PORT CAMPBELL-4

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GEOCHEMICAL EVALUATION

OF

AN OIL SAMPLE FROM

ATTACHMENT
TO WCR
PORT CAMPBELL-4
W484

PORT CAMPBELL-4

OTWAY BASIN

VICTORIA

PREPARED BY: James Preston
Senior Petroleum
Geologist

jp0040

DATE: September 1992

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TABLE OF CONTENTS

Figures

Tables

INTRODUCTION

A range of organic geochemical analyses were performed on a sample of hydrocarbon fluid obtained from the Port Campbell-4 well, located in the onshore Otway Basin, Victoria. These analyses were whole-oil gas chromatography (WOGC), liquid chromatography (LC), saturate-fraction gas chromatography (SGC), saturate-fraction and aromatic-fraction gas chromatography-mass spectrometry (GC-MS), and stable carbon isotope analysis.

Results of these analyses, together with an interpretation of them, are presented in this report.

FLUID CHARACTERISATION

Whole-Oil Gas Chromatography (WOGC)

The whole-oil GC trace for the Port Campbell-4 sample is shown in Figure 1, and a summary of the whole-oil GC data in Table 1. This table includes the results of analysis of gasoline range (C_4-C_8) hydrocarbons, the GC trace of which is shown as Figure 2.

Inspection of Figure 1 shows that the Port Campbell-4 fluid contains peak abundances in the C_9 to C_{10} range (see also Table 1), with a steady decrease in abundances to about C_{19}, and a sharper decrease (with a hint of odd-over-even preference) into the C_{31}+ range. In addition, there appears to be a sharp decrease in the abundances of compounds lighter than C_9, no n-alkanes lighter than C_6 being detected.

Light Hydrocarbon Analysis (C_4-C_8)

Table 1 includes a breakdown of all significant compounds in the C_4-C_8 fraction of the Port Campbell-4 fluid, together with a list of parameters calculated from these data.

The most significant of these parameters are the Paraffin Indices (I and II). These indices are of most value in assessing the maximum temperature to which the fluid has been exposed (this is usually the temperature at which the fluid was expelled from the source rock). Data from the Port Campbell-4 fluid suggest that it was expelled from the source rock at a temperature of about 145 °C, implying that the source rock was at peak-generation levels of thermal maturity (about 1.0% vitrinite reflectance). Ratios of certain of the C_4-C_8 compounds (N/K and J/K) contradict this, suggesting overmaturity. Other parameters (I/M and I/J) suggest that the oil has not been significantly water-washed or biodegraded; however, as Figure 1 shows, losses of lighter compounds from the oil are extreme, suggesting that these compounds have been lost from the fluid during drilling, sampling or storage, or all three. Indeed, because of these losses from the C_4-C_8 fraction, the ratios of these compounds may not be reliable as parameters by which to interpret thermal maturity.

TABLE 1

SUMMARY OF WHOLE OIL ANALYSIS

WELL = PORT CAMPBELL DEPTH 1 = N/A DEPTH UNIT = N/A
COUNTRY = AUS DEPTH 2 = N/A DATE OF JOB = JANUARY 1992
BASIN = unknown

PORT CAMPBELL 4, Crude Oil

COMPOSITION BY CARBON NUMBER

Carbon No.	Rel.Wt%
1 – 3	–
4	–
5	–
6	0.61
7	3.97
8	7.50
9	8.09
10	7.57
11	6.19
12	6.16
13	6.53
14	6.32
15	6.06
16	5.18
17	5.66
18	4.44
19	4.49
20	3.48
21	3.01
22	2.92
23	2.61
24	2.11
25	1.84
26	1.37
27	1.09
28	0.85
29	0.67
30	0.49
31	0.39
32	0.27
33	0.13

COMPOSITION OF C4–C8 FRACTION

Compound	Rel.Wt%
isobutane (A)	–
n–butane (B)	–
isopentane (C)	–
n–pentane (D)	–
2,2–dimethylbutane (E)	–
cyclopentane (F)	–
2,3–dimethylbutane (G)	0.07
2–methylpentane (H)	0.28
3–methylpentane (I)	0.28
n–hexane (J)	3.97
methylcyclopentane (K)	0.90
2,4–dimethylpentane (L)	0.48
benzene (M)	–
cyclohexane (N)	3.02
1,1–dimethylcyclopentane (O)	1.14
2–methylhexane (P)	3.37
3–methylhexane (Q)	4.37
1 cis–3–dimethylcyclopentane (R)	0.97
1 trans–3–dimethylcyclopentane (S)	1.66
1 trans–2–dimethylcyclopentane (T)	0.26
n–heptane (U)	13.70
methylcyclohexane (V)	28.37
1 cis–2–dimethylcyclopentane (W)	0.64
toluene (X)	0.90
n–octane (Y)	30.90
ethylbenzene (Z)	1.81
M+P–xylene (AA)	2.29
O–xylene (BB)	0.62

CALCULATED DATA – C12+ FRACTION

Pristane/Phytane	3.61
Pristane/n–C17	0.45
Phytane/n–C18	0.13
TMTD/Pristane	0.72
(C21+C22)/(C28+C29)	5.30

NOTES :
TMTD = Trimethyltridecane
– = Below detection limit or not measured

CALCULATED DATA – C4–C8 FRACTION

Paraffin Index I	2.67
Paraffin Index II	24.10
N/K (Maturity)	3.36
C/D (Maturity)	–
J/K (Maturity)	4.42
I/M (Water washing)	–
I/J (Biodegradation)	0.07

Paraffin Index I = (P+Q)/(R+S+T)
Paraffin Index II = %U in listed compounds N to V

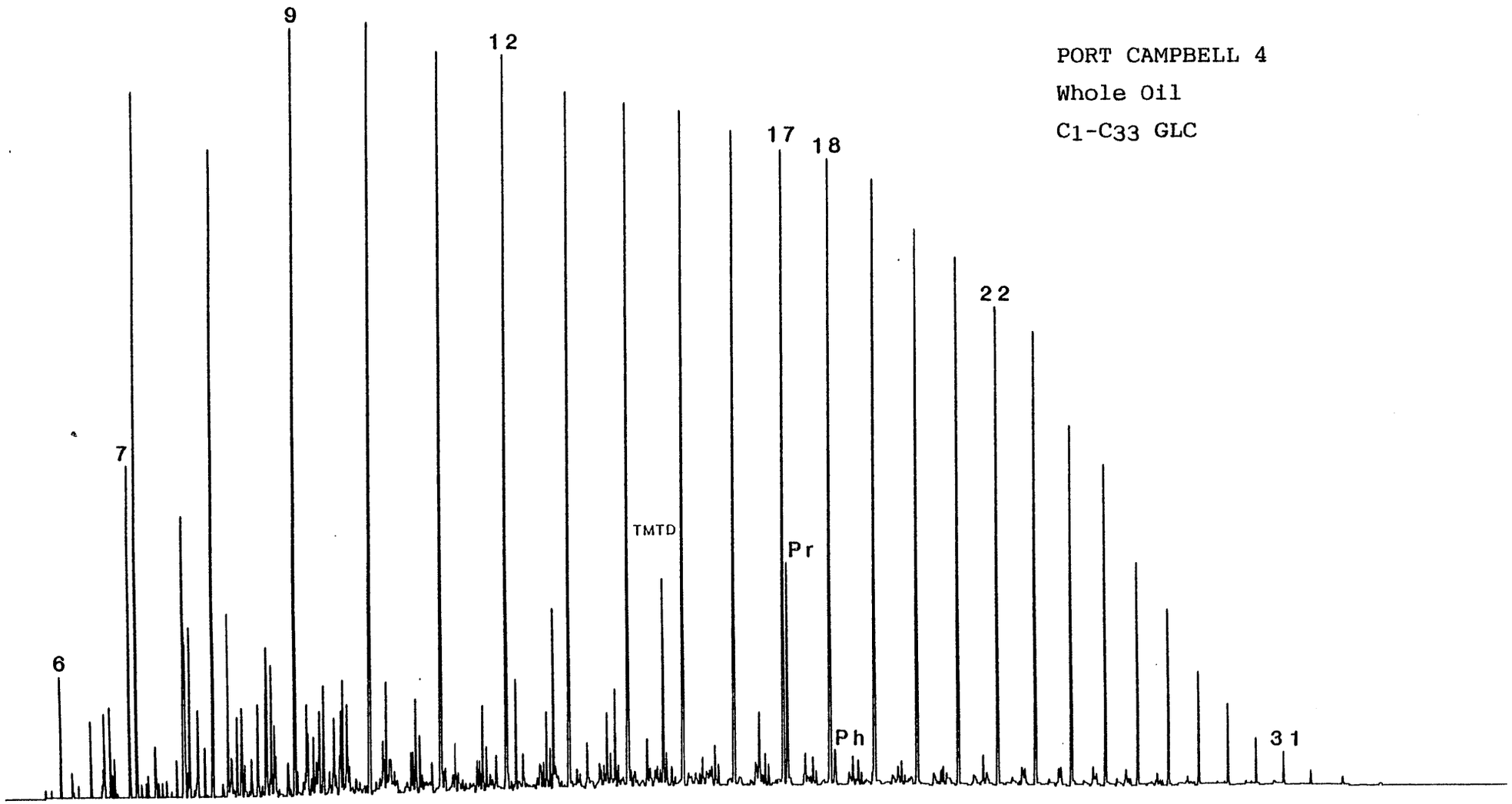
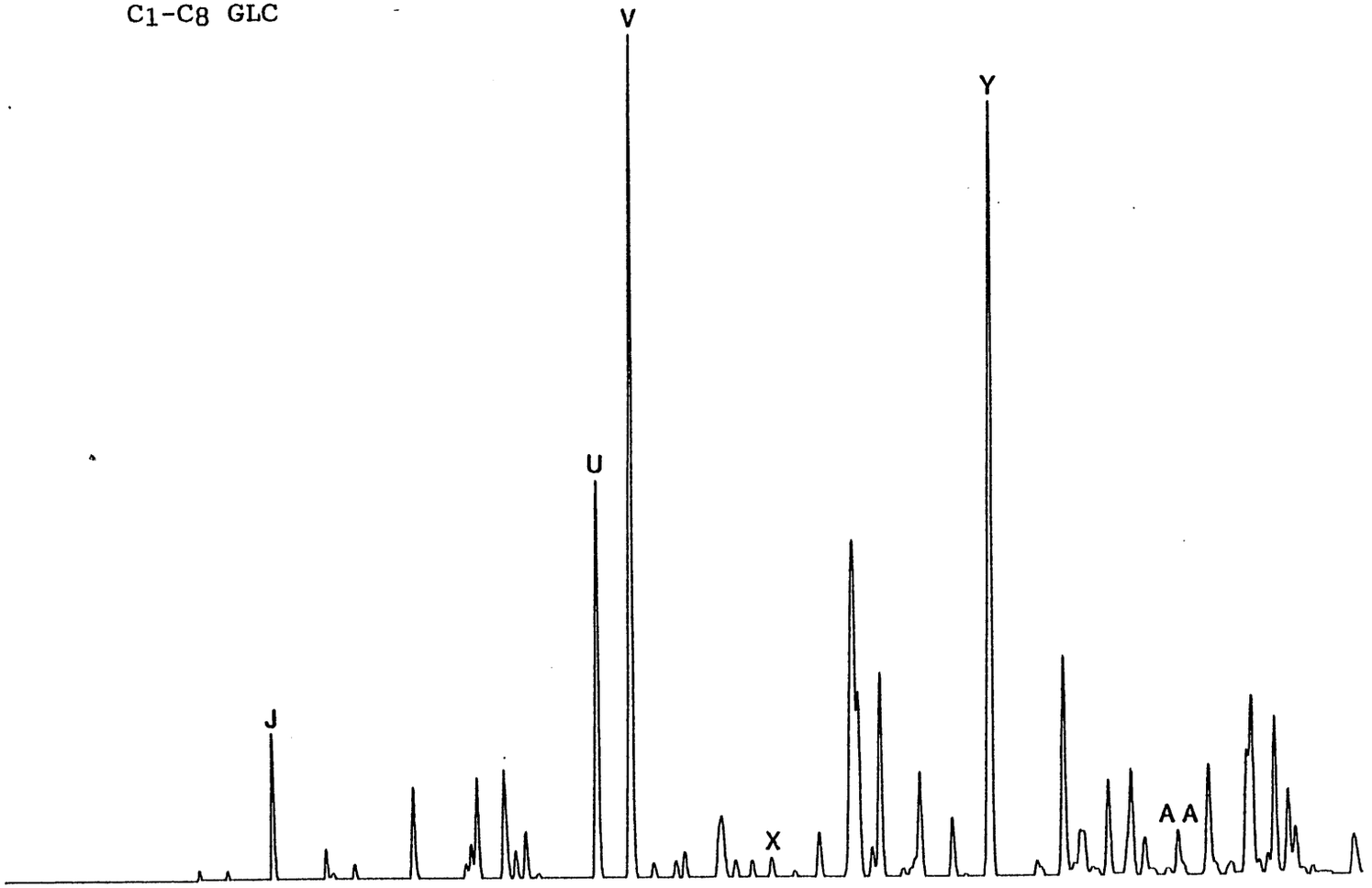

PORT CAMPBELL 4
Whole Oil
C1-C33 GLC
6
7
9
12
TMTD
17
Pr
18
Ph
22
31

Figure 1

PORT CAMPBELL 4

Gasoline Range Whole Oil

C_1-C_8 GLC



C4-C8 COMPOUNDS

A	isobutane
B	n- butane
C	isopentane
D	n- pentane
E	2,2- dimethylbutane
F	cyclopentane
G	2,3- dimethylbutane
H	2- methylpentane
I	3- methylpentane
J	n- hexane
K	methylcyclopentane
L	2,4- dimethylpentane
M	benzene
N	cyclohexane
O	1,1- dimethylcyclopentane
P	2- methylhexane
Q	3- methylhexane
R	1 cis-3- dimethylcyclopentane
S	1 trans-3- dimethylcyclopentane
T	1 trans-2- dimethylcyclopentane
U	n- heptane
V	methylcyclohexane
W	1 cis-2- dimethylcyclopentane
X	toluene
Y	n- octane
Z	ethylbenzene
AA	M+P- xylene
BB	O- xylene

Figure 2

C_{12}+ Fraction

As Figure 1 shows, the Port Campbell-4 fluid is characterised by a compound distribution which peaks in the C_9 to C_{10} range, its compound abundances falling away steadily to the C_{19+} range and more sharply thereafter. While the value of the $(C_{21}+C_{22})/(C_{28}+C_{29})$ ratio (3.61) is typical of aquatically derived organic matter, values calculated for the pristane/phytane and (allowing for maturity) pristane/n-C_{17} ratios are typical of organic matter deposited in a relatively oxidising, terrestrial environment, in which some oxidation of the organic matter had taken place prior to its final incorporation in the sediment. In addition, there is some evidence of an odd-over-even preference in Figure 1, typical of partly matured, land-plant-derived organic matter.

Liquid Chromatography (LC)

The Port Campbell-4 fluid was separated by liquid chromatography, and the results are shown in Table 2. The relatively low proportion of aromatics in the fluid is reflected in the saturates/aromatics ratio of 12.59.

Saturate-Fraction Gas Chromatography (SGC)

The SGC trace for the Port Campbell-4 fluid is shown in Figure 3. As Figure 3 and Table 3 show, the n-alkane abundances remain fairly constant in the C_{12} to C_{19} range and then, like the whole-oil GC trace, decrease sharply with a slight odd-over-even preference to the heavier end of the trace.

The value of the $(C_{21}+C_{22})/(C_{28}+C_{29})$ parameter (2.95) calculated from the SGC data (Table 4) affirms that calculated from the C_{12}+ fraction of the whole-oil GC data, and a similar interpretation could be made from it. However, the CPI values calculated from the saturate-GC data are typical of thermally mature, land-plant derived organic matter, in which an odd-over-even preference is still evident.

The value of pristane/phytane supports this inference regarding the provenance of the source organic matter. This value (5.33) is typical of a relatively oxidising depositional environment (in which organic matter is exposed to oxidation during, or prior to, the

deposition of the host sediment). Conditions such as these are more typical of terrestrial environments than of aquatic/marine. This being so, the CPI values listed in Table 4 are an indication of a moderate degree of thermal maturation, which in turn suggests that the value of the $(C_{21}+C_{22})/(C_{28}+C_{29})$ ratio resulted from the thermal cracking of some higher molecular-weight compounds to lower as maturation proceeded.

TABLE 2

SUMMARY OF LIQUID CHROMATOGRAPHY - OILS

WELL NAME = PORT CAMPBELL 4
COUNTRY = Australia
BASIN = Otway

DEPTH UNIT = Feet
DATE OF JOB = 01-DEC-91

DEPTH 1	DEPTH 2	SATURATES (REL %)	AROMATICS (REL %)	POLARS (REL %)	SAT/ AROM	HC/ non-HC
0.00	0.00	88.98	7.07	3.95	12.59	24.32

SAT = Saturated compounds
HC = Hydrocarbon
AROM = Aromatic compounds
\- = no data

TABLE 3

SUMMARY OF GAS CHROMATOGRAPHY DATA - OILS
ALKANE DISTRIBUTIONS

WELL NAME = PORT CAMPBELL 4
COUNTRY = Australia
BASIN = Otway

DEPTH UNIT = Feet
DATE OF JOB = 01-DEC-91

DEPTH 1	DEPTH 2	nC12	nC13	nC14	TMTD	nC15	nC16	iC18	nC17	iC19	nC18	iC20	nC19	nC20	nC21	nC22	nC23	nC24	nC25	nC26	nC27	nC28	nC29	nC30	nC31	nC32	nC33
0.00	0.00	6.5	6.1	6.1	1.8	6.1	6.0	1.0	6.2	2.7	6.2	.5	6.3	5.9	5.6	5.5	5.4	4.6	4.4	3.2	2.8	2.0	1.8	1.1	.9	.5	.5

i = iso
- = no data
n = normal
TMTD = Trimethyltridecane
N.B. Values are relative %

TABLE 4

SUMMARY OF GAS CHROMATOGRAPHY DATA - OILS
ALKANE COMPOSITIONAL DATA

WELL NAME = PORT CAMPBELL 4
COUNTRY = Australia
BASIN = Otway

DEPTH UNIT = Feet
DATE OF JOB = 01-DEC-91

DEPTH 1	DEPTH 2	ANALYSIS TYPE	PRISTANE/PHYTANE	PRISTANE/n-C17	PHYTANE/n-C18	TMTD/PRISTANE	CPI(I)	CPI(II)	(C21+C22)/(C28+C29)
0.00	0.00	SF	5.33	0.44	0.08	0.68	1.12	1.10	2.95

CPI = Carbon preference index TMTD = Trimethyltridecane - = no data
SF = Saturate fraction WE = Whole extract

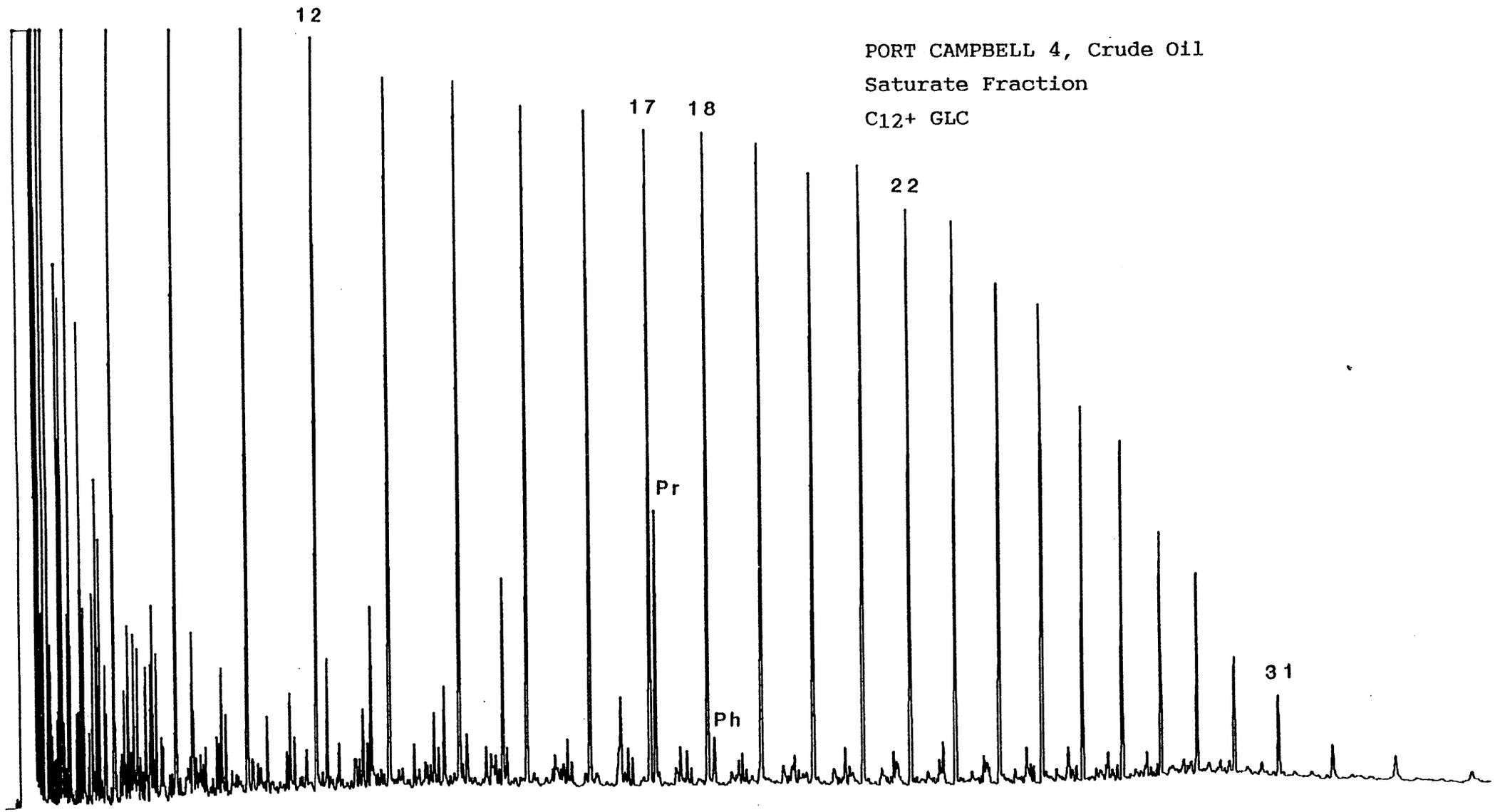

12
17
18
22
31
Pr
Ph
PORT CAMPBELL 4, Crude Oil
Saturate Fraction
C12+ GLC

Figure 3

Gas Chromatography - Mass Spectrometry (GC-MS)

Saturate Fraction

GC-MS analysis was carried out on the saturate fraction of the fluid from Port Campbell-4. The results of this work are summarised in Table 5 (detailed compound analysis) and Table 6 (calculated data); the peak distributions used in the identification of the various biomarker compounds are included in this report as Appendix 1. A number of the calculated parameters are discussed below.

(a) Terpane Parameters

The ratio of C_{27} triterpanes, 18α(H)-hopane/17α(H)-hopane (Ts/Tm), is theoretically useful for the maturity assessment of medium to high maturity oils. With increasing maturity, more of the maturable C_{27} triterpane (Tm) is converted to the stable C_{27} triterpane (Ts). The relative amounts of Ts and Tm were determined for the Port Campbell-4 fluid and its Ts/Ts+Tm ratio calculated. These data indicate a predominance of maturable (Tm) over stable (Ts) C_{27} triterpanes in the fluid (Table 6), suggesting that the source rocks were relatively immature at the time the fluid was generated. It should, however, be noted that the Ts/Ts+Tm parameter is facies-dependent, and that it should be used with some caution as an absolute indicator of thermal maturity.

Moretanes are diastereomers of the hopanes, and being less stable than the latter, are destroyed more rapidly with increasing maturity. The relative abundances of the C_{29} and C_{30} moretanes and hopanes were determined for the Port Campbell-4 fluid and revealed a strong predominance of hopanes over moretanes. The moretane/hopane ratio reaches a steady-state value of 0.10 before vitrinite reflectance reaches about 0.70%; the ratio in the Port Campbell-4 fluid (0.12) therefore implies a source maturity of about 0.70% vitrinite reflectance or greater, the precise level of maturity at which the fluid was expelled from the source rock remaining uncertain.

The C_{31}22S-hopane/C_{31}22R-hopane ratio was determined for the Port Campbell-4 fluid. As maturity increases, the proportion of the 22S isomer increases at the expense of the biologically produced 22R isomer, until equilibrium is reached, at which point the 22S

isomer accounts for about 55-60% of the mixture. (This is achieved soon after the onset of oil generation before significant oil generation has occurred, limiting the use of this parameter at higher levels of maturity). In the case of the Port Campbell-4 fluid, the 22S isomer accounts for 58% of the mixture, implying that isomeric equilibrium has been reached, and that their sources have been thermally matured at least to the point of initiating oil-generation. Note that the 22S isomer of the C_{32} hopanes forms 59% of the isomeric mixture, concurring with the C_{31} hopane data.

