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EVALUATION OF SOURCE ROCK PROPERTIES OF SEDIMENTS PENETRATED BY WELL 31/2-3, NORWAY

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Investigation
9.12.342

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CONTENTS

I INTRODUCTION

A suite of cutting samples and one sidewall sample from the Norwegian off-shore well 31/2-3 have been studied to detect their source rock properties.
A location sketch map is given on figure 1.
The samples cover the interval 1182 - 2601 m.

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 macerals[1], 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 summary of the analytical results is given below. The results are displayed graphically on the geochemical log (enclosure 1) and are detailed on table I.

The results discussed subsequently are partly due to the presence of allochthonous coal particles used as drilling mud-additives and do not visualize source rock properties alone.

a) Source rock properties

- The section 1182 - 1464 m does not supply any source rock indications.
- From the interval 1648 - 1811 m some marginal to genuine SRI values were obtained.
- The section 1828 - 1882 m supplied high SRI values, often >900 units.
- The part 1891 - 2224 m is characterized by values varying irregularly from 0 to >900.
- The interval 2233 - 2263 m shows genuine SRI values, ranging from 120 to >900 units.
- The section 2272 - 2506 m is charcterized by strongly fluctuating (mostly marginal) SRI values.
- From underneath 2510 m no significant SRI values were obtained.

b) Type of organic matter

The type of organic matter has been determined by pyrolysis gas chromatography in some selected samples. All samples showed an intermediate to low hydrogen content ("mixed" to "humic").

c) Organic carbon content

The organic carbon contents, measured in some selected samples, coincide fairly well with the amount of pyrolysable matter.

d) Maceral content

Sample 1660 m: Rare sapropelic organic matter;
rare sporinite, cutinite, liptodetrinite;
few exsudatinite;
rare fusinite.
Few vitrinite (contamination).
Rare solid hydrocarbons.

Sample 1792 m: Rare SOM;
rare liptodetrinite;
few exsudatinite.
Rare vitrinite (contamination).
Few solid hydrocarbons.

Sample 1867 m: Autochthonous vitrinite common;
resinite and liptodetrinite common;
abundant fusinite.
Some oxidation features.

Sample 1873 m: Few SOM;
autochthonous vitrinite common, grading into SOM;
sporinite and liptodetrinite common;
rare cutinite and resinite;
few exsudatinite;
fusinite common.
Vitrinite (contamination) common.
Solid hydrocarbons common.

Sample 1942 m: Few SOM;
few autochthonous vitrinite,grading into SOM;
few sporinite and liptodetrinite;
rare cutinite and resinite;
few exsudatinite;
fusinite common.
Few vitrinite (contamination).
Few solid hydrocarbons.
Pyrite shows oxidation features.

Sample 1996 m: Rare SOM;
few autochthonous vitrinite;
few sporinite and liptodetrinite;
rare cutinite and resinite;
few exsudatinite;
few fusinite.
Abundant vitrinite (contamination).
Pyrite shows oxidation features.

Sample 2233 m: Few SOM;
few vitrinite (autochthonous), grading into SOM;
few liptodetrinite;
rare sporinite and resinite, which shows migration features;
rare microplankton;
few exsudatinite;
few fusinite.
Abundant vitrinite (contamination).
Rare solid hydrocarbons.
Pyrite shows oxidation features.

Sample 2299 m: Rare SOM;
rare autochthonous vitrinite;
rare sporinite, resinite and liptodetrinite;
rare microplankton;
few exsudatinite;
rare fusinite.
Common vitrinite (contamination).
Resins showing migration features.
Sample partly oxidized.

Sample 2404 m: Rare SOM;
rare autochthonous vitrinite;
rare sporinite, cutinite and resinite;
few liptodetrinite;
rare microplankton;
few exsudatinite;
rare fusinite.
Vitrinite (contamination) common.
Few solid hydrocarbons.
Resins showing migration features.
Sample severely oxidized.

Part of the vitrinite, present in all the cutting samples, is characterized by a low maturity level not changing with depth; it does not represent autochthonous organic matter but some mud-additives.

e) Degree of organic metamorphism

In the sidewall sample 1867 m the maturity level could be estimated:
VR.E = 0.55 - 0.62.

