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ROBERTSON RESEARCH INTERNATIONAL LIMITED

REPORT ON A GEOCHEMICAL EVALUATION OF THE INTERVAL 3,681 TO 4,570 METRES IN THE STATOIL 1/9 - 3 WELL, NORWEGIAN NORTH SEA

BA 79-0131-1

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REPORT NO. 4304P

REPORT ON A GEOCHEMICAL EVALUATION OF THE INTERVAL 3,681 TO 4,570 METRES IN THE STATOIL 1/9 - 3 WELL, NORWEGIAN NORTH SEA

by

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June, 1979

ROBERTSON RESEARCH

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SUMMARY

Some fair oil source rocks occur in the interval 3,681 to 4,570 metres of this well. Above 4,080 metres the analysed section is in the middle mature zone, with fair oil and gas source rocks present as medium dark grey shales. Below 4,080 metres the section is late mature, the transition to condensate occurring at about 4,400 metres; some oil and gas may have been generated during maturation. In total the shales containing gas-prone organic matter may together be a fair gas source.

INTRODUCTION

This report presents the results of a geochemical study of the Statoil 1/9-3, well, Norwegian North Sea. The well is located at latitude 56°24'55.684"N, longitude 02°54'15.219"E, 2 kilometres NNE of the 1/9-1 gas/oil discovery well. It was drilled in the period 13 August, 1977 to 3 October, 1978, in 75 metres of water, to a total depth of 4,534† metres, before being plugged and abandoned. The objective was the Danian/Maastrichtian chalk and the Jurassic, as an appraisal of the deep pool 1/9-1. Gas and condensate (49° API) shows occurred in the Maastrichtian/Danian Chalk, but no hydrocarbons were encountered below the Chalk.

For the purpose of this study, 29 wet ditch cuttings samples in sealed cans were provided by Statoil over the interval 3,681 to 4,570 metres; the majority of these are at 30 metre intervals. Samples were submitted for maturation analysis (airspace gaseous hydrocarbons, gasoline range hydrocarbons, spore colouration and vitrinite reflectivity) and for source rock analysis (organic carbon content and pyrolysis). The samples were unsuitable for source rock analysis by solvent extraction because of abundant cavings and lost circulation material.

Age data used in this report are taken from our RRI Report No. 2398.

Assisting in the analytical work were A. G. Collins and J. McEwan.

(† Depth quoted in Foreign Scouting Services Report for November; samples were supplied down to 4,570 metres)

II

RESULTS AND INTERPRETATION

A. THERMAL MATURITY

Oil-prone organic matter is middle to late mature in the analysed section between 3,681 and 4,400 metres, and in the oil/condensate transition zone between 4,400 and 4,570 metres (T.D).

1. Airspace Gas Analysis

No detectable concentrations were found in the 29 canned samples analysed; but it is probable that any gases had escaped due to faulty seals on the cans.

2. Gasoline Hydrocarbon Analysis (Table 1, Figure 1)

Gasoline hydrocarbon abundance over the interval 3,681 to 3,930 metres is between 920 and 4,960 ppb (at common base level of 1% T.O.C.), decreasing to zero in the interval 3,990 to 4,570 metres. These data probably indicate a rapid change from optimum maturity to the condensate zone, but may also indicate an increase in inertinite content.

3. Spore Colouration (Table 2, Figure 2)

Spores are relatively abundant in parts of the analysed section, although the thickness of the section is not ideal for establishing a spore colour gradient for the well. Caved Tertiary palynomorphs occur in the Upper Cretaceous interval, but few indigenous spores. Over the Lower Cretaceous interval 3,813 to 4,080 metres indigenous spores show colour indices of between 5.5 to 7.5, indicative of middle maturity. In the Upper Jurassic and Indeterminate age sediments analysed below approximately 4,200 metres, spore colours are between 7.5 and 8.5, indicative of late maturity and the oil/condensate transition zone.

The analysed section is middle to late mature, passing into the oil/condensate transition zone below 4,400 metres.

4. Vitrinite Reflectivity (Table 2, Figure 3)

Vitrinite is seen rarely in the analysed section and from the minimal amount of data obtained it is not possible to establish a reflectivity gradient. Values are between 0.5% and 0.8%, indicating maturity in gas-prone organic matter.

5. Comparison of Maturation Indices

Despite the lack of data from some of the analyses, it is possible to conclude from the spore colour and gasoline hydrocarbon analyses that the analysed section is middle to late mature for the generation of oil, passing into the oil/condensate transition zone between 4,400 and 4,570 metres (T.D.).

B. SOURCE ROCKS (Tables 3, 4, Figures 4, 5)

The analysed section comprises Upper and Lower Cretaceous, a thin Upper Jurassic and basal sediments of indeterminate age. The washed samples contain variable mixtures of chalk, medium dark grey shale, medium grey shale, light grey shale, and grey-red shale, with abundant lost circulation material over the interval 4,050 to 4,296 metres. Because of the contamination and variety of lithologies in individual samples, it was necessary to hand-pick representative lithologies for organic carbon and pyrolysis analyses. It is not possible to relate the lithologies directly to their stratigraphic location, therefore individual lithologies are described separately below.

Pyrograms obtained for some of the samples appeared to show contamination. After washing in organic solvents, pyrolysis produced similar data. Other samples with low temperatures of "maximum rate of pyrolysis", of less than 400°C, are likely to be contaminated.

Medium Dark Grey Shales (analysed in the interval 3,681 to 4,570 metres)

Organic carbon contents of between 1.25% and 2.88%, average to above average for shales. Pyrolysis analysis indicates a predominantly humic kerogen type, much of which appears to be inertinitic; up to 50% sapropel is thought to be present in the shales from 3,870-900, 3,900-930, and 3,990 to 4,080 metres.

Above 4,080 metres the analysed section is in the middle mature zone and these shales could well have fair oil and gas generating capacity, particularly when optimum maturity is reached. Below 4,080 metres the analysed shales are mainly in the late mature or oil/condensate transition zone where much of their hydrocarbon potential will already have been realised; some oil generation is likely to have occurred during maturation. Some of the basal shales containing humic organic matter can still be fair gas sources.

Medium Grey Shales (analysed in the interval 3,681 to 4,080 metres)

Organic carbon contents of between 0.73% and 2.52%, below to above average for shales. Pyrolysis analysis indicates a humic kerogen type, most of which appears to be inertinite. Potential hydrocarbon yields suggest that these sediments are all poor source rocks with no present hydrocarbon generating capacity.

Light Grey Shales (analysed in the interval 3,681 to 3,930 metres)

Organic carbon contents of between 0.64% and 2.80%, below average to above average for shales. Pyrolysis analysis indicates a humic kerogen type, most of which appears to be inertinitic. Potential hydrocarbon yields suggest that these sediments are all poor source rocks with no present hydrocarbon generating capacity.

Grey-Red Shales (analysed in the interval 3,870 to 3,930 metres)

Organic carbon contents of 0.33% and 0.54%, below average for shales. Pyrolysis analysis was not carried out on these two samples; they are unlikely to represent significant hydrocarbon sources.

Kerogen Type

Because of the late stage of maturity reached by the organic matter, it has been difficult to distinguish accurately between kerogen types, but inertinite has been seen to be the usually dominant component.

