1022

"HYDROCARBON SOURCE ROCK
EVALUATION STUDY
LINDON No 1"

LINDON#1
Hydrocarbon Source Rock
Evaluation study.
(W841)

ANALABS
A Division of Macdonald Hamilton & Co. Pty. Ltd.

OIL AND GAS DIVISION

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PETROLEUM GEOCHEMISTRY

HYDROCARBON SOURCE ROCK

EVALUATION STUDY

LINDON NO. 1

Prepared for

BP DEVELOPMENT AUSTRALIA PTY. LTD.

FEBRUARY 1985

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HYDROCARBON SOURCE ROCK

EVALUATION STUDY

LINDON NO. 1

SUMMARY

Organic geochemical analyses performed on thirty-three (33) cutting samples between 1310 to 2880m, in the Lindon No. 1 well, drilled in PEP-105, onshore Victoria, in the Otway Basin have indicated the following:

- Based on Tmax pyrolysis temperatures, marginal/moderately mature sediments in the early stages of hydrocarbon generation, extend from 1340 to 2500m. From 2650 to 2880m, the samples analysed are considered to have mature temperatures, and to be within the oil window. The rocks towards the bottom of the well, below 2830m may be approaching very mature maturation levels.

- The samples analysed from this well are from the Lower Cretaceous Eumeralla formation, and the results indicate the unit is comprised of five facies, with the following analytical properties:

Facies	TOC	S1	S1+S2	HI	C15-C31 alkene+alkane S2%
1310-1930	0.64	0.14	1.34	100	-
1950-2300	3.43	1.38	10.56	135	1.48
2330-2350	25.14	5.85	94.66	309	11.43
2380-2500	1.30	0.41	2.08	127	-
2650-2880	10.50	3.95	32.22	220	5.72

- The rocks between 1310 to 1930m and 2380-2500m have marginal to at best moderate hydrocarbon source rock characteristics.

- At the top of the interval 1950 to 2300m, the sediments have very good gas/condensate source rock characteristics. The remaining samples have marginal source capability.

- The interval 2330 to 2350m contains extremely rich, oil-prone source rocks, that are interpreted to have excellent oil and gas generating potential, at optimum maturities.

- Between 2650 to 2880m all the samples have favourable organic richness and high pyrolysis yields. Pyrolysis gas chromatography analysis of the coaly sediments between 2650 to 2740m indicate they are oil and gas

prone, and at their mature maturation levels, are probably actively generating and expelling oil and gas. The coaly rocks at 2830m and 2880m, based on pyrolysis gas chromatography are more prone to generate a light oil, gas/condensate petroleum product. This could be due to the quality of the organic deteriorating in the lower portion of the well, or the sediments are becoming post mature for oil generation.

INTRODUCTION

Organic geochemical analyses have been performed on thirty-three (33) cutting samples between 1310 to 2880m in the Lindon No. 1 well, drilled in PEP-105 onshore Victoria, in the Otway Basin.

The purpose of the study has been to evaluate the source richness, quality (oil vs gas) and state of thermal maturity of the sediments penetrated in this well.

Analytical

The samples from this well were assigned the Analabs Job Number 36896. Initially twenty-five (25) cutting samples were sent for analysis. Eight of these were found to contain coaly/carbonaceous shale, and were high graded through picking. These eight picked samples, and the twenty-five unpicked samples were then submitted to % total organic carbon determination. Based on these results, those samples containing greater than 1.00% TOC were selected for Rock-Eval pyrolysis. All eight picked lithologies were submitted to pyrolysis-gas chromatography.

The results of these analyses may be found in the following list of Figures and Tables:

Type of Analysis	Figure	Table
% total organic carbon determination	1	1
Rock-Eval pyrolysis analysis	1	1
Pyrolysis gas chromatography	2	2,3,4

A description of these analyses is provided in the back of this report in the Theory and Methods section.

General Information

Copies of this report have been sent to Mr. Bill Hewitt of BP Development Australia Pty. Ltd., located in Melbourne, Victoria. Any questions related to this study may be directed to either Paul Tybor or Garry Woodhouse of Analabs in Perth, Western Australia.

All data and interpretations given herein are proprietary to BP Development Australia Pty. Ltd., and are treated as highly confidential material by all Analabs personnel.

DISCUSSION OF THE RESULTS

A. Thermal Maturity of Sediments

Based on Tmax pyrolysis temperatures, the thermal maturity of the sediments penetrated by this well range from a marginally mature 431 Deg. C at 1340m, to a mature 444 Deg. C at 2880m.

Marginal/moderately mature sediments extend from 1340 to 2500m, where temperatures are less than 440 Deg. C. These rocks are interpreted to be in the early stages of oil and gas generation. From 2650 to 2880m, the temperature values are all above 440 Deg. C, but less than 460 Deg. C. This temperature range is interpreted to correspond to the oil window. These mature sediments below 2650m, have experienced sufficient time and temperature to have actively generated and expelled oil and gas.

B. Hydrocarbon Source Character

The samples analysed from this well are from the Lower Cretaceous Eumeralla formation. The TOC and pyrolysis results obtained from this study divided the interval between 1310 to 2880m into five organic facies.

Facies	% TOC	S_1 mg/g	S_1+S_2 mg/g	Hydrogen Index	C_{15}-C_{31} alkene+alkane abundance (% of S2)
1310-1930	0.43-1.20 0.64 mean	0.14	1.34	100	no data
1950-2300	0.83-17.94 3.43 mean	0.23-4.64 1.38 mean	1.50-37.14 10.56 mean	106-181 135 mean	1.48
2330-2350	5.26-47.04 25.14 mean	1.11-10.84 5.85 mean	12.15-178.69 94.66 mean	209-372 309 mean	10.84-12.02 11.43 mean
2380-2500	1.18-1.43 1.30 mean	0.35-0.48 0.41 mean	1.86-2.31 2.08 mean	127-127 127 mean	no data
2650-2880	1.37-32.75 10.50mean	0.51-11.60 3.95 mean	3.19-112.92 32.22 mean	150-320 220 mean	2.67-7.98 5.72 mean

The high values are from the picked coaly lithologies. In the intervals 1310 to 1920m and 2380 to 2500m carbonaceous sediments were not analysed. Based on the marginal to moderate potential yields (S_1+S_2; Figure 1; Table 1) recovered, these sediments have marginal oil and gas source rock characteristics. Pyrolysis gas chromatography was not performed on samples from these two facies, and comments concerning the quality of the organic matter in these rocks are limited to hydrogen index (Figure 1; Table 1). The values range from 100 to 127 and suggest the bulk of hydrocarbon generated would be gas or condensate.

The first facies in which carbonaceous sediments were analysed are in the 1950 to 2300m interval. Here, the 1950m sample contains excellent organic richness (% TOC), and produced excellent pyrolysis yields (S_1+S_2). The pyrolysis gas chromatographic analysis of the sample indicates the hydrocarbon generated would be mainly gas/condensate (Figure 2-1), with very little oil associated. The low percentage of C_{15}-C_{31} alkenes + alkanes in the S_2 yield (1.48%; Table 3-1) illustrates the poor oil potential of these sediments. Normally oil-prone rocks that are not post mature have greater than 5% C_{15}-C_{31} alkenes + alkanes comprising the S_2 yield. The remaining rocks from this facies have moderate to good organic richness, but produced only marginal potential yields. As a result, the sediments within the 1950 to 2300m are not considered to have significant hydrocarbon generating capability. The coaly sequence at the top of the interval has significant gas/condensate source rock characteristics, but very little oil potential.

The twenty metre interval between 2330 to 2350m contains extremely organic rich, oil-prone source rocks, and are interpreted to have excellent oil and gas generating potential, at optimum maturities. The picked coaly lithologies at 2330 and 2350m contain 47% and 42% total organic carbon, with both samples producing extremely high pyrolysis yields. The hydrogen indices are over 350 for each sample, and the pyrolysis gc traces exhibit normal alkene/alkane pairing well beyond the C_{15} carbon compounds. The C_{15}-C_{31} alkenes + alkanes S_2 percentages are 12.02% and 10.84%, and are indicative of a very oil-prone organic matter. The bulk samples from 2330 and 2350m are certainly not as rich as the concentrated coaly lithologies, however the sediments are still very organic rich and considered to have significant oil source potential. In summary, the rocks between 2330 to 2350m have excellent oil and gas source potential. Presently, these sediments have generated significant amounts of petroleum, however, it is questionable as to how much hydrocarbon has been expelled at the marginal/moderate maturation levels interpreted to be present at these depths. More mature equivalents could be expected to have expelled significant quantities of petroleum.

Between 2650 to 2880m all the samples analysed contain favourable organic richness. The pyrolysis yields are high, with the picked lithologies providing the highest values. The hydrogen indices of the coaly sediments are greater than 200 and suggest the presence of an oil prone organic matter. Pyrolysis gas chromatography analysis of samples 2650, 2730 and 2740m show the normal alkenes/alkanes extending well into the high molecular weight carbon compounds, and confirms their oil proneness. The two lower samples at 2830 and 2880m do not contain as many high molecular weight normal alkene/alkane pairs as the overlying samples. This suggests the upper portion of the facies is oil and gas prone, while the lower portion tends more to be a gas and or condensate source. Either differences in thermal maturity, or source material could be the reason for the decline in oil proneness with depth. Without the benefit of kerogen or maceral data, we are unable to determine if the quality of the organic matter in the bottom of the facies is any different to that of the top. However, there does seem to be a relationship with depth between an increase in Tmax temperatures and a decrease in the C_{15}-C_{31} alkene+alkane S_2, as shown by the following:

Depth (m)	Tmax (Deg C)	C15-C31 alkene/alkane S2%	Interpreted Maturity	Generating Capability
1950	428	1.48	Immature	Gas/Cond.
2330	436	12.02	Moderate	Early oil & gas
2350	442	10.84	Mature	Early oil & gas
2650	445	7.37	Mature	Oil and gas
2730	443	7.98	Mature	Oil and gas
2740	444	7.17	Mature	Oil and gas
2830	447	3.41	Mature-?V.Mature	?Light oil & gas
2880	449	2.67	Mature-?V.Mature	?Light oil & gas

The above data would indicate the lowermost sediments have experienced a higher geothermal history than the rocks between 2330 to 2740m, and consequently are approaching post oil maturities. However, additional maturity and maceral data are required before this can be established.

In summary, the coaly rocks between 2330 to 2350m have the greatest potential of all samples analysed in this study to source oil and gas, but probably require additional maturation. The coals analysed between 2650 to 2740m are not as organic rich as the overlying sediments between 2330 to 2350m, but are more mature. Consequently, these organic rich rocks may have generated and expelled more petroleum. The rich sediments between 2830 to 2880m have either undergone more maturity than the overlying rocks, or else the quality of organic matter is poorer. Regardless of which is responsible, these deeper organic rich rocks are prone to generate light oil and gas.

PE907702

This is an enclosure indicator page.
The enclosure PE907702 is enclosed within the container PE907701 at this location in this document.

The enclosure PE907702 has the following characteristics:

ITEM_BARCODE = PE907702
CONTAINER_BARCODE = PE907701
NAME = Hydrocarbon Source Rock Evaluation
BASIN = GIPPSLAND
PERMIT = VIC/P1
TYPE = WELL
SUBTYPE = DIAGRAM
DESCRIPTION = Hydrocarbon Source Rock Evaluation ANA_Log (enclosure from Hydrocarbon Source Rock Evaluation Study), for Lindon-1

REMARKS =
DATE_CREATED = 31/01/85
DATE_RECEIVED =
W_NO = W841
WELL_NAME = LINDON-1
CONTRACTOR =
CLIENT_OP_CO = BHP PETROLEUM DEVELOPMENT

(Inserted by DNRE - Vic Govt Mines Dept)

