GeoChem Laboratories (U.K.) Limited

GEOCHEMICAL SERVICE REPORT

Prepared for

BP PETROLEUM DEVELOPMENT OF NORWAY .A.S.

GEOCHEMICAL EVALUATION OF BP's
7/12-3 WELL, NORWEGIAN NORTH SEA.

PetroData as

707-2451

September 1977

17 CASTLE STREET · CHESTER CH1 2DS · ENGLAND

GEOCHEMICAL EVALUATION OF BP's 7/12-3 WELL, NORWEGIAN NORTH SEA

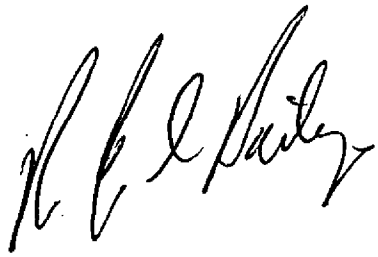
SUMMARY

The section between 3200 metres and 3590 metres in 7/12-3 has been evaluated.

There is very little variation in source character, few of the sediments containing more than 0.5% organic matter which is dominantly woody and coaly in type. They constitute poor (occasionally fair) source rocks for oil and gas but are immature and hence, on-structure, unable to realise even this potential. In a mature state these sediments could generate minor, but not major, hydrocarbon accumulations.

Relatively immature wet gas is present as traces throughout Zone A (3200-3300± metres) and as insignificant traces in Zone B (3300-3480± metres). A mature, medium to light gravity crude oil has diffused into the shales below 3520± metres. Possibly as a result of migrational fractionation during diffusion, condensate-type liquids are present at 3480-3530± metres and traces of mature wet gas occur at 3470 metres.

The source for the oil is probably buried off-structure to at least 4500± metres and belongs to a different organic facies than the sediments examined in this study.



N J L Bailey
GEOCHEM LABORATORIES (UK) LIMITED

INTRODUCTION

This report presents the results of a geochemical evaluation of the section between 3200 metres and 3590 metres in BP Petroleum Development of Norway's 7/12-3 well.

The study was designed to determine the source potential of the section in terms of richness, level of thermal maturation and hydrocarbon product type (oil,gas) and to recognise and characterise migrated hydrocarbons.

This study was authorised by Mr D South, BP Petroleum Development of Norway A.S.

A. ANALYTICAL

Fourteen (14) canned ditch cuttings samples and five (5) sidewall core samples were received from the interval 3200-3590 metres in 7/12-3 . The canned samples were commonly collected on a thirty metre interval. These samples were assigned the Geochem job number 161 and sequential sample numbers from -001 to -019.

Geochem Laboratories received guideline instructions for the analysis of these samples. A total of fourteen light hydrocarbon analyses, forty-five organic carbon analyses, six detailed gasoline range analyses, nine vitrinite reflectance determinations, eleven visual kerogen analyses, seventeen extractions with chromatography and seventeen C_{15+} paraffin-naphthene analyses were performed.

The data are presented in tables 1 through 8 and graphically in figures 1 through 5. A brief description of the analyses is included in the back of the report.

B. GENERAL INFORMATION

Ten (10) copies of this report have been forwarded to Mr D South, BP Petroleum Development of Norway A.S., Stavanger. A copy of the data has been retained by Geochem for future consultation with authorised BP personnel.

The kerogen slides prepared in connection with this study will be forwarded to the client and all remaining sample material will be handled as directed.

RESULTS AND INTERPRETATION

In the following discussion of the section between 3200 metres and 3590 metres in 7/12-3 , each of the parameters relevant to its geochemical evaluation will be considered individually and then synthesised under "Conclusions".

No well logs were available for this study.

A. ORGANIC GEOCHEMICAL ZONATION

This zonation is based upon the light hydrocarbon (C_1-C_7) data. Three (3) Zones are recognised.

Zone A — 3200 metres to 3300± metres, is lithologically varied. The samples above 3265± metres consist of chalky limestones with mixed pale bluish green, medium grey, greyish red and medium greenish grey shales. Medium grey shales are dominant (with significant limestone) at 3290 metres but the sidewall core from 3268 metres is composed of a moderate reddish brown shale. Clearly, cavings are significant within this interval.

No fluorescence was observed in the limestones.

The gaseous (C_1-C_4) hydrocarbons vary within the range 454-1056 ppm and are wet (62-72% C_{2+} in total C_1-C_4), although they have high isobutane to normal butane ratios. With one exception (3200 metres, 517 ppm) the heavier C_5-C_7 fraction lies between 145 ppm and 290 ppm.

Zone B — extends from 3300± metres down to 3480± metres. Medium dark grey shales tend to be dominant throughout this interval, although medium grey to medium greenish grey shales are abundant above 3355± metres. Minor limestones (caved?) are also present above 3355± metres and that from 3320 metres exhibited a minor blue cut.

These sediments are leaner than those of Zone A. The gaseous hydrocarbons range between 202 ppm and 360 (651) ppm whilst the C_5-C_7 hydrocarbons fall within the limits 25-80 ppm. The C_1-C_4 gases are still wet (45-72%,generally below 60% C_{2+}), the wettest sample being at the base of the interval.

Zone C — lies between 3480± metres and the deepest sample at 3590 metres. It is composed of medium dark grey shales.

It is defined by a dramatic increase in richness, the gaseous hydrocarbons jumping from approximately 300 ppm up to 1115-3899 ppm and the C_5-C_7 fraction increasing by two orders of magnitude from 40 ppm up to 1420-4889 ppm. This change is also evident in the composition of the gases, which are now very wet to extremely wet (80-98% C_{2+}) and have low (0.25) isobutane to normal butane ratios. Gas wetness increases with depth.

B. AMOUNT AND TYPE OF ORGANIC MATTER

The amount of organic matter within a sediment is measured by its organic carbon content. Average shales contain approximately one per cent organic carbon and this is the standard to which these samples will be compared.

Organic matter type influences not only hydrocarbon richness but also the character of the hydrocarbon product (gas, oil) and the ease of response to thermal maturation. Richness and oil-proneness decrease in the order: amorphous-herbaceous-stem-woody. Wood has a primary (but not exclusive) potential for gas, whilst coaly (mineral charcoal) material has only a limited hydrocarbon potential.

With one exception, the medium grey to medium greenish grey shales of Zone A have fair values of 0.51-0.70% organic carbon. The other shales are very lean (0.02-0.07% organic carbon) and lean shales also characterise the rest of the section (Zones B and C) only two samples falling above the limits 0.08-0.40% organic carbon. These exceptions are the sidewall cores from 3525 metres and 3555 metres, with 0.64% and 0.62% organic carbon respectively.

Woody and coaly debris are dominant throughout this section. Herbaceous material is variously a significant or a minor component, whilst amorphous kerogen is absent.

No rich or amorphous intervals are present and reworking is evident in many of the samples.

C. LEVEL OF THERMAL MATURATION

Both vitrinite reflectance and organic matter colouration measurements have been used to define thermal maturation levels in this study.

Reworked material is commonly dominant. The indigenous organic matter has vitrinite reflectivity values of 0.36-0.45% Ro throughout this section and no depth-dictated trend is apparent. These values indicate that the sediments are immature. Determinations were performed upon all of the sidewall cores in addition to selected cuttings samples.

Maturation evaluations based upon the colour of the organic matter are complicated not only by the presence of reworked material but also by the sparcity of suitable kerogen for examination. Maturation indices of 1+ to 2- were obtained for all of this section. At this level of maturation, all of the fractions which compose the total organic matter are immature.

The interpretations derived from both sets of data are in agreement and are supported by the C_{15+} paraffin-naphthene chromatograms.

D. HYDROCARBON SOURCE RICHNESS

Assessments of present and potential source richness can be derived from the light hydrocarbon and organic carbon abundances respectively.

The light hydrocarbon (C_1-C_7) data are affected by the presence of migrated hydrocarbons which enhance those indigenous to the sediments, resulting in unrealistically optimistic richness ratings. In this well, Zone A is classified as a potentially poor to fair hydrocarbon source, whilst Zone B is poor and Zone C is fair.

Organic carbon values rate the medium grey to medium greenish grey shales of Zone A as potentially fair source rocks, but the other shales of Zone A and those of Zones B and C are poor, the only exceptions being the 'fair' sidewall core shales from 3525 metres and 3555 metres in Zone C. Overall, Zones A through C are of poor richness and this is emphasised by the woody-coaly character of the organic matter. Cavings should not affect this picture significantly.

