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CORRELATION OF HYDROCARBON STAINING OF SANDSTONE CORES AND OIL 31/3-1

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SUMMARY/ SAMMENDRAG

One oil sample and six sandstone cores were analysed in an attempt to perform hydrocarbon correlation. All the applied methods suggest that the same type of source rock is responsible for the main part of the hydrocarbons extracted from the cores and for the oil.

KEY WORDS/ STIKKORD

Correlation | North Sea
GC-MS | $\delta^{13}C$ isotopes

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1. INTRODUCTION

An attempt to correlate hydrocarbon staining of six sandstone cores with an oil, and then further source rock correlation were performed. The oil was taken from the same depth interval as the cored section in this well, the Upper Jurassic sandstones from 1400-1600m.

A list of the samples analysed follows:

IKU no.	Sample type	Depth (m)
A-9617	oil (FMT 1)	1574.2
A-9620	sst. core (clst?)	1406.22
A-9621	sst. core	1567.86
A-9622	sst. core	1571.89
A-9623	sst. core	1573.03
A-9624	sst. core	1576.32
A-9625	sst. core	1578.59

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

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

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

1.1.1 Source characteristics 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. The amounts of tricyclic terpanes relative to the hopanes are also believed to a certain extent to be characteristic of the source rock. 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.

1.1.2 Maturity 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 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)-trisnorhopane (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 are transformed to the thermally stable 14α(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 increases with increasing maturity.

One of the reactions taking place at an early stage of diagenesis is the aromatisation of steranes, leading to the formation of mono- and

triaromatic analogs. This process is measured as the abundance of triaromatic relative to mono-aromatic compounds (% tri/tri + mono) in the m/z 231 and 253 mass chromatograms, respectively. In addition the degree of side chain cracking, as $\%C_{20}/C_{26,.27}$ 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.

1.1.3 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).

2. EXPERIMENTAL

2.1 Extractable Organic Matter

Approximately 50gm of powdered rock was extracted by flow blending 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.

Squalane was added prior to the extraction as an internal standard.

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

2.2 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 a stream of nitrogen. The oil was separated using the same system.

2.3 Urea adduction

Urea-adduction was performed on the same samples that were analysed on GC-MS. 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.

2.4 Gas Chromatographic Analysis

The saturated and the branched/cyclic hydrocarbon fractions were each diluted with n-hexane and analysed on a HP 5730A gas chromatograph, fitted with a 25m OV-101 fused silica capillary column. Hydrogen (0.7ml/min) was used as carrier gas. The total aromatic fractions were after dilution with n-hexane, analysed on a Carlo Erba Fractovap Series 2150 GC fitted with a 20mm SE-54 fused silica column.

Injections both systems were performed in the split mode (1:20). The temperature program applied was 80°C (2 min) to 260°C at 4°C/min.

In addition the whole oil was analysed on the HP 5730 A GC, applying a temperature program of the GC oven from -50°C (2 min.) to 280°C at 4°C/min. The C_2-C_8 GC's were acquired by hydrogen stripping on a Carlo Erba Fractovap GC. The column used for this was a 30m capillary column coated with squalane.

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

2.5 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.

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.

2.6 $\delta^{13}C$ 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 gravity for the oil was determined to 24.3°API, (Table 1) indicating the oil to be relatively heavy.

3.2 GC of whole oil

The cryogenic gas chromatogram of the whole oil is presented in Figure 1. Hardly any n-alkanes below nC_{10} and only small amounts of higher n-alkanes are revealed in this chromatogram. The main components are branched and cyclic components of low molecular weight. This is probably an indication of microbial alteration of the oil.

3.3 GC of C_2-C_8 hydrocarbons

The hydrogen stripping gas chromatogram in Figure 2 and the quantitative data in Table 2 indicate the same as the whole oil GC above. Very low relative amounts of n-alkanes and highest abundance of mono-cyclic components.

3.4 Extraction and chromatographic separation

Six sandstone cores were extracted before chromatographic separation of the extracted organic matter and of the oil. The weights and relative amounts of the various chromatographic fractions are given in Table 3. Five of the six sandstone are very rich in extractable organic matter, while the last one contains fair amounts.

The oil was seen to contain approximately 40% saturated and 25% aromatic hydrocarbons, making the SAT/ARO ratio equal to 1.7 and hydrocarbons/-nonhydrocarbons equal to 2.1. Most of the sandstone cores contained hydrocarbons with the same distribution of saturated and aromatic hydrocarbons relative to the nonhydrocarbons. The two samples with lowest extractability show lower values compared to the oil, of both SAT/ARO and of hydrocarbons/nonhydrocarbons. This suggests less migrated hydrocarbons in these samples and in particular samples A-9624, supporting what was seen from the extractability data. Sample A-9620 was seen to

consist of both sandstone and claystone, and contamination of the extracted sandstone by claystone cannot be totally excluded. Thus a mixed input might be seen in this sample.

As a whole the distribution of the extractable organic matter in the sandstone cores seems to be similar to the oil.

3.5 Gas chromatography of C_{15}^+ saturated hydrocarbons

Gas chromatograms of saturated hydrocarbons are presented in Figure 3, while data from the chromatograms are given in Table 4. The n-alkane profile of the oil is weakly bimodal, showing maxima at nC_{17} and nC_{28}. An unresolved complex mixture is seen as a hump underneath the alkanes. This low relative abundance of n-alkanes fits in quite well with what would be expected from the whole oil GC. The Pr/nC_{17} is higher in the C_{15}^+ fraction than what was seen in the whole oil chromatogram, a fact probably caused by the separation procedure. With exception of the shallowest core all the other samples exhibit similar alkane profiles as the oil, the bimodality being more or less pronounced. The high Pr/nC_{17} is seen for all the samples. From the relative amount of the internal standard (S in Figure 3) it is obvious that sample A-9624 is less rich in alkanes than the other samples. The shallowest core, A-9620, shows a unimodal alkane distribution with maximum at approximately nC_{16}. This may indicate that the oil and the hydrocarbons in the other cores consist of mixed inputs, one source being responsible for the low molecular weight components, while the heavier components have been generated from a different source. Since the uppermost core sample consists of a mixture of sand and shale, it might be expected that the shale part of the core has been responsible for one part of the hydrocarbons. However, with the low maturity assigned to the claystones at this depth interval generation of mature hydrocarbons would not be expected. The Pr/nC_{17} and CPI are approximately the same in this sample as in the others.

3.6 Gas chromatography of C_{15}^+ branched/cyclic hydrocarbons

Only minor differences could be seen in the chromatograms of the branched/-cyclic hydrocarbons presented in Figure 4. Some of the samples contain some n-alkanes, and A-9624 was seen to contain some unidentified peaks. These are thought to be contamination since they were seen only in the

sample with lowest abundance of hydrocarbons. The overall distribution of the branched components and relative abundance of branched and cyclic components were seen to be similar in all the samples.

3.7 Gas chromatography of C_{15}^{+} aromatic hydrocarbons

The GC traces of aromatic hydrocarbon fractions are shown in Figure 5. Naphthalene and alkylated homologs are the major components in all the chromatograms, supporting what was seen from the saturated hydrocarbon GC's. The oil and the hydrocarbons in the cores are very similar. Even with the poor resolution of the double doublet representing methylphenanthrenes, it is apparent that the second doublet is more abundant than the first one. This indicates that the maturity of all the extracts is similar.

3.8 GC-MS analysis of saturated steranes and terpanes

Mass chromatograms representing terpanes (m/z 191) and steranes (m/z 217 and 218) are presented in Figure 6. Molecular ratios calculated from the chromatograms are given in Table 5 and 6.

Only minor differences are seen in the various ratios that are known to be affected by maturity variations (Table 5). The isomerisation reactions have reached equilibrium, implying that mature hydrocarbons are encountered in all samples. No pronounced difference could be detected between the oil and the core extracts.

Some of the ratios in Table 6 are known to be affected by both type of organic matter and maturity. Those are the Tm/Ts ratio and the relative amount of tricyclic terpanes in the m/z 191 mass chromatograms, and the relative amount of rearranged steranes in the m/z 217 chromatograms. As is seen from the table all these ratios show only minor variations, implying that not only is the maturity but also the type of organic matter similar for the oil and the core extracts.

Of the last three ratios in Table 6 the relative amount of bisnorhopane (Z/E) is known to be characteristic of part of the Kimmeridge Formation in the North Sea. The values for this ratio are very consistent throughout the whole core interval. Only minor variation were also seen for the relative amount of the two unidentified components (Y/E and X/E).

From the triangular diagram showing the molecular weight distribution of regular steranes (Figure 7) a similar trend as above was seen. All the samples cluster together within a fairly narrow range of values. All the molecular ratios and the general distribution of steranes and terpanes suggest that the hydrocarbons extracted from the sandstone cores and the oil from the same depth interval originate from the same type of source rock.

3.9 GC-MS analysis of aromatic hydrocarbons

The total ion chromatograms of the aromatic hydrocarbons showed similar distribution to the gas chromatograms and are not presented. Distributions of alkylated benzenes, naphtalenes and phenanthrenes are presented as composite mass chromatograms in Figure 8.

The same trend as seen from the previously discussed data could be revealed from these mass chromatograms. Only minor differences were detected, implying the samples to be very similar. The methyl phenanthrenes (m/z 192) exhibit the same distribution between the first and second doublet, assigning similar maturity to all the samples.

3.10 $\delta^{13}C$ isotope analysis

Carbon isotope ratios of saturated and aromatic hydrocarbon fractions are presented in Table 7. The values are seen to be very consistent for the saturated hydrocarbons, a slightly higher value is seen for the sample that showed lowest extractability. For the other samples the ratio varies between -28.7 and -28.9, indicating the oil to be similar to the core extracts. The variation for the aromatic hydrocarbons is more pronounced, sample A-9620 and A-9624 giving higher values than the rest of the samples. Values of -27.4 and -27.5 were found for the oil and four of the cores, supporting the theory about these samples being similar. This variation between the samples may indicate that mixed input of hydrocarbons from two different sources has taken place.

4. CONCLUSION

All analyses show that the hydrocarbons in the sandstone cores are very similar to the oil sample.

One core which contained lower abundance of migrated hydrocarbons, showed characteristics somewhat different to the other samples. This could imply a certain extent of mixed inputs, but the main part of the hydrocarbons in the sandstone cores has most probably been generated from the same source rock as the oil. The shallowest core (A-9620) was seen to contain more low molecular weight alkanes than the other cores.

IKU

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Table 1: API gravity

IKU no.	Code	Depth (m)	API gravity
A-9617	FMT 1	1574.2	24.3^{o}

Table 2: Light hydrocarbons C_2-C_8

	A-9617 % of total oil
nC_2	0.03
nC_3	0.08
MC_3	0.3
nC_4	0.07
MC_4	0.2
nC_5	0.09
$2.2DMC_4$	0.07
CyC_5+$2MC_5$	0.6
$3MC_5$	0.3
nC_6	0.1
$MCyC_5$+$2.4DMC_5$	1.0
CyC_6	1.4
$2MC_6$+$3MC_6$	0.4
$1cis3DMCyC_5$	0.3
$1tr3DMCyC_5$	0.2
$2.2.4TMC_5$	0.5
nC_7	0.02
benzene+$2.2DMC_6$+$MCyC_6$	2.9
MC_7	0.1
toluene	0.9

Abbreviations:

nC_2	ethane
nC_3	propane
MC_3	methylpropane
nC_4	butane
MC_4	methylbutane
nC_5	pentane
$2.2DMC_4$	2.2 dimethylbutane
CyC_5+2MC_5	cyclopentane + 2 methylpentane
$3MC_5$	3methylpentane
nC_6	hexane
$MCyC_5+2.4DMC_5$	methylcyclopentane + 2.4 dimethylpentane
CyC_6	cyclohexane
$2MC_6+3MC_6$	2 methylhexane + 3 methylhexane
$1cis3DMCyC_5$	1cis 3 dimethylcyclopentane
$1tr3DMCyC_5$	1tr 3 dimethylcyclopentane
$2.2.4TMC_5$	2.2.4 trimethylpentane
nC_7	heptane
$2.2DMC_6$	2.2 dimethylhexane
$MCyC_6$	methylcyclohexane
MC_7	methylheptane
nC_8	octane

T A B L E : 3.a

CONCENTRATION OF SOM AND CHROMATOGRAPHIC FRACTIONS

IKU-No	DEPTH (m)	Rock Extr. (g)	SOM (mg)	Sat. (mg)	Aro. (mg)	HC (mg)	Non-HC (mg)	TOC (%)
A 9617	1574.20	249.3	238.2	102.0	60.0	162.0	76.2	-1.00
A 9620	1406.22	19.8	71.7	21.7	16.2	37.9	33.8	-1.00
A 9621	1567.36	23.7	524.4	199.6	142.6	342.2	182.3	-1.00
A 9622	1571.89	50.3	653.6	266.5	187.2	453.7	199.9	-1.00
A 9623	1573.03	53.2	1003.2	438.0	288.0	726.0	277.2	-1.00
A 9624	1576.32	50.0	40.2	9.0	9.8	18.8	21.4	-1.00
A 9625	1578.59	50.0	961.6	423.9	277.4	701.3	260.3	-1.00

DATE : 10 - 11 - 93.

T A B L E : 3.b

WEIGHT OF EOM AND CHROMATOGRAPHIC FRACTIONS

(Weight ppm OF rock)

IKU-No	DEPTH (m)	EOM	Sat.	Aro.	HC	Non HC
A 9617	1574.20	955	409	241	650	306
A 9620	1406.22	3621	1096	818	1914	1707
A 9621	1567.86	22127	8422	6017	14439	7688
A 9622	1571.89	12994	5298	3722	9020	3974
A 9623	1573.03	18857	8233	5414	13647	5211
A 9624	1576.32	804	180	196	376	428
A 9625	1578.59	19232	9478	5548	14026	5206

DATE : 10 - 11 - 83.

T A B L E : 3.c

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
A 9617	1574.20	42.8	25.2	68.0	170.0	32.0	212.6
A 9620	1406.22	30.3	22.6	52.9	134.0	47.1	112.1
A 9621	1567.86	38.1	27.2	65.3	140.0	34.7	187.8
A 9622	1571.89	40.8	28.6	69.4	142.4	30.6	227.0
A 9623	1573.03	43.7	28.7	72.4	152.1	27.6	261.9
A 9624	1576.32	22.4	24.4	46.8	91.8	53.2	87.9
A 9625	1578.59	44.1	28.8	72.9	152.8	27.1	269.4

DATE : 10 - 11 - 83.

T A B L E 4

TABULATION OF DATA FROM THE GASCHROMATOGRAMS

IKU No.	DEPTH (m)	PRISTANE / n-C17	PRISTANE / PHYTANE	CPI
A 9617	1574.20	1.1	2.0	1.0
A 9620	1406.22	1.2	2.3	0.9
A 9621	1567.86	1.1	1.9	1.0
A 9622	1571.89	1.1	1.9	1.0
A 9623	1573.03	1.1	2.1	1.0
A 9624	1576.32	1.1	2.3	1.0
A 9625	1578.59	1.1	2.0	0.9

DATE : 21 - 12 - 83.

Table 5: Maturity ratios calculated from sterane and terpane mass chromatograms

			m/z 191		m/z 217	
IKU Code	Depth (m)	Sample type	$\alpha\beta/\alpha\beta+\beta\alpha$ [1]	%22S [2]	%20S [3]	%$\beta\beta$ [4]
A-9617	1574.2	Oil	0.90	63.1	52.4	75.3
A-9620	1406.22	Sst.core (clst?)	0.90	63.0	49.5	72.8
A-9621	1567.86	Sst. core	0.89	58.1	54.4	75.9
A-9622	1571.89	Sst. core	0.89	58.3	52.9	75.2
A-9623	1573.03	Sst. core	0.90	56.1	57.7	72.3
A-9624	1576.32	Sst. core	0.91	59.6	49.6	71.1
A-9625	1578.59	Sst. core	0.90	58.8	55.6	73.2

1) E/E+F in Figure 7
2) J_1/J_1+J_2 in Figure 7
3) q/q+t in Figure 7
4) 2(r+s)/2(r+s)+q+t in Figure 7.

Table 6: Molecular ratios calculated from sterane and terpane mass chromatograms.

IKU Code	Depth (m)	Sample type	m/z 191 Tm/Ts[1)]	m/z 191 TRJ/E[2)]	m/z 191 Z/E	m/z 191 X/E	m/z 217 rearr./reg.[3)]
A-9617	1574.2	Oil	0.61	0.14	0.24	0.30	0.9
A-9620	1406.22	Sst. core (clst?)	0.64	0.20	0.22	0.27	1.0
A-9621	1567.86	Sst. core	0.62	0.18	0.23	0.30	0.9
A-9622	1571.89	Sst. core	0.61	0.14	0.26	0.29	1.0
A-9623	1573.03	Sst. core	0.57	0.10	0.22	0.16	1.1
A-9624	1576.32	Sst. core	0.76	0.23	0.22	0.15	1.0
A-9625	1578.89	Sst. core	0.48	0.13	0.24	0.19	1.1

1) B/A in Figure 7
2) Q/E in Figure 7
3) a+b/h+k in Figure 7

Table 7: $\delta^{13}C$ isotope values for saturated and aromatic hydrocarbons.

IKU Code	Depth (m)	Sample type	SAT	ARO
A-9617	1574.2	Oil	-28.8	-27.5
A-9620	1406.22	Sst. core (clst?)	-28.9	-27.0
A-9621	1567.86	Sst. core	-28.7	-27.4
A-9622	1571.89	Sst. core	-28.9	-27.5
A-9623	1573.03	Sst. core	-28.7	-27.4
A-9624	1576.32	Sst. core	-28.4	-26.4
A-9625	1578.59	Sst. core	-28.7	-27.5

Reference value for NBS-22: - 29.8.

Figure 1

Gas chromatogram of whole oil

MCy-C_5 - methylcyclopentane
Cy-C_6 - cyclohexane
MCy-C_6 - methyl-cyclohexane
Pr - pristane
Ph - phytane

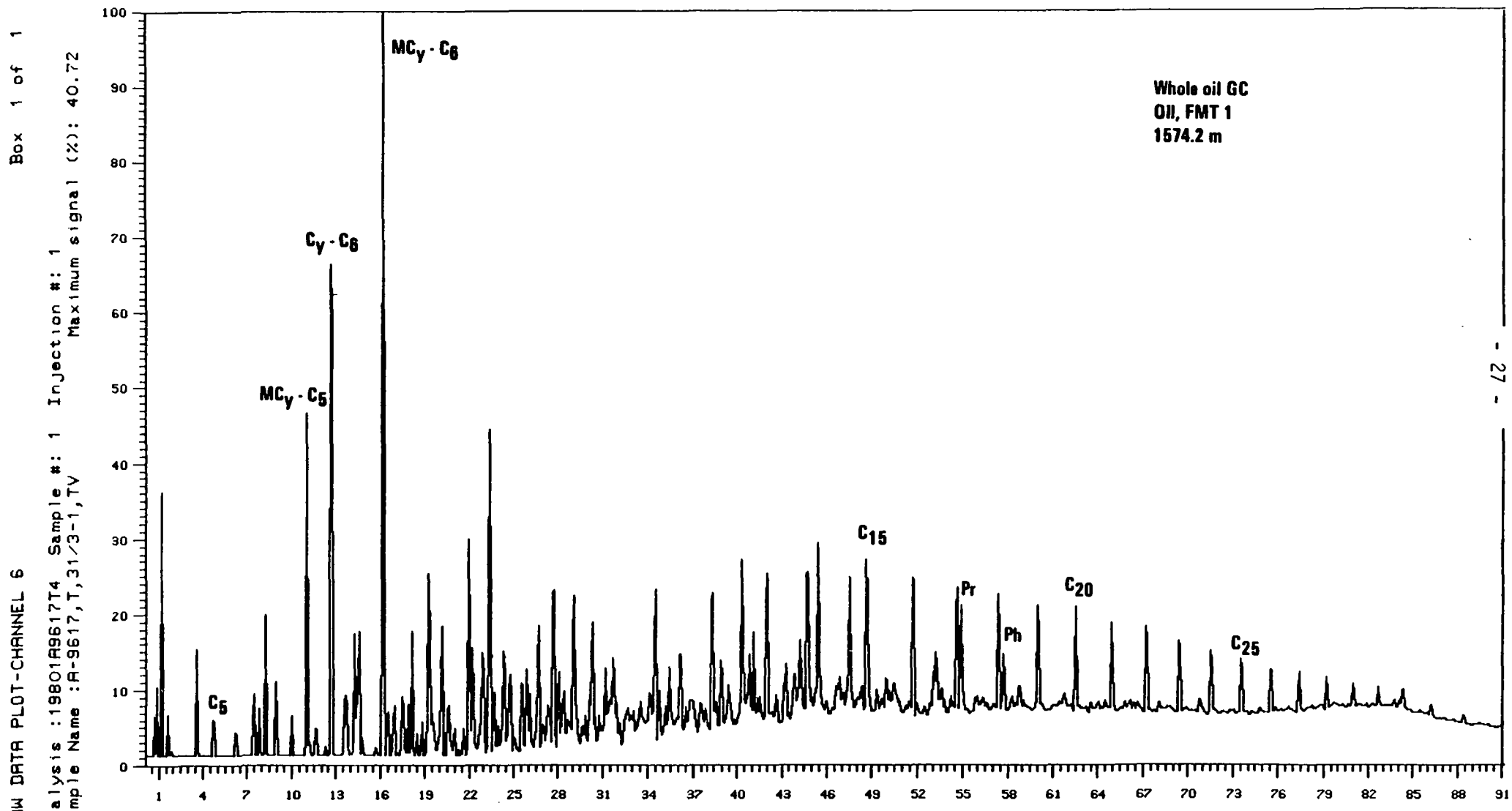
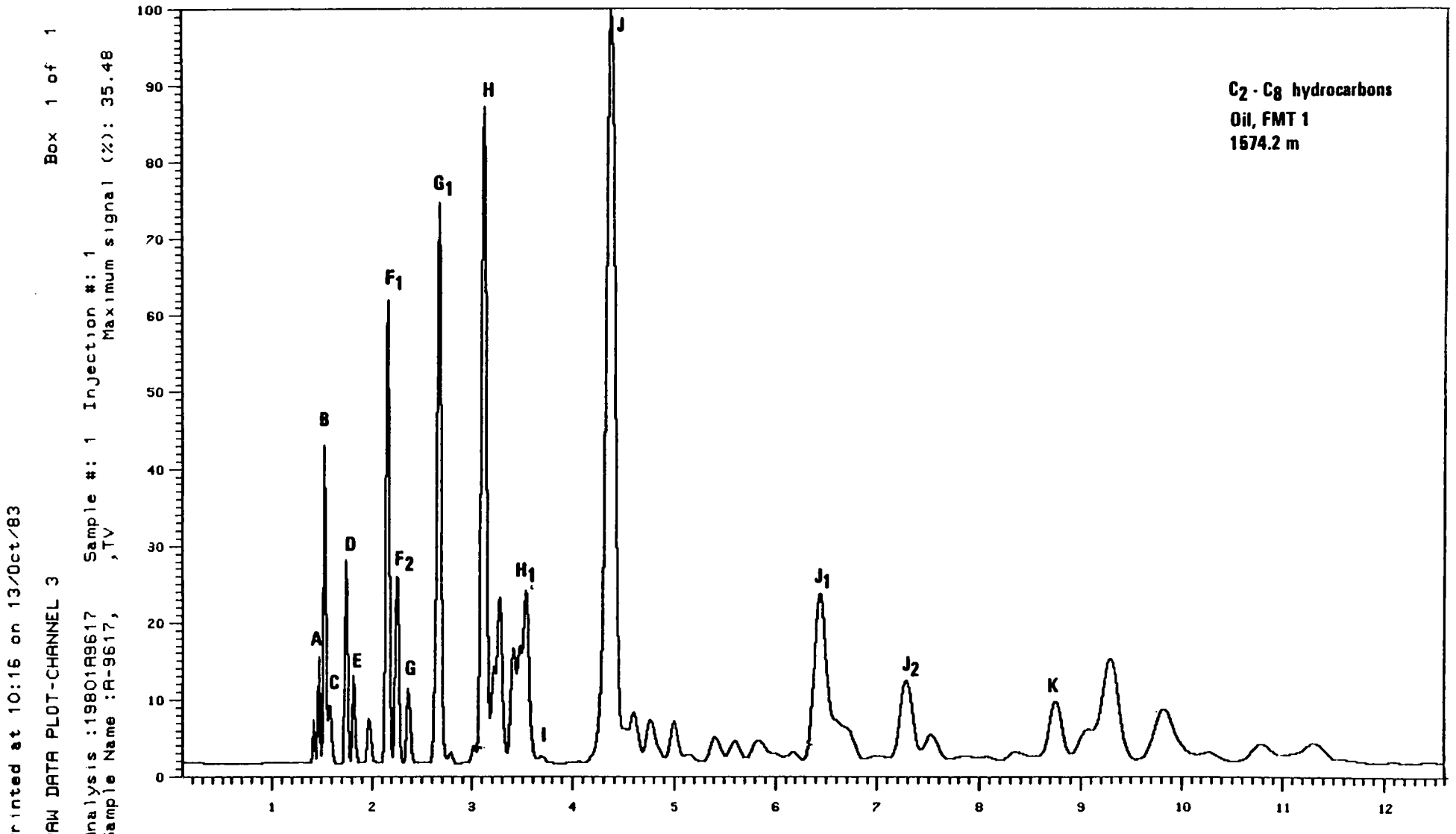

RAW DATA PLOT-CHANNEL 6
Box 1 of 1
Analysis :19801A9617T4 Sample #: 1 Injection #: 1
Sample Name :A-9617,T,31/3-1,TV
Maximum signal (%): 40.72
Whole oil GC
Oil, FMT 1
1574.2 m
MCy - C6
Cy - C6
MCy - C5
C5
C15
Pr
Ph
C20
C25
- 27 -

Figure 2

GC-chromatograms of light hydrocarbons (C_2-C_8)

A - propane (nC_3)
B - methylpropane (MC_3)
C - butane (nC_4)
D - methylbutane (MC_4)
E - pentane (nC_5)
F_1 - cyclopentane (CyC_5)+2 methylpentane ($2MC_5$)
F_2 - 3-methyl-pentane ($3MC_5$)
G - hexane (nC_6)
G_1 - methylcyclopentane ($MCyC_5$)+2.4dimethylpentane ($2.4DMC_5$)
H - cyclohexane (CyC_6)
H_1 - 2methylhexane ($2MC_6$)+3methylhexane ($3MC_6$)
I - heptane (nC_7)
J - benzene + 2.2dimethylpentane ($2.2DMC_5$) + methylcyclohexane ($MCyC_6$)
J_1 - methylheptane (mC_7)
J_2 - octane (nC_8)
K - toluene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RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :19801A9617 Sample #: 1 Injection #: 1
Sample Name :A-9617, ,TV Maximum signal (%): 35.48
A
B
C
D
E
F1
F2
G
G1
H
H1
I
J
J1
J2
K
C2 - C8 hydrocarbons
Oil, FMT 1
1574.2 m
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9
10
11
12

