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HYDRO **Document frontpage**
Exploration and Production

Norsk Hydro a.s Bergen
E&P Research Centre

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Title

PETROLEUM GEOCHEMISTRY

6407/7-5

BA91-1517-1

7 AUG. 1991

REGISTRERT
OLJEDIREKTORATET

Summary/Conclusion//Recommendation

Keywords

Petroleum Geochemistry, Source Rocks,
Migrated Hydrocarbons, maturity and origin.

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1. INTRODUCTION.

Well 6407/7-5 is located on the northern flank of the Njord area on Haltenbanken. The well was spudded 17. December 1990 and reached T.D. at 3725m in Åre Fm. siltstones. A well location map is given in Figure 1.1, and a well summary with formation tops is given in Figure 1.2.

The aims of this study were:
To identify potential source rocks in the Spekk and Ror Fms.
To characterize potential migrated hydrocarbons in the Lower Cretaceous, and in Ile, Tilje and Åre Fms. in the Jurassic, with emphasis on maturity and origin. All data obtained is to be compared with existing data from previously drilled wells in the Njord area.

This report comprises the results from petroleum geochemical analysis of 42 samples, both DCs, CCs and one SWC.

A list of the samples investigated is given in Table 1.1.

All analytical work, interpretation of data and compilation of this report was undertaken by Norsk Hydro Research Center, Bergen Norway.

HYDRO

LIST OF ABBREVIATIONS AND TERMS

Kerogen

Insoluble organic matter which is preserved in sedimentary rocks. Under the increasing influence of temperature and time (maturation), most kerogen produce hydrocarbons.

TOC

Total Organic Carbon: a measure of the organic carbon in a rock, expressed as weight per cent. Used as a fundamental parameter in source rock classification.

RockEval

A commercial technique for the anhydrous pyrolysis of source rocks developed by IFP. It enables the chemical composition of kerogen and hence its hydrocarbon potential, to be determined.

S_1

This is a measure of the already generated oil in source rocks, or oil content in a reservoir. In units of kg/t rock.

S_2

This is a measure of the remaining hydrocarbon potential. In units of kg/t rock.

Tmax

The temperature, in °C, at which the pyrolytic yield of hydrocarbons from a rock sample reaches its maximum, using RockEval.

Hydrogen Index (HI)

A parameter derived from RockEval which measures the hydrogen richness of kerogen. $HI = 100 * S_2 / TOC$. It has a direct relationship with the H/C ratio, and is measured in mg of hydrocarbons/g TOC

Production Index (PI)

A maturity parameter derived from RockEval, which is the ratio of already generated hydrocarbons (or migrated hydrocarbons) to potential hydrocarbons. $PI = S_1 / S_1 + S_2$

Immature samples have values of 0.1 or less, mature samples, 0.1 to 0.4. The PI is high in reservoirs.

Maturation

The process of chemical change in sedimentary organic matter induced by increasing time and temperature. These chemical reactions produce oil and hydrocarbon gases from the appropriate organic matter. The major maturity subdivisons are:

-immature
-early mature
-peak mature
-late mature
-post mature

Vitrinite

The type of organic matter derived from the lignified tissues of higher land plants.

Vitrinite reflectance

A maturity parameter based on the change in the reflectance of polished vitrinite particles with increasing time and temperature. Widely used values for maturity zones are:

<0.55 %. immature
0.55-1.3 %. mature for oil generation
>1.3 %. post mature for oil generation
0.7-3.0 %. mature for gas generation

EOM (Extractable Organic Matter)

Oil and oil-like products removed from rock samples using organic solvents. The amount of extract may be used to determine the level of maturation.

Saturated Hydrocarbons

Hydrocarbons which contain only carbon-carbon single bonds (alkanes).

Aromatic hydrocarbons

Unsaturated hydrocarbons and containing one or more rings with conjugated carbon-carbon double and single bonds.

NSO compounds

Fraction of oils or extracts containing heteroatoms like sulphur. oxygen and nitrogen.

Asphaltenes

The heavy molecular weight components of crude oils and sediment extracts which is soluble in CS_2 and insoluble in n-pentane.

n-C_{17}

n-alkane with 17 carbon atoms

n-alkane carbon number maximum

n-C_{17} maximum indicates algal input

n-C_{16} to n-C_{24} indicates bacterial input

n-C_{27}, n-C_{29}, n-C_{31} indicates higher plant input

Isoprenoids

Isoprenoids are branched and/or cyclic hydrocarbons built from multiples of the isoprene unit and are dominantly derived from plant and bacterial sources.

Pristane

C_{19} regular acyclic isoprenoid derived from the side chain of chlorophyll.

Phytane

C_{20} regular acyclic isoprenoid derived mainly from the side chain in chlorophyll, but have also been found in methanogenic bacteria and archaebacteria.

Pristane/phytane ratio

>3 = oxic conditions

<0.5 = anoxic conditions

The ratio may be affected by many factors

CPI (Carbon Preference Index)

The ratio of abundance of odd carbon number n-alkanes to even number n-alkanes. The preference decreases with increasing maturity until CPI = 1.0.

CPI $>$ 1.1 means oil or extract is of low maturity.

CPI $<$ 1.0 in carbonate source rocks.

Biodegradation

Degradation of oils by bacteria. Normal alkanes are generally the first to be attacked and removed.

GC-MS (Gas chromatography-mass spectrometry)

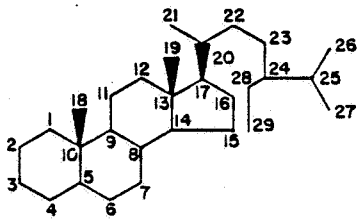
Method for identification of constituents in complex mixtures or for analysis of trace components using Single Ion Monitoring (SIM).

Biomarkers

Compounds found in petroleum or rock extracts which indicate an unambiguous link with a natural product.

Steranes

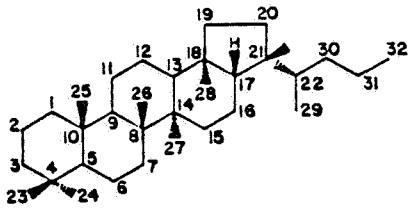
The alkanes derived from steroid natural products. Monitored by GC-MS of M/z 217 and 218.



Sterane

Triterpanes

C_{27} to C_{35} five ring cyclic alkanes derived from triterpenoid hydrocarbons in bacteria, fungi, algae and higher plants. Monitored by GC-MS of M/z 191.



Pentacyclic triterpane

Hopanes

C_{27} to C_{35} pentacyclic alkanes which dominate the triterpanes found in sediments and crude oils. They originate from bacteria.

M/z, m/e

The mass to charge ratio of fragment of molecules from GC-MS.

Table 1.1 List of samples analysed.

	DEPTH m	TYPE	ROCKEVAL	TOC	PYGC	EXTR	GC-SAT	BIOM SAT
1	3075.00	COCH	*	*				
2	3077.00	COCH	*	*				
3	3078.00	COCH	*	*				
4	3079.00	COCH	*	*				
5	3080.00	COCH	*	*				
6	3081.00	COCH	*	*		*	*	*
7	3081.70	COCH	*	*				
8	3082.50	COCH	*	*				
9	3083.00	COCH	*	*				
10	3120.00	DCD	*	*				
11	3122.00	DCD	*	*				
12	3122.00	SWC	*	*	*	*	*	*
13	3125.00	DCD	*	*				
14	3127.00	DCD	*	*				
15	3130.00	DCD	*	*				
16	3132.00	DCD	*	*	*	*	*	*
17	3135.00	DCD	*	*				
18	3137.00	DCD	*	*				
19	3140.00	DCD	*	*				
20	3142.00	DCD	*	*				
21	3145.00	DCD	*	*				
22	3147.00	DCD	*	*				
23	3150.00	DCD	*	*				
24	3176.00	COCH	*	*		*	*	*
25	3177.00	COCH	*	*		*	*	*
26	3182.23	COCH	*	*		*	*	*
27	3190.10	COCH	*	*				
28	3193.45	COCH	*	*				
29	3196.45	COCH	*	*				
30	3198.72	COCH	*	*		*	*	*
31	3204.85	COCH	*	*				
32	3207.00	COCH	*	*				
33	3207.50	COCH	*	*				
34	3208.50	COCH	*	*				
35	3210.50	COCH	*	*				
36	3212.00	COCH	*	*				
37	3214.00	COCH	*	*				
38	3431.00	COCH	*	*		*	*	*
39	3530.00	DCD	*	*				
40	3535.00	DCD	*	*				

Table 2.1 Source rock screening data.

Table 2.1 **SOURCE ROCK SCREENING DATA WELL 6407/7-5**

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Research Centre Bergen

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Depth (m)	% Lithology	Type	S1 kg/t	S2 kg/t	TOC %	HI	PI	Tmax DegC	Company
3075.00		COCH	4.27	6.81	5.3	128	0.39	440	F-BERGEN
3077.00		COCH	0.15	0.13	0.7	19	0.54	468	F-BERGEN
3078.00		COCH	0.09	0.07	0.4	18	0.56	438	F-BERGEN
3079.00		COCH	0.11	0.13	0.6	22	0.46	493	F-BERGEN
3080.00		COCH	2.18	2.79	5.3	53	0.44	444	F-BERGEN
3081.00		COCH	1.00	0.15	0.2	75	0.87	426	F-BERGEN
3081.70		COCH	0.13	0.07	0.5	14	0.65	454	F-BERGEN
3082.50		COCH	0.07	0.09	0.5	18	0.44	480	F-BERGEN
3083.00		COCH	0.34	0.75	1.6	47	0.31	447	F-BERGEN
3120.00		DCD	0.62	2.06	1.4	147	0.23	437	F-BERGEN
3122.00	SH	SWC	2.13	12.36	3.7	334	0.15	432	F-BERGEN
3122.00		DCD	1.22	7.23	2.7	268	0.14	435	F-BERGEN
3125.00		DCD	1.17	6.02	2.4	251	0.16	433	F-BERGEN
3127.00		DCD	1.12	4.86	1.9	256	0.19	424	F-BERGEN
3130.00		DCD	1.28	5.39	2.4	225	0.19	432	F-BERGEN
3132.00		DCD	2.16	9.48	3.6	263	0.19	433	F-BERGEN
3135.00		DCD	1.67	7.43	3.1	240	0.18	433	F-BERGEN
3137.00		DCD	1.12	4.16	2.3	181	0.21	435	F-BERGEN

Table 2.1 **SOURCE ROCK SCREENING DATA WELL 6407/7-5** (cont'd)

Depth (m)	% Lithology	Type	S1 kg/t	S2 kg/t	TOC %	HI	PI	Tmax DegC	Company
3140.00		DCD	0.96	3.05	2.1	145	0.24	434	F-BERGEN
3142.00		DCD	1.13	3.20	2.2	145	0.26	435	F-BERGEN
3145.00		DCD	0.91	2.50	1.7	147	0.27	435	F-BERGEN
3147.00		DCD	0.73	1.39	1.6	87	0.34	435	F-BERGEN
3150.00		DCD	0.84	2.04	2.2	93	0.29	439	F-BERGEN
3176.00	SST	COCH	2.35	0.37	0.4	93	0.86		F-BERGEN
3177.00	SST	COCH	1.78	0.46	0.4	115	0.79		F-BERGEN
3182.23	SST	COCH	1.59	0.05	0.2	25	0.97	392	F-BERGEN
3190.10	SST	COCH	4.98	0.37	0.5	74	0.93	423	F-BERGEN
3193.45	SST	COCH	3.22	0.55	0.4	138	0.85	422	F-BERGEN
3196.45	SST	COCH	4.90	0.49	0.5	98	0.91	422	F-BERGEN
3198.72	SST	COCH	5.74	0.49	0.5	98	0.92	390	F-BERGEN
3204.85	SST	COCH	3.47	0.33	0.5	66	0.91	425	F-BERGEN
3207.00		COCH	0.03	0.46	0.5	92	0.06	508	F-BERGEN
3207.50		COCH	0.15	0.88	1.3	68	0.15	497	F-BERGEN
3208.50		COCH	0.94	6.50	4.8	135	0.13	442	F-BERGEN
3210.50		COCH	0.39	1.93	2.0	97	0.17	446	F-BERGEN
3212.00		COCH	0.19	0.72	1.0	72	0.21	446	F-BERGEN
3214.00		COCH	0.15	0.65	1.0	65	0.19	447	F-BERGEN

Table 2.1 **SOURCE ROCK SCREENING DATA WELL 6407/7-5** (cont'd)

Depth (m)	%	Lithology	Type	S1 kg/t	S2 kg/t	TOC %	HI	PI	Tmax DegC	Company
3431.61		SST	COCH	5.71	0.88	0.6	147	0.87	400	F-BERGEN
3530.00		SST	DCW	0.15	0.70	0.9	78	0.18	448	F-BERGEN
3530.00		COAL	DCW	33.59	209.12	79.9	262	0.14	443	F-BERGEN
3535.00		COAL	DCW	19.16	151.29	50.3	301	0.11	442	F-BERGEN
3535.00		SST	DCW	0.07	0.23	0.0	0	0.23	455	F-BERGEN

Table 2.2 Molecular ratios.

Table 2.3 **SATURATED FRACTION MOLECULAR RATIOS WELL 6407/7-5**

Petroleum Geochemistry Group
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Depth	%	Lithology	Type	Pristane / nC17	Pristane / Phytane	CPI-I	CPI-II	nC15+ / Total	nC20 / nC25
3081.00			COCH	0.79	1.60	1.11	1.01		
3122.00		SH	SWC	1.27	1.16	1.06	1.08		
3132.00			DCD	1.45	1.46	1.00	0.99		
3176.00		SST	COCH	0.69	1.87	1.11	1.05		
3177.00		SST	COCH	0.76	1.85	1.13	0.99		
3182.23		SST	COCH	0.67	1.77	1.10	0.99		
3198.72		SST	COCH	0.62	1.79	1.10	1.02		
3431.61		SST	COCH	0.49	1.34	1.10	1.02		

Table 2.3 Biomarker ratios.

