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REPORT NO. 2518

REPORT ON A SOURCE ROCK POTENTIAL

AND MAXIMUM PALAEOTEMPERATURE STUDY

OF THE

NORWEGIAN NORTH SEA 2/1-1 WELL   • *JJ X S,*   *- ~~~y ~:.2*

by

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'C O N T E N T S

A P P E N D I X

1.   Abbreviations for Table 1.

T A B L E

F I G U R E S

INTRODUCTION

Source rock potential and maximum palaeotemperature analysis was carried out on the Conoco-Gulf 2/1-1 Well, drilled offshore Norway. The samples range in age from Tertiary in the first sample at 3,880', through to ?Jurassic at a depth of 13,600'. Initially the ditch cuttings samples were examined in conjunction with the gamma ray, sonic and lithologic logs for the well in order to identify the major lithologies suitable for source rock potential analysis. On the basis of this examination thirty one samples were selected for analysis; of these, twenty nine were for source rock potential analysis and eighteen were for maximum palaeotemperature analysis.

Drilling mud was removed from the samples by washing in water. The selected samples were then examined to ensure that they were free of any contamination materials or obviously caved cuttings. Three different lithologies were encountered mixed together in the samples from the interval 10,000"-10,600'; hand-picked material from these samples was used in the analysis.

ANALYTICAL AND INTERPRETATION METHODS

ANALYTICAL METHODS

1.   Source Rock Potential Analysis

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Source rock potential 'is defined as the potential of argillaceous sediments and carbonates to generate sufficient hydrocarbons for migration to produce commercial oilfields. The source rock potential analysis involves the determination of the amount of organic matter present in the samples, and the extraction of the fraction of the samples which is soluble in a solvent mixture. The soluble portion is then analysed by quantitative thin layer chromatography for hydrocarbons and other constituents (see Table). The advantage in using thin layer chromatography is that analysis can be completed on small samples in a short time.

The organic carbon % is determined by a measurement of the CO_2 content of the samples which is given by changes in thermal conductivity in a Leco carbon analyser (after the removal of carbonate material), The total organic extract 7. is determined by the extraction of the samples (at minus sixty mesh) with a benzene/methanol solvent over a period of twelve hours, followed by ttie removal of inorganic and particulate contaminants. The extraction ratio % is defined as follows :

$$\frac{\text{Total organic extract 7.}}{\text{Organic carbon 7.}} \times 100$$

The organic extract of the samples comprises hydrocarbons (paraffins and aromatics), resins and asphaltenes. These paraffins, aromatics and resins plus asphaltenes are determined by thin layer chromatography on the cleaned up organic extract. Densitometry is used to measure the TLC fractions. The analytical results are expressed as hydrocarbons ppm, paraffins % in the

hydrocarbons i.e. paraffinicity, and total resins plus asphaltenes '/,. The aromatics 7o in the hydrocarbons is obtained by subtracting the paraffins 7. value from 1007o. Further details on the actual analytical procedures are . of a confidential nature.

2. Maximum Palaeotemperature Analysis

Maximum palaeotemperature is defined as the maximum temperature to which the sample has been subjected In its geological history, i.e. it reflects the degree of organic diagenesis or maturity of the sample. The maximum palaeo-temperature analysis is based on the fact that when kerogen is heated in nature, for example as a result of increasing depth of burial with sedimenta-tion, stable intermediate compounds are formed which are typical of the maximum temperature attained. In our analytical method, these intermediate compounds are quantified using an electron spin resonance spectrometer. The electron spin resonance measurements are then calibrated against established standards and converted to maximum palaeotemperatures. In the analysis, the kerogen present in the samples is concentrated before the electron spin resonance work is carried out. The electron spin resonance-kerogen method and the significance of organic maturity has been discussed recently by Pusey (1973),

INTERPRETATION METHODS

*.. Source Rock Potential Analysis

The analytical results are Interpreted by a petroleum geologist and are initially checked for any anomalous data resulting from the presence of non-indigenous hydrocarbons in the samples which was not detected in the sample selection procedure. The main data credibility check is the extraction ratio (%) » and if this ratio is over 50%, then contamination by non-indigenous hydrocarbons is Indicated in the sample. Again, if resins and asphaltenes are absent or very low in samples where hydrocarbons are detected, contamina-tlon is present.

