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WELLFILE

REPORT ON AN OIL TO SOURCE ROCK CORRELATION BETWEEN OILS FROM JURASSIC AND PALAEOCENE RESERVOIRS IN THE MAUREEN FIELD AND LOWER CRETACEOUS TO UPPER JURASSIC SHALES FROM THE 15/12-2 WELL, NORWEGIAN NORTH SEA

by

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INTRODUCTION

Towards the end of March, two samples of oil, from a Jurassic reservoir and a Palaeocene reservoir respectively, of the Maureen Field, UK North Sea, and wet samples of ditch cuttings taken at 3 metre intervals from 2648 to 2804 and 2816 to 2852 metres depth from the 15/12-2 well Norwegian North Sea, were received for this study.

Selected composite ditch cuttings samples were analysed for their gas and gasoline content and by solvent extraction and column chromatography for their C_{15+} hydrocarbon content. The saturate fractions isolated from the extracts were also analysed by gas chromatography to show concentrations of components in the $\underline{n}$-C_{15} to $\underline{n}$-C_{32} range. At the same time subsamples were submitted for kerogen isolation and determination of spore colour indices.

The oils were analysed by gas chromatography for their gas and gasoline contents, and for their gasoline and heavier components. They were also fractionated by column chromatography into saturates, aromatics and asphaltenes with resenes fractions.

All samples received were of good quality for analysis.

II

RESULTS AND INTERPRETATION

A. LITHOLOGIES

The sequence of samples is believed to range from Lower Cretaceous to Upper/Middle (?) Jurassic in age, although Chalk and Tertiary shale cavings were also detected. The upper part of the section from 2648 to to 2699 metres consists of pale grey calcarous shales, and red and grey marls. From 2708 to 2804 metres grey black bituminous, sometimes silty shale is dominant; white quartzitic sandstone appears in the section from 2816 metres and the associated black shales are probably caved.

B. MATURATION STATE OF SOURCE ROCKS

1. Spore Colouration (Table 1)

Four normal, unoxidised palynological mounts were prepared from the samples from 2648-54, 2708-14, 2768-74 and 2816-2822 metres. The samples at 2648-54 metres yielded a Cretaceous assemblage with spore colour index between 2 and 4 with a mean of 3 to 3.5 indicative of transitionally mature sediments. The dominant kerogen type is inertinite with minor sapropel and vitrinite .

The samples at 2708-14 metres and 2768-74 metres contain abundant sapropelic debris, the higher sample giving kerogen typical of sapropelic shales, whilst the kerogen of the lower sample has the appearance of oil residues. Spore colour indices range from 1.5 to 6, with a mean between 5.5 and 6 at 2708-14 metres, and at 2768-74 metres the range is 2.5 to 8, mean 6 to 6.5.

The sample at 2816-22 metres contains an impoverished organic residue and although in appearance similar to the sample above, many of the palynomorphs appear to be caved and there is not enough in situ material for accurate measurement.

All of the samples contained caved Tertiary palynomorphs with a colour index of 1.5.

The analyses indicate that heavy to medium oils would be generated from sapropelic debris in the interval from 2708 to 2882 metres while the sample from 2648-54 metres is only marginally mature. The rapid change in spore colours with depth is frequently seen in sections of Lower Cretaceous/Upper Jurassic age which have reacted to temperatures of 200° to 250°F and which are overpressured.

2. <u>Cuttings Gas and Gasoline Analysis</u> (Table 2A)

Three shale samples from 2708-14, 2783-89 and 2834-40 metres were analysed for their light hydrocarbon content. They contain high (4 to 121 ppm) gas contents with a predominance of wet gas. Their gasoline contents are also high (4 to 21 ppm) with a predominance of pentanes and hexanes. The analyses indicate that the samples are within the zone of maturation and at a level at which heavy to medium gravity oils are formed from sapropelic debris, although the absence of certain components in the sample from 2708-14 metres indicates that its contained organic matter is only marginally mature.

3. <u>State of Maturation</u>

Each of the parameters used indicates that the zone of maturation is reached at 2700 metres, maturation increasing rapidly with depth so that the total thickness of the zones of oil generation is probably about 300 metres.

C. <u>SOURCE ROCK EVALUATION</u> (Tables 3, Figures 1, 2 and 3)

Fourteen composite ditch cuttings samples were prepared to represent the analysed section of the 15/12-2 well, all of which were analysed for their organic carbon content. Seven of the samples were selected for extraction by solvents to determine their extractable organic matter content and hydrocarbon content. The results are listed in Table 3 and shown in Figures 1, 2 and 3. The samples can be described in terms of their source potential as three groups.

1. Interval 2648 to 2699 metres (Samples 1 and 2)

Lithologically this interval consists of light grey sandstone with minor chalk and grey shale or chalk with minor light grey shale and red shale. The organic carbon content is below average at 0.33% to 0.95% for the gross samples, while picked shale lithologies are more variable. The light grey shales in all the samples were hand selected and were found to be richer in the samples at 2648-654 and 2663-669 with 1.37% and 2.02% carbon respectively while at 2678-684% and 2693-699 metres the shales were lower than average at 0.44% and 0.95% respectively.

Two samples at 2648-654 and 2693-699 metres were solvent extracted and yielded low extractable contents of 135 and 410 ppm, 4.2% and 4.9% of the total organic matter. Hydrocarbon abundance in both samples was low at less than 20 ppm.

These gross samples are organically lower than average and have no hydrocarbon source potential. The light grey Lower Cretaceous (?) shales have variable but generally about average carbon content and may have some minor source potential.

2. Interval 2708 to 2804 metres (Samples 3 to 5)

This interval is dominated by grey black silty carbonaceous shale of presumed Upper Jurassic age. The organic carbon content is well above average at 6.0% to 10.6%. Light grey, presumed caved shale in the sample at 2768-774 metres has below average organic carbon content of 0.74% and the grey red shale in the same sample is very lean with 0.07% organic carbon.

The amount of solvent extractable organic matter is high at 7850 to 11685 ppm representing 9.8% to 11.1% of the organic carbon content. Hydrocarbon abundance is rather more variable and ranges from 1890 to 4410 ppm representing 23% to 38% of the total extractable matter.

Samples 4 and 5 (figure 1) are rated as oil with minor associated gas sources but sample 3 is more gas-prone and will source only limited quantities of liquid hydrocarbons. The richness of the samples as liquid hydrocarbon sources is shown in Figure 2 and samples 3 and 5 are rated as good and sample 4, fair.

