PET OTW

12/77

PEP111 Bge 1 of 24

RESTRICTED INVESTIGATION REPORT 910R

OIL and GAS DIVISION

DEPT. NAT. RES & ENV

PE907743

CSIRO

DOC. No. 89080028

OTWAY BASIN. S.R.A.

OT G+G - GENERAL. SOURCE ROCKS FROM THE OTWAY BASIN

MINERALS RESEARCH LABORATORIES
FUEL GEOSCIENCE UNIT

LOWER CRETACEOUS SOURCE ROCKS FROM THE OTWAY BASIN, VICTORIA

SAXBY ETC. DEC 1977

J.D. SAXBY, A.J.R. BENNETT, L. BRUEN AND J. FRIEDRICH

P.O. BOX 136
NORTH RYDE, NSW
AUSTRALIA 2113

DECEMBER 1977

SOURCE ROCK ANALYSIS BOX C-1-2. BAY A.

OIL and GAS DIVISION

2/24

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

In an earlier report (IR 864R) geochemical analyses on Upper Cretaceous core samples from Voluta No. 1 and Port Campbell No. 2 were presented. As a follow-up to this work, I. McPhee of Beach Petroleum has supplied six samples from the Lower Cretaceous Otway Group (Eumeralla Formation) and the results of source rock and maturation studies on these samples are given in this report. In addition, two condensates recovered from drill-stem tests in Port Campbell No. 1 and Flaxmans No. 1 have been analyzed by gas chromatography and these results are also reported. Descriptions of the cores are given in Table 1 and the locations of all wells are shown in Fig. 1.

2. METHODS AND RESULTS

2.1. Extractable Organic Matter

Part of each sample was crushed and ground to approximately 75% below 70 μm and extracted in a Soxhlet with purified chloroform for 8 hours or until extraction was complete. Evaporation of the solvent under a stream of nitrogen gave the total extract. That part of the total extract soluble in petroleum ether was then transferred to a 5 x 1 cm column of florisil and eluted with petroleum ether to give the aliphatic fraction. Benzene was added to the residue of the total extract and the resulting solution poured onto the florisil column. Elution with more benzene gave the aromatic fraction. Similarly, methanol was added to the residue of the total extract and the resulting solution added to the florisil column. The polar fraction was then eluted with methanol. The total extract and each of these fractions are expressed as parts per million of the original core in Table 2. Any of the total extract not redissolving in petroleum ether, benzene or methanol is shown in Table 2 as "residue". Thus:

$$\underset{\text{(ppm)}}{\text{total extract}} = \underset{\text{(ppm)}}{\text{aliphatic fraction}} + \underset{\text{(ppm)}}{\text{aromatic fraction}} + \underset{\text{(ppm)}}{\text{polar fraction}}$$

$$+ \underset{\text{(ppm)}}{\text{residue}} + \underset{\text{(usually small)}}{\text{losses and material remaining on the column}}$$

The probable error in each of these values is difficult to estimate and depends on the weight of core extracted and the nature of the extract. However, the following ranges should cover virtually all samples:

total extract	± 30 ppm
aliphatic fraction	± 5 ppm
aromatic fraction	± 10 ppm
polar fraction	± 10 ppm
residue	± 5 ppm

The aliphatic fraction was analyzed by gas chromatography for hydrocarbons in the n-C_{15} to n-C_{35} boiling range. The resulting chromatograms are shown in Figs. 2-7.

2.2. Carbon and Sulphur Analyses

Total carbon and total sulphur were determined on a sample of ground core using a Leco analyzer. Organic carbon was determined similarly on a sample which had been previously treated with dilute HCl to remove carbonates. The probable error in all these values is ± 0.05%.

2.3. Reflectance

Part of each core sample was crushed to -0.7 mm and the carbonaceous material was concentrated by froth flotation. The floated material was mounted in cold setting resin, ground and polished. Reflectance measurements were made on vitrinite particles having diameters 5 µm or larger. Readings on definite vitrinite particles are shown by solid lines in Fig. 8; doubtful vitrinite particles are shown by dots. Mean values for the definite particles at 546 nm with oil (refractive index 1.515) are listed in Table 2 and plotted in Fig. 9. A probable error of ± 0.05% corresponding to twice the standard error of the mean is applicable in most cases.

2.4. Condensate Analyses

The two condensates were separated into fractions in the same way as the extracts (Table 3) and gas chromatograms were run on the aliphatic fractions (Figs. 10 and 11).

3. DISCUSSION

When combined with the earlier data, the results given in this report give a better basis from which to assess the hydrocarbon potential of the Otway Basin. In general the conclusions of the previous report (IR 864R) have been confirmed.

1. The total amount of organic carbon in these Lower Cretaceous shales is not high (0.8 - 4.3%) but this is sufficient for a source rock provided the maturity is satisfactory. The range for the Upper Cretaceous samples studied earlier was 0.8 to 1.8%.

2. The total extracts are not large and are somewhat smaller than those obtained earlier from cores in Voluta No. 1 and shallower cores in Port Campbell No. 2. This could be due to an absence of sufficient source rocks for oil in the generating zone (generation and migration of gas will have little effect on amounts of extract) or to a rate of loss due to migration to the surface comparable to the rate of generation.

3. The alkane distributions indicate some generated hydrocarbons but in most cases this has been insufficient to obliterate the pattern of the indigenous alkanes with its odd-carbon preference from immature land plants.

4. The reflectance values are consistent with the present temperature being close to the maximum temperature reached since deposition. From the gradient in Fig. 9 it appears that a reflectance of 1.0% would be reached at ∿ 4000 m in these wells. It would be most interesting to know the nature and amount of organic matter in the sediments from 4000 to 5000 m (if basement has not already been reached).

5. No great variations in geothermal gradient are apparent, although values for the offshore wells (Mussel No. 1 and Voluta No. 1) do appear to be somewhat lower (2.3°C/100 m in Voluta No. 1, 2.1°C/100 m in Mussel No. 1, 2.5°C/100 m in Port Campbell No. 2, 2.3°C/100 m in Port Campbell No. 4 and 2.4°C/100 m in Flaxmans No. 1).

6. Data from the gas chromatograms of the condensates are plotted in Figs. 12 and 13 together with comparable data from some other Australian

crude oils. The Port Campbell and Flaxmans condensates are somewhat different but it is possible they were derived from the same source rock followed by disproportionation during migration and trapping. Neither condensate has undergone appreciable bacterial alteration. It is interesting to note (Fig. 13) that bacterial attack on the Port Campbell condensate would lead to a Moonie type oil, while the Flaxmans condensate would first give a Barrow Island (Jurassic) type oil and finally a Barrow Island Windalia type oil.

4. CONCLUSION

There appears to be source potential in the Lower Cretaceous samples examined, as well as in the Upper Cretaceous cores reported earlier. However, since all the Cretaceous core examined so far have been immature, the question arises as to whether a sufficient volume of such source rocks is or was present in hotter, deeper parts of the basin either now or in the past. The possibility of Jurassic (or older) source rocks also needs examination. The presence of the condensates and the evidence from the extracts for migration are encouraging. However, so far we are unable to be certain that sufficient quantities of lipid-rich organic matter (exinite) have been carried into the generating zone. Unless the rate of oil generation is appreciably higher than the rate of loss from potential reservoirs, significant deposits will not be found.

TABLE 1. LOWER CRETACEOUS CORES FROM THE OTWAY BASIN

(Descriptions supplied by Beach Petroleum)

Lab. No. 57987: Port Campbell No. 2, Core 15

2563.1 To 2565.8 m (recovery 2.4 m)

Top 1.5 m mudstone; dark grey to black to dark brown. Very fine texture, slightly micaceous (muscovite), very slightly sandy in streaks. Carbonaceous material (plant remains) and pyrite nodules. Core contains several slickensided zones, but not badly fractured. Thin edges of fragments are dark brown in colour. Not glauconitic.
0.9 m mudstone as above, but very highly pyritic sandy streaks and pyrite nodules.
Bottom 5 cm sandstone; light grey, very coarse to granule, subrounded to subangular, hard, tight, pyritic quartz sandstone. Pyrite is cementing agent.
Density: 2.6 g/cc. Apparent dip of sandstone streaks: 16°.

