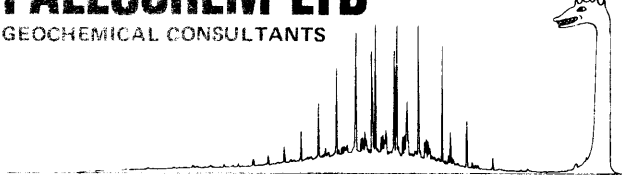


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GEOCHEMICAL CONSULTANTS



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PETROLEUM GEOCHEMISTRY REPORT

PREPARED FOR

SAGA PETROLEUM A/S

Geochemical Source Rock Evaluation and Correlation
Study of Sidewall Cores and Oil Shows from Halten
Bank Well: 6507/12-2.

November 1981.

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Summary

Twenty-two potentially rich sediment sidewall cores and three sandstone sidewall cores, containing oil shows were used to complete a detailed geochemical source rock and reservoir hydrocarbons study. Maturity estimations using Vitrinite Reflectance measurements and Spore Colouration ratings, suggested all the sediments examined to be immature for any hydrocarbon generation.

The hydrocarbon potential of the 22 sediment samples were found to be extremely varied, but good source sections were identified in the Kimmeridgian and Early Jurassic sections of this well. Hydrocarbon typing of these potential source sections suggested the Kimmeridgian to be predominantly oil prone and the Early Jurassic to be likely to source a mixture of hydrocarbon products.

An attempt to correlate the Kimmeridgian potential source rocks to the oil shows was completed, using fingerprinting of the alkane and aromatic fractions from sediment extracts and oil shows. The oil shows and sediments had similar n-alkane and isoalkane distributions resembling diesel fuel, although none was available for comparison purposes. No tie-up could be found between the sterane, pentacyclane and aromatic fingerprints from CGCMS of the sediment extracts and oil shows.

Very high of low similarities of hydrocarbon between potential source rocks and reservoir, bitumen.

*Diesel
fuel*



1. Introduction

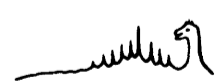
A detailed geochemical study was completed on twenty-five sidewall cores from the depth interval 1835 - 3447.5 m of Well: 6507/12-2, Offshore Norway. Three of the sidewall cores contained oil shows and were treated differently from the other twenty-two. The section examined extended from the Late Cretaceous to Late Triassic. The main emphasis of the study was placed on establishing reliable geochemical parameters for use as well-to-well correlation parameters, in addition to the more traditional tools available to the hydrocarbon explorationist.

TAI
1000 P.
Maturity estimations using spore colouration from Visual Kerogen Descriptions were completed on all the Jurassic core, but only four of the Triassic cores. No Vitrinite Reflectance Data was available, therefore the maturity level discussed in this report can be regarded as a guideline only.

Pyrolyse
C. 100
R. 1000
Pyrolysis techniques were used to establish the hydrocarbon source potential at all stratigraphic levels and the likely hydrocarbon products or source type, where the potentials were sufficiently high. Hydrocarbon typing using pyrolysis was supported by the Visual Kerogen Descriptions completed at the same depth. Total Organic Carbon measurements were also completed, to provide additional information concerning the richness of the sediments, as defined solely by their organic contents.

2. Samples and Techniques

All the sidewall cores except those with oil shows (at 3062, 3808.5 and 3153 m) were washed with water to remove



any trace of drilling mud and then air dried under controlled conditions at 40°C. It was noted that the majority of the samples smelled strongly of hydrocarbons. (L. M. Cox)

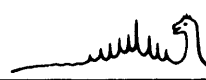
Samples for Visual Kerogen Description were treated with mineral acid. The remaining debris was sedimented onto a microscope slide and examined using a transmitted light microscope. The results of the Visual Kerogen descriptions and assessments of Spore Colouration are shown in Table 1. The range of the Spore Colouration is from 1 - 7 and the colour taken as representing the onset of liquid hydrocarbon generation is 3/4.

Samples for Total Organic Carbon measurements were finely ground and sieved to achieve homogeneity, then digested with fuming hydrochloric acid to remove mineral carbonate. The decarbonated samples were then combusted in a Carlo Erba 1106 Carbon, Hydrogen, Nitrogen analyser and their total organic carbon content determined, relative to those of calibrated standards. The results of these measurements are shown in Table 2.

Samples for Screening Pyrolysis were also ground and sieved and then examined using a modified Hewlett-Packard 5711 Gas Chromatograph, to measure their ultimate hydrocarbon potential. Samples were heated to an initial temperature of 250°C, then ramped to 550°C. Two peaks were evolved, which are conventionally referred to as P1 and P2 and were related to those of a calibrated standard. The results of screening pyrolysis are shown in Table 3.

Ground samples for Extended Pyrolysis were extracted with dichloromethane before being heated to 550°C and examined using a modified Hewlett-Packard 5880 Gas Chromatograph. The hydrocarbons evolved were separated according to their boiling points on a non-polar, fused silica capillary column.

Mass
for
standards
analysis
60000 and
dissolved water



1874
1875
1876

Ground Samples from two cores at 1874 and 1875 m used for Soluble Extract Studies were extracted with geochemical grade dichloromethane, using a high velocity liquid mixer. Excess solvent was removed by evaporation and the remaining extracts were separated on activated silica, to provide saturate alkane and aromatic fractions for gas chromatographic analysis. The saturate alkane fractions were examined by quartz capillary gas chromatography using a Carlo Erba 2151 gas chromatograph with Grob-type splitless injector system. The results of these measurements are represented in Table 4. The saturate alkane fractions were then examined by CGCMS using a modified Finnigan 9500 with Grob-type injector. The aromatic fractions were also examined by CGCMS, as above.

The three sandstone sidewall cores with oil shows were also used for Soluble Extract Studies, but were exhaustively extracted in an unground state using soxhlet extractors. These extracts were separated on activated silica into both saturate alkane and aromatic fractions.

3. Results and Discussion

(a) Maturity

The results of Spore Colouration estimations shown on Table 1 and Vitrinite Reflectance data shown on Table 5, indicate that the sediments examined from this Well are immature for any hydrocarbon generation. A Spore Colour rating of 3/4 and Reflectivity value of $R_o = 0.55\%$ are taken by Paleochem as threshold values for the onset of liquid hydrocarbon generation.

See Table 5
1874, 1875
Important according
to...
#T...
R...
[Signature]

None of the spore colours shown in Table 1 are greater than 2 and the highest reflectivity value seen in sediments from the Late Trias was 0.47%. No spore fluorescence colours were available for supporting the immature reflectivity values and spore colour ratings, but the sterane distributions shown in Fig.1 from the Kimmeridgian sediment at 1873 m are typical of an immature sediment extract.

