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REPORT ON A MATURATION AND SOURCE ROCK POTENTIAL STUDY OF SAMPLES FROM THE MOBIL NORWAY 33/9-3 WELL, NORTH SEA

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INTRODUCTION

A study of light hydrocarbons, vitrinite reflectivity, spore colouration, maximum palaeotemperature, and source rock potential has been carried out on samples from the section 5,500 to 9,810 feet of the Mobil Norway 33/9-3 Well.

Samples were analysed for source rock potential and spore colouration at one hundred foot intervals. Light hydrocarbons, and maximum palaeotemperatures were measured at intervals of approximately two hundred feet while vitrinite reflectivity was determined on a selection of suitable samples.

The samples were obtained as wet ditch cuttings preserved in drilling mud so that it was possible to carry out gaseous and gasoline range hydrocarbons analyses. Core samples were obtained over the interval 7,950 to 8,570 feet.

After washing in cold water to remove any contaminants the samples were observed under the microscope and, where several lithologies occurred in the same sample, the individual lithologies were sampled for their organic carbon content.

The age of the section ranges from Palaeocene to Lower Jurassic.

II

ANALYTICAL RESULTS AND INTERPRETATION

1. Lithology (Table 2)

The lithologies present in the samples analysed from the 33/9-3 well can be briefly described as follows:

5500 - 7210 feet	-	Calcareous mudstones of varying shades from light olive grey to medium grey. Also white to medium grey limestones in most samples, proportions varying from trace to 30% of the sample.
7300 - 8110 feet	-	Light grey calcareous shale throughout the interval. Minor quantities of mudstone at 7300 and 7400 feet. White limestone in minor amounts in samples from 7900 and 8000 feet.
8200 - 8510 feet	-	Dark grey shale with 10% to 40% sand.
8600 - 9310 feet	-	Light or medium grey shale with occasional minor sand. Grey mudstone in the 8800 feet sample, minor limestone in the 9000 feet sample.
9400 - 9810 feet	-	Mottled medium grey and medium dark grey shale with up to 60% white quartz sand and occasional limestone or grey-red mudstone.

2. Maturation State of the Well

Four methods have been used to evaluate the state of maturation attained in this well. These are a) gasoline and gaseous hydrocarbon analysis b) vitrinite reflectivity determination c) spore colouration and d) maximum palaeotemperature analysis.

a. Light Hydrocarbon Analysis (Table 1 and Figures 1 and 2)

The gaseous and gasoline range (C_1 to C_4 and C_5 to C_7) hydrocarbons have been analysed to determine the quantities and relative proportions of the absorbed hydrocarbons in the kerogens. Twenty-six samples have been analysed through the well section.

Gaseous Hydrocarbons

Hydrocarbons in the range C_1 to C_4, (methane through n-butane), were found to be present in very small quantities; in all samples there was less than 1 part per million. These values are rather less than would be expected, some loss of gaseous hydrocarbons having occurred. However, it is believed that the hydrocarbons will have escaped in relatively proportional amounts and the results have been found relevant in determining the maturation state. Within a section the maturity can be determined by comparing the proportion of methane relative to the other C_2 to C_4 hydrocarbons (ethane through to n-butane). For immature sediments only methane of biogenic origin is found, but with increasing maturity the other hydrocarbons in this range are generated causing the relative proportion of methane to decrease.

The results of the analysis are included in Table 1 and Figure 1. Over the interval 5,800 to 7,510 feet the samples were found to contain between 64% and 100% methane. The sediments are considered to be immature to being transitionally mature at around 7,510 feet. The samples below 7,510 feet contain much smaller proportions of methane, (less than 29%), apart from two probably anomalous high values. Below 7,510 feet the section analysed appears mature.

Gasoline Hydrocarbons

Generally, maturity is indicated when all the constituent gasolines as listed in Table 1 are found to be present in approximately equal amounts. The difference in percentage abundance between any two gasoline components should not be greater than one order of magnitude for a mature sediment. Immature sediments usually exhibit some components often in very large percentage

abundance, the total quantity of gasolines present being low and generally less than 100 ppb.

From the results, (Table 1 and Figure 2), the samples between 5,500 and 6,740 feet appear immature as most of the component gasolines are missing. Over the interval 6,900 to 7,320 feet the number of absent components becomes less and the section appears transitional between immature and mature. Over the interval 7,500 to 8,110 feet all the components are present and the largest quantities of gasolines are noted. Over the remaining part of the well section one, two, sometimes three component gasolines are absent. The first four samples from 8,300 to 8,910 feet have in excess of 3000 ppb hydrocarbon, though the remaining five samples are rather lean with 382 ppb to 1581 ppb. However, it is believed that the onset of maturity is at around 7,500 feet agreeing with the gaseous hydrocarbon analysis.

b. Vitrinite Reflectivity (Table 3 and Figure 3)

The results of the vitrinite reflectivity analysis give a fairly complicated picture due to the large amount of caved and reworked material below 7,610 feet. The results are considered satisfactory above 7,600 feet and adequate below, nevertheless, it is thought that the rank gradient as displayed in figure 3 is an accurate representation of the analysed section.

The trend within the Upper Cretaceous is well defined with reflectivities of about 0.35% at 6,000 feet and increasing to only around 0.43% at 7,800 feet. Between this depth and 8,100 feet there occurs a marked increase in vitrinite reflectivity coinciding with the unconformity between the Upper Cretaceous and the Middle Jurassic. At 8,100 feet reflectivities of 0.46% were recorded and with increasing depth values rise to 0.53% at 9,410 feet. Below 9,410 feet it is believed that the material observed was non-indigenous and probably caved. This latter material with a reflectivity ranging from 0.30% to 0.38% is widespread and was noticed in most of the samples between 7,810 and 9,810 feet.

Examination Ultraviolet Light

On examination in ultraviolet light many samples showed variable fluorescence between one cutting and another, spores being common in almost every sample analysed. These spores fluoresced yellow or orange, though yellow fluorescence seemed dominant in the shallower samples. Within the interval 6,010 to 7,610 feet only low to moderate contents of exinite were observed, though below this depth, and down to 9,410 feet the samples showed moderate to rich contents. The samples from 9,610 and 9,810 feet had only trace and moderate contents of exinite.

c. Spore Colouration Analysis (Table 3 and Figure 5)

The maturation of kerogen during diagenesis has been described by a number of workers who have referred specifically to modification of sporopollenin. The process of maturation is considered to increase the visible colour pigmentation of sporopllenin from pale yellow, through orange and brown to black. A ten point scale of colour indices has been used in this study which comprises samples over the section from 5,500 to 9,810 feet. Within the interval 7,950 to 8,570 feet core samples were obtained for analysis while over the remaining depths, ditch cuttings were used.

With increasing depth from 5,500 to 7,950 feet spore colour indices show a uniform increase from around 2.5; indicative of immaturity, to 4.5; indicative of moderate maturity. A sudden increase in the colour index was then noted, the sample from 8,055 feet giving a value of between 5 and 6. This increase is attributed to an unconformity between the Cretaceous and Middle Jurassic. Colour indices of 5.5 were obtained on the sample from 8,570 feet and a uniform increase in spore colouration was seen with increasing depth, values of 6.5 being measured on samples at the base of the analysed section, 9,810 feet. The latter interval from 8,055 feet down, is considered quite mature.

d. Maximum Palaeotemperature (Table 3 and Figure 4)

To some extent the results of the maximum palaeotemperature study give

information of elusive significance, particularly in that a palaeothermal gradient of low value is obtained. It has already been noted in the vitrinite reflectivity study that large amounts of caved and reworked organic material are present and, since this will be present in the total kerogen, in the palaeotemperature analysis these two categories of material will be contributory towards the results.

For this well it can be seen that temperatures both at the top and the bottom of the analysed section are fairly similar, though palaeotemperatures do appear to be slightly higher in the lower part of the section. The majority of the samples have yielded palaeotemperatures of between 250° and 270° F.

e. Comparison of Maturation Indices (Table 3 and Figure 5)

Light hydrocarbon analysis, vitrinite reflectivity, spore colouration and maximum palaeotemperature analysis have been used in a composite evaluation of the well section. The latter three analyses do not coincide above the unconformity at around 8,000 feet between the Upper Cretaceous and Middle Jurassic. Below the unconformity the stages of maturity indicated by each of these parameters approach agreement and appear to coincide near the base of the analysed section, (figure 5). Spore colouration is probably most representative of the true stage of maturation of oil generating organic matter and would indicate the section to be immature above about 6,500 feet and mature from about 7,500 feet downwards. Maturity of humic organic matter is considered likely to produce gas when vitrinite reflectivity values reach 0.4% to 0.5%, this range of values being encountered between 7,000 and 8,000 feet in this section. Light hydrocarbon analysis has indicated the section to be immature above 6,700 feet, transitionally mature between 6,700 and around 7,300 feet and mature below 7,500 feet.

The onset of maturity is thus considered to be found at about 7,500 feet and, between this depth and the base of the analysed section medium gravity oils would be generated from oil-prone types of organic material.

The maximum palaeotemperatures, since they do not give an erratic plot, may reflect the chemical state of the predominant amorphous organic content. This suggests that a short lived period of heating, insufficient in duration to affect vitrinites and spores has occurred and in this tectonic environment may arise from a vertical redistribution of hot connate waters.

