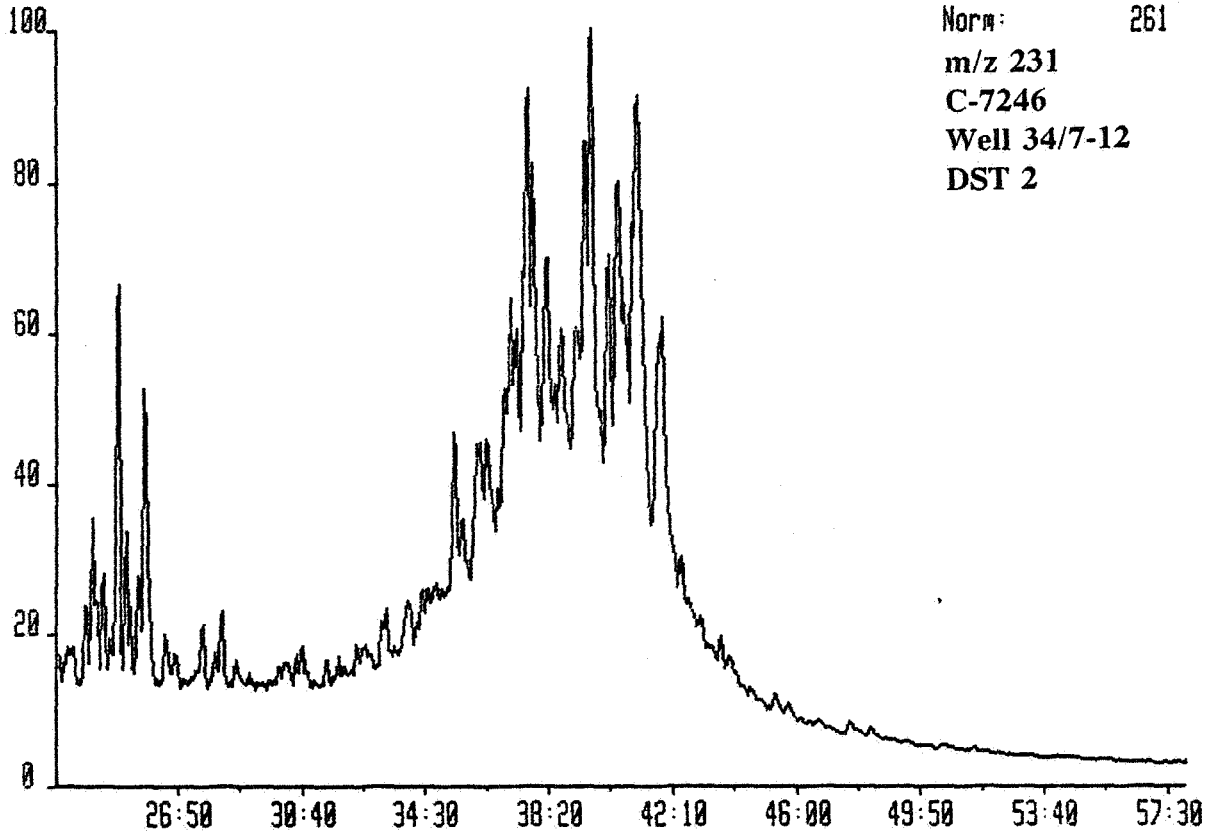
C7248SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
 Sample 1 Injection 1 Group 1 Mass 217.1000
 Text:22.1881 SAGA 34/7-12 C7248SAT



