ROBERTSON RESEARCH INTERNATIONAL LIMITED

REPORT NO. 4664P/D

A PETROLEUM GEOCHEMICAL EVALUATION
OF THE INTERVAL 810m - 4072.5m OF THE
AMOCO NORWAY 34/2 - 2 WELL

by

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SUMMARY

The 810m to 4072.5m (T.D.) interval of the Amoco Norway 34/2-2 well is immature to a depth of 1600m, early mature from 1600m to 3400m, and middle mature between 3400m and 4072.5m.

The major oil source rock in this area, the Kimmeridge Clay Formation, is not represented within the analysed section. None of the sediments analysed have any significant oil generating potential. However, coals in the Early to Middle Jurassic sediments (3455m to 3975m) may generate minor to fair quantities of gas, and possibly traces of condensate, at a higher level of thermal maturity.

Possible minor oil stain from a high maturity source is noted at 1500m - 1550m. The presence of biodegraded oil stain is recorded between 3250m and 3310m, and in very minor quantities down to 3800m. The timing of biodegradation is probably related to one of the periods of uplift and erosion indicated by the unconformities between the Palaeocene and Maastrichtian (2000m) and the Pliocene and Oligocene (1730m). Therefore oil generation occurred at the latest by Miocene times.

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INTRODUCTION

A petroleum geochemical evaluation has been conducted on the 810m to
4072.5m(T.D.) interval of the Amoco Norway 34/2-2 well, drilled in the
Norwegian sector of the Northern North Sea. The samples consisted of both
bagged and canned cuttings samples, and were predominantly composed of
siltstone, shale and mudstone lithologies. Stratigraphically the interval
ranged from Triassic to Pliocene in age; the stratigraphic information used in
this report is obtained from Robertson Research International Limited Report
Number 2652P/A, issued in September 1981.

Airspace gas analysis was conducted on the canned samples from between 3425m
and 4072.5m prior to the cans being opened and the cuttings washed free of any
adhering drilling mud. Wet cuttings samples from between 3425m and 4072.5m
were selected for gasoline hydrocarbon analysis. These, and additional
composited and washed cuttings samples from between 810m and 3430m were air
dried at less than 40°C, contaminants and cavings were removed as far as
possible, and brief lithological descriptions made.

Data obtained from airspace, gas, gasoline hydrocarbon, spore colour index and
vitrinite reflectivity analyses were used to evaluate the thermal maturity
profile of the interval. Hydrocarbon source potential evaluation was based on
analysis of total organic carbon content, pyrolysis, kerogen type, solvent
extraction, extract fractionation and gas chromatography.

Our contact in Amoco Norway during the course of this work has been
Dr. F. G. Stumm.

The following numbers of sample analyses have been performed during the
geochemical investigation of the 34/2-2 well:-

Preparation	39
Airspace Gas Analysis	16
Gasoline Hydrocarbon Analysis	9
Total Organic Carbon Content	44
"Rock-Eval" Pyrolysis	37

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RESULTS AND INTERPRETATION

A.   MATURITY EVALUATION

i.   Summary

The well section is immature to a depth of 1600m, and early mature below this
to a depth of 3400m.   Between 3400m and 4072.5m(T.D.) the section is middle
mature, such that optimum oil generation may be expected from any oil-prone
kerogens in these sediments.

ii.   Airspace Gas Analysis (Table 1, Figure 1)

The abundance of wet gases (C_2 to C_4 hydrocarbons) in the airspace gas of the
canned cuttings samples between 3425m and 4072.5m(T.D.), indicates that these
sediments are fully mature for oil generation.

iii. Gasoline (C_4 - C_7) Hydrocarbon Analysis (Table 2, Figure 2)

An almost complete range of C_4 to C_7 hydrocarbon components in the gasoline
analysis data, with significant contributions of benzene and toluene, and iso
to normal butane and pentane ratios of less than one, indicate that the
sediments in the interval 3425m to 4072.5mT.D., are fully mature for oil
generation.   The rather low total abundances of these hydrocarbons, (between
1260 ppb at 3800m - 3830m, and 3850 ppb at 3730m - 3760m) indicate poor source
potential and little migrant oil staining.

iv.   Spore Colour Index Analysis (Table 3, Figure 3)

The samples between 810m and 4072.5m(T.D.) mostly yielded abundant indigenous
sporomorphs for measurement of spore colour indices.   The spore colour index
gradient increases from 2.5-3 at 810m, up to 6-6.5. at 4072.5m(T.D.), with no
obvious breaks or changes in gradient.   These data indicate that the section is
immature to a depth of 1600m, early mature from 1600m to 3400m, and middle
mature between 3400m and 4072.5m(T.D.).

v.   Vitrinite Reflectivity Analysis (Table 3, Figure 4)

The vitrinite reflectivity gradient increases from an interpreted 0.38% at
1400m, to an interpreted value of about 0.6% at 4072.5m(T.D.).   These values

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areconsistent with the spore colour indices, indicating a middle mature state between 3400m and 4072.5m(T.D.)

B. HYDROCARBON SOURCE POTENTIAL EVALUATION

The kerogen composition data are presented in Table 3, and the chemical analysis data in Tables 4A and 4B. The gas chromatograms of the alkane fractions are presented as Figures 5.1 to 5.11, and a summary of the geochemical data is illustrated in Enclosure 1. For the purpose of discussion the section has been divided with respect to the lithostratigraphic and biostratigraphic breakdowns given in Robertson Research International Limited Report Number 2652P/A.

i. Tertiary: 810m to 2000m

The Tertiary interval comprises mainly silty clays and sandstones to a depth of 1430m and mainly silty shales between 1430m and 2000m depth.

The total organic carbon contents are generally below average between 1500m and 2000m, except where there has been contamination by additive at 1700m - 1750m.

Pyrolysis potential yield data of less than 2000ppm confirm the lack of source potential in this interval. The generally inertinitic kerogen composition of the sediments is indicated by the low hydrogen indices, and confirmed by optical analysis.

Possible minor oil stain from a high maturity source is noted in the 1500m - 1550m sample. The yield of solvent extractable hydrocarbon in this sample is not very high (250ppm), but the alkane distribution (see Figure 5.1) resembles that of a light oil from a high maturity source. It may, however , be due to drilling contamination.

ii. Cromer Knoll Group (Early Cretaceous): 3220m to 3385m

This interval is predominantly shale, but the total organic carbon contents are generally below average for these lithologies. The exception to this is the 3280m - 3310m sample which has a total organic carbon content of 2.87%. However, the kerogen composition of this, and the other samples analysed from this interval, is inertinitic and hence no source potential is envisaged irrespective of maturity.

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Solvent extraction and fractionation analysis reveals the presence of anomalous amounts of hydrocarbon in the 3250m - 3280m sample (1030 ppm of hydrocarbon) and 3280m - 3310m sample (715 ppm hydrocarbon) which is attributed to the presence of migrant oil. The gas chromatograms of the alkane fractions (Figures 5.2. and 5.3.) indicate a mixture of biodegraded oil, with a minor additional contribution of possibly indigenous hydrocarbons. This latter component comprises a mixture of n-alkanes between n-C_{15} and n-C_{33}, with a marked odd over even carbon number preference between n-C_{27} and n-C_{33}. This alkane distribution is compatible with derivation from an early mature humic kerogen as present in this sample.

The biodegraded component of the hydrocarbons as represented by the large unresolved envelope beneath the n-alkane distribution is a major component of the hydrocarbon present in the sample. The presence of biodegraded oil suggests that meteoric waters carrying bacteria and oxygen have been able to penetrate to the formation containing the migrant hydrocarbon during a time when uplift had exposed the area to erosion. The presence of such unconformities at about Danian and Miocene times is suggested by the stratigraphic record, and the latter is considered the most likely time for such alteration to have occurred.

Similar, although very minor staining by biodegraded oil is also noted in the 3340' - 3370' sample (Figure 5.4.).

iii. Humber Group (Late Jurassic): 3385m to 3455m

The dark grey shales and siltstones of this interval contain about average amounts of organic carbon, at 0.80% to 1.20%, but their generally inertinitic kerogen composition precludes the possibility of significant hydrocarbon generation, irrespective of maturity.

A mixture of dominantly biodegraded oil, with minor indigenous hydrocarbons is revealed by the alkane gas chromatograms of the solvent extractable hydrocarbons (Figure 5.5. and 5.6.) for the samples at 3400m - 3430m and 3425 - 3455m. These hydrocarbons are considered to have a similar history of alteration to those noted in the overlying Early Cretaceous interval, but are present only in very minor quantity (245 ppm).

iv. Brent and Dunlin Group Equivalents, Statfjord Formation Equivalent (Middle to Early Jurassic): 3455m to 3975m

This interval comprises dominantly argillaceous siltstones with, in addition, sandstones and minor coals below 3800m. The total organic carbon contents of the samples are about average for their lithologies, generally being between 1% and 2%. However, the kerogen composition of the samples is dominated by inertinite, so the pyrolysis potential yields, and hence oil generating capacity is low.

Given the level of maturity of these samples, hydrocarbon generation would have started in this interval but the pyrolysis data indicate poor source potential so that no significant hydrocarbon generation is anticipated. The organically richest samples in the interval are occasional coals, but they are dominantly inertinitic with secondary vitrinite and liptinite. The pyrolysis data for the coal analysed at 3910m - 3960m suggest minor to fair gas generating potential at optimum maturity. The liptinitic component of the coal may in these circumstances produce traces of condensate.

A number of samples were submitted for solvent extraction, extract fractionation and gas chromatography. The chromatograms obtained show greater or lesser degrees of odd over even carbon number preference in the long-chain components. These distributions, and the generally low quantities, are compatible with the generally poor, humic kerogens of this interval. However, unresolved envelopes representing biodegraded oil are also noted throughout. The coaly nature of the 3870m - 3910m interval is clearly reflected by the high pristane component and pristane/phytane ratio of the alkanes (Figure 5.11). Hence the extractable hydrocarbons in this interval are considered to be a mixture of biodegraded migrant oil and indigenous hydrocarbon.

The relatively high pyrolysis potential yield data of 0.2 indicate oil stain, but the total quantities of hydrocarbon indicate that this is only very minor.

Overall, the Middle to Early Jurassic interval (3455m - 3975m) has little or no oil generating potential, but the coaly intervals are such that at optimum maturity, minor to fair quantities of gas, and possibly traces of condensate,

will be generated.

v.   <u>Triassic</u>: 3975m to 4072.5m(T.D.)

Siltstones and sandstones characterise the samples representing the interval
3960m to 4072.5m(T.D.). The organic carbon contents vary from poor to average,
and the pyrolysis yields are low, at no more than 900 ppm (at 4010m –
4072.5m(T.D.)). Hence this interval is considered to have no significant
source potential, irrespective of maturity.

CONCLUSIONS

The 810m to 4072.5m(T.D.), interval of the Amoco Norway 34/2-2 well has been analysed by geochemical methods, and the following conclusions have been made:

1. The well section is immature to a depth of 1600m, early mature between 1600m and 3400m, and middle mature between 3400m and 4072.5m(T.D.); optimum oil generation may be expected from any oil-prone kerogens in this lowermost interval.

2. The Tertiary interval, 810m - 2000m has no source potential, but possible minor oil-stain from a high maturity source is noted at 1500m - 1550m.

3. Sediments in the Early Cretaceous interval (3220m - 3385m) have no source potential, but have minor oil stain at 3250m - 3310m, and to a lesser extent at 3340m - 3370m which has been biodegraded. This biodegradation may have occurred during either of the phases of uplift and erosion represented by the Miocene and Danian time unconformities at 1430m and 2000m. Therefore the oil must have been generated and emplaced prior to Miocene times.

4. Late Jurassic sediments between 3385m and 3455m have no source potential, but minor amounts of biodegraded oil, with probably the same history of generation and alteration as that of the early Cretaceous interval, is noted between 3400m and 3455m.

5. The Middle to Early Jurassic sediments (3455m to 3975m) have no significant oil generating potential, but the coals may generate minor to fair quantities of gas, possibly with traces of condensate, at a higher level of thermal maturity. Minor biodegraded oil, with probably the same history as that of the Early Cretaceous interval, is noted between 3455m and 3800m.