3. Source Rock Potential (Table 2 and Figures 6, 7 and 8)

On considering the results of the source rock analysis the section has been divided into five parts, each of these intervals being discussed separately.

a. Samples 1 to 16 (5,500 to 7,210 feet)

Within this interval the organic carbon content of the mainly mudstone lithology was found to be below average, the samples having carbon contents ranging from 0.28% to 0.47%. The extractability of the organic material in solvents is also low varying from less than 3.3% to 8.1%, apart from sample 2, 5,600 feet, with a 10% extractability, thought to be due to hydrocarbon contamination. The samples are very lean in hydrocarbons, contents varying from less than 20 ppm to 85 ppm, apart from 220 ppm hydrocarbons in the supposedly contaminated sample 2 mentioned above. Sample no. 6, 6,100 feet, also appears contaminated in view of the high proportion of hydrocarbons in its extract,but general organic leanness. On considering likely products and source rock richness all the samples appear to be too lean in both organic carbon and hydrocarbons to act as source rocks for any type of hydrocarbon accumulation.

b. Samples 17 to 21 (7,300 to 7,710 feet)

Within this short interval, represented by light grey shales, the organic carbon contents increase to just below average values of 0.59% to 0.82%, typical shales usually having contents of 1% to 2%. Extractability is quite variable, from 3.1% (sample 20), to 13.2% (sample 17), though hydrocarbon contents do not exceed 90 ppm in any of the samples. Due to the low content of hydrocarbons this interval is considered void of any prospective

source rocks capable of producing liquid or gaseous hydrocarbon at their present level of maturity.

c. Samples 22 to 29 (7,800 to 8,510 feet)

Organic carbon contents are highly variable over this short interval which is considered to span the unconformity between the Cretaceous and Middle Jurassic sediments. In many samples the carbon content of the shales has been disguised by large proportions of sand, giving values of from 0.52% to 1.24%. Individual black shaly lithologies were hand-picked for organic carbon determination, values of 1.01%, 10.12% and 5.01% being obtained on samples 23, 26 and 27 respectively. Extractabilities are rather variable ranging from 4.9% to 16.6%, though most of the samples gave values between 4.9% and 6.8%. Hydrocarbon contents are highly variable, three samples having low contents of 70 ppm to 80 ppm, two samples having average content of 120 ppm and 250 ppm and two samples having above average contents of 460 ppm and 680 ppm.

On considering likely hydrocarbon products and the richness of the source rocks together, sample 24 and 29 seem rather lean in hydrocarbons indicating source rocks of no value. Sample 23, 7,900-10 feet, is indicated as a very good source rock for oil while in samples 22, 25 and 28 the source rocks seem capable of providing fair quantities of gas-and-oil. Samples 26 and 27,contain organically rich, coaly shales within the sandstone and, if these horizons are of sufficient extent both laterally and in thickness, then they should constitute good gas sources.

d. Samples 30 to 39 (8,600 to 9,510 feet)

These samples comprising grey shales often with sand, (probably caved), have an average organic richness, the shales themselves having contents of between 1.10% and 1.75% organic carbon. Extractability is fairly constant within this interval ranging from 4.2% to 7.1%. Hydrocarbon contents are rather low with a total range of 45 ppm to 130 ppm, though the majority of samples have contents of 80 ppm to 100 ppm hydrocarbons.

On considering the richness of the source rocks, gas in limited quantities seems most likely, good gas sources usually being found only from source rocks with at least 1.5% to 2% organic carbon.

e. Samples 40 to 42 (9,600 to 9,810 feet)

These samples were found to contain large amounts of sand, and when the individual shales were analysed for their carbon content, the values obtained were found to be much higher than those for the bulk sample. The bulk samples had a range in organic carbon content of from 0.20% to 0.34% while the shales in sample 40 and 42 had contents of 1.42% and 2.04% respectively. Extractabilities were found to be on the low side and in no case greater than 6.1%. Hydrocarbon contents obtained were 80 ppm for sample 41 and 130 ppm for sample 42. The proportions of extractable organic carbon and hydrocarbon contents as indicated by figures 6 and 7 suggest that these samples are oil-stained, these indications being based on the low bulk sample carbon contents. If the shales are considered alone then they are more likely to be source rocks capable of producing gas maybe with little associated oil.

III

CONCLUSION

As a result of maturation and source rock potential studies of the section 5,500 to 9,810 feet in the Mobil 33/9-3 Well the following conclusions have been reached.

i. The interval 5,500 to 7,710 is immature or transitionally mature. The samples are fairly lean in organic carbon and in hydrocarbons and the interval is considered non-prospective.

ii. Within the interval 7,800 to 8,510 feet, mature sediments are encountered. Certain shales in this interval are rich or very rich in organic carbon and good contents of hydrocarbons are noticed. A shale from 7,900 feet is regarded as being a potentially very good source rock for medium gravity oil, while other shales are potential sources of gas-with-oil and gas.

iii. The interval 8,600 to 9,510 feet is thermally mature. The shales have an average organic richness, but are lean in hydrocarbons. Gas would be expected from these source rocks, though the interval appears only marginally prospective.

iv. The small interval 9,600 to 9,810 feet at the base of the analysed section contains shales with sufficient organic carbon and hydrocarbon contents to provide possible sources of gas maybe with a little medium to light oil. The interval is mature and could be marginally prospective.

APPENDIX I

ABBREVIATIONS USED IN ANALYTICAL DATA SHEETS

-	-	Sample not analysed
*	-	No results obtained

C.M.T.	-	Cement	L.C.M.	-	Lost circulation material
Cht	-	Chert	Qtz	-	Quartz
Snd	-	Sand	Sst	-	Sandstone
Slt	-	Silt	Sltst	-	Siltstone
Cgl	-	Conglomerate	Mdst	-	Mudstone
Clyst	-	Claystone	Cly	-	Clay
Sh	-	Shale	Dol	-	Dolomite
Lstn	-	Limestone	Chk	-	Chalk
Lig	-	Lignite	Musc	-	Muscovite
Sndy	-	Sandy	Slty	-	Silty
Shly	-	Shaly	Arg	-	Argillaceous
Aren	-	Arenaceous	Carb	-	Carbonaceous
Calc	-	Calcareous	Mic	-	Micaceous
Ool	-	Oolitic	Sil	-	Siliceous
Fer	-	Ferruginous	Lam	-	Laminae/laminated
Frags	-	Fragments	Pp	-	Purple
Brn	-	Brown	Yel	-	Yellow
Gy	-	Grey	Gn	-	Green
Ol	-	Olive	Blk	-	Black
Wht	-	White	Bl	-	Blue
Mtl	-	Mottled	Vgt	-	Variegated
Sft	-	Soft	Hd	-	Hard
Tr	-	Trace	Occ	-	Occasional
Sl	-	Slightly	V	-	Very
Lt	-	Light	Dk	-	Dark
Med	-	Medium	Crs	-	Coarse
Mnr	-	Minor ($< 10\%$)	Pyr	-	Pyrite/pyritic

Gy-gn	-	Greyish green	Gn-gy	-	Greenish grey
Gn/gy	-	Green and/to grey			

TABLE 1

GASEOUS AND GASOLINE RANGE HYDROCARBONS

CLIENT MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

GAS ($C_1 - C_4$)

SAMPLE NO.	1		3		6		9	
DEPTH FEET	5500		5800		6100		6500	
	P. P. M.	% $C_1 - C_4$	P. P. M.	% $C_1 - C_4$	P. P. M.	% $C_1 - C_4$	P. P. M.	% $C_1 - C_4$
C_1	*	*	0.1	71	.124	100	0.087	88
C_2	*	*	<0.01	< 1	<0.01	< 1	0.012	12
C_3	*	*	<0.01	< 1	<0.01	< 1	<0.01	< 1
iC_4	*	*	<0.01	< 1	*	*	<0.01	< 1
nC_4	*	*	0.04	29	<0.01		<0.01	< 1
TOTAL	*	*	0.14	100	0.12	100	0.099	100

GASOLINE RANGE ($C_5 - C_7$)

SAMPLE NO.	1		3		6		9	
DEPTH FEET	5500		5800		6100		6500	
	P. P. B.	% $C_5 - C_7$	P. P. B.	% $C_5 - C_7$	P. P. B	% $C_5 - C_7$	P. P. B.	% $C_5 - C_7$
ISO-PENTANE	*	*	26	3.0	*	*	*	*
N-PENTANE	17	18.3	389	45.1	111	43.2	*	*
CYCLOPENTANE	6	6.5	381	44.2	19	7.4	*	*
2-ME. PENTANE	*	*	*	*	*	*	*	*
3-ME. PENTANE	*	*	12	1.4	46	17.9	*	*
N-HEXANE	20	21.5	*	*	*	*	*	*
ME. CYCLOPENTANE	8	8.6	6	0.7	12	4.7	*	*
CYCLOHEXANE	*	*	31	3.6	*	*	*	*
2-ME. HEXANE	*	*	*	*	*	*	*	*
3-ME. HEXANE	*	*	*	*	*	*	*	*
3-ETHYLPENTANE	*	*	*	*	*	*	*	*
N-HEPTANE	27	29.0	*	*	13	5.1	*	*
BENZENE	15	16.1	*	*	56	21.8	*	*
1,2-DIME. CYC. PENT.	*	*	*	*	*	*	*	*
ME. CYCLOHEXANE	*	*	17	2.0	*	*	*	*
TOTAL	93	100	862	100	257	100	*	*