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The principal parameter which establishes a sample as a rock with source rock potential, is the hydrocarbons ppm value. If the sample has a hydrocarbon content of over 350 ppm, it is considered to be a rock with source rock potential. The higher the hydrocarbons ppm value of a sample is, then generally the greater is its potential as a source rock. Samples with a hydrocarbon content below 350 ppm do not have source rock potential. This threshold value of 350 ppm has been established by extensive analysis of source rocks associated with producing fields and petroliferous basins, on a world-wide basis. If a sample has a hydrocarbon value of 300 to 350 ppra, then obviously it is approaching close to source rock potential status and such samples are noted separately. When the total organic extract of a sample is less than 300 ppra (0.037,,), it cannot be regarded, by the above definition, as a rock with source rock potential. Consequently thin layer chromatography is not carried out on samples which show a total organic extract of less than 0.037,. It must be noted that the hydrocarbon threshold value of 350 ppm is only applicable to our particular analytical procedures.

The most typical source rocks show the following features in their . organic extracts :

.. i.   An extraction ratio of 10-307»,

ii.   A paraffin content of the extractable hydrocarbons of over

607., and conversely an aromatic content of less than 407=.

iii.   A resins plus asphaltenes content of less than about 657».

' These parameters may vary from the above mentioned values in rocks with source rock potential, however this fact does not detract from them having source rock potential. Paraffinicity tends to increase with depth towards the mature end of the zone of potential generation of commercial oil; and there is a corresponding decrease in resins plus asphaltenes values.

There is no cut-off limit on the organic carbon % data, and shales with

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organic carbon contents of less than 1% can be good source rocks. However,
if no organic material is present or is very Low (less than 0.037. organic
carbon), then the sample cannot have source rock potential. A reasonable
organic carbon content in a sample pr-ovides encouraging data with regard
to source rock potential, however the determining factor is the hydrocarbons
ppm value.   - &

2.   Maximum Palaeotemperature Analysis

An immature sample (one that has not generated sufficient hydrocarbons)
has low maximum palaeotemperatures. A mature sample (one that has been hot
enough in its history to generate commercial hydrocarbons) has medium
maximum palaeotemperatures. They'are indicative of oil potential (i.e. oil,
oil and gas zone). Samples which have high maximum palaeotemperatures in
excess of 300°F indicate only thermally generated gas potential (i.e. dry
gas zone). Pusey (1973) has described examples from southern North America
using maximum palaeotemperature analysis.

ANALYTICAL RESULTS AND INTERPRETATION

The results of the source rock potential and maximum palaeotemperature analysis of the thirty one samples are presented in Table 1.

1. Source Rock Potential (Figures 1 and 2)

The quality of the source rock potential analytical data is considered to be very good. Examination of Table 1 and Figures 1 and 2 indicates that the analysed samples fall into four main groups:

a. Samples 3 to 17 from the 5,200'-9,940' interval (Tertiary)

These samples comprise essentially a soft, olive to light olive-grey mudstone and shaly mudstone. They are characterised by an organic carbon content of between 1,487 and 3.327,, and a hydrocarbon content of between 130 ppm and 490 ppm.

Of these fifteen samples, numbers 3 to 6 (5,200'-6,520'), 9 to 11 (7,720'-8,260[1]), 13 (8,680'-8,740') and 17 (9,940') are considered to be rocks with source rock potential since they show hydrocarbon contents which exceed the 350 ppm value dividing source rocks from non-source rocks (see page 4). These samples have paraffin contents of their extractable hydrocarbons ranging from 457. to 90X and resins plus asphaltenes contents of between 62?$_0$ and 87%. Although the resins plus asphaltenes contents of these samples are slightly high, in general the source rock potential parameters compare favourably with those found in typical source rocks (see page 4),

Sample 7 (6,940'-7,000') has a hydrocarbon content of 310 ppm which is very close to the 350 ppm threshold value. The source rock potential parameters are similar to those of the nine potential source rocks.