(b) Source Potential

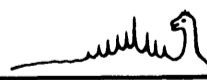
(i) Hydrocarbon Potential

Samples having total organic carbon values below 0.5% are generally regarded as containing insufficient organic material to be of commercial value (2). Thus this value is used as a cut-off point in this report and sediments with organic carbon values less than 0.5% are regarded as having no significant source potential.

Source potential ratings based on conventional geochemical data are given below.

Poor Potential	Less than 0.5%
Moderate Potential	0.5% to 1.5%
Good Potential	Greater than 1.5%

Pyrolytic methods are widely used for estimating the generating capabilities of potential source rocks (3). Pyrolysis techniques have superseded the more traditional method of assessing hydrocarbon potential using total organic carbon measurements, because they provide more meaningful data. Pyrolysis does not take into account any reworked material and/or inertinite present in source rocks, which adds to the organic carbon value, but has very limited or no hydrocarbon potential.



The first peak (P1) is often considered as representative of the quantity of free hydrocarbons that were present in the sediment at the time of sampling. The second peak (P2) is considered to be representative of the quantity of hydrocarbons present in the sediment and yet to be generated. The P2 peak is produced by conversion of the Kerogen in the rock sample by thermal cracking in the instrument. This is generally considered to be a reasonable estimate of the amount of hydrocarbons, which could theoretically be generated by complete conversion of the Kerogen in sediments under natural conditions throughout their geological lifetime. Both the P1 and P2 yields are expressed in Kg./tonne.

Comparison of pyrolysis data with conventional geochemical data to provide a source potential rating gives the P2 hydrocarbon potential in practical exploration terms (4):

Poor	0.1 to 1.5 Kg./tonne
Moderate	1.5 to 5.0 Kg./tonne
Good	Greater than 5.0 Kg./tonne

Sediments from the Late Cretaceous (1835 and 1865 m) had moderate Total Organic Carbon (TOC) values of 1.23 and 0.87% wt. respectively, but were only rated as having poor hydrocarbon potential from Screening Pyrolysis measurements. In the absence of ancillary Kerogen descriptions from Vitrinite Reflectance studies, it can only be speculated that this difference in hydrocarbon potential ratings from these two techniques is due to the presence of significant quantities of reworked material and inertinite.

Sediments of Kimmeridgian age were demonstrated to have good hydrocarbon potential ratings from both TOC

TOC
 1.23
 0.87
 Kimmeridgian
 pyrolysis

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measurements and Screening Pyrolysis. It was noted that these sediments, similar to those from the Late Cretaceous, had significant quantities of in situ hydrocarbons (P1), in relation to the amount of Kerogen breakdown products (P2). It is unfortunate, but during conventional pyrolysis some of the P1 can be eluted with the P2 fraction (5). It is Paleochem practise to extract samples, where the P1 is above a threshold value of 10% of the P2 value and to repeat the measurement of P2 after extraction, to obtain a more accurate measure of hydrocarbon potential.

kimmeridge

*Botryctes
low
S₂ after
Kimmeridge
1873 m*

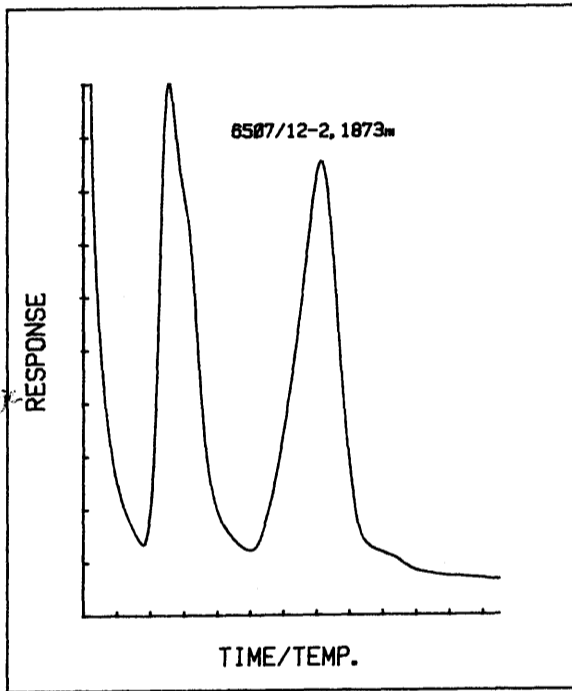


FIG. 1A

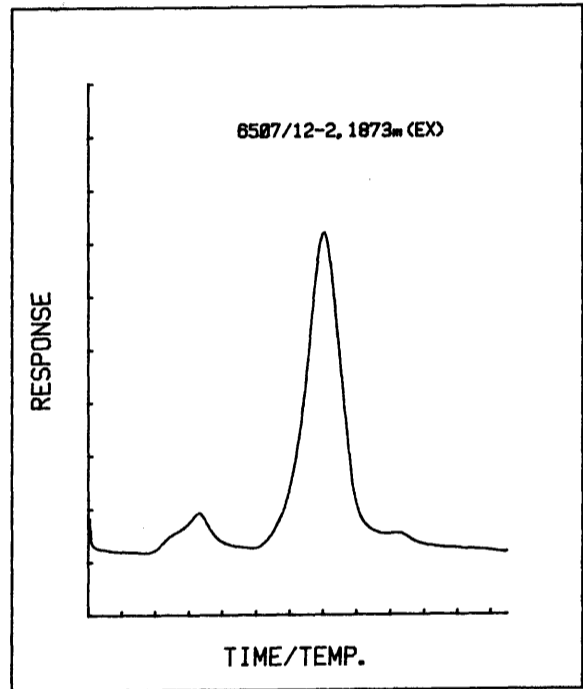


FIG. 1B

Fig.1A shows the sample from 1873 m, where the quantity of in situ hydrocarbons is large, compared with the Kerogen breakdown products. The second trace (Fig.1B) shows the pyrogram of the same sample, after it had been exhaustively extracted with dichloromethane. It is clear from Fig.1B, that the hydrocarbon potential has been reduced

significantly by extraction (Table 3) and the potential measured on the unextracted sample was over optimistic.

There was insufficient sediment available from the 1889 m sidewall core to complete TOC measurements, but Screening Pyrolysis demonstrated this sediment to have only poor hydrocarbon potential. The one sediment examined from the Late/Middle Jurassic had a moderate TOC value of 1.17%, but only a poor pyrolysis yield of only 0.3 Kg./tonne. This discrepancy in hydrocarbon potential ratings is thought to be due to the presence of significant quantities of re-worked material and/or inertinite in these sediments, which we would expect to have been evident during the Vitrinite Reflectance Studies.

