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IKU

REG.NO.	84.091
ACCESSIBILITY	Confidential

REPORT TITLE/ TITTEL

HYDROCARBON CHARACTERISATION OF WELL 31/6-5.

CLIENT/ OPPDRAGSGIVER

Statoil

RESPONSIBLE SCIENTIST/ PROSJEKTANSVARLIG

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DATE/ DATO	REPORT NO./ RAPPORT NR.	NO. OF PAGES/ ANT. SIDER	NO. OF ENCLOSURES/ ANT. BILAG
6.9.84	05.1741.00/01/84	107	—

SUMMARY/ SAMMENDRAG

Two oil/condensate samples and eight cores were analysed to correlate the hydrocarbons in the cores with the two fluid samples. Only one sandstone core, from the oil zone at 1571.50-1571.55m, contained high abundance of hydrocarbons of similar distribution to the fluid samples. Biodegradation has taken place in all three samples. The other cores were seen to contain only traces of hydrocarbons with distribution that is probably similar to the oil and condensate.

KEY WORDS/ STIKKORD

Hydrocarbons	Correlation
Troll Field	

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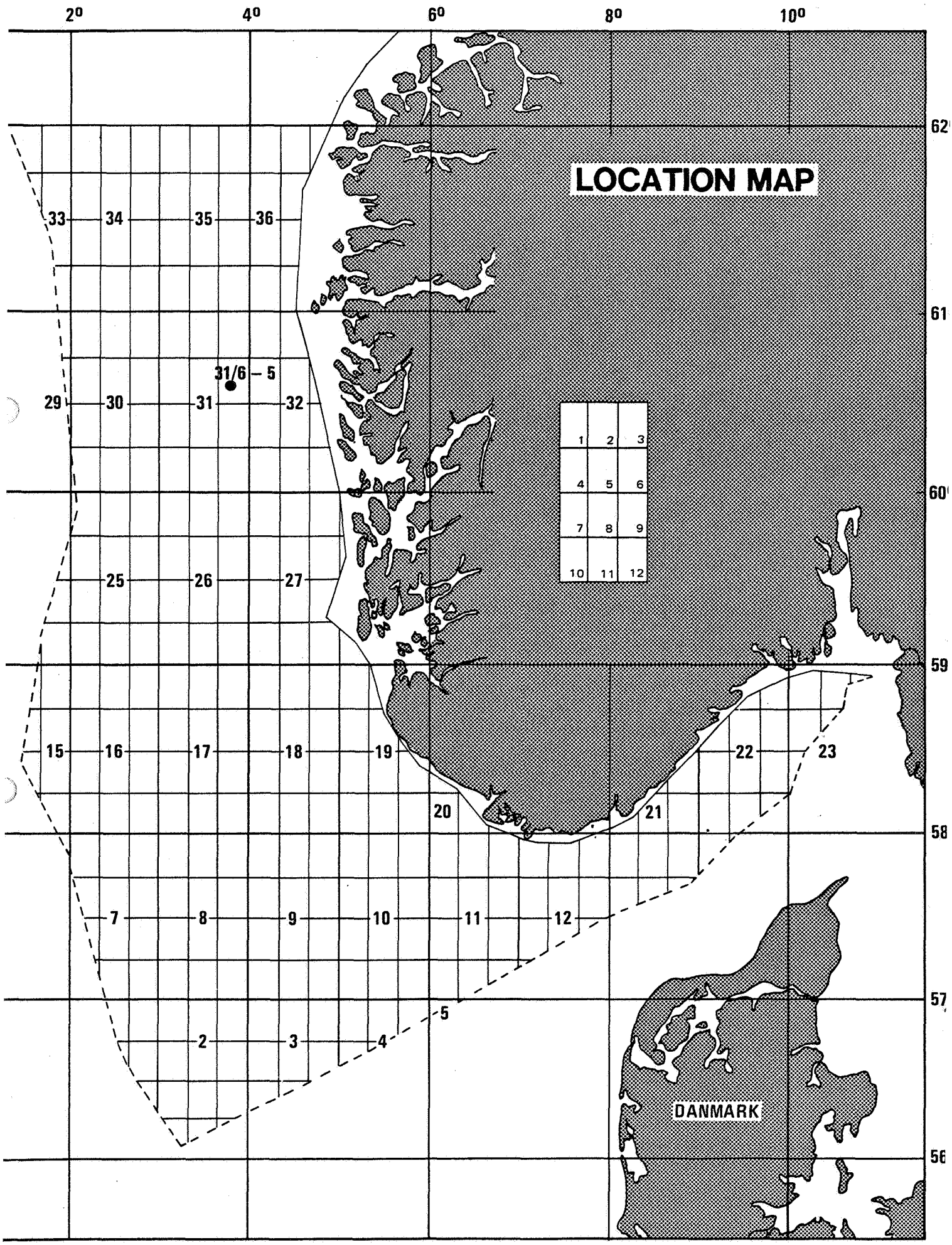
1. INTRODUCTION

A general characterisation was made of hydrocarbons extracted from siltstone and sandstone cores and two fluid samples from well 31/6-5 in the Troll field (see Location Map).

The samples were taken from the following depths:

IKU no.	Sample type	Depth (m)	
B-4631	Oil, DST 1A		
B-4632	Condensate		
B-4623	Core, silt	1488.35-1488.41	Gas zone
B-4624	Core, v.fine sst	1517.79-1517.86	" "
B-4625	Core, med.sst	1527.46-1527.50	" "
B-4626	Core, coarse sst	1546.90-1546.93	" "
B-4627	Core, med.sst	1571.50-1571.55	Oil zone
B-4628	Core, fine-med.sst	1576.26-1576.30	Water zone
B-4629	Core, coarse sst	1580.65-1580.69	" "
B-4630	Core, coarse sst	1587.75-1587.80	" "

Common organic geochemical methods were applied. In addition to extraction and GC analyses, GC-MS and $\delta^{13}C$ isotope data were used in the correlation.


LOCATION MAP
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2. EXPERIMENTAL

2.1 Extractable Organic Matter

Powdered rock was extracted by flowblending for 3 minutes using dichloromethane (DCM) as solvent. The DCM used was of organic geochemical grade and blank analyses showed the occurrence of negligible amounts of contaminating hydrocarbons.

Activated copper fillings were used to remove any free sulphur from the samples.

After extraction the solvent was removed on a Buchi Rotavapor and the amount of extractable organic matter (EOM) was determined.

2.2 Evaporation of the light components in fluid samples

Prior to chromatographic separation of oil/condensate samples, the fractions boiling below 210°C were removed by heating the samples to constant weight at 210°C is obtained. The heating is performed at atmospheric pressure.

The fraction of light components is determined as the weight difference between the original sample and the amount that is left after the heating.

2.3 Chromatographic Separation

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

The same separation procedure was applied to the fractions of oil/condensate samples boiling above 210°C.

2.4 Urea adduction

Urea-adduction was performed on the saturated hydrocarbon fraction. The sample containing 5 mg of n-alkanes was dissolved in 2 ml of n-hexane and 1 ml of acetone was added. A saturated solution of urea in methanol (1 ml) was then added dropwise. The solvent was removed (N_2) and the adduction step repeated twice. The white crystals were rinsed (3x5ml hexane) and the combined extract filtered (cotton wool plug covered with Al_2O_3), to afford a non-adduct. GC analyses were performed on the samples after the urea adduction, using the same conditions as for the other GC analyses.

2.5 Gas Chromatographic Analysis

The C_2-C_8 hydrocarbon fractions were determined by hydrogen stripping on a Carlo Erba Fractovap GC. The column used was a 30m fused silica capillary column coated with SE-54. The temperature program applied was 50^oC (2 min.) to 180^oC at 4^oC/min.

The saturated and the branched/cyclic hydrocarbon fractions were each diluted with n-hexane and analysed on a HP 5730A. The GC is equipped with a 15m DB-1 fused silica column and hydrogen (ca. 2.5 ml/min.) is used as carrier gas. Injections are performed in split mode (split ratio 1:10). The temperature program applied is 80^oC (2 min.) to 280^oC at 4^oC/min.

The total aromatic fractions were, after dilution with n-hexane, analysed on a Carlo Erba Fractovap Series 2150 GC. The GC is equipped with a 30m DB-5 fused silica columns, and hydrogen (2.5 ml/min.) is used as carrier gas. The temperature program applied is 80^oC (2 min.) to 280^oC at 4^oC/min. and injections are performed splitless.

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

2.6 Gas chromatography - mass spectrometry (GC-MS)

GC-MS analyses were performed on a VG Micromass 70-70H GC-MS-DS system. The Varian Series 3700 GC was fitted with a fused silica OV-1 capillary column (30m x 0.3mm i.d.). Helium ($0.7kg/cm^2$) was used as carrier gas and the injections were performed in split mode (1.5µl, split ratio

1:15). The GC oven was programmed from 70°C to 280°C at 4°C/min. after an initial isothermal period of 2 minutes for the aromatic hydrocarbons, while the starting temperature for the saturates was 120°C.

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

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

2.7 $\delta^{13}C$ istotope analyis

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

3. RESULTS AND DISCUSSION

3.1 API gravity

The API gravities given in Table 1, show that one of the samples (B-4631) is a relatively high gravity oil, while B-4632 is a much lighter condensate. The high gravity of B-4631 suggests that this oil is of low maturity and/or is biodegraded.

3.2 C_2-C_8 hydrocarbons

Gas chromatograms in Figure 1 and quantitative data in Table 2 show that only low amounts of n-alkanes are detected in both samples. The high relative abundance of cyclic hydrocarbons suggests that the hydrocarbons have undergone biodegradation.

3.3 Amount of C_{15}+ EOM and hydrocarbons

The two fluid samples were topped to 210°C prior to separation of asphalthenes and chromatographic separation. In good agreement with the API gravity, the data in Table 3 show sample B-4632 to contain very much higher amounts of light components than sample B-4631.

The amounts of asphalthenes are presented in Table 4, while the weights and relative amounts of various chromatographic fractions are given in Table 5.1-5.3. Only one of the cores, B-4627 from the oil zone at 1571.50-1571.55m, was seen to contain very high abundance of extractable organic matter (20600ppm) and of hydrocarbons (13330ppm). The rest of the cores contain hydrocarbons in the range 18-188ppm (average 93.7ppm).

3.4 Gas chromatography of C_{15}+ saturated hydrocarbons

Gas chromatograms of saturated hydrocarbons are presented in Figure 2, while data from the chromatograms are given in Table 6.

The condensate, B-4632, shows a very narrow range of saturated hydrocarbons with hardly any alkanes above n-C_{20}. Isoprenoids are of high abundance relative to the n-alkanes. A similar low relative abundance of n-alkanes to isoprenoids is seen in the chromatogram of the oil sample,

B-4631. This implies that the samples have undergone some degree of biodegradation. The oil sample also shows a bimodal hump of unresolved material, where the most prominent hump is seen in the C_{25}-C_{35} n-alkane range. Triterpenoidal and steroidal hydrocarbons are the main components in this most prominent hump.

Both the oil and the condensate have pristane/phytane ratios of 2.0 or higher. According to Cornford et al. (1983) this is high compared to most North Sea oils and Upper Jurassic source rocks. High pristane/phytane ratios are generally believed to originate from non-marine source rocks.

From the relative amount of the internal standard it is seen that only the core from the oil zone at 1571.50-1571.55m contains high abundance of extractable hydrocarbons. The hydrocarbon distribution in this sample is very similar to the oil sample discussed above. The high relative abundance of isoprenoids, implying biodegradation, and the bimodal hump of unresolved material are seen also in this core. This suggests that the hydrocarbons extracted from this core and the oil are generated from the same source rock.

Of the four samples taken from the gas zone (1488.35-1546.93m) the three lowermost cores show most similarities to the oil. The top core consists of more silty material, a fact that may influence the hydrocarbon distribution. The high abundance of resolved triterpenoidal compounds eluting after the internal standard, could be due to source rock features of the siltstone. All four samples contain some amounts of hydrocarbons with the same high pristane/n-C_{17} and pristane/phytane ratios as the oil and the core from the oil zone.

From the sandstone in the water zone only traces of the hydrocarbons with the oil distribution are extracted. Relatively high abundance of waxy components in the n-C_{20} - n-C_{35} range is, however, seen in all three samples. This is a feature that is often seen in samples taken close to the oil/water contact. They are believed to be indigenous and not contaminants.

3.5 Gas chromatography of branched/cyclic alkanes

The same trends as from the total saturated hydrocarbons can be seen in the branched/cyclic alkane traces (Figure 3). Sample B-4627 from the oil zone is almost identical to the oil. The other cores, excluding the silty sample, show similar patterns in the chromatograms, where pristane is the predominant compound and a more or less prominent unresolved hump is seen.

3.6 Gas chromatography of aromatic hydrocarbons

Gas chromatograms of aromatic hydrocarbons are given in Figure 4, and calculated values of particular aromatic ratios used in estimation of maturity (Radke et al., 1983), are presented in Table 7.

Both the condensate and the oil show predominance of alkylated naphthalenes over the higher molecular weight alkylated phenanthrenes. As seen in the saturated hydrocarbon GC's the oil contains a hump of unresolved material. Due to low intensity of the phenanthrenes no value for the MPI 1 was determined. The predominance of 2- over 1-methyl naphthalene suggests a source of relatively high maturity.

The silty core from the top of the gas zone is the only sample with abundant resolved aromatic steranes in the high molecular weight range. Another feature which makes this sample different is the low MNR of 0.81, while all the other samples have ratios of more than 1.75.

The MPI 1 ratio was possible to determine for only four of the samples. The low values obtained suggest a low maturity source, but due to the generally low abundance of methylphenanthrenes, erroneous results from coelution cannot be excluded.

Generally only minor variations were seen in the aromatic hydrocarbon traces of the sandstone cores and the oil.

3.7 GC-MS analysis of saturated steranes and terpanes

Mass chromatograms representing terpanes (m/z 191) and steranes (m/z 217 and 218) are shown in Figure 5. Molecular ratios calculated from the chromatograms are given in Table 8 and 9.

The two fluid samples show the same general distribution of steranes and terpanes, representative of mature hydrocarbons. The variations seen, e.g. in the relative abundance of tricyclic terpanes (TRI/E in Table 9), are believed to be due to the difference between a light condensate and a heavy oil. Based on the biomarker distribution these two samples may well have been generated from the same source rock.

Of the core samples, the shallow silty B-4623 is significantly different to the other cores. The sterane chromatograms assign this sample to be of low maturity, while the terpane mass chromatogram is dominated by 28,30-bisnorhopane (Z in m/z 191). By inspecting other terpane mass chromatograms another unusual triterpane is seen in relatively high abundance. The mass spectrum and the relative retention time assign the peak to be representing a 25,28,30-trisnorhopane (Volkman et al., 1983).

The immature feature of this siltstone core together with the relatively low extractability suggest that these hydrocarbons are indigenous and not due to migration.

The other seven cores show the same general biomarker distribution, only the three shallowest sandstones showing significant amounts of bisnorhopane (Z). Varying abundance of the tricyclic terpanes is thought to be due to mixed input of the hydrocarbons typical of the oil and the waxy components in the nC_{20}-C_{35} range. The sample with the highest extractability (B-4627) from the oil zone shows molecular ratios very similar to those of the oil. The triangular plot in Figure 6 shows the molecular weight distribution of C_{27}-C_{29} regular 14β,17β-steranes to be nearly identical for the oil (B-4631) and B-4627. A slightly different distribution is seen for the condensate and the other cores. Sample B-4623 is not included in the plot.

Thus the saturated steranes and terpanes suggest that the core in the oil zone contains high abundance of hydrocarbons of the same origin as the oil and probably the condensate. The other cores contain small

amounts of this same type of hydrocarbons mixed with more waxy components of unknown origin.

3.8 GC-MS analysis of aromatic hydrocarbons

The data obtained from the analysis of aromatic hydrocarbons support what was seen from other parameters (Figure 7). The total ion chromatograms (TIC) are similar to the GC traces, apart from some abundant peaks representing sulfur compounds. These peaks partly mask interesting parts of the TIC's. Mass chromatograms representing alkylated homologs of benzene (m/z 92, 106), naphthalene (m/z 142, 156, 170), phenanthrene (m/z 178, 192, 206) in addition to mono- and tri-aromatic steranes (m/z 253 and 231) are presented. The mass chromatograms representing alkylated dibenzothiophenes (m/z 194, 198, 212) were very poor and are not presented.

The variations seen in most of the chromatograms are probably more due to the generally low abundance than to genuine differences in the origin of the hydrocarbons. Only sample B-4623 can be said to be significantly different, particularly from the relative intensity of tri- and mono-aromatic steranes (Table 10). The data support what was said about this sample being less mature than the others.

3.9 $\delta^{13}C$ isotope ratios

Saturated and aromatic hydrocarbon fractions were analysed for their $\delta^{13}C$ isotope ratios. The data is presented in Table 11.

It is seen that the oil and the sandstone core from the oil zone (B-4627) give the same values for both the saturated and the aromatic hydrocarbons. The condensate shows slightly higher value for the saturated and nearly one unit higher value for the aromatic hydrocarbons. This difference may be due to a slight difference in maturity when the oil and condensate were generated.

The silty core (B-4623) is again seen to be different to the other samples. Small sample amounts, especially of the aromatic hydrocarbons, made the analyses difficult for some of the samples. The high value obtained for the saturated hydrocarbons in B-4629 could be caused by some contribution from the waxy components seen in the GC trace.

4. CONCLUSION

All the analyses suggest that the hydrocarbons from the sandstone core in the oil zone (B-4627, 1571.50-55m) are similar to the oil sample (B-4631). The condensate (B-4632) is probably also generated from the same source horizon, but possibly at a slightly higher maturity level.

The other cores contain much lower concentrations of hydrocarbons. Traces of the same type of hydrocarbons as the oil, are seen in all the samples, apart from possibly the shallowest silty core. This core contains mainly components of much lower maturity than the other cores, and shows thus more source rock features. In the deepest cores from the water zone the oil hydrocarbons are mixed with an input of high molecular weight waxy components.

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Table 1. API gravity of oil and condensate.

IKU no.	Sample type	^{o}API
B-4631	Oil, DST 1A	25.4
B-4632	Condensate	48.0

IKU

Table 2. Relative amounts of C_2-C_8 hydrocarbons in the fluid samples.

	B-4632 Condensate % of total oil	B-4631 Oil % of total oil
C_2	-	
C_3	-	
MC_3	0.7	0.2
nC_4	1.1	0.2
MC_4	2.9	0.6
nC_5	1.6	0.3
C_yC_5+2,3DMC_4	4.6	1.3
$2MC_5$	-	-
$3MC_5$	1.9	0.4
nC_6	0.9	0.3
MC_yC_5	5.1	1.6
benzene	-	<0.1
C_yC_6	6.0	2.2
$2MC_6$	-	-
2,3DMC_5	0.9	0.3
$3MC_6$	1.4	0.4
DMC_yC_5 (1,3; 1,2)	2.3	0.7
2,2,4 TMC_5	1.4	0.5
nC_7	-	0.1
MC_yC_6	9.6	3.0
2,4DMC_6	1.4	0.2
Toluene	1.5	0.2
$2MC_7$	0.6	<0.1
$3MC_7$	0.5	<0.1
DMC_yC_6 (1,2)	2.5	0.7
nC_8	1.0	0.4
M/P-xylene	1.0	0.3
O-xylene	-	-

List of C_2-C_8 hydrocarbons in Table 2 and Figure 1.

C_2	ethane
C_3	propane
MC_3	methyl-propane
nC_4	butane
MC_4	methyl-butane
nC_5	pentane
CyC_5+2,3DMC_4	cyclopentane + 2,3-dimethyl-butane
$2MC_5$	2-methyl-pentane
$3MC_5$	3-methyl-pentane
nC_6	hexane
$MCyC_5$	methyl-cyclopentane
	benzene
CyC_6	cyclohexane
$2MC_6$	2-methyl-hexane
2,3DMC_5	2,3-dimethyl-pentane
$3MC_6$	3-methyl-hexane
$DMCyC_5$	dimethyl-cyclopentane
2,2,4TMC_5	2,2,4-trimethyl-pentane
nC_7	heptane
$MCyC_6$	methyl-cyclohexane
2,4DMC_6	2,4-dimethyl-hexane
	toluene
$2MC_7$	2-methyl-heptane
$3MC_7$	3-methyl-heptane
$DMCyC_6$	dimethyl-cyclohexane
nC_8	octane
	m/p-xylene
	o-xylene

Table 3. Amount of light components in oil and condensate.

IKU no.	Sample type	Crude oil (mg)	>210°C (mg)	Light comp. (mg)	(%)
B-4631	Oil, DST 1A	1 735.5	1 641.0	94.5	5.4
B-4632	Condensate	1 900.6	474.0	1 426.6	75.1

Table 4. Amount of asphalthenes in fluid and core samples.

IKU no.	Sample type	Crude oil >210°/EOM	Asphalthenes
B-4631	Oil	1641.0	12.7
B-4632	Condensate	474.0	-
B-4623	Core, silt	54.9	3.4
B-4624	Core, sst	92.0	3.8
B-4625	Core, sst	22.2	2.3
B-4626	Core, sst	9.0	1.2
B-4627	Core, sst	1033.6	9.5
B-4628	Core, sst	47.0	0.9
B-4629	Core, sst	93.3	0.8
B-4630	Core, sst	4.6	0.8

T A B L E : 5.1

CONCENTRATION OF EOM AND CHROMATOGRAPHIC FRACTIONS

IKU-No	DEPTH (m)	Rock Extr. (g)	EOM (mg)	Sat. (mg)	Aro. (mg)	HC (mg)	Non HC (mg)	TOC (%)
B 4631	Oil		137.0	63.2	31.5	94.7	42.3	
B 4632	Condensate		106.0	61.2	11.6	72.8	33.2	
B 4623	1488.41	90.0	54.9	6.1	7.2	13.3	41.6	1.88
B 4624	1517.86	100.0	92.0	6.6	12.2	18.8	73.2	0.55
B 4625	1527.50	100.0	22.2	9.0	3.6	12.6	9.6	0.14
B 4626	1546.93	150.0	9.0	5.4	2.3	7.7	1.3	0.01
B 4627	1571.55	50.0	1033.6	455.3	211.2	666.5	367.1	1.17
B 4628	1576.30	200.0	47.0	15.8	3.9	19.7	27.3	0.01
B 4629	1580.69	200.0	93.3	3.7	1.7	5.4	87.9	0.09
B 4630	1587.80	200.0	4.6	2.3	1.2	3.5	1.1	0.01

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T A B L E : 5.2

WEIGHT OF EOM AND CHROMATOGRAPHIC FRACTIONS

(Weight ppm OF rock)

IKU-No	DEPTH (m)	EOM	Sat.	Aro.	HC	Non HC
B 4631	Oil					
B 4632	Condensate					
B 4623	1488.41	610	68	80	148	462
B 4624	1517.86	920	66	122	188	732
B 4625	1527.50	222	90	36	126	96
B 4626	1546.93	60	36	15	51	9
B 4627	1571.55	20672	9106	4224	13330	7342
B 4628	1576.30	235	79	19	99	137
B 4629	1580.69	467	19	9	27	440
B 4630	1587.80	23	11	6	18	5

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TABLE : 5.3

COMPOSITION IN % OF MATERIAL EXTRACTED FROM THE ROCK

IKU-No	DEPTH (m)	Sat / EOM	Aro / EOM	HC / EOM	SAT / Aro	Non HC / EOM	HC / Non HC
B 4631	Oil	46.1	23.0	69.1	200.5	30.9	223.5
B 4632	Condensate	57.7	10.9	68.7	527.6	31.3	219.3
B 4623	1488.41	11.1	13.1	24.2	84.7	75.8	32.0
B 4624	1517.86	7.2	13.3	20.4	54.1	79.6	25.7
B 4625	1527.50	40.5	16.2	56.8	250.0	43.2	131.2
B 4626	1546.93	60.0	25.6	85.6	234.8	14.4	592.3
B 4627	1571.55	44.0	20.4	64.5	215.6	35.5	181.6
B 4628	1576.30	33.6	8.3	41.9	405.1	58.1	72.2
B 4629	1580.69	4.0	1.8	5.8	217.6	94.2	6.1
B 4630	1587.80	50.0	26.1	76.1	191.7	23.9	318.2

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T A B L E 6.

TABULATION OF DATA FROM THE GASCHROMATOGRAMS

IKU No.	DEPTH (m)	PRISTANE / n-C17	PRISTANE / PHYTANE	CPI
B 4631	Oil	2.0	2.0	1.1
B 4632	Condensate	2.5	2.7	-
B 4623	1488.41	3.6	2.0	0.8
B 4624	1517.86	2.9	3.5	1.0
B 4625	1527.50	4.0	3.2	1.2
B 4626	1546.93	5.0	5.0	1.2
B 4627	1571.55	1.8	2.1	1.0
B 4628	1576.30	5.5	6.0	1.0
B 4629	1580.69	14.4	16.4	1.0
B 4630	1587.80	8.5	8.5	1.1

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Table 7. Aromatic hydrocarbon ratios.

IKU no.	MNR	MPI 1
B-4623	0.81	-
B-4624	4.13	0.48
B-4625	2.00	0.55
B-4626	3.20	0.49
B-4627	3.33	0.47
B-4628	1.85	-
B-4629	3.95	-
B-4630	1.75	-
B-4631	3.22	-
B-4632	2.82	-

MNR = 2/1 MN

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

Table 8. Maturity ratios calculated from peak heights in sterane and terpane mass chromatograms.

IKU code	Depth (m)	Sample type	m/z 191		m/z 217	
			αβ/αβ+βα[1]	%22S[2]	%20S[3]	%ββ[4]
B-4631	-	Oil	0.89	58.8	50.0	70.3
B-4632	-	Condensate	0.93	61.5	50.0	76.9
B-4623	1488.41	Core, silt	-	-	39.2	48.6
B-4624	1517.86	Core, sst	0.92	57.1	34.8	66.7
B-4625	1527.50	"	0.91	61.1	45.7	75.3
B-4626	1546.93	"	0.90	60.0	47.1	74.1
B-4627	1571.55	"	0.92	61.3	47.9	73.3
B-4628	1576.30	"	0.90	61.0	49.0	73.5
B-4629	1580.69	"	0.90	58.7	39.1	71.6
B-4630	1587.80	"	0.90	58.8	43.5	71.3

1) E/E+F in m/z 191.
2) J_1/J_1+J_2 in m/z 191.
3) q/q+t in m/z 217.
4) 2(r+s)/(2(r+s)+q+t) in m/z 217.

Table 9. Molecular ratios calculated from sterane and terpane mass chromatograms.

IKU code	Depth (m)	Sample type	m/z 191 Tm/Ts[1)]	m/z 191 TRI/E[2)]	m/z 191 Z/E	m/z 191 X/E	m/z 217 a/a+j[3)]
B-4631	-	Oil	0.65	0.09	0.2	0.26	0.78
B-4632	-	Condensate	0.45	0.45	0.1	0.07	0.63
B-4623	1488.41	Core, silt	-	0.08	8.5	-	0.11
B-4624	1517.86	Core, sst	0.27	0.17	0.7	0.10	0.36
B-4625	1527.50	"	0.80	1.19	0.6	0.10	0.63
B-4626	1546.93	"	0.53	0.67	0.6	0.11	0.45
B-4627	1571.55	"	0.50	0.08	0.2	0.24	0.78
B-4628	1576.30	"	0.44	0.18	0.2	0.22	0.41
B-4629	1580.69	"	0.27	0.24	0.2	0.10	0.22
B-4630	1587.80	"	0.81	0.06	-	0.02	0.36

1) B/A in m/z 191.
2) Q/E in m/z 191.
3) Relative amounts of C_{27} rearranged steranes (a/a+j in m/z 217).

Table 10. Maturity ratios from aromatic sterane mass chromatograms.

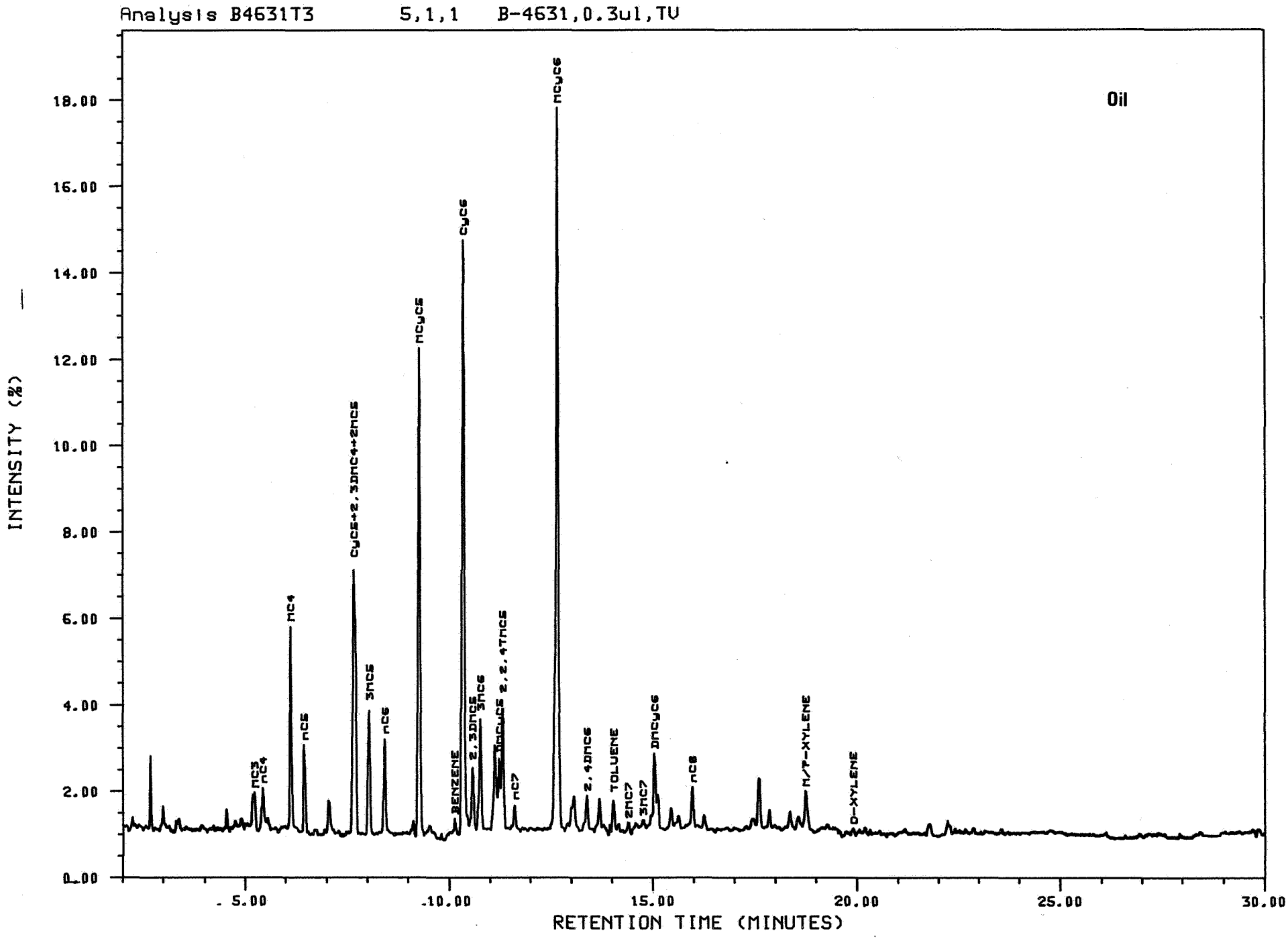
IKU no.	Sample type	m/z 253 $C_{21}/C_{21}+C_{28,29}$	m/z 231 $C_{20}/C_{20}+C_{26,27}$	TRI/TRI+MONO
B-4631	Oil	45.1	19.5	48.9
B-4632	Condensate	-	-	-
B-4623	Core, silt	15.3	-	5.3
B-4624	Core, sst	-	-	-
B-4625	"	33.3	50.0	46.0
B-4626	"	28.6	50.0	41.5
B-4627	"	38.9	42.9	47.0
B-4628	"	27.8	33.3	48.3
B-4629	"	24.7	50.0	50.6
B-4630	"	21.9	-	60.5

Table 11. $\delta^{13}C$ isotope ratios of hydrocarbon fractions.

IKU no.	Sample type	SAT	ARO
B-4631	Oil	-28.8	-27.3
B-4632	Condensate	-28.6	-26.5
B-4623	Core, silt	-30.5	-28.7
B-4624	Core, sst	-28.2	-
B-4625	"	-27.4	-27.7
B-4626	"	-28.0	-
B-4627	"	-28.8	-27.2
B-4628	"	-27.7	-27.4
B-4629	"	-25.9	-

FIGURE 1

C_2-C_8 hydrocarbon GC's


Analysis B4631T3 5,1,1 B-4631,0.3ul,TV
Oil
INTENSITY (%)
RETENTION TIME (MINUTES)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
nC3
nC4
nC4
nC5
CyC5+2,3DMC4+2MC5
3MC5
nC6
MCyC5
CyC6
BENZENE
2,3DMC5
3MC6
2,2,4TMC5
nC7
MCyC6
2,4DMC5
TOLUENE
2MC7
3MC7
DMCyC6
nC8
M/P-XYLENE
O-XYLENE

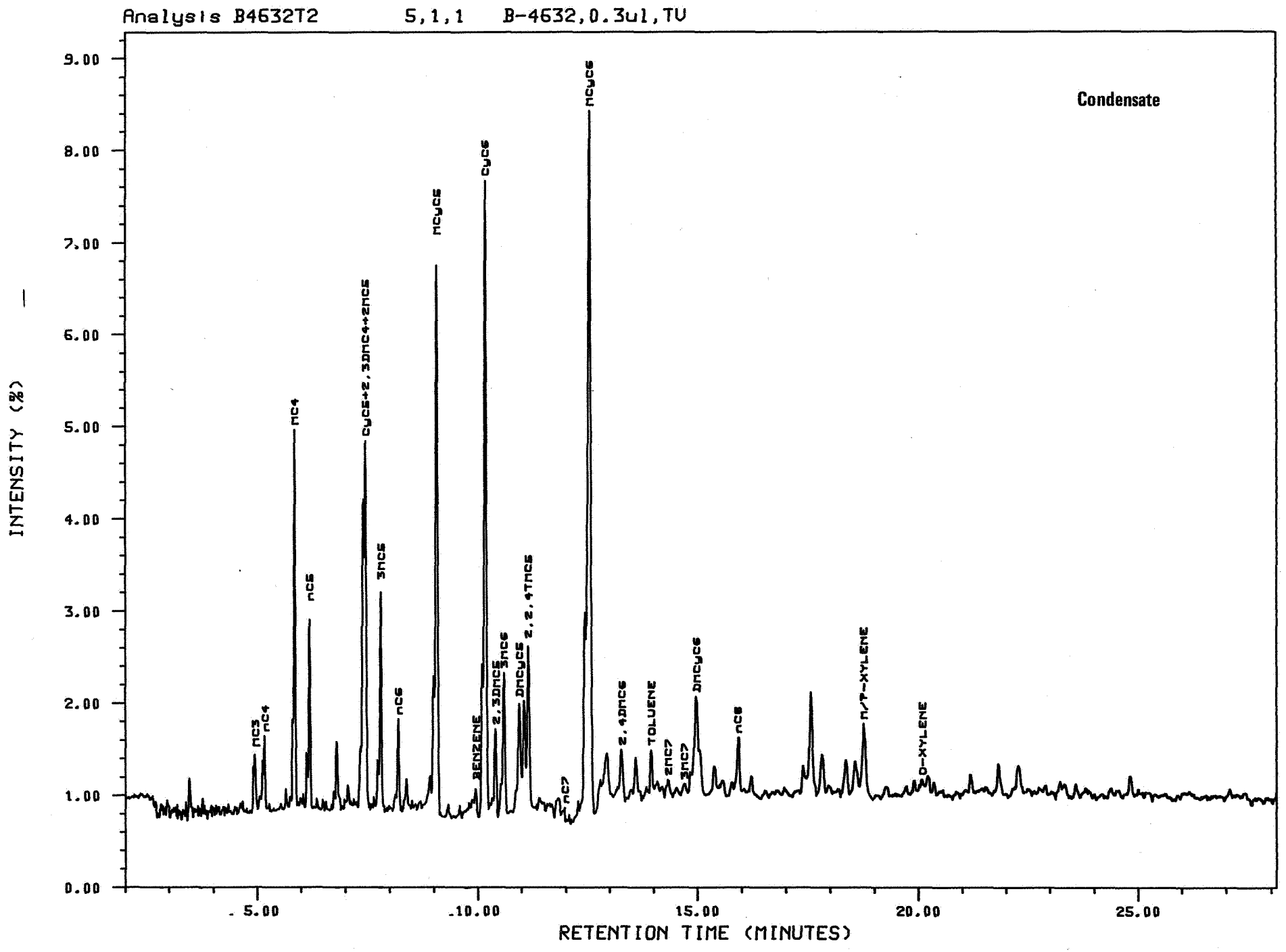
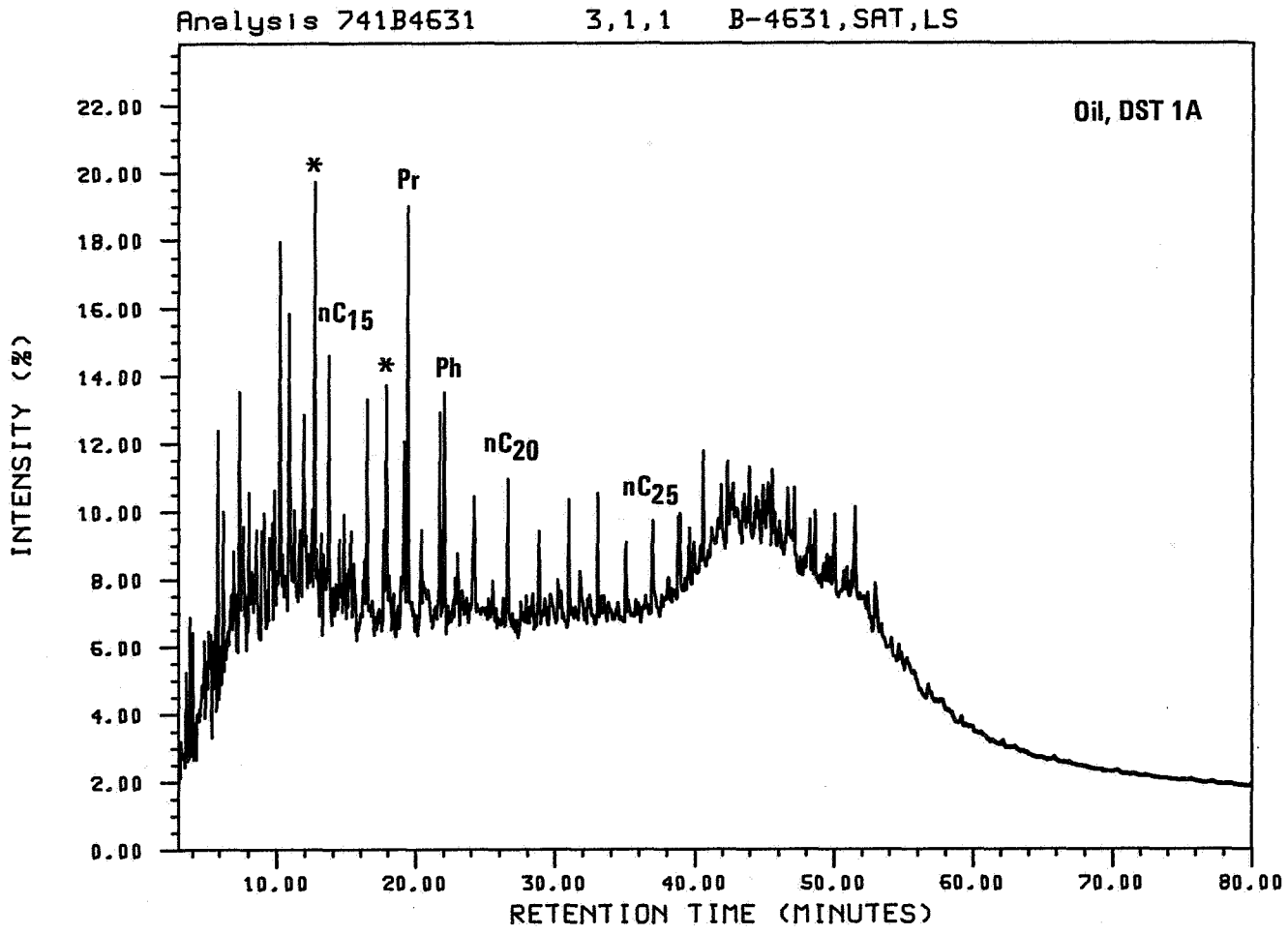
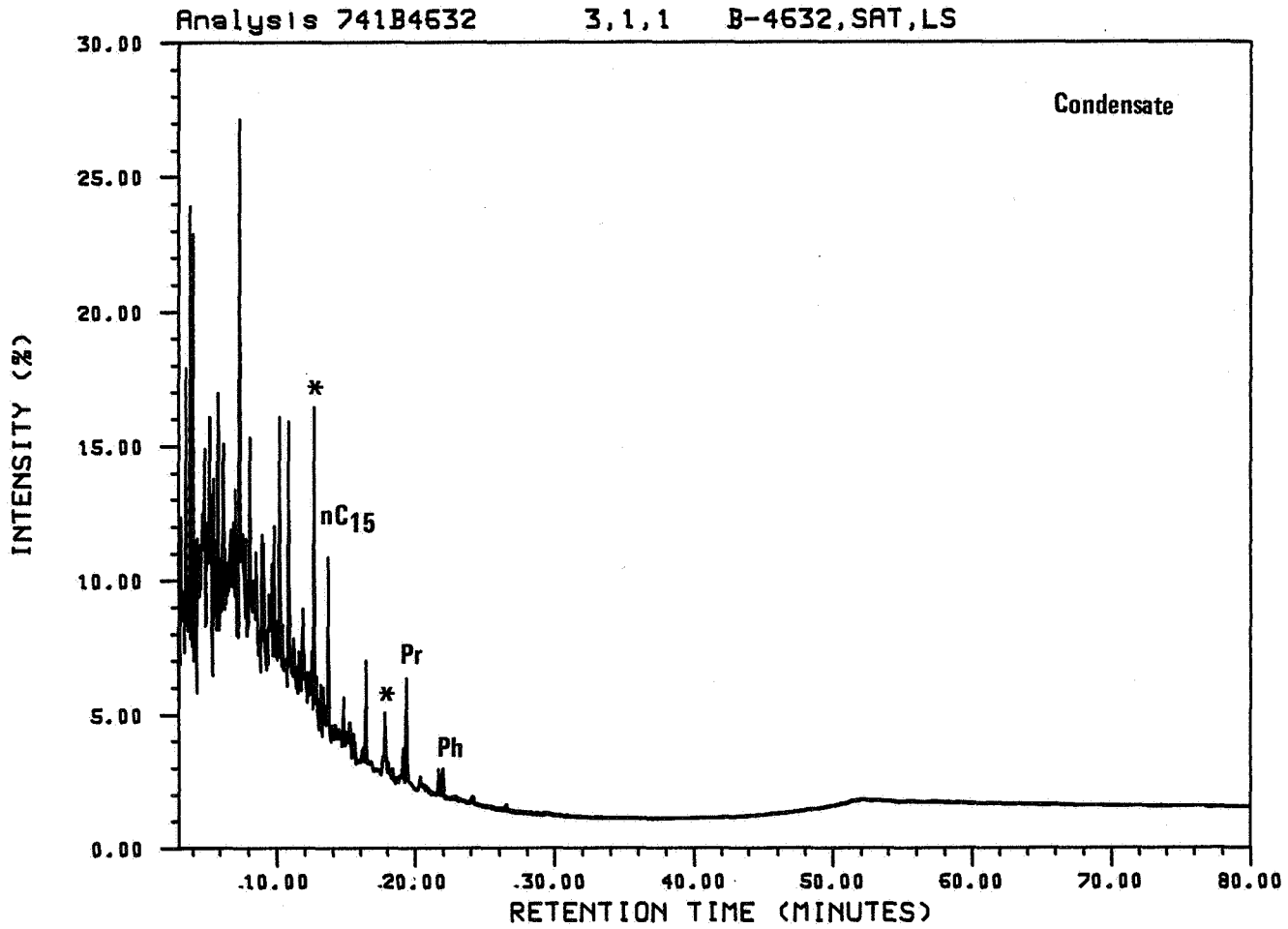

Analysis B4632T2 5,1,1 B-4632,0.3ul,TV
Condensate
INTENSITY (%)
RETENTION TIME (MINUTES)
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
5.00
10.00
15.00
20.00
25.00
nC3
nC4
nC4
nC5
CyC5+2,3DMC4+2MC5
3MC5
nC6
MCyC5
BENZENE
CyC6
2,3DMC5
3MC6
DMCyC5
2,2,4TMC6
nC7
MCyC6
2,4DMC6
TOLUENE
2MC7
3MC7
DMCyC6
nC8
M/P-XYLENE
O-XYLENE

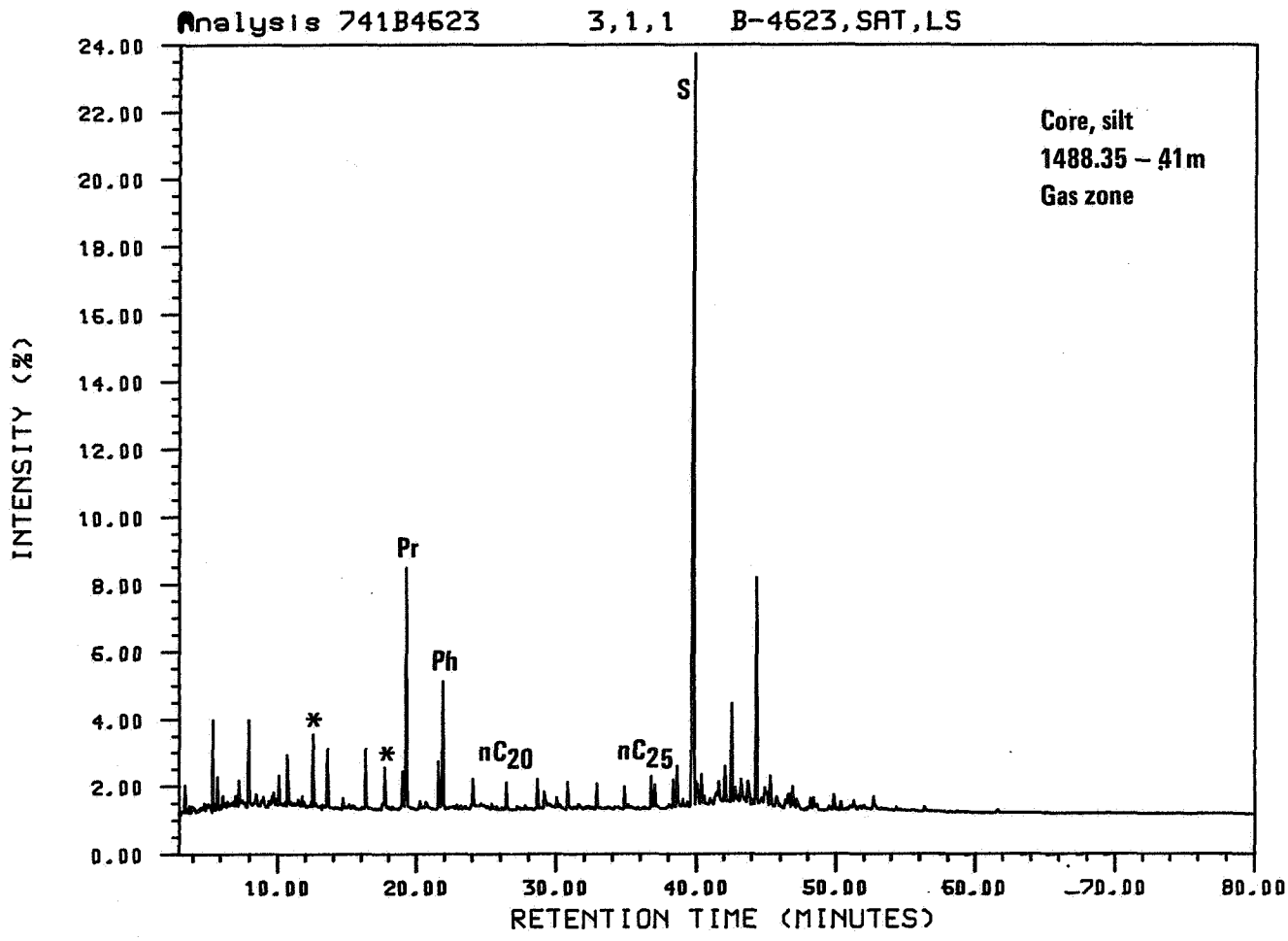
FIGURE 2

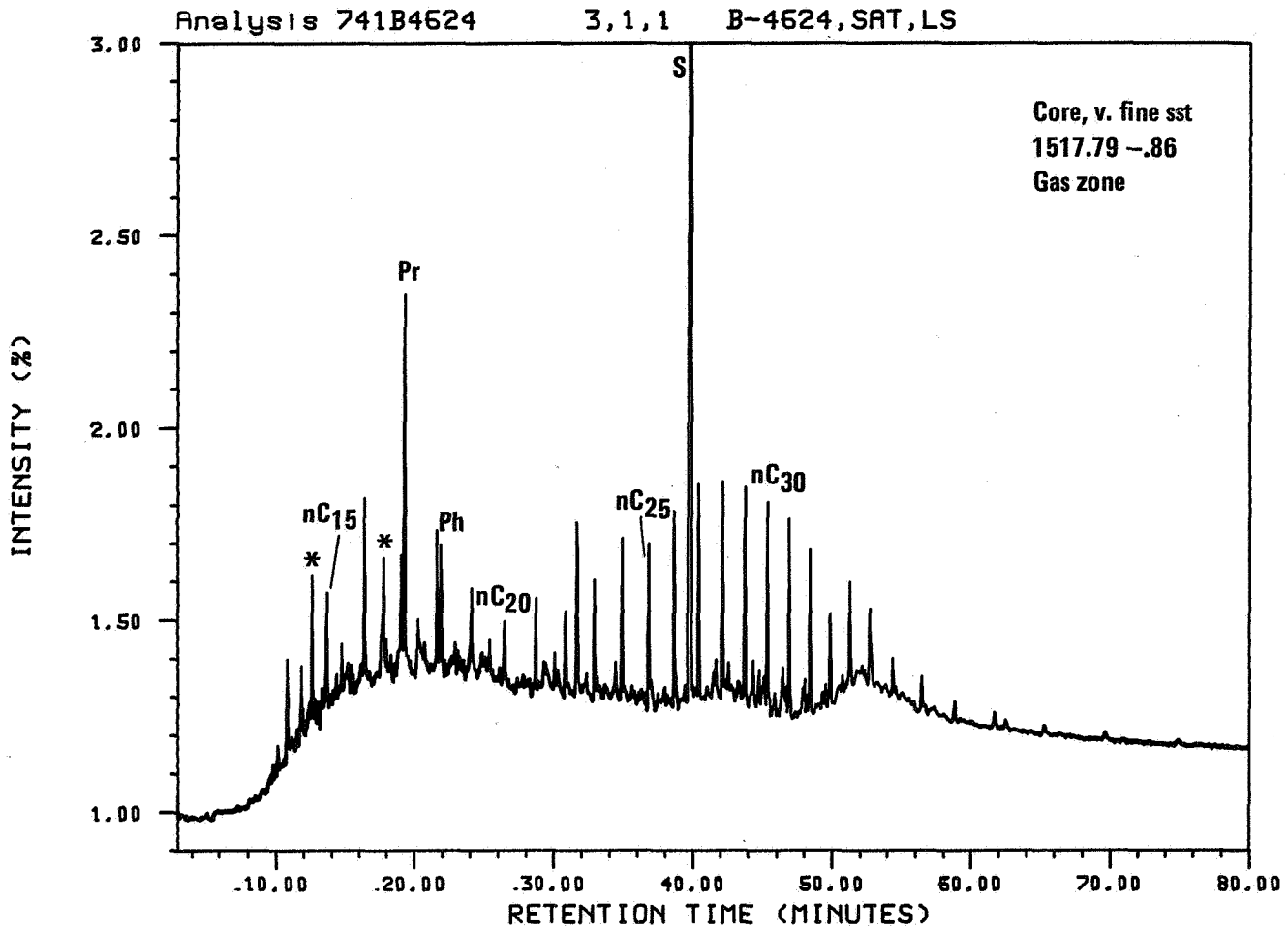
Saturated HC gas chromatograms

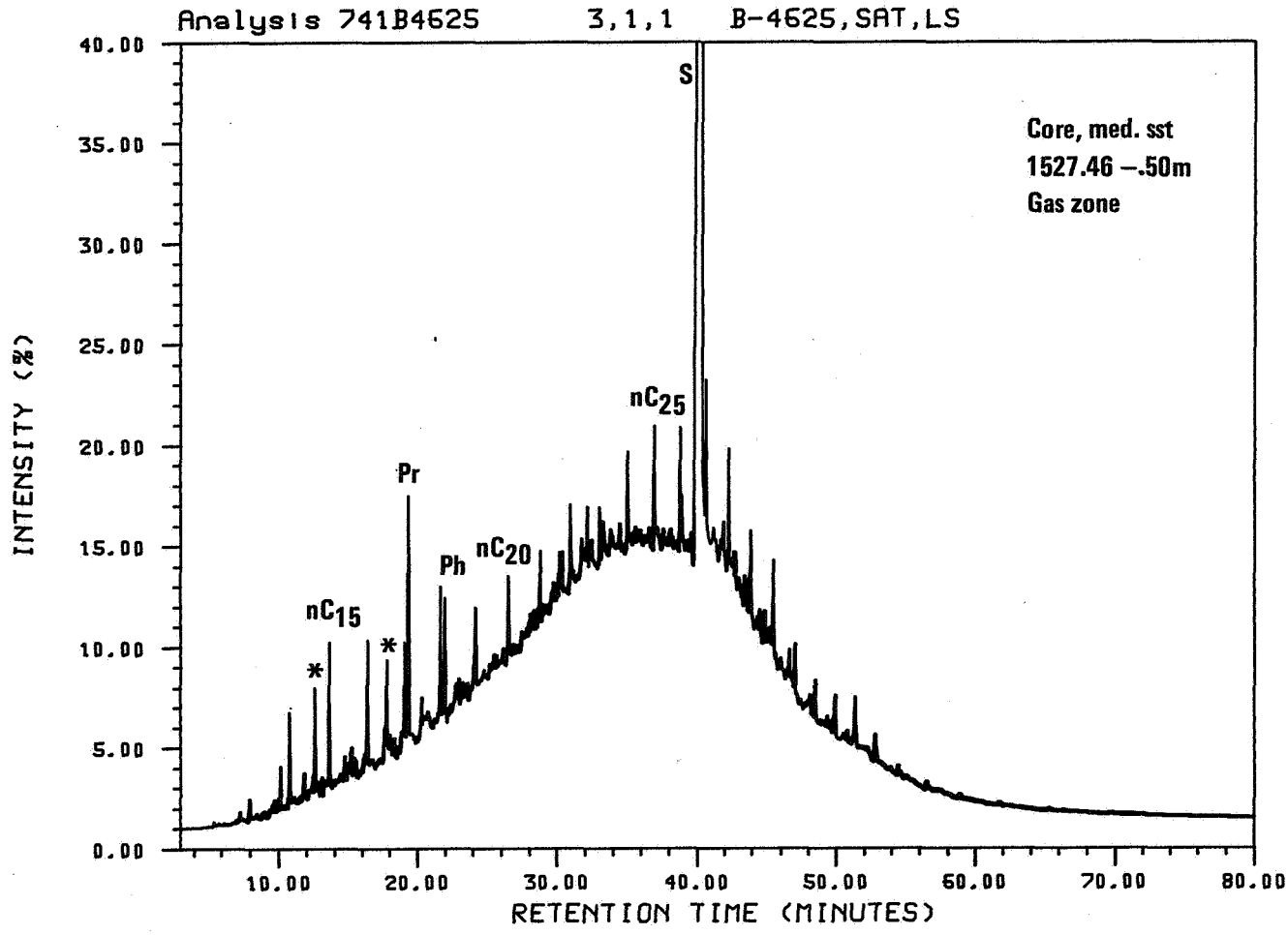
nC_{15} etc. - n-alkanes
Pr - pristane
Ph - phytane
* - acyclic isoprenoids
S - squalane (internal standard)