The remaining five samples have no source rock potential.

b. <u>Samples 18 (Upper Cretaceous : 10,000'-10,600' : picked lithologies)
and 26 (?Lower Cretaceous : 12,220-80')</u>

These two samples, from the top and the base of the chalk,
comprise a medium grey shale. They are characterised by an organic
carbon content of between 0.567- and 1.13%, and by a hydrocarbon
content of between 260 ppm and 510 ppm.

Sample 18 is considered to be a rock with source rock potential
since it has a hydrocarbon content exceeding the 350 ppm threshold
value. The source rock potential parameters of this sample compare
well with similar values from typical source rocks.

Sample 26 has no source rock potential.

c. <u>Samples 19 to 25 from the 10,000'-12,280' interval (Upper Cretaceous)</u>

These samples comprise essentially a very light grey to yellowish
grey chalk (probably slightly impure) with traces of light grey shale.
Sample 19 (hand picked) comprises a greyish red shale. These samples
are characterised by an organic carbon content of between 0.177. and
0.547o and by a hydrocarbon content of between 40 ppm and 1,100 ppm.

Samples 23 to 25 (11,920'-12,280*) are considered to be rocks
with source rock potential since they show hydrocarbon contents
exceeding the 350 ppm threshold value. The source rock potential
parameters of these samples compare very well with similar values
from typical source rocks.

Sample 19 has a hydrocarbon content of 340 ppm which is very
close to the 350 ppn threshold value. The source rock potential
parameters for this sample are similar to the potential source rock
samples 23 to 25.

Samples 20 to 22 have no source rock potential.,

d• <u>Samples 27 to 31 from the 12,880'-13,540' interval (?Lower
Cretaceous-Jurassic)</u>

These five samples comprise a dark grey,calcareous shale. They

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arc characterised by an organic carbon content of between 2.427. and 2.957., and by a hydrocarbon content of between 800 ppm and 2,900 ppm. All of these samples are considered to be rocks with source rock potential since their hydrocarbon contents exceed the 350 ppm threshold value. In general the source rock potential parameters of these samples compare well with those found in typical source rocks.

2.   ~~Maximum Palaeotemperatures (Figures 3 and 4)~~

The quality of the maximum palaeotemperature analytical data is considered to be good.

A calculation of the linear regression between all the maximum palaeo-temperatures yields a maximum palaeotemperature gradient of 1.4°F per 100 feet, a correlation coefficient of 0.93 and a surface intercept of 116°F (see Figure 3).

The lower limit of the zona. of commercial oil potential generally occurs at a maximum palaeotemperature of 300°F (see page 5). From Figure 3 it can be seen that a maximum palaeotemperature of 300°F is reached at a depth of approximately 13,600'.

3.   Conclusions

From the present study of the 2/1-1 Well the following main conclusions can be made :

a. • The Tertiary section analysed between 5,200* and 10,000' comprises soft, olive-grey muds tone; rocks with source rock potential occur in the general interval from 5,200'-8,750'.

b.   The section from approximately 10,000'-12,300' comprises chalk with minor shale occurrences. Mature source rocks occur in the lower section of the chalk (11,920'-12,300').

c.   The section from 12,300'-13,540' comprises essentially a dark g^{re}y calcareous shale. This section is considered to have good source rock potential but lies close to the lower lir.it of the zone of commercial oil potential.

REFERENCES

PUSEY, W.C., 1973. The ESR-Kerogen Method - a new technique of estimating
    the organic maturity of sedimentary rocks. Petroleum Times, January
    12, L973.