DEPTH m	Ts/Tm	Norhopane/ Hopane	C30?/ Hopane	%27R	%28R	%29R	%20S	%abb
3081.00	3.5	0.4	0.3	51	18	31	49	75
3122.00	1.9	0.4	0.1	48	24	28	47	55
3132.00	0.8	0.4	0.1	35	30	35	49	48
3176.00	3.7	0.4	0.6	57	11	32	45	71
3177.00	3.5	0.4	0.5	54	14	32	53	69
3182.23	5.1	0.4	0.7	54	25	21	61	71
3198.72	2.1	0.4	0.4	38	24	38	50	69
3431.60	3.6	0.4	0.7	56	18	26	52	73

Table 3.1 Extraction data I.

Table 3.1 **SOURCE ROCK EXTRACTION DATA WELL 6407/7-5**

Petroleum Geochemistry Group
Research Centre Bergen
HYDRO

Depth (m)	Lithology	Type	EOM(mg)	EOM(%)	Hydrocarbons SAT(%)	ARO(%)	TOTAL(%)	Non Hydrocarbons NSO(%)	ASPH(%)	TOTAL(%)
3081.00		COCH	69.5	0.29	63.00	21.00	84.00	10.00	6.00	16.00
3122.00	SH	SWC	28.7	0.61	22.00	23.00	45.00	35.00	20.00	55.00
3132.00		DCD	72.0	0.42	5.00	9.00	14.00	64.00	22.00	86.00
3176.00	SST	COCH	74.4	0.32	68.00	21.00	89.00	7.00	4.00	11.00
3177.00	SST	COCH	66.9	0.28	70.00	21.00	91.00	7.00	2.00	9.00
3182.23	SST	COCH	60.7	0.27	63.00	25.00	88.00	7.00	5.00	12.00
3198.72	SST	COCH	165.9	0.75	63.00	31.00	94.00	5.00	1.00	6.00
3431.61	SST	COCH	218.2	0.78	63.00	30.00	93.00	4.00	3.00	7.00

Table 3.2 Extraction data II.

Table 3.2 **SOURCE ROCK EXTRACTION DATA WELL 6407/7-5**

Petroleum Geochemistry Group
Research Centre Bergen
HYDRO

Depth	%	Lithology	Type	TOC (%)	EOM(%)/TOC(%)	SAT(%)/TOC(%)	SAT(%)/ARO(%)	HC/Non HC
3081.00			COCH	0.20	1.47	*****	3.00	5.25
3122.00		SH	SWC	3.70	0.17	5.95	0.96	0.82
3132.00			DCD	3.60	0.12	1.39	0.56	0.16
3176.00		SST	COCH	0.40	0.81	*****	3.24	8.09
3177.00		SST	COCH	0.40	0.70	*****	3.33	10.11
3182.23		SST	COCH	0.20	1.37	*****	2.52	7.33
3198.72		SST	COCH	0.50	1.49	*****	2.03	15.67
3431.61		SST	COCH	0.60	1.30	*****	2.10	13.29

APPENDIX I

Pyrolysis Gas Chromatograms.

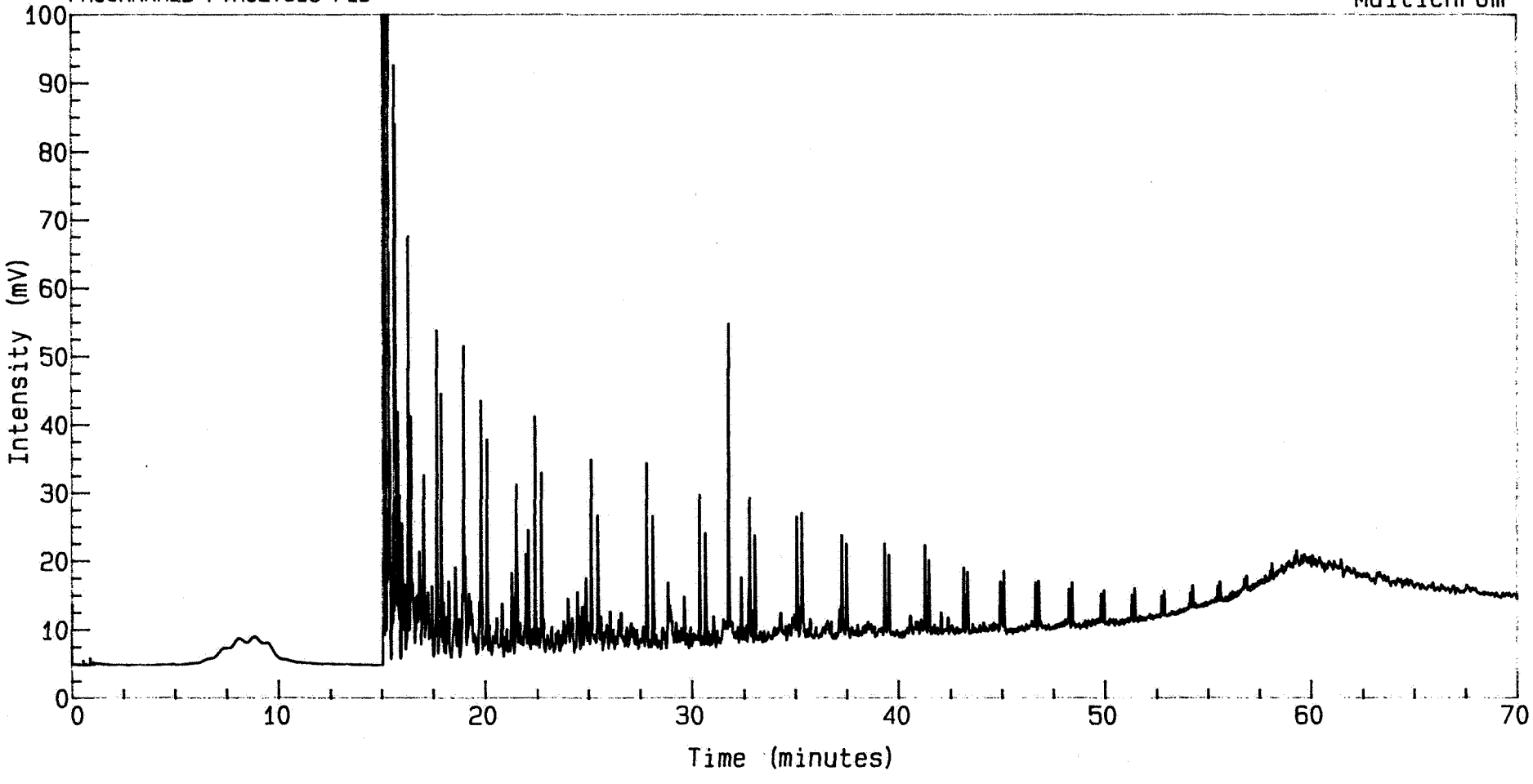
NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 6 W64070705P, 2, 1.

3122 M DC Amount : 39.700

PROGRAMMED PYROLYSIS FID

Multichrom



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Channel Title : PYROLYSIS FID
Lims ID :
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Reported on 7-MAY-1991 at 08:06

Method : PYRO
Calibration : PYRO
Run Sequence : PYRO

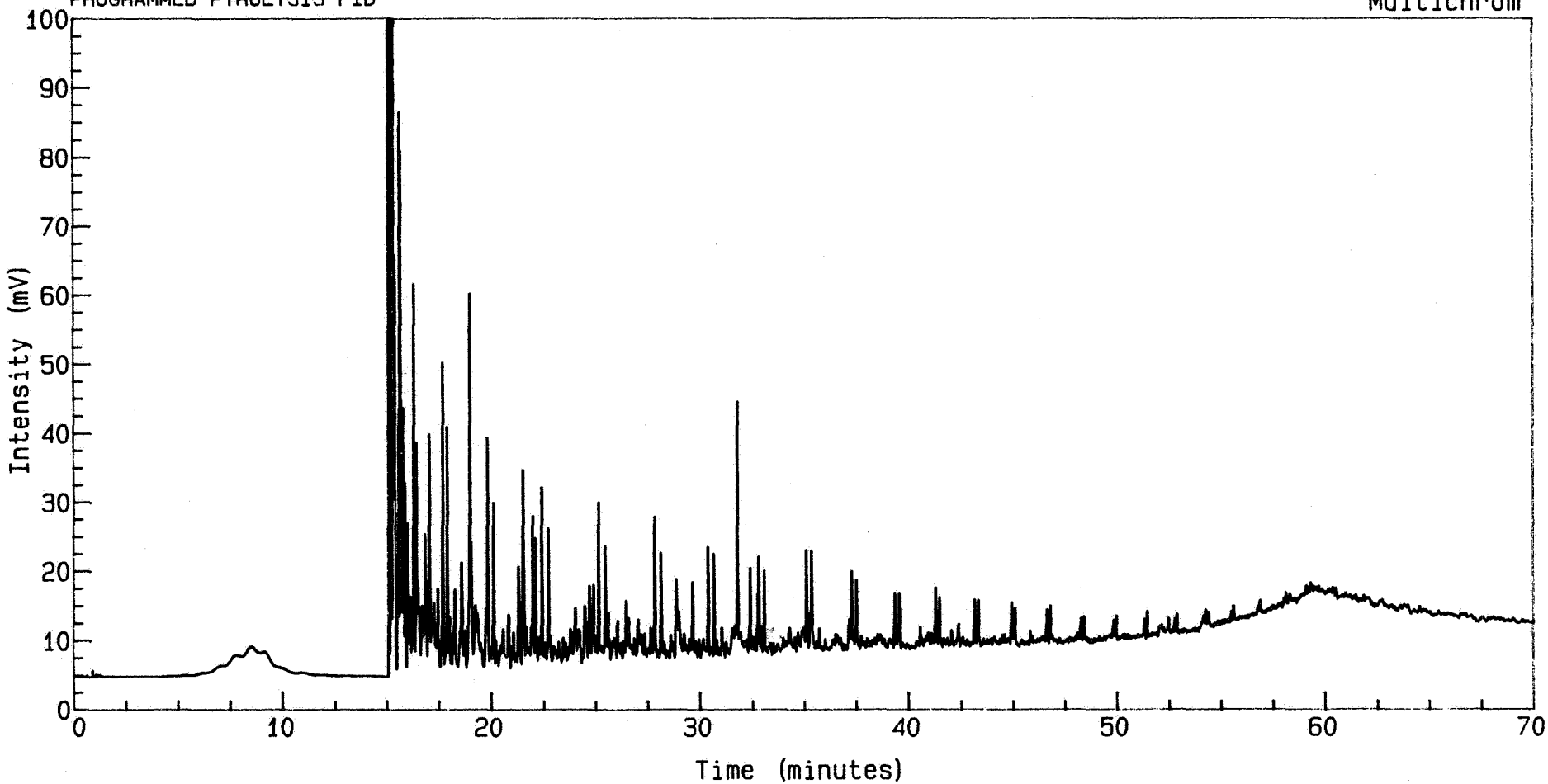
NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 6 W64070705P, 3, 1.

3132 M DC Amount : 43.900

PROGRAMMED PYROLYSIS FID

Multichrom



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Lims ID :
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Reported on 7-MAY-1991 at 08:07

Method : PYRO
Calibration : PYRO
Run Sequence : PYRO

APPENDIX II

Gas Chromatograms of Saturated Hydrocarbons.

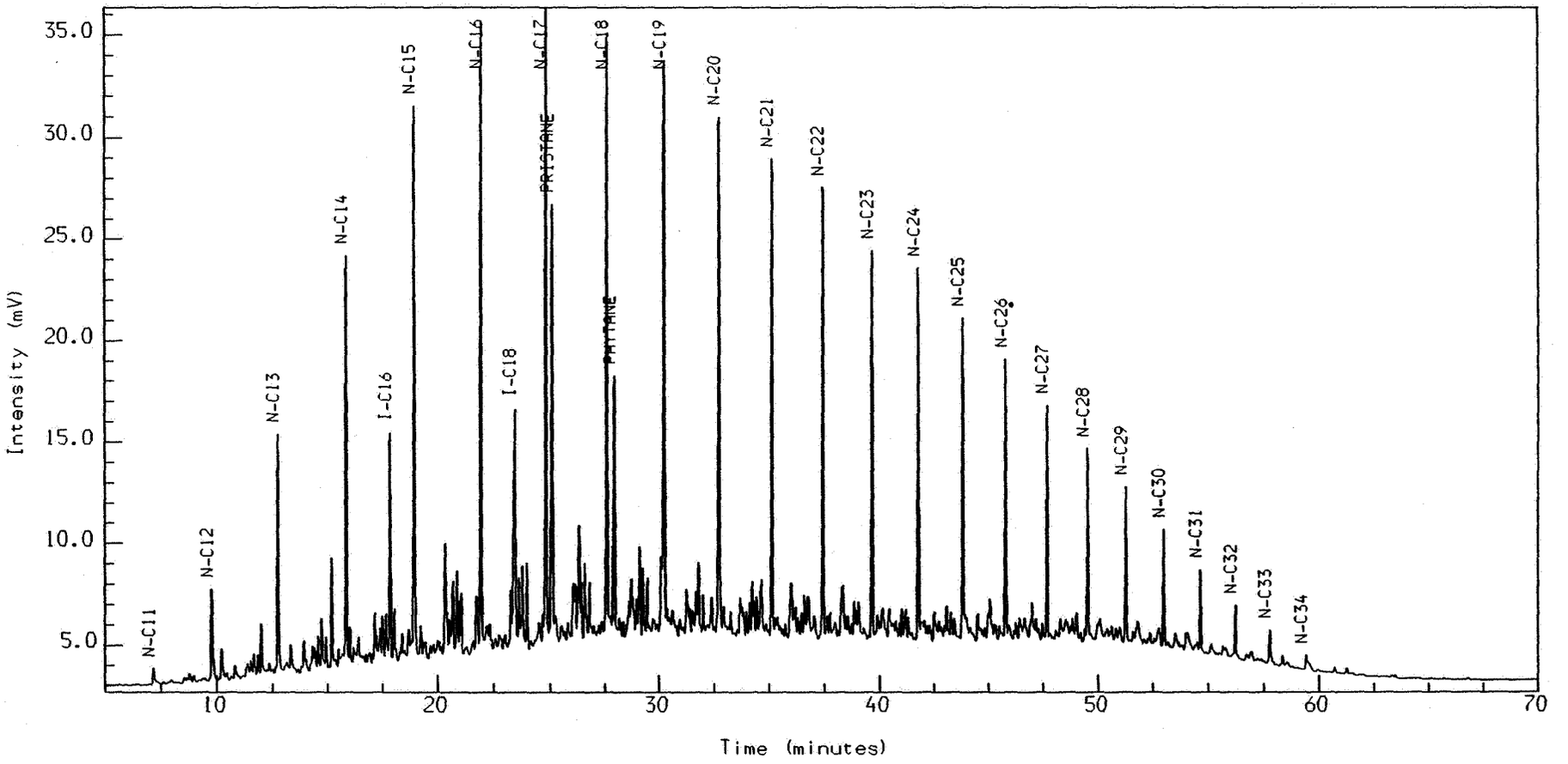
NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 7 W64070705S.2.1.