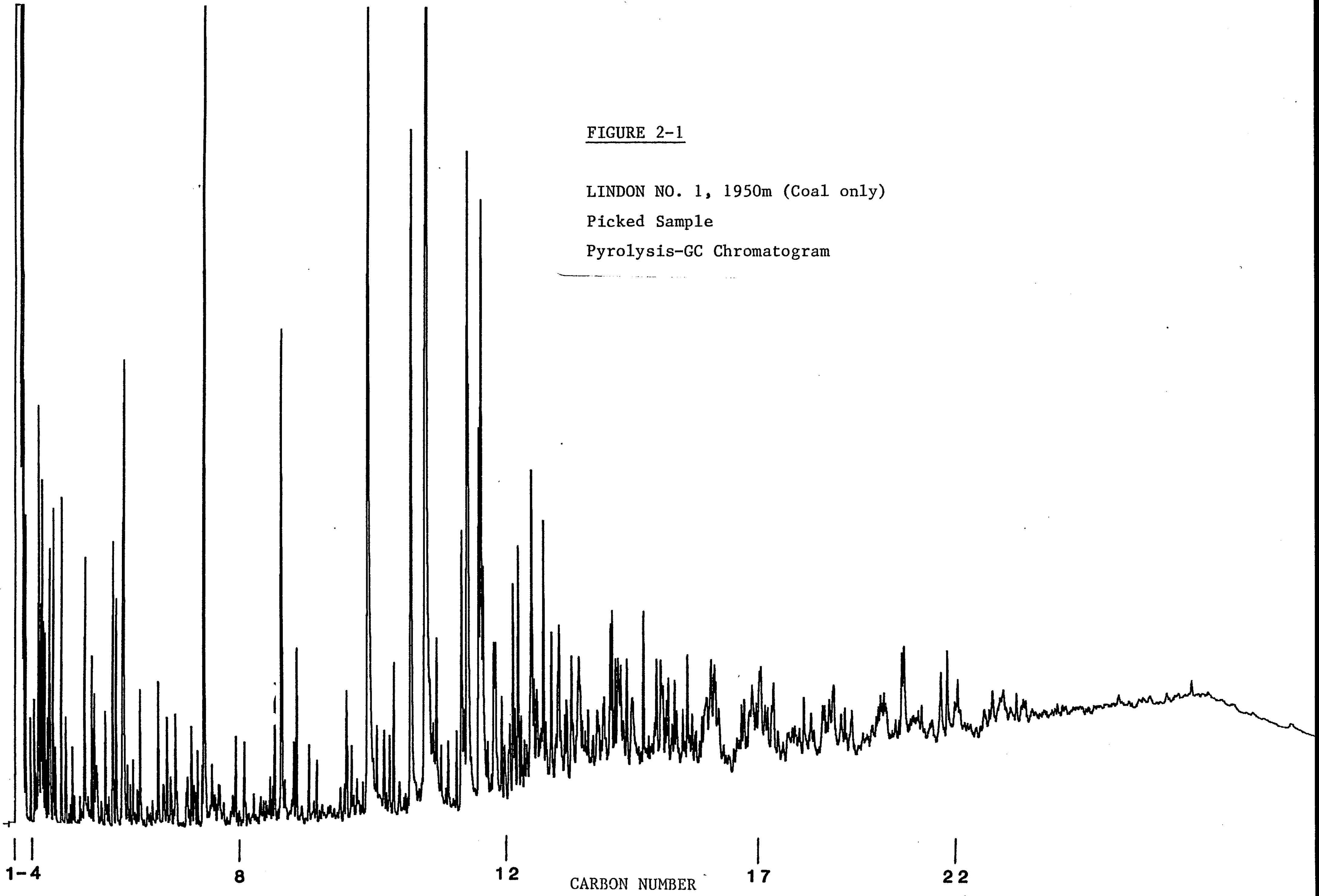


FIGURE 2-1

LINDON NO. 1, 1950m (Coal only)
Picked Sample
Pyrolysis-GC Chromatogram

FIGURE 2-2

LINDON NO. 1, 2330m (Coal only)
Picked Sample
Pyrolysis-GC Chromatogram

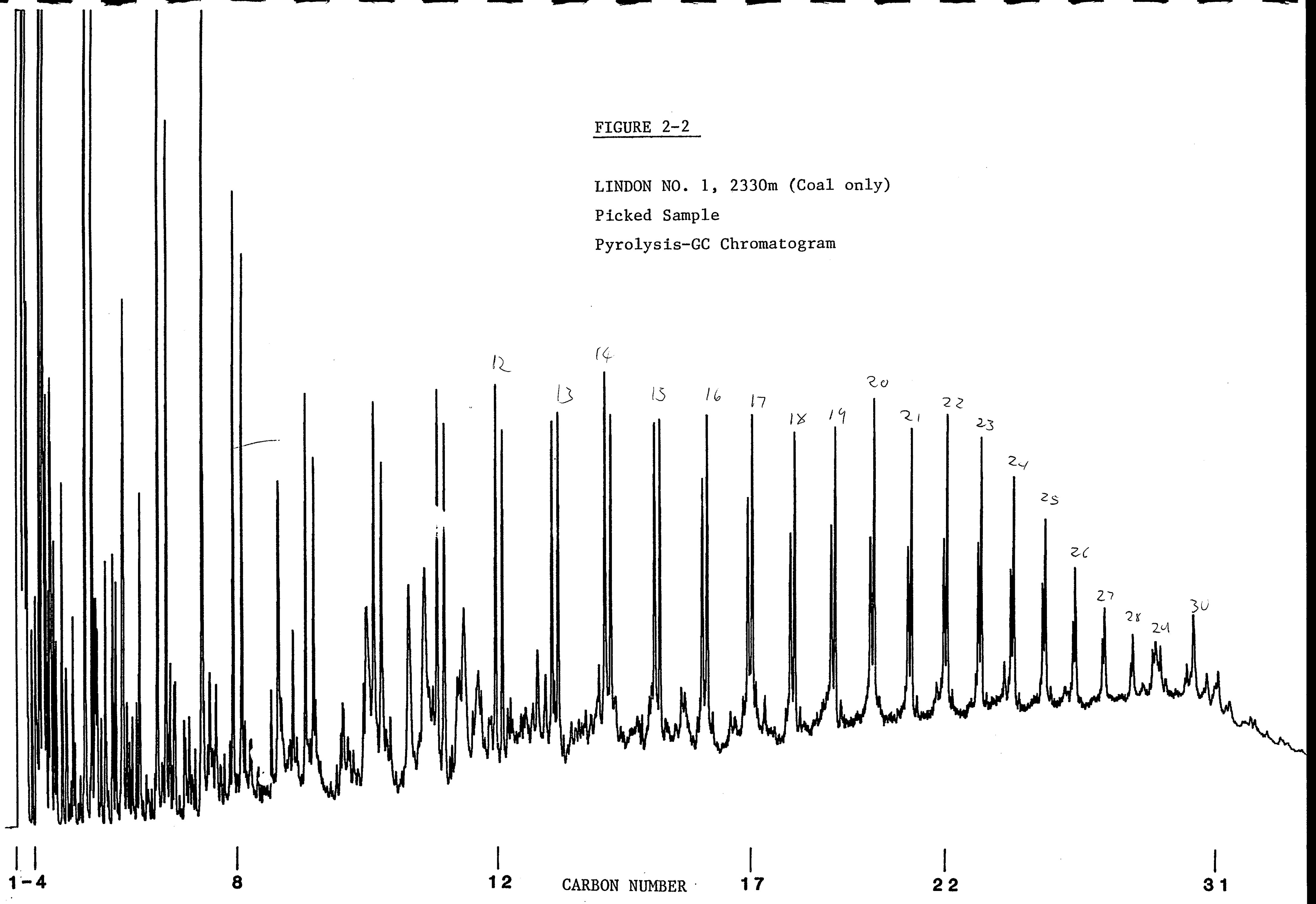


FIGURE 2-4

LINDON NO. 1, 2650m (Coal only)
Picked Sample
Pyrolysis-GC Chromatogram

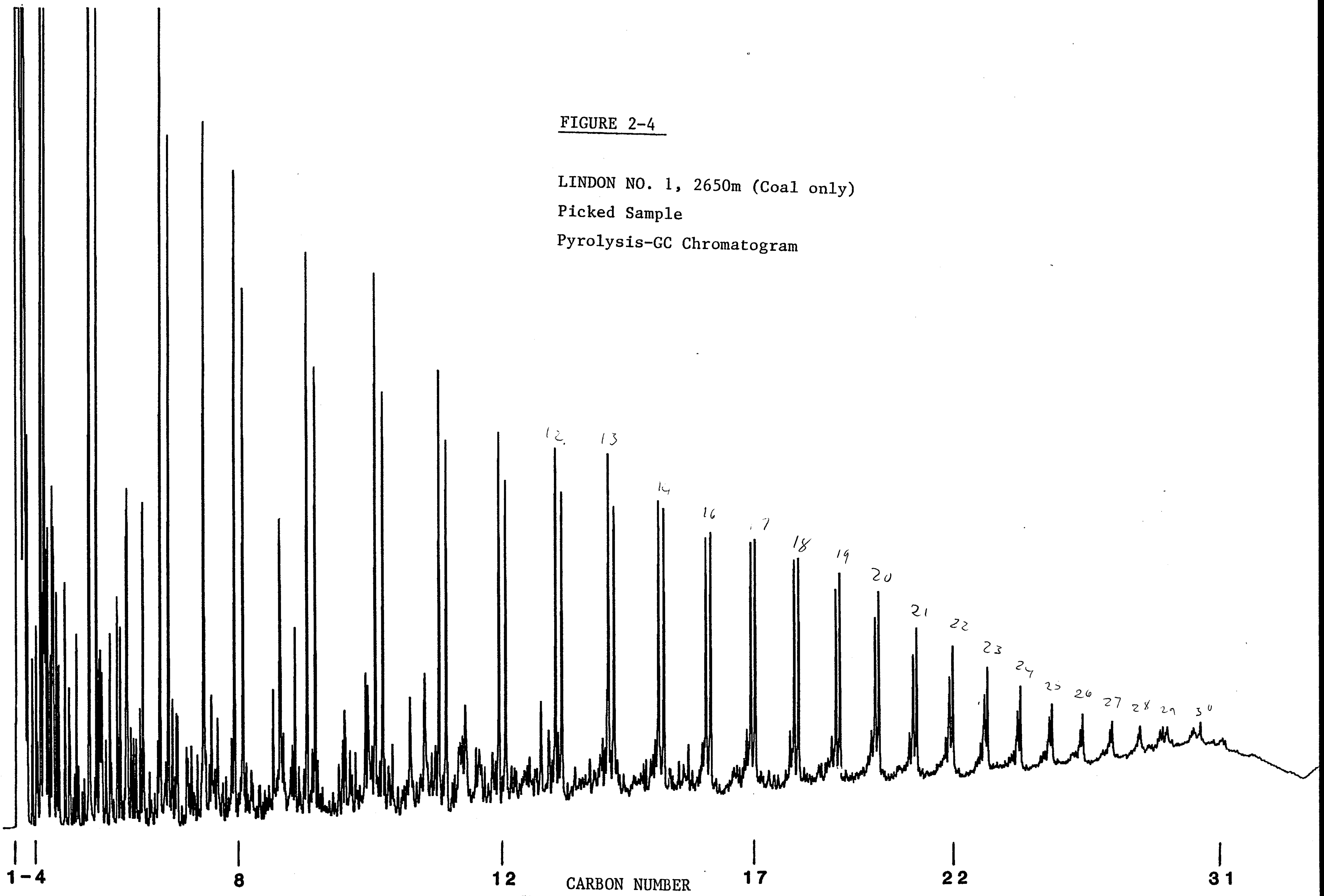


FIGURE 2-5

LINDON NO. 1, 2730m (Coal only)
Picked Sample
Pyrolysis-GC Chromatogram

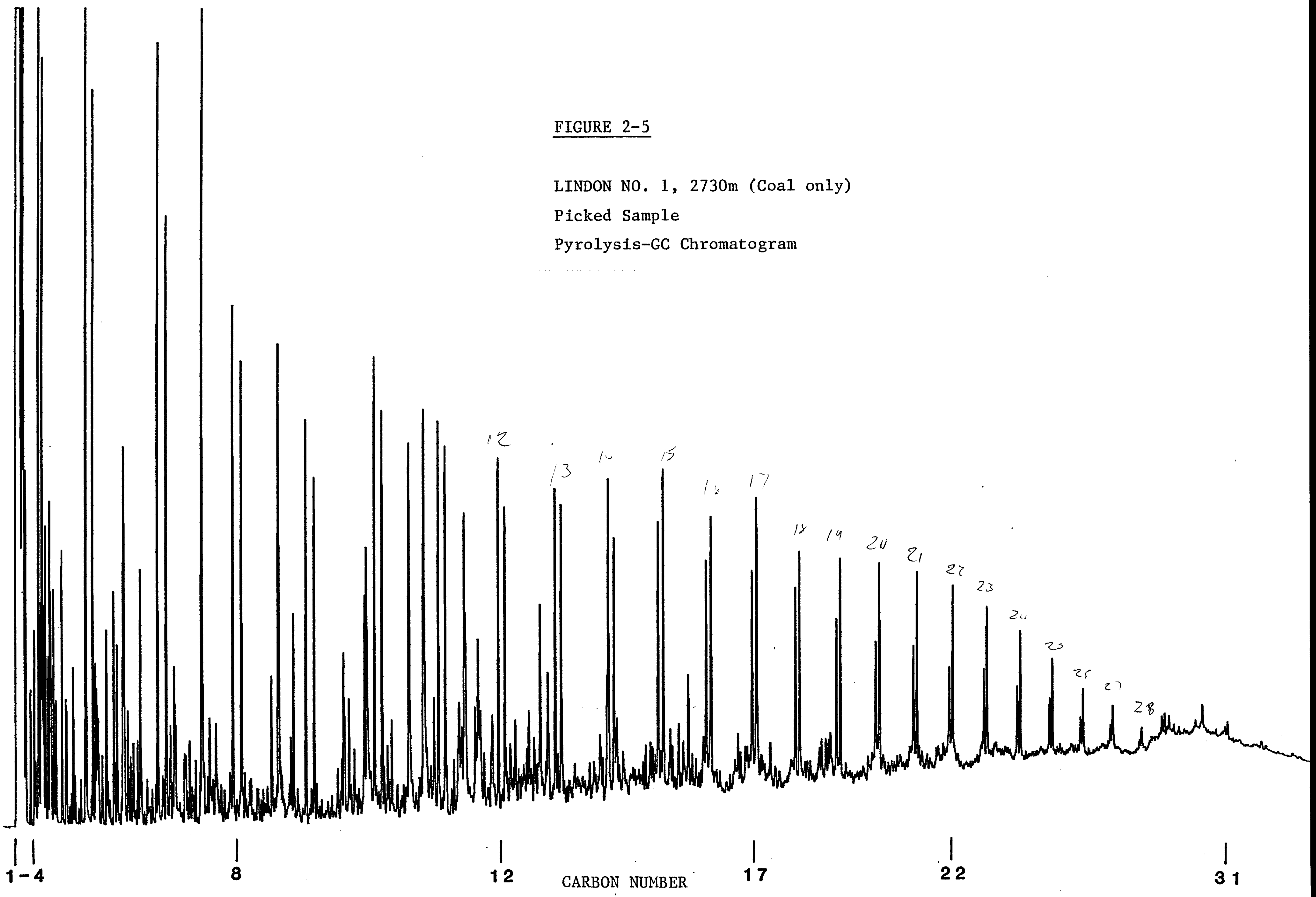


FIGURE 2-6

LINDON NO. 1, 2740m (Coal only)
Picked Sample
Pyrolysis-GC Chromatogram

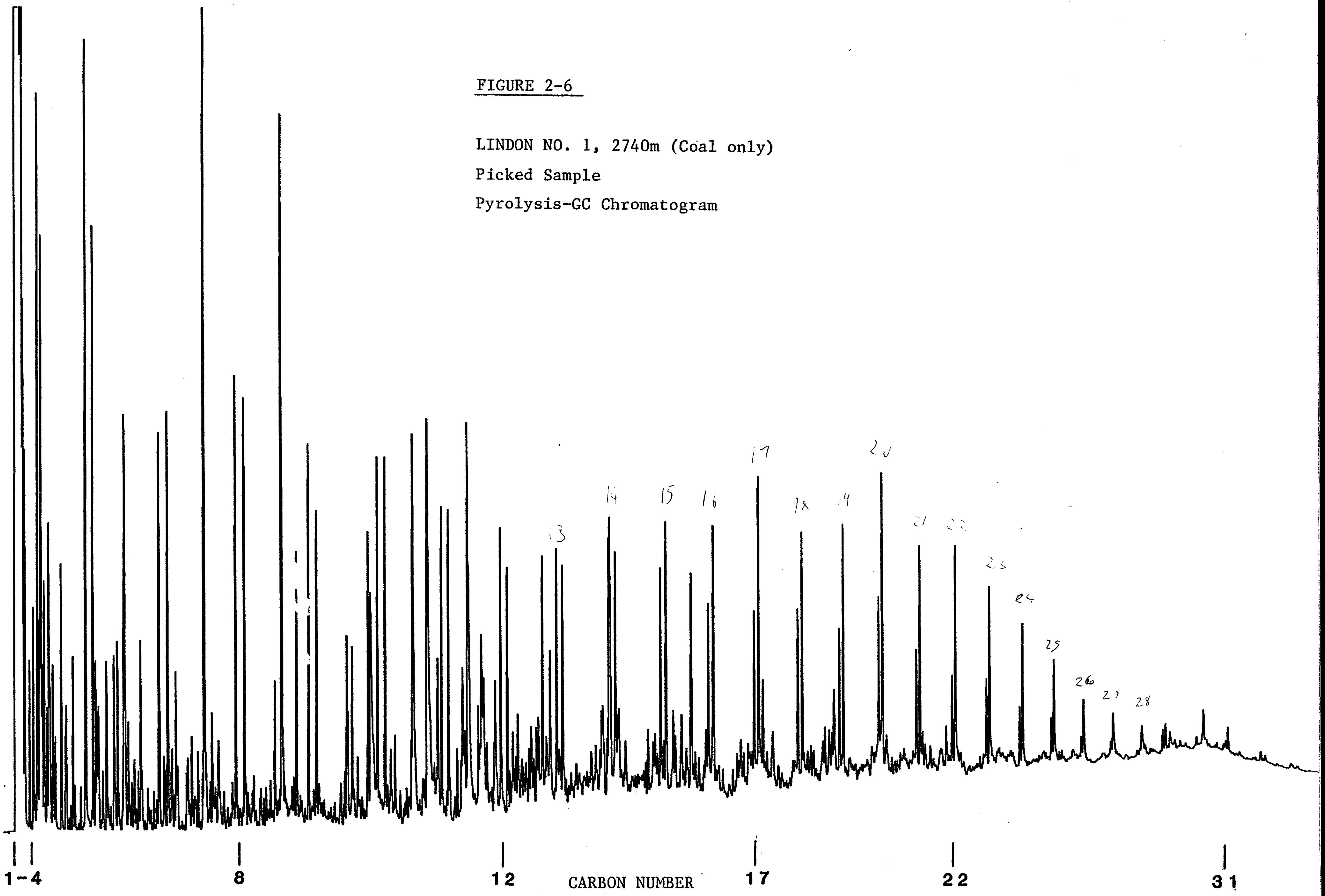
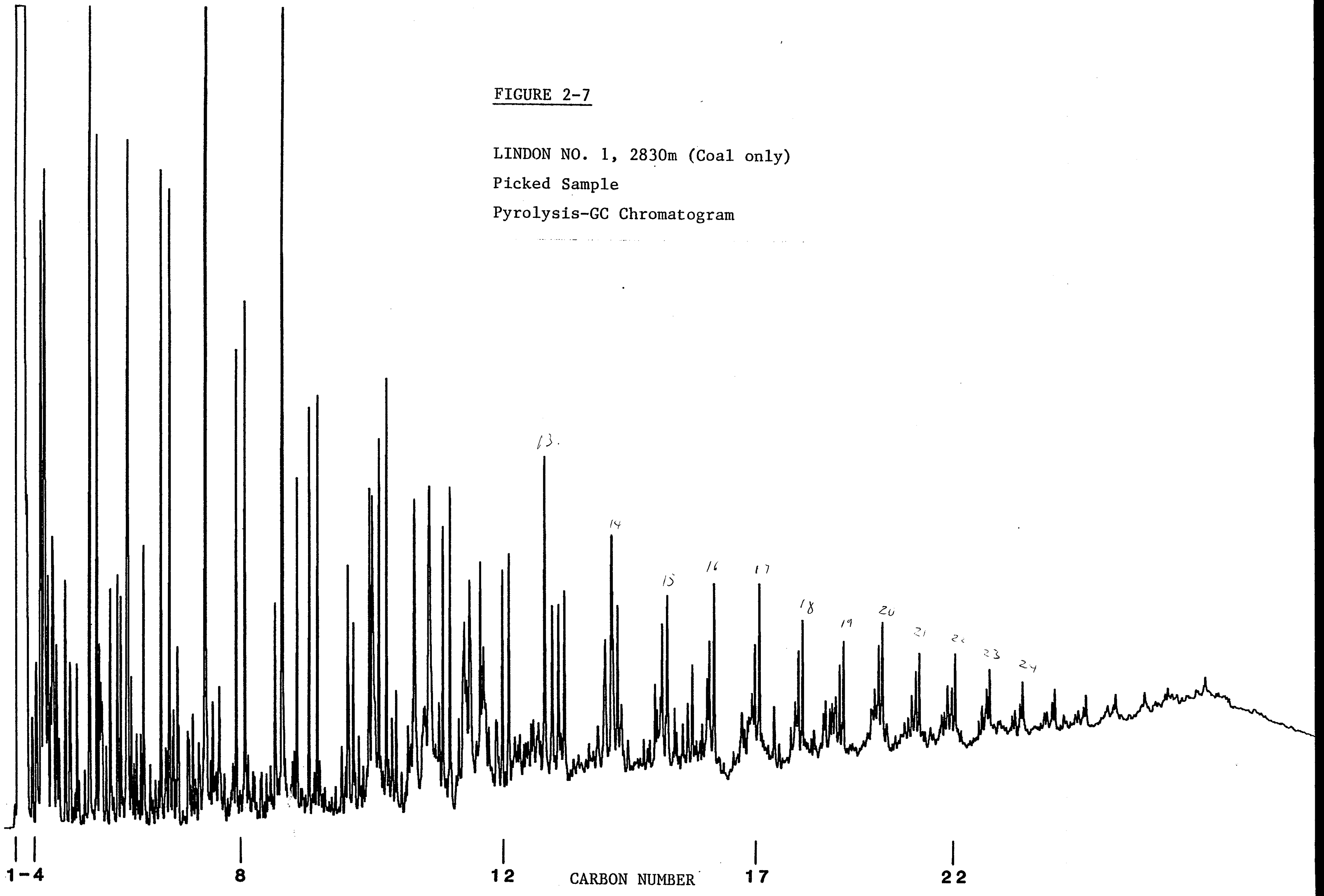


FIGURE 2-7

LINDON NO. 1, 2830m (Coal only)
Picked Sample
Pyrolysis-GC Chromatogram



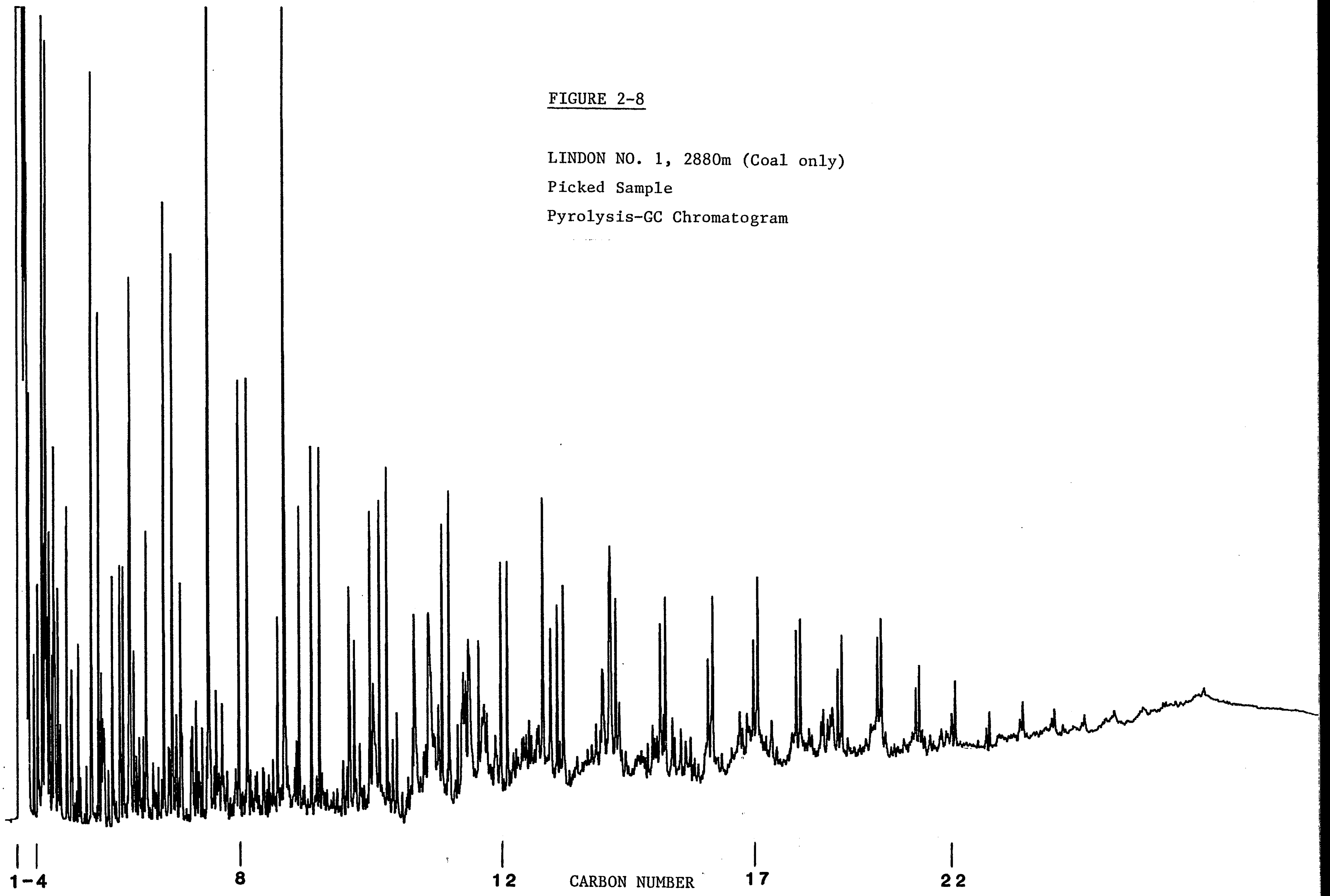


FIGURE 2-8

LINDON NO. 1, 2880m (Coal only)
Picked Sample
Pyrolysis-GC Chromatogram

TABLE 1

ROCK-EVAL PYROLYSIS DATA (one run)

WELLNAME = LINDON #1

DATE OF JOB = JANUARY 1985

DEPTH(m)	TMAX	S1	S2	S3	S1+S2	S2/S3	PI	PC	TOC	HI	OI
1310.0	nd	nd	nd	nd	nd	nd	nd	nd	0.43	nd	nd
1340.0	431	0.14	1.20	0.99	1.34	1.21	0.10	0.11	1.20	100	82
1410.0	nd	nd	nd	nd	nd	nd	nd	nd	0.56	nd	nd
1520.0	nd	nd	nd	nd	nd	nd	nd	nd	0.62	nd	nd
1630.0	nd	nd	nd	nd	nd	nd	nd	nd	0.62	nd	nd
1710.0	nd	nd	nd	nd	nd	nd	nd	nd	0.53	nd	nd
1810.0	nd	nd	nd	nd	nd	nd	nd	nd	0.57	nd	nd
1930.0	nd	nd	nd	nd	nd	nd	nd	nd	0.66	nd	nd
1950.0 coal	428	4.64	32.50	1.60	37.14	20.31	0.12	3.08	17.94	181	8
