KONINKLIJKE / SHELL EXPLORATIE EN PRODUKTIE LABORATORIUM
RIJSWIJK, THE NETHERLANDS

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EVALUATION OF SOURCE ROCK PROPERTIES OF SEDIMENTS PENETRATED BY THE NORWEGIAN OFF-SHORE WELL 31/2-2

by

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Investigation

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CONTENTS

I INTRODUCTION

A source rock evaluation study has been carried out on a suite of cutting samples from the North Sea well 31/2-2, off-shore Norway (for the approximate location see figure 1). The samples cover the interval from 1150 to 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

The analytical results, displayed graphically on the geochemical log and tabulated on table I may be summarized and commented as follows:

a) Source rock indications

The significant source rock indications may be grouped in the following way:

1485 - 1545 m : maximum 290 units
1566 - 1602 m : 30 - 170 units
1662 - 1770 m : up to 180 units
1935 - 1944 m : 65 - 295 units
1977 - 2037 m : mainly > 900 units
2118 - 2157 m : 60 - 260 units
2181 - 2196 m : 45 - 120 units
2361 - 2406 m : 20 - > 900 units.

b) Type of organic matter

Considering the hydrogen-content, most of the samples are of an intermediate type ("mainly humic" to "mainly kerogenous").
In some samples, the results could be slightly influenced (that means shifted towards the "humic" side) by the presence of contaminants (rubber, mud-additives).

c) Organic carbon content

The organic carbon contents, measured in some selected samples, harmonize pretty well with the source rock indications.

d) Maceral descriptions

Sample 1515 m: Sapropelic organic matter (SOM) common;
few vitrinite;
few liptodetrinite;
rare sporinite and tasmanite;
few microplankton;
rare fusinite;
few micrinite.
SOM partly converted; sample slightly oxidised.

Sample 1596 m: SOM common;
rare vitrinite;
rare sporinite and tasmanite;
few liptodetrinite;
few mikroplankton;
rare fusinite;
micrinite common;
SOM partly converted; sample slightly oxidised.
Rare solid hydrocarbons.
Some hydrocarbon - contamination (?).

Sample 1746 m: Rare SOM;
few vitrinite;
rare sporinite, cutinite, resinite and liptodetrinite;
rare fusinite.
Vitrinite grades into SOM and framboidal pyrite.
Sample slightly oxidised.
Some hydrocarbon - contamination (?).

Sample 1998 m: Vitrinite common;
sporinite and liptodetrinite common;
rare resinite;
few exsudatinite;
abundant fusinite.

Sample 2025 m: Few SOM;
abundant vitrinite;
sporinite and liptodetrinite common;
few cutinite and botryococcus;
few exsudatinite;
fusinite present;
few micrinite.
SOM initially converted.
Slightly oxidised.
Vitrinite grades into SOM.
Few solid hydrocarbons.

Sample 2136 m: Few SOM;
few vitrinite;
few sporinite and liptodetrinite;
rare microplankton;
rare exsudatinite;
fusinite common.
Slightly oxidised.
Some hydrocarbon - contamination (?).

Sample 2364 m: Few SOM;
abundant vitrinite;
sporinite and liptodetrinite common;
rare cutinite;
fusinite common.

e) Vitrinite reflectance

No vitrinite suitable for reflectance measurements was present.

In two samples the degree of organic metamorphism could be estimated:

Sample 1998 m: VR.E. = 0.55 - 0.62

Sample 2025 m: VR.E. = 0.60 - 0.70.

III COMMENTS AND CONCLUSIONS

The source rock indications allow the detection of several intervals with significant values suggesting the presence of source rocks. In the following these different sections will be discussed separately. The analyses are biased in some extent by the presence of cavings as well as contaminants of an organic origin (drilling mud-additives) which could not be removed completely.

The section 1485 - 1545 m (Kimmeridge Clay Formation) contains sapropelic organic matter as the main organic constituent. Although oil can be generated theoretically from this maceral, the overall habitat is not very favourable. The section has to be considered therefore as containing gas source rocks only.