3081 M

GC SATURATED HYDROCARBONS

Multichrom



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Channel Title : MSD

Lims ID :

Acquired on 30-APR-1991 at 07:57

Reported on 2-MAY-1991 at 15:44

Method : MSDS

Calibration : MSDS

Run Sequence : MSDS

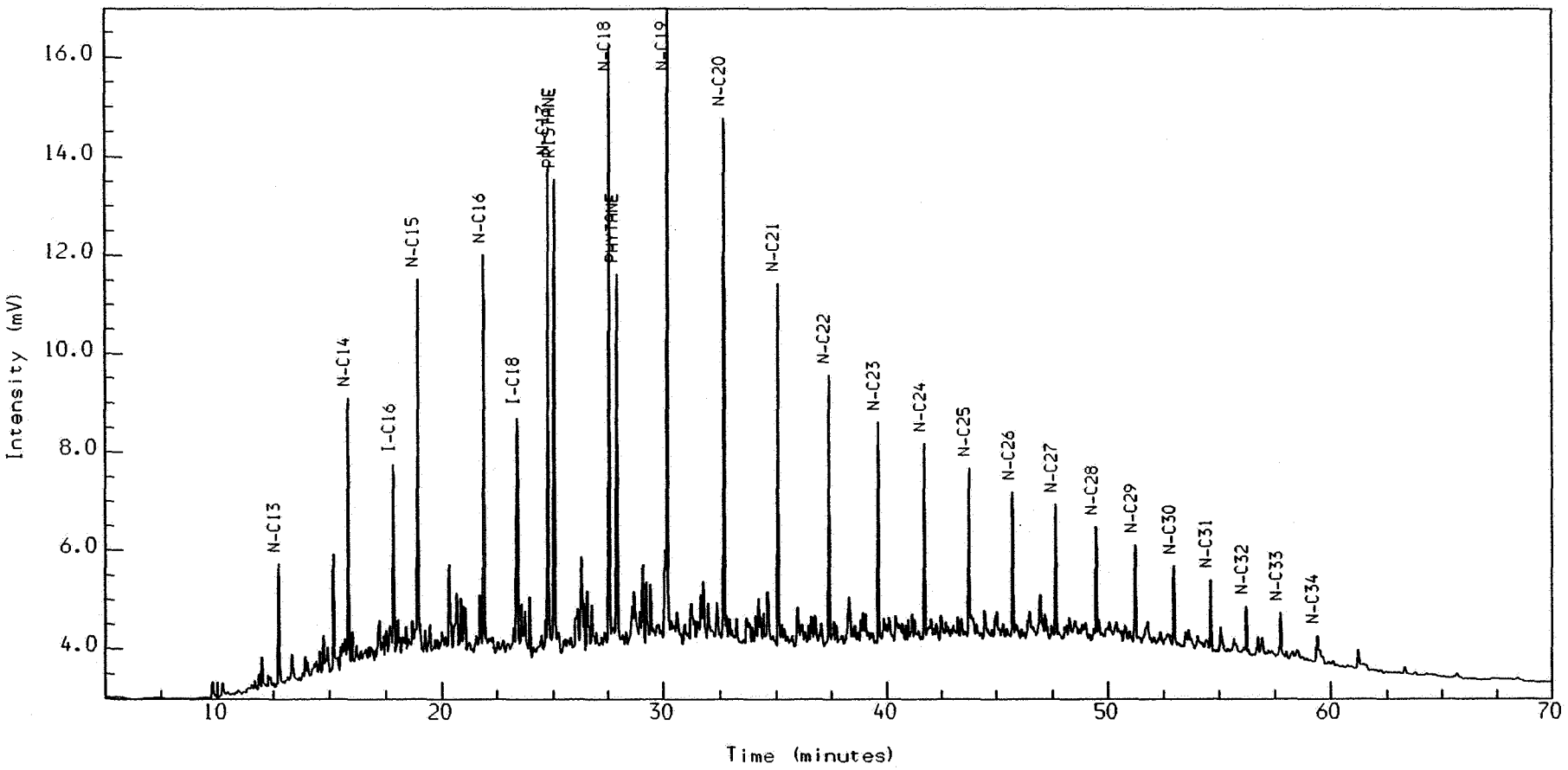
NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 7 W640707055,3,1.

3122 M

GC SATURATED HYDROCARBONS

Multichrom



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Channel Title : MSD

Lims ID :

Acquired on 30-APR-1991 at 09:28

Reported on 30-APR-1991 at 11:23

Method : MSDS

Calibration : MSDS

Run Sequence : MSDS

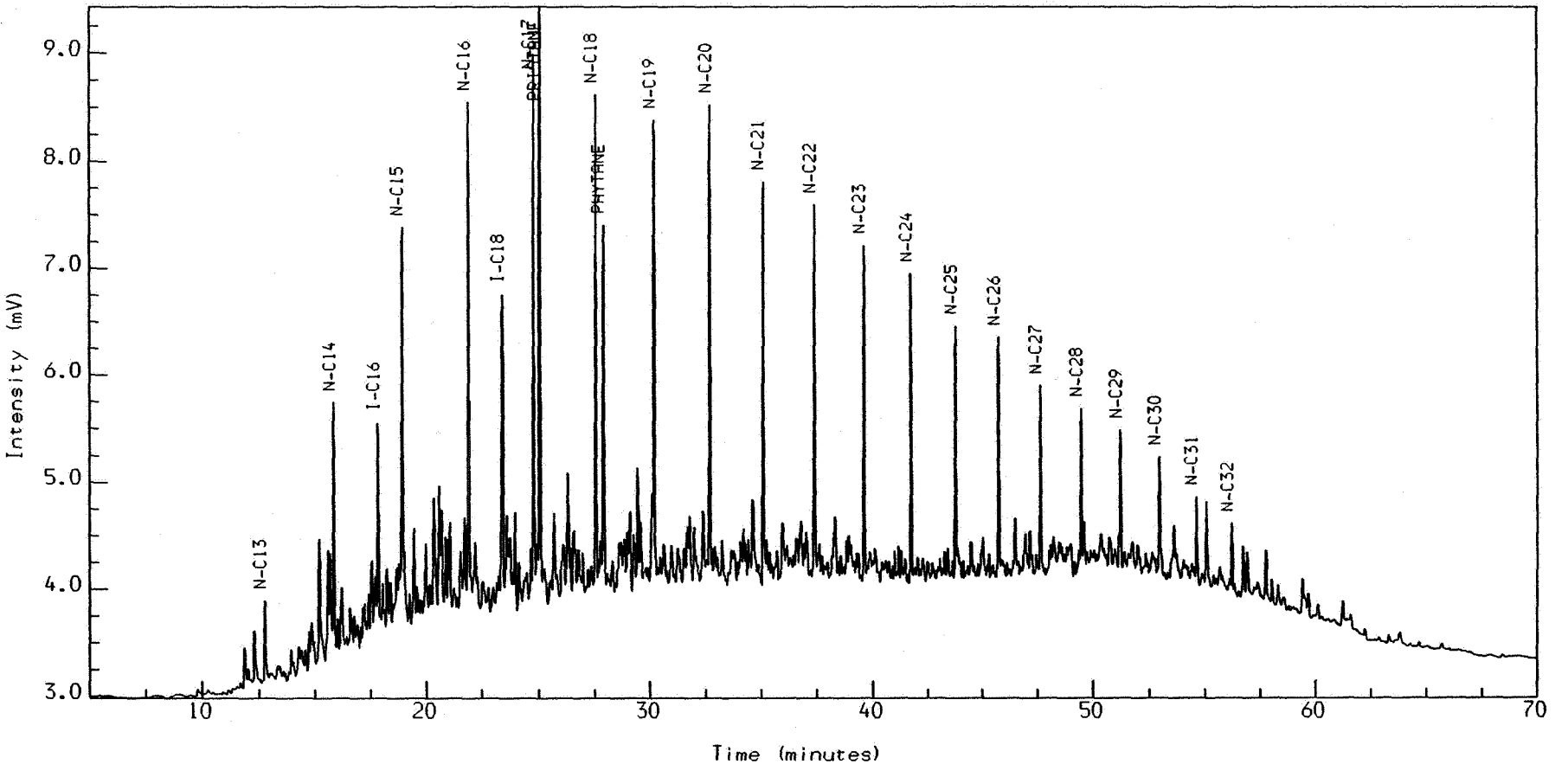
NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 7 W640707055.4.1.

3132 M

GC SATURATED HYDROCARBONS

Multichrom



Instrument : HP5890
Channel Title : MSD
Lims ID :
Acquired on 30-APR-1991 at 11:00
Reported on 2-MAY-1991 at 15:29

Method : MSDS
Calibration : MSDS
Run Sequence : MSDS

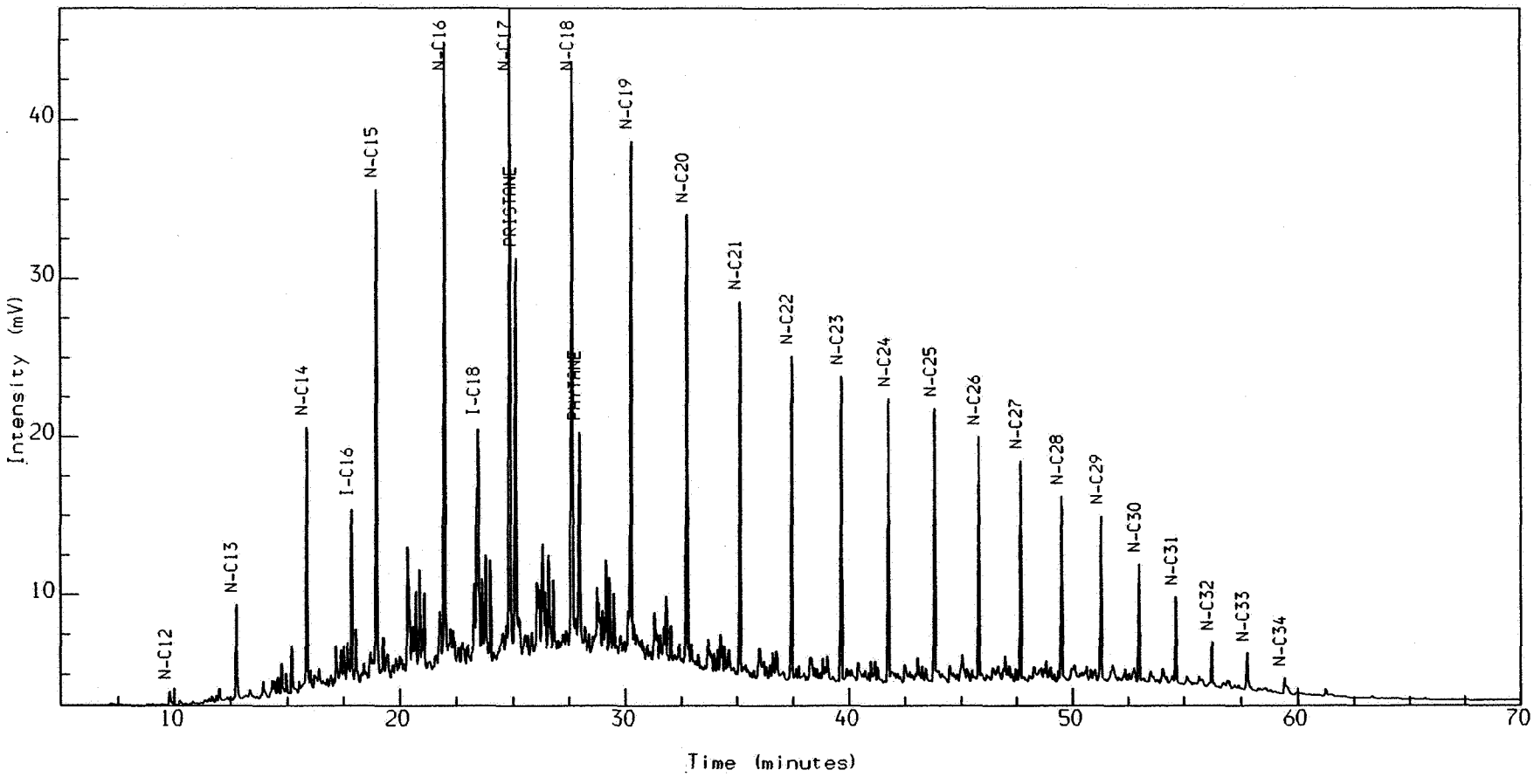
NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 7 W64070705S,5,1.