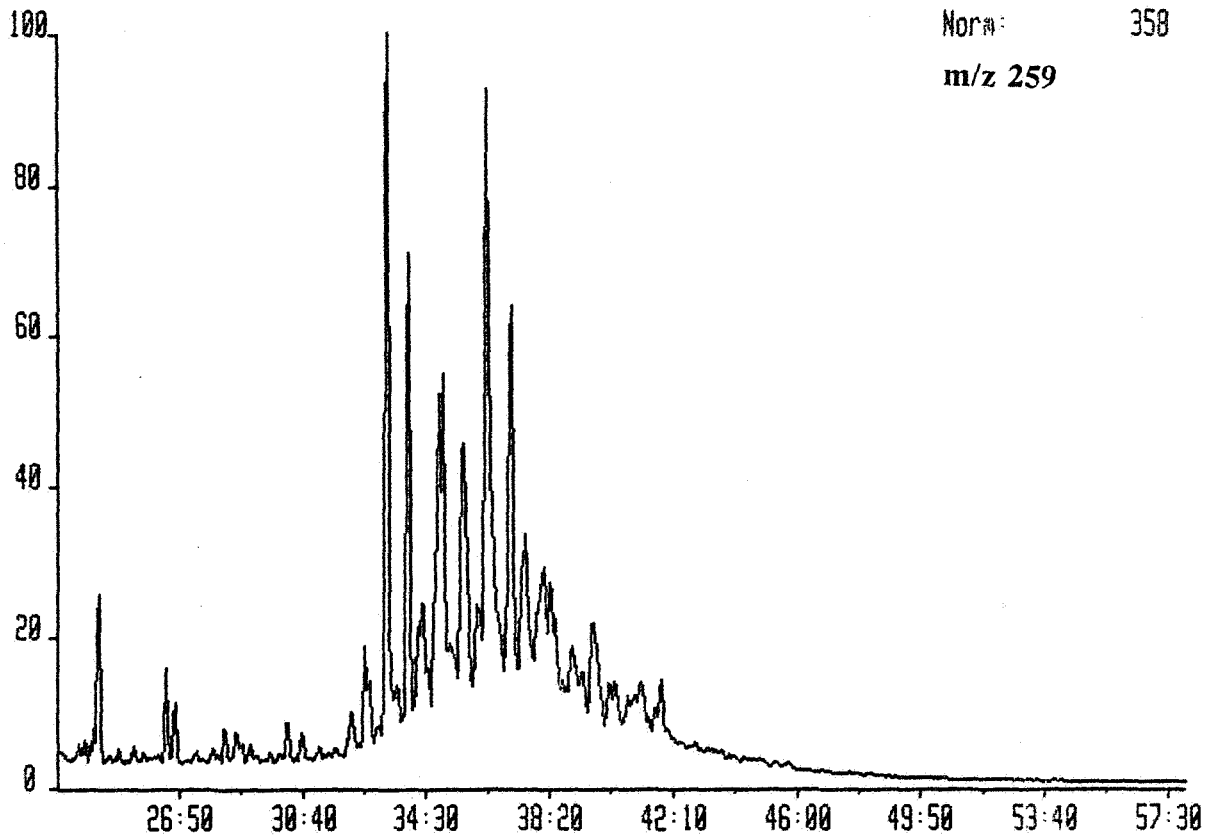
C7248SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
 Sample 1 Injection 1 Group 1 Mass 218.1000
 Text:22.1881 SAGA 34/7-12 C7248SAT