Note that, in Table 5, oleanane was not identified in the Port Campbell-4 fluid. Oleanane is derived from angiosperm land-plants which evolved from the Late Cretaceous onwards. Its absence in the Port Campbell-4 fluid suggests that, since the source organic matter was dominantly terrestrial in origin, the source sediment is no younger than Late Cretaceous.

(b) Sterane Parameters

The relative proportions of the 20S and 20R isomers of the C_{28} and C_{29} $\alpha\alpha\alpha$ (normal) steranes were determined for the Port Campbell-4 fluid. The 20S/20S+20R ratio is perhaps the most reliable biomarker maturity parameter (it is not usually complicated by source variations). Equilibrium, when the 20S isomer forms about 50-55% of the mixture, is reached within the maturity range of most relevance to oil generation, between its onset and peak, at or around 0.75% vitrinite reflectance. In the Port Campbell-4 fluid, the 20S isomer forms 35% of the C_{28} mixture, and 48% of the C_{29} mixture, suggesting a level of thermal maturity close to 0.75% vitrinite reflectance, and therefore expulsion of the fluid from its source sediment before peak-oil generation had occurred. (Note that 20S/20S+20R = 0.48 equates, using an empirically derived algorithm, to a vitrinite reflectance value of about 0.81%).

The relative proportions of C_{29} normal ($\alpha\alpha\alpha$) and iso- ($\alpha\beta\beta$) steranes were determined for the Port Campbell-4 fluid. The normal ($\alpha\alpha\alpha$) steranes, produced biologically, become less dominant relative to the iso-steranes ($\alpha\beta\beta$) with increasing maturity (the $\alpha\beta\beta/\alpha\alpha\alpha$ ratio should be about 1.60 in a mature sample). In the Port Campbell-4 fluid, the iso-steranes slightly dominate the normal steranes ($\alpha\beta\beta/\alpha\alpha\alpha+\alpha\beta\beta$ = 58% or $\alpha\beta\beta/\alpha\alpha\alpha$=1.38), suggesting that the source rock was at least partly matured at the time the fluid was expelled. Note that the relative abundances of normal and iso-steranes are, like certain

other biomarker parameters, facies-dependent and should accordingly be used with caution as indicators of thermal maturity.

The relative abundance of diasteranes in an oil is dependent on both lithofacies and thermal maturity. In respect of the latter, the more stable diasteranes increase relative to regular steranes until, in more mature oils, diasteranes may eventually dominate. This is not the case in the Port Campbell-4 fluid, suggesting that it was not expelled at advanced oil-generative levels of thermal maturity, but the predisposition of the diasterane/total sterane ratio by source provenance and depositional environment should not be overlooked.

The ratio of C_{27}/C_{29} normal steranes in the Port Campbell-4 fluid reflects a strong dominance of C_{29} compounds over C_{27}, suggesting that the fluid was generated from a source sediment rich in land-plant derived organic matter.

Aromatics Fraction

GC-MS analysis was carried out on the aromatics fraction of the Port Campbell-4 fluid. The results of this work are summarised in Table 7 (detailed compound analysis and calculated data); the mass fragmentograms used in the identification of the various biomarker compounds are included in this report as Appendix 2. Certain of the calculated parameters from Table 7 are discussed below.

The primary use of aromatic compounds is for the assessment of thermal maturity. The most important indicators are based upon the naphthalenes and phenanthrenes which have two (di-), three (tri) or four (tetra-) methyl groups attached. Some isomers are more stable than others, resulting in changes in isomer ratios with increase in the thermal maturity of the source sediment. The most important aromatic maturity indicators are shown in Table 7, based on the relative abundances of both alkyl naphthalenes and alkyl phenanthrenes.

MPI-1 (methylphenanthrene index 1) for the Port Campbell-4 fluid is 0.81, and the value for MPI-2 is 0.69. Since the onset of oil generation corresponds to a value of 0.3 for each of these indices, the Port Campbell-4 fluid must be assumed to be oil-generatively mature. This value of MPI-1=0.81 converts into a value of Rc(a) (calculated vitrinite reflectance) of 0.89%, suggesting that the fluid was generated from a source rock close to the peak oil-

generative phase of thermal maturation. This contradicts MPR-1, and several of the parameters calculated from the sterane and triterpane compounds of the saturate-fraction, all of which suggest an early oil-generative phase of thermal maturity.

Values for the naphthalene parameters DNR-1, DNR-6, and TNR-1 are contradictory and inconclusive, suggesting levels of thermal maturity of the Port Campbell-4 fluid equivalent to the early oil-generative window, wet-gas window, and immature phase respectively.

Application of aromatic compounds to source input assessment has been very limited. However, one recent example is the application of certain aromatic parameters to assessment of the relative ages of the source rocks from which oils were generated. Land-plant-derived organic matter present in Early Jurassic or younger rocks is likely to contain some proportion of Araucariaceae pine debris which, on aromatisation, produces certain methylnaphthalene and methylphenanthrene compounds. Enrichment in these compounds, as expressed in the positive values for the 1,7-DMP/X and 1MP/9MP ratios in the Port Campbell-4 fluid (see Table 7), confirms that the oils in question were generated from rocks no older than Early Jurassic.

TABLE 5-1

SATURATE FRACTION SIR GC/MS DATA - OILS

WELL = PORT CAMPBELL 4 DETAILED COMPOUND ANALYSIS DEPTH UNIT = Feet

COUNTRY = Australia DESCRIPTION : DATE OF JOB = 01-DEC-91

BASIN = Otway DEPTH 1 = 0.00 DEPTH 2 = 0.00

COMPOUND	ION	RELATIVE AMOUNT	COMPOUND	ION	RELATIVE AMOUNT
C23 Tricyclic	191	-	C24 Tricyclic	191	-
C25 Tricyclic	191	-	C26 Tricyclic	191	-
C28 Tricyclic	191	-	C29 Tricyclic	191	-
C24 Tetracyclic	191	-			
C27 Hopane (Ts)	191	2680.0	C27 Hopane (Tm)	191	3737.0
C27 Hopane (17B)	191	-			
C28 Hopane (25,30)	191	-	C28 Hopane (28,30)	191	-
C29 Hopane	191	7942.0	C29 Moretane	191	876.0
C29 Demeth. Hopane	191	-	C29 Hopane (BB)	191	-
C30 Hopane	191	14195.0	C30 Moretane	191	1752.0
C30 Hopane (BB)	191	-			
C31S Hopane	191	4318.0	C31R Hopane	191	3175.0
C31S+R Hopane (BB)	191	-	C31S+R Moretane	191	605.0
C32S Hopane	191	2060.0	C32R Hopane	191	1440.0
C32S+R Hopane (BB)	191	-	C32S+R Moretane	191	-
C33S Hopane	191	-	C33R Hopane	191	-
Gammacerane	191	-	Oleanane (18a)	191	-
Unknown 1	191	-	Unknown 2	191	1182.0
Unknown 3	191	2096.0	Unknown 4	191	3402.0
C27 Demeth. Hopane	177	-	C28 Demeth. Hopane	177	-
C29 Hopane	177	-	C29 Demeth. Hopane	177	-
C29 Moretane	177	-	C29 Hopane (BB)	177	-
Unknown 3	177	-			
C30 2-Methylhopane	205	-	C31 2-Methylhopane	205	-
C31S Hopane	205	-	C31R Hopane	205	-
C31S+R Moretane	205	-	C31S+R Hopane (BB)	205	-
C21 Sterane	217	-	C22 Sterane	217	-
C27S Normal Sterane	217	-	C27R Normal Sterane	217	659.0
C27S Isosterane	217	-	C27R Isosterane	217	-
C27S Diasterane	217	-	C27R Diasterane	217	-
C28S Normal Sterane	217	440.0	C28R Normal Sterane	217	828.0
C28S Isosterane	217	-	C28R Isosterane	217	-
C28S Diasterane	217	-	C28R Diasterane	217	-
C29S Normal Sterane	217	2604.0	C29R Normal Sterane	217	2773.0
C29S Isosterane	217	3597.0	C29R Isosterane	217	3687.0
C29S Diasterane	217	2866.0	C29R Diasterane	217	2267.0
C27S+R Isosterane	218	916.0	C28S+R Isosterane	218	2957.0
C29S+R Isosterane	218	9761.0			
C27S Diasterane	259	187.0	C27R Diasterane	259	104.0
C28S Diasterane	259	632.0	C28R Diasterane	259	682.0
C29S Diasterane	259	1440.0	C29R Diasterane	259	947.0
16a Phyllocladane	123	-	16B Phyllocladane	123	-
Beyerene	123	-	Labdane	123	-
Fichtelite	123	-	Rimuane	123	-
Nortetracyclane	123	-	Pimerane	123	-
Isopimerane	123	-	Kaurane	123	-
Norisopimerane	123	-	Unknown 1	123	-
Drimane	123	59572.0	Homodrimane	123	103182.0
Rearranged Drimane 1	123	72639.0	Rearranged Drimane 2	123	40609.0
Eudesmane	123	-			
C15 Alkylcyclohexane	83	-	C17 Alkylcyclohexane	83	-
C21 Alkylcyclohexane	83	-	C22 Alkylcyclohexane	83	-
C25 Alkylcyclohexane	83	-	C29 Alkylcyclohexane	83	-

- = no data IUPAC names corresponding to common names used here are shown at the end of the tables

TABLE 6-1

SATURATE FRACTION SIR GC/MS DATA - OILS

CALCULATED DATA

DESCRIPTION :

WELL = PORT CAMPBELL 4 DEPTH 1(m) = 0.00 DEPTH UNIT = Feet
COUNTRY = Australia DEPTH 2(m) = 0.00 DATE OF JOB = 01-DEC-91
BASIN = Otway

------ TERPANE PARAMETERS ------

PARAMETER	ION(s)	VALUE
% Ts / (Ts + Tm)	191	41.76
% C29 M / (C29 H + C29 M)	191	9.93
% C30 M / (C30 H + C30 M)	191	10.99
% C31S H / (C31S H + C31R H)	191	57.63
% C31S H / (C31S H + C31R H)	205	-
% C32S H / (C32S H + C32R H)	191	58.86
% U1-U4 / (U1-U4 + C30 H)	191	-
% U1 / (U1 + C30 H)	191	-
% U2 / (U2 + C30 H)	191	7.69
% U3 / (U3 + C30 H)	191	12.87
% U4 / (U4 + C30 H)	191	19.33
% C29 H / (C29 H + C30 H)	191	35.88
% C31 2-MeH / (C31 2-MeH + C30 H)	191, 205	-
% C29 BB / (C29 BB + C 29H + C29 M)	191	-
% C29 DeMe / (C29 DeMe + C29H)	177	-
% C28 H's / (C28 H's + C30 H)	191	-
% (Ts + Tm + C28 H's) / C29(H + M) + C30(H + M)	191	-
% Oleanane (18a) / (Oleanane + C30H)	191	-
% Drimane / Homodrimane	123	57.73
% Rea. Drimanes / (Drimane + Homodrimane)	123	69.58
% C22 Alkycyclohex. / C30 H	83, 191	-
% C29 Alkycyclohex. / C30 H	83, 191	-
% C23-C29 Tricyclics / C30 H	191	-
% (C30 H + C30 M) / (C29(NS's + IS's + DS's)	191, 217	89.62

------ STERANE PARAMETERS ------

PARAMETER	ION(s)	VALUE
% C27 ST's / (C27 + C28 + C29) ST's	217	-
% C28 ST's / (C27 + C28 + C29) ST's	217	-
% C29 ST's / (C27 + C28 + C29) ST's	217	-
% C27S NS / (C27S NS + C27R NS)	217	-
% C28S NS / (C28S NS + C28R NS)	217	34.70
% C29S NS / (C29S NS + C29R NS)	217	48.43
% C27 NS's / C29 NS's	217	-
% C27 IS's / C29 IS's	217	-
% C27 DS's / C29 DS's	217	-
% C27 DS's / C27 ST's	217	-
% C28 DS's / C28 ST's	217	-
% C29 DS's / C29 ST's	217	28.85
% C27 IS's / (C27 IS's + C27 NS's)	217	-
% C28 IS's / (C28 IS's + C28 NS's)	217	-
% C29 IS's / (C29 IS's + C29 NS's)	217	57.53

NOTES : H = Hopane M = Moretane Me = Methyl NS = Normal Sterane
IS = Iso Sterane DS = Dia Sterane ST = NS + IS + DS U = Unknown
- = no data available

TABLE 7-1

DI & TRI NUCLEAR AROMATIC GC/MS DATA - OILS

DESCRIPTION :

WELL = PORT CAMPBELL 4
COUNTRY = Australia
BASIN = Otway

DEPTH UNIT = Feet
DATE OF JOB = 01-DEC-91

DEPTH 1 = 0.00 DEPTH 2 = 0.00

A. DETAILED COMPOUND ANALYSIS

COMPOUND	ION	RELATIVE AMOUNT
1,5-Dimethylnaphthalene	156	8962.0
1,6-Dimethylnaphthalene	156	32550.0
1,8-Dimethylnaphthalene	156	-
2,6-Dimethylnaphthalene	156	34537.0
2,7-Dimethylnaphthalene	156	-
1,4+2,3-Dimethylnaphthalene	156	13750.0
1,2,5-Trimethylnaphthalene	170	39394.0
1,2,7-Trimethylnaphthalene	170	-
1,3,6-Trimethylnaphthalene	170	30775.0
1,3,7-Trimethylnaphthalene	170	24600.0
2,3,6-Trimethylnaphthalene	170	14140.0
1,3,5+1,4,6-Trimethylnaphthalene	170	25203.0
Phenanthrene	178	11313.0
1-Methylphenanthrene	192	6290.0
2-Methylphenanthrene	192	4972.0
3-Methylphenanthrene	192	6843.0
9-Methylphenanthrene	192	7920.0
1,7-Dimethylphenanthrene	206	6224.0
Compound X (1,3 + 3,9 + 2,10 + 3,10-DMP)	206	10871.0
Retene	219	41120.0
Cadalene	198	-
Eudalene	184	-

B. CALCULATED DATA

PARAMETER	ION	VALUE
DNR-1 = (2,6-DMN + 2,7-DMN) / 1,5-DMN	156	-
DNR-2 = 2,7-DMN / 1,8-DMN	156	-
DNR-5 = 1,6-DMN / 1,8-DMN	156	-
DNR-6 = ((2,6-DMN + 2,7-DMN) / 1,4+2,3-DMN)*0.91	156	-
TNR-1 = (2,3,6-TMN / 1,3,5+1,4,6-TMN)*0.82	170	0.46
TNR-5 = (1,2,5-TMN / 1,3,6-TMN)*0.75	170	0.96
TNR-6 = 1,2,7-TMN / 1,3,7-TMN	170	-
MPR-1 = (2-MP + 3-MP) / 1-MP	192	1.88
MPI-1 = (1.5 x (2-MP + 3-MP)) / (0.667*Ph + 1-MP + 9-MP)	178,192	0.81
MPI-2 = (3 x 2-MP) / (0.667*Ph + 1-MP + 9-MP)	178,192	0.69
Rc(a) = (0.6 x MPI-1) + 0.4	na	0.89
Rc(b) = (-0.6 x MPI-1) + 2.3	na	1.81
1,7-Dimethylphenantrene / Compound X	206	0.57
Retene / 9-Methylphenantrene	192,219	5.19
1-Methylphenanthrene / 9-Methylphenanthrene	192	0.79

Notes : DMN = Dimethylnaphthalene TMN = Trimethylnaphthalene - = no data
MP = Methylphenanthrene Ph = Phenanthrene na = not applicable

Stable Carbon Isotope Analysis

The results of the stable carbon isotope analysis of the Port Campbell-4 fluid are shown in Table 8.

Stable carbon isotope values typically show increasingly negative values from the NSO fraction, through the aromatic, to the saturate fraction. This is true of the Port Campbell-4 fluid.

It was formerly believed that the stable isotope composition of petroleum was determined almost entirely by the nature of the source organic matter, processes such as maturation, migration and alteration having little influence. Marine organic matter was believed to contain from -18 to -27 per mil of the stable carbon isotope, and terrestrially derived material from -24 to -32 per mil. On this basis, the source organic matter of the Port Campbell-4 fluid could be ascribed to either source provenance. However, it is now recognised that maturation and other secondary processes do affect carbon isotope values, and they are not normally used to indicate source provenance, being of more value (allowing for secondary effects) in oil-to-source and oil-to-oil correlation.

TABLE 8

CARBON ISOTOPE ANALYSIS DATA - OILS

WELL NAME = PORT CAMPBELL 4
COUNTRY = Australia
BASIN = Otway

DEPTH UNIT = Feet
DATE OF JOB = 01-DEC-91

		delta C VALUES					
DEPTH 1	DEPTH 2	OIL	SATURATES	AROMATICS	POLARS	ASPHALTENES	RESINS
0.00	0.00	-25.60	-26.20	-25.00	-24.60	-	-

All values permil relative to PDB
- = no data

NSO = Asphaltenes + resins

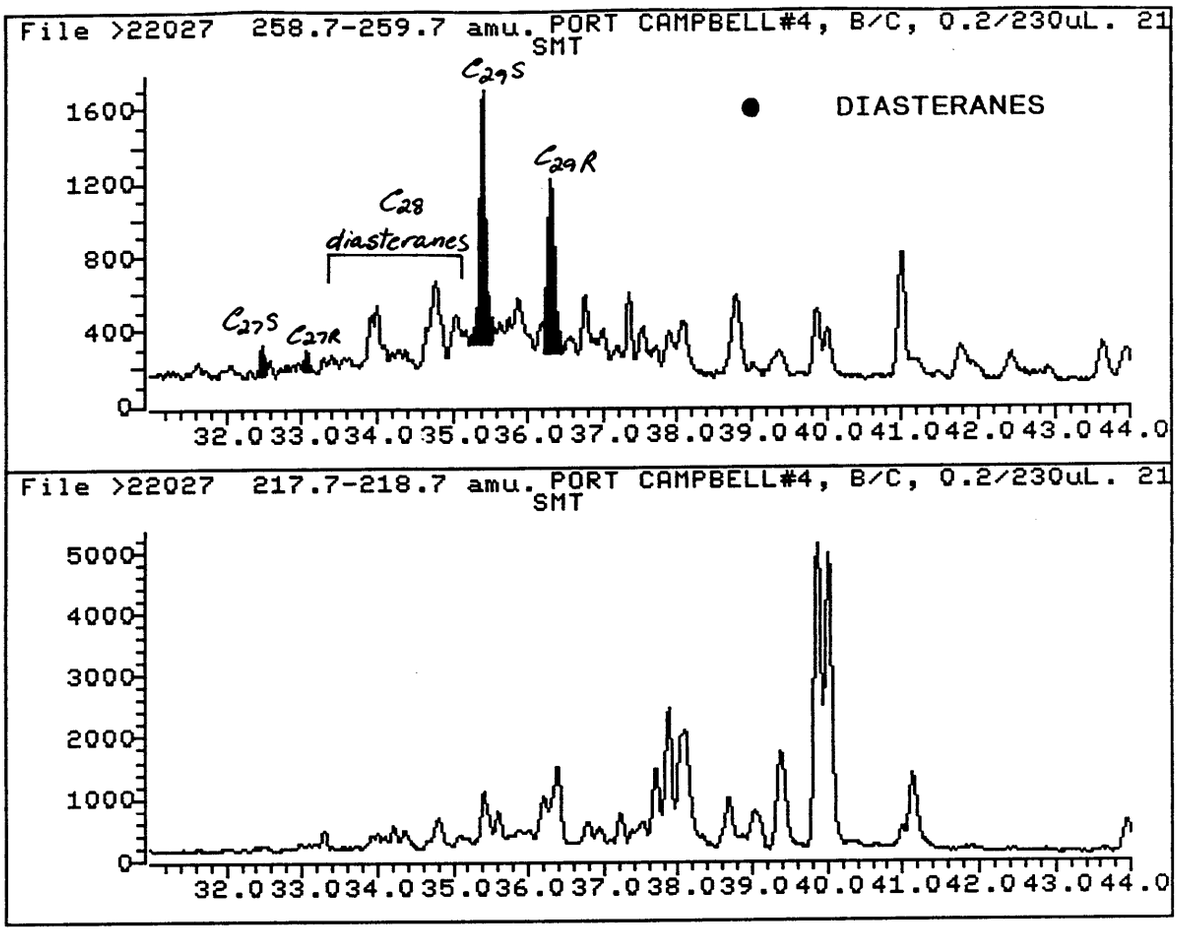
CONCLUSIONS

Whole-oil and saturate-fraction GC data from the Port Campbell-4 fluid reveal an aromatics-poor oil, with a compound distribution characterised by peak abundances in the lighter (up to about C_{19}) range; the sharp decrease in abundances to the C_{31+} range is characterised by a slight odd-over-even preference, typical of terrestrially derived organic matter. This is reflected in the values of certain of the compositional parameters calculated from the whole-oil GC and saturate-fraction GC data, notably the pristane/phytane ratio. Compositional parameters calculated from the relative abundances of gasoline (C_4 to C_8) compounds in the fluid (such as Paraffin Indices) suggest that the Port Campbell-4 fluid was expelled from its source rock at a temperature of about 145°C, equivalent to about 1.0% vitrinite reflectance (peak generation). Values of CPI from the saturate-GC data also indicate a significant degree of maturation.

Saturate-fraction GC-MS data suggest that the Port Campbell-4 fluid was generated from terrestrially derived organic matter, at a thermal maturity equivalent to perhaps 0.75% vitrinite reflectance or greater, in the early to middle part of the oil-generative phase. The precise level of maturity at which the fluid was expelled from the source rock cannot be estimated from the saturate-fraction GC-MS data through the isomeric ratio of the C_{29} normal steranes suggests (by the use of an empirically derived algorithm) an equivalent vitrinite reflectance value of 0.81%.

In an attempt to overcome the difficulties inherent in the assessment of the thermal maturity of oils using conventional (saturated) biomarkers, the aromatic fraction of the Port Campbell-4 fluid was analysed using GC-MS, paying attention to the relative abundances of the alkyl naphthalenes and alkyl phenanthrenes. The value of MPI-1 (perhaps the best calibrated of the aromatic parameters) for the Port Campbell-4 fluid equates to a vitrinite reflectance value of 0.89%, broadly concurring with the level of thermal maturity indicated by the WOGC, saturate-GC and C_{29} normal sterane data. Values of the naphthalene parameters calculated from the aromatics-fraction GC-MS data are unhelpful in the estimation of thermal maturity of the Port Campbell-4 fluid.

