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Resymé/konklusjon/anbefaling
Summary/Conclusion/Recommendation

Two source rock intervals are important in the Njord Field drainage area: the Nesna Formation shales and the Hitra Formation coals.
The Nesna Formation shales have a high potential for liquid hydrocarbons.
The Hitra Formation coals can generate twice as much liquid as gas.
The Njord oils have a marine source rock and correlates well with the Tyrihans oils, while the Draugen oils have a more terrestrial source. The Njord gases may have a mixed source or input from two different source rocks, both marine and terrestrial.

Emneord/Keywords	Sider/Pages - Bilag/Appendix
Subregional evaluation, Source rock characterisation, oil-oil correlation	

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The results from the GC-MS were transferred to a VAX 8600 computer were the fragmentograms were added sequentially in a file and shift corrected using a cross correlation function and normalised using the deuterated internal standards. All the datapoints with variance less than 1.5 were removed and the remaining data were reduced using a maximum entropy method. The resulting data set were analysed by principal component analysis (PCA).

Stable isotopes:
The $\delta^{13}C$ were analysed on the saturated, aromatic and NSO-fractions of the crude oils by the University of Bergen.

Analysis of stable isotopes on the natural gases from the Njord field (6407/7) have been undertaken by IFE.

I.2 Experimental

Light hydrocarbons:

An internal standard (iso-octane) was added to the crude oil and the whole oil was injected in a modified hp5880 gas chromatograph. The gas chromatograph was fitted with a short packed pre-column and a 50 m PONA-fused silica column (HP). The pre-column was backflushed after allowing C_1 to C_{14} to enter the capillary column. The FID signals were processed on a Multichrom lab data system (VG Lab Systems Ltd.).

Saturated and aromatic hydrocarbons:

The crude oils were deasphalted and group type separated using an aminomodified precolumn and a silica main column. The saturated and aromatic hydrocarbons were analysed on a HP5880 gas chromatograph using a 30 m DB-1 and a 60 m DB-5 column (J&W) respectively. The FID-signals were processed on a Multichrom lab data system (VG Lab Systems Ltd.).

Biomarkers:

The crude oils were run through a short silica column to remove the asphaltenes and the NSO-compounds after adding a standard amount of deuterated internal standards (steranes, mono- and tri-aromatic steroids). The fraction containing the saturated and aromatic hydrocarbons were analysed by high resolution GC-MS at 2500 resolving power. the analytical parameters for the GC-MS are given in Fig. I.2.1.

A list of the fragmentograms used in this study and their significance is given in Table I.2.1.

I. OIL-OIL CORRELATION HALTEN SOUTH

I.1 Introduction

In this report the oils from Njord (6407/7), Draugen (6407/9) and Tyrihans (6407/1) are correlated.

These fields are all situated around one common drainage area (Fig. I.1.1.) and may have been sourced from the same source rock. In the Haltenbanken area there are several possible source rock horizons:

1) Nesna Fm.
2) Engelvær Fm.
3) Hitra Fm.

The terrestrial input to the organic matter is increasing going from the Nesna Fm. marine shales to the coals in the Hitra Fm. and it is expected that if the more terrestrially derived source rocks have contributed to the accumulations this will result in compositional differences in the oils.

Four methods have been used in this study:

1) analysis of light hydrocarbons
2) analysis of saturated and aromatic hydrocarbons
3) quantitative and qualitative analysis of biological markers.
4) stable isotopes ($\delta\ ^{13}c$).

when correlating hydrocarbons with a wide range of potential source rock types it is essential to analyse both the light and the heavy end of the hydrocarbons since different sources will contribute to different parts of the molecular weight range.

I.3 Results and discussion

I.3.1 Light hydrocarbons

The quantitative results from the oils included in this study are given in Table I.3.1. Table I.3.2. gives the results on a percentage basis.

Fig. I.3.1. gives an example of the gas chromatogram of the C_1 to C_8 hydrocarbons in a sample from 6407/7-1.

Based on the results in Table 3.1.1. it is obvious that the oils from Njord (6407/7) and Tyrihans (6407/1) are richer in aromatics like toluene and xylenes than the oils from Draugen (6407/9) This may be a result of a contribution to these oils by a more terrestrially derived source rock since these are expected to give a higher proportion of aromatic hydrocarbons originating from humic plant material.

The oils from Draugen are slightly biodegraded as seen on the reduction of n-octane relative to the other hydrocarbons. It does not appear to have affected the lower molecular weight hydrocarbons. The low relative amounts of benzene may however be a result of water washing. The biodegradation may only have affected the n-C_{8+} hydrocarbons through a depletion of the n-alkanes relative to branched- and cyclic hydrocarbons.

The oil from 6407/7-2 appears to be slightly heavier than the oils from 6407/7-1 based on the absolute concentrations of the C_6 to C_9 hydrocarbons.

In Fig. I.3.2. the Heptane value is plotted versus the Isoheptane value for 25 oils and condensates from Haltenbanken (The definitions of these values are given in the footnote below). This plot clearly shows that these are all derived from a marine source. However there may still be varying degrees of mixing of terrestrially derived hydrocarbons with these dominantly marine oils/condensates.

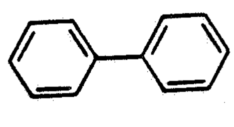
$$\text{Heptane value} = \frac{100 * \text{Heptane}}{(\Sigma\ \text{Cyclohexane} - \text{Methylcyclohexane})}$$

$$\text{Isoheptane value} = \frac{\text{2- + 3-Methylhexane}}{(\text{cis-1,3- + trans-1,3- + cis-1,2-dimethylcyclopentane})}$$

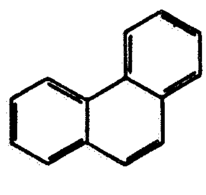
I.3.2. Saturated and aromatic hydrocarbons.

The gas chromatograms of the saturated hydrocarbons from Draugen have high pristane/n-C_{17} ratios and the n-alkanes below n-C_{15} are clearly depleted. This is in accordance with the results from the light hydrocarbons, indicating a slight biodegradation of these oils principally affecting the n-alkanes in the n-C_8 to n-C_{18} range. All the gas chromatograms show a smooth, unimodal distribution of n-alkanes typical of mature oils.

The distribution of aromatic hydrocarbons is also very similar in the studied oils. The oils from Njord appear to have a higher contribution of monoaromatic hydrocarbons showing up as small peaks in the naphthalene region. There are also some small variations in the relative concentration of biphenyls (I) in some of the samples. The samples from Tyrihans showing a higher relative concentration of Biphenyls than the other oils. The samples from Tyrihans appear to be richer in Phenanthrenes (II) than the rest of the oils.



I



II

I.3.3 Biological markers.

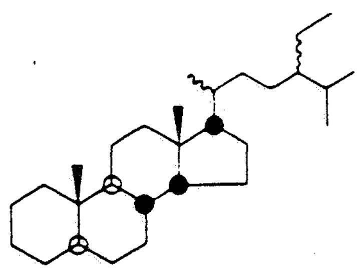
The distribution of biological markers of the sterane (III) and triterpane (IV) type is very sensitive to variations in the organic input to the source rock, maturity differences and variations in depositional environment. In addition, the aromatised steroids (V,VI) can give a good estimation of the thermal maturity of the source rocks that have generated the oils. It should be pointed out however that the maturity based on biomarkers in crude oils is an average maturity, and a result of drainage from source rocks with a wide range of maturities.

Fig. I.3.3. show the results of the data reduction of the biomarker fragmentograms for three different samples. This includes the steranes, triterpanes, mono- and triaromatic steroids. The intensity is normalised to the deuterated sterane added as an internal standard. From this figure it is appearent that samples 7 and 10 (6407/9-1 and 6407/1-3) are much richer in biological markers than sample 5 (6407/7-1 DST#5).

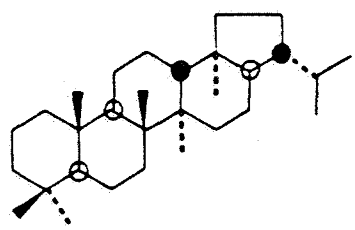
The results of the principal component analysis (PCA) are given in Fig. I.3.4. where the scores on the two first principal components are plotted for each of the samples used in this study. The numbers corresponds to the oils in Table I.3.3.

Sample #	Oil
1	6407/7-1 DST#2
2	6407/7-1 DST#3
3	6407/7-1 DST#4
4	6407/7-1 DST#5
5	6407/7-1 DST#5
6	6407/7-2 DST#1
7	6407/9-1
8	6407/9-2 DST#1
9	6407/1-3 DST#1
10	6407/1-3 DST#1
11	6407/1-2

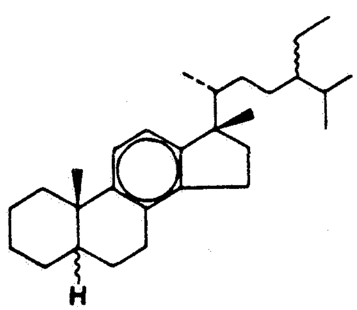
Table I.3.3.: Identification of samples in principal component analysis (PCA).



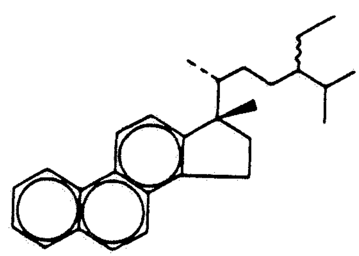
III



IV



V



VI

The score plot in Fig I.3.4. shows that, based on the distribution of the investigated biological markers, the oils fall into three groups. The oils from Draugen and the oil from Tyrihans North (6407/1-3) are in separate groups and are different from the oils in Njord and Tyrihans South (6407/1-2) which are very similar.

The method is validated by running analytical parallells of two samples (4,5 and 9,10). These plot close together and show that the experimental and analytical variations are negligable.

In order to interpret the results of a principal component analysis (PCA) in geochemically meaningful terms one must look at the loadings for each variable. The loading gives a qualitative understanding of the importance of each of the variables used in separating the different oils. Fig. I.3.5. gives the loadings for the first two principal components (Factors) plotted versus variable number. This Figure shows that the first factor only have positive loadings. This suggests that this is just an effect of absolute amounts of biomarkers in these samples. This agrees very well with the results shown in Fig. I.3.3.

In the second factor there is a negative correlation between the mono- and triaromatic steroids (variable 700+), there is a negative correlation between the extended hopanes and the regular hopanes (variable 300-550) and there is a negative correlation between the C_{29}-steranes and the other steranes.

The first two effects described above are clearly a result of different maturity of the source rocks from which these oils are sourced. This maturity effect does not co-vary with the absolute amount of biomarkers since this comes out on the first factor.

The results show that the concentration of biological markers are higher in the oils from Draugen and 6407/1-3 while the oils from Draugen are more mature than the oils from Njord and Tyrihans.

These results are confirmed by the results in Table I.3.5 where the ratio of triaromatic steroids versus tri- plus monoaromatic steroids (T/M+T), aromatic steroids versus aromatic pluss regular steroids (A/A+S) and the concentration of regular steroids in relative units are listed. The results of the PCA are, however, based on the entire distribution of biological markers and gives more reliable results for correlations.

The principal component analysis (PCA) indicates that the oils from Njord are very similar to the oil from 6407/1-2 and that these might have a common source rock and are drained from the same area. The oil from 6407/1-3 are much richer in biomarkers than the oils from Njord and 6407/1-2. The distribution of the biomarkers are similar in these oils and suggests that the oil from 6407/1-3 are sourced from the same or similar source as the oils from Njord and 6407/1-2. The higher concentration of biomarkers in the 6407/1-3 oil may suggest that the average maturity for this oil is lower and that the reservoired hydrocarbons have not been mixed with hydrocarbons generated from high maturity source rocks with low concentrations of biomarkers.

The oils from Draugen are probably partly sourced from another source rock of more terrestrial origin. This is illustrated in Fig. I.3.6. where the m/z 218 fragmentograms for a Draugen and a Njord oil are compared. The Draugen oil is richer in C_{29} $\alpha\beta\beta$ steranes which are typically derived from sterols in higher plants. This could suggest that the oils in Draugen have in part been sourced from coals and coaly shales from the Hitra Fm.

The oil from 6407/9-1 has an unusual sterane distribution (m/z 217) with a C_{29} $\alpha\alpha\alpha$ 20S/20R ratio much higher than the equilibrium value of 60% 20S. This suggests that the steranes have been subjected to severe biodegradation with a preferential microbial attack on the enzymatically formed 20R epimer. The present day biodegradation is however mild and cannot account for the variation in the 20S/20R ratio. This suggests that early mature hydrocarbons rich in biomarkers have migrated into the reservoir at a very shallow burial depth and been subjected to severe biodegradation. The reservoir has later been filled with more mature hydrocarbons with a much lower concentration of biomarkers and these have been subjected to a mild microbial attack principally depleting the n-C_8 to n-C_{18} alkanes.

These early mature hydrocarbons may have been formed when the Hitra Fm. in the main drainage area entered the oil generation zone and this might also explain the high relative concentration of terrestrially derived C_{29}-steranes in the Draugen oils.

I.3.4 Stable isotopes

The results from the analysis of $\delta\,^{13}C$ from C_{15+} fraction for some of the oils in this study are listed in Table I.3.5.

Oil	Saturates	Aromatics	NSO
6407/7-1 DST#2	-29.75	-28.70	-28.92
6407/7-1 DST#3	-29.80	-28.74	-28.96
6407/7-1 DST#4	-29.70	-29.00	-29.19
6407/7-1 DST#5	-29.06	-28.63	-27.90
6407/9-1	-29.01	-28.52	-28.41
6407/9-2 DST#1	-28.83	-27.49	-27.88
6407/1-2	-30.07		-29.26
6407/1-3 DST#1	-29.96	-29.06	-28.79

Table I.3.5.: $\delta\,^{13}C$ values for C_{15+} fractions for oil from Haltenbanken South.

The values in Table I.3.5. are very similar but the oils from Draugen are isotopically slightly heavier than the rest of the oils.

The isotopic composition of the gas samples from Njord have been analysed by IFE and the results are listed in Table I.3.6. The results are plotted in interpretation diagrams in Figs. I.3.7. to I.3.10.

As seen from Table I.3.6. in all the analysed samples the $\delta\,^{13}C$ values for the propane is higher than the $\delta\,^{13}C$ value for the n-butane . This indicates a mixed gas, at least derived from two different sources with one source dominating the C_1-C_3 range and the other source dominating from C_4. This could on a relative basis suggest a gas prone source rock for C_1-C_3 and a more oil prone source for the butanes.

If it assumed that C_1-C_3 are dominately derived from one source the $\delta^{13}C$ values of methane, ethane and propane can be used to indicate the maturity level of the gas. Fig. I.3.7. suggests a source Level of Organic Maturity (LOM) of about 12 which corresponds to a relatively high maturity level in the oil window. It is, however, unlikely that the C_1 - C_3 hydrocarbons should be sourced from only one of these potential source rocks, but have a contribution from both. In this case this will give lower estimates of LOM. This is in accordance with the biomarkers which do not suggest high levels of maturity.

The combined use of the δD methane and $\delta^{13}C$ methane values (Fig. I.3.9) suggests on the other hand, that the gases may have formed at even higher maturity, i.e.in the condensate part of the oil window.

I.4 Conclusions

A detailed correlation of oils and natural gases from the Haltenbanken South area based on light hydrocarbons, saturated and aromatic hydrocarbons, biomarkers coupled with principal component analysis, and stable isotopes of oils and natural gases suggests:

1) There may have been more than one source for some of the oils in the study.

2) The oils from Njord and Tyrihans may originate from the same source rock but at different levels of thermal maturity.

3) The oils from Draugen clearly have an input from a more terrestrially derived source, possibly the Hitra Fm. coals.

4) The oils form Draugen are derived from more mature source rocks than the oils from Njord and Tyrihans.

5) The oils from Draugen may have undergone an early intense biodegradation.

6) The oils from Draugen are slightly biodegraded today.

7) The gases from Njord probably have a mixed source. A terrestrially derived gas prone source rock is likely the principal source of the C_1-C_3 hydrocarbons.

I. OIL-OIL CORRELATION HALTEN SOUTH

TABLES

M/z 177	Demethylated hopanes
M/z 191	Triterpanes, terpanes
M/z 197	n-alkanes
M/z 205	Methylated hopanes
M/z 217	Regular steranes
M/z 218	Regular steranes
M/z 231	Triaromatic steroids
M/z 253	Monoaromatic steroids
M/z 259	Rearranged steranes

Table I.2.1.: Biomarker fragmentograms used in this study.

Table I.3.1.: Quantitative analytical results of C_6 to C_9 hydrocarbons in mg/g crude oil.

LIGHT HYDROCARBONS HALTENBANKEN OILS

OIL	HEXANE	2,2-DM-PENTANE	M-CPENTANE	2,4-DM-PENTANE	BENZENE	3,3-DM-PENTANE	CHEXANE	2-M-HEXANE	2,3-DM-PENTANE
1 6407/1-2	0.4460	0.0120	0.3750	0.0330	0.1000	0.009	0.6760	0.230	0.1020
2 6407/1-3 DST#1	3.8990	0.0560	2.7270	0.1390	2.8410	0.043	4.3240	1.237	0.4860
3 6407/1-3 DST#2	2.1293	0.0327	1.2308	0.0821	1.0543	0.023	1.7907	0.670	0.2481
4 6407/7-1 DST#2	0.7340	0.0170	0.3740	0.0380	0.3010	0.010	0.7150	0.261	0.0850
5 6407/7-1 DST#3	1.0130	0.0023	0.4850	0.5000	0.3760	0.012	0.8900	0.326	0.1030
6 6407/7-1 DST#4	1.0610	0.0210	0.5190	0.0520	0.3850	0.011	0.9320	0.321	0.1150
7 6407/7-1 DST#5	1.1500	0.0220	0.6110	0.0540	0.4020	0.013	1.0810	0.341	0.1110
8 6407/7-2 DST#1	0.6070	0.0130	0.3420	0.0320	0.2190	0.008	0.6320	0.221	0.0740
9 6407/9-1	1.3950	0.0290	0.8600	0.0740	0.0240	0.015	1.2830	0.455	0.1650
10 6407/9-2 DST#1	1.5620	0.0320	0.9430	0.0700	0.0240	0.016	1.3480	0.472	0.1630

OIL	1,1-DM-CYP	3-M-HEXANE	c1,3-DM-CYP	t1,3-DM-CYP	2-ET-PENTAN	t1,2-DM-CYP	HEPTANE	M-CHEXANE	2,2-DMHEX
1 6407/1-2	0.0640	0.3050	0.1080	0.103	0.032	0.2100	0.7280	1.4400	0.084
2 6407/1-3 DST#1	0.2830	1.5990	0.6220	0.590	0.160	1.1660	4.3680	6.8570	0.400
3 6407/1-3 DST#2	0.1325	0.8366	0.2874	0.268	0.081	0.5278	2.2618	2.7848	0.169
4 6407/7-1 DST#2	0.0730	0.3020	0.1030	0.096	0.026	0.1630	0.9000	1.4470	0.090
5 6407/7-1 DST#3	0.0900	0.3710	0.1240	0.115	0.032	0.1940	1.0750	1.6500	0.103
6 6407/7-1 DST#4	0.0940	0.3780	0.1300	0.120	0.035	0.2040	1.1060	1.7060	0.103
7 6407/7-1 DST#5	0.0960	0.3850	0.1430	0.131	0.033	0.2190	1.1450	1.9160	0.102
8 6407/7-2 DST#1	0.0670	0.2610	0.0970	0.090	0.020	0.1600	0.7690	1.2960	0.089
9 6407/9-1	0.1330	0.5330	0.2390	0.220	0.054	0.3690	1.2940	2.5020	0.160
10 6407/9-2 DST#1	0.1370	0.5440	0.2450	0.226	0.052	0.3790	1.2220	2.5060	0.158

OIL	E-CYPENT	2,5-DMHEX	2,4-DMHEX	TOLUENE	2,3-DMHEX	2-MHEPT	4-MHEPT	3-MHEPT	c1,3-DM-CYH	t1,4-DM-CYH
1 6407/1-2	0.096	0.050	0.061	0.616	0.070	0.425	0.114	0.231	0.402	0.135
2 6407/1-3 DST#1	0.603	0.188	0.220	6.103	0.339	1.889	0.508	1.012	1.625	0.562
3 6407/1-3 DST#2	0.255	0.112	0.123	2.140	0.154	0.932	0.248	0.497	0.656	0.222
4 6407/7-1 DST#2	0.056	0.044	0.057	0.726	0.082	0.374	0.108	0.229	0.365	0.135
5 6407/7-1 DST#3	0.063	0.051	0.066	0.809	0.091	0.415	0.120	0.253	0.396	0.146
6 6407/7-1 DST#4	0.066	0.051	0.066	0.815	0.093	0.404	0.104	0.249	0.414	0.154
7 6407/7-1 DST#5	0.074	0.050	0.065	0.957	0.091	0.405	0.119	0.253	0.432	0.165
8 6407/7-2 DST#1	0.054	0.037	0.047	0.566	0.059	0.320	0.099	0.465	0.045	0.124
9 6407/9-1	0.127	0.067	0.089	0.338	0.137	0.506	0.147	0.305	0.592	0.222
10 6407/9-2 DST#1	0.129	0.066	0.089	0.326	0.135	0.501	0.149	0.310	0.587	0.221

LIGHT HYDROCARBONS HALTENBANKEN OILS

OIL		1,1-DM-CYH	c1,4-DM-CYH	N-OCTANE	E-BENZENE	m-XYLENE	p-XYLENE	o-XYLENE
1 6407/1-2		0.056	0.194	1.034	0.248	0.568	0.277	0.324
2 6407/1-3	DST#1	0.237	0.862	4.621	1.628	2.855	1.241	1.823
3 6407/1-3	DST#2	0.091	0.323	2.183	0.528	0.897	0.456	0.531
4 6407/7-1	DST#2	0.057	0.177	0.975	0.122	0.478	0.235	0.229
5 6407/7-1	DST#3	0.062	0.189	1.057	0.129	0.498	0.246	0.235
6 6407/7-1	DST#4	0.063	0.198	1.079	0.184	0.509	0.257	0.242
7 6407/7-1	DST#5	0.064	0.203	1.089	0.153	0.592	0.263	0.277
8 6407/7-2	DST#1	0.049	0.164	0.879	0.102	0.334	0.130	0.203
9 6407/9-1		0.077	0.286	0.811	0.148	0.429	0.279	0.192
10 6407/9-2	DST#1	0.077	0.283	0.448	0.143	0.412	0.269	0.184

Table I.3.2.: Quantitative analytical results of C_6 C_9 hydrocarbons normalized to 100%.

		HEXANE	2,2-DM-PENTANE	M-CPENTANE	2,4-DM-PENTANE	BENZENE	3,3-DM-PENTANE	CHEXANE	2-M-HEXANE	2,3-DM-PENTANE
1	6407/1-2	4.5	0.1	3.8	0.3	1.0	0.1	6.8	2.3	1.0
2	6407/1-3 DST#1	6.7	0.1	4.7	0.2	4.9	0.1	7.4	2.1	0.8
3	6407/1-3 DST#2	8.5	0.1	4.9	0.3	4.2	0.1	7.2	2.7	1.0
4	6407/7-1 DST#2	7.2	0.2	3.7	0.4	3.0	0.1	7.0	2.6	0.8
5	6407/7-1 DST#3	8.2	0.0	3.9	4.1	3.1	0.1	7.2	2.7	0.8
6	6407/7-1 DST#4	8.7	0.2	4.2	0.4	3.1	0.1	7.6	2.6	0.9
7	6407/7-1 DST#5	8.7	0.2	4.6	0.4	3.0	0.1	8.2	2.6	0.8
8	6407/7-2 DST#1	7.0	0.1	3.9	0.4	2.5	0.1	7.3	2.5	0.9
9	6407/9-1	9.6	0.2	5.9	0.5	0.2	0.1	8.8	3.1	1.1
10	6407/9-2 DST#1	10.8	0.2	6.5	0.5	0.2	0.1	9.3	3.3	1.1

		1,1-DM-CYP	3-M-HEXANE	c1,3-DM-CYP	t1,3-DM-CYP	3-ET-PENTAN	t1,2-DM-CYP	HEPTANE	M-CHEXANE	2,2-DMHEX
1	6407/1-2	0.6	3.1	1.1	1.0	0.3	2.1	7.3	14.5	0.8
2	6407/1-3 DST#1	0.5	2.8	1.1	1.0	0.3	2.0	7.5	11.8	0.7
3	6407/1-3 DST#2	0.5	3.4	1.2	1.1	0.3	2.1	9.1	11.2	0.7
4	6407/7-1 DST#2	0.7	3.0	1.0	0.9	0.3	1.6	8.8	14.2	0.9
5	6407/7-1 DST#3	0.7	3.0	1.0	0.9	0.3	1.6	8.7	13.4	0.8
6	6407/7-1 DST#4	0.8	3.1	1.1	1.0	0.3	1.7	9.0	13.9	0.8
7	6407/7-1 DST#5	0.7	2.9	1.1	1.0	0.2	1.7	8.7	14.5	0.8
8	6407/7-2 DST#1	0.8	3.0	1.1	1.0	0.2	1.8	8.9	14.9	1.0
9	6407/9-1	0.9	3.7	1.6	1.5	0.4	2.5	8.9	17.2	1.1
10	6407/9-2 DST#1	0.9	3.8	1.7	1.6	0.4	2.6	8.5	17.4	1.1

		E-CYPENT	2,5-DMHEX	2,4-DMHEX	TOLUENE	2,3-DMHEX	2-MHEPT	4-MHEPT	3-MHEPT	c1,3-DM-CYH	t1,4-DM-CYH
1	6407/1-2	1.0	0.5	0.6	6.2	0.7	4.3	1.1	2.3	4.0	1.4
2	6407/1-3 DST#1	1.0	0.3	0.4	10.5	0.6	3.3	0.9	1.7	2.8	1.0
3	6407/1-3 DST#2	1.0	0.4	0.5	8.6	0.6	3.7	1.0	2.0	2.6	0.9
4	6407/7-1 DST#2	0.5	0.4	0.6	7.1	0.8	3.7	1.1	2.2	3.6	1.3
5	6407/7-1 DST#3	0.5	0.4	0.5	6.6	0.7	3.4	1.0	2.1	3.2	1.2
6	6407/7-1 DST#4	0.5	0.4	0.5	6.7	0.8	3.3	0.8	2.0	3.4	1.3
7	6407/7-1 DST#5	0.6	0.4	0.5	7.2	0.7	3.1	0.9	1.9	3.3	1.2
8	6407/7-2 DST#1	0.6	0.4	0.5	6.5	0.7	3.7	1.1	5.4	0.5	1.4
9	6407/9-1	0.9	0.5	0.6	2.3	0.9	3.5	1.0	2.1	4.1	1.5
10	6407/9-2 DST#1	0.9	0.5	0.6	2.3	0.9	3.5	1.0	2.1	4.1	1.5

		1,1-DM-CYH	c1,4-DM-CYH	N-OCTANE	E-BENZENE	m-XYLENE	p-XYLENE	o-XYLENE
1	6407/1-2	0.6	1.9	10.4	2.5	5.7	2.8	3.3
2	6407/1-3 DST#1	0.4	1.5	8.0	2.8	4.9	2.1	3.1
3	6407/1-3 DST#2	0.4	1.3	8.7	2.1	3.6	1.8	2.1
4	6407/7-1 DST#2	0.6	1.7	9.6	1.2	4.7	2.3	2.2
5	6407/7-1 DST#3	0.5	1.5	8.6	1.0	4.1	2.0	1.9
6	6407/7-1 DST#4	0.5	1.6	8.8	1.5	4.2	2.1	2.0
7	6407/7-1 DST#5	0.5	1.5	8.2	1.2	4.5	2.0	2.1
8	6407/7-2 DST#1	0.6	1.9	10.1	1.2	3.9	1.5	2.3
9	6407/9-1	0.5	2.0	5.6	1.0	2.9	1.9	1.3
10	6407/9-2 DST#1	0.5	2.0	3.1	1.0	2.9	1.9	1.3

OIL			T/M+T	A/S+A	CONC.STER
1	6407/7-1	#2	0.77	0.45	2.85
2	6407/7-1	#3	0.75	0.44	3.09
3	6407/7-1	#4	0.74	0.46	3.03
4	6407/7-1	#5	0.69	0.46	2.29
5	6407/7-1	#5.2	0.69	0.46	2.16
6	6407/7-2		0.69	0.45	2.58
7	6407/9-1		0.66	0.64	4.03
8	6407/9-2		0.66	0.58	4.50
9	6407/1-3	#1	0.62	0.55	5.31
10	6407/1-3	#1.2	0.57	0.55	5.22
11	6407/1-2		0.60	0.54	3.47

T/M+T : triaromatic steroids/tri-+monoaromatic steroids

A/S+A : aromatic steroids/steranes+aromatic steroids

Conc. Ster.: relative concentration of steranes

Table I.3.5.: Aromatic steroid ratios for Haltenbanken oils.

Table I.3.6: Isotopic and volumetric composition of natural gas samples from Njord.

Composition of natural gases from well 6407/7-1

Sample	IFE no.	C_1 %	C_2 %	C_3 %	$i-C_4$ %	$n-C_4$ %	CO_2 %	ΣC_1-C_4	$\frac{\Sigma C_2-C_4}{\Sigma C_1-C_4}$	$\frac{i-C_4}{n-C_4}$
Test 2	4983	79.4	10.5	5.6	0.9	2.0	1.7	98.3	0.19	0.45
Test 3	4984	82.8	9.6	4.2	0.5	1.1	1.8	98.2	0.16	0.45

Isotopic composition of natural gases from well 6407/7-1

Sample	IFE no.	C_1 $\delta^{13}C$	C_1 δD_{SMOW}	C_2 $\delta^{13}C$	C_3 $\delta^{13}C$	$i-C_4$ $\delta^{13}C$	$n-C_4$ $\delta^{13}C$	CO_2 $\delta^{13}C$	CO_2 $\delta^{18}O_{PDB}$
Test 2	4983	-39.6	-200	-29.1	-27.9	-28.8	-28.6	-10.9	- 7.8
Test 3	4984	-40.3	-205	-29.7	-27.9	-27.8	-28.1	- 9.5	-15.6

Volume composition of gas samples from well 6407/7-2

Sample	IFE no.	C_1 %	C_2 %	C_3 %	$i-C_4$ %	$n-C_4$ %	CO_2 %	ΣC_1-C_4	$\frac{\Sigma C_2-C_4}{\Sigma C_1-C_4}$	$\frac{i-C_4}{n-C_4}$
DST 1	6083	81	10	5.1	0.70	1.7	1.4	98.6	0.18	0.41
DST 2	6084	82	9.8	4.4	0.54	1.3	1.5	98.5	0.16	0.42

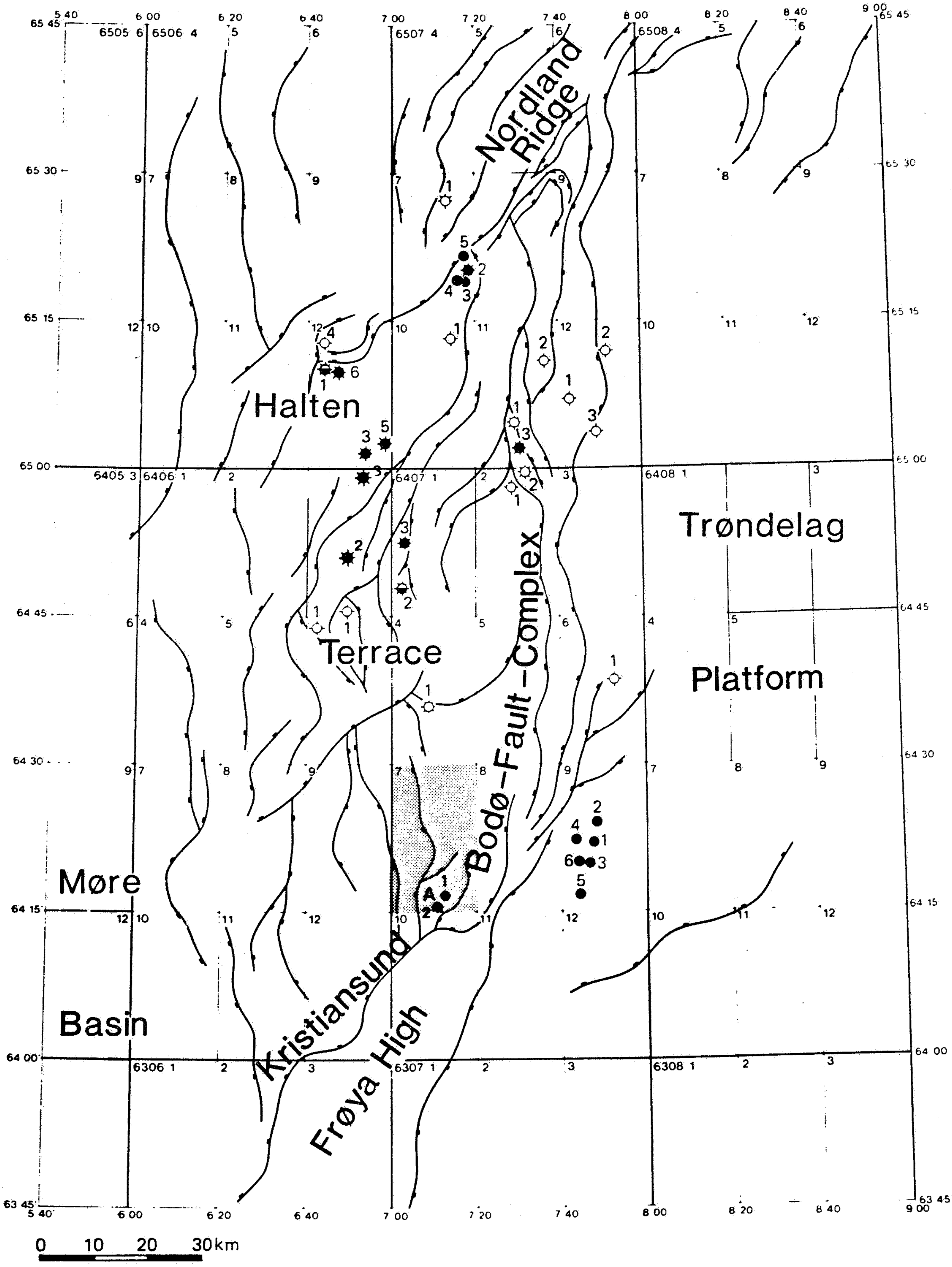
Isotopic composition of gas samples from well 6407/7-2

Sample	IFE no.	C_1 $\delta^{13}C_{PDB}$	C_1 δD_{SMOW}	C_2 $\delta^{13}C_{PDB}$	C_3 $\delta^{13}C_{PDB}$	$i-C_4$ $\delta^{13}C_{PDB}$	$n-C_4$ $\delta^{13}C_{PDB}$	CO_2 $\delta^{13}C_{PDB}$	CO_2 $\delta^{18}O_{PDB}$
DST 1	6083	-39.9	-201	-29.4	-28.4	-28.1	-29.9	-10.4	-10.7
DST 2	6084	-39.6	-207	-29.0	-28.0	-28.1	-28.9	- 9.3	-14.4

I. OIL-OIL CORRELATION HALTEN SOUTH

FIGURES

Figure I.1.1.: Well location map.



Nordland Ridge
Halten
Terrace
Bodø-Fault-Complex
Trøndelag
Platform
Møre
Basin
Kristiansund
Frøya High
6505
6506
6507
6508
6405
6406
6407
6408
6306
6307
6308
0 10 20 30km

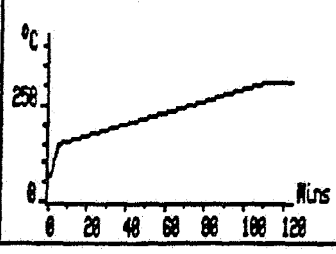
Figure I.2.1.: Analytical parameters from the GC-MS analysis.

SYSTEM:NILS	Parameters for Selective Ion Recording [G# 1 KVE] (Sector)		

DAT	Data filename	B:TEST	IAV	Maximum volts			6000		
REF	Reference filename	PFK	IMR	Maximum mass at IAV			2225		
INS	Instrument	1:70E	GTM	Time 0:35:00 2:00:00 Mode EI+B Gas					
ACN	Customer account		CHN	M(amu)	S(ms)	D(ms)	M(amu)	S(ms)	D(ms)
ACV	Accelerating volts	6000	A	177.1643	80	15			
RES	Instrument resolution	2500	B	191.1800	80	15			
SMP	#Samples	11	C	192.9888	20	15			
INJ	#Injections	1	D	197.2269	10	15			
GRP	#Groups	1	E	217.1956	80	15			
CLS	#Calibration scans	3	F	218.2835	80	15			
CST	Cal. scan time (s)	10	G	221.2288	80	15			
CTL	Cal. tolerance (ppm)	200	H	231.1174	80	15			
CEX	Cal. examination	Y	I	231.2113	80	15			
PEX	Peak examination	Y	J	233.1239	80	15			
LWS	Lock span (peak widths)	2.0	K	245.1956	80	15			
LST	Lock step (peak widths)	0.02	L	253.1956	80	15			
FLO	Fast lock on	N	M	256.2145	80	15			

SYSTEM: GCNILS (GCC) Update Parameters 30-MAR-87 Page 1 of 2

Temperature Ramp Parameters				Acquisition Parameters		
TE1	Temperature 1	(°C)	70	INO	Instrument number	1
TI1	Time 1	(mins)	1.50	AQT	Acquisition type	SIR
RT1	Rate 1	(°C/min)	25.0	AQS	Acquisition system	NILS
TE2	Temperature 2	(°C)	150	DAT	Datafile name	D:NB30037
TI2	Time 2	(mins)	1.00			
RT2	Rate 2	(°C/min)	1.5			
TE3	Temperature 3	(°C)	310			
TI3	Time 3	(mins)	12.00			
RT3	Rate 3	(°C/min)	0.0			
TE4	Temperature 4	(°C)	0			
TI4	Time 4	(mins)	0.00			
RT4	Rate 4	(°C/min)	0.0			
TE5	Temperature 5	(°C)	0			
TI5	Time 5	(mins)	0.00			



?=help RETURN=next ESC=previous ^X=exit CTRL-^=abort ^H=hardcopy
^Q=quit ^G=go "name"=select <=page >=page ^C=create

Figure I.3.1.: Gas chromatogram of light hydrocarbons from 6407/7-1 DST2.

Analysis HALTEN6 8, 1, 1 6407/7-1 DST#2

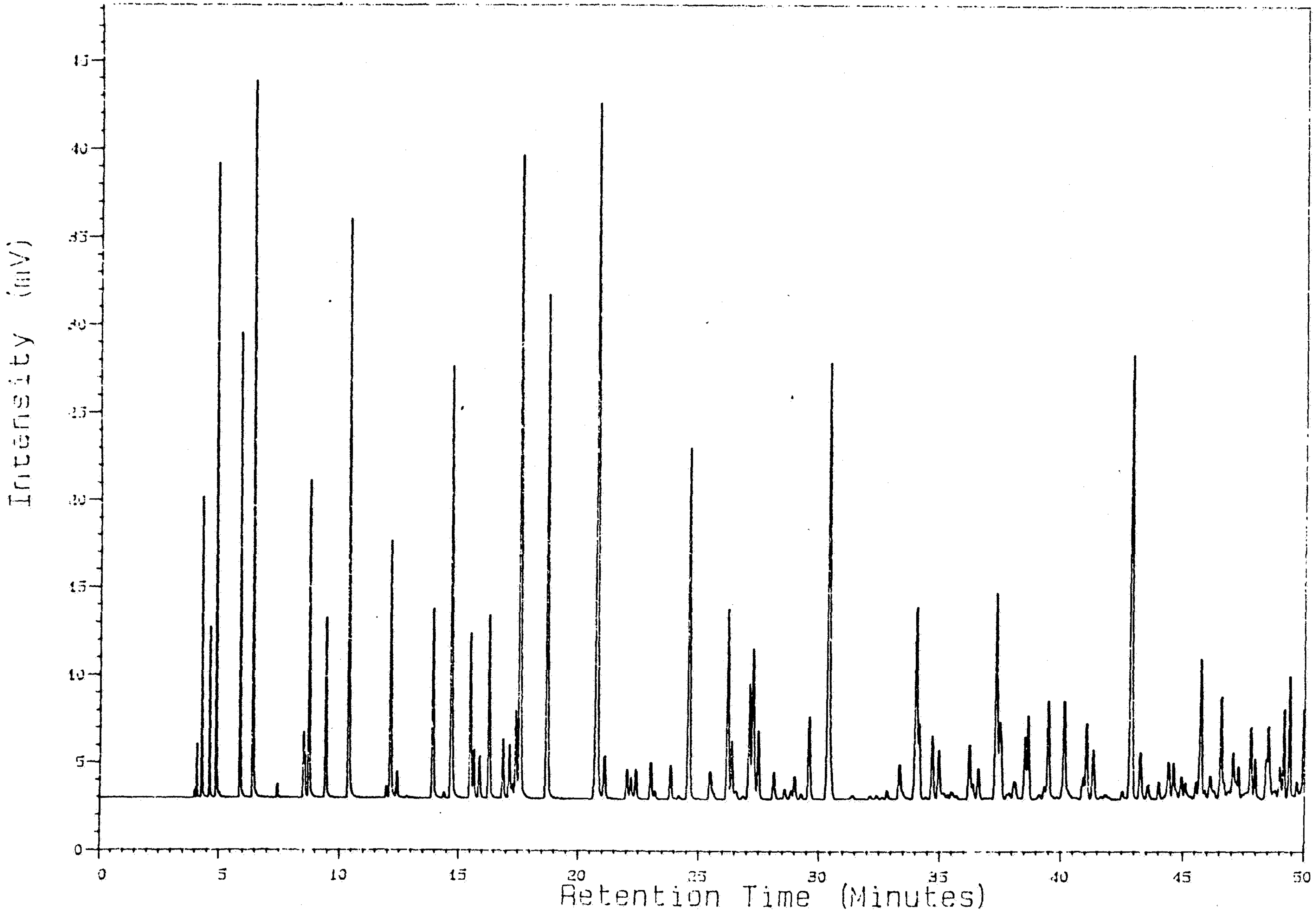


Figure I.3.2.: Heptane values plotted versus Isoheptane values.

HEPTANE RATIOS HALTENBANKEN

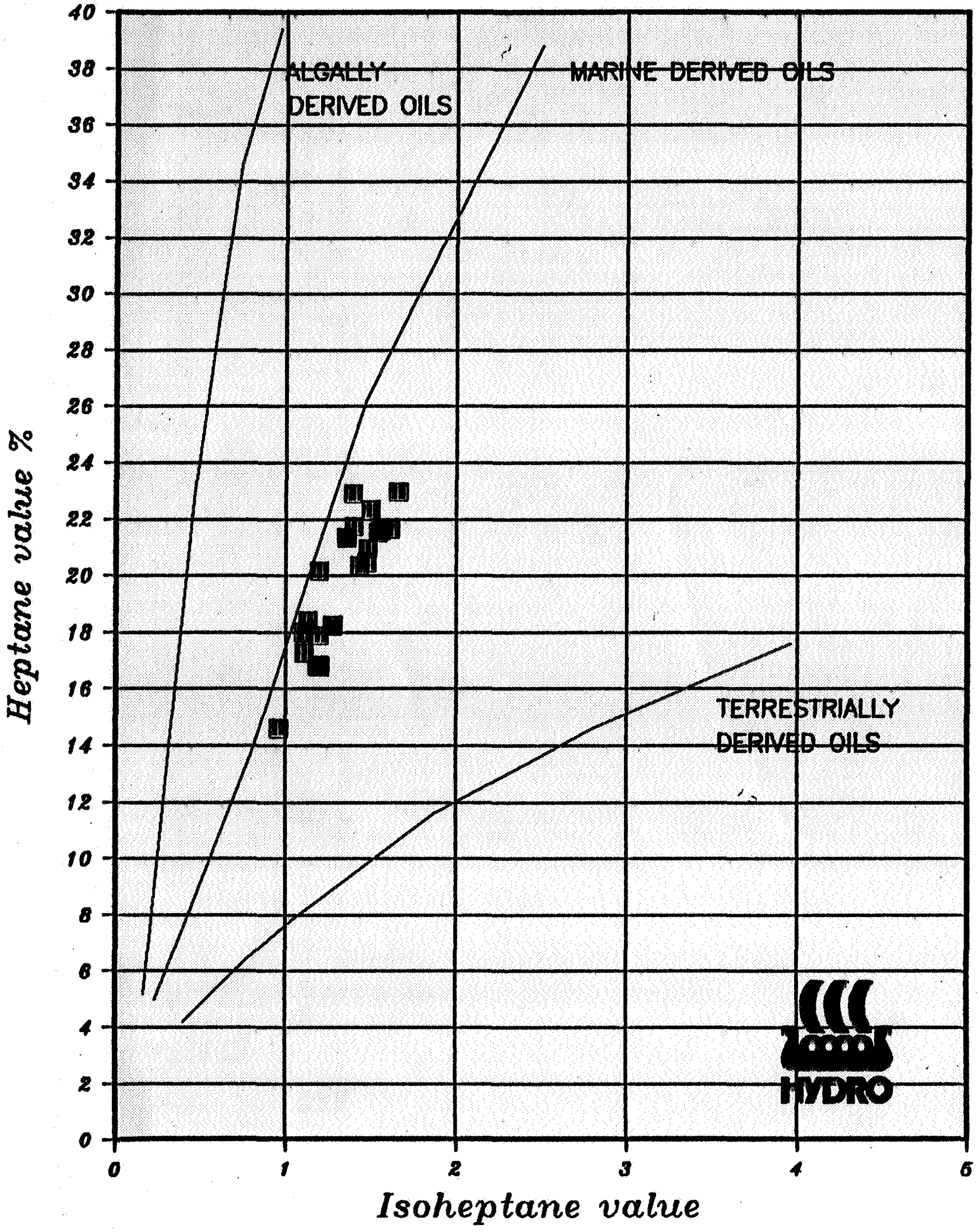


Figure I.3.3.: Reduced biomarker fragmentograms after maximum entropy calculation.

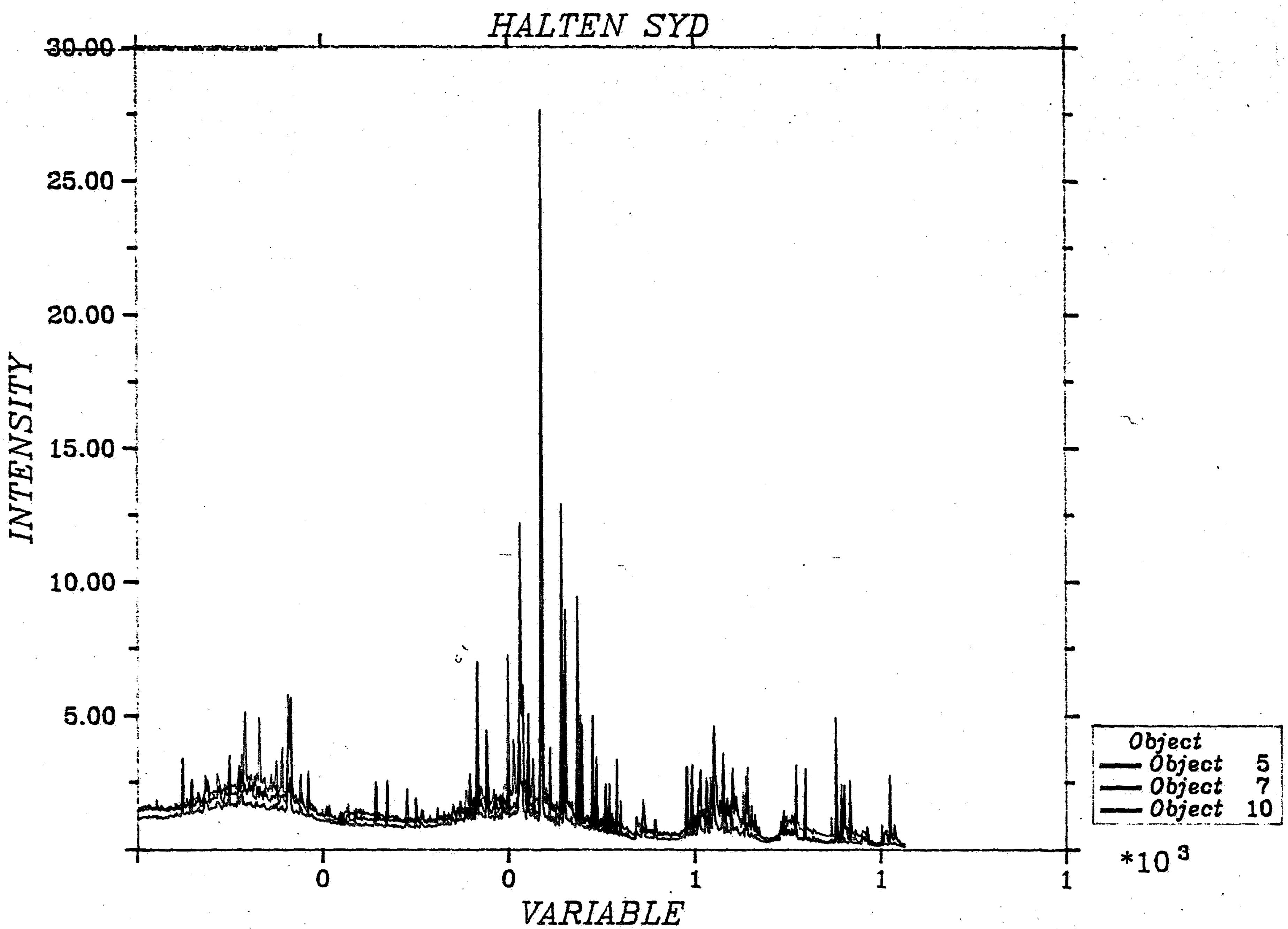

HALTEN SYD
30.00
25.00
20.00
15.00
10.00
5.00
INTENSITY
0
0
1
1
1
VARIABLE
*10 3
Object
Object 5
Object 7
Object 10

Figure I.3.4.: The score on principal component 1 versus the score on principal component 2.

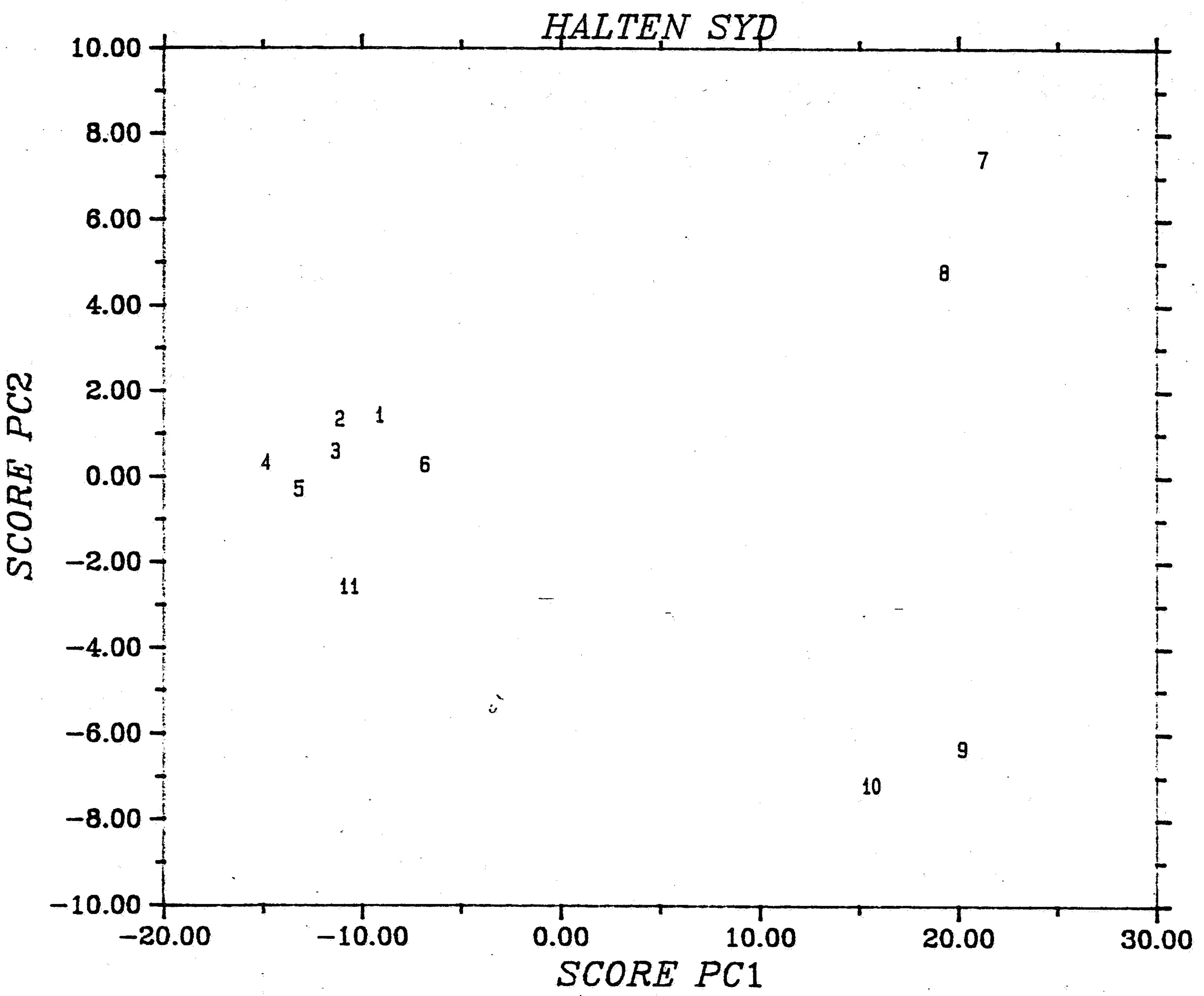

HALTEN SYD
SCORE PC2
10.00
8.00
6.00
4.00
2.00
0.00
−2.00
−4.00
−6.00
−8.00
−10.00
−20.00
−10.00
0.00
10.00
20.00
30.00
SCORE PC1
1
2
3
4
5
6
7
8
9
10
11

Figure I.3.5.: The loadings for principal components 1 and 2 versus variable number.

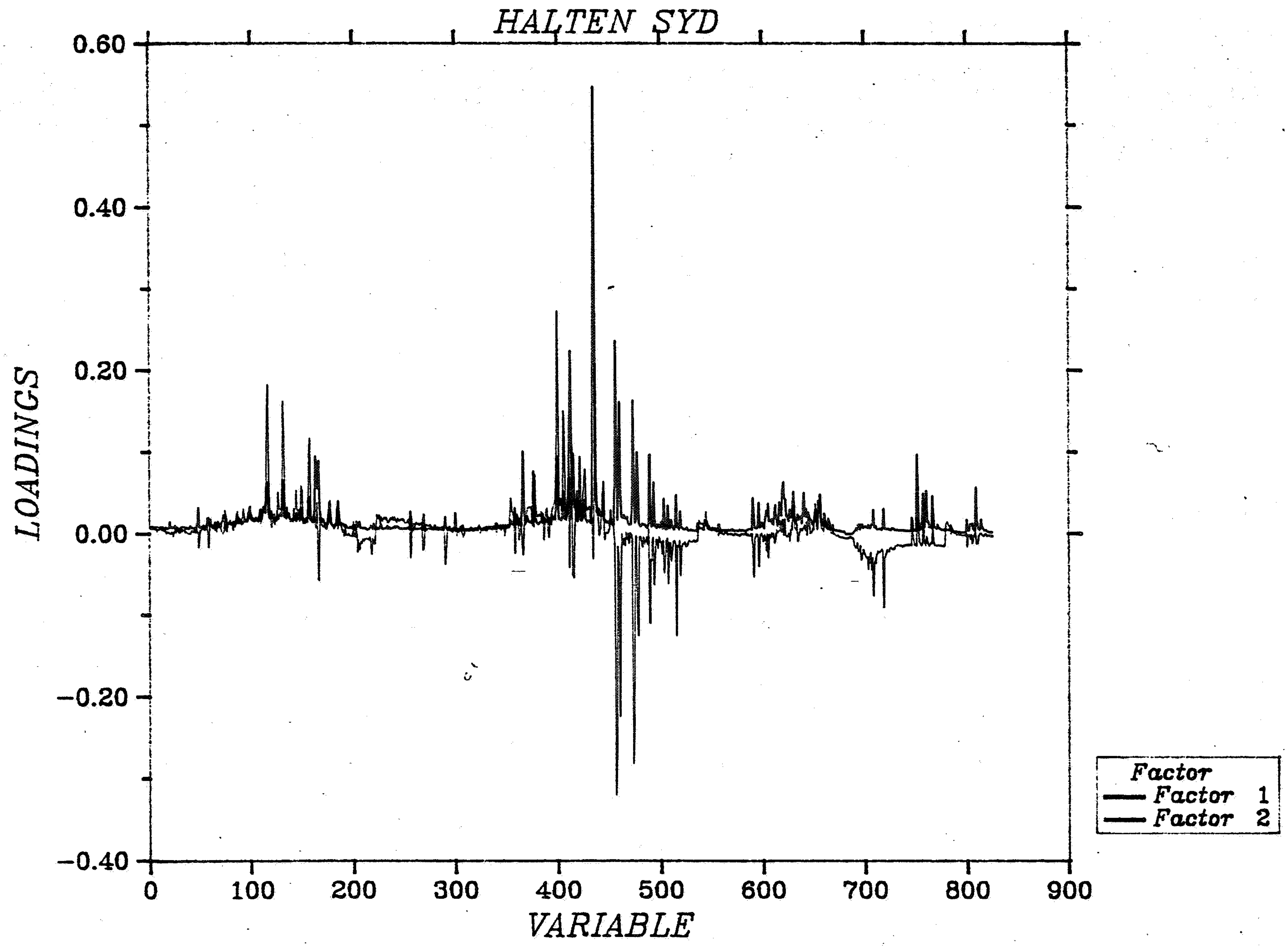
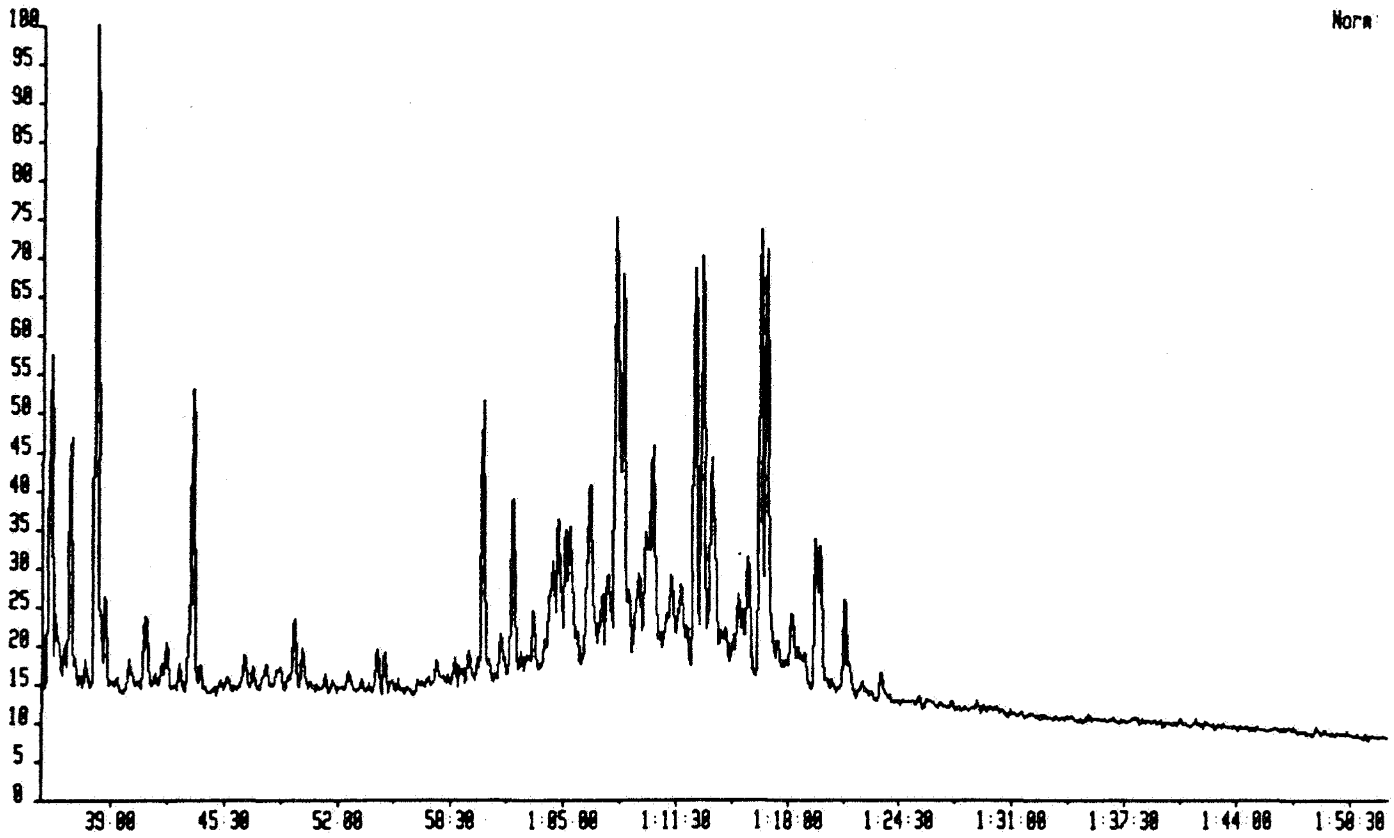

HALTEN SYD
0.60
0.40
0.20
0.00
-0.20
-0.40
LOADINGS
0
100
200
300
400
500
600
700
800
900
VARIABLE
Factor
Factor 1
Factor 2

Figure I.3.6.: M/z 218 fragmentograms from an oil from Njord compared with an oil from Draugen.

