SOURCE EVALUATION OF THE BP 7/12-4 WELL, NORWEGIAN NORTH SEA

By
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Technical Service Report
Number 1610-780-104-1-78

Geological Section
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Continental Oil Company
Research and Development Department
Exploration Research Division

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To Wim van den Bosch - Stavanger

From Harry Dembicki, Jr. - Ponca City

Date April 10, 1978

Subject SOURCE EVALUATION OF THE BP 7/12-4 WELL, NORWEGIAN NORTH SEA

Summary

Organic geochemical analyses were conducted on thirteen canned cuttings samples, twenty sidewall core samples, and two conventional core samples from the BP 7/12-4 well in the Norwegian sector of the North Sea. These samples tested a section beginning in the Lower Cretaceous and extending to the Lower Jurassic. In general the source potential of these sections were accessed as follows: Lower Cretaceous - fair-to-good source for oil or oil/gas-condensate; Upper Jurassic - very good source for oil; Middle Jurassic - very good source for oil; and, Lower Jurassic - fair-to-good source for oil. The entire section was found to be mature. All data are summarized in the text and presented as data sheets and geochemical logs.

Source Potential Analyses

To determine the source potential of the samples, two separate schemes were followed. For the canned cuttings samples, analyses were carried out to determine the amount and types of C_1-C_7 hydrocarbons in the rock. No additional analyses other than organic carbon content were run on these cuttings samples because sidewall core and core samples were available that covered the same interval. For the sidewall core and core sample, the following analyses were done: organic carbon content, Soxhlet solvent extraction, and thin-layer chromatography of the extract.

Canned Cutting Gas Results

Three sections were covered by the canned cuttings samples. They were the Lower Cretaceous, Upper Jurassic, and the Lower Jurassic shales. The Lower Cretaceous samples (sample numbers 1278-47-2 to 1278-47-15) were found to be only fair-to-poor source rocks with a potential for predominantly oil/gas-condensate. The Upper Jurassic samples (sample numbers 1278-47-21 to 1278-47-27) were found to be very good-to-good source rocks for oil and the Lower Jurassic samples (sample numbers 1278-48-3 to 1278-48-7) were found to be fair source rocks for oil. These interpretations were based on the volumetric determinations of the amount of C_1 to C_4 hydrocarbons present in the cuttings. Because these samples were cuttings, the ability of relating these findings to the depths from which these were taken is questionable. However, the overall trends for intervals (such as shown here) can be determined.

C_{15}^+ Hydrocarbon Results

The stratigraphic sections covered by the C_{15}^+ analysis were the Lower Cretaceous, Upper Jurassic, Middle Jurassic, and Lower Jurassic shales. In the Lower Cretaceous section, samples at 3155 and 3170 m appeared to be contaminated by mild oil staining. The sample from 3207 m was found to be a poor source rock which could produce some oil/gas-condensate. The remaining section, 3237 to 3343 m was found to have good source rocks prone to oil production. These results differ from those observed for the same section using canned cuttings gas. Possible reasons for this contradiction can be found in the fundamental nature of the analyses. Canned cuttings gas deals with only the C_1 to C_7 hydrocarbons. As such, the use of such data is more reliable when dealing with gas and condensate source rocks. In this instance, the source rocks appear more prone to oil production. If this oil is a heavy, naphthenic oil which has a low gas-to-oil ratio, then the canned cuttings gas may give inconsistent results.

The Upper Jurassic shale (3353 to 3425 m) was rated as a very good source rock for oil with the exception of the samples at 3410 and 3425 m. These two samples were rated as fair and good, respectively. The samples from 3353 and 3355 m appear at first to possibly be contaminated. However, subsequent examination of the samples established that they were not contaminated.

The Middle Jurassic section was tested by only two samples, from 3440 and 3541 m. Both samples were rated as very good, oil-prone source rocks.

The Lower Jurassic was also represented by only two samples, from 3573 and 3603 m. Both samples were rated as fair-to-good, oil-prone source rocks. Again some inconsistencies with these data and the canned cuttings gas data can be seen. However, these differences are minor and do not require an explanation.

Kerogen Typing

Microscopic examination of the kerogen of the core and sidewall core samples was carried out to determine the approximate concentration of four main types of kerogen. With the exception of only one sample (Middle Jurassic at 3541 m), all the samples show a predominance of amorphous kerogen. Only relatively small amounts of other kerogen types are present in these samples. The sample from 3541 m show equal amounts (30% each) of herbaceous, amorphous, and woody kerogen. Since amorphous type kerogen is generally considered the main oil-producing kerogen type, this section from Lower Cretaceous to Lower Jurassic shows an oil-prone production potential.