APPENDIX 1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C29R
C28
diasteranes
C27S
C27R
DIASTERANES
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1200
800
400
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32.0 33.0 34.0 35.0 36.0 37.0 38.0 39.0 40.0 41.0 42.0 43.0 44.0
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1000
0
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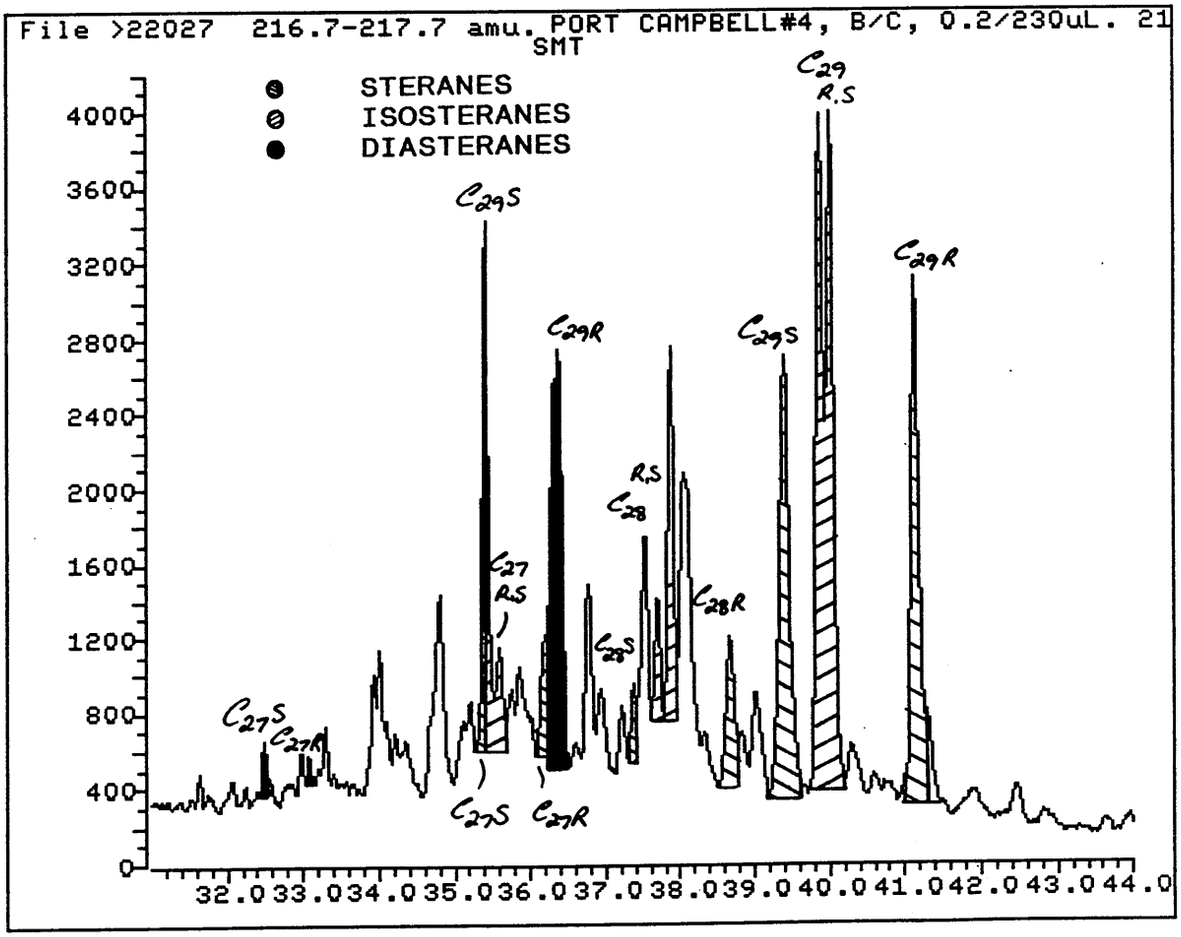
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ISOSTERANES
DIASTERANES
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C29S
C29R
C29S
C29R
R.S
C28
C28R
C28S
C27 R.S
C27S
C27R
C27S
C27R
4000
3600
3200
2800
2400
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400
0
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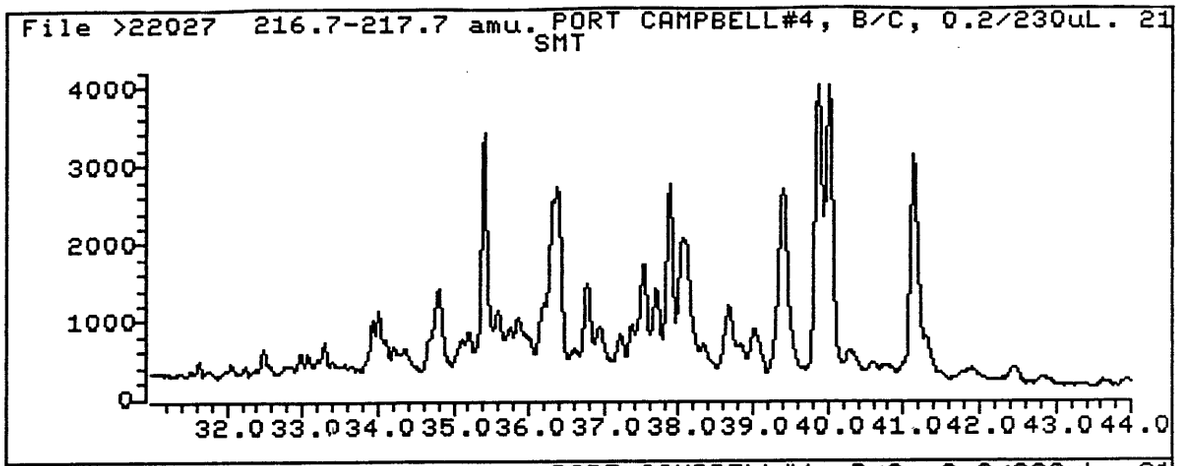
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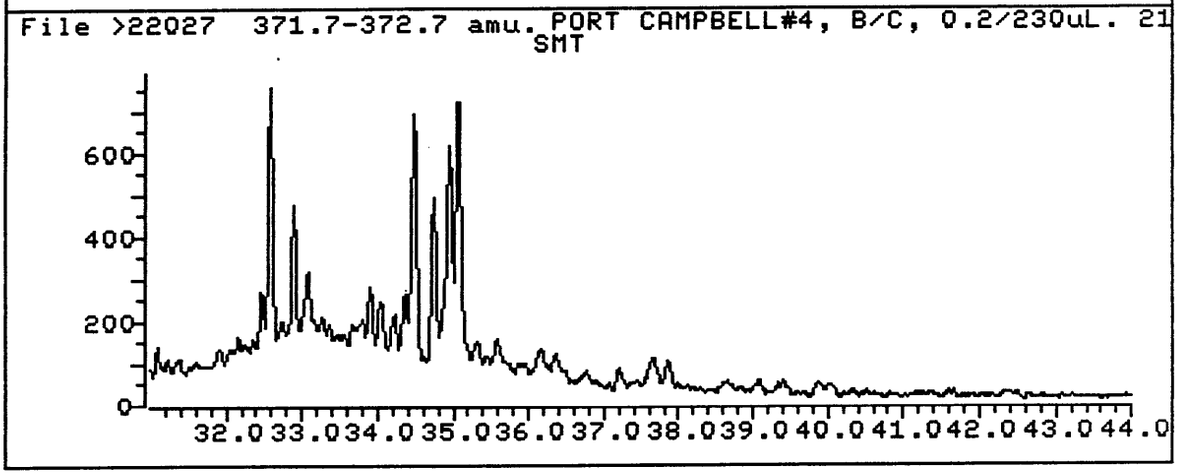
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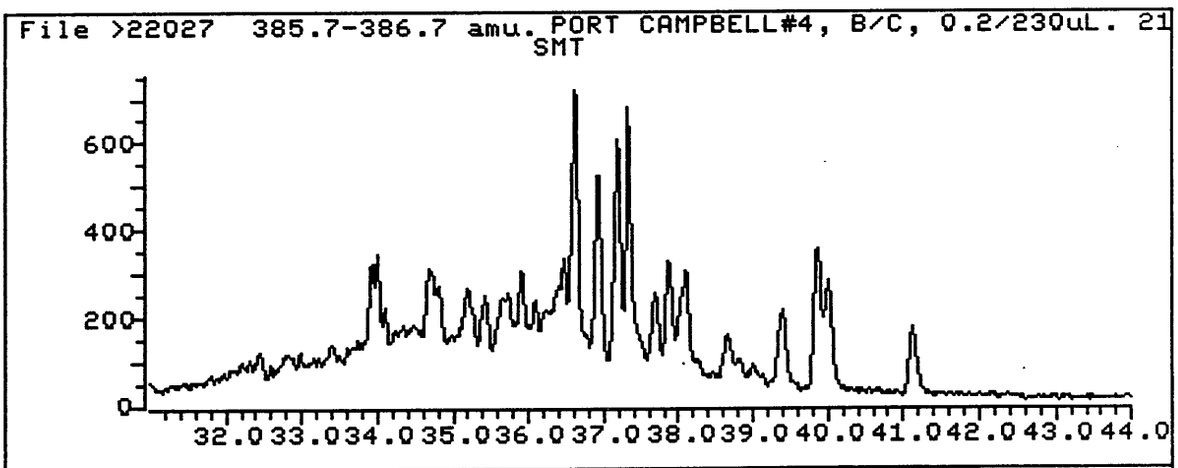
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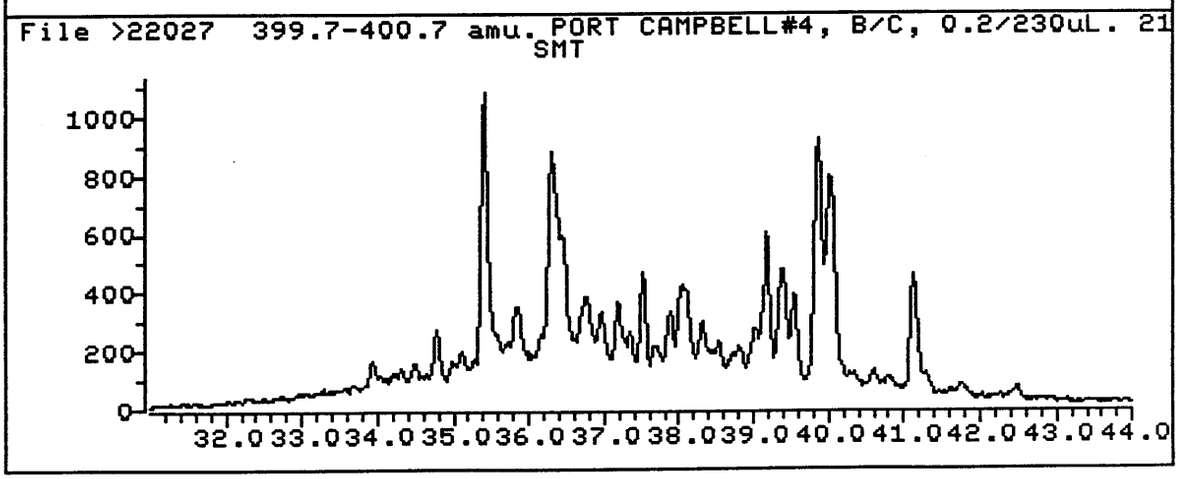
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400
200
0
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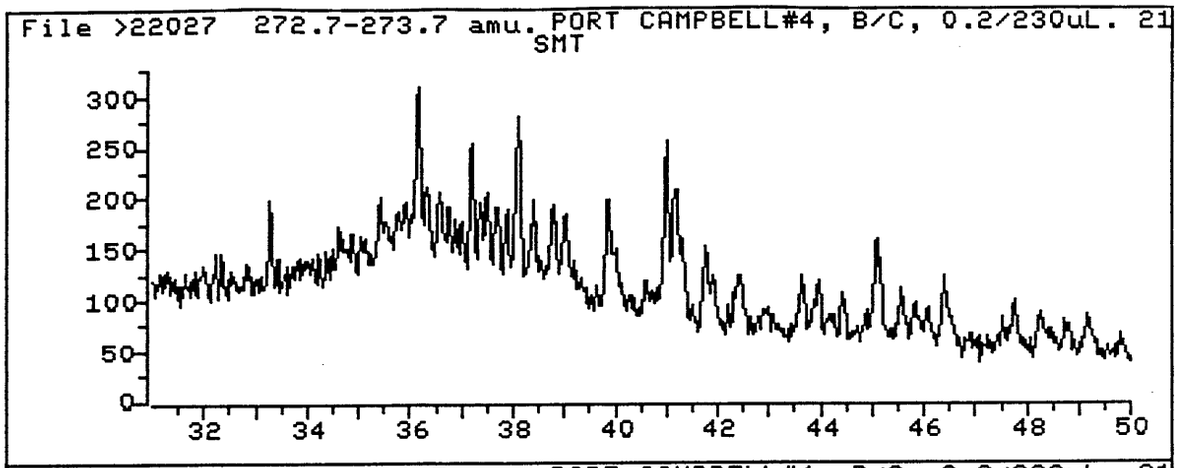
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100
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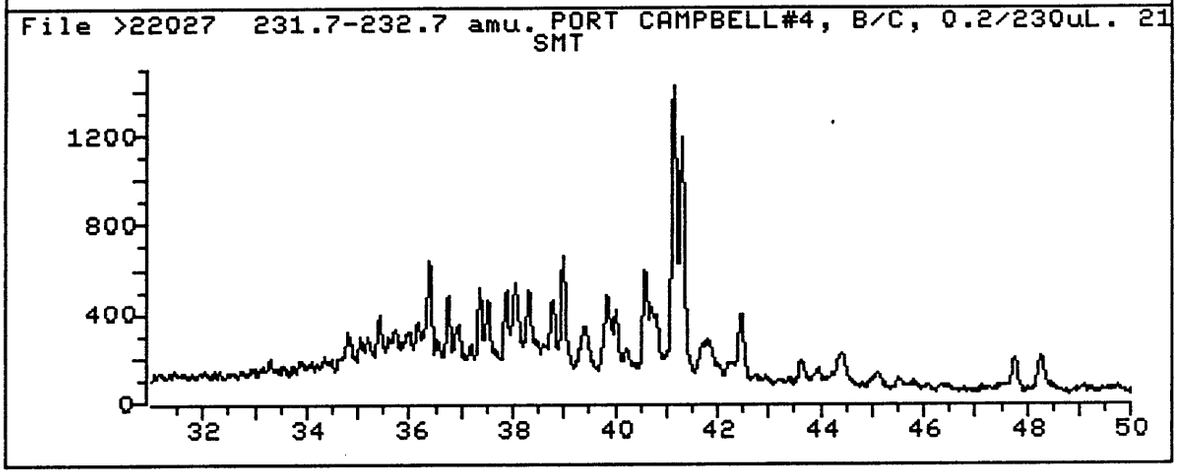
34
36
38
40
42
44
46
48
50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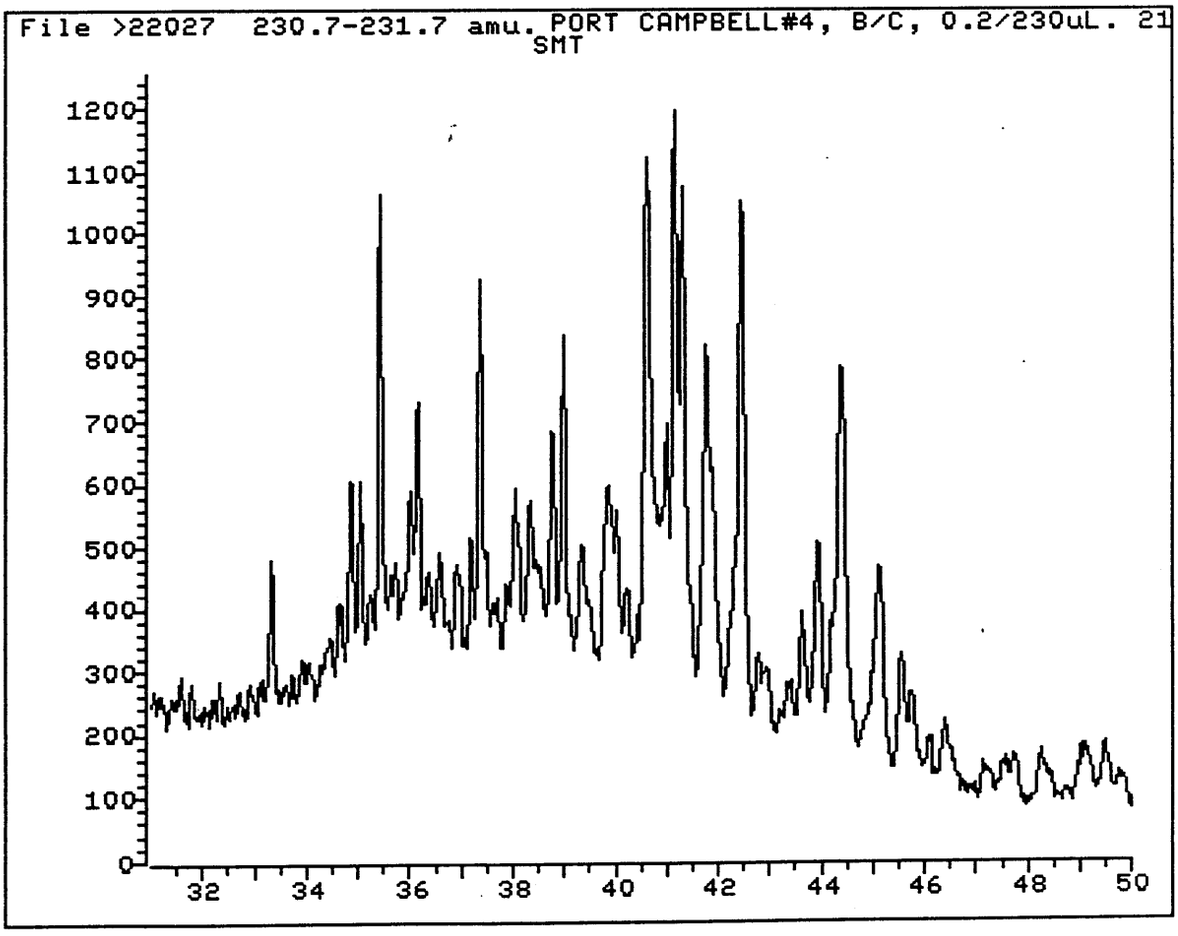
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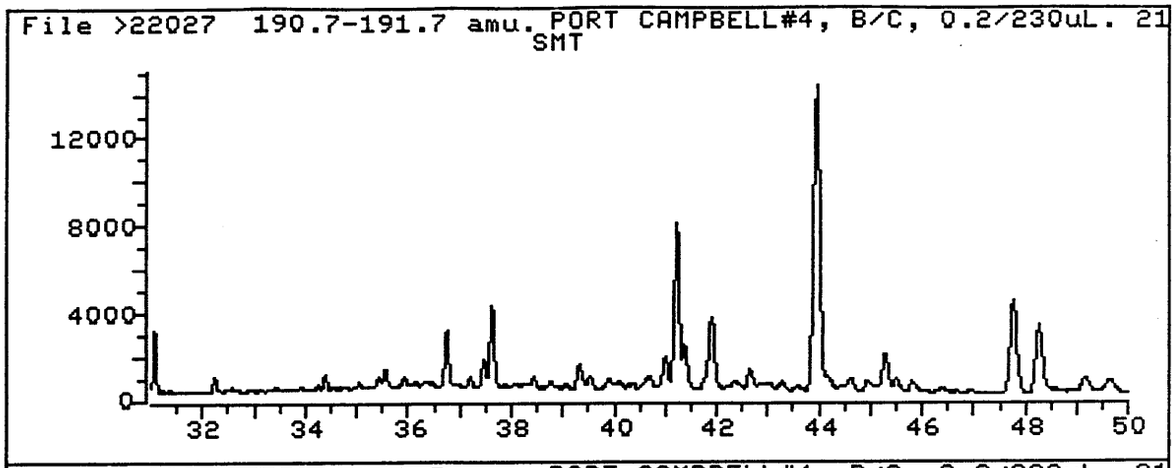
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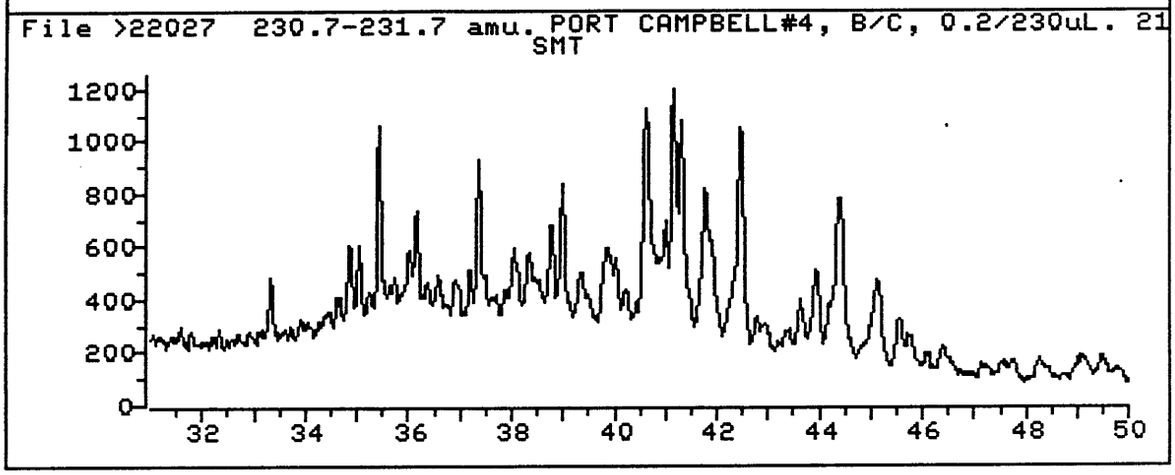
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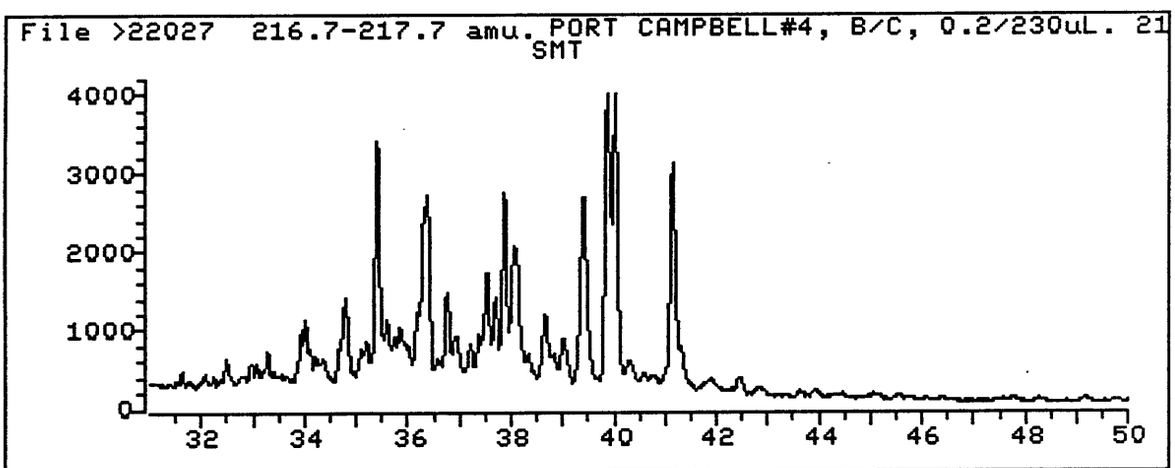
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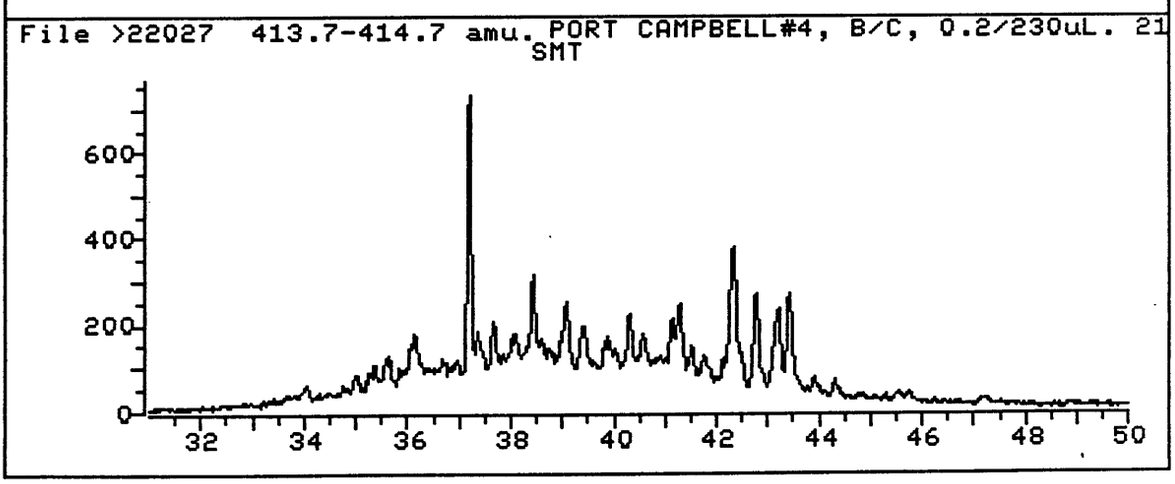
