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GeoChem Laboratories (U.K.) Limited

GEOCHEMICAL SERVICE REPORT

Prepared for

AMOCO NORWAY OIL COMPANY

GEOCHEMICAL EVALUATION OF THE SECTION 3500 - 4367 METRES
IN AMOCO NORWAY'S 2/9—2 WELL

PetroData as

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COMPANY PROPRIETARY

GEOCHEMICAL EVALUATION OF THE SECTION 3500-4367 METRES IN AMOCO NORWAY'S 2/9-2 WELL

SUMMARY

A total of eight (8) geochemical zones are recognised.

The shales which dominate Zones A^1 (3500-3650± metres) and A^2 (3650-3745± metres) are poor and effectively immature source rocks. However the minor interbedded carbonaceous siltstones within Zone A^2 are potentially excellent source rocks for major oil and minor hydrocarbon generation is occurring on-structure.

Interbedded lean shales occur in the upper half of Zone B (3745-3910± metres) but otherwise, Zones B, C (3910-3970± metres) and D (3970-4367± metres, four sub-zones recognised) are composed of shales with a potential for major oil and within which minor generation is occurring.

Traces of migrated crude oil were detected in Zone A^2 and there are minor shows throughout Zones B, C and D (and at 3690-3715± metres in Zone A^2). It is believed that this crude was generated in the more mature off-structure equivalents of the associated shales and then migrated laterally into the structure.

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INTRODUCTION

This report presents a geochemical evaluation of the section between 3550 metres and 4300 metres in Amoco Norway's 2/9-2 well. A preliminary evaluation of the intervals from 3500-3550 metres and 4300-4367 metres is also included in the report.

The study was designed to:

- investigate the hydrocarbon source potential of the section in terms of richness, maturity and organic matter type
- detect and characterise migrated liquid hydrocarbons (crude oil, condensate)
- correlate any migrated hydrocarbons to their parent source rock(s).

This project was authorised by Mr. R.M. Ridley, Amoco Norway Oil Company, Stavanger.

A. ANALYTICAL

A suite of bagged samples, composited at 2-5 metres, was submitted for this study. From these, samples were selected on an interval of fifteen metres for analysis and assigned the Geochem job number 408.

Samples were selected from 3500 metres down to total depth. Those from outside the specified limits of 3550-4300 metres were only screened and these results are reported at no charge.

Only scattered contamination was observed during the sample preparation procedures.

Screening was performed using light hydrocarbon (C_1-C_7) and organic carbon contents and samples for further analysis were selected on the basis of the screen results. A total of one hundred and eighteen organic carbon analyses, fifty nine light hydrocarbon analyses, nineteen visual kerogen analyses, thirteen vitrinite reflectance determination, thirteen detailed gasoline-range analyses, twenty-three pyrolysis analyses, fifteen extractions with chromatography and fifteen high resolution paraffin-naphthene analyses were performed in this study. Due to the fact that the samples were bagged (although wet), the light hydrocarbon air space analysis could not be run and hence, the C_1-C_7 data refer to the cuttings gas.

The data are presented in tables 1 through 9 and graphically in figures 1 through 7. A brief description of the analytical techniques is included in the back of the report.

B. GENERAL INFORMATION

Ten (10) copies of this report have been forwarded to Mr. R.M. Ridley, Amoco Norway Oil Company, together with the kerogen slides prepared for this study. A copy of the data has been retained by Geochem for future consultation with authorised Amoco personnel.

The remaining sample material will be handled as directed.

All of the results and interpretations contained in this report are regarded as highly confidential and are proprietary to the Amoco Norway Oil Company.

RESULTS AND INTERPRETATION

Although only the interval 3550-4300 metres was specified for analysis, screening was performed from 3500 metres down to 4367 metres (TD).

Each of the parameters relevant to the geochemical evaluation of the section will be discussed in turn and then integrated to form the "Conclusions".

No well logs were available for this study.

A. GEOCHEMICAL ZONATION

This zonation is based upon the light hydrocarbon (C_1-C_7) cuttings gas data. Some loss of these volatile hydrocarbons will have been experienced during the period before the samples were received in the laboratory, but the trends will be meaningful. A total of eight (8) zones are recognised.

Zone A^1 — 3500 metres to 3650± metres, is dominated by shales and mudstones which are grossly medium grey in colour and are occasionally silty. Lime mudstones are present above 3535± metres and the samples from 3585-3610± metres and 3630-3635± metres contain significant proportions of "coal".