Maturation Indicators

In order to determine the maturation level of the source rocks from this well, several maturation indicators were used. These include the percent wet gas from the canned gas samples, spore-pollen coloration, vitrinite reflectance, and ESR paleotemperature. General agreement was found among these parameters indicating the section to be mature.

Kerogen Color and Vitrinite Reflectance

The results of the spore-pollen coloration analysis was the assignment of a maturation index of 3- for all samples. The confidence factor for these determinations was rated as good. Vitrinite reflectance was attempted on samples from 3155, 3207, 3343, 3425, and 3603 m. A coal sample from 3534 m was also analyzed for vitrinite reflectance. Historically, our attempts to obtaining meaningful vitrinite reflectance data from the North Sea area has been hampered by the presence of reworked vitrinite in the sediments. This well is no exception. The only vitrinite which appears to be in place is from the coal sample. An average vitrinite reflectance value of R_o = 0.56 was obtained for the coal. This value falls within the range expected for kerogen with a 3- maturation index.

Percent Wet Gas

The percent of C_2 to C_4 hydrocarbons (wet gas) in the C_1 to C_4 range can be used as an indicator of maturation. The threshold is generally considered to be in an area where the wet gas reaches the 30 to 50% mark. All samples analyzed are observed to have wet gas contents of greater than 30% and are thereby indicated to be mature.

ESR Paleotemperature

Difficulties in the past have made ESR paleotemperature analysis in the North Sea area suspect as a maturation indicator. However, in this instance, ESR appears to work rather well. The calculated paleotemperatures are plotted as + symbols on the goechemical log while the straight

line drawn is the geothermal gradient as calculated from the bottom hole temperature of the well. The paleotemperature can be seen to fall closely along the geothermal gradient in this case. The paleotemperatures are in the range which is considered to be mature.

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SOURCE POTENTIAL BASED ON CANNED CUTTINGS GAS

Sample Number	Depth (m)	Source Richness	Source Quality
1278-47-2	3170	Poor	Oil
-4	3200	Fair	Oil/Gas-Condensate
-6	3230	Fair	Oil/Gas-Condensate
-8	3260	Fair	Oil/Gas-Condensate
-10	3290	Poor	Oil/Gas-Condensate
-12	3320	Fair	Oil/Gas-Condensate
-15	3350	Fair	Oil/Gas-Condensate
-21	3380	Very Good	Oil
-24	3410	Good	Oil
-27	3440	Good	Oil
1278-48-3	3570	Fair	Oil
-5	3602	Fair	Oil
-7	3620	Fair	Oil

CUTTINGS GAS DATA SHEET

BP 7/12-4 CENTRAL NORTH SEA NORWAY

SAMPLE NUMBER	DEPTH M	C1-C4 PPM	C5-C7 PPM	C5-C7/ C1-C4	% WET GAS	I-C4/ N-C4
1278 47 2	3170.	844.	521.	.617	56.64	1.02
1278 47 4	3200.	1659.	91.	.055	30.68	.68
1278 47 6	3230.	1472.	479.	.325	35.94	1.12
1278 47 8	3260.	1681.	342.	.203	30.87	1.84
1278 47 10	3290.	836.	265.	.317	46.29	1.39
1278 47 12	3320.	1794.	143.	.080	30.55	.92
1278 47 15	3350.	1376.	403.	.293	56.83	.40
1278 47 21	3380.	31509.	32923.	1.045	92.63	.22
1278 47 24	3410.	12870.	15783.	1.226	93.62	.23
1278 47 27	3440.	14517.	37514.	2.584	93.17	.26
1278 48 3	3570.	5716.	2766.	.484	77.15	.24
1278 48 5	3602.	8647.	9674.	1.119	87.53	.24
1278 48 7	3620.	4246.	4880.	1.149	91.92	.25

C1-C4 PPM = C1 TO C4 HYDROCARBONS IN PPM
C5-C7 PPM = C5 TO C7 HYDROCARBONS IN PPM
C5-C7/C1-C4 = RATIO OF C5-C7 TO C1-C4 HYDROCARBONS
% WET GAS = PERCENT C2-C4 IN THE C1-C4 HYDROCARBONS
I-C4/N-C4 = RATIO OF ISOBUTANE TO N-BUTANE

