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Hydrocarbon characterization of well 31/3-2, the Troll field.			
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SUMMARY/ SAMMENDRAG

One oil and ten sandstone cores were analysed by organic geochemical methods. All the samples were seen to contain the same type of organic matter, with high abundances of mature hydrocarbons. The richness is very high from 1567.80 down to 1593.50m, where it starts decreasing slightly.

KEY WORDS/ STIKKORD

Hydrocarbons

Correlation

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GC-MS

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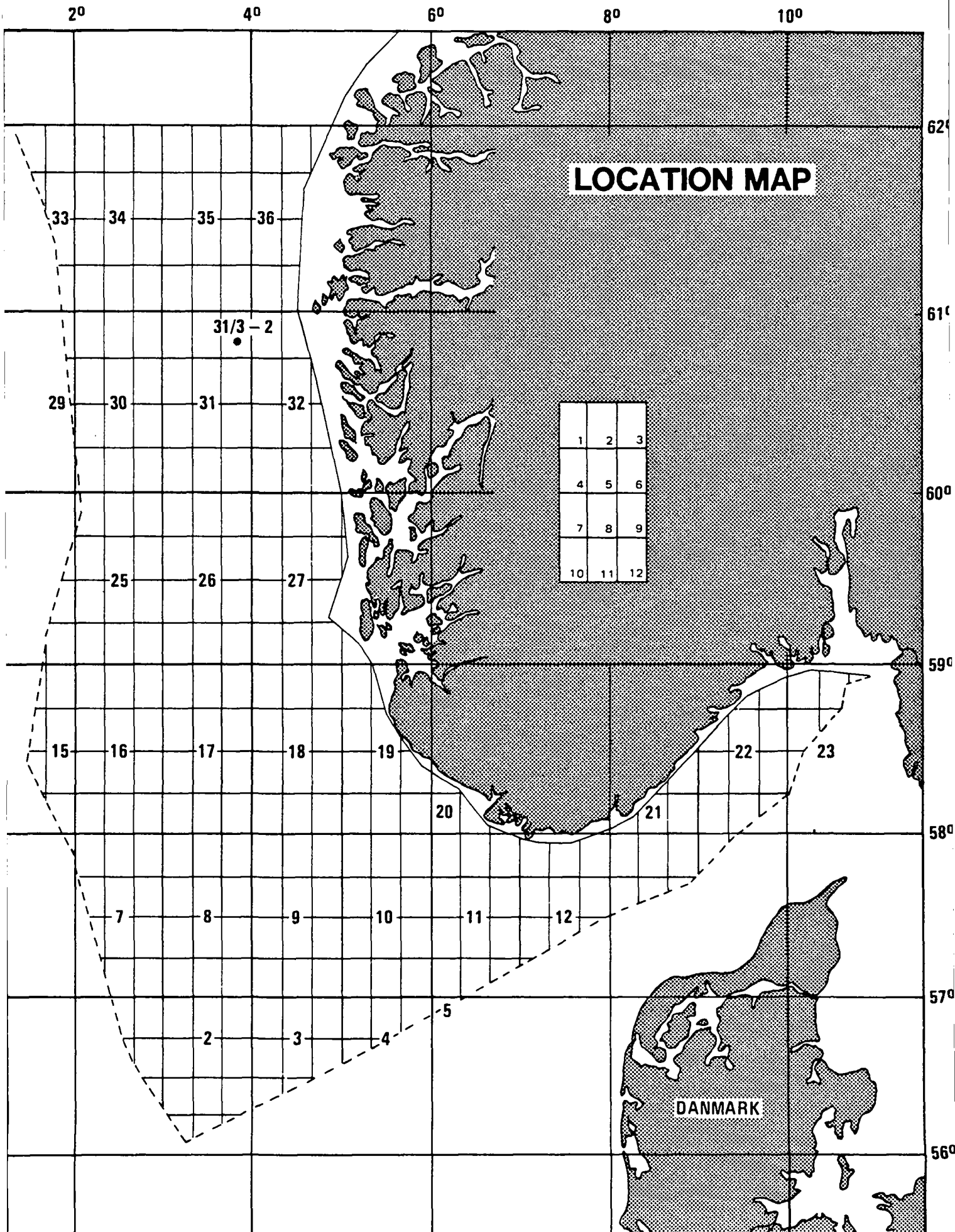
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1. INTRODUCTION

Ten sandstone cores and an oil from well 31/3-2 in the Troll field (Location Map) were analysed for hydrocarbon characterisation and correlation purposes. The samples were taken from the depth interval listed below:

IKU no.	Sample Type	Depth (m)
B-4681	Oil	
B-4682	Core, sst	1567.80
B-4683	"	1571.50
B-4684	"	1573.95
B-4685	"	1581.65
B-4686	"	1586.40
B-4687	"	1587.50
B-4688	"	1590.50
B-4689	"	1593.50
B-4690	"	1595.50
B-4691	"	1628.00

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



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 sample, the fraction boiling below 210°C were removed by heating the sample until 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 Molecular Sieve Adsorption

The sample containing 2mg of n-alkanes was dissolved in 35ml of cyclohexane and 1g of Molecular Sieve pellets (5A) which had been activated at 300°C in 24 hours, were added. This mixture was then refluxed for about 24 hours. While the solution was still hot, the sieve pellets were removed from the solution by filtering. The solvent was then removed on a Buchi Rotavapor. GC analysis was performed on the samples, using the same conditions as for the other GC analysis.

The normal alkanes were recovered from the Molecular Sieve pellets by destruction of the pellets with hydrofluoric acid. The solution was extracted with boric acid and hexane, and the solvent was then removed on a Buchi Rotavapor. GC analysis were performed on the samples, using the same conditions as for the other GC analysis.

2.5 Gas Chromatographic Analysis

The C₂-C₈ 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°C (2 min.) to 180°C at 4°C/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°C (2 min.) to 280°C at 4°C/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 column, and hydrogen (2.5 ml/min.) is used as carrier gas. The temperature program applied is 80°C (2 min.) to 280°C at 4°C/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 ($1.5\mu\text{l}$, split ratio 1:15). The GC oven was programmed from 70°C to 280°C at $4^\circ\text{C}/\text{min}$. after an initial isothermal period of 2 minutes for the aromatic hydrocarbons, while an initial temperature of 120°C was applied for the saturated fractions.

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

The $\delta^{13}\text{C}$ 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 gravity of the oil was determined to 28.1⁰API (Table 1), indicating it to be a relatively high gravity oil, of low maturity and/or possibly biodegraded.

3.2 GC of C₂-C₈ hydrocarbons

Gas chromatogram of C₂-C₈ hydrocarbons in the oil is shown in Figure 1, while the relative distribution of the compounds is given in Table 2. The main compounds are seen to be cyclic, and thus the oil has probably undergone some degree of biodegradation. Very low amounts of n-alkanes are detected.

3.3 Amount of C₁₅+ EOM and hydrocarbons

The oil sample was topped to 210⁰C prior to separation of asphaltenes and chromatographic separation. Approximately 85% of the crude oil was left after the treatment (Table 3), implying the oil to be relatively heavy.

The amounts of asphaltenes (Table 4) are fairly similar in the oil and all the extracts with very rich hydrocarbon content (0.7-5.0% of EOM). The two deepest cores show relatively higher asphaltene content.

Eight of the ten sandstone cores were seen to be very rich both in extractable organic matter, EOM (4771-18027ppm, average 10979ppm) and in hydrocarbons (2000-10827ppm, average 6076ppm). The two deepest cores contain less organic material, but are still rich in EOM (1311-2267ppm, average 1789ppm) and fair-rich in hydrocarbon content (119-535ppm, average 327ppm). The amounts of the EOM and the various chromatographic fractions are presented in Table 5.1-5.3.

3.4 Gas chromatography of C₁₅+ saturated hydrocarbons

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

The oil is seen to exhibit a unimodal n-alkane distribution with maximum at nC₁₇. Isoprenoids are relatively abundant (Pr/n-C₁₇ = 1.0) and the pristane/phytane ratio of 2.0 is high compared to most North Sea oils and Upper Jurassic source rocks (Cornford et al., 1983). The abundant isoprenoids suggest that mild biodegradation might have taken place.

All the extracts from the sandstone cores show the same general distribution of saturated hydrocarbons as the oil, except that the cores have lost most of the low molecular weight compounds (<n-C₁₇). Abundant isoprenoids are seen in all the samples (Pr/n-C₁₇ varies between 1.1 and 1.6), and the pristane/phytane ratios are in the range 1.7-2.5. From the relative amounts of the internal standard (S in Figure 2) the two deepest samples are seen to contain less hydrocarbons than the rest, supporting what was seen in the discussion on the chromatographic separation.

The data discussed so far suggest that the hydrocarbons in the extracted sandstones originate from the same source rock as the oil.

3.5 Branched/cyclic and n-alkanes

The oil and two of the cores were treated with molecular sieve to separate the n-alkanes from the branched and cyclic alkanes. The gas chromatograms are shown in Figure 3a and b, and the amounts are given in Table 7.

Even with the slightly higher intensity of n-alkanes in the C₂₀-C₃₅ range seen in the cores the general distributions in the GC's show that both the n-alkanes and the branched/cyclic hydrocarbons can be said to be of the same type in the three samples.

A quantitative comparison is presented in Table 7. The quantitative results were obtained in two different ways; by simple gravimetry and by integration of the gas chromatograms.

The gravimetric results give approximately 100% recovery for the two core samples, while the oil seems to have lost approximately 50%. This could be due to the difference seen in the GC traces of these three samples. The saturated HC fraction of the oil contained relatively more than the cores of low molecular weight compounds. Thus the weight loss

of the oil may be due to further loss of these compounds. All three samples were seen to have approximately the same ratio of n-alkanes and branched/cyclic hydrocarbons (0.29-0.35).

The results from the GC-integration are lower than the gravimetric. This would be expected since the chromatographic fraction contain higher molecular weight compounds that will not elute through a GC column. A relatively higher proportion in the n-alkane fractions is lost. However, the ratio of n-alkanes to branched/cyclic hydrocarbons is the same for all three samples.

3.6 Gas chromatography of C₁₅+ aromatic hydrocarbons

Gas chromatograms are given in Figure 4, while certain aromatic ratios used in maturity estimation (Radke et al., 1983) are presented in Table 8.

Except for the oil and one sandstone core sample from 1590.5m, the rest of the samples (all sandstone cores) have lost much of the low molecular weight material, i.e. mainly alkyl naphthalenes. This makes the alkyl-naphthalene ratios less accurate. Apart from loss of the alkyl naphthalenes the general aromatic hydrocarbon distribution appears to be similar in all samples including the oil.

Maturity based on MPI 1 appears to be fairly low compared with the alkyl naphthalene ratios. The MPI 1 value varies from 0.59-0.76. The average value is therefore 0.69 (± 0.05 S.D.). The oil has an MPI 1 of 0.71. The estimated vitrinite reflectance of the source for these aromatic hydrocarbons is between 0.7-0.9% with a spot value based on the average MPI 1 equal to 0.8% approximately. This is based on the graph in the aromatics report no. 05.6260.00/01/84 (Hall and Schou, 1984). The methyl naphthalene ratios average 2 for the samples down to 1593.5m (but excluding this sample). It was felt that the methyl naphthalenes peaks were too small to be accurately measured below 1590.5m. The oil had a value of 2.1, whereas the most suitable sandstone core (i.e. the one with most alkyl naphthalenes) gave a value of 1.89. These values are considered to be high relative to the MPI 1 indicated maturity level. A value above 1.5 may be expected for condensates. Similarly values for DMNR (which roughly average 3.3) are not

those seen during the main phase of oil generation (which range from 1.0-2.0 - from aromatics report, Hall and Schou, 1984). Furthermore biphenyl and methyl-biphenyls (figure 4) have been tentatively identified as prominent components of all samples. These compounds are considered to become prominent only in very highly mature oil-prone source rocks (i.e. greater than 1% Ro). This may be an indication of a high maturity source for these hydrocarbons, however coals also appear to have large amounts of these compounds at lower maturities than type II marine source rocks.

The evidence suggests that there may be two sources for the aromatic hydrocarbons in these sandstone cores and the oil. One highly mature yielding mostly wet gas-condensate range hydrocarbons (i.e. mainly alkyl naphthalenes or lower molecular weight hydrocarbons), the second source being oil window mature and yielding a 'normal' oil. The latter has both alkyl naphthalenes and phenanthrenes in which the alkyl naphthalene pattern is marked by the higher maturity source hydrocarbons. There is no indication from the aromatics whether the two sources had similar organic matter (i.e. whether the hydrocarbons are from the same source rock horizon buried to different depths).

3.7 GC-MS analysis of saturated terpane and sterane

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 9 and 10.

The same overall profiles are seen for steranes and terpanes in both the oil and the ten sandstone cores. All the applied molecular ratios suggest that the hydrocarbons are of oil window maturity. The deepest core shows somewhat different chromatograms, a fact that is probably due to generally much lower abundance of hydrocarbons in this sample. One compound elutes at the same retention time as bisnorhopane (Z) in the m/z 191 mass chromatograms. It is, however, not possible from the chromatograms to verify this very tentative determination. The relative abundance of this compound and the other two eluting immediately before and after the C₂₉ 17 α (H),21 β (H)-hopane is similar in all the samples.

The triangular plot in Figure 6 shows the molecular weight distribution of the C₂₇-C₂₉ regular 14 β ,17 β -steranes to be nearly identical for all the samples.

From the sterane and terpane mass chromatograms the hydrocarbons extracted from the sandstone cores can be said to originate from the same or at least a very similar source rock as the oil.

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 one abundant peak representing elemental sulfur (S₈). This peak partly masks an interesting part 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) and dibenzothiophene (m/z 184, 198, 212) in addition to mono- and tri-aromatic steranes (m/z 253 and 231) are presented.

Only minor differences are detected from inspection of mass chromatograms and in the maturity data in Table 11.

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

Saturated and aromatic hydrocarbon fractions were analysed for their $\delta^{13}\text{C}$ isotope ratios. The data are presented in Table 12.

The results vary from -29.5 to -28.3⁰/oo (i.e. 1.2⁰/oo) for the saturated and from -27.9 to -27.1⁰/oo (i.e. 0.80/oo) for the aromatic hydrocarbons.

More than 1⁰/oo variation in the saturated hydrocarbon fractions may be due to generation from different type of source rocks. However, the two samples with the most different values for saturated hydrocarbons (B-4682 and B-4690) gave exactly the same value for the aromatic hydrocarbons. Based on this and on the similarities of the results from the other analyses, the hydrocarbons in the cores and the oil are believed to originate from the same source rock or source rocks.

4. CONCLUSION

All the performed analyses suggest that the oil and the hydrocarbons in the cores have been generated from the same source rock. The amount of hydrocarbons is very high down to 1593.50m where it starts decreasing.

Some of the parameters indicate that more than one source rock, or different maturity stages of the same source rock, may have been responsible for the generation of the hydrocarbons.

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Table 1. API gravity of oil sample.

IKU no.	°API
B-4681	28.1

Table 2. Relative distribution of C₂-C₈ hydrocarbons in the oil sample.

	B-4681 % of total oil
nC ₂	-
nC ₃	-
MC ₃	-
nC ₄	-
MC ₄	0.2
nC ₅	0.1
CyC ₅ +2,3DMC ₄	0.7
2MC ₅	-
3MC ₅	0.2
nC ₆	0.4
MCyC ₅	1.4
benzene	-
C _y C ₆	2.2
2MC ₆	-
2,3DMC ₅	0.3
3MC ₆	0.4
DMCyC ₅ (1,3; 1,2)	0.7
2,2,4 TMC ₅	0.5
nC ₇	-
MCyC ₆	3.3
2,4DMC ₆	0.2
Toluene	-
2MC ₇	<0.1
3MC ₇	<0.1
DMCyC ₆ (1,2)	0.7
nC ₈	0.3
M/P-xylene	0.5
O-xylene	-

List of C₂-C₈ hydrocarbons in Table 2 and Figure 1.

nC ₂	ethane
nC 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 sample.

IKU no.	Crude oil (mg)	>210 ^o C (mg)	Light components (mg) (%)	
B-4681	212.0	180.9	31.1	14.7

Table 4. Asphaltenes and EOM.

IKU No.	Depth (m)	Asphaltenes (mg)	EOM (mg)
B-4681	Oil	7.9	180.9
B-4682	1567.80	6.0	321.9
B-4683	1571.50	14.4	285.8
B-4684	1573.95	7.6	201.2
B-4685	1581.65	6.5	445.5
B-4686	1586.40	13.0	476.2
B-4687	1587.50	5.4	781.3
B-4688	1590.60	5.8	186.1
B-4689	1593.50	15.2	461.1
B-4690	1595.50	2.4	36.3
B-4691	1628.00	8.0	42.4

T A B L E : 5.1



CONCENTRATION OF EOM AND CHROMATOGRAPHIC FRACTIONS

I	:	:	Rock	:	:	:	:	Non	:
I	IKU-No	DEPTH	Extr.	EOM	Sat.	Aro.	HC	HC	:
I	:	:	:	:	:	:	:	:	:
I	:	(m)	(g)	(mg)	(mg)	(mg)	(mg)	(mg)	:
I	:	:	:	:	:	:	:	:	:
I	B 4681	OIL	0.2	180.9	40.2	22.4	62.6	118.3	:
I	B 4682	1567.80	33.2	321.1	135.7	57.3	193.0	128.1	:
I	B 4683	1571.50	33.3	285.8	105.4	45.0	150.4	135.4	:
I	B 4684	1573.95	42.2	201.2	57.6	26.7	84.3	116.9	:
I	B 4685	1581.65	45.1	445.5	168.0	81.2	249.2	196.3	:
I	B 4686	1586.40	29.8	476.2	215.6	107.1	322.6	153.6	:
I	B 4687	1587.50	43.3	781.3	235.5	117.5	353.0	428.3	:
I	B 4688	1590.60	28.0	186.1	56.1	32.8	88.9	97.2	:
I	B 4689	1593.50	32.3	461.1	193.0	85.0	278.0	183.1	:
I	B 4690	1595.50	36.3	82.3	12.8	6.6	19.4	62.9	:
I	B 4691	1628	32.3	42.4	2.6	1.2	3.8	38.6	:

DATE : 16 - 8 - 84.

T A B L E : 5.2



WEIGHT OF EOM AND CHROMATOGRAPHIC FRACTIONS

(Weight ppm OF rock)

I	IKU-No	DEPTH	EOM	Sat.	Aro.	HC	Non HC	I
I	:	(m)	:	:	:	:	:	I
I	B 4681	OIL	:	:	:	:	:	I
I	B 4682	1567.80	9675	4088	1726	5814	3861	I
I	B 4683	1571.50	8575	3162	1350	4512	4062	I
I	B 4684	1573.95	4771	1367	633	2000	2772	I
I	B 4685	1581.65	9871	3723	1799	5522	4350	I
I	B 4686	1586.40	15980	7233	3594	10827	5153	I
I	B 4687	1587.50	18027	5434	2711	8145	9882	I
I	B 4688	1590.60	6635	2000	1171	3171	3463	I
I	B 4689	1593.50	14298	5984	2636	8620	5678	I
I	B 4690	1595.50	2267	354	182	535	1731	I
I	B 4691	1628	1311	82	37	119	1193	I

DATE : 16 - 8 - 84.

TABLE : 5.3



COMPOSITION IN % OF MATERIAL EXTRACTED FROM THE ROCK

I	I	I	I	I	I	I	I	I	I
IKU-No	DEPTH	Sat	Aro	HC	SAT	Non HC	HC		
	(m)	EOM	EOM	EOM	Aro	EOM	Non HC		
B 4681	OIL	22.2	12.4	34.6	179.5	65.4	52.9		
B 4682	1567.80	42.3	17.8	60.1	236.9	39.9	150.6		
B 4683	1571.50	36.9	15.7	52.6	234.2	47.4	111.1		
B 4684	1573.95	28.6	13.3	41.9	215.9	58.1	72.1		
B 4685	1581.65	37.7	18.2	55.9	206.9	44.1	126.9		
B 4686	1586.40	45.3	22.5	67.8	201.3	32.2	210.1		
B 4687	1587.50	30.1	15.0	45.2	200.4	54.8	82.4		
B 4688	1590.60	30.1	17.7	47.8	170.8	52.2	91.6		
B 4689	1593.50	41.9	18.4	60.3	227.1	39.7	151.8		
B 4690	1595.50	15.6	8.0	23.6	194.5	76.4	30.9		
B 4691	1628	6.2	2.8	9.1	220.0	90.9	10.0		

DATE : 16 - 8 - 84.



TABULATION OF DATA FROM THE GASCHROMATOGRAMS

I	:	DEPTH	:	PRISTANE	:	PRISTANE	:	I
I	IKU No.	:	:	-----	:	-----	:	CPI
I	:	(m)	:	n-C17	:	PHYTANE	:	I
I	:	:	:	:	:	:	:	I
I	B 4681	OIL	:	1.0	:	2.0	:	1.0
I	:	:	:	:	:	:	:	I
I	B 4682	1567.80	:	1.3	:	1.8	:	1.1
I	:	:	:	:	:	:	:	I
I	B 4683	1571.50	:	1.2	:	1.8	:	1.1
I	:	:	:	:	:	:	:	I
I	B 4684	1573.95	:	1.6	:	1.7	:	1.1
I	:	:	:	:	:	:	:	I
I	B 4685	1581.65	:	1.3	:	2.0	:	1.0
I	:	:	:	:	:	:	:	I
I	B 4686	1586.40	:	1.2	:	1.9	:	1.0
I	:	:	:	:	:	:	:	I
I	B 4687	1587.50	:	1.1	:	1.9	:	1.0
I	:	:	:	:	:	:	:	I
I	B 4688	1590.60	:	1.2	:	2.2	:	1.0
I	:	:	:	:	:	:	:	I
I	B 4689	1593.50	:	1.1	:	1.9	:	1.0
I	:	:	:	:	:	:	:	I
I	B 4690	1595.50	:	1.3	:	2.0	:	1.0
I	:	:	:	:	:	:	:	I
I	B 4691	1628	:	1.3	:	2.5	:	1.1
I	:	:	:	:	:	:	:	I

DATE : 16 - 8 - 84.

Table 7. Amounts of n-alkanes and branched/cyclic hydrocarbons.

a) Gravimetric results.

IKU no.	Sample type	Depth (m)	SAT (mg)	N-alkanes (mg)	B/C (mg)	N-alkanes+B/C		<u>N-alkanes</u> B+C
						(mg)	(% of SAT)	
B-4681	Oil	-	11.1	1.3	4.5	5.8	52.3	0.29
B-4682	Core, sst	1567.80	10.2	2.6	7.4	10.0	98.0	0.35
B-4684	Core, sst	1573.95	8.9	2.3	7.1	9.4	105.6	0.32

b) Results from integration of gas chromatograms.

IKU No.	Depth (m)	SAT		N-alkanes		B/C		<u>N-alkanes</u> B+C
		(mg)	(% of grav.)	(mg)	(% of grav.)	(mg)	(% of grav)	
B-4681	Oil	4.5	40.5	0.3	24.6	2.3	50.8	0.13
B-4682	1567.80	3.3	32.4	0.9	32.7	4.9	66.2	0.17
B-4684	1573.95	2.9	32.6	0.6	25.2	4.7	66.2	0.12

Table 8. Aromatic hydrocarbon ratios.

IKU No.	Depth (m)	MNR	MPI 1
B-4681	Oil	2.14	0.71
B-4682	1567.80	1.75	0.69
B-4683	1571.50	2.50	0.73
B-4684	1573.95	2.11	0.70
B-4685	1581.65	2.10	0.72
B-4686	1586.40	1.63	0.64
B-4687	1587.50	1.91	0.73
B-4688	1590.60	1.89	0.62
B-4689	1593.50	1.43	0.76
B-4690	1595.50	~1.00	0.72
B-4691	1628.00	1.67	0.59

MNR = 2/1 MN

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

Table 9. Maturity ratios calculated from peak heights in sterane and terpane mass chromatograms.

IKU code	Depth (m)	Sample type	m/z 191		m/z 217	
			$\alpha\beta/\alpha\beta+\beta\alpha$ ¹⁾	%22S ²⁾	%20S ³⁾	%BB ⁴⁾
B-4681	-	Oil	0.91	58.4	49.0	75.6
B-4682	1567.80	Core, sst	0.90	54.8	47.1	76.9
B-4683	1571.50	"	0.90	62.0	42.1	74.7
B-4684	1573.95	"	0.91	55.6	47.9	71.7
B-4685	1581.65	"	0.90	59.1	50.8	76.1
B-4686	1586.40	"	0.90	57.1	50.8	74.9
B-4687	1587.50	"	0.91	56.5	53.2	73.2
B-4688	1590.50	"	0.91	59.1	47.1	73.0
B-4689	1593.50	"	0.91	60.2	53.1	73.6
B-4690	1595.50	"	0.91	61.9	52.3	69.4
B-4691	1628.00	"	0.90	59.1	61.6	73.5

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 10. Molecular ratios calculated from sterane and terpane mass chromatograms.

IKU code	Depth (m)	Sample type	T _m /T _s ¹⁾	m/z 191			m/z 217 a/a+j ³⁾
				TRI/E ²⁾	Z/E	X/E	
B-4681	-	Oil	0.52	0.07	0.17	0.18	0.85
B-4682	1567.80	Core, sst	0.72	0.06	0.18	0.14	0.85
B-4683	1571.50	"	0.53	0.07	0.18	0.17	0.83
B-4684	1573.95	"	0.83	0.05	0.16	0.18	0.83
B-4685	1581.65	"	0.76	0.06	0.19	0.20	0.83
B-4686	1586.40	"	0.76	0.06	0.18	0.17	0.83
B-4687	1587.50	"	0.63	0.08	0.22	0.18	0.86
B-4688	1590.50	"	0.61	0.05	0.23	0.20	0.85
B-4689	1593.50	"	0.70	0.05	0.17	0.16	0.85
B-4690	1595.50	"	0.75	0.05	0.19	0.18	0.82
B-4691	1628.00	"	1.00	0.06	0.17	0.14	0.61

1) B/A in m/z 191.

2) Q/E in m/z 191.

3) Relative amounts of C₂₇ rearranged steranes (a/a+j in m/z 217).

Table 11. Maturity ratios from aromatic sterane mass chromatograms.

IKU no.	Depth (m)	Sample type	$C_{21}/C_{21}+C_{28,29}$	$C_{20}/C_{20}+C_{26,27}$	TRI/TRI+MONO
B-4681	-	Oil	50.0	35.3	70.5
B-4682	1567.80	Core, sst	41.2	35.3	60.5
B-4683	1571.50	"	44.4	50.0	59.8
B-4684	1573.95	"	37.5	35.3	57.9
B-4685	1581.65	"	47.1	36.8	62.4
B-4686	1586.40	"	41.2	31.3	61.3
B-4687	1587.50	"	39.8	40.2	55.2
B-4688	1590.50	"	41.2	37.5	55.1
B-4689	1593.50	"	46.0	35.3	58.2
B-4690	1595.50	"	44.4	36.8	63.2
B-4691	1628.00	"	33.3	33.3	49.5

Table 12. $\delta^{13}\text{C}$ isotope ratios of hydrocarbon fractions.

IKU no.	Depth (m)	Sample type	SAT	ARO
B-4681	-	Oil	-29.1	-
B-4682	1567.80	Core, sst	-29.5	-27.6
B-4683	1571.50	"	-28.7	-27.7
B-4684	1573.95	"	-28.5	-27.6
B-4685	1581.65	"	-28.5	-27.9
B-4686	1586.40	"	-28.7	-27.2
B-4687	1587.50	"	-28.8	-27.1
B-4688	1590.50	"	-28.9	-27.4
B-4689	1593.50	"	-28.9	-27.2
B-4690	1595.50	"	-28.3	-27.6
B-4691	1628.00	"	not sufficient material	

FIGURE 1

C₂-C₈ hydrocarbon gas chromatogram

Analysis B4681T3

5,1,1 B-4681,0.3ul,TU

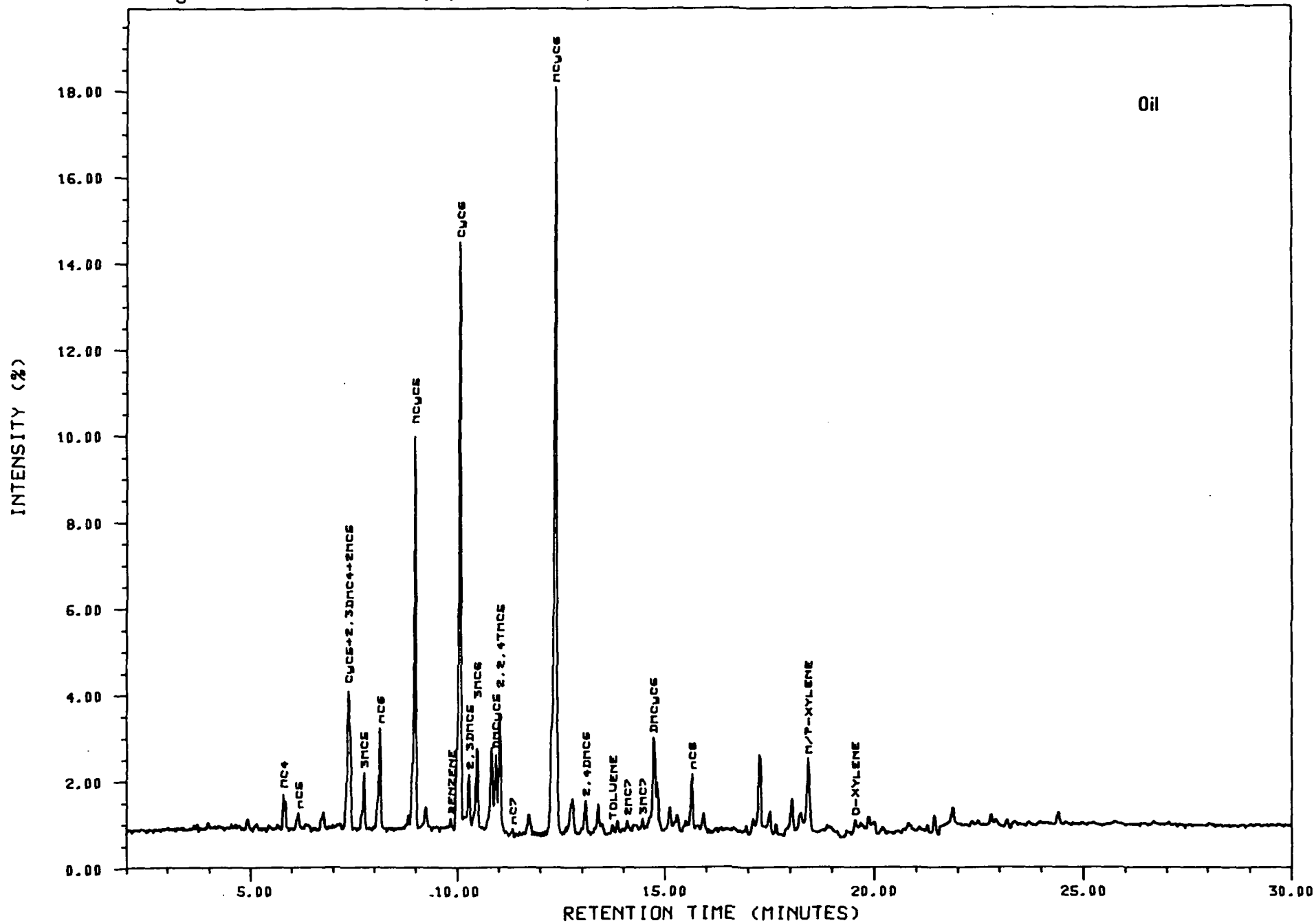
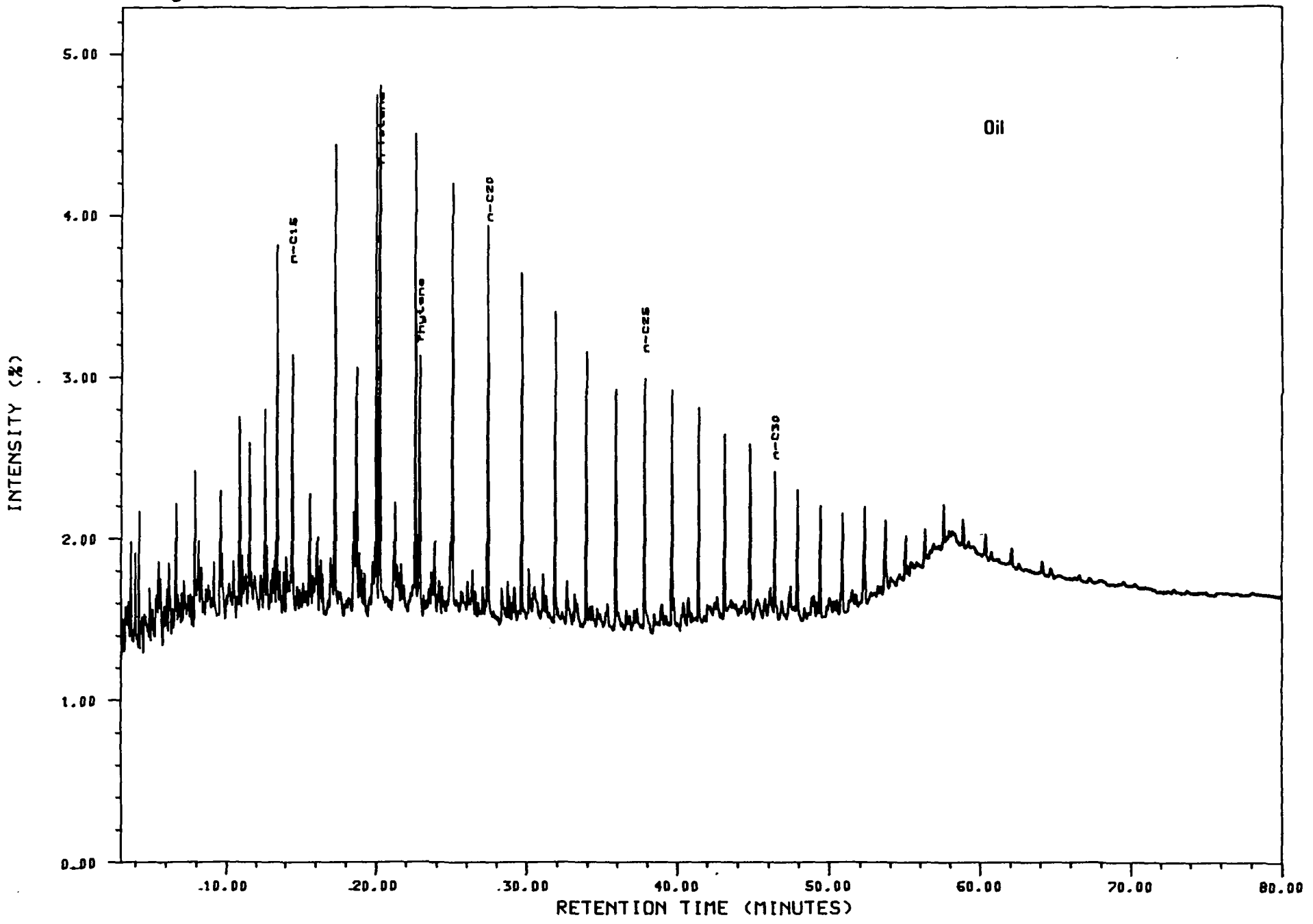


FIGURE 2

Saturated hydrocarbon gas chromatograms

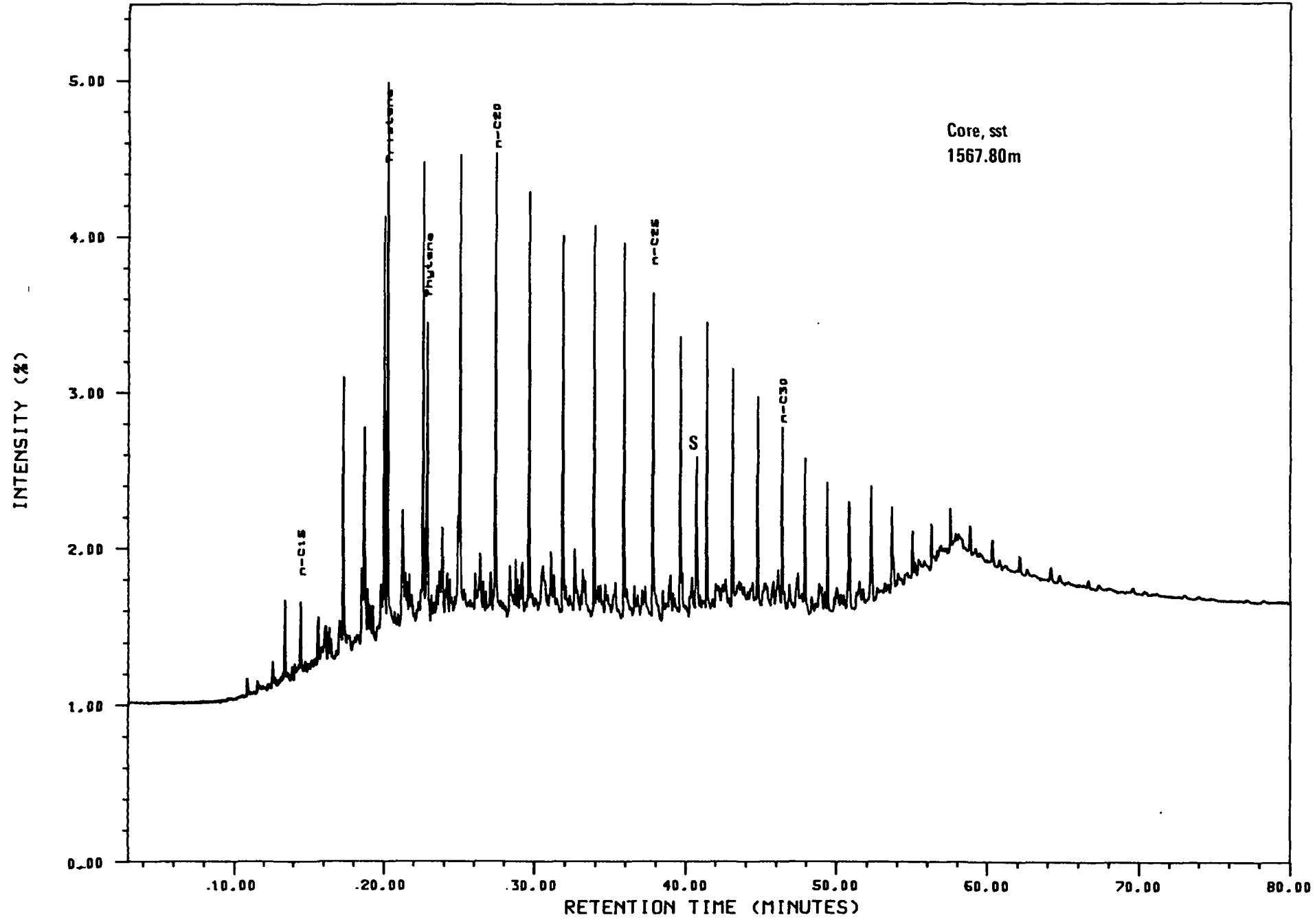
- n-C₁₅ etc. - n-alkanes
- Pr - pristane
- Ph - phytane
- * - acyclic isoprenoids
- S - squalane (internal standard)