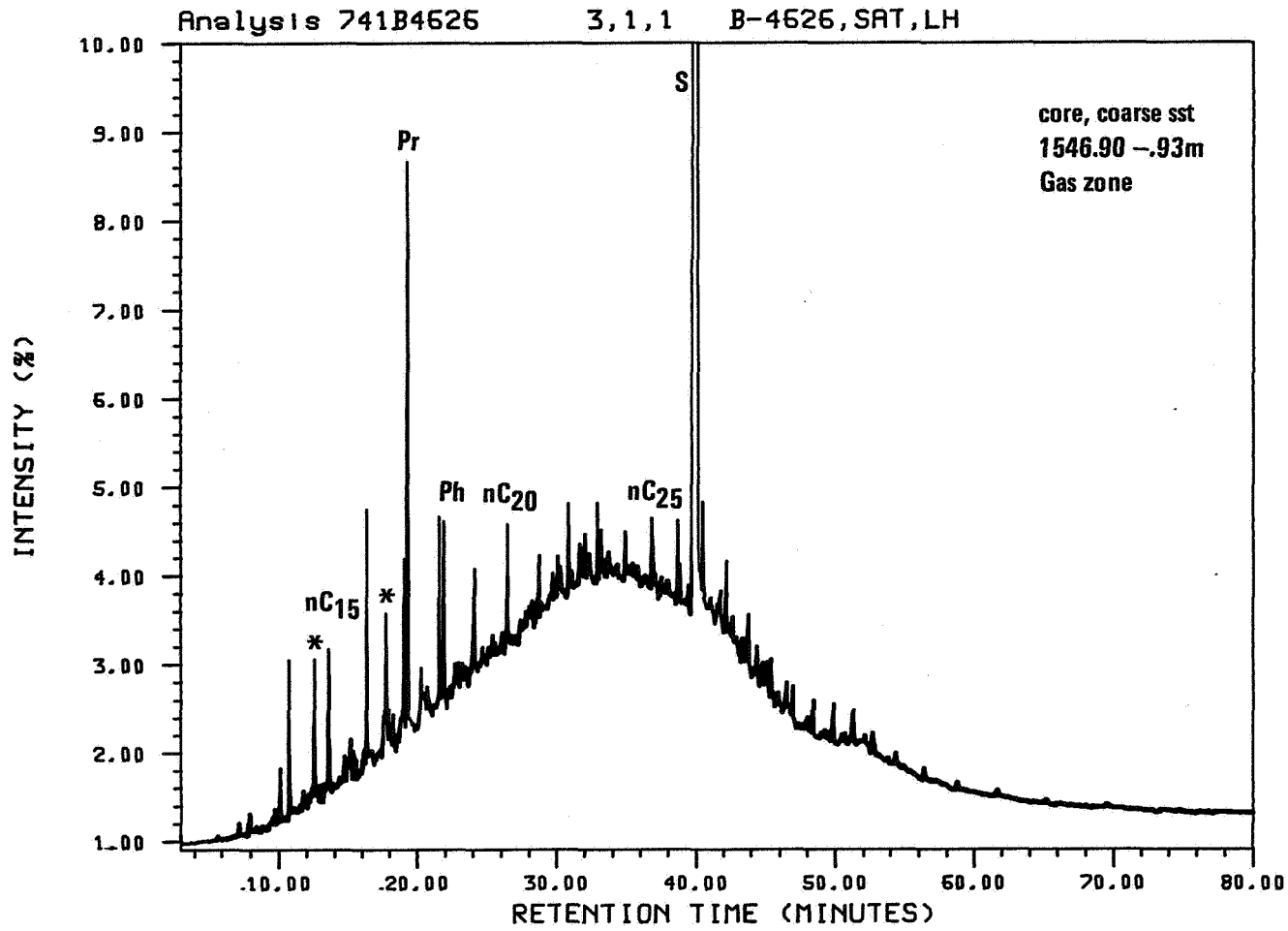

Analysis 741B4631 3,1,1 B-4631,SAT,LS
Oil, DST 1A
INTENSITY (%)
RETENTION TIME (MINUTES)
nC15
Pr
Ph
nC20
nC25
*

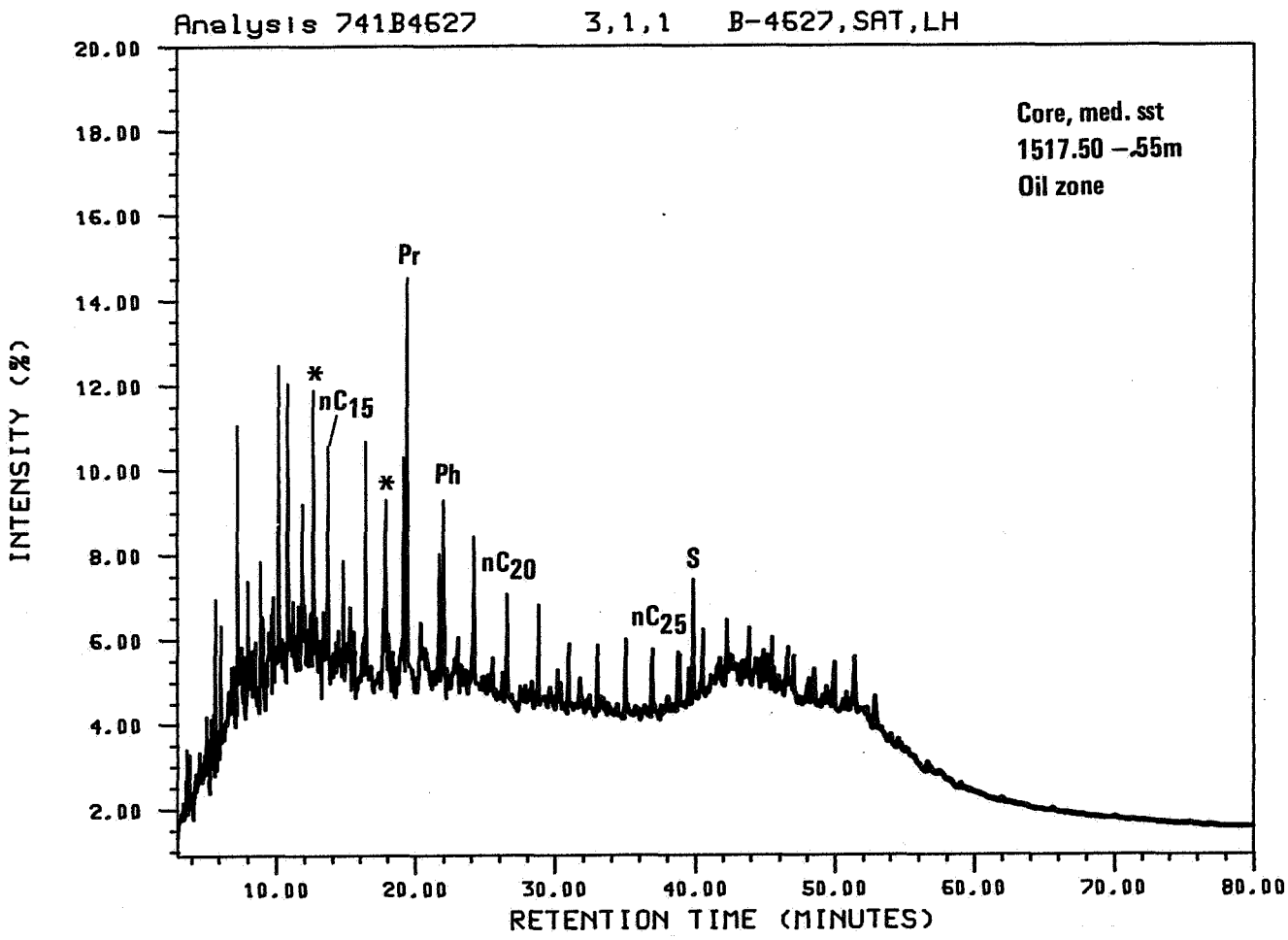

Analysis 741B4632 3,1,1 B-4632,SAT,LS
Condensate
INTENSITY (%)
RETENTION TIME (MINUTES)
nC15
Pr
Ph
*

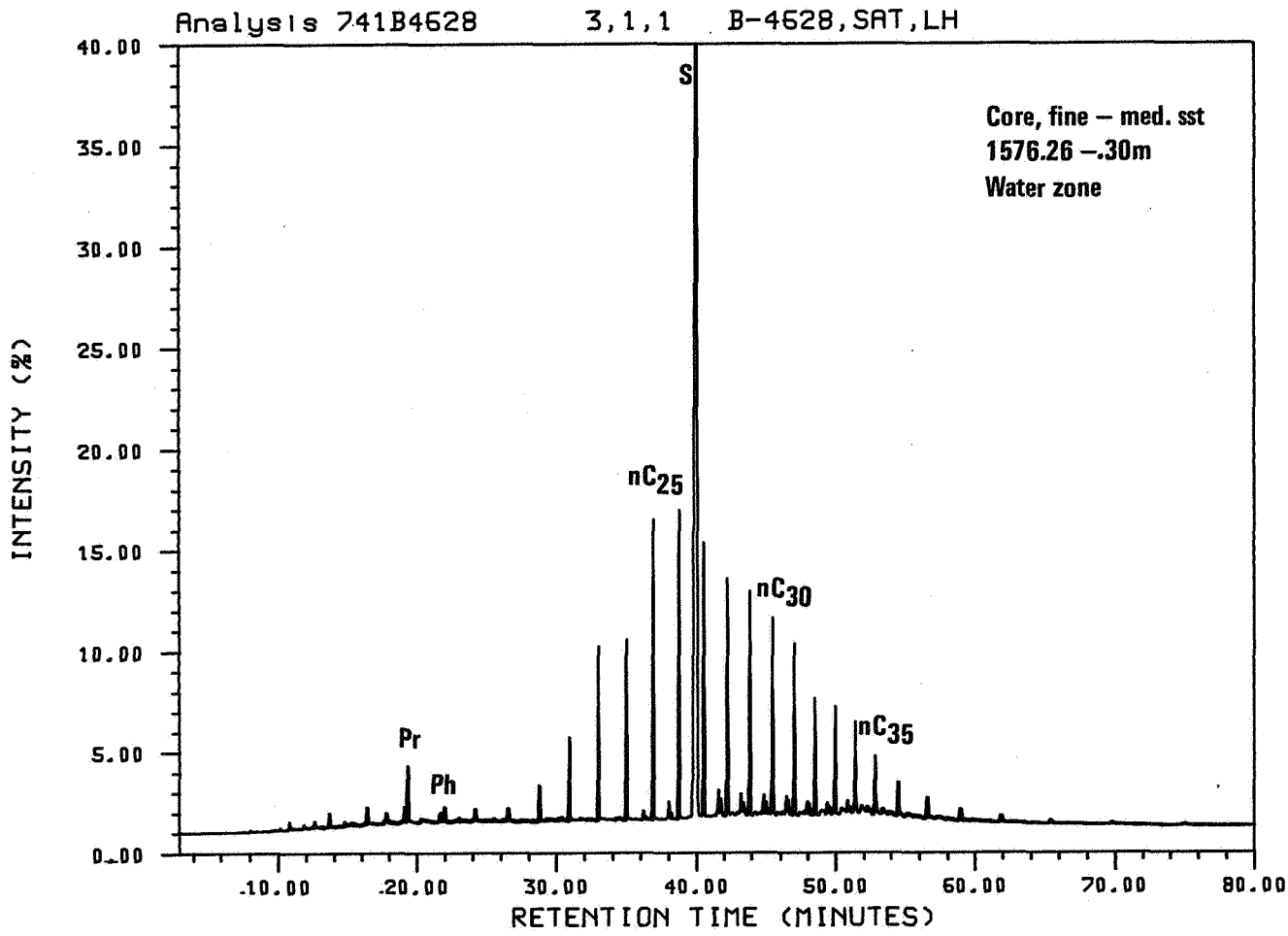

Analysis 741B4623 3,1,1 B-4623,SAT,LS
INTENSITY (%)
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
S
Pr
Ph
*
*
nC20
nC25
Core, silt
1488.35 – 41m
Gas zone
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

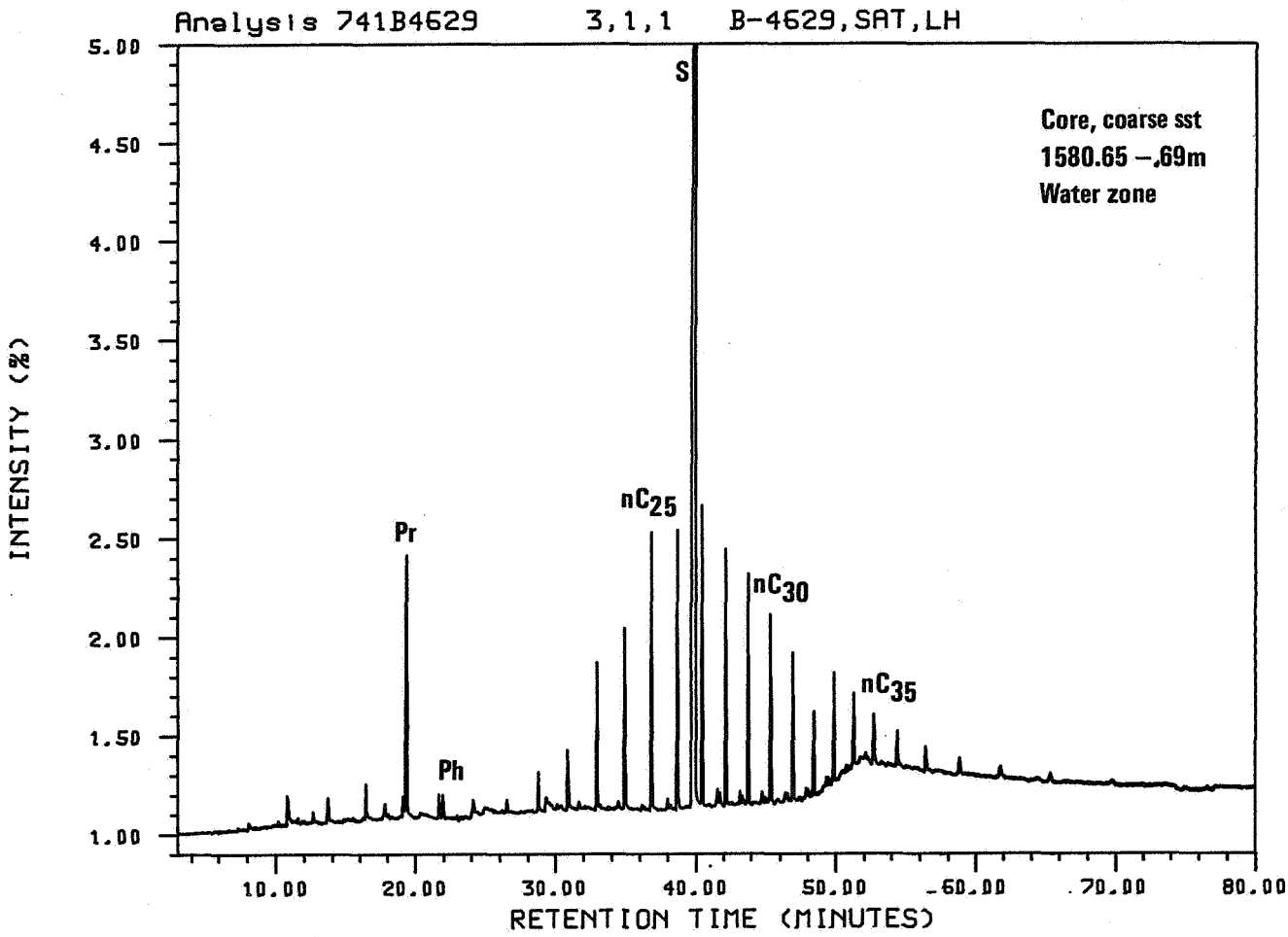

Analysis 741B4624 3,1,1 B-4624,SAT,LS
INTENSITY (%)
3.00
2.50
2.00
1.50
1.00
S
Pr
nC15
*
*
Ph
nC20
nC25
nC30
Core, v. fine sst
1517.79 –.86
Gas zone
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)


Analysis 741B4625 3,1,1 B-4625,SAT,LS
Core, med. sst
1527.46 –.50m
Gas zone
S
Pr
Ph
nC15
nC20
nC25
*
*
INTENSITY (%)
RETENTION TIME (MINUTES)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00


Analysis 741B4626 3,1,1 B-4626,SAT,LH
core, coarse sst
1546.90 –.93m
Gas zone
S
Pr
Ph
nC15
nC20
nC25
*
*
INTENSITY (%)
RETENTION TIME (MINUTES)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00


Analysis 741B4627 3,1,1 B-4627,SAT,LH
Core, med. sst
1517.50 –.55m
Oil zone
Pr
*
nC15
*
Ph
nC20
S
nC25
INTENSITY (%)
RETENTION TIME (MINUTES)


Analysis 741B4628 3,1,1 B-4628,SAT,LH
Core, fine – med. sst
1576.26 –.30m
Water zone
S
nC25
nC30
nC35
Pr
Ph
INTENSITY (%)
RETENTION TIME (MINUTES)


Analysis 741B4629 3,1,1 B-4629,SAT,LH
INTENSITY (%)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
S
Pr
Ph
nC25
nC30
nC35
Core, coarse sst
1580.65 –.69m
Water zone
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

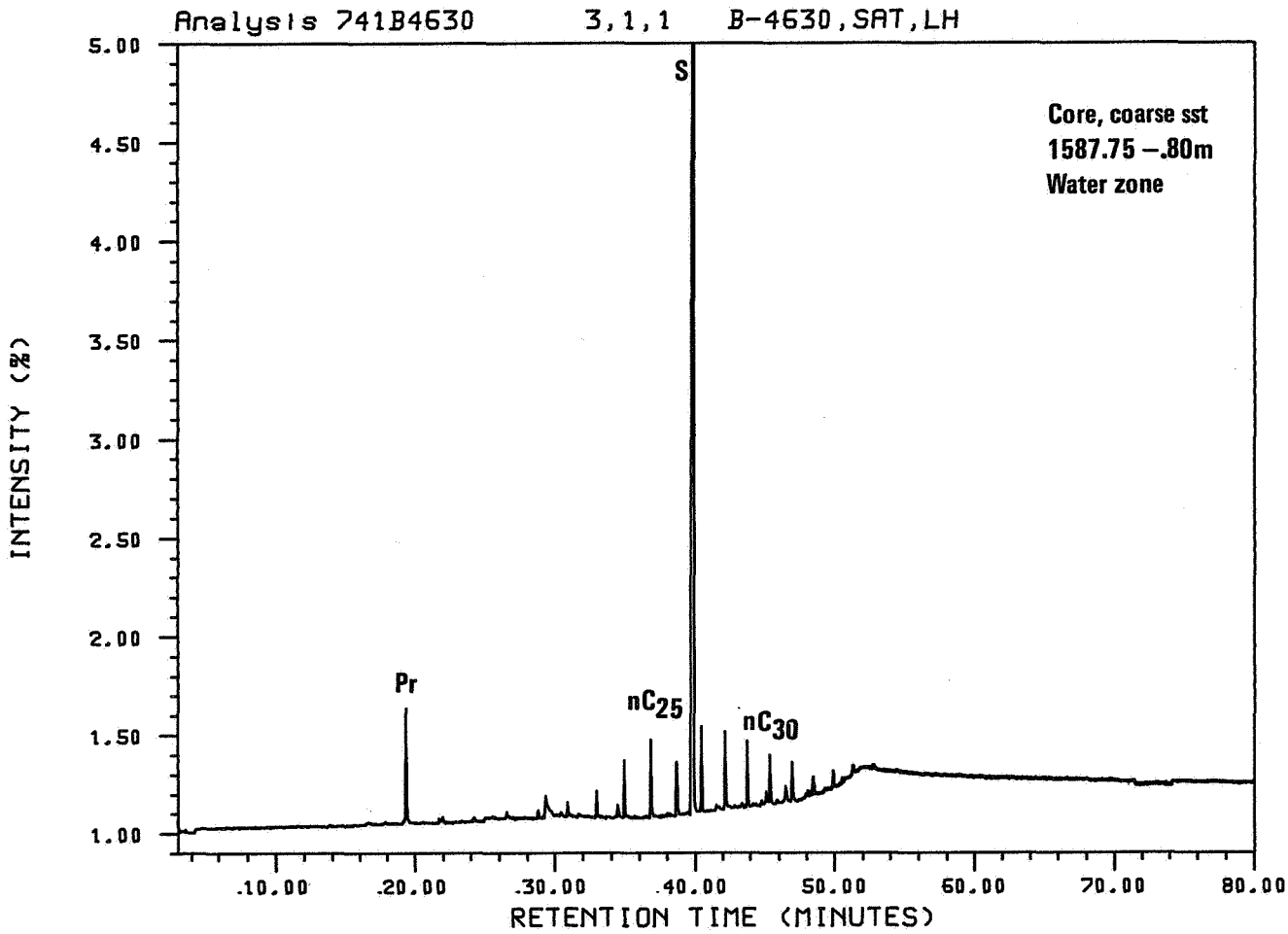
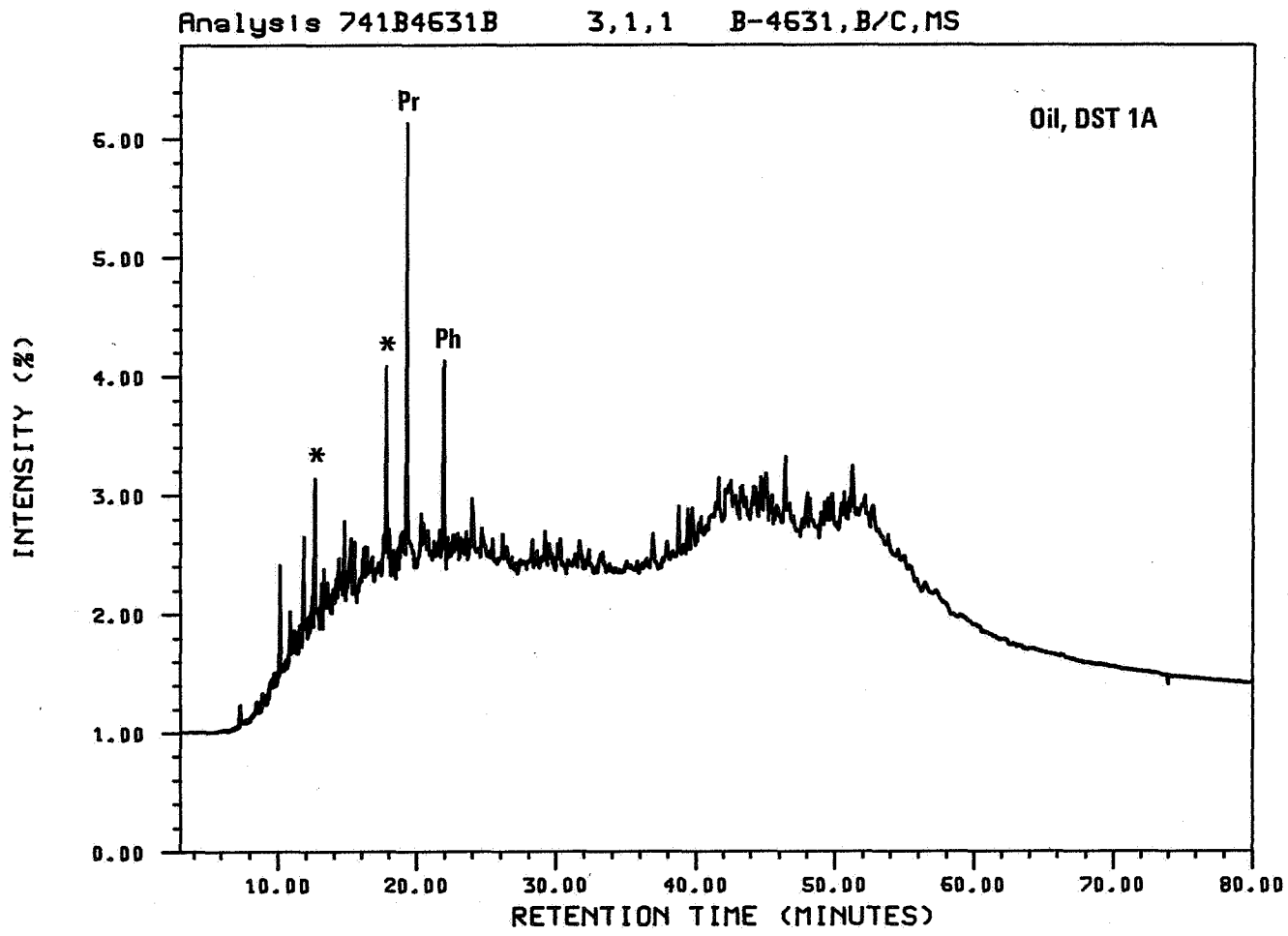
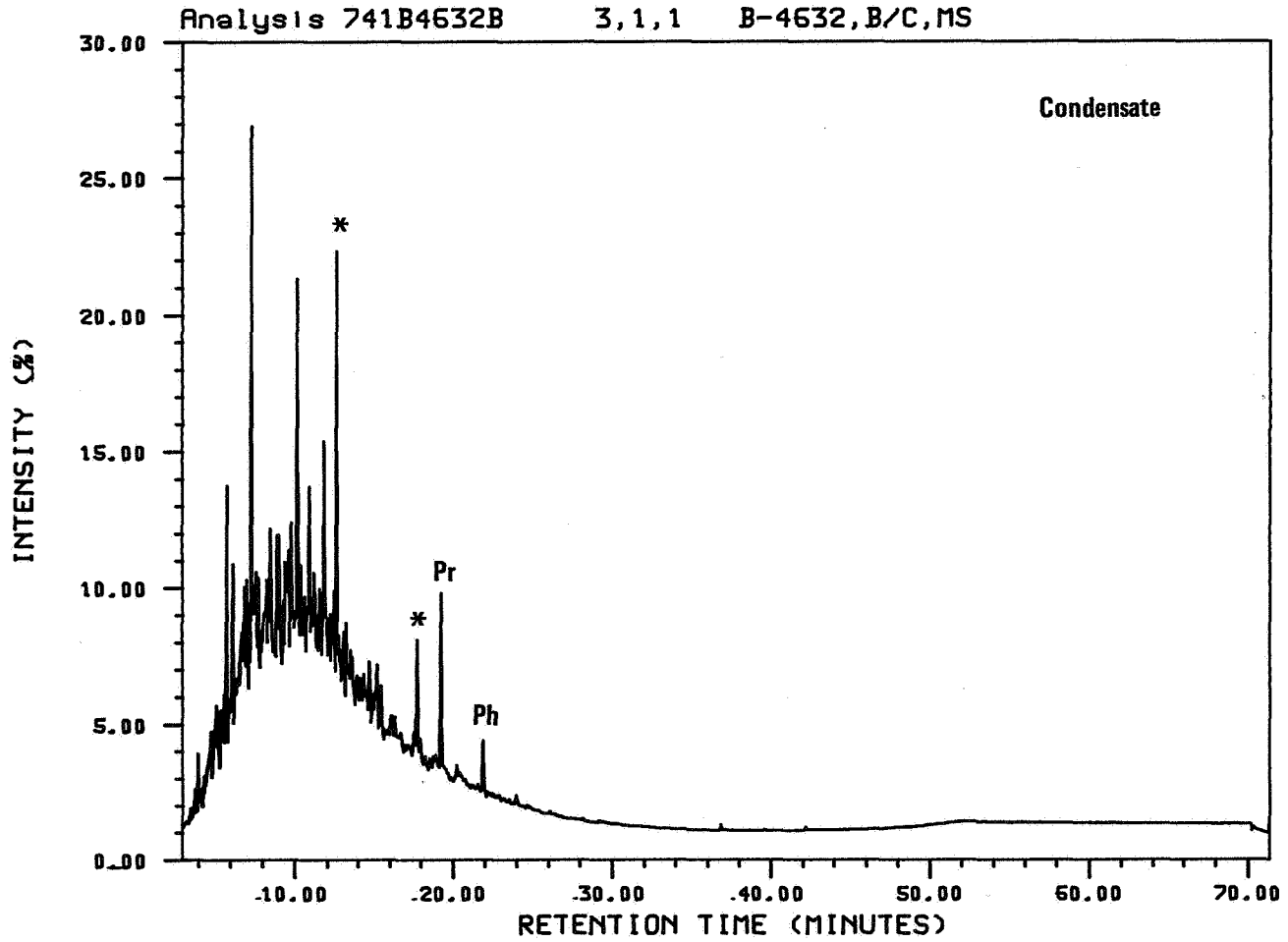

Analysis 741B4630 3,1,1 B-4630,SAT,LH
INTENSITY (%)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
S
Pr
nC25
nC30
Core, coarse sst
1587.75 –.80m
Water zone
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

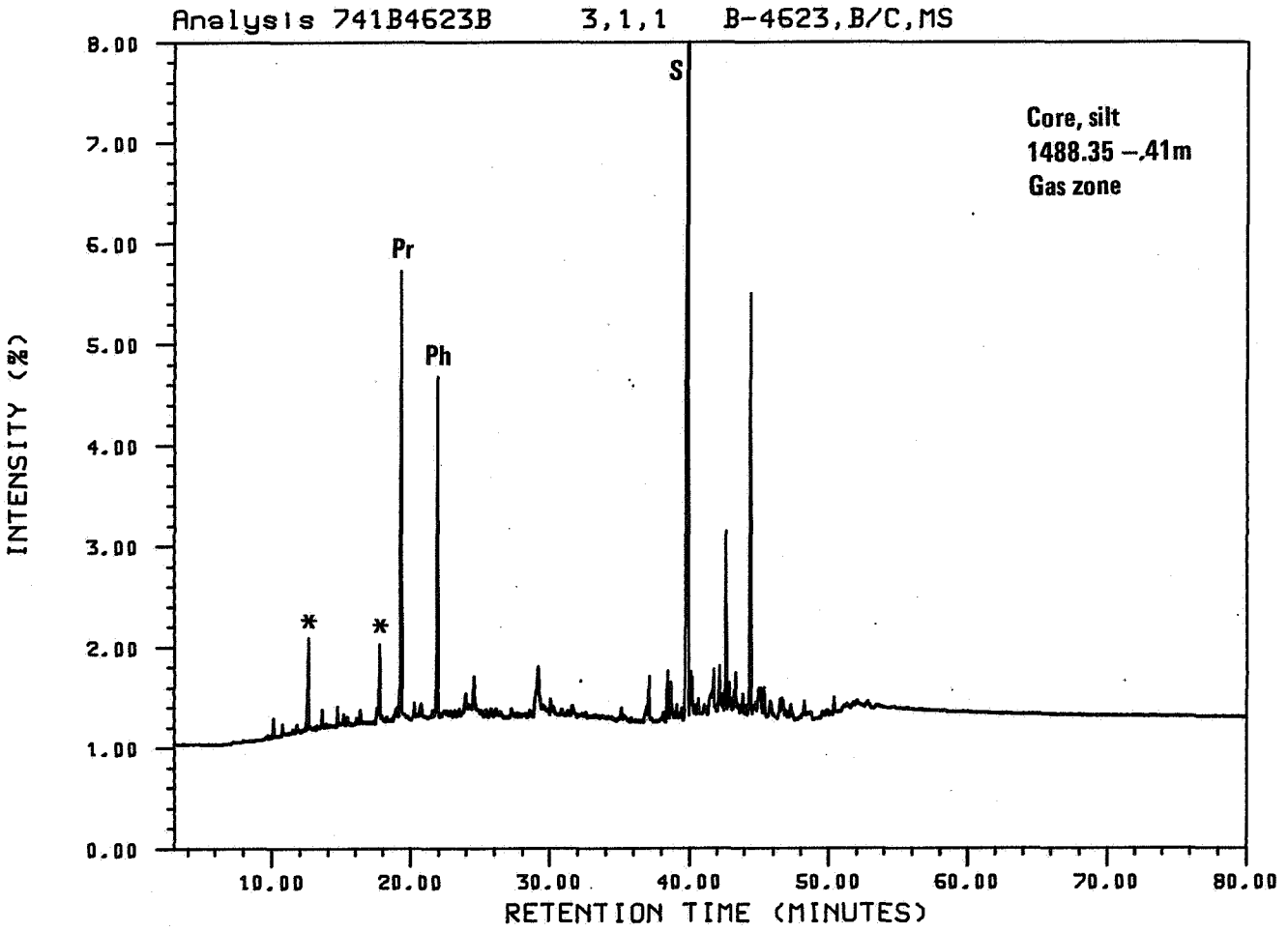
FIGURE 3

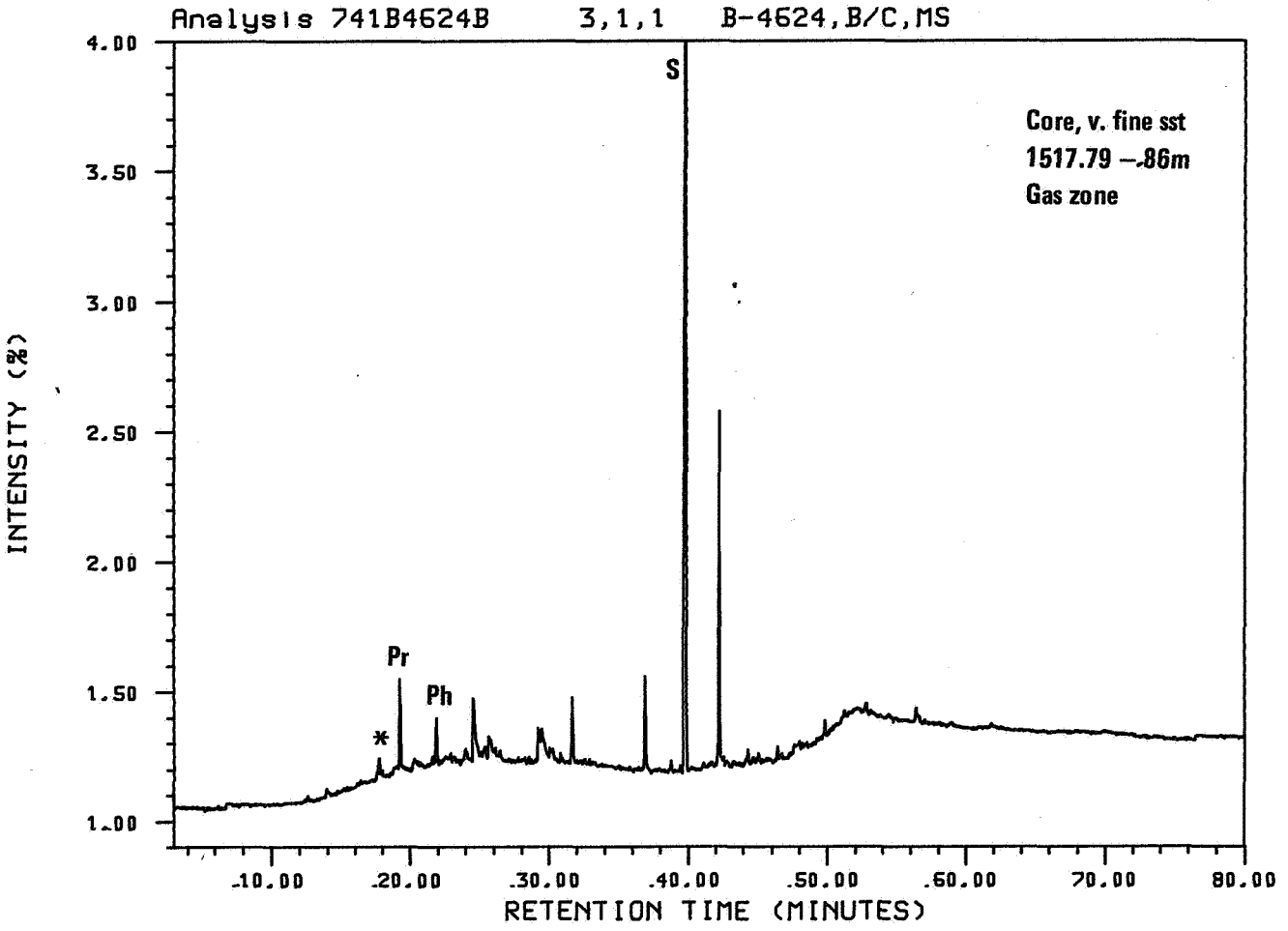
Branched/cyclic HC gas chromatograms

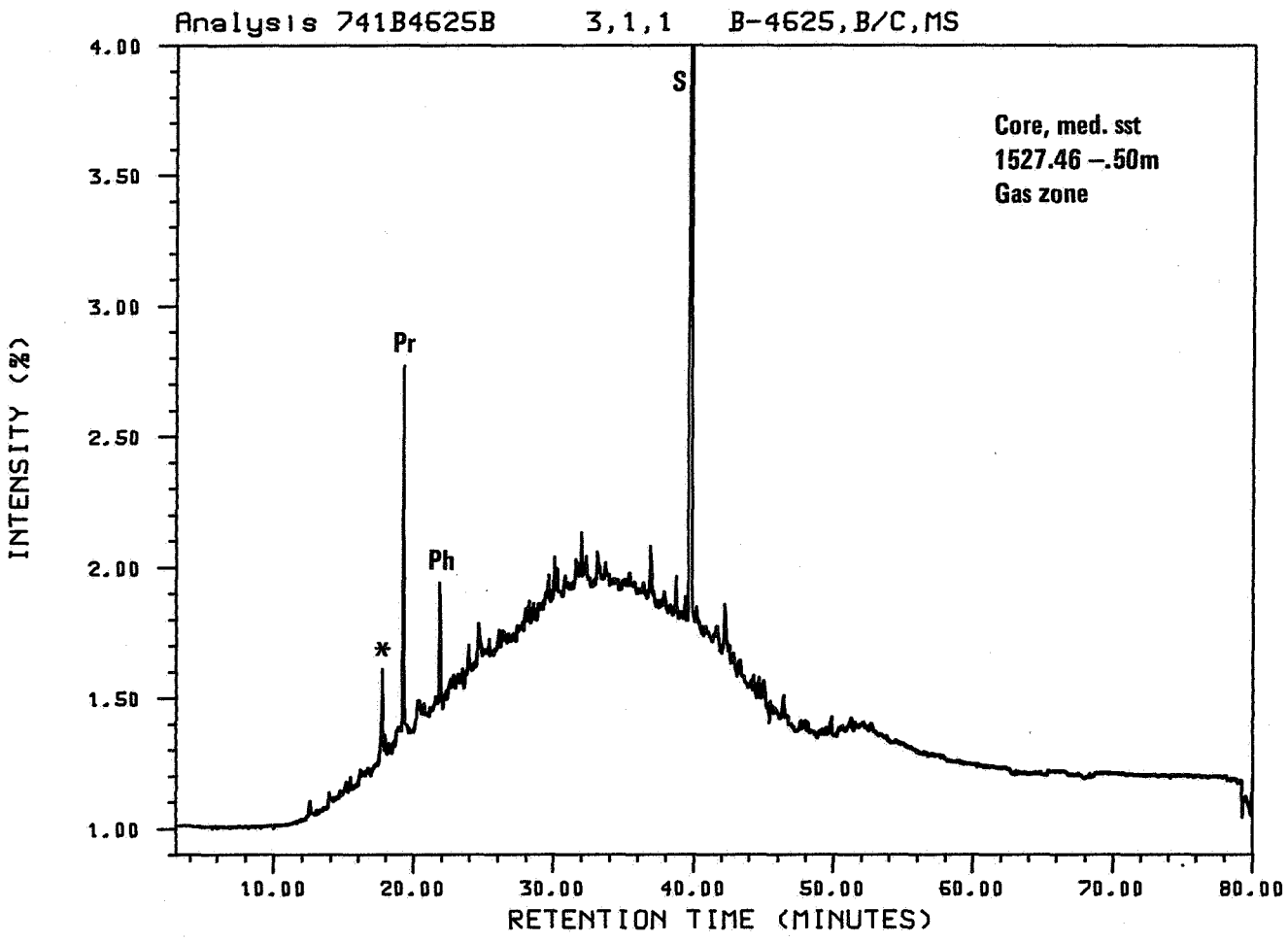
Pr - pristane
Ph - phytane
* - acyclic isoprenoids
S - squalane (internal standard)

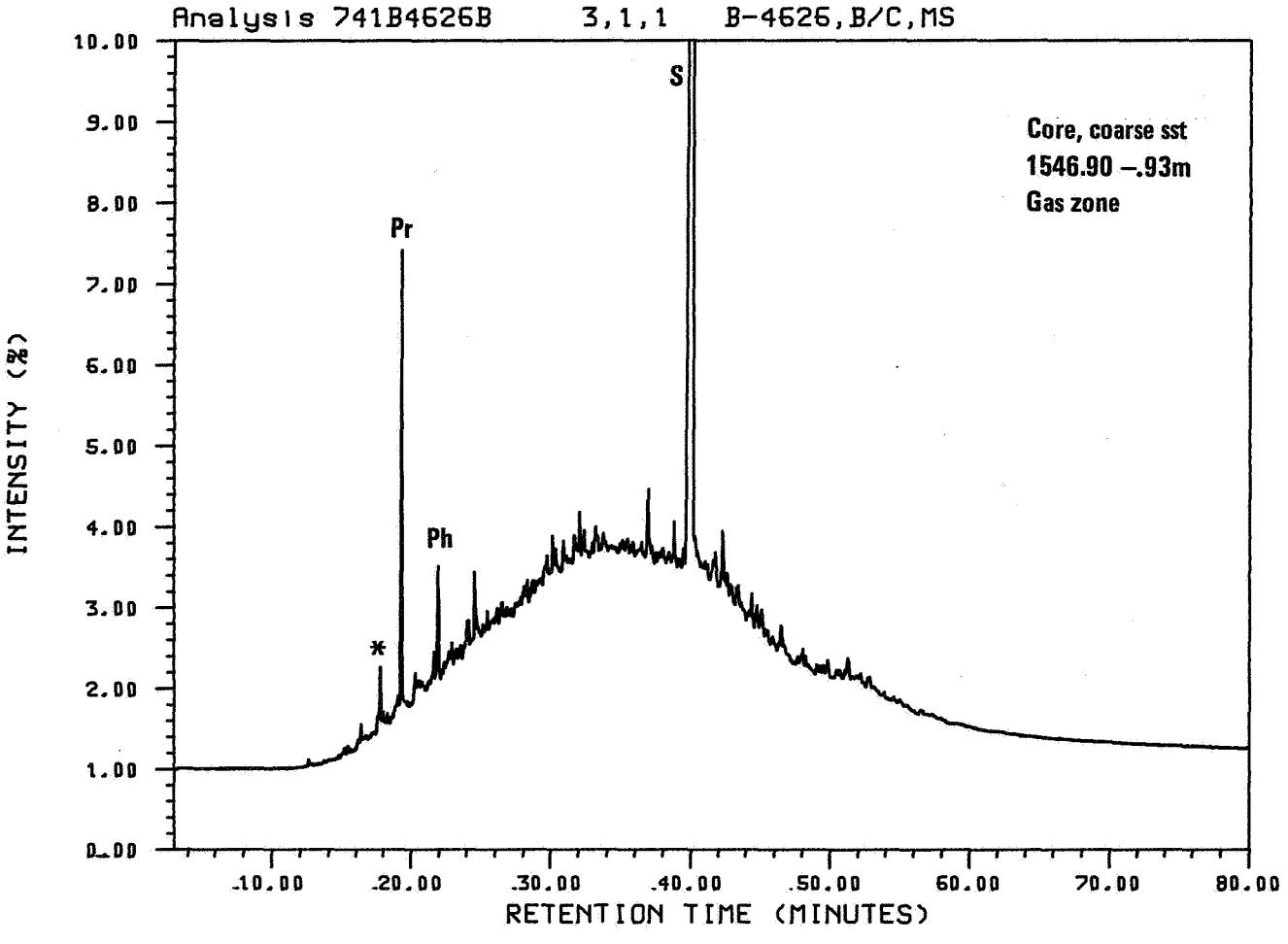

Analysis 741B4631B 3,1,1 B-4631,B/C,MS
Oil, DST 1A
Pr
Ph
*
*
INTENSITY (%)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

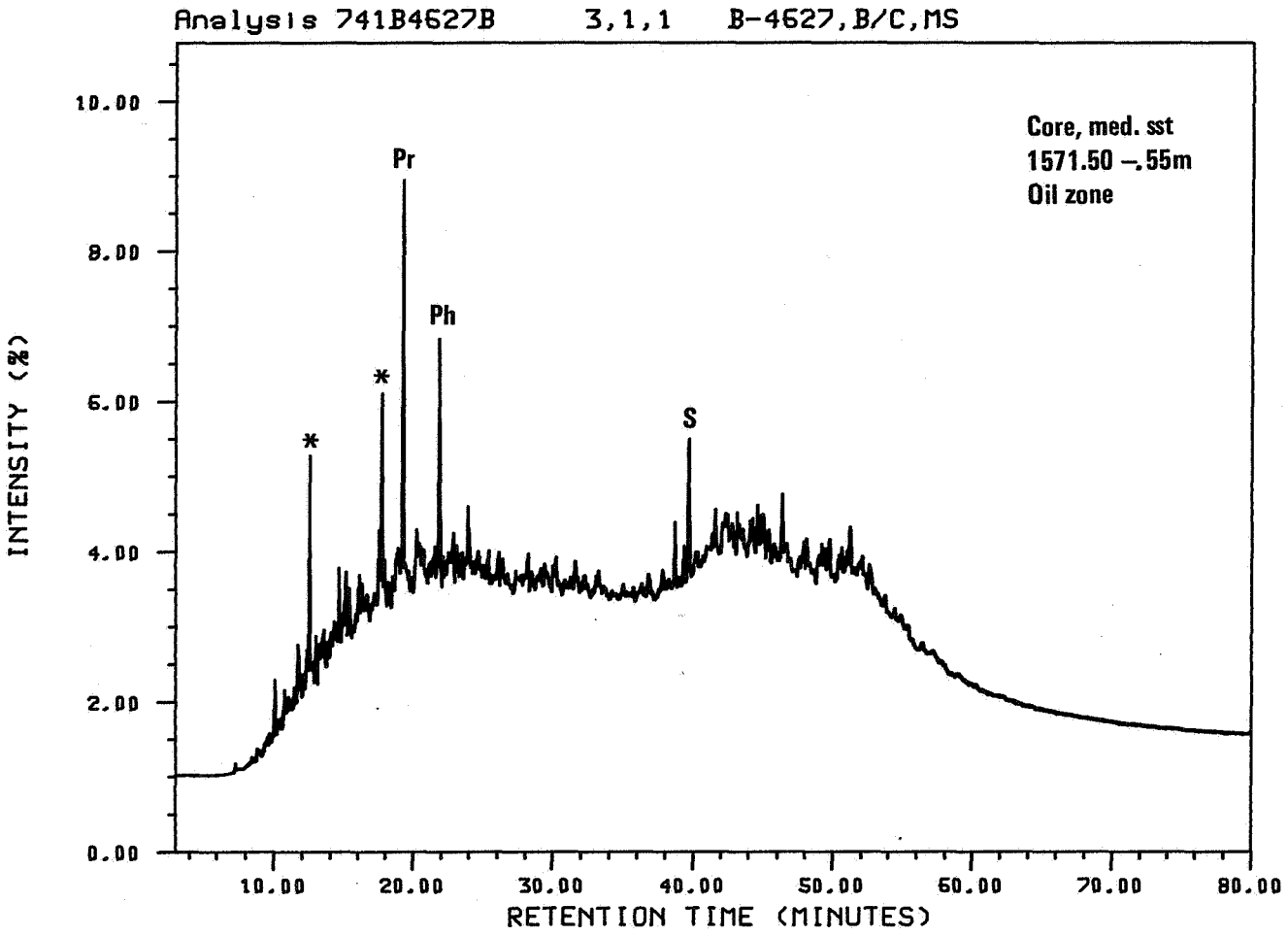

Analysis 741B4632B 3,1,1 B-4632,B/C,MS
Condensate
*
Pr
*
Ph
INTENSITY (%)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
RETENTION TIME (MINUTES)