III DISCUSSION AND CONCLUSIONS

As in nearly the whole section below a depth of approximately 1600 m coal particles have been used as an additive to the drilling mud, the detection of genuine, autochthonous source rock intervals is biased to some extent.
However, a thorough microscopic investigation of a set of selected samples, combined with the lithological information from the completion log, allows the following subdivision:

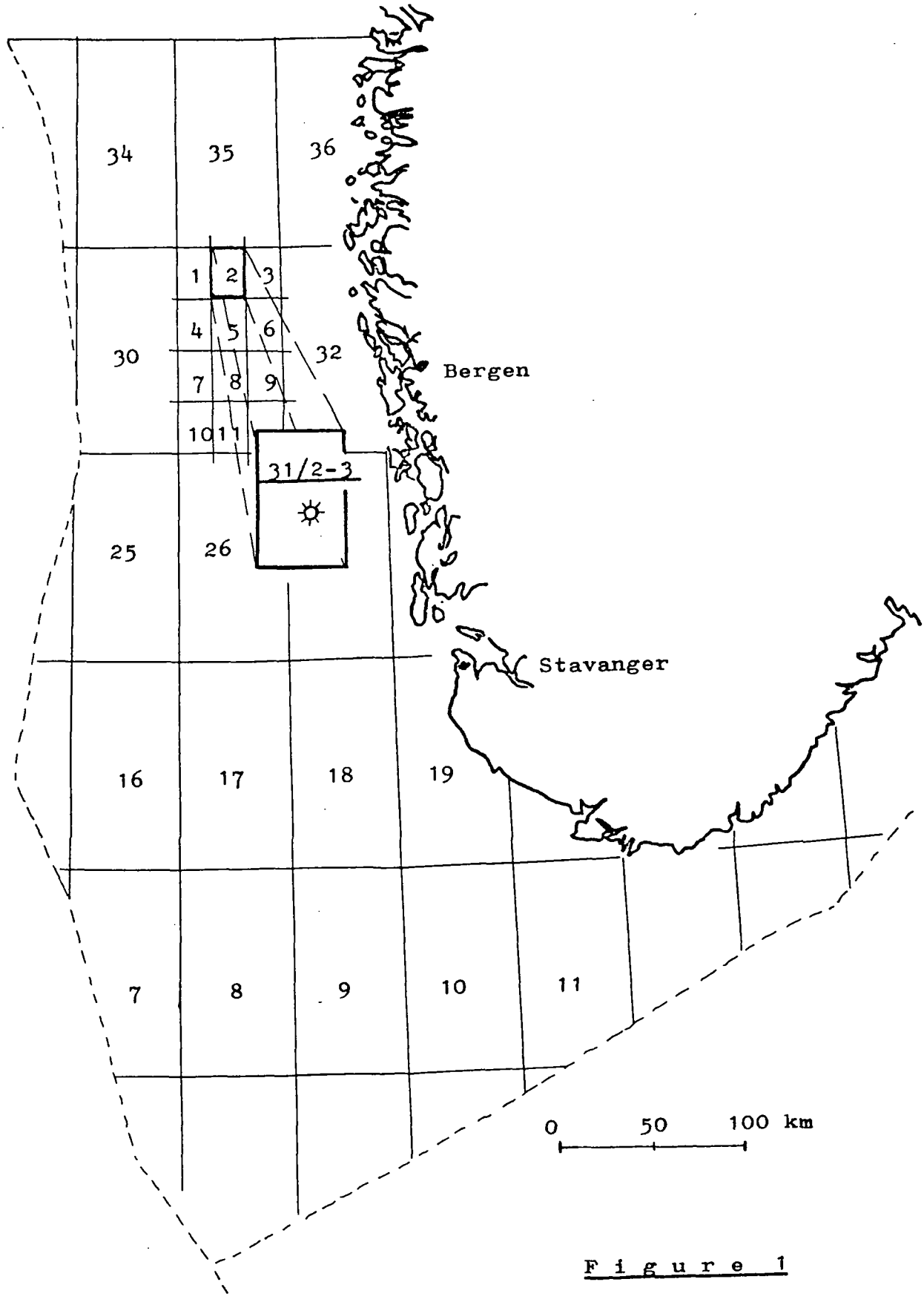
The section 1648 - 1811 m, studied microscopically in the samples 1660 and 1792 m, does not contain enough autochthonous organic matter to qualify as a source rock.

The interval 1828 - 1882 m, representing a coal-section, is characterized by high SRI values (> 900 units in sidewall sample 1867 m). The (autochthonous) maceral composition of the samples 1867 m and 1873 m is dominated by vitrinite, besides of various liptinites and, in sample 1873 m, some SOM. This composition enables the generation of gas mainly. The liptinites and the SOM can be regarded as the precursors of a minor amount of oil.
The maturity level has been estimated as VR.E = 0.55-0.62, indicating an immature stage for any hydrocarbon generation.

The high SRI values and the considerable organic carbon content of the section 1891 - 2224 m are considered to be due to caving from the above-mentioned interval and to the mud-additives.

The coal-bearing interval 2233 - 2263 m was studied microscopically in sample 2233 m. The major part of the vitrinite is regarded as contamination, whereas the SOM, the minor part of the vitrinite and the liptinites are considered as autochthonous organic matter. This composition enables theoretically the generation of gas and oil. The overall habitat of the SOM indicates an inferior oil potential, however. Hence it follows that this interval contains source rocks for gas only. They are immature for oil generation because no conversion of the SOM could be observed.