Analysis AUTO1744

3,2,1

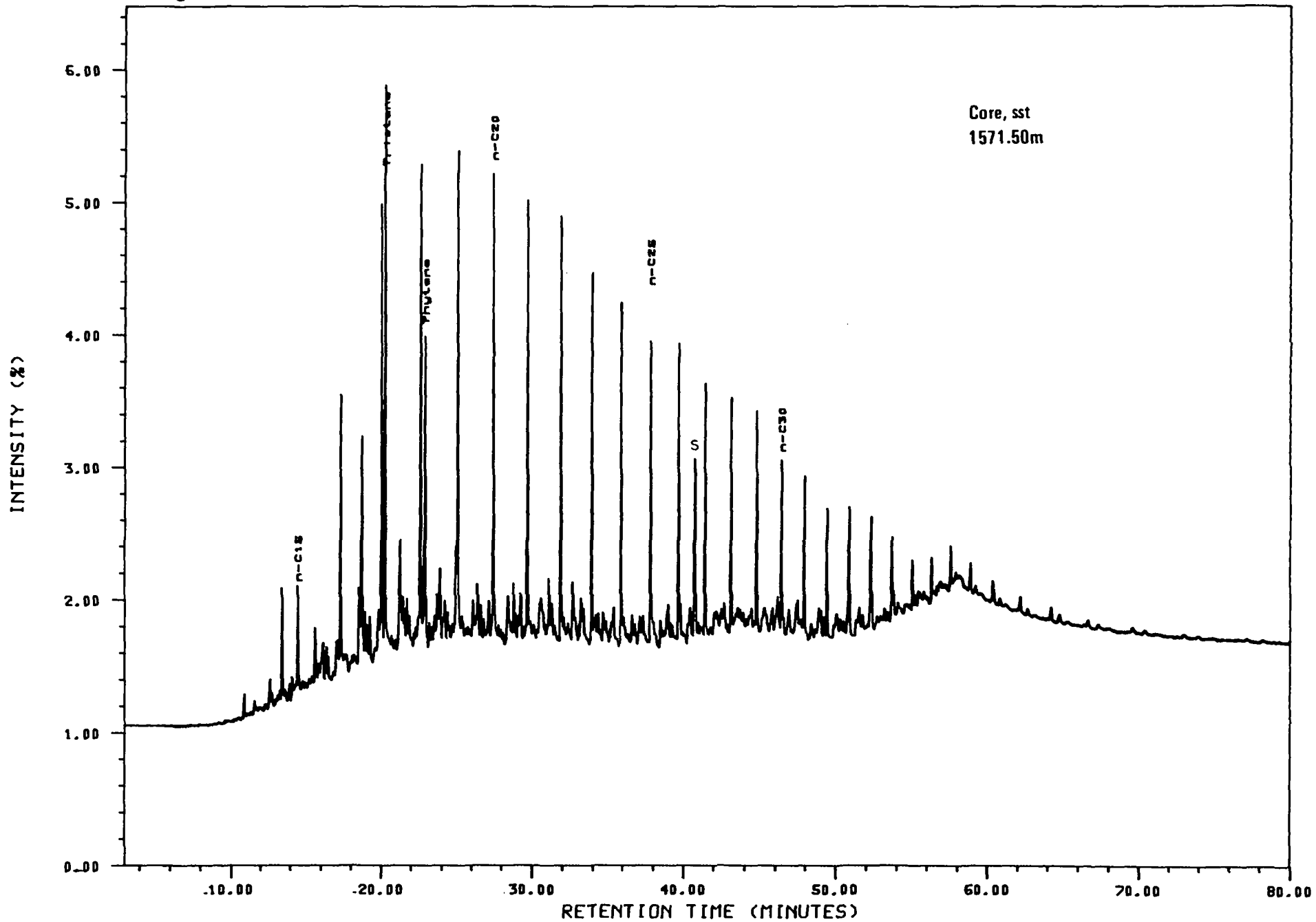
B-4682, SAT, 31/3-2, JA



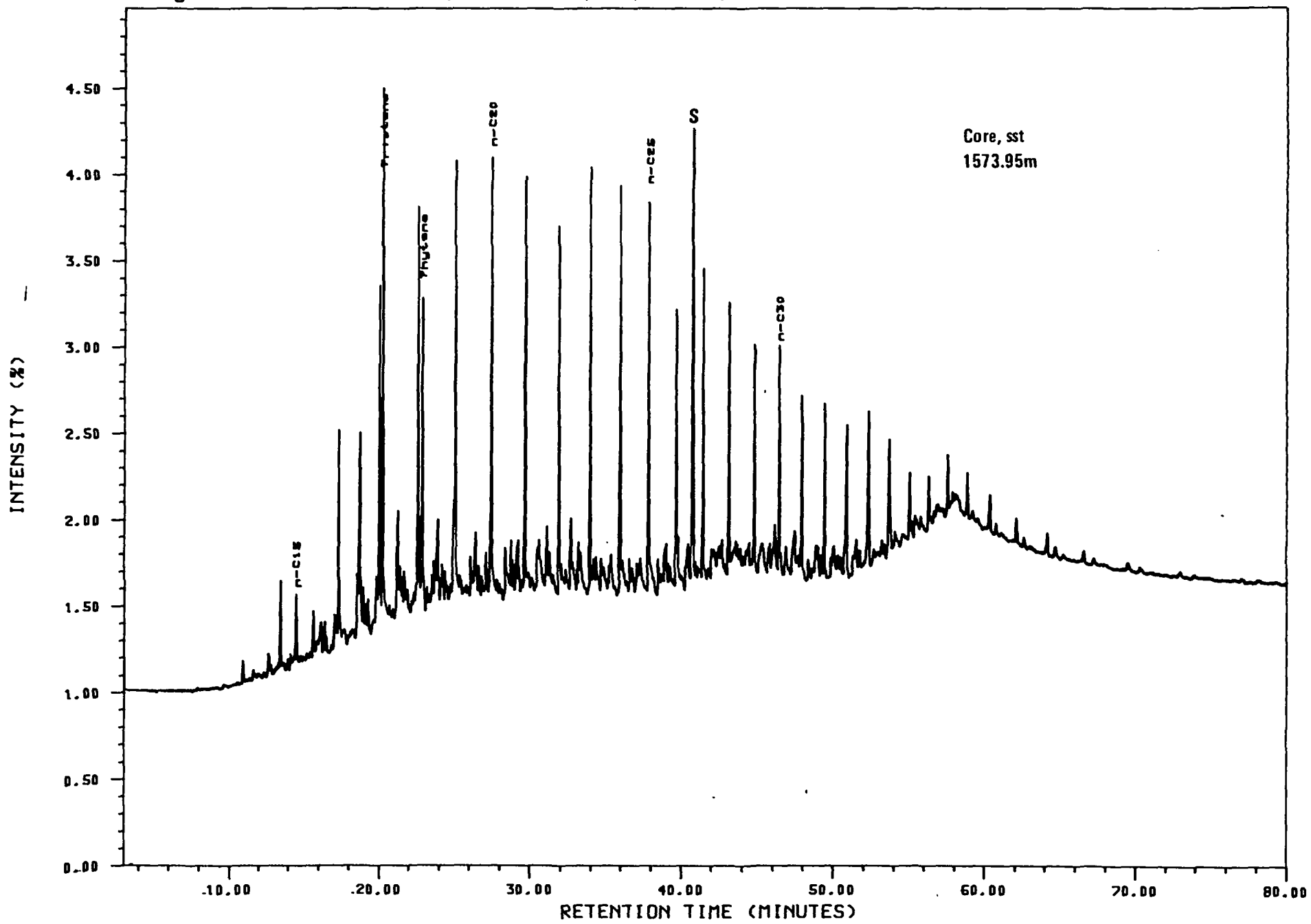
Core, sst
1567.80m

Analysis AUTO1744

3,3,1 B-4683, SAT, 31/3-2, JA



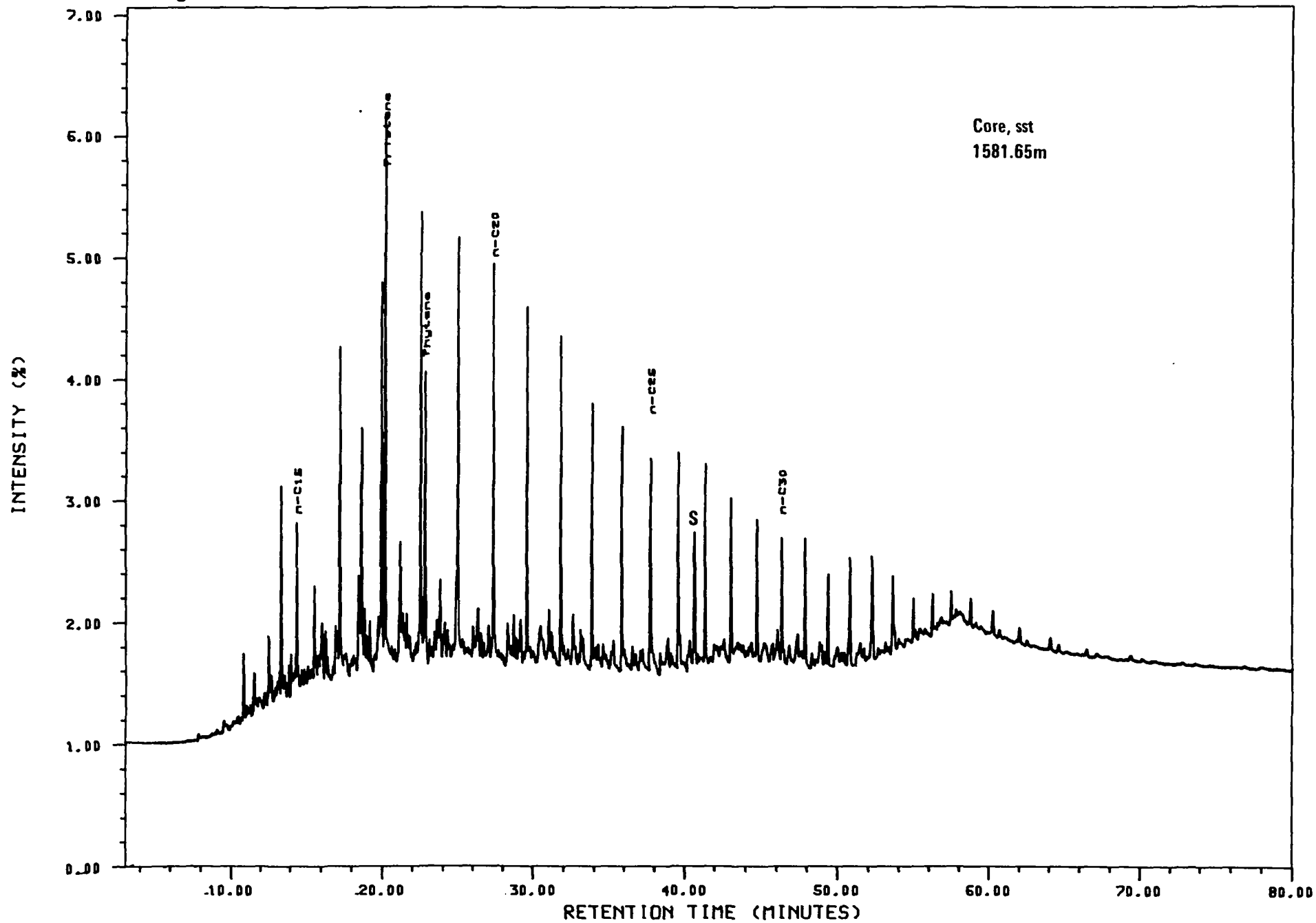
Core, sst
1571.50m



Core, sst
1573.95m

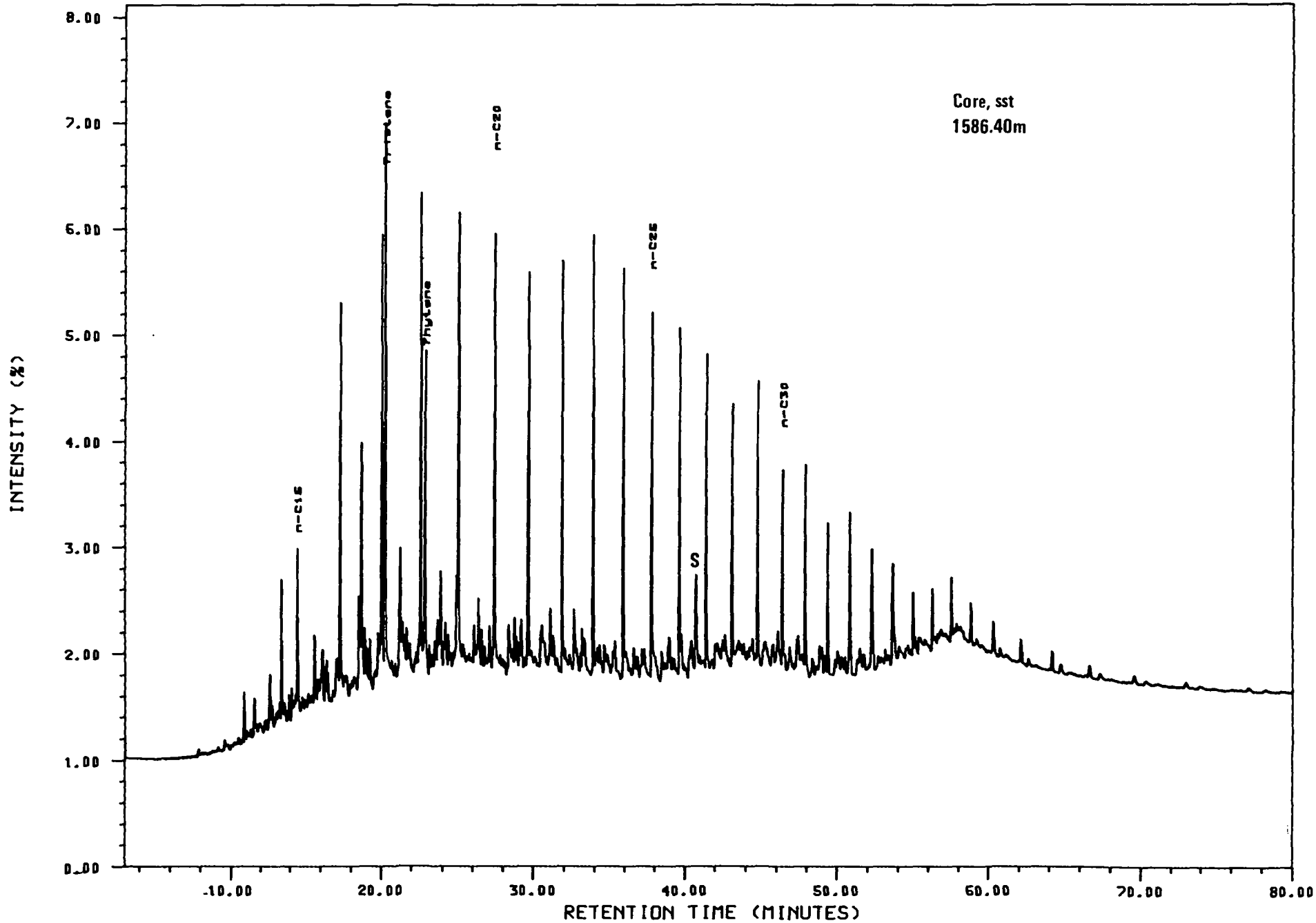
Analysis AUTO1744

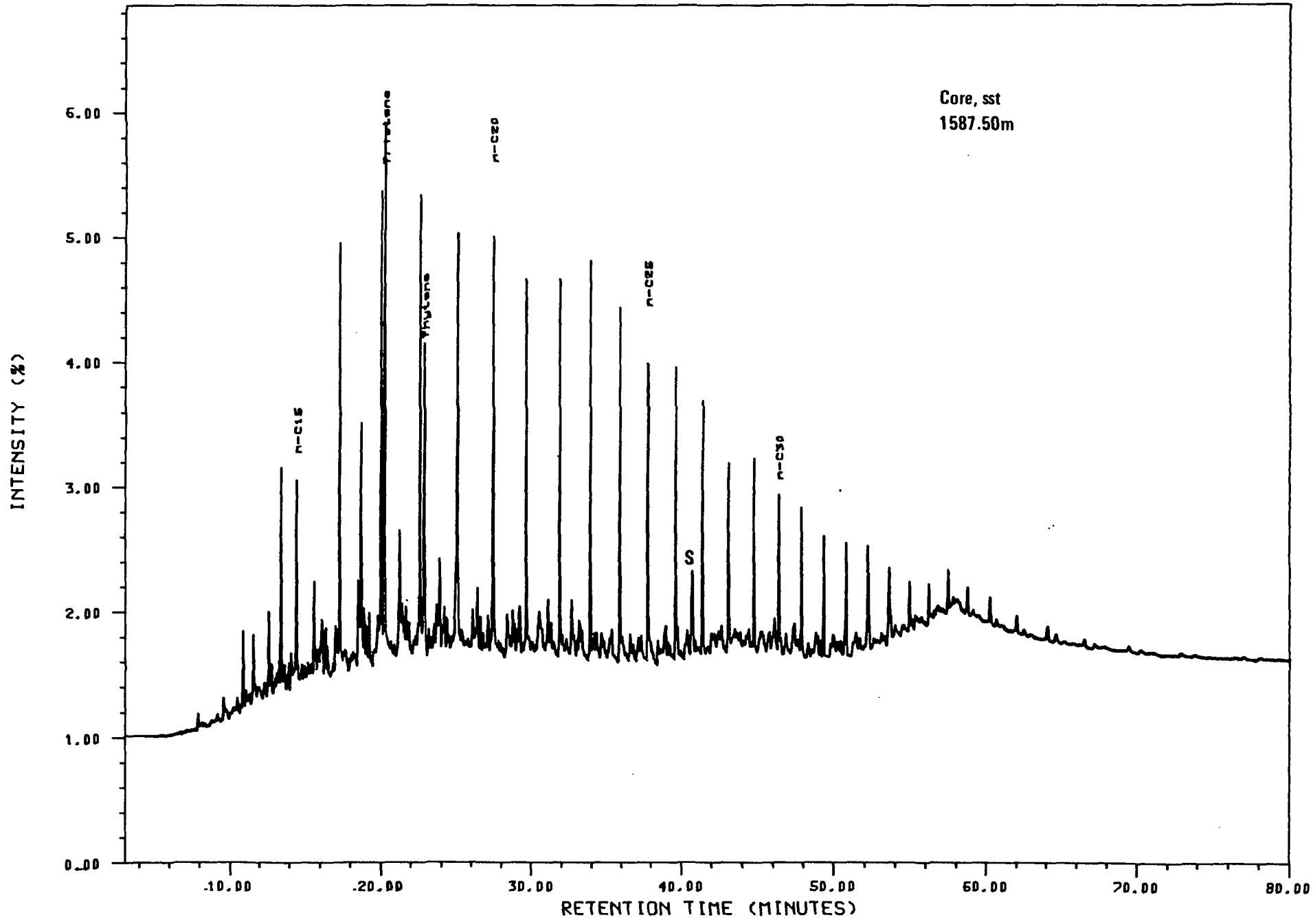
3,5,1 B-4685, SAT, 31/3-2, JA

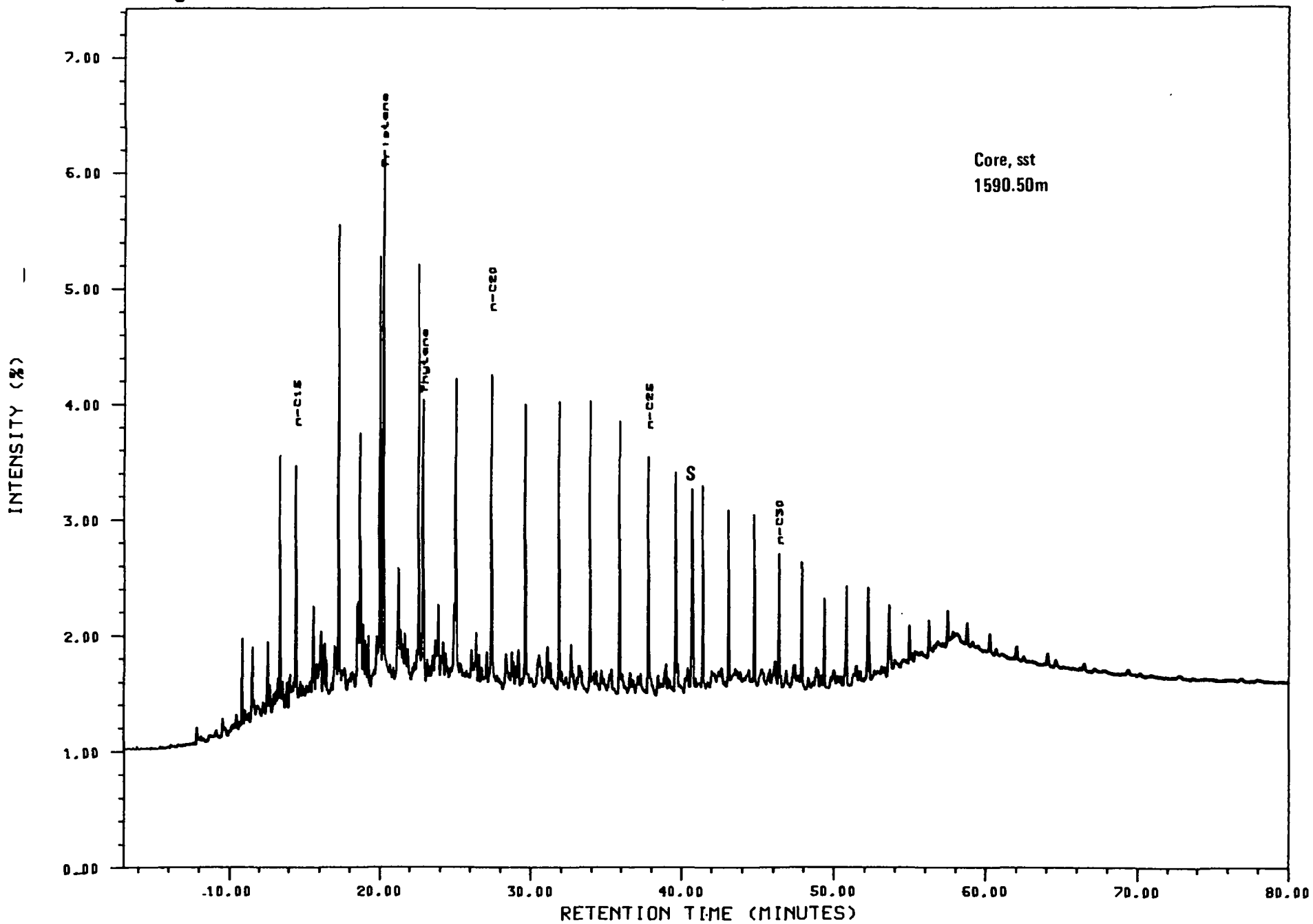


Analysis AUTO1744

3,6,1 B-4686, SAT, 31/3-2, JA



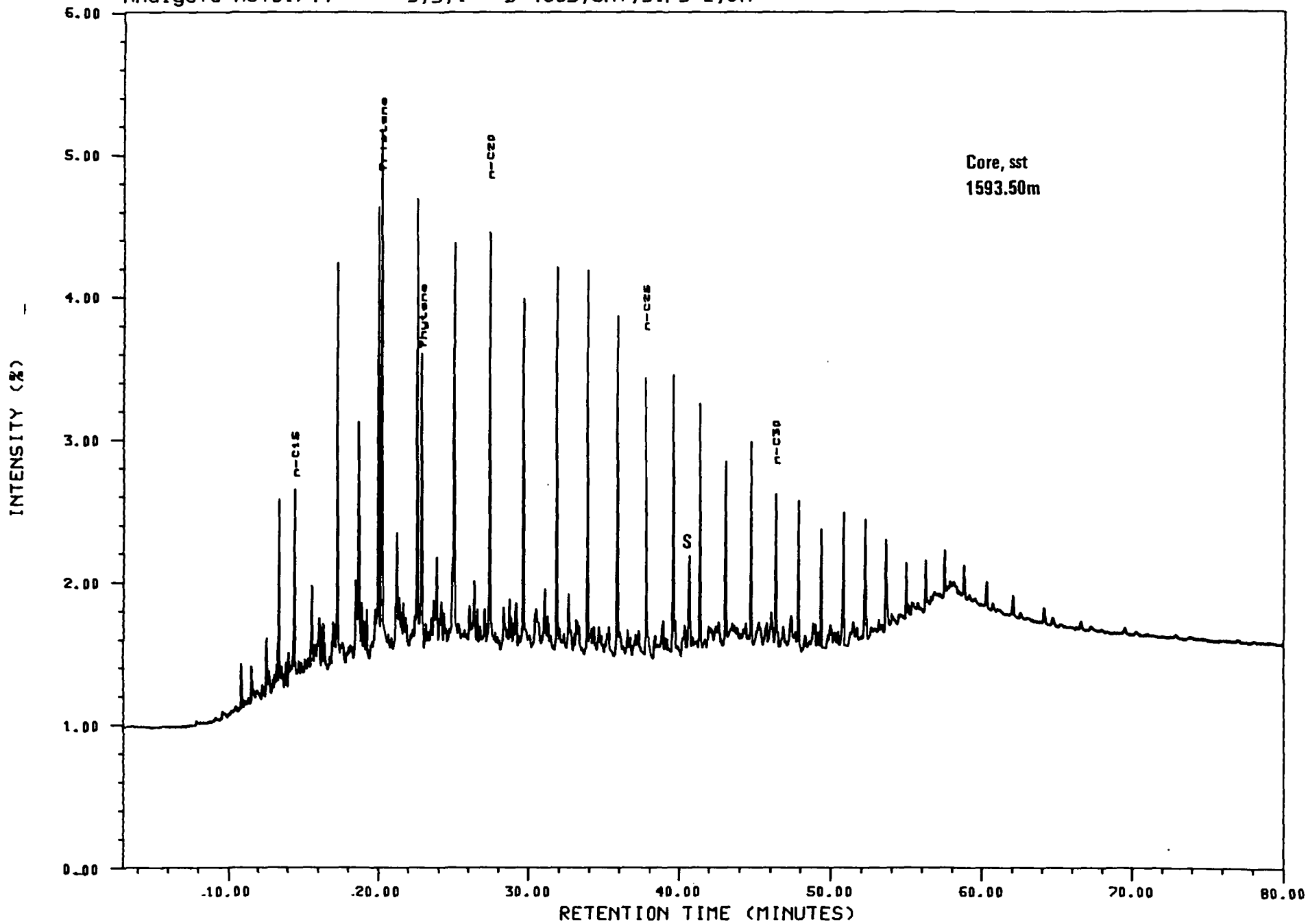




Core, sst
1590.50m

Analysis AUTO1744

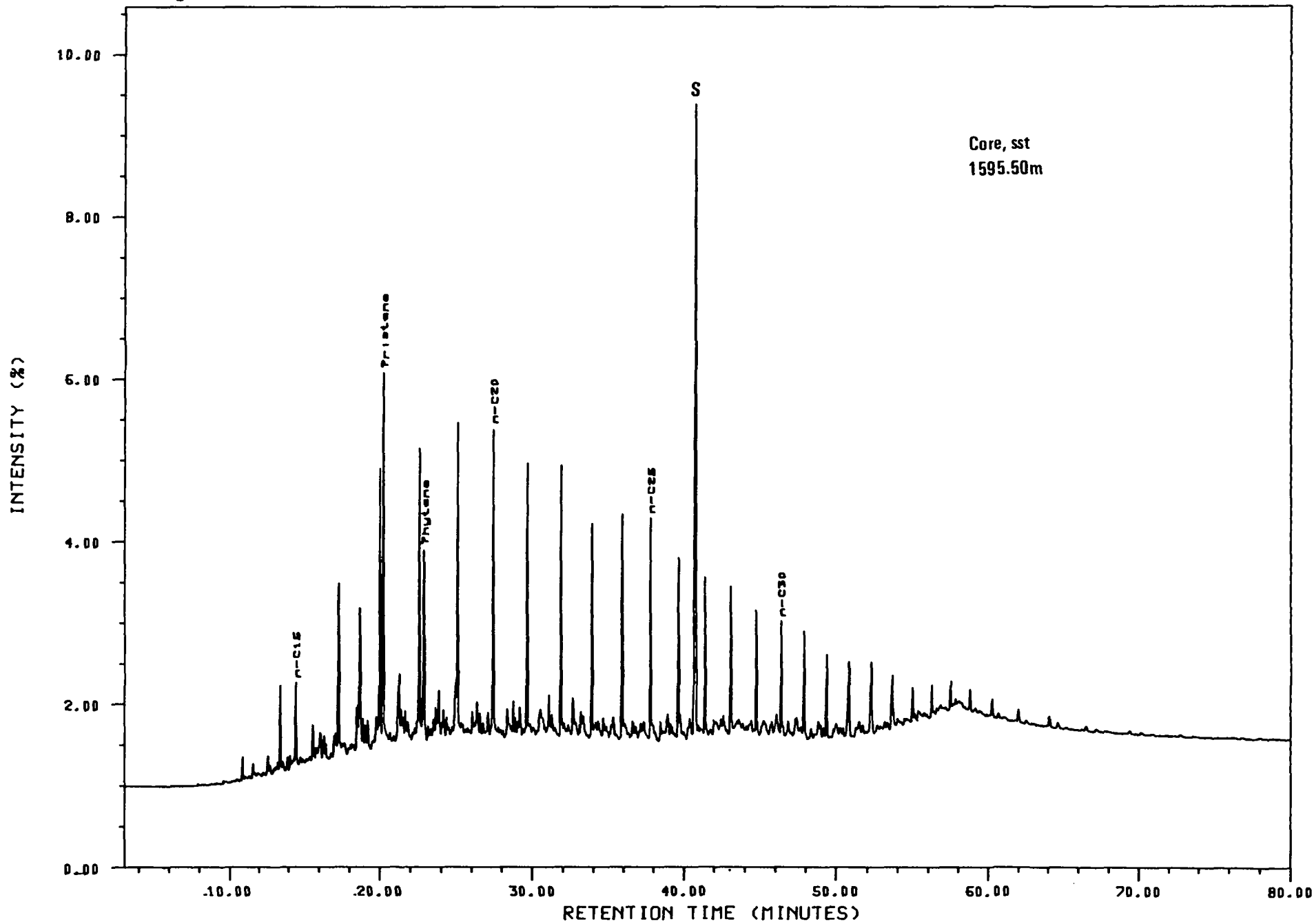
3,9,1 B-4689, SAT, 31/3-2, JA



Analysis AUT01744

3,10,1

B-4690, SAT, 31/3-2, JA



Core, sst
1595.50m

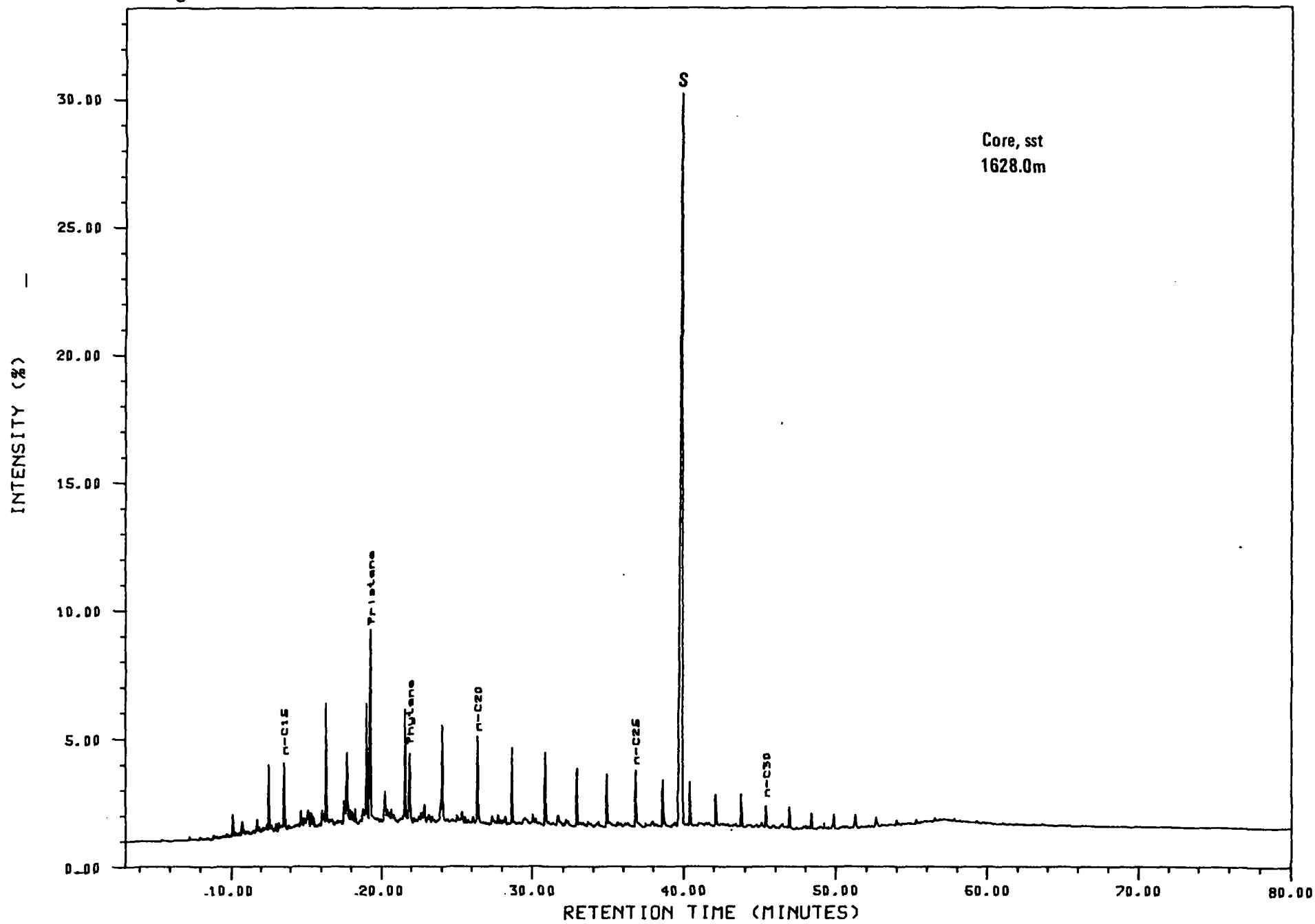
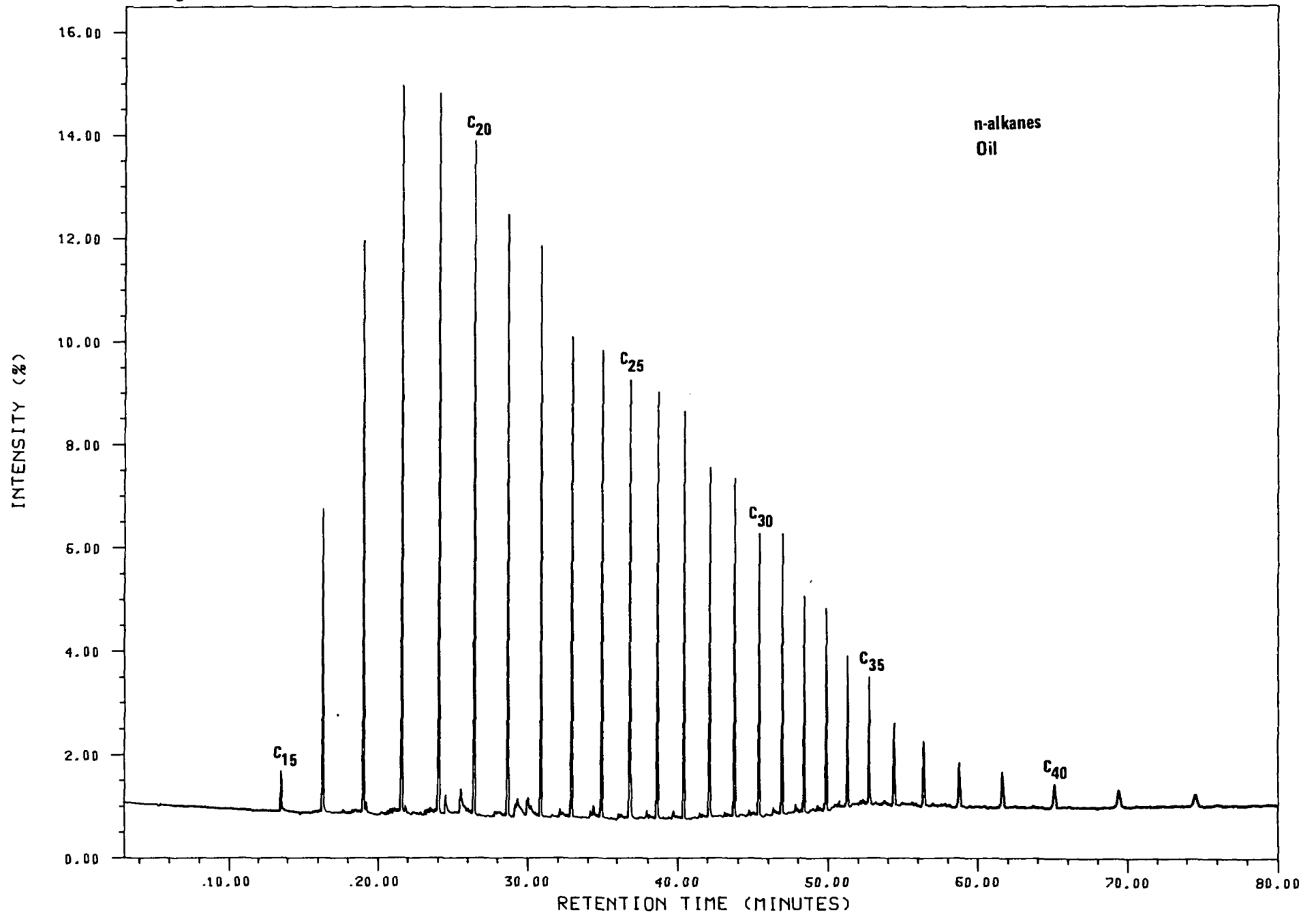
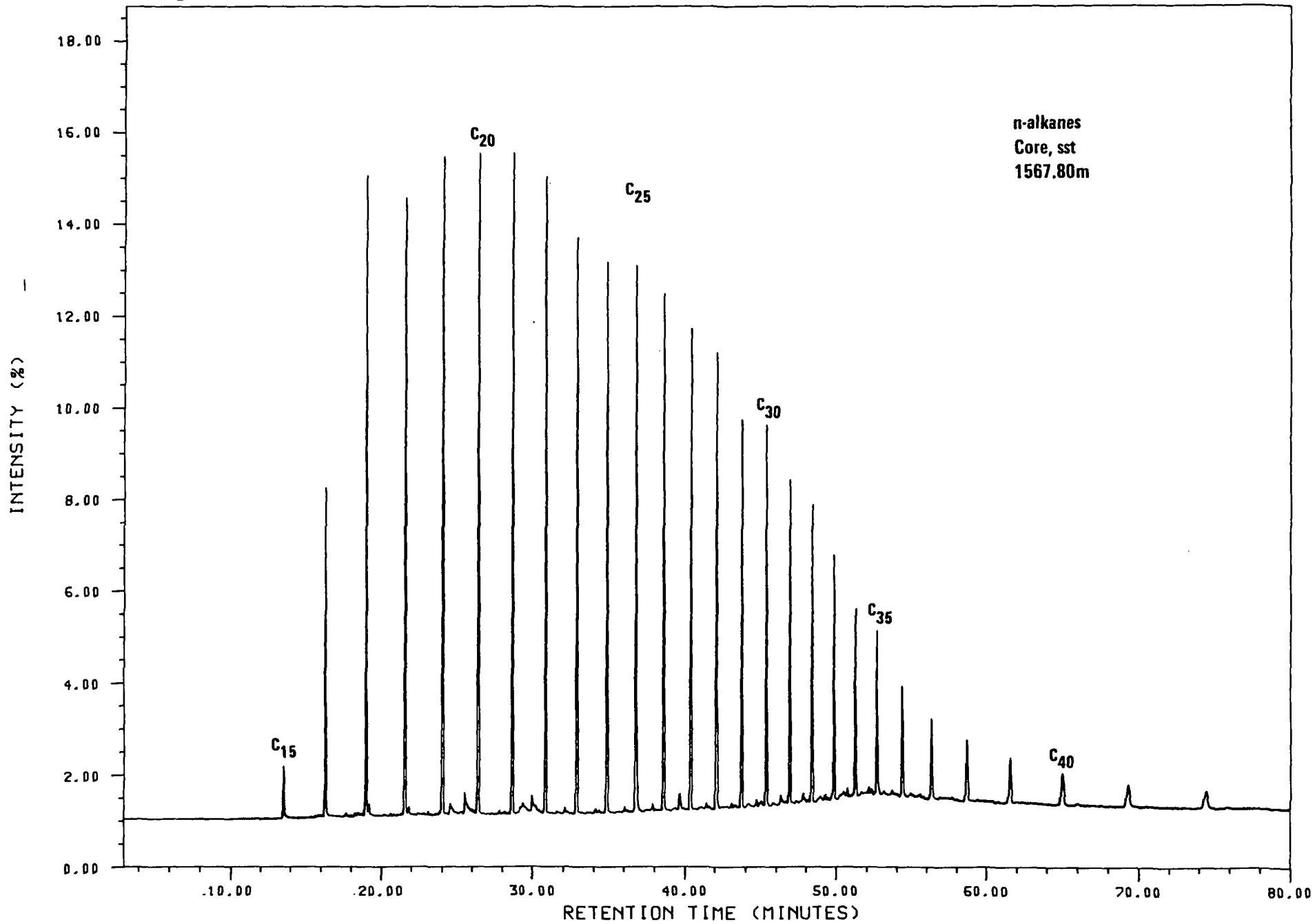


FIGURE 3a

n-alkanes after separation with
molecular sieve

Analysis 744B4681N 3,1,1 B-4681,N,31/3-2,JA





n-alkanes
Core, sst
1567.80m

Analysis 744B4684N 3,1,1 B-4684,N,31/-2,JA

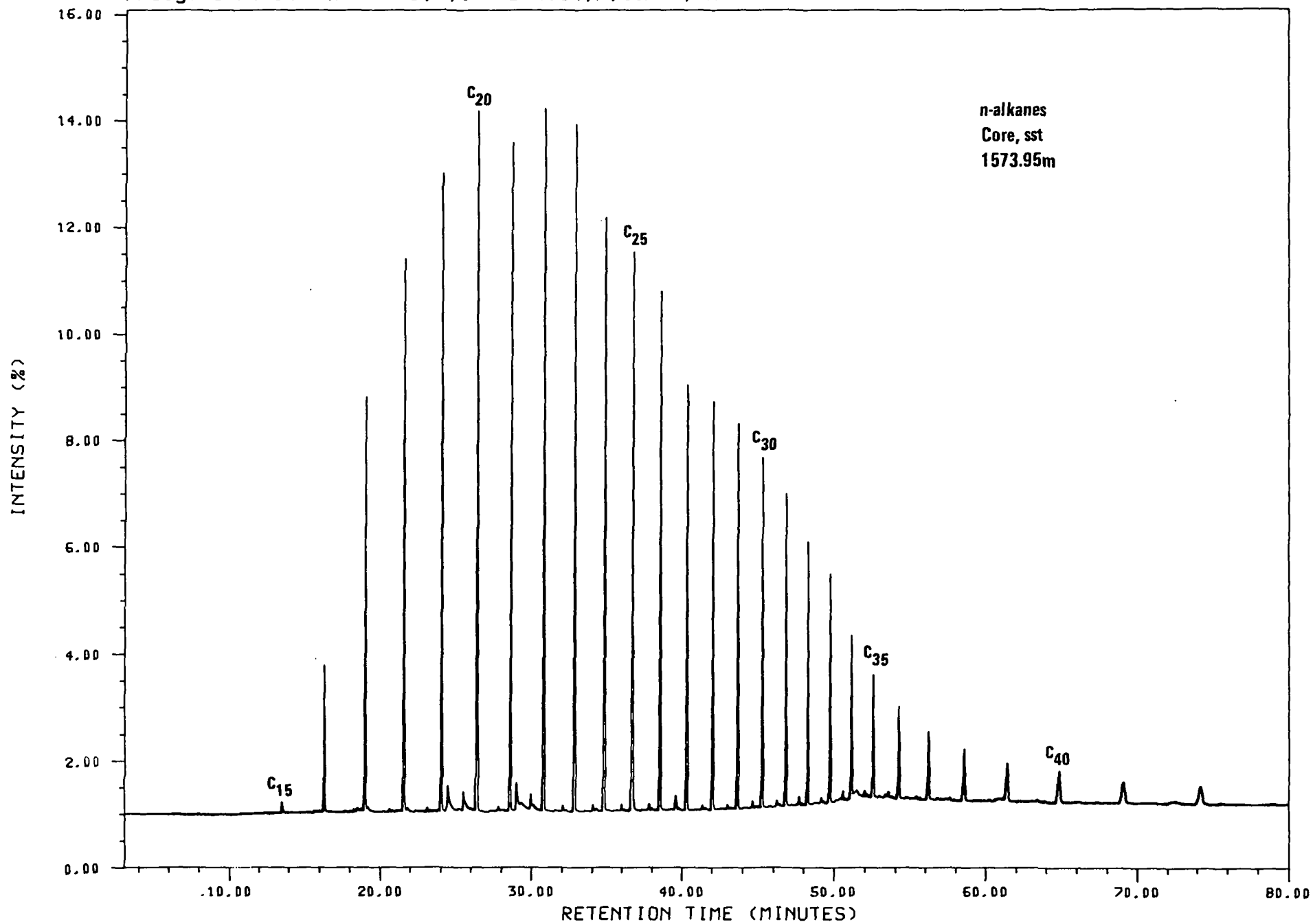
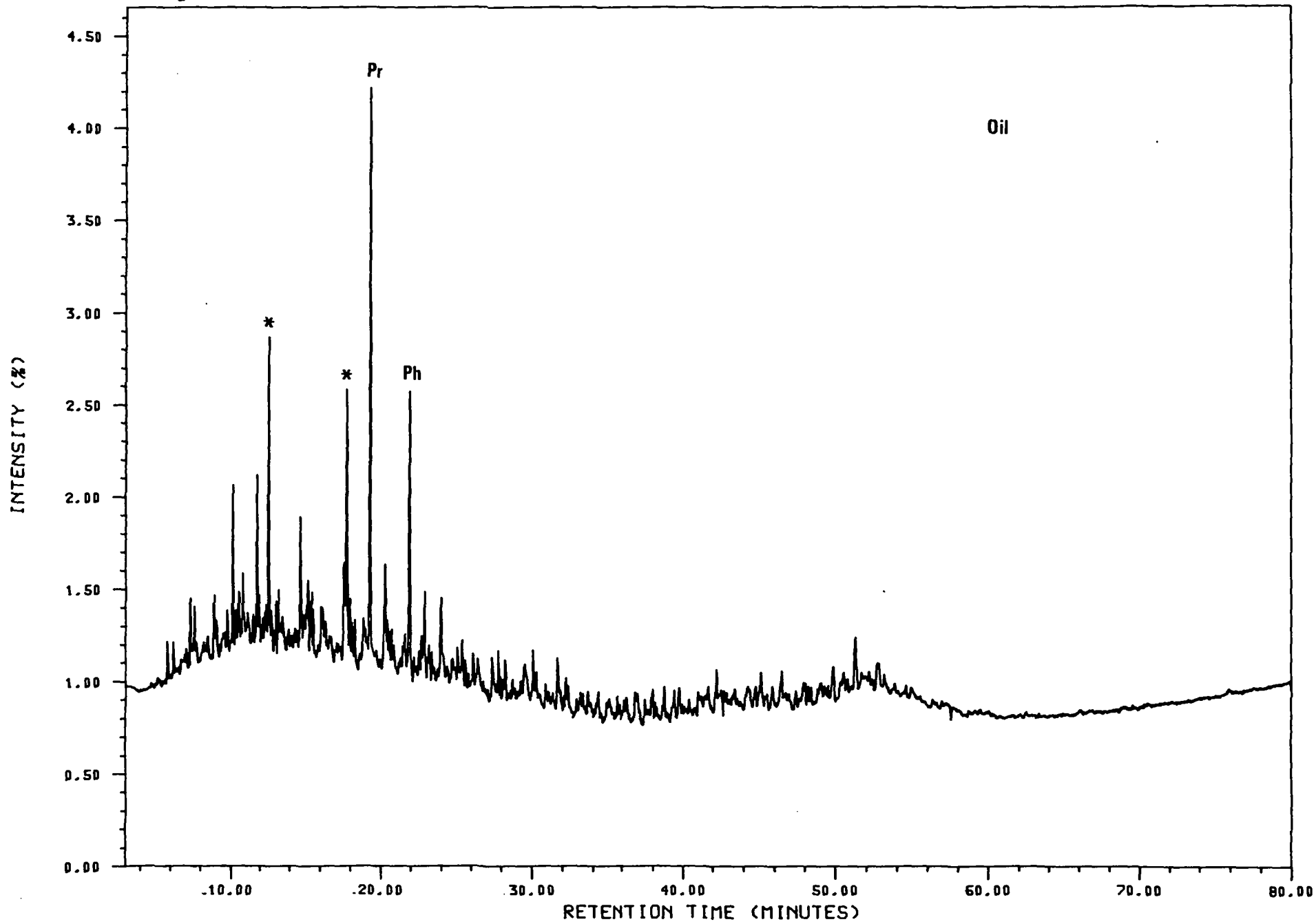


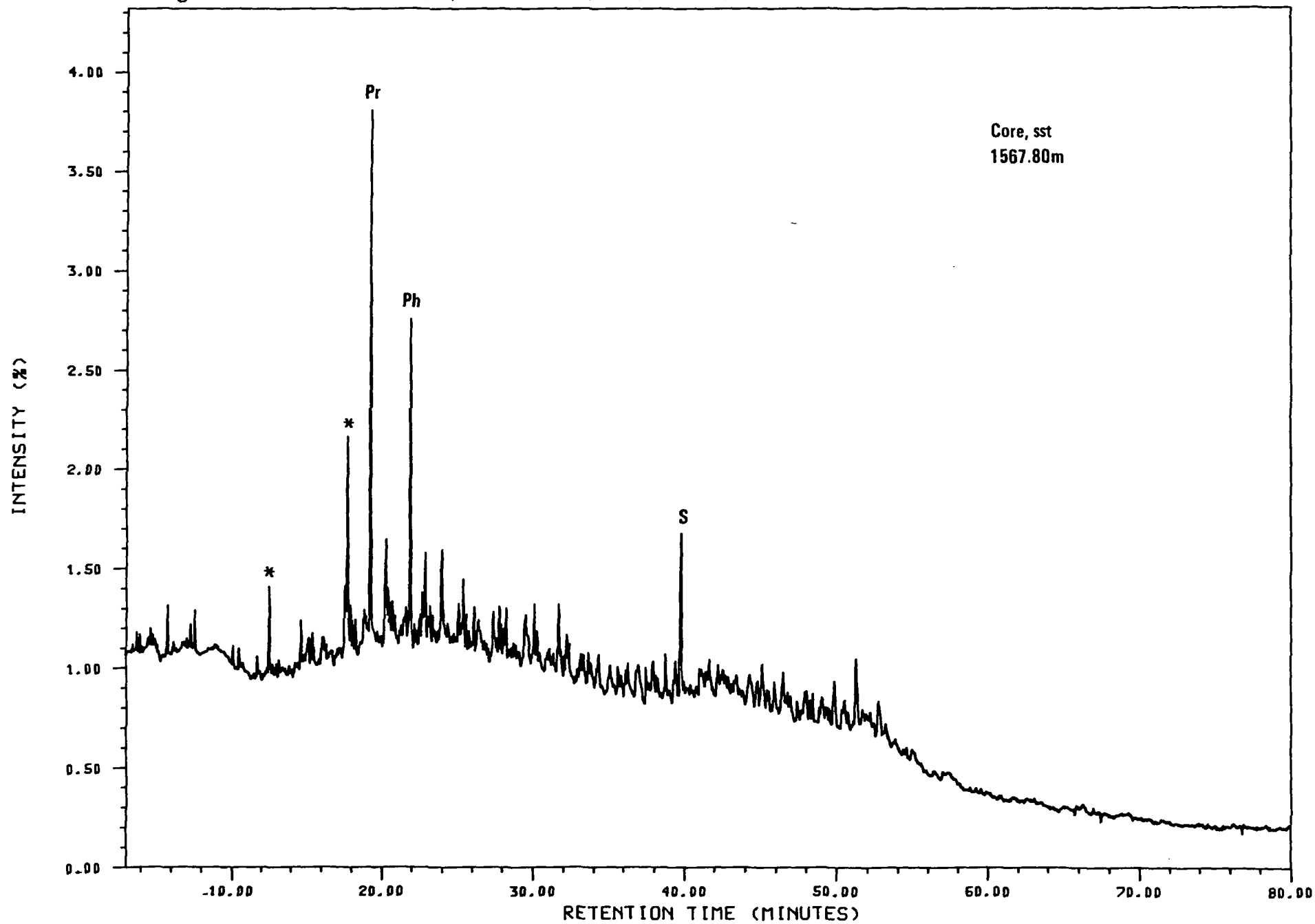
FIGURE 3b

Branched/cyclic hydrocarbons after
removal of n-alkanes with molecular sieve

Analysis 744B4681B 3,1,1 B-4681,B/C,31/3-2,JA



Analysis 744B4682 3,1,1 B-4682,B/C,31/3-2,LH



Core, sst
1567.80m

Analysis 744B4684B 3,1,1 B-4684,B/C,31/3-2,JA

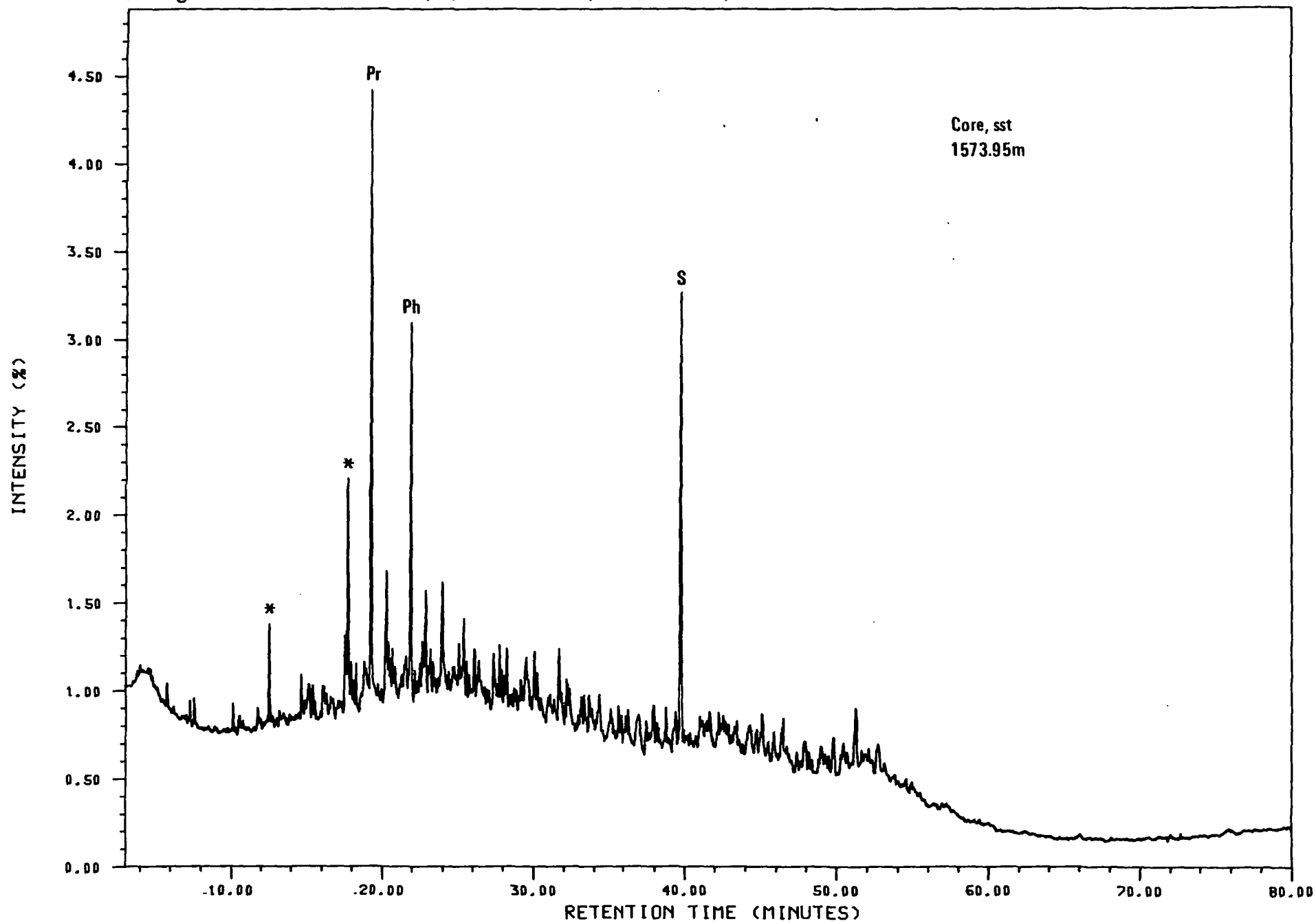
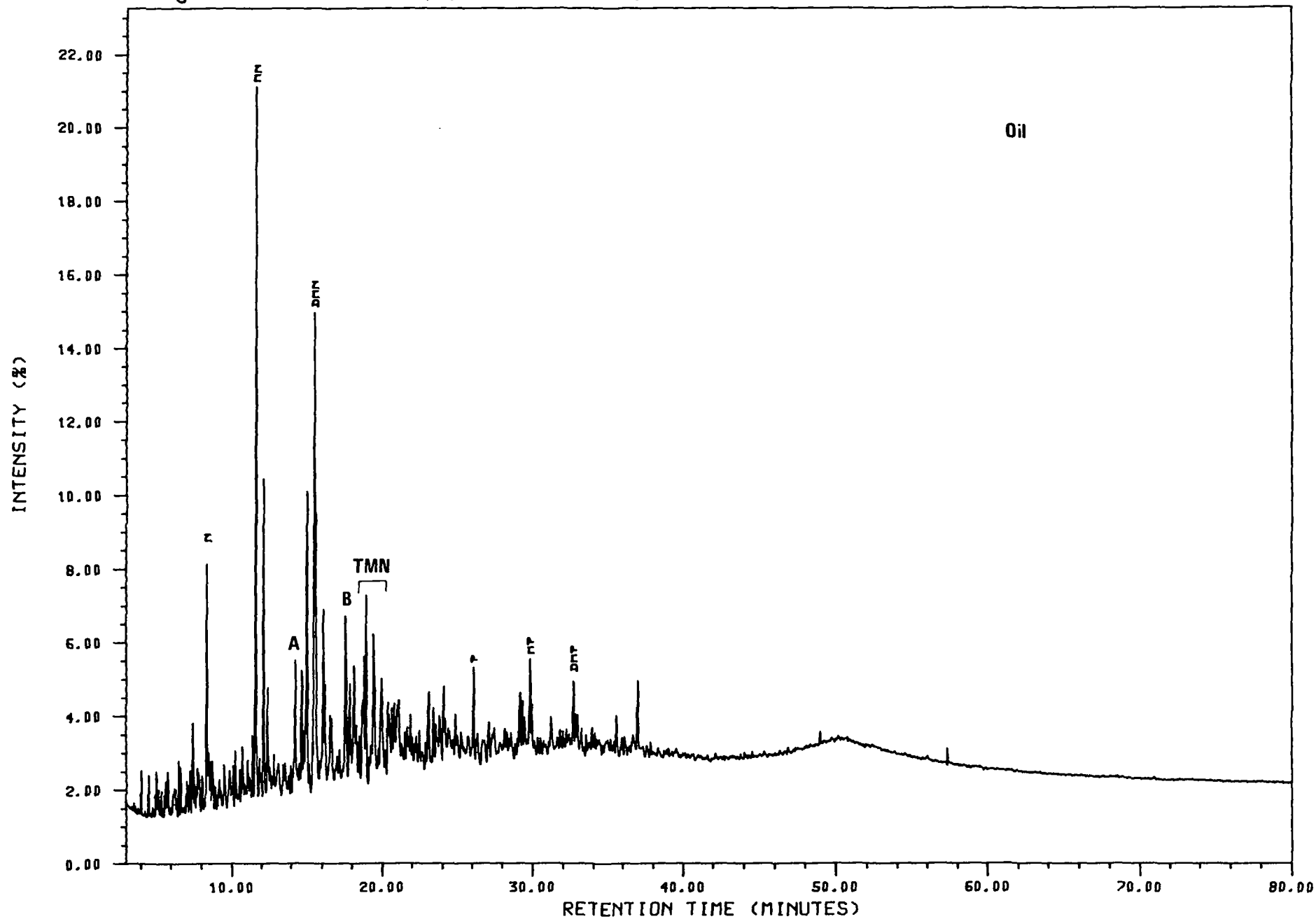


FIGURE 4

Aromatic hydrocarbon gas chromatograms

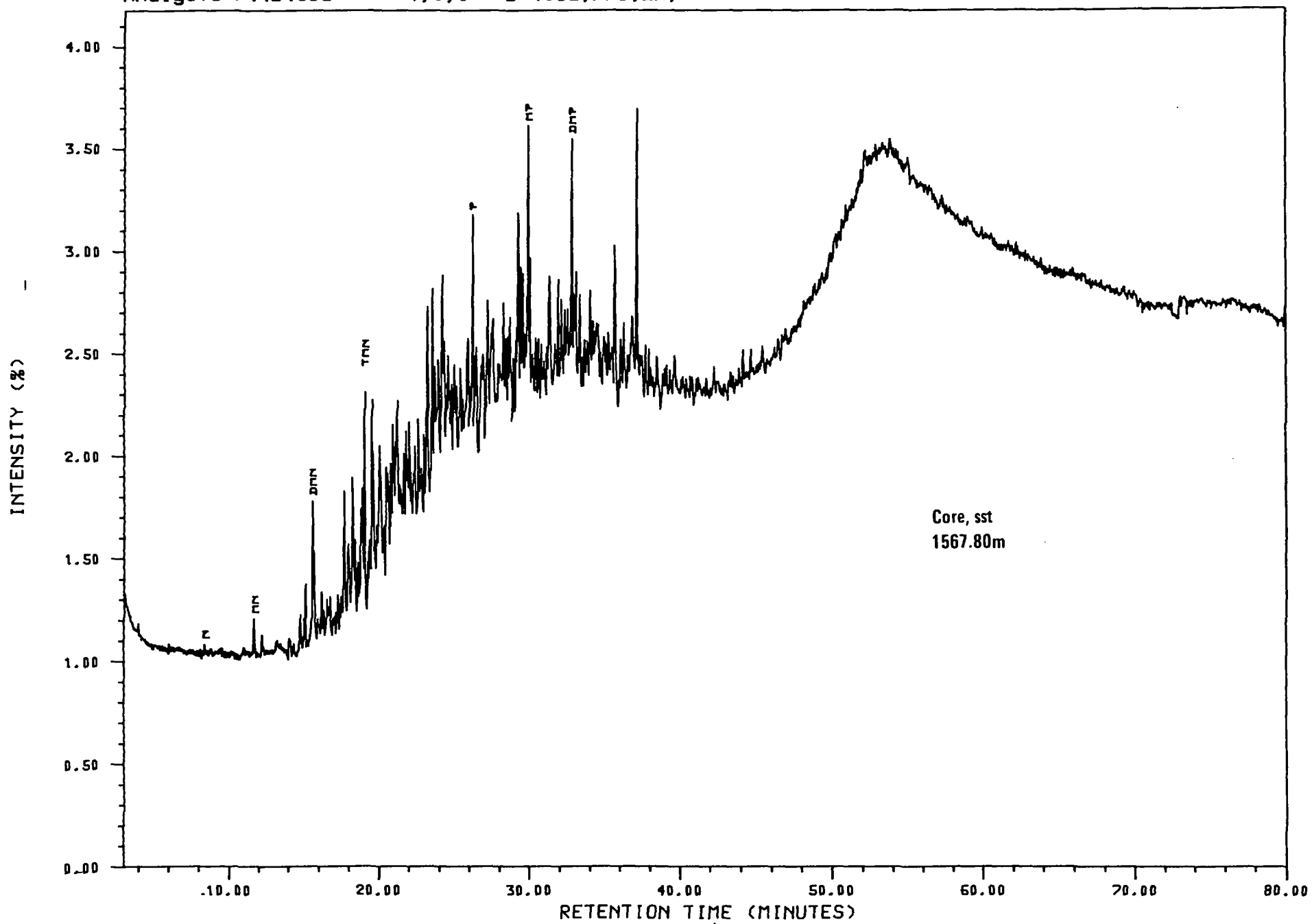
- N - naphthalene
- MN - methylnaphthalenes
- DMN - dimethylnaphthalenes
- TMN - trimethylnaphthalenes
- P - phenanthrene
- MP - methylphenanthrenes
- DMP - dimethylphenanthrenes

Analysis 744B4681A 4,1,1 B-4681,ARO,31/3-2,JA

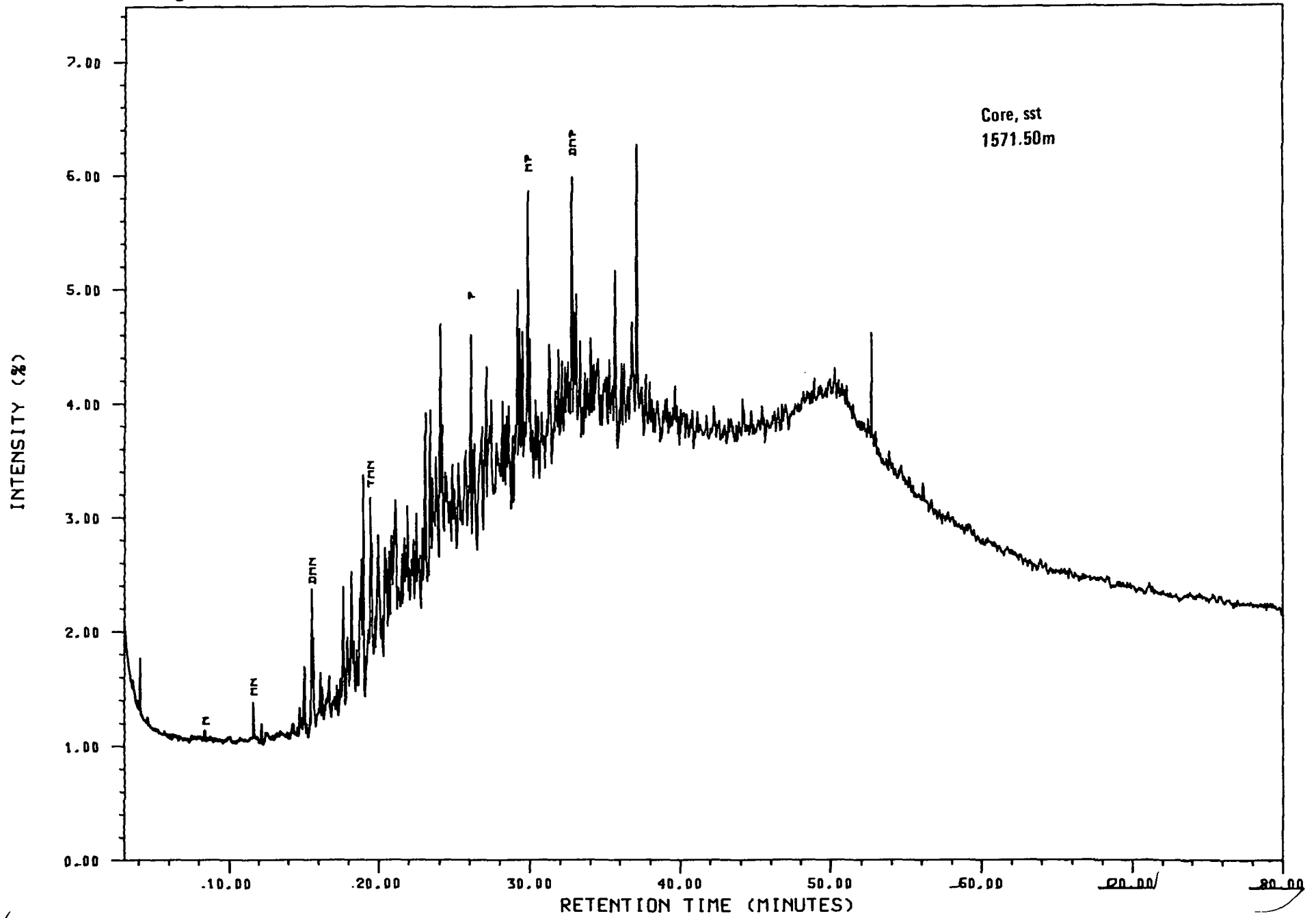


Analysis 744B4582

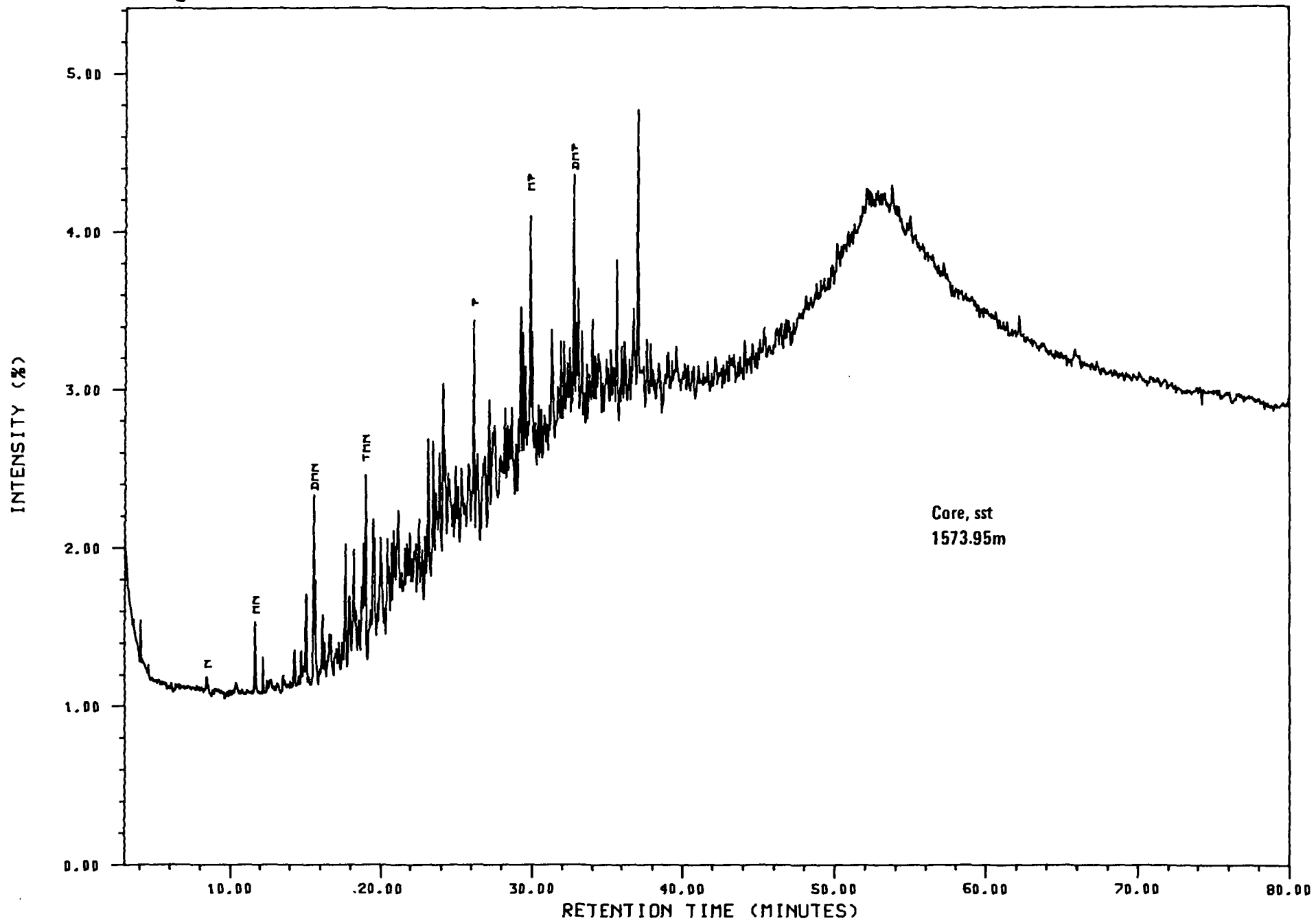
4,1,1 B-4582,ARO,LH,



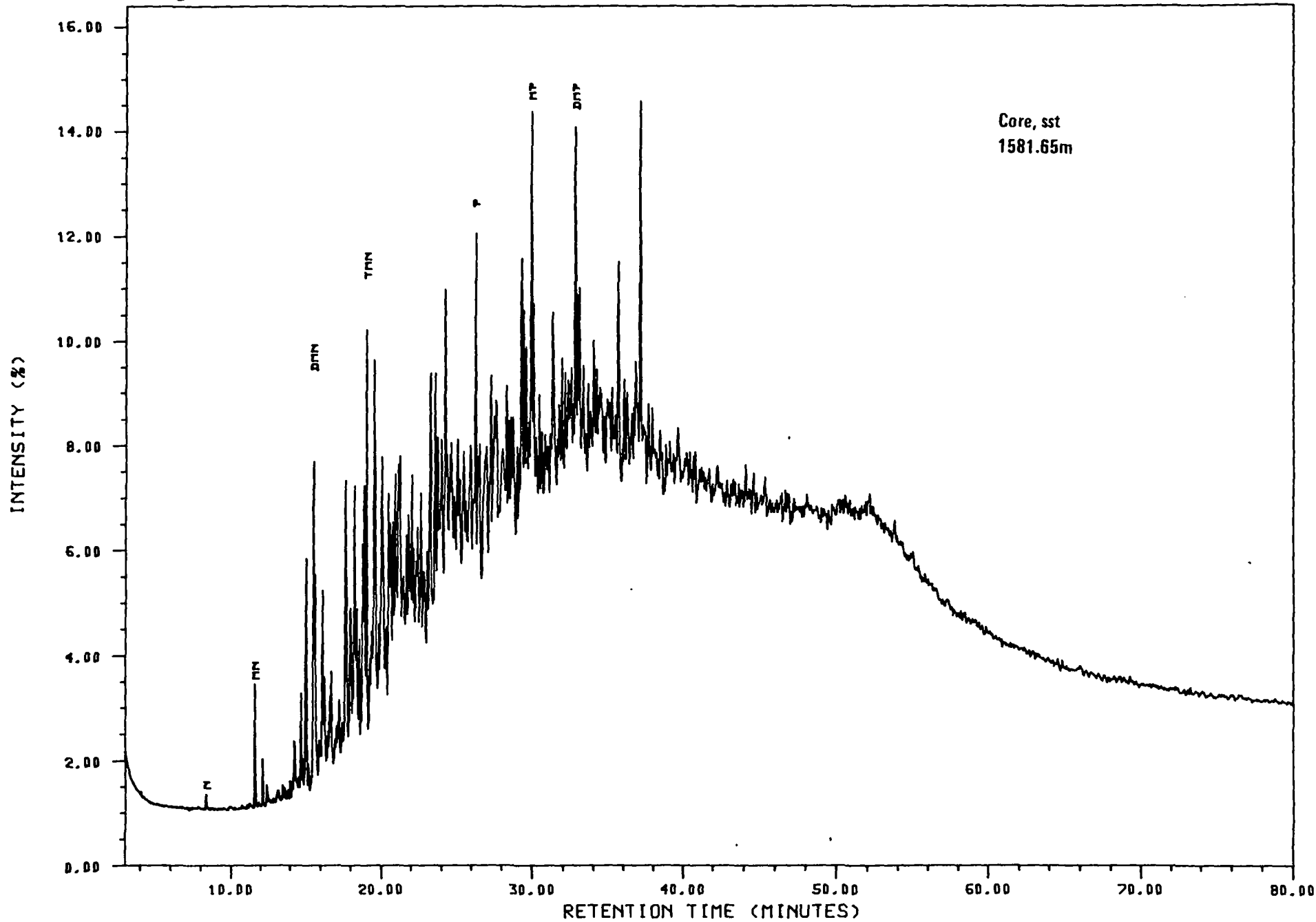
Analysis 744B4683A 4,1,1 B-4683,ARO,31/3-2,JA



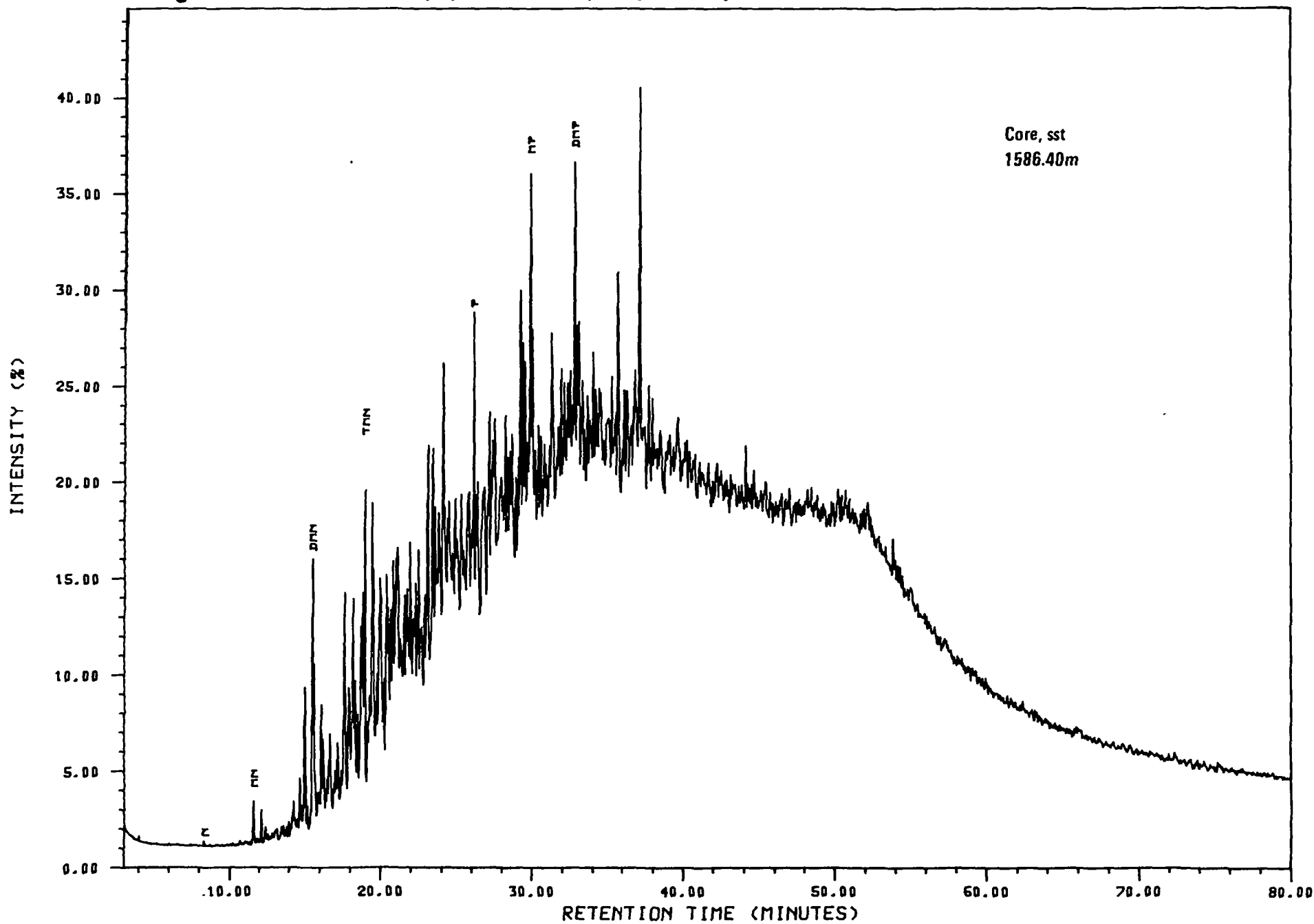
Analysis 74484684 4,1,1 B-4684,AR0,LH,31/3-2



Analysis 744B4685 4,1,1 B-4685,ARD,31/3-2,JA

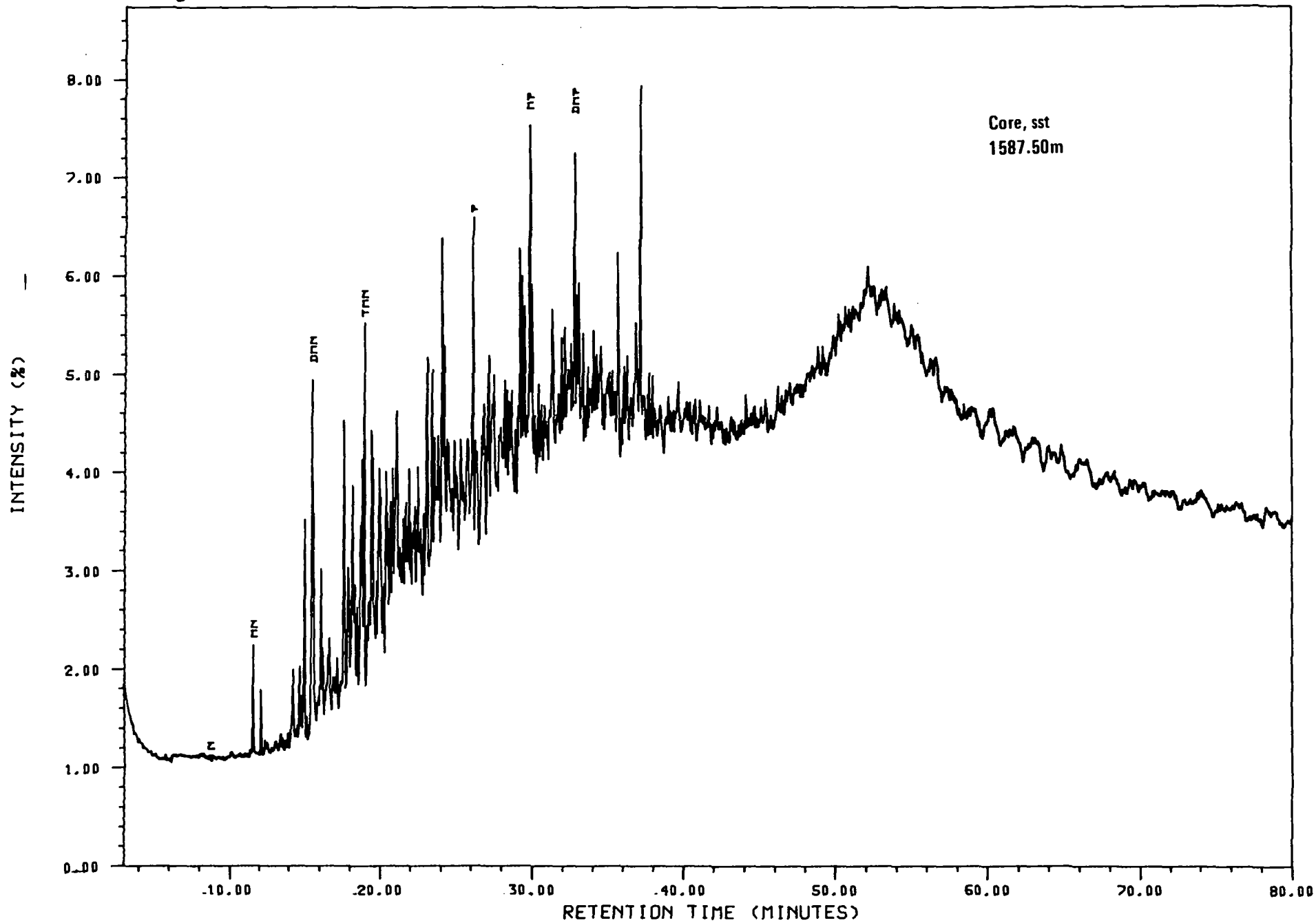


Analysis 744B4686A 4,1,1 B-4686,ARO,31/3-2,JA



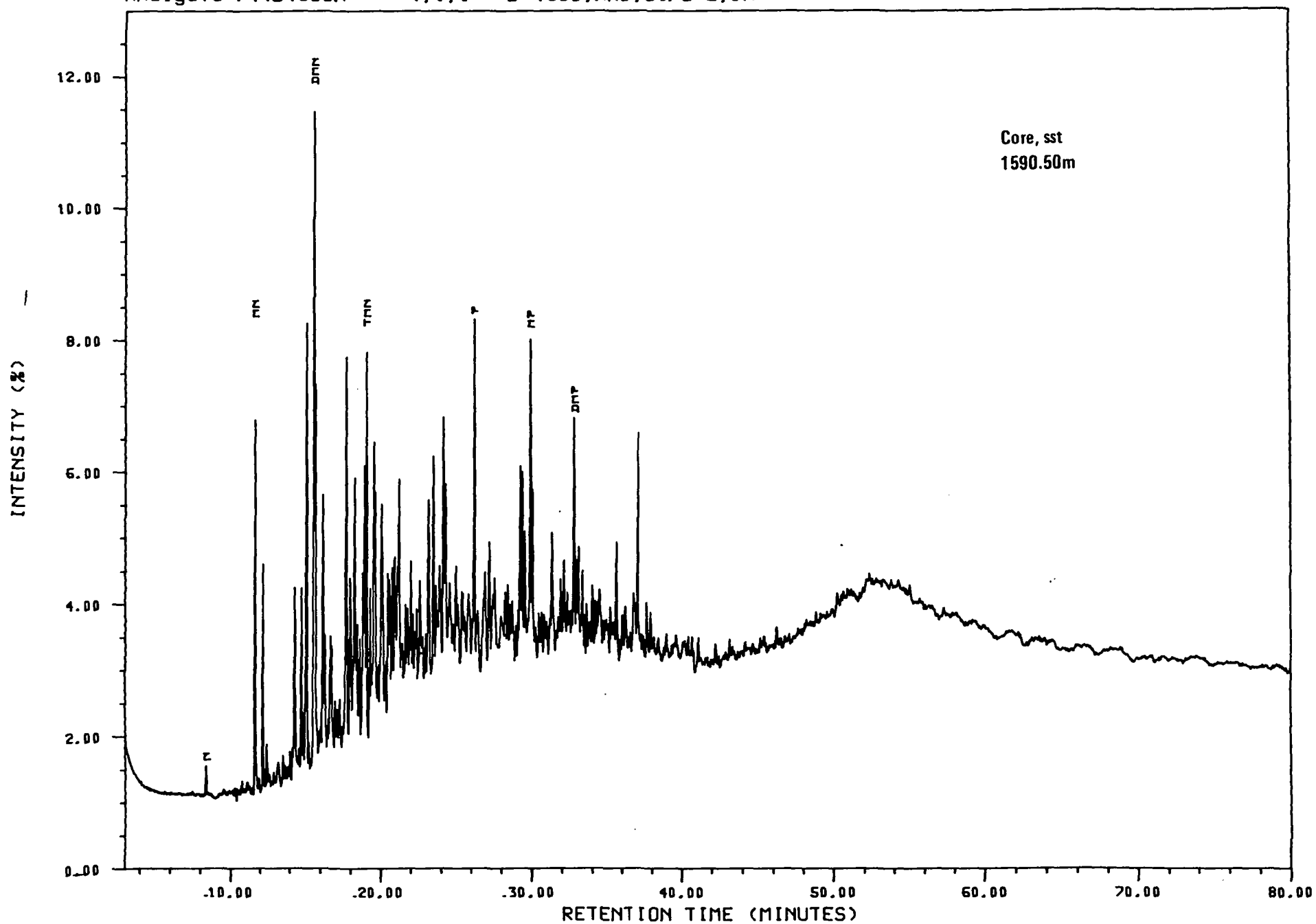
Core, sst
1586.40m

Analysis 744B4687A 4,1,1 B-4687,AR0,31/3-2,JA

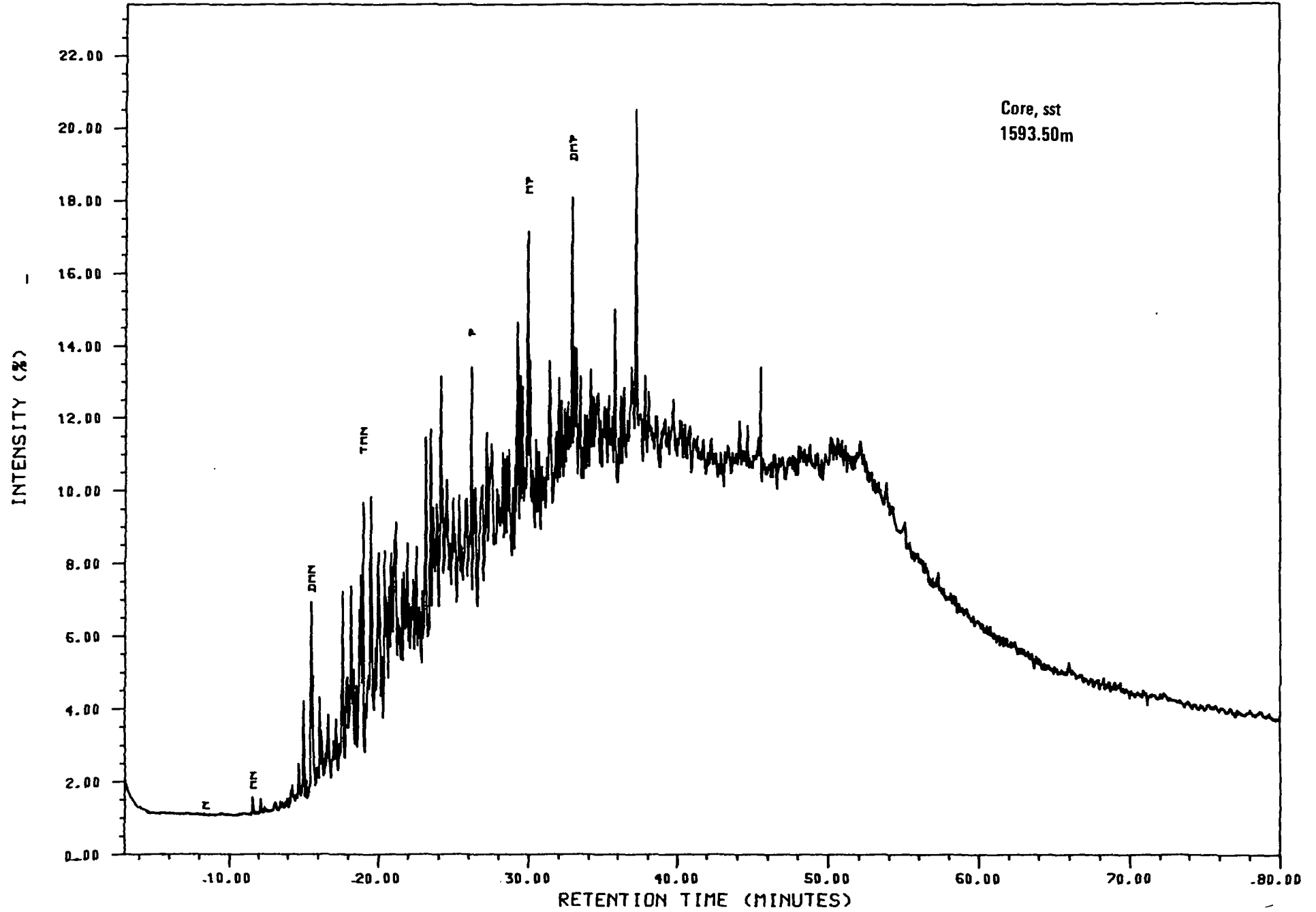


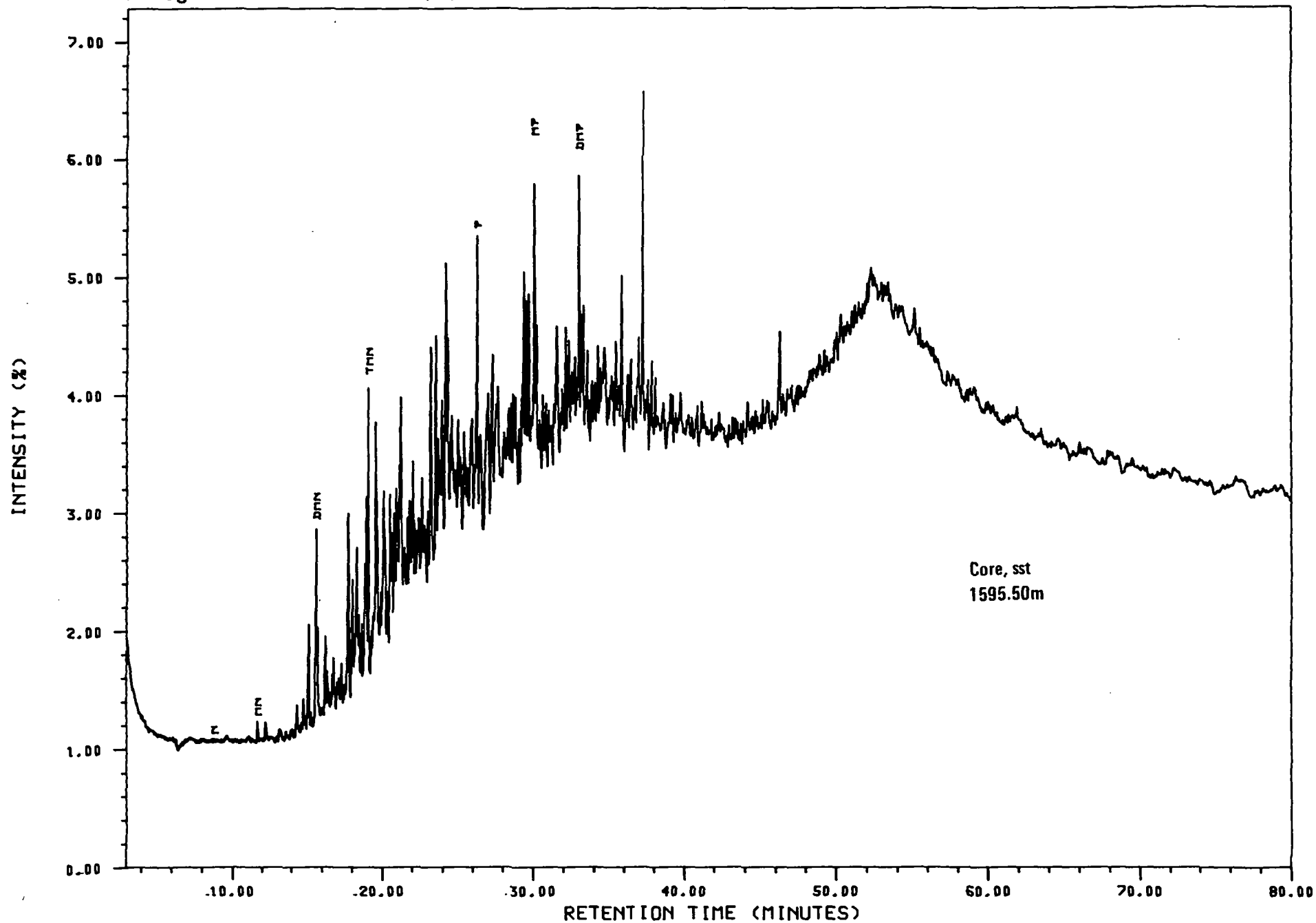
Core, sst
1587.50m

Analysis 744B4588A 4,1,1 B-4688,ARD,31/3-2,JA



Analysis 744B4689A 4,1,1 B-4689,ARO,31/3-2,JA





Core, sst
1595.50m

Analysis 744B4691A 4,1,1 B-4691,ARO,31/3-2,JA

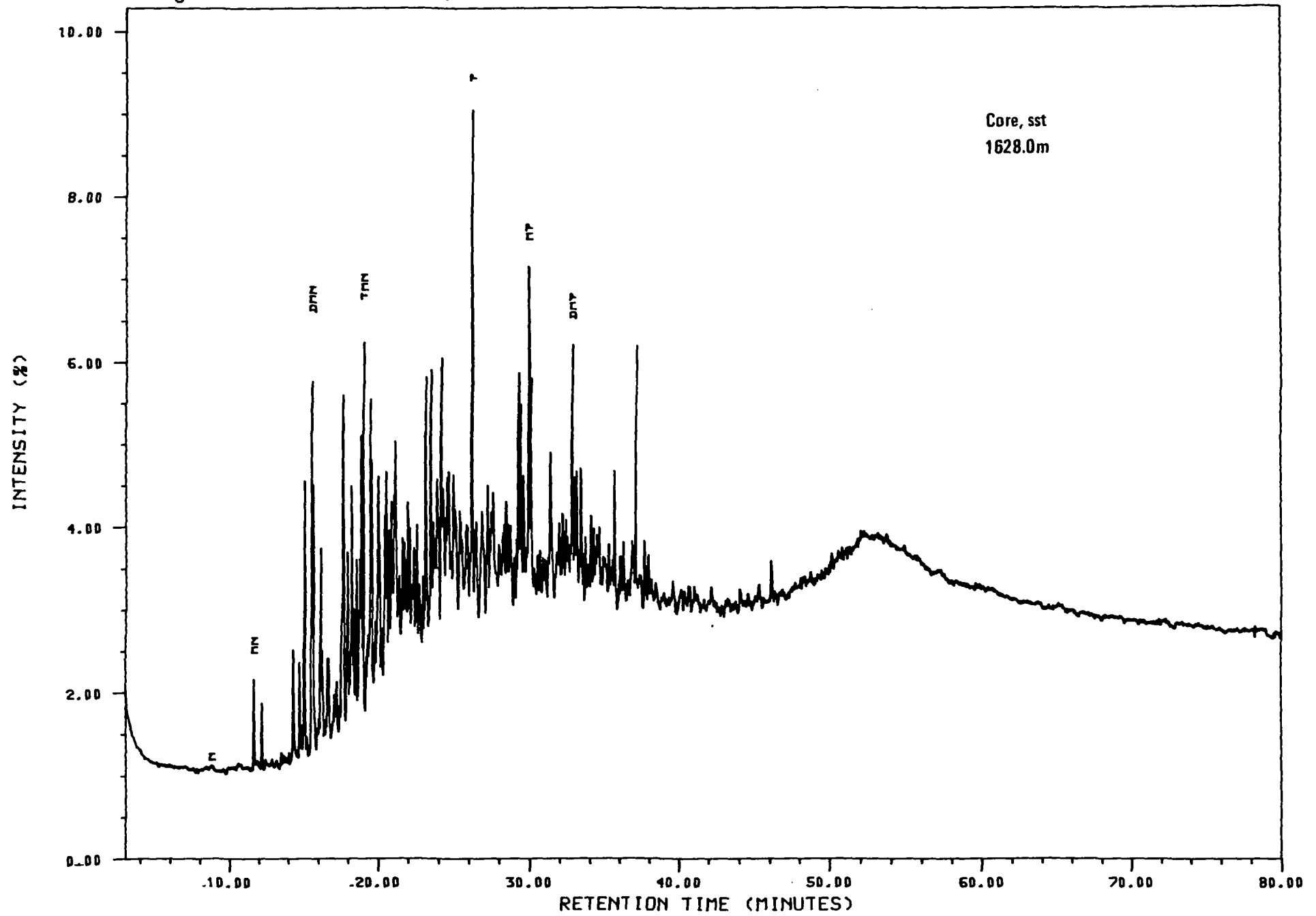
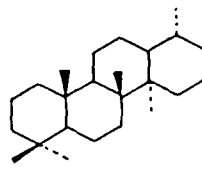
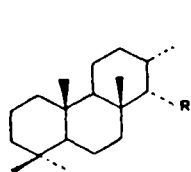
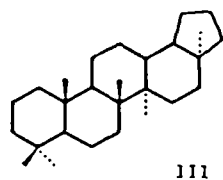
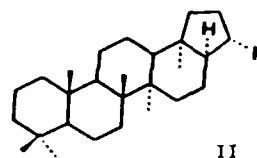
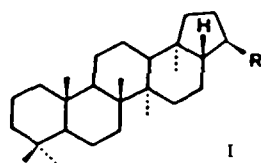
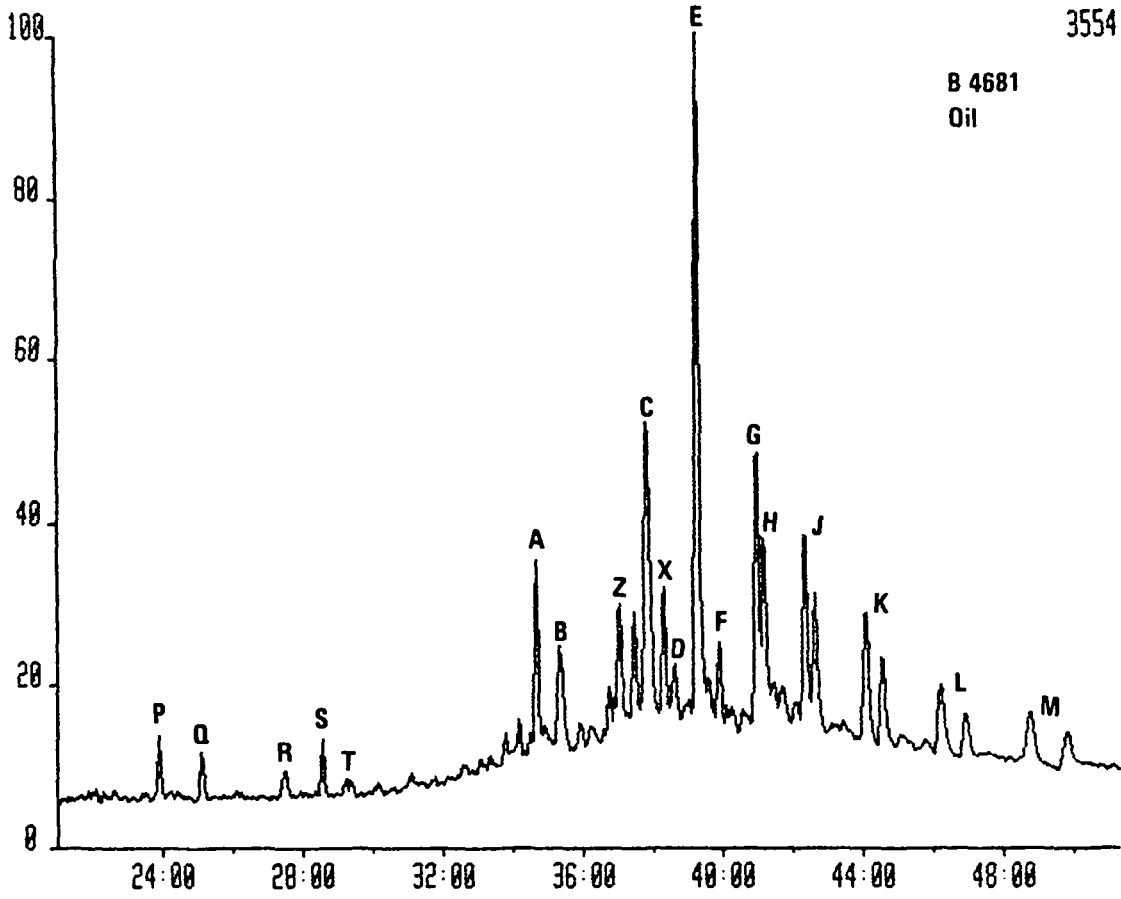