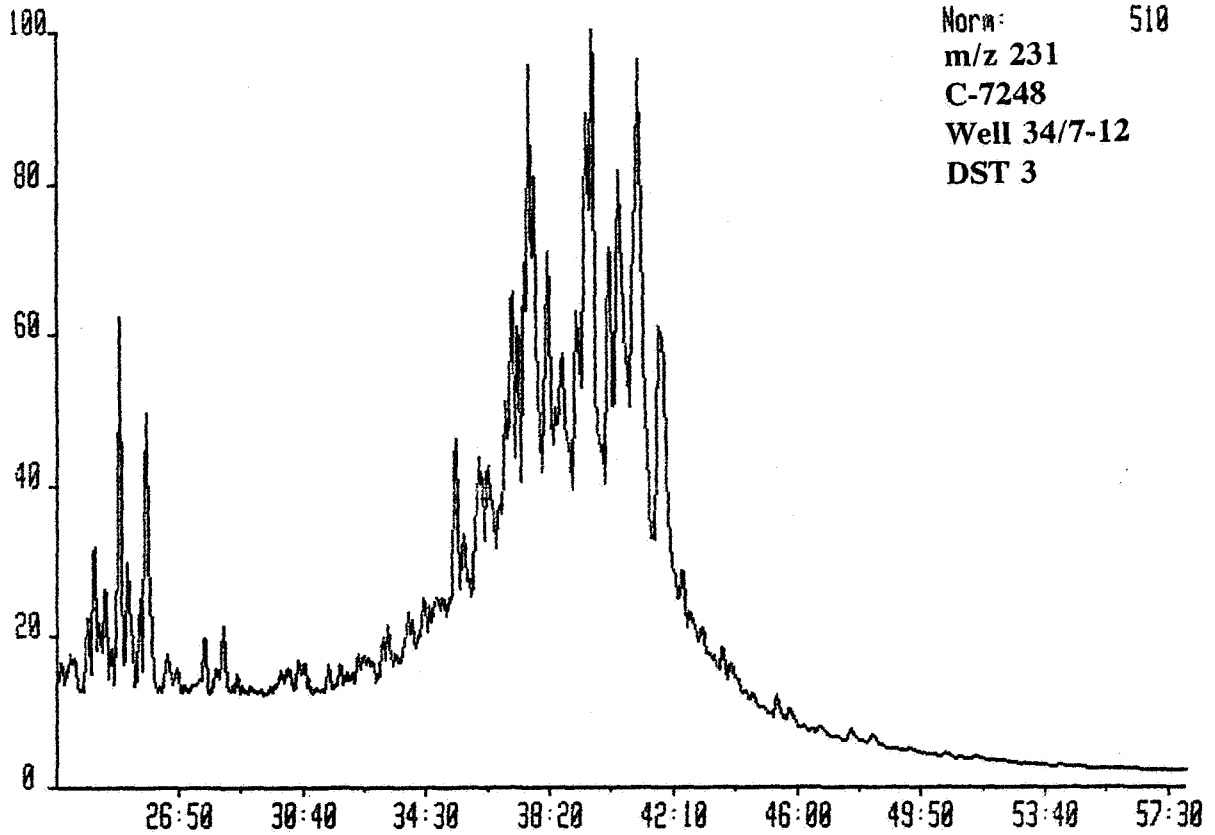
C7246SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
Sample 1 Injection 1 Group 1 Mass 231.1000
Text:22.1881 SAGA 34/7-12 C7246SAT