Lab. No. 57988: Port Campbell No. 4, Core 26

2523.4 To 2529.5 m (recovery 6.1 m)

2.1 m SANDSTONE; light to medium grey, slightly calcareous consists of very fine grained, subangular to subround, white, dull, cloudy, pink feldspar, dark rock fragments, some quartz, white and brown mica and green chlorite set in a white, clayey, slightly calcareous matrix. Black carbonaceous patches up to 1 cm long frequent. Sandstone appears massive with a joint or fracture one foot from the top of the core dipping at 80° and having white calcite filling red-stained with iron oxide in places.

4.0 m SILTSTONE; dark grey, tight, non-fissile, micaceous, carbonaceous and slightly sandy, fractured, subconchoidal. Bedding flat or nearly so. Laminated in places, showing small scale cross-bedding. No hydrocarbons.

Lab. No. 57989: Flaxmans No. 1, Core 27

2194.6 To 2200.7 m (recovery 2.7 m)

Interbedded light to dark grey sandstones made up of fine mainly medium angular to subangular quartz, few soft, white decomposed feldspar grains, green chlorite and carbonaceous material and some calcareous cement, interbedded and laminated with dark grey micaceous and carbonaceous siltstone. Evidence of small scale cross bedding and lenticular structures. Resin common.
No fluorescence in core. Acetone cut slightly positive with pale bluish fluorescence. Dip: 15°.
Density: Sandstone 2.48 g/cc, Siltstone 2.55 g/cc.

TABLE 1 (Cont).

Lab. No. 57990: Flaxmans No. 1, Core 36

2780.7 To 2784.3 m (recovery 2.7 m)

Interbedded light grey, very fine to fine grained feldspathic sandstone (greywacke) and medium to dark grey siltstones and mudstones. Sandstones are made up of feldspar, dark rock fragments, mica and minor quartz, and are calcareous in parts. Siltstones and mudstones are very carbonaceous and micaceous. Core is laminated with dips of 12° to 15° and is uniformly tight. Density: 2.46 g/cc for sandstone, 2.63 g/cc for mudstone. No oil or gas.

Lab. No. 57991: Flaxmans No. 1, Core 41

3292.1 To 3297.0 m (recovery 4.9 m)

Mainly dark grey to brown grey, feldspathic, micaceous and carbonaceous siltstone and mudstone with thin light grey fine grained feldspathic sandstone (greywacke) bands with constituents as before, and very slightly calcareous in parts. Core is cross bedded and has calcite filling in some of the joints. Dip of 17° to 25°. Density: sandstone 2.33 g/cc, mudstone 2.63 g/cc. No apparent oil or gas.

Lab. No. 57992: Mussel No. 1, Core 3

2235.7 To 2242.4 m

Black carbonaceous mudstone.

TABLE 2. ANALYTICAL DATA ON CORE SAMPLES FROM THE OTWAY BASIN

CSIRO Lab. No.	Well	Core	Depth (m)	Total extract (ppm)	Aliphatic fraction (ppm)	Aromatic fraction (ppm)	Polar fraction (ppm)	Residue (ppm)	Reflect-ance (%)	Total sulphur (%)	Carbonate carbon (%)	Organic carbon (%)	Present Temper-ature (°C)*
57987	Port Campbell No. 2	15	2563.1-2565.8	169	45	93	12	2	0.69	0.59	0.05	3.45	84
57988	Port Campbell No. 4	26	2523.4-2529.5	15	3	8	13	1	0.77	0.04	0.00	0.75	78
57989	Flaxmans No. 1	27	2194.5-2200.7	69	3	42	13	4	0.58	0.20	0.00	2.80	73
57990	Flaxmans No. 1	36	2780.7-2784.3	56	30	15	12	1	0.62	0.08	0.00	1.15	87
57991	Flaxmans No. 1	41	3292.1-3297.0	95	4	57	8	3	0.84	0.03	0.01	1.29	100
57992	Mussel No. 1	3	2235.7-2242.4	173	52	57	17	4	0.55	1.29	0.26	4.31	67

*Uncorrected values estimated from data in well logs supplied by Beach Petroleum

TABLE 3. DATA ON OTWAY BASIN CONDENSATES

CSIRO Lab. No.	57993	57994
Well	Port Campbell No. 1	Flaxmans No. 1
Test	Production Test No. 1	Production Test No. 1
Depth (m)	1693–1727	3305–3514
API Gravity	62°	51°
Aliphatic fraction (%)	13.7	30.8
Aromatic fraction (%)	0.2	0.7
Polar fraction (%)	0.3	0.3
Low-boiling material (%)*	85.8	68.2

*Represents material lost during evaporation of aliphatic, aromatic and polar fractions (together with a very small amount of material not eluted from the florisil column).

