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Analyses of Cores, well 30/3-2.			
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**SUMMARY/ SAMMENDRAG**

Four core chips from well 30/3-2 were analysed to determine type of hydrocarbons. The sample from 3073 - 3073.1m has only a small amount of hydrocarbons and is mainly a condensate type. The sample from 3073.9 - 3074.0m and 3077 - 3077.1m have a large abundance of waxy hydrocarbons. These are similar to those found in a core sample from the Brent Formation in well 30/6-4. The sample from 3120.9 - 3121m has a lower abundance of extractable hydrocarbons than the two above, but is also rather waxy.

KEY WORDS/ STIKKORD	Well 30/3-2	Cores
	Cook Formation	Hydrocarbons

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## EXPERIMENTAL AND DESCRIPTION OF INTERPRETATION LEVELS

### 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<sup>0</sup>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 1 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<sup>0</sup>C for 5 minutes.

#### Py-GC

20-30 mg of thermoextracted whole rock sample was programmed pyrolysed in helium (260<sup>0</sup>C to 520<sup>0</sup>C at 35<sup>0</sup>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<sup>o</sup> - 270<sup>o</sup>C at 4<sup>o</sup>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 2-5.

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 DISCUSSIONS

### Rock-Eval Pyrolysis

Quick screening analysis of the four core samples was performed, aliquots of the samples were pyrolysed using the Rock-Eval II instrument. The four samples show different patterns and each will be described below. Since these are reservoir samples, ordinary factors 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.

3073 - 3073.1m: This core sample has a small amount of hydrocarbons, shown by the low  $S_1$  value of 0.13 mg HC/g rock. There is, however, a very large amount of oxygen-containing compounds released during the pyrolysis. This is unnaturally high for the low amount of organic carbon in the sample and might be affected by carbonate decomposition. A detailed study of the mineralogy of the core would show if the sample contains carbonate which decomposes below  $390^{\circ}\text{C}$ . The sample does not seem to contain any significant amount of asphaltenes or kerogen which would have shown up in the  $S_2$  peak. This is in good agreement with the very low organic carbon value.

3073 - 3074m: This sample is significantly different to the sample above. The amount of free hydrocarbons is high, 5.59 mg/g rock and the sample also has a significant amount of hydrocarbons produced during the pyrolysis part shown by the large  $S_2$ , 1.46 mg HC/g rock. The  $S_2$  shows a typical bimodal pattern, where the first mode is probably due to free hydrocarbons which are not released in the first step (below  $200^{\circ}\text{C}$ ) and the second is due to pyrolysis of asphaltenes. This could indicate a paraffinic oil with a large amount of asphaltenes. The amount of oxygen-containing compounds as represented by the  $S_3$  peak is similar to that found in the first core sample. These are probably derived from oxygen compounds found in the asphaltenes.

3077 - 3077.10m: The Rock-Eval results of this sample are similar to that of the sample from 3074m, only more pronounced i.e. a higher  $S_1$  and  $S_2$  with a very clear bimodal distribution of the  $S_2$  peak.

3120 - 3121m: This changes again compared with the samples above. The amount of free hydrocarbons drops drastically, 1.15mg HC/g rock. The S<sub>2</sub> peak is also significant lower, indicating very small amounts of asphaltenes/kerogen. The relative amount compared to the free hydrocarbons is, however, relatively similar to the previous two samples. The greatest difference is the very large S<sub>3</sub> peak, indicating a very large amount of CO<sub>2</sub> being produced during pyrolysis. This could be due to decomposition of carbonates. A detailed mineralogical study would show if carbonates are present.





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. TEMP. INDEX Si S1+S2	TEMP. MAX (C)
A 1113	3073.00- 3073.10	0.13	0.00	0.74	0.03	0	2467	0.13	1.00	438
A 1114	3073.90- 3074.00	5.59	1.46	0.63	0.57	256	111	7.05	0.79	408
A 1115	3077.00- 3077.10	8.15	2.37	0.57	0.77	308	74	10.52	0.77	409
A 1116	3120.90- 3121.00	1.15	0.46	2.70	0.46	100	587	1.61	0.71	418

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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  $300^{\circ}\text{C} - S_1$ ) and the hydrocarbons produced by pyrolysis of the kerogen, if there is any ( $S_2$ ).

3077 - 3077.1m: The sample gives a normal picture for a core containing light hydrocarbons (condensate) in small amounts. The maximum is at  $n\text{C}_{15}$  tailing off sharply towards higher molecular weight hydrocarbons. Hydrocarbons above  $n\text{C}_{21}$  were not detected. Low molecular weight compounds from  $n\text{C}_5$  upwards are present in good abundance (Fig.2). Pyrolysis of the organic remains gave only small amount of hydrocarbons. No particular pattern is seen (Fig.3).

3070.90 - 3074m: The pattern of both the thermo-evaporated material and the pyrolysed organic remains are very different from that of the sample above. The gc of the thermo-evaporated material has a maximum at  $n\text{C}_{18}$  showing a smooth distribution of n-alkanes up to  $n\text{C}_{30}$ . This part of the chromatogram is typical for a waxy oil. The strange part is the lower end of the chromatogram where hardly any compounds below  $n\text{C}_{14}$  were detected and there is a sharp increase from  $n\text{C}_{14}$  to  $n\text{C}_{17}$  (Fig.4). Normally a core would not lose n-alkanes up to  $n\text{C}_{15}$  if it does not have a very high permeability. If there is a large permeability difference between the sample from 3073 - 3073.1m and the one from 3073.90 - 3074m, i.e. the lowermost sample has a higher permeability, then the phenomena seen here can be explained by weathering after sampling. The results shows, however, that there has been a separation effect in the reservoir, with a light condensate at the top and heavier waxy oil lower down. When core samples from the Brent Formation in well 35/8-2 were analysed in a similar manner, it was found that the light end had disappeared and a waxy result were left. These samples were from the pay zone in the Brent Formation which produced gas/condensate. The condensate was found to contain n-alkanes up to  $n\text{C}_{40}$  and would be classified as a waxy oil by gas chromatographic analyses. The condensate went solid in a fordge.

The pyrolysis gc pattern of the organic remains shows some methane and a relatively large amount of  $\text{C}_2 - \text{C}_5$  material. A normal pattern for pyrolysed asphaltenes is seen (Fig.5).

3077 - 3077.1m: The gc of the thermo-evaporated material and the pyrolysed material are very similar to the sample from 3070.9 - 3074m. (Fig.6 and 7).

3120.9 - 3121m: There are only small differences in the gc of the thermoevaporated material compared with the samples from 3073.9 - 74 and 3088.0 - 3077.1m. The main difference is the slightly higher relative abundance of the  $C_1 - C_{15}$  hydrocarbons. This could be due to a lower permeability keeping back more of the light hydrocarbons (Fig.8). The gc of the pyrolysed organic remains are different from the two above. The front end of the gc is relatively similar, but there is no regular pattern of alkenes and alkanes (Fig.9).

## Extraction and Chromatographic Separation

The extraction of the four samples shows:- 1) the sample from 3073-3073.1m has only small amounts of extractable organic matter (151ppm) but a large proportion of it is hydrocarbons (92%), the main bulk (65.3%) being saturated hydrocarbons (Table 5). This composition is relatively similar to that found for crude oil i.e. only a small percentage of non-hydrocarbons. The other three samples have a large abundance of extractable organic matter with the sample from 3077-3077.1m having the highest abundance (Table 3). There is, however, a relatively large difference in the composition of the extractable organic material in the three samples (Table 5), showing that there has been a fractionation effect in the reservoir. We believe the differences seen here represent differences found in the reservoir and not due to weathering effects after sampling.

### Saturated Hydrocarbons

3073-3073.1m: The gas chromatogram of the saturated hydrocarbons of the sample from 3073-3073.1m show a smooth n-alkane distribution with maximum at  $nC_{15}$  and a sharp tailing off both to higher and lower molecular weight. This part of the chromatogram is typical for a condensate. There is, however, a long tail of n-alkanes up to  $nC_{31}$  this is unusual for a condensate (Fig. 10).

3073.9-3074m: The gas chromatogram of the saturated hydrocarbon fraction of the sample from 3073.9-3074m shows a smooth n-alkane distribution with maximum at  $nC_{16}$  and a large abundance of n-alkanes up to  $nC_{40}$ . This pattern is typical for a paraffinic, waxy crude sourced from kerogen type I (Fig. 11).

3077-3077.1m and 3120.9-3121m: The gas chromatograms of the saturated hydrocarbon fractions are almost identical to the one from 3073.9-3074m (Figs. 12 and 13).

### Aromatic Hydrocarbons

The aromatic hydrocarbons in A-1113 (3073 - 3073.1 metres) are dominated by compounds in region C, which includes the C<sub>3</sub>-naphthalenes. C<sub>2</sub>-naphthalenes (B) are also prominent. In the other three samples phenanthrene (P), C<sub>1</sub> and C<sub>2</sub> phenanthrenes (D and E) and the C<sub>3</sub>-naphthalenes dominate of the resolved component. A-1116 (3120 - 3121.0 metres) differs from A-1114 (3073.9 - 3074 metres) and A-1115 (3077 - 3077.1 metres) in that the naphthalene (N) and C<sub>1</sub>-naphthalenes (A) are also prominent. A-1114 and A-1115 also contain a prominent unresolved hump which is not seen in the other two samples. Thus we have three different aromatics distributions

- 1) A-1113 most low molecular weight aromatics
- 2) A-1114 and A-1115 prominent unresolved hump
- 3) A-1116

The saturates suggest a division into two groups

- 1) A-1113 dominated by nC<sub>12</sub> - nC<sub>18</sub> alkanes
- 2) A-1114 - A-1116, as A-1113 but with a prominent shoulder of n-alkanes from nC<sub>20</sub> - nC<sub>30</sub> with n-alkanes right out to nC<sub>40</sub> (i.e. paraffin-rich).