Sediments from the Early Jurassic were rated from TOC measurements as having moderate to good hydrocarbon potential (0.8 - 6.12% wt.) and Screening Pyrolysis rated their hydrocarbon potentials as poor to good (1.3 - 6.8 Kg./tonne). Only one sediment from the Late Trias had any significant hydrocarbon potential (the sediment from 2602 m), which was found to have a good TOC value of 2.33% wt. and moderate Screening Pyrolysis value of 3.1 Kg./tonne. All the other sediments from the Late Trias were given poor ratings from the Late Trias, although one light grey claystone from 3447.5 m had a moderate organic carbon value of 1.11% wt.

It was noted that the ratio of the P2 value from Screening Pyrolysis to the TOC value is extremely variable throughout the organic rich interval (1835 to 2602 m), even in intervals of similar age. This is thought to be due to changes in the relative amounts of inertinite and reworked material present in the sediments, as compared to the autochthonous organic material.



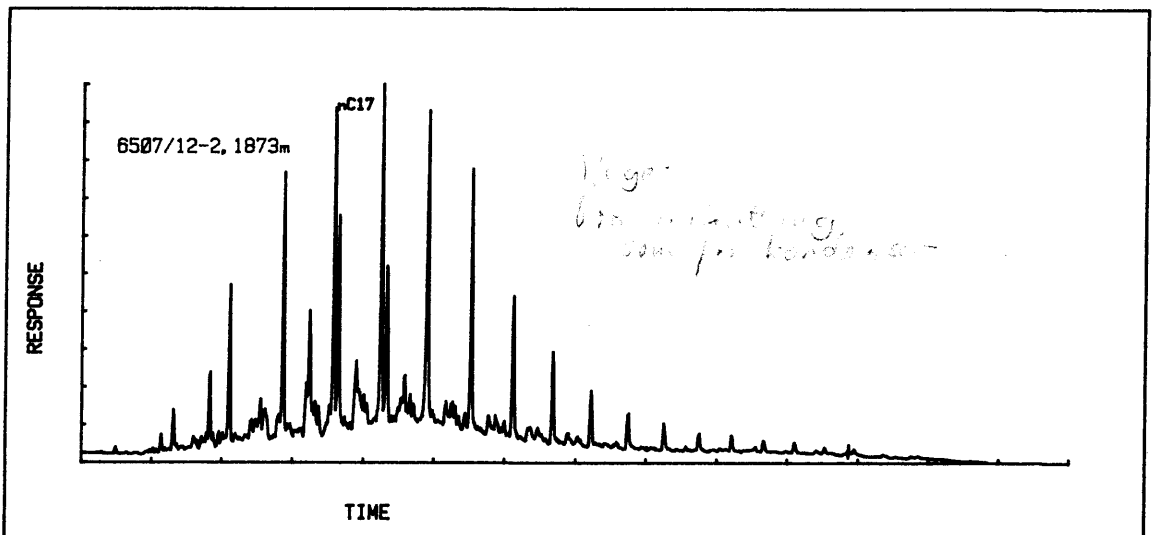
The sidewall cores supplied were not spread evenly over stratigraphic intervals. It is suggested that the interpretation of the trends could be improved substantially by the examination of further cores or cuttings, filling in the missing intervals.

(ii) Hydrocarbon Type

Hydrocarbon typing using Visual Kerogen Descriptions showed a wide variation in both the type and quantity of plant debris present in the sediments examined (Table 1). These variations suggested the likely hydrocarbon products from the organic rich intervals in the Jurassic section of this well, to be varying proportions of both gas and liquids. Soluble Extract Studies completed on sediments from the Kimmeridgian were of little value for assessing Kerogen type, because of extensive hydrocarbon contamination. Contamination was observed during Screening Pyrolysis measurements, as discussed in the previous section of this report. The n-alkane distributions of the two Kimmeridgian extracts were also typical of a diesel fuel n-alkane distribution.

AC
 14
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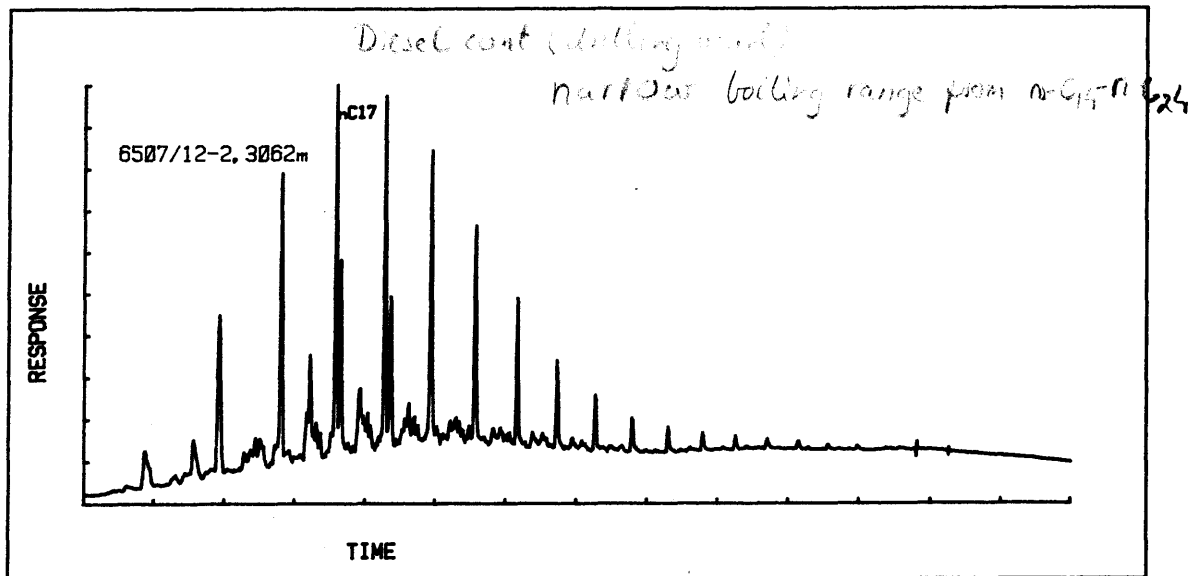


The chromatogram above shows a narrow boiling range of n-alkanes, eluting almost entirely in the n-C₁₄ to n-C₂₄ range