3176 M

GC SATURATED HYDROCARBONS

Multichrom



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Channel Title : MSD

Lims ID :

Acquired on 30-APR-1991 at 12:31

Reported on 30-APR-1991 at 13:54

Method : MSDS

Calibration : MSDS

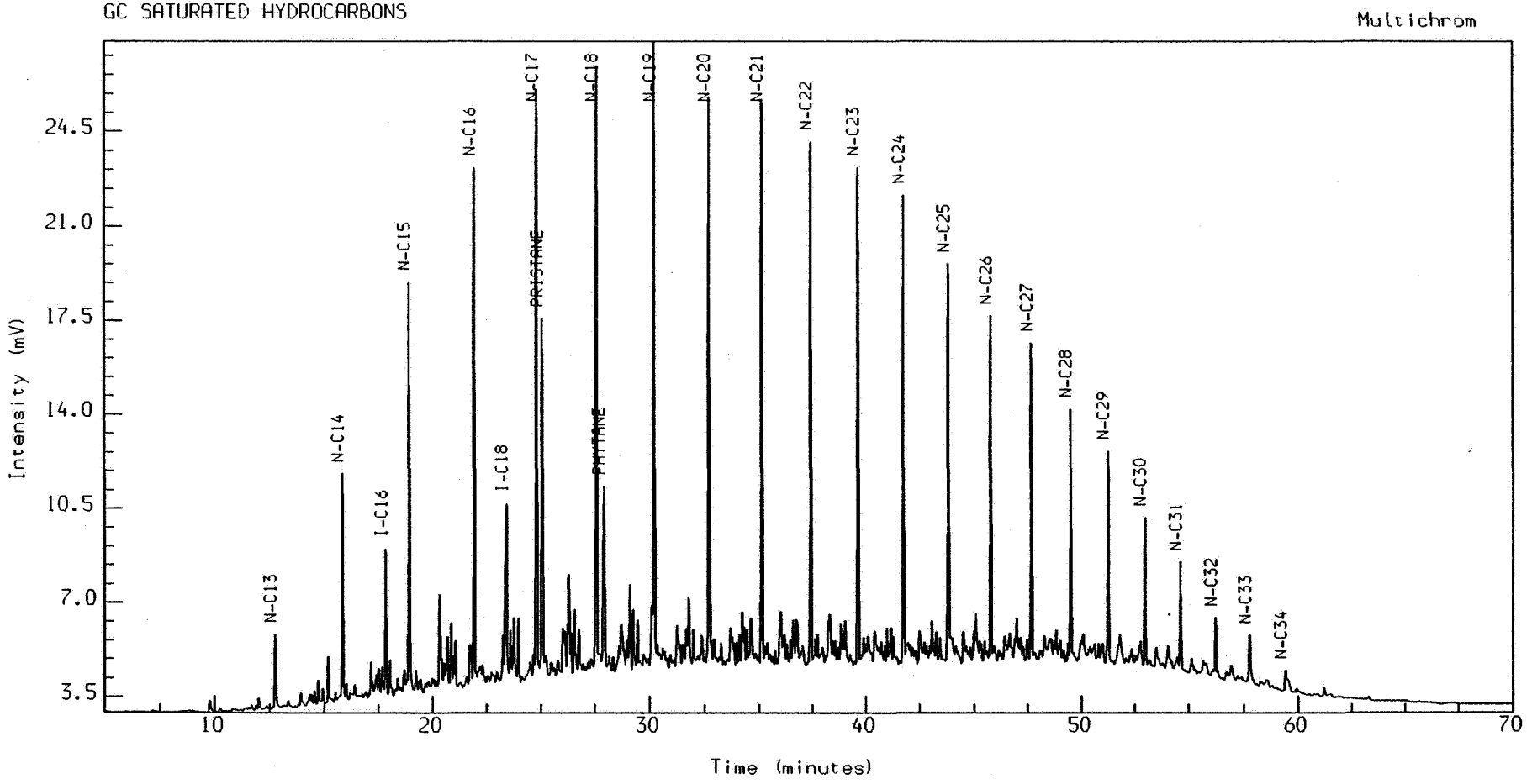
Run Sequence : MSDS

NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 7 W64070705S.6.1.

3177 M

GC SATURATED HYDROCARBONS



Instrument : HP5890

Channel Title : MSD

Lims ID :

Acquired on 30-APR-1991 at 14:02

Reported on 30-APR-1991 at 15:24

Method : MSDS

Calibration : MSDS

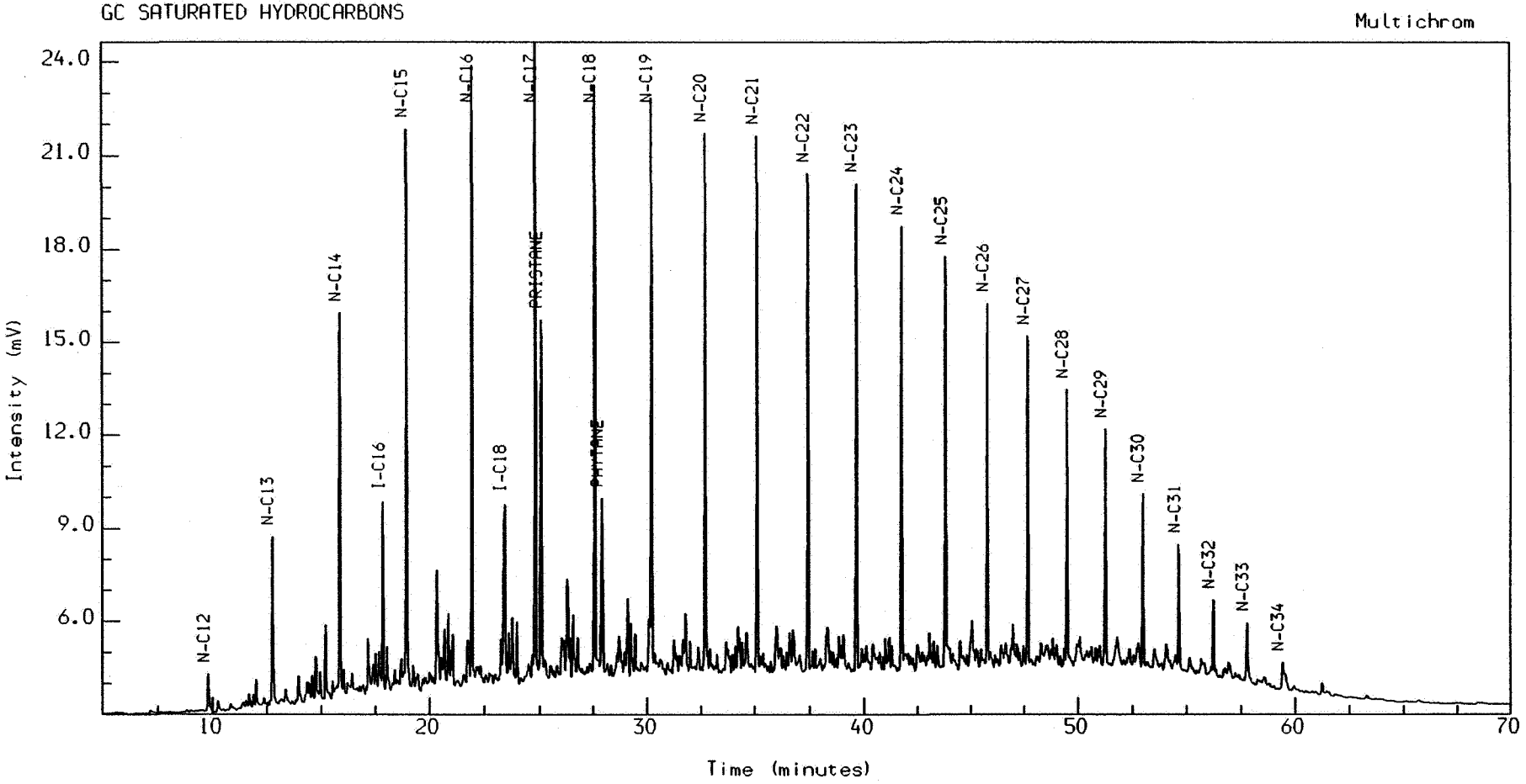
Run Sequence : MSDS

NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 7 W64070705S.7.1.

3182.23 M

GC SATURATED HYDROCARBONS



Instrument : HP5890

Channel Title : MSD

Lims ID :

Acquired on 30-APR-1991 at 15:34

Reported on 30-APR-1991 at 16:56

Method : MSDS

Calibration : MSDS

Run Sequence : MSDS

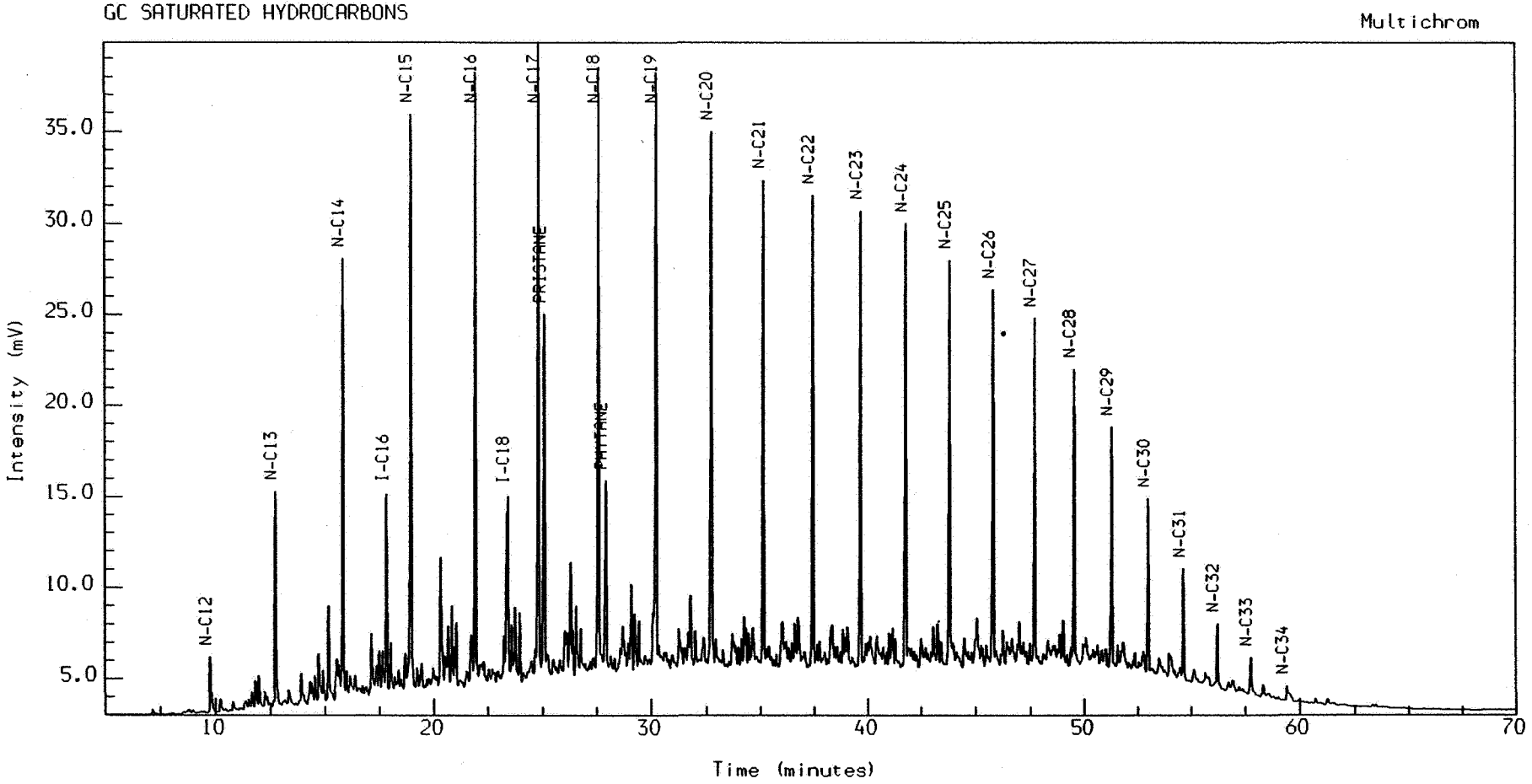
NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 7 W64070705S,8,1.

3198.72 M

GC SATURATED HYDROCARBONS

Multichrom



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Channel Title : MSD
Lims ID :
Acquired on 2-MAY-1991 at 08:09
Reported on 2-MAY-1991 at 09:31

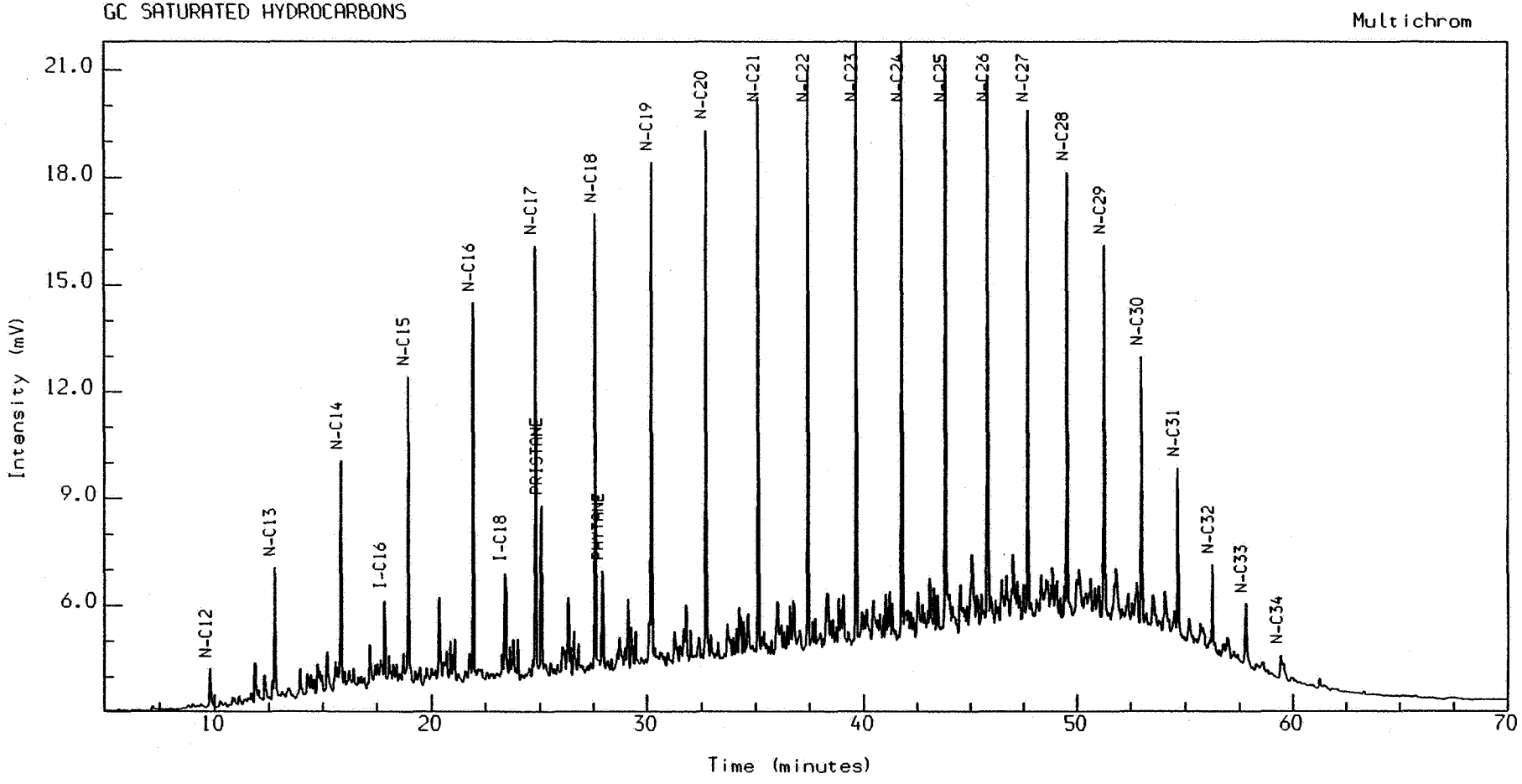
Method : MSDS
Calibration : MSDS
Run Sequence : MSDS

NORSK HYDRO RESEARCH CENTRE

Analysis Name : [PETRO] 7 W64070705S.9,1.

