REPORT TITLE/ TITTEL

Analyses of cores from well 6407/1-2

CLIENT/ OPPDRAGSGIVER

Statoil

RESPONSIBLE SCIENTIST/ PROSJEKTANSVARLIG

Malvin Bjorøy

AUTHORS/ FORFATTERE

Malvin Bjorøy, Peter B. Hall and Torun Vinge

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1.3.83	05.0089	53	

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SUMMARY/ SAMMENDRAG

Ten core samples from well 6407/1-2 were analysed. All the samples contained a light crude oil.

KEY WORDS/ STIKKORD

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CONTENTS

EXPERIMENTAL

Total Organic Carbon (TOC)

Samples were crushed in a centrifugal mill. Aliquots of the samples were then weighed into Leco crucibles and treated with hot 2N HCl to remove carbonate and washed twice with distilled water to remove traces of HCl. The crucibles were then placed in a vacuum oven at 50°C and evacuated to 20 mm Hg for 12 hrs. The samples were then analysed on a Leco E C 12 carbon analyser, to determine the total organic carbon (TOC).

The results are shown in table 5 with the lithological description.

Rock-Eval Pyrolysis

100 mg crushed sample was put into a platinum crucible whose bottom and cover are made of sintered steel and analysed on a Rock-Eval pyrolyser. The results are shown in table 1.

Pyrolysis Gas Chromatography (Py-GC)

Thermoextraction.

20-30 mg of whole rock sample was placed in a boat shaped sample probe and thermoextracted in a stream of helium at 300°C for 5 minutes.

Py-GC

20-30 mg of thermoextracted whole rock sample was programmed pyrolysed in helium (260°C to 520°C at 35°C/min.) in a furnace type pyrolyzer. The outlet of the pyrolyzer was directly connected to a splitter (30:1) and a fused silica capillary column. The pyrolysis product was trapped in a cooled (liq. Nitrogen) U-shaped section at the front of the column.

The outlet of the splitter was directly connected to a FID detector and the course of the pyrolysis could be followed by the detector response of the bulk pyrolysis product (30:1) which was recorded as a

broad peak. At the end of the pyrolysis the pyrolysis product was injected on to the capillary column at ambient temperature (by removing the nitrogen bath) and analysed under the GC conditions given below.

GC-conditions

Column: 25m OV-1, I.D. 0.3 mm, fused silica capillary column.
Carrier gas: Helium with inlet pressure 10 psi. Flow; ca. 1.5. ml/min.
Oven programme: 40^{o} - 270^{o}C at 4^{o}C/min.

Extractable Organic Matter (EOM)

From the TOC results samples were selected for extraction. Of the selected samples, approximately 100 gm of each was extracted in a flow through system (Radke et al,, 1978, Anal. Chem. 49, 663-665) for 10 min. using dichloromethane (DCM) as solvent. The DCM used as solvent was distilled in an all glass apparatus to remove contaminants.

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

After extraction, the solvent was removed on a Buchi Rotavapor and transferred to a 50 ml flask. The rest of the solvent was then removed and the amount of extractable organic matter (EOM) determined.

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 glassvials and dried in a stream of nitrogen. The various results are given in tables 2-4.

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Gas Chromatographic Analyses

The saturated and aromatic hydrocarbon fractions were each diluted with n-hexane and analysed on a HP 5730 A gas chromatograph, fitted with a 25 m OV101 glass capillary column and an automatic injection system. Hydrogen (0.7 ml/min.) was used as carrier gas and the injection was performed in the split mode (1:20).

RESULTS AND DISCUSSION

Rock-Eval Pyrolysis

Quick screening analysis of the ten core samples was performed by pyrolysing aliquots of the samples on a Rock-Eval II instrument. Since these are reservoir samples, ordinary parameters from Rock-Eval pyrolysis such as hydrogen and oxygen indices are meaningless, and we will discuss the non normalised values. The results are shown in Table 1.

The Rock-Eval data shows a slightly decreasing trend with increasing depth down to 3671.9m. The samples between 3676.5 and 3780.5m show very variable values. This could be due to the porosity/permeability of the samples analysed. All of the samples contain free hydrocarbons. None of the samples have a large S_2 peak, indicating that if there are any kerogen or asphalthenes in the samples, these will only give a minor contribution.

Thermal Evaporation with Capillary GC Analysis, and Pyrolysis GC

This method is not a quantitative method, but qualitative. It gives a gas chromatographic picture of the free hydrocarbons in the sample released during heating (at $300^{o}C$-S_1) and the hydrocarbons produced by pyrolysis of the kerogen, if there are any (S_2).

The samples in this study can be placed in two major categories (A and B) and one intermediate group (category C). Category A includes those with a large unresolved envelope in the high molecular weight area, and an abundance of nC_{26}-nC_{30} n-alkanes, and category B comprises those samples which do not have this unusual feature.

Category A; Samples from 3661.4m, 3664.85m, 3676.5m, 3683.65m, 3688.5m and 3692.45m belong in this group. These have a good abundance of C_{10}-C_{25} n-alkanes, indicating a relatively light oil. The pristane/nC_{17} ratio is high while the pristane/phytane ratio is low when compared to a large proportion of oils found in the North Sea. The loss of n-alkanes below nC_{10} is due to the permeability of the cores, the light hydrocar-

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TABLE 1.

R O C K E V A L P Y R O L Y S E S

IKU No.	DEPTH m/ft	S1	S2	S3	TOC (%)	HYDR. INDEX	OXYGEN INDEX	OIL OF GAS CONTENT S1+S2	PROD. INDEX S1/(S1+S2)	TEMP. MAX (C)
A 3129	3661.40	2.83	0.18	0.11	0.06	300	183	3.01	0.94	413
A 3130	3664.85	2.44	0.18	0.12	0.26	69	46	2.62	0.93	407
A 3131	3671.90	2.15	0.27	0.08	0.23	117	35	2.42	0.89	412
A 3132	3676.50	3.12	0.24	0.13	0.25	96	52	3.36	0.93	407
A 3133	3680.10	1.88	0.18	0.09	0.18	100	50	2.06	0.91	410
A 3134	3683.65	0.93	0.29	0.03	0.20	145	15	1.21	0.76	411
A 3135	3688.50	4.06	0.37	0.15	0.10	370	150	4.43	0.92	399
A 3136	3692.45	2.02	0.27	0.10	0.17	159	59	2.29	0.88	415
A 3137	3696.90	2.63	0.39	0.08	0.24	162	33	3.02	0.87	412
A 3138	3700.00	2.09	0.24	0.12	0.24	100	50	2.33	0.90	405

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bons evaporate when the core is brought up to the rig. The gas chromatograms show a large unresolved envelope and an increase in the n-alkane distribution above nC_{25}. This could be due to some residues such as asphalthenes etc. which start to crack and give off hydrocarbons at 300°C.

Category B; The two most typical samples for this category, which have a smooth n-alkane distribution and no unresolved envelope are 3671.9m and 3700m. The front part of the gas chromatograms is similar to that found for the samples from category A, while there is no unresolved envelope and no increase in the n-alkane distribution above nC_{25}. This indicates that these samples do not contain any material which decomposes at 300°C, producing hydrocarbons.

Category C; (Intermediate between A and B). Two samples, 3680.10m and 3696.90m have similar front-end distributions to the other samples but with an increase in n-alkanes from nC_{20} and without the unresolved envelope. These two samples have a smaller pristane/phytane ratio than the other samples. The sample from 3680.10m has a far stronger front-end distribution than the rest of the samples.

The pyrolysis gc patterns of the organic remains vary only slightly for the ten core samples. All the samples have a small methane peak and small amounts of hydrocarbons up to nC_{25} together with an unresolved envelope and large single peaks in the nC_{25}-nC_{30} range, (this is similar to the distribution found for category A, in the thermal extraction analysis). The amounts vary from sample to sample, but the feature is quite distinguishable in all samples.

The samples from category B, (as defined by the thermal evaporation) also have large unresolved envelopes for the pyrolysis gc's, indicating that this phenomena is present in all the samples although it is not seen in some when thermal evaporation is performed.

Extraction and Chromatographic Separation

Extraction of the samples indicates that down to 3676.5m there is a general increase of extractable hydrocarbons with increasing depth. The samples from 3680.1m and 3683.65m have a low abundance of extract-

able hydrocarbons while the sample from 3688.5m has the highest abundance of all the analysed samples. The extractability decreases for the sample from 3692.45m compared with the sample above, then to return to increasing slightly with increasing depth. The abundance of extractable organic material follows the same trends as the abundance of extractable hydrocarbons. This data indicates that the reservoir down to approximately 3676.5m has a high abundance of extractable organic matter with a large percentage of hydrocarbons, probably reflecting good porosity/permeability for the section. The samples from 3680.10-3683.65m have a far lower extractability. This could be due to lighter, less permeable sediment. The samples just below have far higher extractability and higher percentage of hydrocarbons than any other samples indicating a build up of hydrocarbon just below the "seal". The lower part of the analysed section (3692.45-3700m) is similar to the upper part. The extraction results are shown in tables 2-4.

Saturated Hydrocarbons

The gas chromatograms of the saturated hydrocarbon fractions vary only slightly for the analysed samples. All the gc's show a front-biased, smooth n-alkane distribution with moderate pristane/nC_{17} ratios and higher pristane/phytane ratios. The pristane/phytane ratios are higher than those normally found in the North Sea.

Aromatic Hydrocarbons

The aromatic hydrocarbon distribution in these samples is dominated by C_1-naphthalenes (A) and C_2-naphthalenes (B). Other prominent compounds include Napthalene (N) C_3-naphthalenes (C), phenanthrene P, C,- and C_2-phenanthrene (D and E). The peaks marked with an asterisk mark the location of organic sulphur compounds. This distribution is typical for light-medium gravity oils probably with no alteration from biodegradation or water washing (probably derived from type II or mixed type II/III kerogen).

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T A B L E : 2.

CONCENTRATION OF EOM AND CHROMATOGRAPHIC FRACTIONS

IKU-No	DEPTH (m)	Rock Extr. (g)	EOM (mg)	Sat. (mg)	Aro. (mg)	HC (mg)	Non HC (mg)	TOC (%)
A 3129	3661.40	53.5	248.6	128.5	45.3	173.8	74.8	0.23
A 3130	3664.85	50.6	230.4	116.8	27.1	143.9	86.5	0.27
A 3131	3671.90	52.8	233.0	116.6	66.0	182.6	50.4	0.26
A 3132	3676.50	35.0	196.1	88.8	47.2	136.0	60.1	0.23
A 3133	3680.10	50.9	145.3	77.4	15.5	92.9	52.4	0.09
A 3134	3683.65	43.7	71.0	36.0	18.4	54.4	16.6	0.33
A 3135	3688.50	53.3	361.8	220.2	108.0	328.2	33.6	0.24
A 3136	3692.45	54.8	259.5	120.4	59.5	179.9	79.6	0.33
A 3137	3696.90	52.1	226.5	119.8	59.3	179.1	47.4	0.24
A 3138	3700.00	49.4	315.8	136.3	68.8	205.1	110.7	0.21

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T A B L E : 3.

CONCENTRATION OF EOM AND CHROMATOGRAPHIC FRACTIONS

(mg/g TOC)

IKU-No	DEPTH (m)	EOM	Sat.	Aro.	HC	Non HC
A 3129	3661.40	2018.8	1043.5	367.9	1411.4	607.4
A 3130	3664.85	1687.1	855.3	198.4	1053.7	633.4
A 3131	3671.90	1697.9	849.7	481.0	1330.6	367.3
A 3132	3676.50	2436.0	1103.1	586.3	1689.4	746.6
A 3133	3680.10	3169.9	1688.6	338.2	2026.7	1143.2
A 3134	3683.65	492.1	249.5	127.5	377.1	115.1
A 3135	3688.50	2825.7	1719.8	843.5	2563.3	262.4
A 3136	3692.45	2058.9	955.3	472.1	1427.3	631.5
A 3137	3696.90	1811.4	958.1	474.2	1432.3	379.1
A 3138	3700.00	3046.0	1314.7	663.6	1978.3	1067.7

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T A B L E : 4.

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 3129	3661.40	51.7	18.2	69.9	283.7	30.1	232.4
A 3130	3664.85	50.7	11.8	62.5	431.0	37.5	166.4
A 3131	3671.90	50.0	28.3	78.4	176.7	21.6	362.3
A 3132	3676.50	45.3	24.1	69.4	188.1	30.6	226.3
A 3133	3680.10	53.3	10.7	63.9	499.4	36.1	177.3
A 3134	3683.65	50.7	25.9	76.6	195.7	23.4	327.7
A 3135	3688.50	60.9	29.9	90.7	203.9	9.3	976.8
A 3136	3692.45	46.4	22.9	69.3	202.4	30.7	226.0
A 3137	3696.90	52.9	26.2	79.1	202.0	20.9	377.8
A 3138	3700.00	43.2	21.8	64.9	198.1	35.1	185.3

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Lithology and Total Organic Carbon measurements

TABLE NO.: 5.
WELL NO.: 6407/1-2

Sample	Depth (m)	TOC	Lithology
A-3129	3661.4	0.23	Sandstone, light brown, fine-medium grained quartz, angular mostly white some brown, micaceous, a residual black bitumen, which is non-fluor - very slight white cut. General (not overall) yellow (bright) - white fluorescence, with overall immediate fair white cut (not streaming). Hard, non calcareous kaolinite?, cemented - silica.
A-3130	3664.85	0.27	Sandstone, as above, more medium grained with micaceous shale laminae (carbonaceous) very pale yellow-white, immediate intense cut, streaming in part, more intense than A-3129.
A-3131	3671.90	0.26	Sandstone, as above, micaceous laminae, extremely hard, less intense cut than A-3130, no shale laminae.
A-3132	3676.50	0.23	Sandstone, light brown, fine-medium grained, hard, general bright yellow fluor, non-micaceous, immediate intense white cut. Quartz cement, little bitumen, clean sand with subangular grains to sub rounded in part.
A-3133	3680.10	0.09	Sandstone, darker brown some mica laminae again similar to A-3129, silty in part, distinct oil staining, cut as A-3132.

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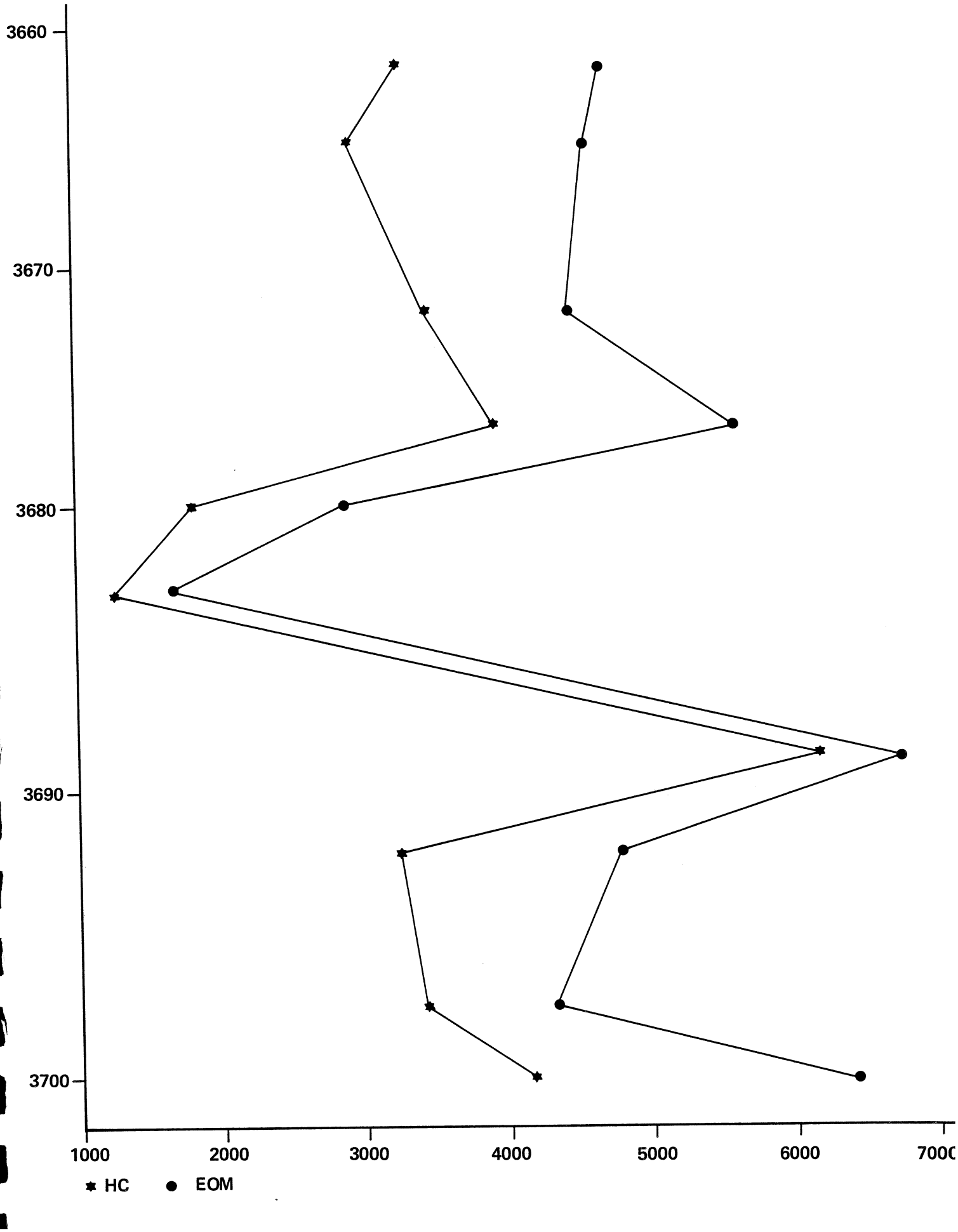
Lithology and Total Organic Carbon measurements

TABLE NO.: 5.
WELL NO.: 6407/1-2

Sample	Depth (m)	TOC	Lithology
A-3134	3683.65	0.33	Sandstone, darker brown as above thick mica laminae, cut as A-3132.
A-3135	3688.50	0.24	Sandstone, medium grained - some coarse quartz, little mica, lighter brown, slightly more brittle, oil stained clearly, fluor bright yellow, immediate intense white cut.
A-3136	3692.45	0.23	Fine-medium grained generally as above, (A-3135) white cut/fluor intens yellow.
A-3147	3696.90	0.24	Medium-coarse grained, hard, otherwise as above. Yellow fluor is darker yellow hue. There is less cut.
A-3138	3700.00	0.21	As above medium grained, fairly brittle, immediate intense (streaming in part) white cut.

Distribution of EOM and EHC with depth.