The C_1-C_4 gaseous hydrocarbons are sparse at 20-59 ppm but are marginally wet (32.7-56.8(62.4)% C_{2+} in total C_1-C_4). Their isobutane to normal butane ratios normally fall within the limits of 0.5-1.0. The heavier C_5-C_7 hydrocarbons are also sparse, never exceeding 67 ppm.

Zone A^2 — 3650± metres to 3745± metres is lithologically rather similar to Zone A^1. The dominant shales are medium dark grey and light brownish grey in colour above and below 3685± metres respectively and are frequently silty. Interbedded carbonaceous siltstones are present (particularly below 3685± metres) and there is a "coal" at 3722-3725± metres.

Geochemically, Zone A^2 is richer and wetter than Zone A^1. Thus the gaseous hydrocarbons, although not abundant, generally lie within the limits of 303-843 ppm and reach 1918-2309 ppm at 3685-3715± metres. They are now very wet (79.3-96.7% C_{2+}) and the richest samples are the wettest. C_5-C_7 abundances jump to 416-804 ppm and reach 1775 ppm at 3707-3710± metres. Finally, the butane ratios drop to the general range of 0.27-0.39.

The enhanced oil-like character of this interval presumably correlates either with the siltier nature of the section or with the presence of carbonaceous interbeds.

Zone B extends from 3745± metres down to 3910± metres. This interval is dominated by dark grey silty shales which, above 3835± metres, are interbedded with light brownish grey shales. Minor light grey mudstones are present below this depth.

Zone B is characterised by slightly enhanced richness. Thus the C_1-C_4 and C_5-C_7 hydrocarbons fall within the limits of (317)617-1847(5824) ppm and (402)737-1440(3450) ppm respectively, the uppermost sample being the richest in each case. The gases are extremely wet (83.3-97.3%) and have low isobutane to normal butane ratios.

Zone C 3910± metres to 3970± metres is a continuation of the dark grey shale section, although the shales are now less silty.

It is still very wet (86.5-92.9% C_{2+}) but is leaner: 483-639 ppm C_1-C_4, 469-577(809) ppm C_5-C_7.

Zone D 3970± metres to 4367± metres, is dominated by dark grey shales (which are occasionally silty) throughout, but four sub-zones are recognised.

Zone D^1 (3970-4165± metres). Below 4060± metres, these shales contain sandy laminae and are bituminous.

This sub-zone is significantly richer than Zone C. The C_1-C_4 gases generally range from (744)936 ppm up to 2469 ppm but reach 3000-3300 ppm at 4023± metres and 4128± metres and 5208 ppm at 4038± metres. They are extremely wet (93.7-98.5% C_{2+}) and have low butane ratios. The C_5-C_7 fraction is also enhanced at (976)1206-2237(2981) ppm and again, the samples from 4015-4045± metres are the richest.

Zone D^2 (4165-4240± metres) contains minor sands. A minor dark yellowish brown silty shale is present in the uppermost sample and yielded a blue cut.

This interval displays a further enhancement in both the C_1-C_4 (3208-5017 ppm) and C_5-C_7 (3330-5184 ppm) fractions. The gases are, again, extremely wet at 96.4-99.0% C_{2+}. The sample from 4233 metres was poor in quality but should probably be included in this sub-zone.

Zone D^3 (4240-4315± metres). These shales are stained, but are leaner and "drier".

The C_1-C_4 gases drop to 1501-2518 ppm and are now "only" (67.7)76.3-87.4% wet, whilst the heavier C_5-C_7 hydrocarbons range from 1765 ppm up to 3032 ppm.

Zone D^4 (4315-4367± metres). These shales are also oil stained.

Geochemically, they resemble those of Zone D^2. Thus the gaseous hydrocarbons return to the range 3254-3323(5019) ppm and are again extremely wet, particularly below 4330± metres (91-95%), whilst the C_5-C_7 fraction lies within the limits 3752-5240 ppm. The sample from 4353 metres is the richest.

Zones A^2 through D^4 are characterised by their (extreme) wetness.

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 percent organic carbon, and this is the standard to which these samples will be compared.