3431.6 M

GC SATURATED HYDROCARBONS



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Channel Title : MSD
Lims ID :
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Reported on 2-MAY-1991 at 11:03

Method : MSDS
Calibration : MSDS
Run Sequence : MSDS

APPENDIX III

Fragmentograms of Terpanes, (Ion 191 m/z).

Fragmentograms of Steranes, (Ion 217 m/z).

Standardized identification of SAT-biomarkers:

Triterpanes:

Numbers from 18 to 35 correspond to the carbon number of the molecule, the subsequent capital letter identifies the stereochemistry and/or the number of rings.

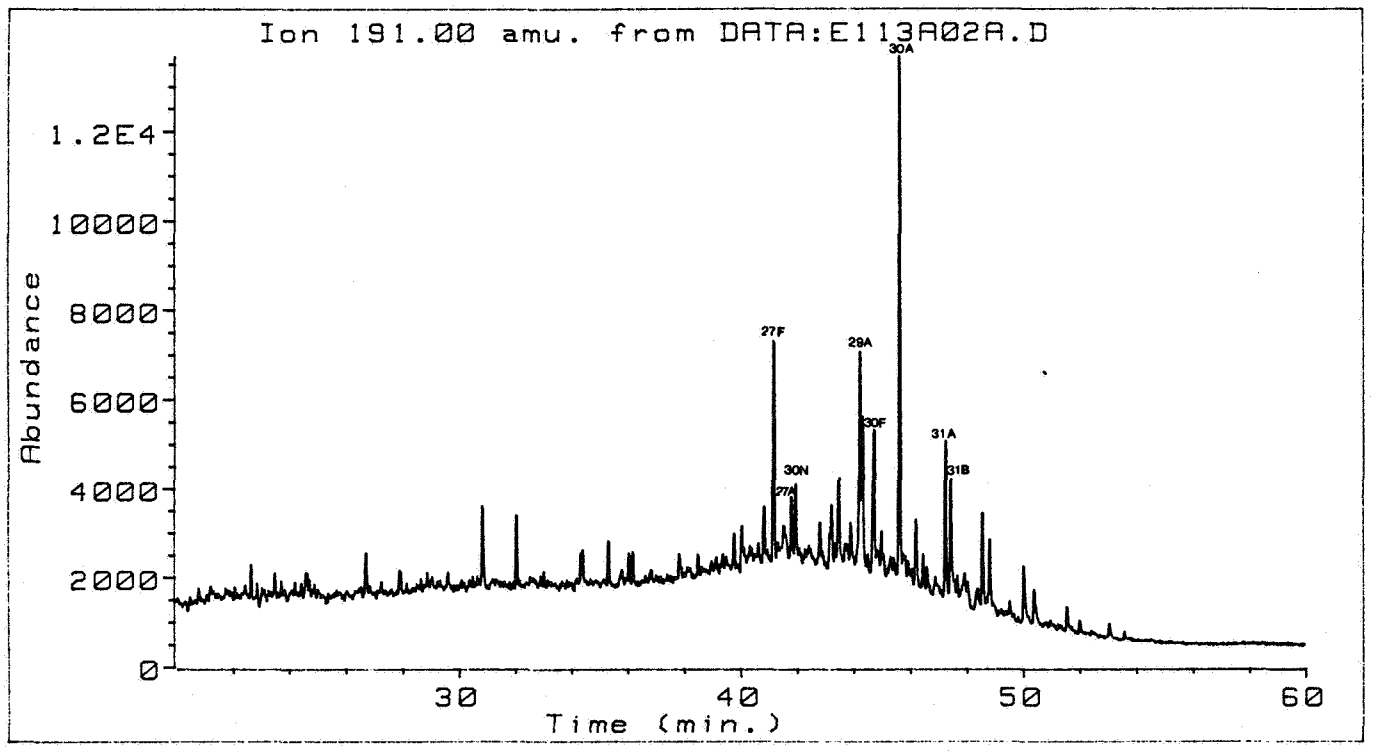
A 17α(H)-hopanes (I) 22S
B 17α(H)-hopanes 22R
C 17β(H)-moretanes (II) 22S
D 17β(H)-moretanes 22R
E 17β(H)-hopanes (III)
F Neohopanes (IV)
G Gammacerane (V)
H Hopenes (VI)
I 25-norhopanes (VII)
L Lupane (VIII)
O 18α(H)-oleanane (IX)
X Tetracyclic terpanes (X)
Y Tricyclic terpanes (XI)
N Unidentified

Steranes:

Numbers from 20 to 30 correspond to the carbon number of the molecules, the subsequent small letter identifies the stereochemistry.

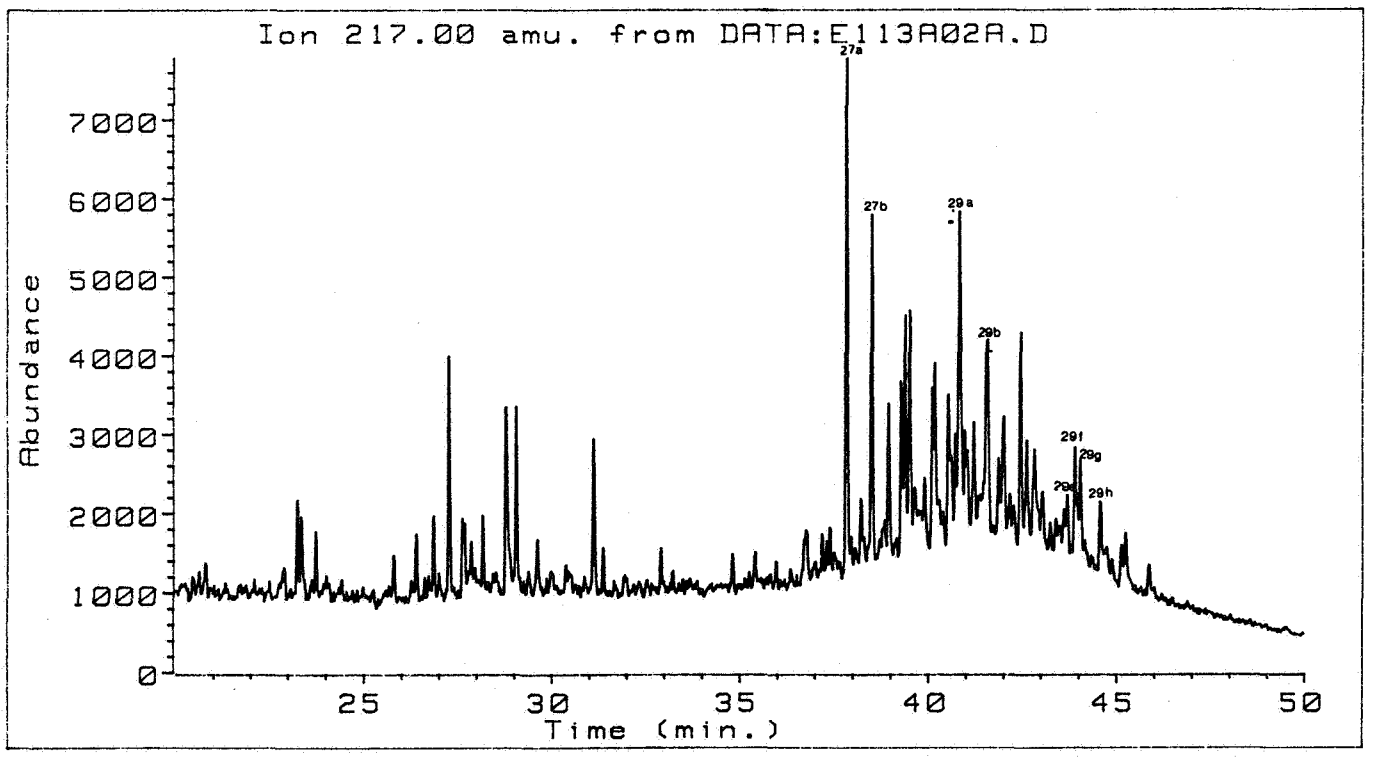
a 13β(H),17α(H)-diasteranes 20S (1)
b 13β(H),17α(H)-diasteranes 20R (2)
c 13α(H),17β(H)-diasteranes 20S (3)
d 13α(H),17β(H)-diasteranes 20R (4)
e 5α(H),14α(H),17α(H)-steranes 20S (5)
f 5α(H),14β(H),17β(H)-steranes 20R (6)
g 5α(H),14β(H),17β(H)-steranes 20S (7)
h 5α(H),14α(H),17α(H)-steranes 20R (8)
i 5β(H),14α(H),17α(H)-steranes (9)
k 4-methylsteranes (10)
n unidentified

Examples: 31B corresponds to 17α(H)-homohopane 22R
29e corresponds to ααα-ethylcholestane 20S