1950.0	437	0.40	1.32	0.66	1.72	2.00	0.23	0.14	1.24	106	53
2040.0	435	0.23	1.68	1.07	1.91	1.57	0.12	0.16	1.19	141	89
2080.0	nd	nd	nd	nd	nd	nd	nd	nd	0.88	nd	nd
2100.0	435	0.26	1.24	1.22	1.50	1.02	0.17	0.12	1.07	115	114
2200.0	nd	nd	nd	nd	nd	nd	nd	nd	0.91	nd	nd
2300.0	nd	nd	nd	nd	nd	nd	nd	nd	0.83	nd	nd
2330.0 coal	436	10.15	168.54	1.75	178.69	96.31	0.06	14.83	47.04	358	3
2330.0	434	1.11	11.04	1.21	12.15	9.12	0.09	1.01	5.26	209	23
2350.0 coal	442	10.84	159.29	0.70	170.13	227.56	0.06	14.12	42.79	372	1
2350.0	436	1.32	16.35	1.33	17.67	12.29	0.07	1.47	5.47	298	24
2380.0	436	0.35	1.51	1.31	1.86	1.15	0.19	0.15	1.18	127	111
2500.0	439	0.48	1.83	1.33	2.31	1.38	0.21	0.19	1.43	127	93
2650.0 coal	445	3.60	33.08	1.20	36.68	27.57	0.10	3.04	10.32	320	11
2650.0	444	0.51	2.68	0.71	3.19	3.77	0.16	0.26	1.37	195	51
2690.0	442	1.32	6.98	1.19	8.30	5.87	0.16	0.69	3.65	191	32
2730.0 coal	443	7.43	68.58	2.05	76.01	33.45	0.10	6.31	26.26	261	7
2730.0	442	2.04	7.54	1.62	9.58	4.65	0.21	0.80	3.95	190	41
2740.0 coal	444	11.60	101.32	2.45	112.92	41.36	0.10	9.37	32.75	309	7
2740.0	441	2.42	6.24	2.11	8.66	2.96	0.28	0.72	3.39	184	62
2810.0	442	1.51	2.97	2.07	4.48	1.43	0.34	0.37	1.98	150	104
2830.0 coal	447	8.88	68.75	2.08	77.63	33.05	0.11	6.44	24.07	285	8
2830.0	440	1.52	3.71	1.89	5.23	1.96	0.29	0.43	2.32	159	81
2880.0 coal	449	4.82	32.84	1.63	37.66	20.15	0.13	3.13	12.95	253	12
2880.0	444	1.78	4.60	1.38	6.38	3.33	0.28	0.53	3.05	150	45