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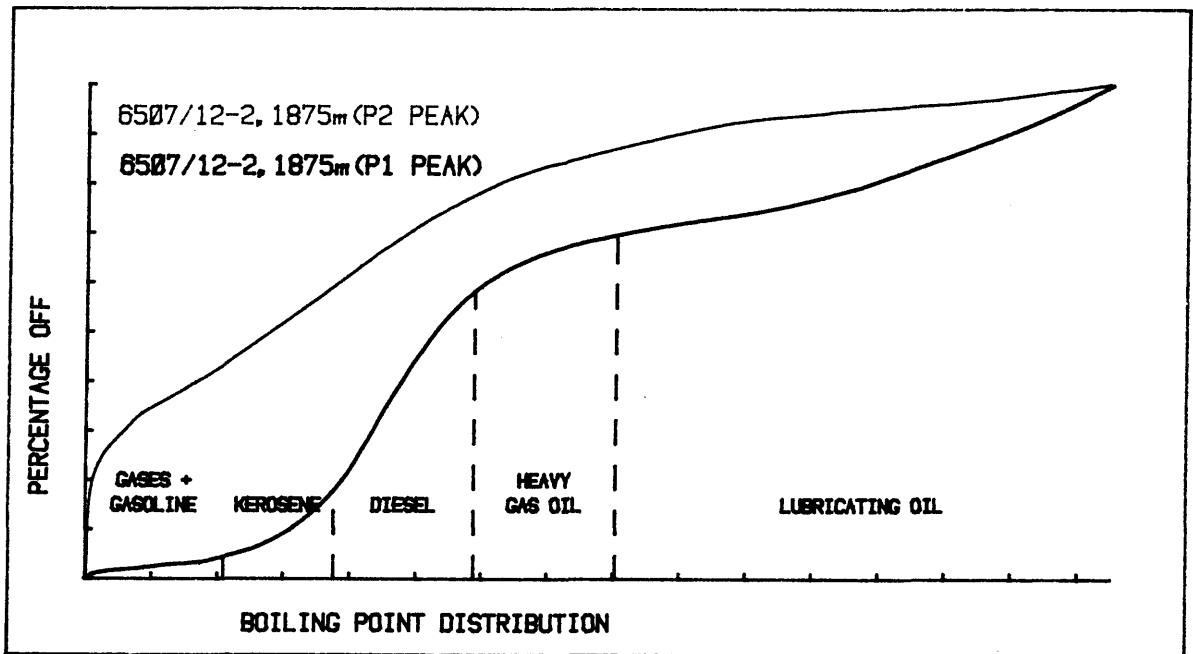
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and typical of a diesel fuel distribution. This "diesel-like" range of hydrocarbons was also observed in the n-alkane distributions of the reservoir sandstones at 3062, 3080.5 and 3143 m as illustrated below.

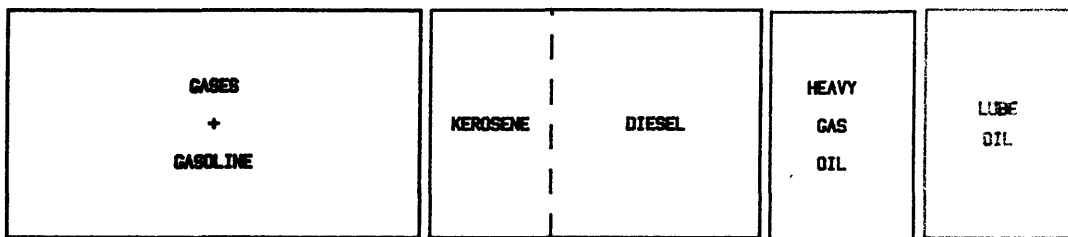


In view of the narrow boiling range of n-alkanes present, it is suggested that this hydrocarbon contamination is probably from diesel fuel added to the drilling mud and not the result of migration of generated hydrocarbons.

Extended Pyrolysis also demonstrated that hydrocarbon contamination was present in the two Kimmeridgian sediments. The distribution of the hydrocarbons from the P1 peak (in situ hydrocarbons) were radically different from those of the P2 peak (Kerogen breakdown products), as shown overleaf.



Hydrocarbon Typing completed on the Kerogen breakdown products from Extended Pyrolysis suggested the Kimmeridgian sediments to be significantly more oil than gas prone. Extended Pyrolysis completed on the moderate to good source sediments identified in the Late/Early Jurassic, Early Jurassic and top Late Triassic (2602 m) supported the Visual Kerogen data, confirming them to be of mixed plant origin and likely to source a mixture of gaseous and liquid hydrocarbon products. The two most "oil prone" of the sediments examined were from 2235 m and 2602 m, as illustrated by the bar chart representations overleaf.



2235m

*Disc
 2/30
 2/30
 2/30
 2/30
 2/30*

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GASES + GASOLINE	KEROSENE	DIESEL	HEAVY GAS OIL	LUBRICATING OIL
------------------------	----------	--------	---------------------	--------------------

2066m

GASES + GASOLINE	KEROSENE	DIESEL	HEAVY GAS OIL	LUBRICATING OIL
------------------------	----------	--------	---------------------	--------------------

2235

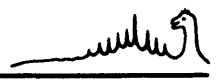
GASES + GASOLINE	KEROSENE	DIESEL	HEAVY GAS OIL	LUBRICATING OIL
------------------------	----------	--------	---------------------	--------------------

2357m

GASES + GASOLINE	KEROSENE	DIESEL	HEAVY GAS OIL	LUBRICATING OIL
------------------------	----------	--------	---------------------	--------------------

2682m

Due to the lack of hydrocarbon potential indicated by Screening Pyrolysis measurements, no hydrocarbon typing was completed on sediments from the Cretaceous, Late Jurassic, Middle to Late Jurassic and majority of the Triassic sediments.



(c) Sediment/Oil Shows Correlation

low p. 1000-1010
high p. 1010-1020
(7011)

A sediment to "oil show" correlation study was completed by CGCMS examination of the extracts from the two Kimmeridgian sediments (1873 and 1875 m) and oil shows from the reservoir sandstones (3062, 3080.5 and 3143 m). The sediment from 1873 m was considered to be the least affected by hydrocarbon contamination, judged by Screening Pyrolysis measurements and was therefore used in the following comparison. The extract from the reservoir sandstone at 3062 m was also chosen for comparison, as it was the largest extract obtained (Table 4).

Detailed comparison was made between the sterane and hopane distributions, together with the distributions of the ~~AB~~ - sterane and rearranged steranes and diasteranes, as illustrated in Figures 1 - 4. No similarities were observed between any of these sets of "fingerprints". It should be emphasised that the comparison has been made between an immature sediment and reservoired hydrocarbon, which by definition should be mature. This difference in maturity would be expected to cause changes in the sterane and hopane distributions, but not to the extent of the disagreement observed in this study.