12/24

Fig. 1. Location of exploration wells in the Otway Basin

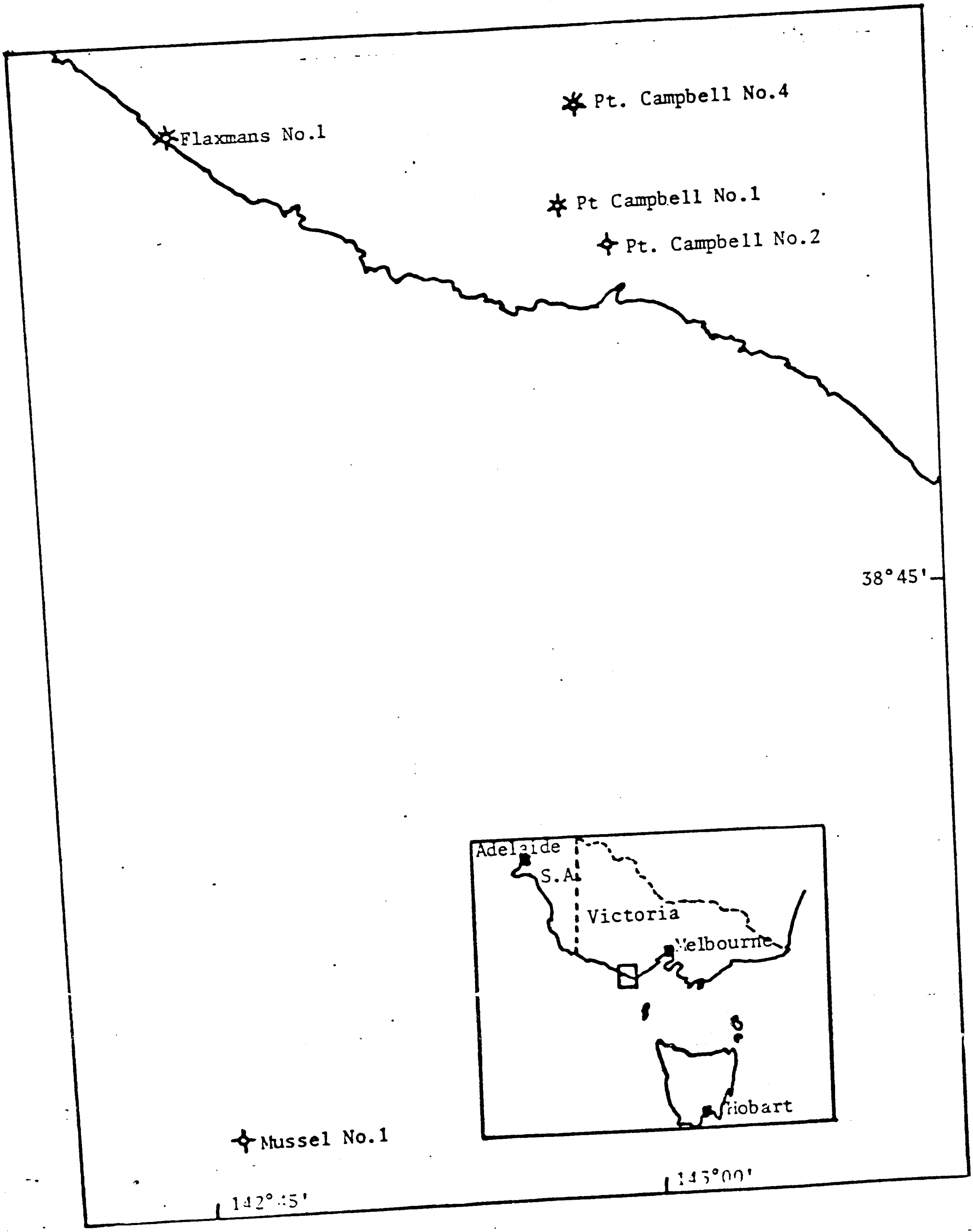
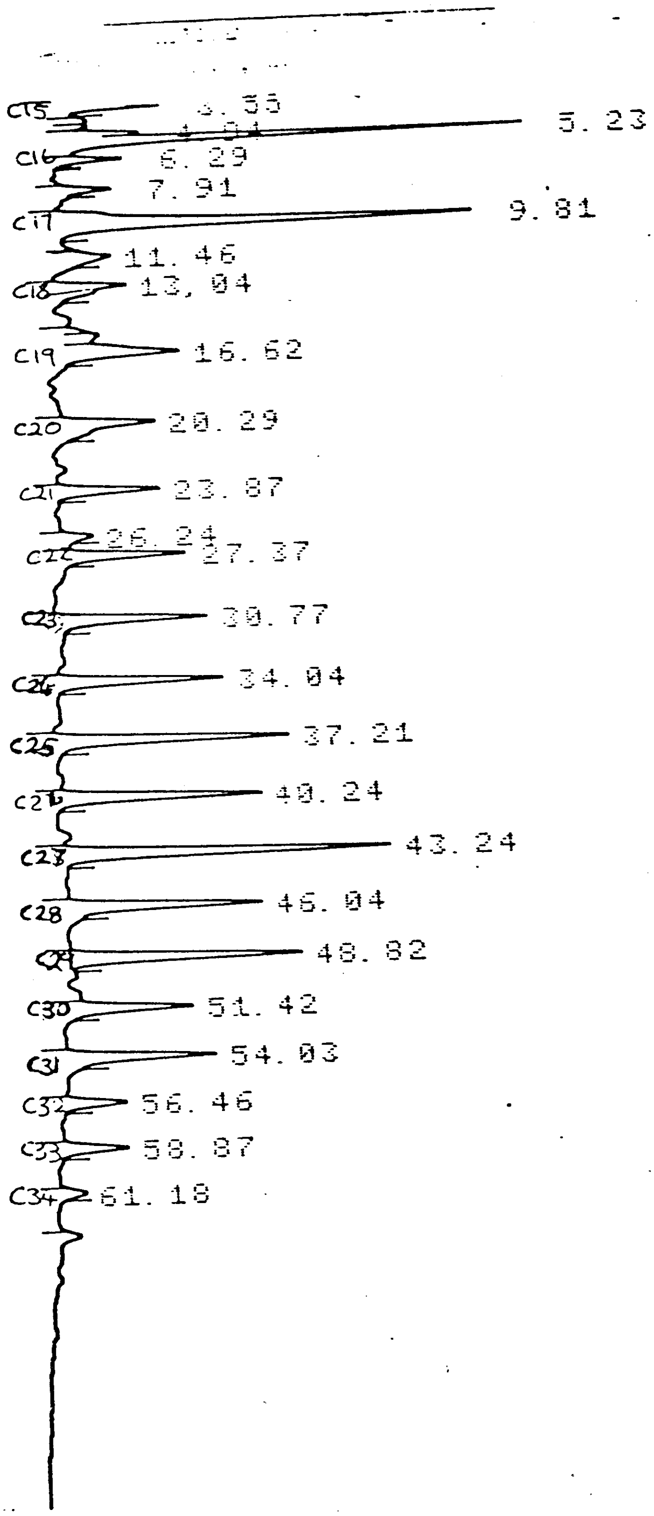


Fig. 2. Gas chromatogram of aliphatic fraction extracted from Core 15, Port Campbell No. 2



L.No. 57987 T 5867

Sample: Petroleum ether extract

Origin: Port Campbell No. 2, Core 15

Depth 2563·1m – 2565·8m

Otway Basin

$CHCl_3$ extracted C587

C.N.	%	C.N.	%	
5		20	2·9	
6		21	2·4	K. ____
7		22	2·8	
8		23	3·7	
9		24	4·0	Pr/Ph ____
10		25	5·8	
11		26	5·0	Pr% ____
12		27	8·1	
13		28	4·7	
14		29	5·7	Ph% ____
15	1·5	30	3·0	
16	7·5	31	3·6	
17	11·2	32	1·6	
18	2·2	33	1·7	
19	2·9	34	0·7	

Fig. 3. Gas chromatogram of aliphatic fraction extracted from Core 2, Port Campbell No. 4

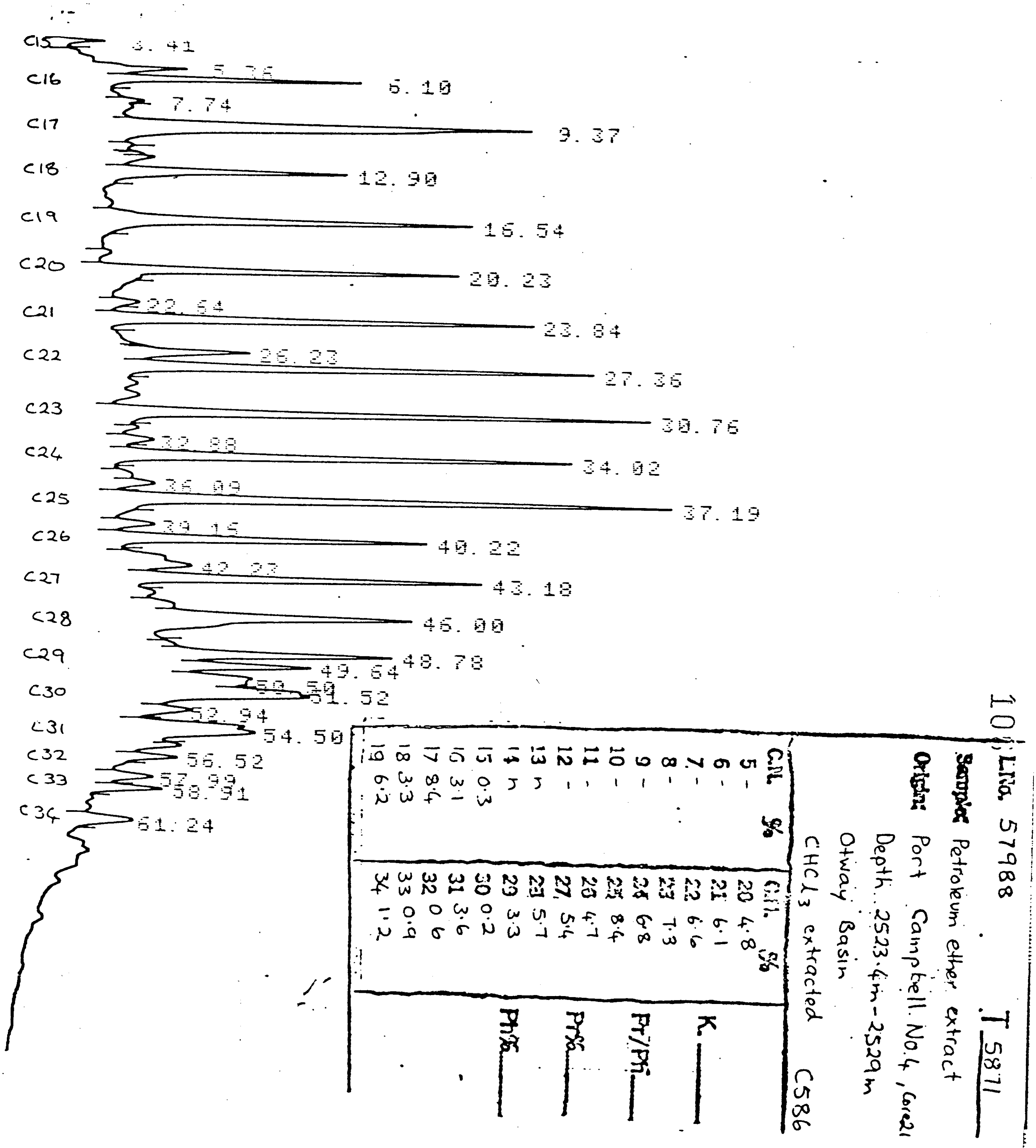
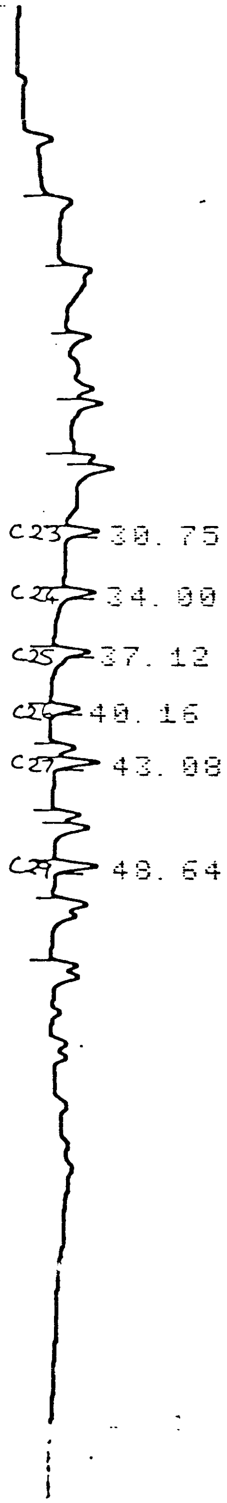


