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Correlation study involving migrated hydrocarbons and potensial source rocks from the 34/10-23, 34/10-21 and 34/10-30 wells

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Abstract Source rock cores and cuttings, reservoir cores and accumulated hydrocarbons (test-samples) have been investigated from all three wells with the purpose to look for the non-Kimmeridgian source for hydrocarbons in well 34/10-23 (DST 1) and staining in the other wells. Two principal crude oil families are identified in well 34/10-23. A Kimmeridge Clay derived oil is identified in this source rock in well 34/10-21 and 23, while a second type is present in the Heather Fm., in the Brent sand and probably in the Drake and Statfjord shales. The source for this oil is probably a mixing of hydrocarbones generated in the Kimmeridgian shales and the coaly fasies mainly occuring in the Ness formation.

Prepared by

GEOCHEM (Chester)
STATOIL, GEOLAB

Textoperator

Approved by

5/6-87 Trygve Meyer
Trygve Meyer

9/6-87 Snorre Olaussen
Snorre Olaussen

Prepared for

STATOIL

CORRELATION STUDY INVOLVING MIGRATED HYDROCARBONS AND POTENTIAL SOURCE ROCKS FROM THE 34/10-23, 34/10-21 AND 34/10-30 WELLS

February 1987

CORRELATION STUDY INVOLVING MIGRATED HYDROCARBONS AND POTENTIAL SOURCE ROCKS FROM THE 34/10-23, 34/10-21 AND 34/10-30 WELLS

EXECUTIVE SUMMARY

Two principal crude oil families are identified in the 34/10-23 well.

The type I oil occurs in the Kimmeridgian of 34/10-23 and correlates with the source rocks, mudstones and shales, in this interval and in the corresponding unit in 34/10-21. Mature equivalents of the host sediments are believed to be the source of this oil.

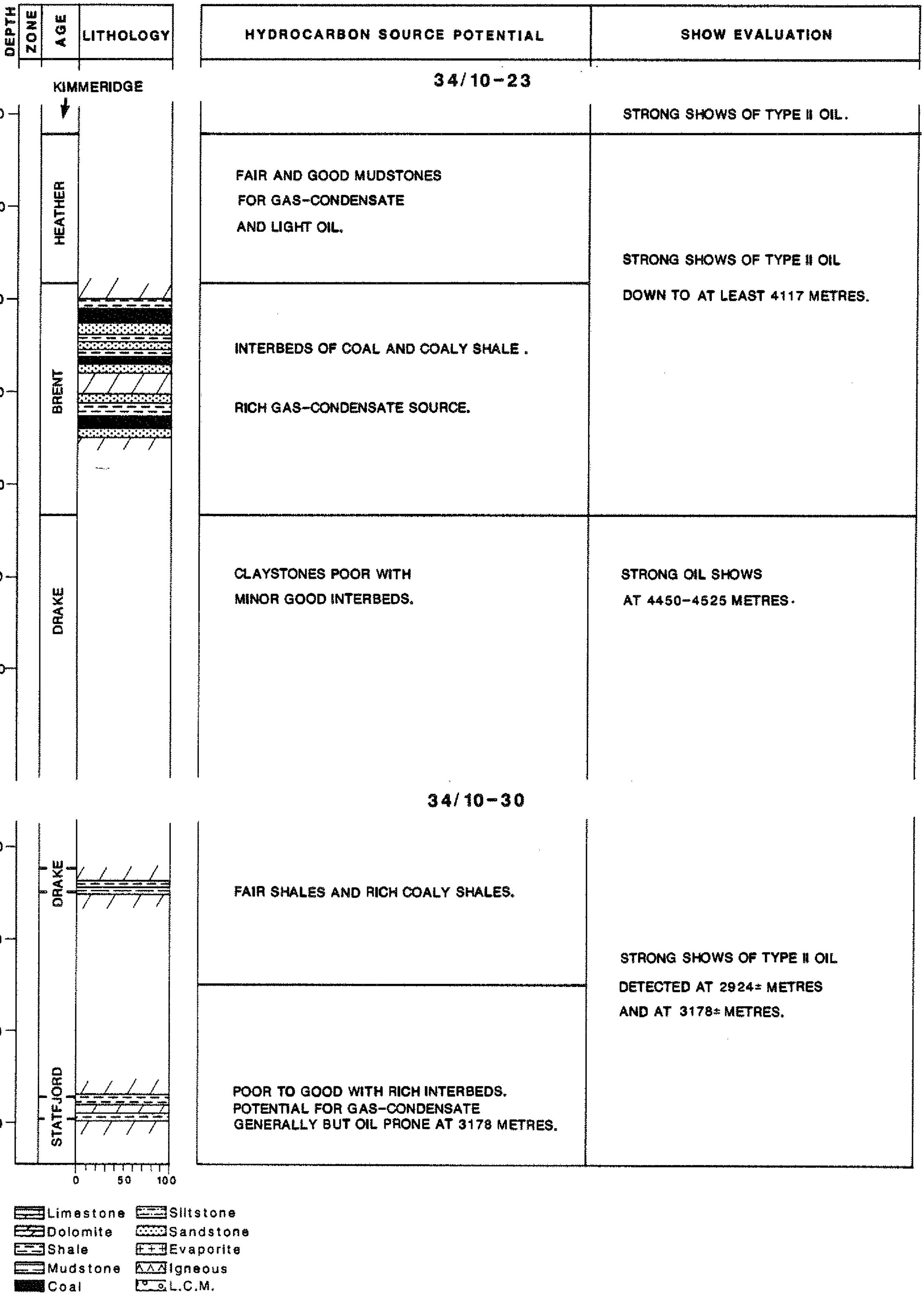
A second (type II) oil, including DST-1, is present in the Heather Formation, in the Brent Sands (of 34/10-23 and 34/10-21) and, most probably, in the Drake shales plus the Statfjord of 34/10-21. The type II oil is believed to be the result of a mixing of hydrocarbons generated in the Kimmeridgian mudstones/shales and the coaly facies, which occur mainly in the Ness.

M.J. Sauer

M.J. SAUER
GEOCHEM LABORATORIES LIMITED

FIGURE 1

SUMMARY CHART



34/10-23

STRONG SHOWS OF TYPE II OIL.

FAIR AND GOOD MUDSTONES FOR GAS-CONDENSATE AND LIGHT OIL.

STRONG SHOWS OF TYPE II OIL DOWN TO AT LEAST 4117 METRES.

INTERBEDS OF COAL AND COALY SHALE.

RICH GAS-CONDENSATE SOURCE.

CLAYSTONES POOR WITH MINOR GOOD INTERBEDS.

STRONG OIL SHOWS AT 4450-4525 METRES.

34/10-30

FAIR SHALES AND RICH COALY SHALES.

STRONG SHOWS OF TYPE II OIL DETECTED AT 2924± METRES AND AT 3178± METRES.

POOR TO GOOD WITH RICH INTERBEDS.
POTENTIAL FOR GAS-CONDENSATE GENERALLY BUT OIL PRONE AT 3178 METRES.

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INTRODUCTION

This report presents a partial geochemical evaluation of selected Jurassic sediments from the 34/10-23 and 34/10-30 wells, a correlation study involving these sediments and shows plus tested hydrocarbons from both wells and a re-appraisal of the hydrocarbons data from the 34/10-21 well geochemical evaluation.

The study was designed to investigate the source of the "second" crude and of the "condensate" described in the 34/10-23 well geochemical evaluation (Geochem February 1986).

This project was approved by S. Ulvoeen, Statoil, Stavanger.

ANALYTICAL

A suite of thirteen (13) core samples from 4106.8-4247.2 metres in 34/10-23 and five (5) core samples from 2942.65-3197.1 metres in 34/10-30 were received and assigned the Geochem job number 1474. Eleven ditch cuttings samples from the 3955-4480 metre interval in 34/10-23 were re-assigned to job 1474 from the original study. The samples are listed in table 1.

The samples were analysed in accordance with a scheme approved by Statoil (telexes 23/09/86).

Analyses performed in this study are as follows:-

ANALYSIS	NUMBER OF ANALYSES
Sample preparation	18
Total organic carbon	14
Pyrolysis	18
C_{15+} extraction and chromatography	10
Capillary GC - paraffin-naphthenes	5
Capillary GC - aromatics	5
Pyrolysis-GC	20
Carbon isotopes - extract fractions	50
Carbon isotopes - pyrolysate	20
Carbon isotopes - kerogen	20
GC-MS biomarker analysis	10

GENERAL INFORMATION

Ten (10) copies of this report have been forwarded to S. Ulvoeen, Statoil, Stavanger.

A copy of the data has been retained by Geochem for future consultation with authorised Statoil personnel. The remaining sample material will be returned as requested.

The results of this study are proprietary to Statoil.

CONCLUSIONS

Source Richness

The Heather Formation (3923-4083 metres) mudstones in 34/10-23 are fair, with good interbeds, source rocks for gas-condensate or light oil.

Interbedded in the Brent sands (chiefly in the Tarbert and Ness) are rich coals and coaly shales which have an excellent potential for gas-condensate. Shales are also present in the 4083-4242 metres interval but they are fair with good interbeds.

Within the Drake Formation (4335 metres to TD) in 34/10-23 the shales are poor to fair occassionally good source rocks for gas-condensate and, apart from a rich coaly shale at 2945± metres, the same is true of the corresponding interval in 34/10-30.

Source richness ranges from poor to rich in the shales and coaly shales (at 3178-3197± metres in 34/10-30 but those at 3906-4005± metres are generally poor source rocks. In general these shales have a potential for gas-condensate but at 3178.3 metres in 34/10-23 they are rich and oil prone.

Oil to Oil Correlation

Strong shows of crude oil in the sands at 3298-3324± metres in 34/10-21 are correlated, by means of their saturates chromatograms with the type II (pre-Kimmeridgian) oil in 34/10-23.

Traces (less than 50ppm) C_{15+} hydrocarbons were extracted from the Ness sandstone core samples at 4136-4247 metres in 34/10-23. These hydrocarbons are similar to those detected at 3354-3363± metres in 34/10-21.

Carbon isotope ratios differentiate between the isotopically light type I (Kimmeridgian) oil and the heavier type II (including DST 1) oils found in the Heather and Brent formations of 34/10-23. Shows of a slightly lighter type II oil were detected in the Drake shales at 4465-4495± metres. The Galimov plot identifies them as type II nonetheless.

GC-MS analyses indicate that the source of the type I oil is rich in a mixture of marine and terrestrial organic matter - with a preponderance of the former. The type II oil is also derived from a mixed source although a greater proportion of terrestrial organic matter is suggested by the steranes distribution. Shows of type II oil were also detected in the Statfjord shales of 34/10-30 but the shows in the Drake Formation in this well and the 34/10-23 are less easily identified. On balance they are closer to the type II but the triterpanes are similar to type I. The association of these "shows" with mature source facies suggests a possible source for the type II oil but the carbon isotope data do not support this conclusion (see below).

Oil to Source Rock Correlation

Carbon isotope ratios of extracted hydrocarbons and of source rock kerogen (kerogen pyrolysate) correlate the type I (Kimmeridgian) oil with the host mudstones and shales in 34/10-23 and 34/10-21.

Saturated and aromatic hydrocarbon carbon isotope ratios of the DST 1 and other type II oils frequently differ by 3^{o}/oo. This divergence is unusually large (a,b) and is believed to be the result of a mixing of hydrocarbons from more than one source. Thus, the saturates in the type II oil have isotope ratios which suggest a Kimmeridgian source. A difference, which is commonly less than 1^{o}/oo. between the aromatics of the type II oils and the kerogen isotopes of the Ness, plus possibly the Statfjord, coals suggests that they are contributing hydrocarbons to this oil. The presence of this "second source" would also explain the greater proportion of land plant derived hydrocarbons (mass fragmentograms) observed in the type II oil. Furthermore it is possible that these coaly facies are responsible for the tendency towards more aromatic low boiling point hydrocarbons at the top of the Brent reservoirs.

References

a. Stahl, W. Source Rock Crude Oil correlation by isotopic type curves: Geochim, Cosmochim, Acta, 42: 1573-1577 (1978)

b. Feux, A.N., The use of stable carbon isotopes in hydrocarbon exploration: Journal of Geochemical Exploration, V7, p155-188 (1977)

DISCUSSION

Included in this discussion are sediments and hydrocarbons from the Heather (3923-4083 metres), Brent (4083-4355 metres), Drake (4335 to 4765 metres, TD) in 34/10-23 and from the Drake (at 2924.65 and 2945.00 metres) and Statfjord (at 3178.24 to 3197.10 metres) in 34/10-30.

In addition to data derived from the analysed sediments, information from the geochemical evaluations of the 34/10-23 well (Geochem February 1986) and 34/10-21 well (Geochem January 1985) have been included in this study.

LITHOLOGICAL DESCRIPTION

Medium dark grey to brownish grey mudstones are present in the Heather Formation. The Tarbert (4083-4124 metres), Ness (4124-4242 metres, Etive (4242-4286 metres) and Rannock (4286-4335 metres) sub-units of the Brent are sandy, with minor to significant interbeds of medium dark grey to medium grey and brownish grey shale, coal and coaly shale. Medium dark grey to brownish grey shales, lighter coloured mudstone and sands are present in the Drake Formation whilst the Statfjord (in 34/10-30) is represented by medium dark grey to brownish grey shales and greyish black to dark grey coaly shales.

ORGANIC FACIES AND SOURCE RICHNESS

The amount of organic matter within a sediment is measured by its organic carbon content. Average shales contain approximately one percent organic carbon.

Organic matter type influences not only source richness but also the character of the hydrocarbon product (oil, gas) and the response of the organic matter to thermal maturation. Richness and oiliness decrease in the order: amorphous-algal-herbaceous-woody. Wood has a primary (but not exclusive) potential for gas whilst inertinitic (oxidised, mineral charcoal) material has only a limited hydrocarbon potential. Pyrolysis-derived hydrogen indices increase with organic matter quality.

Hydrocarbon source richness has been evaluated from the yields of pyrolysate (S2) in association with the total organic carbon (TOC) contents. The following rating scheme has been employed:

	S2 ppm (mg/g)	TOC (%)
POOR SOURCE	below 2000 (2 mg/g)	below 0.5
FAIR SOURCE	2000-3000 (2-3 mg/g)	0.5-1.0
GOOD SOURCE	3000-5000 (3-5 mg/g)	1 - 3
VERY GOOD	5000-10,000 (5-10 mg/g)	3 - 5
RICH SOURCE	over 10,000 (10 mg/g)	over 5

The type of product (oil, gas) has been determined from the gas chromatograms of the pyrolysate (S2) fractions for which the gas-oil indices have also been calculated. Oil-prone sediments have indices of less than 20%, 20-35% indicates a mixed potential for oil and gas, 35-50% for condensate and values in excess of 50% are indicative of dry gas.

The Heather Formation mudstones in 34/10-23 have organic carbon contents of 2.29-3.64%, yielded 2.59-4.67 mg/g pyrolysate and have a fair to good potential for gas-condensate and light oil.

Within the Brent sands are thin coals, chiefly in the Tarbert and Ness, which contain 59.9-80.6% organic carbon. They grade into coaly shales at 13.5% organic carbon and are interbedded with shales with values of 2.3-3.34%. Per unit volume, the coals are rich, generating up to 162.5 mg/g pyrolysate whilst the coaly shales although leaner (15.6 mg/g pyrolysate) are potentially rich source rocks. The shales within this interval have a fair to good (2.14-3.17 mg/g pyrolysate) hydrocarbon potential.

Shales in the 4242-4335 metres interval (Etive-Rannoch) have organic carbon contents of 2.62 to 3.42% but appear to be caved.

Claystones from below 4335 metres, corresponding to the Drake Formation in 34/10-23, have organic carbon contents of up to 3.91% but with one exception (7.44 mg/g at 4465-4480 metres) generated less than 2.06 mg/g pyrolysate. The Drake Formation in 34/10-30 is represented by shale samples (core fragments) at 2924.65 metres (2.0% organic carbon) and at 2945.00 metres (9.50% organic carbon). The first shale has a fair (2.09 mg/g pyrolysate) potential for gas-condensate whilst the second is a rich (26.87 mg/g) source for gas and light oil.

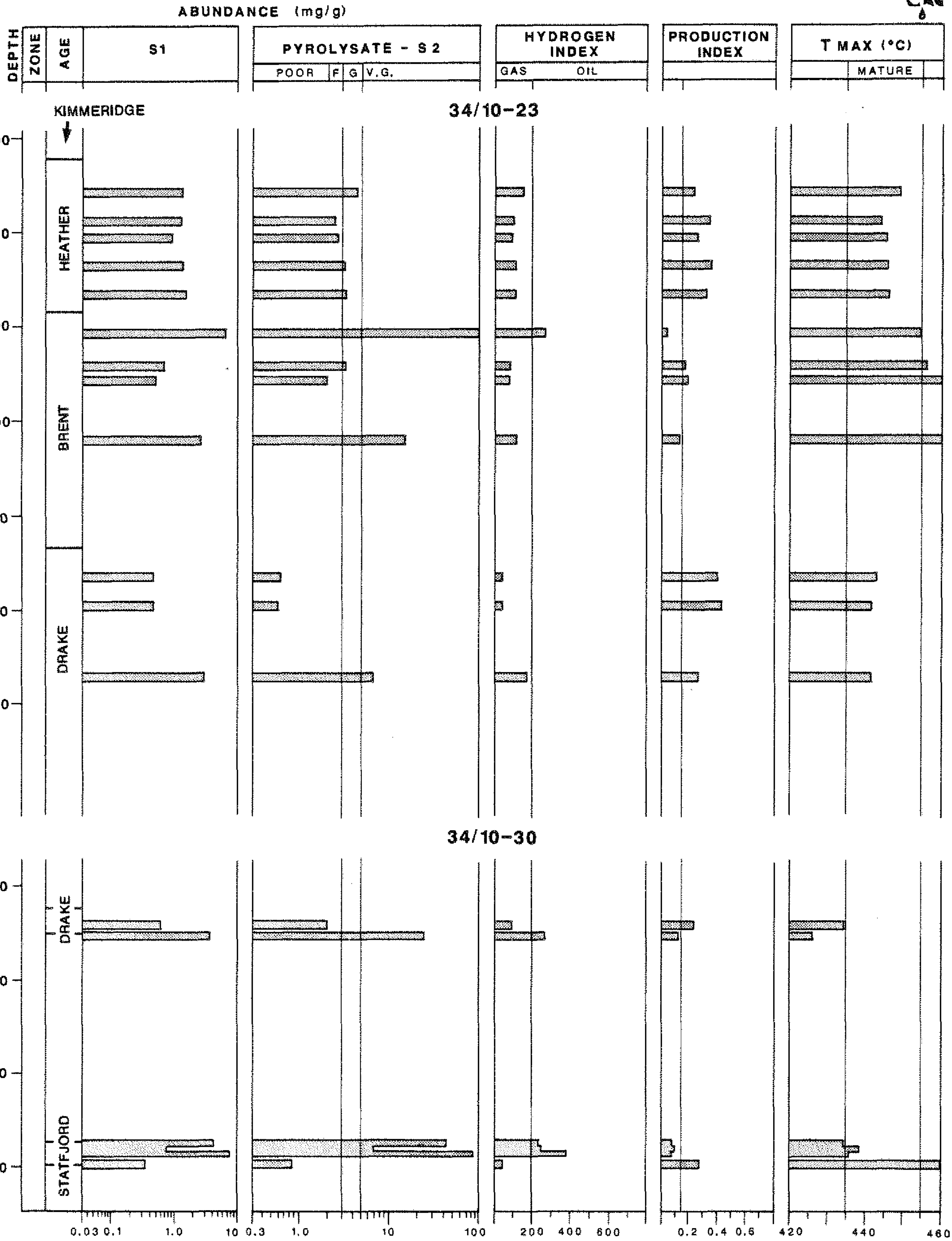
Samples of the Statfjord shales (in 34/10-30) have organic carbon contents which improve from 2.11% to 2.55% rising to 19.7-23.0% in the coaly shales. The former are variously poor and good source rocks for gas-condensate whilst the latter are a rich 46.7 and 89.9 mg/g pyrolysate source. In general the analysed sediments have a potential for gas-condensate or light oil but are not typically oil prone. At 3178.3 metres, however, the pyrolysis-GC trace generated by the coaly shale displays an abundance of alkene-alkane doublets extending to C_{25-30}; which indicates at potential for oil.

<u>Summarising</u>:

Heather -	mudstones are fair to good source rocks for gas-condensate and light oil.
Brent -	interbeds of rich coal or coaly shale, plus shales which are fair with good interbeds, for gas-condensate.
Drake -	fair to good claystones with minor very good and rich interbeds - potential for gas - condensate or light oil
Statfjord -	(34/10-30 well) coaly shales rich and oil prone at 3178± metres but shales generally gas-condensate source and vary from poor to very good and rich.

FIGURE 2

PYROLYSIS



HYDROGEN INDEX = $\frac{S2}{TOC}$ PRODUCTION INDEX = $\frac{S1}{S1 + S2}$

Oil to Oil Correlation

Comparisons between the shows at 3298-3324 metres in 34/10-21 and the shows of crude oil in the Heather and Brent of 34/10-23 are, in the absence of any other suitable data, based upon the saturates chromatograms. Traces from the former have low pristane to nC_{17} ratios and isoparaffin fingerprints which characterise the type II oil in 34/10-23. It may be assumed, therefore, that they have a common origin.

Negligible volumes of hydrocarbons (less than 50 ppm) were extracted from the 4136-4747 metres interval of the Ness sands in 34/10-23. The saturates chromatograms have low pristane and phytane peaks, and a strong paraffinic hump in the C_{25}-C_{30} region. Qualitatively and quantitatively they resemble the saturates from 3354-3363 metres in 34/10-21; although in the latter the hump is shifted to slightly higher carbon numbers, and pristane and phytane are more abundant. For practical purposes, these are clean sands, if the analysed samples are representative of the interval. Because of this leaness, the C_{15+} aromatic chromatograms from the 4136-4247 metres interval in 34/10-23 are of poor quality and contain traces of contamination plus paraffins. They cannot, therefore, be used for correlation purposes.

Galimov plots distinguish the isotopically light shows of type I oil in the Kimmeridgian of 34/10-23 from the heavier type II oil (including DST 1) in the Heather and Brent Formations. There are further shows of oil, which closely resemble the type II oil, in the Drake Formation at 4465-4495 metres (see GC-MS data below). This latter oil is isotopically lighter than the DST 1 crude but on the Galimov plot has characteristics which identify it with the type II rather than the type I oils.

Mass fragmentograms (m/z 217) of the oil shows in the Kimmeridgian of 34/10-23 display an abundance of C_{27} diacholestane (peak A) and of the C_{29} diacholestane (H) but lesser amounts of the other C_{28} and C_{29} steranes. A preponderance of the C_{27} species at m/z 218 indicates a greater contribution from marine organic matter to the source of the type I oil - believed to be the mature equivalents of the host sediments. The C_{30} hopane (peak E) dominates the m/z 191 fragmentograms and the S:R isomer ratio indicates a mature source. Shows in the Heather and Brent are of the type II oil which (at m/z 217 and m/z 218) contains nearly equal proportions of C_{27} and C_{29} steranes corresponding to a mixed, marine and terrestrial, type of source. C_{28} isomers are relatively less abundant at m/z 218 than those of the type I oil, however.

The type II oil is also characterised by strong C_{29} hopane (C) and C_{30} hopane (E) peaks whereas the moretanes (D and F) and C_{28} bisnorphane (Z) are less abundant than those in the type I oil. Sterane R:S isomer ratios are lower in the Ness shows than those in the Heather due, it is suspected, to contributions from indigenous species in the latter. Mere traces of hydrocarbons were extraced from the sandstone cores at 4136-4247 metres in the Ness and the resulting fragmentograms are of poor quality with few identifiable peaks. Grossly, they resemble the type II oil.

Hydrocarbons extracted from the shales and coaly shales of the Drake and Statfjord formations in 34/10-23 and 34/10-30 wells appear to be a mixture of migrated crude oil and source indigenous species. Thus the show at 4465-4480 metres has a triterpane fingerprint which closely resembles those of the type I (Kimmeridgian) oil but the steranes have more in common with the type II oil. In the 34/10-30 well the Drake shale hydrocarbons are closer to the DST 1 (type II) crude in composition. There is a better correlation between the show in the Statfjord shale in the same well and the type II crude. The Drake and Statfjord shales are in the "oil window" in 34/10-23 and the analysed hydrocarbons are believed to be locally generated.

Summarising:-

- two major oil types are identified

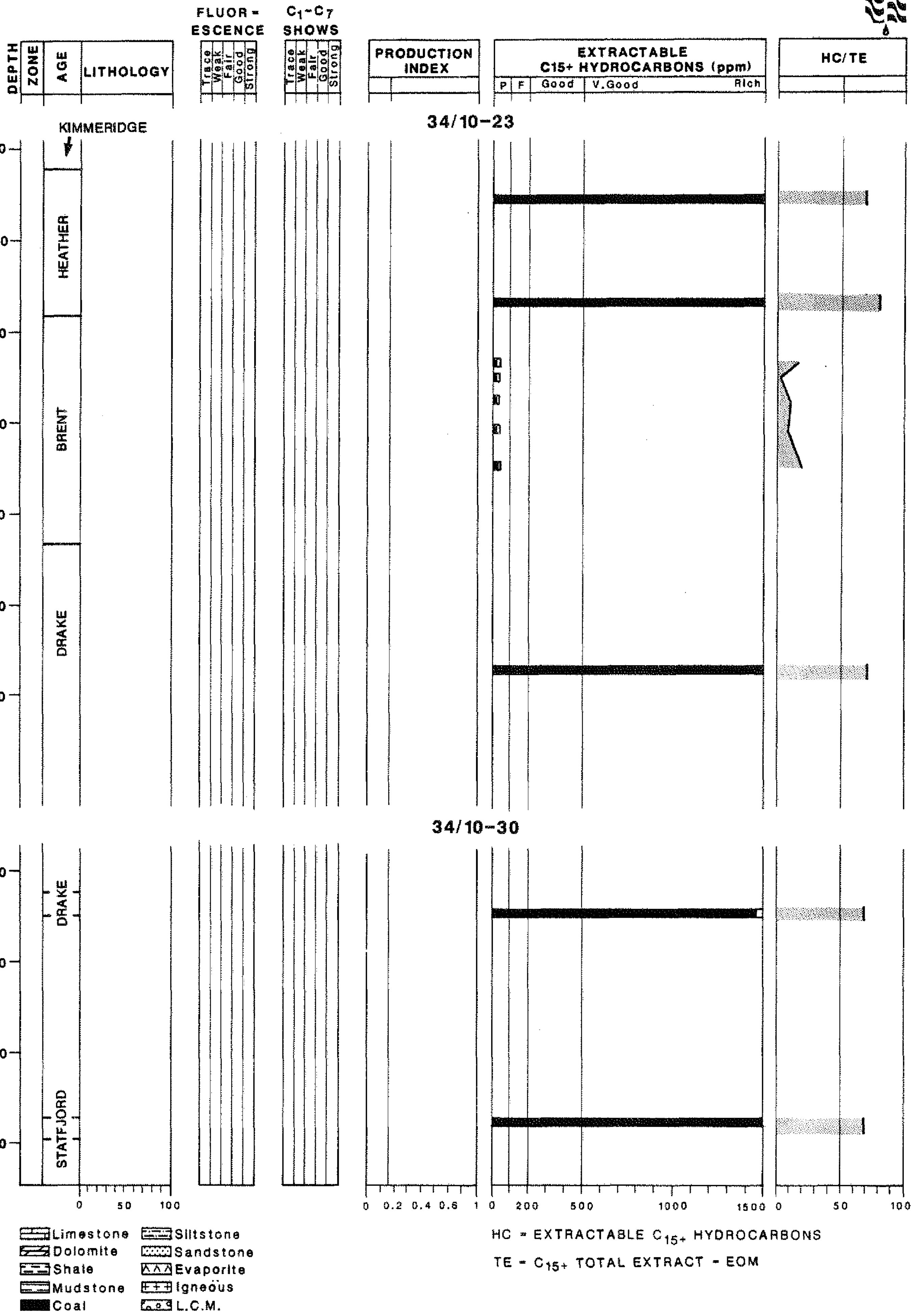
- type I is associated with the Kimmeridgian in 34/10-23

- type II occurs in the Heather and Brent - down to at least 4117 metres in 34/10-23 and at 3298-3323 metres in the 34/10-21 well

- further shows of the type II oil (± type I) were detected in the Drake and Statfjord shales (coaly) in 34/10-23 and 34/10-30. This association between mature source rocks and hydrocarbon shows suggests a possible source for the type II crude oil.

FIGURE 3

SHOW DETECTION



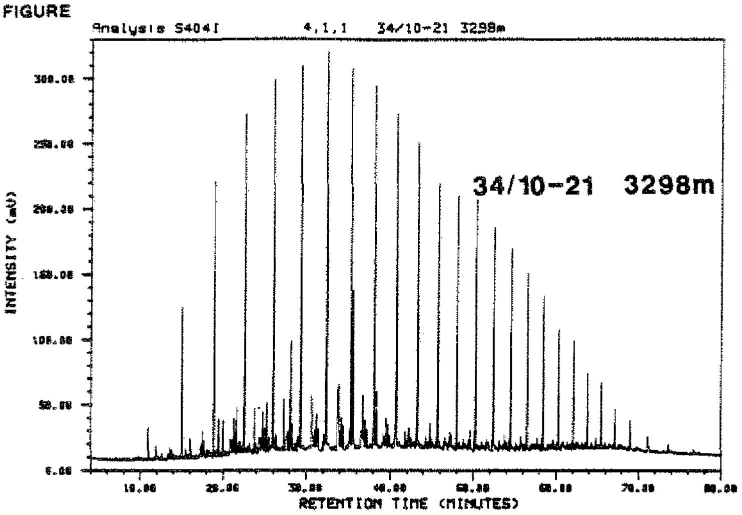
HC = EXTRACTABLE C_{15+} HYDROCARBONS

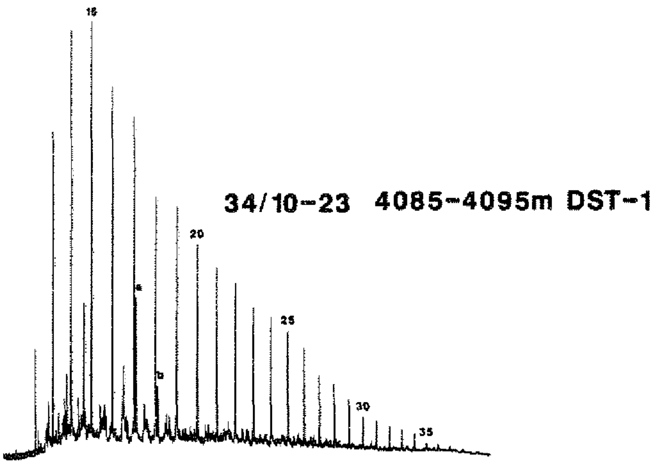
TE = C_{15+} TOTAL EXTRACT = EOM

FIGURE 4a

OIL CORRELATION

TYPE II OIL C_{15+} SATURATES





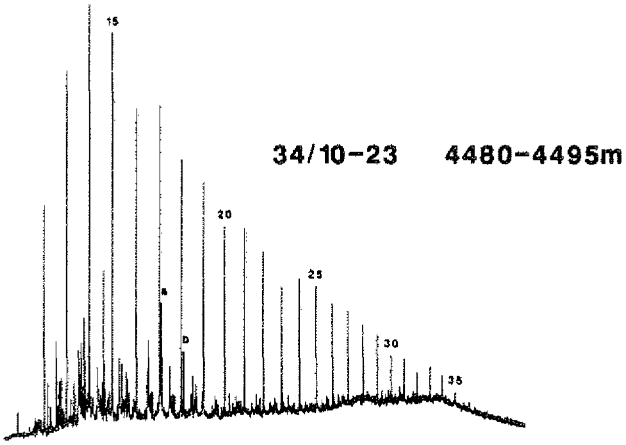
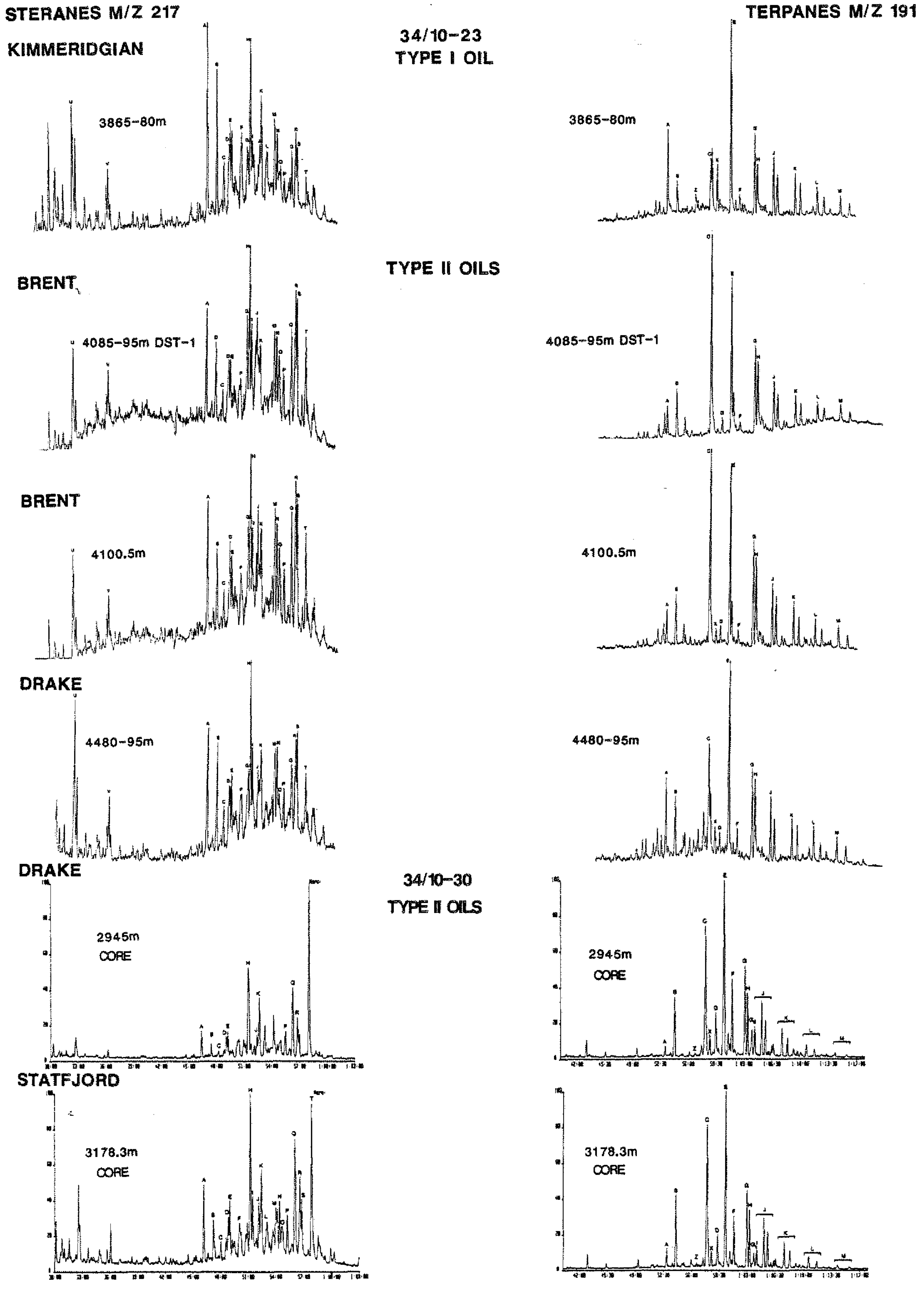


FIGURE 4b

OIL CORRELATION

MASS FRAGMENTOGRAMS



Oil to Source Rock Correlation

In the preceding chapter the oil detected as shows in the sands at 3298-3324 metres in 34/10-21 was identified with the type II oil in 34/10-23. For the purposes of this study the shows are assumed to be of the same oil.

Shows of the type i (Kimmeridgian) oil in 34/10-23 are isotopically light, having saturates delta values of -31.03 to $-30.26^{0}/oo$ and aromatics at -29.34 to $-30.22^{0}/oo$. These values correlate with kerogen isotope ratios of -28.54 to $-29.11^{0}/oo$ and a pyrolysate ratio $-30.9^{0}/oo$ for the host sediments.

Somewhat heavier are the shows of oil in the Drake Formation claystones/shales at 4465-4495 metres in 34/10-23; which have saturated and aromatic hydrocarbon isotope ratios of -29.38 to $-30.07^{0}/oo$ and -28.04 to $-28.85^{0}/oo$, respectively. A similar oil with corresponding values of -28.89 and $-28.59^{0}/oo$ is suspected in the Drake shales at 3639-3654± metres in the 34/10-21 well. These shows correlate, albeit poorly, with the kerogen ratios of -27.12 to $-27.26^{0}/oo$ of the host sediments. Although the shows in the Drake shales resemble the type II oil it is doubtful if these sediments have, with few exceptions (eg at 2945± metres in 34/10-30) the richness to source the extensive oil shows in the Brent sands.

A good correlation normally requires a difference of less than $1\text{-}2^{0}/oo$ in the isotope ratios of oil and source rock. From the available data it would appear that the DST 1 oil and most of the type II shows fail to meet this criterion. However, the Ness coals have kerogen isotope ratios which are commonly less than $1^{0}/oo$ heavier than aromatic fraction of the DST 1 crude and type II oil shows. Similarily the Kimmeridgian/Draupne shales and mudstones in 34/10-23 and 34/10-21 are within $1^{0}/oo$ of the saturates values for the type II oils.

A difference up to $3\ ^{0}/oo$ is not uncommon in the saturate and aromatic isotope ratios of the type II oils. This is unusually large and suggests a mixing of hydrocarbons from two sources a conclusion which is compatible with the discussion in the preceding paragraph.

Summarising:-

- carbon isotope ratios correlate the shows of type I oil in the Kimmeridgian with the host sediments
- the type II oil and DST 1 crude are believed to originate from two sources
- the aromatic fraction of the type II oil is heavily influenced by hydrocarbons from the Ness coals whilst the saturates appear largely to be derived from the Kimmeridgian (Heather).

CARBON ISOTOPES KEY

WELL 34/10-21

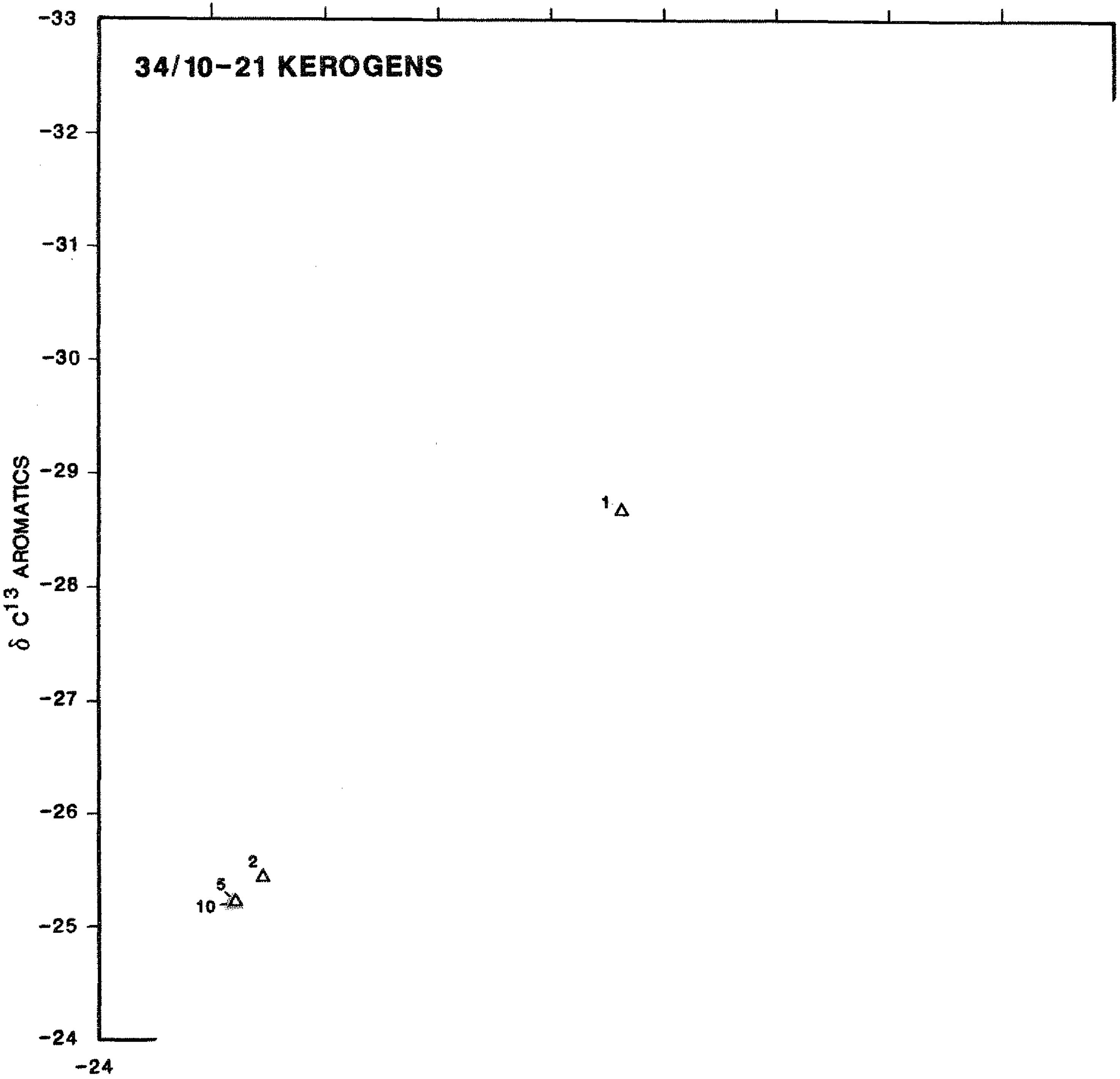
	DEPTH
1.	2920-2935m
2.	2950-2965m
3.	2995-3010m
4.	3040-3055m
5.	3055-3070m
6.	3115-3130m
7.	3160-3175m
8.	3205-3219m
9.	3264-3279m
10.	3399-3414m
11.	3639-3654m
12.	3924-3939m

WELL 34/10-23

	DEPTH
14.	3865-3880m
15.	3910-3925m
45.	3955-3970m
13.	3970-3985m
16.	4000-4015m
17.	4015-4030m
18.	4045-4060m
19.	4060-4075m
20.	4085-4095m
21.	4106.08m
22.	4110.10m
23.	4120.50m
24.	4136.60m
25.	4143.15m
26.	4148.70m
27.	4154.60m
28.	4164.10m
29.	4172.25m
30.	4206.65m
31.	4212-4225m
32.	4220.00m
33.	4235.60m
34.	4247.20m
35.	4360-4375m
36.	4390-4405m
37.	4465-4480m
38.	4480-4495m

WELL-34/10-30

	DEPTH
39.	2942.65m
40.	2945.00m
41.	3178.24m
42.	3178.30m
43.	3178.30m
44.	3197.80m


34/10-21 KEROGENS
δ C13 AROMATICS
-33
-32
-31
-30
-29
-28
-27
-26
-25
-24
-24
1
2
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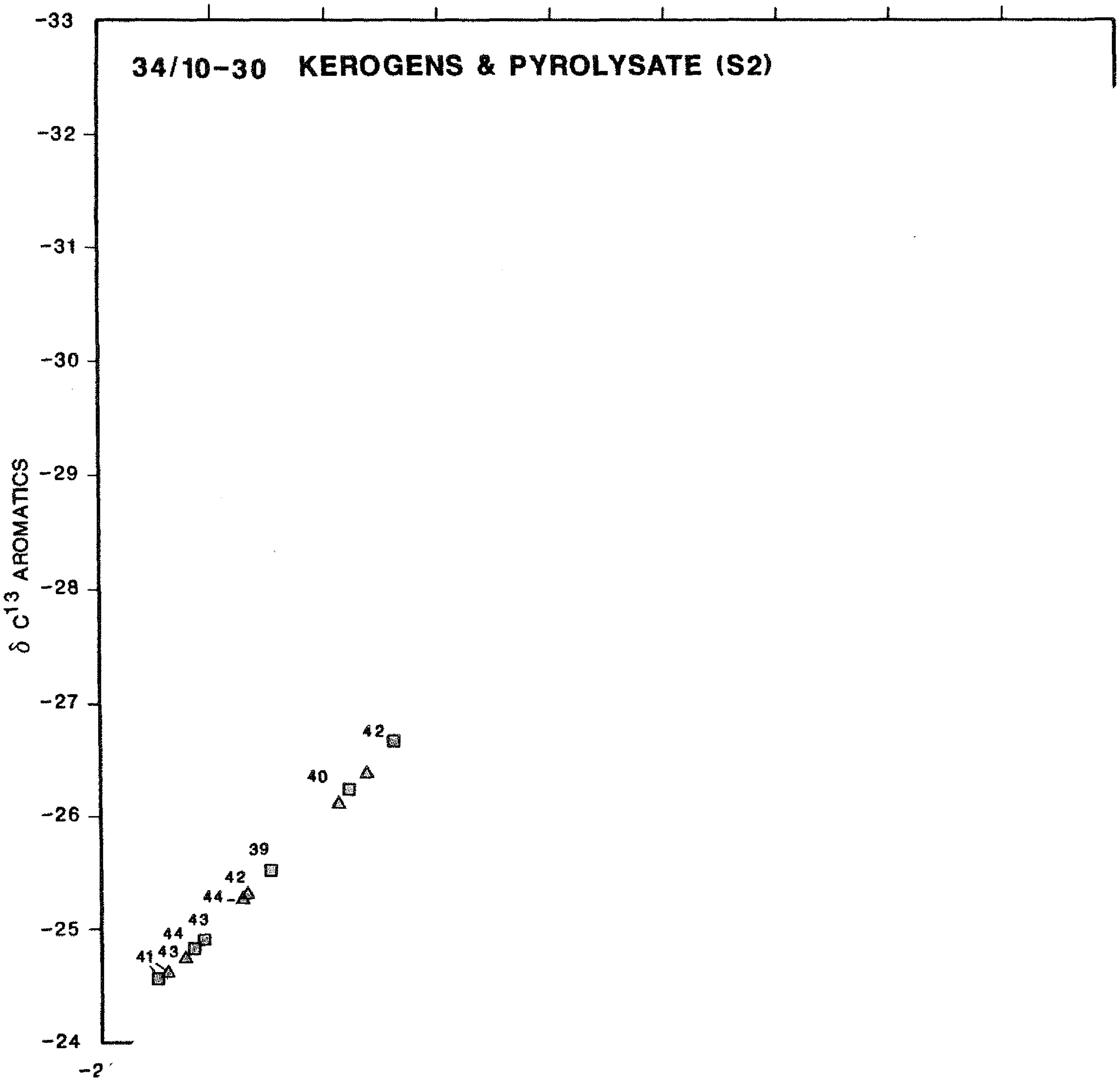
10


34/10-30 KEROGENS & PYROLYSATE (S2)
δ C13 AROMATICS
-33
-32
-31
-30
-29
-28
-27
-26
-25
-24
-2
42
40
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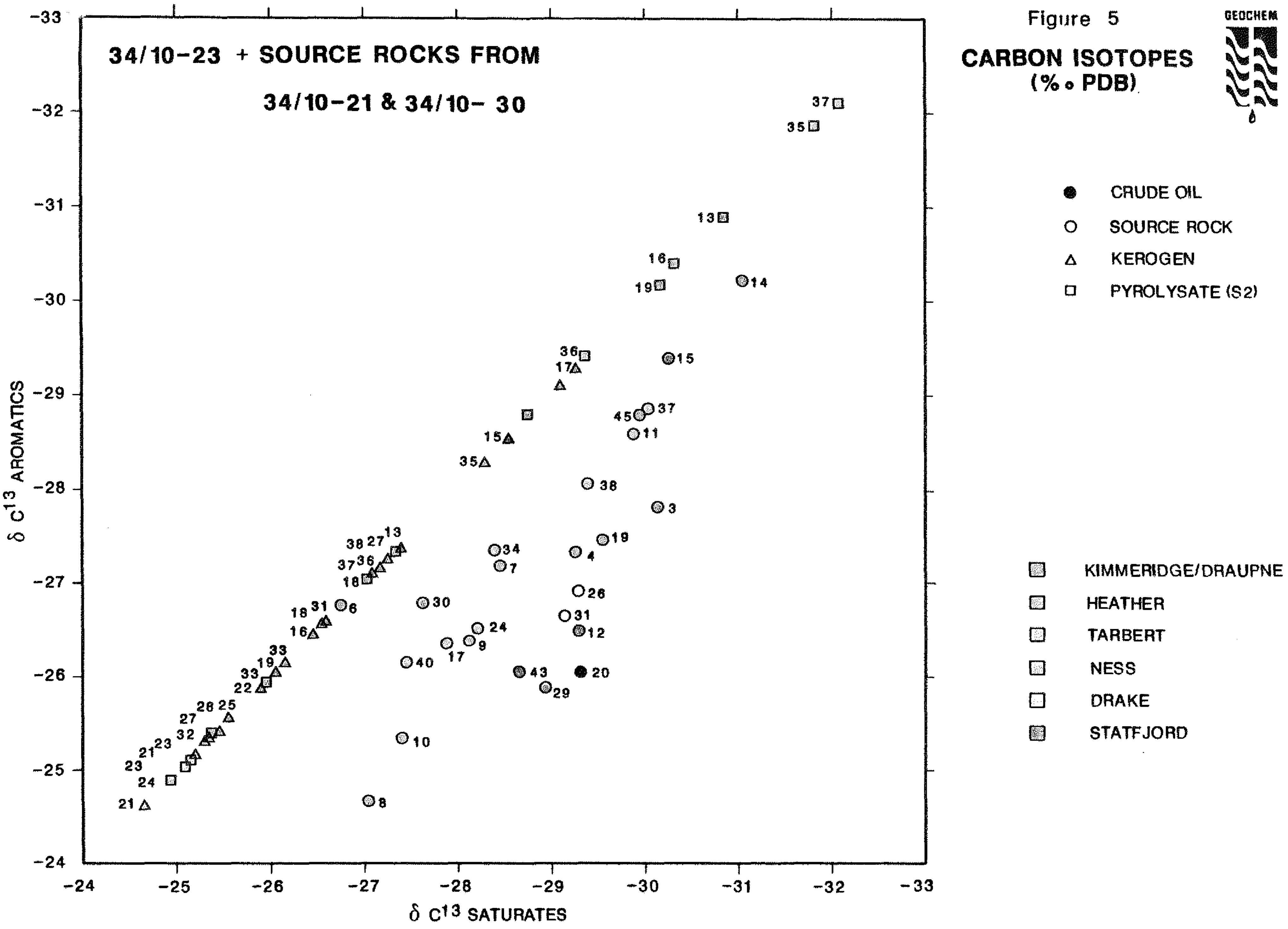
43
44
41
43

Figure 5

CARBON ISOTOPES
(‰ PDB)

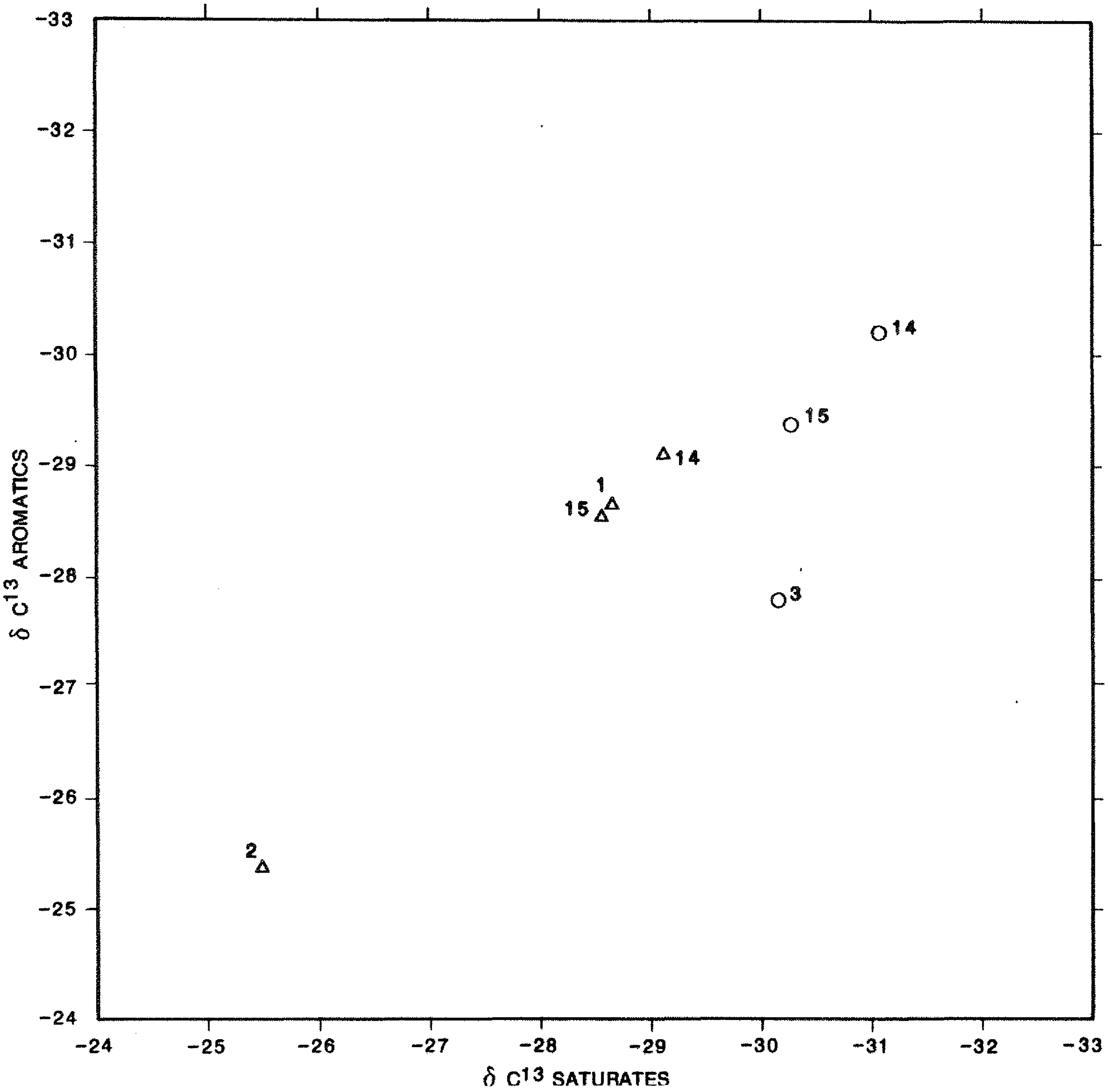


GEOCHEM

Figure 5a

CARBON ISOTOPES
(%• PDB)

(KIMMERIDGR/DRAUPNE)



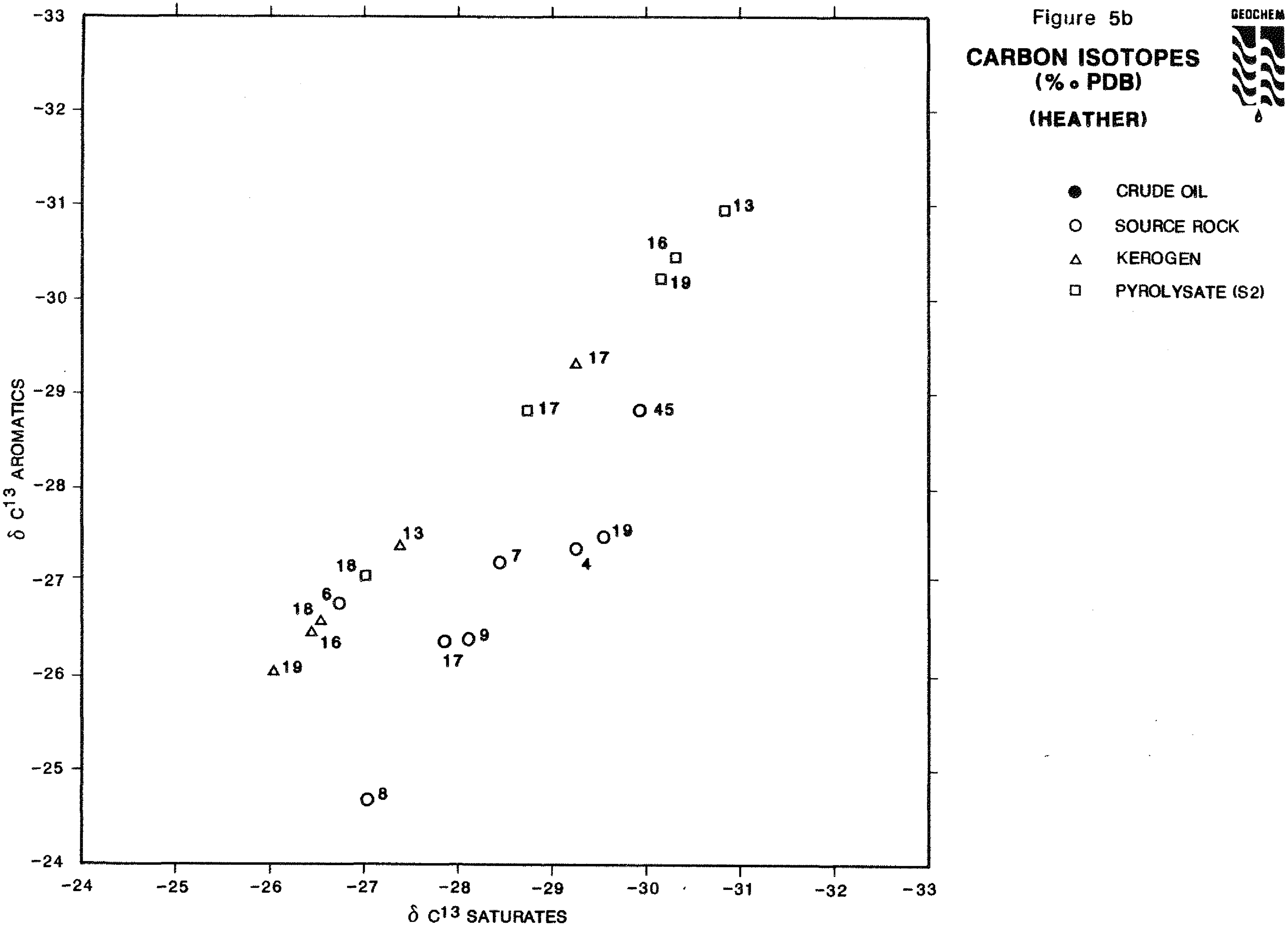


Figure 5b

CARBON ISOTOPES
(‰ PDB)

(HEATHER)

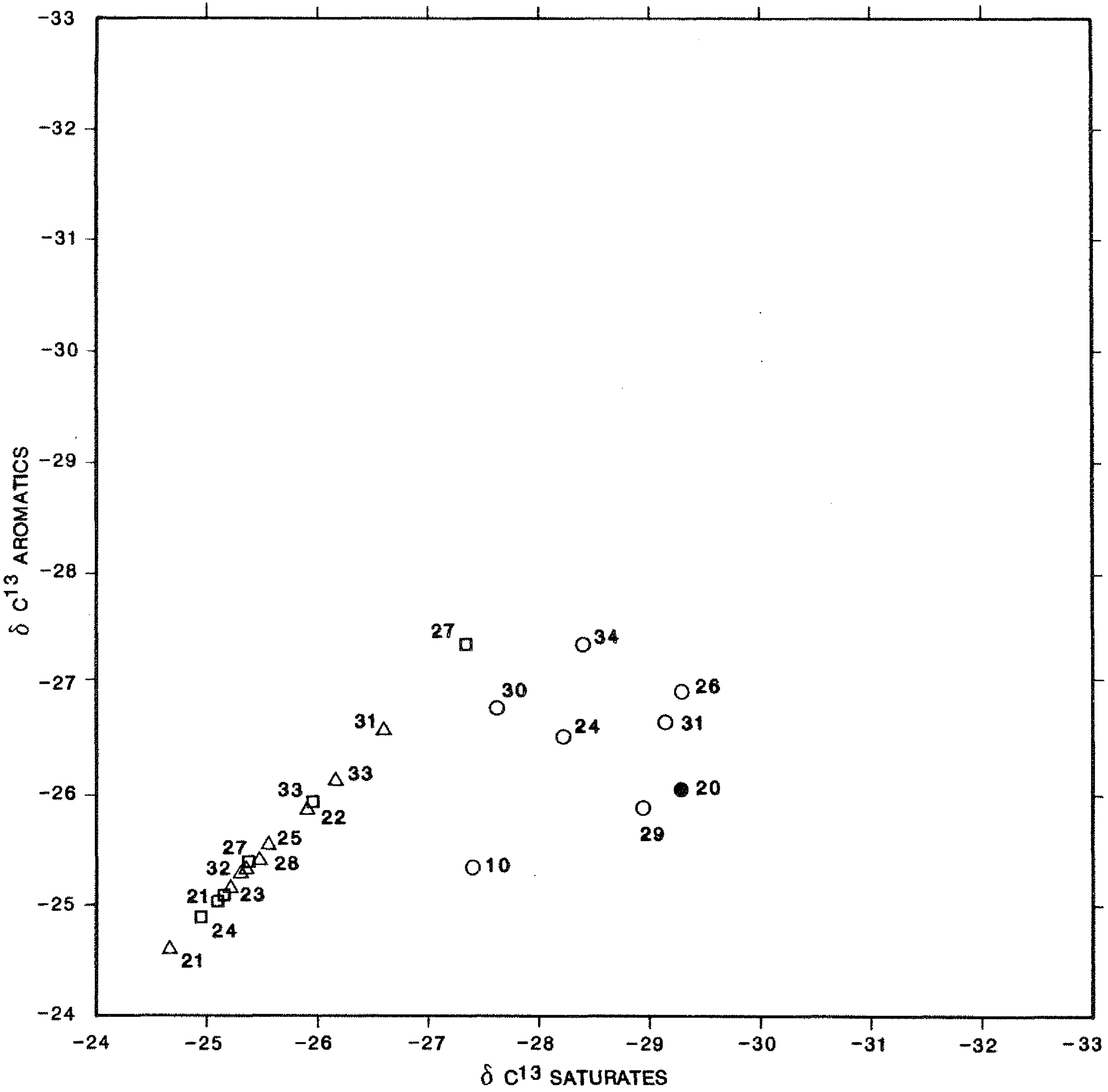


Figure 5c

CARBON ISOTOPES
(‰ PDB)

(TARBERT/NESS)

Figure 5d

CARBON ISOTOPES
(‰ PDB)
(DRAKE/STATFJORD)

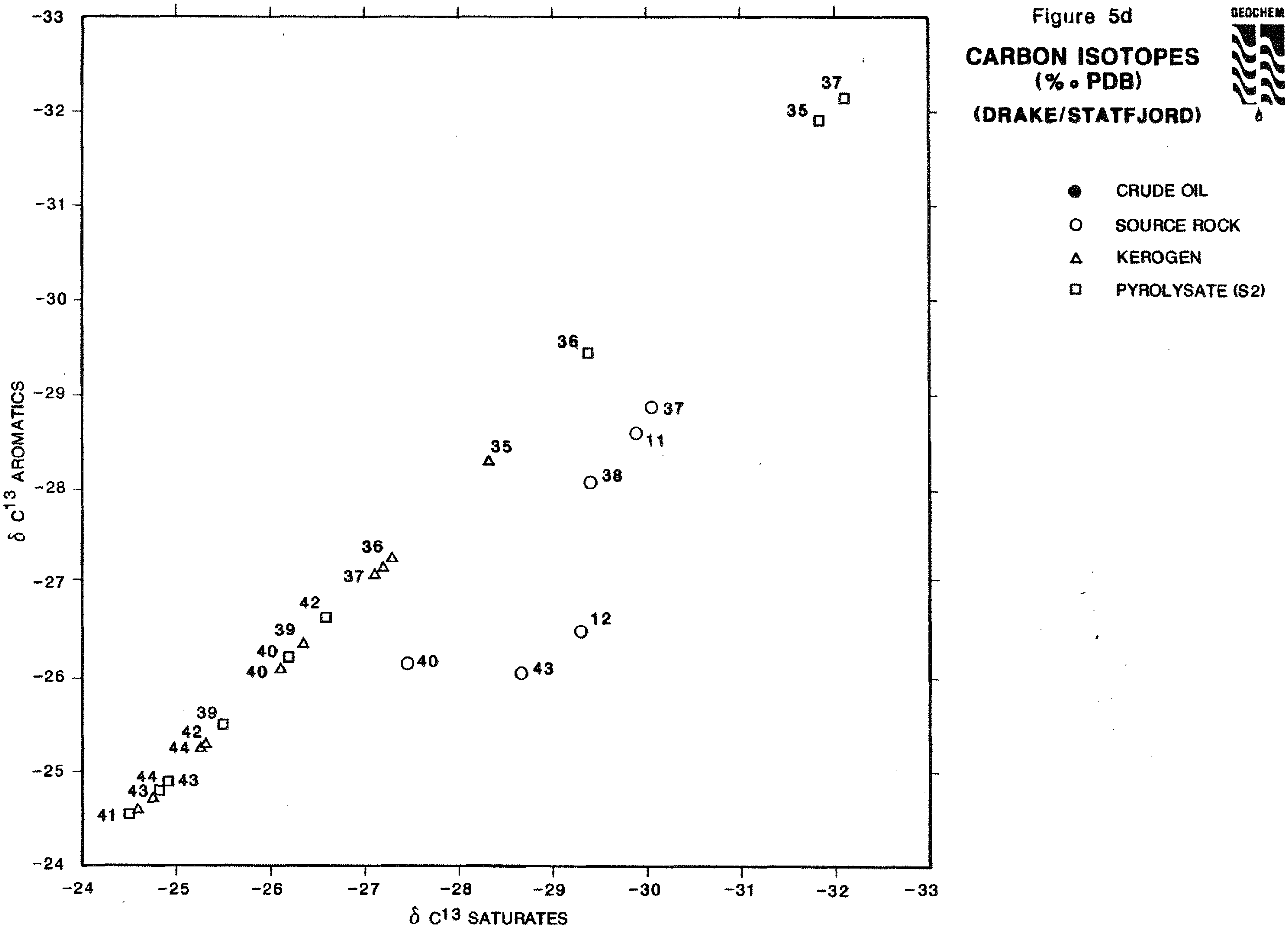


FIGURE 6

GALIMOV CARBON ISOTOPE PLOT
(‰, PDB)