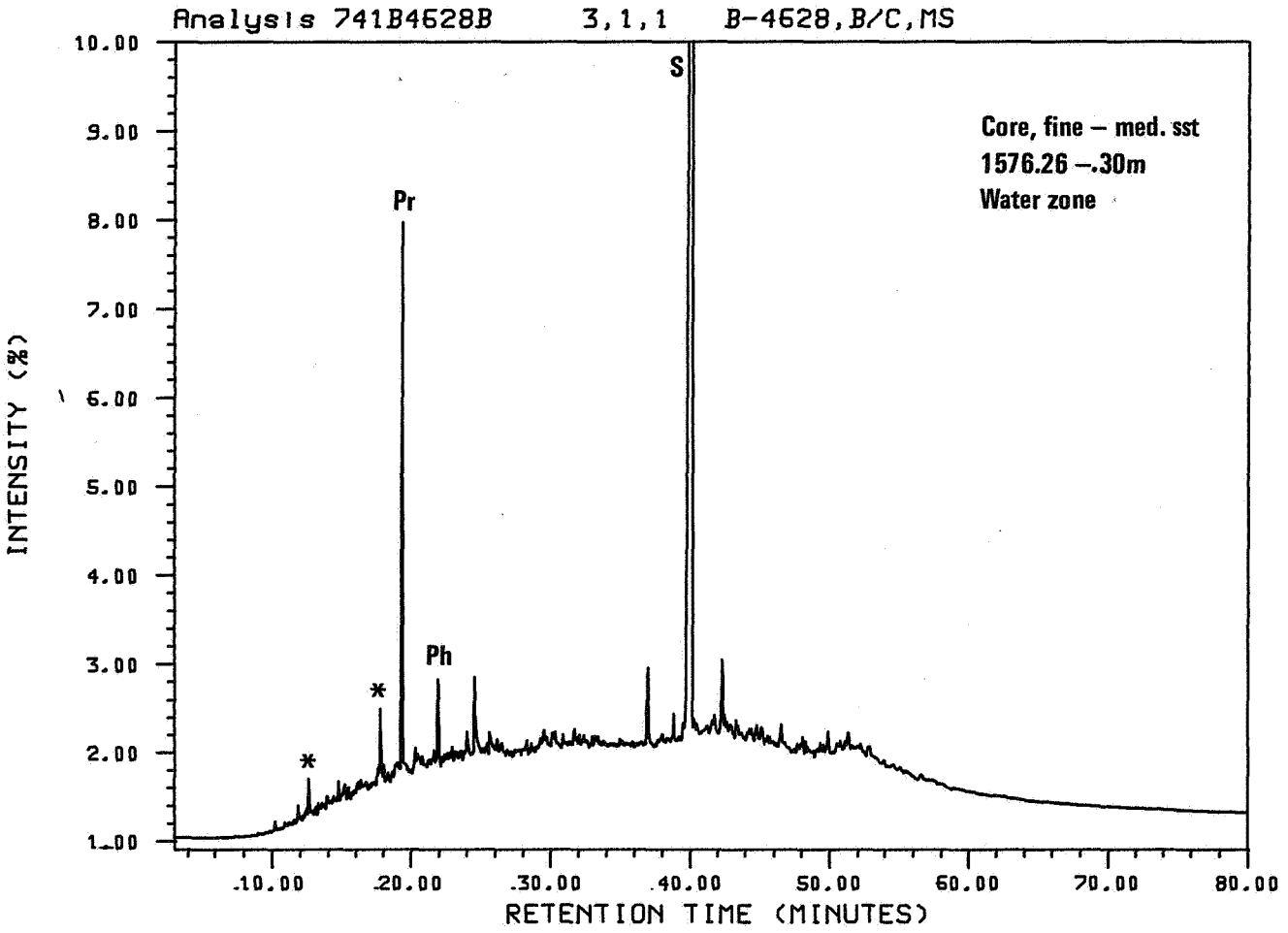

Analysis 741B4623B 3,1,1 B-4623,B/C,MS
INTENSITY (%)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
S
Pr
Ph
*
*
Core, silt
1488.35 –.41m
Gas zone
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

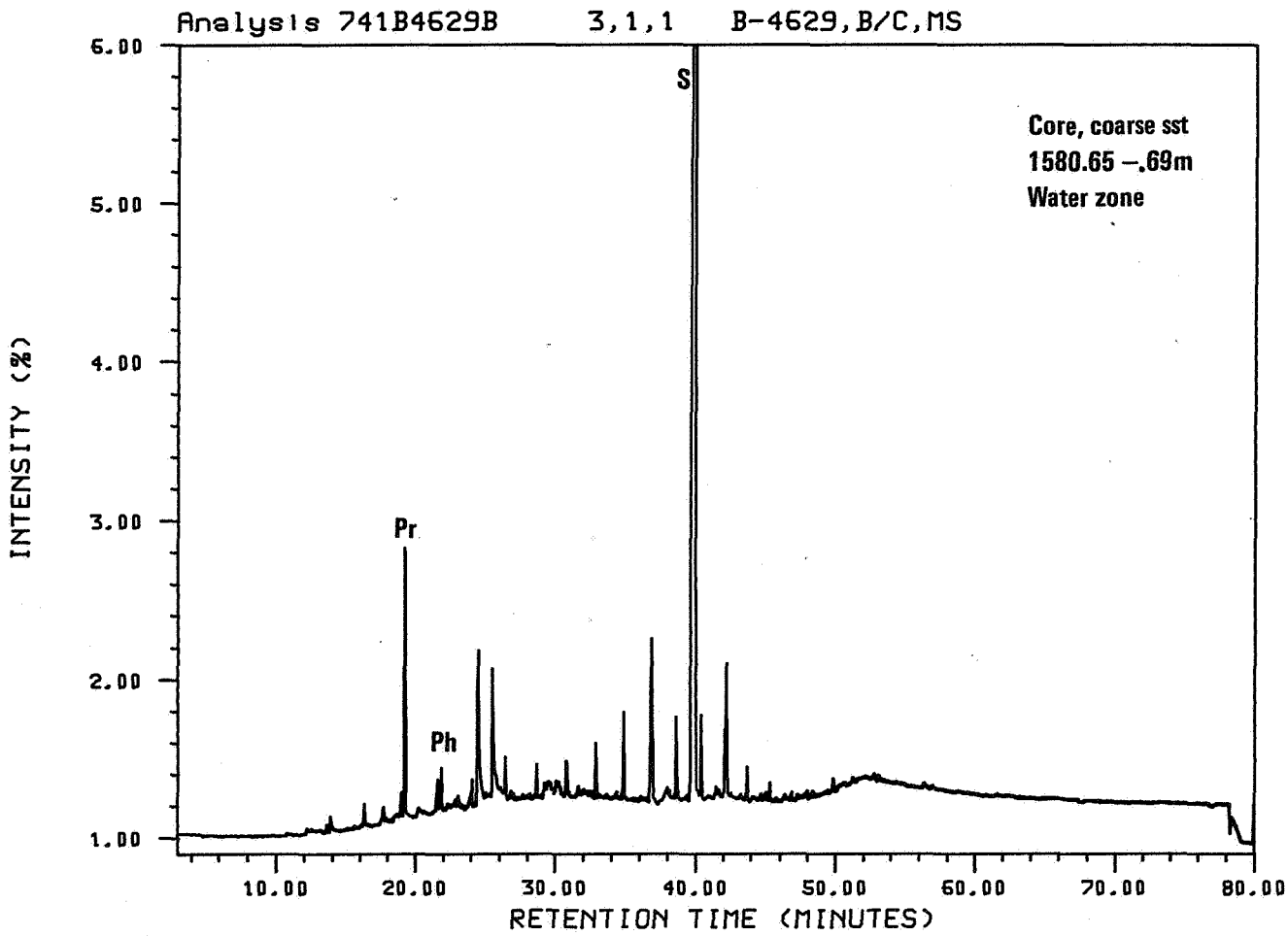

Analysis 741B4624B 3,1,1 B-4624,B/C,MS
INTENSITY (%)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
S
Pr
Ph
*
Core, v. fine sst
1517.79 –.86m
Gas zone
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)


Analysis 741B4625B 3,1,1 B-4625,B/C,MS
Core, med. sst
1527.46 –.50m
Gas zone
S
Pr
Ph
*
INTENSITY (%)
RETENTION TIME (MINUTES)


Analysis 741B4626B 3,1,1 B-4626,B/C,MS
Core, coarse sst
1546.90 –.93m
Gas zone
S
Pr
Ph
*
INTENSITY (%)
RETENTION TIME (MINUTES)


Analysis 741B4627B 3,1,1 B-4627,B/C,MS
Core, med. sst
1571.50 –.55m
Oil zone
Pr
Ph
S
*
*
*
INTENSITY (%)
RETENTION TIME (MINUTES)
10.00
8.00
6.00
4.00
2.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00


Analysis 741B4628B 3,1,1 B-4628,B/C,MS
Core, fine – med. sst
1576.26 –.30m
Water zone
S
Pr
Ph
*
*
*
INTENSITY (%)
RETENTION TIME (MINUTES)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00


Analysis 741B4629B 3,1,1 B-4629,B/C,MS
S
Pr
Ph
Core, coarse sst
1580.65 –.69m
Water zone
INTENSITY (%)
6.00
5.00
4.00
3.00
2.00
1.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

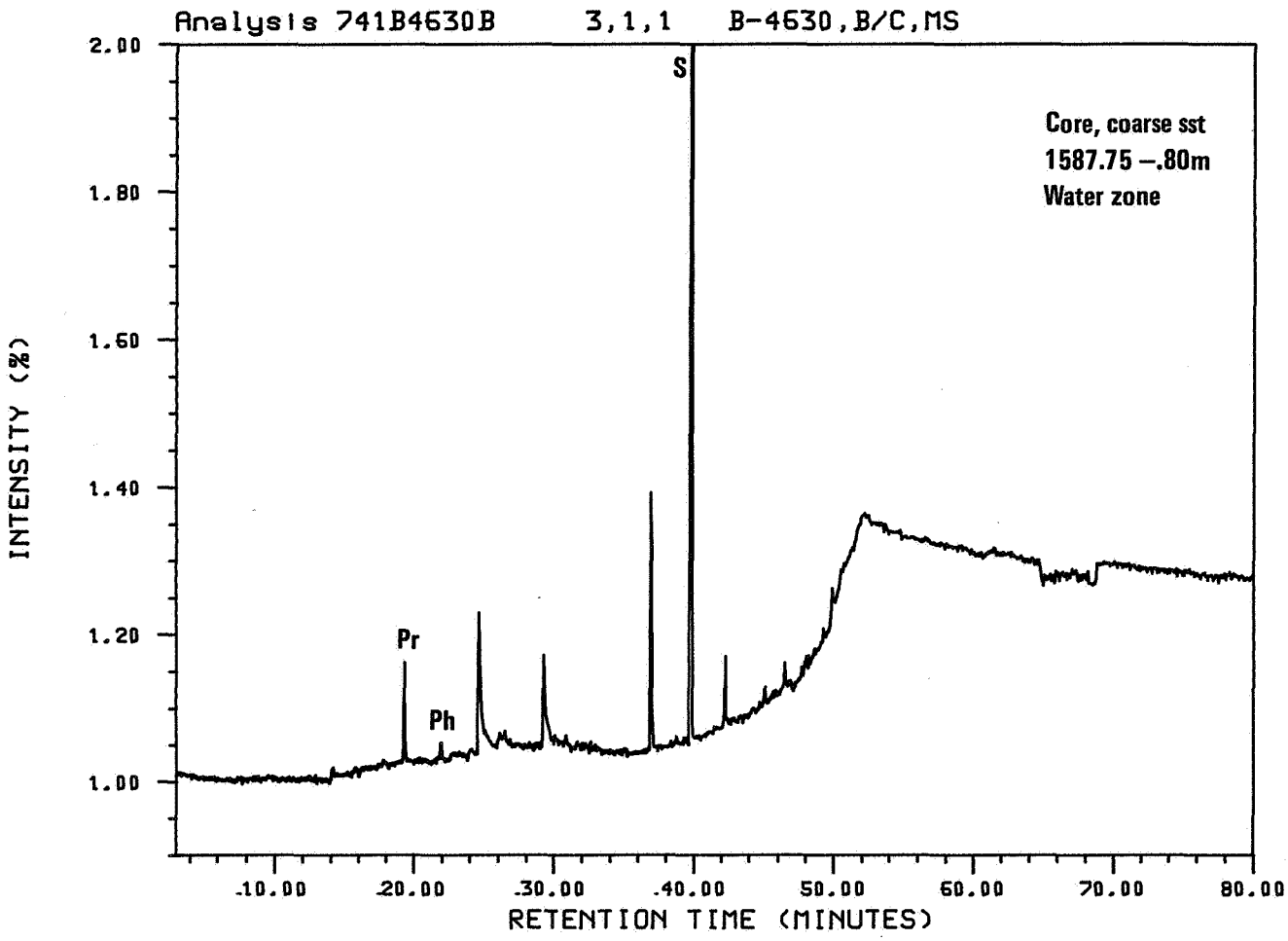
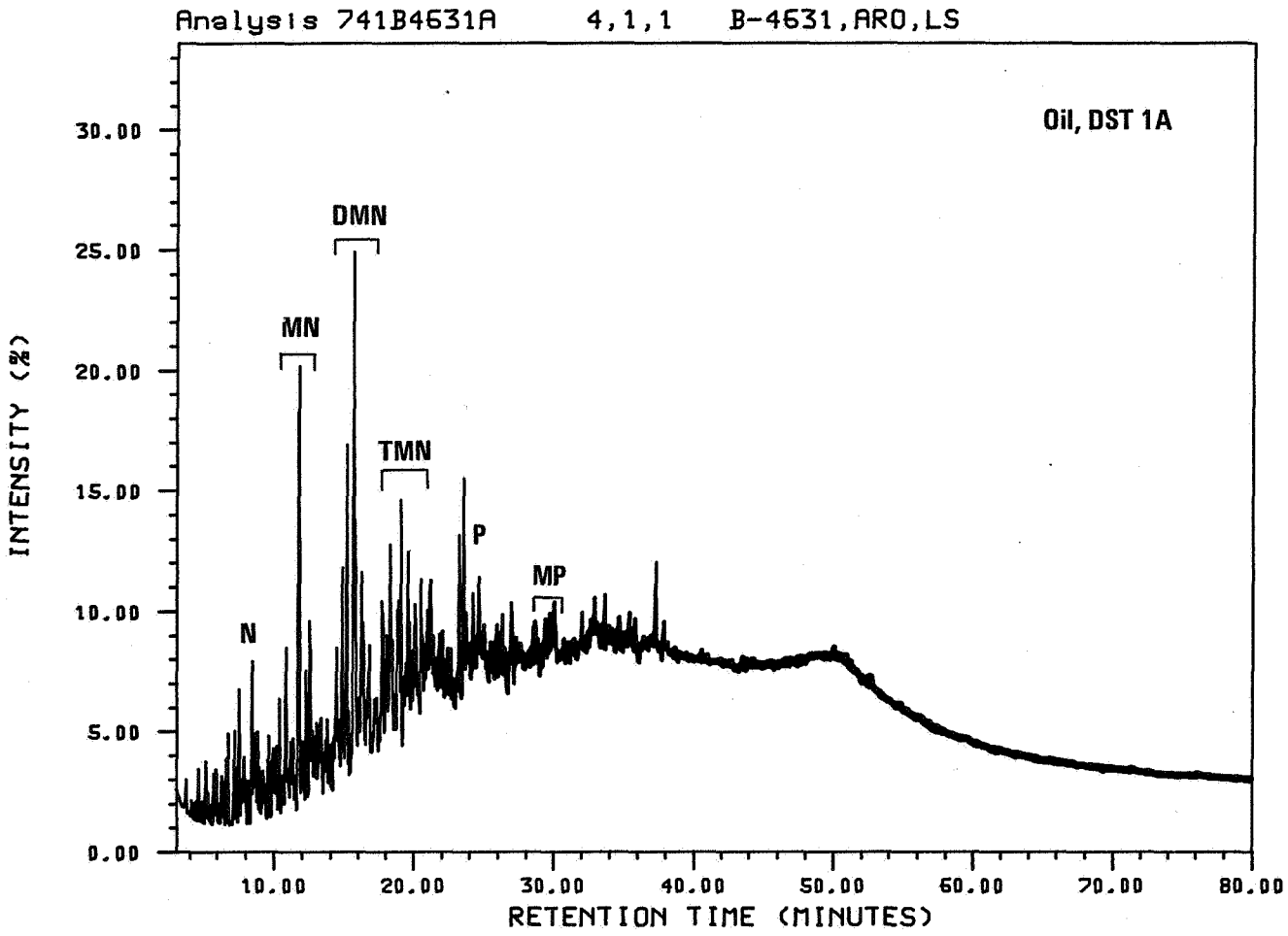
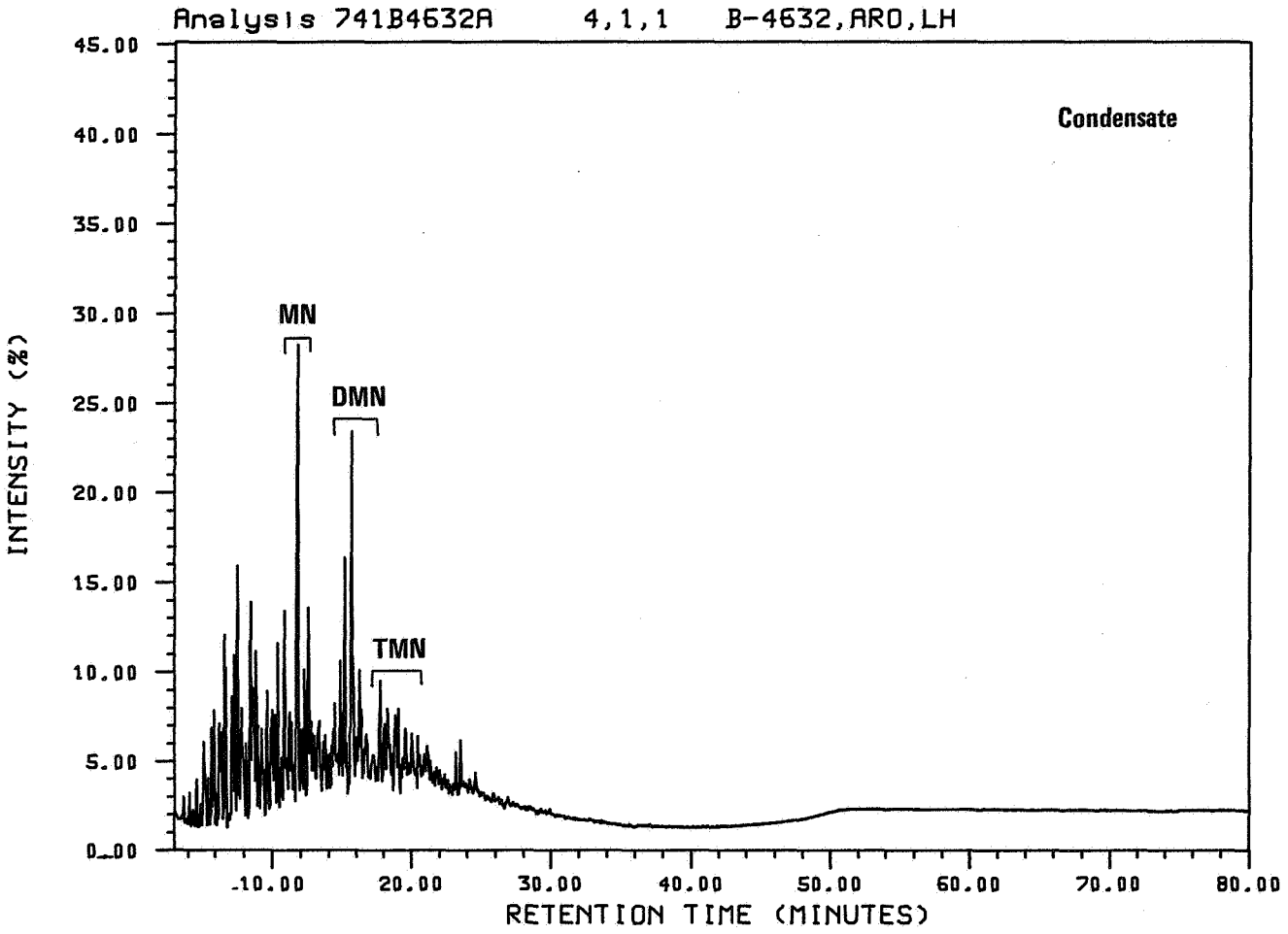

Analysis 741B4630B 3,1,1 B-4630,B/C,MS
S
Pr
Ph
Core, coarse sst
1587.75 –.80m
Water zone
INTENSITY (%)
2.00
1.80
1.60
1.40
1.20
1.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

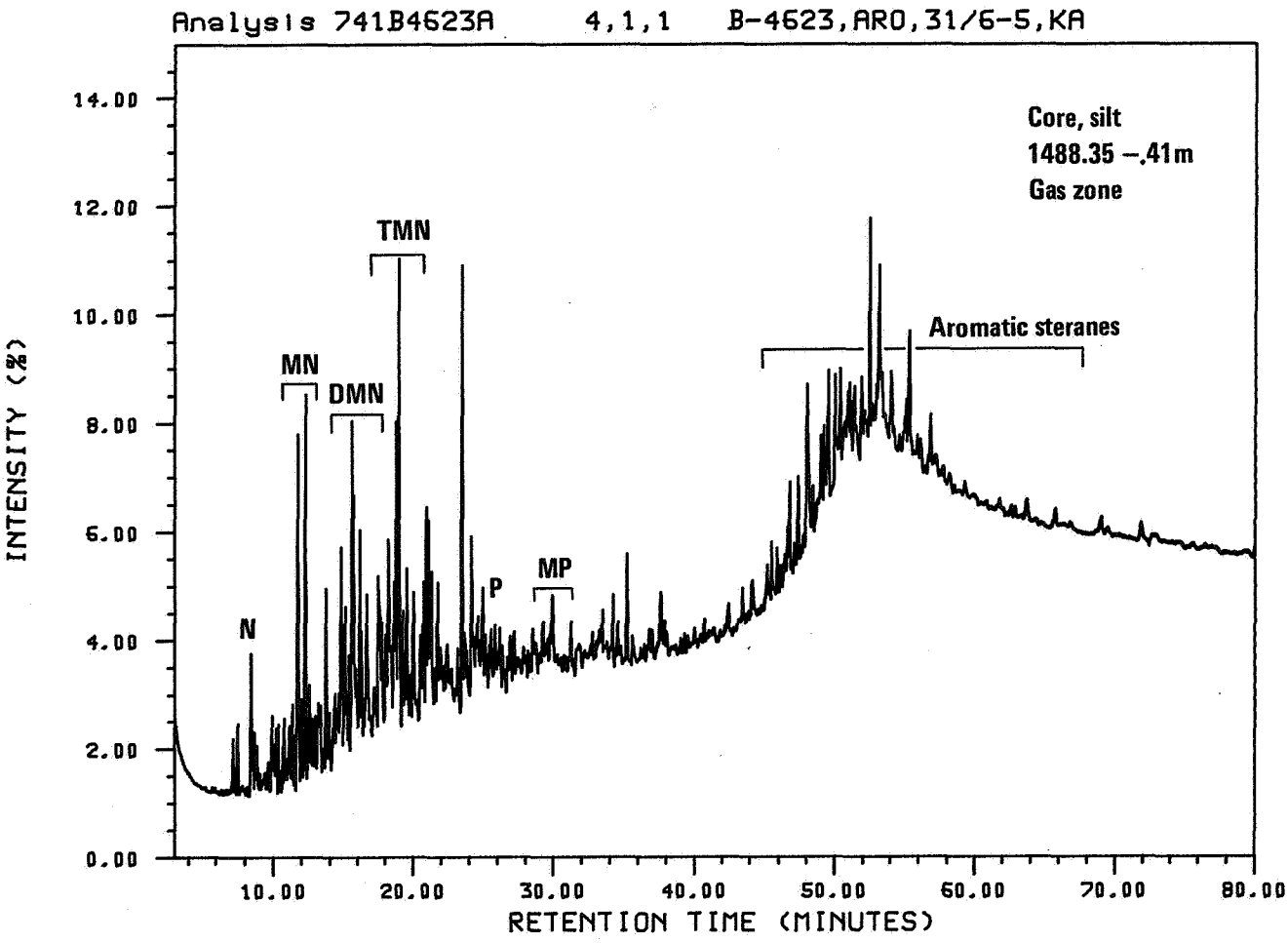
FIGURE 4

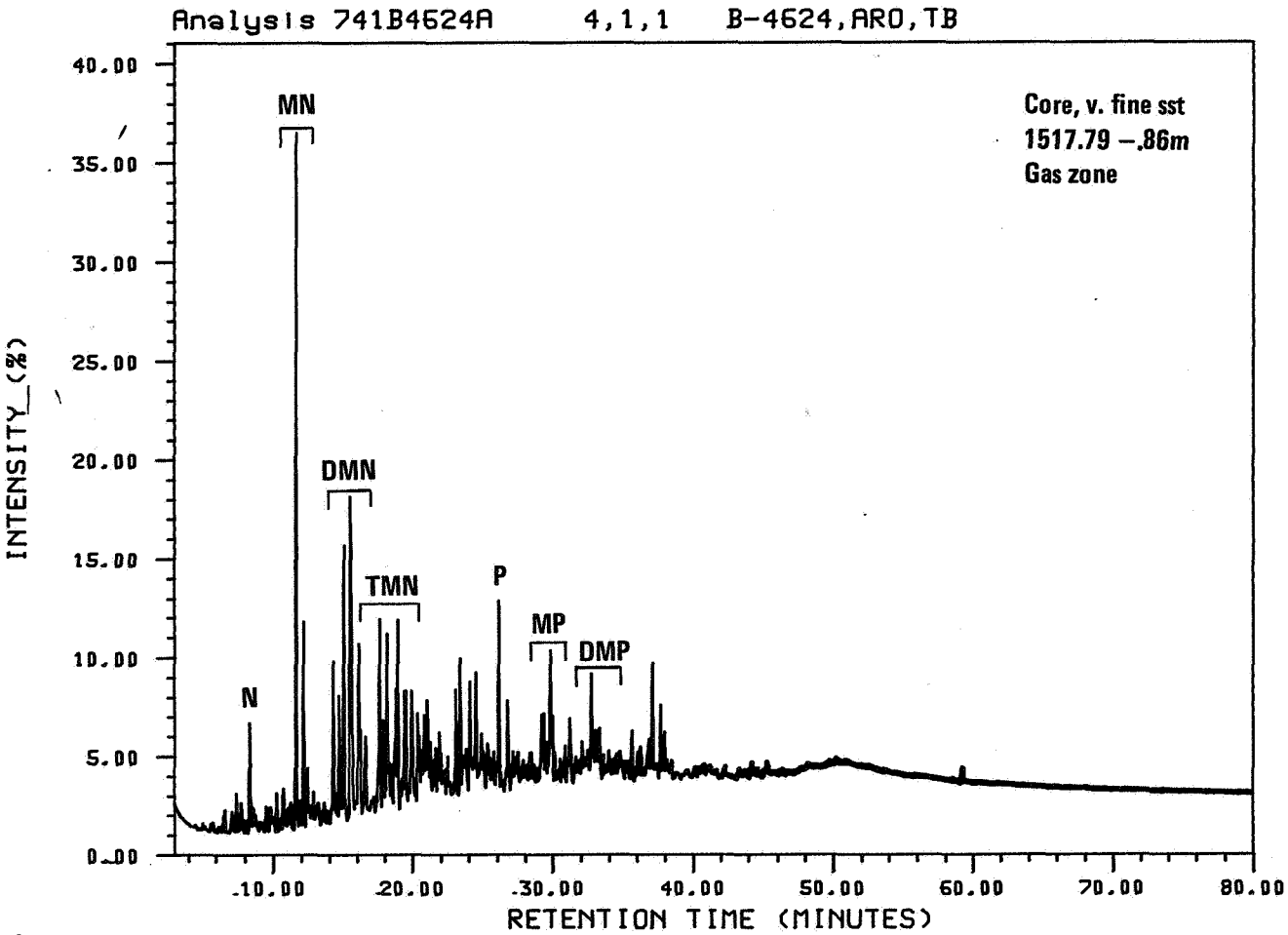
Aromatic HC gas chromatograms

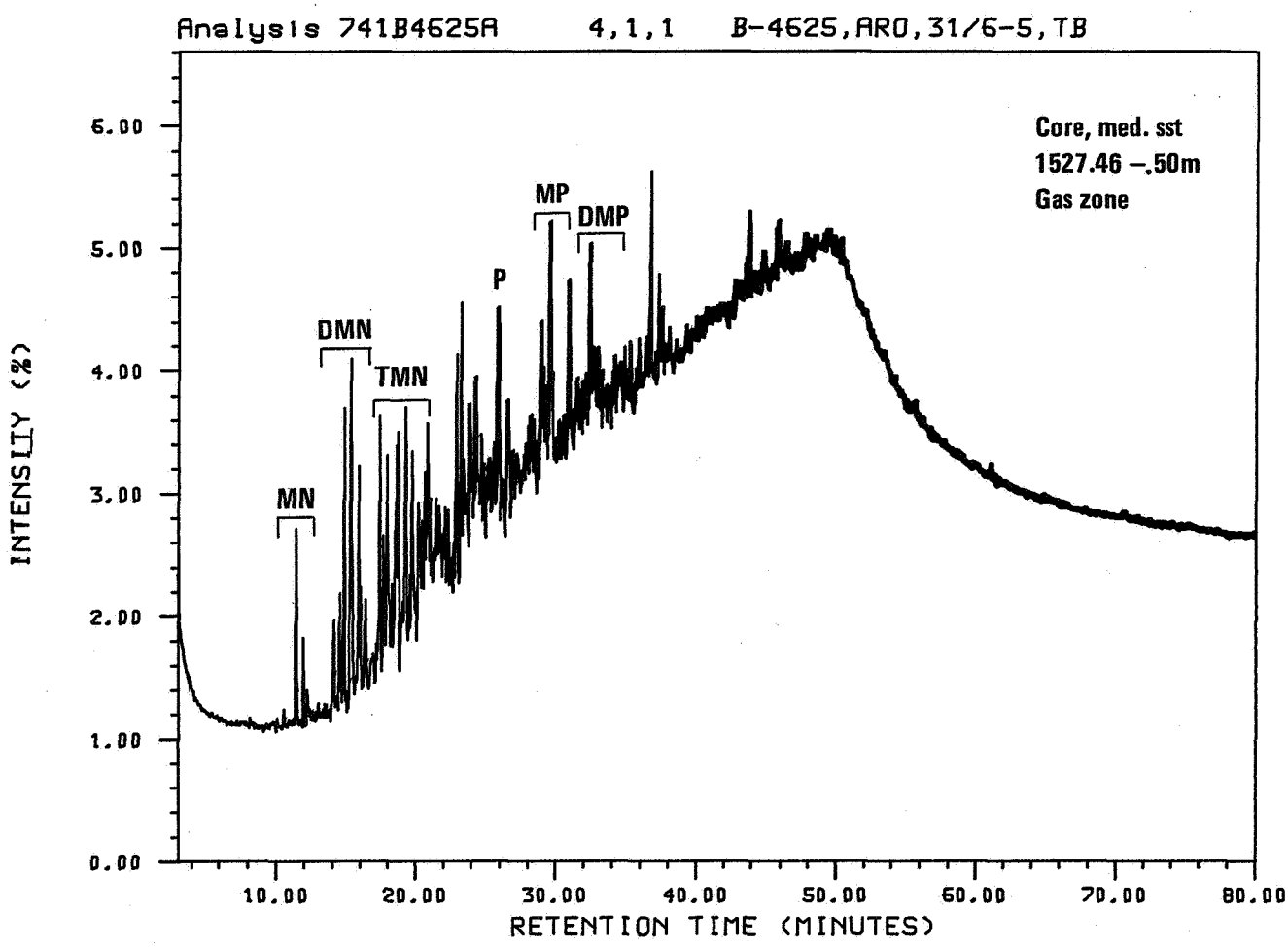
N - naphthalene
MN - methylnaphthalenes
DMN - dimethylnaphthalenes
TMN - trimethylnaphthalenes
P - phenanthrene
M - methylphenanthrenes
DMP - dimethylphenanthrenes

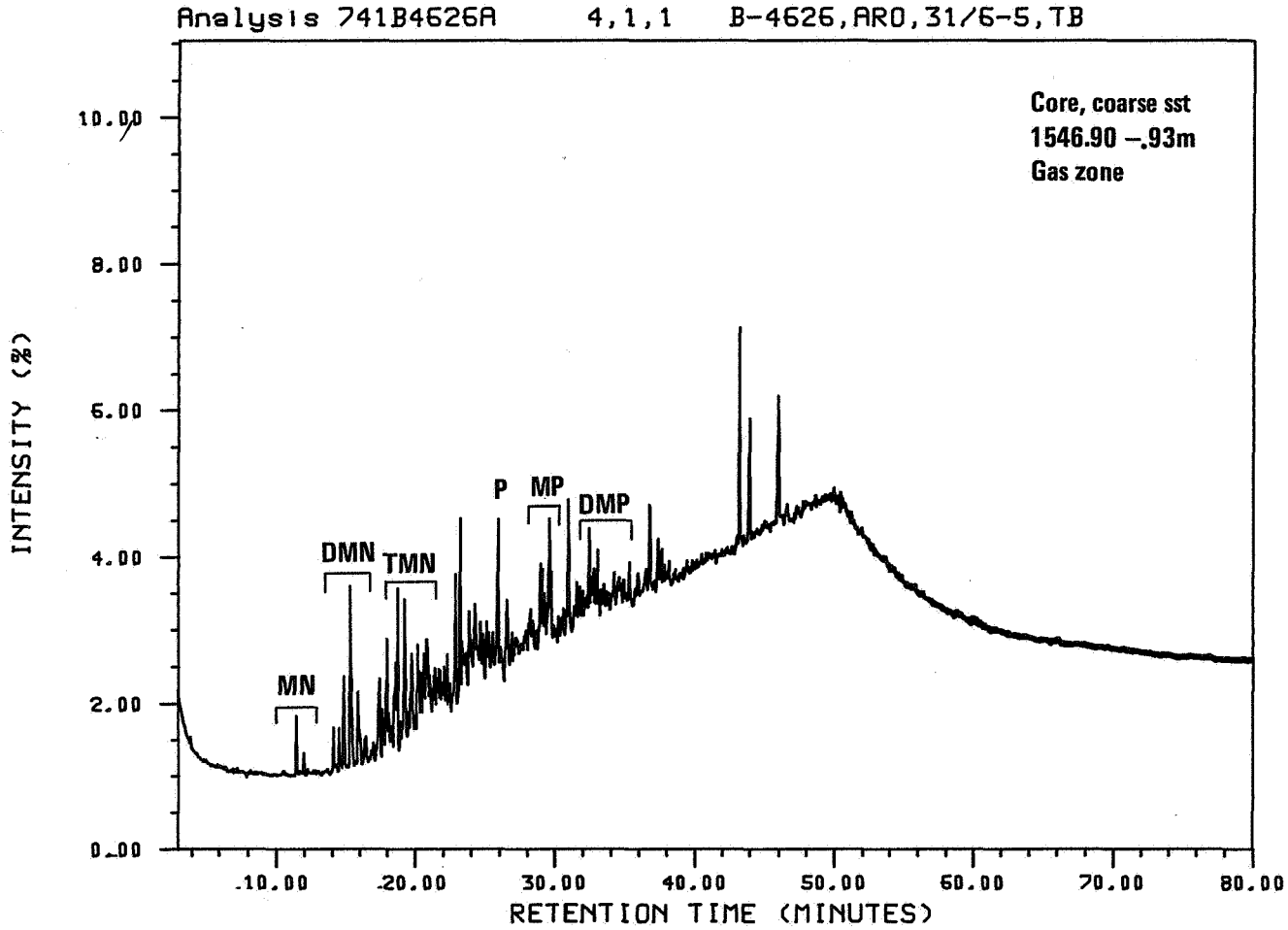

Analysis 741B4631A 4,1,1 B-4631,ARO,LS
Oil, DST 1A
N
MN
DMN
TMN
P
MP
INTENSITY (%)
RETENTION TIME (MINUTES)

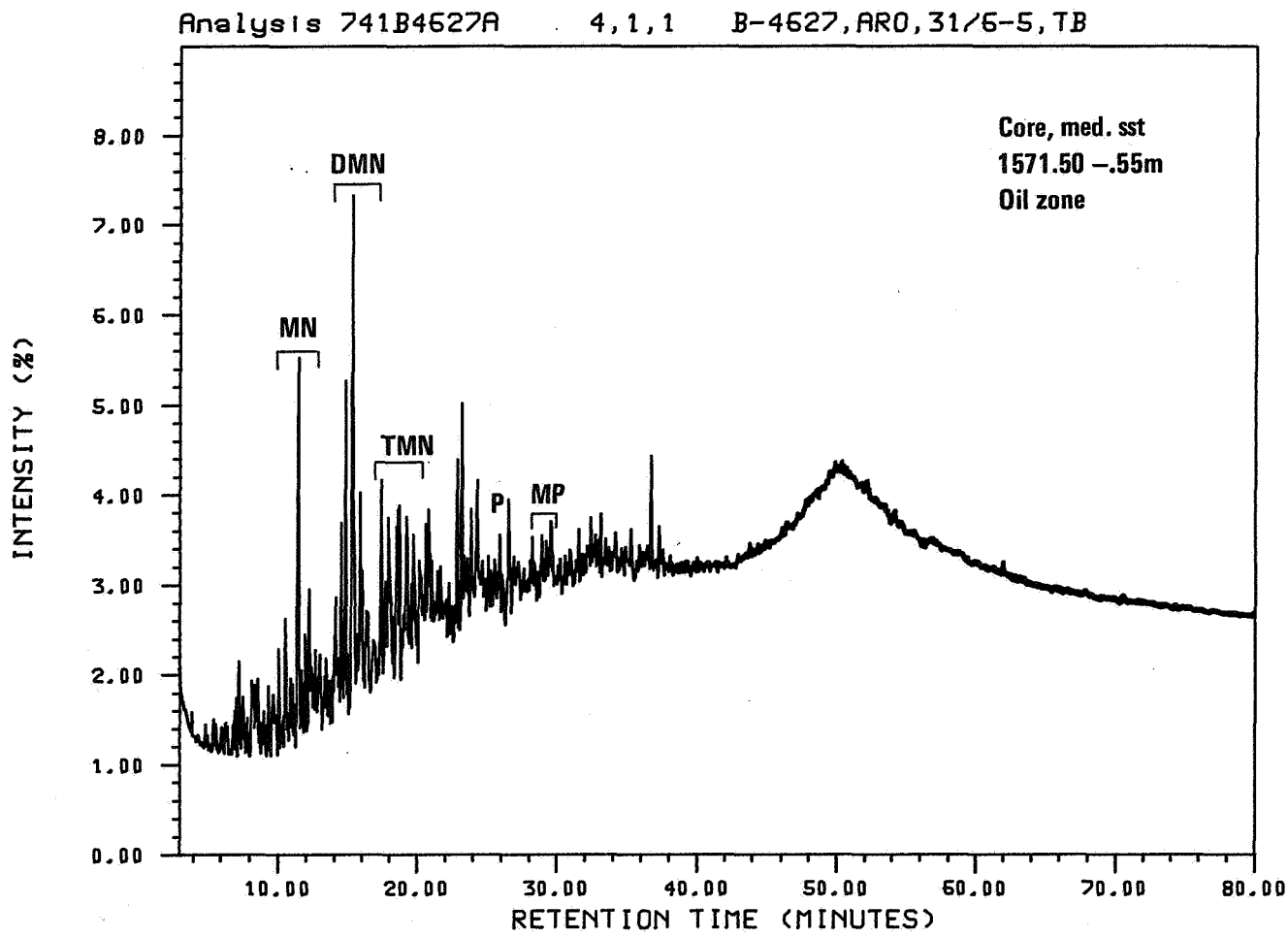

Analysis 741B4632A 4,1,1 B-4632,ARO,LH
Condensate
MN
DMN
TMN
INTENSITY (%)
RETENTION TIME (MINUTES)

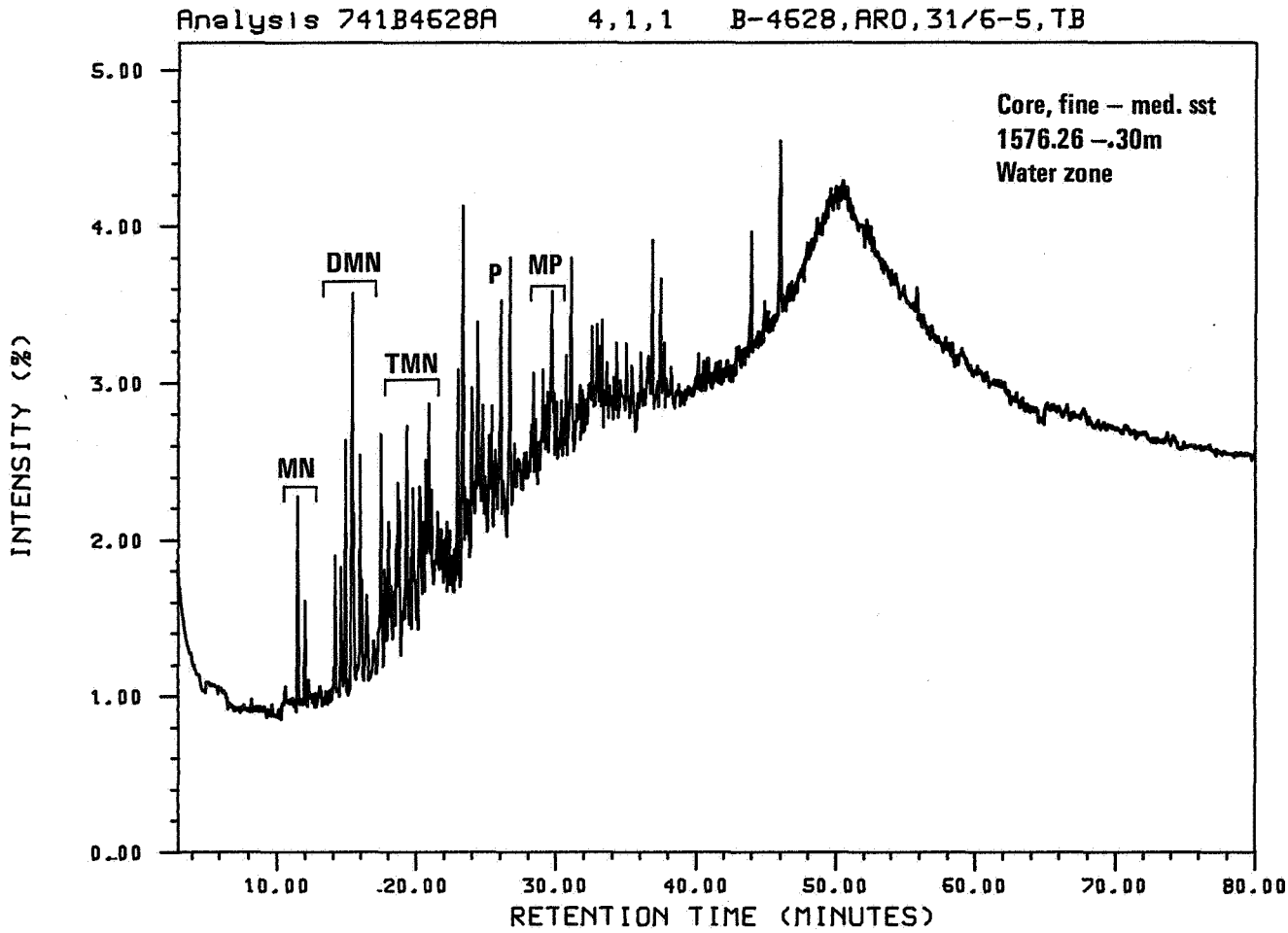

Analysis 741B4623A 4,1,1 B-4623,ARO,31/6-5,KA
Core, silt
1488.35 –.41m
Gas zone
TMN
MN
DMN
Aromatic steranes
P
MP
N
INTENSITY (%)
RETENTION TIME (MINUTES)

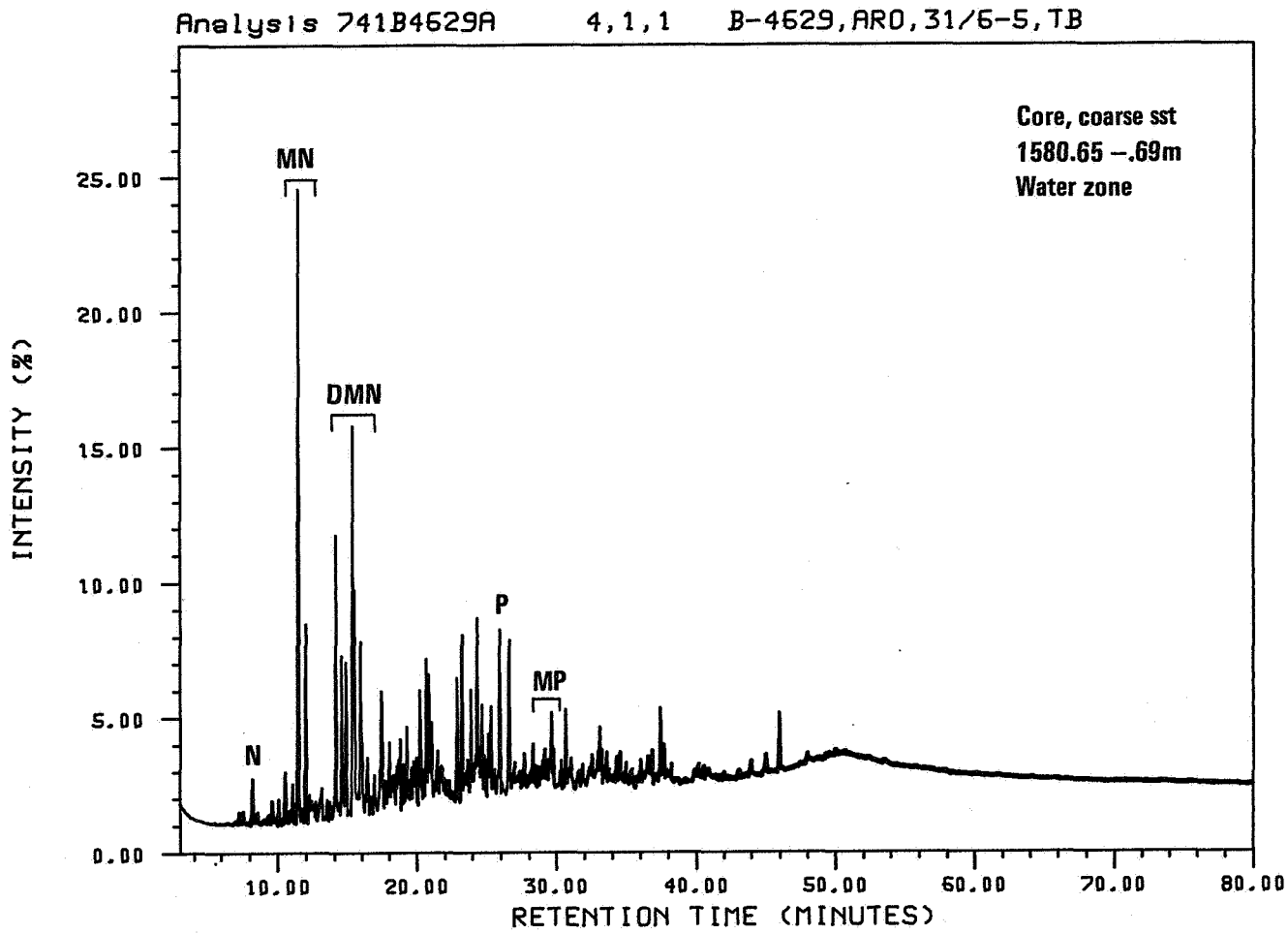

Analysis 741B4624A 4,1,1 B-4624,ARO,TB
Core, v. fine sst
1517.79 –.86m
Gas zone
MN
DMN
TMN
P
MP
DMP
N
INTENSITY (%)
RETENTION TIME (MINUTES)


Analysis 741B4625A 4,1,1 B-4625,ARO,31/6-5,TB
Core, med. sst
1527.46 –.50m
Gas zone
MN
DMN
TMN
P
MP
DMP
INTENSITY (%)
RETENTION TIME (MINUTES)


Analysis 741B4626A 4,1,1 B-4626,ARO,31/6-5,TB
Core, coarse sst
1546.90 –.93m
Gas zone
MN
DMN
TMN
P
MP
DMP
INTENSITY (%)
RETENTION TIME (MINUTES)


Analysis 741B4627A 4,1,1 B-4627,ARO,31/6-5,TB
Core, med. sst
1571.50 –.55m
Oil zone
MN
DMN
TMN
P
MP
INTENSITY (%)
RETENTION TIME (MINUTES)


Analysis 741B4628A 4,1,1 B-4628,ARO,31/6-5,TB
Core, fine – med. sst
1576.26 –.30m
Water zone
MN
DMN
TMN
P
MP
INTENSITY (%)
RETENTION TIME (MINUTES)


Analysis 741B4629A 4,1,1 B-4629,ARO,31/6-5,TB
Core, coarse sst
1580.65 –.69m
Water zone
MN
DMN
P
MP
N
INTENSITY (%)
RETENTION TIME (MINUTES)