TMAX = Max. temperature S2

S1+S2 = Potential yield

PC = Pyrolysable carbon

OI = Oxygen Index

S1 = Volatile hydrocarbons (HC)

S3 = Organic carbon dioxide

TOC = Total organic carbon

nd = no data

S2 = HC generating potential

PI = Production index

HI = Hydrogen index

coal = picked samples (coal only)

TABLE 2-1

ALKANE AND ALKENE COMPONENT ANALYSIS FROM PYROLYSIS-GC

Well name: LINDON #1 Date: 1985

Sample: 1950m picked sample (coal only)

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	1.250	0.4063	0.0226	0.497	0.1615	0.0090	0.753	0.2447	0.0136	0.66
6	0.778	0.2528	0.0141	0.255	0.0829	0.0046	0.523	0.1700	0.0095	0.49
7	0.479	0.1557	0.0087	0.214	0.0695	0.0039	0.265	0.0861	0.0048	0.81
8	0.351	0.1141	0.0064	0.154	0.0500	0.0028	0.197	0.0640	0.0036	0.78
9	0.263	0.0855	0.0048	0.103	0.0335	0.0019	0.160	0.0520	0.0029	0.64
10	0.361	0.1173	0.0065	0.209	0.0679	0.0038	0.152	0.0494	0.0028	1.37
11	0.214	0.0695	0.0039	0.126	0.0409	0.0023	0.088	0.0286	0.0016	1.43
12	0.447	0.1453	0.0081	0.217	0.0705	0.0039	0.230	0.0747	0.0042	0.94
13	0.304	0.0988	0.0055	0.116	0.0377	0.0021	0.188	0.0611	0.0034	0.62
14	0.591	0.1921	0.0107	0.271	0.0881	0.0049	0.320	0.1040	0.0058	0.85
15	0.333	0.1082	0.0060	0.184	0.0598	0.0033	0.149	0.0484	0.0027	1.23
16	0.317	0.1030	0.0057	0.174	0.0565	0.0032	0.143	0.0465	0.0026	1.22
17	0.203	0.0660	0.0037	0.178	0.0578	0.0032	0.025	0.0081	0.0005	7.12
18	0.202	0.0657	0.0037	0.144	0.0468	0.0026	0.058	0.0188	0.0011	2.48
19	0.091	0.0296	0.0016	0.066	0.0214	0.0012	0.025	0.0081	0.0005	2.64
20	0.095	0.0309	0.0017	0.069	0.0224	0.0013	0.026	0.0084	0.0005	2.65
21	0.055	0.0179	0.0010	0.055	0.0179	0.0010	nd	nd	nd	nd
22	0.114	0.0371	0.0021	0.114	0.0371	0.0021	nd	nd	nd	nd
23	0.050	0.0162	0.0009	0.050	0.0162	0.0009	nd	nd	nd	nd
24	0.024	0.0078	0.0004	0.024	0.0078	0.0004	nd	nd	nd	nd
25	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
26	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
27	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
28	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
29	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
30	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
31	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd = no data

A = % of S2

B = mg/g Rock

C = (mg/g Rock)/TOC

TABLE 3-1

PARAMETER SUMMARY FOR PYROLYSIS GAS CHROMATOGRAPHY

Well name: LINDON #1 Date: 1985

Sample: 1950m picked sample (coal only)

Parameter	Value			
	A	B	C	D
C1-C4 abundance (all compounds)	47.70	15.502	0.864	
C5-C8 abundance (all compounds)	12.24	3.977	0.222	
C5-C8 abundance (alkanes+alkenes)	2.86	0.929	0.052	
C9-C14 abundance (all compounds)	27.08	8.803	0.491	
C9-C14 abundance (alkanes+alkenes)	2.18	0.709	0.039	
C15-C31 abundance (all compounds)	12.98	4.218	0.235	
C15-C31 abundance (alkanes+alkenes)	1.48	0.482	0.027	
C5-C31 abundance (all compounds)	52.30	16.998	0.948	
C5-C31 abundance (alkanes+alkenes)	6.52	2.120	0.118	
C5-C31 alkane abundance	3.22	1.046	0.058	
C5-C31 alkene abundance	3.30	1.073	0.060	
C5-C8 alkane/alkene				0.644
C9-C14 alkane/alkene				0.916
C15-C31 alkane/alkene				2.484
C5-C31 alkane/alkene				0.975
C1-C4 abundance/S2				0.477
C5-C31 abundance/S2				0.523
(C1-C5)/C5+ abundance				1.043
R	49.43	16.063	0.895	
PI x PC x TOC				6.909

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC
D = (no units)
R = [(C1-C4)+(Proportion alkenes x (C5-C31))]
N.B. C1-C4 and C5-C31 are for all compounds
PI = Production index
PC = Pyrolysable carbon
S2 = Rock-Eval S2 value
TOC = Total Organic Carbon

1.191 mg/g

TABLE 2-2

ALKANE AND ALKENE COMPONENT ANALYSIS FROM PYROLYSIS-GC

Well name: LINDON #1 Date: 1985

Sample: 2330m picked sample (coal only)

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	3.771	6.3556	0.1351	1.821	3.0691	0.0652	1.950	3.2865	0.0699	0.93
6	3.791	6.3894	0.1358	1.221	2.0579	0.0437	2.570	4.3315	0.0921	0.48
7	2.654	4.4731	0.0951	1.154	1.9450	0.0413	1.500	2.5281	0.0537	0.77
8	2.007	3.3826	0.0719	1.013	1.7073	0.0363	0.994	1.6753	0.0356	1.02
9	1.371	2.3107	0.0491	0.608	1.0247	0.0218	0.763	1.2860	0.0273	0.80
10	1.890	3.1854	0.0677	0.734	1.2371	0.0263	1.156	1.9483	0.0414	0.63
11	1.792	3.0202	0.0642	0.876	1.4764	0.0314	0.916	1.5438	0.0328	0.96
12	1.360	2.2921	0.0487	0.592	0.9978	0.0212	0.768	1.2944	0.0275	0.77
13	1.110	1.8708	0.0398	0.558	0.9405	0.0200	0.552	0.9303	0.0198	1.01
14	1.581	2.6646	0.0566	0.616	1.0382	0.0221	0.965	1.6264	0.0346	0.64
15	1.499	2.5264	0.0537	0.707	1.1916	0.0253	0.792	1.3348	0.0284	0.89
16	1.382	2.3292	0.0495	0.734	1.2371	0.0263	0.648	1.0921	0.0232	1.13
17	0.509	0.8579	0.0182	0.267	0.4500	0.0096	0.242	0.4079	0.0087	1.10
18	1.177	1.9837	0.0422	0.650	1.0955	0.0233	0.527	0.8882	0.0189	1.23
19	0.979	1.6500	0.0351	0.540	0.9101	0.0193	0.439	0.7399	0.0157	1.23
20	0.887	1.4950	0.0318	0.494	0.8326	0.0177	0.393	0.6624	0.0141	1.26
21	0.916	1.5438	0.0328	0.569	0.9590	0.0204	0.347	0.5848	0.0124	1.64
22	1.111	1.8725	0.0398	0.651	1.0972	0.0233	0.460	0.7753	0.0165	1.42
23	0.942	1.5876	0.0338	0.539	0.9084	0.0193	0.403	0.6792	0.0144	1.34
24	0.744	1.2539	0.0267	0.406	0.6843	0.0145	0.338	0.5697	0.0121	1.20
25	0.697	1.1747	0.0250	0.375	0.6320	0.0134	0.322	0.5427	0.0115	1.16
26	0.488	0.8225	0.0175	0.287	0.4837	0.0103	0.201	0.3388	0.0072	1.43
27	0.360	0.6067	0.0129	0.226	0.3809	0.0081	0.134	0.2258	0.0048	1.69
28	0.190	0.3202	0.0068	0.135	0.2275	0.0048	0.055	0.0927	0.0020	2.45
29	0.141	0.2376	0.0051	0.106	0.1787	0.0038	0.035	0.0590	0.0013	3.03
30	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
31	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC

TABLE 3-2

PARAMETER SUMMARY FOR PYROLYSIS GAS CHROMATOGRAPHY

Well name: LINDON #1 Date: 1985

Sample: 2330m picked sample (coal only)

Parameter	Value			
	A	B	C	D
C1-C4 abundance (all compounds)	38.62	65.087	1.384	
C5-C8 abundance (all compounds)	22.56	38.016	0.808	
C5-C8 abundance (alkanes+alkenes)	12.22	20.601	0.438	
C9-C14 abundance (all compounds)	18.81	31.702	0.674	
C9-C14 abundance (alkanes+alkenes)	9.10	15.344	0.326	
C15-C31 abundance (all compounds)	20.02	33.735	0.717	
C15-C31 abundance (alkanes+alkenes)	12.02	20.262	0.431	
C5-C31 abundance (all compounds)	61.38	103.45	2.199	
C5-C31 abundance (alkanes+alkenes)	33.35	56.206	1.195	
C5-C31 alkane abundance	15.88	26.762	0.569	
C5-C31 alkene abundance	17.47	29.444	0.626	
C5-C8 alkane/alkene				0.743
C9-C14 alkane/alkene				0.778
C15-C31 alkane/alkene				1.253
C5-C31 alkane/alkene				0.909
C1-C4 abundance/S2				0.386
C5-C31 abundance/S2				0.614
(C1-C5)/C5+ abundance				0.838
R	49.34	83.160	1.768	
PI x PC x TOC				39.62

nd = no data

A = % of S2

B = mg/g Rock

C = (mg/g Rock)/TOC

D = (no units)

R = [(C1-C4)+(Proportion alkenes x (C5-C31))]

N.B. C1-C4 and C5-C31 are for all compounds

PI = Production index

PC = Pyrolysable carbon

S2 = Rock-Eval S2 value

TOC = Total Organic Carbon

55.7 mg/g

TABLE 2-3

ALKANE AND ALKENE COMPONENT ANALYSIS FROM PYROLYSIS-GC

Well name: LINDON #1 Date: 1985

Sample: 2350m picked sample (coal only)

Carbon No.	----Alkane + Alkene-----			---------Alkane---------			---------Alkene---------			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	3.523	5.6118	0.1311	1.292	2.0580	0.0481	2.231	3.5538	0.0831	0.58
6	4.232	6.7412	0.1575	1.066	1.6980	0.0397	3.166	5.0431	0.1179	0.34
7	2.848	4.5366	0.1060	1.047	1.6678	0.0390	1.801	2.8688	0.0670	0.58
8	2.069	3.2957	0.0770	0.839	1.3364	0.0312	1.230	1.9593	0.0458	0.68
9	1.767	2.8147	0.0658	0.690	1.0991	0.0257	1.077	1.7156	0.0401	0.64
10	1.668	2.6570	0.0621	0.771	1.2281	0.0287	0.897	1.4288	0.0334	0.86
11	1.348	2.1472	0.0502	0.528	0.8411	0.0197	0.820	1.3062	0.0305	0.64
12	1.218	1.9402	0.0453	0.513	0.8172	0.0191	0.705	1.1230	0.0262	0.73
13	1.127	1.7952	0.0420	0.489	0.7789	0.0182	0.638	1.0163	0.0238	0.77
14	1.314	2.0931	0.0489	0.512	0.8156	0.0191	0.802	1.2775	0.0299	0.64
15	1.310	2.0867	0.0488	0.596	0.9494	0.0222	0.714	1.1373	0.0266	0.83
16	1.027	1.6359	0.0382	0.469	0.7471	0.0175	0.558	0.8888	0.0208	0.84
17	1.077	1.7156	0.0401	0.566	0.9016	0.0211	0.511	0.8140	0.0190	1.11
18	0.902	1.4368	0.0336	0.410	0.6531	0.0153	0.492	0.7837	0.0183	0.83
19	0.794	1.2648	0.0296	0.407	0.6483	0.0152	0.387	0.6165	0.0144	1.05
20	0.875	1.3938	0.0326	0.482	0.7678	0.0179	0.393	0.6260	0.0146	1.23
21	0.798	1.2711	0.0297	0.418	0.6658	0.0156	0.380	0.6053	0.0141	1.10
22	0.871	1.3874	0.0324	0.462	0.7359	0.0172	0.409	0.6515	0.0152	1.13
23	0.623	0.9924	0.0232	0.347	0.5527	0.0129	0.276	0.4396	0.0103	1.26
24	0.604	0.9621	0.0225	0.320	0.5097	0.0119	0.284	0.4524	0.0106	1.13
25	0.535	0.8522	0.0199	0.283	0.4508	0.0105	0.252	0.4014	0.0094	1.12
26	0.471	0.7503	0.0175	0.246	0.3919	0.0092	0.225	0.3584	0.0084	1.09
27	0.447	0.7120	0.0166	0.237	0.3775	0.0088	0.210	0.3345	0.0078	1.13
28	0.315	0.5018	0.0117	0.182	0.2899	0.0068	0.133	0.2119	0.0050	1.37
29	0.145	0.2310	0.0054	0.145	0.2310	0.0054	nd	nd	nd	nd
30	0.048	0.0765	0.0018	0.048	0.0765	0.0018	nd	nd	nd	nd
31	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd = no data

A = % of S2

B = mg/g Rock

C = (mg/g Rock)/TOC

TABLE 3-3

PARAMETER SUMMARY FOR PYROLYSIS GAS CHROMATOGRAPHY

Well name: LINDON #1 Date: 1985

Sample: 2350m picked sample (coal only)

Parameter	Value			
	A	B	C	D
C1-C4 abundance (all compounds)	39.28	62.563	1.462	
C5-C8 abundance (all compounds)	24.94	39.730	0.928	
C5-C8 abundance (alkanes+alkenes)	12.67	20.185	0.472	
C9-C14 abundance (all compounds)	17.80	28.350	0.663	
C9-C14 abundance (alkanes+alkenes)	8.44	13.447	0.314	
C15-C31 abundance (all compounds)	17.98	28.647	0.669	
C15-C31 abundance (alkanes+alkenes)	10.84	17.270	0.404	
C5-C31 abundance (all compounds)	60.72	96.727	2.261	
C5-C31 abundance (alkanes+alkenes)	31.96	50.903	1.190	
C5-C31 alkane abundance	13.37	21.289	0.498	
C5-C31 alkene abundance	18.59	29.614	0.692	
C5-C8 alkane/alkene				0.504
C9-C14 alkane/alkene				0.709
C15-C31 alkane/alkene				1.075
C5-C31 alkane/alkene				0.719
C1-C4 abundance/S2				0.393
C5-C31 abundance/S2				0.607
(C1-C5)/C5+ abundance				0.864
R	50.57	80.545	1.882	
PI x PC x TOC				38.49

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC
D = (no units)
R = [(C1-C4)+(Proportion alkenes x (C5-C31))]
N.B. C1-C4 and C5-C31 are for all compounds
PI = Production index
PC = Pyrolysable carbon
S2 = Rock-Eval S2 value
TOC = Total Organic Carbon

30.72.