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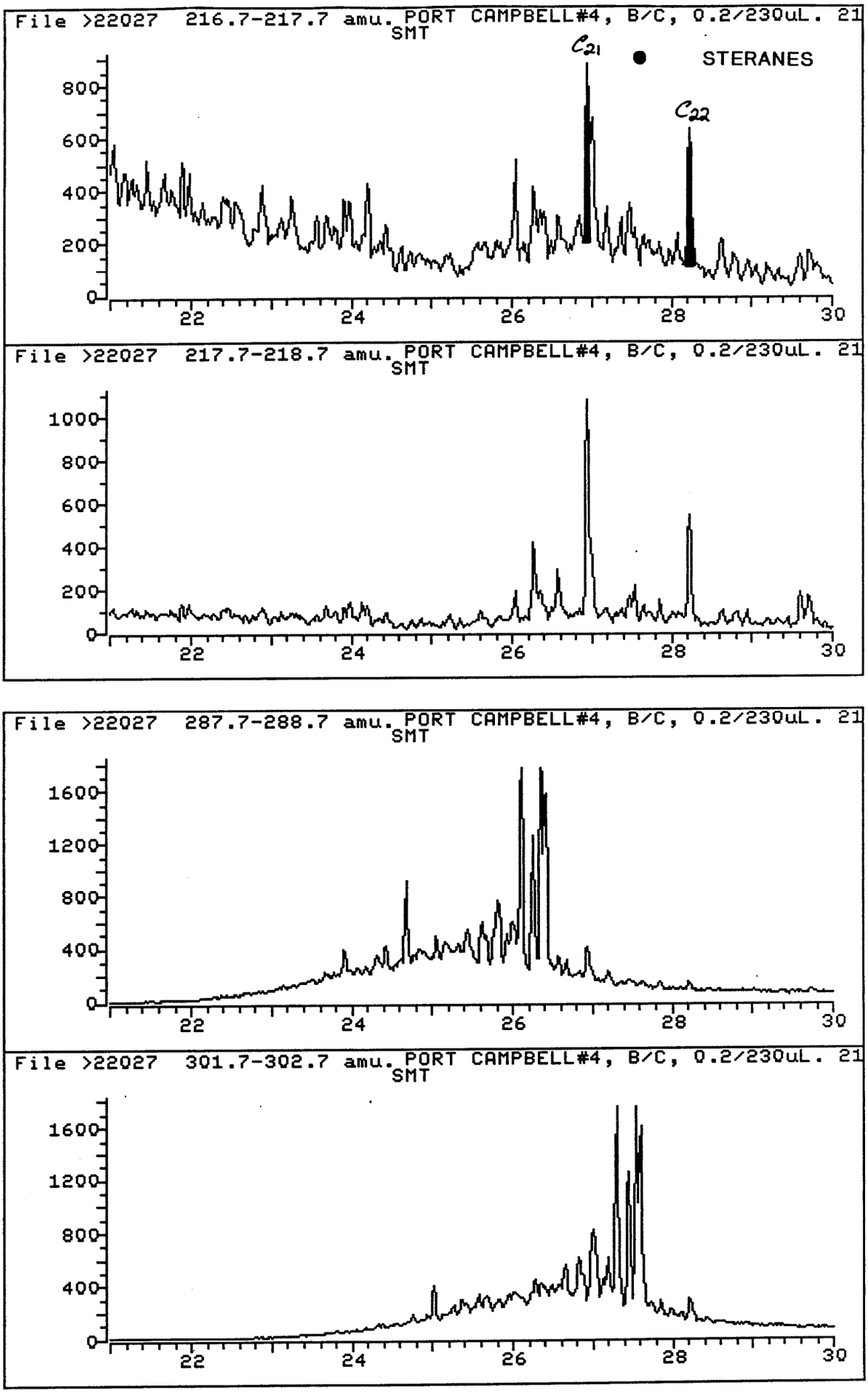
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C22
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22
24
26
28
30
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28
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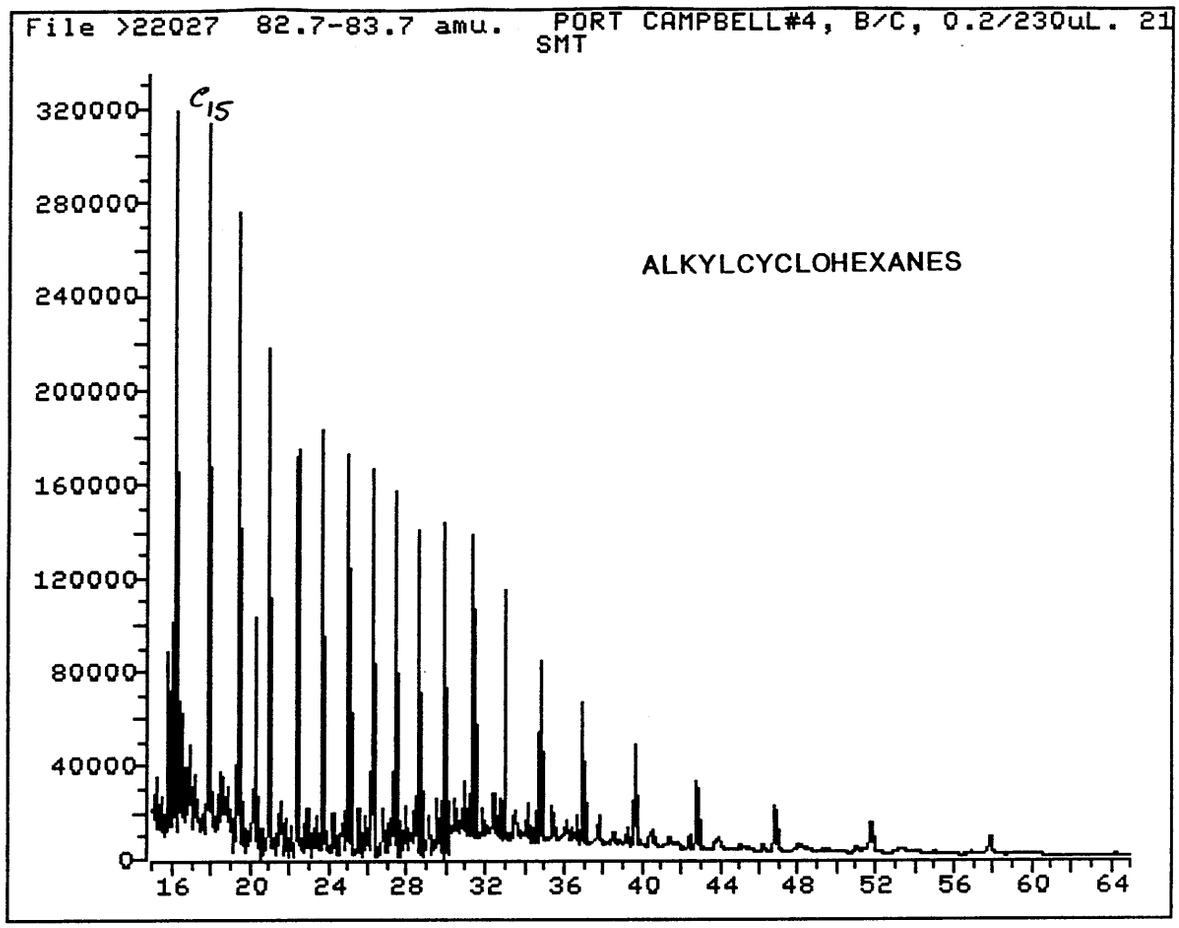
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80000
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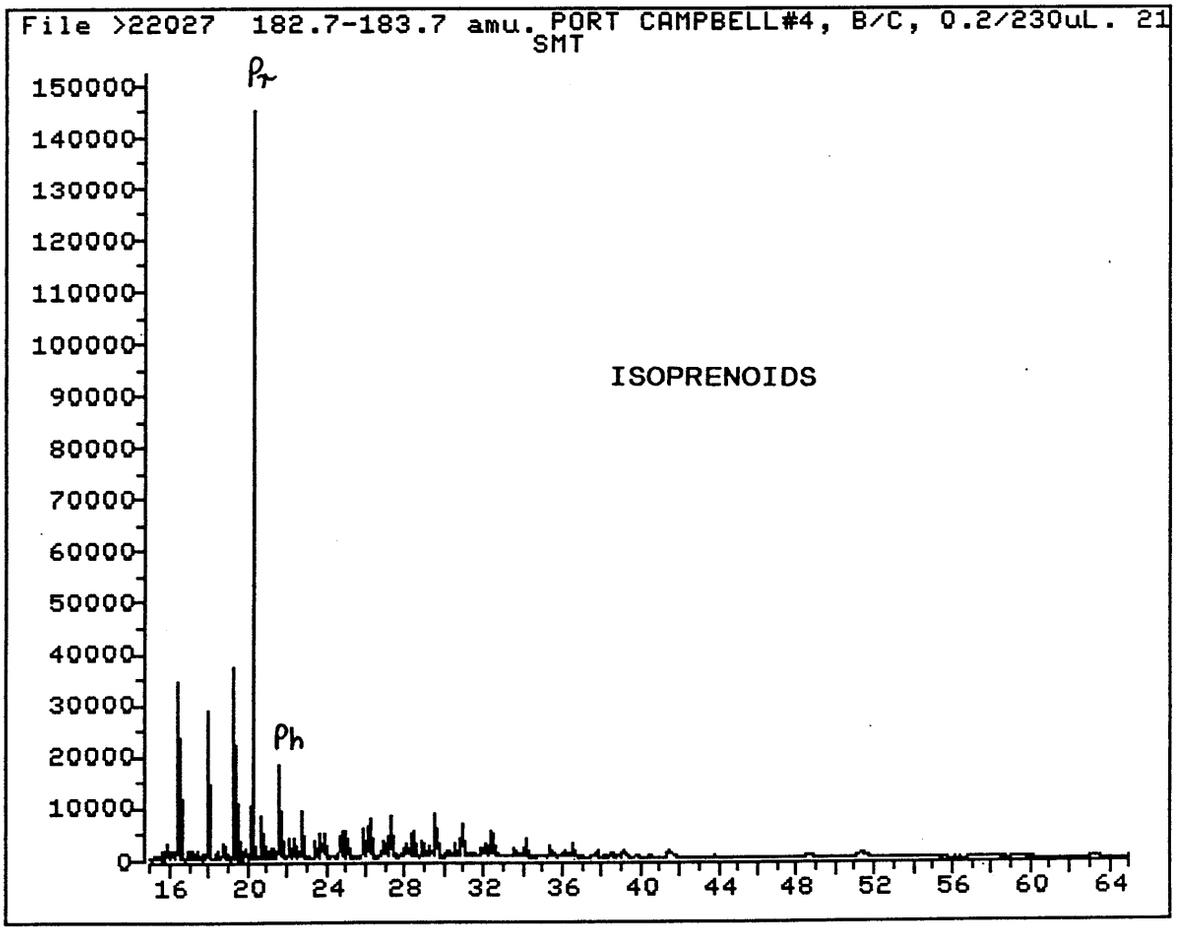
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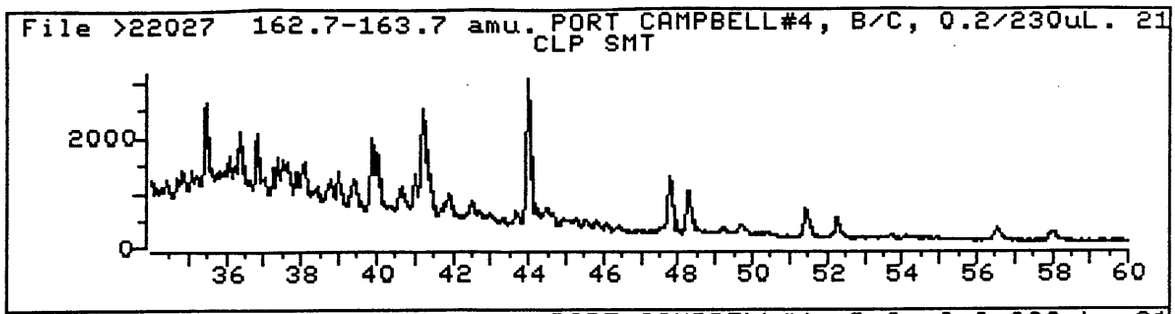
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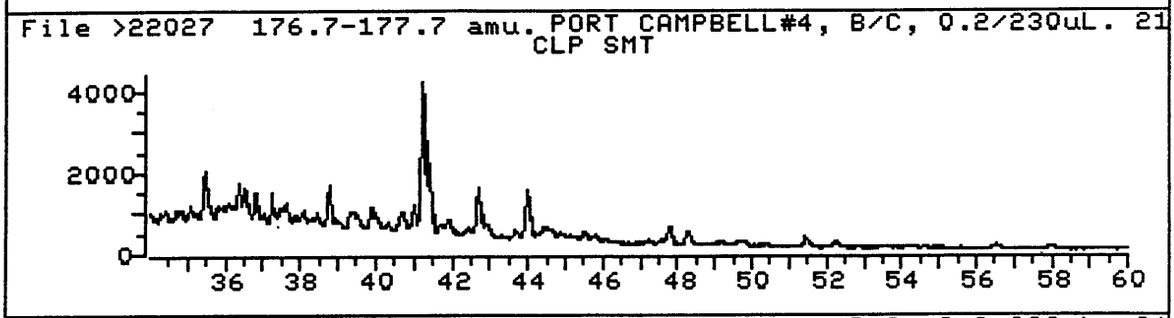
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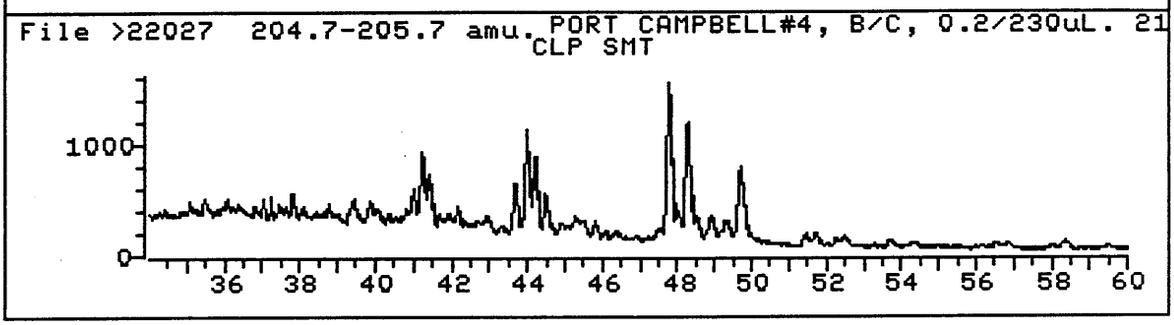
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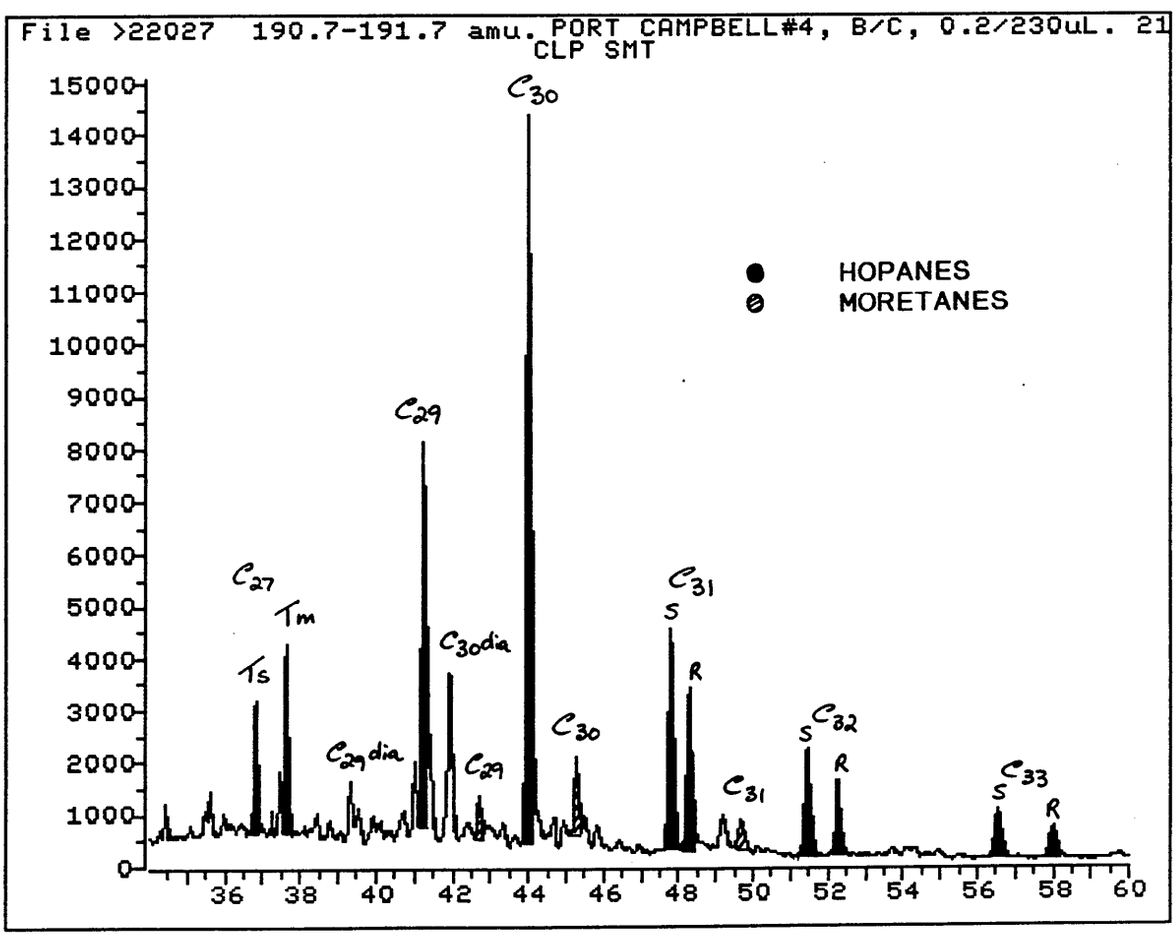
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7000
6000
5000
4000
3000
2000
1000
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HOPANES
MORETANES
C30
C29
C27
Ts
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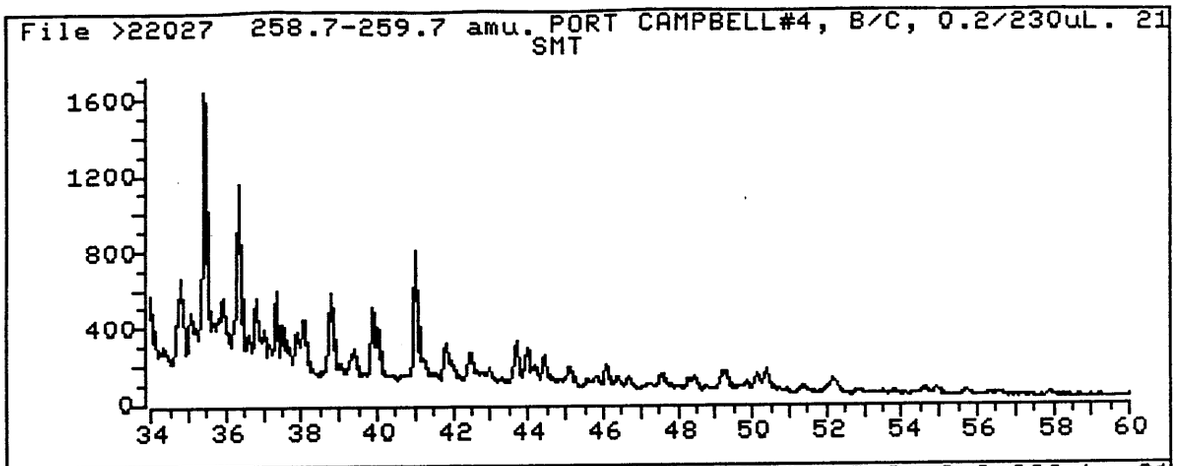
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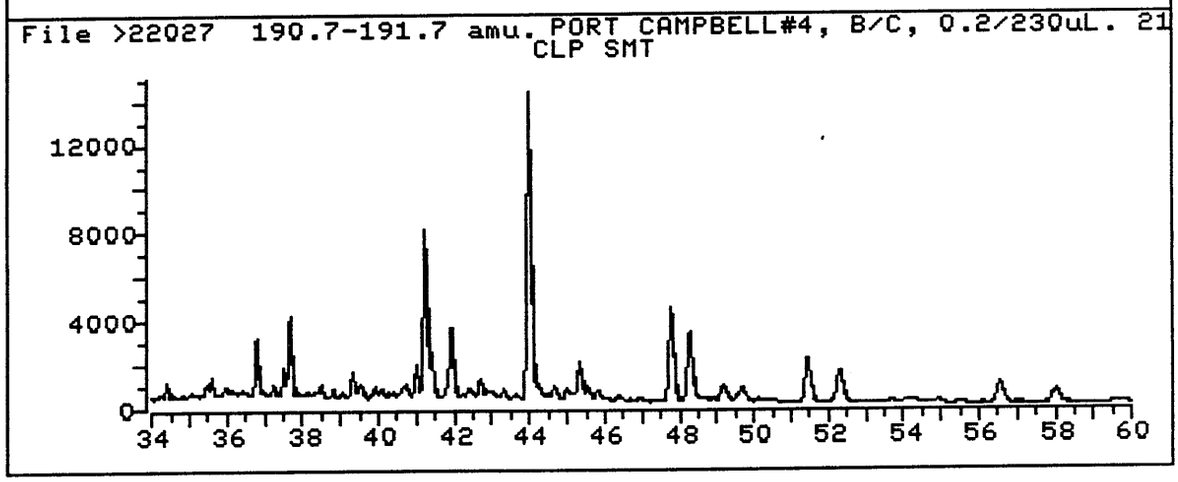
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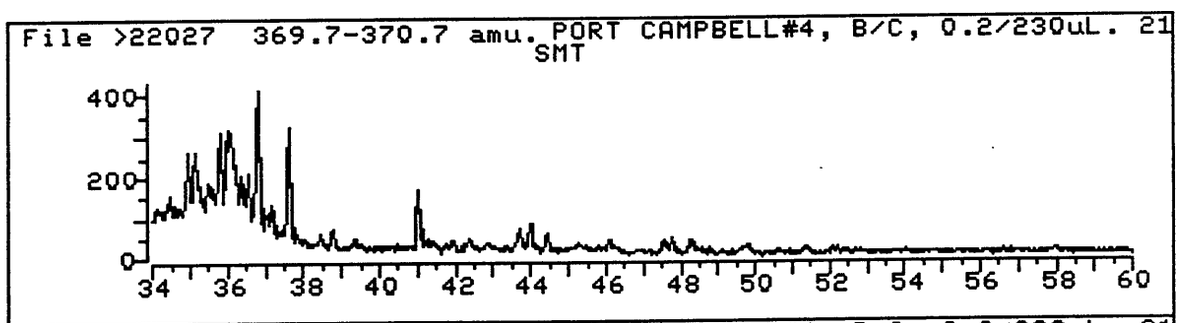
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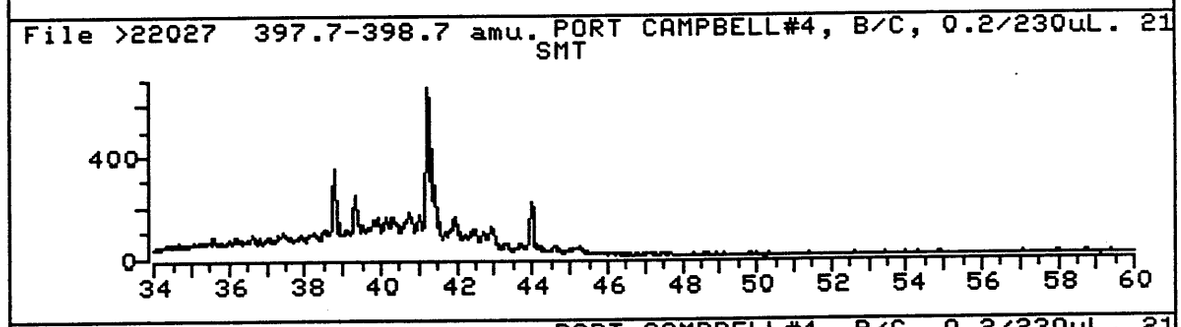
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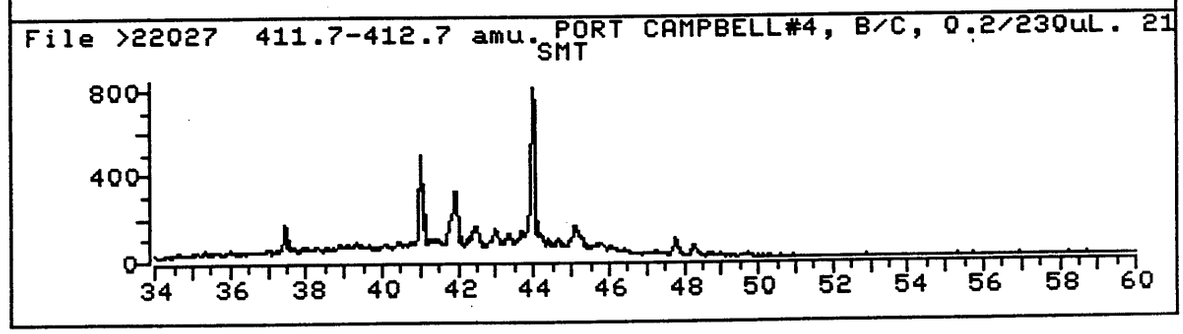
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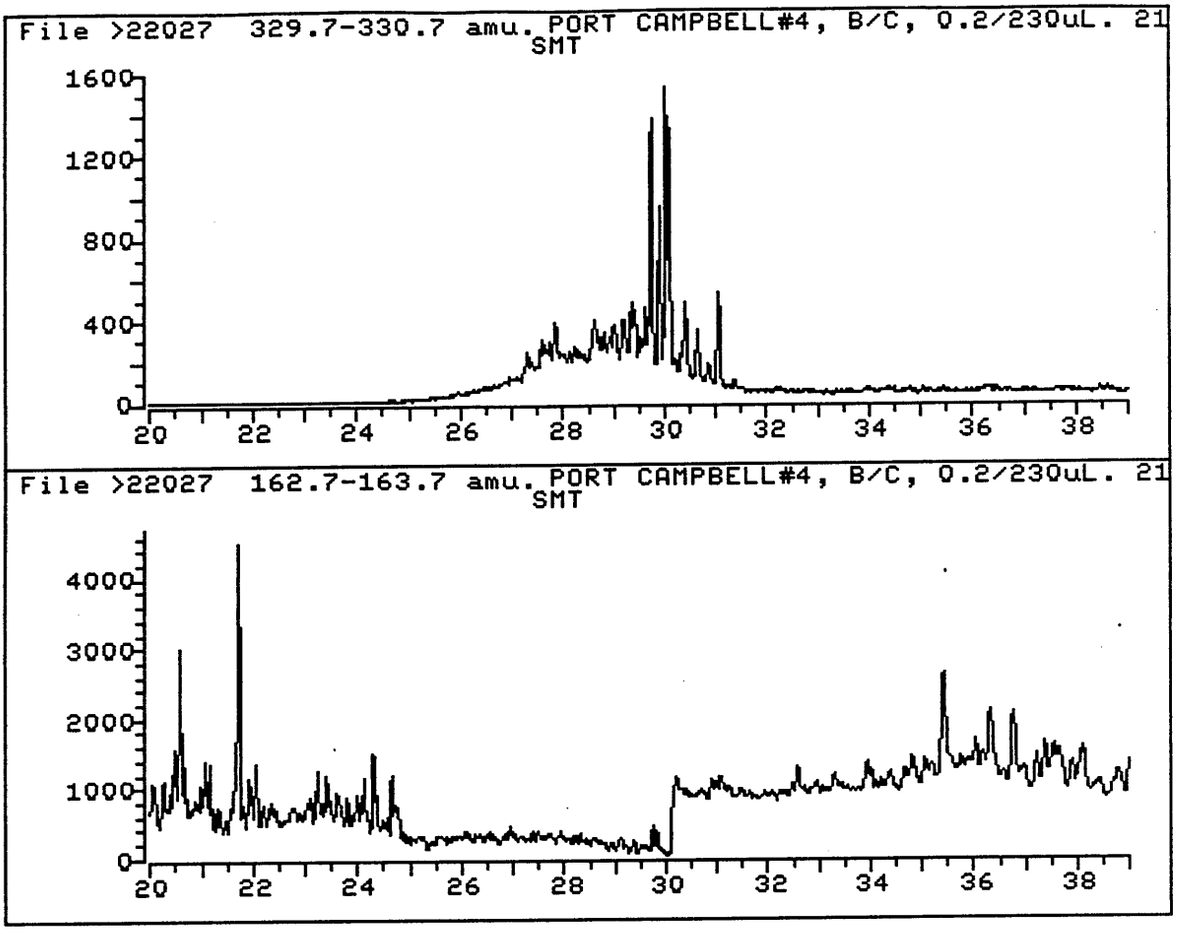
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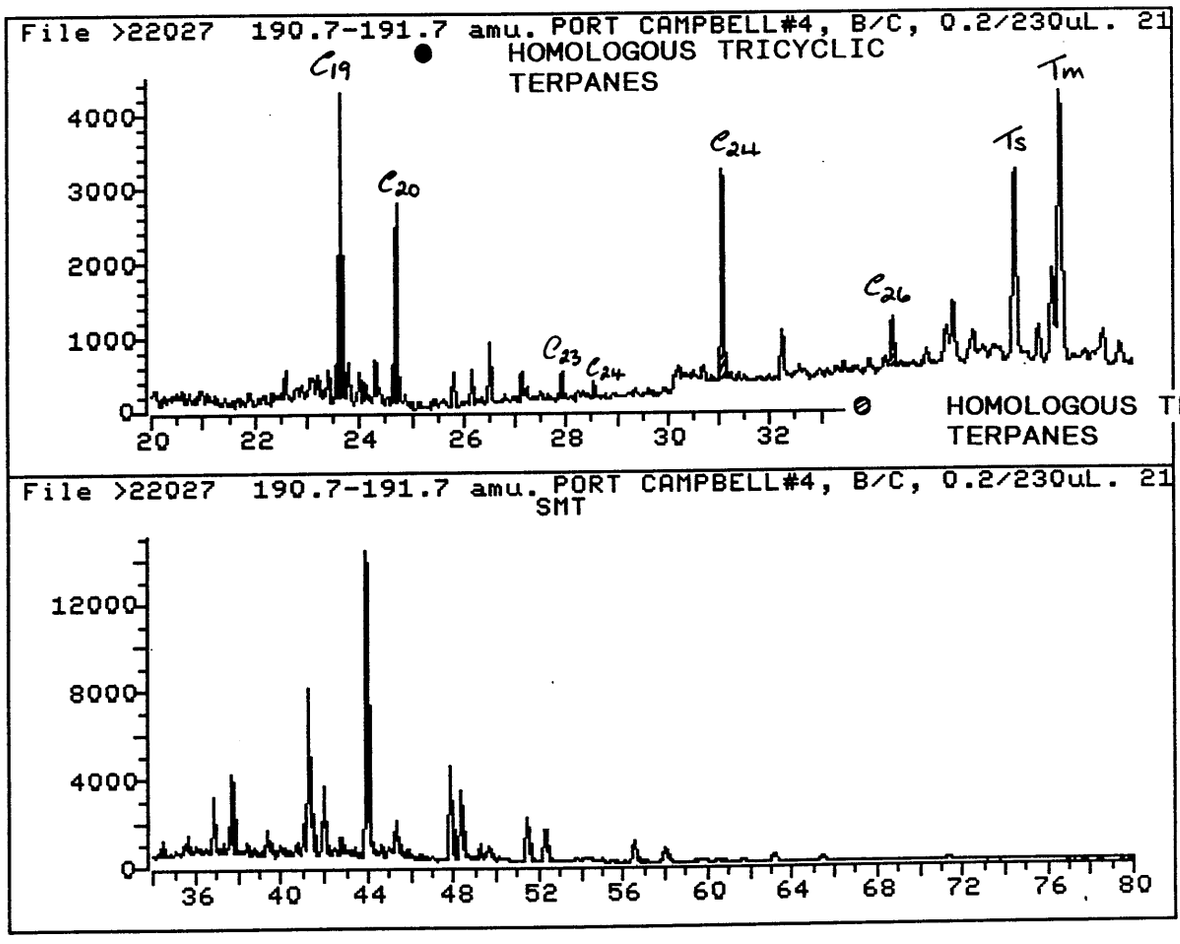
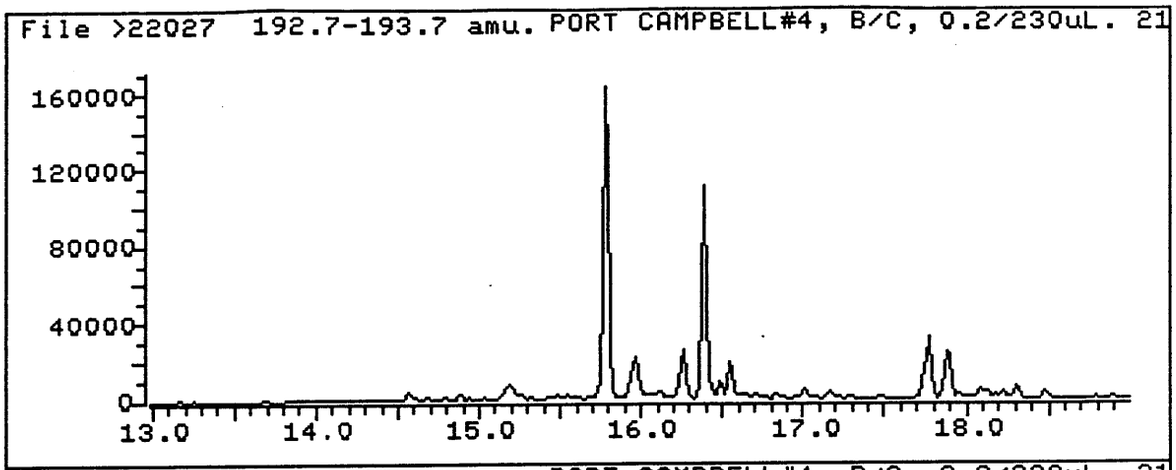
SMT
1600
1200
800
400
0
20 22 24 26 28 30 32 34 36 38
File >22027 162.7-163.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
4000
3000
2000
1000
0
20 22 24 26 28 30 32 34 36 38