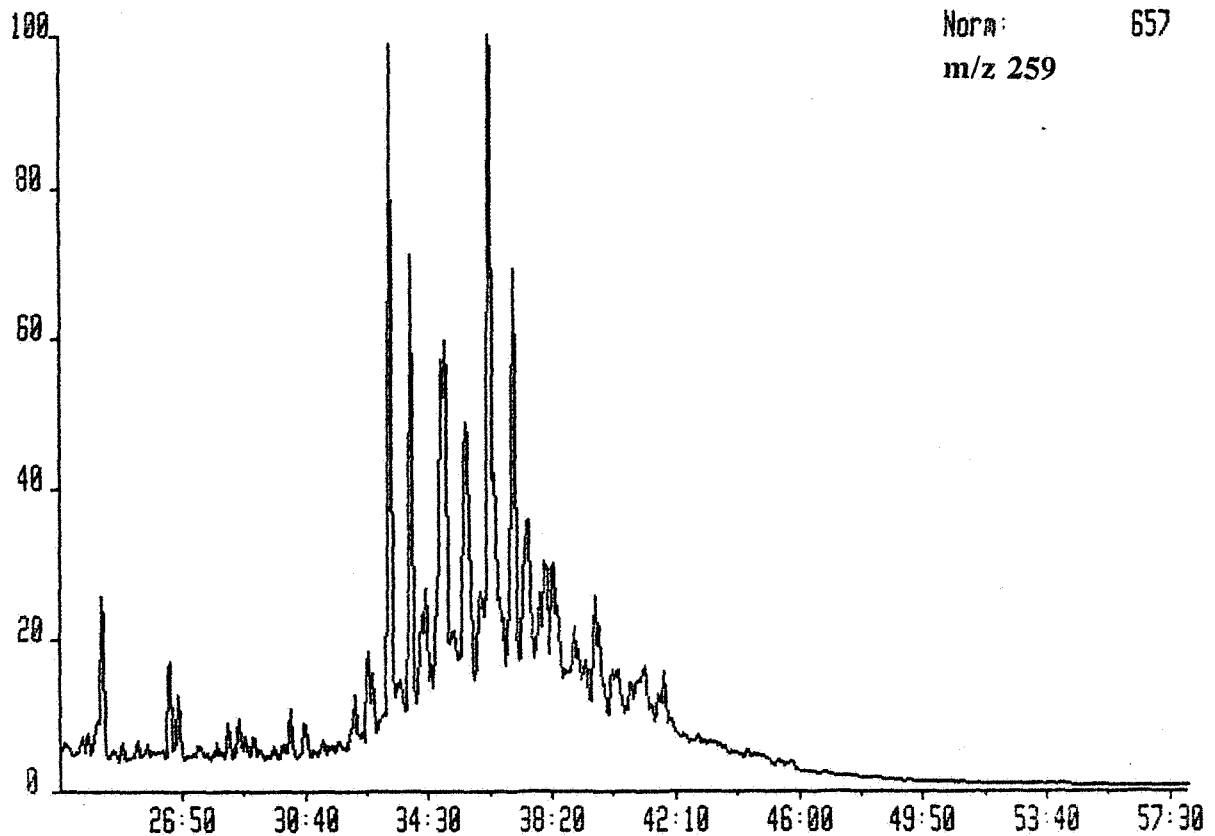
C7246SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
Sample 1 Injection 1 Group 1 Mass 259.1000
Text:22.1881 SAGA 34/7-12 C7246SAT