TABLE 2-4

ALKANE AND ALKENE COMPONENT ANALYSIS FROM PYROLYSIS-GC

Well name: LINDON #1 Date: 1985

Sample: 2650m picked sample (coal only)

Carbon No.	----Alkane + Alkene-----			---------Alkane---------			---------Alkene---------			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	3.066	1.0142	0.0983	1.298	0.4294	0.0416	1.768	0.5849	0.0567	0.73
6	3.336	1.1035	0.1069	1.075	0.3556	0.0345	2.261	0.7479	0.0725	0.48
7	2.407	0.7962	0.0772	1.027	0.3397	0.0329	1.380	0.4565	0.0442	0.74
8	1.882	0.6226	0.0603	0.879	0.2908	0.0282	1.003	0.3318	0.0322	0.88
9	1.609	0.5323	0.0516	0.702	0.2322	0.0225	0.907	0.3000	0.0291	0.77
10	1.598	0.5286	0.0512	0.725	0.2398	0.0232	0.873	0.2888	0.0280	0.83
11	1.389	0.4595	0.0445	0.624	0.2064	0.0200	0.765	0.2531	0.0245	0.82
12	1.109	0.3669	0.0355	0.513	0.1697	0.0164	0.596	0.1972	0.0191	0.86
13	1.114	0.3685	0.0357	0.531	0.1757	0.0170	0.583	0.1929	0.0187	0.91
14	1.040	0.3440	0.0333	0.488	0.1614	0.0156	0.552	0.1826	0.0177	0.88
15	1.070	0.3540	0.0343	0.504	0.1667	0.0162	0.566	0.1872	0.0181	0.89
16	0.954	0.3156	0.0306	0.461	0.1525	0.0148	0.493	0.1631	0.0158	0.94
17	0.945	0.3126	0.0303	0.486	0.1608	0.0156	0.459	0.1518	0.0147	1.06
18	0.775	0.2564	0.0248	0.394	0.1303	0.0126	0.381	0.1260	0.0122	1.03
19	0.591	0.1955	0.0189	0.301	0.0996	0.0096	0.290	0.0959	0.0093	1.04
20	0.658	0.2177	0.0211	0.341	0.1128	0.0109	0.317	0.1049	0.0102	1.08
21	0.512	0.1694	0.0164	0.260	0.0860	0.0083	0.252	0.0834	0.0081	1.03
22	0.448	0.1482	0.0144	0.227	0.0751	0.0073	0.221	0.0731	0.0071	1.03
23	0.384	0.1270	0.0123	0.194	0.0642	0.0062	0.190	0.0629	0.0061	1.02
24	0.262	0.0867	0.0084	0.139	0.0460	0.0045	0.123	0.0407	0.0039	1.13
25	0.219	0.0724	0.0070	0.117	0.0387	0.0038	0.102	0.0337	0.0033	1.15
26	0.171	0.0566	0.0055	0.095	0.0314	0.0030	0.076	0.0251	0.0024	1.25
27	0.137	0.0453	0.0044	0.078	0.0258	0.0025	0.059	0.0195	0.0019	1.32
28	0.082	0.0271	0.0026	0.051	0.0169	0.0016	0.031	0.0103	0.0010	1.65
29	0.102	0.0337	0.0033	0.056	0.0185	0.0018	0.046	0.0152	0.0015	1.22
30	0.035	0.0116	0.0011	0.025	0.0083	0.0008	0.010	0.0033	0.0003	2.50
31	0.028	0.0093	0.0009	0.019	0.0063	0.0006	0.009	0.0030	0.0003	2.11

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC

TABLE 3-4

PARAMETER SUMMARY FOR PYROLYSIS GAS CHROMATOGRAPHY

Well name: LINDON #1 Date: 1985

Sample: 2650m picked sample (coal only)

Parameter	Value			
	A	B	C	D
C1-C4 abundance (all compounds)	45.22	14.958	1.449	
C5-C8 abundance (all compounds)	24.24	8.019	0.777	
C5-C8 abundance (alkanes+alkenes)	10.69	3.537	0.343	
C9-C14 abundance (all compounds)	17.27	5.714	0.554	
C9-C14 abundance (alkanes+alkenes)	7.86	2.600	0.252	
C15-C31 abundance (all compounds)	13.27	4.389	0.425	
C15-C31 abundance (alkanes+alkenes)	7.37	2.439	0.236	
C5-C31 abundance (all compounds)	54.78	18.122	1.756	
C5-C31 abundance (alkanes+alkenes)	25.92	8.575	0.831	
C5-C31 alkane abundance	11.61	3.841	0.372	
C5-C31 alkene abundance	14.31	4.735	0.459	
C5-C8 alkane/alkene				0.667
C9-C14 alkane/alkene				0.838
C15-C31 alkane/alkene				1.034
C5-C31 alkane/alkene				0.811
C1-C4 abundance/S2				0.452
C5-C31 abundance/S2				0.548
(C1-C5)/C5+ abundance				1.094
R	53.06	17.552	1.701	
PI x PC x TOC				3.084

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC
D = (no units)
R = [(C1-C4)+(Proportion alkenes x (C5-C31))]
N.B. C1-C4 and C5-C31 are for all compounds
PI = Production index
PC = Pyrolysable carbon
S2 = Rock-Eval S2 value
TOC = Total Organic Carbon

5.04

TABLE 2-5

ALKANE AND ALKENE COMPONENT ANALYSIS FROM PYROLYSIS-GC

Well name: LINDON #1

Date: 1985

Sample: 2730m picked sample (coal only)

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	2.428	1.6651	0.0634	1.116	0.7654	0.0291	1.312	0.8998	0.0343	0.85
6	2.455	1.6836	0.0641	0.859	0.5891	0.0224	1.596	1.0945	0.0417	0.54
7	1.850	1.2687	0.0483	0.835	0.5726	0.0218	1.015	0.6961	0.0265	0.82
8	1.410	0.9670	0.0368	0.668	0.4581	0.0174	0.742	0.5089	0.0194	0.90
9	1.064	0.7297	0.0278	0.482	0.3306	0.0126	0.582	0.3991	0.0152	0.83
10	1.348	0.9245	0.0352	0.650	0.4458	0.0170	0.698	0.4787	0.0182	0.93
11	1.145	0.7852	0.0299	0.530	0.3635	0.0138	0.615	0.4218	0.0161	0.86
12	0.969	0.6645	0.0253	0.444	0.3045	0.0116	0.525	0.3600	0.0137	0.85
13	1.022	0.7009	0.0267	0.500	0.3429	0.0131	0.522	0.3580	0.0136	0.96
14	1.039	0.7125	0.0271	0.472	0.3237	0.0123	0.567	0.3888	0.0148	0.83
15	1.102	0.7558	0.0288	0.572	0.3923	0.0149	0.530	0.3635	0.0138	1.08
16	0.972	0.6666	0.0254	0.526	0.3607	0.0137	0.446	0.3059	0.0116	1.18
17	1.112	0.7626	0.0290	0.690	0.4732	0.0180	0.422	0.2894	0.0110	1.64
18	0.717	0.4917	0.0187	0.393	0.2695	0.0103	0.324	0.2222	0.0085	1.21
19	0.652	0.4471	0.0170	0.377	0.2585	0.0098	0.275	0.1886	0.0072	1.37
20	0.774	0.5308	0.0202	0.439	0.3011	0.0115	0.335	0.2297	0.0087	1.31
21	0.581	0.3984	0.0152	0.335	0.2297	0.0087	0.246	0.1687	0.0064	1.36
22	0.593	0.4067	0.0155	0.366	0.2510	0.0096	0.227	0.1557	0.0059	1.61
23	0.451	0.3093	0.0118	0.269	0.1845	0.0070	0.182	0.1248	0.0048	1.48
24	0.361	0.2476	0.0094	0.225	0.1543	0.0059	0.136	0.0933	0.0036	1.65
25	0.273	0.1872	0.0071	0.164	0.1125	0.0043	0.109	0.0748	0.0028	1.50
26	0.184	0.1262	0.0048	0.122	0.0837	0.0032	0.062	0.0425	0.0016	1.97
27	0.152	0.1042	0.0040	0.097	0.0665	0.0025	0.055	0.0377	0.0014	1.76
28	0.055	0.0377	0.0014	0.043	0.0295	0.0011	0.012	0.0082	0.0003	3.58
29	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
30	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
31	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC

TABLE 3-5

PARAMETER SUMMARY FOR PYROLYSIS GAS CHROMATOGRAPHY

Well name: LINDON #1 Date: 1985

Sample: 2730m picked sample (coal only)

Parameter	Value			
	A	B	C	D
C1-C4 abundance (all compounds)	46.17	31.663	1.206	
C5-C8 abundance (all compounds)	20.12	13.795	0.525	
C5-C8 abundance (alkanes+alkenes)	8.14	5.584	0.213	
C9-C14 abundance (all compounds)	20.51	14.063	0.536	
C9-C14 abundance (alkanes+alkenes)	6.59	4.517	0.172	
C15-C31 abundance (all compounds)	13.21	9.058	0.345	
C15-C31 abundance (alkanes+alkenes)	7.98	5.472	0.208	
C5-C31 abundance (all compounds)	53.83	36.916	1.406	
C5-C31 abundance (alkanes+alkenes)	22.71	15.574	0.593	
C5-C31 alkane abundance	11.17	7.663	0.292	
C5-C31 alkene abundance	11.53	7.911	0.301	
C5-C8 alkane/alkene				0.746
C9-C14 alkane/alkene				0.877
C15-C31 alkane/alkene				1.374
C5-C31 alkane/alkene				0.969
C1-C4 abundance/S2				0.462
C5-C31 abundance/S2				0.538
(C1-C5)/C5+ abundance				1.073
R	52.38	35.922	1.368	
PI x PC x TOC				16.19

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC
D = (no units)
R = [(C1-C4)+(Proportion alkenes x (C5-C31))]
N.B. C1-C4 and C5-C31 are for all compounds
PI = Production index
PC = Pyrolysable carbon
S2 = Rock-Eval S2 value
TOC = Total Organic Carbon

9.99

TABLE 2-6

ALKANE AND ALKENE COMPONENT ANALYSIS FROM PYROLYSIS-GC

Well name: LINDON #1 Date: 1985

Sample: 2740m picked sample (coal only)

Carbon No.	----Alkane + Alkene-----			----------Alkane----------			----------Alkene----------			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	1.867	1.8916	0.0578	0.882	0.8936	0.0273	0.985	0.9980	0.0305	0.90
6	1.699	1.7214	0.0526	0.629	0.6373	0.0195	1.070	1.0841	0.0331	0.59
7	1.225	1.2412	0.0379	0.578	0.5856	0.0179	0.647	0.6555	0.0200	0.89
8	0.985	0.9980	0.0305	0.483	0.4894	0.0149	0.502	0.5086	0.0155	0.96
9	0.844	0.8551	0.0261	0.394	0.3992	0.0122	0.450	0.4559	0.0139	0.88
10	0.929	0.9413	0.0287	0.460	0.4661	0.0142	0.469	0.4752	0.0145	0.98
11	0.798	0.8085	0.0247	0.381	0.3860	0.0118	0.417	0.4225	0.0129	0.91
12	0.713	0.7224	0.0221	0.303	0.3070	0.0094	0.410	0.4154	0.0127	0.74
13	0.729	0.7386	0.0226	0.350	0.3546	0.0108	0.379	0.3840	0.0117	0.92
14	0.992	1.0051	0.0307	0.360	0.3648	0.0111	0.632	0.6403	0.0196	0.57
15	0.842	0.8531	0.0260	0.483	0.4894	0.0149	0.359	0.3637	0.0111	1.35
16	0.896	0.9078	0.0277	0.561	0.5684	0.0174	0.335	0.3394	0.0104	1.67
17	0.863	0.8744	0.0267	0.569	0.5765	0.0176	0.294	0.2979	0.0091	1.94
18	0.640	0.6484	0.0198	0.373	0.3779	0.0115	0.267	0.2705	0.0083	1.40
19	0.599	0.6069	0.0185	0.367	0.3718	0.0114	0.232	0.2351	0.0072	1.58
20	0.783	0.7933	0.0242	0.495	0.5015	0.0153	0.288	0.2918	0.0089	1.72
21	0.482	0.4884	0.0149	0.311	0.3151	0.0096	0.171	0.1733	0.0053	1.82
22	0.557	0.5644	0.0172	0.374	0.3789	0.0116	0.183	0.1854	0.0057	2.04
23	0.434	0.4397	0.0134	0.291	0.2948	0.0090	0.143	0.1449	0.0044	2.03
24	0.328	0.3323	0.0101	0.231	0.2340	0.0071	0.097	0.0983	0.0030	2.38
25	0.240	0.2432	0.0074	0.169	0.1712	0.0052	0.071	0.0719	0.0022	2.38
26	0.147	0.1489	0.0045	0.115	0.1165	0.0036	0.032	0.0324	0.0010	3.59
27	0.118	0.1196	0.0037	0.097	0.0983	0.0030	0.021	0.0213	0.0006	4.62
28	0.095	0.0963	0.0029	0.084	0.0851	0.0026	0.011	0.0111	0.0003	7.64
29	0.042	0.0426	0.0013	0.042	0.0426	0.0013	nd	nd	nd	nd
30	0.064	0.0648	0.0020	0.064	0.0648	0.0020	nd	nd	nd	nd
31	0.043	0.0436	0.0013	0.043	0.0436	0.0013	nd	nd	nd	nd

nd = no data

A = % of S2

B = mg/g Rock

C = (mg/g Rock)/TOC

TABLE 3-6

PARAMETER SUMMARY FOR PYROLYSIS GAS CHROMATOGRAPHY

Well name: LINDON #1 Date: 1985

Sample: 2740m picked sample (coal only)