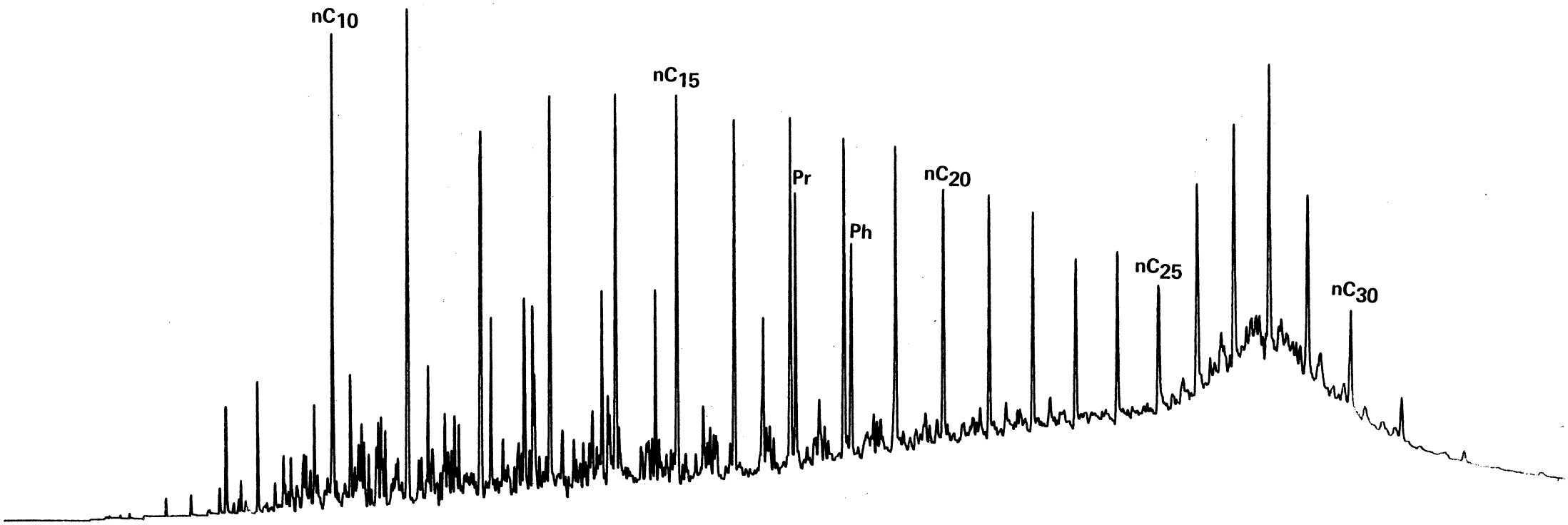


CONCLUSIONS

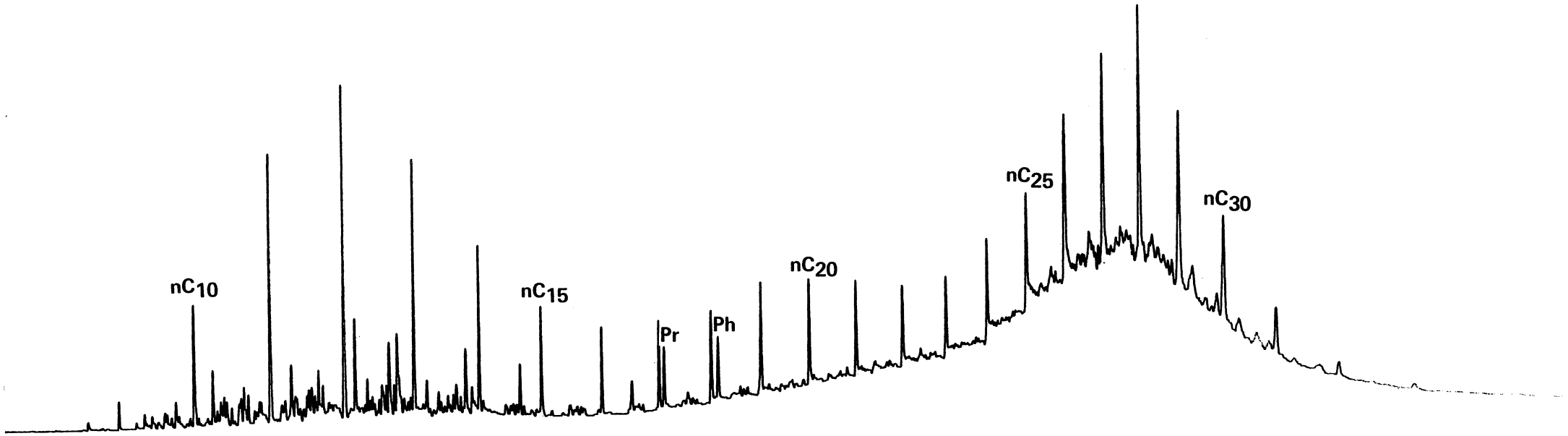
All ten samples from well 6407/1-2 contained free hydrocarbons, indicating that the samples are from a reservoir with light oil. Variation in abundance of hydrocarbons indicates a strong variation in the permeability of the analysed samples.

Large unresolved envelopes and large abundances of nC_{20}-nC_{30} indicate that there might be significant amounts of asphalthenes/residual oil which decompose at 300^{o}C or higher.

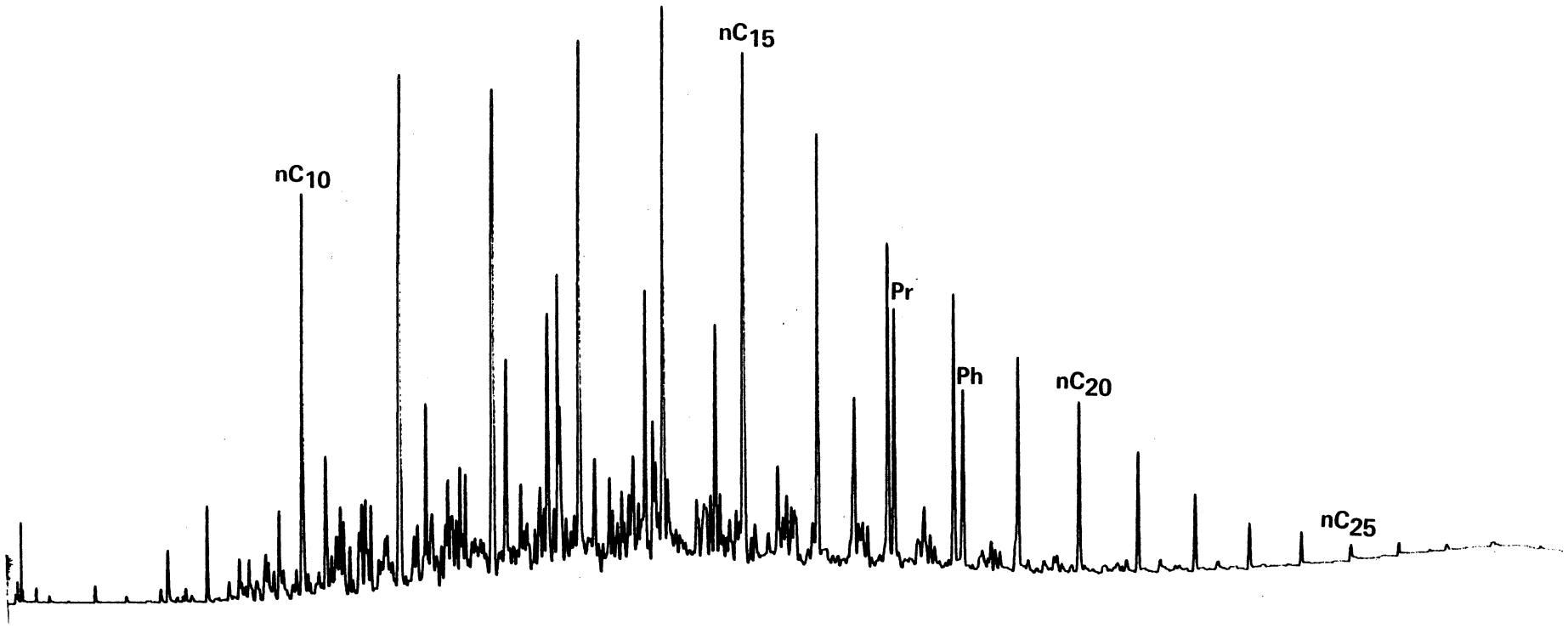
Thermal Evaporation
A - 3129
Core 1
3661.40m



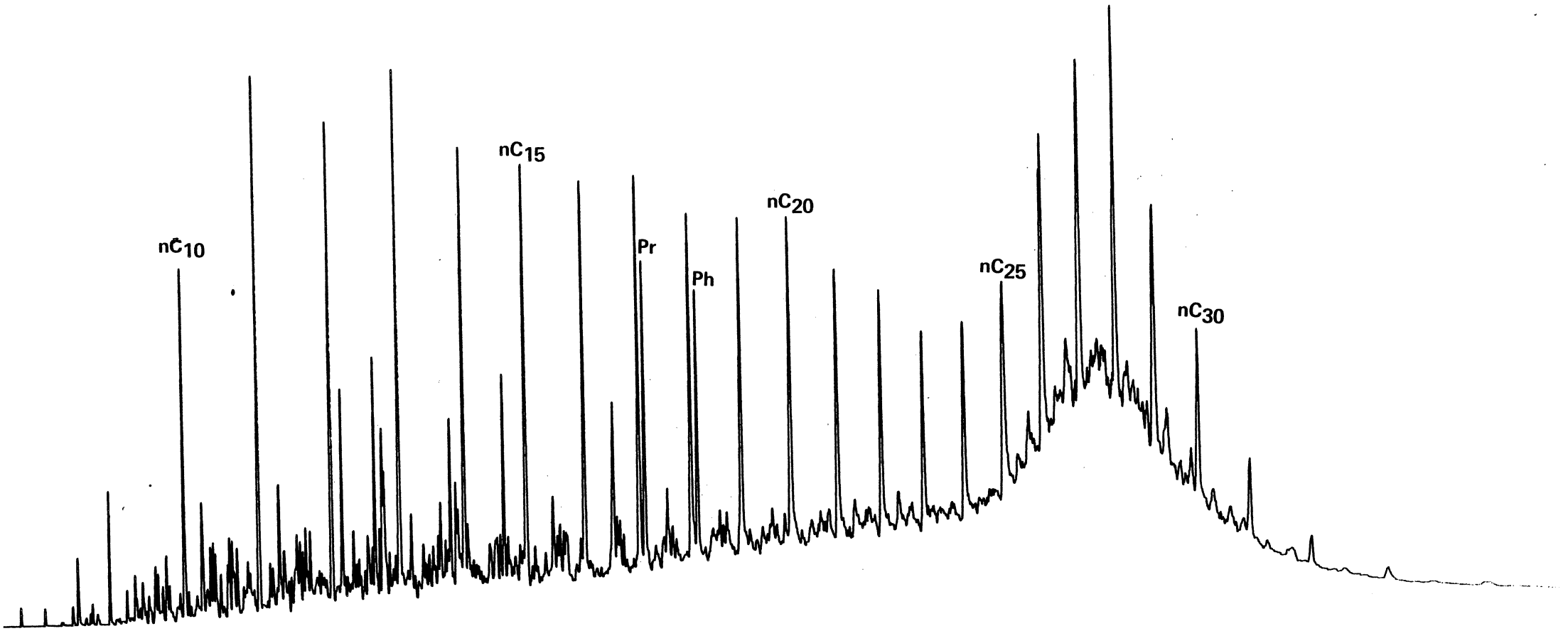
Thermal Evaporation
A - 3130
Core 1
3664.85m



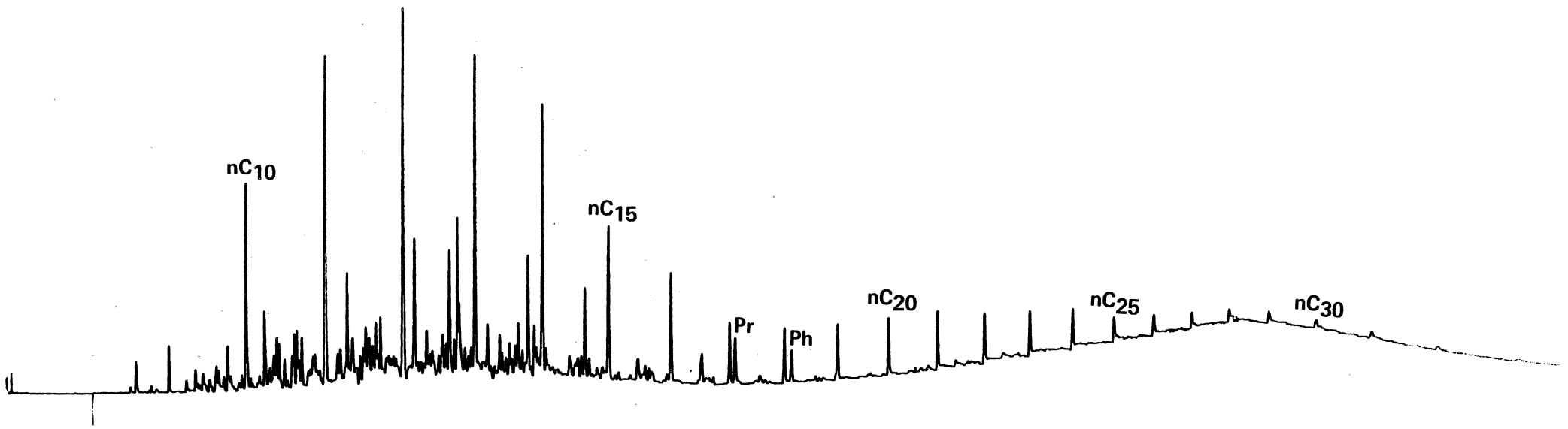
Thermal Evaporation
A - 3131
Core 1
3671.90m

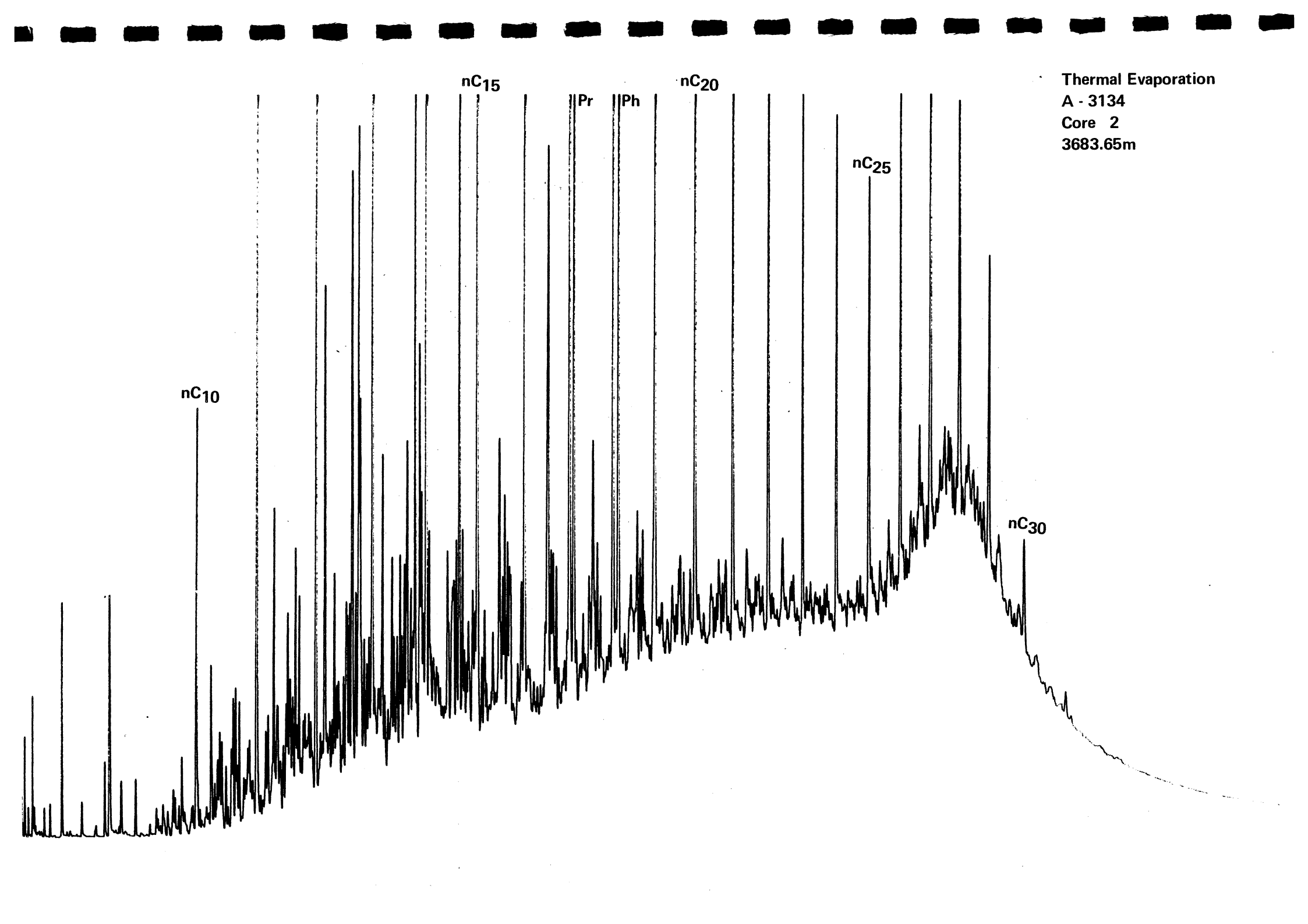


Thermal Evaporation
A - 3132
Core 1
3676.50m

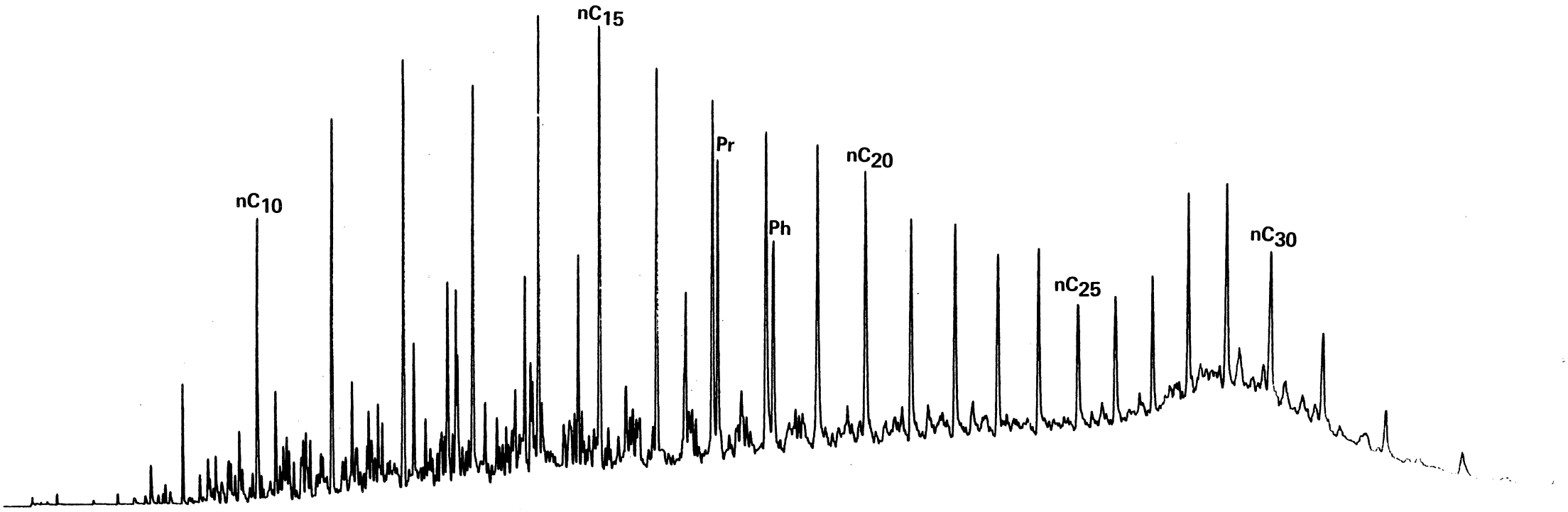


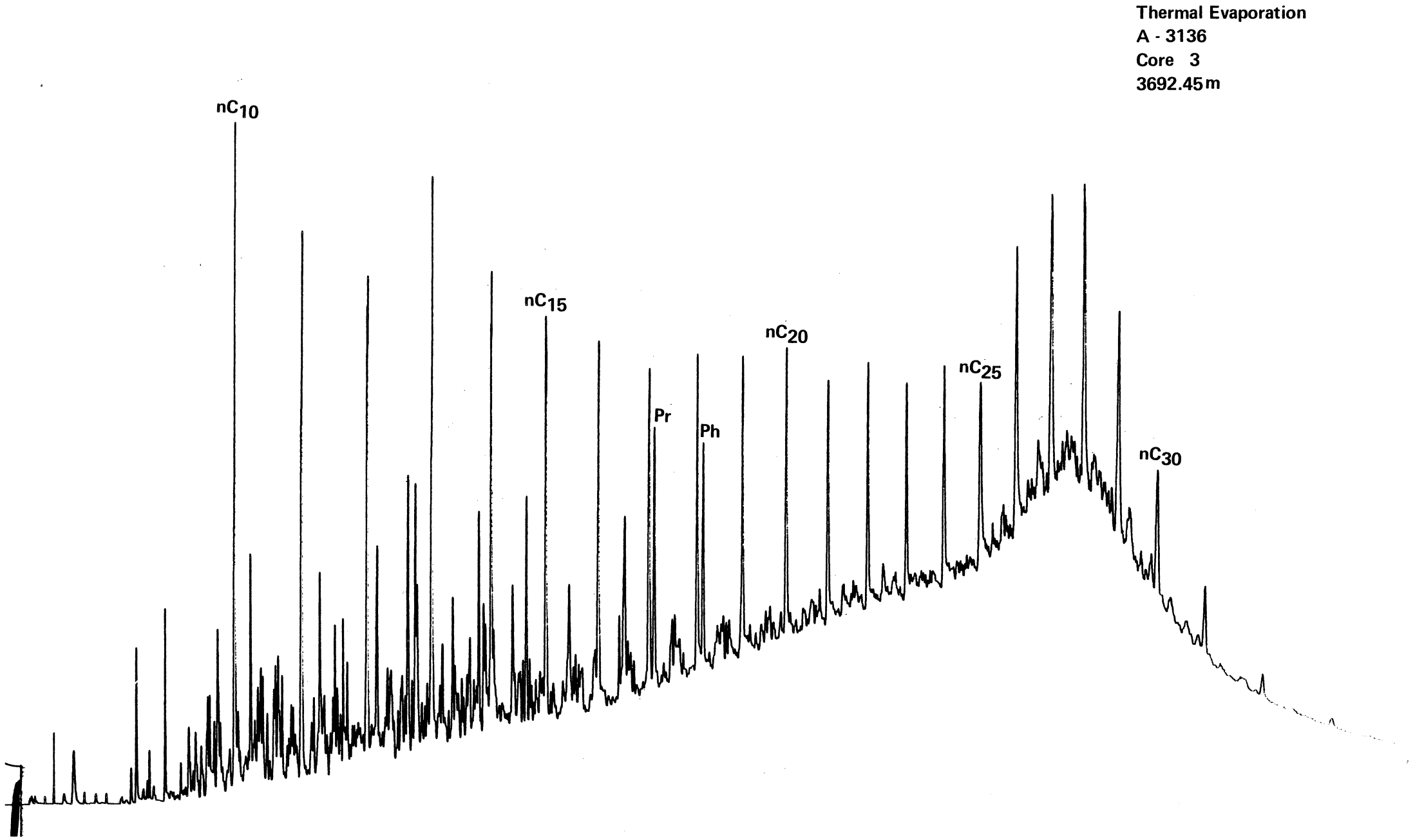
Thermal Evaporation
A - 3133
Core 2
3680.10m