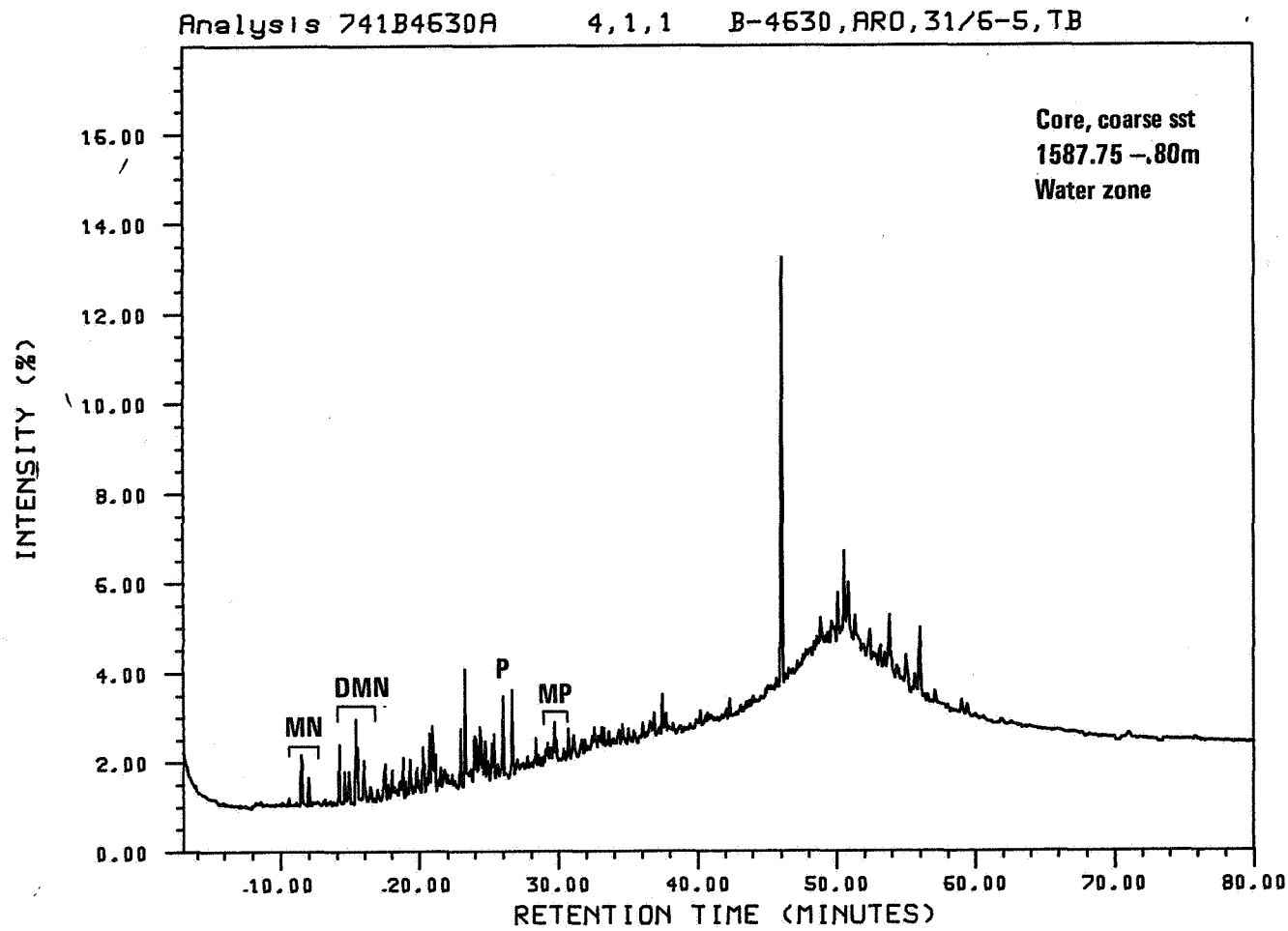
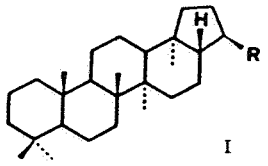

Analysis 741B4630A 4,1,1 B-4630,ARO,31/6-5,TB
Core, coarse sst
1587.75 –.80m
Water zone
MN
DMN
P
MP
INTENSITY (%)
RETENTION TIME (MINUTES)

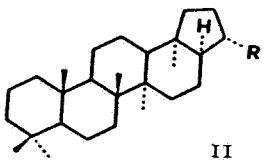
FIGURE 5

Mass chromatograms representing terpanes (m/z 191)

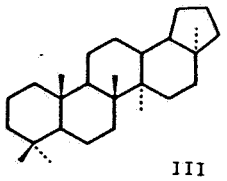
A	T_s, 18α(H)-trisnorneohopane	$C_{27}H_{46}$	(III)
B	T_m, 17α(H)-trisnorhopane	$C_{27}H_{46}$	(I,R=H)
C	17α(H)-norhopane	$C_{29}H_{50}$	(I,R=C_2H_5)
D	17β(H)-normoretane	$C_{29}H_{50}$	(II,R=C_2H_5)
E	17α(H)-hopane	$C_{30}H_{52}$	(I,R=C_3H_7)
F	17β(H)-moretane	$C_{30}H_{52}$	(II,R=C_3H_7)
G	17α(H)-homohopane (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})



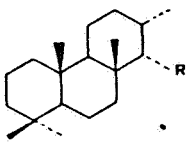
I

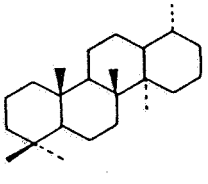


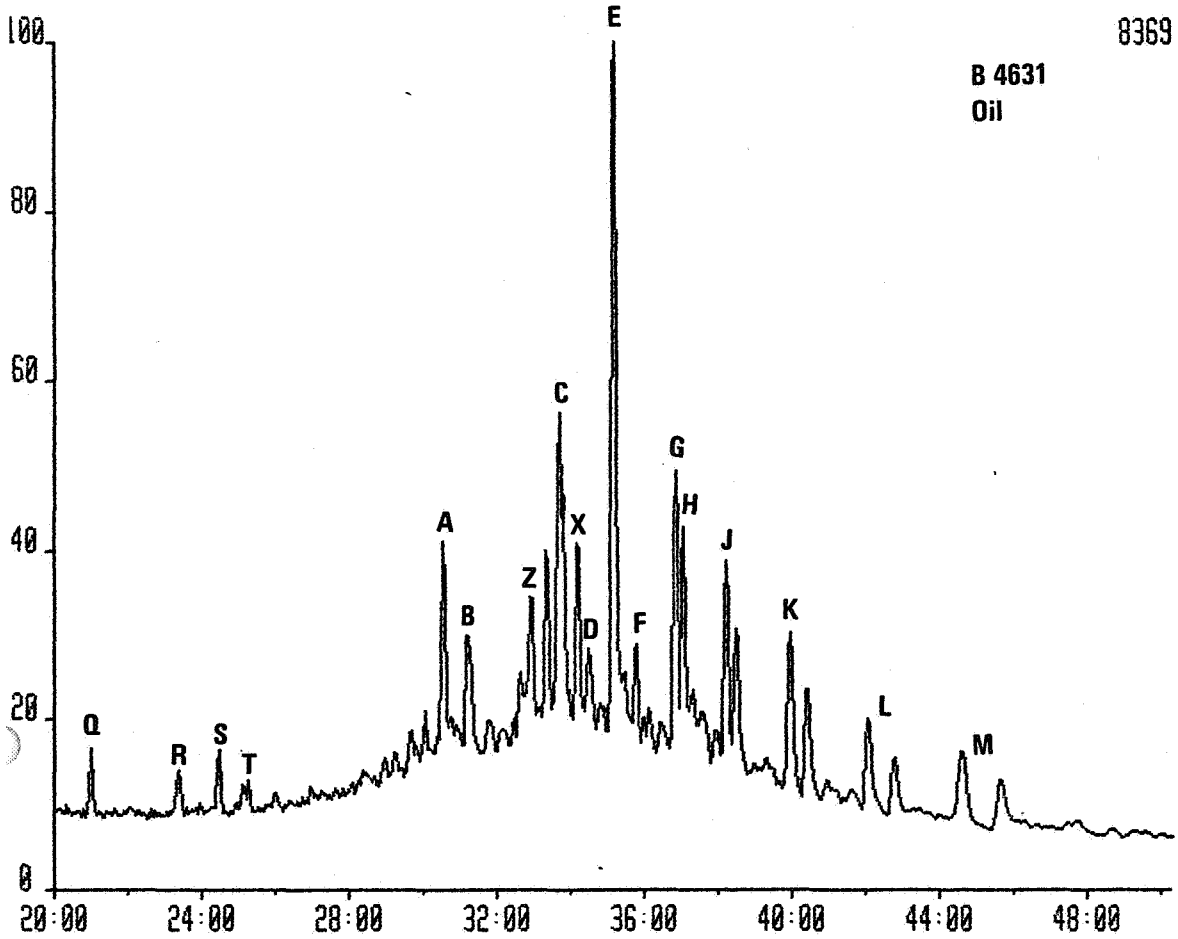
II



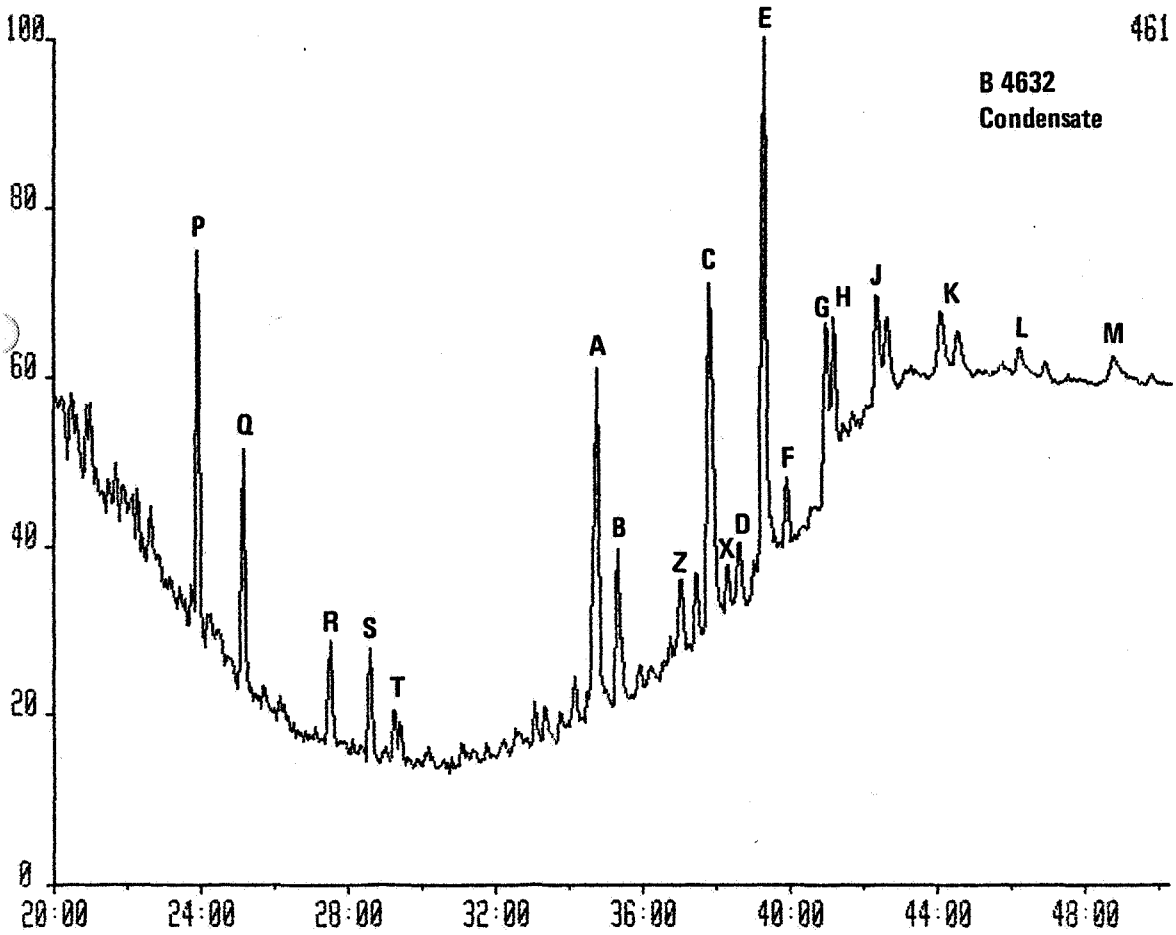
III

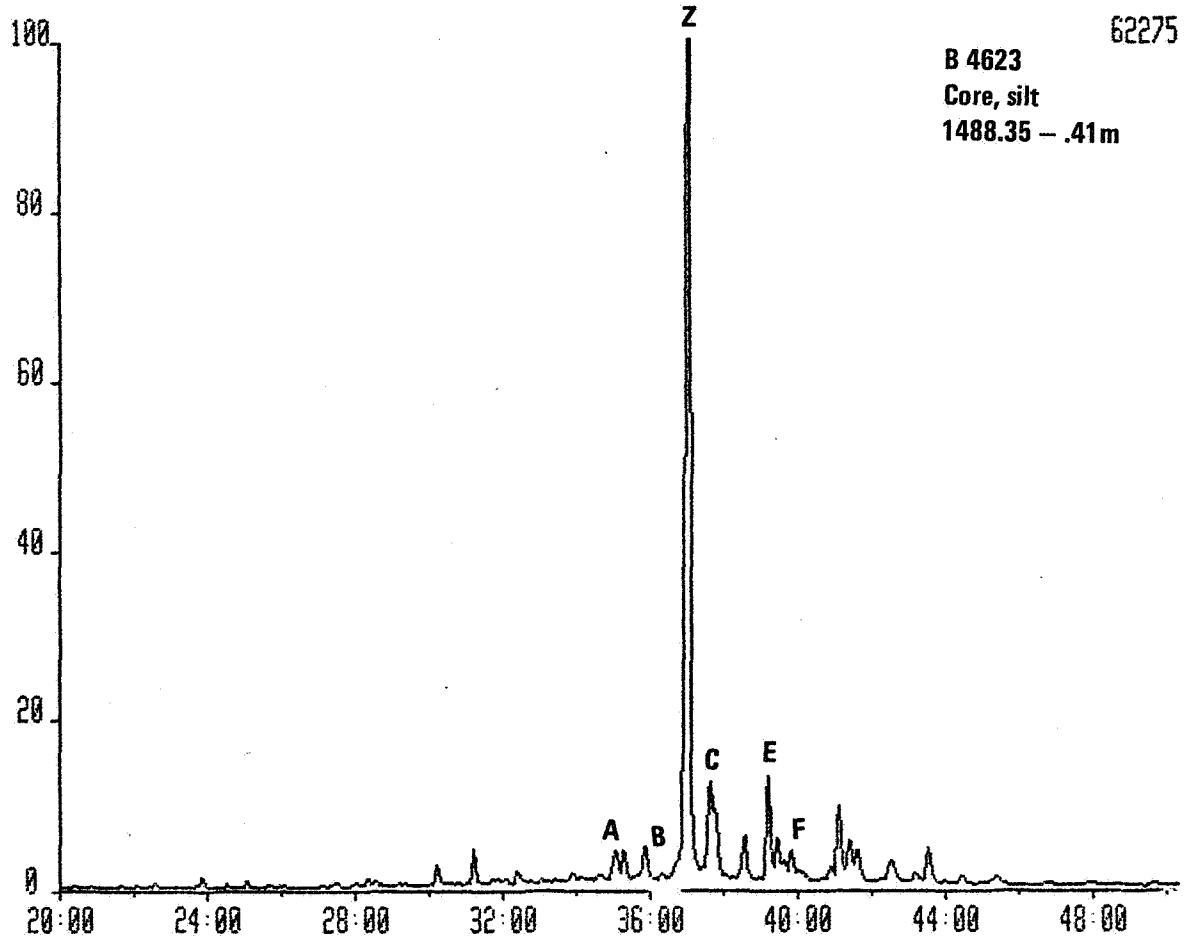




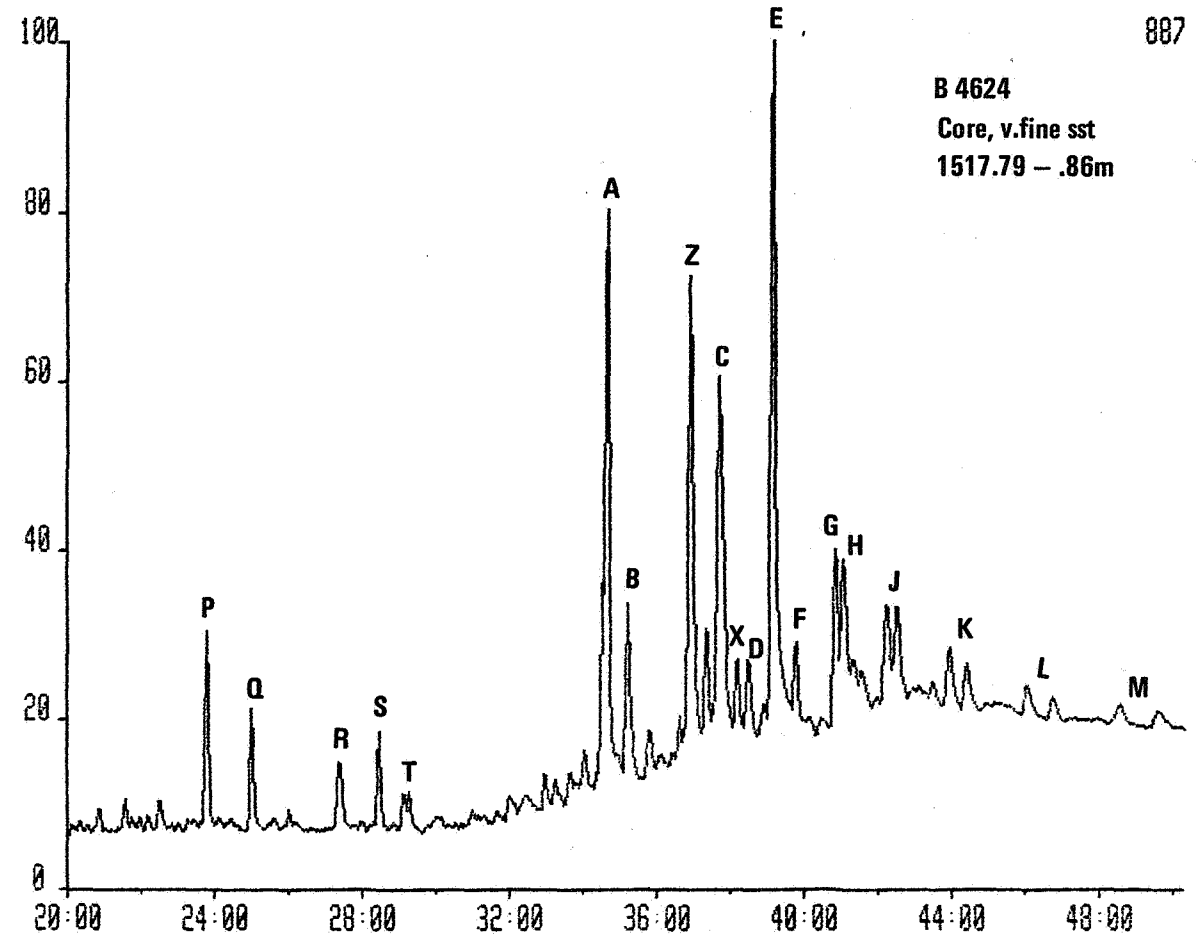


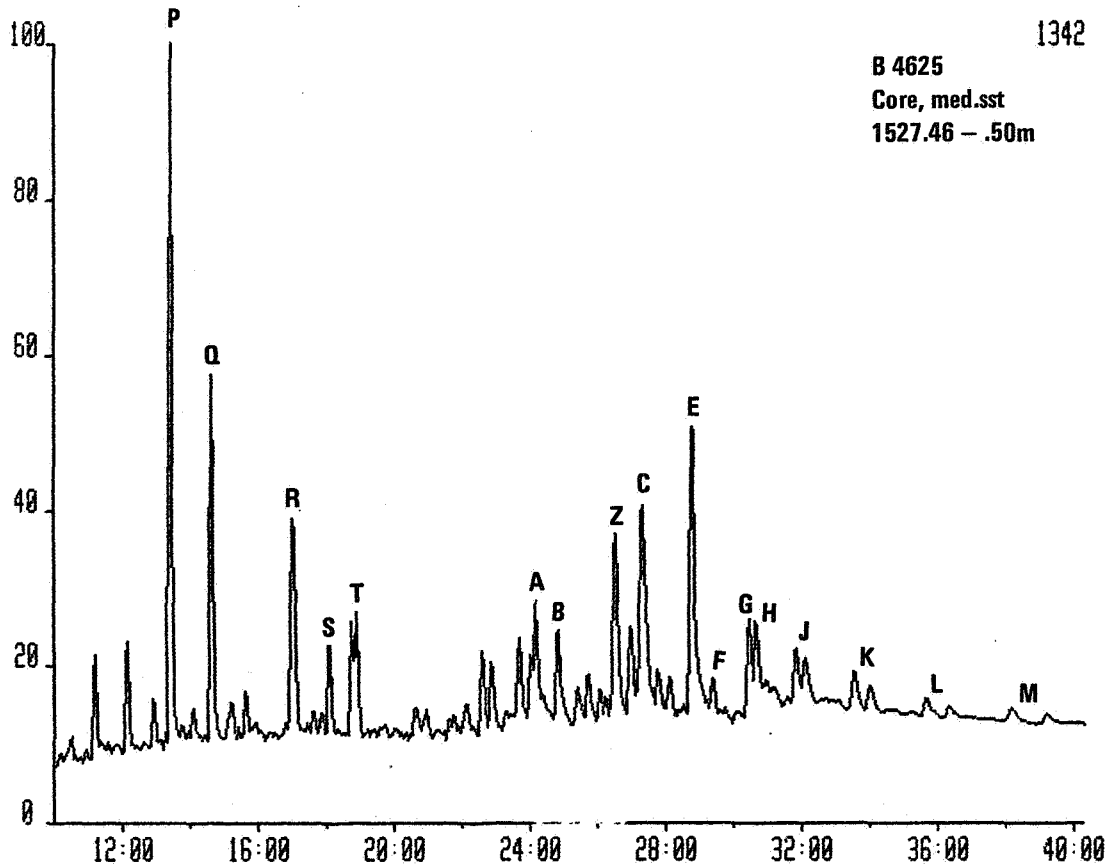
741TROL3 191.1000 G1 I1 S2



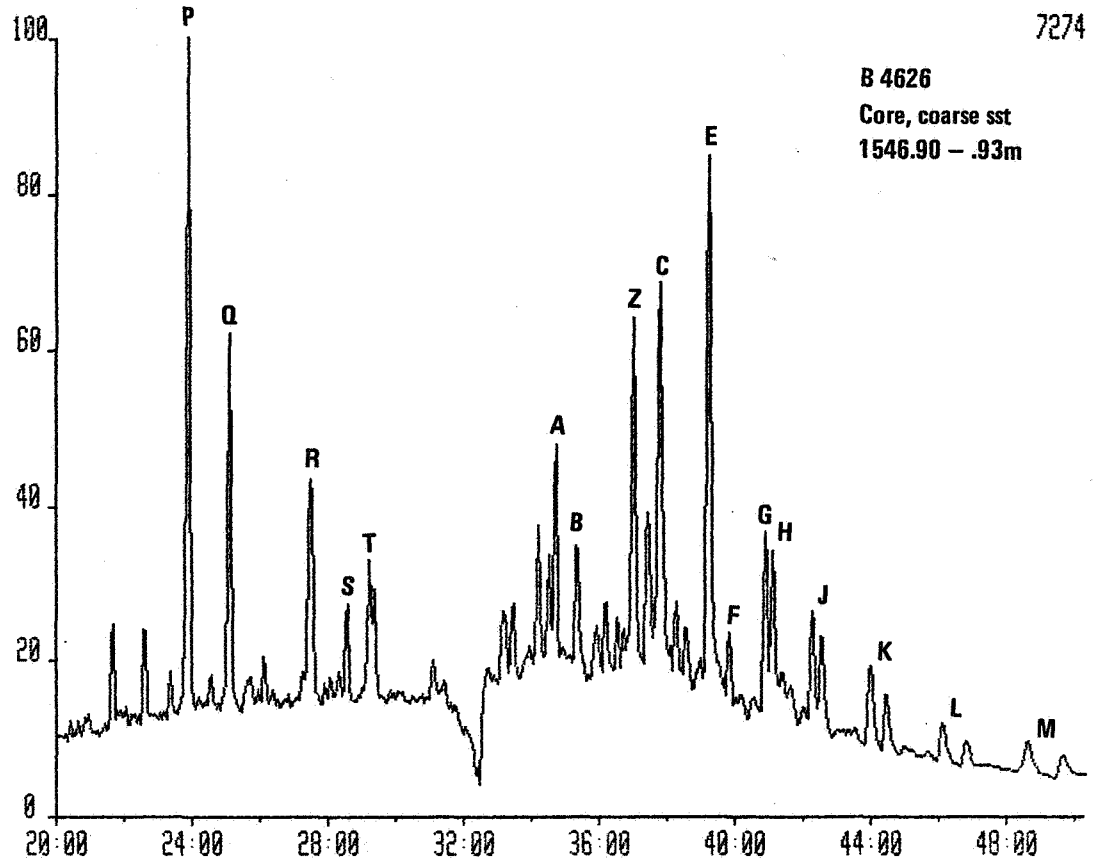


741TROLL 191.1000 G1 I1 S2

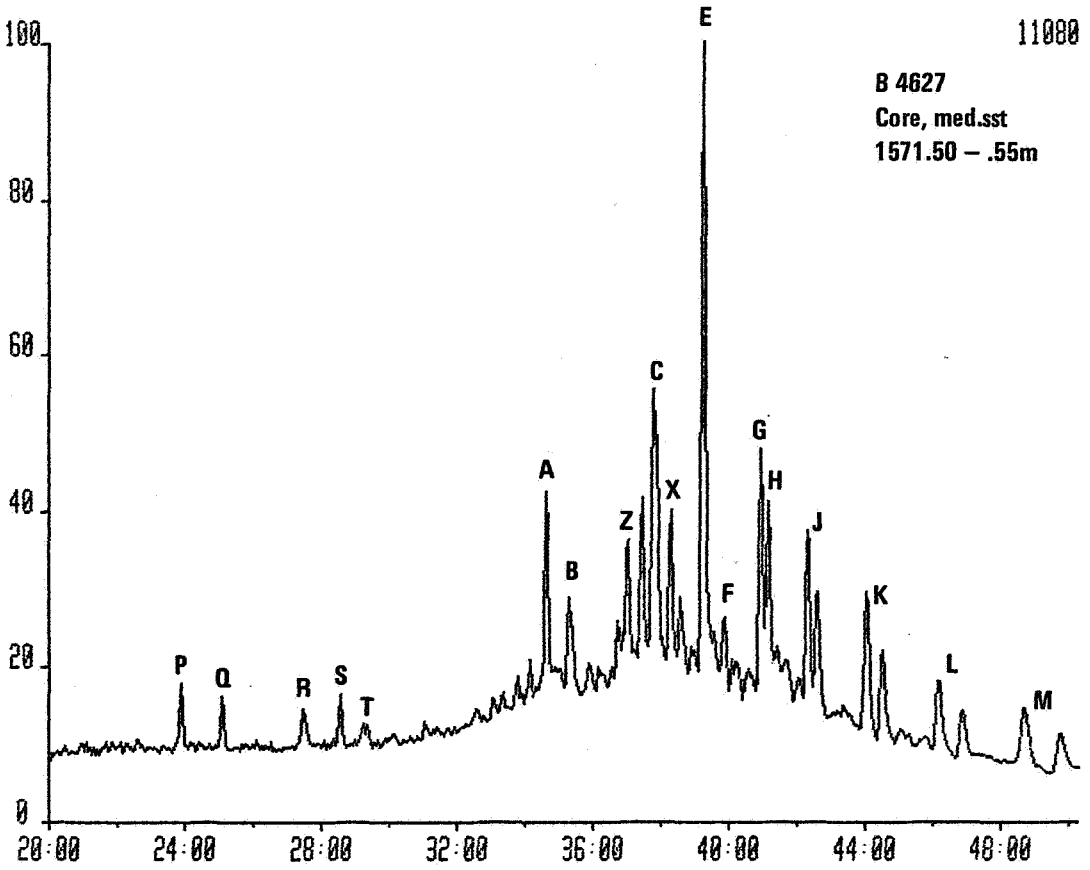




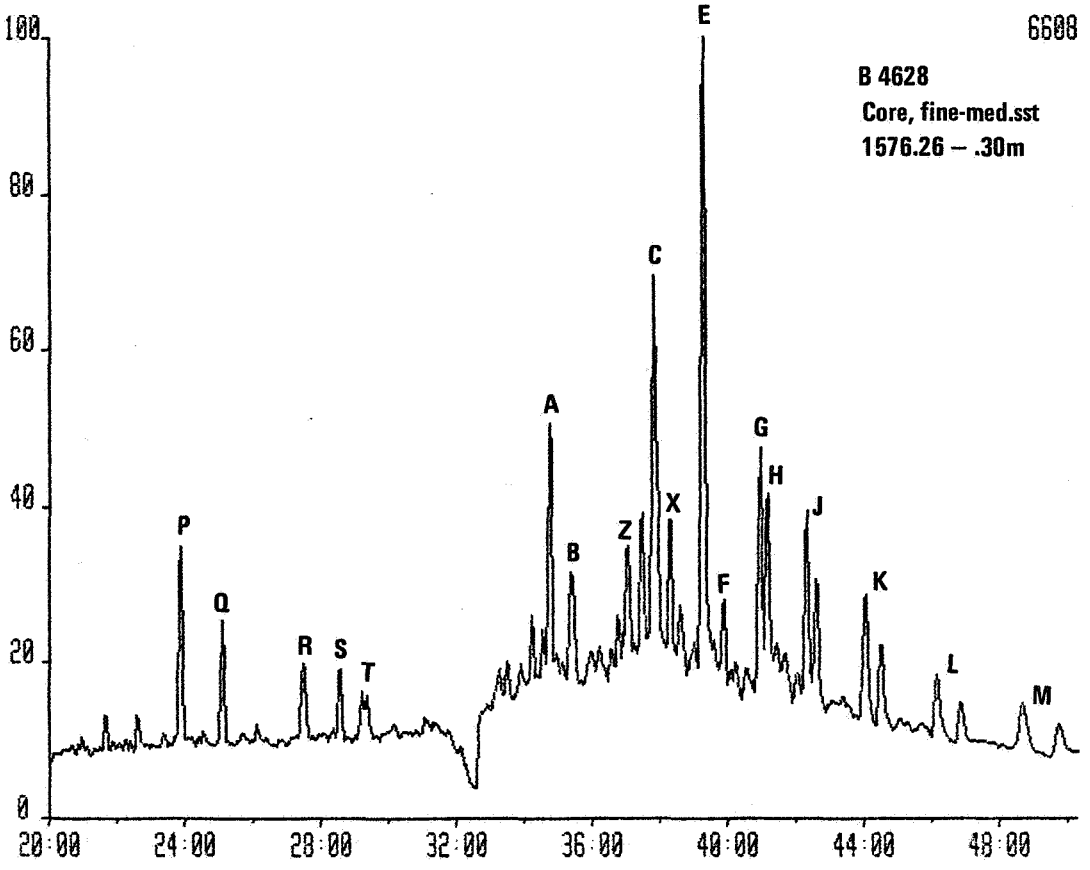
741TROL2 191.1000 G1 I1 S2



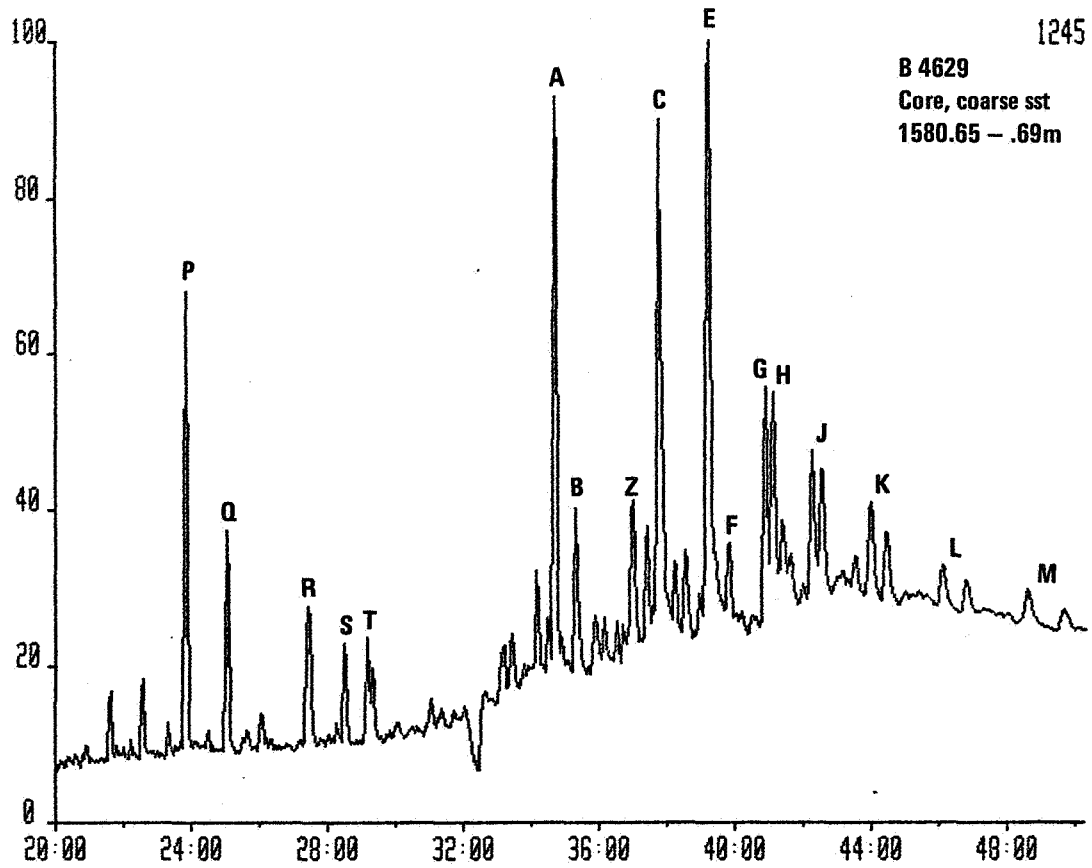
IKU



741TROL2 191.1000 G1 I1 S4



IKU



741TROL2 191.1000 G1 I1 S6

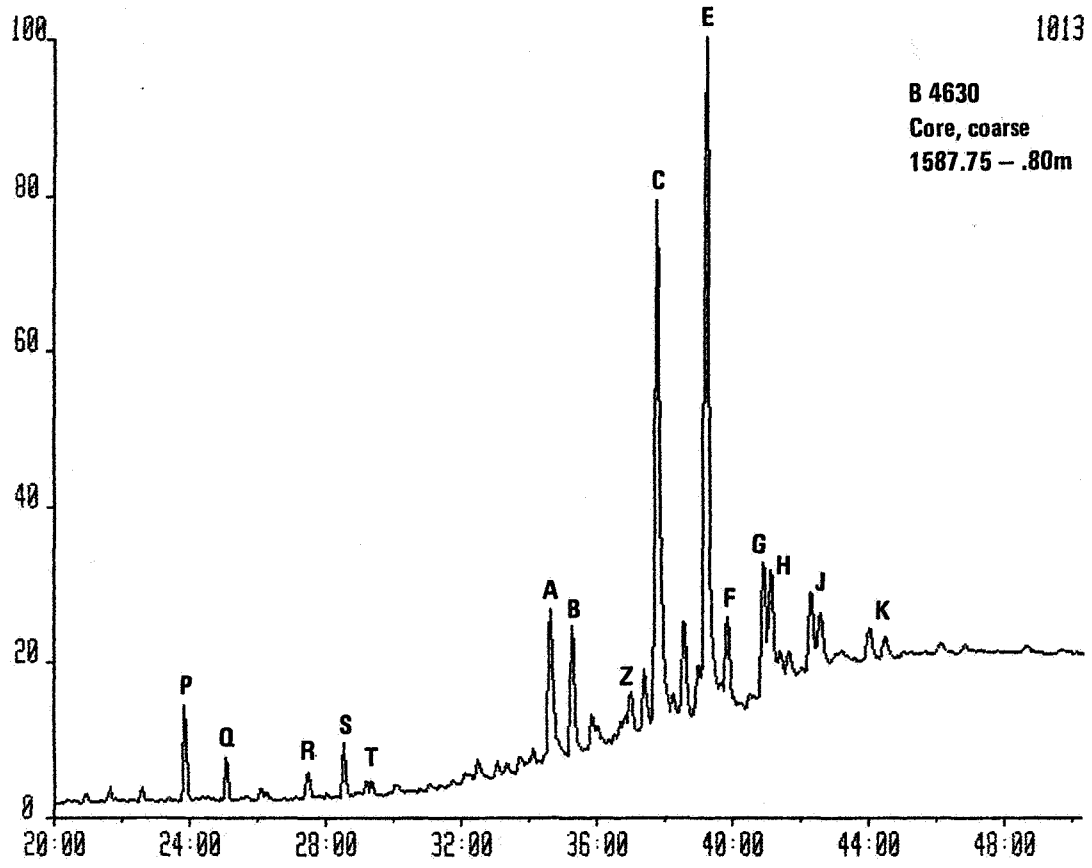
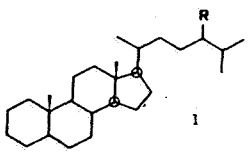


FIGURE 5

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

a	13β(H),17α(H)-diasterane (20S)	$C_{27}H_{48}$	(III,R=H)
b	13β(H),17α(H)-diasterane (20R)	$C_{27}H_{48}$	(III,R=H)
c	13α(H),17β(H)-diasterane (20S)	$C_{27}H_{48}$	(IV,R=H)
d	13α(H),17β(H)-diasterane (20R)	$C_{27}H_{48}$	(IV,R=H)
e	13β(H),17α(H)-diasterane (20S)	$C_{28}H_{50}$	(III,R=CH_3)
f	13β(H),17α(H)-diasterane (20R)	$C_{28}H_{50}$	(III,R=CH_3)
g	13α(H),17β(H)-diasterane (20S)	$C_{28}H_{50}$	(IV,R=CH_3)
	+ 14α(H),17α(H)-sterane (20S)	$C_{27}H_{48}$	(I,R=H)
h	13β(H),17α(H)-diasterane (20S)	$C_{29}H_{52}$	(III,R=C_2H_5)
	+ 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_2H_5)
l	13α(H),17β(H)-diasterane (20S)	$C_{29}H_{52}$	(III,R=C_2H_5)
m	14α(H),17α(H)-sterane (20S)	$C_{28}H_{50}$	(I,R=CH_3)
n	13α(H),17β(H)-diasterane (20R)	$C_{29}H_{52}$	(III,R=C_2H_5)
	+ 14β (H),17β (H)-sterane (20R)	$C_{28}H_{50}$	(II,R=CH_3)
o	14β(H),17β(H)-sterane (20S)	$C_{28}H_{50}$	(II,R=CH_3)
p	14α(H),17α(H)-sterane (20R)	$C_{28}H_{50}$	(I,R=CH_3)
q	14α(H),17α(H)-sterane (20S)	$C_{29}H_{52}$	(I,R=C_2H_5)
r	14β(H),17β(H)-sterane (20R)	$C_{29}H_{52}$	(II,R=C_2H_5)
	+ unknown sterane		
s	14β(H),17β(H)-sterane (20S)	$C_{29}H_{52}$	(II,R=C_2H_5)
t	14β(H),17β(H)-sterane (20R)	$C_{29}H_{52}$	(I,R=C_2H_5)
u	5α(H)-sterane	$C_{21}H_{36}$	(V,R=C_2H_5)
v	5α(H)-sterane	$C_{22}H_{38}$	(IV,R=C_3H_7)



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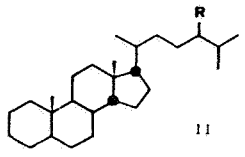
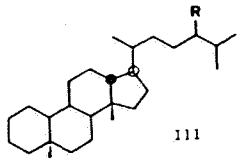
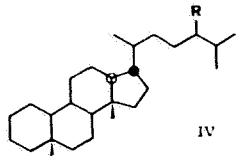