### SUMMARY

From the gas chromatographic patterns and from the extract data; mostly light hydrocarbons (i.e. < nC<sub>20</sub>) are found in the top sample A-1113. A-1114 and A-1115 saturated and aromatic hydrocarbon gas chromatograms appear to be like the saturated and aromatic hydrocarbon gas chromatograms of the oil extracted from the Brent sandstone core in 30/6-4 (Paraffin-rich, and with a large unresolved hump in the aromatic hydrocarbon gas chromatogram). The lowest core sample A-1116 appears to be similar to A-1114 and A-1115, however the aromatics distribution is different and with no obvious unresolved hump.

The middle two core samples are very rich in hydrocarbons (several 1000 ppm) and therefore contain a considerable amount of migrated hydrocarbons. The conclusion is that these two cores contain reservoired, not residual hydrocarbons. The hydrocarbons in core A-1113 are characteristic of a condensate, in A-1114 and A-1115 of a paraffinic oil. A-1116 is similar to A-1114 and A-1115 but has a different aromatic hydrocarbon distribution.



## CONCLUSIONS

The uppermost analysed sample 3073-3073.1m contains almost no hydrocarbons. Those found are of a condensate type. The two core samples from 3073.9-3074m and 3074-3077.1m contains a large quantity of paraffinic hydrocarbons. Almost all the hydrocarbons lighter than  $nC_{14}$  are missing. This might be due to a weathering effect after sampling if the core has a very high permeability. It should then be of far higher permeability than the core sample from 3073-3073.1m. The lowermost sample 3120.9-3121m has a lower hydrocarbon content than the two above, but the saturated hydrocarbons are of a similar type to that found in these samples. The sample from 3073-3073.1m and 3120.9-3121m produce a large quantity of  $CO_2$  upon heating to 280-390°C. This is unusual and might be due to carbonate cement in the cores.

There is a relatively large difference in the composition of extractable material suggesting a separation effect in the reservoir. This is unusual if it was an active reservoir filled with oil.



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 1113	3073.00- 3073.10	49.7	7.5	4.9	2.0	6.9	0.6	0.03
A 1114	3073.90- 3074.00	55.6	417.2	254.1	72.2	326.3	90.9	0.57
A 1115	3077.00- 3077.10	47.7	523.1	362.0	104.9	466.9	56.2	0.77
A 1116	3120.90- 3121.00	52.2	143.1	89.0	22.4	111.4	31.7	0.46

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T A B L E : 3

WEIGHT OF EOM AND CHROMATOGRAPHIC FRACTIONS

(Weight ppm OF rock)

IKU-No	DEPTH (m)	EOM	Sat.	Ar.o.	HC	Non HC
A 1113	3073.00-	151	99	40	139	12
A 1114	3073.90-	7504	4570	1299	5869	1635
A 1115	3077.00-	10969	7591	2200	9790	1178
A 1116	3120.90-	2741	1705	429	2134	607

DATE : 23 - 1 - 83.





T A B L E : 4

CONCENTRATION OF EOM AND CHROMATOGRAPHIC FRACTIONS  
(mg/s TOC)

I	:	:	:	:	:	:	:	:	Non	I				
I	IKU-No	:	DEPTH	:	EOM	:	Sat.	:	HC	HC	I			
I	:	:	:	:	:	:	:	:	:	:	I			
I	:	:	(m)	:	:	:	:	:	:	:	I			
I	:	:	:	:	:	:	:	:	:	:	I			
I	A 1113	:	3073.00-	:	502.7	:	328.4	:	134.1	:	462.5	:	40.2	I
I		:	3073.10	:		:		:		:		:		I
I	A 1114	:	3073.90-	:	1316.4	:	801.8	:	227.8	:	1029.6	:	286.8	I
I		:	3074.00	:		:		:		:		:		I
I	A 1115	:	3077.00-	:	1424.5	:	985.8	:	285.7	:	1271.5	:	153.0	I
I		:	3077.10	:		:		:		:		:		I
I	A 1116	:	3120.90-	:	596.0	:	370.6	:	93.3	:	463.9	:	132.0	I
I		:	3121.00	:		:		:		:		:		I

DATE : 23 - 1 - 83.



T A B L E : 5

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 1113	3073.00- 3073.10	65.3	26.7	92.0	245.0	8.0	1150.0
A 1114	3073.90- 3074.00	60.9	17.3	78.2	351.9	21.8	359.0
A 1115	3077.00- 3077.10	69.2	20.1	89.3	345.1	10.7	830.8
A 1116	3120.90- 3121.00	62.2	15.7	77.8	397.3	22.2	351.4

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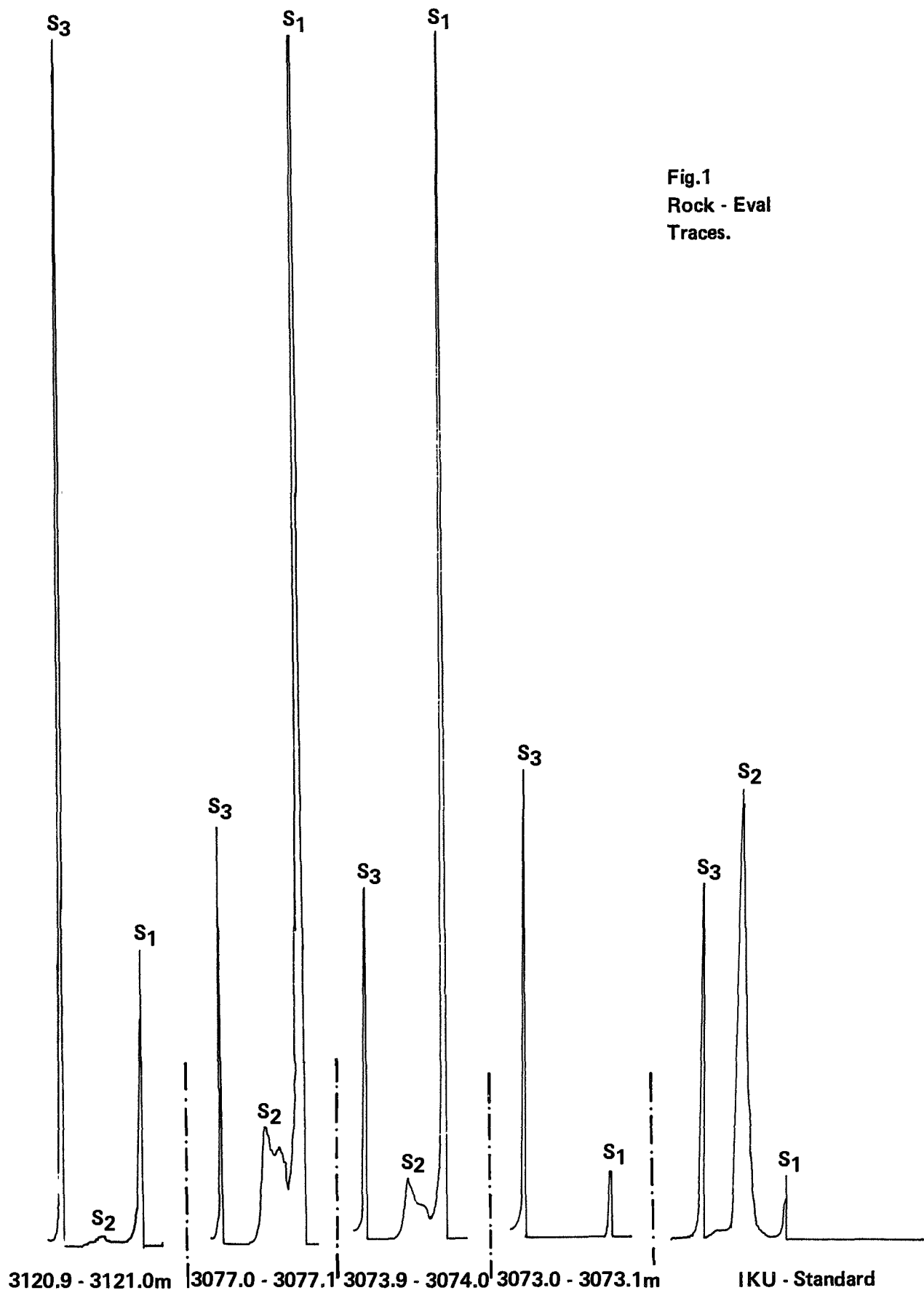


Fig.1  
Rock - Eval  
Traces.