CONCLUSIONS

From our study of the interval 3,681 to 4,570 metres in the 1/9-3 well we conclude that:

i. Oil-prone organic matter is middle to late mature between 3,681 and 4,400 metres, and in the oil/condensate transition zone between 4,400 and 4,570 metres (T.D.).

ii. Hand-picked medium dark grey shales in the analysed section are generally of average to above average organic carbon content, most of which is humic (particularly inertinite). In total these shales may add up to fair gas sources. Some sapropel occurs in the general intervals 3,870 to 3,930 and 3,990 to 4,080 metres; above 4,000 metres these may have fair oil source rocks capacity; below 4,080 metres much of the hydrocarbon potential has already been realised, with some oil generation being likely to have occurred during maturation.

iii. Hand-picked medium grey and light grey shales in the analysed section are generally of average to above average organic carbon content, comprising mainly inertinite. No hydrocarbon generation is likely other than possibly some minor gas.

iv. Hand-picked grey-red shales have below average organic carbon contents and no hydrocarbon generation is likely.

TABLE 1A

GASOLINE HYDROCARBON ANALYSIS DATA

COMPANY: STATOIL **WELL:** 1/9-3 **LOCATION:** NORWEGIAN NORTH SEA

DEPTH: (METRES)	3681	3747	3813	3870	3930	3990	4050
GASOLINE HYDROCARBON COMPONENTS	RELATIVE GASOLINE HYDROCARBON COMPONENT ABUNDANCES (PER CENT)						
i - BUTANE	tr	tr	1	tr	2	*	*
n - BUTANE	3	3	13	3	11	*	*
i - PENTANE	10	3	11	6	12	*	*
n - PENTANE	20	8	23	10	24	*	*
2,2 - DIMETHYL BUTANE	2	1	tr	1	tr	*	*
CYCLOPENTANE	tr	2	1	2	1	*	*
2,3 - DIMETHYL BUTANE	tr	1	tr	1	tr	*	*
2 - METHYL PENTANE	8	4	5	2	4	*	*
3 - METHYL PENTANE	4	3	3	2	3	*	*
n - HEXANE	15	8	11	9	11	*	*
METHYL CYCLOPENTANE	2	3	2	3	2	*	*
2,2 - DIMETHYL PENTANE	tr	2	tr	1	tr	*	*
2,4 - DIMETHYL PENTANE	tr	2	tr	1	tr	*	*
BENZENE	tr	5	1	4	1	*	*
CYCLOHEXANE	1	4	2	2	2	*	*
3,3 - DIMETHYL PENTANE	-	-	-	-	-	-	-
2 - METHYL HEXANE	6	5	3	4	3	*	*
1,1 - DIMETHYL CYCLOPENTANE	4	5	3	4	3	*	*
3 - METHYL HEXANE	1	5	3	5	3	*	*
1, CIS - 3 - DIMETHYL CYCLOPENTANE	1	3	tr	3	tr	*	*
1, TRANS - 3 - DIMETHYL CYCLOPENTANE	-	-	-	-	-	-	-
1, TRANS - 2 - DIMETHYL CYCLOPENTANE	3	4	1	4	8	*	*
3 - ETHYL PENTANE	tr	tr	tr	tr	tr	*	*
n - HEPTANE	13	10	10	14	1	*	*
1, CIS - 2 - DIMETHYL CYCLOPENTANE	tr	tr	tr	tr	tr	*	*
METHYL CYCLOHEXANE	5	6	3	6	3	*	*
ETHYL CYCLOPENTANE	1	5	1	5	2	*	*
TOLUENE	1	8	3	8	4	*	*
TOTAL ABUNDANCE (PPB)	5600	1340	3000	700	2100	*	*
ORGANIC CARBON (PER CENT)	1.13	0.75	1.74	0.76	0.90	0.98	0.83
GASOLINE ABUNDANCE AT 1 PER CENT ORGANIC CARBON	4960	1770	1720	920	2330	*	*

NOTE: TOTAL GASOLINE ABUNDANCE VALUES ARE EXPRESSED AS WEIGHT OF GAS RELATIVE TO WEIGHT OF WET ROCK.

TABLE 1B

GASOLINE HYDROCARBON ANALYSIS DATA

COMPANY: STATOIL **WELL:** 1/9-3 **LOCATION:** NORWEGIAN NORTH SEA

DEPTH: (METRES)	4110	4170	4233	4299	4365	4425	4455
GASOLINE HYDROCARBON COMPONENTS	RELATIVE GASOLINE HYDROCARBON COMPONENT ABUNDANCES (PER CENT)						
i - BUTANE	*	*	Tr	Tr	Tr	Tr	Tr
n - BUTANE	*	*	Tr	Tr	Tr	Tr	Tr
i - PENTANE	*	*	Tr	Tr	Tr	Tr	Tr
n - PENTANE	*	*	Tr	Tr	Tr	Tr	Tr
2,2 - DIMETHYL BUTANE	*	*	Tr	Tr	Tr	Tr	Tr
CYCLOPENTANE	*	*	Tr	Tr	Tr	Tr	Tr
2,3 - DIMETHYL BUTANE	*	*	Tr	Tr	Tr	Tr	Tr
2 - METHYL PENTANE	*	*	Tr	Tr	Tr	Tr	Tr
3 - METHYL PENTANE	*	*	Tr	Tr	Tr	Tr	Tr
n - HEXANE	*	*	Tr	Tr	Tr	Tr	Tr
METHYL CYCLOPENTANE	*	*	Tr	Tr	Tr	Tr	Tr
2,2 - DIMETHYL PENTANE	*	*	Tr	Tr	Tr	Tr	Tr
2,4 - DIMETHYL PENTANE	*	*	Tr	Tr	Tr	Tr	Tr
BENZENE	*	*	Tr	Tr	Tr	Tr	Tr
CYCLOHEXANE	*	*	Tr	Tr	Tr	Tr	Tr
3,3 - DIMETHYL PENTANE	-	-	-	-	-	-	-
2 - METHYL HEXANE	*	*	Tr	Tr	Tr	Tr	Tr
1,1 - DIMETHYL CYCLOPENTANE	*	*	Tr	Tr	Tr	Tr	Tr
3 - METHYL HEXANE	*	*	Tr	Tr	Tr	Tr	Tr
1, CIS - 3 - DIMETHYL CYCLOPENTANE	*	*	Tr	Tr	Tr	Tr	Tr
1, TRANS - 3 - DIMETHYL CYCLOPENTANE	-	-	-	-	-	-	-
1, TRANS - 2 - DIMETHYL CYCLOPENTANE	*	*	Tr	Tr	Tr	Tr	Tr
3 - ETHYL PENTANE	*	*	Tr	Tr	Tr	Tr	Tr
n - HEPTANE	*	*	Tr	Tr	Tr	Tr	Tr
1, CIS - 2 - DIMETHYL CYCLOPENTANE	*	*	Tr	Tr	Tr	Tr	Tr
METHYL CYCLOHEXANE	*	*	Tr	Tr	Tr	Tr	Tr
ETHYL CYCLOPENTANE	*	*	Tr	Tr	Tr	Tr	Tr
TOLUENE	*	*	Tr	Tr	Tr	Tr	Tr
TOTAL ABUNDANCE (PPB)	*	*	Tr	Tr	Tr	Tr	Tr
ORGANIC CARBON (PER CENT)	-	-	-	-	-	-	1.46
GASOLINE ABUNDANCE AT 1 PER CENT ORGANIC CARBON	*	*	Tr	Tr	Tr	Tr	Tr

NOTE: TOTAL GASOLINE ABUNDANCE VALUES ARE EXPRESSED AS WEIGHT OF GAS RELATIVE TO WEIGHT OF WET ROCK.