Definitive richness evaluations involve the C_{15+} hydrocarbons. The analysed samples indicate a general background level throughout this section of approximately 100-200 ppm, superimposed upon which are richer samples with values as high as 5725 ppm. Anomalously high hydrocarbon to organic carbon ratios characterise the richer sediments whilst, in the lower half of Zone C the proportion of hydrocarbons within the total soluble extract is rather high for immature sediments. Both of these parameters suggest the presence of non-indigenous hydrocarbons. Chromatograms of the C_{15+} paraffin-naphthene hydrocarbons indicate the presence of crude oil below 3520± metres (see Section E), whilst drilling-introduced contamination is evident in both the leaner and the richer samples from the overlying section. It is believed therefore, that even the background level of 100-200 ppm is an overstatement of the indigenous source richness and that these sediments are potentially poor, or at best fair, hydrocarbon source rocks. A more detailed breakdown cannot be attempted due to the masking effect of the non-indigenous hydrocarbon species.

A gross correlation is noted between the different richness ratings. In this well, those based upon the organic carbon values are preferred.

E. NON-INDIGENOUS HYDROCARBONS

Potential reservoir facies are represented by the carbonates above 3265± metres and the (minor) limestone interbeds which apparently occur in Zone B and, less abundantly, in Zone C.

The light hydrocarbons indicate the presence of migrated liquid hydrocarbons within Zone C, the extreme wetness of the gases, their low isobutane to normal butane ratios and the relatively good C5-C7 abundance values being definitive. The gases are also anomalously wet for immature sediments throughout Zones A and B, but particularly below 3460± metres and above 3325± metres. However, the C5-C7 fraction is sparse at 3460-3480± metres and 3300-3325± metres and is not abundant above 3300± metres, whilst isobutane to normal butane ratios are fairly high (i.e. not oil-like) in Zone A.

With one exception, the C_{15+} hydrocarbons only constitute in excess of thirty percent of the total soluble extract below 3525± metres. Above this depth, the low values do not suggest the presence of migrated oil. Paraffin-naphthene chromatograms for Zones A and B indicate drilling-introduced contamination but not migrated crude oil. Thus, as most of these samples contain less than 200 ppm C_{15+} hydrocarbons, only insignificant traces of oil could be present in either Zone A or Zone B.

The higher proportion of hydrocarbons in the total soluble extract within the lower half of Zone C reflects the presence of a medium to light gravity mature crude oil below 3520± metres (see paraffin-naphthene chromatograms). Hydrocarbon abundance values suggest that only minor shows are involved (best show at 3590 metres), but all of the analysed samples consist of shales. Presumably, the oil diffused into the shales from interbedded aquifers which are not represented in the samples submitted for analysis and hence, significant shows would be anticipated within the aquifers.

Although drilling-introduced contamination complicates the picture, it would appear that only traces of migrated C_{15+} hydrocarbons can be present in Zone C above 3520± metres. However, the C5-C7 fraction still indicates the presence of migrated liquid hydrocarbons and hence it is possible that they are condensate in type - perhaps as a result of migrational fractionation during diffusion. This would suggest that the parent aquifer(s) lies below 3520± metres. A degree of support for this explanation is provided by the sample from 3470 metres, which is depleted in the C5-C7 fraction, suggesting that it has been invaded by wet gas rather than oil or even condensate.

Wet gases are also indicated in Zone A. In this case however, the relatively high isobutane to normal butane ratios suggest that they are relatively young (not very mature) and derived from a different, less deeply buried source. Insignificant traces of this gas are apparently present throughout Zone B.

In summary:

- traces of wet gas derived from marginally mature parent source rocks are present in Zone A. The more deeply buried lateral equivalents of the adjacent sediments would fulfill the source requirements.
- insignificant traces of this "young" wet gas are present throughout Zone B
- medium to light gravity mature crude oil has invaded the shales below 3520± metres and has presumably diffused into the shales from (a) reservoir facies occurring below this depth. Possibly as a result of migrational fractionation during this upward diffusion, condensate-type liquids are present at 3480-3520± metres and mature wet gas at 3470 metres.
- the source rock (s) responsible for the Zone C oil is (are) much more mature than those which generated the Zone A gases.

F. CONCLUSIONS

Three (3) geochemical Zones are recognised within the section between 3200 metres and 3590 metres in 7/12-3 .

The samples received from Zone A (3200-3300± metres) suggest limestones with mixed shales above 3265± metres overlying a shaly sequence. In general, the medium grey shales have fair organic contents (0.5-0.7% organic carbon), but the other shales are very lean. The medium dark grey shales which dominate Zones B (3300-3480± metres) and C (3480-3590± metres) have lean and poor contents of organic matter, only a few interbeds within Zone C exceeding 0.4% organic carbon and rising to fair levels of 0.6% organic carbon.

Throughout this section, the organic matter is dominantly woody and coaly in type. Minor to significant proportions of herbaceous debris are present but amorphous kerogen is characterised by its absence. No rich or amorphous intervals were detected in this study.

The interbeds of medium grey shale within Zone A are potentially fair source rocks for oil and gas but otherwise, Zones A and B have only a poor source potential. Zone C is potentially a poor source with interbeds of fair source rocks. Overall, there is very little variation and these sediments may be described as poor (occasionally fair) source rocks for oil and gas.

However they are immature and hence unable to realise even this potential. In a mature state they could generate only minor and not major hydrocarbon accumulations.

Oxidising conditions apparently prevailed at the seawater-sediment interface throughout this time period.

In the absence of a maturation gradient within the analysed section, it is not possible to predict the depth at which the off-structure lateral equivalents of these sediments will become mature.

However, marginal maturity is indicated for the source rocks responsible for the traces of young wet gas present within Zone A. Insignificant traces of this gas are present throughout Zone B.

A medium to light gravity crude oil has invaded Zone C below 3520± metres, having presumably diffused into the shales from reservoir facies present below 3520± metres but not represented in the samples submitted for this study. Retardation of the heavier ends by migrational fractionation during the upward diffusion process has apparently resulted in condensate-type liquids at 3480-3520± metres and traces of mature wet gas at 3470 metres.

The parent source rock responsible for this oil is mature and hence must be buried (off-structure) to at least 4500± metres. If the source is age-equivalent to Zone C, then a lateral organic facies change, reducing the proportion of woody and coaly debris in favour of amorphous and herbaceous material, is likely.

TABLE 1A

CONCENTRATION (VOL. PPM OF ROCK) OF C_1 - C_7 HYDROCARBONS IN AIR SPACE GAS

GEOCHEM SAMPLE NUMBER	DEPTH	C_1 Methane	C_2 Ethane	C_3 Propane	iC_4 Isobutane	nC_4 Butane	TOTAL C_1 - C_4	TOTAL C_2 - C_4	% GAS WETNESS	TOTAL C_5 - C_7	$\frac{iC_4}{nC_4}$
161-001	3200m	203	77	165	58	48	551	348	63.1%	40	1.19
161-002	3230m	104	34	66	24	20	248	144	58.2%	27	1.19
161-003	3260m	173	33	56	21	13.6	297	124	41.8%	42	1.58
161-005	3290m	308	115	132	35	20	612	304	49.5%	9.0	1.74
161-006	3320m	241	53	98	37	21	452	209	46.3%	11.3	1.80
161-007	3350m	94	14.2	20	7.8	4.1	140	46	32.9%	-	1.90
161-009	3380m	139	38	42	12.8	9.1	241	102	42.2%	-	1.41
161-010	3410m	93	35	13.3	3.1	3.0	148	55	37.1%	0.1	1.01
161-011	3450m	122	71	37	6.3	7.5	243	121	50.0%	0.3	0.84
161-012	3470m	70	75	35	3.7	8.1	193	122	63.3%	0.2	0.46
161-014	3500m	193	136	208	36	126	700	507	72.4%	206	0.29
161-016	3530m	348	231	328	47	212	1165	817	70.1%	241	0.27
161-018	3570m	24	139	226	30	114	534	510	95.4%	40	0.27
161-019	3590m	20	370	694	71	293	1447	1427	98.6%	415	0.24

