

December 1979

RKER 79.031

SOURCE ROCK AND CARBONISATION EVALUATION
TOGETHER WITH MACERAL ANALYSIS OF
SEDIMENTS PENETRATED BY WELL 31/2-1, NORWAY

by

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Investigation

9.12.266

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KONINKLIJKE / SHELL EXPLORATIE EN PRODUKTIE LABORATORIUM

RIJSWIJK, THE NETHERLANDS

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Enclosure 1

I INTRODUCTION

A source rock evaluation has been carried out on a suite of cutting samples of sediments penetrated by well 31/2-1, Norway.

Source rock evaluation commonly comprises determination of:

1. the presence (or absence) of hydrocarbons source material in the rock samples;
2. the quality of the organic matter as well as the distribution of its specific constituents;
3. the degree of organic metamorphism (= level of maturity).

A source rock is identified by measuring the amount of temperature reactive ("live") organic matter present, i.e. the amount of organic matter that yields hydrocarbons upon pyrolysis. The method excludes any ("dead") organic matter such as inertinites.

In addition, the total organic carbon content can be determined which gives the sum of "live" and "dead" organic carbon. Rocks containing less than 0.5 % organic carbon are not considered to have a potential for commercial oil accumulations.

The source rock indications (SRI), which are a measure of the amount of pyrolysable organic matter, are determined on the original samples and in certain cases also after extraction with organic solvents. A systematically lower value after extraction is due to the presence of extractable hydrocarbons. These may consist of trapped oil, oil generated in situ by a source rock, or e.g. gasoil used in the drilling fluid.

In general, samples with source rock indications of 30 or less do not represent (immature or mature) source rocks. Values between 30 and 100 generally indicate marginal source rocks, while values above 100 commonly indicate good source rocks.

Intervals or samples with high source rock indications are investigated under a microscope to ensure that the high values indicate genuine source rock properties and are not due to contaminants of an organic nature such as lost circulation material.

The quality of a source rock for oil/gas generation depends on the type of organic matter present. Five categories of organic matter can be distinguished, viz.: humic, mainly humic, mixed, mainly kerogenous, kerogenous. This classification

is based on the hydrogen content of the organic matter.

Source rocks with organic matter of kerogenous, mainly kerogenous and/or mixed type generate predominantly oil. Organic matter of humic type generates gas only. Strata with organic matter of mainly humic quality generate either gas, or gas and oil.

In addition to the type and the concentration of the organic matter, the source rock quality is also characterised by the distribution of the typical organic constituents, or macerals¹, in the sediments. The maceral distribution can be used to further qualify the source rock, especially when mainly humic quality is found. For this purpose a microscopic investigation on polished rock fragments is carried out.

The maturity of source rocks is expressed in terms of degree of organic metamorphism. With increasing degree of organic metamorphism the organic matter is gradually carbonised while generating hydrocarbons. With increased carbonification the light reflectance of vitrinite, one of the coal macerals, increases. The degree of organic metamorphism can be assessed by measuring this reflectance.

- 1) maceral: an organic constituent which can be recognised with the microscope (with objectives 25x to 50 x).

II RESULTS

a. Source rock indications.

In general the samples show low source rock indication values (varying from insignificant up to 150 units). Intervals 1200 - 1426, 1716 - 1860 and 2196 - 2286 m show insignificant source rock indication values (smaller than 30 units). Samples 1923, 1941, 2295, 2304 and 2313 m show source rock indication values between 340 units up to larger than 900 units.

b. Vitrinite reflectance measurements.

Only one sample contained suitable vitrinite for reflectance measurements:

sample 1923m: VR = 0.64 ± 0.03 (DOM = 61 ± 1).

c. Type of organic matter.

The type of organic matter was determined in thirteen samples with the following results:

sample 730 m - humic/mainly humic
,, 850 m - humic/mainly humic
,, 900 m - mainly humic
,, 1100 m - mainly humic/mixed
,, 1190 m - mainly humic/mixed
,, 1435 m - mixed
,, 1680 m - mainly humic
,, 1869 m - mainly humic
,, 1923 m - humic
,, 2088 m - kerogenous
,, 2304 m - humic/mainly humic
,, 2349 m - mainly humic
,, 2412 m - kerogenous

d. Organic carbon content.