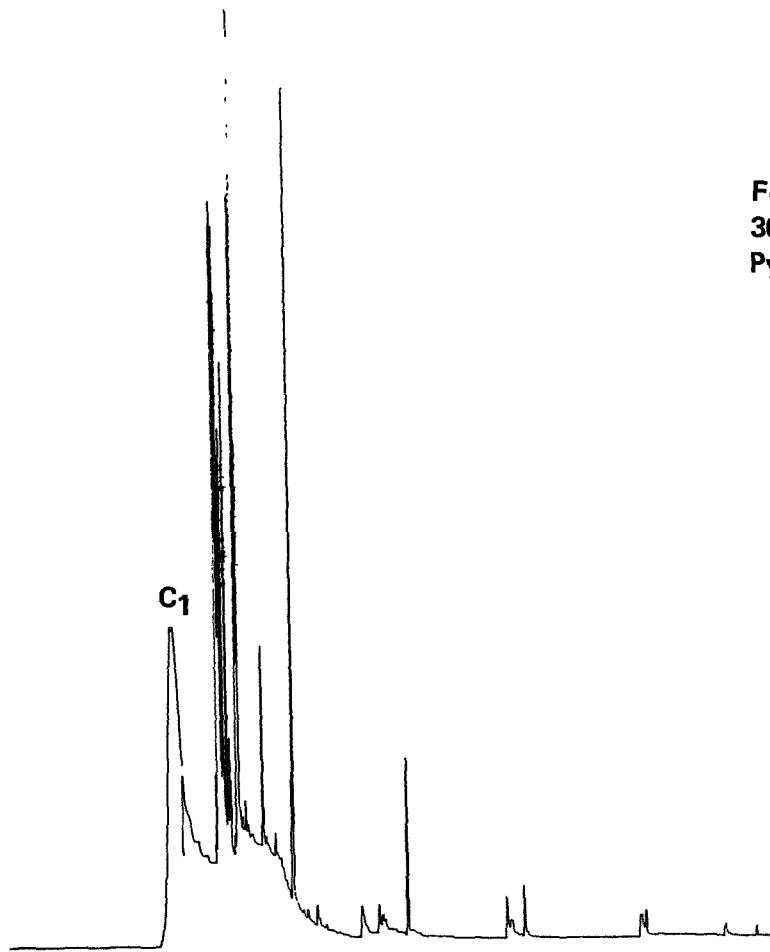


Fig. 3.  
3073.0 - 3073.1m  
Pyrolyses GC

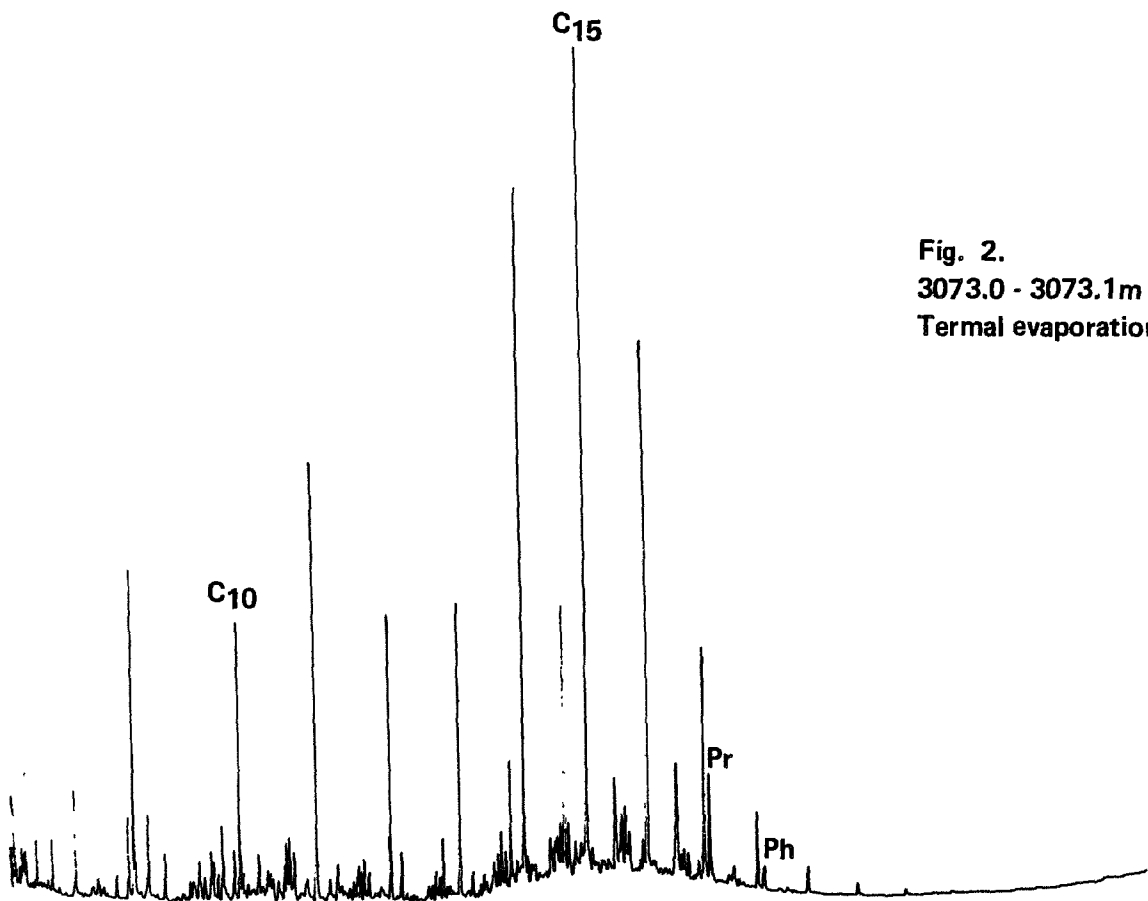


Fig. 2.  
3073.0 - 3073.1m  
Termal evaporation

Fig. 5  
3073.9 - 3074.0m  
Pyrolyses GC

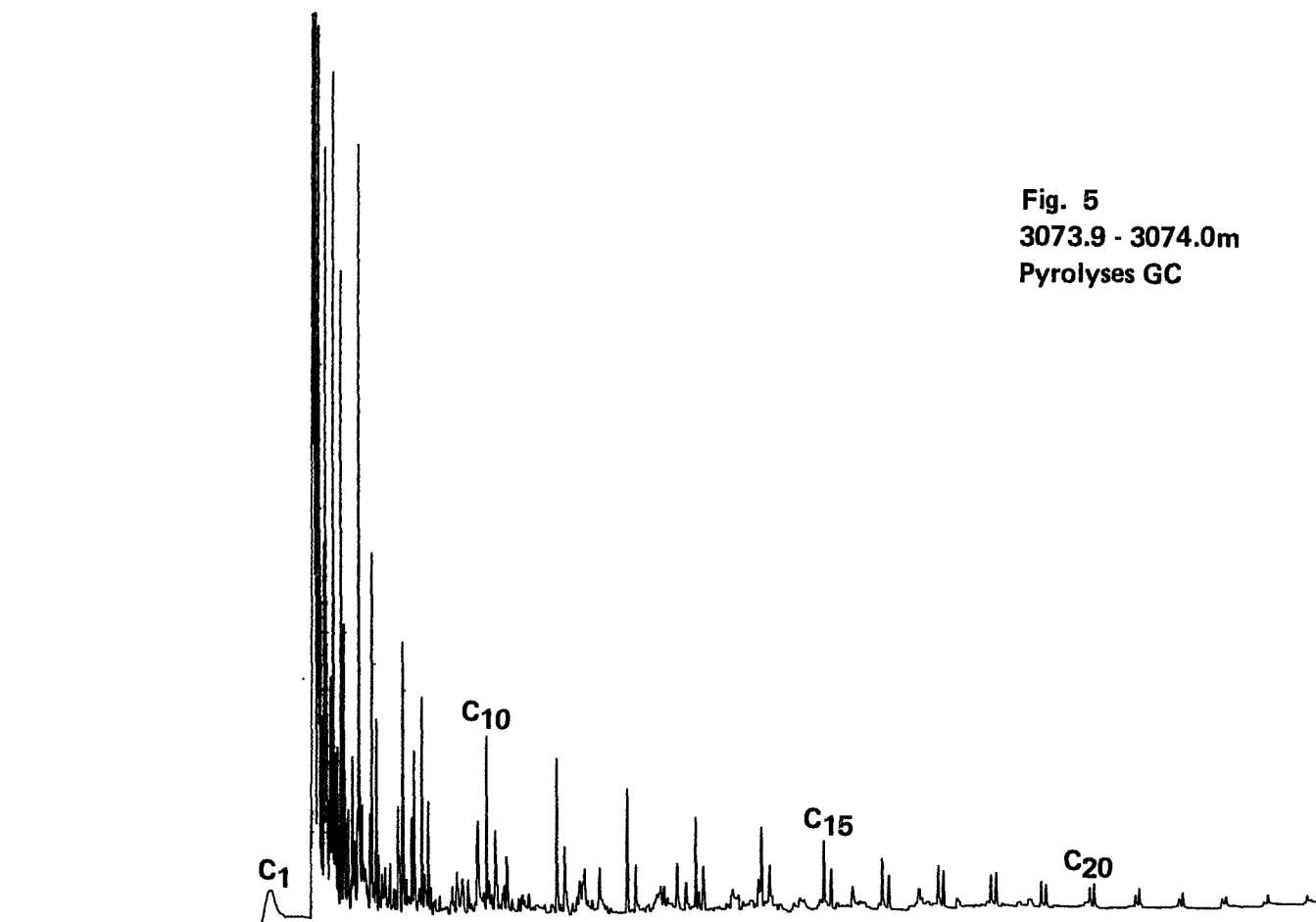