TABLE 1B

CONCENTRATION (VOL. PPM OF ROCK) OF C_1 - C_7 HYDROCARBONS IN CUTTINGS GAS

GEOCHEM SAMPLE NUMBER	DEPTH	C_1 Methane	C_2 Ethane	C_3 Propane	iC_4 Isobutane	nC_4 Butane	TOTAL C_1 - C_4	TOTAL C_2 - C_4	% GAS WETNESS	TOTAL C_5 - C_7	$\frac{iC_4}{nC_4}$
161-001	3200m	36	22	90	71	68	288	252	87.6%	477	1.04
161-002	3230m	27	11.2	64	54	50	207	180	86.9%	118	1.09
161-003	3260m	163	52	168	121	77	582	418	71.9%	248	1.56
161-005	3290m	47	39	160	126	74	447	400	89.5%	219	1.69
161-006	3320m	19.9	66	66	31	18.4	201	181	90.1%	28	1.68
161-007	3350m	17.6	5.4	15.7	12.5	10.3	61	44	71.4%	25	1.21
161-009	3380m	21	12.6	29	19.7	12.9	96	75	77.7%	80	1.53
161-010	3410m	34	29	32	15.0	17.6	128	94	73.4%	65	0.85
161-011	3450m	35	27	31	8.2	15.3	116	81	69.9%	38	0.54
161-012	3470m	24	43	46	8.8	21	143	119	83.0%	36	0.42
161-014	3500m	36	39	126	41	174	417	381	91.3%	2478	0.24
161-016	3530m	126	189	548	198	838	1900	1773	93.3%	4648	0.24
161-018	3570m	71	90	193	67	210	631	560	88.7%	2082	0.32
161-019	3590m	62	238	871	257	1023	2453	2391	97.5%	1005	0.25

TABLE 1C

TOTAL CONCENTRATION (VOL. PPM OF ROCK) OF C_1 - C_7 HYDROCARBONS (1A + 1B)

GEOCHEM SAMPLE NUMBER	DEPTH	C_1 Methane	C_2 Ethane	C_3 Propane	iC_4 Isobutane	nC_4 Butane	TOTAL C_1 - C_4	TOTAL C_2 - C_4	% GAS WETNESS	TOTAL C_5 - C_7	$\frac{iC_4}{nC_4}$
161-001	3200m	239	99	255	129	116	838	599	71.5%	517	1.11
161-002	3230m	131	45	130	78	70	454	323	71.2%	145	1.11
161-003	3260m	336	85	224	142	91	878	541	61.7%	290	1.57
161-005	3290m	355	154	292	161	94	1056	701	66.4%	228	1.71
161-006	3320m	261	119	164	68	39	651	390	60.0%	39	1.73
161-007	3350m	112	19.6	36	20	14.4	202	90	44.6%	25	1.41
161-009	3380m	160	51	71	32	22	336	176	52.4%	80	1.48
161-010	3410m	127	64	45	18.1	21	275	148	53.8%	65	0.88
161-011	3450m	157	98	68	14.5	23	360	203	56.4%	38	0.64
161-012	3470m	94	118	81	12.5	29	335	241	71.9%	36	0.43
161-014	3500m	229	175	334	77	300	1115	886	79.5%	2684	0.26
161-016	3530m	474	420	876	245	1050	3065	2591	84.5%	4889	0.23
161-018	3570m	95	229	419	97	324	1164	1069	91.8%	2122	0.30
161-019	3590m	82	608	1565	328	1316	3899	3817	97.9%	1420	0.25

TABLE 2
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION	G S A Colour Code	TOTAL ORGANIC CARBON (% of Rock)
161-001	3200m	A 30% Shale, blocky to fissile, non calcareous, abundant cavings, medium grey	N5	0.70
		B 30% Shale, blocky to fissile, slightly to non calcareous, cavings, pale blue green	5BG7/2	0.02
		C 30% Chalky limestone, blocky and fissile, abundant cavings, no fluorescence, white	N9	
		D 5% Shale, fissile to blocky, non calcareous, cavings, greyish red	10R4/2	
		E 5% Argillaceous limestone/ calcareous mudstone, blocky, greyish orange pink	10R8/2	
		Minor shale		
161-002	3230m	A 55% Chalky limestone, as 161-001C, no fluorescence	N9	
		B 25% Shale, fissile to blocky, non calcareous, cavings, medium grey to medium greenish grey	N5-5G5/1	0.05
		C 20% Shale, fissile to blocky, non calcareous, cavings, medium dark grey to medium grey	N4-N5	0.24
		Minor shale and mudstone		
161-003	3260m	A 50% Shale, as 161-002B cavings	N5-5G5/1	0.51
		B 40% Chalky limestone, as 161-001C, no fluorescence	N9	
		C 10% Shale, fissile, calcareous, cavings, greyish green	5G5/2	0.07
		Minor cavings		
161-004 SWC	3268m	Shaly mudstone, fissile to blocky, very calcareous, moderate reddish brown	10R4/6	0.25
161-005	3290m	A 70% Shale, as 161-002B, cavings	N5-5G5/1	0.68
		B 20% Limestone, fissile to blocky, no fluorescence, very light grey to white	N8-N9	
		C 10% Shale, fissile, non calcareous, cavings, medium dark grey	N4	0.61
		Minor shale		

TABLE 2
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION	G S A Colour Code	TOTAL ORGANIC CARBON (% of Rock)
161-006	3320m	A 65% Shale, fissile to blocky, non calcareous, cavings, medium dark grey to medium grey	N5-5G5/1	0.24,0.22
		B 20% Shale, fissile, non calcareous, cavings, medium dark grey	N4	0.23
		C 10% Shale, fissile, slightly calcareous, moderate brown	5YR3/4	0.08
		D 5% Limestone, fissile to blocky, white fluorescence and minor blue cut, very light grey to white	N8-N9	
161-007	3350m	A 40% Shale, as 161-006B	N4	0.19
		B 30% Shale, as 161-006A, cavings	N5-5G5/1	0.34
		C 20% Limestone, as 161-006D	N8-N9	
		D 10% Shale, as 161-006C	5YR3/4	0.10,0.08
161-008 swc	3357m	A Shale, fissile, slightly calcareous, medium dark grey to medium grey Very poor sidewall core	N4-N5	0.23
161-009	3380m	A 90% Shale, as 161-006B,cavings	N4	0.18
		B 10% Shale, as 161-006C,cavings	5YR3/4	0.13
		Minor other shale and cavings		
161-010	3410m	A 95% Shale, as 161-006B,cavings	N4	0.23
		B 5% Shale, as 161-006C	5YR3/4	
		Minor shale, cavings		
161-011	3450m	A 95% Shale, as 161-006B,cavings	N4	0.23,0.23
		B 5% Shale, as 161-006C	5YR3/4	
		Minor shale, Minor chalk		
161-012	3470m	A 98% Shale, as 161-006B,cavings	N4	0.27
		Minor shale and limestone		
		Minor lost circulation material		
161-013 swc	3490m	A Shale, fissile to blocky, calcareous, medium dark grey to medium grey	N4-N5	0.40
		and limestone very calcareous, light grey	N7	
		Very poor sample		

TABLE 2
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION	G S A Colour Code	TOTAL ORGANIC CARBON (% of Rock)
161-014	3500m	A 98% Shale, fissile, non calcareous, cavings, medium dark grey Minor other shale and lost circulation material	N4	0.20
161-015 swc	3525m	A Shale, fissile to blocky, non calcareous, olive grey	5Y4/1	0.64
161-016	3530m	A 98% Shale, fissile, non calcareous, medium dark grey to medium grey Minor other shale	N4-N5	0.20,0.23
161-017 swc	3555m	A Shale, fissile to blocky, calcareous, silty, medium grey	N5	0.62
161-018	3570m	A 98% Shale, as 161-016A Minor shale	N4-N5	0.24
161-019	3590m	A 98% Shale, as 161-016A cavings Minor shale	N4-N5	0.20