- Kimmeridge/Draupne
- Heather
- Tarbert
- Ness
- Drake
- Statfjord

WELL 34/10-21
DEPTH

1. 2920-2935m
2. 2950-2965m
3. 3055-3070m
4. 3399-3414m

WELL 34/10-23
DEPTH

6. 3865-80m
7. 3910-25m
5. 3955-70m
37. 3970-85m
8. 4000-015m
9. 4015-30m
10. 4045-60m
11. 4060-75m
12. 4085-95m
13. 4106.08m
14. 4110.10m
15. 4120.50m
16. 4136.60m
17. 4143.15m
18. 4148.70m
19. 4154.60m
20. 4164.10m
21. 4172.25m
22. 4206.65m
23. 4212-225m
24. 4220.00m
25. 4235.60m
26. 4247.20m
27. 4360-075m
28. 4390-405m
29. 4465-480m
30. 4480-495m

WELL-34/10-30
DEPTH

31. 2942.65m
32. 2945.00m
33. 3178.24m
34. 3178.30mA
35. 3178.30mB
36. 3197.10m

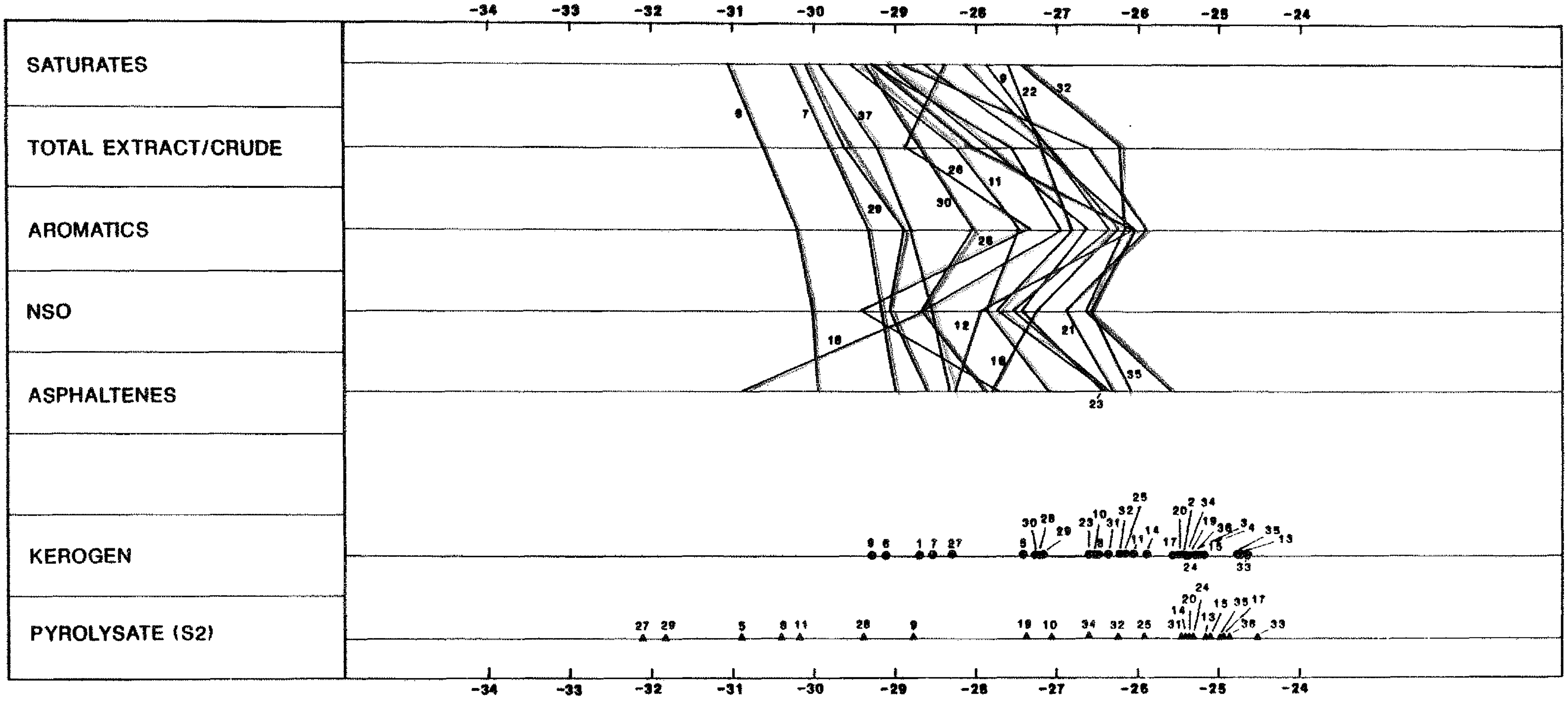


FIGURE 6a

GALIMOV CARBON ISOTOPE PLOT (KIMMERIDGE/DRAUPNE)
(‰, PDB)

WELL 34/10-21
DEPTH

1. 2920-2935m
2. 2950-2965m
3. 3055-3070m
4. 3399-3414m

WELL 34/10-23
DEPTH

6. 3865-80m
7. 3910-25m
5. 3955-70m
37. 3970-85m
8. 4000-015m
9. 4015-30m
10. 4045-60m
11. 4060-75m
12. 4085-95m
13. 4106.08m
14. 4110.10m
15. 4120.50m
16. 4136.60m
17. 4143.15m
18. 4148.70m
19. 4154.60m
20. 4164.10m
21. 4172.25m
22. 4206.65m
23. 4212-225m
24. 4220.00m
25. 4235.60m
26. 4247.20m
27. 4360-075m
28. 4390-405m
29. 4465-480m
30. 4480-495m

WELL-34/10-30
DEPTH

31. 2942.65m
32. 2945.00m
33. 3178.24m
34. 3178.30mA
35. 3178.30mB
36. 3197.10m

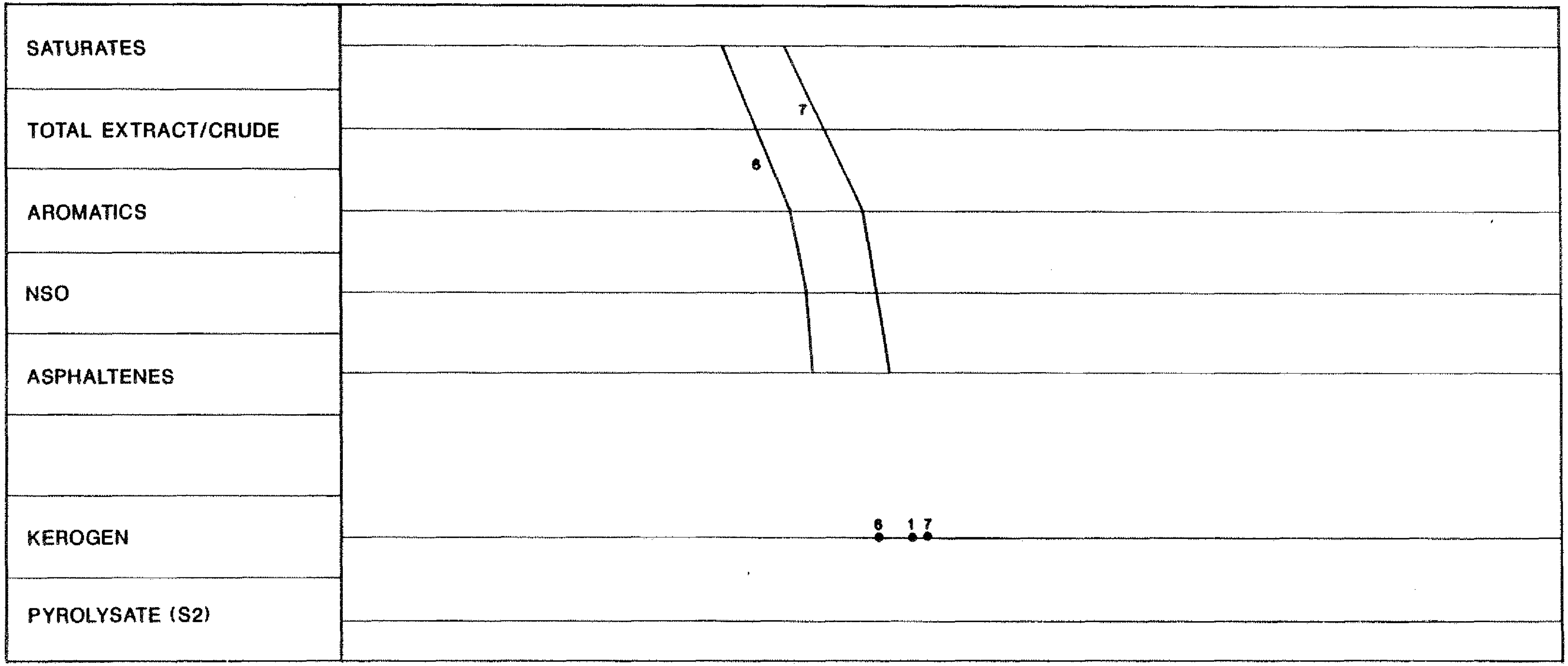


FIGURE 6b

GALIMOV CARBON ISOTOPE PLOT (HEATHER)
(‰, PDB)

WELL 34/10-21
DEPTH

1. 2920-2935m
2. 2950-2965m
3. 3055-3070m
4. 3399-3414m

WELL 34/10-23
DEPTH

6. 3865-80m
7. 3910-25m
5. 3955-70m
37. 3970-85m
8. 4000-015m
9. 4015-30m
10. 4045-60m
11. 4060-75m
12. 4085-95m
13. 4106.08m
14. 4110.10m
15. 4120.50m
16. 4136.60m
17. 4143.15m
18. 4148.70m
19. 4154.60m
20. 4164.10m
21. 4172.25m
22. 4206.65m
23. 4212-225m
24. 4220.00m
25. 4235.60m
26. 4247.20m
27. 4360-075m
28. 4390-405m
29. 4465-480m
30. 4480-495m

WELL-34/10-30
DEPTH

31. 2942.65m
32. 2945.00m
33. 3178.24m
34. 3178.30mA
35. 3178.30mB
36. 3197.10m

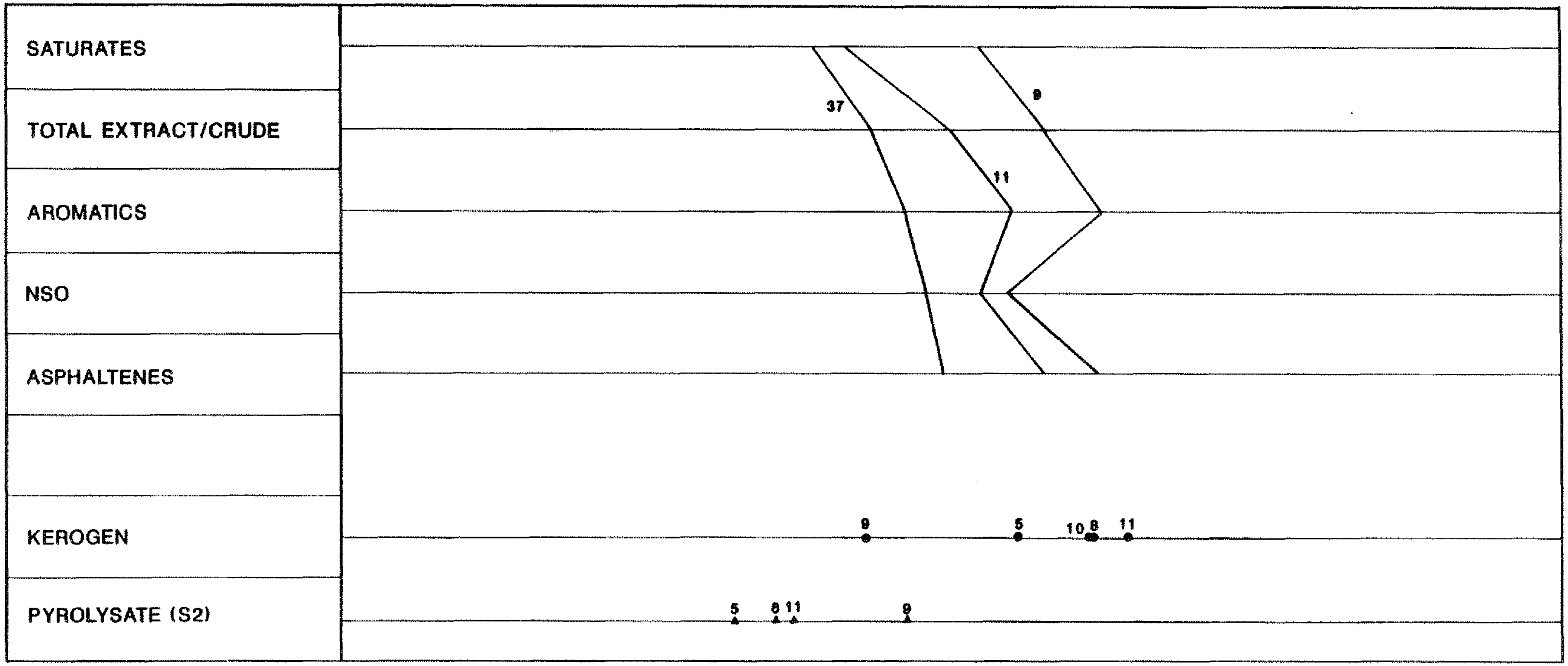


FIGURE 6c

GALIMOV CARBON ISOTOPE PLOT (TARBERT/NESS)
(‰, PDB)

WELL 34/10-21
DEPTH

1. 2920-2935m
2. 2950-2965m
3. 3055-3070m
4. 3399-3414m

WELL 34/10-23
DEPTH

6. 3865-80m
7. 3910-25m
5. 3955-70m
37. 3970-85m
8. 4000-015m
9. 4015-30m
10. 4045-60m
11. 4060-75m
12. 4085-95m
13. 4106.08m
14. 4110.10m
15. 4120.50m
16. 4136.60m
17. 4143.15m
18. 4148.70m
19. 4154.60m
20. 4164.10m
21. 4172.25m
22. 4206.65m
23. 4212-225m
24. 4220.00m
25. 4235.60m
26. 4247.20m
27. 4360-075m
28. 4390-405m
29. 4465-480m
30. 4480-495m

WELL-34/10-30
DEPTH

31. 2942.65m
32. 2945.00m
33. 3178.24m
34. 3178.30mA
35. 3178.30mB
36. 3197.10m

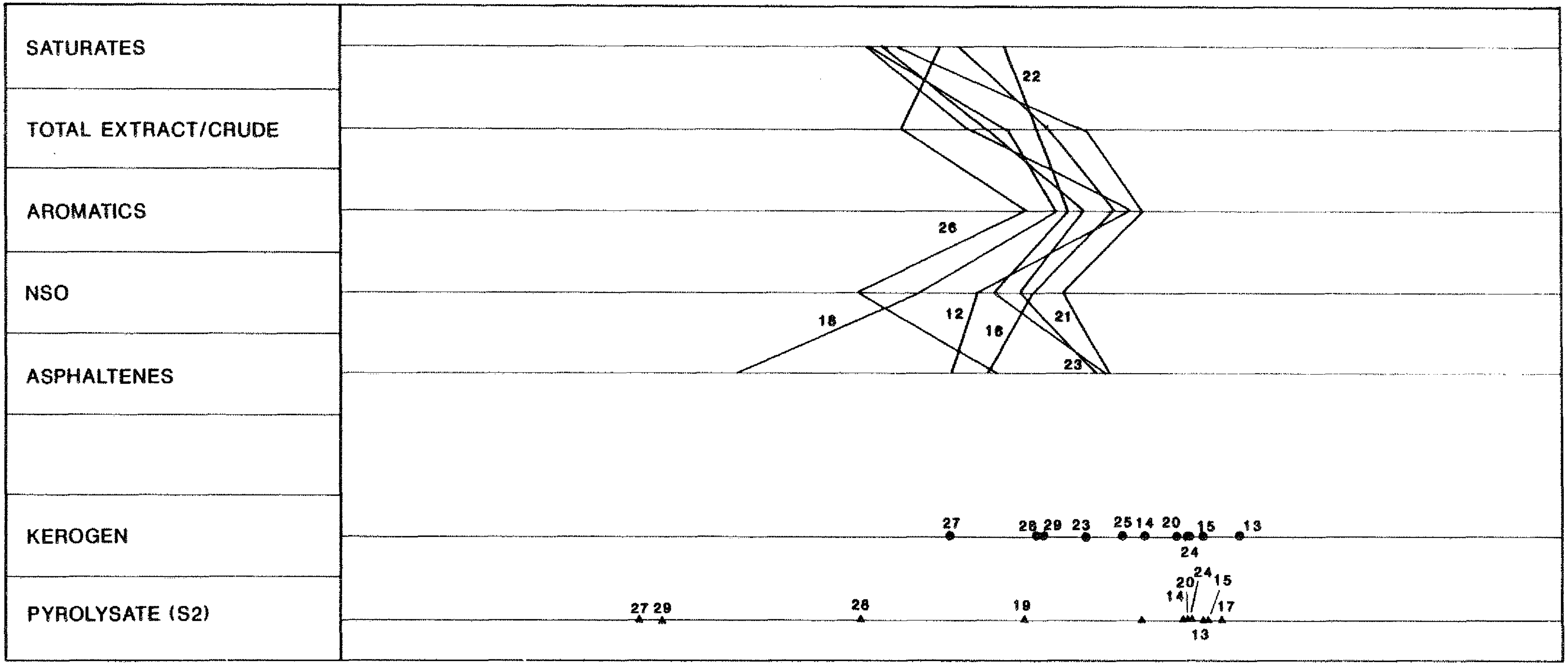


FIGURE 6d

GALIMOV CARBON ISOTOPE PLOT (DRAKE/STATFJORD)
(‰, PDB)

WELL 34/10-21
DEPTH

1. 2920-2935m
2. 2950-2965m
3. 3055-3070m
4. 3399-3414m

WELL 34/10-23
DEPTH

6. 3865-80m
7. 3910-25m
5. 3955-70m
37. 3970-85m
8. 4000-015m
9. 4015-30m
10. 4045-60m
11. 4060-75m
12. 4085-95m
13. 4106.08m
14. 4110.10m

15. 4120.50m
16. 4136.60m
17. 4143.15m
18. 4148.70m
19. 4154.60m
20. 4164.10m
21. 4172.25m
22. 4206.65m
23. 4212-225m
24. 4220.00m
25. 4235.60m

26. 4247.20m
27. 4360-075m
28. 4390-405m
29. 4465-480m
30. 4480-495m

WELL-34/10-30
DEPTH

31. 2942.65m
32. 2945.00m
33. 3178.24m
34. 3178.30mA
35. 3178.30mB
36. 3197.10m

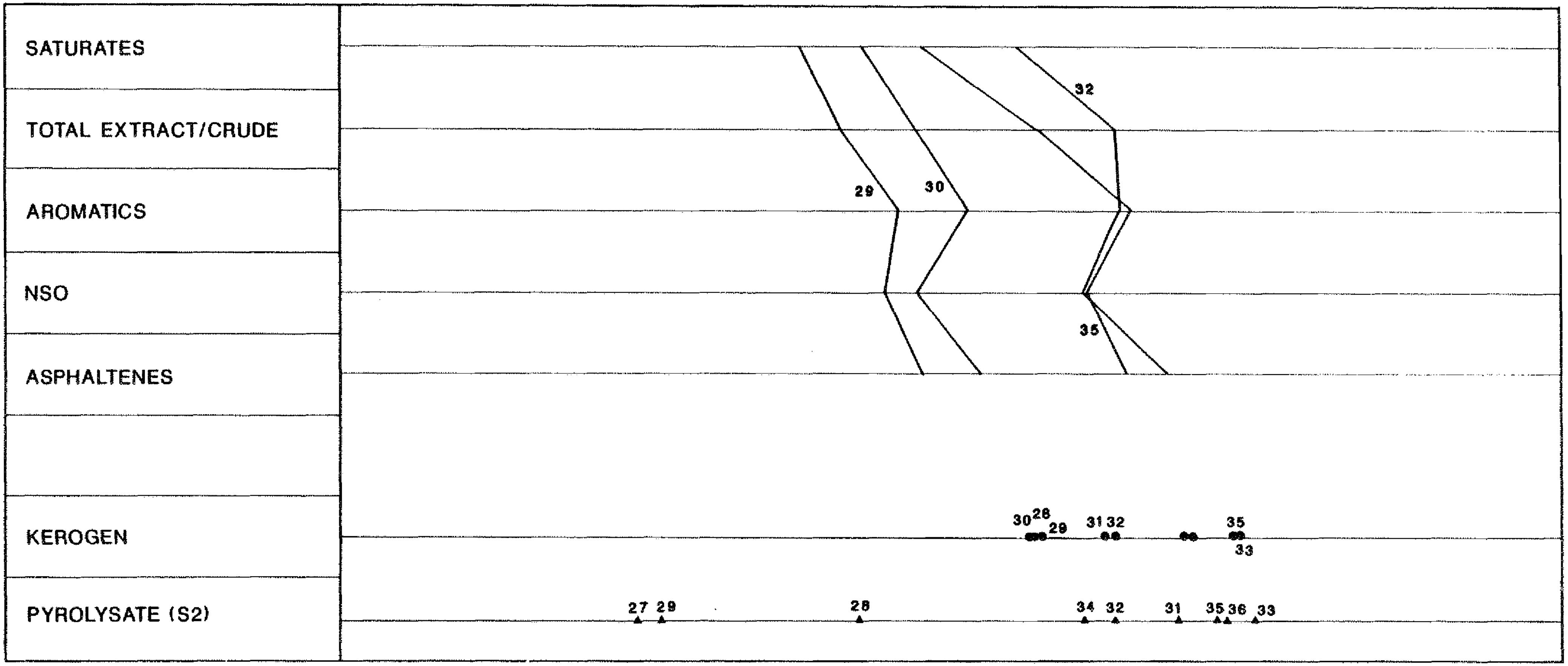


TABLE 1
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION	G S A Colour Code	TOTAL ORGANIC CARBON (Wt. % of Rock)
34/10-23 WELL				
1474-019 1189-162	3955-3970m	A 60% Mudstone, blocky, soft, v. sl. calc., minor cavings, medium dark grey to olive grey B 40% LCM - lignite Minor shale	N4-5YR4/1	2.40
1474-027 1189-163	3970-3985m	A 50% Mudstone, as 1474-019A, minor cavings B 50% LCM - lignite and cement Minor other mudstone and sand	N4-5YR4/1	3.64
1474-020 1189-164	3983-4000m	A 70% Mudstone, as 1474-019A B 30% LCM - lignite and cement	N4-5YR4/1	2.29
1474-021 1189-165	4000-4015m	A 75% Mudstone, as 1474-019A, minor cavings B 25% LCM - lignite and cement	N4-5YR4/1	2.61
1474-029 1189-166	4015-4030m	A 85% Mudstone, blocky, soft, non-calc., B 15% LCM - cement and lignite minor cavings, medium dark grey to olive grey B 15% LCM - cement and lignite	N4-5YR4/1	2.51
1474-022 1189-167	4030-4045m	A 70% Mudstone, as 1474-019A, minor cavings B 30% LCM - lignite and cement	N4-5YR4/1	2.96
1474-028 1189-168	4045-4060m	A 80% Mudstone, as 1474-019A, minor cavings B 20% LCM - lignite and cement	N4-5YR4/1	2.93,2.91
1474-023 1189-169	4060-4075m	A 80% Mudstone, as 1474-029A, minor cavings B 20% LCM - lignite and cement	N4-5YR4/1	3.15
1474-001 CORE	4106.2	A 98% Coaly, shale platy to subfissile, brittle, micaceous, dark grey to greyish black	N3-2	59.9
1474-002 CORE	4110.10	A 98% Coal, blocky, brittle, greyish black	N2	73.7
1474-003 CORE	4121.50	A 98% Coal, blocky, brittle, greyish black	N2	84.7
1474-004 CORE	4136.60	A 98% Sandstone, blocky, fine grained, micaceous laminane, cross bedded pinkish grey to pale orange V. pale milky cut	5YR8/1-10YR7/2	
1474-005 CORE	4143.15	A 98% Shale, subfissile to platy, mod. hard, non-calc., medium dark grey	N4	3.23,3.34
1474-006 CORE	4148.70	A 98% Sandstone, blocky, fine grained, well sorted, sl. micaceous, V. rare coal, V. pale milky cut, pinkish grey to pale orange	5YR8/1-10YR7/2	

Abbreviations = arenaceous, argillaceous, calcareous, Cut, dolomitic, Fluorescence, foraminifera, fossiliferous
Lost Circulation Material, moderately, occasionally, slightly, very

TABLE 1
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION		G S A Colour Code	TOTAL ORGANIC CARBON (Wt. % of Rock)
1474-007 CORE	4154.60	A 98%	Shale, subfissile, mod. hard, non-calc., medium dark grey to medium grey Minor carbonaceous inclusions	N4-5	2.30
1474-008 CORE	4164.10	A 98%	Coal, blocky, hard, argillaceou? dark grey	N3	51.9
1474-009 CORE	4172.25	A 98%	Sandstone, blocky, medium grained subangular, fairly well sorted, grain - supported, V. pale milky cut, pale orange	10YR7/2	
1474-010 CORE	4206.65	A 98%	Sandstone, blocky, medium grained, subangular, fairly well sorted, "Sulpherous" smell, strong milky cut, pale orange	10YR7/2	
1474-011 CORE	4220.00	A 98%	Coaly shale, subfissile, hard, non-calc., "soapy" texture, dark grey to medium brownish black	N3-5YR3/1	13.5
1474-012 CORE	4235.60	A 98%	Coal, blocky, brittle, dark grey to to greyish black	N3-2	80.6
1474-013 CORE	4247.20	A 98%	Sandstone, blocky, medium grained, fairly well sorted, V. pale milky cut, white	N9	
1474-024 1189-188	4360-4375m	A 95%	Claystone, blocky, soft, non-calc., minor cavings, medium grey to medium brownish grey	N5-5YR5/1	2.20,2.23
		B 5%	LCM - lignite		
1474-025 1189-190	4390-4405m	A 95%	Claystone, as 1474-024A	N5-5YR5/1	1.50
		B 5%	LCM - lignite		
1474-026 1189-195	4465-480m	A 40%	Sand, as 1189-194A	N9	
		B 30%	Shale, as 1189-194C, sig. cavings	N4	3.93,3.89
		C 15%	Claystone, as 1189-194B minor cavings	N5-5YR5/1	1.64
		D15%	LCM - lignite		

Abbreviations = arenaceous, argillaceous, calcareous, Cut, dolomitic, Fluorescence, foraminifera, fossiliferous
Lost Circulation Material, moderately, occasionally, slightly, very

TABLE 1
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION	G S A Colour Code	TOTAL ORGANIC CARBON (Wt. % of Rock)
34/10-30 WELL				
1474-014 CORE	2942.65	A 98% Shale, subfissile, soft to mod. hard, non-calc., medium dark grey	N4	2.00
1474-015 CORE	2945.00	A 98% Shaly claystone, blocky to subfissile, mod. hard, non-calc., Coal inclusive, medium dark grey to brownish grey	N4-5YR4/1	9.28,9.70
1474-016 CORE	3178.24	A 98% Carbonaceous shale, blocky, mod. hard, non-calc., greyish black to dark grey	N2-3	19.7
1474-017 CORE	3178.30	A 60% Shale, subfissile, mod. hard, non-calc., brownish grey	5YR4/1	2.55
		B 40% Coaly shale, blocky to subfissile, mod. hard, non-calc., dark grey	N3	23.0
1474-018 CORE	3197.10	A 98% Shale, platy, mod. hard, non-calc., 'Satin' luste, medium dark grey	N4	2.11

Abbreviations = arenaceous, argillaceous, calcareous, Cut, dolomitic, Fluorescence, foraminifera, fossiliferous
Lost Circulation Material, moderately, occasionally, slightly, very

TABLE 2

ROCKEVAL PYROLYSIS DATA (34/10-23 Well)

GEOCHEM SAMPLE NUMBER	DEPTH	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Production INDEX	Hydrogen INDEX	Oxygen INDEX	Tmax (%C)
1474-019A	3955-3970	1.48	4.67	0.47	0.24	165.0	16.6	449
1474-020A	3985-4000	1.35	2.59	0.63	0.34	113.1	27.5	444
1474-021A	4000-4015	1.04	2.85	0.56	0.27	109.2	21.5	446
1474-022A	4030-4045	1.55	3.13	0.57	0.33	105.7	19.3	446
1474-023	4060-4075	1.50	3.30	0.46	0.31	104.8	14.6	446
1474-001A	4106.80	6.66	162.53	2.73	0.04	271.3	4.6	455
1474-005A	4143.15	0.66	3.17	1.22	0.17	98.1	37.8	457
1474-007A	4154.60	0.51	2.14	2.52	0.19	93.0	109.6	461
1474-011A	4220.00	2.61	15.63	0.47	0.14	115.8	3.5	465
1474-024	4360-4375	0.49	0.68	0.19	0.42	43.9	12.3	443
1474-025	4390-4405	0.46	0.60	0.14	0.43	40.0	9.3	441
1474-026	4465-4480	3.04	7.29	0.71	0.29	186.4	18.2	442

TABLE 2

ROCKEVAL PYROLYSIS DATA (34/10-30 Well)

GEOCHEM SAMPLE NUMBER	DEPTH	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Production INDEX	Hydrogen INDEX	Oxygen INDEX	Tmax (%C)
1474-014A	2942.65	0.61	2.09	1.07	0.23	104.5	53.5	435
1474-015A	2945.00	4.26	26.87	2.28	0.14	289.5	24.6	427
1474-016A	3178.24	4.42	46.69	0.97	0.09	237.0	4.9	434
1474-017A	3178.30	0.77	6.80	0.49	0.10	266.7	19.2	438
1474-017B	3178.30	8.06	89.90	1.96	0.08	390.9	8.5	436
1474-018A	3197.10	0.34	0.88	0.85	0.28	41.7	40.3	489

TABLE 3
GAS – OIL INDEX

GEOCHEM SAMPLE NUMBER	DEPTH	DRY GAS	WET GAS	GASOLINES KEROSENES	GAS OIL DISTILLATE	GAS-OIL INDEX
		% C_1	% $C_2 - C_5$	% $C_6 - C_{14}$	% C_{15+}	$\frac{\% C_1 - C_5}{\text{TOTAL}}$
34/10-23						
1474-019A	3955-3970	21.39	42.86	35.24	0.52	64.25
1474-021A	4000-4015	20.71	38.41	40.60	0.28	59.12
1474-023A	4060-4075	32.24	29.28	38.22	0.26	61.51
1474-001A	4106.80	53.46	12.04	27.57	6.93	65.50
1474-002A	4110.10	55.99	10.29	23.91	9.81	66.28
1474-003A	4121.50	51.96	8.17	27.86	12.01	60.13
1474-005A	4143.15	49.02	24.69	24.98	1.30	73.71
1474-007A	4154.60	60.80	9.19	24.84	5.17	69.98
1474-008A	4164.10	59.20	15.32	21.30	4.19	74.51
1474-011A	4220.00	62.36	9.45	23.05	5.14	71.81
1474-012A	4235.60	60.26	8.77	22.21	8.76	69.03
1474-024A	4360-4375	25.13	32.35	42.27	0.26	57.48
1474-025A	4390-4405	28.45	41.33	29.87	0.36	69.78
1474-026B	4465-4480	25.02	32.98	41.78	0.22	58.00

TABLE 3

GAS – OIL INDEX

GEOCHEM SAMPLE NUMBER	DEPTH	DRY GAS	WET GAS	GASOLINES KEROSENES	GAS OIL DISTILLATE	GAS-OIL INDEX
		% C_1	% $C_2 - C_5$	% $C_6 - C_{14}$	% C_{15+}	$\frac{\% C_1 - C_5}{\text{TOTAL}}$
34/10-30						
1474-014A	2942.65	28.55	26.72	36.25	8.48	55.27
1474-015A	2945.00	38.04	19.86	36.61	5.49	57.90
1474-016A	3178.24	35.68	23.98	32.64	7.70	59.66
1474-017A	3178.30	37.01	28.41	29.51	5.07	65.41
1474-017B	3178.30	14.77	9.29	54.05	21.90	24.06
1474-018A	3197.10	44.18	20.93	27.87	7.02	65.11

TABLE 4

METHYL PHENANTHRENE INDEX (1) AND (2)

34/10-23 WELL

SAMPLE NUMBER	DEPTH	% AREA	% HEIGHT	% AREA	% HEIGHT
1474-004A	4136.60	2.42	2.25	0.79	0.98
1474-006A	4148.70	1.21	1.29	2.23	2.36
1474-009A	4172.25	1.51	1.46	0.76	0.86
1474-010A	4206.65	1.31	1.32	2.08	1.90
1474-013A	4247.20	0.71	0.73	0.48	0.56

TABLE 5a
CONCENTRATION (PPM) OF EXTRACTED C_{15+} MATERIAL IN ROCK

JOB	LITHO	DEPTH	TOTAL EXTRACT	HYDROCARBONS			NON HYDROCARBONS			
GEOCHEM SAMPLE NUMBER				Saturates	Aromatics	TOTAL	Preciptd. Asphaltenes	Eluted NSO's	Non-eluted NSO's	TOTAL
34/10-23 WELL										
1474-019		3955-70	4900	2581	657	3238	908	745	8	1661
1474-023		4060-75	3569	2106	653	2759	127	674	10	810
1474-004A		4136.60	126	15	6	21	92	13	0	105
1474-006A		4148.70	440	12	3	15	405	18	1	425
1474-009A		4172.25	126	7	6	14	105	7	0	112
1474-010A		4206.65	333	22	6	28	290	14	0	304
1474-013A		4247.20	161	26	4	30	93	38	1	131
1474-026		4465-80	5913	3270	836	4106	965	836	6	1807

S – shale, **SS** – sandstone, **L** – limestone, **D** – dolomite, **M** – mixed, see Table 1.

TABLE 5a
CONCENTRATION (PPM) OF EXTRACTED C_{15+} MATERIAL IN ROCK

JOB GEOCHEM SAMPLE NUMBER	LITHO	DEPTH	TOTAL EXTRACT	HYDROCARBONS			NON HYDROCARBONS			
				Saturates	Aromatics	TOTAL	Preciptd. Asphaltenes	Eluted NSO's	Non-eluted NSO's	TOTAL
34/10-30 WELL										
1474-015A		2945.0	2996	1452	583	2035	369	586	6	961
1474-017B		3178.30	6323	3216	1190	4406	937	969	12	1917

S – shale, **SS** – sandstone, **L** – limestone, **D** – dolomite, **M** – mixed, see Table 1.

TABLE 5b

COMPOSITION (NORMALISED %) OF C_{15+} MATERIAL

JOB	LITHO	DEPTH	HYDROCARBONS		NON HYDROCARBONS		
GEOCHEM SAMPLE NUMBER			Saturates	Aromatics	Preciptd. Asphaltenes	Eluted NSO's	Non eluted NSO's
34/10-23 WELL							
1474-019		3955-70	52.68	13.42	18.53	15.21	0.16
1474-023		4060-75	59.01	18.29	3.55	18.87	0.27
1474-004A		4136.60	11.85	4.53	73.17	10.10	0.35
1474-006A		4148.70	2.80	0.67	92.14	4.13	0.27
1474-009A		4172.25	5.88	4.90	83.66	5.23	0.33
1474-010A		4206.65	6.67	1.89	87.11	4.22	0.11
1474-013A		4247.20	15.93	2.65	57.52	23.45	0.44
1474-026		4465-80	55.31	14.14	16.32	14.14	0.11

S – shale, SS – sandstone, L – limestone, D – dolomite, M – mixed, see Table 1.

TABLE 5b
COMPOSITION (NORMALISED %) OF C_{15+} MATERIAL

JOB GEOCHEM SAMPLE NUMBER	LITHO	DEPTH	HYDROCARBONS Saturates	 Aromatics	NON HYDROCARBONS Preciptd. Asphaltenes	 Eluted NSO's	 Non eluted NSO's
34/10-30 WELL							
1474-015A		2945.0	48.47	19.46	12.33	19.55	0.19
1474-017B		3178.30	50.86	18.83	14.81	15.32	0.18

S – shale, SS – sandstone, L – limestone, D – dolomite, M – mixed, see Table 1.

TABLE 6
SIGNIFICANT RATIOS (%) OF C_{15+} FRACTIONS AND ORGANIC CARBON

JOB GEOCHEM SAMPLE NUMBER	LITHO	DEPTH	ORGANIC CARBON (wt. %)	HYDROCARBONS / TOTAL EXTRACT	HYDROCARBONS / ORG. CARBON	TOTAL EXTRACT / ORG. CARBON	SATURATES / AROMATICS
34/10-23 WELL							
1474-019		3955-70	3.07	66.09	10.55	15.96	3.93
1474-023		4060-75	3.31	77.31	8.34	10.78	3.23
1474-004A		4136.60	0.34	16.38	0.61	3.71	2.62
1474-006A		4148.70	0.12	3.46	1.27	36.66	4.20
1474-009A		4172.25	0.16	10.78	0.85	7.88	1.20
1474-010A		4206.65	0.19	8.56	1.50	17.52	3.53
1474-013A		4247.20	0.08	18.58	3.75	20.16	6.00
1474-026		4465-80	3.27	69.44	12.56	18.08	3.91

S – shale, SS – sandstone, L – limestone, D – dolomite, M – mixed, see Table 1.

TABLE 6
SIGNIFICANT RATIOS (%) OF C_{15+} FRACTIONS AND ORGANIC CARBON

JOB GEOCHEM SAMPLE NUMBER	LITHO	DEPTH	ORGANIC CARBON (wt. %)	HYDROCARBONS / TOTAL EXTRACT	HYDROCARBONS / ORG. CARBON	TOTAL EXTRACT / ORG. CARBON	SATURATES / AROMATICS
34/10-30 WELL							
1474-015A		2945.0	8.47	67.93	2.40	3.54	2.49
1474-017B		3178.30	25.00	69.68	1.76	2.53	2.70

S – shale, SS – sandstone, L – limestone, D – dolomite, M – mixed, see Table 1.

34/10-23 WELL

TABLE 7

COMPOSITION (NORMALISED %) OF C_{15+} SATURATE (PARAFFIN – NAPHTHENE) HYDROCARBONS

GEOCHEM SAMPLE NUMBER	004A	006A	009A	010A	013A
DEPTH	4136.6	4148.7	4172.3	4206.6	4247.2
SAMPLE TYPE					
nC15	.63	.60	.55	.47	.36
nC16	.42	.69	.71	1.23	.82
nC17	1.88	1.45	1.26	3.48	1.79
nC18	3.40	3.48	1.75	3.81	2.41
nC19	4.86	4.22	1.47	2.88	2.79
nC20	3.65	4.02	2.50	2.91	2.66
nC21	3.38	3.48	1.58	2.25	2.41
nC22	3.40	3.78	2.15	2.41	3.05
nC23	3.75	3.97	2.61	3.02	3.27
nC24	5.31	5.47	4.09	5.03	4.81
nC25	7.95	8.02	6.92	8.53	7.60
nC26	9.67	9.57	9.98	10.75	9.83
nC27	11.17	10.65	12.27	12.19	11.19
nC28	10.52	9.87	12.82	10.79	10.40
nC29	9.69	9.18	11.80	9.89	10.00
nC30	7.18	6.93	10.48	7.76	8.39
nC31	5.48	5.59	7.23	5.40	6.59
nC32	3.22	3.54	5.37	3.23	4.51
nC33	2.20	2.67	2.39	2.08	2.92
nC34	1.13	1.60	1.45	1.19	2.30
nC35	1.12	1.20	.60	.69	1.91
Paraffin	46.09	36.03	54.29	54.77	41.79
Isoprenoid	1.75	1.11	.89	1.93	1.03
Naphthene	52.16	62.86	44.82	43.30	57.17
CPI 1 Index	1.05	1.03	1.03	1.06	1.04
CPI 2 Index	1.08	1.08	1.01	1.08	1.06
CPI 3 Index	1.11	1.10	1.08	1.13	1.11
Prist/Phytane	.97	.73	.71	1.45	.93
Prist/nC17	1.00	.89	.54	.60	.66
Phytane/nC18	.57	.51	.55	.38	.53

$$\text{C.P.I. } 1 = \frac{1}{2}\ \frac{C21+C23+C25+C27}{C20+C22+C24+C26} + \frac{C21+C23+C25+C27}{C22+C24+C26+C28}$$

Job Number : 1474

$$\text{C.P.I. } 2 = \frac{1}{2}\ \frac{C25+C27+C29+C31}{C24+C26+C28+C30} + \frac{C25+C27+C29+C31}{C26+C28+C30+C32}$$

$$\text{C.P.I. } 3 = \frac{2x\ \ (C27)}{C26+C28}$$

CT – ditch cuttings **CO**– core **SWC** – sidewall core

NBS 22 STANDARD

TABLE 8
CARBON ISOTOPE COMPOSITIONS (^{o}/oo, PDB)

GEOCHEM SAMPLE NUMBER	DEPTH	TOTAL EXTRACT WHOLE OIL	SATURATES	AROMATICS	NSO	ASPHALTENES	KEROGEN	PYROLYSATE S2
34/10-23								
1189-156B	3865-3880		-31.03	-30.22	-30.04	-29.96	-29.11	
1189-159	3910-3925		-30.26	-29.34	-29.18	-28.98	-28.54	
1474-019	3955-3970	-29.23	-29.95	-28.81	-28.56	-28.36		
1474-027	3970-3985						-27.39	-30.88
1474-020	3985-4000							
1474-021	4000-4015						-26.48	-30.39
1474-029	4015-4030							-28.75
1189-166A	4015-4030		-27.86	-26.36	-27.56	-26.39	-26.14	
1474-022	4030-4045							
1474-028	4045-4060						-26.54	-27.03
1474-023	4060-4075	-28.23	-29.54	-27.47	-27.86	-27.06	-26.03	-30.18
1189-001	4085-4095	-28.05	-29.30	-26.05	-27.91	-28.23		
DTS 1								
1474-001A	4106.80						-24.65	-25.13
1474-002A	4110.10						-25.89	-25.38
1474-003A	4121.50						-25.17	-25.11
1474-004A	4136.60	-27.11	-28.20	-26.26	-27.26	-27.82		
1474-005A	4143.15						-25.52	-24.94
1474-006A	4148.70	-27.59	-29.30	-26.94	-28.64	-30.88		
1474-007A	4154.60						-25.33	-27.37
1474-008A	4164.10						-25.46	-25.36
1474-009A	4172.25	-26.61	-28.97	-25.90	-26.82	-26.29		
1474-010A	4206.65	-27.22	-27.62	-26.82	-27.73	-26.31		

NBS 22 STANDARD	

TABLE 8
CARBON ISOTOPE COMPOSITIONS (^{o}/oo, PDB)

GEOCHEM SAMPLE NUMBER	DEPTH	TOTAL EXTRACT WHOLE OIL	SATURATES	AROMATICS	NSO	ASPHALTENES	KEROGEN	PYROLYSATE S2
1189-181	4212-4225		-29.12	-26.63	-27.44	-26.41	-26.59	
1474-011A	4220.00						-25.36	-25.32
1474-012A	4235.60						-26.15	-25.92
1474-013A	4247.20	-28.87	-28.38	-27.36	-29.41	-27.71		
1474-024	4360-4375						-28.28	-31.82
1474-025	4390-4405						-27.19	-29.39
1474-026	4465-4480	-29.63	-30.07	-28.85	-29.06	-28.62	-27.12	-32.10
1189-196	4480-4495		-29.38	-28.04	-28.65	-27.91	-27.26	

NBS 22 STANDARD	

TABLE 8
CARBON ISOTOPE COMPOSITIONS (^{o}/oo, PDB)

GEOCHEM SAMPLE NUMBER	DEPTH	TOTAL EXTRACT WHOLE OIL	SATURATES	AROMATICS	NSO	ASPHALTENES	KEROGEN	PYROLYSATE S2
34/10-21								
972-126	2920-2935m						-28.67	
972-127A	2935-2950m			-28.88				
972-128	2950-2965m						-25.44	
972-131A	2995-3010m		-30.13	-27.83				
972-134A	3040-3055m		-29.25	-27.36				
972-135	3055-3070m						-25.20	
972-139A	3115-3130m		-26.75*	-26.78				
972-142	3160-3175m		-28.46	-27.23				
972-146A	3205-3219m		-27.05	-24.70				
972-150A	3264-3279m		-28.10	-26.36				
972-153A	3399-3414m		-27.38	-25.36			-25.20	
972-169A	3639-3654m		-29.89	-28.59				
972-182A	3834-3849m			-25.79				
972-188A	3924-3939m		-29.30*	-26.50				

* Extremely small sample size, treat data with caution

NBS 22 STANDARD

TABLE 8
CARBON ISOTOPE COMPOSITIONS (°/oo, PDB)

GEOCHEM SAMPLE NUMBER	DEPTH	TOTAL EXTRACT WHOLE OIL	SATURATES	AROMATICS	NSO	ASPHALTENES	KEROGEN	PYROLYSATE S2
34/10-30								
1474-014A	2942.65						-26.36	-25.42
1474-015A	2945.00	-26.22	-27.47	-26.15	-26.66	-25.59	-26.19	-26.23
1474-016A	3178.24						-24.67	-24.51
1474-017A	3178.30						-25.32	-26.60
1474-017B	3178.30	-27.20	-28.65	-26.04	-26.56	-26.06	-24.74	-24.97
1474-018A							-25.26	-24.84

TABLE 9
BIOMARKER MOLECULAR RATIOS

GEOCHEM SAMPLE NUMBER	SAMPLE DEPTH/ IDENTITY	SAMPLE TYPE	STERANES (m/z 217, 218)				TERPANES (m/z 191, 177)					
			$C_{29}\ \frac{\alpha\alpha\alpha\ 20S\ [Q]}{\alpha\alpha\alpha\ 20R\ [T]}$	$C_{29}\ \frac{\alpha\beta\beta\ 20R\ [R]}{\alpha\alpha\alpha\ 20R\ [T]}$	$C_{27}\ \frac{20S DIAST [A]}{20R DIAST [B]}$	$\frac{C_{27}\ \beta\beta}{C_{29}\ \beta\beta}$ (218)	$\frac{Tm [B]}{Ts [A]}$	$\frac{C_{29'}\ 17\alpha\text{-NH [C]}}{[C] + C_{30'}\ 17\alpha\text{-H [E]}}$	$C_{29}\ \frac{NM [D]}{[D] + NH [C]}$	$\frac{28, 30\text{-BNH [Z]}}{[Z] + C_{29'}\ 17\text{-NH [C]}}$	$\frac{28, 30\text{-BNH [Z]}}{[Z] + 25, 28, 30\text{-TNH (177)}}$	$C_{31}\ \frac{20S [G]}{[G] + 20R [H]}$ %
<u>34/10-23</u>												
1474-019	3955-3970m		1.11	0.72	1.61	1.39	0.31	0.26	0.18	0.07		0.40
1474-023	4060-4075m		1.62	1.99	1.57	1.01	0.20	0.25	0.07	0.14		0.26
1474-026	4465-4480m		1.43	2.03	1.54	1.28	0.15	0.26	0.03	0.25		0.55
<u>34/10-30</u>												
1474-015	2945.0m		0.44	0.24	2.00	0.68	10.9	0.41	0.21	0.007		0.63
1474-017	3178.3m		0.85	0.57	1.64	0.78 0.82	5.99	0.47	0.13	0.003		0.59

[A] etc. REFERS TO IDENTIFICATION ON APPROPRIATE MASS FRAGMENTOGRAM **DIAST** – DIASTERANES **H** – HOPANE **NH** – NORHOPANE **BNH** – BISNORHOPANE

CT – ditch cuttings **CO** – core **SWC** – sidewall core **TNH** – TRISNORHOPANE **NM** – NORMORETANE

TABLE 10a

PEAK HEIGHTS - STERANES AND TERPANES

	MZ 217					MZ 218		MZ 191							
	A	B	Q	R	T	A&B	E&F	A	B	C	D	E	Z	G	H
1474-019	120	70	38	33	37	60&42	36&35	41	18	41	8	123	5	47	71
1474-017	59	32	88	61	115	120&83	120&200	14	54	105	24	131	2	58	44
1474-015	20	10	53	30	130	46&15	55&42	8	44	98	32	130	3	66	47
1474-023	116	69	28	50	28	107&77	86&76	72	12	36	4	103	6	43	124
1474-026	117	71	22	43	19	96&68	62&53	60	9	40	2	120	10	42	35

TABLE 10b

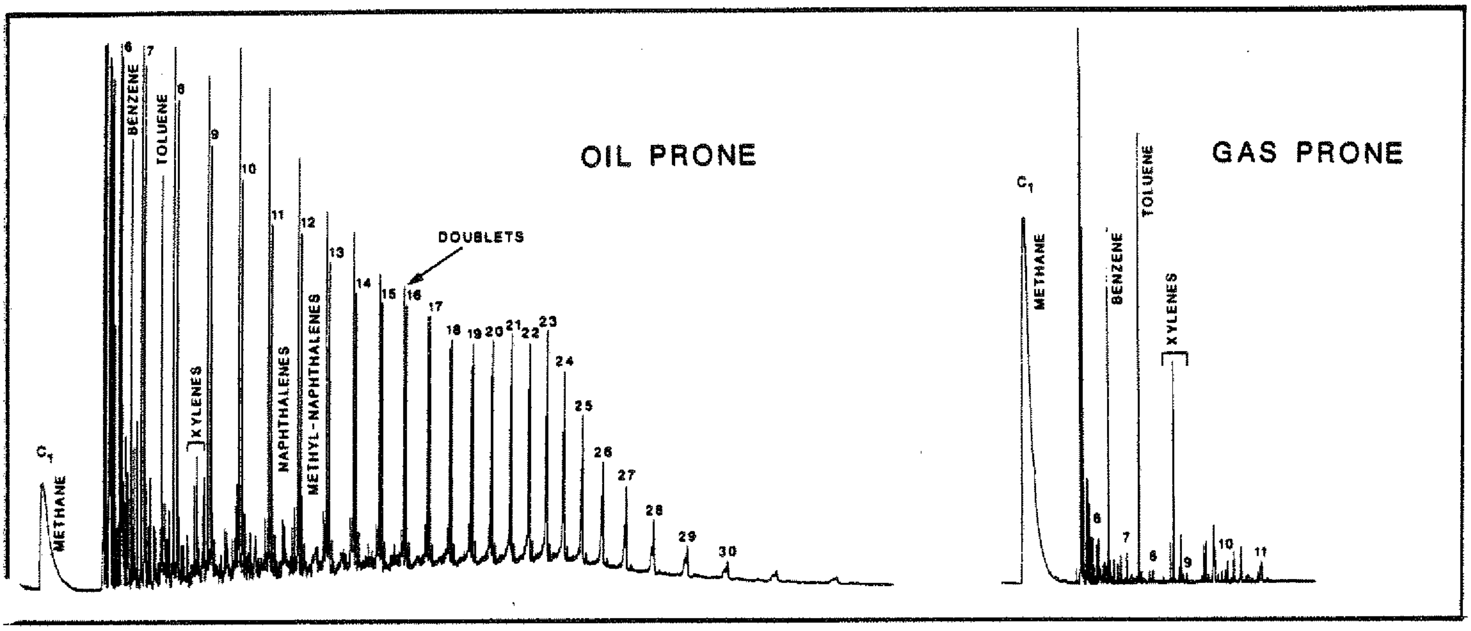
PEAK AREAS - STERANES & TERPANES

	MZ 217					MZ 218		MZ 191							
SAMPLE NO	A	B	Q	R	T	A&B	E&F	A	B	C	D	E	Z	G	H
1474-019	413.6	256.1	189.8	123.5	170.8	402.1	289.7	444.8	139.7	436.6	93.7	1267.7	32.6	716.8	619.5
1474-017	539.2	327.7	1201.7	816.0	1718.3	1165.4 109.3	1411.9 1392.3	869.6	5205.2	12911.7	1939.7	14643.8	37.3	5252.6	3688.5
1474-015	459.4	228.1	1592.3	877.8	3632.5	940.7	1380.5	302.9	3305.0	8426.6	2191.3	11966.6	57.8	5008.7	2929
1474-023	640.2	406.9	294.6	361	181.8	738.7	731.6	660.7	131.2	729	55.1	2180.8	116.4	857.5	2487
1474-026	1212	788.9	398	565.2	278.4	1329.3	1039.8	1239	183.6	1009.2	34.3	2889.0	342.6	878.8	726

FIGURE 7a

PYROLYSIS GC

WELL 34/10-23



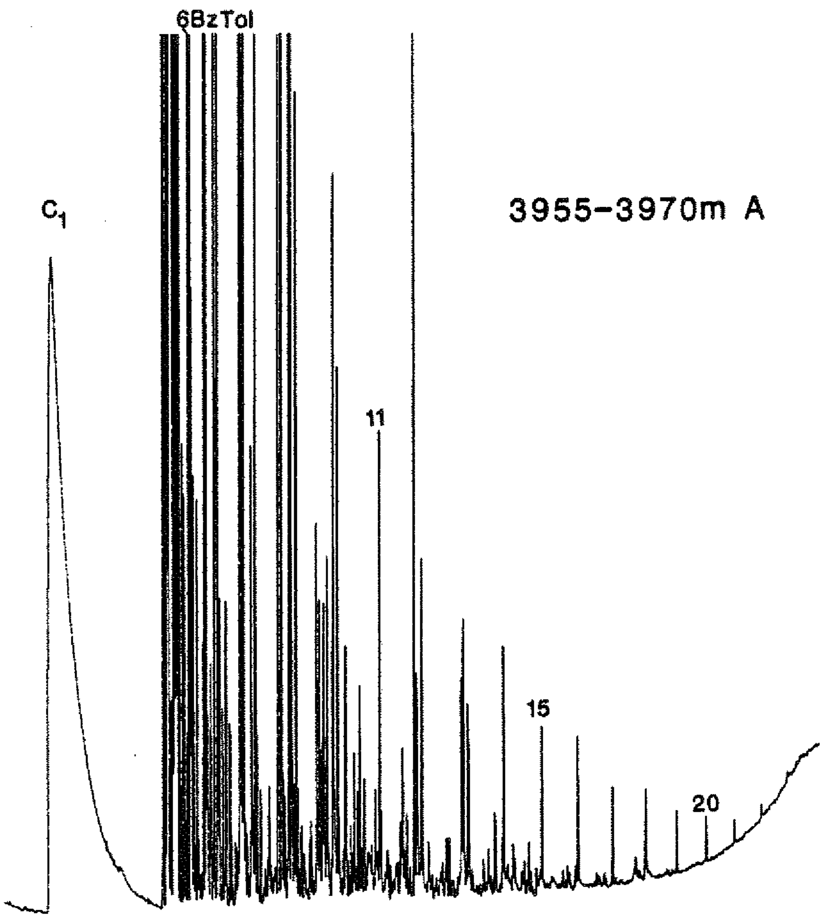
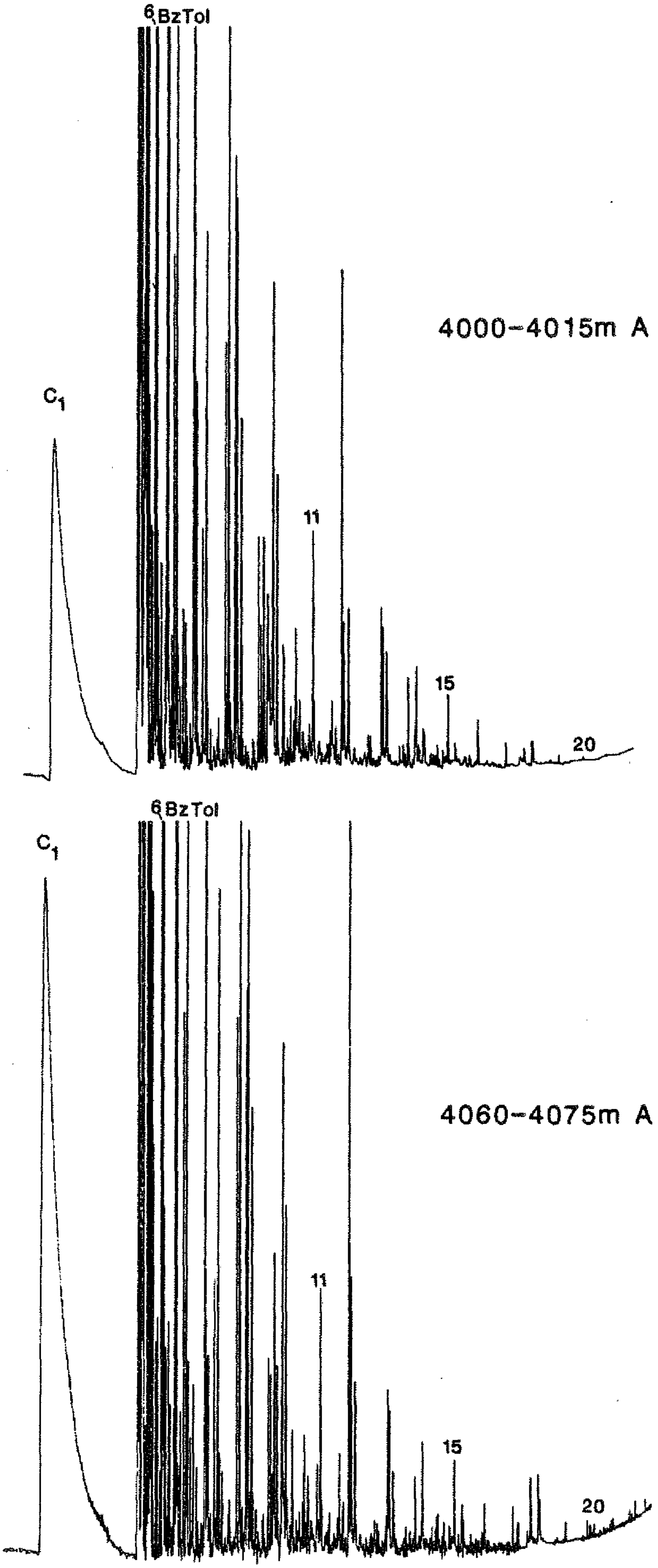


FIGURE 7b

WELL 34/10-23

PYROLYSIS GC



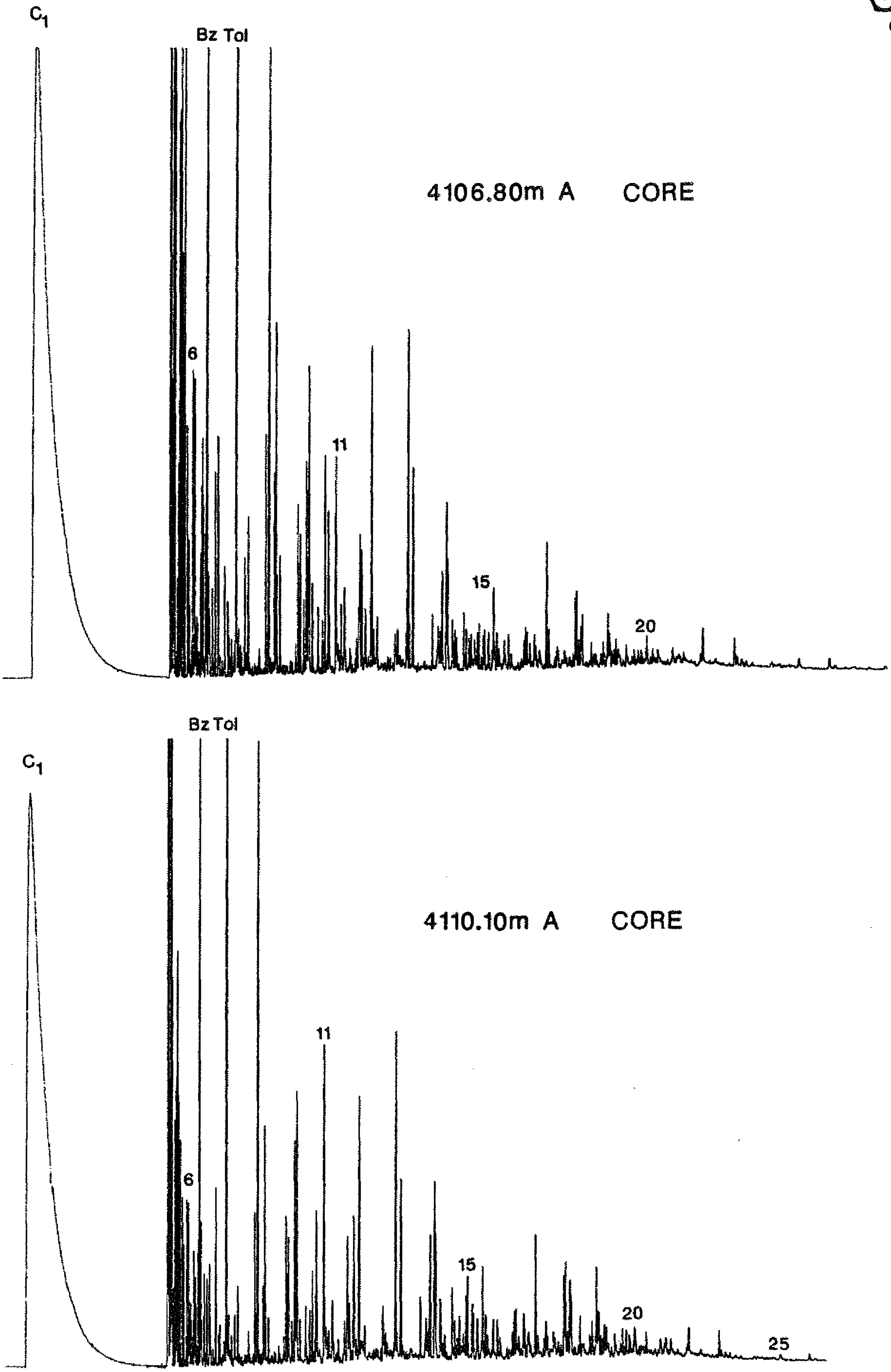
STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

Bz - Benzene
To - Toluene

FIGURE 7c

PYROLYSIS GC

WELL 34/10-23



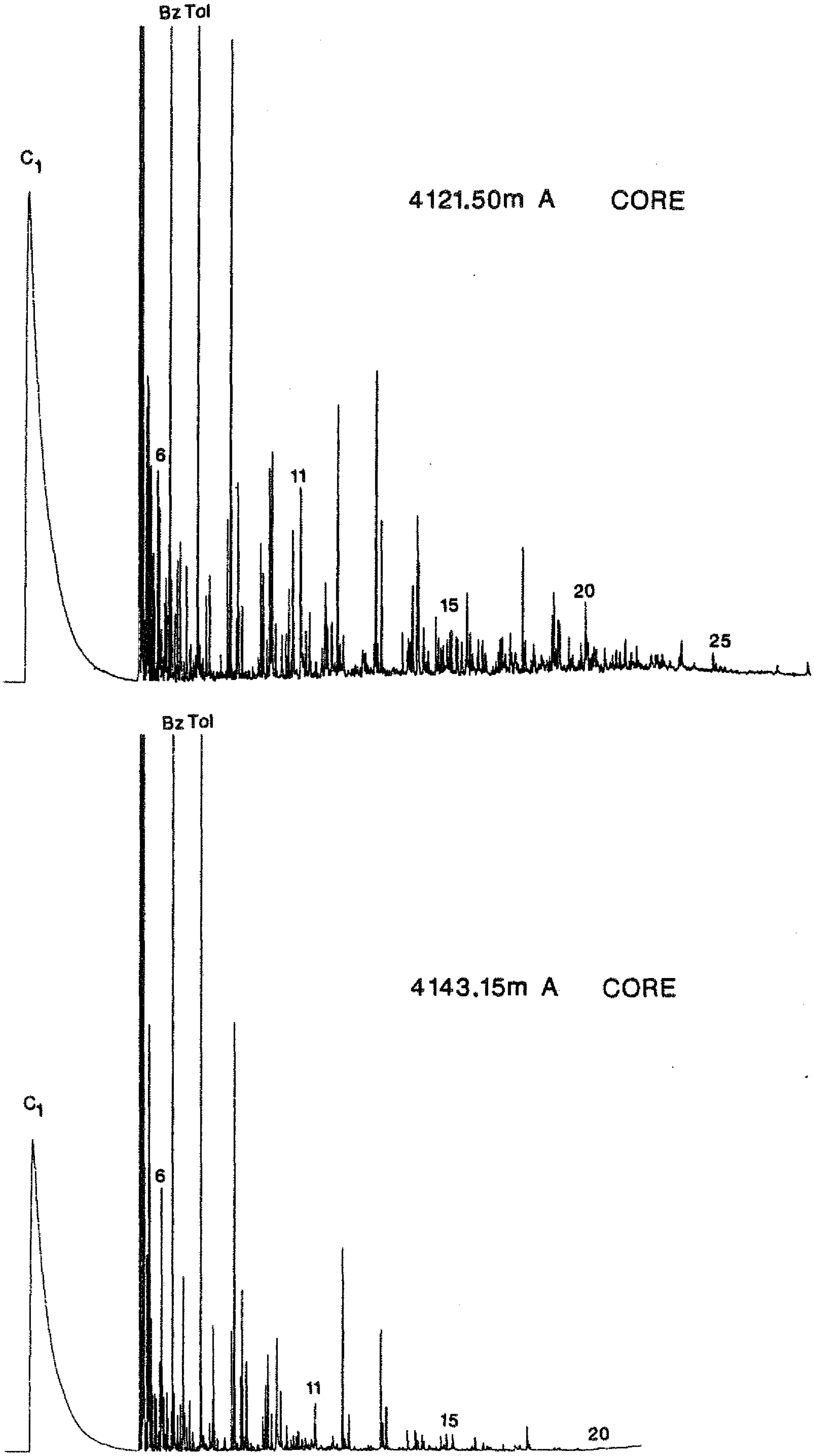
STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