Fig. 4  
3073.9 - 3074.0m  
Thermal evaporation

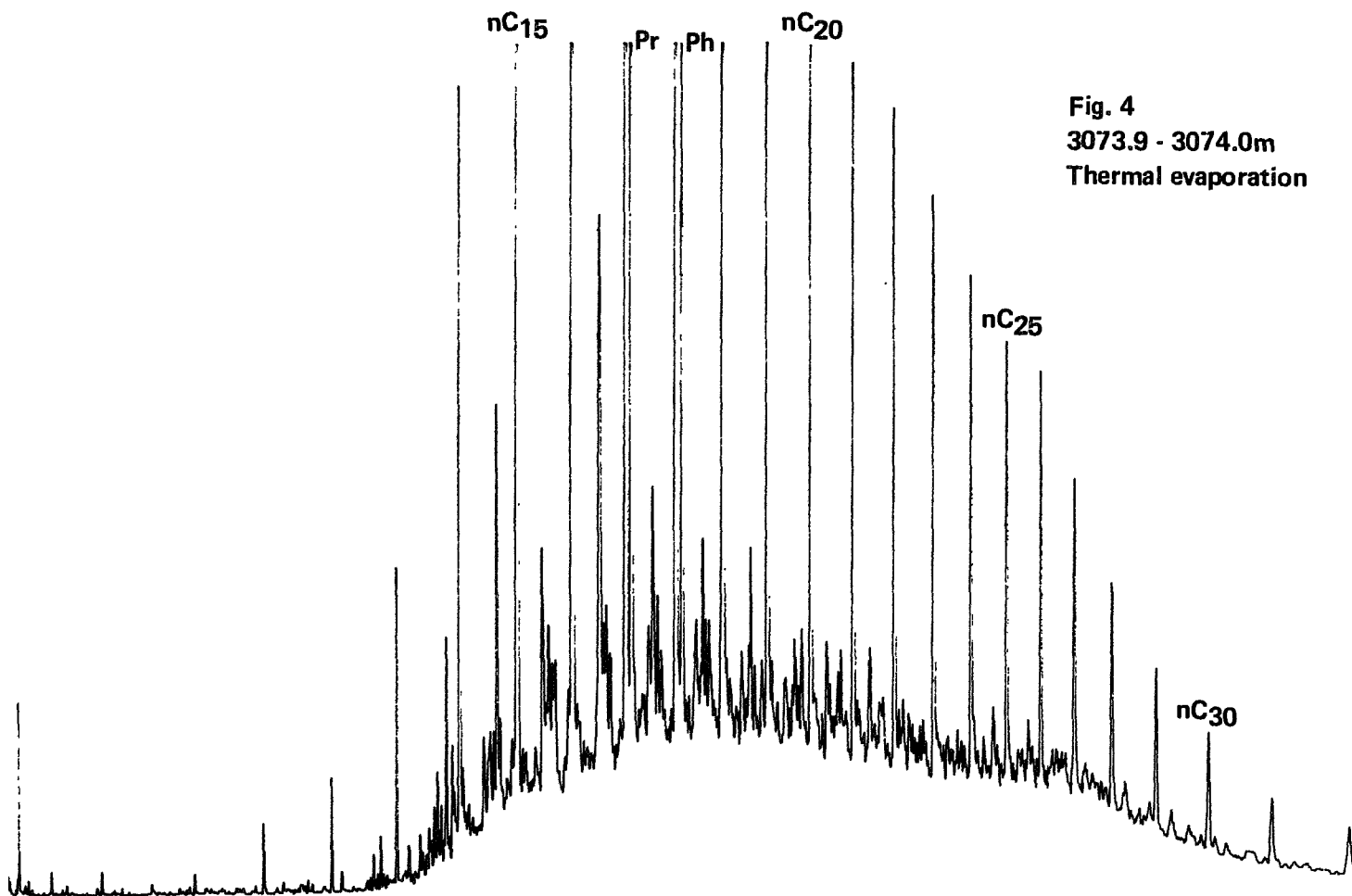


Fig. 7.  
3077.0 - 3077.1m  
Pyrolyses GC

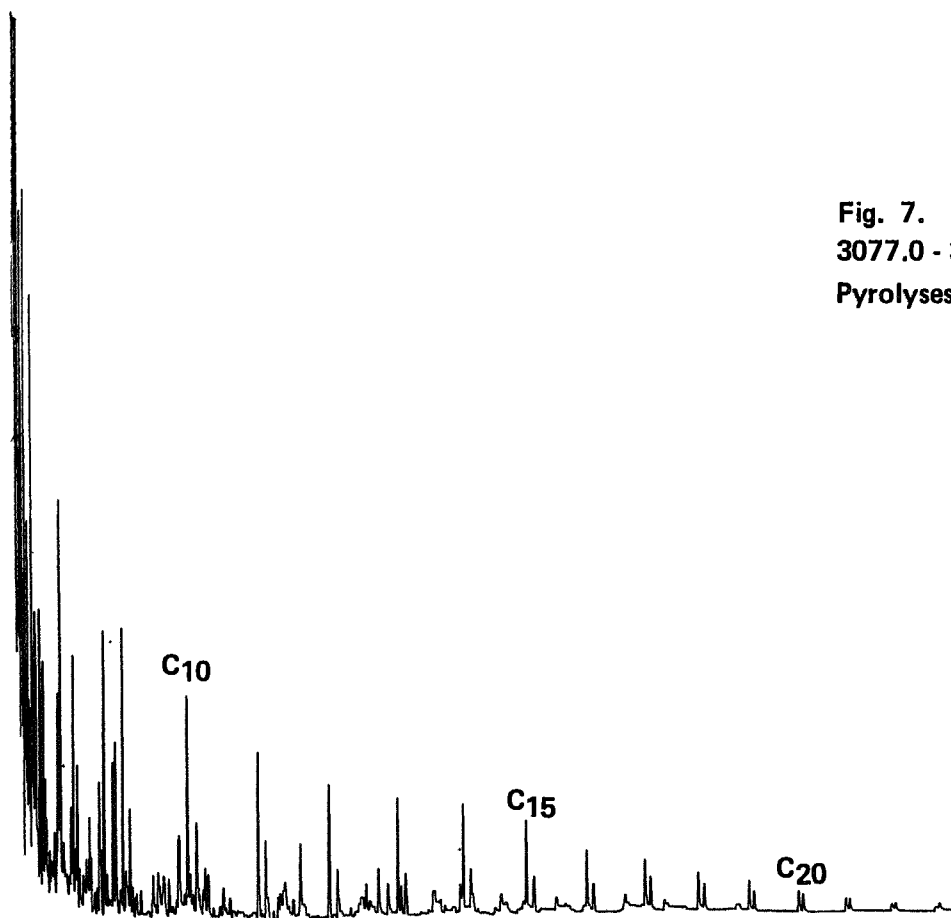
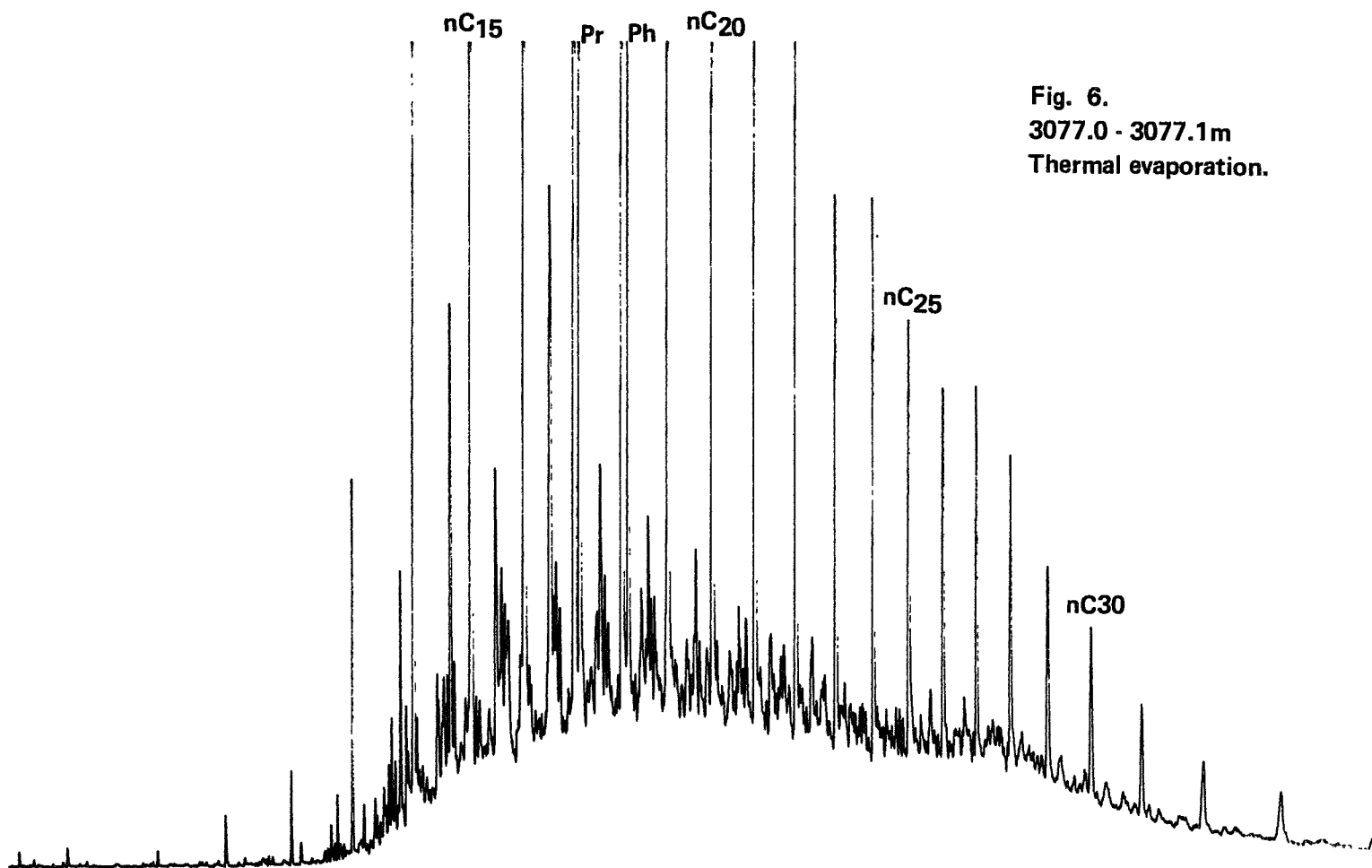


Fig. 6.  
3077.0 - 3077.1m  
Thermal evaporation.