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

The dominant shales (and the lime mudstones) of Zones A^1 and A^2 generally contain 0.12-0.36% organic carbon and hence, are of well-below average richness. However, the pale reddish brown and medium dark grey shales above 3505± metres and the minor brownish grey shale at 3573± metres reach 0.75-1.10% organic carbon. The "coals" within this interval are rich (20.0-31.9%) and are discussed under Section C whilst the greyish black carbonaceous silts within Zone A^2 also have very good values of 2.10-3.70% organic carbon.

Woody organic matter is very dominant in the shales, although minor to significant proportions of herbaceous and algal debris are also present. Within the "coals", the organic matter is almost exclusively woody in type but, in the Zone A^2 carbonaceous siltstones, is only a minor to significant constituent. These are characterised by an herbaceous-amorphous assemblage in which the herbaceous fraction shows partial alteration towards the amorphous state.

Interbedded light brownish grey shales apparently occur within Zone B (particularly above $3835^{\pm}$ metres) and resemble those of Zone A^2, containing 0.24-0.32% organic carbon. However, Zone B is dominated by brownish black and dark grey shales. These contain 1.60-2.36(2.89)% organic carbon and hence, are not only much richer than the overlying sediments but are also of above-average richness. In the brownish black shales (above $3805^{\pm}$ metres), herbaceous kerogen is the major constituent whilst amorphous, woody$\pm$algal materials are significant. The underlying dark grey shales are characterised by a woody-herbaceous assemblage accompanied by significant proportions of amorphous kerogen.

Zones C through D^4 are still richer and are relatively uniform, as their major dark grey shales fall within the limits of 2.26-2.95(3.40)% organic carbon. The richest samples (2.6+%) are scattered throughout Zone D, whose sub-zones are not distinctively different:-

Zone C, 2.27-2.58%
Zone D^1, 2.26-2.83(3.06)%
Zone D^2, 2.38-2.59(3.40)%
Zone D^3, 2.51-2.95%
Zone D^4, 2.27-2.70%

Wood is generally the major constituent of the organic matter but herbaceous debris is always significant and sometimes, particularly in Zone D^1, shares the major role whilst in Zone D^2 it is dominant. Algal remains are significant in Zones C and D^1. Together with the herbaceous debris, they display partial alteration towards the amorphous state and indeed, there are significant proportions of amorphous kerogen in Zones D^2, D^3 and D^4.

Scattered minor light grey mudstones occur in Zones C through D^4 and are lean (0.29-0.42% organic carbon) but the occasional light brownish grey mudstones in Zones D^2 and D^3 are improved at 0.49-0.54(1.24)% organic carbon. The minor dark yellowish brown silty shale at $4173^{\pm}$ metres in Zone D^2 is extremely rich. It contains 19.24% organic carbon and its organic matter, like that of the dark grey shales in Zone D^2, is dominated by herbaceous debris which shows scattered sapropelisation and is accompanied by significant proportions of amorphous and woody kerogens.

A fairly constant environment of deposition is suggested for the dark grey shales of Zones B through D^4. Most of the organic matter was derived from land plants and weakly reducing conditions probably prevailed at the seawater-sediment interface, although they may have been slightly more reducing in Zone B, D^2, D^3 and D^4 times. However, no richly amorphous units were detected.

In the Zone D^2 shales the organic matter, although still largely land plant in type, is different in composition as herbaceous debris (rather than wood) is now dominant, which suggests the possibility of a change in environment. Indeed, Zone D^2 suggests similarities to the brownish black shales at the top of Zone B and the carbonaceous siltstones of Zone A^2, although a moderately reducing regime may have prevailed in both of these.

A different, but again uniform, environment of deposition (closer to shore?) is suggested for the leaner shales which characterise Zones A^1 and A^2.

C. LEVEL OF THERMAL MATURATION

Thermal maturity has been evaluated with the organic matter (spore) colouration and vitrinite reflectance techniques.

The spore colouration method indicates a thermal index of 2- at the top of the analysed section. Although some material with an index of 2 was detected at 3963± metres and 4365± metres, the sediments do not actually achieve a value of 2 by total depth.

At these levels of maturity the amorphous, algal and herbaceous fractions of the total organic matter are marginally mature (minor hydrocarbon generation) but wood is still immature. Hence Zones A^1 and A^2 are effectively immature, with the exception of the carbonaceous silts of Zone A^2 which are marginally mature. The brownish black shales at the top of Zone B and the shales of Zone D^2 are marginally mature but otherwise the sediments of Zones B through D^4 are transitional between the immature (wood) and marginally mature (non-woody fractions) states, with minor hydrocarbon generation from the non-woody organic matter.

