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GEOCHEMICAL SERVICE REPORT

Prepared for
MOBIL EXPLORATION NORWAY INC.

SOURCE ROCK POTENTIAL OF THE SHALE
from
CORE 1 IN MOBIL'S 33/9-4 WELL, NORWEGIAN NORTH SEA.

November 1975

17 CASTLE STREET · CHESTER CH1 2DS · ENGLAND

SOURCE ROCK POTENTIAL OF THE SHALE FROM CORE 1 IN MOBIL'S 33/9-4 WELL, NORWEGIAN NORTH SEA

SUMMARY

This study is based upon a composite shale sample from core number 1 in Mobil's 33/9-4 Well.

On structure this shale is mature but does not fall into the zone of peak hydrocarbon generation and hence is not realising its maximum potential. It is a fair source rock for medium gravity oil but does not have the capacity to generate major oil accumulations in associated reservoirs.

The more mature, down-dip equivalents of this shale should be able to yield significant oil, probably with a good gas-to-oil ratio.

N J L Bailey
GEOCHEM LABORATORIES (UK) LIMITED

INTRODUCTION

This report presents the results of a geochemical study of a composite shale sample from core number 1 in Mobil Exploration Norway's 33/9-4 Well, drilled in the Norwegian sector of the North Sea.

The study, authorised by Mr H P Raveling, was designed to evaluate the hydrocarbon source potential of the shale.

A. ANALYTICAL

Six polythene bags containing shale were submitted from core number 1 in Mobil's 33/9-4 Well. Material was taken from each bag to form a composite sample which was assigned the Geochem job number 53 and the sample number -001.

The sample was analysed for organic carbon, visual kerogen, C_{15+} extraction with chromatography and the C_{15+} paraffin-naphthene analysis.

The data are presented in tables 1 through 5 and in figures 1 and 2. A brief description of the analyses performed in this study is included in the back of the report.

B. GENERAL INFORMATION

Ten copies of this report have been sent to Mr H P Raveling, Mobil Exploration Norway, Stavanger. A copy of the data has been retained by Geochem for future consultation with authorised Mobil personnel.

The remaining sample material, extract fractions and the glass kerogen slide will be held pending further instructions.

All of the data and interpretations related to this study are regarded as highly confidential and are proprietary to Mobil Exploration Norway Inc.

efficient migration (i.e. source and reservoir in close association) it could probably generate significant oil. It is unlikely to source major oil.

D. CONCLUSIONS

This shale is mature but, on-structure, is not realising its maximum potential for hydrocarbons. It is classified as a fair source rock for medium gravity oil and, as such, does not have the richness required for the North Sea exploration theatre.

The down-dip lateral equivalents of this shale could probably generate significant, but not major, oil. Due to the character of the organic matter, this oil should have a good gas-to-oil ratio.

This sediment was deposited under reducing, or weakly oxidising, conditions.

RESULTS AND INTERPRETATION

The data pertaining to each of the relevant source rock parameters will be discussed separately and then combined in the "Conclusions".

A. AMOUNT AND TYPE OF ORGANIC MATTER

The sample under study is a medium dark grey to olive grey calcareous shale.

It contains 0.88% organic carbon. Average shales contain rather more than one percent organic carbon and hence this sample is of average to below average organic richness.

The organic matter is dominantly amorphous and woody in type together with less abundant herbaceous material. Amorphous kerogen is the most favourable for the generation of oil whilst, per unit of kerogen, herbaceous debris can yield major oil and gas. Woody material is dominantly gas prone.

Hence this shale is of average richness and contains organic matter which is of a type favourable for the generation of oil and gas.

B. LEVEL OF THERMAL MATURATION

The thermal maturation index of this sample is 2 to 2+. At this level of alteration amorphous kerogen, although not yet realising its maximum potential for hydrocarbons, is mature and generating oil. This is also true of the herbaceous kerogen but a higher level of maturation is required for a significant response from wood.

The gas chromatogram of the C15+ paraffin-naphthene fraction also indicates organic matter which is mature but not very mature.

On structure, this interval should yield medium gravity oil. It is likely that the down-dip equivalents of the shale will be within the zone of peak hydrocarbon generation but a complete well study would be required to confirm this point.