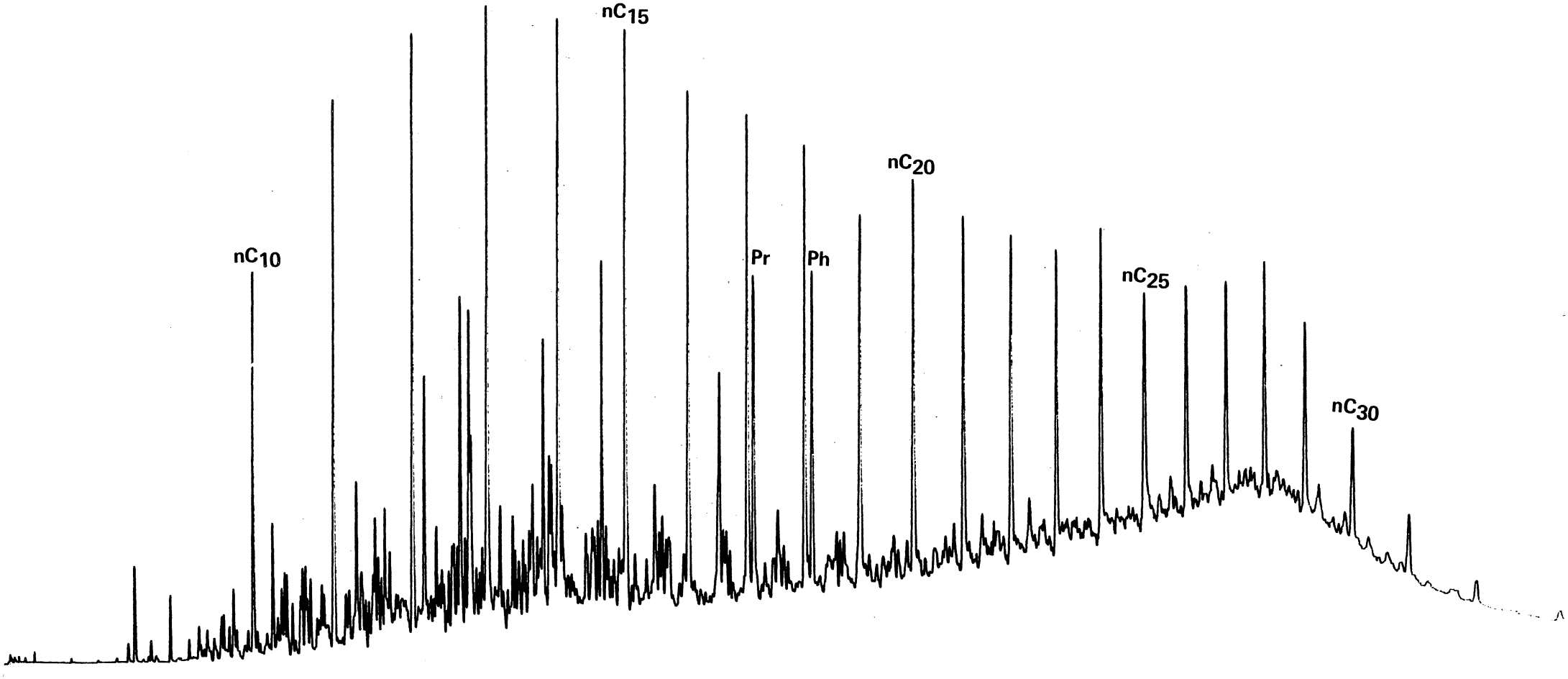

nC15
Pr
Ph
nC20
nC25
nC30
nC10
Thermal Evaporation
A - 3134
Core 2
3683.65m

Thermal Evaporation
A - 3135
Core 2
3688.50m

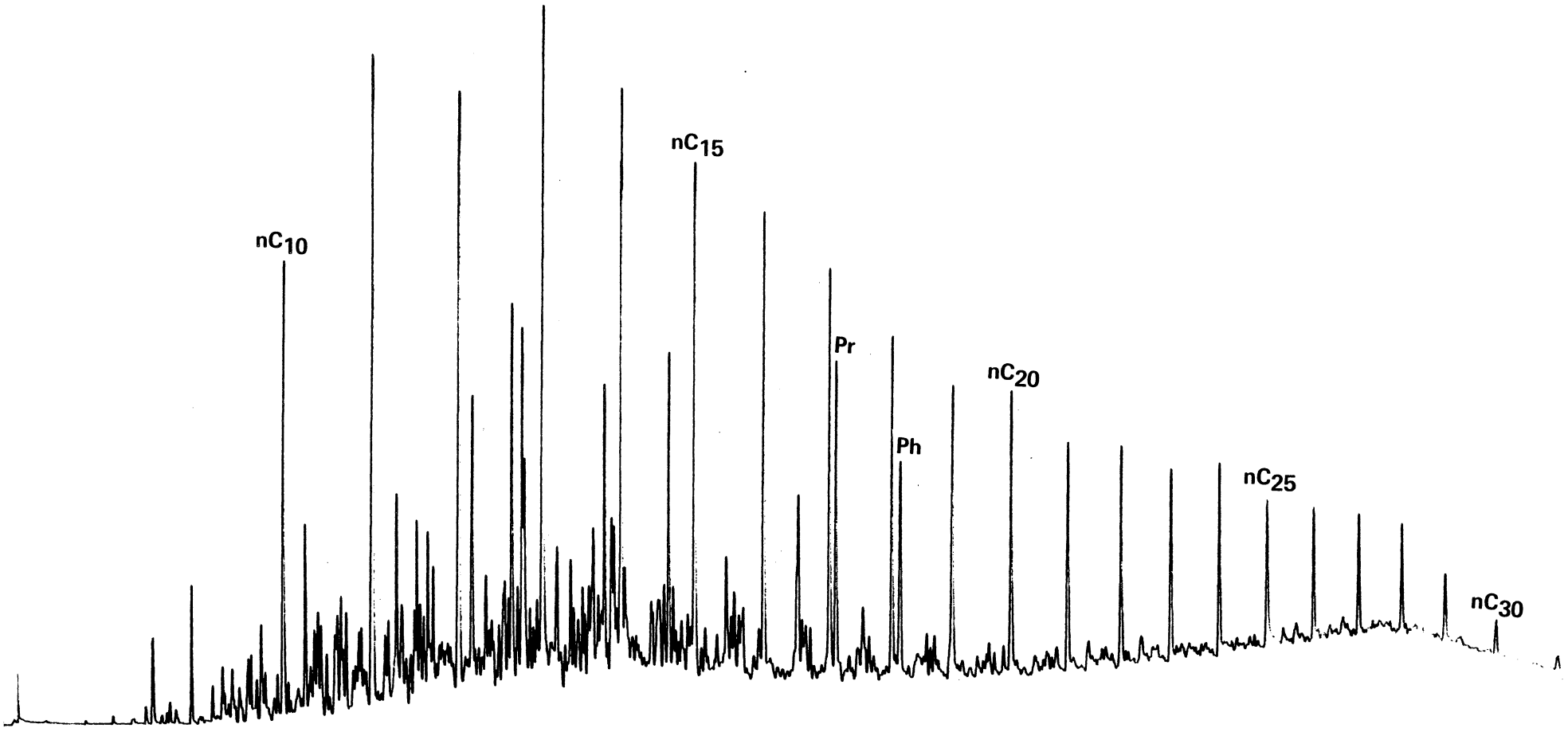



Thermal Evaporation
A - 3136
Core 3
3692.45 m
nC10
nC15
Pr
Ph
nC20
nC25
nC30

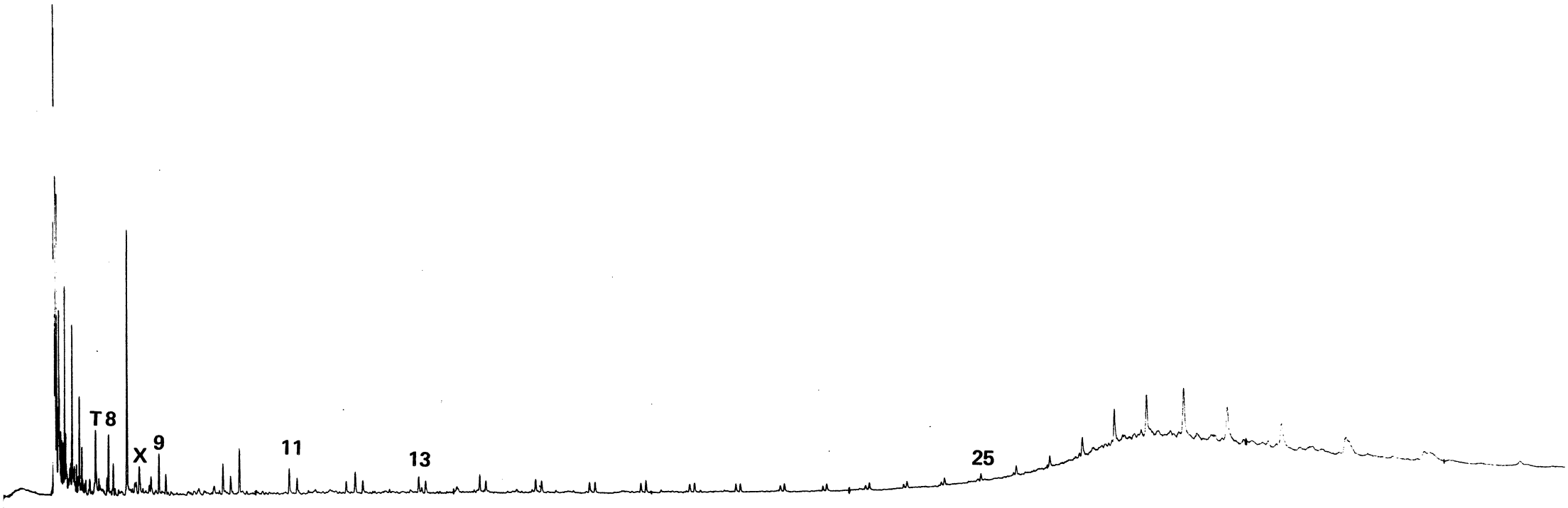
Thermal Evaporation
A - 3137
Core 3
3696.90m