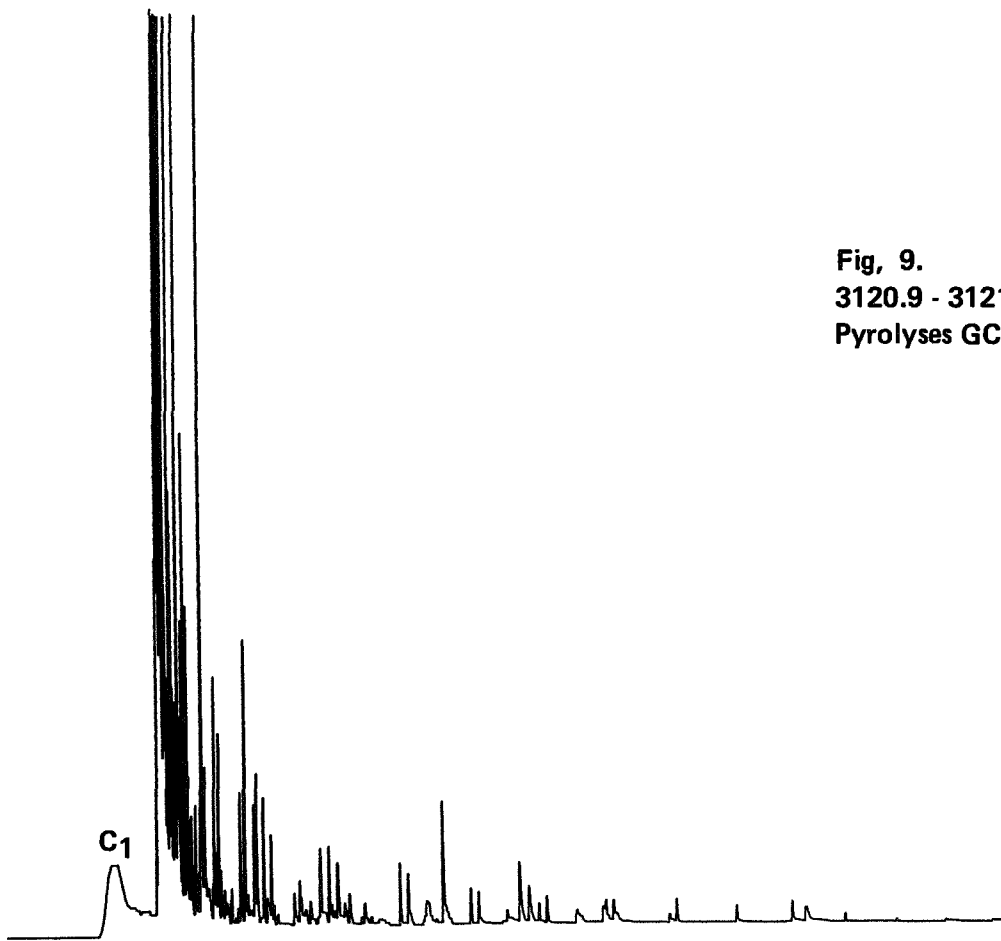


Fig. 9.  
3120.9 - 3121.0m  
Pyrolyses GC

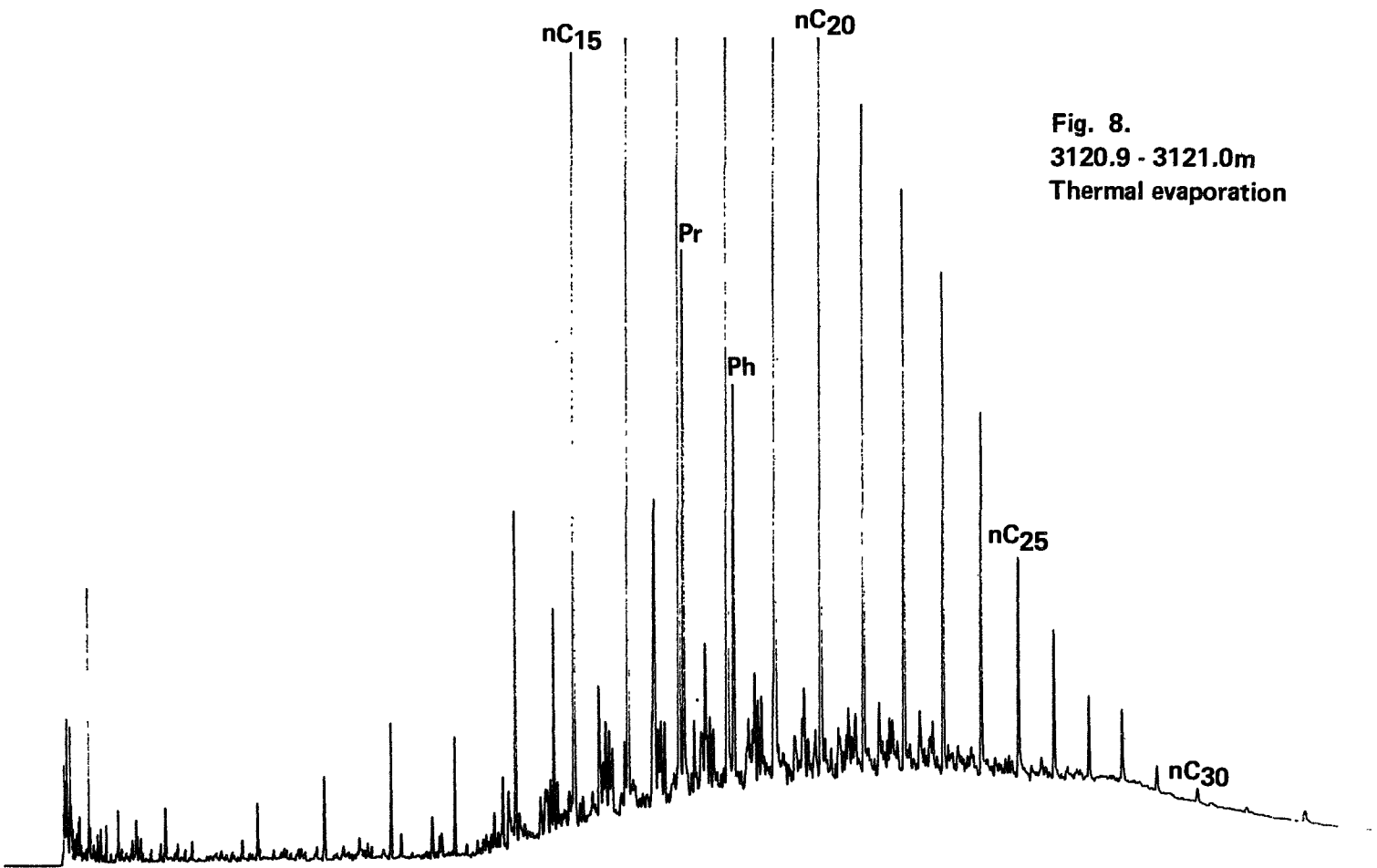


Fig. 8.  
3120.9 - 3121.0m  
Thermal evaporation

Analysis : 050705T0ILS1 Sample #: 1 Injection #: 1  
Sample Name : A-1113,S,30/6-2,TY Maximum value : 6357

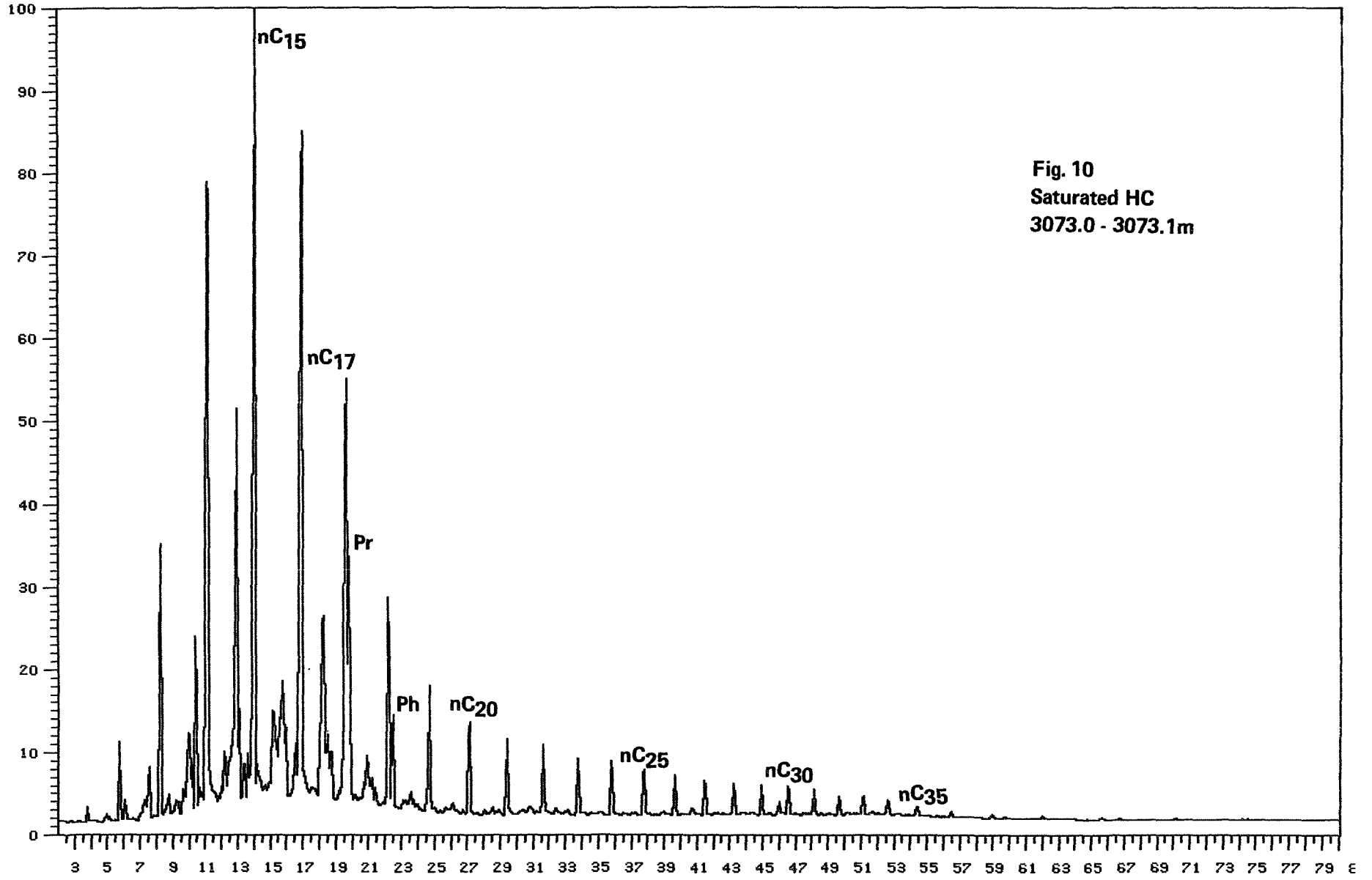


Fig. 10  
Saturated HC  
3073.0 - 3073.1m



Analysis : 05070STOILS1 Sample #: 2 Injection #: 1  
Sample Name : R-1114,S,30/6-2,TV Maximum value : 3791