It was commonly possible to take a satisfactory number of vitrinite reflectance readings and indeed, fifty-nine readings were obtained from the "coal" at 3588 metres. This was the only sample to give a single population of data points. All of the rest yielded a spread of values in the general range of 0.25-1.3% Ro within which it is possible to recognise approximately five separate populations, none of which are dominant. The only exception to this generalisation is the "coal", which gave a tight single population at 0.35% Ro. The "coal" particles are fine-grained, well sorted and sub-rounded and it is believed that this material is, in fact, a mud additive - although it is vitreous and does not resemble common lignite. Significant populations in the range of 0.29-0.35% Ro are present in all of the underlying samples and again, are believed to result from contamination.

Eliminating these data points, there is still a wide spread of values, the highest of which are almost certainly due to reworking.

Those chosen to represent the indigenous organic matter correlate with the lowest of the remaining populations. In some samples, this population is represented by only one reading, but there are fairly good reference points at 3558 metres and 4248 metres. This choice is admittedly subjective but is supported by four lines of evidence: it gives a good trend against depth; it is reasonably compatible with the spore colouration indices; the heavy ends of the paraffin-naphthene chromatograms suggest this sort of maturity; yellow-orange and light orange spore fluorescence colours indicate values of approximately 0.4-0.5% Ro.

The trend line fitted to the chosen data points reaches values of 0.45% Ro and 0.53% Ro at depths of approximately 3600± metres and 4300± metres respectively. They should correlate with thermal maturation indices of 2- and 2 and hence the agreement between the two methods is acceptable and supports the maturation profile discussed above. The top of the mature zone (significant oil generation but not oil window) apparently lies at approximately total depth.

D. SOURCE RICHNESS

Preliminary assessments of present and potential source richness can be obtained from the light hydrocarbon (C_1-C_7) and organic carbon abundances.

Light hydrocarbon data assign a poor source rating to Zone A^1. Over the rest of the section the gases are anomalously wet and in addition, there is the danger of the loss of light ends from these bagged samples. Organic carbon values indicate a poor rating for the dominant shales of Zones A^1 and A^2 although the carbonaceous siltstones within Zone A^2 have a very good source potential. The darker shales of Zone B are potentially good source rocks whilst the dark grey shales of Zones C through D^4 are potentially very good sources for oil and gas.

The dominant shales of Zones A^1 and A^2 yielded 108-168 ppm C_{15+} hydrocarbons. This suggests a poor to fair source rating but the relatively high proportion of hydrocarbons in the total extract is suspicious and examination of the paraffin-naphthene chromatograms indicates the presence of some non-indigenous species. Allowing for this, the source-indigenous hydrocarbons are probably less abundant than 100 ppm and hence, a poor rating is more realistic.

The siltstones within Zone A^2 and the major brownish black and dark grey shales of Zones B through D^4 are much richer. They contain 754-2447 ppm C_{15+} hydrocarbons which constitute, except at the base of Zone B and the top of Zone C, (54)61-73(84)% of the total extract. Not only are these ratios too high for sediments at this level of maturity but there is a gross correlation between "leaner" samples and lower ratio values. Non-indigenous hydrocarbons are indicated. The paraffin-naphthene chromatograms are similar throughout and particularly below Zone B. Their sterane-terpane background envelope humps, the odd carbon preference amongst the normal paraffins beyond approximately nC_{23} and, in some samples, the strength of the pristane peak, are immature features. On the other hand however, the general normal paraffin distribution is too mature and suggests the presence of non-indigenous hydrocarbons in addition to those which are source-related. Crude oil is believed to be present and hence, the source richnesses as indicated by the C_{15+} hydrocarbon abundances are too optimistic. Nevertheless, these sediments would still be expected to be potentially good to very good source rocks for oil.

The pyrolysis technique has been employed to overcome the problem of non-indigenous hydrocarbons. This method provides a laboratory simulation of the maturation process and enables us to measure source richness under optimum (oil window) maturation conditions. The medium dark grey to light brownish grey shales of Zones A^1 and A^2 yielded 350-729 ppm pyrolysate and are classified as poor source rocks. In contrast, the carbonaceous siltstone from 3693 metres in Zone A^2 is extremely rich at 21,335 ppm pyrolysate (confirmed on extracted sample) and hence, is a potentially rich source for oil. Relative to their organic carbon contents, the "coals" are significantly leaner, have relatively low pyrolysate to organic carbon ratios and have a primary potential for gas with associated liquids.