TABLE 3
DETAILED GASOLINE RANGE ($C_4 - C_7$) ANALYSIS

GEOCHEM SAMPLE NUMBER	-001	-003	-014	-016	-018	-019
DEPTH	3200m	3260m	3500m	3530m	3570m	3590m
NORMALISED COMPOSITION						
isobutane	6.51	4.06	8.96	2.20	3.20	2.65
n - butane (nB)	9.94	6.70	13.89	6.36	8.81	11.92
isopentane	13.94	12.49	8.08	3.51	6.70	9.78
n - pentane (nP)	12.79	9.55	18.03	8.68	13.93	14.18
2,2 - dimethylB	0.37	0.12	0.19	0.17	0.23	1.01
cyclopentane (CP)	1.35	1.71	1.70	1.54	1.10	1.62
2,3 - dimethylB	1.49	1.46	0.96	0.85	0.99	1.24
2 - methylP	6.39	8.04	5.17	7.39	6.05	6.86
3 - methylP	3.43	3.71	2.83	4.84	3.58	4.00
n - hexane (nH)	5.65	5.97	8.78	13.12	10.82	10.06
methylCP (MCP)	6.89	10.56	5.85	8.50	6.73	6.55
2,2 - dimethylP	0.27	0.44	0.11	0.96	0.72	0.84
benzene	4.07	5.95	4.41	6.44	5.67	4.40
2,4 - dimethylP	0.10	0.09	0.11	0.23	0.21	0.04
2,2,3 - trimethylB	1.87	0.50	3.22	0.50	0.97	0.20
cyclohexane (CH)	2.07	3.17	2.27	4.43	3.26	3.54
3,3 - dimethylP	2.01	0.01	0.02	0.01	0.03	0.01
1,1 - dimethylCP	0.02	0.02	0.03	0.21	0.80	0.22
2 - methylH	1.40	1.96	1.24	2.89	2.64	2.28
2,3 - dimethylP	1.34	1.28	0.90	1.72	1.25	1.26
1,c,3 - dimethylCP	-	-	-	-	-	-
3 - methylH	1.32	1.80	0.84	1.69	1.25	1.23
1,t,3 - dimethylCP	-	-	-	-	-	-
1,t,2 - dimethylCP	2.50	3.80	1.64	3.32	2.52	2.39
3 - ethylP	0.05	0.03	0.05	0.05	0.03	0.02
n - heptane	3.37	3.42	3.42	6.74	5.72	4.53
1,c,2 - dimethylCP	0.65	0.81	0.70	1.37	1.10	1.04
methylCH (MCH)	8.29	10.95	5.91	11.69	11.27	7.57
toluene	1.91	1.40	0.68	0.59	0.52	0.51
ABUNDANCE (ppm)	610	538	1757	6474	2398	1756
MCP/benzene	1.69	1.77	1.33	1.32	1.19	1.49
MCP/MCH	0.83	0.96	0.99	0.73	0.60	0.86
CH/MCP	0.30	0.30	0.39	0.52	0.48	0.54
iP/nP	1.09	1.31	0.45	0.40	0.48	0.69
%n - PARAFFINS	31.75	25.64	44.12	34.90	39.28	40.70
% ISOPARAFFINS	40.48	33.99	32.69	27.01	27.79	31.42
% NAPHTHENES	21.78	31.02	18.10	31.06	26.73	22.97
% AROMATICS	5.98	7.35	5.09	7.03	6.19	4.91

TABLE 4

VISUAL KEROGEN DATA

GEOCHEM SAMPLE NUMBER	DEPTH	ORGANIC MATTER DESCRIPTION				THERMAL MATURATION INDEX
		TYPES	REMARKS	PARTICLE SIZE	PRESERV-ATION	
161-001A	3200m	W;C;H	sparse organic matter. Contamination	F-M	P	2- (?)
161-004 swc	3268m	W-C;-;(H)	very sparse organic matter, unreliable.	M	P	
161-005C	3290m	C-W;H;S	very sparse organic matter. Some at 2 to 2+	F	P-F	2- (?)
161-006A	3320m	W-C;-;-	very sparse organic matter, unreliable.	F-M	P	
161-007A	3350m	C-W;-;-	very sparse organic matter, unreliable.	M	P	
161-008 swc	3357m	C-W;H;-	sparse organic matter.	F-M	F	1+ to 2-
161-010A	3410m	W-C;H;-	sparse organic matter. Reworked material (2 to 2+/2+).	F-M	F	2- (?)
161-013 swc	3490m	C-W;-;H	very sparse organic matter.	F	F	
161-015 swc	3525m	W;C-H;-	sparse organic matter	F-M	F	1+ to 2-
161-017 swc	3555m	W;C;H		M	F	1+ to 2-
161-019A	3590m	W;C;H	sparse organic matter.	M	F	1+ to 2-

reworked organic matter present throughout

Algal, Amorphous, Coaly, Herbaceous, Stem, Woody.

TABLE 5

VITRINITE REFLECTANCE DATA

GEOCHEM SAMPLE NUMBER	DEPTH	SAMPLE TYPE	AVERAGE REFLECTIVITY Ro (%)			NUMBER OF PARTICLES			REMARKS
			1	2	3	1	2	3	
161-001A	3200m	CUTTINGS	0.43	0.67		3	4		low organic content, only trace of true vitrinite
161-004	3268m	S.W.C.	0.44			3			low organic content
161-006A	3320m	CUTTINGS	0.43			19			
161-008	3357m	S.W.C.	0.45			18			
161-010A	3410m	CUTTINGS	0.51	0.80*		2	3		low organic content. *reworked
161-013	3490m	S.W.C.	0.36	1.49*		5	15		* reworked
161-015	3525m	S.W.C.	0.45			9			low-moderate organic content
161-017	3555m	S.W.C.	1.69*			13			* reworked, no true vitrinite
161-019A	3590m	CUTTINGS	0.39	0.65		18	2		

TABLE 6A

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

GEOCHEM SAMPLE NUMBER	INTERVAL	ROCK EXTRACTED	TOTAL EXTRACT OBTAINED	TOTAL EXTRACT		nC_5 SOLUBLE FRACTION				
				Precipitd. Asphaltenes	nC_5 soluble	Paraffin – Naphthenes	Aromatics	Eluted NSO's	Non-eluted NSO's	Sulphur
161-001	3200m	36.5344	0.0204 =	0.0148 +	0.0056	0.0024	0.0018	0.0014	–	–
161-002	3230m	35.1316	0.0211	0.0134	0.0077	0.0027	0.0023	0.0026	0.0001	–
161-003	3260m	40.4385	0.0272	0.0168	0.0104	0.0051	0.0027	0.0026	–	–
161-004 swc	3268m	8.0711	0.0207	0.0158	0.0049	0.0018	0.0014	0.0016	0.0001	–
161-005B	3290m	3.8690	0.0131	0.0083	0.0048	0.0021	0.0010	0.0017	–	–
161-006D	3320m	2.0509	0.0172	0.0128	0.0044	0.0016	0.0016	0.0012	–	–
161-007	3350m	29.9791	0.0176	0.0130	0.0046	0.0021	0.0008	0.0017	–	–
161-008 swc	3357m	0.7677	0.0147	0.0097	0.0050	0.0020	0.0015	0.0015	–	–
161-011	3450m	42.1226	0.0238	0.0148	0.0090	0.0034	0.0031	0.0025	–	–
161-012	3470m	49.0887	0.0251	0.0172	0.0079	0.0040	0.0021	0.0018	–	–
161-013 swc	3490m	0.6114	0.0138	0.0087	0.0051	0.0024	0.0011	0.0016	–	–
161-014	3500m	46.7835	0.0188	0.0104	0.0084	0.0041	0.0020	0.0023	–	–
161-015 swc	3525m	4.4423	0.0220	0.0138	0.0082	0.0037	0.0023	0.0022	–	–
161-016	3530m	47.1174	0.0339	0.0145	0.0194	0.0074	0.0064	0.0055	0.0001	–
161-017 swc	3555m	4.3859	0.0186	0.0102	0.0084	0.0043	0.0020	0.0021	–	–
161-018	3570m	62.1518	0.0242	0.0122	0.0120	0.0059	0.0031	0.0030	–	–
161-019	3590m	50.4483	0.0342	0.0139	0.0203	0.0090	0.0065	0.0048	–	–

TABLE 6B

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
161-001	3200m	558	66	49	115	405	38	–	–	443
161-002	3230m	601	77	65	142	381	74	3	–	458
161-003	3260m	673	126	67	193	415	14	–	–	480
161-004	swc3268m	2565	223	173	396	1958	198	12	–	2168
161-005B	3290m	3386	543	258	801	2145	439	–	–	2585
161-006D	3320m	8387	780	780	1560	6241	585	–	–	6826
161-007	3350m	587	70	27	97	434	57	–	–	490
161-008	swc3357m	19148	2605	1954	4559	12635	1954	–	–	14589
161-011	3450m	565	81	74	154	351	59	–	–	411
161-012	3470m	511	81	43	124	350	37	–	–	387
161-013	swc3490m	22571	3925	1799	5725	14230	2617	–	–	16847
161-014	3500m	402	88	43	130	222	49	–	–	271
161-015	swc3525m	4952	833	518	1351	3106	495	–	–	3602
161-016	3530m	719	157	136	293	308	117	2	–	427
161-017	swc3555m	4241	980	456	1436	2326	479	–	–	2804
161-018	3570m	389	95	50	145	196	48	–	–	245
161-019	3590m	678	178	129	307	276	95	–	–	371