File >22027 190.7-191.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
HOMOLOGOUS TRICYCLIC TERPANES
C19
C20
C23
C24
C24
C26
Ts
Tm
4000
3000
2000
1000
0
20 22 24 26 28 30 32
HOMOLOGOUS TETRACYCLIC TERPANES
File >22027 190.7-191.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
12000
8000
4000
0
36 40 44 48 52 56 60 64 68 72 76 80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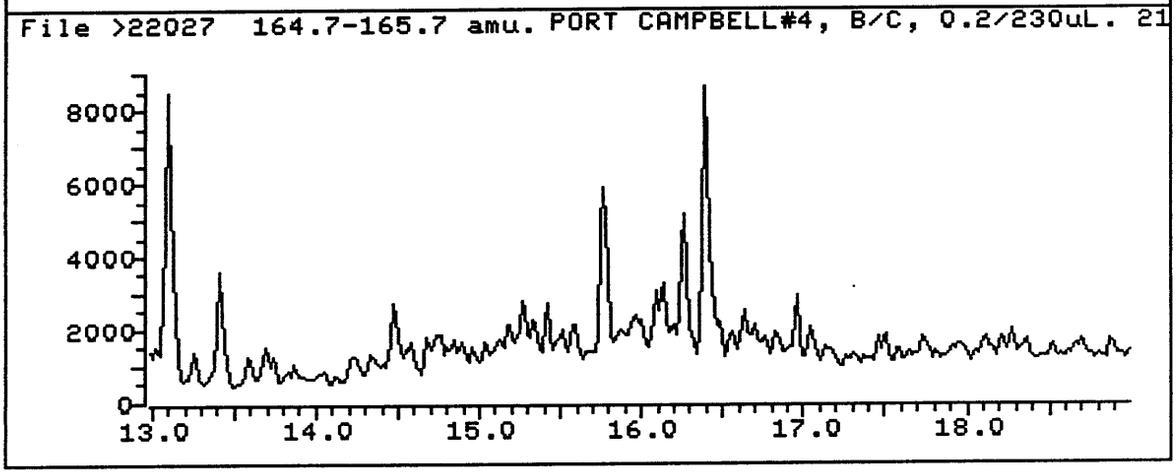
160000
120000
80000
40000
0
13.0
14.0
15.0
16.0
17.0
18.0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8000
6000
4000
2000
0
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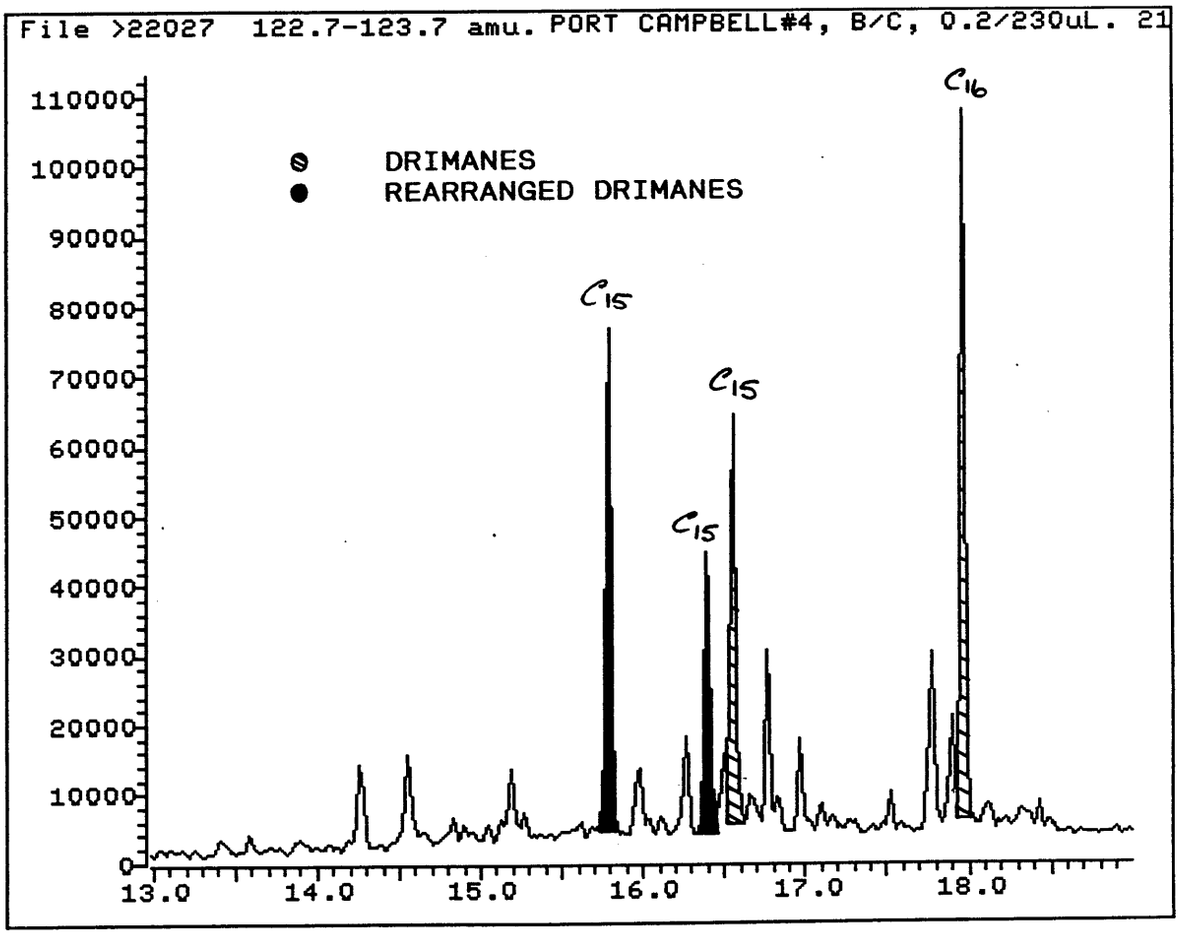
14.0
15.0
16.0
17.0
18.0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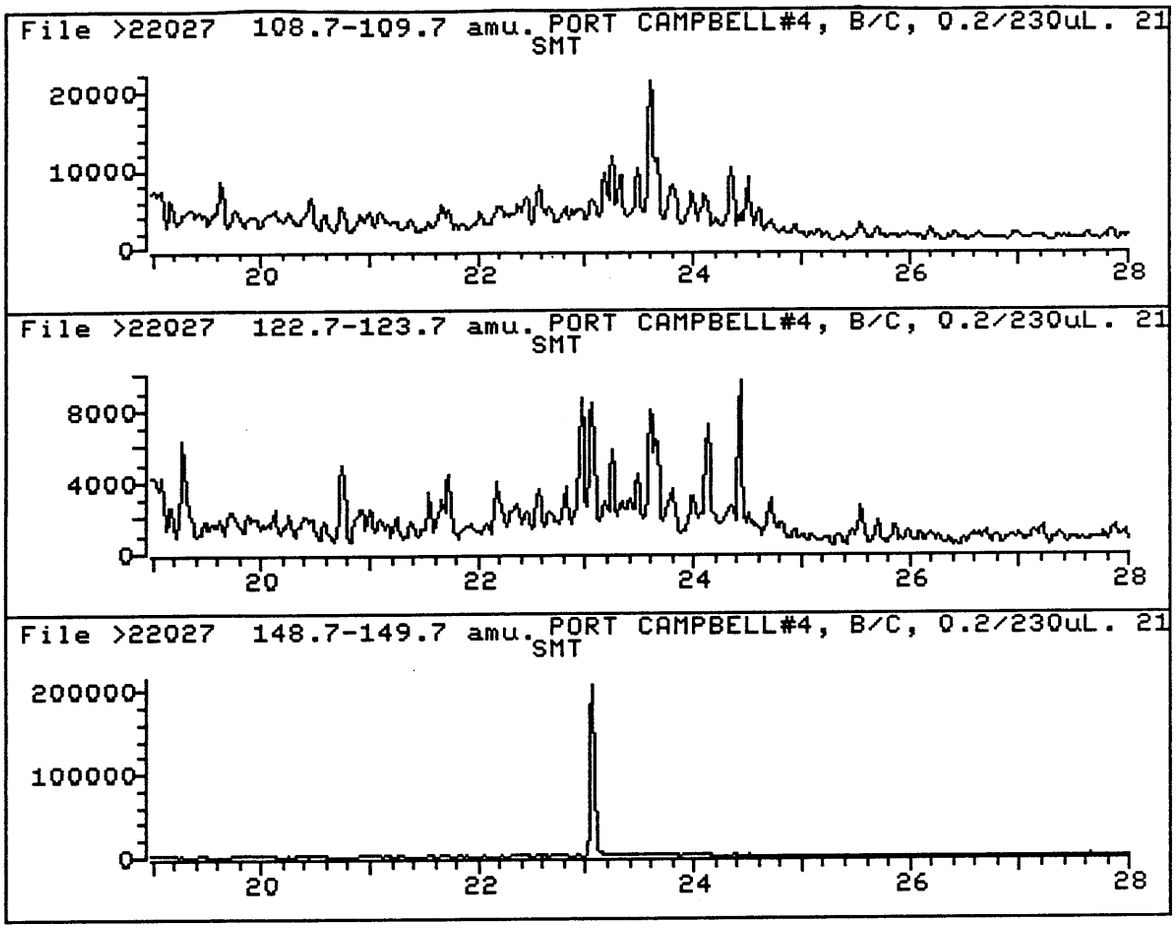
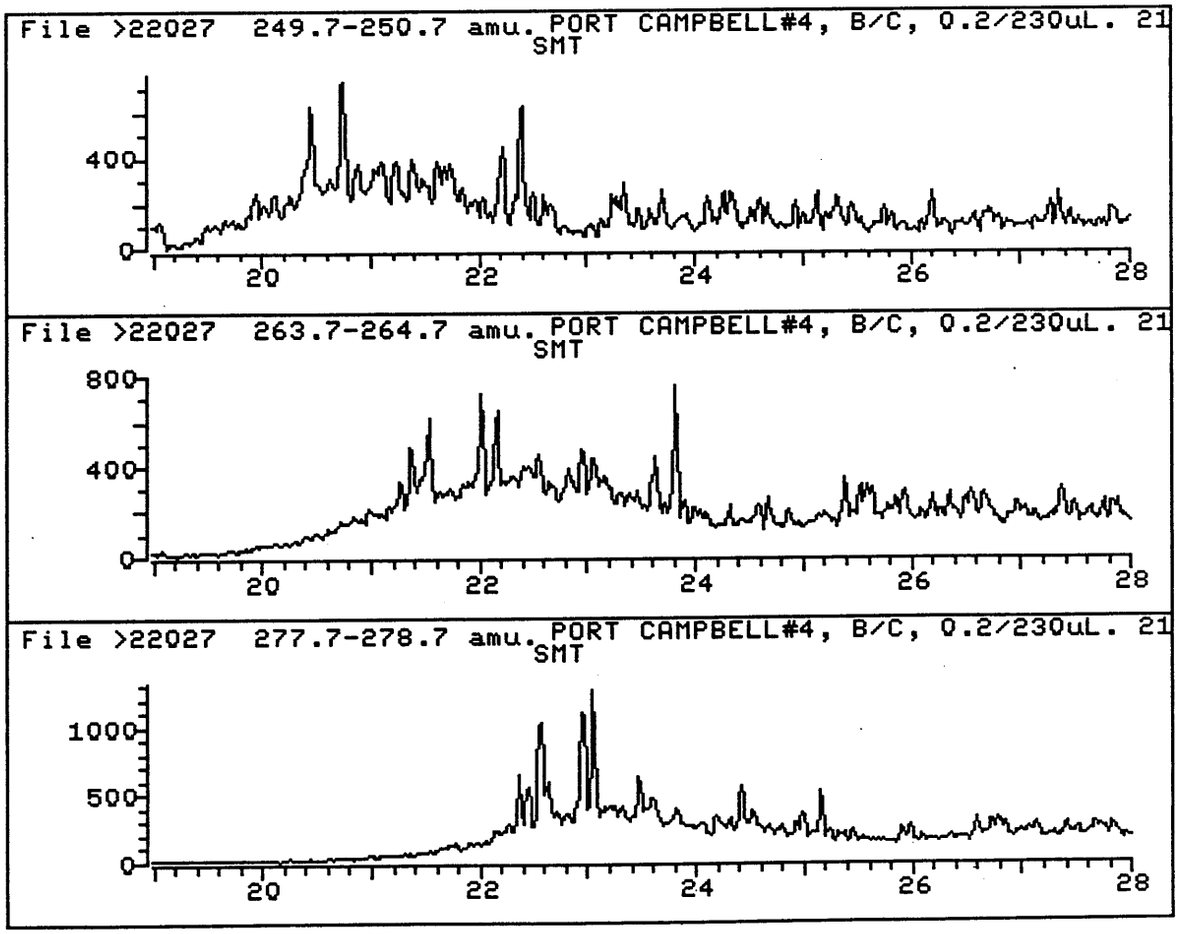
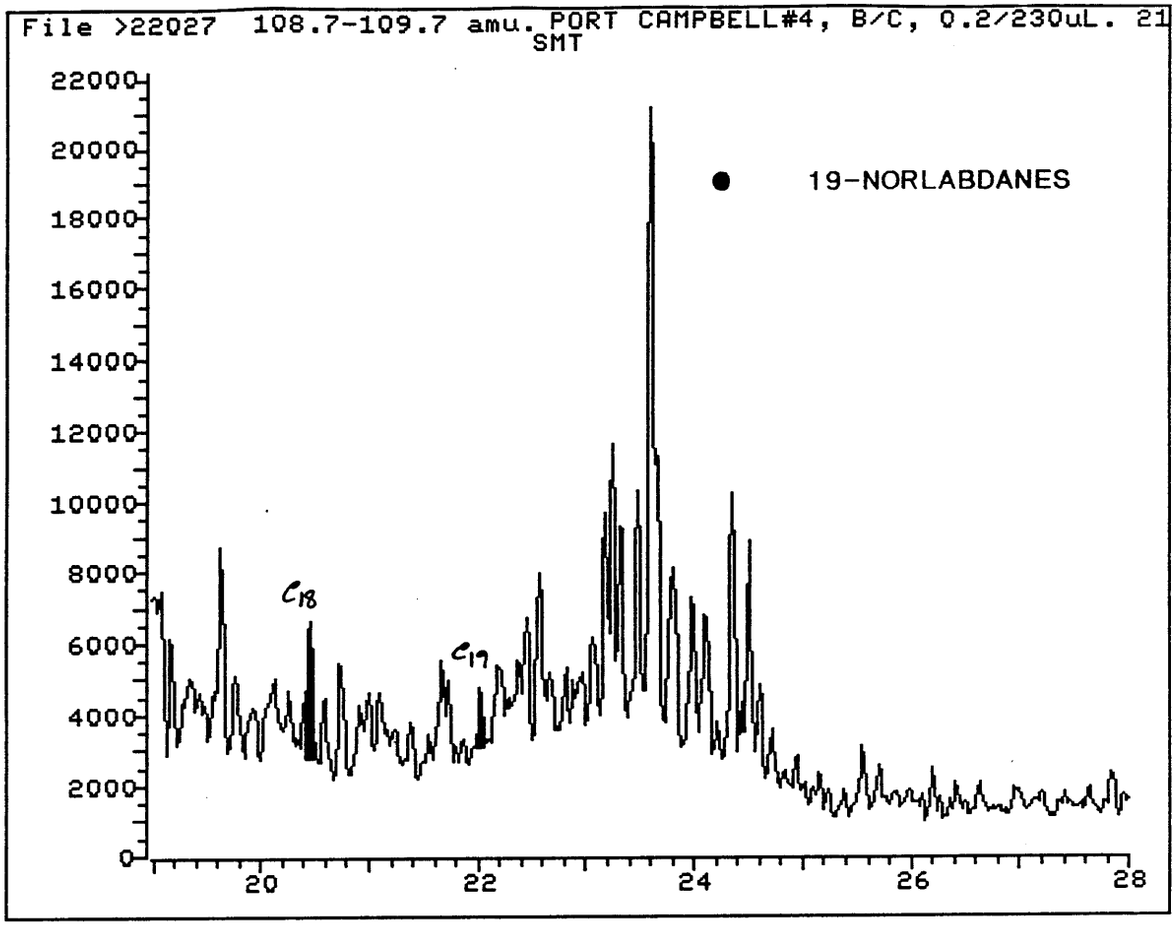
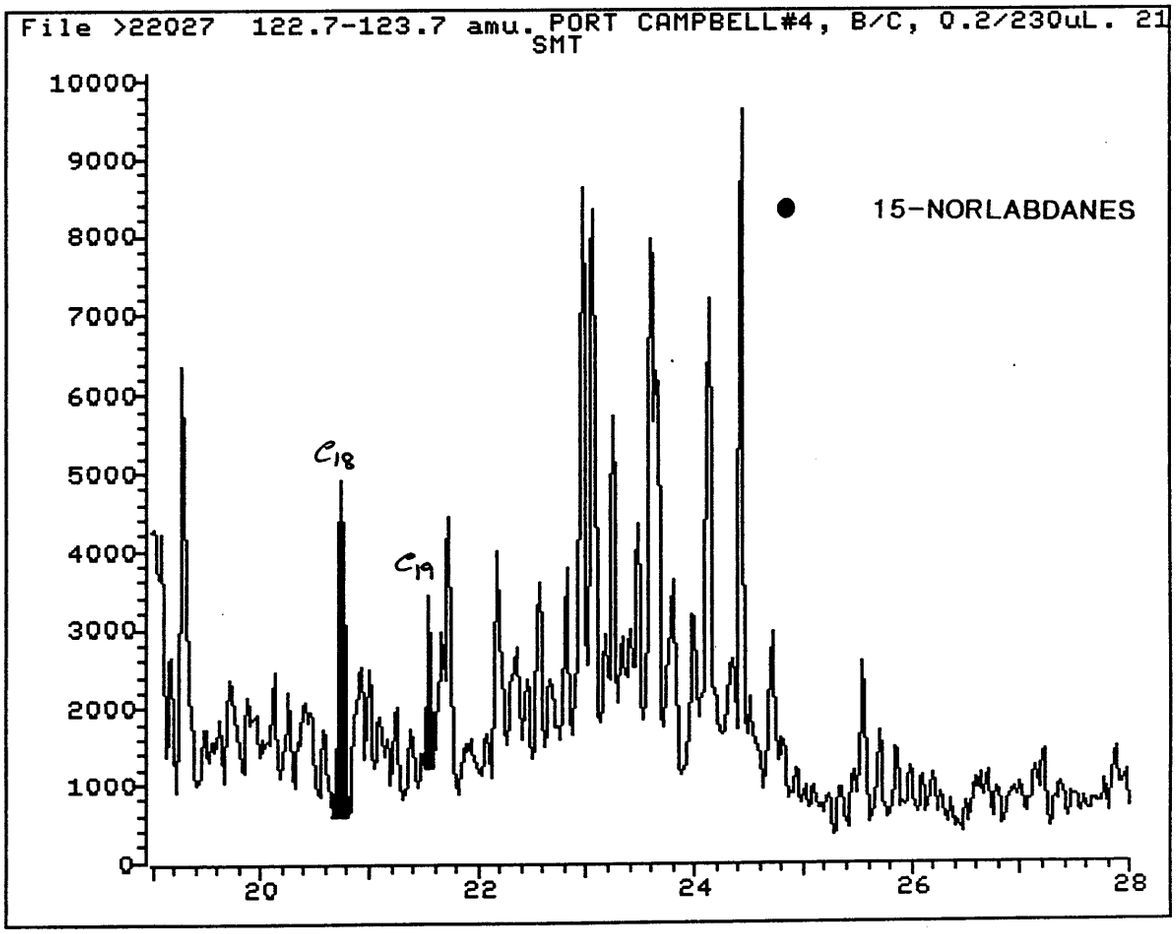
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
DRIMANES
REARRANGED DRIMANES
C15
C15
C15
C16
13.0
14.0
15.0
16.0
17.0
18.0