TABLE 1 (Cont'd)

GASEOUS AND GASOLINE RANGE HYDROCARBONS

CLIENT MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

GAS ($C_1 - C_4$)

SAMPLE NO.	11		13		15		17	
DEPTH FEET	6700		6900		7100		7300	
	P. P. M.	% $C_1 - C_4$	P. P. M.	% $C_1 - C_4$	P. P. M.	% $C_1 - C_4$	P. P. M.	% $C_1 - C_4$
C_1	0.0158	76	0.067	87	0.408	79	0.072	78
C_2	0.036	17	<0.01	< 1	0.049	9	<0.010	< 1
C_3	0.014	7	<0.01	< 1	0.052	10	<0.01	< 1
iC4	<0.01	< 1	<0.01	< 1	<0.01	< 1	<0.01	< 1
nC4	<0.01	< 1	0.01	13	0.01	2	0.02	22
TOTAL	0.21	100	0.077	100	0.52	100	0.09	100

GASOLINE RANGE ($C_5 - C_7$)

SAMPLE NO.	11		13		15		17	
DEPTH FEET	6700		6900		7100		7300	
	P. P. B.	% $C_5 - C_7$	P. P. B.	% $C_5 - C_7$	P. P. B	% $C_5 - C_7$	P. P. B.	% $C_5 - C_7$
ISO-PENTANE	2	1.4	1	0.2	1	0.5	128	4.8
N-PENTANE	111	78.7	4	1.0	5	2.3	149	5.6
CYCLOPENTANE	5	3.5	*	*	*	*	19	0.7
2-ME. PENTANE	*	*	34	8.4	*	*	241	9.0
3-ME. PENTANE	17	12.1	*	*	14	6.6	123	4.6
N-HEXANE	*	*	62	15.4	7	3.3	433	16.2
ME. CYCLOPENTANE	6	4.3	*	*	56	26.3	151	5.6
CYCLOHEXANE	*	*	2	0.5	2	0.9	150	5.6
2-ME. HEXANE	*	*	3	0.7	9	4.2	147	5.5
3-ME. HEXANE	*	*	53	13.2	2	0.9	172	6.4
3-ETHYLPENTANE	*	*	24	6.0	20	9.4	144	5.4
N-HEPTANE	*	*	139	34.5	30	14.1	444	16.6
BENZENE	*	*	49	12.2	9	4.2	36	1.3
1,2-DIME. CYC. PENT.	*	*	*	*	5	2.3	*	*
ME. CYCLOHEXANE	*	*	32	7.9	53	24.9	337	12.6
TOTAL	141	100	403	100	213	100	2674	100

GASEOUS AND GASOLINE RANGE HYDROCARBONS

CLIENT MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

GAS ($C_1 - C_4$)

SAMPLE NO.	19		21		23		25	
DEPTH FEET	7500		7700		7900		8100	
	P. P. M.	$\%C_1 - C_4$	P. P. M.	$\%C_1 - C_4$	P. P. M.	$\%C_1 - C_4$	P. P. M.	$\%C_1 - C_4$
C_1	0.075	64	0.092	28	0.083	24	0.053	6
C_2	<0.01	< 1	0.051	16	0.01	< 1	0.025	3
C_3	0.011	9	0.111	34	0.015	4	0.047	52
iC_4	<0.01	< 1	<0.01	< 1	0.057	16	0.049	6
nC_4	0.031	26	0.070	22	0.195	56	0.274	33
TOTAL	0.12	100	0.32	100	0.35	100	0.83	100

GASOLINE RANGE ($C_5 - C_7$)

SAMPLE NO.	19		21		23		25	
DEPTH FEET	7500		7700		7900		8100	
	P. P. B.	$\%C_5 - C_7$	P. P. B.	$\%C_5 - C_7$	P. P. B	$\%C_5 - C_7$	P. P. B.	$\%C_5 - C_7$
ISO-PENTANE	213	2.4	314	5.9	997	5.3	130	1.4
N-PENTANE	373	4.3	431	8.2	3692	19.8	322	3.5
CYCLOPENTANE	40	0.5	60	1.1	80	0.4	48	0.5
2-ME. PENTANE	343	4.0	339	6.4	1067	5.7	281	3.1
3-ME. PENTANE	180	2.1	165	3.1	541	2.9	151	1.7
N-HEXANE	416	4.8	339	6.4	1423	7.6	521	5.7
ME. CYCLOPENTANE	251	2.9	291	5.5	655	3.5	291	3.2
CYCLOHEXANE	279	3.2	310	5.9	716	3.8	325	3.6
2-ME. HEXANE	459	5.3	229	4.3	960	5.1	256	2.8
3-ME. HEXANE	913	10.5	432	8.2	1371	7.3	345	3.8
3-ETHYLPENTANE	347	4.0	203	3.8	496	2.7	180	2.0
N-HEPTANE	2166	25.0	997	18.9	3988	21.3	1002	11.0
BENZENE	866	10.0	168	3.2	168	0.9	4224	46.5
1,2-DIME.CYC.PENT.	71	0.8	24	0.5	120	0.6	19	0.2
ME. CYCLOHEXANE	1746	20.2	985	18.6	2412	12.9	985	10.8
TOTAL	8663	100	5287	100	18686	100	9080	100

TABLE 1 (Cont'd)

GASEOUS AND GASOLINE RANGE HYDROCARBONS

CLIENT MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

GAS ($C_1 - C_4$)

SAMPLE NO.	27		29		31		33	
DEPTH FEET	8300		8500		8700		8900	
	P.P.M.	$\%C_1 - C_4$	P.P.M.	$\%C_1 - C_4$	P.P.M.	$\%C_1 - C_4$	P.P.M.	$\%C_1 - C_4$
C_1	0.028	54	0.089	11	0.01	8	<0.01	*
C_2	<0.01	<1	0.015	2	<0.01	<1	<0.01	*
C_3	0.012	23	0.213	27	0.059	46	<0.01	*
iC_4	<0.01	<1	0.092	12	0.012	9	<0.01	*
nC_4	0.012	23	0.391	49	0.046	36	0.02	*
TOTAL	0.052	100	0.80	100	0.13	0.02	0.02	*

GASOLINE RANGE ($C_5 - C_7$)

SAMPLE NO.	27		29		31		33	
DEPTH FEET	8300		8500		8700		8900	
	P.P.B.	$\%C_5 - C_7$	P.P.B.	$\%C_5 - C_7$	P.P.B	$\%C_5 - C_7$	P.P.B.	$\%C_5 - C_7$
ISO-PENTANE	464	4.1	40	0.7	274	4.7	328	10.8
N-PENTANE	1083	9.5	129	2.3	668	11.6	375	12.4
CYCLOPENTANE	187	1.6	10	0.2	84	1.5	67	2.2
2-ME. PENTANE	525	4.6	106	1.9	255	4.4	229	7.5
3-ME. PENTANE	275	2.4	56	1.0	138	2.4	127	4.2
N-HEXANE	841	7.3	244	4.4	411	7.1	315	10.4
ME. CYCLOPENTANE	646	5.6	115	2.1	229	4.0	218	7.2
CYCLOHEXANE	677	5.9	507	9.0	228	3.9	230	7.6
2-ME. HEXANE	290	2.5	286	5.1	173	3.0	126	4.2
3-ME. HEXANE	364	3.2	259	4.6	175	3.0	123	4.1
3-ETHYLPENTANE	263	2.3	255	4.6	93	1.6	308	10.1
N-HEPTANE	139	1.2	232	4.1	944	16.4	234	7.7
BENZENE	4379	38.3	2737	48.8	1310	22.7	*	*
1,2-DIME. CYC. PENT.	*	*	12	0.2	*	*	*	*
ME. CYCLOHEXANE	1313	11.5	615	11.0	791	13.7	356	11.7
TOTAL	11446	100	5603	100	5773	100	3036	100

TABLE 1 (Cont'd)

GASEOUS AND GASOLINE RANGE HYDROCARBONS

CLIENT MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

GAS ($C_1 - C_4$)

SAMPLE NO.	35		37		39		41	
DEPTH FEET	9100		9300		9500		9700	
	P.P.M.	$\%C_1 - C_4$	P.P.M.	$\%C_1 - C_4$	P.P.M.	$\%C_1 - C_4$	P.P.M.	$\%C_1 - C_4$
C_1	0.016	10	0.013	2	0.040	52	0.010	14
C_2	<0.01	<1	<0.01	<1	<0.01	<1	<0.01	<1
C_3	0.061	38	0.270	45	0.023	30	0.028	40
iC_4	0.019	12	0.060	10	<0.01	<1	0.010	14
nC_4	0.066	41	0.260	43	0.014	18	0.022	31
TOTAL	0.16	100	0.6	100	0.08	100	0.07	100

GASOLINE RANGE ($C_5 - C_7$)