The positive response upon pyrolysis of the samples from the interval 1566 - 1602 m is most likely to be due to cavings deriving from the interval mentioned above.

The interval 1665 - 1770 m supplies marginal to genuine SRI values. The microscopic study of sample 1746 m reveals a subordinate amount of organic matter only. It seems that the interval does not contain enough autochthonous organic matter to qualify as source rock. The positive pyrolysis yield is likely to be due to allochthonous organic material, being on one hand caving from the Kimmeridge Clay Formation, on the other hand contaminants (mud-additives).

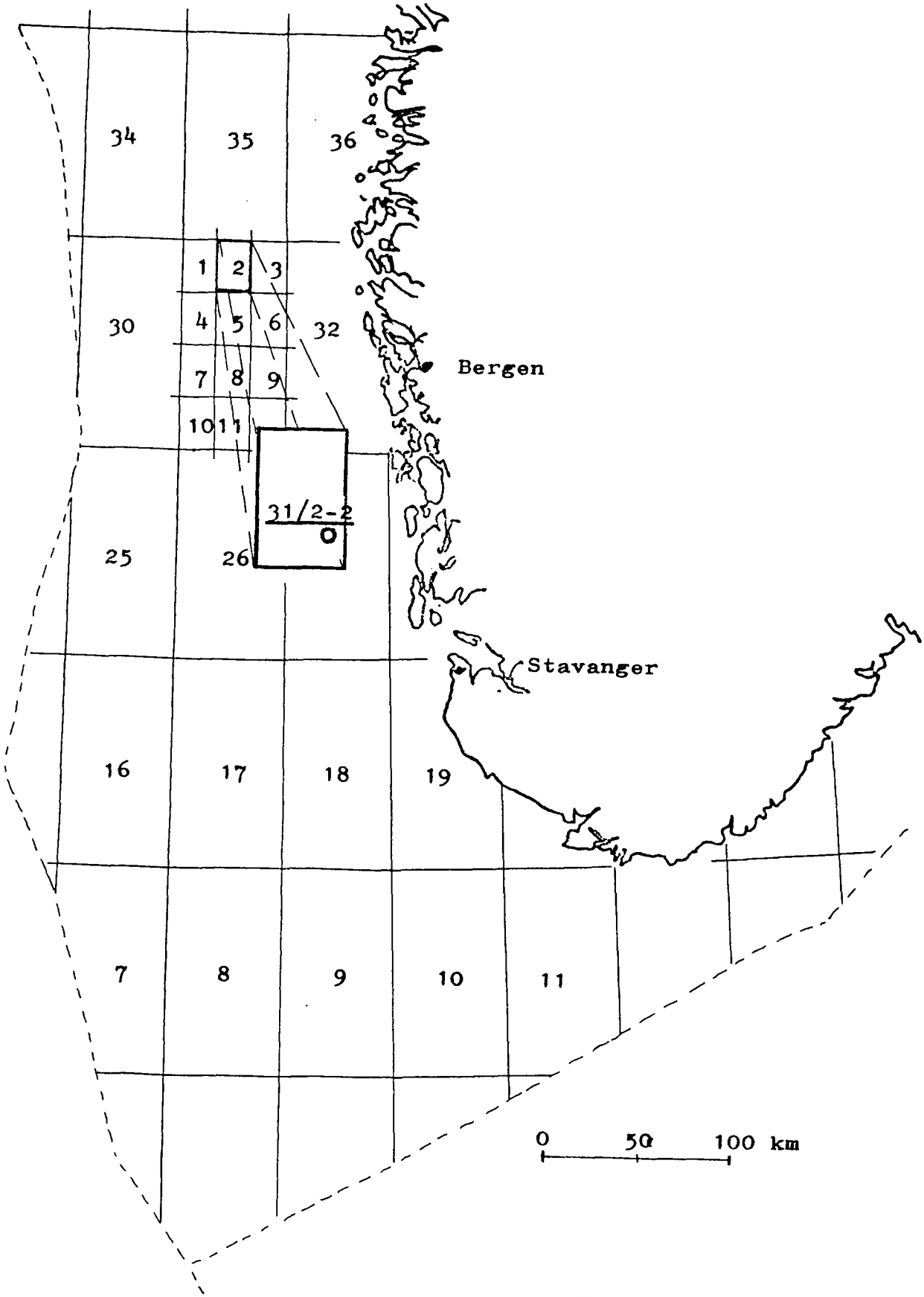
From the intervals 1935 - 1944 m and 1977 - 2037 m two samples have been studied microscopically.
In side wall sample 1998 m the major maceral is vitrinite, allowing the formation of gas.