Bz - Benzene
To - Toluene

FIGURE 7d

PYROLYSIS GC

WELL 34/10-23



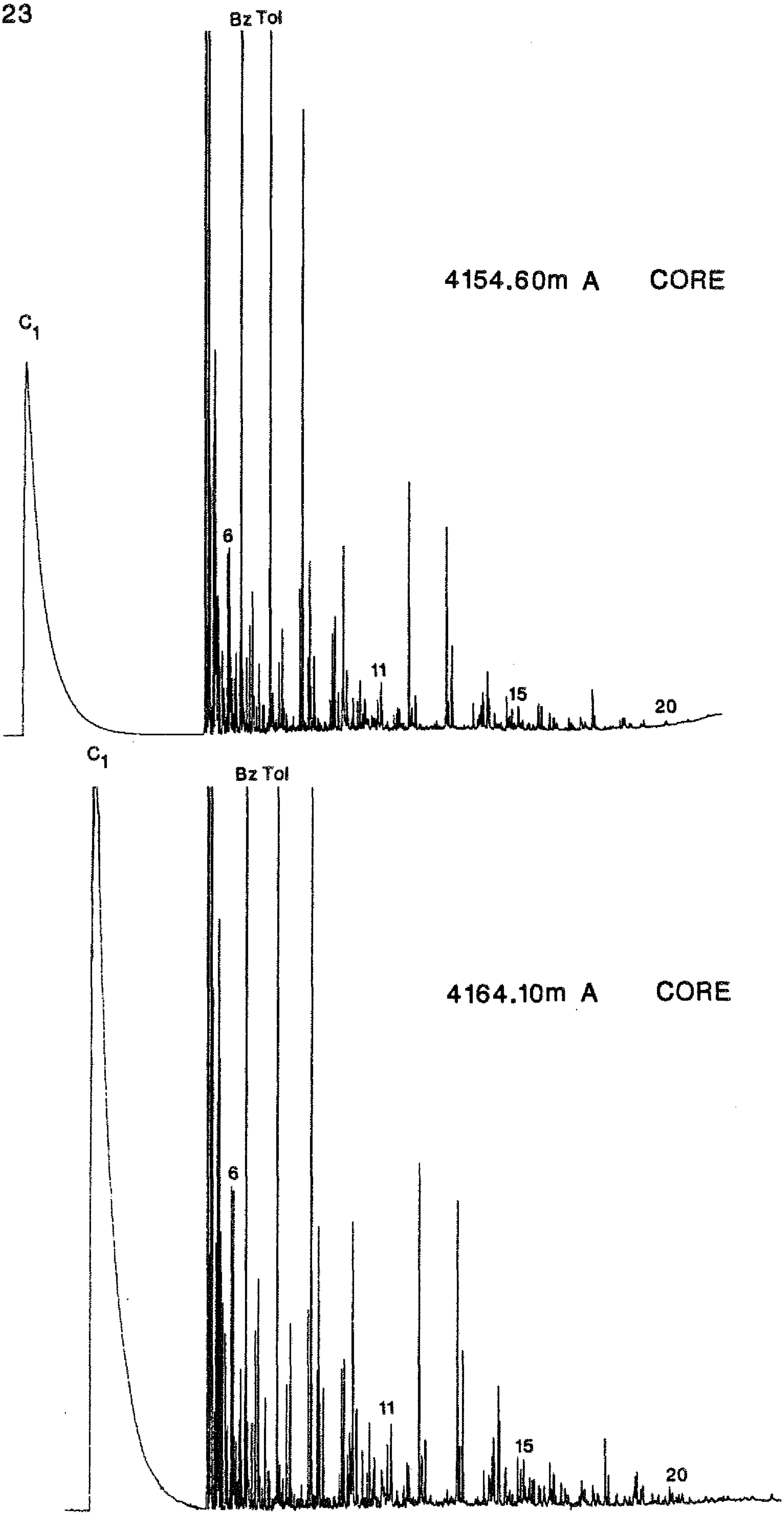
STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

Bz - Benzene
To - Toluene

FIGURE 7e

WELL 34/10-23

PYROLYSIS GC



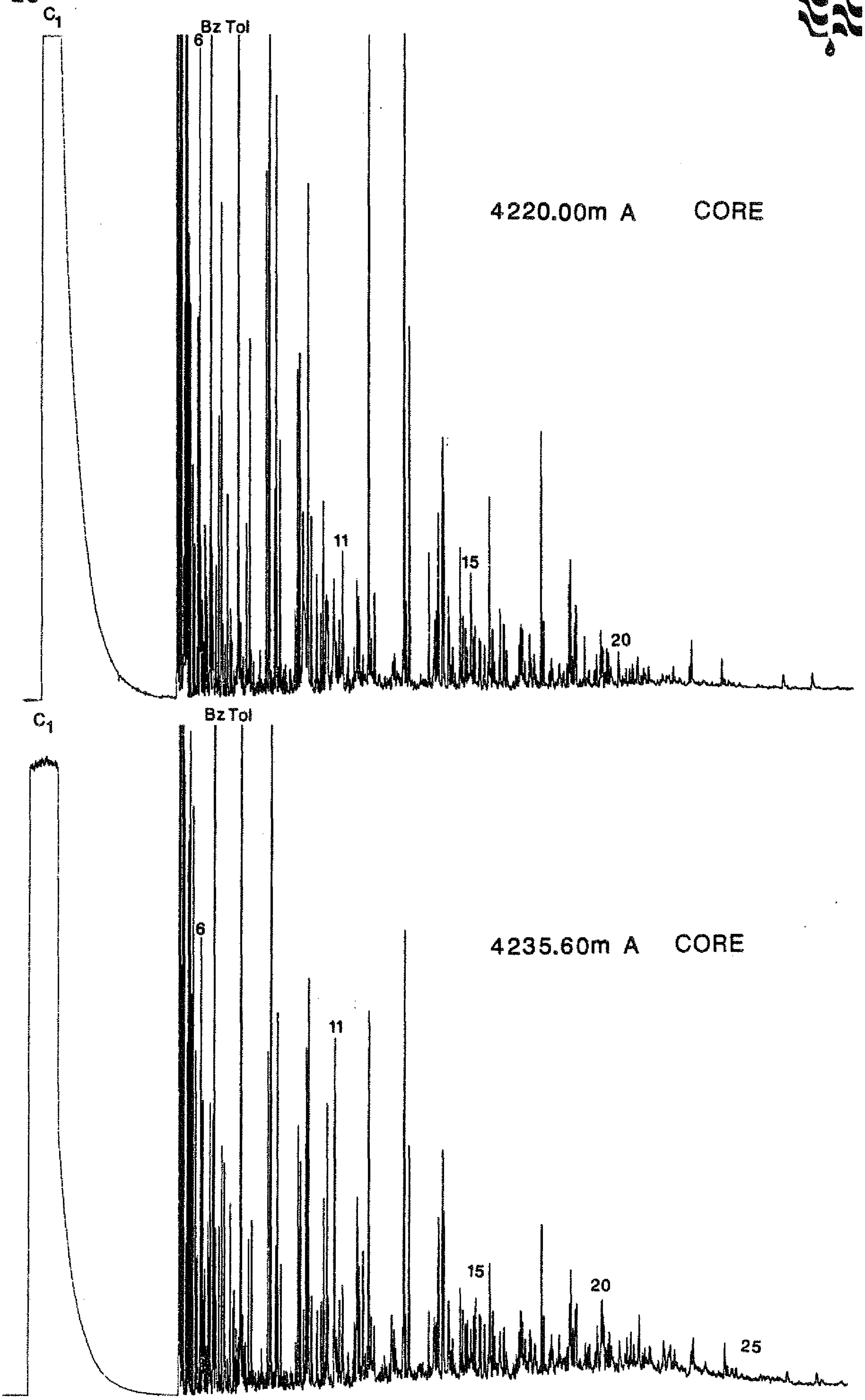
STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

Bz - Benzene
To - Toluene

FIGURE 7f

PYROLYSIS GC

WELL 34/10-23



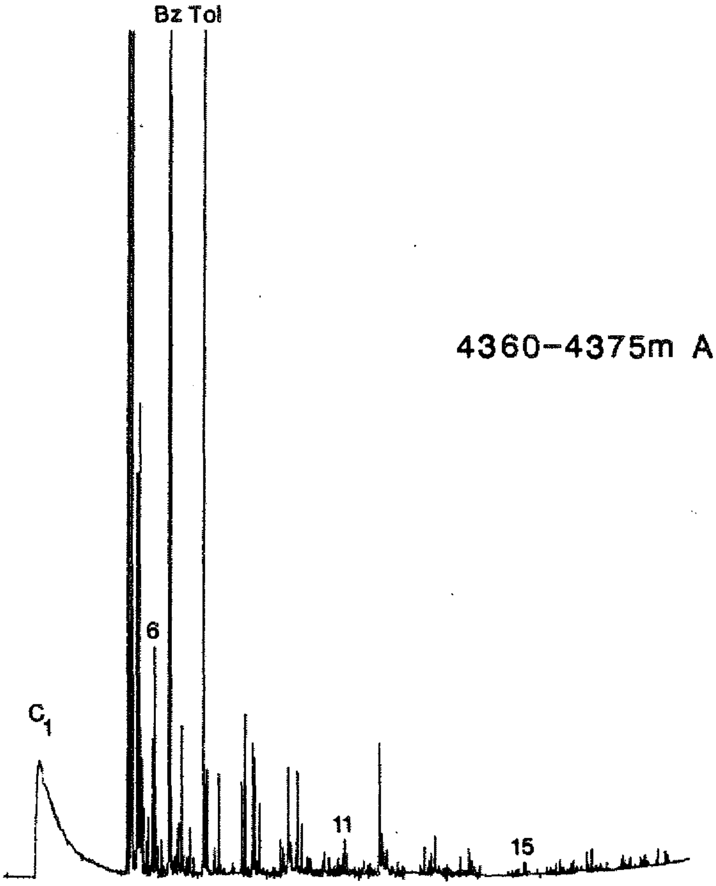
STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

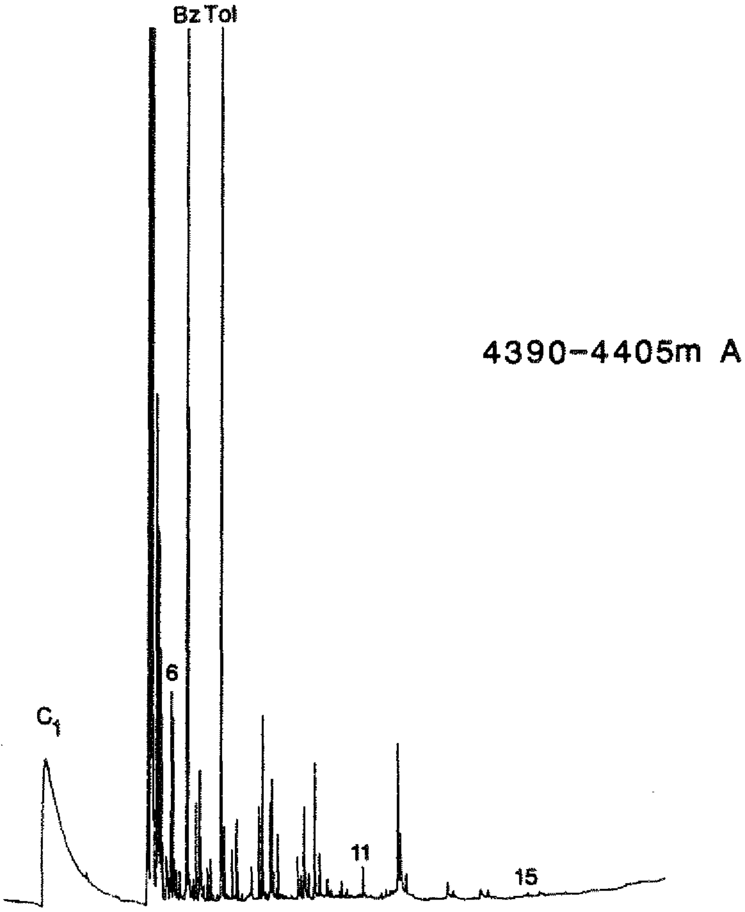
Bz - Benzene
To - Toluene

FIGURE 7g

WELL 34/10-23

PYROLYSIS GC





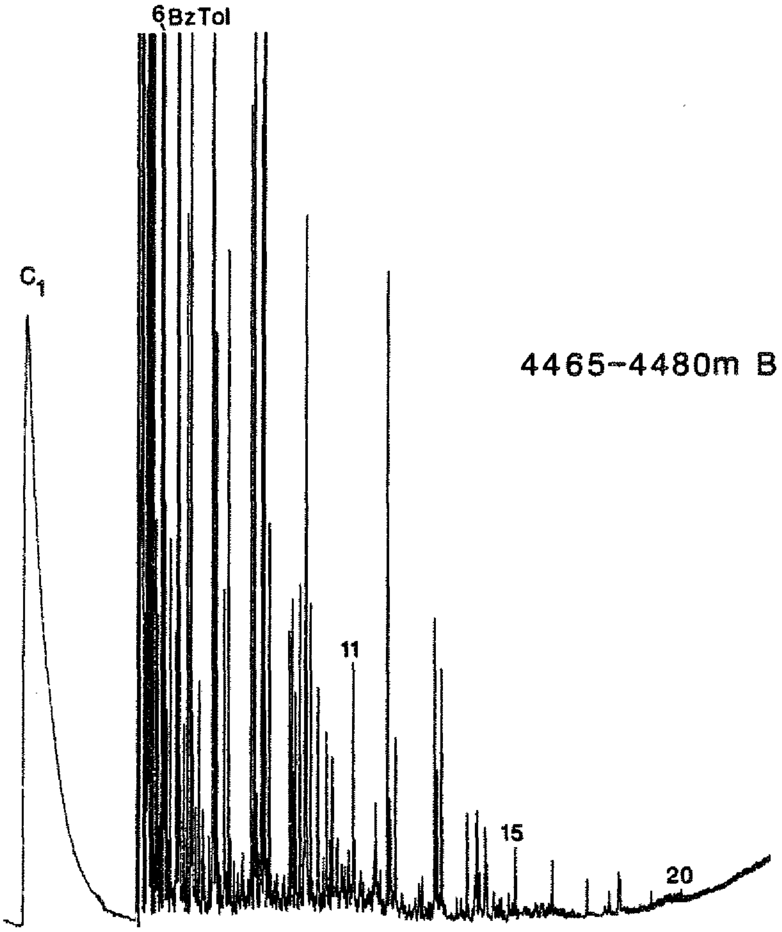
STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

Bz - Benzene
To - Toluene

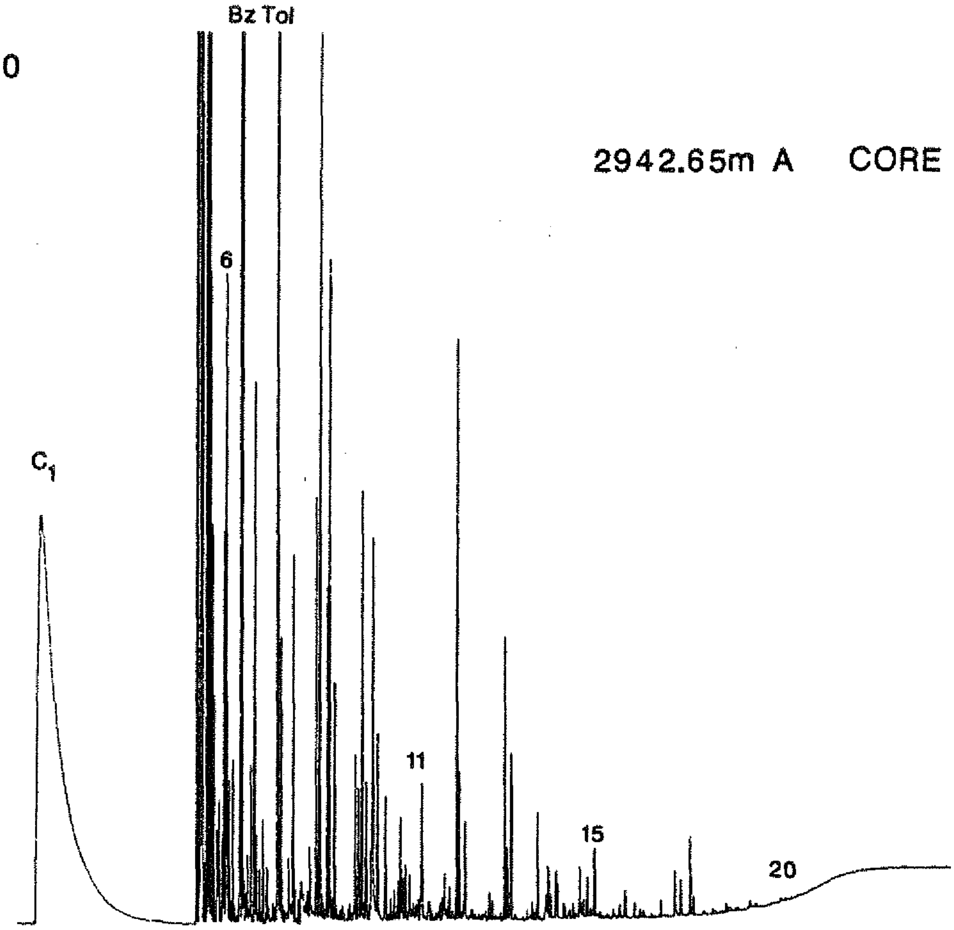
FIGURE 7h

PYROLYSIS GC

WELL 34/10-23



WELL 34/10-30



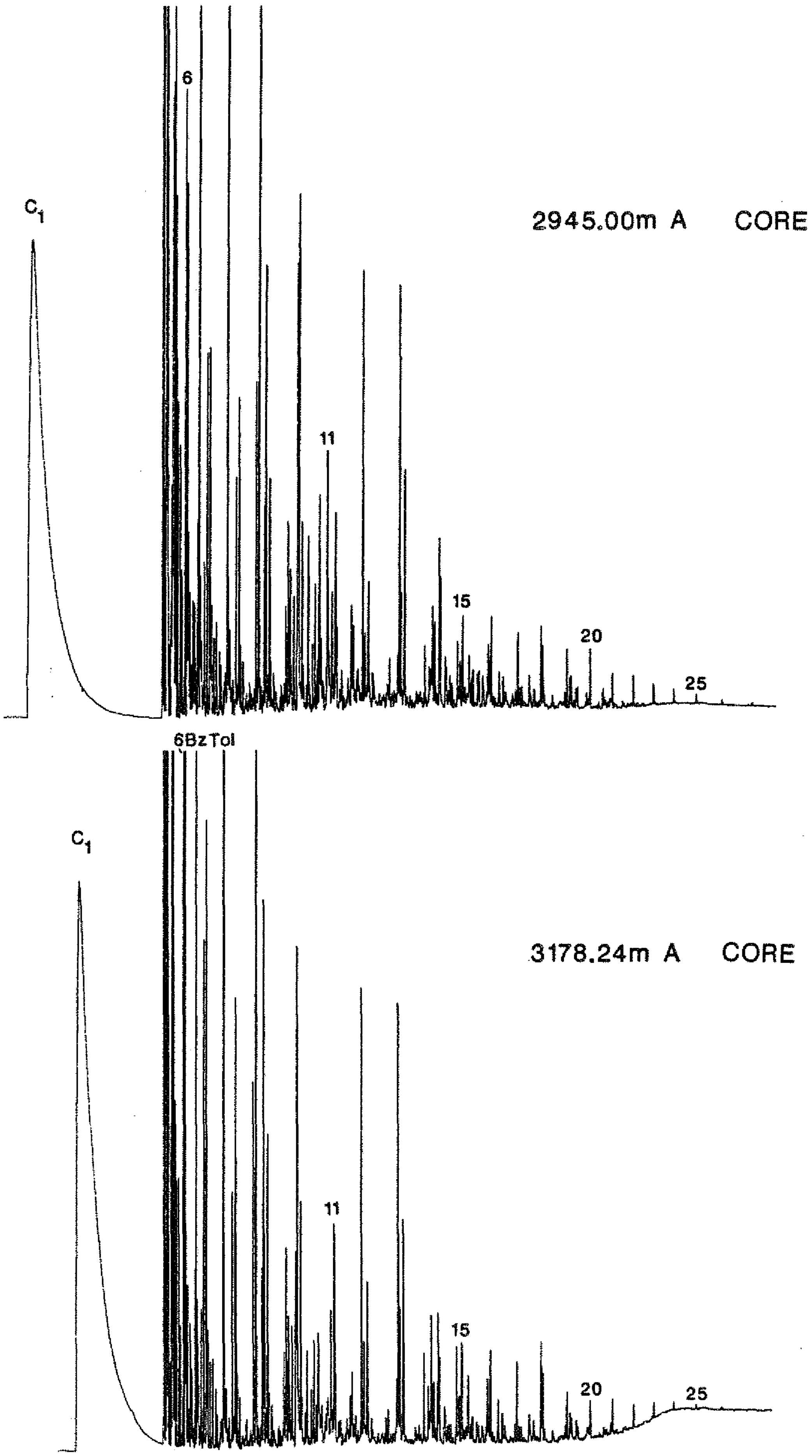
STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

Bz - Benzene
To - Toluene

FIGURE 7i

WELL 34/10-30

PYROLYSIS GC



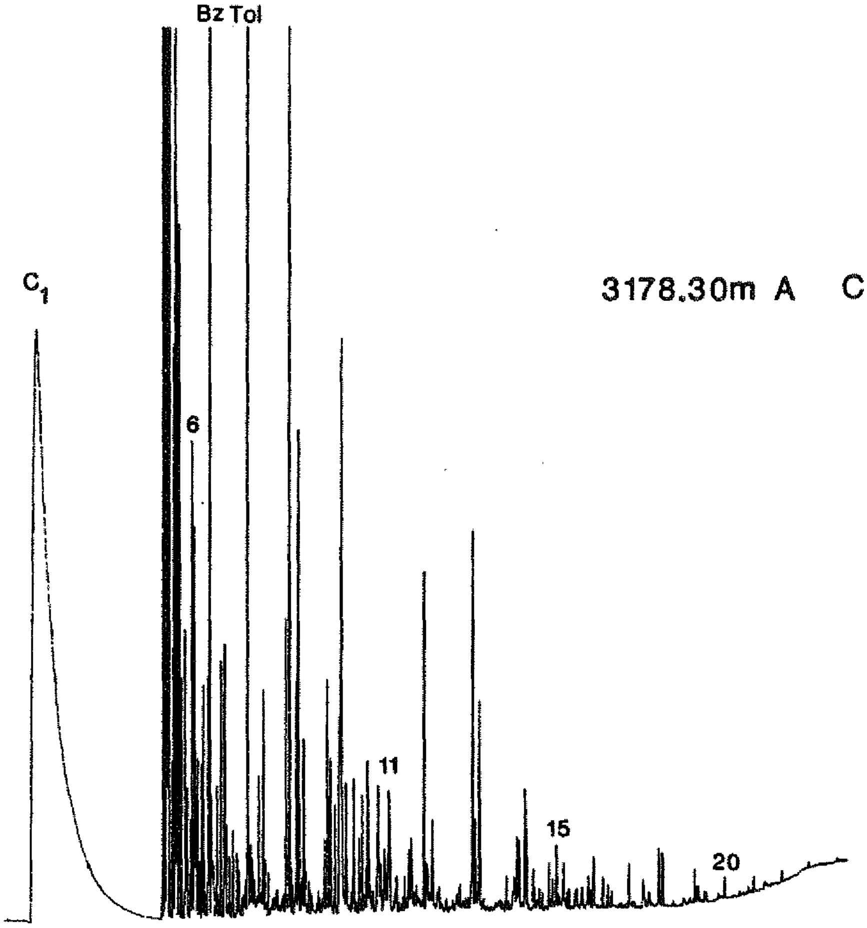
STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

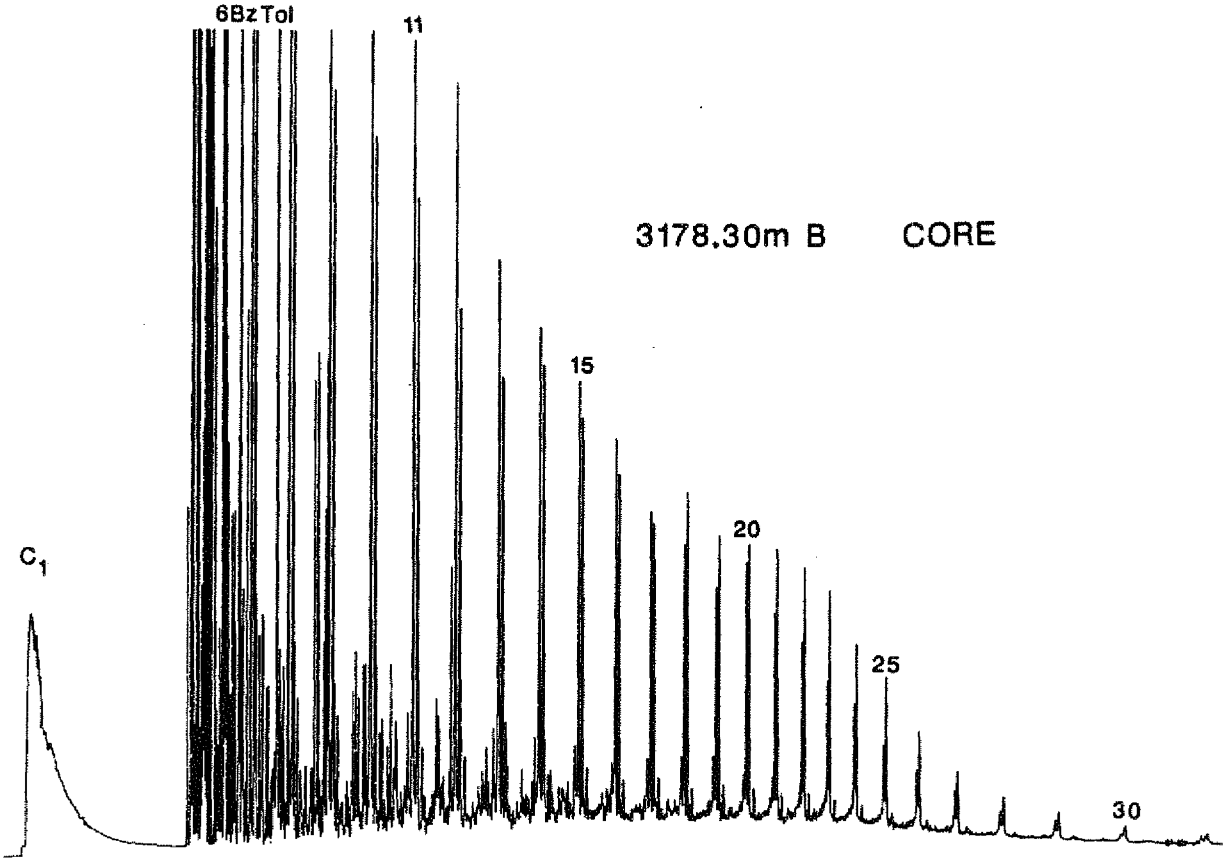
Bz - Benzene
To - Toluene

FIGURE 7j

WELL 34/10-30

PYROLYSIS GC





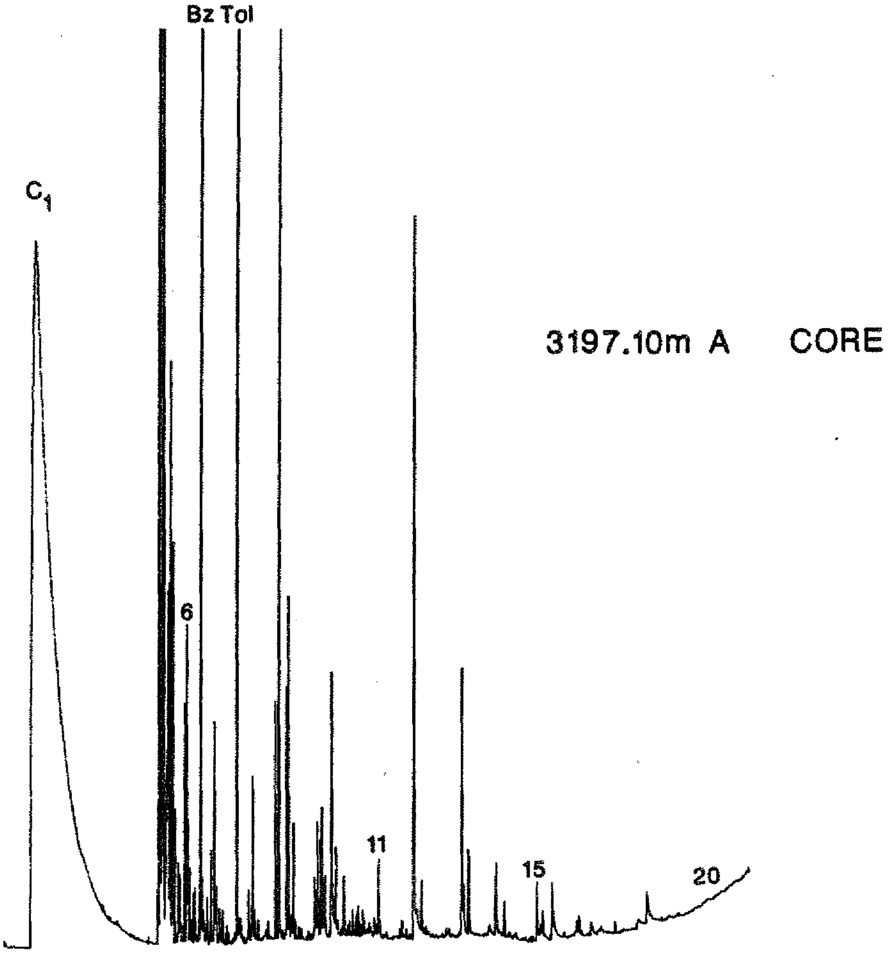
STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

Bz - Benzene
To - Toluene

FIGURE 7k

WELL 34/10-30

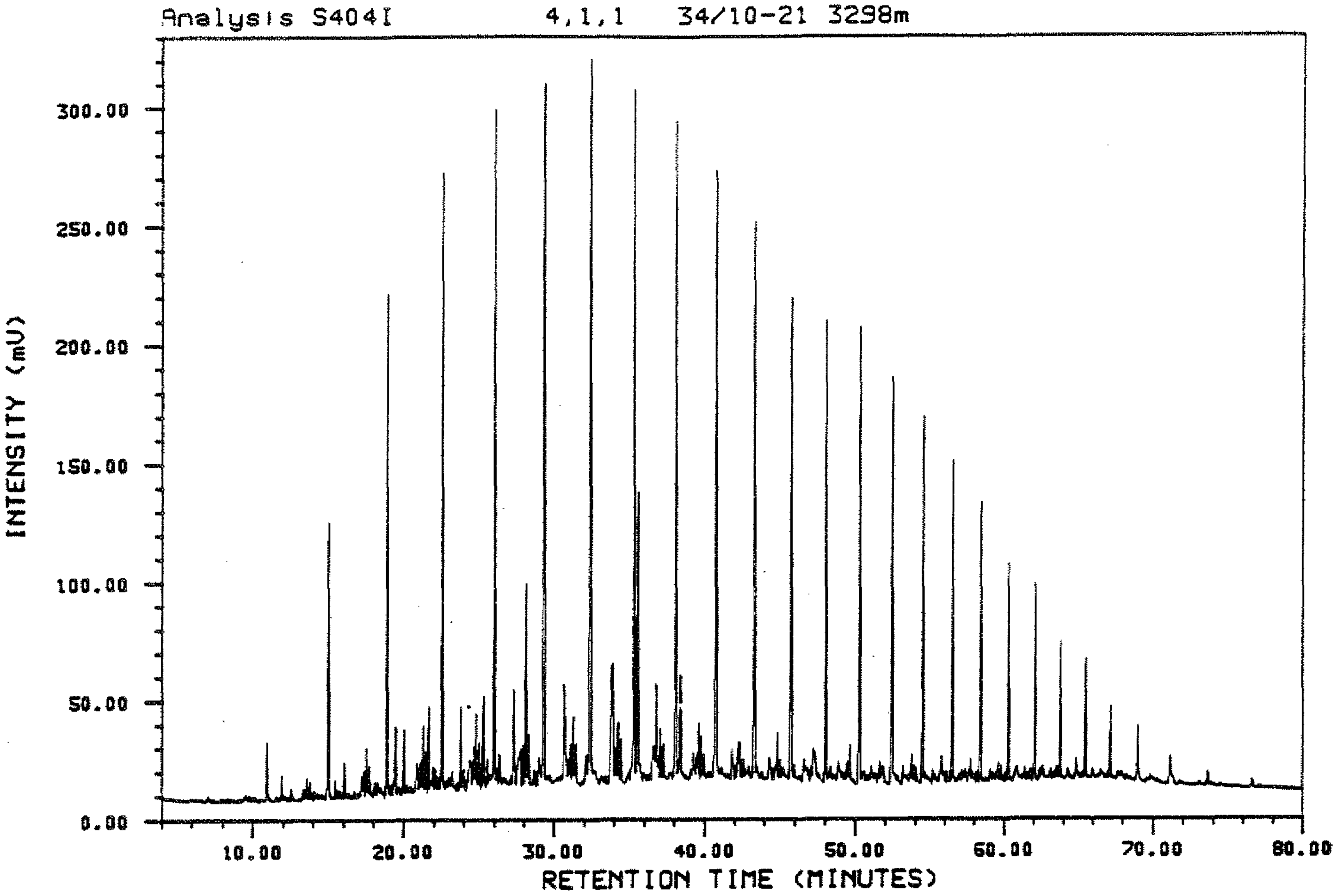
PYROLYSIS GC



STANDARD TRACES ILLUSTRATED ON FIRST SHEET
NORMAL ALKENE/ALKANE DOUBLETS
IDENTIFIED BY CARBON NUMBERS

Bz - Benzene
To - Toluene

FIGURE 8a


Analysis S404I
4,1,1
34/10-21 3298m
INTENSITY (mU)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

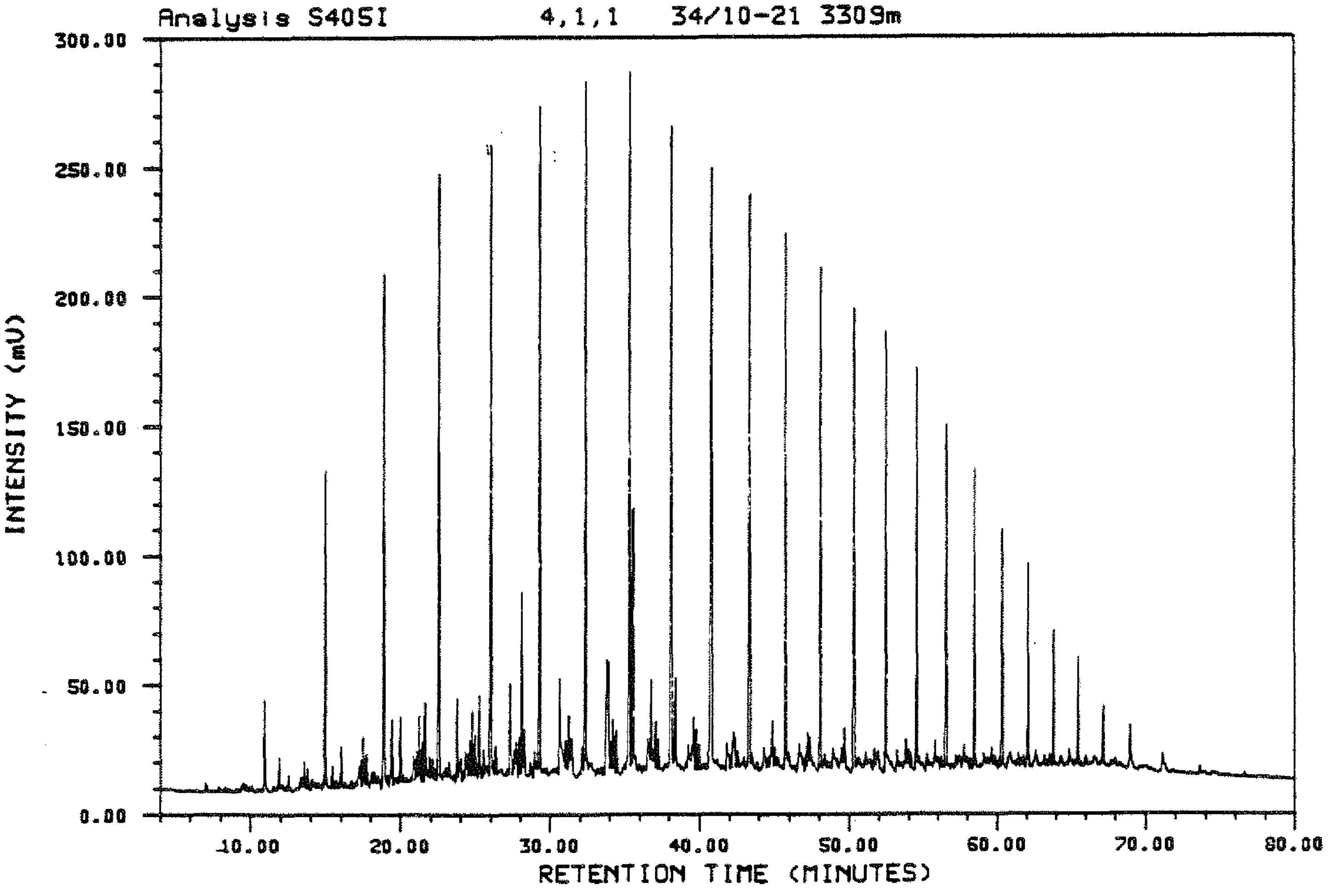

Analysis S405I
4,1,1
34/10-21 3309m
INTENSITY (mU)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

FIGURE 8b

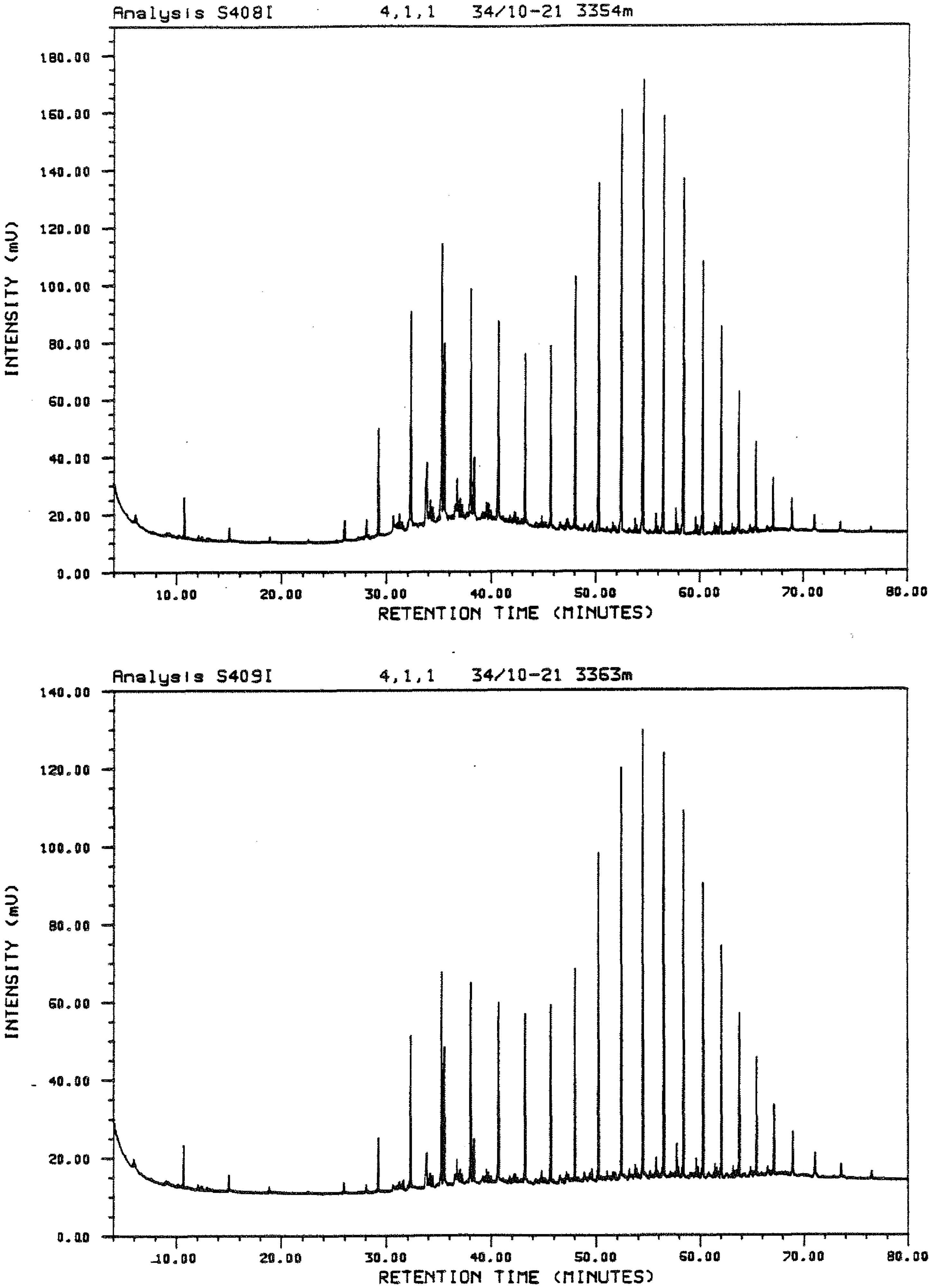
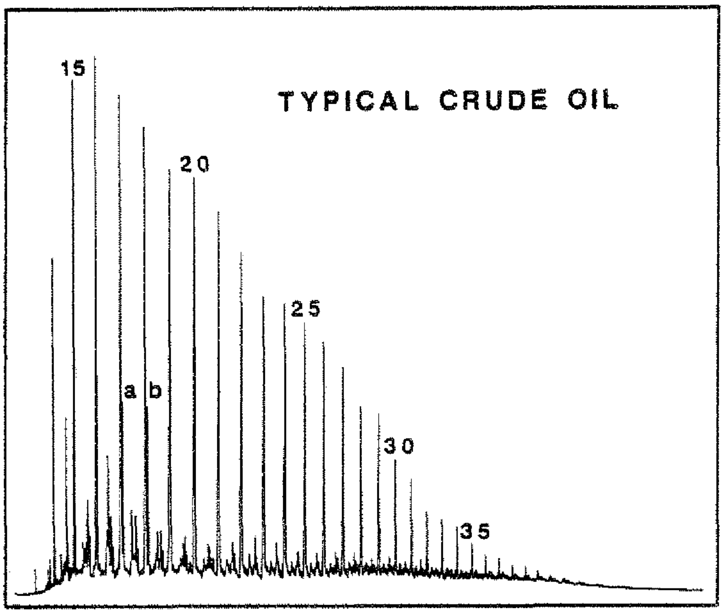
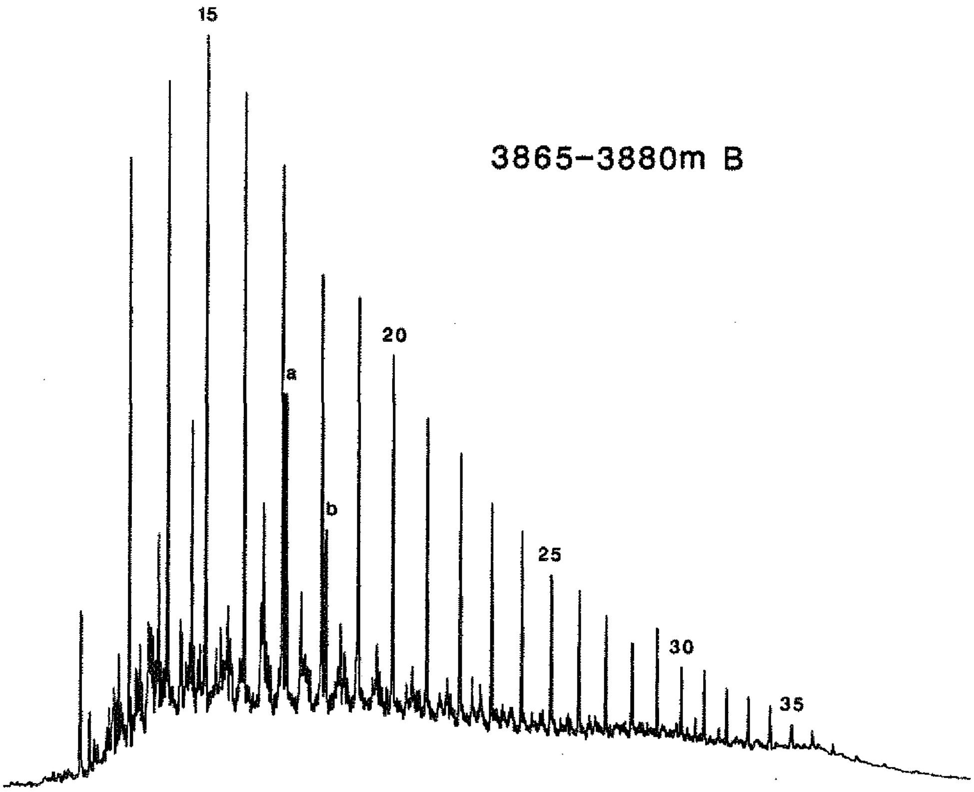

Analysis S408I 4,1,1 34/10-21 3354m
INTENSITY (mU)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)
Analysis S409I 4,1,1 34/10-21 3363m
INTENSITY (mU)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

FIGURE 8c C_{15+} SATURATES CHROMATOGRAMS

WELL 34/10-23





a - PRISTANE

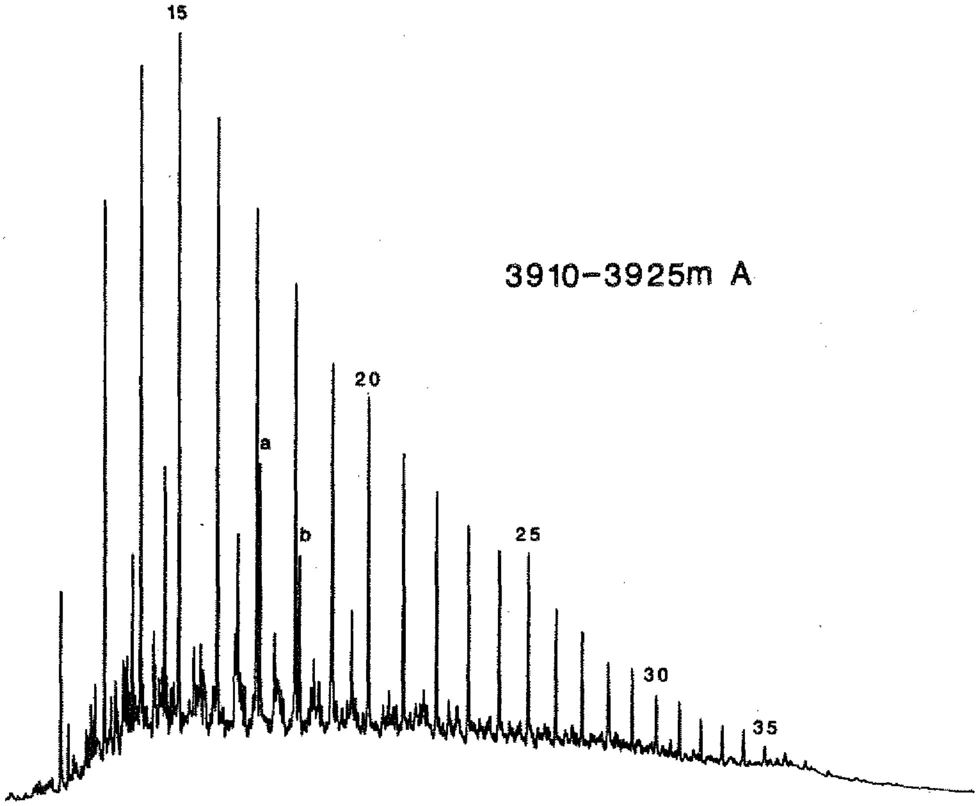
b - PHYTANE

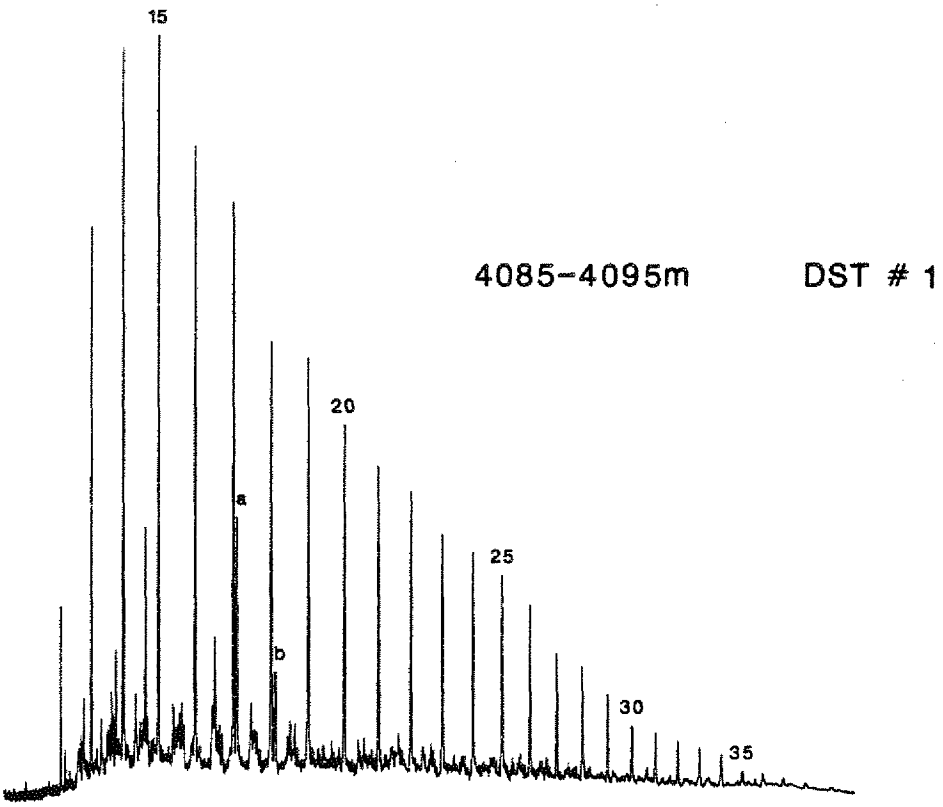
CARBON NUMBERS OF NORMAL PARAFFINS INDICATED (20-nC_{20})

FIGURE 8d

C_{15+} SATURATES CHROMATOGRAMS

WELL 34/10-23





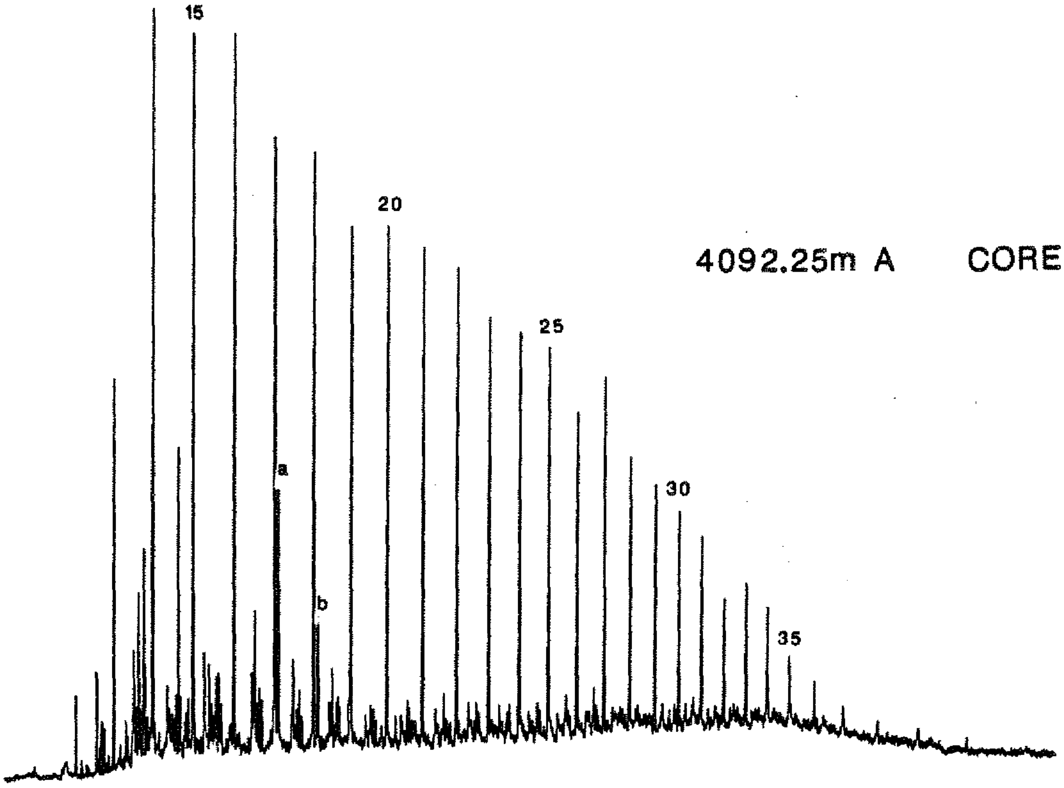
a - PRISTANE

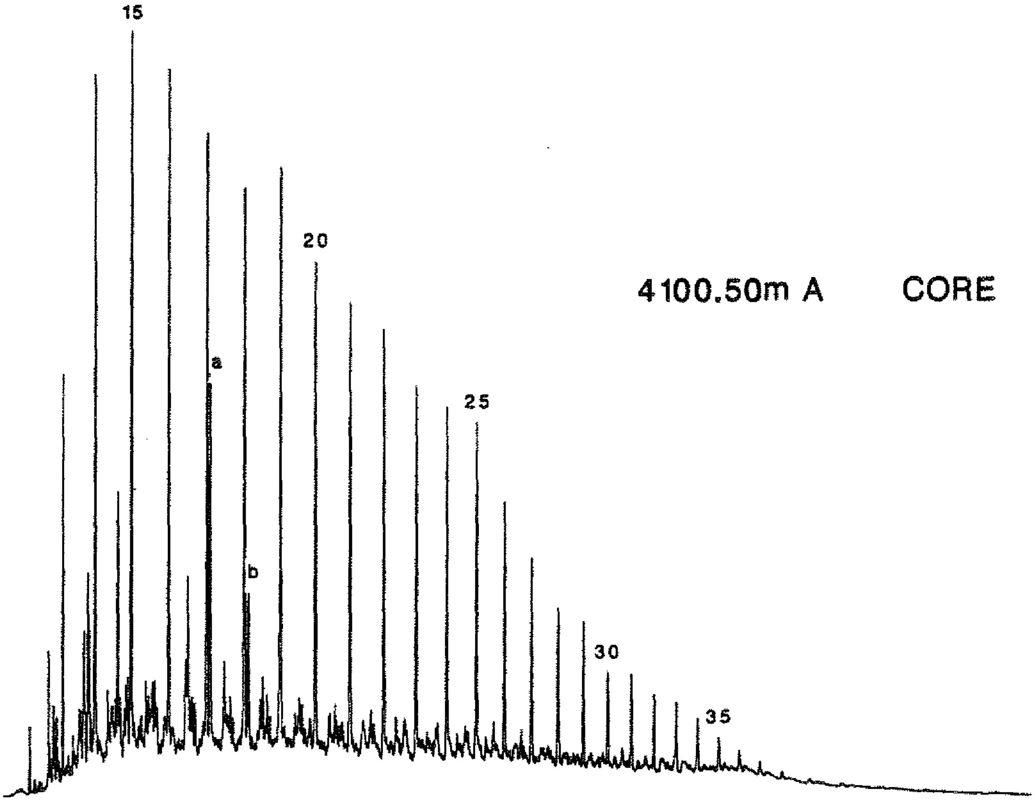
b - PHYTANE

CARBON NUMBERS OF NORMAL PARAFFINS INDICATED (20 - nC_{20})

FIGURE 8e C_{15+} SATURATES CHROMATOGRAMS

WELL 34/10-23





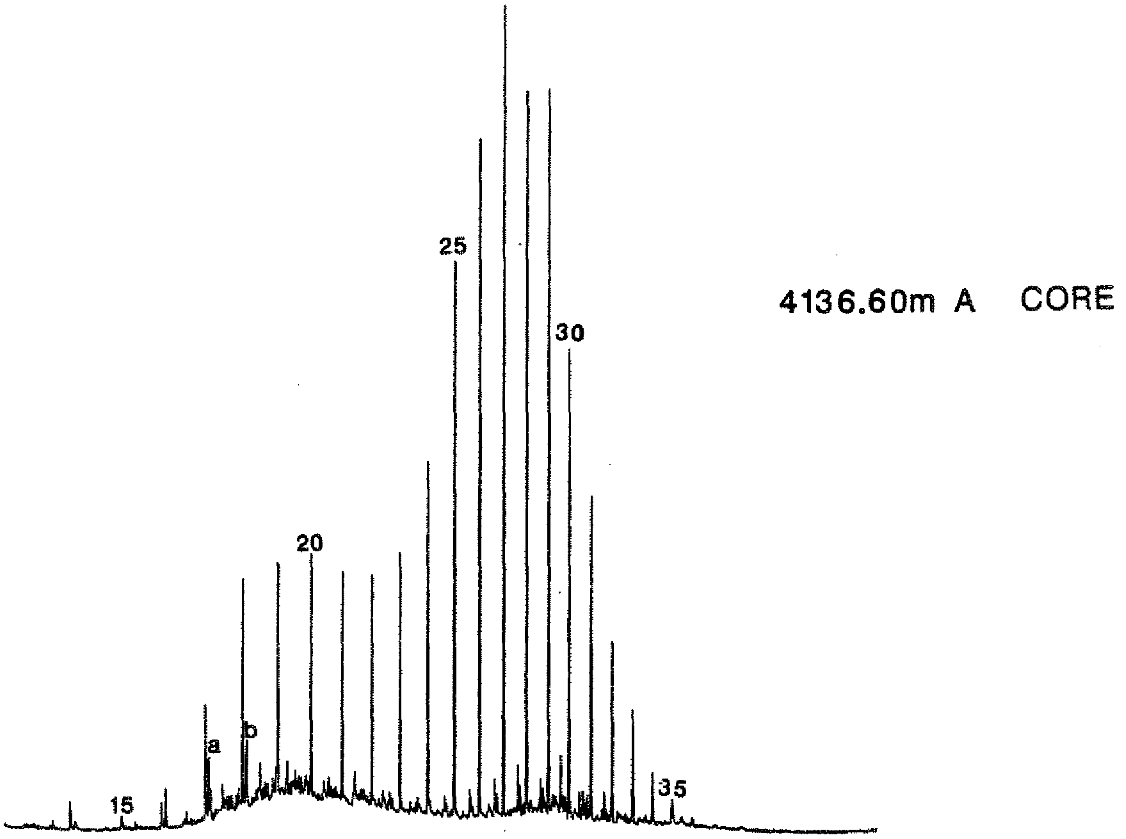
a - PRISTANE
b - PHYTANE

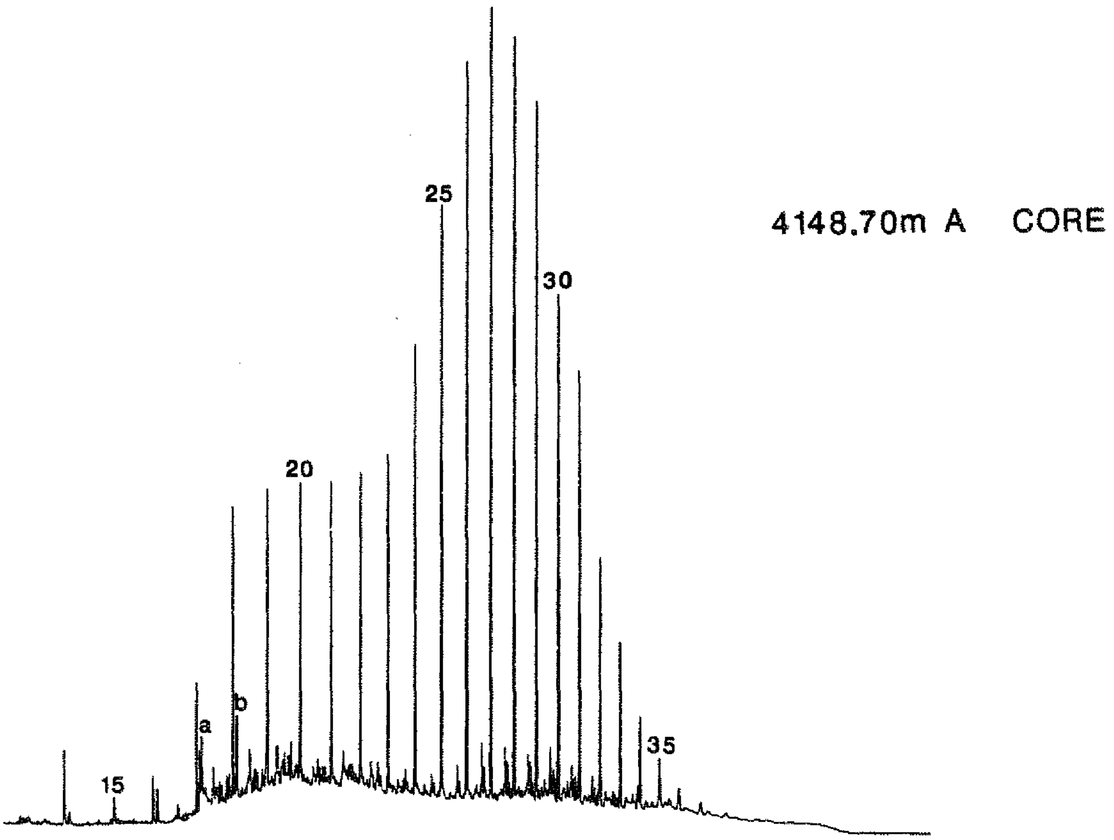
CARBON NUMBERS OF NORMAL PARAFFINS INDICATED (20 - nC_{20})

FIGURE 8f

C_{15+} SATURATES CHROMATOGRAMS

WELL 34/10-23





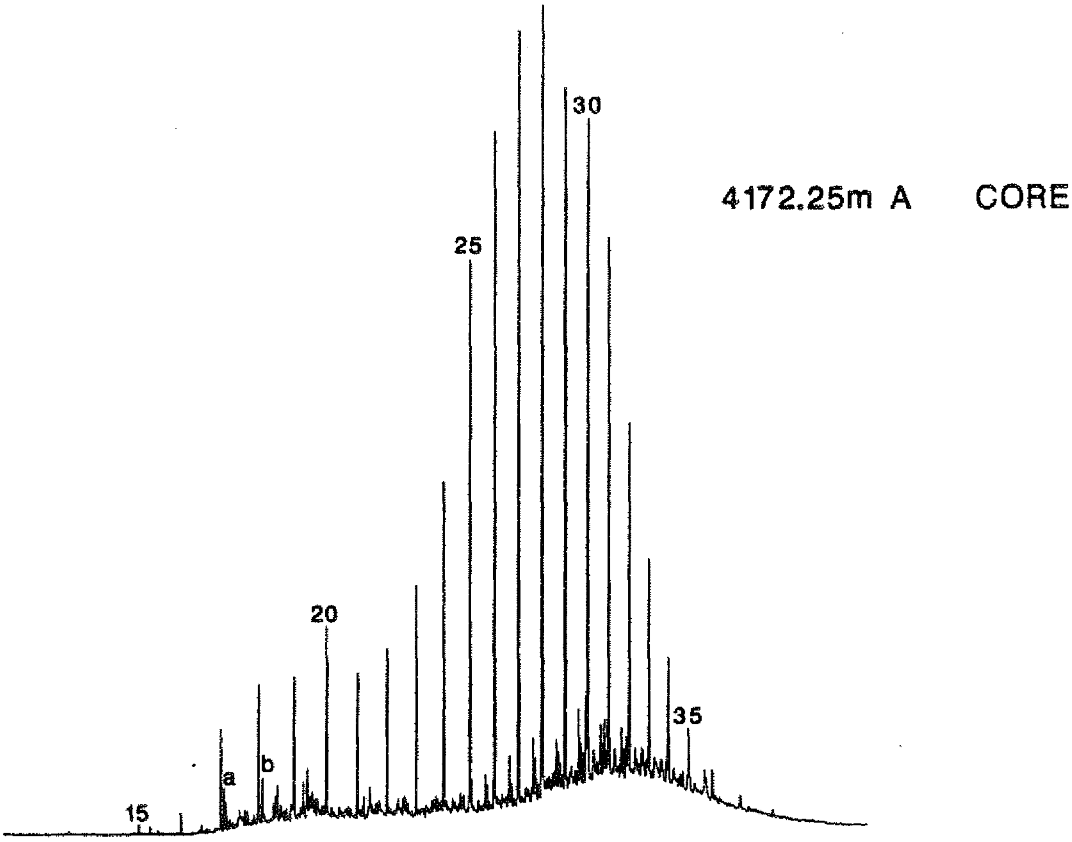
a - PRISTANE
b - PHYTANE

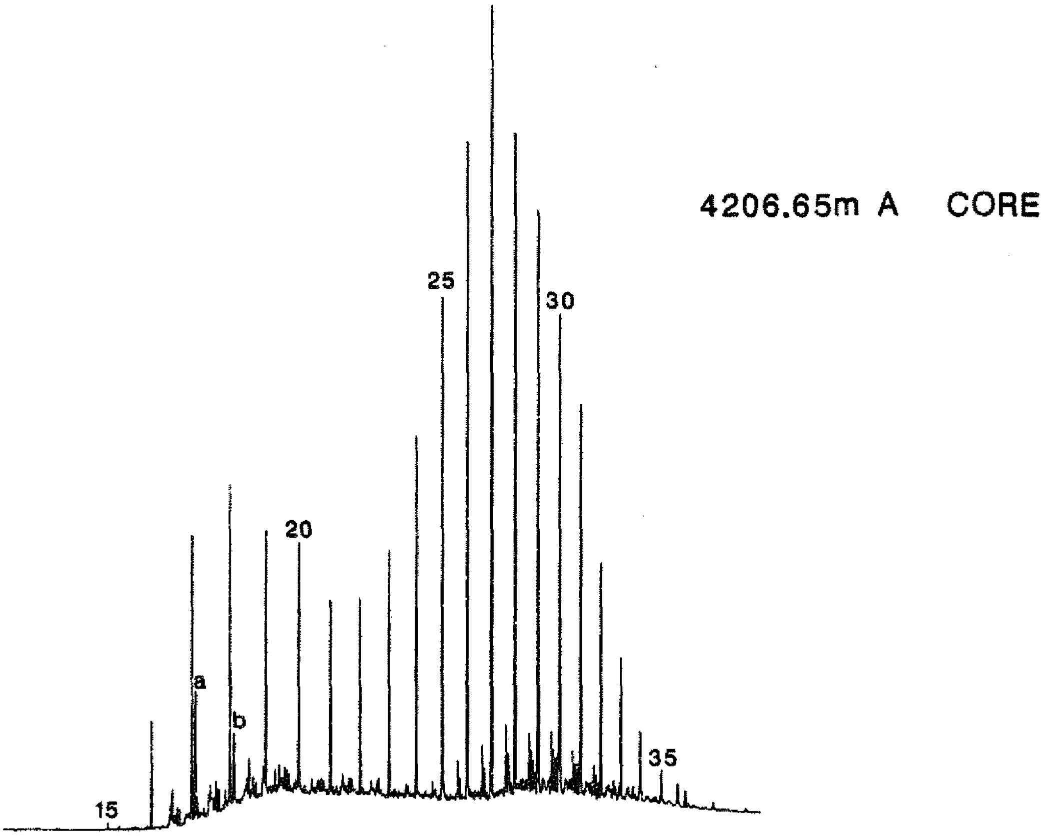
CARBON NUMBERS OF NORMAL PARAFFINS INDICATED (20 - nC_{20})