TABLE 6C

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

GEOCHEM SAMPLE NUMBER	INTERVAL	HYDROCARBONS			NON HYDROCARBONS					HC / NON HC
		Paraffin – Naphthenes	Aromatics	P – N / AROM	Precipitd. Asphaltenes	Eluted NSO's	Non eluted NSO's	Sulphur	ASPH / NSO	
161-001	3200m	11.76	8.82	1.33	72.55	6.86	–	–	10.57	0.26
161-002	3230m	12.80	10.90	1.17	63.51	12.32	0.47	–	4.96	0.31
161-003	3260m	18.75	9.93	1.89	61.76	9.56	–	–	6.46	0.40
161-004 swc	3268m	8.70	6.76	1.29	76.33	7.73	0.48	–	9.29	0.16
161-005B	3290m	16.03	7.63	2.10	63.36	12.98	–	–	4.88	0.31
161-006D	3320m	9.30	9.30	1.00	74.42	6.98	–	–	10.67	0.23
161-007	3350m	11.93	4.55	2.63	73.86	9.66	–	–	7.65	0.20
161-008 swc	3357m	13.61	10.20	1.33	65.99	10.20	–	–	6.47	0.31
161-011	3450m	14.29	13.03	1.10	62.18	10.50	–	–	5.92	0.38
161-012	3470m	15.94	8.37	1.90	68.53	7.17	–	–	9.56	0.32
161-013 swc	3490m	17.39	7.97	2.18	63.04	11.59	–	–	5.44	0.34
161-014	3500m	21.61	10.64	2.05	55.32	12.23	–	–	4.52	0.48
161-015 swc	3525m	16.82	10.45	1.61	62.73	10.00	–	–	6.27	0.37
161-016	3530m	21.83	18.88	1.16	42.77	16.22	0.29	–	2.59	0.69
161-017 swc	3555m	23.12	10.75	2.15	54.84	11.29	–	–	4.80	0.51
161-018	3570m	24.38	12.81	1.90	50.41	12.40	–	–	4.07	0.59
161-019	3590m	26.32	19.01	1.38	40.64	14.64	–	–	2.90	0.83

TABLE 7

SIGNIFICANT RATIOS (%) OF C_{15+} FRACTIONS AND ORGANIC CARBON

GEOCHEM SAMPLE NUMBER		DEPTH	ORGANIC CARBON	HYDROCARBONS / TOTAL EXTRACT	HYDROCARBONS / ORGANIC CARBON	TOTAL EXTRACT / ORGANIC CARBON
161-001		3200m	0.47	20.61	2.45	11.87
161-002		3230m	0.44	23.63	3.23	13.66
161-003		3260m	0.54	28.68	3.57	12.46
161-004	SWC	3268m	0.26,0.26	15.44	15.23	98.65
161-005B		3290m	0.53	23.66	15.11	63.89
161-006D		3320m	0.37	18.60	42.16	226.68
161-007		3350m	0.41	16.52	2.37	14.32
161-008	SWC	3357m	1.02	23.81	44.70	187.73
161-011		3450m	0.33	27.26	4.67	17.12
161-012		3470m	0.32,0.32	24.27	3.88	15.97
161-013	SWC	3490m	0.57	25.36	100.44	395.98
161-014		3500m	0.32	32.34	4.06	12.56
161-015		3525m	0.66	27.28	20.47	75.03
161-016		3530m	0.40	40.75	7.33	17.98
161-017	SWC	3555m	0.70,0.70	33.86	20.51	60.59
161-018		3570m	0.38	37.28	3.82	10.24
161-019		3590m	0.40	45.28	7.68	16.95

TABLE 8

COMPOSITION (NORMALISED %) OF C_{15+} PARAFFIN – NAPHTHENE HYDROCARBONS

GEOCHEM SAMPLE NUMBER	-001	-002	-003	-004	-005B	-006D	-007	-008
DEPTH	3200m	3230m	3260m	3268m	3290m	3320m	3350m	3357m
SAMPLE TYPE				SWC				SWC
nC_{15}	5.3	16.2	18.4	8.8	17.9	20.2	26.9	10.5
nC_{16}	9.0	16.3	18.9	16.8	22.7	21.5	26.1	13.4
nC_{17}	13.8	13.2	16.1	15.1	18.1	16.9	17.1	11.6
nC_{18}	15.2	10.5	12.5	11.1	12.1	11.6	10.6	8.6
nC_{19}	8.9	9.1	9.3	7.6	7.8	7.8	6.7	6.0
nC_{20}	8.4	8.4	7.2	5.8	5.4	5.8	4.6	4.6
nC_{21}	6.1	6.9	5.2	4.6	4.5	4.9	2.6	4.1
nC_{22}	6.1	5.4	4.2	3.8	3.2	3.7	1.9	3.7
nC_{23}	4.5	3.4	2.7	2.7	2.0	2.3	1.3	3.4
nC_{24}	3.5	2.2	1.8	2.1	1.3	1.4	1.0	4.1
nC_{25}	2.9	1.3	1.0	2.4	0.9	0.9	0.4	5.2
nC_{26}	3.0	1.3	0.9	2.9	0.8	0.8	0.4	5.6
nC_{27}	2.6	1.2	0.6	3.2	0.6	0.6	0.3	5.4
nC_{28}	2.4	0.8	0.3	3.2	0.6	0.5	0.1	4.5
nC_{29}	3.0	1.3	0.4	3.4	0.7	0.5	-	3.8
nC_{30}	2.4	0.7	0.1	2.7	0.5	0.3	-	2.4
nC_{31}	1.6	0.8	0.2	2.1	0.5	0.3	-	1.7
nC_{32}	0.4	0.3	0.1	0.9	0.2	0.2	-	0.8
nC_{33}	0.4	0.2	-	0.4	0.2	0.2	-	0.4
nC_{34}	0.2	0.1	-	0.1	0.1	-	-	0.1
nC_{35}	0.2	-	-	0.1	-	-	-	0.1
PARAFFIN	17.6	32.1	31.1	25.4	31.3	27.3	18.5	33.7
ISOPRENOID	2.7	3.9	5.5	2.8	3.9	3.2	2.4	2.9
NAPHTHENE	79.7	63.9	63.4	71.8	64.9	69.6	79.1	63.5
CPI INDEX A	0.92	1.04	0.99	0.97	1.05	1.07	0.95	1.00
CPI INDEX B	1.07	1.21	1.17	1.07	1.06	1.06	-	1.08
PRISTANE/PHYTANE	1.39	1.74	1.28	1.59	1.76	1.75	1.82	1.56
PRISTANE/nC_{17}	0.65	0.59	0.62	0.45	0.44	0.44	0.49	0.45