ABBREVIATIONS FOR TABLE 1

max palaeoT ^{o}F   —   Maximum Palaeotemperature computed as weighted mean

O.C. %   Q —   Organic Carbon %

K. C. %   —   Kerogen Carbon $^{o}/_{a}$

w   —   Width

extract %   —   Total Organic Extract %

epoc   —   Extract Ratio % = $\dfrac{\text{Total organic extract \%}}{\text{Organic carbon \%}} \times 100$

HC ppm   —
                    Hydrocarbons ppm

paraffins X —
                    Paraffins in Hydrocarbons %

rasp $%_a$ —
                    Total Resins plus Asphaltenes %

T"g"   —
                    Maximum Palaeotemperature computed on "g" value

TNg   —
                    Maximum Palaeotemperature computed on Ng value

RSD   — Raw Spin Density x 10

                    —
                    not analysed

sft   —   soft

si   —   slightly

calc   —   calcareous

shly   —   shaly

sh   —   shale

mdst   —   mudstone

sst   —   sandstone

carb   —   carbonate

Colour Coding after 'Rock-Color Chart Committee[1], Geol. Soc. America.

Sample (Feet)	Lichology	type	SR	PT	Max ipalaeoT °F	O.C.7,	K.C.%	"g"	w	N?> inl7	colour	extract; %	cpoc	ilC Dpm!	~it)ir'--f-"	zasp %	T"g"	TNgJRSD
1 -4180-2*40	5Y 6/1 mdst, with fine sst and carb.	Cuttings	-	/ I	180	1.65	25.2	34.4	7.2	1.1	-	-	-	-	-	-	230	80 1.(
2.4660-720	15Y 6/1-N6 sft shly mdst) with carb.	"	-	/ !	209	1.85	19.9	33.1	6.3	1.6	-	-	-	-	-	-	257	114 1.(
3.5200-260	5Y 6/1-N6 sft shly mdst	"	-	-	-	2.32	-	-	-	-	2	0.1U	4.8	420	90	62	-	- i
4.5630-740	5Y 6/1 sft mdst	"	i / I	/ I"	198	2.03	19.2	34.4	6.5	2,Q	2	0.183	9.0	490	71	73	230	
r 5.6220-780	"	"	/ !	/ !	203	2.14	1S.J.	35.2	7.4	3.4	5	0.119	5jb6	J160	82	69	213	182 2.>
6.6460-520	"	"	/	-	-	2.39	-	-	-	-	5	0.149	6.2	380	7 5	7 5	-	-
17.6940-7000	I5Y 4/1-5/1 sft shly mdst	"	!/ I / !		224	3.09	23.7	34.6	7.6	5.3	10	0.239	7.7	310	56	87	225	223 5.?
S.7130-240	SYR 3/1-4/1 sft shly imdst	".	j /	/ j	205	3.32	29.3	35.9	7.0	5.1	8	0.237	7.1	130	65	95	198	220i 6.:
9.7720-780	5Y 3/1-5/1 sft shly si icalc mdst	"		-	-	2.67	-	-	-	-	8	0.216	8.1	480	60	78	-	-
10.7960-S020	J5Y 5/1 sft shly calc mdst	"	j /	/	211	2.19	18.3	34*6	7.6	3.4	5	0.143	6.5	390	75	73	225	182 34
11.8200-260	5Y 3/1-5/1 sft shly imd.s.t.	""	/	/	208	3.25	25.2	35.8	7.6	5.4	10	0.269	8,3	350	73	87	200	225, 6.:
J12.3440-500	I 5Y 4/1-&/J- sft mdst	"	/	-	-	2.85	-	-	-	-	7	0.187	6.6	290	45	:85	-	-
113.8680-740	"	"	/	/	206	2.43	16.5	35.3	6.8	4.0	2	0.1411	5.8	360	45	^ J ^ i	210	ISli 3.:
14.8920-980	5Y 4/1-6/1 ft shly mdst	"		-	-	2.02	-	-	-	-	5	0.074	3.7	200	60	73	-	-

Pclasotemperature No. ....   Total Source Rof-ks ....   Table ......1........

Source rock V,o. ....●..   Total. Max palaeoT ....●...   Date of Submission ....