It seems reasonable to assume that the interval 2753 to 2804 metres metres has a good oil source potential while the interval 2708 to about 2730 metres is more gas-prone.

3. Interval 2816 to 2852 metres (Samples 6 and 7)

This interval is predominantly white sandstone with minor caved grey-black shale which has affected the generally low sandstone organic carbon contents so that the range of values is from 0.52% to 2.16%. Amounts of extractable organic matter (495 to 1710 ppm) and of hydrocarbons (80 to 415 ppm) probably reflect the level of contamination by the grey black shale in the sandstone.

D. GAS CHROMATOGRAPHIC ANALYSIS (Figure 4)

Gas chromatographic analysis of the alkanes was carried out on a 110 metre capillary column, OV-101 coated, with oven temperature programmed from 80°C to isothermal 270°C.

The gas chromatographic traces show the homologous *n*-alkanes with carbon numbers between *n*-C_{15} and *n*-C_{32} and the isoprenoid alkanes, pristane and phytane, adjacent to the *n*-C_{17} and *n*-C_{18} alkanes as the predominant component peaks. Other minor components are branched and cyclic alkanes, those in the *n*-C_{25} to *n*-C_{32} range being the polycyclic steranes and triterpanes.

Overall the following points are noted

(i) Phytane is present in significantly large quantities which, with a predominance (CPI;0.85) of even numbered alkanes in the *n*-C_{18} to *n*-C_{26} range, indicates accumulation of sapropelic debris in a reducing environment.

(ii) There is only a slight tendency for predominance of odd numbered alkanes in the *n*-C_{27} to *n*-C_{31} range, (CPI;1.2) indicating a very small contribution from land plant material.

(iii) A simple pattern of polycyclic alkanes is seen in the *n*-C_{25} to *n*-C_{32} range, indicating a mostly sapropelic kerogen in the early stages of maturation.

(iv) Significant molecular ratios are:

Depth metres	Pristane/n-C_{17}	Phytane/n-C_{18}
2723-29	1.27	1.17
2753-59	1.25	1.07
2798-804	1.35	1.47

E. ANALYSES OF OILS

Each of the oils was fractionated by column chromatography over silica gel into saturates, aromatics and asphaltenes with resenes; with the following results.

	Saturate (%)	Aromatics (%)	Asphaltenes + Resenes (%)
Jurassic reservoir oil	54	24	22
Palaeocene reservoir oil	53	36	11

The Palaeocene oil has a lower asphaltenic content and higher aromatic content and indicates a more mature source than the Jurassic oil.

Gas chromatographic analysis of samples of unfractionated oils (on 110 metre capillary columns coated with OV-101) gave gas-chromatographic traces shown in Figure 5. The analyses are in general, similar, with a dominance of lighter components below n-C_{15}, the Palaeocene oil containing more of this light fraction than the Jurassic oil. The distributions of the n-alkanes show some irregularity, particularly at n-C_{23}, n-C_{20}, n-C_{17} and n-C_{15} but no particular pattern of odd or even numbered dominance can be seen. Phytane and pristane are present in significant amounts. In general the Palaeocene oil is lighter and different in detail from the Jurassic oil.

A more detailed analysis of the gasoline components shows the presence of all the major components, although the benzene content is fairly low. The analyses are consistent with an origin from source rocks which are in the middle to later stages of maturity. These source rocks would be distinctive in containing sapropelic organic matter accumulated in a reducing environment.

Pertinent molecular ratios are as follows:

	Pristane/n-C_{17}	Phytane/n-C_{18}	Isopentane/n-pentane
Jurassic Oil	0.67	0.55	0.76
Palaeocene Oil	0.94	0.40	0.42
15/12-2 shales	1.2-1.35	1.07-1.47	0.86-1.05

III

CONCLUSIONS

As a result of the present study of oils from the Maureen field and of source rocks from the 15/12-2 Well, the following main conclusions may be drawn:

(i) The oils are distinctly different from the analysed source rocks.

(ii) The analysed source rocks contain sapropelic organic matter accumulated with sediments in a reducing environment and they are likely to yield a heavy oil which has a high wet gas but low gasoline content.

(iii) The oils are medium to light oils in Maureen in which the abundance of components decreases relative to their molecular size. They are similar enough to have been generated from a common source rock at differing levels of maturity, the 'Palaeocene' oil being from the more advanced level of maturity.

(iv) The source rocks analysed could, at higher levels of maturity, have sourced the oils.

(v) There are unlikely to be other source rocks in the section which could have generated the oils. Off structure it is probable that any Palaeocene source rocks do not reach sufficient depth to produce oils of this type and it seems probable that the Lower Cretaceous source rocks contain humic types of kerogen which are likely to be gas-prone. The possibility of Palaeozoic source rocks, particularly Devonian Orcadian facies, could be considered, but lack of evidence precludes conclusive opinion.

TABLE 1

MATURATION DATA

COMPANY: STATOIL WELL: 15/12-2 LOCATION: NORWEGIAN N. SEA

SAMPLE DEPTH, METRES	SPORE COLOUR RANGE	SPORE COLOUR AVERAGE	KEROGEN TYPE
2648-54	2-4	3-3.5	Inertinite, sapropel, vitrinite
2708-14	1.5-6	5.5-6	Sapropel
2768-74	2.5-8	6-6.5	Sapropel, oleogenous
Caved 2816-22	2.5-8	6-6.5	Sapropel

Cavings			
Tertiary		1.5	
Cretaceous		4.5	

TABLE 2A

GASEOUS AND GASOLINE HYDROCARBON DATA

CLIENT STATOIL WELL 15/12-2 LOCATION NORWEGIAN N. SEA

GAS ($C_1 - C_4$)

SAMPLE NO.								
DEPTH (METRES)	2708 - 14		2783 - 89		2834 - 40			
	P. P. B.	%C_1 - C_4	P. P. B.	%C_1 - C_4	P. P. B.	%C_1 - C_4	P.P.B.	%C_1 - C_4
C_1	919	0.89	633	2.0	1669	40.4		
C_2	3720	3.2	34	0.1	33	0.8		
C_3	48803	40.3	3377	10.8	622	15.1		
iC_4	9813	8.2	9600	31.7	267	6.5		
nC_4	58573	48.3	17613	56.3	1536	37.2		
TOTAL	121828	100	31257	100	4127	100		

GASOLINE RANGE ($C_5 - C_7$)