SOURCE POTENTIAL BASED ON C_{15}+ HYDROCARBONS

Sample Number	Depth (m)	Source Richness	Source Quality
1278-47-1	3155	Oil Stained	Oil Stained
-3	3173	Oil Stained	Oil Stained
-5	3207	Poor	Oil/Gas-Condensate
-7	3237	Good	Oil
-9	3267	Good	Oil
-11	3297	Good	Oil
-13	3322	Very Good	Oil
-14	3343	Good	Oil
-16	3353	Very Good	Oil
-17	3355	Very Good	Oil
-18	3359	Very Good	Oil
-19	3365	Very Good	Oil
-20	3374	Very Good	Oil
-22	3385	Very Good	Oil
-23	3400	Very Good	Oil
-25	3410	Fair	Oil
-26	3425	Good	Oil
-28	3440	Very Good	Oil
1278-48-2	3541	Very Good	Oil
-4	3573	Fair-to-Good	Oil
-6	3603	Fair-to-Good	Oil

C15+ HYDROCARBON DATA SHEET

BP 7/12-4 CENTRAL NORTH SEA NORWAY

SAMPLE NUMBER	DEPTH M	ORGC %	TE PPM	EPOC %	HC PPM	HC/OC %	SAT %	ARO %	RASP %	HC/TE %
1278 47 1	3155	.40	1770.	44.25	885.	22.12	25.47	24.53	50.01	49.99
1278 47 3	3173	.20	590.	29.50	352.	17.59	37.79	21.84	40.37	59.63
1278 47 5	3207	.33	120.	3.64	46.	1.39	27.29	10.92	61.79	38.21
1278 47 7	3237	.25	470.	18.80	286.	11.45	36.97	23.95	39.09	60.91
1278 47 9	3267	.48	370.	7.71	180.	3.76	32.87	15.89	51.24	48.76
1278 47 11	3297	.49	370.	7.55	185.	3.77	34.33	15.62	50.05	49.95
1278 47 13	3322	.99	680.	6.87	379.	3.83	32.91	22.84	44.26	55.75
1278 47 14	3343	.46	530.	11.52	253.	5.50	25.31	22.43	52.26	47.74
1278 47 16	3353	4.53	12700.	28.04	7152.	15.79	25.97	30.34	43.69	56.31
1278 47 17	3355	1.87	6560.	35.08	4031.	21.56	30.74	30.71	38.55	61.45
1278 47 18	3359	4.23	8750.	20.69	5646.	13.35	32.81	31.71	35.48	64.52
1278 47 19	3365	2.65	5490.	20.72	3225.	12.17	28.60	30.15	41.25	58.75
1278 47 20	3374	3.18	5730.	18.02	3272.	10.29	28.37	28.74	42.89	57.11
1278 47 22	3385	1.45	1010.	6.97	638.	4.40	38.82	24.37	36.81	63.19
1278 47 23	3400	.51	679.	13.31	379.	7.43	32.56	23.23	44.21	55.79
1278 47 25	3410	.53	320.	6.04	136.	2.56	25.79	16.58	57.63	42.37
1278 47 26	3425	.54	450.	8.33	208.	3.84	26.65	19.49	53.87	46.13
1278 47 28	3440	.85	1310.	15.41	791.	9.30	29.41	30.96	39.64	60.37
1278 48 2	3541	6.82	4150.	6.09	1651.	2.42	17.99	21.81	60.21	39.80
1278 48 4	3573	.43	320.	7.44	159.	3.70	28.97	20.70	50.33	49.67
1278 48 6	3603	.65	520.	8.00	169.	2.60	17.31	15.16	67.53	32.47

ORGC % = PERCENT ORGANIC CARBON
TE PPM = PPM OF EXTRACT IN ROCK
EPOC = EXTRACT AS A PERCENT OF ORGANIC CARBON
HC PPM = PPM OF HYDROCARBONS IN ROCK BY TLC
HC/OC % = HYDROCARBONS AS A PERCENT OF ORGANIC CARBON
SAT % = PERCENT SATURATES IN EXTRACT BY TLC
ARO % = PERCENT AROMATICS IN EXTRACT BY TLC
RASP % = PERCENT RESINS AND ASPHALTENES IN EXTRACT BY TLC
HC/TE % = HYDROCARBONS AS A PERCENT OF EXTRACT BY TLC