6. The Triassic sediments have no hydrocarbon generating potential irrespective of maturity.

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SAMPLE DEPTH METRES	RELATIVE GASEOUS HYDROCARBON COMPONENT ABUNDANCE (%)					TOTAL ABUNDANCE (ppm)	TOTAL $C_2 - C_4$ (%)	RATIO i- Butane / n- Butane
	C_1	C_2	C_3	i-C_4	n-C_4			
3425–455	63.8	18.7	13.2	2.3	2.0	35480	36.2	1.14
3457.5–487.5	–	–	–	–	–	–	–	–
3490–520	–	–	–	–	–	–	–	–
3522.5–550	71.1	14.8	10.0	2.3	1.7	38040	28.9	1.34
3552.5–580	68.9	16.1	10.7	2.5	1.8	52300	31.1	1.36
3582.5–610	56.9	20.6	16.2	3.2	3.1	27850	43.1	1.02
3612.5–646	57.9	18.4	16.7	3.3	3.8	21640	42.1	0.86
3642.5–670	58.2	17.7	16.8	3.8	3.5	29570	41.8	1.07
3672.5–700	70.1	15.3	11.1	1.8	1.7	52200	29.9	1.05
3702.5–730	57.7	19.0	16.9	3.2	3.3	34190	42.3	0.97
3730–760	64.0	16.0	14.4	2.8	2.6	31160	36.0	1.08
*3760–800	50.8	19.1	20.5	4.8	4.7	3550	49.2	1.02
3800–830	53.6	19.6	18.8	3.8	4.1	20310	46.4	0.91
3830–870	82.8	9.0	6.0	1.1	1.2	66900	17.2	0.89
3870–910	83.7	11.3	3.9	0.5	0.5	97600	16.3	0.99
3910–960	87.4	8.1	3.3	0.6	0.6	81200	12.6	0.94
3960–4010	77.5	9.4	9.0	1.8	2.3	25360	22.5	0.80
4010–072.5 (T.D)	88.4	7.6	3.0	0.4	0.5	79200	11.6	0.82

* Small Airspace

Note: Total gaseous hydrocarbon abundance values are expressed as volume of hydrocarbon gases relative to volume of airspace

TABLE 1   Airspace Gaseous Hydrocarbon Analysis Data

COMPANY: AMOCO NORWAY   WELL: 34/2-2   LOCATION: OFFSHORE NORWAY

DEPTH: METRES	3425 -455	3490 -520	3552.5 -580	3612.5 -640	3672.5 -700	3730 -760	3800 -830
GASOLINE HYDROCARBON COMPONENTS	RELATIVE GASOLINE HYDROCARBON COMPONENT ABUNDANCES (%)						
i - BUTANE	14.65	12.71	15.61	11.97	15.85	14.00	14.96
n - BUTANE	23.24	24.18	24.70	22.69	29.74	25.95	24.86
i - PENTANE	13.93	6.23	9.22	9.75	9.91	10.23	10.53
n - PENTANE	13.83	9.70	12.23	13.32	12.97	14.26	12.91
2, 2 – DIMETHYL BUTANE	0.57	*	0.75	0.76	0.37	0.55	0.79
CYCLOPENTANE	0.75	1.35	1.07	1.18	1.32	0.70	} 1.66
2, 3 – DIMETHYL BUTANE	0.50	0.74	0.94	0.55	0.41	0.29	}
2 – METHYL PENTANE	2.35	2.69	2.76	2.49	1.87	2.99	2.14
3 – METHYL PENTANE	1.03	1.56	1.69	1.73	1.42	1.69	1.58
n – HEXANE	4.06	4.11	3.20	3.70	3.43	5.32	3.40
2, 2 – DIMETHYL PENTANE / METHYL CYCLOPENTANE	*	5.24	1.69	2.46	2.06	2.05	2.45
2, 4 – DIMETHYL PENTANE	*	*	*	0.14	1.28	1.97	1.66
BENZENE	5.13	8.21	4.26	4.25	3.70	2.88	3.17
3, 3 – DIMETHYL PENTANE	0.57	*	*	*	*	0.10	*
CYCLOHEXANE	3.53	7.58	4.39	5.81	3.79	4.18	4.43
2 – METHYL HEXANE +	2.60	2.16	1.50	2.04	0.82	1.04	1.66
1, 1 – DIMETHYL CYCLOPENTANE	0.57	*	0.56	0.90	0.14	0.21	*
3 – METHYL HEXANE	1.39	2.48	1.13	1.87	0.64	0.81	0.95
1, cis – 3 – DIMETHYL CYCLOPENTANE	*	*	0.38	0.76	0.18	0.23	0.32
1, trans – 3 – DIMETHYL CYCLOPENTANE	*	*	0.50	0.76	0.23	0.27	*
1, trans – 2 – DIMETHYL CYCLOPENTANE	*	*	0.69	0.18	0.23	0.23	0.32
3 – ETHYL PENTANE	–	–	–	–	–	–	–
n – HEPTANE	1.46	2.62	2.13	1.83	1.64	1.69	1.50
1, cis – 2 – DIMETHYL CYCLOPENTANE / METHYL CYCLOHEXANE	5.20	4.04	5.45	5.88	4.07	4.60	5.78
ETHYL CYCLOPENTANE	*	*	1.00	0.42	0.27	0.29	*
TOLUENE	4.63	4.42	4.14	3.01	3.29	3.06	3.48
TOTAL ABUNDANCE (ppb)	2800	2830	1600	2890	2200	3850	1260
ORGANIC CARBON (%)	1.20	0.97	1.45	1.17	1.77	2.31	1.47
GASOLINE ABUNDANCE AT 1% ORGANIC CARBON	2330	2920	1100	2470	1240	1670	860

Note: Total gasoline abundance values are expressed as weight of gas relative to weight of wet rock.

TABLE 2A   Gasoline Hydrocarbon Analysis Data

COMPANY: AMOCO NORWAY   WELL: 34/2-2   LOCATION: OFFSHORE NORWAY

DEPTH: METRES	3870-910	4010-072.5					
GASOLINE HYDROCARBON COMPONENTS	RELATIVE GASOLINE HYDROCARBON COMPONENT ABUNDANCES (%)						
i – BUTANE	15.52	12.20					
n – BUTANE	28.56	24.77					
i – PENTANE	9.01	9.66					
n – PENTANE	10.81	11.82					
2, 2 – DIMETHYL BUTANE	0.12	*					
CYCLOPENTANE	} 2.32	} 2.44					
2, 3 – DIMETHYL BUTANE							
2 – METHYL PENTANE	1.80	2.44					
3 – METHYL PENTANE	0.96	1.59					
n – HEXANE	1.92	2.63					
2, 2 – DIMETHYL PENTANE / METHYL CYCLOPENTANE	2.79	3.10					
2, 4 – DIMETHYL PENTANE	0.65	*					
BENZENE	7.28	6.29					
3, 3 – DIMETHYL PENTANE	*	*					
CYCLOHEXANE	3.56	4.50					
2 – METHYL HEXANE +	0.56	1.22					
1, 1 – DIMETHYL CYCLOPENTANE	0.19	*					
3 – METHYL HEXANE	0.40	0.84					
1, *cis* – 3 – DIMETHYL CYCLOPENTANE	0.28	0.38					
1, *trans* – 3 – DIMETHYL CYCLOPENTANE	0.37	0.47					
1, *trans* – 2 – DIMETHYL CYCLOPENTANE	0.59	0.84					
3 – ETHYL PENTANE	–	–					
n – HEPTANE	0.81	1.31					
1, *cis* – 2 – DIMETHYL CYCLOPENTANE / METHYL CYCLOHEXANE	4.15	5.44					
ETHYL CYCLOPENTANE	0.31	1.31					
TOLUENE	7.03	6.75					
TOTAL ABUNDANCE (ppb)	3230	1070					
ORGANIC CARBON (%)	2.24	1.19					
GASOLINE ABUNDANCE AT 1% ORGANIC CARBON	1440	900					

Note: Total gasoline abundance values are expressed as weight of gas relative to weight of wet rock.

TABLE 2B   Gasoline Hydrocarbon Analysis Data

SAMPLE DEPTH (METRES)	SAMPLE TYPE	GENERALISED LITHOLOGY	SPORE COLOUR INDEX (1-10)	VITRINITE REFLECTIVITY IN OIL, R av %	KEROGEN COMPOSITION (%)		
					INERTINITE	VITRINITE	SAPROPEL
810-840	Ctgs	MDST, gn-gy	2.5-3	0.13(2)	minor	100	–
1010-040	"	A/a+SND	2.5-3 4.5-7	0.18(5)	70	30	– mnr Sp
1210-240	"	A/a	3 4.5-7.5	*	70	30	– mnr Sp
1410-440	"	A/a	3 4-5	0.26(5) 0.35(1) 0.48(3) 0.65(2)	70	30	– mnr Sp
1600-650	"	SLTST, gy-gn+ 20% MDST, lt ol-gy	3.5	*	70	30	– mnr Sp
1800-850	"	SLTST, gy-gn/dk gn-gy/dk ol-gy	3	*	20	80	– mnr Sp
1950-2000	"	SLTST, dk gy/ gy-gn/lt ol-gy	4	0.44(4) 0.61(1)	70	30	– mnr Sp
3220-250	"	SH, dk gy+10% SLTST, pale red +mnr SND	4.5-5 6-7	0.36(2) 0.45(2) 0.65(1)	90	10	– mnr Sp
3400-430	"	SH, dk gy/med gy/gy-red	?3.5	0.57(6) 0.78(10) 0.93(2)	?40	?30	?30 –
3490-520	"	SLTST, med-dk gy	5.5	*	90	10	?mnr mnr Sp
3582.5-610	"	A/a	5.5-6	*	90	10	–
3672.5-700	"	SLTST, med-dk gy/gy-brn	6	0.30(4) 0.43(8) 0.64(1)	80	20	– mnr Sp
3760-780	"	A/a	5.5	0.55(11) 0.72(20) 0.86(6)	80	20	–
3830-870	"	SLTST, med-dk gy	6-6.5	0.51(15) 0.59(20)	70	30	–
3910-960	"	SLTST, med-dk gy+30% SND+ tr COAL	6-6.5	0.50(15) 0.64(1) 0.73(9)	70	30	–
4010-4072.5	"	SLTST, a/a+40% SLTST, gy-brn+ 20% SND	6-6.5	0.50(17)	60	40	–

TABLE 3 Maturity Evaluation Data

Table 4A CHEMICAL ANALYSIS DATA

COMPANY: AMOCO-NORWAY   **WELL:** 34/2-2   **LOCATION:** OFFSHORE NORWAY

SAMPLE DEPTH METRES	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TEMP-ERATURE °C	HYDROGEN INDEX	OXYGEN INDEX	PRODUCTION INDEX	POTENTIAL YIELD (ppm)	TOTAL EXTRACT (ppm)	HYDRO-CARBONS (ppm)	EXTRACT % OF ORGANIC CARBON	mg/g OF ORGANIC CARBON	% OF EXTRACT	ALKANES % OF HYDRO-CARBONS
		TERTIARY:PLIOCENE												
810-840	Ctgs	CMT+mnr MDST, gn-gy	-											
1010-040	"	MDST, gn-gy+20% SND	-											
1210-240	"	A/a	-											
1410-440	"	A/a	-											
		OLIGOCENE-EOCENE (Top 1430m)												
1500-550	"	MDST, lt ol-gy	1.44	428	76	81	0.2	1100	585	250	4.1	17	43	65
1550-600	"	MDST, a/a+20% SLTST, gy-gn	0.91	431	31	80	0.2	300						
1600-650	"	SLTST, a/a+20% MDST, a/a	0.42											
1650-700	"	SLTST, gy-gn/dk gn-gy+mnr MDST	0.39											
1700-750	"	SLTST, a/a+additive	7.76	*	74	169	0.8	5800	320	35	0.4	0.5	11	55
1750-800	"	SLTST, a/a	0.85	434	31	224	0.3	300						
1800-850	"	SLTST, gy-gn+20% SLTST, dk gn-gy+40% SLTST, dk ol-gy	0.83	435	24	174	0.2	200						
		LATE PALAEOCENE (Top 1880m)												
1850-900	"	SLTST, dk gy+30% SLTST, gy-gn+20% SLTST, lt ol-gy	0.73	433	16	133	0.2	100						
1900-950	"	SLTST, a/a+20% SLTST, a/a+10% SLTST, a/a	0.41											
1950-2000	"	SLTST, a/a+10% SLTST, a/a +10% SLTST, a/a	0.38											
		E.CRETACEOUS: CROMER KNOLL GROUP (Top 3220m)												
3220-250	"	SH, dk gy+10% SLTST, pale red+mnr SND	0.75	432	34	121	0.3	300						
	P	SH, dk gy	0.72											
3250-280	Ctgs	SH, a/a+mnr SLTST, a/a+10% SND	0.94	434	86	93	0.2	800	1240	1030	13.2	110	83	79
3280-310	"	SH, a/a+mnr SLTST, a/a+mnr SND	2.87	440	68	84	0.1	2000	1330	715	4.6	25	54	78
	P	SH, dk gy	0.91	439	27	16	0.4	300						
3310-340	Ctgs	SH, dk gy/med gy+mnr SND	0.79	443	32	94	0.2	300						
3340-370	"	SH, a/a+mnr SND	0.89	442	31	98	0.3	300	290	225	3.3	29	87	72
	P	SH, dk gy/med gy	0.76	442	29	12	0.4	200						
		L.JURASSIC:HUMBER GROUP (Top 3385m)												
3370-400	Ctgs	SH, a/a+10% SH, gy-red+mnr SND	0.80	443	31	46	0.3	300						
3400-430	"	SH, a/a+mnr SH, a/a	0.97	436	34	46	0.3	300	425	245	4.4	25	57	65
	P	SH, dk gy/med gy	1.08	441	33	9	0.3	400						