Figure 5

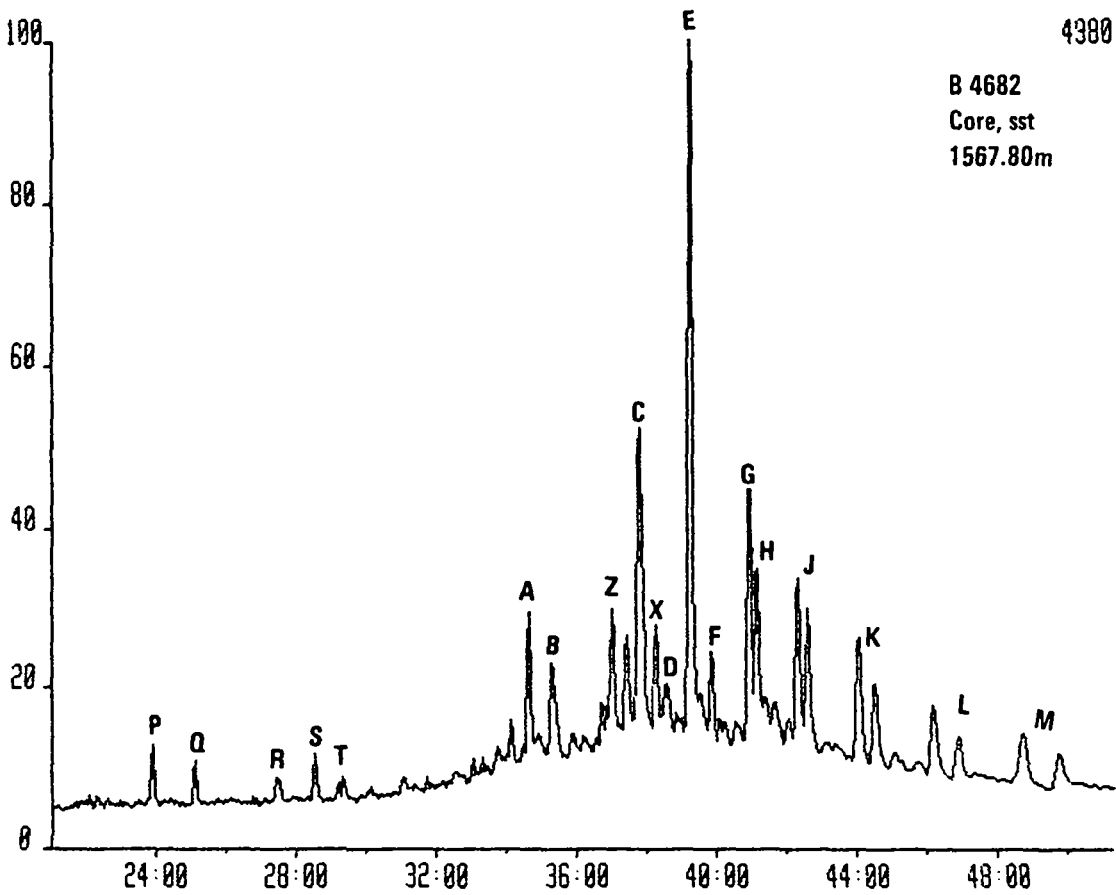
Mass chromatograms representing terpanes (m/z 191)

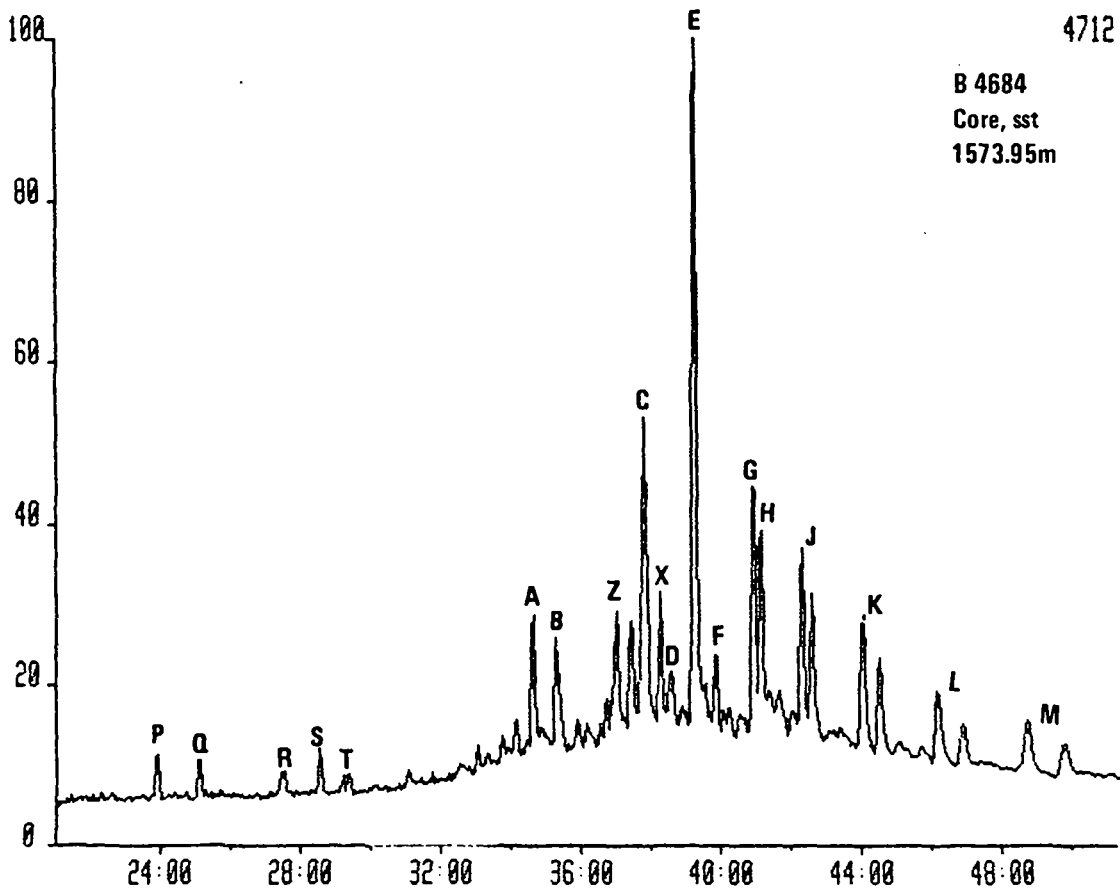
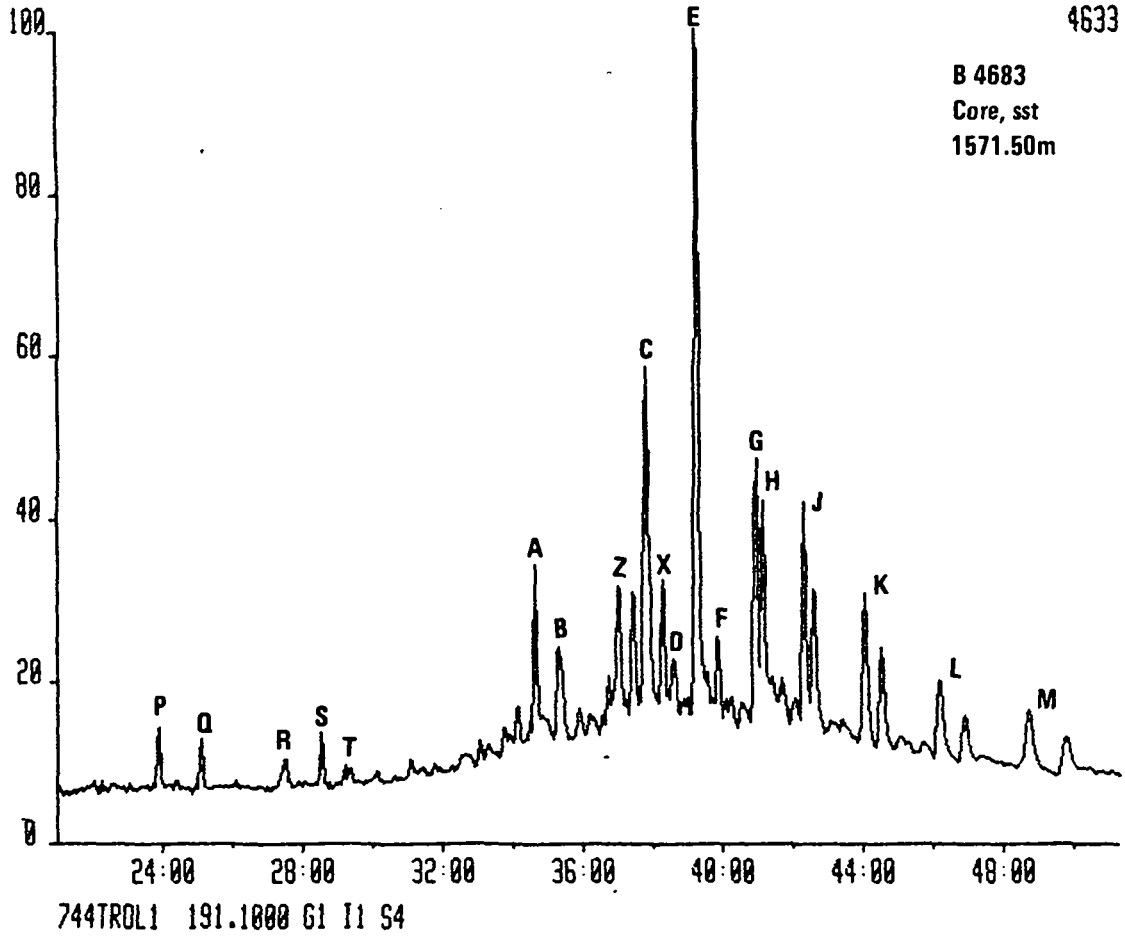
A	T _s , 18 α (H)-trisorneohopane	C ₂₇ H ₄₆	(III)
B	T _m , 17 α (H)-trisorhopane	C ₂₇ H ₄₆	(I, R=H)
C	17 α (H)-norhopane	C ₂₉ H ₅₀	(I, R=C ₂ H ₅)
D	17 β (H)-normoretane	C ₂₉ H ₅₀	(II, R=C ₂ H ₅)
E	17 α (H)-hopane	C ₃₀ H ₅₂	(I, R=C ₃ H ₇)
F	17 β (H)-moretane	C ₃₀ H ₅₂	(II, R=C ₃ H ₇)
G	17 α (H)-homohopane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

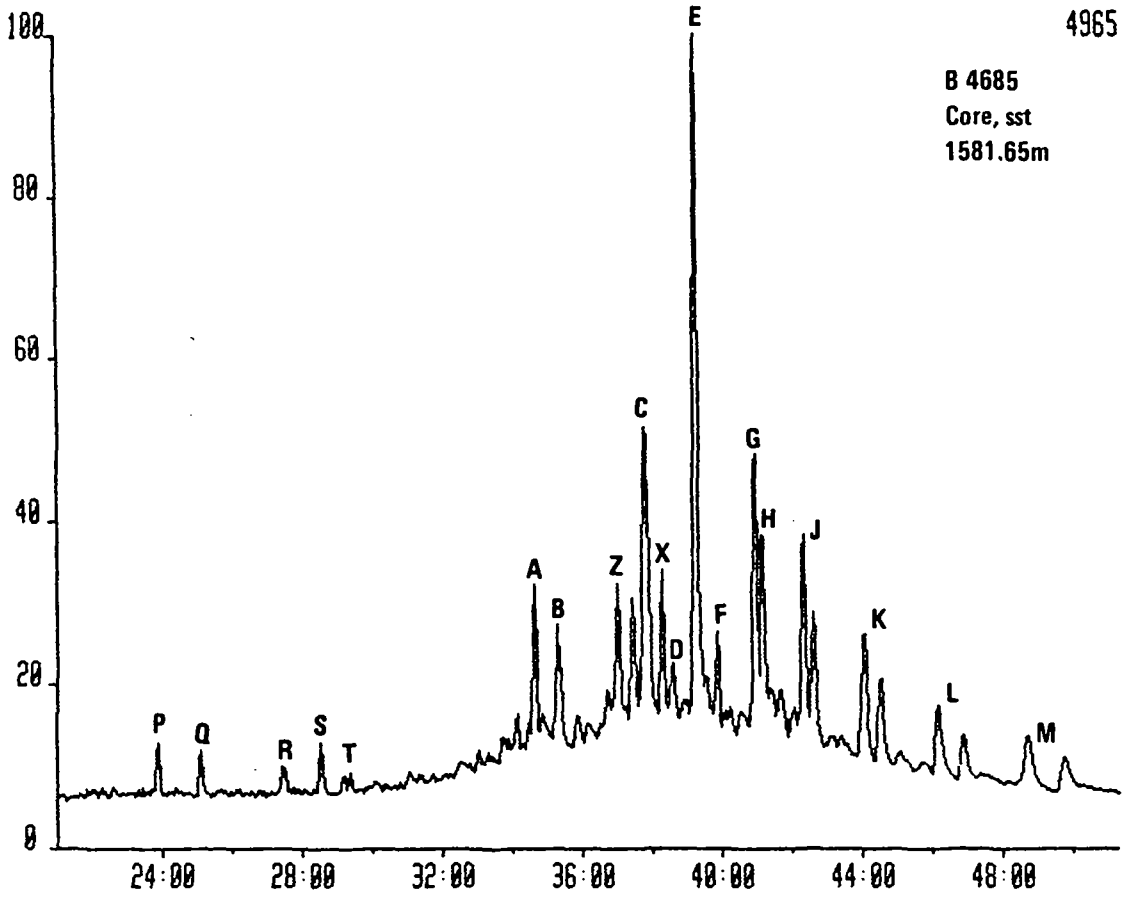




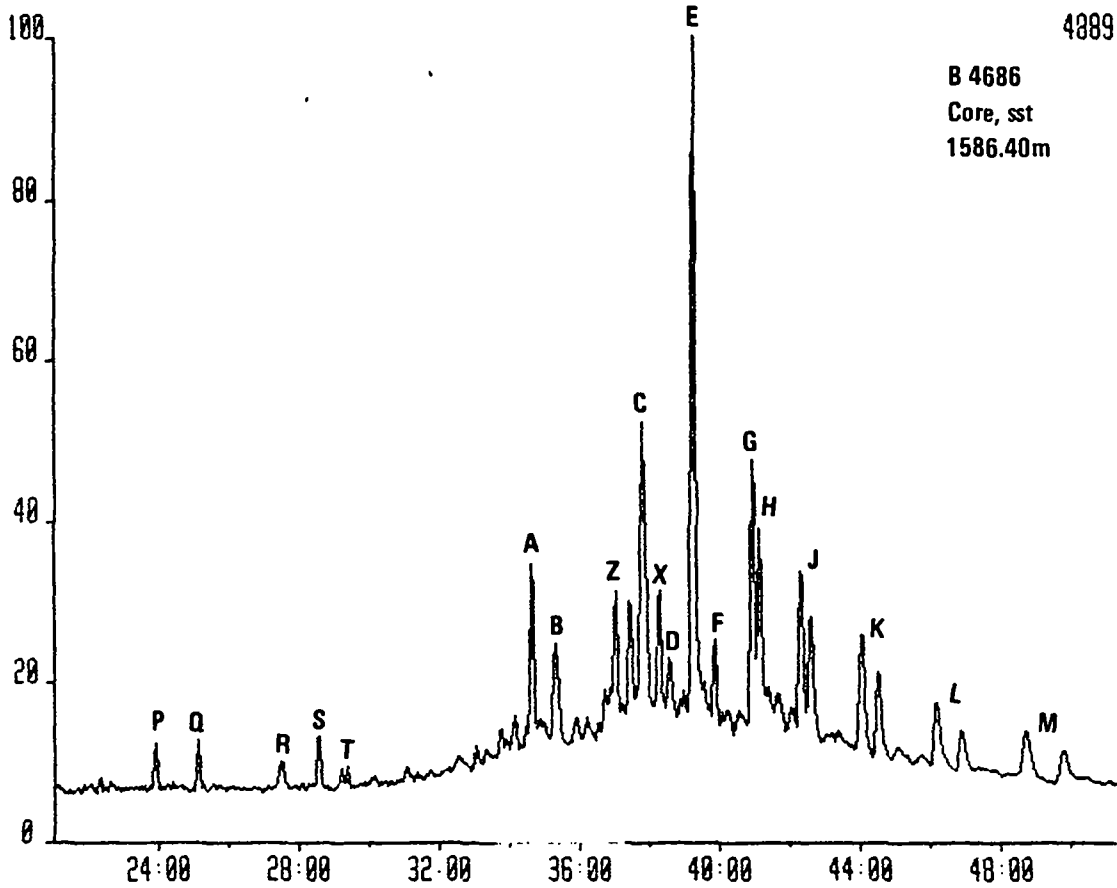
744TROL1 191.1000 G1 I1 S2

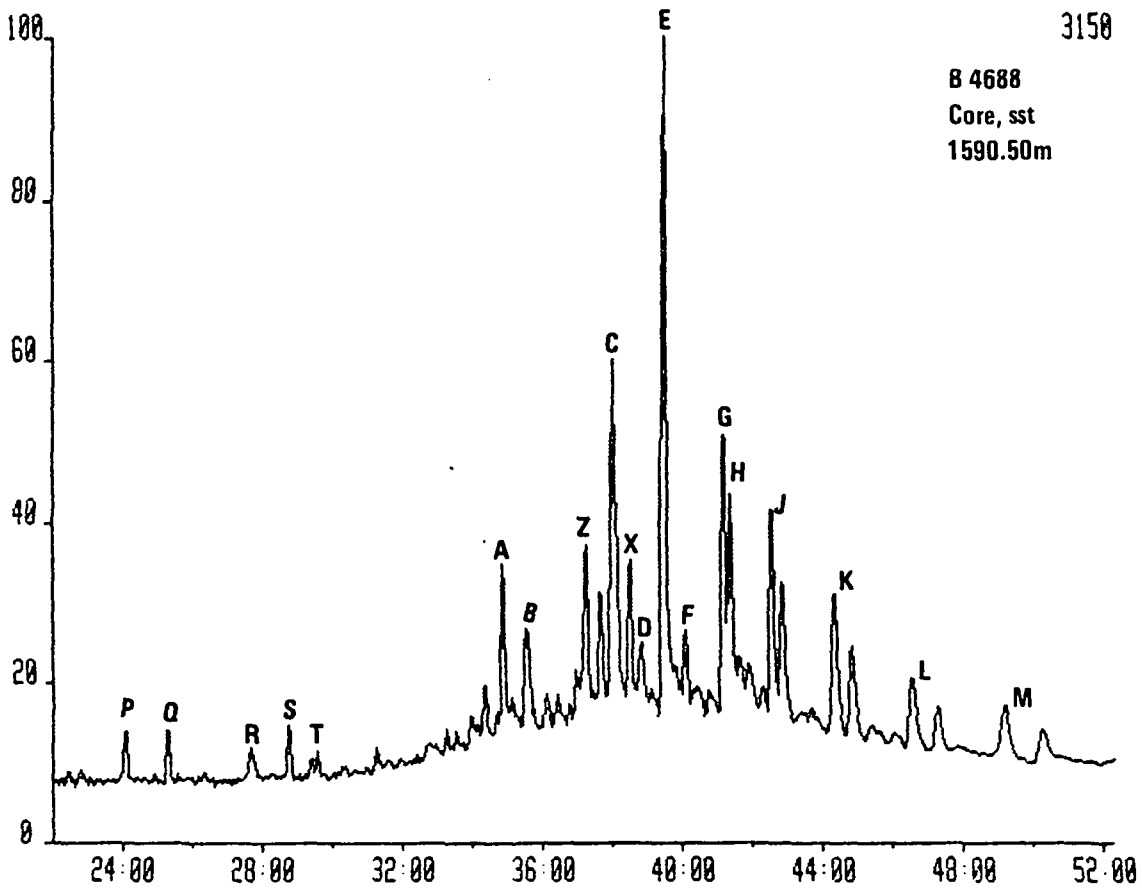
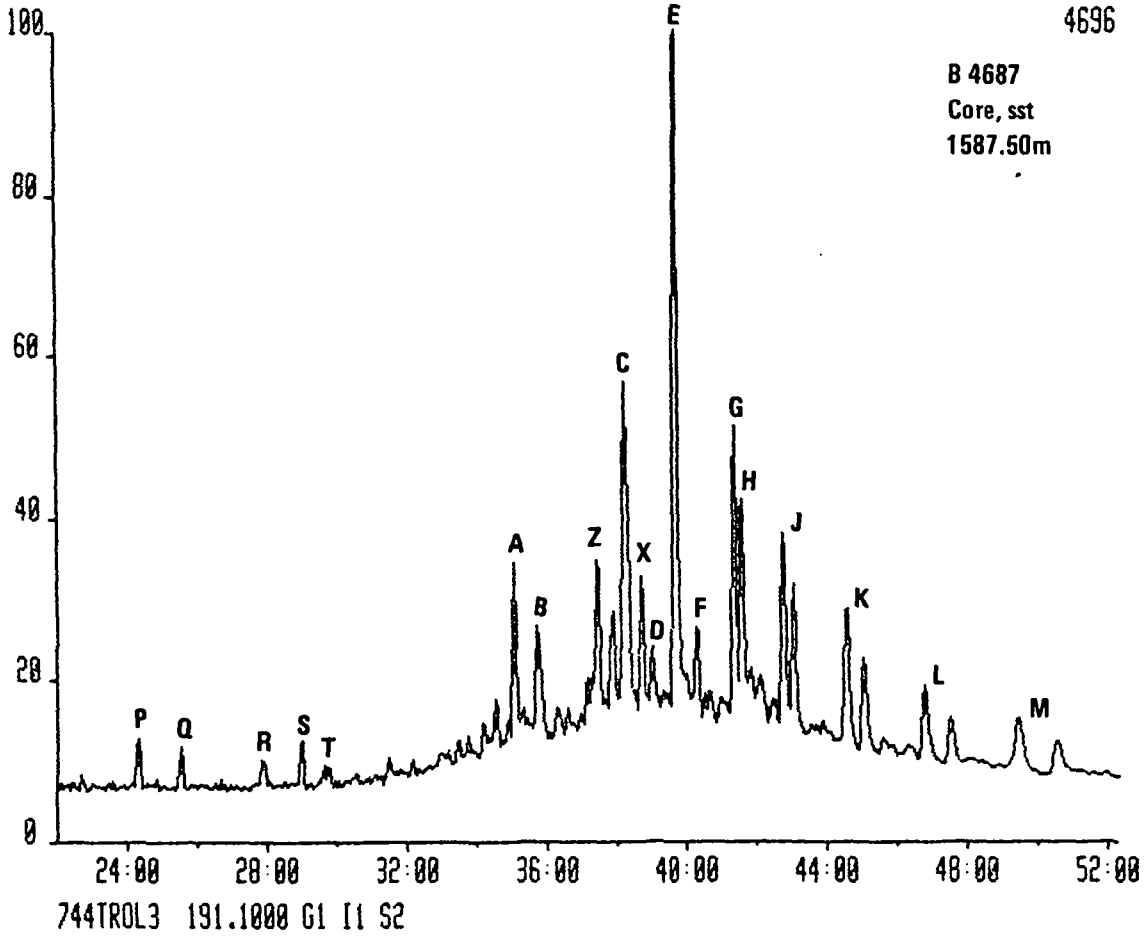


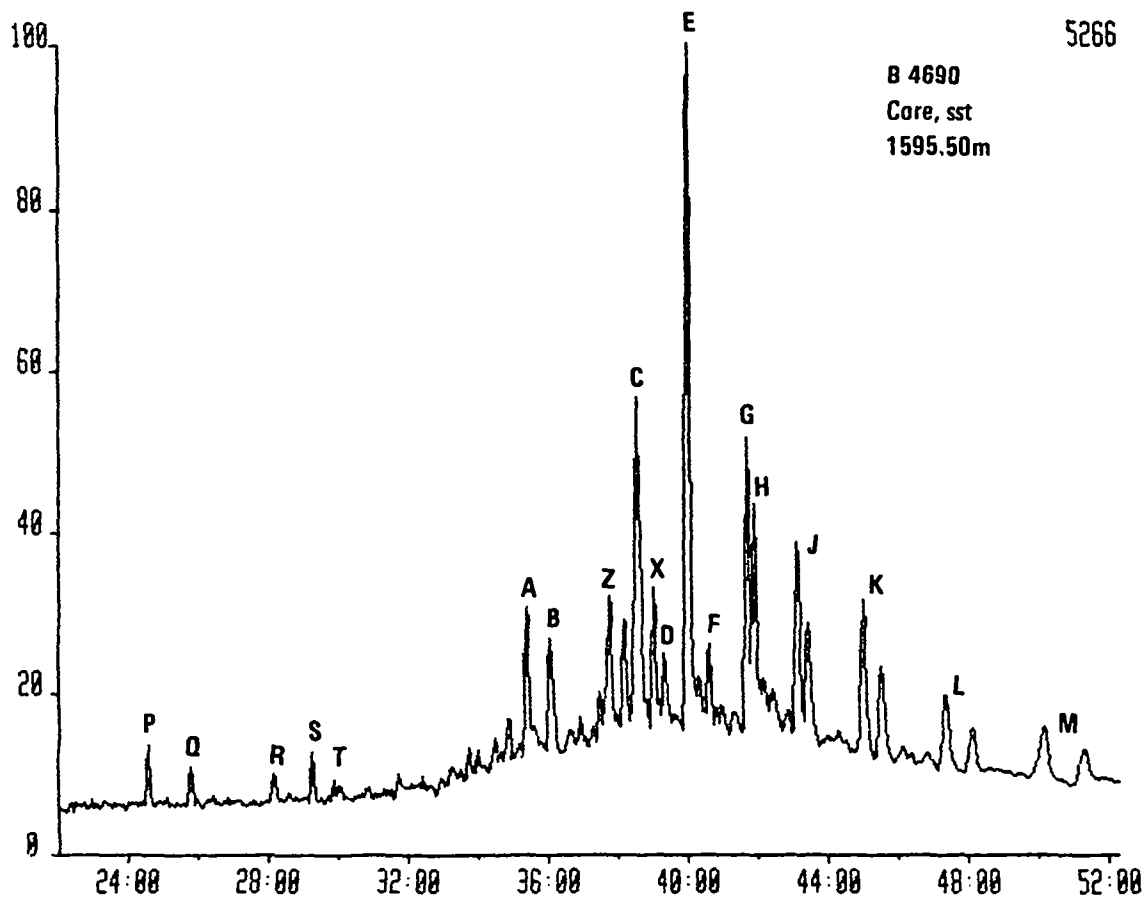
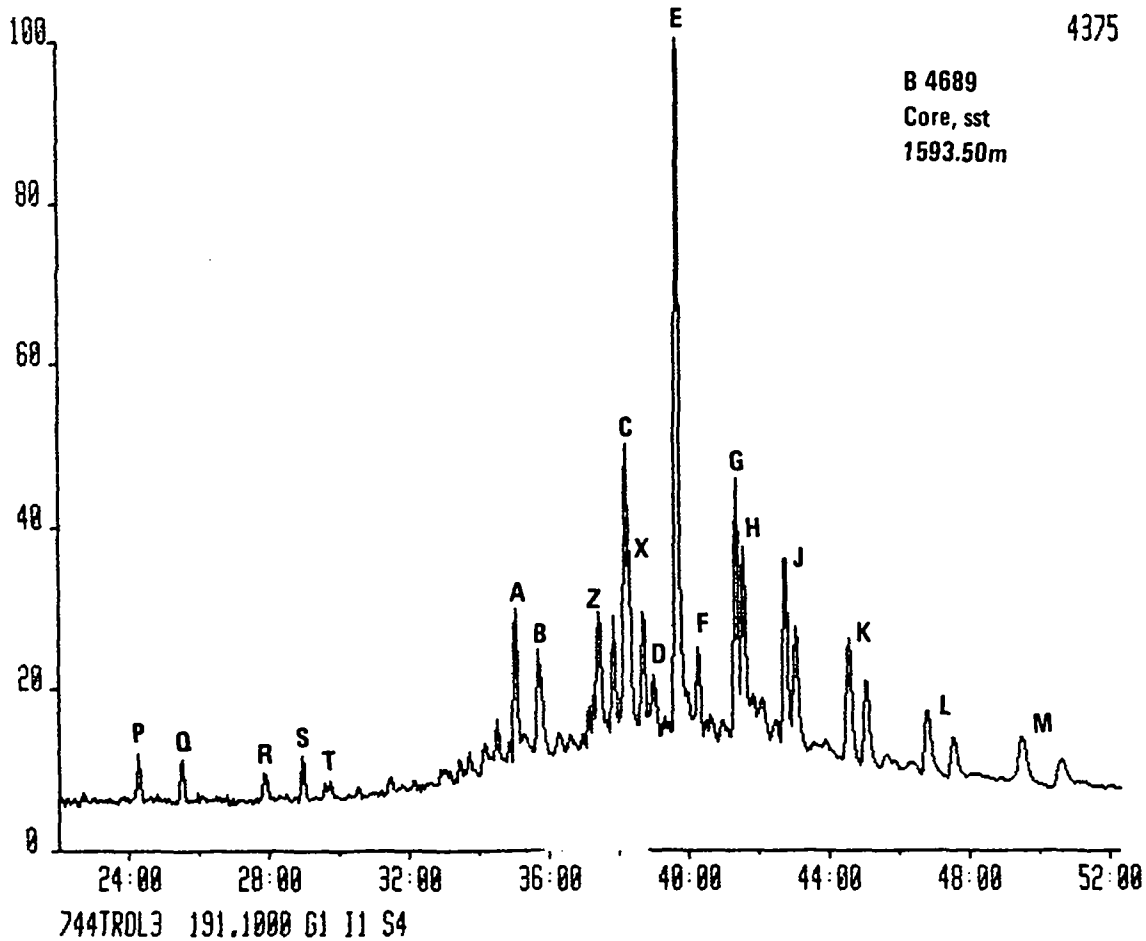




744TROL2 191.1000 G1 I1 S2







20098

B 4691
Core, sst
1628.0m

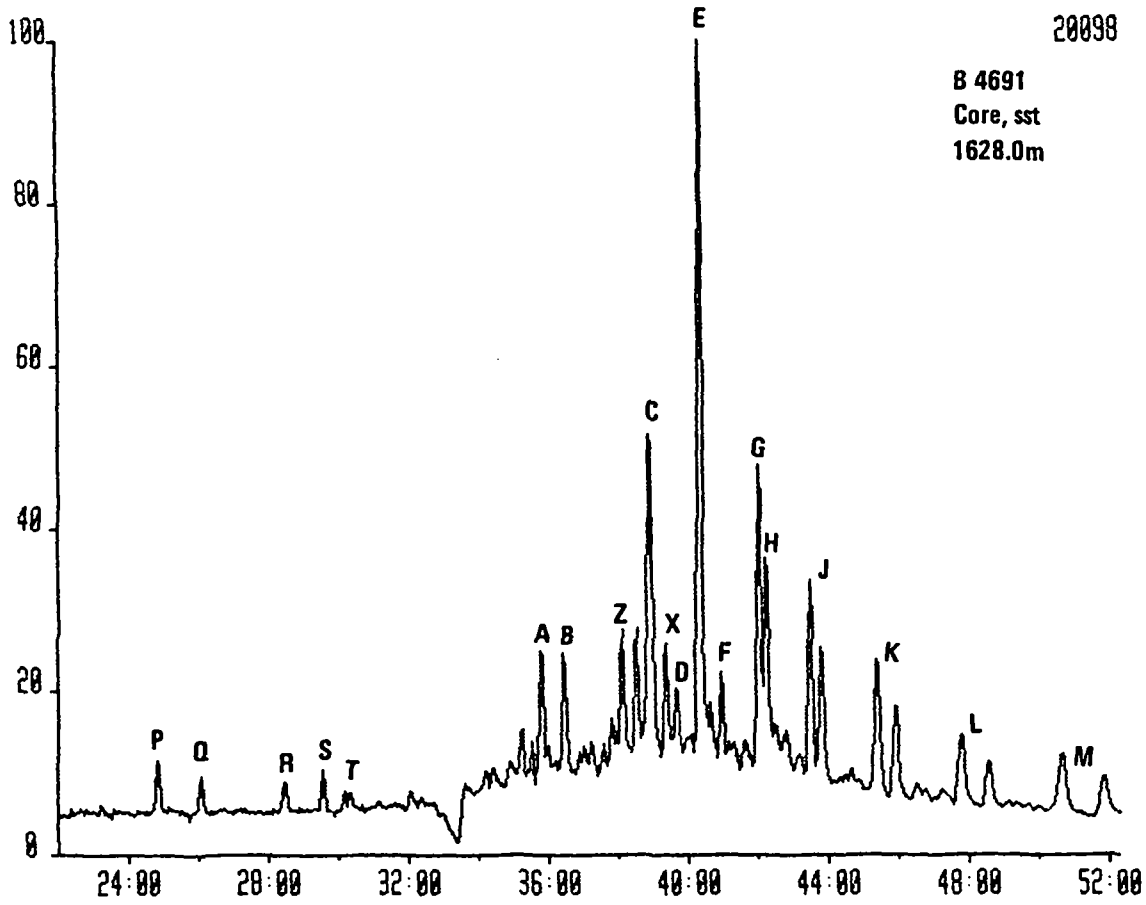
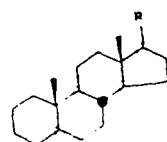
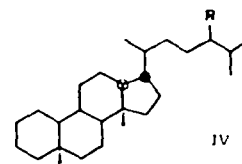
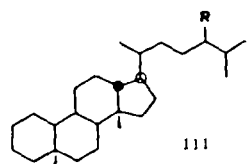
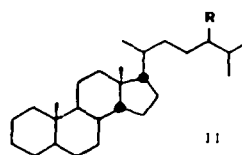
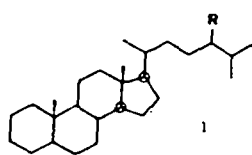