SAMPLE NO.								
DEPTH(METRES)	2708 - 14		2783 - 89		2834 - 40			
	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	11089	51.3	4960	35.2	839	21.3		
N-PENTANE	7858	36.5	4681	33.3	975	24.7		
CYCLOPENTANE	1289	6.0	634	4.5	196	5.0		
2-ME. PENTANE	586	2.7	1072	7.6	345	8.7		
3-ME. PENTANE	227	1.1	447	3.2	168	4.3		
N-HEXANE	108	0.5	370	2.6	222	5.6		
ME. CYCLOPENTANE	313	1.5	659	4.7	426	10.8		
CYCLOHEXANE	26	0.1	166	1.2	141	3.6		
2-ME. HEXANE	*	*	80	0.6	50	1.3		
3-ME. HEXANE	*	*	169	1.2	104	2.6		
3-ETHYLPENTANE	14	0.1	116	0.8	80	2.0		
N-HEPTANE	*	*	173	1.2	97	2.5		
BENZENE	44	0.2	40	0.3	29	0.7		
DIME. PENTANE	*	*	*	*	*	*		
ME. CYCLOHEXANE	*	*	510	37	276	70		
TOTAL	21554	100	14077	100	3948	100		

TABLE 2B

GASEOUS AND GASOLINE HYDROCARBON DATA

CLIENT STATOIL WELL MAUREEN OILS LOCATION U.K. N. SEA

GAS ($C_1 - C_4$)

SAMPLE NO.								
DEPTH								
	P. P. B.	$\%C_1 - C_4$	P. P. B.	$\%C_1 - C_4$	P. P. B.	$\%C_1 - C_4$	P. P. B.	$\%C_1 - C_4$
C_1								
C_2								
C_3								
iC_4								
nC_4								
TOTAL								

GASOLINE RANGE ($C_5 - C_7$)

SAMPLE NO.	JURASSIC		PALAEOCENE					
DEPTH	RES. OIL		RES. OIL					
	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	4476	11.6	767	2.8				
N-PENTANE	5886	15.2	1811	6.7				
CYCLOPENTANE	679	1.8	456	1.7				
2-ME. PENTANE	4080	10.6	1957	7.2				
3-ME. PENTANE	1657	4.3	917	3.4				
N-HEXANE	4622	12.0	3209	11.9				
ME. CYCLOPENTANE	2425	6.3	2102	7.8				
CYCLOHEXANE	3394	8.8	2709	10.0				
2-ME. HEXANE	1057	2.7	1057	3.9				
3-ME. HEXANE	1557	4.0	1885	7.0				
3-ETHYLPENTANE	492	1.3	1280	4.7				
N-HEPTANE	2583	6.7	3773	13.9				
BENZENE	2220	5.8	470	1.7				
DIME. PENTANE	Tr	*	Tr	*				
ME. CYCLOHEXANE	3501	9.1	4650	17.2				
TOTAL	38629	100	27043	99.9				

TABLE 3

SOURCE ROCK EVALUATION DATA

COMPANY : STATOIL WELL: 15/12-2 LOCATION : NORWEGIAN N. SEA

SAMPLE DEPTH (METRES OR NOTATION	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M.	EXTRACT % OF ORGANIC CARBON	HYDRO-CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	TOTAL ALKANES % HYDRO-CARBONS
1. 2648-654	Ctgs	Lt gy glauc calc sst +10% chk+10% med-lt sh	0.32	135	4.2	<20	*	*
2663-669	"	Lt gn-gy sst+10% gy-red marl/sh+10% med-lt gy sh	0.95					
2678-684	"	Chk+30% med-lt gy calc sh+mnr red-gy sh	0.39					
2. 2693-699	"	Ditto+60% ditto+mnr ditto	0.84	410	4.9	20	5	68
2708-714	"	Gy-blk slty carbarg-illite+mnr (caved?) lt gy sh+chk	9.3					
3. 2723-729	"	Ditto+mnr ditto	8.4	8050	9.6	1890	23	61
2738-744	"	Ditto	10.0					
4. 2753-759	"	Ditto	10.6	11685	11.0	4410	38	72
2768-774	"	Ditto+mnr med-lt gy sh+mnr chk+mnr red-gy sh (Caved??)	6.0					
2783-789	"	Ditto	7.7					
5. 2798-804	"	Ditto+mnr caved sh	7.1	7850	11.1	2790	36	49
6. 2816-822	"	Wht qtz snd+50% gy-blk sh	2.16	1710	7.9	415	24	69
7. 2834-840	"	Ditto+mnr gy-blk sh (caved?)	0.53	495	9.3	80	16	62
2846-852	"	Ditto/sst+20% gy-blk sh (caved??)	0.52					
		Picked Lithologies						
2648-654		Med-lt gy sh	1.37					
2663-669		Ditto	2.02					
2678-684		Ditto	0.44					
2693-699		Various lt gy sh	0.95					
2768-774		Ditto	0.74					
2768-774		Gy-red sh	0.07					