SAMPLE NO.	35		37		39		41	
DEPTH FEET	9100		9300		9500		9700	
	P.P.B.	$\%C_5 - C_7$	P.P.B.	$\%C_5 - C_7$	P.P.B	$\%C_5 - C_7$	P.P.B.	$\%C_5 - C_7$
ISO-PENTANE	38	7.0	10	1.0	44	2.8	25	6.5
N-PENTANE	76	14.0	18	1.8	171	10.8	46	12.0
CYCLOPENTANE	5	0.9	3	0.3	33	2.1	*	*
2-ME. PENTANE	32	5.9	15	1.5	113	7.1	16	4.2
3-ME. PENTANE	16	3.0	8	0.8	74	4.7	9	2.4
N-HEXANE	57	10.5	32	3.3	432	27.3	53	13.9
ME. CYCLOPENTANE	36	6.7	17	1.7	65	4.1	26	6.8
CYCLOHEXANE	45	8.3	19	1.9	112	7.1	26	6.8
2-ME. HEXANE	22	4.1	22	2.2	19	1.2	30	7.9
3-ME. HEXANE	*	*	35	3.6	59	3.7	31	8.1
3-ETHYLPENTANE	56	10.4	20	2.0	*	*	13	3.4
N-HEPTANE	59	10.9	92	9.4	115	7.3	60	15.7
BENZENE	*	*	595	60.5	223	14.1	*	*
1,2-DIME.CYC.PENT.	*	*	*	*	*	*	*	*
ME. CYCLOHEXANE	99	18.3	97	9.9	121	7.7	47	12.3
TOTAL	541	100	983	100	1581	100	382	100

TABLE 1 (Cont'd)

GASEOUS AND GASOLINE RANGE HYDROCARBONS

CLIENT MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

GAS ($C_1 - C_4$)

SAMPLE NO.	42							
DEPTH FEET	9800							
	P.P.M.	$\%C_1 - C_4$	P.P.M.	$\%C_1 - C_4$	P.P.M.	$\%C_1 - C_4$	P.P.M.	$\%C_1 - C_4$
C_1	0.016	27						
C_2	0.003	5						
C_3	0.012	20						
iC_4	0.007	12						
nC_4	0.021	36						
TOTAL	0.06	100						

GASOLINE RANGE ($C_5 - C_7$)

SAMPLE NO.	42							
DEPTH FEET	9800							
	P.P.B.	$\%C_5 - C_7$	P.P.B.	$\%C_5 - C_7$	P.P.B	$\%C_5 - C_7$	P.P.B.	$\%C_5 - C_7$
ISO-PENTANE	16	2.8						
N-PENTANE	19	3.3						
CYCLOPENTANE	*	*						
2-ME. PENTANE	36	6.3						
3-ME. PENTANE	16	2.8						
N-HEXANE	55	9.6						
ME. CYCLOPENTANE	25	4.4						
CYCLOHEXANE	*	*						
2-ME. HEXANE	61	10.6						
3-ME. HEXANE	59	10.3						
3-ETHYLPENTANE	*	*						
N-HEPTANE	140	24.4						
BENZENE	84	14.7						
1,2-DIME. CYC. PENT.	*	*						
ME. CYCLOHEXANE	62	10.8						
TOTAL	573	100						

MAXIMUM PALAEOTEMPERATURE AND SOURCE ROCK POTENTIAL (C_{15+} FRACTION) DATA

OPERATOR MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

TABLE 2

SAMPLE NUMBER	DEPTH FEET	TYPE OF SAMPLE	LITHOLOGY	MAXIMUM PALAEO-TEMP (°F)	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M. OF ROCK	EXTRACT % OF ORGANIC CARBON	HYDRO-CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	SATURATES* % OF HYDRO-CARBON	REMARKS
1	5,500-20	Ctgs.	Lt ol-gy mdst+40% gn-gy sl calc mdst+10% wht lstn	-	0.31	140	4.5	20	-	-	
2	5,600-20	"	Gn-gy sl calc mdst+10% wht lstn	-	0.31	310	10.0	220	71	93	
3	5,800-20	"	Gn-gy sl calc mdst+30% ol-gy sl calc mdst+tr wht lstn	-	0.39	150	3.8	20	-	-	
4	5,900-20	"	Ditto	253	0.32	140	4.4	25	18	> 80	
5	6,000-20	"	Lt ol-gy mdst+30% ol-gy sl calc mdst+10% v lt gy lstn	-	0.33	120	3.6	45	36	> 80	
6	6,100-20	"	Gn-gy mdst+50% ol-gy calc mdst+mnr med gy lstn	268	0.33	120	3.6	85	68	> 90	
7	6,200-40	"	Lt ol-gy calc mdst+30% ol-gy calc mdst+mnr wht lstn+tr pyrites	-	0.36	120	3.3	20	16	> 80	
8	6,300-40	"	Gn-gy calc mdst+10% wht lstn+mnr med gy lstn + tr pyrites	251	0.32	180	5.6	50	29	> 90	
9	6,500-40	"	Ditto+ditto+ditto+mnr ol-gy mdst	-	0.37	< 120	-	-	-	-	
10	6,600-40	"	Lt ol-gy sl calc mdst+ 20% med lst gy mic mdst +mnr yell-gy calc mdst +tr wht lstn	-	0.34	< 120	-	-	-	-	

*SATURATES = Sum of naphthenes normal and iso-paraffins.

MAXIMUM PALAEOTEMPERATURE AND SOURCE ROCK POTENTIAL (C_{15+} FRACTION) DATA

TABLE 2 (Cont'd) OPERATOR MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

SAMPLE NUMBER	DEPTH FEET	TYPE OF SAMPLE	LITHOLOGY	MAXIMUM PALAEO-TEMP (°F)	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M. OF ROCK	EXTRACT % OF ORGANIC CARBON	HYDRO-CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	SATURATES* % OF HYDRO-CARBON	REMARKS
11	6,700-40	Ctgs.	Lt ol-gy calc mdst+30% v lt gy lstn+tr pyrites + med dk gy lstn	242	0.28	< 120	-	-	-	-	
12	6,800-20	"	Lt ol-gy calc mdst+10% wht lstn + mnr med gy lstn	-	0.41	< 120	-	-	-	-	
13	6,900-40	"	Mtl med lt gy/lt ol-gy calc shly mdst+10% pale red calc mdst	239	0.47	< 220	-	-	-	-	
14	7,000-20	"	Ditto	-	0.47	380	8.1	60	16	> 90	
15	7,100-20	"	Lt gy sl calc mdst+50% v lt gy sl calc mdst + mnr med dk gy lstn	255	0.39	< 120	-	-	-	-	
16	7,200-10	"	Lt gy calc mdst+50% v lt gy calc mdst+20% med lt gy calc shly mdst	-	0.46	< 180	-	-	-	-	
17	7,300-20	"	Mtl lt gy/med lt gy calc slty sh+10% lt gy calc mdst	242	0.59	780	13.2	60	8	> 90	
18	7,400-10	"	Ditto+mnr pale red mdst	-	0.68	500	7.4	70	13	90	
19	7,500-10	"	Ditto	-	0.81	450	5.6	60	13	83	
20	7,600-10	"	Ditto	-	0.80	250	3.1	35	14	> 90	
21	7,700-10	"	Ditto	261	0.82	510	6.2	90	18	33	

*SATURATES = Sum of naphthenes normal and iso-paraffins

MAXIMUM PALAEOTEMPERATURE AND SOURCE ROCK POTENTIAL (C_{15+} FRACTION) DATA

TABLE 2 (cont'd.) OPERATOR MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

SAMPLE NUMBER	DEPTH FEET	TYPE OF SAMPLE	LITHOLOGY	MAXIMUM PALAEO-TEMP (°F)	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M. OF ROCK	EXTRACT % OF ORGANIC CARBON	HYDRO-CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	SATURATES* % OF HYDRO-CARBON	REMARKS
22	7,800-20	Ctgs.	Mtl lt gy/med lt gy calc slty sh+10% lt gy calc mdst+mnr pale red mdst	266	0.82	400	4.9	140	35	64	
23	7,900-10	"	Ditto+30% wht lstn	255	0.95	1580	16.6	680	43	73	
24	8,000-10	"	Mtl lt gy/med-lt gy sh + mnr wht lstn	-	0.67	400	6.0	80	19	68	
25	8,100-10	"	Ditto	265	1.24	1200	9.7	250	21	41	
26	8,200-10	"	Ditto+10% dk gy sh+10% snd+mnr wht mic sltst	-	1.11	1390	12.5	460	33	76	
27	8,300-10	"	Ditto + 10% ditto + 40% snd	264	0.81	500	6.2	75	15	57	
28	8,400-10	"	Ditto+30% snd	-	0.52	600	11.5	120	20	67	
29	8,500-10	"	Ditto+30% snd	265	1.14	720	6.3	70	10	57	
30	8,600-10	"	Ditto	-	1.10	750	6.8	90	12	62	
31	8,700-10	"	Ditto	261	1.12	790	7.1	100	13	55	
32	8,800-10	"	Ditto+20% med lt gy mdst	-	1.14	550	4.8	45	8	> 80	
33	8,900-10	"	Mtl med lt gy/med dk gy sh	257	1.32	590	4.5	80	14	85	

*SATURATES = Sum of naphthenes normal and iso-paraffins

MAXIMUM PALAEOTEMPERATURE AND SOURCE ROCK POTENTIAL (C_{15+} FRACTION) DATA

OPERATOR MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

TABLE 2 (cont'd)

SAMPLE NUMBER	DEPTH FEET	TYPE OF SAMPLE	LITHOLOGY	MAXIMUM PALAEO-TEMP (°F)	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M. OF ROCK	EXTRACT % OF ORGANIC CARBON	HYDRO-CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	SATURATES* % OF HYDRO-CARBON	REMARKS
34	9,000-10	Ctgs.	Mtl med lt gy/med dk gy sh+mnr wht lstn+mnr snd	-	1.29	540	4.2	130	24	91	
35	9,100-10	"	Ditto	269	1.37	620	4.5	80	13	89	
36	9,200-10	"	Ditto+mnr snd	-	1.34	650	4.9	80	13	86	
37	9,300-10	"	Mtl med gy/med dk gy sh	252	1.37	640	4.7	100	16	86	
38	9,400-10	"	Ditto+40% crs wht snd	-	0.71	430	6.1	110	25	81	
39	9,500-10	"	Ditto+50%ditto	258	0.52	260	5.0	80	29	> 90	
40	9,600-10	"	Ditto+30% ditto+mnr gn-red mdst	-	0.20	< 120	-	-	-	-	
41	9,700-10	"	Ditto+60% ditto!ditto+ tr wht lstn	256	0.23	140	6.1	80	59	> 90	
42	9,800-10	"	Ditto+50% snd/sst+mnr gy-red sh	-	0.34	160	4.7	130	82	94	
	ORGANIC CARBON DETERMINATION										
1			Wht lstn		0.11						
3			Wht lstn		0.10						
5			Ol-gy sl calc mdst		0.19						
8			Gn-gy calc mdst		0.35						

*SATURATES = Sum of naphthenes normal and iso-paraffins.