Sample (Feet)	Lithology	type	SR	BT	Max palaeoT|°-Ct/* Op	K.C.7,	V •	w	Ng x 1017	colour	ex'cr.-.c'H %	CPOC	HC pp.r.	-ins 7,	rasp "U		RSI
15. 9240	i5Y 4/1-6/1 sft shly imdst	Cuttings	/	/1 224 i	1.43	17.0	34.0	7.3	4.0	7	0.088	5.9	210	67	76	12.38 i 197i	3.4
16. 9700	15Y 4/1-5YR 4/1 sft si calc mdst	M	/	—i —	1.90 1	-	—	—	—	7	0.122	6.4	200	50	84	- i - I -	
17. 9940	15Y 4/1-6/1 shly mdst	"	/	/| 223	1.95	20.4	33.9	7.4	3.7	7	0.179	9.2	370	63	1 SO	240 ; f9o.	3 j
	• HAND PICKED LITHOLOGY														1 •		
10,000-	18. N5 sh	«·	/	-i -	i.i3 i	- i	-	•	•	3		9.6	510	72	53	- i -	-
	119. 5R 4/2 sh	II	/	-1 -.	0.35	•	- 1 -•	—		1	0.060	17.1	340	86	43	- i - 1 -	
-10j 600	20. N8 chalk	tl	/	•1 •	0.17	••	••	••		1	0.039	22.9	200	69	50	- i - i -	
21. 11000	*N8-5Y 8/1 si dirty 1 chalk & trace sh	»	/	-i -	0.23	•	-	-		1	0.044	19.1	140	58	*N8 68	- 1 - i	
22. 11500	!N8-5Y 8/1 si dirty chalk & trace sh	"	/	/I 262 S	0.20	7.2 !	31.4	5.3	2.3	1	0.029	14.5	40	63	86	293 |201	o.t
23. 11920	1N8-5Y 8/1 si dirty chalk & trace sh	»	/	./S 277 J	0.25	20,4	31.1	5.8	4.2	2	0.068	27.2	350	80	48	1300 \230	4.C
24. 12160	IN3-5Y 8/1 si dirty <• chalk & trace sh	"	i/ 1	-i -	0.35 j	-	-	-	-	5	0.113	32.3	740	72	34	- i -	-
25.12220- 80	IN8-5Y 8/1 si dirty \ ch Ik & trace sh	"e-s	/	/! 280	0.54	15.1	31.5	5.2	9.9	7 J	0.214	39.6	1100	82	i 49	291 '257	5.
26. 12640	U^T 4-5 sh	ii	/	/; 305	0.56	9.7	29.8	5.5	11.3	3 '	0.059	10.5	260	68	'55	327 • 262	4.
27.12880- 940	i N3 calc sh	"	/	-	2.42 !	•	-	-	- i	12	0.476	19.7	2900	48	40	- i -	-
28 13120- 80	iN3 calc sh	" 1/	/	309	2.31	20.8	29.6	5.3	12.2	12	0.408	14.5	1400	66	'66	331 i 266	12.f
29.13240- 300	N3 calc sh	ii	/	/| 312	2.69	25.9	29.3	5.6	11.2"	11	0.51-5	19.1	2400	57	53	338 !261	13.

Palaeotemperature No. ....   Total Source Rocks ....

Source rock No.• ....●··   Total Max palaeoT _____ "●···   Date of Submission ....!..........

CLIENT CoNoCo EURoPE   LOCATION NORWEGIAM NOKTI^ SEA   wILL #_2/J.J.   PROJECT NO. RR1/723/IL1B/182 and RRI/734/L1D/2016

ample ^ (Feet)	Lithology	type	j SR	PT	Max palaeoT °F	O.C.%	K.C.7.	l.g"	w	Ng x 1017	colour	extract %	epoc	HC ppm	paraf -ins 7.	rasp ')»	T"g"	TNgi	RSD
.13360- 420	N3 calc sh	Cuttings	/	–	-	2.95	—	~		-	11	0.414	14.0	1400	64	66	–	~	-1
.13430- 540	N3 calc sh	"	/	/	303	2.76	21.5	29.9	5.4	10.5	10	J3.299	10.8	800	41	68	325	239	111.6

P?.laeotemperature No, ...●......   Total' Source Rocks ...2●...   ┌ .Table" .A./.Cont,d1....