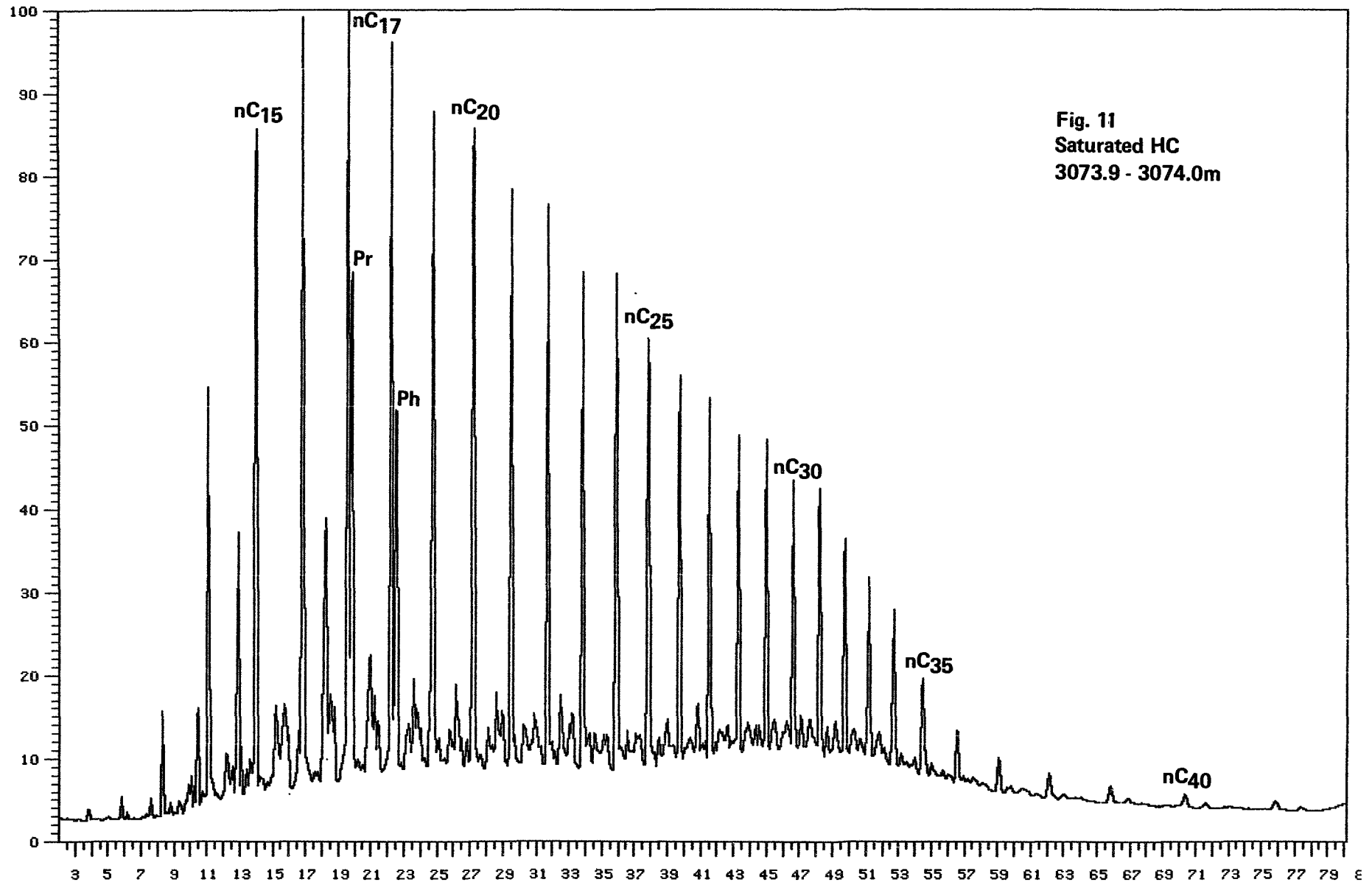


Fig. 11  
Saturated HC  
3073.9 - 3074.0m

Analysis : 05070ST0ILS1 Sample #: 3 Injection #: 1  
Sample Name : R-11115,S,30/6-2,TV Maximum value : 4058

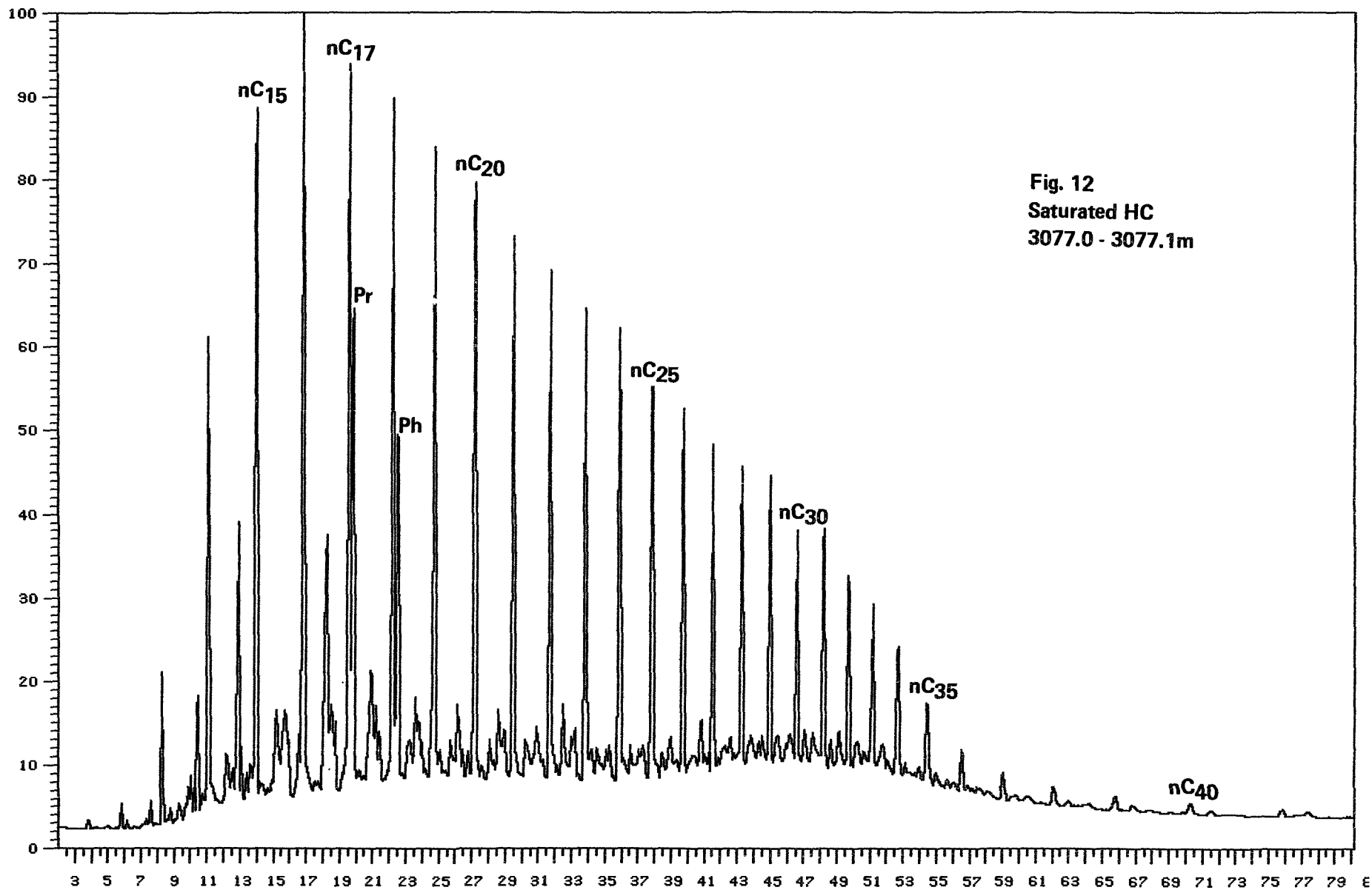


Fig. 12  
Saturated HC  
3077.0 - 3077.1m

Analysis : 05070STOILS2 Sample #: 1 Injection #: 1  
Sample Name : R-1116,S,30/6-2,TY Maximum value : 3796