MAXIMUM PALAEOTEMPERATURE AND SOURCE ROCK POTENTIAL (C_{15+} FRACTION) DATA

TABLE 2 (cont'd) OPERATOR MOBIL NORWAY WELL 33/9-3 LOCATION NORTH SEA

SAMPLE NUMBER	DEPTH	TYPE OF SAMPLE	LITHOLOGY	MAXIMUM PALAEO-TEMP (°F)	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M. OF ROCK	EXTRACT % OF ORGANIC CARBON	HYDRO-CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	SATURATES* % OF HYDRO-CARBON	REMARKS
	ORGANIC CARBON DETERMINATION (cont'd)										
18			Pale red mdst		0.14						
23			Mtl med lt gy banded slty sh		1.01						
26			Dk gy sh		10.12						
27			Ditto		5.01						
33			Med dk gy sh		1.75						
38			Ditto		1.50						
39			Ditto		1.30						
40			Ditto		1.42						
42			Ditto		2.04						

*SATURATES = Sum of naphthenes normal and iso-paraffins

TABLE 3

MATURITY DETERMINATIONS

COMPANY..MOBIL NORWAY... LOCATION...NORTH SEA..... WELL..33/9-3.....

Sample No. or Sample Depth in feet	Type of Sample	Remarks	Maximum Palaeo. Temp. °F	V.R. %	S.C. Index
5500-20	Ctgs		-	-	2.5 - 3
5600-20	"		-	-	2.5 - 3
5800-20	"		-	0.43	3
5900-20	"		253	-	3
6000-20	"		-	0.34; 0.64	3
6100-20	"		268	-	3
6200-40	"		-	0.75	3
6300-40	"		251	-	3-3.5
6500-50	"		-	0.28; 0.38	3.5
6600-40	"		-	0.36	3.5
6700-40	"		242	-	-
6800-20	"		-	0.36	3.5
6900-40	"		239	-	4
7000-20	"		-	no determination	4
7100-20	"		255	-	4
7200-10	"		-	no determination	4
7300-20	"		242	-	4
7400-10	"		-	0.41; 0.76; 1.02	4-4.5
7500-10	"		-	-	4-4.5
7600-10	"		-	0.48	4.5
7700-10	"		261	0.41	4.5
7800-10	"		266	0.34; 0.46	4.5
7900-10	"		255	0.40; 0.77; 1.22	3-4-5
8000-10	)		-	0.49	5-6
8100-10	)		265	0.46	5-6
8200-10	) Ctgs		-	0.33	-
8300-10	) and		264	0.46; 0.60	-
8400-10	) Core		-	0.33	5-6
8500-10	)		265	0.38;0.57	5-5.5

TABLE 3 (Cont'd)

MATURITY DETERMINATIONS

COMPANY. MOBIL NORWAY... LOCATION. NORTH SEA..... WELL...33/9-3.....

Sample No. or Sample Depth in feet	Type of Sample	Remarks	Maximum Palaeo. Temp. °F	V.R. %	S.C. Index
8610-10	Ctgs		-	0.37	5.6-6
8700-10	"		261	no determination	5.5-6
8800-10	"		-	0.31; 0.62	6-6.5
8900-10	"		257	0.48; 0.66	6-6.5
9000-10	"		-	0.45 0.30; 0.57	6-6.5
9100-10	"		269	0.61	6-6.5
9200-10	"		-	0.30; 0.53	6-6.5
9300-10	"		252	no determination	6-6.5
9400-10	"		-	0.39; 0.53; 1.12	5-6.5
9500-10	"		258	no determination	5-6.5
9600-10	"		-	0.32	5-6.5
9700-10	"		256	no determination	-
9800-10	"		-	0.37	5-6.5

FIGURE I

GASEOUS ($C_1 - C_4$) HYDROCARBONS

COMPANY : MOBIL NORWAY WELL : 33/9-3 LOCATION : NORTH SEA

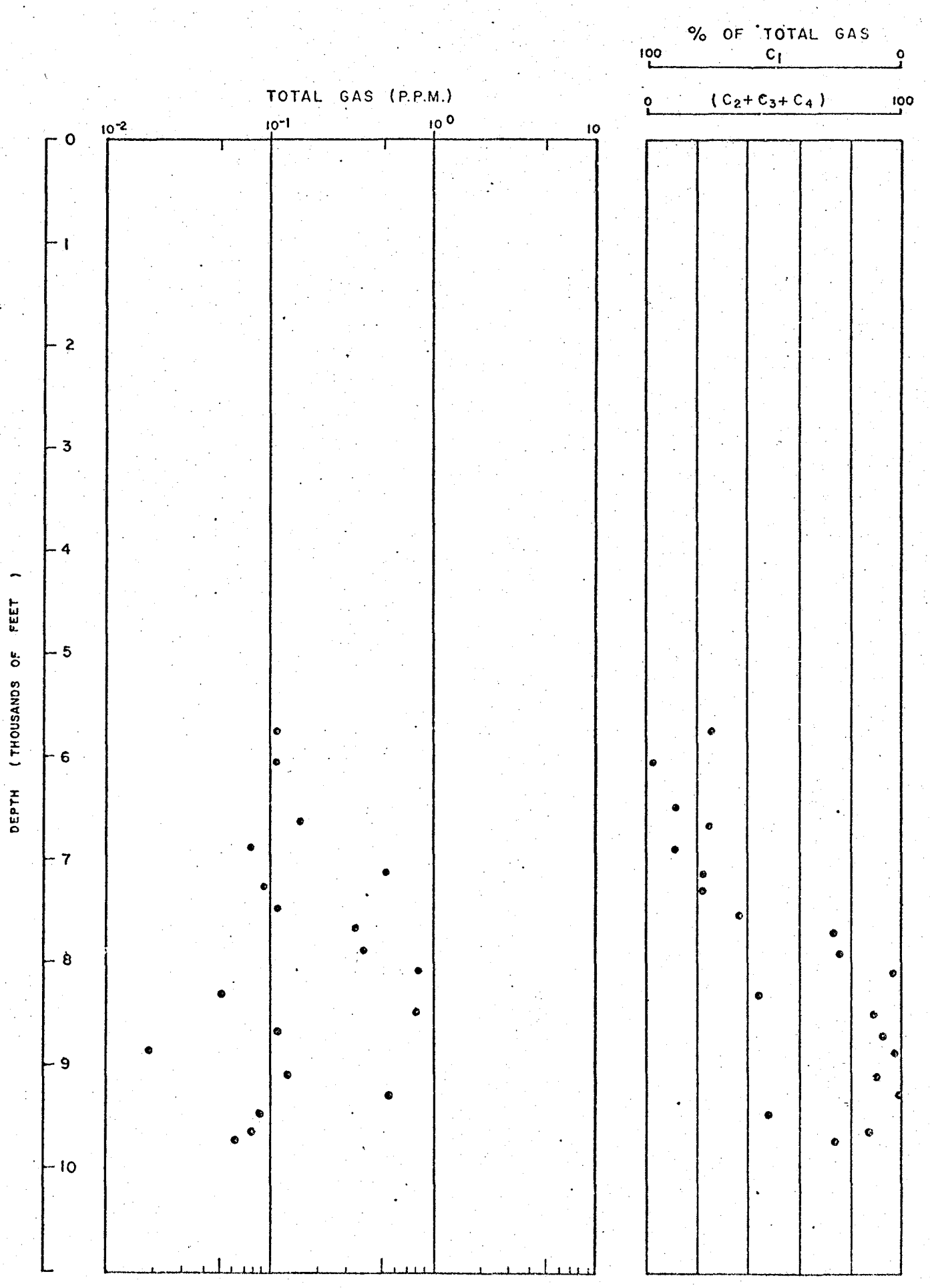
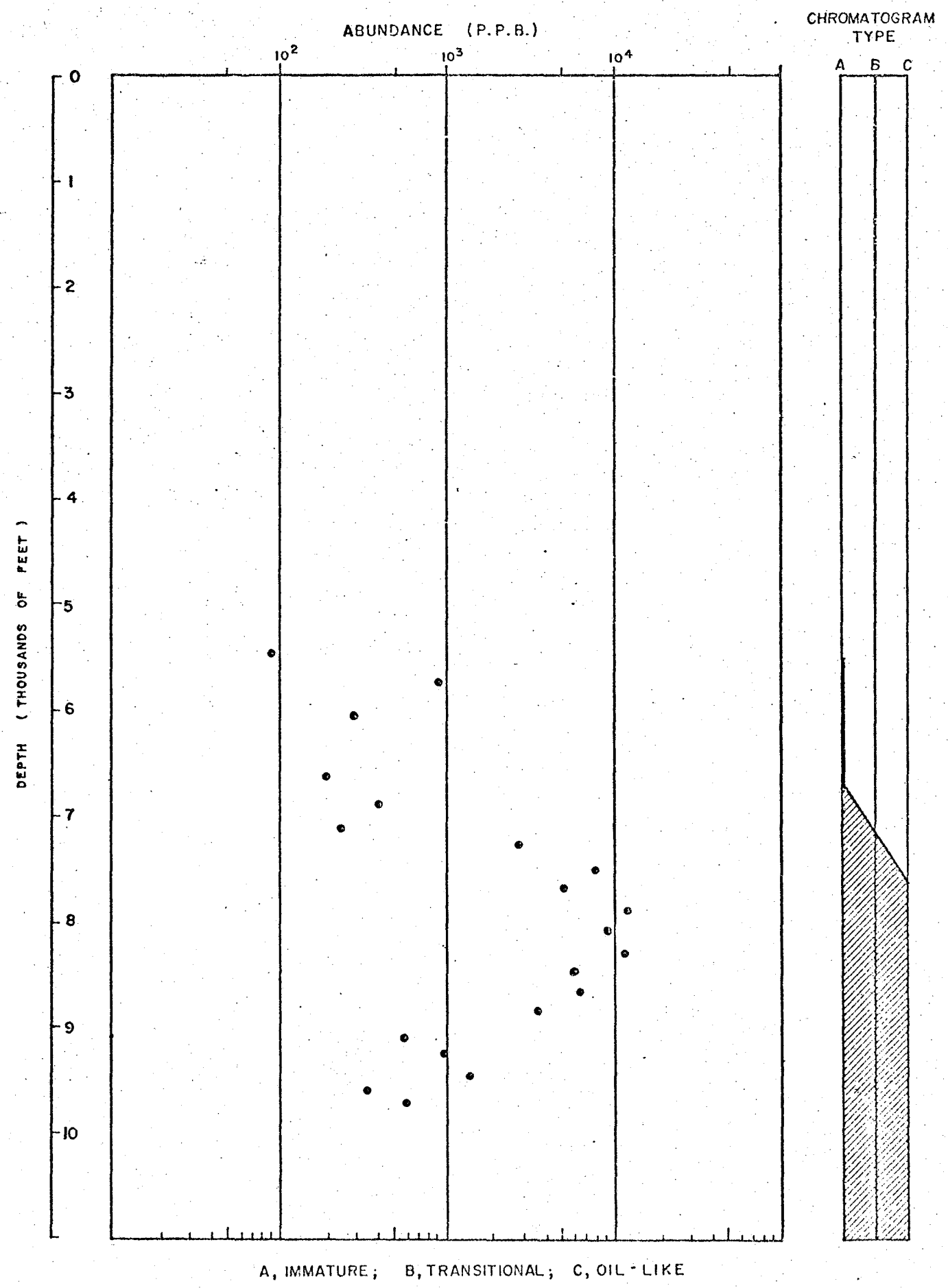