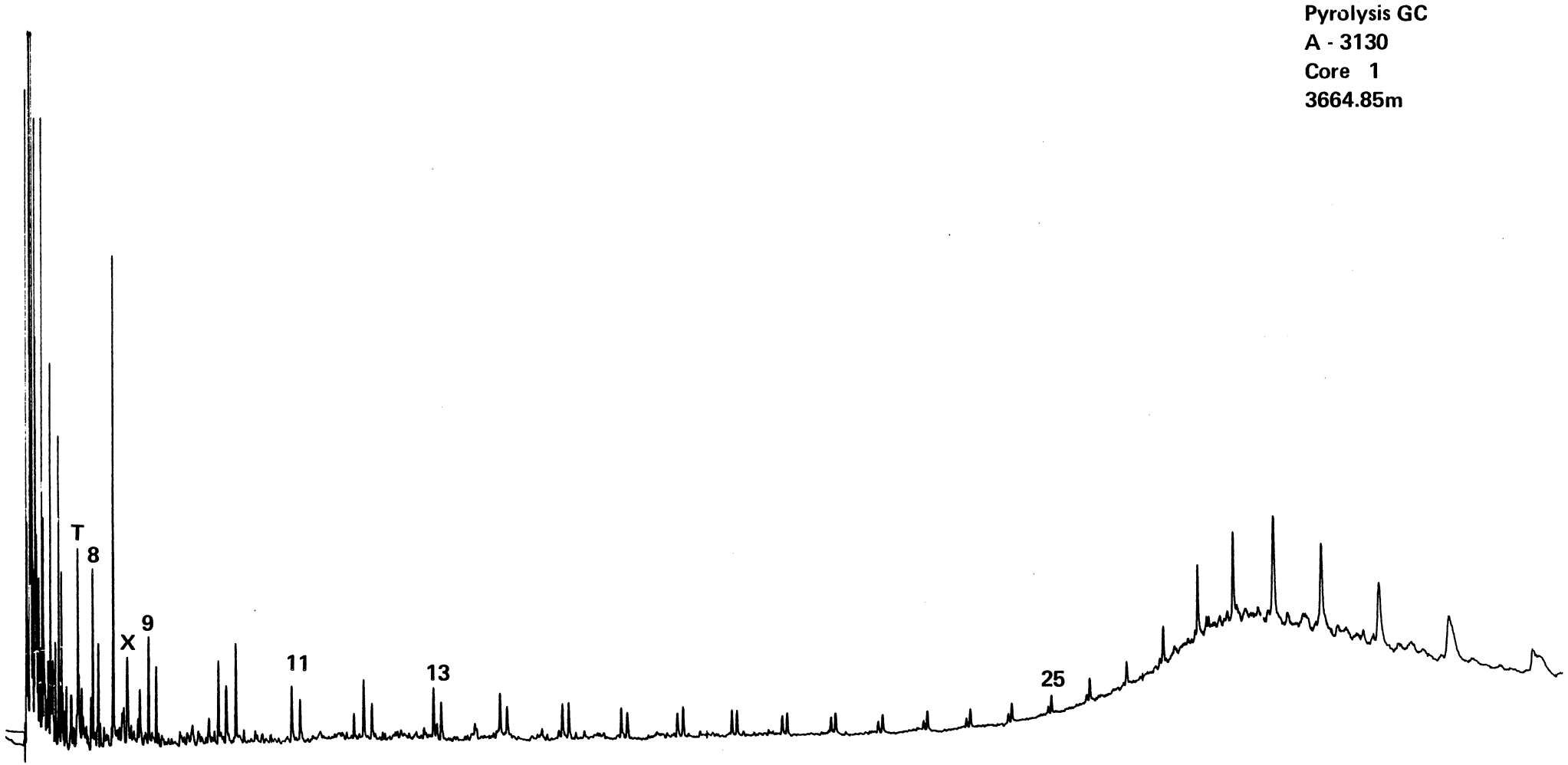


Thermal Evaporation
A - 3138
Core 3
3700.00m

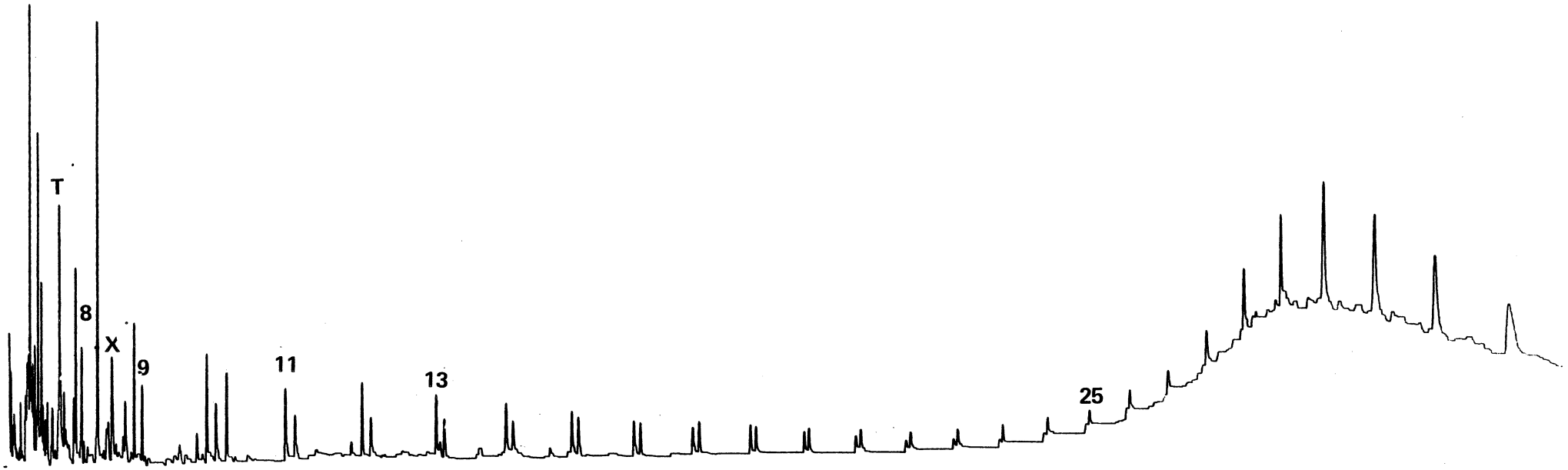


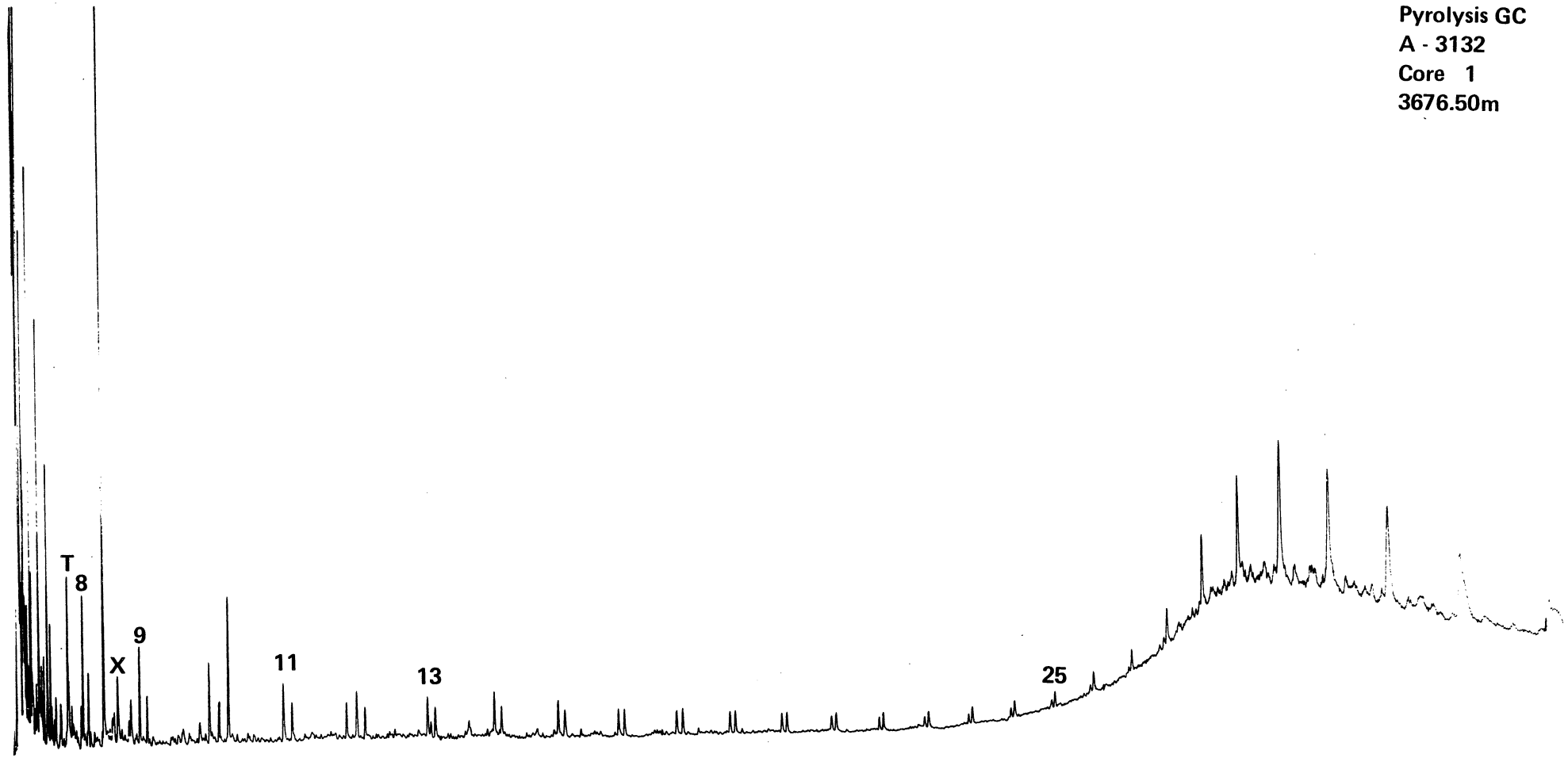
Pyrolysis GC
A - 3129
Core 1
3661.40m

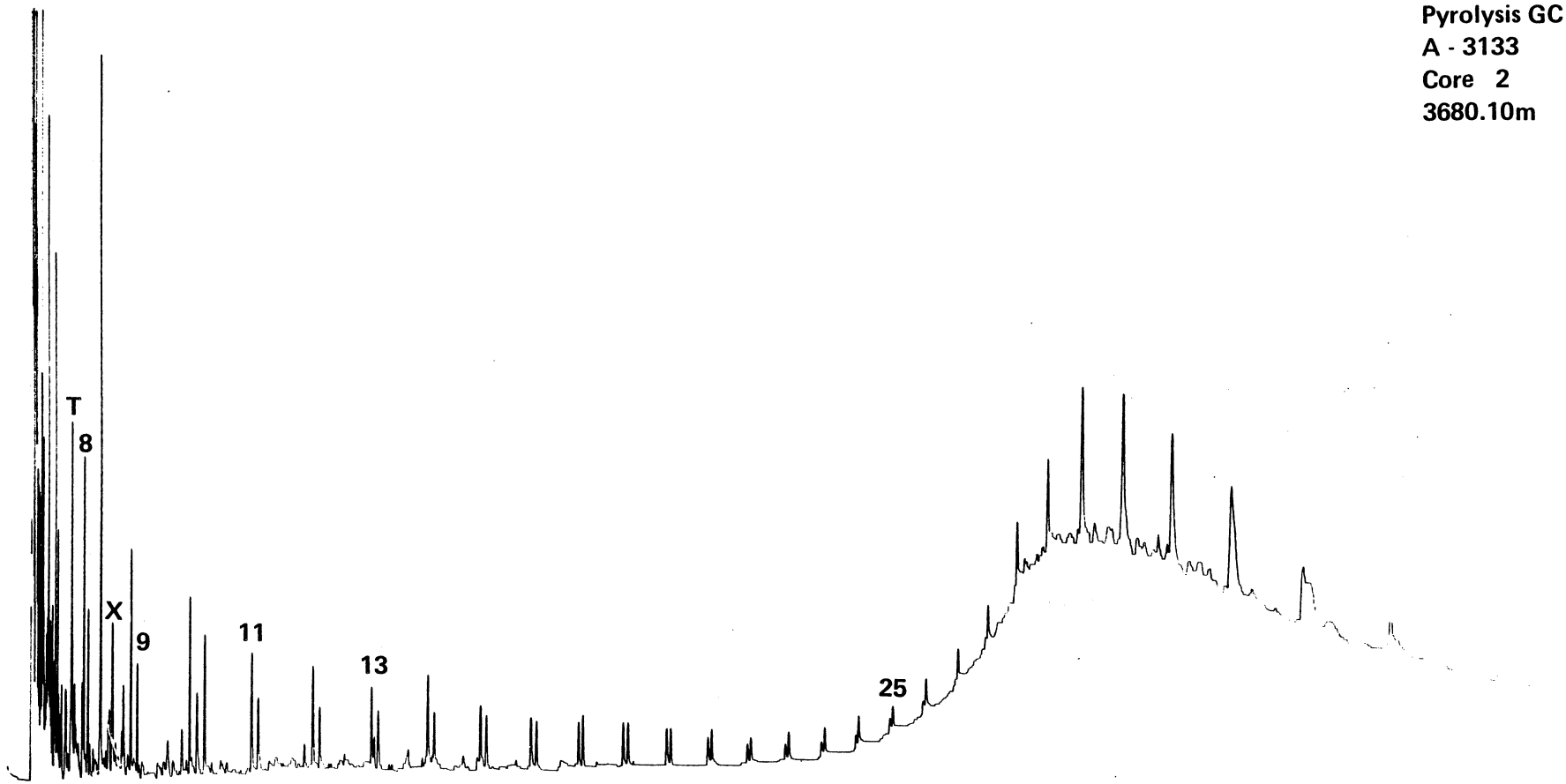



Pyrolysis GC
A - 3130
Core 1
3664.85m
T
8
X
9
11
13
25

Pyrolysis GC
A - 3131
Core 1
3671.90m

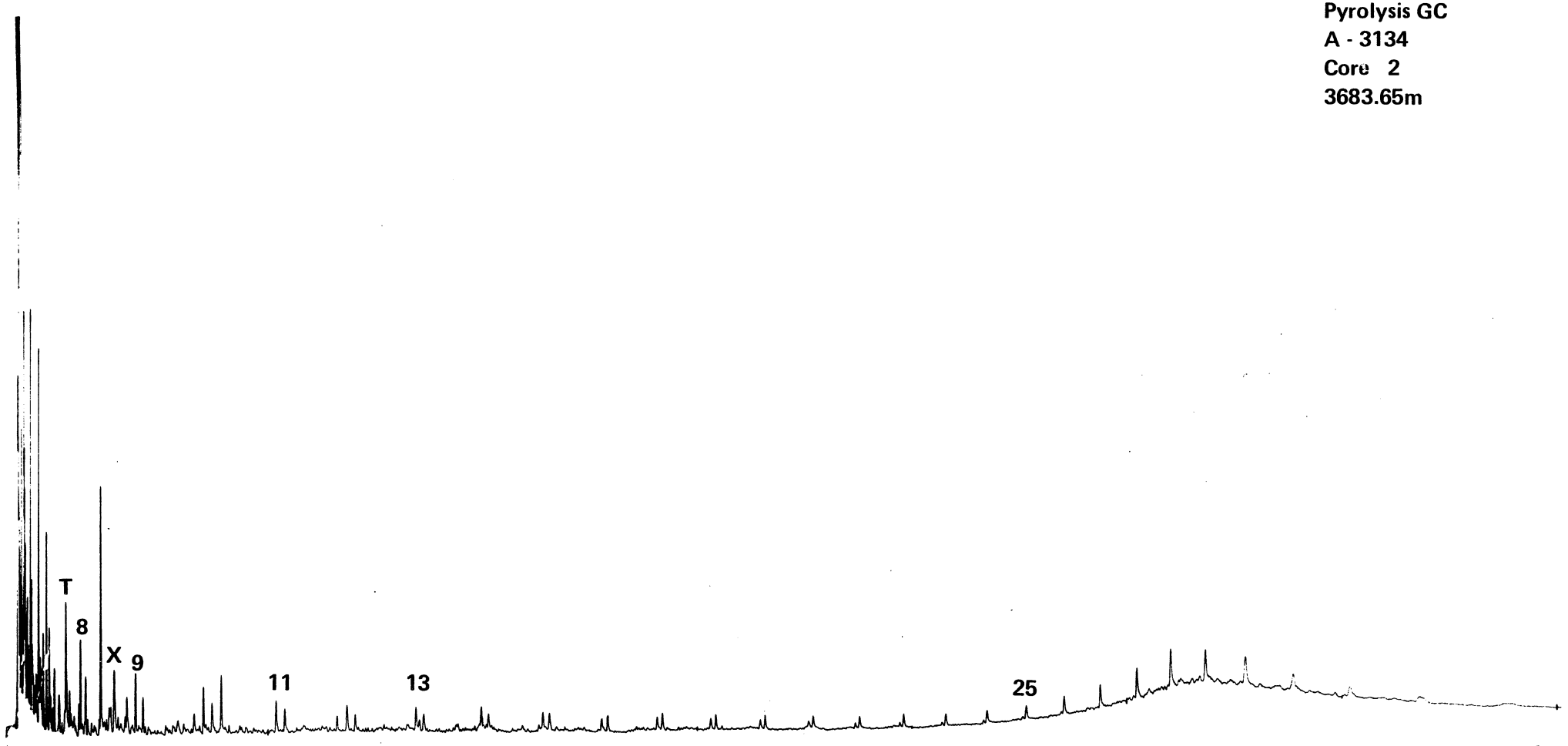



Pyrolysis GC
A - 3132
Core 1
3676.50m
T
8
X
9
11
13
25

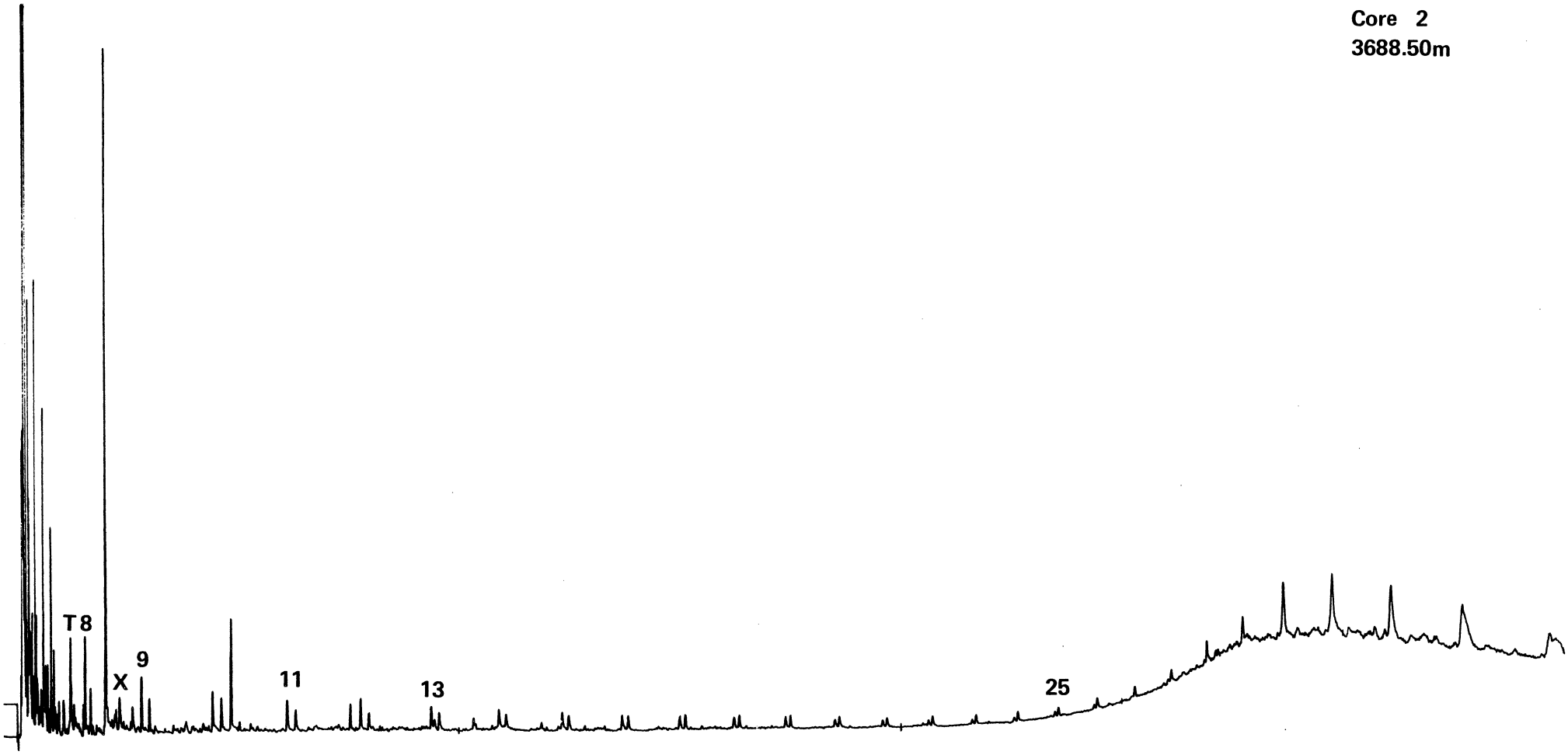


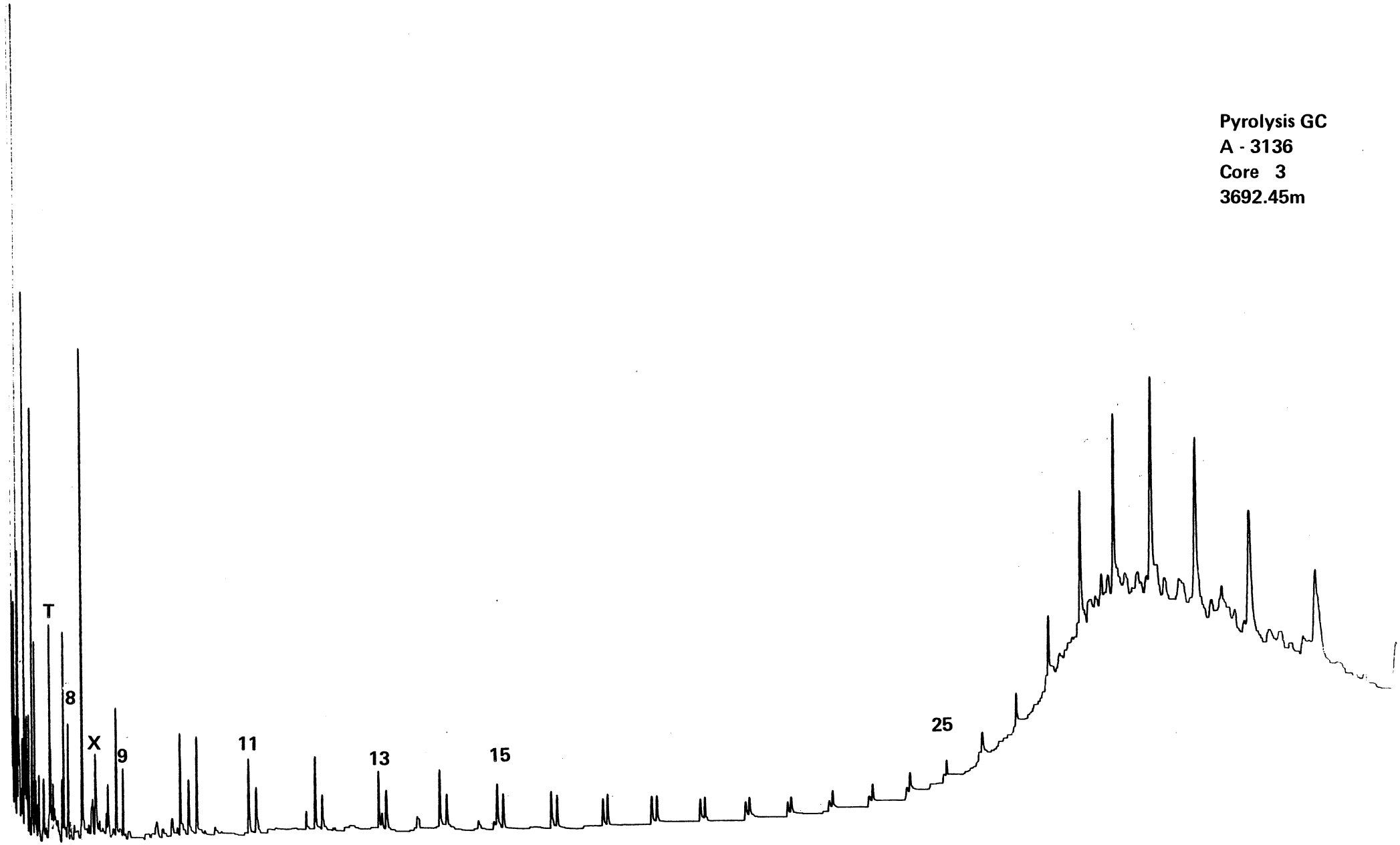
Pyrolysis GC
A - 3133
Core 2
3680.10m

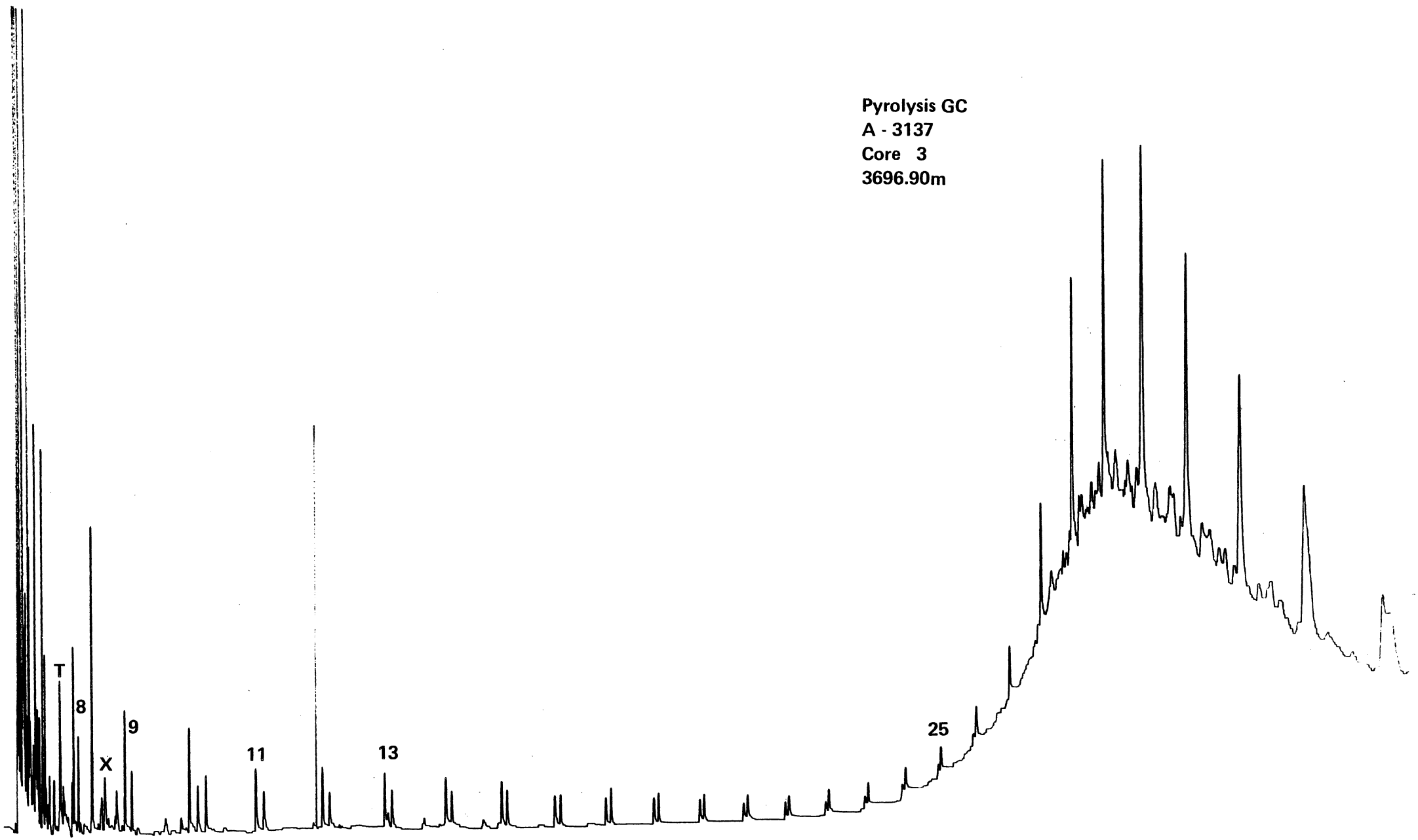
Pyrolysis GC
A - 3134
Core 2
3683.65m



Pyrolysis GC
A - 3135
Core 2
3688.50m