File >22027 108.7-109.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
20000
10000
0
20
22
24
26
28
File >22027 122.7-123.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
8000
4000
0
20
22
24
26
28
File >22027 148.7-149.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
200000
100000
0
20
22
24
26
28


File >22027 249.7-250.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
400
0
20
22
24
26
28
File >22027 263.7-264.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
800
400
0
20
22
24
26
28
File >22027 277.7-278.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
1000
500
0
20
22
24
26
28


File >22027 108.7-109.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
20
22
24
26
28
19-NORLABDANES
C18
C19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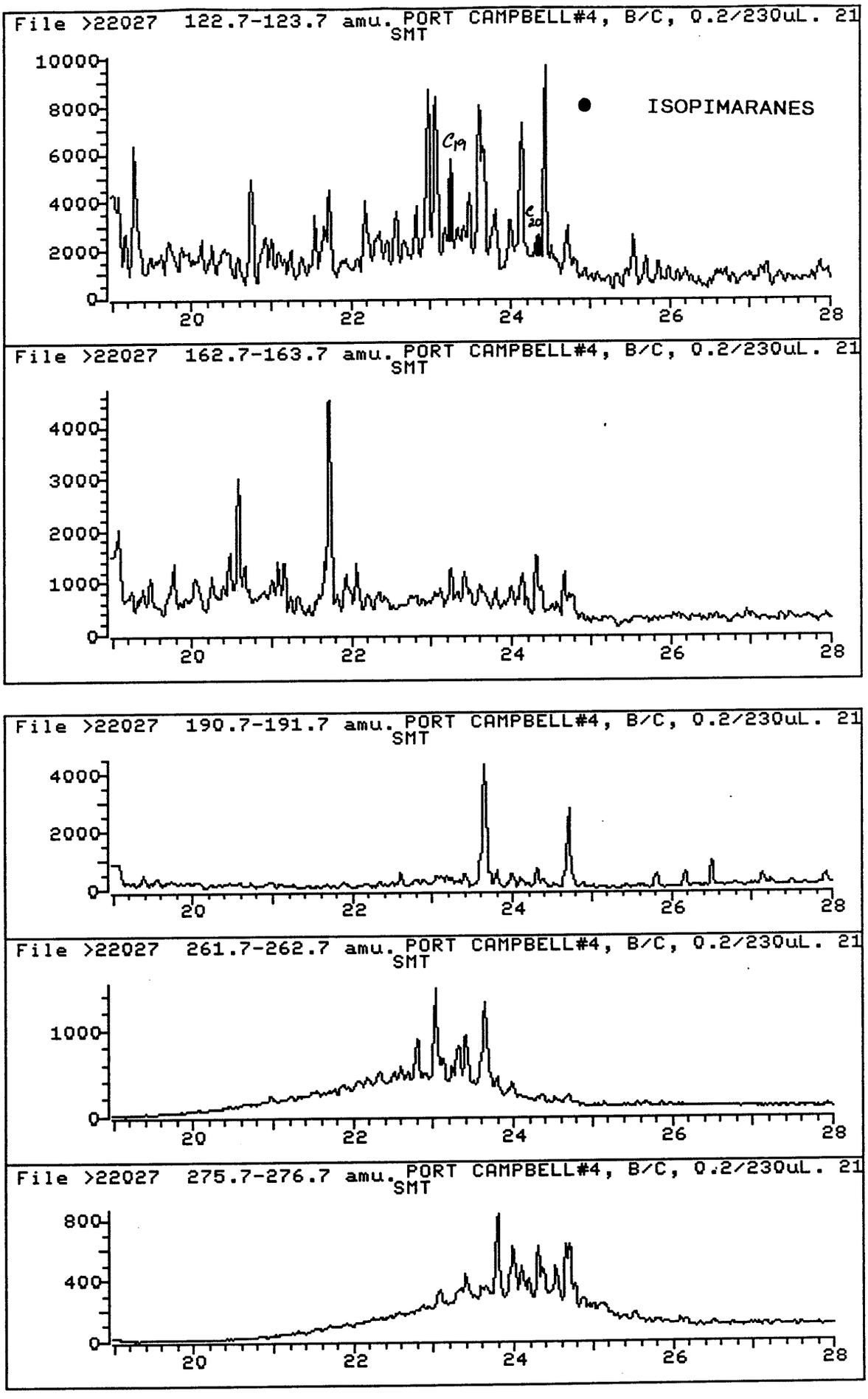
SMT
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
20
22
24
26
28
15-NORLABDANES
C18
C19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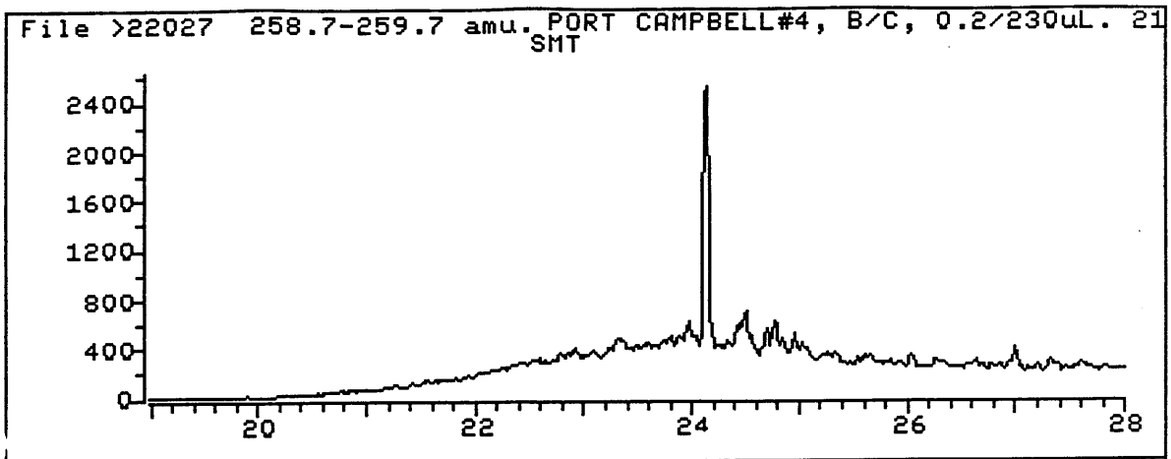
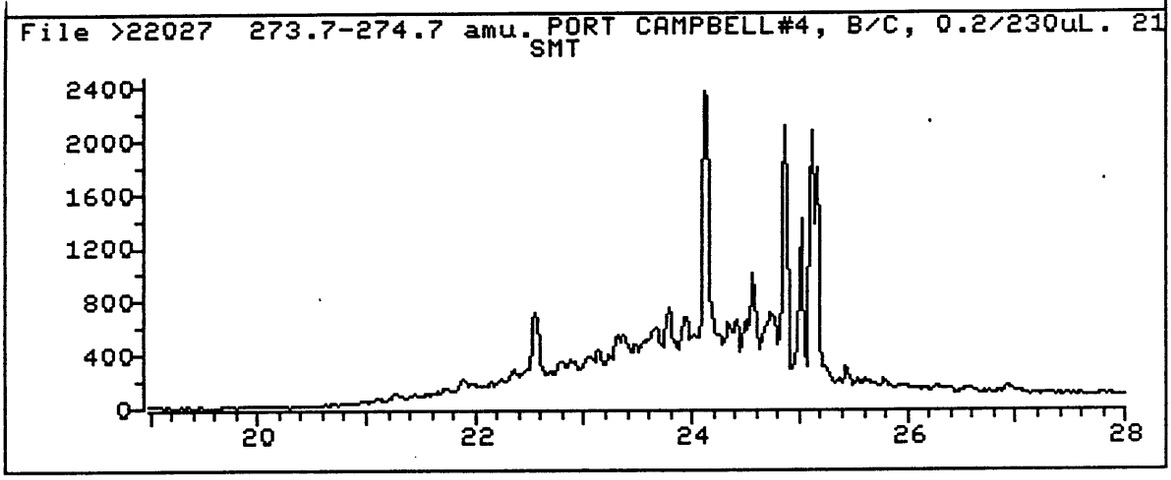
SMT
10000
8000
6000
4000
2000
0
20
22
24
26
28
ISOPIMARANES
C19
C20
File >22027 162.7-163.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
4000
3000
2000
1000
0
20
22
24
26
28
File >22027 190.7-191.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
4000
2000
0
20
22
24
26
28
File >22027 261.7-262.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
1000
0
20
22
24
26
28
File >22027 275.7-276.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
800
400
0
20
22
24
26
28


File >22027 258.7-259.7 amu. PORT CAMPBELL#4, B/C, 0.2/230uL. 21
SMT
2400
2000
1600
1200
800
400
0
20
22
24
26
28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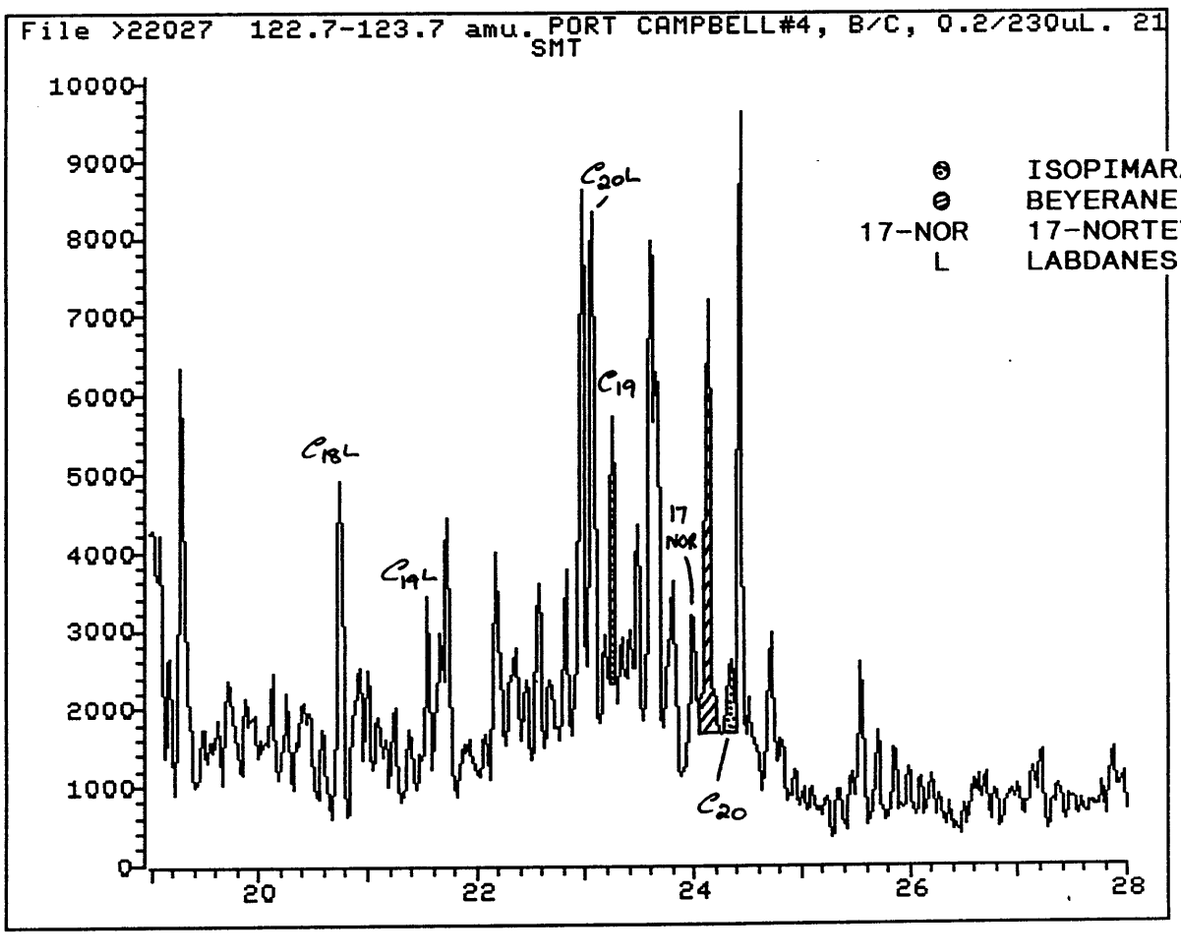
SMT
2400
2000
1600
1200
800
400
0
20
22
24
26
28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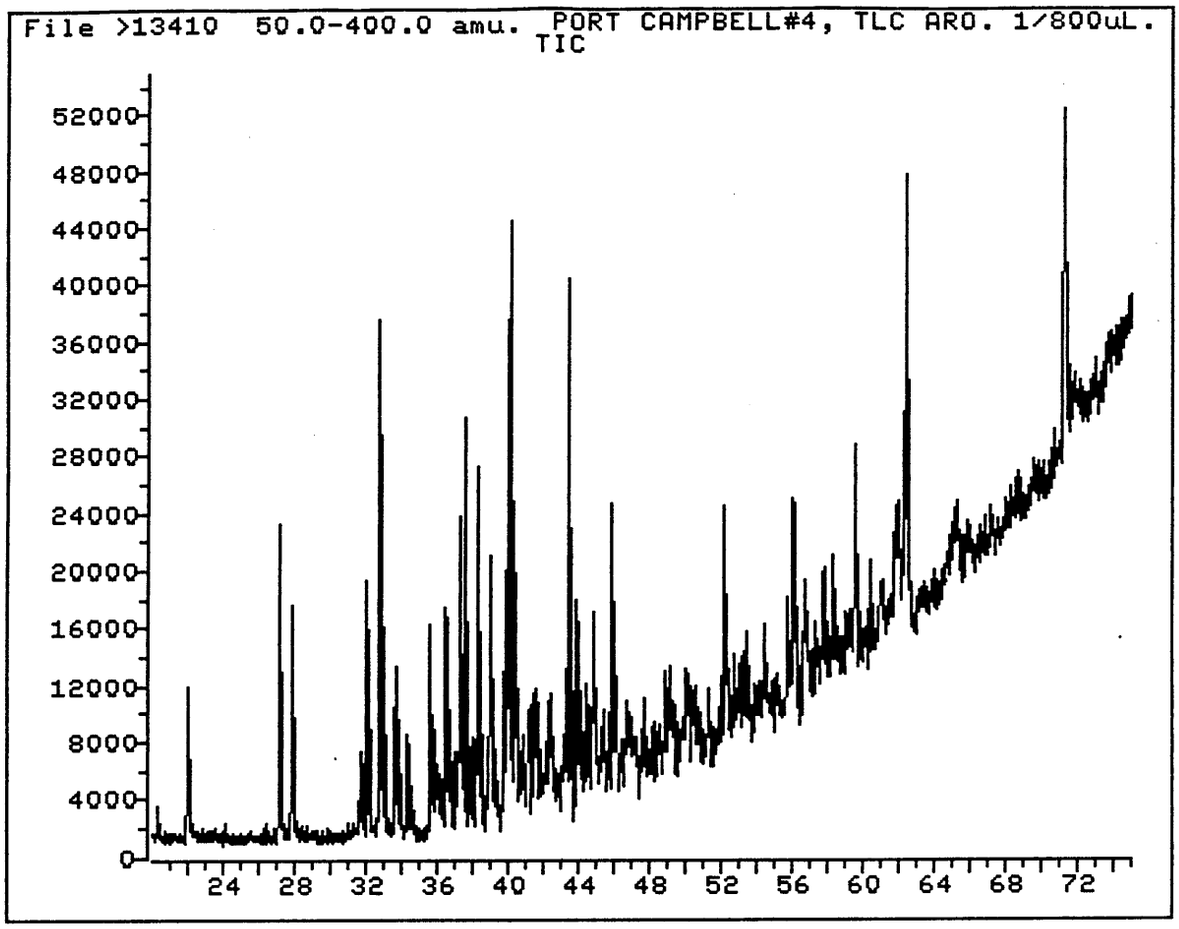
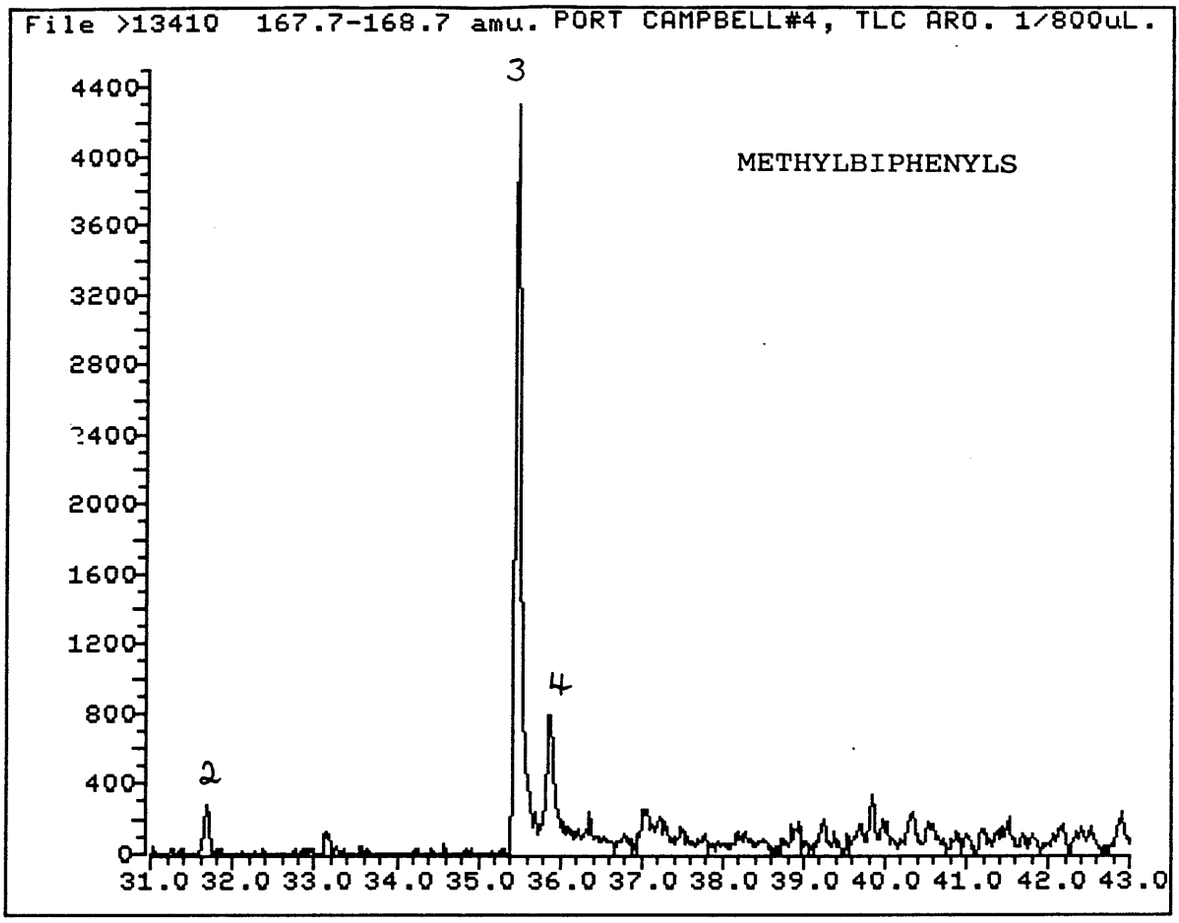
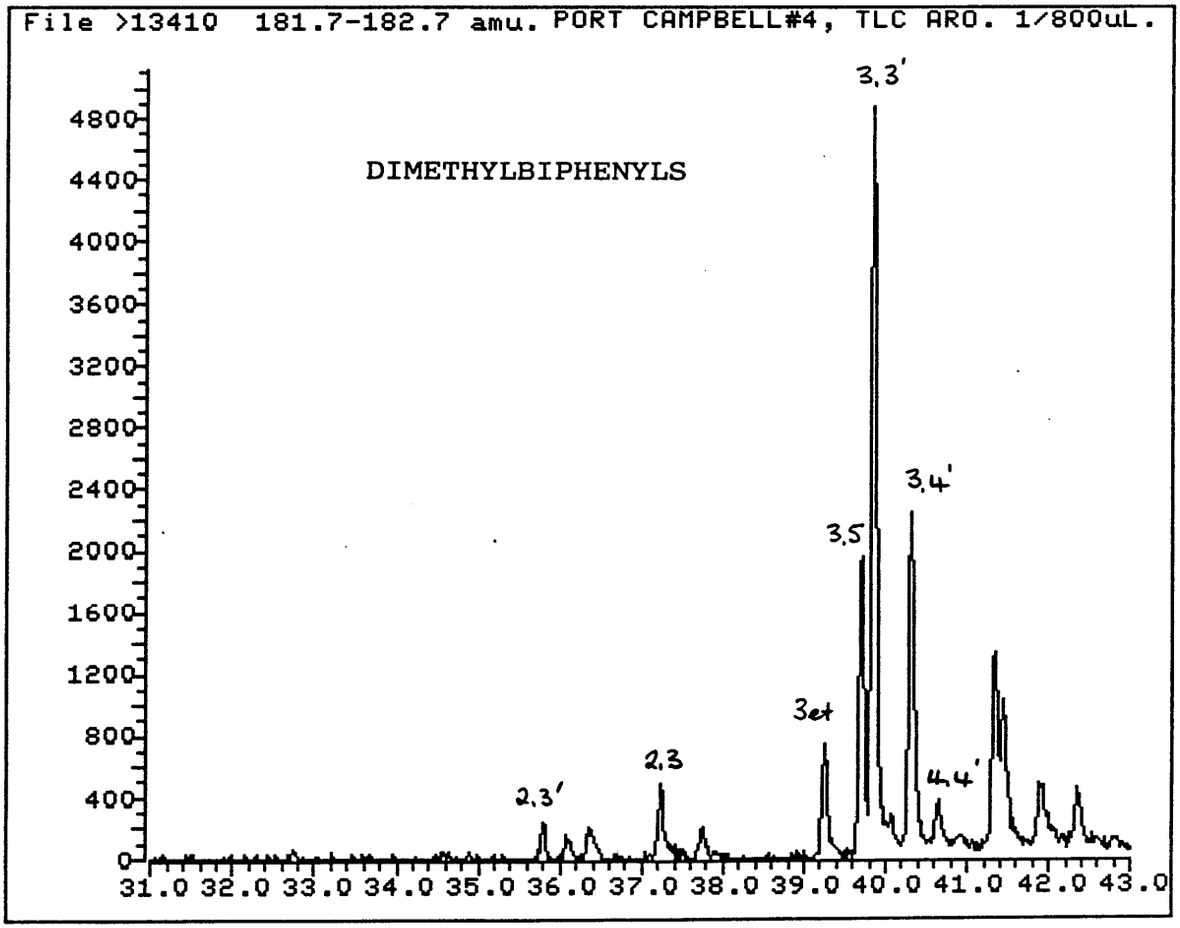
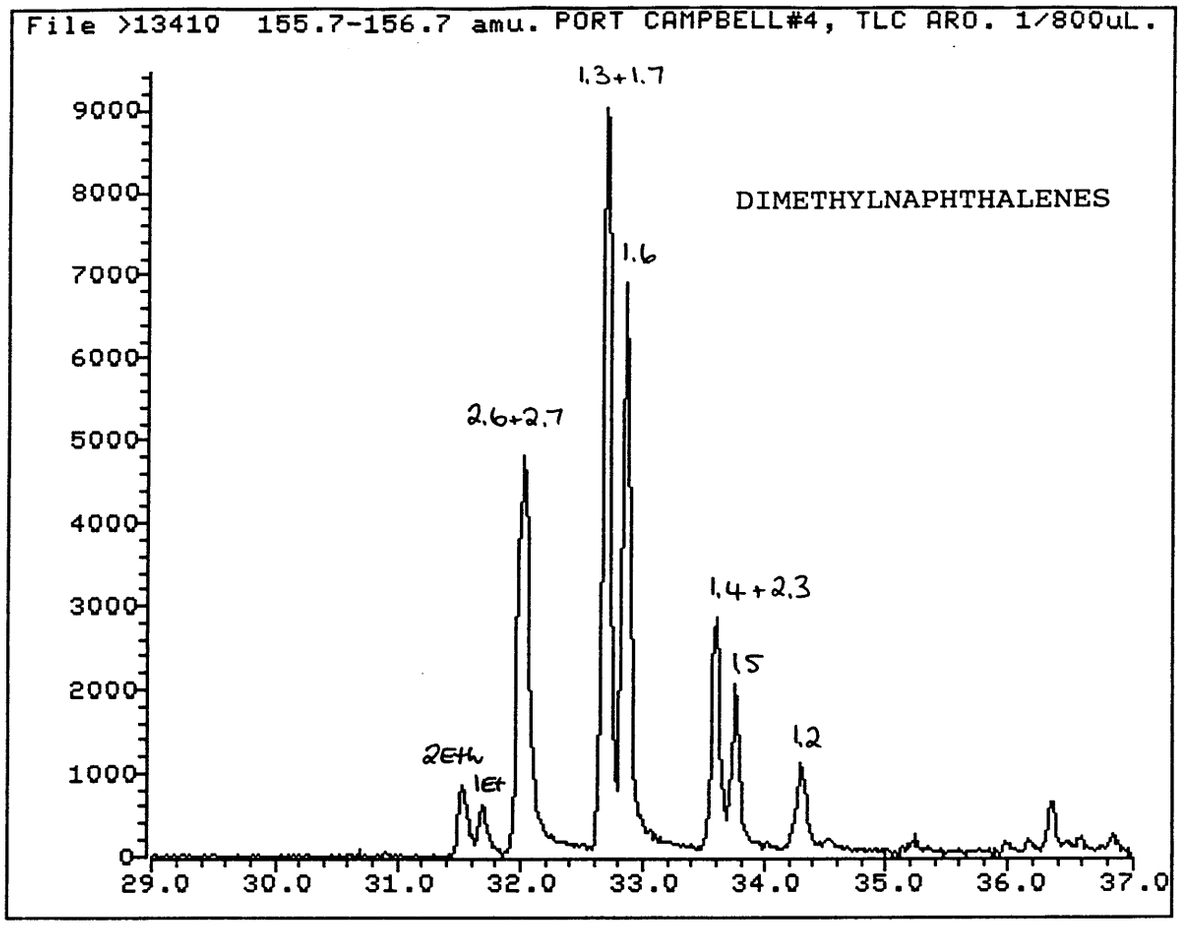
SMT
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
20
22
24
26
28
C20L
C19
C18L
C19L
17 NOR
C20
Θ ISOPIMARANES
Θ BEYERANE
17-NOR 17-NORTETRACYCLANE
L LABDANES