Fig. 4. Gas chromatogram of aliphatic fraction extracted from Core 27, Flaxmans No. 1



L.No. 57989 T 5875

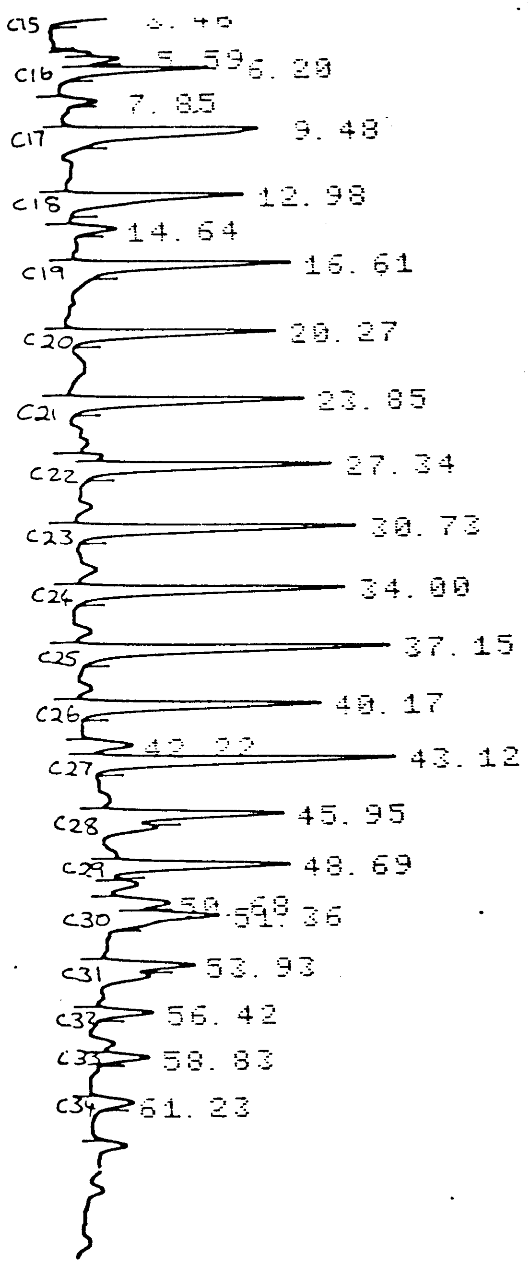
Sample: Petroleum ether extract

Origin: Flaxman's No. 1, Core 27
Depth 2194.6m – 2200.6m
Otway Basin
$CHCl_3$ extracted C588

C.N.	%	C.N.	%	
5	–	20	n	
6	–	21	n	K. ______
7	–	22	n	
8	–	23	15.0	
9	–	24	14.8	Pr/Ph ______
10	–	25	13.5	
11	–	26	13.0	Pr% ______
12	n	27	21.0	
13	n	28	n	
14	n	29	22.6	Ph% ______
15	n	30	–	
16	n	31	–	
17	n	32	–	
18	n			
19	n			

Operator L.B. Date 28.9.77
COLUMN No. 2B Length 2m Dia. 3m.m.
Coating SE 30 Concn. 0.5%
Support CHROMOSORB G Mesh. 80–100
TEMP: Col: Init. 110°C 2min °C Final 260 °C
Rate ______ °C/min. Det. 300 °C Inj. 270 °C
CARRIER GAS Helium, Rate 30 ml./min.
Pressures: Inlet 60 p.s.i. Outlet 15 p.s.i.
Hydrogen 50 ml./min. Air 500 ml./min.
DETECTOR: F.I.D ; ______ ma. ______ volts
Scavenger ______, Rate ______ ml./min.
Sens. 16 X 10³ Rec. range 4 mv.
SAMPLE T5867 Size 1µl
Solvent Hexane Concn. 20µl

Fig. 5. Gas chromatogram of aliphatic fraction extracted from Core 36, Flaxmans No. 1



L.No. 57990 T 5879

Extract Petroleum ether extract

Origin Flaxman's No.1, Core 36
Depth 2780·7m–2784·3 m
Otway Basin
$CHCl_3$ extracted C589

C.N.	%	C.N.	%
5	–	20	5·2
6	–	21	6·0
7	–	22	5·9
8	–	23	7·2
9	–	24	7·1
10	–	25	8·6
11	–	26	6·5
12	–	27	8·2
13	n	28	3·8
14	n	29	4·5
15	1·7	30	2·7
16	2·3	31	1·5
17	6·8	32	1·5
18	5·2	33	1·3
19	5·2	34	1·2

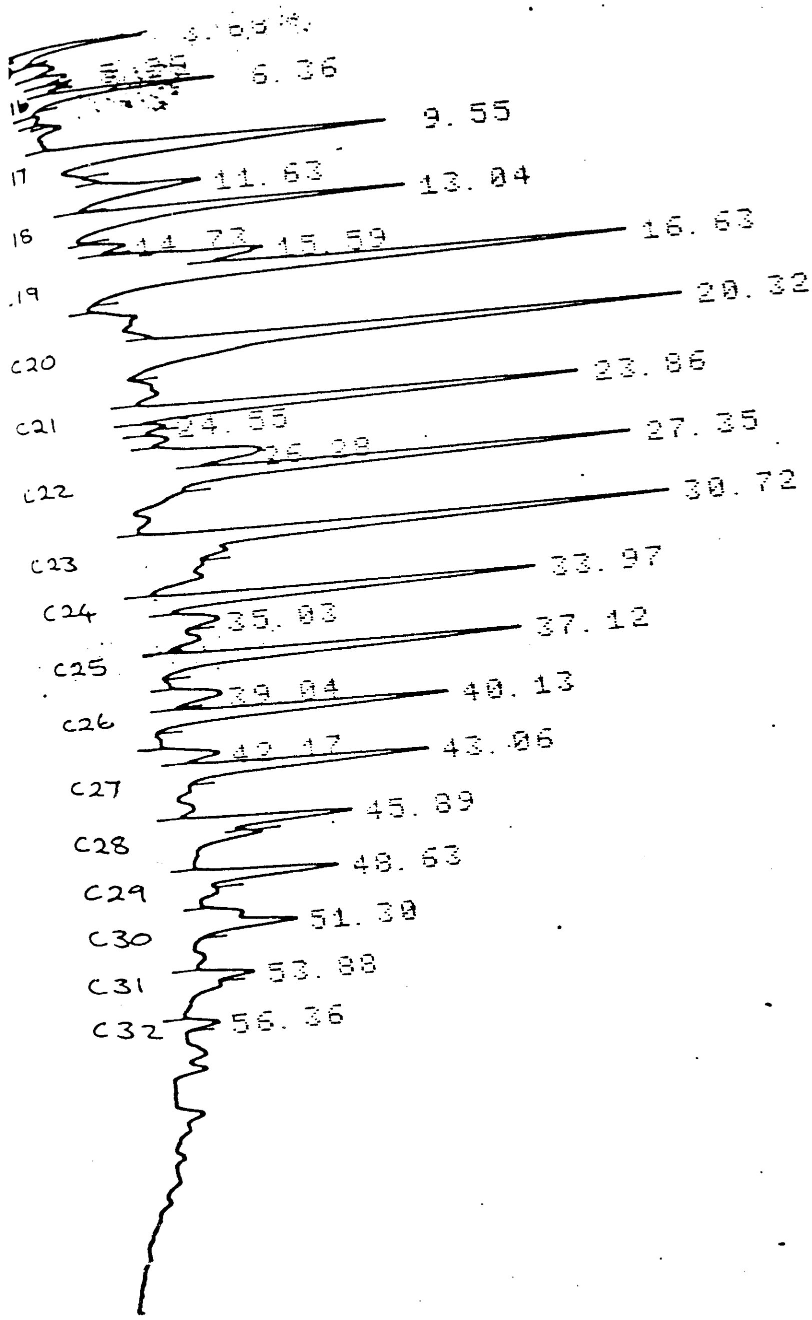
K. ....