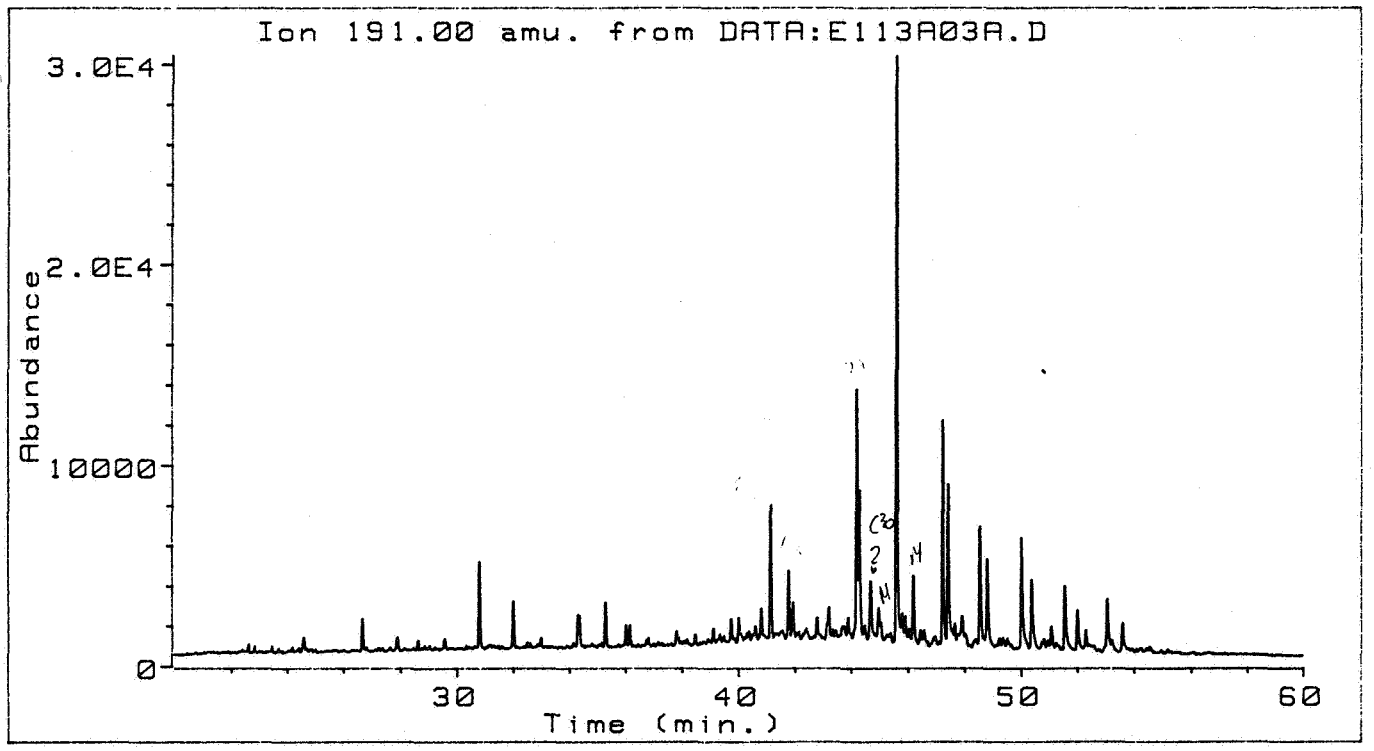
6407/7-5

3081 m



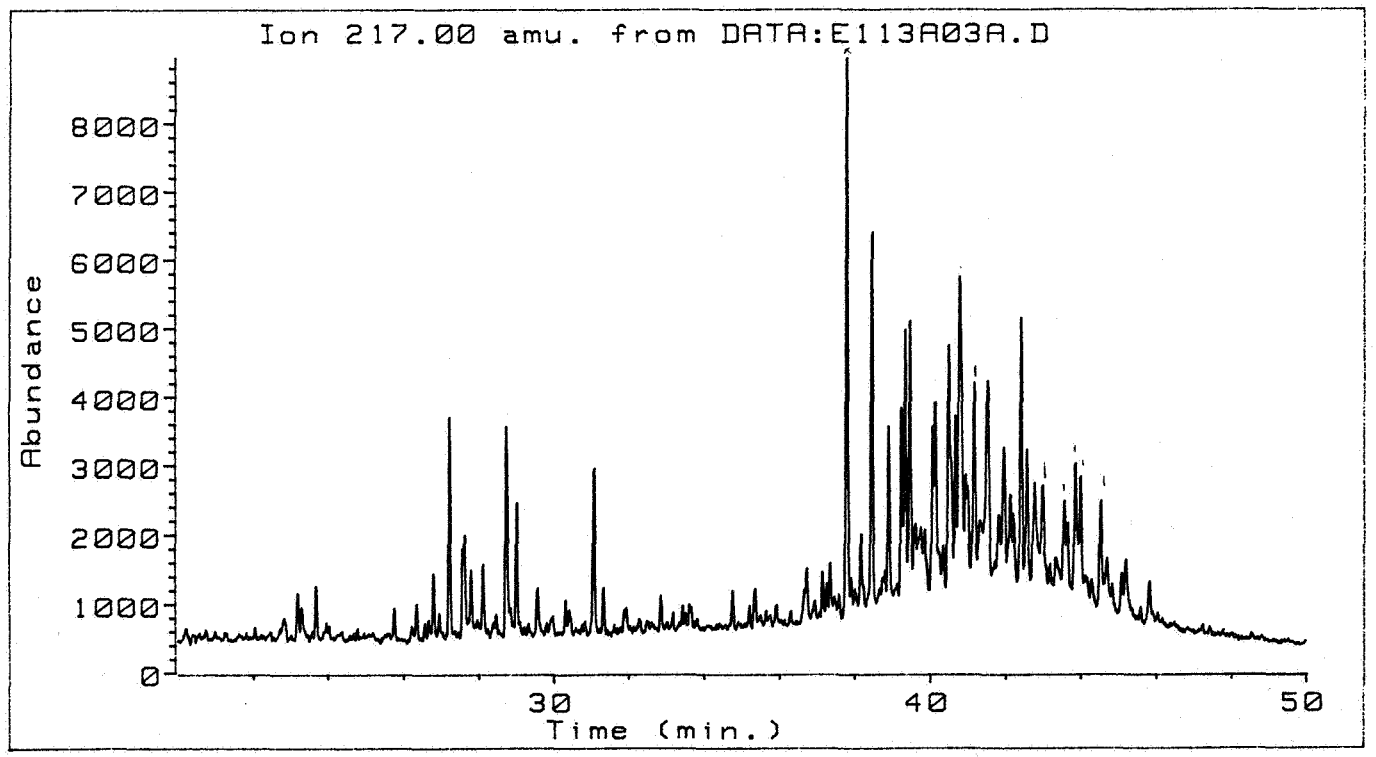
6407/7-5

3081 m



6407/7-5

3122 m



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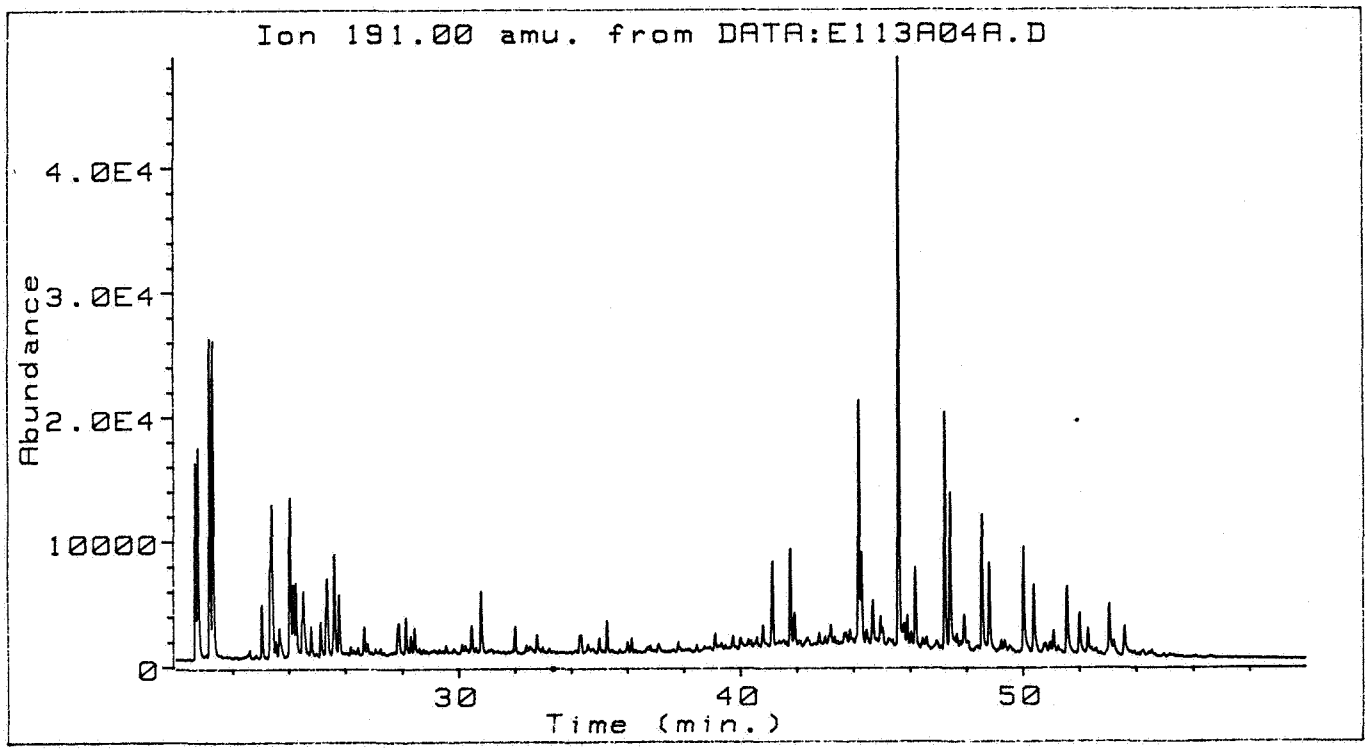
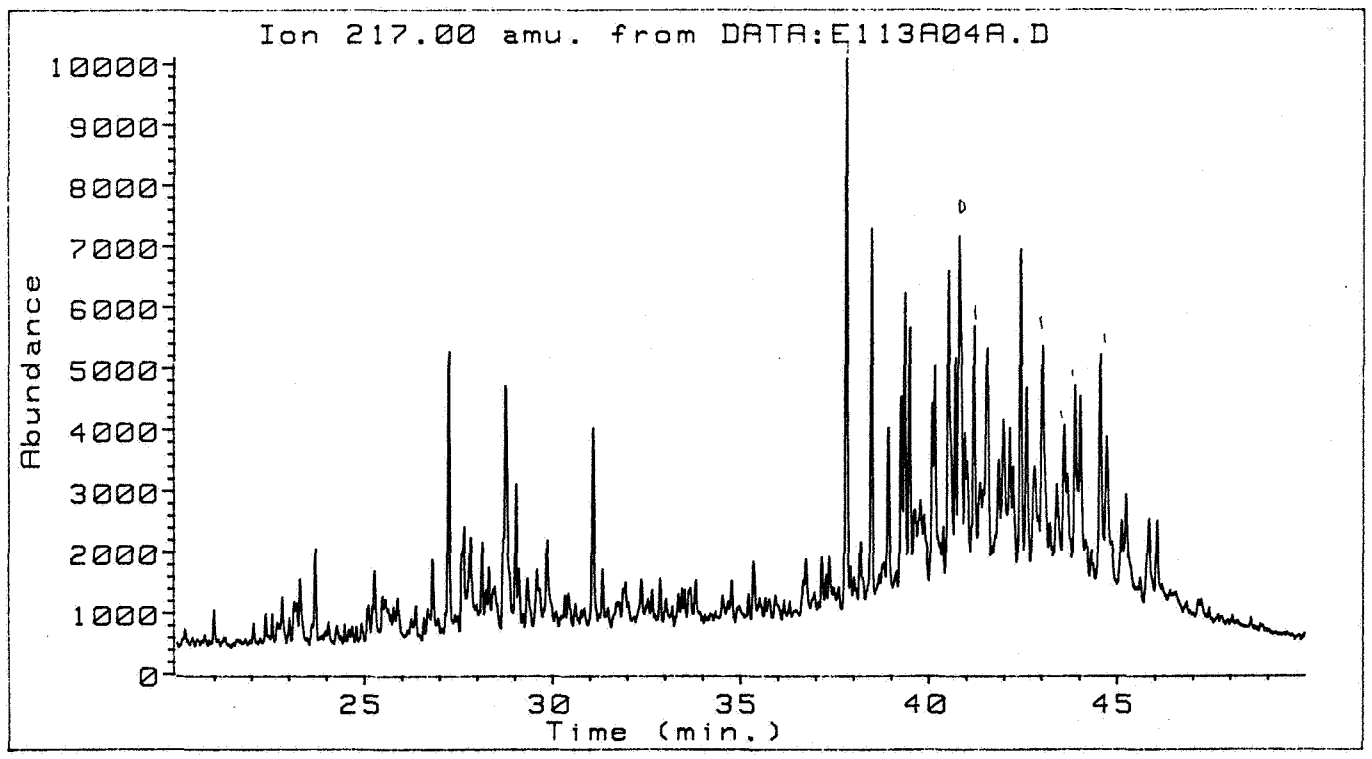


6407/7-5

3132 m



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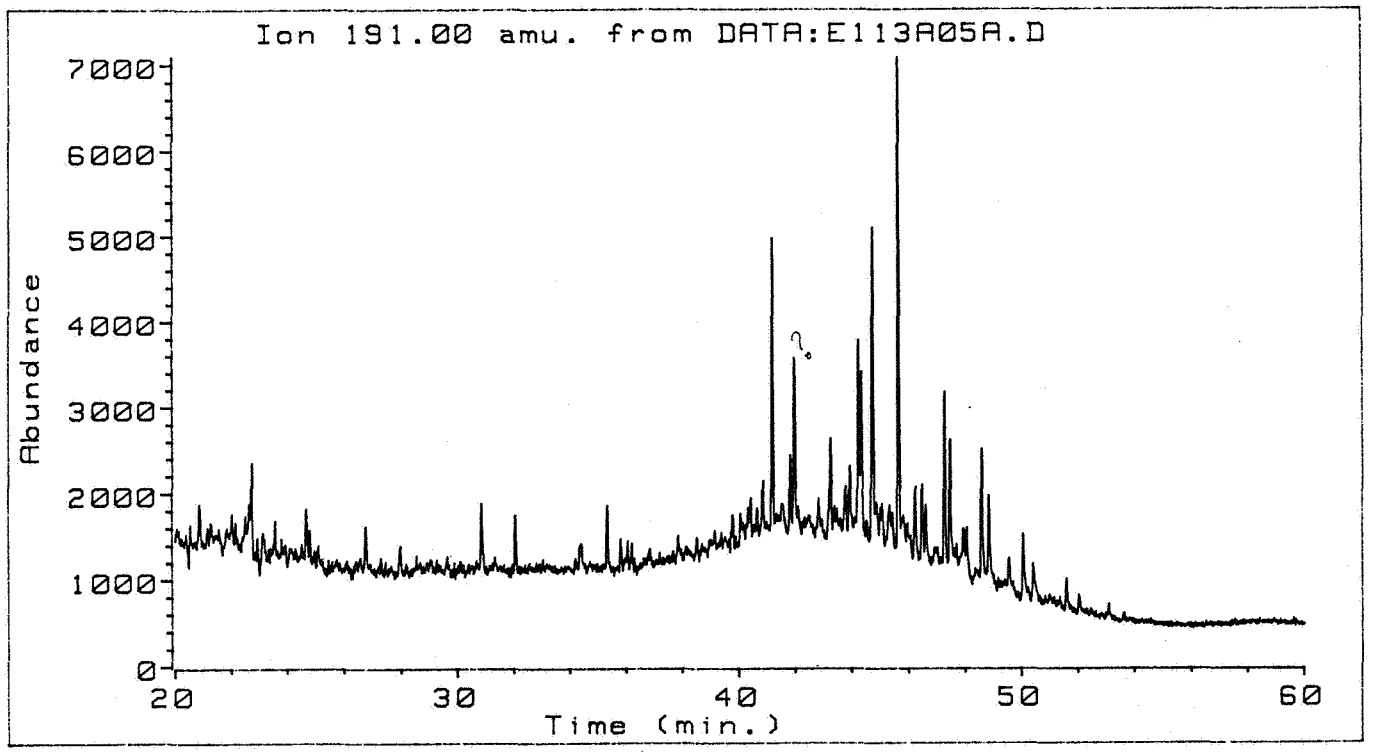
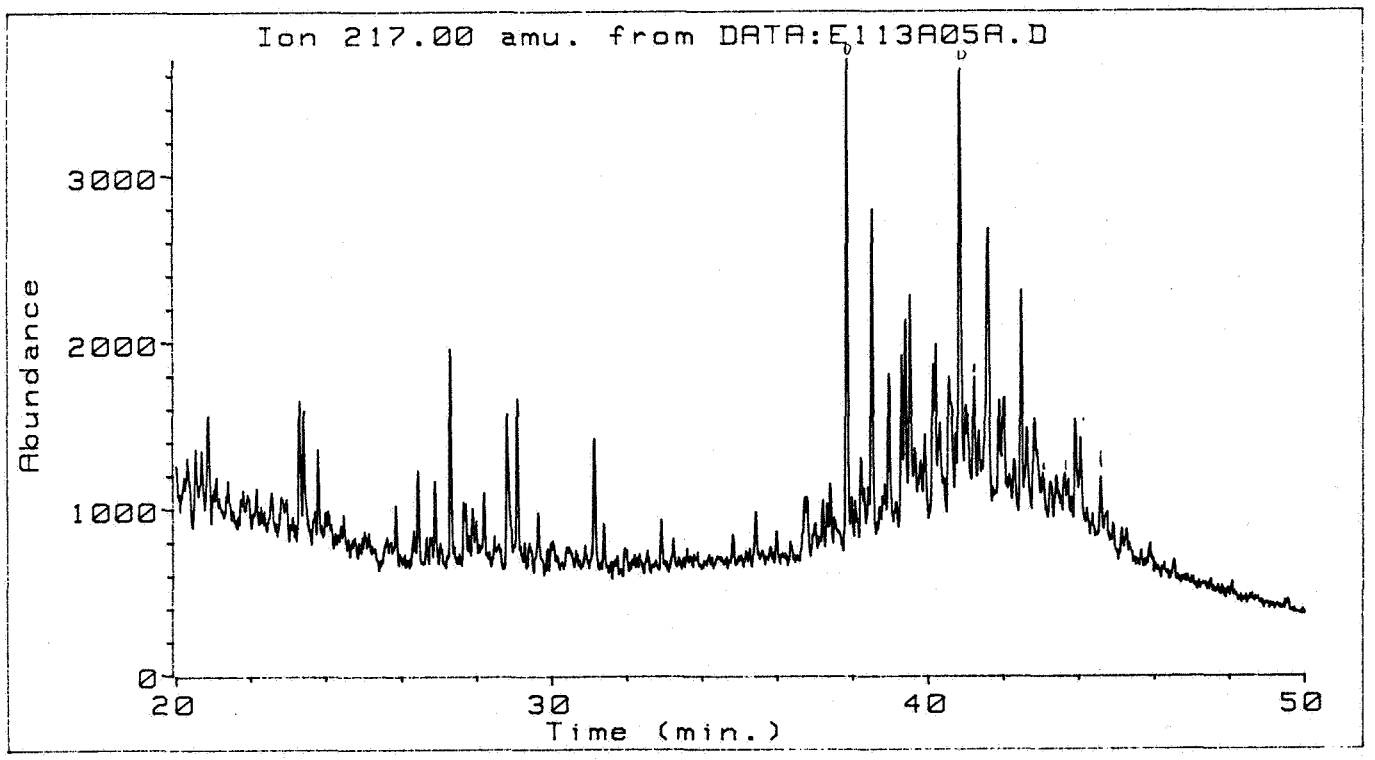