TABLE 8

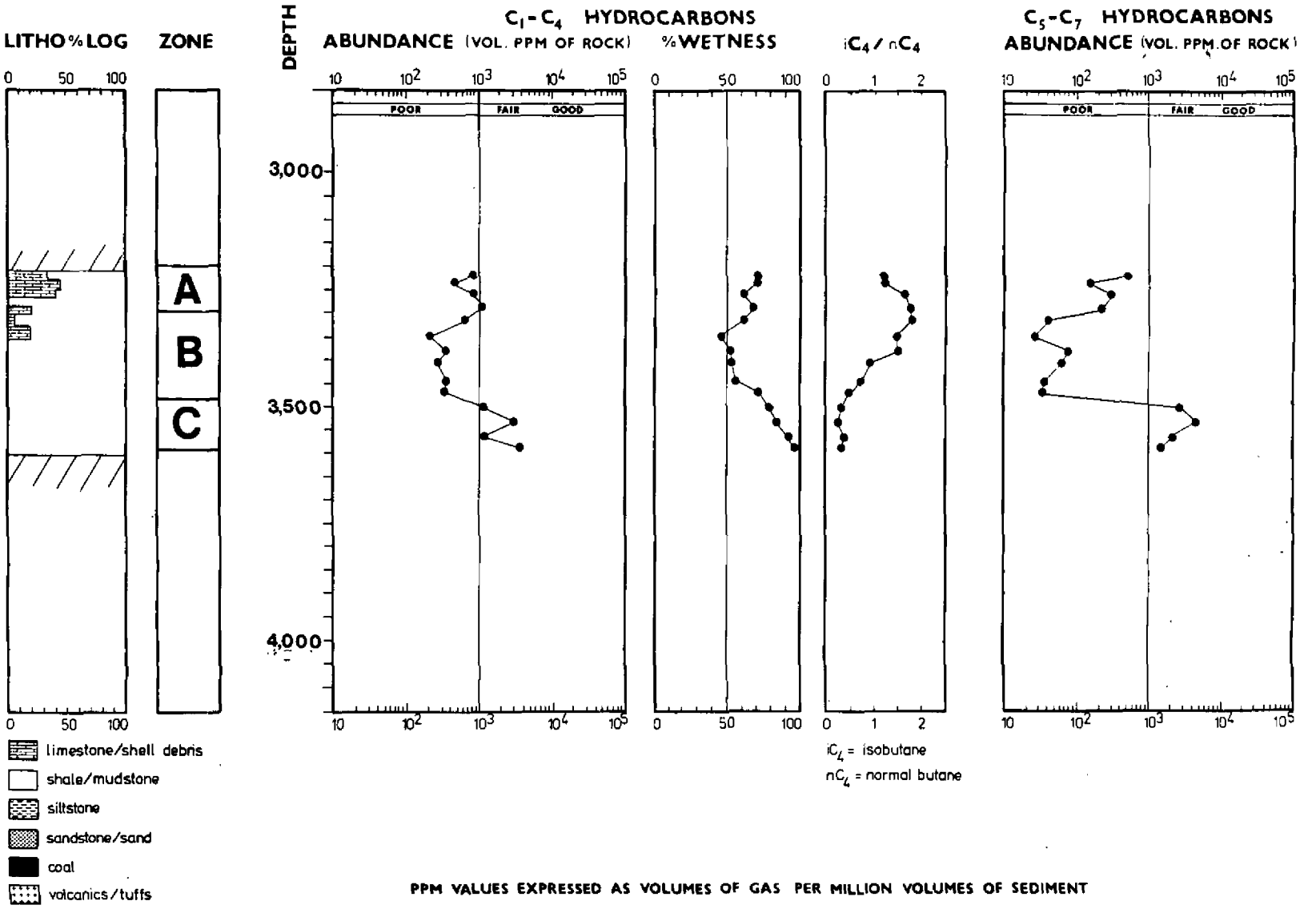
COMPOSITION (NORMALISED %) OF C_{15+} PARAFFIN – NAPHTHENE HYDROCARBONS

GEOCHEM SAMPLE NUMBER	-011	-012	-013	-014	-015	-016	-017	-018	-019
DEPTH	3450m	3470m	3490m	3500m	3525m	3530m	3555m	3570m	3590m
SAMPLE TYPE			SWC		SWC				
nC_{15}	18.5	25.5	27.2	20.3	22.3	17.8	22.5	22.1	15.3
nC_{16}	17.1	22.8	24.5	18.5	19.9	15.8	20.0	19.0	14.9
nC_{17}	11.5	14.3	16.7	13.1	14.1	13.0	12.7	13.7	12.1
nC_{18}	7.9	9.2	10.5	9.0	9.8	10.3	7.7	9.5	9.6
nC_{19}	7.0	5.7	6.6	6.1	7.4	8.6	4.8	7.6	8.4
nC_{20}	7.3	4.5	4.7	4.7	6.1	7.3	3.4	6.2	7.6
nC_{21}	6.6	3.5	2.9	4.0	4.6	5.5	2.5	4.7	6.2
nC_{22}	6.0	2.4	2.0	3.3	4.1	5.1	2.4	4.3	5.7
nC_{23}	3.9	1.8	1.3	3.1	3.0	3.9	2.3	3.1	4.5
nC_{24}	2.5	1.4	1.0	2.2	2.4	3.1	2.7	2.4	3.6
nC_{25}	2.1	1.3	0.6	2.3	1.7	2.3	3.4	1.7	2.8
nC_{26}	1.9	1.3	0.6	2.4	1.3	1.9	3.6	1.4	2.4
nC_{27}	1.9	1.0	0.4	2.3	1.0	1.3	3.6	1.0	1.8
nC_{28}	1.7	1.0	0.4	2.0	0.7	1.0	2.9	1.4	1.3
nC_{29}	1.6	1.4	0.3	2.0	0.7	1.5	2.3	0.8	1.3
nC_{30}	1.1	0.8	0.1	1.5	0.4	0.6	1.5	0.5	0.9
nC_{31}	0.8	1.0	–	1.4	0.4	0.5	0.9	0.3	0.8
nC_{32}	0.5	0.4	–	0.9	0.2	0.1	0.4	0.1	0.4
nC_{33}	0.2	0.4	–	0.5	0.1	0.1	0.2	0.1	0.3
nC_{34}	–	0.1	–	0.3	–	–	–	–	0.1
nC_{35}	–	0.1	–	0.2	–	–	–	–	–
PARAFFIN	29.3	23.4	24.6	31.5	31.2	28.7	36.9	26.0	29.9
ISOPRENOID	2.5	2.3	2.6	2.9	3.3	3.4	2.9	2.7	3.5
NAPHTHENE	68.2	74.3	72.8	65.6	65.5	67.8	60.2	71.3	66.6
CPI INDEX A	1.01	1.02	0.96	1.06	0.98	0.95	1.00	0.92	0.99
CPI INDEX B	1.04	1.18	–	1.08	1.09	1.18	1.08	0.93	1.08
PRISTANE/PHYTANE	1.70	1.92	1.67	2.04	1.54	1.51	1.84	1.90	1.62
PRISTANE/nC_{17}	0.47	0.45	0.39	0.48	0.46	0.55	0.40	0.50	0.60