ESR DATA SHEET

BP 7/12-4 CENTRAL NORTH SEA NORWAY

SAMPLE NUMBER	DEPTH M	TOTC	"G"	W	NG	T"G" F	T NG F	T X F	K
1278 47 1	3155	38.50	32.10	5.95	4.49	268.	231.	256.	1.019
1278 47 3	3173	9.83	31.00	6.55	.56	292.	145.	243.	1.080
1278 47 7	3237	11.50	32.50	5.47	4.91	259.	235.	251.	1.056
1278 47 9	3267	6.09	30.60	5.95	35.27	300.	317.	306.	.987
1278 47 11	3297	6.69	30.50	5.62	18.77	302.	290.	298.	1.015
1278 47 14	3343	42.50	30.40	5.64	9.08	305.	260.	290.	1.094
1278 47 16	3353	48.80	29.20	5.85	6.50	330.	247.	302.	1.140
1278 47 17	3355	45.00	25.70	4.63	.91	406.	165.	326.	1.679
1278 47 19	3365	32.50	30.10	5.35	13.87	311.	278.	300.	1.287
1278 47 20	3374	35.40	30.60	6.12	9.38	300.	262.	287.	1.024
1278 47 22	3385	22.70	29.30	4.52	9.43	328.	262.	306.	1.587
1278 47 23	3400	32.20	29.60	3.69	5.68	322.	241.	295.	1.938
1278 47 25	3410	34.00	29.80	3.93	3.82	318.	224.	287.	1.720
1278 47 26	3425	47.20	29.50	4.69	11.22	324.	269.	306.	1.453
1278 48 2	3541	61.50	30.10	7.06	12.60	311.	274.	299.	.837
1278 48 4	3573	33.70	30.00	4.62	15.31	313.	282.	303.	1.405
1278 48 6	3603	59.10	30.00	5.64	19.16	313.	291.	306.	1.100

TOTC = TOTAL CARBON CONTENT
"G" = SPECTRA POSITION
W = SIGNAL WIDTH
NG = SPIN DENSITY CONCENTRATION
T"G" F = PALEOTEMPERATURE BASED ON "G" IN DEGREES FAHRENHEIT
NG F = PALEOTEMPERATURE BASED ON NG IN DEGREES FAHRENHEIT
TX F = WEIGHTED AVERAGE PALEOTEMPERATURE IN DEGREES FAHRENHEIT
K = SHAPE FACTOR

VISUAL KEROGEN DATA SHEET

BP 7/12-4 CENTRAL NORTH SEA NORWAY

SAMPLE NUMBER			DEPTH M	% AMOR.	% HERB.	% WOODY	% COALY	CF KT	MATUR INDEX	CF MI	VITRN REFLT	FLUOR
1278	47	1	3155	75.	10.	5.	10.	F	3-	G		
1278	47	5	3207	70.	15.	5.	10.	P	3-	G		W
1278	47	7	3237	75.	15.	5.	10.	P	3-	G		W
1278	47	9	3267	80.	5.	5.	10.	P	3-	G		W
1278	47	11	3297	80.	5.	5.	10.	P	3-	G		
1278	47	14	3343	80.	10.	5.	5.	P	3-	G		S
1278	47	16	3353	80.	10.	5.	5.	P	3-	G		
1278	47	19	3365	80.	10.	5.	5.	P	3-	G		S
1278	47	20	3374	60.	20.	10.	10.	P	3-	G		S
1278	47	22	3385	70.	10.	0.	20.	P	3-	G		
1278	47	23	3400	50.	5.	10.	35.	P	3-	G		
1278	47	26	3425	70.	15.	5.	10.	P	3-	G		W
1278	48	1	3534	0.	0.	0.	0.				.56	
1278	48	2	3541	30.	30.	30.	10.	P	3-	G		W
1278	48	4	3573	70.	10.	10.	10.	P	3-	G		
1278	48	6	3603	70.	10.	10.	10.	P	3-	G		W

% AMOR. = PERCENT AMORPHOUS KEROGEN
% HERB. = PERCENT HERBACEOUS KEROGEN
% WOODY = PERCENT WOODY KEROGEN
% COALY = PERCENT COALY KEROGEN
CFKT = CONFIDENCE FACTOR FOR KEROGEN TYPING: E = EXCELLENT
G = GOOD F = FAIR P = POOR
MATUR INDEX = MATURATION INDEX
CFMI = CONFIDENCE FACTOR FOR MATURATION INDEX: E = EXCELLENT
G = GOOD F = FAIR P = POOR
VITRN REFLT = VITRINITE REFLECTANCE
FLUOR = FLOURESCENCE: S = STRONG W = WEAK N = NONE

WELL IDENTIFICATION BP 7/12-4 NORTH SEA,NORWAY

SAMPLE NUMBER 1278-47-1

SAMPLE DEPTH 3155 M

VITRINITE REFLECTANCE VALUES

1.39	1.16	1.29	1.10	1.15	0.95
1.36	0.98	1.19	1.07	0.71	1.54
1.23	1.64	1.01	0.69	0.49	1.45
1.26	1.14	0.95	1.04	1.07	0.85
0.45	0.93	1.33	0.54	1.06	1.34
0.89	1.53	1.60	0.99	0.60	0.87
1.22	1.01	1.43			