FIGURE 1

TYPE OF HYDROCARBON PRODUCT FROM SOURCE ROCKS

COMPANY : STATOIL WELL : 15/12-2 LOCATION : NORWEGIAN N. SEA

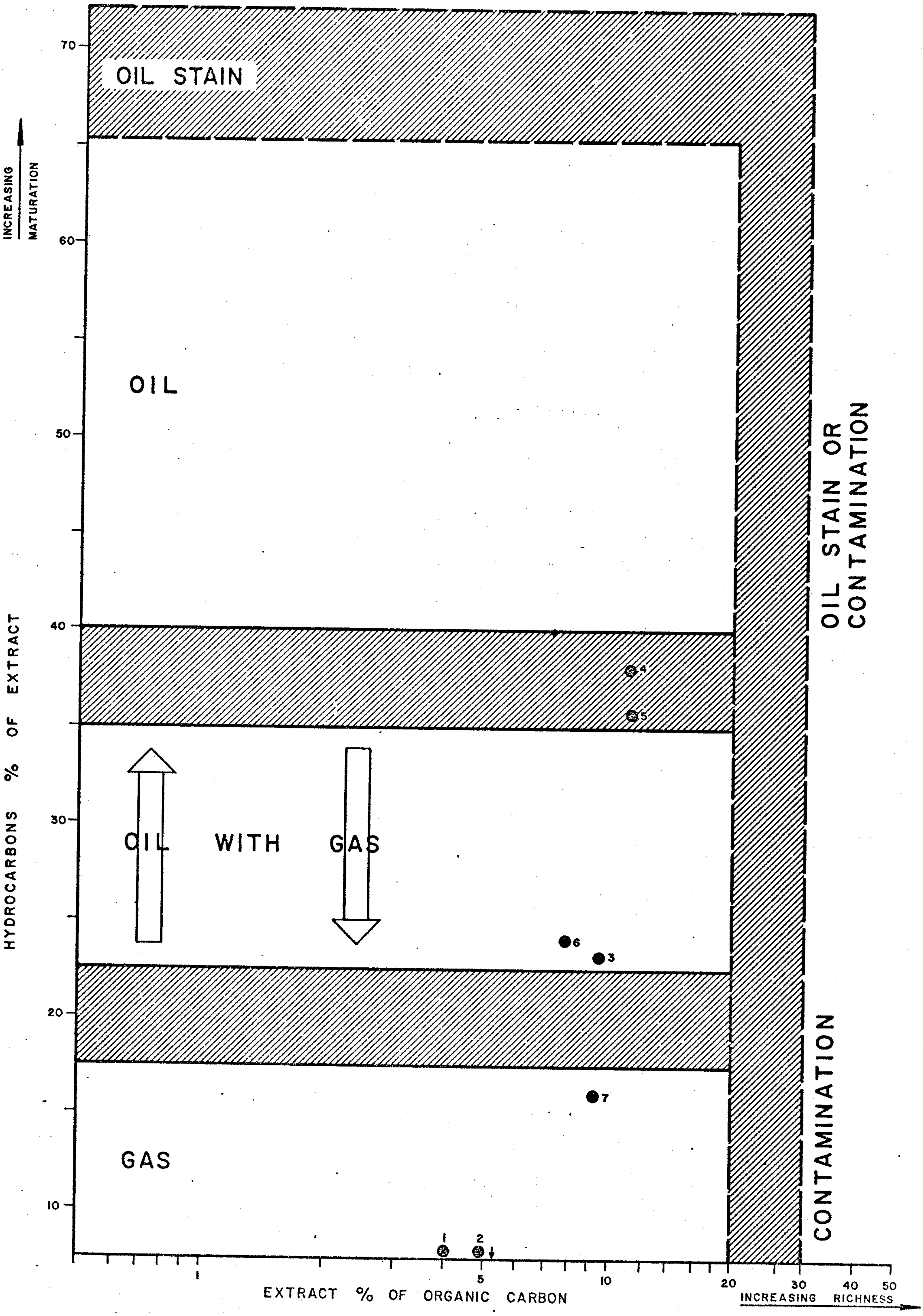
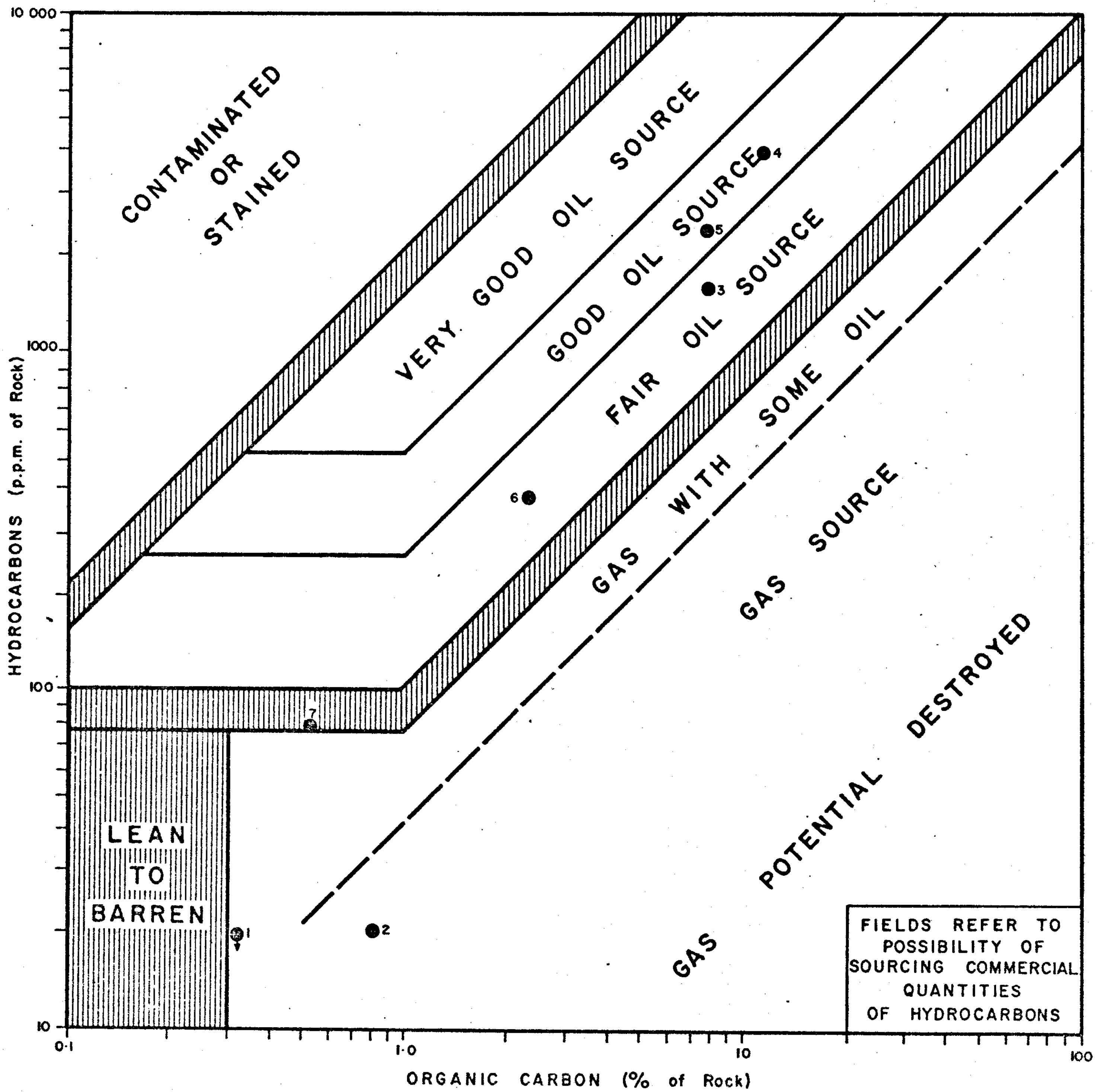