FIGURE 8g

C_{15+} SATURATES CHROMATOGRAMS

WELL 34/10-23





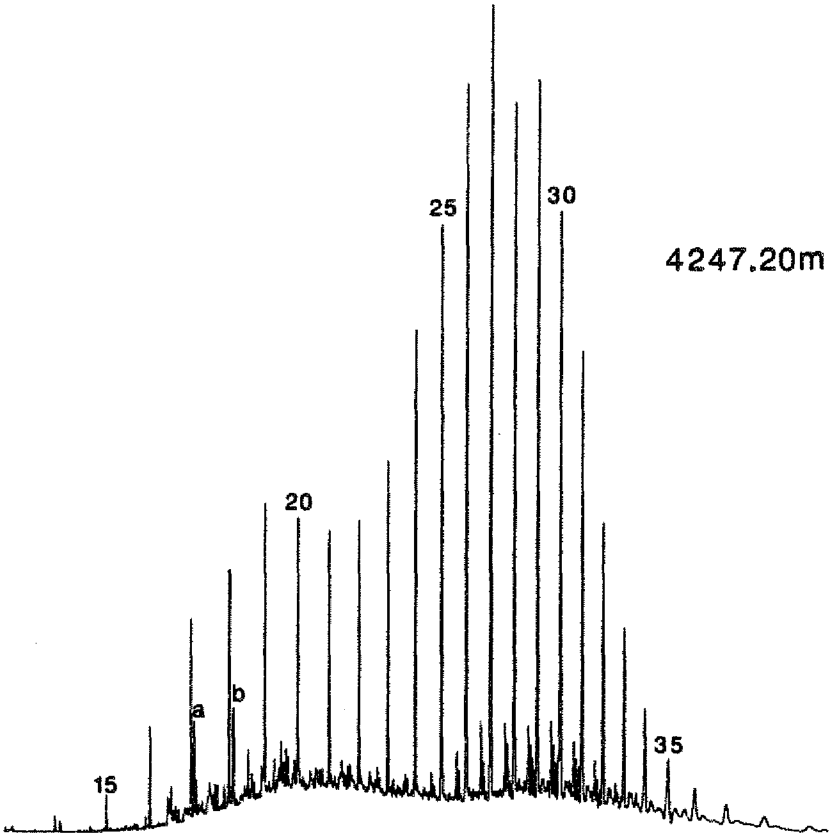
a - PRISTANE
b - PHYTANE

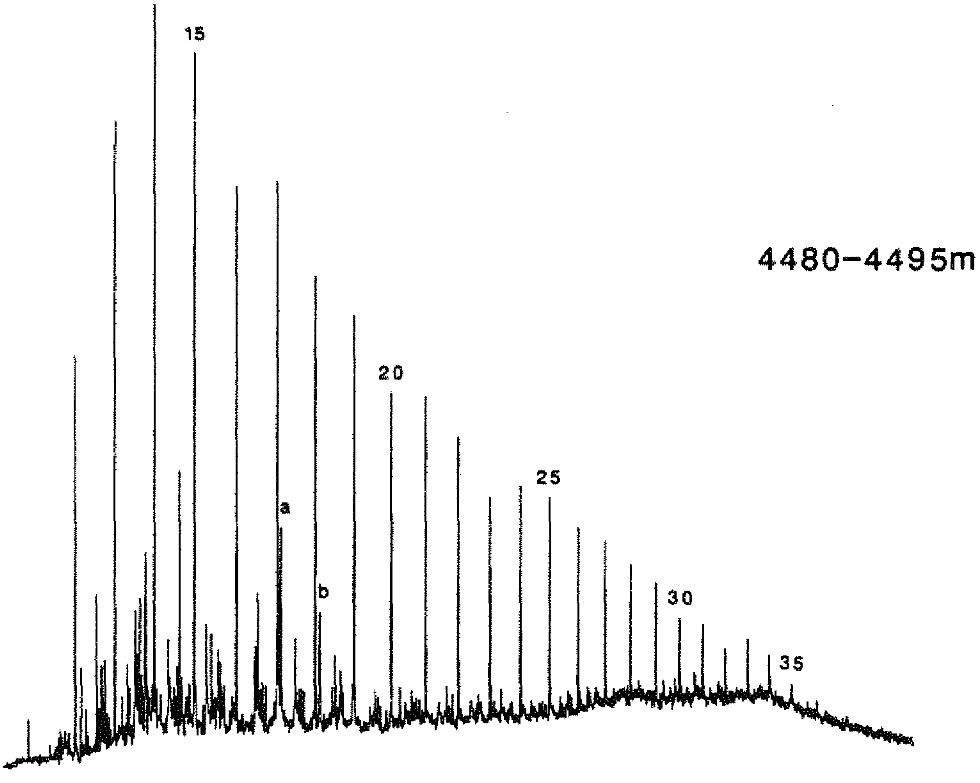
CARBON NUMBERS OF NORMAL PARAFFINS INDICATED (20 - nC_{20})

FIGURE 8h

WELL 34/10-23

C_{15+} SATURATES CHROMATOGRAMS



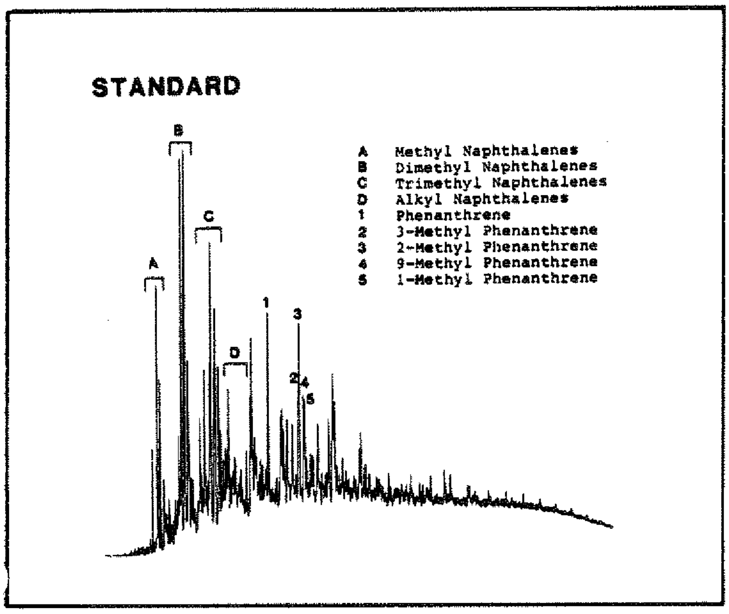


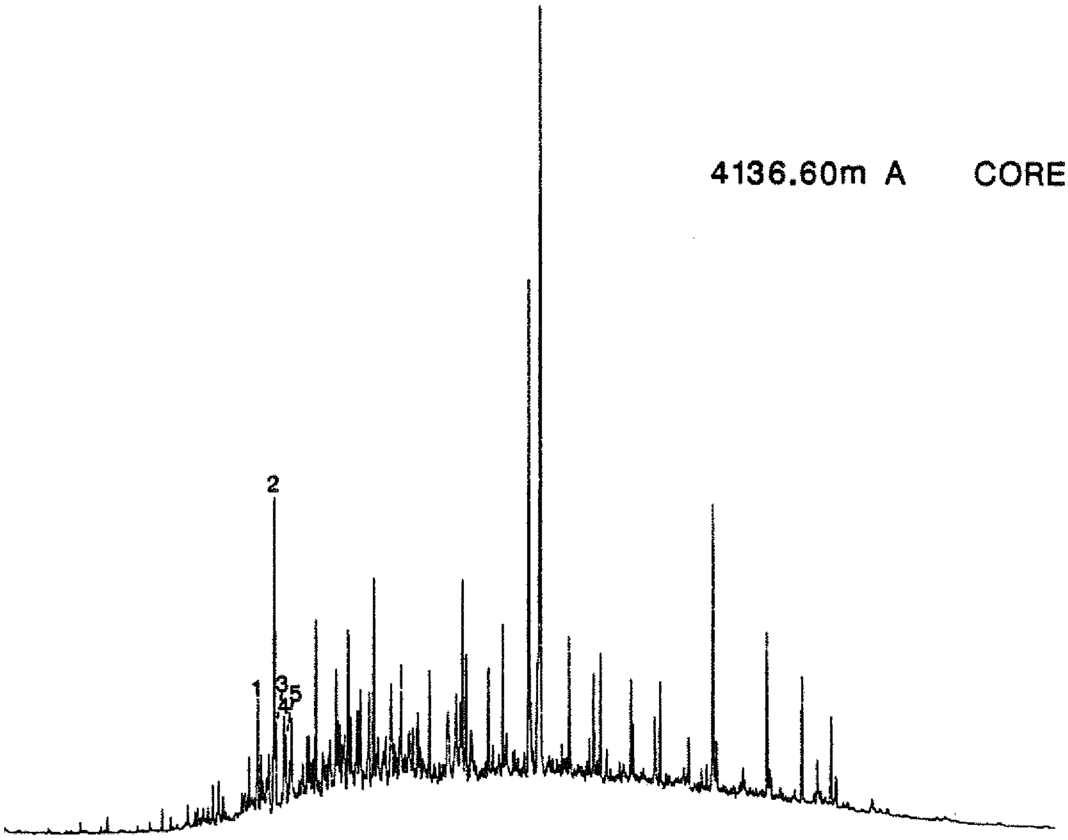
a - PRISTANE
b - PHYTANE

CARBON NUMBERS OF NORMAL PARAFFINS INDICATED (20 - nC_{20})

FIGURE 9a C_{15+} AROMATIC CHROMATOGRAMS

WELL 34/10-23





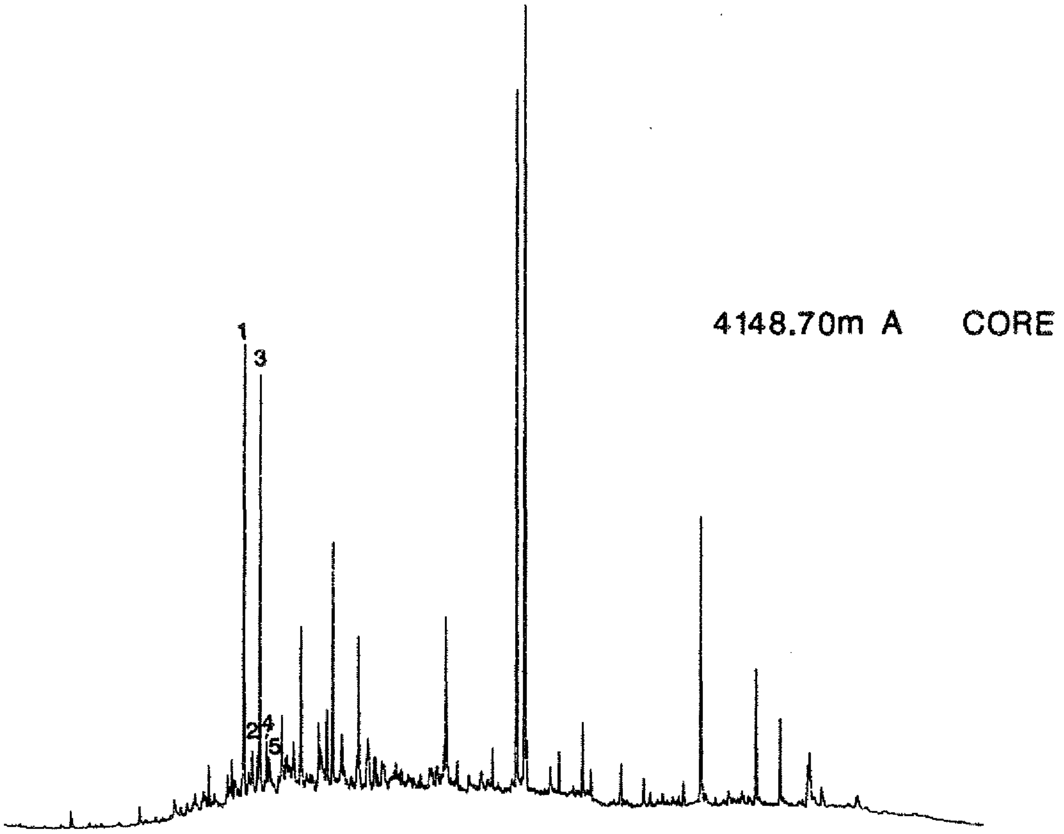
4136.60m A CORE

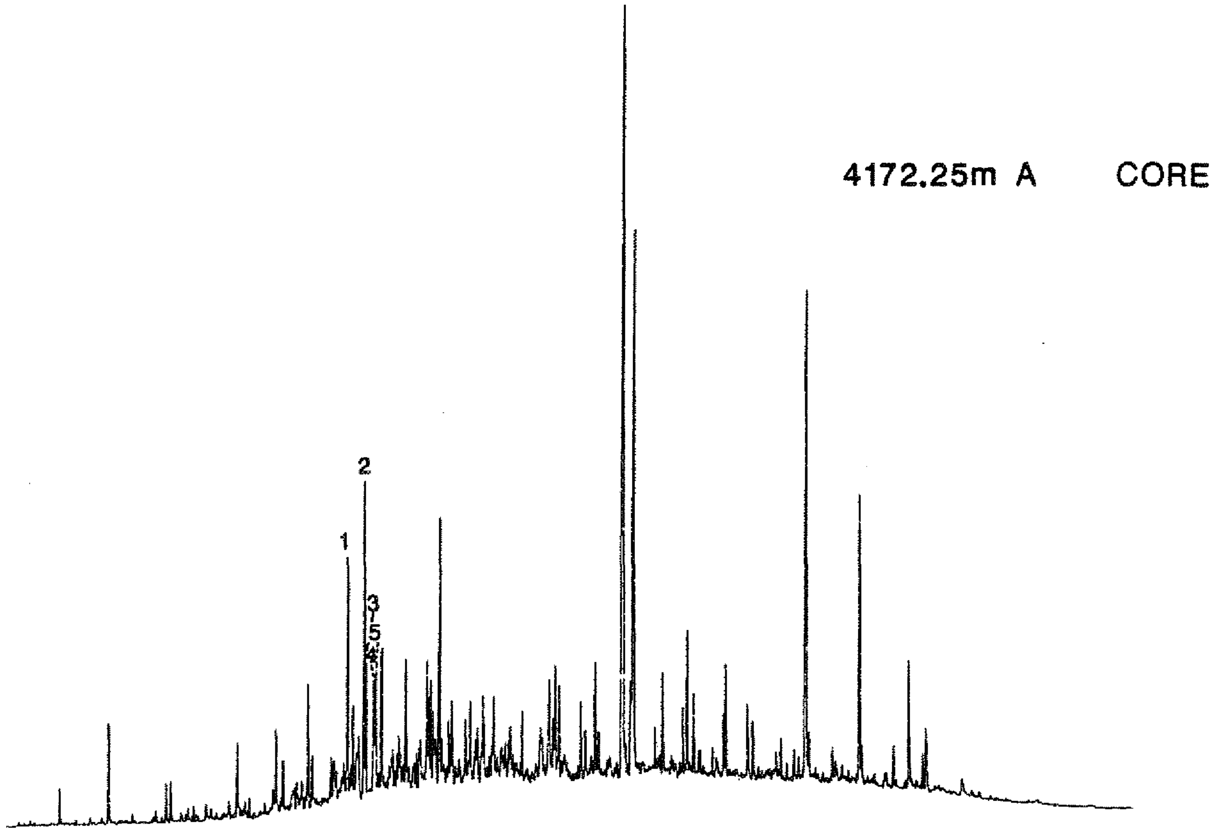
FIGURE 9b

C_{15+} AROMATIC CHROMATOGRAMS

WELL 34/10-23

GEOCHEM



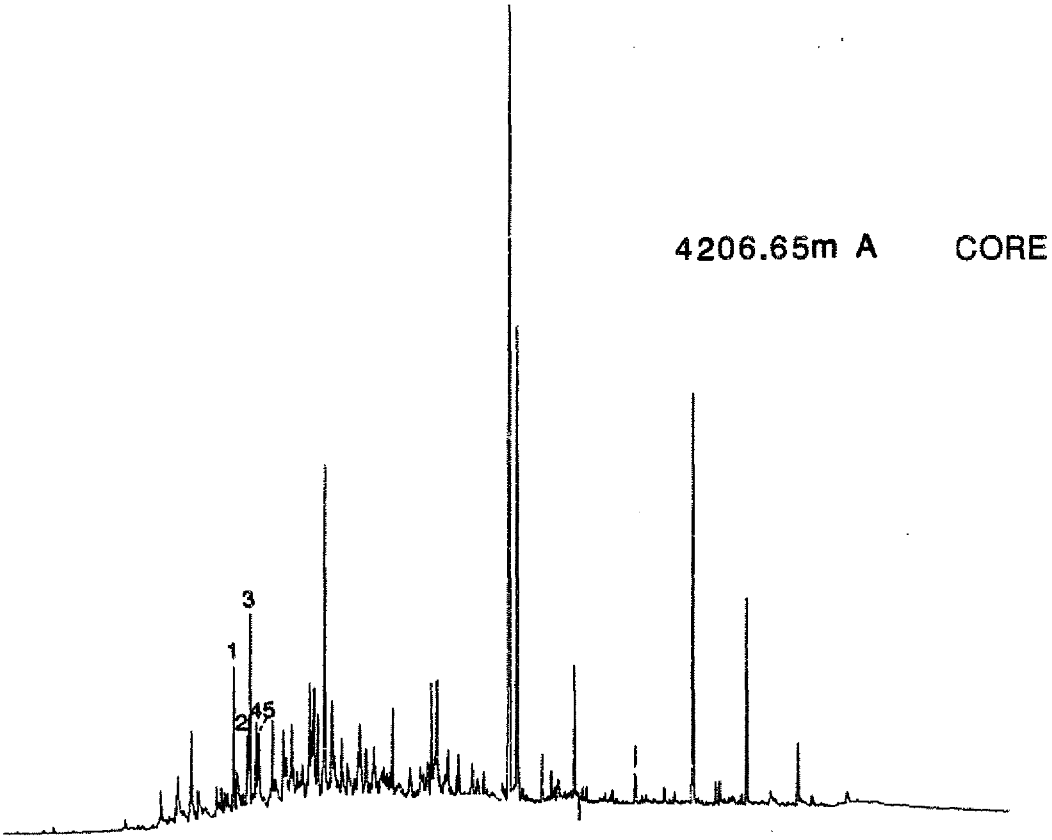


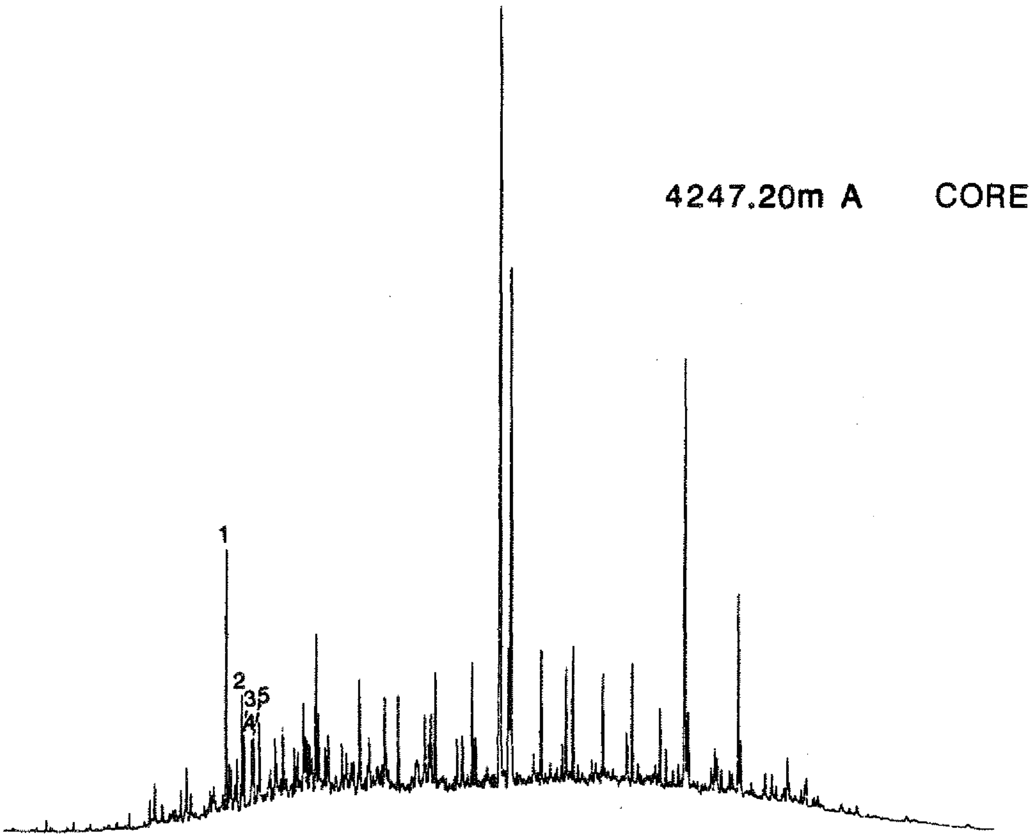
PEAK IDENTIFICATION ON FIRST SHEET

FIGURE 9c

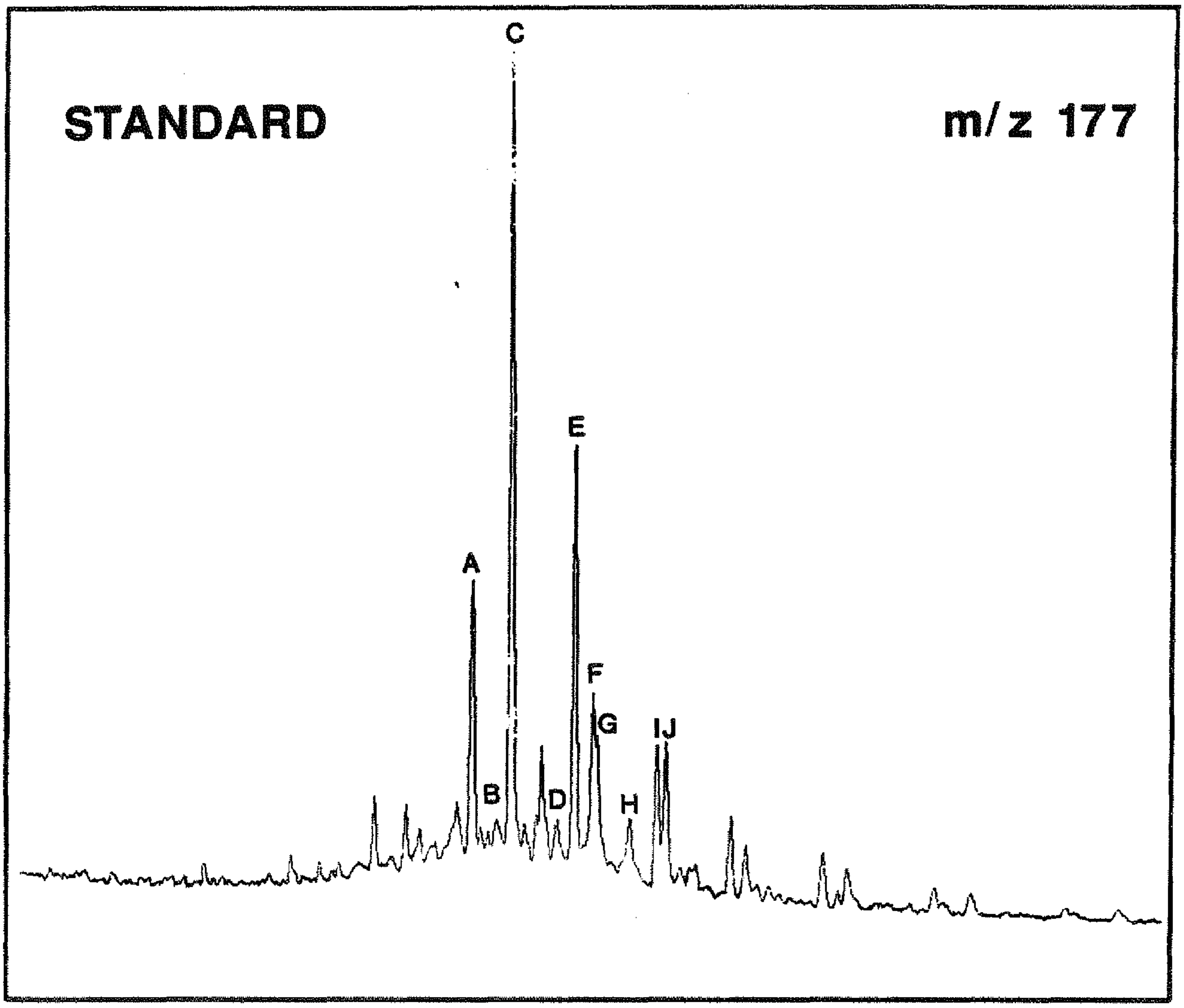
C_{15+} AROMATIC CHROMATOGRAMS

WELL 34/10-23





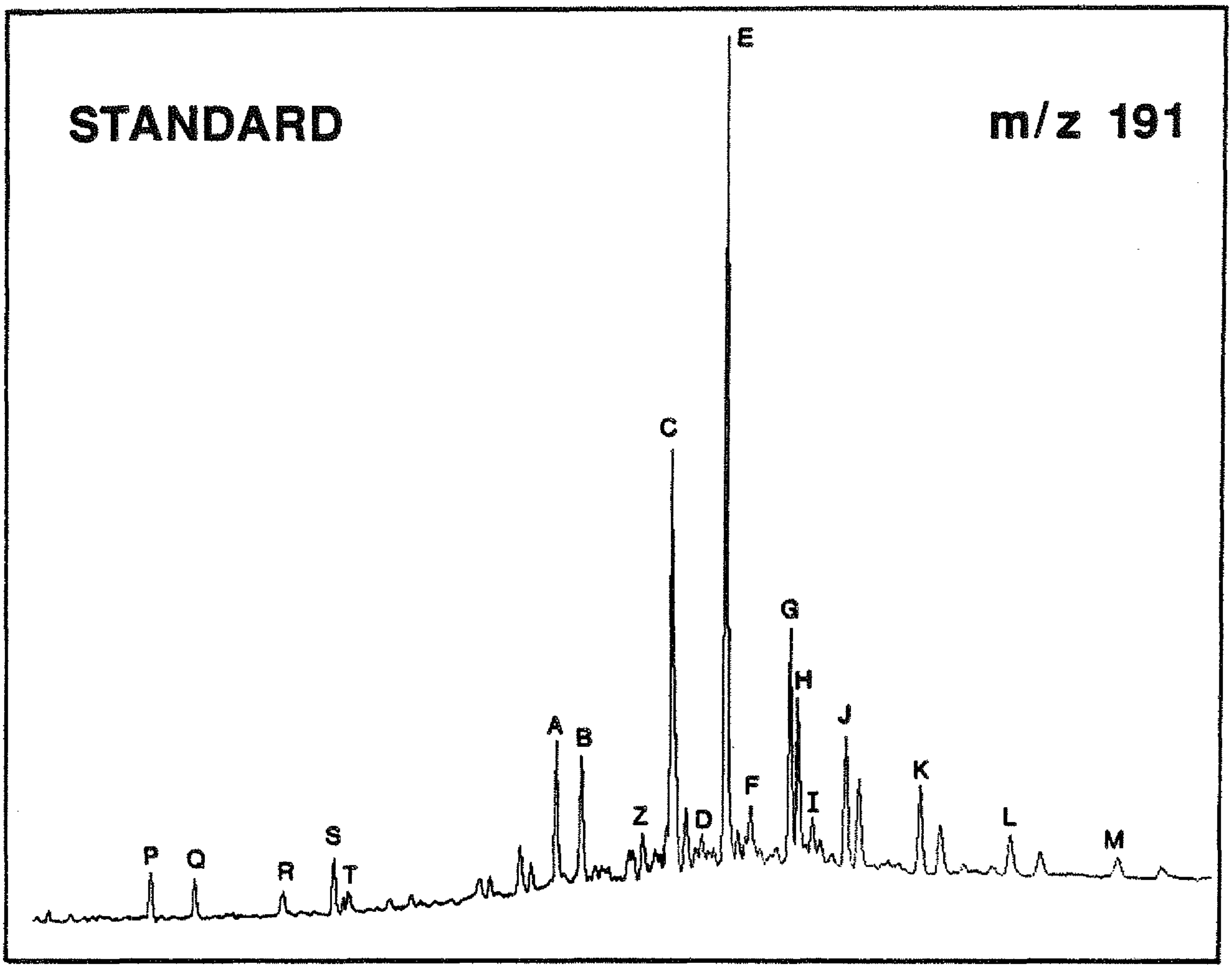
PEAK IDENTIFICATION ON FIRST SHEET



DEMETHYLATED HOPANES

(m/z 177 FRAGMENTOGRAM)

	COMPOUND	
A	17α (H), 18α (H), 21β (H) 25, 28, 30 - trisnorhopane	C_{27}
B	17β (H), 18α (H), 21α (H) 25, 28, 30 - trisnormoretane	
C	17α (H) -25, 30 - bisnorhopane	C_{28}
D	17α (H), 18α (H), 21β (H) -28, 30 bisnorhopane	
E	17α (H) -25 - norhopane	
F	17α (H) -30 - norhopane	
G	?	
H	17β (H) -30 - normoretane	
I	(22S) -17α (H) -25 - norhomohopane	
J	(22R) -17α (H) - homohopane	



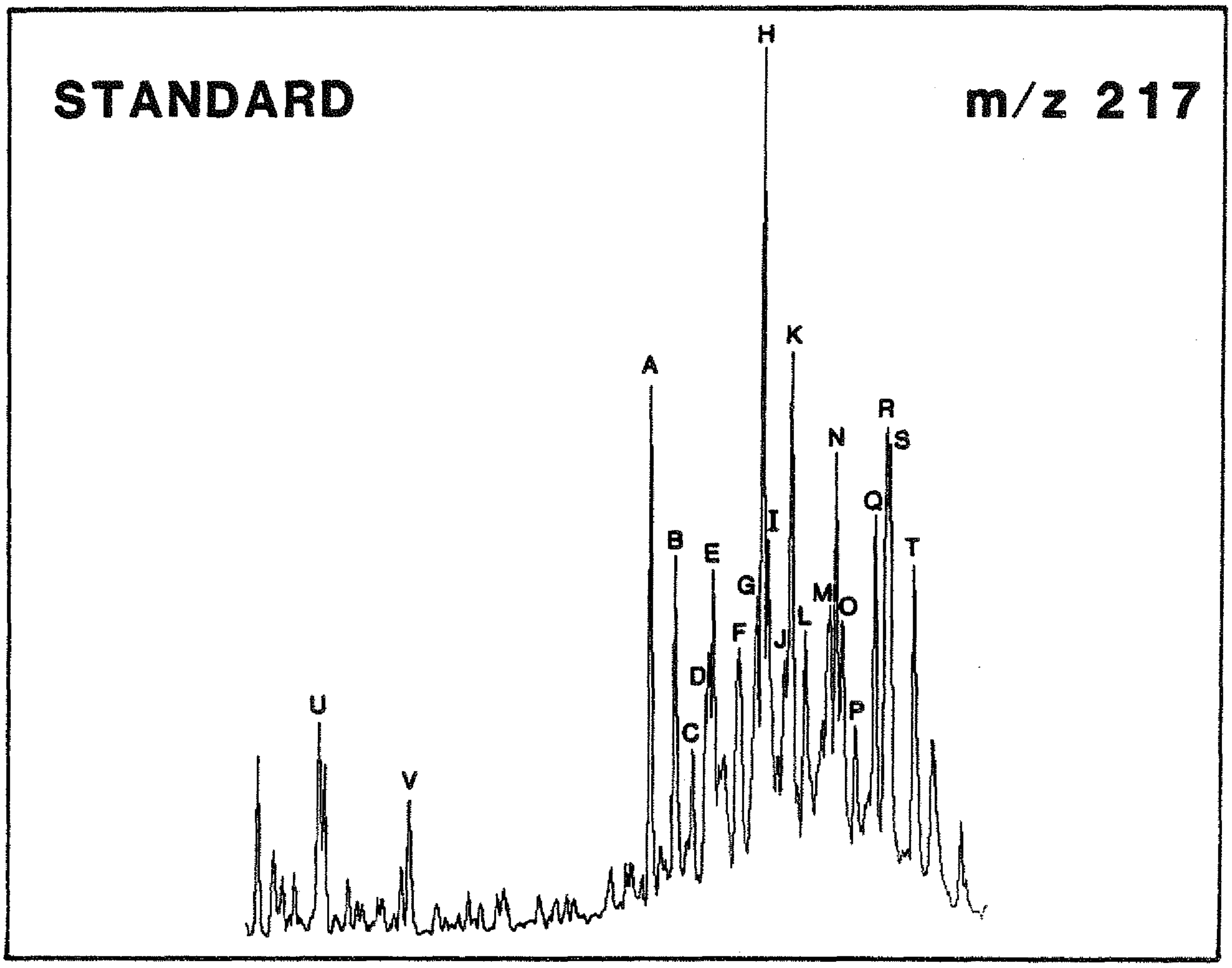
TRITERPANE IDENTIFICATION

(M/Z 191 FRAGMENTOGRAM)

	COMPOUND	ELEMENTAL COMPOSITION
A	18 (H),21 (H)-trisnorneohopane (Ts)	$C_{27}H_{46}$
B	17 (H),21 (H)-trisnorhopane (Tm)	$C_{27}H_{46}$
C	17 (H),21 (H)-norhopane	$C_{29}H_{50}$
D	17 (H),21 (H)-norhopane (normoretane)	$C_{29}H_{50}$
E	17 (H),21 (H)-hopane	$C_{30}H_{52}$
F	17 (H),21 (H)-hopane (moretane)	$C_{30}H_{52}$
G	17 (H),21 (H)-homohopane (22S)	$C_{31}H_{54}$
H	17 (H),21 (H)-homohopane (22R)	$C_{31}H_{54}$
I	17 (H),21 (H)-homohopane (homomoretane)	$C_{31}H_{54}$
J	17 (H),21 (H)-bishomohopane (22S and 22R)	$C_{32}H_{56}$
K	17 (H),21 (H)-trishomohopane (22S and 22R)	$C_{33}H_{58}$
L	17 (H),21 (H)-tetrakishomohopane (22S and 22R)	$C_{34}H_{58}$
M	17 (H),21 (H)-pentakishomohopane (22S and 22R)	$C_{35}H_{60}$
Z	= C_{28} bisnorhopane	

TRICYCLIC AND TETRACYCLIC TERPANES (M/Z 191)

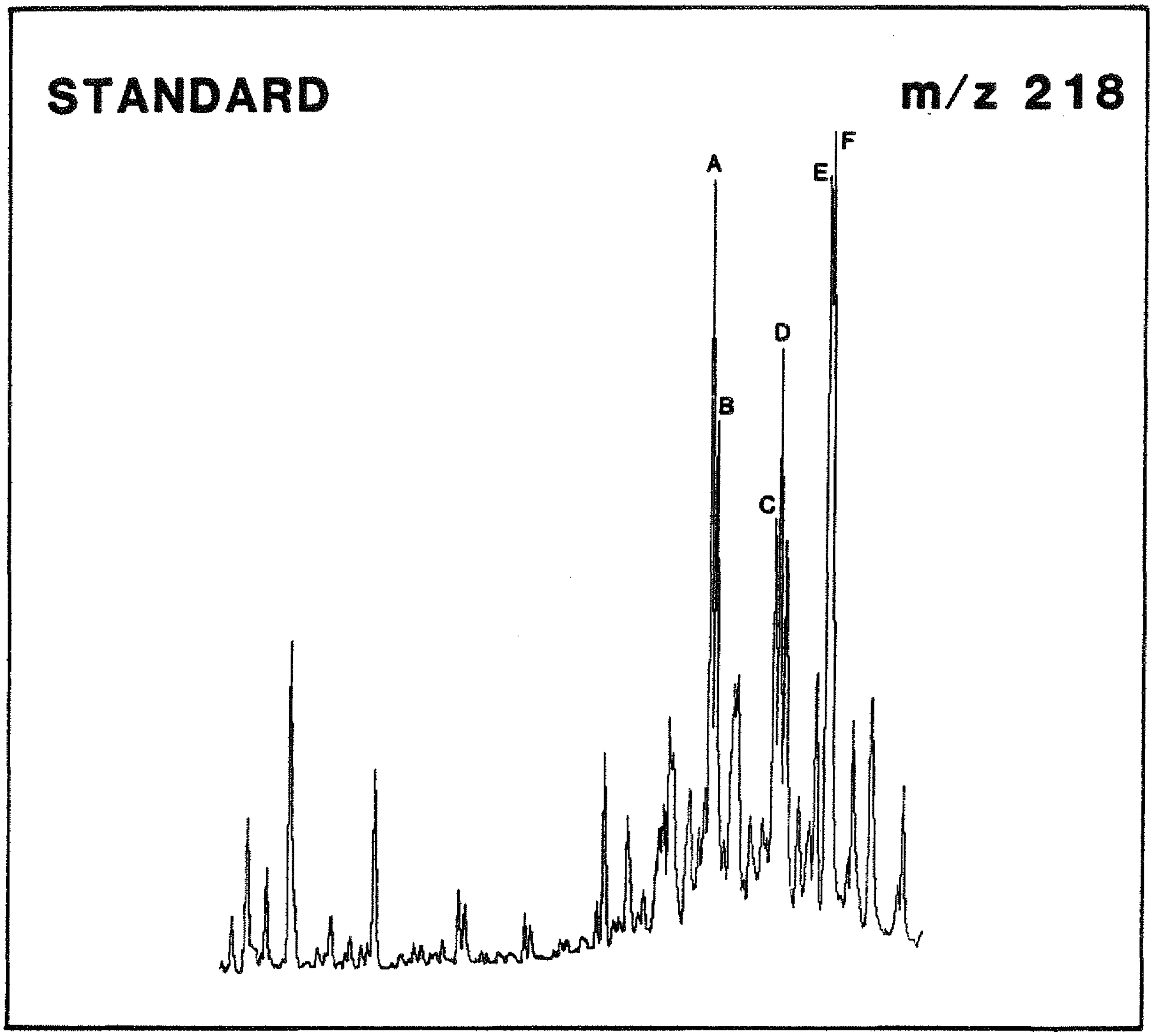
P	$C_{23}H_{42}$
Q	$C_{24}H_{44}$
R	$C_{25}H_{46}$
S	$C_{24}H_{42}$
T	$C_{26}H_{48}$



STERANE IDENTIFICATION

(M/Z 217 FRAGMENTOGRAM)

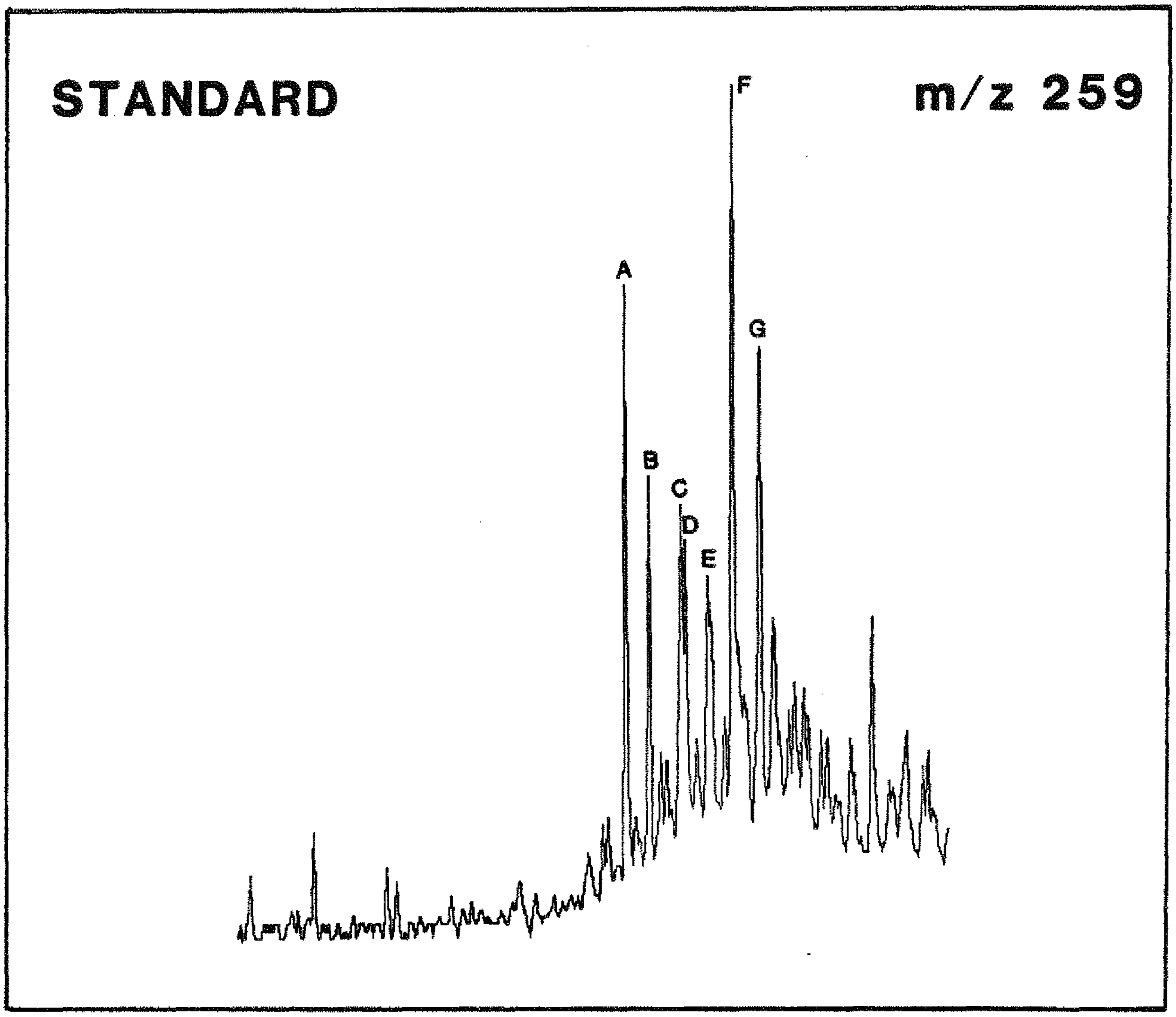
	COMPOUND	ELEMENTAL COMPOSITION
A	13β,17α-diacholestane (20S)	$C_{27}H_{48}$
B	13β,17α-diacholestane (20R)	$C_{27}H_{48}$
C	13α,17β-diacholestane (20S)	$C_{27}H_{48}$
D	13α,17β-diacholestane (20R)	$C_{27}H_{48}$
E	24-methyl-13β,17α-diacholestane (20S)	$C_{28}H_{50}$
F	24-methyl-13β,17α-diacholestane (20R)	$C_{28}H_{50}$
G	24-methyl-13α,17β-diacholestane (20S)	$C_{28}H_{50}$
+	14α,17α-cholestane (20S)	$C_{27}H_{48}$
H	24-ethyl-13β,17α-diacholestane (20S)	$C_{29}H_{52}$
+	14β,17β-cholestane (20R)	$C_{27}H_{48}$
I	14β,17β-cholestane (20S)	$C_{27}H_{48}$
+	24-methyl-13α,17β-diacholestane (20R)	$C_{28}H_{50}$
J	14α,17α-cholestane (20R)	$C_{27}H_{48}$
K	24-ethyl-13β,17α-diacholestane (20R)	$C_{29}H_{52}$
L	24-ethyl-14α,17β-diacholestane (20S)	$C_{29}H_{52}$
M	24-methyl-13α,17α-cholestane (20S)	$C_{28}H_{50}$
N	24-ethyl-13α,17β-diacholestane (20R)	$C_{29}H_{52}$
+	24-methyl-14β,17β-cholestane (20R)	$C_{28}H_{50}$
O	24-methyl-14β,17β-cholestane (20S)	$C_{28}H_{50}$
P	24-methyl-14α,17α-cholestane (20R)	$C_{28}H_{50}$
Q	24-ethyl-14α,17α-cholestane (20S)	$C_{29}H_{52}$
R	24-ethyl-14β,17β-cholestane (20R)	$C_{29}H_{52}$
+	UNKNOWN STERANE	
S	24-ethyl-14β,17β-cholestane (20S)	$C_{29}H_{52}$
T	24-ethyl-14α,17α-cholestane (20R)	$C_{29}H_{52}$
U	5α(H)-pregnane	$C_{21}H_{36}$
V	5α(H)-bisnorcholane	$C_{22}H_{38}$



STERANE IDENTIFICATION

(M/Z 218 FRAGMENTOGRAM)

	COMPOUND	ELEMENTAL COMPOUND
A	14β,17β-cholestane (20R)	$C_{27} H_{48}$
B	14β,17β-cholestane (20S)	$C_{27} H_{48}$
C	24-methyl-14β,17β-cholestane (20R)	$C_{28} H_{50}$
D	24-methyl-14β,17β-cholestane (20S)	$C_{28} H_{50}$
E	24-ethyl-14β,17β-cholestane (20R)	$C_{29} H_{52}$
F	24-ethyl-14β,17β-cholestane (20S)	$C_{29} H_{52}$



STERANE IDENTIFICATION

(M/Z 259 FRAGMENTOGRAM)

	COMPOUND	ELEMENTAL COMPOSITION
A	13β,17α-diacholestane (20S)	$C_{27} H_{48}$
B	13β,17α-diacholestane (20R)	$C_{27} H_{48}$
C	13α,17β-diacholestane (20R)	$C_{27} H_{48}$
D	24,-methyl-13β,17α-diacholestane (20S)	$C_{28} H_{50}$
E	24,-methyl-13β,17α-diacholestane (20R)	$C_{28} H_{50}$
F	24,-ethyl-13β,17α-diacholestane (20S)	$C_{29} H_{52}$
G	24,-ethyl-13β,17α-diacholestane (20R)	$C_{29} H_{52}$

FIGURE 10a

MASS FRAGMENTOGRAMS

WELL 34/10-23

STERANES m/z 217

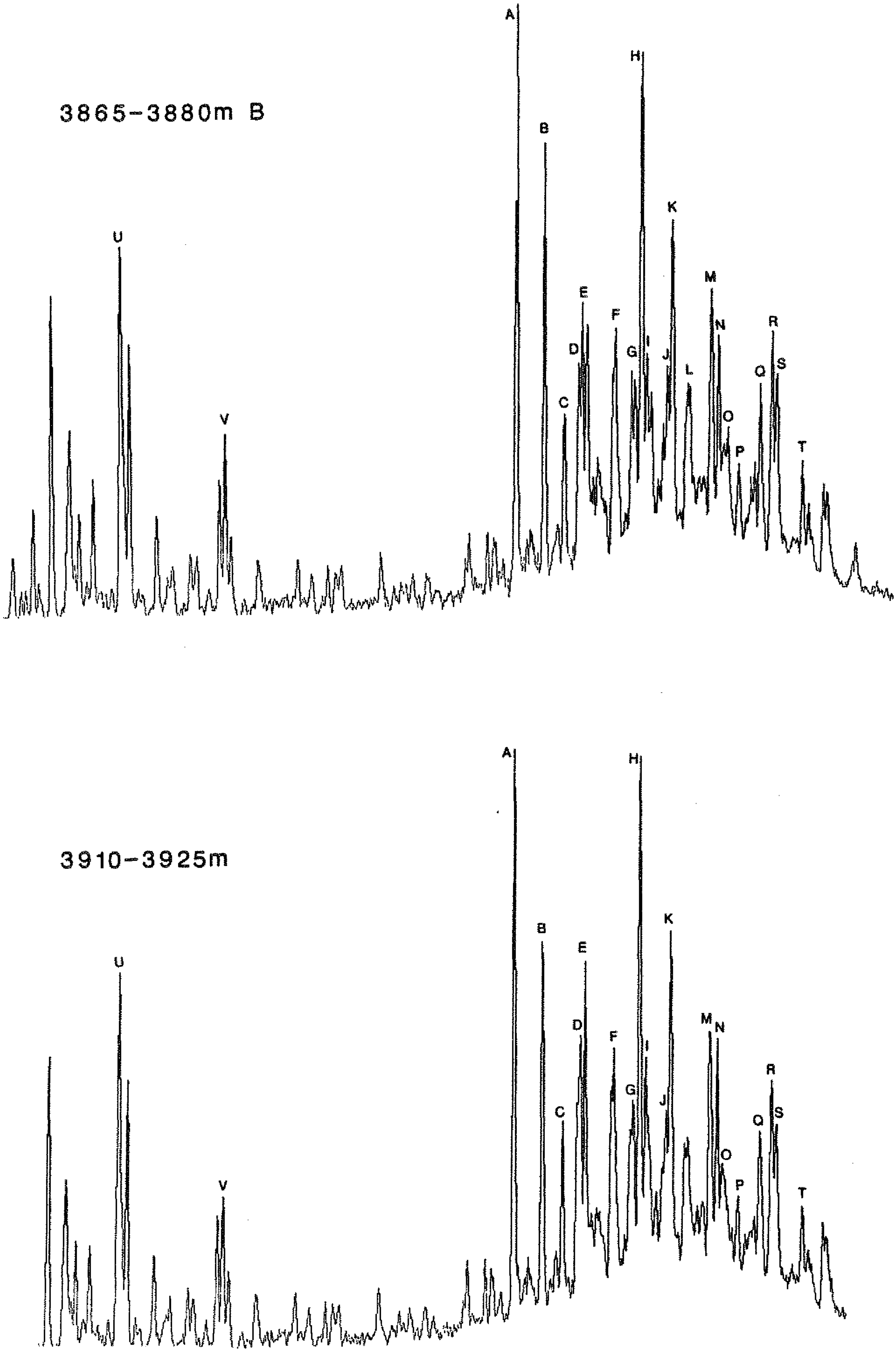


FIGURE 10b

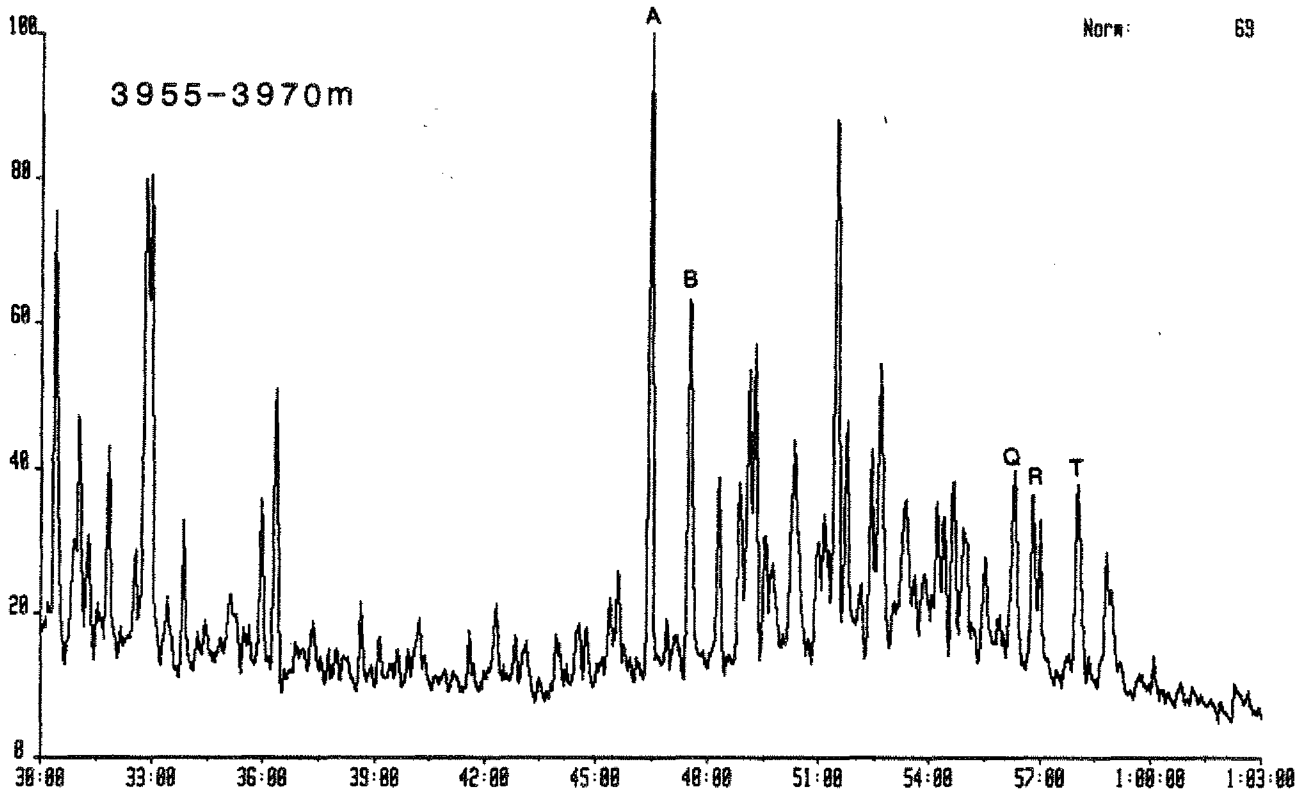
MASS FRAGMENTOGRAMS

GEOCHEM

WELL 34/10-23

STERANES m/z 217

```
1474019   27-JAN-87   Sir:Magnetic TS250   Acnt:STATOIL        System:BIOMARKER
Sample 1   Injection 1   Group 1   Mass 217.1956
Text:BIOMARKERS
```



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1474023   27-JAN-87   Sir:Magnetic TS250   Acnt:STATOIL        System:BIOMARKER
Sample 1   Injection 1   Group 1   Mass 217.1956
Text:BIOMARKERS
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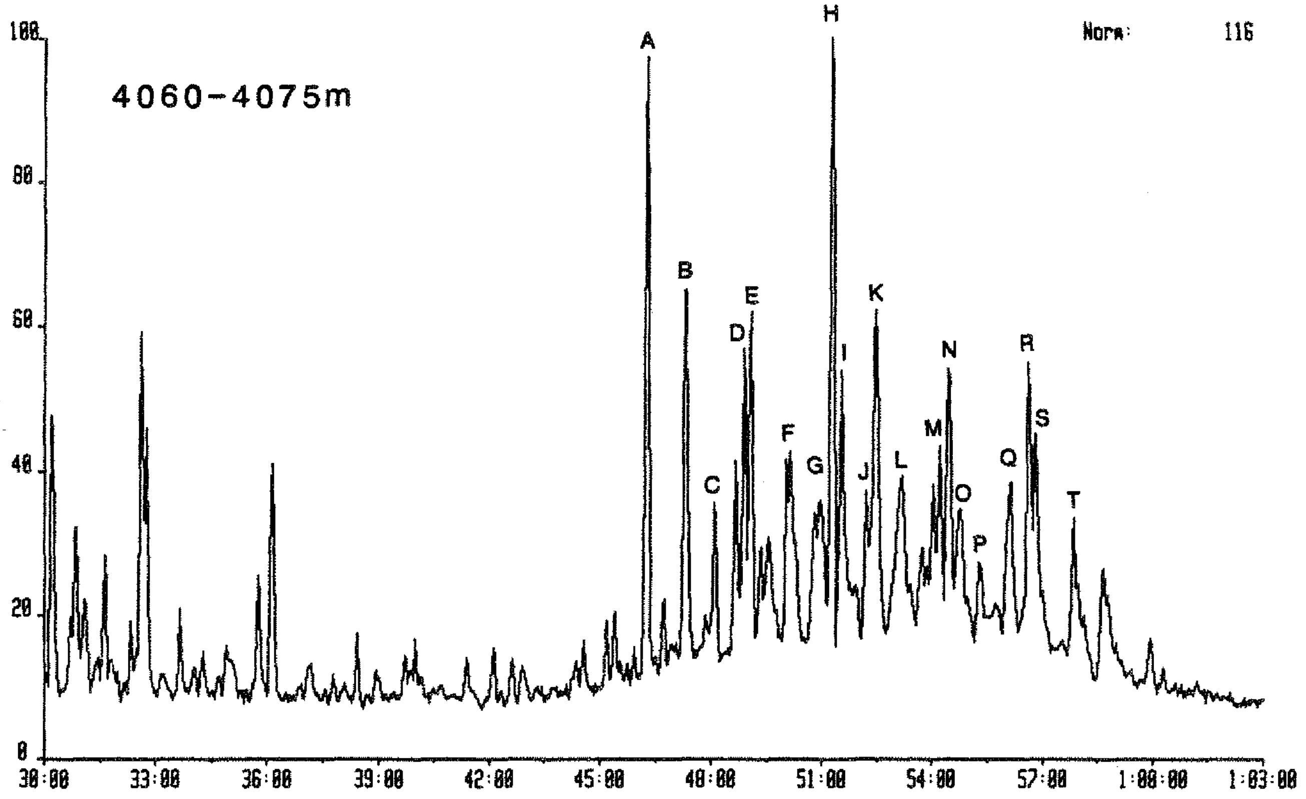


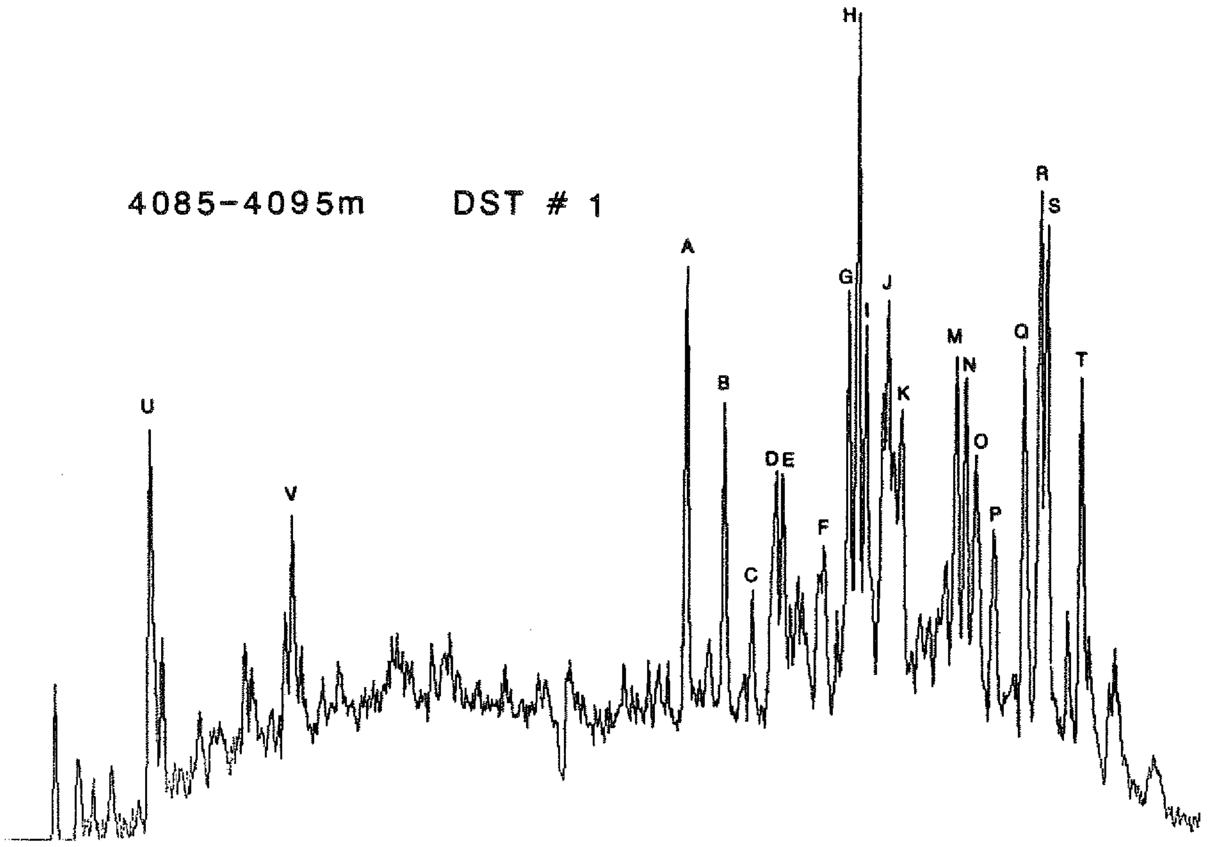
FIGURE 10c

WELL 34/10-23

MASS FRAGMENTOGRAMS

STERANES m/z 217

4085-4095m DST # 1



4092.25m CORE

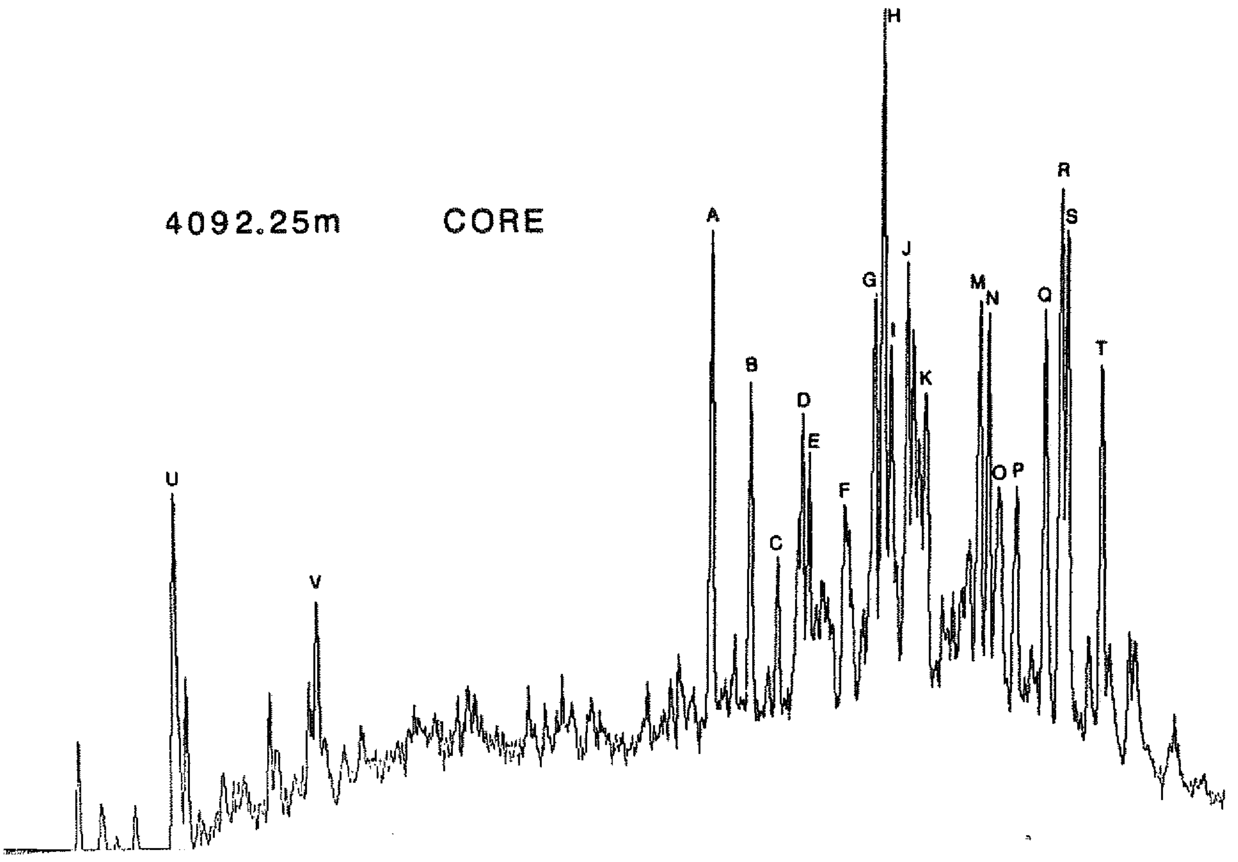


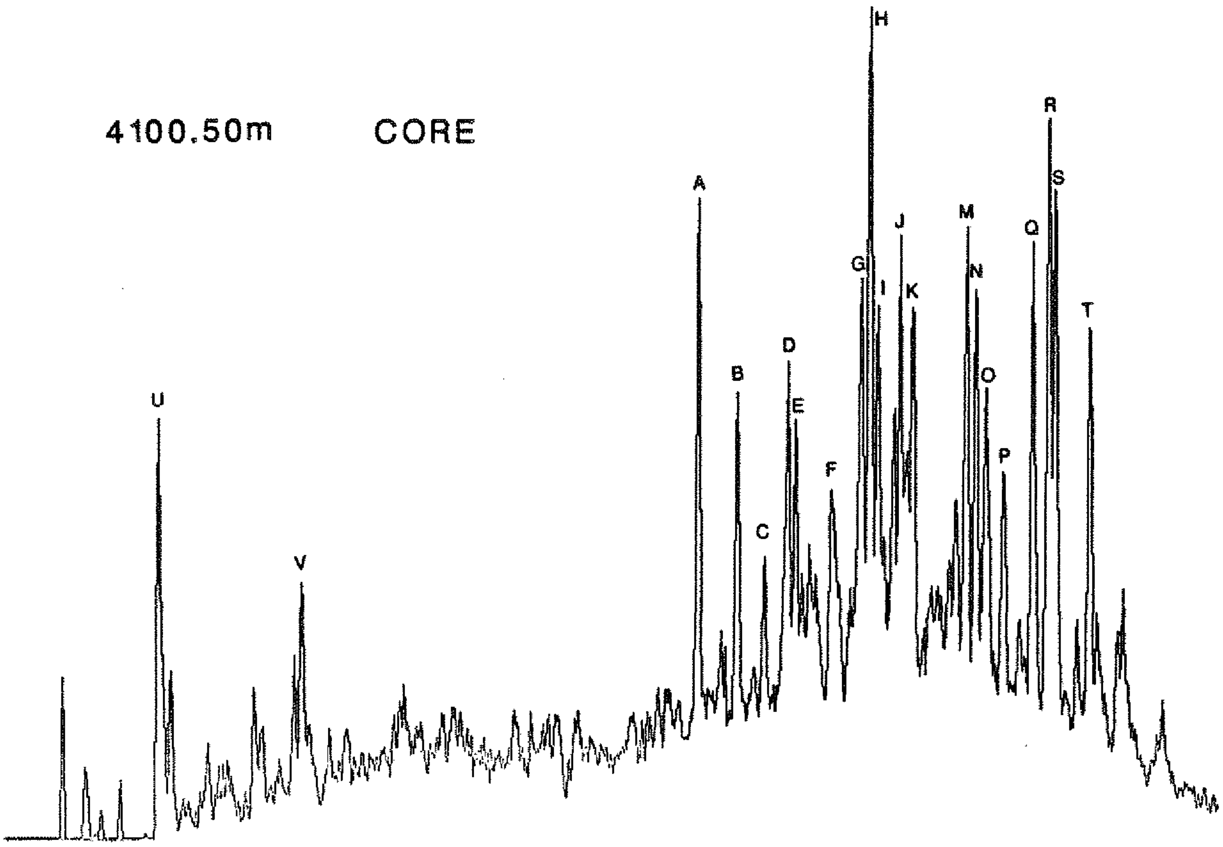
FIGURE 10d

MASS FRAGMENTOGRAMS

WELL 34/10-23

STERANES m/z 217

4100.50m CORE



1474004R 5-JAN-87 Sir Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 217.1956
Text:WELL 34/10-23 4136-60'