TABLE 1C

GASOLINE HYDROCARBON ANALYSIS DATA

COMPANY: STATOIL WELL: 1/9-3 LOCATION: NORWEGIAN NORTH SEA

DEPTH: METRES	4545						
GASOLINE HYDROCARBON COMPONENTS	RELATIVE GASOLINE HYDROCARBON COMPONENT ABUNDANCES (PER CENT)						
i - BUTANE	Tr						
n - BUTANE	Tr						
i - PENTANE	Tr						
n - PENTANE	Tr						
2,2 - DIMETHYL BUTANE	Tr						
CYCLOPENTANE	Tr						
2,3 - DIMETHYL BUTANE	Tr						
2 - METHYL PENTANE	Tr						
3 - METHYL PENTANE	Tr						
n - HEXANE	Tr						
METHYL CYCLOPENTANE	Tr						
2,2 - DIMETHYL PENTANE	Tr						
2,4 - DIMETHYL PENTANE	Tr						
BENZENE	Tr						
CYCLOHEXANE	Tr						
3,3 - DIMETHYL PENTANE	–						
2 - METHYL HEXANE	Tr						
1,1 - DIMETHYL CYCLOPENTANE	Tr						
3 - METHYL HEXANE	Tr						
1, CIS - 3 - DIMETHYL CYCLOPENTANE	Tr						
1, TRANS - 3 - DIMETHYL CYCLOPENTANE	–						
1, TRANS - 2 - DIMETHYL CYCLOPENTANE	Tr						
3 - ETHYL PENTANE	Tr						
n - HEPTANE	Tr						
1, CIS - 2 - DIMETHYL CYCLOPENTANE	Tr						
METHYL CYCLOHEXANE	Tr						
ETHYL CYCLOPENTANE	Tr						
TOLUENE	Tr						
TOTAL ABUNDANCE (PPB)	Tr						
ORGANIC CARBON (PER CENT)	2.88						
GASOLINE ABUNDANCE AT 1 PER CENT ORGANIC CARBON	Tr						

NOTE: TOTAL GASOLINE ABUNDANCE VALUES ARE EXPRESSED AS WEIGHT OF GAS RELATIVE TO WEIGHT OF WET ROCK.

TABLE 2 MATURITY EVALUATION DATA

COMPANY: STATOIL WELL: 1/9-3 LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH (METRES)	SAMPLE TYPE	GENERALISED LITHOLOGY	SPORE COLOUR INDEX (1 - 10)	VITRINITE REFLECTIVITY IN OIL, R av%	KEROGEN COMPOSITION (%)		
					INERTINITE	VITRINITE	SAPROPEL
3681-711	Ctgs	CHK+SH	(3.5) *	*	80	20	*
3747-777	"	" + "	(3.5) *	*	80	20	*
3813-843	"	SH + CHK	(3.5) 5-6	?0.53 (7)	40	60	*
3870-900	"	" + "	6.5	*	80	20	*
3930-960	"	" + "	6.5	*	80	20	*
3990-4020	"	" + "	7.0-7.5	*	90	10	*
4050-080	"	" + "	7.5	*	*	*	*
4332-362	"	" + "	?8.0	?0.81 (1)	?100	*	*
4485-515	"	"	?8.0-8.5	*	?100	*	*
4545-570	"	"	?8.0-8.5	*	?100	*	*
			( ) Caved	( ) no. of measurements			

TABLE 3A

SOURCE ROCK EVALUATION DATA

COMPANY: STATOIL   WELL: 1/9-3   LOCATION: NORWEGIAN NORTH 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
3681-711	Ctgs	CHK, gy-wht+50% SH, med dk gy/gy/lt gy	-					
	HP	SH, med dk gy	1.75					
	HP	SH, med gy	2.52					
	HP	SH, lt gy	2.05					
3714-744	"	CHK, a/a+40% SH, a/a	-					
3747-777	"	" +40% SH, a/a	-					
	HP	SH, med dk gy	1.66					
3780-810	"	" +40% SH, a/a	-					
3813-843	"	" +70% SH, a/a	-					
	HP	SH, med dk gy	2.48					
	HP	SH, med gy	1.99					
	HP	SH, lt gy	2.80					
3840-870	"	" +70% SH, a/a	-					
	HP	SH, med dk gy	1.44					
	HP	SH, med gy	0.95					
3870-900	"	" +70% SH, a/a+ mnr SH, gy-red	- -					
	HP	SH, med dk gy	1.25					
	HP	SH, gy-red	0.54					
3900-930	"	" 70% SH,a/a+red	-					
	HP	SH, med dk gy	1.65					
	HP	SH, med gy	0.73					
	HP	SH, lt gy	0.64					
	HP	SH, gy-red	0.33					
3930-960	"	" +60% SH, a/a	-					
	HP	SH, med dk gy	1.53					
	HP	SH, med gy	1.27					
3960-990	"	" +70% SH, a/a	-					
	HP	SH, med dk gy	1.88					
3990-4020	"	" +60% SH, a/a	-					
	HP	SH, med dk gy	1.53					
4020-050	"	" +60% SH, a/a	-					
	HP	SH, med dk gy	1.68					
4050-080	"	" +60% SH, a/a+ mnr LCM	-					

Cont'd.

TABLE 3B

SOURCE ROCK EVALUATION DATA

COMPANY: STATOIL WELL: 1/9-3 LOCATION: NORWEGIAN NORTH 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
Cont'd.								
	HP	SH, med dk gy	1.59					
	HP	SH, med gy	1.00					
4080-110	Ctgs	LCM +10% CHK/SH	-					
4110-140	"	" +10% "	-					
4140-170	"	" +10% "	-					
4170-200	"	" +10% "	-					
4203-233	"	" +10% "	-					
4233-263	"	" +10% "	-					
4266-296	"	" +20% "	-					
4299-329	"	CHK,a/a+60% SH,a/a+ 10% LCM	-					
4332-362	"	" +60% SH, a/a	-					
	HP	SH, med dk gy	2.27					
4365-395	"	" +SH,a/a+90% LCM	-					
4395-425	"	" +SH,a/a+90% LCM	-					
4425-455	"	" +60% SH,a/a+ 20% LCM	-					
4455-485	"	SH,a/a+mnr LST,SLT, SND	-					
	HP	SH,med dk gy	1.46					
4485-515	"	" +mnr a/a	-					
4515-545	"	" +mnr a/a	-					
4545-570	"	" +mnr a/a	-					
	HP	SH, med dk gy	2.88					