Pr/Ph..........

Pr%..........

Ph%..........

Fig. 6. Gas chromatogram of aliphatic fraction extracted from Core 14, Flaxmans No. 1



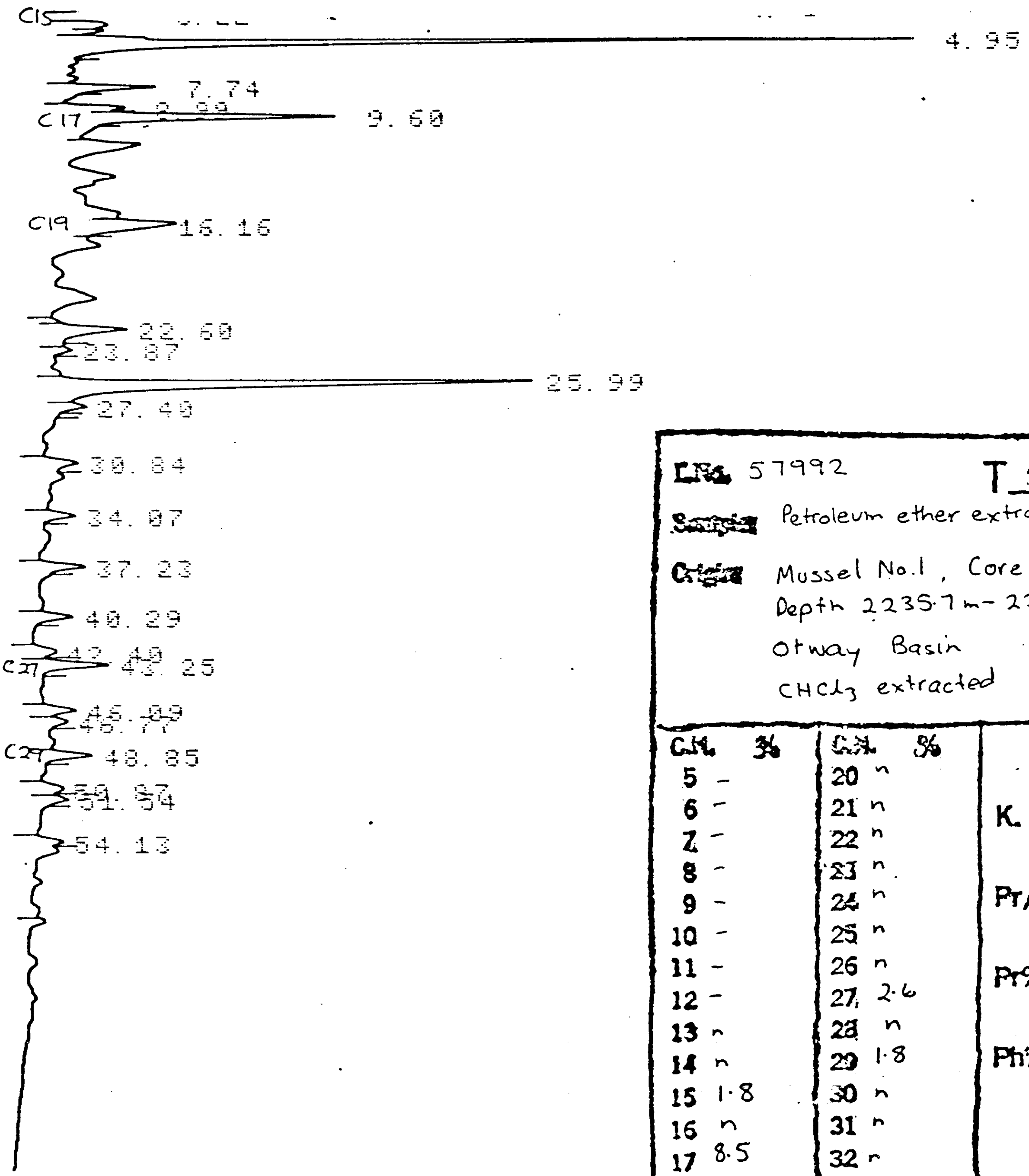
L.No. 57991 T 5883

Sample: Petroleum ether extract

Origin: Flaxmans No.1, Core 14
Depth 3292.1m – 3297.0m
Otway Basin
$CHCl_3$ extracted C590

C.N.	%	C.N.	%	
5	–	20	9.9	K. ....
6	–	21	6.2	
7	–	22	7.0	Pr/Ph........
8	–	23	8.3	
9	–	24	5.5	Pr%........
10	–	25	5.6	
11	–	26	4.3	Ph%........
12	?	27	4.0	
13	n	28	1.9	
14	n	29	2.0	
15	1.5	30	5.5	
16	1.9	31	0.6	
17	6.6	32	0.5	
18	5.4			
19	10.5			

Fig. 7. Gas chromatogram of aliphatic fraction extracted from Core 3, Mussel No. 1



L.No. 57992 T 5887

Sample: Petroleum ether extract

Origin: Mussel No.1, Core 3
Depth 2235·7m–2242·4m
Otway Basin
$CHCl_3$ extracted

C591

C.N.	%	C.N.	%	
5	–	20	n	
6	–	21	n	K.
7	–	22	n	
8	–	23	n	
9	–	24	n	Pr/Ph
10	–	25	n	
11	–	26	n	Pr%
12	–	27	2·6	
13	n	28	n	
14	n	29	1·8	Ph%
15	1·8	30	n	
16	n	31	n	
17	8·5	32	n	
18	n			
19	3·9			