The section below 2263 m is considered to be barren of source rocks. As shown in cutting samples 2299 and 2404 m, the significant pyrolysis yields are owing to the common vitrinite regarded as mud-additives.


34
35
36
1
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6
30
32
7
8
9
10
11
31/2-3
25
26
Bergen
Stavanger
16
17
18
19
7
8
9
10
11
0
50
100 km

Figure 1

TABLE I (PART 1) WELL: 31/2-3

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.		TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %W
1182	C	20	-			-
1191	C	20	-			-
1200	C	20	-			-
1209	C	5	-			-
1218	C	10	-			-
1227	C	25	-			-
1236	C	10	-			-
1245	C	10	-			-
1254	C	20	-			-
1263	C	10	-			-
1272	C	10	-			-
1281	C	10	-			-
1290	C	15	-			-
1299	C	10	-			-
1308	C	20	-			-
1317	C	10	-			-
1326	C	15	-			-
1335	C	10	-			-
1344	C	10	-			-
1362	C	15	-			-
1374	C	5	-			-
1383	C	20	-			-
1392	C	10	-			-
1401	C	15	-			-
1413	C	10	-			-
1464	C	5	-			-
1648	C	45	90	C		-
1666	C	145	105	C	M	1.0
1669	C	60	50	C		-
1678	C	25	-			-

TABLE I (PART 2) WELL: 31/2-3

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.		TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT % W
1696	C	5	-			-
1699	C	5	-			-
1726	C	5	-			-
1728	C	20	-			-
1729	C	15	-			-
1736	C	35	20	C		-
1747	C	30	40	|		-
1756	C	20	-	|		-
1768	C	30	20	|		-
1774	C	45	40	C		-
1783	C	60	70	C		-
1792	C	60	50	|	M	-
1803	C	65	70	|		.8
1811	C	60	40	C		-
1826	C	200	170			-
1837	C	415	430			-
1848	C	> 900	> 900			-
1860	C	> 900	> 900			-
1864	C	> 900	> 900		MH	-
1867	C	> 900	> 900		MH	-
1875	C	> 900	> 900			-
1882	C	> 900	700			9.1
1891	C	200	190			-
1900	C	365	260	C		-
1909	C	625	510	C		-
1924	C	> 900	720	C		-
1933	C	450	340	|		-
1942	C	> 900	> 900	|		-
1951	C	75	60	|		-
1963	C	335	320	C		-

TABLE I (PART 2) WELL: 31/2-3

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.		SOURCE ROCK INDICATION AFTER EXTR.		TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
m							%
1984	C	265		190	C		2.6
1990	C	> 900	>	900	|	MH	-
2017	C	600		500	|		-
2026	C	110		100	|		-
2035	C	30		20	C		-
2044	C	210		200	C		-
2055	C	70		50	|		-
2062	C	205		140	|		-
2071	C	300		285	|		-
2080	C	410		330	C	M	-
2092	C	100		90	C		-
2110	C	5		-	|		-
2140	C	100		70	|		-
2149	C	170		100	|		-
2160	C	50		40	C		-
2167	C	90		40	C		1.1
2176	C	190		130	|		-
2185	C	120		80	|		-
2194	C	70		30	|		-
2205	C	130		80	C		-
2215	C	270		170	C		-
2224	C	120		90			-
2233	C	> 900	>	900		M	14.1
2233	C	> 900	>	900		M	14.3
2245	C	830		280			-
2254	C	490		380			-
2263	C	190		120			-
2272	C	60		40	C		-
2281	C	210		130	|		-
2290	C	65		60	C		-

TABLE I (PART 4) WELL: 3172-3

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.		TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %
2295	C	155	130	C		-
2306	C	10	-			-
2317	C	10	-			-
2326	C	110	90			-
2335	C	60	70	C		-
2347	C	65	80	C		-
2359	C	75	50			-
2366	C	60	40			-
2377	C	35	30	C		-
2386	C	10	-			-
2395	C	10	-			-
2404	C	230	200	C		-
2416	C	95	110			-
2425	C	150	140			-
2437	C	155	80	C		-
2446	C	100	150	C		-
2456	C	155	165		MH	-
2464	C	100	90			-
2475	C	65	80	C		1.0
2486	C	25	-			-
2497	C	45	30	C		-
2506	C	40	40	C		-
2515	C	5	-			-
2524	C	25	-			-
2533	C	10	-			-
2542	C	20	-			-
2551	C	5	-			-
2560	C	20	-			-
2572	C	5	-			.2
2581	C	5	-			-

TABLE I (PART B) WELL: 3172-3

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %
2596	C	S	-		-
2599	C	CS	-		-

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

CONTAMINATION : W = WALNUT FRAGMENTS OR SOME SIMILAR PRODUCT, E = CELLOPHANE SHEDS, 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

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