No similarities were observed between the aromatic "fingerprints" of the naphthalenes and phenanthrenes, as illustrated in Figures 5 and 6. This supports the conclusion that it is probable that the Kimmeridgian sediments are not the source of the hydrocarbons encountered in the sandstone sidewall cores at 3062, 3080.5 and 3143 m.

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Vol. 63/12 pp.2227 - 2232
(1979).



Well: 6507/12-2

VISUAL KEROGEN DATA

PALEOCHEM

Depth m	Cuticle	Brown Wood	Black Wood & Inertinite	Amorphous	Predominant Source Type	Colour Maturation Rating
	<i>Sample 1835</i>					1-7
1835	Common	-	Abundant	Trace	Gas	1
1865	Common	-	Common	Trace	Gas	1
1873	Common	-	Common	Abundant	Oil/Gas	2
1875	Common	-	Common	Abundant	Oil/Gas	2
1889	Trace	-	Trace	Trace	None	2
1913	Common	-	Common	Trace	Gas	2
<u>2026</u>	Abundant	-	Trace	Trace	Gas	1
2038	Common	-	Trace	Common	Gas/Sub.Oil?	1
2066	Common	Abundant	Trace	Common	Gas	1
2235	Common	-	Common	Common	Gas/Sub.Oil?	2
2357	Common	-	Common	Trace	Gas	2
2602	Trace	-	Common	Trace	None /?Gas	2

Table 1.

Sample 1835

Well: 6507/12-2

VISUAL KEROGEN DATA

Depth m	Cuticle	Brown Wood	Black Wood & Inertinite	Amorphous	Predominant Source Type	Colour Maturation Rating
3305	Trace	-	Trace	-	None	2
3360	Trace	-	Trace	-	None	Barren
3447.5	Trace	-	Trace	-	None	2

Table 1 - continued.

PALEOCHEM

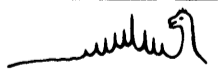
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Well: 6507/12-2

General Well Data

Sample Type	Stratigraphy (by Paleoservices)	Depth m.	Lithology	Total Organic Carbon Content (TOC) % wt.
SWC	Late Cretaceous	1835	Grey Claystone	1.23
SWC	Late Cretaceous	1865	Grey Claystone	0.87
SWC	Kimmeridgian	1873	Dark Grey micaceous Siltstone	9.35
SWC	Kimmeridgian	1875	Dark Grey micaceous Siltstone	5.73
SWC	Late Jurassic	1889	Dark Grey micaceous Siltstone	*
SWC	Late/Mid Jurassic	1913	Grey micaceous Siltstone	1.17
SWC	Early Jurassic	2026	Grey micaceous Siltstone	0.80
SWC	Early Jurassic	2038	Grey Siltstone	1.66
SWC	Early Jurassic	2066	Pale Grey/Brown Claystone	1.35
SWC	Early Jurassic	2235	Dark Grey micaceous Siltstone	6.12
SWC	Early Jurassic	2357	Grey micaceous Siltstone	3.34
SWC	Late Triassic	2602	Grey/Red Claystone	2.33
SWC	Late Triassic	3053	Red Claystone	0.09
SWC	Late Triassic	3062	Sandstone	-
SWC	Late Triassic	3080.5	Sandstone	-
SWC	Late Triassic	3143	Sandstone	-

Table 2.



PALEOCHEM

Well: 6507/12-2

General Well Data

Sample Type	Stratigraphy (by Paleoservices)	Depth m.	Lithology	Total Organic Carbon Content (TOC) % wt
SWC	Late Triassic	3175	Red Claystone	0.20
SWC	Late Triassic	3280	Red Claystone (+Evaporite?)	0.15
SWC	Late Triassic	3305	Grey Claystone	0.15
SWC	Late Triassic	3320	Red Claystone	0.14
SWC	Late Triassic	3360	Pale Grey Claystone	0.19
SWC	Late Triassic	3378	White Sand- stone (+Rust?)	0.05
SWC	Late Triassic	3413	White Sand- stone (+Rust?)	0.13
SWC	Late Triassic	3425	Grey Claystone	0.35
SWC	Late Triassic	3447.5	Light Grey Claystone	1.11 <i>nlc marked</i>

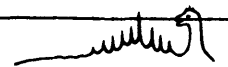
Table 2 - continued.

* Insufficient sample for analysis.

Pyrolysis Data

Depth m.	Yield (Kg/tonne)	
	P1 Peak	P2 Peak
1835	0.3	1.1
1865	0.2 (0.1 Rpt)	0.4 (0.4 Rpt)
1873	2.3	10.8
1875	2.4	10.3
1873*	0.6	7.6
1875*	0.7	6.9
1889	0.2 (0.2 Rpt)	0.7 (0.6 Rpt)
1913	<0.1 (<0.1 Rpt)	0.3 (0.4 Rpt)
2026	0.1 (<0.1 Rpt)	1.3 (1.0 Rpt)
2038	0.2	3.7
2066	0.3 (0.3 Rpt)	3.4 (3.5 Rpt)
2235	0.2 (0.3 Rpt)	6.8 (7.2 Rpt)
2357	<0.1	4.0
2602	0.7	3.1
3053	<0.1	<0.1
3175	<0.1	<0.1
3280	<0.1 (<0.1 Rpt)	<0.1 (<0.1 Rpt)
3305	<0.1	0.1
3320	<0.1	<0.1
3360	<0.1 (<0.1 Rpt)	<0.1 (<0.1 Rpt)
3378	<0.1	0.1
3413	<0.1	<0.1
3425	0.1	0.2
3447.5	0.2	0.4

Table 3.



Well No: 6507/12-2

SOLUBLE EXTRACT DATA

PALEOCHEM

Depth m.	Total Soluble Extract (TSE) % wt.	Saturate Alkane Content (SAC) % of TSE	Aromatics Content (AC) % of TSE	Carbon Preferece Index (CPI)
1873	0.199	47.0	0.2	NP
1875	0.217	46.8	1.2	NP
3062	0.706	28.9	15.3	NP
3080.5	0.607	41.1	20.7	NP
3143	0.170	15.7	26.1	NP

NP - CPI values could not be calculated due to short range of saturate alkanes present in samples.

Table 4.

5/4 by Gordon
7/2
dist. from ...
NP -> by dense bodies

Handwritten signature

Well: 6507/12-2

VITRINITE REFLECTANCE DATA (as detailed in Saga Telex
No. 81/3369).