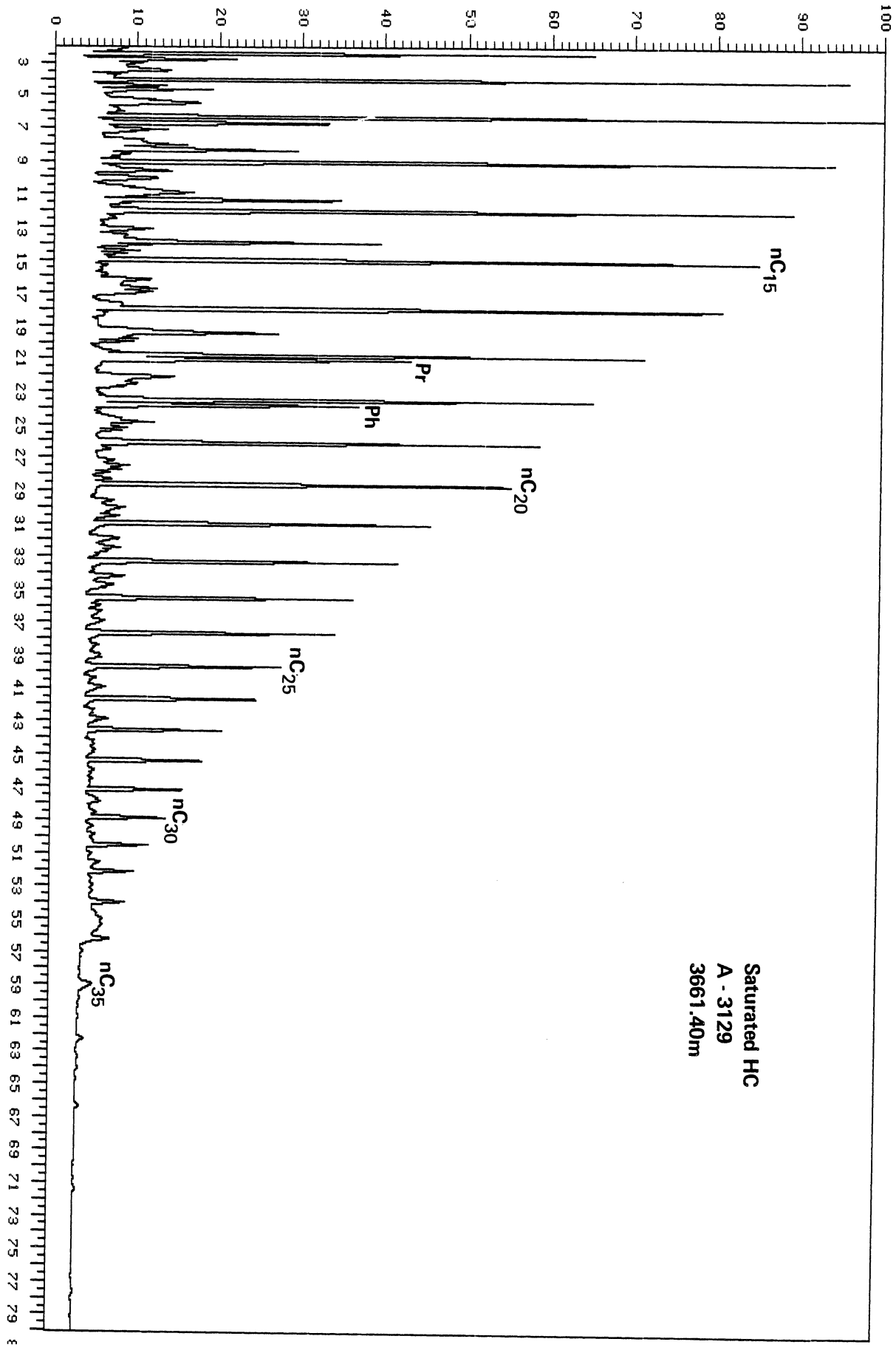

Pyrolysis GC
A - 3136
Core 3
3692.45m
T
8
X
9
11
13
15
25


Pyrolysis GC
A - 3137
Core 3
3696.90m
T
8
9
X
11
13
25

RAW DATA PLOT-CHANNEL 6

Box 1 of 1

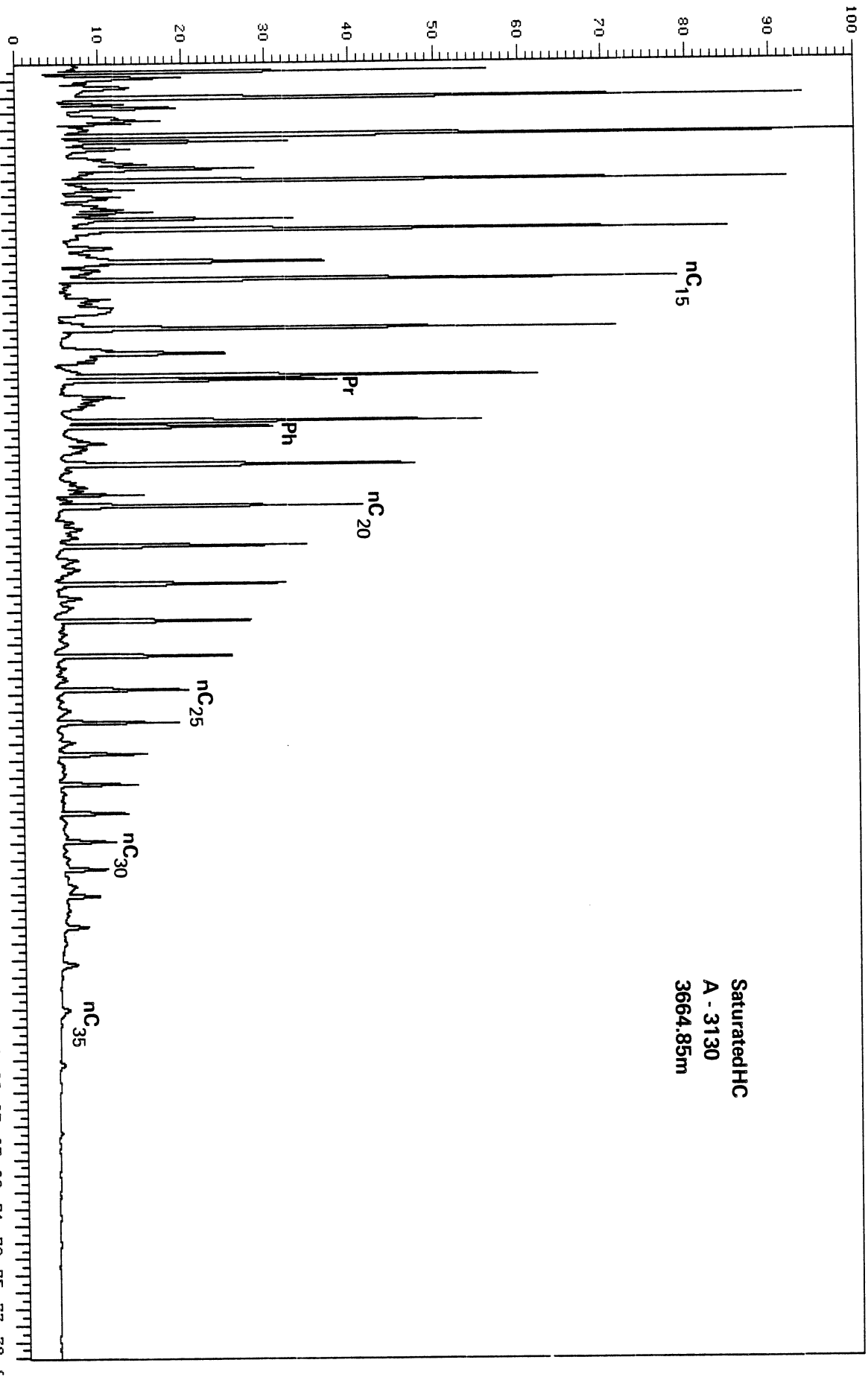
Analysis :0089A3129S1 Sample £: 1 Injection £: 1
Sample Name :A-3129,S,6407/1-2,TV Maximum value : 5116



RAW DATA PLOT-CHANNEL 6

Box 1 of 1

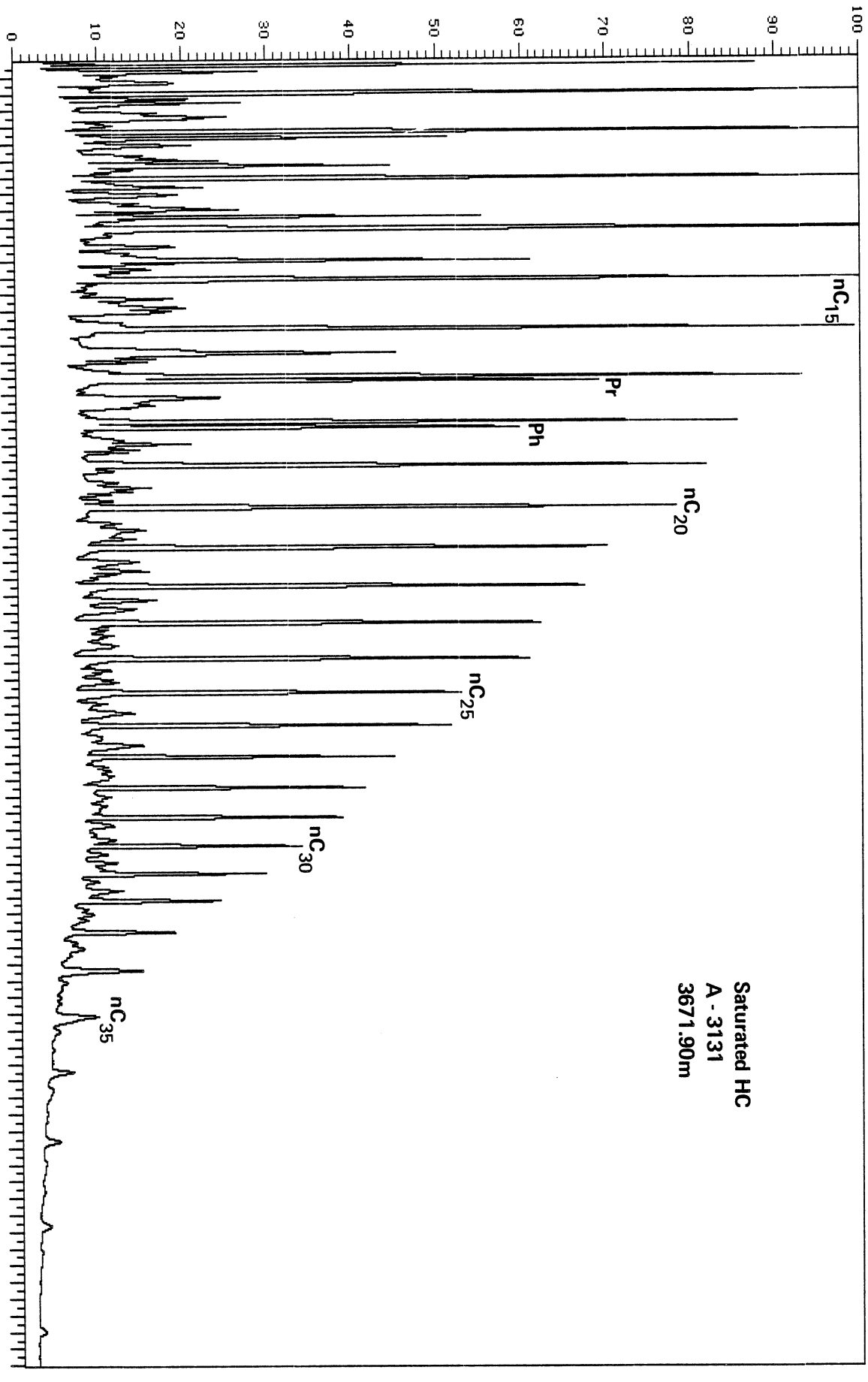
Analysis :05008981 Sample £: 1 Injection £: 1
Sample Name :A-3130,S,6407/1-2,TV Maximum value : 4447



RAW DATA PLOT-CHANNEL 6

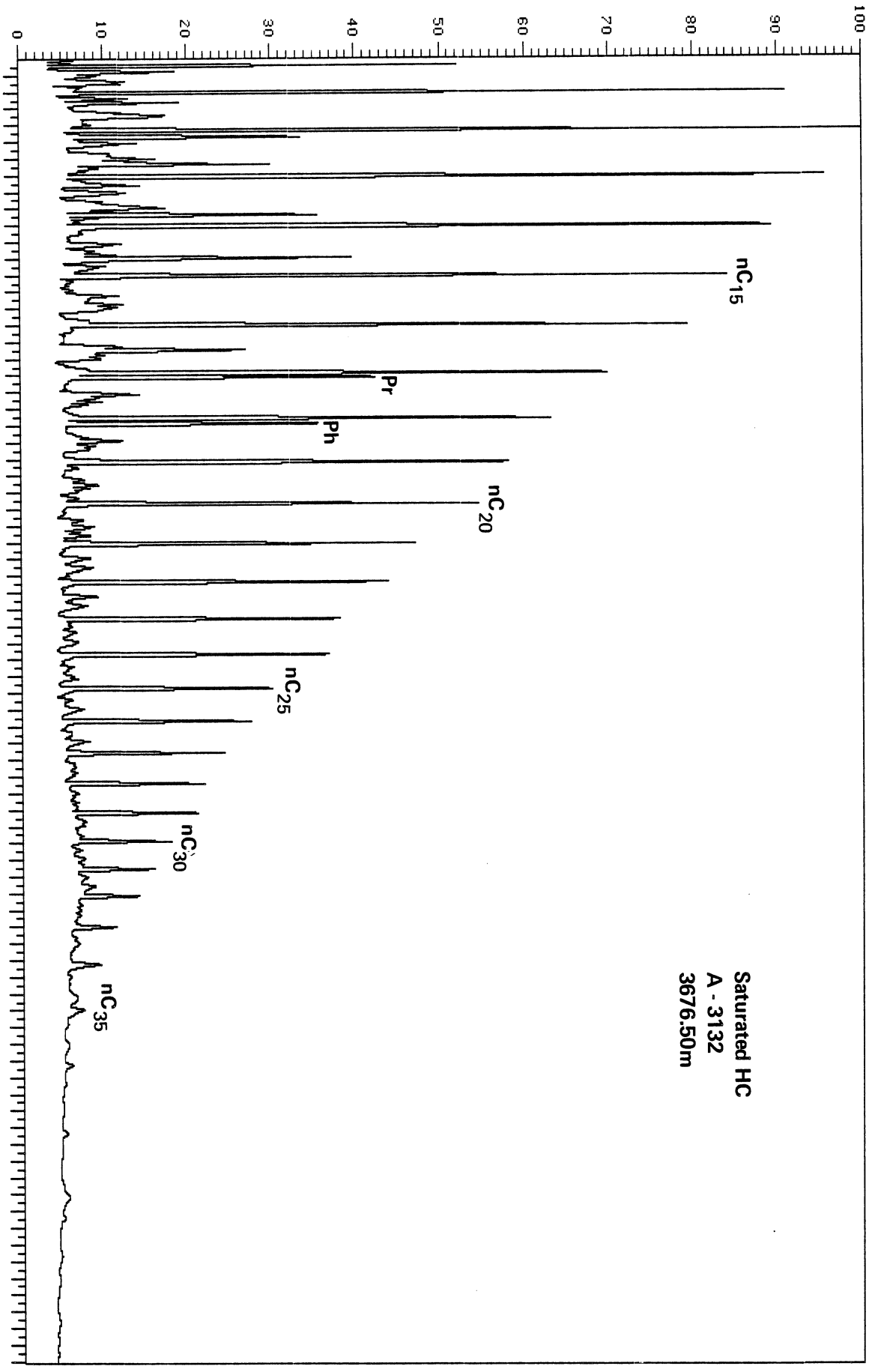
Box 1 of 1

Analysis :0089A3131S1 Sample £: 1 Injection £: 1
Sample Name :A-3131,S,6407/1-2,TV Maximum value : 16383