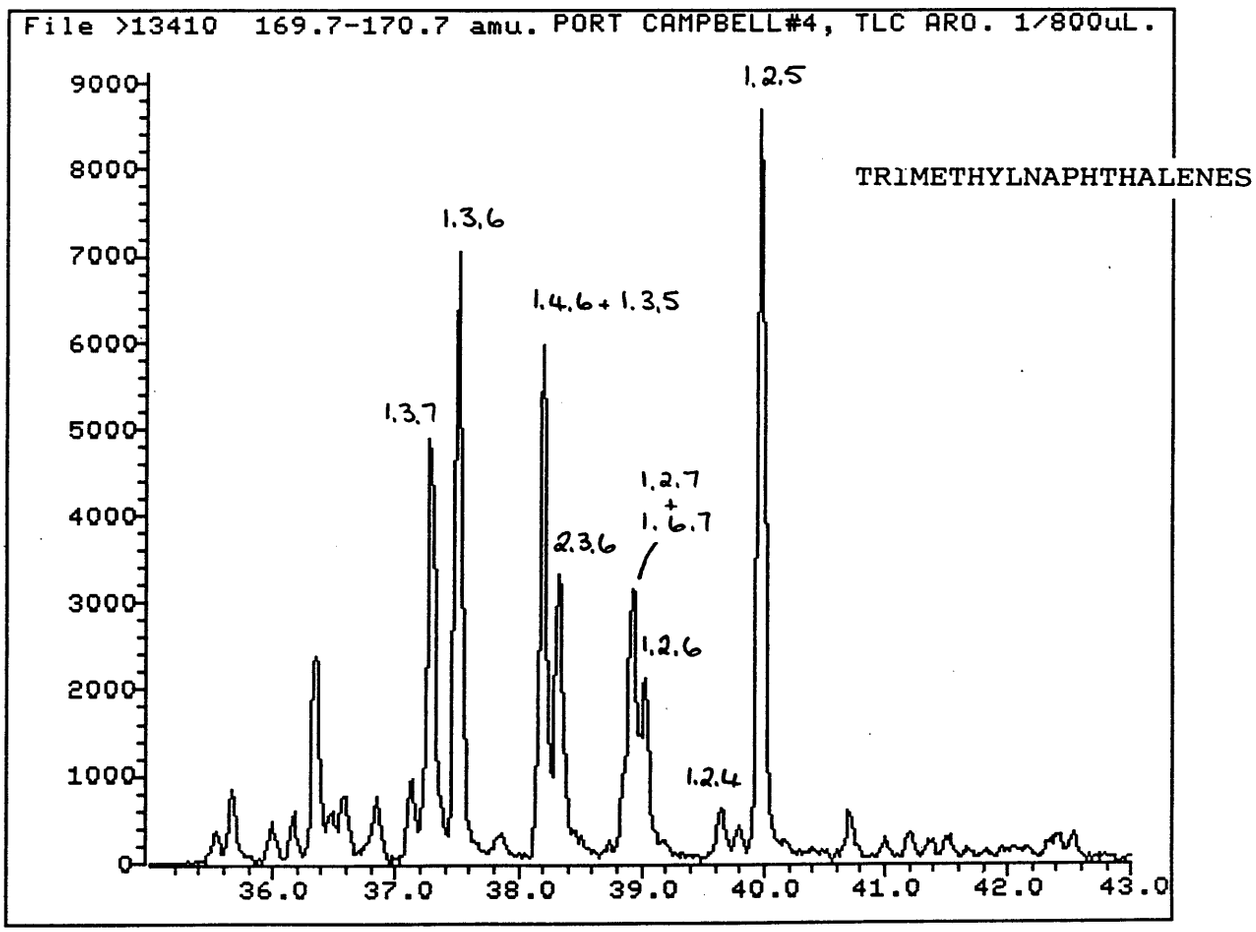
APPENDIX 2


File >13410 50.0-400.0 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
TIC
52000
48000
44000
40000
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
24
28
32
36
40
44
48
52
56
60
64
68
72

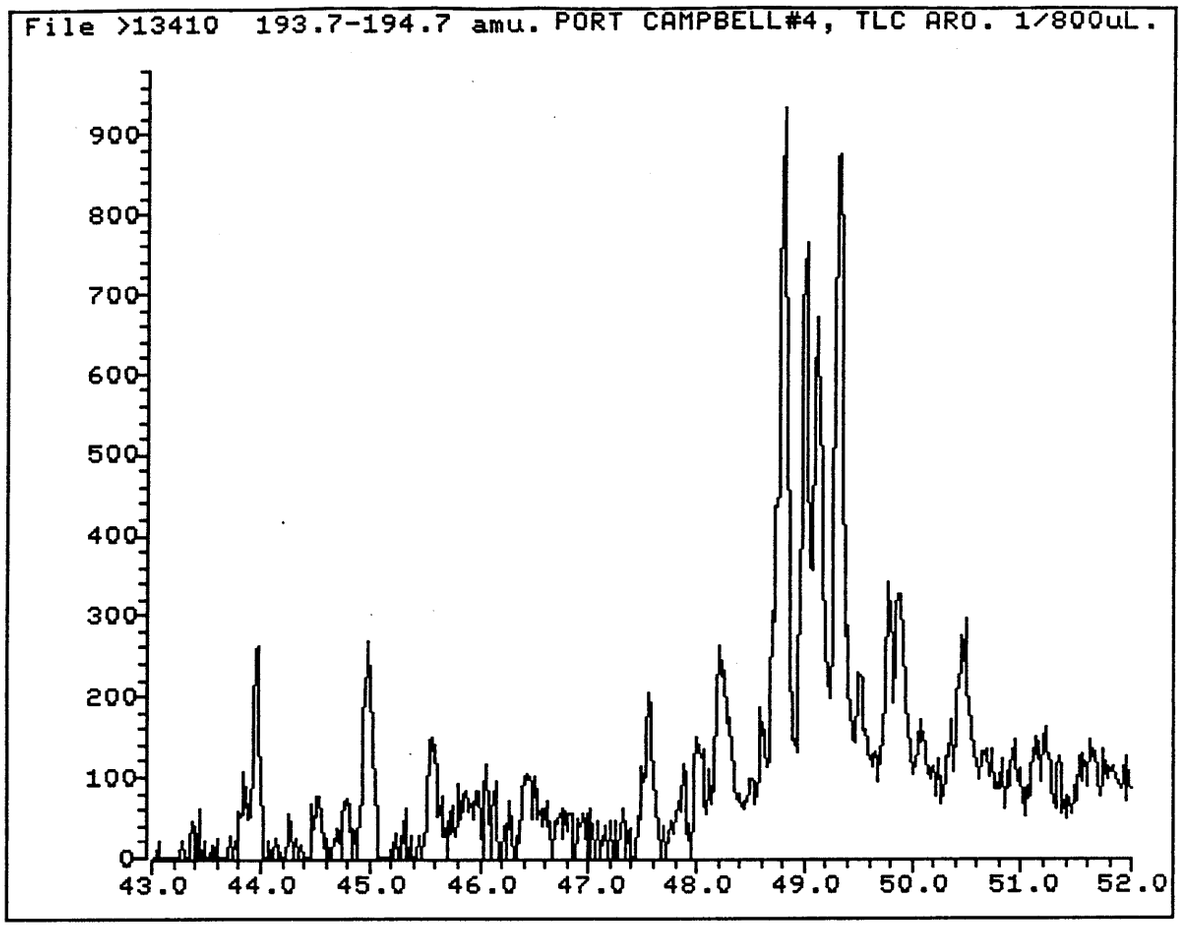

File >13410 167.7-168.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
METHYLBIPHENYLS
3
4
2
4400
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
31.0 32.0 33.0 34.0 35.0 36.0 37.0 38.0 39.0 40.0 41.0 42.0 43.0

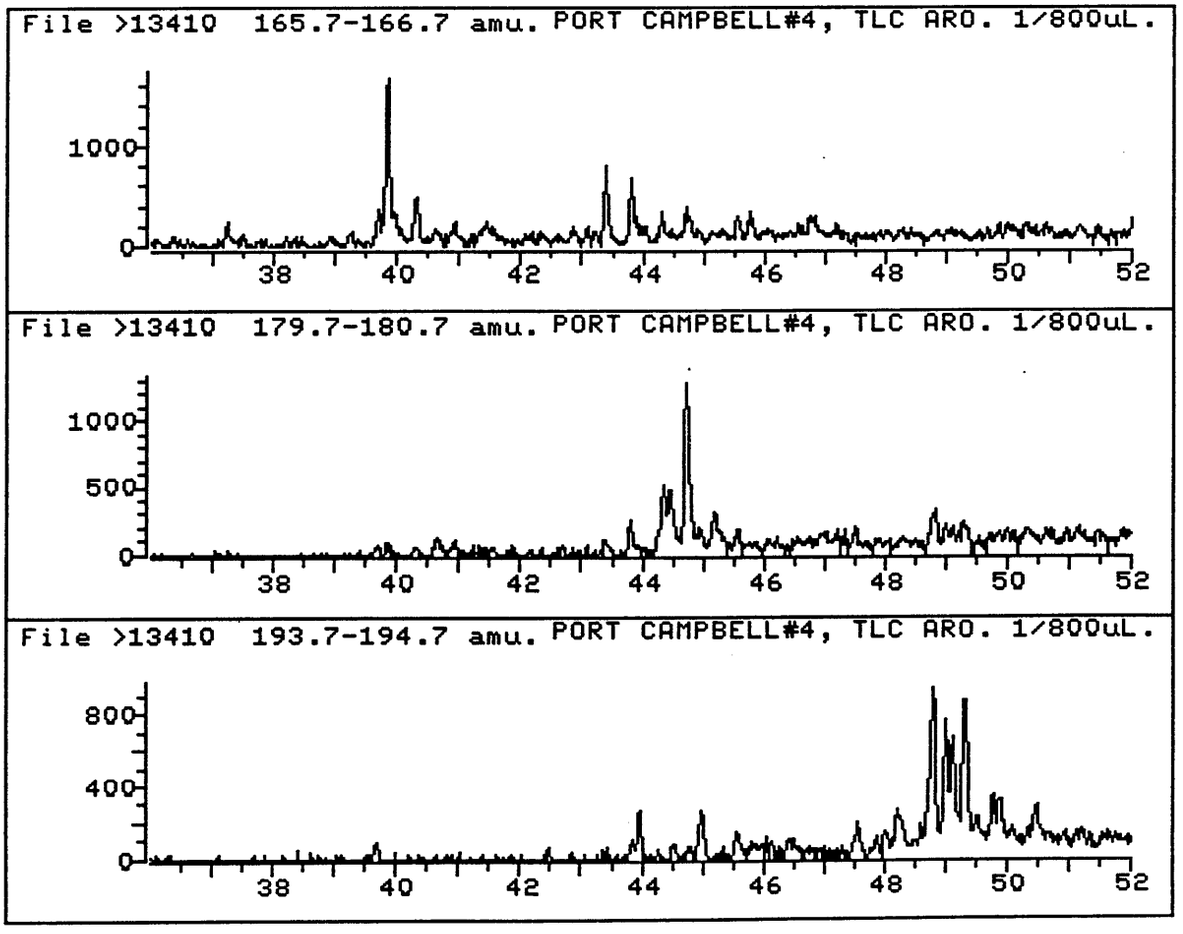

File >13410 181.7-182.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
DIMETHYLBIPHENYLS
3,3'
3,4'
3,5
3et
2,3
2,3'
4,4'
4800
4400
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
31.0 32.0 33.0 34.0 35.0 36.0 37.0 38.0 39.0 40.0 41.0 42.0 43.0

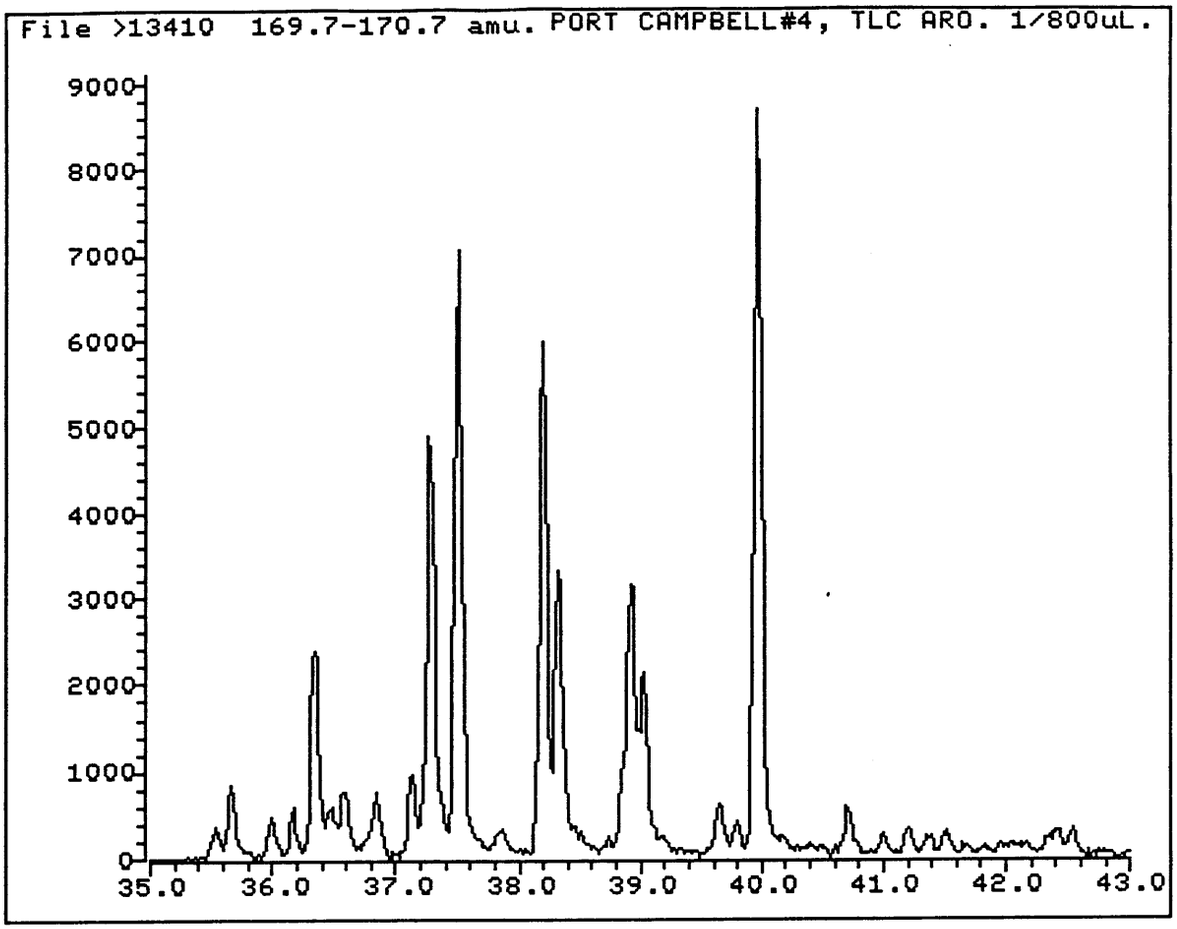

File >13410 155.7-156.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
DIMETHYLNAPHTHALENES
1.3+1.7
1.6
2.6+2.7
1.4+2.3
1.5
1.2
2Eth
1Et
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
29.0
30.0
31.0
32.0
33.0
34.0
35.0
36.0
37.0

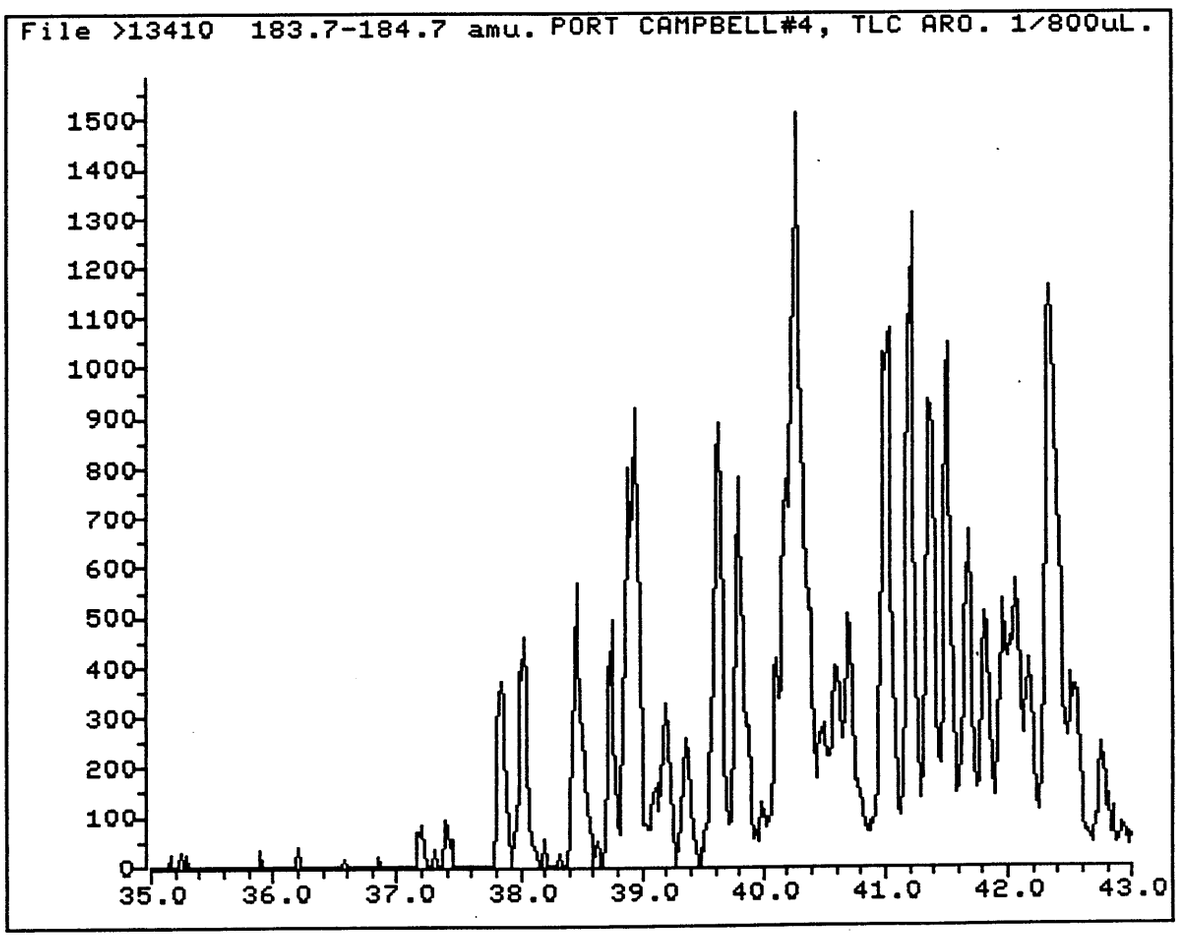

File >13410 169.7-170.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
TRIMETHYLNAPHTHALENES
1.2.5
1.3.6
1.4.6+1.3.5
1.3.7
1.2.7
+
1.6.7
2.3.6
1.2.6
1.2.4
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
36.0
37.0
38.0
39.0
40.0
41.0
42.0
43.0

FLUORENES


File >13410 193.7-194.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
900
800
700
600
500
400
300
200
100
0
43.0
44.0
45.0
46.0
47.0
48.0
49.0
50.0
51.0
52.0


File >13410 165.7-166.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
1000
0
38
40
42
44
46
48
50
52
File >13410 179.7-180.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
1000
500
0
38
40
42
44
46
48
50
52
File >13410 193.7-194.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
800
400
0
38
40
42
44
46
48
50
52


File >13410 169.7-170.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
35.0
36.0
37.0
38.0
39.0
40.0
41.0
42.0
43.0