TABLE 4

ROCK - EVAL. PYROLYSIS DATA

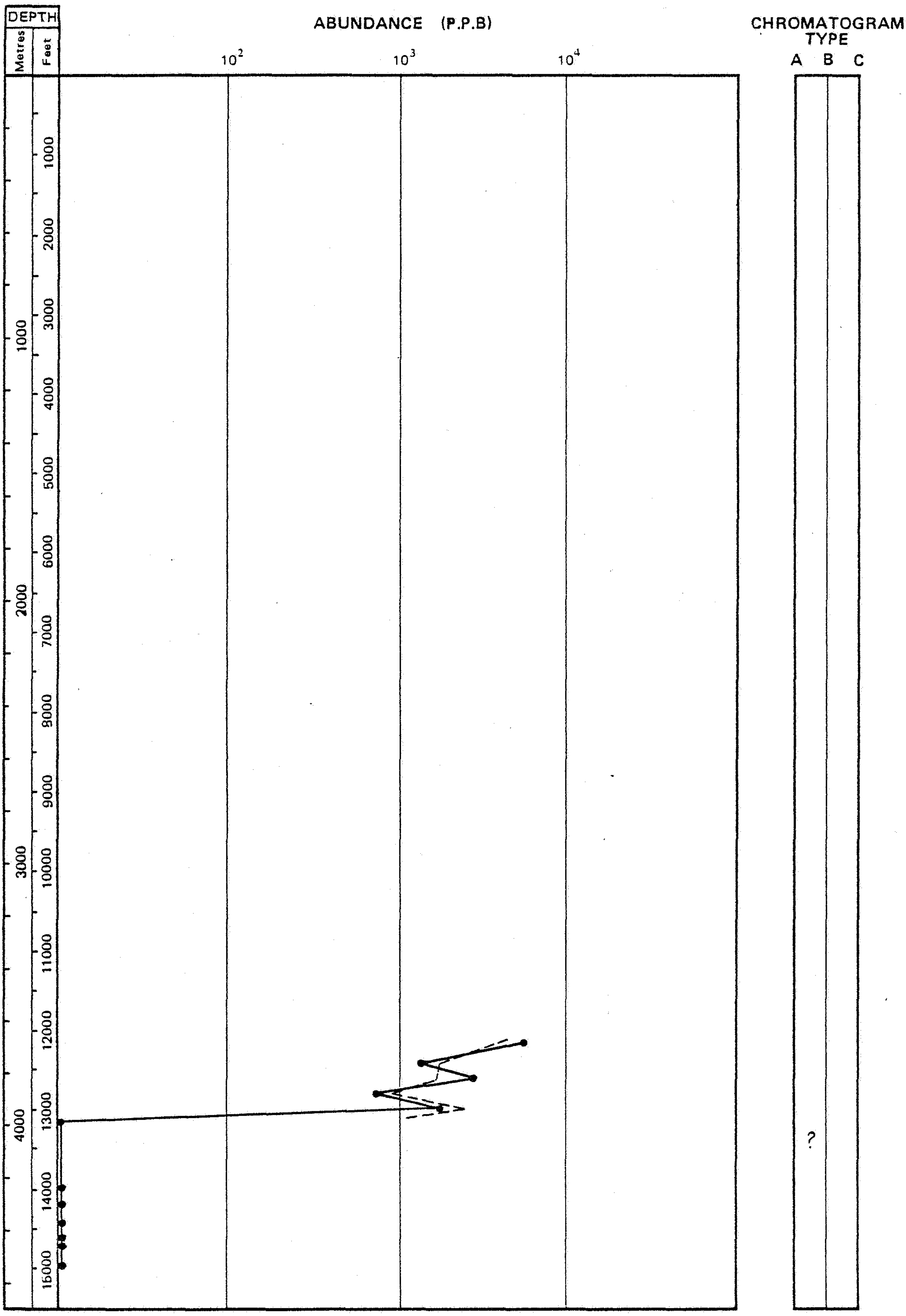
COMPANY: STATOIL WELL: 1/9-3 LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH (METRES) OR NOTATION	GENERALISED LITHOLOGY	ORGANIC CARBON (%)	TEMPERATURE (°C)	HYDROGEN INDEX	OXYGEN INDEX	PRODUCTION INDEX	POTENTIAL YIELD (PPM)
	ALL SAMPLES HP						
3681-711	SH, med dk gy	1.75	442	41	36	0.2	600
	SH, med gy	2.52	430	73	15	0.1	1900
3747-777	SH, med dk gy	1.66	*	98	43	0.1	1500
3813-843	SH, med dk gy	2.48	439	89	28	0.1	2000
	SH, med gy	1.99	429	100	33	*	2100
	SH, lt gy	2.80	*	124	22	0.3	3500
3840-870	SH, med dk gy	1.44	360?	76	68	0.2	1000
3870-900	SH, med dk gy	1.25	350?	52	68	0.2	600
3900-930	SH, med dk gy	1.65	345?	22	45	0.2	300
3930-960	SH, med dk gy	1.53	*	44	42	0.3	700
	SH, med gy	1.27	*	63	57	0.2	600
3960-990	SH, med dk gy	1.88	431	40	33	0.1	700
3990-4020	SH, med dk gy	1.53	*	33	31	0.1	500
4020-050	SH, med dk gy	1.68	*	38	38	0.2	600
4050-080	SH, med dk gy	1.59	432	39	41	0.3	600
	SH, med gy	1.00	*	43	74	0.2	300
4332-362	SH, med dk gy	2.27	450	180	57	0.2	2400
4455-485	SH, med dk gy	1.46	380?	155	57	0.2	2000
4545-570	SH, med dk gy	2.88	*	41	25	0.2	1100

TEMPERATURE (°C) = TEMPERATURE AT MAXIMUM RATE OF PYROLYSIS
PRODUCTION INDEX = AN ESTIMATE OF PRESENT HYDROCARBON GENERATING POTENTIAL COMPARED TO THAT AT OPTIMUM MATURITY
POTENTIAL YIELD = AN ESTIMATE OF HYDROCARBON PRODUCTION AT OPTIMUM MATURITY