RAW DATA PLOT-CHANNEL 6 Box 1 of 1

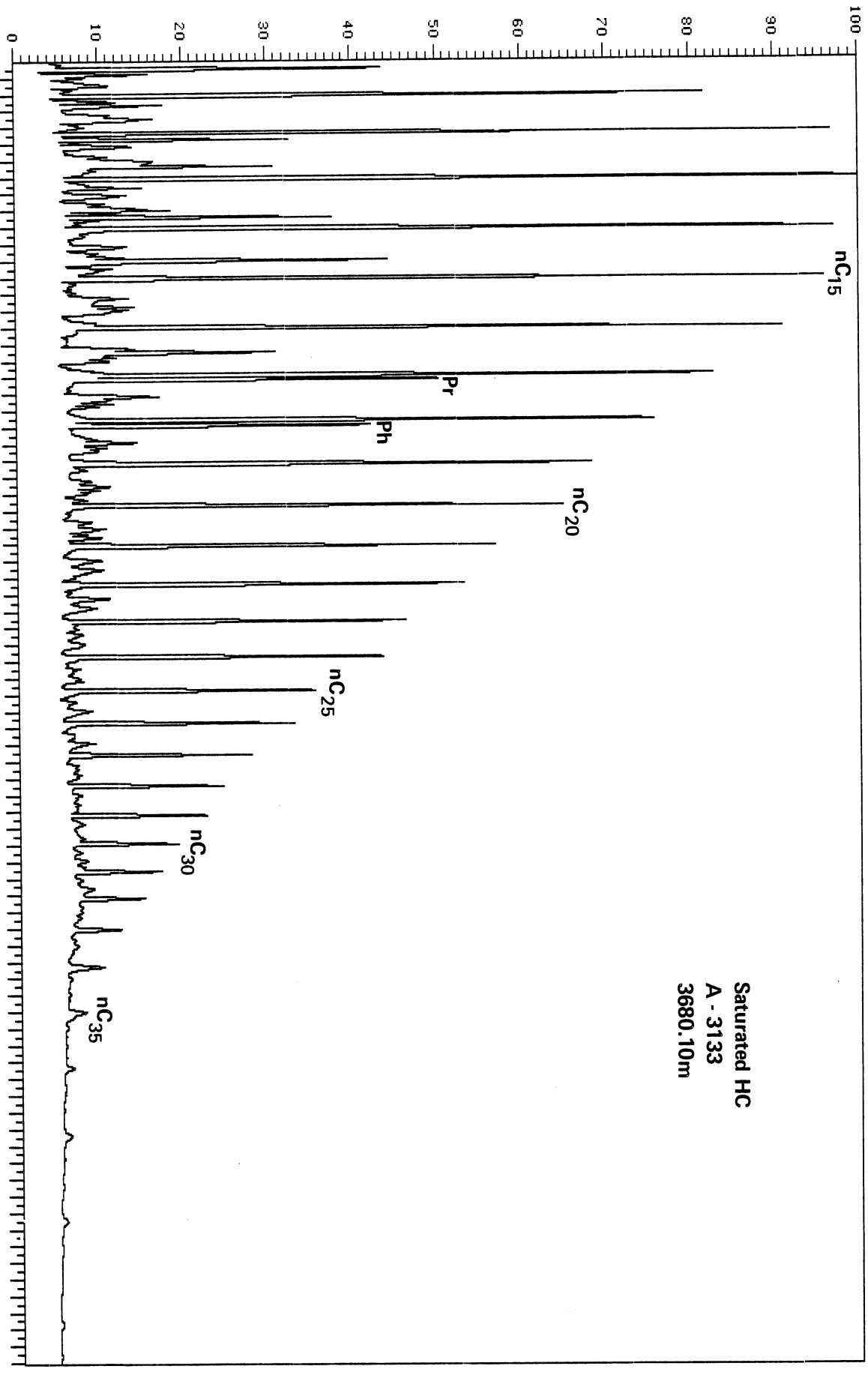
Analysis :0089A3132S1 Sample £: 1 Injection £: 1
Sample Name :A-3132,S,6407/1-2,TV Maximum value : 5468



RAW DATA PLOT-CHANNEL 6

Box 1 of 1

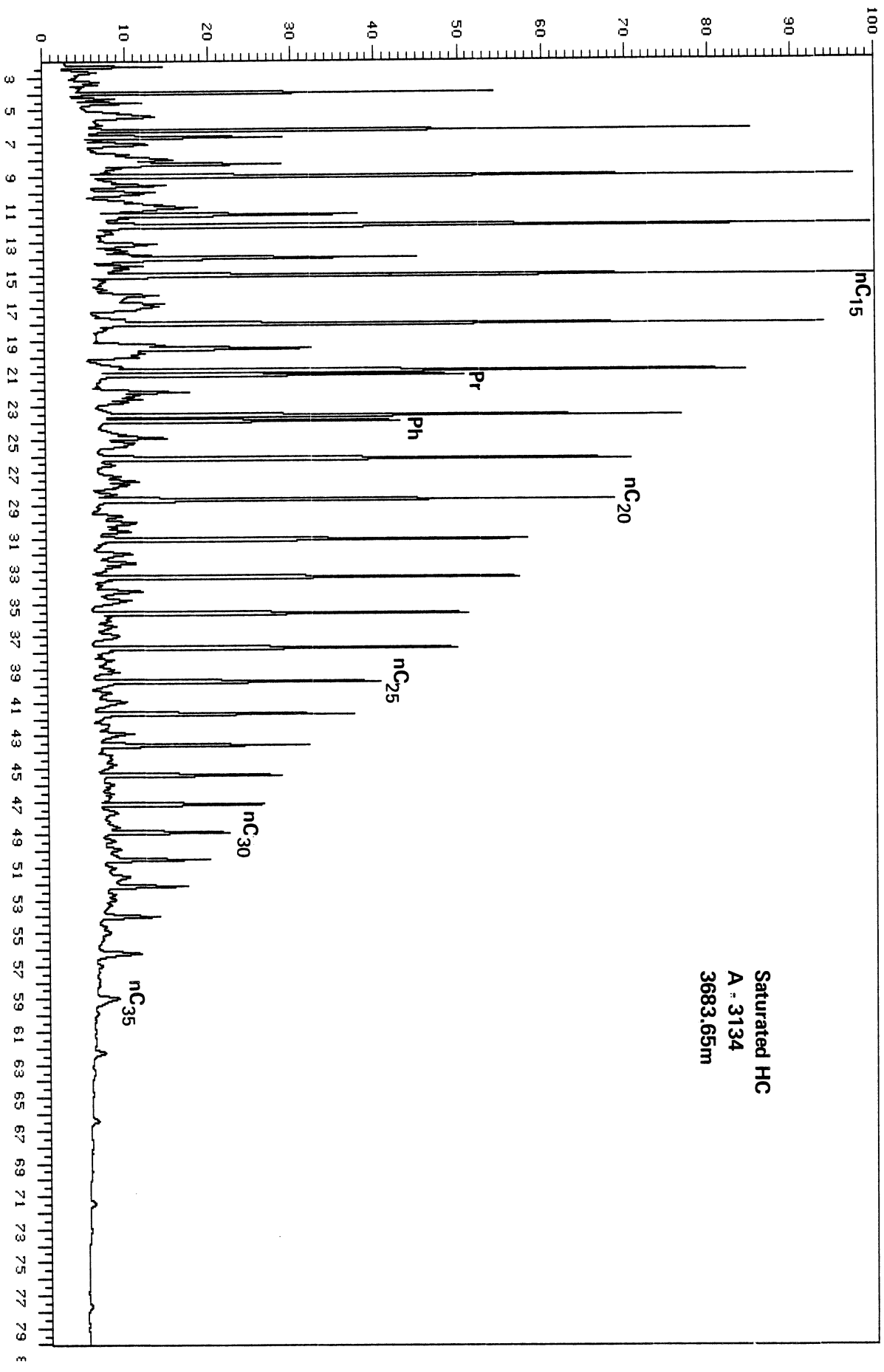
Analysis :0089A3133S1 Sample £: 1 Injection £: 1
Sample Name :A-3133,S,6407/1-2,TV Maximum value : 4528



RAW DATA PLOT-CHANNEL 6

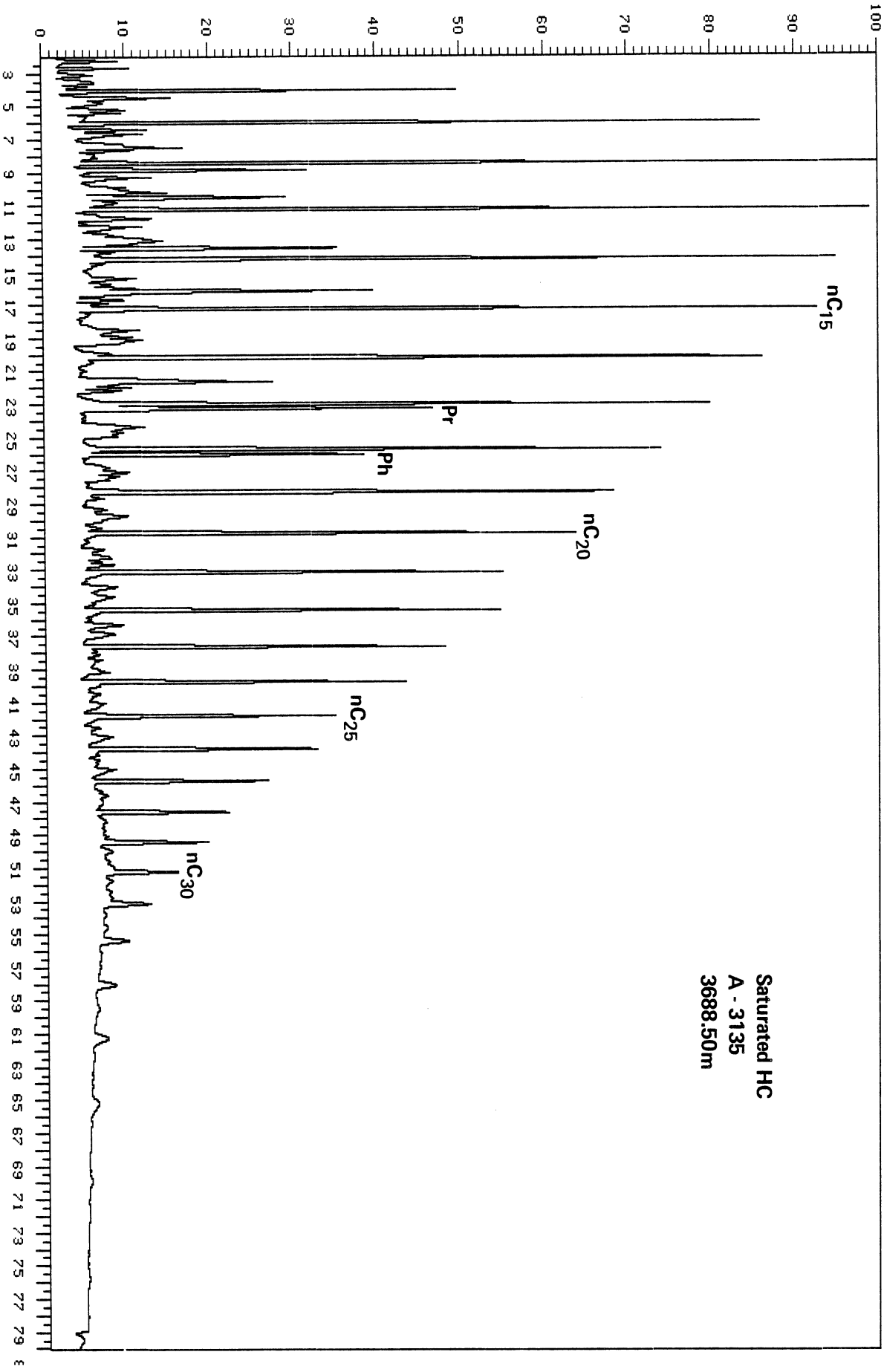
Box 1 of 1

Analysis :0089A3134S1 Sample £: 1 Injection £: 1
Sample Name :A-3134,S,6407/2-1,TV Maximum value : 4454



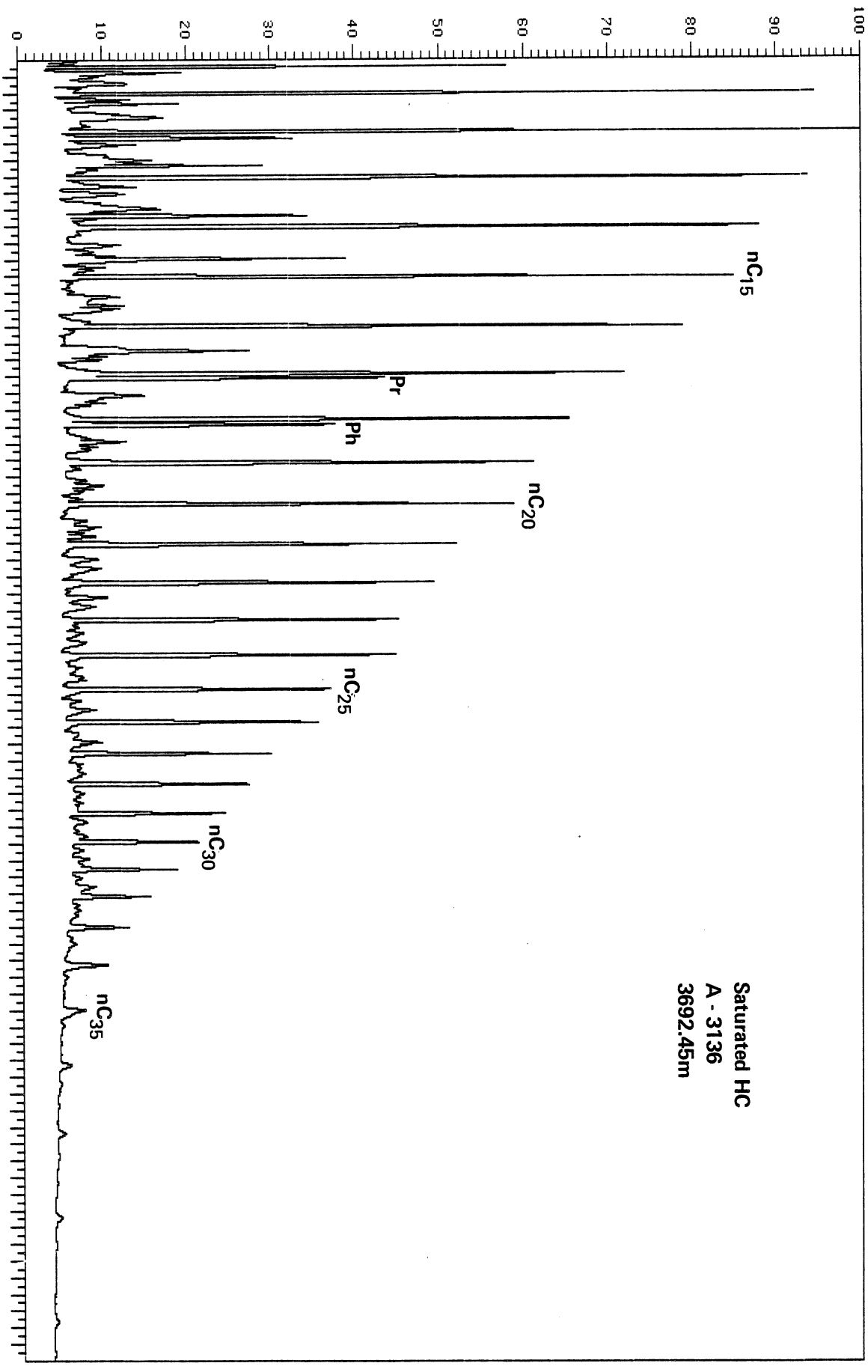
RAW DATA PLOT-CHANNEL 7 Box 1 of 1

Analysis :0089A3135S1 Sample £: 1 Injection £: 1
Sample Name :A-3135,S,6407/1-2,TV Maximum value : 8027



RAW DATA PLOT-CHANNEL 6 Box 1 of 1

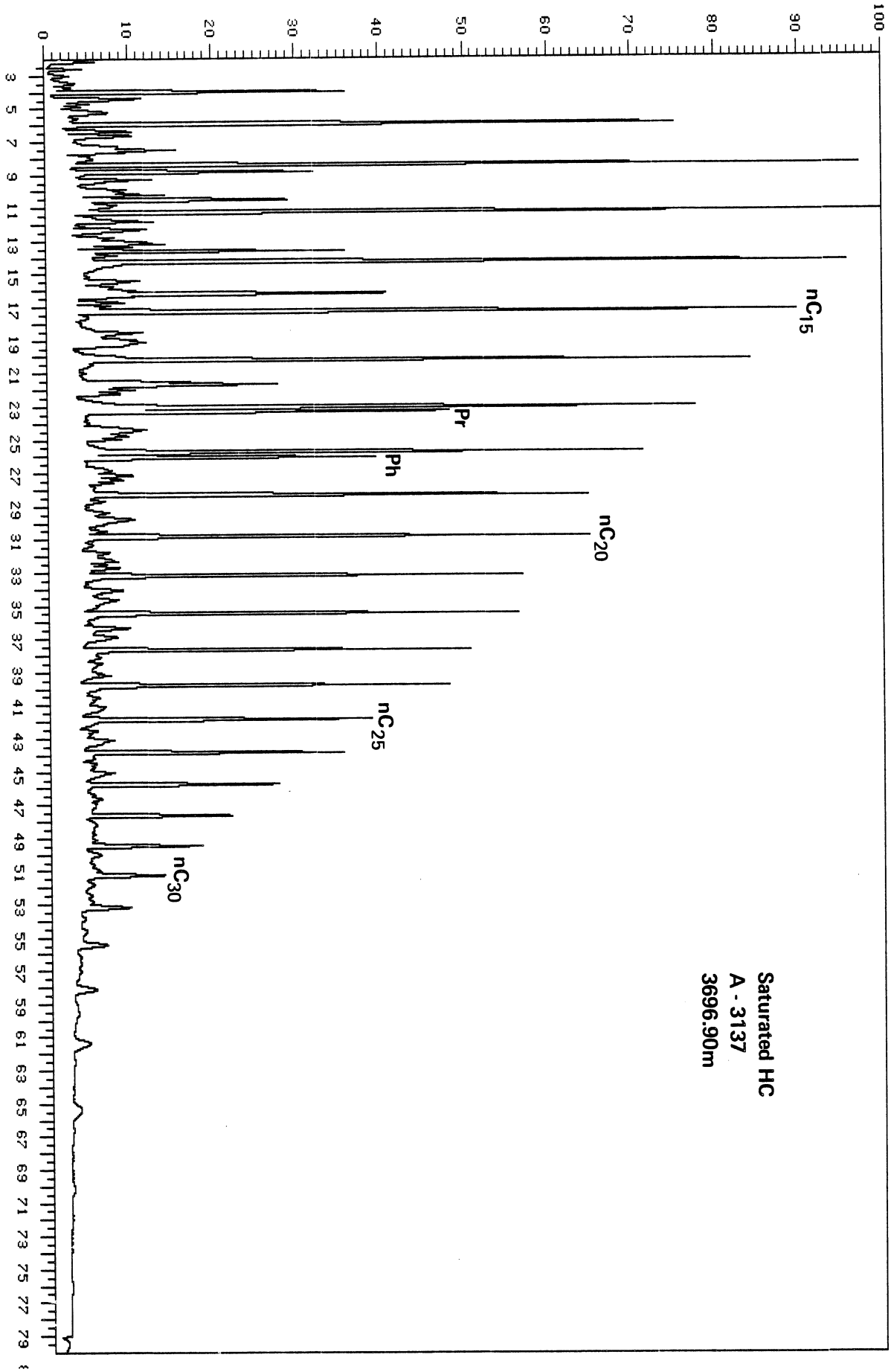
Analysis :0089A3136S1 Sample £: 1 Injection £: 1
Sample Name :A-3136,S,6407/1-2,TV Maximum value : 5640