FIGURE 2

GASOLINE RANGE ($C_5 - C_7$) HYDROCARBONS

COMPANY : MOBIL NORWAY WELL : 33/9-3 LOCATION : NORTH SEA



A, IMMATURE; B, TRANSITIONAL; C, OIL-LIKE

FIGURE 3

VITRINITE REFLECTIVITY AGAINST DEPTH

COMPANY : MOBIL NORWAY WELL : 33/9-3 LOCATION : NORTH SEA

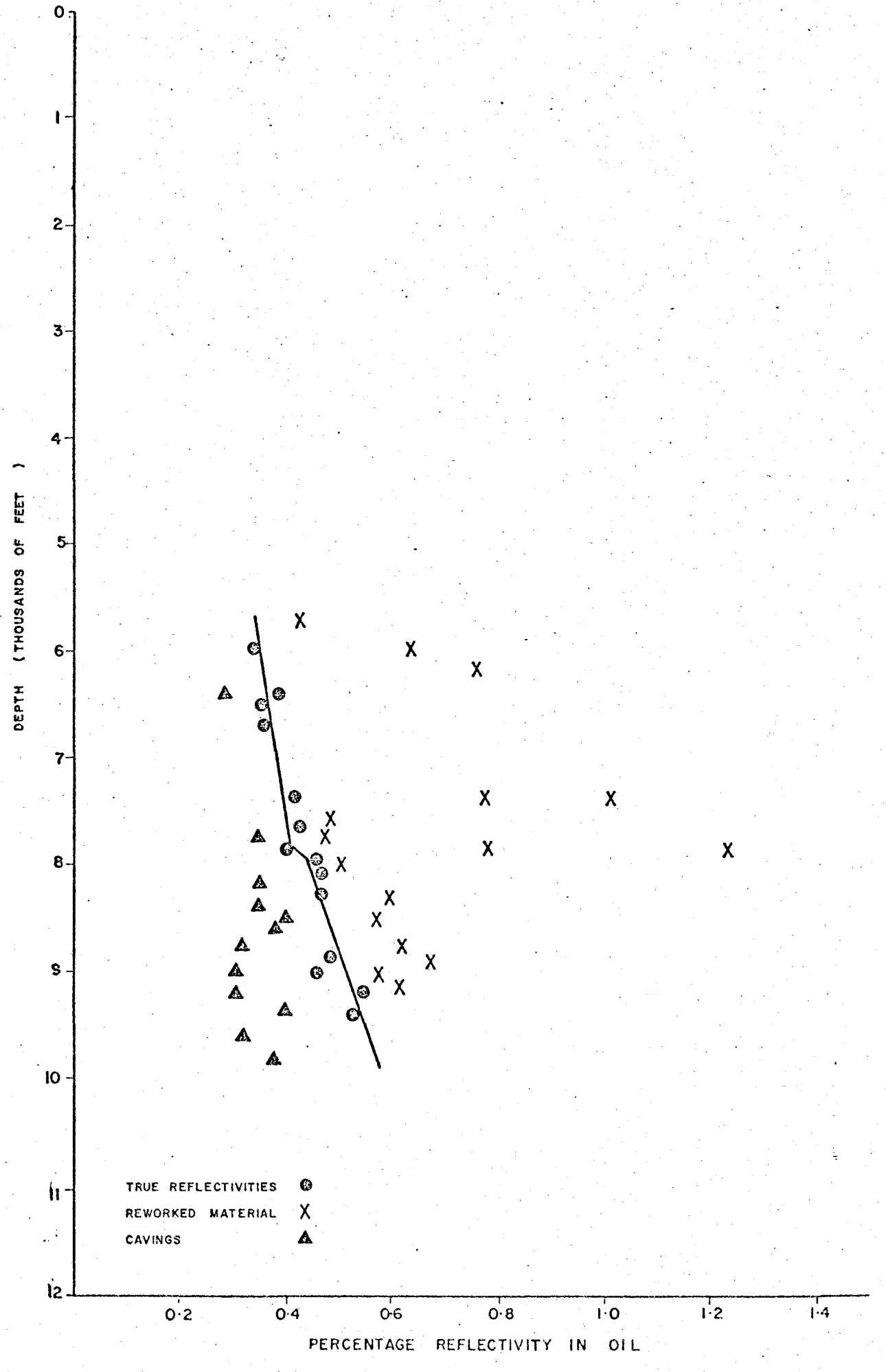


FIGURE 4

MAXIMUM PALAEOTEMPERATURE AGAINST PRESENT DEPTH OF BURIAL