Sample 2025 m shows gradation of the vitrinite into SOM. In the same sample, two different types of coal have been observed, showing different VR.E's of respectively 0.60 - 0.70 and ± 0.40. The latter type is interpreted as not being autochthonous (contamination ?). Although it has to be taken into account that this allochthonous organic matter influences both pyrolysis yield and organic carbon content, it may be concluded that the intervals contain good source rocks for gas and some marginal source rocks for oil.

In the intervals 2128 - 2157 m and 2181 - 2196 m, sample 2136 m was chosen for a microscopic investigation. The main organic constituents are vitrinite and sapropelic organic matter. The amount and the habitat of the organic matter suggest that both intervals can be interpreted as containing marginal to genuine source rocks for gas.

The section 2361 - 2406 m, studied microscopically in sample 2364 m, characterizes as containing good source rocks for gas.

Concerning the degree of maturity, the following comments can be made:
No vitrinite suitable for reflectance measurements was present. In two samples the degree of organic metamorphism could be estimated (sample 1998 m: VR.E = 0.55 - 0.62; sample 2025 m: VR.E = 0.60 - 0.70). Hence it follows that the lower part of the well is approaching maturity for oil generation. It is fully immature for gas generation. The conversion of the sapropelic organic matter observed in some samples (1515, 1596 and 2025 m) is not due to an advanced degree of coalification but has to be considered as the result of oxidation.


34
35
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32
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11
31/2-2
25
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Bergen
Stavanger
16
17
18
19
7
8
9
10
11
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50
100 km

Figure 1

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

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %
1150	C	25	-		-
1155	C	20	-		-
1161	C	55	40		-
1167	C	35	25		-
1173	C	20	-		-
1179	C	25	-		-
1185	C	40	40		-
1191	C	15	-		-
1197	C	10	-		-
1203	C	15	-		-
1209	C	15	-		-
1215	C	15	-		-
1221	C	20	-		-
1227	C	10	-		-
1233	C	15	-		1.2
1239	C	15	-		-
1245	C	10	-		-
1251	C	20	-		-
1257	C	15	-		-
1263	C	10	-		-
1269	C	5	-		-
1275	C	10	-		-
1281	C	5	-		-
1287	C	5	-		-
1293	C	5	-		-
1299	C	5	-		-
1305	C	5	-		-
1311	C	5	-		-
1317	C	5	-		-
1323	C	10	-		-

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

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %W
1329	C	5	-		-
1335	C	10	-		-
1341	C	5	-		-
1347	C	5	-		.5
1353	C	10	-		-
1359	C	5	-		-
1365	C	10	-		-
1371	C	10	-		-
1377	C	5	-		-
1383	C	5	-		-
1389	C	5	-		-
1395	C	10	-		-
1401	C	5	-		-
1407	C	5	-		-
1413	C	5	-		-
1419	C	10	-		-
1425	C	10	-		-
1431	C	5	-		-
1437	C	10	-		-
1443	C	10	-		-
1449	C	10	-		-
1455	C	5	-		-
1461	C	10	-		-
1467	C	5	-		-
1473	C	10	-		-
1479	C	15	-		-
1485	C	40	35		-
1488	C	180	145		-
1491	C	350	225		-
1494	C	155	190		-