C7248SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
Sample 1 Injection 1 Group 1 Mass 231.1000
Text:22.1881 SAGA 34/7-12 C7248SAT



C7248SAT 24-FEB-88 Sir:Voltage 7070H Sys: TRISTER
Sample 1 Injection 1 Group 1 Mass 259.1000
Text:22.1881 SAGA 34/7-12 C7248SAT



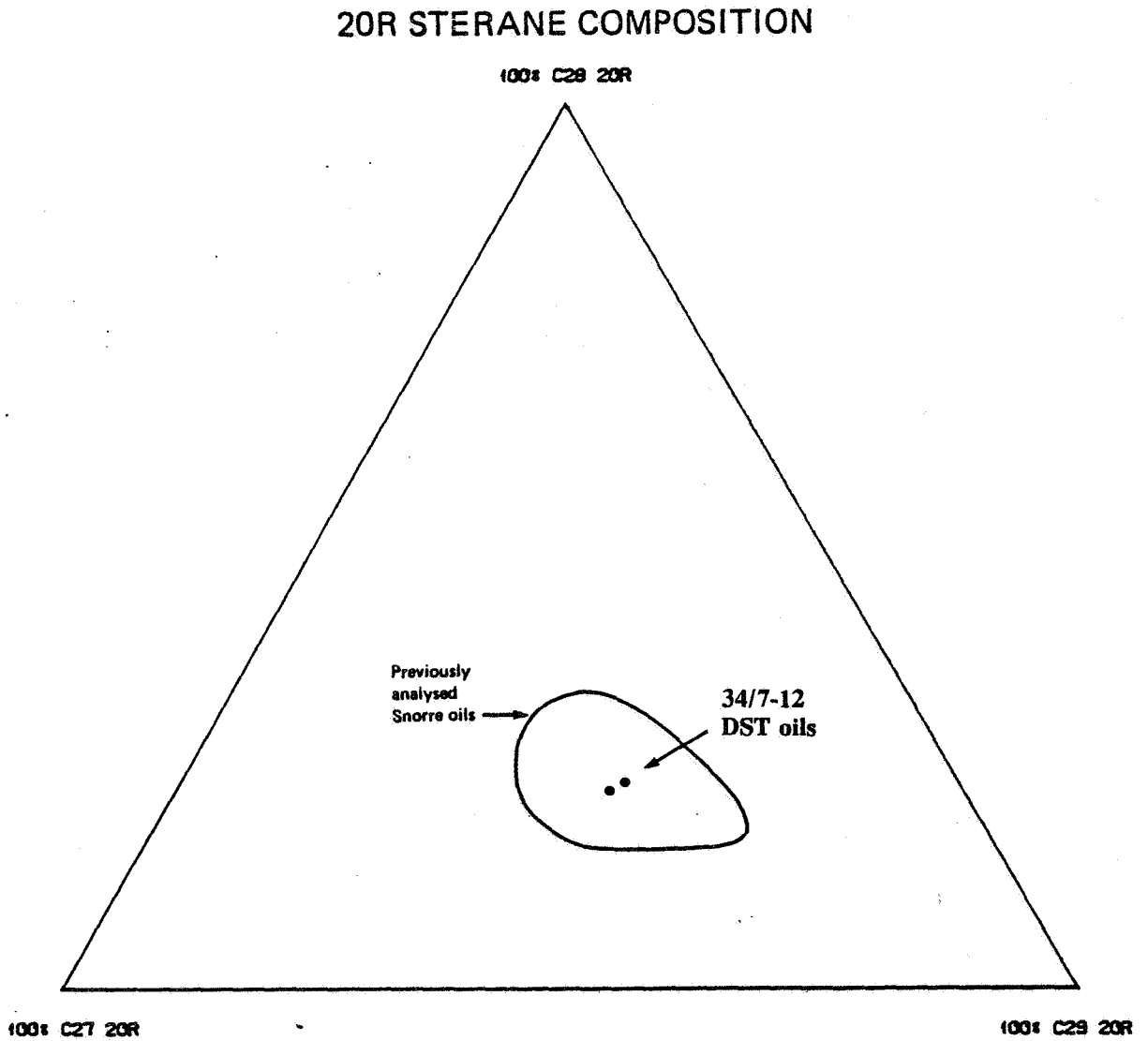


Figure 12. 5α 20R Sterane Composition of DST Oils.