COMPANY : MOBIL NORWAY WELL : 33/9-3 LOCATION : NORTH SEA

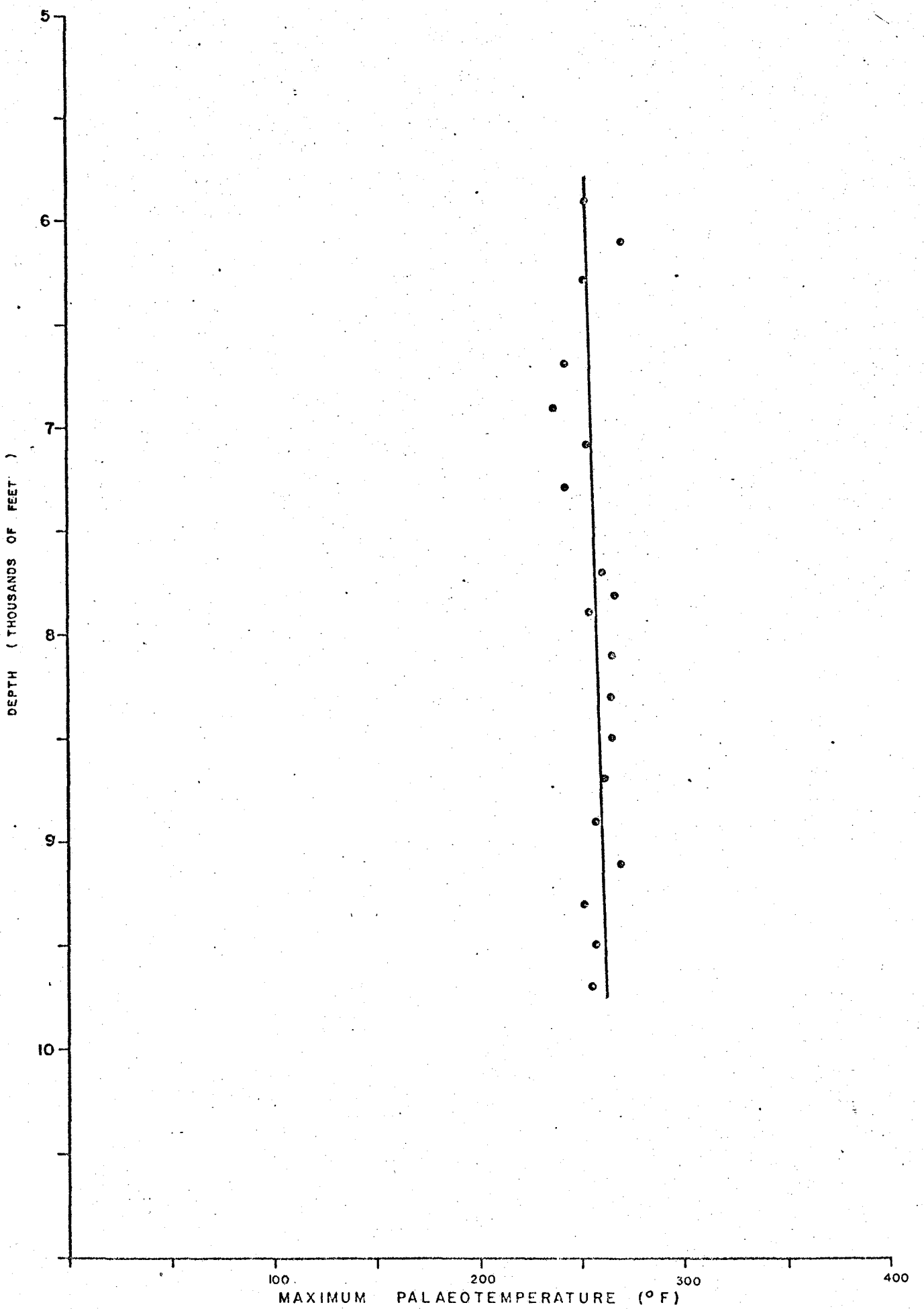


FIGURE 3

COMPARISON OF MATURATION INDICES

COMPANY: MOBIL NORWAY WELL : 33/9-3 LOCATION : NORTH SEA

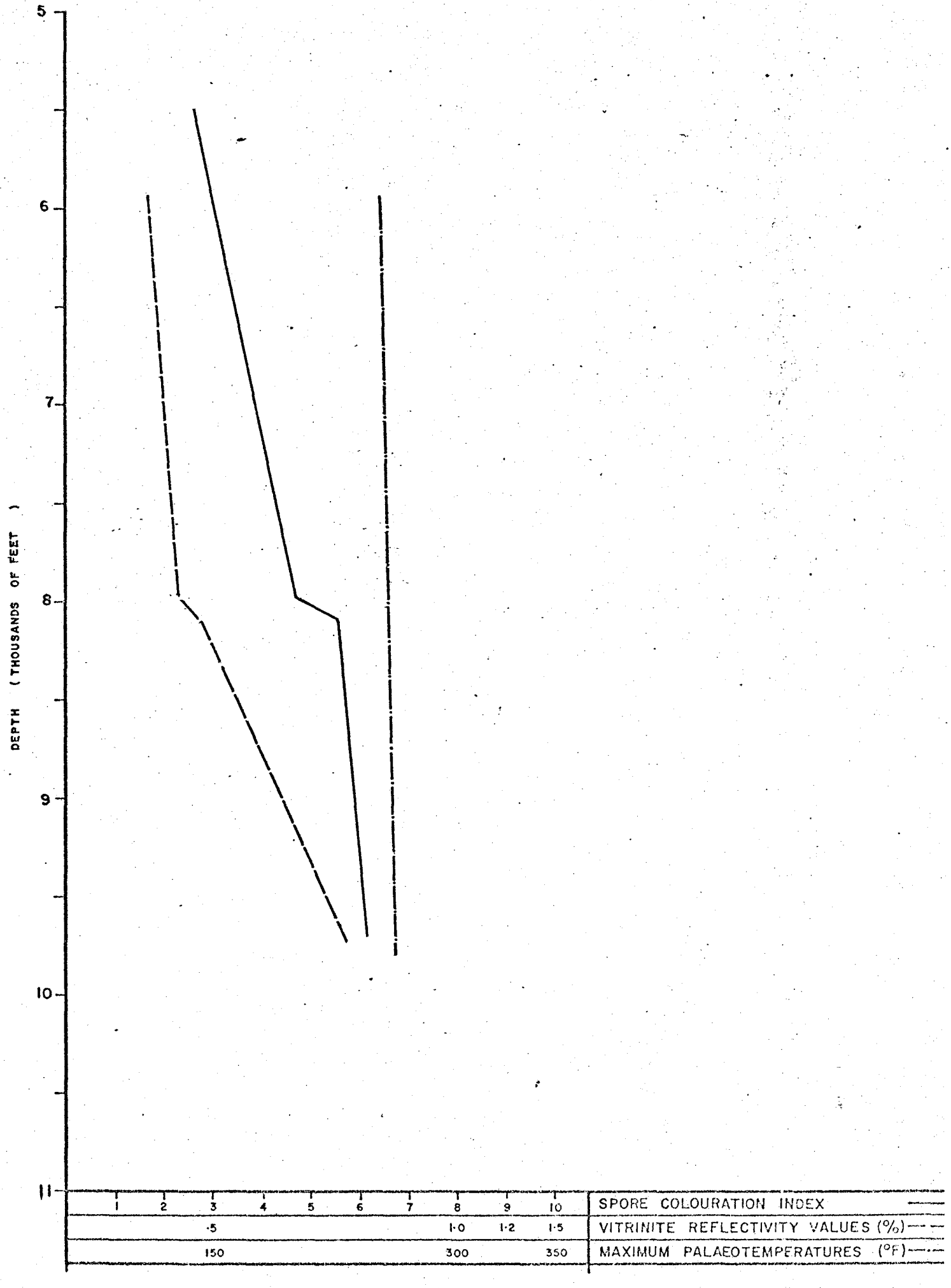


FIGURE 6

TYPE OF HYDROCARBON PRODUCT FROM SOURCE ROCKS

COMPANY : MOBIL NORWAY WELL : 33/9-3 LOCATION : NORTH SEA