The dark grey shales of Zones B through D^4 (and the brownish black shales at the top of Zone B) yielded between (5675)7446 ppm and 18515 ppm pyrolysate and are rated as excellent source rocks for oil, whilst the dark yellowish brown shales from $4173^{\pm}$ metres is extremely rich at 88,987 ppm pyrolysate. Values for the extracted bulk samples are of the same order of magnitude.

Hence, rich source rocks with a potential for major oil are represented by the siltstones of Zone A^2 and by the dark grey (and brownish black) shales of Zones B through D^4.

E. MIGRATED HYDROCARBONS

Although silty shales (and siltstones) are relatively common within this section, sands are only present in the sample from $4172\text{-}4175^{\pm}$ metres, with traces of sandstone down to $4255^{\pm}$ metres. No fluorescence was detected in the sands but it was observed in the shales from $4170\text{-}4190^{\pm}$ metres, whilst the shales appeared to be oil-stained at $4125\text{-}4165^{\pm}$ metres, $4245\text{-}4270^{\pm}$ metres, $4293^{\pm}$ metres and $4320\text{-}4360^{\pm}$ metres.

The light hydrocarbons were measured upon bagged samples and hence, some loss must have occurred. Nevertheless, the gases of Zones A^2 through D^4 are extremely wet and indicate the presence of migrated liquid hydrocarbons. With the exception of the siltstones at 3690-3715± metres, hydrocarbon abundances are relatively low in Zones A^2 and C, whilst the best shows correlate with Zones D^2 and D^4 and with 3752-3755± metres at the top of Zone B. If they are present at all, only insignificantly minor traces of migrated liquid hydrocarbons could occur in Zone A^1.

Chromatograms of the C_{15+} paraffin-naphthenes show some immature features in the abundance of steranes and in their odd carbon preference indices, but the overall configuration of the normal paraffins suggests the presence of migrated crude oil in addition to the source-indigenous hydrocarbons. Due to the presence of two populations of hydrocarbons, it is difficult to be certain regarding the character of the crude, but a light to medium gravity oil derived from only moderately mature parent source rocks is suggested. Only relatively minor shows appear to be involved, particularly within the interval 3815-4010± metres.

The more mature off-structure lateral equivalents of these shales, and particularly the zones richer in amorphous kerogen, could well have sourced the crude.

In summary:

- migrated, out of place liquid hydrocarbons were not detected in Zone A^1.
- minor traces of crude oil appear to have diffused into Zone A^2, whilst there is a show correlating with the siltstones at 3690-3715± metres.
- minor shows of crude occur throughout the rest of the section. The best shows correlate with Zones D^2 and D^4 and with the top of Zone B and the weakest with the gross interval 3815-4010± metres and particularly with Zone C.
- the best shows correlate with the rich intervals with the highest proportion of non-woody organic matter, suggesting that the oil was probably derived from the lateral equivalents of the shales present on-structure.

F. CONCLUSIONS

This report is primarily concerned with the section between 3550 metres and 4300 metres in 2/9-2 but a preliminary evaluation was also performed over the intervals 3500-3550 metres and 4300-4367 metres. A total of eight (8) zones are recognised.

Zone A^1 (3500-3650± metres) is dominated by shales and mudstones which are grossly medium grey in colour. They generally contain

0.13-0.36% organic carbon and their organic matter is dominantly woody in type, with minor to significant proportions of herbaceous and algal debris. The pale reddish brown and medium dark grey shales above 3505± metres and the minor brownish grey mudstone at 3573± metres are improved at 0.75-1.10% organic carbon but are apparently limited in volume. This interval is effectively immature but, even in a mature state, would be a poor source and of no exploration significance.

The "coals" present at 3585-3610± metres and 3630-3635± metres (and at 3722-3725± metres in Zone A^2) are believed to be a mud additive and certainly, are "out of place".

The medium dark grey and light brownish grey shales of Zone A^2 (3650-3745± metres) are similar in richness (0.12-0.36%) and organic matter type to the medium dark grey shales of Zone A^1. They are also poor and effectively immature source rocks. However, interbedded greyish black carbonaceous siltstones are also present and these are much richer at 2.10-3.70% organic carbon. This enhancement is complimented by the fact that wood is now only a minor to significant constituent of the organic matter, which is dominated by a mixed herbaceous-amorphous assemblage, the herbaceous fraction showing partial alteration towards the amorphous state. These siltstones are potentially excellent source rocks for oil and minor hydrocarbon generation is occurring on-structure. Unfortunately, except at 3692-3695± metres, they appear to be rather limited in volume.