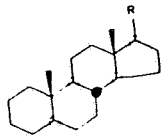
II

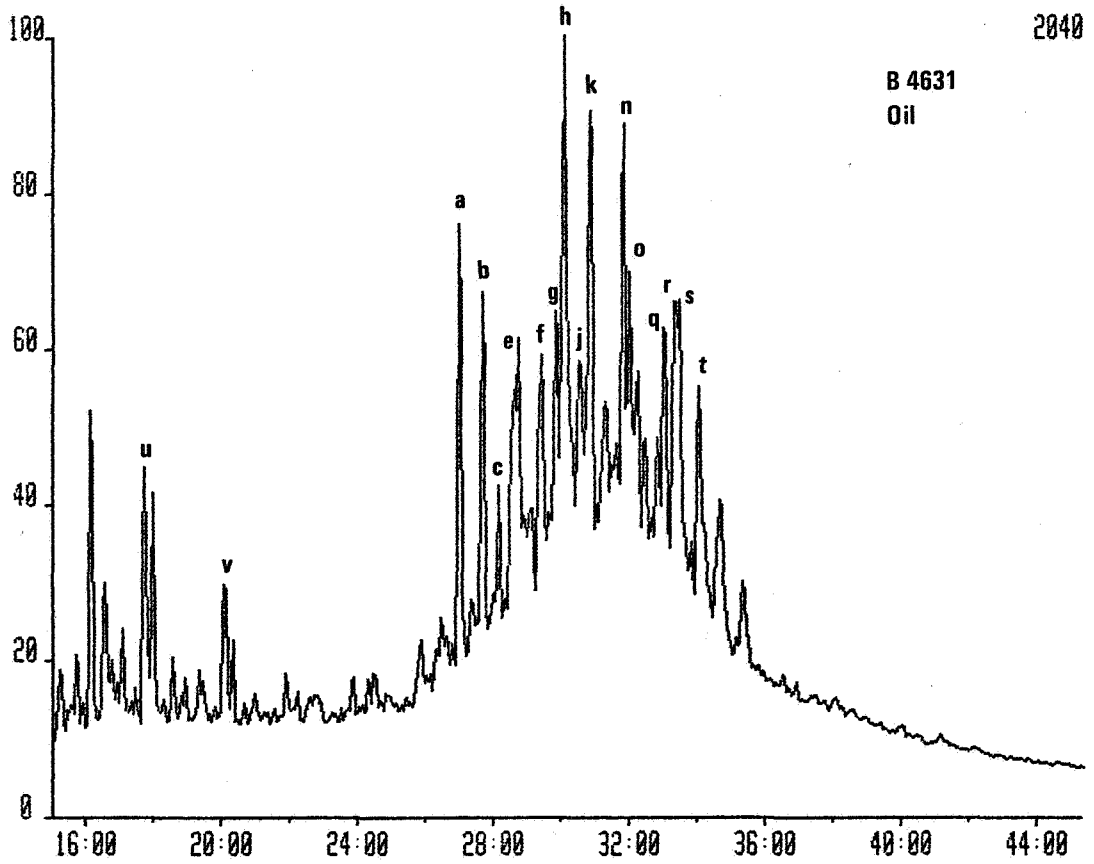


III

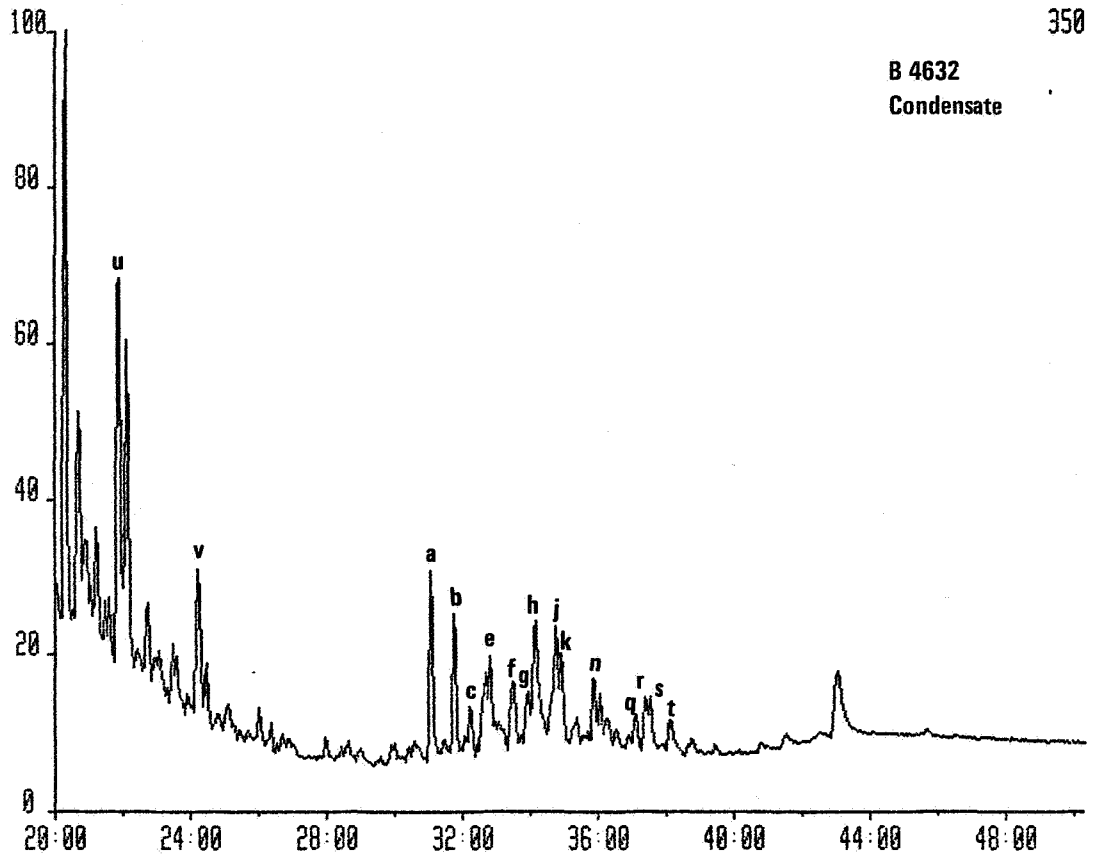


IV

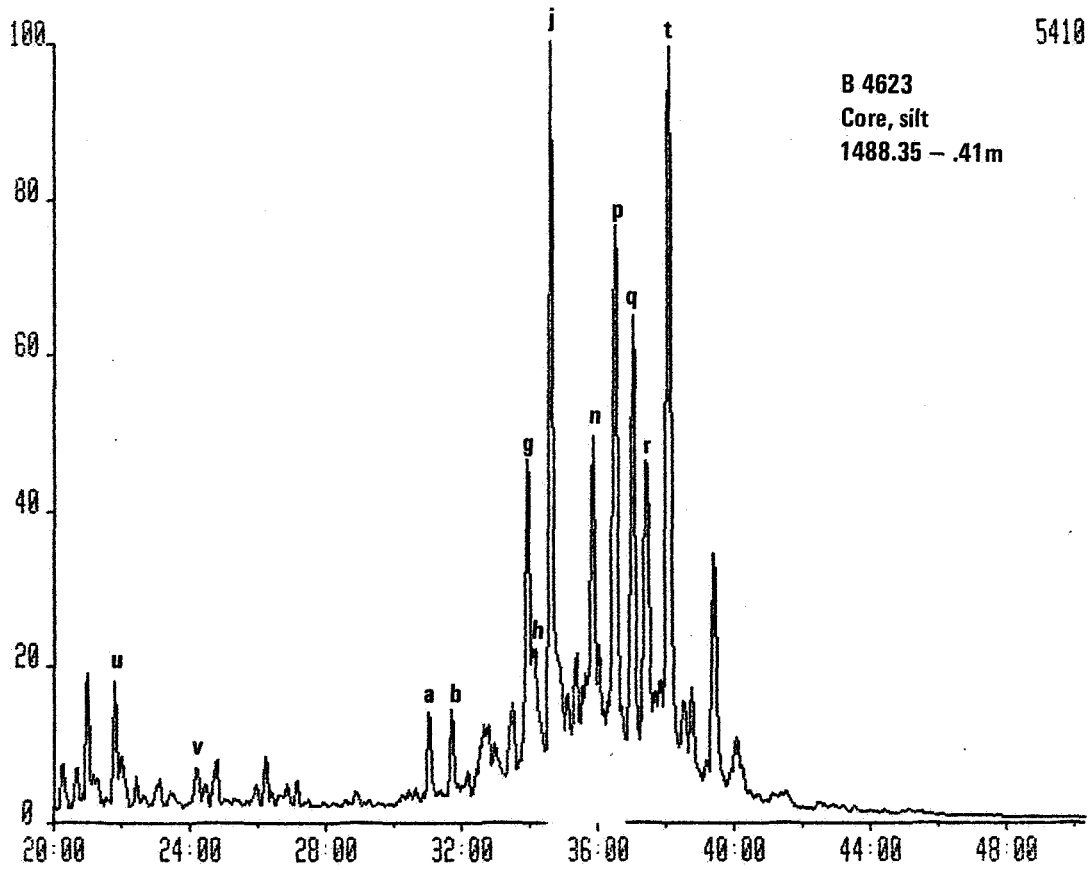




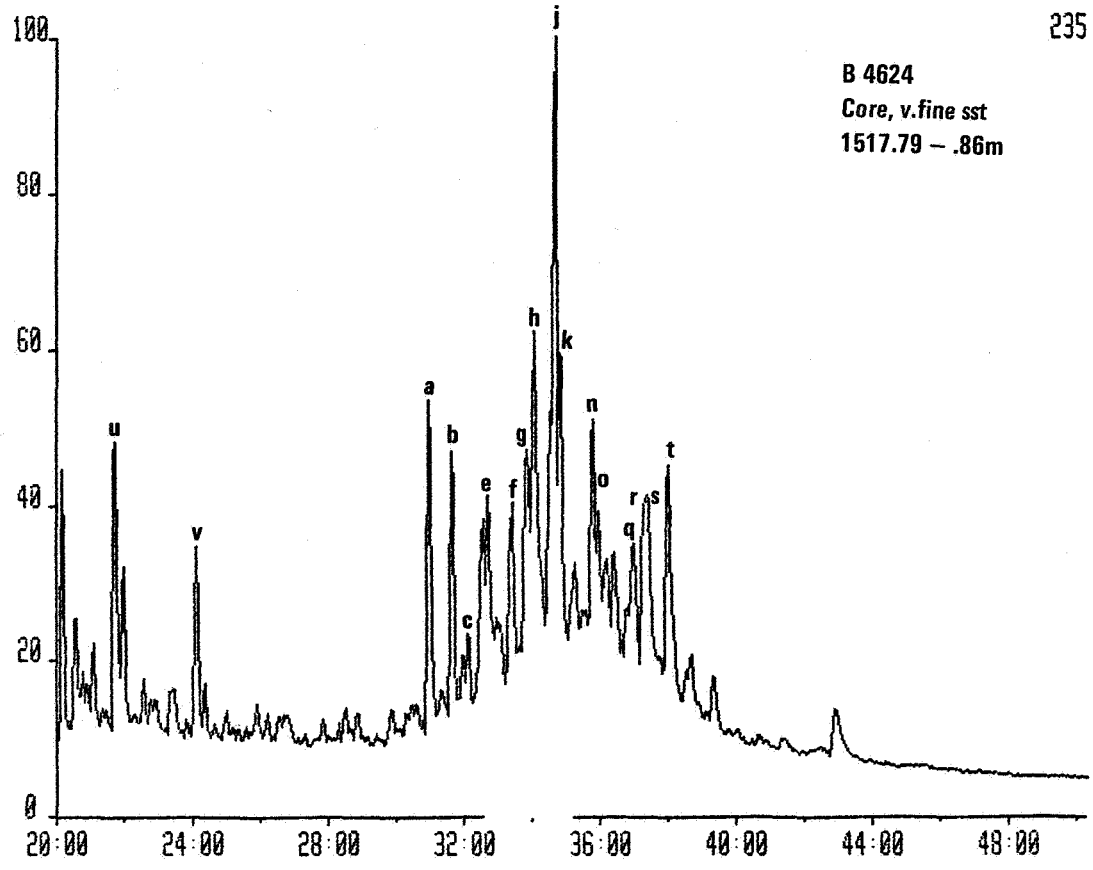
741TROL3 217.1000 G1 I1 S2

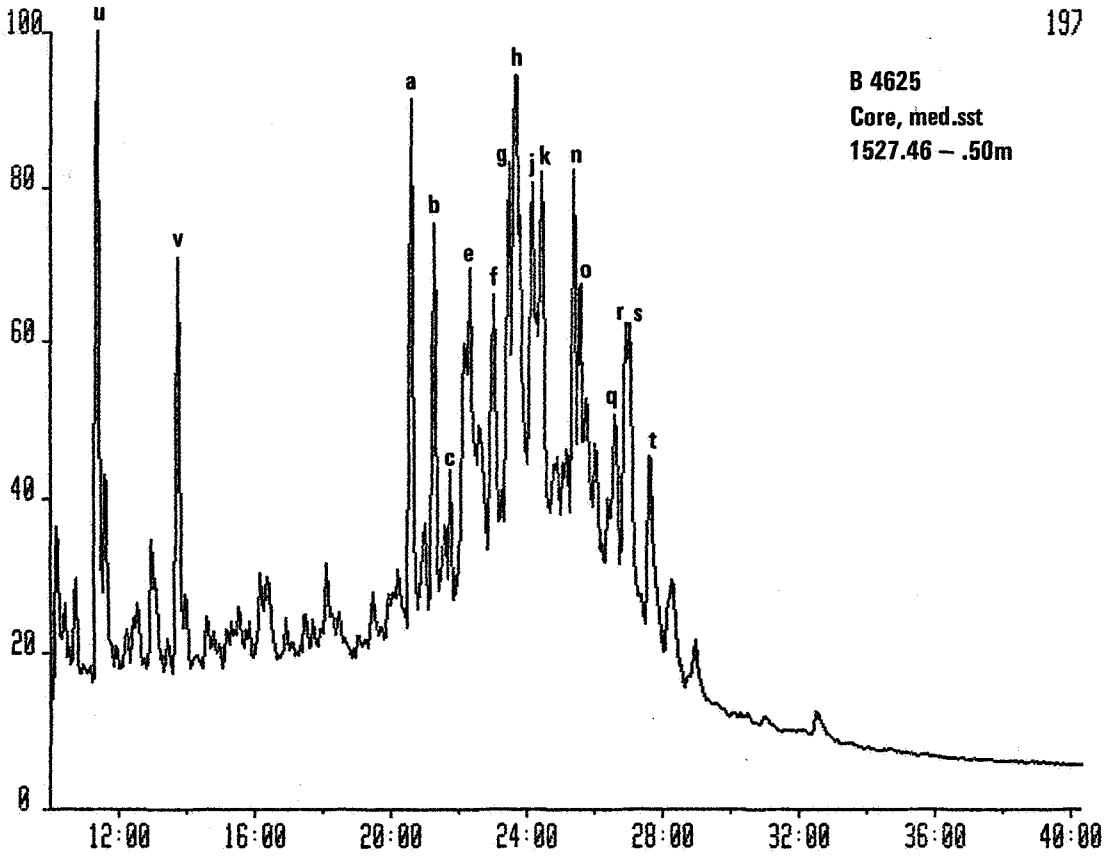


741TROLL 217.1000 G1 I1 S1

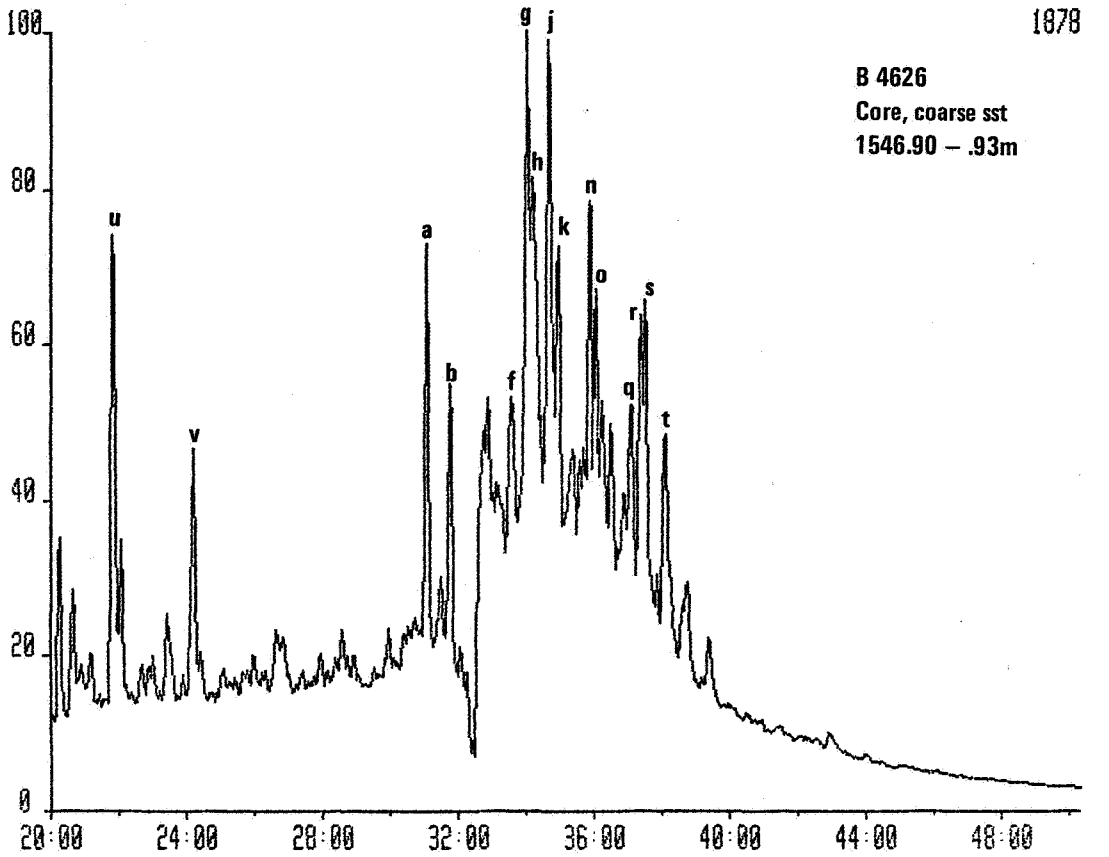


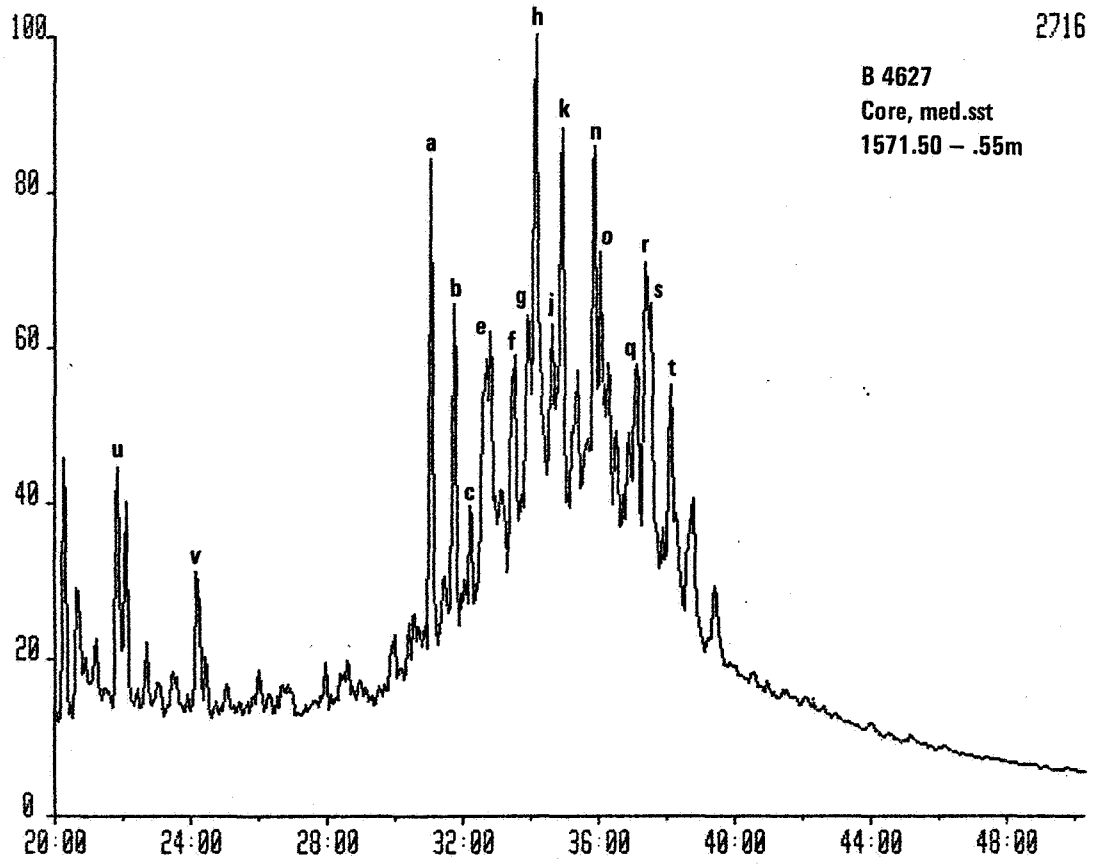
741TROLL 217.1000 G1 I1 S2

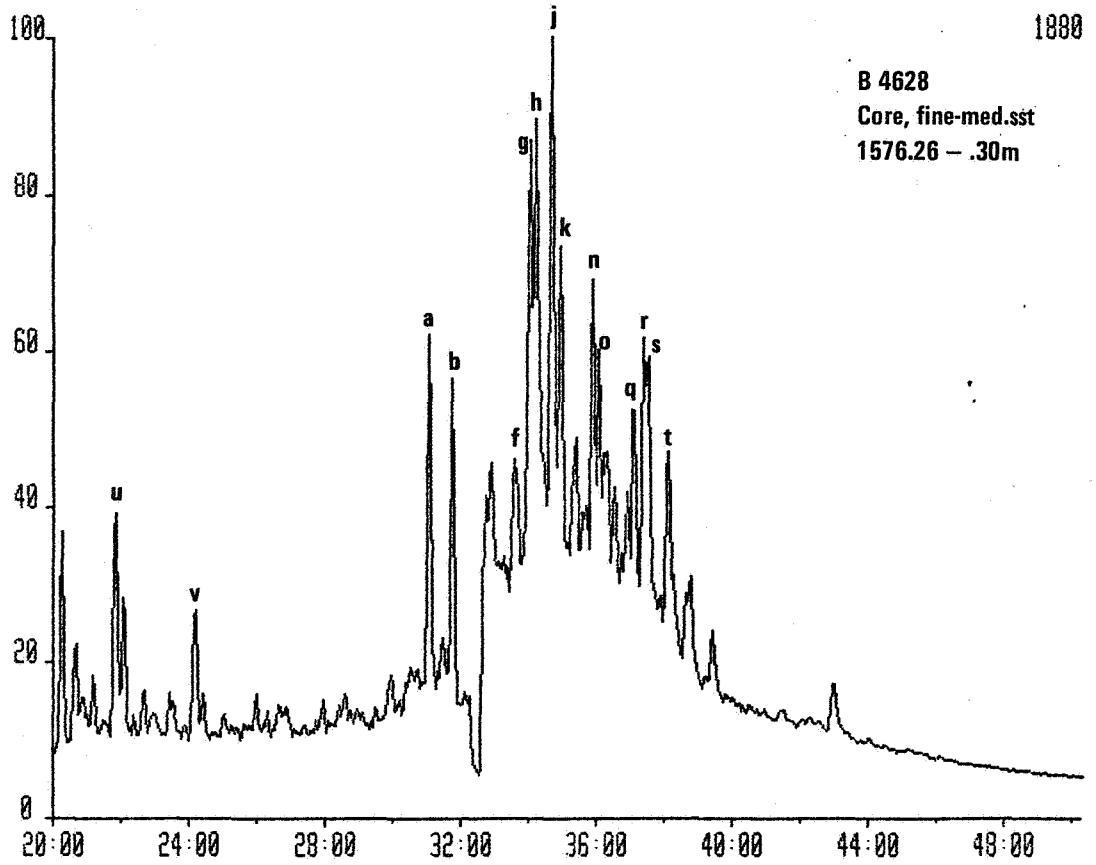


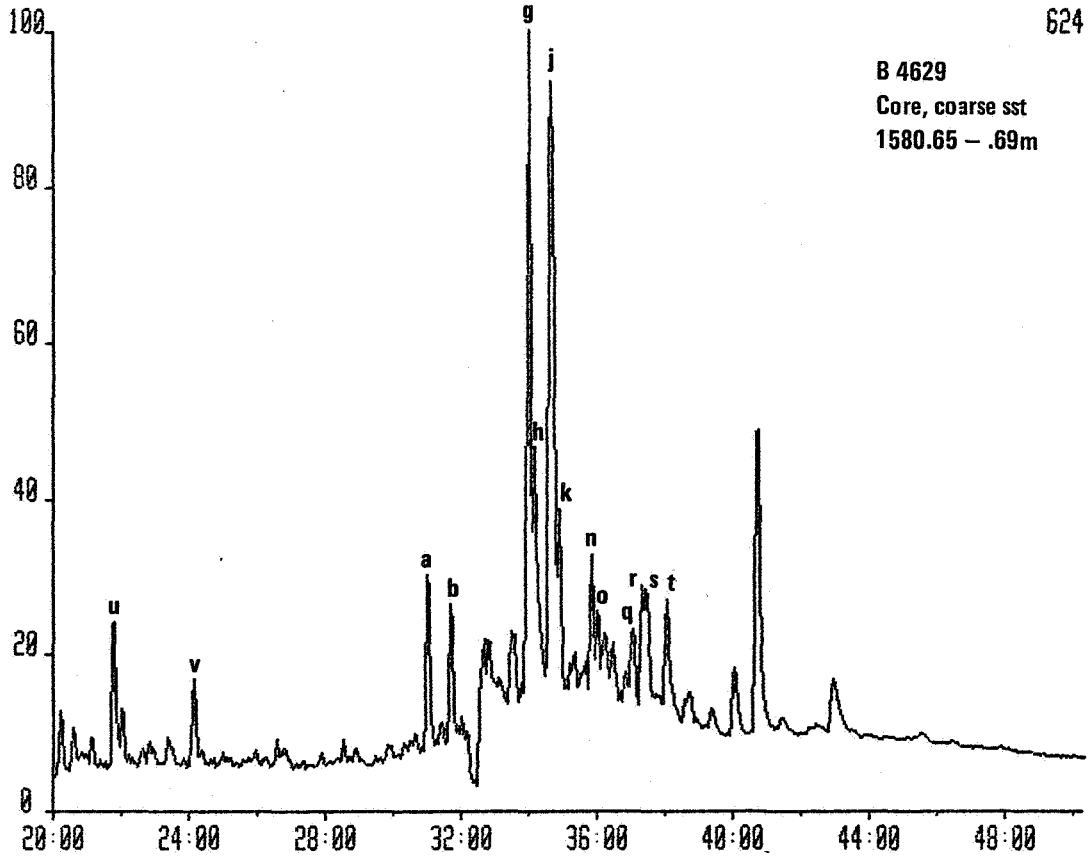


741TROL2 217.1000 G1 I1 S2

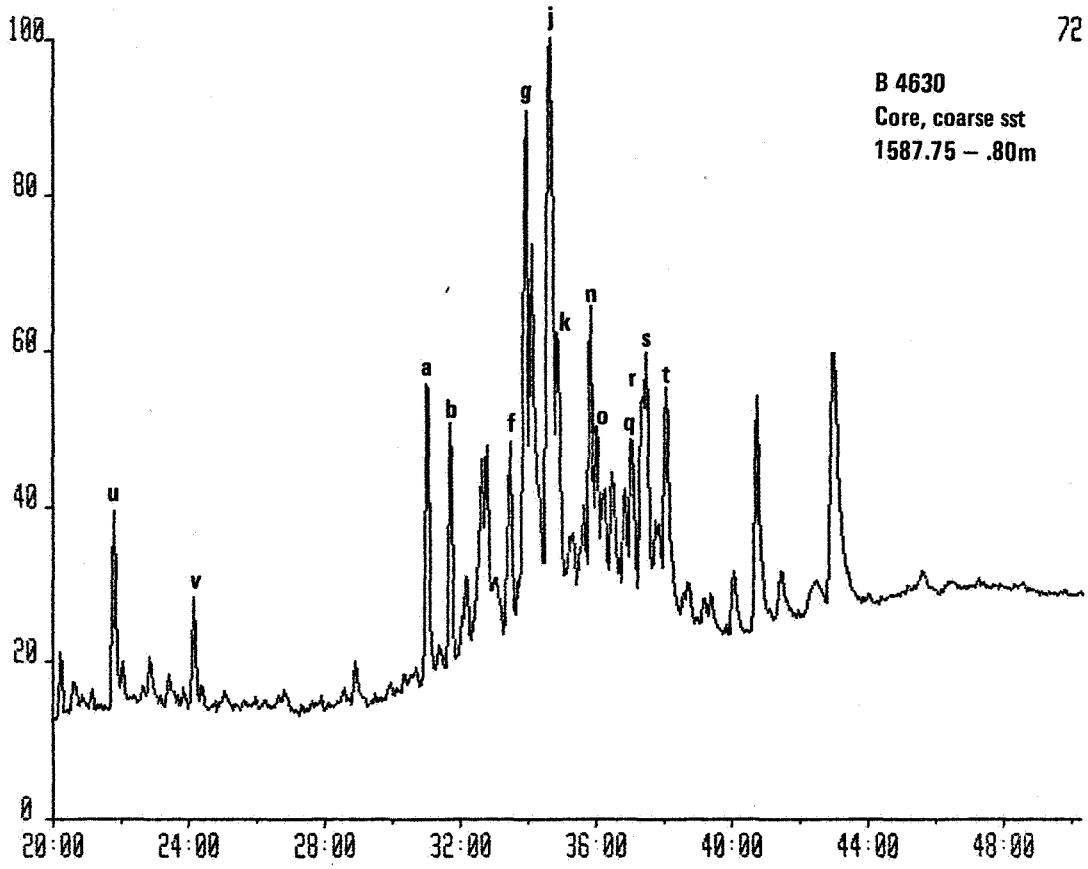


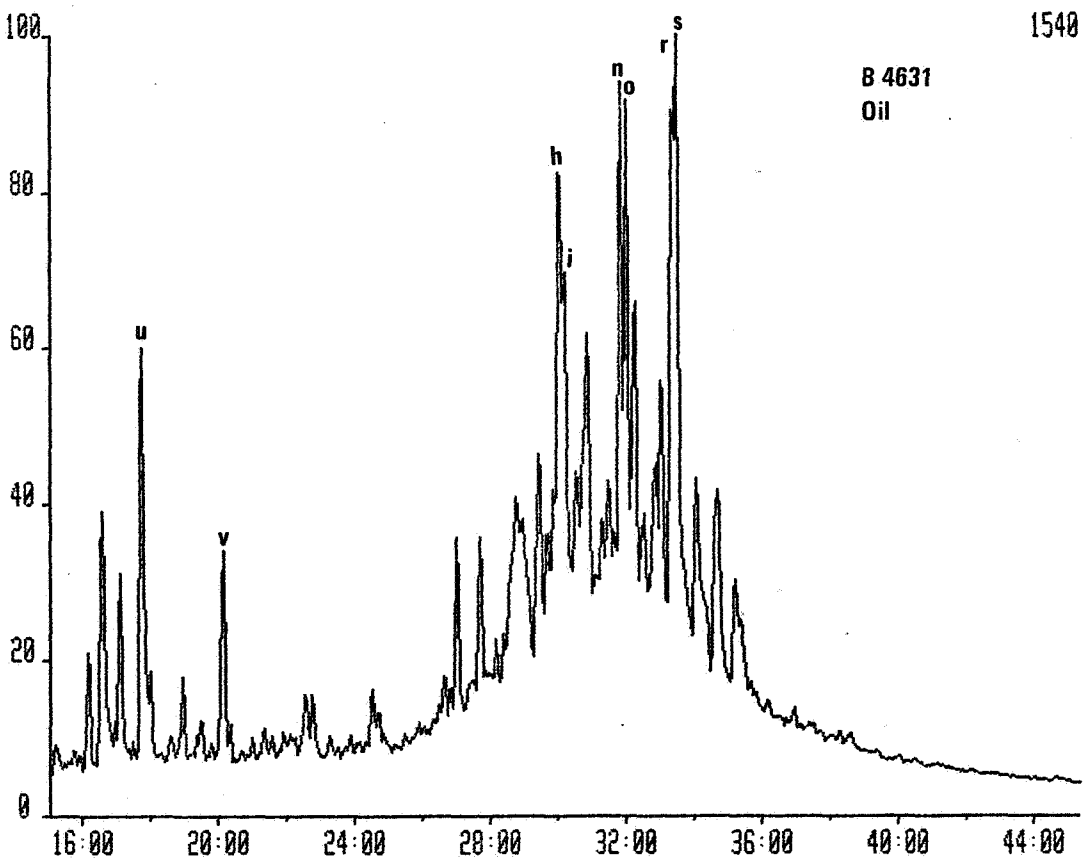

2716
B 4627
Core, med.sst
1571.50 – .55m
100
80
60
40
20
0
20:00
24:00
28:00
32:00
36:00
40:00
44:00
48:00
a
b
c
e
f
g
h
j
k
n
o
q
r
s
t
u
v


1880
B 4628
Core, fine-med.sst
1576.26 – .30m
100
80
60
40
20
0
20:00
24:00
28:00
32:00
36:00
40:00
44:00
48:00
a
b
f
g
h
j
k
n
o
q
r
s
t
u
v

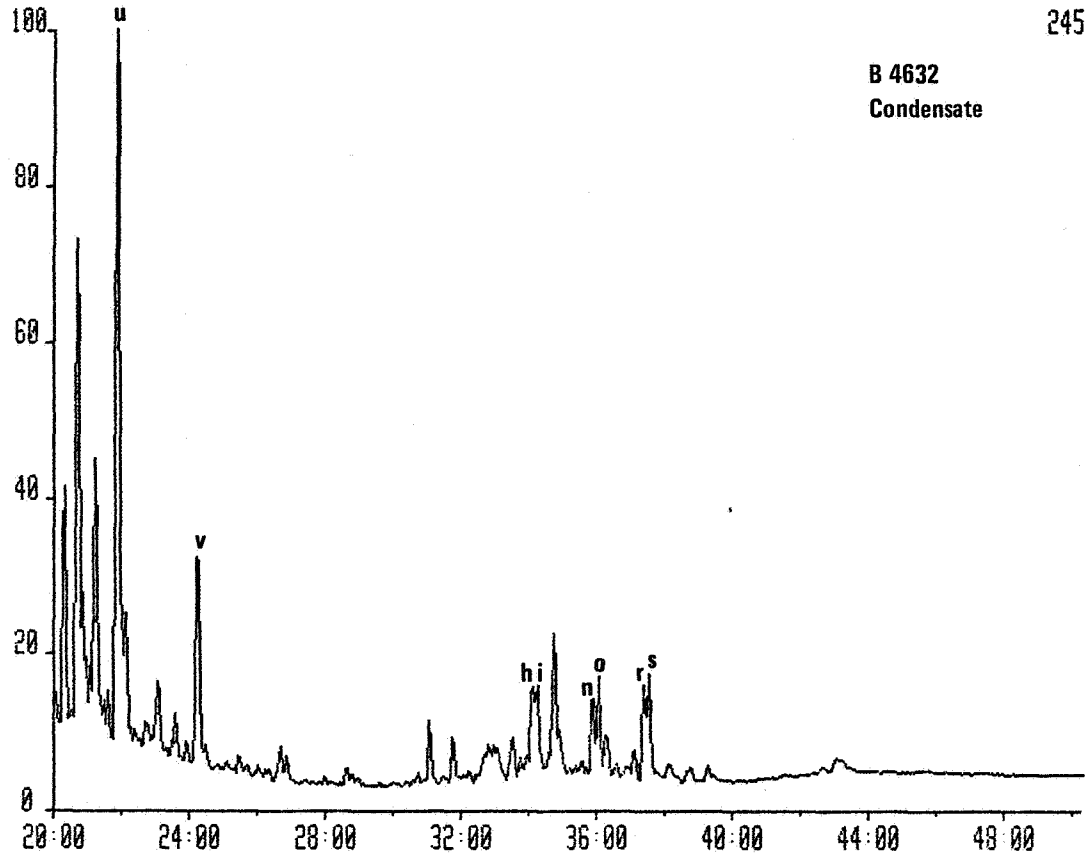


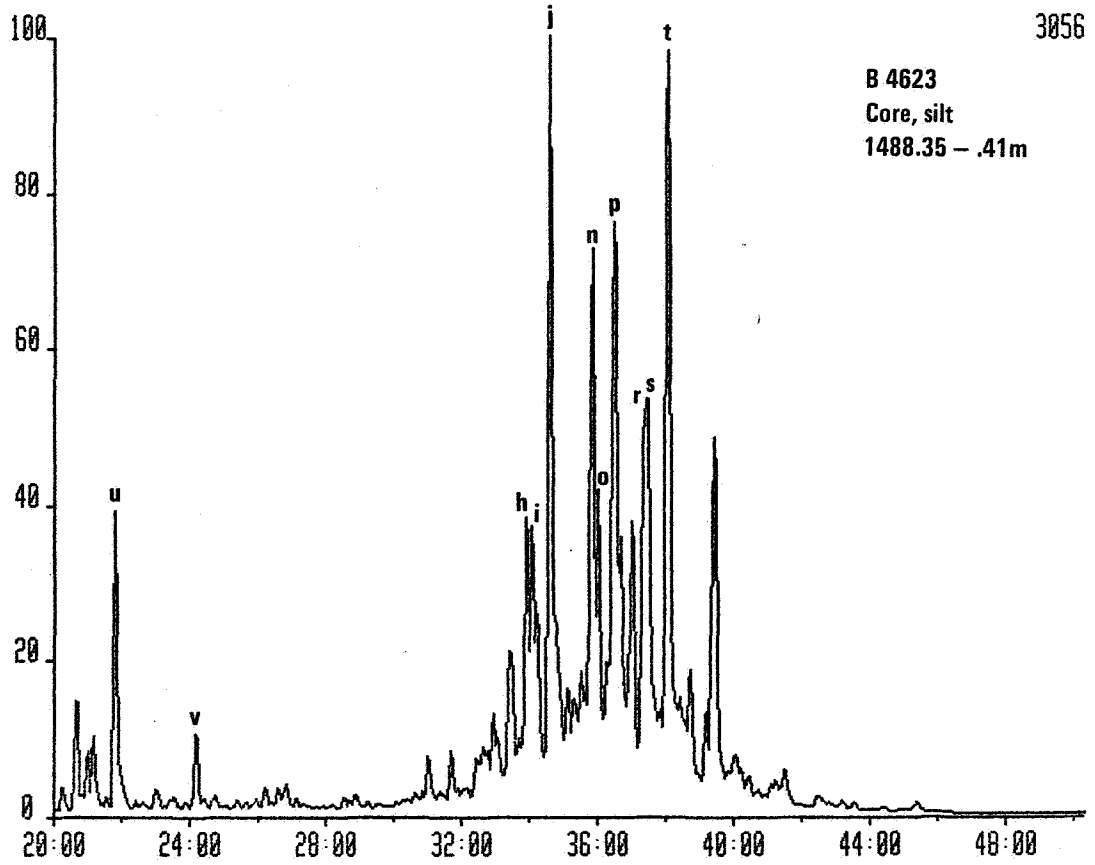
741TROL2 217.1000 G1 I1 S6





741TROL3 218.1000 G1 I1 S2





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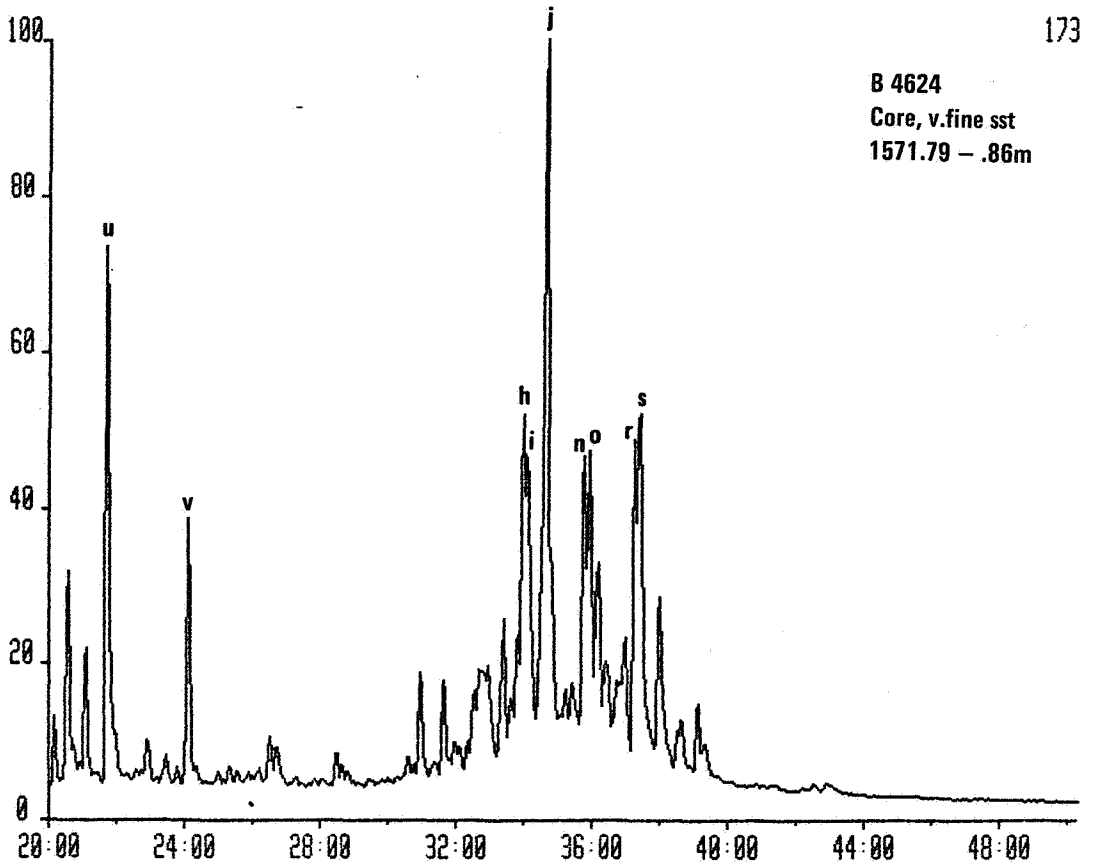
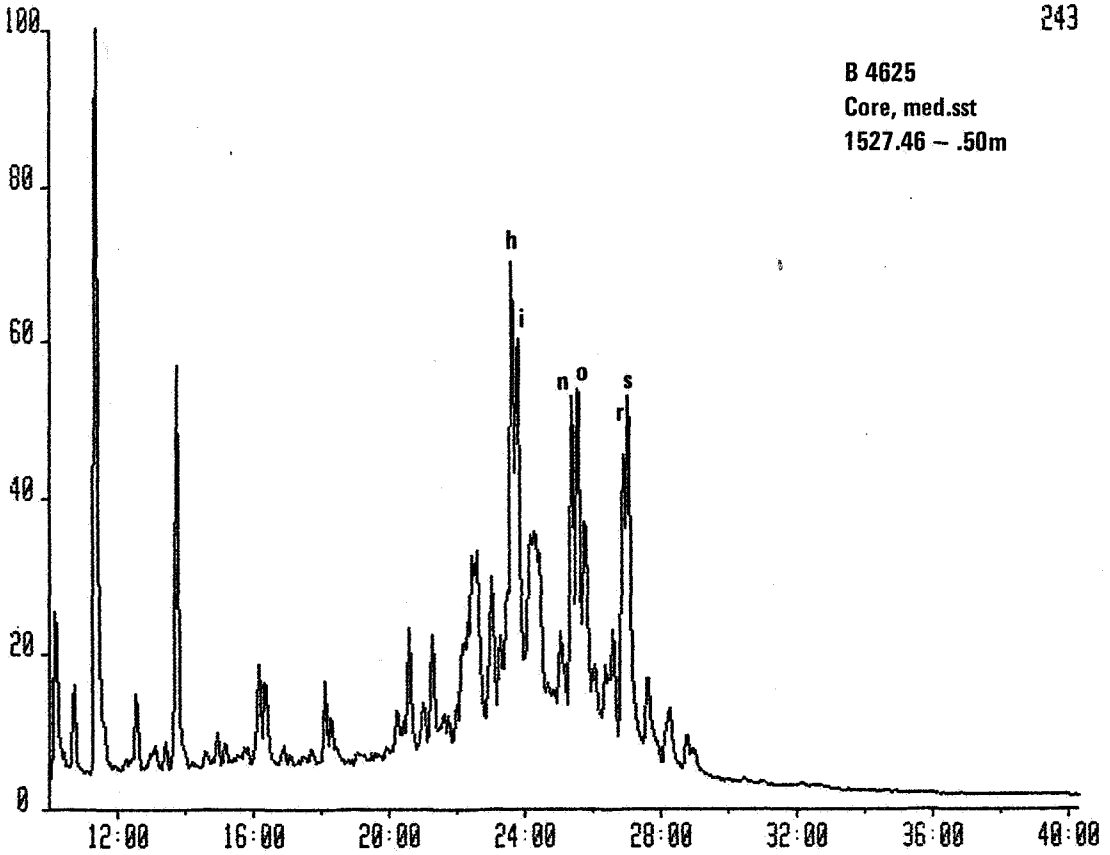


243

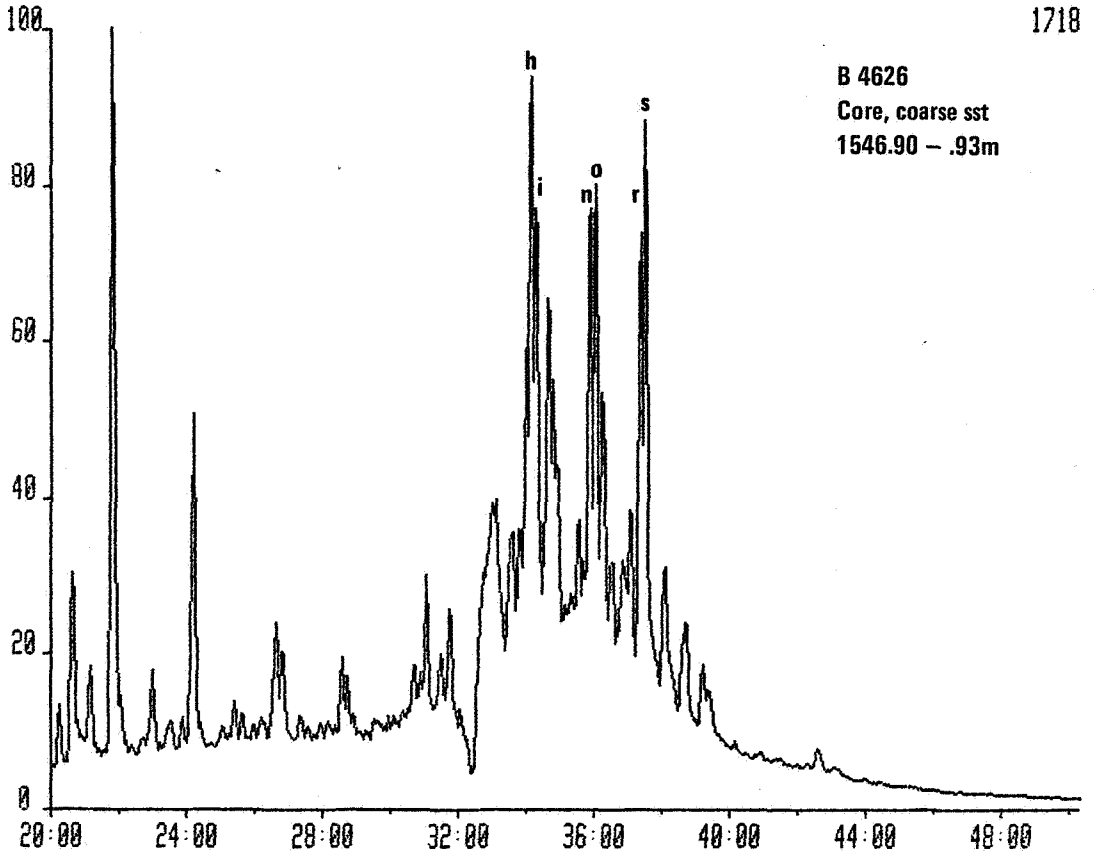
B 4625
Core, med.sst
1527.46 – .50m

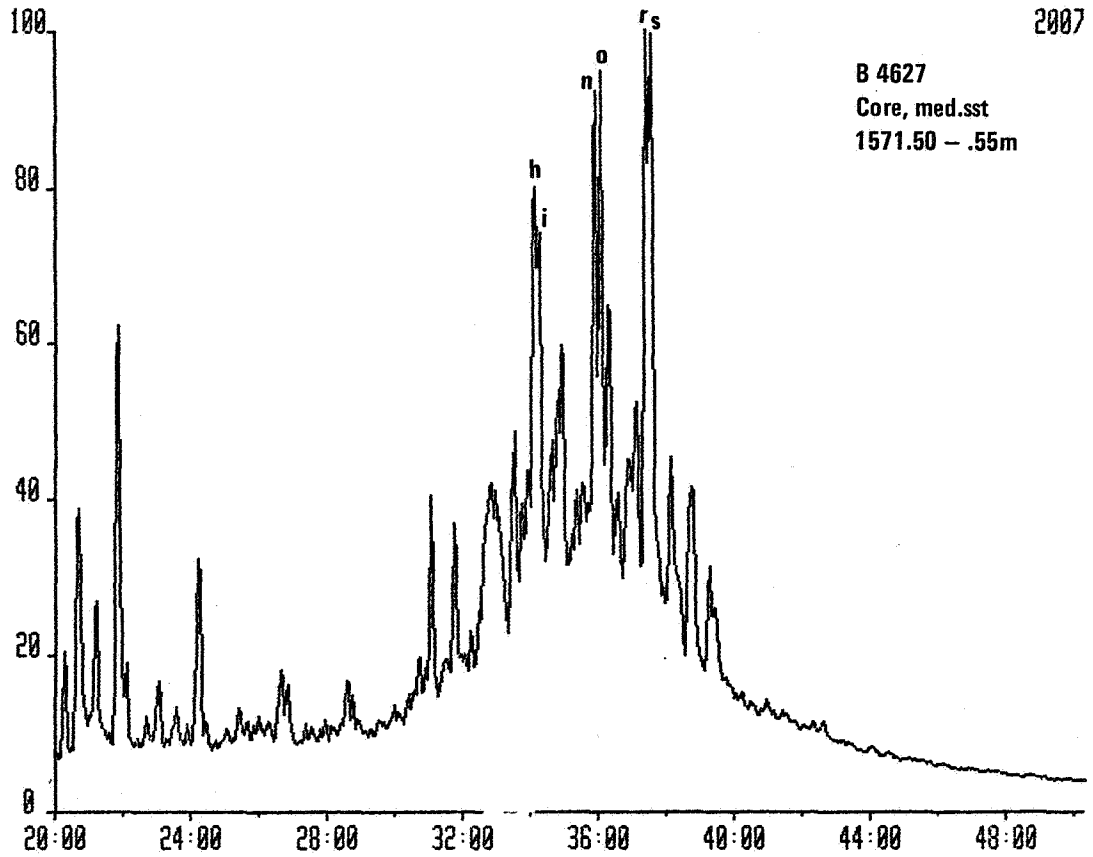


741TROL2 218.1000 G1 I1 S2

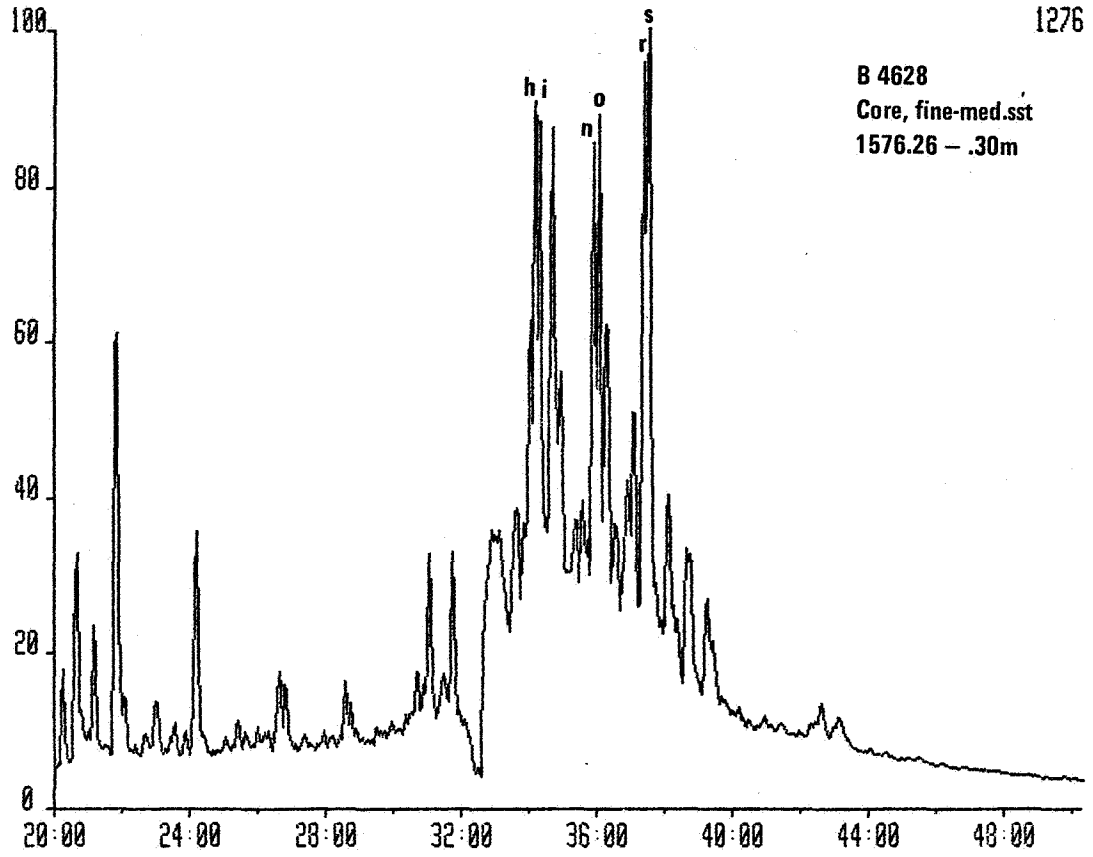
1718

B 4626
Core, coarse sst
1546.90 – .93m

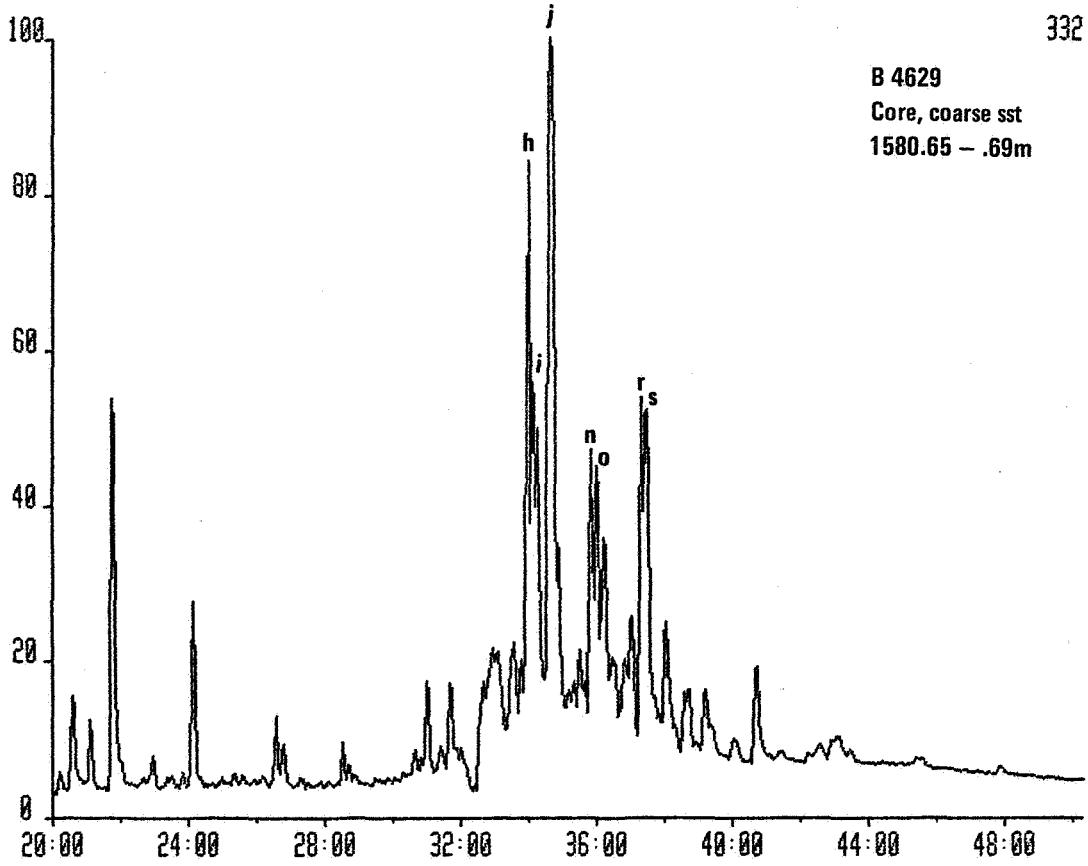




741TROL2 218.1000 G1 I1 S4



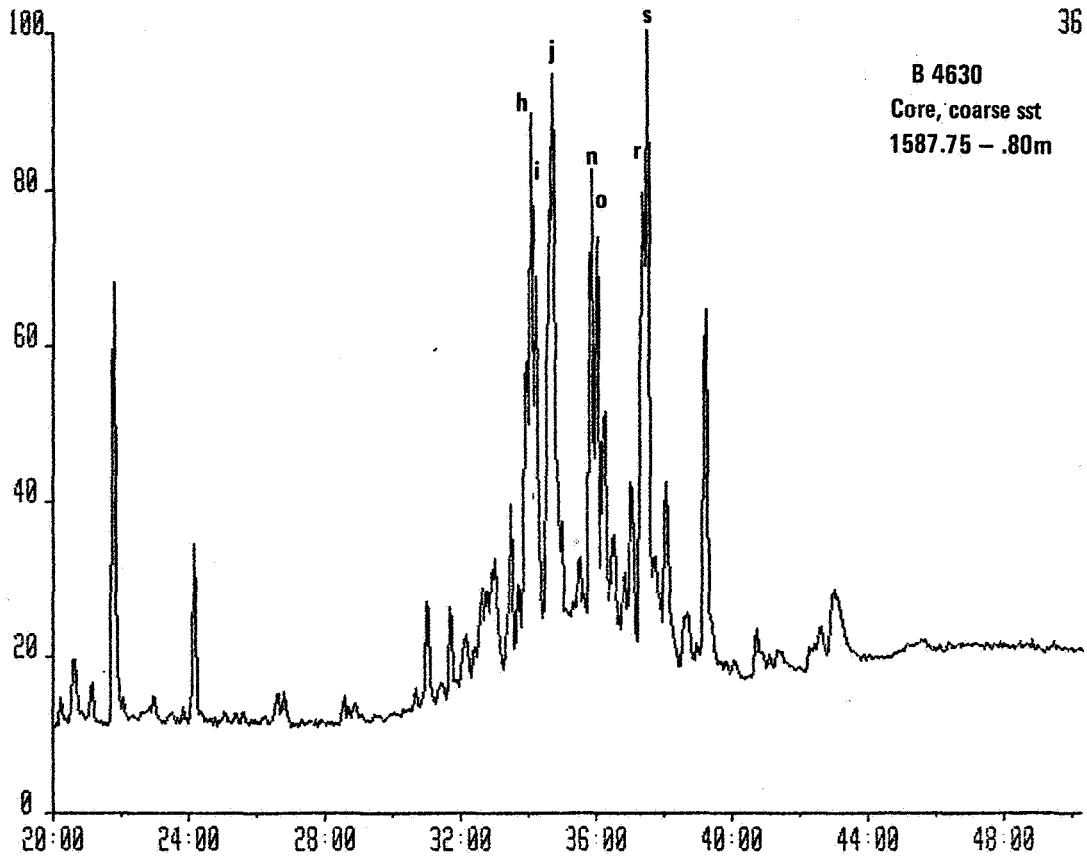
IKU



332

B 4629
Core, coarse sst
1580.65 – .69m

741TROL2 218.1000 G1 I1 S6



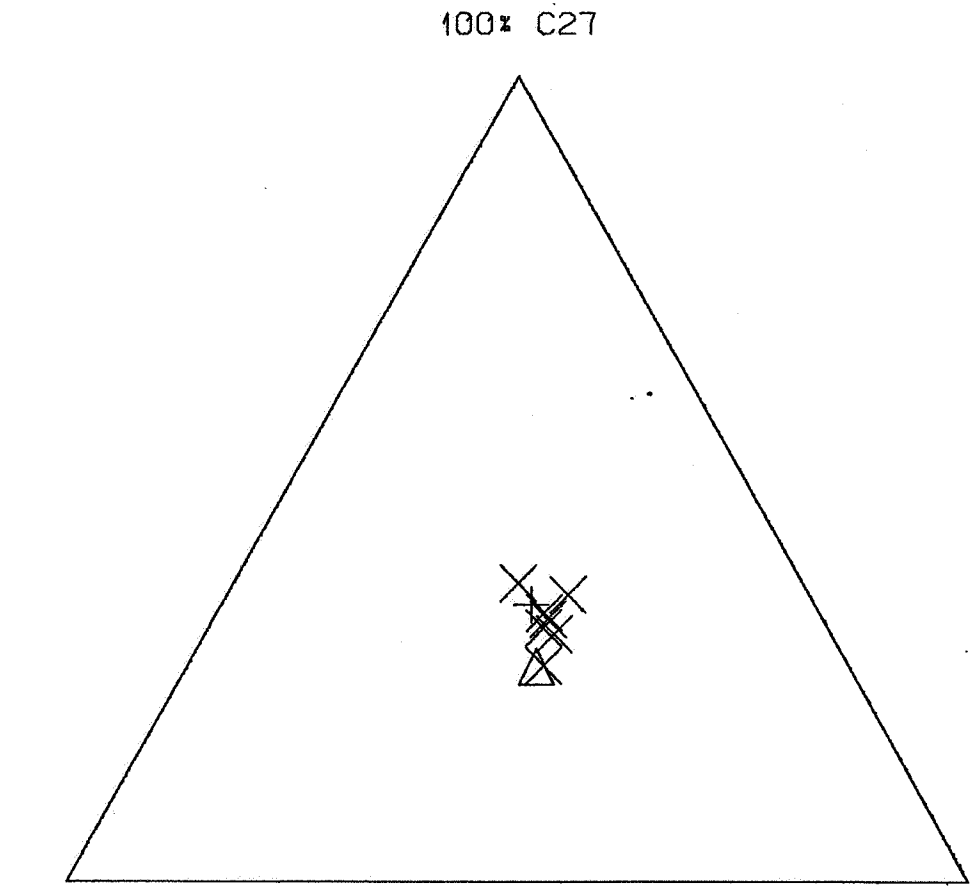
36

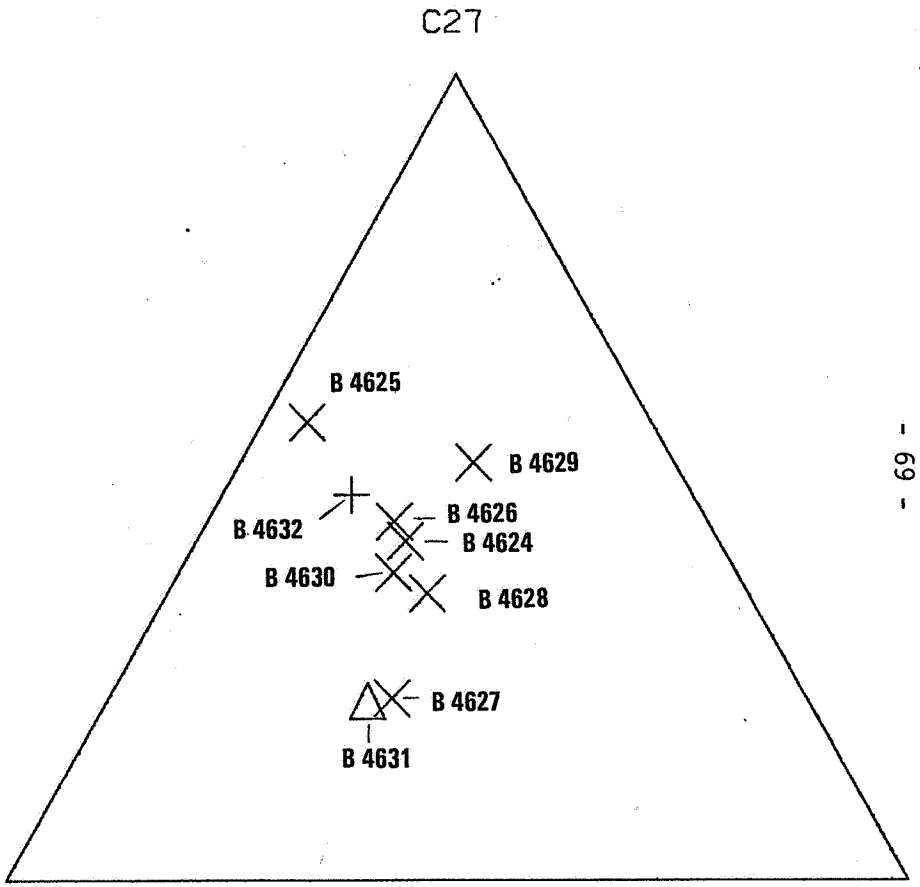
B 4630
Core, coarse sst
1587.75 – .80m

FIGURE 6

Triangular plots of molecular weight distribution
of C_{27}-C_{29} regular 14β,17β-steranes