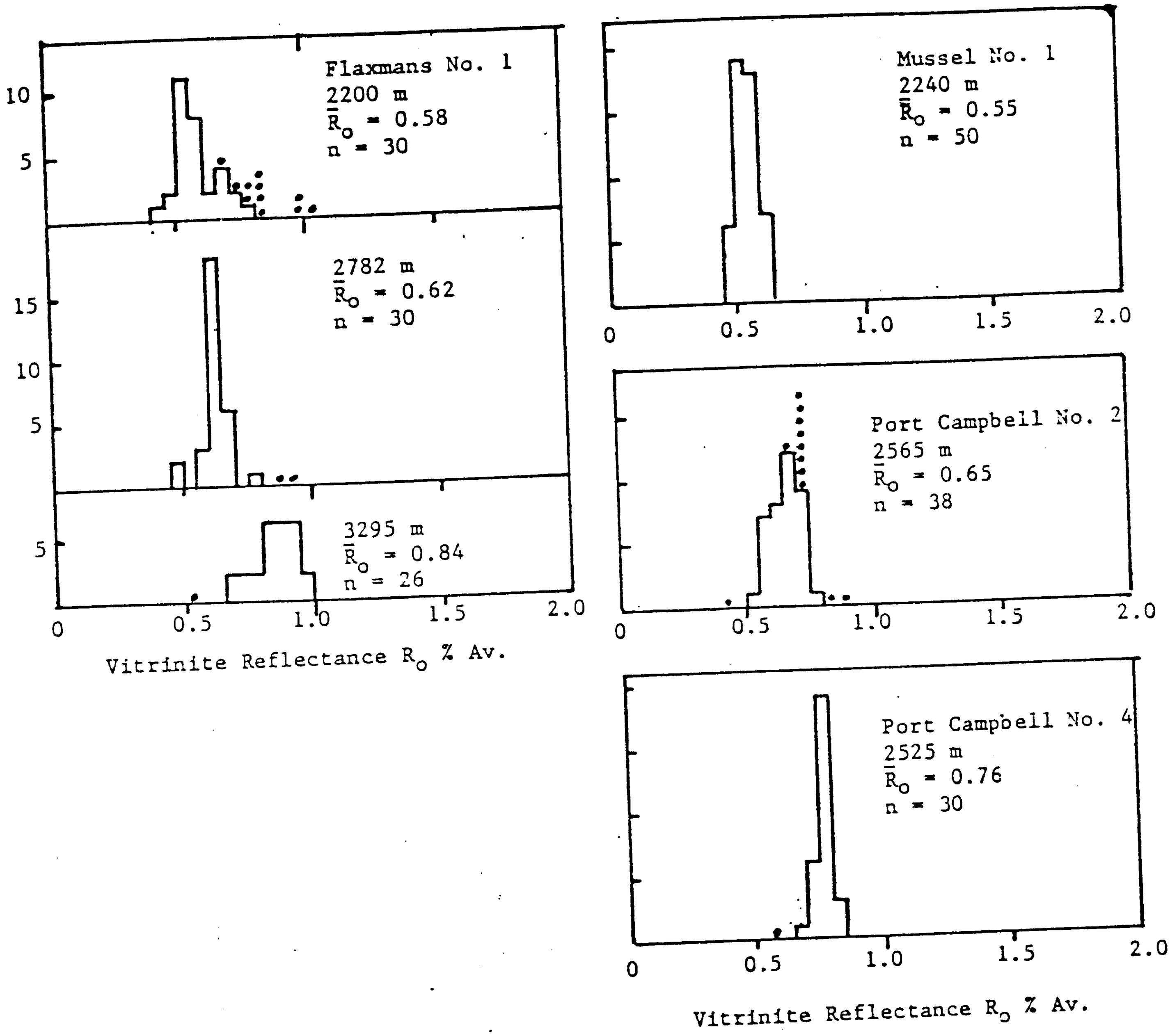


Fig. 8. Reflectance histograms for Flaxmans No. 1, Port Campbell Nos. 2 and 4, and Mussel No. 1, Otway Basin, Vic.

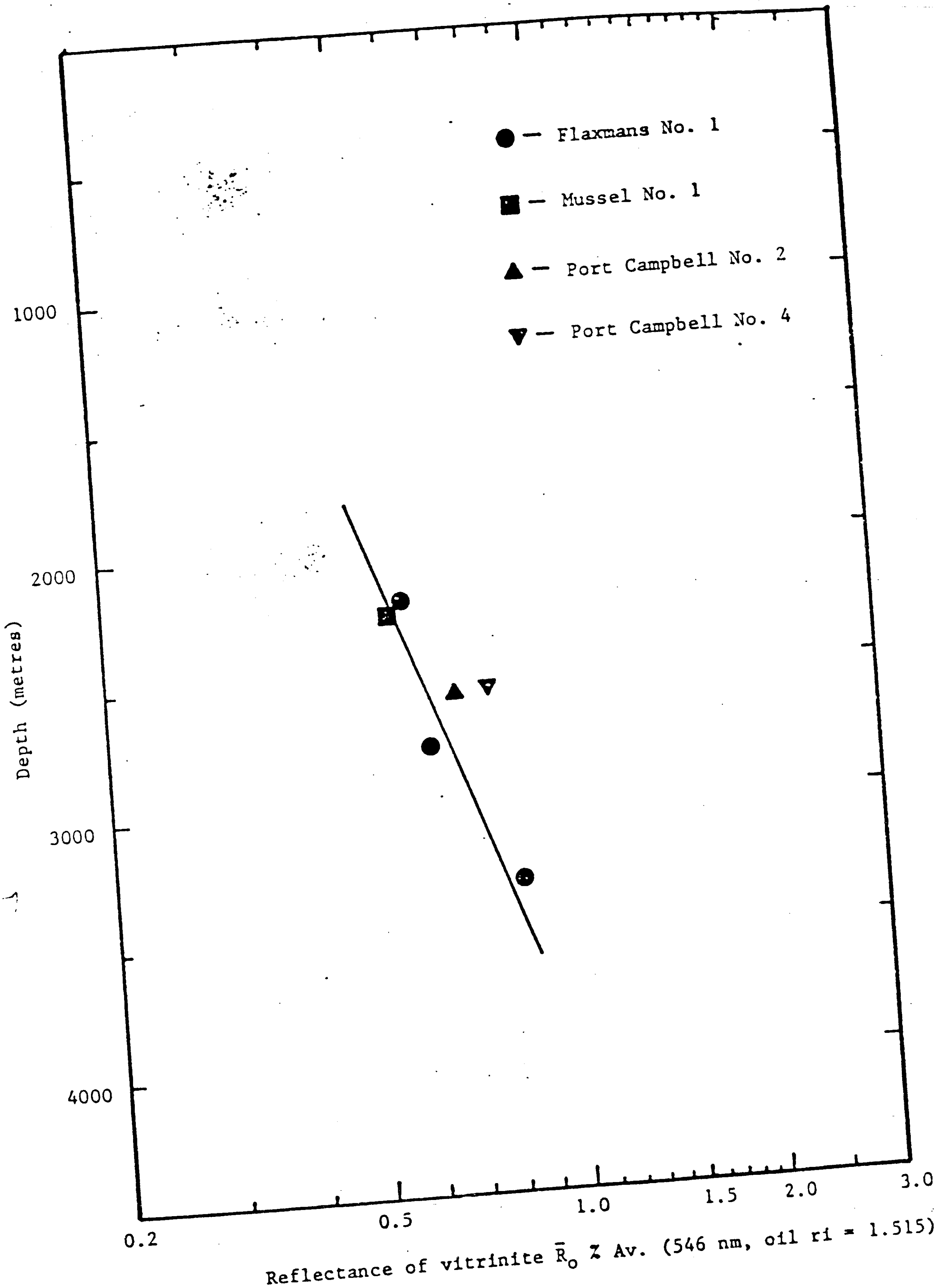
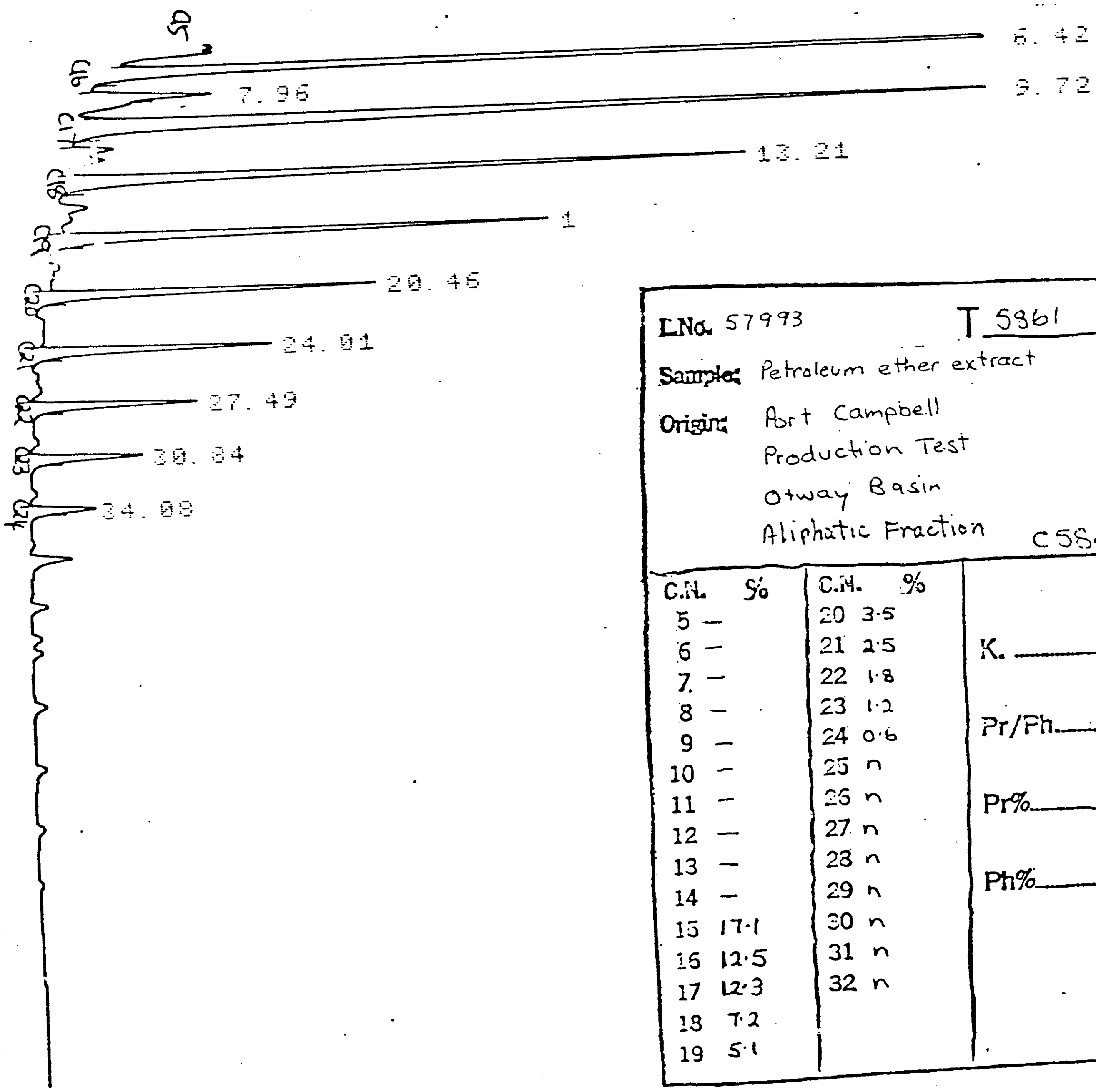