MB30037 30-MAR-87 Sir:Voltage 70E Acnt: System:GCMILS
Sample 1 Injection 1 Group 1 Mass 218.2035
Text:6407/7-1 DST2



MB30037 30-MAR-87 Sir:Voltage 70E Acnt: System:GCMILS
Sample 7 Injection 1 Group 1 Mass 218.2035
Text:6407/9-1

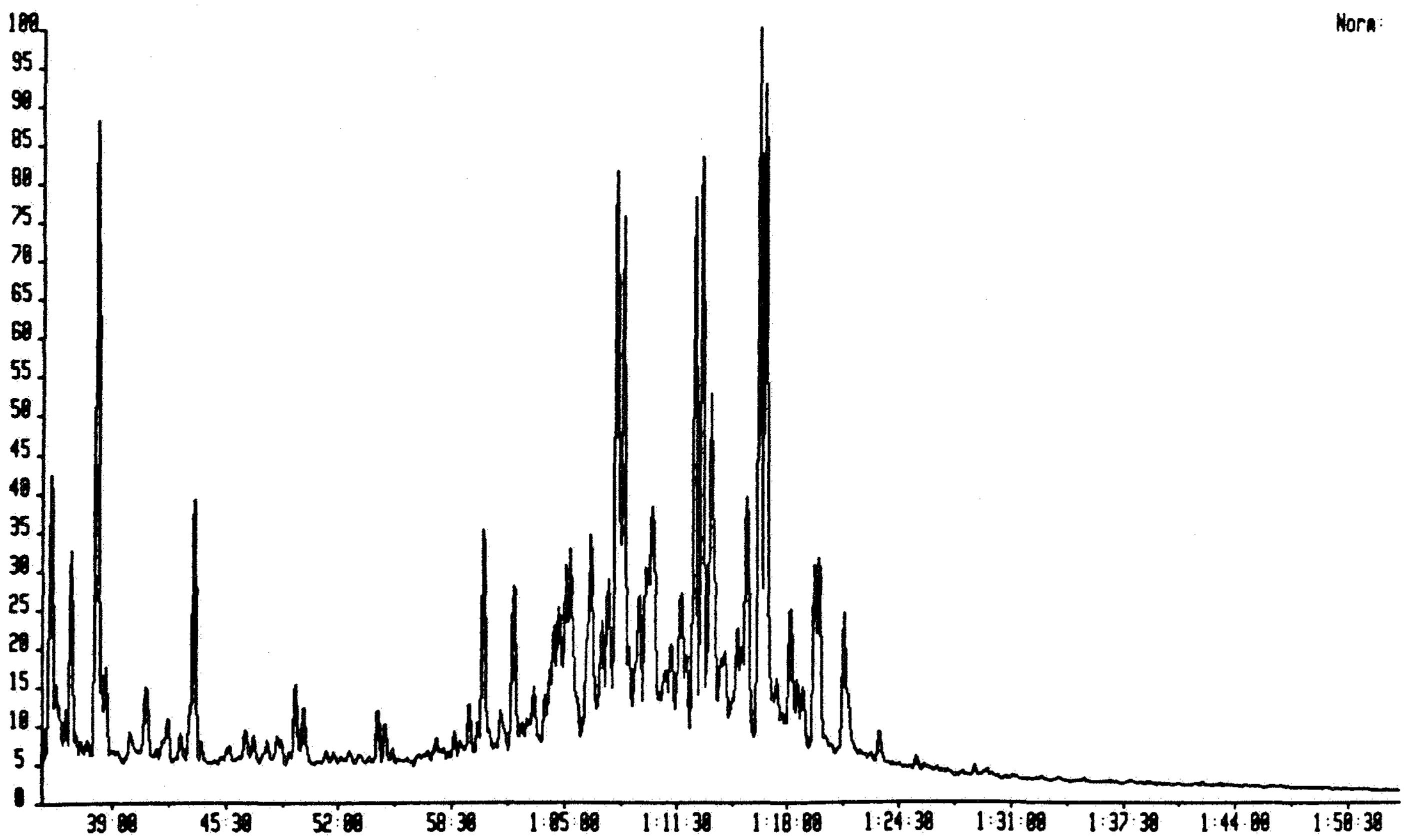


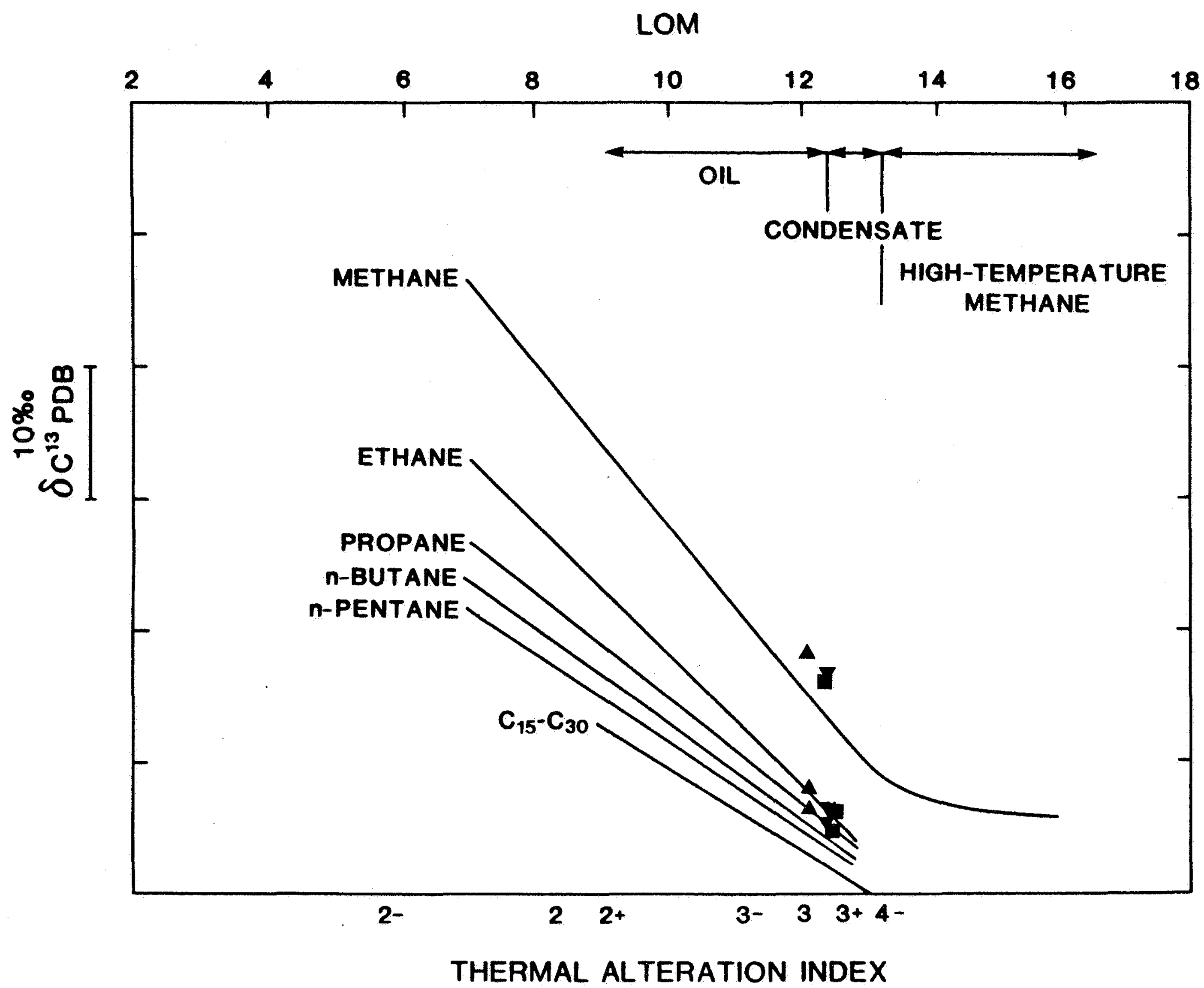
Figure I.3.7 .: Variations of molecular composition in natural gases from Njord related to the isotope variations of methane.
TT(m) and TT(h) are non-associated gases from marine and terrestrial sources. M are mixed primary gases.

● 6407/7-1 DST2

■ 6407/7-1 DST3

▲ 6407/7-2 DST1

▼ 6407/7-2 DST2



LOM
2
4
6
8
10
12
14
16
18
OIL
CONDENSATE
HIGH-TEMPERATURE METHANE
METHANE
ETHANE
PROPANE
n-BUTANE
n-PENTANE
C_{15}-C_{30}
10‰
δC^{13} PDB
2-
2
2+
3-
3
3+
4 -
THERMAL ALTERATION INDEX

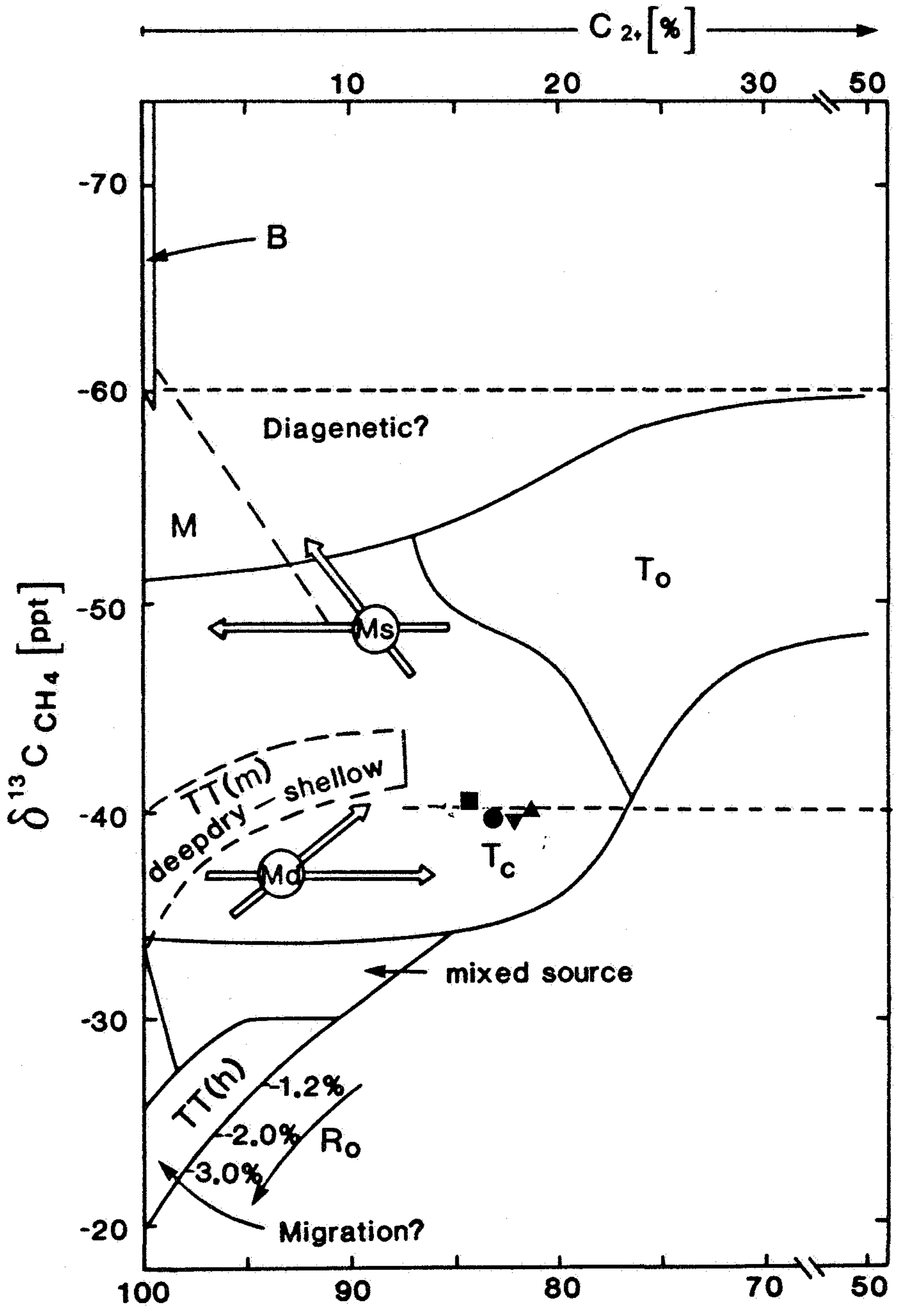
Figure I.3.8.: Carbon isotopic separation from Njord are plotted on a maturity diagram (James,1983)

● 6407/7-1 DST2

■ 6407/7-1 DST3

▲ 6407/7-2 DST1

▼ 6407/7-2 DST2



C 2+ [%]
10
20
30
50
-70
-60
-50
-40
-30
-20
B
Diagenetic?
M
Ms
T_o
$\delta^{13}C_{CH_4}$ [ppt]
TT(m)
deepdry
shellow
Md
T_c
mixed source
TT(h)
-1.2%
-2.0%
-3.0%
R_o
Migration?
100
90
80
70
50

Figure I.3.9.: Carbon and hydrogen isotope variations in methanes.

To-gases associated with petroleum in an initial stege of generation.

Tc-gases associated with condensates

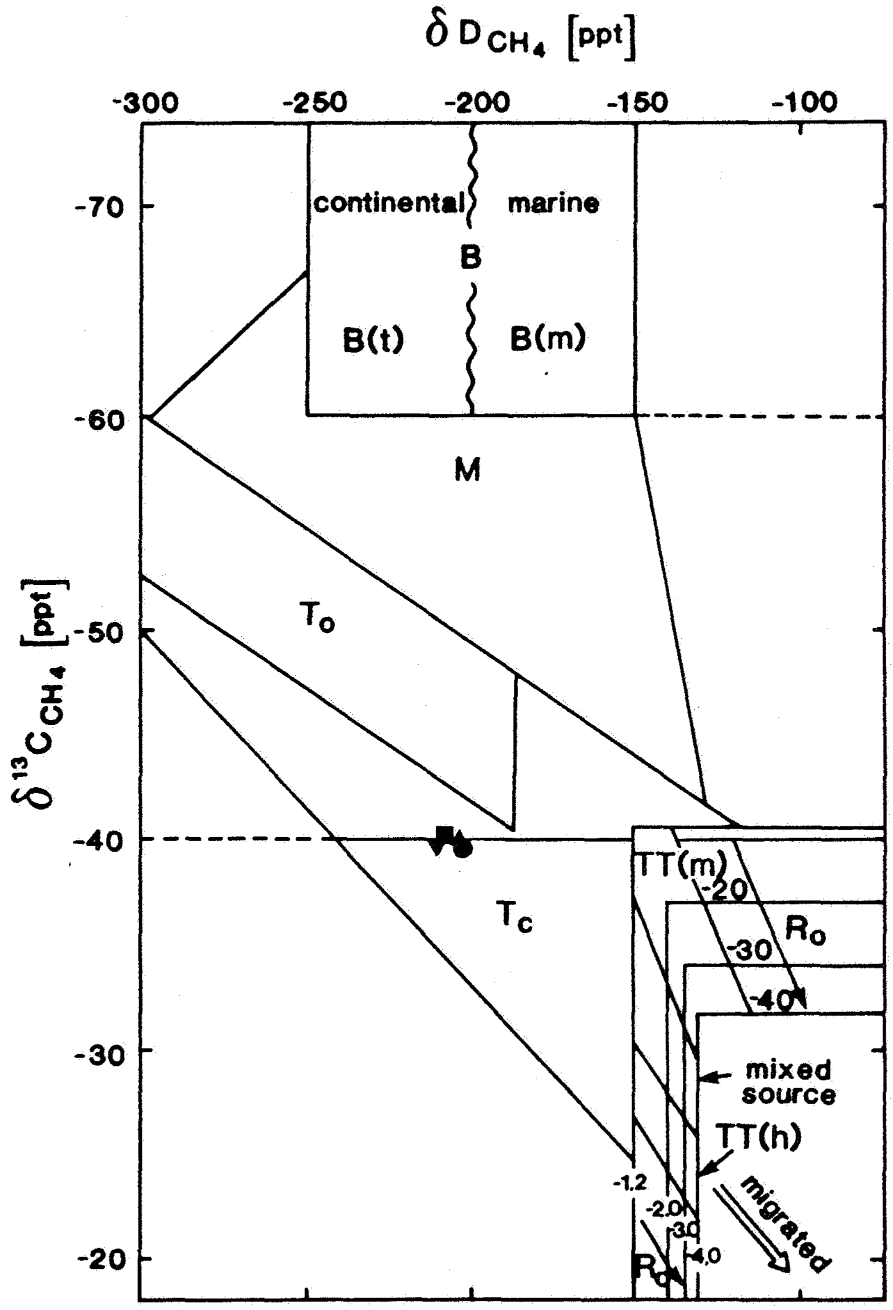
B -biogenic gas

● 6407/7-1 DST2

■ 6407/7-1 DST3

▲ 6407/7-2 DST1

▼ 6407/7-2 DST2



δD_{CH_4} [ppt]
-300
-250
-200
-150
-100
$\delta^{13}C_{CH_4}$ [ppt]
-70
-60
-50
-40
-30
-20
continental
marine
B
B(t)
B(m)
M
T_o
T_c
TT(m)
-20
-30
-40
R_o
mixed source
TT(h)
migrated
-1,2
-2,0
3,0
-4,0
R_o

Figure I.3.10.: Carbon isotope variations in ethane related to carbon isotope variations in methane.

I -associated gas

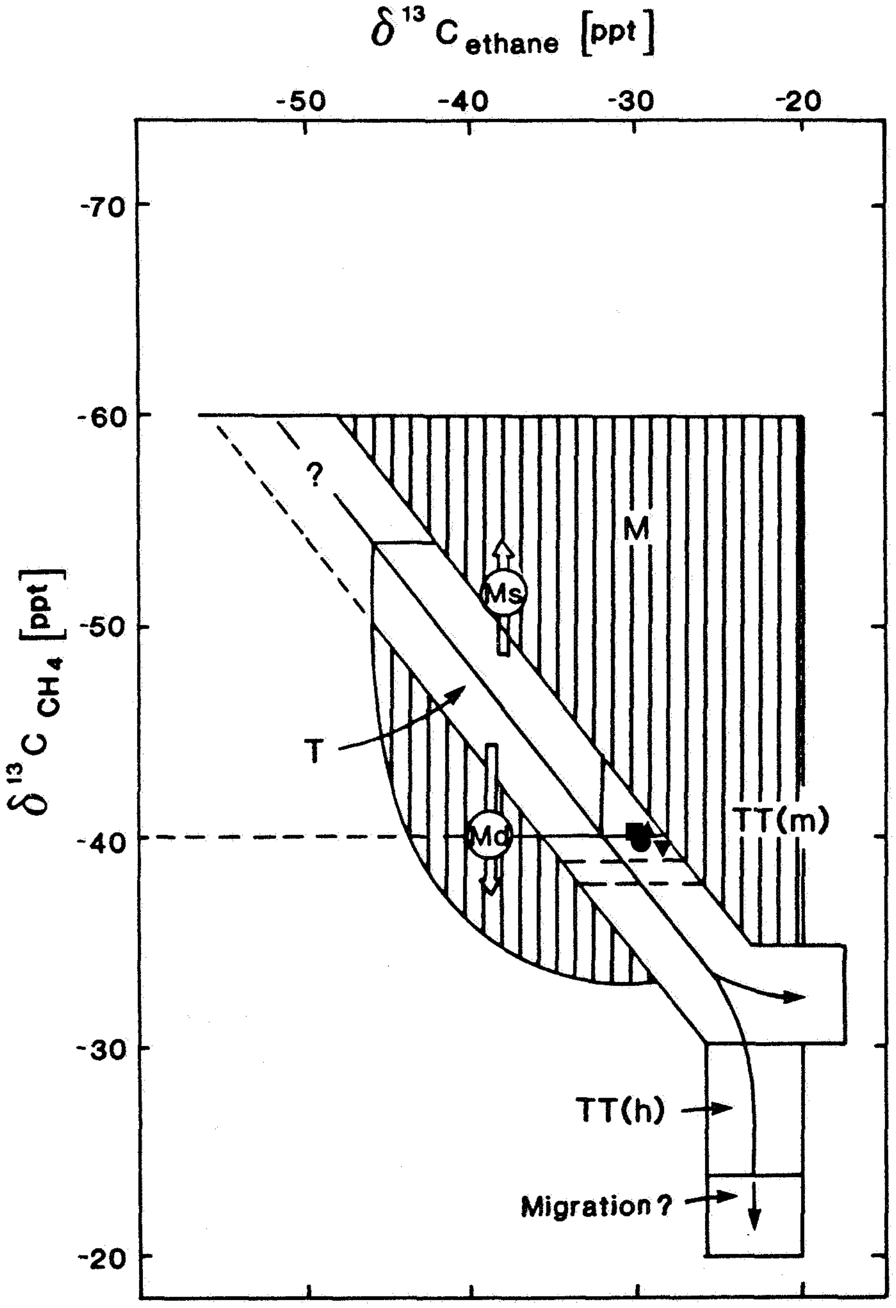
II -non-associated gas

● 6407/7-1 DST2

■ 6407/7-1 DST3

▲ 6407/7-2 DST1

▼ 6407/7-2 DST2



$\delta^{13}C_{ethane}$ [ppt]
-50
-40
-30
-20
-70
-60
-50
-40
-30
-20
$\delta^{13}C_{CH_4}$ [ppt]
?
M
Ms
T
Md
TT(m)
TT(h)
Migration ?

II. ISOTOPE PROFILING OF CRUDE OILS.

II.1. Introduction

The source of the oils in the Haltenbanken area is generally believed to be the Upper Jurassic Nesna Fm. with possible contributions from the coal bearing Hitra Fm.

The oils are reservoired at different levels and spread over a large geographical area. There is a possibility that depositional environment, organic facies and thermal maturity variations are present within the Upper Jurassic Nesna Fm., which is considered to be the main source rock. In addition there may be a varying contribution from other more terrestrially derived sources such as the Hitra Fm. and the Engelvær Fm. The detailed analysis of the crude oils in the southern part of the Haltenbanken area indeed reveals such variations.

Biomarker analysis, the determination of the distribution of chemical fossils present in oils , is generally considered to be a sensitive indicator of the type of organic material which was deposited and incorporated into the source rock kerogen. The families of compounds most frquently used for biomarker analysis are the steranes and the triterpanes, because of their resistance to degradation.

In an attempt to explain the differences in isotopic composition of the crude oils in the Haltenbanken South area a carbon isotope profile of some of the oils together with a standard Oseberg oil was constructed by measuring the carbon stable isotope ratio ($\delta\,^{13}C$) of distillation cuts and the residuum of the distillation. Distillation cuts representing the boiling points of n-alkanes from C_8 to C_{24} (pseudo components) were collected and the $\delta\,^{13}C$ values were plotted versus n-alkane carbon number. The shape of the profile and its relationship to the whole oil $\delta\ ^{13}C$ values are important for oil-oil correlation purposes. Deviations from the normal slope of these curves may be interpreted in terms of maturity and source differences.

II.2. Results and discussion.

Stable isotope values for the distillation cuts are given in Table II.1. All results are $\delta\ ^{13}C$ versus PDB.

The results are plotted versus carbon number in Fig. II.1.

The results from the standard Oseberg oil are very similar to the results from the oil from Draugen (6407/9-1). The results from the oil from Njord (6407/7-1 DST#2) show the same general shape, but is isotopically lighter.

The isotope ratio of the kerogen is changed little by converting some of it to oil, since there is minimal isotopic fractionation between kerogen and whole oil. Similarly, the isotope ratio of the oil generated remains relatively constant with increasing maturity. The shape of the isotopic profile changes during the process. The $\delta\ ^{13}C$ value of the residuum, which is very similar to the whole oil, changes very little. During early generation, the isotope ratio of distillation cuts can be quite different from that of the residuum, either isotopically heavier, isotopically lighter, or both, depending on the kerogen type. As maturity increases the isotope profile flattens out. Towards the end of the oil generation window, the volatile fractions are increasingly enriched in heavy carbon with each successive generation step. The volatile fractions become isotopically heavier than the residuum, creating a steep profile sloping downward. This is opposite to what is expected from thermal exposure after expulsion.

Fig. II.1. shows a steep downward profile suggesting that these oils are generated from source rocks in the end of the oil window at moderate to high maturities.

There is no apparent deviation from the smooth isotope profiles and this indicates that there is only one main source rock type for these oils.

The discrepancy between the isotope profiles from 6407/7-1 and 6407/9-1 suggests that these oils have been generated from different facies of the Nesna Fm. and that they do not share a common drainage area. These results are supported by the analysis of biological markers.

It is difficult based on these results to draw conclusions on the relative influence of terrestrially derived organic matter to the accumulated oils.

II. ISOTOP PROFILING OF CRUDE OIL

TABLES

Table II.1.: Stable isotope ratios for destillation cuts and residuum (C_{24+}) for three crude oils.

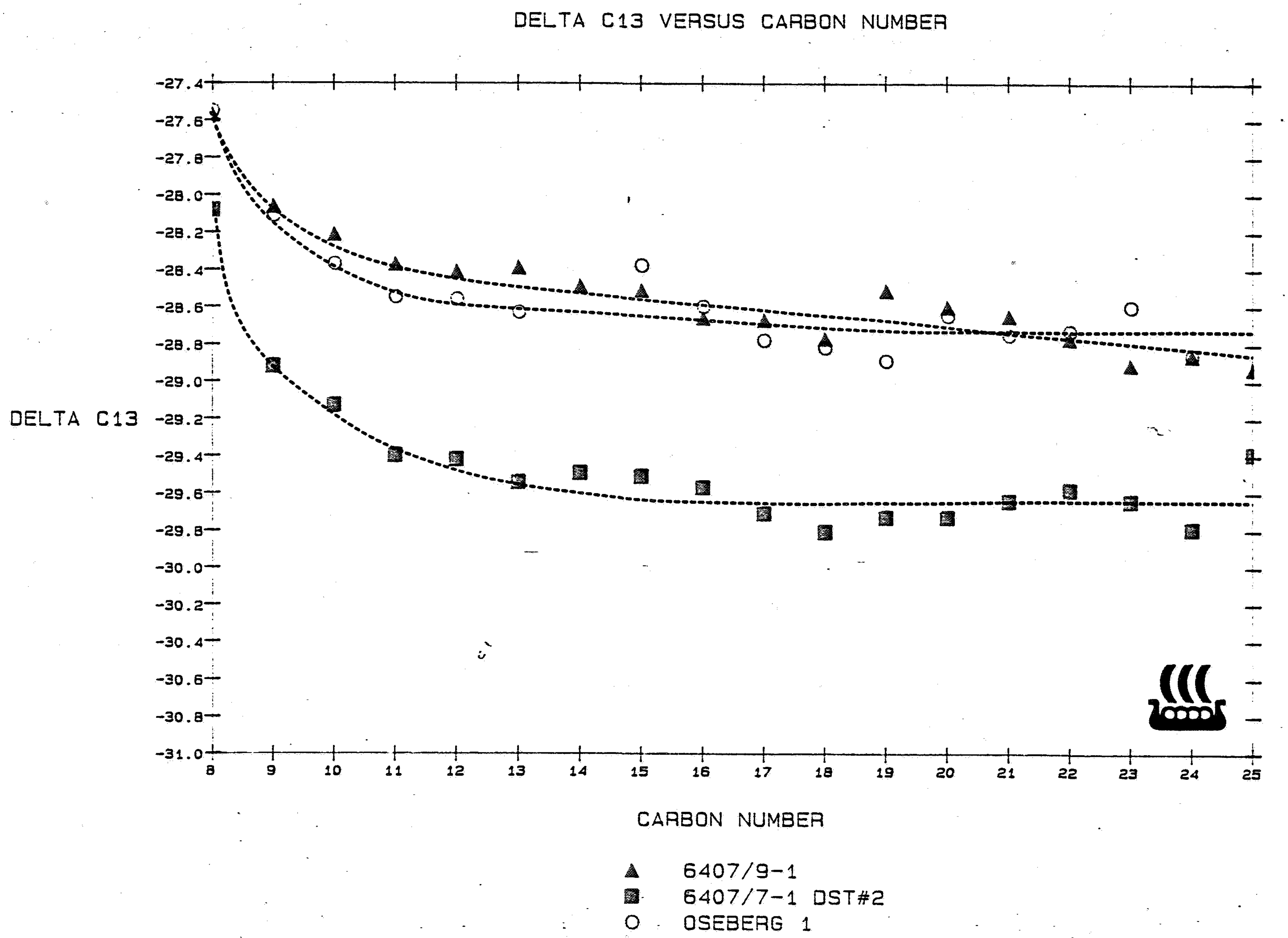
ISOTOPIC COMPOSITION OF
DESTILLATION CUTS

CARBON NUMBER	6407/9-1	6407/7-1	OSEBERG
8	-27.57	-28.08	-27.55
9	-28.06	-28.92	-28.11
10	-28.21	-29.13	-28.37
11	-28.37	-29.40	-28.55
12	-28.41	-29.42	-28.56
13	-28.39	-29.54	-28.63
14	-28.49	-29.49	
15	-28.51	-29.51	-28.38
16	-28.66	-29.57	-28.60
17	-28.67	-29.71	-28.78
18	-28.77	-29.81	-28.82
19	-28.51	-29.73	-28.89
20	-28.60	-29.73	-28.65
21	-28.65	-29.64	-28.75
22	-28.77	-29.58	-28.73
23	-28.91	-29.64	-28.60
24	-28.86	-29.79	-28.86
24+	-28.93	-29.39	

II. ISOTOP PROFILING OF CRUDE OIL

FIGURES

Figure II.1.: Isotope profiles for three crude oils.



DELTA C13 VERSUS CARBON NUMBER
DELTA C13
-27.4
-27.6
-27.8
-28.0
-28.2
-28.4
-28.6
-28.8
-29.0
-29.2
-29.4
-29.6
-29.8
-30.0
-30.2
-30.4
-30.6
-30.8
-31.0
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
CARBON NUMBER
6407/9-1
6407/7-1 DST#2
OSEBERG 1

III. KEROGEN DISTRIBUTION AND EVALUATION

III.1 Introduction

As an input to the basin model for estimating the amount of oil and gas generated, an assessment of the kerogen in several wells has been performed. The study is based on visual kerogen analysis and pyrolysis gas chromatography.

III.2 Kerogen analysis and classification

By visual analysis the kerogen is subdivided into different classes, and these classes have in the following been combined to give a classification according to kerogen types. This classification and corresponding kerogen types are shown in Table III.1.

Kerogen class	Kerogen type
Palynomorphs Algal material (also amorphous) Cuticula	II
Wood (also amorphous)	III
Opaque wood (Inertinite)	IV

Table III.1. Kerogen classes and types

The model assumes oil generation from a Type II kerogen and gas generation from a Type III kerogen (via liquid generation). The Type IV kerogen has no source potential for neither oil nor gas.

The pyrolysis gas chromatographic (PY-GC) analysis results in pyrograms containing various amounts of aromatic and aliphatic hydrocarbons with carbon atom numbers from C_1 to more than C_{25}, depending upon the source quality. Terrestrially derived organic matter of Type III tend to give more light weight and aromatic compounds which demonstrates the gas potential of this kerogen type. Kerogen of Type II, often of more marine origin, yield more high molecular weight compounds dominated by n-alkanes and alkenes, demonstrating the oil potential of this type.

According to this there should be a correspondance between the visual kerogen analysis and the results obtained by PY-GC. The kerogen analysis and PY-GC results have therefore been compared in four wells with available data and the results will be discussed below.

Of the different potential source rock formations in the Haltenbanken area, two formations have been looked at in further detail: The Nesna Fm. and the Hitra Fm. The wells investigated and the depth to the different formations are given in Table III.2.

Well	Nesna Fm.		Hitra Fm.	
	Top	Bottom	Top	Bottom
6407/4-1	Not evaluated		4500 m	4801 m
6407/7-1	2698 m	2706 m	3017 m	3177 m
6407/7-2	2637 m	2651 m	2877 m	2934 m
6407/9-1	1591 m	1621 m	2134 m	2253 m

Table III.2. Wells and formations investigated.

The results of the visual kerogen analysis are given in Tables III.3 to III.6, where the different kerogen classes have been combined to the three kerogen types according to Table III.1.

The peaks in the pyrograms have been quantified and are normally combined to three fractions: C_1-C_5, C_6-C_{14} and C_{15+} which represents gas, condensate and oil, respectively. One problem with this classification is that the kerogen analysis gives two types sourcing gas or oil;, there is no allowance for the condensate fraction. In this study the apparantly best correspondance between the visual kerogen data and the pyrograms is obtained by combining the gas and condensate fractions to gas obtained from a Type III kerogen.

The gas and oil potentials, combining the gas and condensate fractions from the PY-GC analyses to "gas", are also given in Tables III.3 to III.6.

In well 6407/4-1 only the Hitra Fm. was analysed for kerogen by visual analysis. The Hitra Fm. is deeply buried at this location and the kerogen is totally dominated by a Type III kerogen, and the kerogen type are uniformally distributed ranging from 60 to 90 % Type III kerogen. The Type II kerogen consitutes only a minor part. This could be due to the break-down and oil generation from this organic matter at an earlier point and only the more gas prone Type III kerogen is left. However, the difficulty in comparing visual data with PY-GC is here demonstrated by the two samples at 4651 m and 4657 m which indicate ca. 30 % oil potential although the samples was found to contain no Type II kerogen. Studying the pyrograms of these samples no regular distribution of n-alkanes/-alkenes can be observed. The high molecular weight compounds computed to be oil potential seem to be more naphthenic and aromatic in nature and hence a rather poor oil yield may be expected from these coals.

Well 6407/7-1 contains a larger fraction of Type II kerogen, on average 62 % in the Nesna Fm. and 25 % in the Hitra Fm. The oil potential of the two formations is apparently about the same judging from the PY-GC results. Again the pyrograms show distinct differences with a much smoother distribution of n-alkanes/-alkenes in the samples from the Nesna Fm. As discussed above the apparant high oil yield from the coals are due mostly to aromatic and more polar compounds.

In well 6407/7-2 the Nesna and Hitra Fm. are located at approximately the same depth as in well 6407/7-1. The content of Type II kerogen is lower in 6407/7-2 averaging 13 % and 20 % in the Nesna and Hitra Fms., respectively. This is also reflected in the PY-GC results which show a lower oil potential for the Nesna Fm. and a much lower oil potential for the Hitra Fm. There is a discrepancy of the Type IV kerogen in these two wells. For example, the Hitra Fm. of 6407/7-1 contains 53 % Type IV kerogen versus 8 % Type IV (few samples) of well 6407/7-2.

The Nesna Fm. of well 6407/9-1 contains about 24 % Type II. Still the oil potential is only 42 %. The pyrograms shows that this is a result of abundant aromatic compounds of low molecular weight which outweights the otherwise smooth distribution of n-alkanes extending up to at least C_{27}. This is a result of the low maturity of the Nesna Fm. at only 1600 m depth in this well. Although containing less Type II kerogen the Hitra Fm. has a higher oil potential in this well at the present time. The pyrograms show distributions of regular alkanes up to C_{26+} with less amounts of aromatic and naphthenenic compounds produced from the Hitra Fm. in the other wells investigated.

III.3 Conclusion

The combination of different kerogen classes to three broad types of kerogen (II,III and IV) has been performed. Due to differences in the visual kerogen analysis the dominating kerogen type in the area change between Type II and III for the Nesna Fm., whereas the Hitra Fm. contains mostly Type III. The comparison with PY-GC results has been shown to be very important. PY-GC results, specially from coals, must be carefully checked in order not to overestimate the oil potential by considering high molecular weight aromatic and more polar compounds in the chromatograms. These compounds may easily be adsorbed during migration and do possibly not contribute to oil accumulation in the same manner as nonpolar alkanes.

III. KEROGEN DISTRIBUTION AND EVALUATION

TABLES

KEROGEN DISTRIBUTION AND OIL/GAS POTENTIAL OF WELL 6407/4-1

FORMATION	DEPTH (m)	TYPE II %	TYPE III %	TYPE IV %	OIL %	GAS %
1 HITRA	4579	10	80	10		
2	4582	20	75	5		
3	4606				3.6	96.4
4	4609	0	95	5		
5	4621	0	90	10		
6	4624	0	90	10		
7	4645	5	90	5		
8	4651	0	60	40	34.8	65.2
9	4657	0	70	30	36.6	63.4
10	4695	5	80	15		
11	4708	0	90	10		
12	4711	0	90	10		
13	4714	0	90	10		
14	4717	5	85	10		
15	4720	0	90	10		
16	4750	0	80	20		
17	4753	0	90	10		
18	4756	0	95	5		
19	4759	0	95	5		
20	4762	0	90	10		
21	4765	0	80	20		
22	4801	0	80	20		
23	MEAN	2	85	13	25.0	75.0

Table III.3. Data for well 6407/4-1

KEROGEN DISTRIBUTION AND OIL/GAS POTENTIAL OF WELL 6407/7-1

FORMATION	DEPTH (m)	TYPE IV %	TYPE III %	TYPE II %	OIL %	GAS %
NESNA	2699.00	17.2	34.5	48.3		
	2700.00				59.2	40.8
	2702.00	13.3	6.7	80.0		
	2703.00				52.3	47.7
	2704.00	21.0	21.0	58.0		
	MEAN	17.0	21.0	62.0	56.0	44.0
HITRA	3027.00				65.6	34.4
	3037.00	75.0	25.0	0.0		
	3039.00				41.3	58.7
	3040.85	10.0	20.0	70.0		
	3064.00				56.7	43.3
	3075.00				57.0	43.0
	3092.00	73.3	22.2	4.5		
	MEAN	53.0	22.0	25.0	55.0	45.0

Table III.4. Data for well 6407/7-1

KEROGEN DISTRIBUTION AND OIL/GAS POTENTIAL OF WELL 6407/7-2

	FORMATION	DEPTH (m)	TYPE II %	TYPE III %	TYPE IV %	OIL %	GAS %
1	NESNA	2638	14	78	8	33.3	66.4
2		2640				47.8	52.2
3		2647				57.4	43.6
4		2650	12	88	0	41.0	59.0
5		2884				32.7	67.3
6		MEAN	13	83	4	42.0	58.0
7							
8	HITRA	2888	21	69	10	44.2	55.8
9		2905	12	74	14	27.2	72.8
10		2913	26	70	4	32.4	67.6
11		2923	20	76	4	38.2	61.8
12		MEAN	20	72	8	36.0	64.0

Table III.5. Data for well 6407/7-2

KEROGEN DISTRIBUTION AND OIL/GAS POTENTIAL WELL 6407/9-1

	FORMATION	DEPTH (m)	TYPE II %	TYPE III %	TYPE IV %	OIL %	GAS %
1	NESNA	1591	20	70	10	48.8	51.2
2		1594	25	70	5	47.8	52.2
3		1600	20	75	5	49.9	50.1
4		1606	20	75	5	50.2	49.8
5		1609	20	75	5	47.5	52.5
6		1612	30	60	10	48.7	51.3
7		1615	20	70	10	46.0	54.0
8		1618	20	70	10	46.5	53.5
9		1621				42.0	58.0
10		MEAN	24	71	7	45.0	55.0
11	HITRA	2134				37.9	62.1
12		2137				43.4	56.6
13		2140				35.0	65.0
14		2146	5	90	5		
15		2149	5	90	5		
16		2155	10	80	10		
17		2158	5	90	5		
18		2191	0	100	0		
19		2197				59.4	40.6
20		2212				49.3	50.7
21		2215	30	50	20	56.2	43.8
22		2224	20	70	10	50.0	50.0
23		2227				47.5	52.5
24		2230	25	55	20		
25		2233	15	70	15	53.8	46.2
26		2236				47.5	52.5
27		2251				49.3	50.7
28		MEAN	13	77	10	56.0	44.0

Table III.6. Data for well 6407/9-1

IV. SUBREGIONAL SYNTHESIS

IV.1 Introduction

This discussion is based on data from four wells; 6407/7-1, 6407/7-2, 6407/4-1 and 6407/9-1 located in the southern part of Halten area.

IV.2 Nesna Fm., source rock properties

Nesna Fm. has been encountered in all four wells. The encountered sequences vary in thickness and depth of burial/state of maturity.

Some average data of important source rock parameters are compiled in Table IV.2.1. The similarities in the data from one well to the other are great. However, certain discrepancies exist:

- The dominating kerogen varies a lot. Particular 6407/7-2 with dominantly woody material is in disagreement with the regional trend seen by the other wells which contain dominantly algal and amorphous material. A reason for this large descripancy is, as discussed in Appendix IV, probably a result of different interpretation at the various institutions which have carried out the kerogen work. It is reasonable to suggest that the real difference is less, which is supported by the chemical data.

- The variations in hydrogen index is likely due to different state of maturity and a slight regional quality change. In well 6407/4-1, top Nesna Fm. is buried to 3710 m, and is as suggested previously (Appendix III) located in the oil window. The Nesna Fm. has obviously lost some of its hydrocarbon potential which will influence on and lower the HI.

The average TOC values are remarkable constant over the Nesna Fm. in the four wells. As in 6407/9-1 and to some extent 6407/4-1 TOC, S_2 and HI show only small vertical variations in 6407/7-1 and -2 , Figs. IV.2.1 and IV.2.2.

The hydrocarbon potentials in 6407/7-1 and -2 are about equal; approximately 20 kg/t. Over in well 6407/9-1, although the visual kerogen content is promising the HC potential has dropped to approx. 15 kg/t which indicates a slight lateral decrease in source quality. Despite this the pyrolysis GC data suggest a gas-oil ratio (GORP) of 0.17, which is the best average value of all four horizons in terms of liquid potential. The only comparable sequence is in 6407/7-1. The reason for the apparent quality drop can be due to higher input of inertinitic material to this sequence.

In terms of both total potential and liquid potential well 6407/4-1 is the poorest sequence. However, due to its likely loss of hydrocarbon potential (discussed in Appendix III) a calculation based on production index (S_1 and S_2) suggested its original quality to be HI ~ 400. This will bring its starting S_2 up to over 20 kg/t and its liquid potential to over 16 kg/t, which is similar to 6407/7-1. (In this calculation TOC has assumed to be constant. TOC is decreasing with HC production and should consequently lower the HI in the mentioned calculation.)

Conclusively, the Nesna Fm. in the southern Halten region has a considerable potential for liquid HC. Suggested average values are 15 kg/t for oil and condensate and 3.5 kg/t for gas.

IV.3 Hitra Fm., source rock properties

Hitra Fm. is very poorly developed in wells 6407/7-1 and -2 and coals are hardly encountered. Source rock data for these two wells are shown in Figs. IV.3.1 and IV.3.2. The discussion will consequently concentrate on wells 6407/4-1 and 6407/9-1. Average source properties for the Hitra Fm. coals are listed in Table IV.3.1.

Table IV.3.1 suggests that the volume of coals are considerable larger in well 6407/4-1 and are measured to be exactly twice to that of 6407/9-1.

The other data show that the average quality of coals in these two wells is similar. However, the present day depth of burial and consequently the thermal maturity is much larger for coals in well 6407/4-1. It is therefore reasonable to believe, if the average values in Table IV.3.1 are representative, that the quality of the coals in terms of liquid potentials is increasing on approaching the area around 6407/4-1.

The liquid potential in well 6407/9-1 is quite high and the gas-oil ratio is 0.26. The few values from 6407/4-1 vaguely indicate, taking the thermal maturity into account, that the original liquid potential may have been very high.

The shale/silty horizons interbedding the coals and sandstones in Hitra Fm. have also been analysed thoroughly in these wells. However, their source rock properties are poor with average TOC values less than 2.65 % and S_2 less than 3 kg/t. These units are less likely to produce anything but gas. On the other hand because the rocks are fairly silty they represent porous intervals and active surfaces which can mop up and retain liquid hydrocarbons produced from neighbouring coals or carbargillites.

Generation potential:

In terms of HC generation from the two source units in the Halten area a quick calculation can illustrate the total possible production of HC per m^2 in Hitra (6407/9-1) and Nesna (6407/7-1) by using the following equation:

$$HC = S_2 \times h \times sp.W. \times 10^{-3} \ (t/m^2)$$

where h is thickness of the source bed and Sp.W. is spesific weight of rock.

Sp.W. for coals is set to 1.8 t/m^3 and for shales 2.3 t/m^3.

$$HC_{Nesna} = 22.17 \times 15 \times 2.3 \times 10^{-3} = 0.76 \ t \ HC/m^2$$

By use of gas-oil ratio potential (GORP), it gives <u>0.59 t liquid/m^2</u>, or per volume unit 0.04 t liquid/m^3.

$$HC_{Hitra\ coal} = 69.3 \times 26 \times 1.8 \times 10^{-3} = 3.24 \ t \ HC/m^2$$

A

By use of gas-oil ratio potential 14.4/55.4 it gives <u>2.40 t liquid/m^2</u> or per volume unit 0.09 t liquid/m^3.

This demonstrates that the Hitra coals theoretically can generate more than twice as much liquid hydrocarbons as the Nesna Fm. per volume unit. However, there may be several reasons that can reduce this relationship when it comes to expulsion, migration and accumulation of these liquid hydrocarbons:

a) The liquid produced from coals and carbargillites may contain a large proportion of heavy aromatics and polar compounds which are less prone to primary migration. Pyrograms, particular of mature coals indicate this.

b) Coals may be less expulsion prone than shales because of its absorbing capability, so that the likely expulsion products are cracked giving condensate and gas.

c) Although coals are concentrates of organic carbon with high suceptibility to produce large amounts of hydrocarbons per unit volume a certain concentration of coal beds with beneficial location to migration routes and traps is needed. If the density of coal beds is not high enough, the expulsion products will easily be dispersed and retained by the surrounding mineral matrix.

IV.4 Source rock - crude oil correlations

This part of the study is base on biological marker and stable carbon isotope analysis. Biomarker ratios for the oils and sediments are given in Table IV.4.1 and IV.4.2, and plotted versus depth in Figures IV.4.1-4. Stable isotope data are listed in Table I.3.5. and plotted in Galimov plots, Fig. IV.4.5.

Nesna Fm. extracts in 6407/7-1 indicate a fairly homogeneous vertical composition. The maturity suggested by 20R-20S epimerisation indicates a sequence at HC generation threshold.

The source parameter C_{27}:C_{28}:C_{29} indicates a sediment deposited in marine environment (C_{27} sterane dominates in marine environment and C_{29} dominates in humic type material). The relative concentration of steranes and triterpanes (St/Tr) and sterane/n-alkanes (St/n-alk) (~0.38 and 3.0 respectively) suggests also a marine environment of deposition. (Sterane concentration is high in marine organic matter and is low in terrestrial organic matter). The hopane type triterpanes is abundant in terrestrially material and bacterially reworked marine sediments.

6407/9-1, Nesna Fm. indicates also a homogeneous vertical quality by the $C_{27}:C_{28}:C_{29}$ parameter. However, these samples contain less C_{27} than the 6407/7-1 samples. This shift in the C_{27} versus C_{29} content may be due to a slight shift in environment of deposition from marine in 6407/7-1 to more nearshore or lagoonal type environment in 6407/9-1.

The St/Tr is of the same order of magnitude in the two wells. The St/n-alk ratios are slightly larger in the 6407/9-1 samples which can be an effect of a maturity difference.

In Hitra Fm., well 6407/7-1, some of the coal samples are showing as expected very high C_{29} sterane content (e.g. 15:14:71). In these samples the sterane/triterpane ratios are very low (< 0.1). The St/n-alk and Tr/n-alk do not have the same systematic variation as St/Tr, but the Tr/n-alk appears to be large (> 2.0) and St/n-alk is low (< 1.0).

In Hitra extracts, well 6407/9-1 the $C_{27}:C_{28}:C_{29}$ have not been measured. However,the St/Tr is generally low, particular in the deepest 100 m of the formation.

Only 4 samples have been analysed in 6407/4-1 and are showing similar features as the Hitra samples in 6407/7-1 and 6407/9-1.

Oils from 6407/7-1 and 6407/9-1 have been analysed for stable carbon isotope composition. Of the four DST's of 6407/7-1 DST 2, 3 and 4 are isotopically lighter than DST 5. They also tend to correlate well with each other. DST 5 is isotopically heavier and may have gained organic material from a different part of the source.

The 6407/9-1 oil is slightly heavier than DST 2 - 4 of 6407/7-1, but matches better with the DST 5 oil.

It is not unlikely that oils from DST 5 from 6407/7-1 and the 6407/9-1 oil have a similar origin.

The biomarker content of these oils supports the conclusion based on isotopes that DST 2, 3 and 4 are similar oils whilst DST 5 has a slightly more terrestrial signature. This signature is less pronounced for the 6407/9-1 oil which is an intermediate between e.g. 6407/7-1, DST 2 and 6407/7-1, DST 5.

Conclusively 2 types of oils exist in 6407/7-1, one with dominantly marine material and the other with some terrestrial contribution. The 6407/9-1 oil may have had less terrestrial contribution in comparison to 6407/7-1, DST 5.

IV. SUBREGIONAL SYNTHESIS

TABLES

Table IV.2.1: Comparison of average source rock properties of the Nesna Fm. from 4 Haltenbanken Wells

	Thickness	Top Fm.	TOC	S_2	HI	Dominating Kerogen	Gas Potential	Liquid Potential	GORP
6407/7-1*	15	2698	5.10	22.17	422	Amorphous	3.9	16.6	0.23
6407/7-2	14	2638	5.12	19.1	373	Woody	4.6 kg/t	14.5 kg/t	0.32
6407/4-1	60.5	3710.5	5.42	8.8	152	Am-Al	3.3	6.1	0.54
6407/9-1	33	1591	5.29	14.9	282	Al	2.2 kg/t	12.7	0.17

* Combined Nesna (2698 - 2706 m) and Frøya (2706 - 2713 m) Fm.'s based on 9 samples

Table IV.3.1: Comparison of Source Properties of Coals, Hitra Fm. in 4 Haltenbanken Wells

	Accumulative Thickness	Top Fm.	TOC	S_2	HI	Dominating Kerogen	Gas Potential	Liquid Potential
6407/7-1	Neglectable amounts	3017						
6407/7-2	Neglectable amounts							
6407/4-1	52 m	4500	41.30	60.5	151	woody	32*	44*
6407/9-1	26 m	2073	43.0	69.3	161	woody	14.4	55.4

* Based on only 3 samples

Table IY.4.1 Biomarker ratios for oils, Halten area.

Oljer/ Kondensater	Triterpaner						Steraner									
	22S %	TS %	$\frac{C_{28}}{C_{29}}$	$\frac{C_{27}}{C_{28}}$	$\frac{C_{30}?}{C_{30}}$	$\frac{C_{27}}{-Me}$	20S %	αββ %	$C_{27}:C_{28}:C_{29}$	$\frac{C_{30}}{C_{29}}$	$\frac{C_{20}}{C_{27}}$	$\frac{St}{tr}$	$\frac{St}{n\text{-}alk}$	$\frac{tr}{n\text{-}alk}$	Pr/Ph	CPI
6407/7-1,# 2	61	84	0.47	3.2	0.18		50	70	45:23:32			0.46	0.42	0.91	1.85	
6407/7-1,# 3	65	82	0.42	3.7	0.20		53	72	46:23:31			0.45	0.40	0.87	1.57	
6407/7-1,# 4	60	81	0.50	2.9	0.17		54	70	47:20:33	0.57		0.49	0.41	0.82	1.77	
6407/7-1,# 5	64	79	0.27	2.8	0.29		47		31:26:43			0.54	0.35	0.64	1.94	
6407/9-1	62	68	0.50	1.9	0.09	+	56	60	42:19:39			0.26	0.71	2.68	1.70	

Table IV.4.2 Biomarker ratios for sediments, 6407/7-1

6407/7-1

Sedimenter	Triterpaner						Steraner									
Nesna Fm.	22S %	TS %	$\frac{C_{28}}{C_{29}}$	$\frac{C_{27}}{C_{28}}$	$\frac{C_{30}?}{C_{30}}$	$\frac{C_{27}}{-Me}$	20S %	αββ %	$C_{27}:C_{28}:C_{29}$	$\frac{C_{30}}{C_{29}}$	$\frac{C_{20}}{C_{27}}$	$\frac{St}{tr}$	$\frac{St}{n\text{-}alk}$	$\frac{tr}{n\text{-}alk}$	Pr/Ph	CPI
2699.00		27	0.01		0.03		27	12	48:23:29	0.32	0.2	0.39	2.92	7.56	3.20	1.042
2700.00	59	33	0.10		0.04		26	13	52:21:27	0.45	0.14	0.43	2.78	6.46	2.40	1.24
2702.00		33	0.12				27	21	45:26:29	n.d.	0.14	0.37	3.39	9.13	2.90	0.952
2703.00		33	0.15				31	21	48:25:27	n.d.	0.14	0.32	3.52	10.99	2.60	1.0211
2704.00		35	0.01		0.03		28		49:24:27	0.56	0.14	0.38	2.72	7.21	2.60	1.001
2704.50		38	0.01		0.02		25	12	52:26:22	0.68	0.15	0.37	3.98	10.75	2.70	0.896
2705.50												0	0	0.13	2.40	1.102
2706.00		25	0.01		0.03		35	19	45:20:35	0.13		0.33	0.41	1.25	2.70	1.001
<u>Hitra Fm.</u>																
3017.20	62	10	0.03		0.07		48	44	15:14:71			0.08	0.44	5.34	5.40	1.429
3240.00		83	0.48	4.17	0.22		46	73	45:23:32	0.21	0.44	0.41	0.21	0.52	1.80	0.964
3027.83		82	0.58	3.46	0.20		52	74	46:24:30	0.22	0.57	0.34	0.14	0.40	1.70	1.036
3032.30	61	13	0.03		0.05		48	50	21:25:54		0.55	0.06	0.14	2.09	2.10	0.997
3034.20								0				0.05	0.44	8.7	8.10	1.161
3039.40												0	0	9.14	4.70	1.365
3064.37		69	0.32	4.46	0.18		51	77	40:22:38	0.19	0.79	0.27	0.17	0.63	1.80	0.950
3071.57		2	0.01		0.05		47	27	5:17:78	0.19	0	0.05	0.50	9.77	9.10	1.289
3075.45		2	0.01		0.04		49	38				0.04	0.17	4.68	10.50	1.221
3081.50		75	0.24		0.22				43:26:31		0.40	0.37	0.24	0.65	1.80	1.001

IV. SUBREGIONAL SYNTHESIS

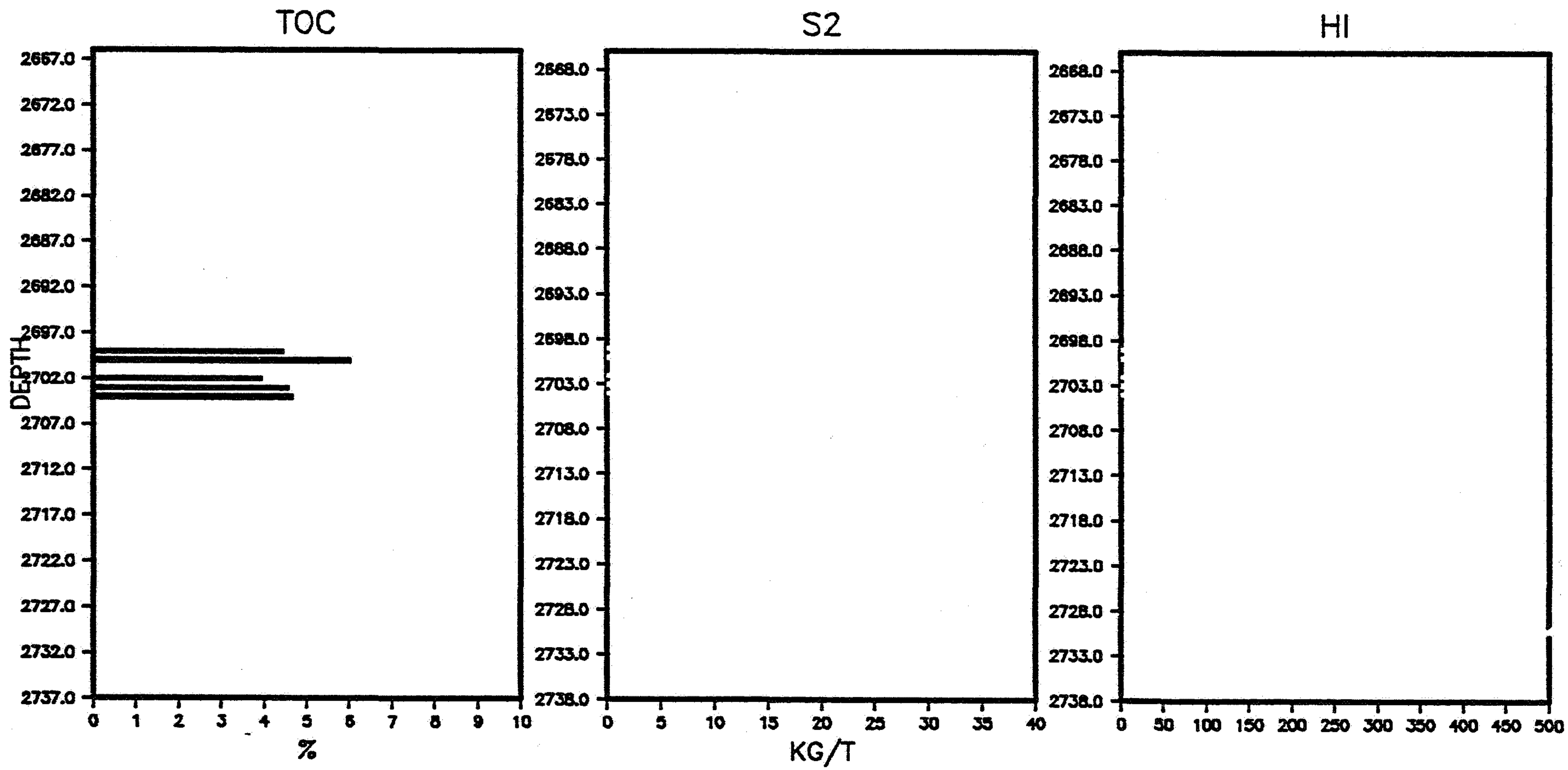
FIGURES

FIG. VI.2.1 A AND B

PLOTS OF TOC,S2 AND HI VERSUS DEPTH,

NESNA FM. 6407/7-1

NESNA FM. WELL 6407/7-1



NESNA FM. WELL 6407/7-1

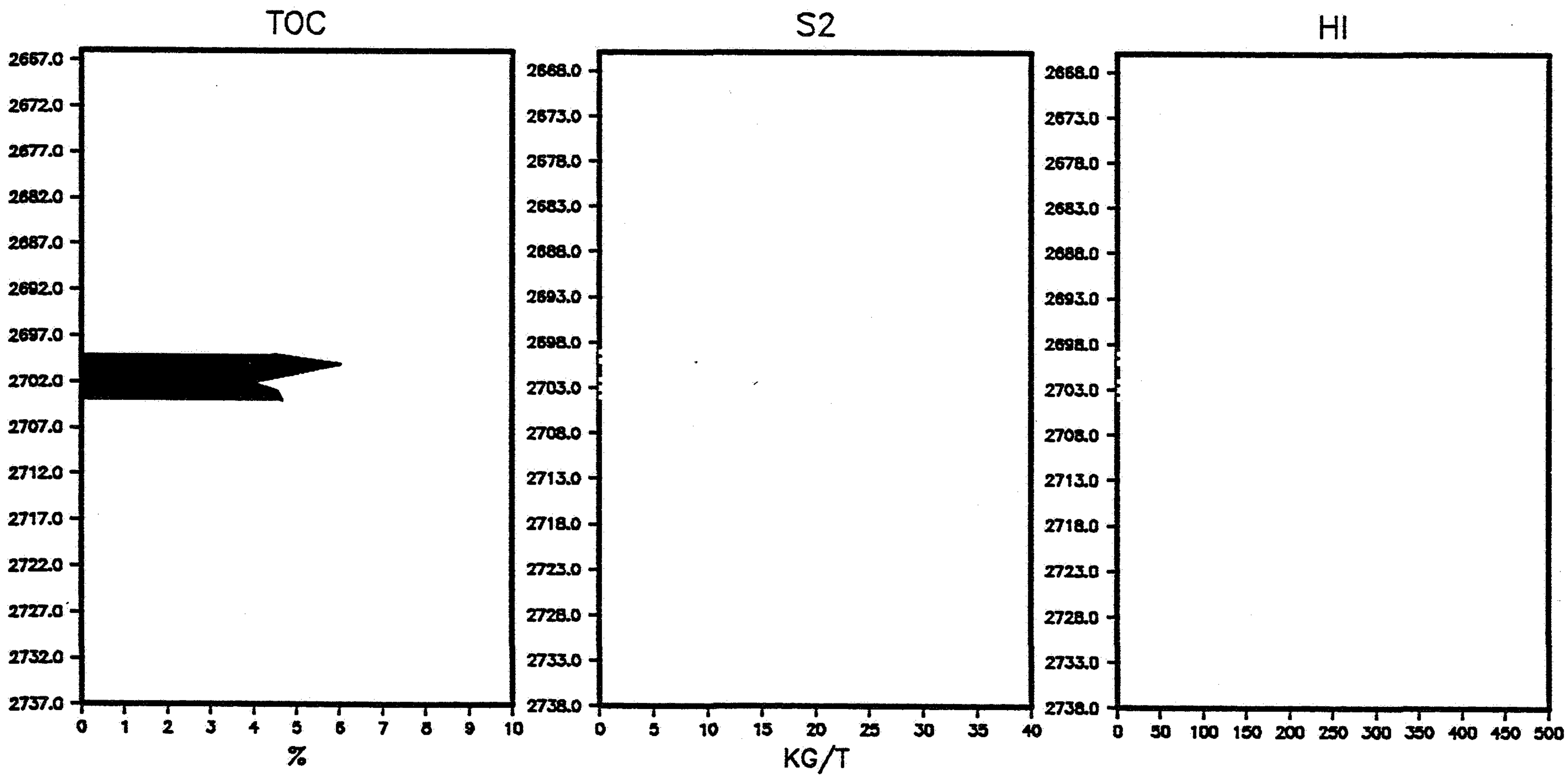
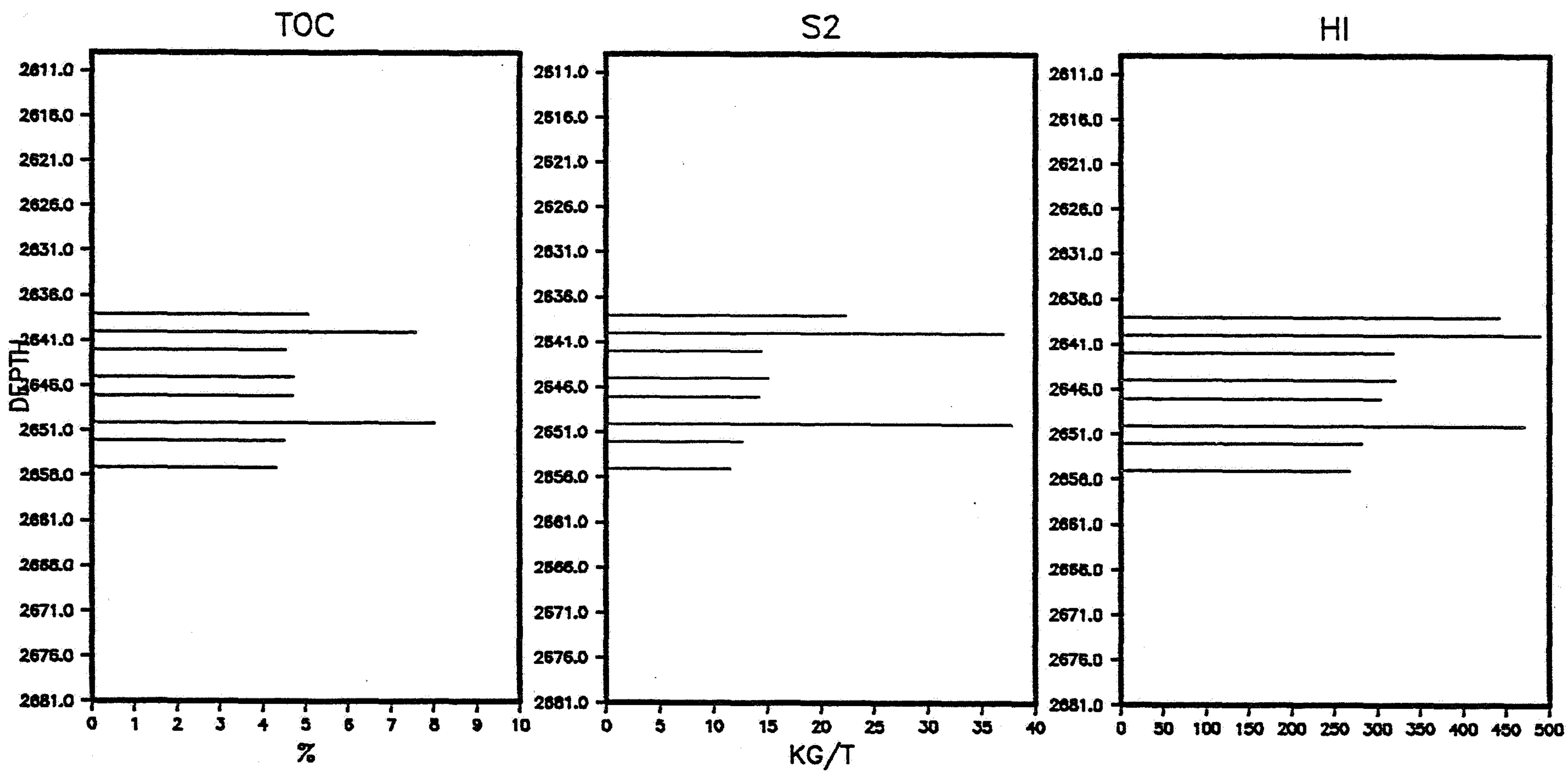