C. HYDROCARBON SOURCE RICHNESS

This sample contains 1021 ppm total C15+ extract, including 127 ppm sulphur. However, the hydrocarbons constitute only 176 ppm (17.2% of the total extract, 2% of the organic carbon) and hence the shale can only be regarded as a fair source for oil. On structure, it could not yield major reserves to associated reservoirs, but in a very mature state under conditions of

TABLE 1

ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	INTERVAL	GROSS LITHOLOGIC DESCRIPTION	G S A COLOUR CODE	TOTAL ORGANIC CARBON (% OF ROCK)
53-001	CORE 1	Shale, fissile to blocky, very calcareous, micaceous, medium dark grey and olive grey	N4 + 5Y4/1	0.87, 0.88

TABLE 2

VISUAL KEROGEN DATA

GEOCHEM SAMPLE NUMBER	INTERVAL	ORGANIC MATTER TYPE	REMARKS	THERMAL MATURATION INDEX
53-001	CORE 1	Am-W;H;-	marine algae	2 to 2+

TABLE 3A

WEIGHT (GRAMMES) OF C_{15+} EXTRACTS AND CHROMATOGRAPHIC FRACTIONS

GEOCHEM SAMPLE NUMBER	INTERVAL	ROCK EXTRACTED	TOTAL EXTRACT OBTAINED	TOTAL EXTRACT		nC_5 SOLUBLE FRACTION				
				Preciptd. Asphaltenes	nC_5 soluble	Paraffin – Naphthenes	Aromatics	Eluted NSO's	Non-eluted NSO's	Sulphur
53-001	Core 1	103.2898	0.1237	0.0855	0.0382	0.0085	0.0097	0.0057	0.0012	0.0131

TABLE 3B

CONCENTRATION (PPM) OF EXTRACTED C_{15+} MATERIAL IN ROCK

GEOCHEM SAMPLE NUMBER	INTERVAL	TOTAL EXTRACT	HYDROCARBONS			NON HYDROCARBONS				
			Paraffin – Naphthenes	Aromatics	TOTAL	Preciptd. Asphaltenes	Eluted NSO's	Non-eluted NSO's	Sulphur	TOTAL
53-001	Core 1	1198	82	94	176	828	55	11	127	1021

TABLE 3C

COMPOSITION (NORMALISED %) OF C_{15+} MATERIAL EXTRACTED FROM ROCK

GEOCHEM SAMPLE NUMBER	INTERVAL	HYDROCARBONS			NON HYDROCARBONS					
		Paraffin – Naphthenes	Aromatics	$\frac{P-N}{AROM}$	Preciptd. Asphaltenes	Eluted NSO's	Non eluted NSO's	Sulphur	$\frac{ASPH}{NSO}$	$\frac{HC}{NON\ HC}$
53-001	Core 1	6.9	7.9	0.87	69.2	4.6	0.9	10.6	15.05	0.20

TABLE 5

SIGNIFICANT RATIOS

GEOCHEM SAMPLE NUMBER	INTERVAL	%(HYDROCARBON / TOTAL EXTRACT)	%(HYDROCARBON / ORGANIC CARBON)	%(TOTAL EXTRACT / ORGANIC CARBON)
53-001	CORE 1	17.2	2.0	11.6

TABLE 4

SATURATED HYDROCARBON ANALYSES

NORMALISED PARAFFIN DISTRIBUTION

	53-001
nC_{15}	9.3
nC_{16}	8.1
nC_{17}	7.7
nC_{18}	7.0
nC_{19}	6.4
nC_{20}	6.0
nC_{21}	5.2
nC_{22}	5.6
nC_{23}	5.3
nC_{24}	5.0
nC_{25}	4.7
nC_{26}	4.4
nC_{27}	5.2
nC_{28}	3.7
nC_{29}	4.3
nC_{30}	3.1
nC_{31}	3.5
nC_{32}	1.9
nC_{33}	2.1
nC_{34}	0.8
nC_{35}	0.7

% Paraffin	20.6
% Isoprenoid	2.7
% Naphthene	76.7
CPI Index A	1.03
CPI Index B	1.22
$ip\text{-}C_{19}/ip\text{-}C_{20}$	2.06