FIGURE 1

C_1-C_7 HYDROCARBONS

PRESENTATION OF ANALYTICAL DATA



PPM VALUES EXPRESSED AS VOLUMES OF GAS PER MILLION VOLUMES OF SEDIMENT

FIGURE 2

C_4-C_7 HYDROCARBONS

PRESENTATION OF ANALYTICAL DATA

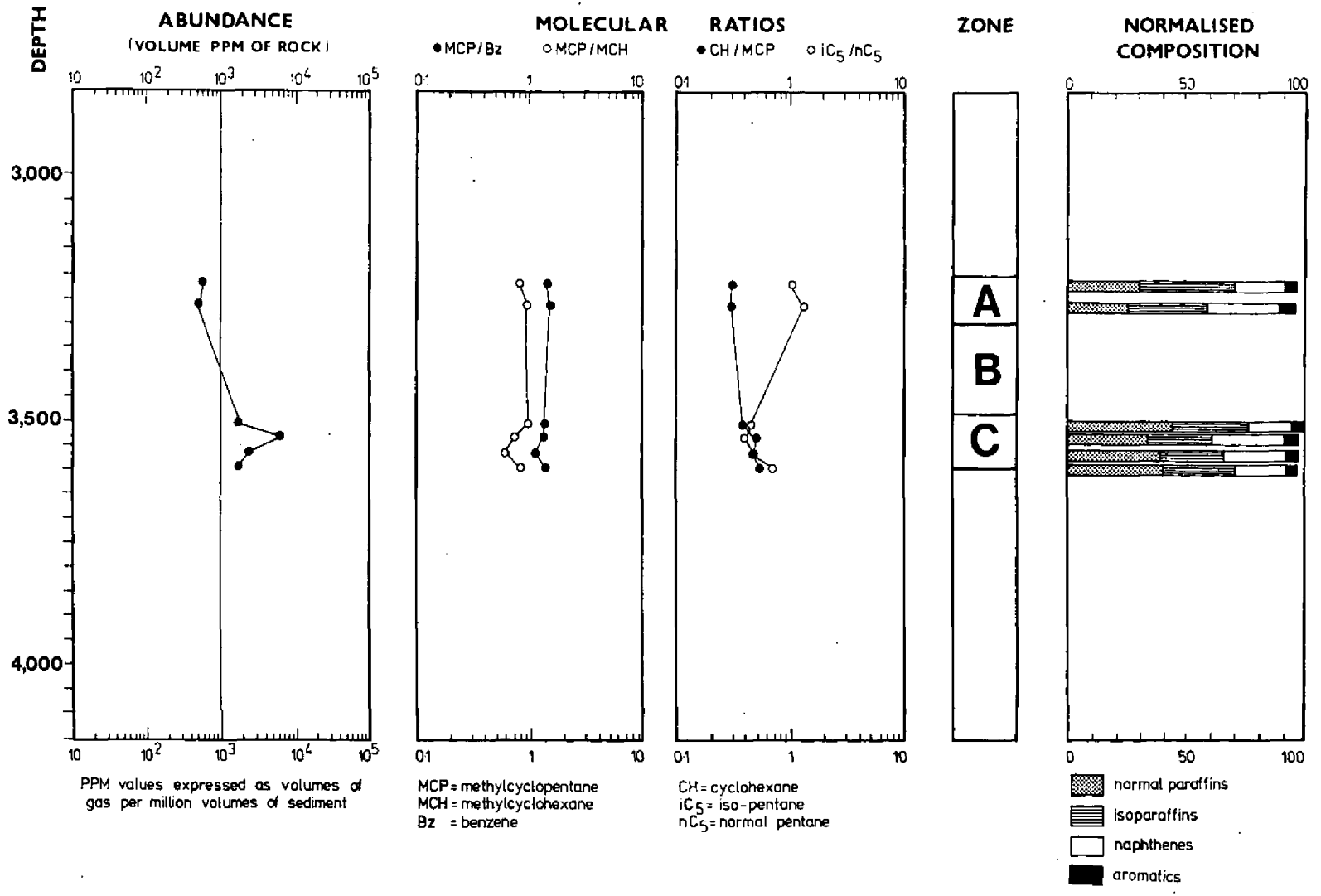


FIGURE 3

C_{15+} HYDROCARBONS — RICHNESS

PRESENTATION OF ANALYTICAL DATA

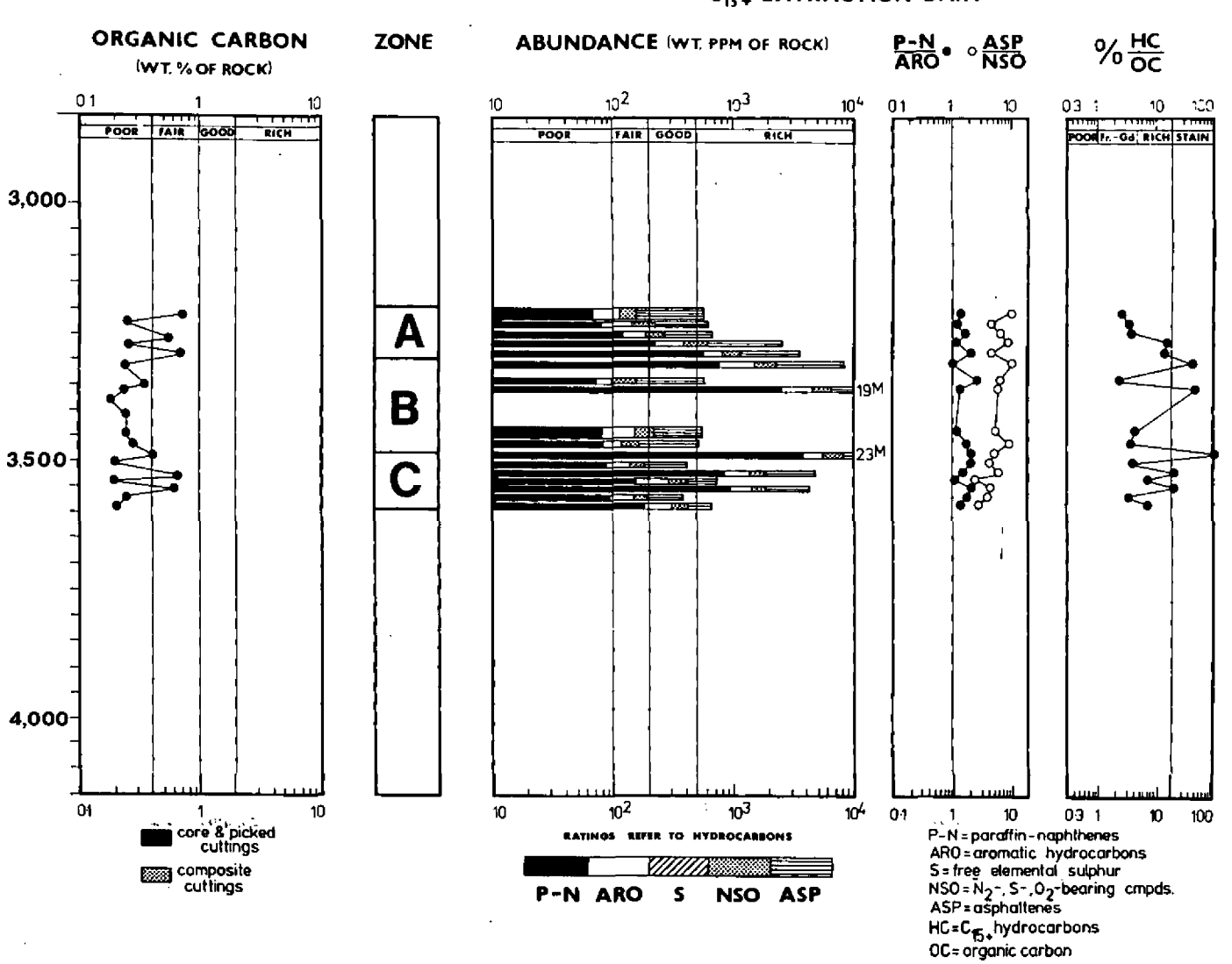


FIGURE 4a