FIG. VI.2.2 A AND B

PLOTS OF TOC, S2 AND HI VERSUS DEPTH,

NESNA FM. 6407/7-2

NESNA FM. WELL 6407/7-2



NESNA FM. WELL 6407/7-2

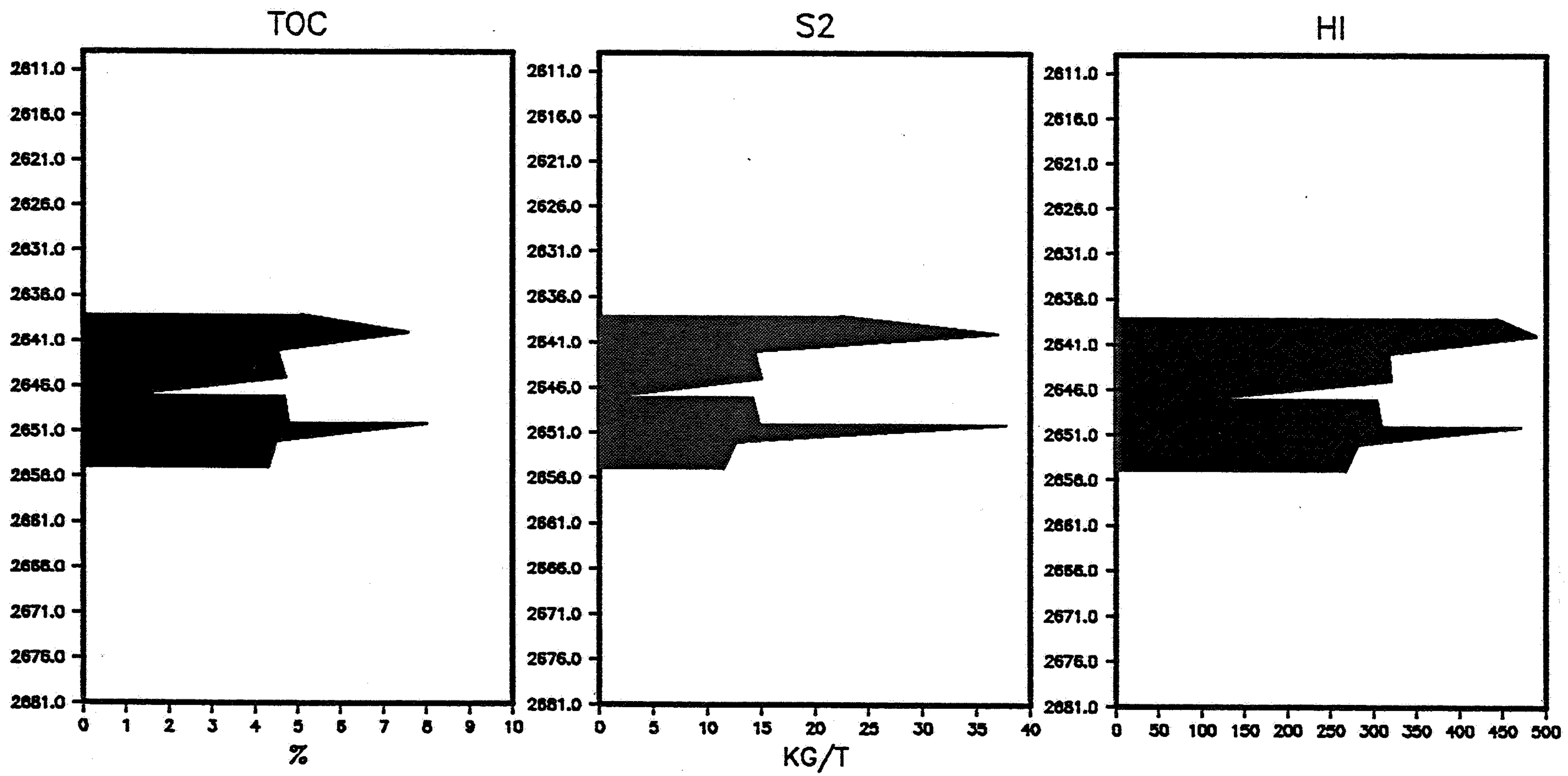
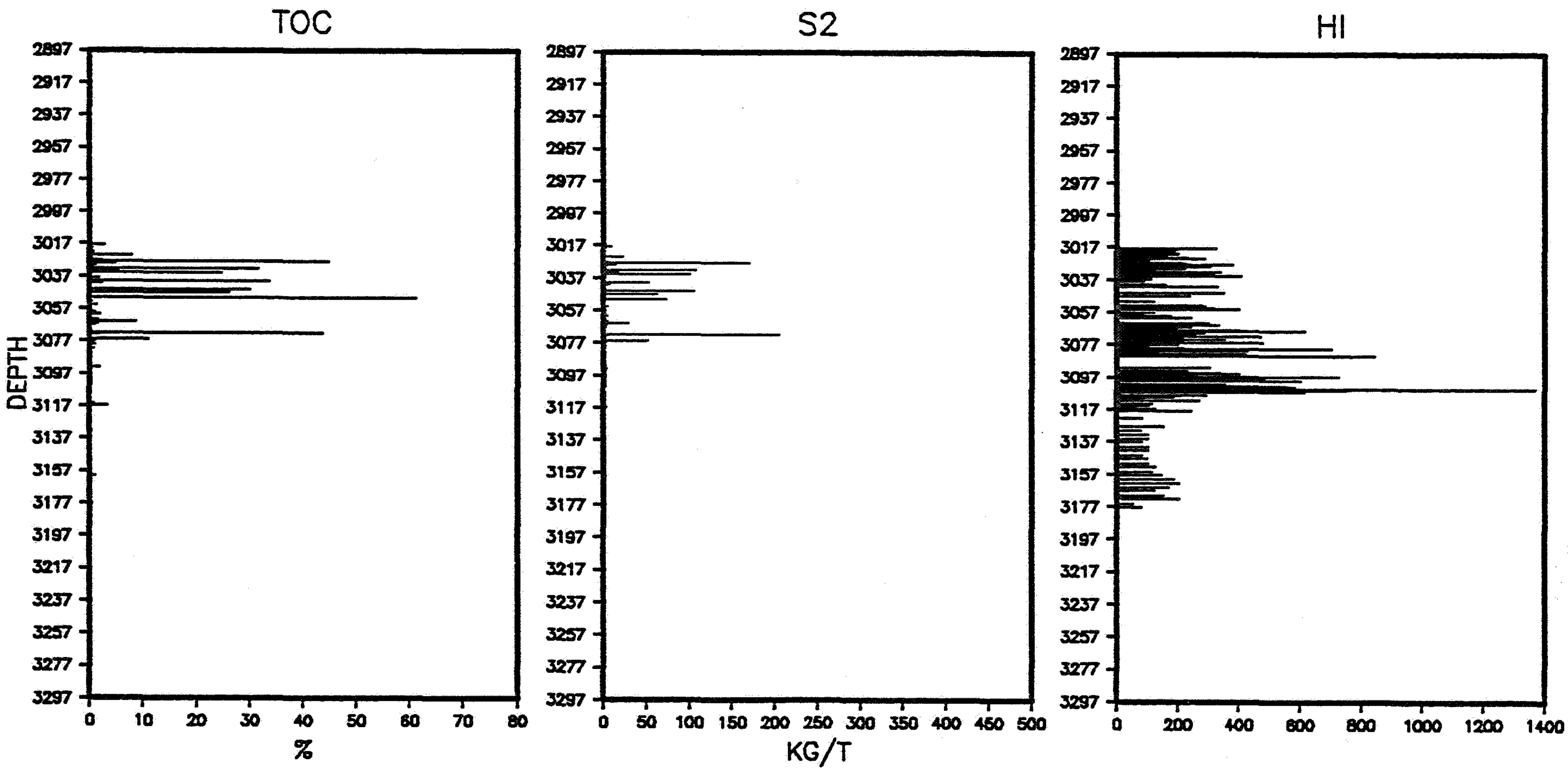


FIG. VI.3.1 A AND B

PLOTS OF TOC, S2 AND HI VERSUS DEPTH,

HITRA FM.6407/7-1

HITRA FM. WELL 6407/7-1



HITRA FM. WELL 6407/7-1

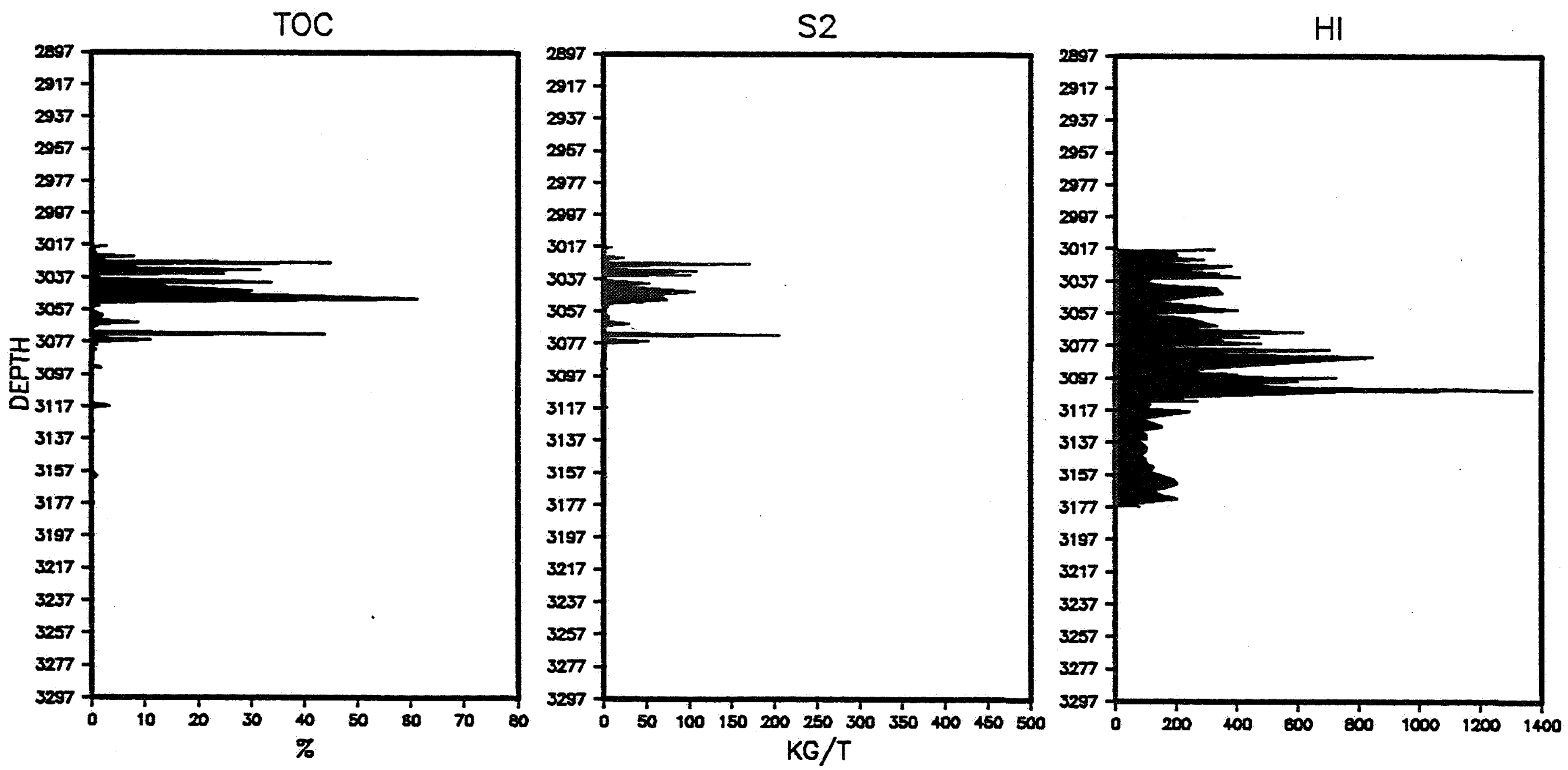
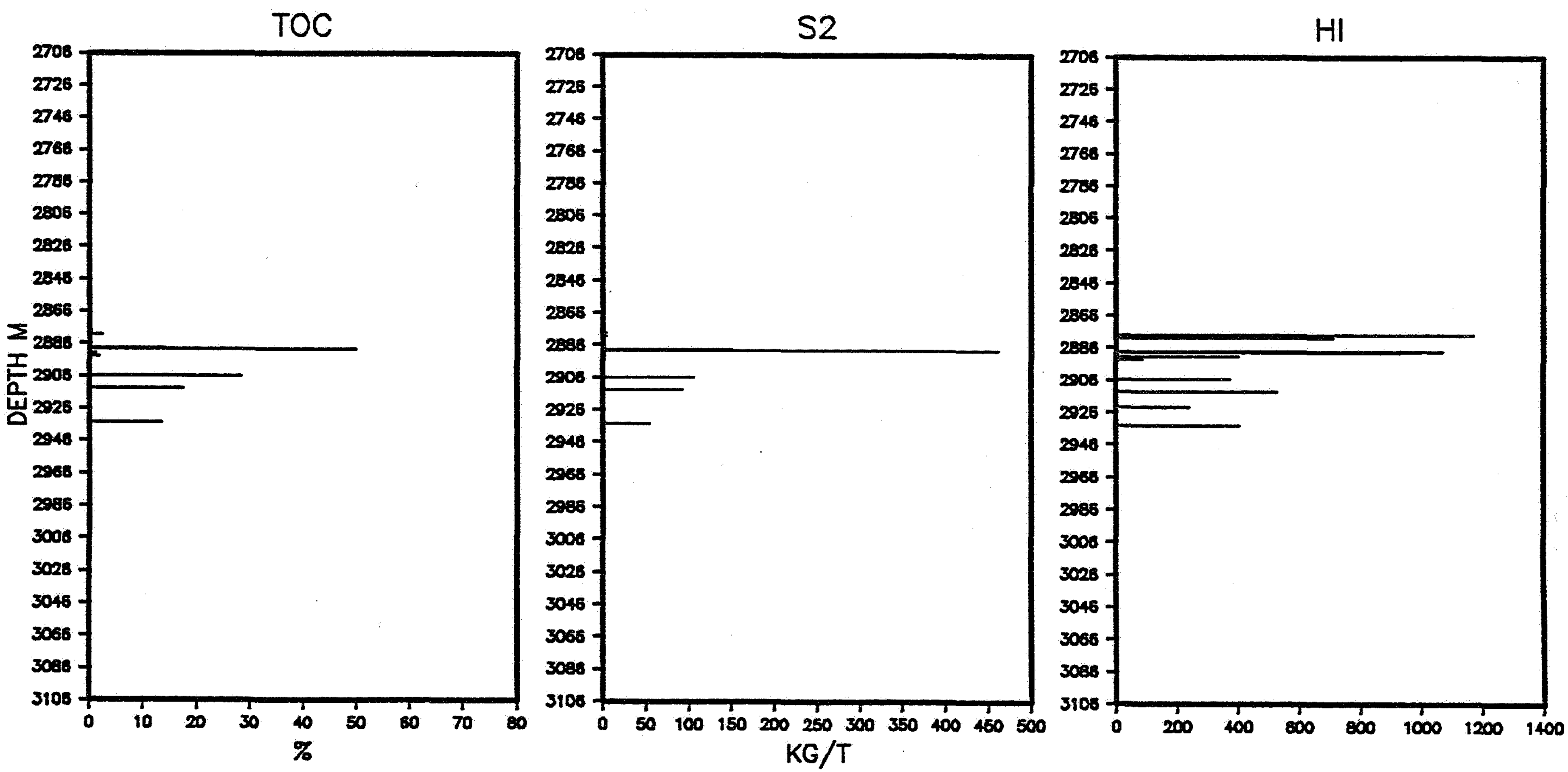


FIG. VI.3.2 A AND B

PLOTS OF TOC, S2 AND HI VERSUS DEPTH,

HITRA FM. 6407/7-2

HITRA FM. WELL 6407/7-2



HITRA FM. WELL 6407/7-2

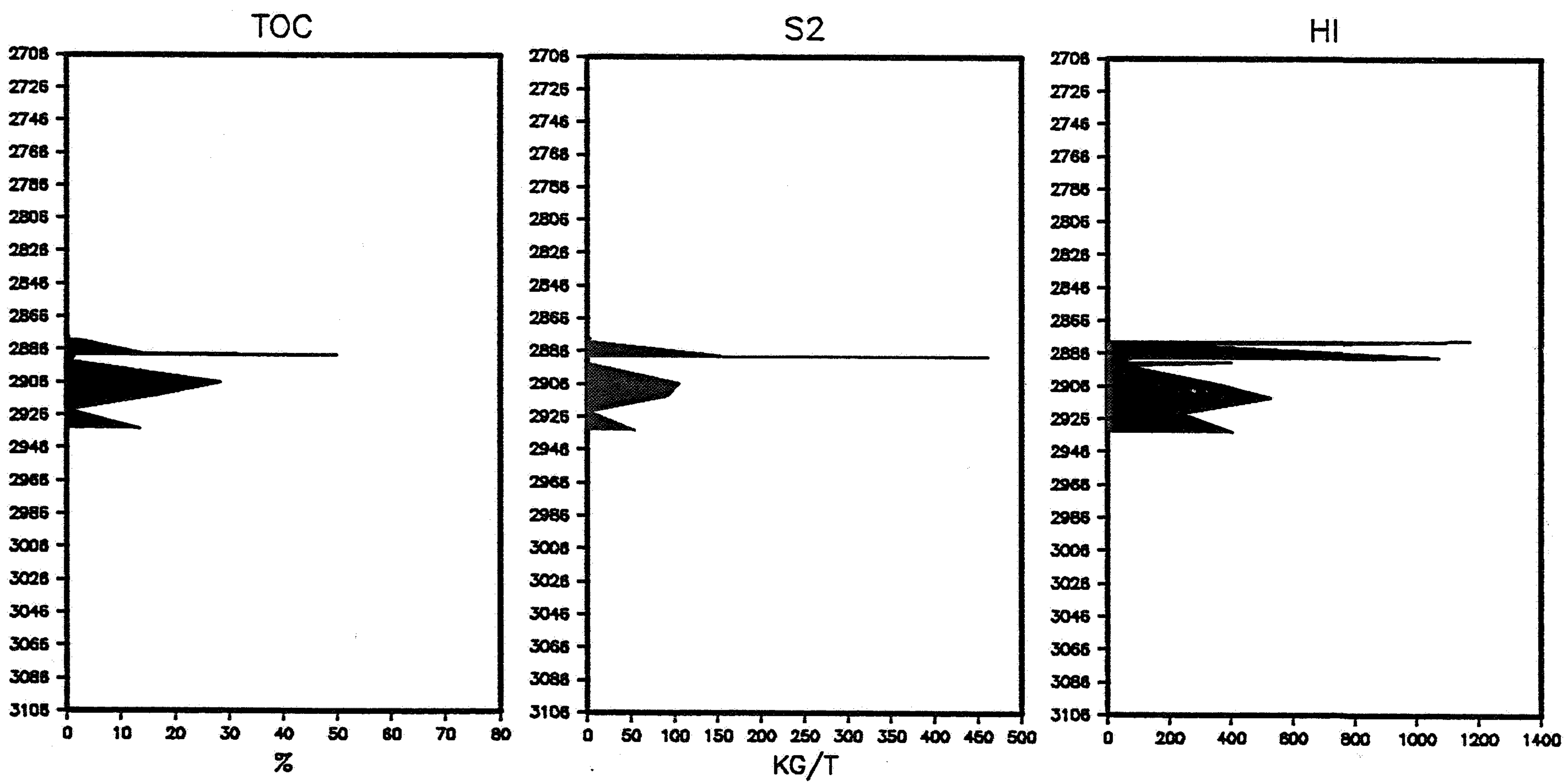


FIG. VI.4.1

PLOT OF BIOMARKER RATIOS VERSUS DEPTH,

NESNA FM. 6407/7-1

NESNA FM. WELL 6407/7-1

BIOMARKER RATIOS

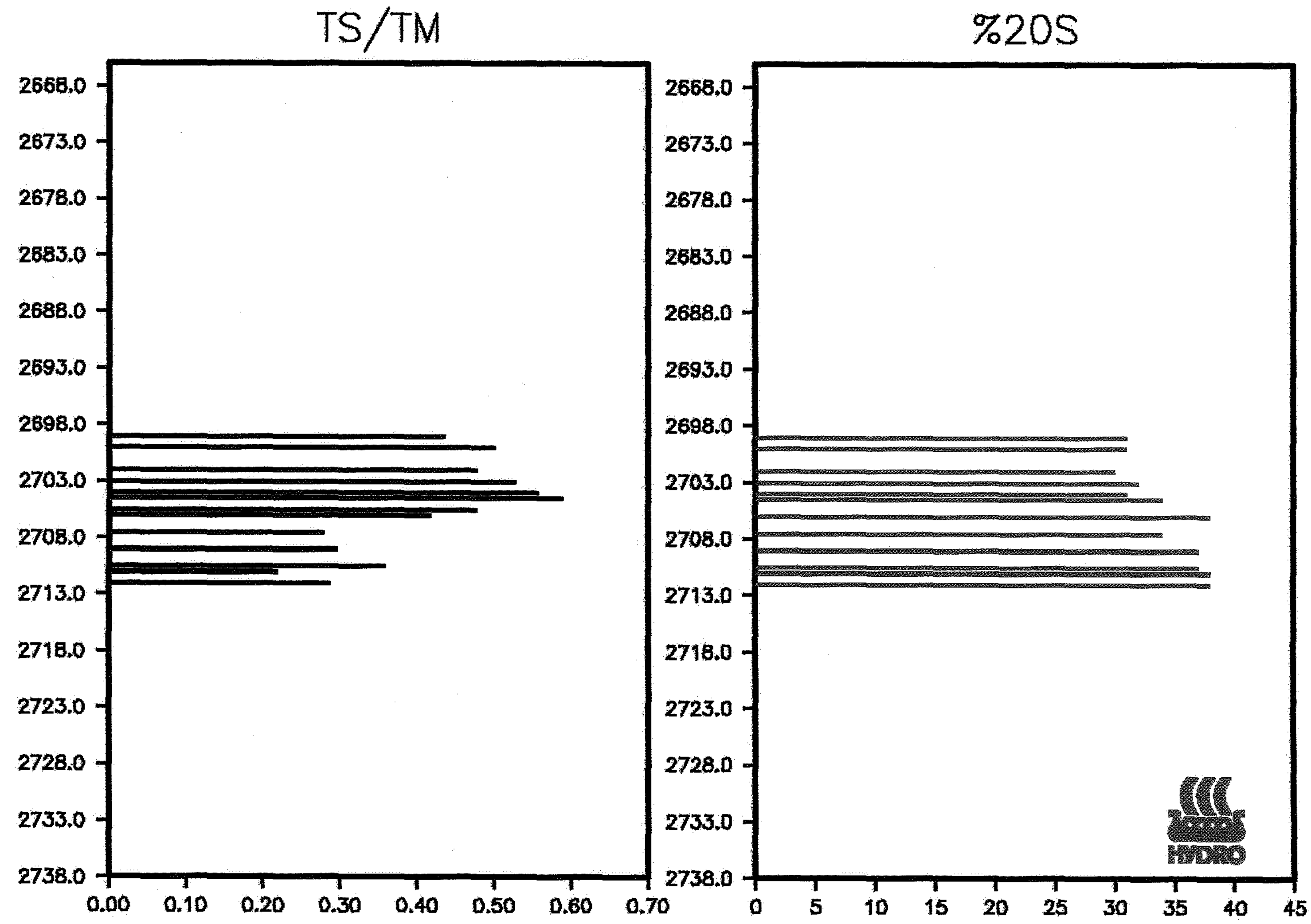


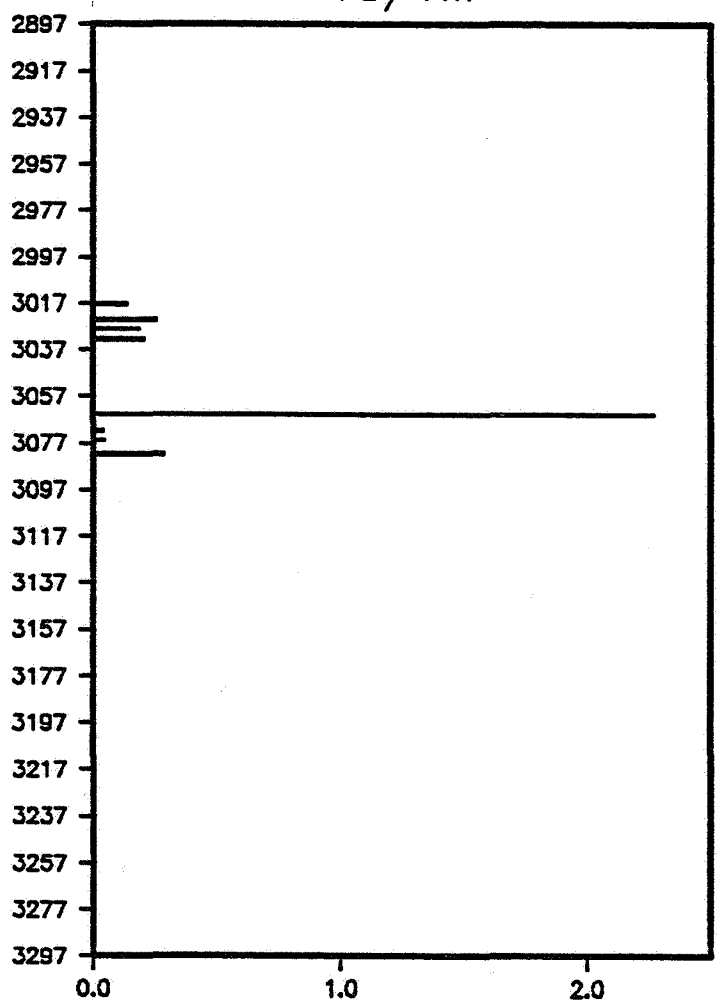
FIG. VI.4.2

PLOT OF BIOMARKER RATIOS VERSUS DEPTH,

HITRA FM. 6407/7-1

HITRA FM. WELL 6407/7-1

BIOMARKER RATIOS



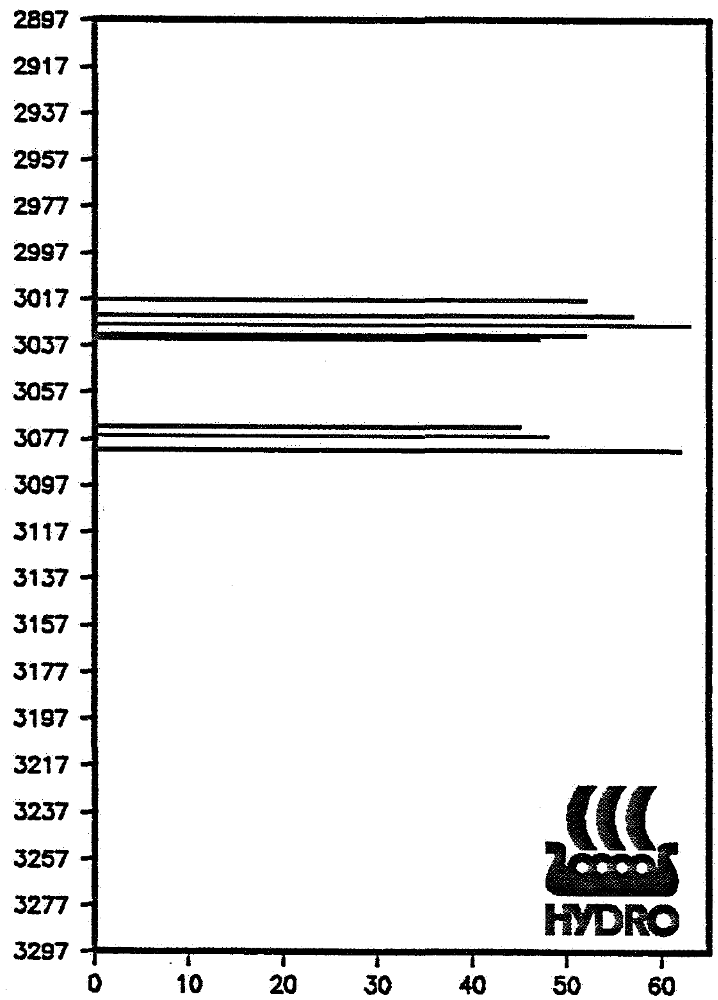


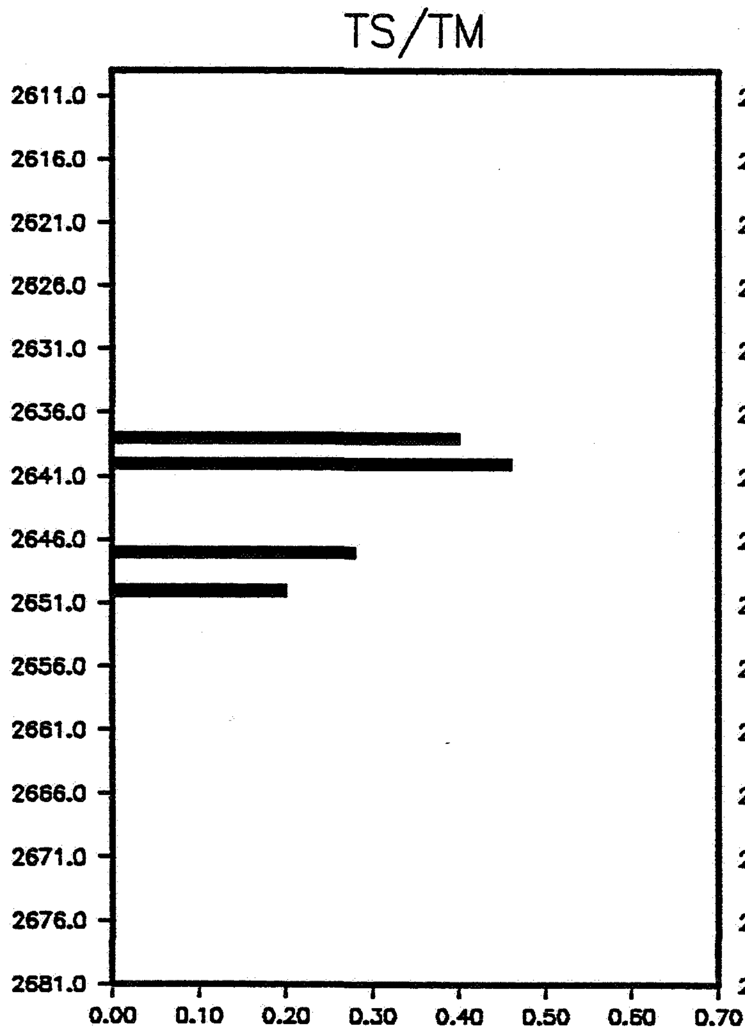
FIG. VI.4.3

PLOT OF BIOMARKER RATIOS VERSUS DEPTH,

NESNA FM. 6407/7-2

NESNA FM. WELL 6407/7-2

BIOMARKER RATIOS



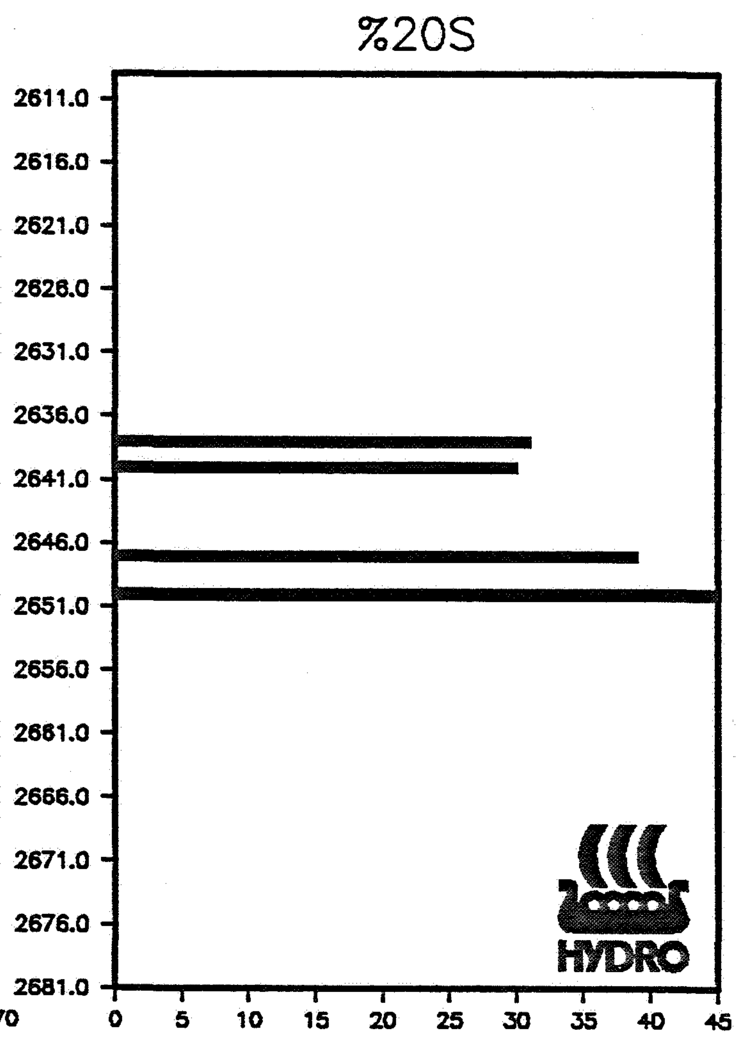


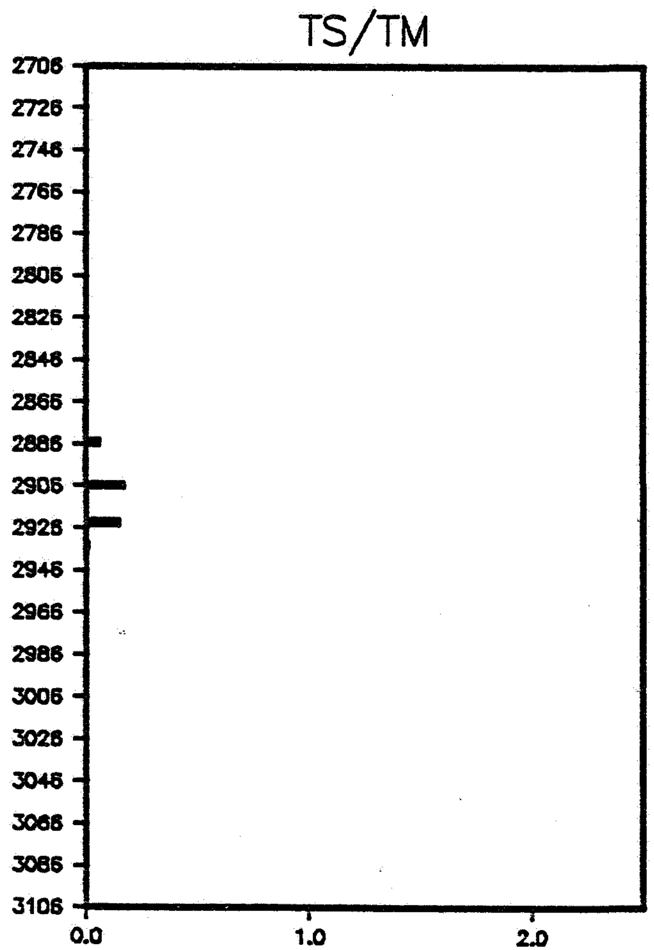
FIG. VI.4.4

PLOT OF BIOMARKER RATIOS VERSUS DEPTH,

HITRA FM. 6407/7-2

HITRA FM. WELL 6407/7-2

BIOMARKER RATIOS



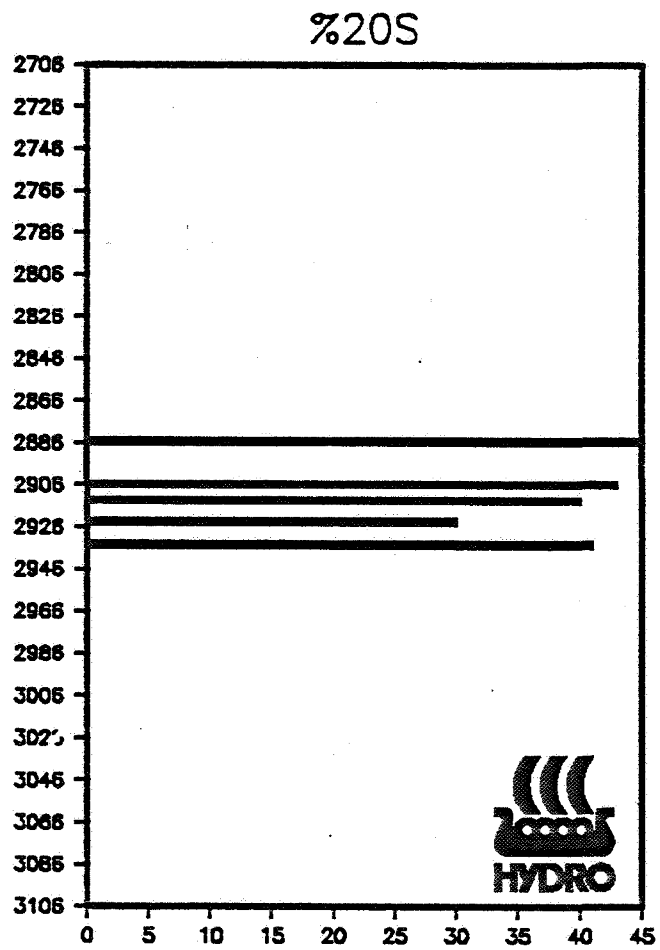
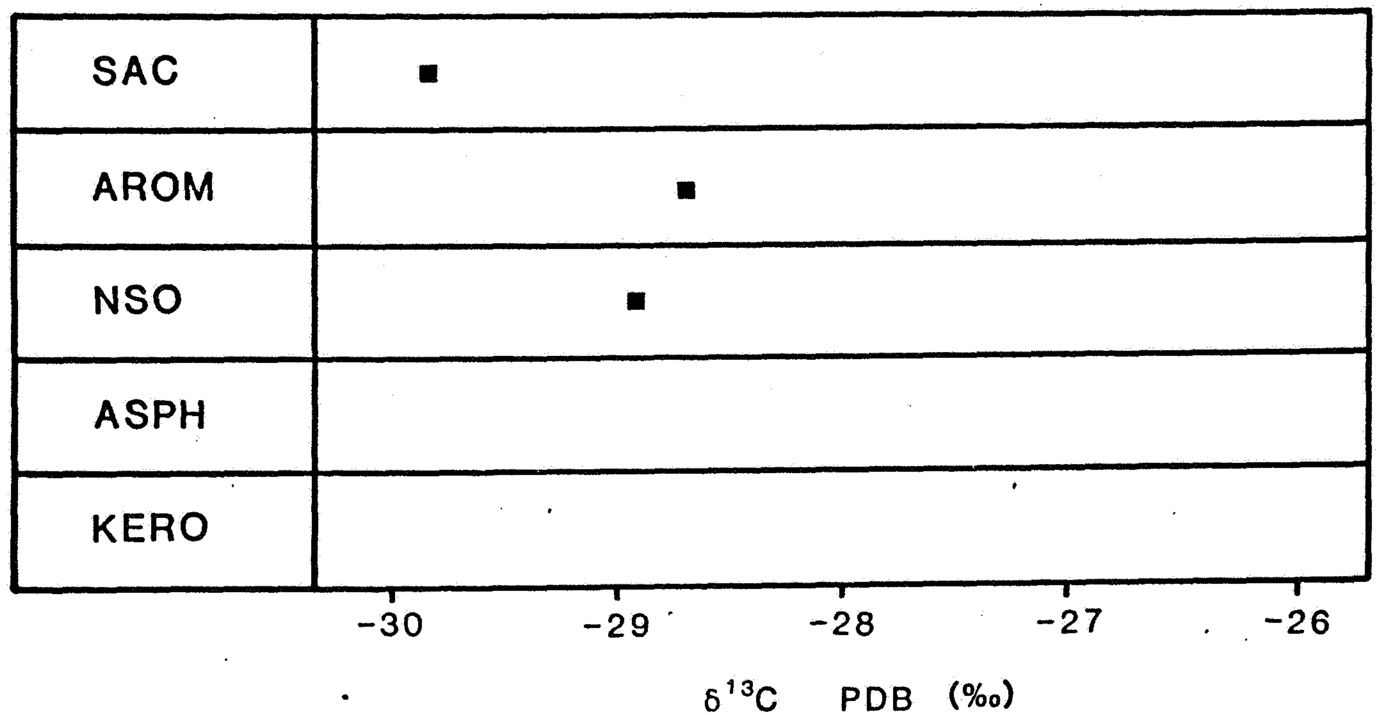


FIG. IV.4.5

GALIMOV PLOTS OF OILS FROM WELLS 6407/7-1 and 6407/9-1

6407/7-1
DST 2

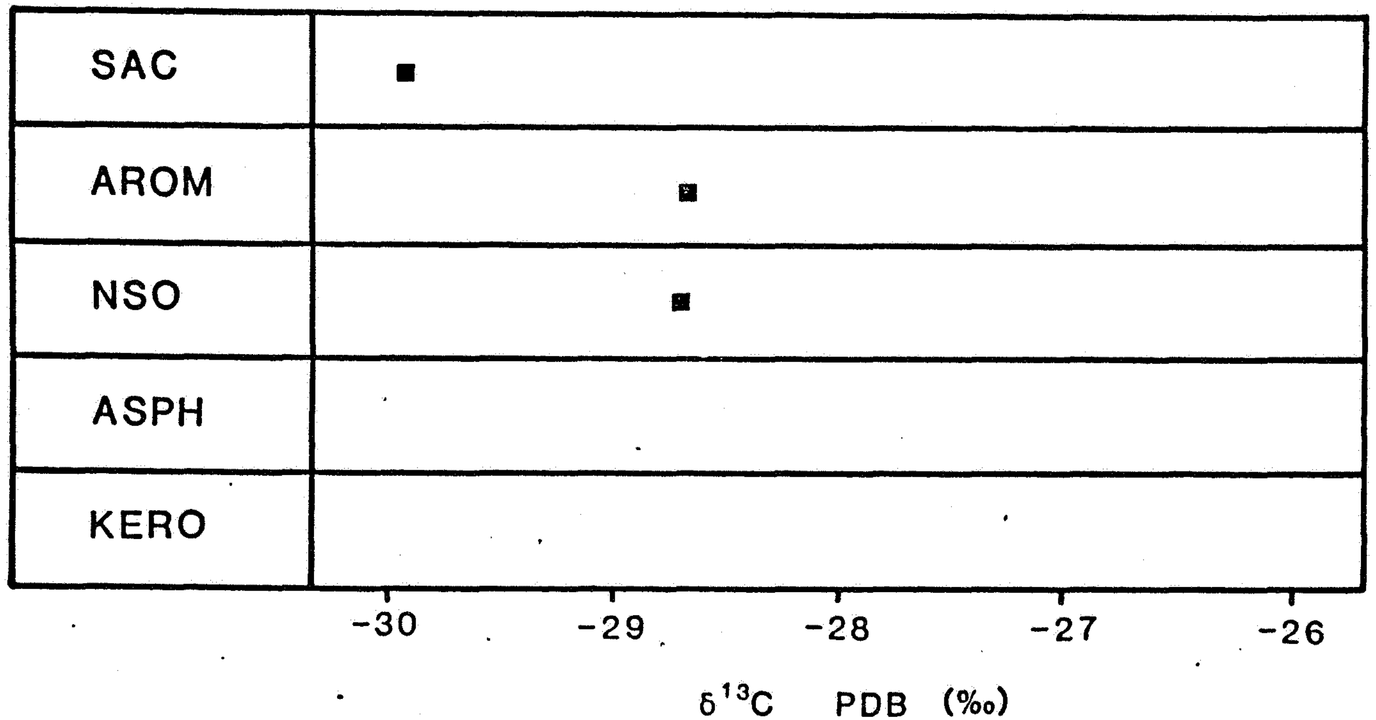


WHOLE OIL $\delta^{13}C$ =

WHOLE EXTRACT $\delta^{13}C$ =

PYROLYSATE $\delta^{13}C$ =

6407/7-1
DST 3

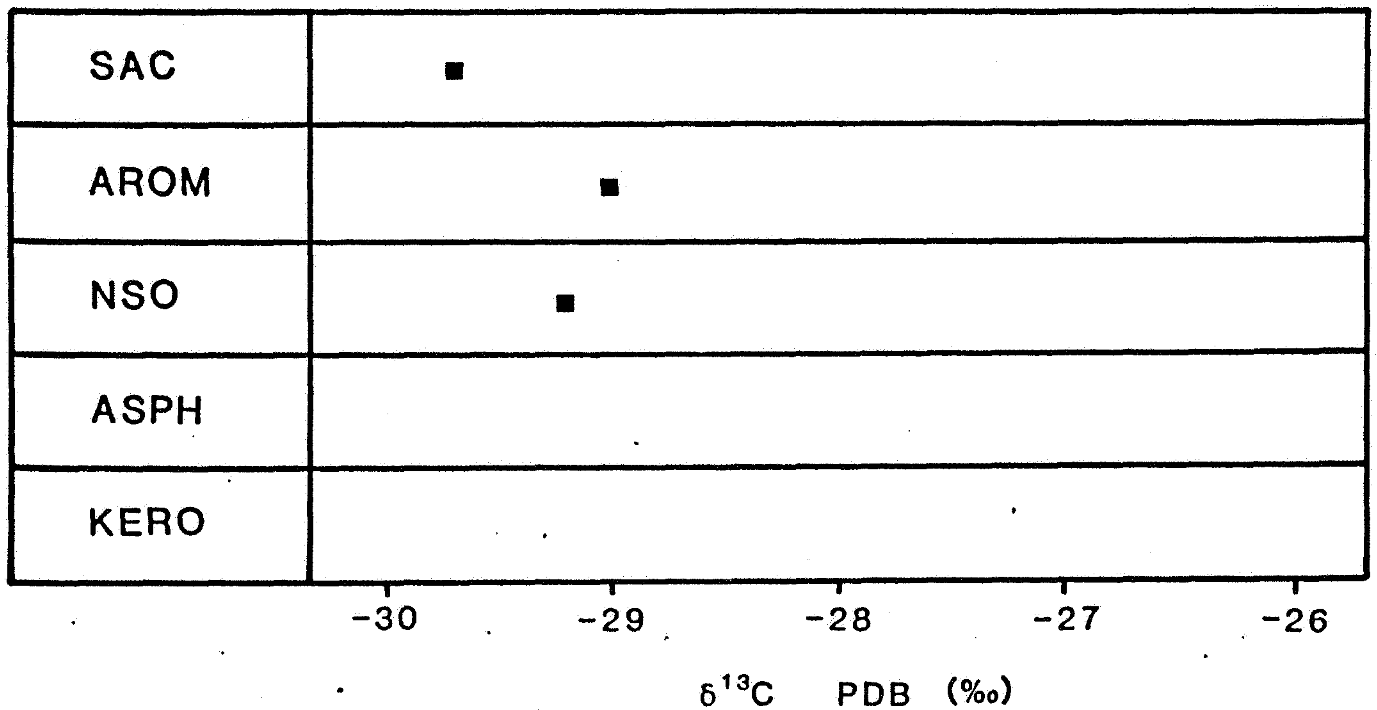


WHOLE OIL $\delta^{13}C$ =

WHOLE EXTRACT $\delta^{13}C$ =

PYROLYSATE $\delta^{13}C$ =

6407/7-1
DST 4

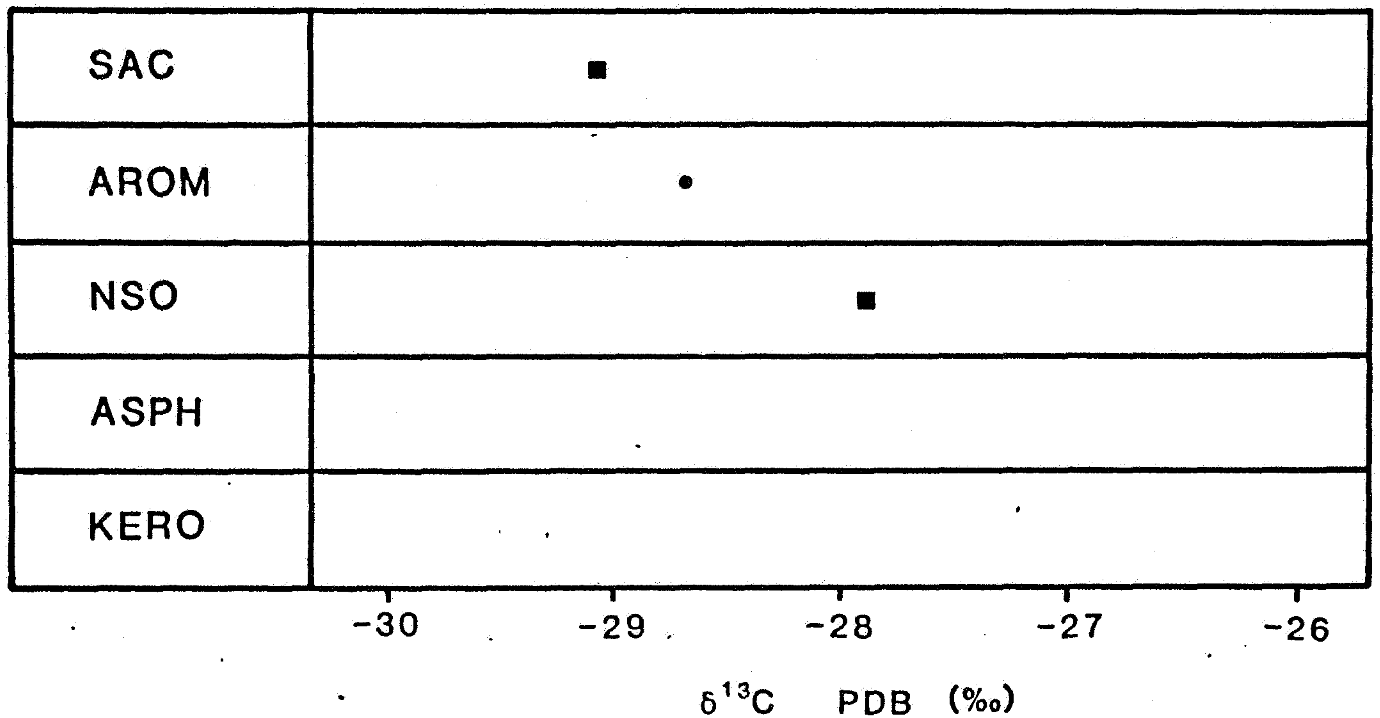


WHOLE OIL $\delta^{13}C$ =

WHOLE EXTRACT $\delta^{13}C$ =

PYROLYSATE $\delta^{13}C$ =

6407/7-1
DST 5

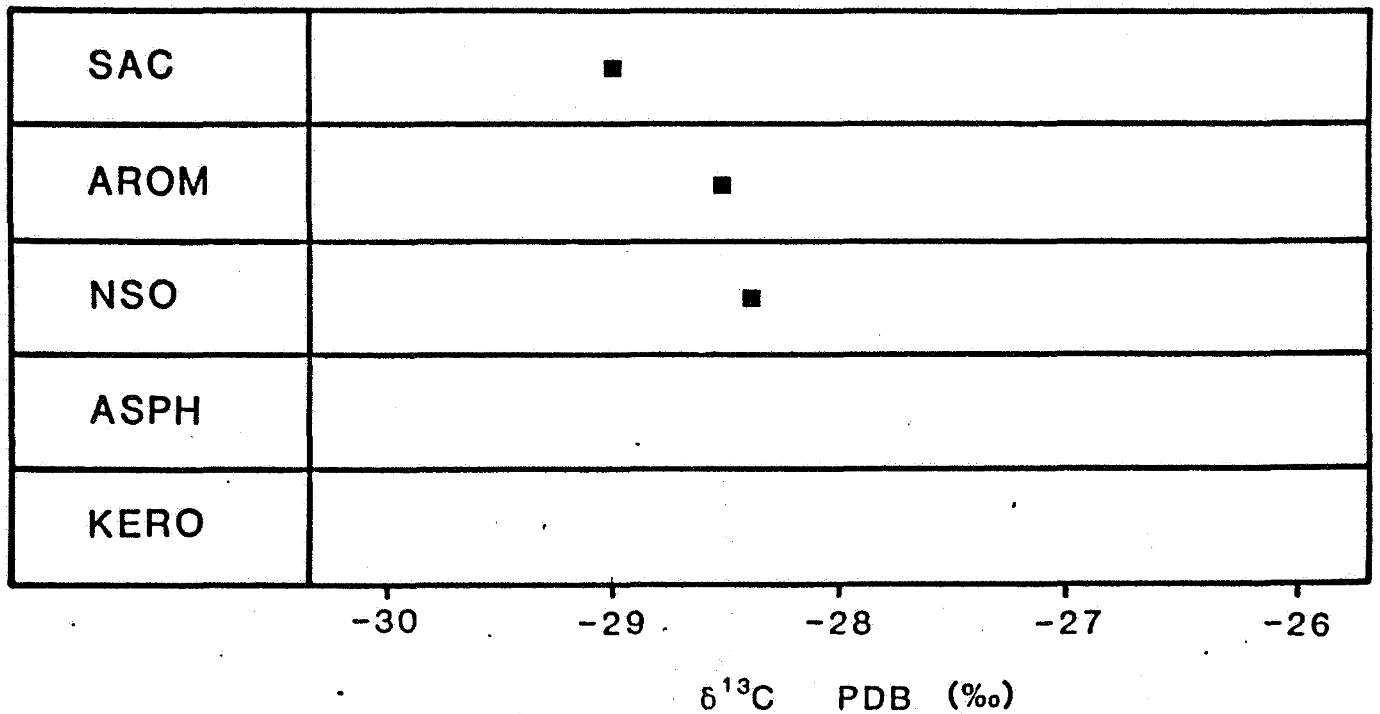


WHOLE OIL $\delta^{13}C$ =

WHOLE EXTRACT $\delta^{13}C$ =

PYROLYSATE $\delta^{13}C$ =

6407/9-1



WHOLE OIL $\delta^{13}C =$

WHOLE EXTRACT $\delta^{13}C =$

PYROLYSATE $\delta^{13}C =$

SOURCE ROCK EVALUATION

6407/7-1

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INTRODUCTION

In this report the results of extraction and chromatographic analyses of 66 Sidewall Core and Core samples from well 6407/7-1 are reported together with the results of the vitrinite reflectance measurements and the visual kerogen analyses.
The samples are collected from the interval 1189 (Oligocene) to 3081.50 m (Lower Jurassic) based on the Exlog rigsite geochemistry results.
The well location is given in Fig. 1.

RIG SITE GEOCHEMISTRY

A geochemical evaluation log based on the Exlog rig site geochemistry is given in Fig. 2. This is based on all available samples including ditch cuttings, sidewall cores and core samples.
The results of the rigsite geochemistry are reported in "Norsk Hydro Geochemical Report Well 6407/7-1" produced by Exlog.

Analysis of biomarkers:

The m/z 191 (triterpanes) and m/z 217 (steranes) fragmentograms are given in Appendix III.
Different biomarker ratios used in this report are listed in Table 5.
The isomerisation (% $\alpha\beta\beta$) and epimerisation (% 20S) of the C_{29} steranes appears to be increasing with depth reflecting the increase in maturity.
The ratio of steranes to triterpanes varies from 0.03 in some of the coaly intervals to 0.99 in the sample from 2725.07 m.
The ratio of Tm to Ts also shows strong variations from 0.44 to 24.70. There is a good correlation between the high Tm/Ts values and low sterane/triterpane values.
The epimerisation of the extended hopanes (% 22S) appears to have reached equilibrium in all the analysed samples.

RESULTS AND DISCUSSION

Extraction and group type separation:

34 side wall cores and 32 core samples were extracted in the interval 1189.91 m to 3081.50 m with special emphasis on the interval from 2699 (Ryazanian) to 2730 m (Late Bajocian/Early Bathonian)
The results of the extractions are listed in Table 1.
The yields ranges from 80 to 31000 ppm with the richer samples corresponding to the main reservoir sandstones. The amount of extractable organic material (EOM) is plotted versus depth in Fig. 3, and in Fig. 4 EOM/TOC (total organic carbon) is plotted versus depth.
The high EOM/TOC values in the interval from 2760 to approx 3000 m are a result of the migrated hydrocarbons in the sandstone intervals.
There appears to be an increase in the EOM in the interval from 1700 to 1850 m (Paleocene) and in the intervals 2699 to 2714 m and 3000 to 3100 m (Lower Jurassic).
The interval from 2699 to 2705 m (Ryazanian) have an average EOM of 3080 ppm indicating a very good source rock potential.
Some of the coaly samples in the interval 3000 to 3100 m also have EOM values indicating very good to excellent source potential.
Some of the extracts from the shallow samples are very low in EOM and are analysed further as whole extracts.

The results of the deasphalting and the group type separation are listed in Table 2.
The ratio of saturated to aromatic hydrocarbons are plotted versus depth in Fig. 5.
The Sat/Arom ratio is quite uniform in the interval from 2699 to 2723 m. The two samples at 2723.12 m and 2724.10 m have very high Sat/Arom ratios. The deeper samples have varying Sat/Arom ratios due to some of the coaly horizons with low values interbedded with sandstones impregneted with migrated hydrocarbons with a higher Sat/Arom value.

Gas chromatographic analysis:

The gas chromatograms of the saturated hydrocarbons are given in Appendix I.
The Pristane/Phytane and Pristane/n-C_{17} ratios are listed in Table 3, and are plotted versus depth in Fig. 6.
The Pristane/Phytane ratio is almost constant in the interval from 2699 to 2707 m. Some of the coaly sequences in the interval from 3000 to 3100 m show high Pristane/Phytane ratios, indicating a more oxidizing depositional environment.
Some of the gas chromatograms from the shallower samples appears to be very immature and since these are analysed as total extracts the CPI (Carbon Preference Index) is difficult to calculate. The samples in the interval from 1990 m to 2170 m appear immature with CPIs ranging from 1.42 to 1.31. Most of the deeper samples all have a CPI close to 1.0 reflecting the increasing maturity with depth.
The saturated gas chromatograms in the interval from 2699 to 2713.23 m all seems to be dominated by marine algal material. The deeper samples show varying amounts of terrigenous input, i.e. the sample at 3017.20 m appears to be dominated by terrestrially derived organic matter.

The gas chromatograms of the aromatic fractions are given in Appendix II.
MPI-1 (Methylphenanthrene Index 1) and MPI-2 are listed in Table 4.
There is a general increase in the ratio of the 3- and 2-methylphenanthrenes relative to the 9- and 1- isomers with increasing depth.

Pyrolysis gas chromatography:

The results of the pyrolysis gas chromatography are given in Appendix IV, and the quantitative results are listed in Table 6.
The two samples at 1824.82 m and (Late Paleocene) and 2085.50 m (Campanian) are mainly gas/condensate prone.
The samples from 2700 m (Ryazanian) to 2722 m (Late Bajocian /Early Bathonian) all contains significant amounts of liptinitic material with increasing contents of humic material with depth. The potential changes from a good source for oil to a condensate prone source.
The samples at 2725.07 and 2726.05 meters are mainly gas prone.
The sample from from 2757 m (late Bajocian/Early Bathonian) is very rich in algal material and is an excellent source for oil.The samples from 2837 m (Early Toarcian/Late Pliensbachian) to 3000.50 m (Pliensbachian-Sinemurian) all contains varying amounts of liptinitic material and are oil/condensate or condensate prone.
The deeper samples are mainly dominated by humic material and are considered condensate and/or gas prone.

MATURITY BASED ON VITRINITE REFLECTANCE EVALUATIONS

The mean vitrinite reflectance (Ro %) values for 34 measured samples (exclusively sidewall cores and core chips) are shown in Fig. 7; Tab. 7.

In the upper and middle part of the section (1180 to 3113 m) there is a marked spread in the values. It is especially apparent between about 1900 and 2550 m where most of the values are above Ro 0.5%. The relatively high reflecting vitrinite material in this part of the well is considered to be reworked from older deposits. In addition, a coal sample from 3039.4 metres show an exceptionally high reflectivity. This is considered to be due to oxidation of the vitrinite.

An evaluation of type of woody material, the spread in reflectivity values, and the number of counts in each sample has been performed. Based on this, samples which are considered to represent the most reliable reflectivity values have been selected. These samples are designated with green coloured circles in the diagram (Fig. 7). A best fit curve is calculated for the values, and give a regression of 0.88 which is considered to be significant.

Provided there exsist no major loss in the sedimentary succession, the regression line should show a reflection value at the sea bottom of about 0.1 to 0.2 % Ro. In this case the value is 0.12 % Ro.

Maturity: According to the intepreted Ro % values, a middle mature stage is reached at about 3000 m depth in this well. The sediments between 1100 and about 2200 metres are organically immature, whereas the succession from here down to about 3000 m is in a early mature stage.

SOURCE ROCK QUALITY BASED ON VISUAL KEROGEN DESCRIPTIONS

A total of 38 (SWC and CC) samples have been analysed semi-quantitatively in a microscope. The histograms in Fig 8 and Table 8, show the results of the analyses.

Commonly a simple classification of kerogen types, i.e. Type I to III or IV is used to describe the kerogen content of sediments. Type I consists of algal material (Tasmanites sp. Botrycoccus sp.) and resinite. Type II: palynomorphs (spores, pollen, dinocysts, acritarchs), cuticula fragments, and a varying amount of woody material from land plants. Type III usually defines material of brown to black wood (dense or structured i.e. vitrinite). Type IV consits exclusively of opaque wood (inertinite).

According to this, the sedimentary succession in the well could be divided into six main parts. As seen from the summary below, based on semi-quantitative optical kerogen studies, there is not always a clearcut separation of the kerogen types II and III) as often intepreted in the literature.

Kerogen types:

1800 - 1927 m: Type II with degraded material of type III.

1946 - 2425 m: Type II with large amounts of wood.

2590 - 2649 m: Type III (conatin pyritized wood) with small amounts of palynomorphs.

2670 - 2711 m: Type II with palynomorphs, wood and opaque wood. Considerable amounts of amorphous material derived from palynomorphs.

2713 - 2781 m: Type III with a small amount of palynomorphs.

2781 - 3092 m: Both type II, III and IV are present here.

Hydrocarbon potential

The hydrocarbon potential of the succession (based on visual kerogen analyses) is as follows:

1800 -1927 m: Partly, the kerogen content points to a good potential, but the amount of degraded woody material lowers the potential significantly.

1946 - 2425 m: This interval is dominated by woody material. Opaque wood constitutes a major part: Poor potential.