Figure 3

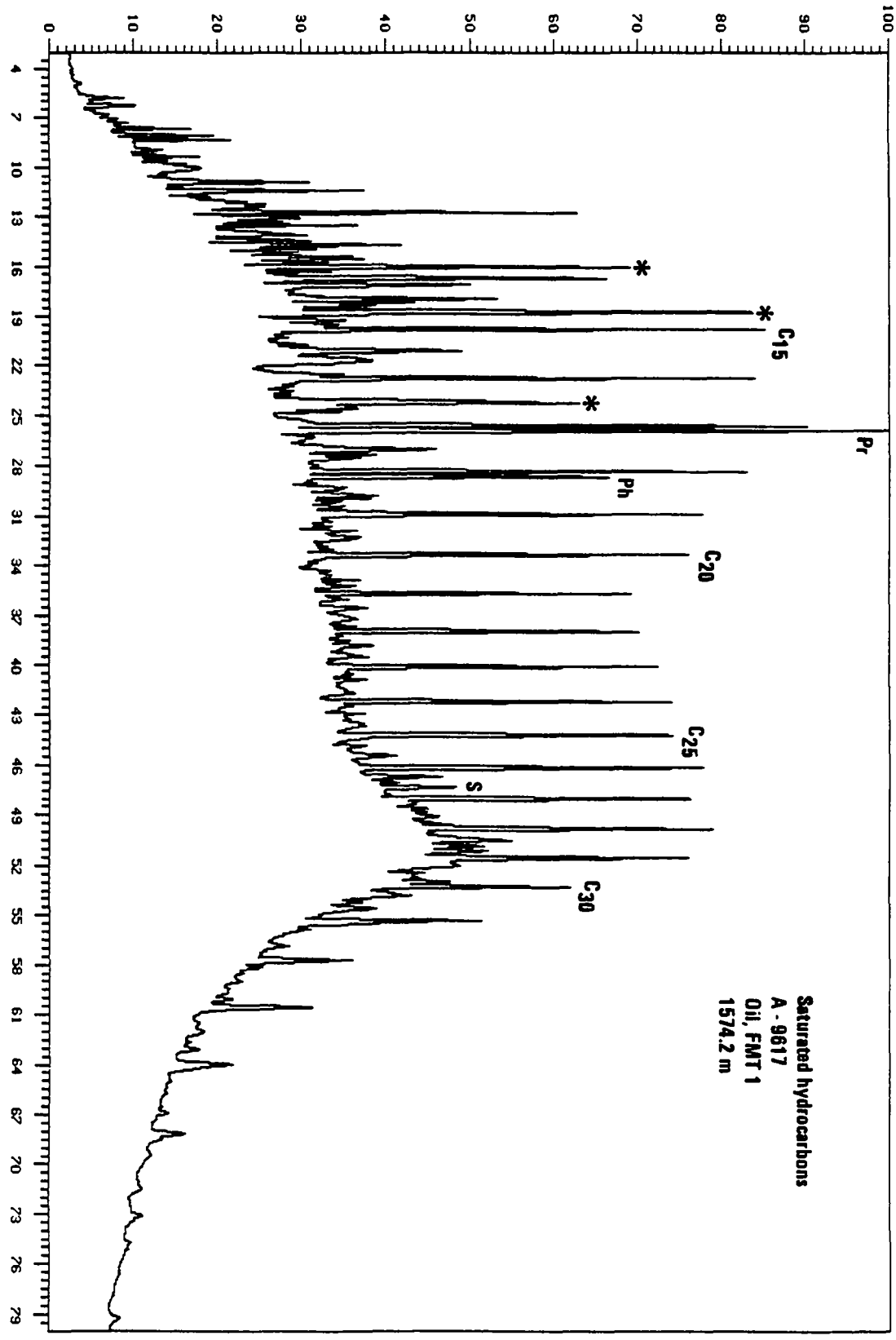
Gas chromatograms of C_{15}+ saturated hydrocarbons

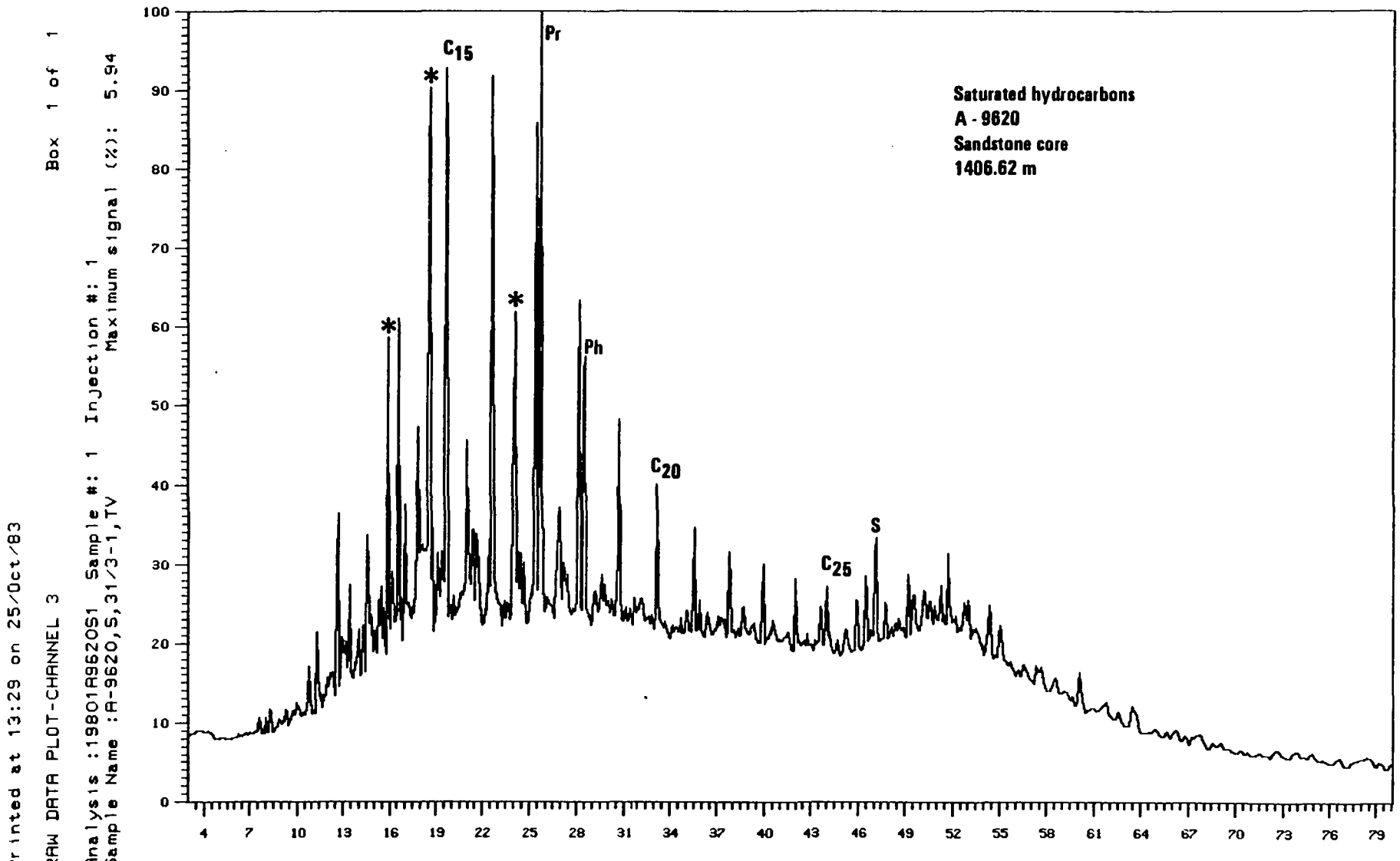
Pr - pristane
Ph - phytane
S - squalane (internal standard)
* - isoprenoid alkanes

Printed at 07:45 on 27/Oct/83

RAW DATA PLOT-CHANNEL 3 Box 1 of 1

Analysis :19801A9617S1 Sample #: 1 Injection #: 1
Sample Name :A-9617,S,31/3-1,TV Maximum signal (%): 28.27

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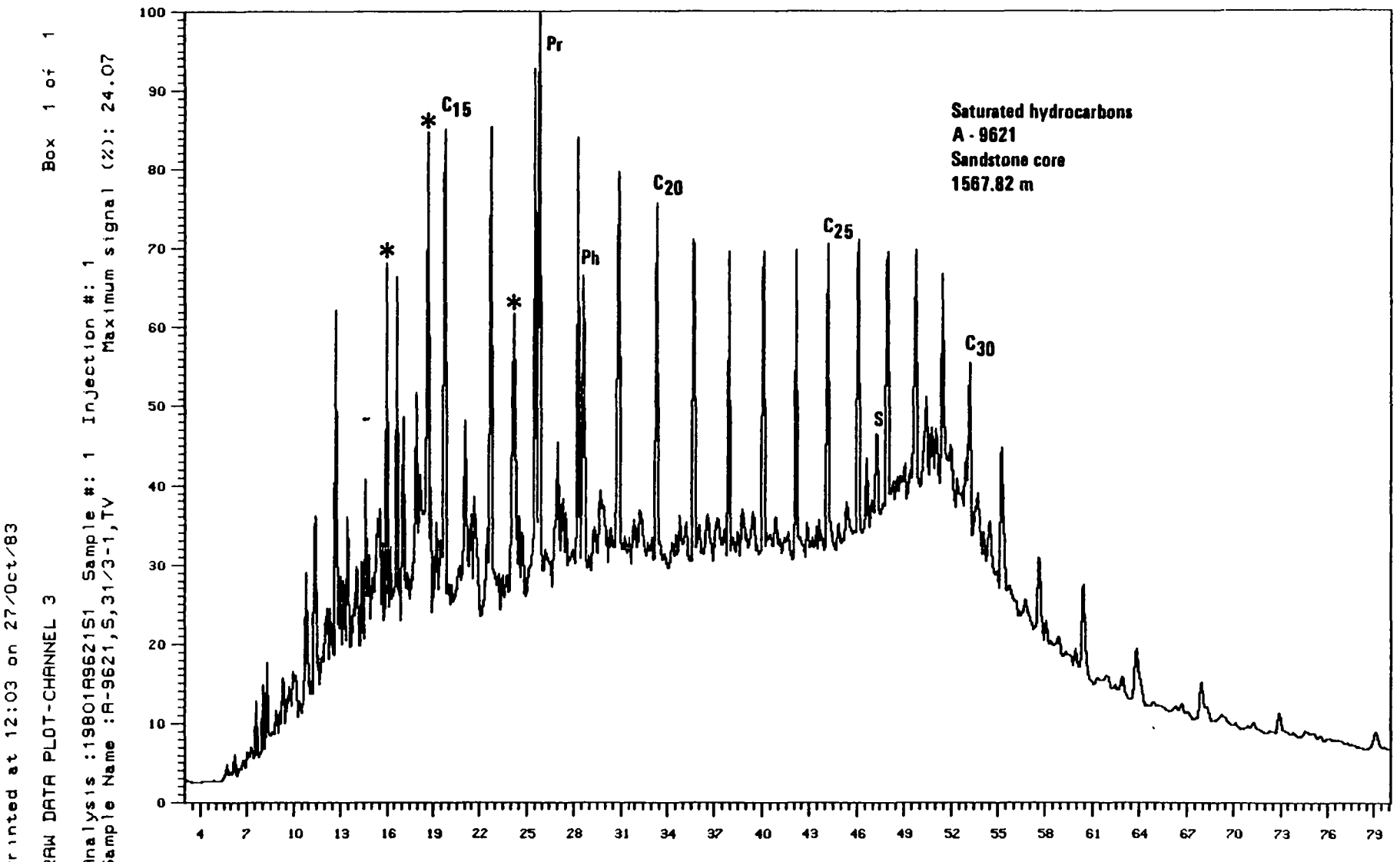
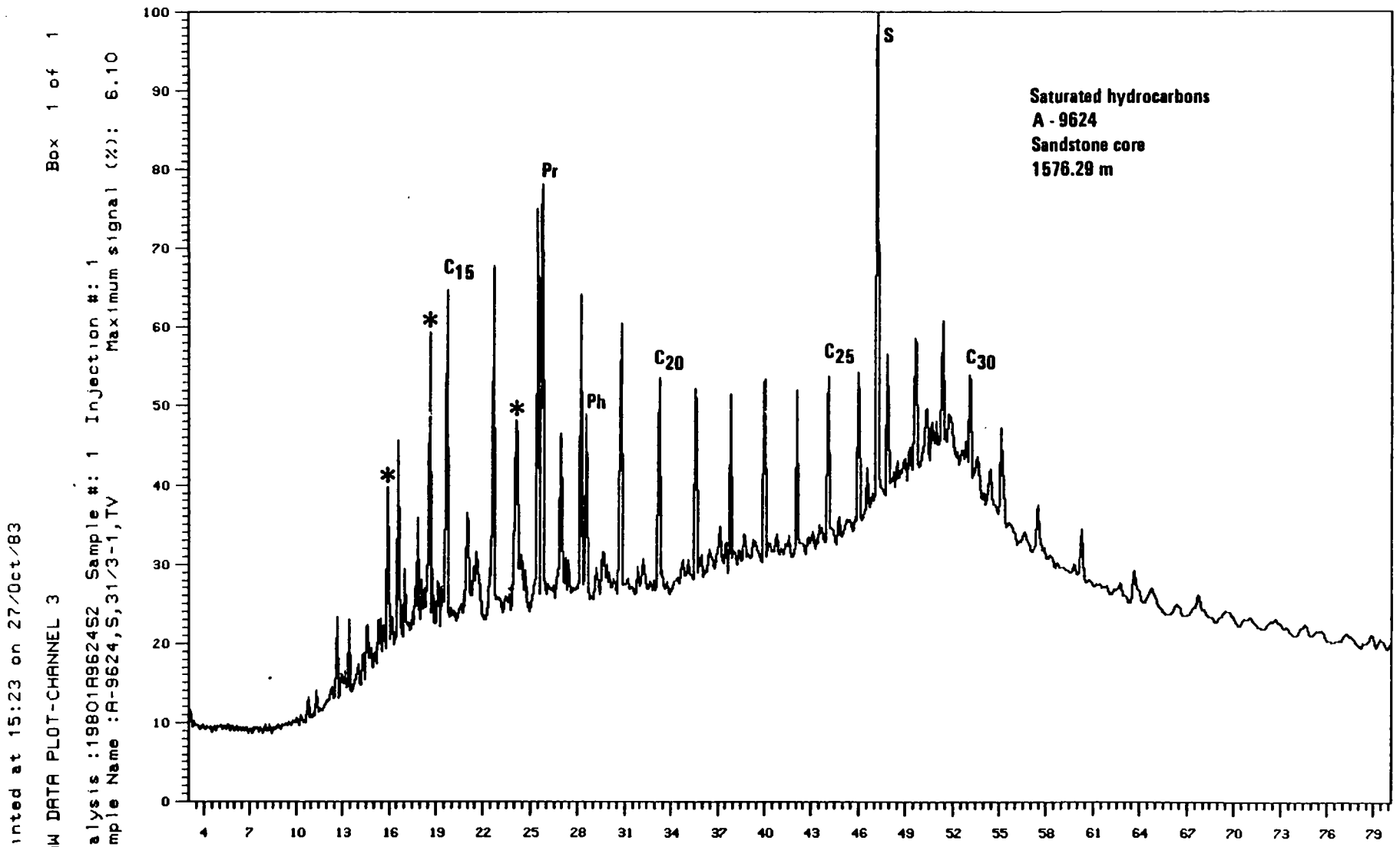
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :19801A9620S1 Sample #: 1 Injection #: 1
Sample Name :A-9620,S,31/3-1,TV Maximum signal (%): 5.94
Saturated hydrocarbons
A - 9620
Sandstone core
1406.62 m
C15
Pr
Ph
C20
C25
S
*
*
*
100
90
80
70
60
50
40
30
20
10
0
4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79


Printed at 12:03 on 27/Oct/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :19801A9621S1 Sample #: 1 Injection #: 1
Sample Name :A-9621,S,31/3-1,TV Maximum signal (%): 24.07
Saturated hydrocarbons
A - 9621
Sandstone core
1567.82 m
Pr
Ph
C15
C20
C25
C30
S
*
100
90
80
70
60
50
40
30
20
10
0
4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79

Printed at 07:58 on 26/Oct/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :1980IR9622S1 Sample #: 1 Injection #: 1
Sample Name :R-9622,S,31/3-1,TV
Maximum signal (%): 26.63
Saturated hydrocarbons
A - 9622
Sandstone core
1571.86 m
Pr
Ph
C15
C20
C25
C30
S
*
*
100
90
80
70
60
50
40
30
20
10
0
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79

Printed at 09:17 on 28/Oct/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :19801R96235Z Sample #: 1 Injection #: 1
Sample Name :R-9623,S,31/3-1,TV
Maximum signal (%): 4.56
Saturated hydrocarbons
A - 9623
Sandstone core
1573.01 m
C15
Pr
Ph
C20
C25
S
C30
*
100
90
80
70
60
50
40
30
20
10
0
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79


Printed at 15:23 on 27/Oct/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :19801R9624S2 Sample #: 1 Injection #: 1
Sample Name :A-9624,S,31/3-1,TV
Maximum signal (%): 6.10
Saturated hydrocarbons
A - 9624
Sandstone core
1576.29 m
S
Pr
Ph
C15
C20
C25
C30
*
100
90
80
70
60
50
40
30
20
10
0
4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79

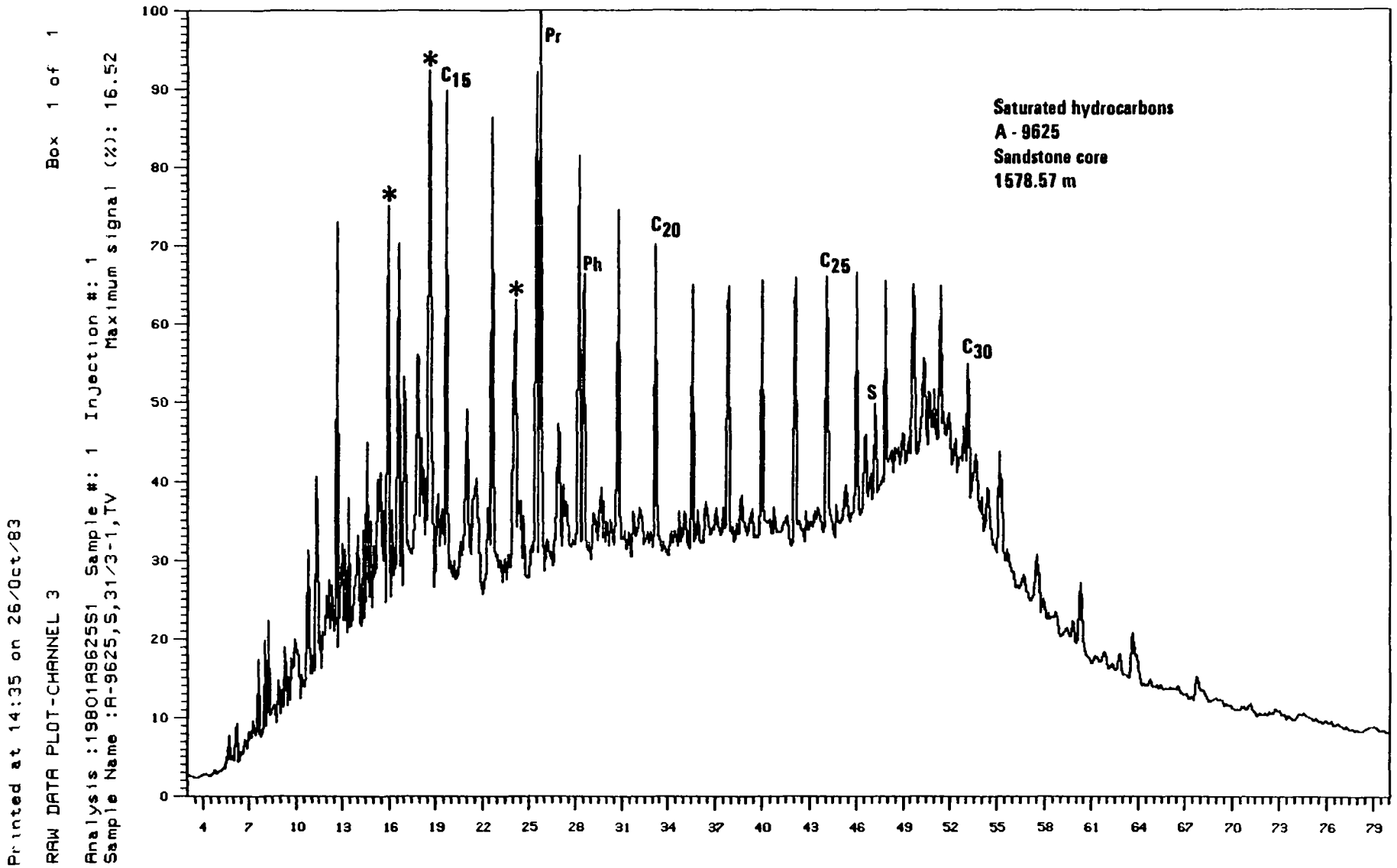
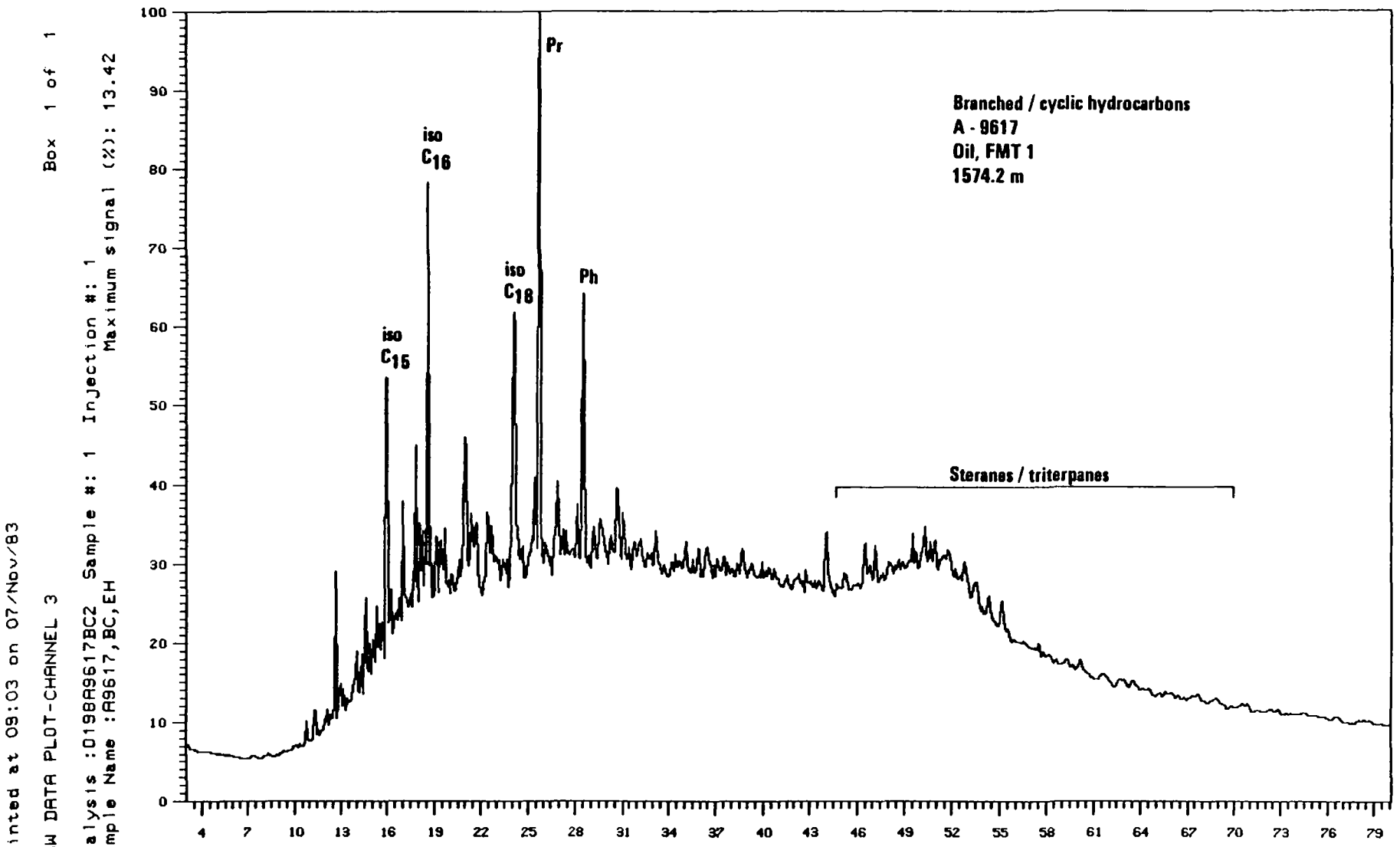
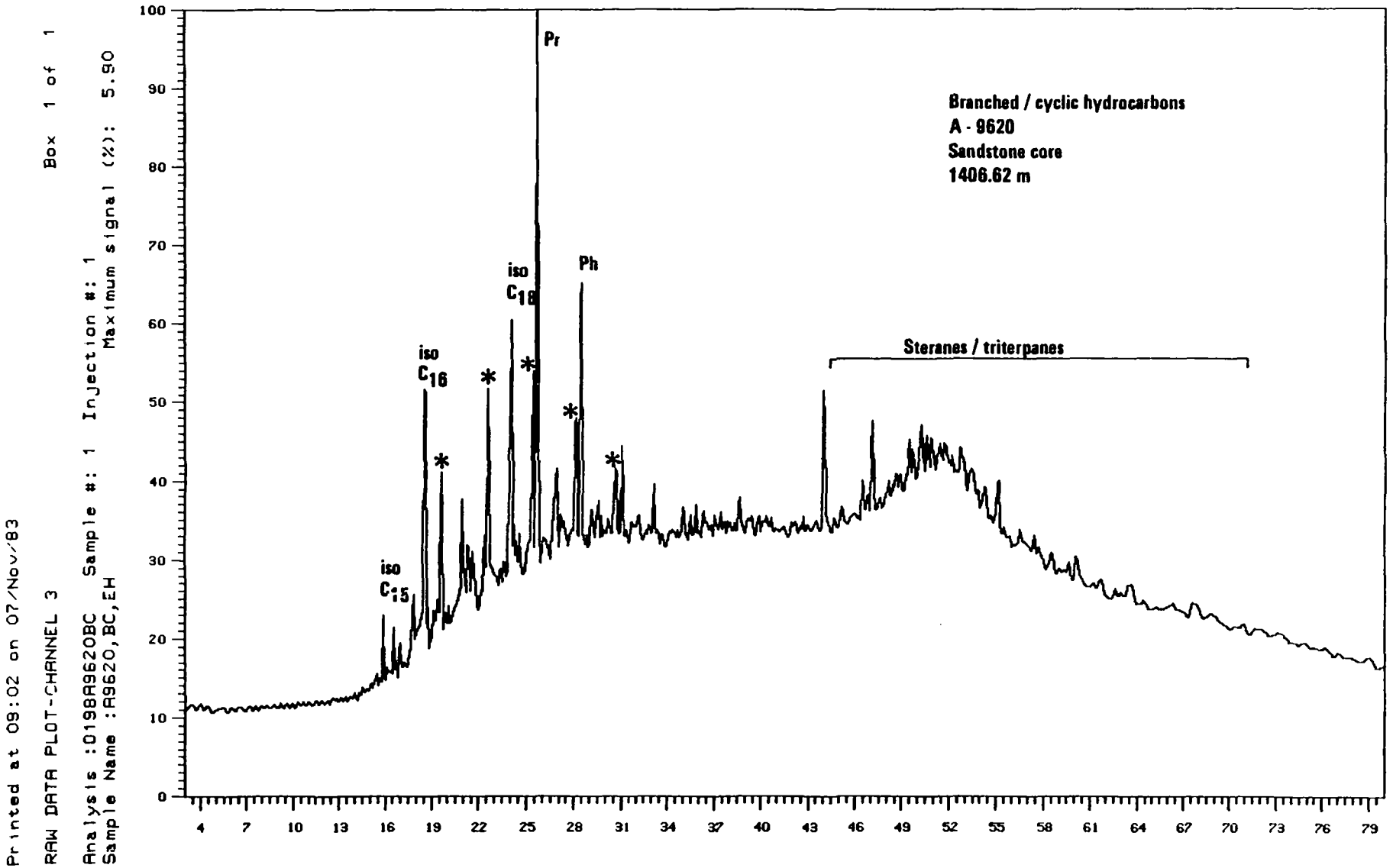