4136.60m CORE

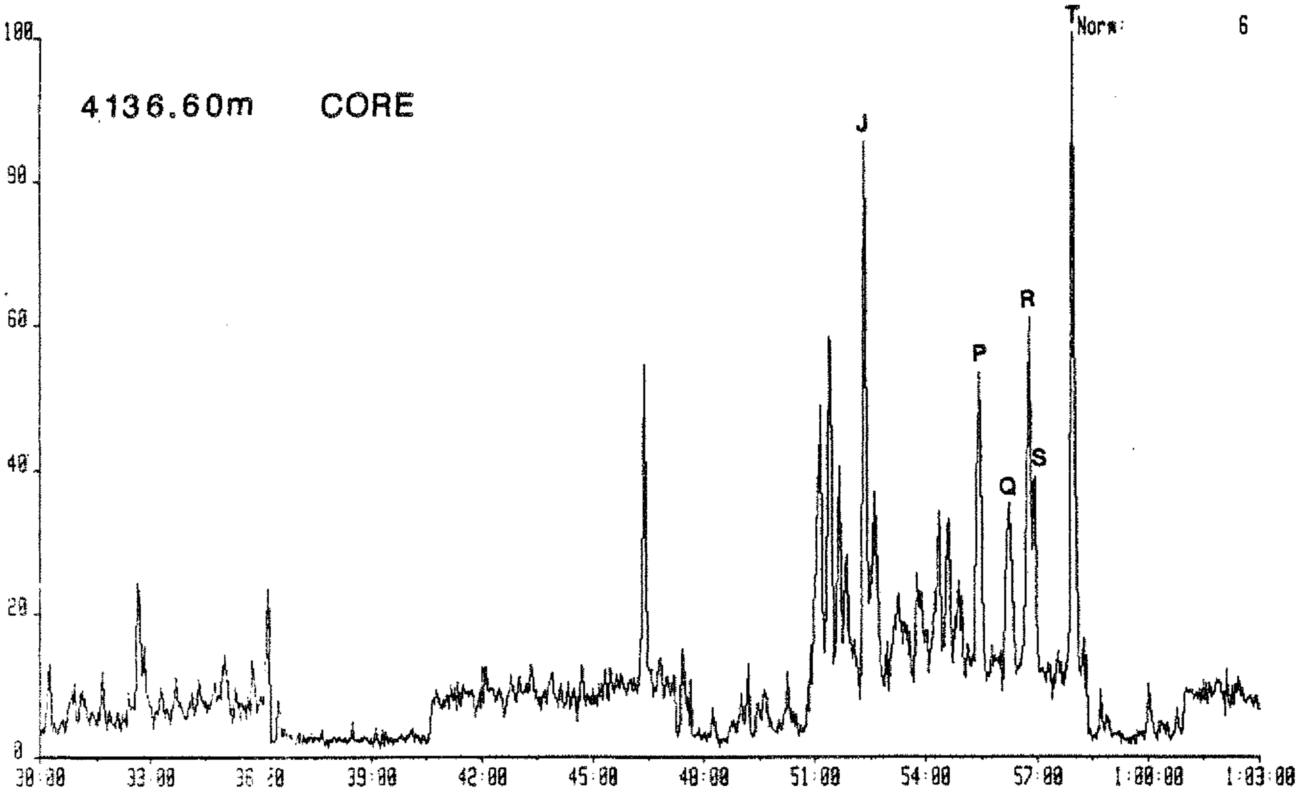


FIGURE 10e

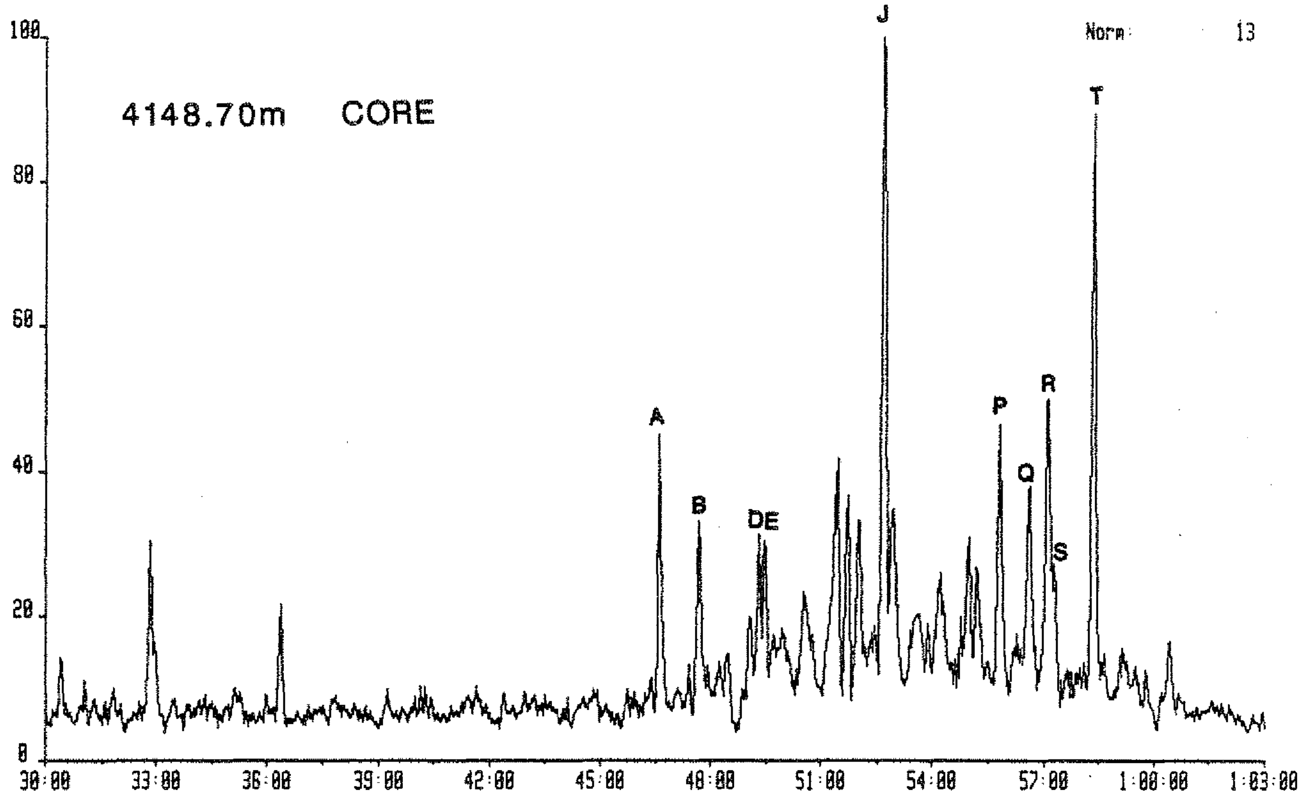
MASS FRAGMENTOGRAMS

GEOCHEM

WELL 34/10-23

STERANES m/z 217

1474006 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 217.1956
Text:WELL 34/10-23 4148-70'



1474009 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 217.1956
Text:WELL 34/10-23 4172-25'

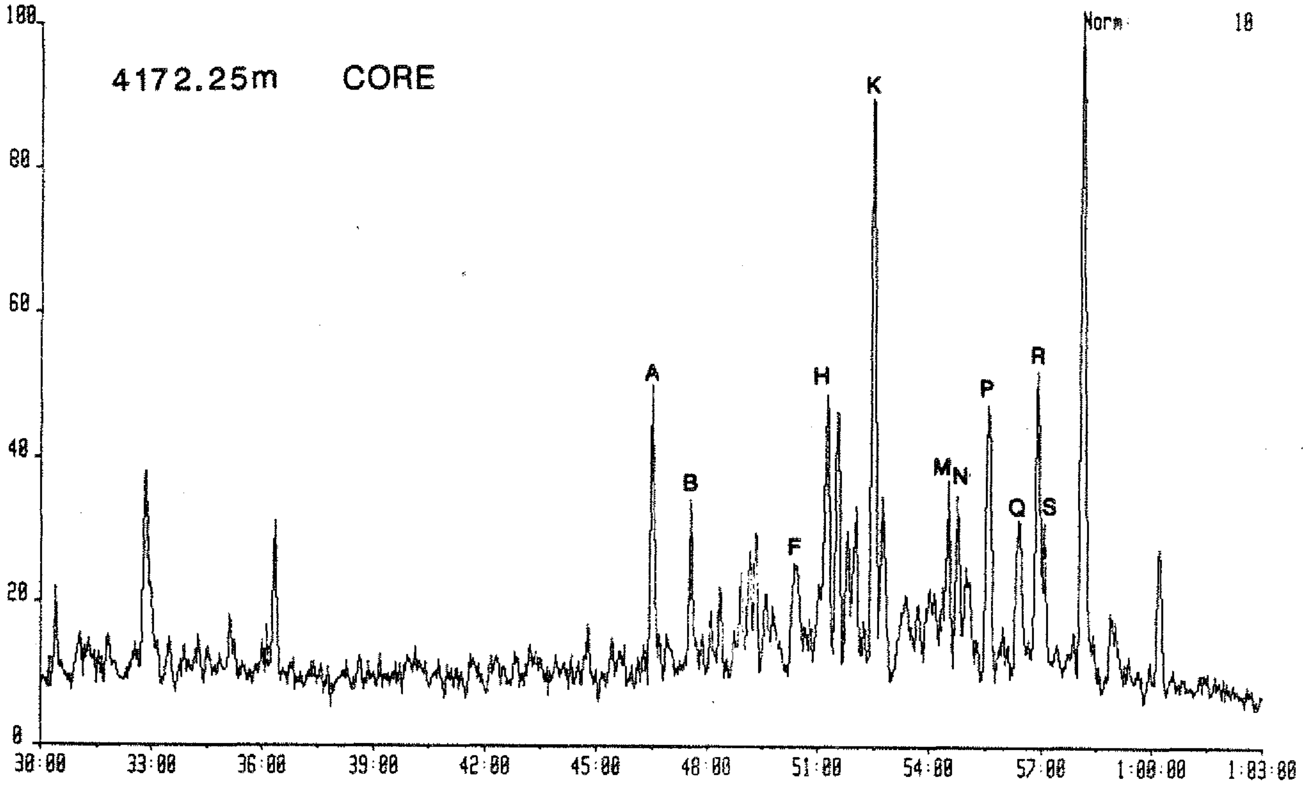


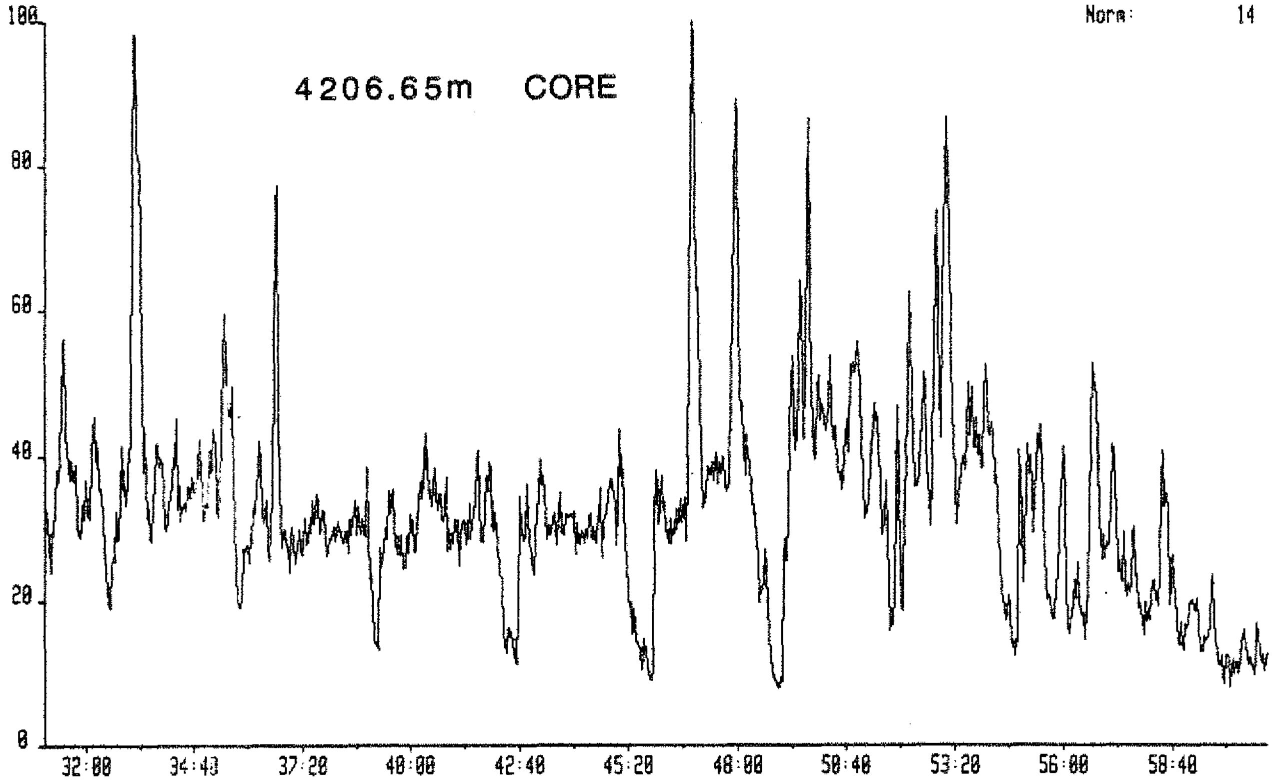
FIGURE 10f

MASS FRAGMENTOGRAMS

WELL 34/10-23

STERANES m/z 217

1474010 6-JAN-92 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 217.1956
Text:WELL 34/10-23 4206.65M



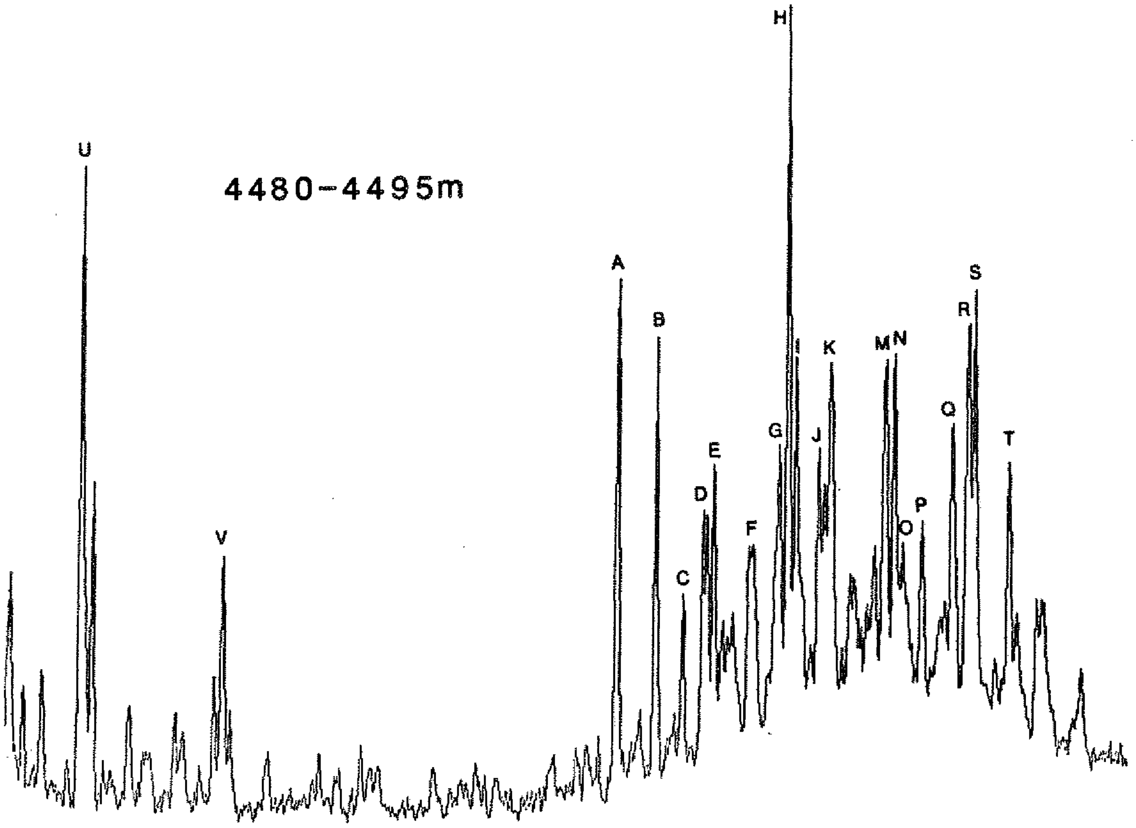
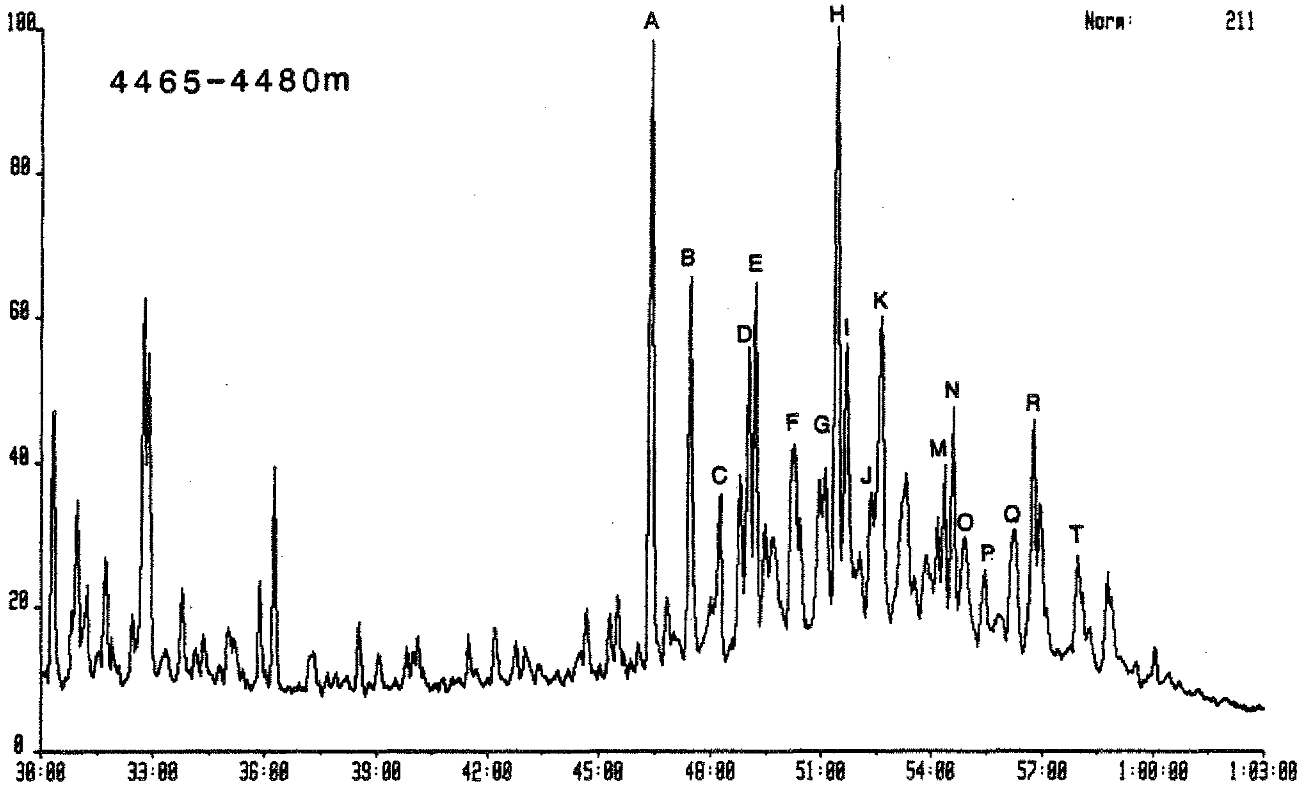


FIGURE 10g MASS FRAGMENTOGRAMS

WELL 34/10-23 STERANES m/z 217

1474026 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 217.1956
Text:BIOMARKERS



WELL 34/10-30

1474015 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 217.1956
Text:BIOMARKERS

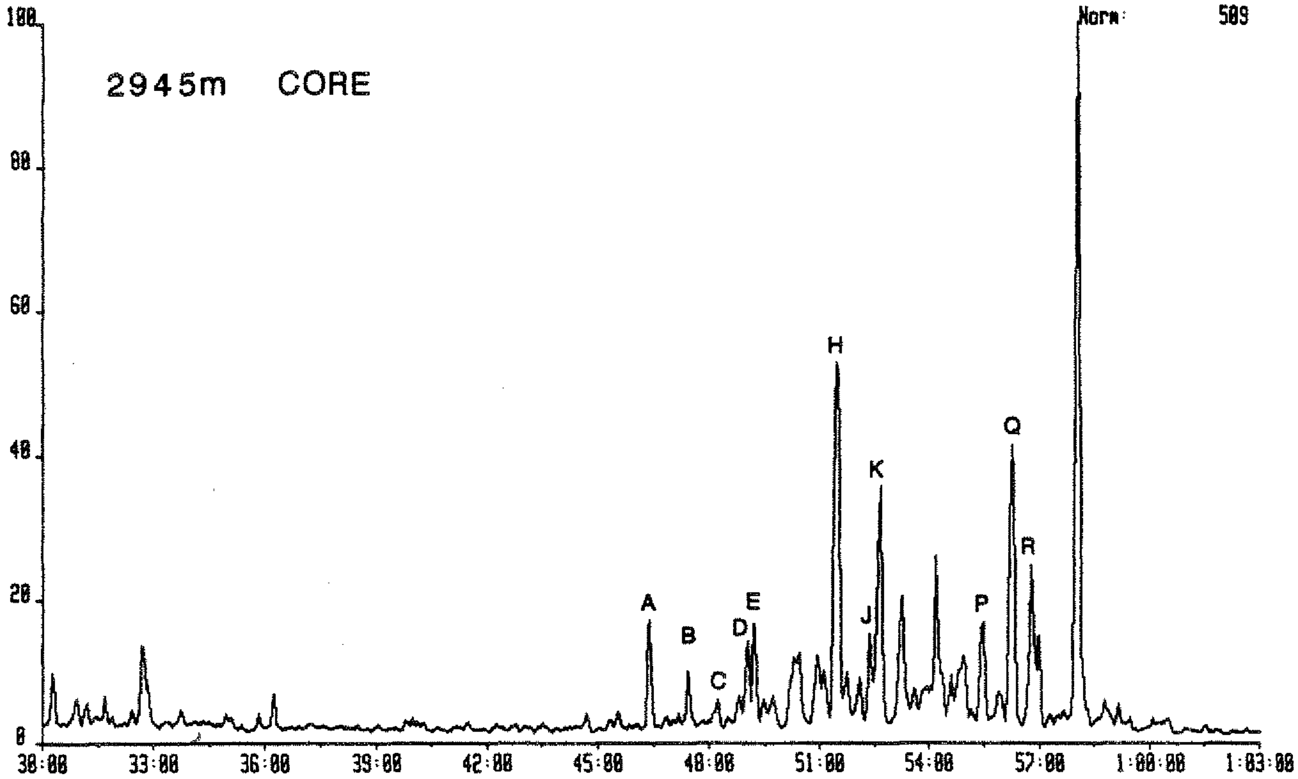


FIGURE 10h

MASS FRAGMENTOGRAMS

WELL 34/10-30

STERANES m/z 217

1474017 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 217.1956
Text:BIOMARKERS

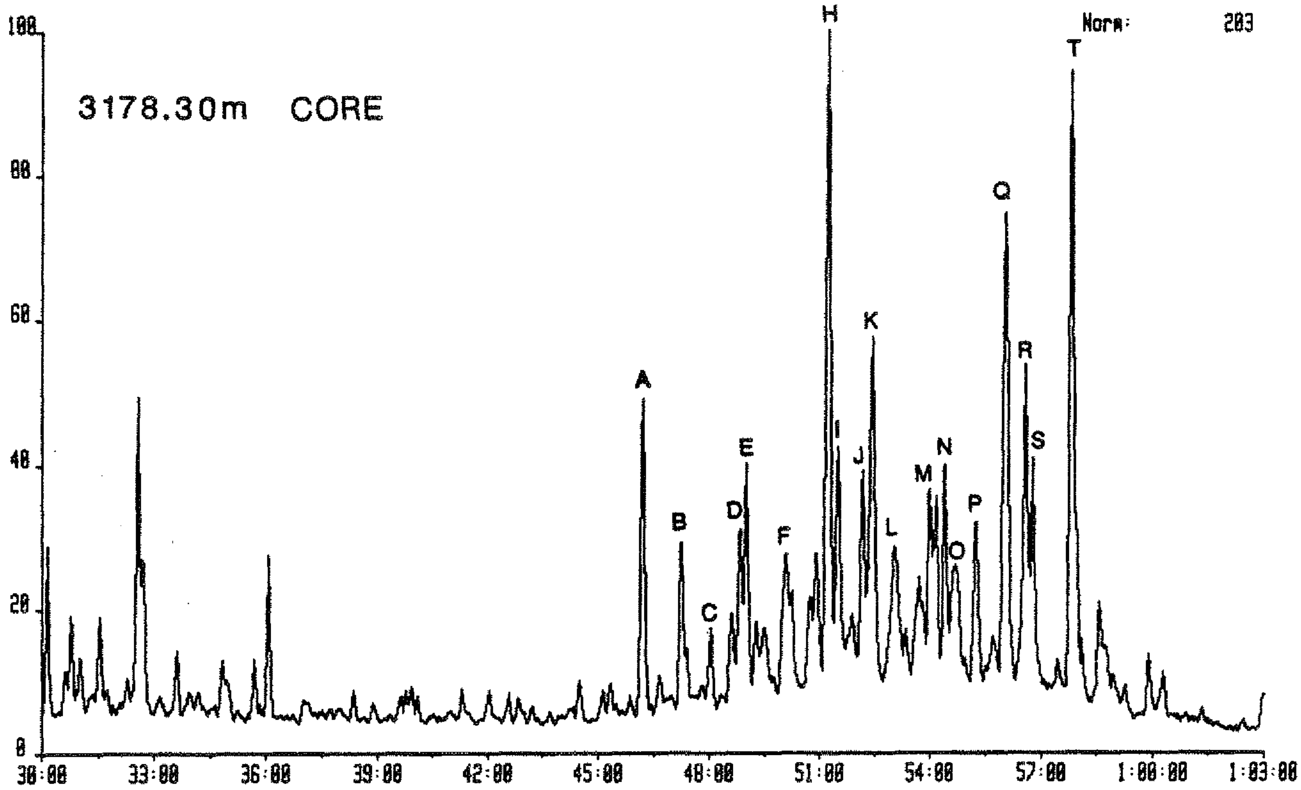


FIGURE 11a

MASS FRAGMENTOGRAMS

GEOCHEM

WELL 34/10-23 $\beta\beta$ STERANES m/z 218

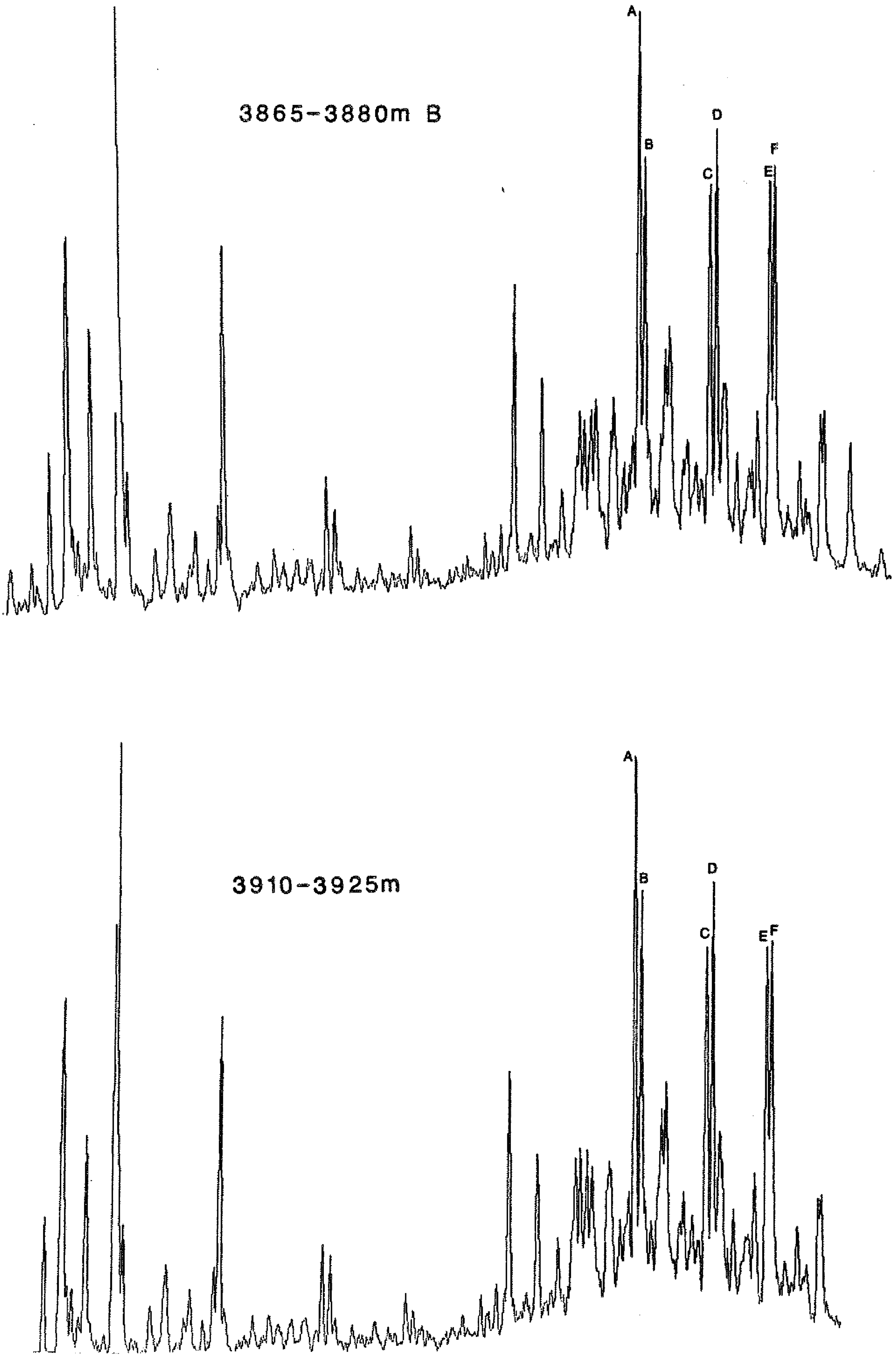


FIGURE 11b

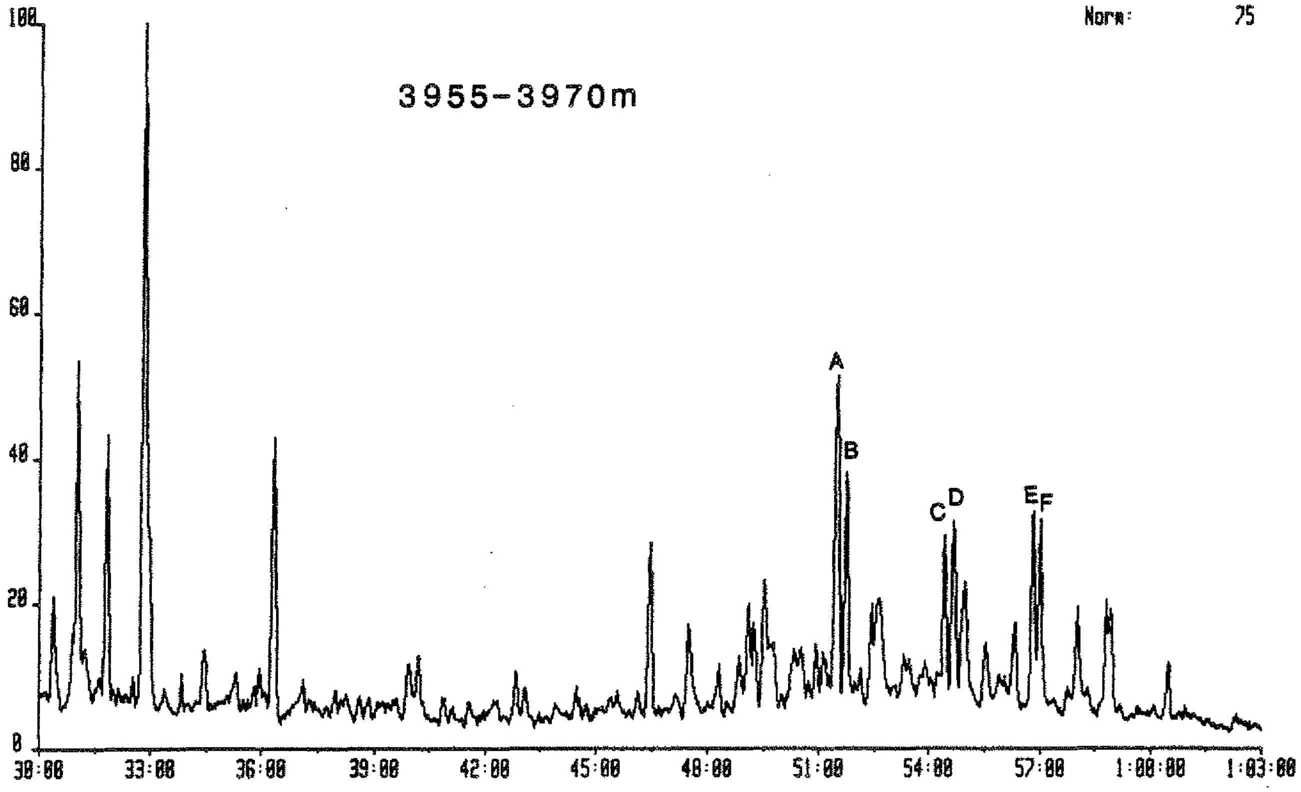
MASS FRAGMENTOGRAMS

GEOCHEM

WELL 34/10-23

ββ STERANES m/z 218

1474019 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 218.2034
Text:BIOMARKERS



1474023 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 218.2034
Text:BIOMARKERS

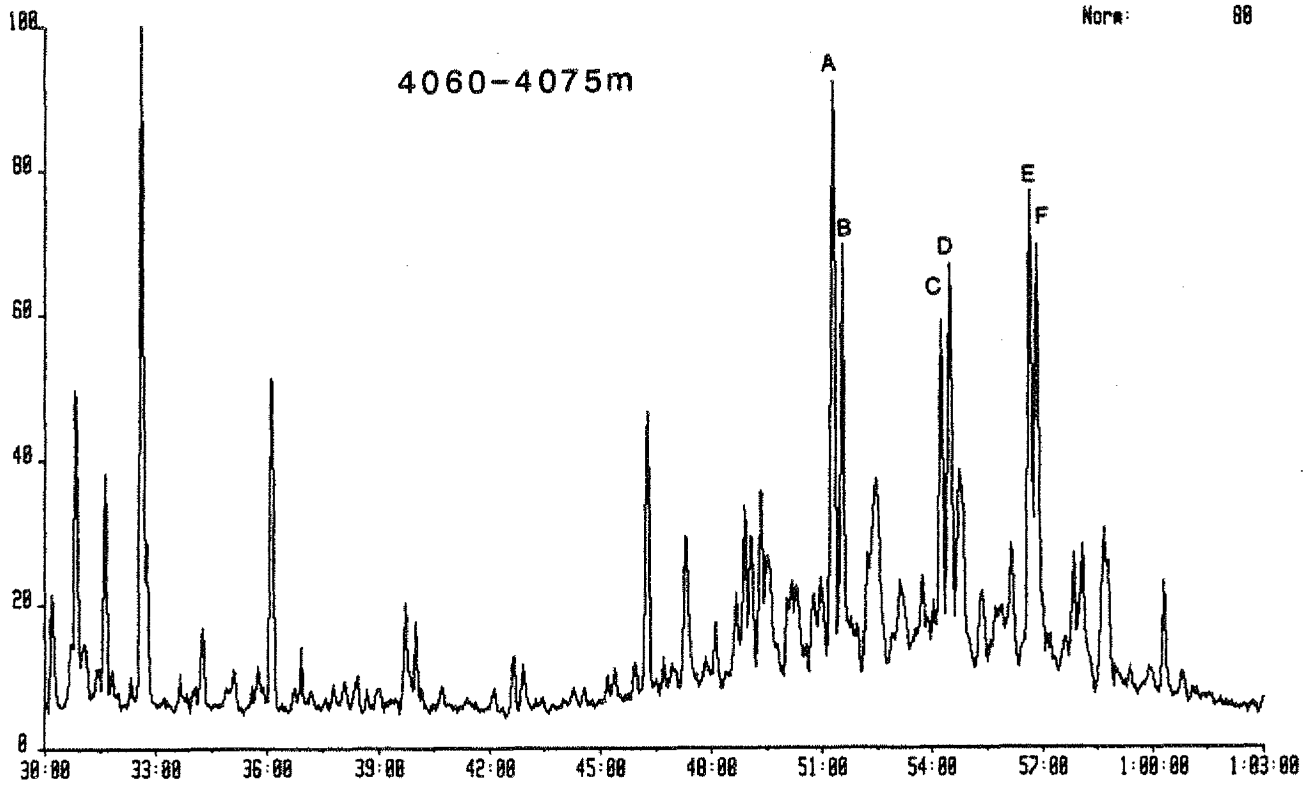


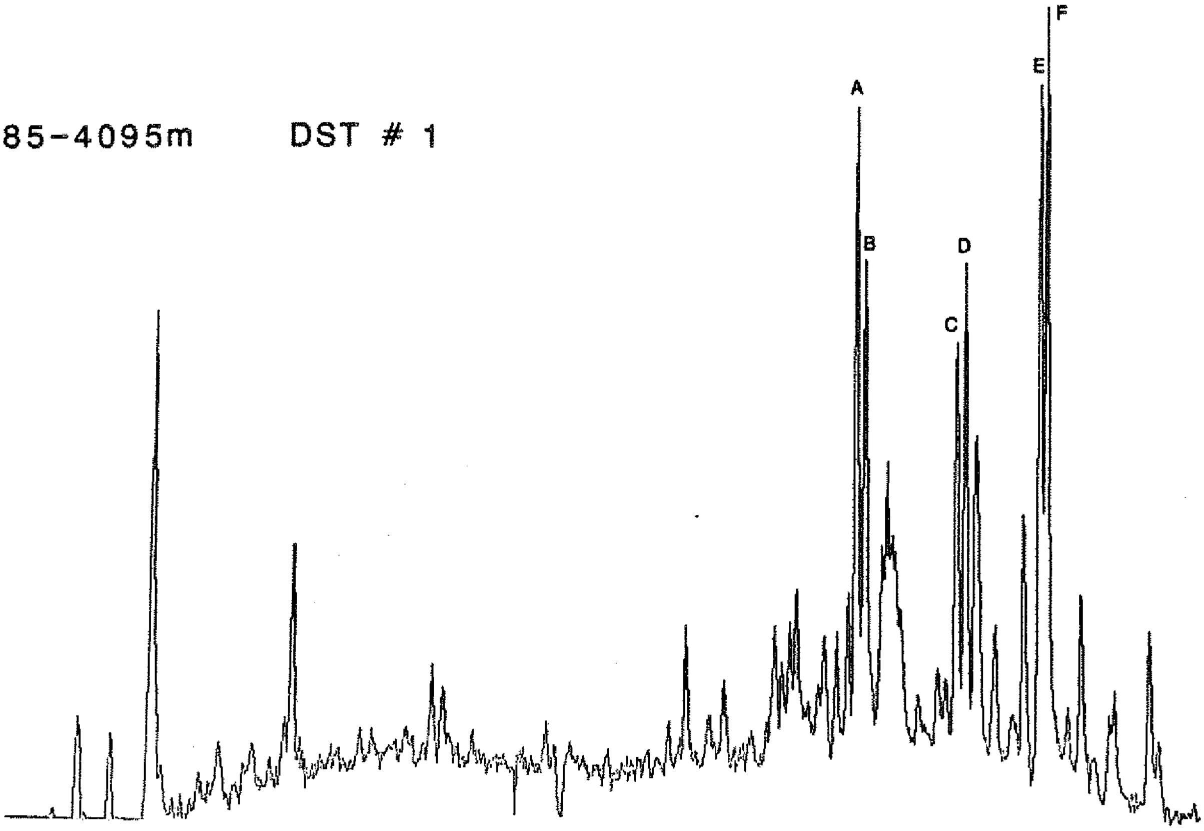
FIGURE 11c

MASS FRAGMENTOGRAMS

WELL 34/10-23

$\beta\beta$ STERANES m/z 218

4085-4095m DST # 1



4092.25m CORE

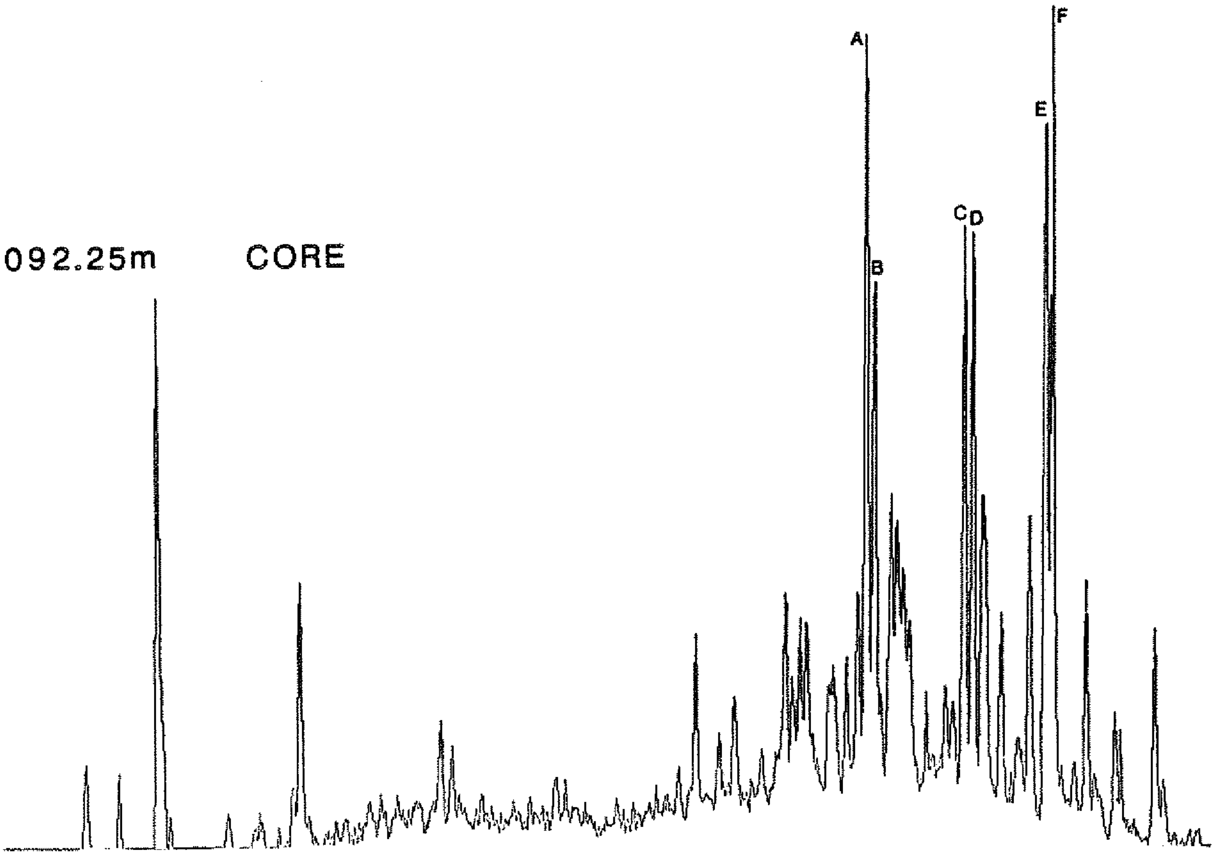


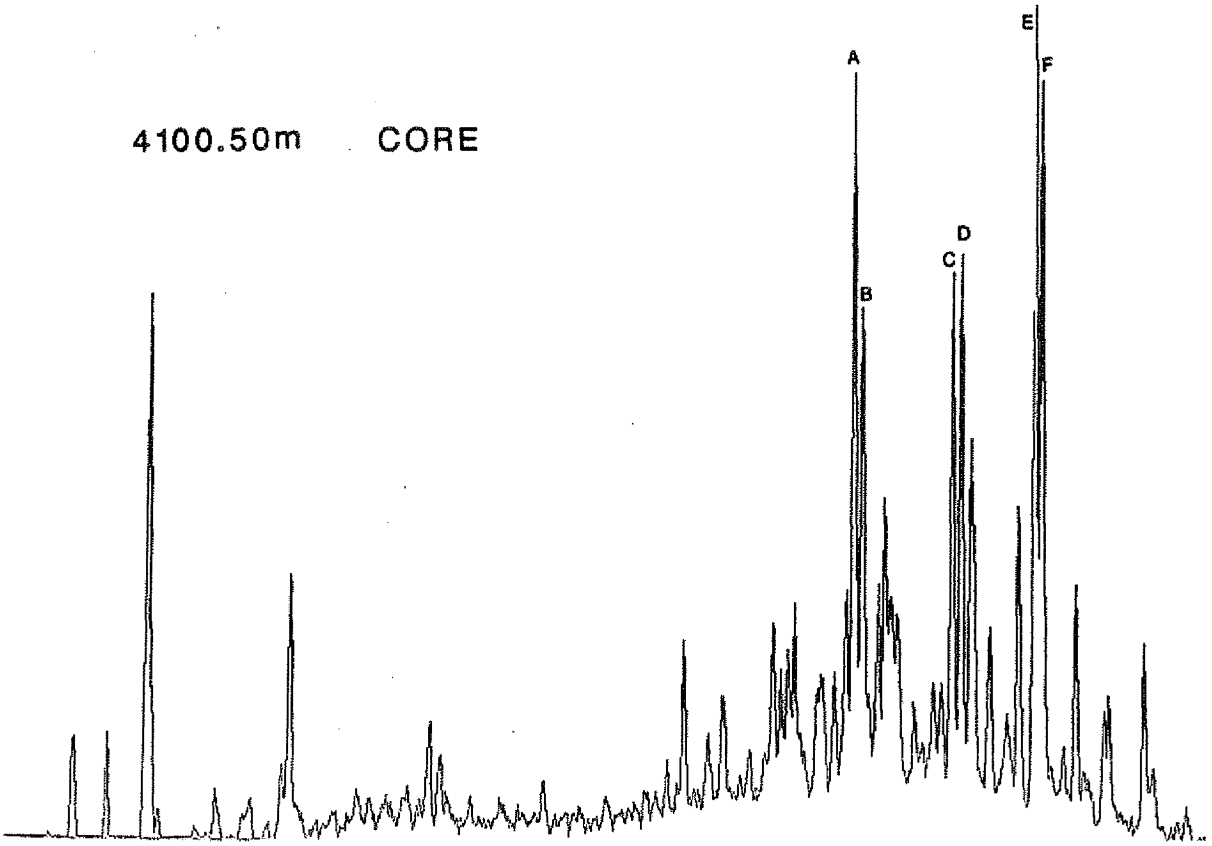
FIGURE 11d

MASS FRAGMENTOGRAMS

WELL 34/10-23

$\beta\beta$ STERANES m/z 218

4100.50m CORE



```
1474004R   5-JAN-87     Str:Magnetic TS250    Acnt:STATOIL        System:BIOMARKER
Sample 1   Injection 1   Group 1   Mass 218.2034
Text:WELL 34/10-23 4136-60'
```

4136.60m CORE

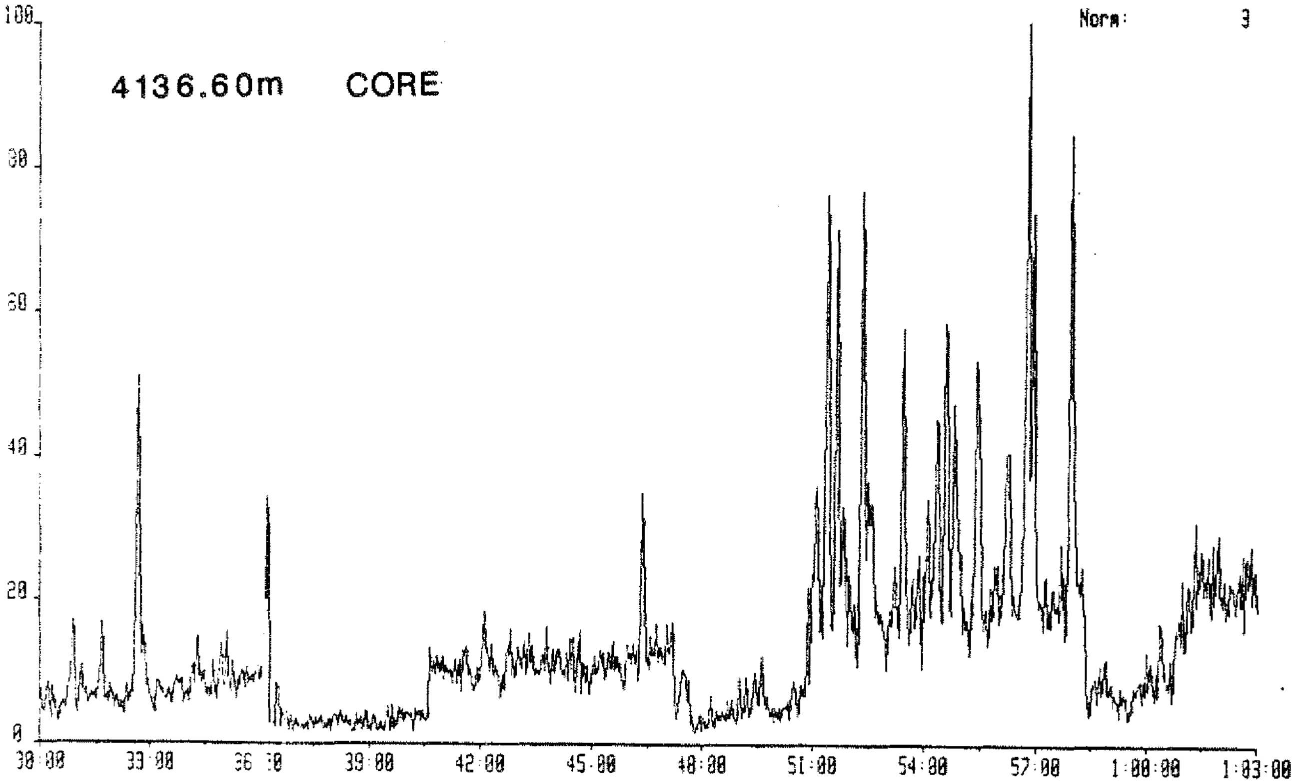


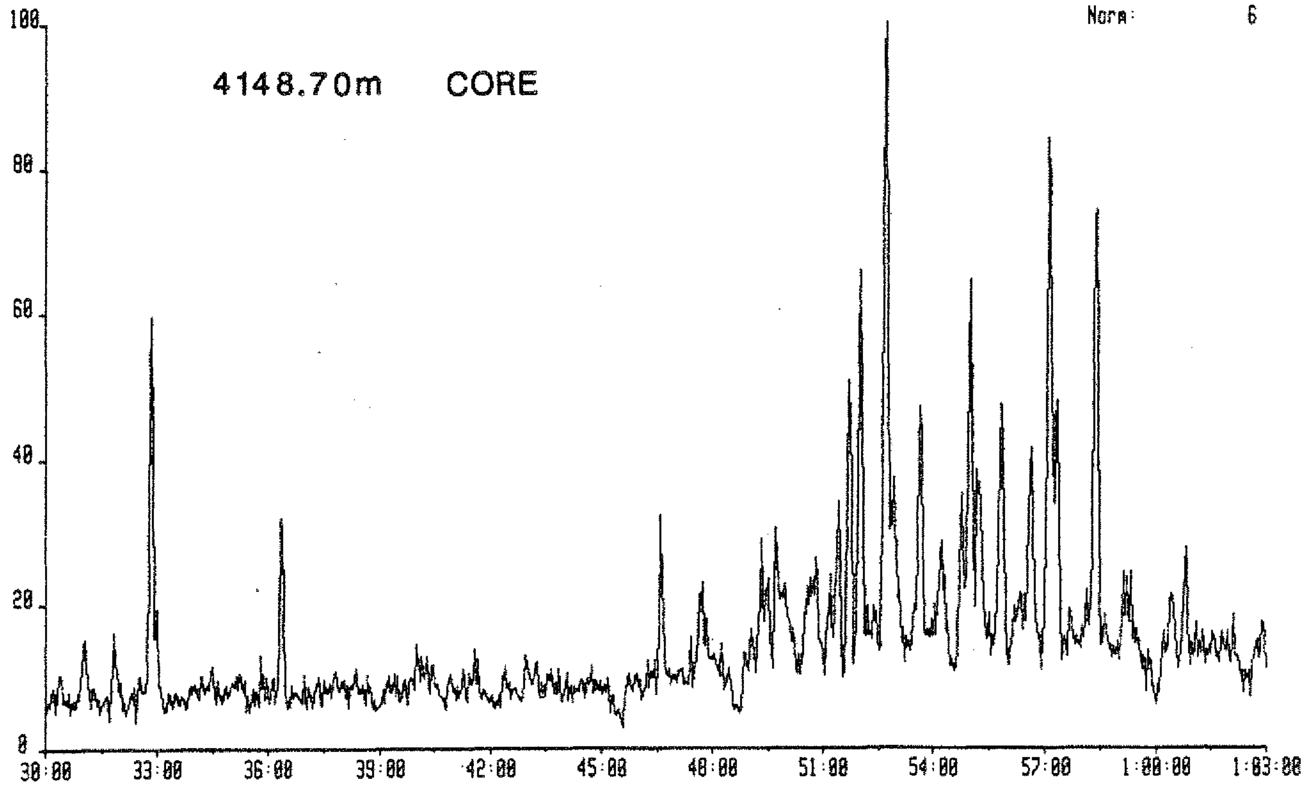
FIGURE 11e

MASS FRAGMENTOGRAMS

WELL 34/10-23

ββ STERANES m/z 218

1474006 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 218.2034
Text:WELL 34/10-23 4148-70'



1474009 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 218.2034
Text:WELL 34/10-23 4172-25'

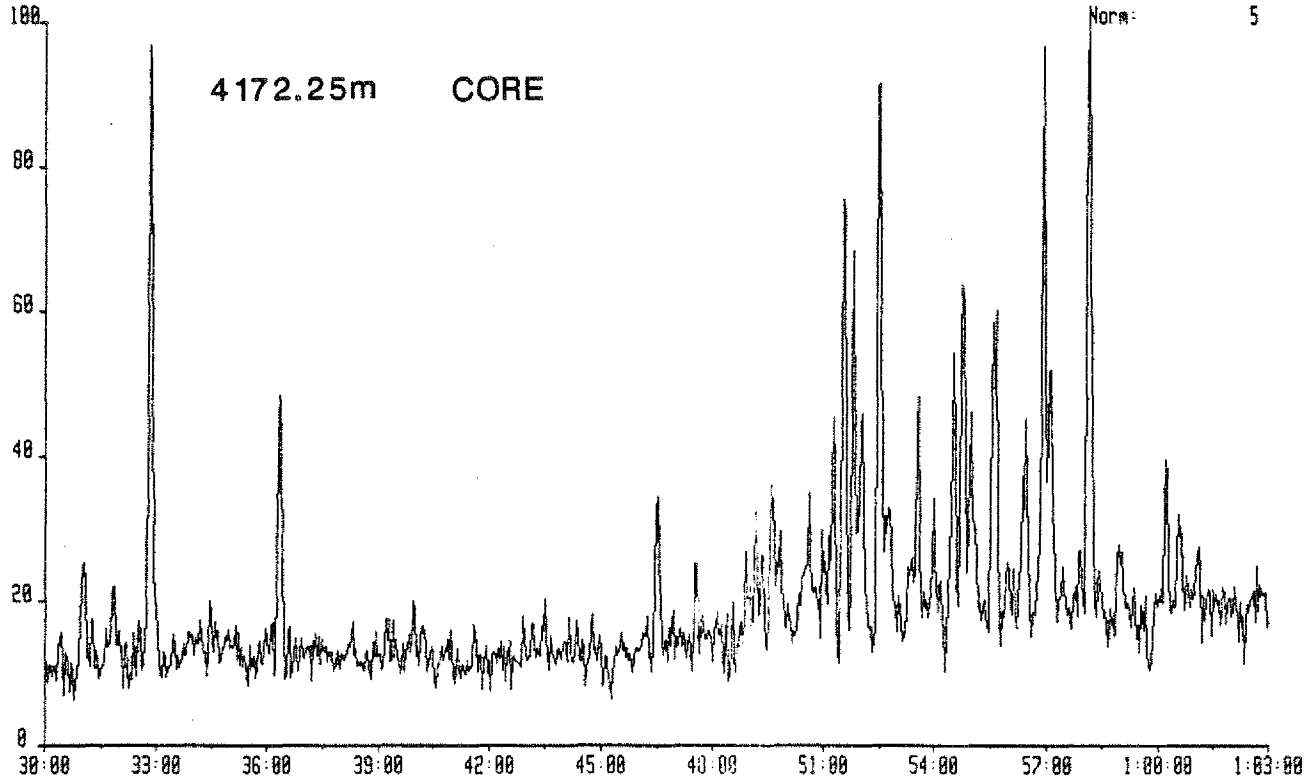
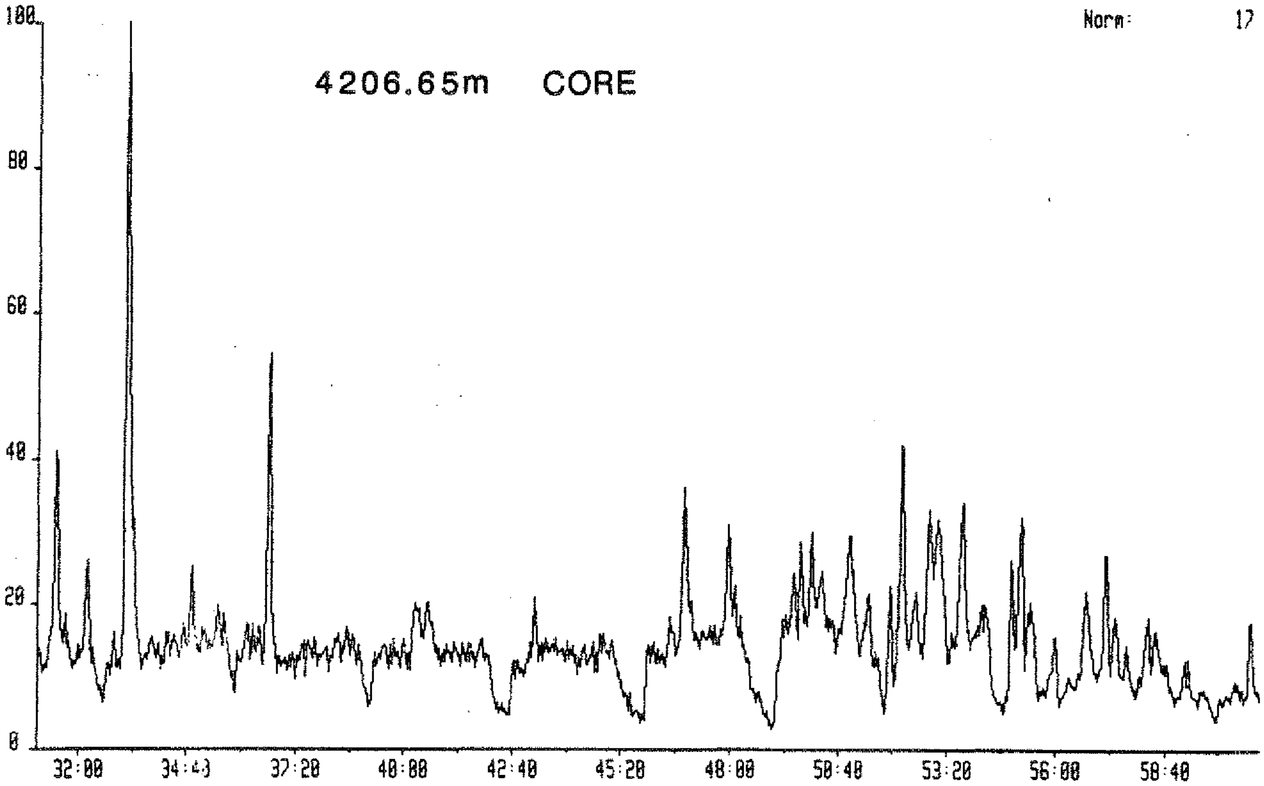


FIGURE 11f

MASS FRAGMENTOGRAMS

WELL 34/10-23 $\beta\beta$ STERANES m/z 218

1474010 6-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group I Mass 218.2034
Text:WELL.34/10-23 4206.65M



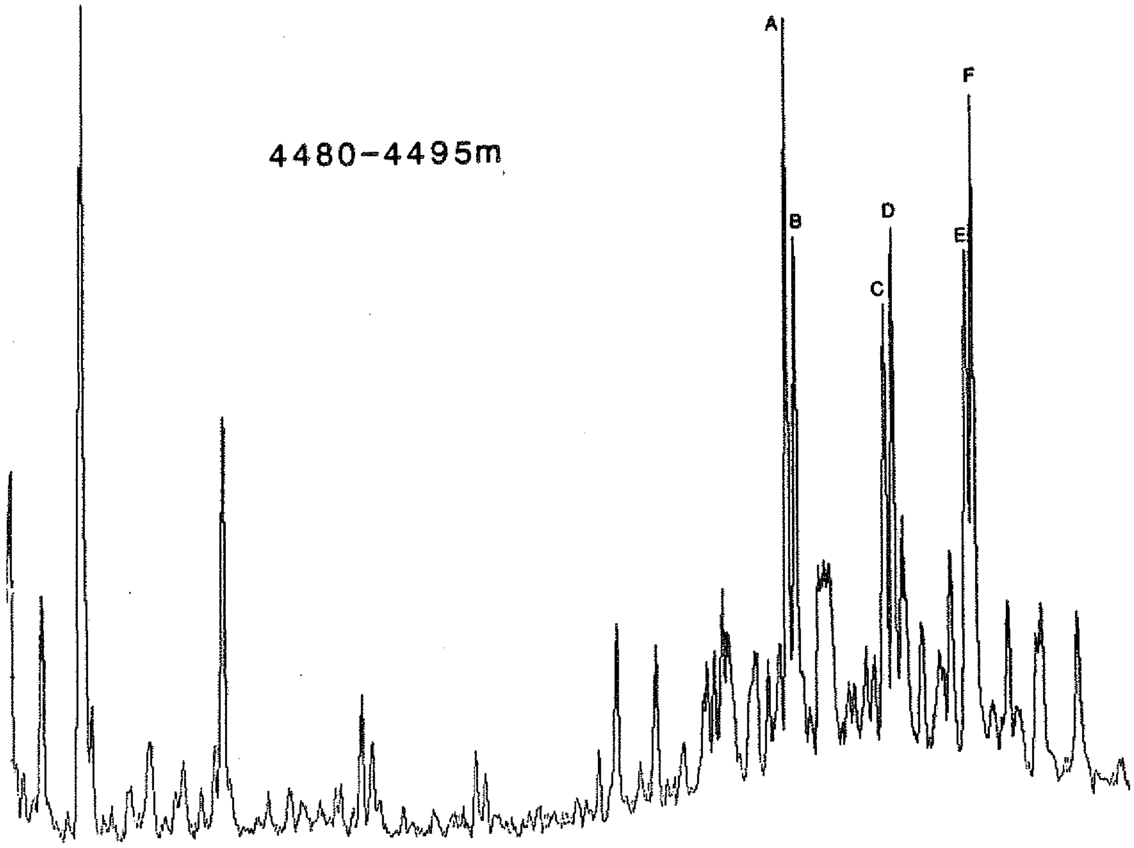


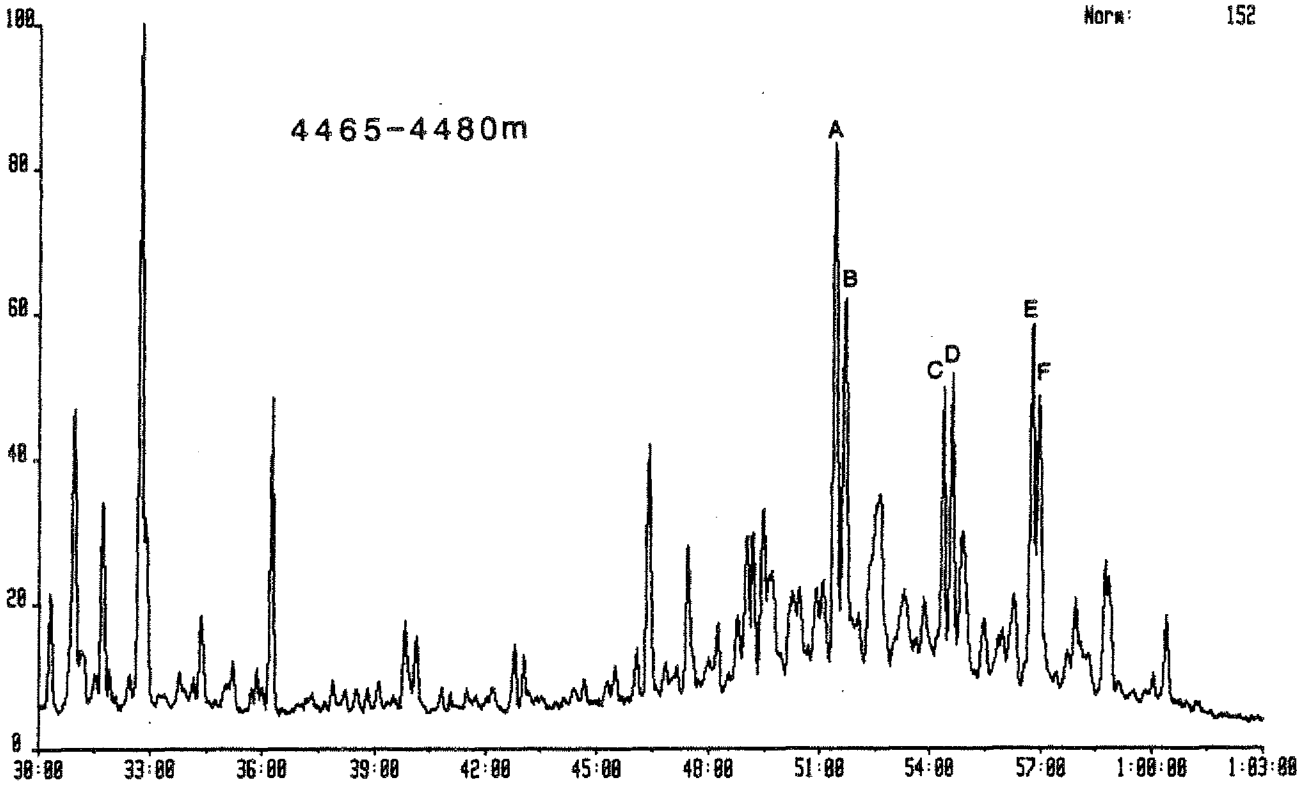
FIGURE 11g

MASS FRAGMENTOGRAMS

WELL 34/10-23

ββ STERANES m/z 218

```
1474026    27-JAN-87    Sir:Magnetic TS250    Acnt:STATOIL    System:BIOMARKER
Sample 1   Injection 1    Group 1   Mass 218.2034
Text:BIOMARKERS
```