2590 - 2649 m: Pyritized wood and woody material dominate. Palynomorphs are present. The potential is very poor.

2670 - 2711 m: Dominating content of palynomorphs, but wood is present in varying amounts. Large amounts of amorphous material derived from palynomorphs characterize this sequence. The potential is regarded to be very good.

2713 - 2781 m: Characterized by woody material with considerable amounts of opaque wood. Some samples have larger amounts of palynomorphs and cuticula fragments (oil prone). A sample from 2830.03 m is remarkable because it contain large amounts of palynomorphs, cuticula fragments, and amorphous material of palynomorph origin.

The intepretation of hydrocarbon potentials (based on visual kerogen analyses) is in most cases comparable with the **hydrogen indices.**

Figure 9 show a comparison between the relative amount of palynomorphs in each sample versus the hydrogen index (HI).

In general, the comparison show that when the HI is high, the palynomorph content is high, and vice versa.

Some anomalies are apparent, however, most of which could be explained when other kerogen components than palynomorphs are considered.

CONCLUSIONS

The main conclusions from this report are summarised in Fig. 10.

Maturity:

The interpreted vitrinite measurements indicate onset of oil generation (Ro 0.55 %) at approx. 3000 m in this well.
This observation is supported by the biomarker analysis.
The interval from 2200 m to 3000 m is considered early mature (Ro 0.35 - 0.55 %), while the shallower sections are immature.

Kerogen type:

The interval from 2000 m to 2590 m consists mainly of type II kerogen with degraded type III, and contains large amounts of woody material.
The interval from 2590 m to 2697 m is rich in pyritized wood an consists of type III kerogen.
The interval from 2697 m to 2713 m contains large amounts of amorphous material, and is mainly a type II kerogen.
The interval from 2713 m to 2780 m contains inertinite and is considered a type III/IV kerogen.
The interval from 2780 m to 3200 m consits of varying kerogen types from samples containing a lot of woody material to samples dominated by palynomorphs.
Some samples contains cuticular fragments.

Petroleum potential:

The interval down to 2697 m have a poor to fair potential mainly for gas/condensate.
The section from 2697 m to 2713 m have an excellent potential for oil/condensate. The quality decreases with depth within this interval.
The interval from 2780 m to 3200 m have a varying petroleum potential ranging from no to excellent, and from oil prone to gas prone source rocks.

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The interval from 2697 m to 2713 m contains large amounts of amorphous material, and is mainly a type II kerogen.
The interval from 2713 m to 2780 m contains inertinite and is considered a type III/IV kerogen.
The interval from 2780 m to 3200 m consits of varying kerogen types from samples containing a lot of woody material to samples dominated by palynomorphs.
Some samples contains cuticular fragments.

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The interval down to 2697 m have a poor to fair potential mainly for gas/condensate.
The section from 2697 m to 2713 m have an excellent potential for oil/condensate. The quality decreases with depth within this interval.
The interval from 2780 m to 3200 m have a varying petroleum potential ranging from no to excellent, and from oil prone to gas prone source rocks.

EXPERIMENTAL

Sample preparation:

SWC and core samples were rinsed to remove contaminants. Samples from the 1-2 mm fraction were handpicked from drill cuttings.

Extractable organic matter (EOM):

The samples were soxhlet extracted for 24 hours with 93:7 DCM/Methanol. Activatated copper was added to the flask during extraction to remove elemental sulphur.

Desphaltening:

The EOM was heated overnight in hexane (60 ul/mg) and the hexane insoluble fraction reported as asphaltenes.

Group Type separation:

The hexane soluble part of the EOM was separated into saturate, aromatic and polar fractions using MPLC with a cyano/amino modified silica as precolumn and a silica main column. The fractions were quantified using a Pye LCM2 moving wire detector.

Gas chromatographic analysis:

The saturate fractions were analysed on a HP 5880 gas chromatograph using a 30 meter DB-1 (J&W) fused silica column with helium as carrier gas. The temperature program was 80 ^{0}C initial temperature for 2 min. followed by 6 ^{0}/min. to 300 ^{0}C and held for 15 min.. The aromatic fractions were analysed on a HP 5880 gas chromatograph using a 25 meter 5% crosslinked methyl-phenyl silicone fused silica column (HP). The temperature program was an initial hold at 2 min. at 80 ^{0}C followed by programming at 4 ^{0}C/min. to 300 ^{0}C and held for 15 min.

Gas chromatography-mass spectrometry (GCMS):

Selected saturated alkane fractions were analysed in the voltage selected ion recording (VSIR) mode using a VG 7070E mass spectrometer coupled to a HP 5790 gas chromatograph.

Pyrolysis gas chromatography:

The pre extracted samples were pyrolysed in an oven programmed from 300 to 550 ^{0}C. The first part of the column was cooled in liquid nitrogen during the pyrolysis and then programmed from 35 ^{0}C to 300 ^{0}C at 4 ^{0}/min.

Vitrinite reflectance:

Samples were washed on a sieve with warm water to remove drilling mud. After drying, they were mounted in Bakelite resin blocks. The samples were then ground on a diamond lap and subsequently polished with two grades of Corundum paper. The grinding and polishing was carried out using isopropyl alcohol as a lubricant. The samples were finally polished using three grades of alumina, 5/20, 3/50 and Gamma. Reflectance measurements were carried out on a Leitz M.P.V. microphotometer under oil immersion, R.I. 1.516 at a wavelength of 546 nm.

Visual kerogen analysis:

Samples for visual kerogen analysis were selected from Rock-Eval screening analyses. The samples were crushed and demineralised with HCl and HF and mounted on slides for subsequent microscopic study.

APPENDIX I

SOURCE ROCK EVALUATION 6407/7-1

TABLES

EXTRACTION YIELDS

DEPTH m	EOM ppm	EOM/TOC mg/g TOC	DEPTH m	EOM ppm	EOM/TOC mg/g TOC
1189.91	400	16.3	2718.04	300	26.5
1209.94	500	14.5	2719.10	400	17.2
1299.99	100	10.2	2720.05	400	13.9
1419.92	80	5.7	2721.10	700	16.0
1639.93	100	7.0	2722.03	500	15.2
1739.88	400	25.6	2723.12	200	23.3
1824.82	1500	60.0	2724.10	160	25.8
1939.00			2725.07	500	43.1
1990.00	200	22.7	2726.05	200	11.0
2085.50	200	28.6	2747.00	100	6.2
2155.00	200	19.8	2757.00	600	5.0
2170.00	80	11.1	2765.04	7500	238.1
2270.00	100	11.5	2780.60	6000	600.0
2370.00	80	8.5	2837.00	31000	
2446.50	100	8.8	2840.00	3000	
2699.00	1700	38.3	2877.00	11000	846.2
2700.00	5000	83.1	2905.00	13000	849.7
2702.00	2400	60.9	2915.00	13000	1171.2
2703.00	3000	65.8	2956.00	8000	740.7
2704.00	3400	72.8	2966.00	13000	1203.7
2704.50	3000		3000.50	3500	42.7
2705.50	600		3017.20	1100	41.7
2706.00	800		3024.00	10000	126.4
2707.50	2000		3027.83	11000	24.5
2709.00	700		3032.30	20000	63.4
2710.50	300		3034.20	8000	32.4
2711.00	1400	27.1	3039.40	7000	20.8
2712.00	800		3064.37	7500	87.7
2712.50	1700		3071.57	14000	32.1
2713.00	1700		3075.45	4000	36.9
2713.25	300	61.2	3081.50	200	26.3
2714.20	500	40.3			
2715.05	500	104.2			
2716.23	300	24.8			
2716.97	500	29.9			

Table 1: Extraction yields in ppm of dry sediment and in mg/ g TOC.

GROUP TYPE SEPARATION

DEPTH m	ASPHALTENES %	SAT %	AROM. %	NSO %
1189.91	39.50			
1209.94	37.50			
1299.99	41.70			
1419.92	33.30			
1639.93	17.60			
1739.88	30.60	16.7	16.7	66.6
1824.82	66.25	29.2	12.5	58.3
1939.00		40.8	44.2	14.9
1990.00	20.00			
2085.50	25.80			
2155.00	30.00	12.3	19.3	68.4
2170.00	33.30	7.8	36.8	55.4
2270.00	34.80	7.4	38.8	53.7
2370.00	38.50			
2446.50	20.00			
2699.00	9.70	27.0	41.7	31.2
2700.00	10.70	20.5	34.3	45.2
2702.00	7.90	29.5	36.7	33.8
2703.00	19.00	22.5	31.8	45.7
2704.00	7.10	34.4	31.2	34.4
2704.50	27.10	30.5	37.9	31.6
2705.50	40.00	31.2	25.3	43.3
2706.00	24.10			
2707.50	33.90	31.6	45.0	23.4
2709.00	28.00	50.3	28.1	21.7
2710.50	33.30	53.2	25.0	21.8
2711.00	47.60	28.2	39.7	32.1
2712.00	39.50	47.3	25.9	26.7
2712.50	52.00	28.2	36.5	35.3
2713.00	56.60	31.8	37.2	30.9
2713.25	33.30	50.3	21.9	27.8
2714.20	35.30			
2715.05	9.70			

Table 2: Results from deaspalting and group type separation. Saturates, aromatics and NSO- compounds are reported as % of deasphalted material.

DEPTH m	ASPHALTENES %	SAT %	AROM. %	NSO %
2716.23	34.60	34.1	30.9	35.0
2716.97	49.50	23.1	36.7	40.3
2718.04	28.20	32.7	34.1	33.2
2719.10	73.90	16.2	40.7	43.1
2720.05	54.90	20.4	36.3	43.3
2721.10	42.40	25.1	34.6	40.4
2722.03	30.90	27.3	35.2	37.5
2723.12	7.80	74.1	2.2	23.7
2724.10	29.50	68.6	3.2	28.1
2725.07	23.80	50.0	29.6	20.4
2726.05	56.70	22.2	33.1	44.7
2747.00	55.60	13.4	29.1	57.5
2757.00	22.20	23.2	39.5	37.3
2765.04	0.60	77.6	17.3	4.9
2780.60	0.50	76.4	18.2	5.4
2837.00	15.80	24.2	47.6	28.2
2840.00	7.20	65.2	22.3	12.4
2877.00	0.50	74.3	18.9	6.8
2905.00	0.20	74.6	17.1	8.3
2915.00	0.20	72.4	18.9	8.7
2956.00	0.20	73.5	18.3	8.2
2966.00		81.2	10.4	8.4
3000.50	26.70	28.6	39.7	31.8
3017.20	38.30	34.4	44.8	20.9
3024.00	7.50	70.5	13.1	16.4
3027.83	10.60	66.9	16.3	16.7
3032.30	34.10	57.4	30.5	12.1
3034.20	65.70	14.9	54.1	30.9
3039.40	96.00	7.5	45.5	46.9
3064.37	58.60	42.4	39.8	17.8
3071.57	42.30	21.4	46.5	32.2
3075.45	30.10	27.5	47.1	25.3
3081.50	13.00	55.6	20.2	24.2

Table 2 continued

DEPTH m	Pr/Ph	Pr/nC17	CPI-1[1]	CPI-3[2]
1189.91	0.56	0.52	1.044	1.042
1209.94	0.61	0.57	0.924	0.834
1299.99	0.30	1.35	1.153	1.167
1419.92	0.47	1.09	1.114	0.819
1639.93	1.70	2.30	0.727	0.579
1739.88	4.60	8.70	1.138	0.670
1824.82	2.70	6.00		
1939.00	1.40	0.70	1.046	0.863
1990.00	0.98	0.88	1.099	1.271
2085.50	0.78	0.76	0.766	0.422
2155.00	3.70	3.40	1.312	1.957
2170.00	2.90	1.20	1.461	2.122
2270.00	2.90	1.40	1.395	1.947
2370.00	2.54	0.90	1.270	1.688
2446.50	2.88	1.00	1.281	1.638
2699.00	3.20	2.40	1.042	0.880
2700.00	2.40	2.50	1.241	1.120
2702.00	2.90	2.90	0.952	0.814
2703.00	2.60	2.40	1.021	0.800
2704.00	2.60	2.90	1.001	0.900
2704.50	2.70	1.90	0.896	0.701
2705.50	2.40	0.90	1.102	1.072
2706.00	2.70	1.00	1.001	0.950
2707.50	2.80	1.10	1.082	1.006
2709.00	2.90	1.20	1.055	1.055
2710.50	3.10	2.30	1.089	1.120
2711.00	3.30	2.00	1.126	1.116
2712.00	4.00	2.20	1.098	1.133
2712.50	3.90	1.90	1.121	1.089
2713.00	3.70	1.80	1.104	1.403
2713.25	1.50	0.90	1.129	1.120
2714.20	1.51	1.10	1.059	1.095
2715.05	2.39	1.03	1.080	1.052
2716.23	2.90	1.00	1.118	1.091
2716.97	5.60	2.80	1.256	1.447
2718.04	4.00	1.30	1.257	1.605
2719.10	5.30	2.30	1.353	1.650
2720.05	3.80	1.30	1.289	1.511
2721.10	3.30	1.20	1.316	1.594

Table 3: Molecular ratios from the gas chromatograms of the saturated hydrocarbons.

DEPTH m	Pr/Ph	Pr/nC17	CPI-1	CPI-3
2722.03	3.20	1.40	1.288	1.530
2723.12	2.70	0.70	1.093	1.028
2724.10	2.90	0.70	1.102	1.000
2725.07	3.30	0.80	1.143	1.071
2726.05	3.70	2.50	1.097	1.173
2747.00	2.10	0.70	1.171	1.271
2757.00	3.70	0.80	1.257	1.373
2765.04	2.00	0.70	1.031	0.997
2780.60	1.90	0.70	1.002	1.016
2837.00	1.90	0.50	0.993	0.958
2840.00	1.80	0.80	0.989	1.039
2877.00	1.90	0.80	0.994	1.000
2905.00	1.70	0.80	0.989	1.011
2915.00	1.90	0.80	0.965	0.948
2956.00	1.90	0.80	0.938	0.996
2966.00	1.90	0.80	0.978	0.912
3000.50	8.50	3.30	1.286	1.366
3017.20	5.40	3.80	1.429	1.767
3024.00	1.80	0.80	0.964	0.941
3027.83	1.70	0.70	1.036	0.983
3032.30	2.10	0.60	0.997	0.941
3034.20	8.10	1.70	1.161	1.271
3039.40	4.70	0.30	1.365	1.143
3064.37	1.80	0.60	0.950	1.007
3071.57	9.10	1.90	1.289	1.367
3075.45	10.50	4.90	1.221	1.330
3081.50	1.80	0.80	1.001	1.016

1) $CPI\text{-}1 = \frac{1}{2}\ \frac{25+27+29+31}{24+26+28+30} + \frac{25+27+29+31}{26+28+30+32}$

2) CPI-3 = 2x27/26+28

Table 3 continued

DEPTH m	MPI-1 [1]	MPI-2 [2]	DEPTH m	MPI-1	MPI-2
1189.91			2716.23	0.586	0.428
1209.94			2716.97	0.542	0.372
1299.99			2718.04	0.548	0.399
1419.92			2719.10	0.581	0.474
1639.93			2720.05	0.598	0.488
1739.88			2721.10	0.777	0.624
1824.82			2722.03	0.573	0.445
1939.00	0.794	0.918	2723.12	0.636	0.592
1990.00			2724.10	0.572	0.543
2085.50			2725.07	0.626	0.524
2155.00	0.783	0.929	2726.05	0.557	0.499
2170.00	0.618	0.692	2747.00	0.558	0.552
2270.00	0.459	0.503	2757.00	0.683	0.617
2370.00			2765.04	0.649	0.605
2446.50			2780.60	0.673	0.654
2699.00	0.716	0.421	2837.00	0.649	0.557
2700.00	0.645	0.376	2840.00	0.629	0.525
2702.00	0.697	0.388	2877.00	0.638	0.627
2703.00	0.719	0.416	2905.00	0.657	0.665
2704.00	0.660	0.382	2915.00	0.625	0.615
2704.50	0.615	0.393	2956.00	0.658	0.655
2705.50	0.689	0.568	2966.00	0.598	0.553
2706.00			3000.50	0.551	0.516
2707.50	0.553	0.404	3017.20	0.597	0.490
2709.00	0.610	0.483	3024.00	0.622	0.539
2710.50	0.638	0.588	3027.83	0.609	0.506
2711.00	0.600	0.396	3032.30	0.527	0.491
2712.00	0.587	0.458	3034.20	0.515	0.436
2712.50	0.549	0.373	3039.40	0.555	0.530
2713.00	0.589	0.390	3064.37	0.641	0.593
2713.25	0.567	0.491	3071.57	0.478	0.434
2714.20			3075.45	0.512	0.470
2715.05			3081.50	0.982	1.091

1) $\text{MPI-1} = \dfrac{1.5(\text{3-MP} + \text{2-MP})}{\text{P} + \text{9-MP} + \text{1-MP}}$

2) $\text{MPI-2} = \dfrac{3(\text{2-MP})}{\text{P} + \text{9-MP} + \text{1-MP}}$

Table 4: Molecular ratios from the gas chromatograms of the aromatic hydrocarbons.

BIOMARKER RATIOS

DEPTH (m)	% 22S	Tm/Ts	N/N+H	% 20S	% abb	STR/TRIT.
1736.88				22	13	0.07
1824.84						0.19
1939.00	58	1.10	0.46	51	54	0.71
2155.00	67					0.56
2170.00						
2270.00	12		0.34			0.05
2699.00	58	2.30	0.40	31	25	0.39
2700.00	58	2.00	0.36	31	26	0.44
2702.00	63	2.10	0.35	30	26	0.37
2703.00	58	1.90	0.38	32	26	0.33
2704.00	58	1.80	0.38	31	27	0.38
2704.50	59	1.70	0.37	34	29	0.37
2705.50	59	2.10	0.37			
2706.00	60	2.40	0.37	38	32	0.43
2707.50	58	3.60	0.38	34	28	0.21
2709.00	58	3.40	0.37	37	27	0.28
2710.50	61	2.80	0.37	37	33	0.29
2711.00	59	4.60	0.37	38	27	0.17
2712.00	59	3.50	0.38	38	32	0.22
2713.35	59	2.90	0.38	40	40	0.21
2716.23	60	3.70	0.36	34	31	0.15
2716.97	60	16.00	0.41	29	30	0.06
2718.04	58	7.10	0.39	33	29	0.06
2719.10	61	22.00	0.44	26	26	0.09
2720.05	60	14.80	0.45	32	33	0.11
2721.10	58	10.00	0.42	31	29	0.11
2722.03	58	10.30	0.43	31	28	0.12
2723.12	63	2.60	0.39	38	42	0.28
2724.10	63	2.30	0.40	46	48	0.21
2725.07	61	2.90	0.40	41	38	0.99
2726.05	57	8.00	0.29	35	33	0.15
3017.20	61	7.30	0.37	52	42	0.08
3024.00	62	3.90	0.27	57	65	0.43
3027.83	65	5.30	0.27	63	67	0.39
3032.30	60	4.80	0.46	52	45	0.08
3034.20	59		0.48	47	33	0.05
3039.40						0.35
3064.37	61	0.44	0.33			0.40
3071.57	58	24.70	0.48	45	32	0.05
3075.45	59	22.00	0.57	48	38	0.03
3081.50	62	3.50	0.31	62	68	0.40

1) %22S homohopane
2) norhopane/norhopane+hopane
3) %20S aaa 24-ethylcholestane
4) %abb 24-ethylcholestanes
5) steranes/triterpanes

Table 5 : Biomarker ratios from m/z 191 and 217 fragmentograms.

PYROLYSIS GC RESULTS

DEPTH (m)	METHANE	C2-C5	C6-C14	C15+
1824.82	6.9	19.6	45.3	28.2
2085.50	4.2	16.3	43.1	36.4
2700.00	2.6	11.7	26.4	59.2
2703.00	2.8	14.1	30.7	52.3
2709.00	5.2	15.8	42.6	36.4
2711.00	3.3	11.7	27.8	57.2
2713.00	3.7	12.8	33.0	50.4
2718.04	3.3	15.6	36.4	44.8
2725.07	8.1	18.8	45.6	27.5
2726.05	8.1	24.3	63.1	4.5
2757.00	2.9	13.1	30.3	53.7
2837.00	5.9	12.1	23.0	59.0
2840.00	2.1	9.9	28.3	59.7
2877.00	6.1	18.4	36.8	38.8
3000.50	3.8	10.6	29.1	56.6
3027.83	3.7	6.7	24.0	65.6
3039.40	6.0	16.1	36.6	41.3
3064.37	6.9	12.8	23.5	56.7
3075.45	0.5	10.6	31.9	57.0

Table 6: Results from the pyrolysis-GC in % of total area.

Table 7: Results of vitrinite reflectance measurements.

VITRINITE REFLECTANCE

DEPTH (m)	Ro %	No OF PARTICLES	DEPTH (m)	Ro %	No OF PARTICLES
1189.91	0.24	6	2550.00	0.40	1
1209.94	0.26	4	2590.00	0.52	2
1249.96	0.44	4	2590.00	0.50	4
1299.99	0.29	1	2700.00	0.44	23
1419.92	0.29	2	2702.00	0.45	11
1639.93	0.37	7	2703.00	0.43	21
1739.88	0.34	10	2704.00	0.40	20
1824.82	0.29	20	2719.10	0.51	6
1844.94	0.29	20	2747.00	0.47	5
1939.00	0.69	4	2757.00	0.50	8
1990.00	0.58	13	2837.00	0.52	21
2083.50	0.59	20	2994.55	0.46	23
2170.00	0.57	4	3037.60	0.63	20
2270.00	0.62	8	3039.40	0.96	20
2370.00	0.58	4	3071.57	0.66	20
2446.00	0.63	2	3113.00	0.67	2
2446.50	0.54	4			

Tab.8: Relative amount of 6 kerogen types, amorphous material, total amount of organic carbon (TOC), hydrogen indices (HI), and maximum temperature (pyrolysis) T max. Well 6407/7-1.

VISUAL KEROGEN ANALYS..

	DEPTH IN M	OPAQUE WOOD	DENSE WOOD	STRUCT. WOOD	PALYNO-MORPHS	PYRIT. WOOD	CUTICULA	AMORPH. MATERIAL	SAMPLE TYPE	TOC	HI	T.MAX	DEPTH IN M
1	1805.15	1.3	9.1		89.6			100	SWC	2.46	149	416	1805.15
2	1824.82	0.5	1.0	4.6	93.9			100	SWC	2.50	200	425	1824.82
3	1844.84	1.7		0.8	97.5			70	SWC	2.15	188	415	1844.84
4	1898.08	17.6	3.9	3.9	74.6				SWC	0.48	400		1898.08
5	1927.00	15.6	7.8	6.3	70.3				SWC	0.66	195		1927.00
6	1946.00	90.0	10.0						SWC		0		1946.00
7	1981.00	67.8		9.2	23.0				SWC	0.63	167		1981.00
8	2121.00	60.5	3.2	6.0	30.3				SWC	1.05	290	430	2121.00
9	2190.00	75.9	3.0	7.8	13.3				SWC	0.80	224	453	2190.00
10	2276.50	31.5	5.5	18.2	44.8				SWC	2.01	116		2276.50
11	2314.00	100.0							SWC	0.98	228		2314.00
12	2425.00	48.3	6.9	8.0	36.8				SWC	1.17	136		2425.00
13	2590.00			5.7	28.6	65.7			SWC	0.94	106	446	2590.00
14	2630.00			2.5	5.9	91.6			SWC	1.10	100	439	2630.00
15	2649.00			3.4	16.6	80.0			SWC	0.95	80	441	2649.00
16	2670.00	47.7	12.0	8.6	29.4		2.3		SWC	0.61	144		2670.00
17	2699.00	17.2	27.6	6.9	48.3			15	SWC	4.44	368	427	2699.00
18	2702.00	13.3		6.7	80.0			50	SWC	3.94	379	423	2702.00
19	2704.00	21.0	10.5	10.5	58.0			30	SWC	4.67	367	424	2704.00
20	2711.00	46.6		6.7	46.7			100	SWC	5.17	329	424	2711.00
21	2713.25	75.3	1.4	13.7	9.6				CC	0.49	88	426	2713.25
22	2720.05	66.3		26.5	7.2				CC	2.88	70	435	2720.05
23	2747.00	78.4	1.0	13.4	7.2				SWC	1.62	59	430	2747.00
24	2757.00	32.3		15.6	52.1				SWC	12.11	515	424	2757.00
25	2774.00	62.5	10.9	14.1	12.5				CC	1.27	160	437	2774.00
26	2781.00	90.0		6.0	4.0				CC	0.90	150	440	2781.00
27	2790.00	20.3	3.4	28.8	47.5				CC	1.63	339	440	2790.00
28	2821.80	4.6	3.8	30.8	59.3		1.5		CC	1.30	467	438	2821.80
29	2830.03				85.0		15.0	80	CC	2.53	633	436	2830.03
30	2837.00	100.0							SWC		0		2837.00
31	2871.00	8.0	12.0	14.7	52.0		13.3		CC	1.58	163	433	2871.00
32	2890.00	21.3	9.0	9.0	47.2		13.5		CC	1.18	196	422	2890.00
33	2911.00	31.9	10.6	6.4	44.7		6.4		CC	1.75	263	441	2911.00
34	2992.00	60.0	40.0						CC	1.04	122		2992.00
35	3037.60	75.0	25.0						CC	1.78	88	456	3037.60
36	3040.85	10.0			20.0		70.0		CC	2.19	326	445	3040.85
37	3045.00	100.0							SWC	26.18	239	442	3045.00
38	3092.40	73.3	22.2		1.5		3.0		CC	1.61	226	434	3092.40

NB! The amount of cuticula fragments is not representative for the total because the larger fragments are not included in the slide material.

APPENDIX I

SOURCE ROCK EVALUATION 6407/7-1

FIGURES

HALTENBANKEN

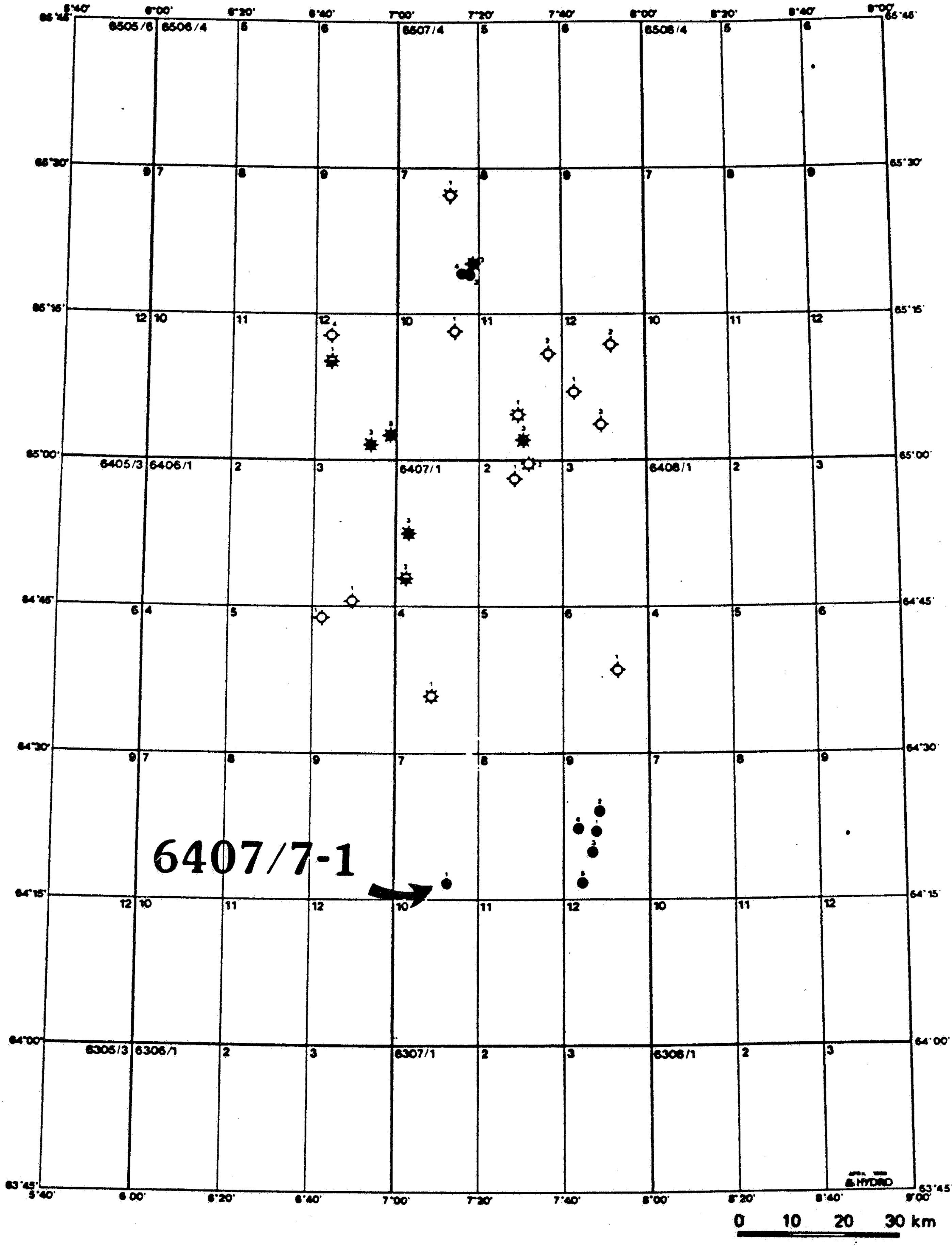


Figure 1: Well location map.

Well : 6407/7-1

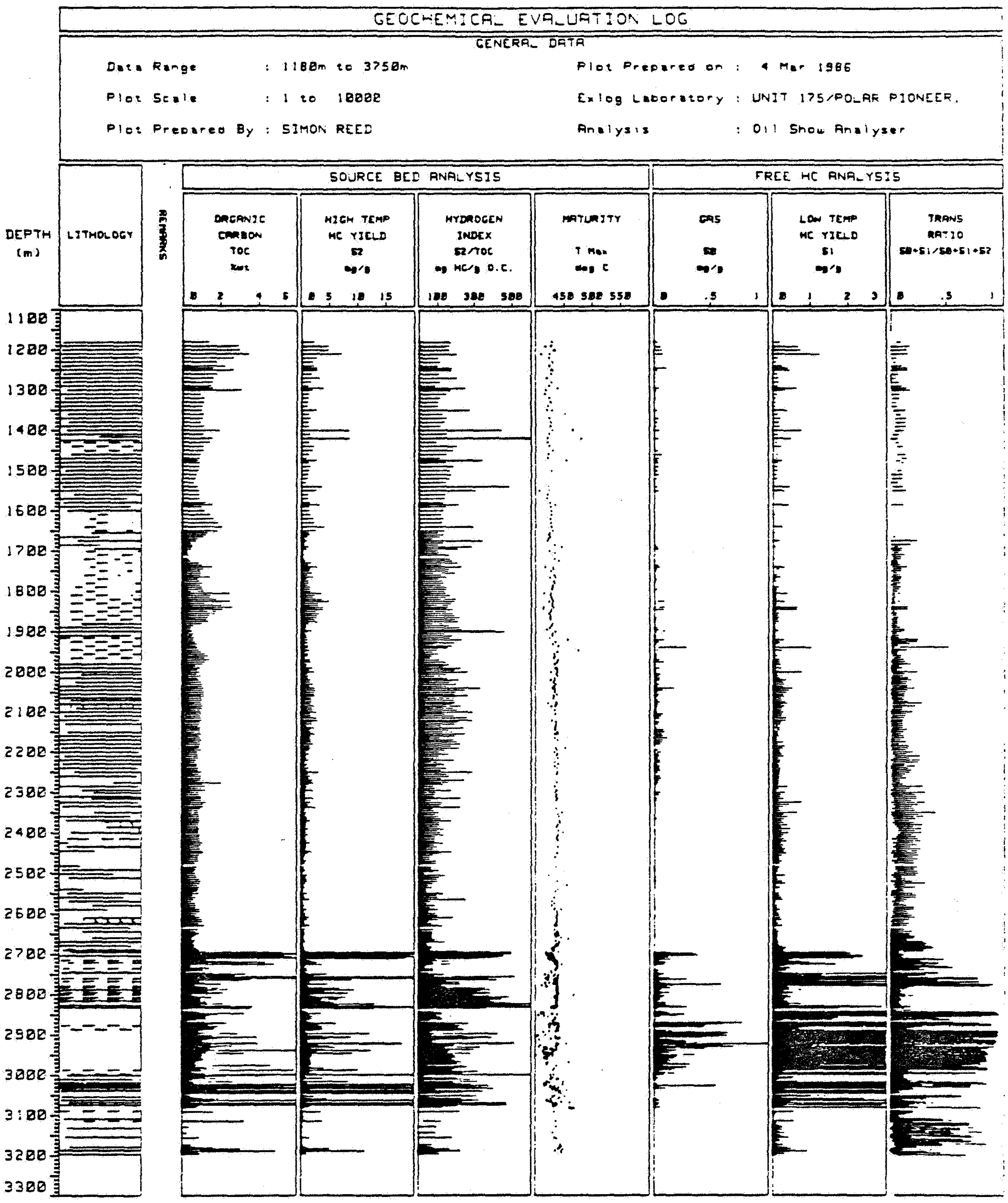
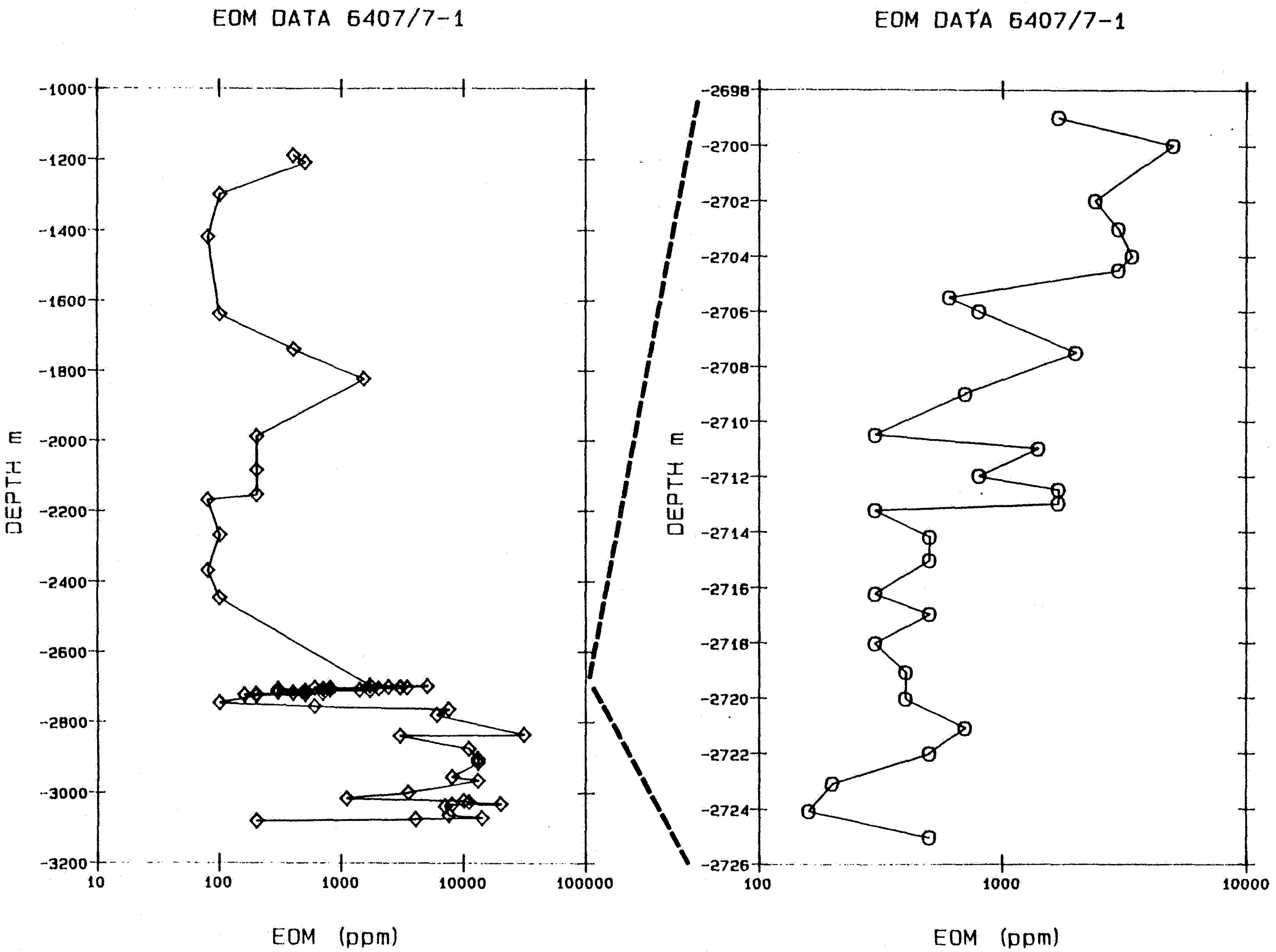


Figure 2: Geochemical Evaluation log well 6407/7-1.

Figure 3: EOM (ppm) plotted versus depth.



EOM DATA 6407/7-1
DEPTH m
-1000
-1200
-1400
-1600
-1800
-2000
-2200
-2400
-2600
-2800
-3000
-3200
10
100
1000
10000
100000
EOM (ppm)
EOM DATA 6407/7-1
DEPTH m
-2698
-2700
-2702
-2704
-2706
-2708
-2710
-2712
-2714
-2716
-2718
-2720
-2722
-2724
-2726
100
1000
10000
EOM (ppm)

Figure 4: EOM/TOC plotted versus depth

WELL: 6407/7-1 EOM/TOC

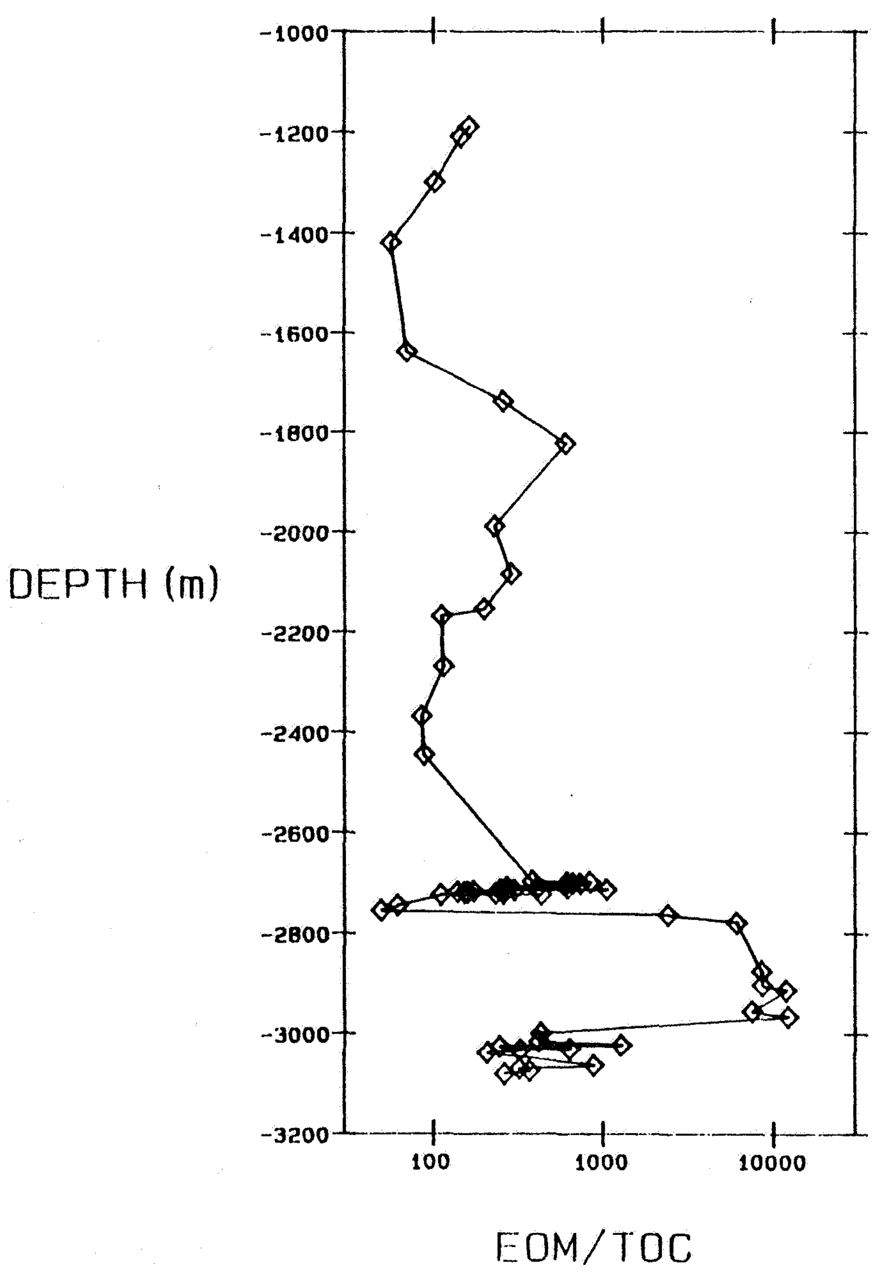
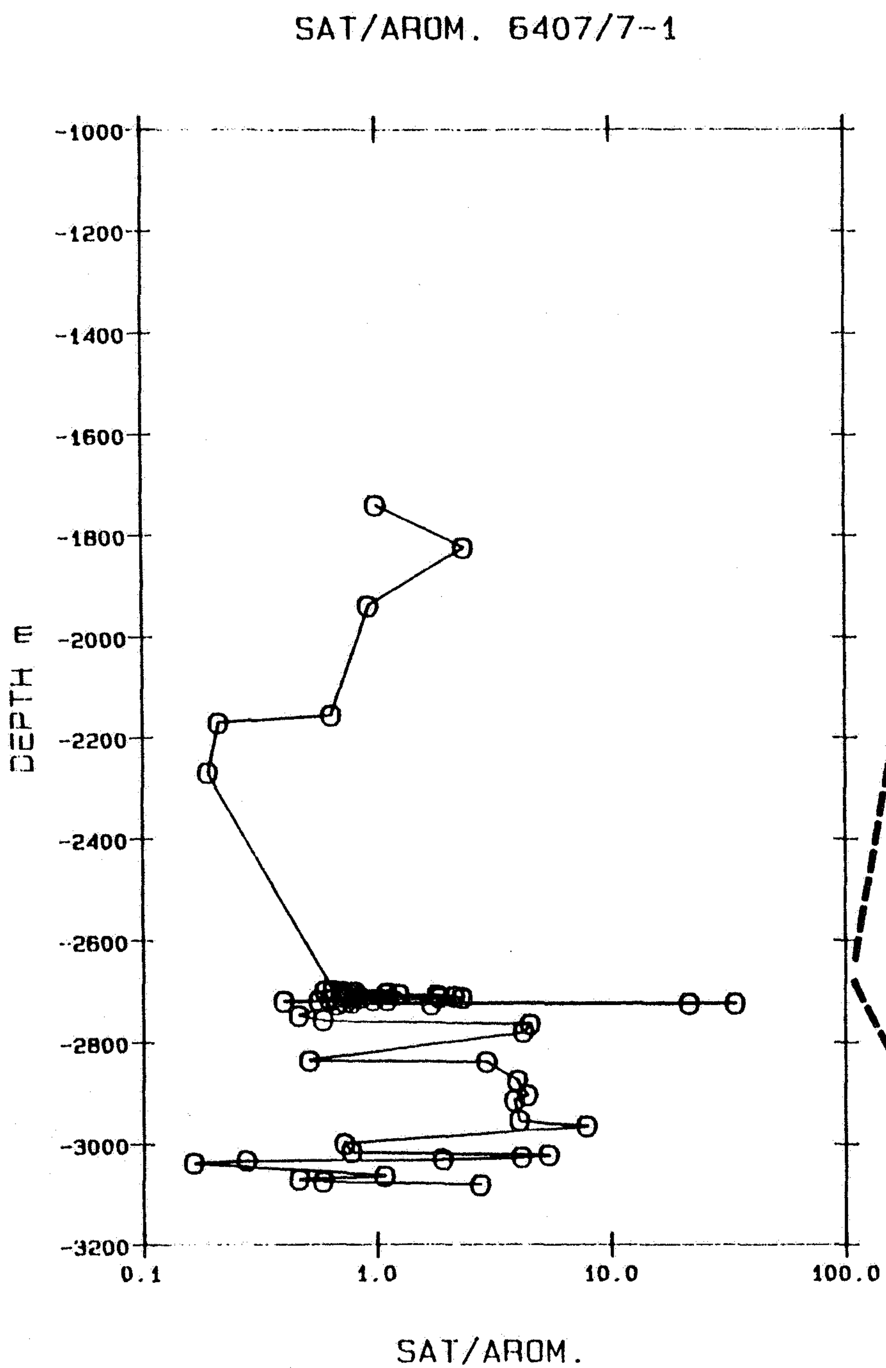
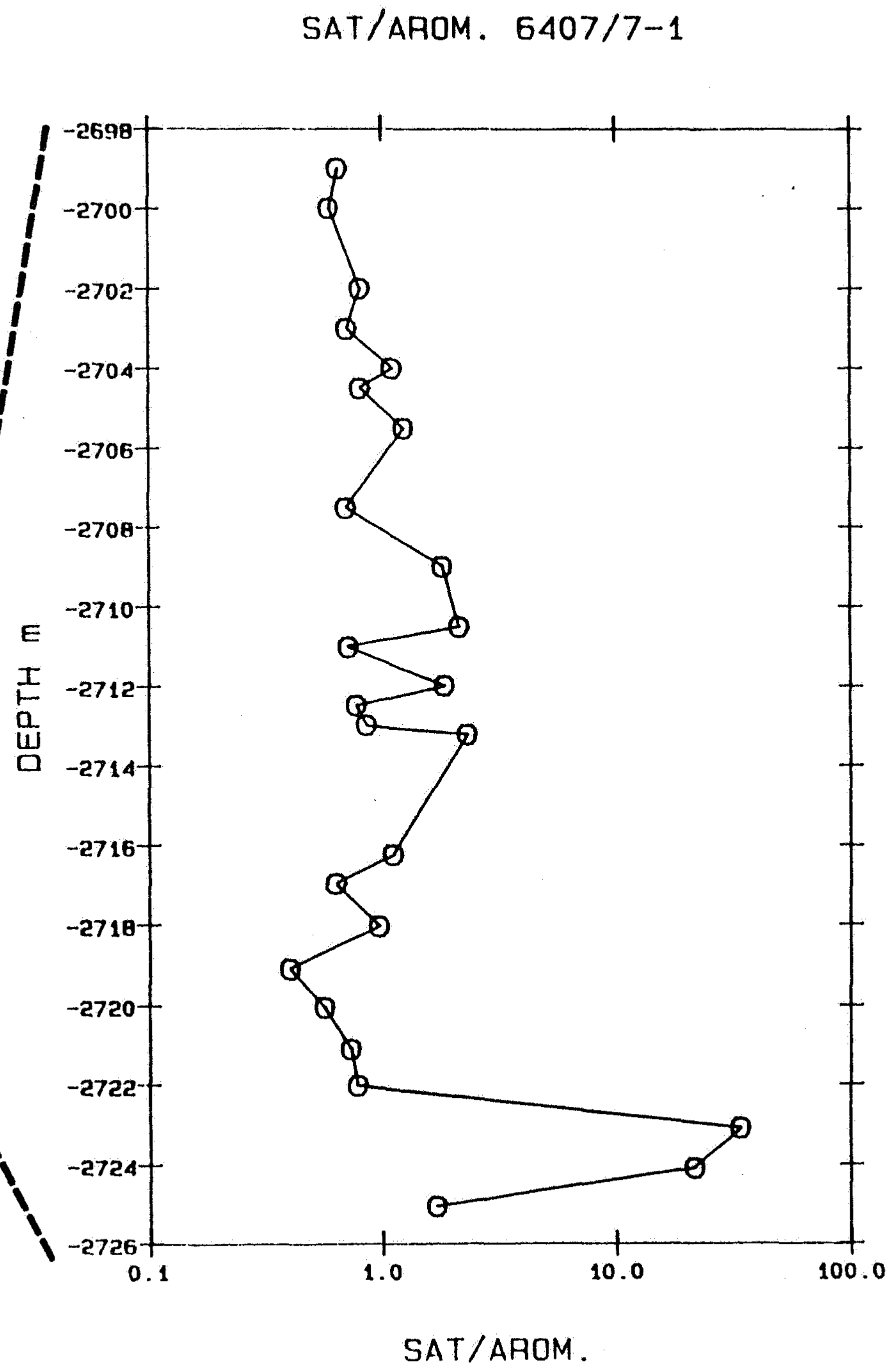


Figure 5: Saturates/aromatic hydrocarbons plotted versus depth.



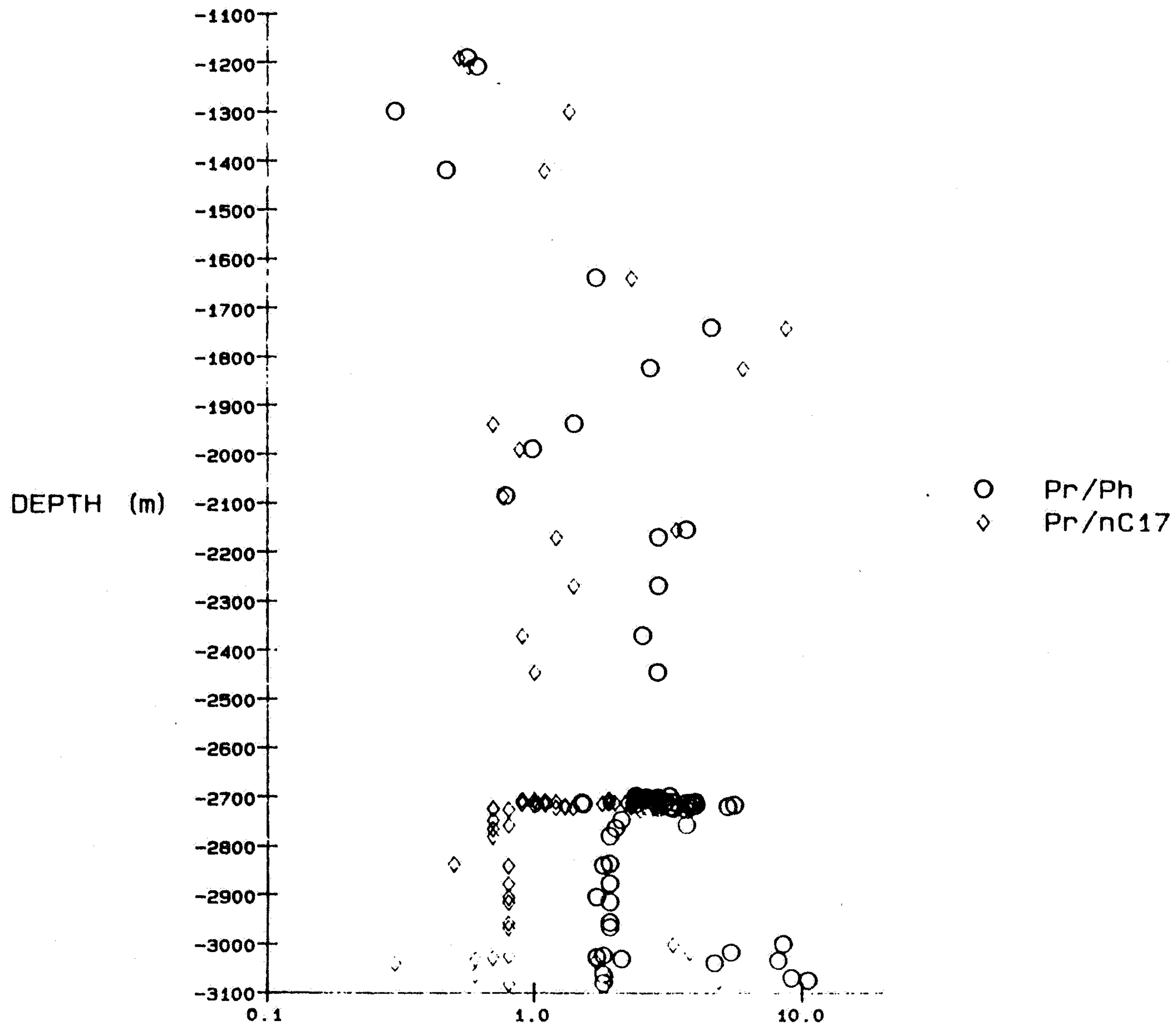
SAT/AROM. 6407/7-1
DEPTH m
-1000
-1200
-1400
-1600
-1800
-2000
-2200
-2400
-2600
-2800
-3000
-3200
0.1
1.0
10.0
100.0
SAT/AROM.



SAT/AROM. 6407/7-1
DEPTH m
-2698
-2700
-2702
-2704
-2706
-2708
-2710
-2712
-2714
-2716
-2718
-2720
-2722
-2724
-2726
0.1
1.0
10.0
100.0
SAT/AROM.

Figure 6: Pristane/phytane and pristane/n-C_{17} plotted versus depth.

GC DATA 6407/7-1



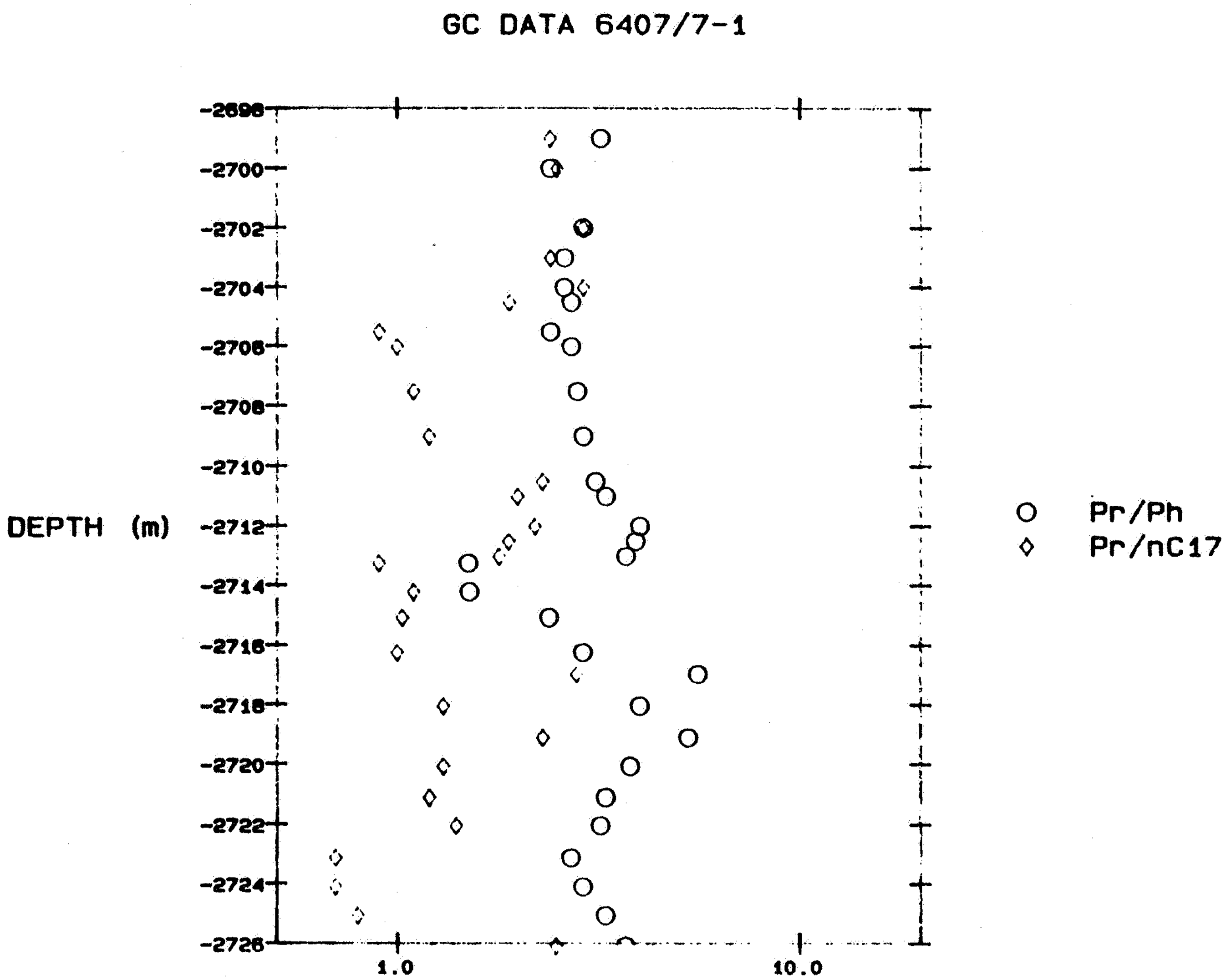

GC DATA 6407/7-1
DEPTH (m)
-2698
-2700
-2702
-2704
-2706
-2708
-2710
-2712
-2714
-2716
-2718
-2720
-2722
-2724
-2726
1.0
10.0
Pr/Ph
Pr/nC17

Fig.7: Vitrinite reflectance (mean Ro%) versus depth, well 6407/7-1.