FIGURE 2

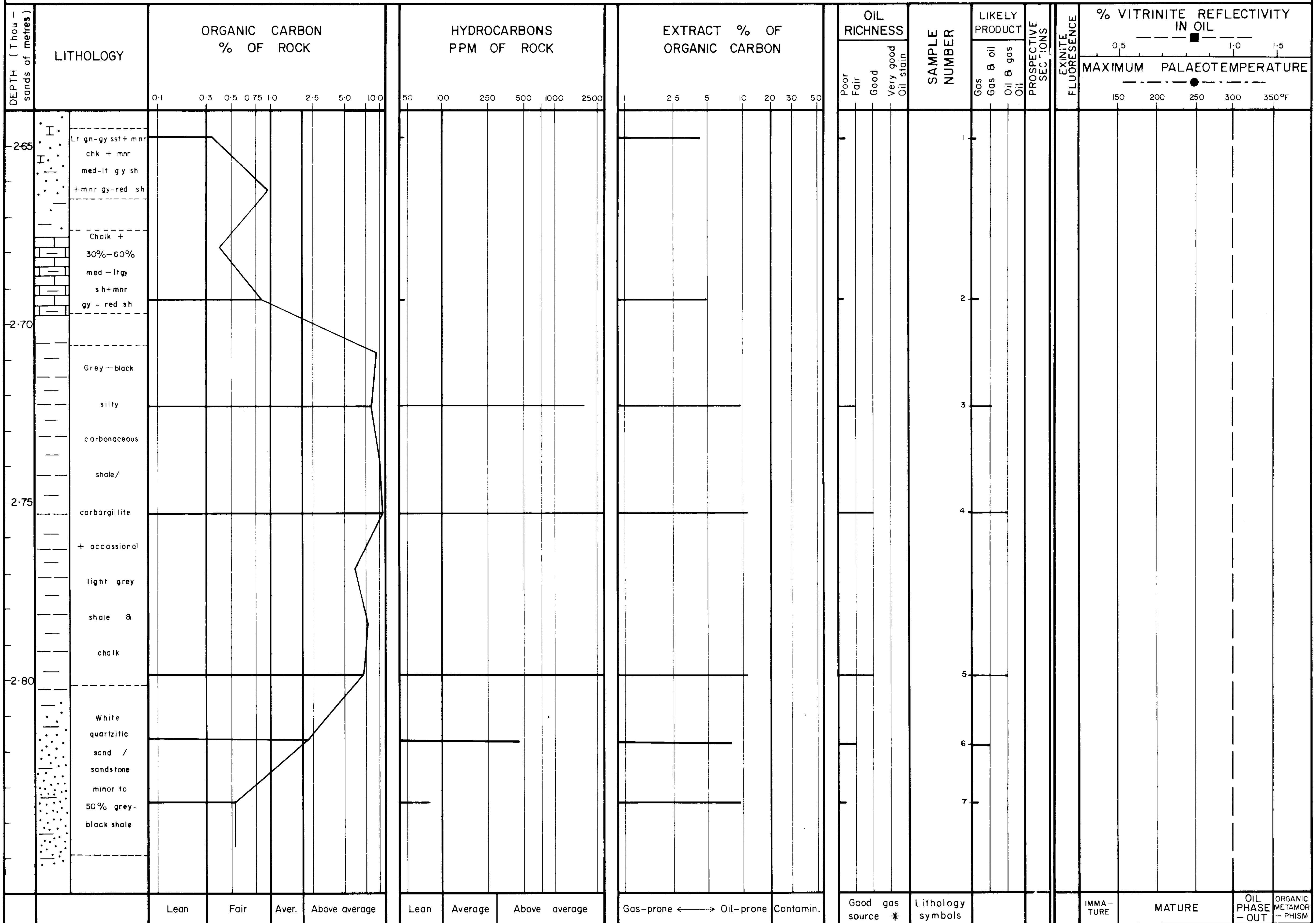
MATURE SOURCE ROCK RICHNESS

COMPANY : STATOIL WELL : 15/12-2 LOCATION : NORWEGIAN N. SEA



SOURCE ROCK SUMMARY CHART

COMPANY : STATOIL WELL : 15/12-2 LOCATION : NORWEGIAN NORTH SEA



Drawing No. 076P/2305/3409

EXINITE FLUORESCENCE: Abundant exinite content B, Moderate exinite content b} Orange-brown; O, o} Orange; Y, y} Yellow; G, g} Yellow-green; No observed fluorescence X