Zone B (3745-3910± metres) consists of interbedded brownish black and light brownish grey shales above 3805± metres and of dark grey silty shales (with interbedded light grey to light brownish grey shales to 3835± metres, then minor) below this depth. The light brownish grey shales are lean (0.24-0.32% organic carbon) but the darker shales contain 1.60-2.36(2.89)% organic carbon. Significant proportions of amorphous kerogen are present but, whereas a woody-herbaceous assemblage is dominant in the dark grey variety, herbaceous debris is dominant in the brownish black shales and wood is now only a significant (rather than major) component. Due to these variations in organic matter type, the brownish black shales are marginally mature (minor hydrocarbon generation) whilst the dark grey shales are transitional between the immature (wood) and marginally mature (herbaceous-amorphous) states. However if mature, these shales could yield major oil to associated reservoirs.

Zones C (3910-3970± metres) and D (3970-4367± metres) are dominated by dark grey shales which are occasionally silty and in which, sandstone laminae occur below 4060± metres in Zone D^1 (3970-4165± metres) and in Zone D^2 (4165-4240± metres). These shales are enhanced relative to those of Zone B and are of relatively uniform richness, falling within the limits of 2.26-2.95(3.40)% organic carbon. Although the zones cannot be distinguished by their carbon values, there are some differences in organic matter type. Thus, wood is generally dominant and is accompanied by significant proportions of herbaceous debris. However, the herbaceous fraction sometimes shares the major role as in Zone D^1 and is dominant in Zone D^2, whilst algal material is significant in Zones C and D^1 (and shows partial sapropelisation) and significant proportions of amorphous kerogen are present in Zones D^3 (4240-4315± metres) and D^4 (4315-4367± metres).

Minor light grey and light brownish grey shales (Zones D^3 and D^4) occasionally occur. The former are lean (0.29-0.42%) but the latter are improved at 0.49-0.54(1.24)% organic carbon. In contrast, the minor dark yellowish brown silty shale (carbargillite) at 4173± metres (Zone D^2) is not only extremely rich (19.24%) but has good quality organic matter: herbaceous kerogen (partially sapropelised) is dominant and significant proportions of amorphous and woody debris are also present.

Zone D^2 is marginally mature and minor hydrocarbon generation is also occurring in the non-woody organic matter of the other zones. In a mature state, the dark yellowish brown shale (carbargillite) from 4173± metres would be an extremely rich oil source and indeed, all of the dark grey shales from Zones C through D^4 have a potential for major oil.

A distinct break in the environment of deposition is suggested at the base of Zone A^2, although the light brownish grey shales within Zone B represent a depositional facies similar to that of Zone A. Otherwise a stable, moderately reducing environment is indicated throughout Zones B through D^4. The units with higher proportions of amorphous kerogen suggest slightly more reducing interludes, although no richly amorphous sediments were detected.

Traces of crude oil have diffused into Zone A^2 and there are minor shows throughout the underlying section and also at 3690-3715± metres in Zone A^2 (apparently correlating with the presence of the siltstones). The weakest shows are over the interval 3815-4010± metres (particularly in Zone C) whilst the best shows (Zones D^2, D^4 and the top of Zone B) suggest a correlation with those intervals containing the highest proportions of the most oil prone and most easily matured organic matter. In turn, this suggests generation from the more mature off-structure equivalents of these units followed by lateral migration. This would be compatible with the character of the crude, which is apparently a light to medium gravity oil derived from moderately mature parent source rocks.

The top of the mature zone (significant hydrocarbon generation, not oil window) approximates total depth.