FIGURE 1 GASOLINE ($C_5 - C_7$) HYDROCARBONS AGAINST DEPTH

COMPANY: STATOIL WELL: 1/9-3 LOCATION: NORWEGIAN NORTH SEA



A - IMMATURE B - TRANSITIONAL C - OIL LIKE

---- ABUNDANCE (PPB) CALCULATED AT 1% ORGANIC CARBON CONTENT

FIGURE 2 SPORE COLOURATION INDICES AGAINST DEPTH

COMPANY: STATOIL WELL: 1/9-3 LOCATION: NORWEGIAN NORTH SEA

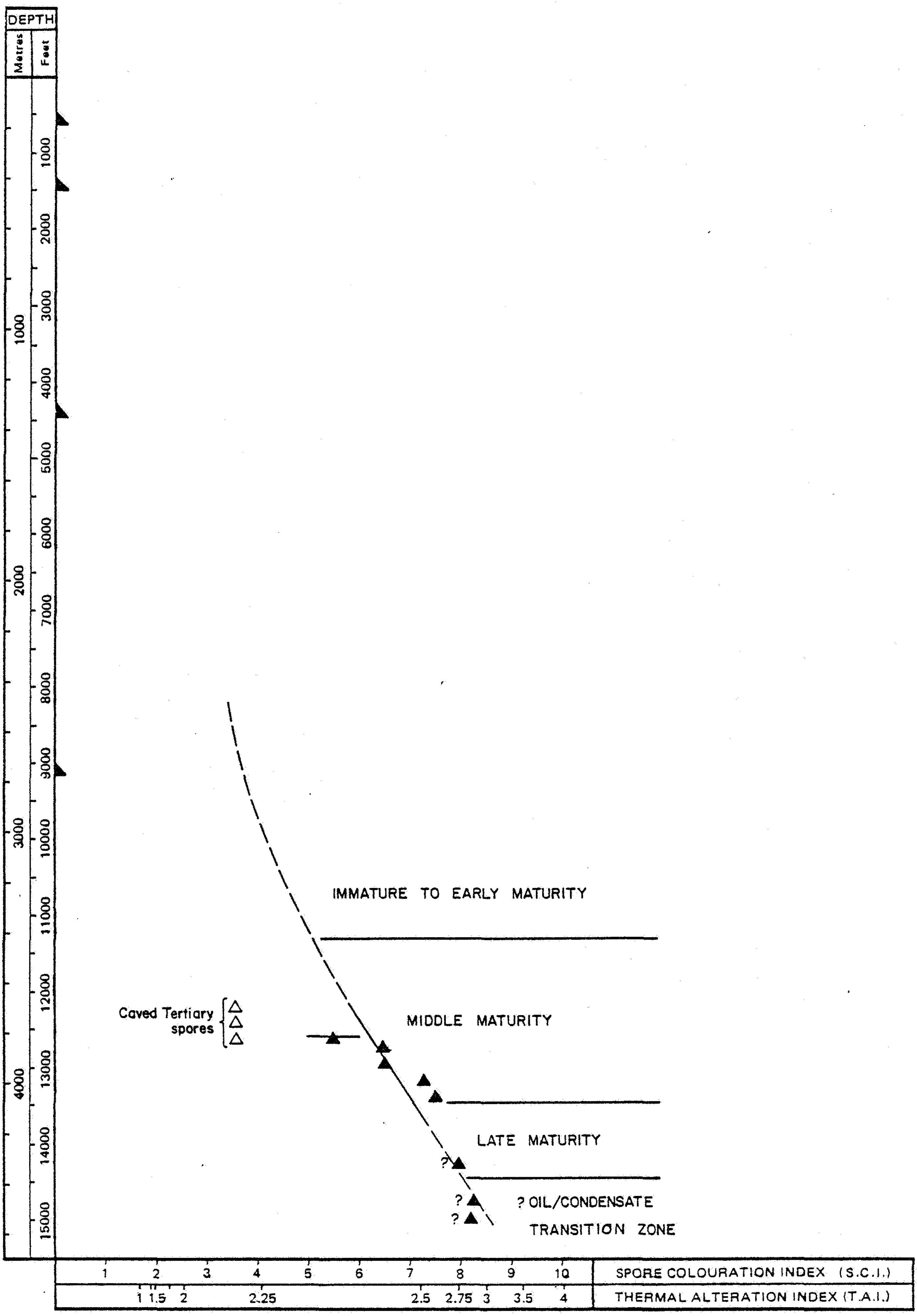


FIGURE 3 VITRINITE REFLECTIVITY AGAINST DEPTH

COMPANY: STATOIL | WELL: I/9-3 | LOCATION: NORWEGIAN NORTH SEA

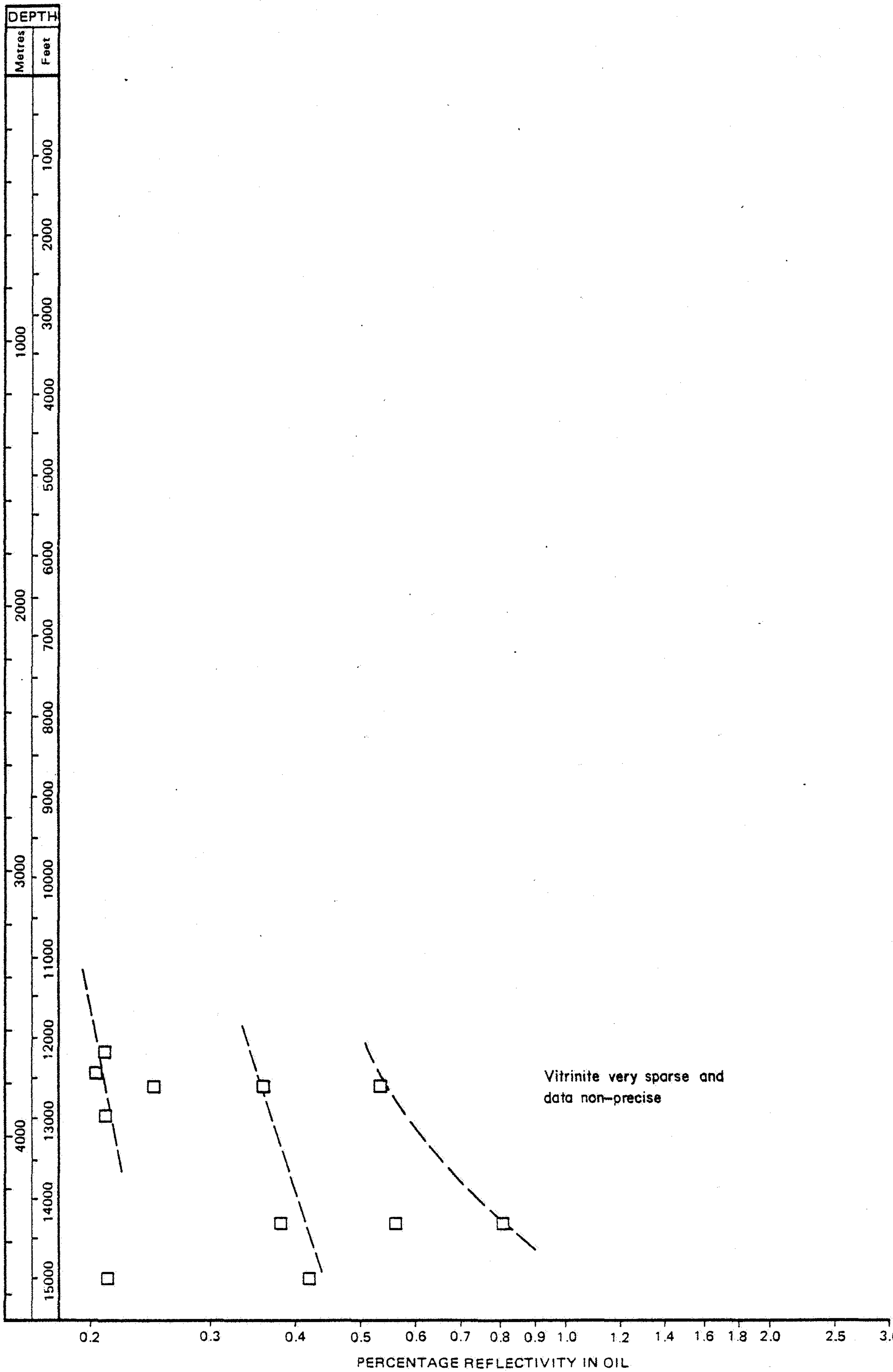
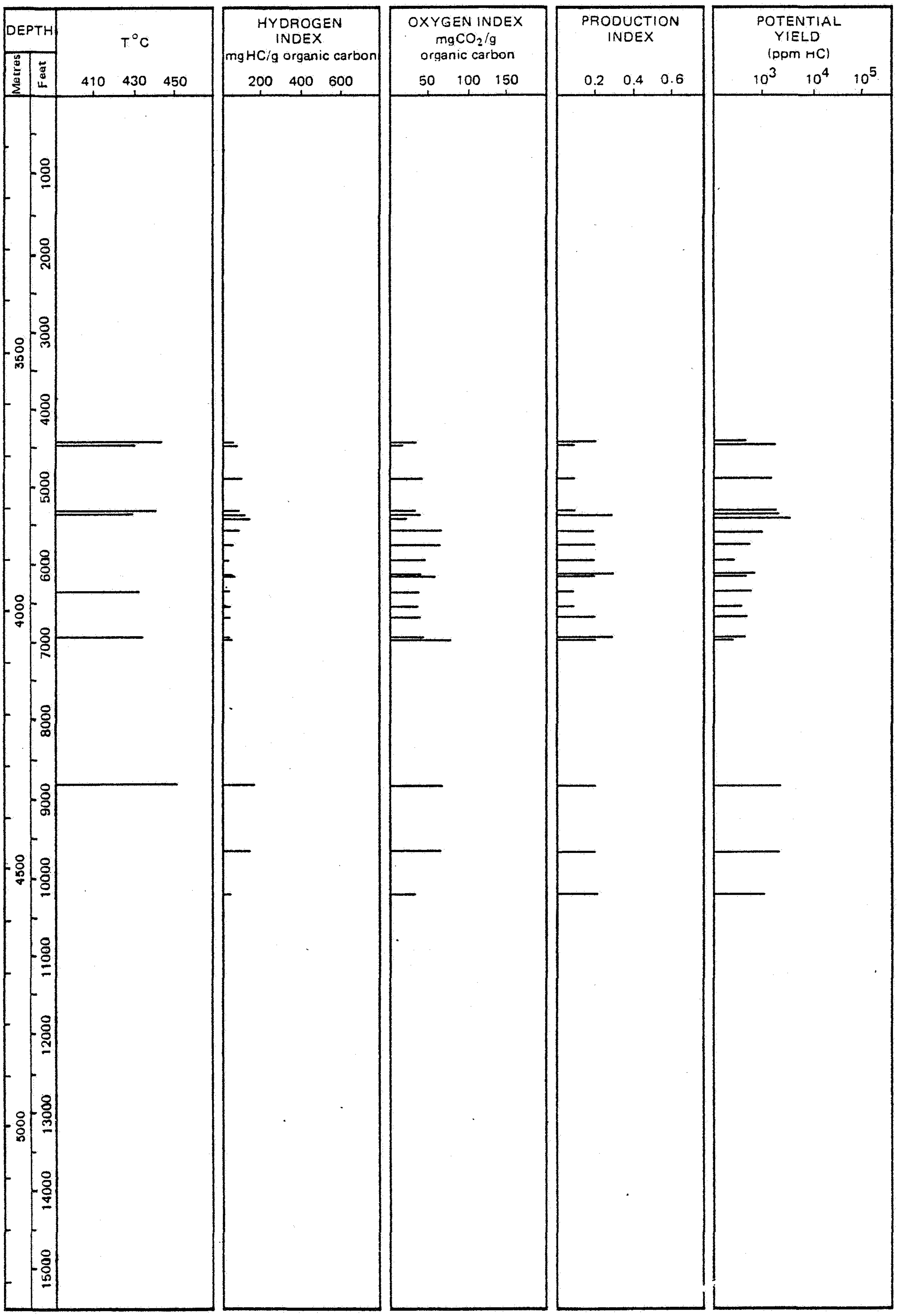