MIN.=0.45 MAX.=1.64

MEAN=1.09 STD.DEV.=0.30

NUMBER OF POINTS= 39

```
PTS.  CELL
  1   0.45 I*
  1   0.50 I*
  1   0.55 I*
  1   0.60 I*
  0   0.65 I
  2   0.70 I**
  0   0.75 I
  0   0.80 I
  2   0.85 I**
  1   0.90 I*
  3   0.95 I***
  4   1.00 I****
  4   1.05 I****
  1   1.10 I*
  3   1.15 I***
  2   1.20 I**
  2   1.25 I**
  1   1.30 I*
  3   1.35 I***
  1   1.40 I*
  2   1.45 I**
  0   1.50 I
  2   1.55 I**
  1   1.60 I*
  1   1.65 I*
           +----+----+----+
           0    5    10   15
           FREQUENCY
```

SAMPLE NUMBER 1278-47-5

SAMPLE DEPTH 3207 M

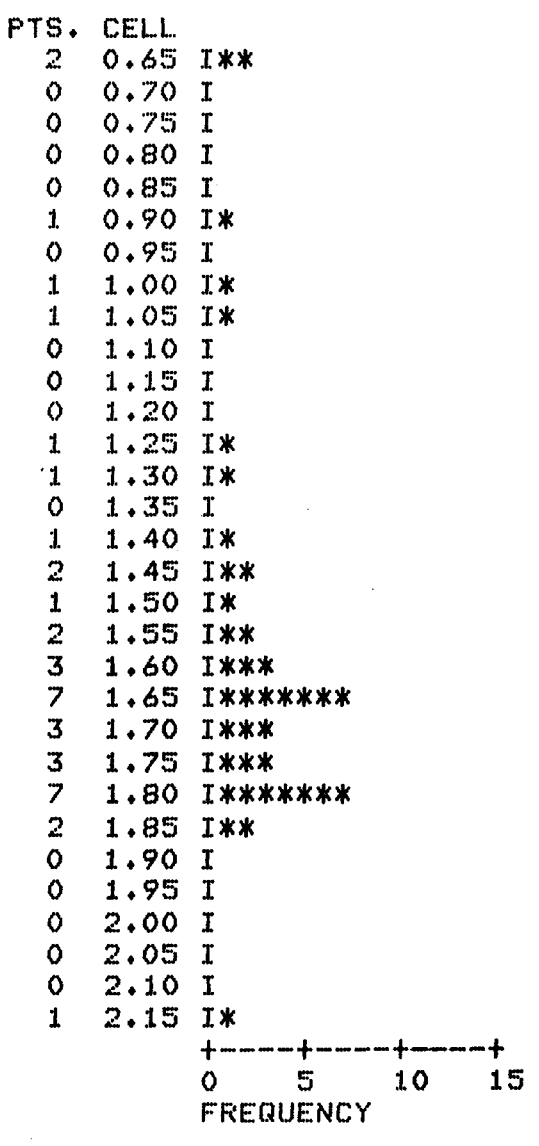
VITRINITE REFLECTANCE VALUES

0.65	1.43	1.66	1.65	1.83	1.79
1.66	1.62	1.78	1.87	0.64	1.78
1.82	1.64	1.70	1.26	1.73	1.76
1.47	1.06	1.80	1.53	1.81	1.67
1.67	1.74	1.60	1.53	1.72	1.39
1.31	1.01	1.51	1.78	1.60	2.16
1.66	1.68	0.91			