TABLE 1

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	iC_4 / nC_4
408-001	3500-502.5m	11	4	3	1	2	20	9	45.8	34	0.63
408-002	3512.5-515m	17	2	1	1	3	25	7	29.5	27	0.27
408-003	3527.5-520m	31	7	4	2	2	47	16	33.5	45	0.73
408-004	3542.5-545m	29	5	2	3	4	43	14	32.7	46	0.55
408-005	3557.5-560m	23	7	6	6	5	46	23	49.8	67	1.20
408-006	3572.5-575m	24	5	3	5	3	40	16	39.2	29	1.53
408-007	3587.5-590m	34	5	4	5	6	54	20	36.4	29	0.92
408-008	3602.5-605m	18	3	2	2	3	29	11	37.0	28	0.80
408-009	3617.5-620m	19	4	5	7	8	44	25	56.8	60	0.89
408-010	3632.5-635m	22	5	10	11	10	59	37	62.4	38	1.04
408-011	3647.5-650m	21	4	4	3	5	38	17	44.2	43	0.61
408-012	3662.5-665m	89	25	168	194	366	843	753	89.4	669	0.53
408-013	3677.5-680m	63	12	25	50	152	303	240	79.3	590	0.33
408-014	3692.5-695m	64	84	913	240	617	1918	1854	96.6	416	0.39
408-015	3707.5-710m	77	26	524	370	1312	2309	2232	96.7	1775	0.28
408-016	3722.5-725m	21	5	74	54	201	356	335	94.1	774	0.27
408-017	3737.5-740m	89	53	105	86	257	591	502	84.9	804	0.34
408-018	3752.5-755m	157	109	1885	735	2937	5824	5667	97.3	3450	0.25
408-019	3767.5-770m	116	74	171	129	438	928	812	87.5	923	0.29
408-020	3782.5-785m	71	35	154	113	479	853	782	91.6	951	0.24
408-021	3797.5-800m	112	67	147	144	590	1059	947	89.5	1440	0.24
408-022	3812.5-815m	47	8	156	109	485	806	759	94.1	1340	0.23
408-023	3827.5-830m	76	45	114	86	296	617	541	87.7	737	0.29
408-024	3842.5-845m	28	9	76	37	167	317	289	91.0	402	0.22
408-025	3857.5-860m	69	70	528	168	618	1454	1385	95.2	737	0.27
408-026	3872.5-875m	52	29	556	199	840	1676	1624	96.9	1261	0.24
408-027	3887.5-890m	163	44	218	123	425	973	810	83.3	790	0.29
408-028	3902.5-905m	77	27	584	222	936	1847	1770	95.8	1167	0.24
408-029	3917.5-920m	58	42	188	72	259	620	562	90.6	469	0.28
408-030	3932.5-935m	45	9	124	84	377	639	594	92.9	809	0.22

TABLE 1

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	iC_4 / nC_4
408-031	3947.5-950m	76	30	124	71	257	558	482	86.5	541	0.28
408-032	3962.5-965m	58	13	92	59	260	483	424	88.0	577	0.23
408-033	3977.5-980m	59	16	253	117	491	936	877	93.7	1206	0.24
408-034	3992.5-995m	55	10	214	148	634	1061	1006	94.8	1563	0.23
408-035	4007.5-010m	38	20	139	99	448	744	706	94.9	1273	0.22
408-036	4022.5-025m	50	39	1166	378	1674	3306	3256	98.5	2237	0.23
408-037	4037.5-040m	148	165	2046	587	2261	5208	5060	97.1	2981	0.26
408-038	4052.5-055m	72	43	832	282	1240	2469	2397	97.1	1860	0.23
408-039	4067.5-070m	86	56	701	263	1061	2166	2080.	96.0	2010	0.25
408-040	4082.5-085m	77	16	183	152	786	1214	1137	93.7	1743	0.19
408-041	4097.5-100m	90	91	724	265	959	2129	2039	95.8	1359	0.28
408-042	4112.5-115m	71	29	488	152	653	1393	1322	94.9	976	0.23
408-043	4127.5-130m	812	65	754	314	1069	3015	2023	73.1	1814	0.29
408-044	4142.5-145m	64	32	546	172	766	1580	1516	96.0	1210	0.22
408-045	4157.5-160m	102	73	667	245	948	2034	1932	95.0	1652	0.26
408-046	4172.5-175m	156	86	1440	535	2572	4789	4633	96.7	4175	0.21
408-047	4187.5-190m	48	48	1562	652	2707	5017	4969	99.0	5184	0.24
408-048	4202.5-205m	90	32	828	420	1837	3208	3118	97.2	4341	0.23
408-049	4217.5-220m	152	156	1548	518	1826	4200	4048	96.4	3330	0.28
408-050	4232.5-235m	44	8	76	47	264	439	394	89.9	804	0.18
408-051	4247.5-250m	348	79	382	138	555	1501	1154	76.8	1765	0.25
408-052	4262.5-265m	316	100	751	284	1065	2518	2202	87.4	2479	0.27
408-053	4277.5-280m	309	68	473	236	1049	2134	1825	85.5	3032	0.22
408-054	4292.5-295m	406	122	250	164	775	1717	1311	76.3	2747	0.21
408-055	4307.5-310m	508	74	309	117	564	1572	1064	67.7	2010	0.21
408-056	4322.5-325m	601	82	704	349	1528	3264	2663	81.6	3752	0.23
408-057	4337.5-340m	301	83	898	351	1622	3254	2954	90.8	4589	0.22
408-058	4352.5-355m	387	73	1079	576	2904	5019	4632	92.3	5240	0.20
408-059	4365-367m	164	29	833	387	1910	3323	3159	95.1	4355	0.20