FIGURE 4 PYROLYSIS DATA SUMMARY CHART

COMPANY: STATOIL WELL: 1/9-3 LOCATION: NORWEGIAN NORTH SEA



APPENDIX I

ABBREVIATIONS USED IN ANALYTICAL DATA SHEETS

Alg	-	Algae	
Aren	-	Arenaceous	
Arg	-	Argillaceous	
Bit	-	Bitumen/bituminous	
Bl	-	Blue	
Blk	-	Black	
Brn	-	Brown	
Calc	-	Calcareous	
Carb	-	Carbonaceous	
Chk	-	Chalk	
Cht	-	Chert	
Cgl	-	Conglomerate	
Cly	-	Clay	
CMT	-	Cement	
Crs	-	Coarse	
Ctgs	-	Ditch cuttings	
Dk	-	Dark	
Dol	-	Dolomite	
F	-	Fine	
Fer	-	Ferruginous	
Flu	-	Fluorescence	
Fm	-	Formation	
Foram	-	Foraminifera	
Fr	-	Friable	
Frags	-	Fragments	
Glc	-	Glauconite	
Gn	-	Green	
Gy	-	Grey	
Gyp	-	Gypsum	
Hd	-	Hard	
Inert	-	Inertinite	
Lam	-	Laminae/laminated	
LCM	-	Lost circulation material	
Lig	-	Lignite/lignitic	
Lst	-	Limestone	
Lt	-	Light	
Mdst	-	Mudstone	
Med	-	Medium	
Mic	-	Micaceous	
Mnl	-	Mineral	
Mnr	-	Minor	

Mtl	-	Mottled
Musc	-	Muscovite
NS	-	No sample
Occ	-	Occasional
Ol	-	Olive
Ool	-	Oolite/oolitic
Orng	-	Orange
Pnk	-	Pink
Pop	-	Population
Pp	-	Purple
Pyr	-	Pyrite/pyritic
Qtz	-	Quartz
Ref	-	Reflectivity
Sap	-	Sapropel
Sft	-	Soft
Sh	-	Shale
Shly	-	Shaly
Sil	-	Siliceous
Slt	-	Silt
Sltst	-	Siltstone
Slty	-	Silty
Snd	-	Sand
Sndy	-	Sandy
Sst	-	Sandstone
SWC	-	Sidewall core
Tr	-	Trace
V	-	Very
Vgt	-	Variegated
Vit	-	Vitrinite
Wht	-	White
Yel	-	Yellow
-	-	Sample not analysed
*	-	No results obtained
Gy-gn	-	Greyish green
Gn/gy	-	Green to/and grey
Gn-gy	-	Greenish grey
HP	-	Hand picked lithology
i/b	-	Interbedded

TYPE OF KEROGEN		DOMINANT HYDROCARBON PRODUCT: OIL	GAS	NONE
SAPROPELIC	EXINITES	SPOROPOLLENIN (Spores and pollen)		
		CUTINITE (Land plant cuticle)		
	LIPTINITES	ALGINITE (Algal fragments and masses in oil shales)		
		RESINITE (Land plant exudates, e.g. Amber)		
		AMORPHOUS SAPROPEL		
HUMIC	VITRINITES Most abundant coal maceral		TELINITE (Cellular tissue)	
			COLLINITE (Amorphous)	
	INERTINITES Mainly oxidised woody organic matter			FUSINITE (Opaque, often as broken cell walls)
			SEMI-FUSINITE (Intermediate between fusinite and vitrinite)	
			MICRINITE (Granular inertinite)	

APPENDIX II . KEROGEN COMPONENTS OF ORGANIC MATTER AND THEIR DOMINANT HYDROCARBON PRODUCTS.

For further information see STACH'S textbook of COAL PETROLOGY, Gebruder Borntraeger, Berlin - Stuttgart, 1975

APPENDIX III. ANALYTICAL PROCEDURES AND TECHNIQUES

This appendix summarises the main steps in the analyses carried out in the Robertson Research geochemistry laboratories. Conditions for chemical analyses are given and interpretation guidelines are defined. Techniques may in certain circumstances be adapted to suit particular samples or conditions.

1. Sample Preparation

Following airspace gas analysis of the canned samples, the cuttings are washed. After setting aside a wet sub-sample for gasoline analysis, the remainder is oven-dried at 50°C and described. Obvious cavings and particulate contaminants are removed and the significant lithologies hand-picked for organic carbon screening analysis. Coals if present are picked for vitrinite reflectivity measurement and splits of the total cuttings are made for the preparation of kerogen concentrates. Subsequently the bulk samples except those containing much loose sand or coal are crushed to pass through a 250 micron (60 - mesh) sieve and submitted for organic carbon screening analysis.

2. Maturity Evaluation

Maturation is assessed by measurement of spore colour and vitrinite reflectivity and the analysis of airspace gas and gasolines. Kerogen concentrates for microscopic analysis are prepared using standard palynological procedures (i.e. acid maceration) but without oxidation and acetolysis. Mineral residues, particularly pyrite, are separated from the kerogen by a combination of ultrasonic vibration and zinc bromide flotation. For spore colour measurement and kerogen typing, mounts are prepared of both the total kerogen and the coarser-than-20-micron size fraction. Sample blocks for measurement of vitrinite reflectivity are prepared by mounting the coarser-than-20-micron kerogen fraction in an epoxy resin, followed by polishing with carborundum and alumina.