Parameter	Value			
	A	B	C	D
C1-C4 abundance (all compounds)	52.57	53.269	1.627	
C5-C8 abundance (all compounds)	15.50	15.702	0.479	
C5-C8 abundance (alkanes+alkenes)	5.78	5.852	0.179	
C9-C14 abundance (all compounds)	19.42	19.680	0.601	
C9-C14 abundance (alkanes+alkenes)	5.01	5.071	0.155	
C15-C31 abundance (all compounds)	12.50	12.669	0.387	
C15-C31 abundance (alkanes+alkenes)	7.17	7.268	0.222	
C5-C31 abundance (all compounds)	47.43	48.051	1.467	
C5-C31 abundance (alkanes+alkenes)	17.95	18.191	0.555	
C5-C31 alkane abundance	9.49	9.614	0.294	
C5-C31 alkene abundance	8.46	8.577	0.262	
C5-C8 alkane/alkene				0.803
C9-C14 alkane/alkene				0.815
C15-C31 alkane/alkene				1.865
C5-C31 alkane/alkene				1.121
C1-C4 abundance/S2				0.526
C5-C31 abundance/S2				0.474
(C1-C5)/C5+ abundance				1.333
R	56.59	57.337	1.751	
PI x PC x TOC				31.53

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC
D = (no units)
R = [(C1-C4)+(Proportion alkenes x (C5-C31))]
N.B. C1-C4 and C5-C31 are for all compounds
PI = Production index
PC = Pyrolysable carbon
S2 = Rock-Eval S2 value
TOC = Total Organic Carbon

12.34

TABLE 2-7

ALKANE AND ALKENE COMPONENT ANALYSIS FROM PYROLYSIS-GC

Well name: LINDON #1 Date: 1985

Sample: 2830m picked sample (coal only)

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	2.721	1.8707	0.0777	1.628	1.1193	0.0465	1.093	0.7514	0.0312	1.49
6	1.886	1.2966	0.0539	0.772	0.5307	0.0221	1.114	0.7659	0.0318	0.69
7	1.378	0.9474	0.0394	0.700	0.4812	0.0200	0.678	0.4661	0.0194	1.03
8	1.053	0.7239	0.0301	0.540	0.3712	0.0154	0.513	0.3527	0.0147	1.05
9	0.915	0.6291	0.0261	0.455	0.3128	0.0130	0.460	0.3163	0.0131	0.99
10	0.999	0.6868	0.0285	0.515	0.3541	0.0147	0.484	0.3328	0.0138	1.06
11	0.671	0.4613	0.0192	0.360	0.2475	0.0103	0.311	0.2138	0.0089	1.16
12	0.610	0.4194	0.0174	0.334	0.2296	0.0095	0.276	0.1898	0.0079	1.21
13	0.622	0.4276	0.0178	0.322	0.2214	0.0092	0.300	0.2063	0.0086	1.07
14	0.595	0.4091	0.0170	0.251	0.1726	0.0072	0.344	0.2365	0.0098	0.73
15	0.503	0.3458	0.0144	0.299	0.2056	0.0085	0.204	0.1402	0.0058	1.47
16	0.508	0.3493	0.0145	0.334	0.2296	0.0095	0.174	0.1196	0.0050	1.92
17	0.439	0.3018	0.0125	0.262	0.1801	0.0075	0.177	0.1217	0.0051	1.48
18	0.317	0.2179	0.0091	0.167	0.1148	0.0048	0.150	0.1031	0.0043	1.11
19	0.241	0.1657	0.0069	0.134	0.0921	0.0038	0.107	0.0736	0.0031	1.25
20	0.373	0.2564	0.0107	0.201	0.1382	0.0057	0.172	0.1182	0.0049	1.17
21	0.276	0.1898	0.0079	0.170	0.1169	0.0049	0.106	0.0729	0.0030	1.60
22	0.218	0.1499	0.0062	0.132	0.0908	0.0038	0.086	0.0591	0.0025	1.53
23	0.172	0.1182	0.0049	0.094	0.0646	0.0027	0.078	0.0536	0.0022	1.21
24	0.126	0.0866	0.0036	0.086	0.0591	0.0025	0.040	0.0275	0.0011	2.15
25	0.086	0.0591	0.0025	0.055	0.0378	0.0016	0.031	0.0213	0.0009	1.77
26	0.084	0.0578	0.0024	0.048	0.0330	0.0014	0.036	0.0247	0.0010	1.33
27	0.044	0.0303	0.0013	0.032	0.0220	0.0009	0.012	0.0082	0.0003	2.67
28	0.027	0.0186	0.0008	0.027	0.0186	0.0008	nd	nd	nd	nd
29	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
30	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
31	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC

TABLE 3-7

PARAMETER SUMMARY FOR PYROLYSIS GAS CHROMATOGRAPHY

Well name: LINDON #1 Date: 1985

Sample: 2830m picked sample (coal only)

Parameter	Value			
	A	B	C	D
C1-C4 abundance (all compounds)	60.63	41.680	1.732	
C5-C8 abundance (all compounds)	15.33	10.537	0.438	
C5-C8 abundance (alkanes+alkenes)	7.04	4.839	0.201	
C9-C14 abundance (all compounds)	15.48	10.639	0.442	
C9-C14 abundance (alkanes+alkenes)	4.41	3.033	0.126	
C15-C31 abundance (all compounds)	8.57	5.894	0.245	
C15-C31 abundance (alkanes+alkenes)	3.41	2.347	0.098	
C5-C31 abundance (all compounds)	39.38	27.070	1.125	
C5-C31 abundance (alkanes+alkenes)	14.86	10.219	0.425	
C5-C31 alkane abundance	7.92	5.444	0.226	
C5-C31 alkene abundance	6.95	4.775	0.198	
C5-C8 alkane/alkene				1.071
C9-C14 alkane/alkene				1.029
C15-C31 alkane/alkene				1.487
C5-C31 alkane/alkene				1.140
C1-C4 abundance/S2				0.606
C5-C31 abundance/S2				0.394
(C1-C5)/C5+ abundance				1.863
R	63.36	43.561	1.810	
PI x PC x TOC				17.74

12.986

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC
D = (no units)
R = [(C1-C4)+(Proportion alkenes x (C5-C31))]
N.B. C1-C4 and C5-C31 are for all compounds
PI = Production index
PC = Pyrolysable carbon
S2 = Rock-Eval S2 value
TOC = Total Organic Carbon

TABLE 2-8

ALKANE AND ALKENE COMPONENT ANALYSIS FROM PYROLYSIS-GC

Well name: LINDON #1 Date: 1985

Sample: 2880m picked sample (coal only)

Carbon No.	Alkane + Alkene			Alkane			Alkene			Alkane/Alkene
	A	B	C	A	B	C	A	B	C	
1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
3	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
4	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
5	1.890	0.6207	0.0479	0.933	0.3064	0.0237	0.957	0.3143	0.0243	0.97
6	1.387	0.4555	0.0352	0.560	0.1839	0.0142	0.827	0.2716	0.0210	0.68
7	1.290	0.4236	0.0327	0.639	0.2098	0.0162	0.651	0.2138	0.0165	0.98
8	1.003	0.3294	0.0254	0.492	0.1616	0.0125	0.511	0.1678	0.0130	0.96
9	0.821	0.2696	0.0208	0.397	0.1304	0.0101	0.424	0.1392	0.0108	0.94
10	0.826	0.2713	0.0209	0.410	0.1346	0.0104	0.416	0.1366	0.0105	0.99
11	0.778	0.2555	0.0197	0.367	0.1205	0.0093	0.411	0.1350	0.0104	0.89
12	0.548	0.1800	0.0139	0.258	0.0847	0.0065	0.290	0.0952	0.0074	0.89
13	0.469	0.1540	0.0119	0.250	0.0821	0.0063	0.219	0.0719	0.0056	1.14
14	0.682	0.2240	0.0173	0.256	0.0841	0.0065	0.426	0.1399	0.0108	0.60
15	0.484	0.1589	0.0123	0.267	0.0877	0.0068	0.217	0.0713	0.0055	1.23
16	0.345	0.1133	0.0087	0.230	0.0755	0.0058	0.115	0.0378	0.0029	2.00
17	0.380	0.1248	0.0096	0.242	0.0795	0.0061	0.138	0.0453	0.0035	1.75
18	0.289	0.0949	0.0073	0.164	0.0539	0.0042	0.125	0.0410	0.0032	1.31
19	0.265	0.0870	0.0067	0.160	0.0525	0.0041	0.105	0.0345	0.0027	1.52
20	0.335	0.1100	0.0085	0.193	0.0634	0.0049	0.142	0.0466	0.0036	1.36
21	0.167	0.0548	0.0042	0.100	0.0328	0.0025	0.067	0.0220	0.0017	1.49
22	0.149	0.0489	0.0038	0.093	0.0305	0.0024	0.056	0.0184	0.0014	1.66
23	0.079	0.0259	0.0020	0.053	0.0174	0.0013	0.026	0.0085	0.0007	2.04
24	0.108	0.0355	0.0027	0.062	0.0204	0.0016	0.046	0.0151	0.0012	1.35
25	0.044	0.0144	0.0011	0.030	0.0099	0.0008	0.014	0.0046	0.0004	2.14
26	0.016	0.0053	0.0004	0.016	0.0053	0.0004	nd	nd	nd	nd
27	0.009	0.0030	0.0002	0.009	0.0030	0.0002	nd	nd	nd	nd
28	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
29	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
30	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
31	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

nd = no data

A = % of S2

B = mg/g Rock

C = (mg/g Rock)/TOC

TABLE 3-8

PARAMETER SUMMARY FOR PYROLYSIS GAS CHROMATOGRAPHY

Well name: LINDON #1 Date: 1985

Sample: 2880m picked sample (coal only)

Parameter	Value			
	A	B	C	D
C1-C4 abundance (all compounds)	58.77	19.299	1.490	
C5-C8 abundance (all compounds)	16.93	5.560	0.429	
C5-C8 abundance (alkanes+alkenes)	5.57	1.829	0.141	
C9-C14 abundance (all compounds)	16.18	5.312	0.410	
C9-C14 abundance (alkanes+alkenes)	4.12	1.354	0.105	
C15-C31 abundance (all compounds)	8.13	2.669	0.206	
C15-C31 abundance (alkanes+alkenes)	2.67	0.877	0.068	
C5-C31 abundance (all compounds)	41.23	13.541	1.046	
C5-C31 abundance (alkanes+alkenes)	12.36	4.060	0.314	
C5-C31 alkane abundance	6.18	2.030	0.157	
C5-C31 alkene abundance	6.18	2.030	0.157	
C5-C8 alkane/alkene				0.891
C9-C14 alkane/alkene				0.887
C15-C31 alkane/alkene				1.540
C5-C31 alkane/alkene				1.000
C1-C4 abundance/S2				0.588
C5-C31 abundance/S2				0.412
(C1-C5)/C5+ abundance				1.753
R	61.32	20.136	1.555	
PI x PC x TOC				5.181

2.23

nd = no data
A = % of S2
B = mg/g Rock
C = (mg/g Rock)/TOC
D = (no units)
R = [(C1-C4)+(Proportion alkanes x (C5-C31))]
N.B. C1-C4 and C5-C31 are for all compounds
PI = Production index
PC = Pyrolysable carbon
S2 = Rock-Eval S2 value
TOC = Total Organic Carbon

TABLE 4

SUMMARY OF PYROLYSIS GAS CHROMATOGRAPHY DATA

Well name: LINDON #1 Date: 1985

Sample	Parameter	% of S2	RATIO	mg/g Rock
1950m	C1-C5 abundance (all compounds)	51.05	1.04	16.59
	C6+ abundance (all compounds)	48.95		15.91
2330m	C1-C5 abundance (all compounds)	45.60	0.84	76.85
	C6+ abundance (all compounds)	54.40		91.69
2350m	C1-C5 abundance (all compounds)	46.36	0.86	73.85
	C6+ abundance (all compounds)	53.64		85.44
2650m	C1-C5 abundance (all compounds)	52.24	1.09	17.28
	C6+ abundance (all compounds)	47.76		15.80
2730m	C1-C5 abundance (all compounds)	51.75	1.07	35.49
	C6+ abundance (all compounds)	48.25		33.09
2740m	C1-C5 abundance (all compounds)	57.14	1.33	57.90
	C6+ abundance (all compounds)	42.86		43.42
2830m	C1-C5 abundance (all compounds)	65.07	1.86	44.74
	C6+ abundance (all compounds)	34.93		24.01
2880m	C1-C5 abundance (all compounds)	63.68	1.75	20.91
	C6+ abundance (all compounds)	36.32		11.93

THEORY AND METHODS

This section details a series of geochemical methods which are commonly used in our laboratory, including those used to obtain the data presented in this report. Where applicable, the discussion is accompanied by a summary of the general theory used to interpret the data generated by each method.