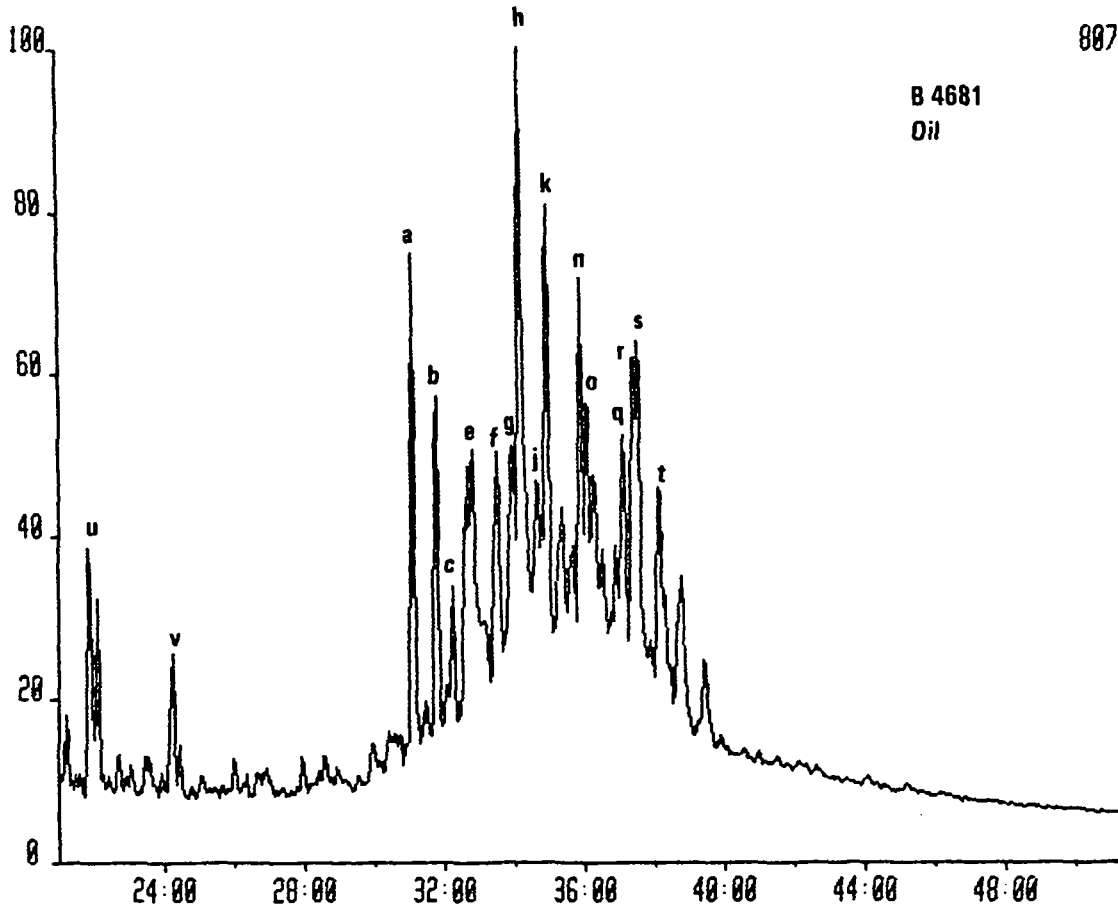
Figure 5

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

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



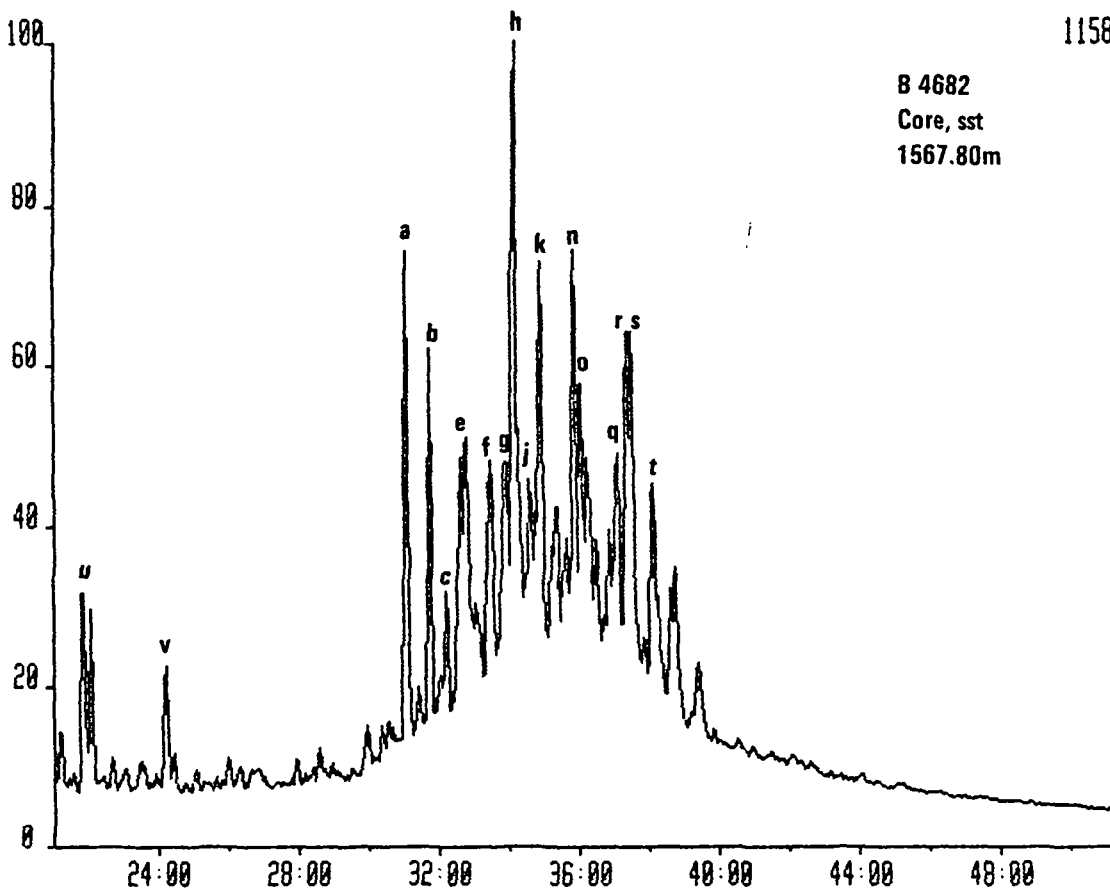
887



B 4681
Oil

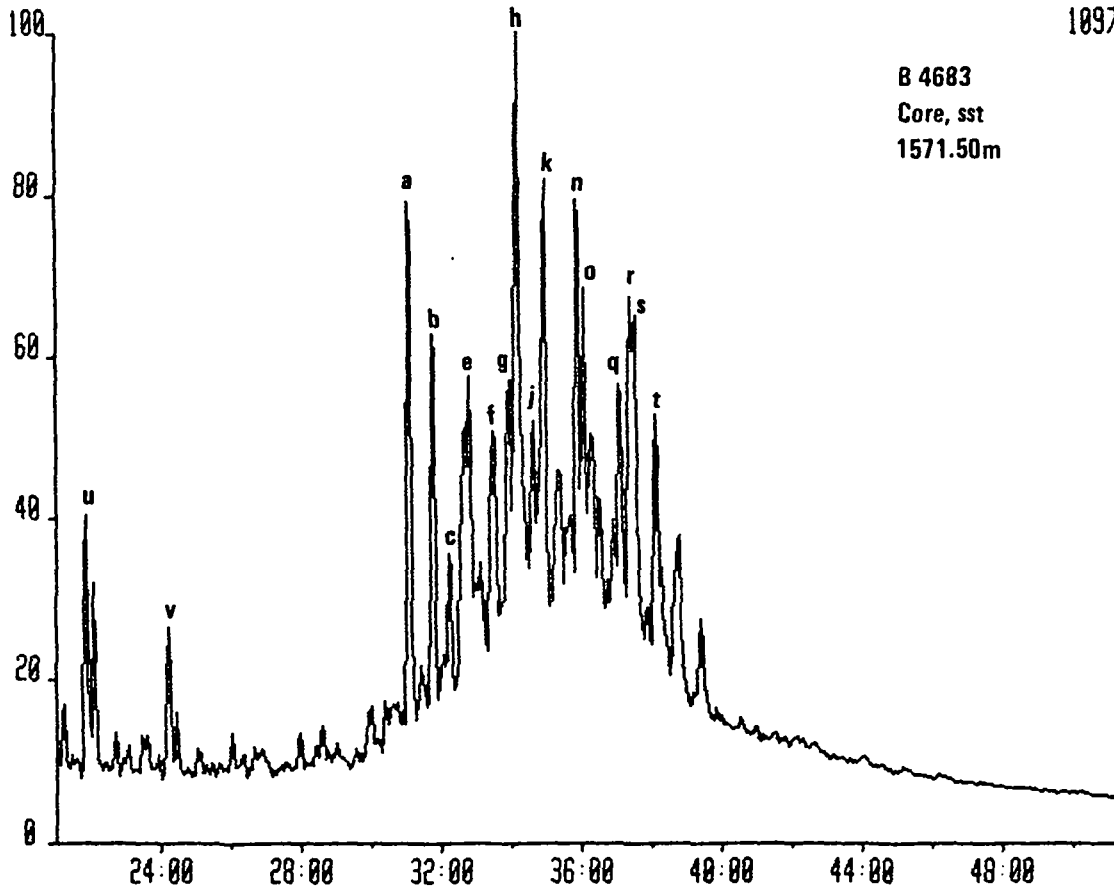
744TROL1 217.1000 G1 I1 S2

1158



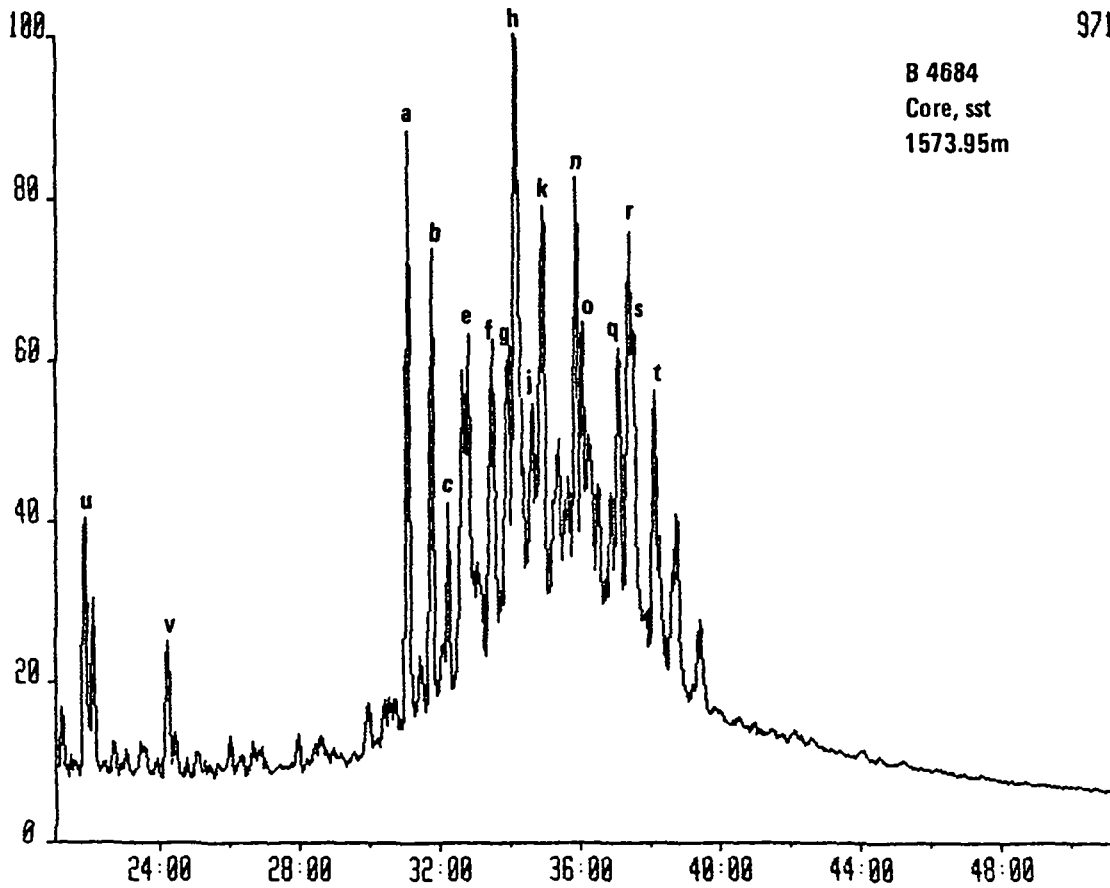
B 4682
Core, sst
1567.80m

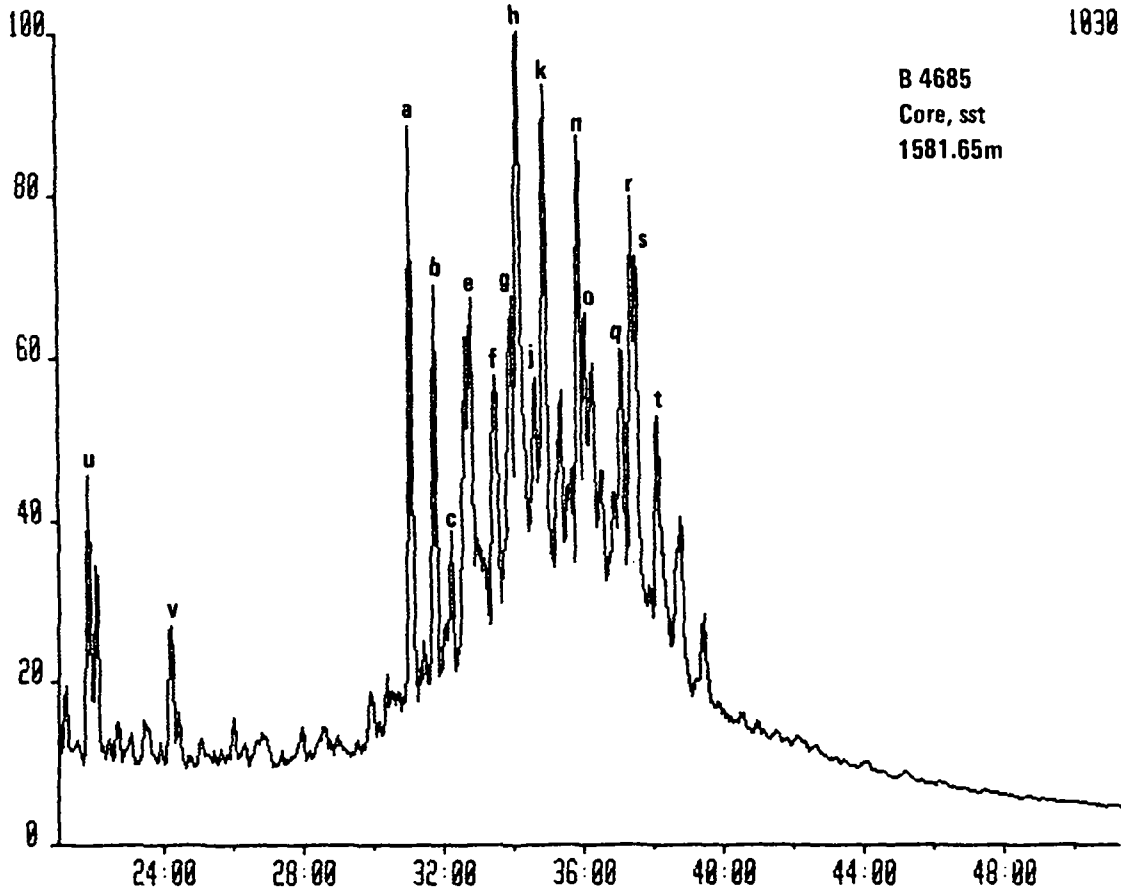
1097



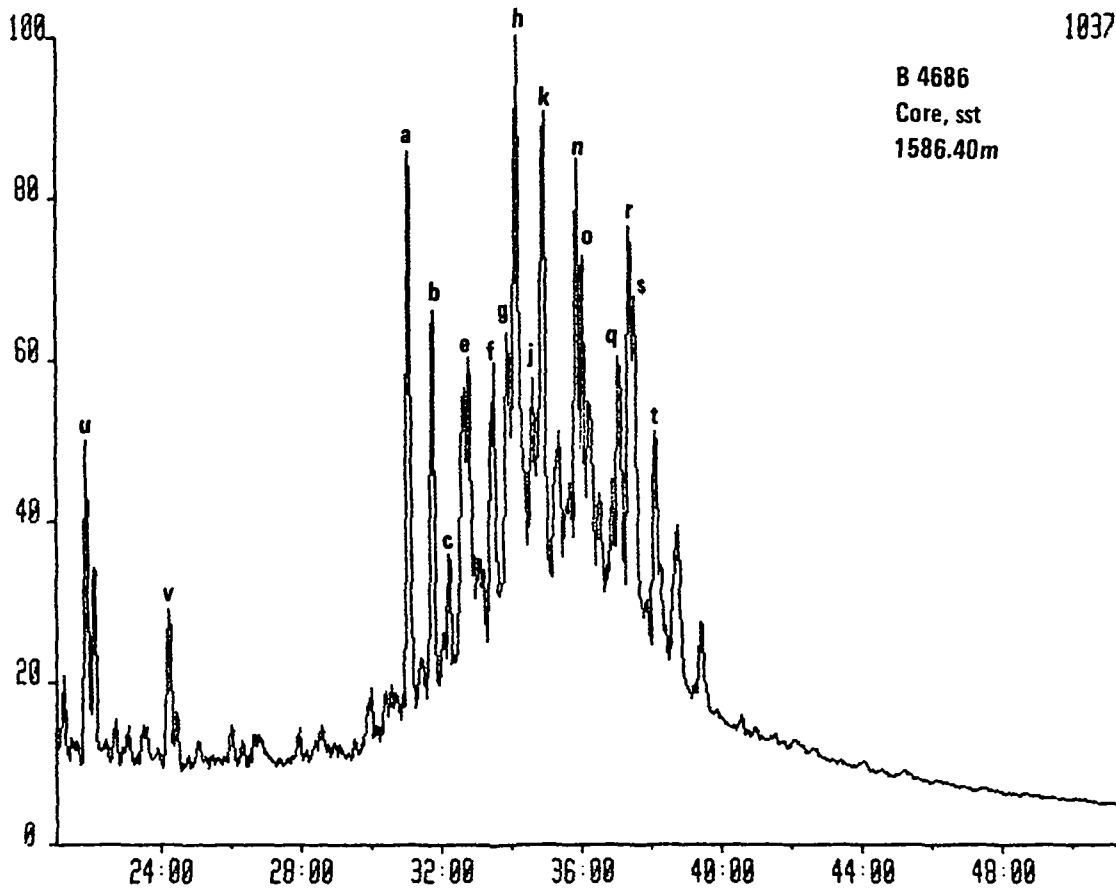
744TROL1 217.1000 G1 I1 S4

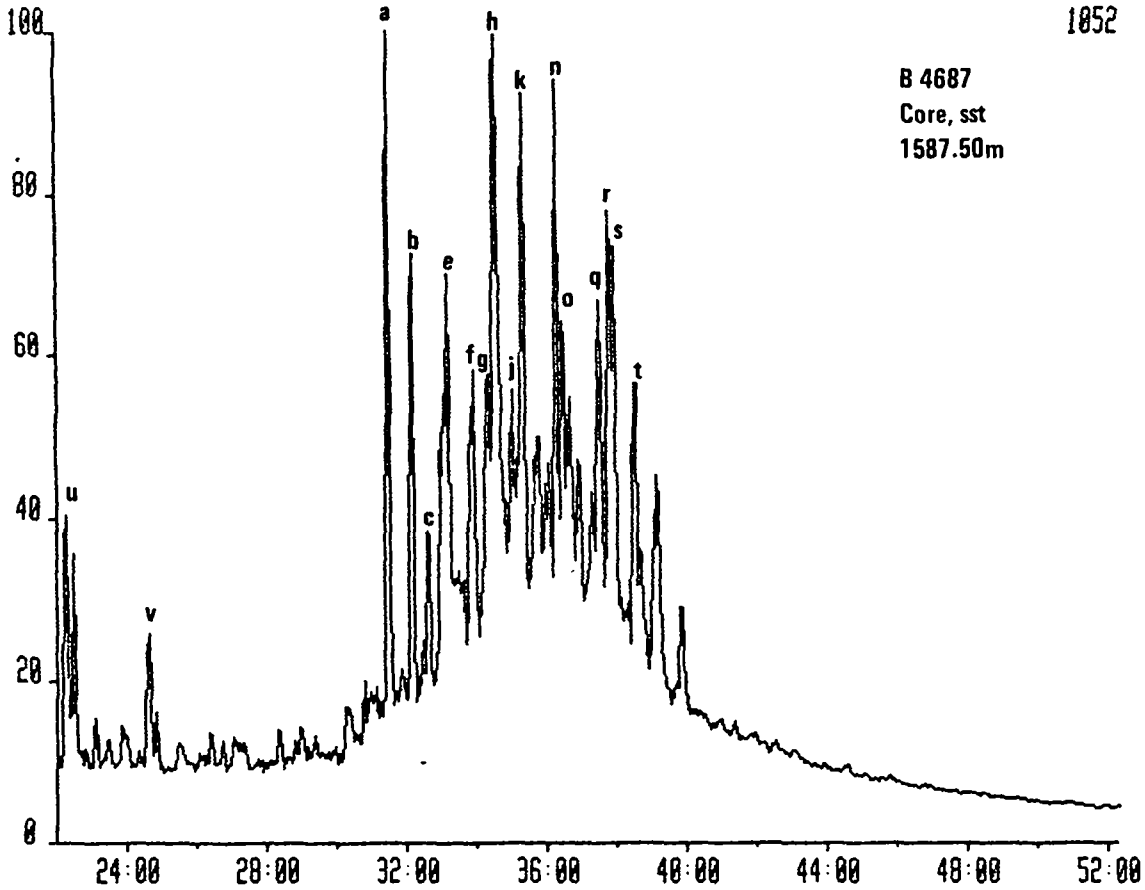
971



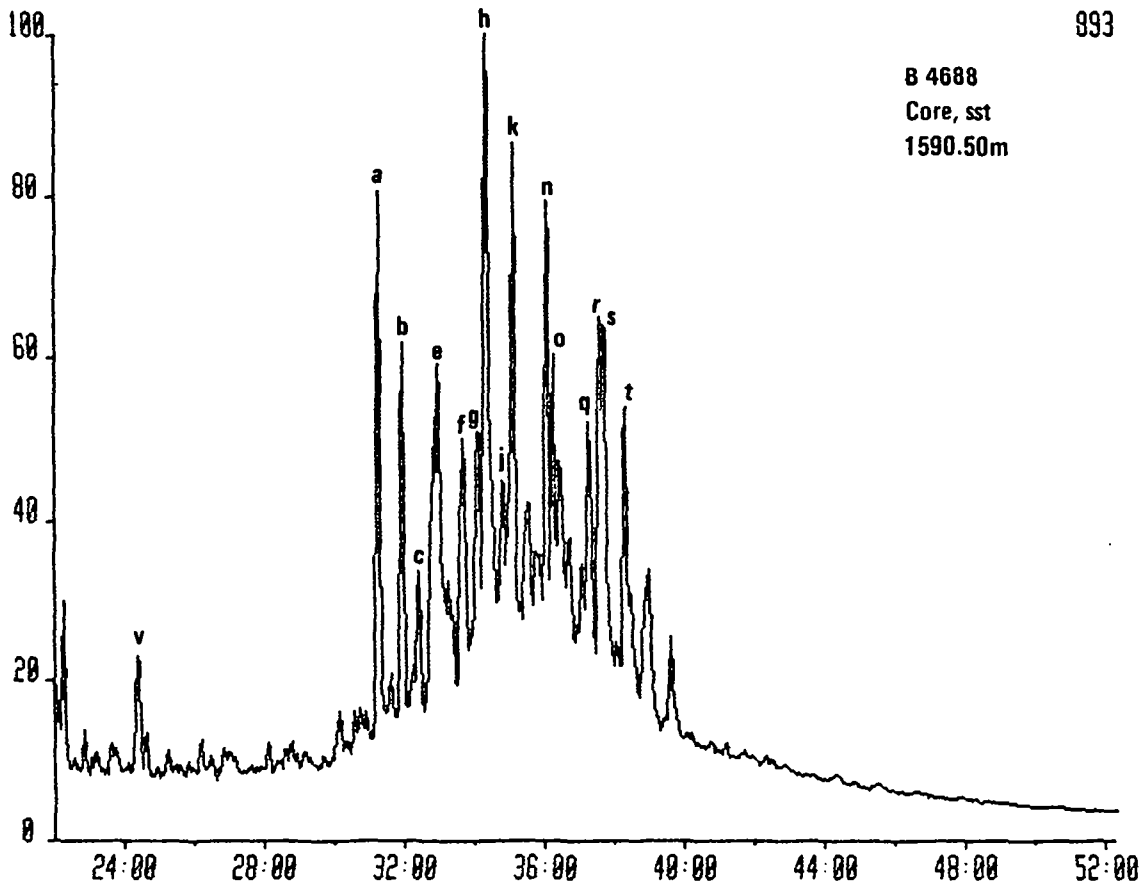


744TROL2 217.1000 G1 I1 S2

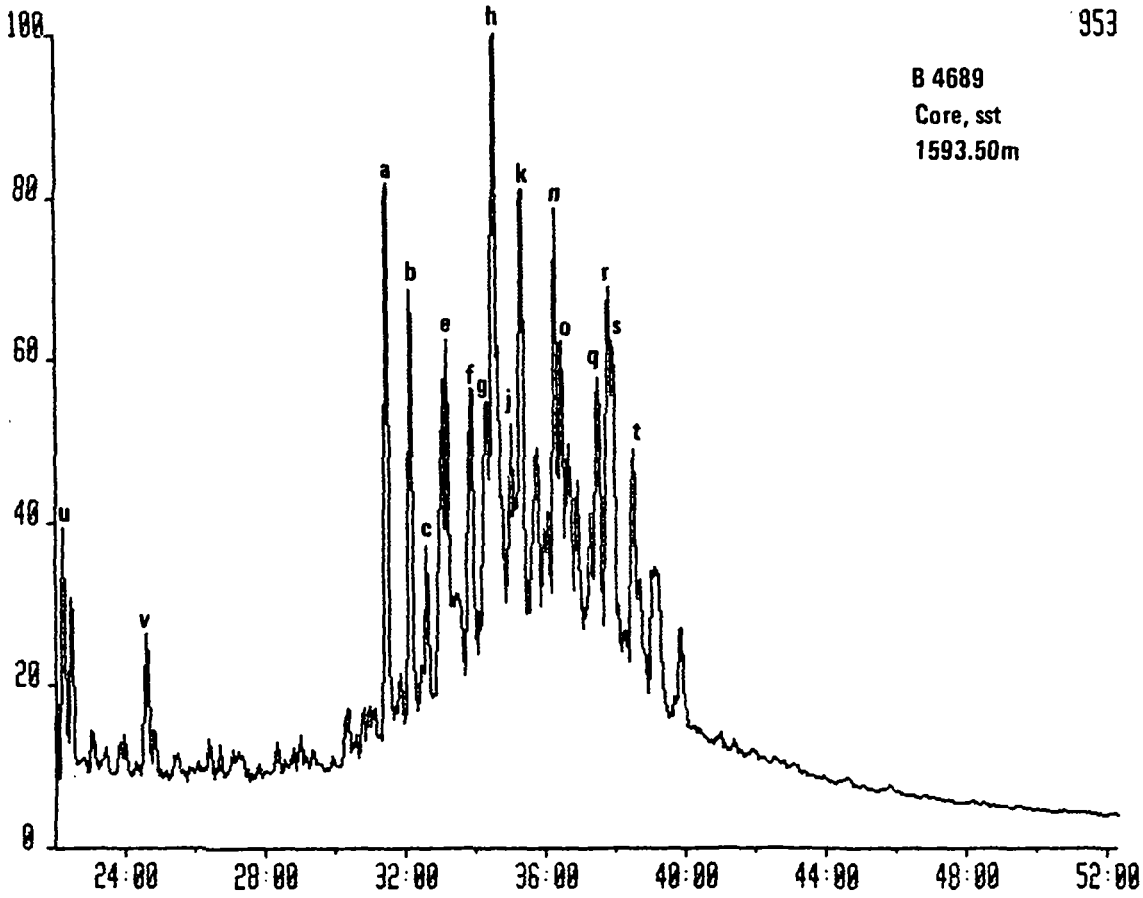




744TROL3 217.1000 G1 I1 S2

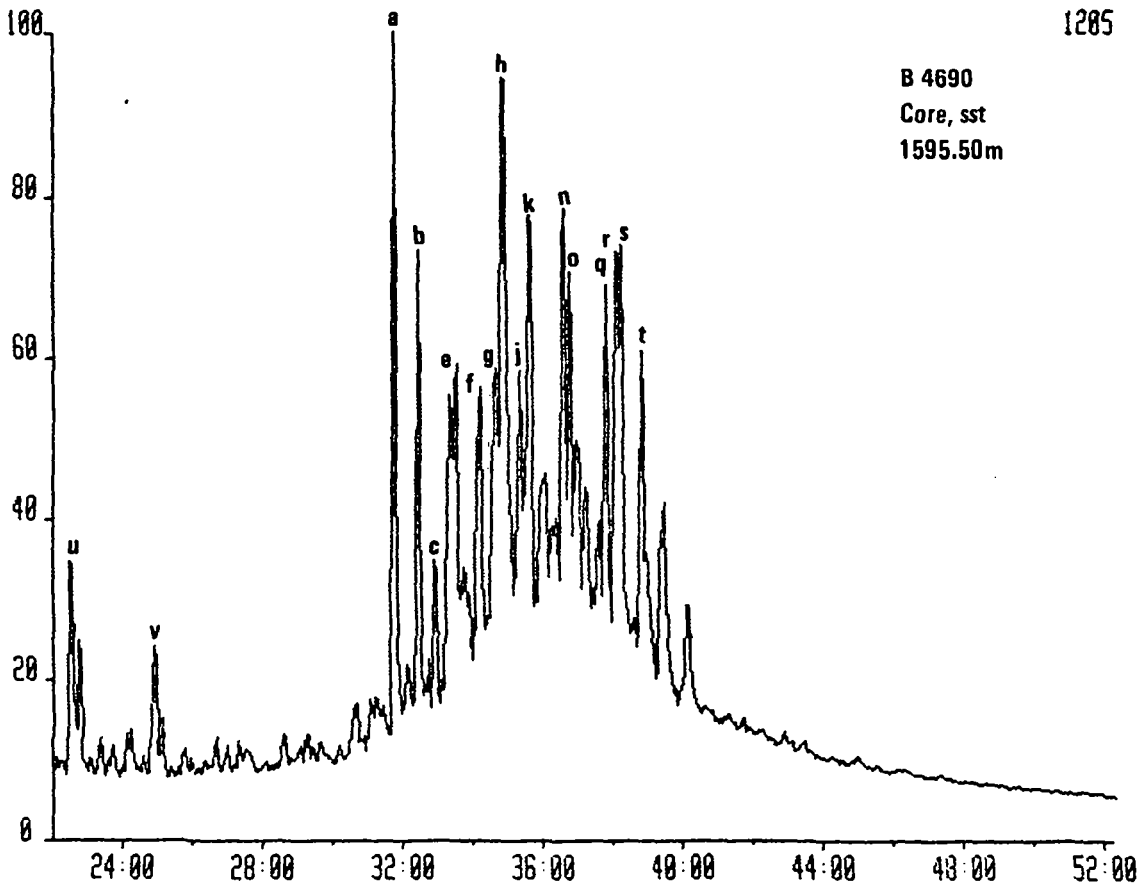


953



B 4689
Core, sst
1593.50m

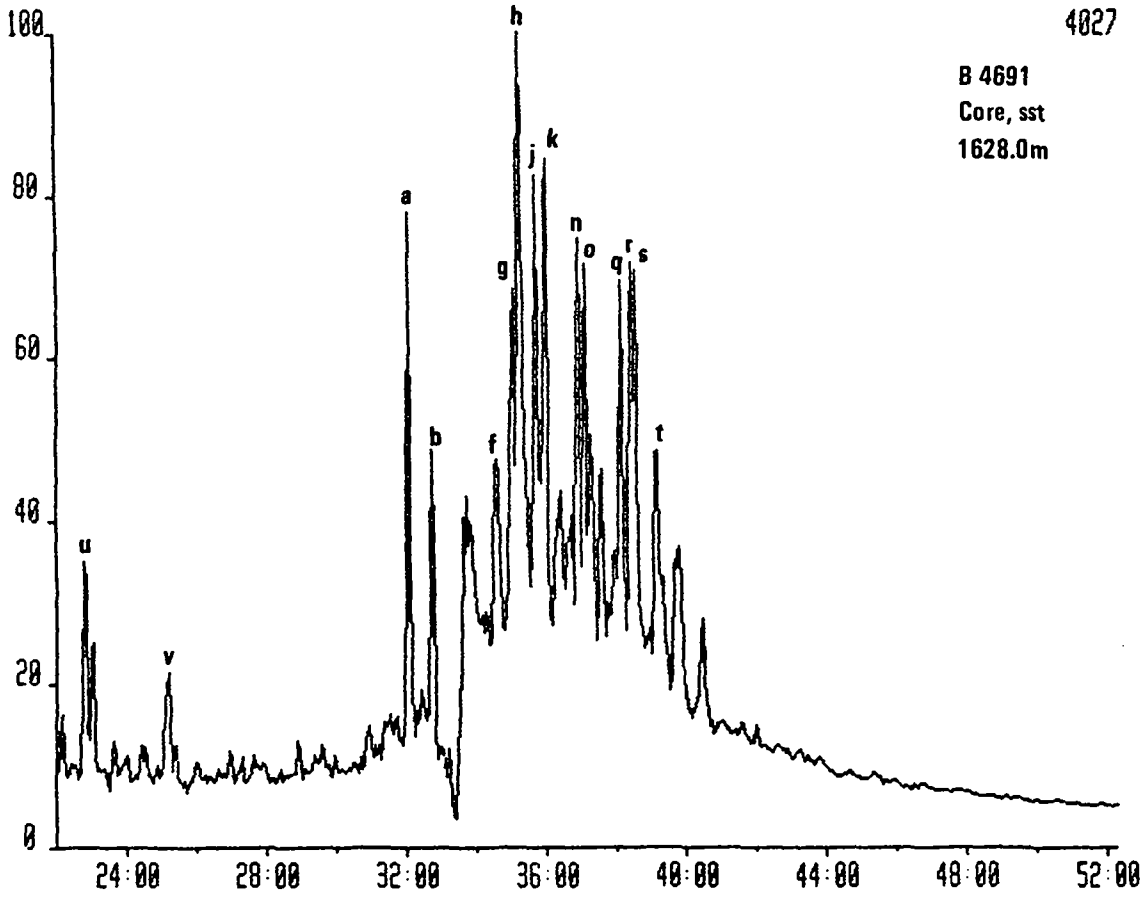
1285

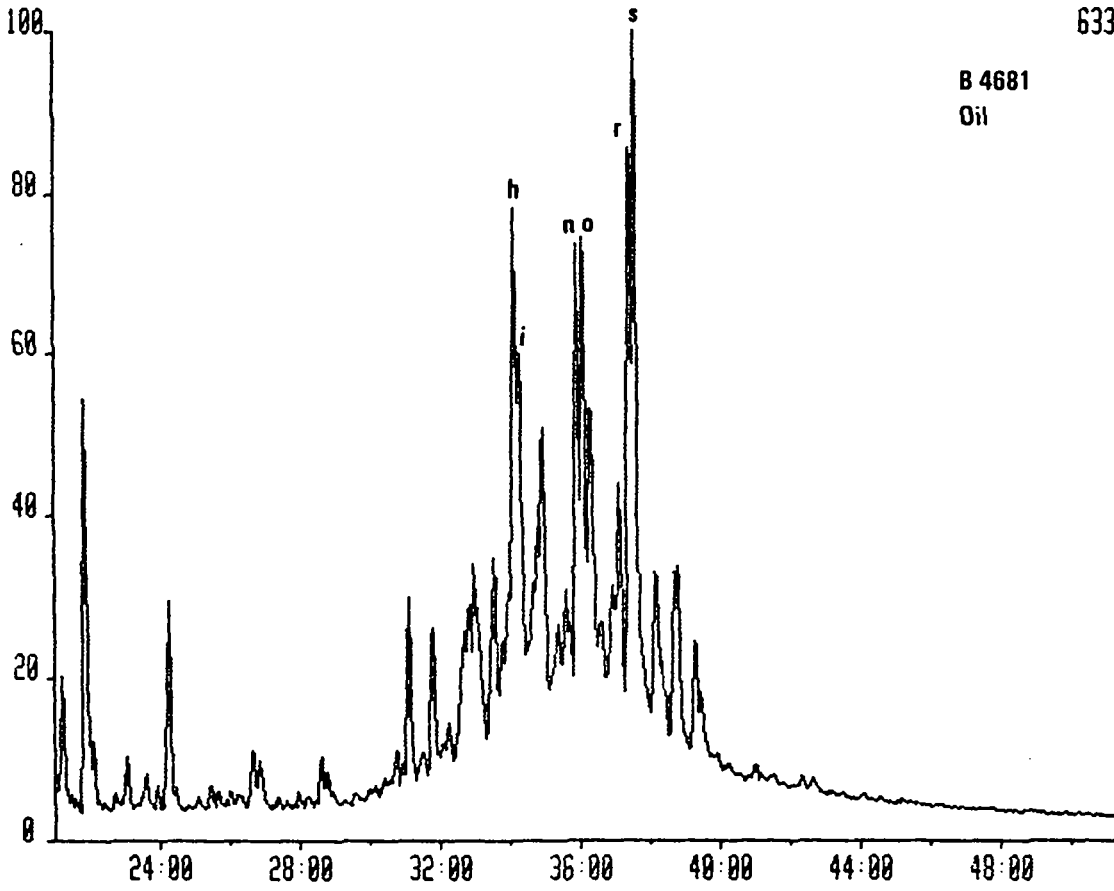


B 4690
Core, sst
1595.50m

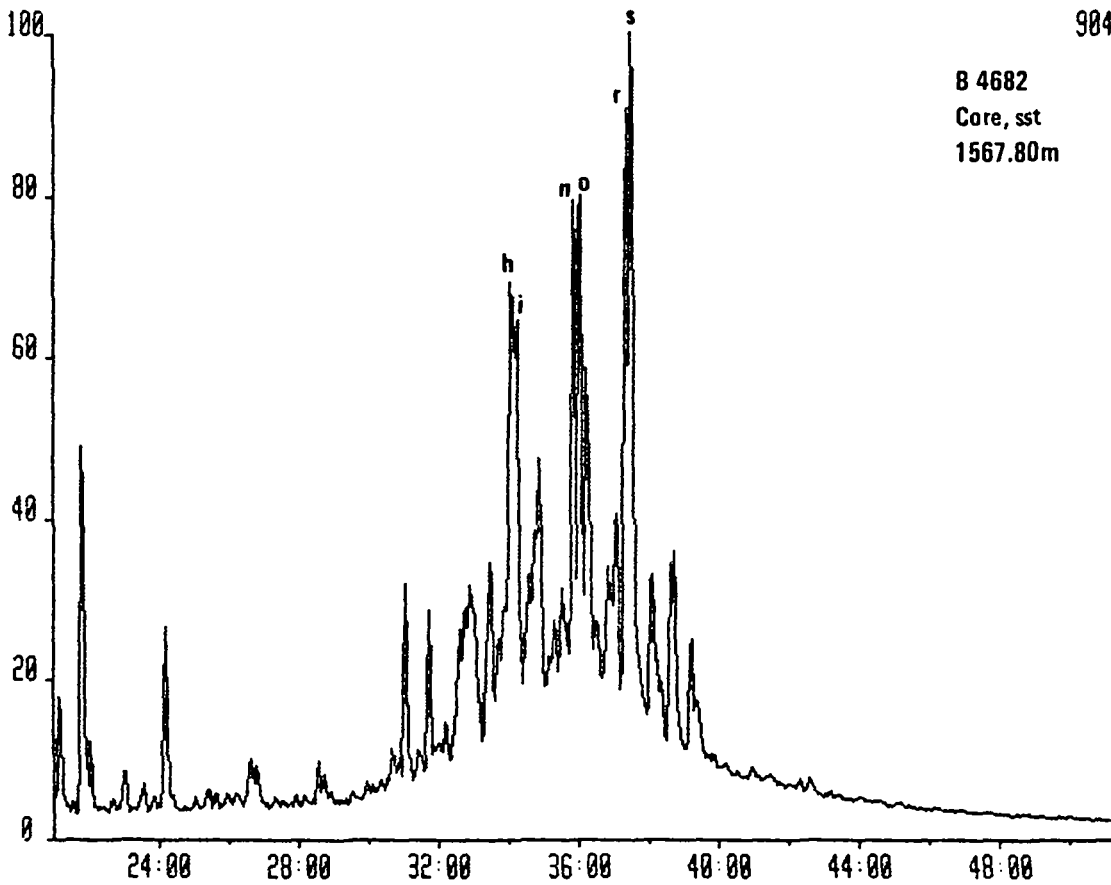
4027

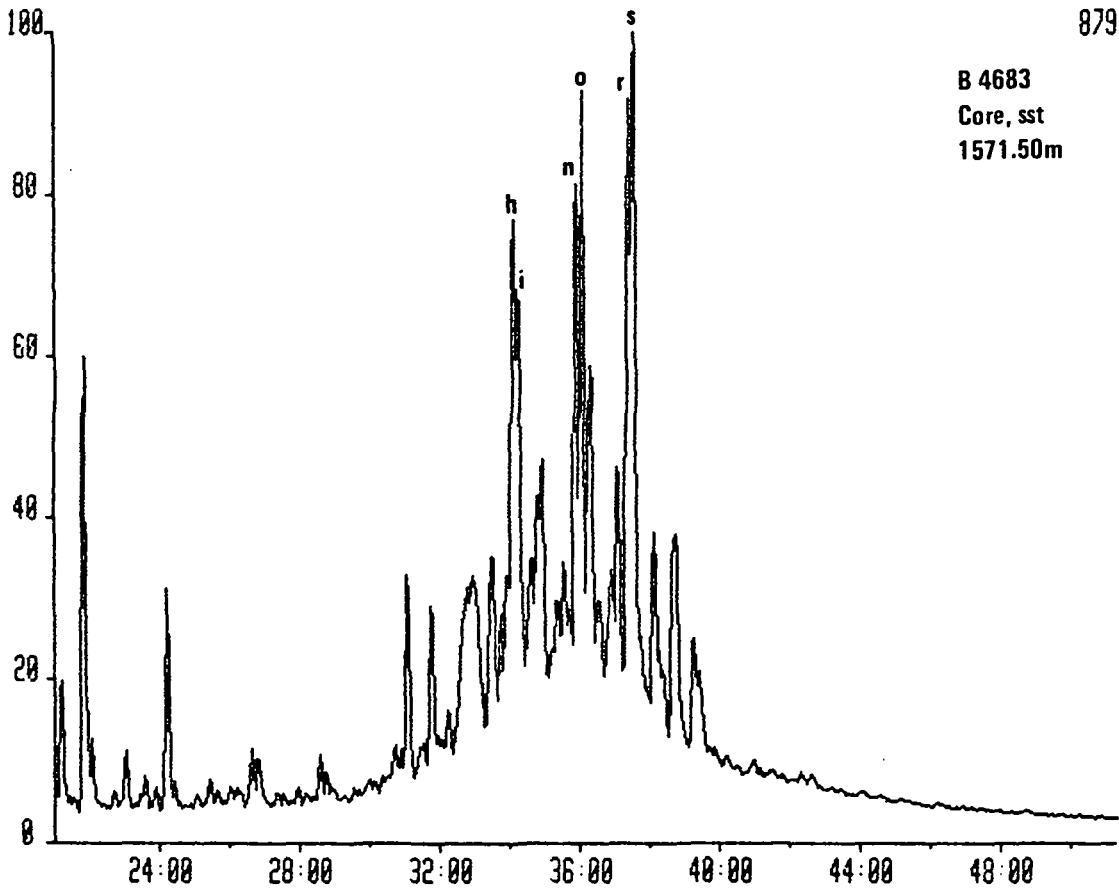
B 4691
Core, sst
1628.0m





744TROL1 218.1000 G1 I1 S2

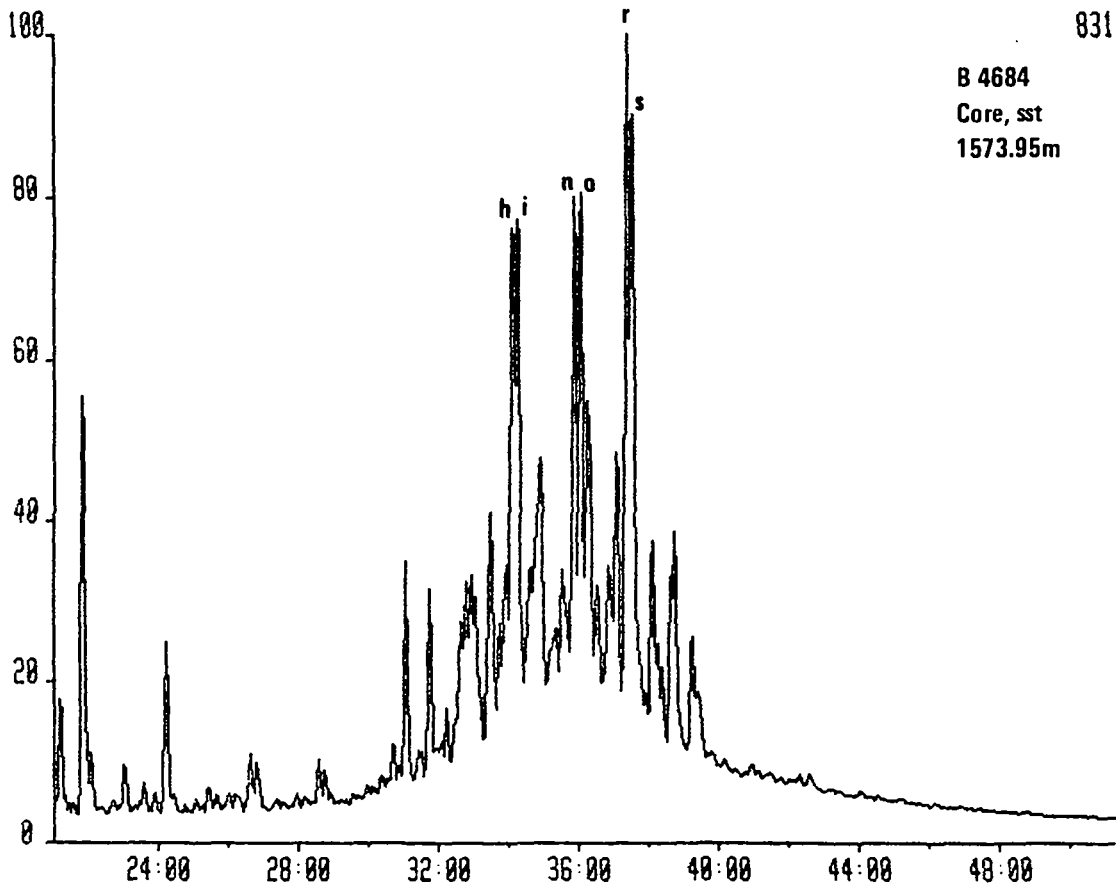




879

B 4683
Core, sst
1571.50m

744TROL1 218.1000 G1 I1 S4

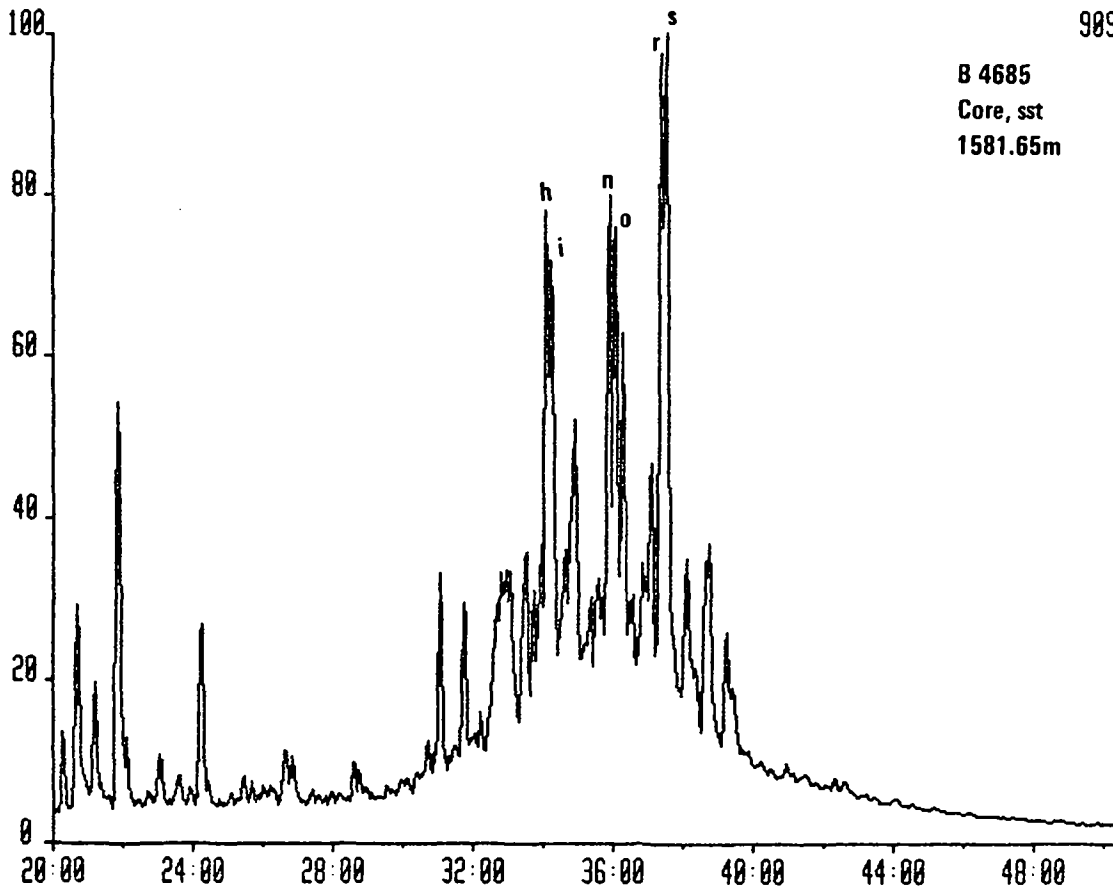


831

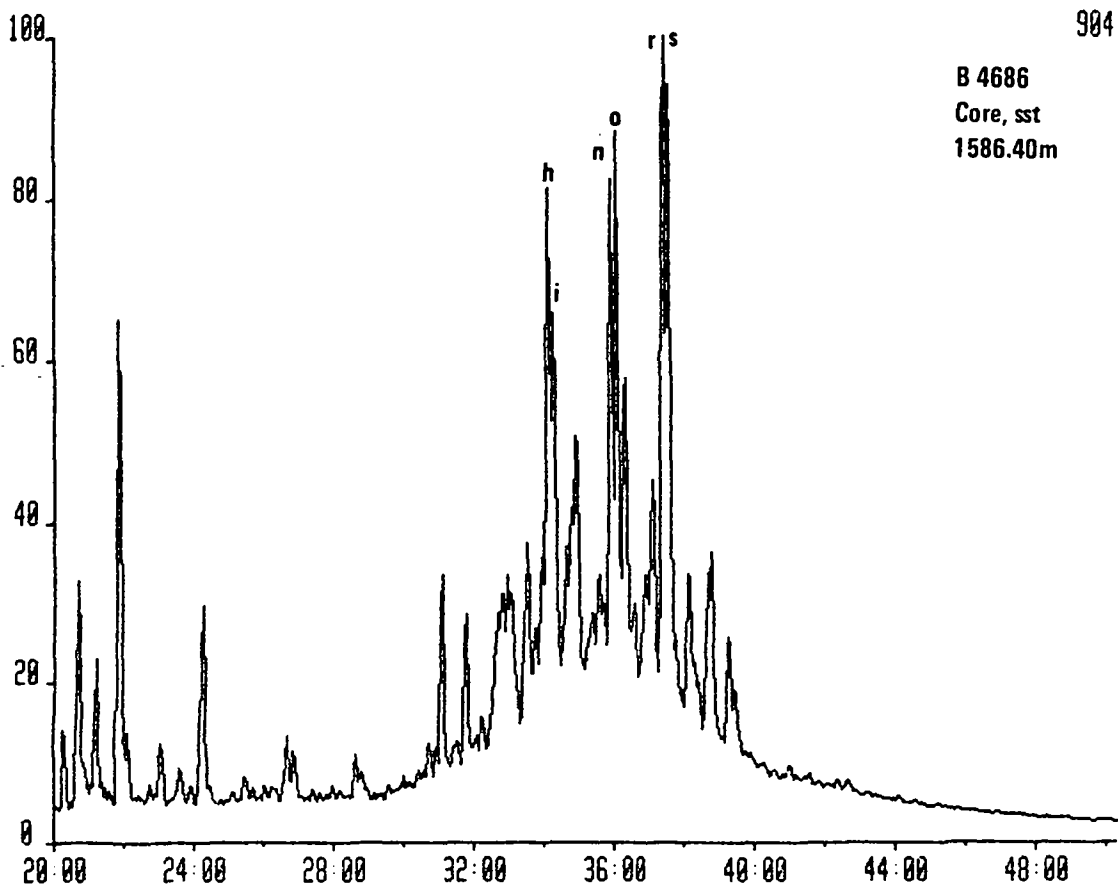
B 4684
Core, sst
1573.95m

744TROL2 218.1000 G1 I1 S1

- 80 -

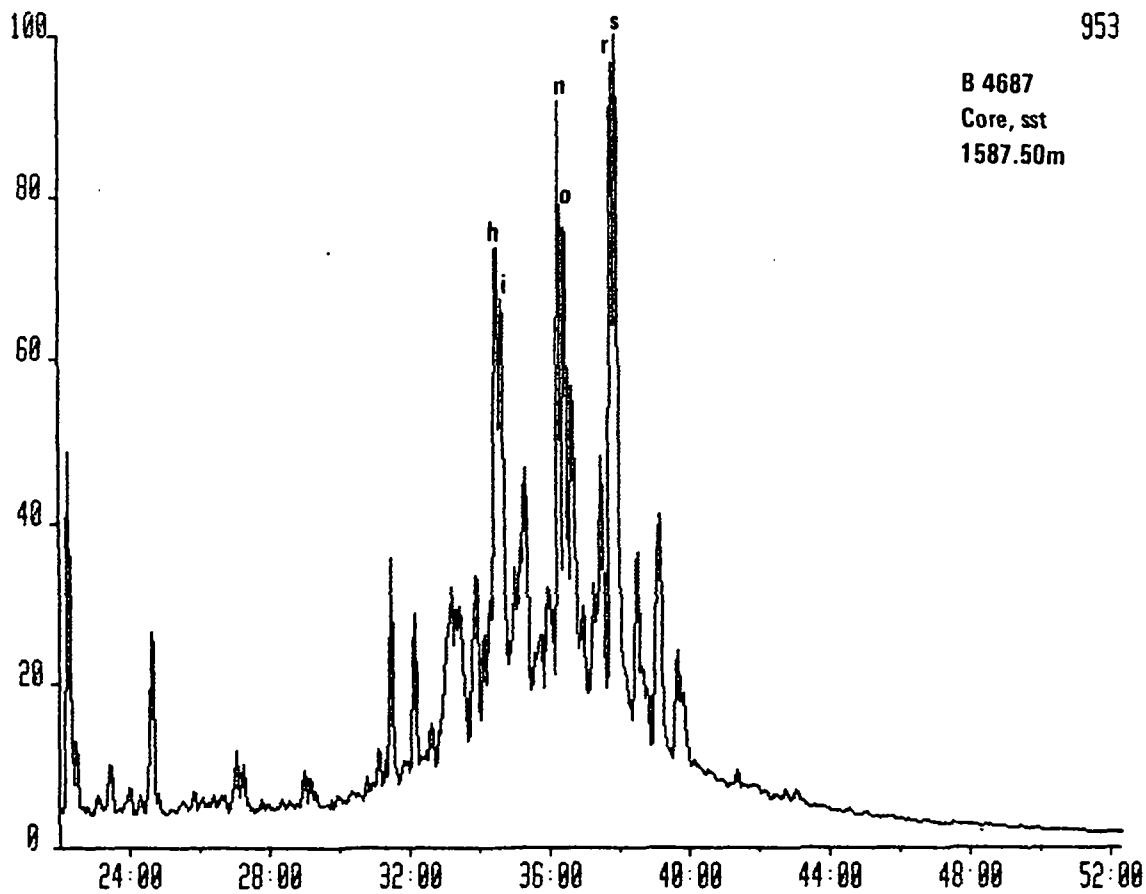


744TROL2 218.1000 G1 I1 S2



953

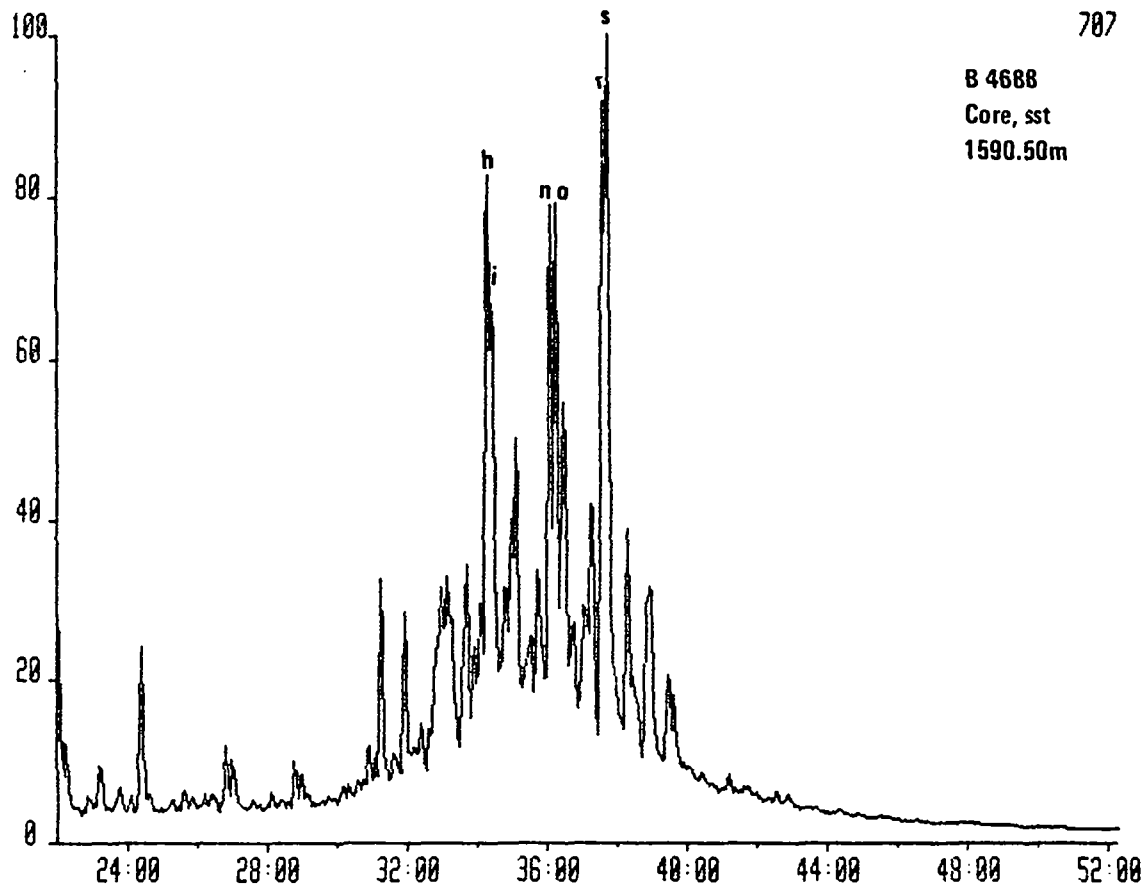
B 4687
Core, sst
1587.50m

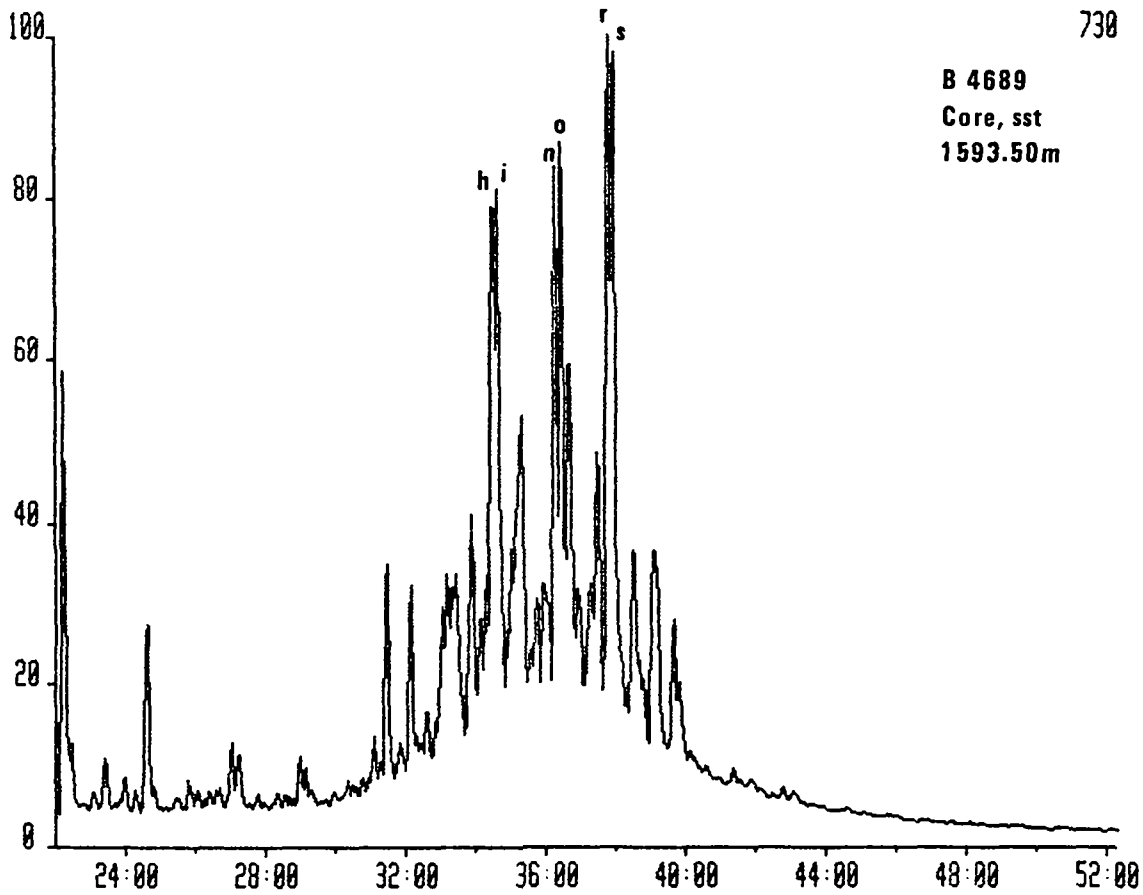


744TROL3 218.1000 G1 I1 S2

707

B 4688
Core, sst
1590.50m

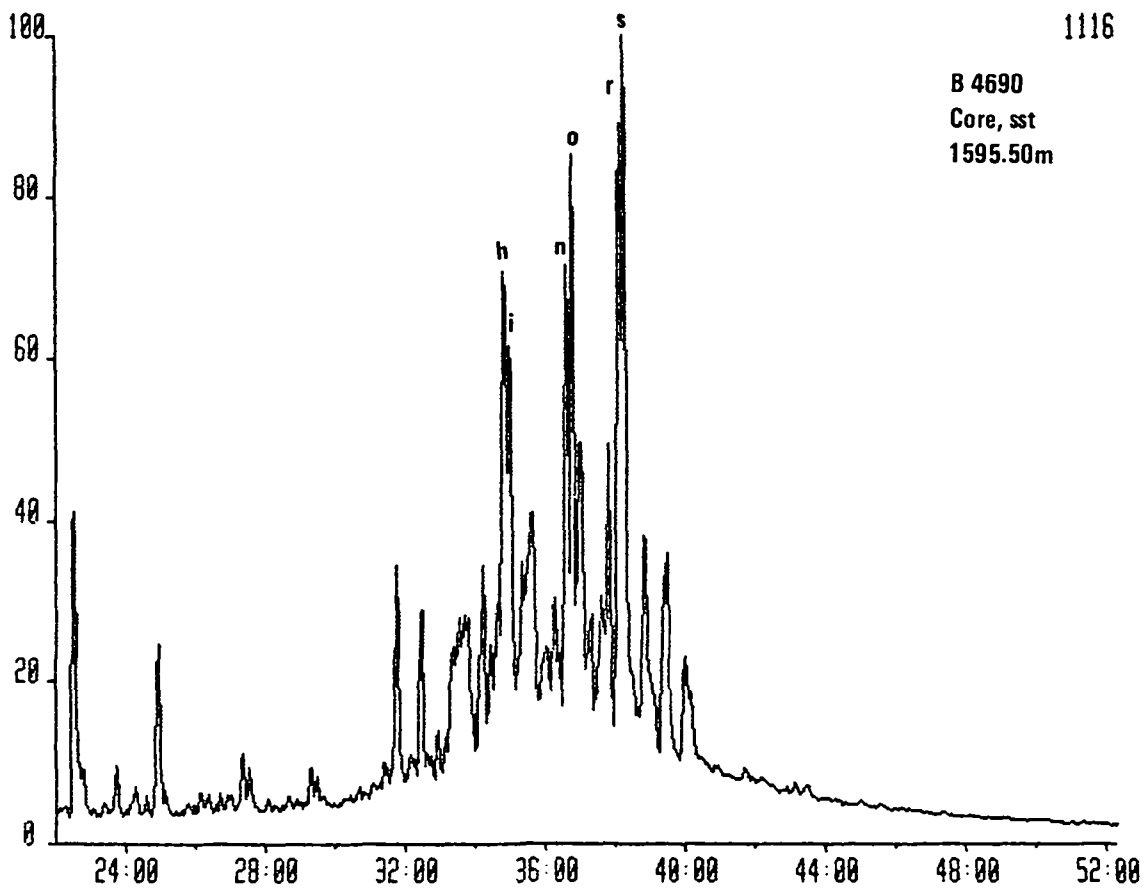




B 4689
Core, sst
1593.50m

730

744TROL3 218.1000 G1 I1 S4



B 4690
Core, sst
1595.50m

1116

3571

B 4691
Core, sst
1628.0m

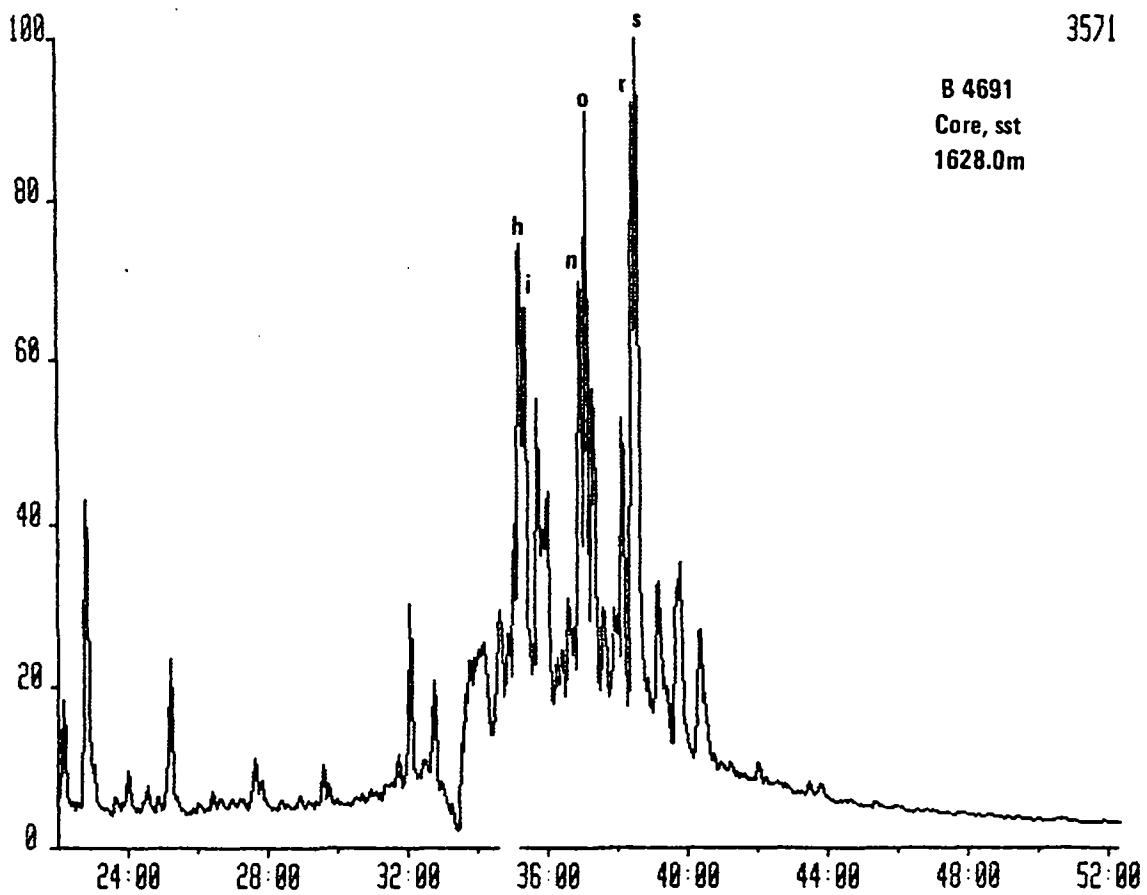
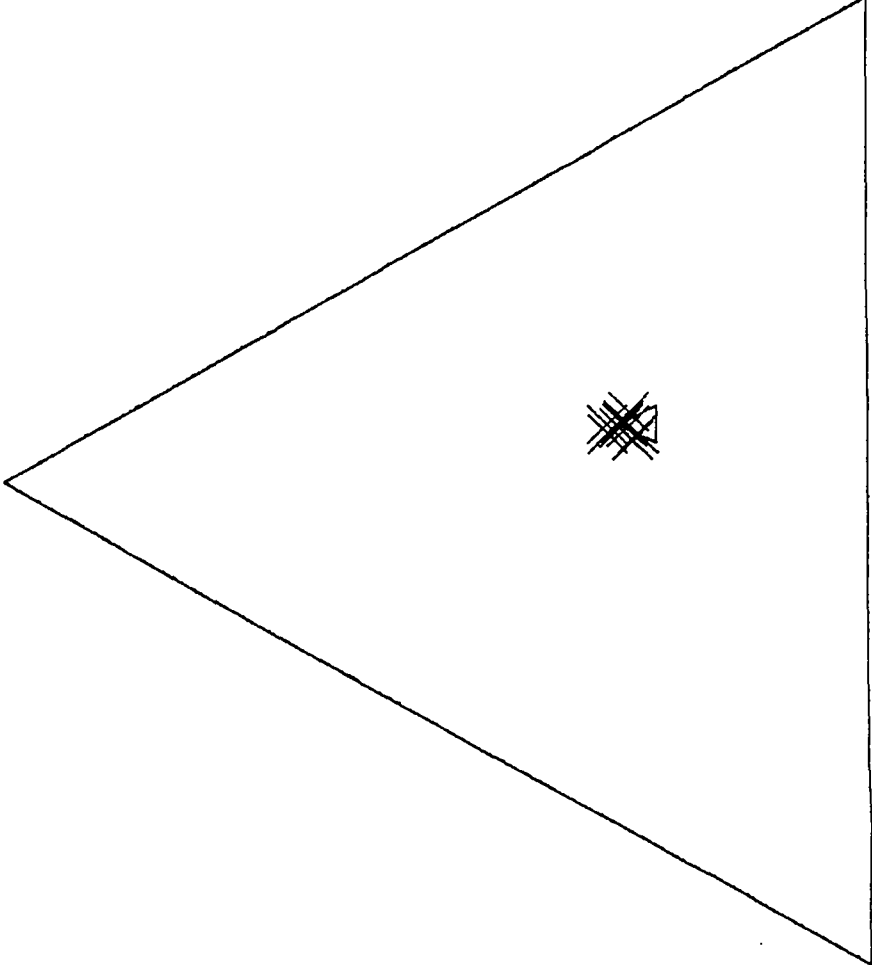


FIGURE 6

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

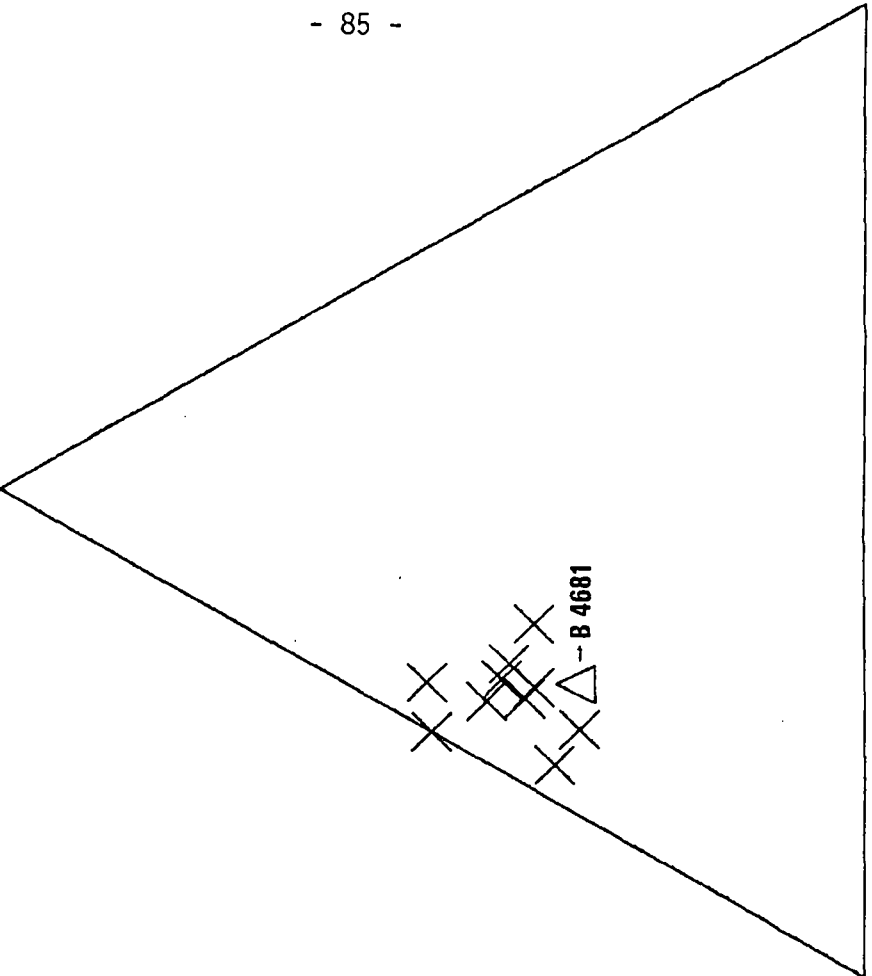
TROLL 31/3-2

100% C27



100% C28

C27



100% C29 C28

- C27 (20-40%)
- C28 (20-40%)
- C29 (40-60%)

FIGURE 7

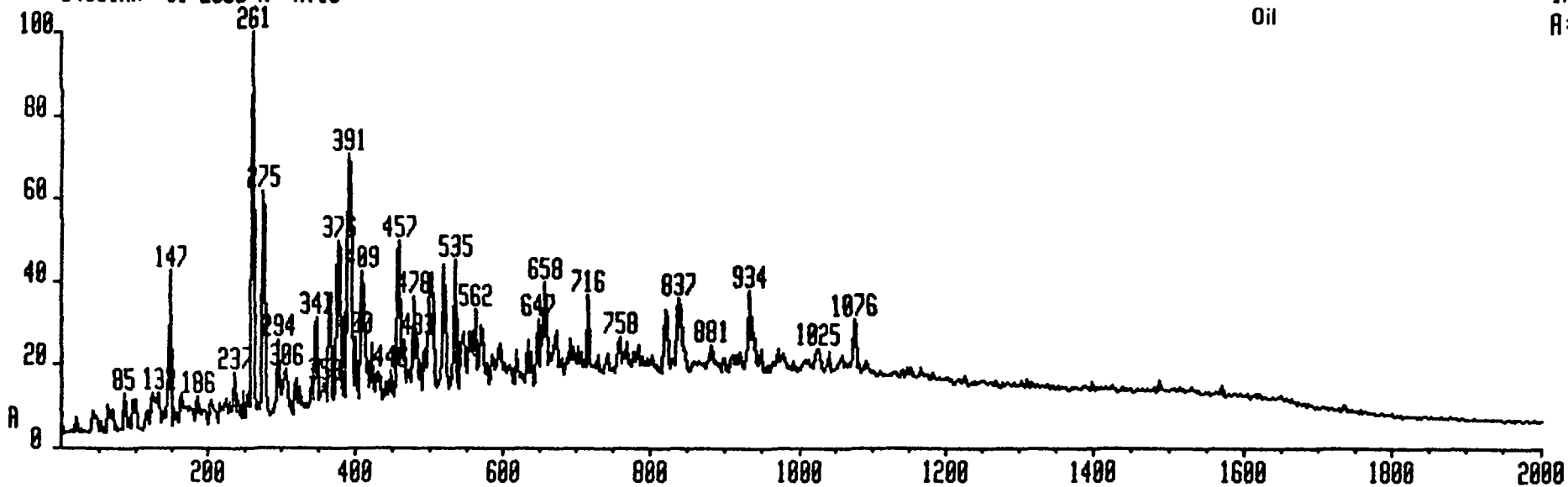
Mass chromatograms of aromatic hydrocarbons

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 184, 198, 212	-	alkylated dibenzothiophenes
m/z 231	-	triaromatic steranes
m/z 253	-	monoaromatic steranes