The organic carbon content was measured in thirteen samples with the following results:

sample	730 m	-	1.6 %C
,,	850 m	-	1.1 %C
,,	900 m	-	2.8 %C
,,	1100 m	-	1.2 %C
,,	1190 m	-	1.0 %C
,,	1435 m	-	1.4 %C
,,	1680 m	-	1.9 %C
,,	1869 m	-	0.8 %C
,,	1923 m	-	30.3 %C
,,	2088 m	-	1.1 %C
,,	2304 m	-	22.1 , 21.3 %C
,,	2349 m	-	4.3 , 4.3 %C
,,	2412 m	-	0.6 %C

V MACERAL DESCRIPTION

For a better understanding of the source rock evaluation it was felt necessary to carry out maceral description. Twelve samples were investigated at 610, 730, 900, 1100, 1435, 1680, 1869, 1923, 2088, 2304, 2349 and 2412 m.

Sample 610 m: rare sapropelic organic matter (SOM); rare detrital vitrinite; rare liptodetrinite/microplankton. Contamination observed.

Sample 730 m: few SOM; rare detrital vitrinite; rare liptodetrinite/microplankton.

Sample 900 m: SOM present; few detrital vitrinite; few liptodetrinite, expulsion products and micrinite; rare microplankton. Some oxidation features observed. Solid hydrocarbons observed.

Sample 1100 m: few SOM; rare detrital vitrinite; rare liptodetrinite/microplankton. Some oxidation features.

Sample 1435 m: rare SOM; rare detrital vitrinite; rare liptodetrinite/microplankton; rare micrinite; expulsion products present. Solid hydrocarbons observed.

Sample 1680 m: rare SOM; rare liptodetrinite/microplankton; few expulsion products. Abundant coal particles resembling fossil wood (contamination?).

Sample 1869 m: rare liptodetrinite/microplankton; few expulsion products. Some coal particles observed, resembling fossil wood (contamination?).

Sample 1923 m: few SOM; abundant vitrinite; sporinite, liptodetrinite, fusinite and micrinite present; rare resinite and expulsion products.

Sample 2088 m: few SOM; rare detrital vitrinite; liptodetrinite and expulsion products present; few microplankton. Solid hydrocarbons observed.

Sample 2304 m: few SOM; abundant vitrinite; sporinite, liptodetrinite and micrinite present; rare cutinite, expulsion products; few microplankton and fusinite.

Sample 2349 m: few SOM; rare detrital vitrinite; rare sporinite, cutinite, liptodetrinite, expulsion products and fusinite. Some oxidation features. Some coal particles observed (contamination?).

Sample 2412 m: rare SOM; rare detrital vitrinite; few liptodetrinite/microplankton and expulsion products. Solid hydrocarbons observed. Sample partly severely oxidised.

On the basis of microscope observations, we conclude that samples 610, 1680 and 1869 contain too small amounts of organic matter to qualify as source rock.

The type of the organic matter in samples 730, 900, 1100, 1435, 2088, 2349 and 2412 is sapropelic organic matter (SOM) together with some detrital vitrinite and some liptodetrinite/microplankton, and is therefore considered favourable for oil and gas generation. The type of the organic matter in samples 1923 and 2304 is predominantly vitrinite and SOM, together with liptinites, and is therefore considered favourable for both gas and (some) oil generation.

The amount and the habit of the organic matter in the samples lead to the following conclusions:

- samples 730, 1100, 1435, 2088, 2349 and 2412 contain gas source rocks only;
- samples 900, 1923 and 2304 are considered to contain gas source rock and marginal oil source rock.

Microscope observations of samples in interval 480 - 650 m shows that all samples are severely contaminated. The autochthonous matter contains no source rock particles.

Samples 1680, 1869 and 2349 (?) contain coal particles resembling fossil wood. These coal particles are interpreted as contamination (mud-additive?).

The organic matter in samples 1435, 1923 and 2304 shows initial conversion features.

Samples 900, 1435, 2088 and 2412 contain solid hydrocarbons.

VI CONCLUSIONS

A suite of cutting samples of sediments (interval 480 - 2430 m) penetrated by well 31/2-1, Norway, has been investigated for the presence of source rock and maceral content.

The results indicate that interval 480 - 650 m is severely contaminated. Microscopically no source rocks were detected in this interval.

Interval 710 - 1190 m contains source rock for gas. Within this interval marginal, immature source rocks for oil are present in interval 880 - 950 m. The quality of the organic matter is humic to mixed. The organic carbon content ranges between 1.0 and 2.8 %C.