TROLL 31/6-5



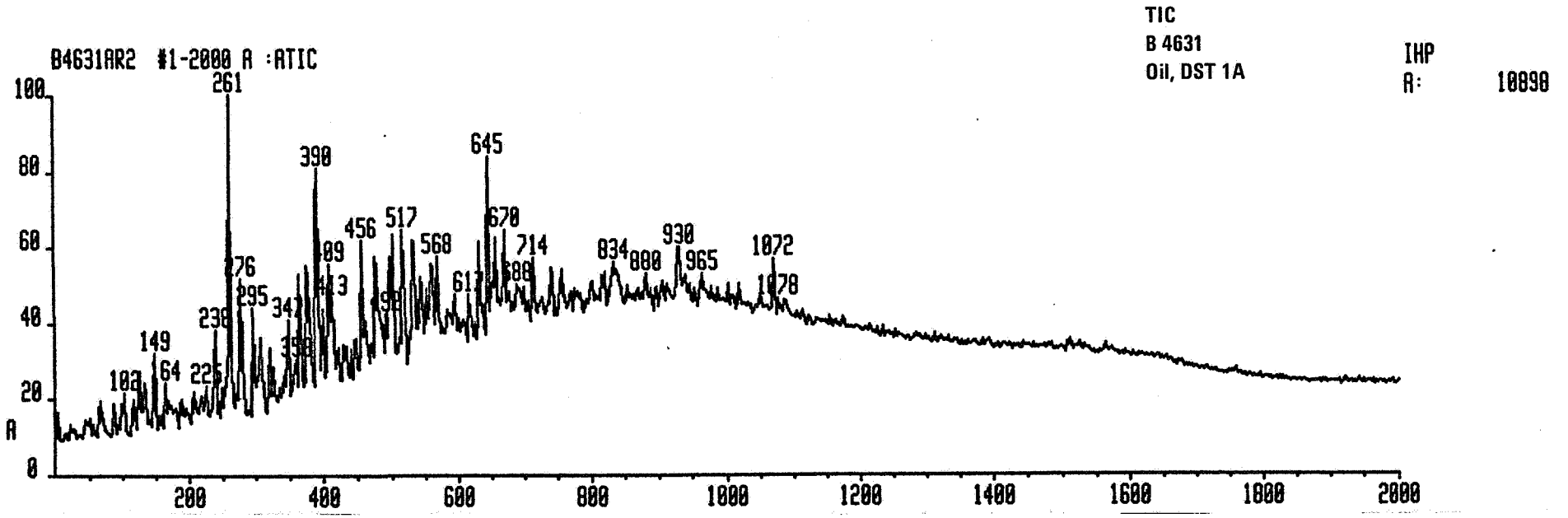


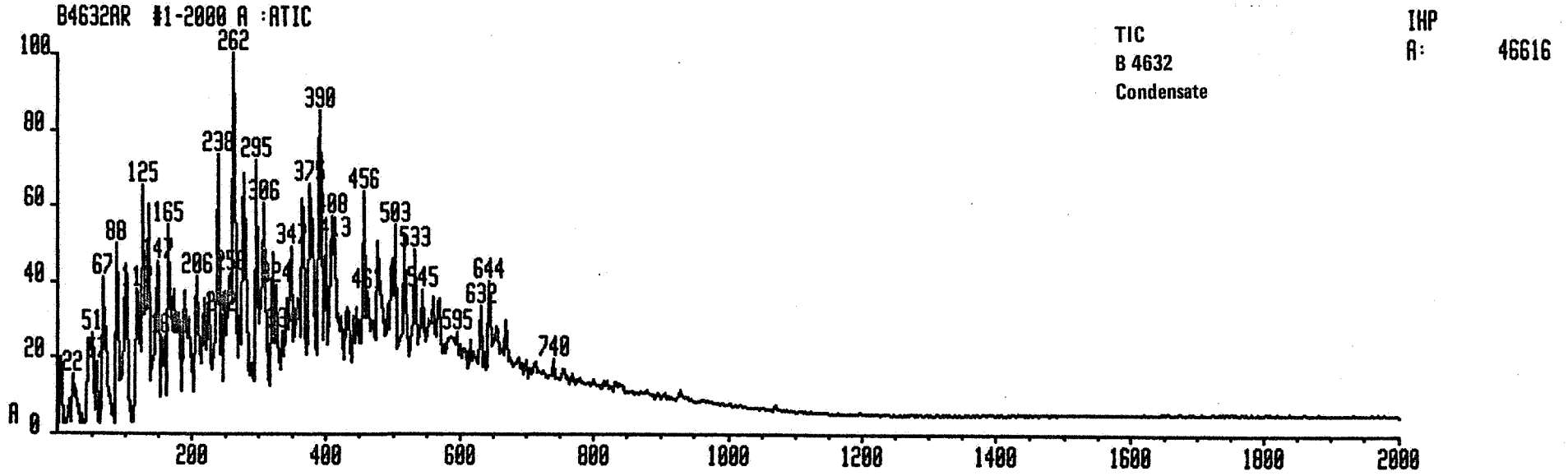
C27 (20-50%)
C28 (20-50%)
C29 (30-60%)

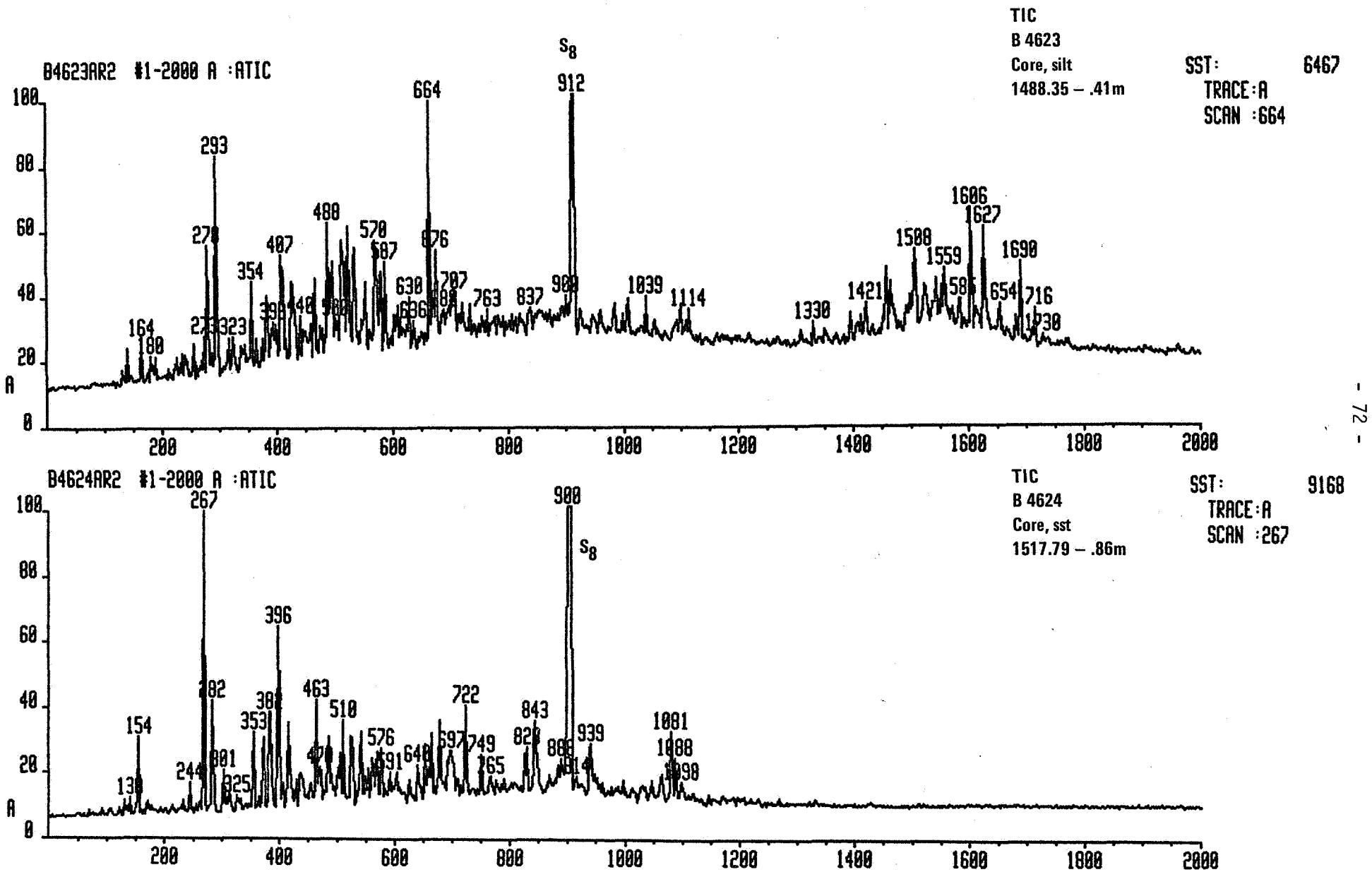
FIGURE 7

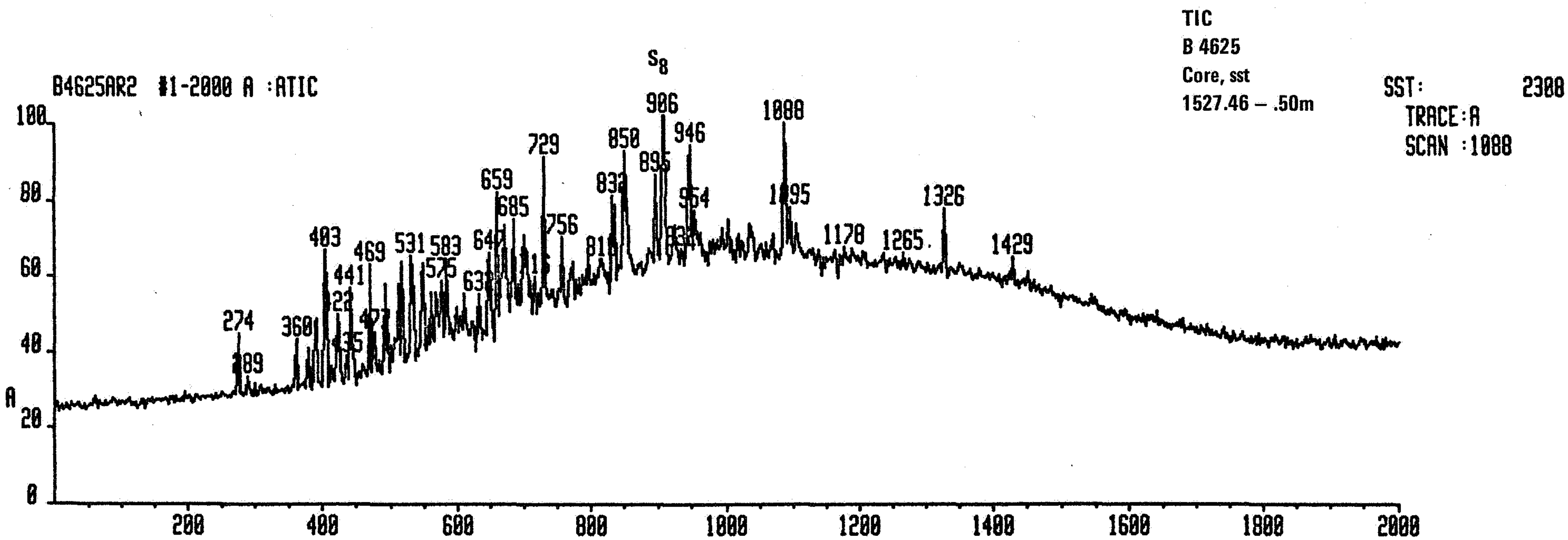
Mass chromatograms of aromatic HC's

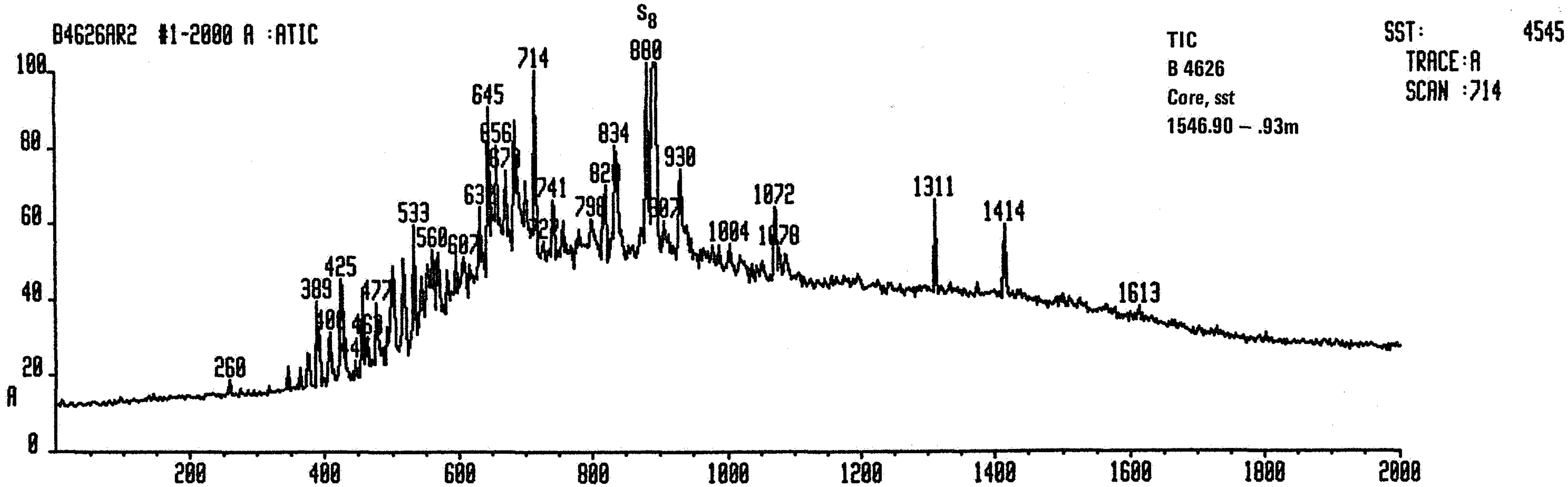
TIC	- total ion chromatogram
m/z 92,106	- alkylated benzenes
m/z 142,156,170	- alkylated naphthalenes
m/z 178,192,206	- alkylated phenanthrenes
m/z 231	- triaromatic steranes
m/z 253	- monoaromatic steranes

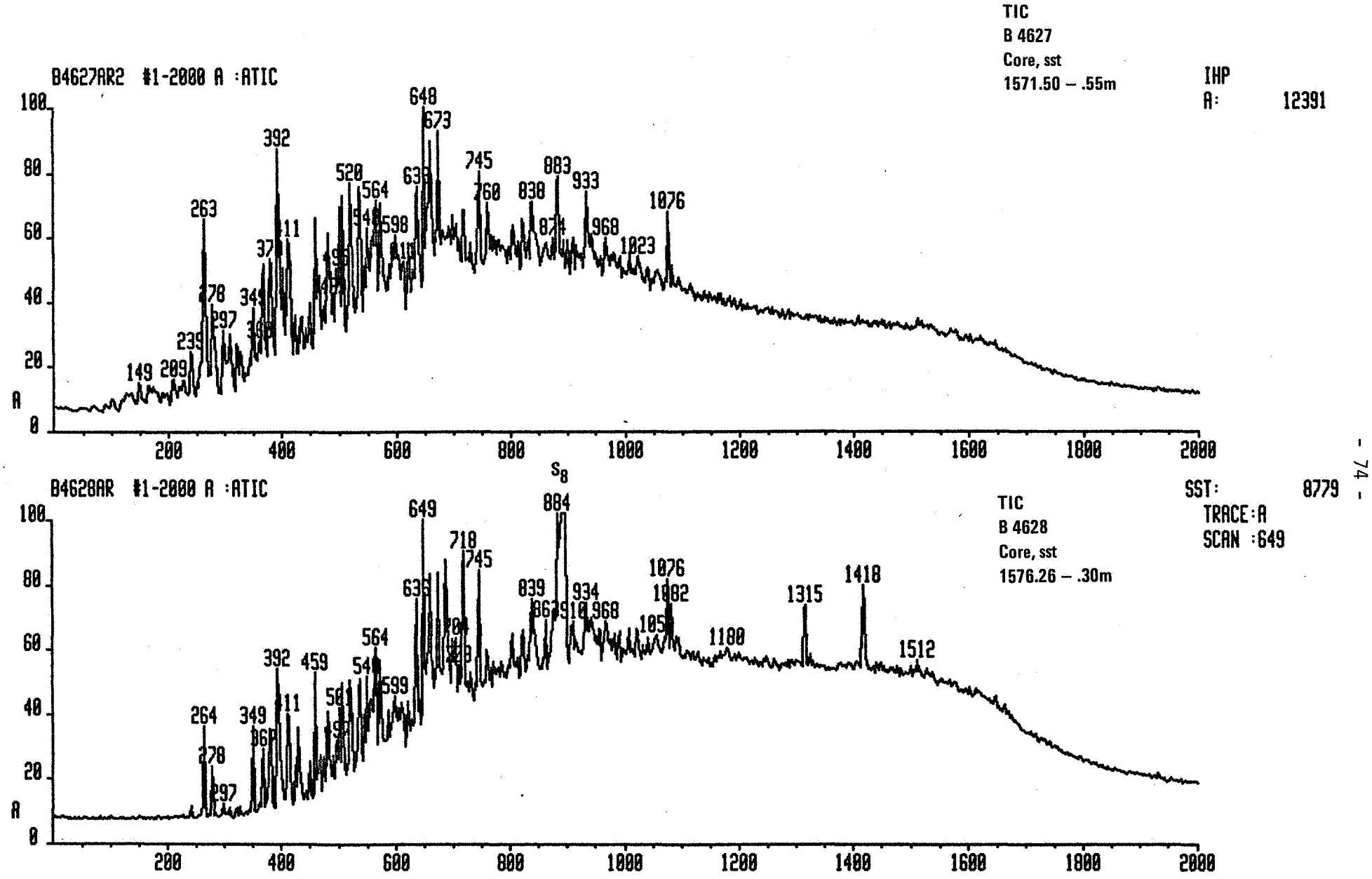

B4631AR2 #1-2000 A :ATIC
TIC
B 4631
Oil, DST 1A
IHP
A: 10898
261
390
645
456
517
670
568
714
834
930
1072
880
965
1078
149
64
225
238
295
342
A
0
20
40
60
80
100
200
400
600
800
1000
1200
1400
1600
1800
2000

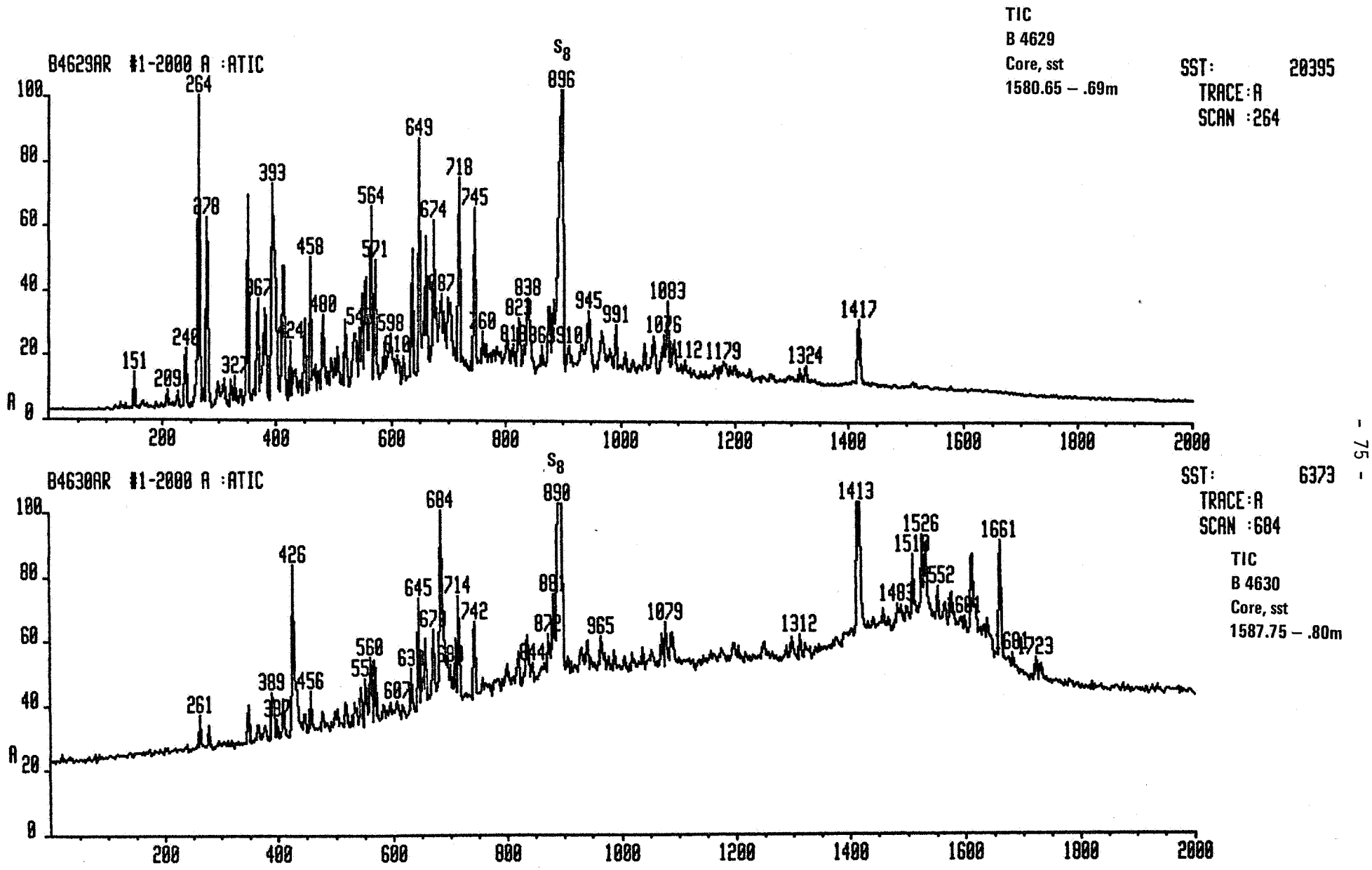

B4632AR #1-2000 A :ATIC
TIC
B 4632
Condensate
IHP
A: 46616
262
390
238
295
125
165
88
67
456
503
533
644
632
595
740
51
22
A
0
20
40
60
80
100
200
400
600
800
1000
1200
1400
1600
1800
2000

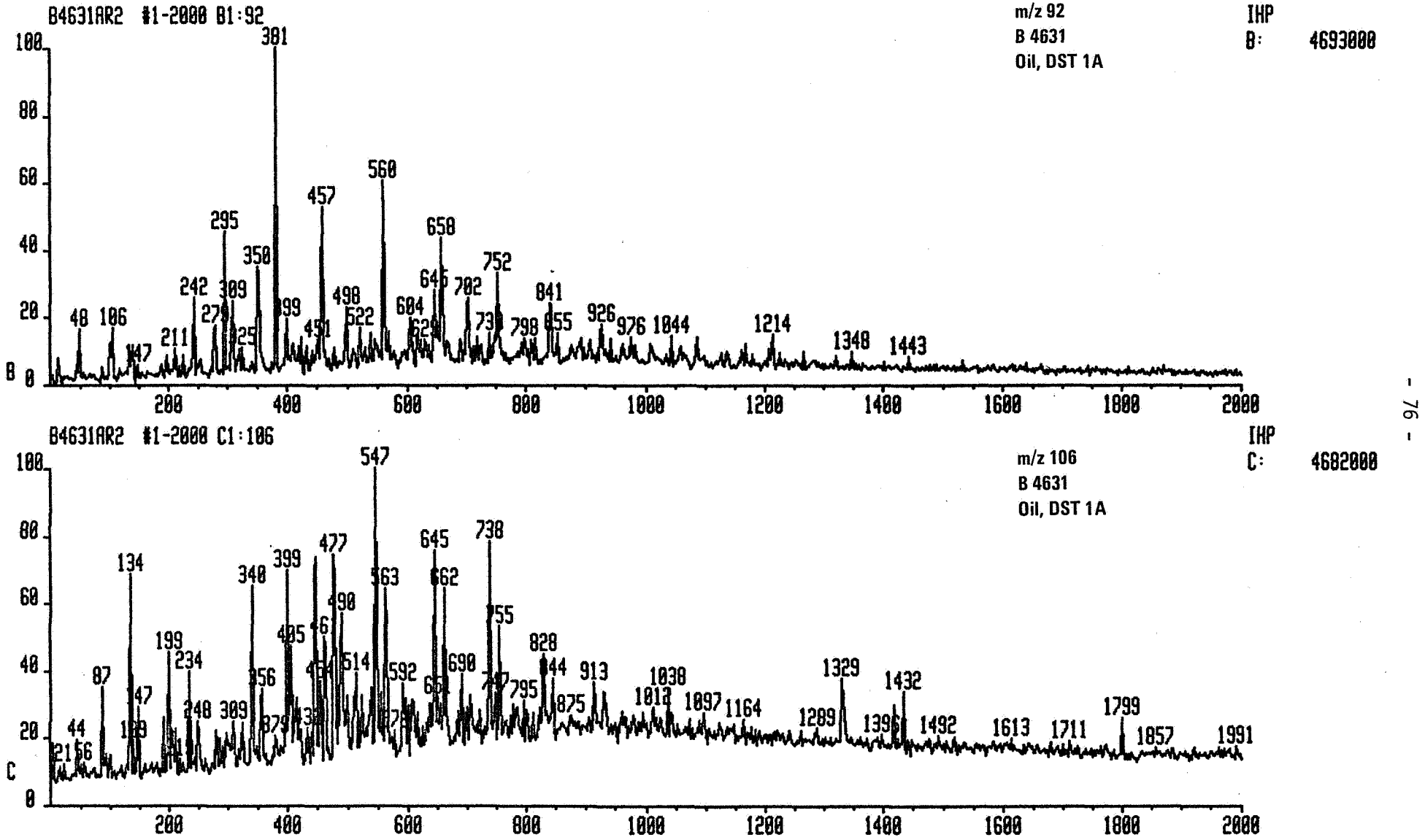

B4623AR2 #1-2000 A :ATIC
TIC
B 4623
Core, silt
1488.35 – .41m
SST: 6467
TRACE:A
SCAN :664
S_8
912
664
293
488
570
1606
1627
1508
1559
1690
1039
1114
1330
1421
B4624AR2 #1-2000 A :ATIC
TIC
B 4624
Core, sst
1517.79 – .86m
SST: 9168
TRACE:A
SCAN :267
900
S_8
267
396
463
510
722
843
939
1081
1088
A
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
2000

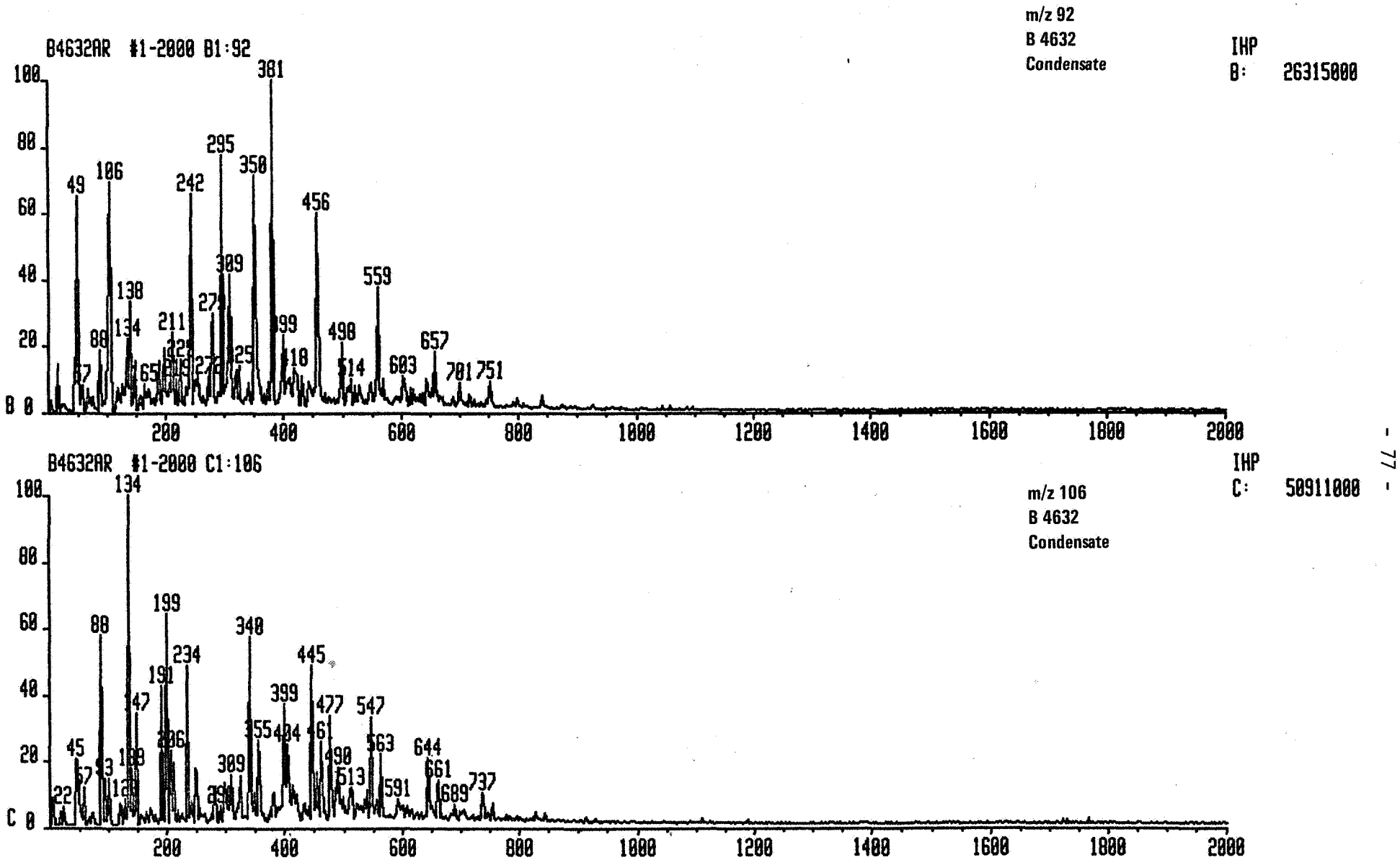

B4625AR2 #1-2000 A :ATIC
TIC
B 4625
Core, sst
1527.46 – .50m
SST: 2308
TRACE:A
SCAN :1088
S_8

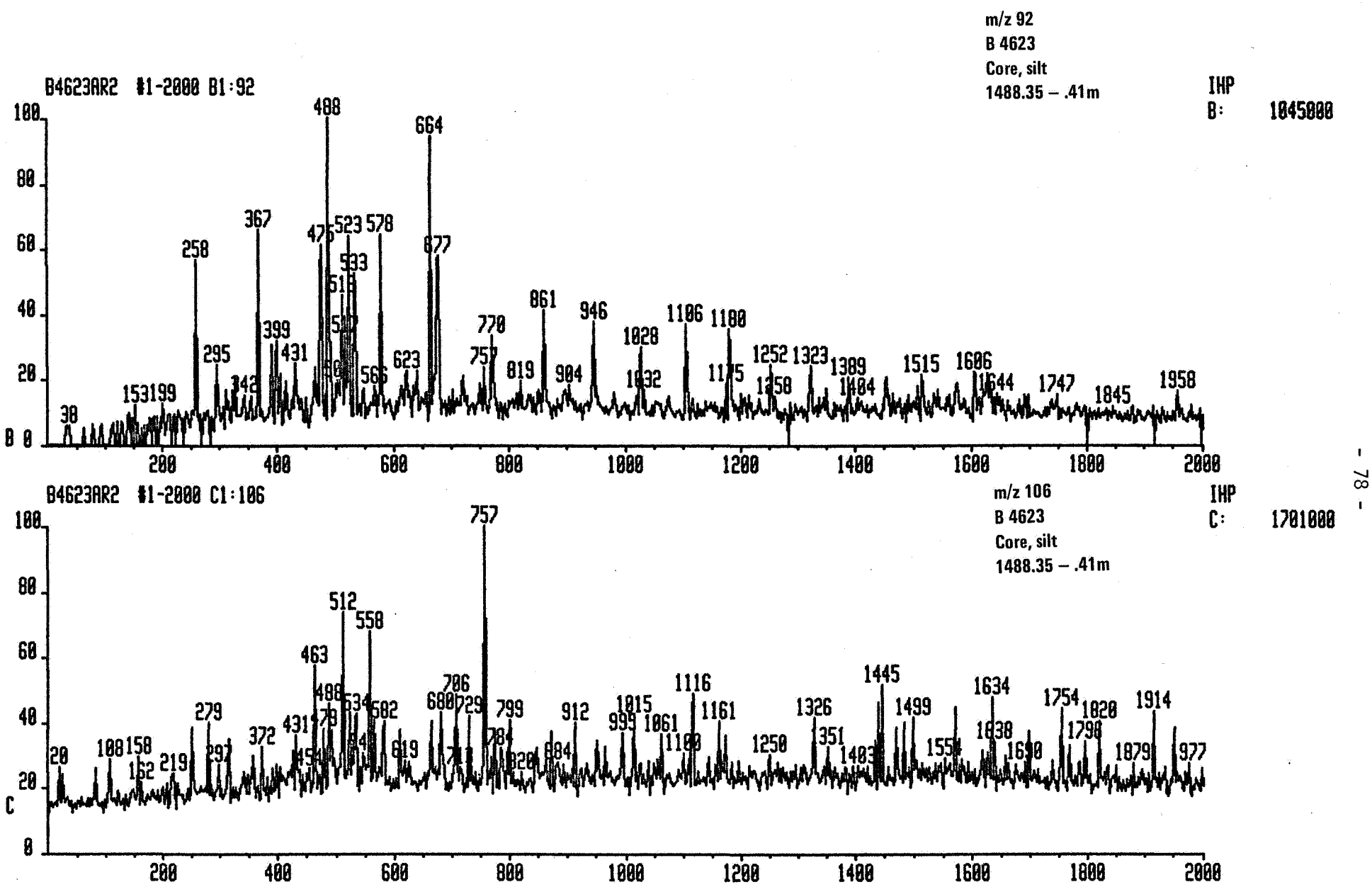

B4626AR2 #1-2000 A :ATIC
TIC
B 4626
Core, sst
1546.90 – .93m
SST: 4545
TRACE:A
SCAN :714
S_8

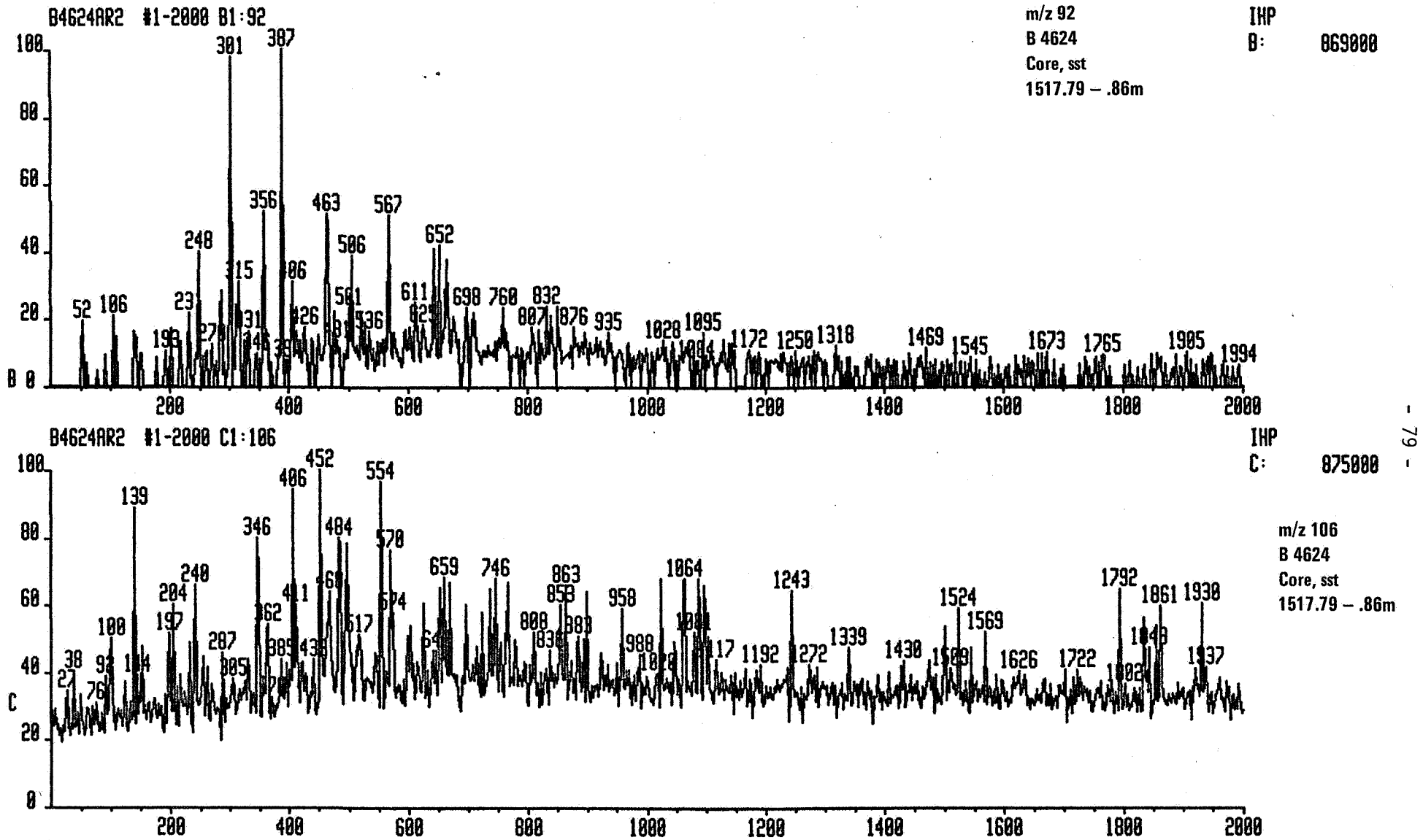

B4627AR2 #1-2000 A :ATIC
TIC
B 4627
Core, sst
1571.50 – .55m
IHP
A: 12391
B4628AR #1-2000 A :ATIC
TIC
B 4628
Core, sst
1576.26 – .30m
SST: 8779
TRACE:A
SCAN :649
S_8
A
0
20
40
60
80
100
200
400
600
800
1000
1200
1400
1600
1800
2000

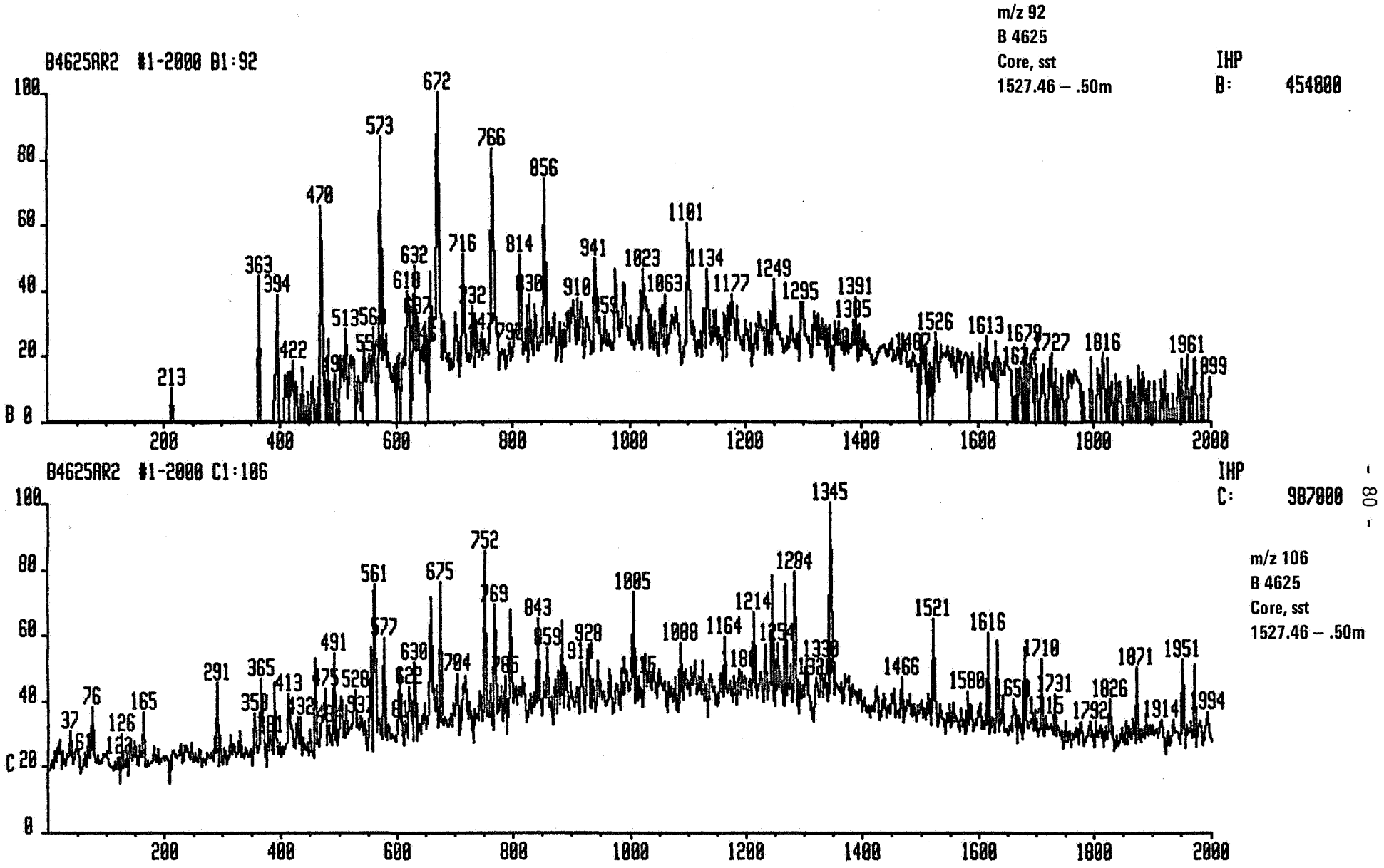

B4629AR #1-2000 A :ATIC
TIC
B 4629
Core, sst
1580.65 – .69m
SST: 20395
TRACE:A
SCAN :264
B4630AR #1-2000 A :ATIC
SST: 6373
TRACE:A
SCAN :684
TIC
B 4630
Core, sst
1587.75 – .80m
A
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
2000

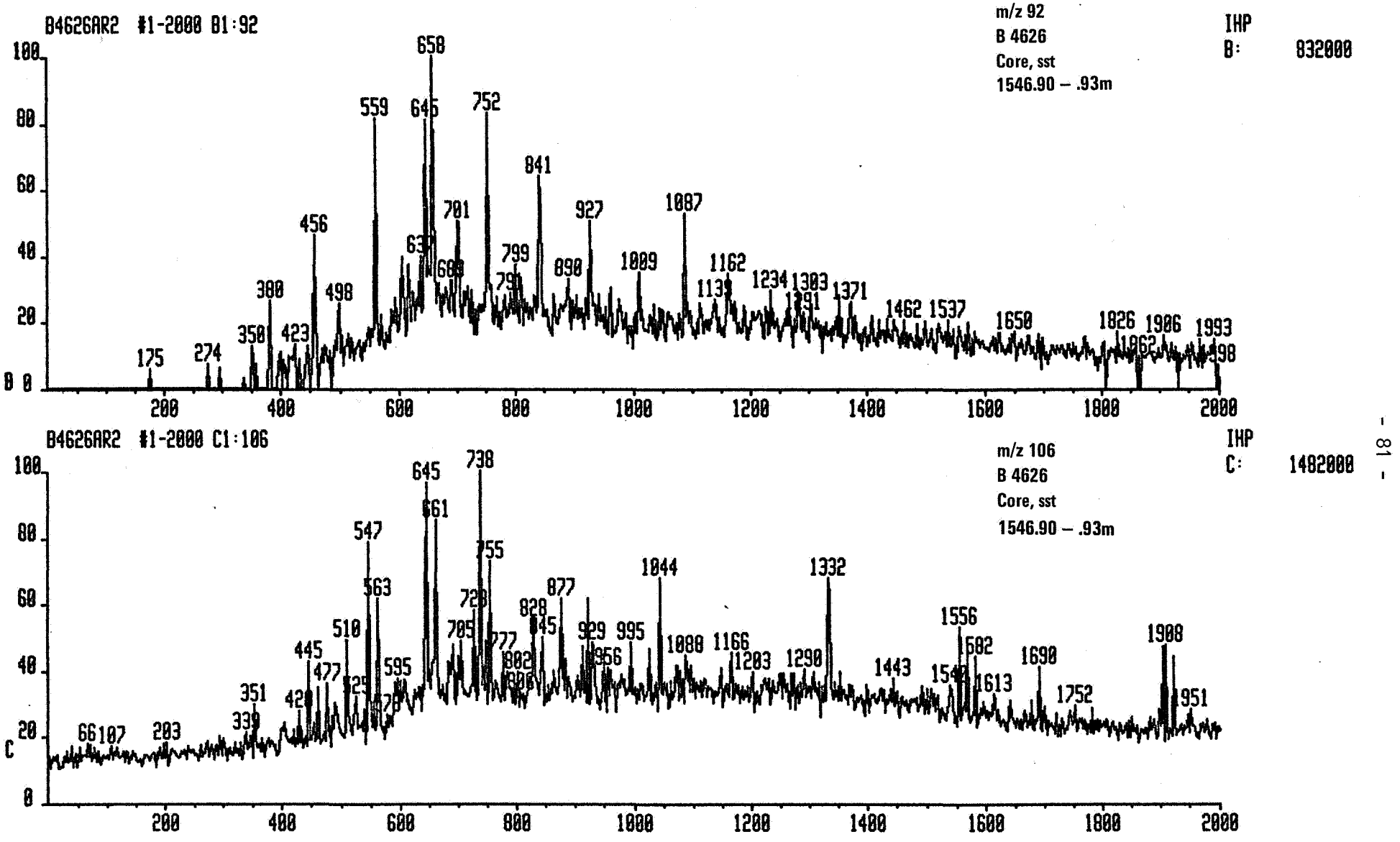

B4631AR2 #1-2000 B1:92
m/z 92
B 4631
Oil, DST 1A
IHP
B: 4693000
B4631AR2 #1-2000 C1:106
m/z 106
B 4631
Oil, DST 1A
IHP
C: 4682000