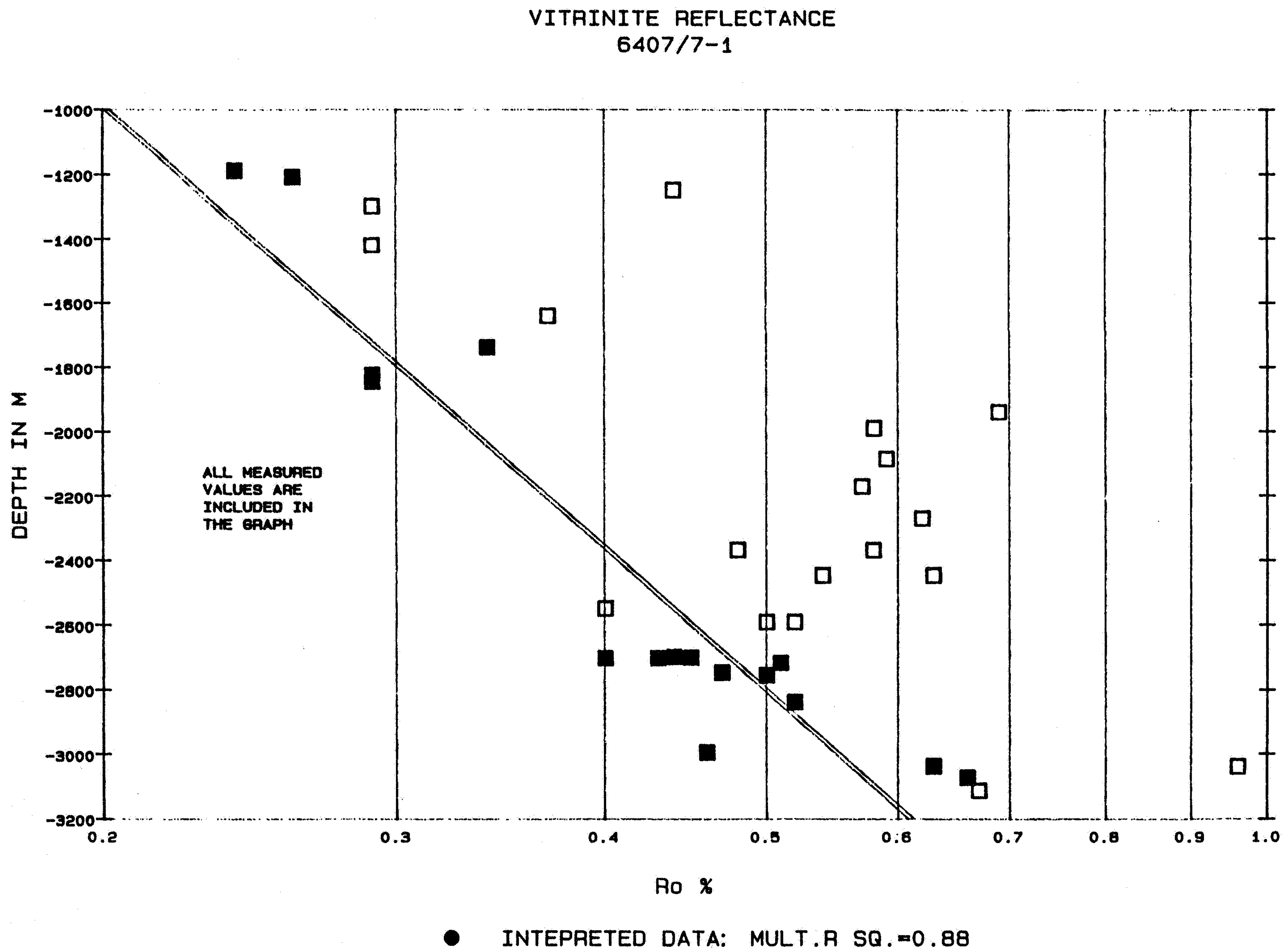
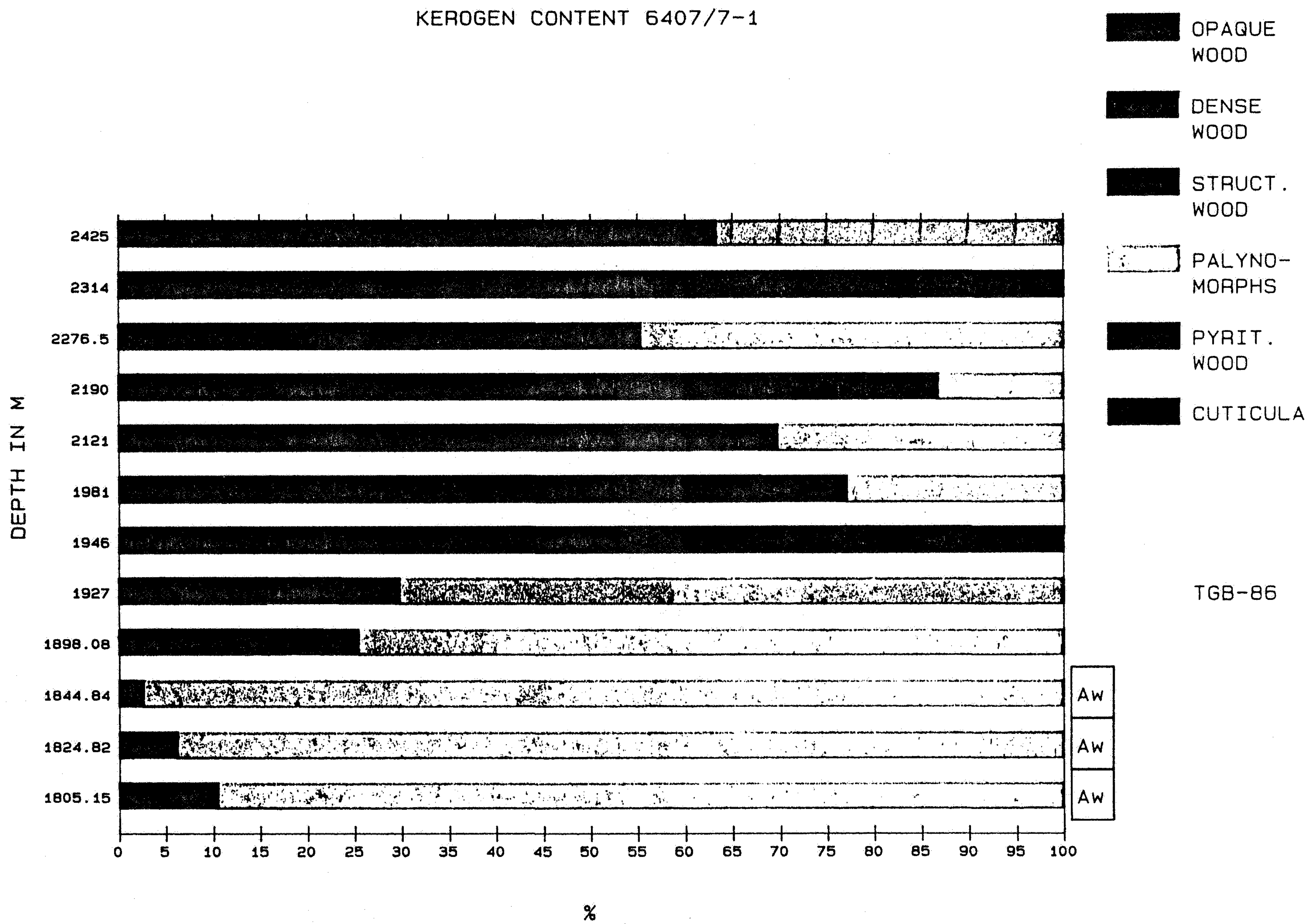
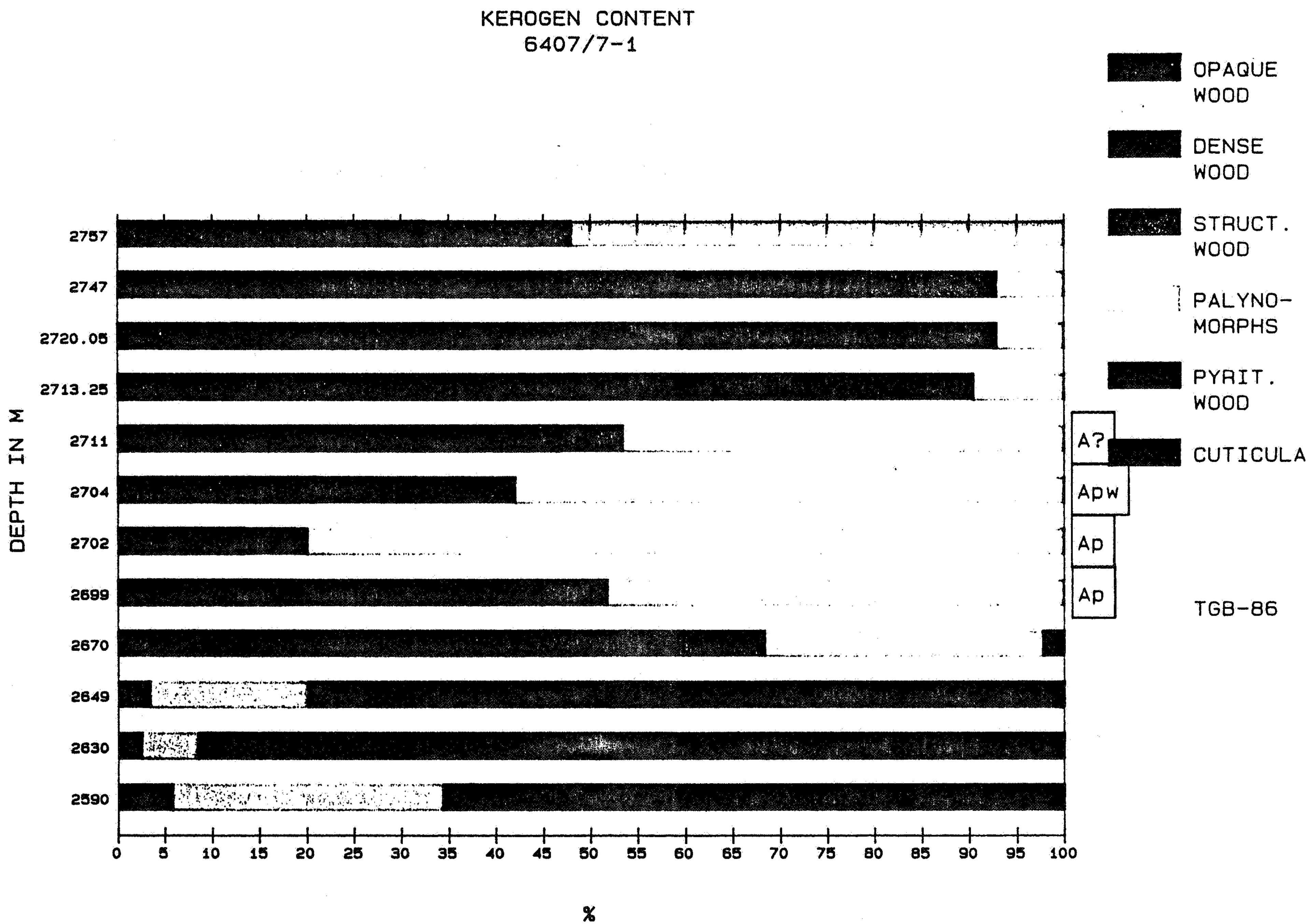

VITRINITE REFLECTANCE
6407/7-1
DEPTH IN M
-1000
-1200
-1400
-1600
-1800
-2000
-2200
-2400
-2600
-2800
-3000
-3200
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Ro %
ALL MEASURED
VALUES ARE
INCLUDED IN
THE GRAPH
INTEPRETED DATA: MULT.R SQ.=0.88

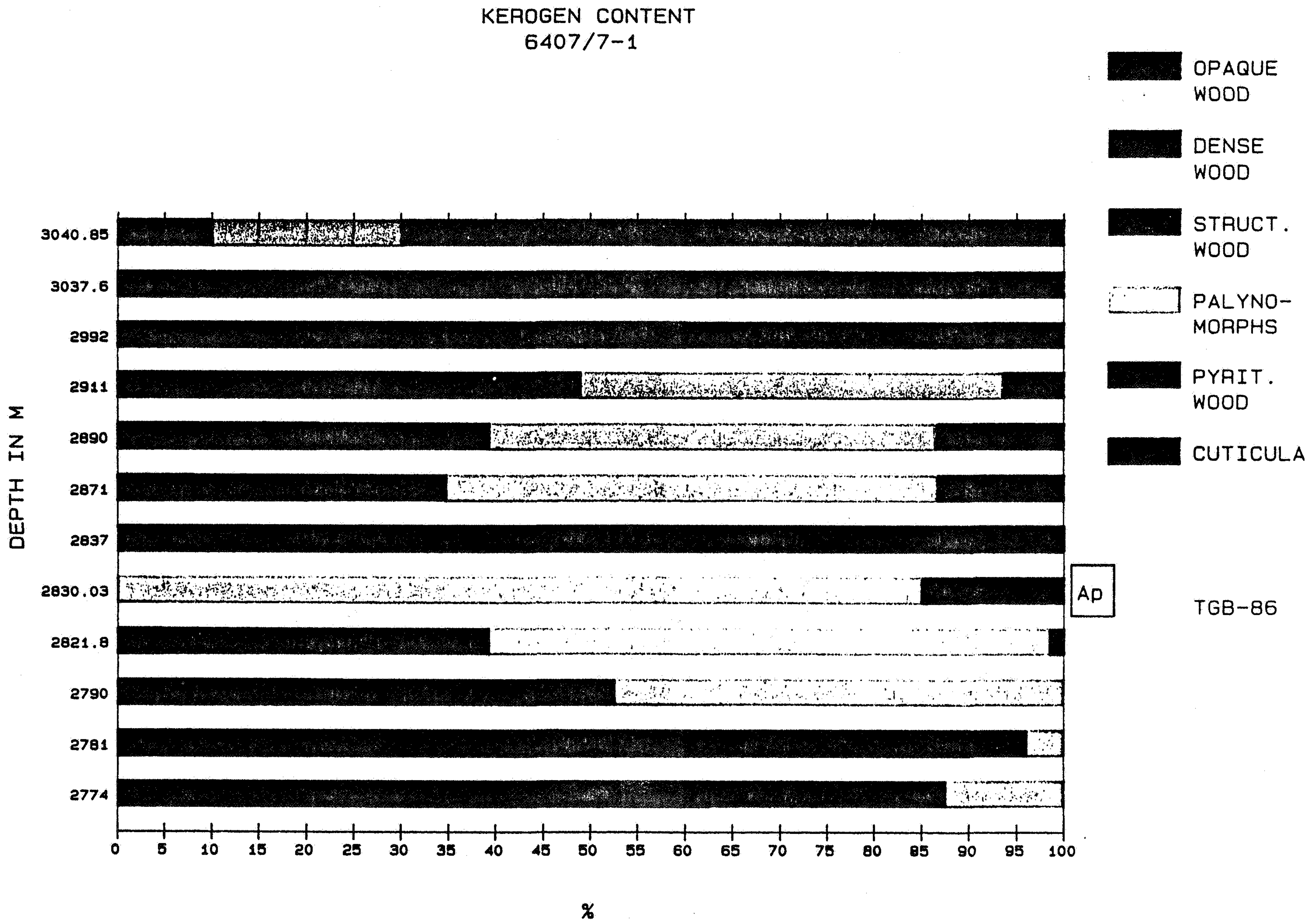
Fig.8: Relative amount of kerogen types in each sample, well 6407/7-1.



KEROGEN CONTENT 6407/7-1
OPAQUE WOOD
DENSE WOOD
STRUCT. WOOD
PALYNO-MORPHS
PYRIT. WOOD
CUTICULA
DEPTH IN M
2425
2314
2276.5
2190
2121
1981
1946
1927
1898.08
1844.84
1824.82
1805.15
Aw
Aw
Aw
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
%
TGB-86



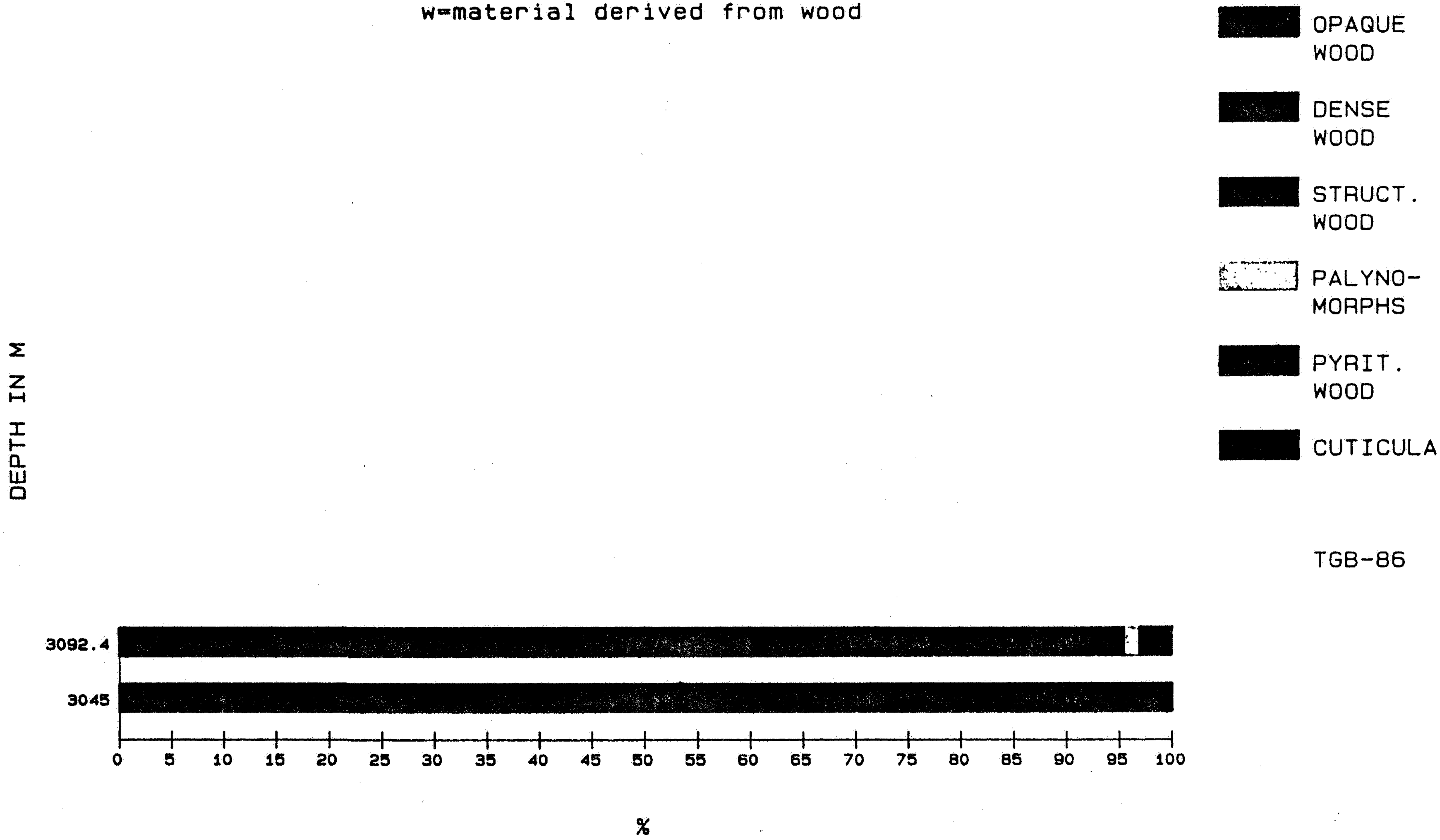
KEROGEN CONTENT
6407/7-1
OPAQUE WOOD
DENSE WOOD
STRUCT. WOOD
PALYNO-MORPHS
PYRIT. WOOD
CUTICULA
DEPTH IN M
2757
2747
2720.05
2713.25
2711
2704
2702
2699
2670
2649
2630
2590
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
%
A?
Apw
Ap
Ap
TGB-86



KEROGEN CONTENT
6407/7-1
DEPTH IN M
3040.85
3037.6
2992
2911
2890
2871
2837
2830.03
2821.8
2790
2781
2774
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
%
Ap
OPAQUE WOOD
DENSE WOOD
STRUCT. WOOD
PALYNO-MORPHS
PYRIT. WOOD
CUTICULA
TGB-86

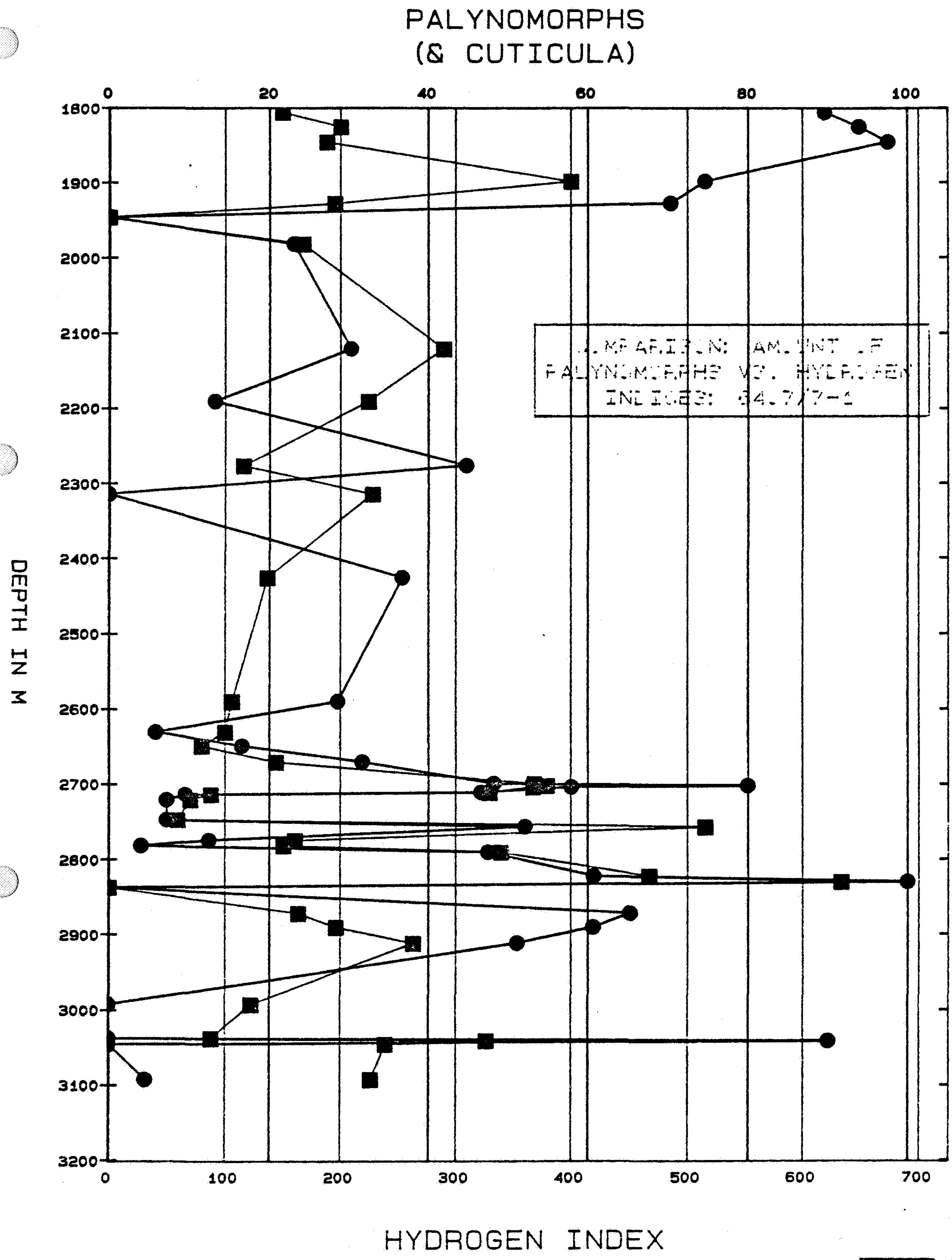
KEROGEN CONTENT
6407/7-1

A=amorphous material
p=material derived from palynomorphs
w=material derived from wood



TGB-86

Fig.9: Relation between hydrogen indices (HI) and amount of palynomorphs (and cuticula fragments) versus depth, well 6407/7-1.



PALYNOMORPHS
(& CUTICULA)
0
20
40
60
80
100
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
DEPTH IN M
0
100
200
300
400
500
600
700
HYDROGEN INDEX

MATURITY	KEROGEN	PETROLEUM POTENTIAL
2000M EARLY MATURE	II (DEGRADED III) LARGE AMOUNTS OF WOOD 2590M	1980M POOR-FAIR POOR
2697M	PYRITIZED WOOD III	
2713M	II LARGE AMOUNTS OF AMORPHOUS MATERIAL	VERY GOOD
3000M	III/IV 2780M	
MIDDLE MATURE 3200M	II III/IV (CUTICULA FRAGMENTS)	NO TO EXCELLENT

Figure 10: Summary of the source rock evaluation of well 6407/7-1.

SOURCE ROCK EVALUATION

6407/7-2

TABLE OF CONTENTS

PAGE

I. INTRODUCTION

This report gives the results of the source rock evaluation and maturity estimations of well 6407/7-2.

Well 6407/7-2 was drilled by Norsk Hydro Produksjon A/S, was spudded 19.11.86 and reached T.D. at 3323 m RKB in Triassic interbedded sandstones/claystones.

A well location map is given in Fig. 1.1.

Screening by 'OilShow Analyser' of the Jurassic section in the well was undertaken by Exlog. Based on these results intervals to be covered by Side Wall Cores (SWC) were selected. Selected SWCs and CCs (Core Cuttings) were analysed in Norsk Hydro Research Center in Bergen, Norway.
The aim of these analyses were to define organic facies and depositional environments within this well, and to establish a reliable maturity profile.

Vitrinite reflectance measurements have been undertaken by Geooptics in Newcastle upon Tyne. Interpretation and compilation of this report has been carried out at Norsk Hydro Research Center in Bergen.

A list of samples selected for geochemical analysis is given in Table I.1.

Fig. I.2. gives a summary of the source rock evaluation and thermal maturities for well 6407/7-2.

II. SOURCE ROCK EVALUATION

II.1. RockEval and TOC analysis.

Well 6407/7-2 has been screened by Oil Show Analyser giving both the traditional RockEval parameters and TOC results. Analysis were carried out on 76 cuttings samples, 110 core samples and 75 SWCs. In addition, some samples from coaly horizons have been analysed by Norsk Hydro Research Center in Bergen.

The RockEval and TOC data are listed in Table II.1.1. All the Exlog data have been plotted versus depth in Fig. II.1.1..

Based on these results the well can be divided into four facies based on lithology and content of organic matter:

Organic Facies 1 (1716 m -2638 m) Tertiary/Cretaceous:

This section consisting mainly of grey to brown claystones gave low pyrolysis yields (S_2). This suggests a poor source rock potential. TOC values average 1.2%. The amount of pyrolysable hydrocarbons (S_2) are averaging 1.5 kgHC/t rock. Some horizons, however, display values in excess of 2 kgHC/t rock of pyrolysable hydrocarbons. One sample (2587 m) show excellent source rock properties with a TOC value of 8.05 % and S_2 of 29.9 kgHC/t rock.

Organic Facies 2 (2638 m - 2679 m) Upper Jurassic:

This section which consists of Upper Jurassic dark grey to green shales of the Nesna and Engelvær Fms. can according to the screening data be classified as good source rocks. Average organic matter content is 3.96 % TOC, and 11.3 kgHC/t rock of pyrolysable hydrocarbons. This gives an average Hydrogen Index (100 x S_2/TOC) of 285 mgHC/g TOC. Two SWC samples (2640 m and 2650 m) show an excellent source potential with TOC values of 7.56 % and 8.00 % and S_2 values of 36.9 and 37.7 kgHC/t rock respectively.

The Hydrogen Indices (HI) for the two rich SWCs indicate a Type II kerogen (488 and 471 mgHC/g TOC). The rest of the Hydrogen Indices suggest a mixed Type II/III to dominantly Type III kerogen.

TOC values are plotted versus depth in Fig. II.1.2. and show that the source rock quality in general is best in the Upper part of the interval (Nesna Fm.) decrease downwards in the Engelvær Fm. There is a slight increase in quality in the bottom part of the interval.

Organic Facies 3 (2679 m - 2934 m) Middle/Lower Jurassic:

This facies consists mainly of sandstone with thin interbedded claystones, shales and coals. Most of the analysed samples in the cored section are appearantly heavily contaminated by migrated hydrocarbons. Analysis of the uncontaminated fine grained argillaceous and coaly sections suggest mainly a poor source rock potential.

Some thin shales/coals in the lower part of the section (2838 m - 2913 m) have excellent source potential with pyrolysis yields extending up to 200 kgHC/t rock with high Hydrogen Indices indicating oil prone organic matter.

Organic Facies 4 (2934 m - 3315 m) Triassic:

This section consists of massive sandstones with interbedded claystones. The highest TOC values recorded from this section is 1.14 %. Pyrolysable hydrocarbon yield is consistently low, averaging 0.2 kgHC/t rock

II.3. Gas chromatography of saturated hydrocarbons.

All gas chromatograms including the normalised distribution of the n-alkanes and regular isoprenoids are given in Appendix I. Some samples have not been group type separated due to limited amounts of extractable organic matter. The chromatograms of the total EOM are given.

Table II.3.1. lists some of the molecular ratios calculated from the integrated gas chromatograms of the saturated hydrocarbons.

In the samples down to 2500 m, biomarkers are clearly visible in the gas chromatograms indicating a relatively low maturity of this section. This is supported by the high Pristane/n-C_{17} ratio of these samples. This ratio decreases with depth reflecting the generation of n-alkanes from the kerogen with increasing thermal stress resulting in higher Pristane/n-C_{17} ratios. Exceptions, however, are seen in the coal samples from 2881 to 2913 m.

The Pristane/Phytane ratio is relatively high in all samples, which could suggest an oxic depositional environment. This ratio is also influenced by the type of organic matter which could contribute to the high ratio, particularly in the interval from 2638 to 2661 m. The Pristane/n-C_{17} and Pristane/Phytane ratios are plotted versus depth in Figure II.3.1.

The two samples at 2673 and 2678.8 m display a smooth unimodal n-alkane distribution suggesting contamination by migrated hydrocarbons. The other samples down to the sandstone at 2870 m show a n-alkane distribution dominated by heavy compounds and high CPI-1 indices, indicating immature sediments with input of mixed organic matter.

The sandstones at 2872, 2874 and 2876 m are clearly impregnated by migrated, fairly mature hydrocarbons, displaying a smooth unimodal n-alkane distribution with a maximum below n-C_{17} and a low Pristane/n-C_{17} ratio.

The gas chromatograms of the coal samples show a very broad hump of unresolved compounds caused by a high content of naphthenes.

II.4. Gas chromatography of aromatic hydrocarbons.

All gas chromatograms of the aromatic hydrocarbons are given in Appendix II.

The chromatograms of the samples of the upper part of the well (1716 - 2251 m) appear without any distinct pattern typical of the aromatic fraction of very immature samples. Retene (1-methyl-7-isopropylphenanthrene) seems to be present in these samples, indicating contribution from terrestrially derived organic matter.

From 2425 m down there is a maturation of the aromatic fraction resulting in a gradual appearance of only substituted polycyclic aromatic hydrocarbons like naphthalene and phenanthrene. The methylated phenanthrenes seem to dominate over the naphthalenes, but this is most likely due to an artifact caused by the concentration procedure.

There is no appearent maturation trend in the distribution of the methyl phenanthrene isomers. The 1- and 9-methyl phenanthrenes isomerise to the 2- and 3-methyl phenanthrenes with increased thermal stress, but this reaction is influenced by the matrix (type of organic matter) being much slower in a Type II than a type III kerogen.

II.5. Biological marker distribution.

The saturated and aromatic hydrocarbon fractions have been analysed by GC-MS using Selected Ion Monitoring (SIM) for the distribution of biological markers of the sterane and triterpane type in the saturated fractions, and aromatic steroids in the aromatic fractions.

Biomarker fragmentograms (m/z 191 and 217 from the saturated fractions and m/z 231 and 253 from the aromatic fractions) are given in Appendix III together with a tentative identification of selected peaks.

II.5.1. Steranes and Triterpanes.

The two samples from 1716 m and 1824 m are totally dominated by 28,30-bisnorhopane. The relative high concentrations of C_{30} and C_{27} steranes suggest a predominantly marine source. There is a very low concentration of rearranged steranes indicating a low abundance of acidic clay minerals in this section.

The sample at 1956.5 m is totally dominated of C_{27} steranes typical of marine deposits, while the triterpanes are dominated by thermodynamically unstable neohopenes typical of low maturity sediments.

The samples from 2025 m to 2632.5 m all contain mixed marine/terrestrial organic matter and is immature. Some of the samples are analysed only as deasphalted extracts, and the m/z 217 fragmentograms are often contaminated by non-hydrocarbons. The sample at 2075 m and 2251 m are rich in low molecular weight (C_{20}-C_{22}) steranes and these compounds thus appears to be source specific and not principally related to maturity.

The Upper Jurassic samples in the interval 2638 m to 2650 m (Nesna Fm.) are all dominated by C_{27} steranes indicating an organic matter of marine origin. The distribution of the triterpanes is very uniform within this interval. The samples from 2653 m to 2695 m (Engelvær Fm.) display a gradual increase in the relative concentration of C_{29} steranes with depth, indicating a higher input of terrestrially derived material in this interval.

In the other samples down to T.D., except those that are obviously contaminated by mature migrated hydrocarbons, the extracts are dominated by C_{29} steranes, indicating a further increase in the input of terrestrially derived organic matter.

The non-contaminated triterpanes all have low Ts/Tm ratios typical of terrestrially derived organic matter. Most of the samples and particularly the coal samples contain an unidentified C_{30}-triterpane eluting between hopane and moretane. This compound might be a terrestrial marker, typical for many of the coals in the Haltenbanken area.

The samples at 2872 m, 2874 m, 2876 m, 2952 m, 3032 m, 3109.5 m, 3243 m and 3298 m are obviously contaminated by migrated hydrocarbons because they appear to have a higher maturity than the trend within this well.

II.5.2. Aromatic Steroids.

The aromatic steroids may also be used as sensitive source indicators, particularly the carbon number distribution of the monoaromatic steroids can be used in this context.

The m/z 231 and m/z 253 fragmentograms are given in Appendix III.

There is a considerable variation in the distribution of the monoaromatic steroids (M/z 253) in the Tertiary/Cretaceous part of the well reflecting both maturity and source variations.

In the Jurassic part of the well many of the features observed in the nonaromatic steroids are reflected in the monoaromatic steroids. This is normal since the monoaromatic steroids are believed to be derived from the non-aromatic steroids.

The two lower samples in the Nesna Fm. (2647 m and 2650 m) have a much higher relative abundance of monoaromatic C_{27} steroids than the samples from 2638 m and 2640 m. This might suggest a higher marine influence in the lower section of the Nesna Fm.. The two samples from 2653 m and 2673 m (Engelvær Fm.) are richer in C_{29} monoaromatic steroids suggesting a higher terrestrial input to the organic matter in this interval.

In most of the deeper samples the m/z 253 fragmentograms are of very poor quality probably as a result of the group type separation.

II.6. Pyrolysis-Gas chromatography.

The pyrolysis-gas chromatograms (pyrograms) are given in Appendix IV, and the quantitative results are listed in Table II.6.1.

The sample from 2611 m (Cretaceous) is dominated by non-liptinitic material and gaseous hydrocarbons typical of gas-prone source rocks of predominantly marine origin.

The pyrograms from the interval 2638 m to 2653 m are all rich in liptinitic material, and are dominated by a homologous series of alkane/alkenes extending up to C_{30}. The ratio of xylene/n-octene is less than 1 in all these samples suggesting a predominantly marine organic matter. All the samples contain prist-1-ene typical of oil-prone organic matter at low maturities.

In the samples in the interval from 2661 m to 2695 m (Engelvær Fm) there is a gradual increase in the relative contents of humic material with depth. The xylene/n-octene ratio changes from 0.93 to 1.59. This parallells the change in the composition of the steranes which also indicate an increase in the input of terrestrially derived humic material with depth through the Engelvær Fm.

The sample at 2739.4 m (Tomma/Leka Fm.) are relatively rich in liptinitic material, but the homologous series of n-alkanes/alkenes does not extend beyond C_{22} suggesting that this section is mainly condensate prone while there is a predominance condensate range products from the pyrolysis-GC.

The coaly samples in the interval 2888.1 m to 2913 m are all dominated by gaseous hydrocarbons and aromatic hydrocarbons derived primarily from humic material. These will give rise to gas only.

The sample from 2934 m (Hitra Fm.) is richer in liptinitic material than the coaly material above and will be condensate prone. There is very little high molecular weight liptinitic material in this sample.

II.7. Visual Kerogen Analysis.

The results from the visual kerogen analysis are listed in Table II.7.1. and are presented as bar graphs in Fig. II.7.1.

The Cretaceous samples are dominated by woody and coaly material indicating a Type III kerogen. The relative amount of herbaceous material (spores, pollen and leaf cuticles) is increasing in the Upper Jurassic section (Nesna Fm.) indicating organic matter with better oil potential. The two samples from the Engelvær Fm. (2673 m and 2695 m) have higher relative amounts of herbaceous material than the Draupne Fm.. In contrast the other analysis clearly indicate that the organic material is be more terrestrially dominated. This suggests that there is another type of herbaceous material in the Engelvær Fm. compared to the Nesna Fm. The samples from Engelvær Fm. also contains some coaly material, suggesting a poorer preservation of the organic matter in this section.

The samples from the Leka Fm. (2750 m and 2760 m) are very rich in herbaceous material and this is supported by the Py-GC results.

The rest of the samples are dominated by woody and coaly material and are classified as a Type III kerogen with good gas potential.

III. MATURITY

III.1. Vitrinite Reflectance.

Vitrinite reflectance measurements have been carried out on 35 selected samples.

Histograms of the readings are given in Appendix V, and the mean values of the vitrinite reflectance populations are listed in Table III.1.1.. In Fig. III.1.1. the interpreted, true mean vitrinite reflectance measurements are plotted versus depth.

The interpreted vitrinite reflectance measurements changes from 0.31 at 1824 m in the Skomvær Group to 0.56 in coals at 2905.30 m. The rich source rocks in the Nesna Fm. have a maturity of 0.43 % R_o.

A number of the samples in the Tertiary/Cretaceous section are dominated by reworked matrial typical of this interval in the Haltenbanken area. Based on the results from this well and from well 6407/7-1 the reading of 0.31 at 1824 m is considered reliable.
Even the Upper Jurassic samples display a considerable spread, partly as a result of variations in the organic matter.

This indicates that most of the samples have not yet reached the main stage of oil generation and that only the bottom part of the well is marginally mature with respect to generation.

The source rocks in the Nesna/Engelvær Fms. are not mature enough to have generated significant amounts of hydrocarbons.

III.2. Thermal Alteration Indices.

This analysis have not been carried out on these samples.

III.3. Biological markers.

Epimerisation and isomerisation of steranes and pentacyclic triterpanes give good estimates of the thermal stress in immature and marginally mature sediments that have not been contaminated by migrated hydrocarbons.

The calculated sterane biomarker ratios are listed in Table III.3.1., and the epimerisation and isomerisation of regular C_{29} steranes are plotted versus depth in Fig. III.3.1.

% $\alpha\alpha\alpha$ 20S steranes varies from 16 % at 1716 m indicating clearly immature sediments with respect to oil generation, to near equilibrium at 58% at 3298 m indicating marginally mature sediments. These changes are also reflected in the %$\alpha\beta\beta$ values which increases with depth. This ratio is however more susceptible to variations in the depositional environment and source input due to the coelution with $\beta\alpha\alpha$ steranes.

The samples at 2625 m and 2632.5 m are clearly contaminated by mature migrated hydrocarbons of the same type as found in the interval 2872 m to 2876 m.

Based on these results it is obvious that only the deepest part of the well is marginally mature with respect to hydrocarbon generation.

The maturation trend from the isomerisation of steranes are confirmed by the epimerisation of the extended hopanes (% 22S). There is also a general decrease in the relative concentration of the thermodynamically unstable neohopenes and $\beta\beta$-hopanes with depth until they have disappeared at 2400 m. There is also a general decrease in the ratio of moretane/hopane with depth, except for the coaly sequences in the Middle Jurassic section (Table III.3.2.: Triterpane biological marker ratios). These results confirm the vitrinite reflectance results that only the deeper part of the well i marginally mature with respect to oil generation.

The general increase in the ratio of triaromatic steroids/monoaromatic steroids with depth reflects the higher thermal stability of the triaromatic steroids.

IV. SUMMARY

Four organic facies have been defined based upon richness and type of organic matter.

1) The Tertiary/Cretaceous section have a poor source rock potential. The Lower Cretaceous section is partly contaminated by migrated hydrocarbons.

2) The Upper Jurassic section (Nesna and Engelvær Fms.) have a good source potential for oil and gas. The relative amount of terrestrially derived organic matter is highest in the Engelvær Fm.

3) The Middle/Lower Jurassic sandstones have no source potential but are heavily contaminated by migrated hydrocarbons, and are partly oil stained. Thin shale/coal stringers interbedded in the sandstones have excellent source potential for oil and gas.

4) The Triassic section have no source potential.

The rich Upper Jurassic source rocks are marginally mature with respect to oil generation (Ro 0.43 %), and have not yet generated significant amounts of hydrocarbons.

Lateral, mature equivalent of the Upper Jurassic source rocks may have generated significant amounts of liquid hydrocarbons.

APPENDIX II

SOURCE ROCK EVALUATION 6407/7-2

TABLES

TABLE I.1

Samples analysed

Survey of analyses

EPTH m	SAMPLE TYPE	ROCK EVAL	TOC	EXTR.	ASPH.	GROUP SEP.	GCMS SAT,ARO	GCMS EOM	Ro	Pyr. GC	KER. TYPE
716.00	SWC	2	2	1	1	1	1		4		
775.00	SWC	2	2								
824.00	SWC	2	2	1	1	1	1		4		
956.50	SWC	2	2	1	1	1	1		4		
958.00	SWC	2	2								
975.00	SWC	2	2								
008.50	SWC	2	2								
025.00	SWC	2	2	1	1	1	1		4		
050.00	SWC	2	2								
075.00	SWC	2	2	1	1	1	1		4		
100.00	SWC	2	2								
139.00	SWC	2	2								
225.00	SWC	2	2								
251.00	SWC	2	2	1	1	1	1		4		
275.00	SWC	2	2								
300.00	SWC	2	2								
349.00	SWC	2	2								
425.00	SWC	2	2	1	1	1	1		4		
474.50	SWC	2	2								
482.85	CORE	2	2								
522.50	SWC	2	2								
550.00	SWC	2	2								
553.00	SWC	2	2	1	1			1	4		3
560.00	DC	2	2								
565.00	DC	2	2								
567.00	DC	2	2								
570.00	DC	2	2								
572.00	DC	2	2								
575.00	DC	2	2								
575.00	SWC	2	2								
577.00	DC	2	2								
580.00	DC	2	2								
582.00	DC	2	2								
585.00	DC	2	2								
587.00	DC	2	2								
587.00	SWC	2	2								
590.00	DC	2	2								
592.00	DC	2	2								
595.00	DC	2	2								
597.00	DC	2	2								
600.00	DC	2	2								
602.00	DC	2	2								
605.00	DC	2	2								
607.00	DC	2	2								
610.00	DC	2	2								
611.00	SWC	2	2	1	1			1	4	1	3
612.00	DC	2	2								
615.00	DC	2	2								
617.00	DC	2	2								
620.00	DC	2	2								
622.00	DC	2	2								
622.00	SWC	2	2								
625.00	DC	2	2								
625.00	SWC	2	2	1	1	1	1		4		3

DEPTH m	SAMPLE TYPE	ROCK EVAL	TOC	EXTR.	ASPH.	GROUP SEP.	GCMS SAT,ARO	GCMS EOM	Ro	Pyr. GC	KER. TYPE
2627.00	DC	2	2								
2630.00	DC	2	2								
2631.00	SWC	2	2								
2632.00	DC	2	2								
2632.50	SWC	2	2	1				1	4		3
2635.00	DC	2	2								
2637.00	DC	2	2								
2638.00	SWC	2	2	1	1	1	1		4	1	3
2640.00	DC	2	2								
2640.00	SWC	2	2	1	1	1	1		4	1	
2642.00	DC	2	2								
2645.00	DC	2	2								
2647.00	DC	2	2								
2647.00	SWC	2	2	1	1	1	1		4	1	
2650.00	DC	2	2								
2650.00	SWC	2	2	1	1	1	1		4	1	3
2652.00	DC	2	2								
2653.00	SWC	2	2	1	1	1	1		4	1	3
2655.00	DC	2	2								
2657.00	DC	2	2								
2660.00	DC	2	2								
2661.00	SWC	2	2	1	1	1	1		4	1	
2662.00	DC	2	2								
2665.00	DC	2	2								
2667.00	DC	2	2								
2672.00	DC	2	2								
2673.00	CORE	2	2								
2673.00	SWC	2	2	1	1	1	1		4	1	3
2674.00	CORE	2	2								
2675.00	CORE	2	2								
2676.00	CORE	2	2								
2677.10	CORE	2	2								
2678.00	CORE	2	2								
2678.80	CORE	1	1	1	1	1	1		4	1	
2678.80	CORE	2	2								
2679.00	CORE	2	2								
2680.00	CORE	2	2								
2681.00	CORE	2	2								
2681.75	CORE	1	1	1	1	1	1		4		
2681.75	CORE	2	2								
2682.00	CORE	2	2								
2683.00	CORE	2	2								
2684.00	CORE	2	2								
2684.65	CORE	1	1								
2684.65	CORE	2	2								
2685.00	CORE	2	2								
2685.40	CORE	1	1								
2685.40	CORE	2	2								
2686.00	CORE	2	2								
2686.10	CORE	2	2								
2690.00	DC	2	2								
2690.00	SWC	2	2								
2692.00	DC	2	2								
2693.00	SWC	2	2								

LEGEND :

1 : Norsk Hydro
3 : University of Bergen
2 : [illegible]
4 : Geo Optic

Well 6407/7-2

Survey of analyses

DEPTH m	SAMPLE TYPE	ROCK EVAL	TOC	EXTR.	ASPH.	GROUP SEP.	GCMS SAT,ARO	GCMS EOM	Ro	Pyr. GC	KER. TYPE
2695.00	DC	2	2								
2695.00	SWC	2	2	1	1	1	1		4	1	3
2698.00	SWC	2	2								
2701.00	CORE	2	2								
2702.00	DC	2	2								
2702.00	CORE	2	2								
2703.00	CORE	2	2								
2704.00	CORE	2	2								
2705.00	DC	2	2								
2705.00	CORE	2	2								
2706.00	CORE	2	2								
2707.00	DC	2	2								
2707.00	CORE	2	2								
2708.00	CORE	2	2								
2708.90	CORE	2	2								
2710.00	DC	2	2								
2710.00	CORE	2	2								
2711.00	CORE	2	2								
2712.00	DC	2	2								
2712.00	CORE	2	2								
2714.00	CORE	2	2								
2715.00	DC	2	2								
2715.00	CORE	2	2								
2716.00	CORE	2	2								
2717.00	CORE	2	2								
2717.90	CORE	2	2								
2718.40	CORE	2	2								
2718.50	CORE	2	2								
2718.80	CORE	2	2								
2723.00	CORE	2	2								
2724.00	CORE	2	2								
2725.00	CORE	2	2								
2726.00	CORE	2	2								
2728.00	CORE	2	2								
2729.00	CORE	2	2								
2730.00	CORE	2	2								
2732.00	CORE	2	2								
2733.00	CORE	2	2								
2735.00	CORE	1	1								
2735.00	CORE	2	2								
2735.01	CORE	2	2								
2738.00	CORE	2	2								
2739.40	CORE	1	1	1	1	1	1		4	1	
2739.40	CORE	2	2								
2739.50	CORE	2	2								
2740.00	DC	2	2								
2742.00	DC	2	2								
2745.00	DC	2	2								
2747.00	DC	2	2								
2750.00	DC	2	2								3
2750.00	SWC	2	2								
2752.00	DC	2	2								
2755.00	DC	2	2								
2755.00	SWC	2	2	1	1	1	1		4		
2760.00	DC	2	2								
2760.00	SWC	2	2	1	1	1	1		4		3
2768.00	SWC	2	2								
2772.00	SWC	2	2	1	1	1	1		4		
2775.00	CORE	2	2								
2777.00	CORE	2	2								
2779.00	CORE	2	2								
2781.00	CORE	2	2								
2783.00	CORE	2	2								
2785.00	CORE	2	2								
2786.00	CORE	2	2								
2787.00	CORE	2	2								
2791.50	CORE	2	2								
2792.00	CORE	2	2								
2793.00	CORE	2	2								
2795.00	CORE	2	2								
2796.00	CORE	2	2								
2798.00	CORE	2	2								
2799.00	CORE	2	2								
2800.00	CORE	2	2								
2800.75	CORE	1	1	1	1	1	1		4		
2800.75	CORE	2	2								
2801.00	CORE	2	2								
2804.50	CORE	2	2								
2806.00	CORE	2	2								
2808.00	CORE	2	2								
2810.00	CORE	2	2								
2812.00	CORE	2	2								
2813.70	CORE	2	2								
2815.00	CORE	2	2								
2817.00	CORE	2	2								
2819.00	CORE	2	2								
2821.00	CORE	2	2								
2823.00	CORE	2	2								
2823.30	CORE	2	2								
2823.50	CORE	2	2								
2824.00	CORE	2	2								
2827.00	CORE	2	2								
2829.00	CORE	2	2								
2831.00	CORE	2	2								
2832.00	DC	2	2								
2833.00	CORE	2	2								
2834.00	CORE	2	2								
2835.00	DC	2	2								
2835.00	CORE	2	2								
2836.00	CORE	2	2								
2837.50	CORE	1	1								
2837.50	CORE	2	2								
2838.00	CORE	2	2								
2839.60	CORE	1	1								
2839.60	CORE	2	2								
2840.00	DC	2	2								
2840.00	CORE	2	2								
2840.90	CORE	2	2								

LEGEND :

1 : Norsk Hydro

2 : EXLOG

3 : University of Bergen

4 : Geo Optic

Survey of analyses

DEPTH m	SAMPLE TYPE	ROCK EVAL	TOC	EXTR.	ASPH.	GROUP SEP.	GCMS SAT,ARO	GCMS EOM	Ro	Pyr. GC	KER. TYPE
2848.70	CORE	1	1								
2848.70	CORE	1	2								
2849.40	CORE	1	1								
2849.40	CORE	2	2								
2865.00	DC	2	2								
2867.00	DC	2	2								
2871.00	SWC	2	2								
2872.00	SWC	2	2	1	1	1	1				
2873.00	SWC	2	2								
2874.00	SWC	2	2	1	1	1	1				
2875.00	SWC	2	2								
2876.00	SWC	2	2	1	1	1	1				
2878.00	SWC	2	2								
2880.00	CORE	1	1								
2880.00	CORE	2	2								
2880.00	SWC	2	2								
2884.85	CORE			1	1	1	1		4	1	
2888.10	CORE	2	2	1	1	1	1		4	1	3
2889.00	CORE	1	1								
2889.00	CORE	2	2								
2889.10	CORE	2	2								
2889.20	CORE	1	1								
2889.20	CORE	2	2								
2891.60	CORE	1	1								
2891.60	CORE	2	2								
2893.50	CORE	1	1								
2893.50	CORE	2	2								
2905.30	CORE	2	2	1	1	1	1		4	1	3
2913.00	CORE	2	2	1	1	1	1		4	1	3
2923.00	SWC	2	2	1	1			1	4	1	3
2934.00	SWC	2	2	1	1	1	1		4		
2952.00	SWC	2	2	1				1			3
2995.00	DC	2	2								
2996.50	SWC	2	2								
2997.00	DC	2	2								
3000.00	DC	2	2								
3002.00	DC	2	2								
3005.00	DC	2	2								
3020.00	DC	2	2								
3022.00	DC	2	2								
3030.00	DC	2	2								
3032.00	DC	2	2	1				1	4		
3032.00	SWC	2	2								
3040.00	SWC	2	2								
3042.00	DC	2	2								
3042.00	SWC	2	2								
3097.00	SWC	2	2								
3105.00	SWC	2	2								
3109.50	SWC	2	2	1				1	4		
3120.00	SWC	2	2								
3128.00	SWC	2	2								
3177.00	SWC	2	2								
3243.00	SWC	2	2	1				1	4		
3263.00	SWC	2	2								
3268.00	SWC	2	2						4		
3272.50	SWC	2	2								
3276.00	SWC	2	2								
3283.00	SWC	2	2								
3298.00	SWC	2	2	1				1	4		
3305.00	SWC	2	2								
3315.00	SWC	2	2								

LEGEND :

1 : Norsk Hydro

3 : University of Bergen

TABLE II.1.1

Rock Eval and TOC data

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2

Petroleum Geochemistry Group
Research Center Bergen

HYDRO

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
1716.00	SKLINNA		SH	SWC	0.2	2.8		1.4	211.1		0.1	426	EXLOG
1775.00	SKOMVAER			SWC	0.3	1.9		1.8	104.9		0.1	419	EXLOG
1824.00	SKOMVAER		SH	SWC	0.3	3.1		1.9	166.1		0.1	431	EXLOG
1956.50	SKOMVAER		SH	SWC	0.4	0.7		1.5	47.7		0.4	422	EXLOG
1958.00	SKOMVAER			SWC	0.1	0.4		1.0	36.5		0.2	422	EXLOG
1975.00	FINNVAER			SWC	0.5	0.9		0.7	124.3		0.4	424	EXLOG
2008.50	FINNVAER			SWC	0.2	0.8		1.0	78.0		0.2	428	EXLOG
2025.00	FINNVAER		SLTY.SH	SWC	0.4	1.4		1.1	128.6		0.2	427	EXLOG
2050.00	FINNVAER			SWC	0.2	1.3		1.1	122.6		0.1	430	EXLOG
2075.00	FINNVAER		SLST	SWC	0.4	1.6		1.0	156.7		0.2	429	EXLOG
2100.00	FINNVAER			SWC	0.4	1.2		0.8	143.4		0.2	430	EXLOG
2139.00	FINNVAER			SWC	0.1	0.6		0.7	76.7		0.1	425	EXLOG
2225.00	FINNVAER			SWC	0.2	0.6		0.8	69.5		0.2	429	EXLOG
2251.00	FINNVAER		SH	SWC	0.2	0.8		0.9	78.9		0.2	431	EXLOG
2275.00	FINNVAER			SWC	0.2	1.0		1.3	80.6		0.2	431	EXLOG
2300.00	FINNVAER			SWC	0.2	1.0		1.1	89.6		0.1	433	EXLOG
2349.00	FINNVAER			SWC	0.2	0.7		1.0	63.8		0.3	428	EXLOG
2425.00	FINNVAER		SH	SWC	0.4	0.9		1.1	79.8		0.3	429	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2474.50	FINNVAER			SWC	0.5	0.7		1.0	77.1		0.4	427	EXLOG
2482.85	FINNVAER			CORE	11.8	112.1		19.0	590.4		0.1	423	EXLOG
2522.50	FINNVAER			SWC	0.3	0.4		0.8	47.5		0.4	423	EXLOG
2550.00	FINNVAER			SWC	0.3	0.4		0.8	60.0		0.4	423	EXLOG
2553.00	FINNVAER		CLYST	SWC	0.0	0.3		0.1	275.0		0.0	450	EXLOG
2560.00	FINNVAER		CLYST	DC	0.7	0.8		0.4	200.0		0.4	415	EXLOG
2565.00	FINNVAER			DC	0.3	0.9		0.5	206.5		0.3	416	EXLOG
2567.00	FINNVAER			DC	0.4	0.6		0.5	128.6		0.4	415	EXLOG
2570.00	FINNVAER			DC	0.7	1.9		2.2	89.8		0.3	427	EXLOG
2572.00	FINNVAER			DC	0.6	1.4		1.5	95.2		0.3	427	EXLOG
2575.00	FINNVAER			DC	0.7	1.3		1.2	104.1		0.4	423	EXLOG
2575.00	FINNVAER		CLYST	SWC	0.0	2.1		1.1	181.7		0.0	503	EXLOG
2577.00	FINNVAER		CLYST	DC	0.6	0.9		0.9	96.7		0.4	423	EXLOG
2580.00	FINNVAER			DC	0.6	0.9		1.0	96.9		0.4	426	EXLOG
2582.00	FINNVAER			DC	0.6	0.8		0.7	105.5		0.4	421	EXLOG
2585.00	FINNVAER			DC	0.6	0.8		0.9	89.1		0.4	427	EXLOG
2587.00	FINNVAER			DC	0.4	0.6		1.0	62.5		0.4	427	EXLOG
2587.00	FINNVAER		CLYST	SWC	2.0	29.8		8.1	369.8		0.1	425	EXLOG
2590.00	FINNVAER		CLYST	DC	0.4	0.6		0.9	68.8		0.4	425	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Petroleum Geochemistry Group
Research Center Bergen

HYDRO

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2592.00	FINNVAER			DC	0.7	0.9		1.0	85.0		0.4	420	EXLOG
2595.00	FINNVAER			DC	0.3	0.4		1.1	36.4		0.5	430	EXLOG
2597.00	FINNVAER			DC	0.3	0.4		0.9	48.8		0.5	426	EXLOG
2600.00	FINNVAER			DC	0.4	0.5		0.8	59.7		0.5	401	EXLOG
2602.00	FINNVAER			DC	0.4	0.8		2.2	37.5		0.3	431	EXLOG
2605.00	FINNVAER			DC	0.3	0.4		1.2	32.0		0.4	430	EXLOG
2607.00	FINNVAER			DC	0.3	0.3		1.1	31.2		0.5	429	EXLOG
2610.00	FINNVAER			DC	0.3	0.4		1.3	32.1		0.4	430	EXLOG
2611.00	FINNVAER		CLYST	SWC	0.1	0.7		1.6	41.1		0.1	523	EXLOG
2612.00	FINNVAER			DC	1.3	8.0		4.2	189.8		0.1	431	EXLOG
2615.00	FINNVAER			DC	0.3	0.5		1.5	34.7		0.4	431	EXLOG
2617.00	FINNVAER			DC	0.4	0.6		1.3	43.1		0.4	432	EXLOG
2620.00	FINNVAER			DC	0.4	0.9		1.9	44.7		0.3	436	EXLOG
2622.00	FINNVAER			DC	0.5	1.1		2.0	55.0		0.3	430	EXLOG
2622.00	FINNVAER		CLYST	SWC	0.1	0.2		0.3	64.3		0.2		EXLOG
2625.00	FINNVAER		CLYST	DC	0.4	0.6		1.2	45.5		0.4	428	EXLOG
2625.00	FINNVAER		CLYST	SWC	0.0	0.0		0.0	100.0		0.6		EXLOG
2627.00	FINNVAER		CLYST	DC	0.5	0.6		1.3	51.2		0.4	427	EXLOG
2630.00	FINNVAER			DC	0.2	0.5		1.0	44.2		0.3	424	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2631.00	FINNVAER		CLYST	SWC	0.0	0.0		0.0	100.0		0.0		EXLOG
2632.00	FINNVAER			DC	0.2	0.2		0.4	56.8		0.5	412	EXLOG
2632.50	FINNVAER		CLYST	SWC	0.0	0.0		0.1	0.0				EXLOG
2635.00	FINNVAER			DC	0.2	0.2		0.4	55.6		0.5	416	EXLOG
2637.00	FINNVAER			DC	0.2	0.2		0.3	54.8		0.5	420	EXLOG
2638.00	NESNA		CLYST	SWC	1.9	22.2		5.0	441.3		0.1	428	EXLOG
2640.00	NESNA		CLYST	SWC	2.8	36.9		7.6	488.5		0.1	425	EXLOG
2640.00	NESNA			DC	0.7	4.7		2.3	204.8		0.1	429	EXLOG
2642.00	NESNA		CLYST	DC	1.3	14.3		4.5	316.8		0.1	428	EXLOG
2645.00	NESNA			DC	1.4	15.0		4.7	319.8		0.1	429	EXLOG
2647.00	NESNA			DC	1.5	14.2		4.7	303.0		0.1	428	EXLOG
2647.00	NESNA		CLYST	SWC	0.3	0.9		0.9	102.3		0.3	425	EXLOG
2650.00	NESNA		CLYST	DC	1.7	14.8		4.8	308.8		0.1	430	EXLOG
2650.00	NESNA		CLYST	SWC	3.6	37.7		8.0	470.8		0.1	425	EXLOG
2652.00	NESNA		CLYST	DC	1.4	12.6		4.5	281.3		0.1	430	EXLOG
2653.00	ENGELVAER		CLYST	SWC	0.9	9.8		3.3	294.6		0.1	427	EXLOG
2655.00	ENGELVAER			DC	1.5	11.5		4.3	266.4		0.1	430	EXLOG
2657.00	ENGELVAER			DC	1.3	10.8		3.9	272.8		0.1	432	EXLOG
2660.00	ENGELVAER			DC	1.2	8.1		3.8	211.3		0.1	431	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Petroleum Geochemistry Group
Research Center Bergen

HYDRO

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2661.00	ENGELVAER		CLYST	SWC	2.0	14.1		5.1	276.4		0.1	430	EXLOG
2662.00	ENGELVAER			DC	1.1	7.5		4.1	182.2		0.1	432	EXLOG
2665.00	ENGELVAER			DC	1.1	8.0		4.3	183.9		0.1	432	EXLOG
2667.00	ENGELVAER			DC	1.3	8.0		4.1	196.8		0.1	431	EXLOG
2672.00	ENGELVAER			DC	1.5	7.3		4.9	149.9		0.2	431	EXLOG
2673.00	ENGELVAER		CLYST	CORE	0.4	1.3		1.0	135.4		0.2	432	EXLOG
2673.00	ENGELVAER		CLYST	SWC	0.8	6.1		2.7	221.9		0.1	463	EXLOG
2674.00	ENGELVAER		SLST/SST	CORE	0.6	2.3		1.5	152.0		0.2	433	EXLOG
2675.00	ENGELVAER		SLST/SST	CORE	0.6	3.6		2.0	179.5		0.1	431	EXLOG
2676.00	ENGELVAER		SLST/SST	CORE	0.3	0.8		0.8	97.4		0.3	435	EXLOG
2677.10	ENGELVAER		SLST/SST	CORE	0.8	2.8		2.6	106.5		0.2	431	EXLOG
2678.00	ENGELVAER		SLST/SST	CORE	1.3	11.2		4.9	229.9		0.1	426	EXLOG
2678.80	ENGELVAER	100	SLST	CORE	0.9	11.9	0.4	4.1	290.2	9.8	0.1	429	F-BG
2678.80	ENGELVAER		SLST/SST	CORE	1.3	11.4		4.9	233.1		0.1	428	EXLOG
2679.00	ENGELVAER		SLST/SST	CORE	2.0	23.0		5.9	390.7		0.1	424	EXLOG
2680.00	ENGELVAER		SLST/SST	CORE	0.6	1.7		1.8	93.4		0.3	431	EXLOG
2681.00	ENGELVAER		SLST/SST	CORE	1.0	5.9		3.0	194.1		0.1	430	EXLOG
2681.75	ENGELVAER	100	SH	CORE	0.5	5.1	0.1	2.1	242.9	4.8	0.1	439	F-BG
2681.75	ENGELVAER		SLST	CORE	0.6	5.7		2.8	205.4		0.1	434	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2682.00	ENGELVAER		SLST	CORE	0.5	3.8		2.2	174.9		0.1	435	EXLOG
2683.00	ENGELVAER		CLYST/SLST	CORE	0.3	2.5		1.3	196.8		0.1	434	EXLOG
2684.00	ENGELVAER		CLYST/SLST	CORE	0.4	2.2		1.1	192.2		0.1	431	EXLOG
2684.65	ENGELVAER		CLYST/SLST	CORE	0.3	2.9	0.0	1.1	263.6	0.0	0.1	436	F-BG
2684.65	ENGELVAER		CLYST/SLST	CORE	0.3	2.4		1.1	211.3		0.1	434	EXLOG
2685.00	ENGELVAER		CLYST/SLST	CORE	0.4	3.2		1.4	220.1		0.1	431	EXLOG
2685.40	ENGELVAER		CLYST/SLST	CORE	0.2	2.2	0.0	1.0	220.0	0.0	0.1	436	F-BG
2685.40	ENGELVAER		CLYST/SLST	CORE	0.3	2.1		1.4	153.7		0.1	433	EXLOG
2686.00	ENGELVAER		CLYST	CORE	0.3	2.2		1.2	181.3		0.1	431	EXLOG
2686.10	ENGELVAER		CLYST	CORE	0.4	1.2		0.9	127.4		0.3	430	EXLOG
2690.00	ENGELVAER			DC	0.6	3.8		1.8	215.9		0.1	430	EXLOG
2690.00	ENGELVAER		CLYST	SWC	0.4	0.9		1.1	78.9		0.3	457	EXLOG
2692.00	ENGELVAER		CLYST	DC	0.5	2.8		2.4	115.8		0.2	432	EXLOG
2693.00	ENGELVAER		CLYST	SWC	0.3	1.3		1.5	85.7		0.2	462	EXLOG
2695.00	ENGELVAER		CLYST	DC	0.3	0.5		0.9	51.6		0.4	427	EXLOG
2695.00	ENGELVAER		CLYST	SWC	0.2	1.3		0.5	275.0		0.1	437	EXLOG
2698.00	TOMMA		CLYST	SWC	1.0	5.7		0.6	1030.9		0.1	497	EXLOG
2701.00	TOMMA		SST	CORE	0.9	1.5		2.4	63.8		0.4	433	EXLOG
2702.00	ENGELVAER		CLYST	DC	0.3	1.1		1.8	59.9		0.2	435	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2702.00	TOMMA		SST	CORE	0.6	0.5		0.2	282.4		0.6	362	EXLOG
2703.00	TOMMA		SST	CORE	1.6	2.1		1.9	111.5		0.4	432	EXLOG
2704.00	TOMMA		SST	CORE	1.2	2.4		1.5	158.9		0.3	433	EXLOG
2705.00	TOMMA		SST	DC	0.3	1.0		1.2	84.6		0.3	435	EXLOG
2705.00	TOMMA		SST/CLYST	CORE	2.6	1.9		0.8	233.7		0.6	427	EXLOG
2706.00	TOMMA		SST/CLYST	CORE	1.4	1.6		1.0	160.6		0.5	431	EXLOG
2707.00	TOMMA		SST/CLYST	DC	0.3	0.9		0.9	96.8		0.3	434	EXLOG
2707.00	TOMMA		SST/CLYST	CORE	2.6	1.5		0.6	226.2		0.6	418	EXLOG
2708.00	TOMMA		SST/CLYST	CORE	2.2	1.4		0.6	258.2		0.6	426	EXLOG
2708.90	TOMMA		SST/CLYST	CORE	2.1	2.4		1.5	152.3		0.5	431	EXLOG
2710.00	TOMMA		SST/CLYST	DC	0.4	1.1		1.5	72.8		0.3	435	EXLOG
2710.00	TOMMA		SST/CLYST	CORE	0.6	1.2		1.1	107.3		0.3	434	EXLOG
2711.00	TOMMA		SST	CORE	1.1	2.4		2.0	117.7		0.3	434	EXLOG
2712.00	TOMMA		SST	DC	0.3	0.8		1.0	81.2		0.3	433	EXLOG
2712.00	TOMMA		SST	CORE	0.7	2.0		1.4	142.9		0.3	434	EXLOG
2714.00	TOMMA		SST/SLST	CORE	0.7	1.9		1.4	132.4		0.3	433	EXLOG
2715.00	TOMMA		SST/SLST	DC	0.4	0.9		0.9	104.7		0.3	431	EXLOG
2715.00	TOMMA		SST/SLST	CORE	0.9	3.0		1.5	197.4		0.2	433	EXLOG
2716.00	TOMMA		SST/SLST	CORE	0.9	3.4		2.1	161.4		0.2	434	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

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Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2717.00	TOMMA		SST/SLST	CORE	0.5	0.8		0.7	114.5		0.4	431	EXLOG
2717.90	TOMMA		SST/SLST	CORE	0.8	0.9		0.7	122.2		0.5	429	EXLOG
2718.40	TOMMA		SST/SLST	CORE	0.2	0.1		0.1	128.6		0.7	460	EXLOG
2718.50	TOMMA		SST/SLST	CORE	2.0	1.6		0.7	224.7		0.6	430	EXLOG
2718.80	TOMMA		SST/SLST	CORE	2.1	1.7		0.7	250.7		0.6	427	EXLOG
2723.00	TOMMA		SST/SLST	CORE	0.6	0.5		0.4	112.2		0.6	433	EXLOG
2724.00	TOMMA		SLST/SST	CORE	0.3	0.8		0.3	304.0		0.3	435	EXLOG
2725.00	TOMMA		SST/SLST	CORE	0.5	0.3		0.2	158.8		0.6	430	EXLOG
2726.00	TOMMA		SST/SLST	CORE	0.3	0.4		0.2	211.8		0.5	434	EXLOG
2728.00	TOMMA		SLST/SST	CORE	0.3	0.3		1.3	20.3		0.5	432	EXLOG
2729.00	LEKA		SST/SLST	CORE	0.2	0.1		0.4	13.6		0.7	427	EXLOG
2730.00	LEKA		SST/SLST	CORE	0.4	0.6		0.2	229.2		0.4	432	EXLOG
2732.00	LEKA		SST/SLST	CORE	0.2	0.2		0.3	82.1		0.5	433	EXLOG
2733.00	LEKA		SST/SLST	CORE	0.5	1.8		0.5	338.9		0.2	436	EXLOG
2735.00	LEKA		CLYST/SST	CORE	0.2	2.1	0.2	0.9	233.3	22.2	0.1	438	F-BG
2735.00	LEKA		CLYST/SST	CORE	0.4	2.3		0.8	272.6		0.2	436	EXLOG
2735.01	LEKA		CLYST/SST	CORE	0.3	2.4		1.2	191.9		0.1	436	EXLOG
2738.00	LEKA		CLYST/SST	CORE	1.1	8.2		2.5	326.7		0.1	434	EXLOG
2739.40	LEKA		CLYST/SST	CORE	0.7	7.4		2.7	272.2		0.1	437	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