Printed at 14:35 on 26/Oct/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :19801A9625S1 Sample #: 1 Injection #: 1
Sample Name :A-9625,S,31/3-1,TV
Maximum signal (%): 16.52
Saturated hydrocarbons
A - 9625
Sandstone core
1578.57 m
Pr
Ph
C15
C20
C25
C30
S
*
100
90
80
70
60
50
40
30
20
10
0
4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79

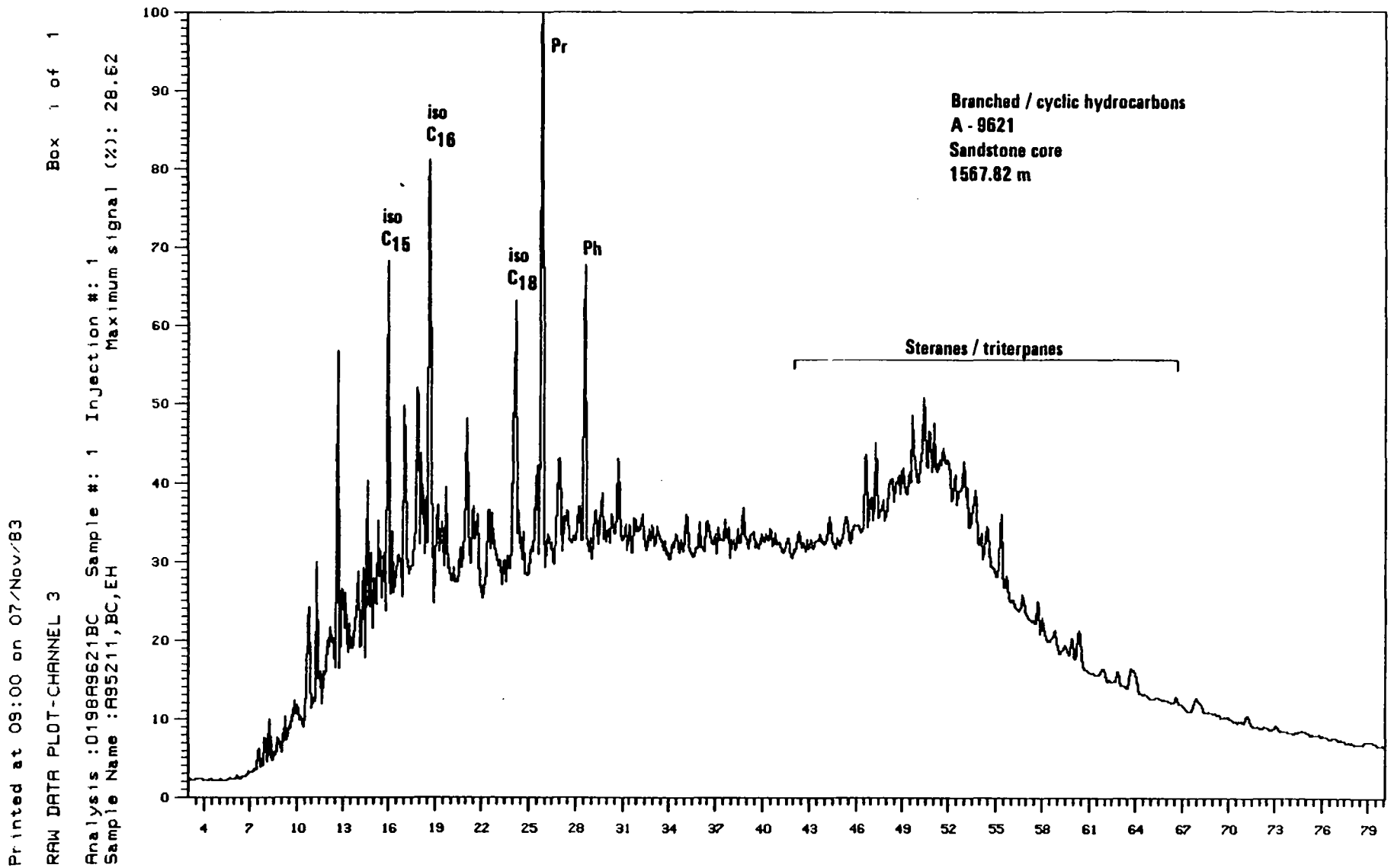
Figure 4

Gas chromatograms of branched/cyclic hydrocarbons

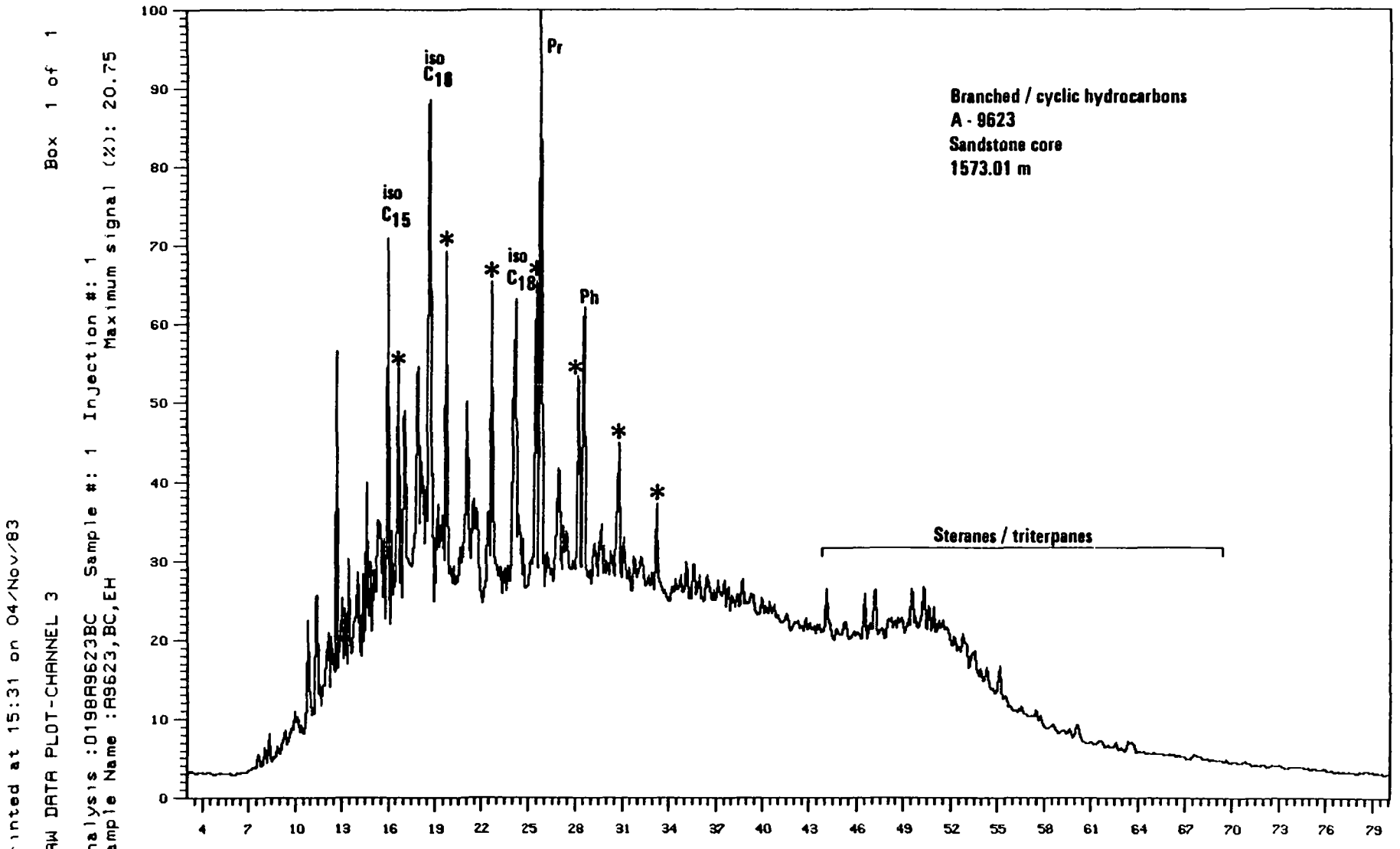
iso C_{15}, C_{16}, C_{18}	isoprenoids with the respective C-numbers
Pr	pristane
Ph	phytane
*	n-alkanes

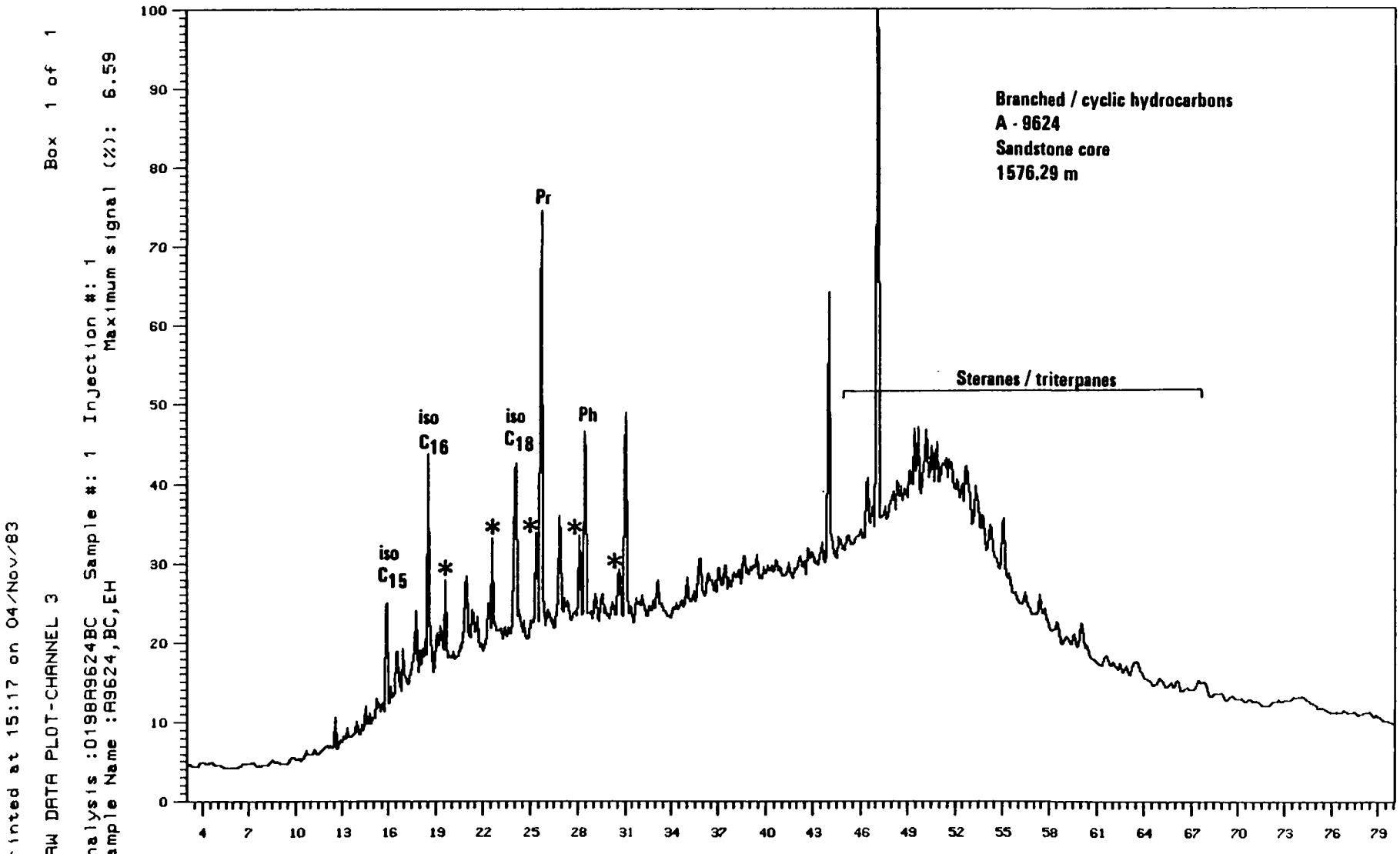

Printed at 09:03 on 07/Nov/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :0198A9617BC2 Sample #: 1 Injection #: 1
Sample Name :A9617,BC,EH
Maximum signal (%): 13.42
Branched / cyclic hydrocarbons
A - 9617
Oil, FMT 1
1574.2 m
iso C15
iso C16
iso C18
Pr
Ph
Steranes / triterpanes
100
90
80
70
60
50
40
30
20
10
0
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79

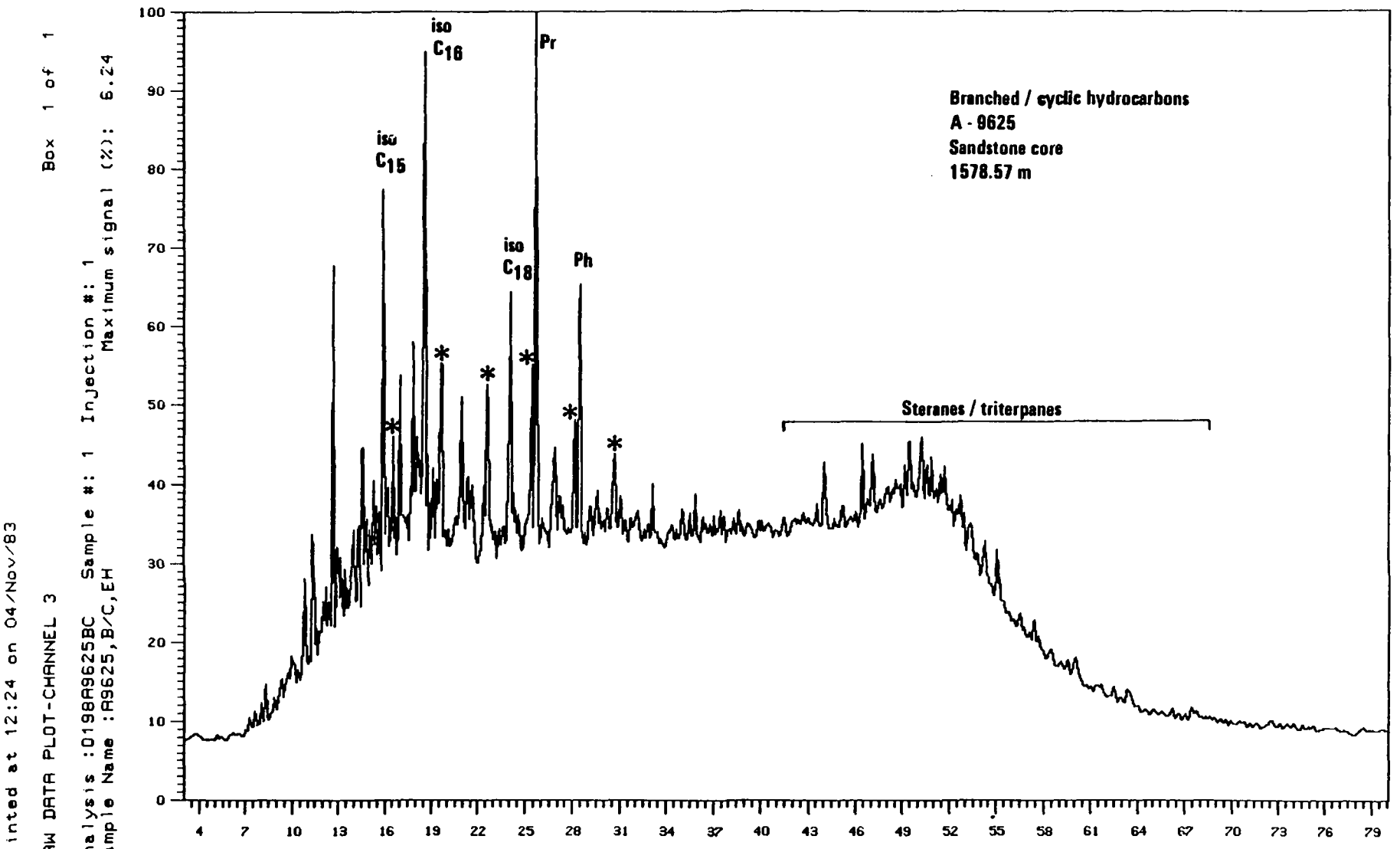

Printed at 09:02 on 07/Nov/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :0198A9620BC Sample #: 1 Injection #: 1
Sample Name :A9620,BC,EH
Maximum signal (%): 5.90
Branched / cyclic hydrocarbons
A - 9620
Sandstone core
1406.62 m
Pr
Ph
iso C15
iso C16
iso C18
Steranes / triterpanes
100
90
80
70
60
50
40
30
20
10
0
4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79


Printed at 09:00 on 07/Nov/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :0198A9621BC Sample #: 1 Injection #: 1
Sample Name :A95211,BC,EH
Maximum signal (%): 28.62
Branched / cyclic hydrocarbons
A - 9621
Sandstone core
1567.82 m
iso C15
iso C16
iso C18
Pr
Ph
Steranes / triterpanes
100
90
80
70
60
50
40
30
20
10
0
4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79

Printed at 08:58 on 07/Nov/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :0198R96222BC Sample #: 1 Injection #: 1
Sample Name :R9622,BC,EH
Maximum signal (%): 5.32
Branched / cyclic hydrocarbons
A - 9622
Sandstone core
1571.86 m
Steranes / triterpanes
Pr
Ph
iso C18
iso C16
iso C15


Printed at 15:31 on 04/Nov/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :0198A9623BC Sample #: 1 Injection #: 1
Sample Name :A9623,BC,EH Maximum signal (%): 20.75
Branched / cyclic hydrocarbons
A - 9623
Sandstone core
1573.01 m
iso C15
iso C18
Pr
iso C18
Ph
Steranes / triterpanes
0
10
20
30
40
50
60
70
80
90
100
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79


Printed at 15:17 on 04/Nov/83
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :0198A9624BC Sample #: 1 Injection #: 1
Sample Name :A9624,BC,EH
Maximum signal (%): 6.59
Branched / cyclic hydrocarbons
A - 9624
Sandstone core
1576.29 m
iso C15
iso C16
iso C18
Pr
Ph
Steranes / triterpanes
100
90
80
70
60
50
40
30
20
10
0
4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79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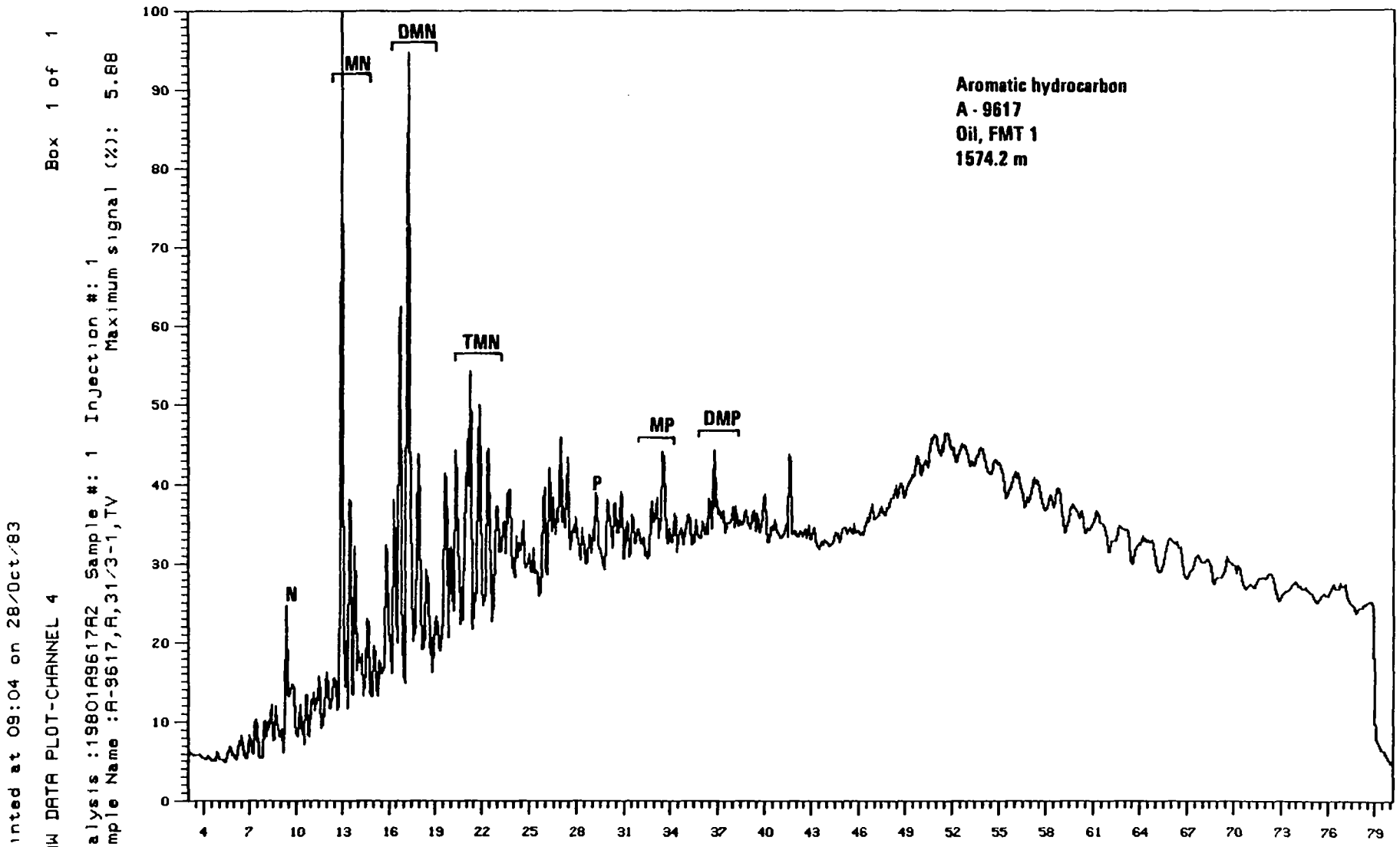
RAW DATA PLOT-CHANNEL 3
Box 1 of 1
Analysis :0198A9625BC Sample #: 1 Injection #: 1
Sample Name :A9625,B/C,EH
Maximum signal (%): 6.24
iso C15
iso C16
Pr
iso C18
Ph
Steranes / triterpanes
Branched / cyclic hydrocarbons
A - 9625
Sandstone core
1578.57 m
100
90
80
70
60
50
40
30
20
10
0
4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79

Figure 5

Gas chromatograms of C_{15}+ aromatic hydrocarbons

N - naphtalene
MN - C_1-naphtalenes
DMN - C_2-naphtalenes
TMN - C_3-naphtalenes
P - phenanthrene
MP - C_1-phenanthrenes
DMP - C_2-phenanthrenes


Printed at 09:04 on 28/Oct/83
RAW DATA PLOT-CHANNEL 4
Box 1 of 1
Analysis :19801A9617A2 Sample #: 1 Injection #: 1
Sample Name :A-9617,A,31/3-1,TV
Maximum signal (%): 5.88
Aromatic hydrocarbon
A - 9617
Oil, FMT 1
1574.2 m
N
MN
DMN
TMN
P
MP
DMP
0
10
20
30
40
50
60
70
80
90
100
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79

Printed at 08:35 on 27/Oct/83
RAW DATA PLOT-CHANNEL 4
Box 1 of 1
Analysis :19801R9620R1 Sample #: 1 Injection #: 1
Sample Name :R-9620,R,31/3-1,TV
Maximum signal (%): 27.62
Aromatic hydrocarbons
A - 9620
Sandstone core
1406.62 m
N
MN
DMN
TMN
P
MP
DMP
DMP
0
10
20
30
40
50
60
70
80
90
100
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79

Printed at 08:44 on 27/Oct/83
RAW DATA PLOT-CHANNEL 4
Box 1 of 1
Analysis :1980IR9621R1 Sample #: 1 Injection #: 1
Sample Name :R-9621,R,31/3-1,TV
Maximum signal (%): 19.47
Aromatic hydrocarbon
A - 9621
Sandstone core
1567.82 m
MN
DMN
N
TMN
P
MP
DMP
100
90
80
70
60
50
40
30
20
10
0
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79