C_{15+} PARAFFIN – NAPHTHENE HYDROCARBONS

PRESENTATION OF ANALYTICAL DATA

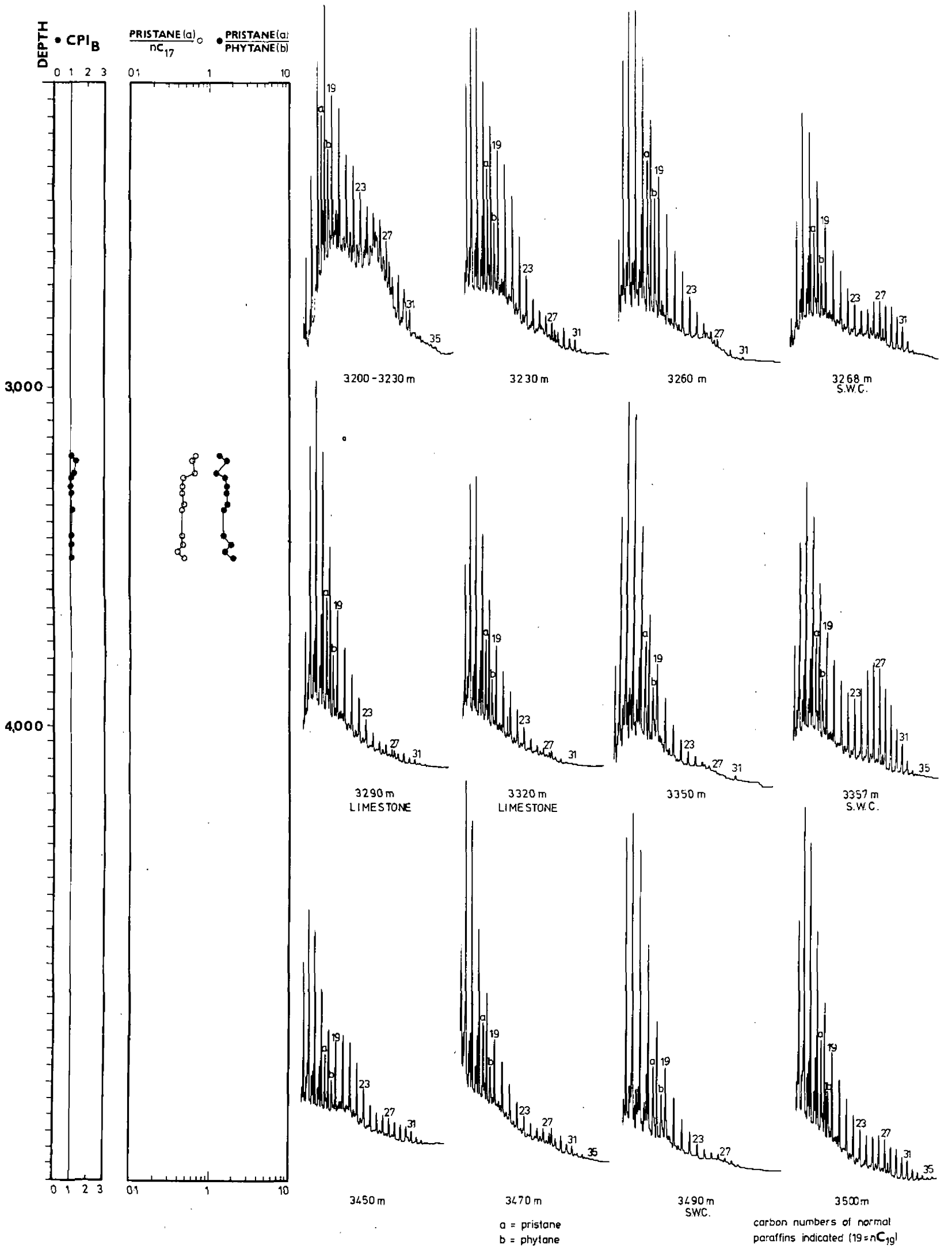


FIGURE 4b

C_{15+} PARAFFIN — NAPHTHENE HYDROCARBONS

PRESENTATION OF ANALYTICAL DATA

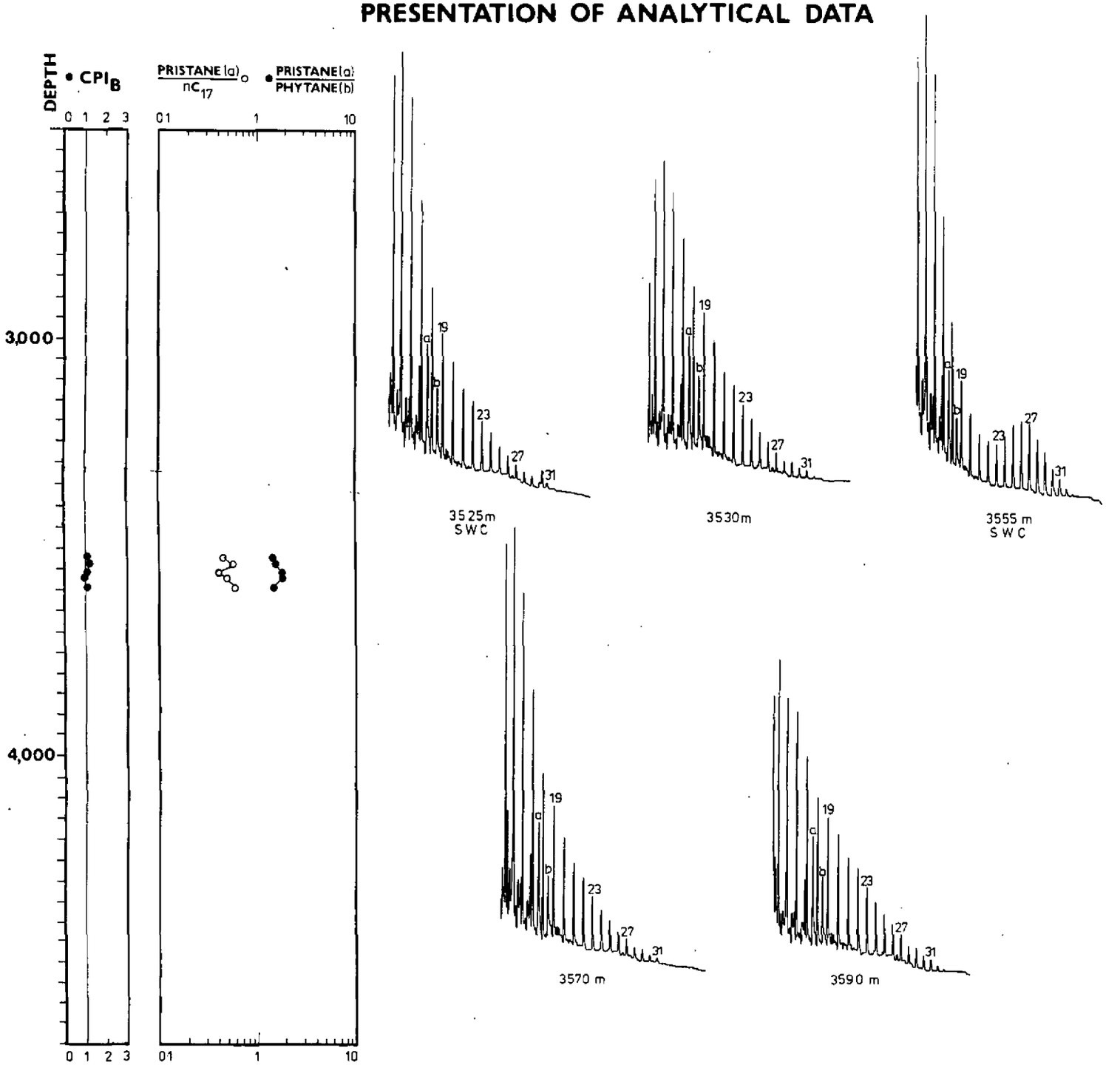
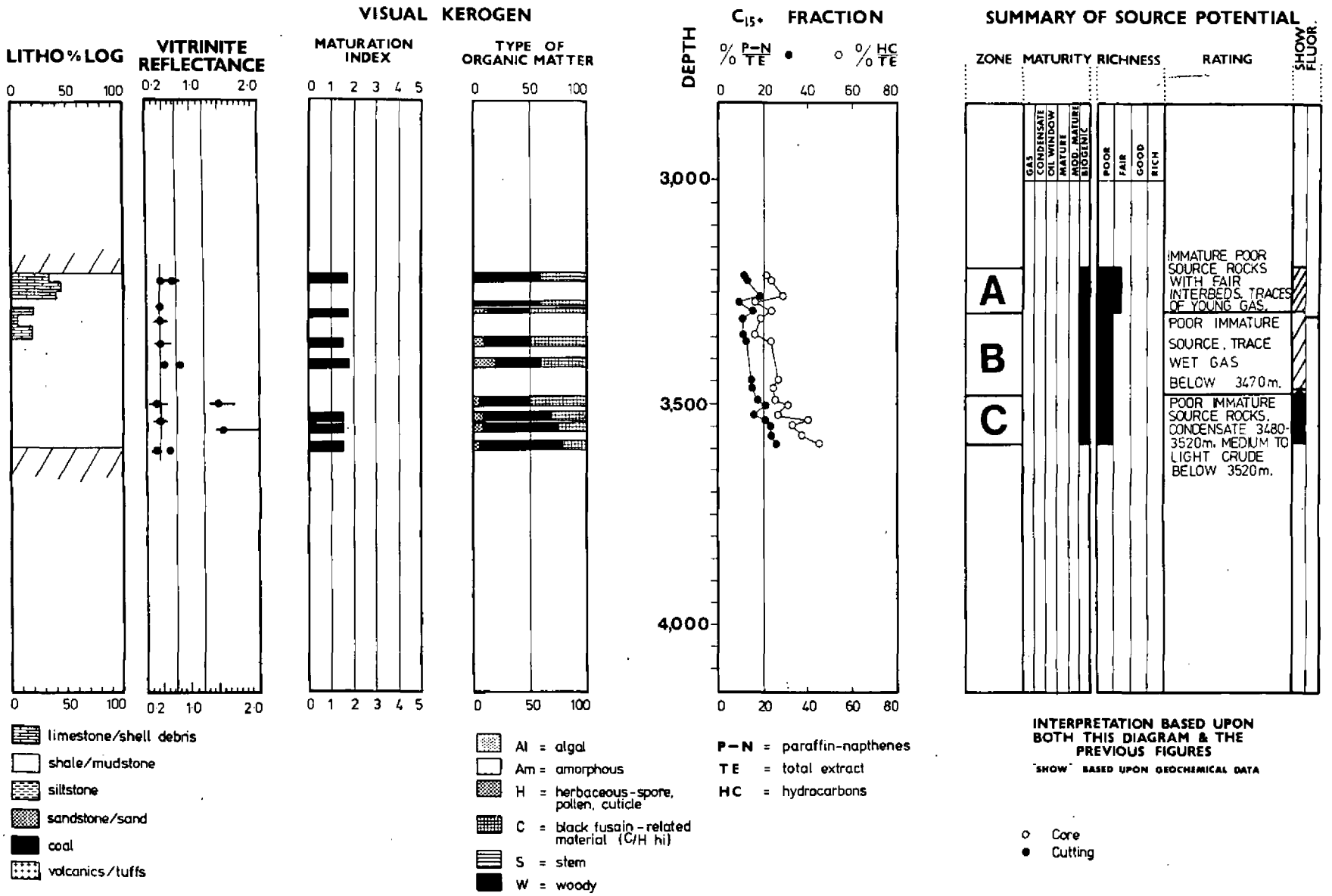


FIGURE 5

INTERPRETATION DIAGRAM

SOURCE TYPE MATURATION RATING



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.