Airspace Gas Analysis

If samples of wet cuttings are collected at the well-site and sealed in an airtight can, the headspace gases can be analysed in the laboratory to provide a rapid assessment of maturity. The gas is extracted from the sealed can using a can piercer fitted with a septum and analysed by gas liquid chromatography. The proportions of methane, ethane, propane and butane are calculated by comparison with a standard mixture of these gases. Methane is usually the dominant gas and comprises 90-100% from immature sediments and 30-70% from mature sediments. Abrupt departures from composition/depth trends may indicate faults with migrant gases or reservoir rocks.

Gasoline Analysis

Cuttings samples received wet, preferably in sealed containers, are suitable for gasoline analysis. A portion of the washed cuttings sample is retained wet, pulverised in a sealed shaker and warmed to expel the gasoline components into the shaker airspace. A sample of this airspace gas is then removed and analysed by gas chromatography. 28 hydrocarbon species are identified in the C_4 to C_7 range and their relative proportions calculated with reference to standard mixtures. Immature source rocks yield mixtures dominated by a small number of components but mature source rocks usually contain a full range of identified hydrocarbons in similar orders of concentration. The onset of maturity may also be indicated by an increase in total gasolines relative to the organic carbon content of the host rock (+200 ppm hydrocarbons per 1% organic carbon). Occasionally, oil stain will be recognised by the presence of anomalous amounts and it may be possible to identify its source rock by a similarity in distribution of components.

Spore Colouration

The maturity of oil-prone organic matter present in kerogen concentrates is assessed by visual examination of the indigenous sporomorphs. With increasing thermal maturity, spore colours change from pale yellow, through orange and brown, to black. Measurement is made using a standard reference set of sporomorphs. Spore colouration indices measured are on the Robertson Research scale of 1 to 10. Our experience shows that values of 3.0 to 3.5 are representative of the transition zone between immaturity and maturity. The range 3.5 to 8.0 is arbitrarily divided into zones of organic maturity: 3.5 to 5.0, early maturity; 5.0 to 7.0, middle maturity; 7.0 to 8.0 late maturity. Direct comparison with source rock data indicates that, given the presence of oil-prone organic matter, low gravity oils are likely to be generated in the zone of early maturity, medium gravity oils in the zone of middle maturity and high gravity oils in the zone of late maturity. The onset of generation of condensate, wet gas and, ultimately, dry gas is characterised by spore colour indices above 8.0.

Vitrinite Reflectivity

Vitrinite, a humic degradation product largely derived from the anaerobic decomposition of the lignin, cellulose and nitrogen-containing compounds of woody tissues, is the chief component of coals and is also common in fine-grained clastic rocks. The reflectivity of an optically flat surface is defined as the percentage of normally incident light reflected from the surface. Reflectivity can be used to define the level of thermal maturity of sedimentary organic matter since it increases from approximately 0.2% to 5.0% at a relatively uniform rate through the coal rank series. Zones of oil and gas generation can be related to the coal rank series and therefore defined in terms of vitrinite reflectivity, even though vitrinite is not an oil source but generates gas. The onset of oil generation has been placed at between 0.35% and 0.6% reflectivity, depending on the type of sedimentary basin; 0.5% is a widely accepted threshold value. The floor for oil generation is characterised by a vitrinite reflectivity of approximately 1.2%. Wet gas generation peaks at a reflectivity of about 1.0% and ceases at the 2.0% level. Dry gas generation peaks at a reflectivity of about 1.5% and ceases at the 3% level. However, to define the appropriate limits for a particular basin, vitrinite reflectivity must be correlated with other thermal maturation parameters.

3. Source Rock Evaluation

Organic Carbon Content

On average, between 1% and 2% of argillaceous sediments consist of organic carbon. Since major hydrocarbon accumulations are the exception rather than the rule it is likely that their sources are of above average organic carbon content. Sediments containing less than 0.3% organic carbon are regarded as having no source potential, and those containing between 0.3% and 1.0% are marginal sources. Obviously the kerogen type is also of fundamental importance in determining the source potential of a rock.

Organic carbon values are obtained as follows. A 0.1 or 0.5 g sample, depending on lithotype, of crushed rock is treated with concentrated hydrochloric acid to remove carbonates and the residue filtered onto a glass fibre paper prior to ignition in a 'Leco' carbon analyser.

Extract Analysis

The soluble organic materials present in rocks can be extracted with organic solvents, fractionated and analysed. The type and amount of material extracted depends largely upon the nature of the contained organic matter and its maturity.

A maximum of 40 g of crushed sample is extracted for a minimum of 12 hours in a 'Soxhlet' apparatus by a 2 : 1 mixture of laboratory redistilled dichloromethane and methanol. The weight of the 'total extract' after final evaporation is expressed as ppm of the total rock. The more volatile components (up to C-15) are lost during extraction. The total extract is dissolved in hexane and a known volume separated by high pressure liquid chromatography into saturate hydrocarbon (alkanes), aromatic hydrocarbon and resene-asphaltene fractions.

Extract analysis provides a measure of source-rock richness in the oil-generation maturity zone. In addition to organic carbon contents, five parameters are calculated; total extract, extract/organic carbon x 100 i.e. extractability or EPOC, hydrocarbons as ppm of rock, hydrocarbons as percent of extract and alkanes as percent of hydrocarbons.

The extractability of oil-prone sapropelic organic matter increases rapidly in the oil generation zone and diminishes to very low values in post-mature sediments. Overall the extractability of sapropelic organic matter is greater than that of gas-prone humic organic matter for similar levels of maturity. Samples with extractabilities of greater than 20% generally contain migrated oil or are contaminated with mud additives.

The hydrocarbon content of a rock is the sum of the alkane and aromatic fractions of the total extract. As maturation proceeds in the oil generation zone the proportion of hydrocarbons in the total extract increases from less than 20% to a maximum in the most productive horizons of around 60%. This trend is reversed as the oil-condensate zone is entered. The relative proportions of alkanes to aromatics can be used as a check for low levels of contamination.

Pyrolysis

Pyrolysis data are obtained using the IFP-Fina "ROCK-EVAL" apparatus. The method involves the heating of samples from 250° to 550°C at 25°C/minute in a stream of inert gas. During this time, three pulses of gases are released and recorded as weights of gas. The first of these pulses relates to hydrocarbons present in the sediment which could normally be extracted by organic solvents; these are either the adsorbed hydrocarbons indicating present source potential, or reservoired hydrocarbons. The second gas pulse is of hydrocarbons released by the thermal breakdown of kerogen (optimum source potential), and simultaneously the temperature of maximum rate of evolution is measured. The third pulse comprises carbon dioxide.

The parameters used in interpretation are the hydrogen index (ratio of released hydrocarbons to organic carbon content), the oxygen index (ratio of released carbon dioxide to organic carbon content), the temperature of maximum rate of pyrolysis, and the production index (ratio of the amount of hydrocarbons released in the first stage of heating to the total amount of released hydrocarbons). Kerogens rich in sapropelic matter exhibit a high hydrogen index and a low oxygen index while those in which humic debris predominates will display a low hydrogen index and a high oxygen index. Hydrogen and oxygen indices for a particular type of kerogen are also susceptible to a reduction in their values during the course of thermal maturation.

The hydrogen index is a measure of the hydrocarbon generating potential of the kerogen. Immature, organically rich source rocks and oil shales give values above 500, mature oil source rocks give values between 200 and 550.

The temperature of maximum rate of pyrolysis depends on the nature of the organic matter, but the transition from immature to mature organic matter is marked by temperatures between 415^{o} and 435^{o}C. The maturity transition from oil and wet gas generation to dry gas generation is marked by temperatures between 455^{o} and 460^{o}C. In practice, greater variation than these ideal temperature ranges may be seen, but they are nevertheless useful as general guides to the level of maturity attained by the sediment.