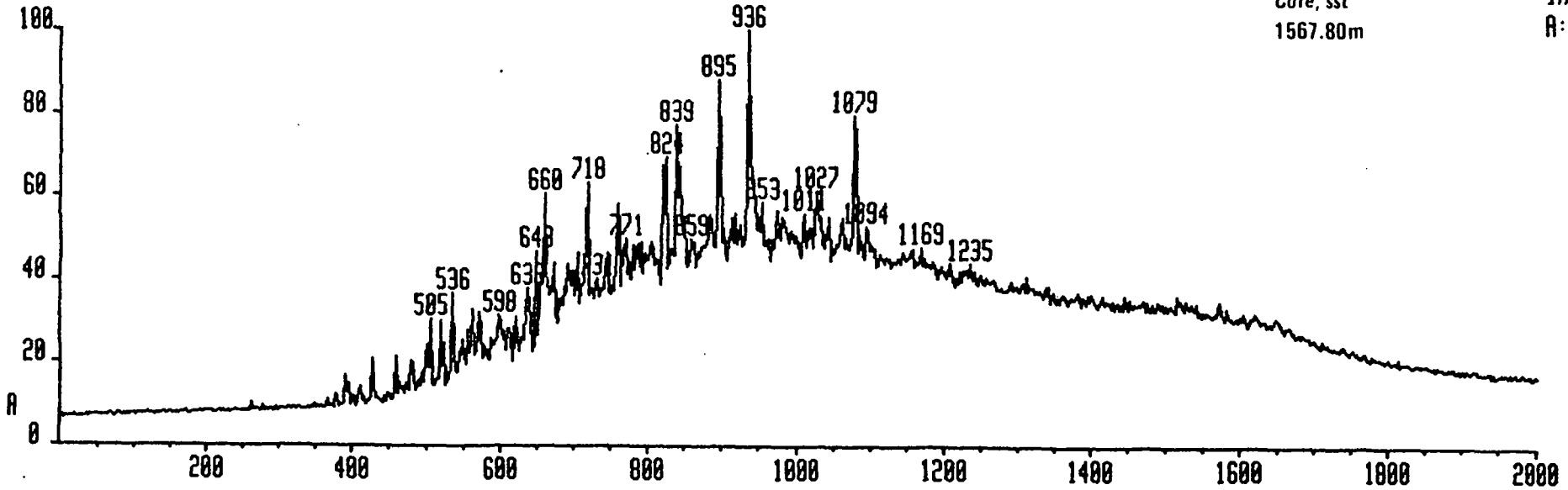
B4681AR #1-2000 A :ATIC

TIC
B 4681
Oil

IHP
A: 20146



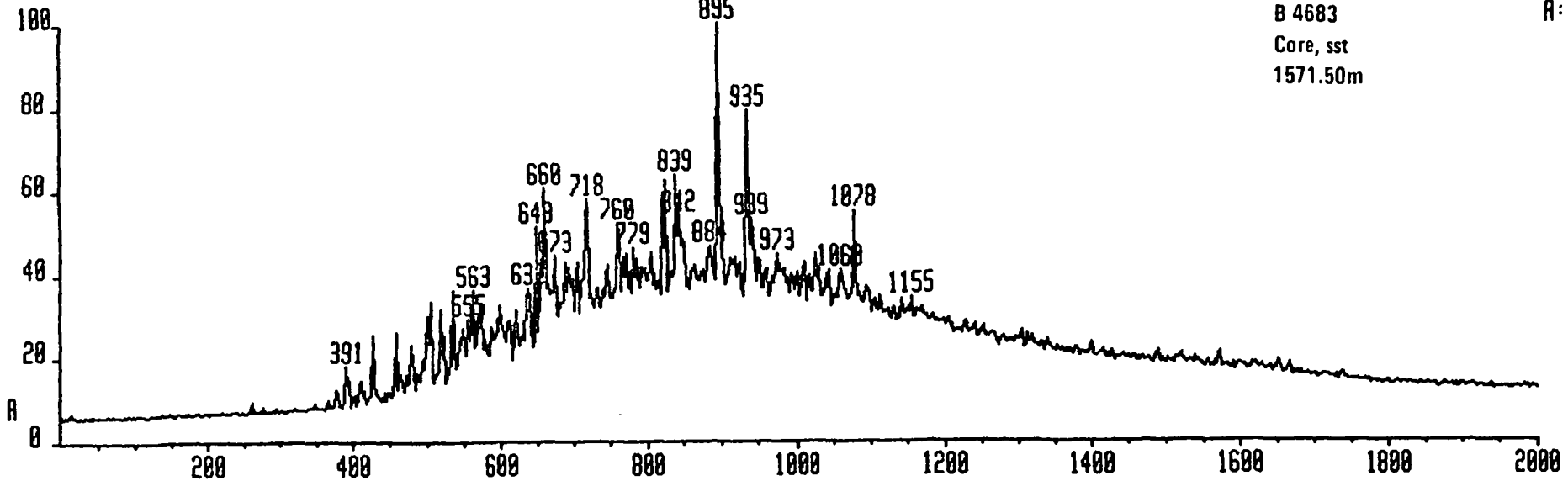
B4682AR #1-2000 A :ATIC



TIC
B 4682
Core, sst
1567.80m

IHP
A: 7565

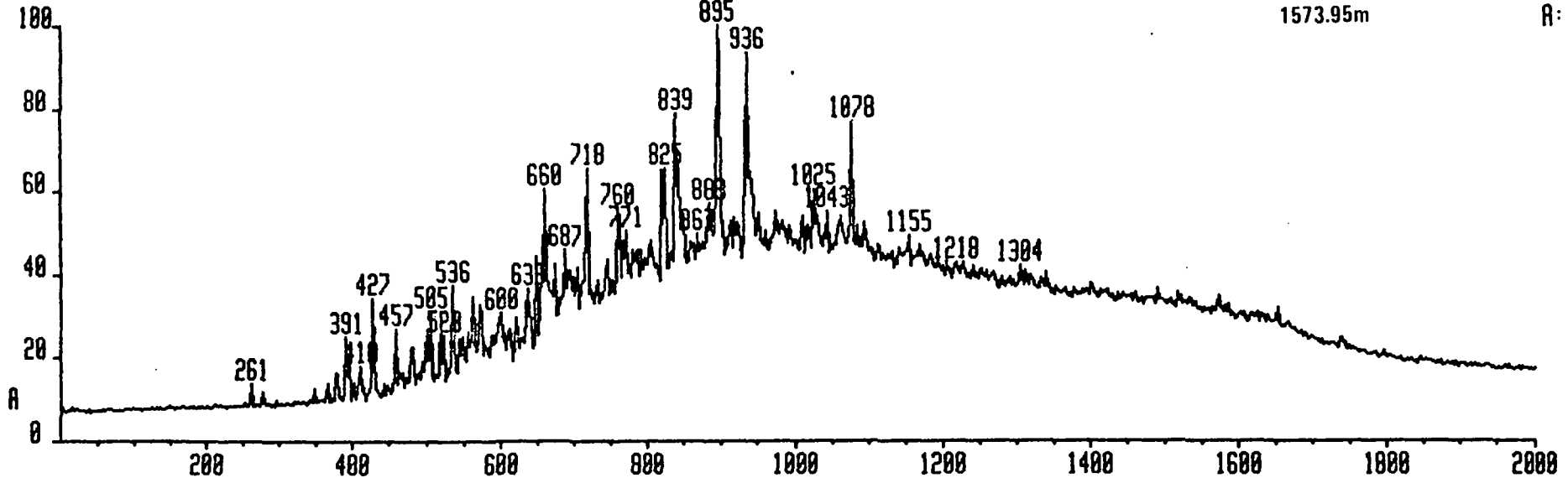
B4683AR #1-2000 A :ATIC



TIC
B 4683
Core, sst
1571.50m

IHP
A: 8922

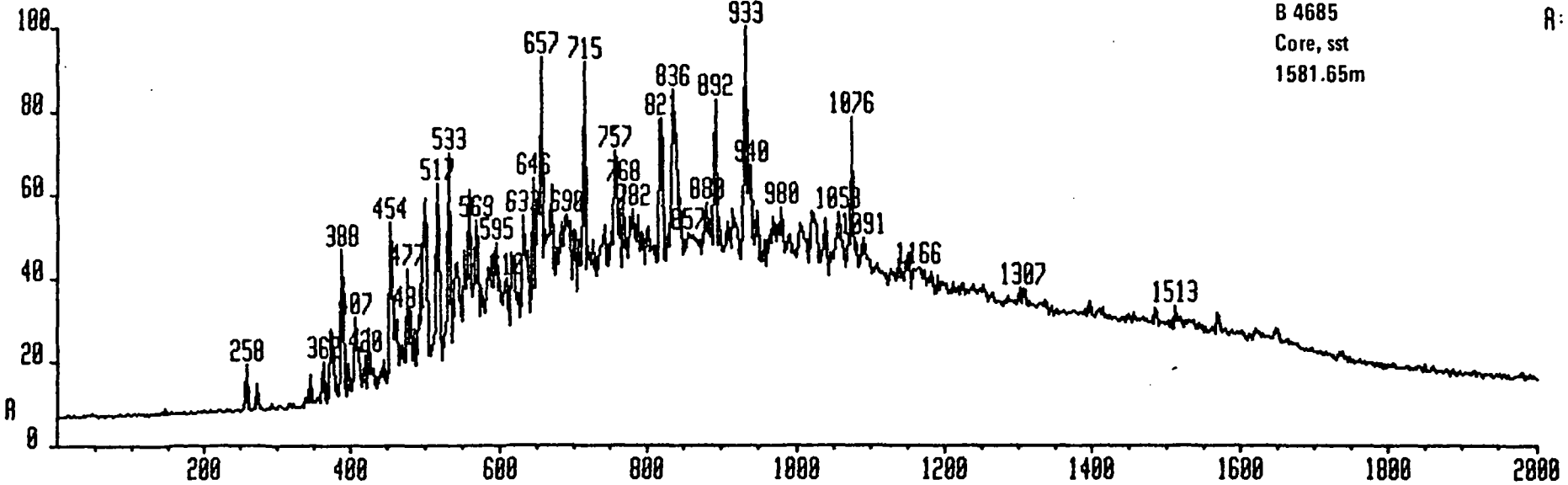
B4684AR #1-2000 A :ATIC



TIC
B 4684
Core, sst
1573.95m

IHP
R: 7237

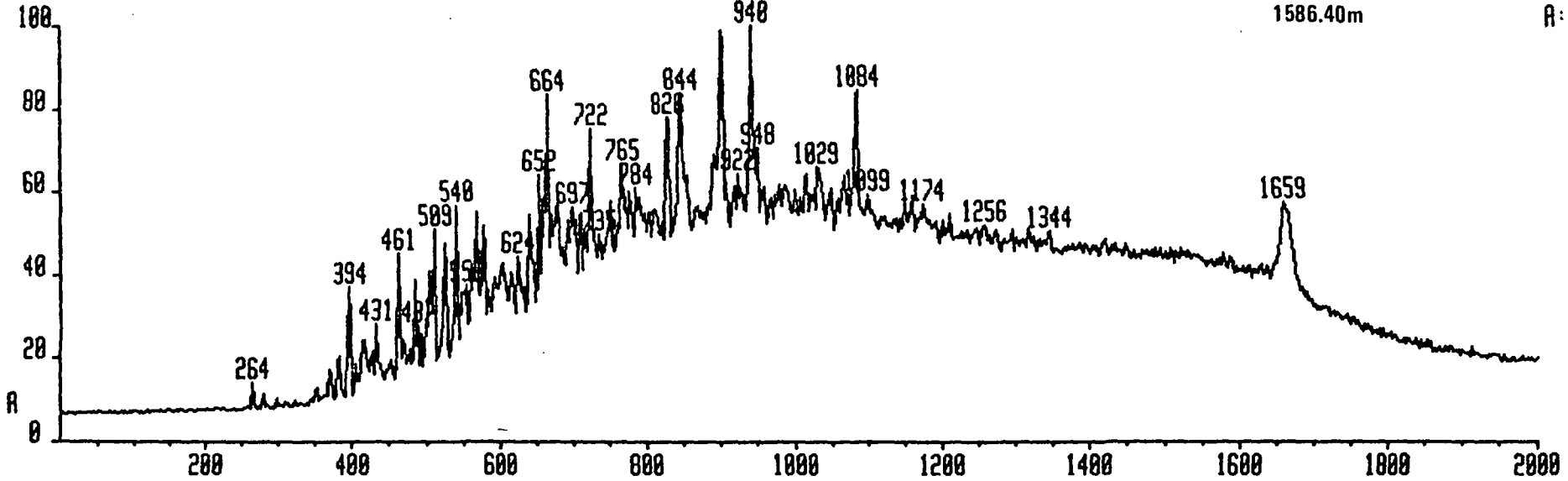
B4685AR #1-2000 A :ATIC



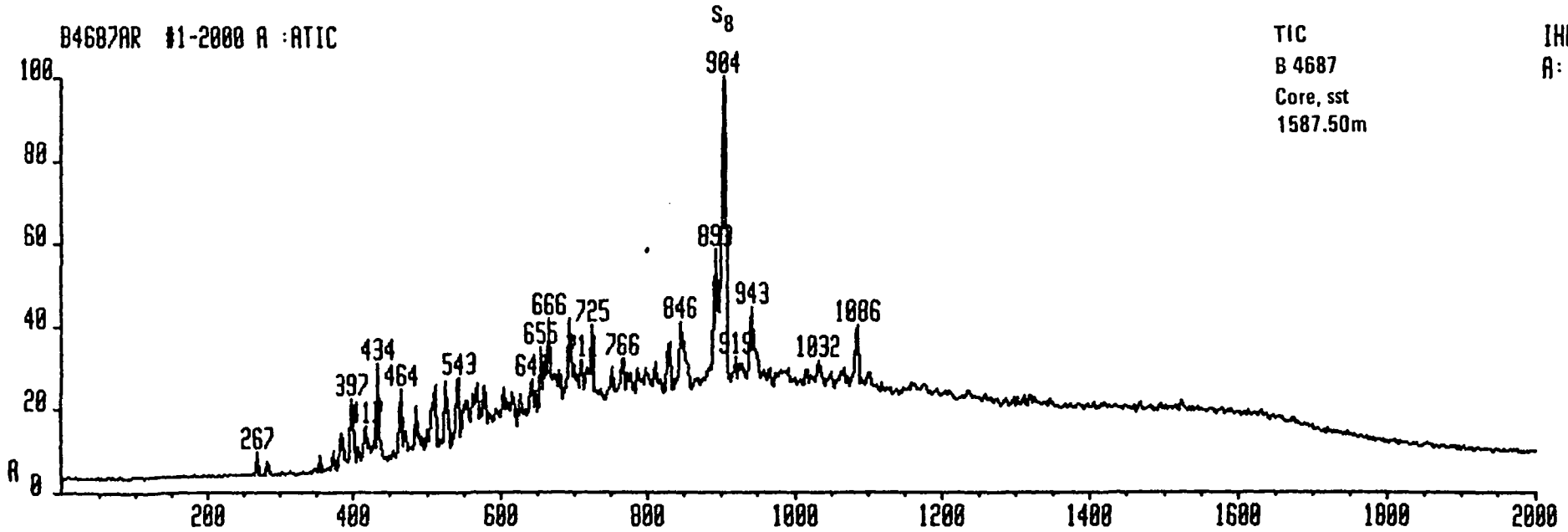
TIC
B 4685
Core, sst
1581.65m

IHP
R: 7570

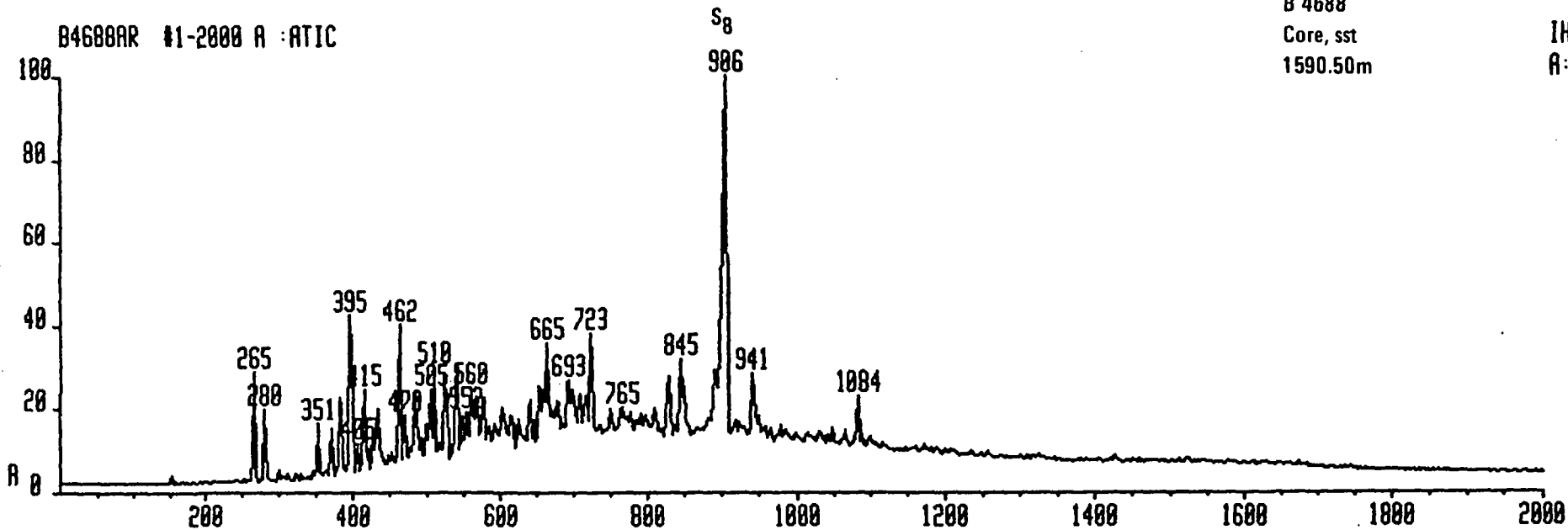
B4686AR #1-2000 A :ATIC



B4687AR #1-2000 A :ATIC



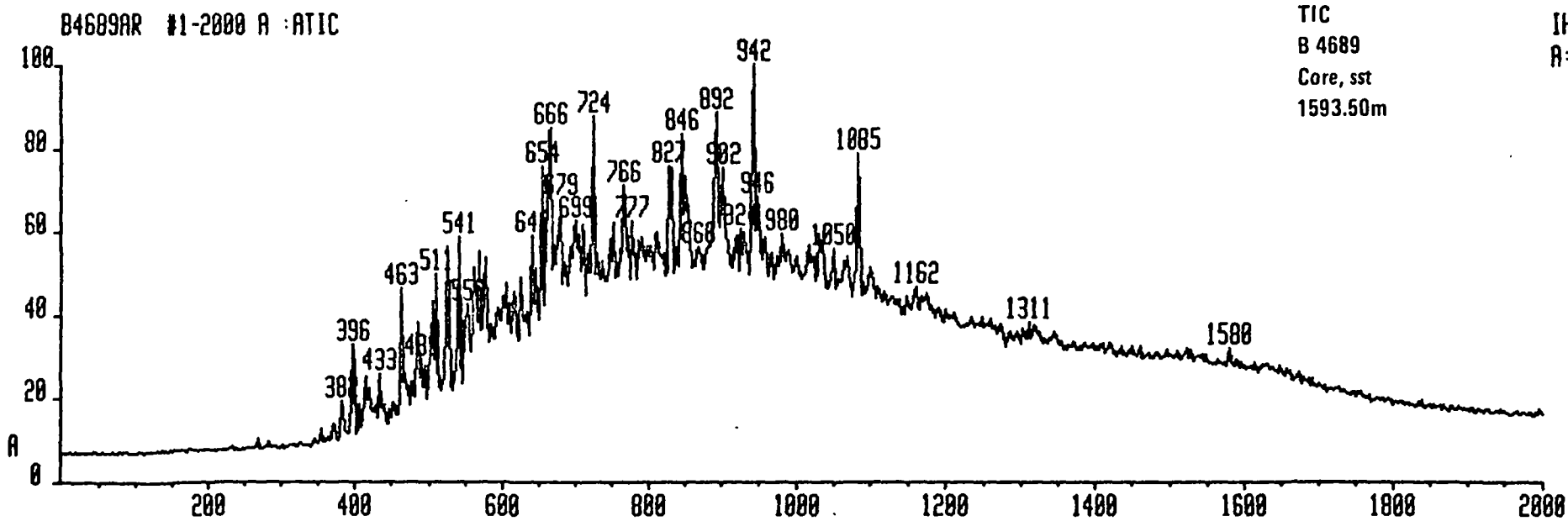
B4688AR #1-2000 A :ATIC



TIC
B 4688
Core, sst
1590.50m

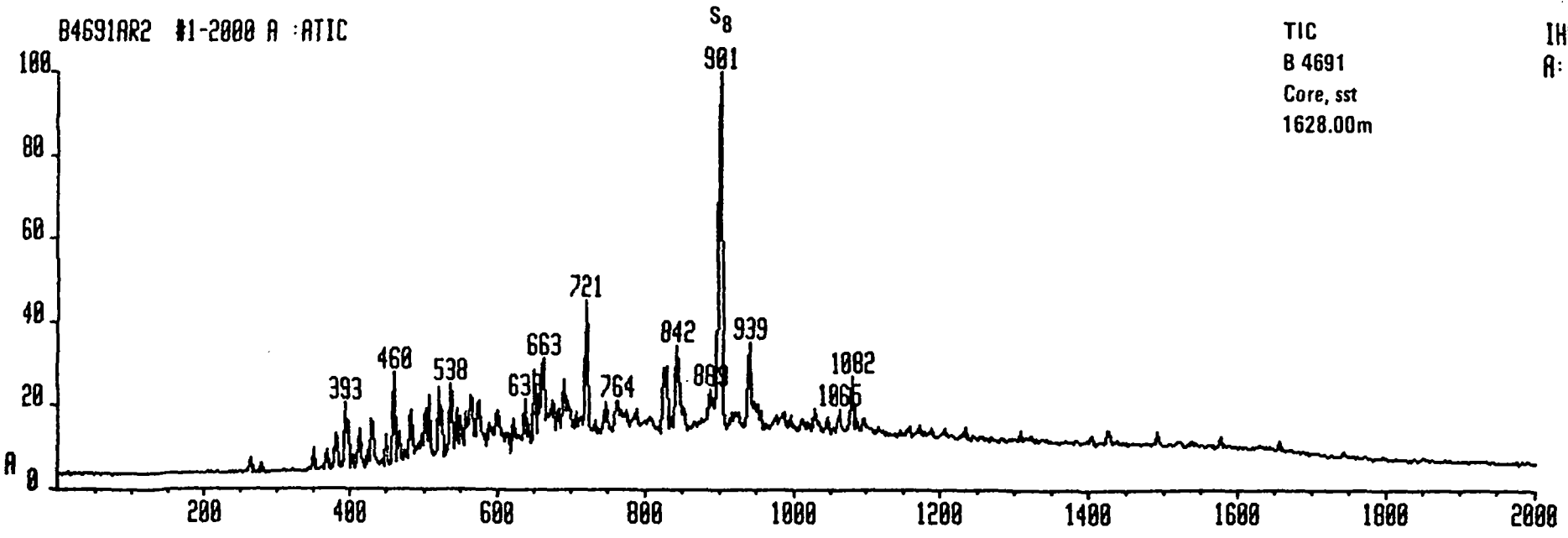
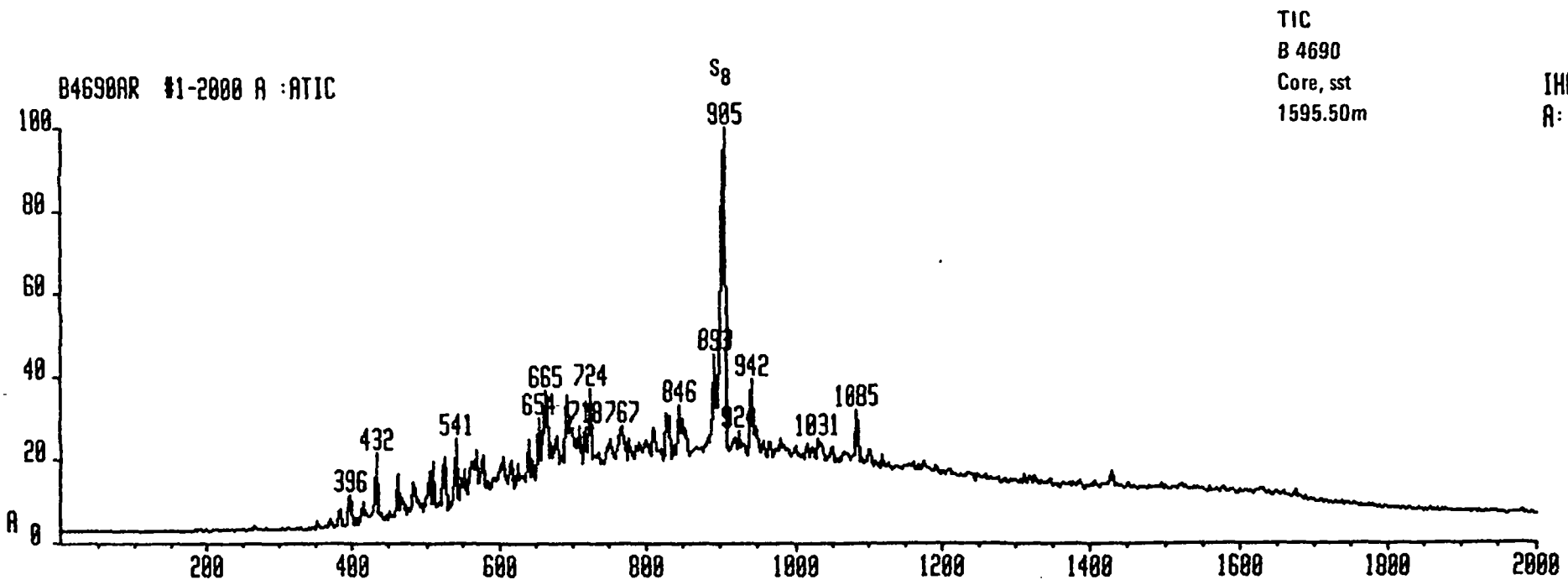
IHP
A: 33386

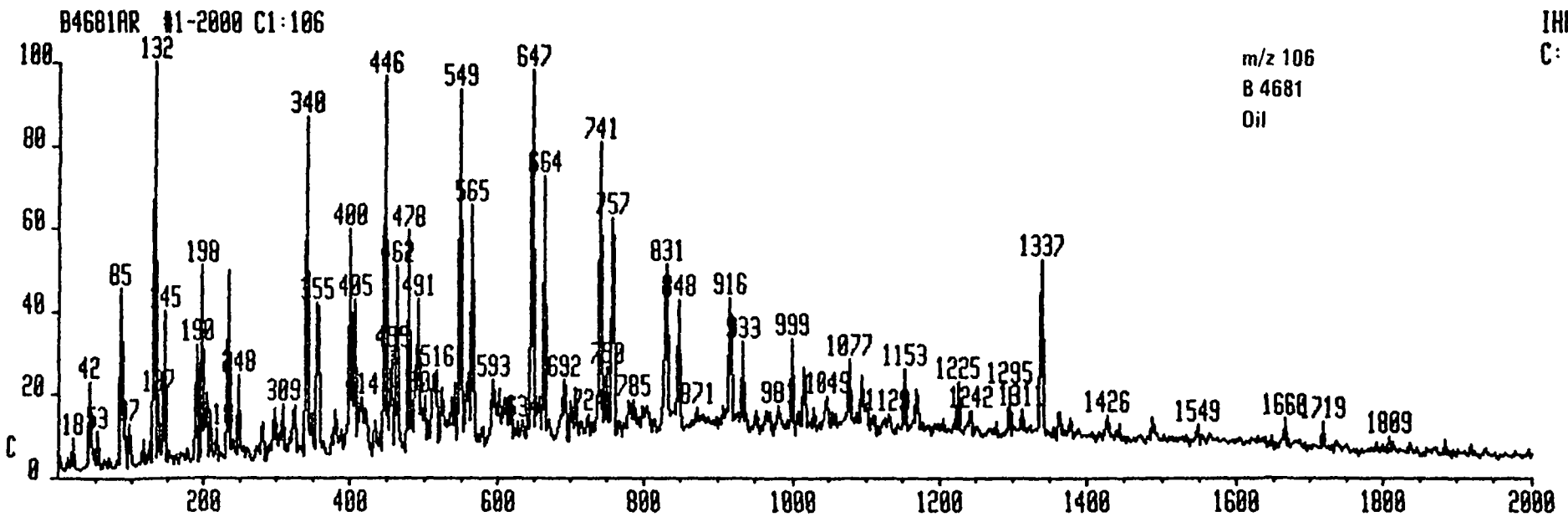
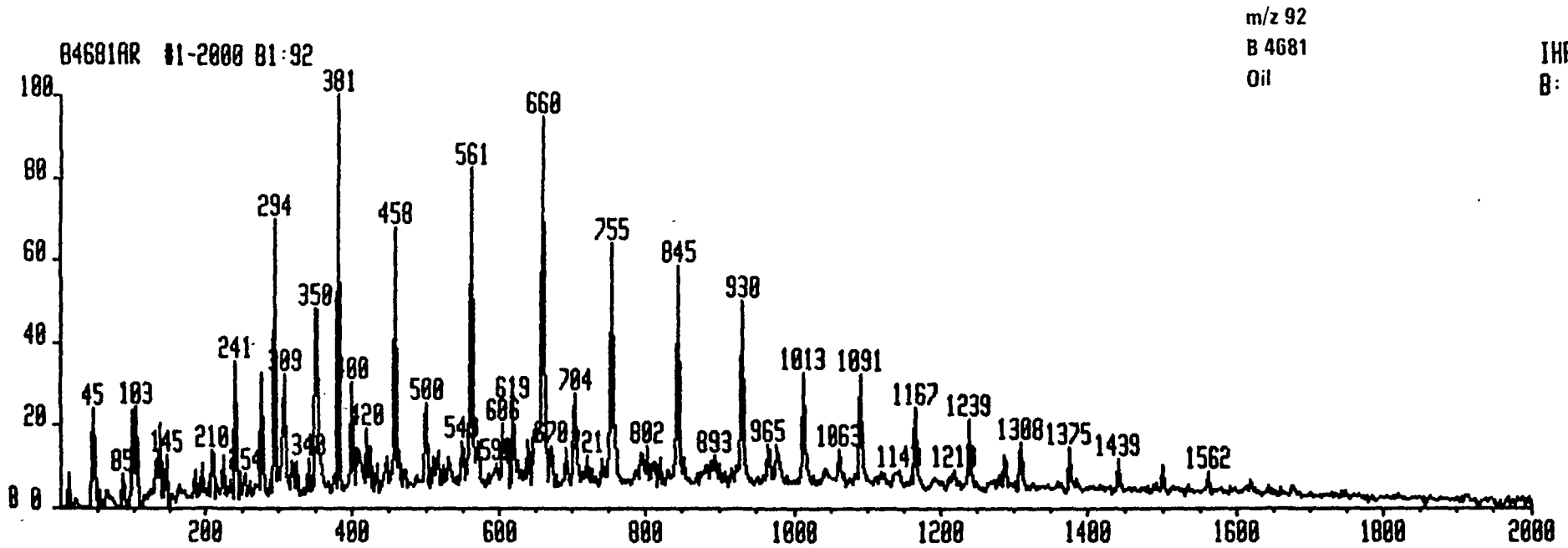
B4689AR #1-2000 A :ATIC



TIC
B 4689
Core, sst
1593.50m

IHP
A: 9313

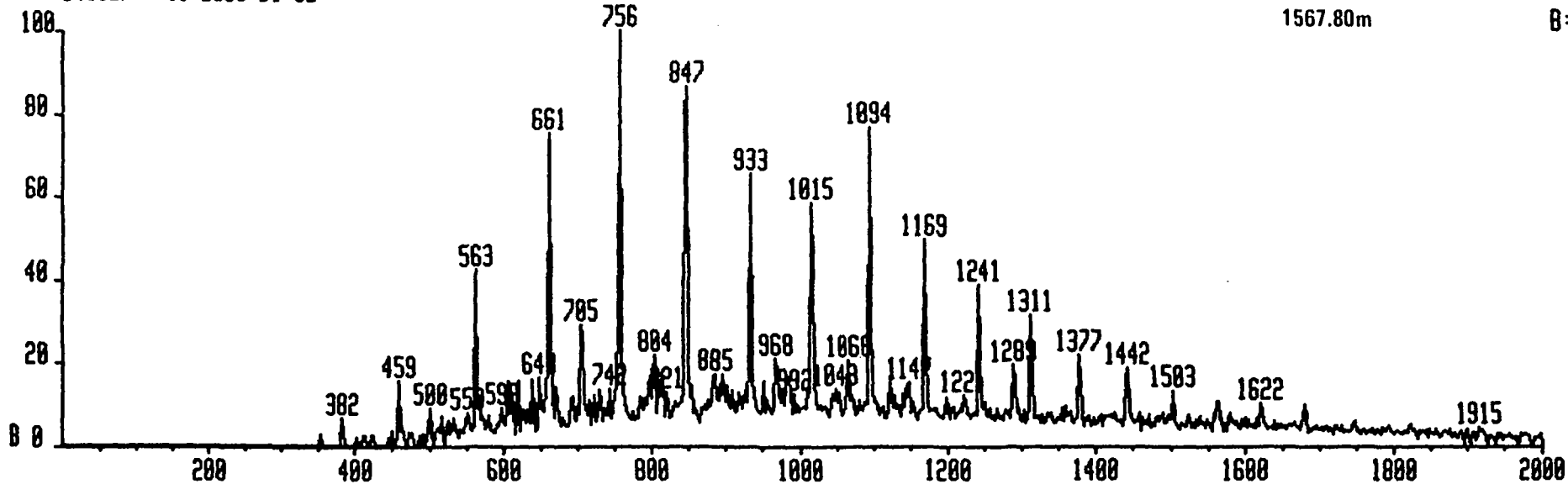




B4682AR #1-2000 B1:92

m/z 92
B 4682
Core, sst
1567.80m

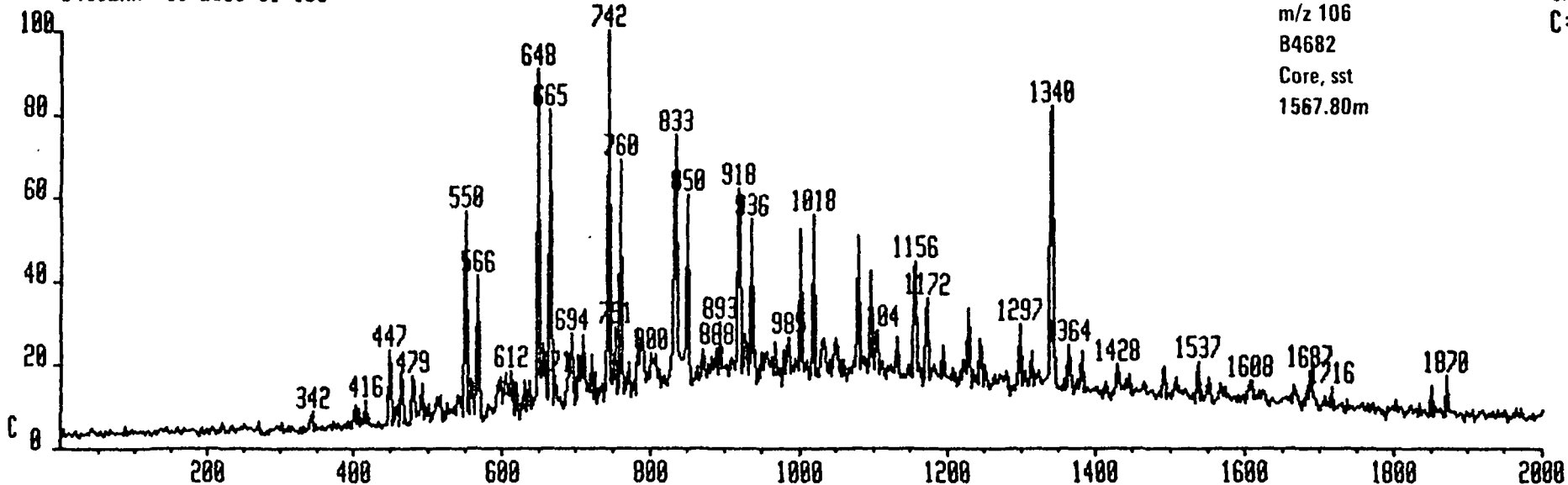
IHP
B: 2855000

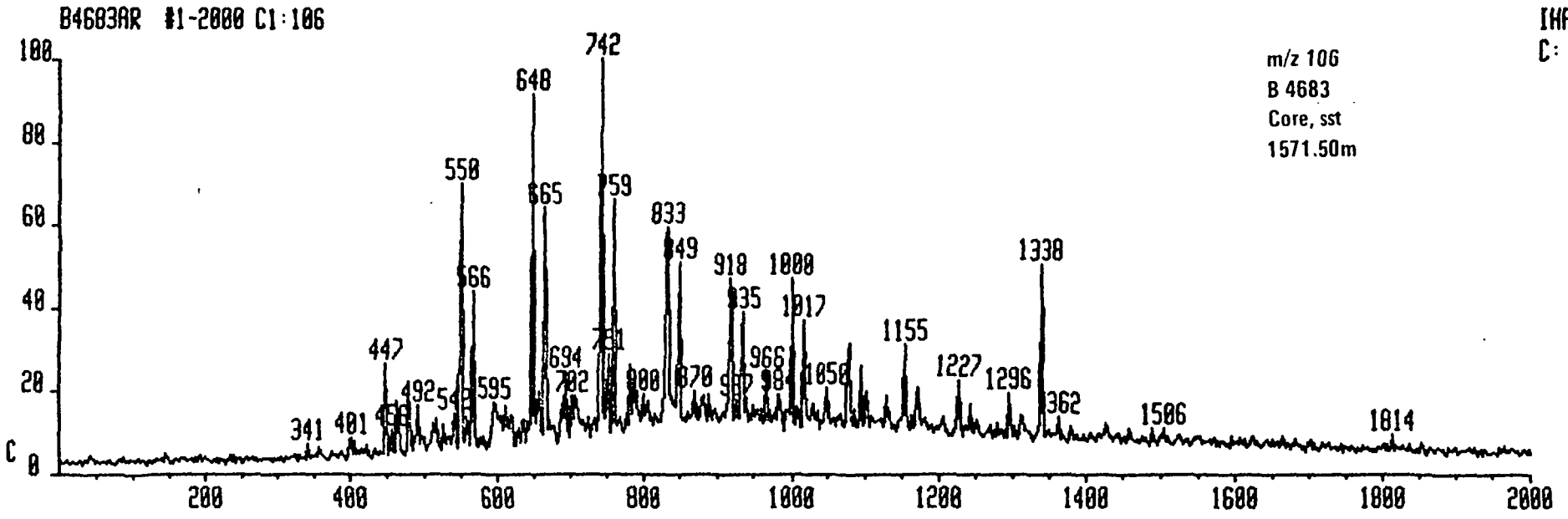
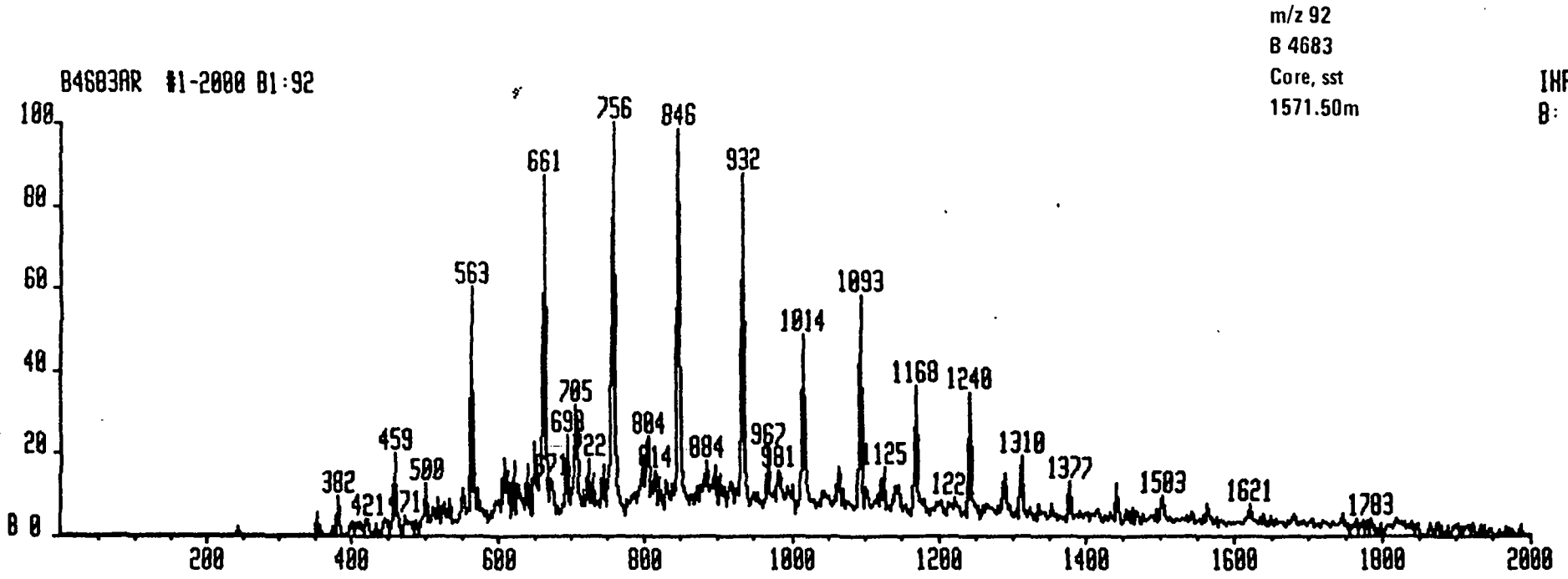


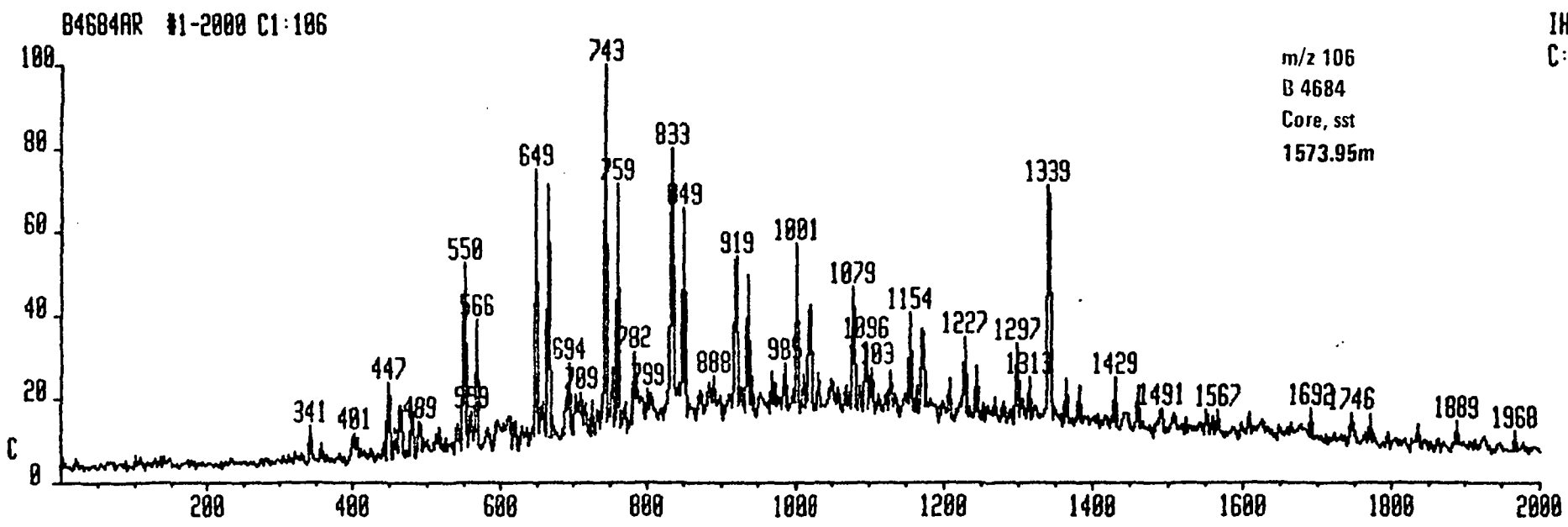
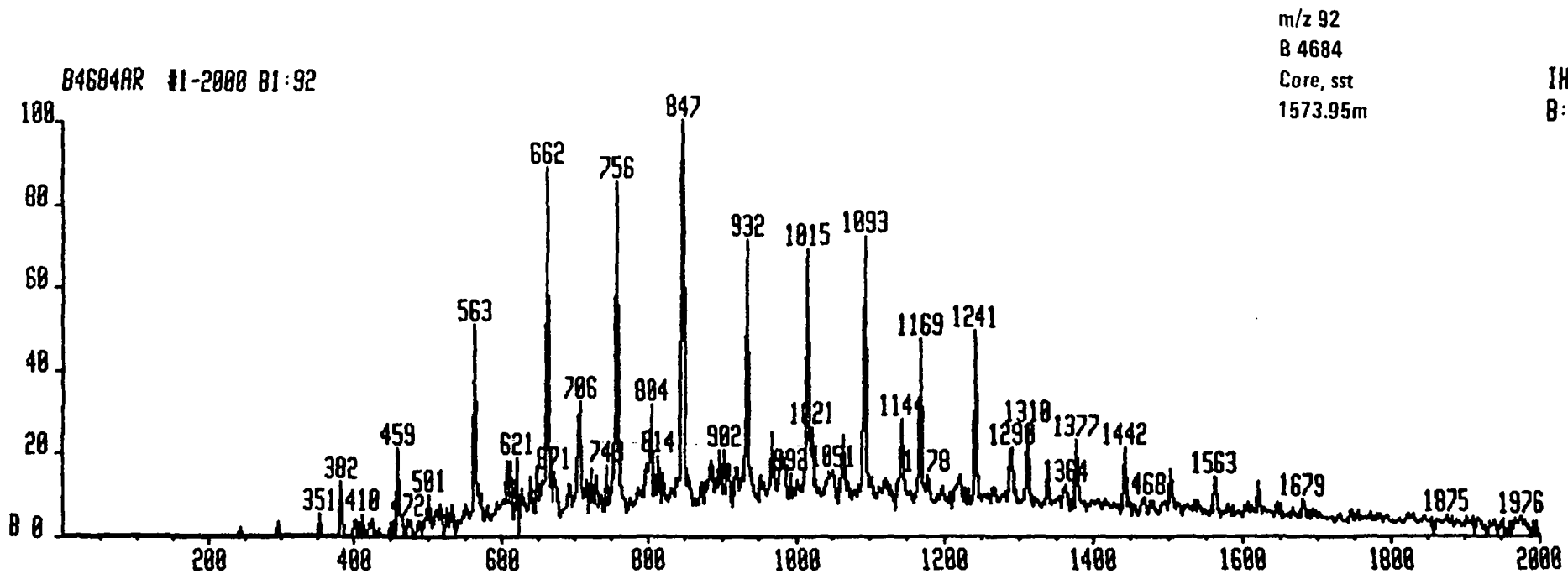
B4682AR #1-2000 C1:106

m/z 106
B4682
Core, sst
1567.80m

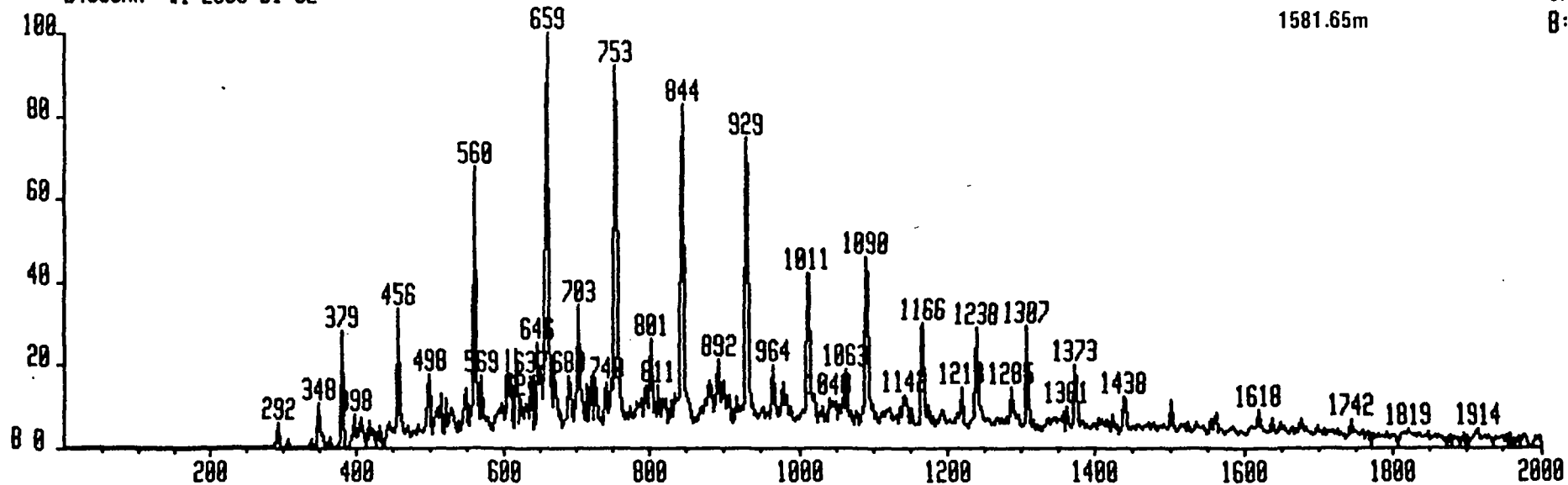
IHP
C: 3651000







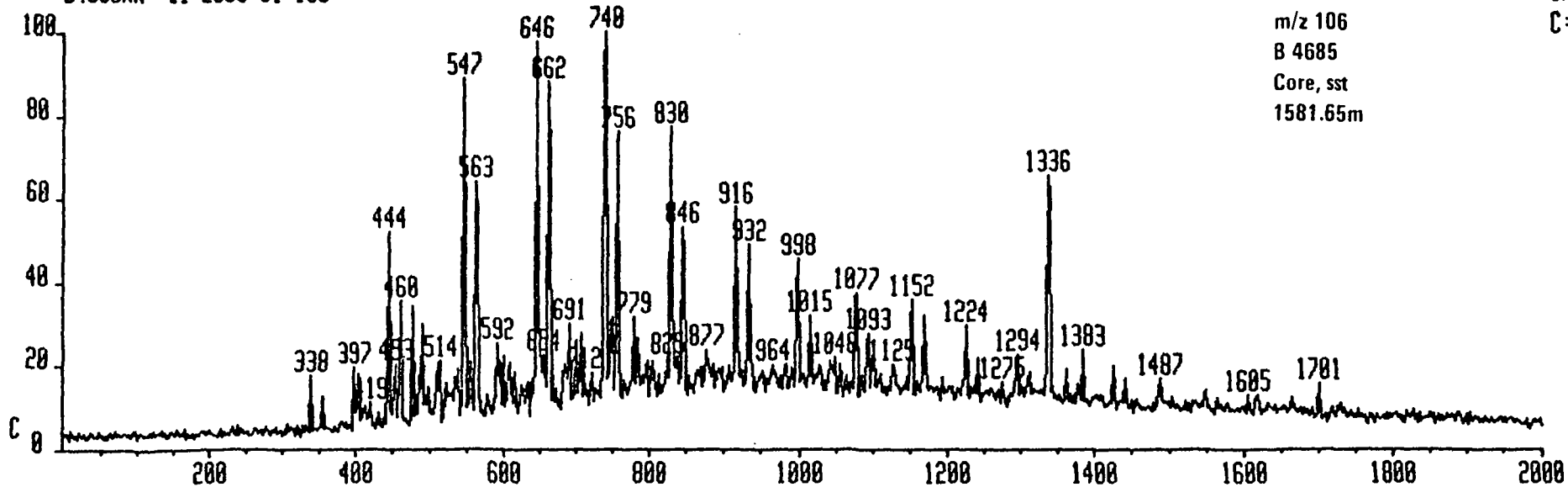
B4685AR #1-2000 01:92



m/z 92
B 4685
Core, sst
1581.65m

IHP
B: 3006000

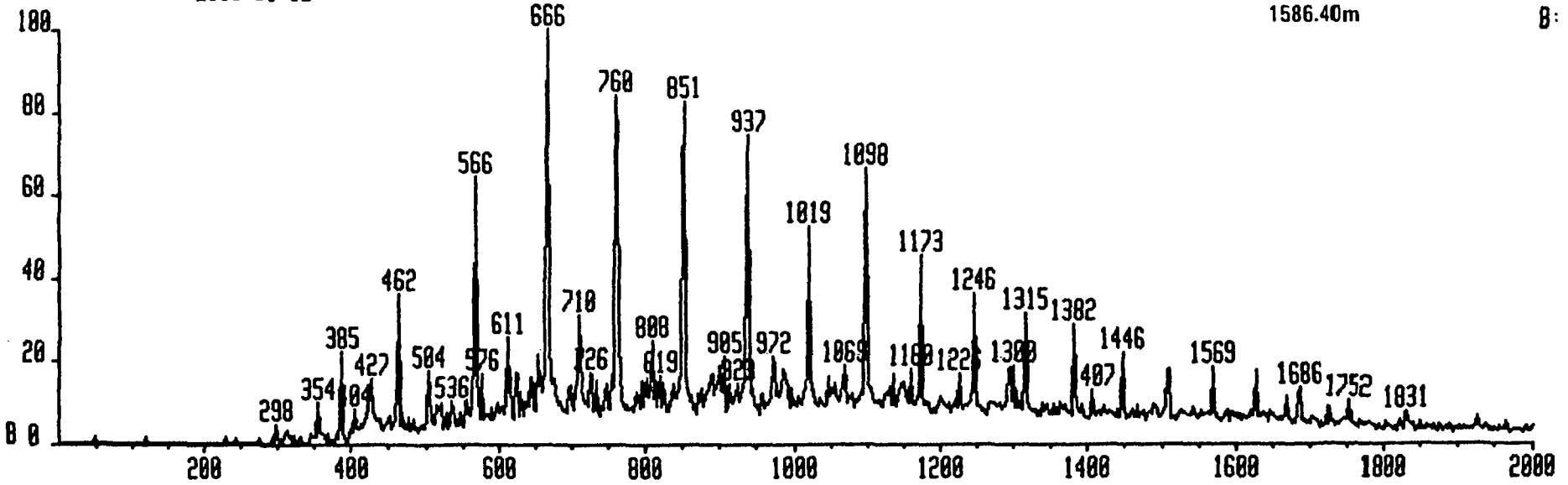
B4685AR #1-2000 C1:106



m/z 106
B 4685
Core, sst
1581.65m

IHP
C: 4102000

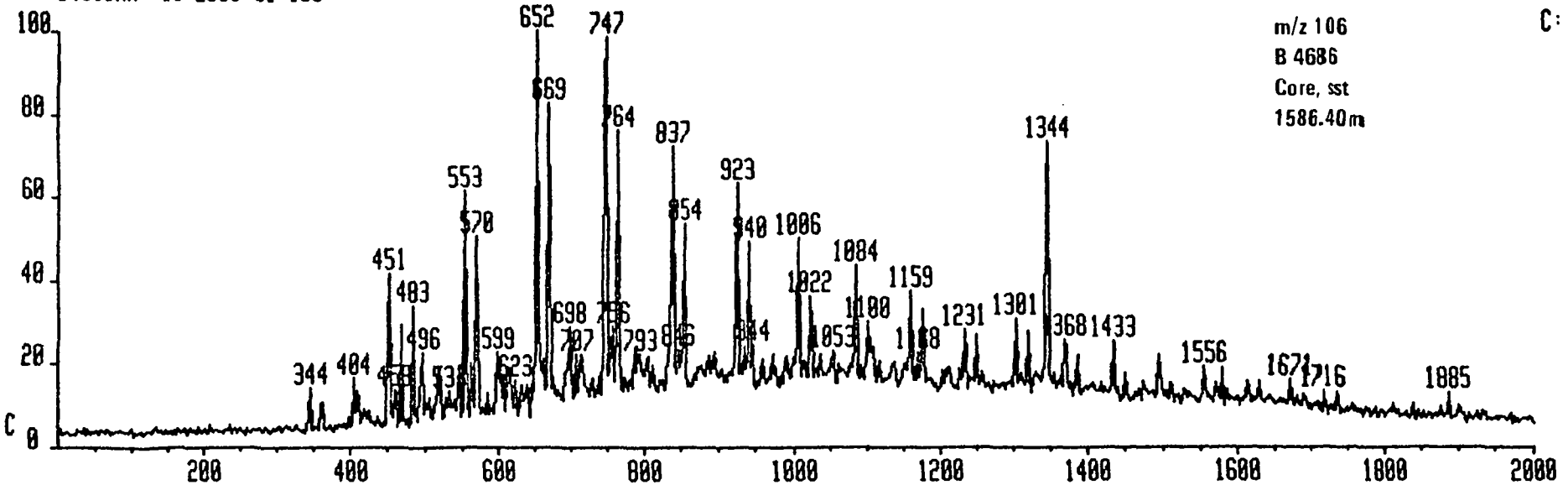
B4686AR #1-2000 B1:92



m/z 92
B 4686
Core, sst
1586.40m

IHP
B: 3910000

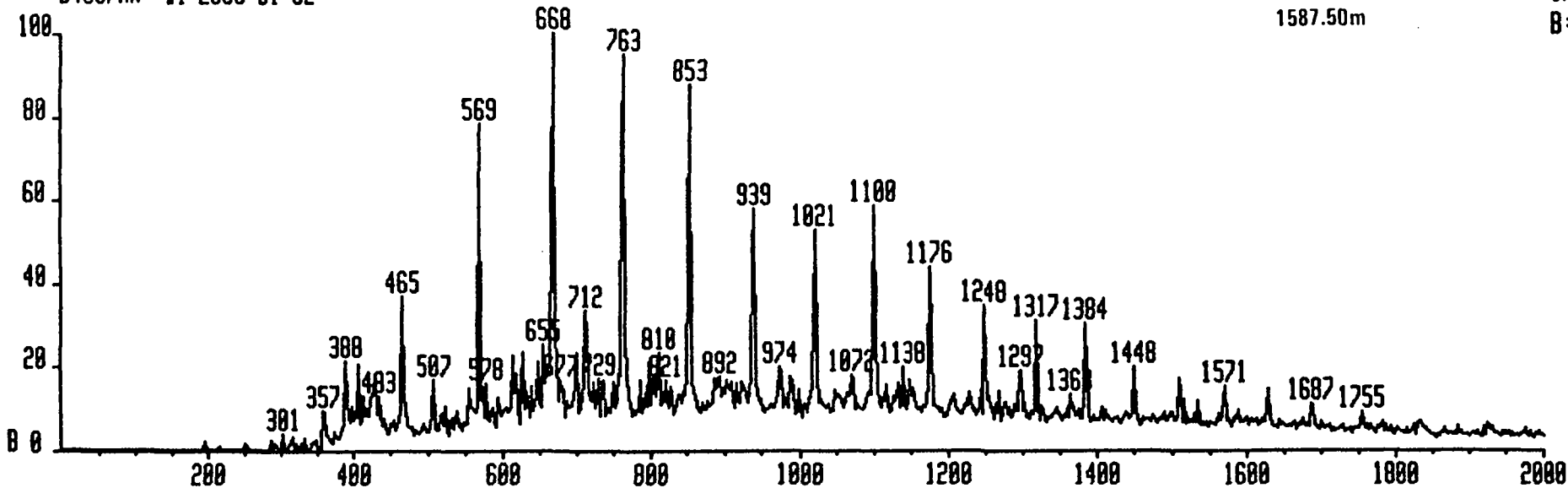
B4686AR #1-2000 C1:106



m/z 106
B 4686
Core, sst
1586.40m

IHP
C: 5510000

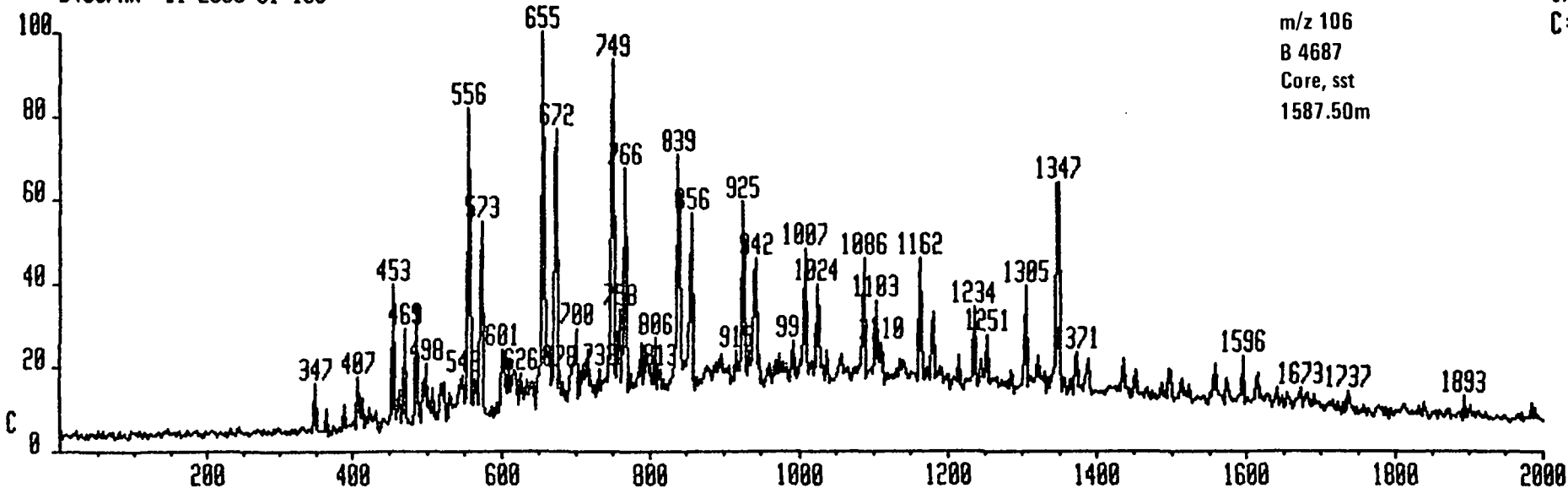
B4607AR #1-2000 B1:92



m/z 92
B 4687
Core, sst
1587.50m

IHP
B: 3437000

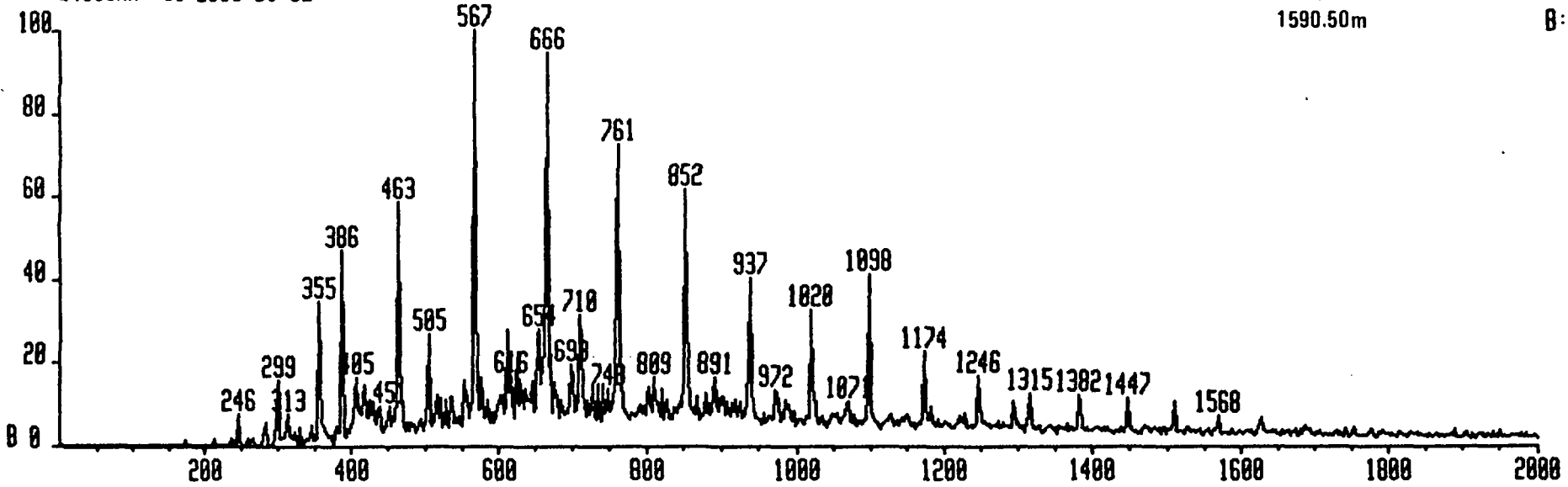
B4607AR #1-2000 C1:106



m/z 106
B 4687
Core, sst
1587.50m

IHP
C: 4661000

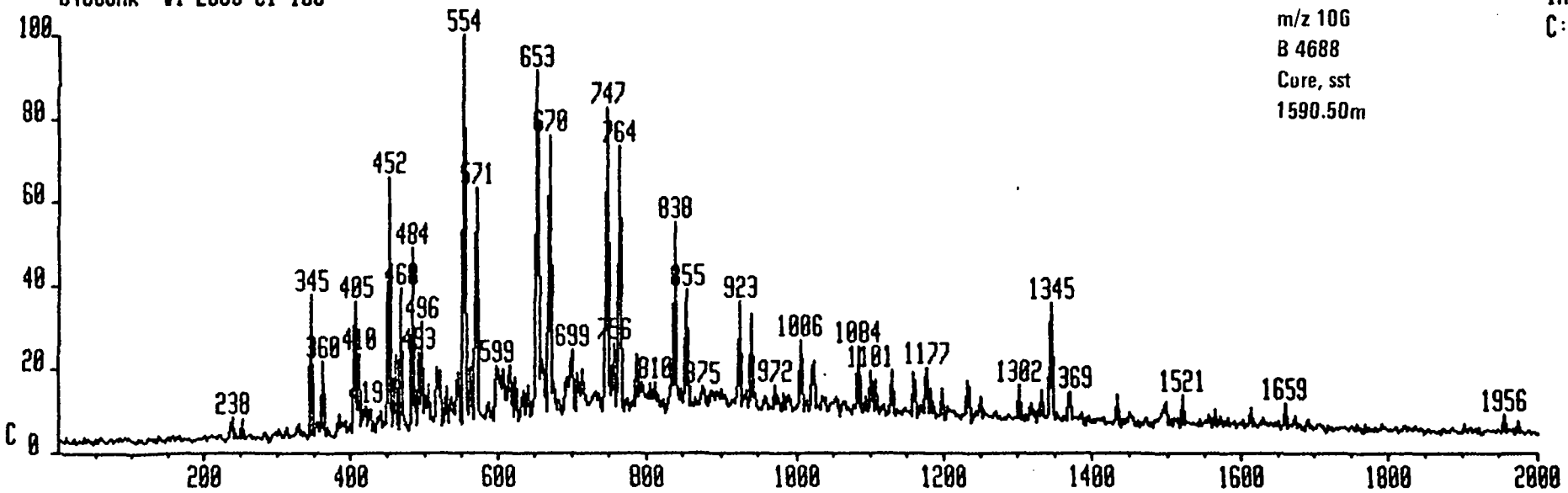
B4688AR #1-2000 B1:92



m/z 92
B 4688
Core, sst
1590.50m

IHP
B: 4378000

B4688AR #1-2000 C1:106

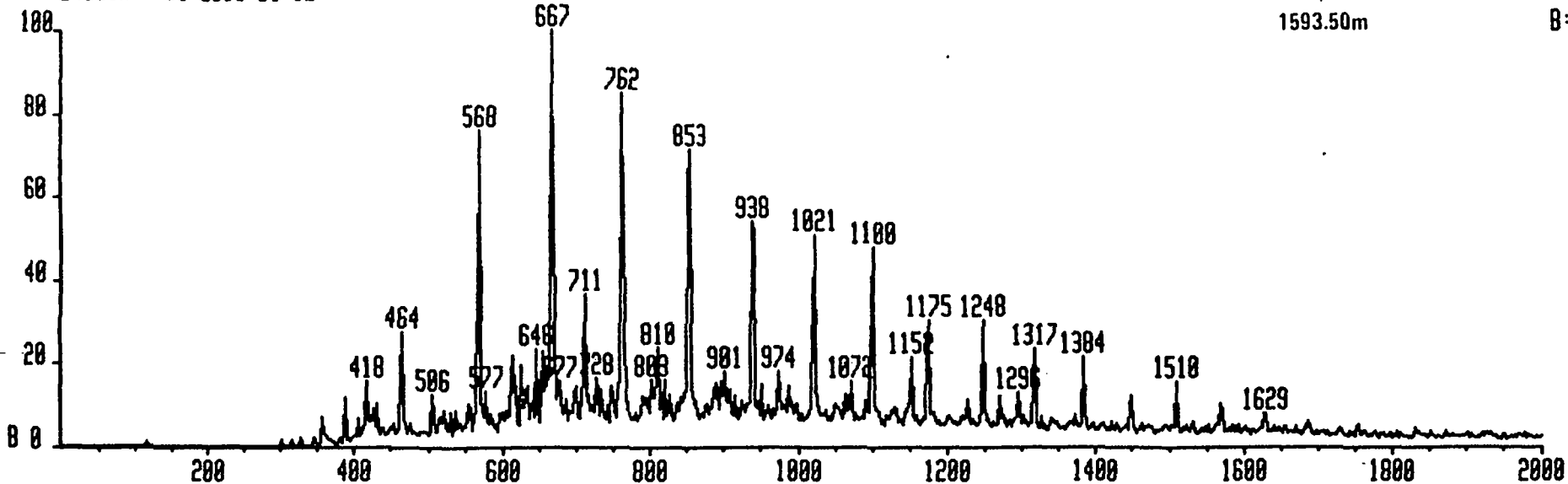


m/z 106
B 4688
Core, sst
1590.50m

IHP
C: 6002000

100

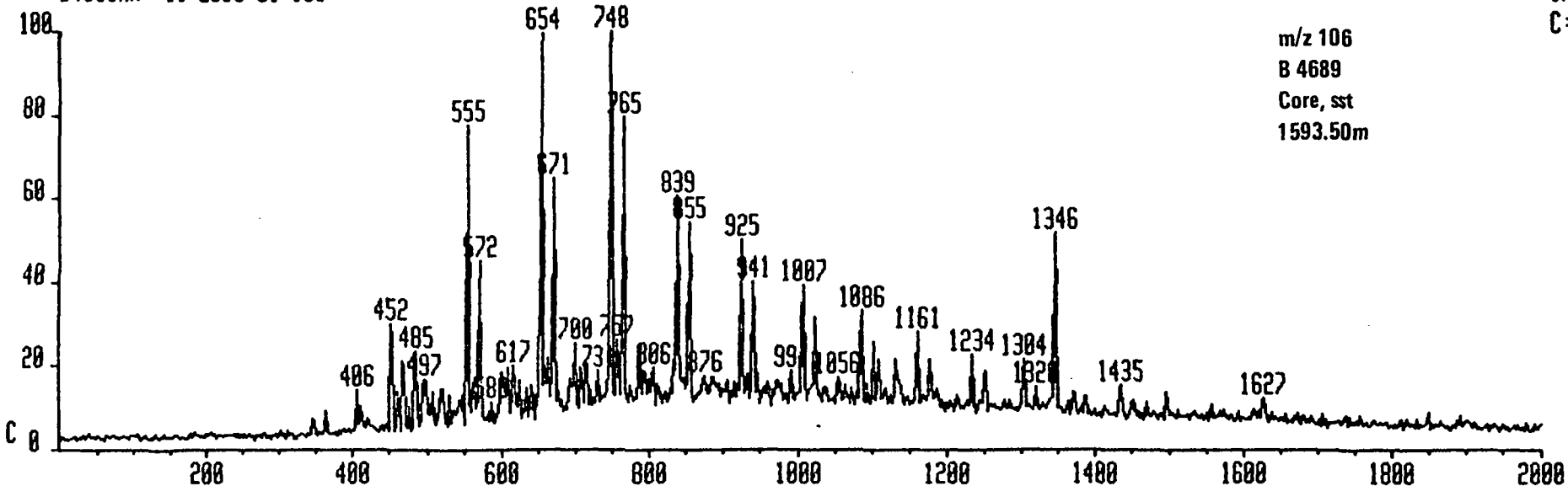
B4689AR #1-2000 B1:92



m/z 92
B 4689
Core, sst
1593.50m

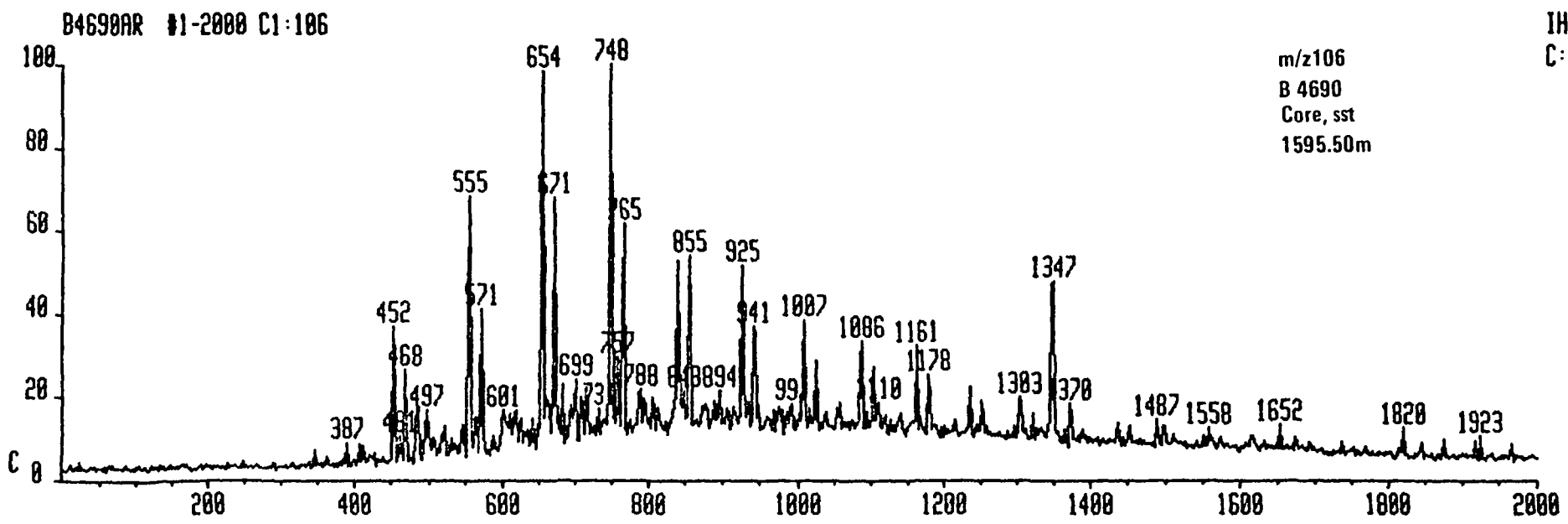
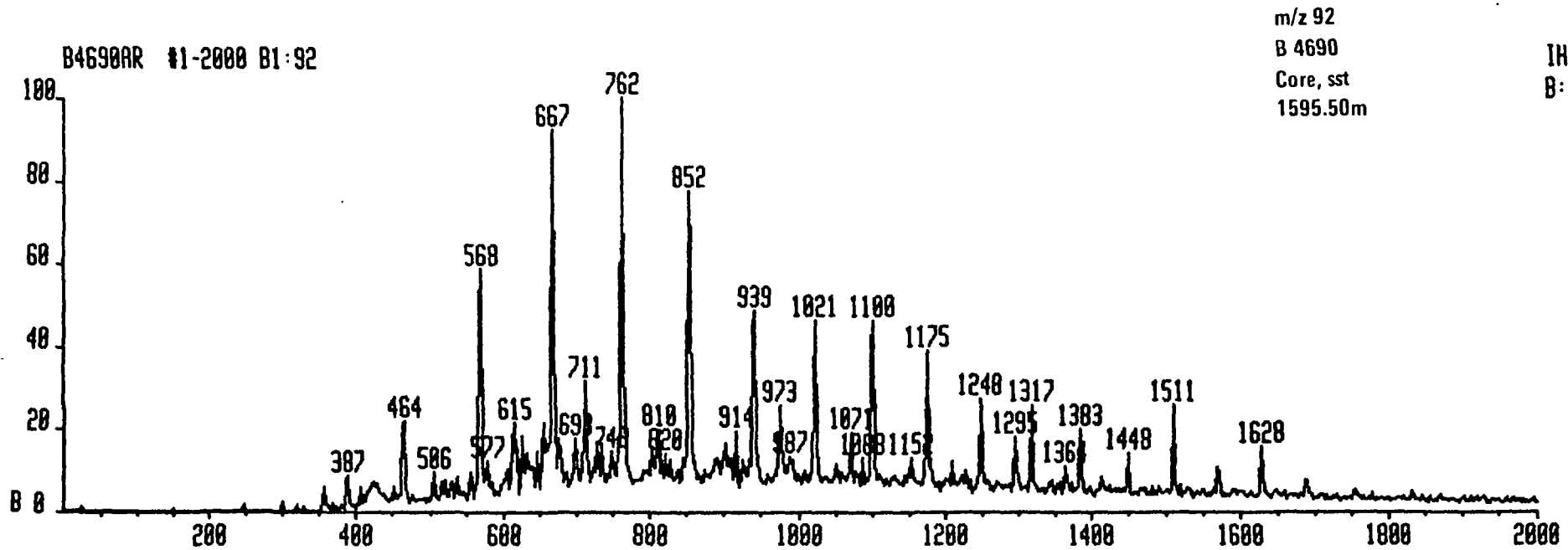
IHP
B: 4265000