Intervals 1435 - 1450 m, 1869 - 2187 m and 2295 - 2421 m contain source rock for gas. The quality of the organic matter is humic to mixed. Samples 2088 and 2412 show a quality of kerogenous type; this is probably due to the presence of solid hydrocarbons in these samples. The organic carbon content ranges between 0.6 and 30.3 %C. Within these intervals, samples 1923, 1941, 2295, 2304 and 2313 contain also immature/mature, marginal source rock for oil. These samples can be described as containing SOM-coaly shales and coal particles. The organic carbon content of these samples ranges between 21.3 and 30.3 %C. The quality of the organic matter of these samples is humic to mainly humic.

In a number of samples solid hydrocarbons are detected.

Some samples contain coal particles resembling fossil wood; these particles are interpreted as contamination (mud-additive ?).

VITRINITE REFLECTANCE

COUNTRY : NORWAY
WELL/OUTCROP : 31/2-1
DEPTH/SAMPLE NR. : 1923 M
SAMPLE TYPE : CUTTING SAMPLE

MEAN : 0.64
DEVIATION : 0.03
MODE : MULTI
MEASUREMENTS : 14

ANALIST: LHT D. D. : 09-JAN-80

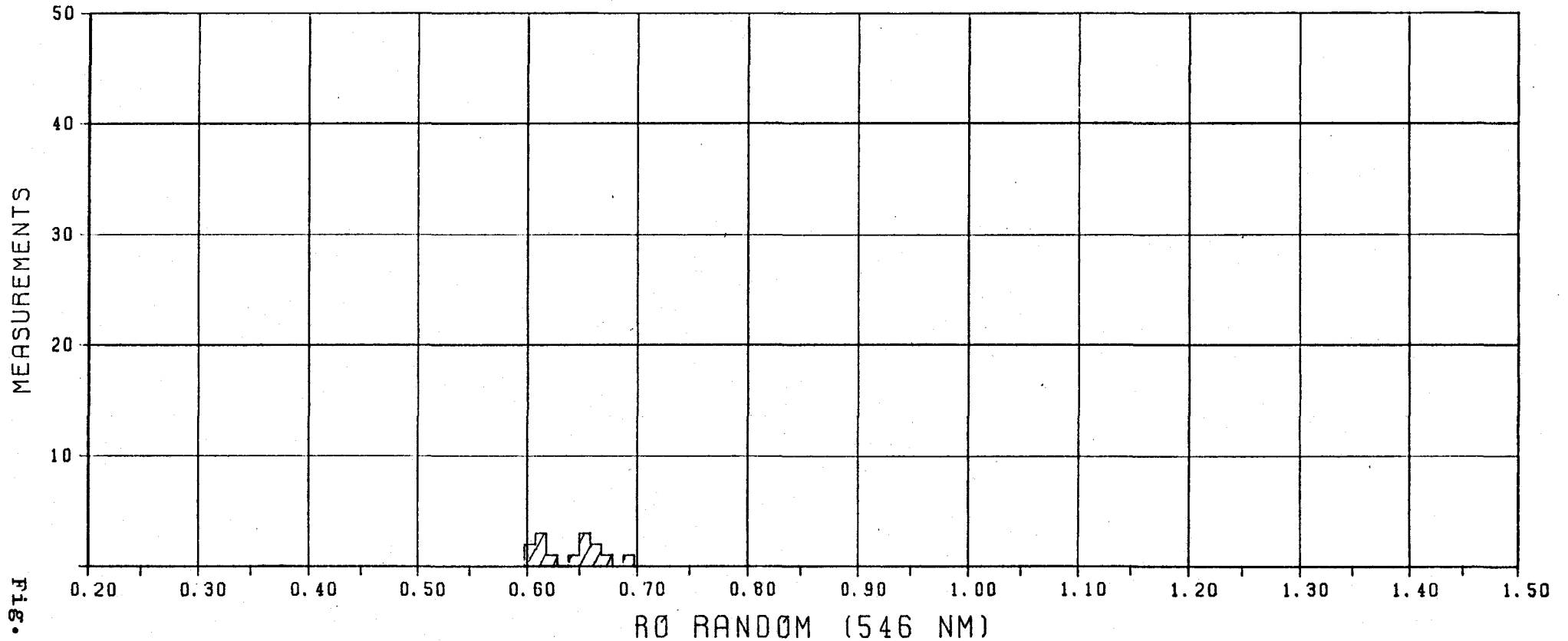


FIG. 1

VITRINITE REFLECTANCE HISTOGRAM

TABLE I (PART 1)

WELL:

31/2-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
M		BEFORE EXTR.	AFTER EXTR.		%W
480	C	50 C	40 C		-
490	C	15 C	- C		-
500	C	125 C	145 C		-
510	C	50 C	45 C		-
520	C	15 C	- C		-
530	C	35 C	65 C		-
540	C	20 C	- C		-
550	C	35 C	40 C		-
560	C	15 C	- C		-
570	C	10 C	- C		-
580	C	40 C	40 C		-
590	C	50 C	50 C		-
600	C	40 C	65 C		-
610	C	100 C	55 C		-
620	C	90 C	100 C		-
630	C	100 C	30 C		-
640	C	170 C	65 C		-
650	C	15 C	- C		-
660	C	20	-		-
670	C	15	-		-
680	C	15	-		-
690	C	25	-		-
700	C	20	-		-
710	C	45 C	25 C		-
720	C	75 C	35 C		-
730	C	35	35	H/MH	1.6
740	C	25	-		-
750	C	20	-		-
760	C	30	30		-
770	C	45 C	35 C		-

TABLE I (PART 2)

WELL:

31/2-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
M		BEFORE EXTR.	AFTER EXTR.		%
780	C	25	-		-
790	C	35	20		-
800	C	20	-		-
810	C	75	25		-
820	C	15	-		-
830	C	30	30		-
840	C	30	30		-
850	C	45	40	H/MH	1.1
860	C	40	30		-
870	C	40	40		-
880	C	145	90		-
890	C	140	105		-
900	C	170	125	MH	2.8
910	C	140	155		-
920	C	125	130		-
930	C	165	145		-
940	C	125	125		-
950	C	100	95		-
960	C	85	80		-
970	C	75	70		-
980	C	50	60		-
990	C	65	65		-
1000	C	65	60		-
1010	C	40	65		-
1020	C	30	45		-
1030	C	40	55		-
1040	C	35	50		-
1050	C	50	55		-
1060	C	35	30		-
1070	C	45	50		-

TABLE I (PART 3)

WELL:

31/2-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
M		BEFORE EXTR.	AFTER EXTR.		%W
1080	C	35	35		-
1090	C	40	65		-
1100	C	40	50	MH/M	1.2
1110	C	40	45		-
1120	C	30	30		-
1130	C	15	-		-
1140	C	20	-		-
1150	C	15	-		-
1160	C	30	30		-
1170	C	30	25		-
1180	C	35	35		-
1190	C	45	40	MH/M	1.0
1200	C	15	-		-
1210	C	20	-		-
1220	C	25	-		-
1230	C	20	-		-
1240	C	20	-		-
1250	C	20	-		-
1260	C	20	-		-
1270	C	20	-		-
1280	C	15	-		-
1290	C	15	-		-
1300	C	15	-		-
1310	C	10	-		-
1320	C	10	-		-
1330	C	5	-		-
1339	C	5	-		-
1348	C	10	-		-
1357	C	10	-		-
1366	C	10	-		-

TABLE I (PART 4)

WELL:

31/2-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
M		BEFORE EXTR.	AFTER EXTR.		%W
1375	C	10	-		-
1384	C	5	-		-
1390	C	10	-		-
1399	C	10	-		-
1408	C	10	-		-
1417	C	20	-		-
1426	C	15	-		-
1435	C	40	55	M	1.4
1444	C	50 C	35 C		-
1450	C	45 C	45 C		-
1671	C	40 C	20 C		-
1680	C	160 C	155 C	MH	1.9
1689	C	35 C	20 C		-
1698	C	20	-		-
1707	C	65 C	30 C		-
1716	C	20	-		-
1725	C	25	-		-
1734	C	25	-		-
1743	C	10	-		-
1752	C	20	-		-
1761	C	10	-		-
1770	C	5	-		-
1779	C	5	-		-
1788	C	5	-		-
1797	C	5	-		-
1806	C	5	-		-
1815	C	5	-		-
1824	C	10	-		-
1833	C	15	-		-
1842	C	20	-		-

TABLE I (PART 5)

WELL:

31/2-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
M		BEFORE EXTR.	AFTER EXTR.		%
1851	C	15	-		-
1860	C	20	-		-
1869	C	50 C	40 C	MH	.8
1878	C	15	-		-
1887	C	10	-		-
1896	C	35	55		-
1905	C	130	85		-
1914	C	60	75		-
1923	C	900	900	H	30.3
1932	C	160	110		-
1941	C	465	340		-
1950	C	155	150		-
1959	C	130	100		-
1968	C	125	90		-
1971	C	25	-		-
1980	C	35	40		-
1989	C	50	25		-
1998	C	50	50		-
2007	C	20	-		-
2016	C	65	50		-
2025	C	25	-		-
2034	C	30	35		-
2043	C	20	-		-
2052	C	20	-		-
2061	C	55	45		-
2070	C	70	60		-
2079	C	70	70		-
2088	C	100	70	K	1.1
2097	C	35	45		-
2106	C	40	40		-