RAW DATA PLOT-CHANNEL 7

Box 1 of 1

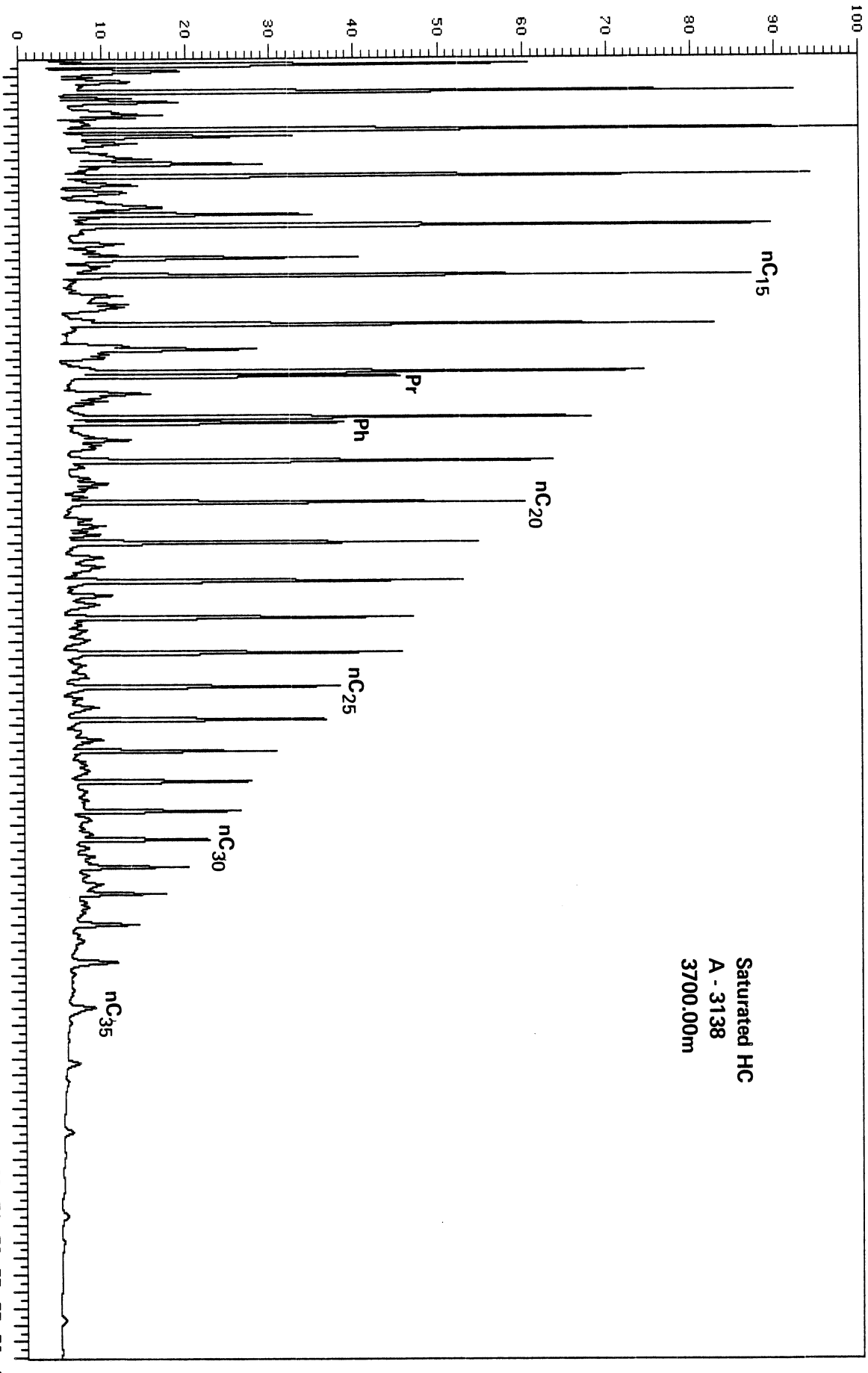
Analysis :0089A3137S1 Sample £: 1 Injection £: 1
Sample Name :A-3137,S,6407/1-2,TV Maximum value : 13938



RAW DATA PLOT-CHANNEL 6

Box 1 of 1

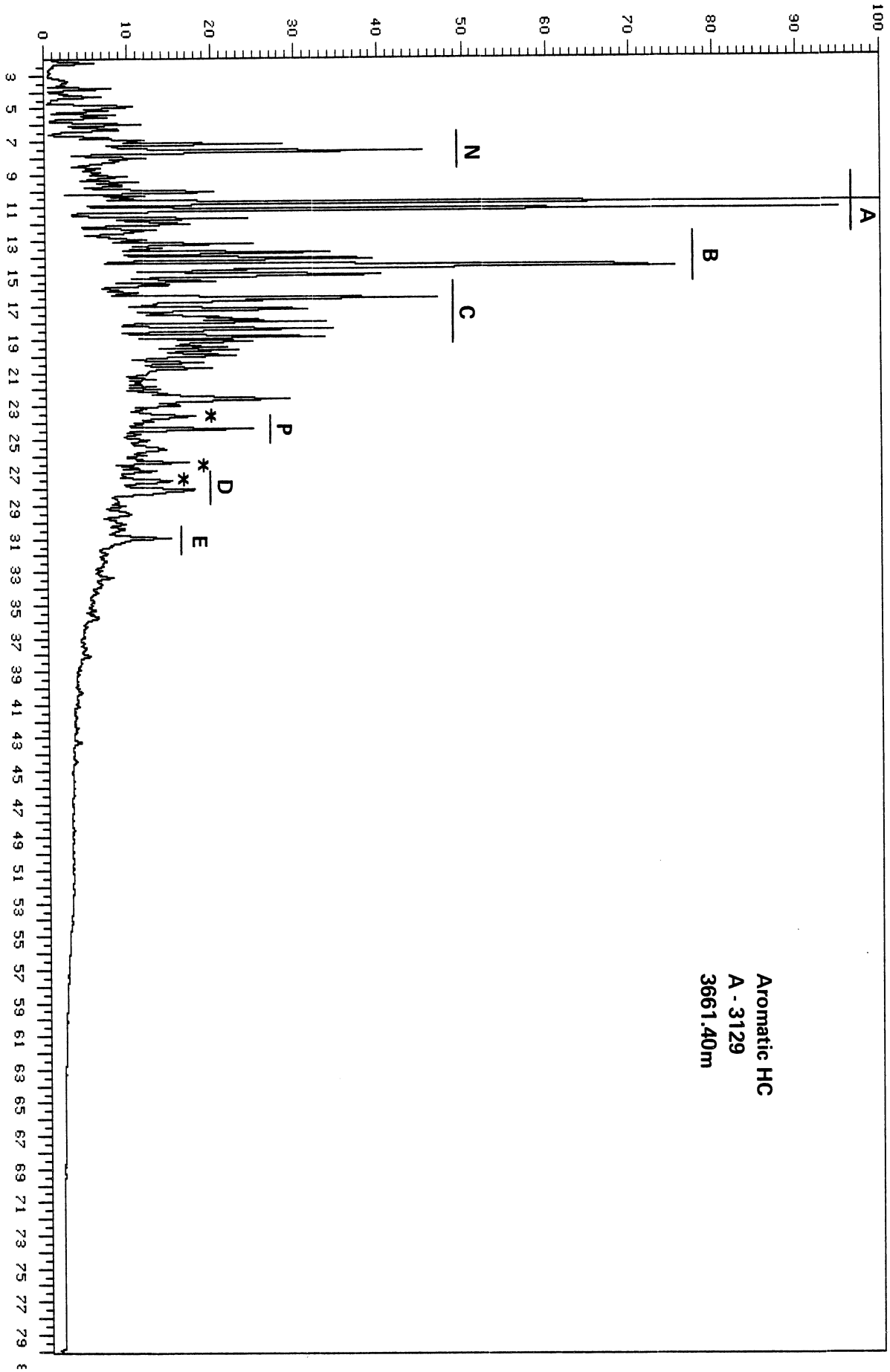
Analysis :0089A3138S1 Sample #: 1 Injection #: 1
Sample Name :A-3138,S,6407/1-2,TV Maximum value : 5137



RAW DATA PLOT-CHANNEL 7

Box 1 of 1

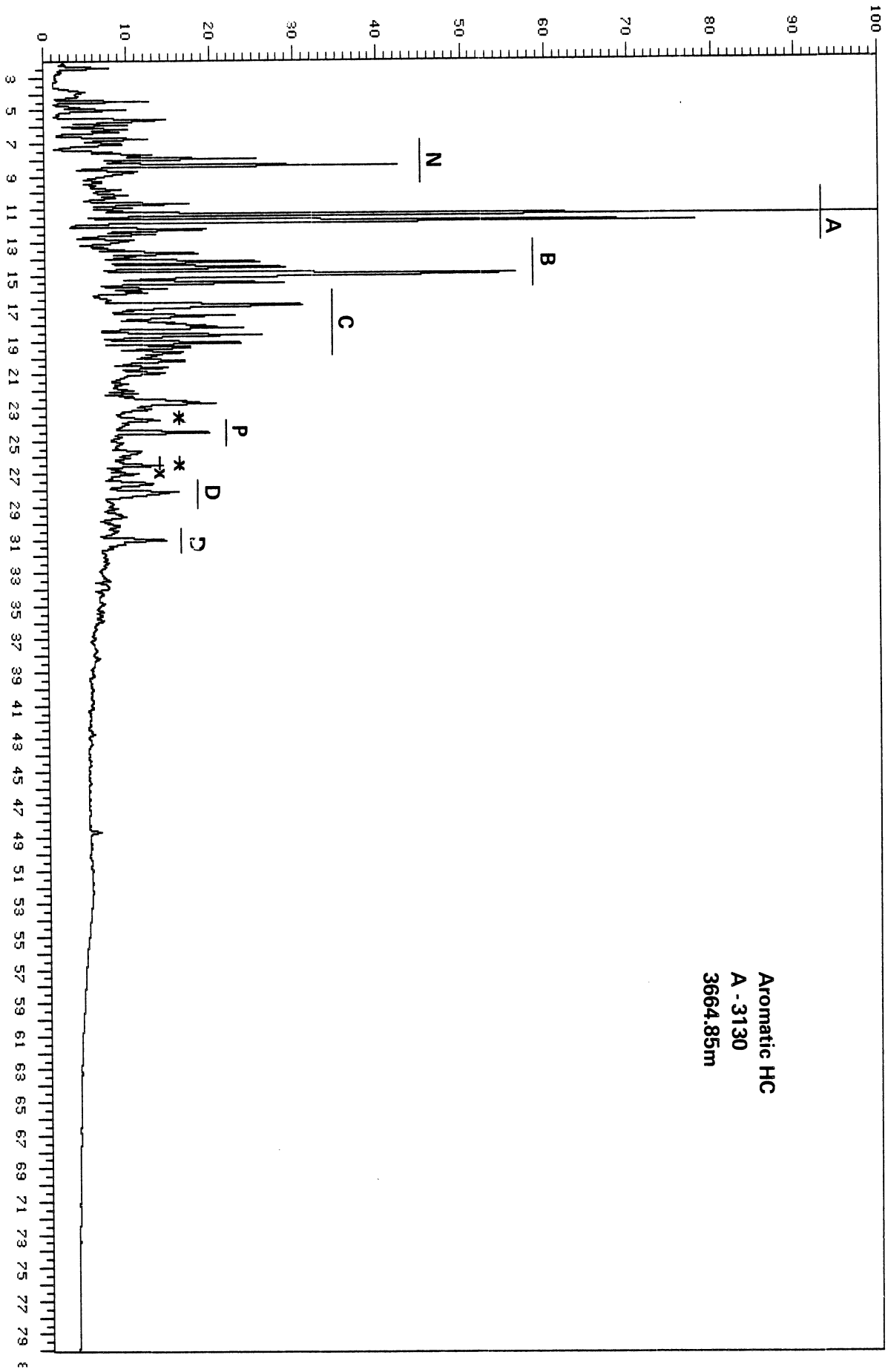
Analysis :0089A3129A1 Sample £: 1 Injection £: 1
Sample Name :A-3129,A,6407/1-2,TV Maximum value : 16383



RAW DATA PLOT-CHANNEL 7

Box 1 of 1

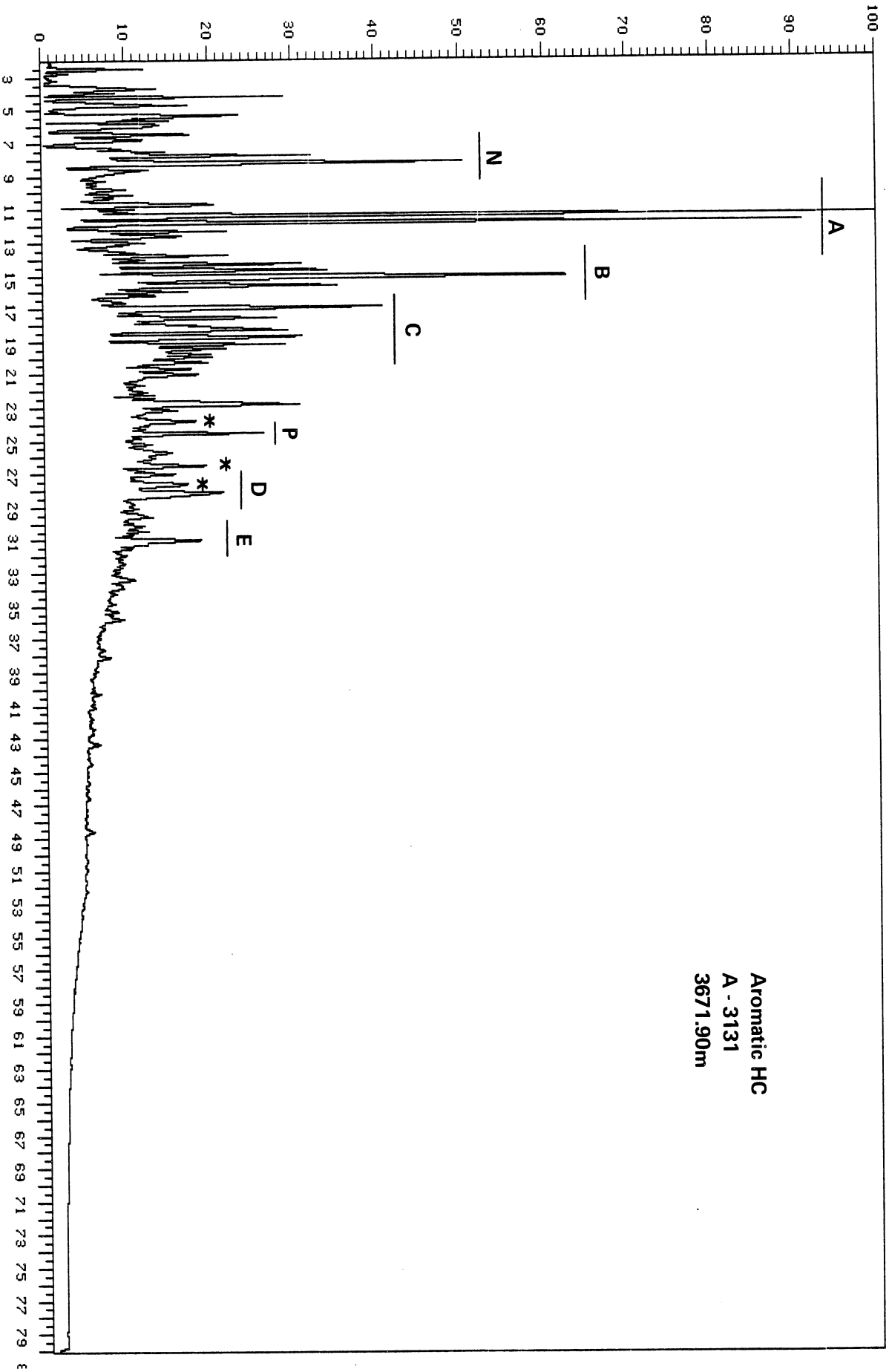
Analysis :0089A3130A1 Sample £: 1 Injection £: 1
Sample Name :A-3130,A,6407/1-2,TV Maximum value : 11358



RAW DATA PLOT-CHANNEL 7

Box 1 of 1

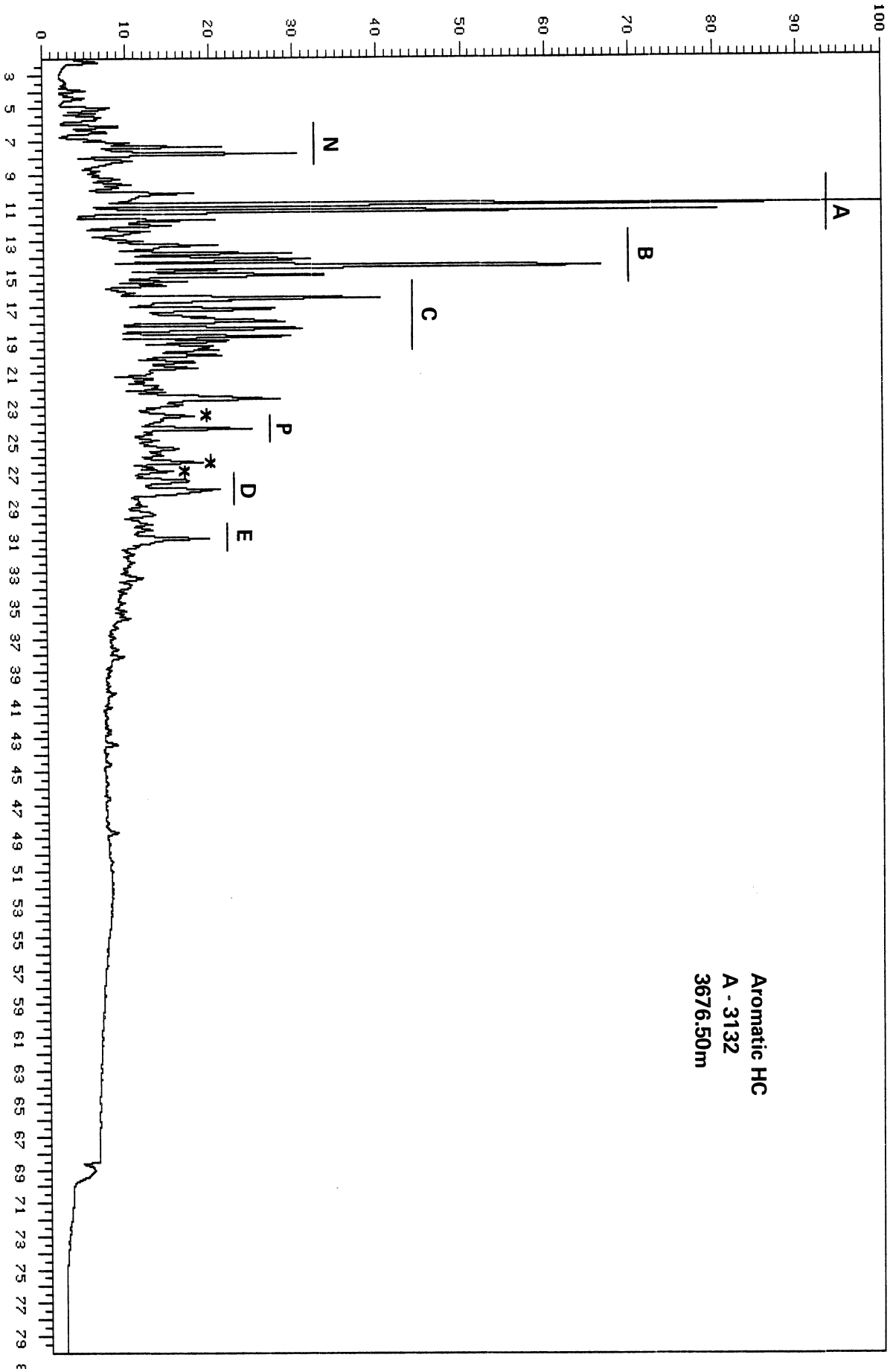
Analysis :0089A3131A1 Sample £: 1 Injection £: 1
Sample Name :A-3131,A,6407/1-2,TV Maximum value : 16383