FIGURE 3

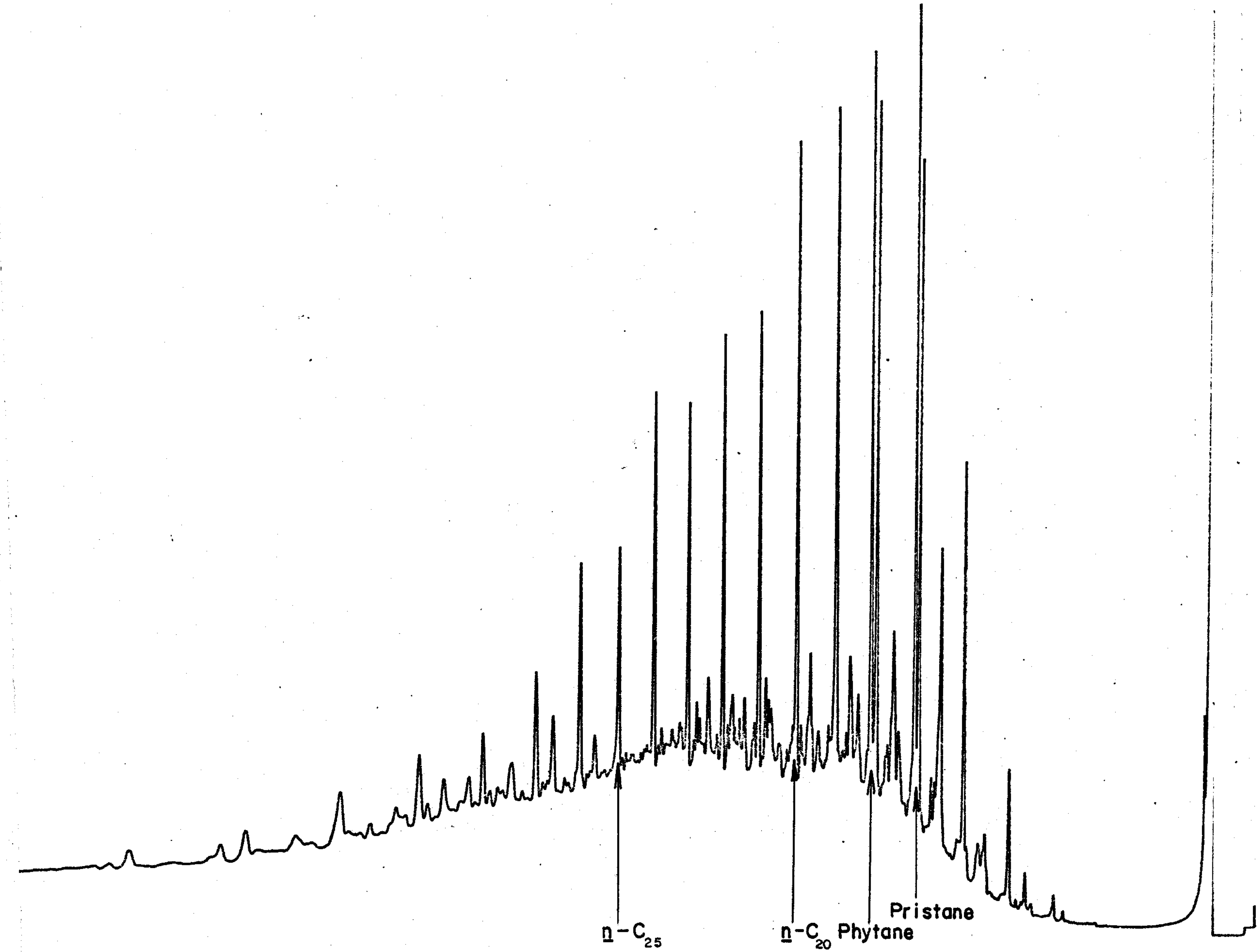
FIGURE 4

GAS CHROMATOGRAMS OF SOURCE ROCKS

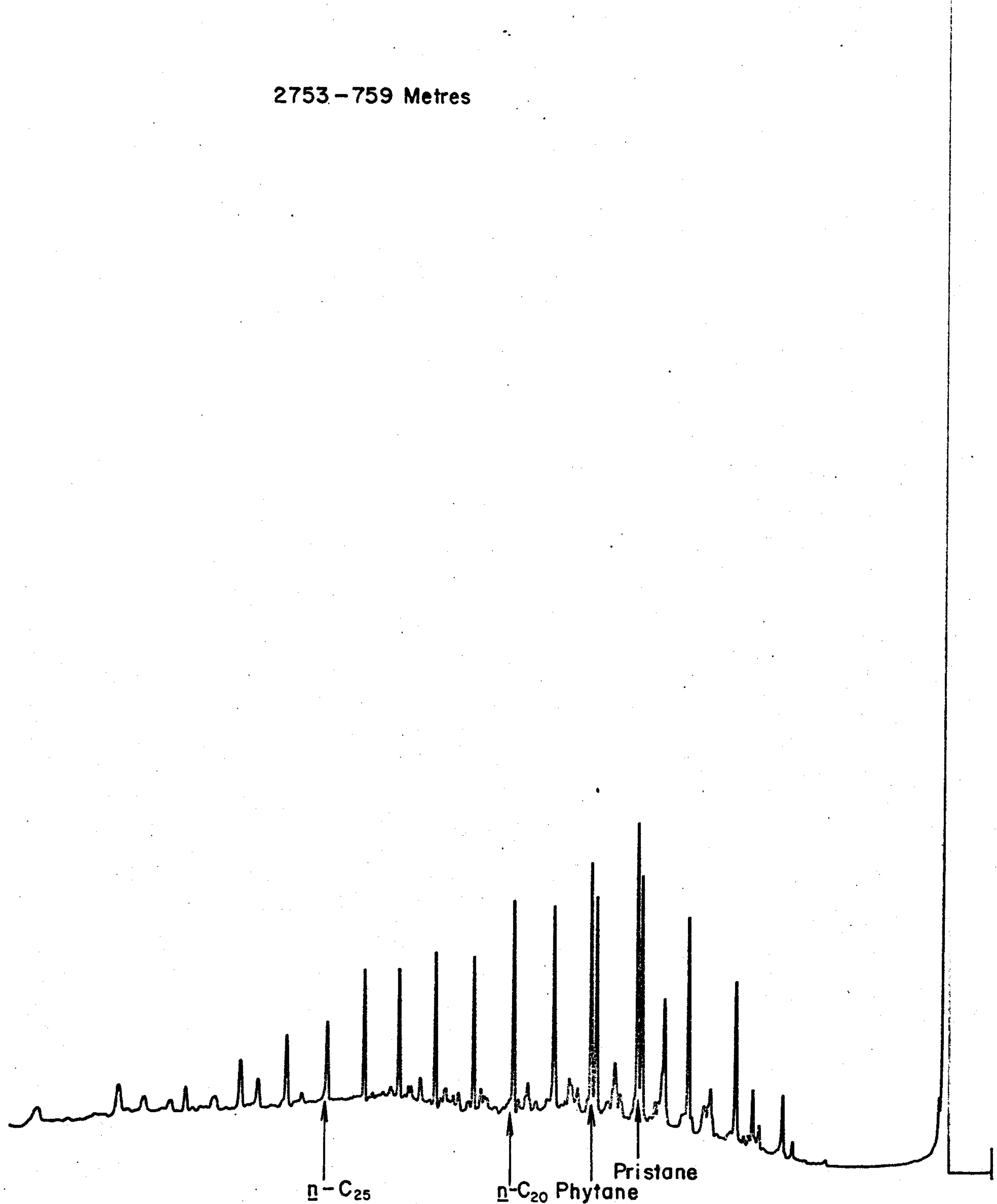
COMPANY: STATOIL   WELL: 15/12-2   LOCATION: NORWEGIAN N. SEA

2723-729 Metres	:	Grey-black silty carbonaceous shale
2753-759 Metres	:	Ditto
2798-804 Metres	:	Ditto
2816-822 Metres	:	White quartz sand + 5% grey-black shale
2834-840 Metres	:	Ditto + minor ditto