COMPANY: AMOCO-NORWAY   **WELL:** 34/2-2   **LOCATION:** OFFSHORE NORWAY

| SAMPLE DEPTH METRES	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TEMPERATURE °C	HYDROGEN INDEX	OXYGEN INDEX	PRODUCTION INDEX	POTENTIAL YIELD (ppm)	TOTAL EXTRACT (ppm)	HYDROCARBONS (ppm)	EXTRACT % OF ORGANIC CARBON	mg/g OF ORGANIC CARBON	% OF EXTRACT	ALKANES % OF HYDROCARBONS
3425-455	Ctgs	SLTST, med-dk gy+mnr SLTST, gy-brn	1.20	439	39	15	0.2	500	375	275	3.1	23	73	72
		M/E JURASSIC: BRENT GROUP EQUIVALENT (Top 3455m)												
3457.5-3487.5	"	A/a	0.96	440	42	22	0.2	400						
		DUNLIN GROUP EQUIVALENT (Top 3480m)												
3490-520	"	SLTST, med-dk gy	0.97	439	48	18	0.2	500						
3522.5-3550	"	A/a	1.15	442	48	15	0.2	600	150	95	1.3	8	64	72
3552.5-3580	"	A/a+additive	1.45	442	70	61	0.2	1000	200	165	1.4	11	83	71
3582.5-610	"	A/a	1.43	444	64	16	0.2	900	385	220	2.7	15	57	70
3612.5-640	"	SLTST, a/a+10% SLTST, gy-brn +mnr SST, pnk-gy	1.17	441	63	16	0.2	800						
3642.5-670	"	SLTST, a/a+10% SLTST, a/a+ 10% SST, a/a	1.10	440	66	18	0.2	800						
3672.5-700	"	SLTST, a/a+mnr SLTST, a/a	1.77	442	72	12	0.2	1300	450	280	2.6	16	62	66
3702.5-	"	SLTST, med-dk gy	1.51	442	67	15	0.2	1000						
3730-760	"	SLTST, a/a+mnr SLTST, gy-brn	2.31	443	57	21	0.2	1300	480	285	2.1	12	60	79
3760-800	"	A/a	1.83	444	59	17	0.2	1100	350	190	1.9	10	54	70
3800-830	"	SLTST, med-dk gy	1.47	444	56	20	0.2	800						
		STATFJORD EQUIVALENT (Top 3835m)												
3830-870	"	SLTST, a/a+mnr SND	1.48	443	68	12	0.2	1000						
3870-910	"	SLTST, a/a+50% SND+tr COAL	2.24	444	91	6	0.1	2100	635	350	2.8	16	56	31
	P	SLTST, med-dk gy	2.05	454	56	8	0.1	1200						
3910-960	Ctgs	SLTST, a/a+30% SND+tr COAL	1.33	442	63	14	0.2	900						
	P	COAL	23.20	453	213	4	0.04	49400						
		? TRIASSIC (Top (3975m)												
3960-4010	Ctgs	SLTST, a/a+40% SLTST, gy-brn +20% SND	0.64											
	P	SLTST, med-dk gy	1.45	446	48	8	0.2	700						
	P	SLTST, gy-brn	0.18											
		LATE TRIASSIC												
4010-072.5	Ctgs	SLTST, med-dk gy+40% SLTST, gy-brn+20% SND	1.19	446	57	14	0.2	700						
	P	SLTST, med-dk gy	1.51	450	55	8	0.1	900						
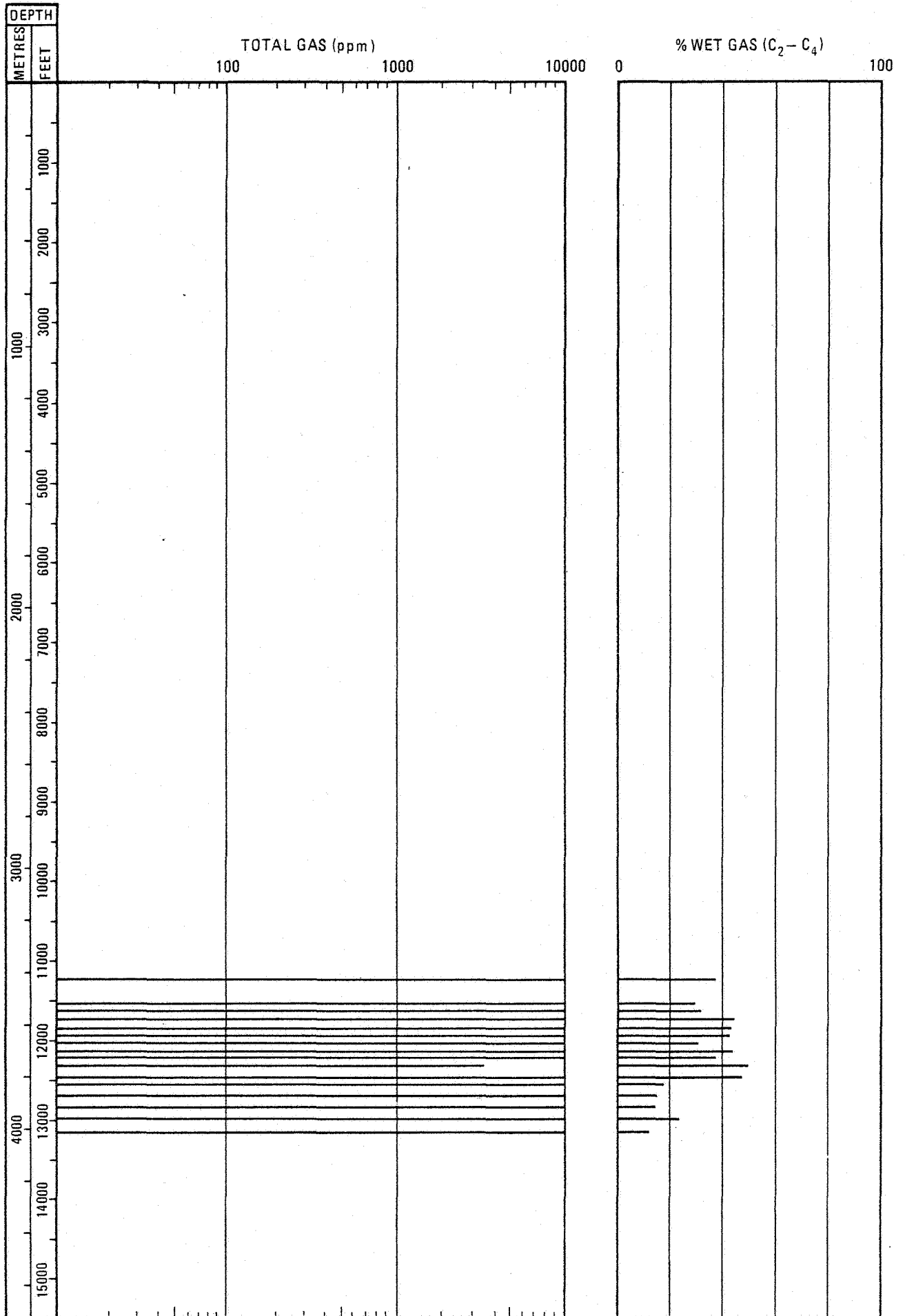
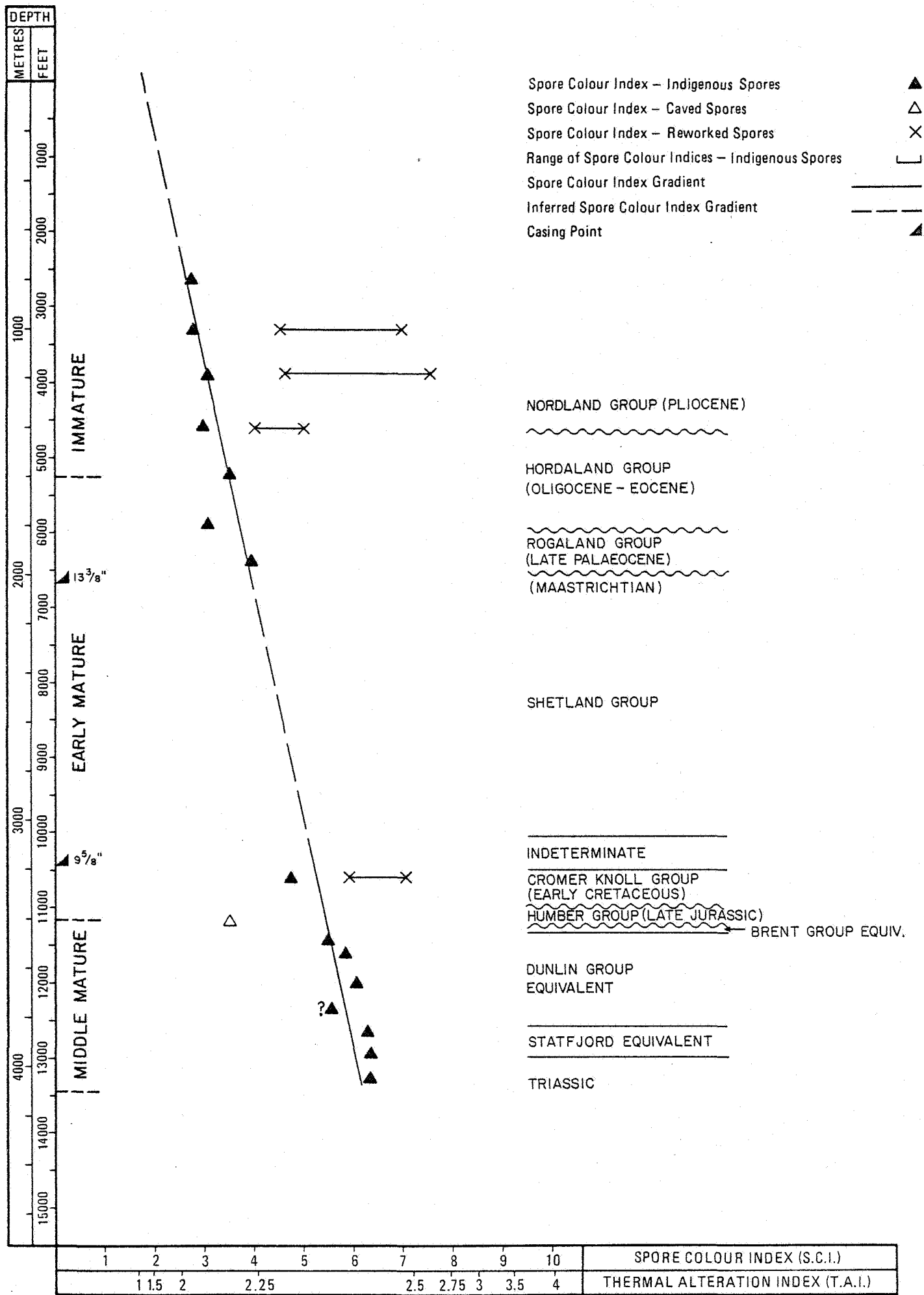FIGURE 1   Airspace $(C_1 - C_4)$ Hydrocarbons against Depth