FIGURE 1

'SOURCE CHARACTER' ANALYSES

PRESENTATION OF ANALYTICAL DATA

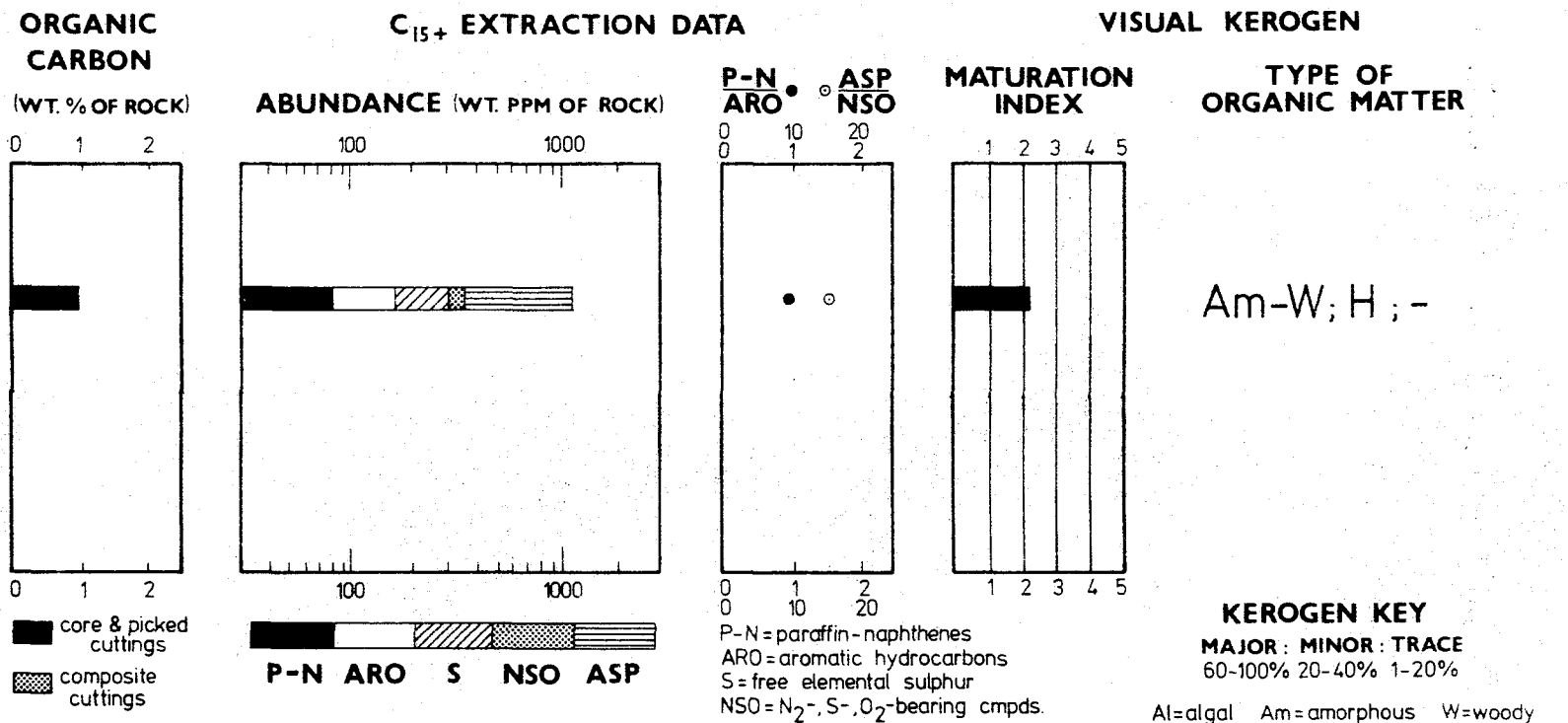
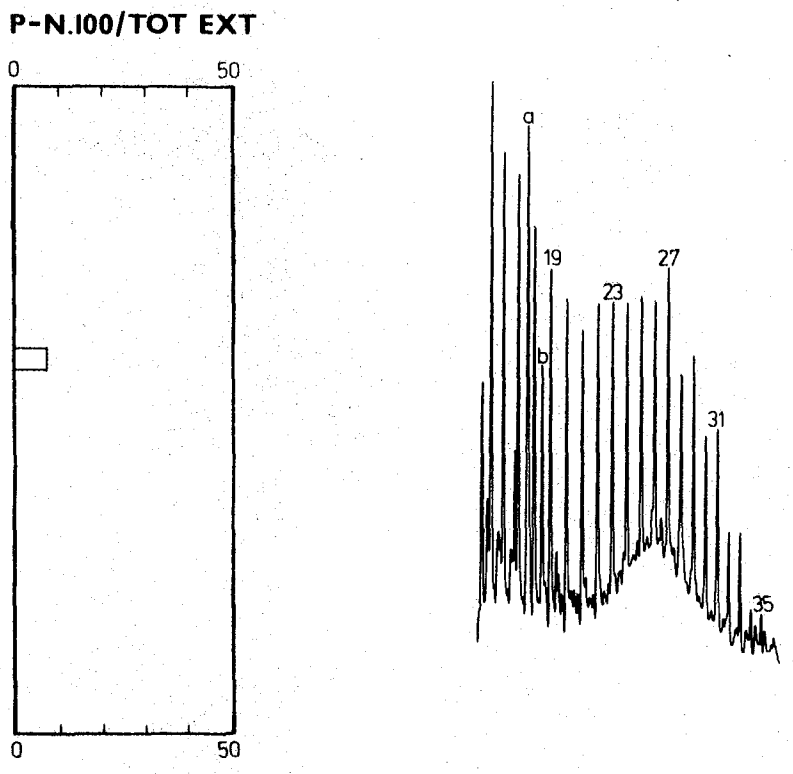