Printed at 08:58 on 28/Oct/83
RAW DATA PLOT-CHANNEL 4
Box 1 of 1
Analysis :19801R9622R1 Sample #: 1 Injection #: 1
Sample Name :R-9622,R,31/3-1,TV
Maximum signal (%): 18.68
Aromatic hydrocarbons
A - 9622
Sandstone core
1571.86 m
MN
DMN
TMN
N
P
MP
DMP
100
90
80
70
60
50
40
30
20
10
0
4
7
10
13
16
19
22
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64
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70
73
76
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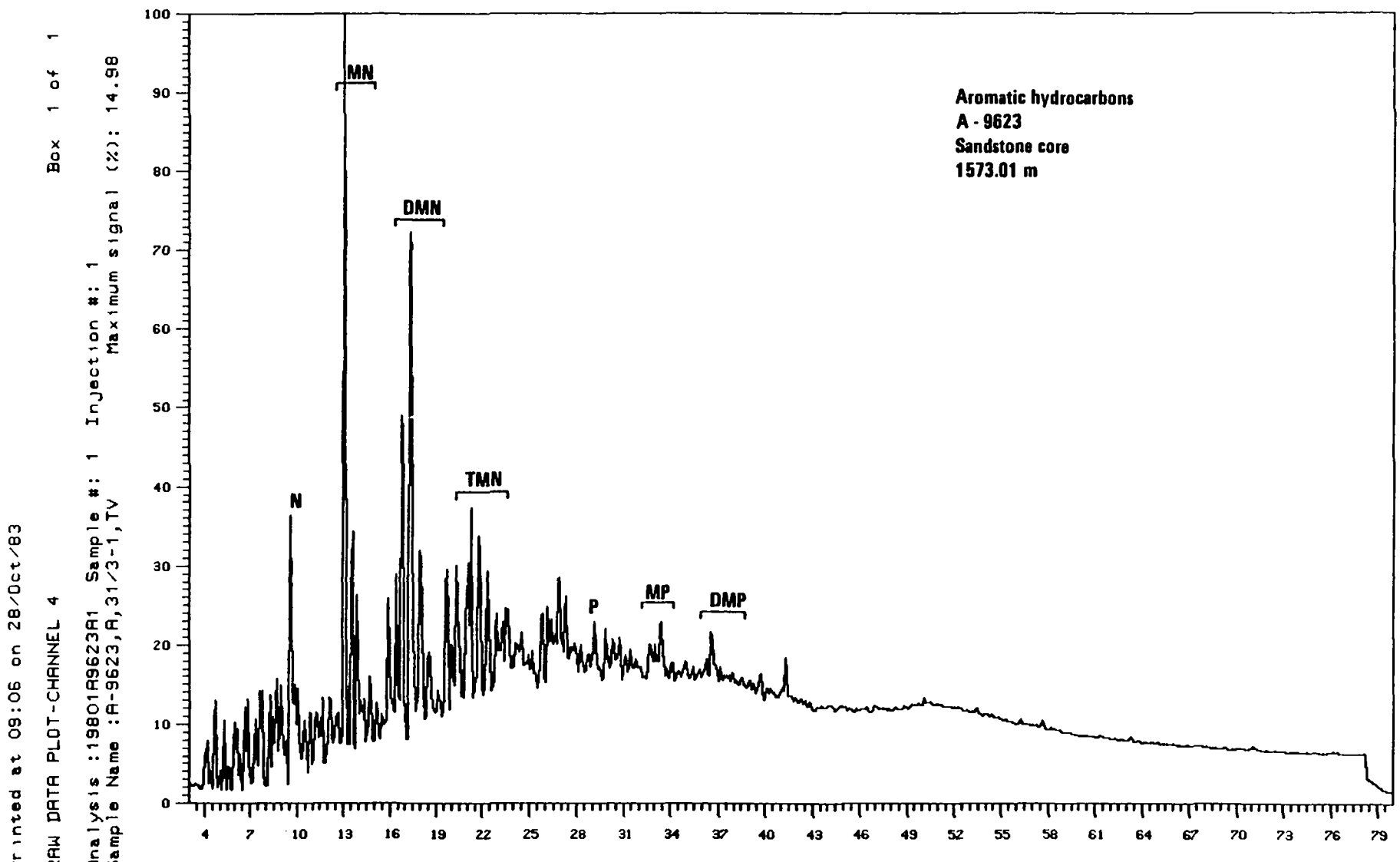
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RAW DATA PLOT-CHANNEL 4
Box 1 of 1
Analysis :19801A9623A1 Sample #: 1 Injection #: 1
Sample Name :A-9623,A,31/3-1,TV Maximum signal (%): 14.98
Aromatic hydrocarbons
A - 9623
Sandstone core
1573.01 m
N
MN
DMN
TMN
P
MP
DMP
0
10
20
30
40
50
60
70
80
90
100
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79

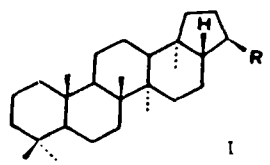
Printed at 09:02 on 28/Oct/83
RAW DATA PLOT-CHANNEL 4
Box 1 of 1
Analysis :19801R9624R1 Sample #: 1 Injection #: 1
Sample Name :R-9624,R,31/3-1,TV
Maximum signal (%): 11.35
Aromatic hydrocarbons
A - 9624
Sandstone core
1576.29 m
N
MN
DMN
TMN
P
MP
DMP
100
90
80
70
60
50
40
30
20
10
0
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79

Printed at 09:08 on 28/Oct/83
RAW DATA PLOT-CHANNEL 4
Box 1 of 1
Analysis :19801R9625R1 Sample #: 1 Injection #: 1
Sample Name :R-9625,R,31/3-1,TV
Maximum signal (%): 45.96
Aromatic hydrocarbons
A - 9625
Sandstone core
1578.57 m
N
MN
DMN
TMN
P
MP
DMP
100
90
80
70
60
50
40
30
20
10
0
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79

Figure 6a

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) + unknown triterpane (gammacerane?)	$C_{31}H_{54}$	(I,R=C_4H_9)
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})



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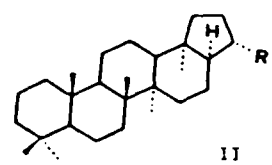

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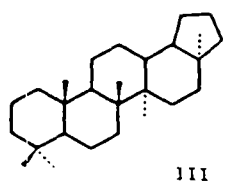

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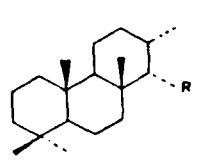
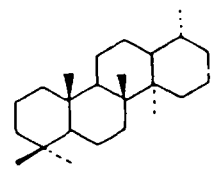
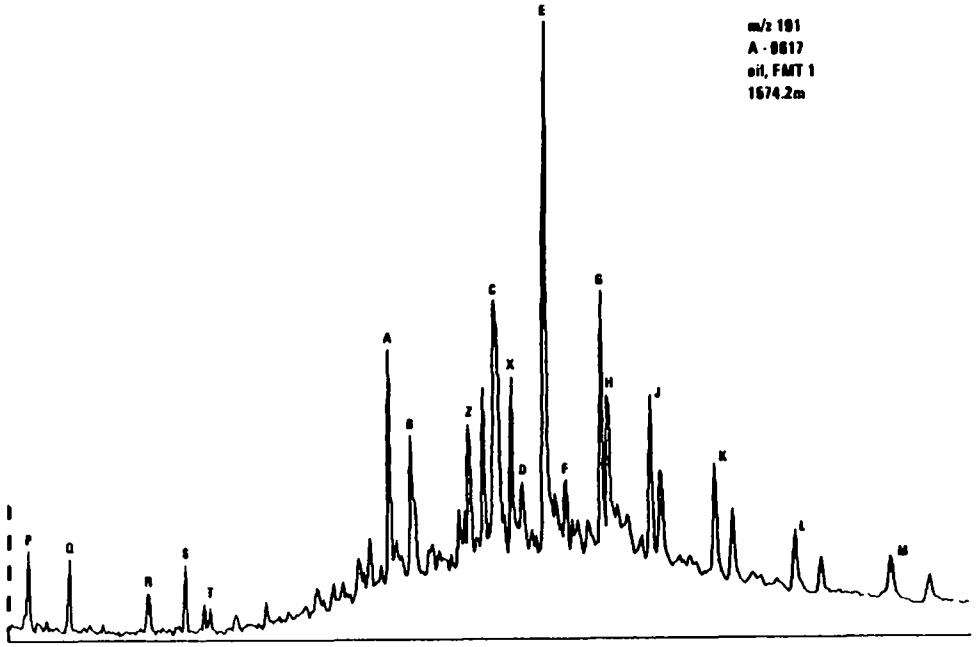
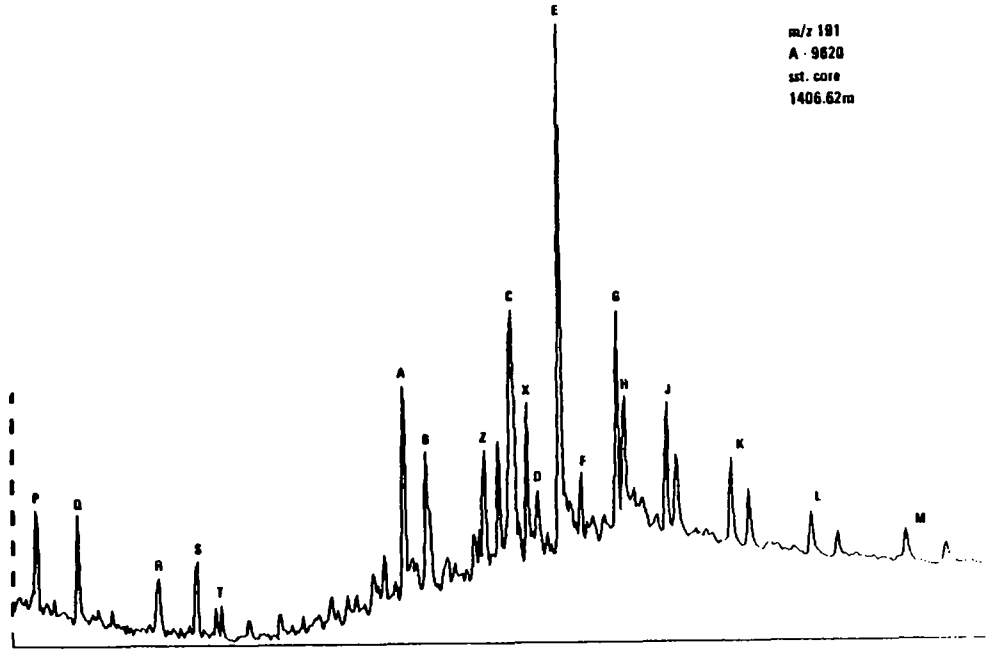





m/z 191
A - 9617
oil, FMT 1
1674.2m
P
Q
R
S
T
A
B
Z
C
X
D
E
F
G
H
J
K
L
M


m/z 191
A - 9620
sst. core
1406.62m
P
Q
R
S
T
A
B
Z
C
X
D
E
F
G
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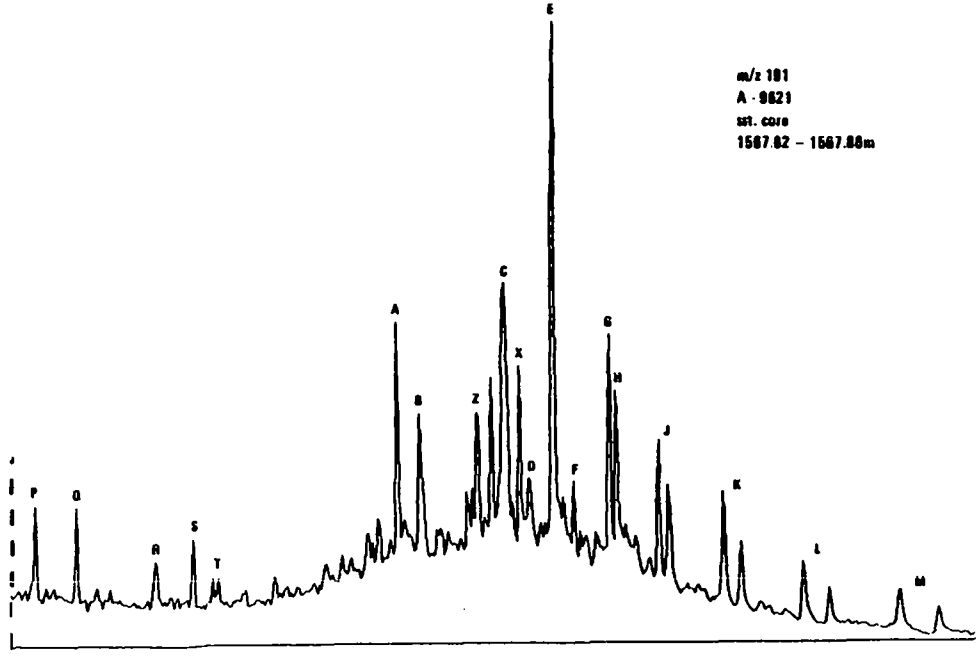
J
K
L
M


m/z 191
A - 9621
sst. core
1567.82 – 1567.88m
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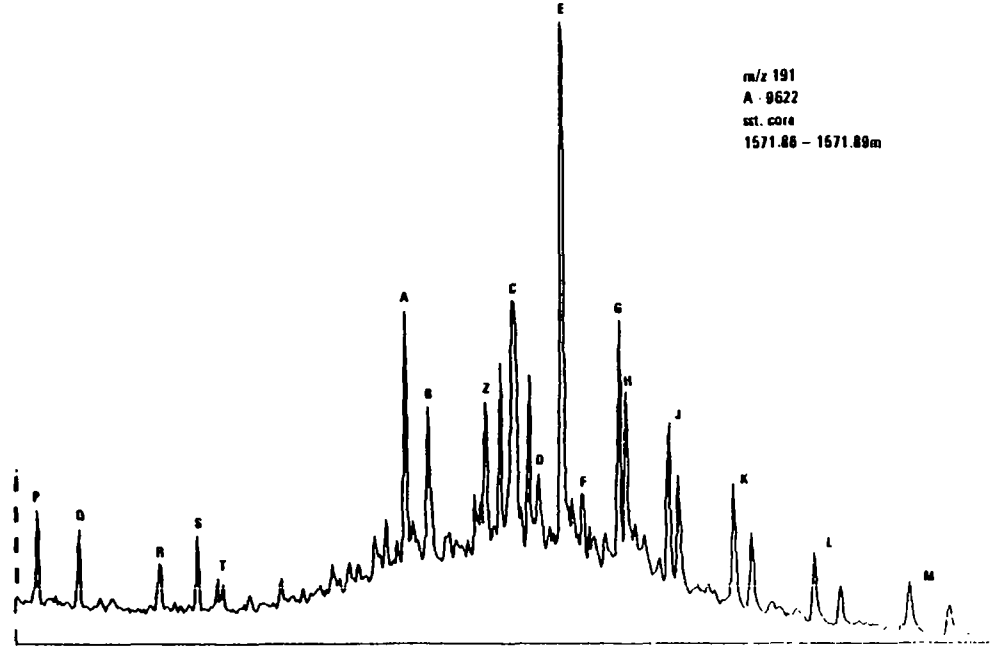
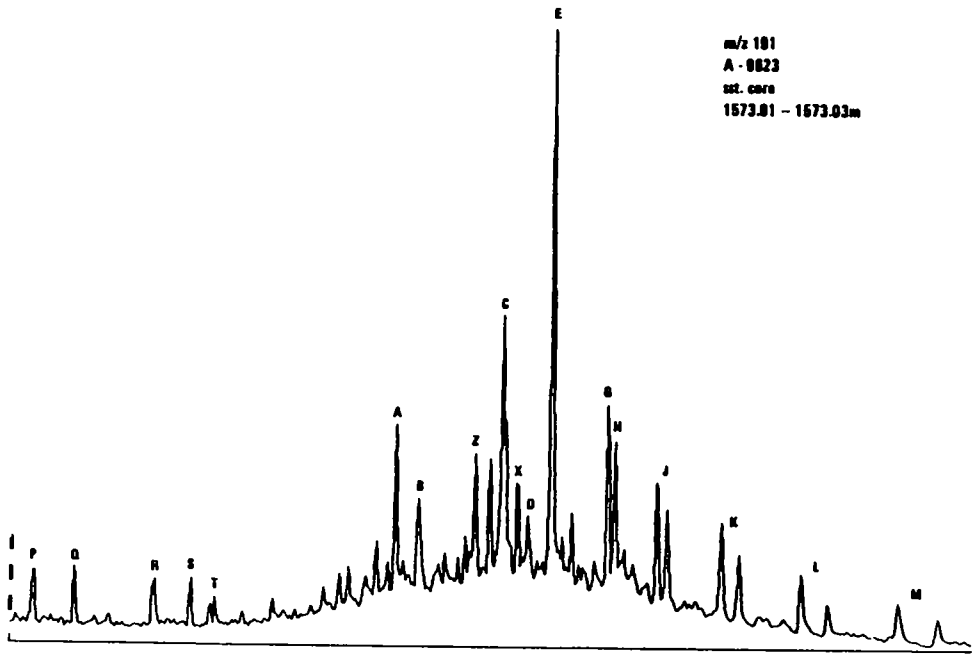
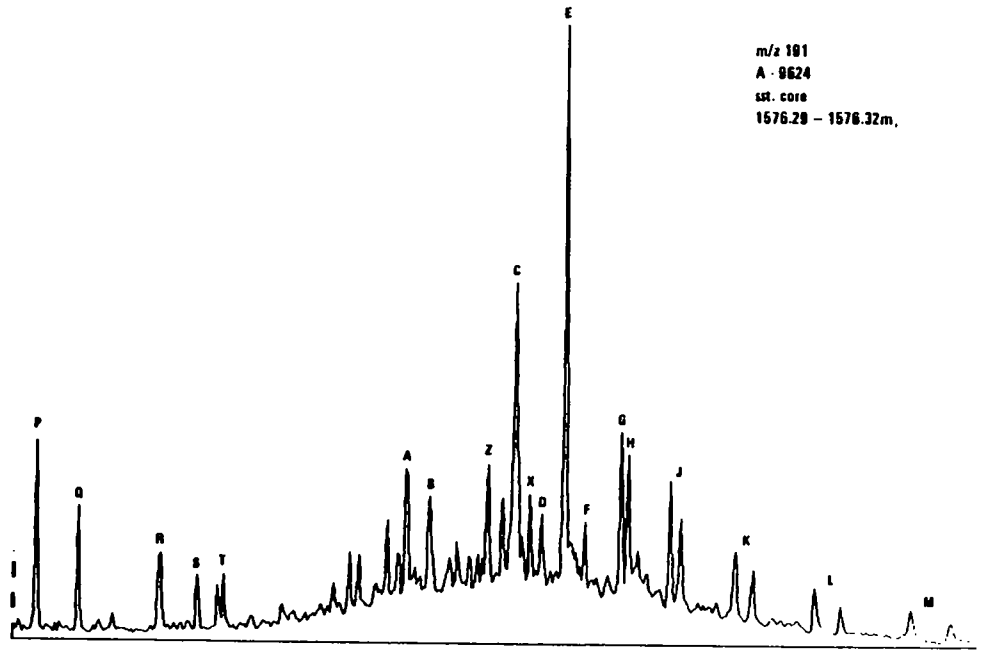

m/z 191
A - 9622
sst. core
1571.86 – 1571.89m
P
Q
R
S
T
A
B
Z
C
D
E
F
G
H
J
K
L
M


m/z 191
A - 9623
sst. core
1573.81 – 1573.03m
P
Q
R
S
T
A
B
Z
C
X
D
E
F
G
H
J
K
L
M


m/z 191
A - 9624
sst. core
1576.29 – 1576.32m,
P
Q
R
S
T
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B
Z
C
X
D
E
F
G
H
J
K
L
M

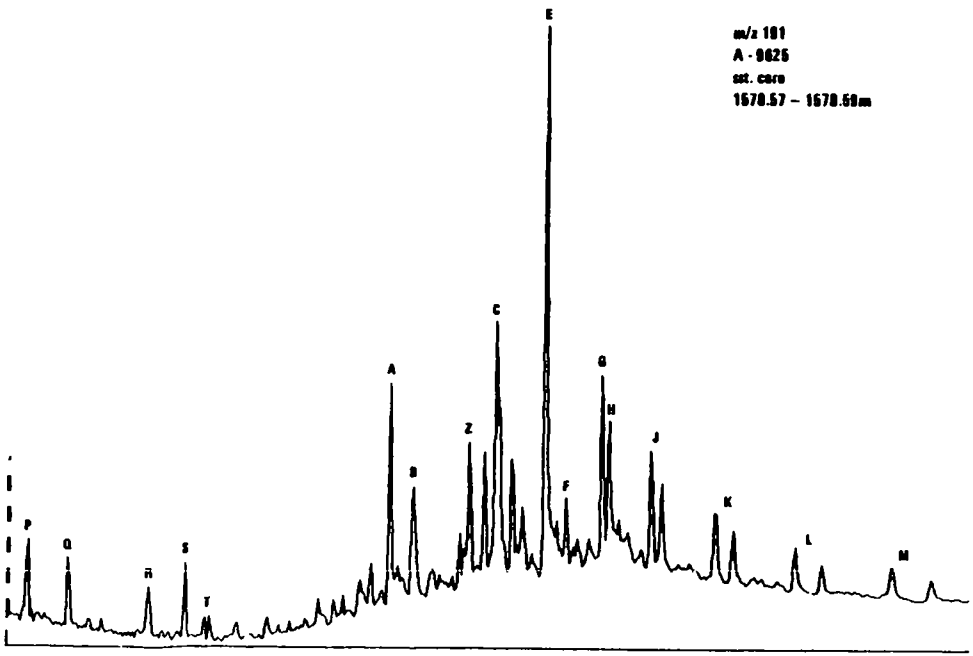
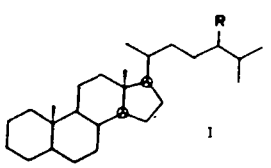

m/z 191
A - 9625
sst. core
1578.57 – 1578.59m
P
Q
R
S
T
A
B
Z
C
D
E
F
G
H
J
K
L
M

Figure 6b

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)
	+ 14α(H),17α(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	14α(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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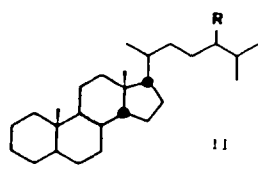

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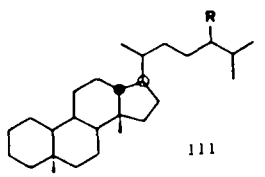

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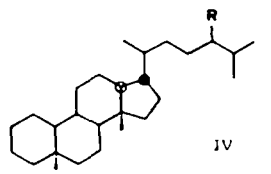