FIGURE 3 Spore Colour Indices against Depth
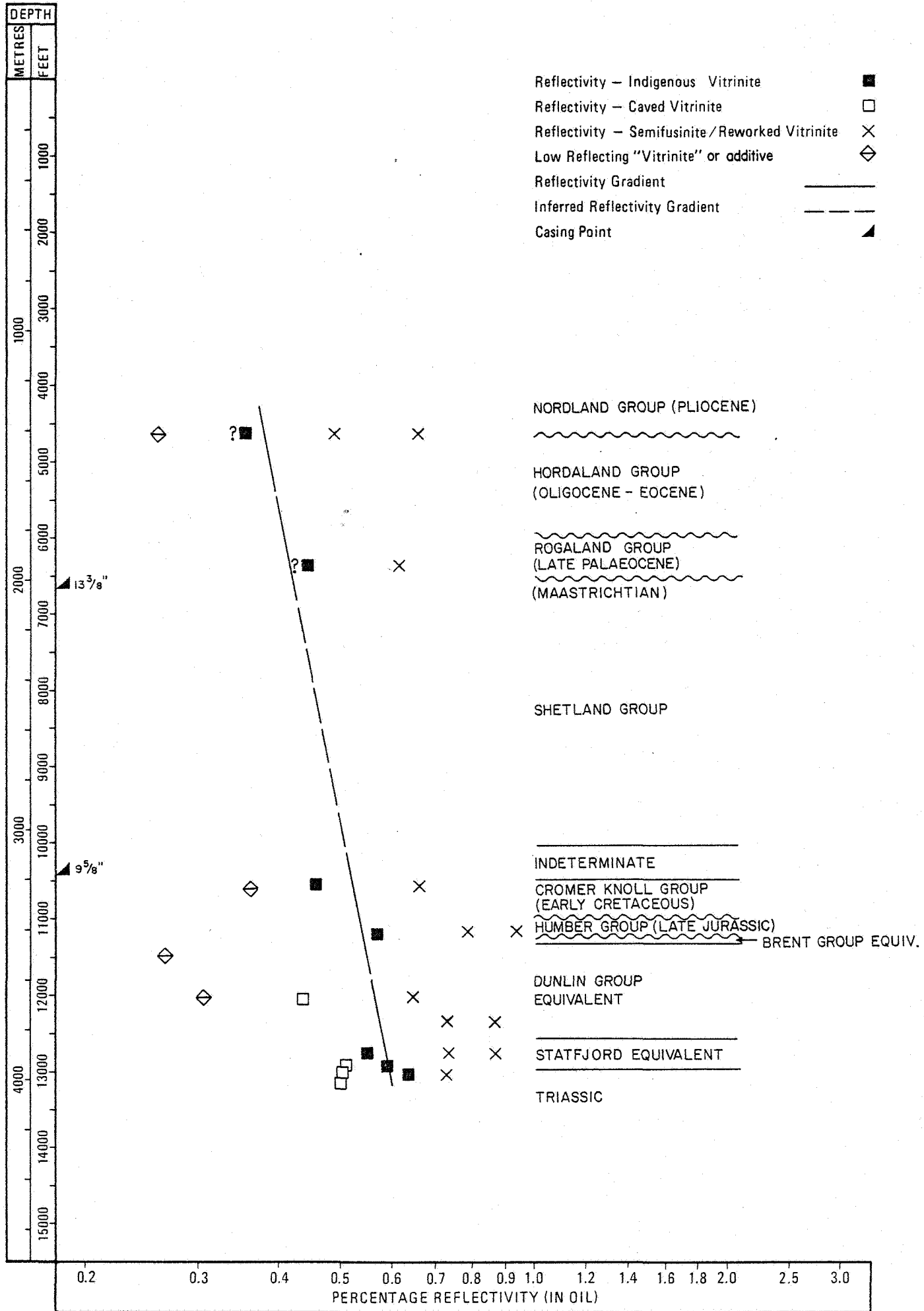
FIGURE 4 Vitrinite Reflectivity against Depth

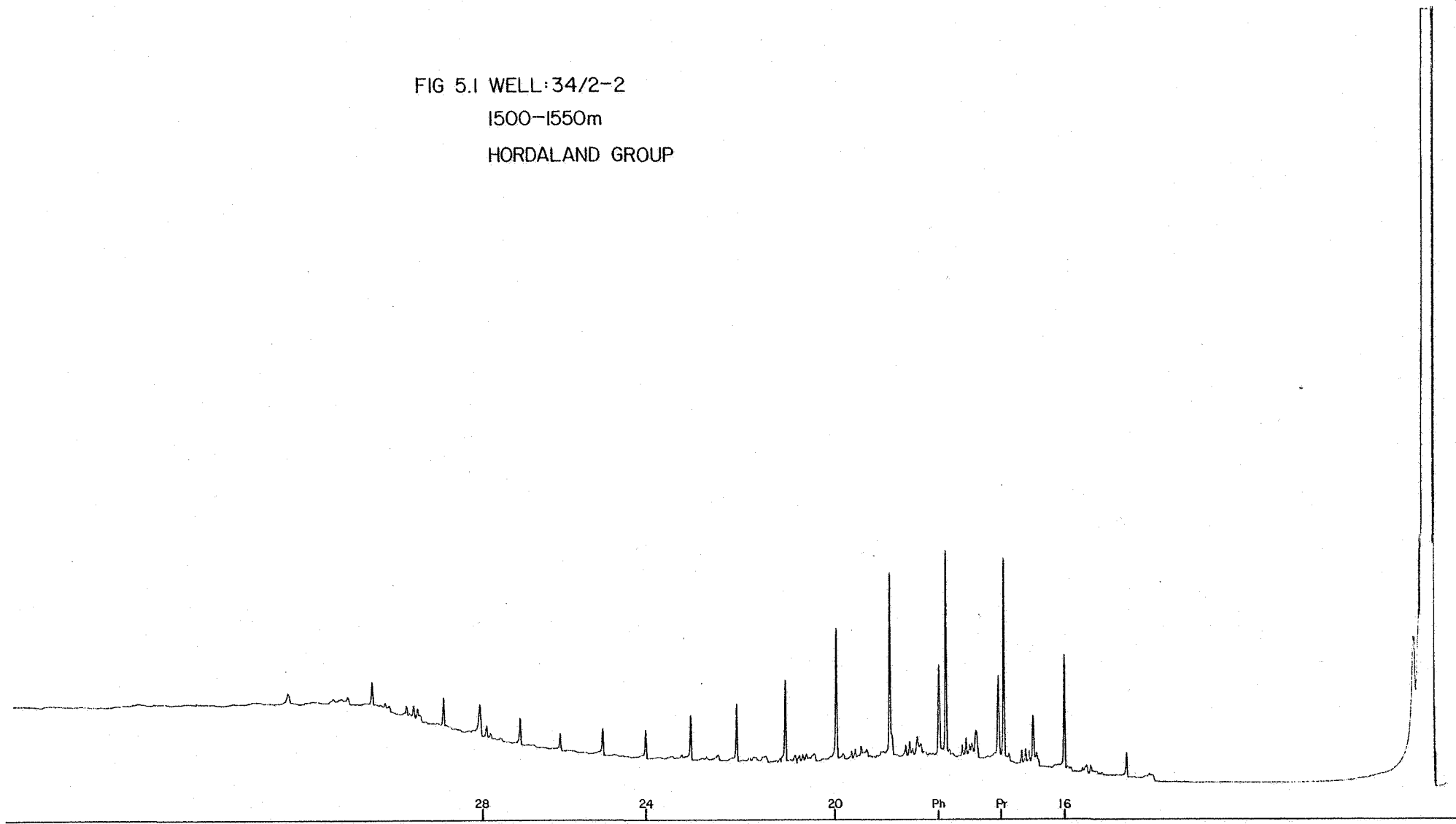FIG 5.1 WELL: 34/2-2

1500-1550m

HORDALAND GROUP

28   24   20   Ph   Pr   16
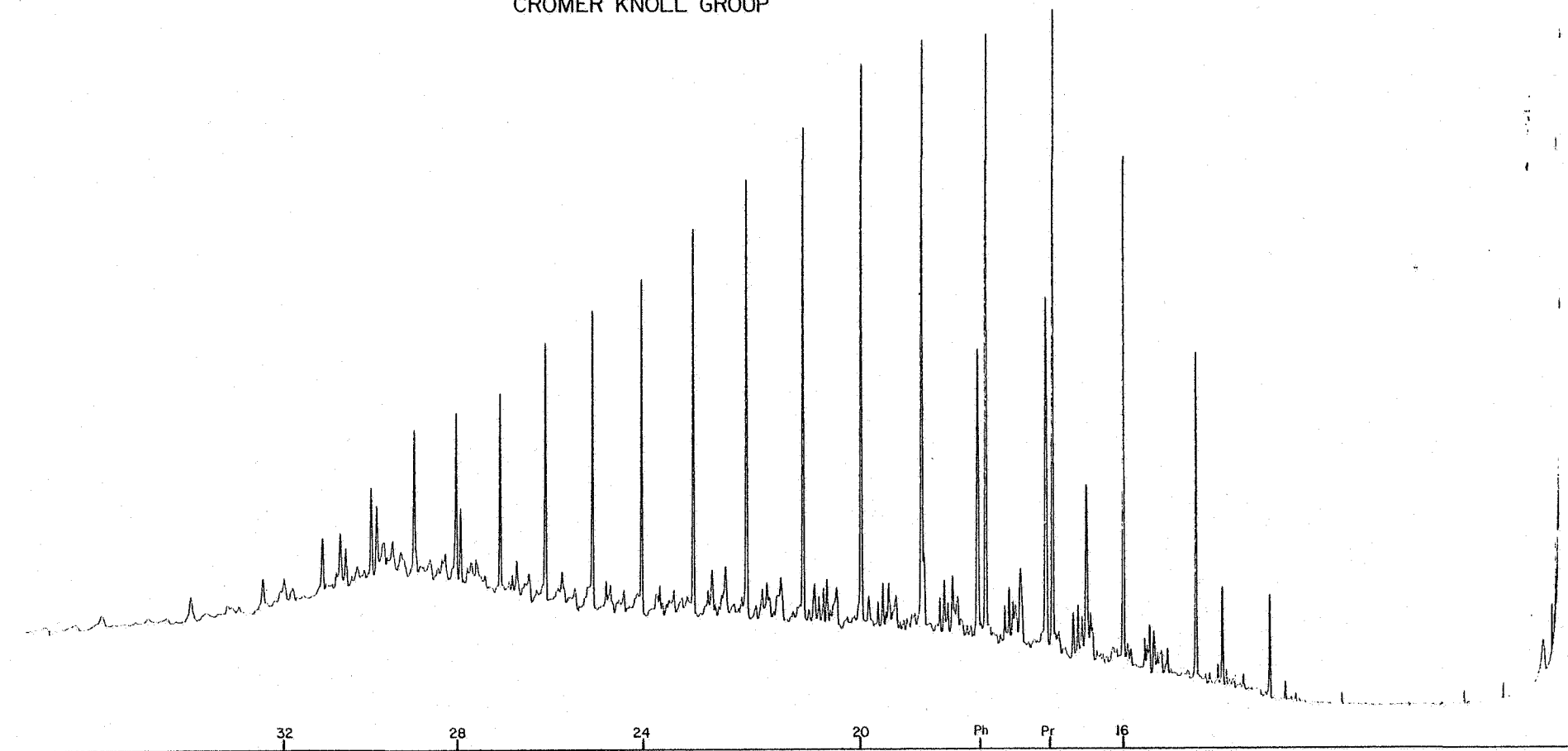
FIG 5.2 WELL: 34/2-2