RAW DATA PLOT-CHANNEL 7

Box 1 of 1

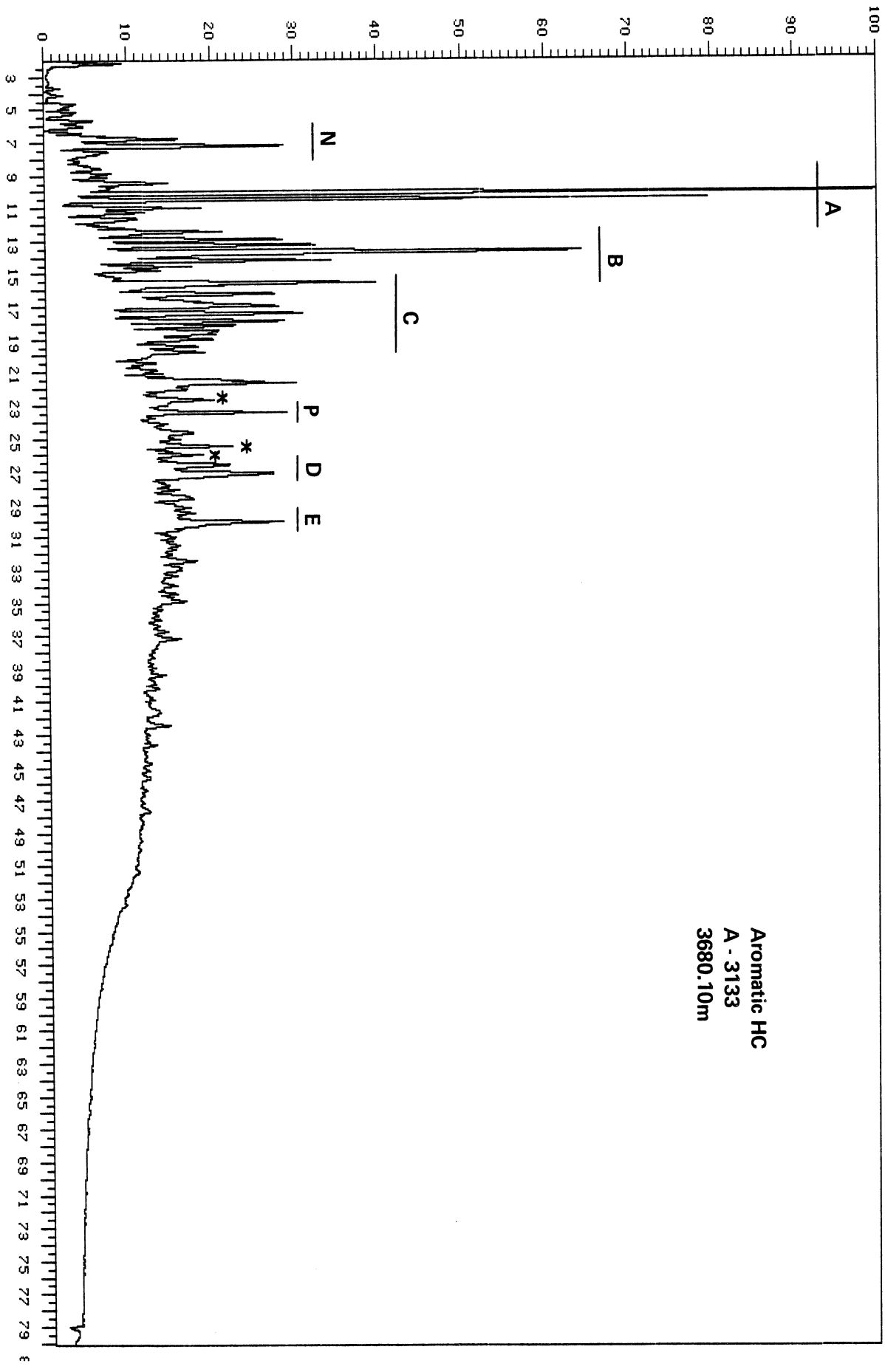
Analysis :0089A3132A1 Sample £: 1 Injection £: 1
Sample Name :A-3132,A,6407/1-2,TV Maximum value : 6602



RAW DATA PLOT-CHANNEL 7

Box 1 of 1

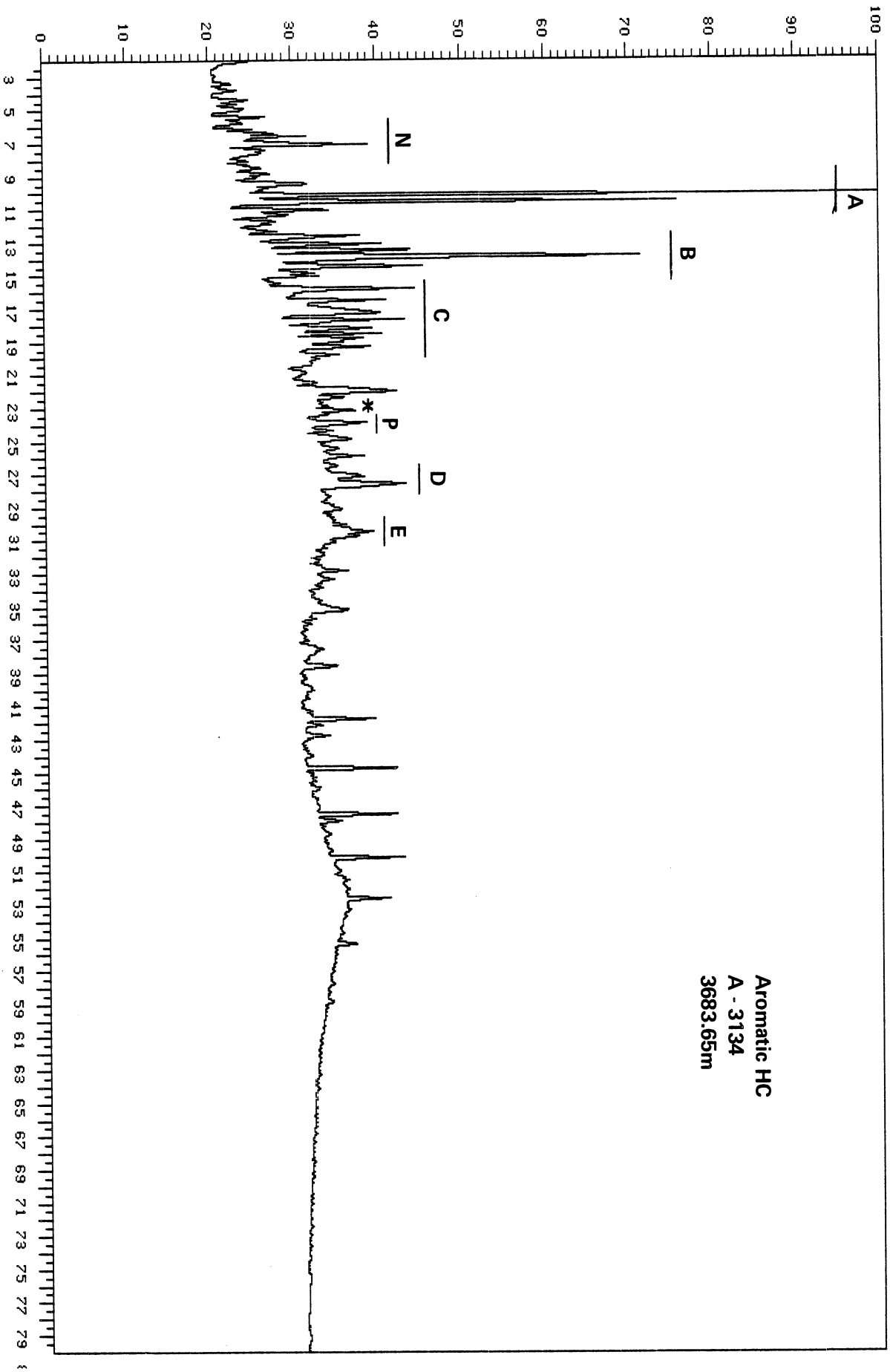
Analysis :0089A3133A2 Sample #: 1 Injection #: 1
Sample Name :A-3133,A,6407/1-2,TV Maximum value : 9513



RAW DATA PLOT-CHANNEL 2

Box 1 of 1

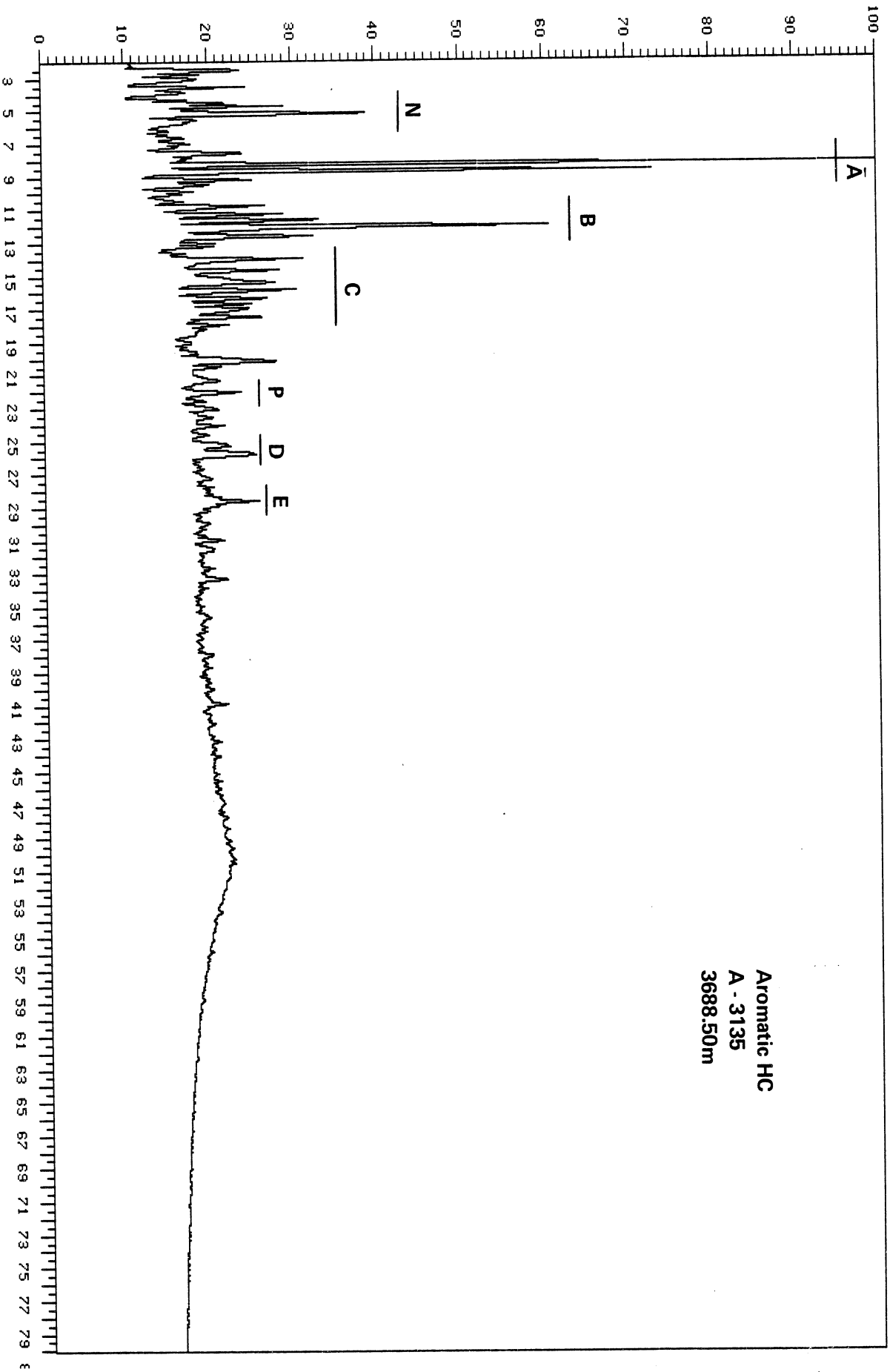
Analysis :0089A3134A1 Sample £: 1 Injection £: 1
Sample Name :A-3134,A,6407/1-2,TV Maximum value : 294



RAW DATA PLOT-CHANNEL 2

Box 1 of 1

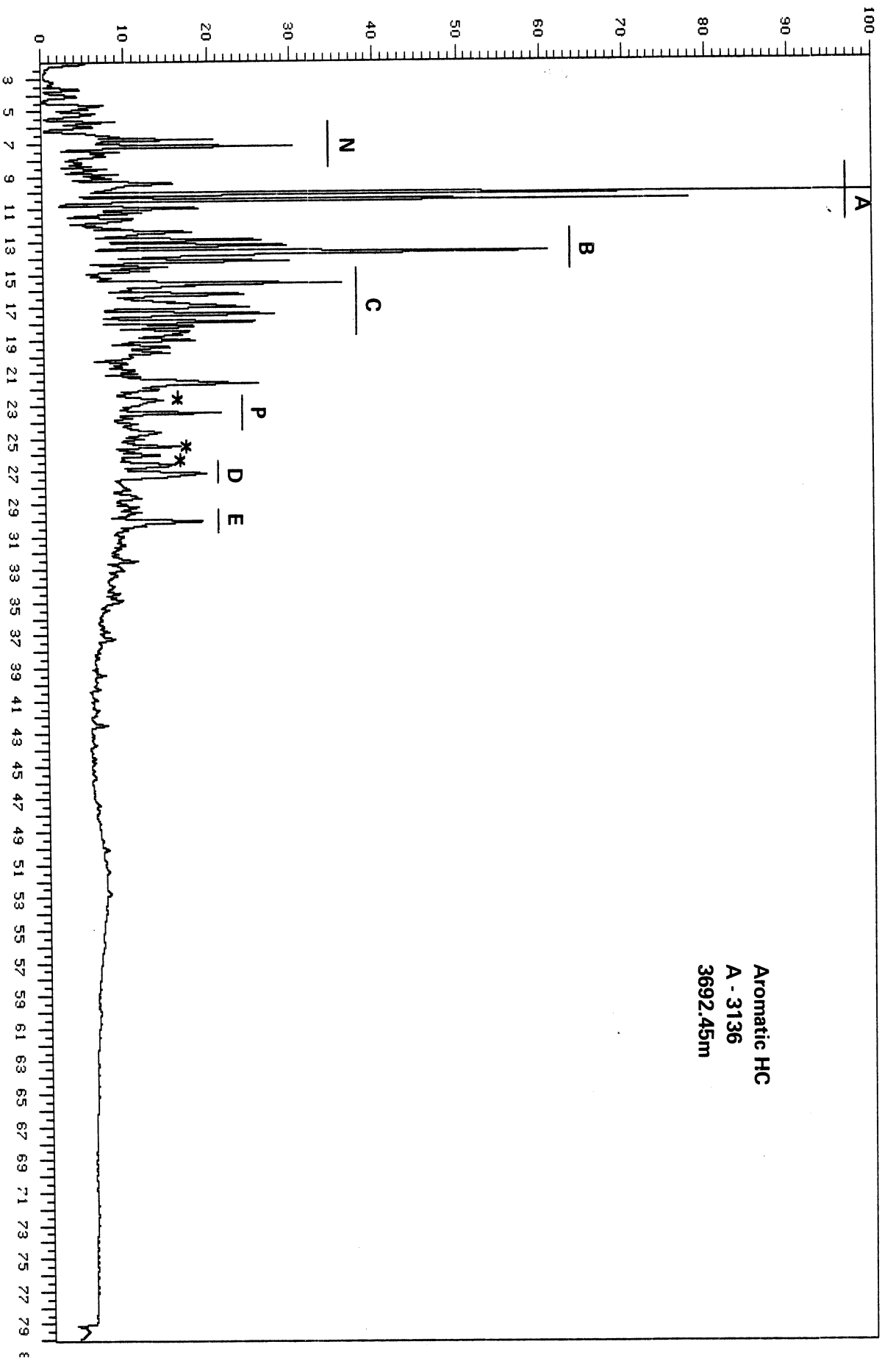
Analysis :0089A3135A1 Sample #: 1 Injection #: 1
Sample Name :A-3135,A,6407/1-2,TV Maximum value : 605



RAW DATA PLOT-CHANNEL 7

Box 1 of 1

Analysis :0089A3136A1 Sample #: 1 Injection #: 1
Sample Name :A-3136,A,6407/1-2,TV Maximum value : 5055



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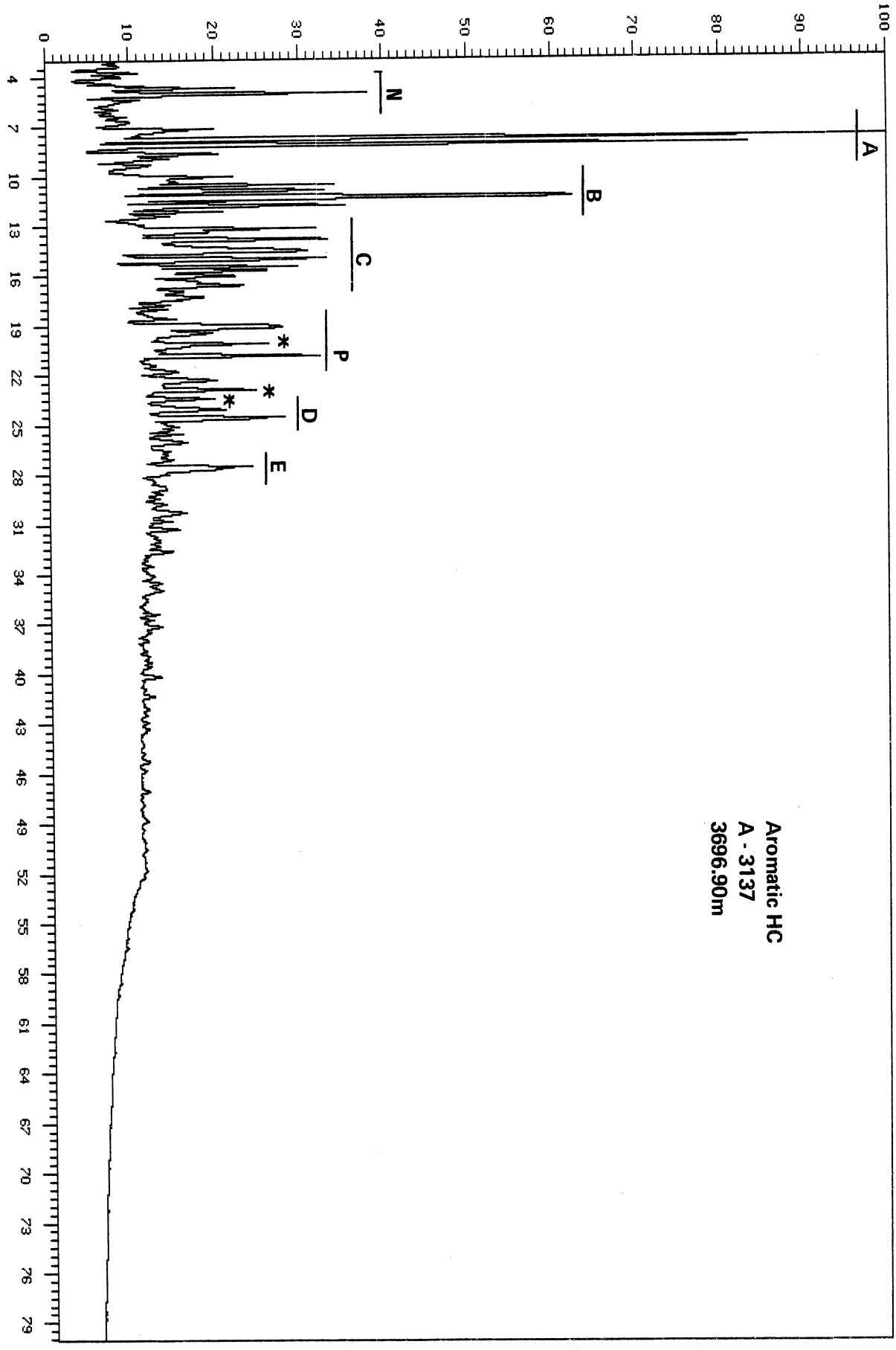
RAW DATA PLOT-CHANNEL 6

Box 1 of 1

Analysis :0089A3137A1 Sample #: 1 Injection #: 1
Sample Name :A-3137,A,6407/1-2,TV Maximum signal (%): 18.14



RAW DATA PLOT-CHANNEL 6 Box 1 of 1

Analysis :0089A3138A1 Sample #: 1 Injection #: 1
Sample Name :A-3138,A,6407/1-2,TV Maximum value : 2810