TABLE I (PART 6)

WELL:

31/2-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
M		BEFORE EXTR.	AFTER EXTR.		%W
2115	C	50	50		-
2124	C	90	75		-
2133	C	30	30		-
2142	C	40	50		-
2151	C	75	55		-
2160	C	45	30		-
2169	C	45	40		-
2178	C	40	35		-
2187	C	35	10		-
2196	C	15	-		-
2205	C	20	-		-
2214	C	10	-		-
2223	C	20	-		-
2232	C	10	-		-
2241	C	20	-		-
2250	C	15	-		-
2259	C	20	-		-
2268	C	20	-		-
2277	C	15	-		-
2286	C	15	-		-
2295	C	650	610		-
2304	C	900	900	H/MH	22.1
2304	C	900	900	H/MH	21.3
2313	C	450	420		-
2322	C	65	55		-
2331	C	60	40		-
2340	C	50	45		-
2349	C	210 C	185 C	MH	4.3
2349	C	215 C	185 C	MH	4.3
2358	C	20	-		-

TABLE I (PART 7)

WELL:

31/2-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
M		BEFORE EXTR.	AFTER EXTR.		%W
2367	C	20	-		-
2376	C	40	25		-
2385	C	30	15		-
2394	C	30	10		-
2403	C	25	-		-
2412	C	75	30	K	.6
2421	C	50	30		-
2430	C	20	-		-

TYPE OF SAMPLE C = CUTTINGS, R = CORE, S = SIDEWALL SAMPLE

CONTAMINATION : W = WALNUT FRAGMENTS OR SOME SIMILAR PRODUCT,
E = CELLOPHANE SHREDS, F = FIBRES, P = PLASTIC OR PAINT AND
C = CONTAMINATED BUT KIND NOT SPECIFIED

A DASH (-) INDICATES TEST NOT MADE, ASTERISKS INDICATE THE
ORGANIC CARBON CONTENT IS THE AVERAGE FOR THE SAMPLES CONCERNED

INITIAL DISTRIBUTION

38 copies area

GEOCHEMICAL LOG

WELL

31/2-1

SCALE 1:5000

LOCATION

REGIO IDENTIFIER

AGE	FORMATION	DEPTH IN M	LITHOLOGY	DOM	SOURCE ROCK INDICATION OF ORIGINAL SAMPLE						TYPE OF SAMPLE	SOURCE ROCK INDICATION OF SAMPLE AFTER EXTRACTION WITH CHLOROFORM						CONTAMINATION	DEPTH IN M	ORG. CARBON (PCT. WT)	TYPE OF ORGANIC MATTER
					100	200	300	400	500	600		100	200	300	400	500	600				
		0																			
		100																			
		200																			
		300																			
		400																			
		500																			
		600																			
		700																1.8		HUMIC TO MAINLY HUMIC	
		800																1.1		HUMIC TO MAINLY HUMIC	
		900																2.8		MAINLY HUMIC	
		1000																			
		1100																			
		1200																			
		1300																			
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		1800																			
		1900																			
		2000																			
		2100																			
		2200																			
		2300																			
		2400																			
		2500																			

VALUES SMALLER THAN 30 ARE CONSIDERED
NOT TO BE OF SIGNIFICANCE

INTERVAL 880- 950M CONTAINS
MARGINAL SOURCE ROCK FOR OIL.

INTERVAL 710- 1190M CONTAINS
SOURCE ROCK FOR GAS.

INTERVAL 1435- 1450M CONTAINS
SOURCE ROCK FOR GAS.

INTERVAL 1869- 2187M
AND
INTERVAL 2285- 2421M
CONTAIN SOURCE ROCK
FOR GAS.

SAMPLES 1923, 1941, 2285, 2304
AND 2313M CONTAIN MARGINAL
SOURCE ROCK FOR OIL.

NUMBER OF SAMPLES ANALYSED 188

NUMBER OF SAMPLES ANALYSED 104

LEGEND

TYPE OF SAMPLE
 @ = CORE
 p = SIDEWALL SAMPLE
 CONTAMINATION
 C = UNSPECIFIED
 M = MALLNUTS
 E = CELLOPHANE
 F = FIBRES
 P = PLASTIC OR PAINT

NO. ANALYSE/DEPTH
 EXPLANATION OF ABBREVIATIONS

GEOCHEMICAL LOG OF
 31/2-1
 NORWAY