3250-3280m

CROMER KNOLL GROUP
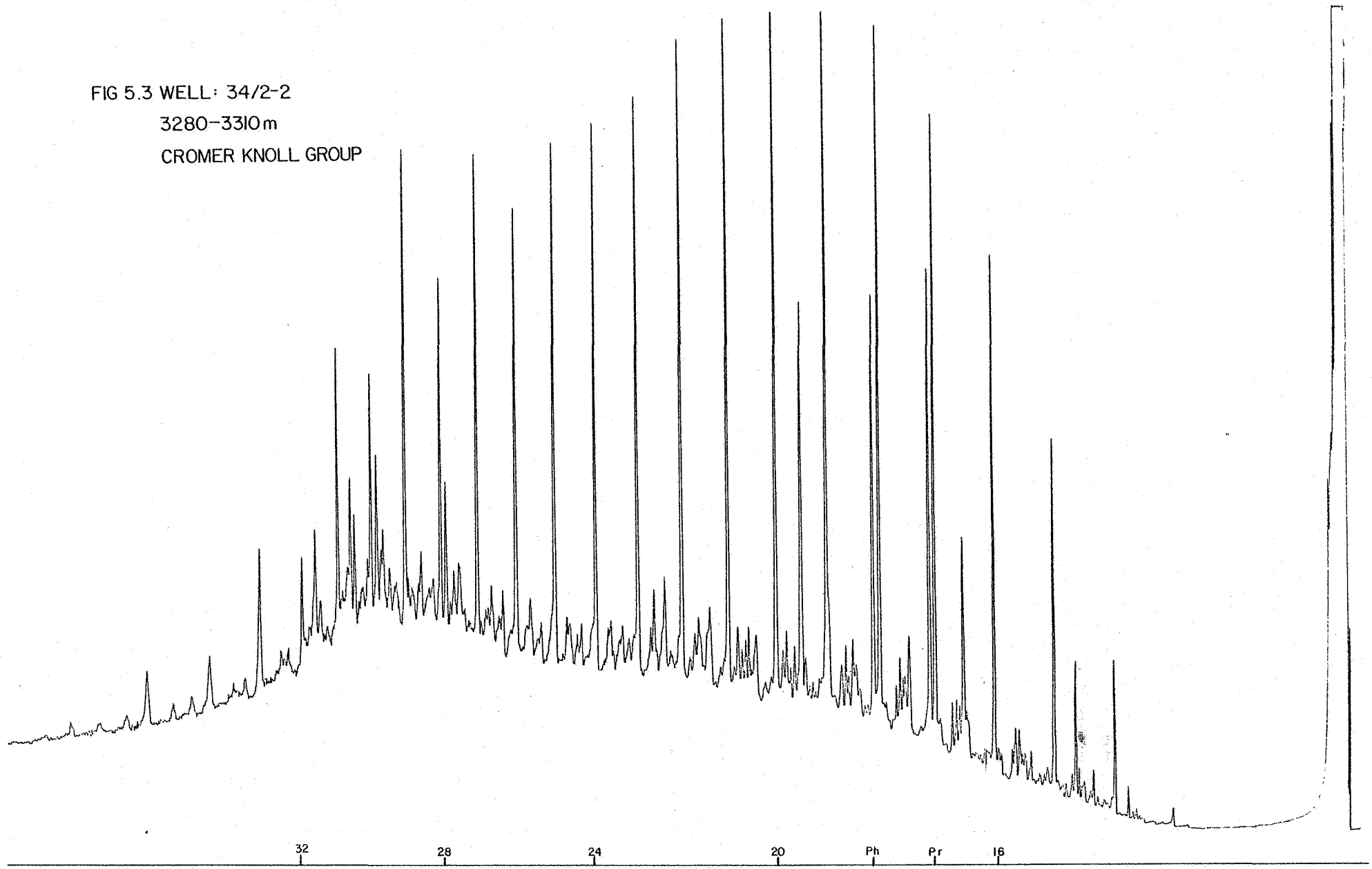
FIG 5.3 WELL: 34/2-2
3280-3310 m
CROMER KNOLL GROUP

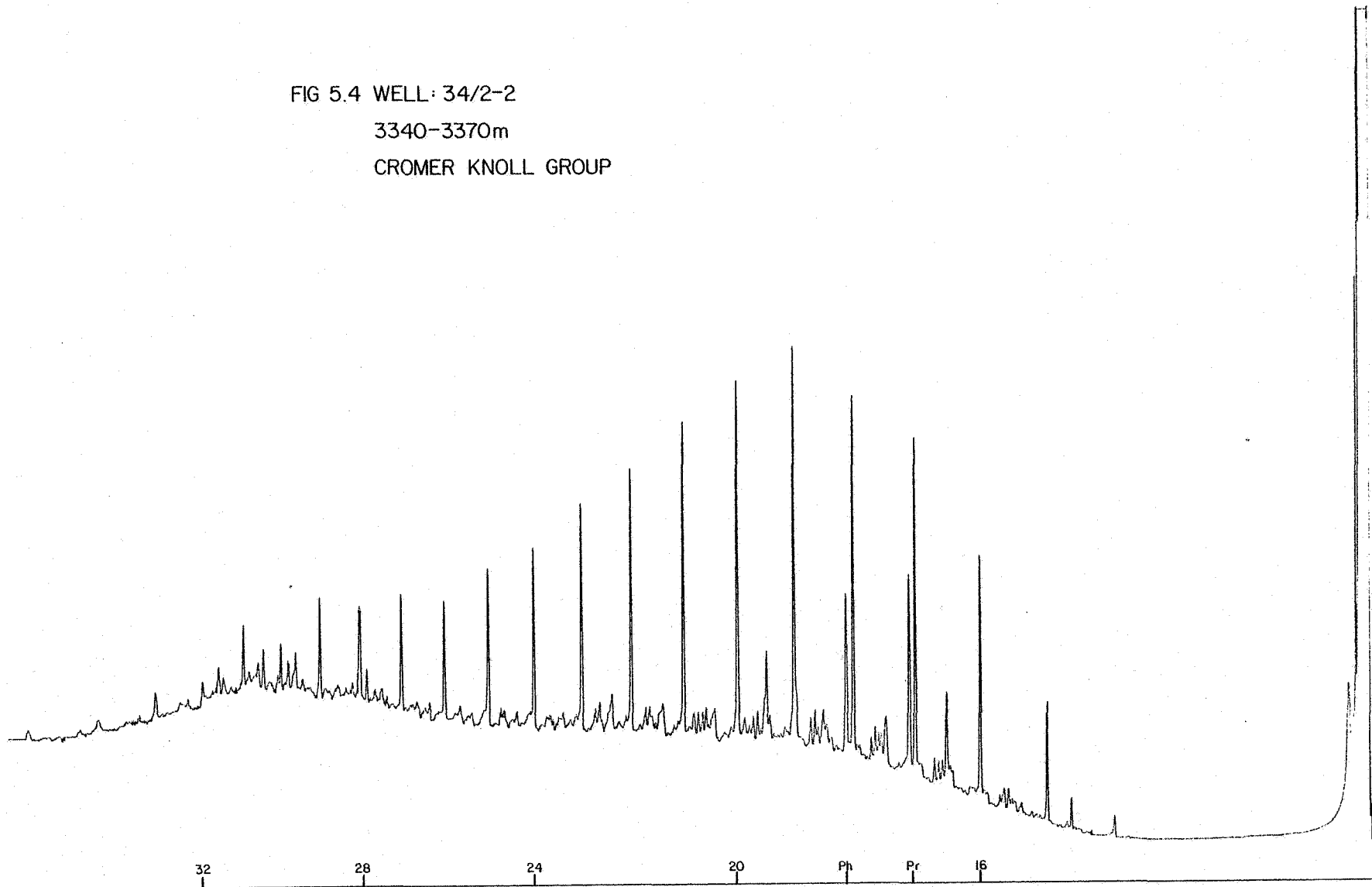FIG 5.4 WELL: 34/2-2
3340-3370m
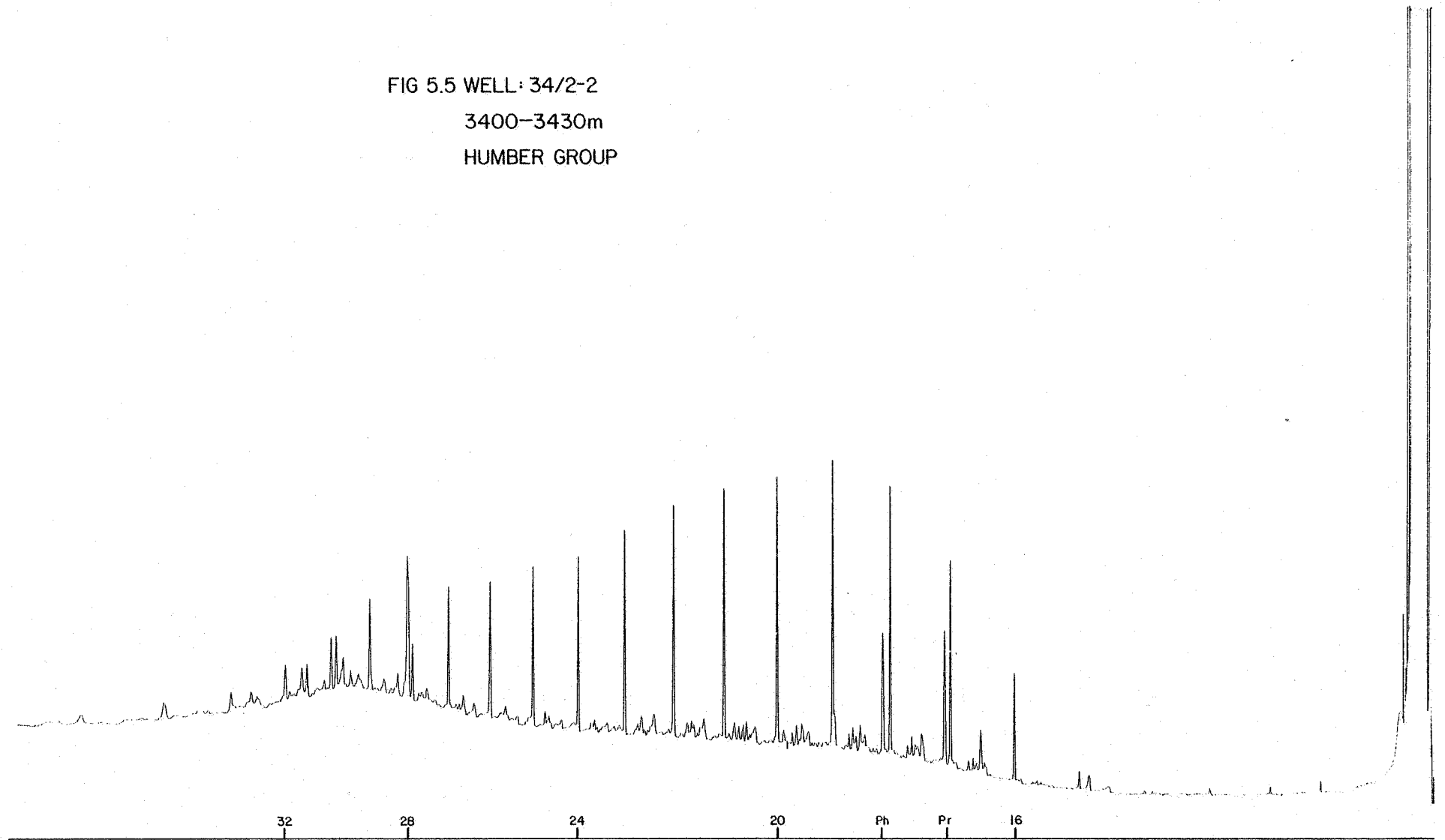CROMER KNOLL GROUP