WELL 34/10-30

```
1474015    27-JAN-87    Sir:Magnetic TS250    Acnt:STATOIL    System:BIOMARKER
Sample 1   Injection 1    Group 1   Mass 218.2034
Text:BIOMARKERS
```

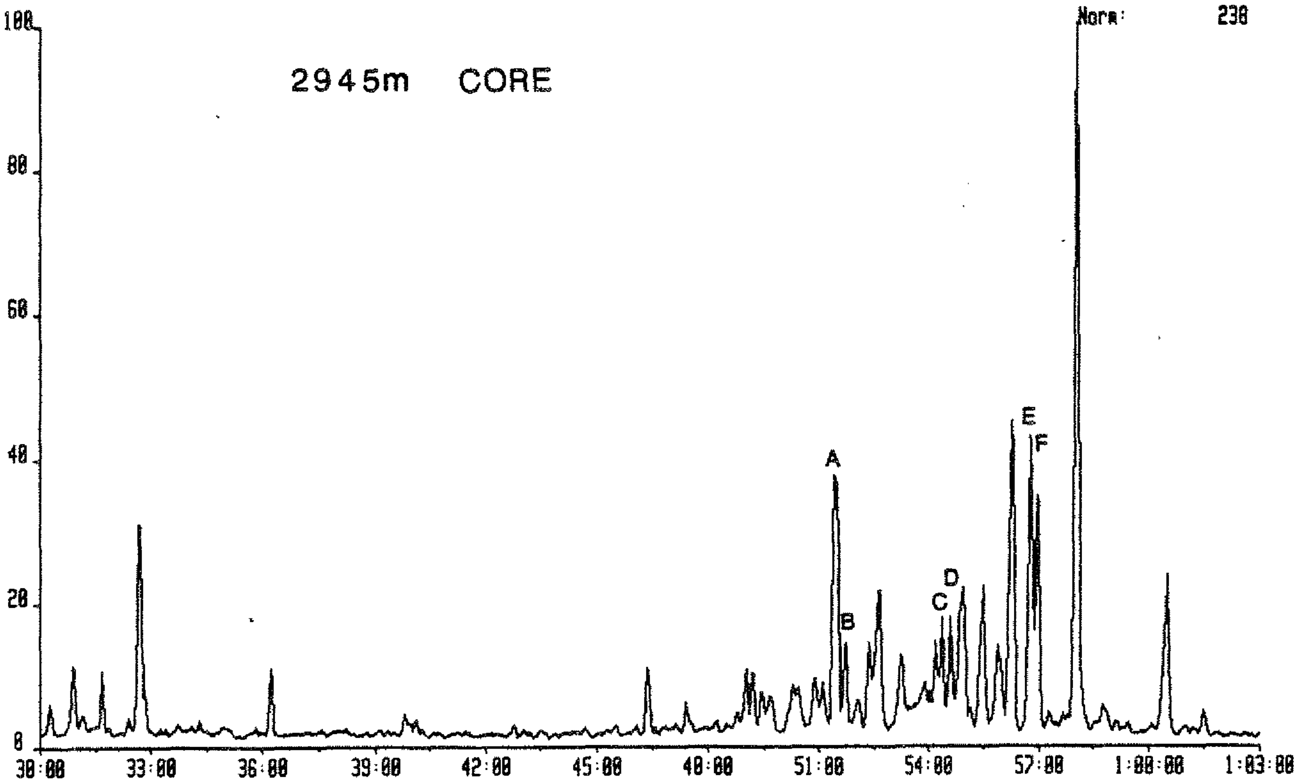


FIGURE 11h

MASS FRAGMENTOGRAMS

WELL 34/10-30

$\beta\beta$ STERANES m/z 218

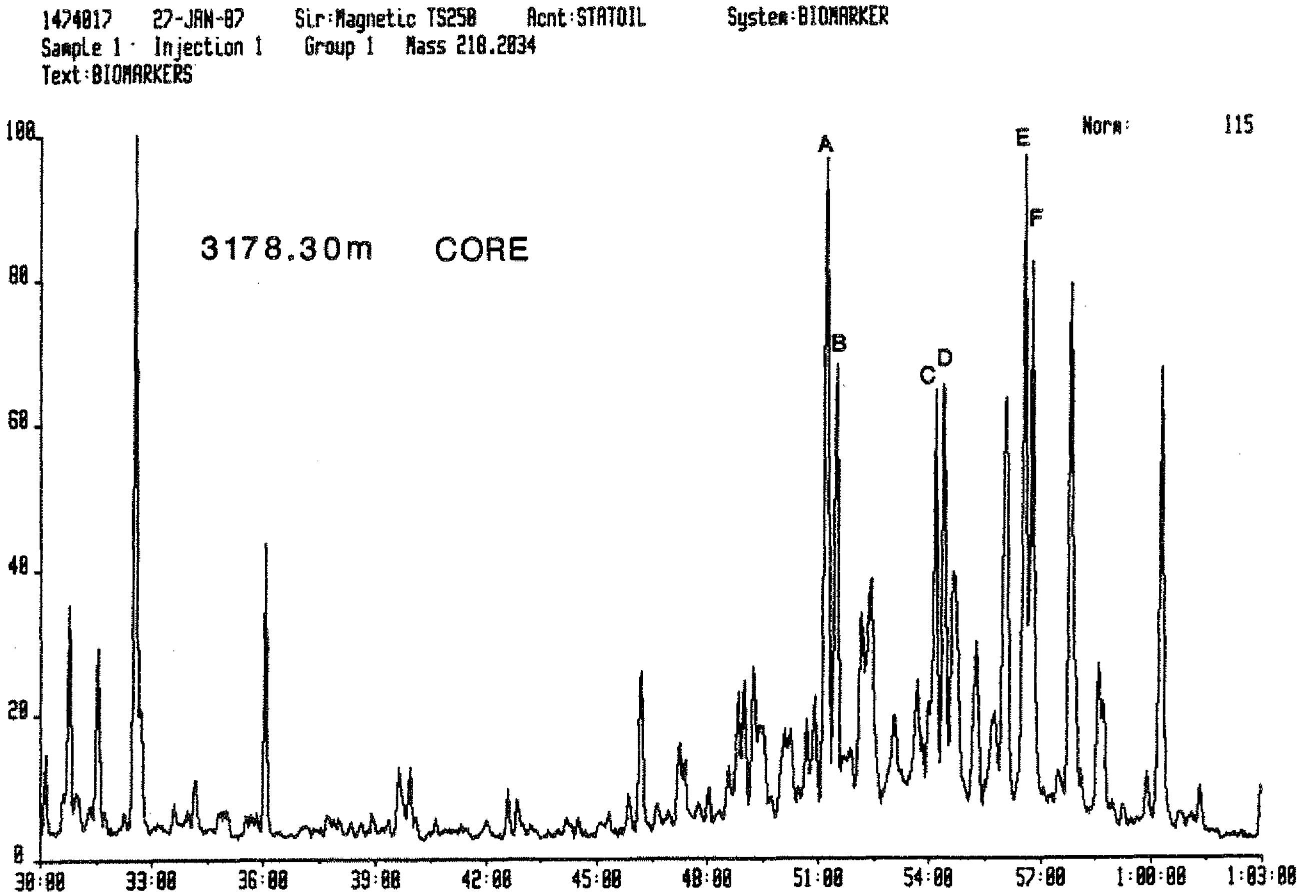
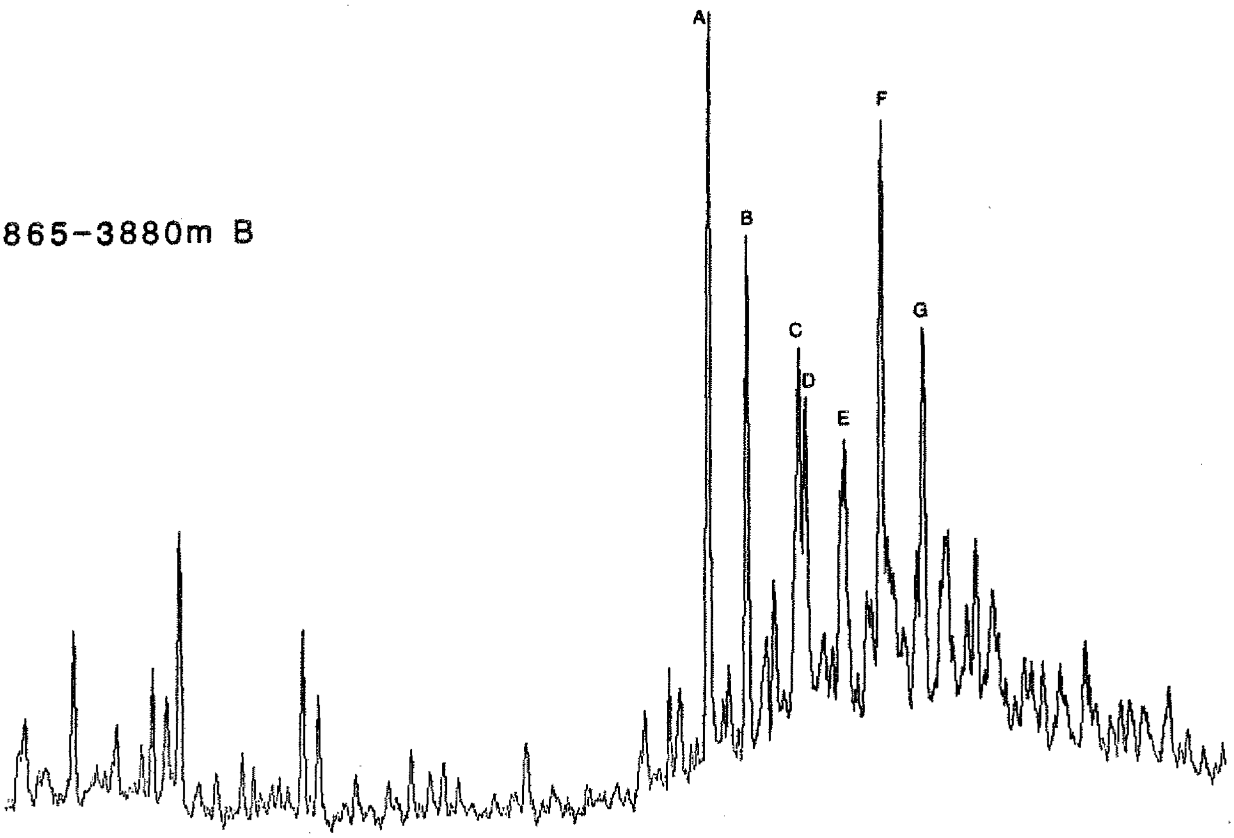


FIGURE 12a

MASS FRAGMENTOGRAMS

WELL 34/10-23 REARRANGED STERANES m/z 259

3865-3880m B



3910-3925m

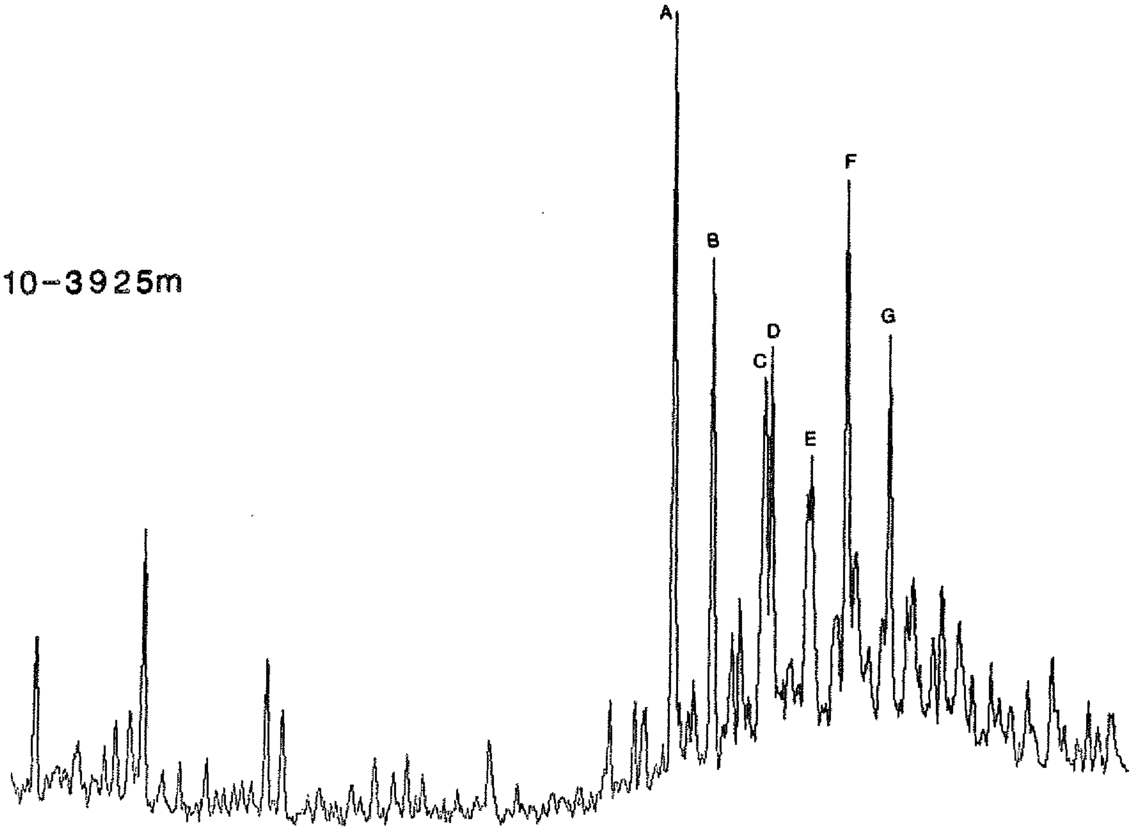


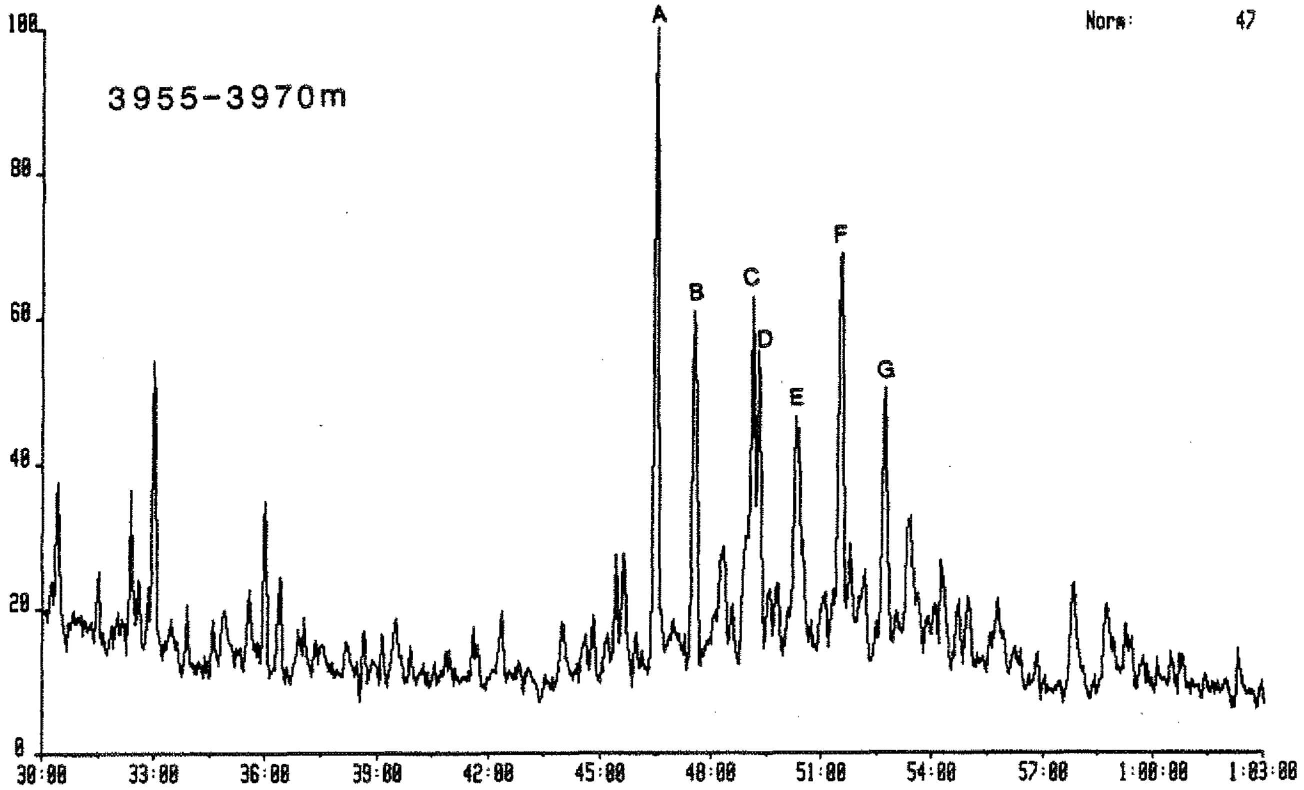
FIGURE 12b

MASS FRAGMENTOGRAMS

WELL 34/10-23 REARRANGED STERANES m/z 259

GEOCHEM

1474019 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 259.2427
Text:BIOMARKERS



1474023 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 259.2427
Text:BIOMARKERS

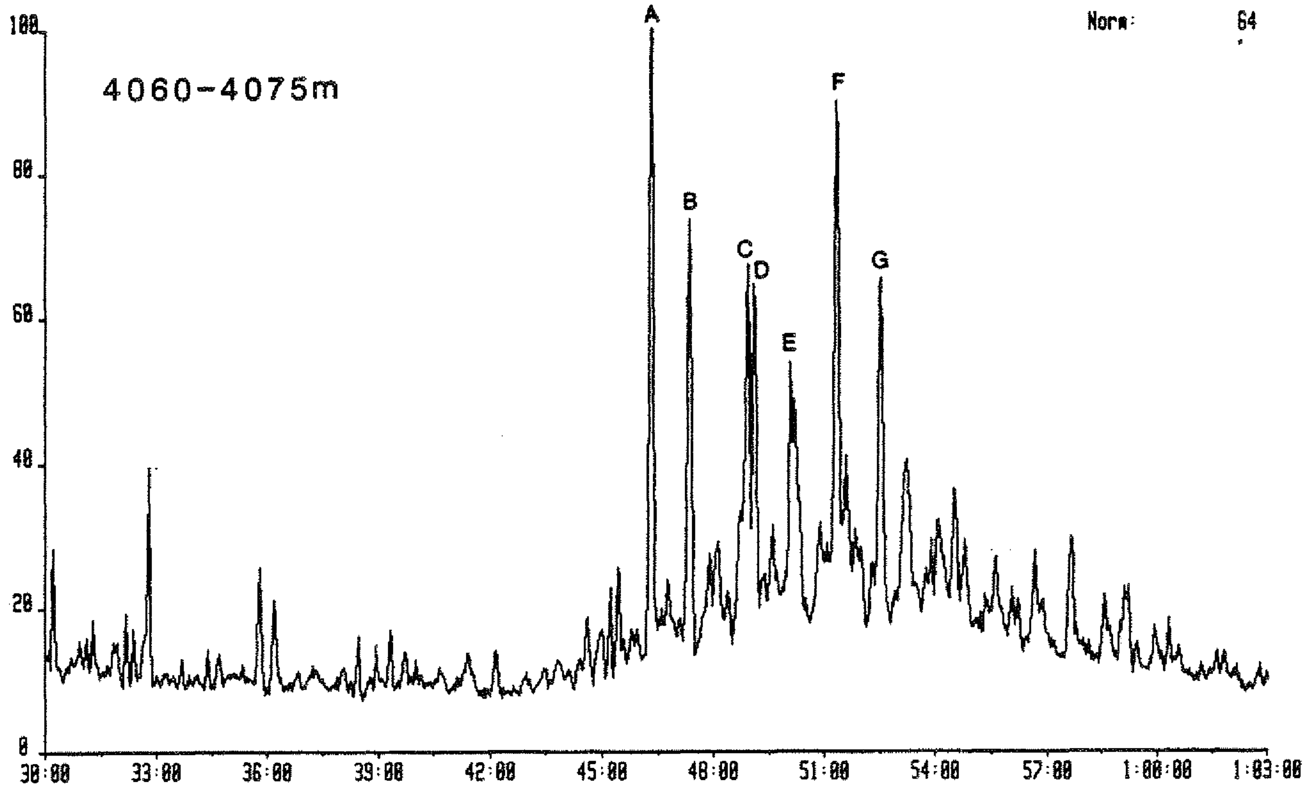
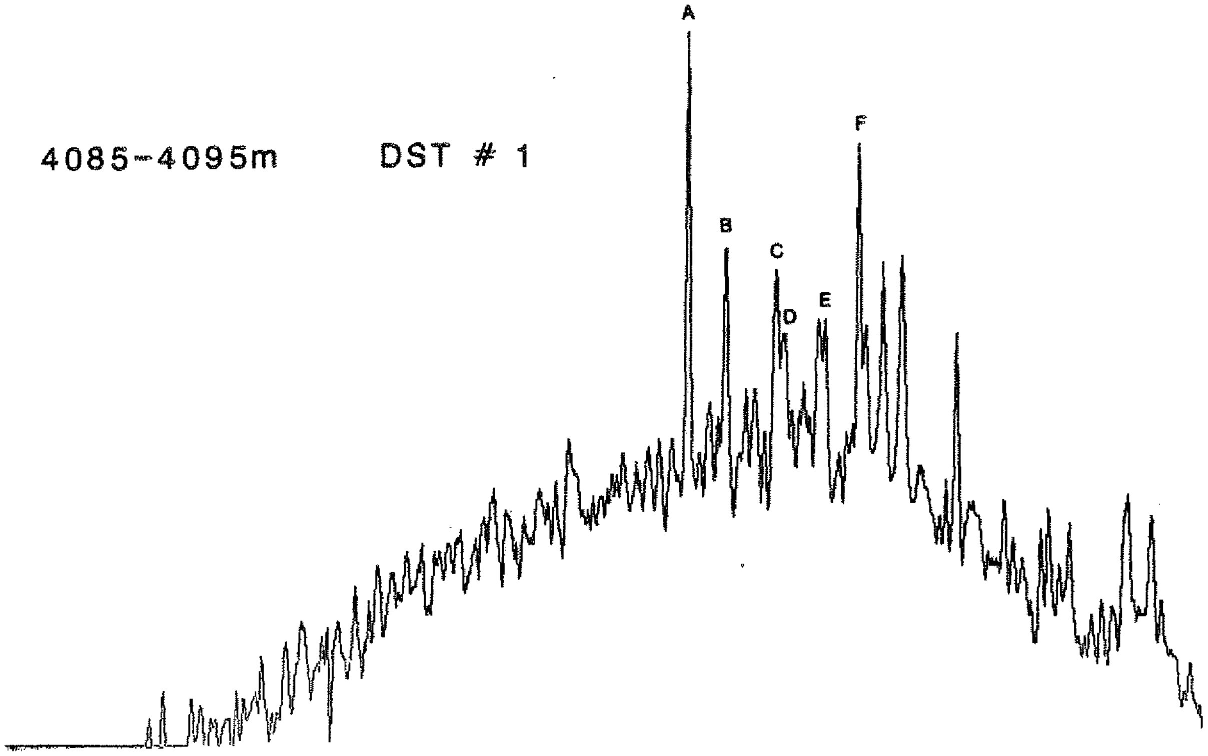


FIGURE 12c

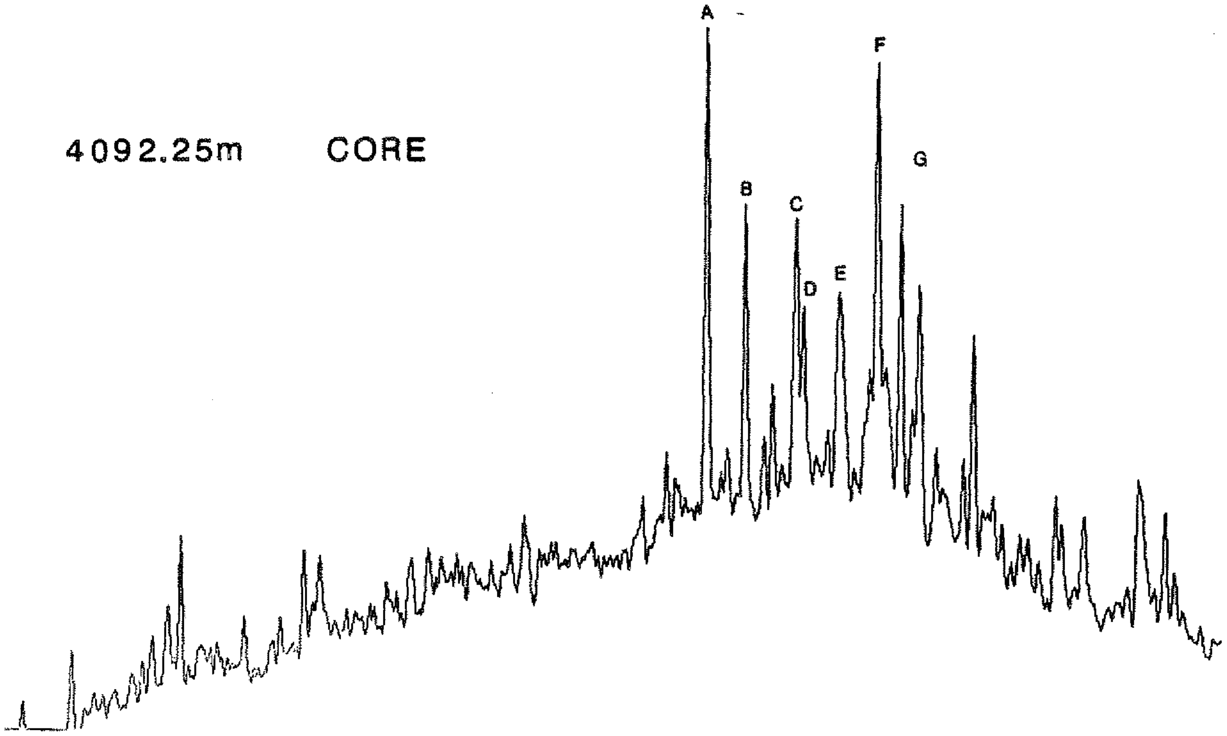
MASS FRAGMENTOGRAMS

WELL 34/10-23

REARRANGED STERANES m/z 259



4085-4095m DST # 1

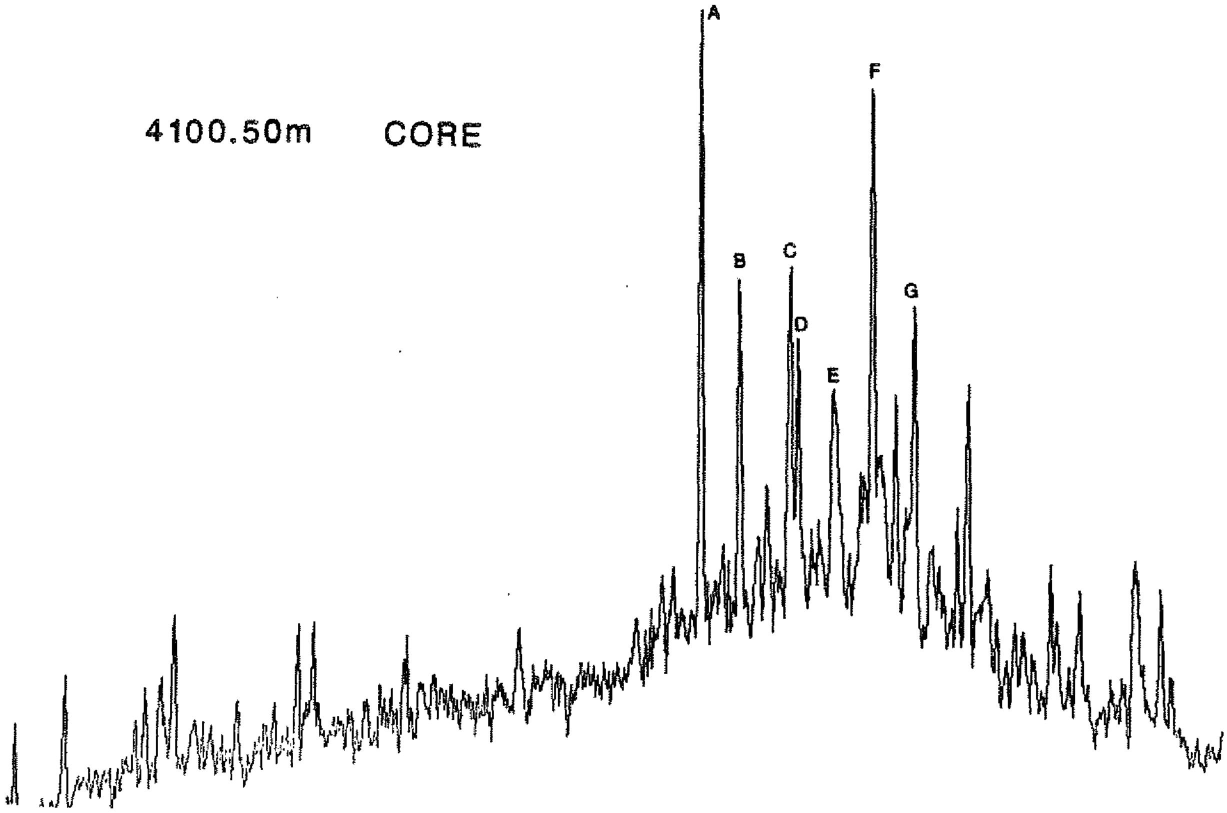


4092.25m CORE

FIGURE 12d

MASS FRAGMENTOGRAMS

WELL 34/10-23 REARRANGED STERANES m/z 259



```
1474004R   5-JAN-87     Sir:Magnetic TS250    Acnt:STATOIL        System:BIOMARKER
Sample 1   Injection 1    Group 1   Mass 259.2427
Text:WELL 34/10-23 4136-60'
```

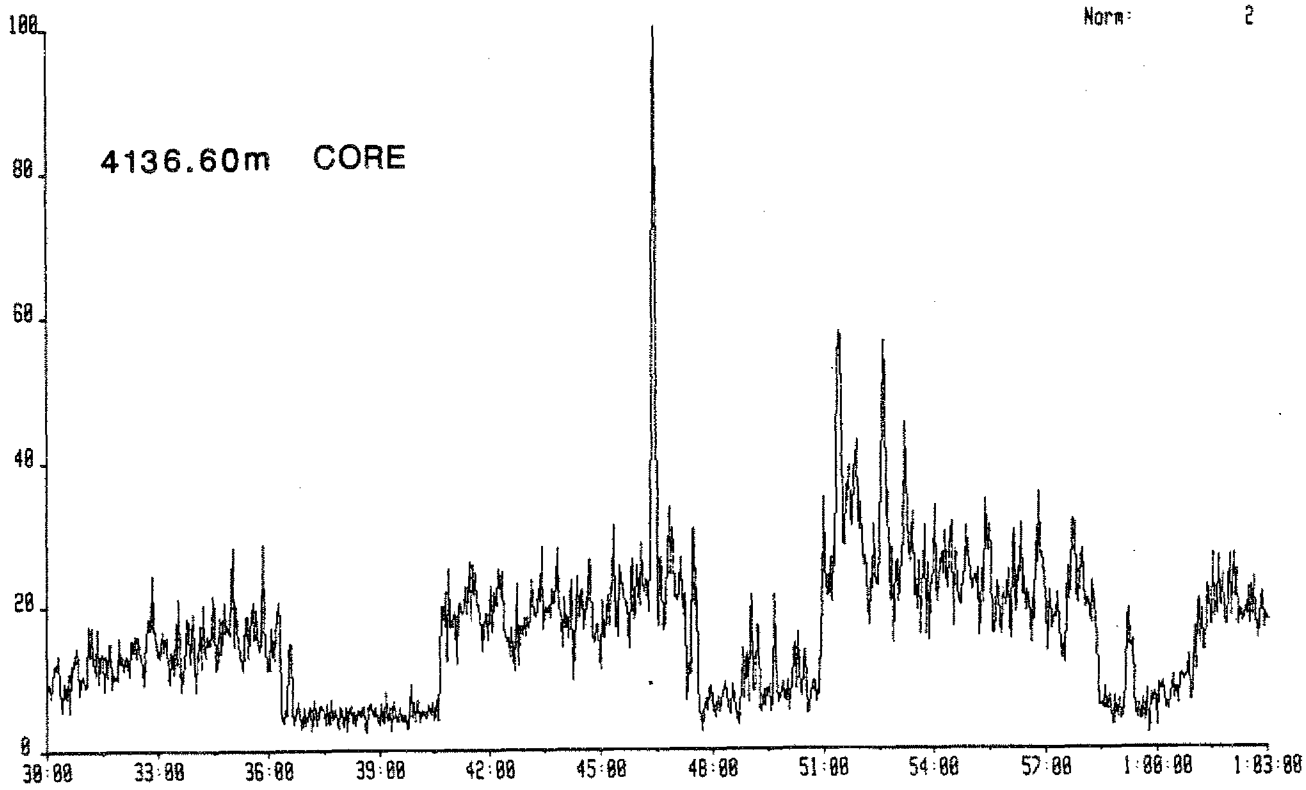
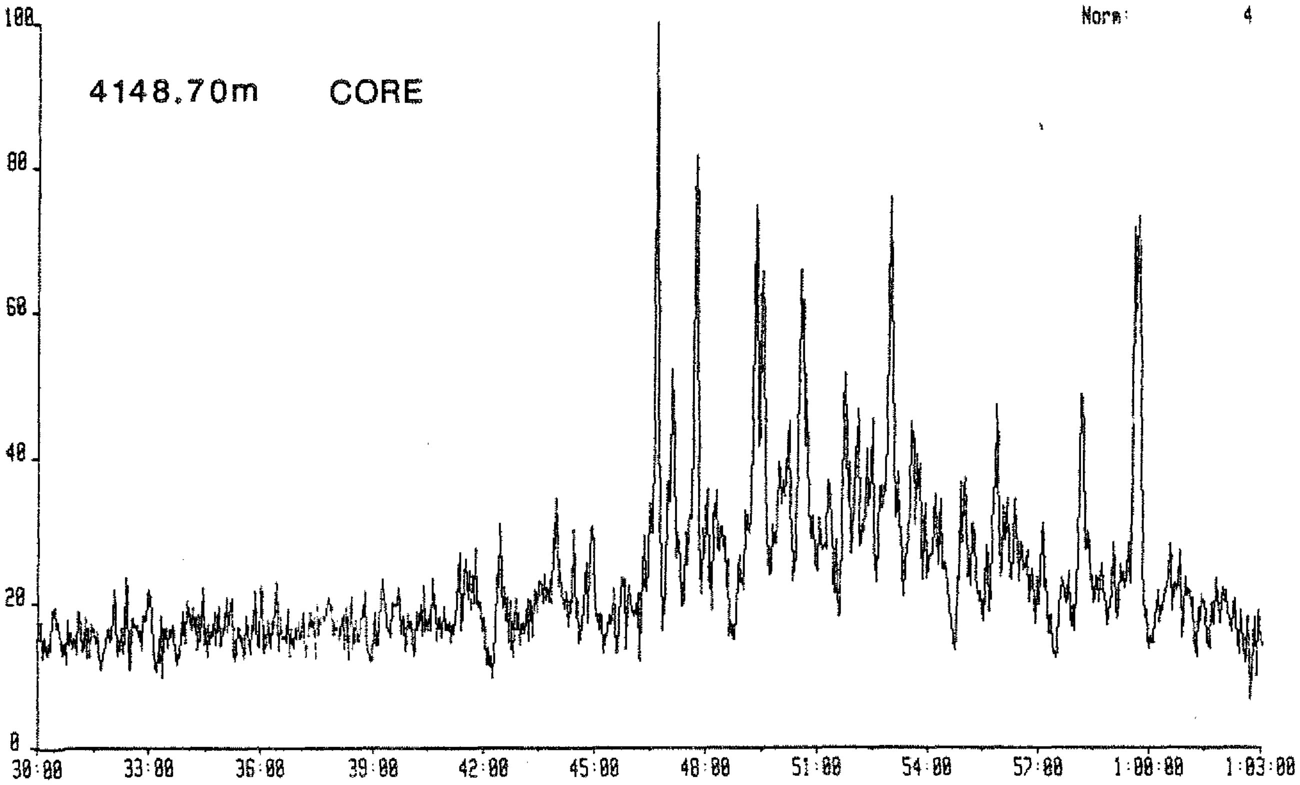


FIGURE 12e

MASS FRAGMENTOGRAMS

WELL 34/10-23 REARRANGED STERANES m/z 259

1474006 5-JAN-87 Sir Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 259.2427
Text:WELL 34/10-23 4148-70'



1474009 5-JAN-87 Sir Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 259.2427
Text:WELL 34/10-23 4172-25'

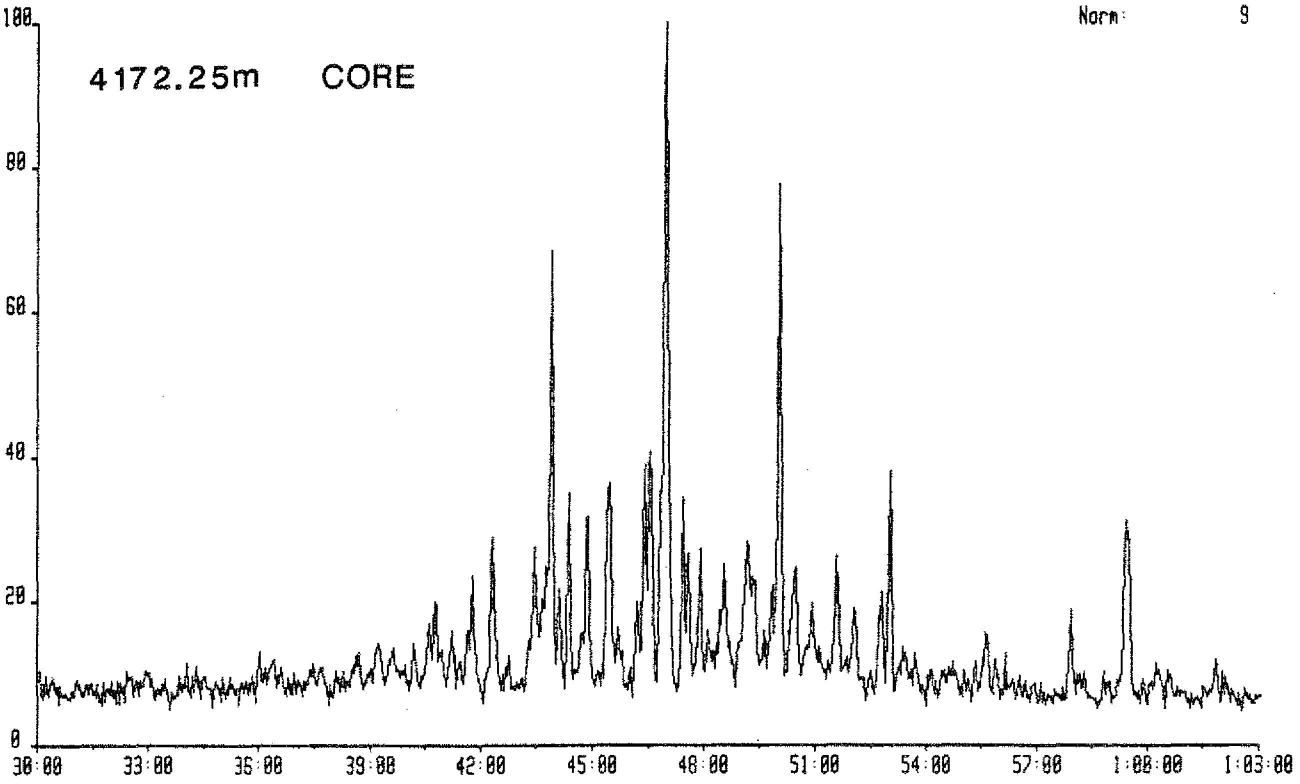
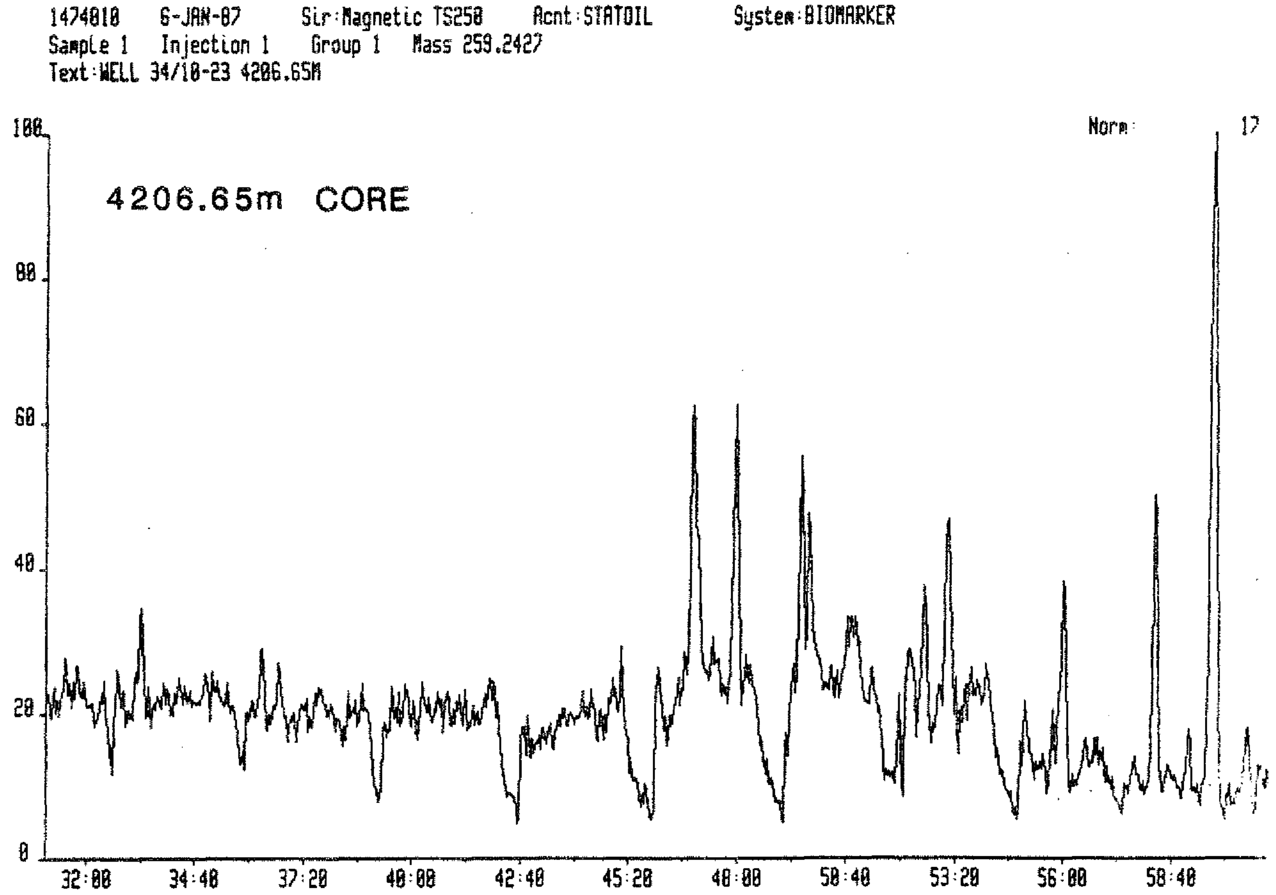


FIGURE 12f

MASS FRAGMENTOGRAMS

WELL 34/10-23 REARRANGED STERANES m/z 259



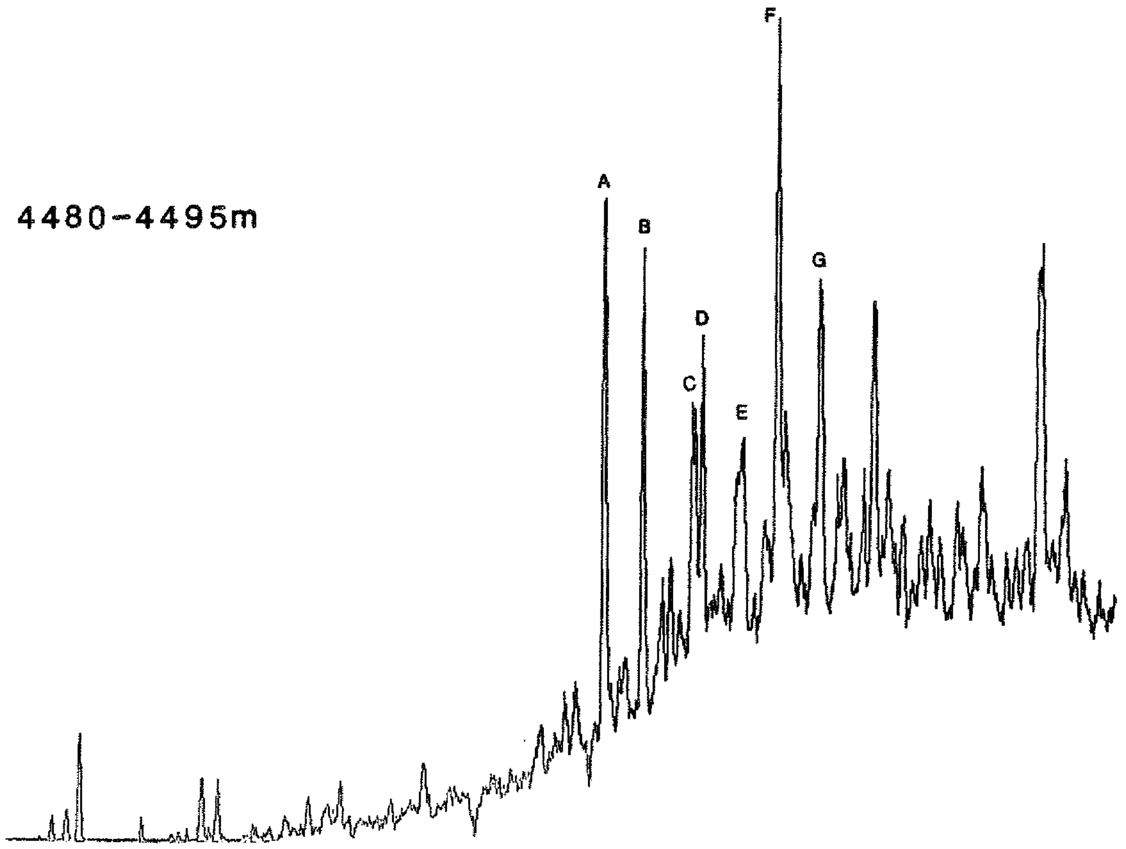


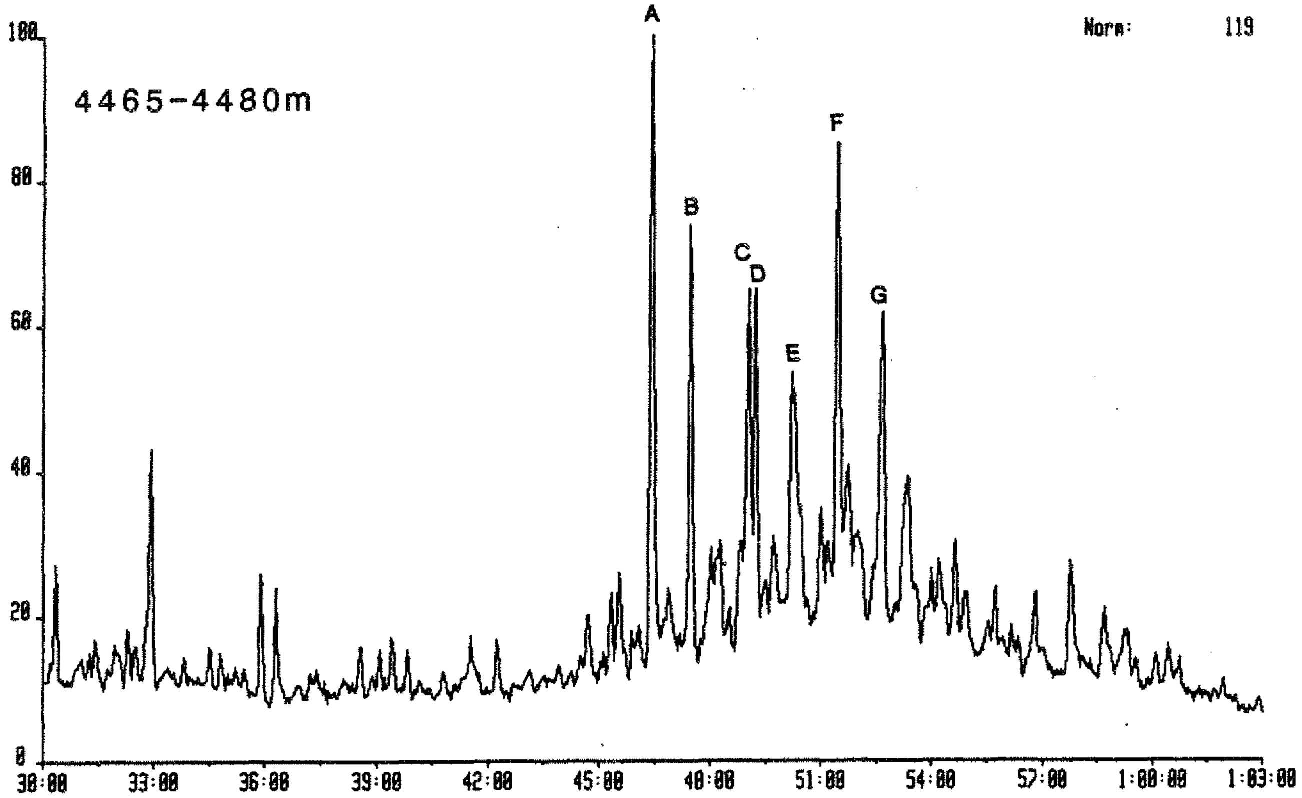
FIGURE 12g

MASS FRAGMENTOGRAMS

GEOCHEM

WELL 34/10-23 REARRANGED STERANES m/z 259

1474026 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 259.2427
Text:BIOMARKERS



WELL 34/10-30

1474015 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 259.2427
Text:BIOMARKERS

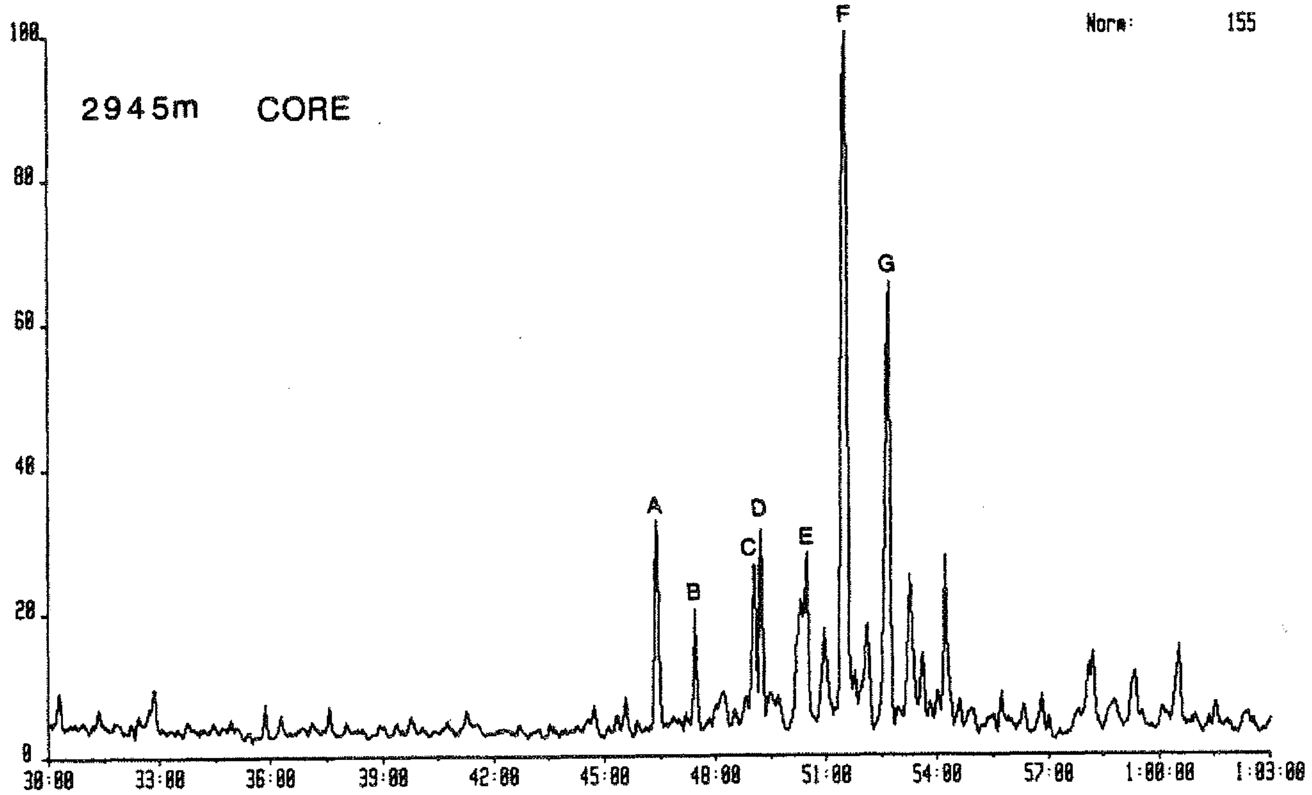


FIGURE 12h

MASS FRAGMENTOGRAMS

WELL 34/10-30 REARRANGED STERANES m/z 259

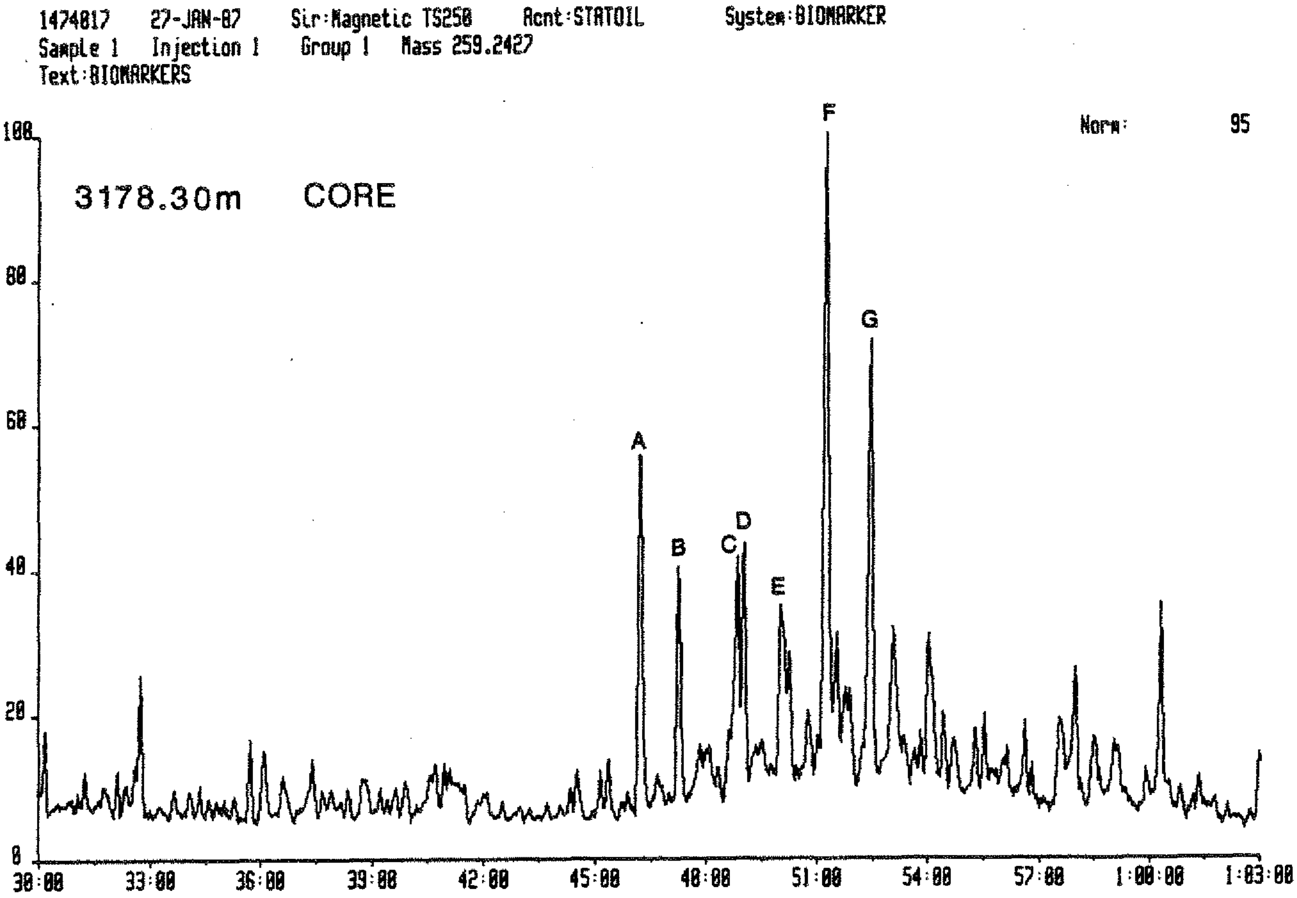


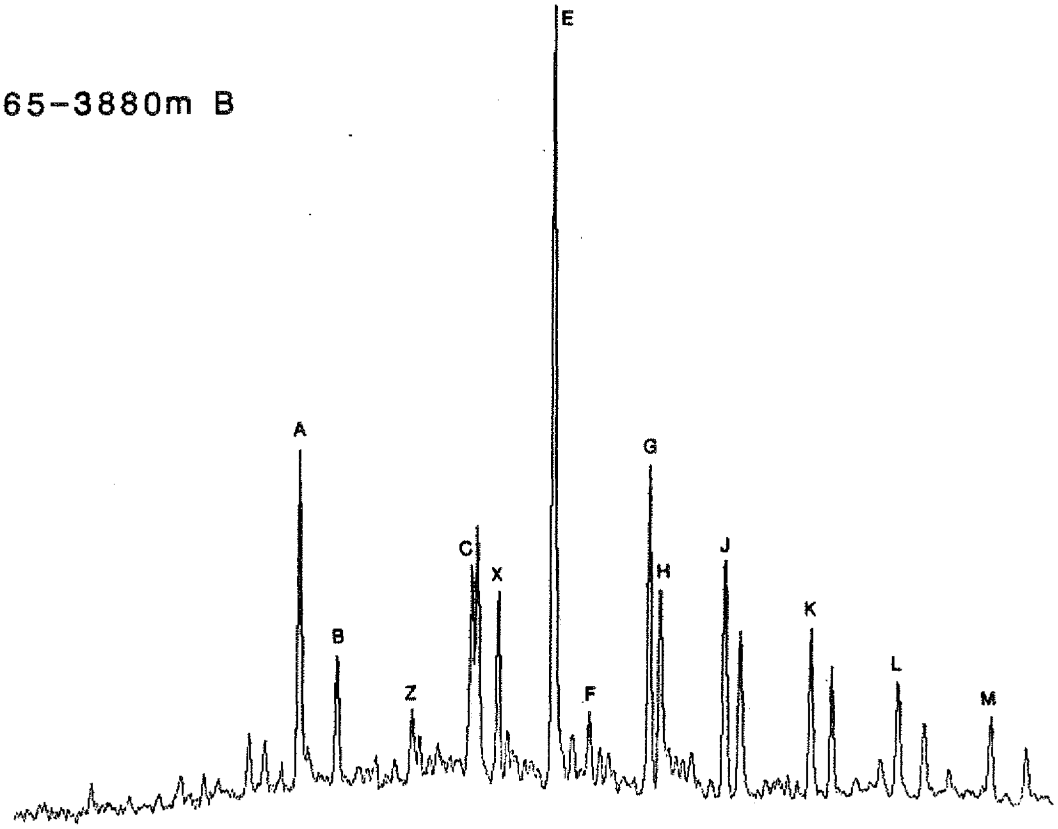
FIGURE 13a

MASS FRAGMENTOGRAMS

WELL 34/10-23

TRITERPANES m/z 191

3865-3880m B



3910-3925m

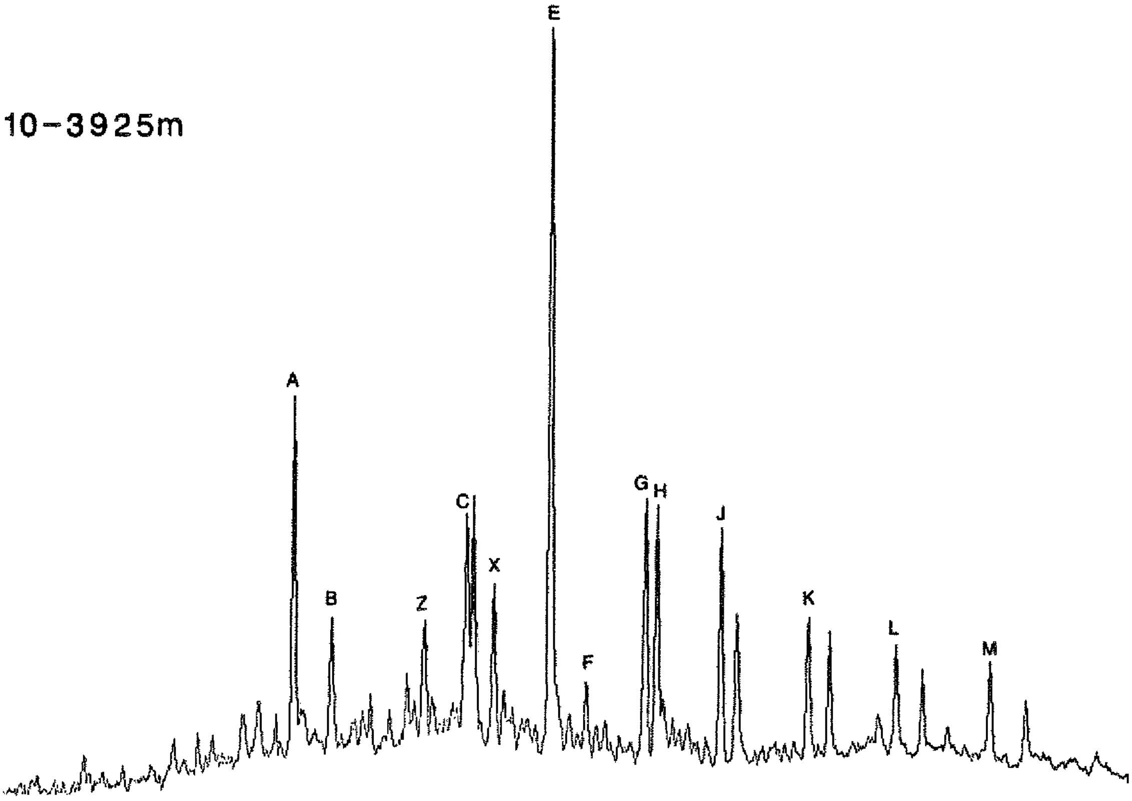


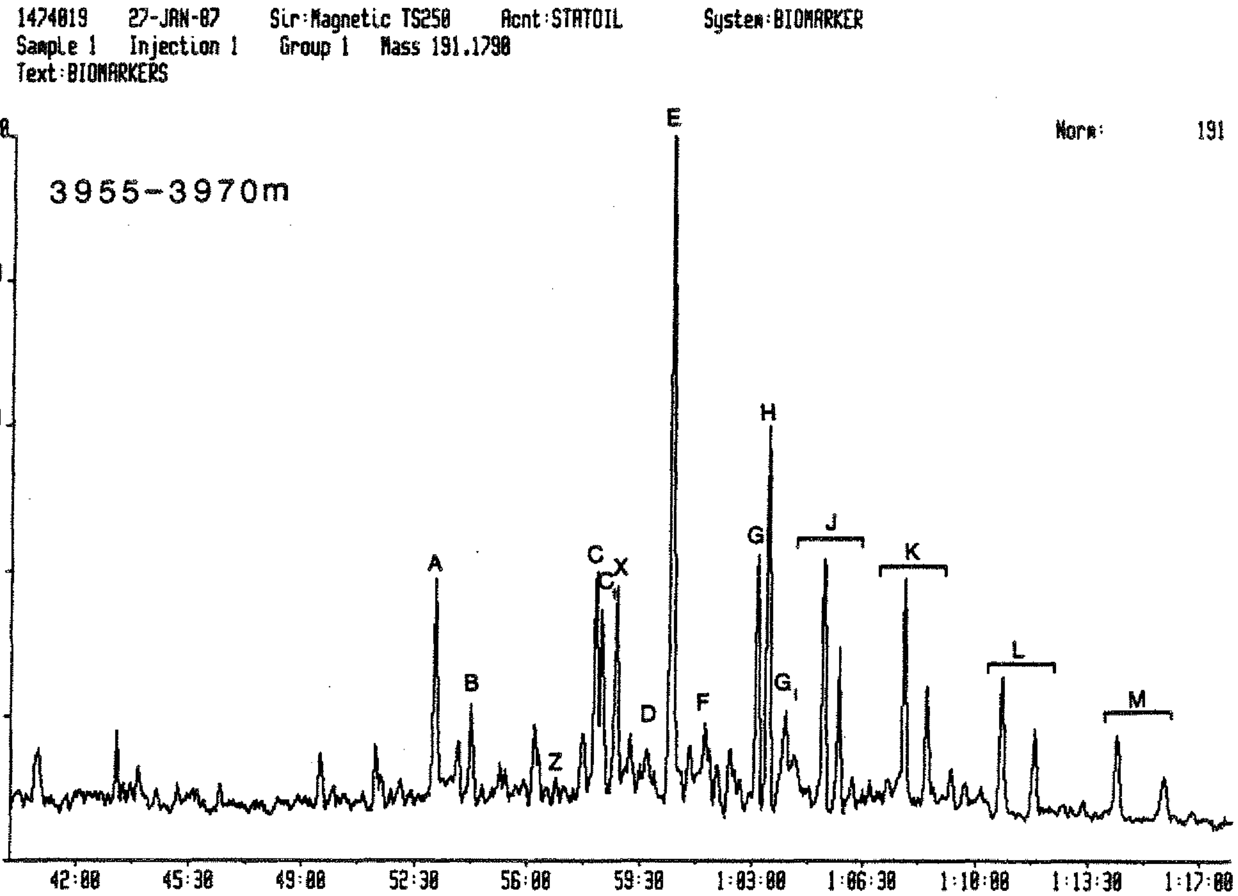
FIGURE 13b

MASS FRAGMENTOGRAMS

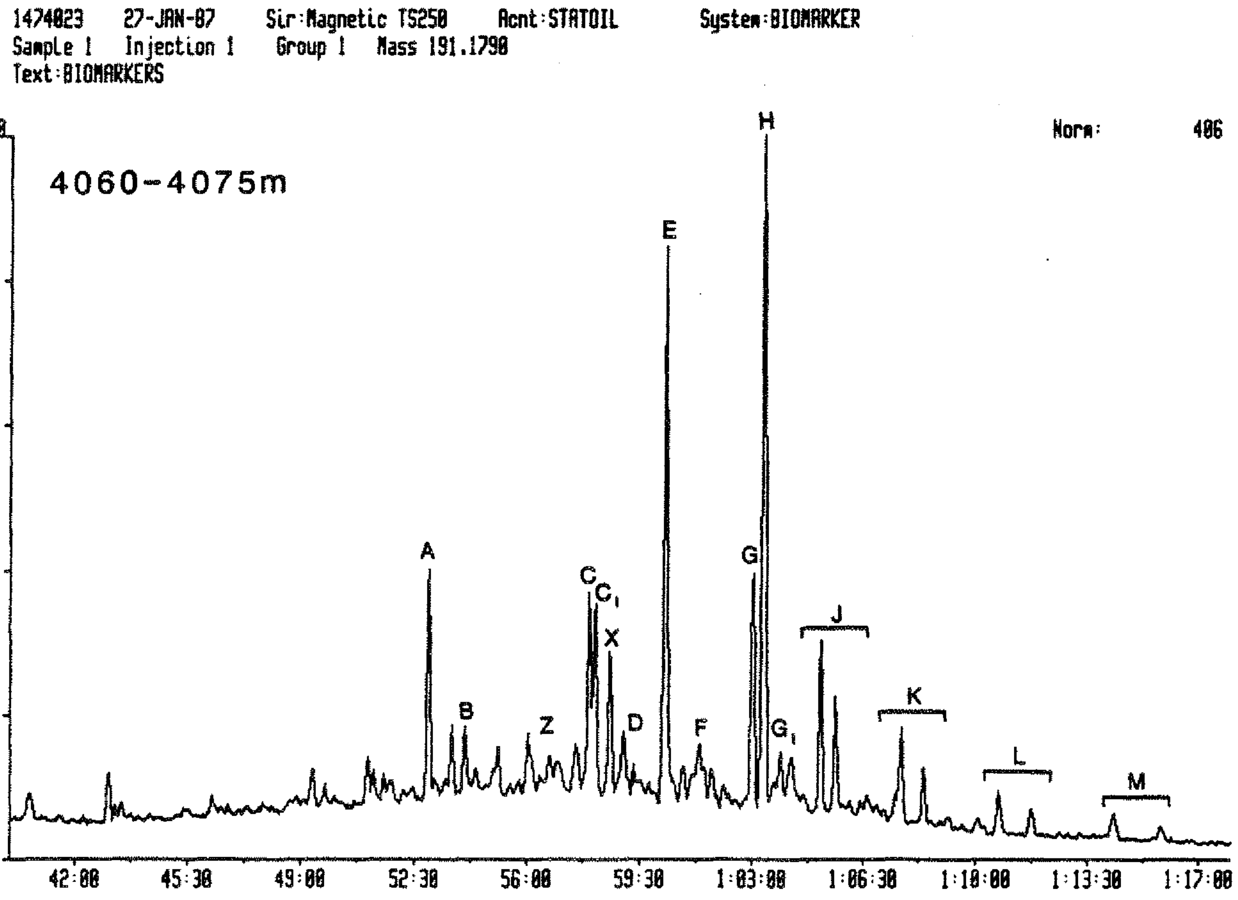
GEOCHEM

WELL 34/10-23

TRITERPANES m/z 191



```
1474019   27-JAN-87   Sir:Magnetic TS250   Acnt:STATOIL      System:BIOMARKER
Sample 1   Injection 1   Group 1   Mass 191.1790
Text:BIOMARKERS
```