MIN.=0.64 MAX.=2.16

MEAN=1.56 STD.DEV.=0.32

NUMBER OF POINTS= 39



SAMPLE NUMBER 1278-47-14

SAMPLE DEPTH 3343 M

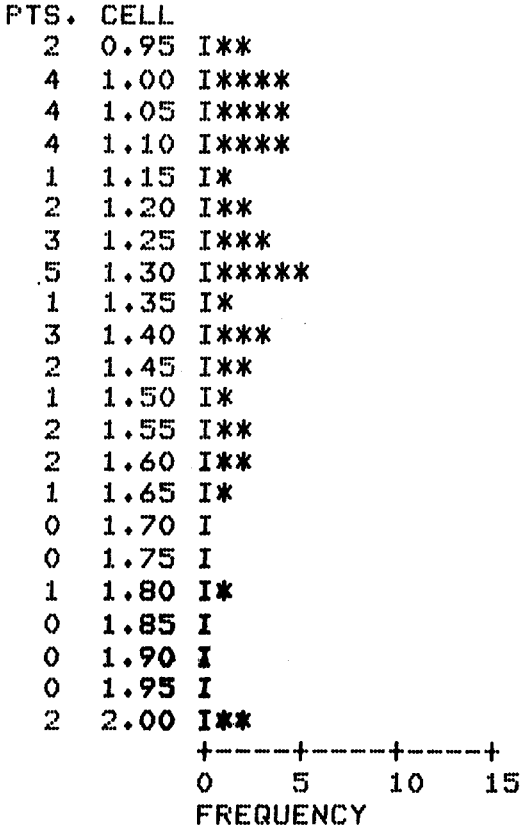
VITRINITE REFLECTANCE VALUES

1.11	2.00	1.58	1.09	1.32	1.32
1.03	1.23	1.46	0.99	1.80	1.57
2.02	1.55	1.35	1.01	1.08	1.02
1.24	1.39	1.22	1.28	1.03	1.06
1.61	1.03	1.66	0.96	1.52	1.39
0.95	1.47	0.99	1.41	1.25	1.29
1.17	1.19	1.32	1.09		

MIN.=0.95 MAX.=2.02

MEAN=1.30 STD.DEV.=0.27

NUMBER OF POINTS= 40



SAMPLE NUMBER 1278-47-26

SAMPLE DEPTH 3425 M

VITRINITE REFLECTANCE VALUES

0.71	1.63	1.90	1.27	1.15	1.52
0.90	1.07	0.95	1.32	1.20	1.24
1.16	1.84	1.54	1.02	1.84	1.34
1.23	0.95	1.52	0.95	0.88	1.22
1.72	1.43	1.30	1.36	1.14	0.75
1.23	1.41	1.23	1.10	1.31	1.04
0.87	0.73	1.52			

MIN.=0.71 MAX.=1.90

MEAN=1.24 STD.DEV.=0.31

NUMBER OF POINTS= 39

```
PTS.  CELL
  1   0.70 I*
  2   0.75 I**
  0   0.80 I
  1   0.85 I*
  2   0.90 I**
  3   0.95 I***
  1   1.00 I*
  2   1.05 I**
  1   1.10 I*
  3   1.15 I***
  2   1.20 I**
  5   1.25 I*****
  3   1.30 I***
  2   1.35 I**
  1   1.40 I*
  1   1.45 I*
  3   1.50 I***
  1   1.55 I*
  0   1.60 I
  1   1.65 I*
  1   1.70 I*
  0   1.75 I
  0   1.80 I
  2   1.85 I**
  1   1.90 I*
          +----+----+----+
          0    5    10   15
          FREQUENCY
```

WELL IDENTIFICATION BP 7/12-4 NORTH SEA,NORWAY

SAMPLE NUMBER 2178-48-1

SAMPLE DEPTH 3534.2 M

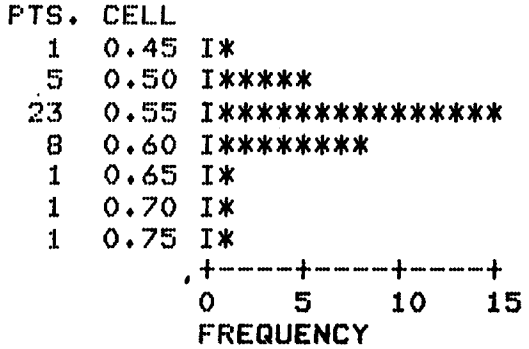
VITRINITE REFLECTANCE VALUES

0.58	0.53	0.52	0.57	0.54	0.55
0.58	0.54	0.54	0.47	0.53	0.75
0.52	0.55	0.51	0.56	0.53	0.55
0.56	0.54	0.58	0.58	0.51	0.58
0.56	0.53	0.51	0.58	0.55	0.58
0.53	0.56	0.53	0.63	0.56	0.58
0.55	0.72	0.56	0.56		

MIN.=0.47 MAX.=0.75

MEAN=0.56 STD.DEV.=0.05

NUMBER OF POINTS= 40



SAMPLE NUMBER 1278-48-6

SAMPLE DEPTH 3603 M

VITRINITE REFLECTANCE VALUES

0.98	1.51	1.27	1.43	2.17	0.78
1.57	1.57	1.08	0.93	0.89	1.39
1.54	1.92	1.57	1.69	1.11	1.45
1.05	0.91	0.96	0.83	1.22	1.36
0.86	0.98	1.27	0.99	1.11	0.92
0.83	0.78	1.04	1.03	0.84	0.89
0.78	1.22	2.03	1.39		