Sourca rock No.   ....   Total Max palaeoT ...18.....   , Date ,of 'Submission ....●.............
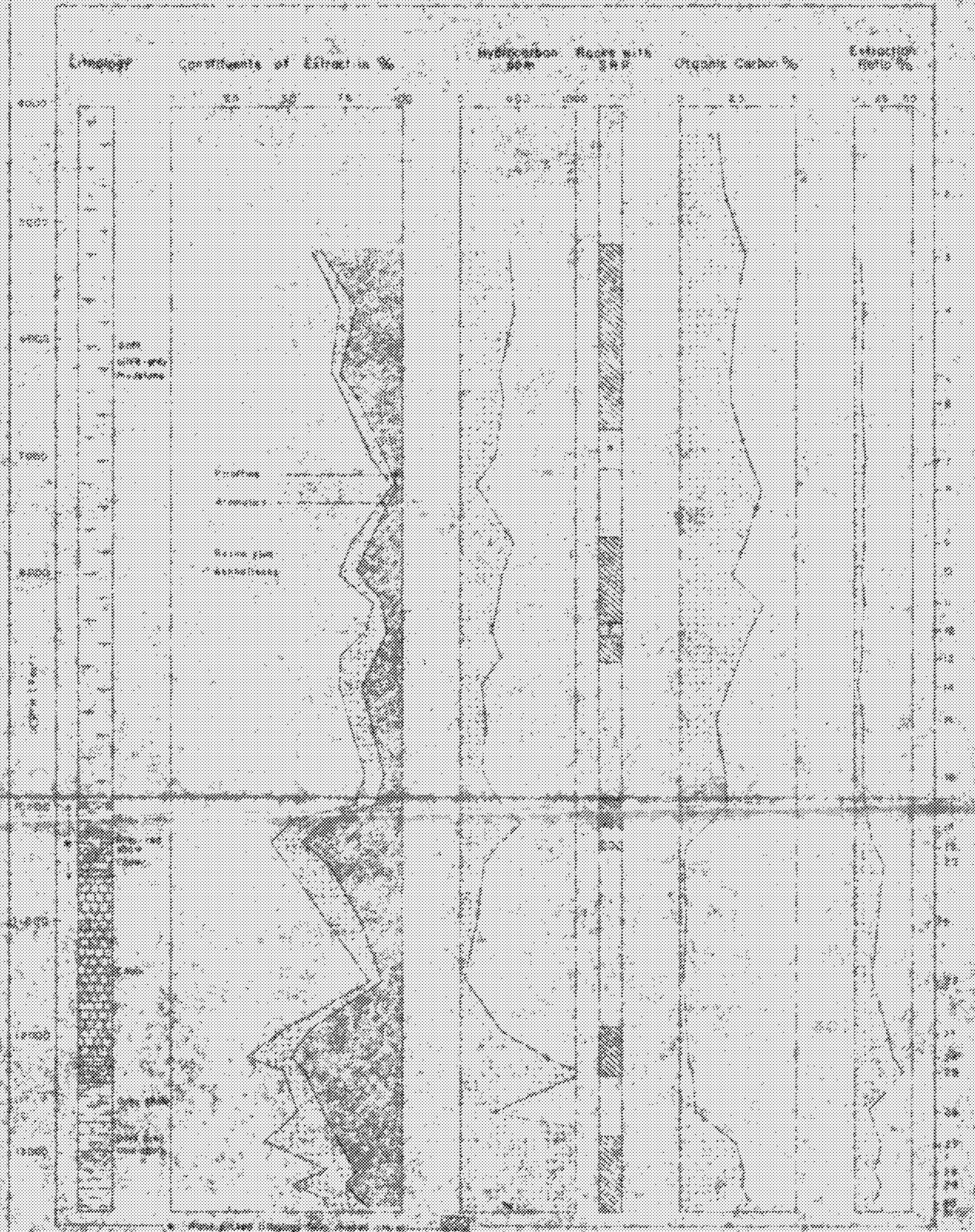