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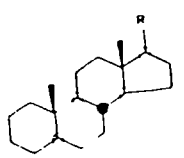
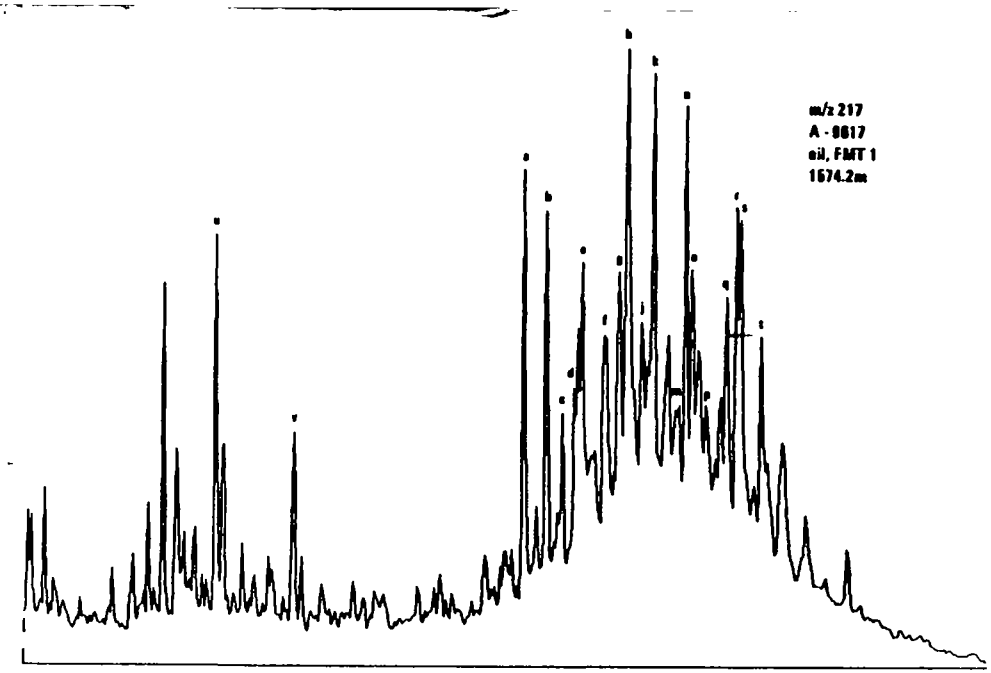
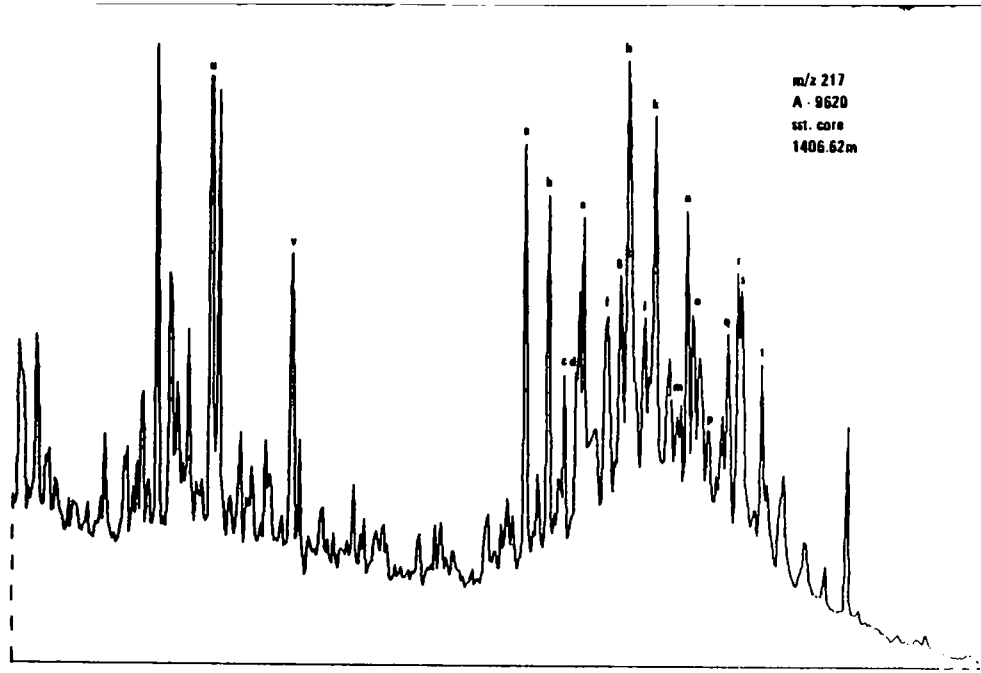
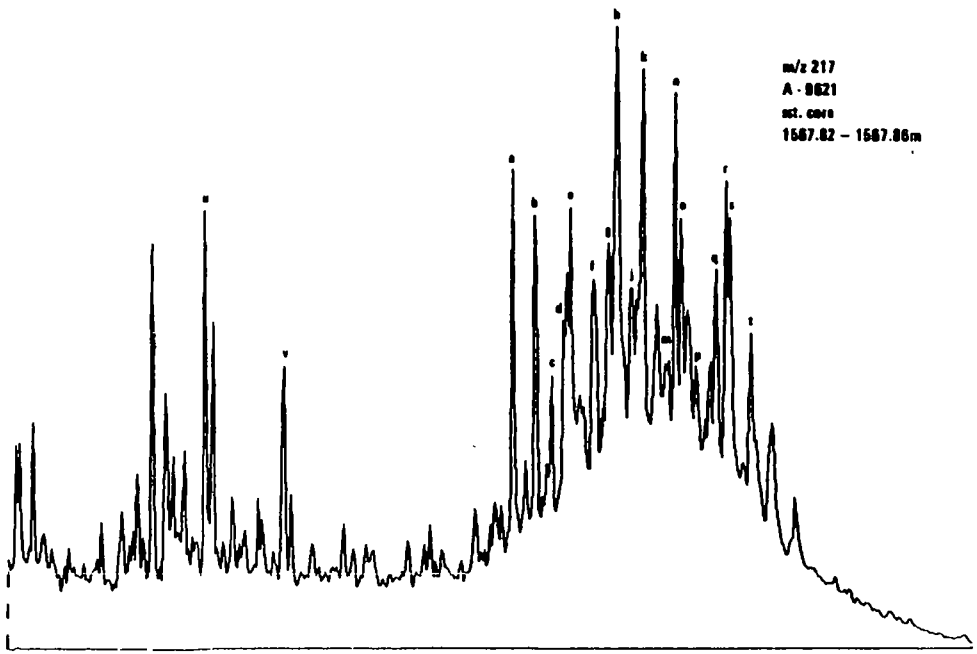
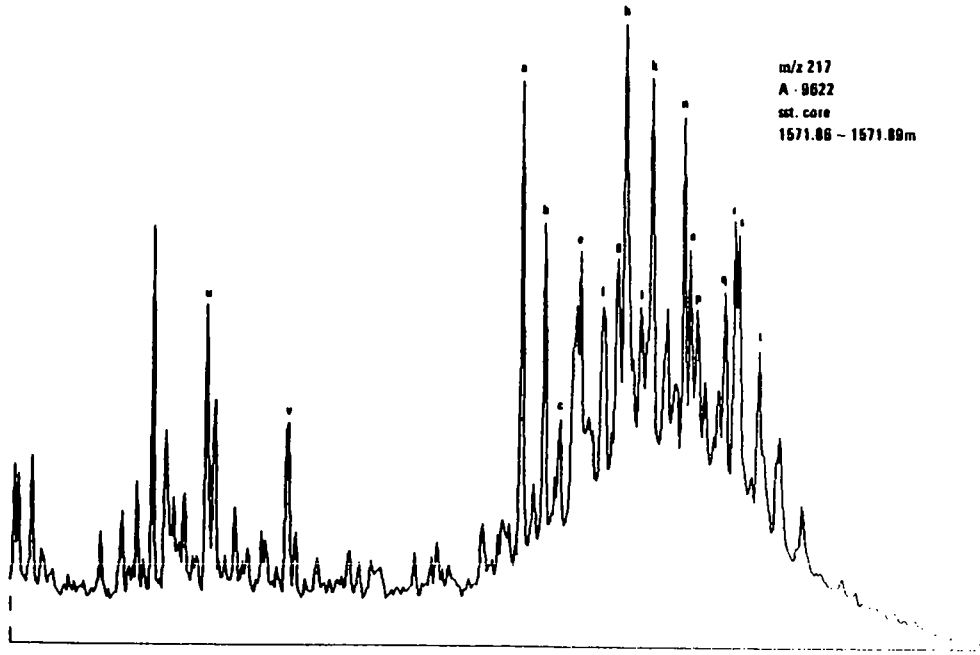
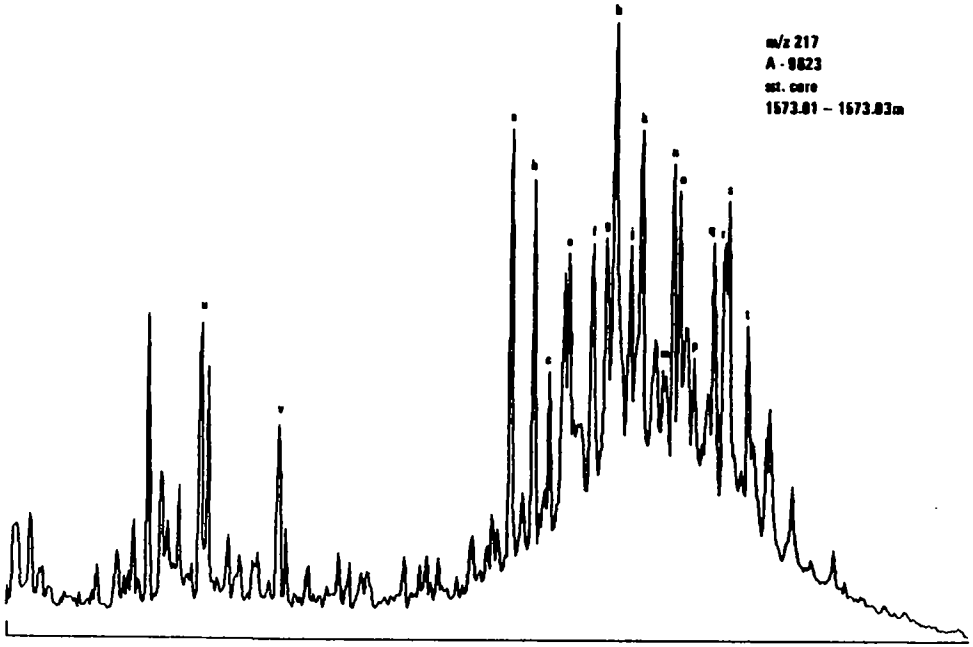


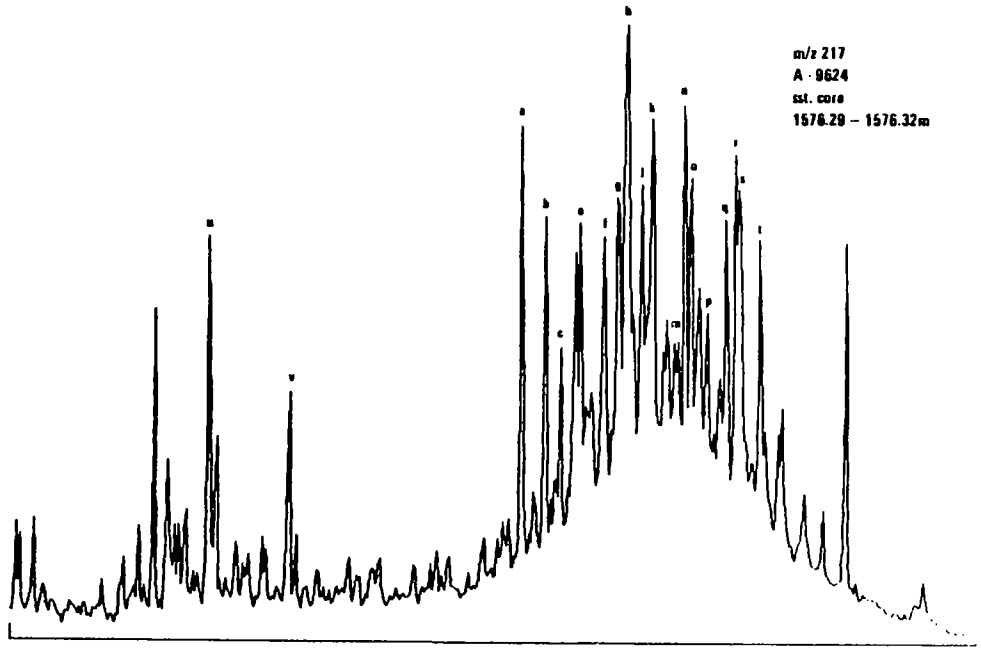

m/z 217
A - 9617
oil, FMT 1
1574.2m

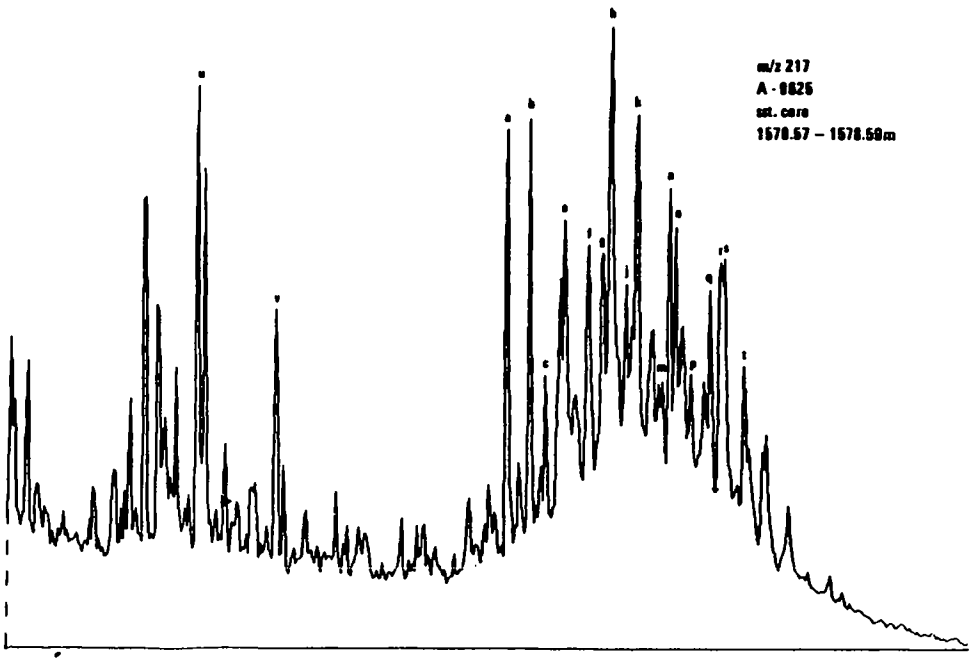

m/z 217
A - 9620
sst. core
1406.62m

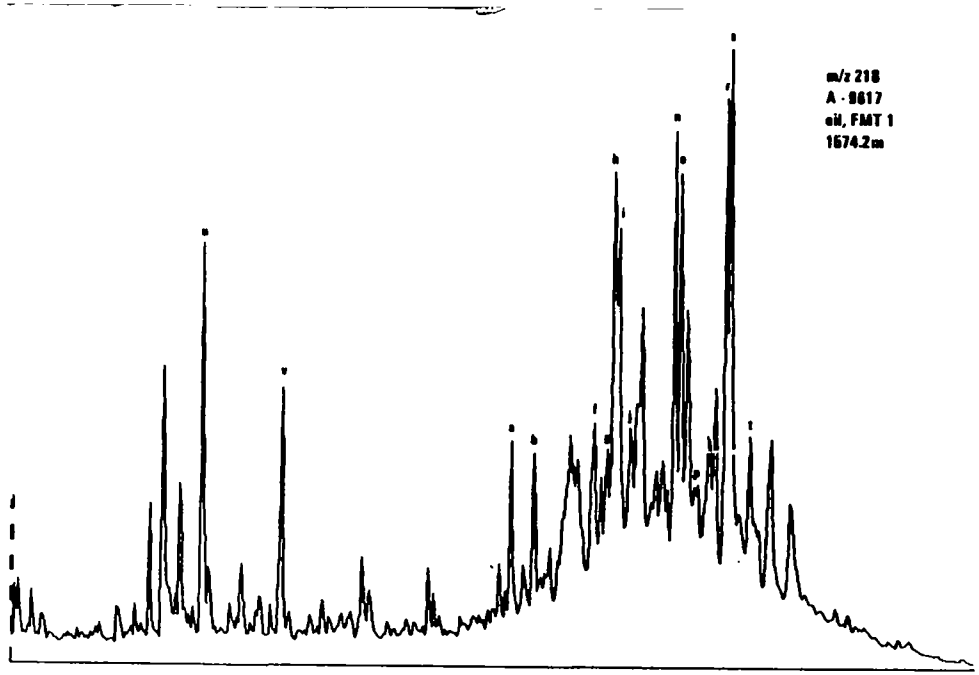

m/z 217
A - 9621
sst. core
1567.82 – 1567.86m

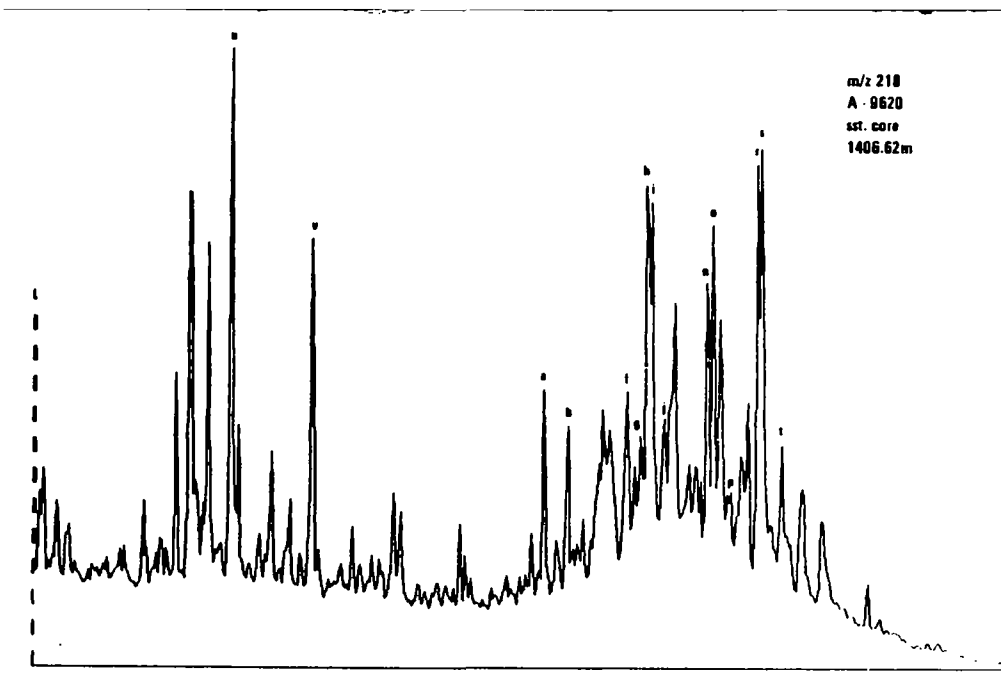

m/z 217
A - 9622
sst. core
1571.86 – 1571.89m

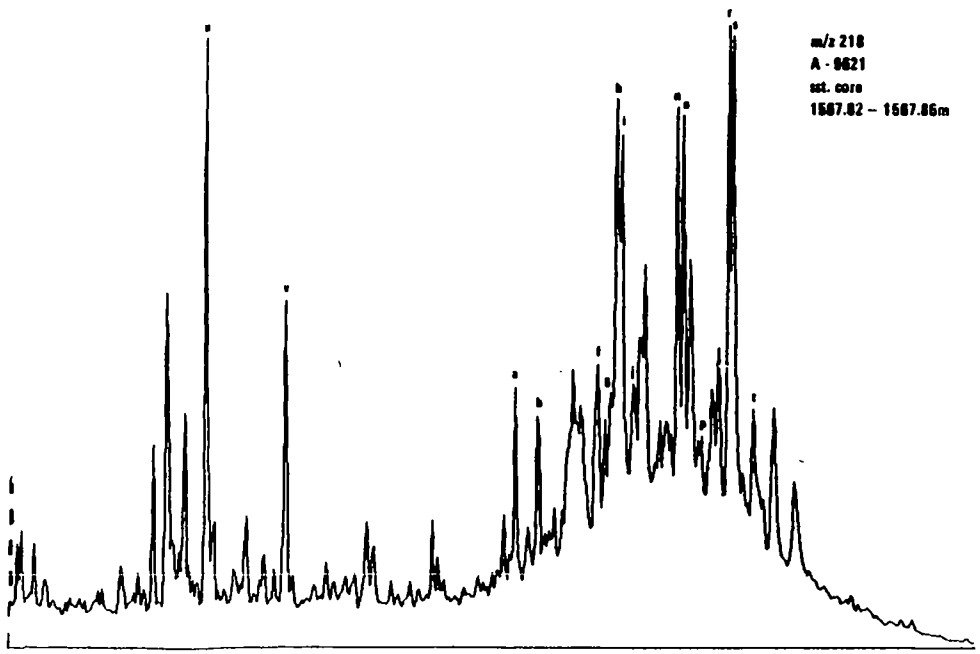

m/z 217
A - 9623
sst. core
1573.01 – 1573.03m

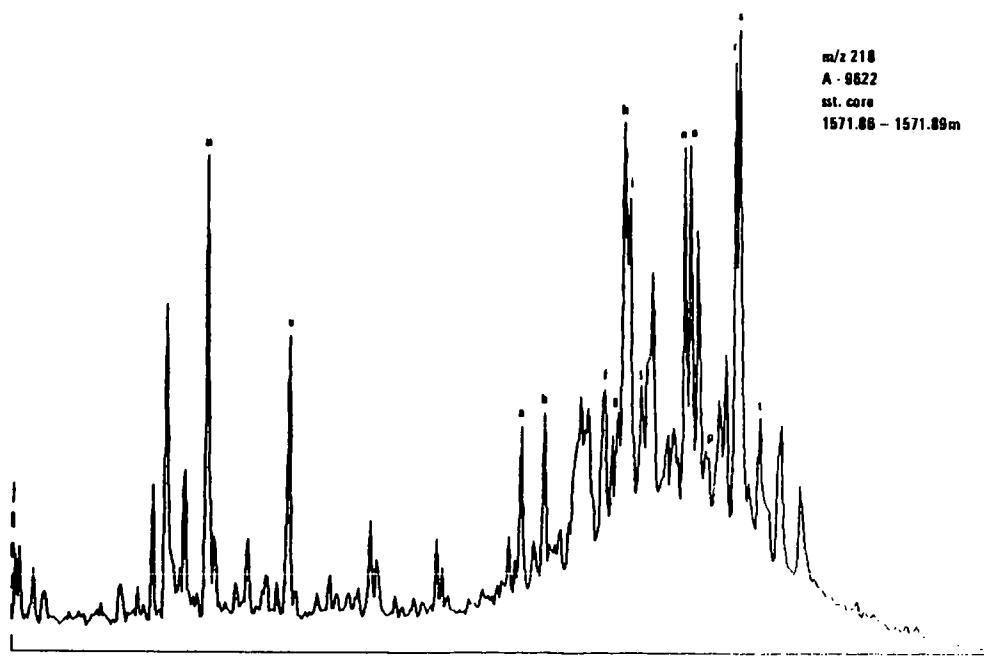

m/z 217
A - 9624
sst. core
1576.29 – 1576.32m

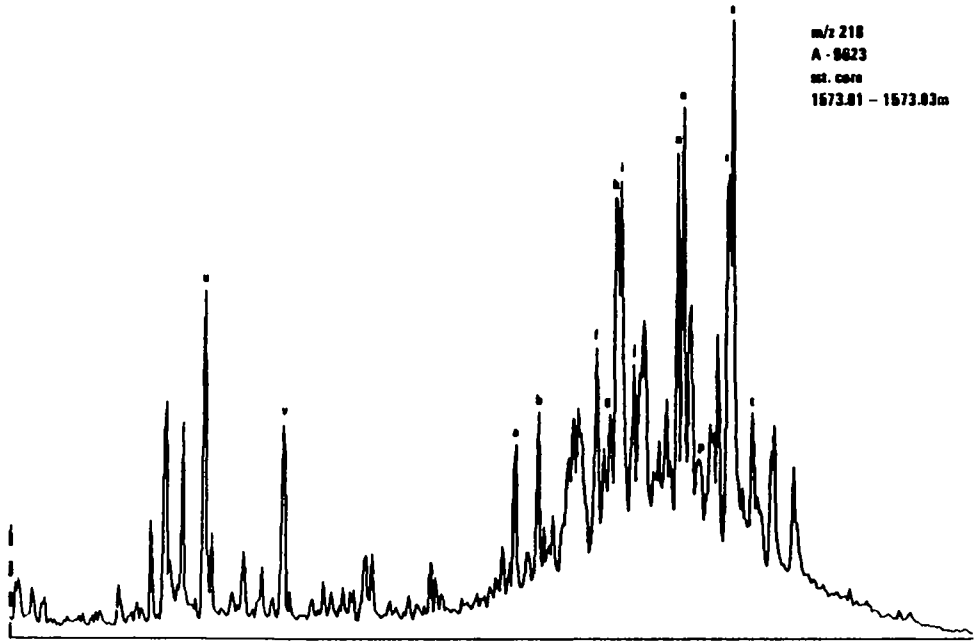

m/z 217
A - 9625
sst. core
1578.57 – 1578.59m

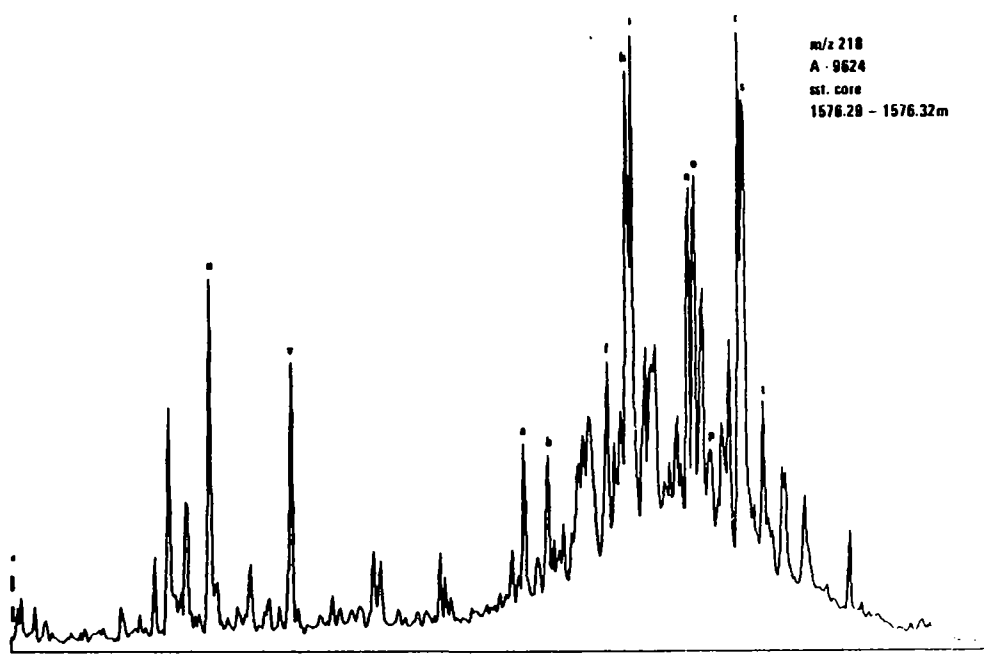

m/z 218
A - 9617
oil, FMT 1
1574.2m


m/z 218
A - 9620
sst. core
1406.62m


m/z 218
A - 9621
sst. core
1587.82 – 1587.86m


m/z 218
A - 9622
sst. core
1571.86 – 1571.89m


m/z 218
A - 9623
sst. core
1573.81 – 1573.93m


m/z 218
A - 9624
sst. core
1576.29 – 1576.32m

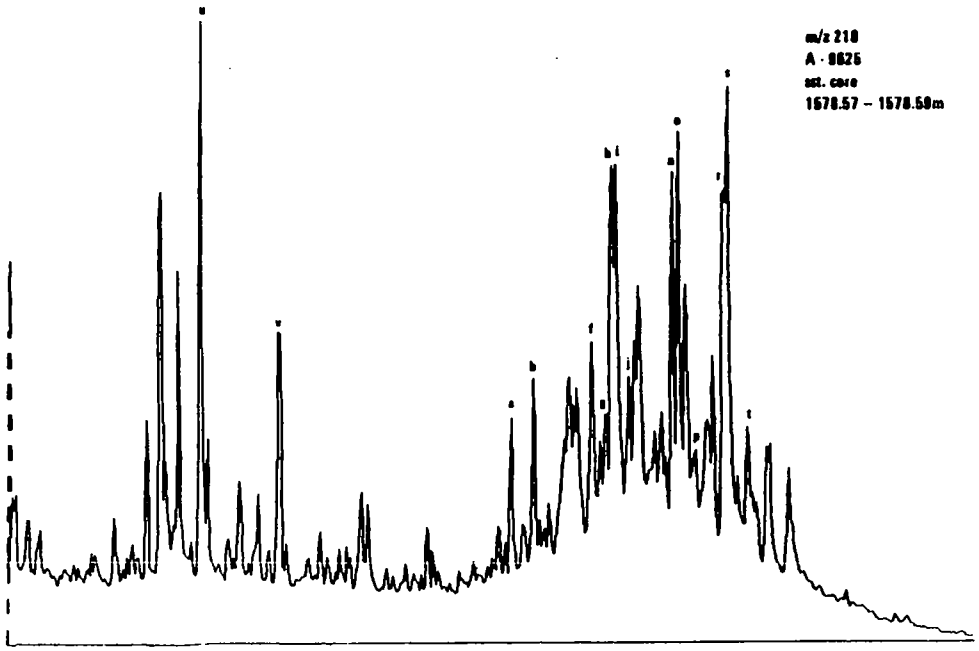
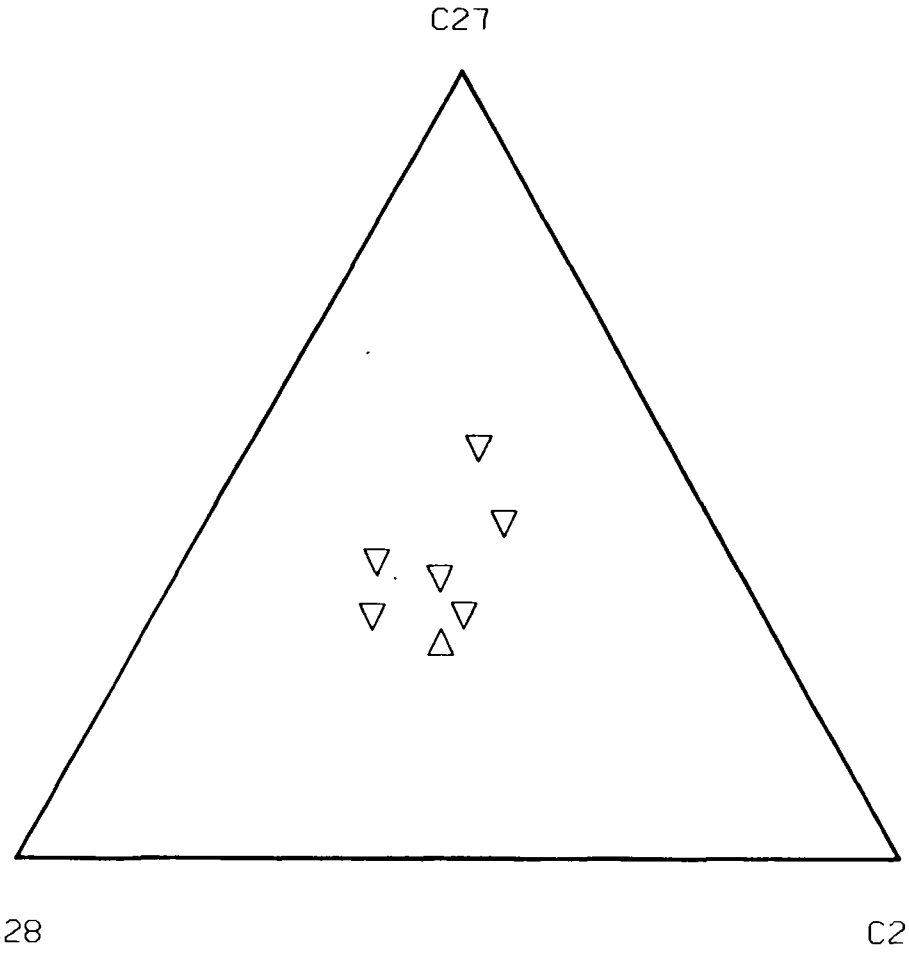
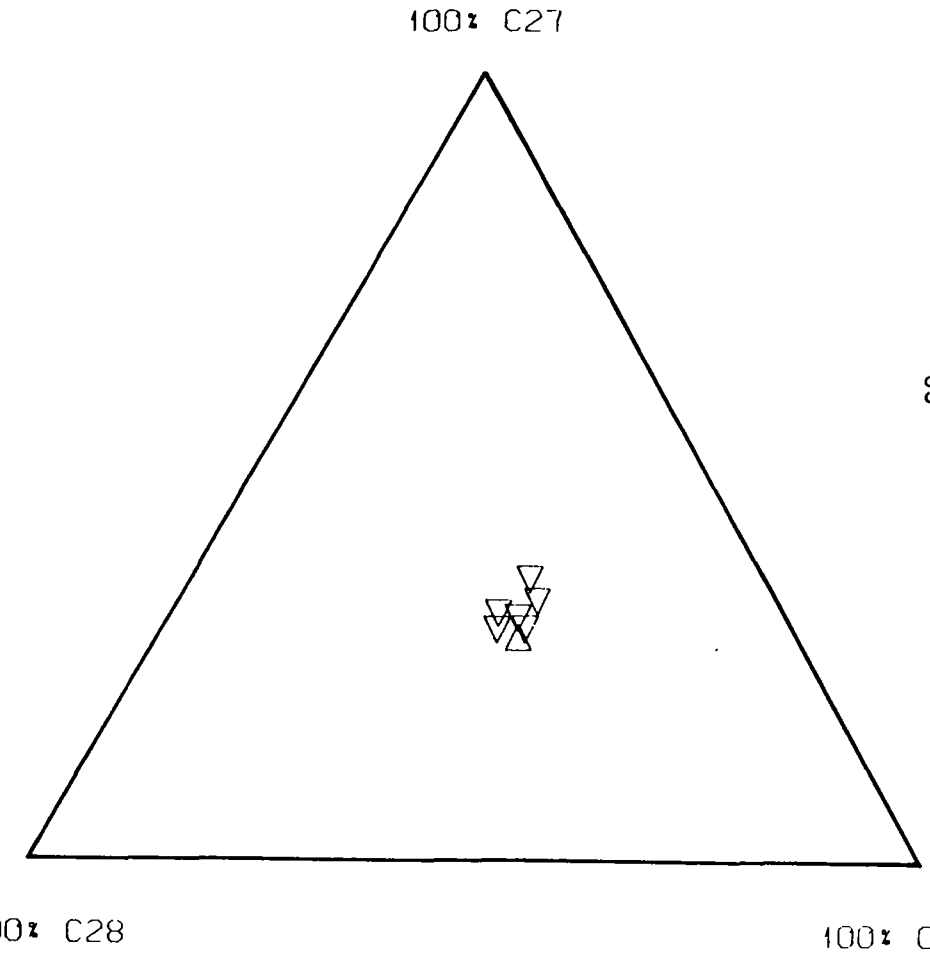