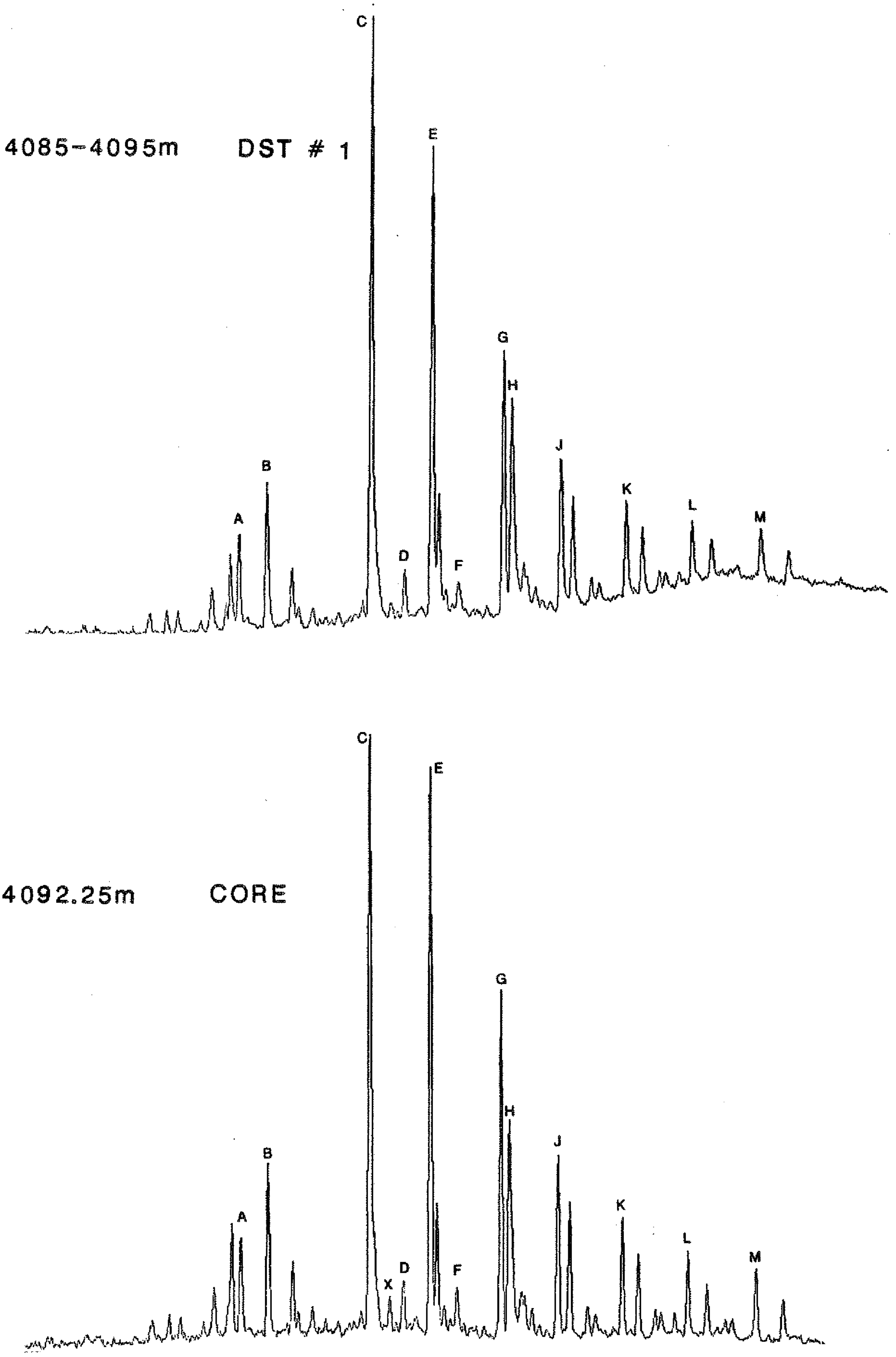


```
1474023   27-JAN-87   Sir:Magnetic TS250   Acnt:STATOIL      System:BIOMARKER
Sample 1   Injection 1   Group 1   Mass 191.1790
Text:BIOMARKERS
```

FIGURE 13c

MASS FRAGMENTOGRAMS

WELL 34/10-23 TRITERPANES m/z 191



4085-4095m DST # 1

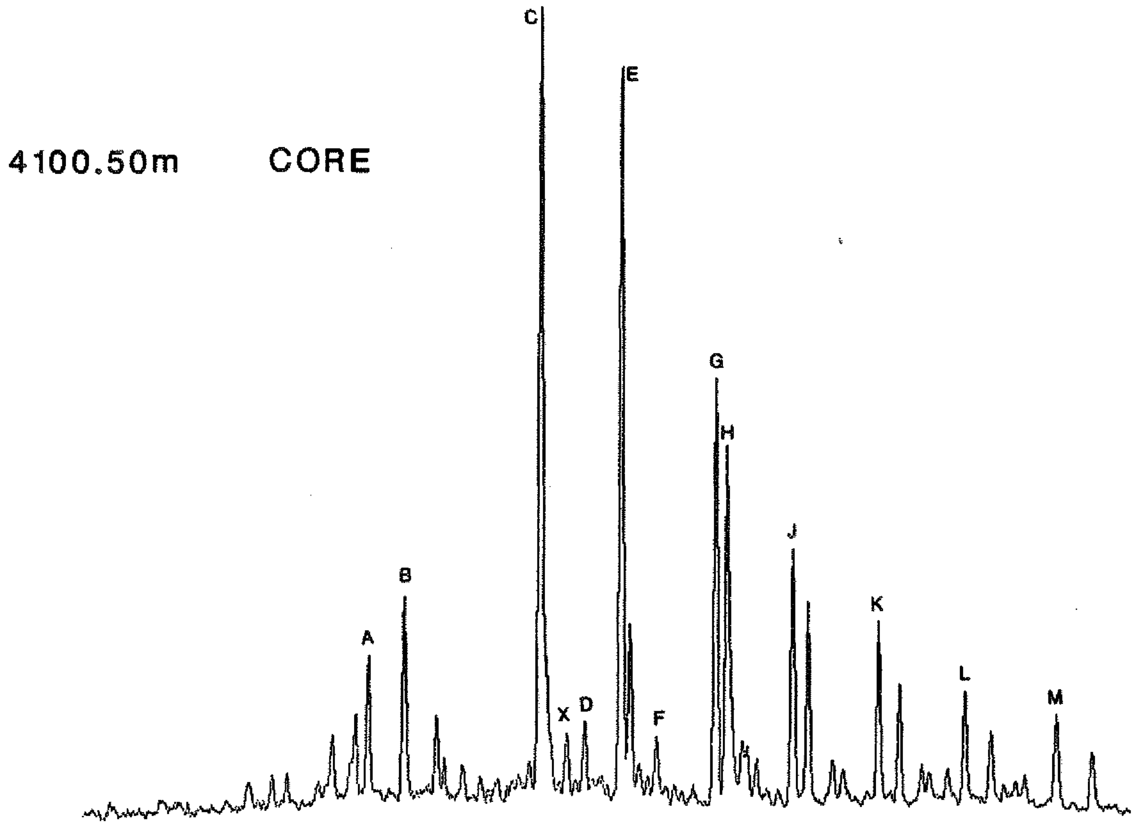
4092.25m CORE

FIGURE 13d

MASS FRAGMENTOGRAMS

WELL 34/10-23

TRITERPANES m/z 191



```
1474004R   5-JAN-87      ir Magnetic TS250     Acnt:STATOIL        System:BIOMARKER
Sample 1   Injection 1    Group 1   Mass 191.1790
Text:WELL 34/10-23 4136-62'
```

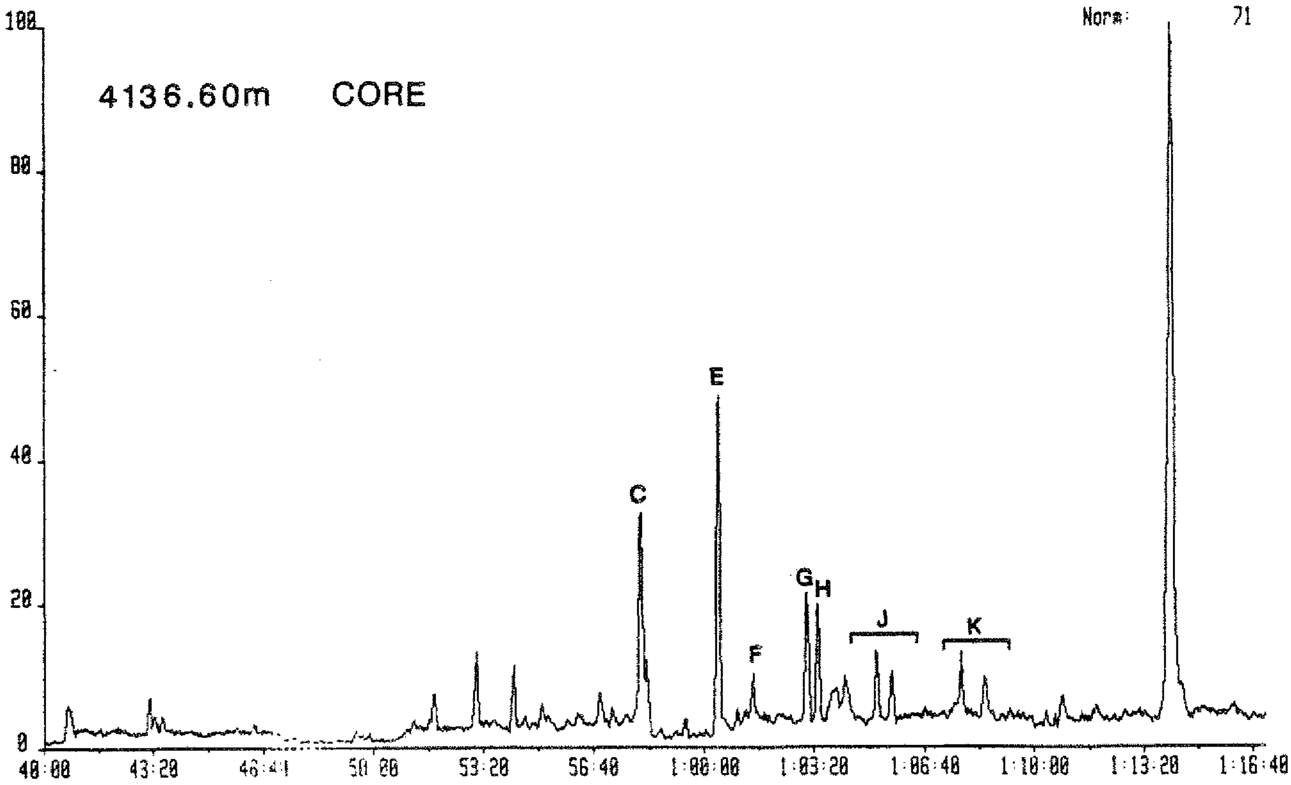


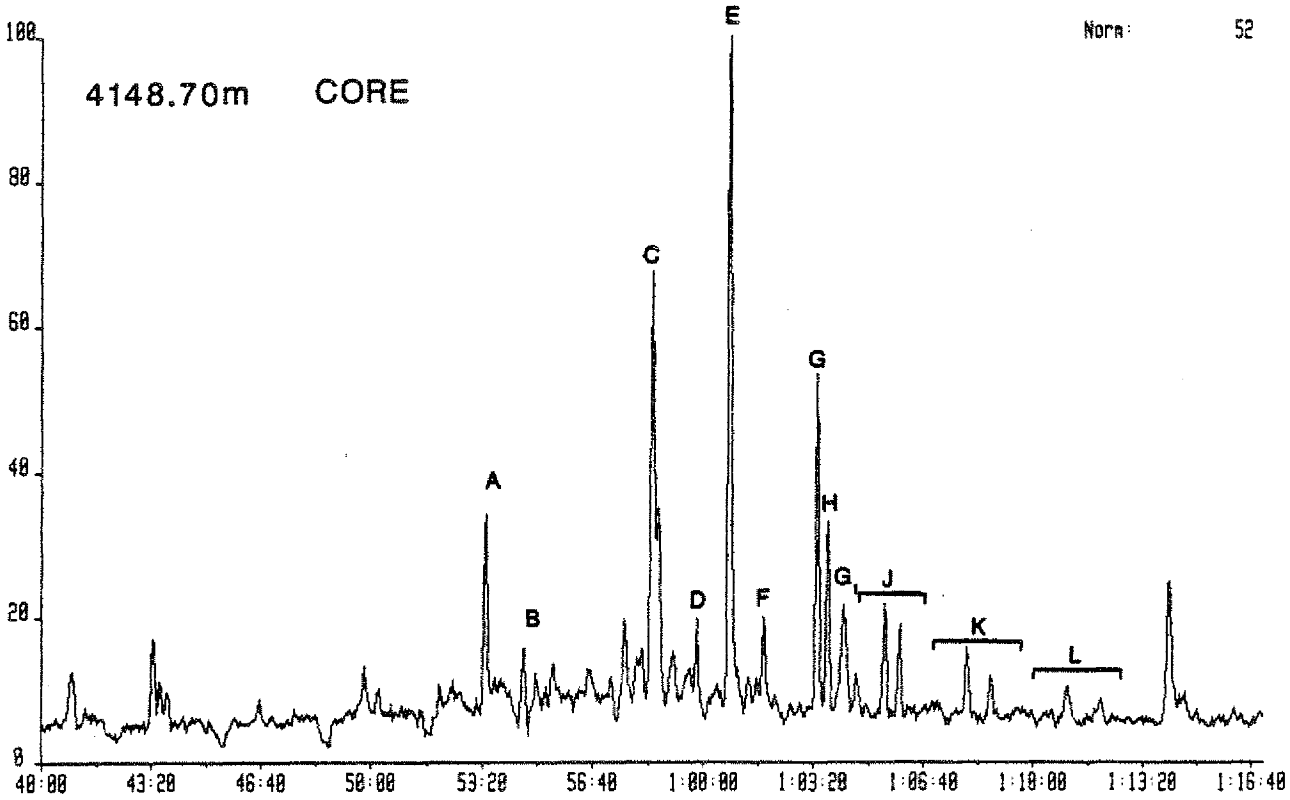
FIGURE 13e

MASS FRAGMENTOGRAMS

WELL 34/10-23

TRITERPANES m/z 191

1474006 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 191.1790
Text:WELL 34/10-23 4148-70'



1474009 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 191.1790
Text:WELL 34/10-23 4172-25'

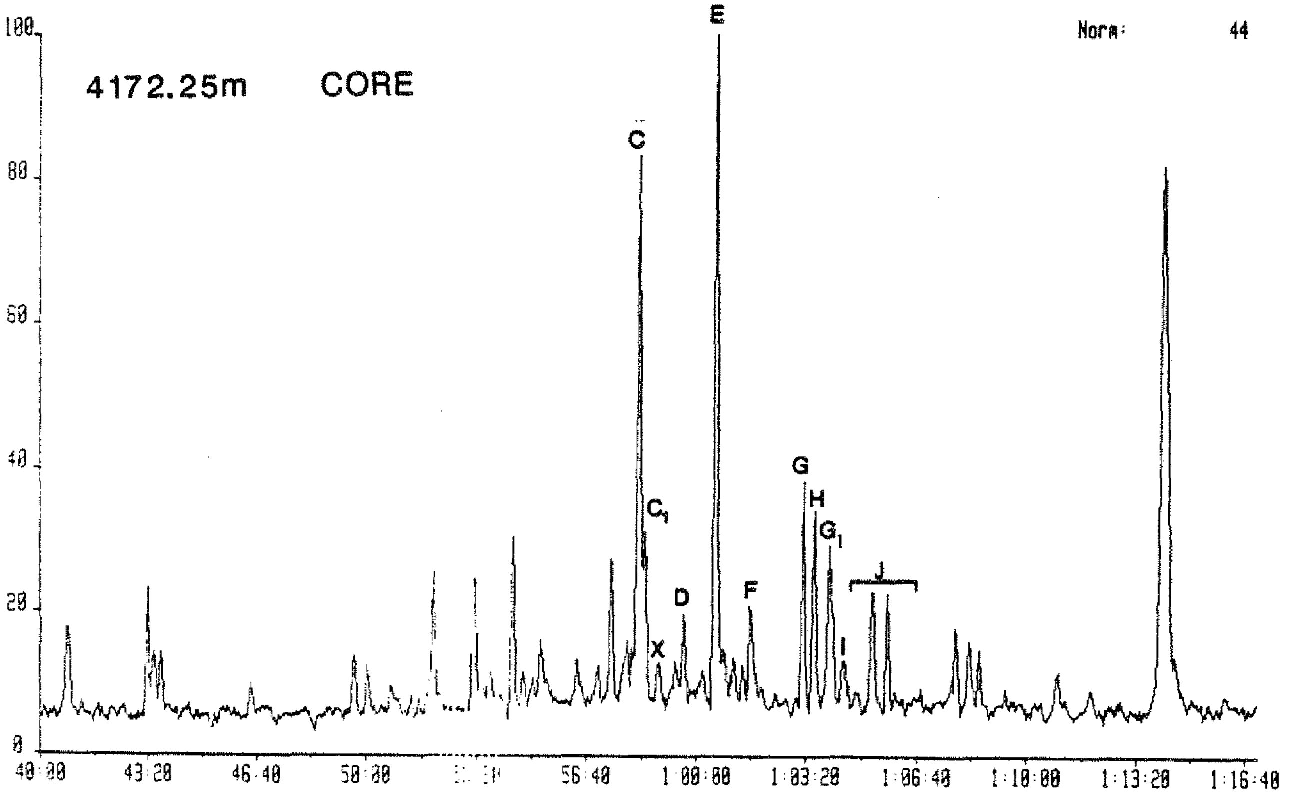


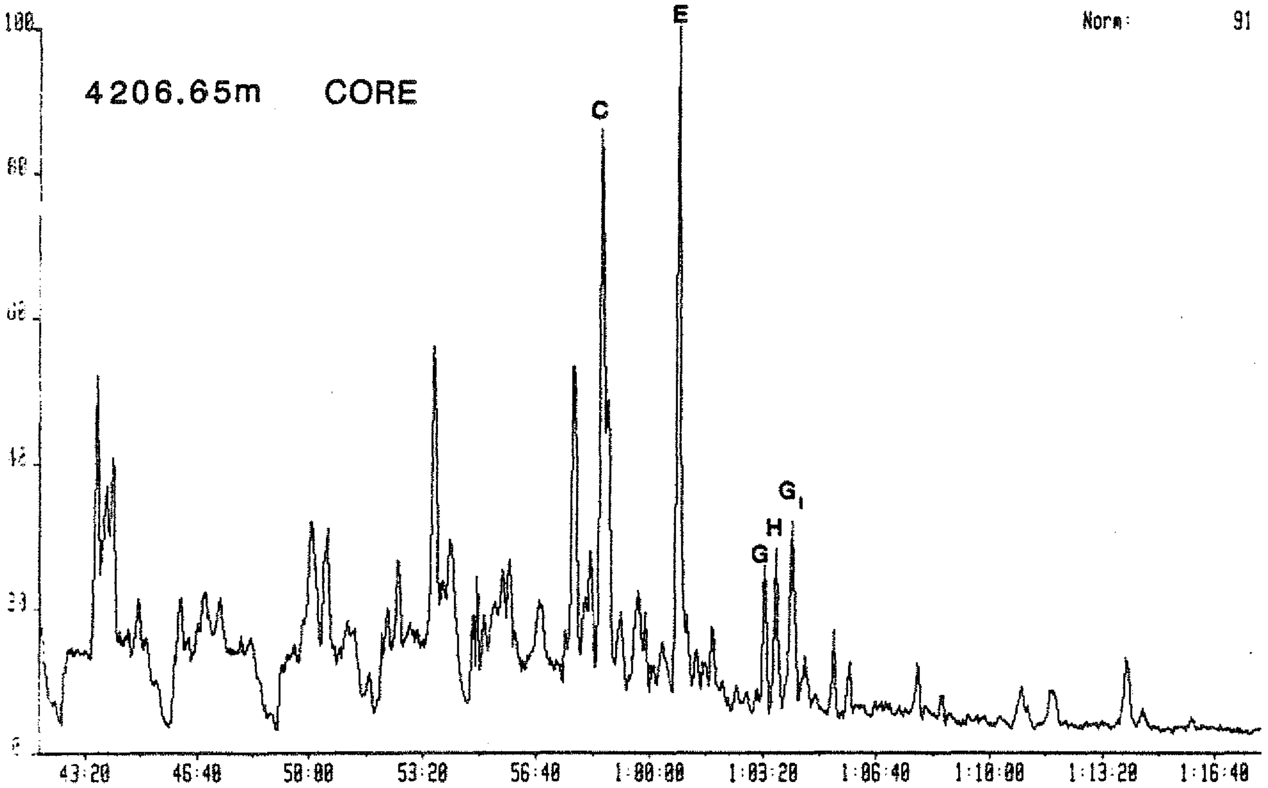
FIGURE 13f

MASS FRAGMENTOGRAMS

WELL 34/10-23

TRITERPANES m/z 191

```
1474010    6-JAN-87      Sir:Magnetic TS250     Acnt:STATOIL        System:BIOMARKER
Sample 1   Injection 1   Group 1   Mass 191.1798
Text:WELL 34/10-23 420S.65M
```



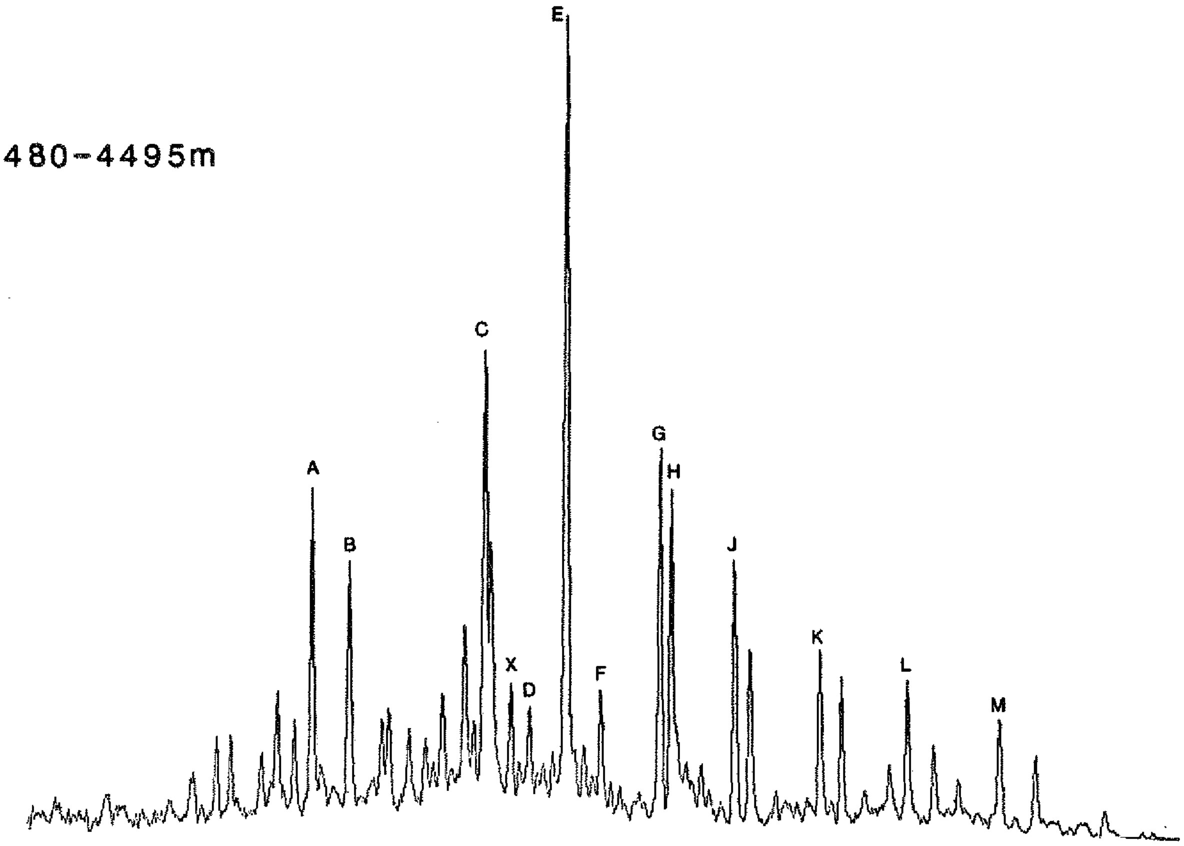


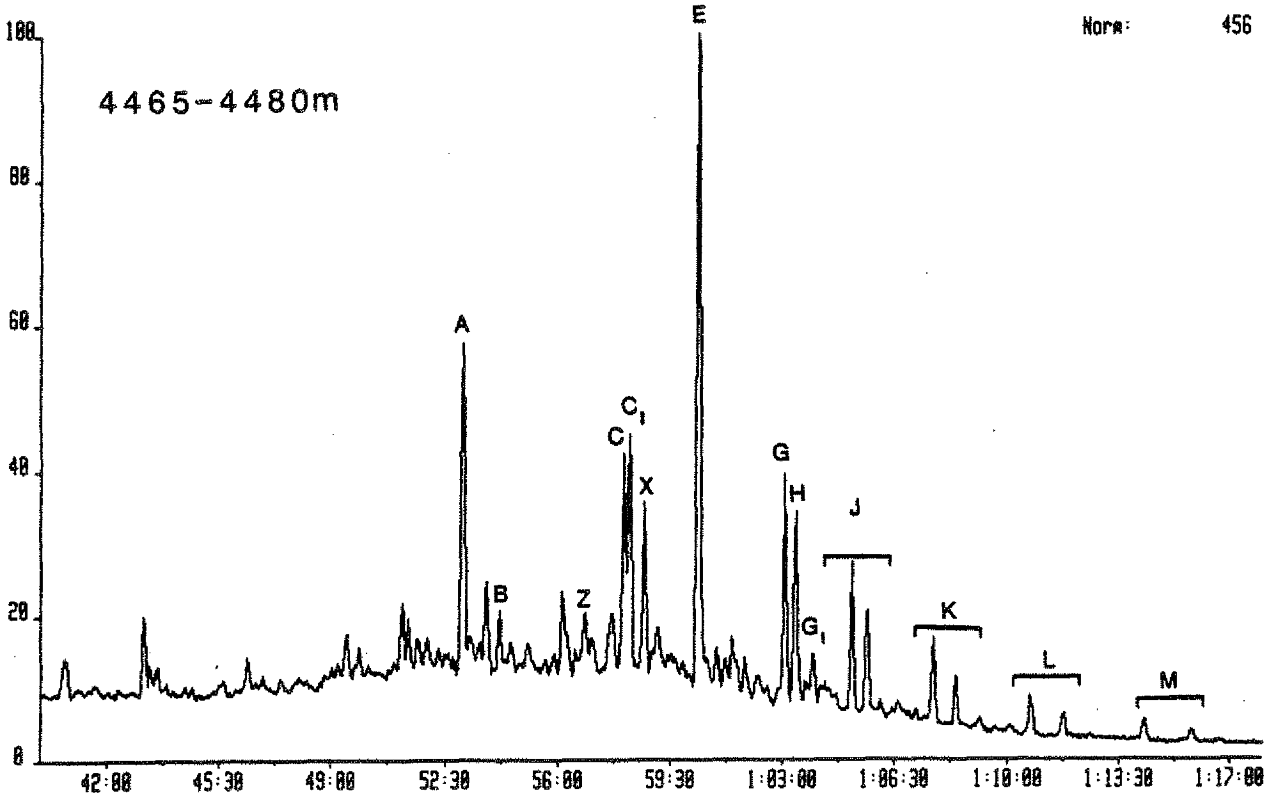
FIGURE 13g

MASS FRAGMENTOGRAMS

WELL 34/10-23

TRITERPANES m/z 191

1474026 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 191.1790
Text:BIOMARKERS



WELL 34/10-30

1474015 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 191.1790
Text:BIOMARKERS

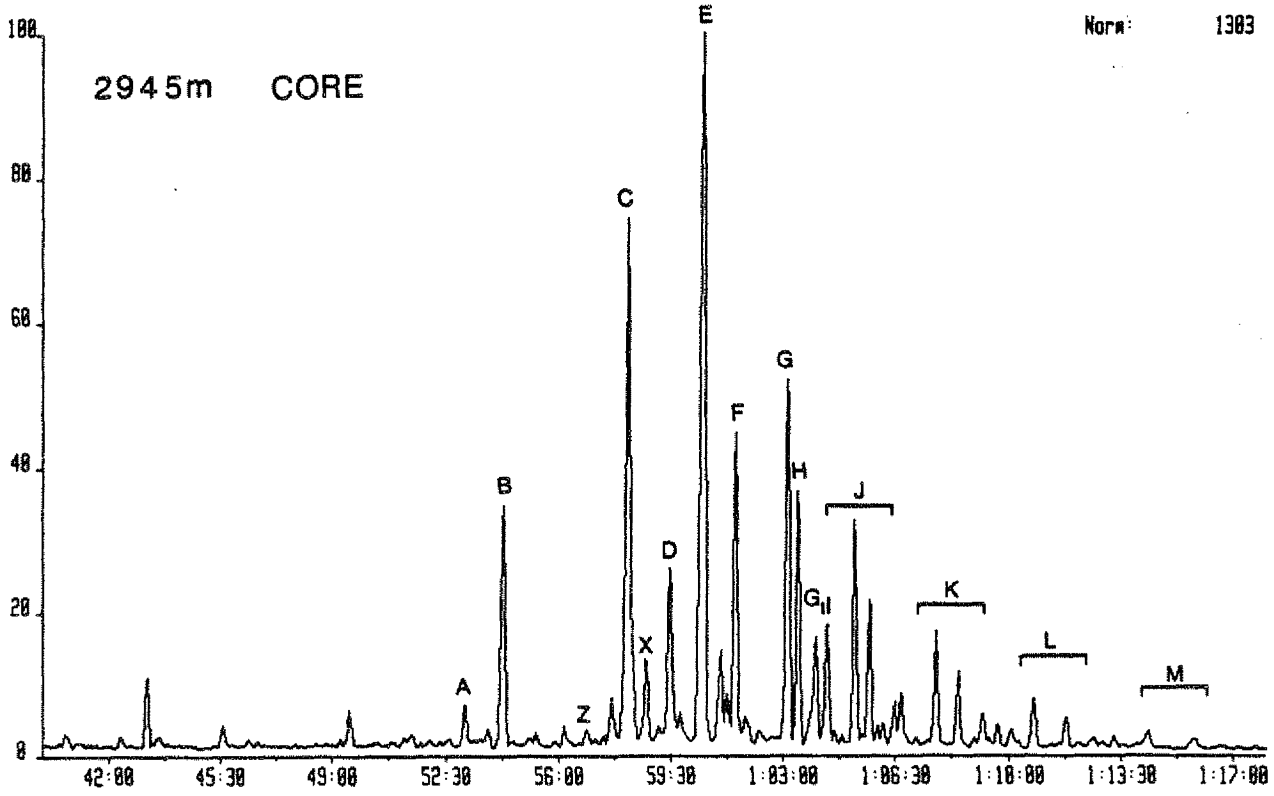


FIGURE 13h

MASS FRAGMENTOGRAMS

WELL 34/10-30

TRITERPANES m/z 191

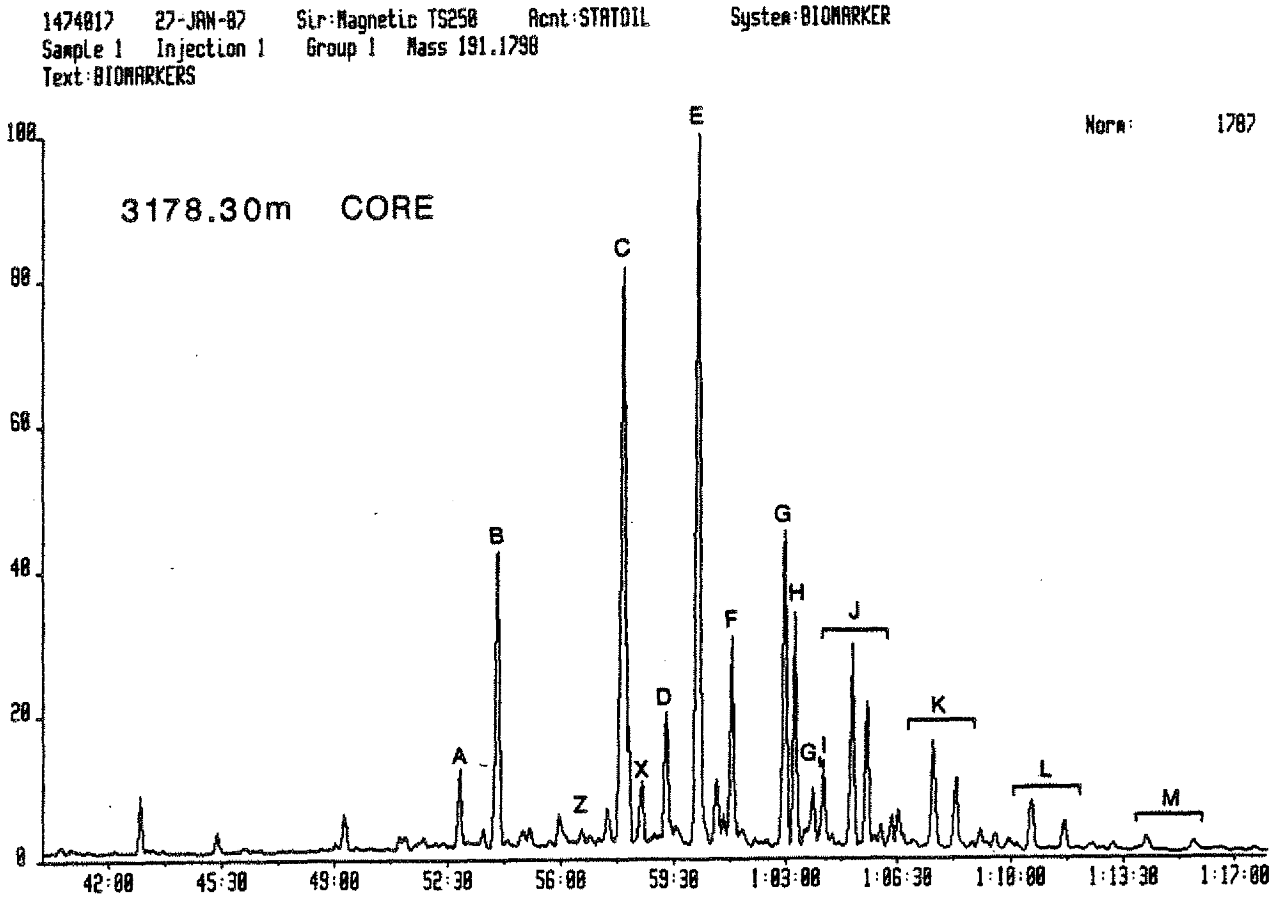
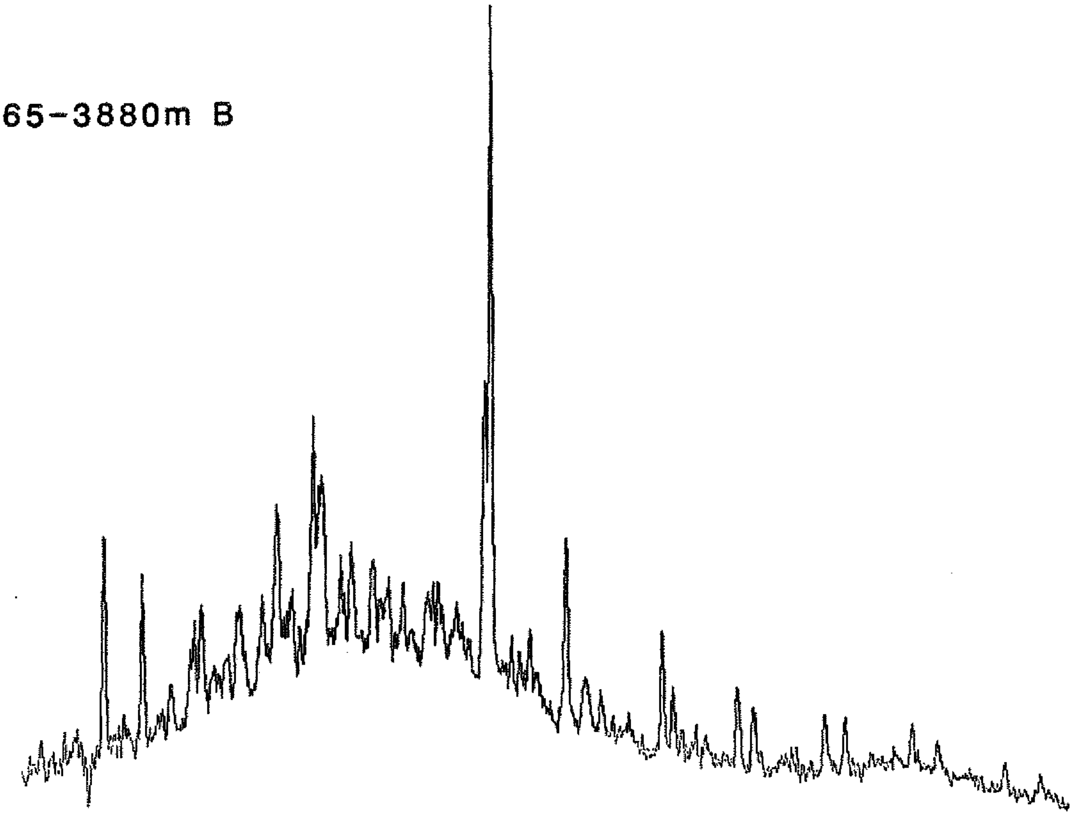


FIGURE 14a

MASS FRAGMENTOGRAMS

WELL 34/10-23 DEMETHYLATED HOPANES m/z 177

3865-3880m B



3910-3925m

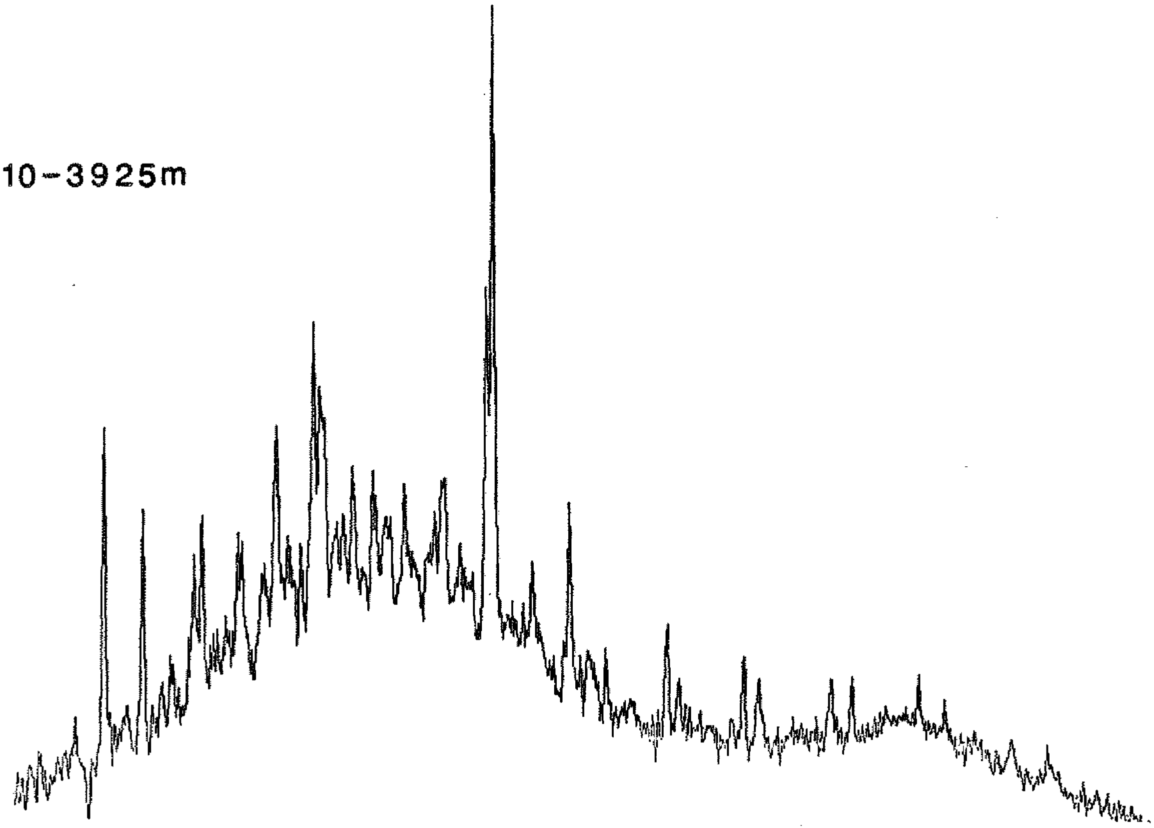
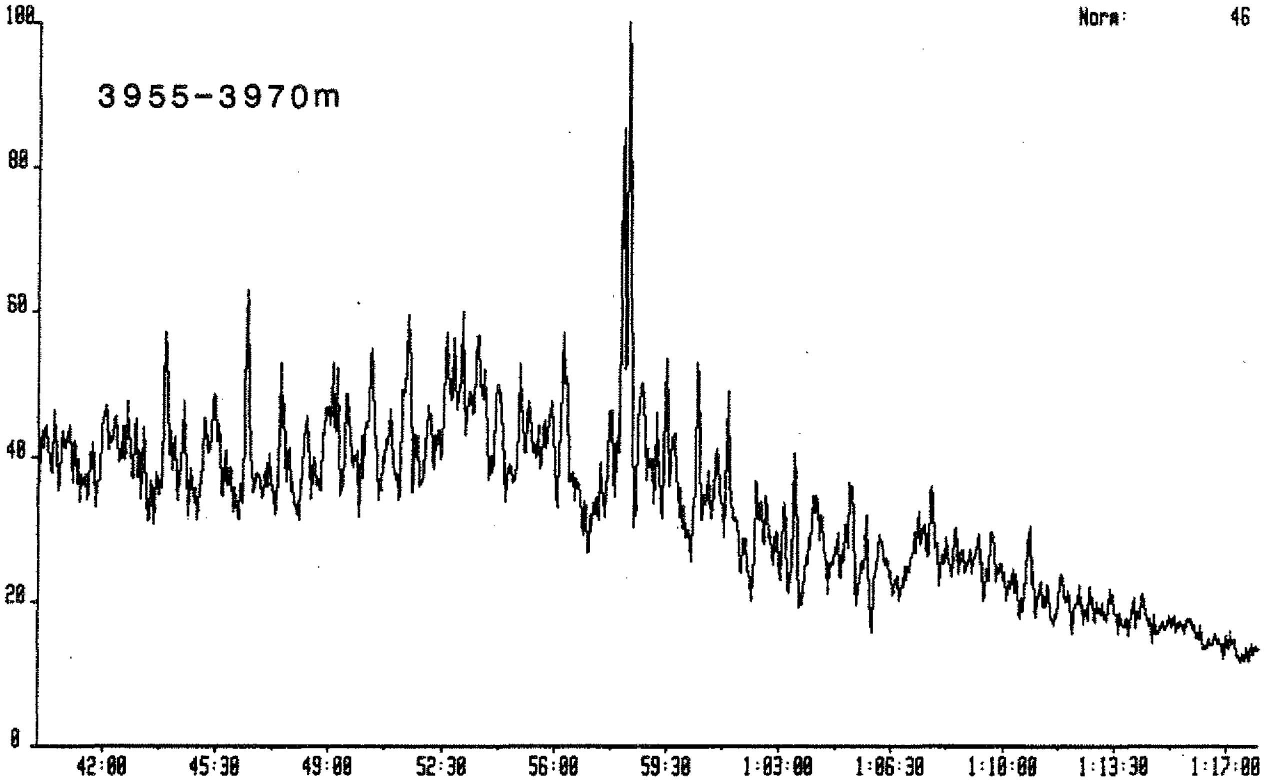


FIGURE 14b

MASS FRAGMENTOGRAMS

WELL 34/10-23 DEMETHYLATED HOPANES m/z 177

1474019 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 177.1642
Text:BIOMARKERS



1474023 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 177.1042
Text:BIOMARKERS

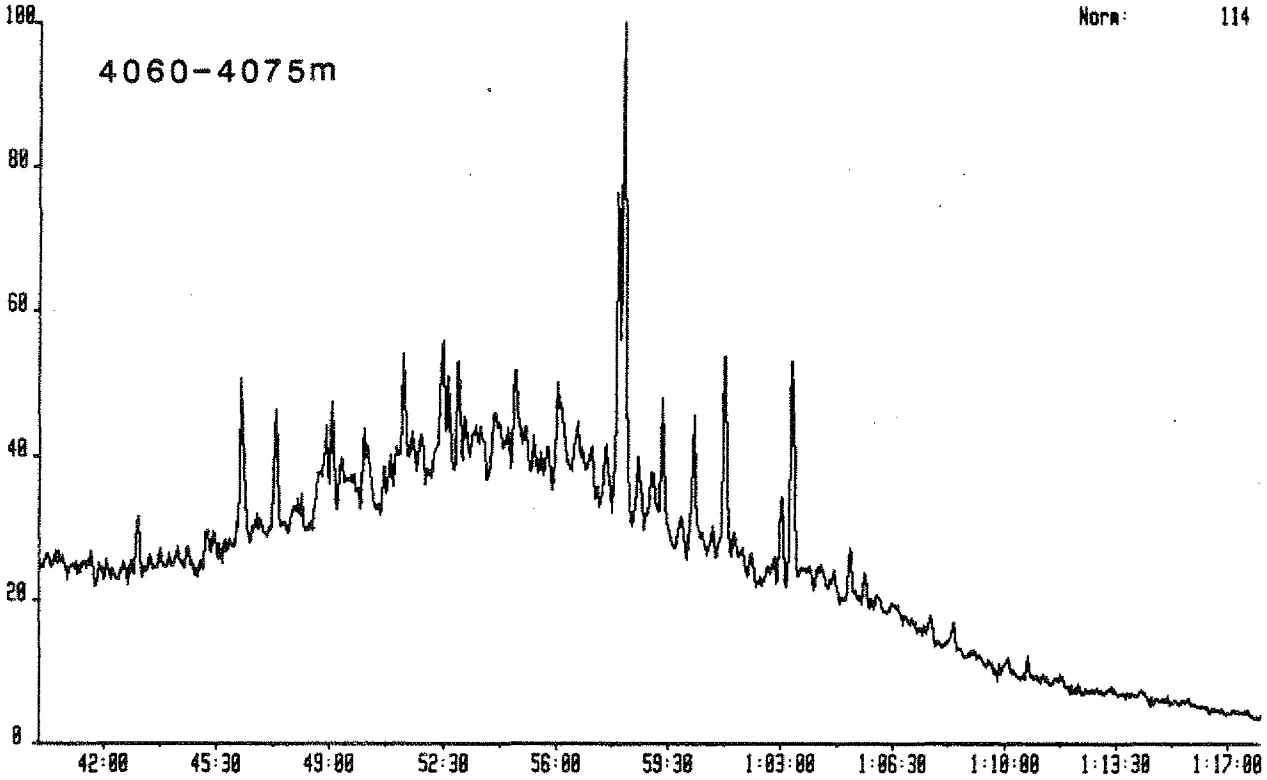
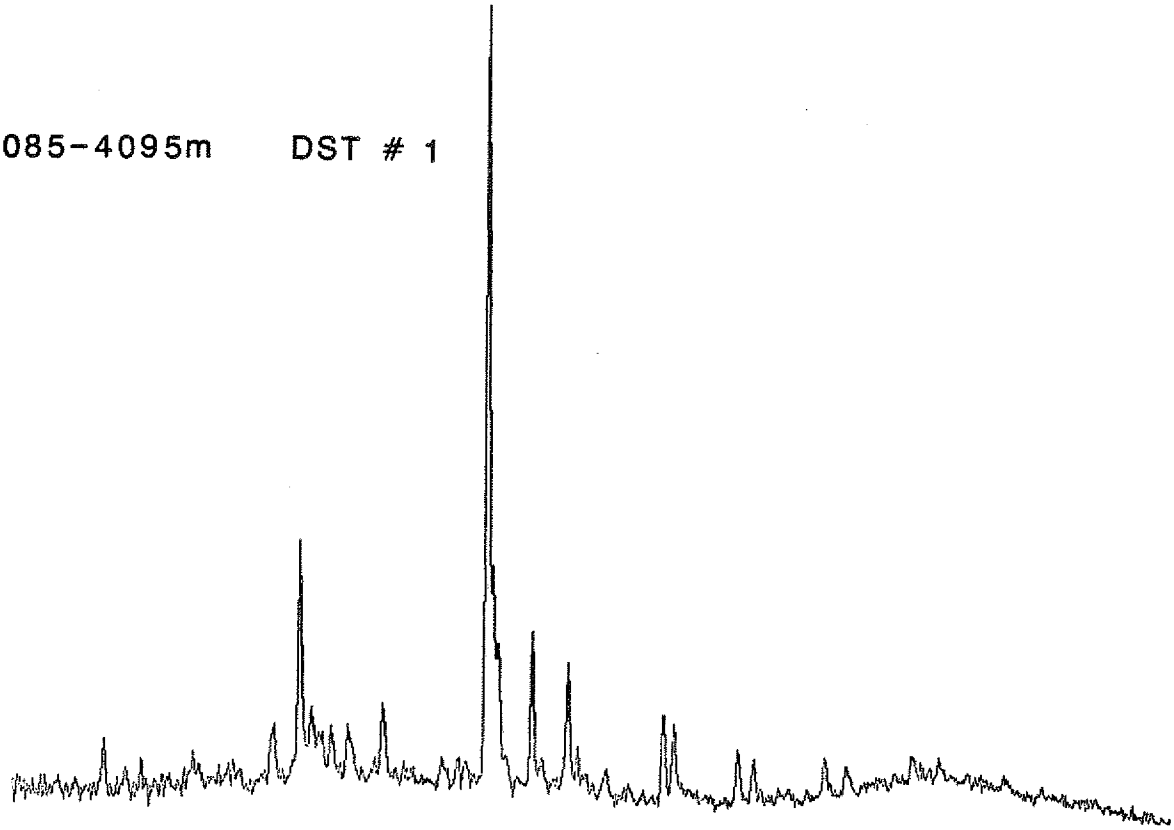


FIGURE 14c **MASS FRAGMENTOGRAMS**

WELL 34/10-23 DEMETHYLATED HOPANES m/z 177



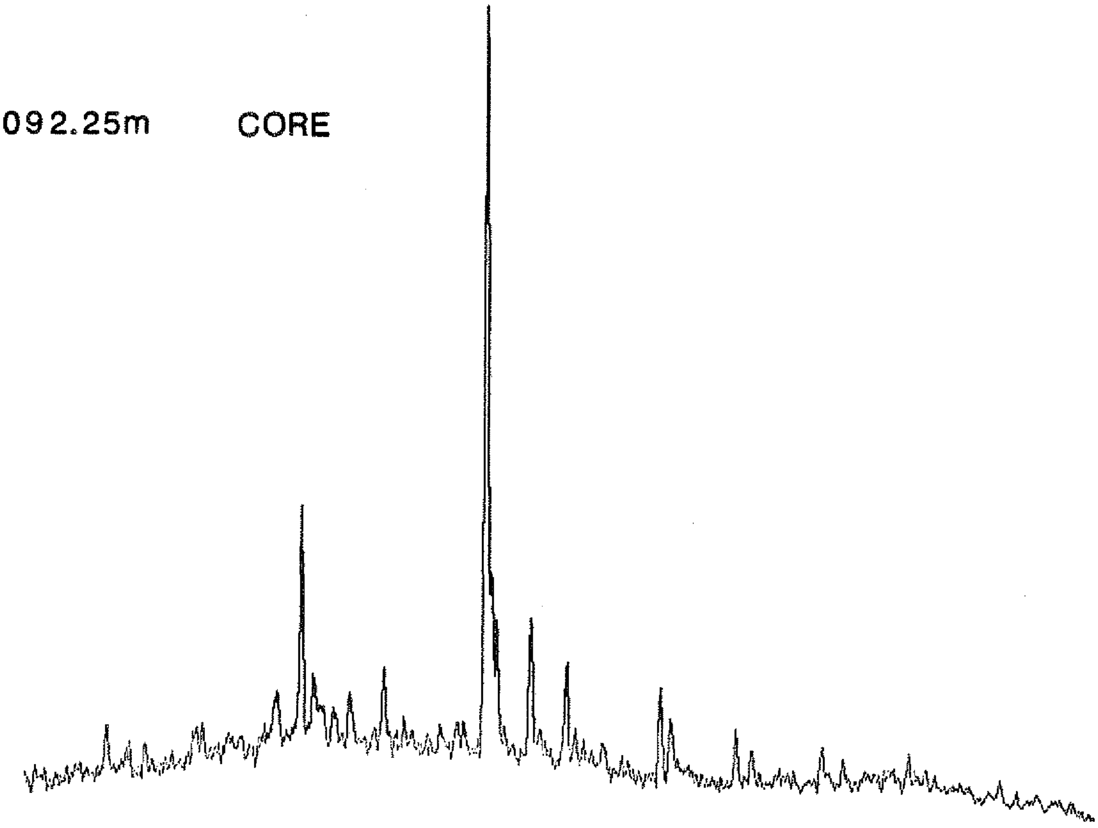
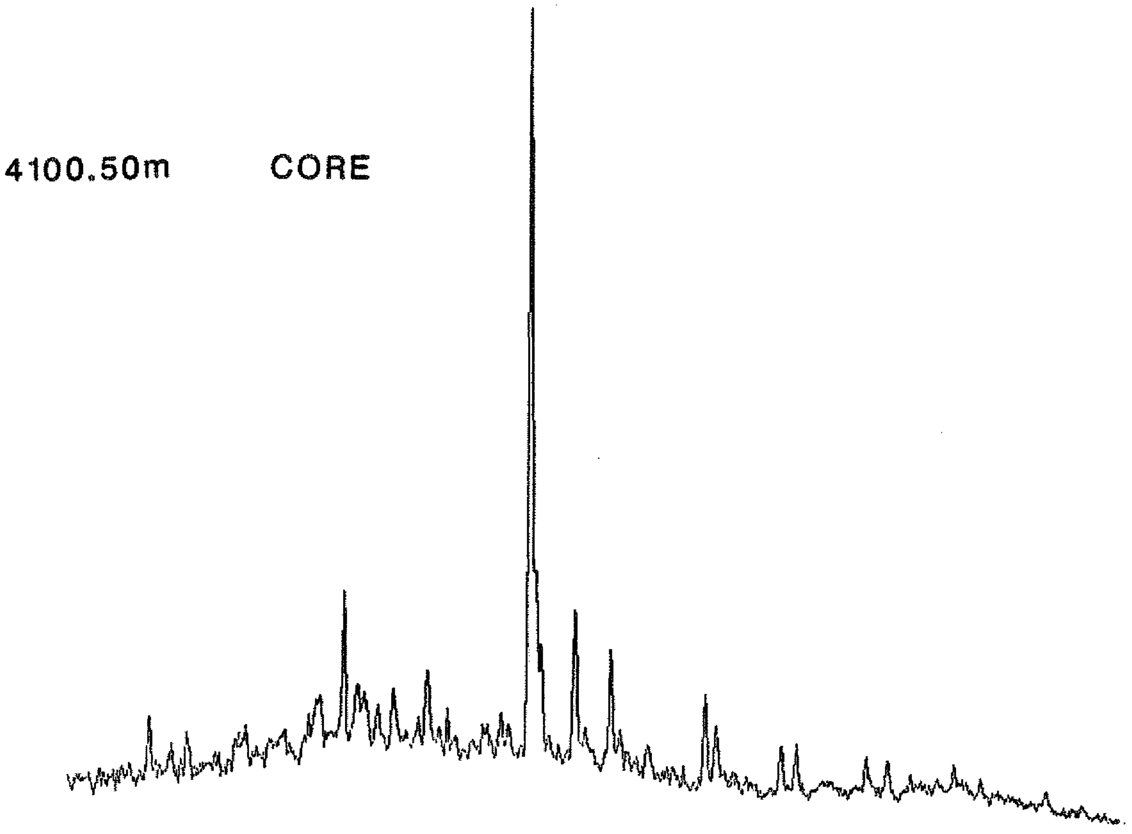


FIGURE 14d

MASS FRAGMENTOGRAMS

WELL 34/10-23 DEMETHYLATED HOPANES m/z 177



```
1474004R   5-JAN-87     Sir:Magnetic TS250     Acnt:STATOIL        System:BIOMARKER
Sample 1   Injection 1    Group 1   Mass 177.1642
Text:WELL 34/10-23 4136-66'
```

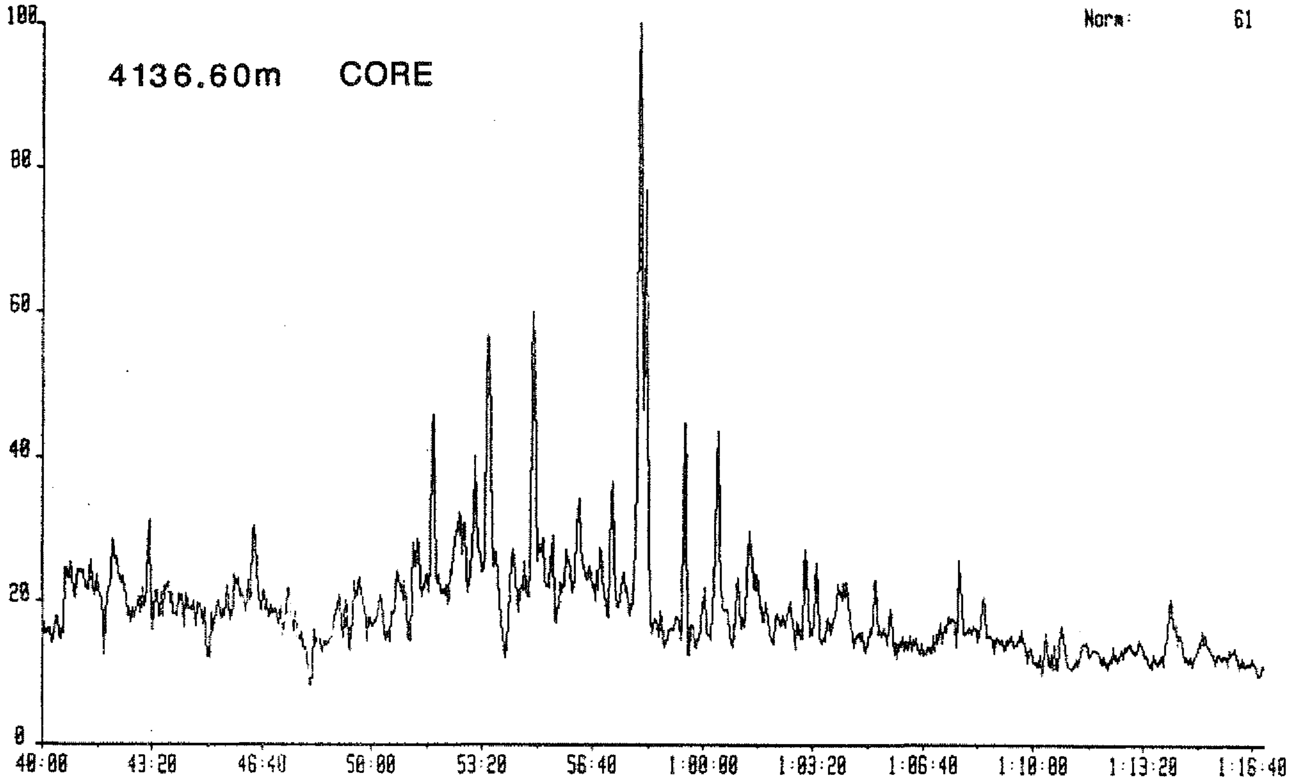
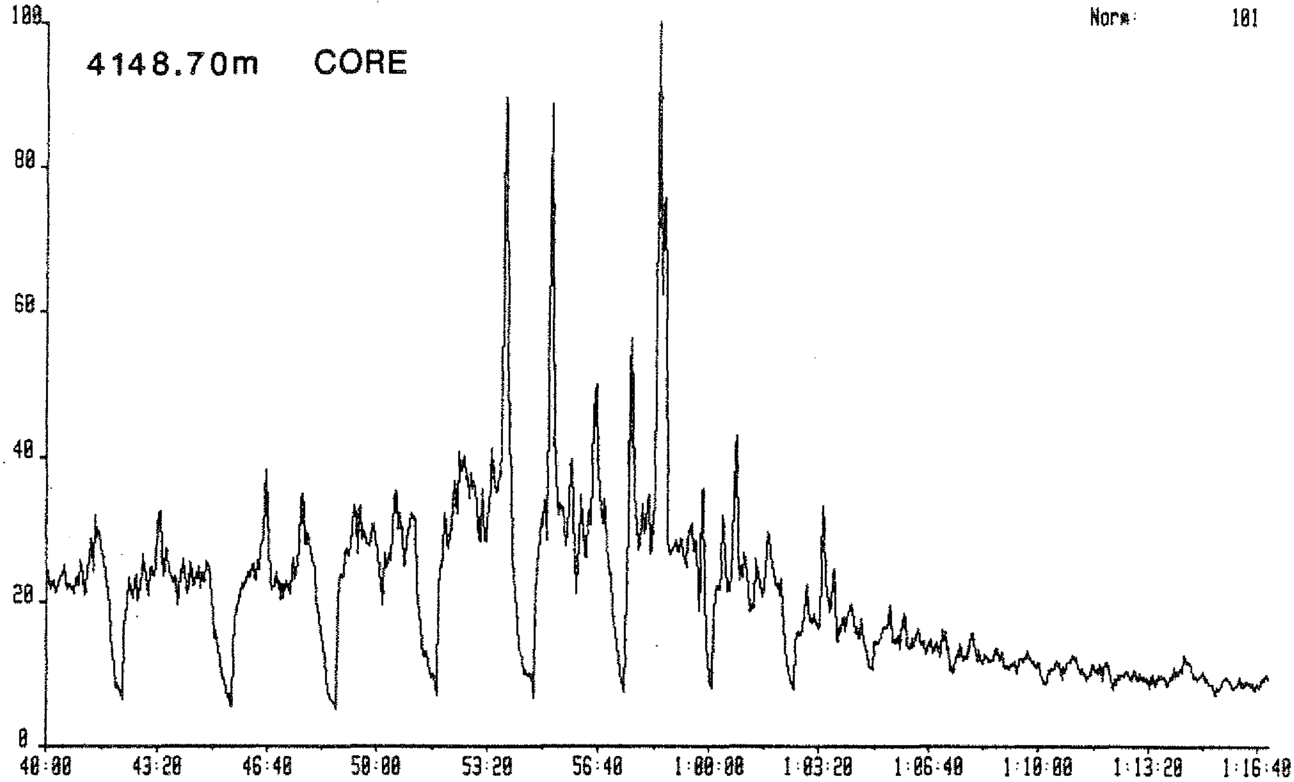


FIGURE 14e MASS FRAGMENTOGRAMS

WELL 34/10-23 DEMETHYLATED HOPANES m/z 177

1474008 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 177.1642
Text:WELL 34/10-23 4148-70'