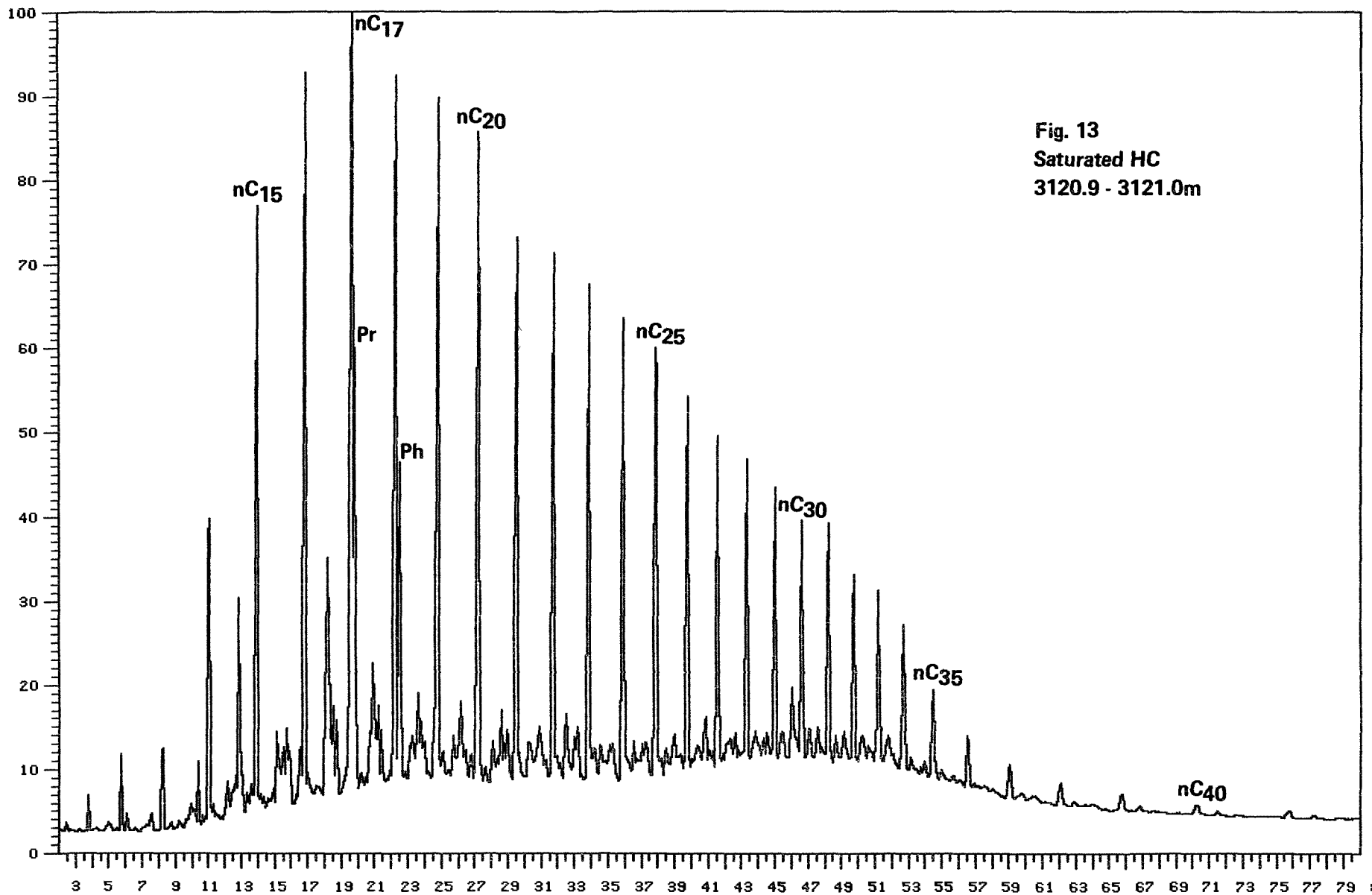
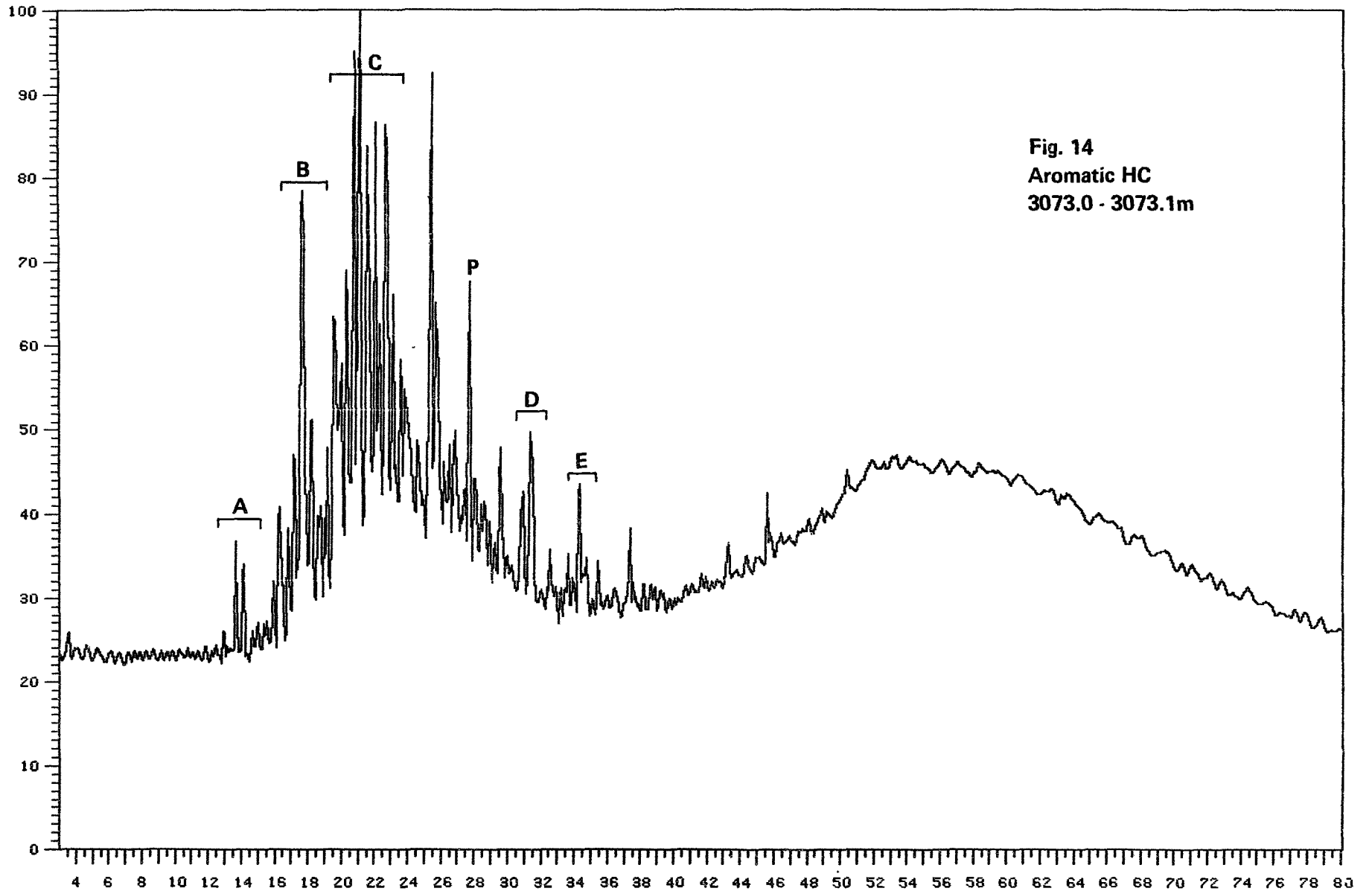


Fig. 13  
Saturated HC  
3120.9 - 3121.0m

Analysis : 05070A1113A2 Sample #: 1 Injection #: 1  
Sample Name : A-1113, A, 30/6-2, TV Maximum value : 301



Analysis : 05070R1114R1 Sample #: 1 Injection #: 1  
Sample Name : A-1114, A, 30/6-2, TV Maximum value : 366