The production index increases with maturity from values near zero for immature organic matter to maximum values of 0.15 during the late stages of oil generation. Anomalously high values indicate the presence of free oil. The hydrocarbon yield is an indication of the potential yield of hydrocarbons from the source rock at optimum maturity and is a measure of the quality of the source rock. A value of 0 to 2000 of hydrocarbon in ppm of rock characterises a poor source rock, 2000 to 6000 ppm fair, 6000 to 20,000 ppm good and above 20,000 ppm very good.

Visual Examination of Kerogen Concentrates

All palynological preparations are examined in transmitted white and ultraviolet light and the relative abundances of vitrinite, inertinite and sapropel (essentially a fine-grained, apparently amorphous mixture of liptinite and exinite) estimated. The coarser-than-20-micron fractions are also examined in reflected white and ultraviolet light.

Gas Chromatography of C-15+ Alkanes

A portion of the "total extract" obtained from Soxhlet extraction is eluted with pentane through a short silica column to yield the saturate hydrocarbon fraction. This fraction is evaporated to dryness in a stream of dry nitrogen at room temperature. A small portion of the fraction is then taken up in methylene dichloride and injected on to a 25 metre, wall-coated, open-tubular, glass capillary column coated with OV-1 mounted in a Perkin Elmer F-17 gas chromatograph and programmed from 80^{o}C to 260^{o}C at 4^{o}C/minute.

Distributions of _n_-alkanes and the relative abundances of steranes and triterpanes are noted and the ratios pristane/_n_-C_{17} and phytane/_n_-C_{18} are measured. The CPI may also be measured. Inspection of the chromatograms may reveal information about the kerogen type of the source rock, its maturity and conditions of deposition and, if migrant oil is present, whether this has been water-flushed or biodegraded. Drilling mud additives may be identified.

Drawing No. 304P/2094/4419

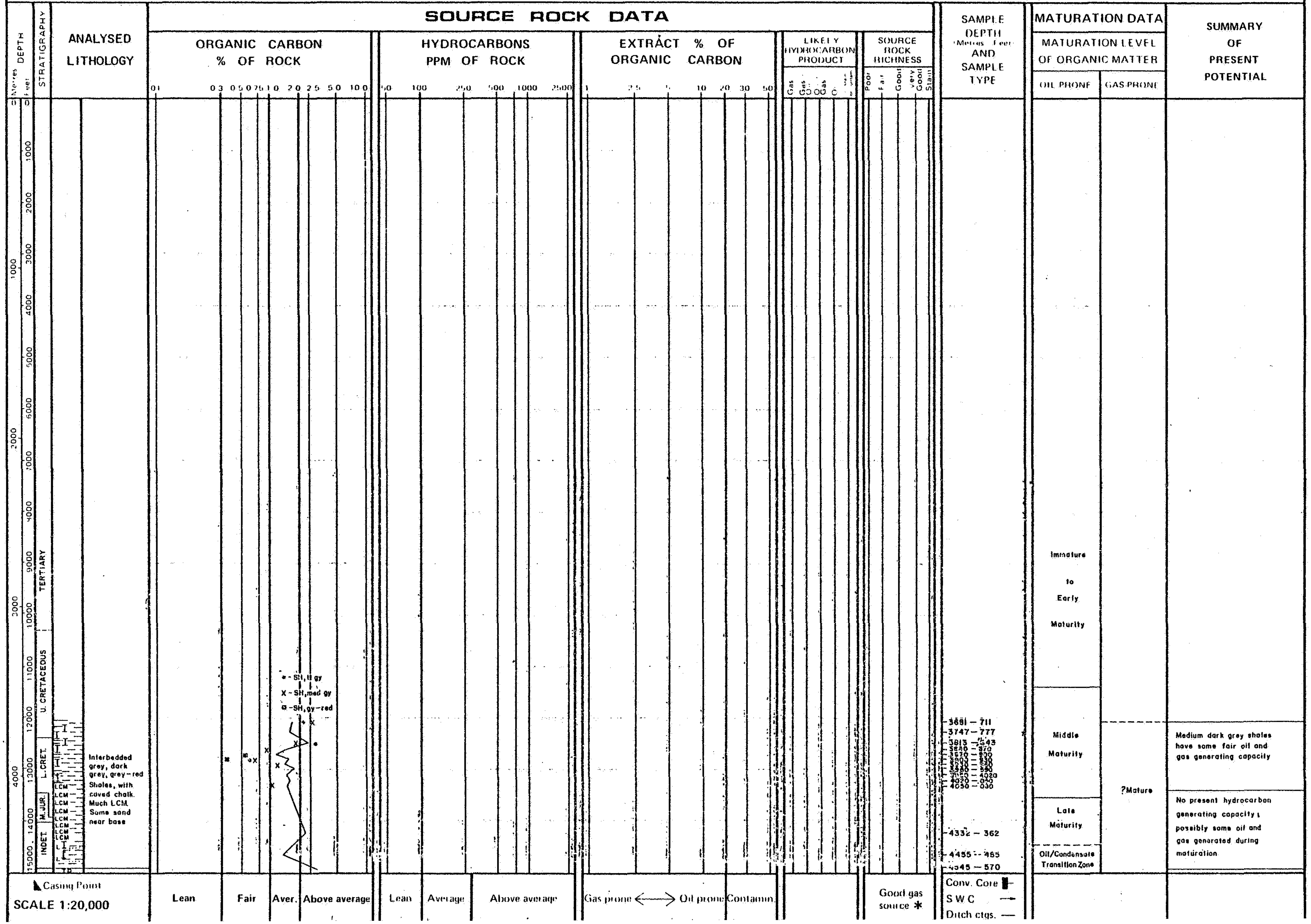
COMPANY: STATOIL

GEOCHEMICAL SUMMARY CHART

WELL: 1/9-3

LOCATION: NORWEGIAN NORTH SEA

FIGURE 5



SUMMARY CHART

FIGURE 5

LOCATION: NORWEGIAN NORTH SEA

DATA: EXTRACT % OF ORGANIC CARBON (2.5, 5, 10, 20, 30, 50)	LIKELY HYDROCARBON PRODUCT (Gas, Gas-Oil, Oil-Gas, Oil, Oil stain or contam.)	SOURCE ROCK RICHNESS (Poor, Fair, Good, Very Good, Stain)	SAMPLE DEPTH (Metres Feet) AND SAMPLE TYPE	MATURATION DATA: MATURATION LEVEL OF ORGANIC MATTER — OIL PRONE	MATURATION DATA: MATURATION LEVEL OF ORGANIC MATTER — GAS-PRONE	SUMMARY OF PRESENT POTENTIAL
				Immature to Early Maturity		
			3681 – 711 3747 – 777 3813 – 843 3840 – 870 3870 – 900 3900 – 930 3930 – 960 3960 – 990 3990 – 4020 4020 – 050 4050 – 080	Middle Maturity		Medium dark grey shales have some fair oil and gas generating capacity
			4332 – 362 4455 – 485 4545 – 570	Late Maturity Oil/Condensate Transition Zone	?Mature	No present hydrocarbon generating capacity; possibly some oil and gas generated during maturation
one ⟷ Oil-prone; Contamin.		Good gas source *	Conv. Core ▮– S W C → Ditch ctgs. —			

Drawing No. 304P/2094/4419

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GEOCHEMICAL SU

WELL: 1/9-3

SOURCE ROCK DAT