<u>Depth.</u>	<u>Reflectivity</u>
2350	0.38
2460	0.43
2470	0.39
2480	0.36
2490	0.38
2500	0.38
2510	0.42
2520	0.42
2543	0.38
2553	0.40
2556A	0.40
2556B	0.40
2586	0.40
2616A	0.41
2616B	0.43
2661	0.47

Table 5.



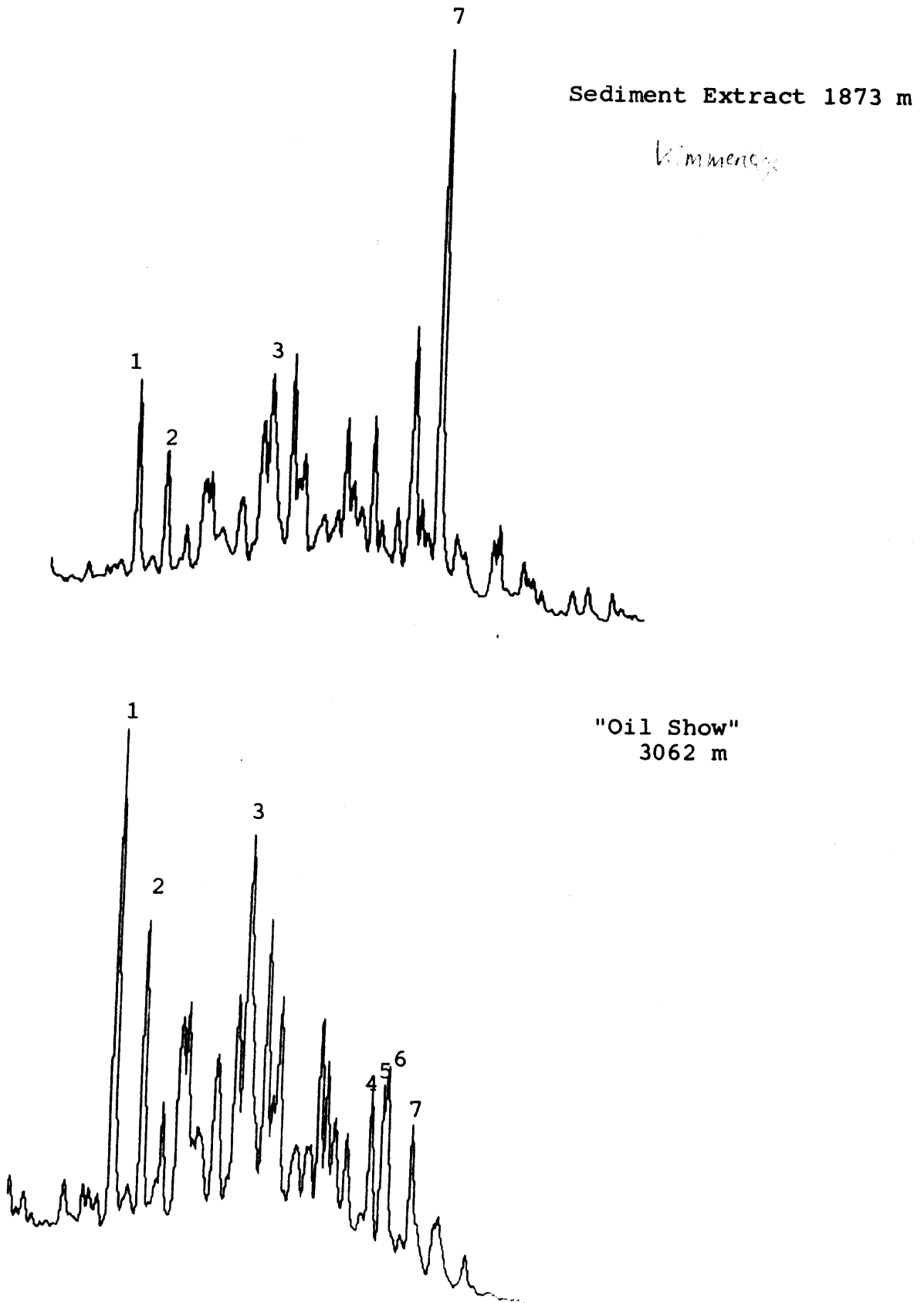


Fig.1 - Steranes

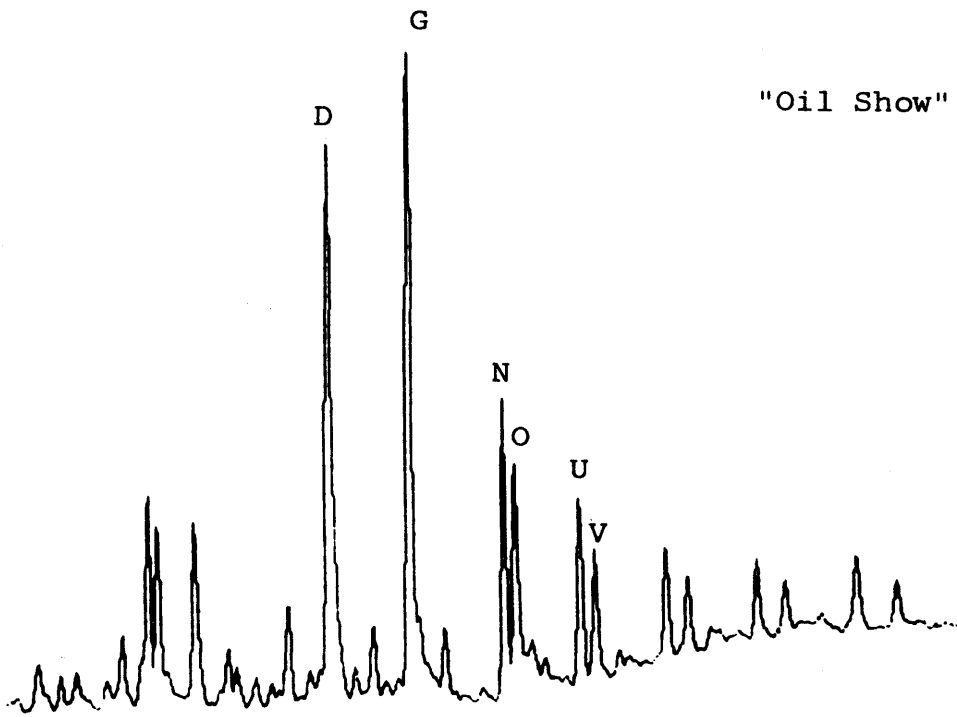
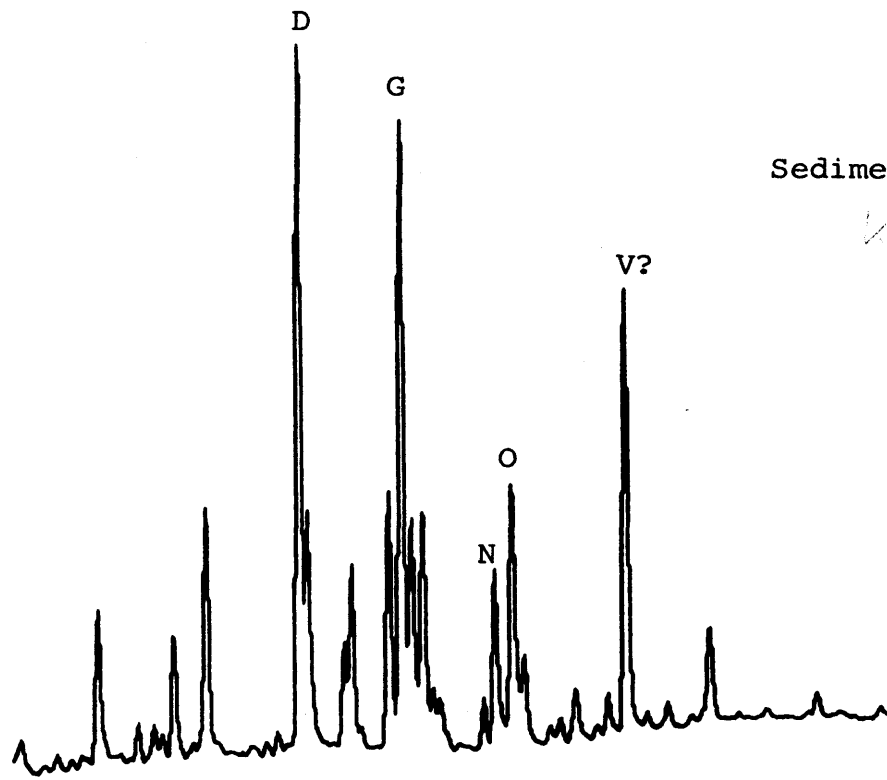