1. SEDIMENTARY GAS ANALYSIS

a) Headspace Analysis

Headspace analysis is carried out using sealed containers (usually tinned cans) of wet cuttings. The containers are approximately three quarters filled with the cuttings and water to leave an appreciable headspace into which volatile hydrocarbons contained in the cuttings diffuse.

After covering about 1cm2 of the container lid with silicone and allowing the silicone to dry, the procedure involves placing a small hole in the lid through the silicone, then sampling an aliquot of the headspace gas with a gas injection syringe, and finally gas chromatographing this sample of gas under the following conditions: instrument = Shimadzu GC-8APF; column = 6' x 1/8" Chromosorb 102; column temperature = 110 Deg. C; carrier gas = nitrogen at 23mls/min; injector temperature = 120 Deg. C.; analysis cycle = C1-C4 components are flushed from the column in the forward direction and then the C5-C7 compounds are removed from the column by backflushing.

The integrated areas of peaks representing each of the C1-C7 components of the headspace gas are compared to the areas of corresponding components of a standard gas of known composition. The calculated amount of each component in the sample gas is adjusted for the total headspace volume and reported as ppm (parts of gas per million parts of sediment by volume).

Data from headspace analysis is commonly used to identify the zone of oil generation by plotting gas wetness (C2-C4/C1-C4) expressed as a % against sediment burial depth. Gas containing appreciable quantities of C2-C4 components, termed wet gas (Fuex, 1977), is generally considered to be gas associated with oil generation. In addition, the ratio of isomeric butanes can sometimes be used for assessment of sediment maturity (Alexander et. al., 1981). The amount of gas in sediments can be used to identify zones of significant gas generation and out-of-place gas (LeTran et. al., 1975).

b) Cuttings Gas Analysis

This analysis is the same as Headspace Analysis with the exception that instead of analysing the gas in the container headspace, a known volume of the wet cuttings are transferred to the blender bowl of a Kenwood electronic blender with the lid modified to incorporate a septum, water at 75 Deg. C is added to leave a headspace of 160ml, and the mixture is blended at maximum speed for 2 minutes. Following a 2 minute settling period 1ml of the blending bowl headspace gas is analysed as described in section 1a.

It is recommended that for the most meaningful gas data both headspace and cuttings gas analysis are carried out. In such cases we provide tabulations of the headspace, gas, and combined headspace/cuttings gas data. Normally, the combined data is used for plotting purposes.

2. SAMPLE PREPARATION

a) Cuttings

Cuttings samples are inspected by our qualified geological staff and then water washed according to the drilling mud content and lithology. In special cases (e.g. diesel contamination) it is necessary to lightly solvent wash samples. After washing, the samples are air dried, either sieved or picked free of cavings, and crushed to 0.1mm using a ring pulveriser.

b) Sidewall Cores

Sidewall samples are freed of mud cake and any other visible contaminants, and are also inspected for lithologic homogeneity. For homogeneous samples, the minimum amount of material required for the requested analyses is air dried and handcrushed to 0.1mm. For non-homogeneous samples, the whole sample is air dried and handcrushed to 0.1mm.

c) Conventional Core and Outcrop Samples

These sample types are firstly inspected for visible contaminants, and where applicable, are freed of these contaminants to the best of our ability. Commonly, the surface of conventional core and outcrop samples are lightly solvent washed. The samples are then crushed to approximately 1/8" chips using a jaw crusher, air dried, and finally further crushed to 0.1mm using a ring pulveriser.

d) Petroleum/Aqueous Mixtures

The most common sample type in this category are RFT tests containing oil, water and mud. The mixture is placed in a separation funnel and allowed to stand for several hours which enables the petroleum and water/mud fractions to separate. The neat petroleum is isolated by removal of the lower layer (water/mud) from the funnel. To remove the last traces of water and mud, the neat petroleum is centrifuged at moderate speed.

When the volume of petroleum accounts for only a very small part of the sample the method above is unsatisfactory and the petroleum is solvent extracted from the mixture with dichloromethane. The petroleum is recovered by careful evaporation of the solvent from the organic layer.

3. TOTAL ORGANIC CARBON DETERMINATION

The total organic carbon value (TOC) is determined on the unextracted sediment sample. The value is determined by treating a known weight of sediment with hot dilute HCl for 1 hour to remove carbonate minerals, and then heating the residue to 1700 Deg. C (Leco Induction Furnace CS-044) in an atmosphere of pure oxygen. The carbon dioxide produced is transferred to an infra-red detector which has been calibrated with a series of standards, and the microprocessor of the Leco unit then automatically calculates the % TOC in the sample. To ensure reliable data a standard is run after every 10 samples, regular sample repeats are carried out, and at least one blank determination is carried out for each batch of samples.

The following scales are normally used for source rock classification based on % TOC data:

Classification	Clastics	Carbonates
Poor	0.00 - 0.50	0.00 - 0.25
Fair	0.50 - 1.00	0.25 - 0.50
Good	1.00 - 2.00	0.50 - 1.00
Very Good	2.00 - 4.00	1.00 - 2.00
Excellent	> 4.00	> 2.00

4. ROCK-EVAL PYROLYSIS

Although a preliminary source rock classification is made using TOC data a more accurate assessment accounting for organic source type and maturity is made by pyrolysis analysis. Two types of Rock-Eval pyrolysis services are offered: "one run" which involves pyrolysis of the crushed but otherwise untreated sediment and "two run" which involves pyrolysis of both the crushed, untreated sediment and sediment which has been rendered free of carbonate minerals by treatment with hot dilute HCl. The two run service offers considerably more reliable S3 data.

The method involves accurately weighing approximately 100mg of the sample into a sintered steel crucible and subjecting it to the following pyrolysis cycle:

Stage (i) - Sample purged with helium for 3.5 minutes in unheated part of pyrolysis furnace;

Stage (ii) - Sample heated at 300 Deg. C for 3 minutes to liberate free petroleum (S1 peak);

Stage (iii) - Sample heated from 300 Deg. C to 550 Deg. C at 25 Deg. C/minute to produce petroleum from kerogen (S2 peak). The furnace is maintained at 550 Deg. C for one minute. Carbon dioxide produced during this pyrolysis up to 390 Deg. C in the case of "one run" and 550 Deg. C for "two run" is absorbed on a molecular sieve trap;

Stage (iv) - During the cool down period the carbon dioxide produced during pyrolysis is measured (S3 peak).

The units used for Rock-Eval data are as follows:

S1, S2, S3 = kg/tonne or mg/g of rock

Tmax = Deg. C

$$\text{Hydrogen Index} = \frac{S2}{TOC} \times \frac{100}{1}$$

$$\text{Oxygen Index} = \frac{S3}{TOC} \times \frac{100}{1}$$

Rock-Eval data is most commonly used in the following manner:

(i) S1 - indicates the level of oil and or/gas already generated by the sample according to the following scale:

S1 (mg/g or kg/tonne)	Classification
0.00 - 0.20	Poor
0.20 - 0.40	Fair
0.40 - 0.80	Good
0.80 - 1.60	Very Good
> 1.60	Excellent

(ii) S1+S2 - referred to as the genetic potential this parameter is used for source rock classification according to the following criteria:

S1+S2 (mg/g or kg/tonne)	Classification
0.00 - 1.00	Poor
1.00 - 2.00	Marginal
2.00 - 6.00	Moderate
6.00 - 10.00	Good
10.00 - 20.00	Very Good
> 20.00	Excellent

(iii) S1/(S1+S2)- this parameter is the production index (PI) which is a measure of the level of maturity of the sample. For oil prone sediments, values less than 0.1 are indicative of immaturity, the values increase from 0.1 to 0.4 over the oil window and values greater than 0.4 represent over maturity. For gas prone sediments, the PI data shows a relatively smaller change with increasing maturity.

(iv) Tmax - the temperature corresponding to the S2 maxima. This temperature increases with increasingly mature sediments. Values less than 430 Deg. C are indicative of immaturity while values from 430/435 to 460 Deg. C represent the maturity range of the oil window. Tmax values greater than 460 Deg. C are indicative of over maturity.

(v) HI, OI - the hydrogen ((S2 x 100)/TOC) and oxygen ((S3 x 100)/TOC) indices when plotted against one another provide information about the type of kerogen contained in the sample and the maturity of the sample. Both parameters decrease in value with increasing maturity. Samples with large HI and low OI are dominantly oil prone and conversely samples with low HI and large OI are at best gas prone.

5. EXTRACTION OF SEDIMENT SAMPLES

Crushed sediment (maximum of 250g) and 300mls of purified dichloromethane are placed in a 500ml conical flask and are then blended for ten minutes with a Janke and Kunkel Ultra-Turrax T45/2G high efficiency disperser. After a ten minute settling period the solvent is separated from the sediment using a large Buchner filtration system. The extract is recovered by careful evaporation of the solvent on a steam bath and weighed. The weight of extract is used to calculate % EOM and ppm EOM using the following formulae:

$$\%\ \text{EOM} = \frac{\text{Wt EOM}}{\text{Wt Sediment Extracted (g)}} \times \frac{100}{1}$$

$$\text{ppm EOM} = \frac{\text{Wt EOM (mg)}}{\text{Wt Sediment Extracted (kg)}}$$

The following scale is used to classify the source rock richness of samples based on C12+ extractables:

Classification	ppm Total Extract
Poor	0 - 500
Fair	500 - 1000
Good	1000 - 2000
Very Good	2000 - 4000
Excellent	> 4000

6. SEPARATION OF PETROLEUM INTO CONSTITUENT FRACTIONS

Sediment extracts and crude oil or condensate samples are separated into saturate, aromatic and NSO (asphaltenes plus resins) fractions by medium pressure liquid chromatography (MPLC). That part of the petroleum which is soluble in pentane is applied to the MPLC system via a sample loop and is then pumped using pentane to a partially activated silicic acid pre-column which prevents further movement of the non-hydrocarbon compounds. The hydrocarbon components are pumped further to a Merck Si60 column where the saturate fraction is obtained by forward flushing and the aromatic fraction is recovered by reverse flushing. This separation procedure is monitored using a refractive index detector. To complete the separation the pre-column is removed from the MPLC system and flushed with dichloromethane: methanol (1:10). This non-hydrocarbon fraction is combined with the pentane insoluble material which is not applied to the MPLC system, and is labelled as the NSO fraction. The neat fractions are recovered by careful removal of the solvent by distillation and are weighed.

The weight of each fraction is used to calculate the % of each fraction in the sediment according to the following formulas:

$$\%\ \text{Fraction} = \frac{\text{Wt Fraction}}{\text{Wt all Fractions}} \times \frac{100}{1}$$

$$\text{ppm Fraction} = \frac{\text{Wt Fraction (mg)}}{\text{Wt Sediment Extracted (kg)}}$$

The ppm hydrocarbon (saturates and aromatics) and ppm saturate values can be used to classify source rock richness and oil source potential respectively according to the following criteria:

Classification	ppm Hydrocarbon	ppm Saturates
Poor	0 - 300	0 - 200
Fair	300 - 600	200 - 400
Good	600 - 1200	400 - 800
Very Good	1200 - 2400	800 - 1600
Excellent	> 2400	> 1600

The composition of the extracts can also provide information about their levels of maturity and/or source type (LeTran et. al., 1974; Philippi, 1974). Generally, marine extracts have relatively low concentrations of saturated and NSO compounds at low levels of maturity, but these concentrations increase with increased maturation. Terrestrially derived organic matter often has a low level of saturates and large amount of aromatic and NSO compounds irrespective of the level of maturity.

N.B. If requested by a client the NSO fraction is separated into asphaltenes and resins by conventional methods.

7. EXTRACTABLE/TOTAL ORGANIC CARBON RATIOS

The ratios of EOM(mg)/TOC(g) and SAT(mg)/TOC(g) are determined from the appropriate data. The EOM(mg)/TOC(g) ratio can be used as a maturation indicator, especially if the parameter is plotted against depth for a given sedimentary sequence. In an absolute sense it is less reliable as a maturation indicator, although previous work (Tissot et. al., 1971; LeTran et. al., 1974) suggests that the following criteria can be used to determine maturity with this parameter.

< 50	Low maturity
50 - 100	Moderate maturity
> 100	High maturity

The ratios of EOM(mg)/TOC(g) and SAT(mg)/TOC(g) can be used collectively to provide information about source type. For example, if SOM(mg)/TOC(g) is > 100, suggesting a high level of maturity, but the SAT(mg)/TOC(g) < 20 it is very likely that the organic matter is gas prone. Conversely, the same EOM(mg)/TOC(g) value with a SAT(mg)/TOC(g) value > 40 suggests oil prone source type.

8. PYROLYSIS GAS CHROMATOGRAPHY

Pyrolysis-gas chromatography (PGC) incorporates a Chemical Data System Pyroprope 150 flash pyrolysis unit interfaced with a capillary gas chromatograph. A sample (5-10mg) of extracted sediment is placed in a quartz tube inside the element coil of the pyrolysis probe and is then heated to 610 Deg. C in a few milliseconds, and is maintained at this temperature for 20 seconds. Products generated from the pyrolysis are swept onto the bonded phase capillary column of the gas chromatograph and are chromatographed from -20 Deg. C (isothermal for two minutes) to 280 Deg. C at 4 Deg. C/minute. The product distribution is dominated by the nature of the kerogen from which it is derived.

9. C12+ GAS CHROMATOGRAPHY

C12+ gas chromatography is commonly carried out on the saturate fraction but in certain instances is carried out on neat oil, condensate or extract. The analysis is carried out under the following conditions: instrument = Shimadzu GC-9A; column = 50m x 0.2mm ID OV101 vitreous silica; column temperature = programmed from 60 Deg. C to 280 Deg. C at 4 Deg. C/min; injection system = Grob splitless using a 30 second dump time and split ratio of 25:1, carrier gas = hydrogen at 2mls/min; sample = 1µl of 0.5% soln in pentane.

The following information is commonly obtained from C12+ gas chromatographic analysis:

(a) n-Alkane Distribution - The C12-C31 n-alkane distribution is determined from the area under peaks representing each of these n-alkanes. This distribution can yield information about both the level of maturity and the source type (LeTran et. al., 1974).