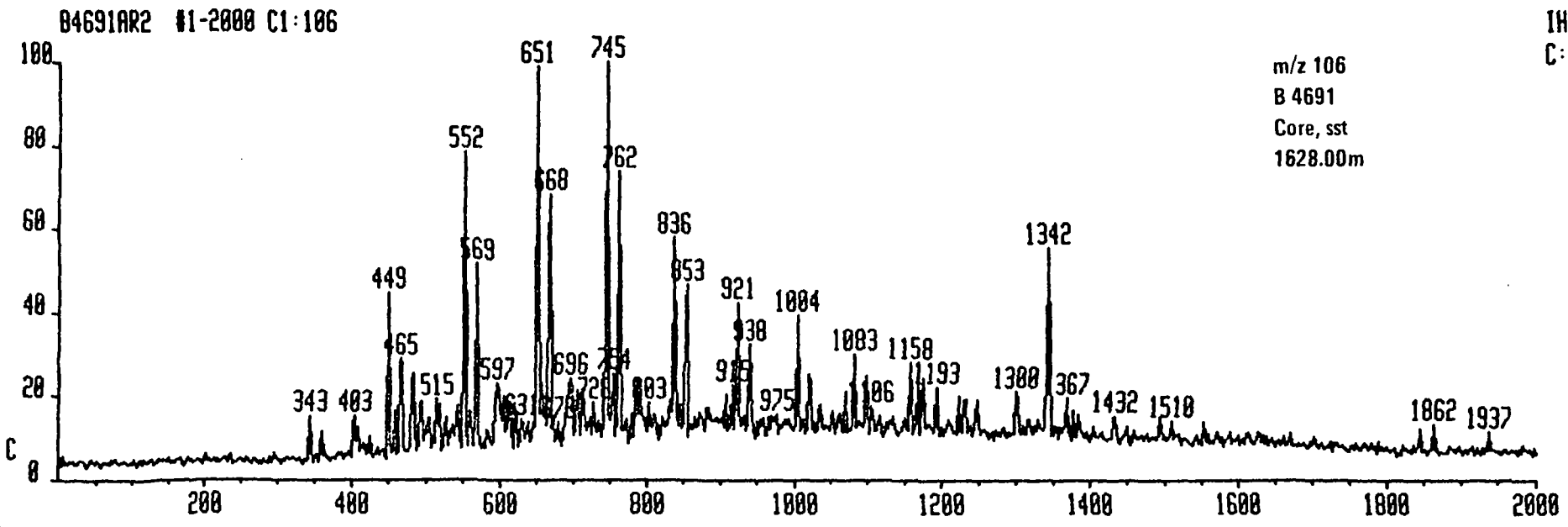
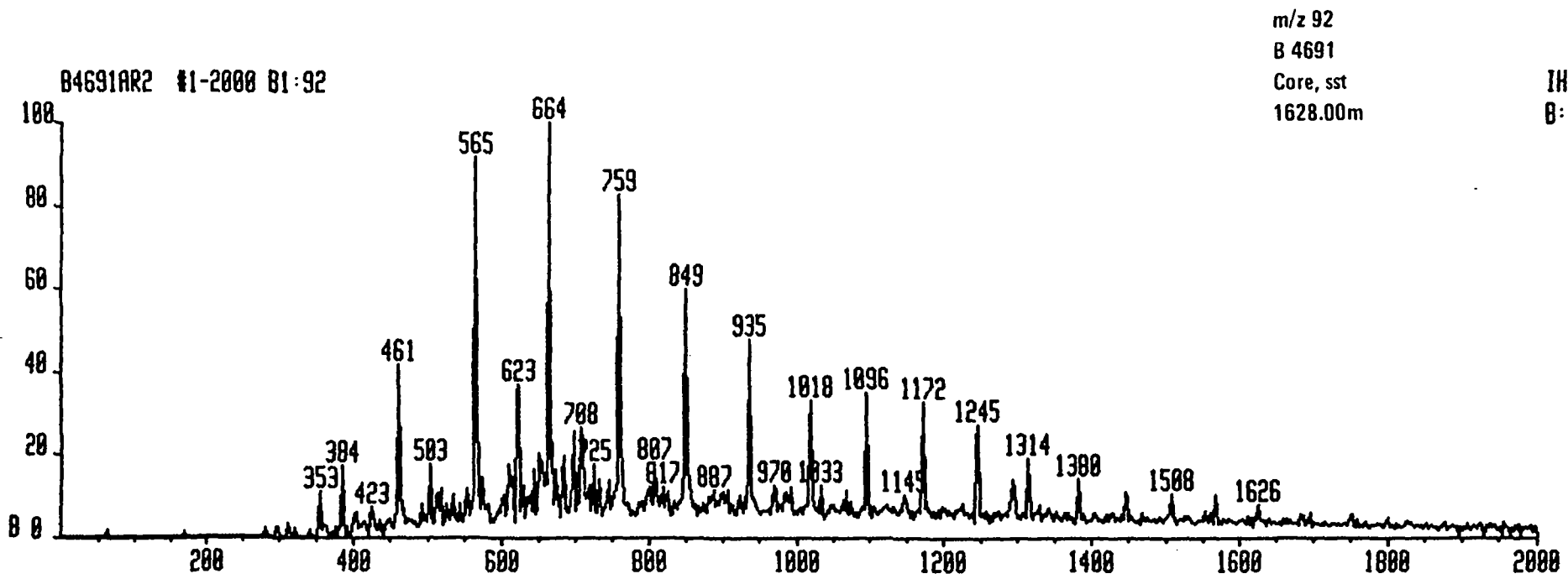
B4689AR #1-2000 C1:106



m/z 106
B 4689
Core, sst
1593.50m

IHP
C: 6103000



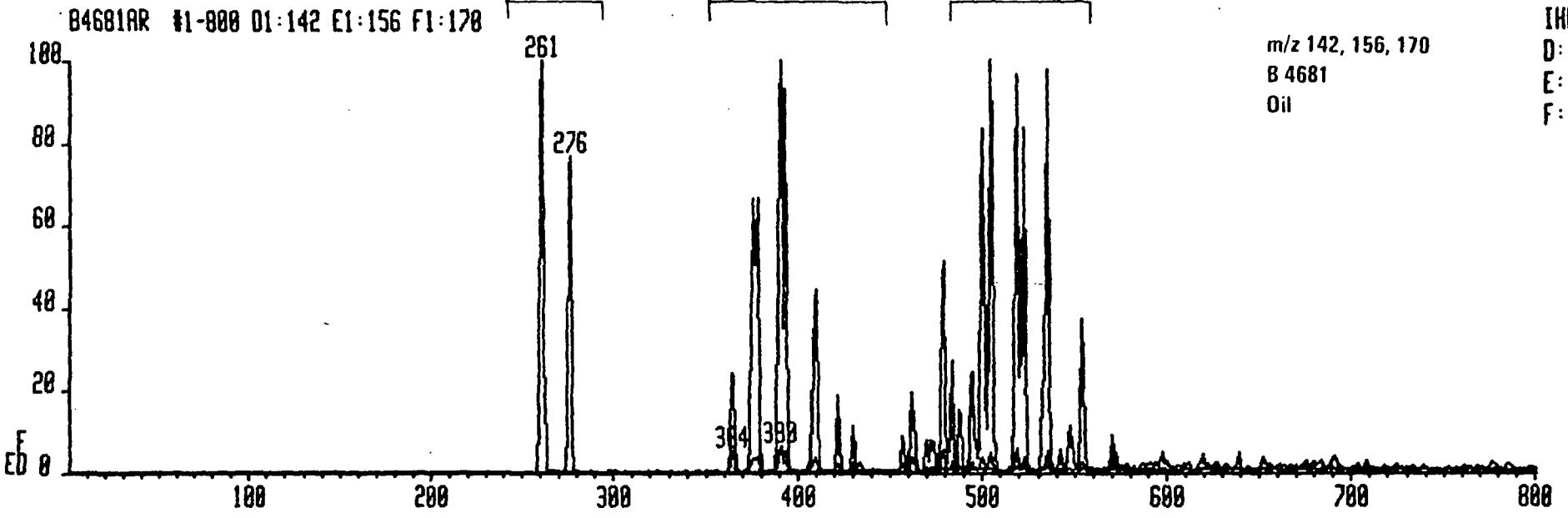


B4681AR #1-800 01:142 E1:156 F1:178

MN

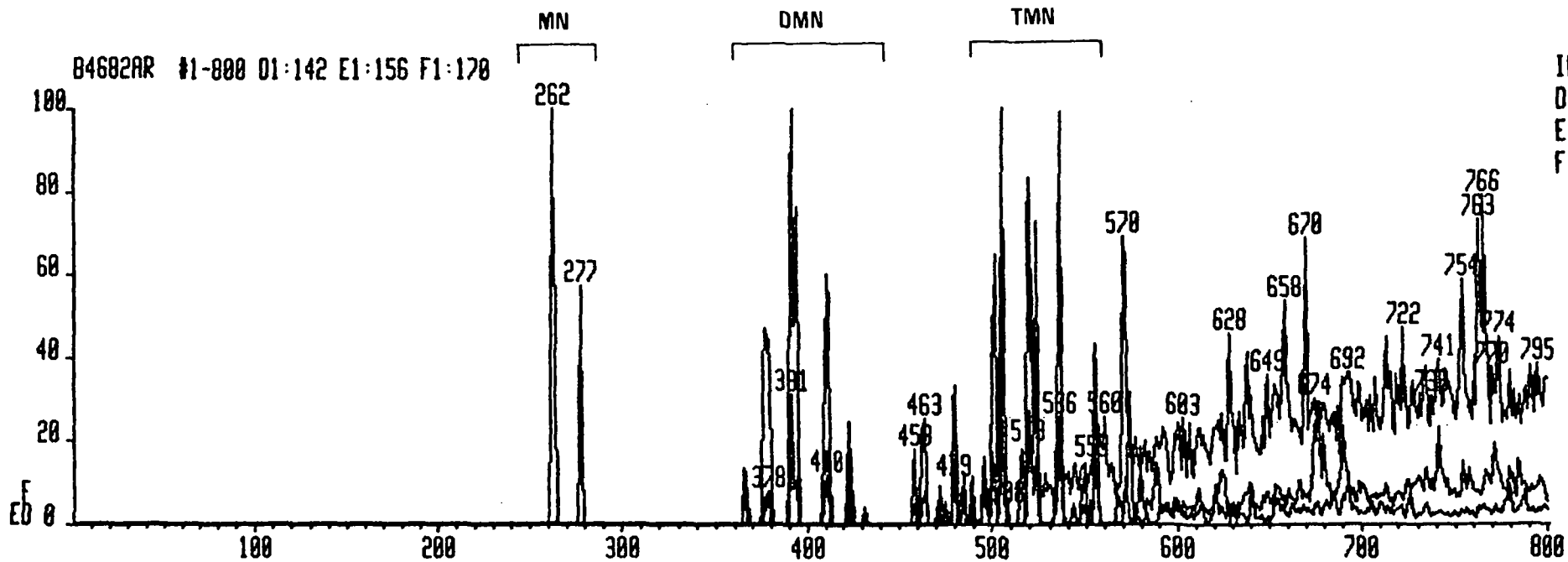
DMN

TMN



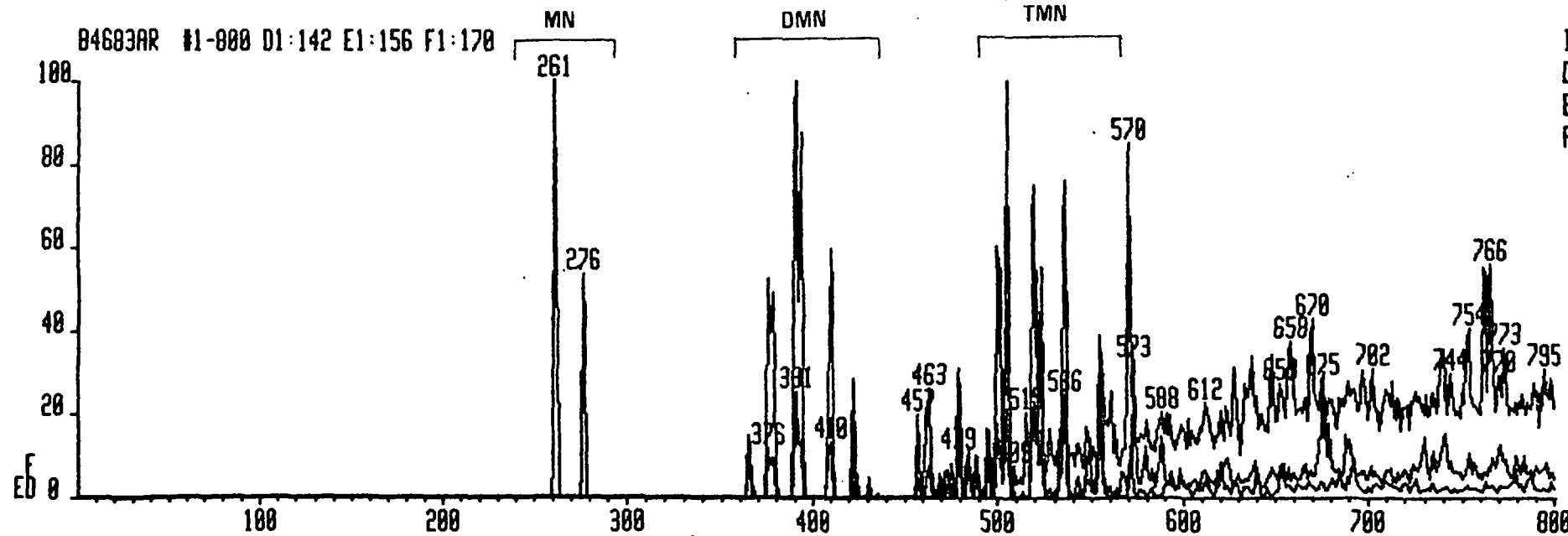
m/z 142, 156, 170
B 4681
Oil

IHP
D: 65534800
E: 52221800
F: 23686800



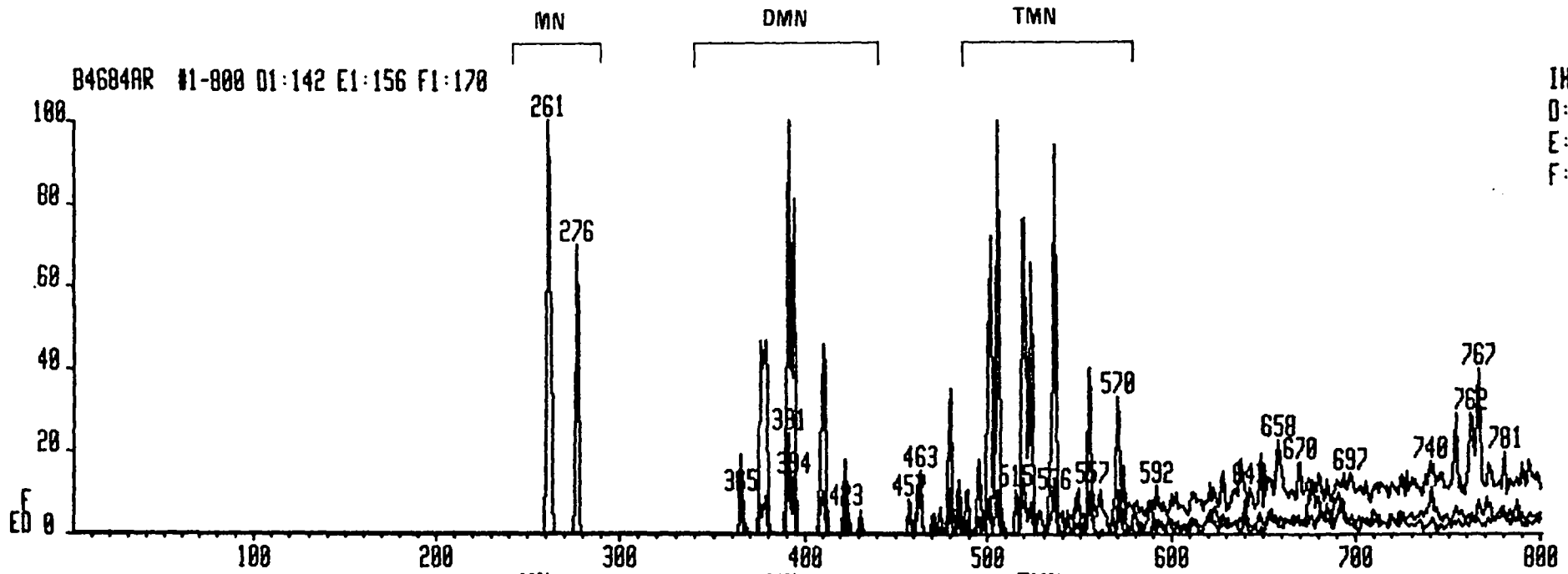
IHP
 D: 941800
 E: 2378000
 F: 5492000

m/z 142, 156, 170
 B 4682
 Core, sst
 1567.80m



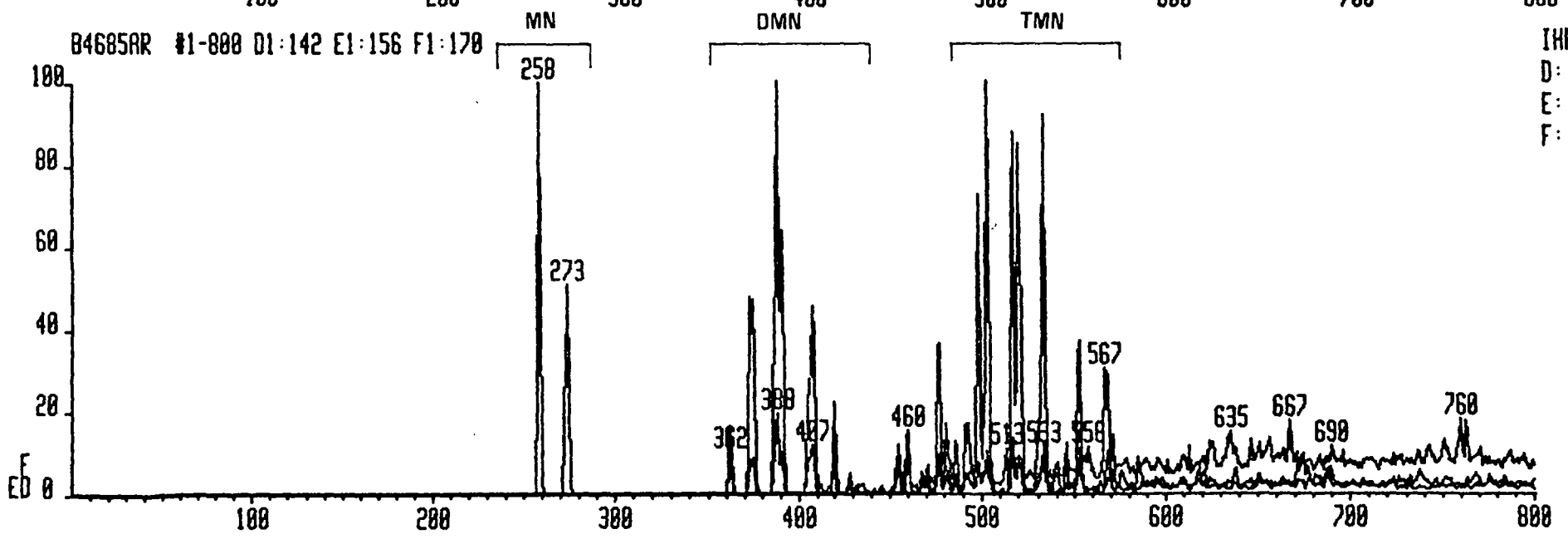
IHP
 D: 1312000
 E: 3435000
 F: 8220000

m/z 142, 156, 170
 B 4683
 Core, sst
 1571.50m



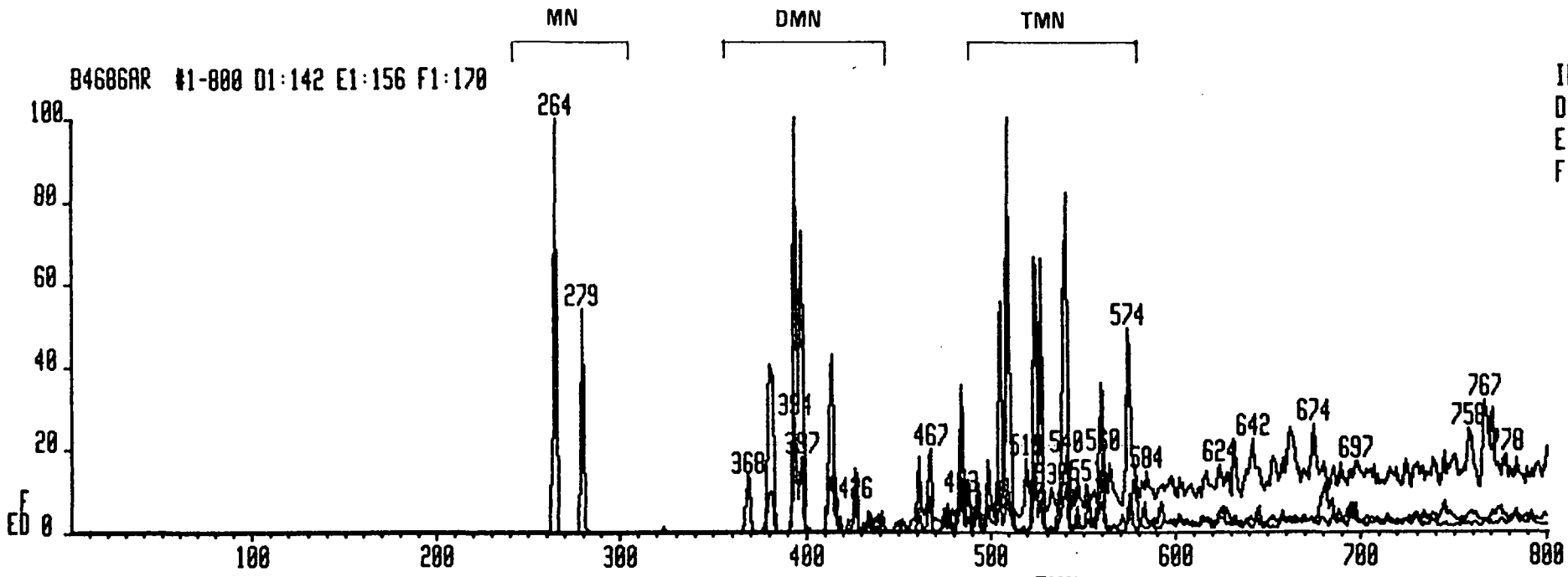
IHP
 D: 2003000
 E: 4655000
 F: 5721000

m/z 142, 156, 170
 B 4684
 Core, sst
 1573.95m



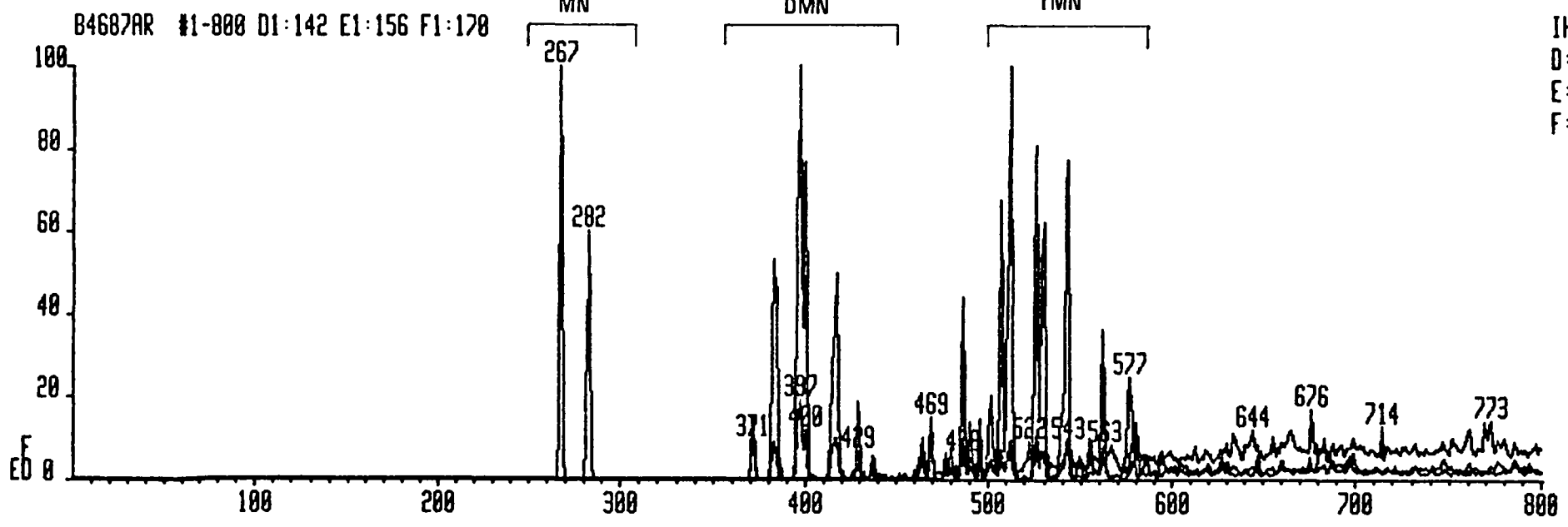
IHP
 D: 4682000
 E: 11676000
 F: 13197000

m/z 142, 156, 170
 B 4685
 Core, sst
 1581.65m



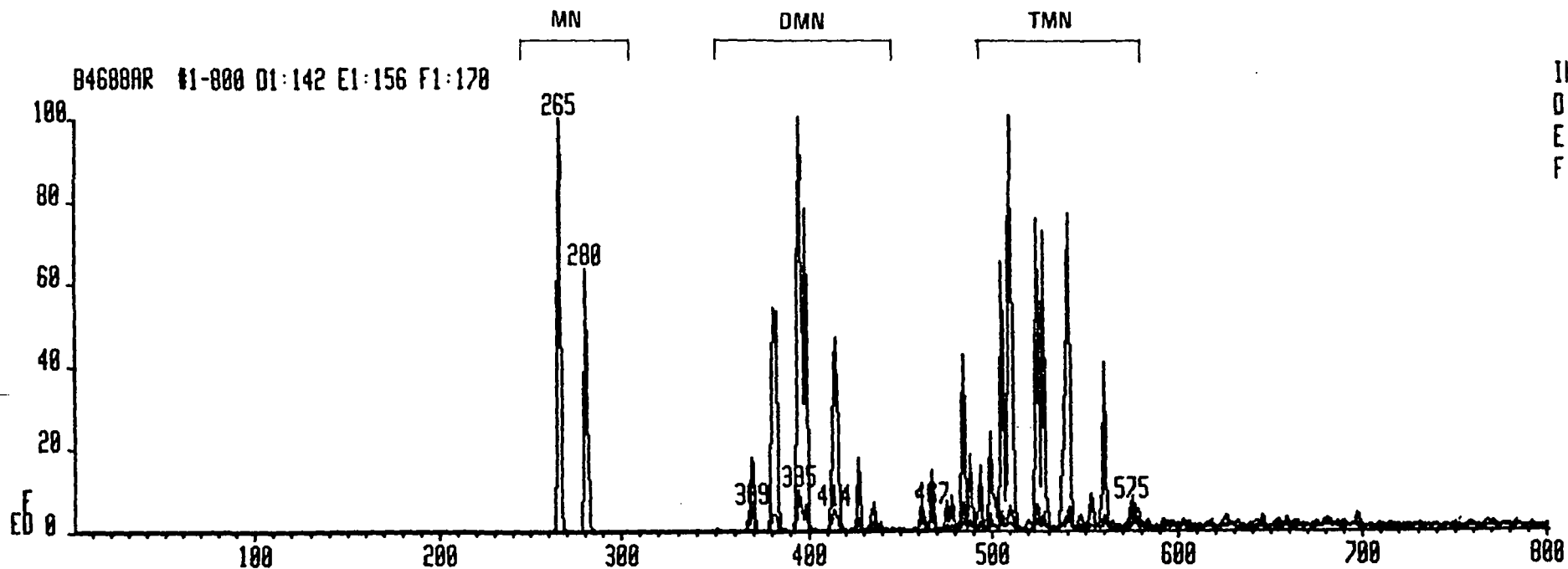
IHP
D: 3355000
E: 1119000
F: 14606000

m/z 142, 156, 170
B 4686
Core, sst
1586.40m



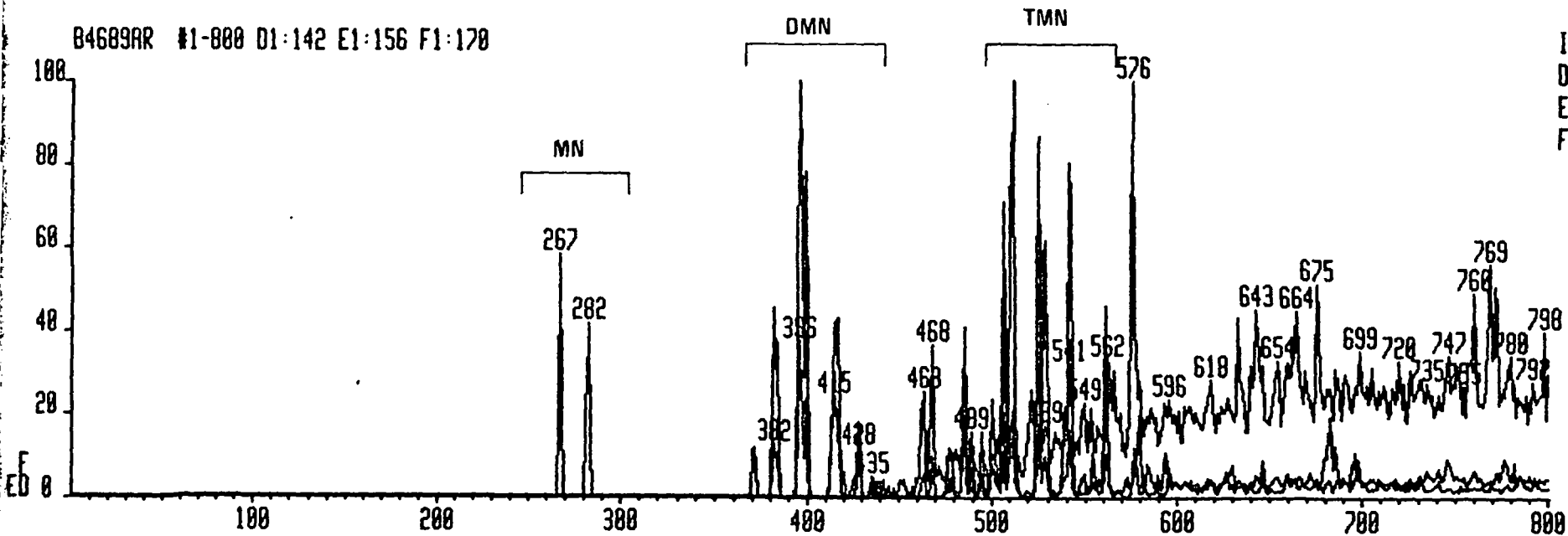
IHP
D: 5644000
E: 13065000
F: 13781000

m/z 142, 156, 170
B 4687
Core, sst
1587.50m



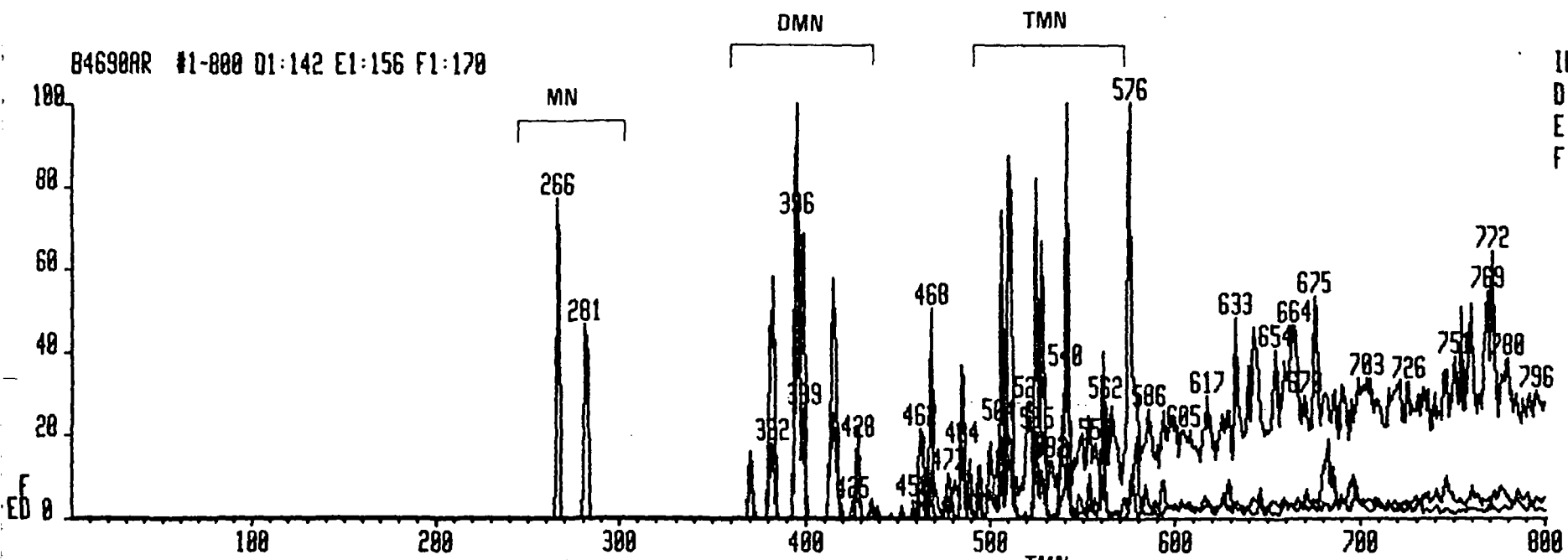
IHP
 D: 43039000
 E: 58595000
 F: 32426000

m/z 142, 156, 170
 B 4688
 Core, sst
 1590.50m



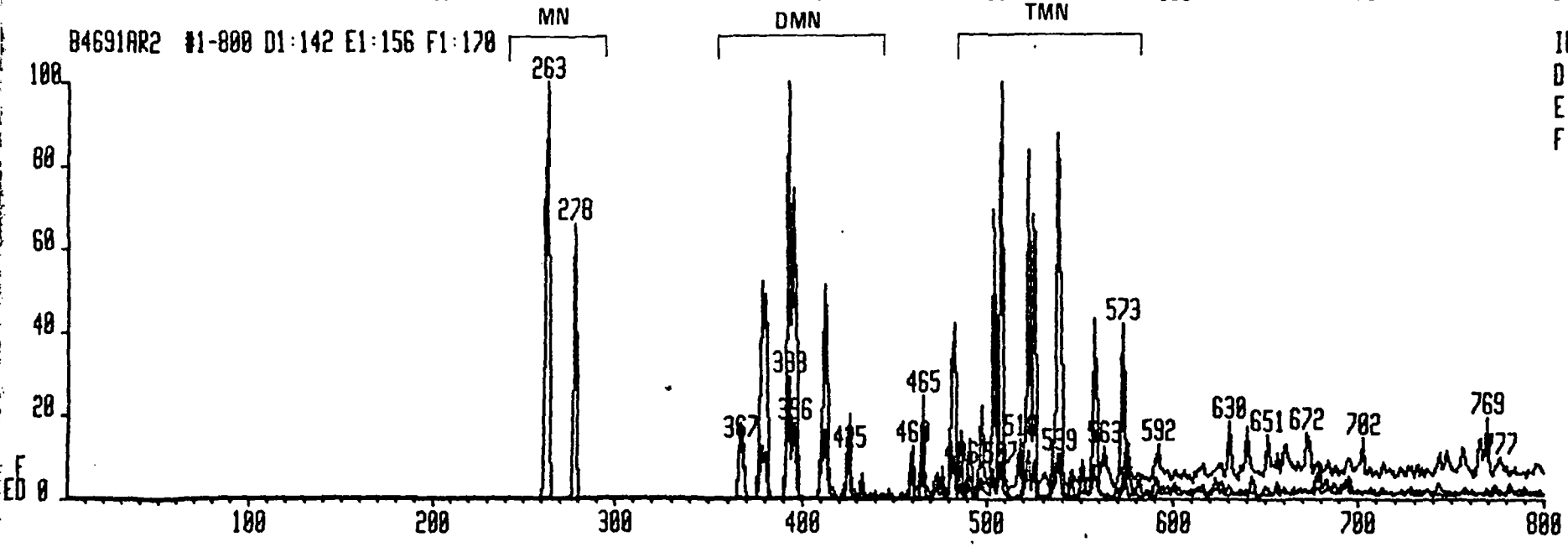
IHP
 D: 18800000
 E: 82100000
 F: 12634000

m/z 142, 156, 170
 B 4689
 Core, sst
 1593.50m



IHP
D: 1515000
E: 756000
F: 12024000

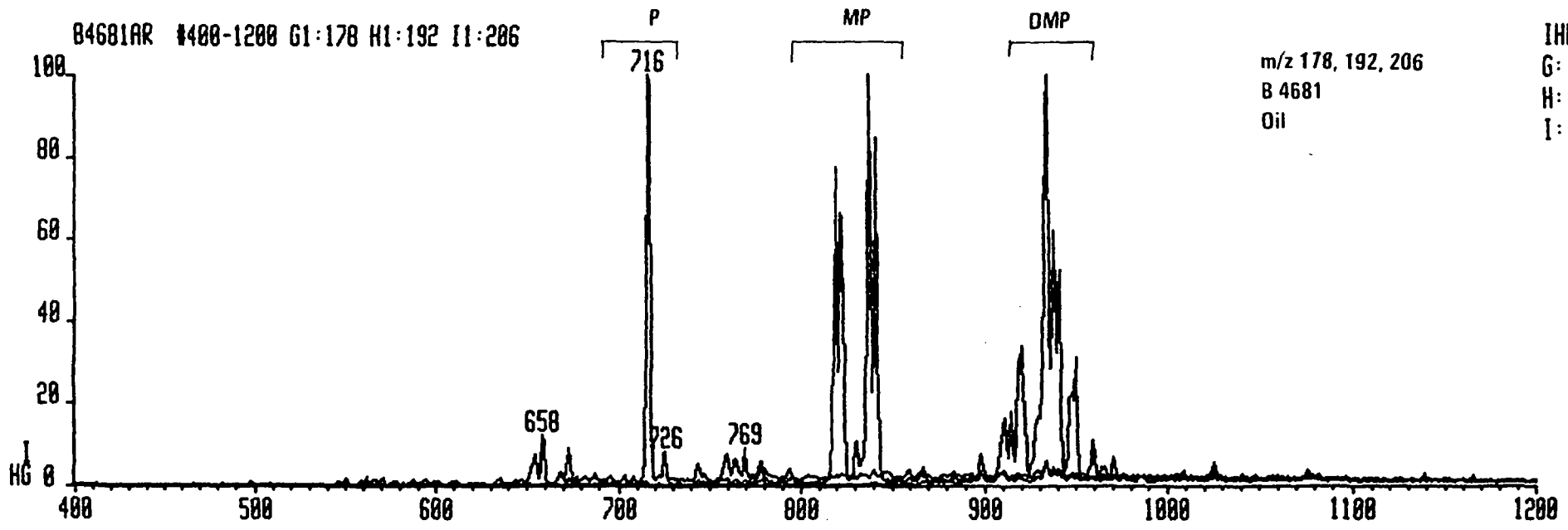
m/z 142, 156, 170
B 4690
Core, sst
1595.50m



IHP
D: 4099000
E: 1446000
F: 14376000

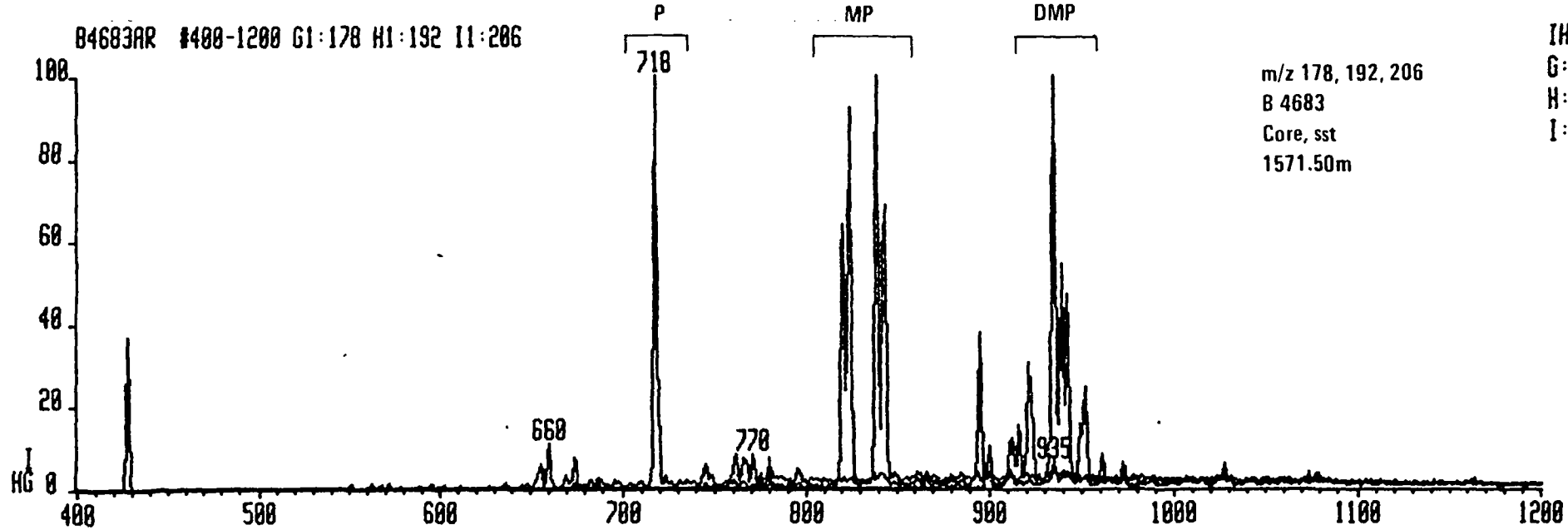
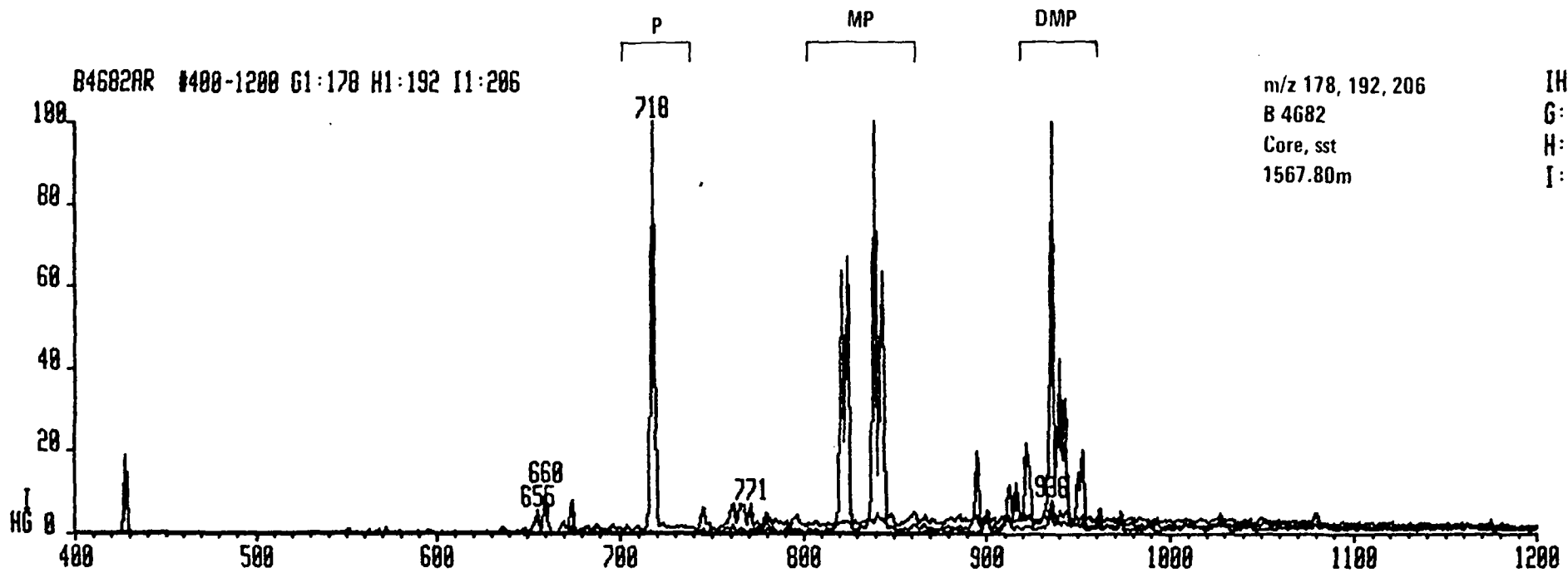
m/z 142, 156, 170
B 4691
Core, sst
1628.00m

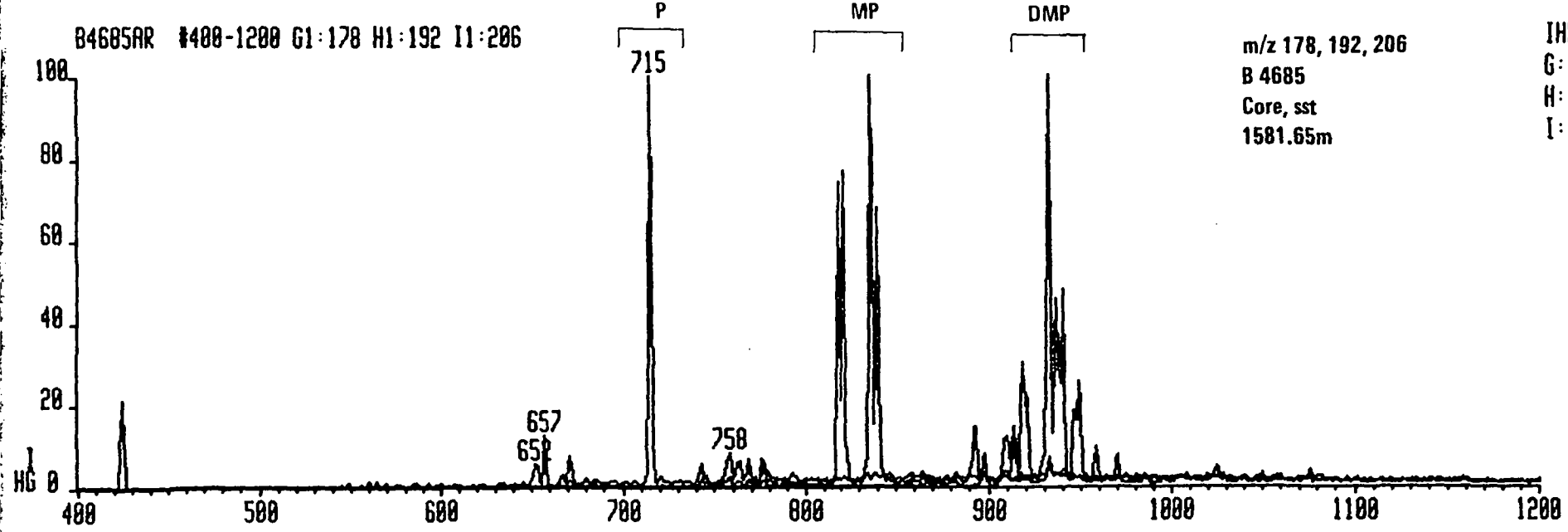
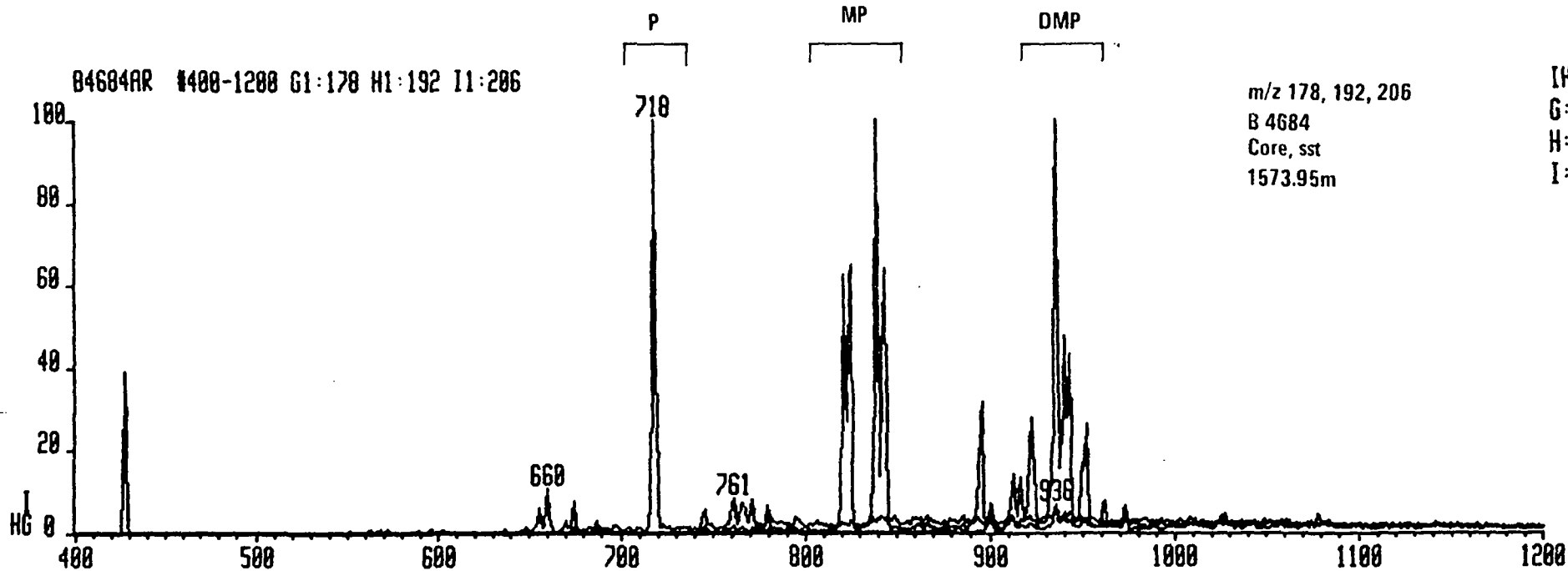
B4681AR #400-1200 G1:178 H1:192 I1:206

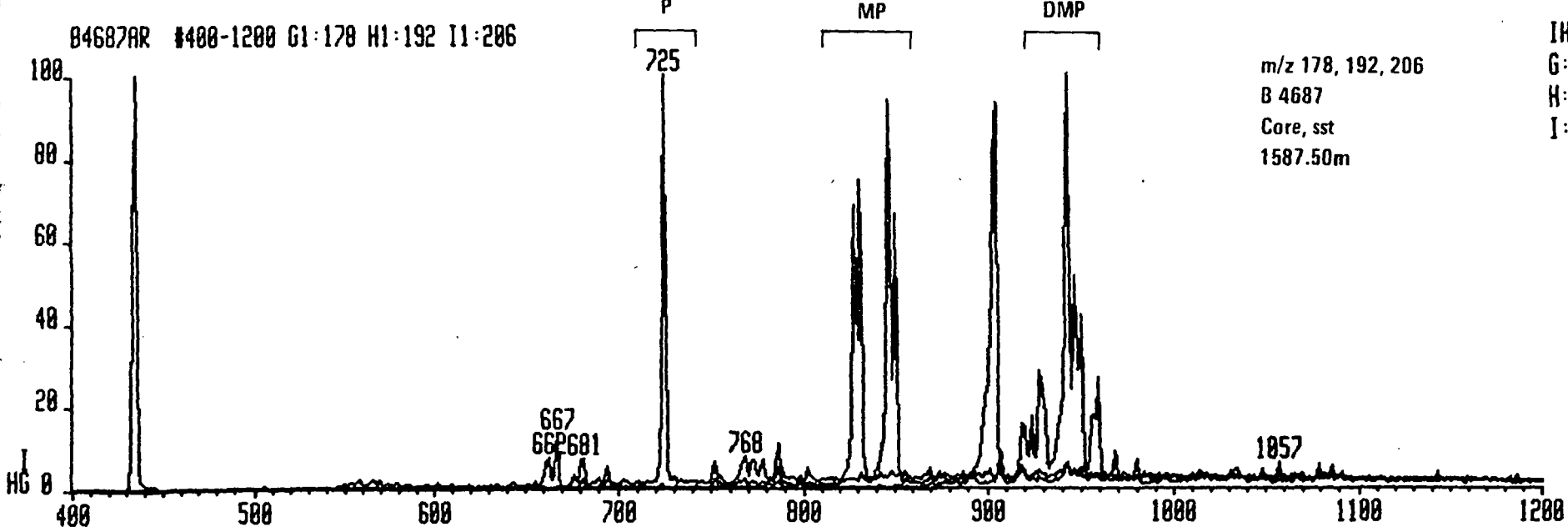
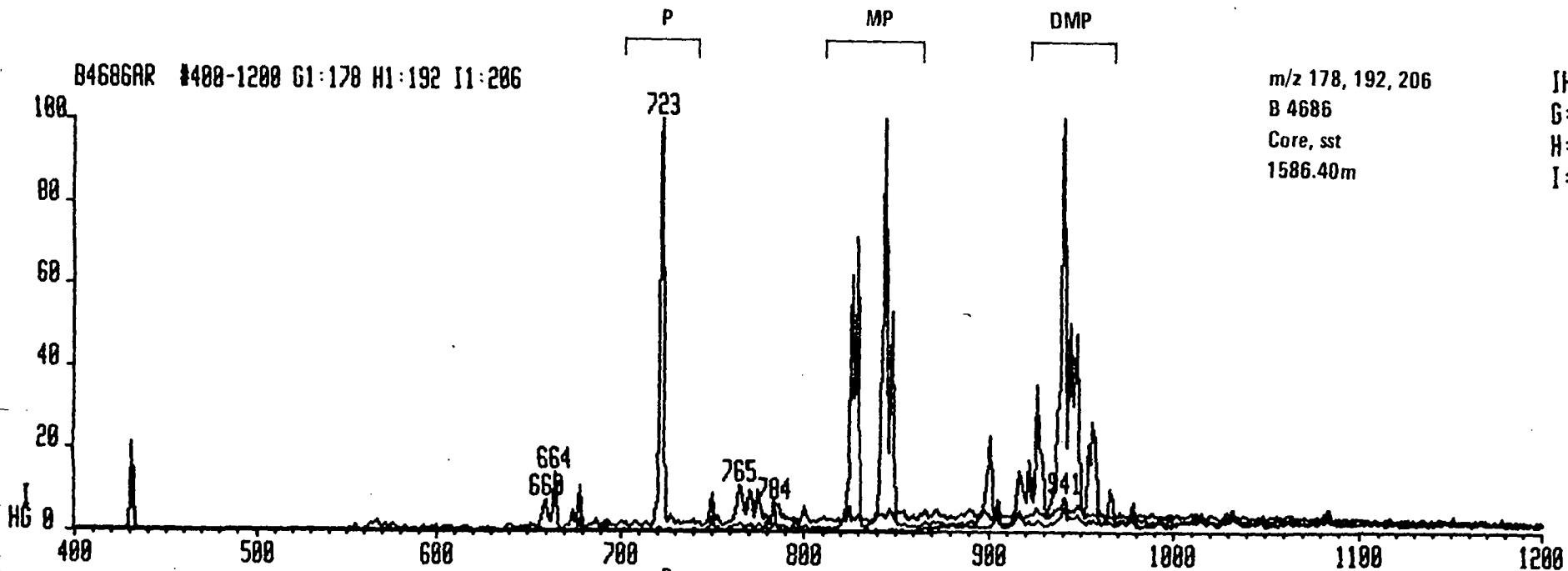


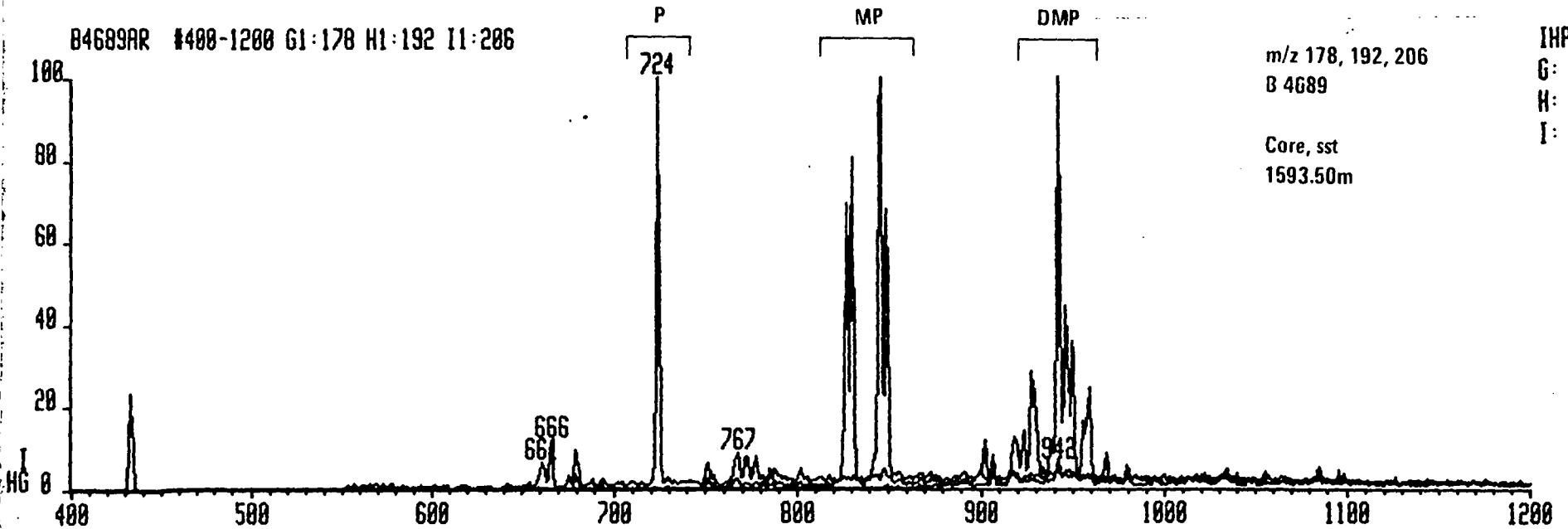
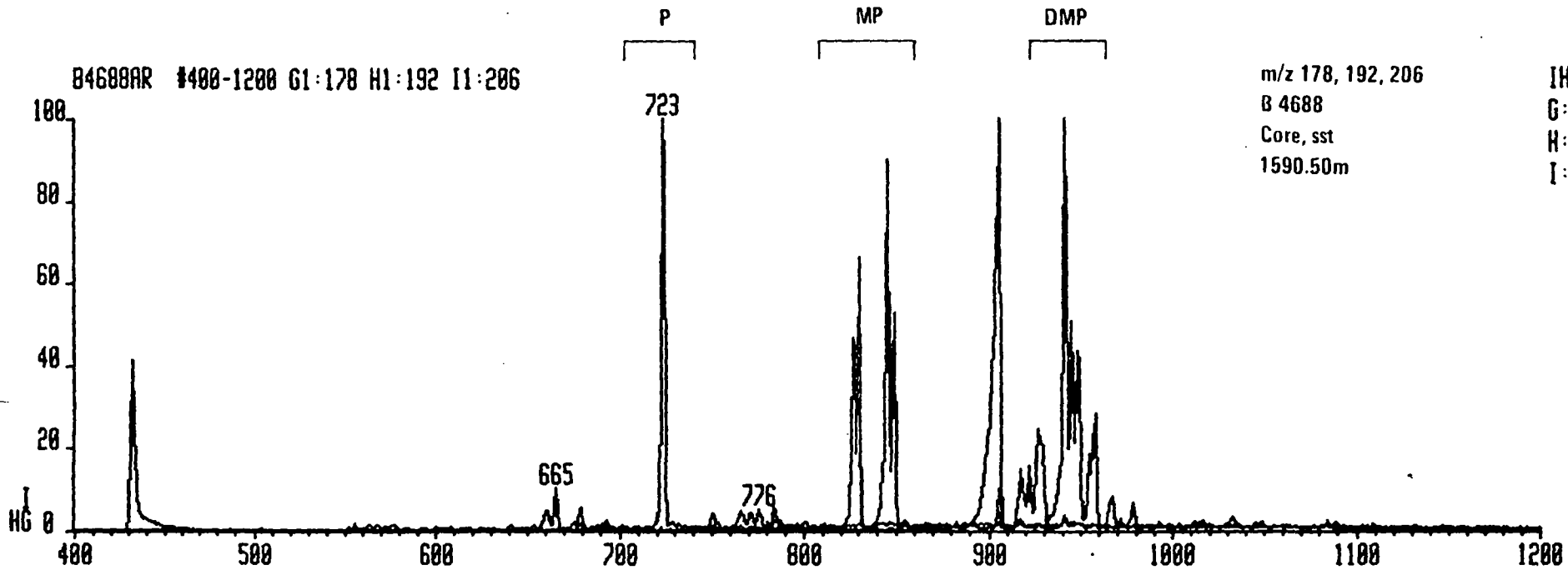
m/z 178, 192, 206
B 4681
Oil

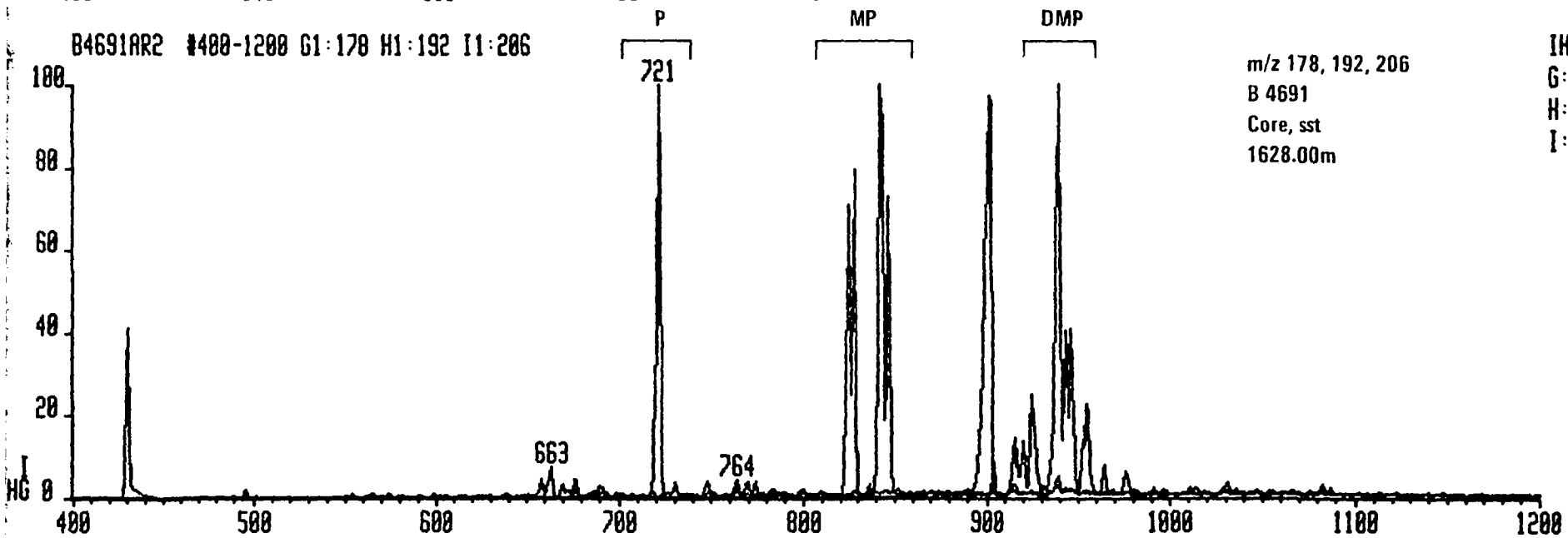
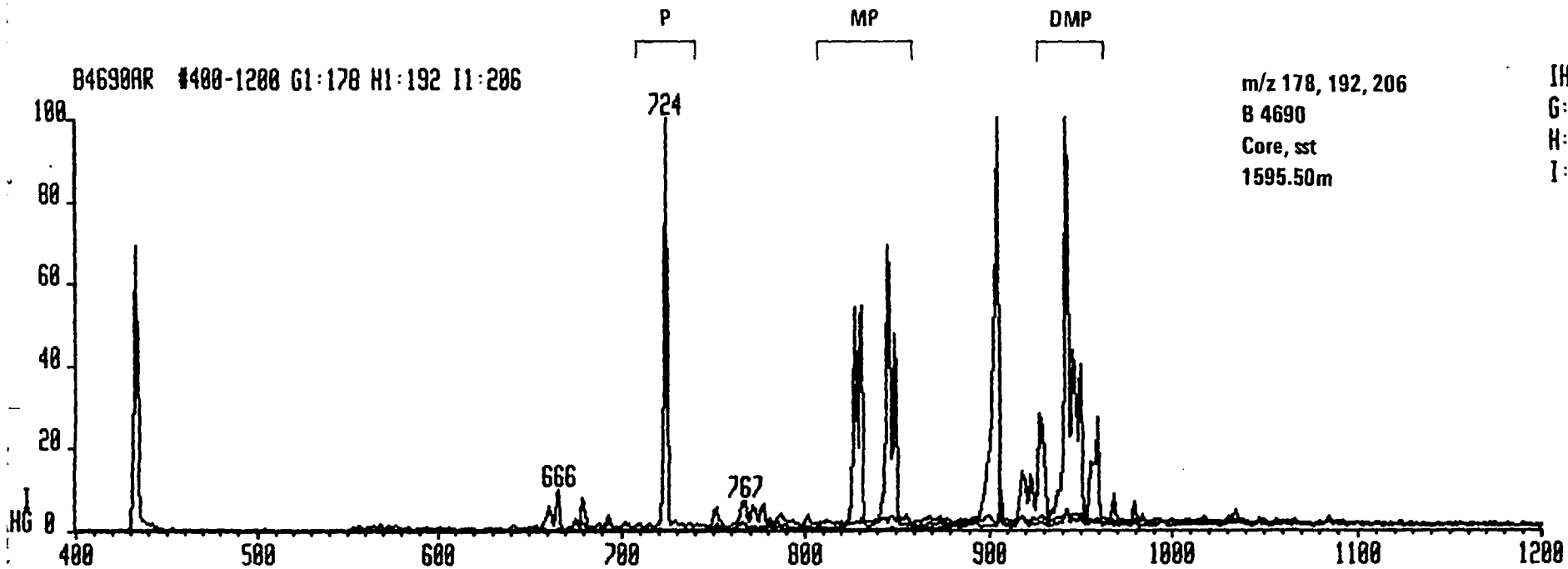
IHP
G: 24652888
H: 17887888
I: 13685888