Fig.2 - Hopanes

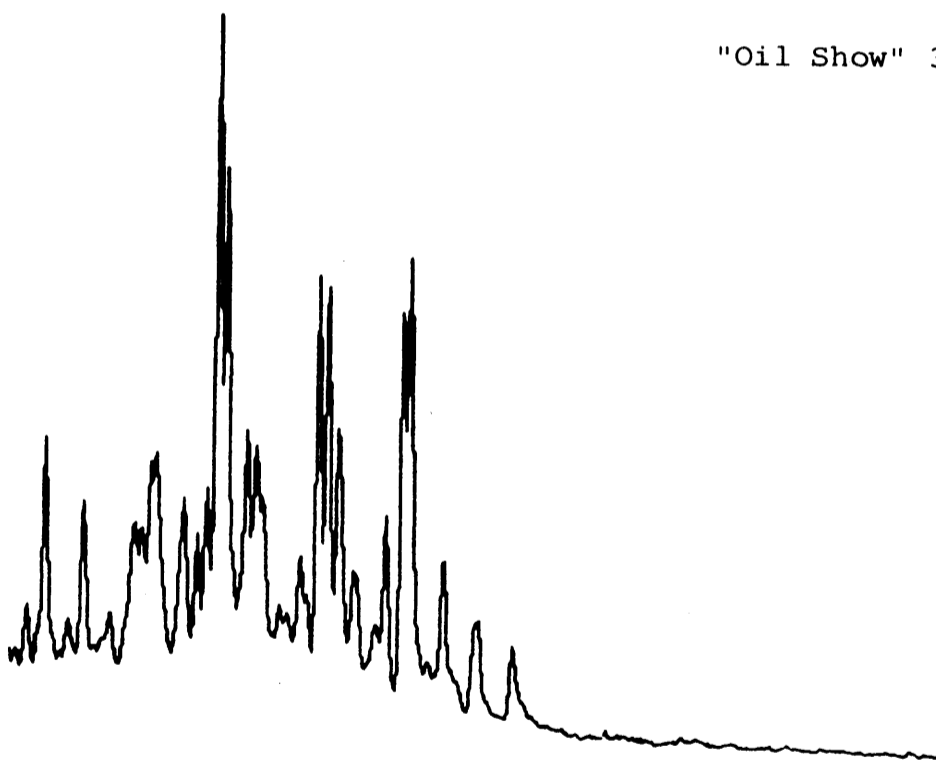
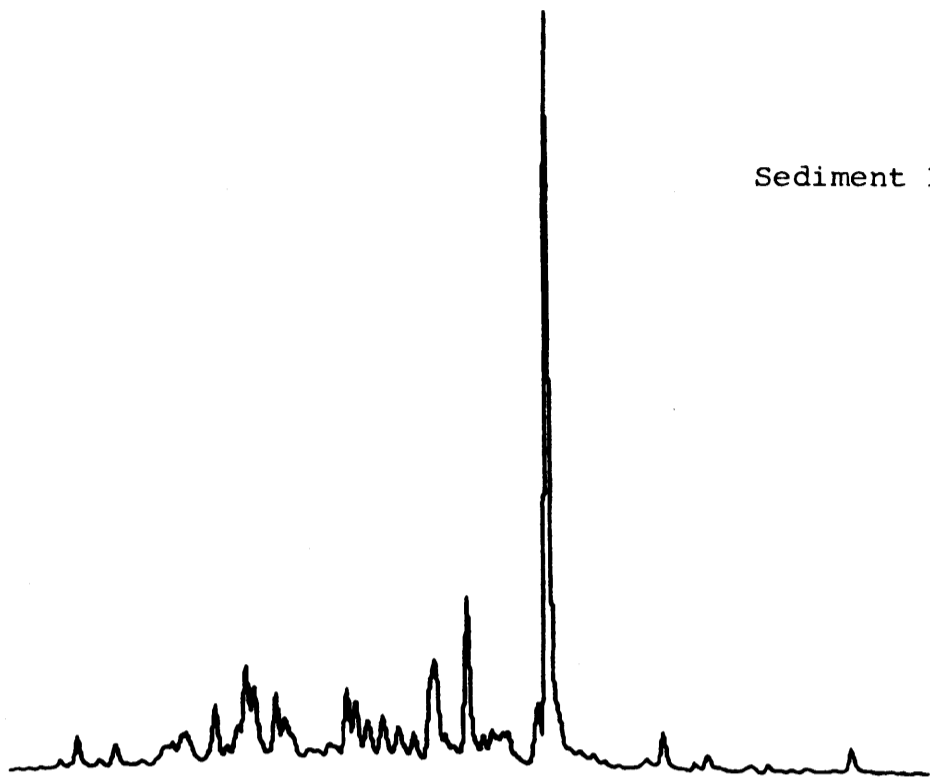
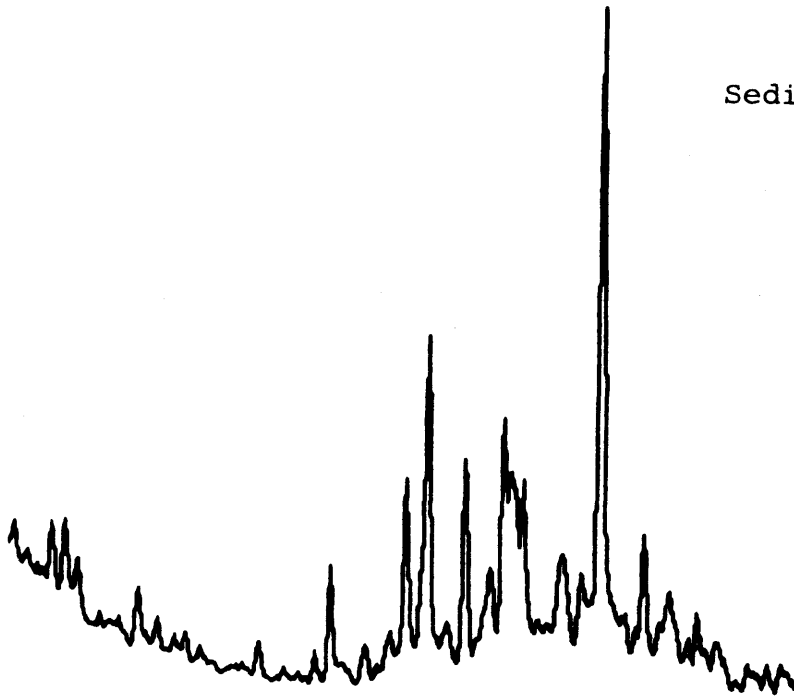