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

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %W
1497	C	360	285		-
1500	C	170	155		-
1503	C	375	215		-
1506	C	175	135		-
1509	C	310	245		-
1512	C	150	140		-
1515	C	300	250	M	3.2
1518	C	260	230		-
1521	C	225	215		-
1524	C	285	155		-
1527	C	285	170		-
1530	C	295	165		-
1533	C	325	265		-
1536	C	335	290		-
1539	C	200	175		-
1542	C	255	190		-
1545	C	80	70		-
1554	C	25	-		-
1560	C	10	-		-
1566	C	35	30		-
1572	C	115	100		-
1575	C	125	60		-
1578	C	105	105		-
1581	C	40	35		-
1584	C	115	55		-
1587	C	105	65		-
1590	C	180	145		-
1593	C	140	125		-
1596	C	235	170	H	2.8
1602	C	80	65		-

TABLE I (PART 4) WELL: 31/2-2

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT % W
1608	C	20	-		-
1614	C	40	15		-
1620	C	20	-		-
1626	C	20	-		-
1632	C	45	35		-
1638	C	15	-		-
1644	C	10	-		-
1650	C	20	-		-
1656	C	10	-		-
1662	C	50	30		-
1665	C	150	115	MK/M	1.3
1668	C	105	80		-
1671	C	95	85		-
1674	C	85	70		-
1677	C	125	85		-
1680	C	170	140		-
1683	C	135	130		-
1686	C	175	180		-
1689	C	55	60		-
1692	C	55	65		-
1695	C	45	45		-
1698	C	60	40		-
1701	C	55	40		-
1704	C	45	45		-
1707	C	30	10		.9
1710	C	30	5		-
1713	C	40	35		-
1716	C	35	30		-
1719	C	40	30		-
1722	C	25	-		-

TABLE I (PART 5) WELL: 31/2-2

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %
1725	C	40	55		.9
1728	C	70	65		-
1731	C	20	-		-
1734	C	20	-		-
1737	C	60	80		-
1740	C	85	85		-
1743	C	125	85		-
1746	C	155	130	M	-
1749	C	110	120		-
1752	C	105	110		-
1755	C	100	70		-
1758	C	40	50		-
1761	C	175	135		-
1764	C	65	65		-
1767	C	115	90		-
1770	C	55	70		-
1776	C	20	-		-
1782	C	10	-		-
1788	C	30	30		-
1794	C	25	-		-
1800	C	5	-		-
1806	C	5	-		-
1812	C	5	-		-
1818	C	5	-		-
1824	C	5	-		-
1830	C	25	-		-
1836	C	35	30		-
1842	C	10	-		-
1851	C	5	-		-
1857	C	0	-		-

TABLE I (PART 6) WELL: 31/2-2

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %W
1863	C	60	-		-
1872	C	5	-		-
1875	C	5	-		-
1881	C	10	-		-
1887	C	5	-		-
1893	C	5	-		-
1899	C	5	-		-
1899	C	5	-		-
1905	C	5	-		-
1911	C	5	-		-
1917	C	15	-		-
1923	C	55	-		-
1929	C	10	-		-
1935	C	50	65		-
1938	C	115	150		-
1941	C	375	295	MH	5.1
1944	C	80	95		-
1947	C	10	-		-
1950	C	15	-		-
1953	C	5	-		-
1959	C	5	-		-
1965	C	15	-		-
1971	C	20	-		-
1977	C	65	75		-
1983	C	120	165		-
1986	C	85	170		-
1989	C	> 900	> 900		-
1992	C	> 900	> 900	H	57.6
1995	C	> 900	> 900		-
1998	C	> 900	> 900		-