m/z 218
A - 9625
sst. core
1578.57 – 1578.59m

Figure 7

Triangular plots showing molecular weight distributions of C_{27}, C_{28} and C_{29} regular 14β(H), 17β(H)-steranes



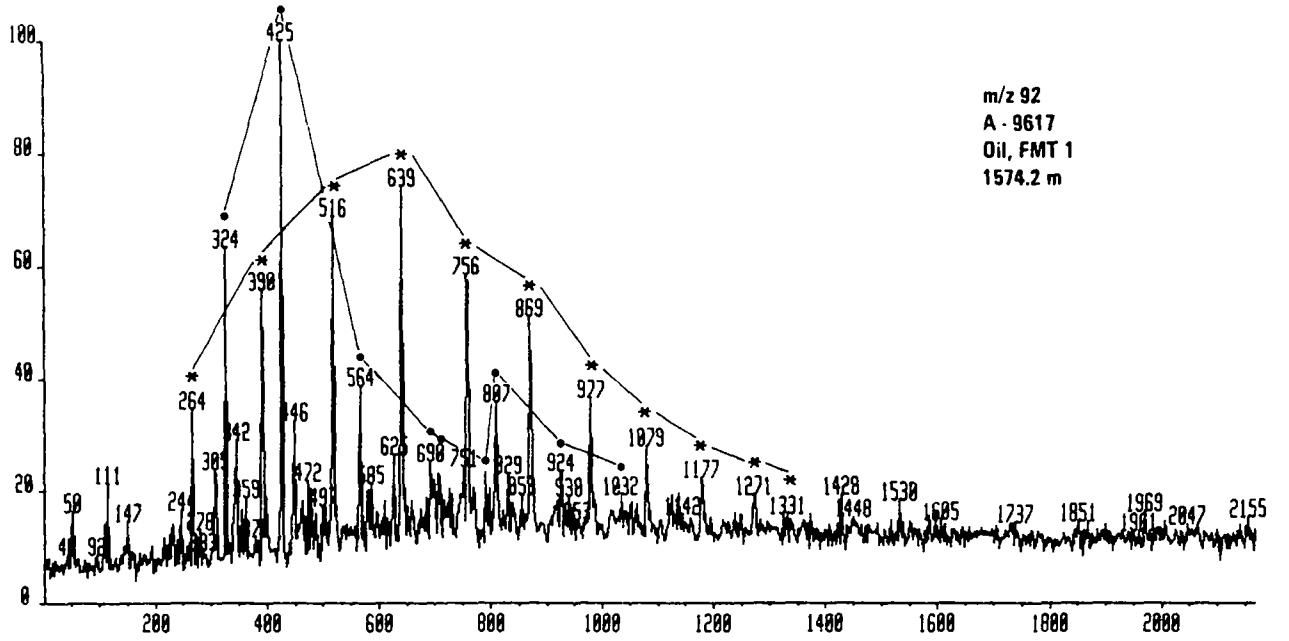


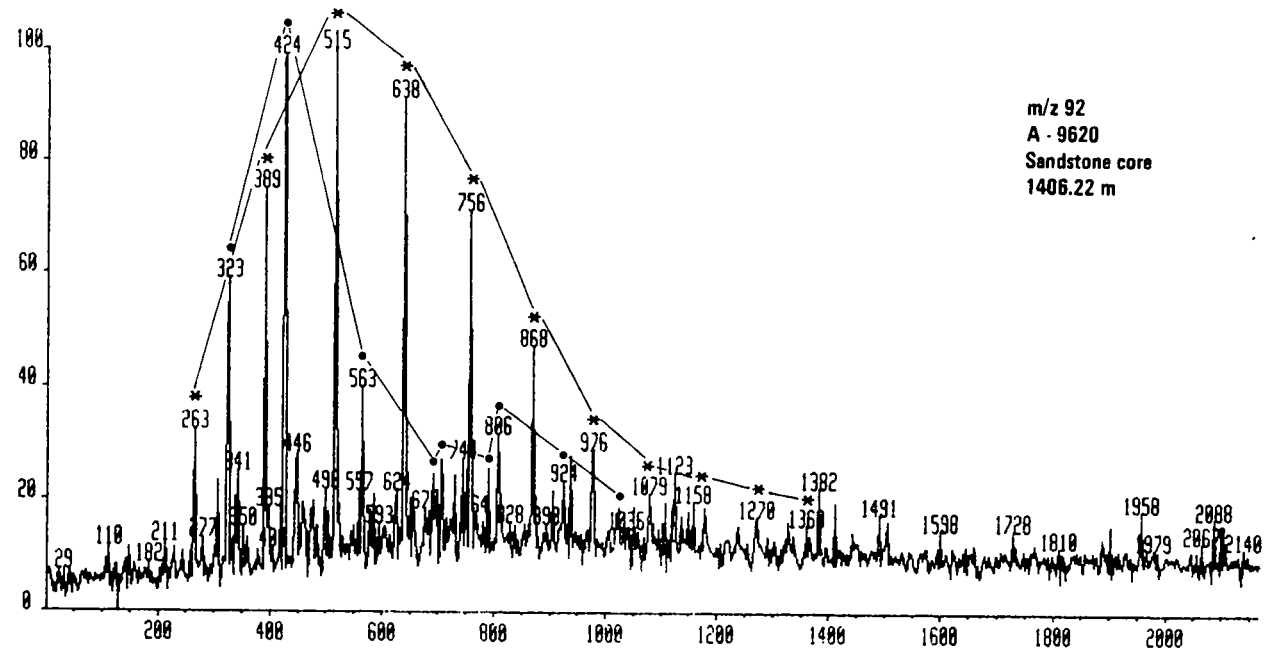
C27 (20-50%)
C28 (20-50%)
C29 (30-60%)

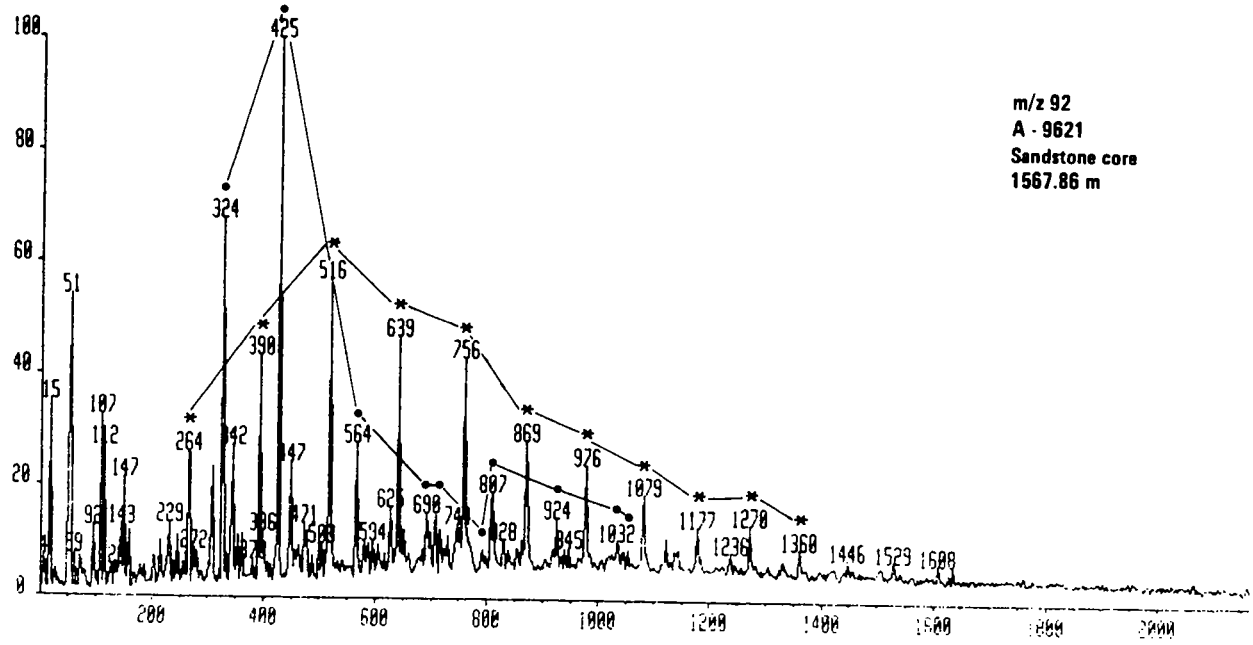
Figure 8

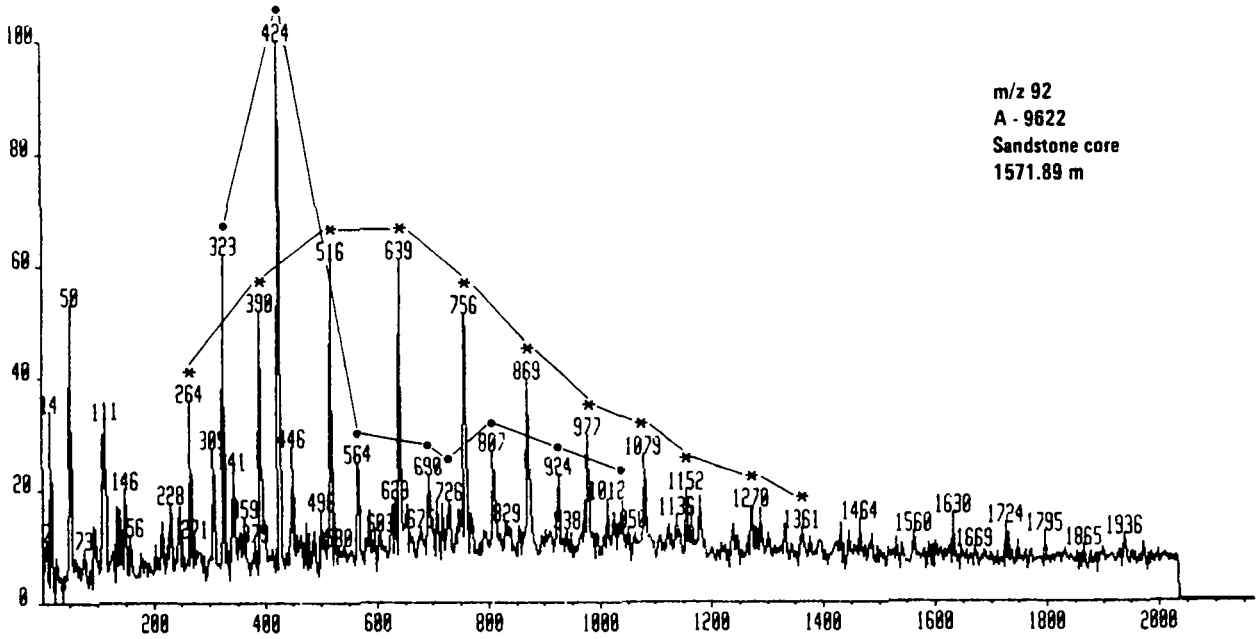
Mass chroamtograms representing
aromatic hydrocarbons

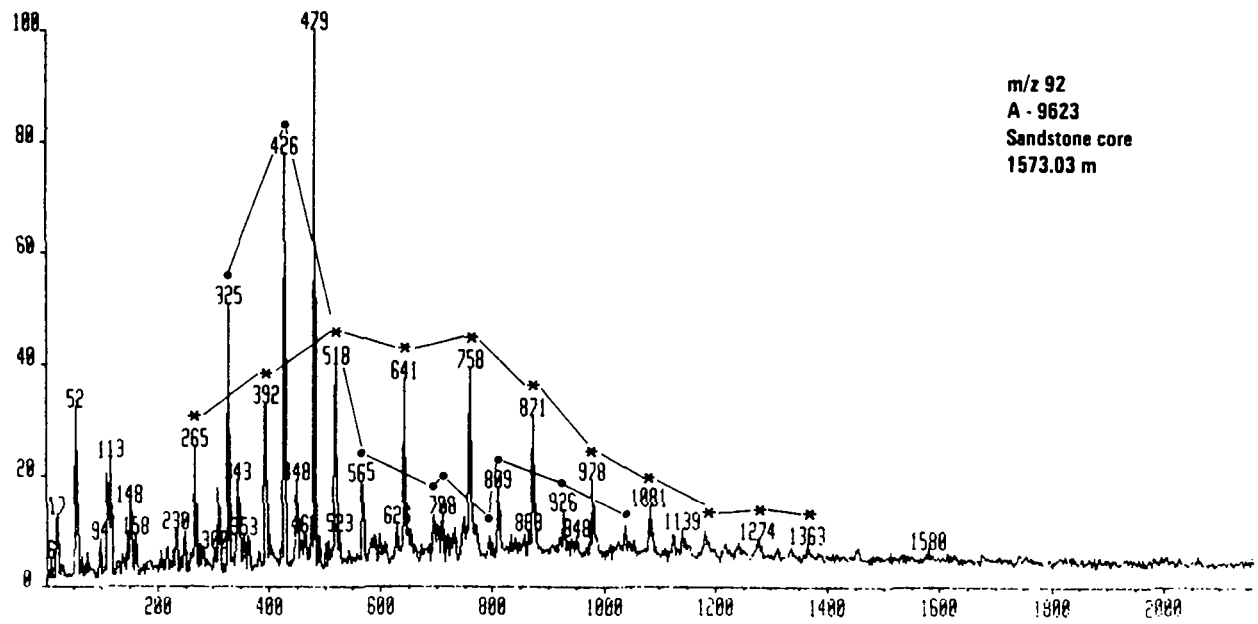
m/z 92 + 106	monoaromatic hydrocarbons
m/z 142	C_1-naphtalenes
m/z 156	C_2-naphtalenes
m/z 170	C_3-naphtalenes
m/z 178	phenanthrene
m/z 192	C_1-phenanthrenes
m/z 206	C_2-phenanthrenes

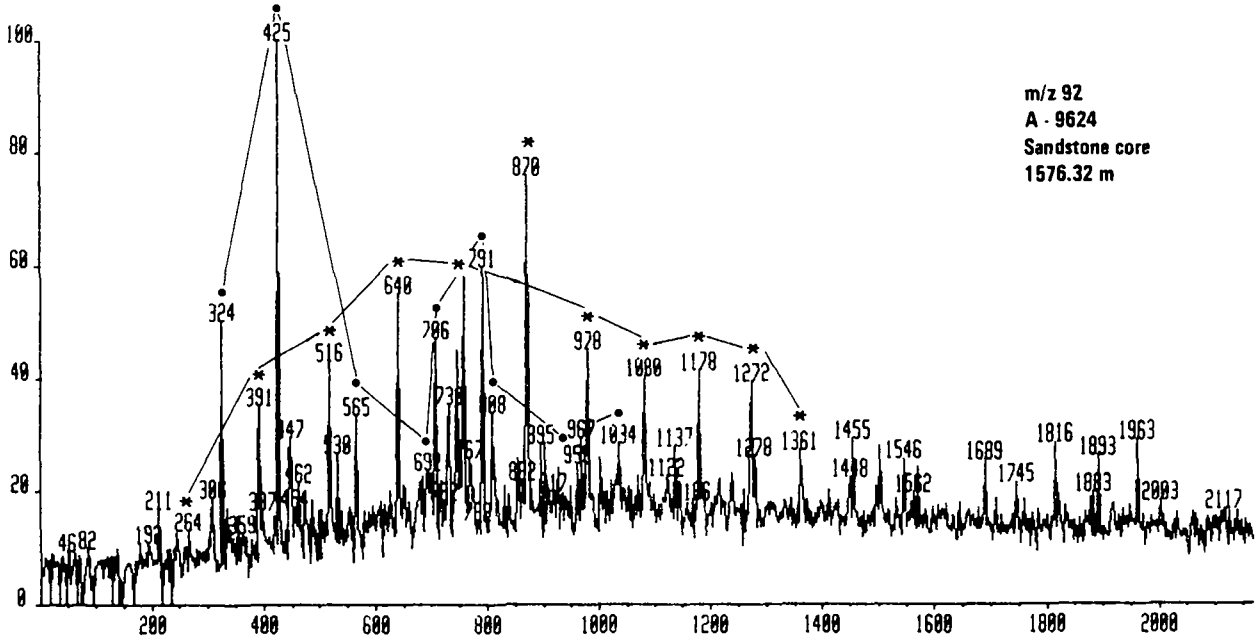

m/z 92
A - 9617
Oil, FMT 1
1574.2 m
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
2000
425
324
390
516
639
756
869
264
564
807
977
1079
924
1032
1177
1271
1331
1428
1448
1530
1605
1737
1851
1969
2047
2155
111
147
50
342
446
472
625
690
829
938
1142