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Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2739.40	LEKA	100	SLTY.SH	CORE	0.3	3.7	0.3	4.4	84.1	6.8	0.1	439	F-BG
2739.50	LEKA		CLYST/SST	CORE	0.8	5.3		1.9	285.5		0.1	434	EXLOG
2740.00	TOMMA		SST/SLST	DC	0.3	0.7		1.0	72.3		0.3	432	EXLOG
2742.00	LEKA		CLYST/SST	DC	0.5	1.5		0.8	189.0		0.2	433	EXLOG
2745.00	LEKA		CLYST/SST	DC	0.3	1.1		0.7	150.7		0.2	434	EXLOG
2747.00	LEKA		CLYST/SST	DC	0.6	1.1		0.6	186.4		0.3	433	EXLOG
2750.00	LEKA		CLYST	SWC	0.2	1.4		0.8	177.5		0.1	434	EXLOG
2750.00	LEKA		CLYST/SST	DC	0.5	1.5		0.7	220.9		0.2	434	EXLOG
2752.00	LEKA		CLYST	DC	0.5	1.3		0.7	194.2		0.3	436	EXLOG
2755.00	LEKA		CLYST	DC	0.5	1.2		0.6	210.5		0.3	432	EXLOG
2755.00	LEKA		CLYST	SWC	0.3	3.1		0.8	408.0		0.1	439	EXLOG
2760.00	LEKA		CLYST	DC	0.5	1.6		0.8	203.7		0.2	434	EXLOG
2760.00	LEKA		CLYST	SWC	0.3	4.0		1.1	362.7		0.1	437	EXLOG
2768.00	LEKA		CLYST	SWC	0.4	2.9		0.8	345.2		0.1	439	EXLOG
2772.00	ALDRA		CLYST	SWC	0.9	5.7		1.6	367.3		0.1	440	EXLOG
2775.00	ALDRA		CLYST/SST	CORE	4.2	2.7		1.1	251.9		0.6	432	EXLOG
2777.00	ALDRA		CLYST/SST	CORE	1.0	3.3		1.4	237.7		0.2	437	EXLOG
2779.00	ALDRA		CLYST/SST	CORE	1.2	3.0		1.4	219.0		0.3	435	EXLOG
2781.00	ALDRA		SST/CLYST	CORE	9.0	2.4		1.1	223.9		0.8	423	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

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HYDRO

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2783.00	ALDRA		SST/CLYST	CORE	8.9	2.8		1.0	269.2		0.8	422	EXLOG
2785.00	ALDRA		SST/CLYST	CORE	9.5	2.9		1.1	264.9		0.8	426	EXLOG
2786.00	ALDRA		SST/CLYST	CORE	1.4	2.5		1.0	256.6		0.4	437	EXLOG
2787.00	ALDRA		SST/CLYST	CORE	9.2	3.2		1.1	274.8		0.7	420	EXLOG
2791.50	ALDRA		SST/CLYST	CORE	11.4	4.2		1.4	297.9		0.7	419	EXLOG
2792.00	ALDRA		SST/CLYST	CORE	3.9	5.1		2.0	246.3		0.4	437	EXLOG
2793.00	ALDRA		SST/CLYST	CORE	9.4	3.2		1.2	261.0		0.7	426	EXLOG
2795.00	ALDRA		SST/CLYST	CORE	8.4	6.7		2.4	276.3		0.6	423	EXLOG
2796.00	ALDRA		SST/CLYST	CORE	0.7	0.7		0.1	530.8		0.5	585	EXLOG
2798.00	ALDRA		CLYST/SST	CORE	3.2	6.7		3.3	207.1		0.3	430	EXLOG
2799.00	ALDRA		SST/CLYST	CORE	0.8	1.0		0.5	208.0		0.4	437	EXLOG
2800.00	ALDRA		SST/CLYST	CORE	2.1	4.0		1.8	226.7		0.3	437	EXLOG
2800.75	ALDRA	100	SLTY.SH	CORE	0.5	4.1	1.1	1.5	273.3	73.3	0.1	442	F-BG
2800.75	ALDRA		SST/CLYST	CORE	0.7	5.7		2.1	265.4		0.1	439	EXLOG
2801.00	ALDRA		SST	CORE	11.9	3.9		1.4	271.5		0.8	426	EXLOG
2804.50	ALDRA		SST/CLYST	CORE	1.3	4.1		1.4	283.2		0.2	432	EXLOG
2806.00	ALDRA		SST/CLYST	CORE	9.9	3.3		1.4	244.1		0.7	424	EXLOG
2808.00	ALDRA		SST/CLYST	CORE	1.5	2.0		0.9	241.2		0.4	435	EXLOG
2810.00	ALDRA		SST/CLYST	CORE	11.0	3.5		1.3	269.5		0.8	411	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2812.00	ALDRA		SST	CORE	4.4	1.9		0.7	286.6		0.7	417	EXLOG
2813.70	ALDRA		CLYST/SST	CORE	2.2	8.1		2.5	326.7		0.2	435	EXLOG
2815.00	ALDRA		SST/CLYST	CORE	10.5	4.2		1.6	259.6		0.7	425	EXLOG
2817.00	ALDRA		SST/CLYST	CORE	7.2	3.1		1.1	271.3		0.7	426	EXLOG
2819.00	ALDRA		SST/CLYST	CORE	5.4	2.3		0.8	301.3		0.7	411	EXLOG
2821.00	ALDRA		SST/CLYST	CORE	9.0	3.3		1.1	298.2		0.7	422	EXLOG
2823.00	ALDRA		SST/CLYST	CORE	9.8	3.5		1.2	293.3		0.7	425	EXLOG
2823.30	ALDRA		SST/CLYST	CORE	8.5	22.1		8.8	250.5		0.3	424	EXLOG
2823.50	ALDRA		SST/CLYST	CORE	0.7	0.9		0.2	445.0		0.4	587	EXLOG
2824.00	ALDRA		SST/CLYST	CORE	4.5	6.9		2.2	312.7		0.4	436	EXLOG
2827.00	ALDRA		SST/CLYST	CORE	3.2	4.6		2.2	211.0		0.4	437	EXLOG
2829.00	ALDRA		CLYST/SST	CORE	9.9	4.5		1.4	324.6		0.7	383	EXLOG
2831.00	ALDRA		SST/CLYST	CORE	7.2	3.2		1.1	289.3		0.7	419	EXLOG
2832.00	LEKA		CLYST/SST	DC	0.8	1.3		1.4	96.4		0.4	423	EXLOG
2833.00	ALDRA		SST/CLYST	CORE	9.2	3.5		1.2	298.3		0.7	424	EXLOG
2834.00	ALDRA		SST/CLYST	CORE	4.3	4.0		1.3	309.4		0.5	433	EXLOG
2835.00	ALDRA		CLYST/SST	DC	4.0	5.1		2.0	250.0		0.4	433	EXLOG
2835.00	ALDRA		SST/CLYST	CORE	4.9	4.4		2.1	215.0		0.5	429	EXLOG
2836.00	ALDRA		SST/CLYST	CORE	1.6	1.9		0.9	220.5		0.5	432	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2837.50	ALDRA		SST/CLYST	CORE	0.2	2.8	2.0	1.1	254.5	181.8	0.1	431	F-BG
2837.50	ALDRA		SST/CLYST	CORE	0.3	2.6		1.2	208.9		0.1	439	EXLOG
2838.00	ALDRA		SST/CLYST	CORE	1.0	3.6		1.4	264.0		0.2	436	EXLOG
2839.60	ALDRA		COAL	CORE	25.2	155.4	1.1	71.0	218.9	1.5	0.1	437	F-BG
2839.60	ALDRA		SST/CLYST	CORE	41.3	143.3		22.2	645.9		0.2	431	EXLOG
2840.00	ALDRA		SST/CLYST	DC	14.1	125.7		28.1	447.7		0.1	426	EXLOG
2840.00	ALDRA		SST/CLYST	CORE	9.1	48.2		16.4	294.0		0.2	427	EXLOG
2840.90	ALDRA		SST/CLYST	CORE	4.4	2.7		1.3	209.3		0.6	420	EXLOG
2848.70	ALDRA		COAL	CORE	12.4	125.4	1.4	42.0	298.6	3.3	0.1	430	F-BG
2848.70	ALDRA		SST/CLYST	CORE	17.6	136.9		40.7	336.4		0.1	424	EXLOG
2849.40	ALDRA		COAL	CORE	6.8	60.2	0.0	25.0	240.8	0.0	0.1	433	F-BG
2849.40	ALDRA		SST/CLYST	CORE	12.4	69.8		14.1	494.1		0.2	423	EXLOG
2865.00	ALDRA		SST/CLYST	DC	1.9	1.1		1.3	84.7		0.6	423	EXLOG
2867.00	ALDRA		SST/CLYST	DC	1.1	1.5		1.0	154.5		0.4	431	EXLOG
2871.00	ALDRA		SST	SWC	8.5	3.5		1.2	300.0		0.7	496	EXLOG
2872.00	ALDRA		SST	SWC	10.7	1.6		1.2	136.4		0.9	411	EXLOG
2873.00	ALDRA		SST	SWC	1.3	8.0		2.6	310.0		0.1	430	EXLOG
2874.00	ALDRA		SST	SWC	5.6	5.6		1.1	529.2		0.5	496	EXLOG
2875.00	ALDRA		SST	SWC	2.4	0.9		0.4	231.7		0.7	453	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2876.00	ALDRA		SST	SWC	4.1	1.9		0.7	263.4		0.7	499	EXLOG
2878.00	HITRA		SST	SWC	0.1	3.9		0.3	1169.7		0.0		EXLOG
2880.00	HITRA		CLYST	CORE	0.2	2.6	0.0	1.1	236.4	0.0	0.1	436	F-BG
2880.00	HITRA		CLYST	CORE	0.3	3.7		2.3	164.9		0.1	433	EXLOG
2880.00	HITRA		CLYST	SWC	0.0	0.8		0.1	709.1		0.0		EXLOG
2888.10	HITRA		CLYST	CORE	18.7	149.5		14.0	1069.7		0.1	412	EXLOG
2889.00	HITRA		CLYST	CORE	16.3	461.2		49.8	926.8		0.0	506	EXLOG
2889.00	HITRA		COAL	CORE	8.1	155.9	0.0	48.9	318.8	0.0	0.0	429	F-BG
2889.10	HITRA		CLYST	CORE	17.9	185.2		38.3	483.9		0.1	433	EXLOG
2889.20	HITRA		CLYST	CORE	0.1	1.1	0.0	1.5	73.3	0.0	0.1	445	F-BG
2889.20	HITRA		CLYST	CORE	0.2	1.2		1.6	76.6		0.1	443	EXLOG
2891.60	HITRA		MRL	CORE	0.0	0.4	1.1	0.1	400.0	1100.0	0.0	440	F-BG
2891.60	HITRA		MRL	CORE	0.1	0.2		1.1	19.1		0.2	455	EXLOG
2893.50	HITRA		CLYST	CORE	0.1	0.9	0.0	1.1	81.8	0.0	0.1	459	F-BG
2893.50	HITRA		CLYST	CORE	0.2	0.9		1.6	57.4		0.2	454	EXLOG
2905.30	HITRA		CLYST	CORE	6.2	105.3		28.3	371.9		0.1	426	EXLOG
2913.00	HITRA		SST	CORE	7.3	92.0		17.5	526.7		0.1	421	EXLOG
2923.00	HITRA		CLYST	SWC	0.0	0.6		0.2	239.1		0.1	483	EXLOG
2934.00	HITRA		CLYST	SWC	2.6	53.5		13.4	400.2		0.0	437	EXLOG

Table 2.1.1. SOURCE ROCK SCREENING DATA WELL 6407/7-2 (cont'd)

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
2952.00	INT TRIAS E		CLYST	SWC	0.0	0.2		0.0	600.0		0.0	515	EXLOG
2995.00	HITRA		SST/CLYST	DC	0.1	0.3		0.2	144.4		0.2	436	EXLOG
2996.50	INT TRIAS E			SWC	0.0	0.3		0.1	483.3		0.1		EXLOG
2997.00	INT TRIAS E		CLYST	DC	0.2	0.8		0.4	197.5		0.2	413	EXLOG
3000.00	INT TRIAS E			DC	0.1	0.1		0.1	100.0		0.5		EXLOG
3002.00	INT TRIAS E			DC	0.1	0.1		0.3	51.9		0.3		EXLOG
3005.00	INT TRIAS E			DC	0.1	0.1		0.1	63.6		0.5		EXLOG
3020.00	INT TRIAS E			DC	0.1	0.3		0.2	166.7		0.2		EXLOG
3022.00	INT TRIAS E			DC	0.0	0.1		0.1	90.9		0.2		EXLOG
3030.00	INT TRIAS E			DC	0.0	0.0		0.0	0.0				EXLOG
3032.00	INT TRIAS E		CLYST	DC	0.0	0.0		0.1	14.3		0.5		EXLOG
3032.00	INT TRIAS E		CLYST	SWC	0.0	0.2		0.2	106.7		0.0	433	EXLOG
3040.00	INT TRIAS E		CLYST	SWC	0.0	0.0		0.1	50.0		0.3		EXLOG
3042.00	INT TRIAS E		CLYST	DC	0.0	0.0		0.0	0.0				EXLOG
3042.00	INT TRIAS E		CLYST	SWC	0.1	0.1		0.0	700.0		0.5	484	EXLOG
3097.00	INT TRIAS E		CLYST	SWC	0.0	0.0		0.0	100.0		0.6		EXLOG
3105.00	INT TRIAS E		SST	SWC	0.0	0.1		0.1	233.3		0.0		EXLOG
3109.50	INT TRIAS E		CLYST	SWC	0.0	0.0		0.1	40.0		0.0		EXLOG
3120.00	INT TRIAS E		LST	SWC	0.1	0.3		0.1	236.4		0.2	557	EXLOG

Table 2.1.1. **SOURCE ROCK SCREENING DATA WELL 6407/7-2** (cont'd)

Depth (m)	Group/Fm	%	Lithology	Sample	S1 Kg/t	S2 Kg/t	S3 Kg/t	TOC %	HI	OI	PI	Tmax Deg.c	Company
3128.00	INT TRIAS E		CLYST	SWC	0.0	0.0		0.0	0.0		1.0		EXLOG
3177.00	INT TRIAS E		CLYST	SWC	0.0	0.4		1.1	36.0		0.1	523	EXLOG
3243.00	INT TRIAS E		CLYST	SWC	0.4	0.6		0.9	62.5		0.4	406	EXLOG
3263.00	INT TRIAS E		CLYST	SWC	0.1	0.4		0.2	182.6		0.2		EXLOG
3268.00	INT TRIAS E		CLYST	SWC	0.0	0.1		0.2	22.7		0.0	329	EXLOG
3272.50			CLYST	SWC	0.0	0.0		0.2	14.3		0.4		EXLOG
3276.00			CLYST	SWC	0.0	0.0		0.3	8.8		0.0	347	EXLOG
3283.00			CLYST	SWC	0.0	0.0		0.1	0.0				EXLOG
3298.00			CLYST	SWC	0.0	0.2		0.2	62.5		0.2		EXLOG
3305.00			CLYST	SWC	0.0	0.2		0.1	190.9		0.0	429	EXLOG
3315.00			CLYST	SWC	0.0	0.1		0.2	23.8		0.2	434	EXLOG

TABLE II.2.1

Results from extraction and group type separation

Table 2.2.1. SOURCE ROCK EXTRACTION DATA I WELL 6407/7-2

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Depth(m)	Group/Fm	EOM(mg)	EOM(%)	Hydrocarbons SAT(%)	Hydrocarbons ARO(%)	Hydrocarbons TOTAL(%)	Non Hydrocarbons NSO(%)	Non Hydrocarbons ASPH(%)	Non Hydrocarbons TOTAL(%)
1716.00	SKLINNA	12.70	0.07	8	16	24	23	53	76
1824.00	SKOMVAER	16.90	0.08	13	14	27	17	56	73
1956.50	SKOMVAER	3.30	0.03	12	16	28	27	45	72
2025.00	FINNVAER	7.00	0.04	21	15	36	11	53	64
2075.00	FINNVAER	8.10	0.05	9	18	27	19	54	73
2251.00	FINNVAER	5.50	0.04	8	17	25	19	56	75
2425.00	FINNVAER	4.90	0.03	12	18	30	23	47	70
2553.00	FINNVAER	0.70	0.01					57	57
2611.00	FINNVAER	1.10	0.01					64	64
2625.00	FINNVAER	3.60	0.02	32	13	45	47	8	55
2632.50	FINNVAER	0.30	0.01						
2638.00	NESNA	21.00	0.49	20	18	38	16	46	62
2640.00	NESNA	46.00	0.70	22	18	40	16	44	60
2647.00	NESNA	62.60	0.62	18	17	35	17	48	65
2650.00	NESNA	73.60	0.78	17	16	33	19	48	67
2653.00	ENGELVAER	18.70	0.28	15	16	31	10	59	69
2661.00	ENGELVAER	23.40	0.30	17	13	30	9	61	70
2673.00	ENGELVAER	12.10	0.15	22	16	38	5	57	62

Table 2.2.1. SOURCE ROCK EXTRACTION DATA I WELL 6407/7-2 (cont'd)

Depth(m)	Group/Fm	EOM(mg)	EOM(%)	Hydrocarbons SAT(%)	Hydrocarbons ARO(%)	Hydrocarbons TOTAL(%)	Non Hydrocarbons NSO(%)	Non Hydrocarbons ASPH(%)	Non Hydrocarbons TOTAL(%)
2678.80	ENGELVAER	14.50	0.23	16	13	29	9	62	71
2681.75	ENGELVAER	14.20	0.15	13	12	25	12	63	75
2695.00	ENGELVAER	4.10	0.08	44	6	50	8	42	50
2739.40	LEKA	10.00	0.09	25	11	36	11	53	64
2755.00	LEKA	2.80	0.05	11	20	31	12	57	69
2760.00	LEKA	3.50	0.07	17	11	28	9	63	72
2772.00	ALDRA	6.70	0.11	28	18	46	9	45	54
2800.75	ALDRA	8.50	0.11	30	13	43	9	48	57
2872.00	ALDRA	125.40	1.25	80	15	95	4	1	5
2874.00	ALDRA	62.30	0.64	79	14	93	5	2	7
2876.00	ALDRA	47.40	0.55	70	18	88	9	3	12
2884.85	HITRA	226.00	9.70	2	10	12	5	83	88
2888.10	HITRA	116.80	3.30	5	23	28	10	62	72
2905.30	HITRA	310.20	7.80	2	8	10	4	86	90
2913.00	HITRA	163.80	5.00	7	16	23	11	66	77
2923.00	HITRA	1.40	0.03					71	71
2934.00	HITRA	31.40	0.62	12	16	28	5	67	72
2952.00	INT TRIAS EV	0.40	0.00						
3032.00	INT TRIAS EV	0.50	0.01						

Table 2.2.1. SOURCE ROCK EXTRACTION DATA I WELL 6407/7-2 (cont'd)

Depth(m)	Group/Fm	EOM(mg)	EOM(%)	Hydrocarbons SAT(%)	ARO(%)	TOTAL(%)	Non Hydrocarbons NSO(%)	ASPH(%)	TOTAL(%)
3109.50	INT TRIAS EV	0.40	0.00						
3243.00	INT TRIAS EV	0.70	0.01						
3298.00		0.40	0.10						

TABLE II.2.2

Extraction yield ratios

Table 2.2.2. SOURCE ROCK EXTRACTION DATA II WELL 6407/7-2

Depth(m)	Group/Fm	TOC (%)	EOM(%)/TOC(%)	SAT(%)/TOC(%)	SAT(%)/ARO(%)	HC/non HC
1716.00	SKLINNA	1.35	0.05	5.93	0.50	0.32
1824.00	SKOMVAER	1.86	0.04	6.99	0.93	0.37
1956.50	SKOMVAER	1.49	0.02	8.05	0.75	0.39
2025.00	FINNVAER	1.12	0.04	18.75	1.40	0.56
2075.00	FINNVAER	1.04	0.05	8.65	0.50	0.37
2251.00	FINNVAER	0.95	0.04	8.42	0.47	0.33
2425.00	FINNVAER	1.09	0.03	11.01	0.67	0.43
2553.00	FINNVAER	0.12	0.08			
2611.00	FINNVAER	1.63	0.01			
2625.00	FINNVAER				2.46	0.82
2638.00	NESNA	5.04	0.10	3.97	1.11	0.61
2640.00	NESNA	7.56	0.09	2.91	1.22	0.67
2647.00	NESNA	0.87	0.71	20.69	1.06	0.54
2650.00	NESNA	8.00	0.10	2.13	1.06	0.49
2653.00	ENGELVAER	3.34	0.08	4.49	0.94	0.45
2661.00	ENGELVAER	5.12	0.06	3.32	1.31	0.43
2673.00	ENGELVAER	2.74	0.05	8.03	1.38	0.61
2678.80	ENGELVAER	4.10	0.06	3.90	1.23	0.41

Table 2.2.2. **SOURCE ROCK EXTRACTION DATA II WELL 6407/7-2** (cont'd)

Depth(m)	Group/Fm	TOC (%)	EOM(%)/TOC(%)	SAT(%)/TOC(%)	SAT(%)/ARO(%)	HC/non HC
2681.75	ENGELVAER	2.10	0.07	6.19	1.08	0.33
2695.00	ENGELVAER	0.48	0.17	91.67	7.33	1.00
2739.40	LEKA	4.40	0.02	5.68	2.27	0.56
2755.00	LEKA	0.75	0.07	14.67	0.55	0.45
2760.00	LEKA	1.10	0.06	15.45	1.55	0.39
2772.00	ALDRA	1.56	0.07	17.95	1.56	0.85
2800.75	ALDRA	1.50	0.07	20.00	2.31	0.75
2872.00	ALDRA	1.18	1.06	67.80	5.33	19.00
2874.00	ALDRA	1.06	0.60	74.53	5.64	13.29
2876.00	ALDRA	0.71	0.77	98.59	3.89	7.33
2884.85	HITRA				0.20	0.14
2888.10	HITRA	13.98	0.24	0.36	0.22	0.39
2905.30	HITRA	28.32	0.28	0.07	0.25	0.11
2913.00	HITRA	17.46	0.29	0.40	0.44	0.30
2923.00	HITRA	0.23	0.13			
2934.00	HITRA	13.36	0.05	0.90	0.75	0.39
3032.00	INT TRIAS EV	0.15	0.07			
3243.00	INT TRIAS EV	0.88	0.01			
3298.00		0.24	0.42			

TABLE II.3.1

Molecular ratios from gas chromatograms

MOLECULAR RATIOS FROM THE GC OF THE SATURATED HYDROCARBONS

DEPTH (M)	CPI-1	CPI-2	Prist/C17	Phyt/C18	Prist/Phyt	C17/C27
1716.00		1.8	5.2	3.1	1.8	0.5
1824.00		1.4	6.7	1.8	4.0	0.6
1956.00	1.5	1.6	2.9	0.8	1.3	1.4
2025.00	1.1	1.1	1.1	0.5	2.8	2.8
2075.00	1.6	1.2	4.3	1.4	2.7	0.5
2251.00	1.5	1.4	3.5	0.9	2.5	0.3
2425.00	1.8	1.6	1.7	0.3	3.0	0.3
2553.00	3.5	1.9				
2611.00	5.2	4.5		0.1	3.4	
2625.00	1.4	1.0	1.0	0.8	0.8	0.4
2632.50	4.6	0.9		0.8		0.7
2638.00	1.1	1.0	3.2	1.7	2.3	2.5
2640.00	1.1	0.9	2.8	1.9	2.0	2.8
2647.00	1.1	1.0	2.9	1.5	2.3	2.9
2650.00	1.1	1.0	3.1	1.6	2.7	2.4
2653.00	1.1	0.9	3.4	1.5	2.0	1.0
2661.00	1.2	1.1	2.9	1.3	2.7	1.0
2673.00	1.2	1.0	0.9	0.4	2.2	4.2
2678.80	1.2	0.9	0.9	0.4	2.2	3.3
2681.75	1.6	1.5	1.9	0.5	2.9	0.4
2695.00	2.0	1.0	0.8	0.5	1.4	2.1
2739.40	1.6	1.4	0.9	0.3	0.3	1.2
2755.00	1.3	1.1	0.8	0.3	1.7	0.7
2760.00	1.4	1.2	1.7	0.4	3.1	0.7
2772.00	1.7	1.8	0.6	0.2	4.4	0.5
2800.75	1.7	1.7	1.0	0.2	3.0	0.3
2872.00	1.1	0.9	0.9	0.5	1.8	3.2
2874.00	1.1	0.9	0.9	0.5	1.8	3.2
2876.00	1.1	1.0	0.9	0.5	1.9	3.4
2884.85	1.3	1.2	2.8	1.0	3.6	3.5
2888.10	1.6	1.3	2.7	0.4	6.9	1.9
2905.30	1.0	0.7	1.2	1.1	1.9	4.8
2913.00	1.8	1.7	23.3	2.2	10.8	2.6
2923.00			1.3	2.7	0.5	
2934.00	1.9	1.3	0.6	0.1	4.2	0.5
2952.00		1.0	0.8	0.7	0.4	0.3
3032.00	2.5	1.0	0.6	0.5	0.6	2.4
3109.50	6.0	0.9		1.5		0.9
3243.00	1.4	1.0	0.7	0.6	0.5	1.1
3298.00		1.8		0.6		0.7

TABLE II.6.1

Quantitative results from pyrolysis GC

Table 2.6.1. PYROLYSIS-GASCHROMATOGRAPHY DATA 6407/7-2

Depth (m)	Group/Fm	C1 (%)	C2-C5 (%)	C1-C5 (%)	C6-C14 (%)	C15+ (%)	GORP C1-5/C6+	C1-C6 (%)	C7-C14 (%)	GOPI C1-6/C7+
2611.00	FINNVAER	10.50	7.40	17.90	37.40	44.70	0.22			
2638.00	NESNA	4.60	19.50	24.10	42.60	33.30	0.32			
2640.00	NESNA	3.60	14.80	18.40	33.80	47.80	0.23			
2647.00	NESNA	3.40	9.20	12.60	30.00	57.40	0.14			
2650.00	NESNA	5.10	16.90	22.00	37.00	41.00	0.28			
2653.00	ENGELVAER	2.80	14.70	17.50	45.60	36.90	0.21			
2661.00	ENGELVAER	6.40	17.60	24.00	36.00	40.00	0.32			
2673.00	ENGELVAER	5.60	18.80	24.40	41.50	34.10	0.32			
2695.00	ENGELVAER	3.60	21.00	24.60	54.40	21.00	0.33			
2884.85	HITRA	17.70	16.10	33.80	33.50	32.70	0.51			
2888.10	HITRA	11.70	14.20	25.90	30.20	44.20	0.35			
2905.30	HITRA	20.10	23.00	43.10	29.70	27.20	0.76			
2913.00	HITRA	13.40	17.60	31.00	36.60	32.40	0.45			
2934.00	HITRA	11.90	18.00	29.90	31.90	38.20	0.43			

TABLE II.7.1

Semiquantitative maceral composition

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Table 2.7.1. **KEROGEN COMPOSITION, SPORE AND POLLEN COMPOSITION WELL 6407/7-2**

Depth (m)	Group/Fm	Amorphous matr.	Woody	Inert- inite	Palyno- morphs	Algal	Herbaceous	Reworked (%)	Particle size	Preserv. (1-3)
2553.00	FINNVAER		65.00	30.00	5.00					
2611.00	FINNVAER		82.00	8.00	10.00					
2625.00	FINNVAER		80.00	20.00						
2632.50	FINNVAER		78.00	22.00						
2638.00	NESNA		78.00	8.00	14.00					
2650.00	NESNA			88.00	12.00					
2653.00	ENGELVAER		84.00		16.00					
2673.00	ENGELVAER		77.00	11.00	12.00					
2695.00	ENGELVAER		28.00	8.00	64.00					
2750.00	LEKA		24.00	2.00	74.00					
2760.00	LEKA		25.00		75.00					
2888.10	HITRA		69.00	10.00	21.00					
2905.30	HITRA		74.00	14.00	12.00					
2913.00	HITRA		70.00	4.00	26.00					
2923.00	HITRA		76.00	4.00	20.00					
2952.00	INT TRIAS EV		83.00	13.00	4.00					
3298.00		10.00	50.00	30.00	10.00					

TABLE III.1.1.

Vitrinite reflectance, spore colouration and fluorescence

Table 3.1.1. VITRINITE REFLECTANCE DATA WELL 6407/7-2
Average values

Depth	Group/Fm	Population I	Population II	Population III
1716.00	SKLINNA	0.44 (9)		
1824.00	SKOMVAER	0.31 (10)		
1956.50	SKOMVAER	0.44 (6)		
2025.00	FINNVAER	0.42 (11)		
2075.00	FINNVAER	0.48 (10)		
2251.00	FINNVAER	0.50 (12)		
2425.00	FINNVAER	0.51 (5)		
2553.00	FINNVAER	0.49 (1)		
2638.00	NESNA	0.43 (22)		
2640.00	NESNA	0.42 (22)		
2647.00	NESNA	0.45 (21)		
2650.00	NESNA	0.41 (22)		
2653.00	ENGELVAER	0.49 (20)		
2661.00	ENGELVAER	0.52 (21)		
2673.00	ENGELVAER	0.53 (21)		
2678.80	ENGELVAER	0.52 (23)		
2681.75	ENGELVAER	0.51 (20)		
2695.00	ENGELVAER	0.53 (9)		

Table 3.1.1. **VITRINITE REFLECTANCE DATA WELL 6407/7-2** (cont'd)
Average values

Depth	Group/Fm	Population I	Population II	Population III
2739.40	LEKA	0.48 (21)		
2755.00	LEKA	0.53 (7)		
2760.00	LEKA	0.50 (21)		
2772.00	ALDRA	0.48 (22)		
2800.75	ALDRA	0.54 (20)		
2884.85	HITRA	0.42 (21)		
2888.10	HITRA	0.52 (21)		
2905.30	HITRA	0.56 (20)		
2913.00	HITRA	0.48 (22)		
2923.00	HITRA	0.39 (1)		
2934.00	HITRA	0.71 (20)		

TABLE III.3.1.

Sterane biomarker ratios

BIOMARKER RATIOS
STERANE ISOMERISATION

DEPTH (M)	20S aaa %	20S+R aBB %	20Raaa/ HOMOPRE.
1716.00			
1824.00	29		11.70
1956.00			
2025.00	19	36	2.10
2075.00	21	43	1.10
2251.00	24	46	0.82
2425.00	24	36	2.20
2553.00			
2611.00			
2625.00	54	55	0.81
2632.50	51	56	0.57
2638.00	31	23	5.70
2640.00	30	24	7.00
2647.00	39	27	3.40
2650.00	45	29	2.70
2653.00	39	26	6.10
2661.00	39	26	6.50
2673.00	36	25	4.80
2678.80	36	26	9.05
2681.75	37	25	10.30
2695.00	45	49	1.80
2739.40	43	24	5.04
2755.00	43	28	2.50
2760.00	42	31	1.60
2772.00	33	26	7.00
2800.75	42	28	10.30
2872.00	58	56	0.41
2874.00	64	59	0.29
2876.00	65	58	0.29
2881.10	42	30	3.60
2884.85	45	36	5.70
2905.30	43	32	
2913.00	40	29	7.80
2923.00	30	25	0.43
2934.00	41		
2952.00	52	58	0.56
3032.00	49	53	0.90
3109.50	50	55	1.00
3243.00	53	52	1.00
3298.00		54	0.37

TABLE III.3.2.

Triterpane biomarker ratios

BIOMARKER RATIOS
TRITERPANE ISOMERISATION

DEPTH (M)	TS/TM	NOR/ NOR+HOP	BNO BNO+NOR	MORET/ HOPAN	22S %
1716.00					
1824.00					
1956.00		0.34	0.34	0.63	43
2025.00	0.66	0.30	0.22	0.17	21
2075.00	0.69	0.28	0.17	0.16	23
2251.00	0.20	0.31		0.36	17
2425.00	0.05	0.40		0.60	37
2553.00	0.12	0.47		0.52	56
2611.00	0.14	0.49		0.54	60
2625.00	0.79	0.43	0.08	0.20	55
2632.50	1.08	0.46	0.14	0.14	55
2638.00	0.40	0.40		0.24	55
2640.00	0.46	0.36		0.23	54
2647.00	0.28	0.39		0.23	56
2650.00	0.20	0.38		0.24	57
2653.00	0.19	0.37		0.28	55
2661.00	0.20	0.37		0.30	57
2673.00	0.25	0.37		0.25	57
2678.80	0.18	0.34		0.26	58
2681.75	0.21	0.36		0.29	56
2695.00	0.79	0.43	0.08	0.17	58
2739.40	0.18	0.38	0.13	0.27	58
2755.00	0.23	0.39	0.08	0.27	57
2760.00	0.16	0.46	0.10	0.32	56
2772.00	0.28	0.36		0.29	55
2800.75	0.16	0.37		0.32	57
2872.00	1.50	0.31	0.26	0.17	57
2874.00	1.90	0.26	0.32	0.13	57
2876.00	2.00	0.27	0.32	0.13	58
2881.10		0.55	0.28	0.29	53
2884.85	0.06	0.43	0.06	0.40	58
2905.30	0.17	0.40	0.23	0.25	58
2913.00		0.43	0.13	0.40	55
2923.00	0.15	0.37	0.20	0.39	58
2934.00	0.01	0.45		0.54	58
2952.00	1.10	0.41	0.14	0.12	62
3032.00	1.02	0.43	0.09	0.13	66
3109.50	1.00	0.44	0.09	0.11	64
3243.00	0.97	0.44	0.09	0.13	67
3298.00	1.30	0.32	0.26	0.13	64

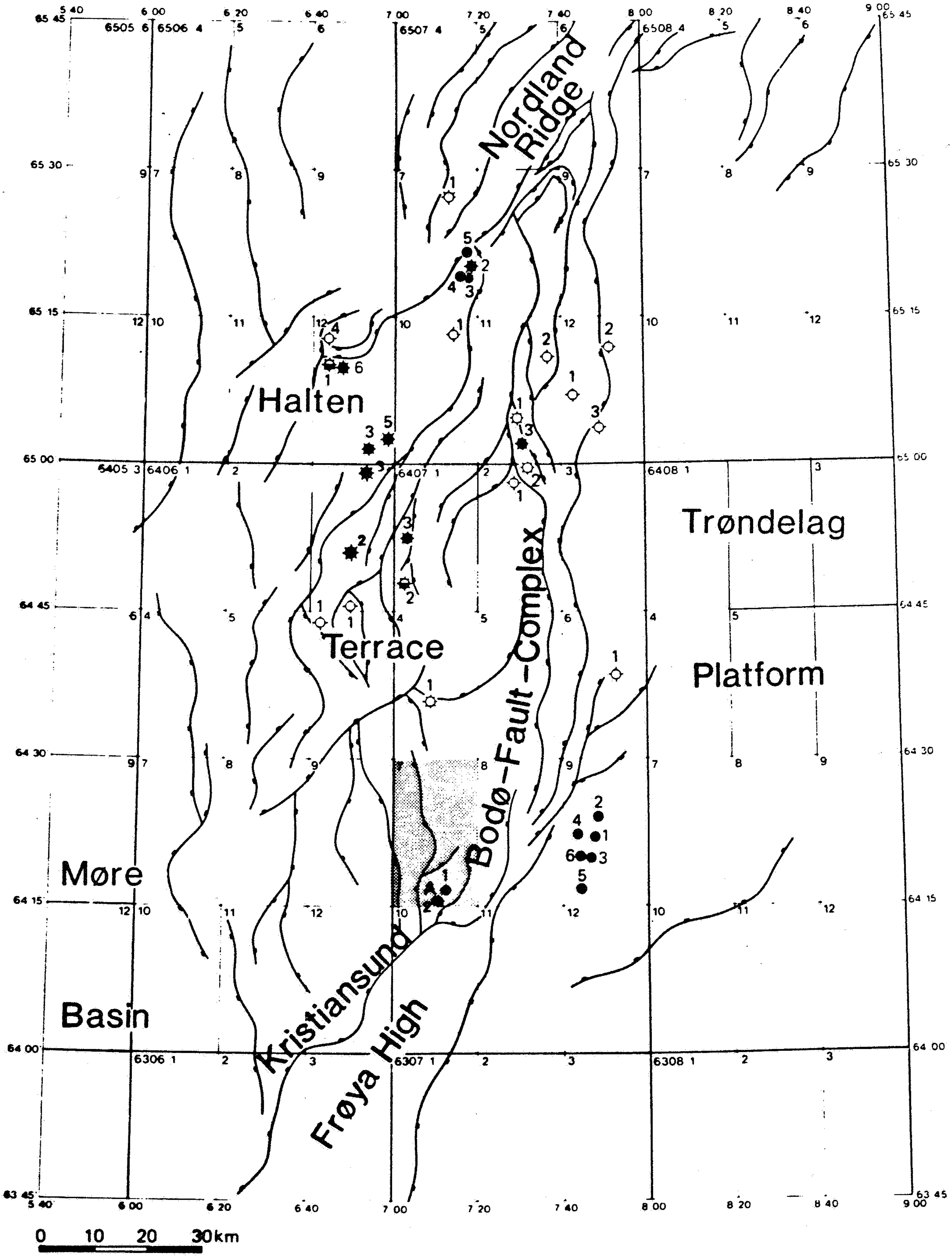
APPENDIX II

SOURCE ROCK EVALUATION 6407/7-2

FIGURES

FIGURE I.1.

Well location map



Nordland Ridge
Halten
Terrace
Bodø-Fault-Complex
Trøndelag
Platform
Møre
Basin
Kristiansund
Frøya High
0 10 20 30km

FIGURE I.2

Summary of source rock potential

SOURCE ROCK EVALUATION

	DEPTH (m)	SOURCE POTENTIAL	KEROGEN TYPE	MATURITY
TERT/CRET	1716			
		POOR	III	IMMATURE
	2638			
JURASSIC		GOOD	II	MARGINALLY
	2679			MATURE
		POOR/ EXCELLENT	II	
TRIASSIC	2934			
		NO		
	3315			

FIGURE II.1.1

Results from rigsite geochemistry

EXLOG NORSK HYDRO

Well : 6407/7-2

GEOCHEMICAL EVALUATION LOG

GENERAL DATA

Data Range : 1716 m to 3315 m

Plot Prepared on : 9 Mar 1987

Plot Scale : 1 to 10000

Exlog Laboratory :

Plot Prepared By :

Analysis : Oil Show Analyser

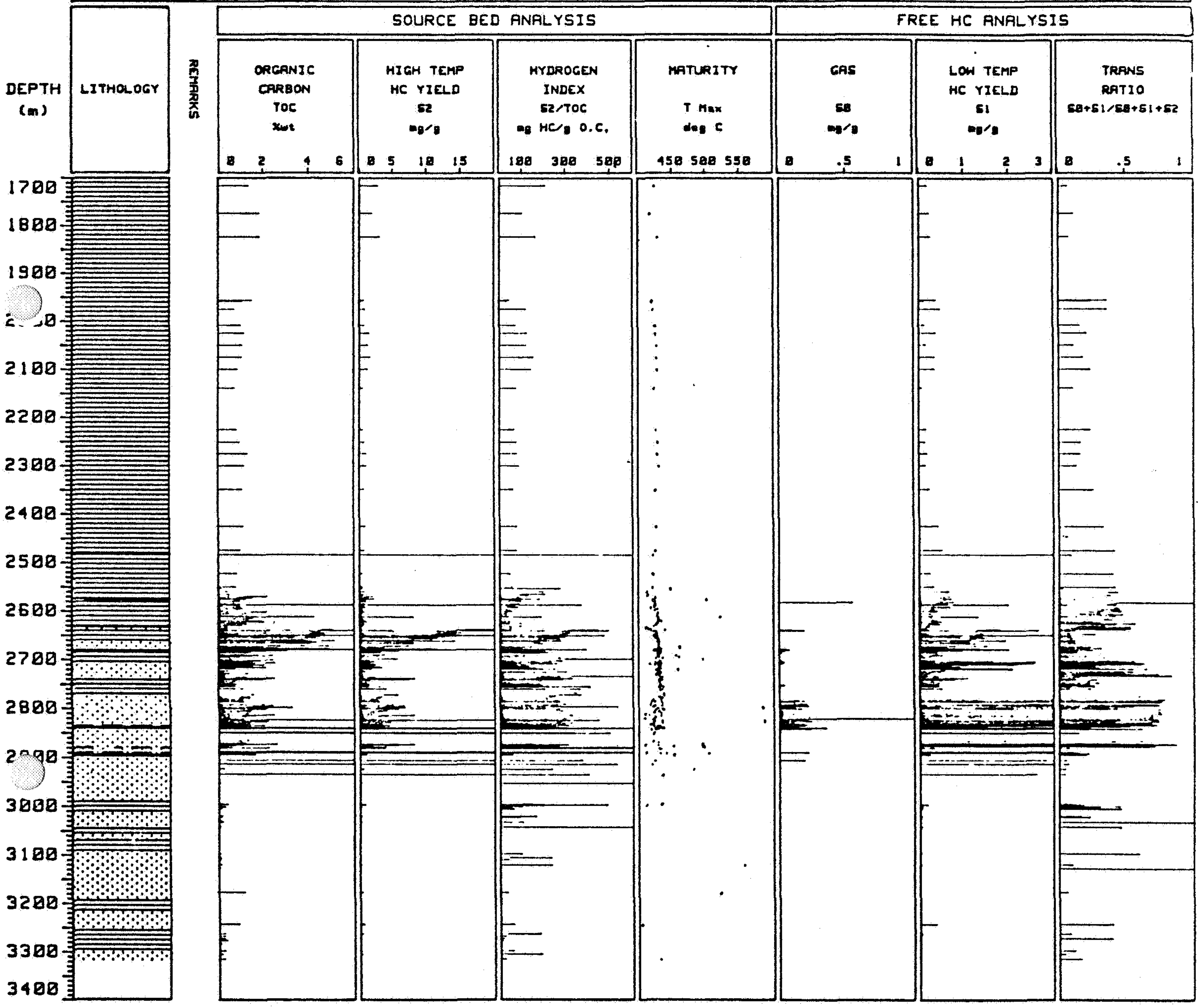


FIGURE II.1.2

TOC values versus depth

TOTAL ORGANIC CARBON
WELL: 6407/7-2

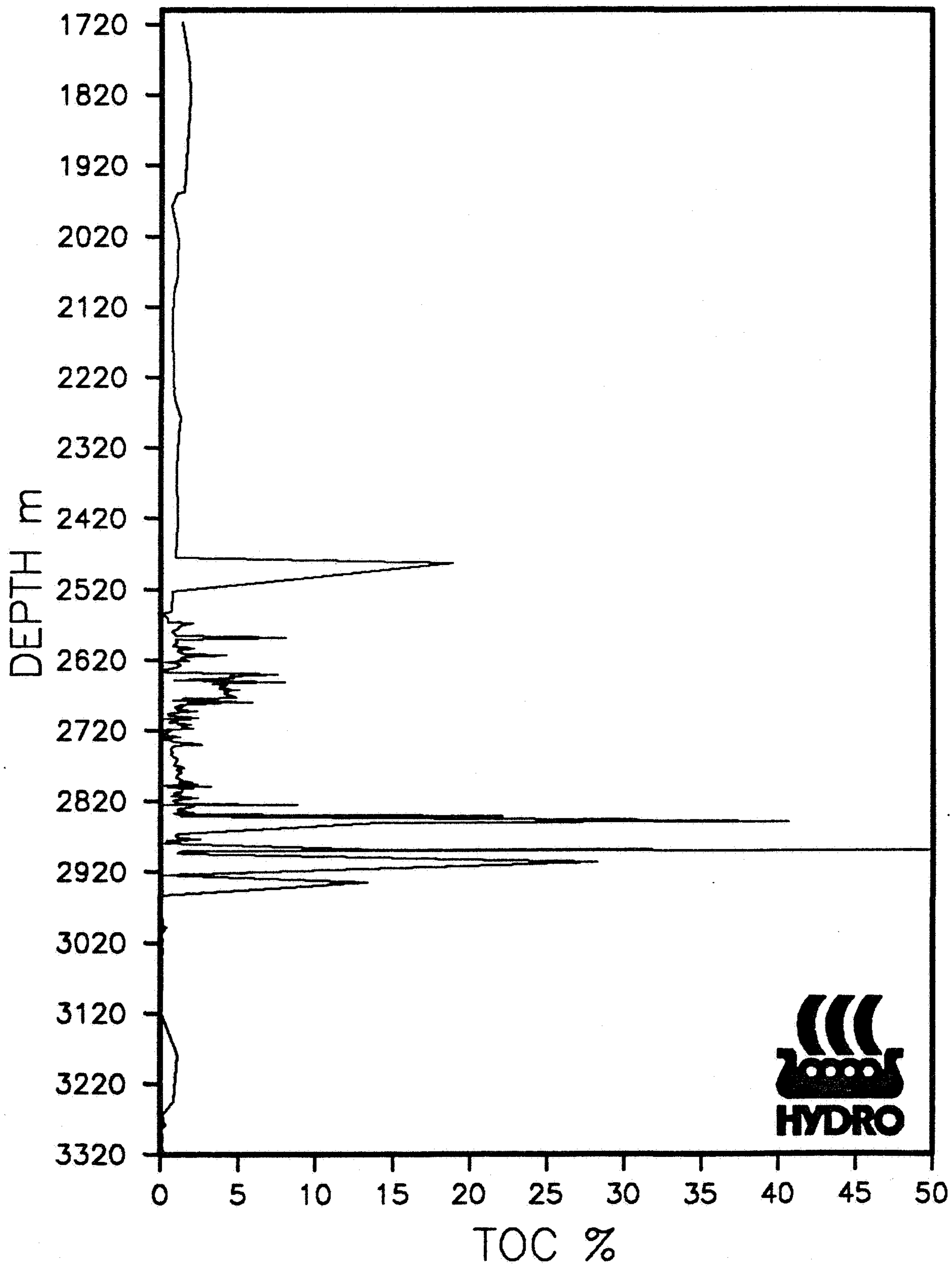


FIGURE II.2.1

EOM(ppm) versus depth

EOM (ppm) OF WELL 6407/7-2

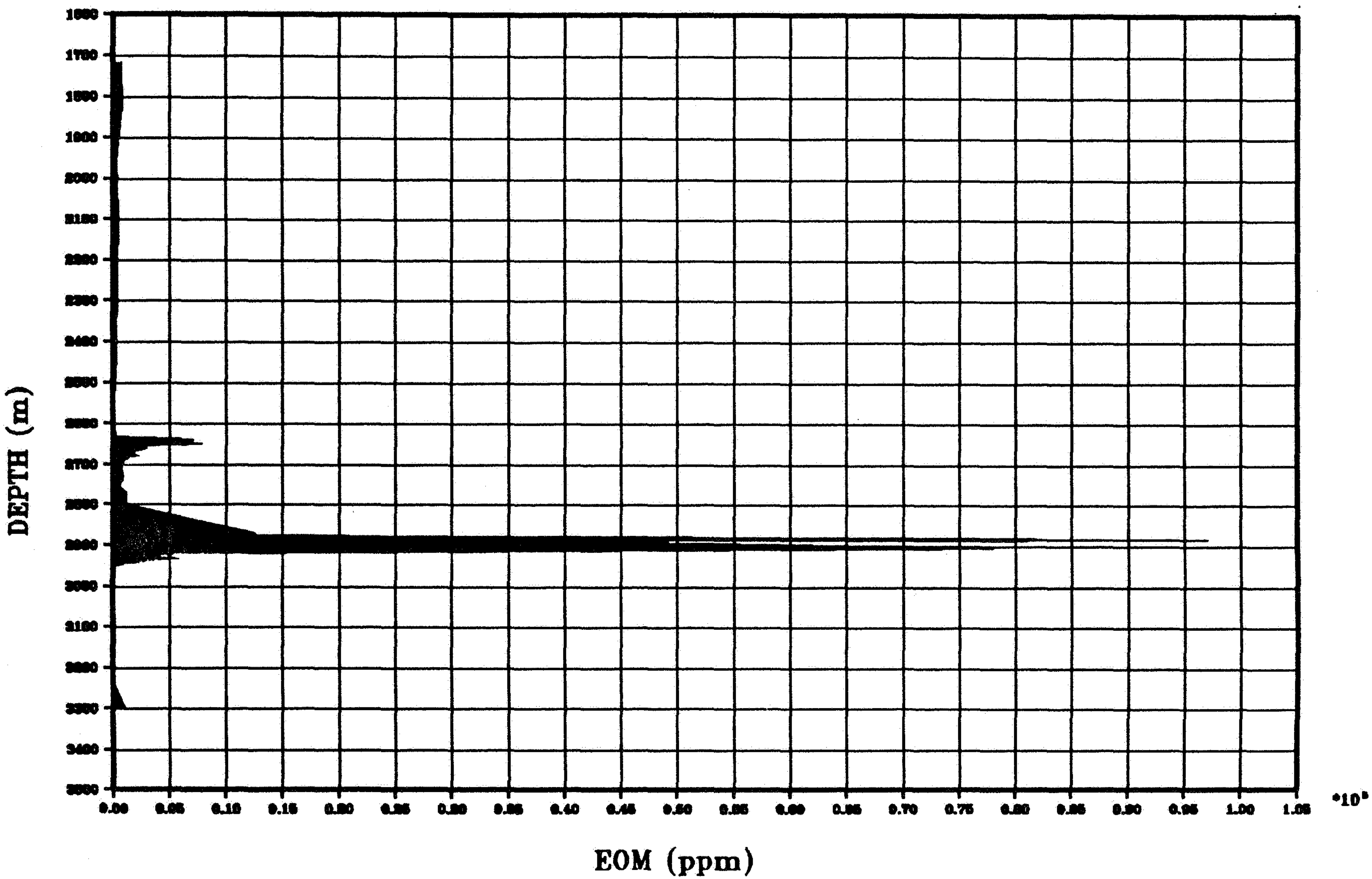
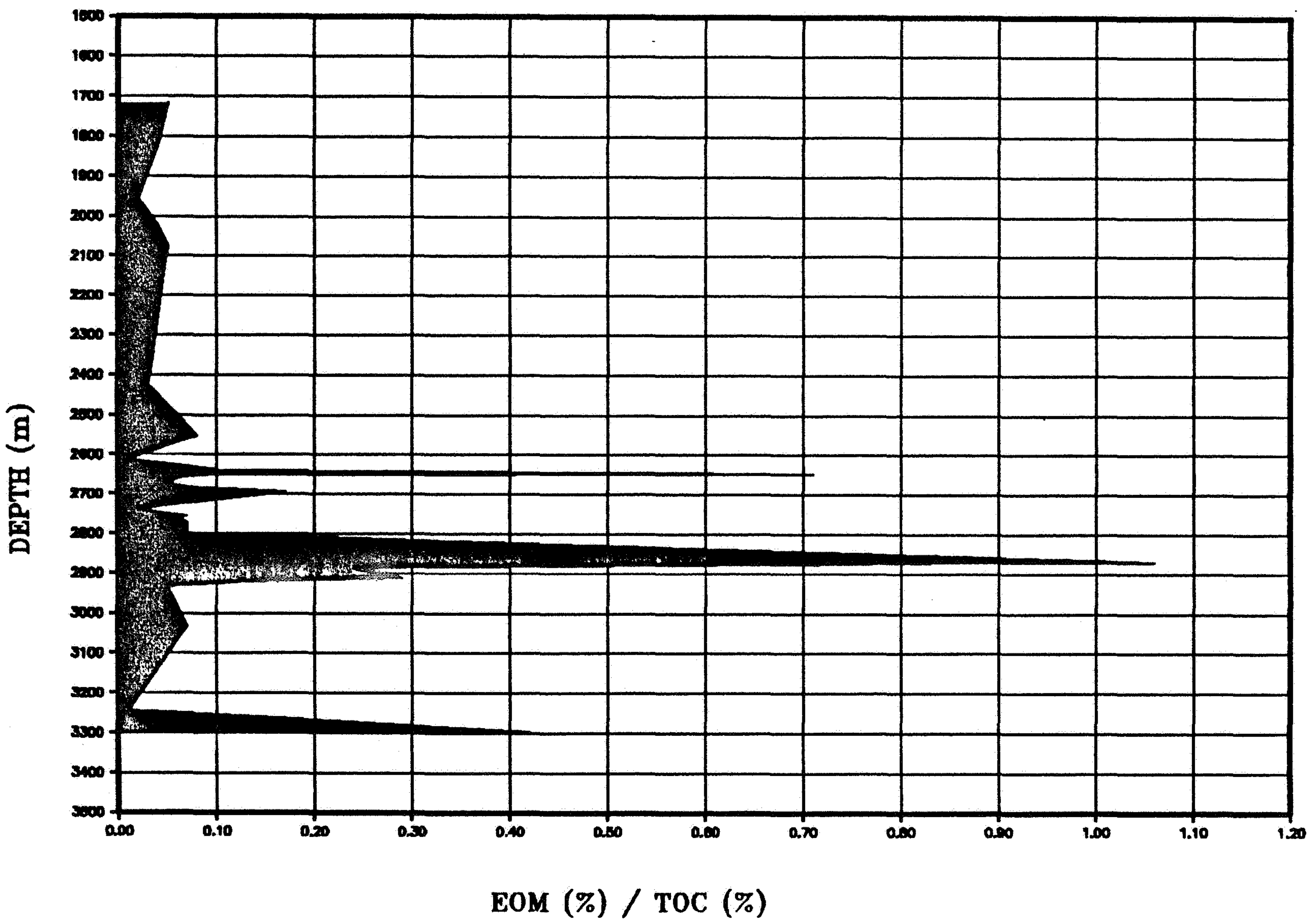


FIGURE II.2.2

EOM/TOC versus depth

EOM/TOC FROM WELL 6407/7-2

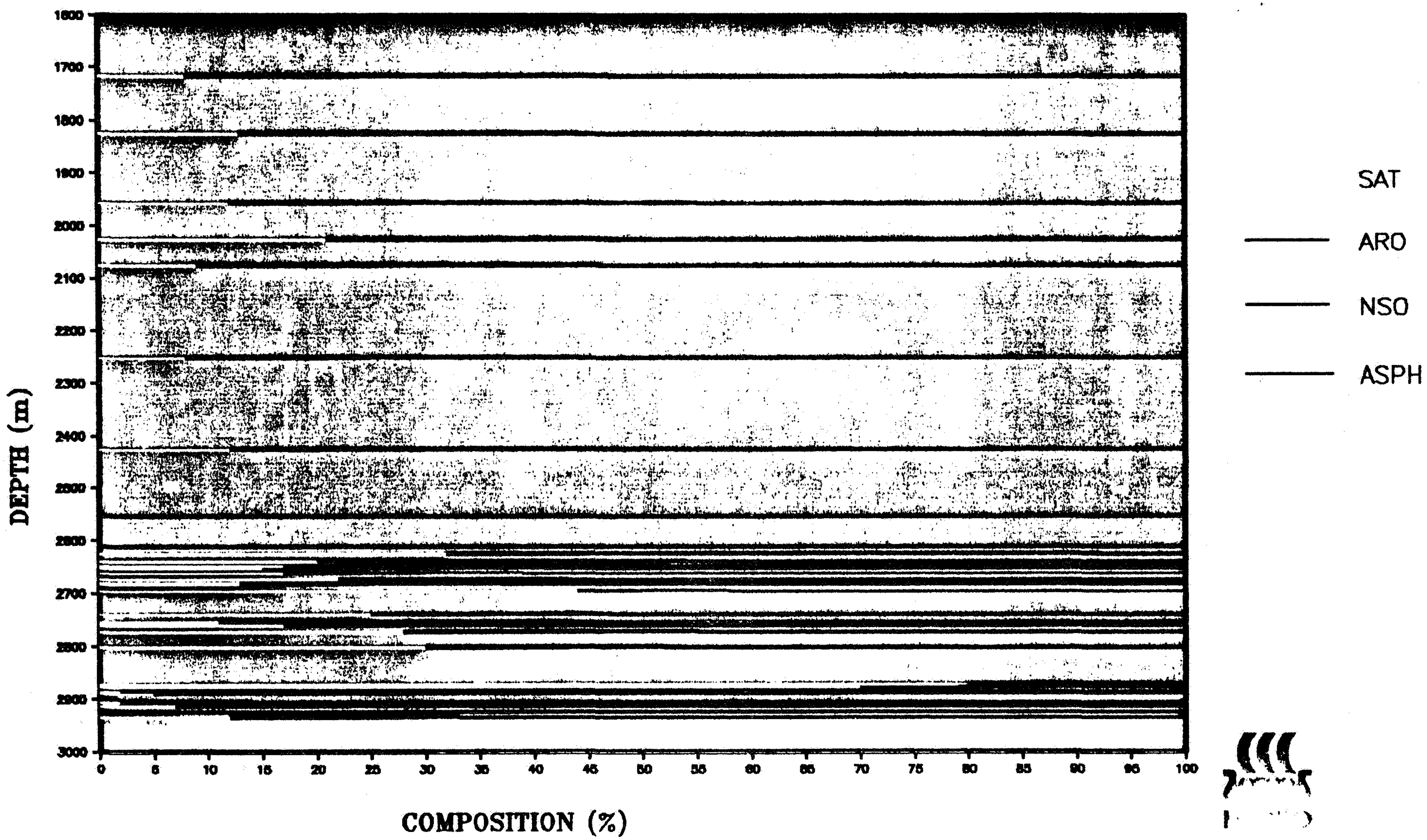


HYDRO

FIGURE II.2.3

Composition of EOM versus depth

EOM COMPOSITION OF WELL 6407/7-2



EOM COMPOSITION OF WELL 6407/7-2

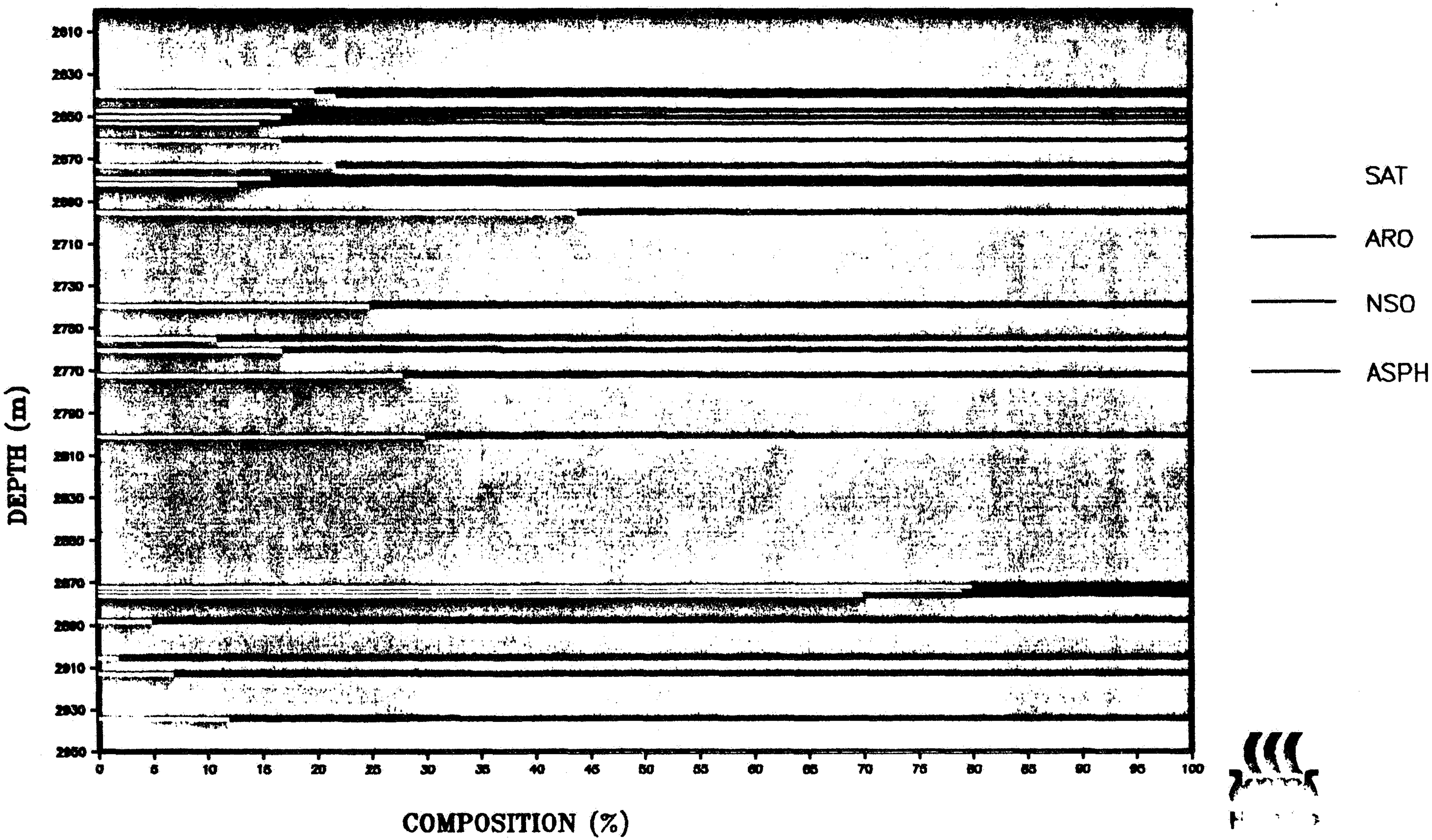
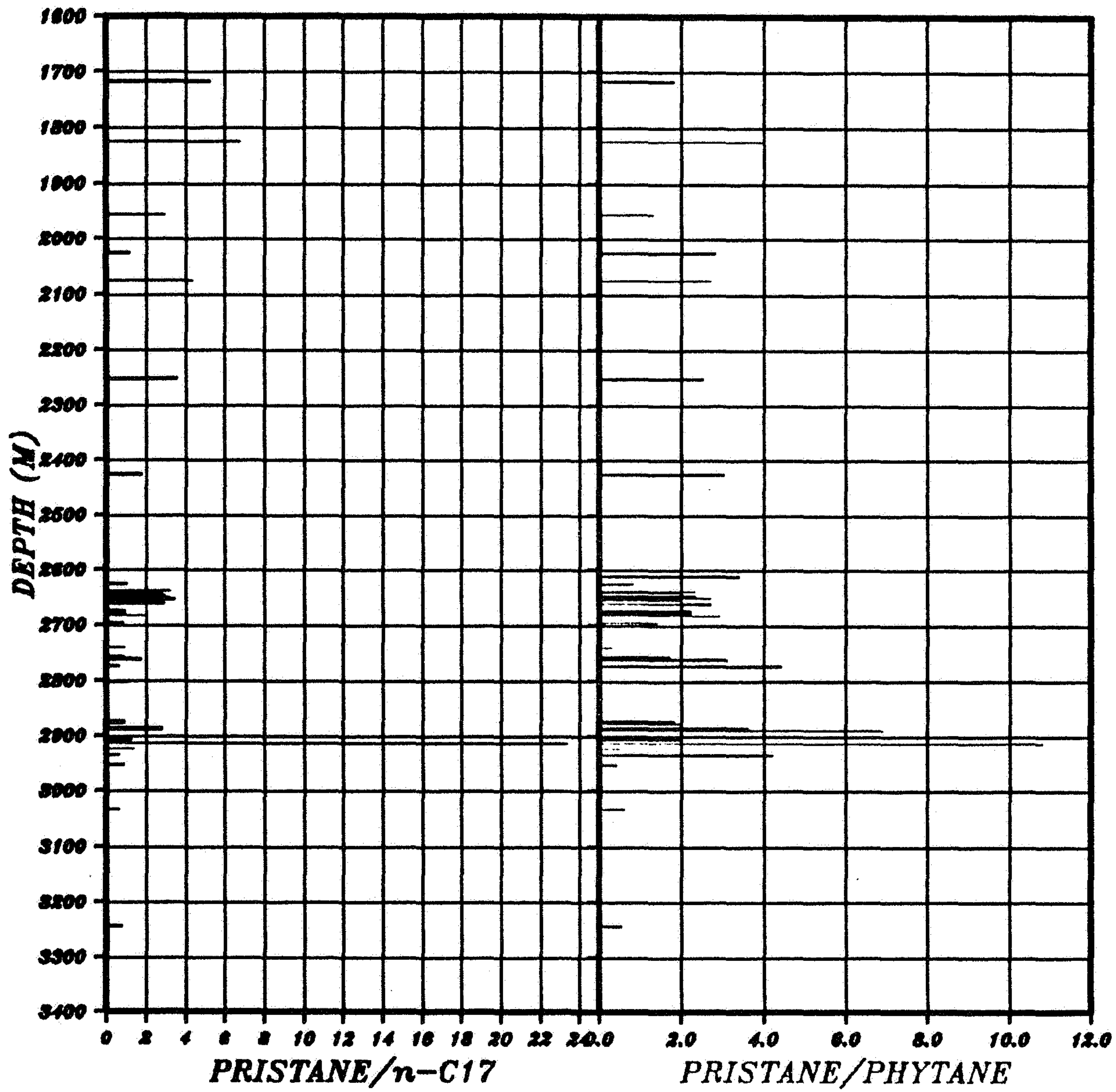