(b) Carbon Preference Index - Two values are determined:

$$\text{CPI (1)} = \frac{(C23 + C25 + C27 + C29)\ \text{Wt\%} + (C25 + C27 + C29 + C31)\ \text{Wt\%}}{2 \times (C24 + C26 + C28 + C30)\ \text{Wt\%}}$$

$$\text{CPI (2)} = \frac{(C23 + C25 + C27)\ \text{Wt\%} + (C25 + C27 + C29)\ \text{Wt\%}}{2 \times (C24 + C26 + C28)\ \text{Wt\%}}$$

The CPI is believed to be a function of both the level of maturity (Cooper and Bray, 1963; Scalan and Smith, 1970) and the source type (Tissot and Welte, 1978). Marine extracts tend to have values close to 1.0 irrespective of maturity whereas values for terrestrial extracts decrease with maturity from values as high as 20 but do not usually reach a value of 1.0

(c) (C21+C22)/(C28+C29) - This parameter provides information about the source of the organic matter (Philippi, 1974). Generally, terrestrial source material gives values <1.2 whereas a aquatic source material results in values >1.5.

(d) Pristane/Phytane Ratio - This value was determined from the areas of peaks representing these compounds. The ratio renders information about the depositional environment according to the following scale (Powell and McKirdy, 1975):

< 3.0	Relatively reducing depositional environment
3.0-4.5	Reducing/oxidizing depositional environment
>4.5	Relatively oxidizing depositional environment

(e) Pristane/n-C17 Ratio - This ratio was determined from the areas of peaks representing these compounds. The value can provide information about both the depositional environment and the level of maturation (Lijmbach, 1975). Very immature crude oil has a pristane/n-C17 ratio >1.0, irrespective of the depositional environment. However, the following classification can be applied to mature crude oil:

<0.5	Open water depositional environment
0.5-1.0	Mixed depositional environment
>1.0	Peat-swamp depositional environment

In the case of sediment extracts these values are significantly higher and the following classification is used:

<1.0	Open water depositional environment
1.0-1.5	Mixed depositional environment
>1.5	Peat-swamp depositional environment

(f) Phytane/n-C18 Ratio - This ratio was determined from the areas of peaks representing these compounds. The value usually only provides information about the level of maturity of petroleum. The value decreases with increased maturation.

(g) Relative Amounts of n-Alkanes and Naphthenes - Since n-alkanes and naphthenes are the two dominant classes of compounds in the saturate fraction, a semi-quantitative estimate of the relative amounts of these compounds can be made from saturate GLC's. This information can be used to assess the degree of maturation and/or the source type of the petroleum (Philippi, 1974; Tissot and Welte, 1978). Very immature petroleum has only small proportions of n-alkanes, but as maturity increases the relative amount of n-alkanes increases. In addition, terrestrial petroleum has a greater proportion of high molecular weight naphthenes than petroleum comprising aquatic source material.

10. API/SPECIFIC GRAVITY

A specific gravity (SG) bottle was accurately weighed, then filled with crude oil at 60 Deg. F and finally reweighed. The weight difference was divided by the weight of an equal volume of water at 60 Deg. F to obtain the specific gravity. The following formula was then used to calcuate the API gravity:

$$\text{API Gravity} = \left[\frac{141.5}{\text{SG (60 Deg. F)}}\right] - 131.5$$

The reported gravity value is the average of duplicate determinations.

11. SULPHUR DETERMINATION

The % sulphur by weight is determined by dissolving 0.5g of the petroleum in 50mls kerosene and then analysing this mixture with an inductively coupled plasma (ICP) instrument which has been calibrated with a series of sulphur standards.

This parameter is influenced by the nature of the source material from which a crude is derived, the depositional environment of the source rocks, and reservoir alteration processed such as bacterial alteration.

12. C1-C31 WHOLE SAMPLE GAS CHROMATOGRAPHY

This method of analysis is normally only applied to oil or condensate samples. The technique provides a "picture" of the sample which shows good resolution of the low, medium and high molecular weight components. Whole sample GC data is considered to be more useful than C12+ saturate fraction GC data for oil or condensate samples.

The analysis is carried out under the same conditions as for the C12+ GC analysis with the following exceptions: column temperature = programmed from -20 Deg. C to 280 Deg. C at 4 Deg. C/min (uses cryogenic mode); injection is carried out in split mode; sample = 0.1 µl of neat petroleum.

C1-C31 analysis data can be used to obtain the same information as that obtained from C12+ GC but further provides detailed compositional data on the C1-C11 fraction and enables calculation of the distillation range of the sample.

13. MOLECULAR SIEVE EXTRACTION

This technique is used to isolate the branched/cyclic alkanes from the saturate fraction for gas chromatography/mass spectometry analysis. A mixture of saturates: 5A molecular sieves: purified benzene in the proportions 1:5:12 by weight is placed in a 100ml round bottom flask and refluxed for 24 hours. After cooling, the seives are filtered from the liquid phase and are washed with 4 x 10ml aliquots of benzene. The liquid phase plus washing are freed of benzene by distillation yielding the branched/cyclic compounds.

14. COMPUTERIZED GAS CHROMATOGRAPHY/MASS SPECTOMETRY (GC/MS)

Gas chromatography/mass spectrometry employs a capillary column gas chromatograph linked in series with a mass spectrometer and data system (GC/MS/DS). As molecules are eluted from the capillary column they are bled into the analyser tube of the mass spectrometer where they are bombarded with high energy electrons and consequently fragment to form several ions each with molecular weights less than that of the parent molecule. The fragmentation pattern is characteristic of the particular molecular type. The spectrum of these ions (referred to as a mass spectrum) is recorded approximately once every second and all of the mass spectra recorded during a GC/MS/DS analysis are memorised by the data system. Since any given class of molecules will breakdown in the analyser type to give one or more characteristic ion fragments of known molecular weight, after a GC/MS/DS analysis it is possible to examine the distribution of compounds within a given class by having the data system reproduce a mass fragmentogram (plot of ion concentration against gas chromatography retention time) representative of the particular class.

GC/MS/DS analyses can be carried out using one of the two following modes of operation:

(i) Acquire mode - in which all ions in each mass spectrum are memorised by the data system;

(ii) Selective ion monitoring (SIM) mode - in which only selected ions of interest are memorised by the data system.

At present the sterane/triterpane/bicyclane fraction of petroleum is considered most useful for GC/MS/DS analysis and therefore we commonly use the second of the above mentioned modes of operation and run the following twenty-two ions which are pertinent to the sterane/triterpane/bicuclane fraction.

Ion	Molecular Type
177	Demethylated triterpanes
191	Normal triterpanes
205	Methyl triterpanes
163	Specific dethylated triterpanes
356	Parent ion - C26 triterpanes
370	Parent ion - C27 triterpanes
384	Parent ion - C28 triterpanes
398	Parent ion - C29 triterpanes

412	Parent ion - C30 triterpanes
426	Parent ion - C31 triterpanes
183	Isoprenoids
217	Normal steranes
218	Normal steranes
231	4-methylsteranes
259	Diasteranes
358	Parent ion - C26 steranes
372	Parent ion - C27 steranes
386	Parent ion - C28 steranes
400	Parent ion - C29 steranes
414	Parent ion - C30 steranes

GC/MS/DS analysis of the sterane/triterpane/bicyclane fraction can often provide information about the maturity and source type of petroleum and whether it has been affected by micro-organisms. This technique is also often useful for oil:oil and oil:source rock correlation. The following sections indicate which parameters are used to obtain this information and summarize the theory behind their use.

Maturity

(i) Based on Steranes

(a) The biologically produced $\alpha\alpha\alpha$ (20R) sterioisomer is converted in sediment to a mixture of the $\alpha\alpha\alpha$ (20R) and $\alpha\alpha\alpha$ (20S) compounds. The ratio of

$$\mathrm{C29}\ \frac{\alpha\alpha\alpha\ (20S)}{\alpha\alpha\alpha\ (20R) + \alpha\alpha\alpha\ (20S)}$$

expressed as a percentage is about 25% at the onset of oil generation and increases almost linearily to a value of about 50% at the peak of oil generation.

(ii) Based on Triterpanes

(a) The C31, C32, C33, C34 and C35 hopanes have the biological R configuration at C22. On mild thermal maturation equilibration occurs to produce a 60/40 mixture of S/R. This equilibration occurs before the onset of oil generation.

(b) The conversion of the biological $17\beta,21\beta$ hopanes to the corresponding $17\alpha,21\beta$ and $17\beta,21\alpha$ compounds is also maturation dependant. For C30 triterpanes the ration of

$$\frac{17\beta\ ,21\alpha}{17\alpha\ ,21\beta}$$

decreases steadily from a value of about 0.4 at the onset of oil generation to a value of about 0.1 at peak oil generation.

(c) Two of the C27 triterpanes can also be used as maturity indicators. The ratio of 18 α(H) trisnorhopane to 17 α(H) trisnorhopane increases exponentially with increasing maturity from a value of approximately 0.2 at the onset of oil generation to approximately 1.0 at peak oil generation.

(d) It is our experience that the ratio of the C27 18α(H) + C27 17α (H) triterpanes to C30 $17\alpha\ ,21\beta$ triterpane is maturity dependent. The ratio decreased from values around 1.0 at the onset of oil generation to a value of approximately 0.4 at peak oil generation. With increasing maturity at levels greater than that equivalent to peak oil generation the ratio increases steadily to values greater than 3.0.

Source Type

(i) Based on Steranes
Algal organic matter contains steranes in which the C27 compounds are more abundant than the C29 compounds. General aquatic organic matter has approximately equivalent amounts of the C27 and C29 compounds while organic matter rich in land-plants usually has a lot more of the C29 steranes.

(ii) Based on Triterpanes
The triterpane components in petroleum can be derived from both bacteria and higher plants. The common bacterial products are the C27-C35 hopanes and moretanes whereas the higher plant triterpanes are compounds other than hopanes or moretanes and are commonly C30 compounds.

(iii) Based on Diasteranes
The diasteranes are not produced biologically but are formed during early diagenesis from sterane precursors. The diasterane ratios $\frac{\mathrm{C27(20R)}}{\mathrm{C29(20R)}}$ and $\frac{\mathrm{C27(20R+20S)}}{\mathrm{C29(20R+20S)}}$ should reflect the nature of the organic matter in the same manner as that outlined above for the steranes.

Biodegradation

It has been observed that in severely biodegraded petroleum the series of normal hopanes are converted to a series of A ring demethylated hopanes and the C29 (20R) sterane is selectively removed. For altered crudes which have not been degraded to this extent the severity of biodegradation can often be gauged by studying the isoprenoid and aromatic fractions. However, this type of investigation extends beyond a standard GC/MS/DS analysis.

Correlation

Our present approach to oil:oil or oil:source rock correlation problems is as follows:

(i) Compare the distribution of compounds in the 123, 177, 191, 205, 217, 218, 231 and 259 mass fragmentograms for an oil or sediment extract to the distribution of compounds in the respective fragmentograms for the other oil(s) or sediment extract(s). It is necessary in this type of comparison to make allowance for small variations due to possible maturity differences.

(ii) Examine the fragmentograms for peaks or sets of peaks which may represent compounds that are specific to the geological system under investigation. Normal steranes, diasteranes and bacterial hopanes cannot be used for this purpose because they are present in virtually all crude oils and sediment extracts. However, compounds like higher plant triterpanes, bisnorhopane and botryococcane can often prove very useful for this purpose.

15. CARBON ISOTOPE ANALYSIS

The measurement is carried out on one or more of the following mixtures; topped oil; saturate fraction; aromatic fraction; NSO fraction. The organic matter is combusted at 860 Deg. C in oxygen and the carbon dioxide formed is purified and transferred to an isotope mass spectrometer. The carbon isotope ratio is measured relative to a standard gas of known isotopic composition. In our case the standard gas is prepared from the NBS No. 22 oil. However, since the isotopic relationship between NBS No. 22 oil and the international reference PDB limestone are known, the values are adjusted to be relative to PDB limestone.

Although carbon isotope data has been commonly used for oil:oil and oil:source rock correlation its most significant application is the identification of the source of gas according to the following criteria (Fuex, 1977):

δ13C (PDB)	Gas Type
-85 to -58	Biogenic methane
-58 to -40	Wet gas/associated with oil
-40 to -25	Thermal methane

16. VITRINITE REFLECTANCE MEASUREMENT

Vitrinite is a coal maceral which responds to increasing levels of thermal maturity. This response can be measured by the percent of light reflected off a polished surface of a vitrinite particle immersed in oil. Reflectance measurements are made on a number (40 if possible) of vitrinite particles in each sample, in order to establish a range and mean for reflectance values. Immature rocks have low reflectance values (0.2% Ro to 0.6% Ro), with mature values ranging from 0.6% Ro to 1.2% Ro. Very mature values are between 1.2 % Ro and 1.8% Ro, while severely altered rocks have reflectances above 1.8% Ro.

Vitrinite reflectance results are best obtained from coals or rocks deposited in environments receiving large influxes of terrestrially-derived organic matter. Unfortunately, these environments are not conducive to the accumulation of large quantities of oil-prone organic mater. Also vitrinite reflectance cannot be performed on rocks older than Devonian Age, due to the absence of land plants in the older geological time periods.

17. VISUAL KEROGEN

Visual kerogen assessment is carried out by the coal petrologist and/or the palynologist. In the case of the petrologist the assessment is made in reflected light using the plug prepared for vitrinite reflectance measurement, and reports the relative amounts of alginite, exinite, vitrinite and inertinite particles.

Visual study of kerogen by the palynologist is carried out in transmitted light and can indicate the relative abundance, size and state of preservation of the various recognizable kerogen types and hence indicates the source character of a sedimentary rock. In addition, the colour of the kerogen is related to the thermal maturity of the sediments and is often used as a maturation indicator.

The preparation of slides for visual kerogen assessment by the palynologist firstly involves concentration of the organic matter by removal of the rock matrix using hydrochloric and hydrofluoric acid treatment and heavy liquid separation. The organic concentrate is then mounted on a glass slide using Petropoxy.

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