File >13410 183.7-184.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
35.0
36.0
37.0
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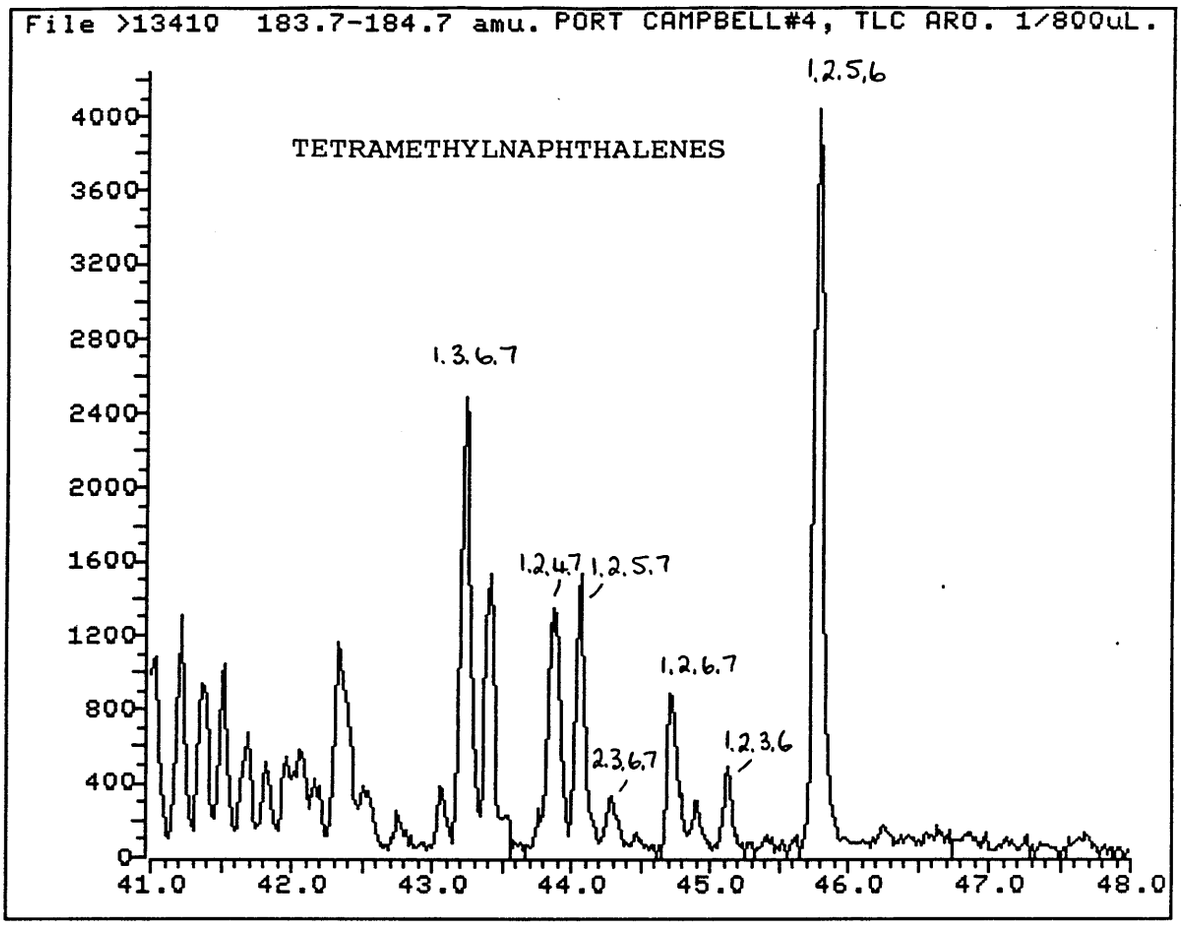
43.0


File >13410 183.7-184.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
TETRAMETHYLNAPHTHALENES
1.2.5,6
1.3.6.7
1.2.4.7
1.2.5.7
1.2.6.7
1.2.3.6
2.3.6.7
4000
3600
3200
2800
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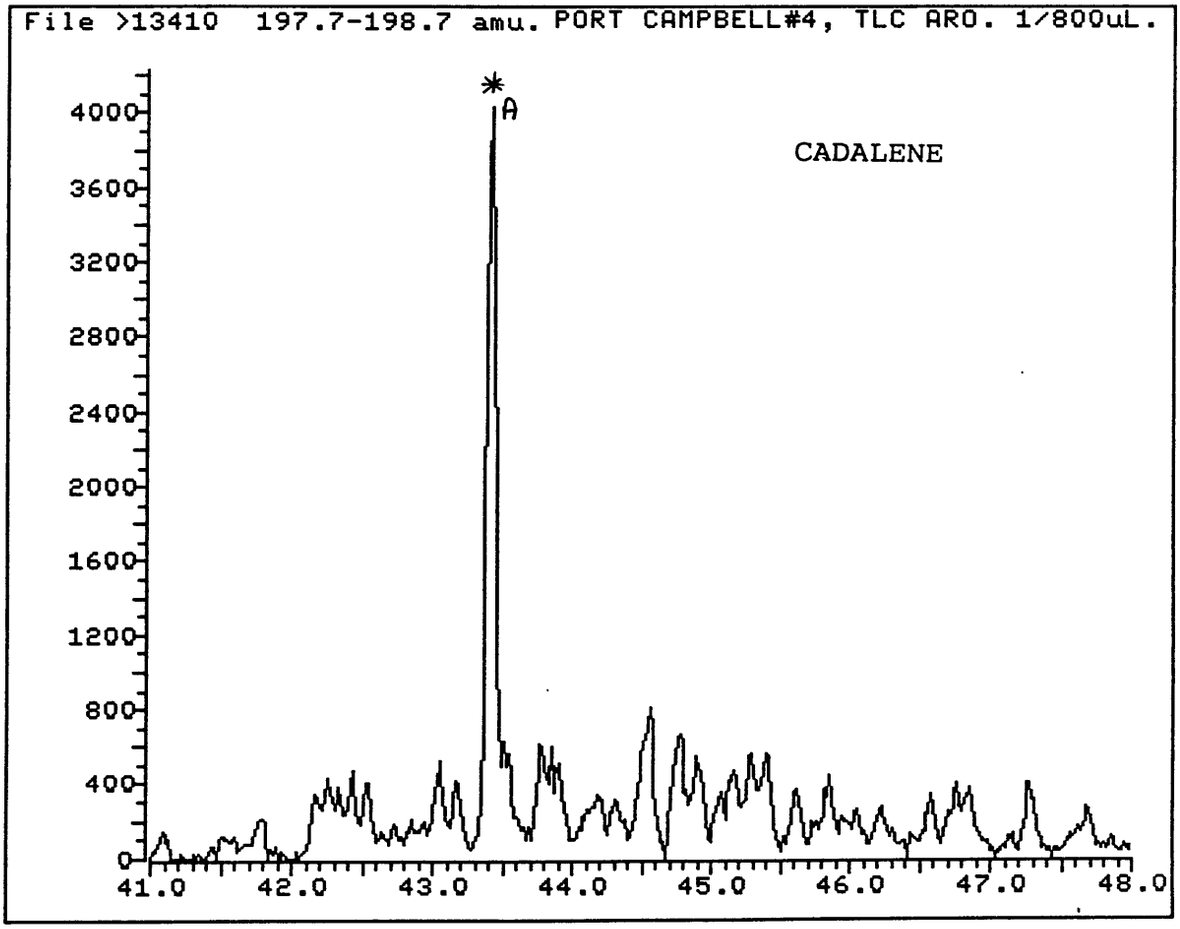
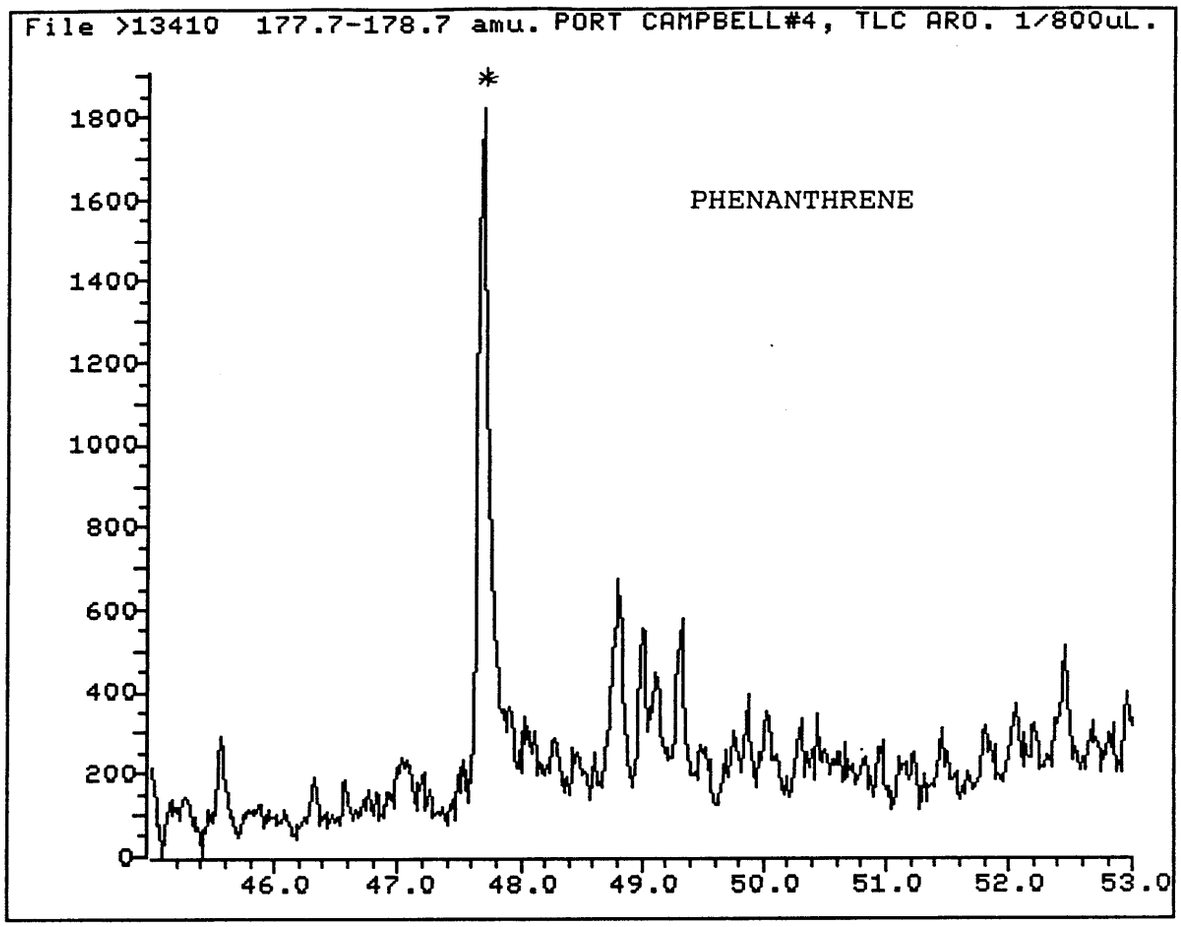
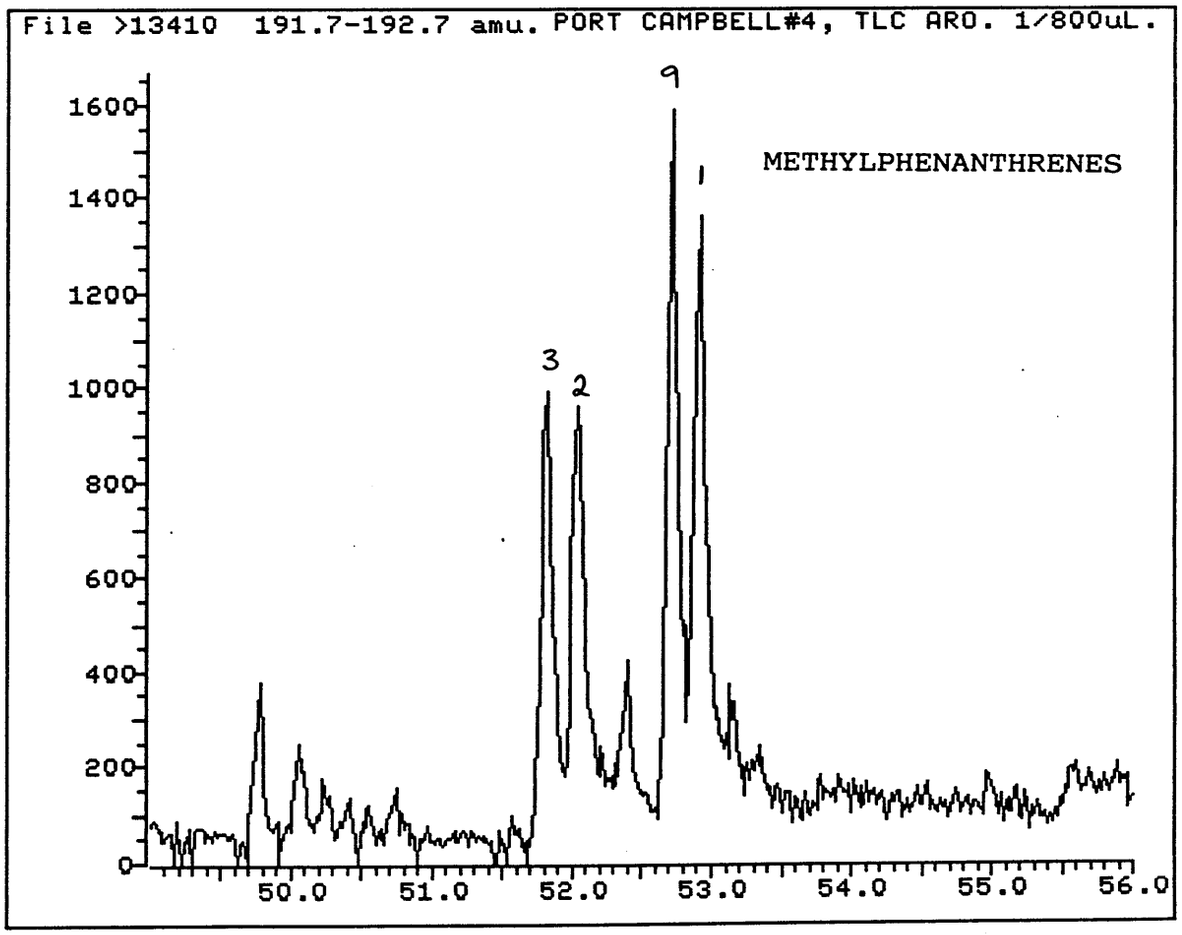
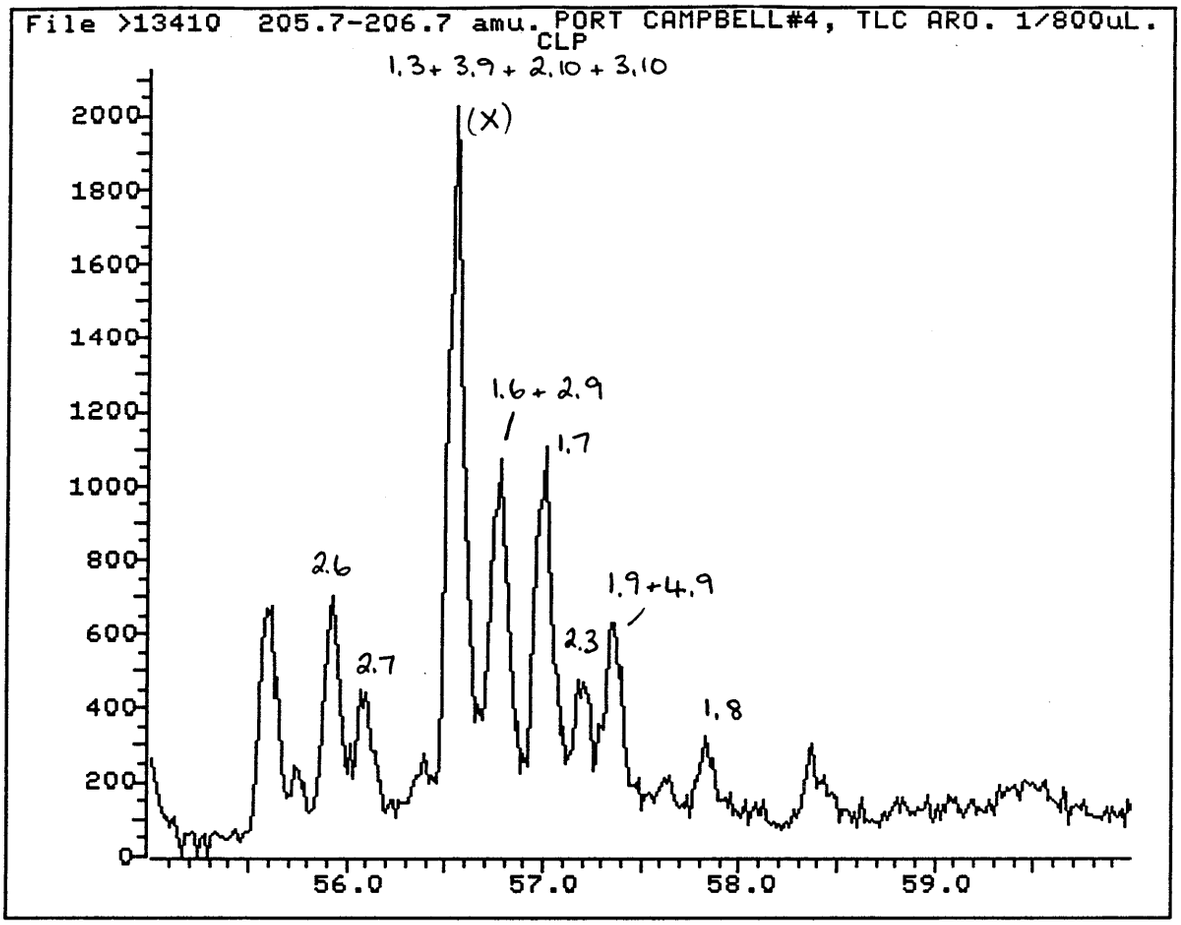
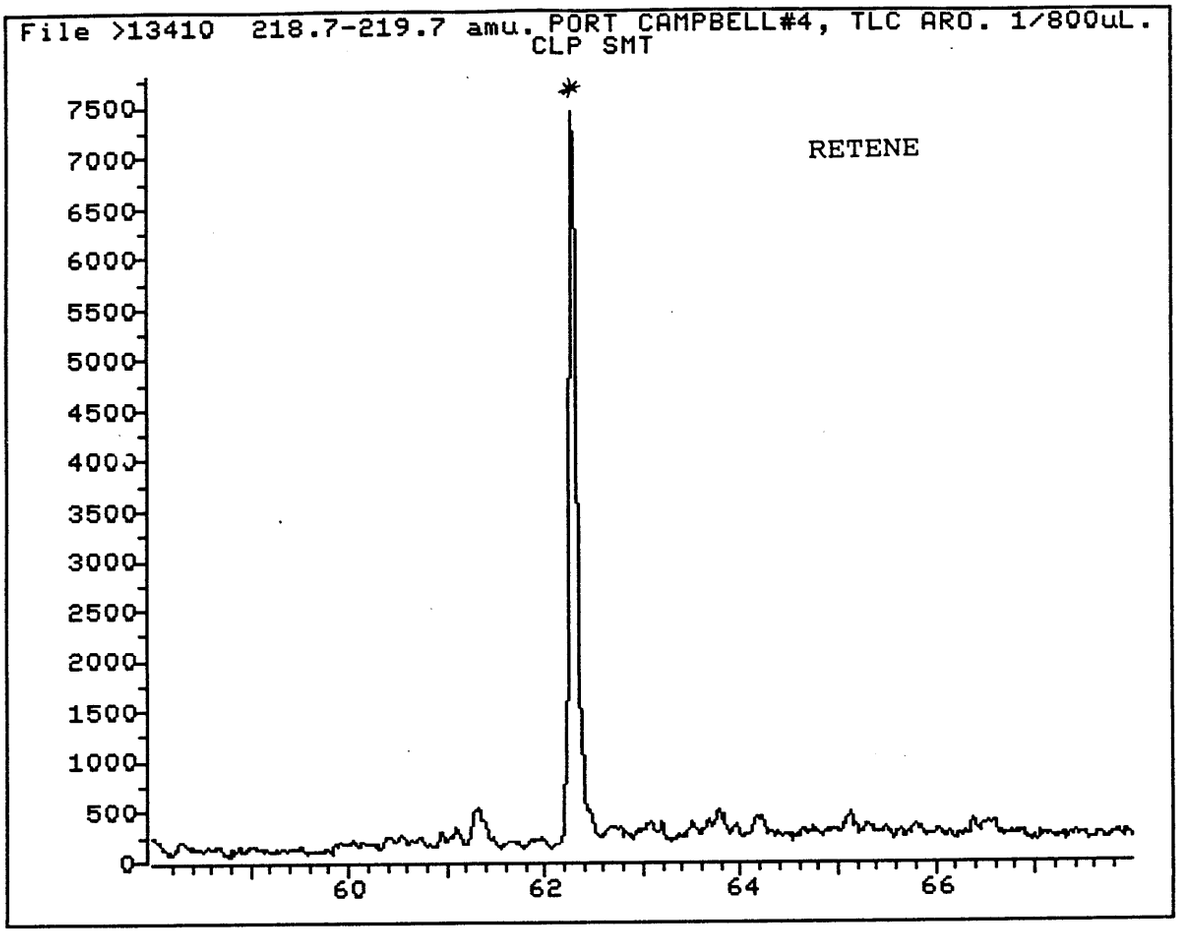

File >13410 197.7-198.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
CADALENE
*A
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
41.0
42.0
43.0
44.0
45.0
46.0
47.0
48.0

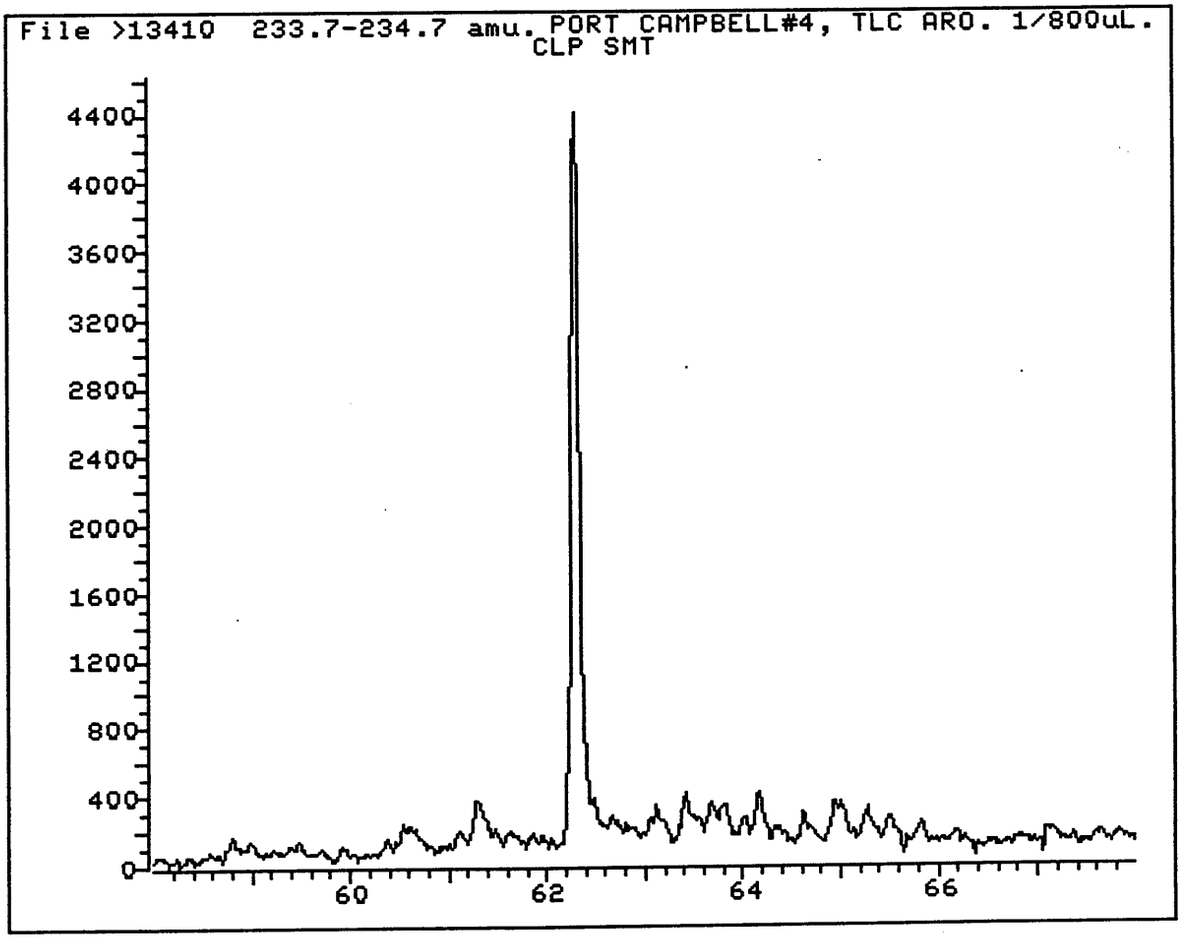

File >13410 177.7-178.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
*
PHENANTHRENE
1800
1600
1400
1200
1000
800
600
400
200
0
46.0
47.0
48.0
49.0
50.0
51.0
52.0
53.0


File >13410 191.7-192.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
9
1
3
2
METHYLPHENANTHRENES
1600
1400
1200
1000
800
600
400
200
0
50.0
51.0
52.0
53.0
54.0
55.0
56.0



DIMETHYLPHENANTHRENES


File >13410 218.7-219.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
CLP SMT
RETENE
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
60
62
64
66


File >13410 233.7-234.7 amu. PORT CAMPBELL#4, TLC ARO. 1/800uL.
CLP SMT
4400
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
60
62
64
66