FIGURE II.3.1

Molecular ratios versus depth

WELL: 6407/7-2

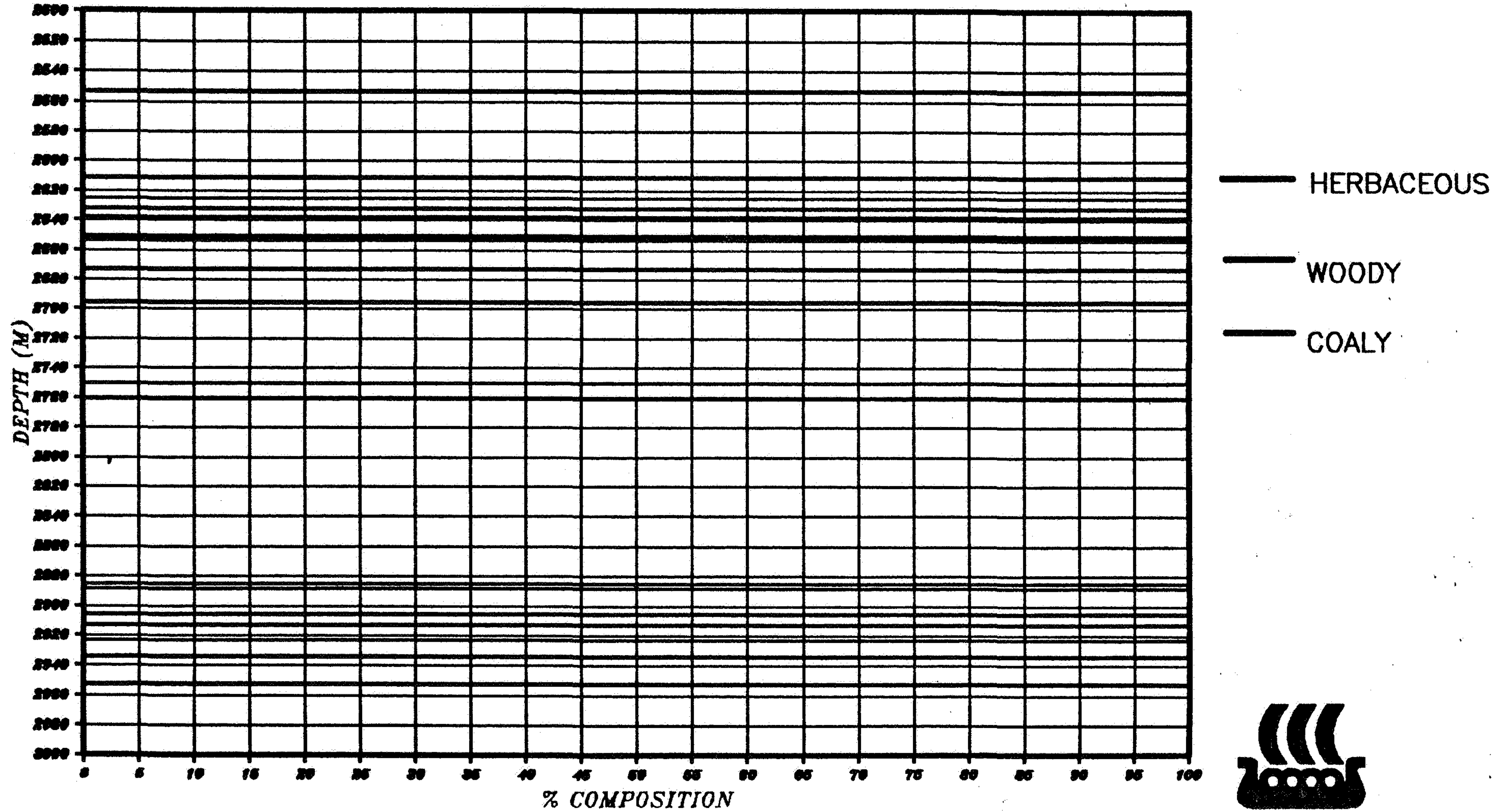


DEPTH (M)
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
0 2 4 6 8 10 12 14 16 18 20 22 24
PRISTANE/n-C17
0.0 2.0 4.0 6.0 8.0 10.0 12.0
PRISTANE/PHYTANE

FIGURE II.7.1

Semiquantitative maceral composition

VISUAL KEROGEN WELL: 6407/7-2

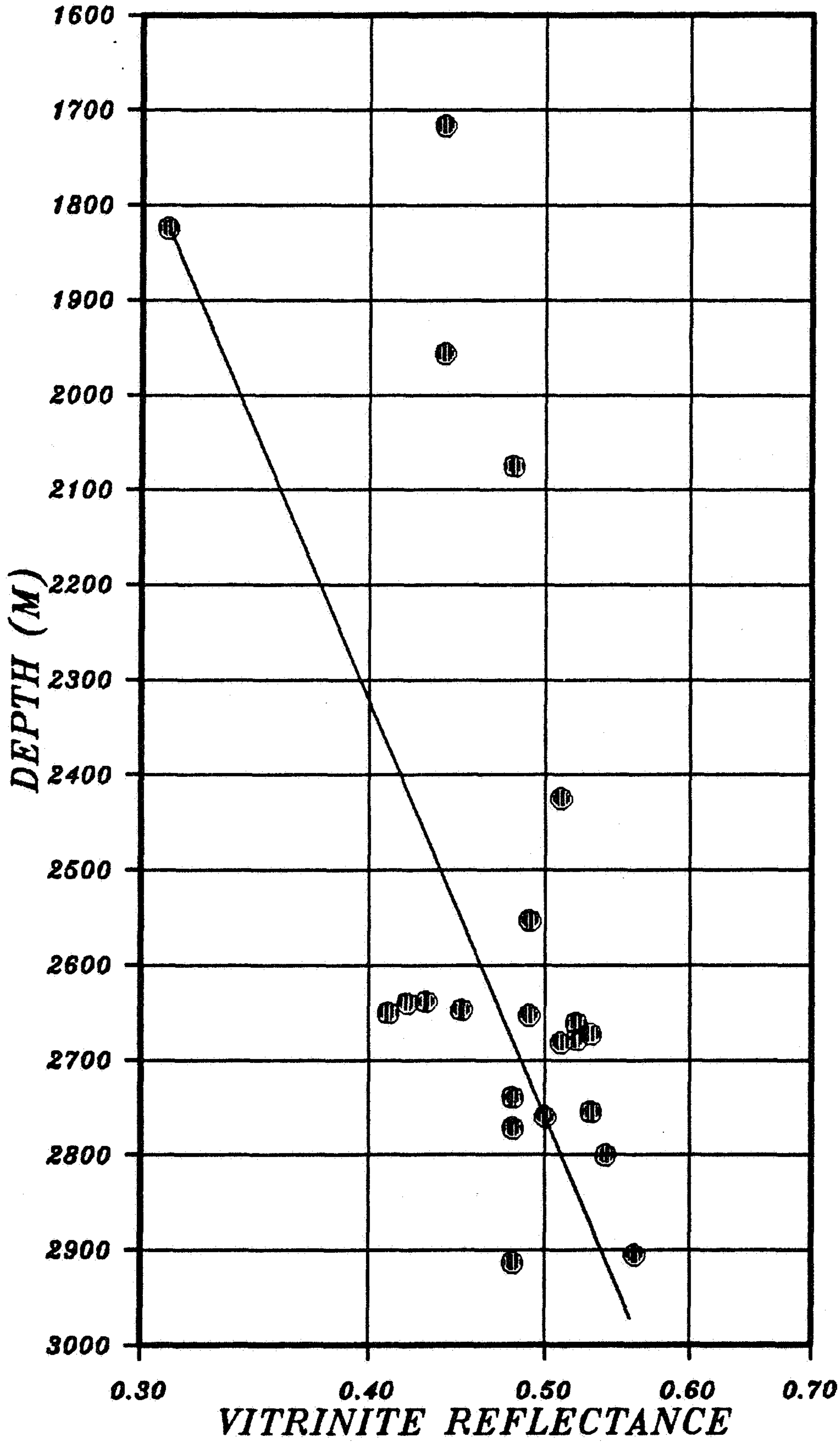


HYDRO

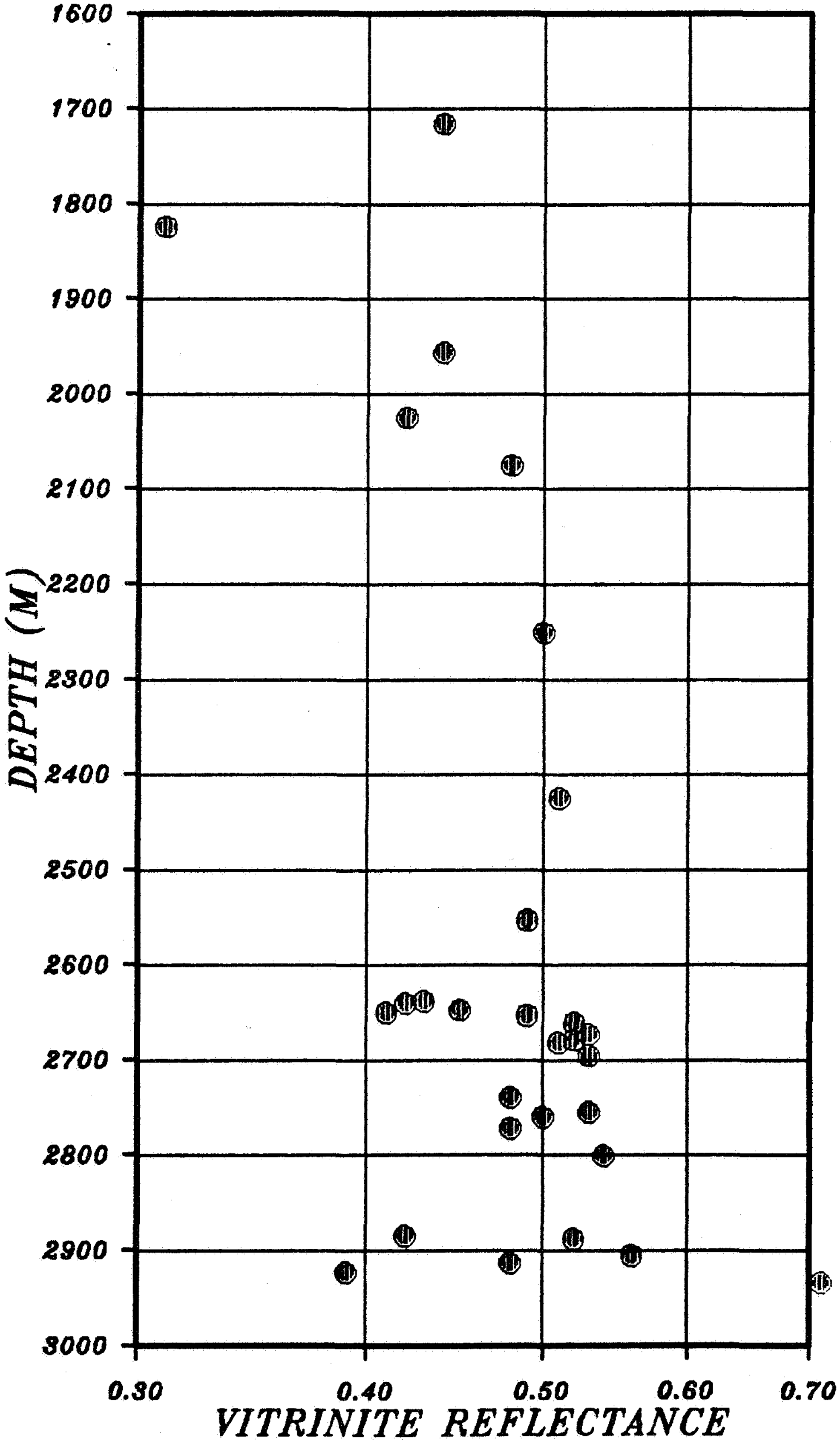
FIGURE III.1.1.

Vitrinite reflectance versus depth

WELL 6407/7-2


1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
DEPTH (M)
0.30
0.40
0.50
0.60
0.70
VITRINITE REFLECTANCE

WELL: 6407/7-2

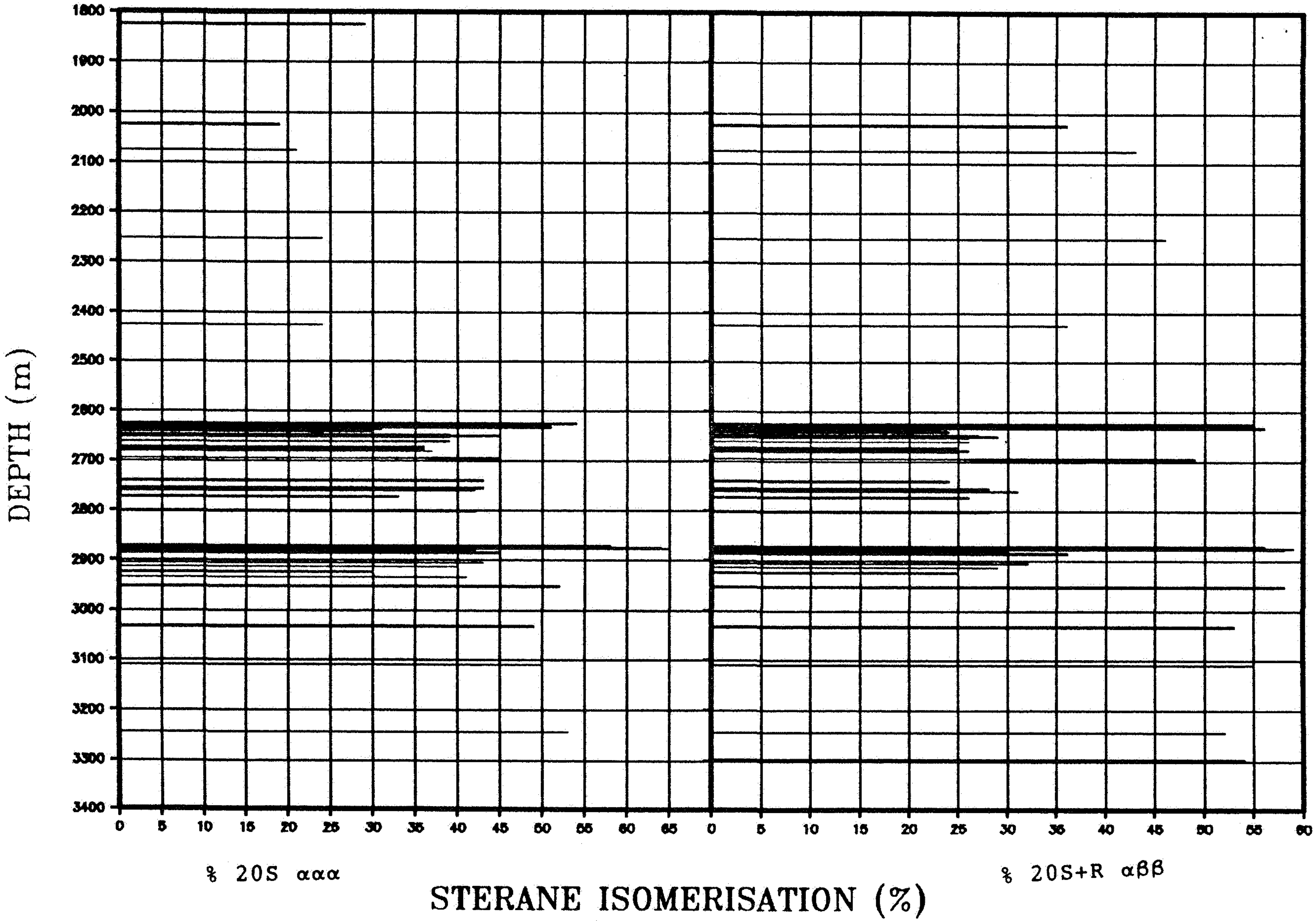


HYDRO

FIGURE III.3.1.

Sterane isomerisation versus depth

BIOMARKER RATIOS WELL 6407/7-2



APPENDIX III

SOURCE ROCK EVALUATION 6407/4-1

AIII.1 Introduction

The data from 6407/4-1 are taken from Geolab Nor and Norsk Hydro Research Centre.

This study is concentrating on evaluation of the Upper Jurassic Nesna Fm. and coal seams and carbargillites in the Lower Jurassic Hitra Fm.

AIII.2 Nesna Fm. 6407/4-1

AIII.2.1 Rock Eval and TOC

The data from the 60 m thick Upper Jurassic sequence are plotted versus depth in Figs. AIII.2.1a and b.

The sample material is a combination of ditch cuttings and SWC. The ditch cuttings are covering 10 m intervals and the SWC's are evenly spread through the sequence.

Vertical quality variations as seen in Figs. AIII.2.1a and b are minor. However, a slight decrease in quality is seen in the hydrogen index (HI) plot in the middle of the formation.
Average values for this horizon are based on the 18 best SWC : S_2 = 8.80 kg/t , TOC = 5.42 % and HI = 152 kg HC/t TOC.

T_{max} values range from 432°C to 453°C indicating mature source rocks within the Oil Window. Production indices range from 0.29 to 0.51 and support the T_{max} values. This indicates a source rock sequence approaching peak oil generation. Some of these samples may have realized nearly half of their HC potential. Provided these samples can be regarded as closed systems (no migration of HC in or out) the approximate original potential can be calculated setting an original PI = 0.05. Reconstruction of an average Nesna sample, e.g. 3720 m, where S_1 = 5.8 kg/t, S_2 = 8.7 kg/t and PI = 0.40 gives an original S_2 of 13.8 kg/t.

Because this horizon is located in a zone of active oil generation and expulsion, it is likely to believe that the S_1 values seen in Appendix VI indicate the oil saturation in the shale necessary to achieve before net expulsion from the source rock can occur. The average S_1 for the 18 best SWC's are 5.4 kg/t. The main proportion of these liquid hydrocarbons will probably be retained in the source rock and at a higher temperature region be cracked down and may be leave the source rock as gas and condensate.

AIII.2.2 Pyrolysis GC

Pyrolysis gaschromatography (PY-GC) has been carried out by Geochem Lab on 10 SWC samples in conjunction with the geochemistry carried out on well 6407/4-1. (Flash pyrolysis in this case).

These data suggest a fairly homogeneous "low oil" and "high gas/condensate" potential throughout the sequence. However, as this sequence is buried to over 3700 m and is located in the oil window it is realistic to believe that some of the heavy liquid potential is realized and that this potential may have been better at lower thermal maturity.

Average values based on 10 SWC samples reveal gas, condensate and oil potentials of 2.9, 5.0 and 1.3 kg/t, respectively, for this Nesna sequence. This gives a total liquid potential of 6.3 kg/t.

Visual inspection of the pyrograms in general, suggest a fair alkane potential remaining in the Upper Jurassic source sequence.

AIII.2.3 Extraction data and gas chromatography of saturated fractions

Four samples have been extracted and the extracts have been analysed by gas chromatography (2 SWC and 2 DC).

The extraction yields are high (0.78 - 1.03 %) and classify this horizon, compared with TOC, as a good - excellent source rock, actively expelling oil.

EOM/TOC is plotted versus depth in Fig. AIII.2.2 and indicates a homogeneous quality.

The chromatograms of the saturated fractions show an unimodal paraffinic distribution. The CPI indices are close to 1.0 suggesting a marine environment of deposition possible mixed with small amounts of terrestrially derived material.

The pristane/phytane and Pr/n-C_{17} ratios from these chromatograms suggest a marine siliciclastic source rock. These ratios are plotted versus depth in Fig. III.2.3.

AIII.2.4 Visual kerogen

Four samples (all SWC's) have been analysed. The data suggest the best quality material to be located in the upper part of the Nesna Fm. slightly decreasing towards the bottom (i.e. algal (Al) and amorphous (Am) material are dominating in samples 3710 and 3720 m while woody inertinite dominates in the lower 2 samples, 3742.50 and 3763.80 m). Although apparently large quality differences exist between the upper and lower samples, the difference in HI is not that dramatic, but follows the trend with the upper two samples having higher HI than the lower two samples.

The selected samples seem to represent approximately average values for the upper and the lower part of the sequence, and the average visual kerogen quality for these samples may be regarded as an approximate average for the whole sequence.

An estimate of the average kerogen content suggests an equal distribution between the four groups Al, Am, woody and inertinite with a very low (~ 2 %) content of herbaceous material.

AIII.3 Hitra Fm. 6407/4-1

AIII.3.1 Rock Eval and TOC

The data for this evaluation is from the routine geochemical evaluation of well 6407/4-1 performed by Geochem Labs LTD, UK, and by analysing DC samples over certain intervals to achieve better resolution. Data (TOC, S_2 and HI) from both studies are plotted versus depth in Fig. III.3.1a and b and average values for coals and clays/siltstone respectively have been calculated and listed in Table AIII.3.1. .

The Geochem study covers the upper Units of the Hitra Fm. (4500 - 4580 m) fairly well. Although the sampling intervals are large, the cuttings seem to indicate the average values for these fairly thick coal measures. These upper coal beds have S_2 values in the range 55 to 104 kg/t and HI of 144 to 231. T_{max} values are generally higher than 460°C and indicate a thermal maturity well down in the oil and gas window.

The coal seams in this upper unit have an average S_2 value of 82 kg/t.

Interbedded shales have low values and will not have generated enough HC to overcome the necessary HC saturation prior to expulsion (S_2 < 5 kg/t).

In the middle unit the coal usually represents approximately 20 % of the DC samples, and explains why Geochem avoided coals in their study.

Average values for coals found in this part of Hitra Fm. are: S_2 = 71.7 kg/t, TOC = 42.5 % and HI = 165

The interbedded shales are again poor in quality and TOC is generally less than 2 % and S_2 is less than 2 kg/t.

In the lower-middle unit the DC samples contain even lower amounts of coals.

The average values indicate a general lowering of organic carbon content in these samples and they may be classified as carbargillites.

Average values are: TOC = 36.1 %, S_2 = 96.4 kg/t and HI = 167.

Interbedded shales are again very low in source rock quality (Appendix VI).

In the lower unit the quality and organic carbon content drop even further.

Average values are: TOC = 36.1, S_2 = 96.4 kg/t and HI = 167.

Interbedded clays have very little potential as source rocks, even for gas.

AIII.3.2 Pyrolysis GC

Three samples were analysed for PY-GC by Geolab Nor, and 12 samples both DC and a few core samples were analysed by Norsk Hydro.

These samples are all basically gas prone. Some minor variations exist but for practical use and calculations these coal samples have potential for gas only.

However, as these samples are mature samples, which have exhausted their liquid potentials, a source rock reconstruction would be valuable to assess their original potential.

AIII.3.3 Extraction data and gas chromatographic data

Only one carbargillite was extracted in the routine well study. At Geolab Nor 17 samples have been analysed, however, all of these are shales with low TOC's. Highest TOC = 3.7 % and these rocks cannot be regarded as any but a poor source rock.

The chromatograms have all a mature looking n-alkane distribution. The EOM/TOC ratio and the Pr/Ph and Pr/n-C_{17} ratios are plotted versus depth in Figures AIII.3.2 and AIII.3.3, respectively.

AIII.3.4 Visual kerogen data

The discussion is based on a combination of data from Geochem's routine report and results from Geolab Nor.

Geochem's data, Table AIII.3.2, suggest dominantly woody, inertinitic material.

The kerogen work undertaken both Geochem and Geolab Nor have been carried out nearly entirely on shales and silt.

The Geolab Nor data suggest dominantly woody material for the coals (4529, 4582, 4645 and 4651 m).

From 4695 m and down to 4819 m all samples seem to be clays. These clays suggest dominating amorphous humic type of organic material. Herbaceous material is present in some samples.

AIII.3.5 Biological markers

Only four extracts have been analysed by GC-MS. (Fragmentograms are given in Appendix IV). Biomarker ratios have been calculated and they are plotted versus depth in Fig. AIII.3.4.

The first sample (4621 m) did not contain any biomarkers. The second sample enabled measuring of %22S and %20S (triterpane and sterane isomerisation). 22S = 63 % and 20S = 37.5 % which is exceptionally low for the present day maturity of samples at 4621 m.

The sterane/triterpane ratio is 0.09 which is typical of samples with terrestrial organic matter.

The extract from the sample at 4762 m has been analysed. Again %22S is that of oil window threshold and sterane isomerisation is 33% which suggests early oil window maturity in the North Sea in general. The sterane/triterpane ratio is 0.01, typical for that of terrestrially derived organic matter.

The lowermost sample has the same characteristic as the two previous samples, e.g. Sterane/Triterpane ratio is 0.04.

APPENDIX III

SOURCE ROCK EVALUATION 6407/4-1

TABLES

Table AIII.3.1: Coal/shale units in Hitra Fm. 6407/4-1 and their average source quality

Unit	Unit Interval	Unit Thickn.	Thickn.* Coal	Thickn.** Shale	Coals, Average TOC	S_2	HI	Shales, Average TOC	S_2	HI
Upper	4500-4590	90	13	5.5	45.7	58.3	128	2.26	1.9	90
Middle	4950-4660	70	20.5	19	42.56	71.7	165	2.67	2.1	64
Lower Middle	4660-4750	90	8	52	38.1	61.7	150	1.07	0.9	
Lower	4750-4835	85	10.5	49	36.1	40.0	153	1.78	1.05	46

* Measured from the well log

** Taken from description of DC

DEPTH m	AMORPHOUS	ALGAL	HERBACEOUS	WOODY	INERTINITE
4460.0	3	2	15	45	35
4501.0	5	15	15	50	15
4570.0	45	9	7	31	8
4606.3	8	20	13	54	5
4614.4	40	20	10	22	8
4650.0	35	15	5	35	10
4740.0	2	4	10	44	40
4760.0	5	5	14	41	35
4835.0	5	5	15	40	35

TableAIII.3.2 Visual kerogen, Hitra fm. 6407/4-1

APPENDIX III

SOURCE ROCK EVALUATION 6407/4-1

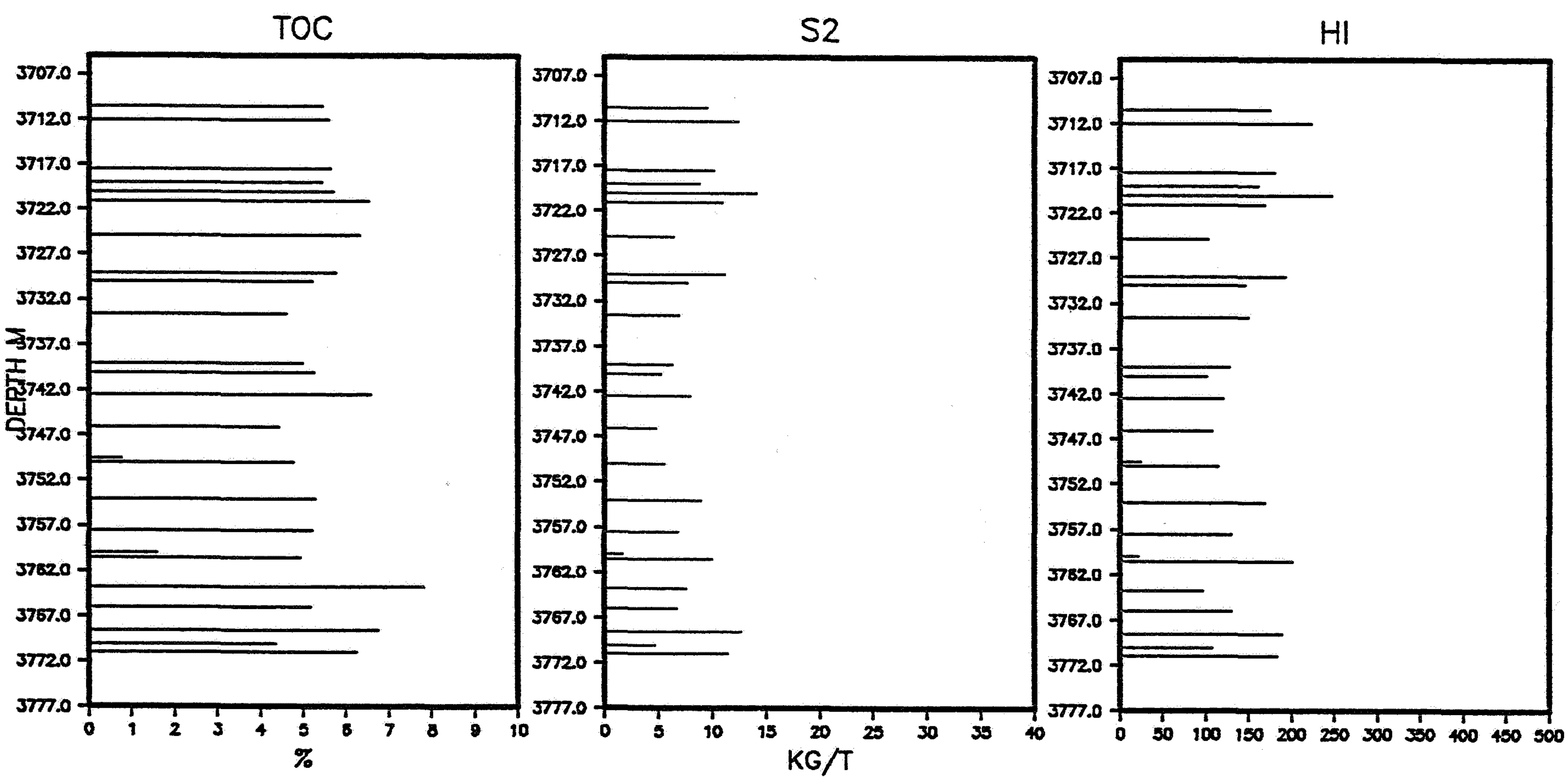
FIGURES

FIG III.2.1 A AND B

PLOTS OF TOC,S2 AND HI VERSUS DEPTH,

NESNA FM. 6407/4-1

NESNA FM. WELL 6407/4-1



NESNA FM. WELL 6407/4-1

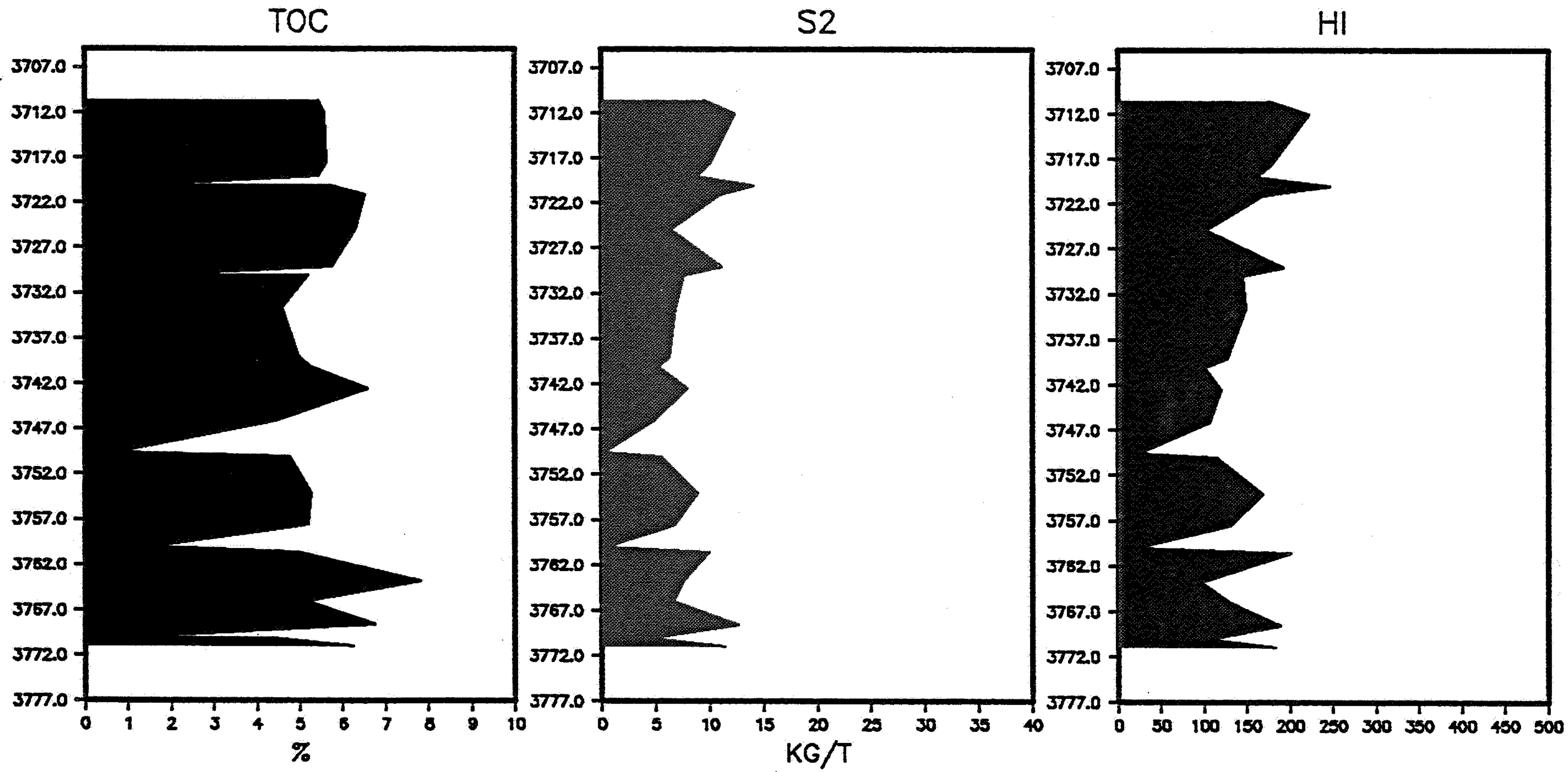


FIG. III.2.2

PLOT OF EOM/TOC VERSUS DEPTH, NESNA FM. 6407/4-1

NESNA FM. WELL 6407/4-1

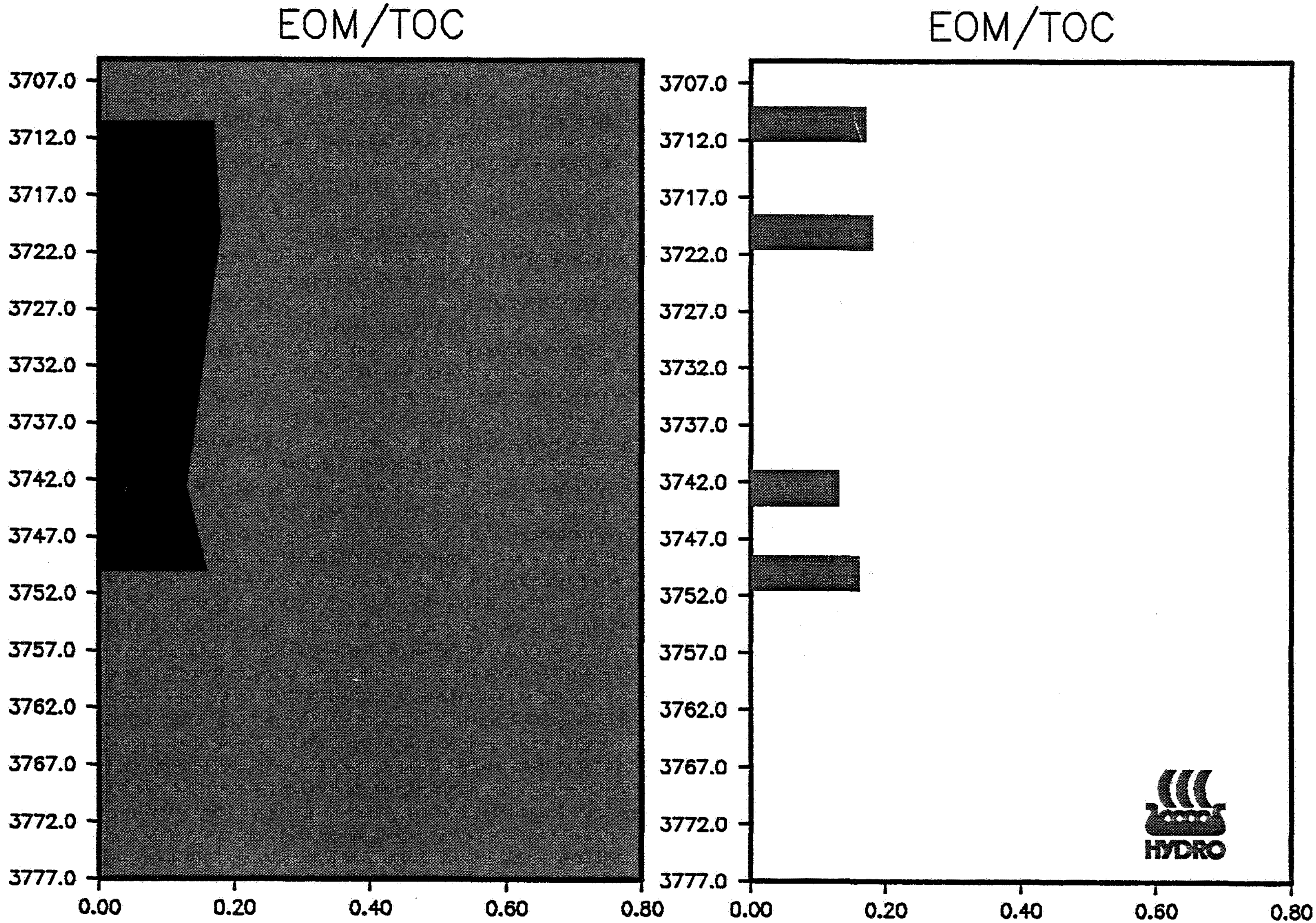


FIG. III.2.3

PLOT OF PR/PH AND PR/n-C17 VERSUS DEPTH,

NESNA FM. 6407/4-1

NESNA FM. WELL 6407/4-1

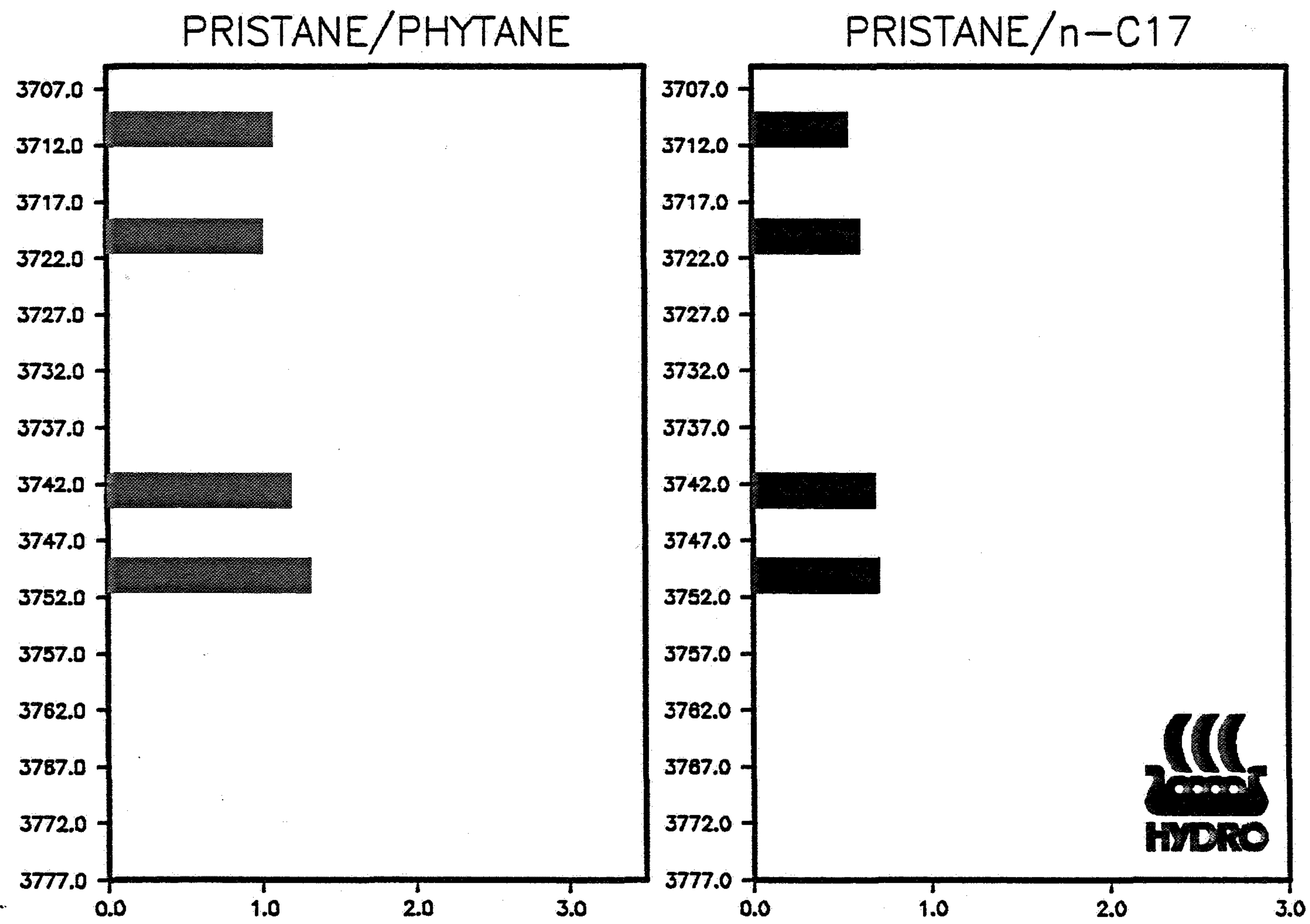
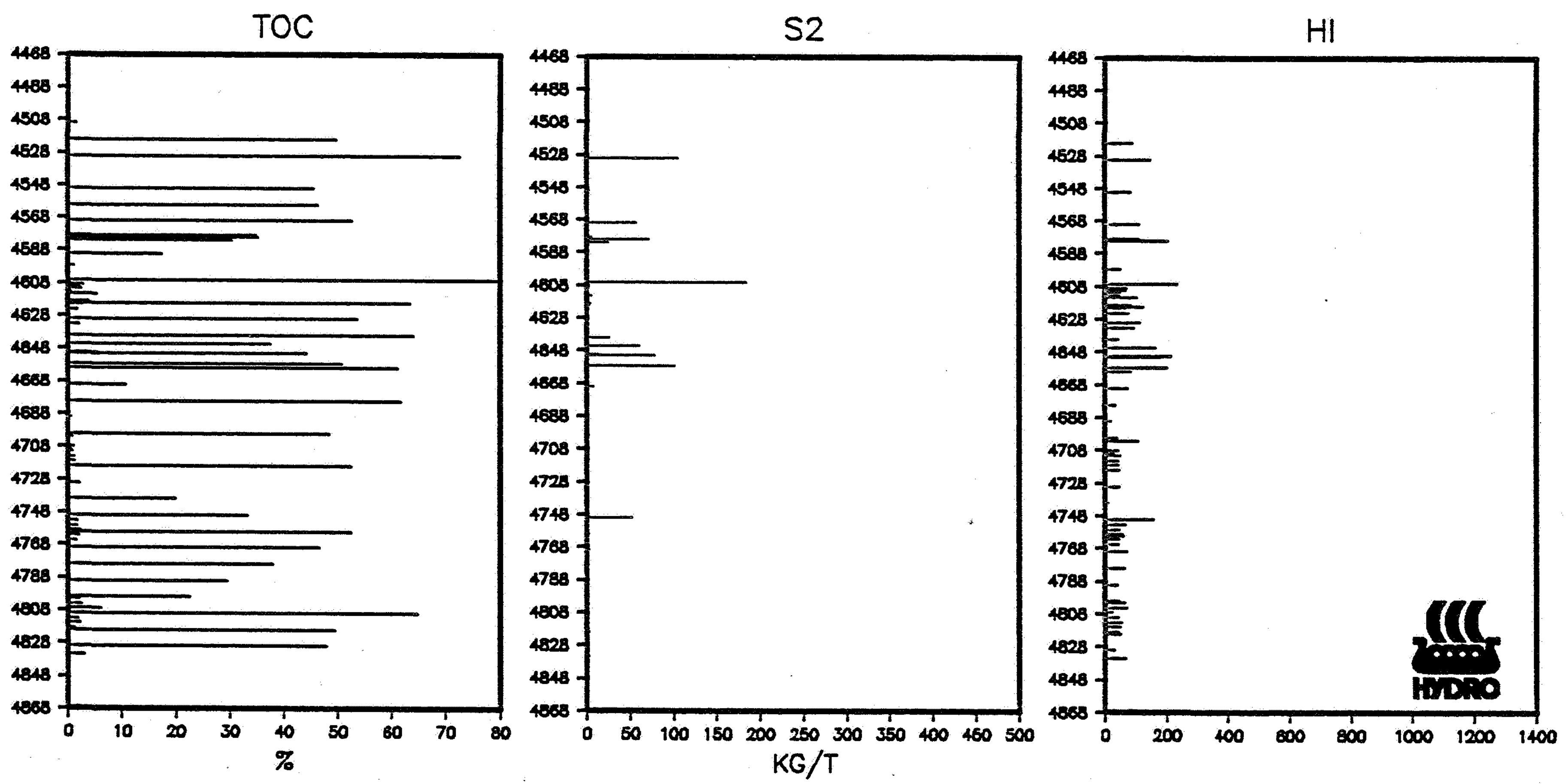


FIG. III.3.1 A AND B

PLOTS OF TOC, S2 AND HI VERSUS DEPTH,

HITRA FM. 6407/4-1

HITRA FM. 6407/4-1



HITRA FM. WELL 6407/4-1

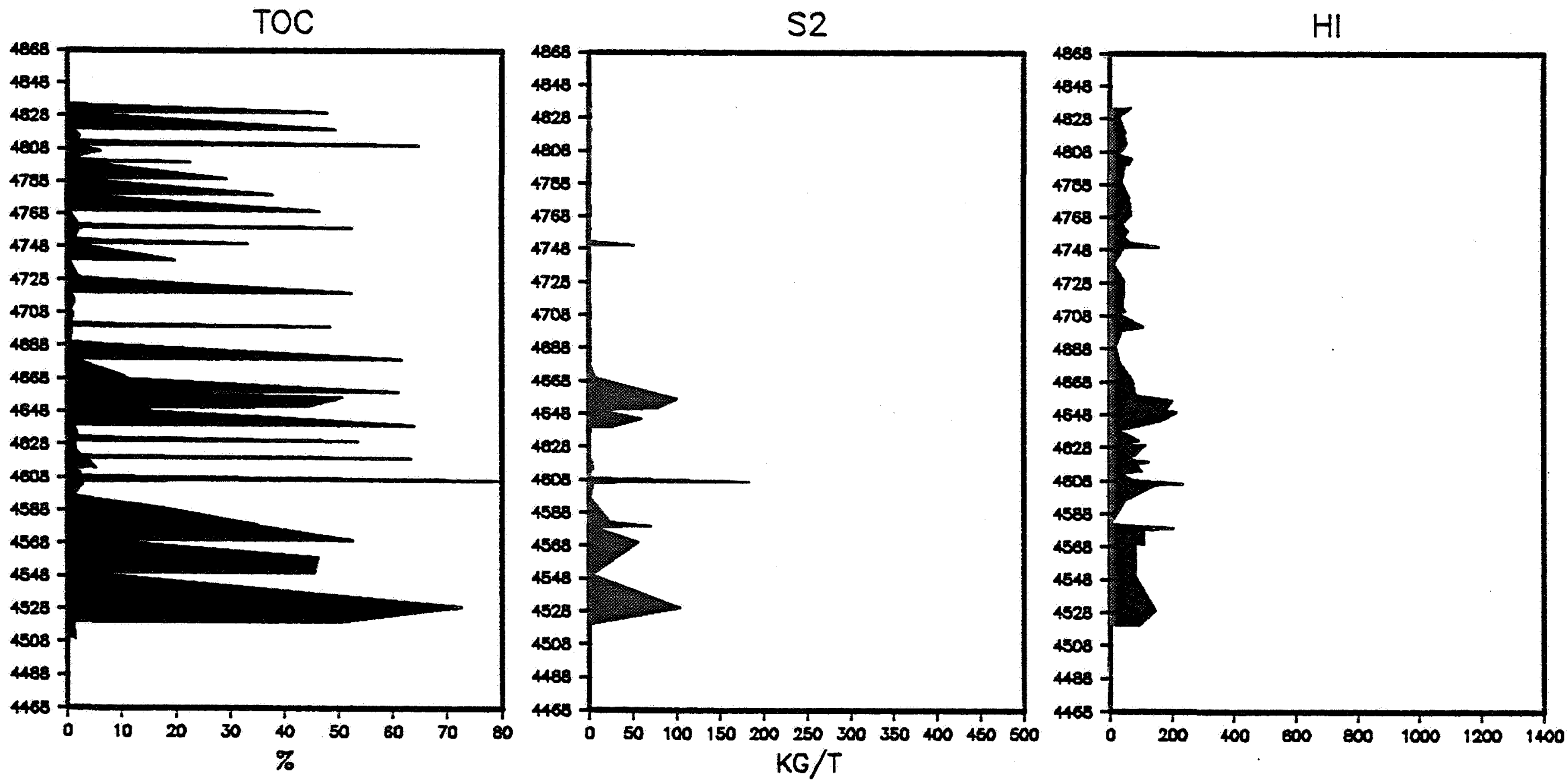
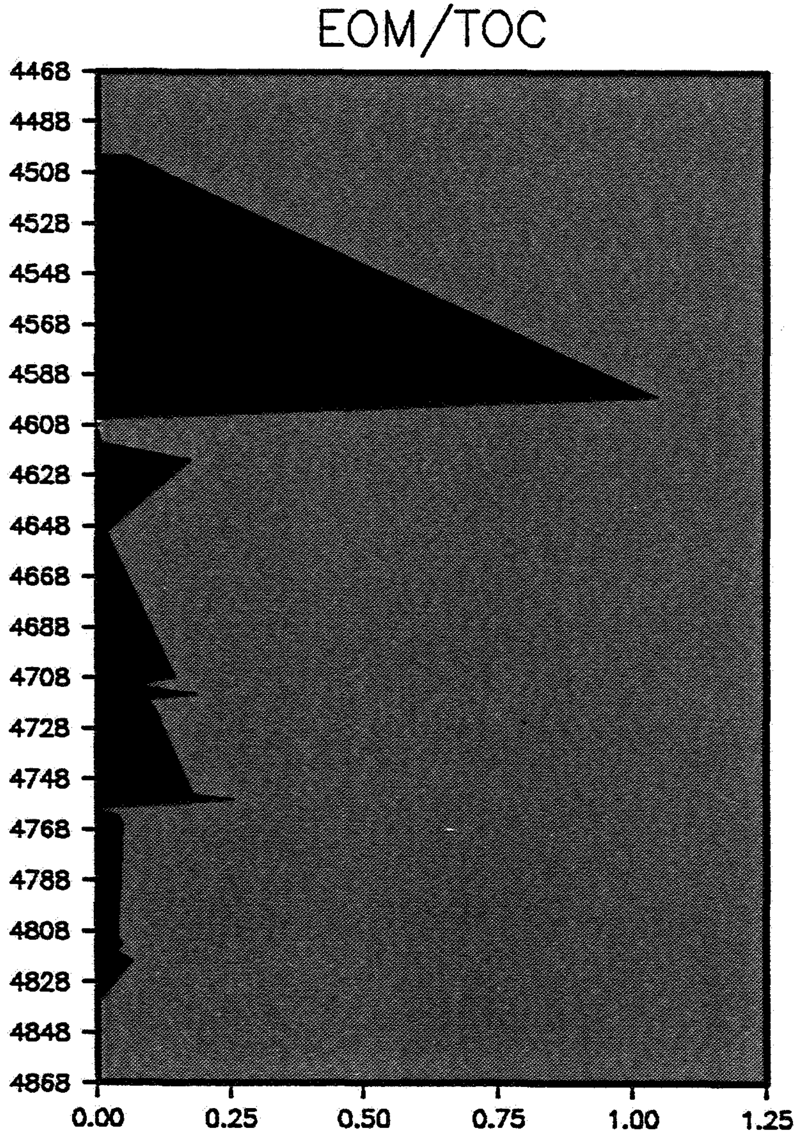


FIG. III.3.2

PLOT OF EOM/TOC VERSUS DEPTH, HITRA FM. 6407/4-1

HITRA FM. WELL 6407/4-1



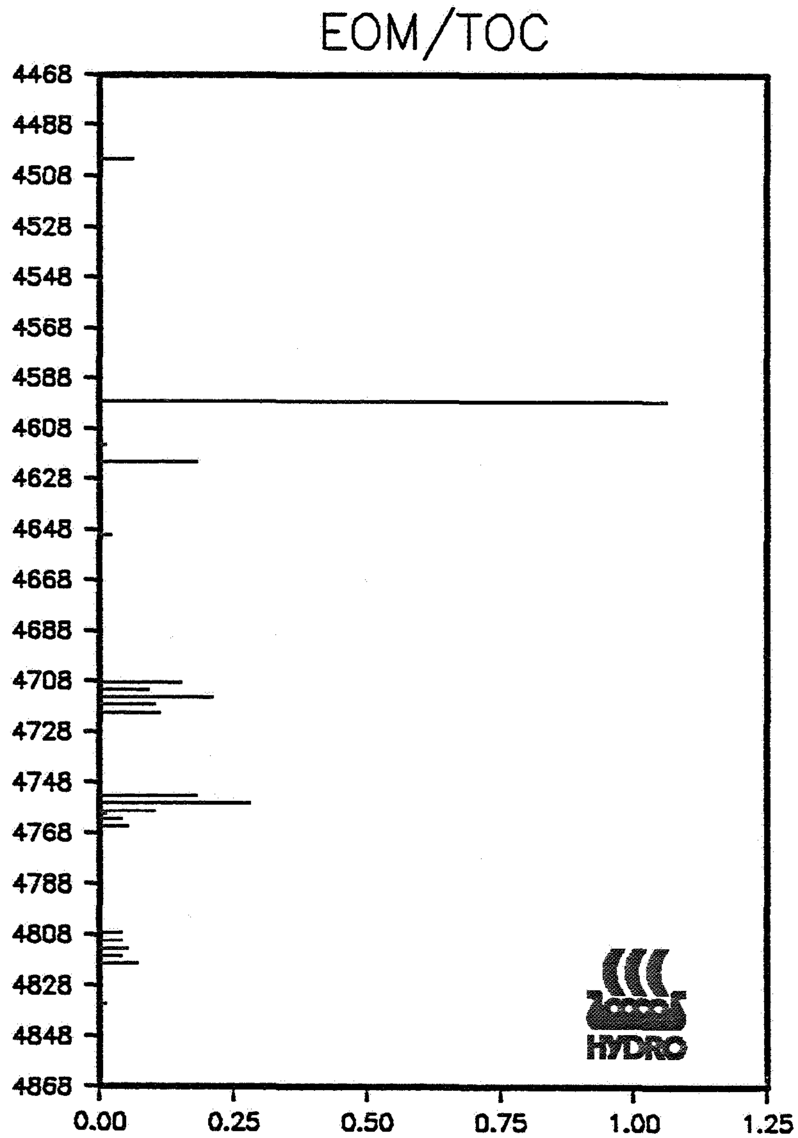
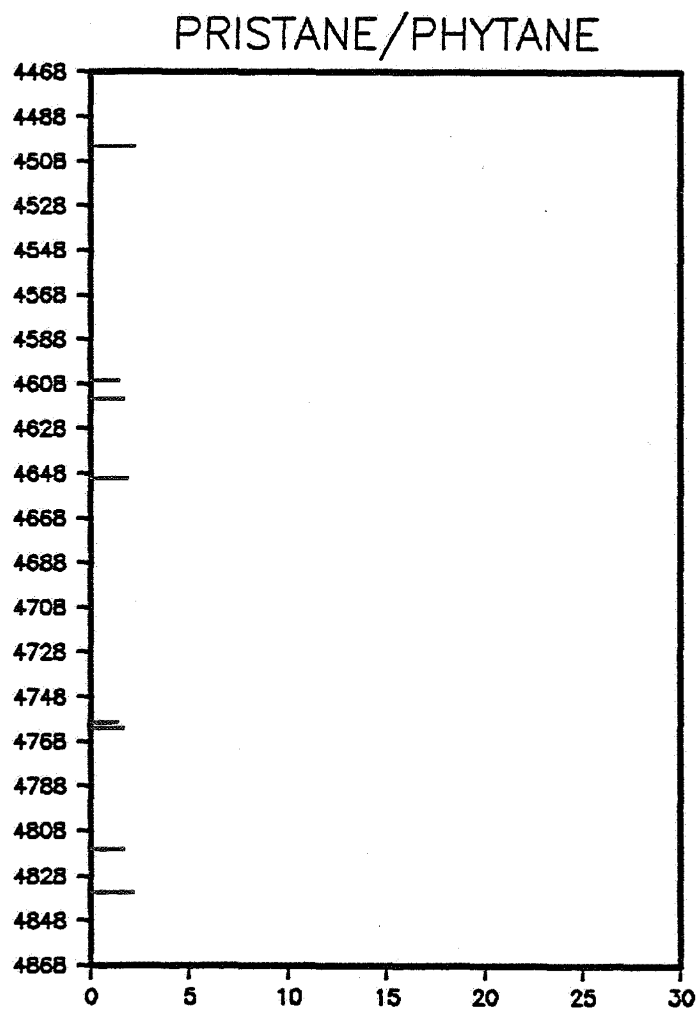


FIG. III.3.3

PLOT OF PR/PH AND PR/n-C17 VERSUS DEPTH,

HITRA FM. 6407/4-1

HITRA FM. WELL 6407/4-1



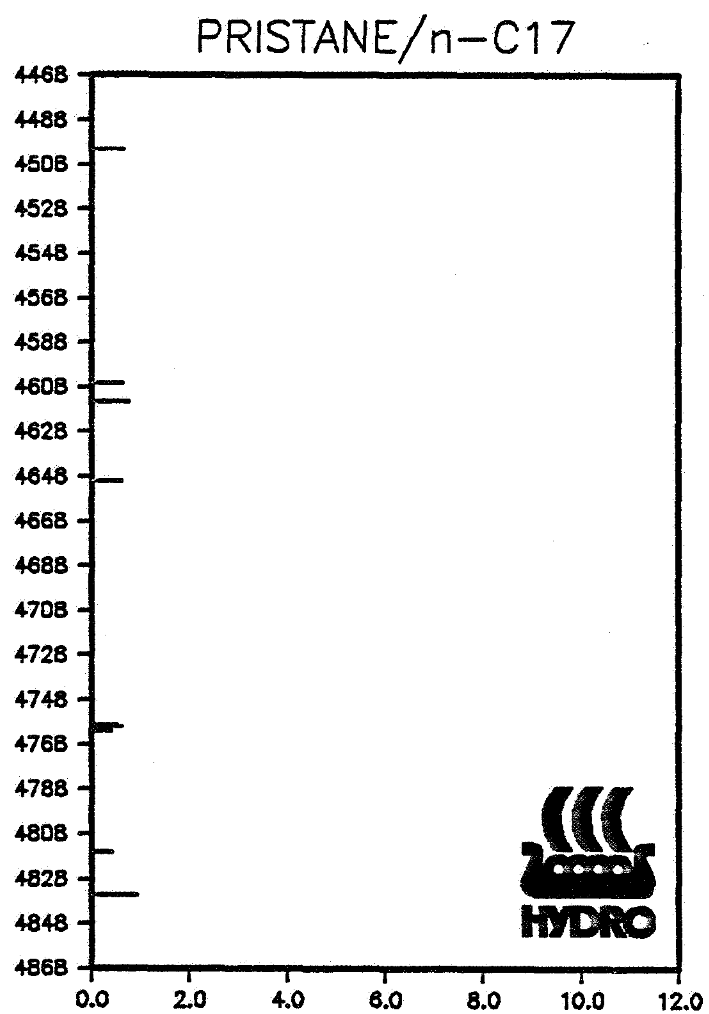


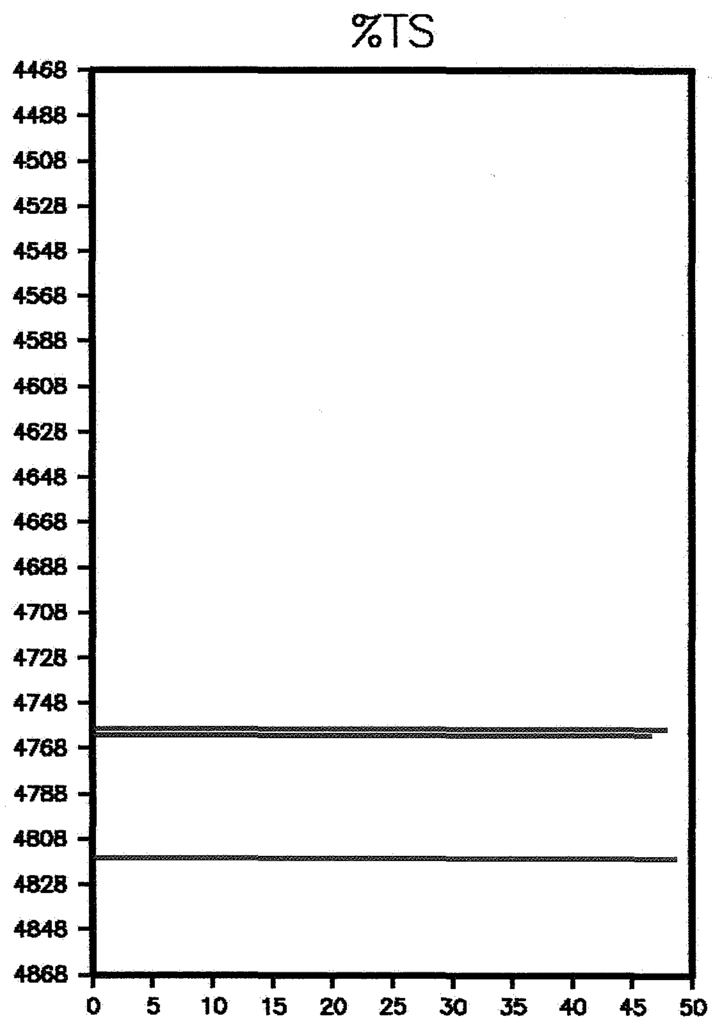
FIG. III.3.4

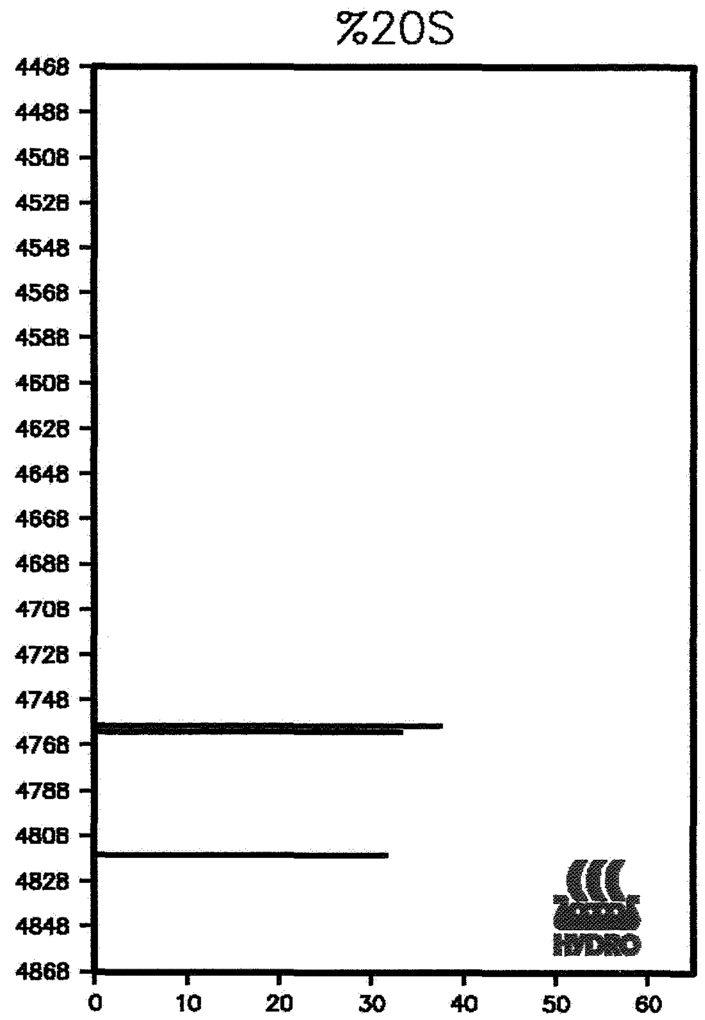
PLOT OF BIOMARKER RATIOS VERSUS DEPTH,

HITRA FM. 6407/4-1

HITRA FM. WELL 6407/4-1

BIOMARKER RATIOS





APPENDIX IV

SOURCE ROCK EVALUATION 6407/9-1

AIV.1 Introduction

The data base for this well has been established by Geolab Nor and Norsk Hydro Research Centre. The sample material has been entirely ditch cuttings. Samples have been selected to cover the Upper Jurassic/Lower Cretaceous Nesna Fm. and coals seams and clayey horizons in the Lower Jurassic Hitra Fm.