FIG 5.5 WELL: 34/2-2
3400–3430m
HUMBER GROUP

FIG 5.6 WELL: 34/2-2
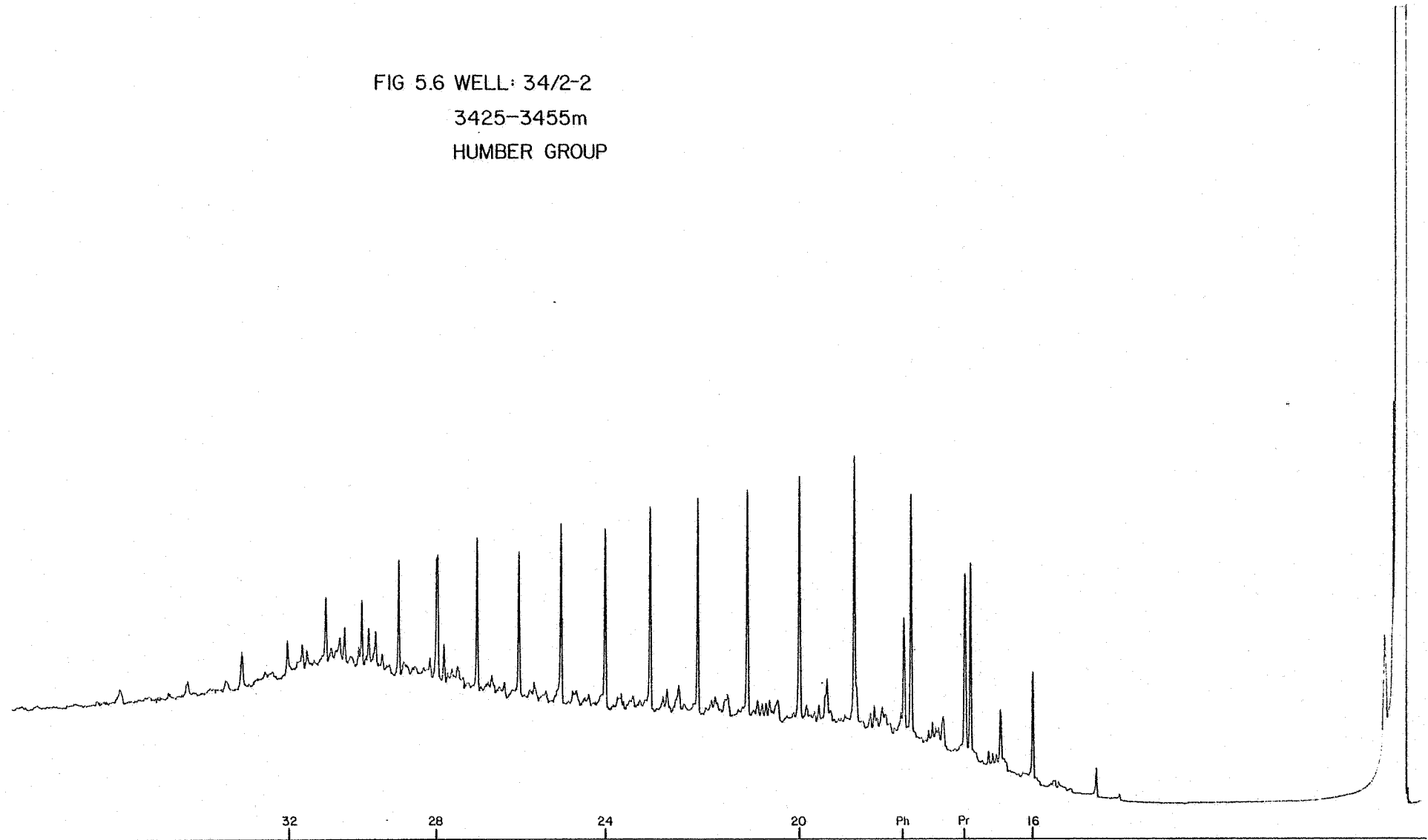3425-3455m
HUMBER GROUP

FIG. 5.7 WELL: 34/2-2
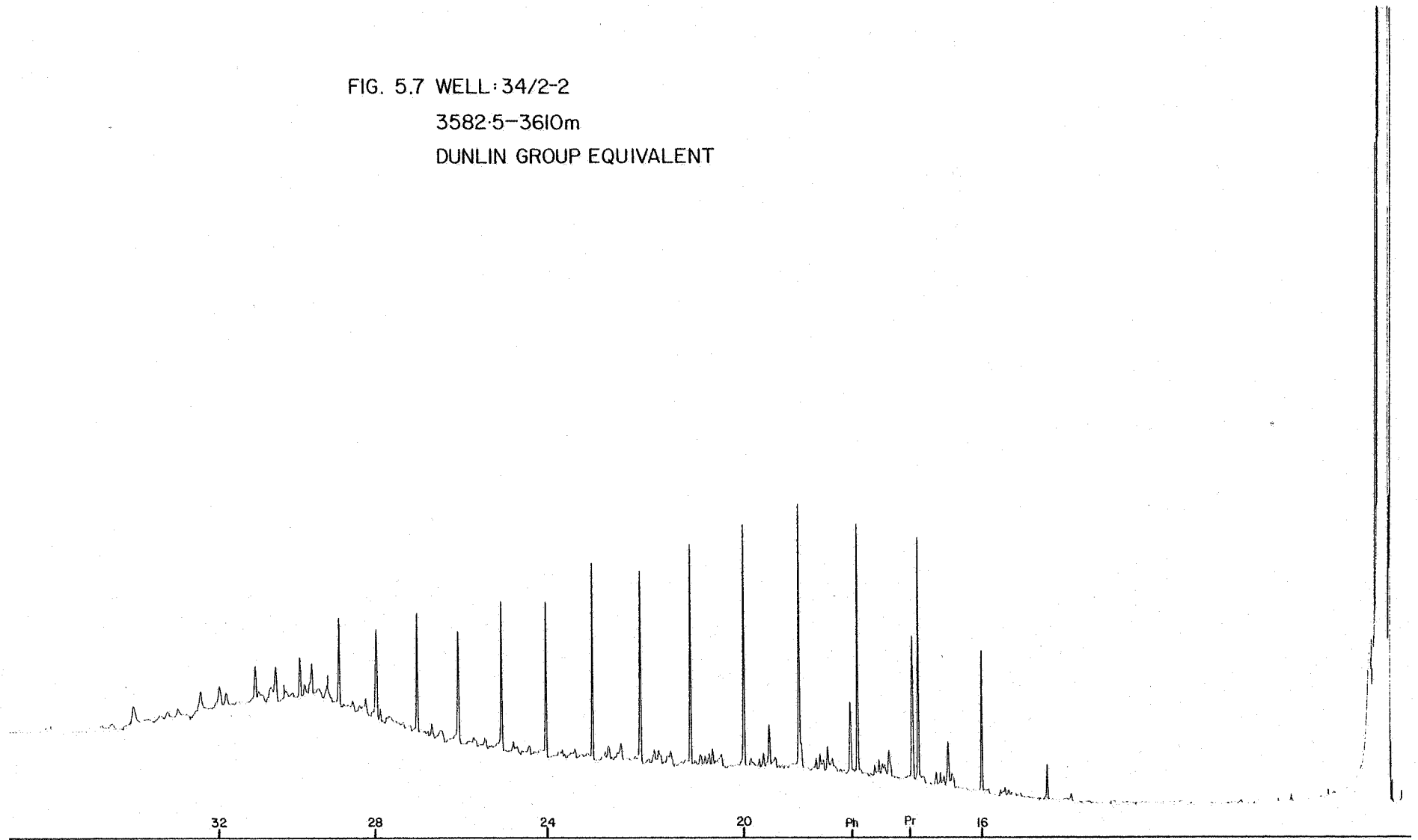3582·5—3610m
DUNLIN GROUP EQUIVALENT

FIG 5.8 WELL: 34/2-2
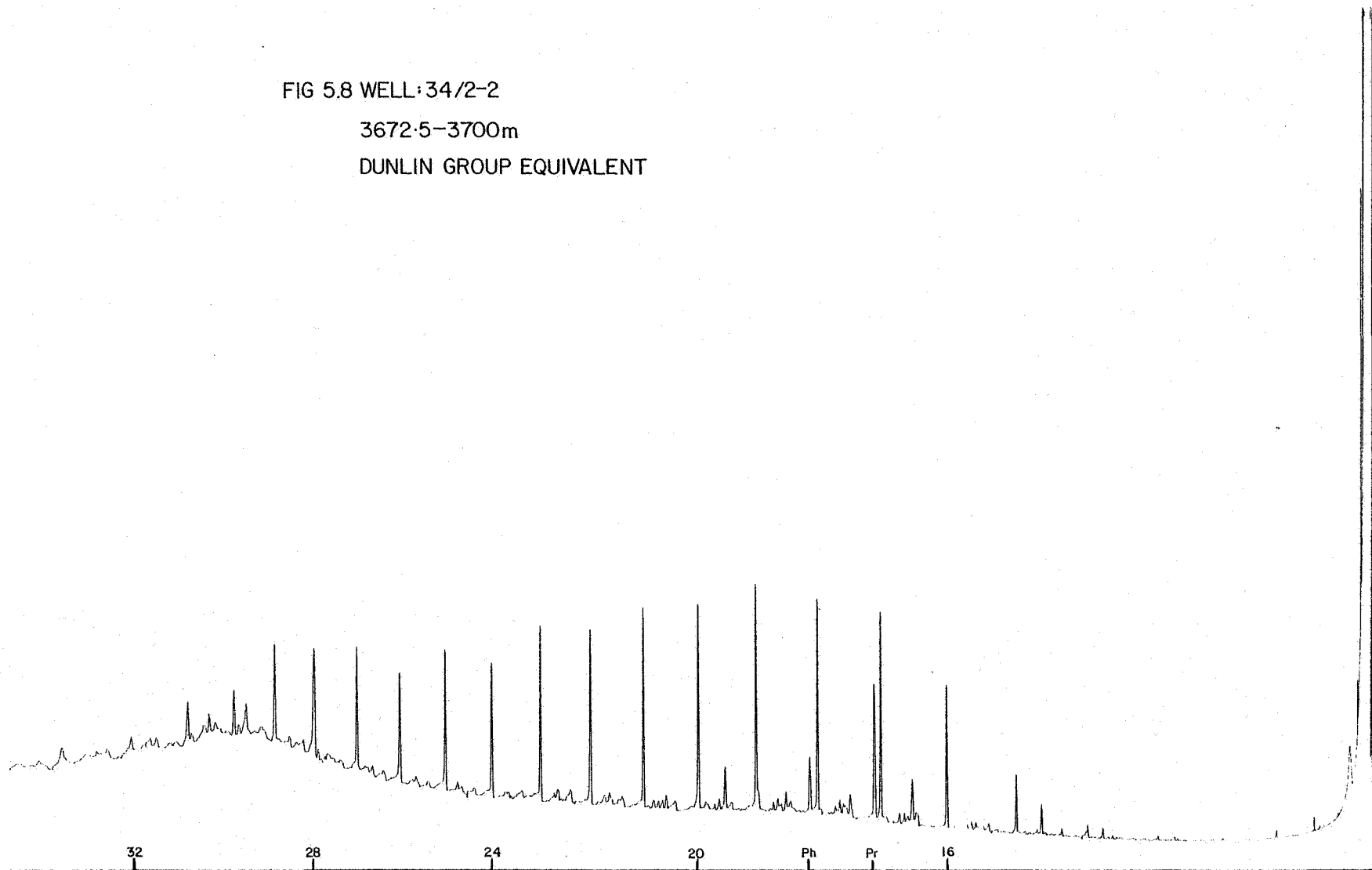3672.5-3700m
DUNLIN GROUP EQUIVALENT