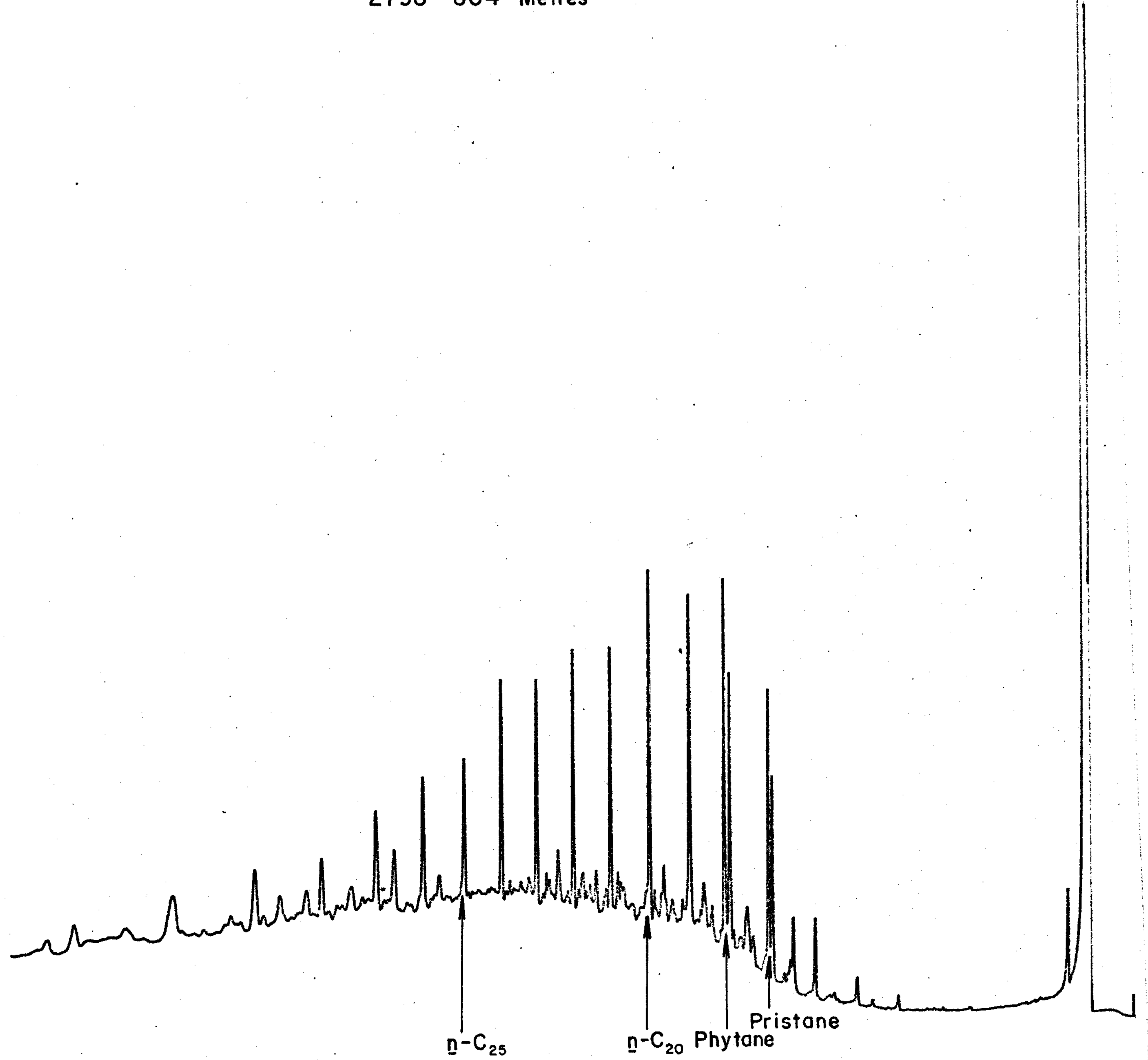
2723-729 Metres



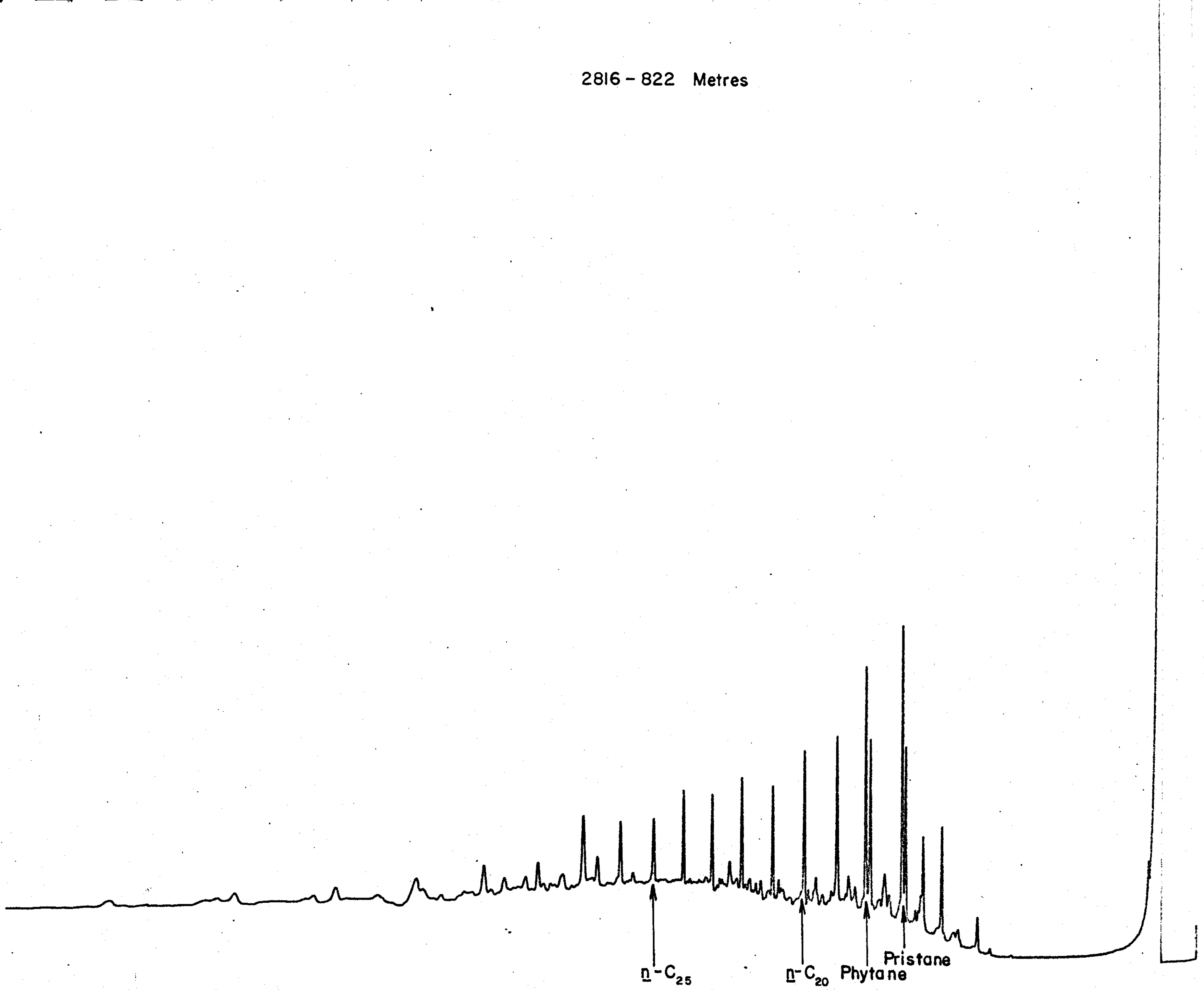
2753-759 Metres



2798 – 804 Metres



2816 - 822 Metres



2834 - 840 Metres

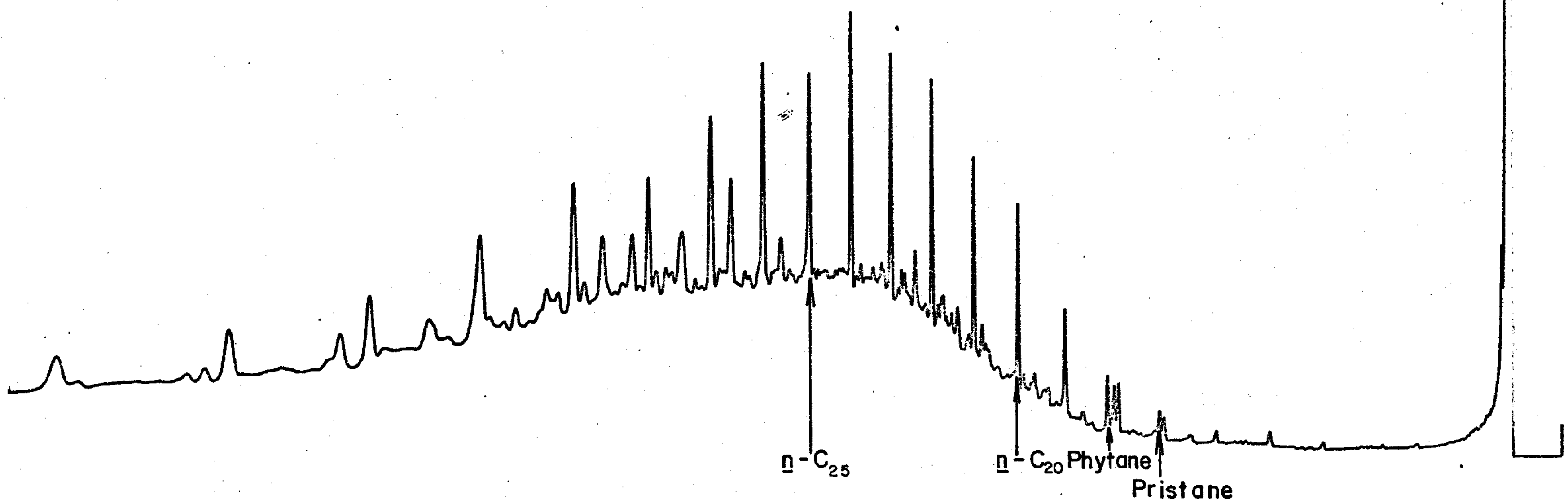