6407/7-5

3176 m



6407/7-5

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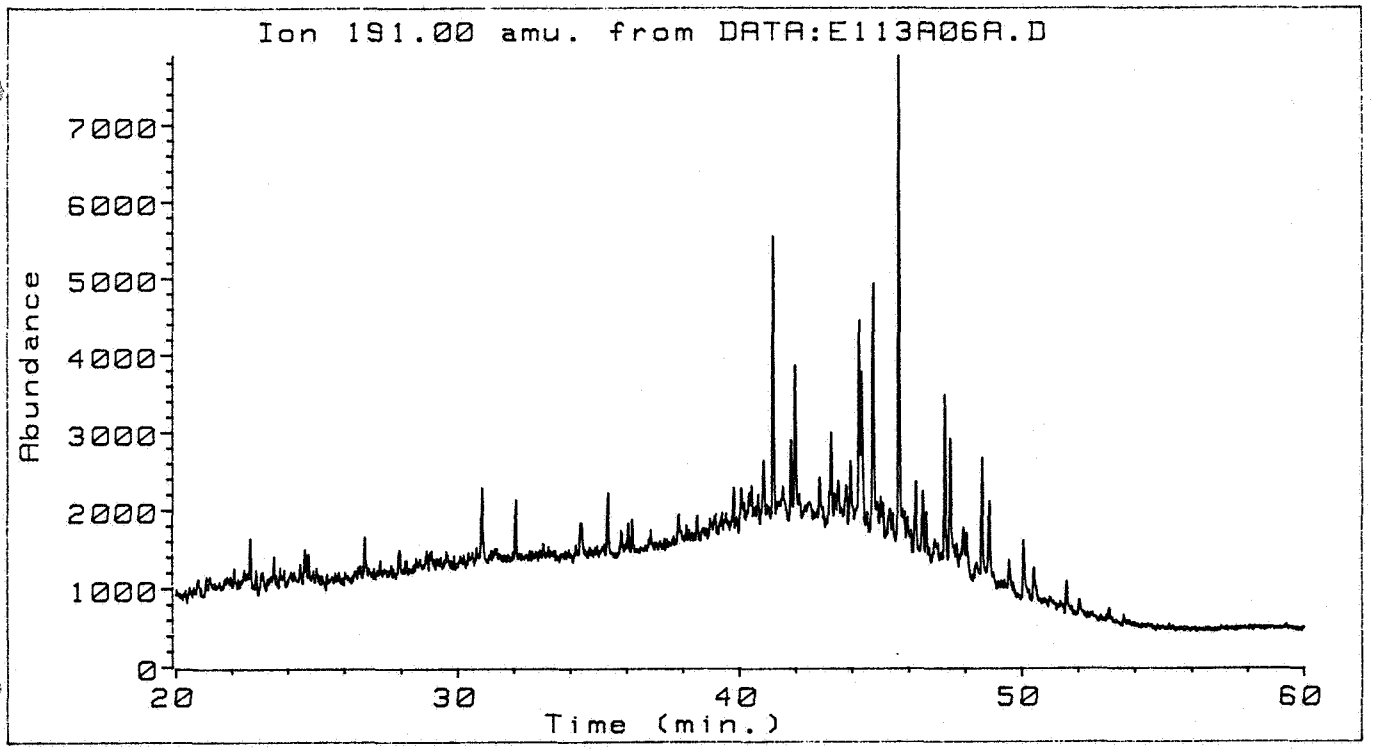
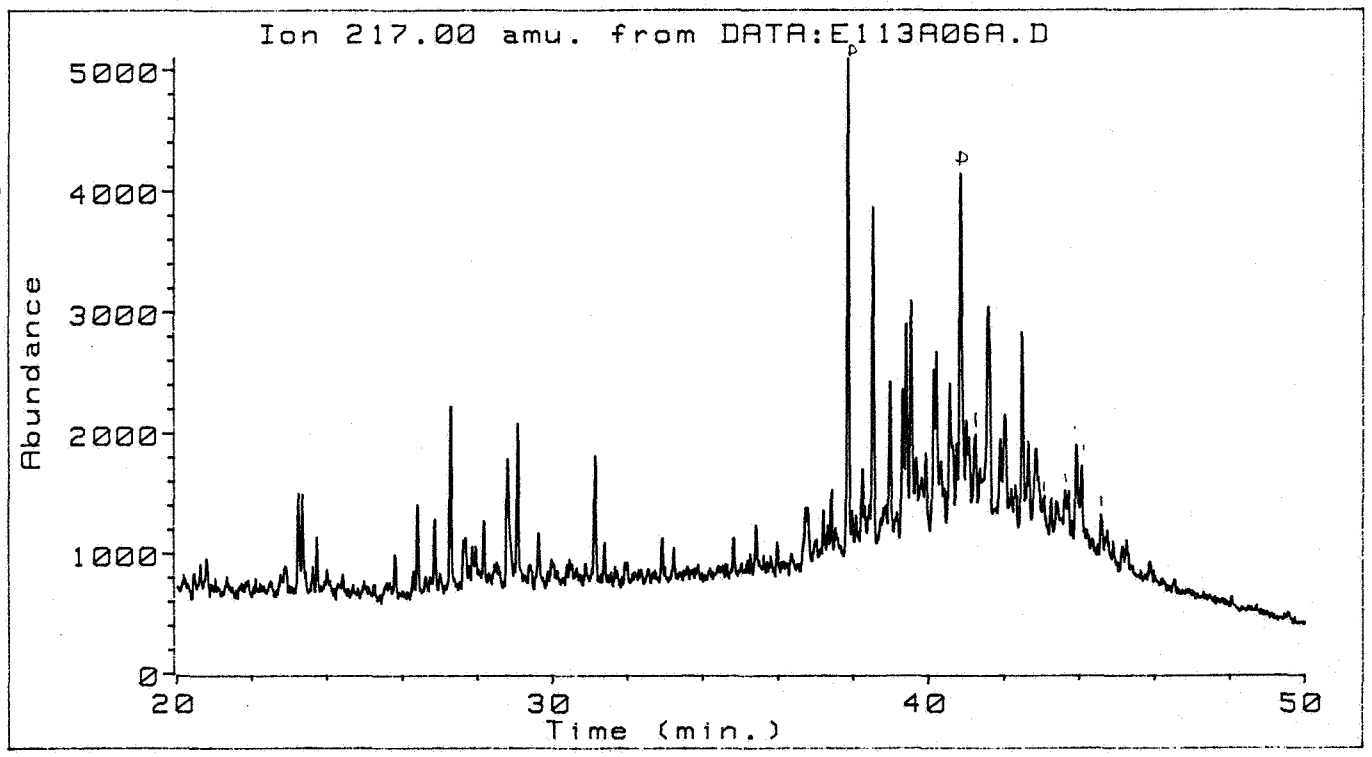


6407/7-5

3177 m



6407/7-5

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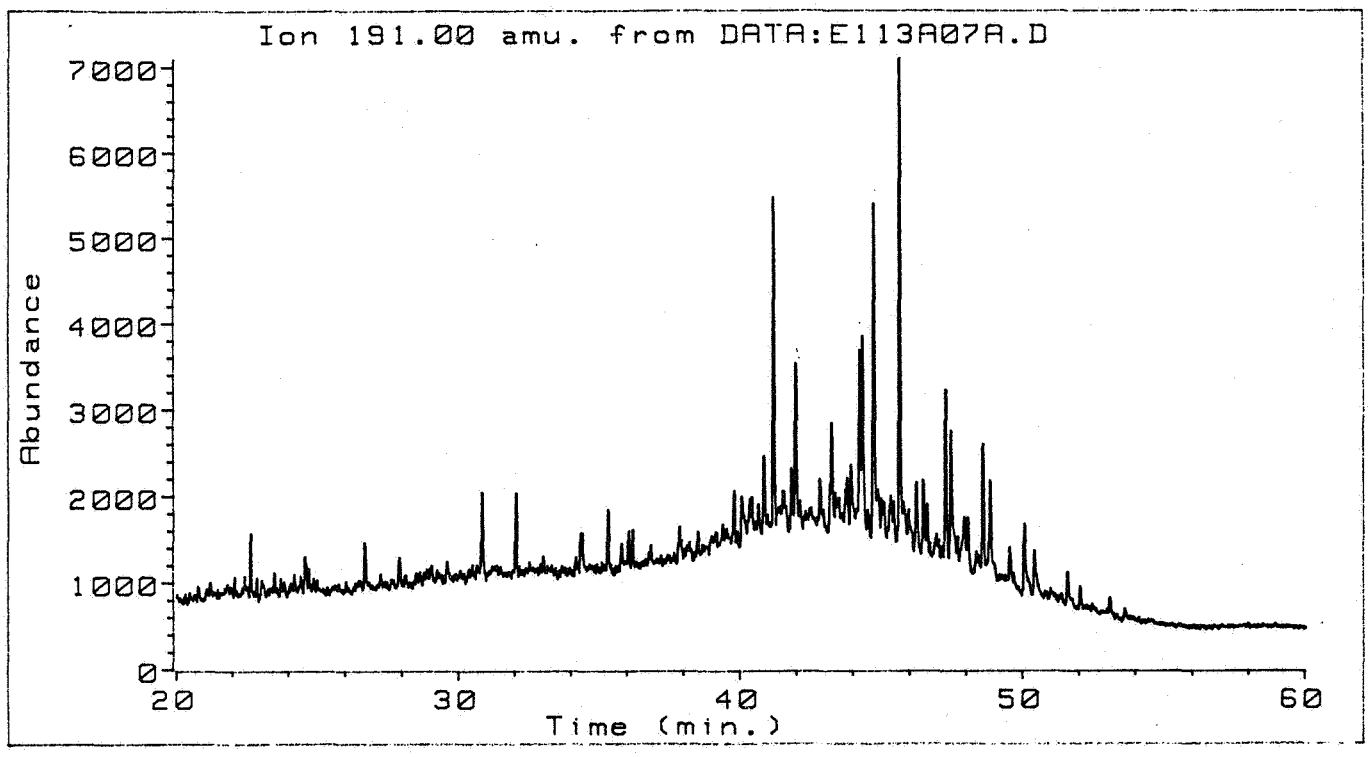

6407/7-5

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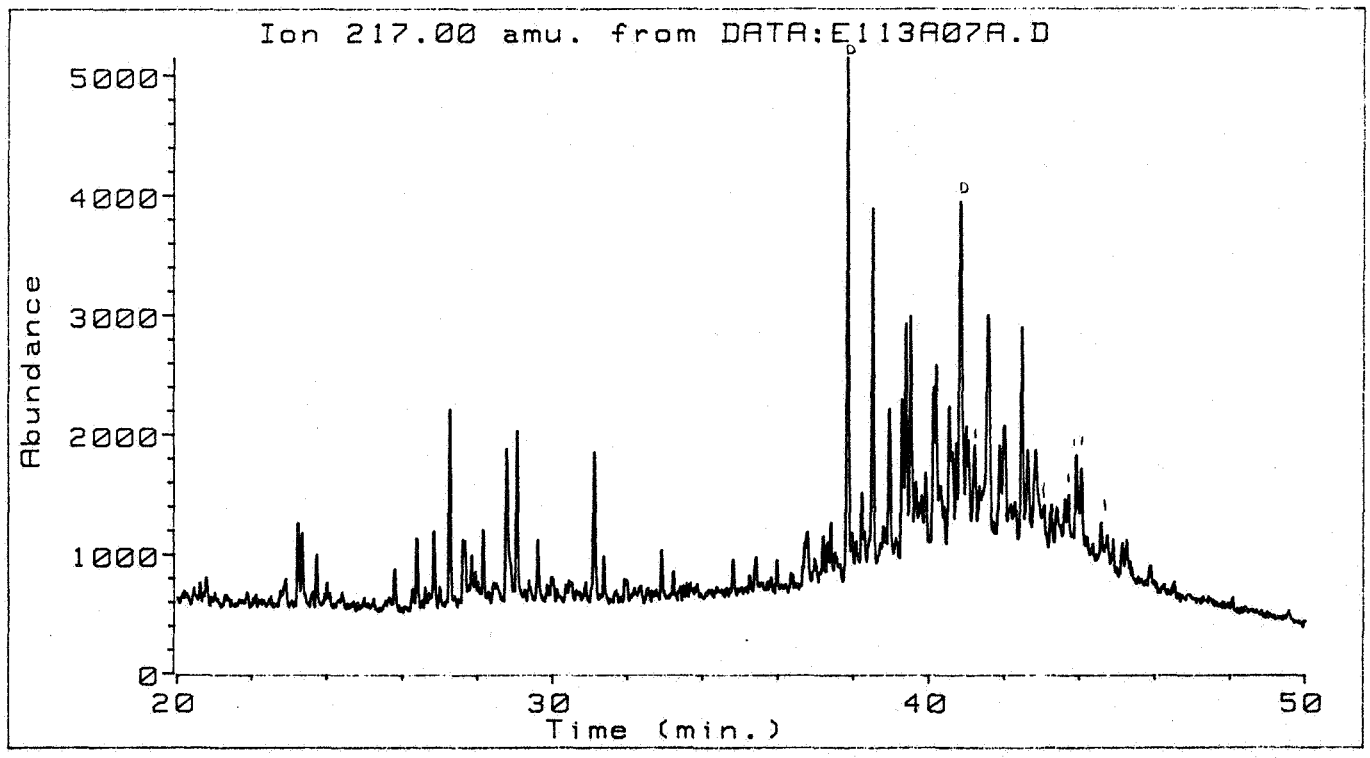