Fig. 9. Depth/reflectance curves for Flaxmans No. 1, Port Campbell Nos. 2 and 4, and Mussel No. 1, Otway Basin, Vic.

Fig. 10. Gas chromatogram of aliphatic fraction extracted from production test, Port Campbell condensate



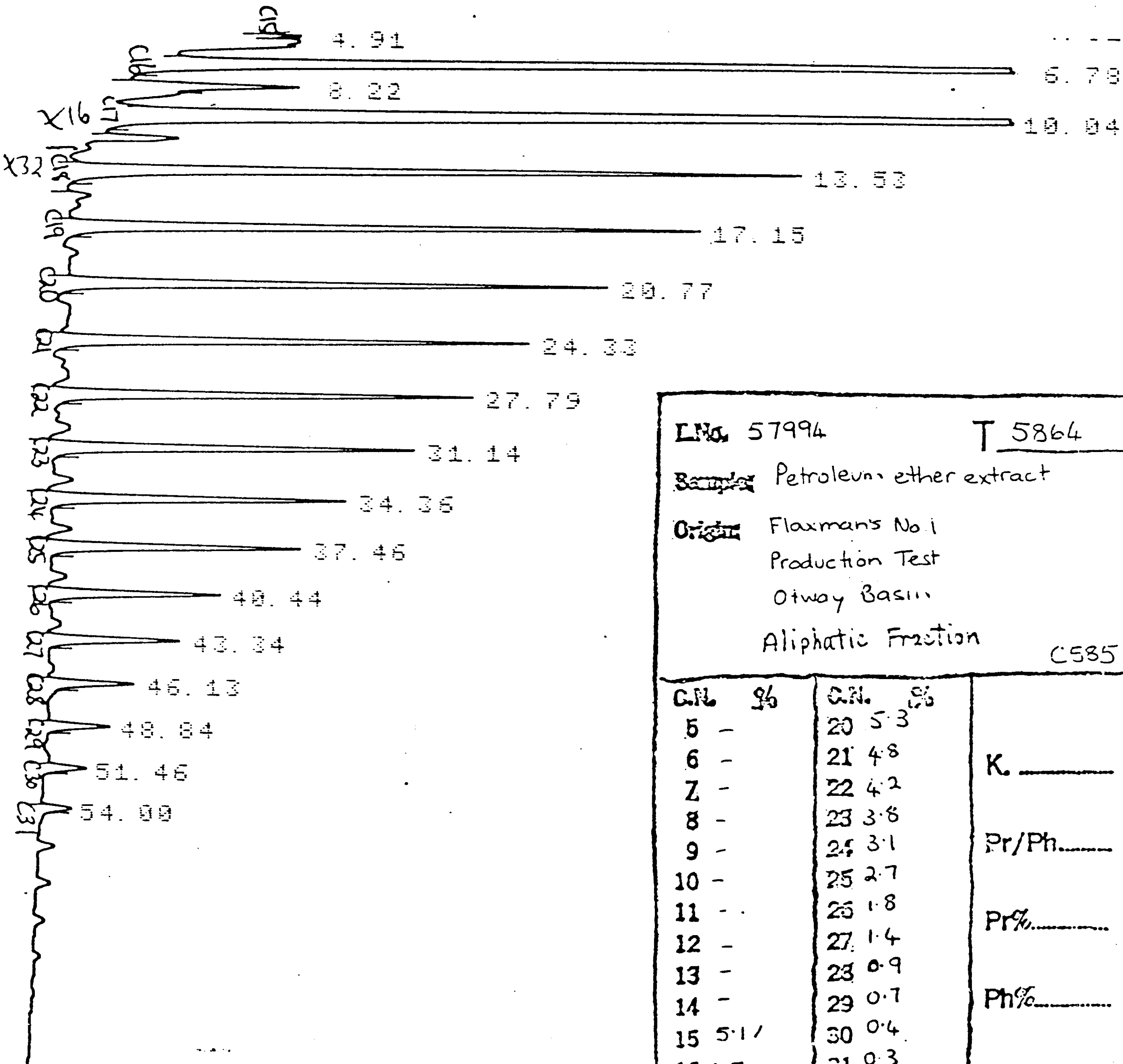
I.No. 57993 T 5861

Sample: Petroleum ether extract

Origin: Port Campbell
Production Test
Otway Basin
Aliphatic Fraction C584

C.N.	%	C.N.	%	
5	—	20	3·5	
6	—	21	2·5	K.
7	—	22	1·8	
8	—	23	1·2	
9	—	24	0·6	Pr/Ph.
10	—	25	n	
11	—	26	n	Pr%.
12	—	27	n	
13	—	28	n	
14	—	29	n	Ph%.
15	17·1	30	n	
16	12·5	31	n	
17	12·3	32	n	
18	7·2			
19	5·1			

Fig. 11. Gas chromatogram of aliphatic fraction extracted from production test, Flaxmans No. 1 condensate



L.No. 57994 T 5864

Sample: Petroleum ether extract

Origin: Flaxman's No 1
Production Test
Otway Basin
Aliphatic Fraction

C585

C.N.	%	C.N.	%	
5	–	20	5.3	
6	–	21	4.8	K.
7	–	22	4.2	
8	–	23	3.8	
9	–	24	3.1	Pr/Ph.
10	–	25	2.7	
11	–	26	1.8	
12	–	27	1.4	Pr%.
13	–	28	0.9	
14	–	29	0.7	Ph%.
15	5.1	30	0.4	
16	4.7	31	0.3	
17	5.1	32	h	
18	7.4			
19	6.3			