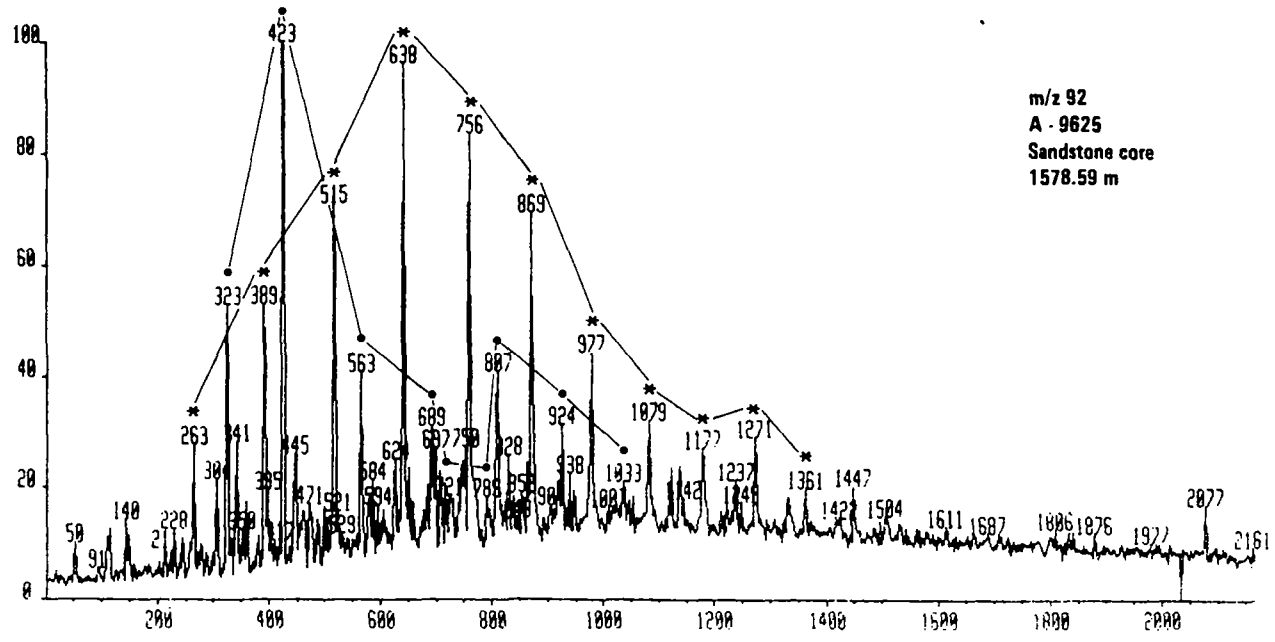

m/z 92
A - 9620
Sandstone core
1406.22 m

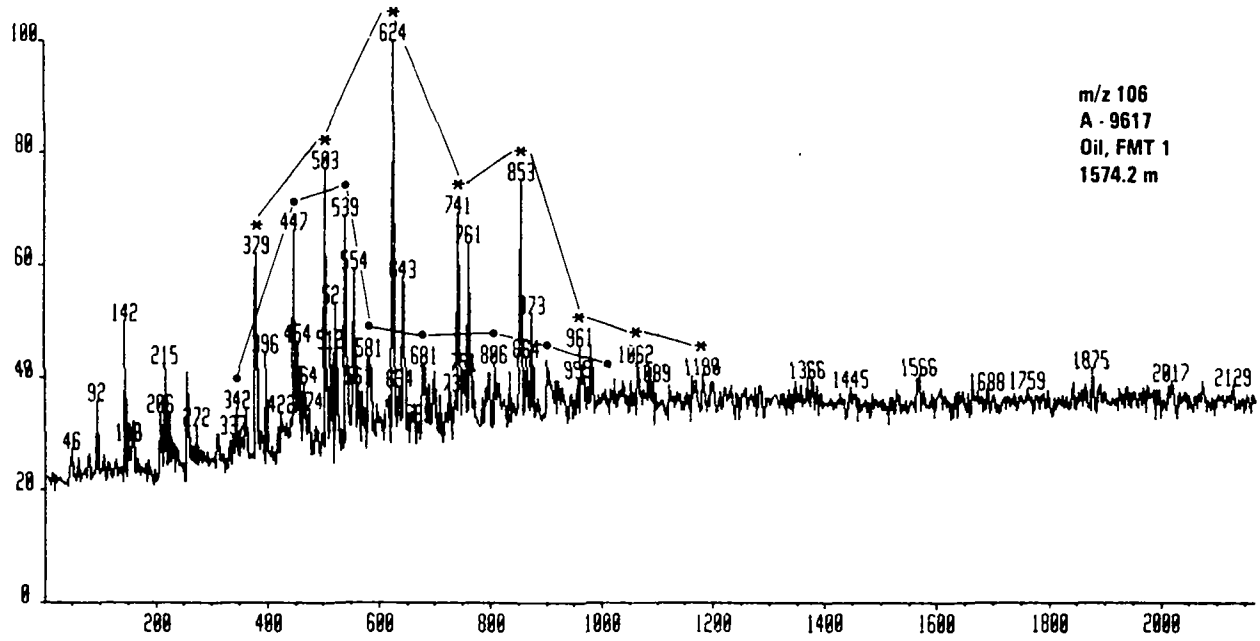

m/z 92
A - 9621
Sandstone core
1567.86 m

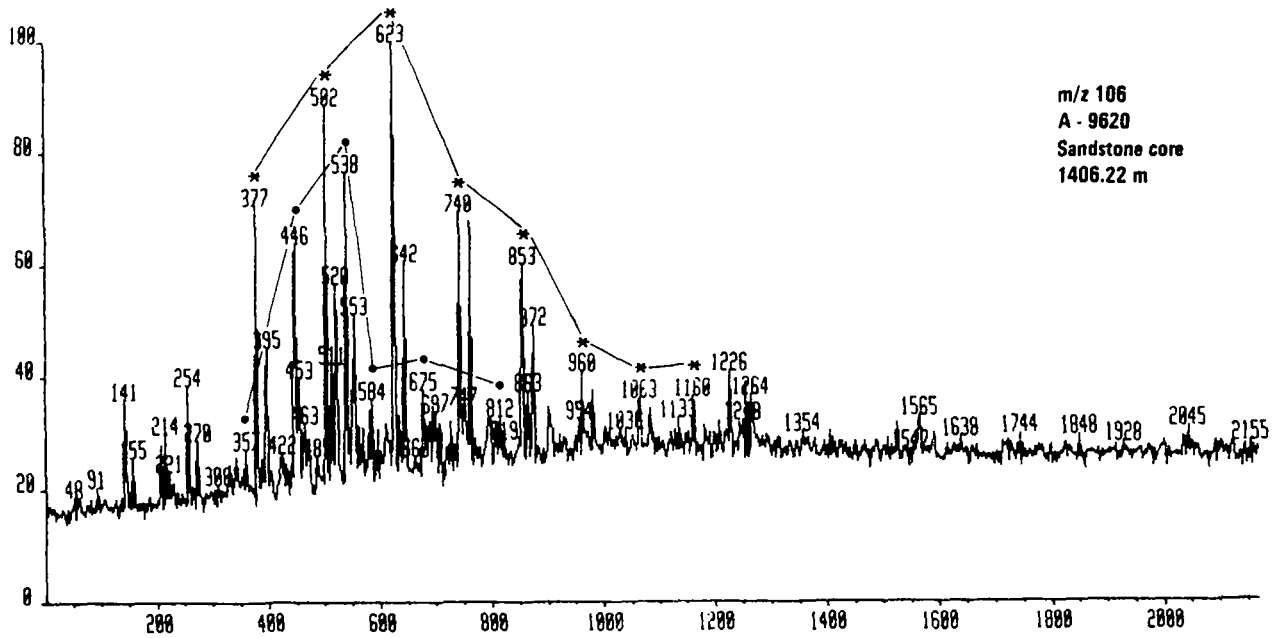

m/z 92
A - 9622
Sandstone core
1571.89 m

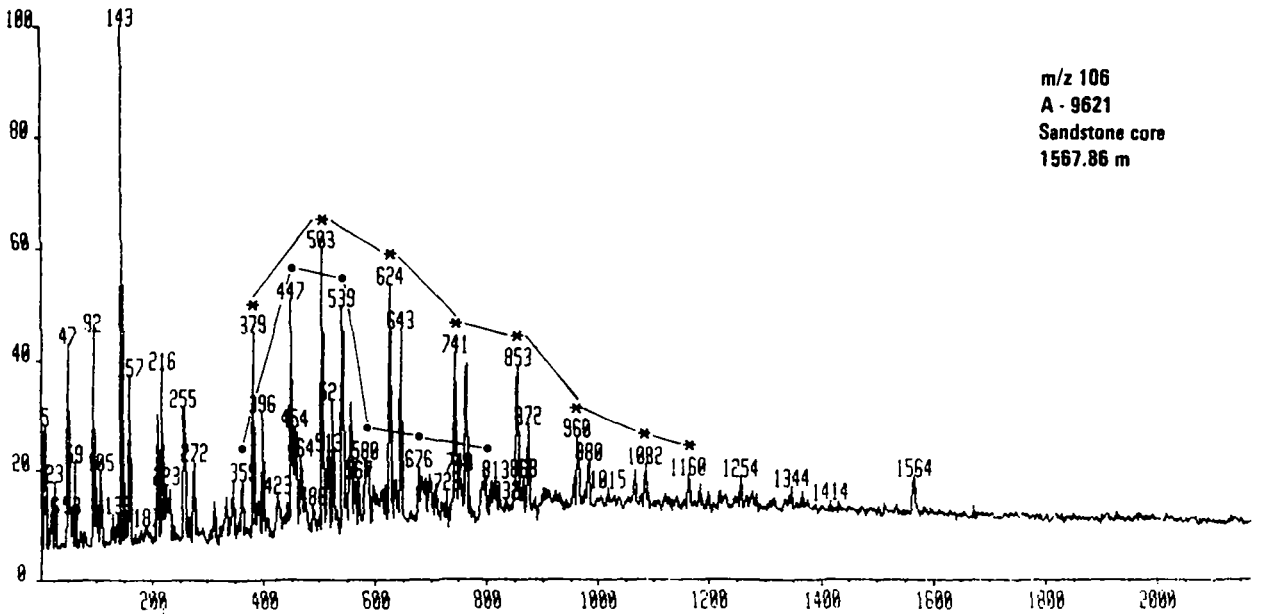

m/z 92
A - 9623
Sandstone core
1573.03 m

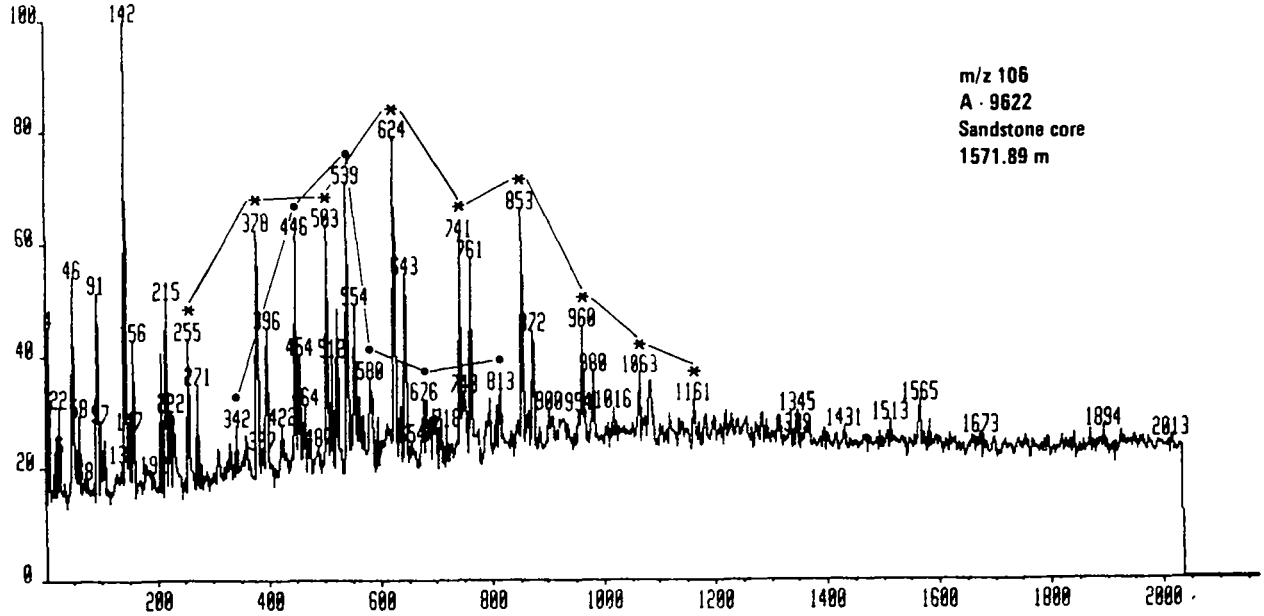

m/z 92
A - 9624
Sandstone core
1576.32 m

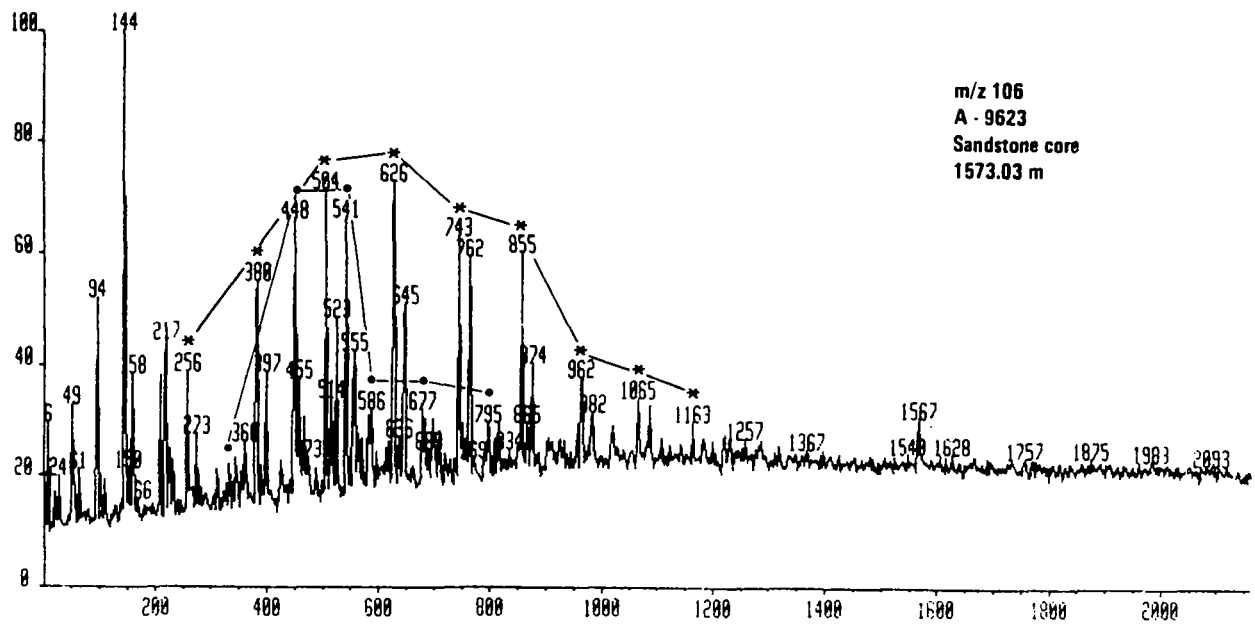

m/z 92
A - 9625
Sandstone core
1578.59 m


m/z 106
A - 9617
Oil, FMT 1
1574.2 m
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
2000


m/z 106
A - 9620
Sandstone core
1406.22 m


m/z 106
A - 9621
Sandstone core
1567.86 m


m/z 106
A - 9622
Sandstone core
1571.89 m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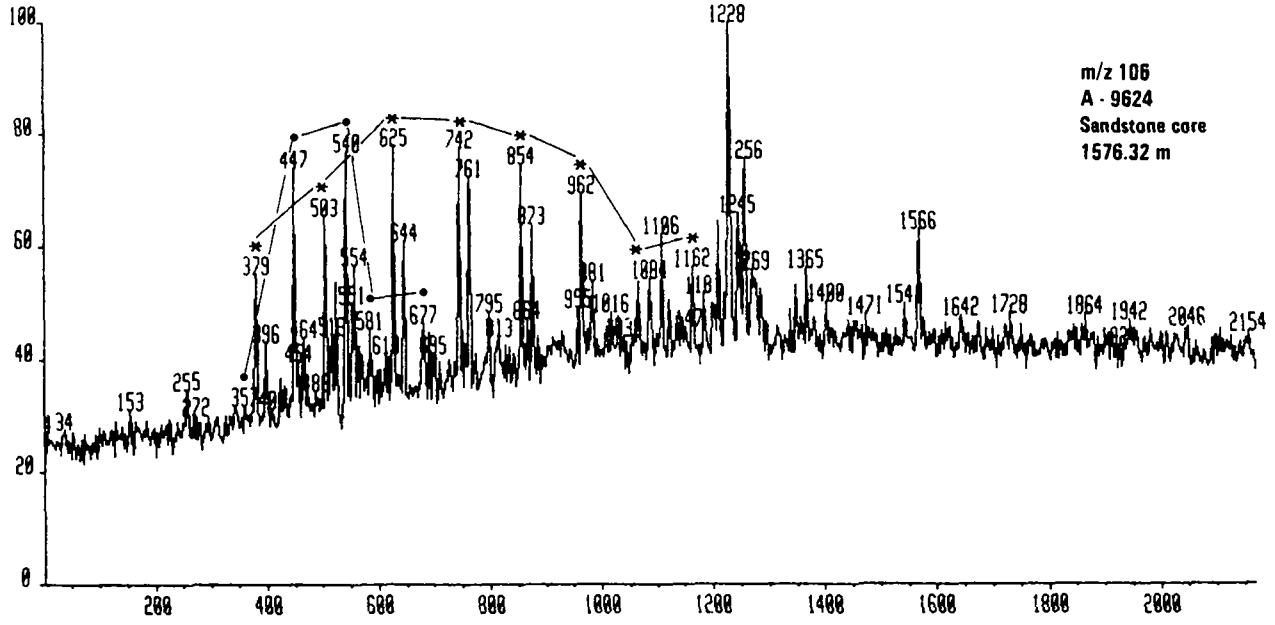
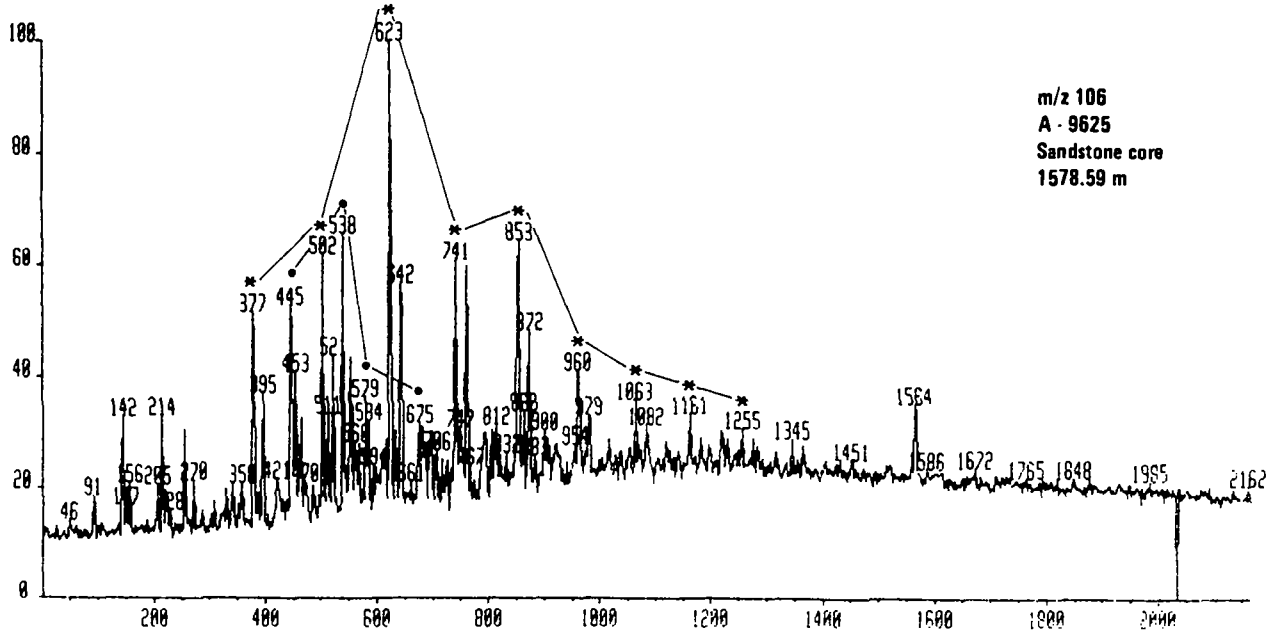
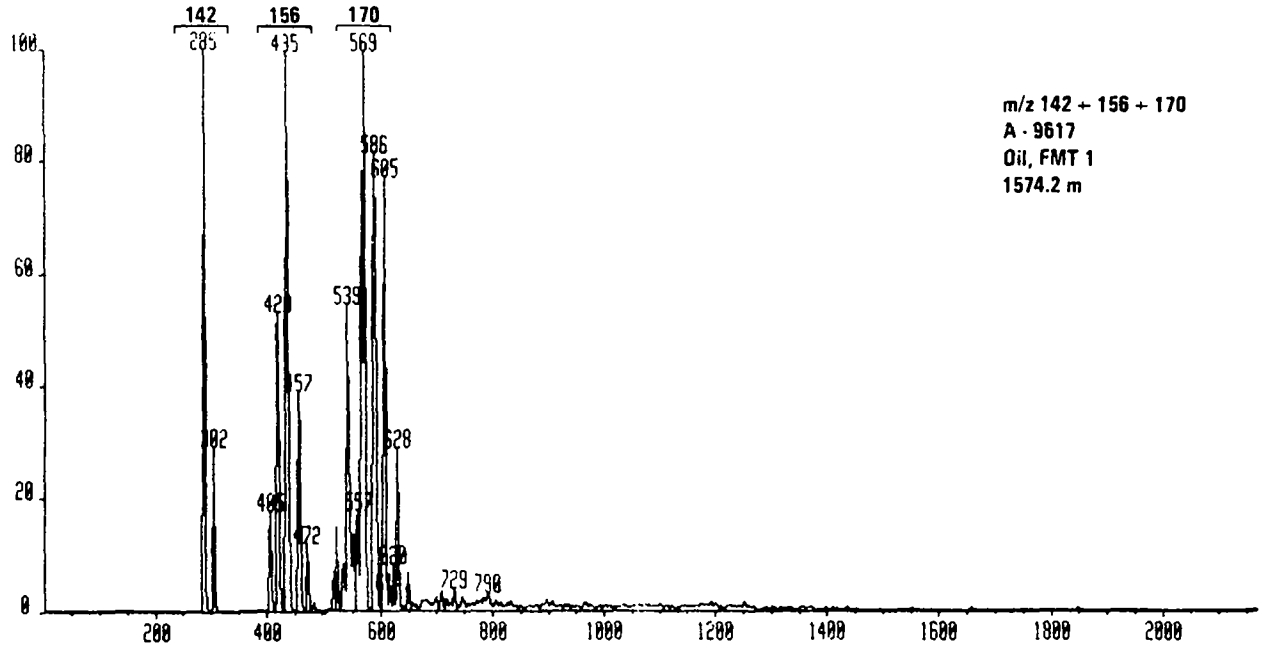
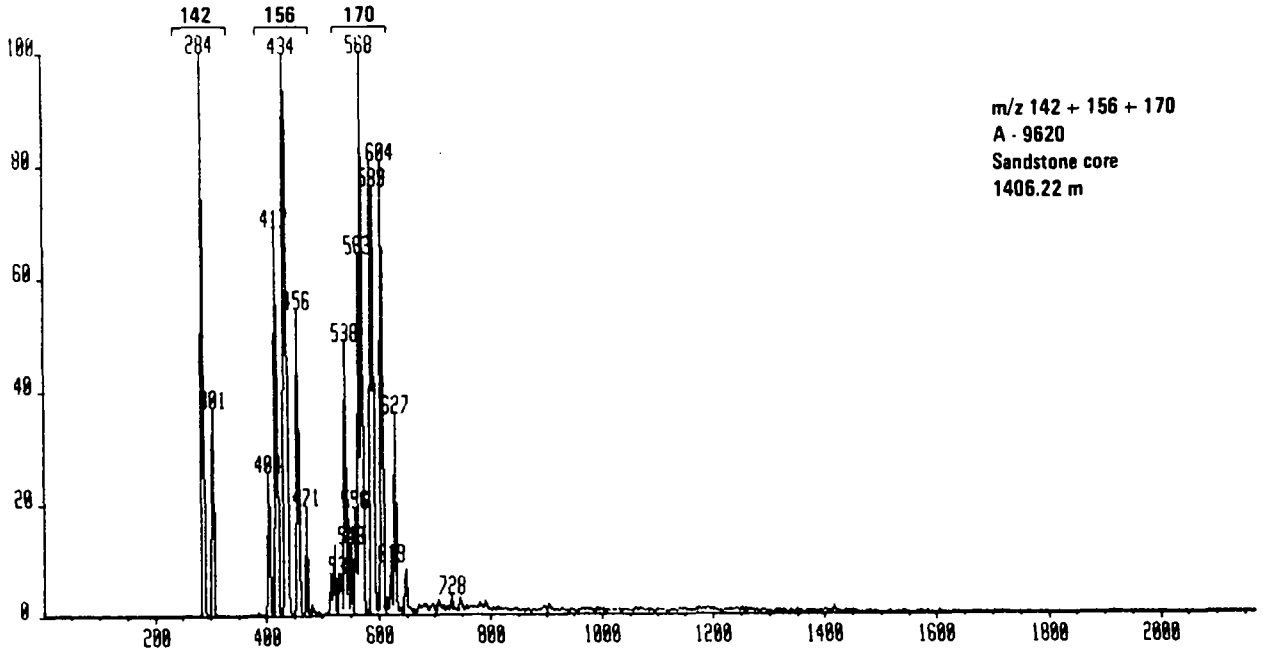
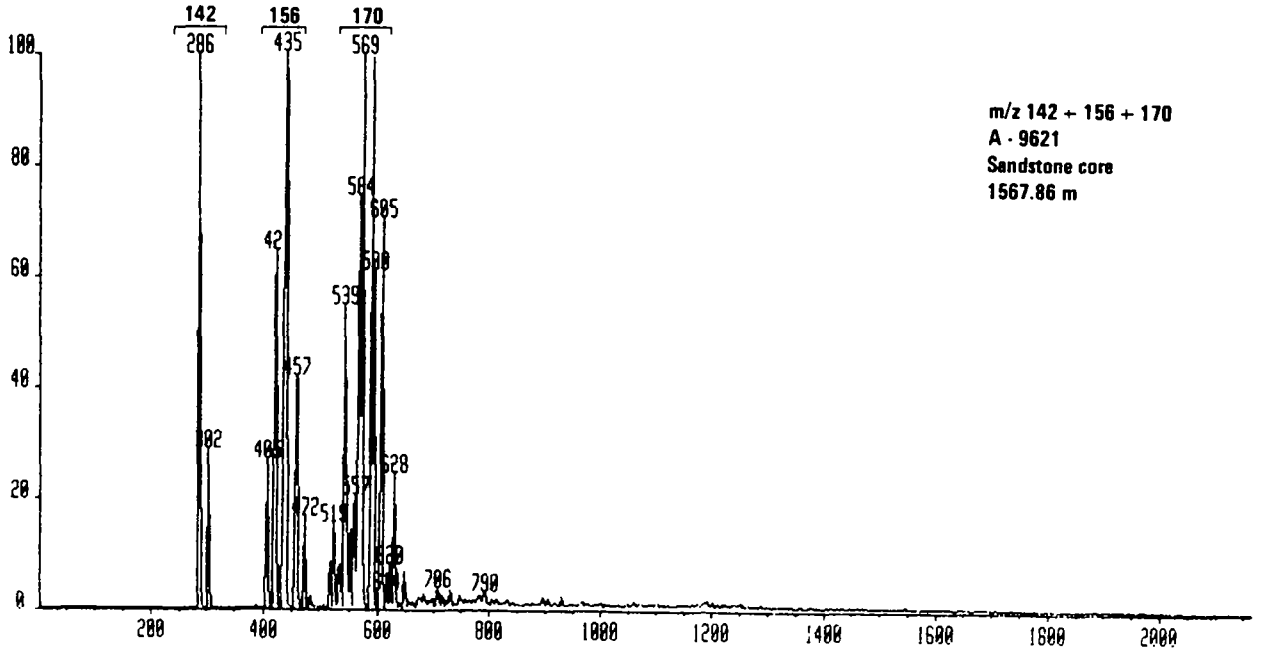
A - 9623
Sandstone core
1573.03 m

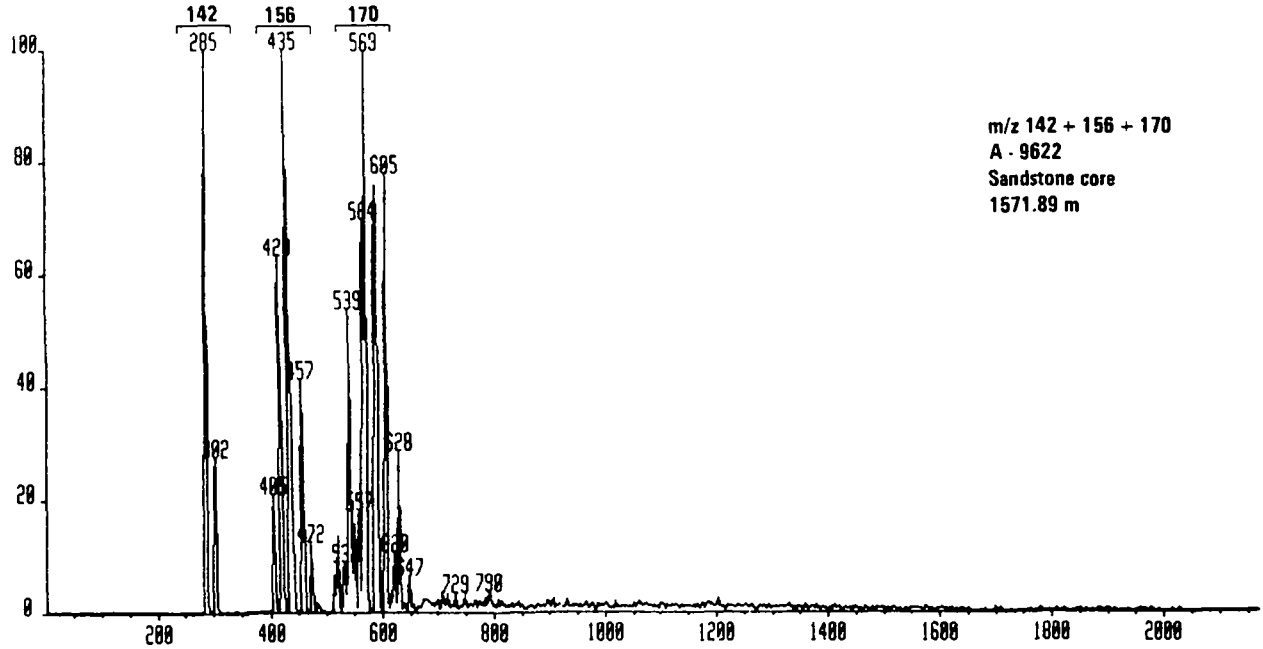

m/z 106
A - 9624
Sandstone core
1576.32 m


m/z 106
A - 9625
Sandstone core
1578.59 m

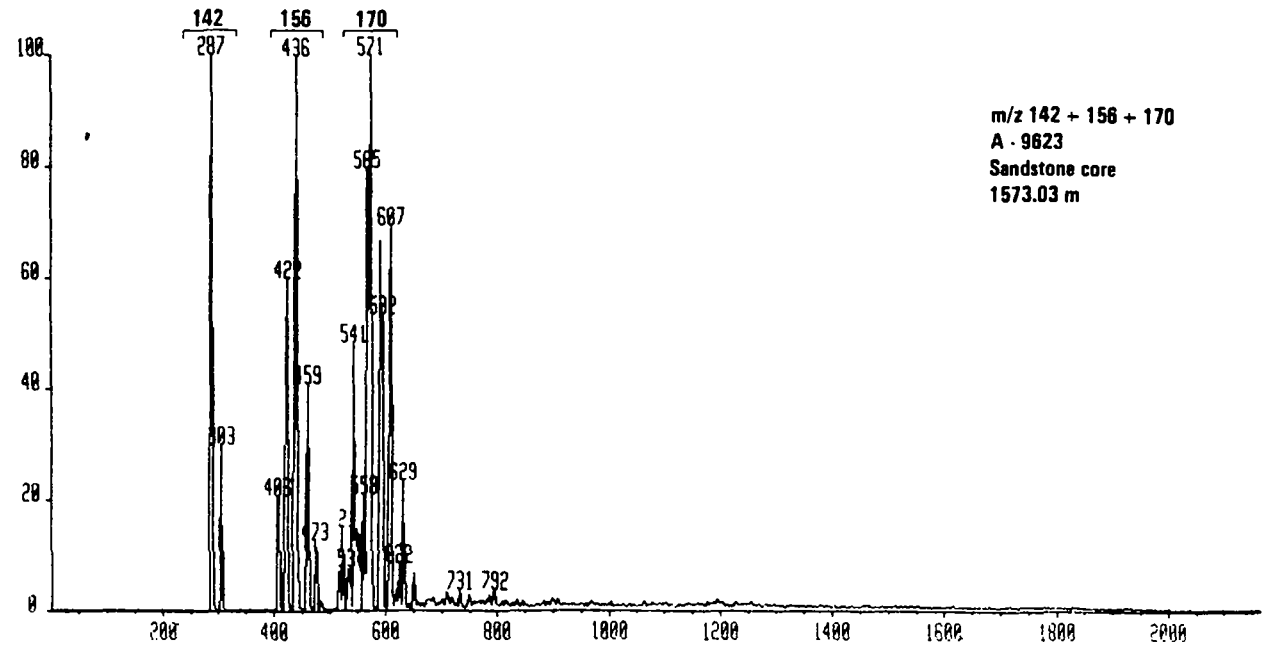

142
156
170
285
435
569
586
605
539
628
729
790
m/z 142 + 156 + 170
A - 9617
Oil, FMT 1
1574.2 m