FIGURE 2

C_{15+} SATURATE HYDROCARBONS

PRESENTATION OF ANALYTICAL DATA



P-N paraffin-naphthene hydrocarbons = **SATURATES**
TOT EXT total extract (includes **SATURATES**)

BRIEF DESCRIPTION OF THE ANALYSES PERFORMED BY GEOCHEM

"Screen Analyses" are described in sections A and C, "Sample Preparation" in section B and "Follow-up Analyses" in sections C through G. The analyses can be run on either core or cuttings material with the proviso that samples must be canned for the C_1 - C_7 analysis and should be canned (or sealed wet in a plastic bag) for the C_4 - C_7 analysis. The other analyses can also be used on outcrop samples.

A) C_1 - C_7 LIGHT HYDROCARBON ANALYSIS

The abundance and composition of the C_1 - C_7 hydrocarbons in sediments reflects their source type, source quality, thermal maturity and the possible presence of migrated hydrocarbons. As this analysis not only provides a lot of information but is also economical, it is excellent for screening samples to decide which of them merit further analysis.

During the time which elapses between the collection of the sample at the wellsite and its analysis in the laboratory, a fraction of the total gas passes from the rock to the air space at the top of the can. For this reason, both the air space and the cuttings are analysed.

The analysis involves the gas chromatographic separation of the individual C_1 - C_4 gaseous hydrocarbons (methane, ethane, propane, isobutane and normal butane) and a partial resolution of the C_5 - C_7 gasoline-range hydrocarbons (for their complete resolution see Section D). The p.p.m. abundance of the five gases and of the total C_5 - C_7 hydrocarbons are calculated from their electronically integrated peak areas (not from peak height) by comparison with a standard.

In the report, the following data are tabulated: the abundance and composition of the air space gas, of the cuttings gas and of the combined air space and cuttings gases. The combined results are also presented graphically.

B) SAMPLE WASHING AND HAND PICKING

All of the analyses described in subsequent sections are run on washed and hand picked samples.

Cuttings are washed to remove the drilling mud, care being taken not to remove soft clays and fine sand during the washing procedure. Using the C_1 - C_7 hydrocarbon data profile of the well, or the organic carbon profile (if this analysis is used for screening), electric logs (if supplied) and the appearance of the

cuttings under the binocular microscope, samples are selected to represent the lithological and geochemical zones penetrated by the well. These samples are then carefully hand picked and the lithology of the uncaved material is described. It is these samples which are submitted for further analysis.

The remaining samples (also washed) are dried and packaged in labelled plastic bags for return to the client. Any hand picked sample remaining after analysis is also returned together with the extracted rock material.

Our reports normally incorporate a gross lithological description of all the samples which have been analysed and litho percentage logs are featured on all of the figures. As screen analyses are recommended at narrow intervals, a complete lithological profile is obtained.

C) ORGANIC CARBON ANALYSIS

The organic carbon content of a rock is a measure of its total organic richness. Combined with the visual kerogen, C_1 - C_7, C_4 - C_7 and C_{15+} analyses, the organic carbon content is used to evaluate the hydrocarbon source quality of the sediment. Not only is this analysis an integral part of a total evaluation, but it can also be used as an economical screen analysis for dry samples (when the C_1 - C_7 analysis cannot be used).

Hand picked samples are dried, crushed and then acidised to remove the inorganic calcium and magnesium carbonates. The actual analysis involves combustion in a Leco carbon analyser. Blanks, standard and duplicates are run routinely for purposes of quality control at no extra cost to the client.

The data are tabulated and presented diagramatically in our reports in a manner which facilitates comparison with the gross lithology (see section B) of the samples.

D) DETAILED C_4 - C_7 HYDROCARBON ANALYSIS

The abundance and composition of the C_4 - C_7 gasoline-range hydrocarbons in sediments reflects their source quality, level of thermal maturation and organic facies. In addition, the data also reveal the presence of migrated hydrocarbons and can be used for crude oil-parent source rock correlation studies.

This powerful analysis, performed upon hand picked lithologies, is employed as a follow-up to confirm the potential of samples which have been selected using the initial screen analysis. It is used in conjunction with the organic carbon, visual kerogen and C_{15+} analyses.