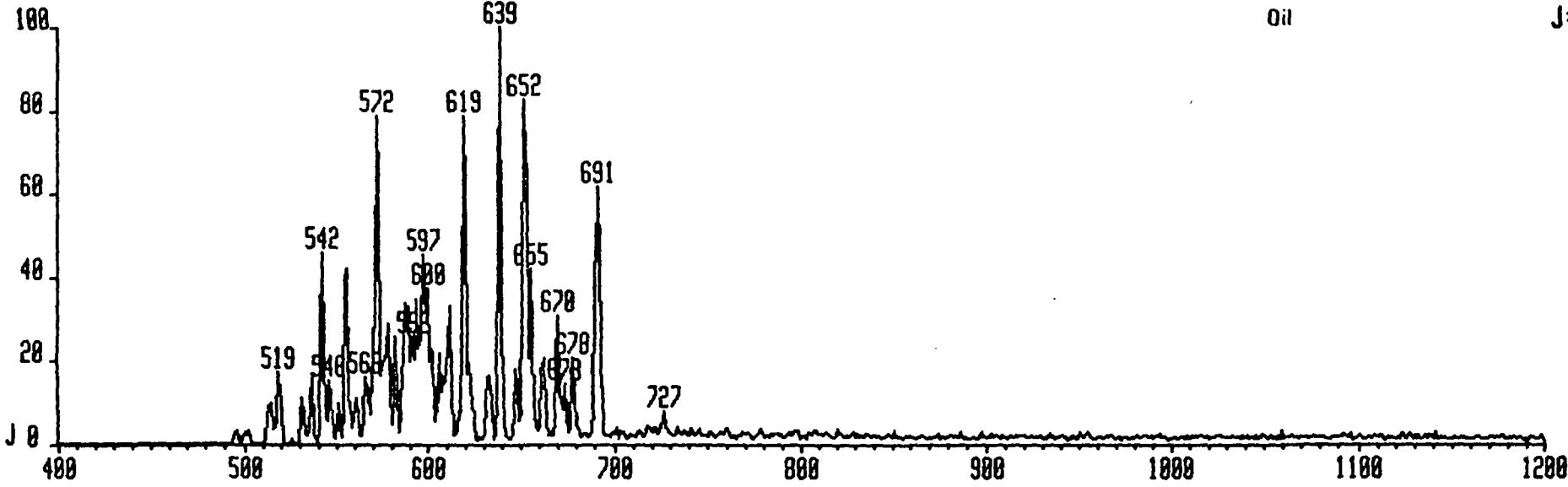








B4681AR #400-1200 J1:184



m/z 184

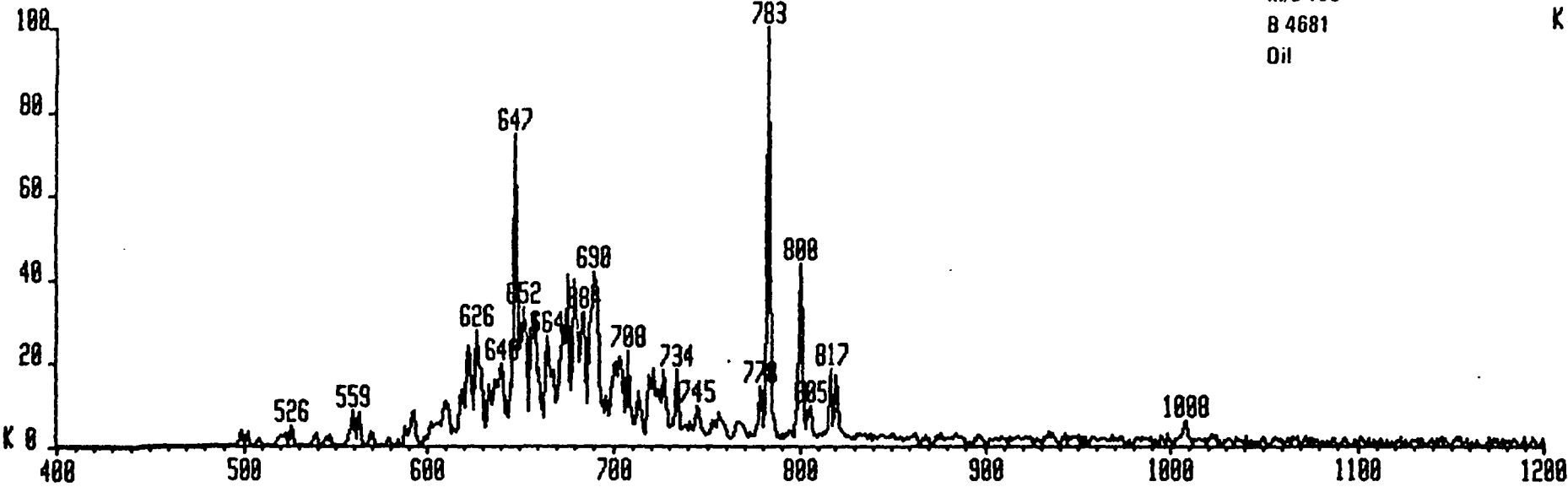
B 4681

Oil

IHP

J: 7166000

B4681AR #400-1200 K1:198



m/z 198

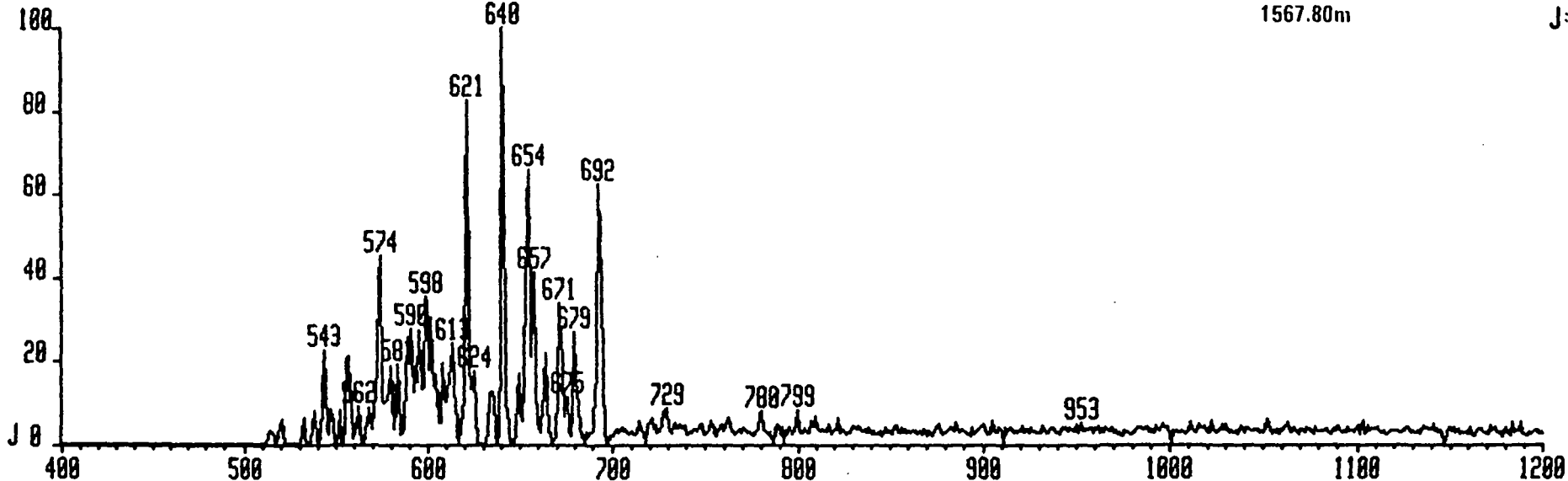
B 4681

Oil

IHP

K: 4430000

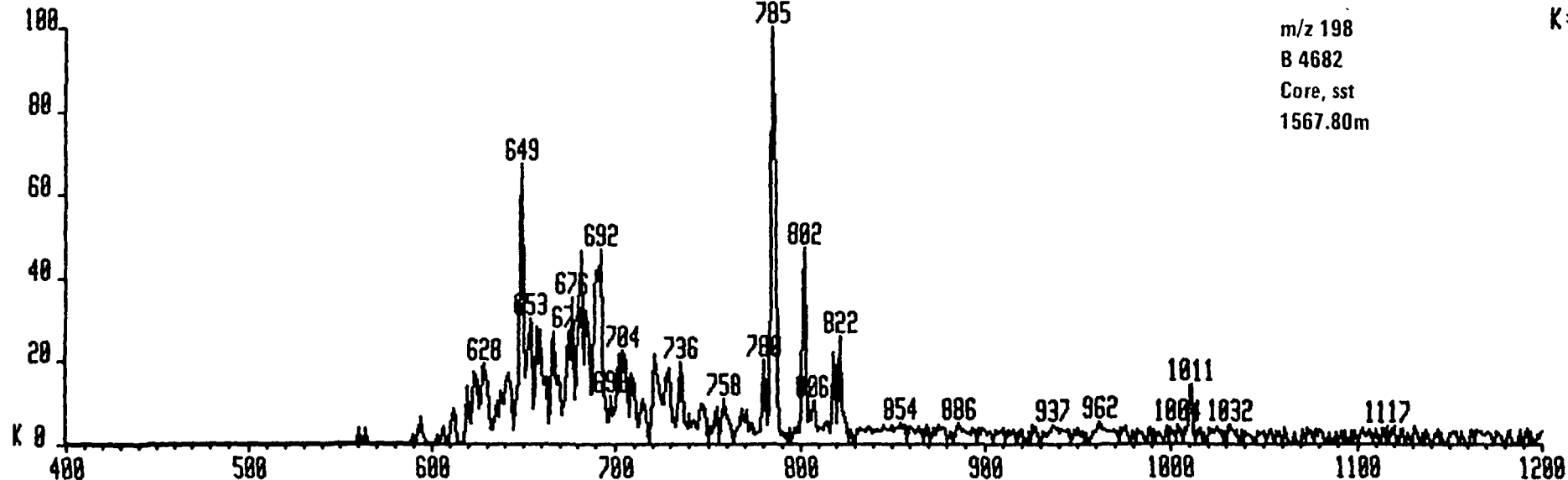
B4682AR #400-1200 J1:184



m/z 184
B 4682
Core, sst
1567.80m

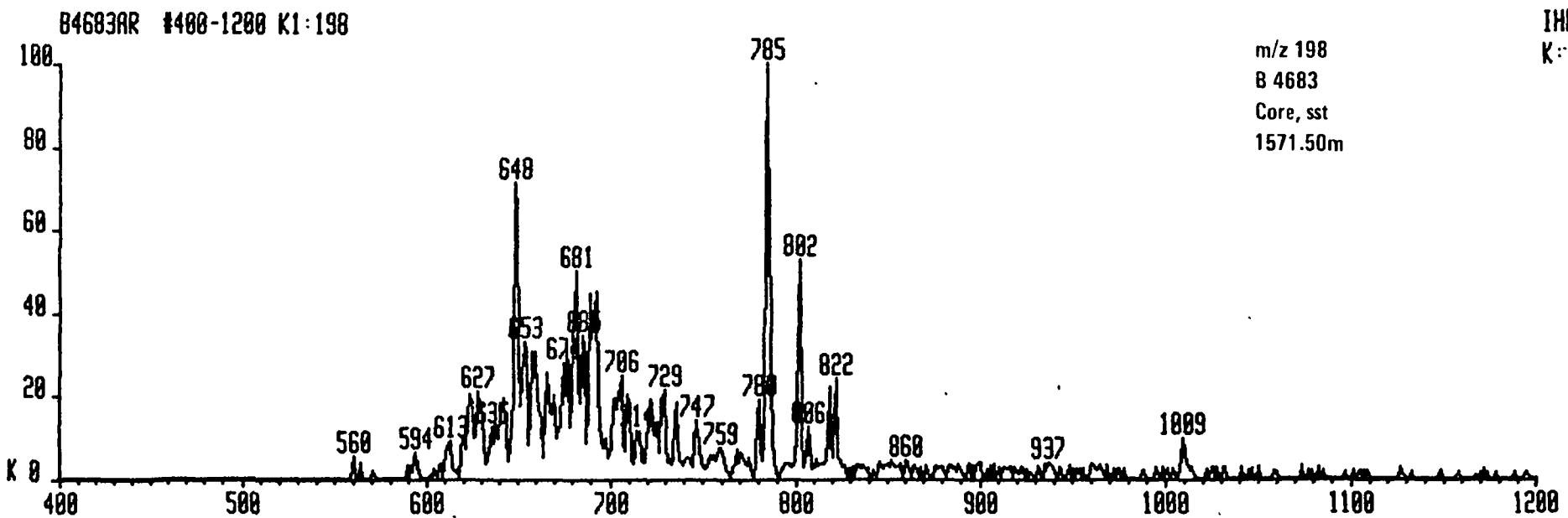
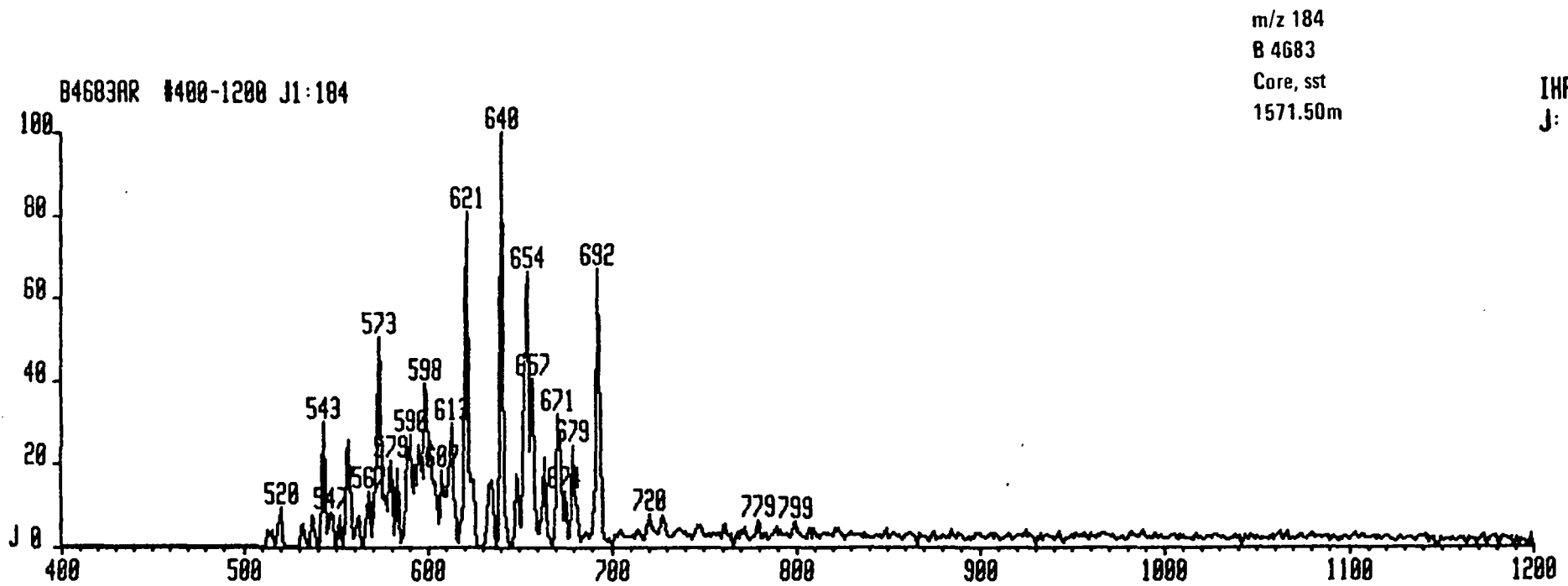
IHP
J: 3490000