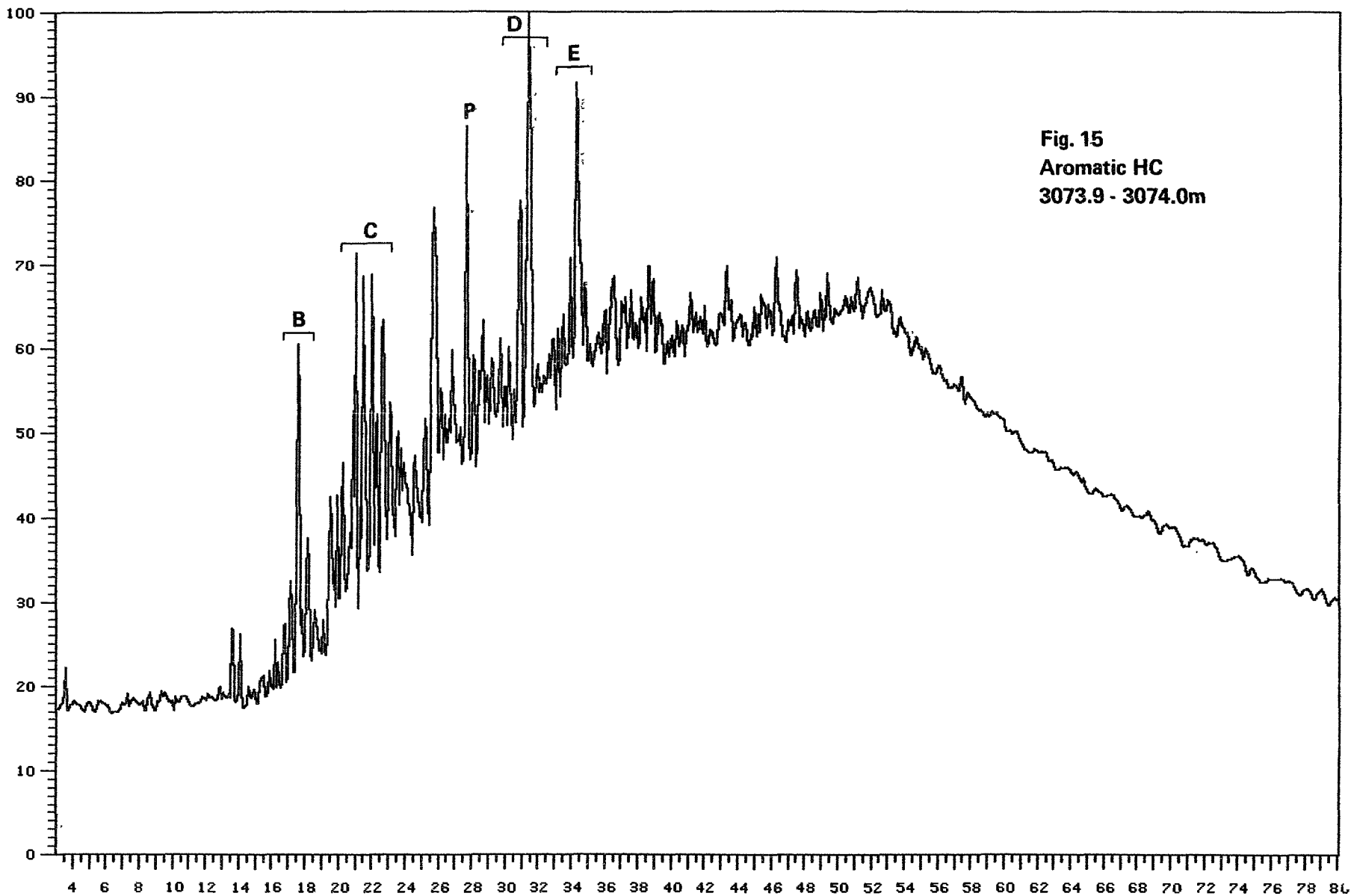


Fig. 15  
Aromatic HC  
3073.9 - 3074.0m

Analysis : 05070STOILR1 Sample #: 2 Injection #: 1

Sample Name : R-1115,R,30/6-2,TY

Maximum value : 754

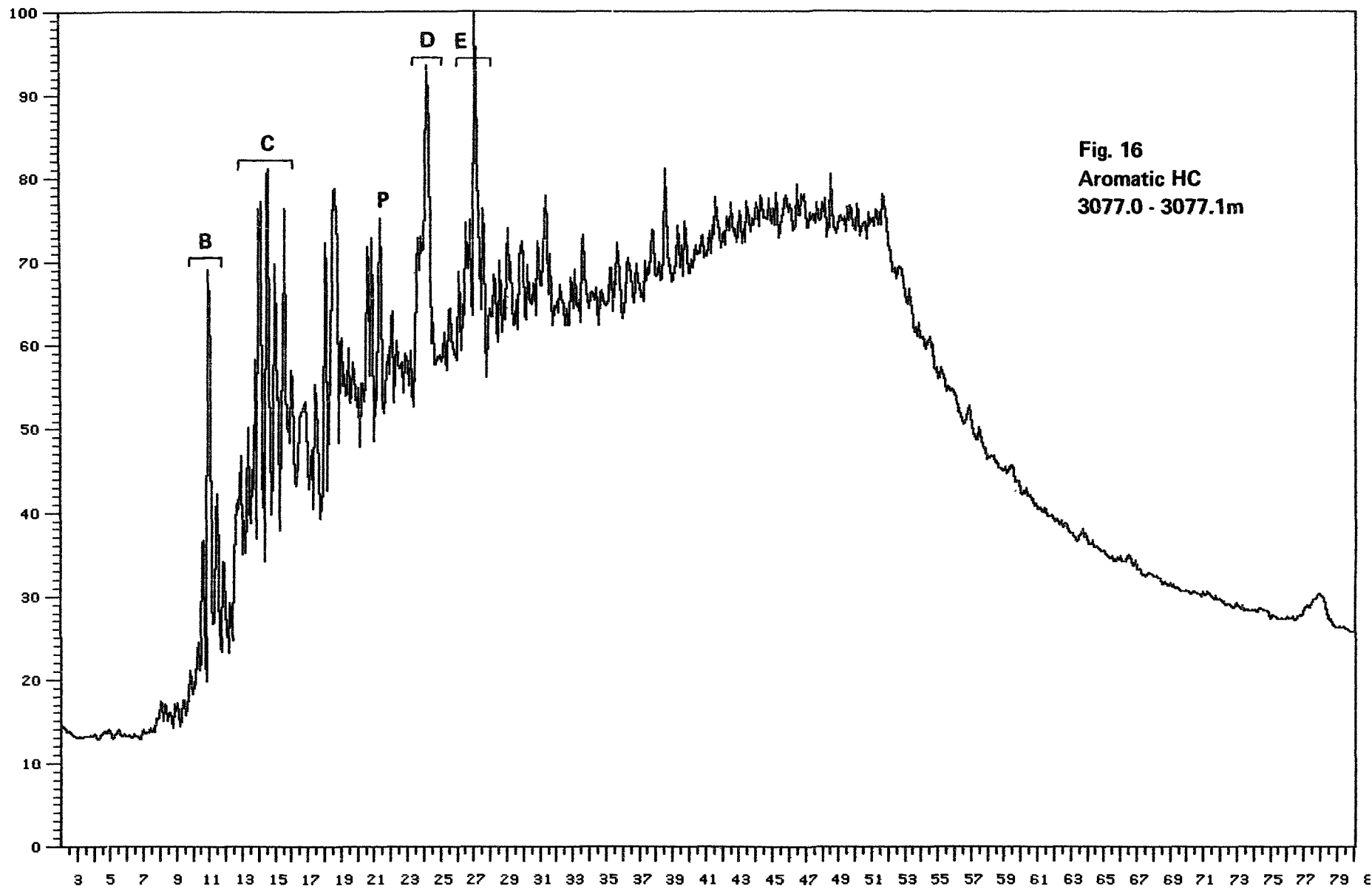


Fig. 16  
Aromatic HC  
3077.0 - 3077.1m

Analysis : 05070R1116R1 Sample #: 1 Injection #: 1  
Sample Name : R-1116,R,30/6-2.TV Maximum value : 316

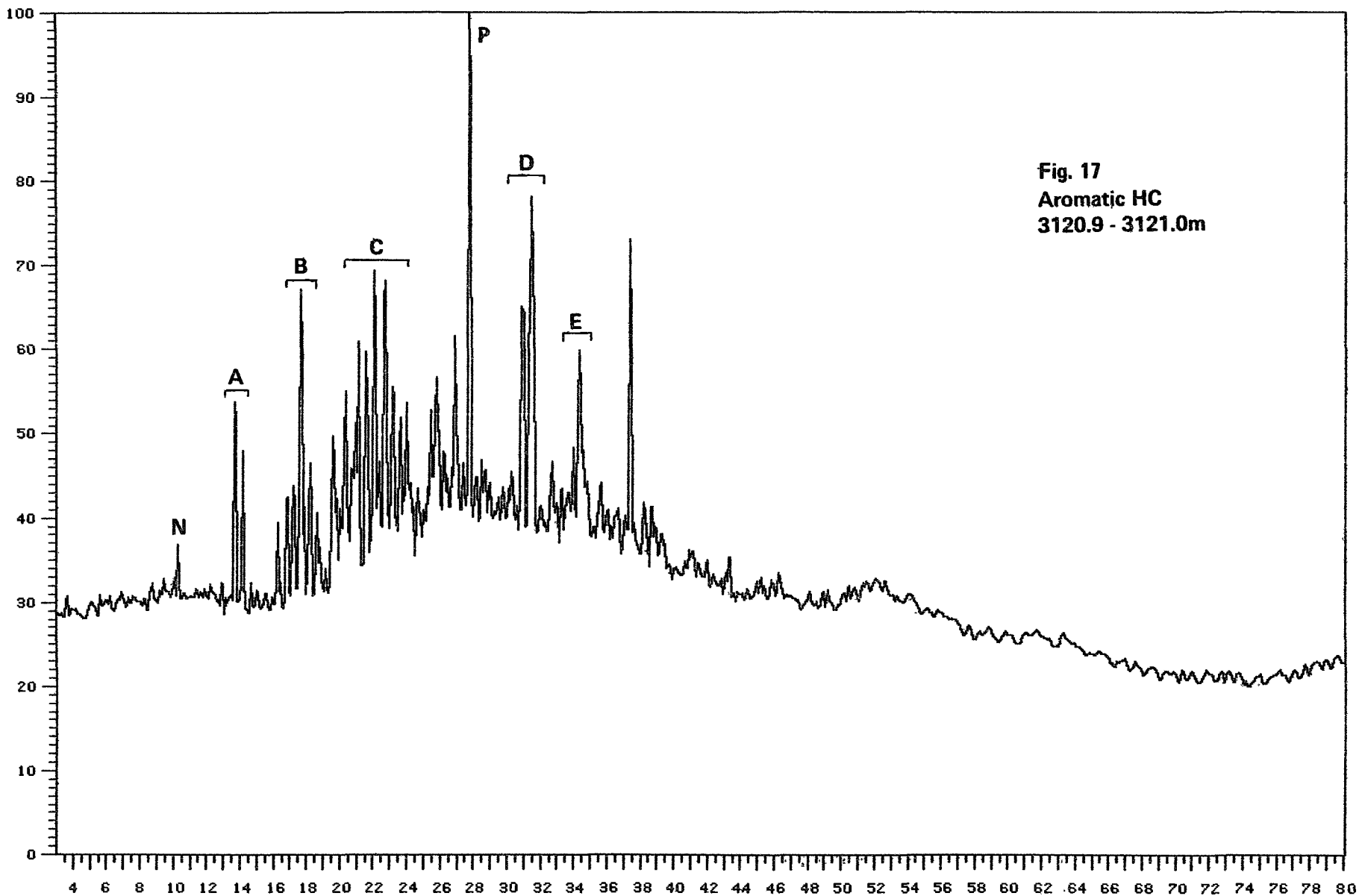


Fig. 17  
Aromatic HC  
3120.9 - 3121.0m