Fig.3 - $\beta\beta$ - Steranes

Sediment Extract 1873 m



"Oil Show" 3062 m

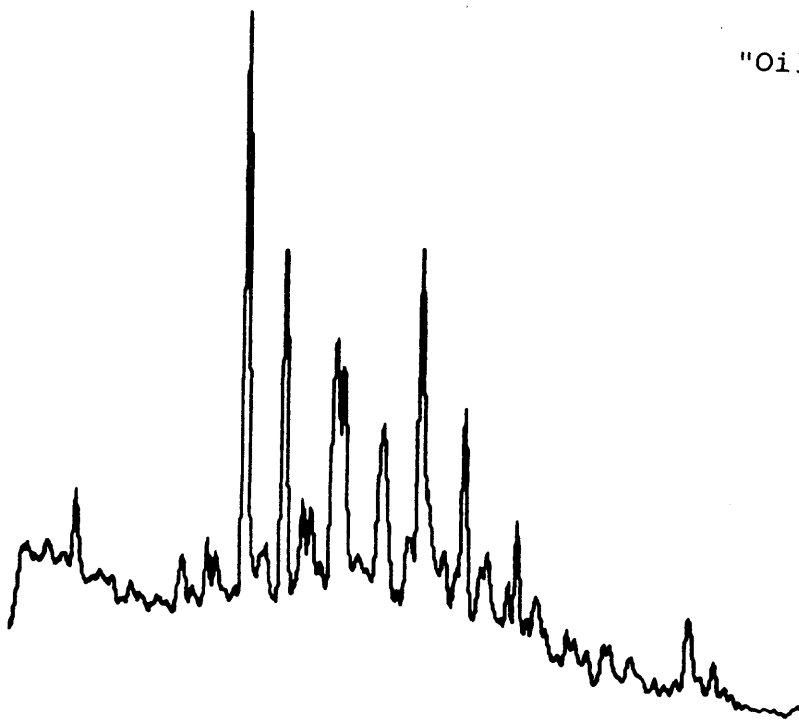
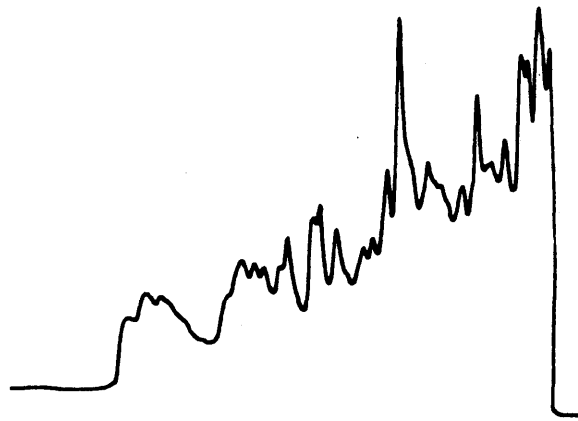
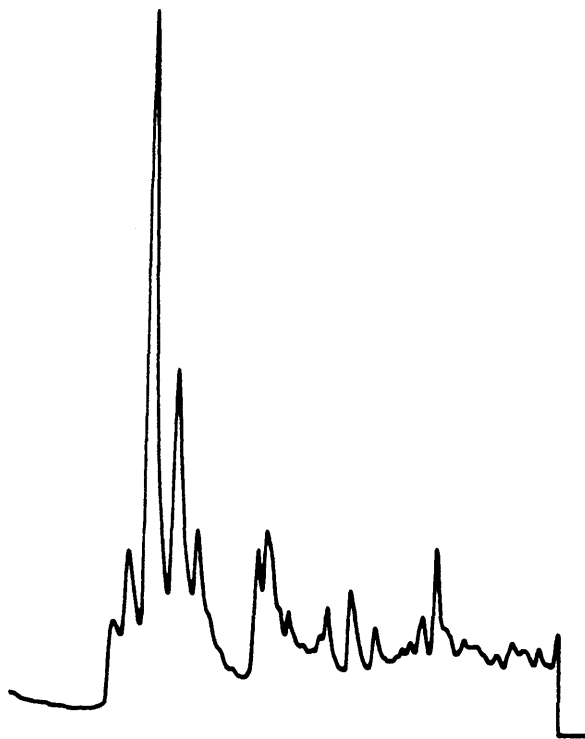


Fig. 4 - Rearranged Steranes and Diasteranes



Sediment Extract
1873 m



"Oil Show"
3062 m

Fig.5 - methyl and dimethylnaphthalenes

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