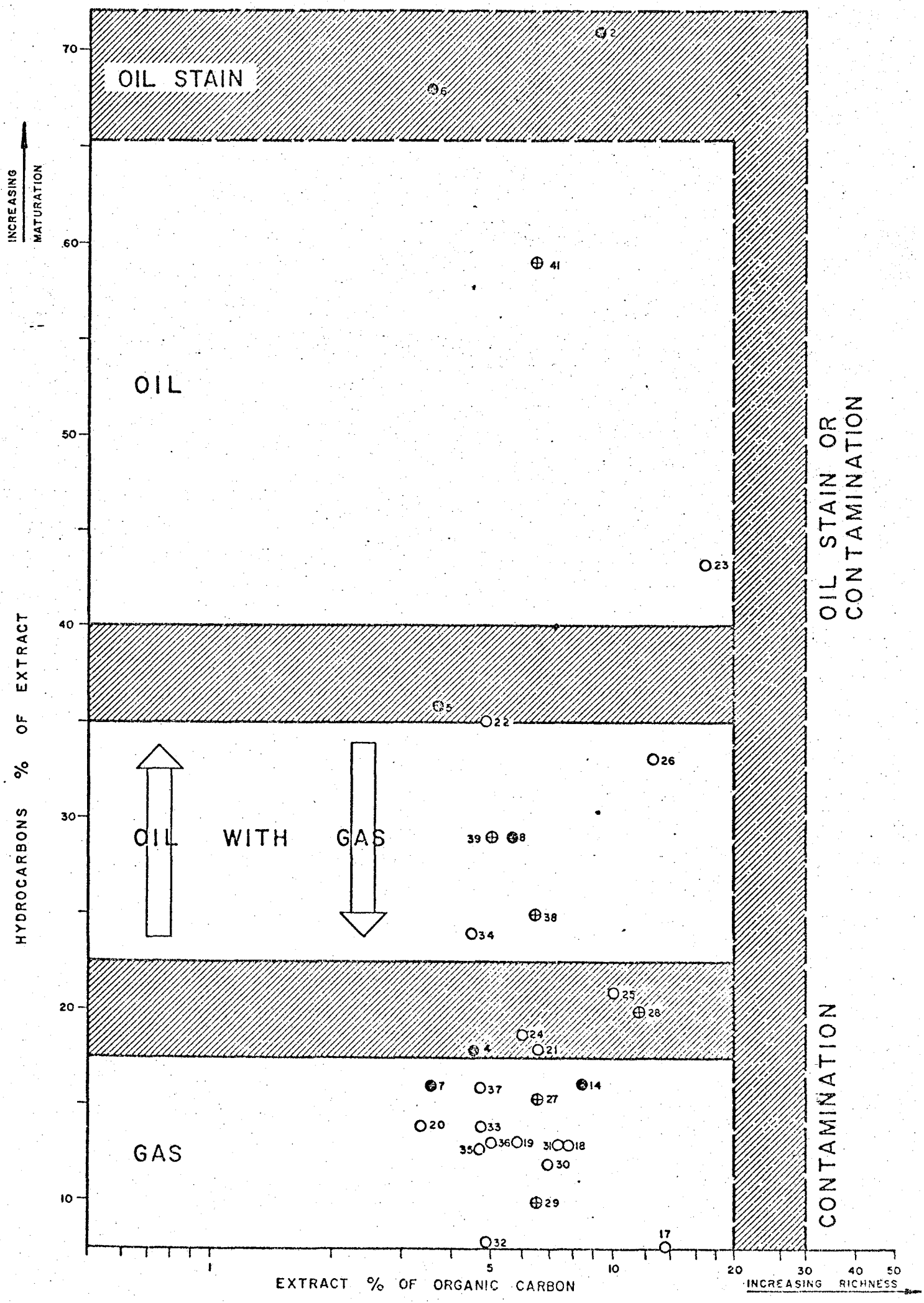
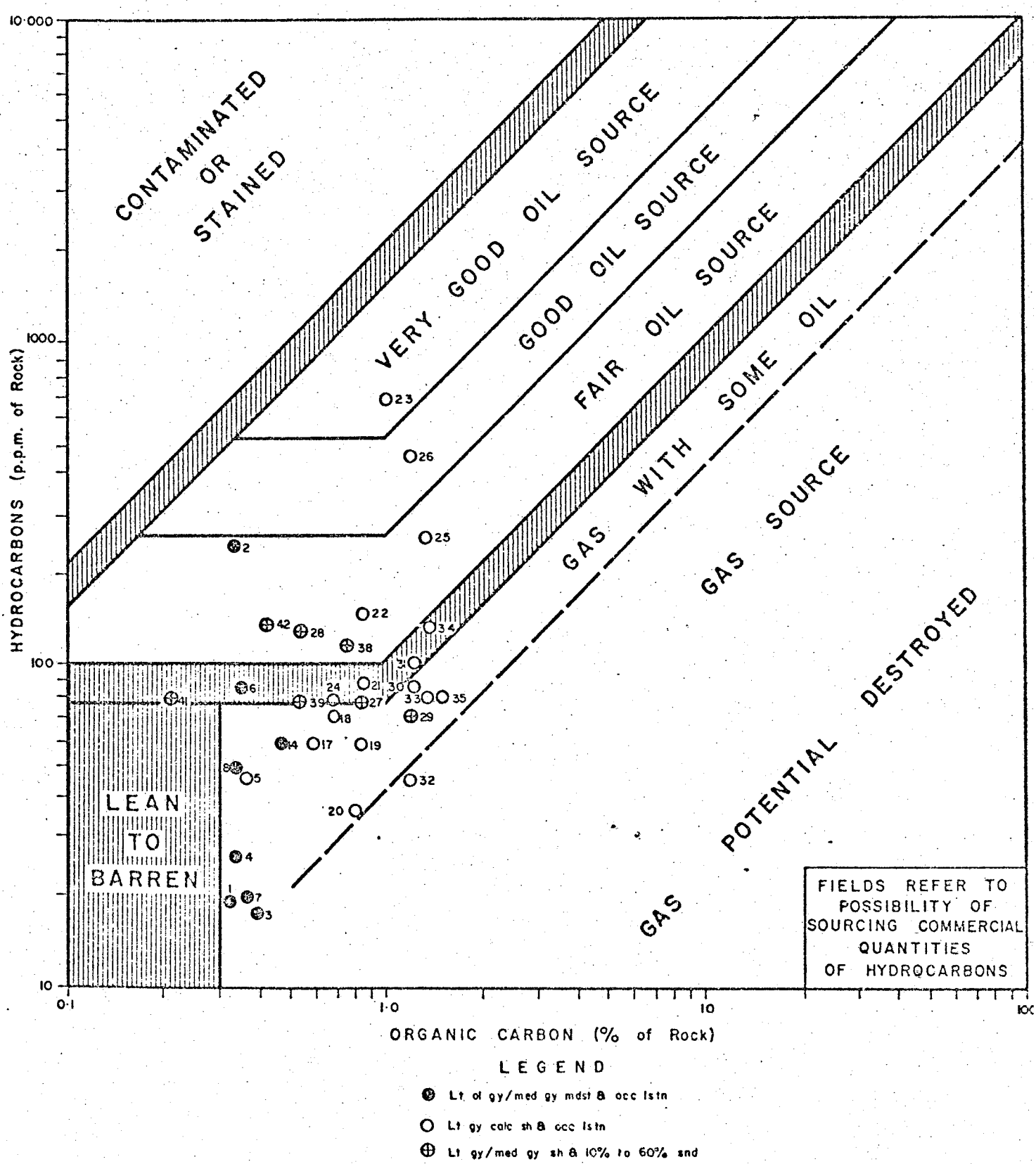


FIGURE 7

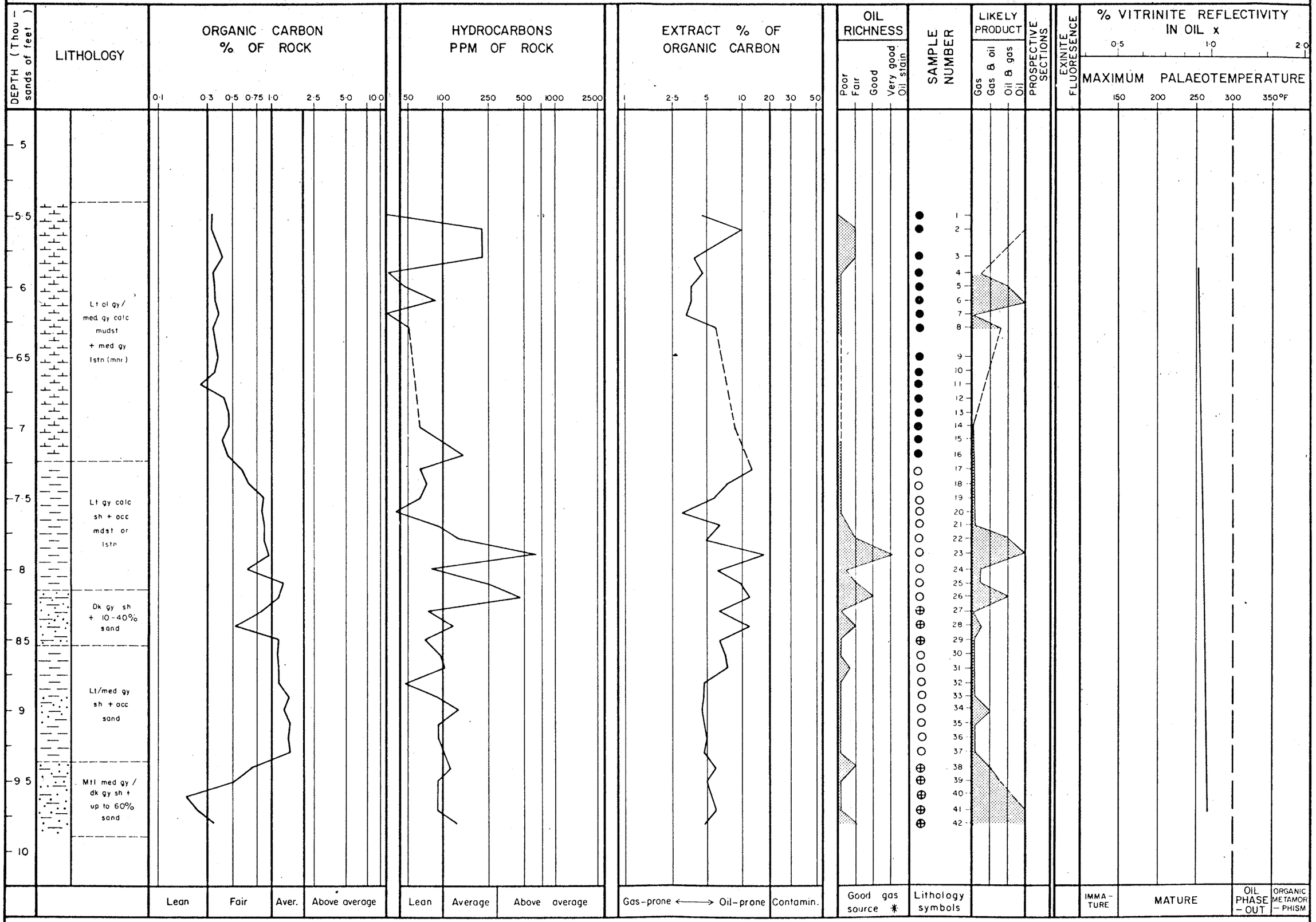
MATURE SOURCE ROCK RICHNESS

COMPANY : MOBIL NORWAY WELL : 33/9–3 LOCATION : NORTH SEA



SOURCE ROCK SUMMARY CHART

COMPANY : MOBIL NORWAY WELL : 33/9-3 LOCATION : NORTH SEA



Drawing No. 840 / 2026 / 2928

FIGURE 8