FIG 5.9 WELL: 34/2-2
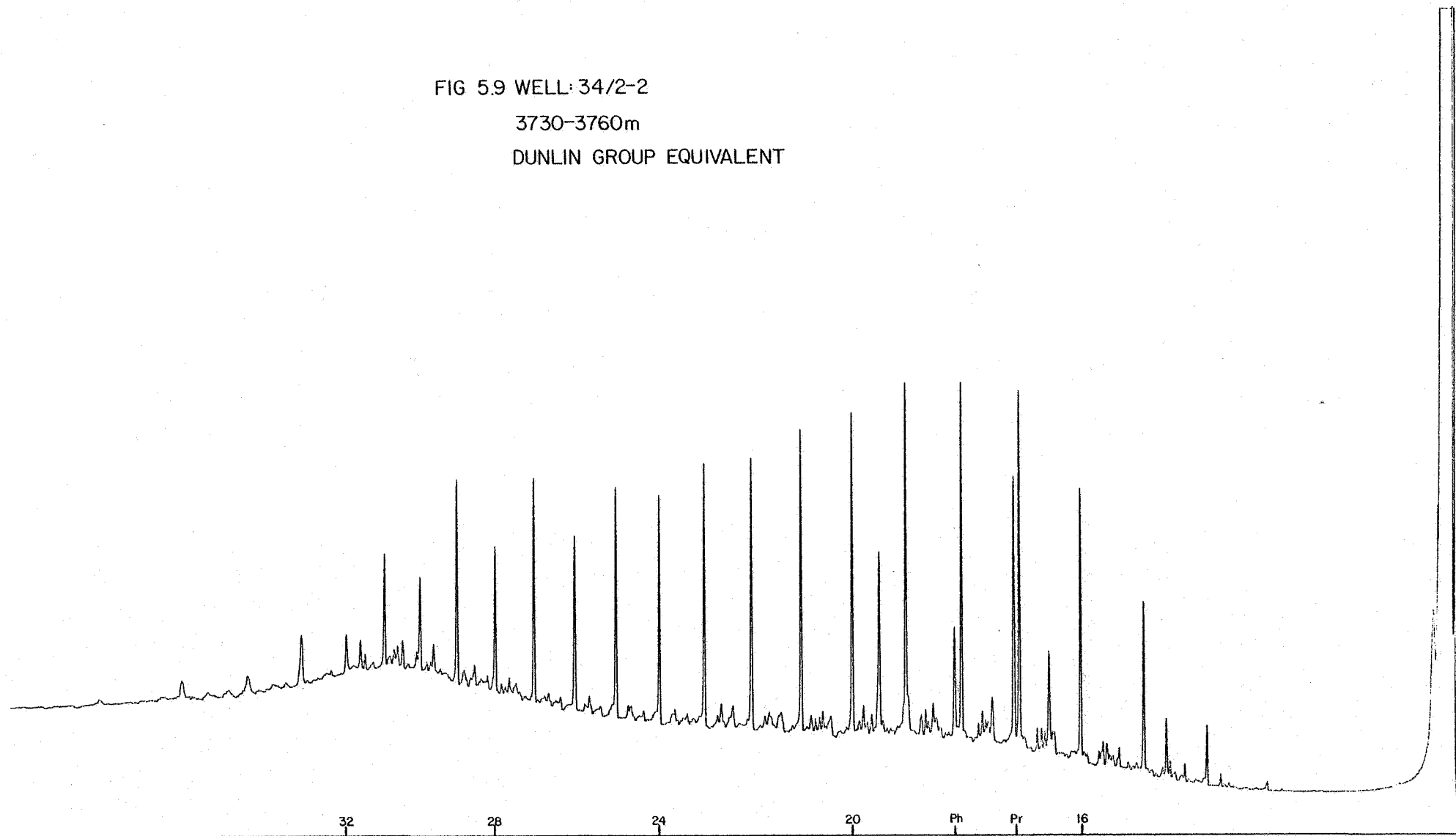3730-3760m
DUNLIN GROUP EQUIVALENT

FIG 5.10 WELL: 34/2-2
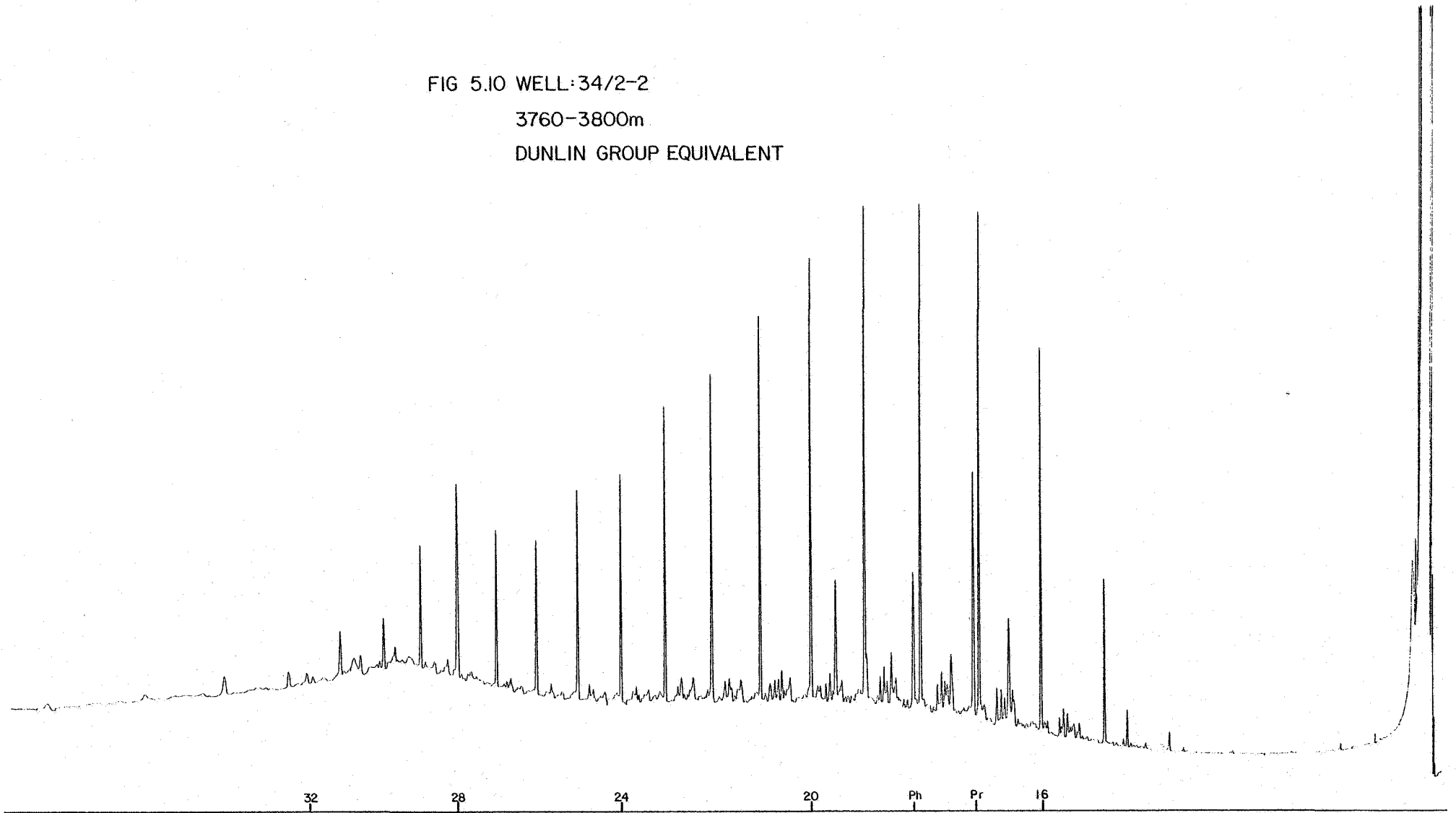3760-3800m
DUNLIN GROUP EQUIVALENT

FIG 5.11 WELL: 34/2-2
3870-3910m
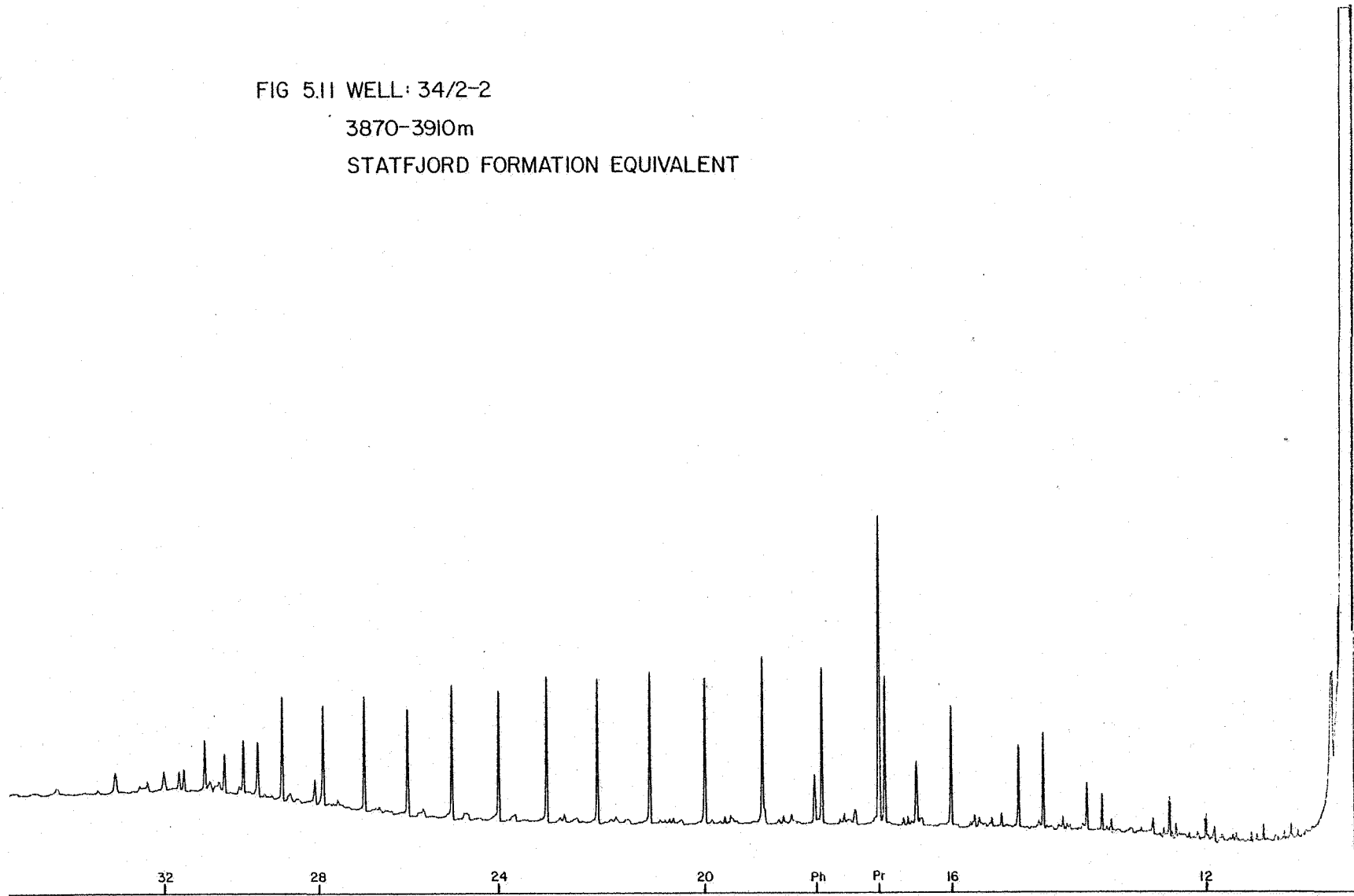STATFJORD FORMATION EQUIVALENT

ABBREVIATIONS USED IN ANALYTICAL DATA SHEETS

a/a	-	as above	med	-	medium
Add	-	mud additive	MET	-	metamorphic rock
Al	-	algae	mic	-	mica/micaceous
Am	-	amorphous	min	-	mineral
ang	-	angular	mnr	-	minor
ANH	-	anhydrite	mod	-	moderate
aren	-	arenaceous	MRL	-	marl(y)
arg	-	argillaceous	mtl	-	mottled
bd	-	bedded/bedding	NA	-	not available
becm	-	becoming	nod	-	nodule/nodular
Bit	-	bitumen/bituminous	NS	-	no sample
bl	-	blue	occ	-	occasional
blk	-	black	ol	-	olive
brn	-	brown	ool	-	oolitic
calc	-	calcareous	orng	-	orange
carb	-	carbonaceous	OS	-	oil stain
CHK	-	chalk	pnk	-	pink
CHT	-	chert	por	-	porous/porosity
CGL	-	conglomerate	pp	-	purple
CLYST	-	claystone	predom	-	predominantly
CMT	-	cement	pyr	-	pyrite/pyritic
Comp	-	composite	QTZ(T)	-	quartz(ite)
crs	-	coarse	Re	-	resin
CSG	-	casing point/shoe	rew	-	reworked
Ctgs	-	ditch cuttings	rnd	-	round(ed)
Cu	-	cuticle	Sap	-	sapropel
cvd	-	caved	SCI	-	Spore colour index
Df	-	dinoflagellates	sft	-	soft
dk	-	dark	sh	-	shale
DOL	-	dolomite/dolomitic	shly	-	shaly
dsky	-	dusky	sig	-	significant
Ex	-	exinite	sil	-	siliceous
Exs	-	exsudatinite	sks	-	slickenside surface
fer	-	ferruginous	sl	-	slight(ly)
flu	-	fluorescence	SLT(ST)	-	silt(stone)
fm	-	formation	slty	-	silty
fn	-	fine	SND(Y)	-	sand(y)
foss	-	fossils/fossiliferous	Sp	-	spores
fr	-	friable	SST	-	sandstone
fract	-	fracture	strks	-	streaks
frags	-	fragments	subang	-	subangular
glauc	-	glauconite/glauconitic	subrnd	-	subrounded
gn	-	green	suc	-	sucrosic
grd	-	graded/grading to	surf	-	surface
grns	-	grains	SWC	-	side wall core
gy	-	grey	TD	-	total depth
GYP	-	gypsum	tr	-	trace(s)
hd	-	hard	transp	-	transparent
hor	-	horizontal	v	-	very
P	-	picked lithology	vgt	-	variegated
i/b	-	inter-bedded	Vit	-	vitrinite
IGN	-	igneous rocks	vn	-	vein
incr	-	increasing	VOLC	-	volcanic rocks
Inert	-	inertinite	VR	-	vitrinite reflectivity
lam	-	laminae/laminated	wht	-	white
LCM	-	lost circulation material	xln	-	crystalline
LIG	-	lignite/lignitic	yel	-	yellow
lns	-	lens(es)			
LRV	-	low reflecting vitrinite			
lse	-	loose	-	-	no analysis
LST	-	limestone	*	-	analysed but no data obtained
lt	-	light	gy-gn	-	greyish green
mass	-	massive	gy/gn	-	grey-green (gradation)
MDST	-	mudstone	gn-gy	-	greenish grey

Note: (Maturity data tables only). Number in brackets refers to number of reflectivity values averaged to give quoted result.