6407/7-5

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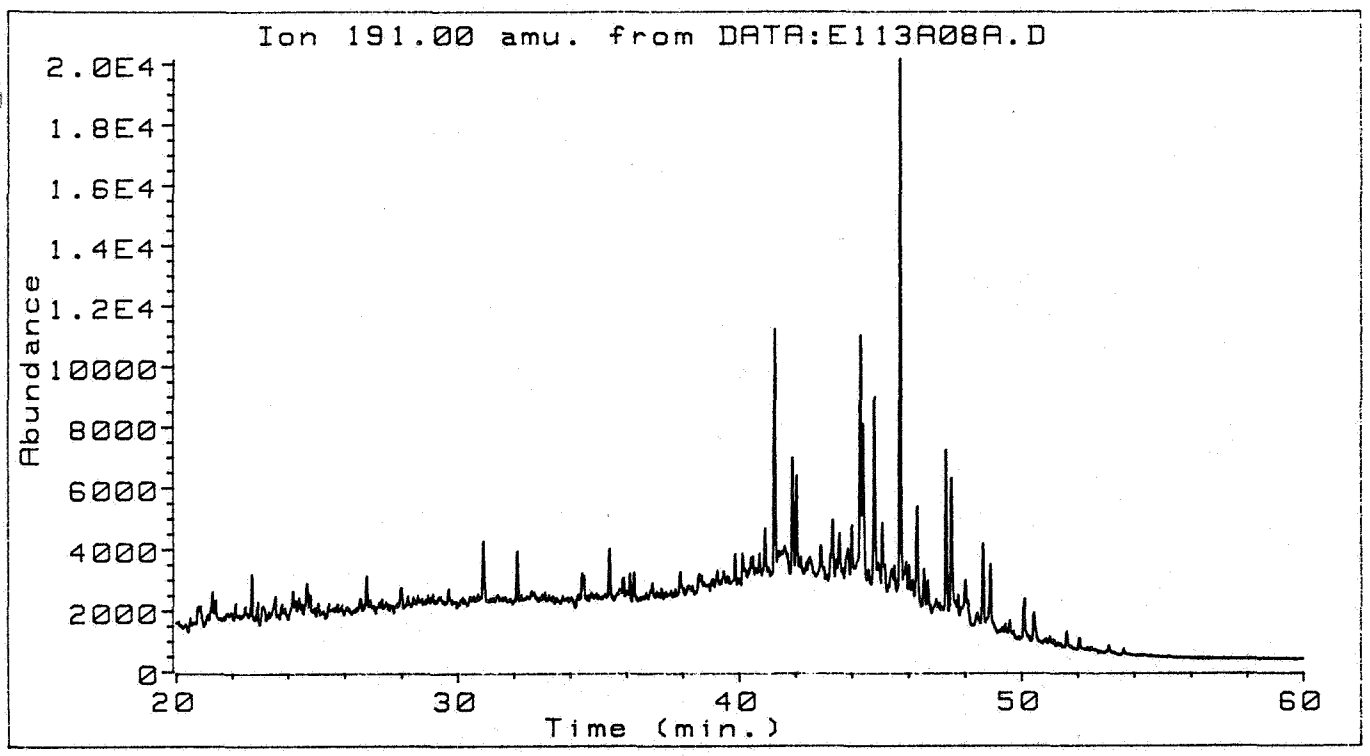

6407/7-5

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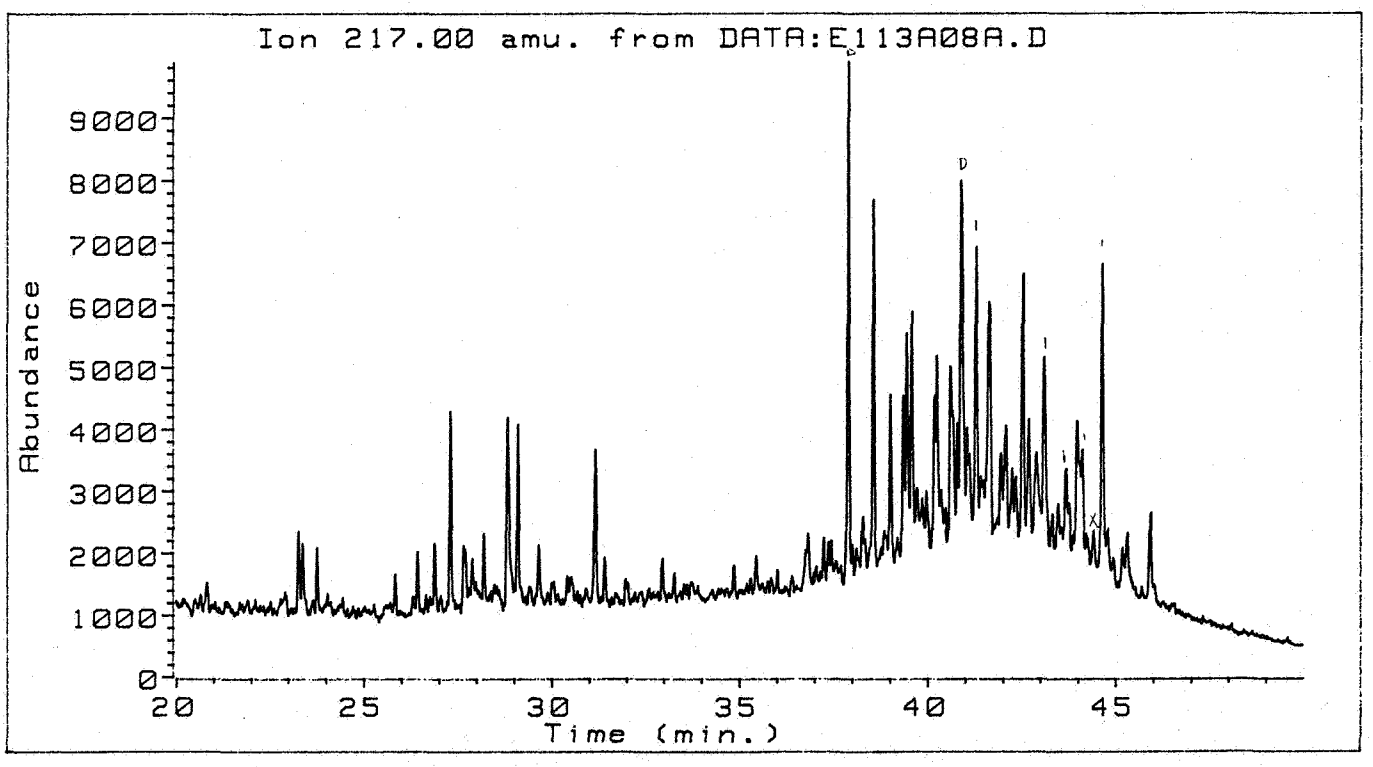

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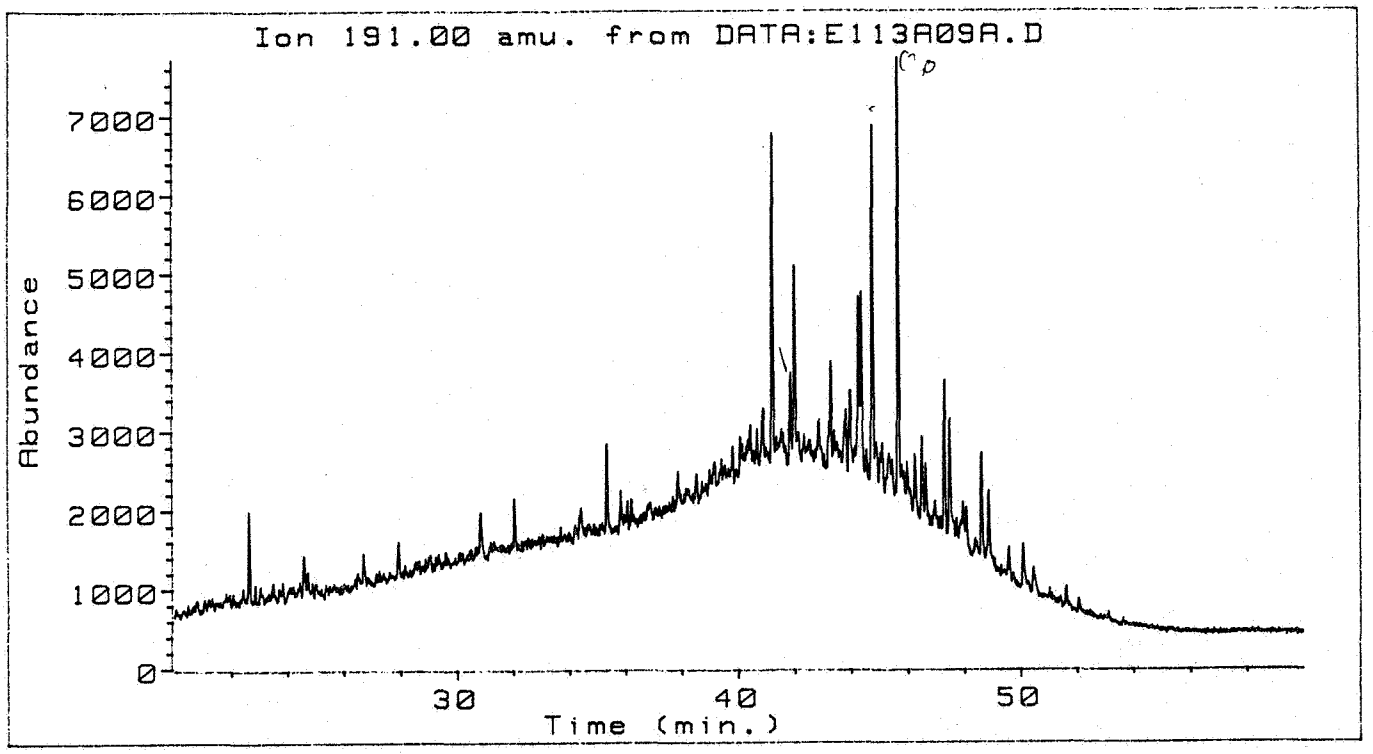
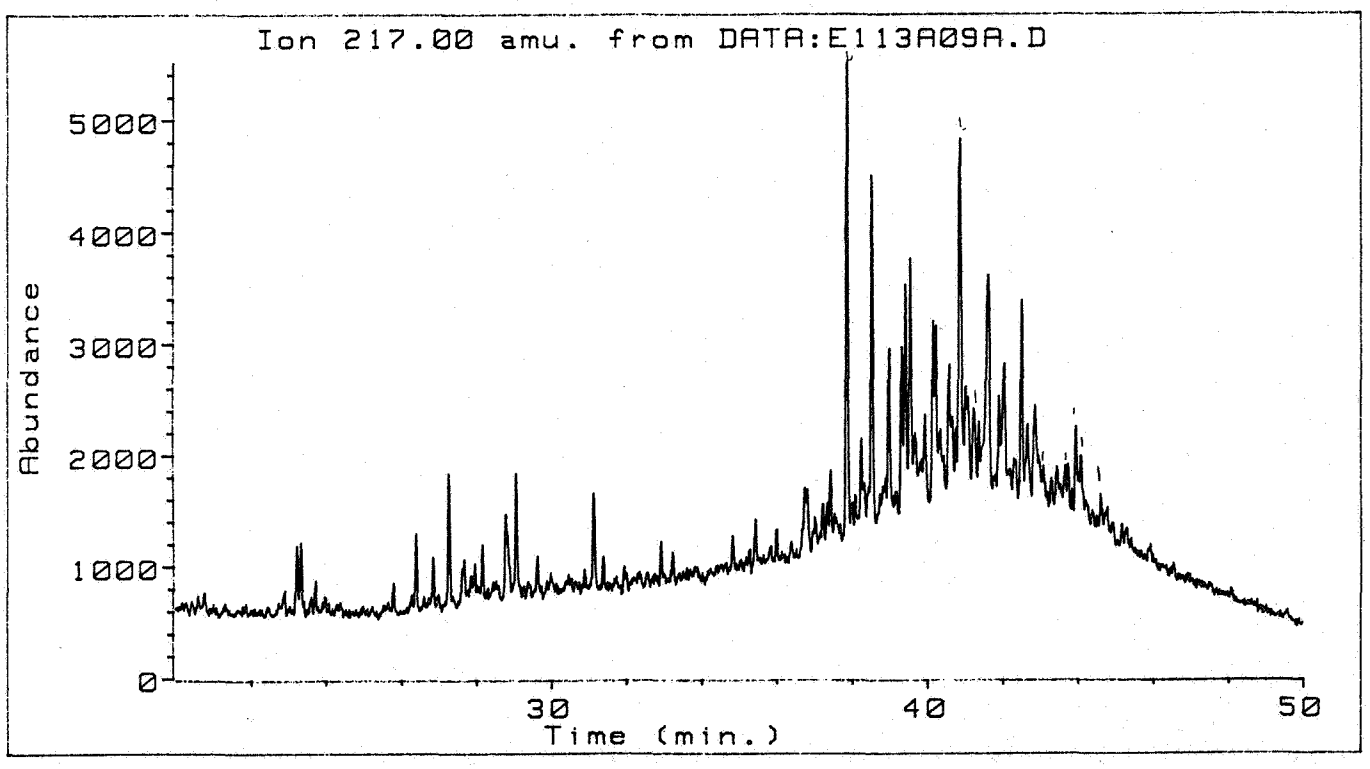


6407/7-5

3431.6 m



6407/7-5

3431.6 m