The individual normal paraffins, isoparaffins, naphthenes and aromatics with between four and seven carbon atoms in the molecule (but also including toluene) are resolved gas chromatographically and their peak areas electronically integrated.

Tabulation of the composition and p.p.m. abundance of the total gasoline-range fraction is achieved by comparison with a standard. In the report, the data are also presented graphically.

E) C_{15+} EXTRACTION, DEASPHALTENING AND CHROMATOGRAPHIC SEPARATION

Sections "A" and "D" dealt with analyses covering the light end of the hydrocarbon spectrum. This section is concerned with the solvent extractable organic material in the rock with more than fourteen carbon atoms in the molecule (ie. the heavy end). The amount and composition of this fraction indicates source quality, source type, the level of thermal maturation and the possible presence of migrated hydrocarbons. The individual parts into which the total fraction is split, can be submitted for further analyses (carbon isotopes, gas chromatography, high mass spectroscopy) which are primarily designed to correlate crude oils to their parent source rocks (but also see section "F").

These results are integrated with those derived from the visual kerogen, organic carbon and C_4 - C_7 analyses.

The techniques involved in this analysis have been designed to give very reproducible results. Hand picked samples are ground and then solvent extracted in a soxhlet apparatus with benzene-methanol (the solvent system can be adapted to client's specifications). The total extract obtained is then separated by column chromatography into the following fractions: paraffin-naphthene hydrocarbons, aromatic hydrocarbons, eluted NSO's (nitrogen-, sulphur-, and oxygen- containing non-hydrocarbons), non-eluted NSO's and precipitated asphaltenes. Note that the non-hydrocarbons are split into three fractions instead of being reported as a gross value.

For convenience and thoroughness, these data are reported in three formats: the weights of the fractions, their p.p.m. abundance and the percentage composition of the total extract. The data are also presented diagramatically.

Upon completion of the study, the extracts and extracted rock are both returned to the client.

F) GC ANALYSIS OF C_{15+} PARAFFIN-NAPHTHENE HYDROCARBONS

The molecular composition of the heavy C_{15+} paraffin-naphthene hydrocarbons reflects source quality, source type, the degree of thermal maturation and the presence of migrated hydrocarbons.

This analysis provides a useful cross-correlation with the visual kerogen, C_{15+} chromatography and light hydrocarbon (C_1 - C_7, C_4 - C_7) analyses.

The paraffin-naphthene hydrocarbons obtained by column chromatography are introduced into the gas chromatograph using a solid rod injection system to ensure that all of the sample, including the heaviest ends, is analysed. Excellent resolution of the individual normal paraffins and of the significant isoprenoids and other isoparaffins is achieved.

The normal paraffin carbon preference indices (C.P.I.) are calculated using the following formulae:

$$C.P.I_A = \frac{\frac{C_{21} + C_{23} + C_{25} + C_{27}}{C_{20} + C_{22} + C_{24} + C_{26}} + \frac{C_{21} + C_{23} + C_{25} + C_{27}}{C_{22} + C_{24} + C_{26} + C_{28}}}{2}$$

$$C.P.I_B = \frac{\frac{C_{25} + C_{27} + C_{29} + C_{31}}{C_{24} + C_{26} + C_{28} + C_{30}} + \frac{C_{25} + C_{27} + C_{29} + C_{31}}{C_{26} + C_{28} + C_{30} + C_{32}}}{2}$$

The chromatograms are reproduced in the report for use as visual fingerprints and in addition, the following data are tabulated: normalised normal paraffin distributions; proportions of paraffins, isoprenoids and naphthenes in the total paraffin-naphthene fraction; C.P.IA and C.P.IB; pristane to phytane ratio.

G) VISUAL KEROGEN ANALYSIS

Kerogen is the insoluble organic matter in rocks. Visual examination of the kerogen gives a direct measure of the level of thermal maturation and organic facies and indicates the source quality of the sediment. Source quality is confirmed using the analyses discussed above.

The type of hydrocarbon (oil or gas) generated by a source rock is a function of the types of organic matter present in the sediment and its level of thermal maturation. Both of these parameters are measured directly by this method.

Kerogen is separated from the inorganic rock matrix by methods which avoid oxidation of the organic matter. It is then mounted on a glass slide and examined under a high power microscope.

This examination gives the following data: the types (amorphous, algal, herbaceous etc.) and proportions of the organic matter present, the colour and hence level of thermal maturation of the organic matter and the state of preservation of the organic matter.

Our reports include colour transparencies of the kerogen. Upon completion of the study, the glass slides are sent to the client.