CARBON ISOTOPE PROFILES FOR OIL FRACTIONS FROM 34/7-12

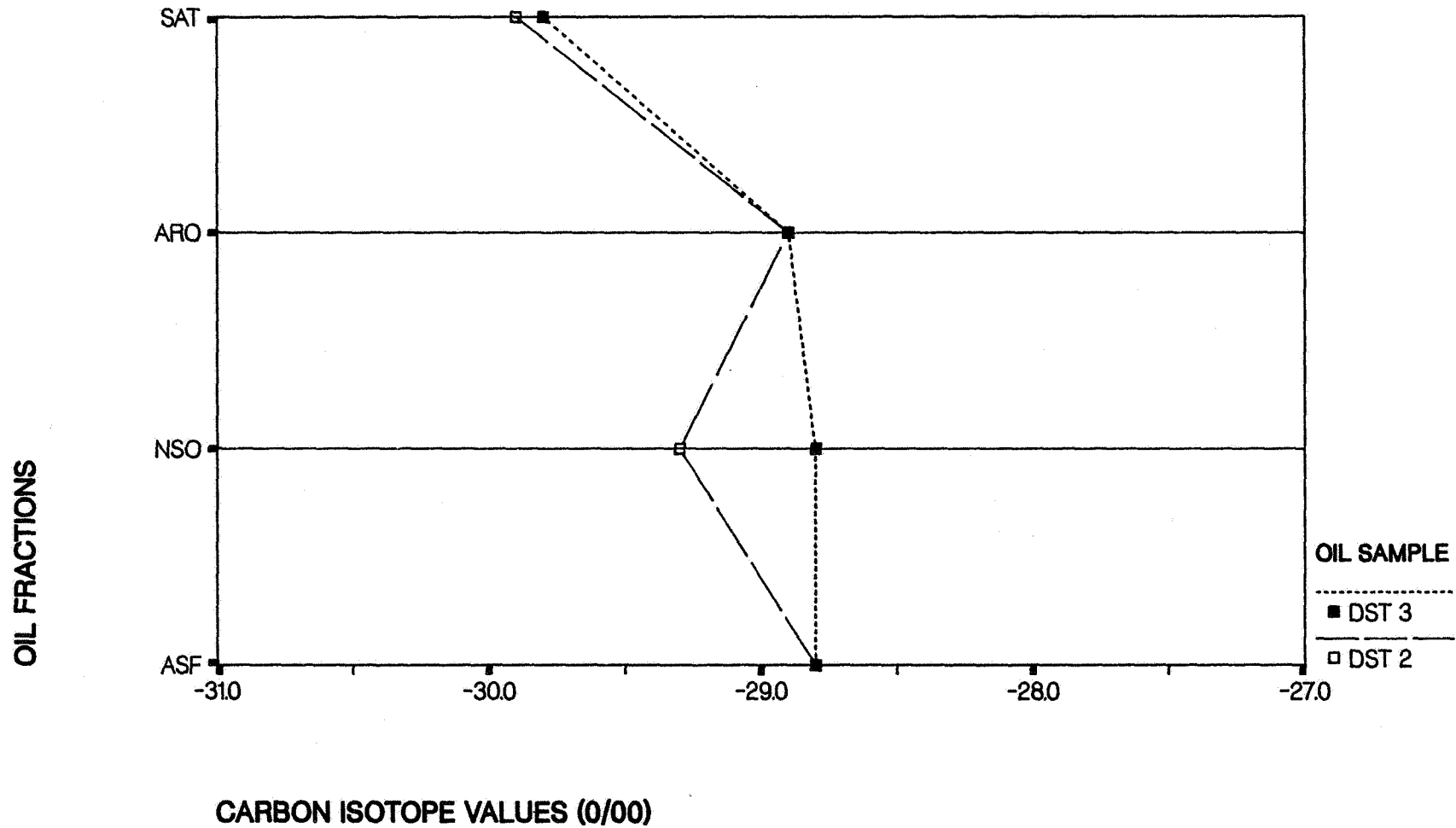


Figure 13. Carbon Isotope Profiles for Oil Fractions from 34/7-12.

APPENDIX 1

MOLECULAR RATIOS FROM TERPANE AND STERANE MASS CHROMATOGRAMS APPLIED AS MATURITY AND SOURCE CHARACTERISTIC PARAMETERS

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

Source characteristic parameters

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

Maturity dependent parameters

The biological isomers of the hopanes, the $17\beta(H)$, $21\beta(H)$ -hopanes, undergo structural changes during the maturation process. The isomerisation reactions are thought to be produced via the $17\beta(H)$, $21\alpha(H)$ -hopanes (moretanes) to the most stable $17\alpha(H)$, $21\beta(H)$ -hopanes. At equilibrium 100% of the $17\alpha(H)$ -hopanes are seen. The ratio $\alpha\beta/\alpha\beta+\beta\alpha$ is used to describe this reaction. In the extended hopanes ($>C_{31}$), the thermally stable S configurations at C-22 become increasingly more abundant as compared to the biologically preferred R configurations at increased maturity level. The equilibrium ratio is approximately 60% of the 22S configuration. Another ratio that is known to change with maturity is the T_m/T_s (Seifert et al., 1978) of the C_{27} hopanes. The maturable $18\alpha(H)$ -trishnorhopane (T_m) is reduced in intensity relative to the more stable $17\alpha(H)$ -trishnorhopane (T_s), causing

the Tm/Ts to decrease at increased maturity. This ratio is also believed to be source dependant, and this should be born in mind when applying the ratio for maturity comparison. The amount of tricyclic terpanes is also to a certain extent seen to be maturity dependant.

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

One of the reactions taking place at an early stage of diagenesis is the aromatisation of steranes, leading to the formation of mono- and triaromatic analogs. This process is measured as the abundance of triaromatic relative to mono-aromatic compounds (% tri/tri + mono) in the m/z 231 and 253 mass chromatograms, respectively. In addition the degree of side chain cracking, as %C₂₀/C_{26,27} and %C₂₁/C_{28,29} respectively, is applied. These cracking processes are also taking place during early diagenesis, and are used for maturity assignment together with the previously mentioned ratios.

Migration and weathering

The effect on the geochemical fossils of migration and weathering, is less apparent than the maturity induced changes. Migration is believed to cause an increase in the relative amounts of rearranged and 14 β (H),17 β (H) regular steranes (Seifert and Moldowan, 1978, 1981). Severe biological alteration leads to the formation of desmethyl-hopanes (Seifert and Moldowan, 1979).