142
284
156
434
170
568
m/z 142 + 156 + 170
A - 9620
Sandstone core
1406.22 m

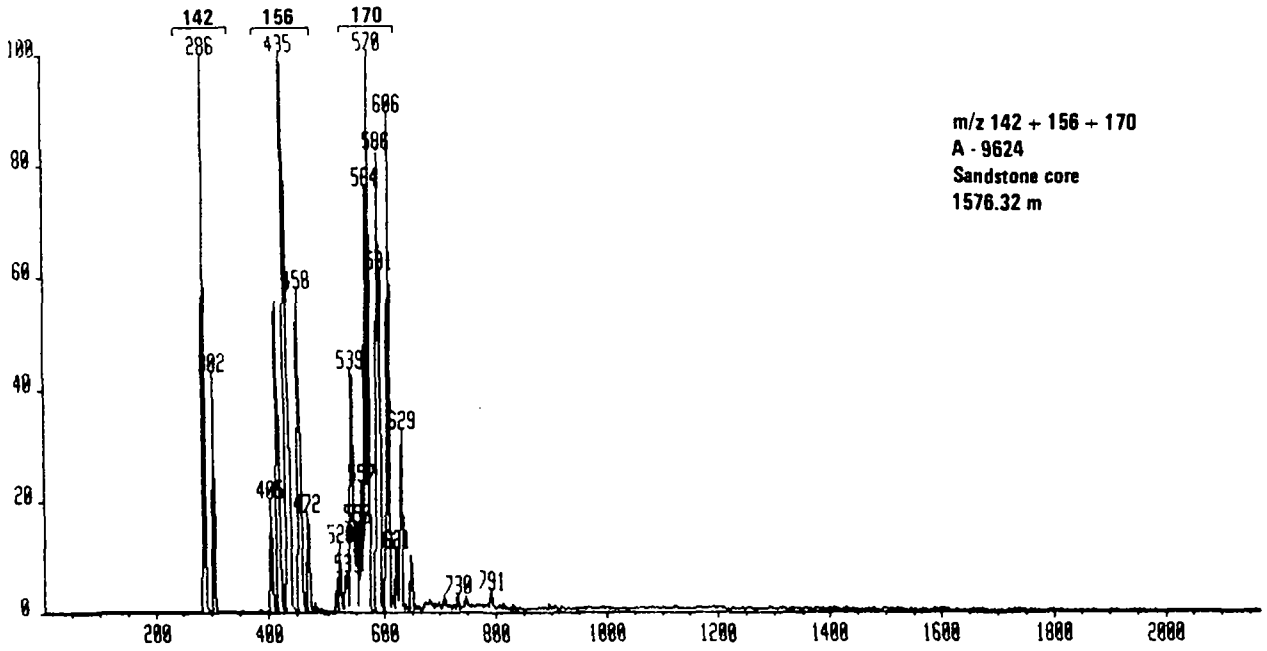

142
286
156
435
170
569
m/z 142 + 156 + 170
A - 9621
Sandstone core
1567.86 m



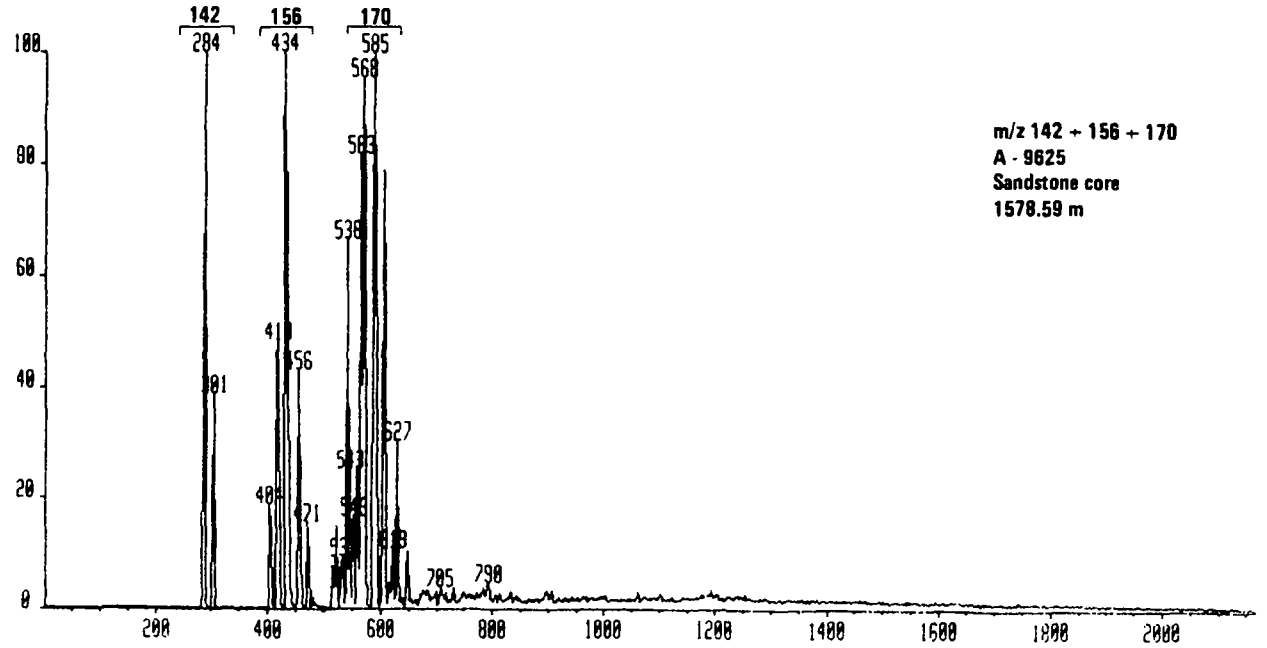
m/z 142 + 156 + 170
A - 9622
Sandstone core
1571.89 m



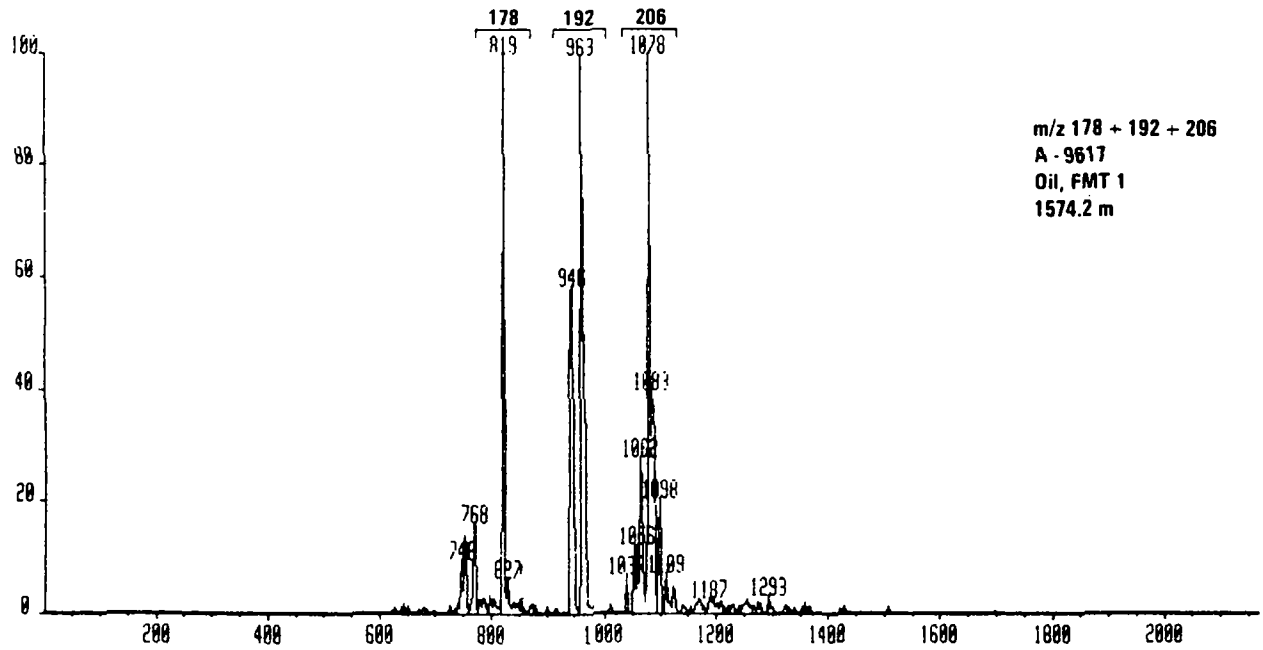
m/z 142 + 156 + 170
A - 9623
Sandstone core
1573.03 m

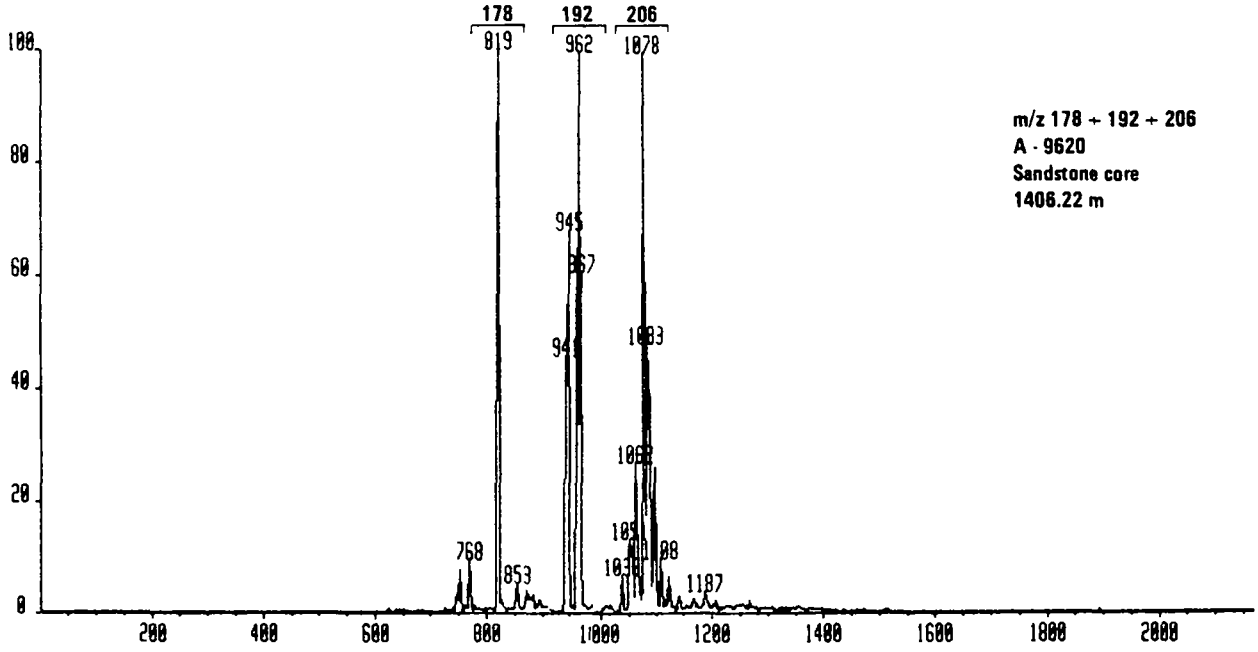


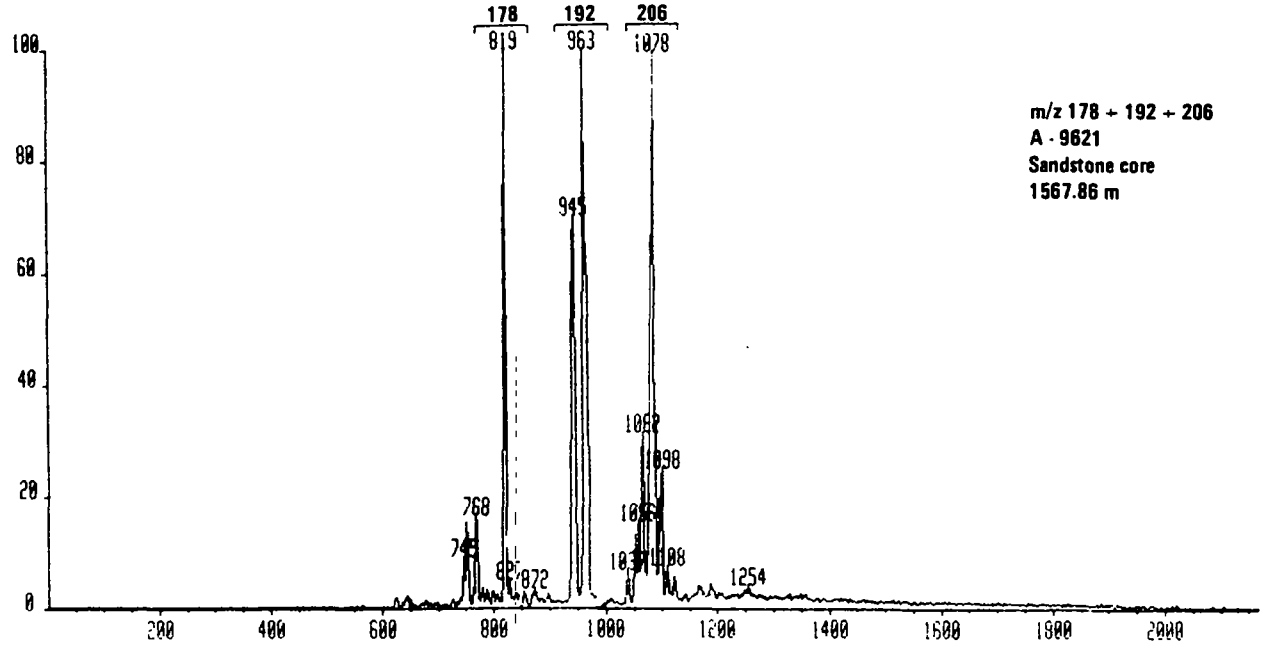
m/z 142 + 156 + 170
A - 9624
Sandstone core
1576.32 m

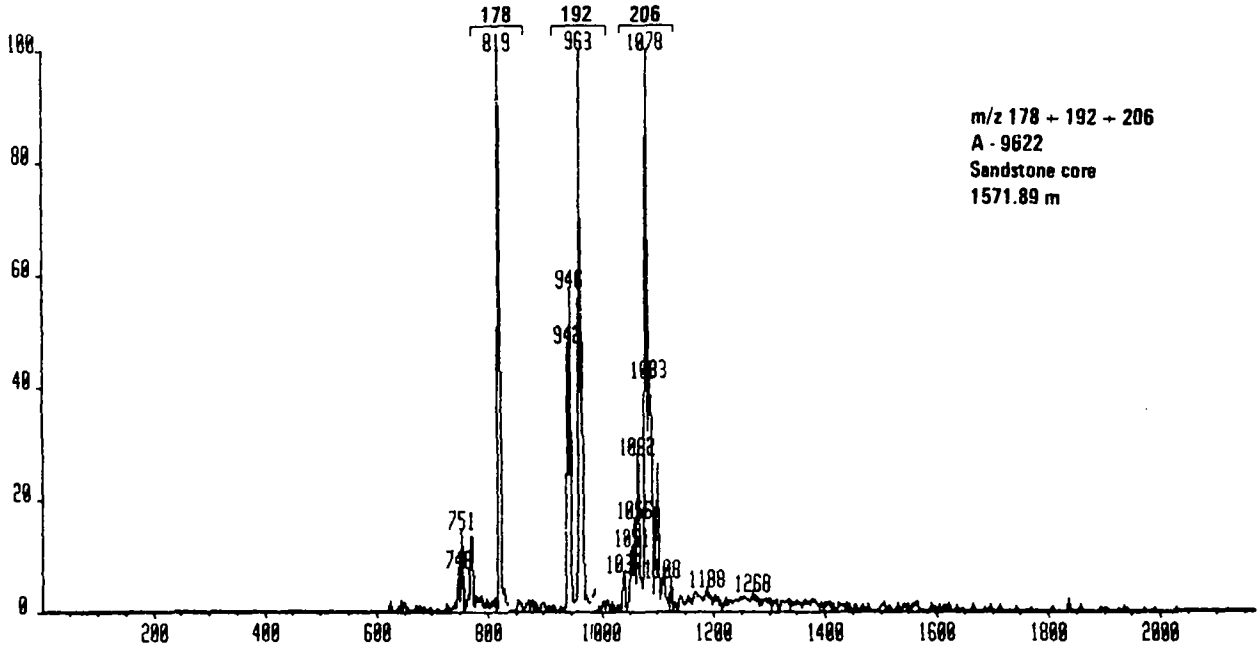


m/z 142 + 156 + 170
A - 9625
Sandstone core
1578.59 m


178
819
192
963
206
1078
m/z 178 + 192 + 206
A - 9617
Oil, FMT 1
1574.2 m
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
2000
768
1187
1293


178
819
192
962
206
1078
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
2000
768
853
945
1187
m/z 178 + 192 + 206
A - 9620
Sandstone core
1406.22 m


178
819
192
963
206
1078
100
80
60
40
20
0
200
400
600
800
1000
1200
1400
1600
1800
2000
768
945
1254
m/z 178 + 192 + 206
A - 9621
Sandstone core
1567.86 m


178
819
192
963
206
1078
m/z 178 + 192 + 206
A - 9622
Sandstone core
1571.89 m
751
1188
1268
100
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60
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20
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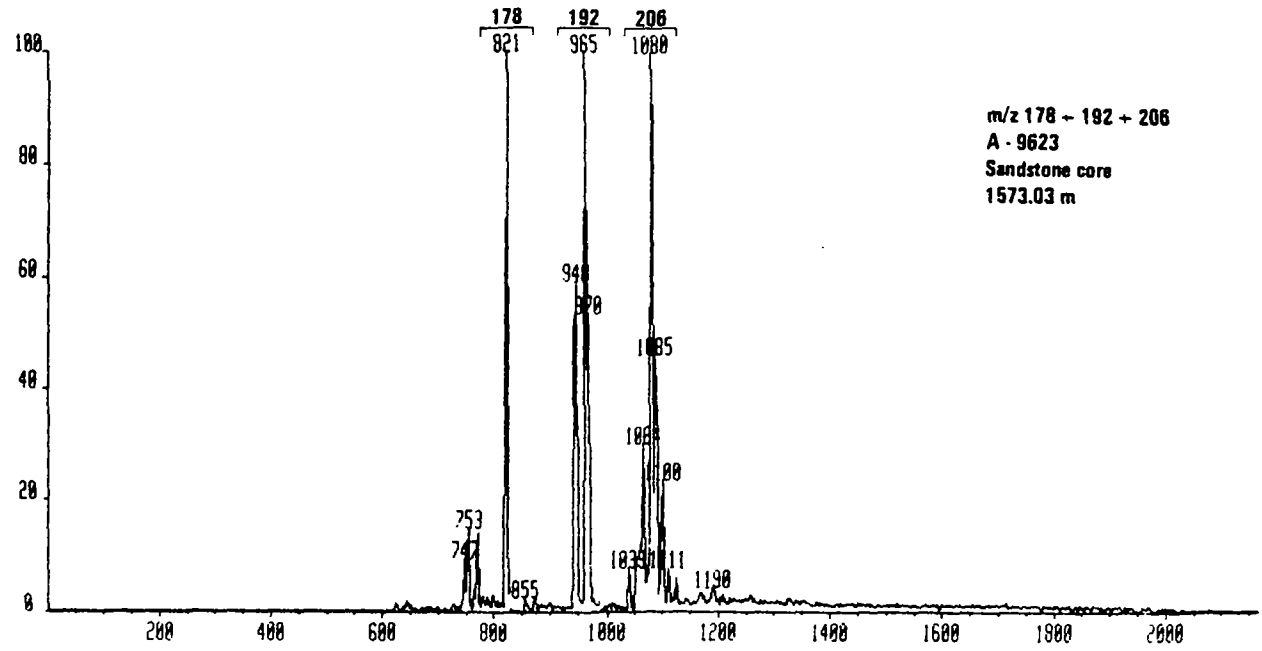
600
800
1000
1200
1400
1600
1800
2000


178
821
192
965
206
1080
m/z 178 + 192 + 206
A - 9623
Sandstone core
1573.03 m
753
855
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600
800
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1200
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1600
1800
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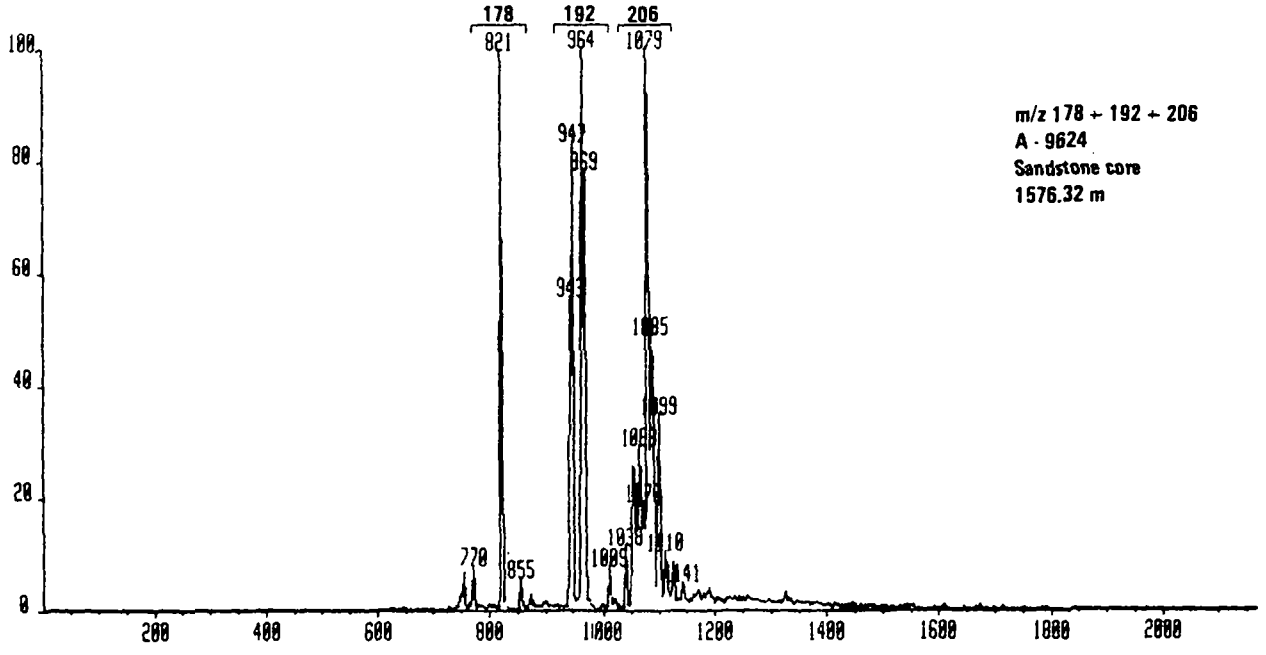
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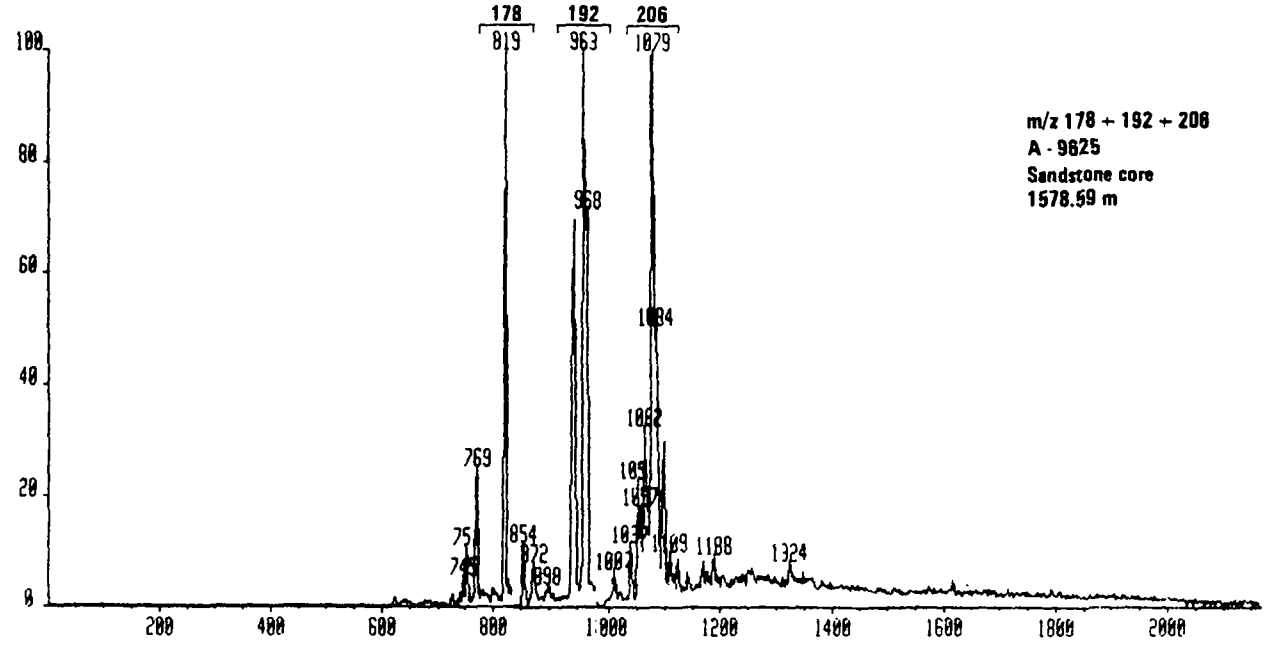
821
192
964
206
1079
m/z 178 + 192 + 206
A - 9624
Sandstone core
1576.32 m


178
819
192
963
206
1079
m/z 178 + 192 + 206
A - 9625
Sandstone core
1578.59 m