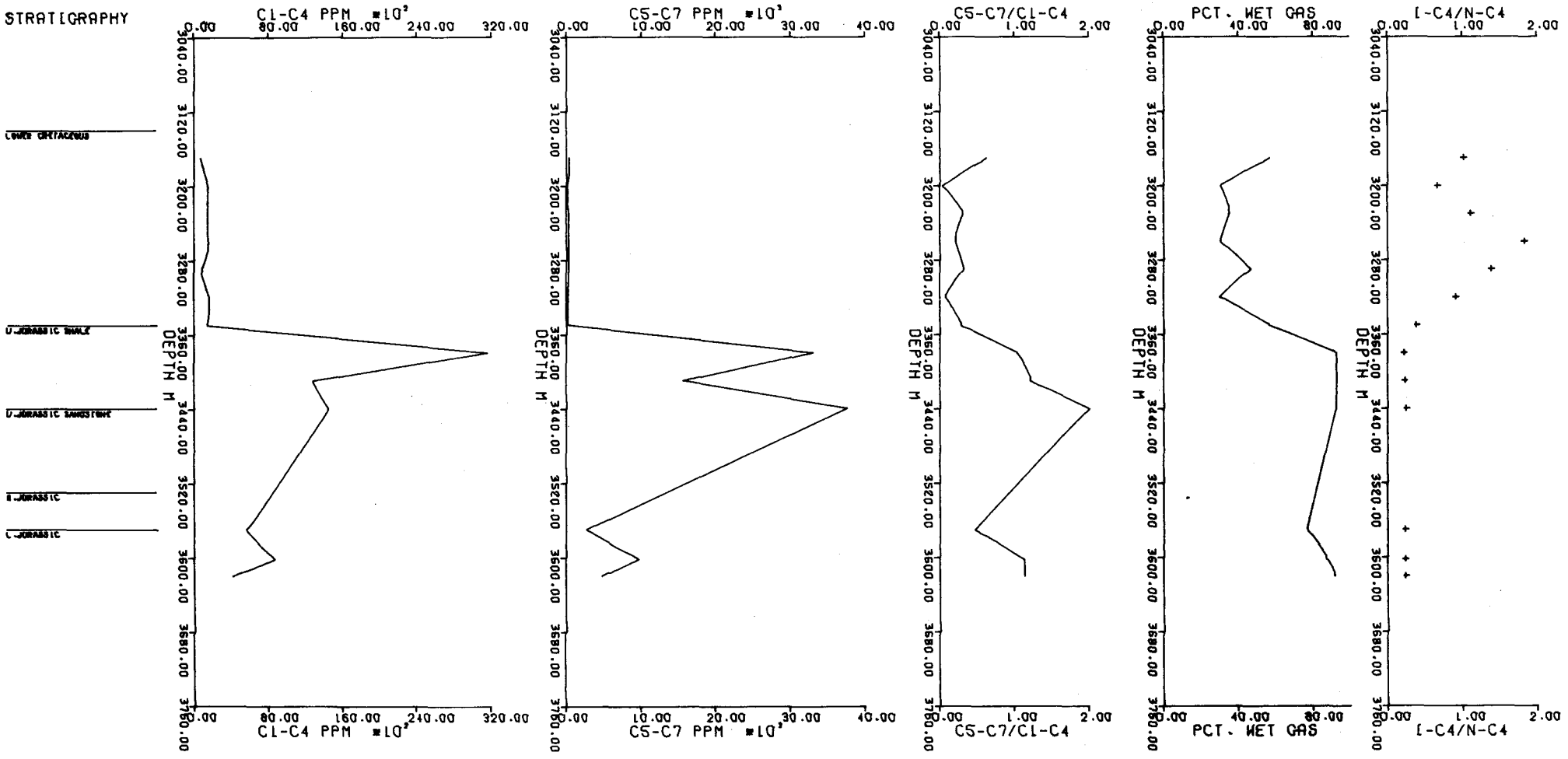
MIN.=0.78 MAX.=2.17

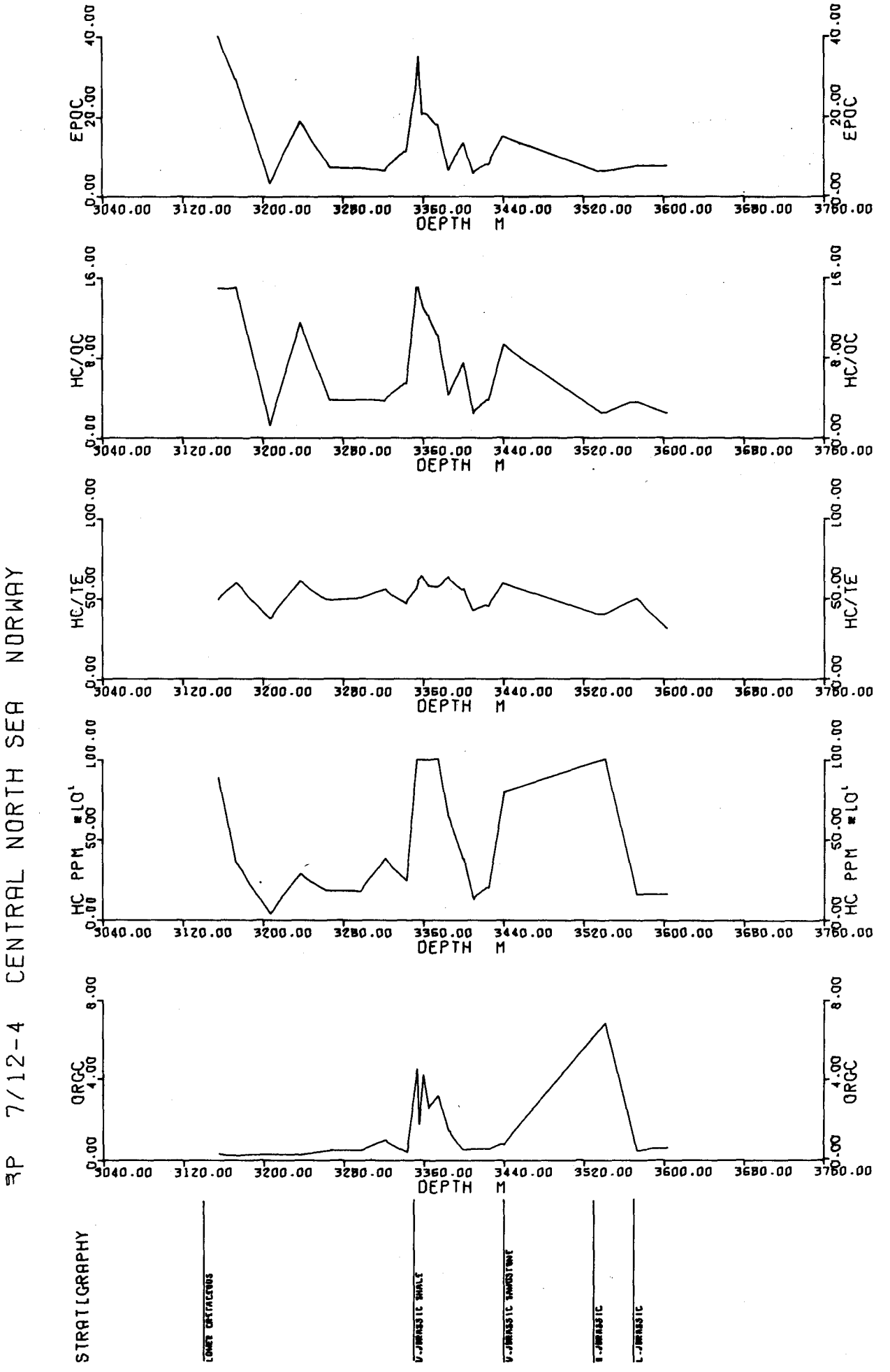
MEAN=1.20 STD.DEV.=0.36

NUMBER OF POINTS= 40

```
PTS.  CELL
  3   0.80 I***
  4   0.85 I****
  4   0.90 I****
  2   0.95 I**
  3   1.00 I***
  3   1.05 I***
  3   1.10 I***
  0   1.15 I
  2   1.20 I**
  2   1.25 I**
  0   1.30 I
  1   1.35 I*
  2   1.40 I**
  2   1.45 I**
  1   1.50 I*
  4   1.55 I****
  0   1.60 I
  0   1.65 I
  1   1.70 I*
  0   1.75 I
  0   1.80 I
  0   1.85 I
  1   1.90 I*
  0   1.95 I
  0   2.00 I
  1   2.05 I*
  0   2.10 I
  1   2.15 I*
          +----+----+----+
          0    5    10   15
          FREQUENCY
```

BP 7/12-4 CENTRAL NORTH SEA NORWAY




SP 7/12-4 CENTRAL NORTH SEA NORWAY
EPOC
HC/OC
HC/TE
HC PPM *LO'
ORGC
DEPTH M
3040.00
3120.00
3200.00
3280.00
3360.00
3440.00
3520.00
3600.00
3680.00
3760.00
STRATIGRAPHY
LOWER CRETACEOUS
U.JURASSIC SHALE
U.JURASSIC SANDSTONE
M.JURASSIC
L.JURASSIC

RP 7/12-4 CENTRAL NORTH SEA NORWAY