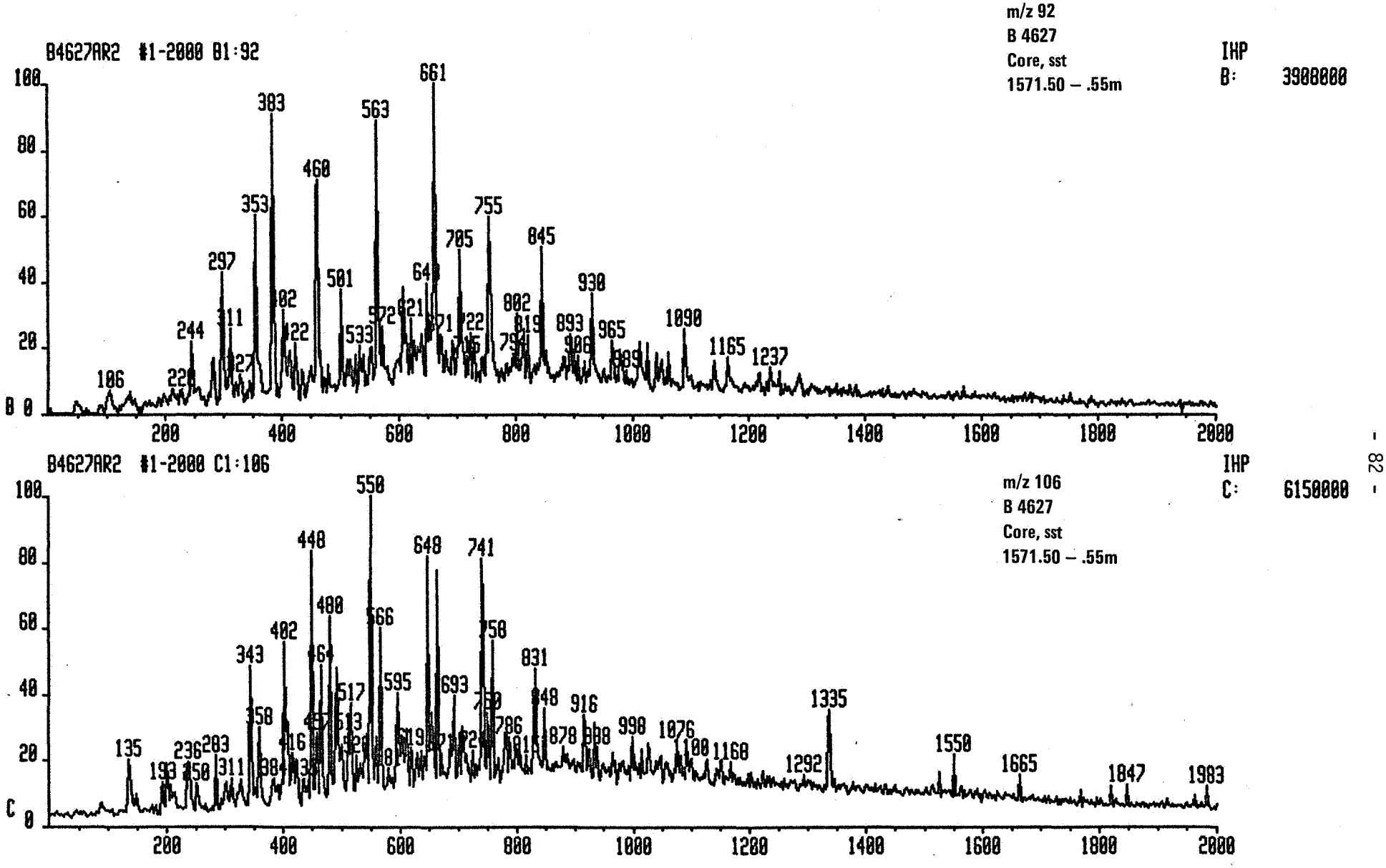

B4632AR #1-2000 B1:92
m/z 92
B 4632
Condensate
IHP
B: 26315000
B4632AR #1-2000 C1:106
m/z 106
B 4632
Condensate
IHP
C: 50911000

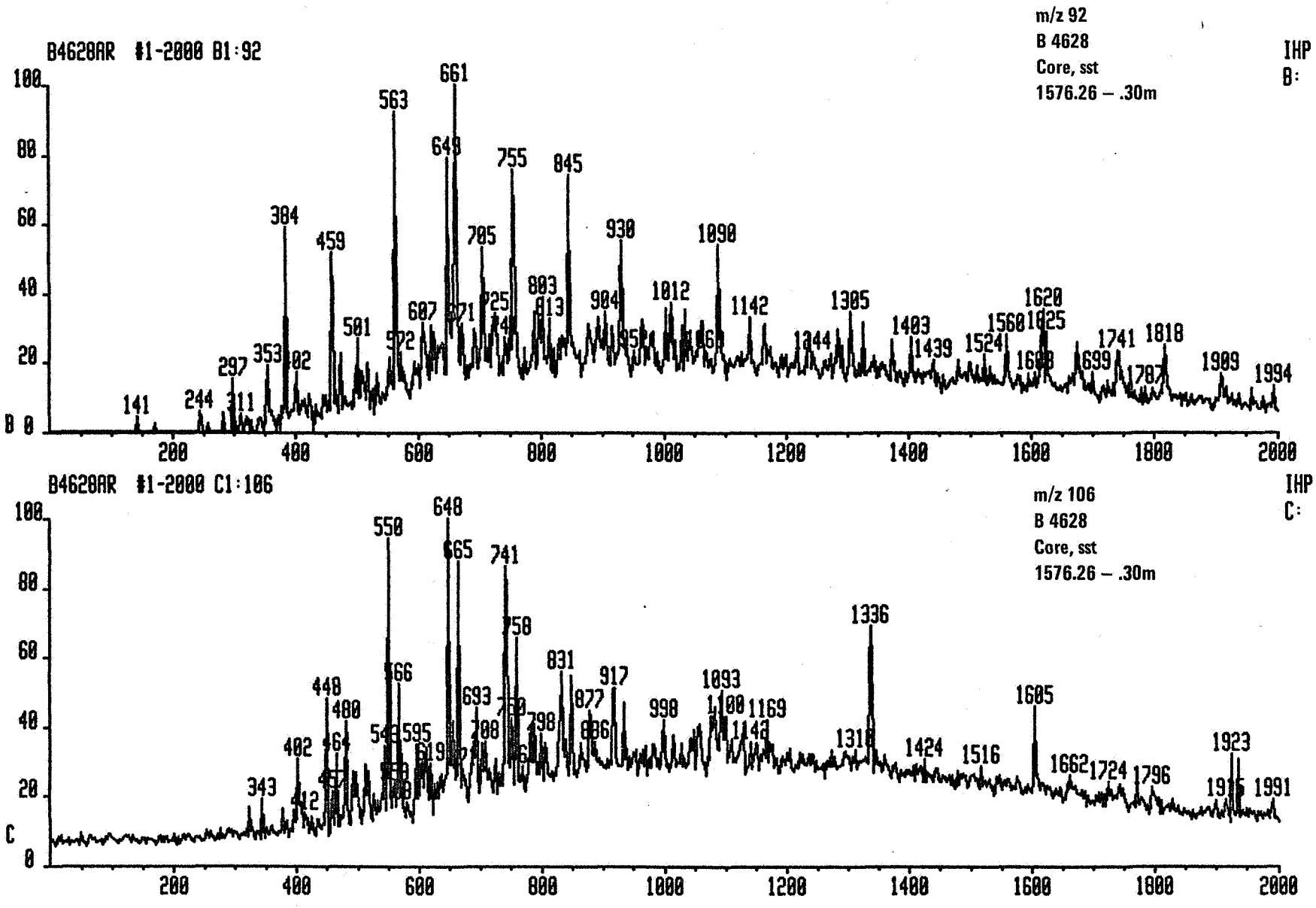

B4623AR2 #1-2000 B1:92
m/z 92
B 4623
Core, silt
1488.35 – .41m
IHP
B: 1045000
B4623AR2 #1-2000 C1:106
m/z 106
B 4623
Core, silt
1488.35 – .41m
IHP
C: 1701000

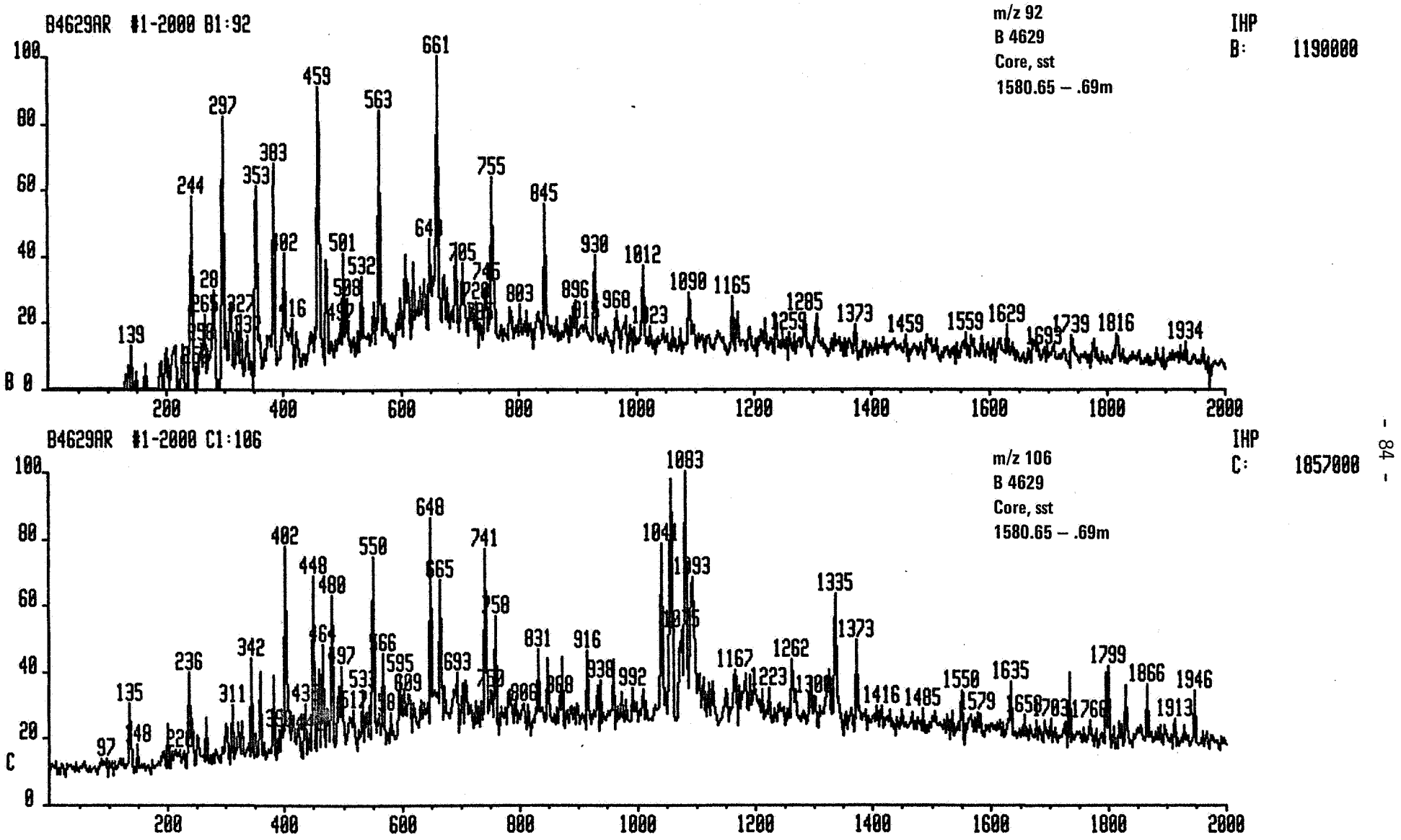

B4624AR2 #1-2000 B1:92
m/z 92
B 4624
Core, sst
1517.79 – .86m
IHP
B: 869000
B4624AR2 #1-2000 C1:106
IHP
C: 875000
m/z 106
B 4624
Core, sst
1517.79 – .86m


B4625AR2 #1-2000 B1:92
m/z 92
B 4625
Core, sst
1527.46 – .50m
IHP
B: 454000
B 0
213
363
394
422
470
573
672
766
856
1101
1134
1249
1391
1526
1613
1727
1816
1961
B4625AR2 #1-2000 C1:106
IHP
C: 987000
m/z 106
B 4625
Core, sst
1527.46 – .50m
C 20
0
37
76
126
165
291
365
413
491
561
675
752
769
843
928
1005
1214
1284
1345
1521
1616
1710
1731
1826
1871
1951
1994
200
400
600
800
1000
1200
1400
1600
1800
2000


B4626AR2 #1-2000 B1:92
m/z 92
B 4626
Core, sst
1546.90 – .93m
IHP
B: 832000
B4626AR2 #1-2000 C1:106
m/z 106
B 4626
Core, sst
1546.90 – .93m
IHP
C: 1482000


B4627AR2 #1-2000 B1:92
m/z 92
B 4627
Core, sst
1571.50 – .55m
IHP
B: 3900000
B 0
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
2000
661
383
563
460
353
755
705
845
297
501
930
244
311
106
1090
1165
1237
B4627AR2 #1-2000 C1:106
m/z 106
B 4627
Core, sst
1571.50 – .55m
IHP
C: 6150000
C 0
550
448
648
741
480
402
343
566
758
831
595
693
517
916
1335
135
236
283
1550
1665
1847
1983
1292
1076
998
1168
878
786


B4628AR #1-2000 B1:92
m/z 92
B 4628
Core, sst
1576.26 – .30m
IHP
B: 1700000
B4628AR #1-2000 C1:106
m/z 106
B 4628
Core, sst
1576.26 – .30m
IHP
C: 2916000


B4629AR #1-2000 B1:92
m/z 92
B 4629
Core, sst
1580.65 – .69m
IHP
B: 1190000
B 0
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
2000
139
244
297
353
383
459
563
661
755
845
930
1012
1090
1165
1285
1373
1459
1559
1629
1739
1816
1934
B4629AR #1-2000 C1:106
m/z 106
B 4629
Core, sst
1580.65 – .69m
IHP
C: 1857000
C
135
236
311
342
402
448
480
550
648
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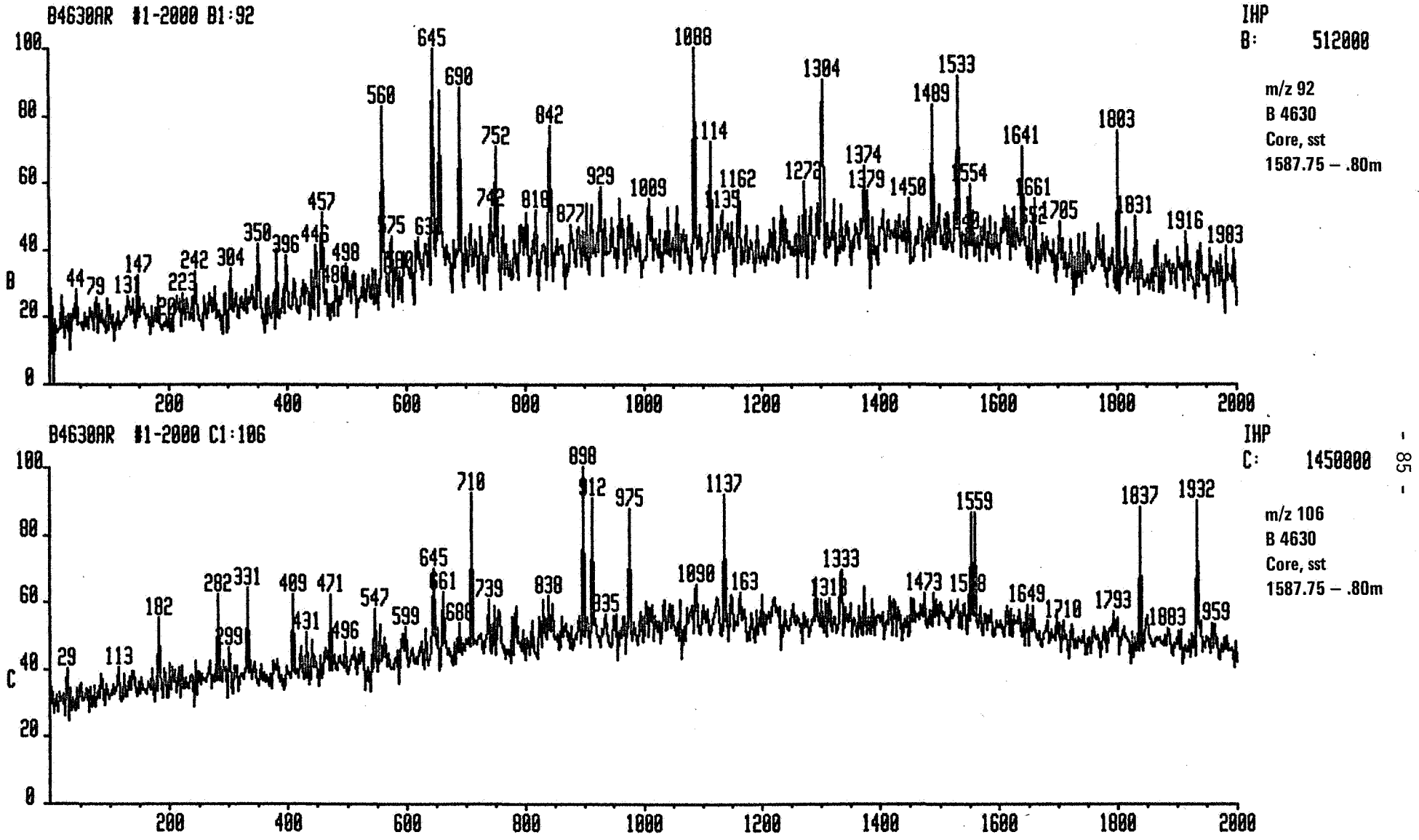
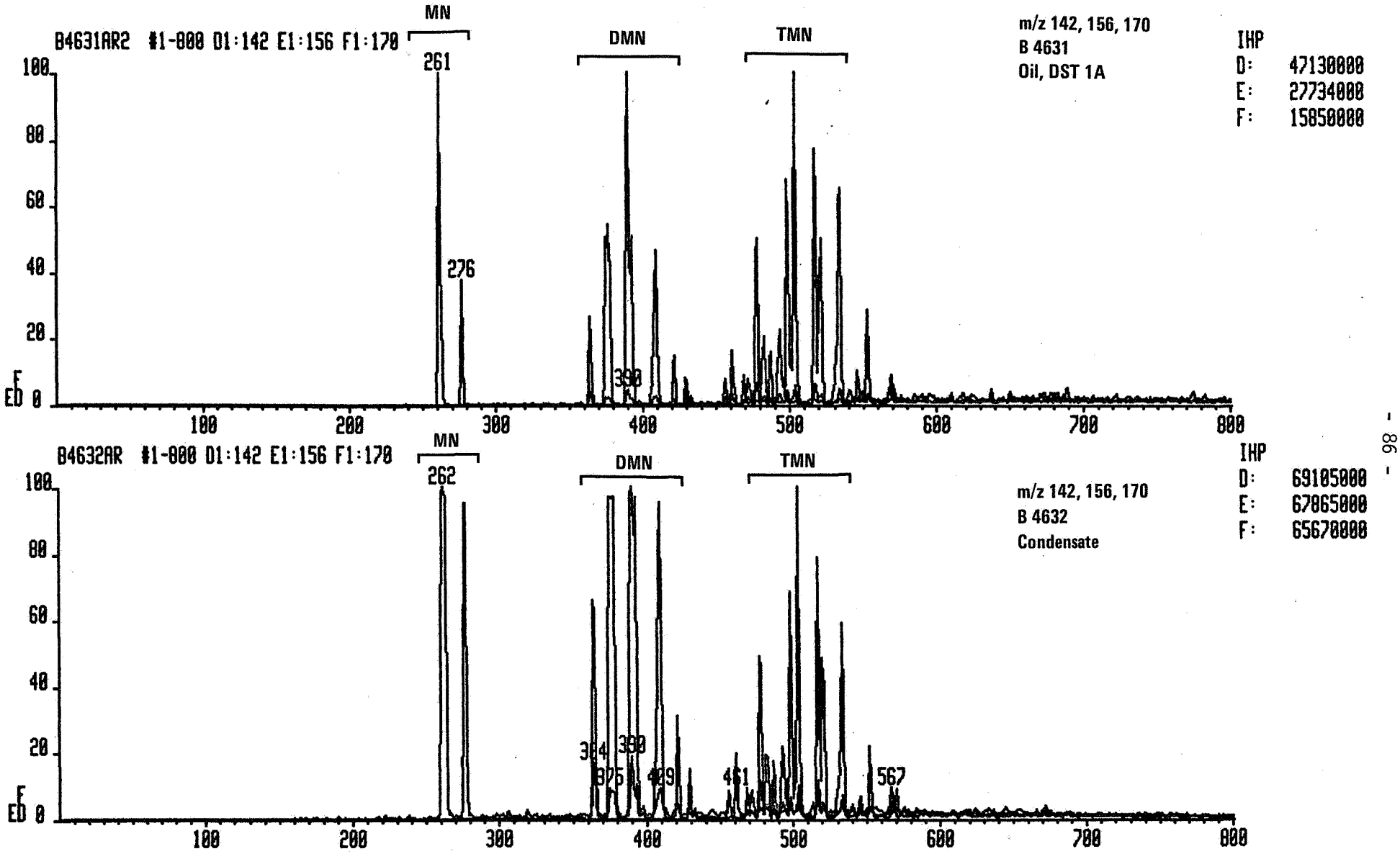
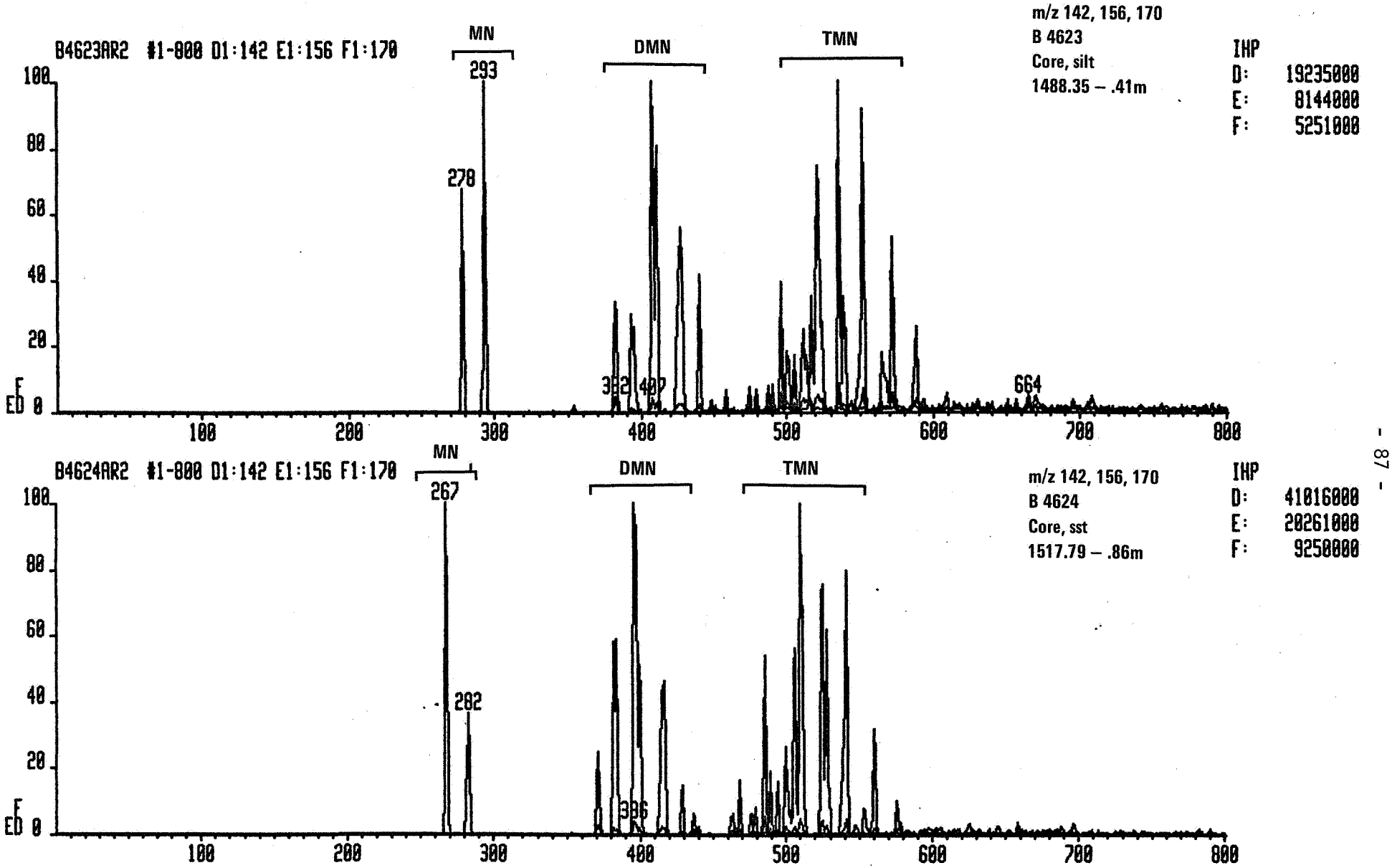
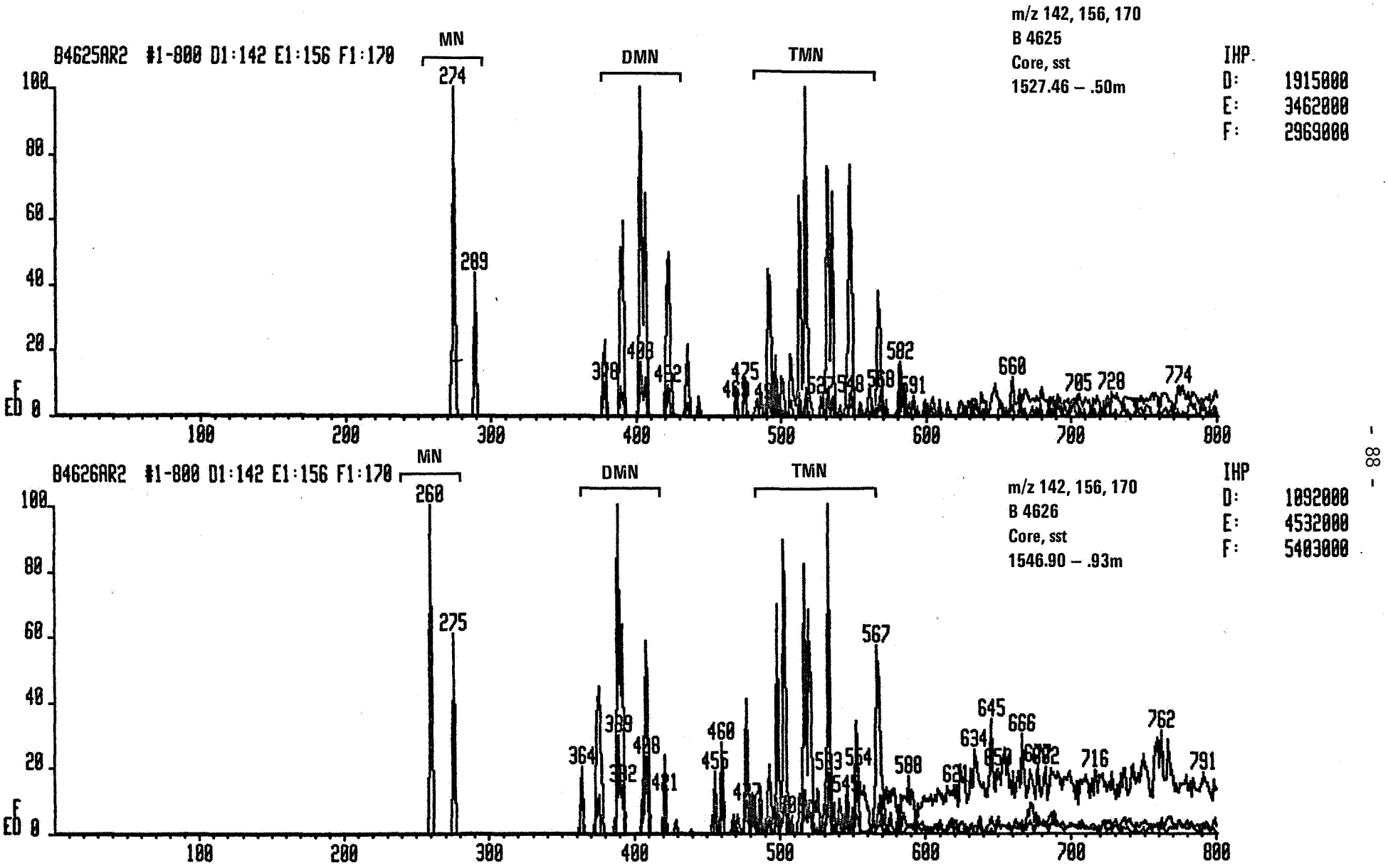
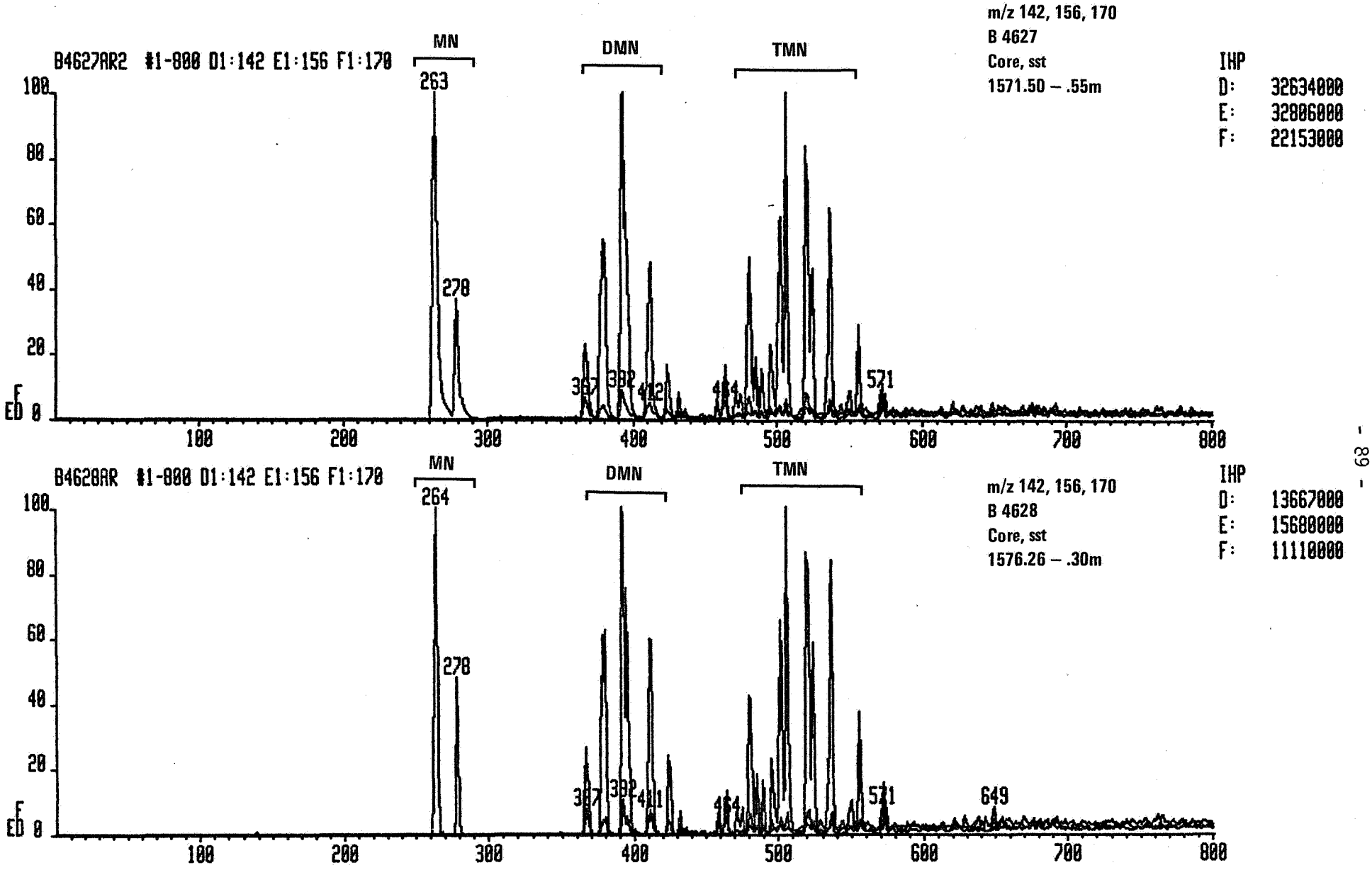
916
1083
1167
1262
1335
1373
1550
1635
1799
1866
1946
1913


B4630AR #1-2000 B1:92
IHP
B: 512000
m/z 92
B 4630
Core, sst
1587.75 – .80m
B
B4630AR #1-2000 C1:106
IHP
C: 1450000
m/z 106
B 4630
Core, sst
1587.75 – .80m
C
0
20
40
60
80
100
200
400
600
800
1000
1200
1400
1600
1800
2000


B4631AR2 #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
261
276
390
m/z 142, 156, 170
B 4631
Oil, DST 1A
IHP
D: 47130000
E: 27734000
F: 15850000
B4632AR #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
262
364
390
425
429
461
567
m/z 142, 156, 170
B 4632
Condensate
IHP
D: 69105000
E: 67865000
F: 65670000
100
80
60
40
20
0
100
200
300
400
500
600
700
800


B4623AR2 #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
293
278
382
400
664
m/z 142, 156, 170
B 4623
Core, silt
1488.35 – .41m
IHP
D: 19235000
E: 8144000
F: 5251000
B4624AR2 #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
267
282
386
m/z 142, 156, 170
B 4624
Core, sst
1517.79 – .86m
IHP
D: 41016000
E: 20261000
F: 9250000
100
80
60
40
20
0
100
200
300
400
500
600
700
800


B4625AR2 #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
274
289
m/z 142, 156, 170
B 4625
Core, sst
1527.46 – .50m
IHP
D: 1915000
E: 3462000
F: 2969000
B4626AR2 #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
260
275
567
m/z 142, 156, 170
B 4626
Core, sst
1546.90 – .93m
IHP
D: 1092000
E: 4532000
F: 5403000
100
80
60
40
20
0
100
200
300
400
500
600
700
800


B4627AR2 #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
263
278
387
382
412
464
571
m/z 142, 156, 170
B 4627
Core, sst
1571.50 – .55m
IHP
D: 32634000
E: 32806000
F: 22153000
B4628AR #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
264
278
387
382
411
464
571
649
m/z 142, 156, 170
B 4628
Core, sst
1576.26 – .30m
IHP
D: 13667000
E: 15680000
F: 11110000
100
80
60
40
20
0
100
200
300
400
500
600
700
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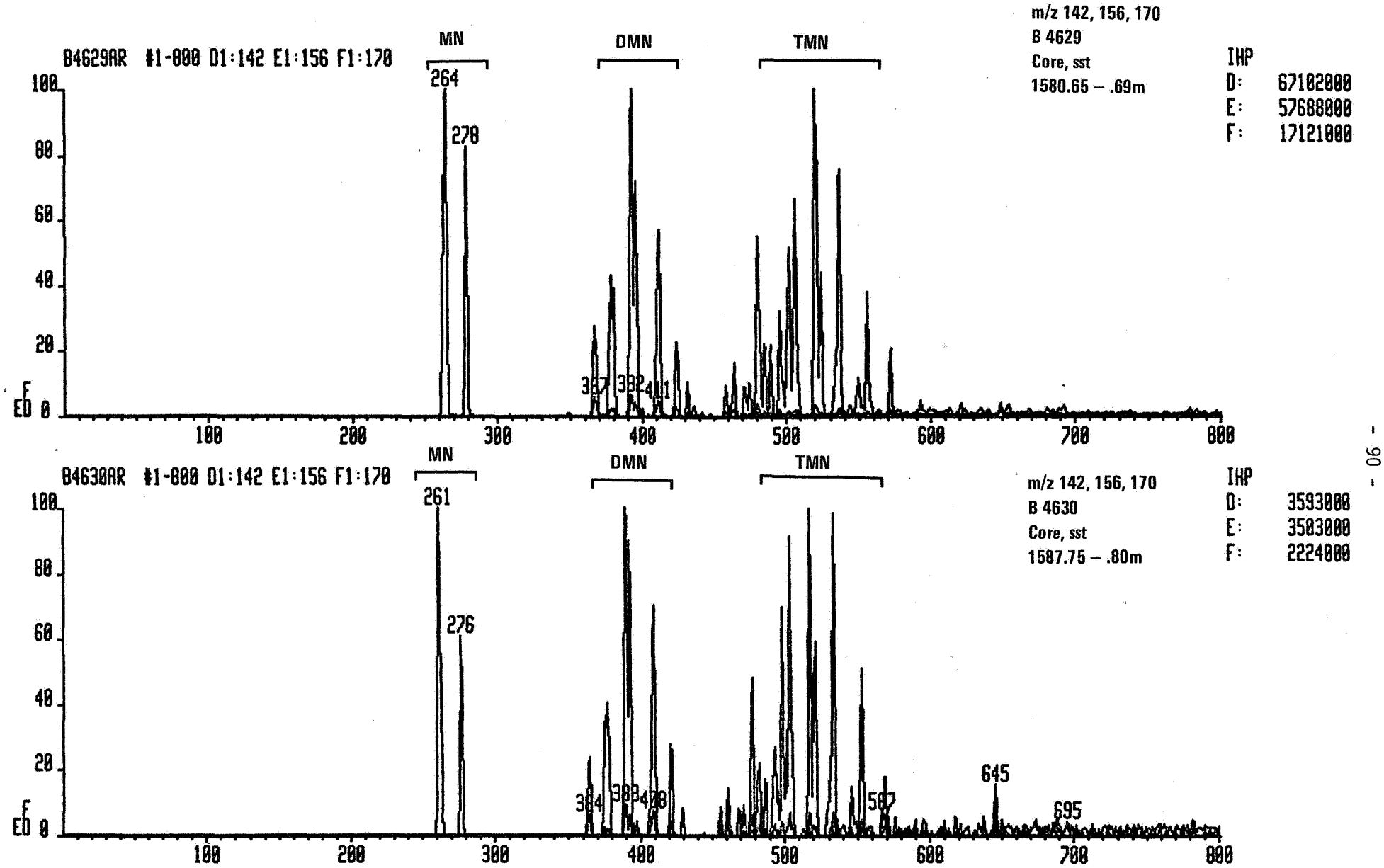
B4629AR #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
264
278
387
382
411
m/z 142, 156, 170
B 4629
Core, sst
1580.65 – .69m
IHP
D: 67102000
E: 57688000
F: 17121000
B4630AR #1-800 D1:142 E1:156 F1:170
MN
DMN
TMN
261
276
384
389
428
567
645
695
m/z 142, 156, 170
B 4630
Core, sst
1587.75 – .80m
IHP
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40
20
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100
200
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400
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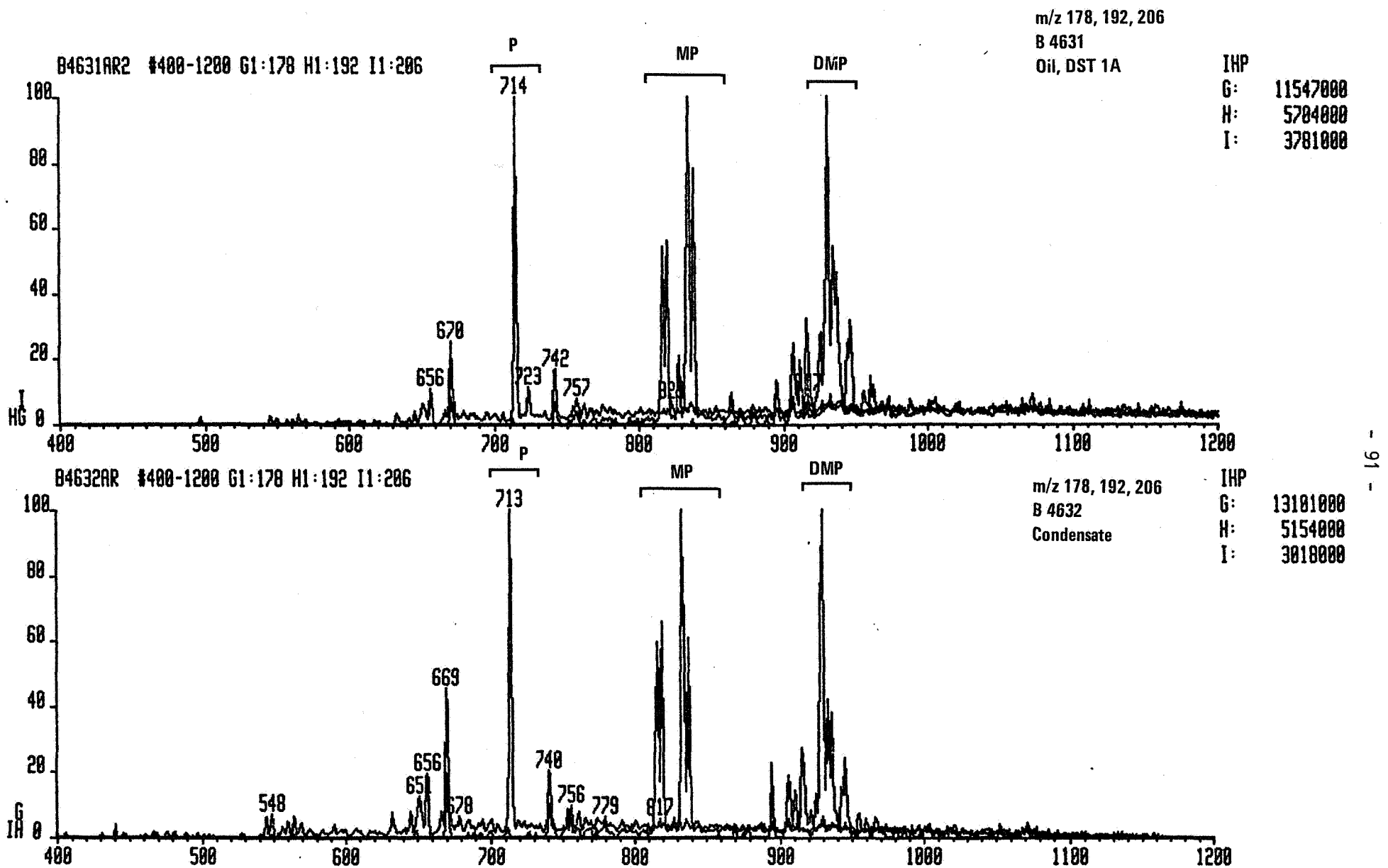
600
700
800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m/z 178, 192, 206
B 4631
Oil, DST 1A
IHP
G: 11547000
H: 5704000
I: 3781000
P
MP
DMP
714
670
656
723
742
757
HG I
B4632AR #400-1200 G1:178 H1:192 I1:206
m/z 178, 192, 206
B 4632
Condensate
IHP
G: 13181000
H: 5154000
I: 3018000
713
669
656
651
548
678
740
756
779
617
IA G
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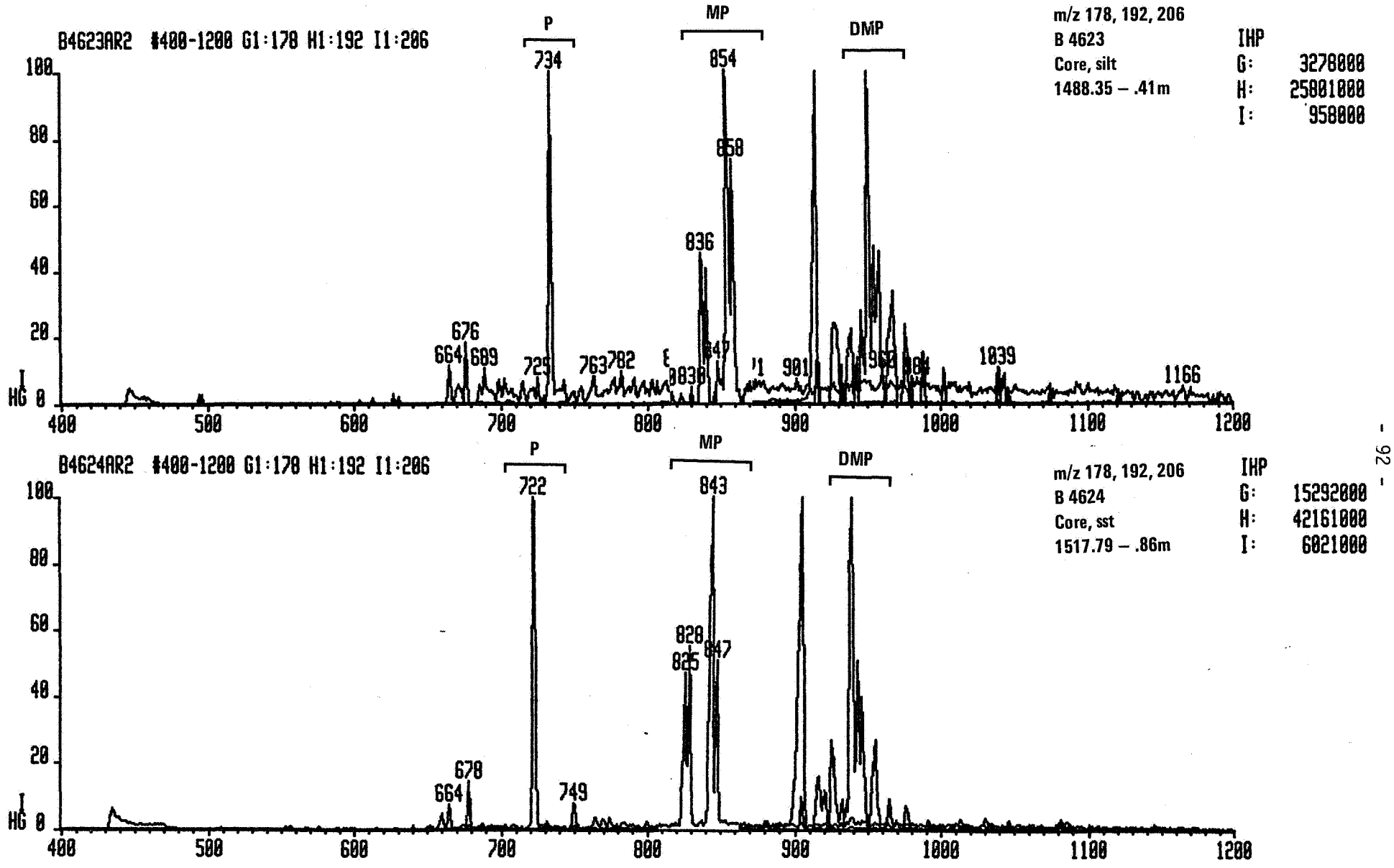
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MP
DMP
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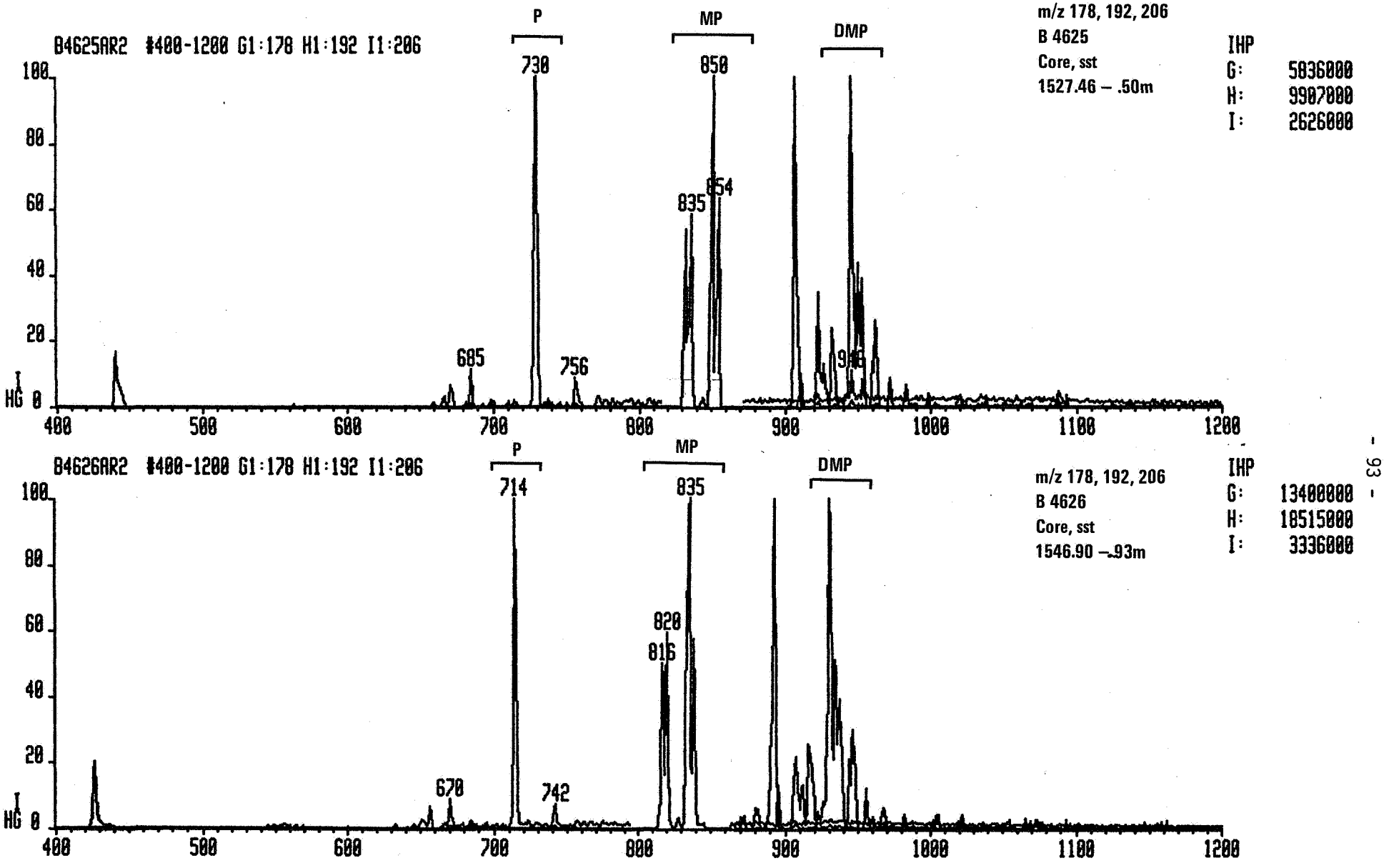
854
858
836
676
664
689
729
763
782
838
847
901
1039
1166
100
80
60
40
20
HG 0
400
500
600
700
800
900
1000
1100
1200
m/z 178, 192, 206
B 4623
Core, silt
1488.35 – .41m
IHP
G: 3270000
H: 25801000
I: 958000
B4624AR2 #400-1200 G1:170 H1:192 I1:206
P
MP
DMP
722
843
828
825
847
678
664
749
100
80
60
40
20
HG 0
400
500
600
700
800
900
1000
1100
1200
m/z 178, 192, 206
B 4624
Core, sst
1517.79 – .86m
IHP
G: 15292000
H: 42161000
I: 6021000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MP
DMP
730
850
835
854
685
756
946
m/z 178, 192, 206
B 4625
Core, sst
1527.46 – .50m
IHP
G: 5836000
H: 9907000
I: 2626000
B4626AR2 #400-1200 G1:178 H1:192 I1:206
P
MP
DMP
714
835
820
816
670
742
m/z 178, 192, 206
B 4626
Core, sst
1546.90 – .93m
IHP
G: 13400000
H: 18515000
I: 3336000
HG
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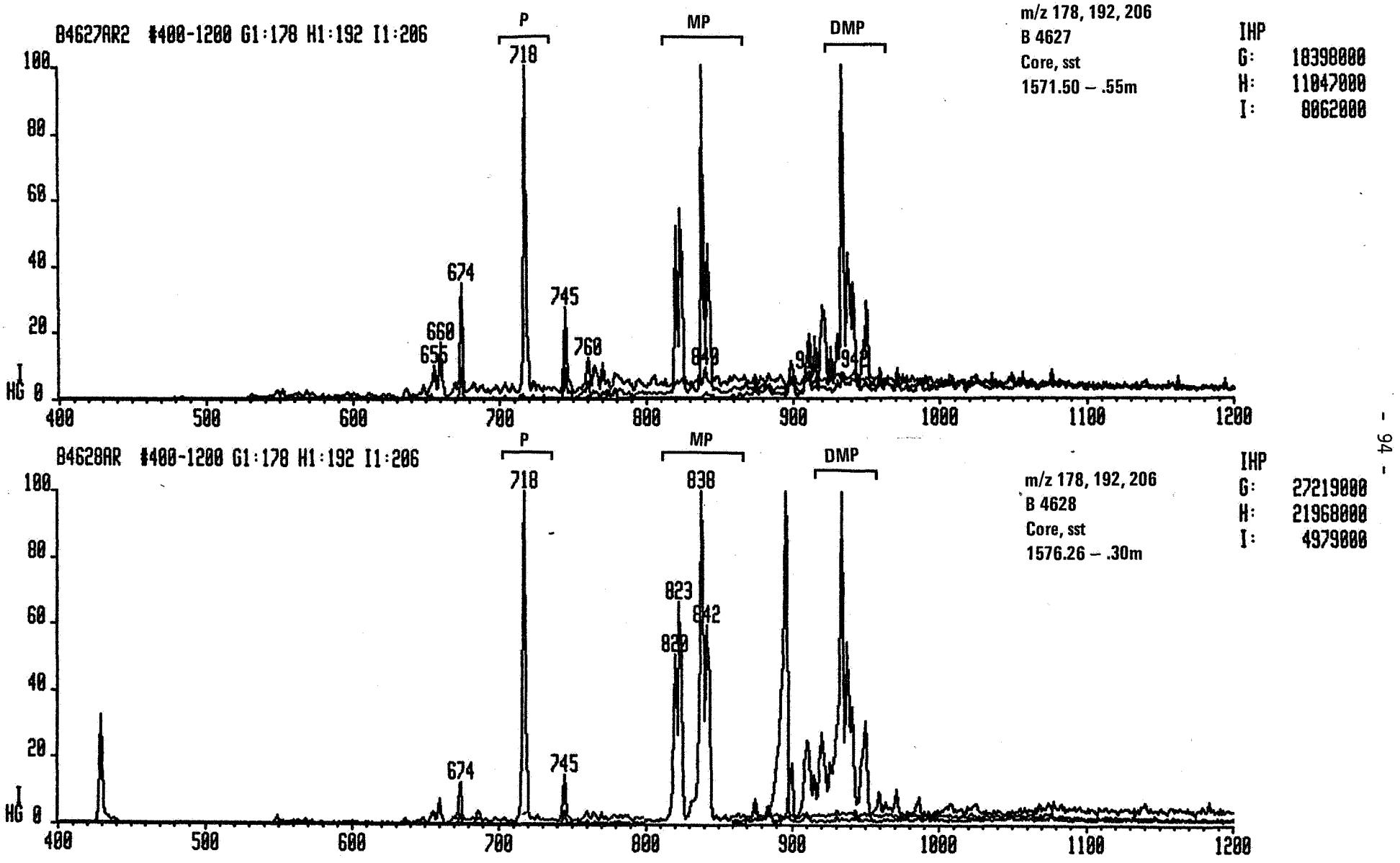
80
60
40
20
0
400
500
600
700
800
900
1000
1100
1200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MP
DMP
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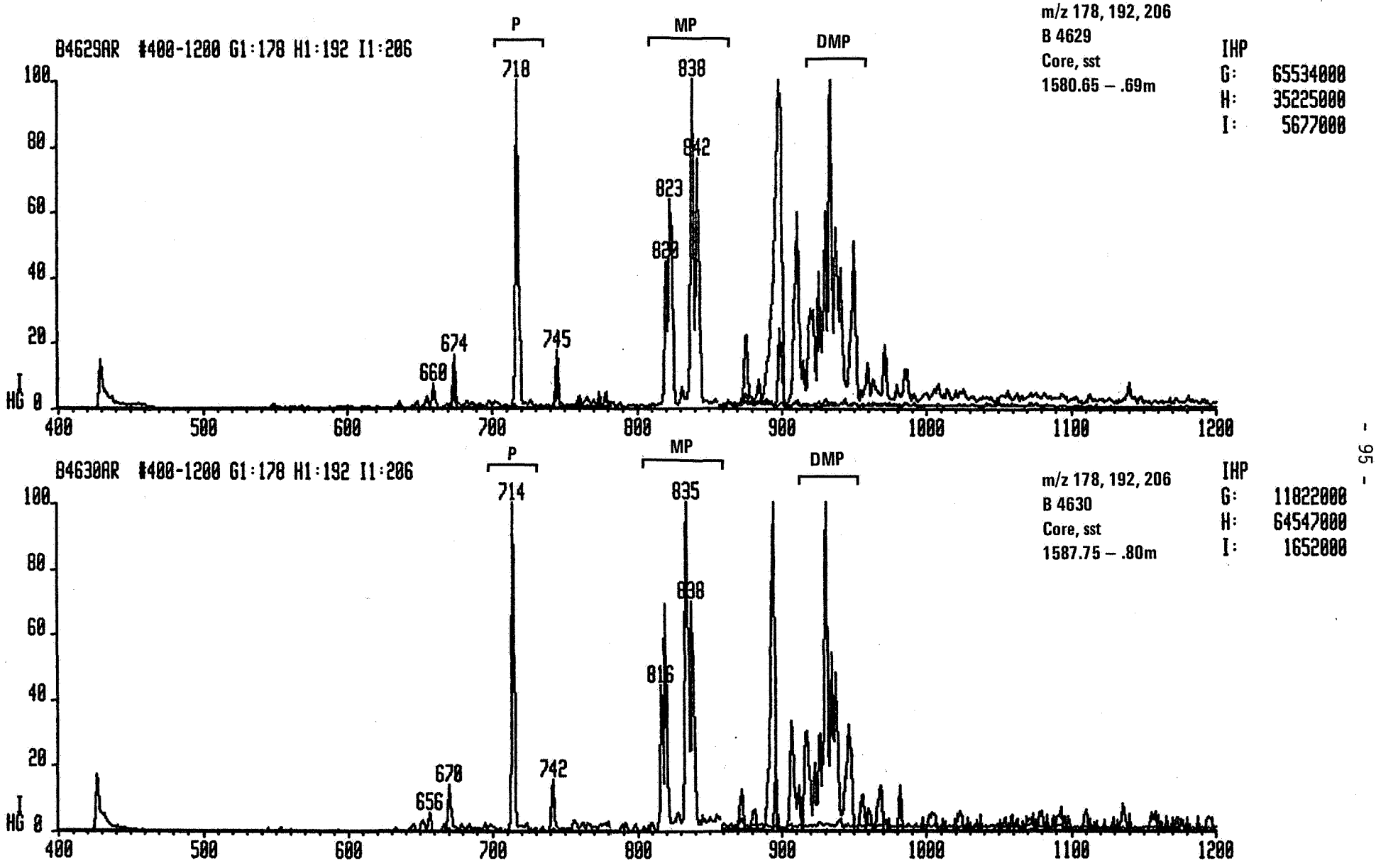
674
745
660
655
760
m/z 178, 192, 206
B 4627
Core, sst
1571.50 – .55m
IHP
G: 18398000
H: 11047000
I: 8062000
HG
I
100
80
60
40
20
0
400
500
600
700
800
900
1000
1100
1200
B4628AR #400-1200 G1:178 H1:192 I1:206
P
MP
DMP
718
838
823
842
820
674
745
m/z 178, 192, 206
B 4628
Core, sst
1576.26 – .30m
IHP
G: 27219000
H: 21968000
I: 4979000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MP
DMP
718
838
842
823
674
660
745
m/z 178, 192, 206
B 4629
Core, sst
1580.65 – .69m
IHP
G: 65534000
H: 35225000
I: 5677000
B4630AR #400-1200 G1:178 H1:192 I1:206
714
835
838
816
670
656
742
m/z 178, 192, 206
B 4630
Core, sst
1587.75 – .80m
IHP
G: 11822000
H: 64547000
I: 1652000
HG I
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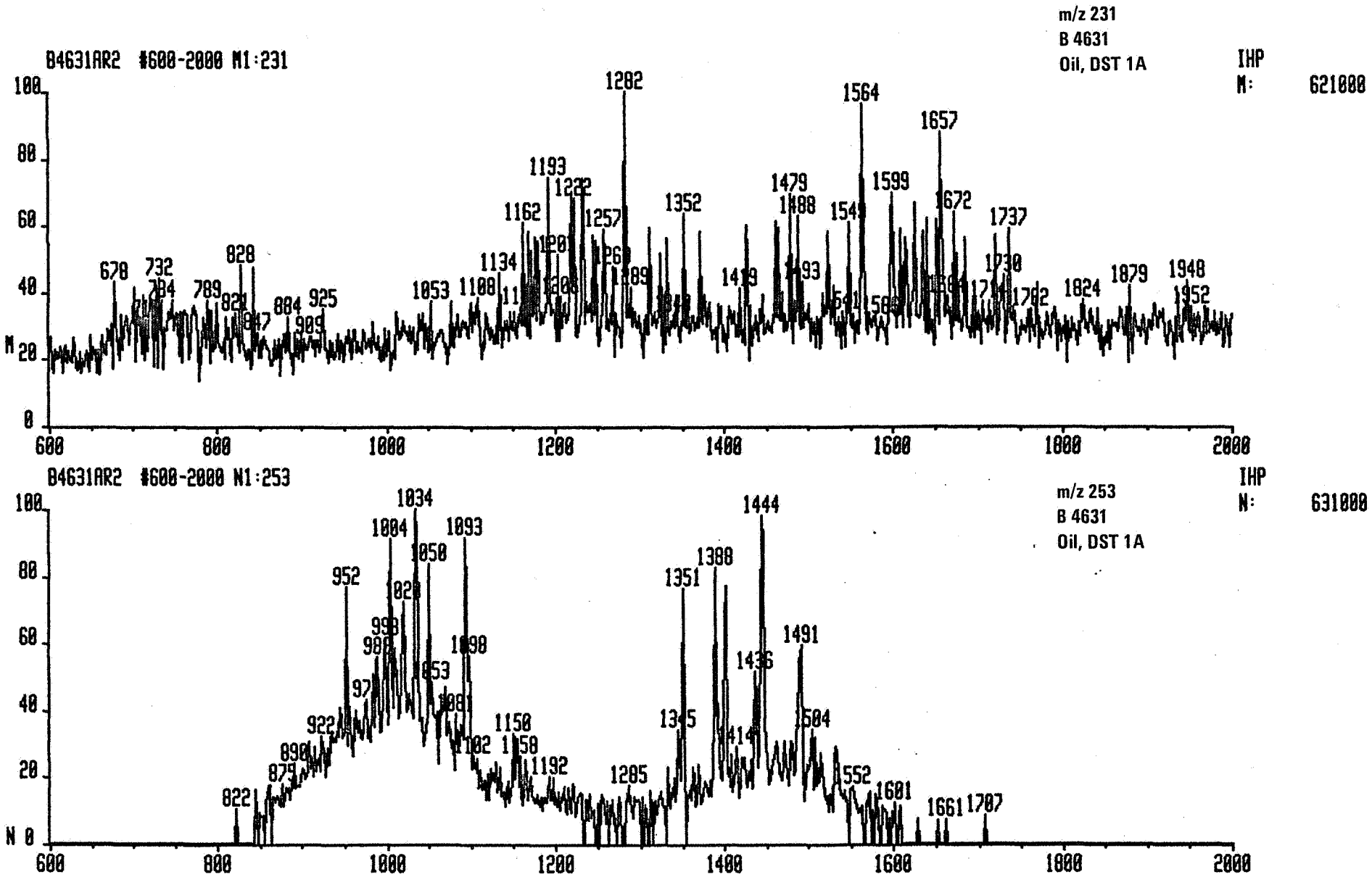
80
60
40
20
0
400
500
600
700
800
900
1000
1100
1200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m/z 231
B 4631
Oil, DST 1A
IHP
M: 621000
M
B4631AR2 #600-2000 N1:253
m/z 253
B 4631
Oil, DST 1A
IHP
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800
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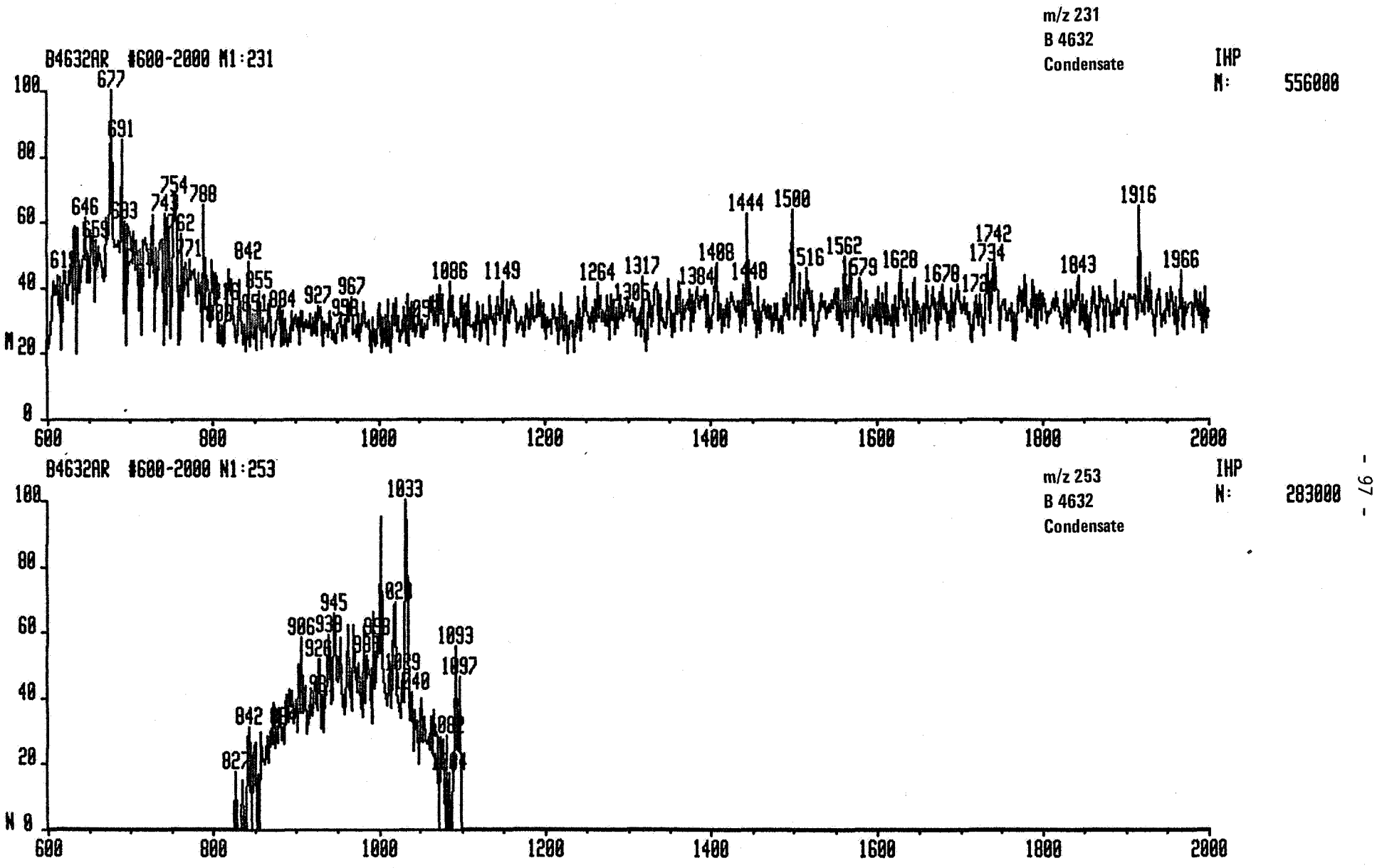
1200
1400
1600
1800
2000