GRAPH SHOWING HYDROCARBONS ppm VERSUS ORGANIC CARBON %
FIGURE 1
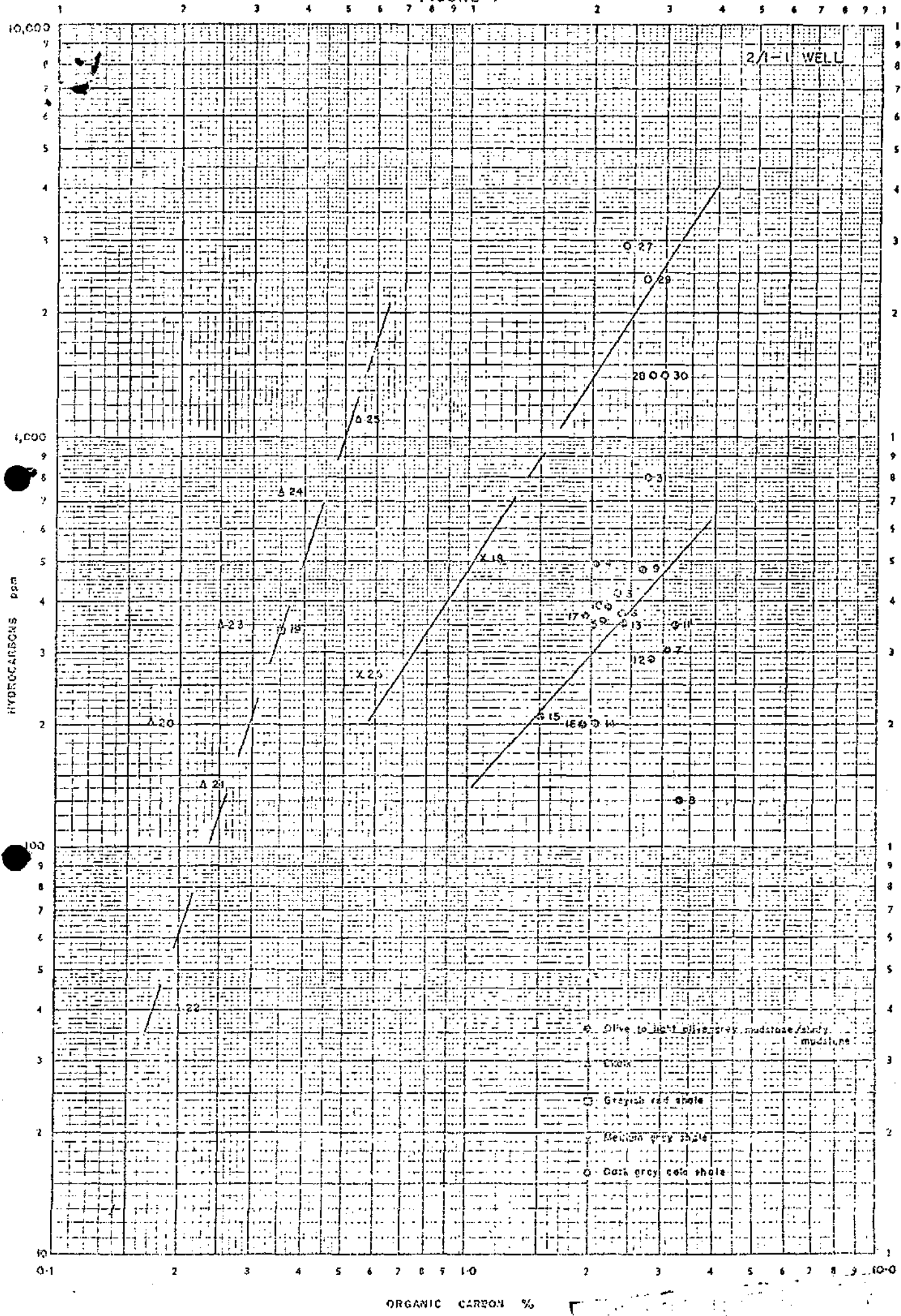
SOURCE ROCK POTENTIAL ANALYTICAL DATA
Figure 2