AIV.2 Nesna Fm.

AIV.2.1 Rock Eval and TOC

Data from this 30 m thick sequence (1591-1621 m) is plotted in Figs. AIV.2.1a and b. The sample material is entirely ditch cuttings generally covering 3 m intervals.

The vertical source rock quality over this horizon is homogeneous with average values 6.3 %, 14.9 kg/t and 238 for TOC, S_2 and HI respectively suggesting a predominance of mixed type II/III kerogen.

T_{max} values are ranging from 404°C to 414°C suggesting a immature source sequence. This is supported by production indices which are quite low (average approx. 0.04).

AIV.2.2 Pyrolysis GC

All nine samples have been analysed by temperature programmed pyrolysis gas chromatography (PY-GC).

These samples all have a high relative oil potential and a low gas potential. A potential for liquid hydrocarbons (condensate and oil) characterizes these samples. Apart from minor variations in the distribution and the shape of the unresolved envelope the pyrograms are very similar.

Based on the PY-GC data the Rock Eval hydrocarbon potentials have been divided into gas, condensate and oil potential.

Average gas, condensate and oil potentials are 2.2 kg/t, 5.6 kg/t and 7.1 kg/t, respectively, giving a total liquid potential of 12.7 kg/t in this source horizon.

AIV.2.3 Extraction data and gas chromatography of saturated fractions

All nine samples from the Nesna Fm. have been extracted and yields are good, in the range of 0.24 - 0.32 % with one sample approaching 0.68 %.

EOM/TOC values are plotted versus depth in Fig. AIV.2.2 and indicate a constant quality downwards with a slight increase in the two lowermost samples. The hydrocarbons (SAT + AROM) are remarkably low relative to non-hydrocarbons (NSO + Asph).

The alkane distributions are, although not particular pronounced, bimodal. The sterane envelope is present in all samples and odd n-alkanes dominate over even n-alkanes. Pristane and phytane are much higher than their neighbouring n-alkanes.

The general features of these chromatograms suggests a marine type material of low thermal maturity.

Two molecular ratios Pr/Ph and Pr/n-C_{17} are plotted versus depth (Fig. AIV.2.3) and confirm the homogeneous vertical quality seen by visual inspections of SAT chromatograms. However, in the Pr/n-C_{17} plot some minor variations exist and an apparent drop exists for samples 1606 and 1618 suggesting minor variations in relative input of organic material (e.g. relative contribution of terrestrially derived material).

AIV.2.4 Visual kerogen

The kerogen slides for Nesna Fm. have been prepared and evaluated by Geolab Nor. A large descripancy between the interpretion of Geolab Nor and that of Geochem Labs for equivalent horizons in this region was found and the 8 kerogen slides from this horizon were sent to Geochem for reevaluation. Two versions of Geolab's original interpretation are listed in Table AIV.2.1 and AIV.2.2.

Geolab's data suggest a fairly homogeneous composition of the material deposited. The material consists of traces of algal and amorphous material, fair amounts of herbarceous (~ 20 %) and inertinitic (~ 5 - 10 %) material and is dominated by woody (~ 70 %) material. According to this classification virtually all material deposited is land derived. This is not consistent with the chromatographic data which suggest a significant contribution from marine algal type material.

Geochem's reevaluated data are compiled in Table AIV.2.3. In this interpretation algal material dominates (40 - 60 %). Herbaceous, woody and inertinite are < 5 %, < 10 % and < 5 % respectively. It should be noted that differentiation between Al and Am was very difficult due to presence of material resembling contamination and to the finely dispersed character of the organic matter.

AIV.2.5 Biological markers, steranes and triterpanes

All nine SAT samples have been analysed for biological marker content. Traditional biomarker ratios are calculated and listed in Table AIV.2.4. and plotted versus depth in Fig. AIV.2.4.

The triterpanes (ratio % 22S and visual inspection) suggest low maturity samples (22S = 7-17 % and $\beta\beta$ hopanes are present). This is supported by steranes where none of the samples contain any C_{29} $\alpha\alpha\alpha$ 20S.

The distribution between C_{27}, C_{28} and C_{29} steranes (27:28:29) suggests a signature of sediments deposited in lagoon/restricted bay environments. (C_{27} is more abundant in marine algal material and C_{29} is abundant in terrestrially derived material.)

The distribution within the horizon is fairly homogeneous supporting the situation suggested by all other parameters previously discussed.

The sterane/triterpane, sterane/n-alkane and triterpane/n-alkane ratios (ST/TR, ST/N-ALK and TR/N-ALK) indicate some variations which may be significant. Steranes are usually abundant in marine environment and very low in terrestrial and lacustrine environments. Triterpanes are derived from either bacteria or plant material and are usually abundant in both marine and terrestrial material.

The ratio between steranes and triterpanes appears to be 0.3 - 0.4 in low maturity marine source rock and less than 0.1 for coals and deltaplain shales. It appears that steranes relative to n-alkanes are low in marine shales and very low in coals. Triterpanes relative to n-alkanes are fairly high in both coals and shales and it seems that they are significantly more abundant in shales relative to coals. This is not unexpected as coals often contain large amounts of waxy material.

AIV.3 Hitra Fm.

AIV.3.1 Rock Eval and TOC

The results have been listed in Appendix VI and are plotted versus depth in Figs. AIV.3.1a and b. The samples selected for analyses are from intervals containing coal seams and shales. 8 intervals have been sampled and are called Unit I through to Unit VIII. This is shown in Fig. AIV.3.2 and average values for coals and clays/siltstone respectively have been calculated and listed in Table AIV.3.1.

The Hitra Fm. consists of alternating sand and shales interbedded with coals and carbargillites and represent a deltaplain/swamp type of depositional environment.

Both coals/carbargillites and shales/mudstone/siltstone have been analysed in several samples where these lithologies are present.

In the coals/carbargillites there are a clear vertically decrease in organic carbon content downwards. This can be clearly seen in Fig. AIV.3.1A. Also within the various units there is a decrease (57 - 26 %) in organic carbon with increasing depth. The quality in terms of HI tends to follow the same rules.

The shales are very low in organic material. The trend seen in TOC seems to some extent parallel that of the coaly material (2.65 - 0.55 %). Hydrogen indices are often high for samples being very low in organic carbon, and is an artifact. This is particular clear in the lower part of Unit VIII.

AIV.3.2 Pyrolysis GC

PY-GC has only been performed on selected, rich samples from the various units.

Unit I pyrograms display fairly similar features with a high paraffin content in the n-C_{20} to n-C_{25} region, suggesting a significant contribution from higher plants to the kerogen. The gas:condensate:oil distribution suggests dominantly liquid prone samples. The average distribution is 16.5 : 28.5 : 46.4 kg/t (gas:condensate:oil).

Unit II samples (7) also suggest fairly high liquid potentials with considerable contents of high molecular weight n-alkanes, particular in the upper samples 2125-2134 m. The lower three samples 2137-2159 m have a lower liquid potential with less n-paraffins in the higher molecular weight range.

This suggests a quality drop in the lowermost coalbeds which contain the largest volumes of coal in this unit. These 2 subunits probably represent slightly different depositional environments with more humic material in the lower subunit and more herbaceous material in the upper subunit.

Average values are:

	Gas kg/t	Condensate kg/t	Oil kg/t
Upper subunit:	13.2	32.5	53.0
Lower subunit:	15.8	19.5	22.8

The lowermost sample 2152 m is not taken into account in the above calculation because it is a shale with low total HC potential (5.4 kg/t).

It should also be noted that the uppermost sample 2125 m has an extremely high liquid potential (~ 105 kg/t) and may represent a third subunit.

In Unit III only one sample has been analysed. The pyrogram (Appendix VII) indicates a fair amount of normal alkanes in the liquid zone, but a relative large chromatographic unresolved area in the heavy molecular area indicates a high amount of heavy aromatic compounds, less prone to primary migration, to be present. The high liquid potential (36+87 kg/t) is probably much larger than what is available for expulsion.

Unit IV contains, according to the values in Appendix VI, a fairly homogeneous sequence of interbedded coal seams with high liquid potential (C_{15+}, oil is 47 - 59 %). However, by visual inspection of the pyrograms some obvious differences exist in terms of molecular content.

The uppermost (2212 m) and lowermost (2236 m) samples display very low content of normal alkanes relative to that of aromatic and polar compound. The latter is less susceptible to primary migration and a net expulsion liquid potential is believed to be considerable lower than the values achieved from direct integration of the pyrograms.

Although some variations exist the other samples in this unit contain more paraffinic hydrocarbons and their liquid potentials in terms of net expulsion are believed to be fairly high.

The average potentials of the 4 samples 2215 through to 2233 m are:

Gas kg/t	Condensate kg/t	Oil kg/t
13.6	18.2	27.6

Based on these data it is suggested that the upper coal band is of a poorer quality in terms of liquid potential and probably contains more humic type material. As the next sample is better in quality it is believed that this upper coal band grade downwards into a better kerogen type with higher input of harbaceous material.

The middle coal band retains the same quality as the bottom of the upper. The lowest coal band probably contains more "gas prone" humic type material.

In Unit V only one coal sample has been analysed together with three shales. The coal sample has a similar pyrogram to some of the middle Unit IV samples with a reasonable liquid potential.

The shales are basically gas prone samples. Their S_2 yields are so small that a net expulsion of liquid is less likely to happen. (Some of these pyrograms are also contaminated.)

In this unit only 5 % or less coal has been found in DC samples below 2251 m and has therefore not been picked and analysed. It is reasonable to believe that in the middle and lower parts of this unit the coal seams are very thin. Average potentials are:

Gas kg/t	Condensate kg/t	Oil kg/t
18.7	26.8	44.2

Unit VI starts with a shale with low liquid (and total HC) potential.

The breakdown of pyrograms into distribution of gas and liquid potentials suggests a fairly liquid prone sequence of coal seams with variable potential.

The uppermost coal sample, from the upper coal layer in the unit, has a fairly high n-paraffin distribution and has probably got a fair amount of herbaceous or algal material to account for the paraffinic looking pattern in the C_{15+} region.

The samples from 2290 m to 2314 m have less n-paraffins in the C_{15+} region and probably contain more humic material. Average gas liquid potential for these samples which are derived from fairly thin coal horizons at 2302-2305 m:

Gas kg/t	Condensate kg/t	Oil kg/t
17.0	16.0	36.7

For the three lowermost samples n-paraffin content appears to be better although variations exist. The middle sample 2323 m has a high n-alkane content in the C_{15+} range. The average gas and liquid potentials for these samples are:

Gas kg/t	Condensate kg/t	Oil kg/t
11.5	14.6	26.7

The lowermost samples in Unit VI are shales with only fair HC potentials (3.4-8.6 kg/t). Their pyrograms indicate mainly gas-condensate prone material.

The same is found in the only sample analysed from Unit VIII.

Only small amounts of coals have been found in DC material from the Units VII and VIII which indicate that only thin coal horizons exist in these sequences.

AIV.3.3 Extraction data and gas chromatography of saturated fractions

Thirty three samples from Hitra Fm. in 6407/9-1 have been extracted. The EOM/TOC ratio and Pr/Ph and Pr/n-C_{17} ratios are plotted versus depth in Figs. AIV.3.3 and AIV.3.4, respectively.

The plot suggests some variations within the various units. However, there is no indication of an actively expelling source rock apart from samples in the Units VII and VIII which probably are contaminated.

Qualitywise, the various EOM ratios like SAT/AROM etc. do not seem to vary with variations seen by PY-GC data on coals.

A significant feature in this data set is the shift seen in various EOM parameters between coal samples and shale (e.g. SAT/TOC which for coals are < 1.0 and for shales are >> 1.0). Are these SAT hydrocarbons in the shales indigenous or have they acquired hydrocarbons from the neighbouring rich coals? Unfortunately, no chromatographic data are available from these shale samples.

The general feature with all SAT-chromatograms is a high odd over even dominance combined with a very high Pr/Ph ratio. The high CPI values indicate that these are immature samples which also have been suggested by other parameters like T_{max}. The Pr/Ph ratio together with CPI suggest these samples to have been dominated by terrestrial input.

The variations in the saturated fractions, either within or between units, are the bimodality and the ratios between the two alkane profiles, which describes the relative contribution of different type of source material to the sediment.

AIV.3.4 Visual kerogen

The visual kerogen slides have been interpreted by Geolab Nor only and a discrepancy between older data from other Haltenbanken wells interpreted by Geochem may be expected.

The data are listed in Table AIV.3.2 (three component system) and in Table AIV.3.3 (five component system). A dominant feature of these data are the total lack of algal or amorphous organic material combined with dominating woody material.

Within Unit I only one sample is analysed. It suggests low herbaceous material (10 %) and very high woody and inertinitic content (75 % and 15%).

In Unit II PY-GC suggested a better quality upper coal layer with higher concentrations of more humic coals in the lower part of the sequence. The visual data tend to support this as herbaceous material is lightest in samples 2119 and 2122 m (10 - 2 % He) decreasing with depth and only traces are contained in the bottom sample at 2158 m. HI are 240 and 299 for the upper two samples and 139 in the deepest sample.

Unit III, containing one small coal bed has a good liquid potential (2197 m). The sample analysed for kerogen content (2191 m) contains 100 % woody material. For this sample relative to the 2197 m sample a drop in HI from 238 to 156 was experienced supporting a possible drop in quality from 2197 to 2191 m.

Pyrolysis GC suggested Unit IV to have a good liquid potential in the middle with poorer top and bottom samples.

The 2215 m pyrogram suggested a liquid prone sample with a fairly high C_{15+} n-alkane content which may be derived from higher plants. In this sample 30 % herbaceous material is found. Further down the sequence the pyrograms and visual content in terms of herbaceous content tend to support each other.

The good trend seen in Unit IV tend to continue in samples 2263 and 2266 with 20 % herbaceous content.

Unit VI has less herbaceous input, 10 % in all samples. The ratio woody/inertinite varies slightly and increases with depth.

In Unit VII detection was impossible.

AIV.3.5 Biological marker content

Calculated ratios and parameters from the mass fragmentograms are listed in Table AIV.3.4. Some of these ratios are plotted versus depth in Fig. AIV.3.5.

The thermal maturity monitored by the 22R-22S epimerisation of triterpanes and the 20R-20S epimerisation of C_{29} steranes are both showing immature sediments well above the zone of oil generation.

By visual inspection of the sterane fragmentograms it appears that C_{29} steranes tend to dominate which indicate a terrestrially derived material.

In Unit II both samples tend to give higher sterane/triterpane ratios than the other Hitra extracts which can suggest a certain influence a marine/brackish depositional environment for these uppermost samples of Hitra coals. In other samples from Unit II, III and upper Unit IV there is a similar tendency of a possible marine/brackish influence. From middle Unit IV the St/Tr ratio combined with St/n-alkane ratio suggest consistently dominating terrestrial material.

APPENDIX IV

SOURCE ROCK EVALUATION 6407/9-1

TABLES

DEPTH m	AMORPHOUS	ALGAL	HERBACEOUS	WOODY	INERTINITE
1591			20	70	10
1594			25	70	5
1600			20	75	5
1606			20	75	5
1609			20	75	5
1612		10	20	60	10
1615			15	70	10
1618			20	70	10

Table AIV.2.1 Visual kerogen, Nesna fm. 6407/9-1

DEPTH m	VITRINITE	LIPTINITE	INERTINITE
1591	70	20	10
1594	70	25	5
1600	75	20	5
1606	75	20	5
1609	75	20	5
1612	60	30	10
1615	70	15	10
1618	70	20	10

TableAIV.2.2 Visual kerogen, Nesna fm. 6407/9-1

DEPTH m	AMORPHOUS	ALGAL	HERBACEOUS	WOODY	INERTINITE
1591	30	60	<5	<10	<10
1594	30	60	<5	<10	<10
1600	45	40	<5	<10	<10
1606	35	50	<5	<10	<10
1609	45	40	<5	<10	<10
1612	45	40	<5	<5	<10
1615	35	45	<5	<10	<10
1618	30	55	<5	<10	<10

Table AIV.2.3 Reevaluation of kerogen slides,
Nesna fm. 6407/9-1

Table 4IV.2.4 Biomarkers ratios, Nesna fm. 6407/9-1

BIOMARKER RATIOS
WELL: 6407/9-1 NESNA FM

DEPTH m	22S%	TS%	C28/C29	C30?/C30	20S%	ABB%	27:28:29	ST/TR	ST/N-ALK	TR/N-ALK
1591	14						43:22:35	0.39	7.6	19.6
1594	18	9					43:21·36	0.28	5.7	20.2
1600	12	10					44:20:36	0.20	6.2	32.0
1606	11	7					45:19:36	0.19	5.2	28.2
1609	10	9					46:20:34	0.24	6.1	25.1
1612	9	7					46:21:33	0.29	5.0	17.5
1615	10	9					46:22:32	0.29	5.9	20.3
1618	9	10					46.23:30	0.42	3.9	9.3
1621	19	17	0.13				43:25:32	0.30	1.4	4.7

Table AIV.3.1: Coal/shale units in Hitra Fm. 6407/9-1 and their average source quality data.

Unit No.	Unit Interv.	Interv. Thickn.	Thickn. Coal	Thickn. Shale	Coals Average		Shales/silt Average	
					TOC	HI	TOC	HI
1	2071-2083	12	1.0	18	57.47	159	u.a	u.a
2	2116-2158	42	6.25	29	42.18	176	u.a	u.a
3	2188-2197	11	1.0	0	62.85	215	2.65	140.5
4	2209-2236	27	5.0	19	46.33	169	u.a	u.a
5	2248-2266	18	2.7	13	38.15	140	0.75	375.5
6	2281-2353	72	9.0	58	40.15	116	2.30	163.0
7	2365-2377	12	0	11	34.6	108	0.43	109
8	2407-2440	33	1.5	30	26.45	122	0.55	

DEPTH m	VITRINITE	LIPTINITE	INERTINITE
2074	75	10	15
2119	75	10	15
2122	75	20	5
2143	90	5	5
2146	90	5	5
2149	65	5	30
2155	80	10	10
2158	90	5	5
2191	100		
2215	50	30	20
2224	70	20	10
2230	55	25	20
2233	70	15	15
2263	50	20	30
2266	60	20	20
2296	70	10	20
2299	50	10	40
2305	50	10	40
2320	60	10	30
2323	70	10	20
2413	80		20

Table AIV.3.2 Visual kerogen, Hitra fm. 6407/9-1

(Three component system)

DEPTH m	AMORPHOUS	ALGAL	HERBACEOUS	WOODY	INERTINITE
2074			10	75	15
2119			10	75	15
2122			20	75	5
2143			5	90	5
2146			5	90	5
2149			5	65	30
2155			10	80	10
2158			5	90	5
2191				100	
2215			30	50	20
2224			20	70	10
2230			25	55	20
2233			15	70	15
2263			20	50	30
2266			20	60	20
2296			10	70	20
2299			10	50	40
2305			10	50	10
2320			10	60	30
2323			10	70	20
2413				80	20

TableAIV.3.3 Visual kerogen, Hitra fm. 6407/9-1

(Five component system)

TableAIV.3.4 Biomarker ratios, Hitra fm. 6407/9-1

BIOMARKER RATIOS
WELL: 6407/9-1 HITRA FM

DEPTH m	22S%	TS%	C28/C29	C30?/C30	20S%	ABB%	27:28:29	ST/TR	ST/N-ALK	TR/N-ALK
2080	12.2	10	0.38	0.07				0.47	1.1	2.2
2083	12.0	15	0.48	0.09	8	48		0.47	1.3	2.8
2131	14.0			0.03	5	39		0.11	0.2	1.9
2197	17.0		0.14	0.11	7	47		0.08	0.5	6.0
2212	11.0		0.32	0.13	7	37		0.15	1.5	9.6
2215	14.0		0.05	0.07	4	29		0.14	0.2	1.0
2224	23.0		0.06	0.06				0.06	0.2	0.3
2227	23.0		0.06	0.04	5	28		0.04	0.2	4.9
2233	25.0		0.10	0.07	10	41		0.04	0.3	7.4
2236	23.0		0.10	0.06	6	38		0.05	0.3	5.1
2290	27.0		1.06	0.03	5	22		0.06	0.4	6.3
2299	26.0		0.09	0.0[illegible]	8	23		0.06	0.3	4.9
2305	28.0		0.11	0.06	8	23		0.06	0.3	5.1
2308	27.0		0.05	0.05	5	19		0.06	0.3	5.2
2314	39.0		0.05	0.08	14	45		0.03	0.3	7.8
2320	29.0			0.06	6	23		0.04	0.2	3.5
2323	31.0			0.06	4	20		0.05	0.1	2.3
2326	32.0			0.06	5	24		0.06	0.2	3.0

APPENDIX IV

SOURCE ROCK EVALUATION 6407/9-1

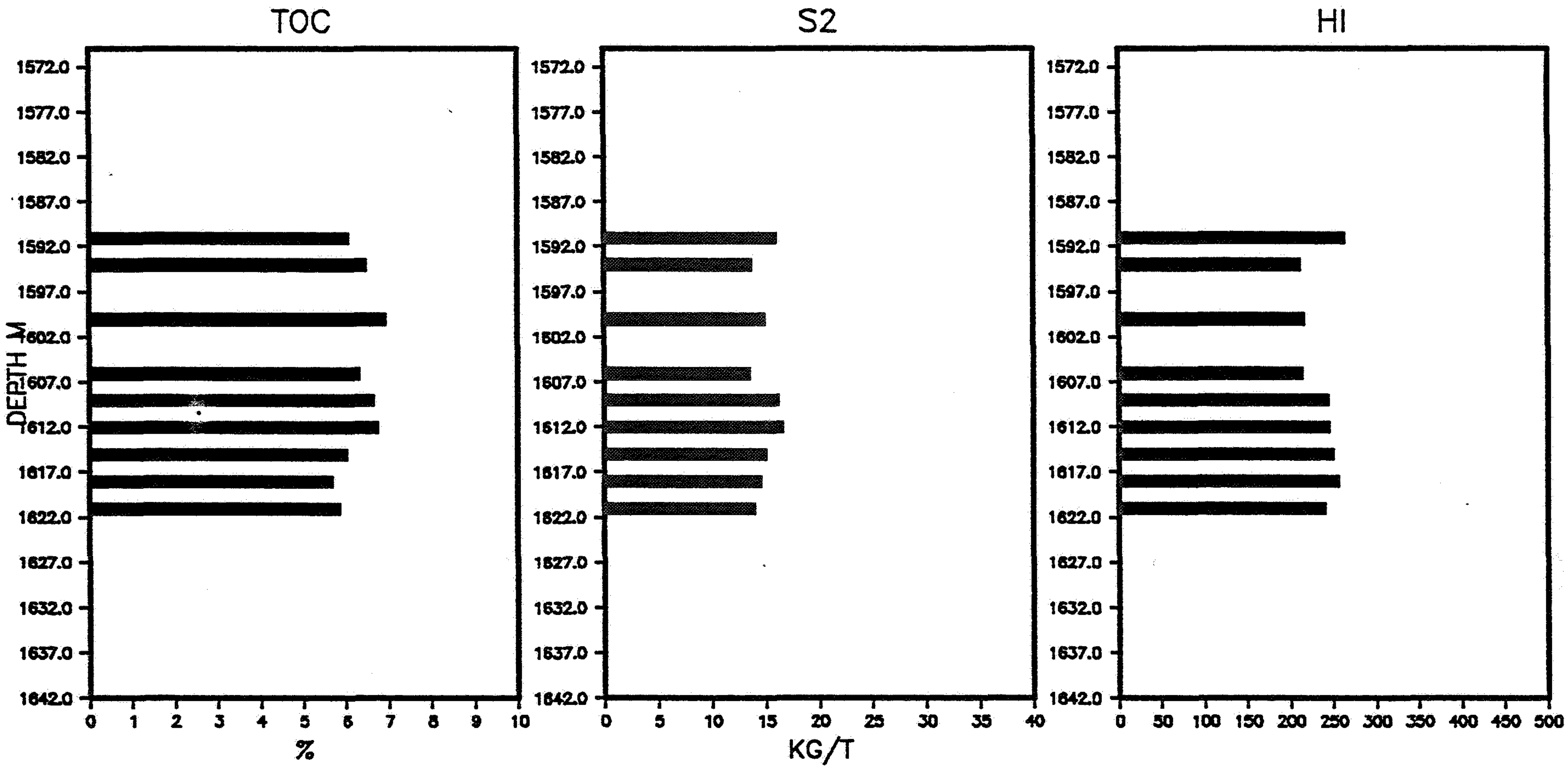
FIGURES

FIG. IV.2.1 A AND B

PLOTS OF TOC, S2 AND HI VERSUS DEPTH,

NESNA FM. 6407/9-1

NESNA FM. WELL 6407/9-1



NESNA FM. WELL 6407/9-1

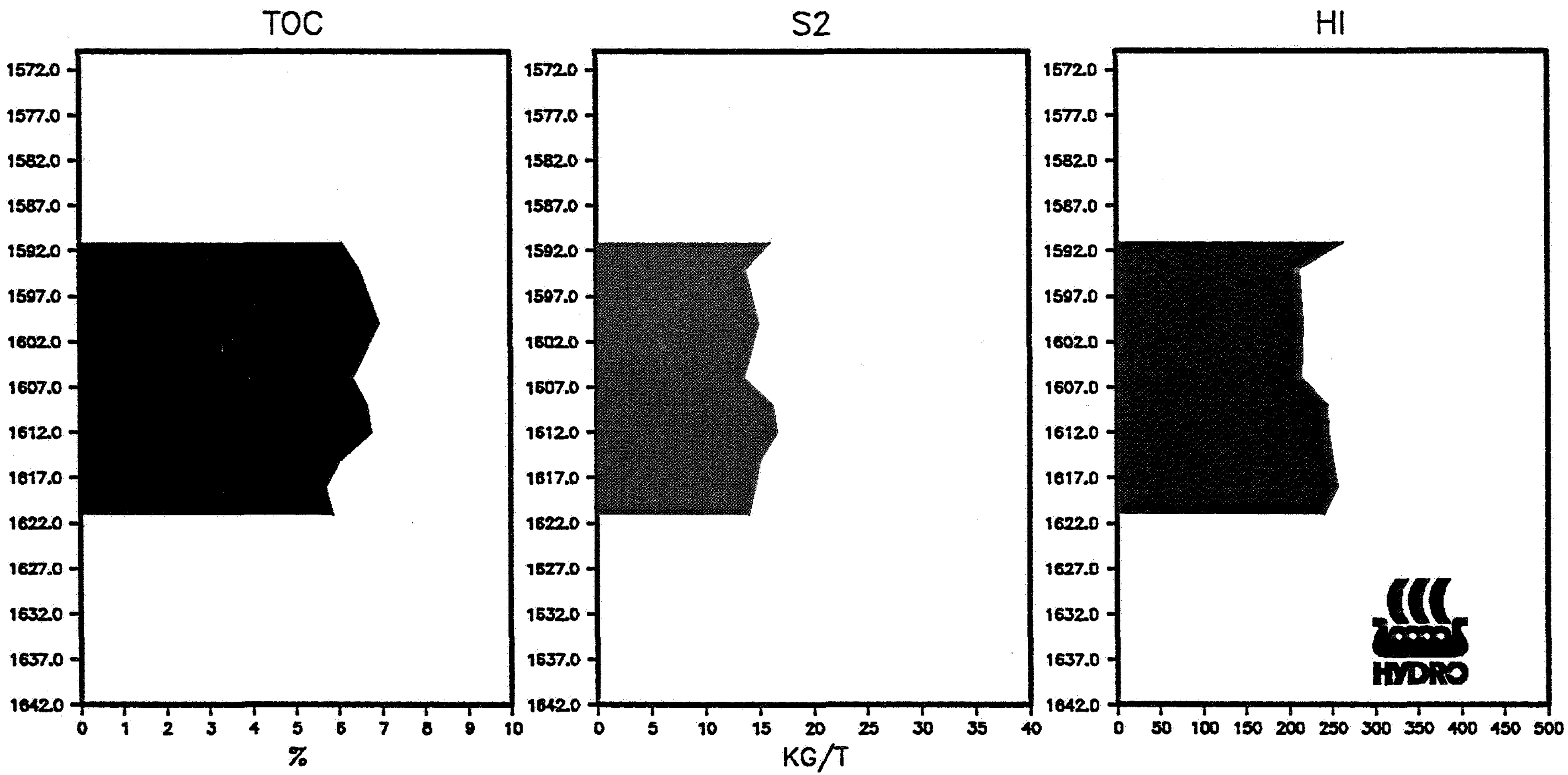


FIG. IV.2.2

PLOT OF EOM/TOC VERSUS DEPTH, NESNA FM. 6407/9-1

NESNA FM. WELL 6407/9-1

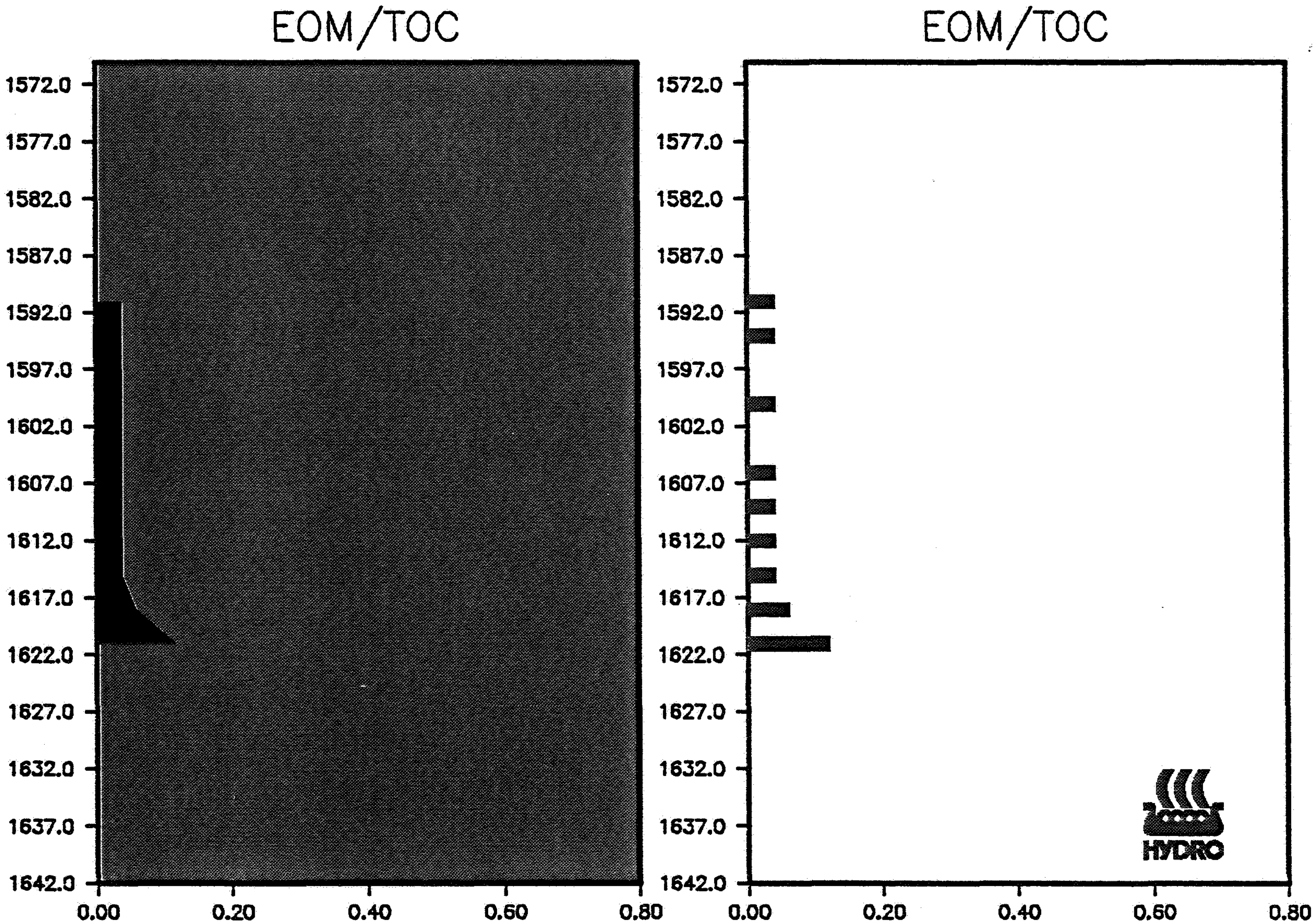


FIG. IV.2.3

PLOT OF PR/PH AND PR/n-C17 VERSUS DEPTH,

NESNA FM. 6407/9-1

NESNA FM. WELL 6407/9-1

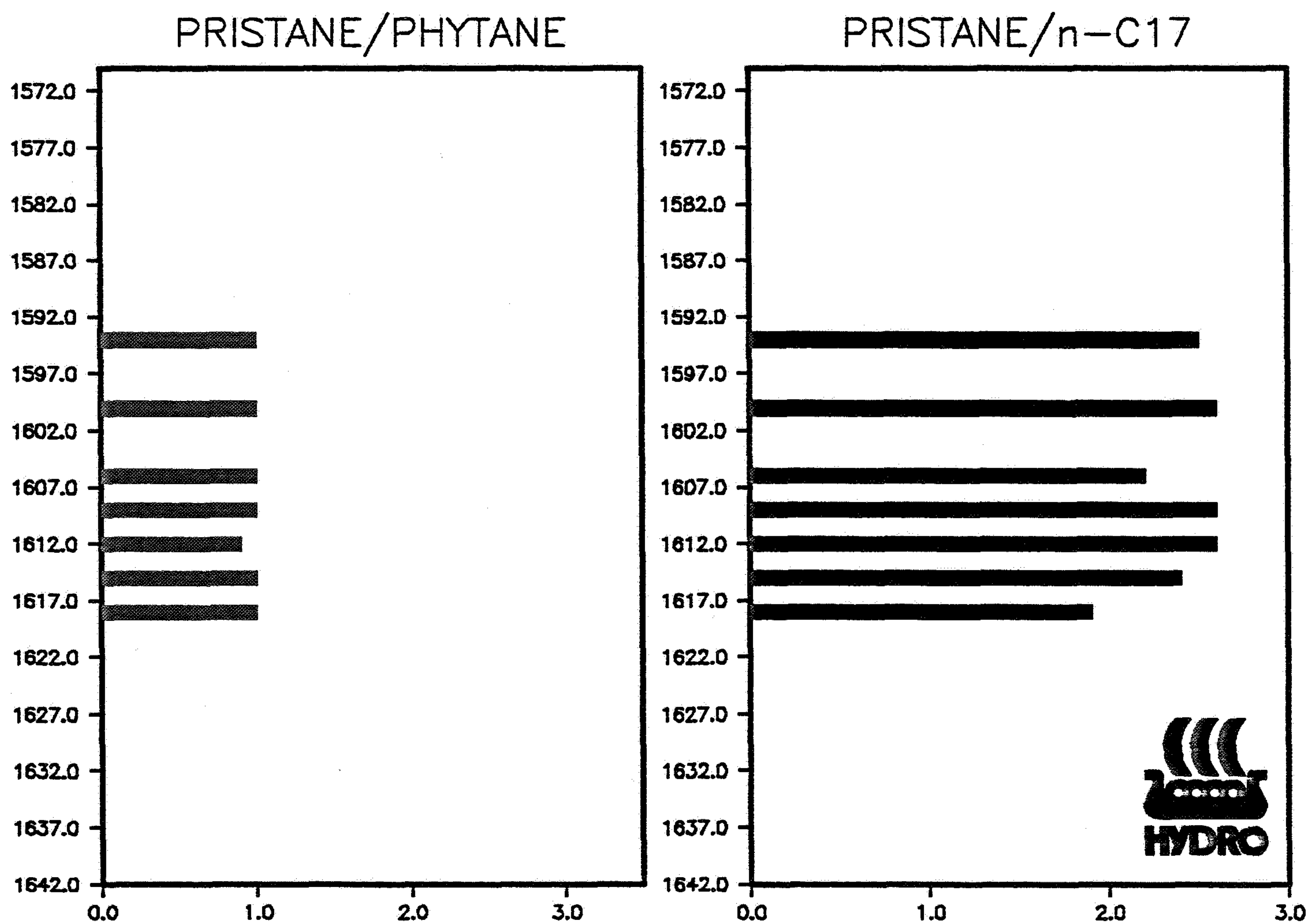


FIG. IV.2.4

PLOT OF BIOMARKER RATIOS VERSUS DEPTH,

NESNA FM. 6407/9-1

NESNA FM. WELL 6407/9-1

BIOMARKER RATIOS

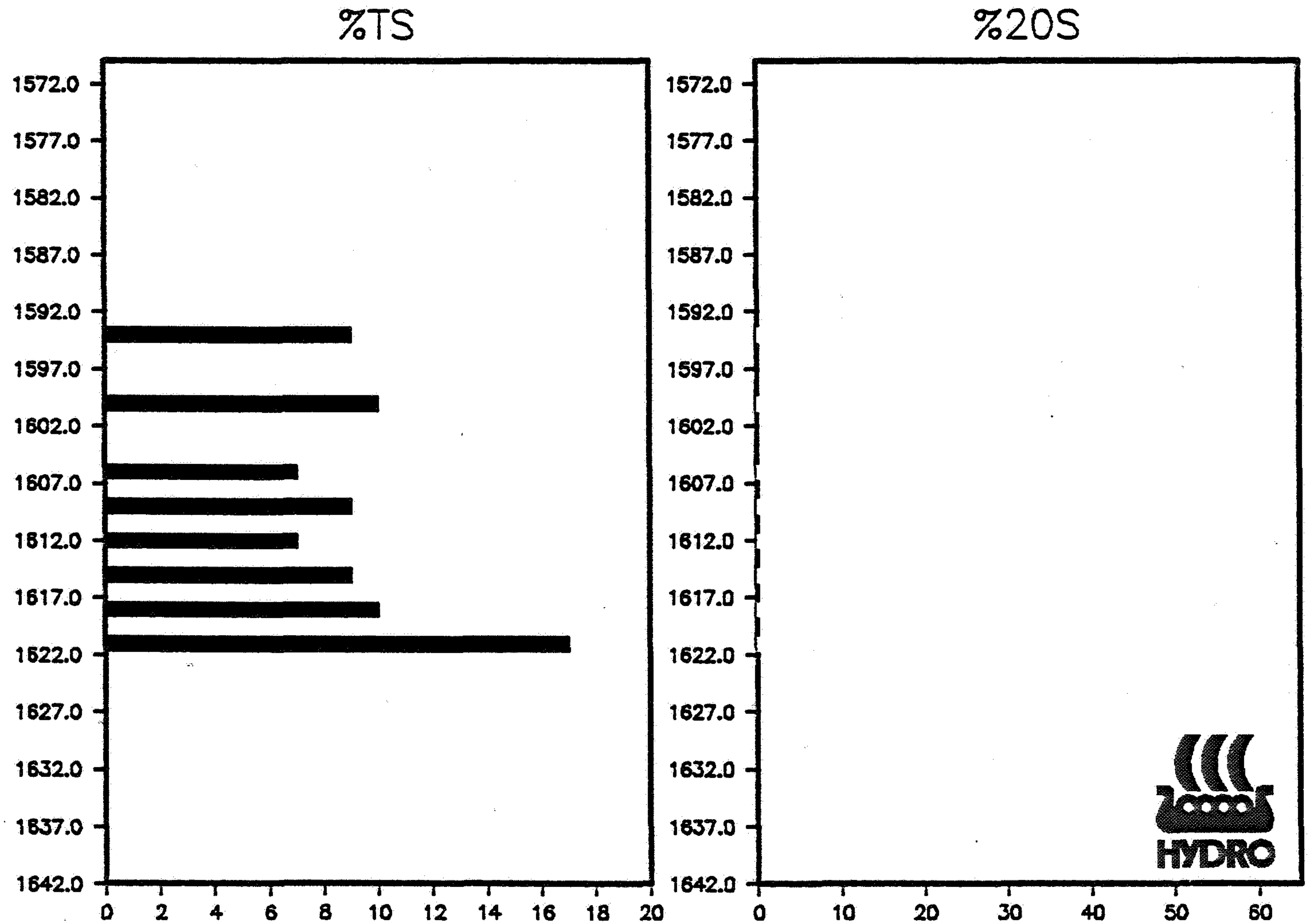
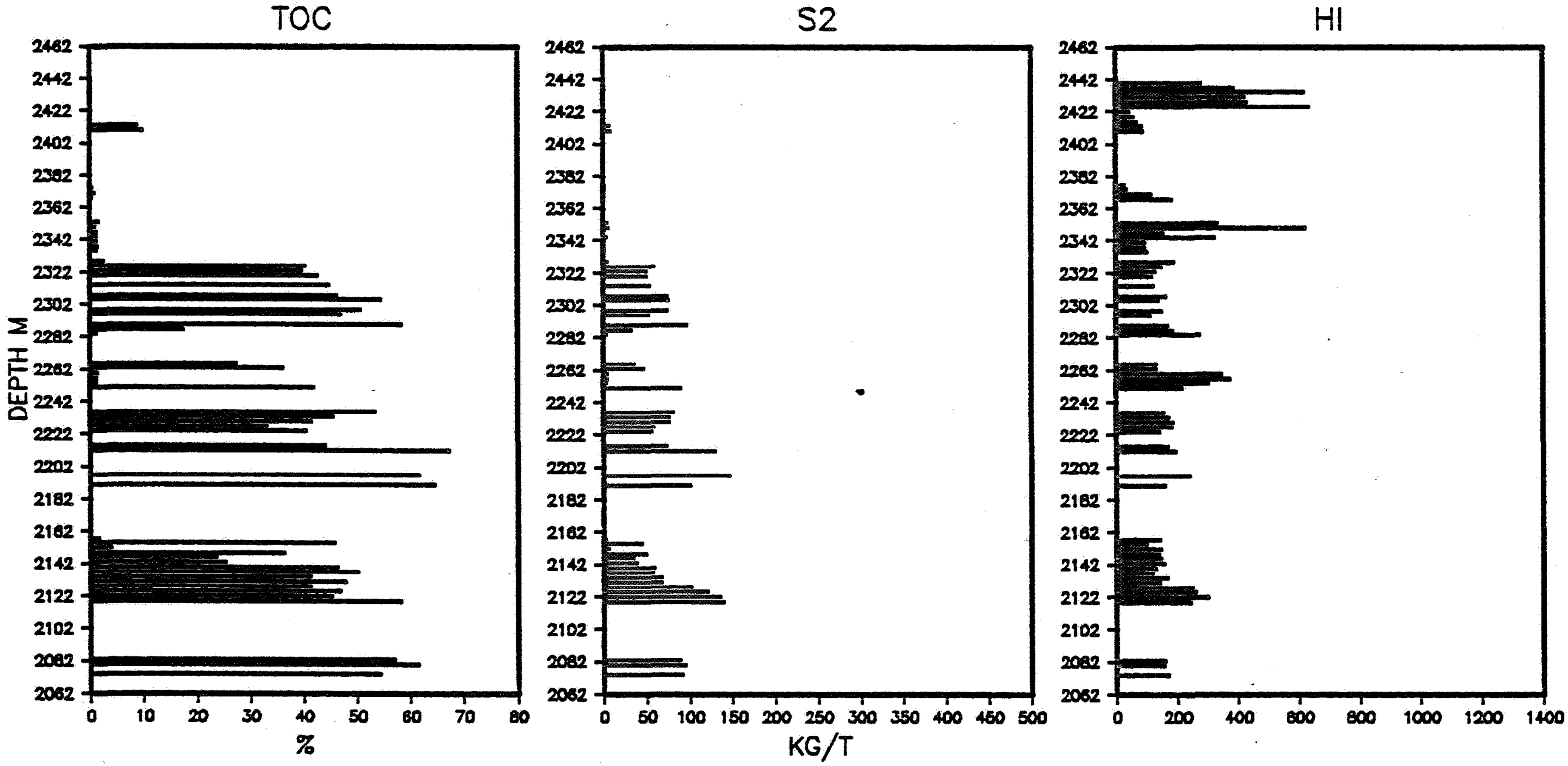


FIG. IV.3.1 A AND B

PLOTS OF TOC, S2 AND HI VERSUS DEPTH,

HITRA FM. 6407/9-1

HITRA FM. WELL 6407/9-1



HITRA FM. WELL 6407/9-1

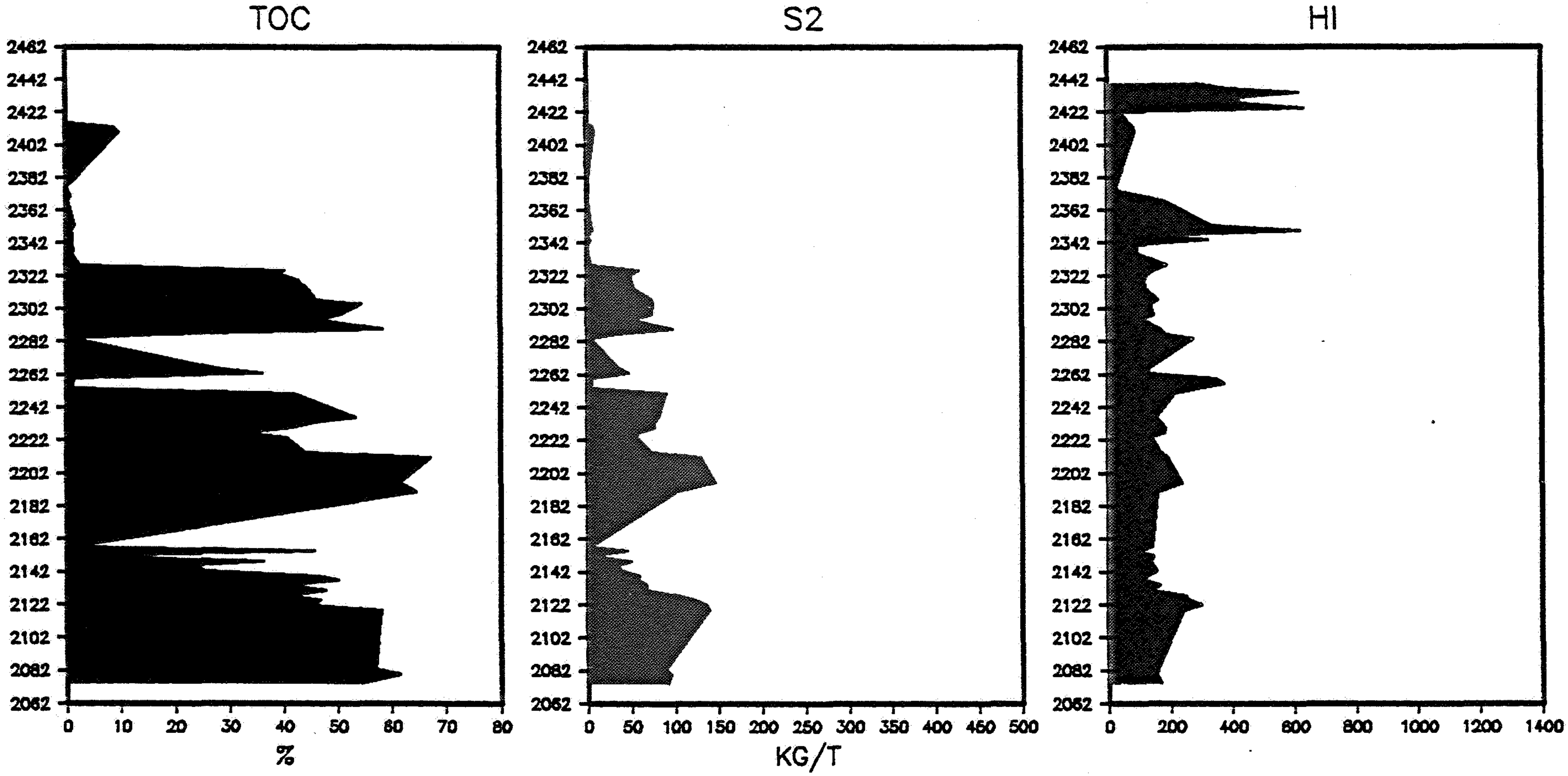


FIG. IV.3.2

COAL UNITS, HITRA FM. 6407/9-1

HITRA FM.

6407/9-1

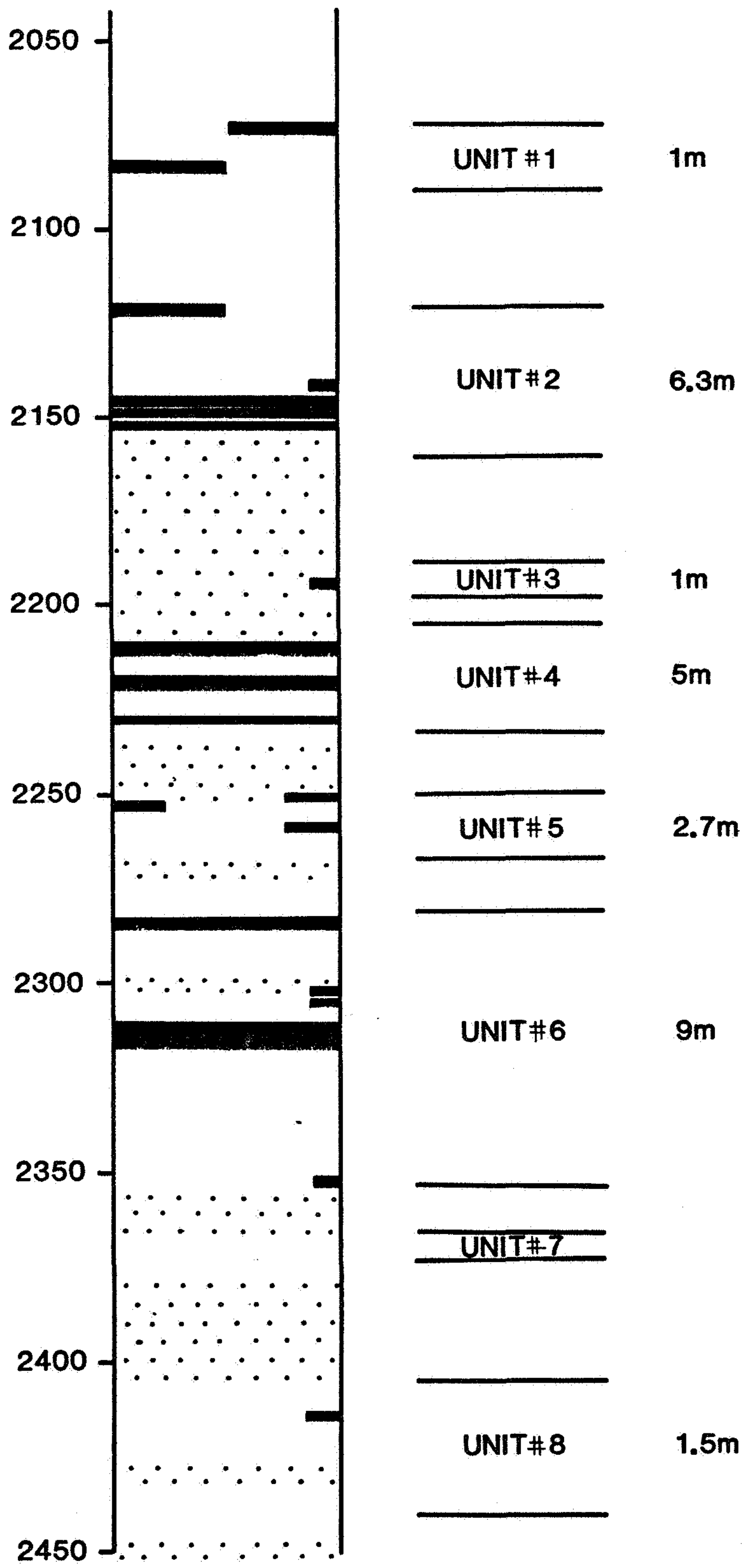


FIG. IV.3.3

PLOT OF EOM/TOC VERSUS DEPTH, HITRA FM. 6407/9-1

HITRA FM. WELL 6407/9-1

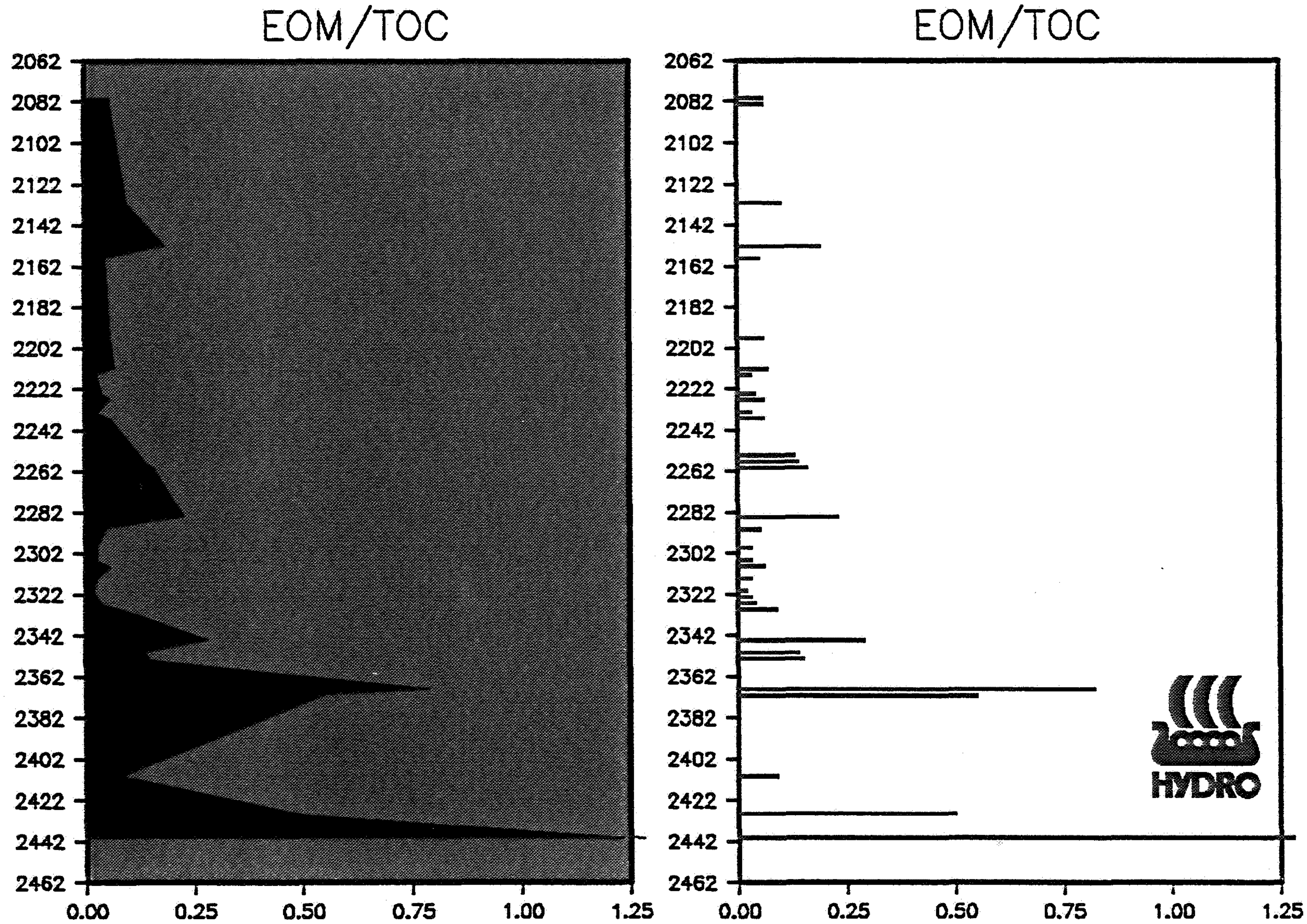


FIG. IV.3.4

PLOT OF PR/PH AND PR/n-C17 VERSUS DEPTH,

HITRA FM. 6407/9-1

HITRA FM. WELL 6407/9-1

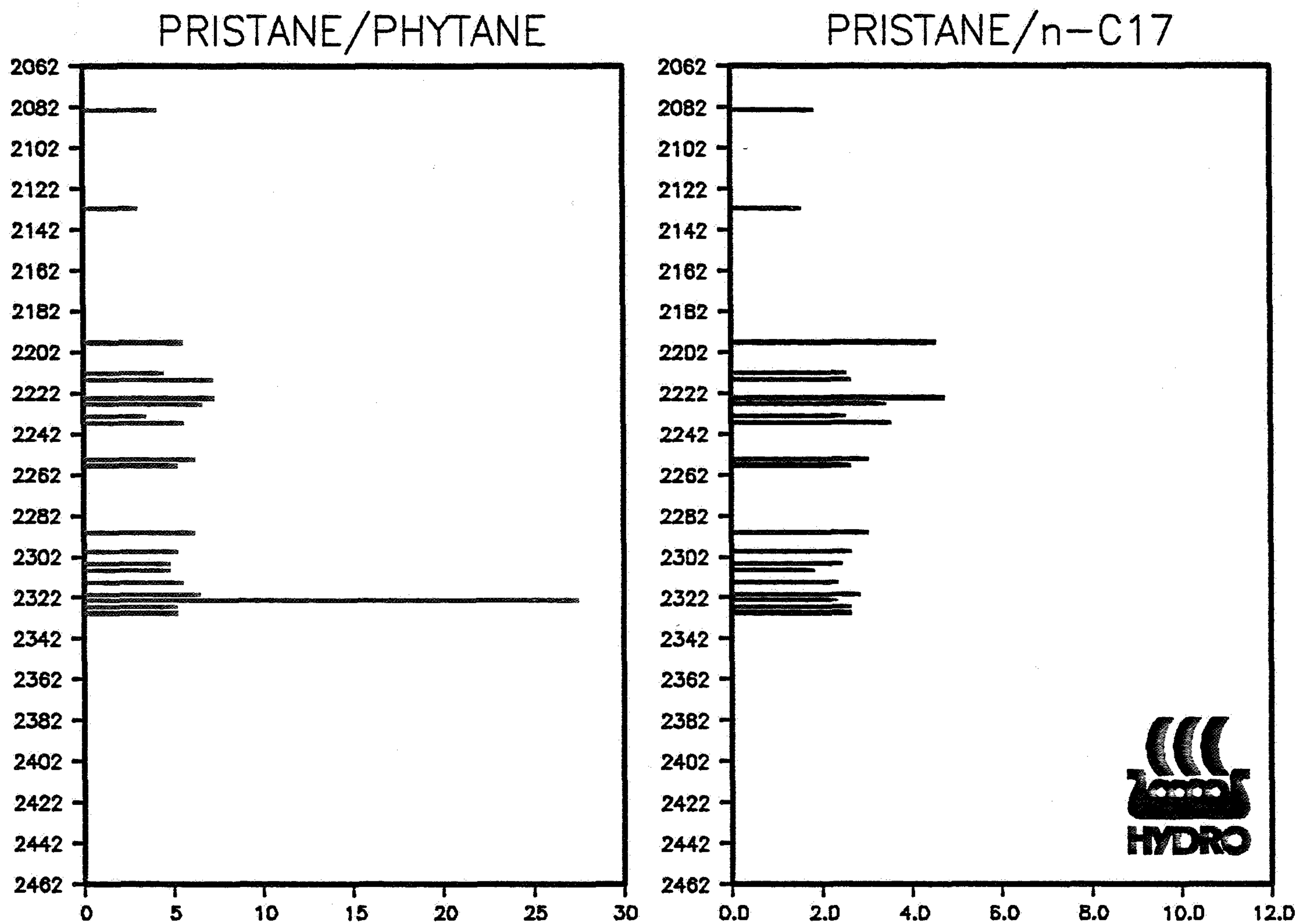


FIG. IV.3.5

PLOT OF BIOMARKER RATIOS VERSUS DEPTH,

HITRA FM. 6407/9-1

HITRA FM. WELL 6407/9-1

BIOMARKER RATIOS