APPENDIX II . ANALYTICAL PROCEDURES AND TECHNIQUES

This appendix summarises the main steps in the analyses carried out in the Robertson Research geochemistry laboratories. Conditions for chemical analyses are given and interpretation guidelines are defined. Techniques may in certain circumstances be adapted to suit particular samples or conditions.

1. Sample Preparation

Following airspace gas analysis of the canned samples, the cuttings are washed. After setting aside a wet sub-sample for gasoline analysis, the remainder is oven-dried at 50°C and described. Obvious cavings and particulate contaminants are removed and the significant lithologies hand-picked for organic carbon screening analysis. Coals if present are picked for vitrinite reflectivity measurement and splits of the total cuttings are made for the preparation of kerogen concentrates. Subsequently the bulk samples except those containing much loose sand or coal are crushed to pass through a 250 micron (60 - mesh) sieve and submitted for organic carbon screening analysis.

2. Maturity Evaluation

Maturation is assessed by measurement of spore colour and vitrinite reflectivity and the analysis of airspace gas and gasolines. Kerogen concentrates for microscopic analysis are prepared using standard palynological procedures (i.e. acid maceration) but without oxidation and acetolysis. Mineral residues, particularly pyrite, are separated from the kerogen by a combination of ultrasonic vibration and zinc bromide flotation. For spore colour measurement and kerogen typing, mounts are prepared of both the total kerogen and the coarser-than-20-micron size fraction. Sample blocks for measurement of vitrinite reflectivity are prepared by mounting the coarser-than-20-micron kerogen fraction in an epoxy resin, followed by polishing with carborundum and alumina.

Airspace Gas Analysis

If samples of wet cuttings are collected at the well-site and sealed in an airtight can, the headspace gases can be analysed in the laboratory to provide a rapid assessment of maturity. The gas is extracted from the sealed can using a can piercer fitted with a septum and analysed by gas liquid chromatography. The proportions of methane, ethane, propane and butane are calculated by comparison with a standard mixture of these gases. Methane is usually the dominant gas and comprises 90-100% from immature sediments and 30-70% from mature sediments. Abrupt departures from composition/depth trends may indicate faults with migrant gases or reservoir rocks.

Gasoline Analysis

Cuttings samples received wet, preferably in sealed containers, are suitable for gasoline analysis. A portion of the washed cuttings sample is retained wet, pulverised in a sealed shaker and warmed to expel the gasoline components into the shaker airspace. A sample of this airspace gas is then removed and analysed by gas chromatography. 28 hydrocarbon species are identified in the C_4 to C_7 range and their relative proportions calculated with reference to standard mixtures. Immature source rocks yield mixtures dominated by a small

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number of components but mature source rocks usually contain a full range of identified hydrocarbons in similar orders of concentration. The onset of maturity may also be indicated by an increase in total gasolines relative to the organic carbon content of the host rock (+200 ppm hydrocarbons per 1% organic carbon). Occasionally, oil stain will be recognised by the presence of anomalous amounts and it may be possible to identify its source rock by a similarity in distribution of components.

Spore Colouration

The maturity of oil-prone organic matter present in kerogen concentrates is assessed by visual examination of the indigenous sporomorphs. With increasing thermal maturity, spore colours change from pale yellow, through orange and brown, to black. Measurement is made using a standard reference set of sporomorphs. Spore colouration indices measured are on the Robertson Research scale of 1 to 10. Our experience shows that values of 3.0 to 3.5 are representative of the transition zone between immaturity and maturity. The range 3.5 to 8.0 is arbitrarily divided into zones of organic maturity: 3.5 to 5.0, early maturity; 5.0 to 7.0, middle maturity; 7.0 to 8.0 late maturity. Direct comparison with source rock data indicates that, given the presence of oil-prone organic matter, low gravity oils are likely to be generated in the zone of early maturity, medium gravity oils in the zone of middle maturity and high gravity oils in the zone of late maturity. The onset of generation of condensate, wet gas and, ultimately, dry gas is characterised by spore colour indices above 8.0.

Vitrinite Reflectivity

Vitrinite, a humic degradation product largely derived from the anaerobic decomposition of the lignin, cellulose and nitrogen-containing compounds of woody tissues, is the chief component of coals and is also common in fine-grained clastic rocks. The reflectivity of an optically flat surface is defined as the percentage of normally incident light reflected from the surface. Reflectivity can be used to define the level of thermal maturity of sedimentary organic matter since it increases from approximately 0.2% to 5.0% at a relatively uniform rate through the coal rank series. Zones of oil and gas generation can be related to the coal rank series and therefore defined in terms of vitrinite reflectivity, even though vitrinite is not an oil source but generates gas. The onset of oil generation has been placed at between 0.35% and 0.6% reflectivity, depending on the type of sedimentary basin; 0.5% is a widely accepted threshold value. The floor for oil generation is characterised by a vitrinite reflectivity of approximately 1.2%. Wet gas generation peaks at a reflectivity of about 1.0% and ceases at the 2.0% level. Dry gas generation peaks at a reflectivity of about 1.5% and ceases at the 3% level. However, to define the appropriate limits for a particular basin, vitrinite reflectivity must be correlated with other thermal maturation parameters.

3. Source Rock Evaluation

Organic Carbon Content

On average, between 1% and 2% of argillaceous sediments consist of organic carbon. Since major hydrocarbon accumulations are the exception rather than the rule it is likely that their sources are of above average organic carbon content. Sediments containing less than 0.3% organic carbon are regarded as having no source potential, and those containing between 0.3% and 1.0% are

marginal sources. Obviously the kerogen type is also of fundamental importance in determining the source potential of a rock.

Organic carbon values are obtained as follows. A 0.1 or 0.5 g sample, depending on lithotype, of crushed rock is treated with concentrated hydrochloric acid to remove carbonates and the residue filtered onto a glass fibre paper prior to ignition in a 'Leco' carbon analyser.

Extract Analysis

The soluble organic materials present in rocks can be extracted with organic solvents, fractionated and analysed. The type and amount of material extracted depends largely upon the nature of the contained organic matter and its maturity.

A maximum of 40 g of crushed sample is extracted for a minimum of 12 hours in a 'Soxhlet' apparatus by a 2 : 1 mixture of laboratory redistilled dichloromethane and methanol. The weight of the 'total extract' after final evaporation is expressed as ppm of the total rock. The more volatile components (up to C-15) are lost during extraction. The total extract is dissolved in hexane and a known volume separated by high pressure liquid chromatography into saturate hydrocarbon (alkanes), aromatic hydrocarbon and resene-asphaltene fractions.

Extract analysis provides a measure of source-rock richness in the oil-generation maturity zone. In addition to organic carbon contents, five parameters are calculated; total extract, extract/organic carbon x 100 i.e. extractability or EPOC, hydrocarbons as ppm of rock, hydrocarbons as percent of extract and alkanes as percent of hydrocarbons.

The extractability of oil-prone sapropelic organic matter increases rapidly in the oil generation zone and diminishes to very low values in post-mature sediments. Overall the extractability of sapropelic organic matter is greater than that of gas-prone humic organic matter for similar levels of maturity. Samples with extractabilities of greater than 20% generally contain migrated oil or are contaminated with mud additives.

The hydrocarbon content of a rock is the sum of the alkane and aromatic fractions of the total extract. As maturation proceeds in the oil generation zone the proportion of hydrocarbons in the total extract increases from less than 20% to a maximum in the most productive horizons of around 60%. This trend is reversed as the oil-condensate zone is entered. The relative proportions of alkanes to aromatics can be used as a check for low levels of contamination.

Pyrolysis

Pyrolysis data are obtained using the IFP-Fina "ROCK-EVAL" apparatus. The method involves the heating of samples from 250° to $550^{\circ}C$ at $25^{\circ}C$/minute in a stream of inert gas. During this time, three pulses of gases are released and recorded as weights of gas. The first of these pulses relates to hydrocarbons present in the sediment which could normally be extracted by organic solvents; these are either the adsorbed hydrocarbons indicating present source potential, or reservoired hydrocarbons. The second gas pulse is of hydrocarbons released by the thermal breakdown of kerogen (optimum source potential), and simultaneously the temperature of maximum rate of evolution is measured. The third pulse comprises carbon dioxide.

The parameters used in interpretation are the hydrogen index (ratio of released hydrocarbons to organic carbon content), the oxygen index (ratio of released carbon dioxide to organic carbon content), the temperature of maximum rate of pyrolysis, and the production index (ratio of the amount of hydrocarbons released in the first stage of heating to the total amount of released hydrocarbons). Kerogens rich in sapropelic matter exhibit a high hydrogen index and a low oxygen index while those in which humic debris predominates will display a low hydrogen index and a high oxygen index. Hydrogen and oxygen indices for a particular type of kerogen are also susceptible to a reduction in their values during the course of thermal maturation.

The hydrogen index is a measure of the hydrocarbon generating potential of the kerogen. Immature, organically rich source rocks and oil shales give values above 500, mature oil source rocks give values between 200 and 550.

The temperature of maximum rate of pyrolysis depends on the nature of the organic matter, but the transition from immature to mature organic matter is marked by temperatures between 415° and $435^\circ C$. The maturity transition from oil and wet gas generation to dry gas generation is marked by temperatures between 455° and $460^\circ C$. In practice, greater variation than these ideal temperature ranges may be seen, but they are nevertheless useful as general guides to the level of maturity attained by the sediment.

The production index increases with maturity from values near zero for immature organic matter to maximum values of 0.15 during the late stages of oil generation. Anomalously high values indicate the presence of free oil. The hydrocarbon yield is an indication of the potential yield of hydrocarbons from the source rock at optimum maturity and is a measure of the quality of the source rock. A value of 0 to 2000 of hydrocarbon in ppm of rock characterises a poor source rock, 2000 to 6000 ppm fair, 6000 to 20,000 ppm good and above 20,000 ppm very good.

Visual Examination of Kerogen Concentrates

All palynological preparations are examined in transmitted white and ultraviolet light and the relative abundances of vitrinite, inertinite and sapropel (essentially a fine-grained, apparently amorphous mixture of liptinite and exinite) estimated. The coarser-than-20-micron fractions are also examined in reflected white and ultraviolet light.

Gas Chromatography of C-15+ Alkanes

A portion of the "total extract" obtained from Soxhlet extraction is eluted with pentane through a short silica column to yield the saturate hydrocarbon fraction. This fraction is evaporated to dryness in a stream of dry nitrogen at room temperature. A small portion of the fraction is then taken up in methylene dichloride and injected on to a 25 metre, wall-coated, open-tubular, glass capillary column coated with OV-1 mounted in a Perkin Elmer F-17 gas chromatograph and programmed from $80^\circ C$ to $260^\circ C$ at $4^\circ C$/minute.

Distributions of n-alkanes and the relative abundances of steranes and triterpanes are noted and the ratios pristane/n-C_{17} and phytane/n-C_{18} are measured. The CPI may also be measured. Inspection of the chromatograms may reveal information about the kerogen type of the source rock, its maturity and conditions of deposition and, if migrant oil is present, whether this has been water-flushed or biodegraded. Drilling mud additives may be identified.