TABLE I (PART 7) WELL: 31/2-2

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT % W
2004	C	265	230		-
2010	C	630	590	MH	-
2013	C	895	605		-
2016	C	235	230		-
2019	C	755	620		-
2022	C	> 900	> 900		-
2025	C	> 900	> 900	MH/H	27.1
2028	C	> 900	> 900		-
2031	C	195	195		-
2037	C	100	95		-
2043	C	15	-		-
2049	C	5	-		-
2055	C	5	-		-
2061	C	5	-		-
2067	C	5	-		-
2073	C	5	-		-
2079	C	115	115		-
2082	C	50	45		-
2085	C	10	-		-
2088	C	5	-		-
2091	C	15	-		-
2094	C	70	75		-
2097	C	65	55		-
2100	C	60	125	MH/M	2.1
2103	C	20	-		-
2106	C	20	-		-
2109	C	65	70		-
2112	C	50	55		-
2115	C	5	-		-
2118	C	45	80		-

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

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %W
2121	C	70	60		-
2124	C	105	120		-
2127	C	135	170		-
2130	C	265	130		-
2133	C	85	145		-
2136	C	260	145	MP/H	5.2
2139	C	180	260		-
2142	C	140	185		-
2145	C	115	130		-
2148	C	130	170		-
2151	C	215	180		-
2154	C	125	155		-
2157	C	230	205		-
2163	C	25	-		-
2169	C	5	-		-
2175	C	5	-		-
2181	C	110	120		-
2184	C	50	50		-
2187	C	100	100		2.5
2193	C	55	45		-
2196	C	100	85		-
2199	C	30	20		-
2202	C	15	-		-
2205	C	40	35		-
2208	C	30	30		-
2211	C	35	25		-
2214	C	20	-		-
2217	C	40	30		-
2220	C	15	-		-
2223	C	60	25		-

TABLE I (PART 9) WELL: 31/2-2

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT % W
2229	C	10	-		-
2235	C	10	-		-
2241	C	10	-		-
2253	C	5	-		-
2259	C	5	-		-
2265	C	5	-		-
2271	C	10	-		-
2277	C	10	-		-
2283	C	5	-		-
2289	C	5	-		-
2295	C	5	-		-
2301	C	5	-		.2
2307	C	5	-		-
2313	C	5	-		-
2319	C	5	-		-
2325	C	5	-		-
2331	C	15	-		-
2337	C	5	-		-
2343	C	15	-		-
2349	C	15	-		-
2355	C	20	-		-
2361	C	> 900	> 900		-
2364	C	> 900	> 900	MH /M	28.6
2367	C	> 900	> 900		-
2370	C	> 900	780		-
2373	C	70	45		-
2376	C	150	90		-
2379	C	300	195		-
2382	C	290	165		-
2385	C	310	185		-

TABLE I (PART 10) WELL: 31/2-2

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %W
2388	C	345	220		-
2391	C	175	100		-
2394	C	95	70		-
2397	C	55	40		-
2400	C	35	20		-
2403	C	700	65		-
2406	C	325	205		-
2409	C	25	-		-
2412	C	15	-		-
2415	C	95	20		-
2418	C	20	-		-
2421	C	550	40		1.5
427	C	15	-		-
2433	C	5	-		-
2439	C	10	-		-
2445	C	5	-		-
2451	C	5	-		-
2457	C	5	-		-
2463	C	5	-		-
2469	C	5	-		-
2475	C	5	-		-
2481	C	5	-		-
2487	C	5	-		-
2493	C	20	-		-
2499	C	5	-		-
2505	C	5	-		-
2511	C	5	-		-
2517	C	5	-		-
2523	C	5	-		-
2529	C	5	-		-

TABLE I (PART 11) WELL: 31/2-2

DEPTH M	TYPE OF SAMPLE	SOURCE ROCK INDICATION BEFORE EXTR.	SOURCE ROCK INDICATION AFTER EXTR.	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT %W
2535	C	5	-		-
2541	C	5	-		-
2547	C	5	-		-
2553	C	5	-		-
2559	C	5	-		-
2565	C	5	-		.2
2571	C	5	-		-
2577	C	5	-		-
2583	C	5	-		-
2589	C	5	-		-
2595	C	5	-		-
2601	C	5	-		-

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

3 copies area