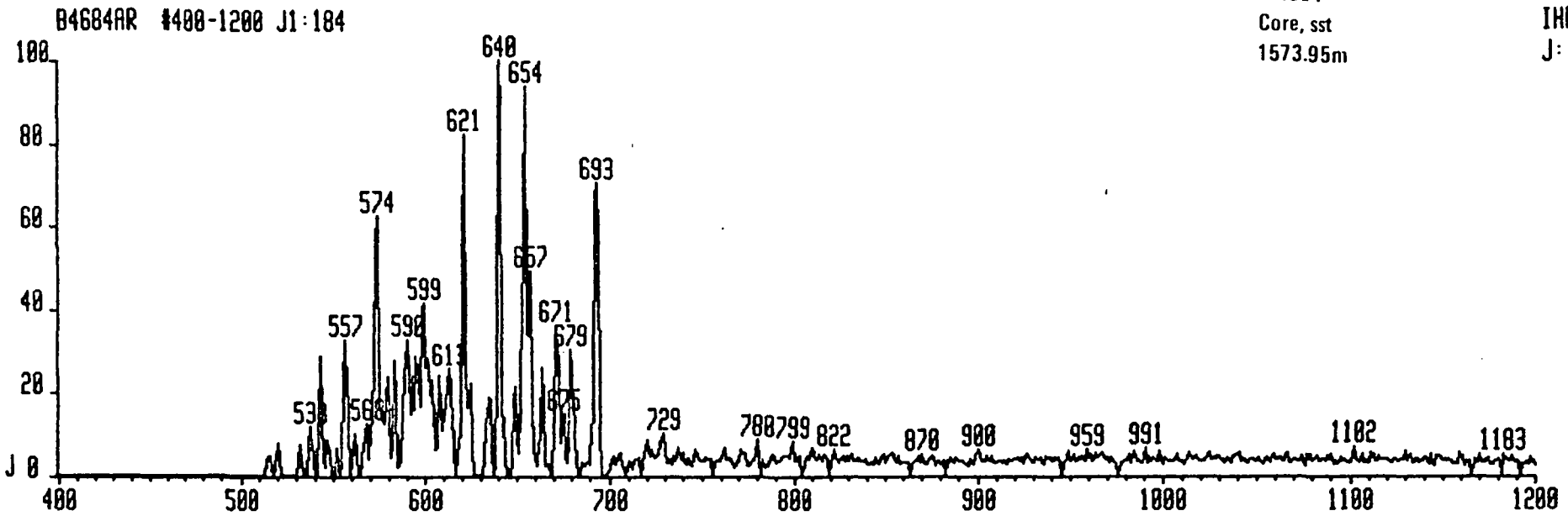
B4682AR #400-1200 K1:198



m/z 198
B 4682
Core, sst
1567.80m

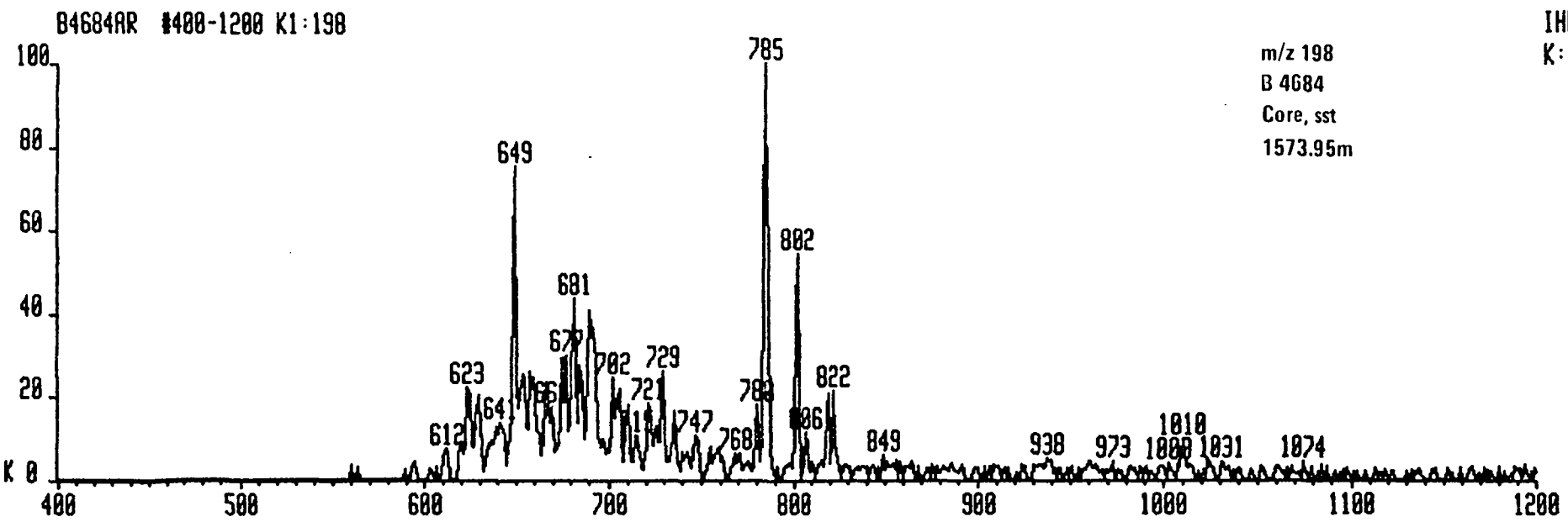
IHP
K: 2650000





m/z 184
 B 4684
 Core, sst
 1573.95m

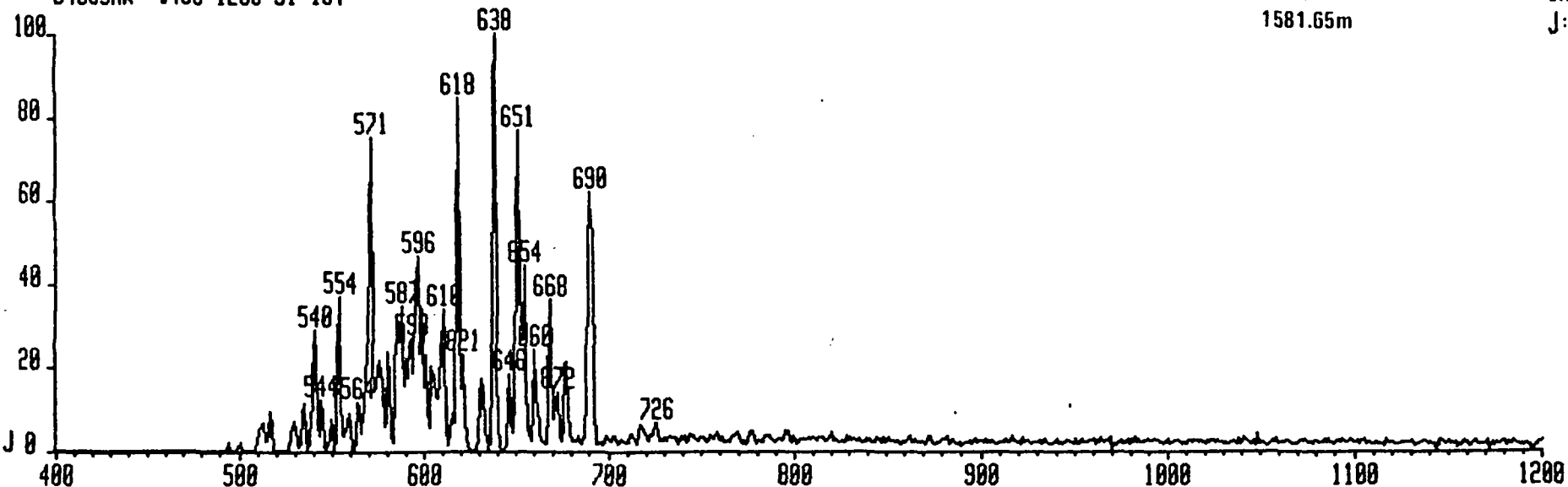
IHP
 J: 2667000



m/z 198
 B 4684
 Core, sst
 1573.95m

IHP
 K: 2527000

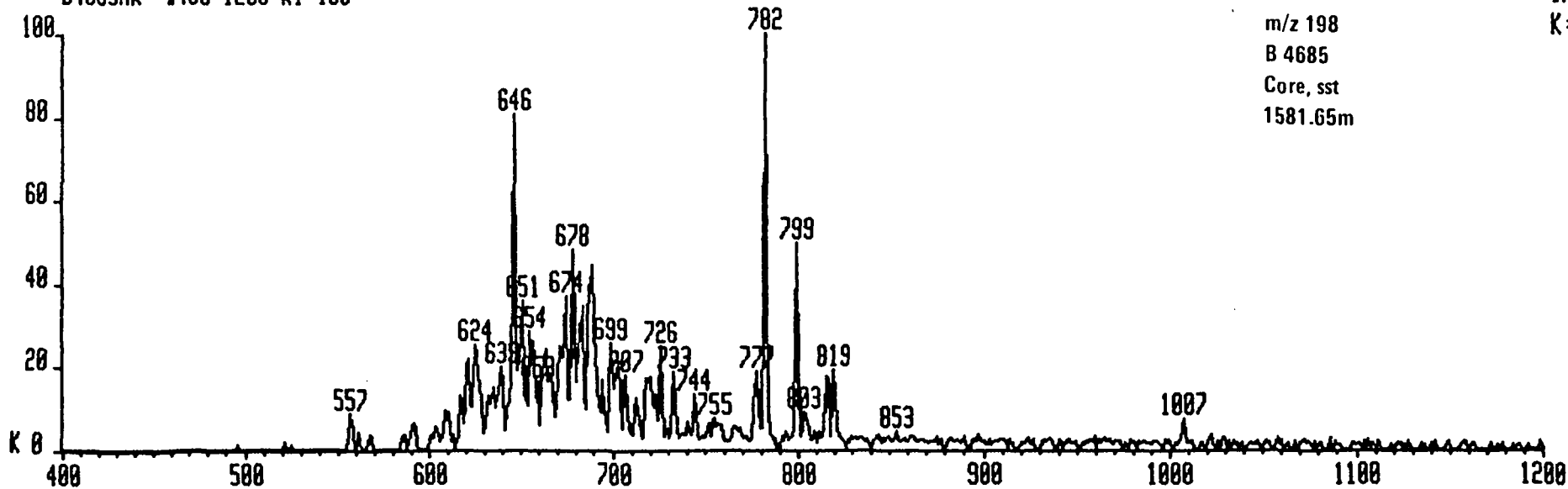
B4685AR #400-1200 J1:184



m/z 184
B 4685
Core, sst
1581.65m

IHP
J: 5481000

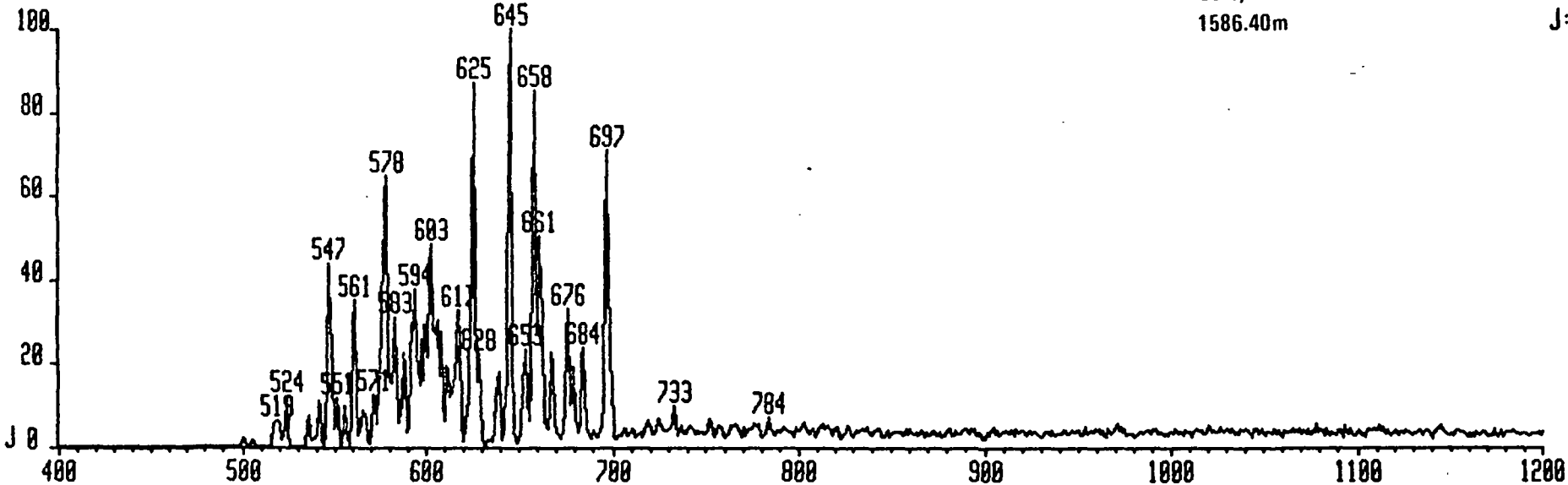
B4685AR #400-1200 K1:198



m/z 198
B 4685
Core, sst
1581.65m

IHP
K: 3859000

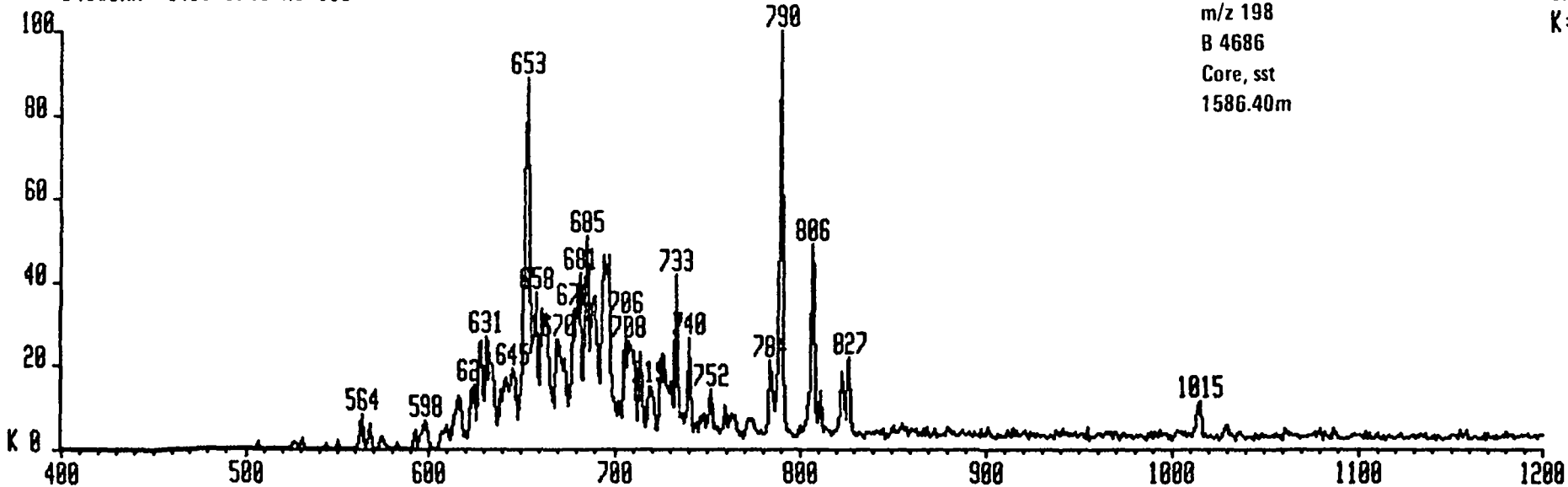
B4686AR #400-1200 J1:184



m/z 184
B 4686
Core, sst
1586.40m

IHP
J: 5466000

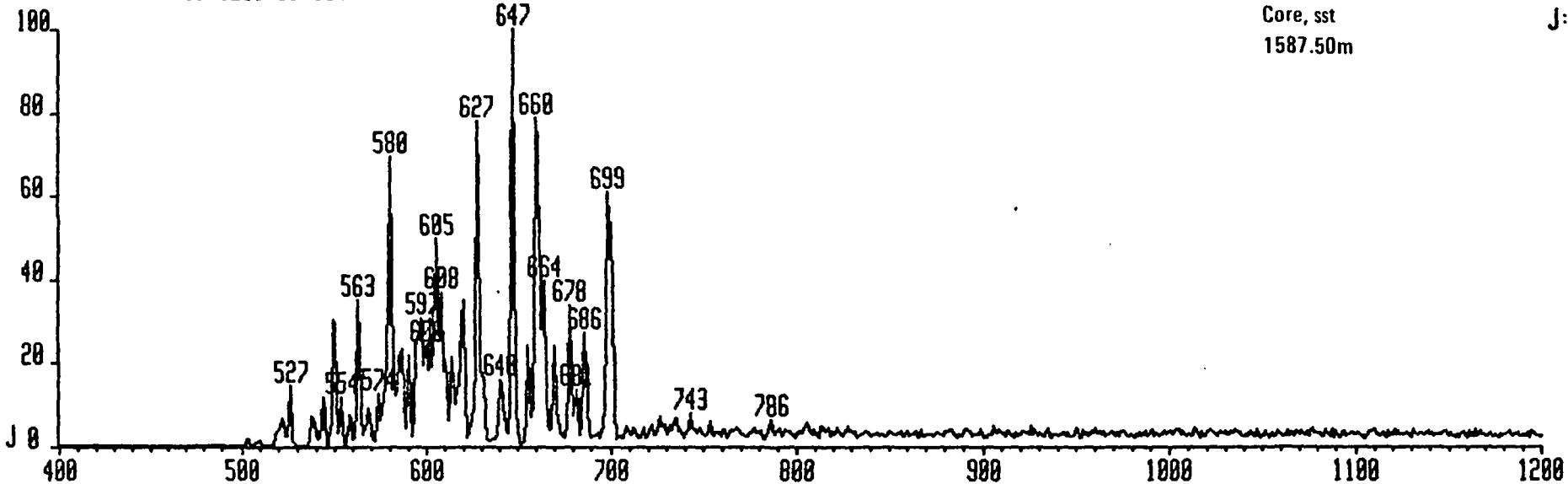
B4686AR #400-1200 K1:198



m/z 198
B 4686
Core, sst
1586.40m

IHP
K: 3744000

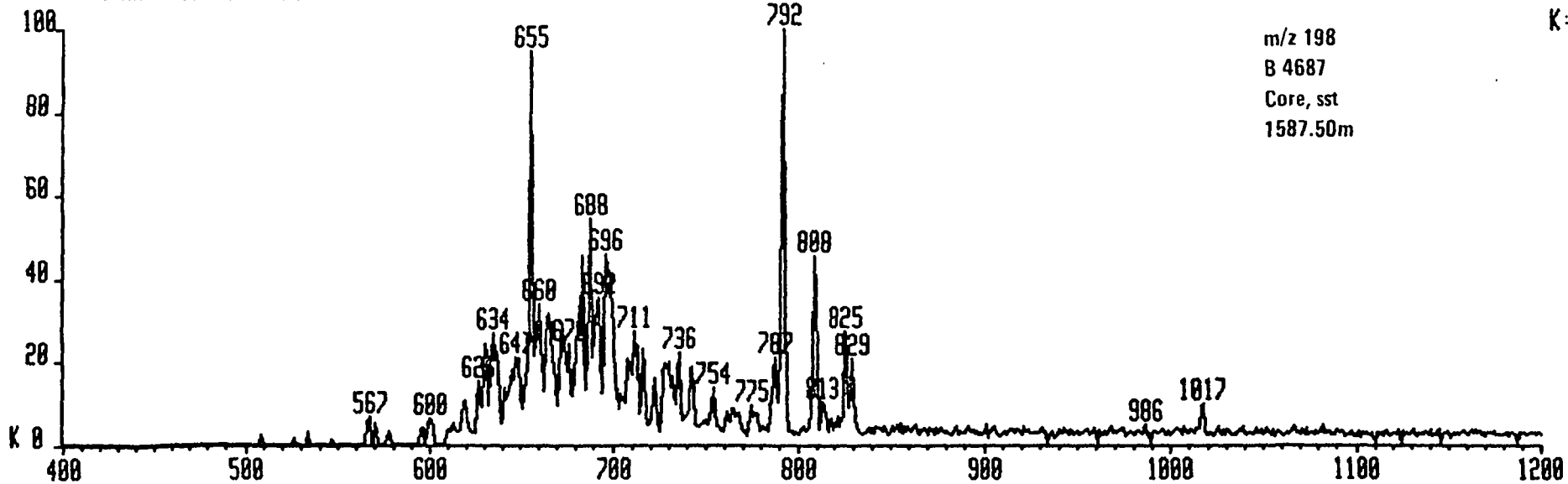
B4687AR #400-1200 J1:184



m/z 184
B 4687
Core, sst
1587.50m

IHP
J: 5347800

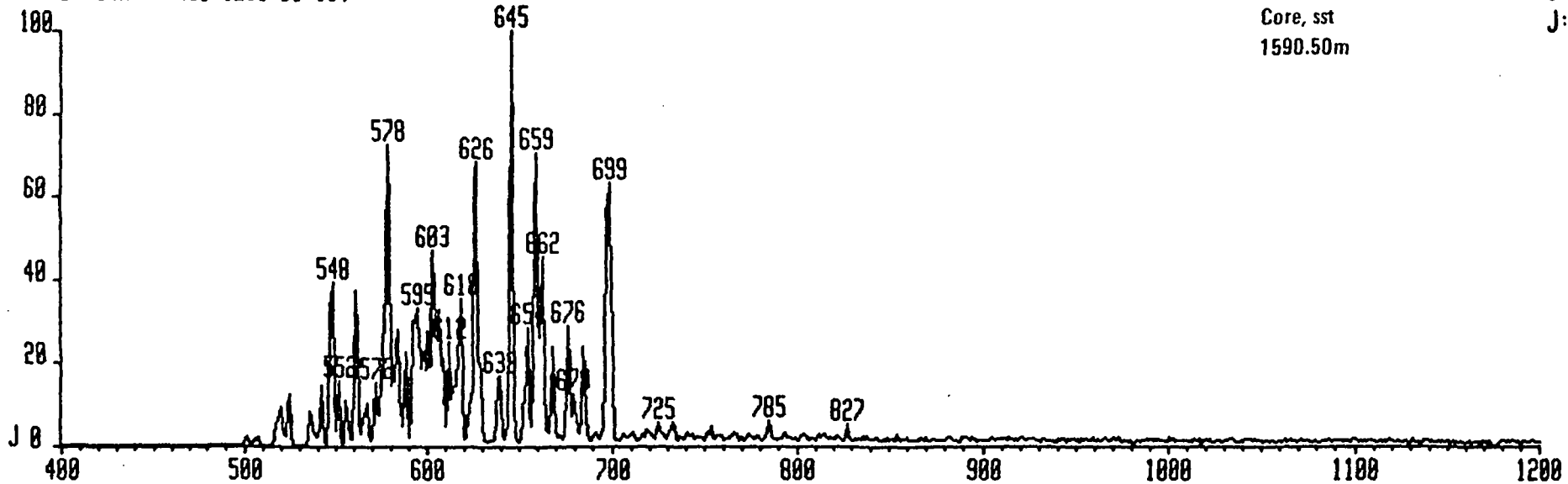
B4687AR #400-1200 K1:198



m/z 198
B 4687
Core, sst
1587.50m

IHP
K: 3413800

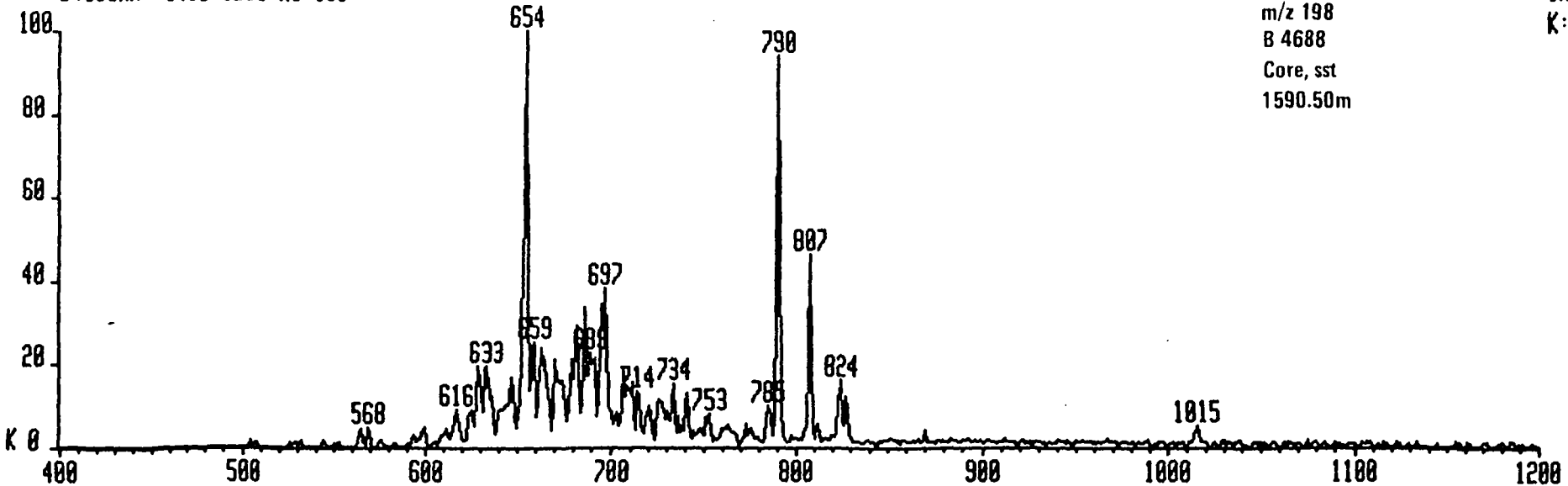
B4688AR #400-1200 J1:184



m/z 184
B 4688
Core, sst
1590.50m

IHP
J: 0716000

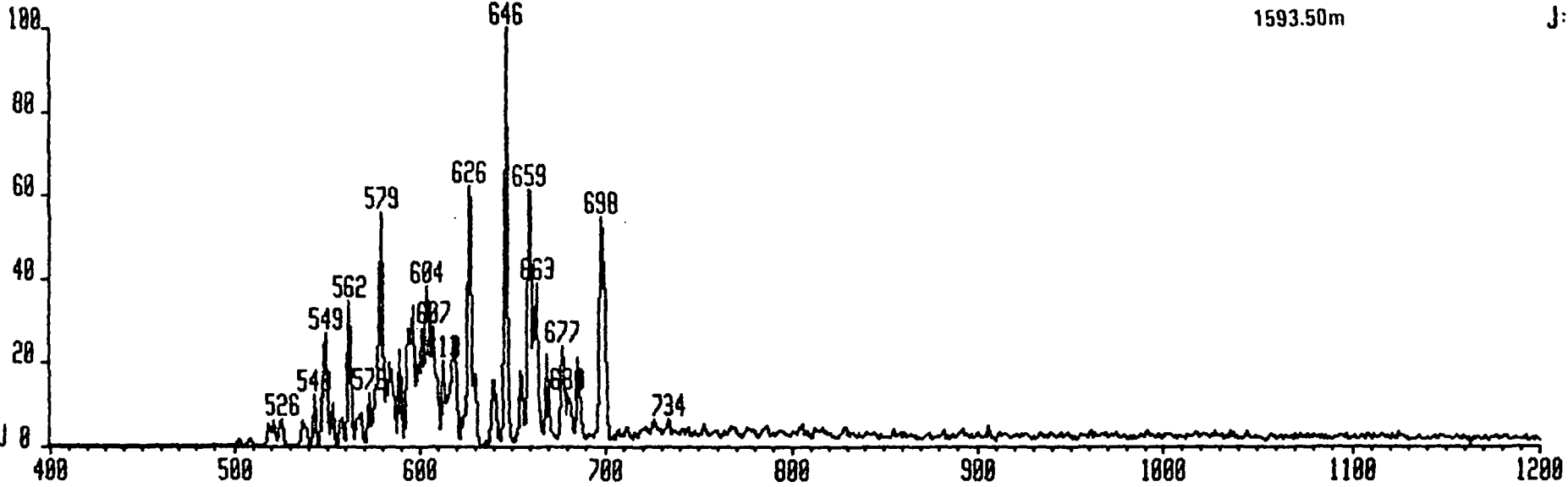
B4688AR #400-1200 K1:198



m/z 198
B 4688
Core, sst
1590.50m

IHP
K: 0800000

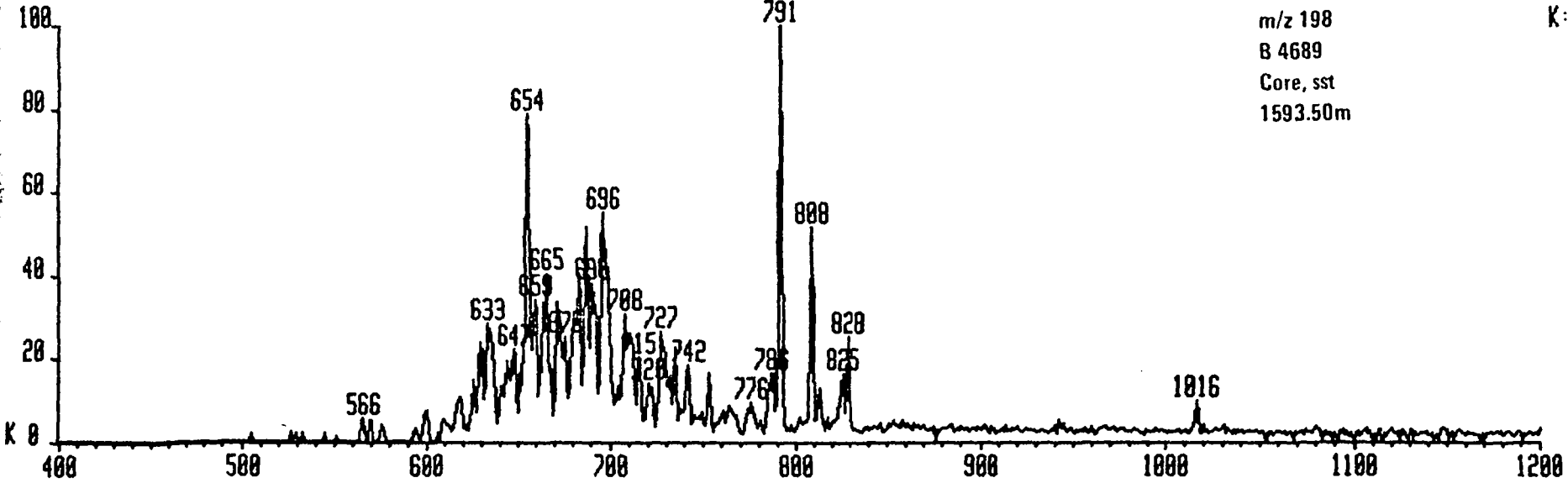
B4689AR #400-1200 J1:184



m/z 184
B 4689
Core, sst
1593.50m

IHP
J: 6555000

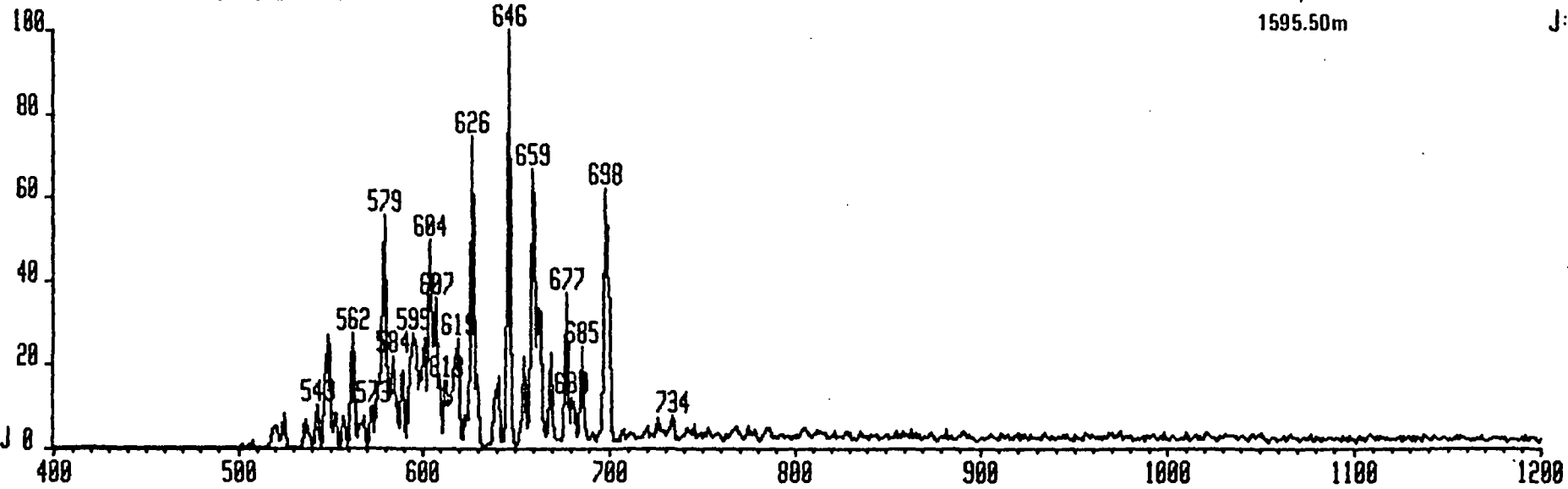
B4689AR #400-1200 K1:198



m/z 198
B 4689
Core, sst
1593.50m

IHP
K: 3735000

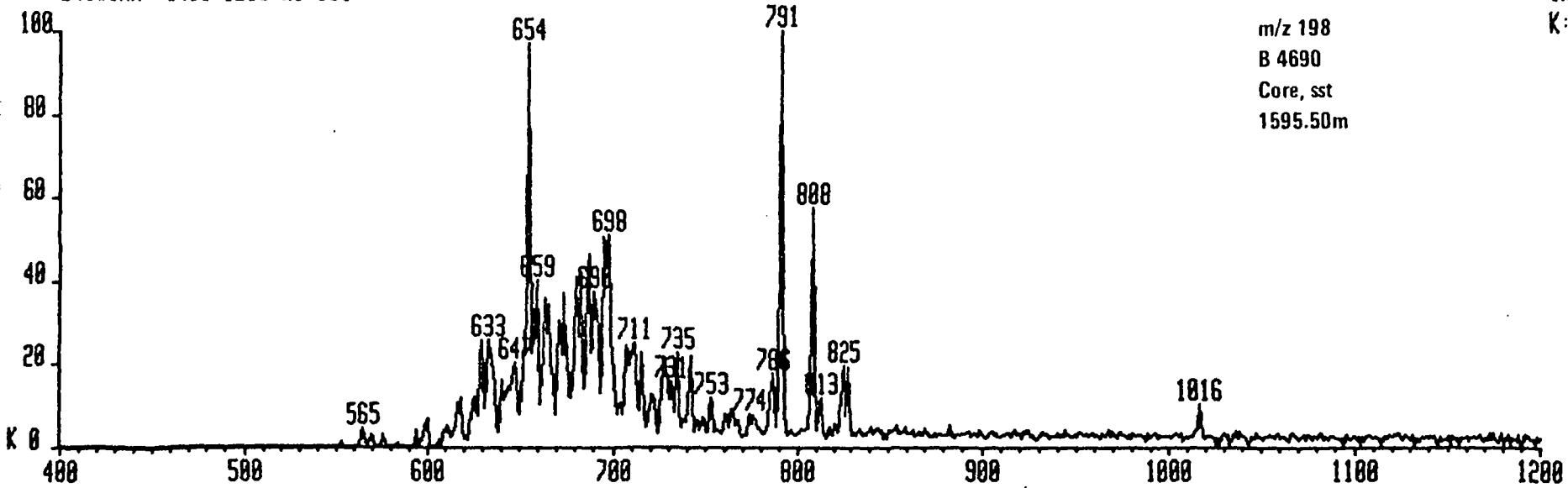
B4690AR #400-1200 J1:104



m/z 184
B 4690
Core, sst
1595.50m

IHP
J: 6238000

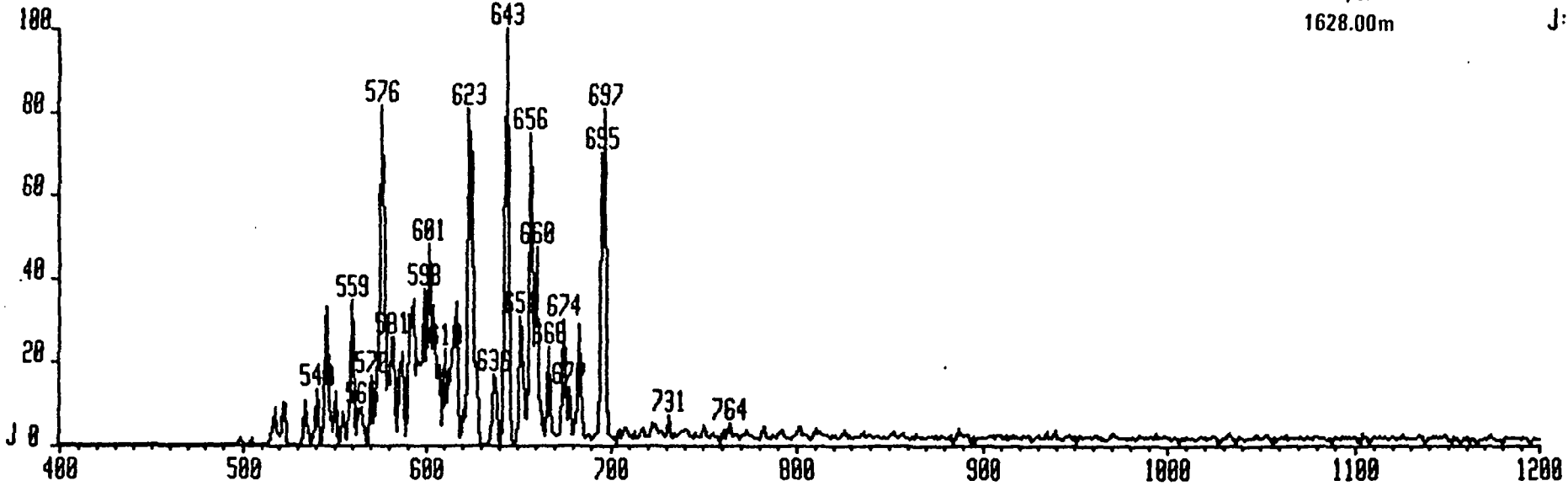
B4690AR #400-1200 K1:198



m/z 198
B 4690
Core, sst
1595.50m

IHP
K: 3691000

B4691AR2 #400-1200 J1:184



m/z 184

B 4691

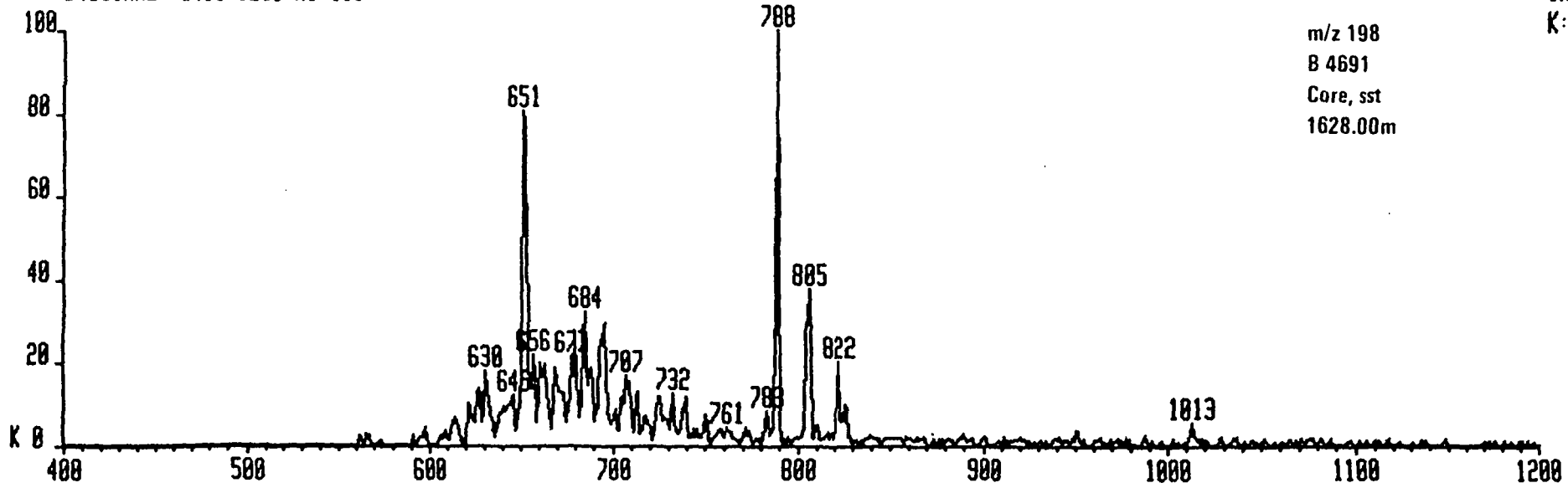
Core, sst

1628.00m

IHP

J: 5039000

B4691AR2 #400-1200 K1:198



m/z 198

B 4691

Core, sst

1628.00m

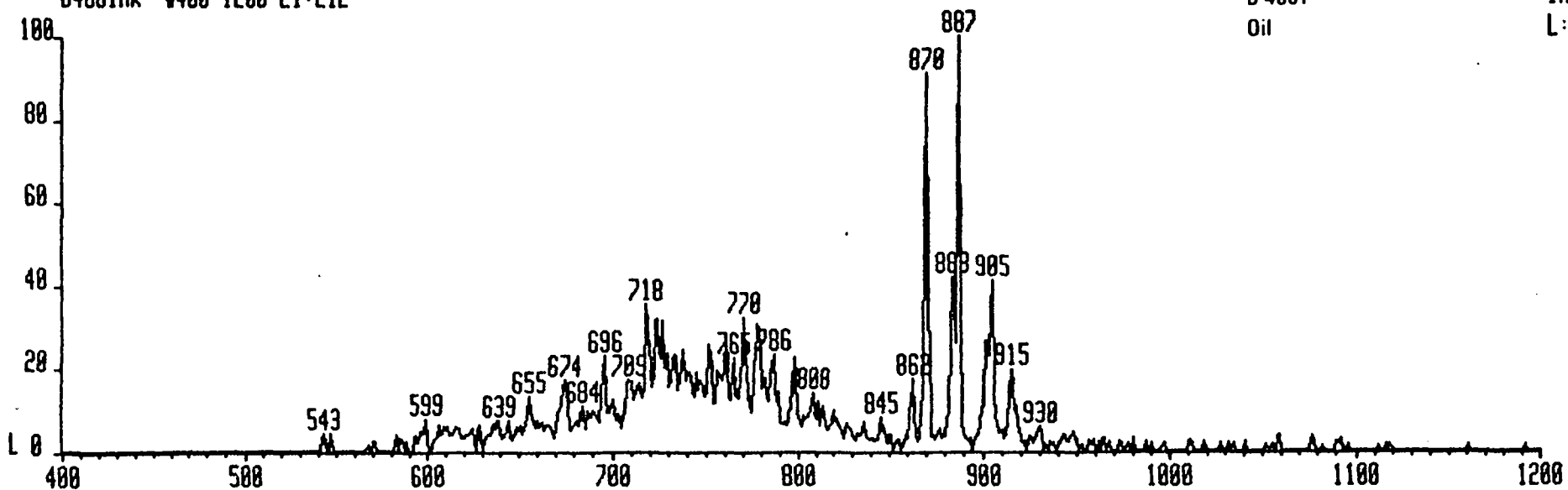
IHP

K: 5144000

B4681AR 1400-1200 L1:212

m/z 212
B 4681
Oil

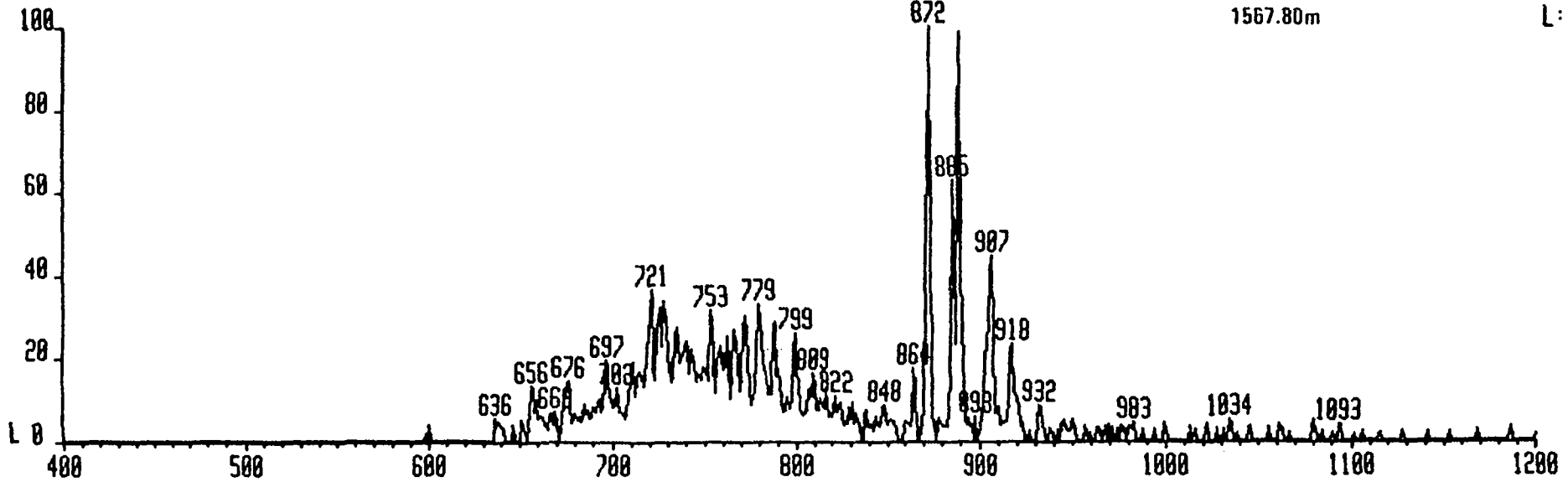
IHP
L: 2733000



m/z 212
B 4682
Core, sst
1567.80m

IHP
L: 1060000

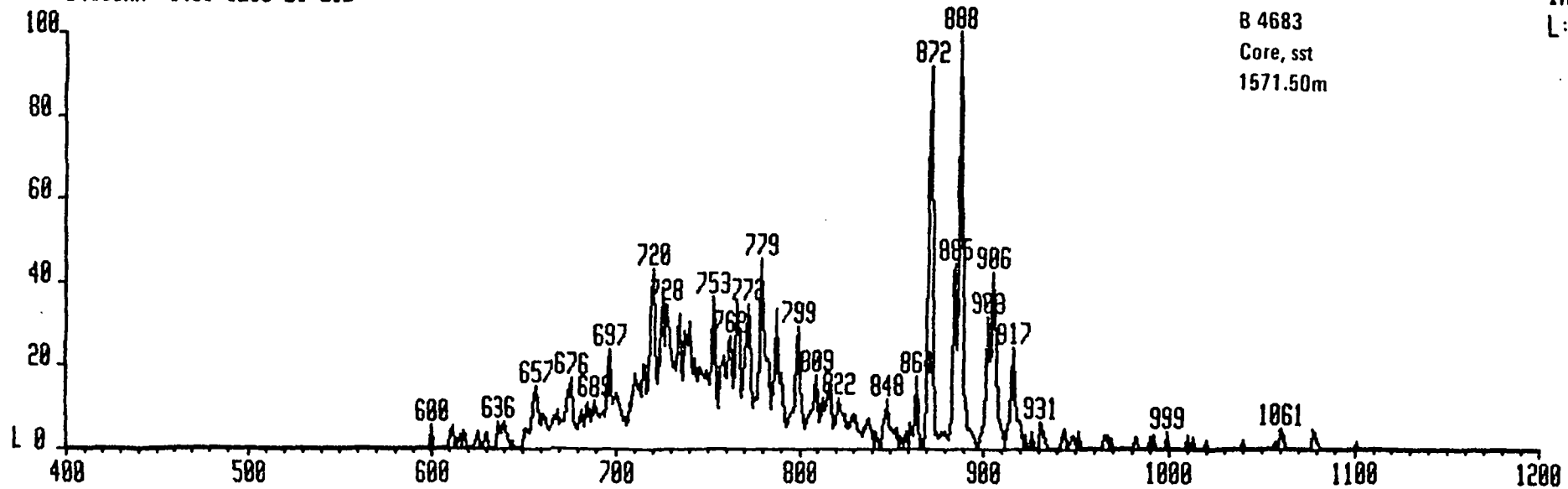
B4602AR #400-1200 L1:212



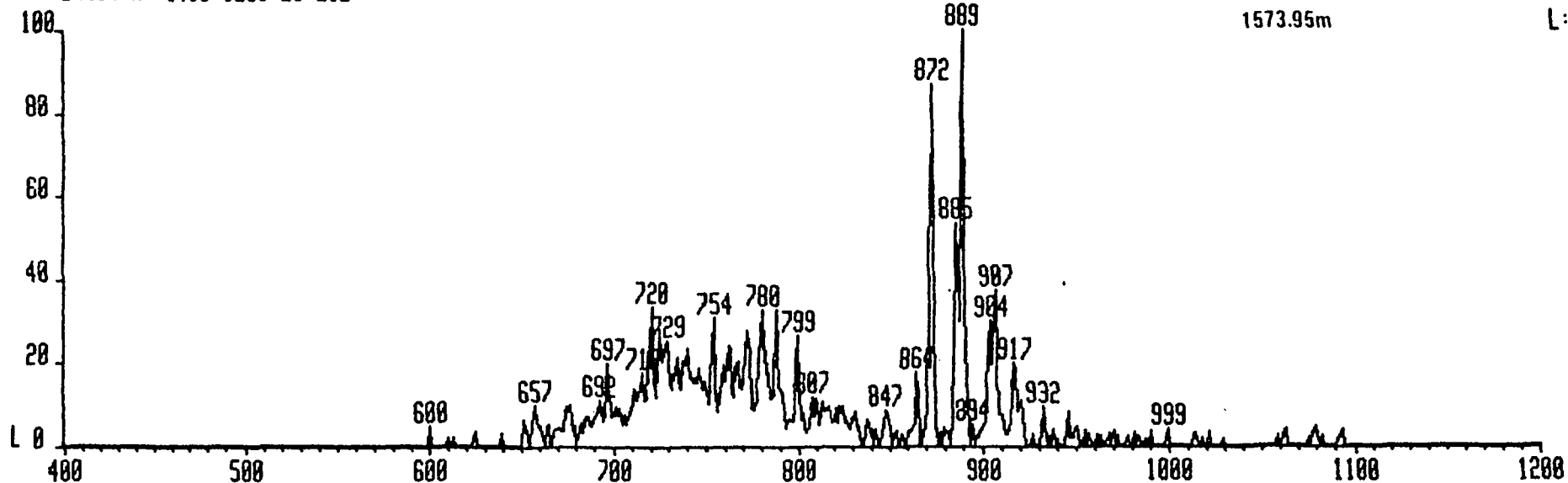
m/z 212
B 4683
Core, sst
1571.50m

IHP
L: 1904000

B4603AR #400-1200 L1:212



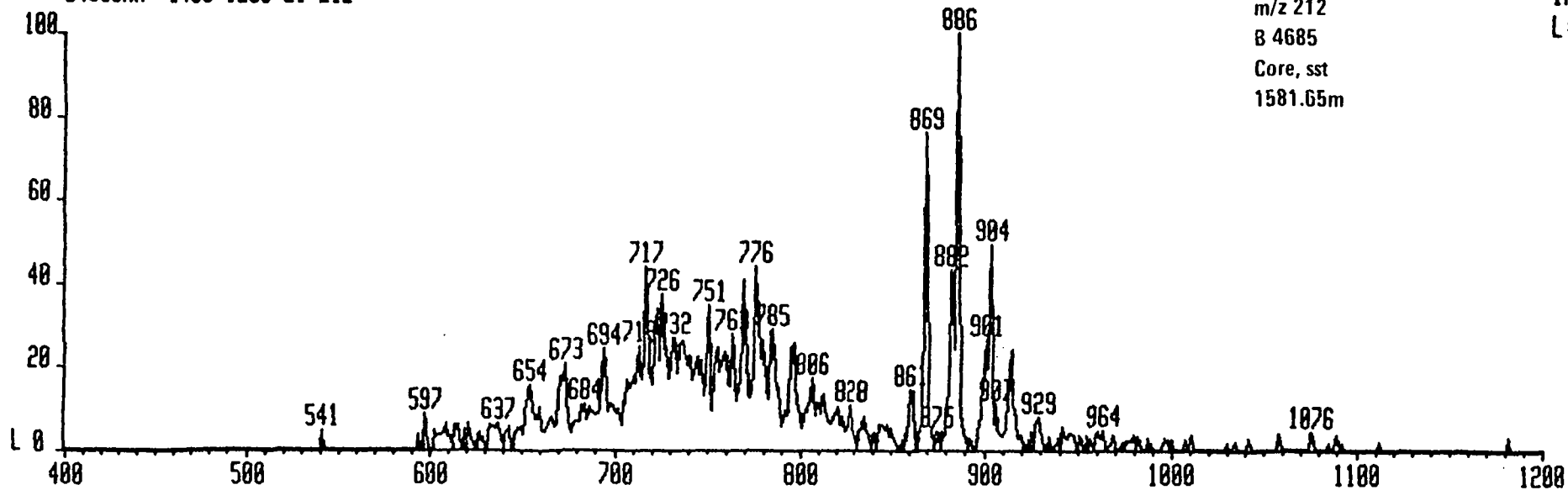
B4684AR #400-1200 L1:212



m/z 212
B 4684
Core, sst
1573.95m

IHP
L: 1919000

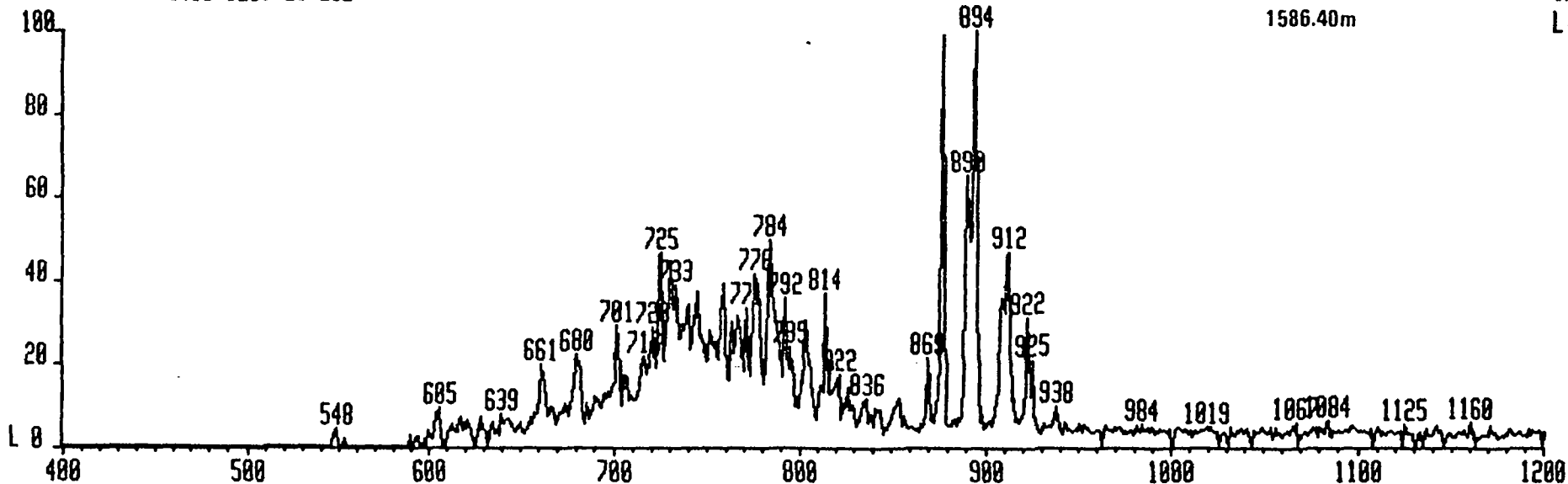
B4685AR #400-1200 L1:212



m/z 212
B 4685
Core, sst
1581.65m

IHP
L: 2261000

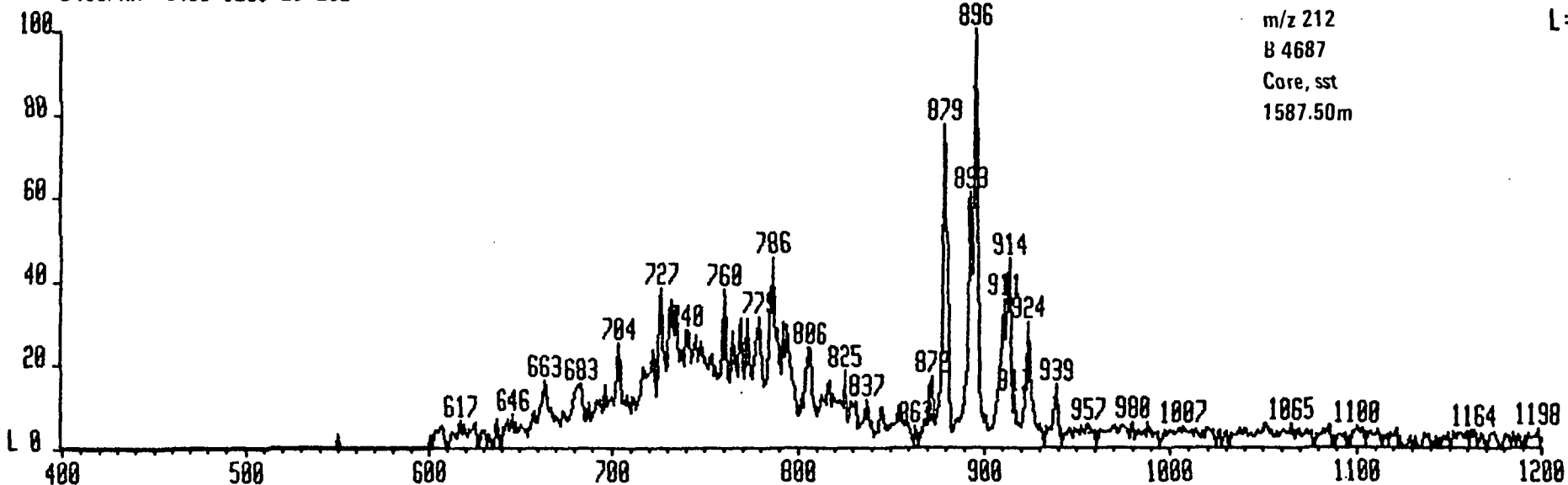
B4686AR #400-1200 L1:212



m/z 212
B 4686
Core, sst
1586.40m

IHP
L: 2280000

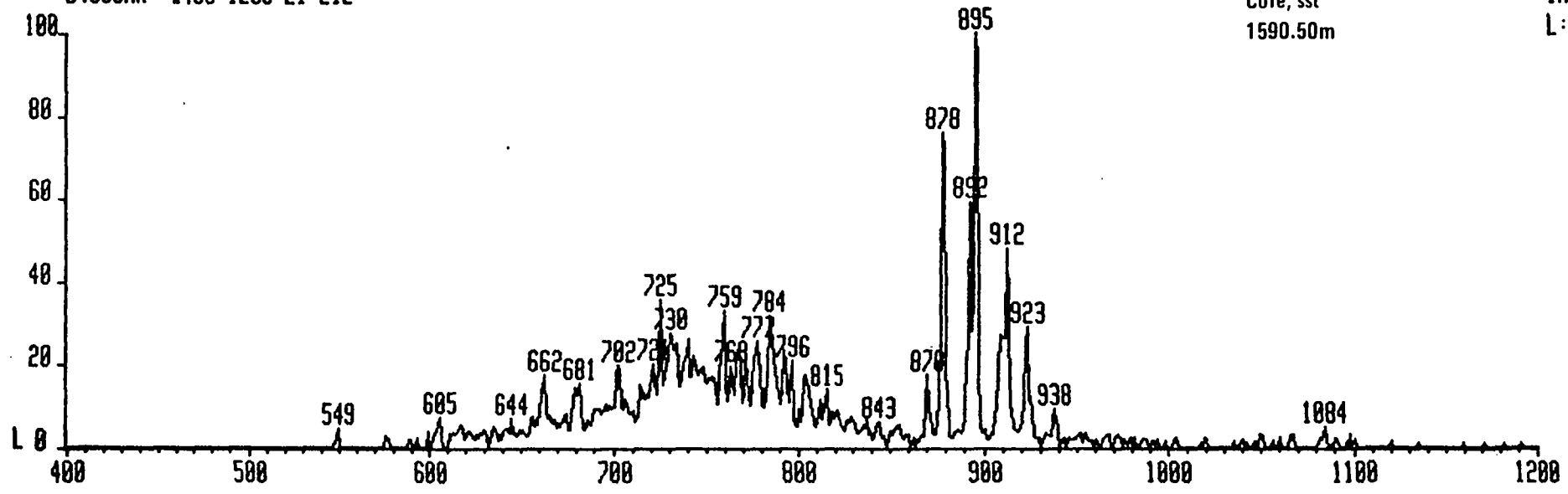
B4687AR #400-1200 L1:212



m/z 212
B 4687
Core, sst
1587.50m

IHP
L: 2270000

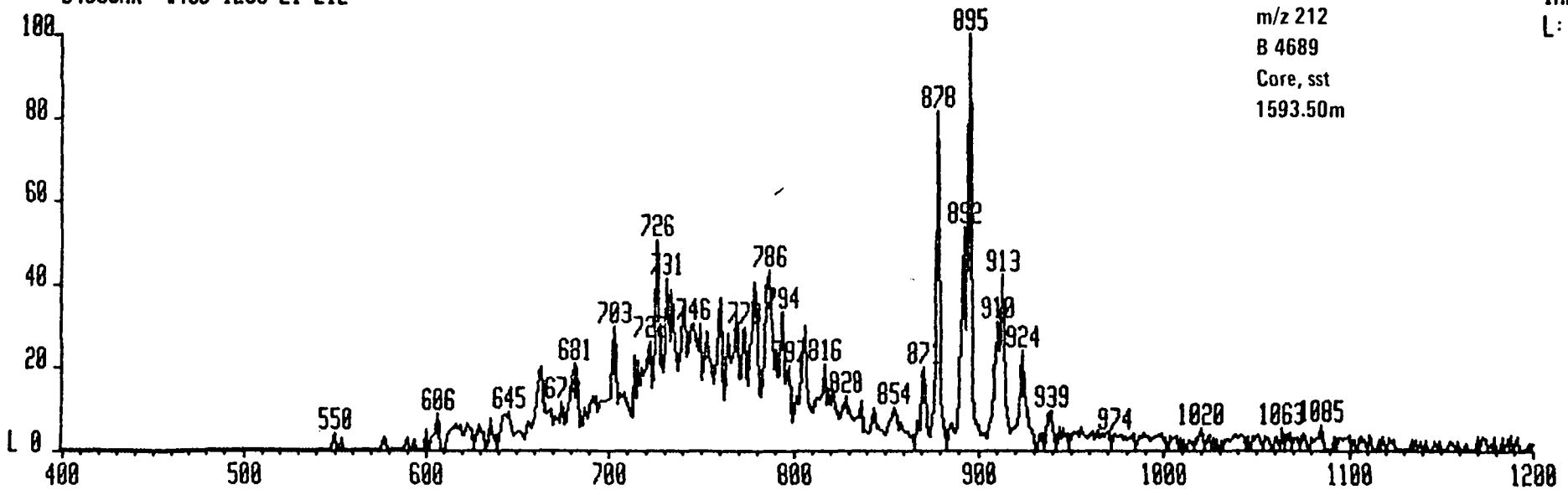
B4688AR #400-1200 L1:212



m/z 212
B 4688
Core, sst
1590.50m

IHP
L: 3045000

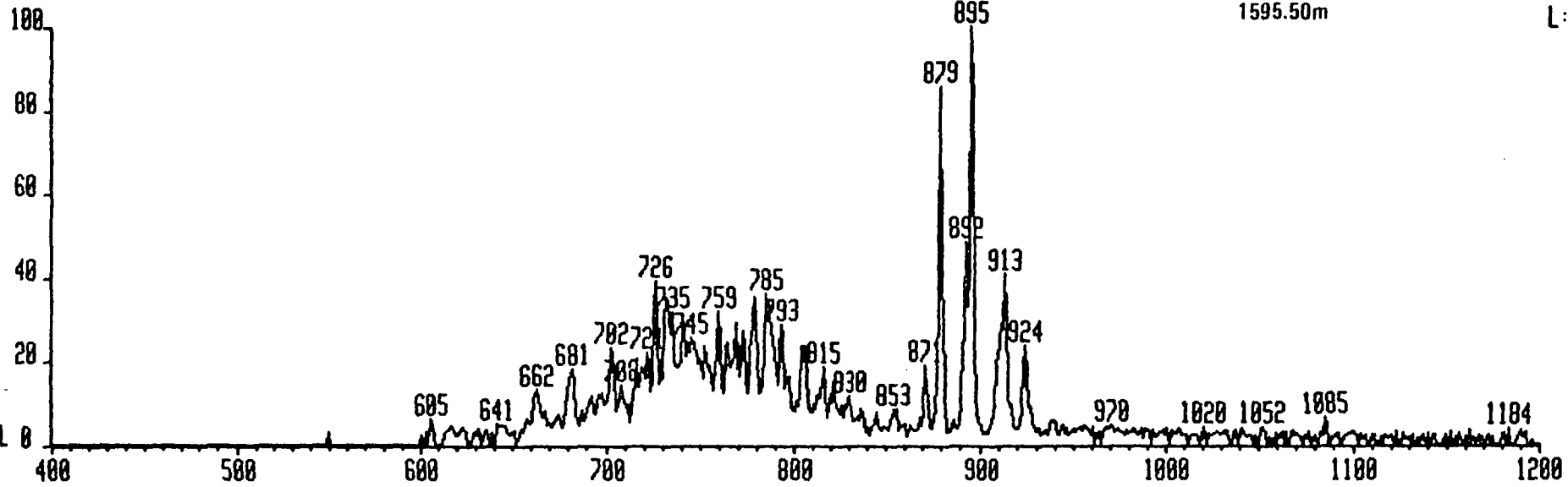
B4689AR #400-1200 L1:212



m/z 212
B 4689
Core, sst
1593.50m

IHP
L: 2315000

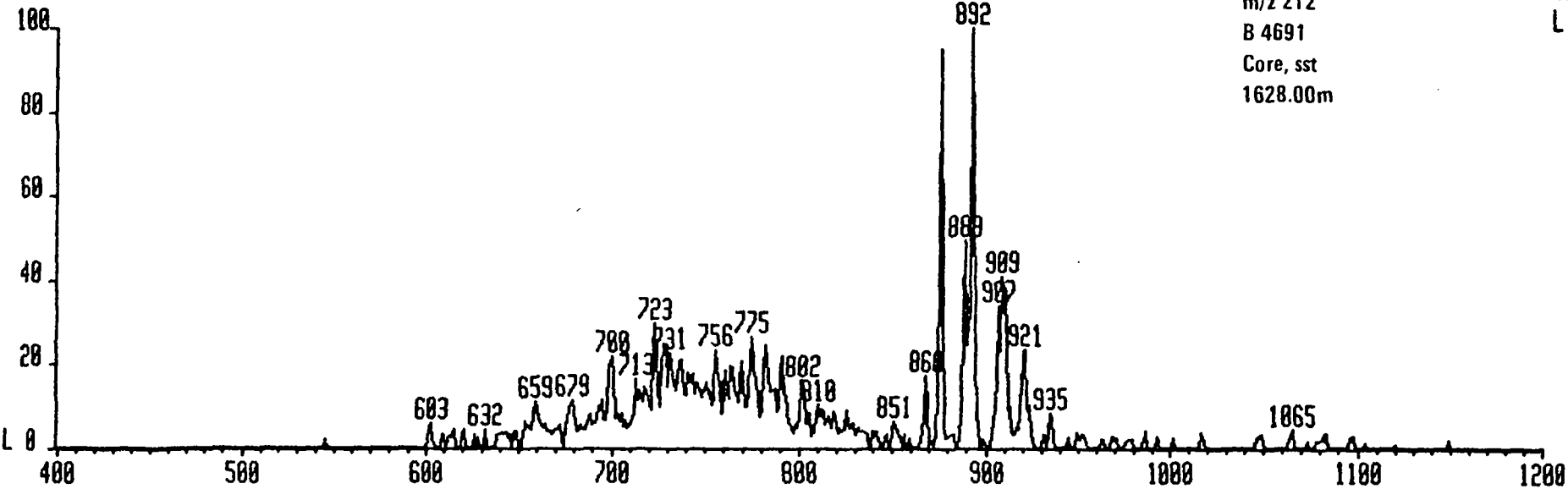
B4690AR #400-1200 L1:212



m/z 212
B 4690
Core, sst
1595.50m

IHP
L: 2485000

B4691AR2 #400-1200 L1:212



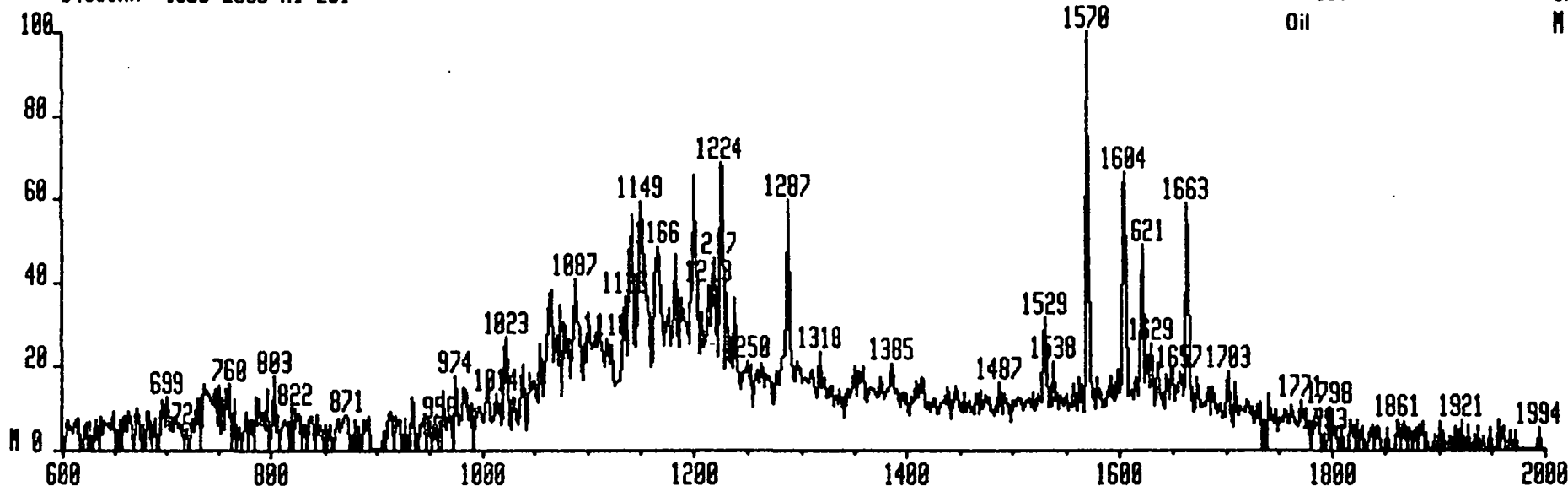
m/z 212
B 4691
Core, sst
1628.00m

IHP
L: 2500000

B4681AR #600-2000 M1:231

m/z 231
B 4681
Oil

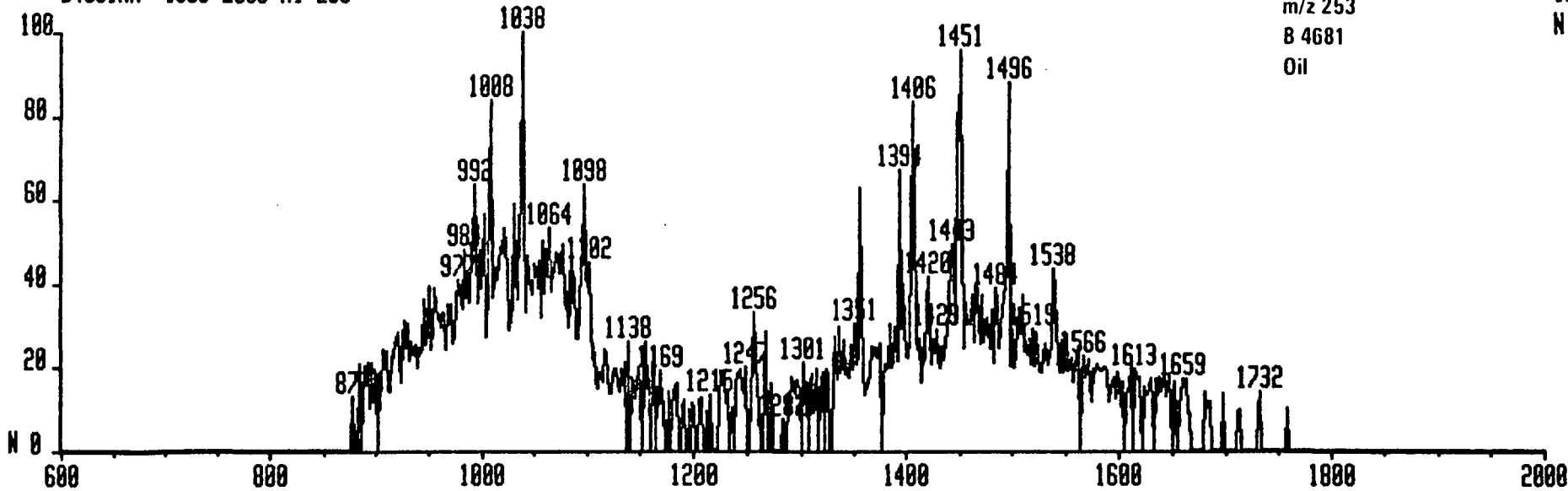
IHP
M: 1031000



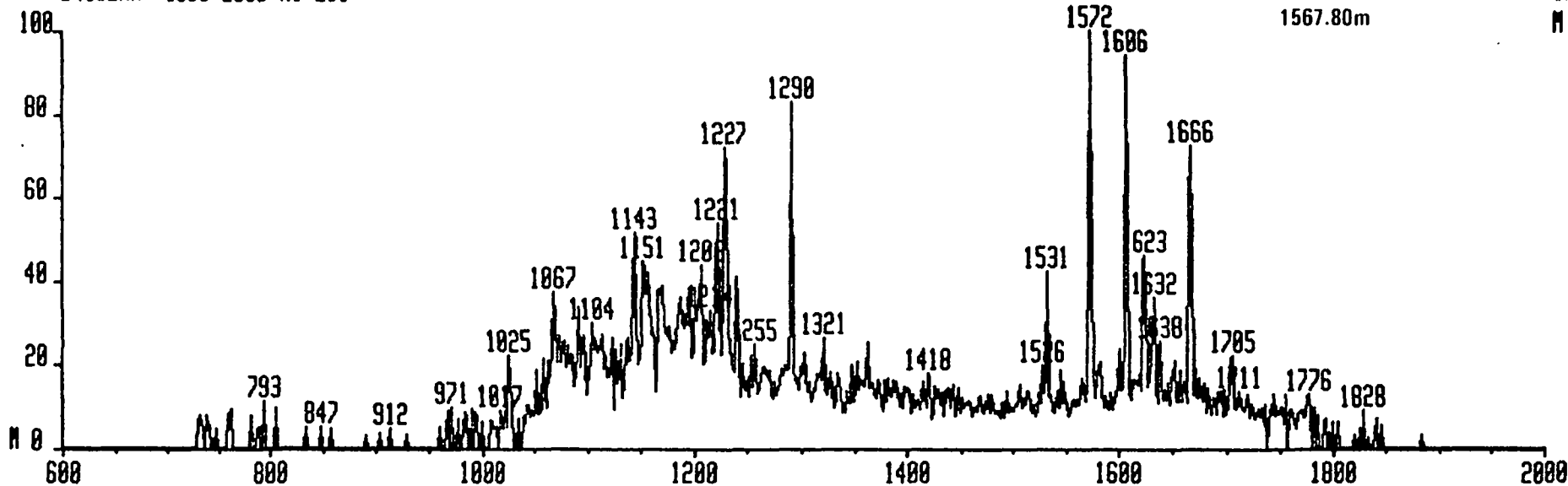
B4681AR #600-2000 M1:253

m/z 253
B 4681
Oil

IHP
N: 432000

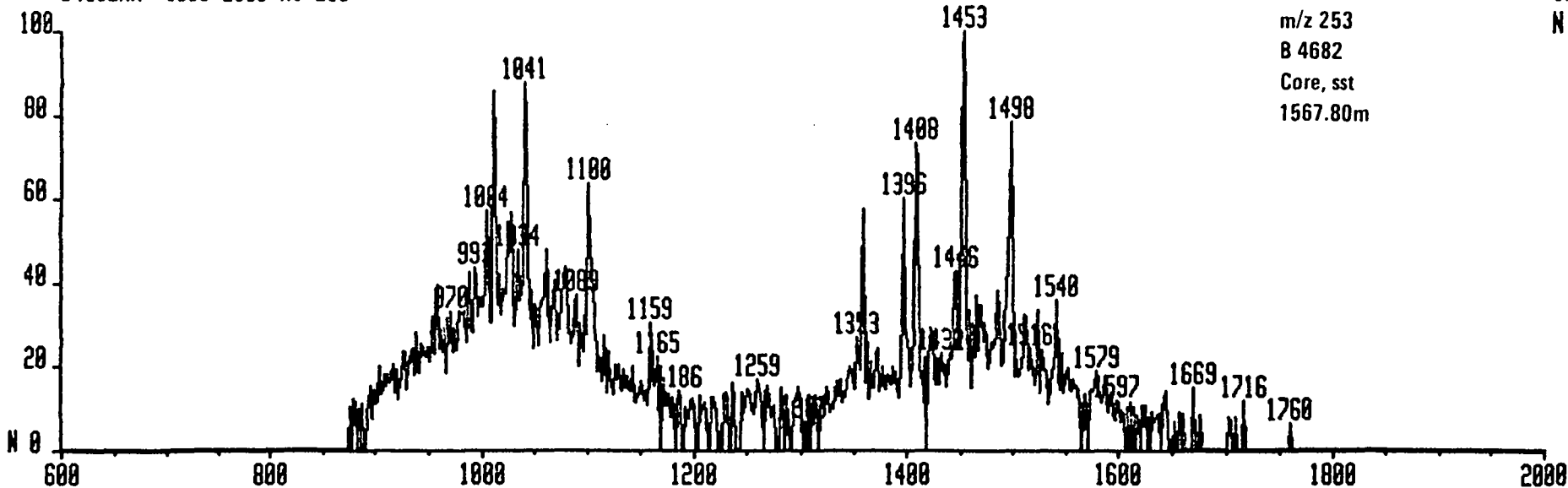


B4682AR #600-2000 M1:231

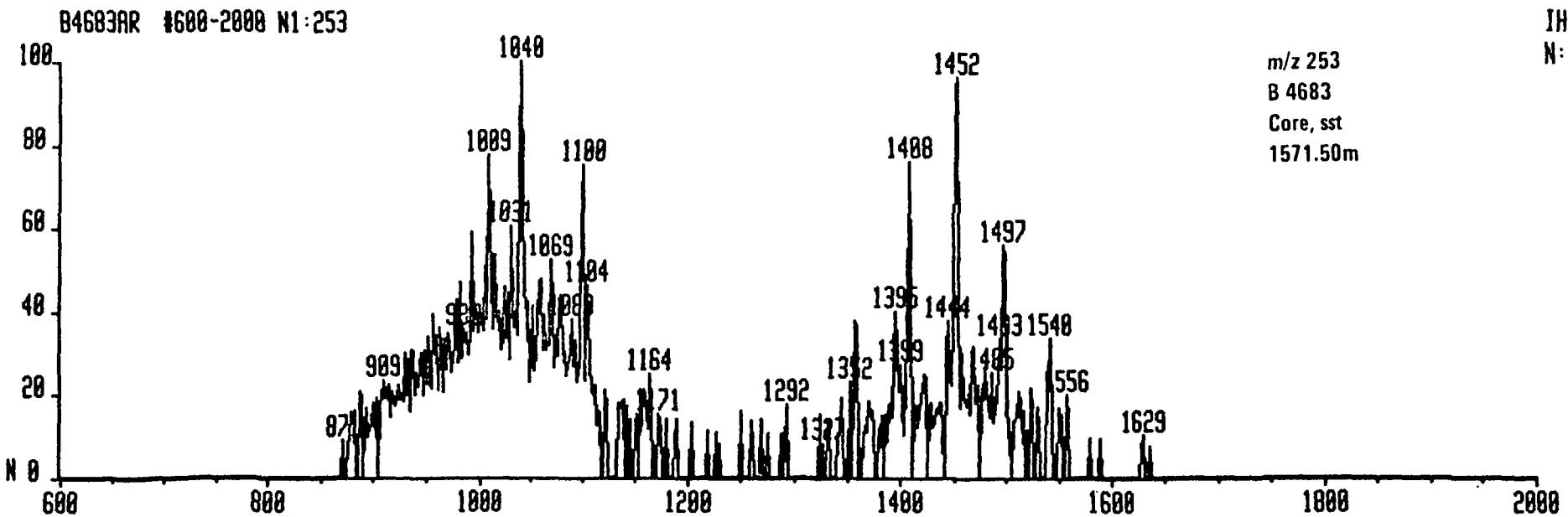
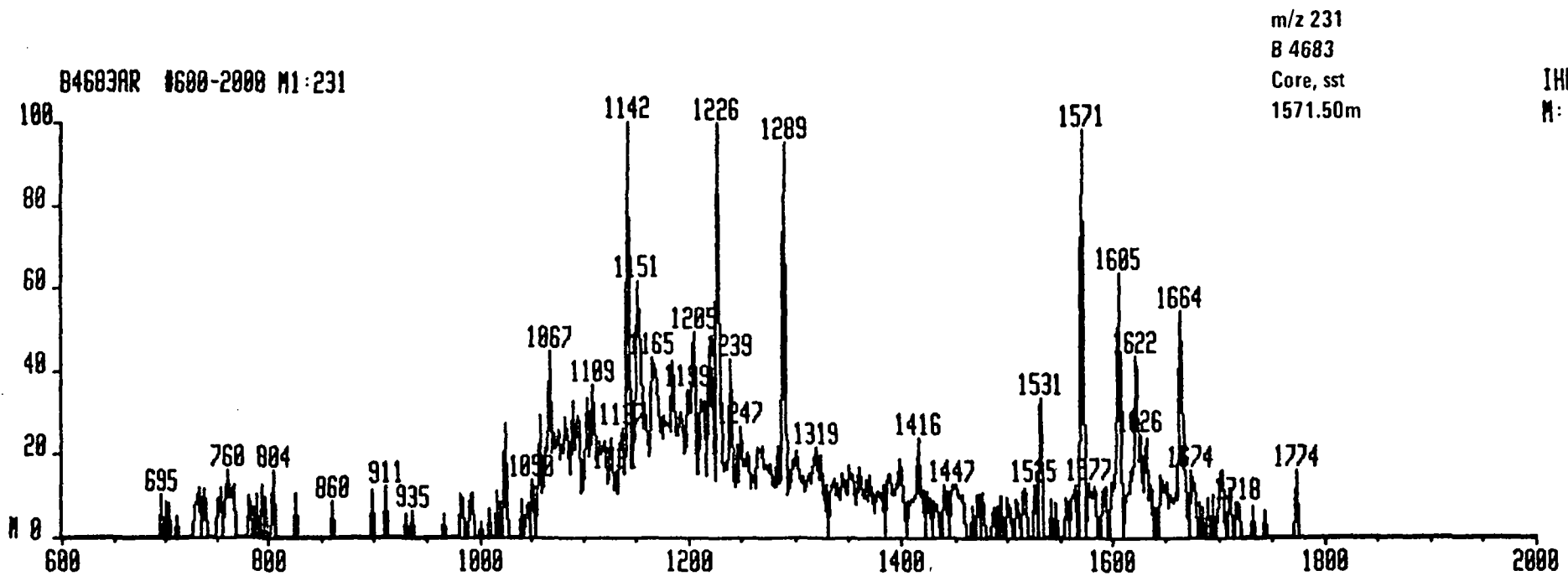


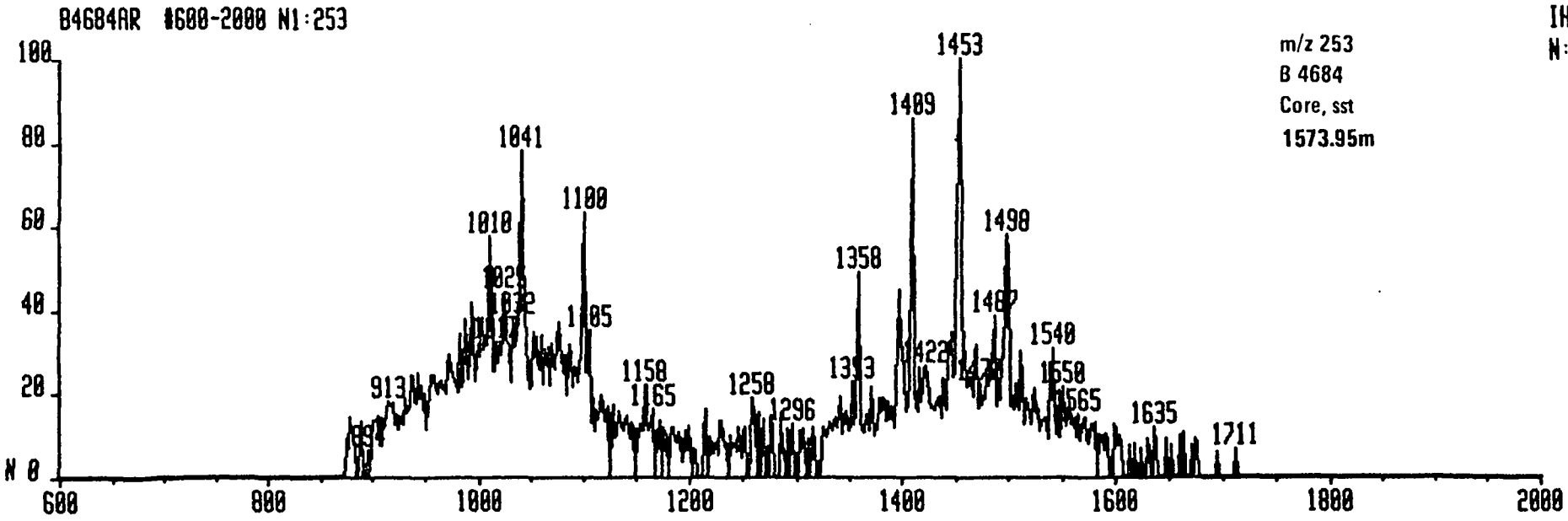
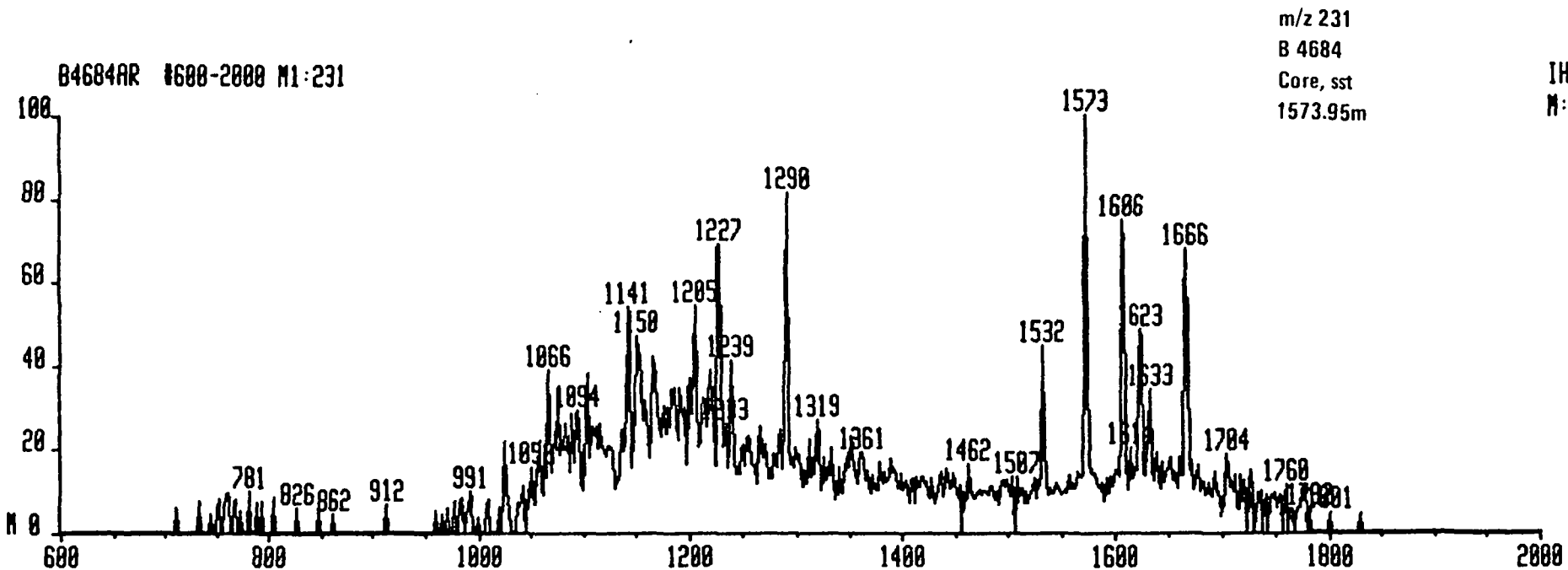
IHP
M: 912000

B4682AR #600-2000 M1:253

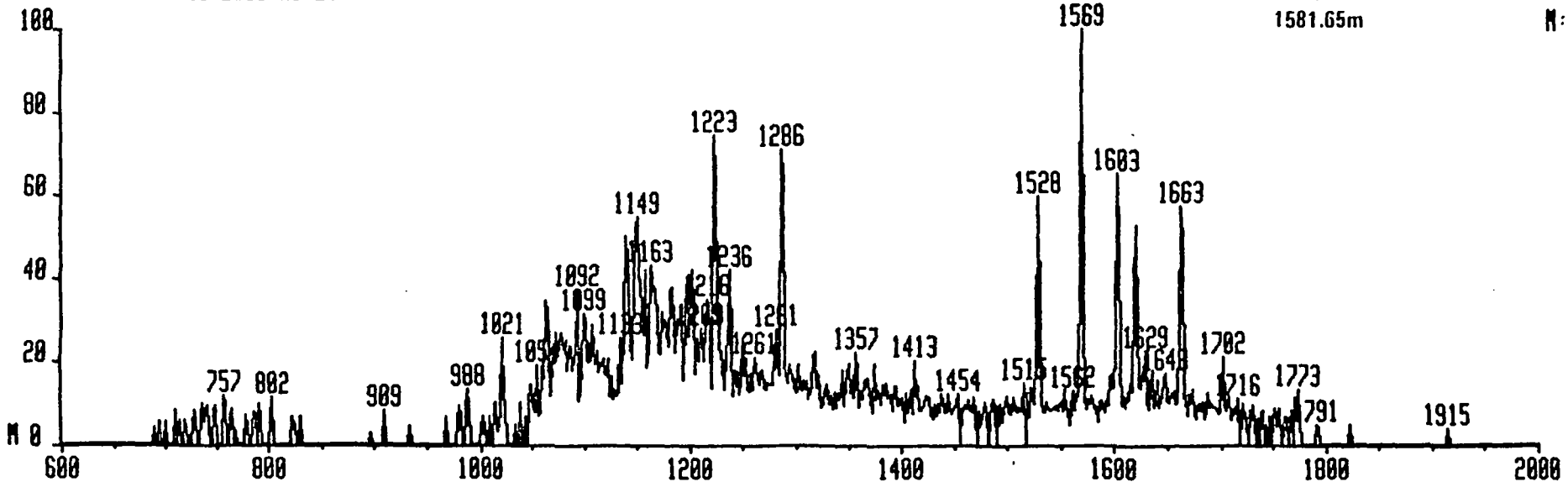


IHP
M: 595000





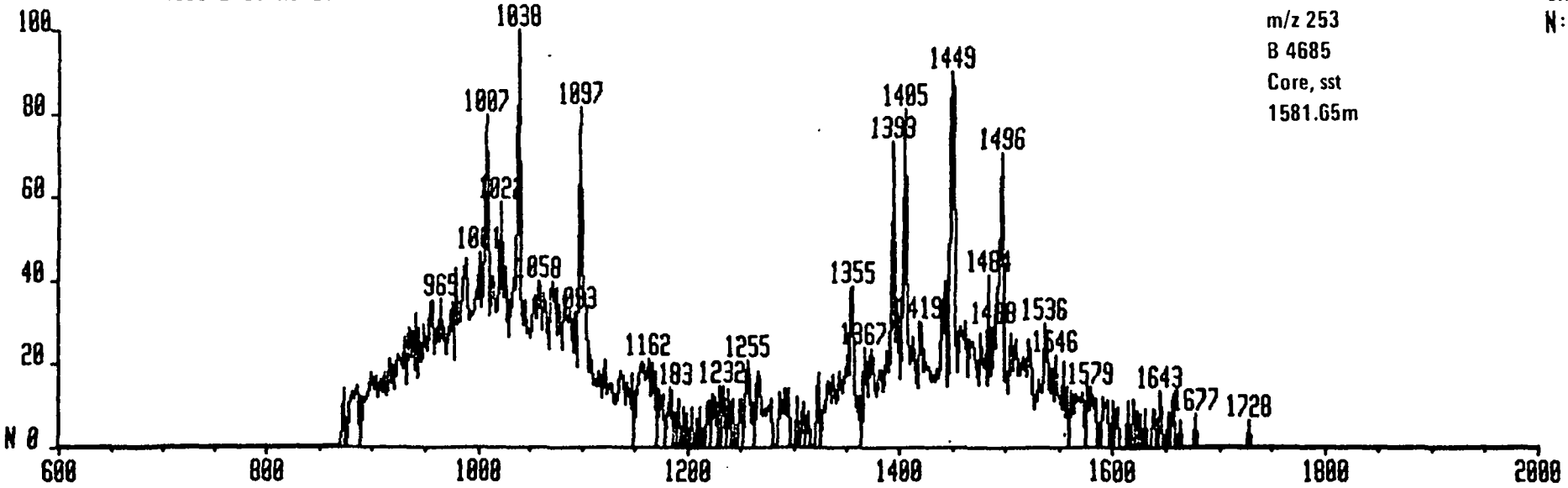
84685AR #600-2000 M1:231



m/z 231
B 4685
Core, sst
1581.65m

IHP
N: 961000

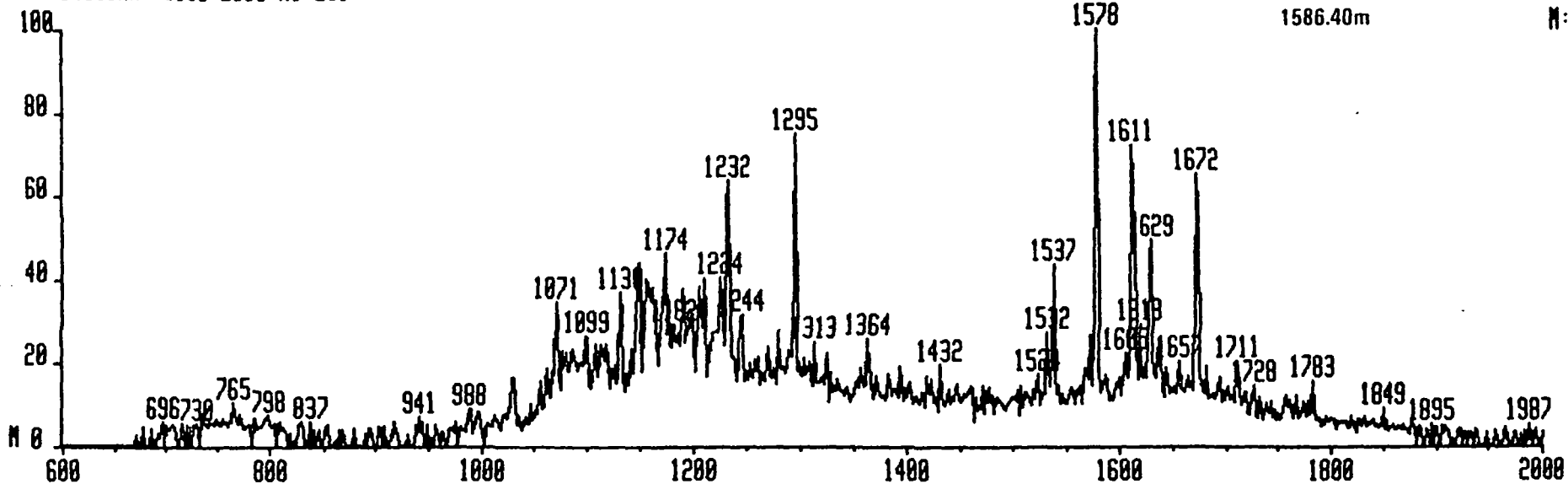
84685AR #600-2000 M1:253



m/z 253
B 4685
Core, sst
1581.65m

IHP
N: 579000

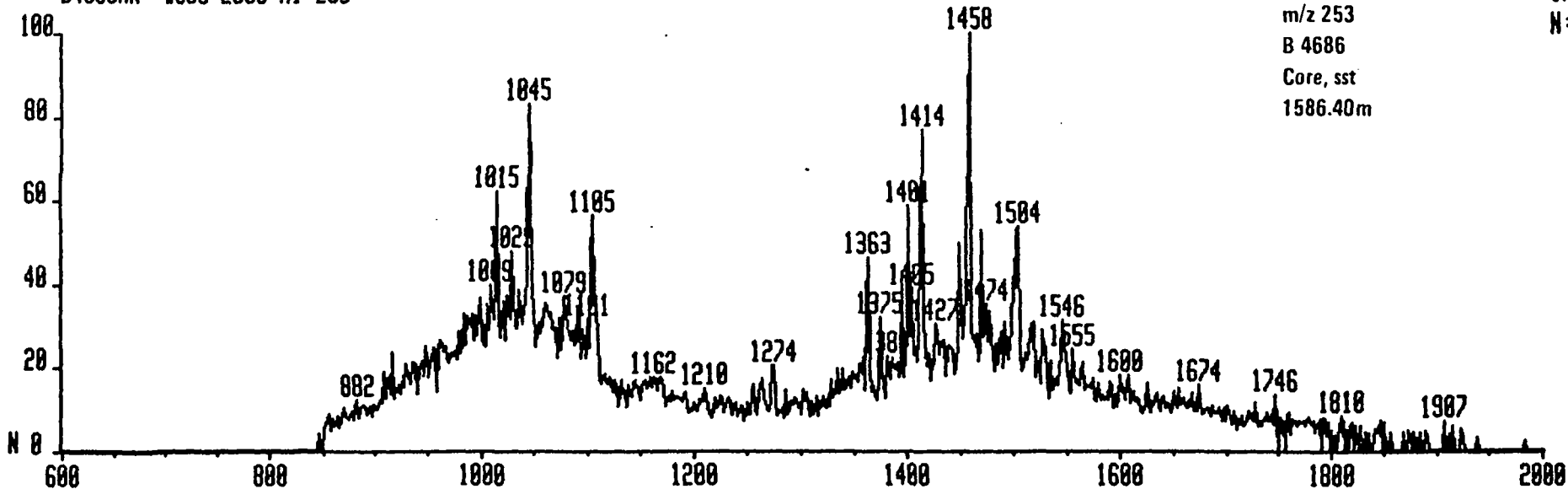
B4606AR #600-2000 M1:231



m/z 231
B 4686
Core, sst
1586.40m

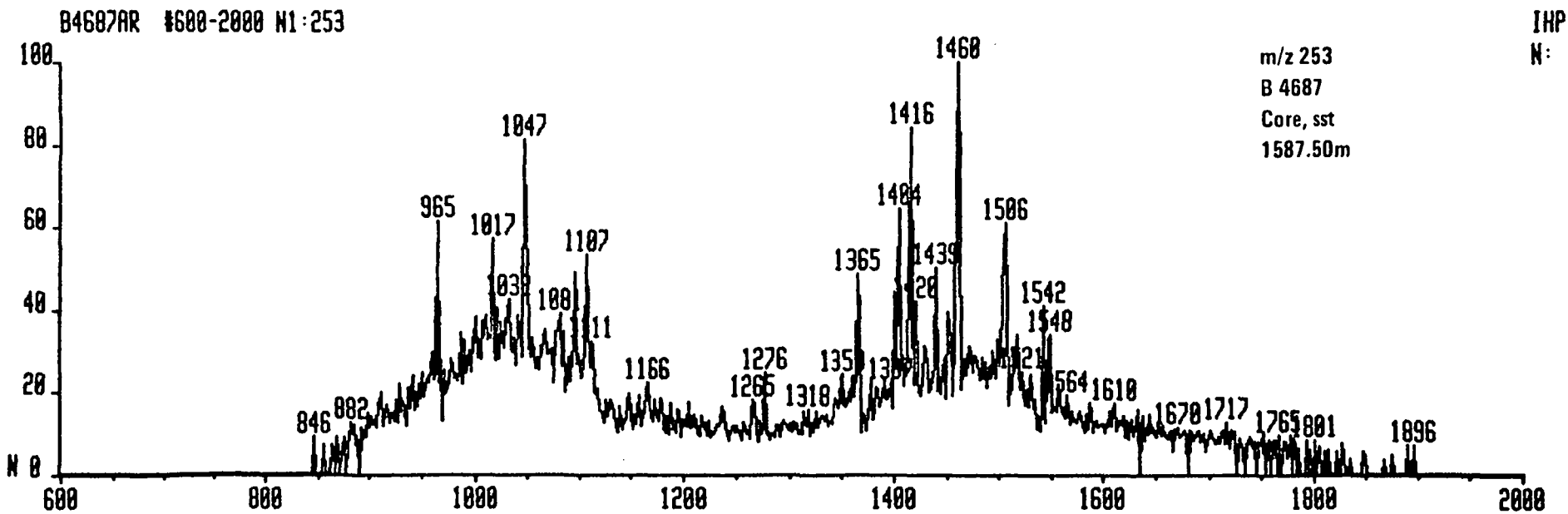
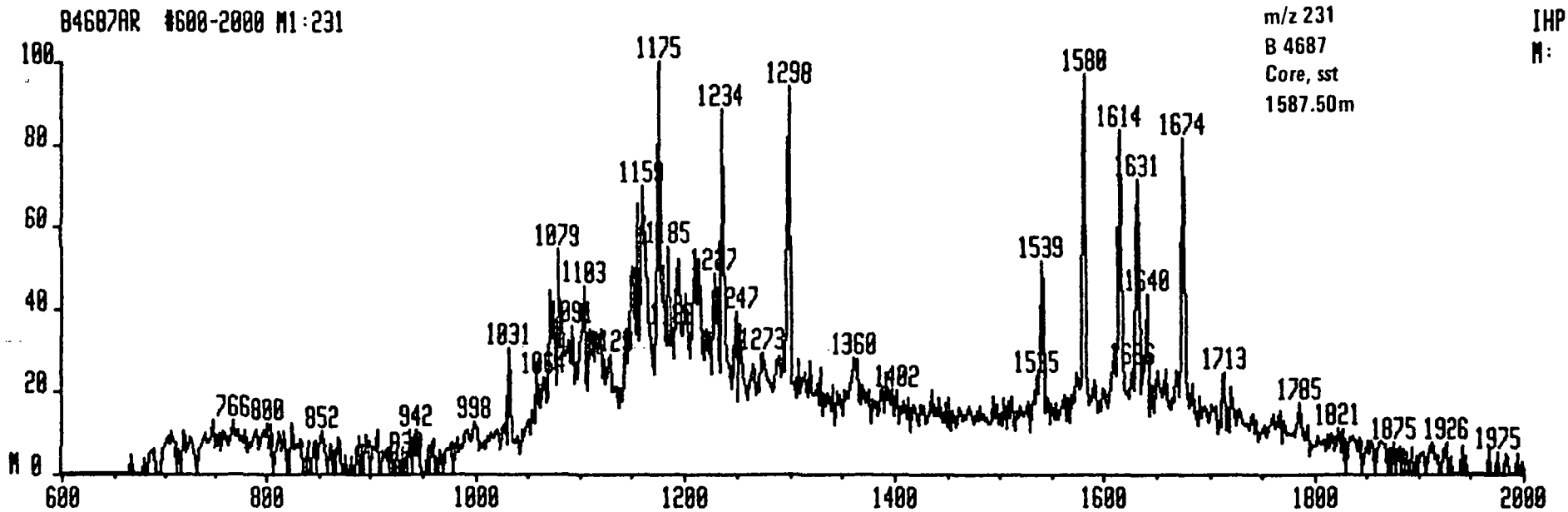
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B4606AR #600-2000 M1:253

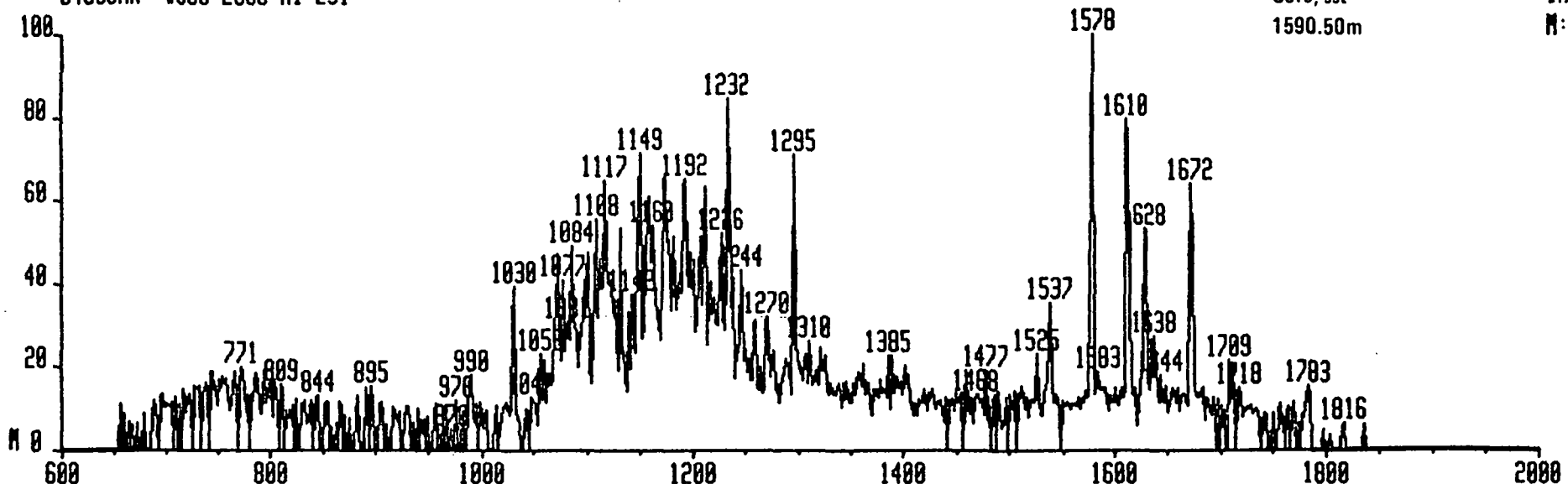


m/z 253
B 4686
Core, sst
1586.40m

IHP
M: 1061000



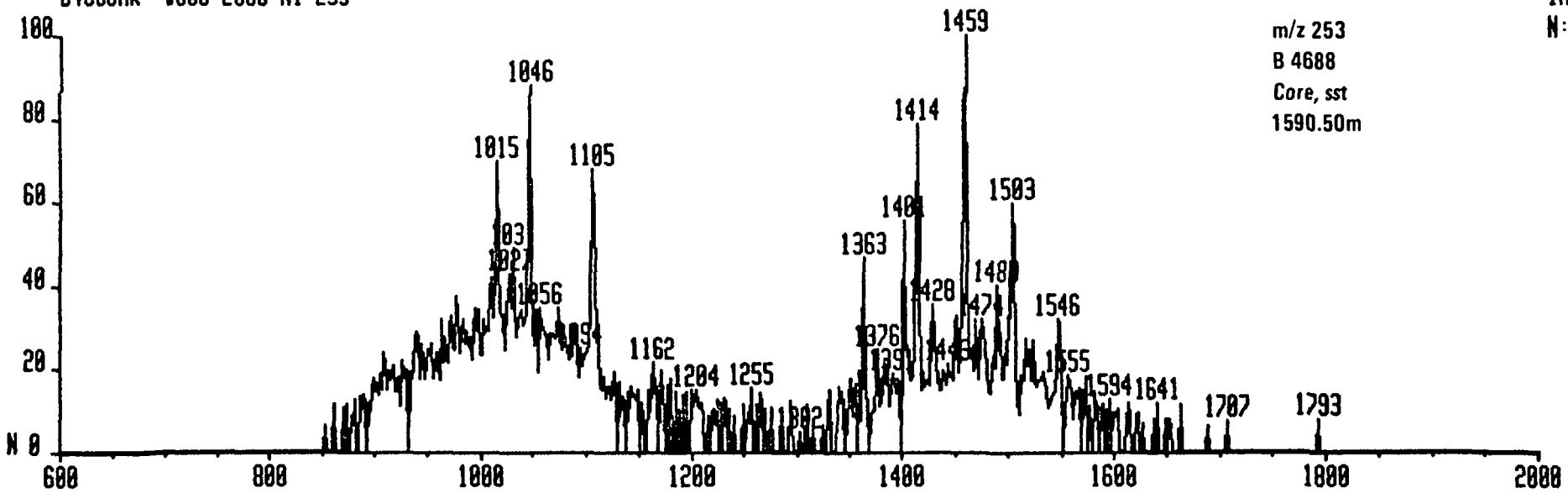
B4688AR #600-2000 M1:231



m/z 231
B 4688
Core, sst
1590.50m

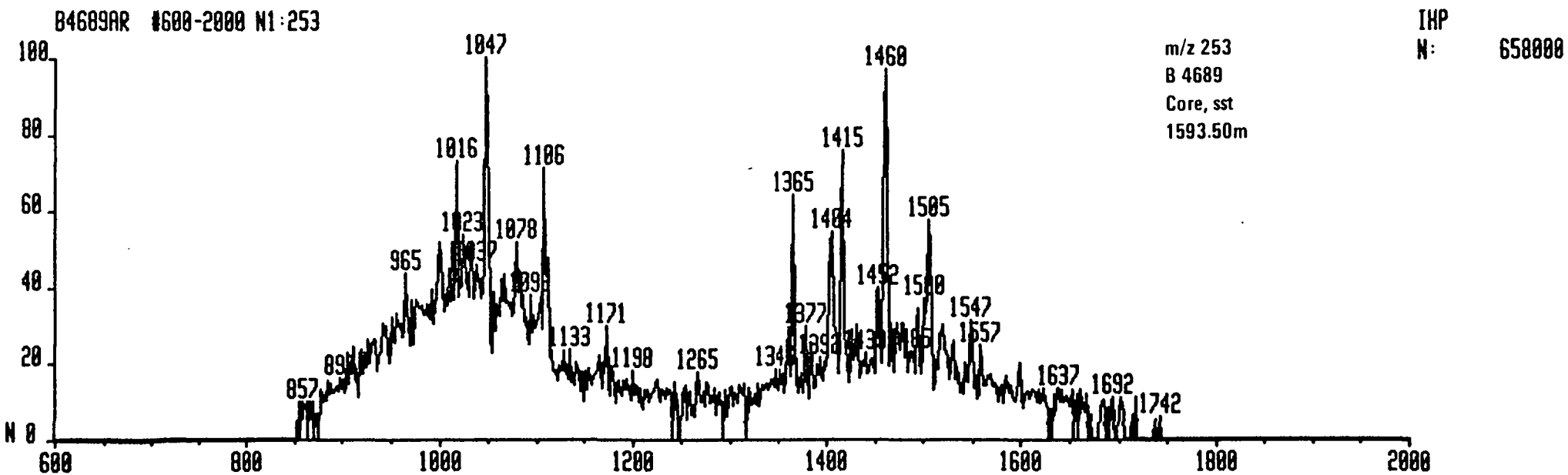
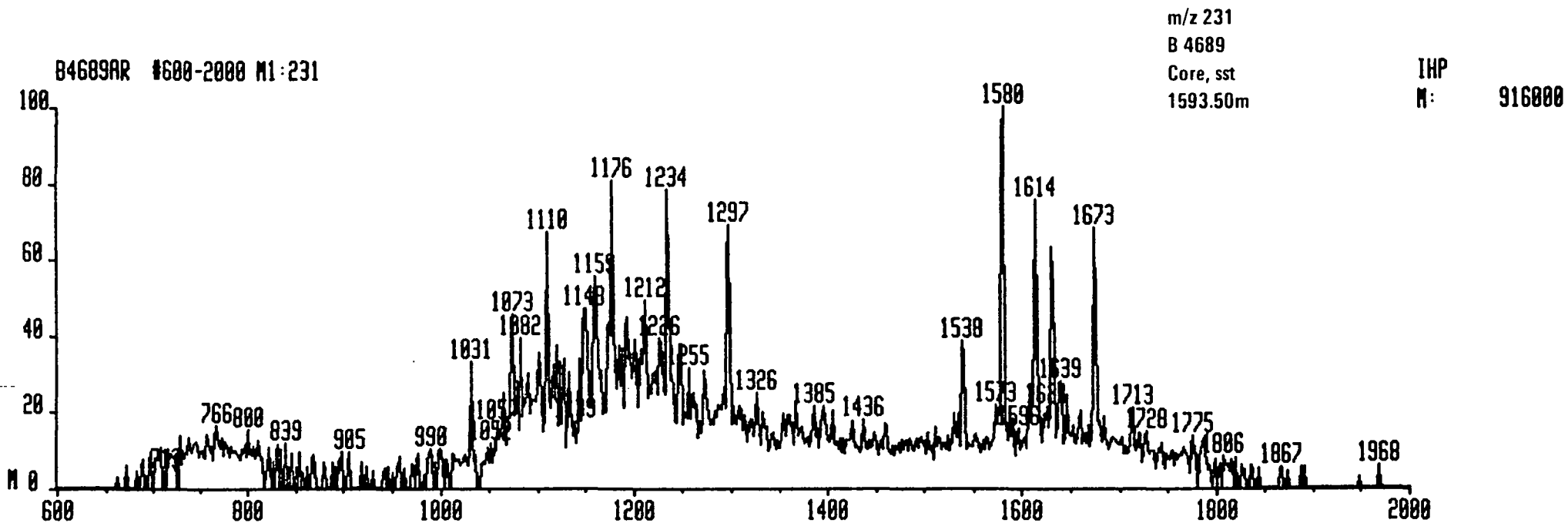
IHP
M: 691000

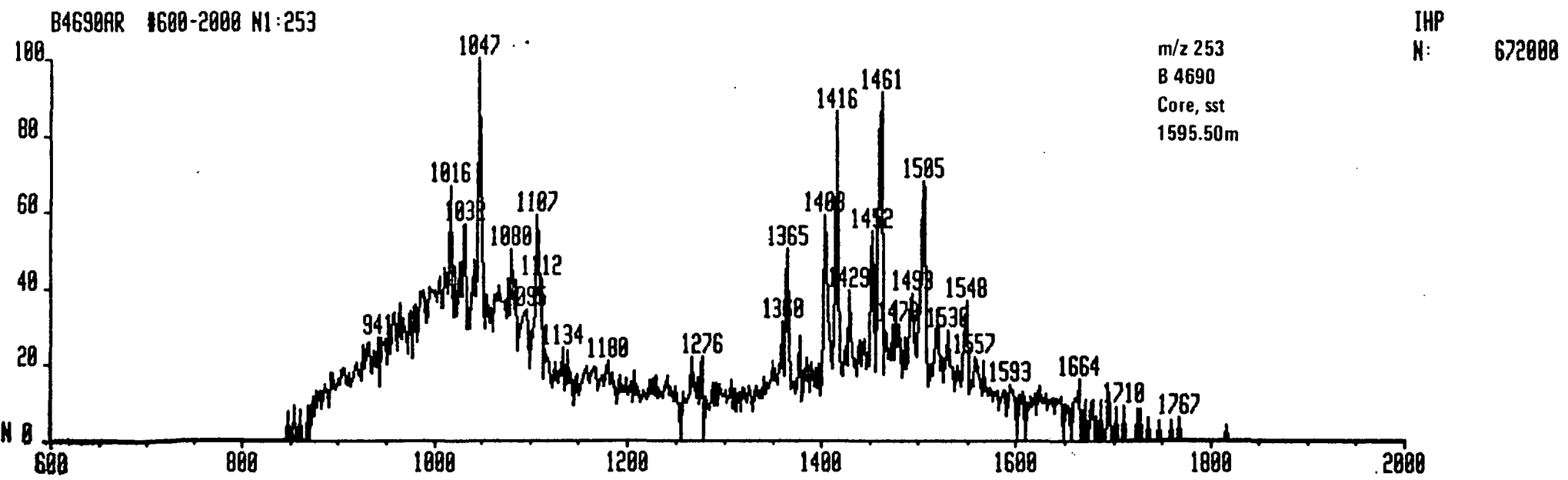
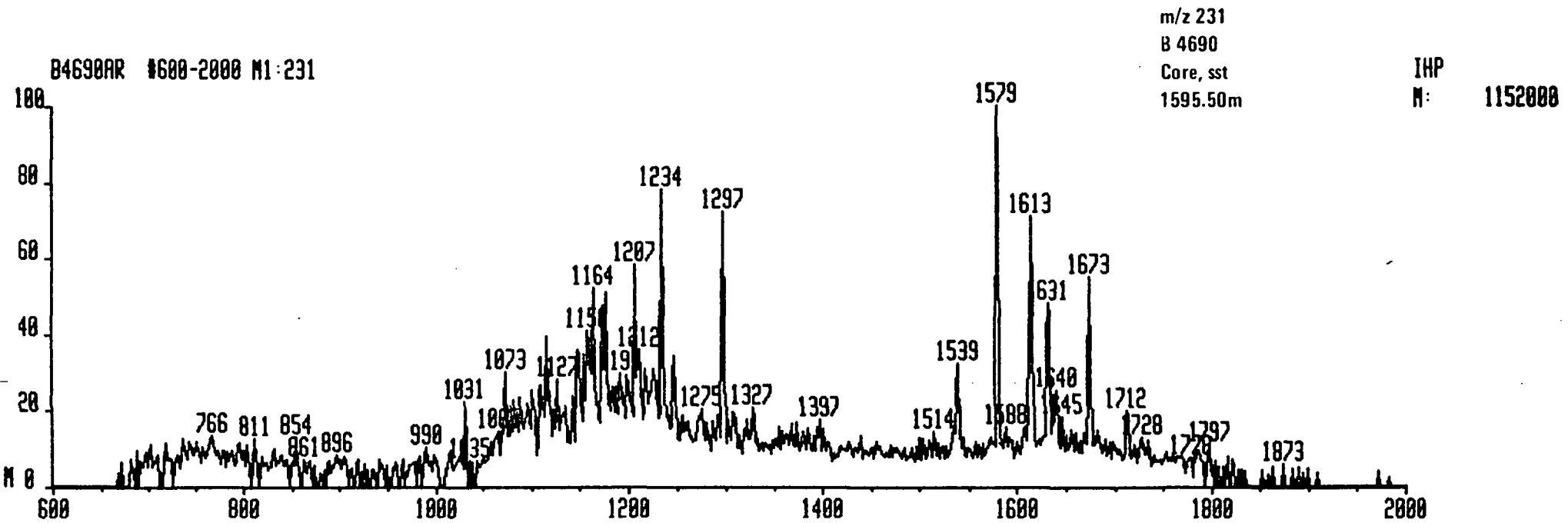
B4688AR #600-2000 N1:253



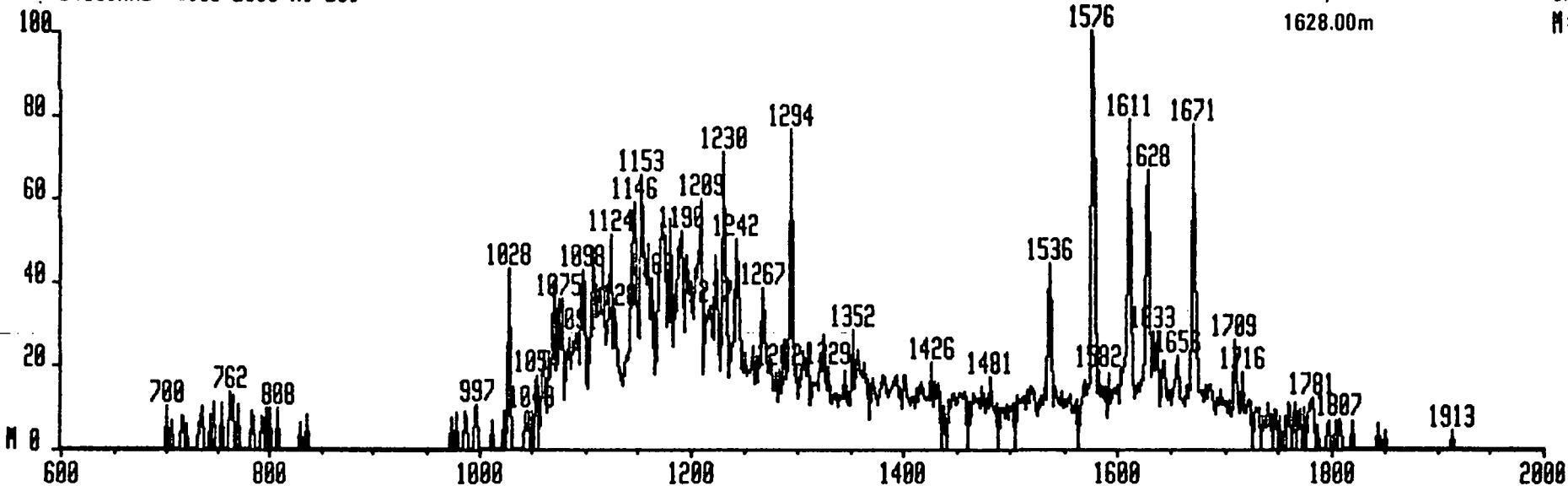
m/z 253
B 4688
Core, sst
1590.50m

IHP
M: 563000





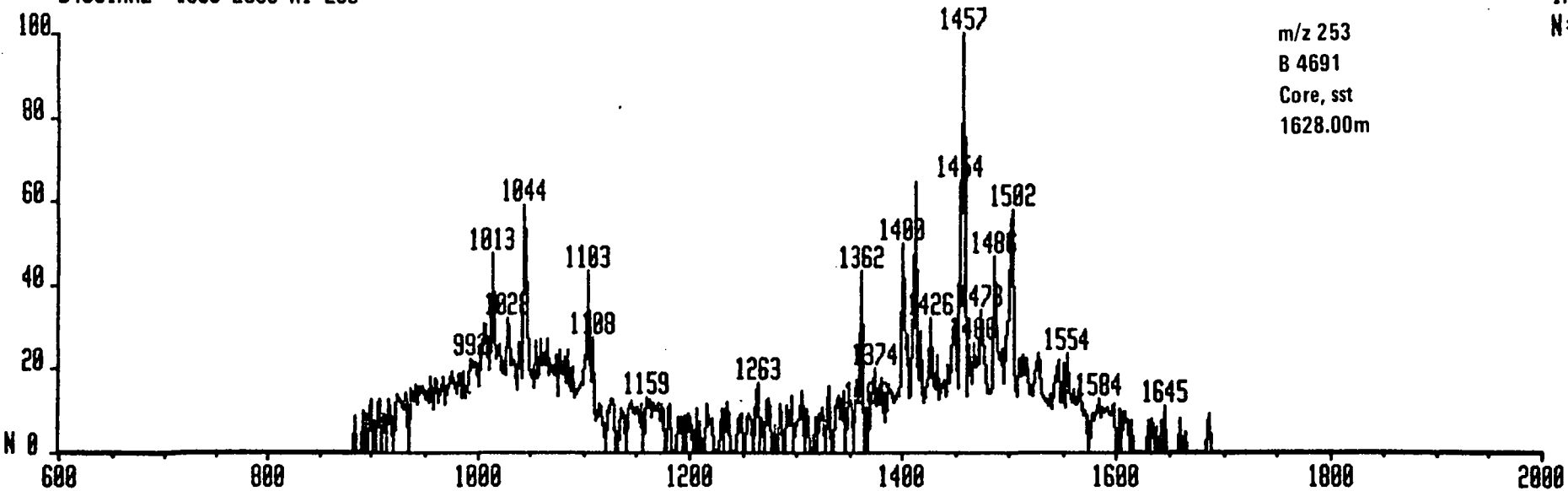
B4691AR2 #600-2000 M1:231



m/z 231
B 4691
Core, sst
1628.00m

IHP
M: 681000

B4691AR2 #600-2000 M1:253



m/z 253
B 4691
Core, sst
1628.00m

IHP
N: 696000

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.

1.2.1 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} $17\alpha(H)$ -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.

1.2.2 Maturity dependant 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 ($\geq C_{31}$), 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 T_m/T_s (Seifert et al., 1978) of the C_{27} hopanes. The maturable $18\alpha(H)$ -trisanorhopane (T_m) is reduced in intensity relative to the more stable

17 α (H)-trisanorhopane (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 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 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 %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).