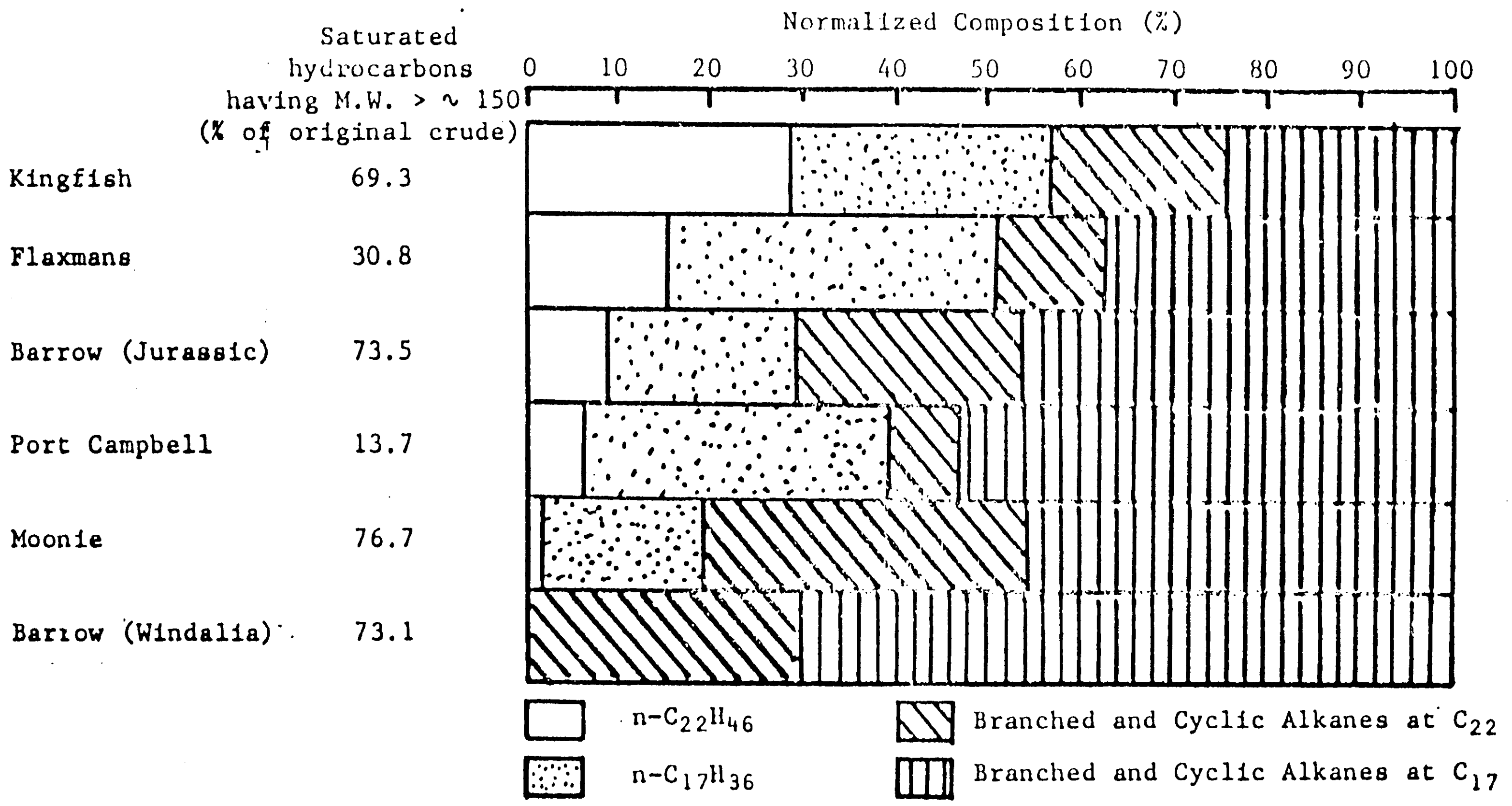


Fig. 12. Distribution of hydrocarbons in Port Campbell and Flaxmans condensates and in selected Australian crudes (Arranged in approximate order of decreasing wax content)

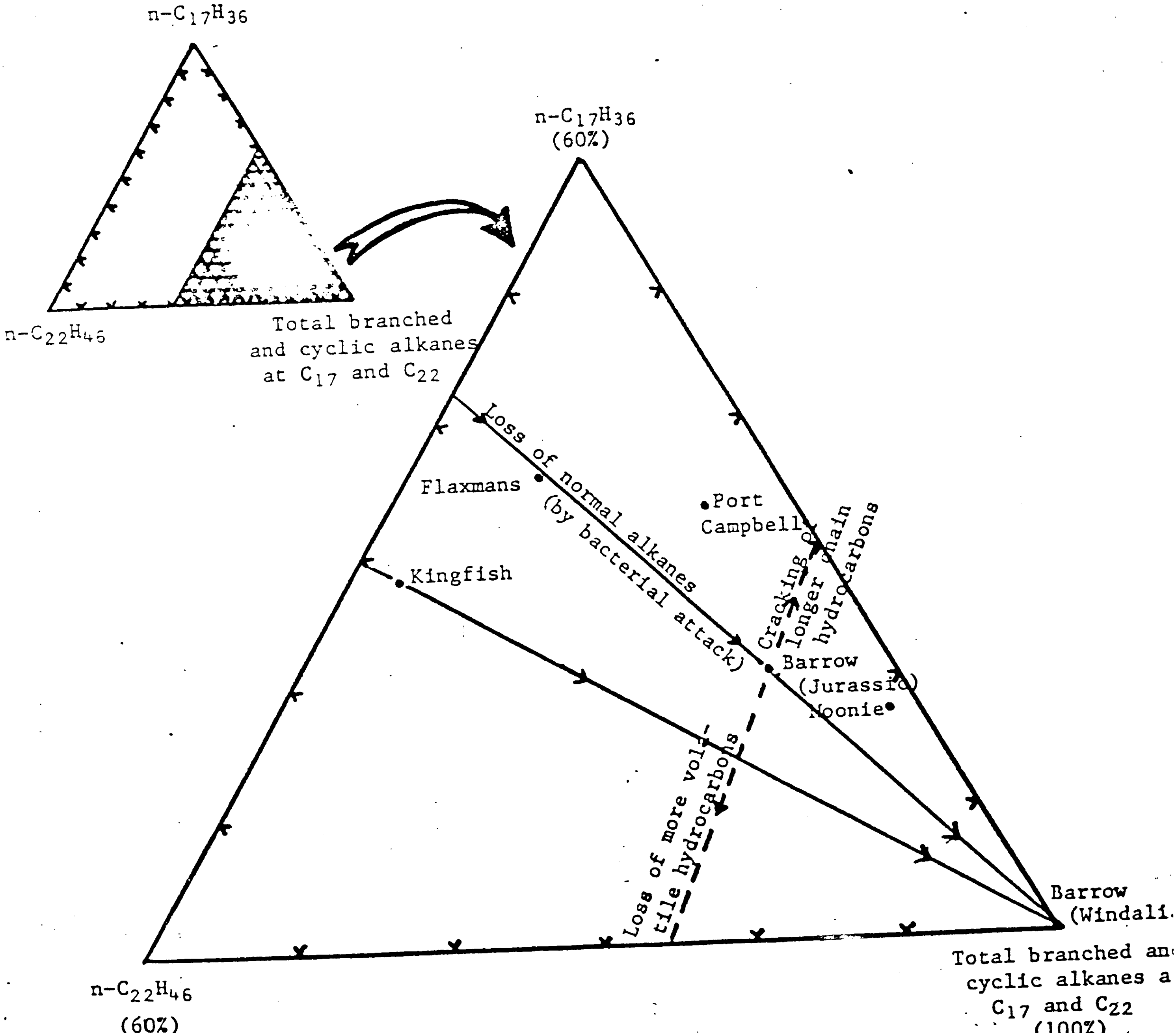


Fig. 13. **Compositions and alteration pathways of crude oils**