FIGURE 5

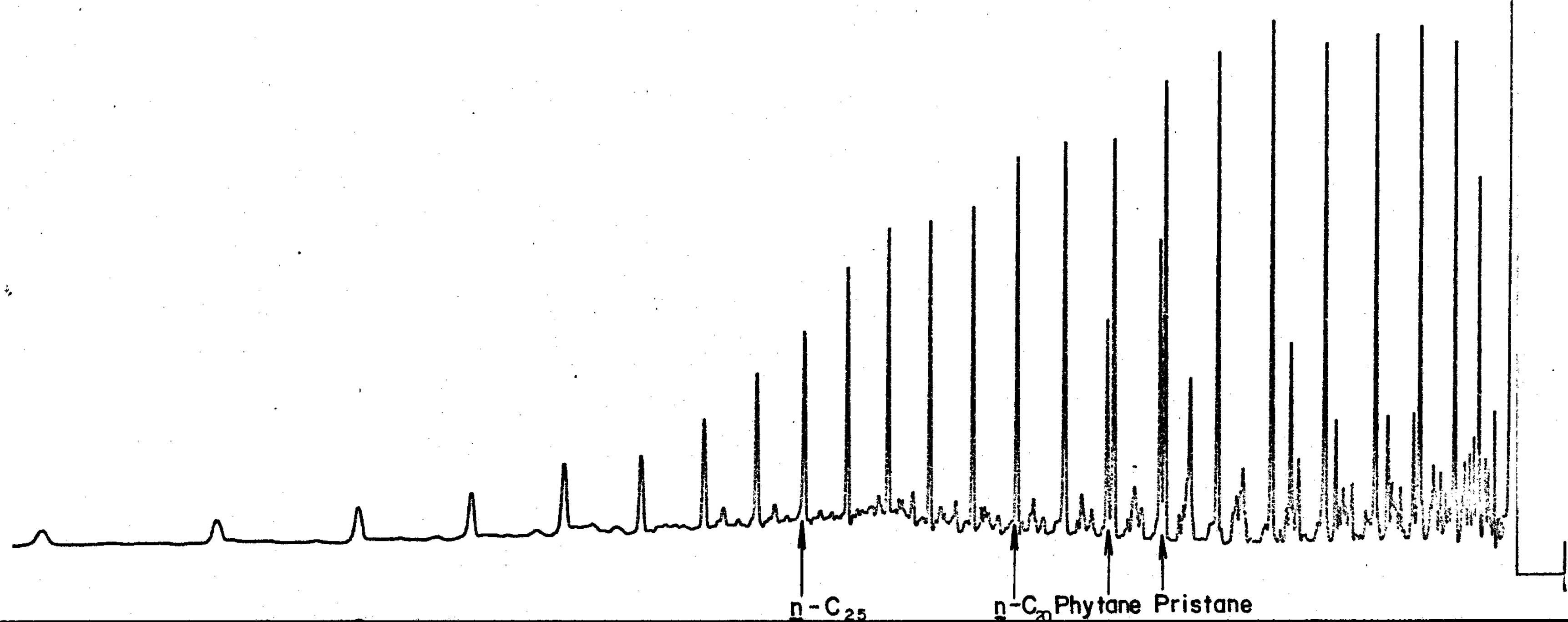
GAS CHROMATOGRAMS OF OILS

COMPANY: STATOIL WELL: 15/12-2 LOCATION: NORWEGIAN N. SEA

PALAEOCENE TEST

JURASSIC TEST

JURASSIC TEST



PALAEOCENE TEST