1474009 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 177.1642
Text:WELL 34/10-23 4172-25'

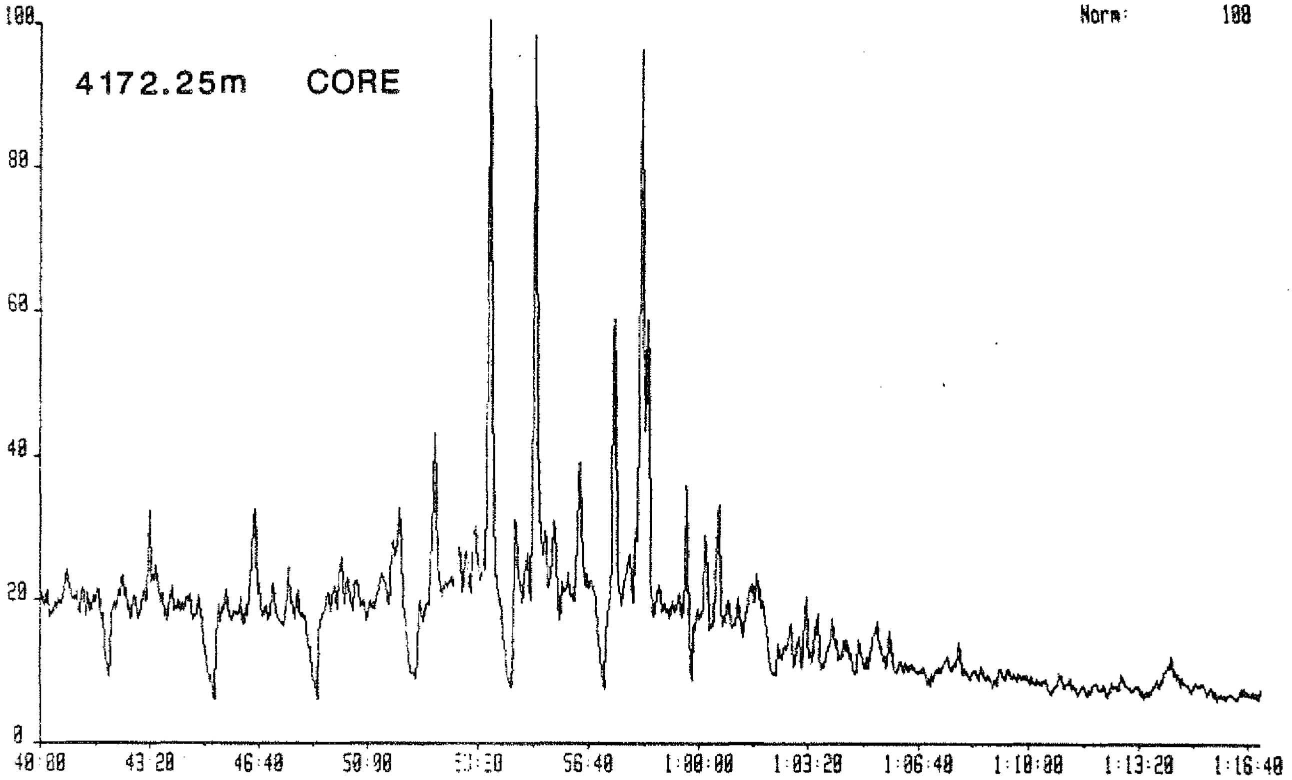
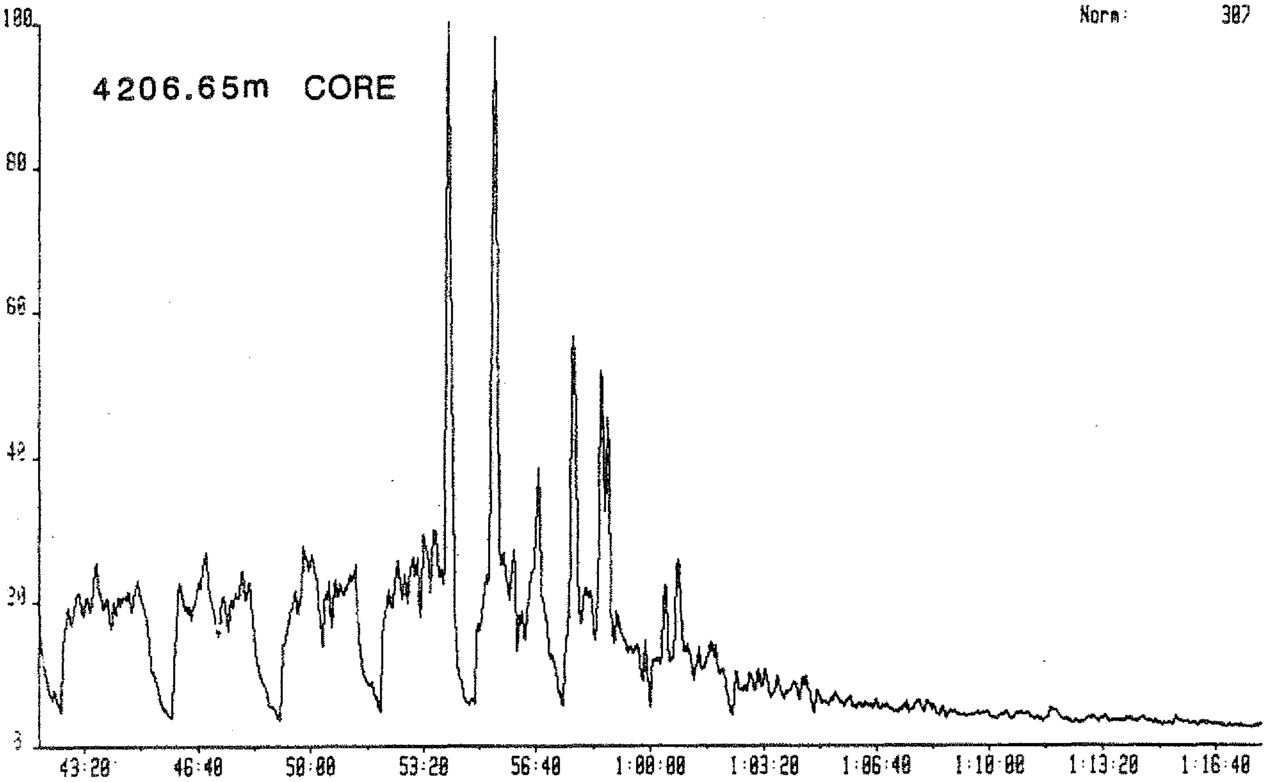


FIGURE 14f MASS FRAGMENTOGRAMS

WELL 34/10-23 DEMETHYLATED HOPANES m/z 177

1474010 6-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 177.1642
Text:WELL 34/10-23 4206.65M



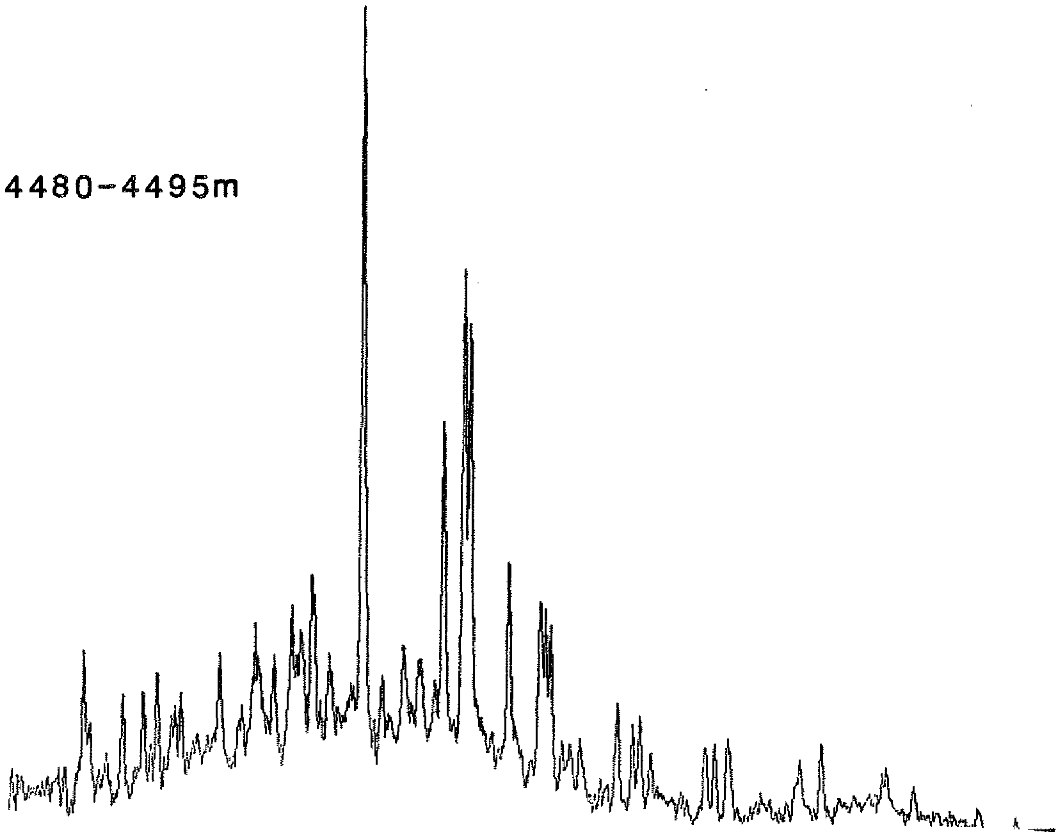
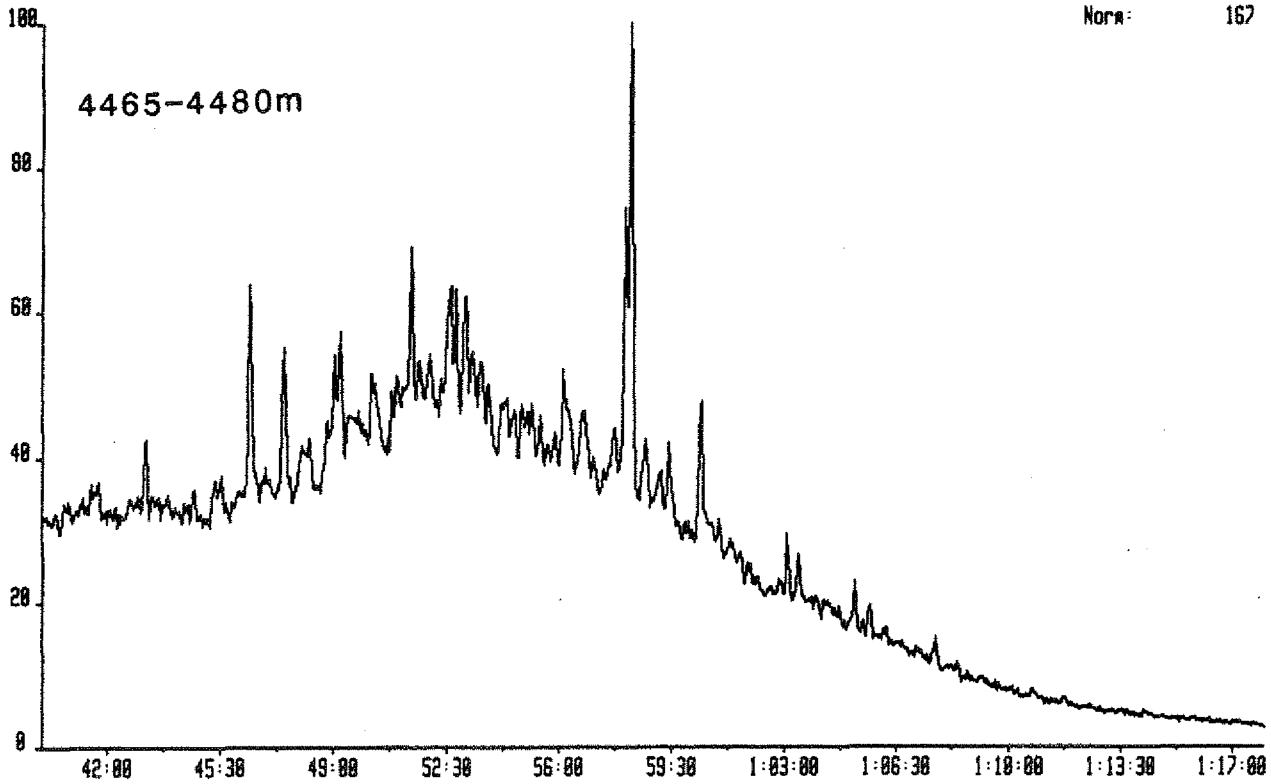


FIGURE 14g

MASS FRAGMENTOGRAMS

WELL 34/10-23 DEMETHYLATED HOPANES m/z 177

1474026 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 177.1642
Text:BIOMARKERS



WELL 34/10-30

1474015 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 177.1642
Text:BIOMARKERS

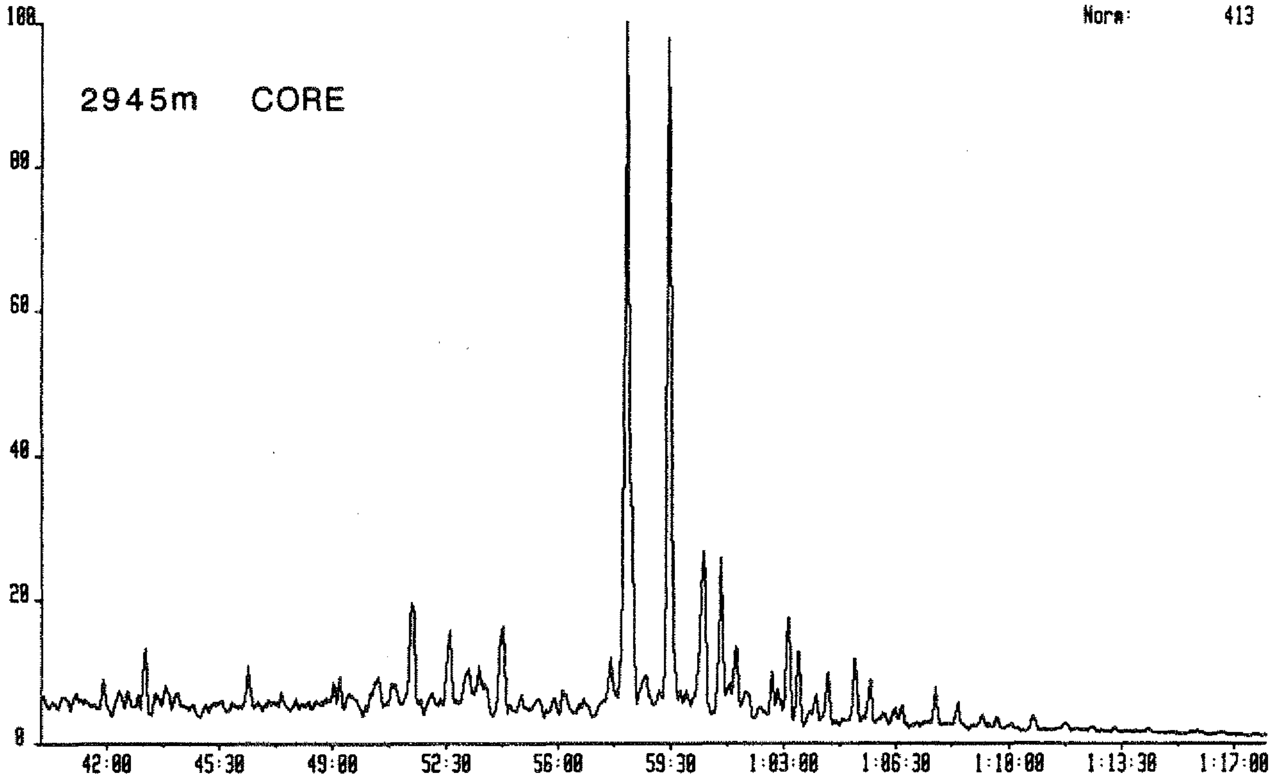


FIGURE 14h

MASS FRAGMENTOGRAMS

WELL 34/10-30 DEMETHYLATED HOPANES m/z 177

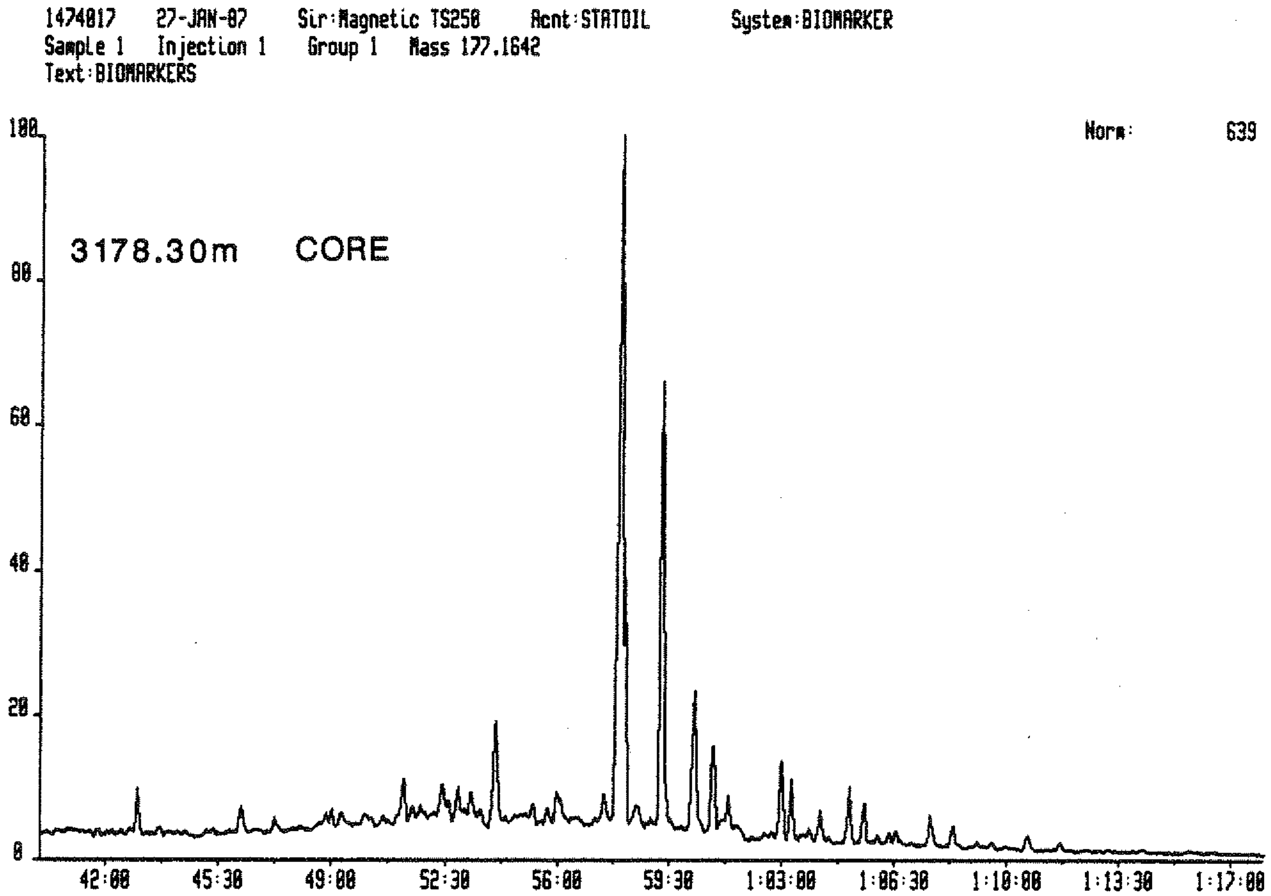
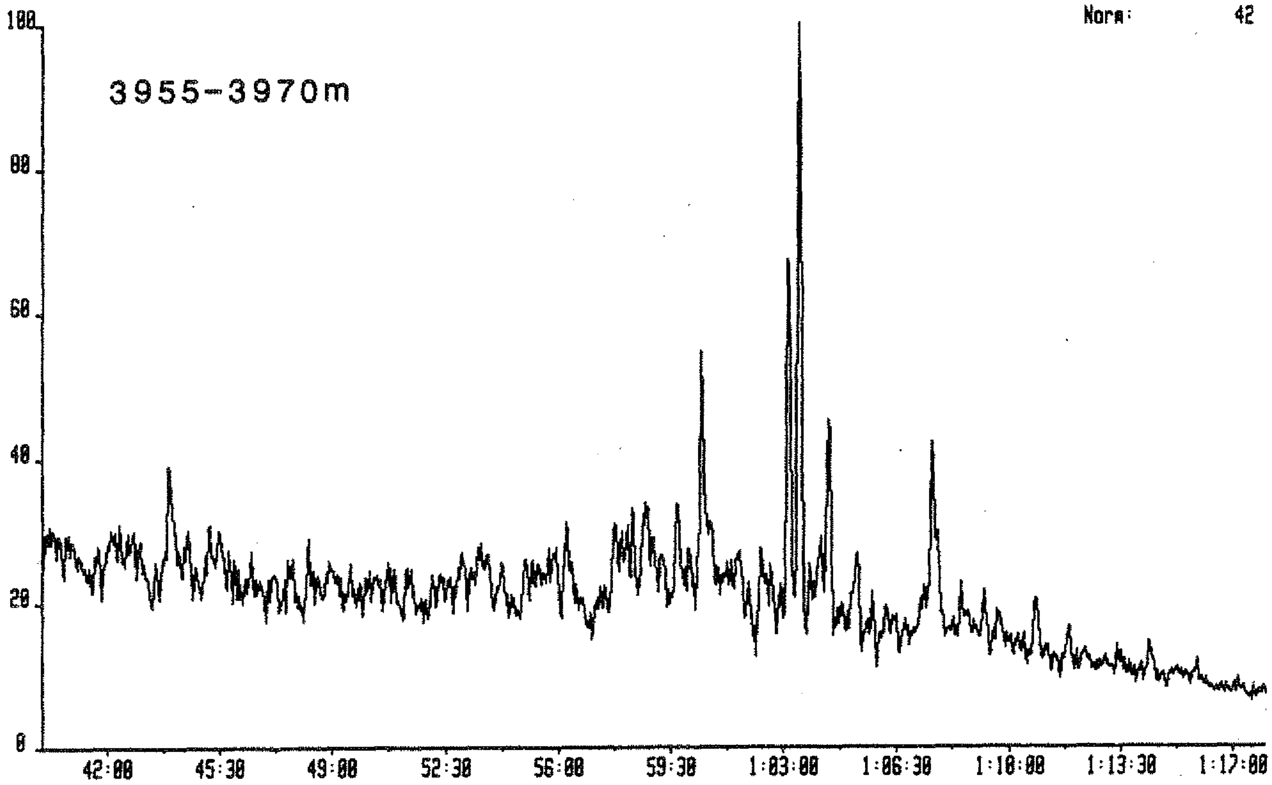


FIGURE 15a

MASS FRAGMENTOGRAMS

WELL 34/10-23 METHYL HOPANES m/z 205

1474019 27-JAN-87 Sir:Magnetic TS250 Rcnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 205.1956
Text:BIOMARKERS



1474023 27-JAN-87 Sir:Magnetic TS250 Rcnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 205.1956
Text:BIOMARKERS

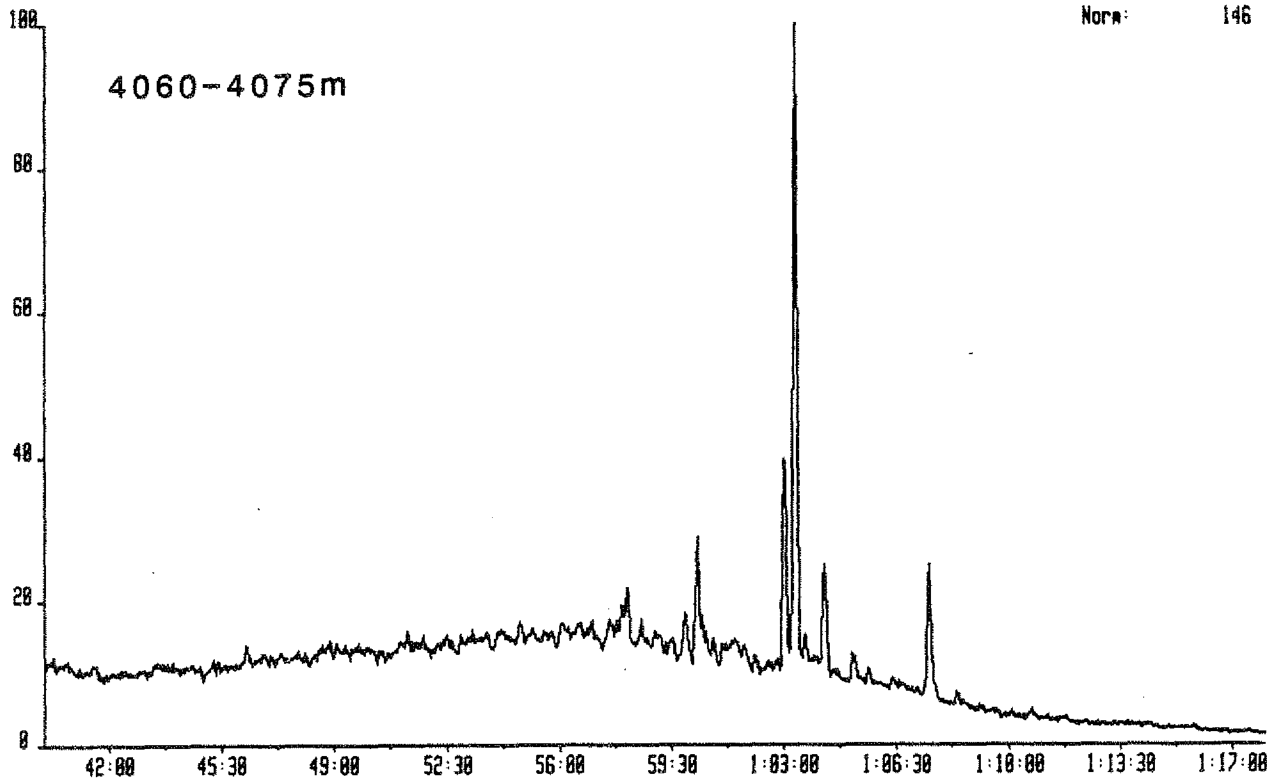
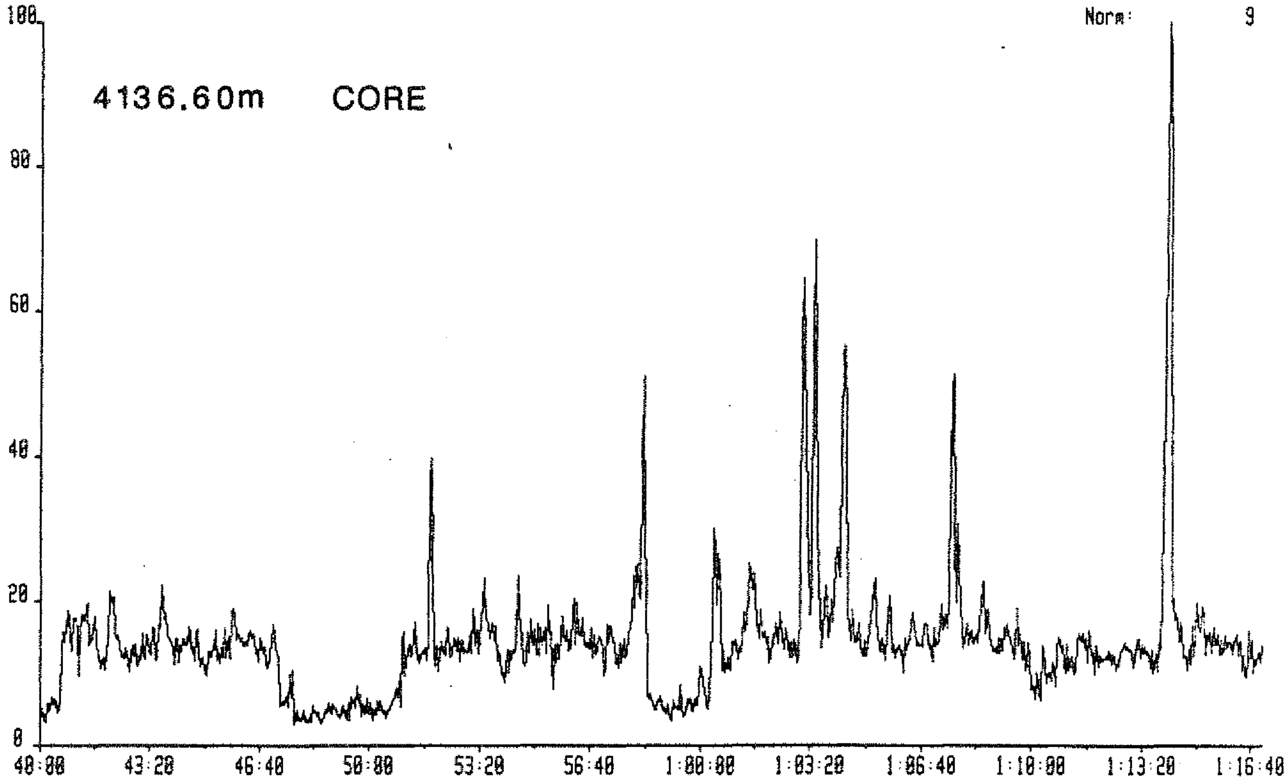


FIGURE 15b

MASS FRAGMENTOGRAMS

WELL 34/10-23 METHYL HOPANES m/z 205

1474004R 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 205.1956
Text:WELL 34/10-23 4136-60'



1474006 5-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 205.1956
Text:WELL 34/10-23 4148-70'

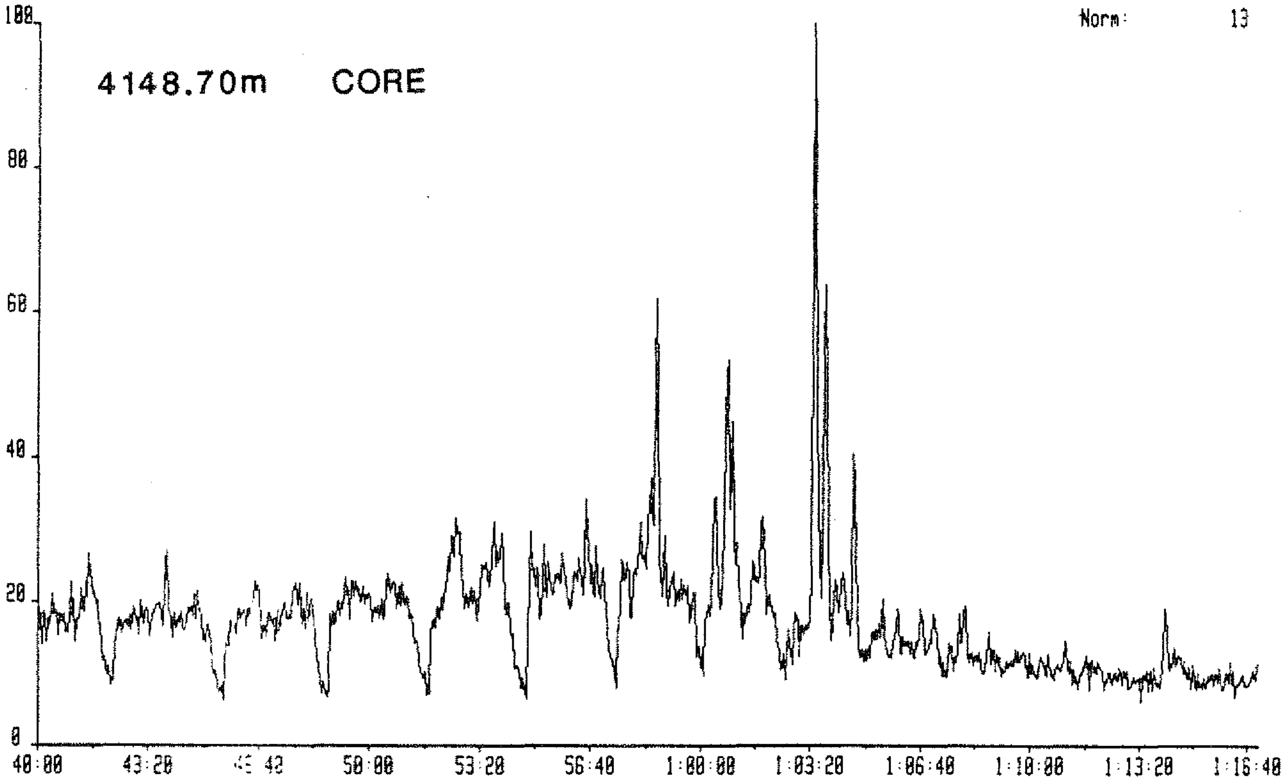


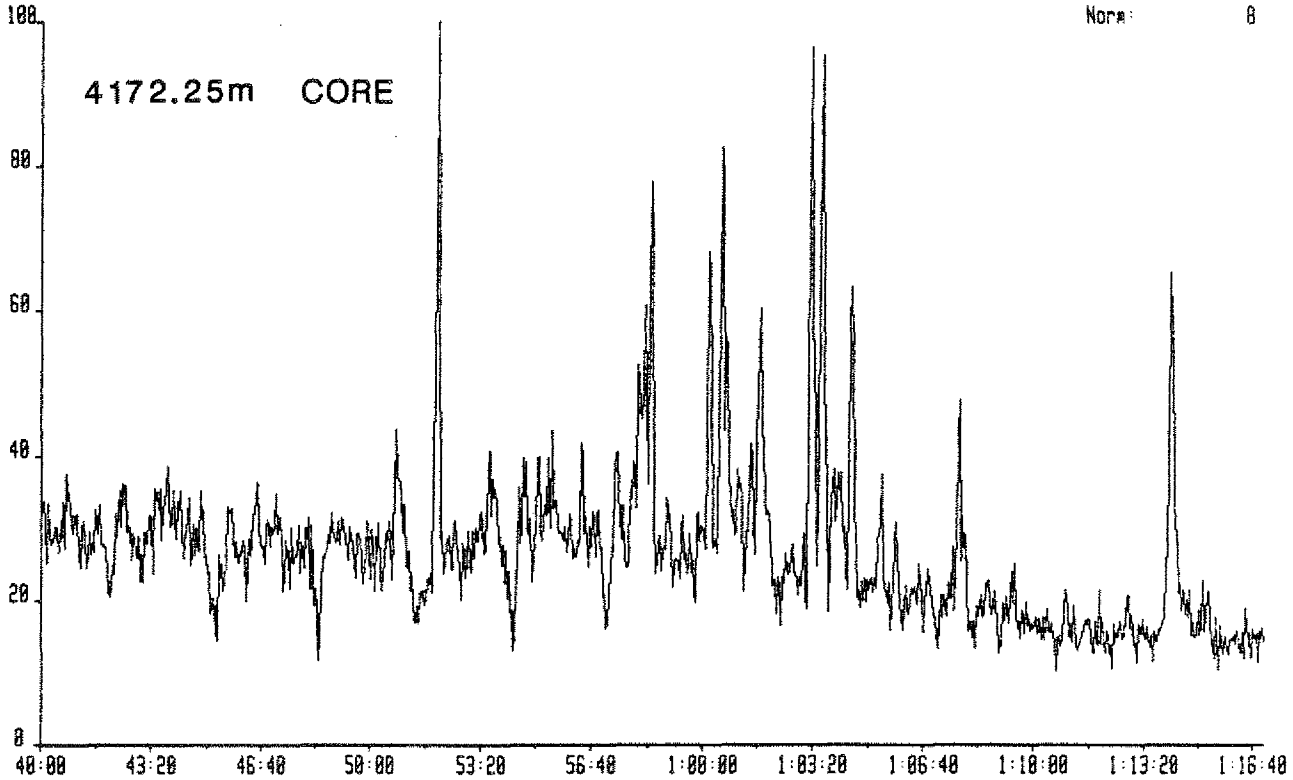
FIGURE 15c

MASS FRAGMENTOGRAMS

WELL 34/10-23

METHYL HOPANES m/z 205

1474009   5-JAN-87   Sir:Magnetic TS250   Acnt:STATOIL   System:BIOMARKER
Sample 1   Injection 1   Group 1   Mass 205.1956
Text:WELL 34/10-23 4172-25'



1474010   6-JAN-87   Sir:Magnetic TS250   Acnt:STATOIL   System:BIOMARKER
Sample 1   Injection 1   Group 1   Mass 205.1956
Text:WELL 34/10-23 4206.65M

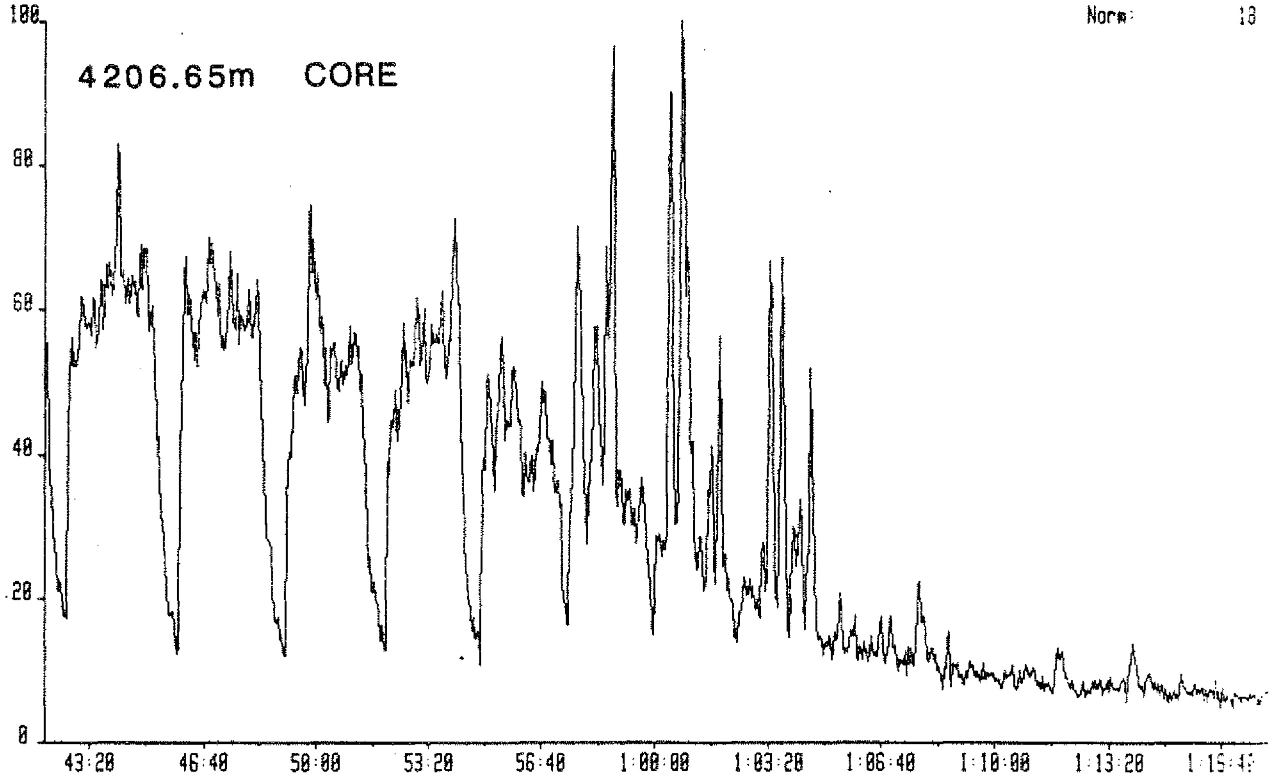
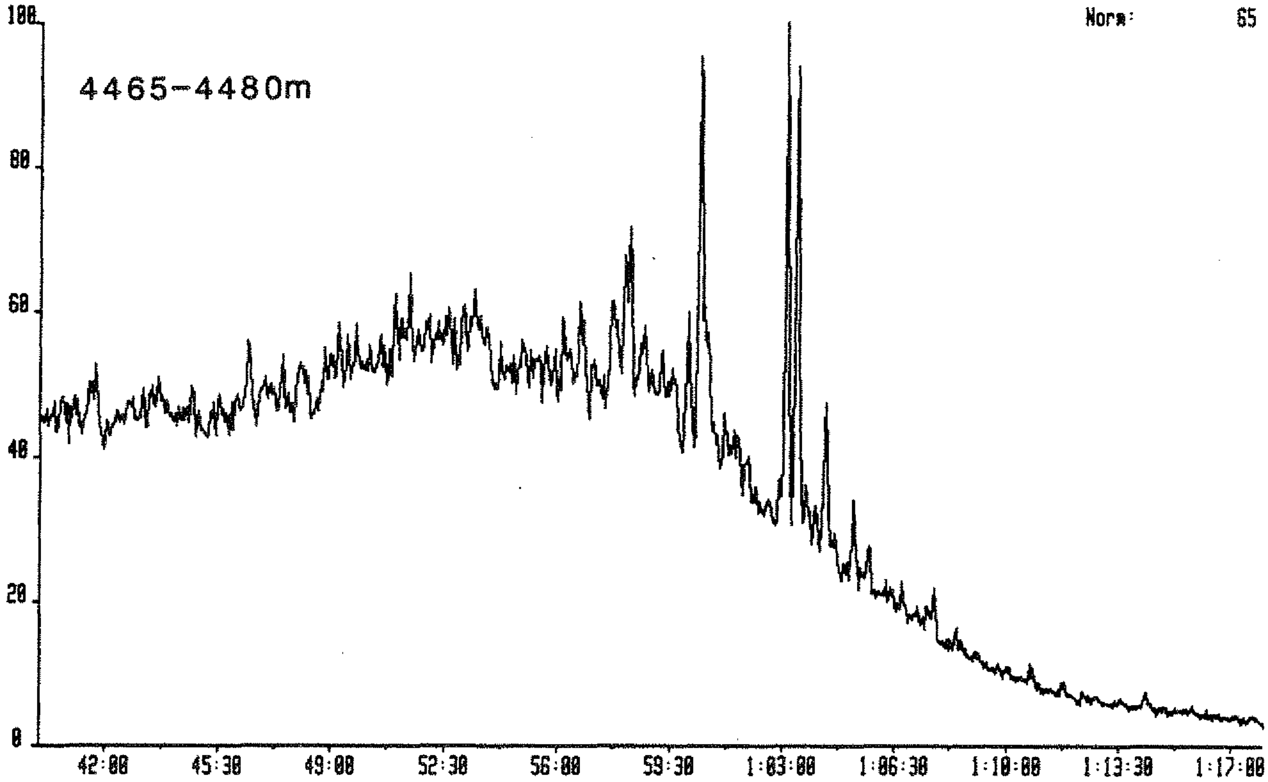


FIGURE 15d

MASS FRAGMENTOGRAMS

WELL 34/10-23 METHYL HOPANES m/z 205

1474026 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 205.1956
Text:BIOMARKERS



WELL 34/10-30

1474015 27-JAN-87 Sir:Magnetic TS250 Acnt:STATOIL System:BIOMARKER
Sample 1 Injection 1 Group 1 Mass 205.1956
Text:BIOMARKERS

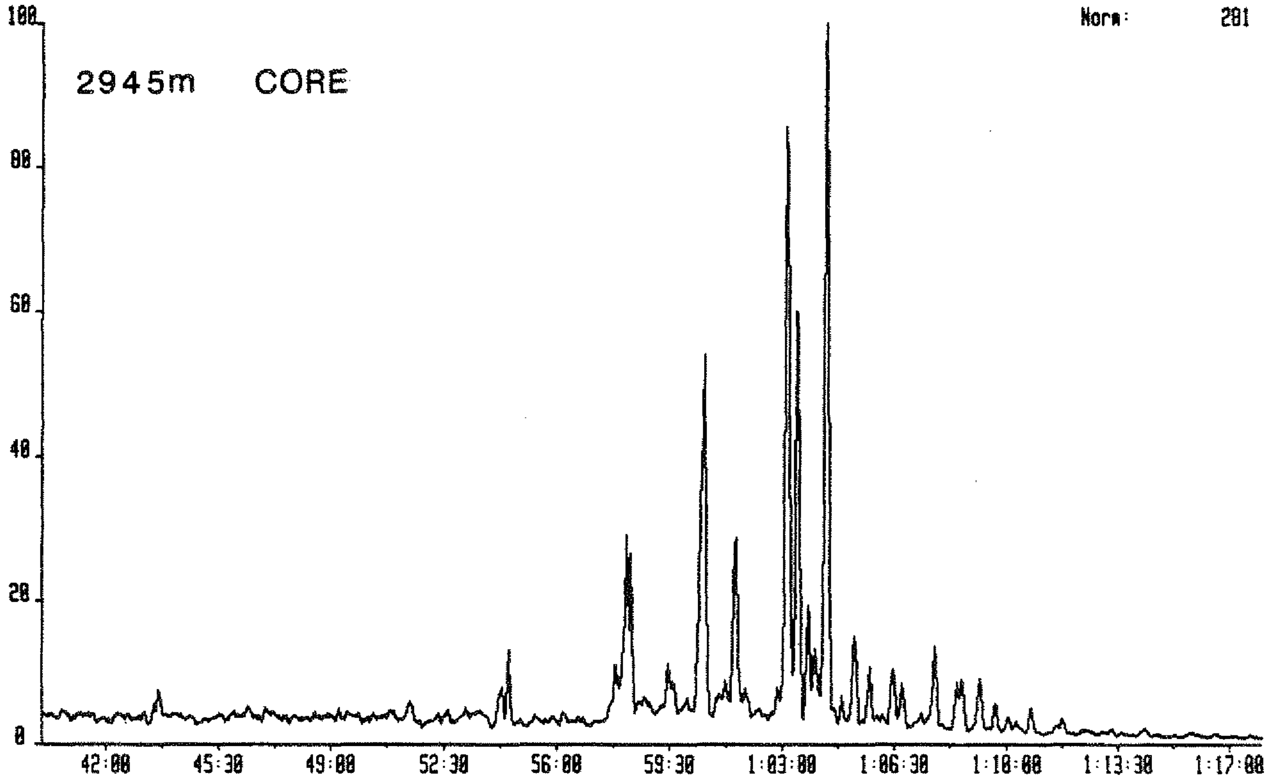
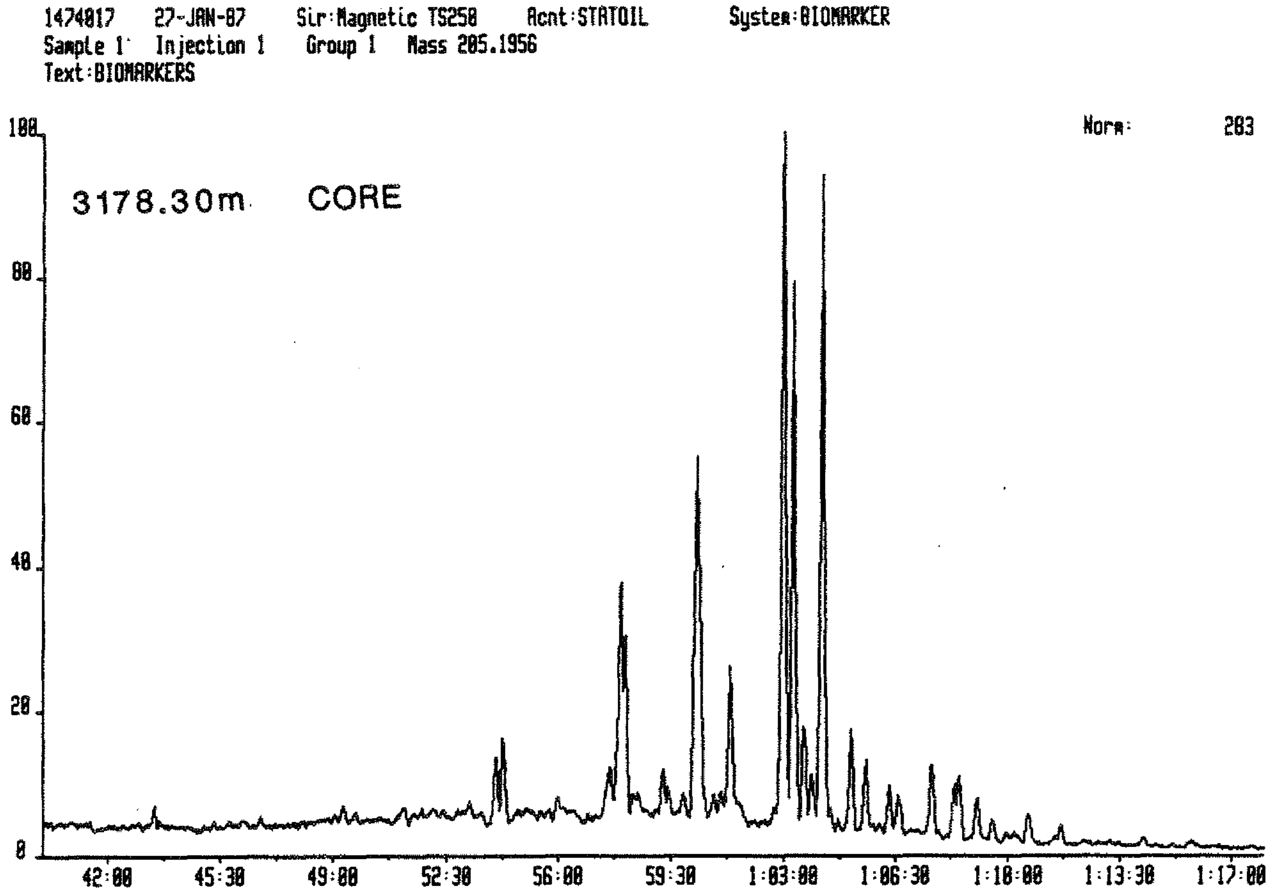


FIGURE 15e

MASS FRAGMENTOGRAMS

WELL 34/10-30

METHYL HOPANES m/z 205



BRIEF DESCRIPTION OF THE ANALYSES PERFORMED BY GEOCHEM

"Screen Analyses" are described in sections A, C and D, "Sample Preparation" in section B, "Follow-up Analyses" in sections E through K and "Correlation Studies" in section L. The analyses can be run on either core or cuttings material with the proviso that samples must be canned for the C_1-C_7 analysis and should be canned (or at least wet) for the C_4-C_7 analysis. The other analyses can be run on both canned and bagged samples.

A) C_1-C_7 LIGHT HYDROCARBON ANALYSIS

The abundance and composition of the C_1-C_7 hydrocarbons in sediments reflects their source richness, maturity and the character of the hydrocarbons they can yield. Most importantly, it is extremely sensitive to the presence of migrated hydrocarbons and is an excellent method for their detection. As it provides the information on most of the critical parameters and is also economical, this analysis is excellent for screening samples to decide which of them merit further analysis.

During the time which elapses between the collection of the sample at the wellsite and its analysis in the laboratory, a fraction of the total gas passes from the rock to the air space at the top of the can. For this reason, both the air space and the cuttings are analysed.

The analysis involves the gas chromatographic separation of the individual C_1-C_4 gaseous hydrocarbons (methane, ethane, propane, isobutane and normal butane) and a partial resolution of the C_5-C_7 gasoline-range hydrocarbons (for their complete resolution see Section E). The ppm abundance of the five gases and of the total C_5-C_7 hydrocarbons are calculated from their electronically integrated peak areas (not from peak height) by comparison with a standard.

In the report, the following data are tabulated: the abundance and composition of the air space gas, of the cuttings gas and of the combined air space and cuttings gases. The combined results are also presented graphically.

B) SAMPLE WASHING AND HAND PICKING

All of the analyses described in subsequent sections are run on washed and hand picked samples.

Cuttings are washed to remove the drilling mud, care being taken not to remove soft clays and fine sand during the washing procedure. Using the C_1-C_7 hydrocarbon data profile of the well, or the organic carbon profile (if this analysis is used for screening), electric logs (if supplied) and the appearance of the cuttings under the binocular microscope, samples are selected to represent the lithological and geochemical zones penetrated by the well. These samples are then carefully hand picked and the lithology of the uncaved material is described. It is these samples which are submitted for further analysis.

Sample material remaining after analysis is retained for six months. Unless instructions are received to the contrary, Geochem Laboratories may then destroy the samples.

Our reports incorporate a gross lithological description of all the samples which have been analysed and litho percentage logs. As screen analyses are recommended at narrow intervals, a complete lithological profile is obtained.

C) ORGANIC CARBON ANALYSIS

The organic carbon content of a rock is a measure of its total organic richness. Combined with the visual kerogen, C_1-C_7, C_4-C_7, pyrolysis and C_{15+} analyses, the organic carbon content is used to evaluate the potential (not necessarily actual) hydrocarbon source richness of the sediment. This analysis is an integral part of a total evaluation and it can also be used as an economical screen analysis for dry samples (when the C_1-C_7 analysis cannot be used).

Hand picked samples are dried, crushed and then acidised to remove the inorganic calcium and magnesium carbonates. The actual analysis involves combustion in a Leco carbon analyser. Blanks, standards and duplicates are run routinely for purposes of quality control at no extra cost to the client.

The data are tabulated and presented diagramatically in our reports in a manner which facilitates comparison with the gross lithology (see Section B) of the samples.

D) MINI-PYROLYSIS

An ideal screen analysis which provides a definitive measure of potential source richness upon those samples whose organic carbon contents suggest fair or good source potential. This is described in detail in section K.

E) DETAILED C_4-C_7 HYDROCARBON ANALYSIS

The abundance and composition of the C_4-C_7 gasoline-range hydrocarbons in sediments reflects their source quality, level of thermal maturation and organic facies. In addition, the data also reveal the present of migrated hydrocarbons and can be used for crude oil-parent source rock correlation studies.

This powerful analysis, performed upon hand picked lithologies, is employed as a follow-up to confirm the potential of samples which have been selected using the initial screen analysis. It is used in conjunction with the organic carbon, visual kerogen and C_{15+} analyses.

The individual normal paraffins, isoparaffins, naphthenes and aromatics with between four and seven carbon atoms in the molecule (but also including toluene) are resolved by capillary gas chromatography and their peak areas electronically integrated.

Normalised compositions, selected ratios and the ppm abundance of the total gasoline-range fraction are tabulated in the report and also presented graphically.

F) KEROGEN TYPE AND MATURATION

Kerogen is the insoluble organic matter in rocks. Visual examination of the kerogen gives a direct measure of thermal maturity and of the composition of the organic matter (organic facies) and indicates the source quality of the sediment - which is confirmed using the organic carbon, light hydrocarbon, pyrolysis and C_{15+} analyses.

The type of hydrocarbon (oil or gas) generated by a source rock is a function of the types and level of thermal maturation of the organic matter which are present. Both of these parameters are measured directly by this method.

Kerogen is separated from the inorganic rock matrix by acid digestion and flotation methods which avoid oxidation of the organic matter. It is then mounted on a glass slide and examined at high and low magnifications with a Leitz microscope. Chemical methods measure the total kerogen population but, with this technique, individual particles can be selected for examination and spurious material identified. This is particularly valuable in reworked, contaminated and turbodrilled sediments.

The following data are generated: the types of the organic matter present and their relative abundances, an estimate of the proportion of reworked material, preservation state, the thermal maturity of the non-reworked organic matter using the spore colouration technique.

Our maturation scale has been developed to digitise small but recognisable changes in organic matter colouration resulting from increasing maturity and to place particular emphasis upon the immature to mature transition. In the absence of a universal colouration scale, the most significant points on our scale have been calibrated against equivalent vitrinite reflectance values. The following maturation stages are recognised at the low end of the scale:-

a) immature; thermal index less than 2- (0.45% Ro)
b) marginally mature; indices between 2- and 2. Minor hydrocarbon generation from amorphous and herbaceous (± algal) organic matter
c) mature; indices between 2 (0.53% Ro) and 2 to 2+ (0.72% Ro), significant generation from amorphous, algal and herbaceous organic matter but wood only marginally mature
d) oil window; indices of 2 to 2+ (0.72% Ro) through to 3 (1.2% Ro). Peak hydrocarbon generation.

The condensate zone starts at a thermal index of 3 whilst indices of 3+ (2.0% Ro) and higher indicate the eometamorphic dry gas stage.

A total of fourteen types of organic matter are sought based upon the major categories of algal, amorphous, herbaceous (spore, pollen, cuticle), wood, inertinite and resin. This detail is essential for a proper understanding of hydrocarbon source potential as the different sub-groups within each category have different properties.

Upon completion of the study, the kerogen slides are sent to the client.

G) VITRINITE REFLECTANCE

Vitrinite reflectance is an alternative/confirmatory method for evaluating thermal maturation which is used in conjection with the visual kerogen analysis. The reflectivity of vitrinite macerals increases in response to thermal alteration and is used to define maturation levels and, by projection, to predict maturity at depth or the thicknesses of section removed by erosion.

Measurements are made upon kerogen separations in conjunction with polished whole rock samples. In general, this analysis is performed upon the same samples as the visual kerogen analysis, thus facilitating a direct comparison of the two sets of results.

If possible, forty to fifty measurements are taken per sample - unless the sediments are organically lean, vitrinite is sparse or only a single uniform population is present. The data are plotted in a histogram which distinguishes the indigenous vitrinite from possible reworked or caved material. Averages are calculated for each population. Comments upon exinite fluorescence and upon the character of the phytoclasts are noted on the histograms. The reports contain the tabulated data, histograms and the reflectivities plotted against depth.

The vitrinite and visual kerogen techniques provide mutually complementary information upon maturity, organic matter type and diagenesis.

H) C_{15+} EXTRACTION, DEASPHALTENING AND CHROMATOGRAPHIC SEPARATION

Sections "A" and "E" dealt with analyses covering the light end of the hydrocarbon spectrum. This section is concerned with the solvent extractable oranic material in the rock with more than fourteen carbon atoms in the molecule (i.e. the heavy end). The amount and composition of this extract indicates source richness and type, the level of thermal maturation and the possible presence of migrated hydrocarbons.

These results are integrated with those derived from the pyrolysis, visual kerogen, organic carbon and light hydrocarbon analyses.

The techniques involved in this analysis employ pure solvents and have been designed to give reproducible results. Hand picked samples are ground and then solvent extracted in a soxhlet apparatus, or by blending, with dichloromethane (the solvent system can be adapted to client's specifications). After asphaltene precipitation, the total extract is separated by column chromatography or high pressure liquid chromatography into the following fractions: paraffin-naphthene hydrocarbons, aromatic hydrocarbons, eluted NSO's (nitrogen-, sulphur-, and oxygen- containing non-hydrocarbons) and non-eluted NSO's. Note that the non-hydrocarbons are split into three fractions and not reported as a gross value. These fractions can be submitted for further analyses (carbon isotopes, gas chromatography, mass spectroscopy) including correlation studies.

For convenience and thoroughness, the data are reported in three formats: the weights of the fractions, ppm abundances and normalised percentage compositions. The data are also presented diagramatically.

J) GC ANALYSIS OF C_{15+} PARAFFIN-NAPHTHENE HYDROCARBONS

The gas chromatographic configurations of the heavy C_{15+} paraffin-naphthene hydrocarbons reflect source type, the degree of thermal maturation and the presence and character of migrated hydrocarbons or contamination.

Not only is this analysis an integral part of any source rocks study but it also provides a fingerprint for correlation purposes and helps to define the geochemical/palynological environmental character of the source rocks from which crude oils were derived.

The paraffin-naphthene hydrocarbons obtained by column chromatography are separated by high resolution capillary chromatography. Excellent resolution of the individual normal paraffins, isoprenoids and significant individual isoparaffins and naphthenes is achieved. Runs are normally terminated at nC_{35}. A powerful in-house microprocessor system is being introduced to correct for the change in response factor with chain length.

The normal paraffin carbon preference indices (C.P.I.) indicate if odd (values in excess of 1) or even (values less than 1) normal paraffins are dominant.

Strong odd preferences (± strong pristane peaks) are characteristic of immature land plant organic matter whilst even preferences (± strong phytane peaks) suggest a reducing environment of deposition. With increasing maturity, values approach 1.0 and oils are typically close to 1.0. The indices are calculated using the following formulae:

$$C.P.I_A = \frac{\begin{matrix} C_{21} + C_{23} + C_{25} + C_{27} \\ C_{20} + C_{22} + C_{24} + C_{26} \end{matrix} + \begin{matrix} C_{21} + C_{23} + C_{25} + C_{27} \\ C_{22} + C_{24} + C_{26} + C_{28} \end{matrix}}{2}$$

$$C.P.I_B = \frac{\begin{matrix} C_{25} + C_{27} + C_{29} + C_{31} \\ C_{24} + C_{26} + C_{28} + C_{30} \end{matrix} + \begin{matrix} C_{25} + C_{27} + C_{29} + C_{31} \\ C_{26} + C_{28} + C_{30} + C_{32} \end{matrix}}{2}$$

Chromatograms are reproduced in the report for use as visual fingerprints and in addition, the following data are tabulated: normalised normal paraffin distributions; proportions of paraffins, isoprenoids and naphthenes in the total paraffin-naphthene fraction; $C.P.I_A$ and $C.P.I_B$; pristane to phytane ratio; pristane to nC_{17} ratio.

K) PYROLYSIS

The process of thermal maturation can be simulated in the laboratory by pyrolysis, which involves heating the sample under specified conditions and measuring the oil-like material which is freed/generated from the rock. With this analysis, the potential richness of immature sediments can be determined and, by coupling the pyrolysis unit to a gas chromatograph, the liberated material can be characterised. These results are correlated with those obtained from the organic carbon, kerogen and C_{15+} analyses.

Small amounts of powdered sample are heated in helium to release the thermal bitumen (up to 340°C) and pyrolysate (340-550°C). The thermal bitumen correlates with the solvent extractable material (see above) whilst the pyrolysate fraction does not exist in a "free" state but is generated from the kerogen, thus simulating maturation in the subsurface. Abundances (weight ppm of rock) are measured with a flame ionisation detector against a standard. Thermal bitumen includes source indigenous, contaminant and migrated hydrocarbons but the pyrolysate abundance is a measure of ultimate source richness. The capillary gas chromatogram of the pyrolysate is used to evaluate the character of the parent organic matter and whether it is oil or gas prone. Peak temperature(s) of pyrolysate evolution is recorded. Carbon dioxide can be measured if requested but is normally ignored as the separation of the organic and inorganic species has been found to be artificial and unreliable.

Pyrolysate yields provide a definitive measure of potential source richness which avoids the ambiguities of the organic carbon data and the problem of contamination. This analysis is also used to evaluate the quality and character of the organic matter and the degree to which it has realised its ultimate hydrocarbon potential. Geochem does not employ the pyrolysis technique to evaluate maturation, preferring the kerogen and vitrinite reflectance analyses which avoid the problem of reworking and hence, are more reliable.

Capillary chromatograms produced for the pyrolysate hydrocarbons range from C_1 (methane) out towards C_{35} but exhibit considerable variations. They are used to define whether a source rock will yield oil, condensate or gas. With this new technique, it is now possible to complete the evaluation of a source rock.

The data are tabulated and presented graphically. MINI-PYROLYSIS includes ppm thermal bitumen and ppm pyrolysate. PYROLYSIS also provides the above together with the temperature of peak pyrolysate evolution. The capillary chromatograms of the pyrolysate obtained by PYROLYSIS-GC are reproduced in the report. The Mini-Pyrolysis analysis is recommended as a screening technique.

L) CORRELATION STUDY ANALYSES

Oil to oil and oil to parent source rock correlation studies require high resolution analytical techniques. This requirement is satisfied by some of the analyses discussed above but others have been selected specifically for correlation work. Many of these analyses also provide information upon the character of the environment of deposition of the parent source rocks.

- detailed C_4-C_7 hydrocarbon (gasoline range) analysis. See Section E. Although these hydrocarbons can be affected by migrational/alteration processes, they commonly provide a very useful correlation parameter.

- capillary gas chromatography of the C_{15+} paraffin-naphthenes. See section J. The branched±normal paraffin distributions are used to "fingerprint" the samples.

- capillary chromatograms of whole oils and of the C_{4+} fraction of source rocks.

- capillary gas chromatography of C_{15+} aromatic hydrocarbons. Separate chromatograms of the hydrocarbons and of the sulphur-bearing species are reproduced.

- high pressure liquid chromatograms.

- mass spectrometric carbon isotope analyses of crude oil and rock extract fractions and of kerogen separations. A powerful tool for comparing hydrocarbons and correlating hydrocarbons to organic matter. With this technique the problem of source rock contamination can be avoided. The data are recorded on x-y or Galimov plots.

- mass fragmentograms (mass chromatograms) of fragment ions characteristic of selected hydrocarbon groups such as the steranes and terpanes. The fragmentograms provide a convenient and simple means of presenting detailed mass spectrometric data and are used as a sophisticated fingerprinting technique. This provides the ultimate resolution for correlating hydrocarbons and facilitates the examination of hydrocarbon classes.

- vanadium and nickel contents.

Suites of (rather than single) analyses are employed in correlation studies, the actual selection depending upon the complexity of the problem. See also section N.

M) ANALYSES FOR SPECIAL CASES

M-1) ELEMENTAL KEROGEN ANALYSIS

This analysis evaluates source quality, whether the sediments are oil or gas prone, the character of the organic matter and its level of thermal maturation. It is the chemical equivalent of the visual kerogen analysis. The pyrolysis analysis is generally preferred to this technique, both methods providing similar information.

M-2) SULPHUR ANALYSIS

The abundance of sulphur in source rocks and crude oils.

M-3) CARBONATE CONTENT

The mineral carbonate content of sediments is determined by acid treatment. These data are particularly useful when used in conjunction with organic carbon contents as a screening technique.

M-4) NORMAL PARAFFIN ANALYSIS

Following the removal of the branched paraffins and naphthenes from the total paraffin-naphthene fraction, a chromatogram of the normal paraffins is obtained. The resulting less complicated chromatogram facilitates the examination of normal paraffin distributions.

M-5 SOLID BITUMEN EVALUATION

Residual solid bitumen after crude oil is generated by three prime processes; the action of waters, gas deasphalting, thermal alteration. Thus it provides a means of determining the reservoir history of a crude and of evaluating whether adjacent traps will or will not be prospective for oil. In carbonate sections, where organic matter is sometimes sparse, this technique is also used to evaluate thermal maturation levels.

The analysis involves the determination of the solubility (in CS_2) of the solid bitumen and of the atomic hydrogen to carbon ratio of the insoluble fraction.

N) CRUDE OIL ANALYSIS

N-1) API GRAVITY

This can be performed upon large (hydrometer) and small (SG bottle, pycnometer) samples and even upon stains extracted from sediments (refractive index).

N-2) SULPHUR CONTENTS (ASTM E30-47)

N-3) POUR POINT (ASTM D97-66, IP15/67)

N-4) VISCOSITY (ASTM D445-72, IP71/75)

N-5) FRACTIONAL DISTILLATION

Graph of cumulative distillation yield against temperature. Five percent cuts taken for further analysis. Mass spectrometric studies of these fractions provide a detailed picture of the distribution of paraffins and of the various naphthene and aromatic groups within a crude, which is useful both for correlation and for refinery evaluation purposes.

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