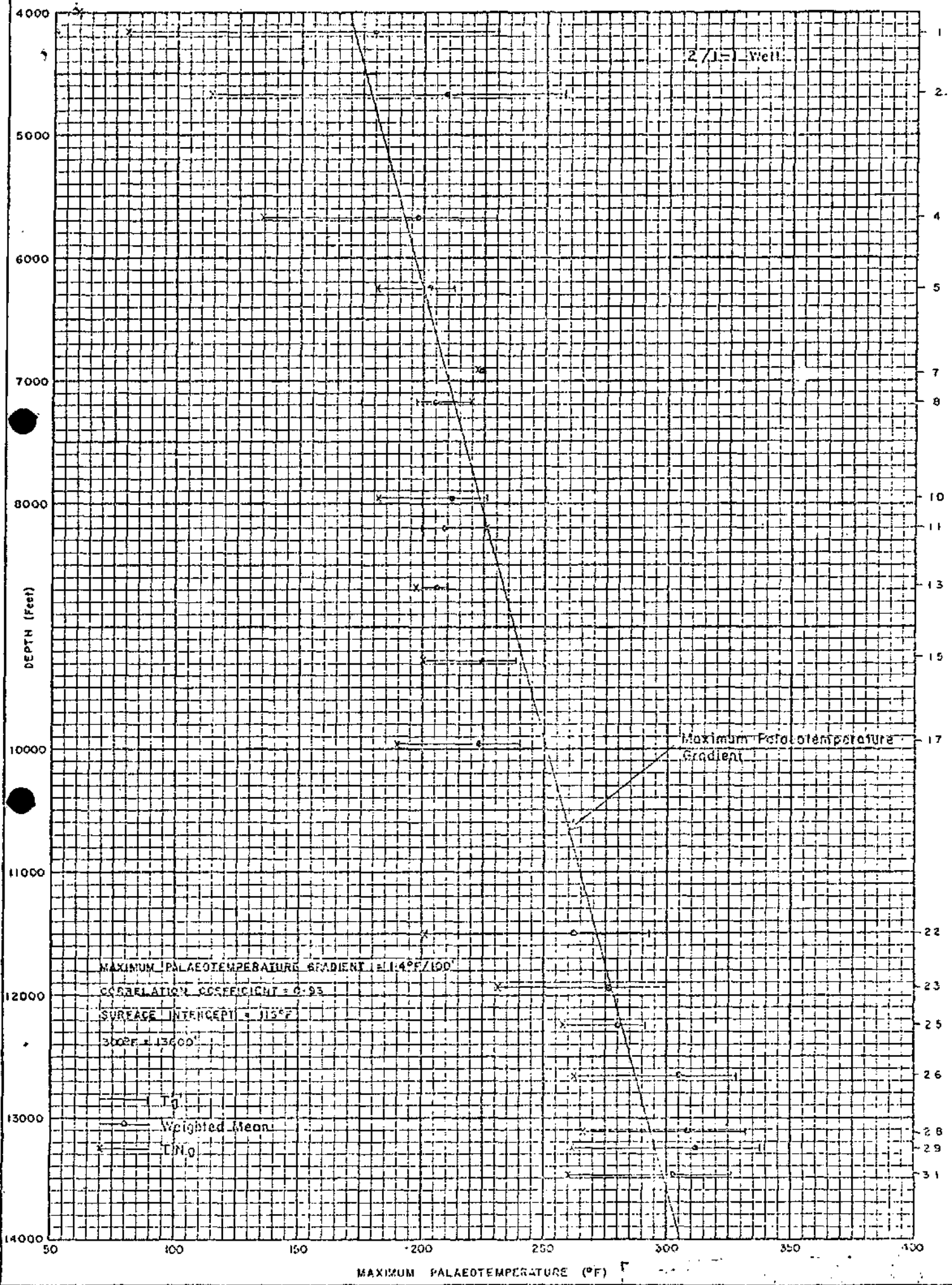GRAPH SHOWING MAXIMUM PALAEOTEMPERATURE VERSUS DEPTH

FIGURE 3

FIGURE 4

Operator___CONOCO___ Lease_____ Location___EUROPE___