B4632AR #600-2000 M1:231
m/z 231
B 4632
Condensate
IHP
N: 556000
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691
646
659
683
743
754
762
771
788
842
855
884
927
967
998
1086
1149
1264
1305
1317
1384
1408
1444
1448
1500
516
1562
1579
1628
1670
1734
1742
1843
1916
1966
B4632AR #600-2000 N1:253
m/z 253
B 4632
Condensate
IHP
N: 283000
1033
945
906
926
842
827
1093
1097
N
100
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60
40
20
0
600
800
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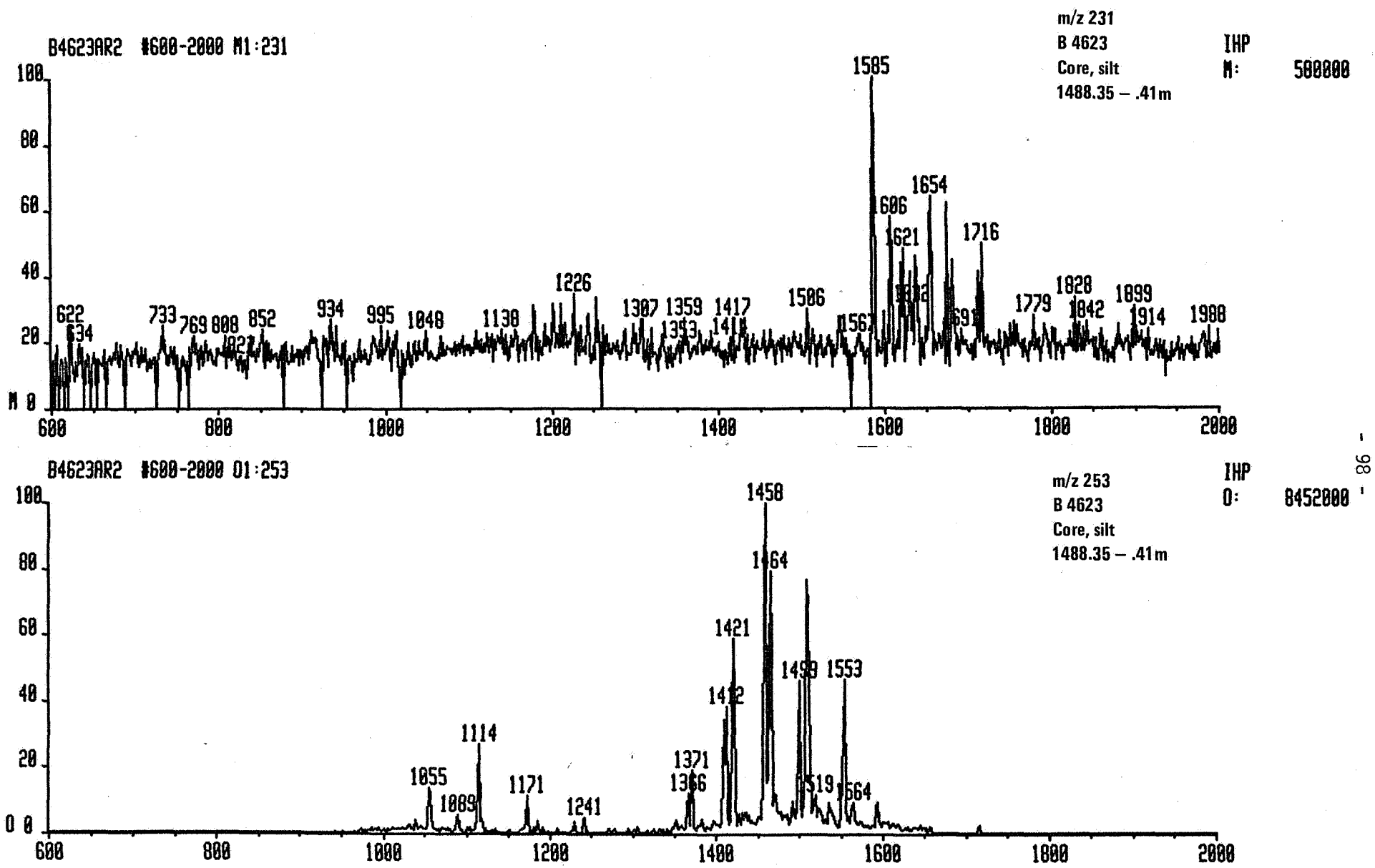
1400
1600
1800
2000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m/z 231
B 4623
Core, silt
1488.35 – .41m
IHP
M: 500000
100
80
60
40
20
M 0
622
634
733
769
808
852
934
995
1048
1138
1226
1307
1359
1417
1506
1585
1606
1621
1654
1716
1779
1828
1842
1899
1914
1988
600
800
1000
1200
1400
1600
1800
2000
B4623AR2 #600-2000 01:253
m/z 253
B 4623
Core, silt
1488.35 – .41m
IHP
0: 8452000
100
80
60
40
20
0 0
1055
1089
1114
1171
1241
1371
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1464
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1519
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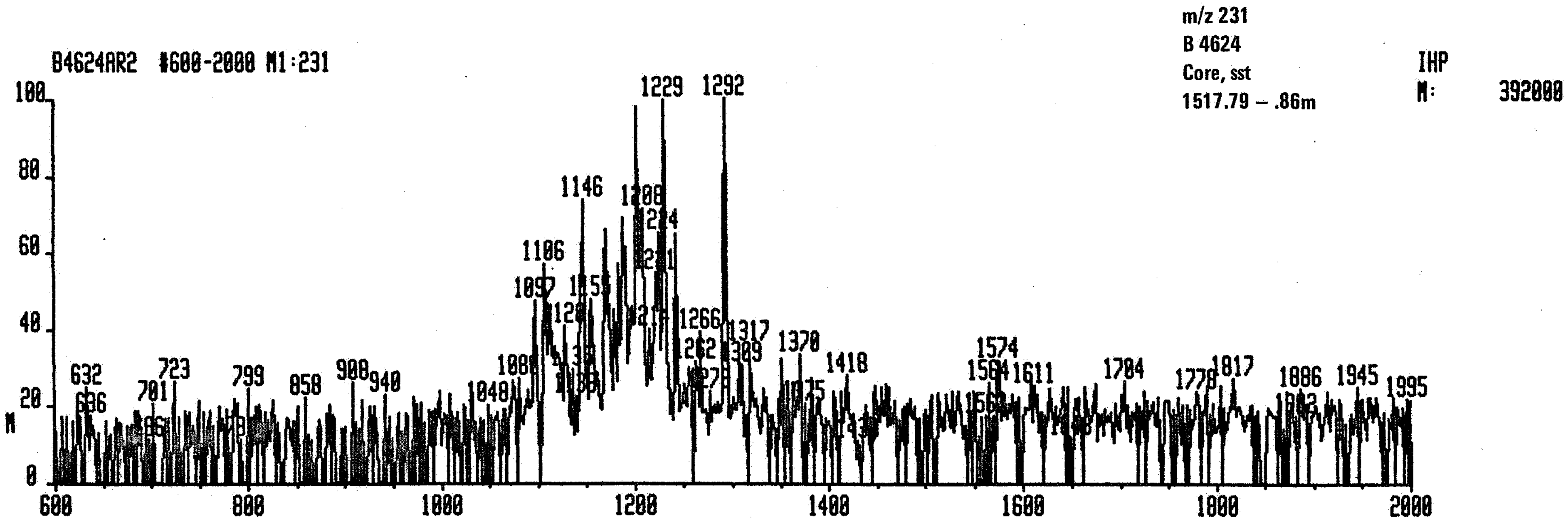
1400
1600
1800
2000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m/z 231
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Core, sst
1517.79 – .86m
IHP
M: 392000
1229
1292
1146
1208
1224
1106
1097
1155
1266
1317
1309
1370
1418
1574
1564
1611
1704
1778
1817
1886
1945
1995
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723
799
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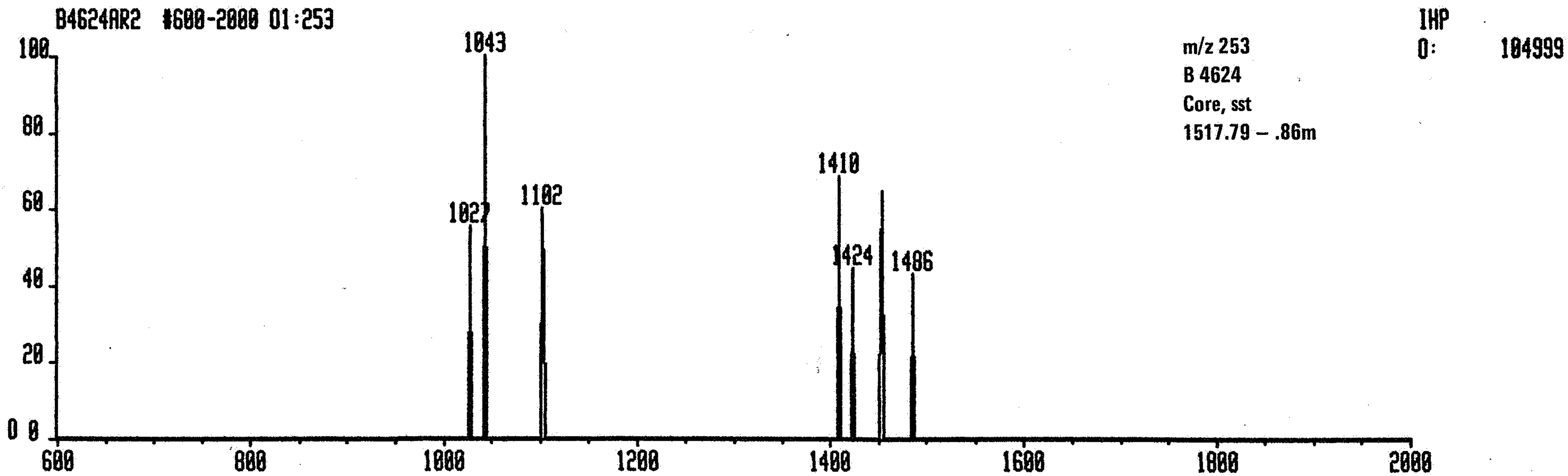
1400
1600
1800
2000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m/z 253
B 4624
Core, sst
1517.79 – .86m
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1027
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1400
1600
1800
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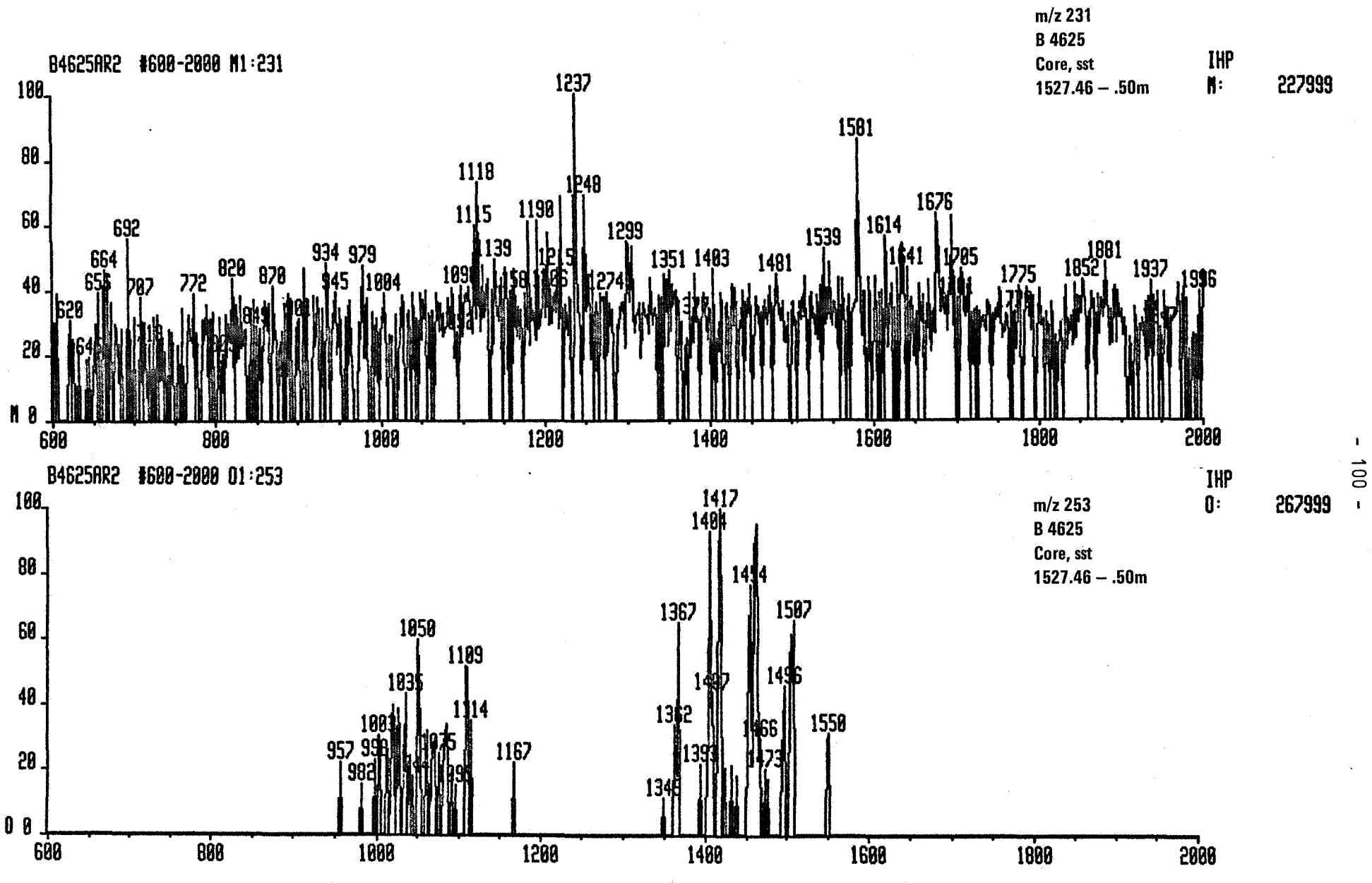
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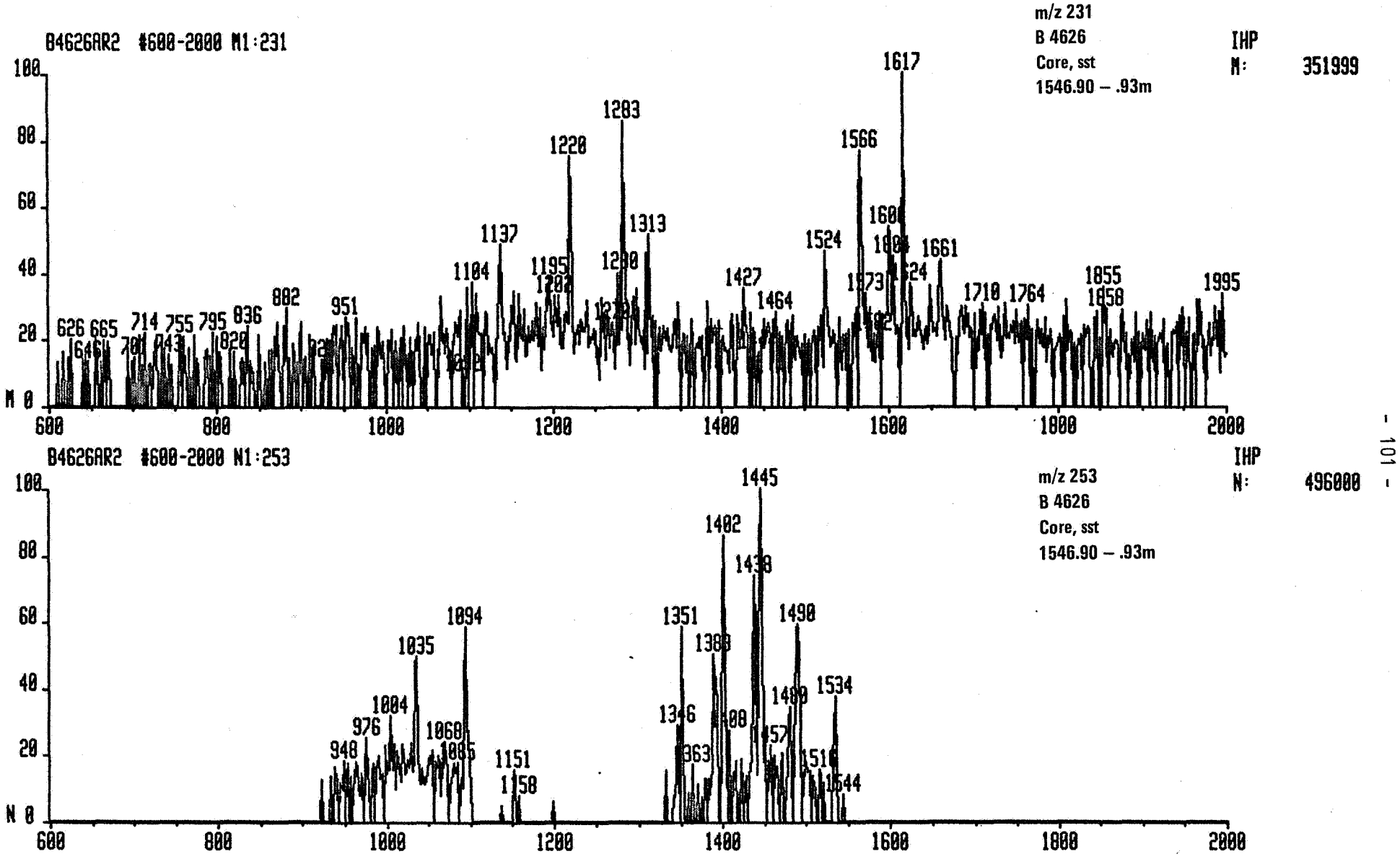
m/z 231
B 4625
Core, sst
1527.46 – .50m
IHP
M: 227999
B4625AR2 #600-2000 O1:253
m/z 253
B 4625
Core, sst
1527.46 – .50m
IHP
O: 267999
600
800
1000
1200
1400
1600
1800
2000


B4626AR2 #600-2000 M1:231
m/z 231
B 4626
Core, sst
1546.90 – .93m
IHP
M: 351999
100
80
60
40
20
M 0
600
800
1000
1200
1400
1600
1800
2000
626
665
714
755
795
836
882
951
1104
1137
1195
1220
1283
1313
1427
1464
1524
1566
1617
1661
1710
1764
1855
1995
B4626AR2 #600-2000 N1:253
m/z 253
B 4626
Core, sst
1546.90 – .93m
IHP
N: 496000
N 0
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1004
1035
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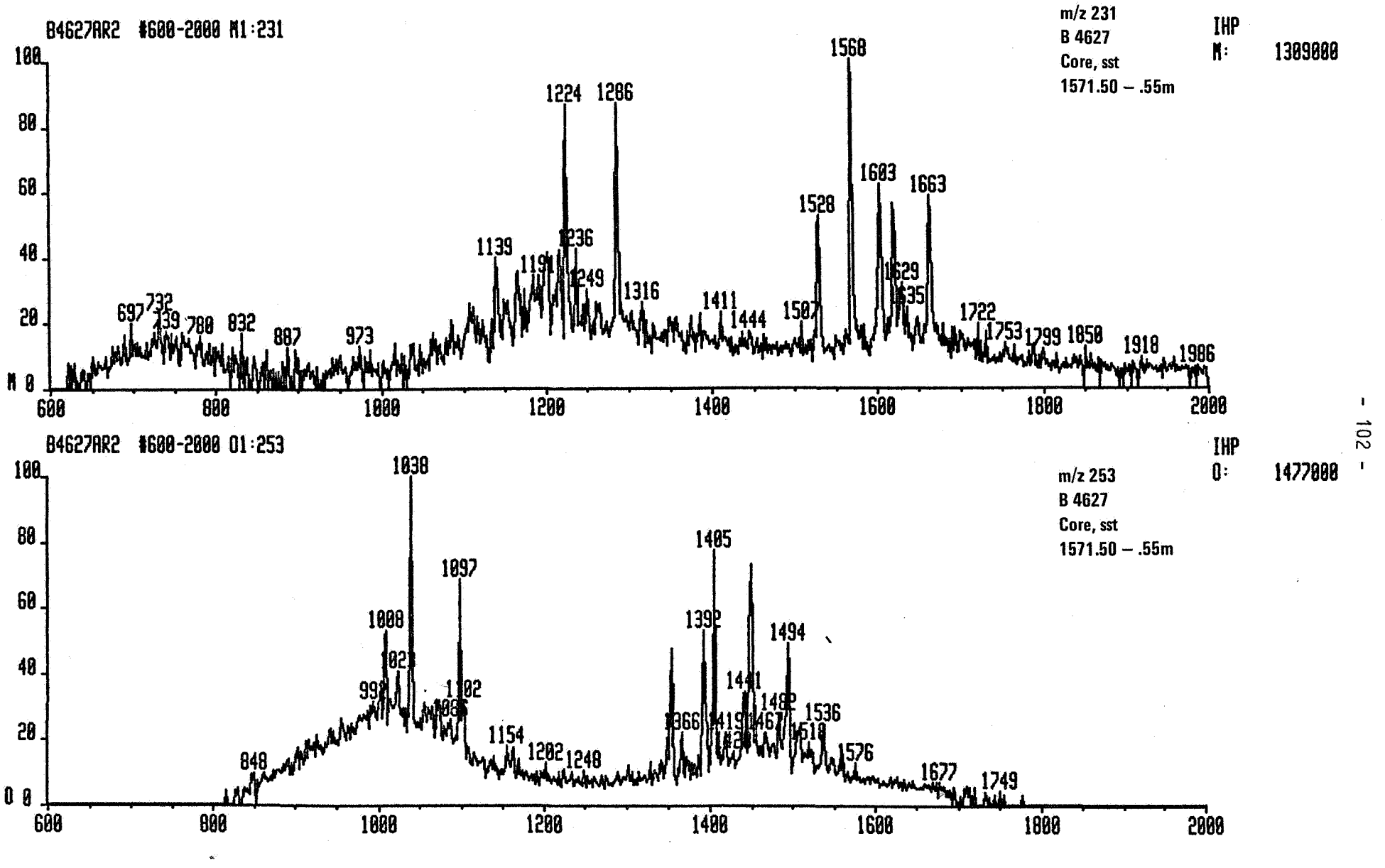
1351
1402
1445
1490
1534


B4627AR2 #600-2000 M1:231
m/z 231
B 4627
Core, sst
1571.50 – .55m
IHP
M: 1309000
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m/z 253
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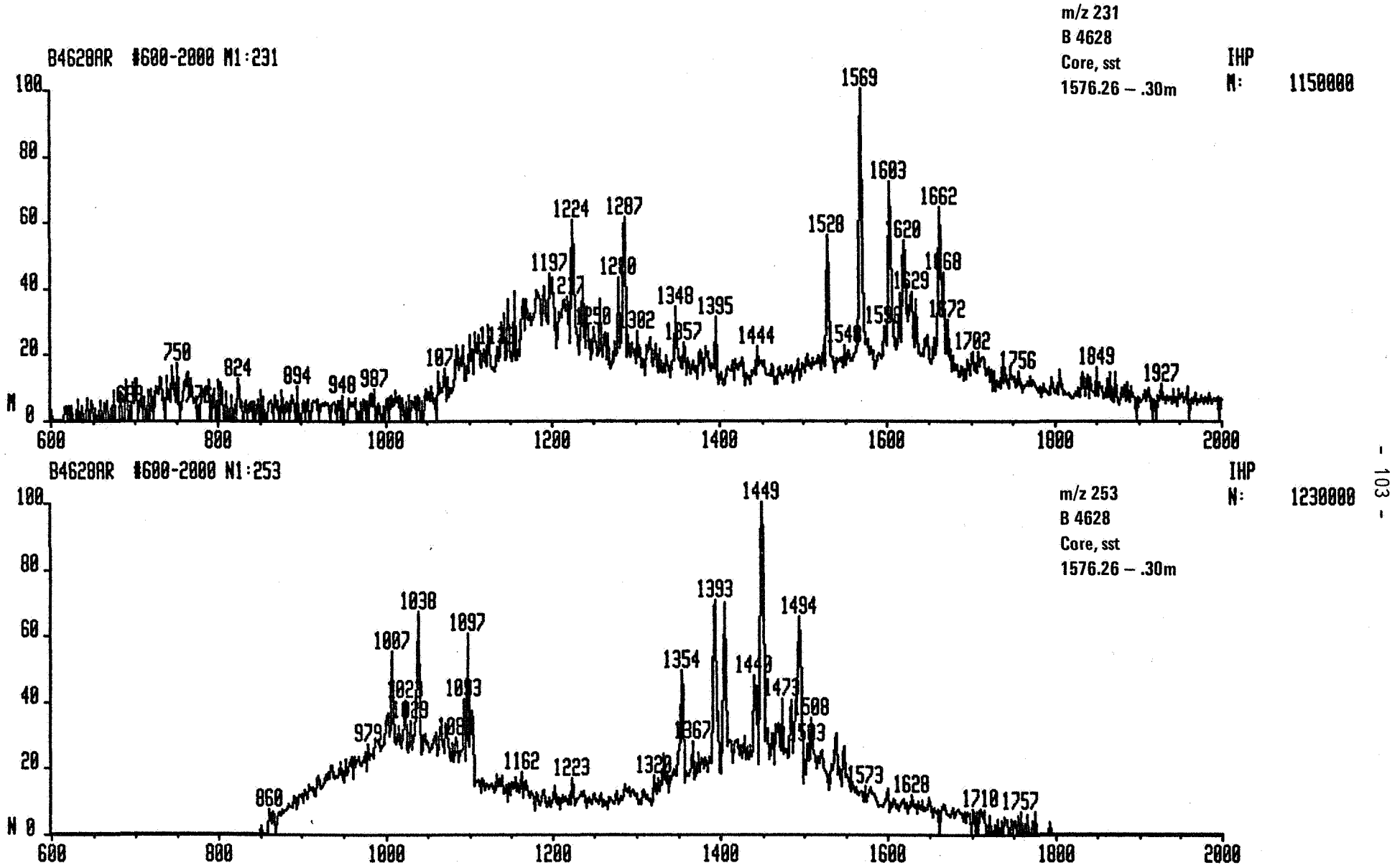
Core, sst
1571.50 – .55m
IHP
0: 1477000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Core, sst
1576.26 – .30m
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60
40
20
0
600
800
1000
1200
1400
1600
1800
2000
750
824
894
948
987
1107
1197
1224
1287
1348
1395
1444
1528
1569
1603
1620
1662
1702
1756
1849
1927
B4628AR #600-2000 N1:253
m/z 253
B 4628
Core, sst
1576.26 – .30m
IHP
N: 1230000
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979
1007
1038
1097
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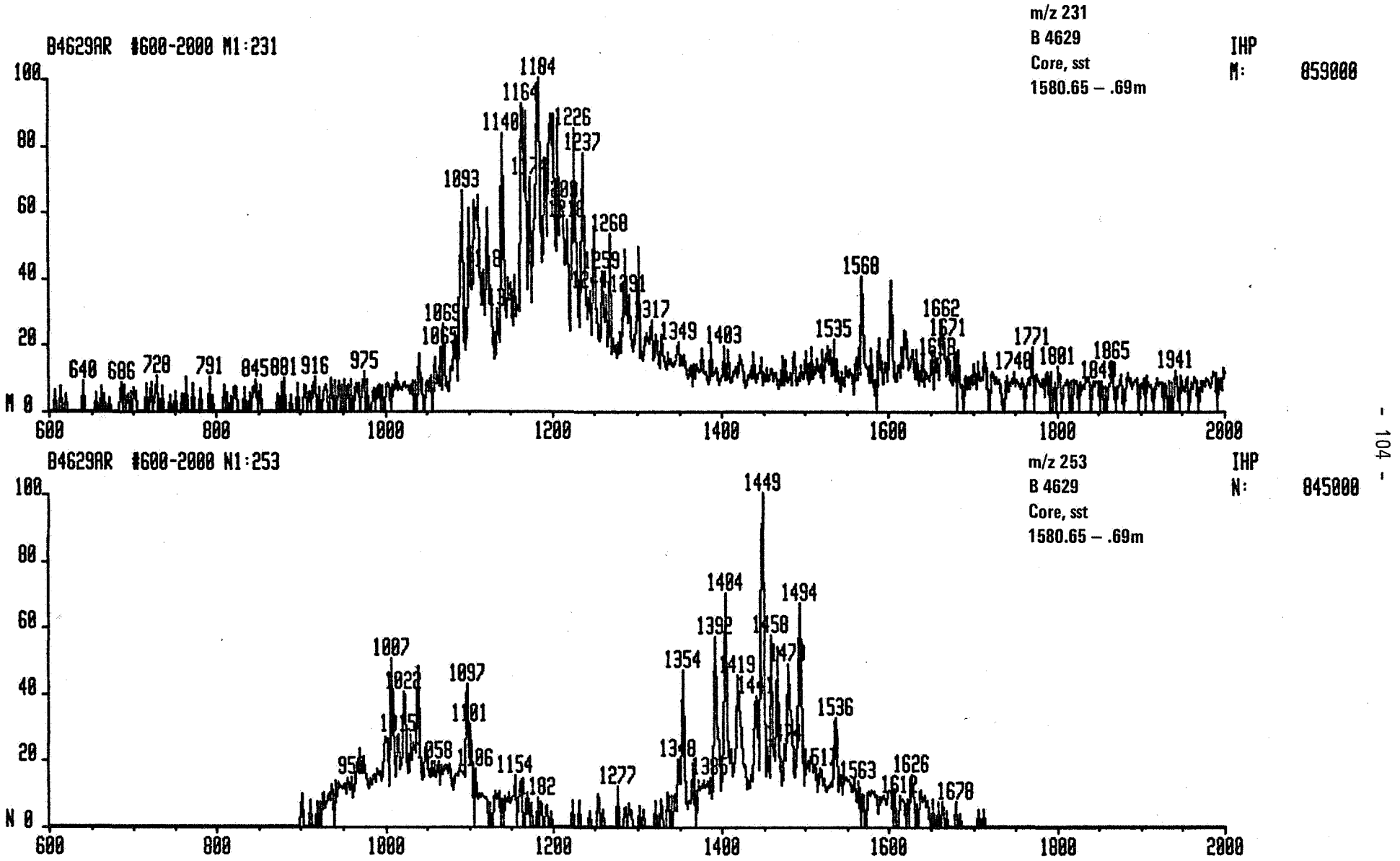
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60
40
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600
800
1000
1200
1400
1600
1800
2000
1184
1164
1140
1226
1237
1893
1268
1568
1662
1671
1771
1865
1941
1535
1403
1349
1317
1069
1065
975
916
845
791
728
686
640
B4629AR #600-2000 N1:253
m/z 253
B 4629
Core, sst
1580.65 – .69m
IHP
N: 845000
N 0
1449
1484
1494
1458
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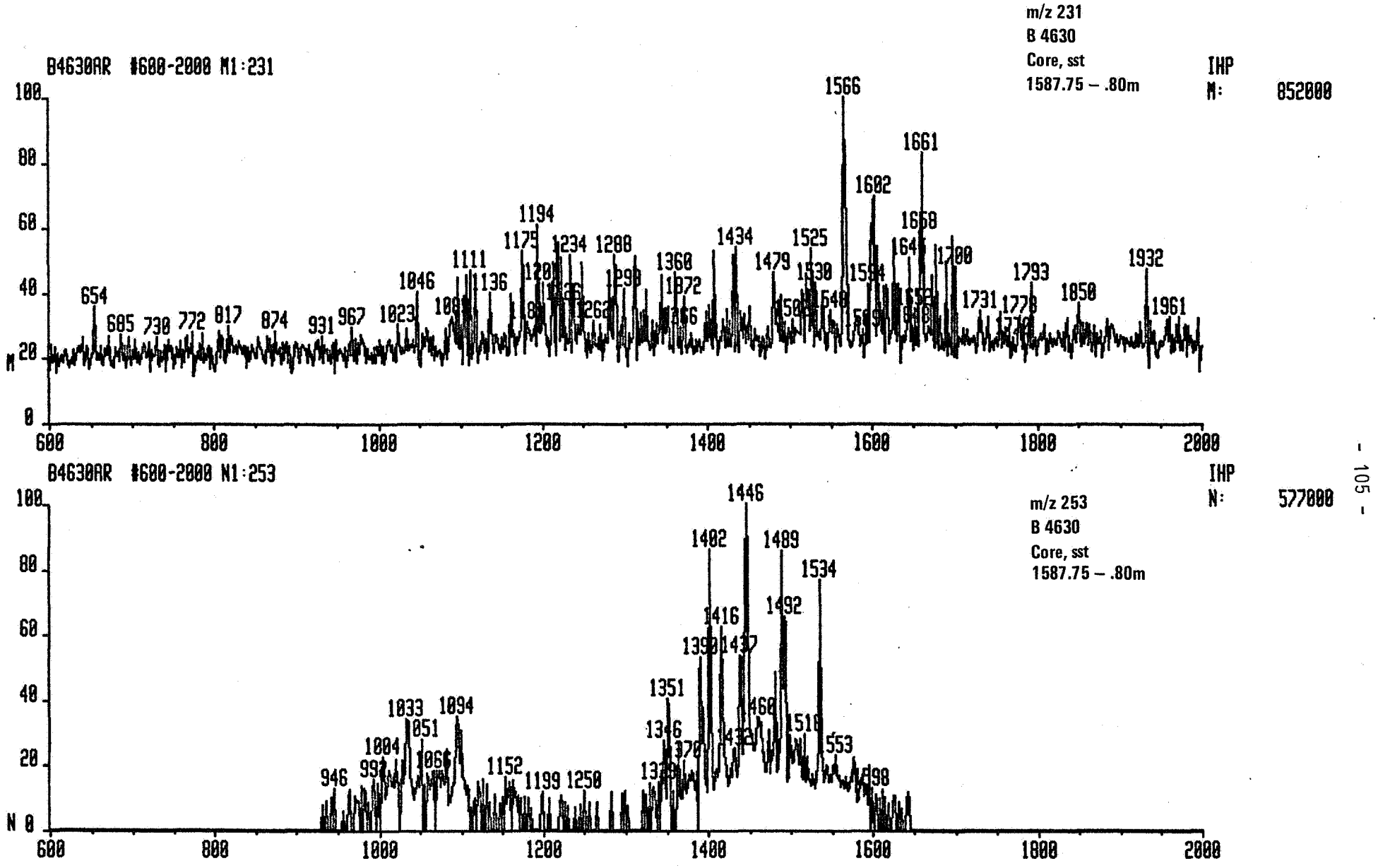
1106
1058
954


B4630AR #600-2000 M1:231
m/z 231
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Core, sst
1587.75 – .80m
IHP
M: 852000
M
100
80
60
40
20
0
600
800
1000
1200
1400
1600
1800
2000
654
685
730
772
817
874
931
967
1023
1046
1111
1136
1194
1175
1234
1288
1360
1434
1479
1525
1566
1661
1602
1668
1793
1850
1932
1961
B4630AR #600-2000 N1:253
IHP
N: 577000
m/z 253
B 4630
Core, sst
1587.75 – .80m
N
946
1033
1051
1094
1152
1199
1250
1351
1402
1446
1489
1534
1492
1416
1516
553

APPENDIX

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, representing terpanes, the hopanes and moretanes are the major components in most extracts and oils. Of the hopanes the C_{27} and C_{29}-C_{35} homologs are ubiquitous, while the C_{28} bisnorhopane is believed to be typical of certain types of source rocks. This is also the case for the component, probably gammacerane, sometimes seen to coelute with the 22S isomer of the C_{31} 17α(H)-hopanes (H). In the sterane mass chromatograms, m/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 dependant parameters

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

17α(H)-trisnorneohopane (Ts), 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 14α(H), 17α(H)-isomers of the regular steranes is transformed to the thermally stable 14β(H), 17β(H)-steranes, the %ββ approaching 75% at equilibrium. An equilibrium concentration of 50% is seen of the stable S configuration at C-20 as opposed to the 100% of the biological 20R epimer (Mackenzie et al., 1980). The abundance of rearranged steranes increased with increasingly 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 tri-aromatic analogs. This process is measured as the abundance of tri-aromatic relative to mono-aromatic compounds (% tri/tri + mono) in the m/z 231 and 253 mass chromatograms, respectively. In addition the degree of side chain cracking, as $\%C_{20}/C_{26,\ 27}$ and $\%C_{21}/C_{28,29}$ respectively, is applied. These cracking processes are also taking place during early diagenesis, and are used for maturity assignment together with the previously mentioned ratios.

Migration and weathering

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