TABLE 2
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION	GSA Colour Code	TOTAL ORGANIC CARBON (% of Rock)
401-001	3500-502.5m	A 25% Shale, blocky, soft to hard, non calcareous, pale reddish brown to pale brown	10R5/4-5YR5/2	1.10
		B 25% Shale, platy to blocky, hard, calcareous, medium dark to dark grey	N4-N3	0.75
		C 25% Mudstone, platy, soft, thinly fissile, calcareous, light brownish grey	5YR6/1	0.36
		D 25% Lime-mudstone, blocky, soft, calcareous, very light grey to white	N8-N9	0.32
408-002	3512.5-515m	A 50% Lime-mudstone, as 408-001D	N8-N9	0.24,0.24
		B 50% Lost circulation material - cement, metal, fibre Minor shale, pyrite		
408-003	3527.5-530m	A 50% Lime-mudstone, as 408-001D	N8-N9	0.24
		B 50% Lost circulation material - cement, metal, fibre Minor pyrite, shale		
408-004	3542.5-545m	A 75% Shale, platy to blocky, silty in parts, slightly pyritic, calcareous, medium grey	N5	0.26
		B 20% Mudstone, platy, brittle, calcareous, light grey	N7	0.32
		C 5% Lost circulation material - metal, paint Minor shell fragments		
408-005	3557.5-560m	A 80% Shale, as 408-004A, minor cavings	N5	0.27
		B 20% Lost circulation material - metal, fibre, paint, cement Minor mudstone		
408-006	3572.5-575m	A 50% Shale, blocky to platy, pyritic silty in parts, non to slightly calcareous, medium grey	N5	0.28,0.28
		B 30% Shale, platy, slightly silty, slightly to non calcareous, brownish grey	5YR4/1	0.95
		C 18% Lost circulation material - metal, cement		
		D Minor lime-mudstone, as 408-001D	N8-N9	

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)
408-007	3587.5-590m	A 60% Shale, blocky to platy, pyritic silty in parts, non to slightly calcareous, medium grey	N5	0.20
		B 15% Lost circulation material - metal		
		C 15% Coal, finely ground, hard, irregular fracture, black	N1	22.16
		D 10% Mudstone, platy, brittle, calcareous, light grey	N7	0.17
408-008	3602.5-605m	A 60% Coal, as 408-007C	N1	21.49
		B 30% Shale, blocky to platy, soft to hard, non calcareous, light brownish grey	5YR6/1	0.59,0.59
		C 10% Lost circulation material - metal		
408-009	3617.5-620m	A 90% Shale, blocky to platy, slightly calcareous, medium grey	N5	0.26
		B 8% Lost circulation material - metal		
		C 2% Mudstone, as 408-007D	N7	
		Minor finely ground coal		
408-010	3632.5-635m	A 75% Shale, blocky to platy, slightly calcareous, occasionally pyritic, brownish grey to medium grey	5YR4/1-N5	0.27
		B 20% Coal, as 408-007C	N1	31.90
		C 5% Lost circulation material - metal		
		Minor mudstone		
408-011	3647.5-650m	A 90% Shale, as 408-010A	5YR4/1-N5	0.35
		B 10% Mudstone, as 408-007D	N7	0.13
		Minor coal,		
		Lost circulation material - metal		
408-012	3662.5-665m	A 70% Shale, platy, brittle, slightly pyritic, silty in parts, non calcareous, medium dark grey	N4	0.32,0.31
		B 30% Mudstone, platy, brittle, rarely pyritic, slightly calcareous, light grey	N7	0.20
		C Minor carbargillite		3.60
		Minor lost circulation material - metal		

TABLE 2
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION	GSA Colour Code	TOTAL ORGANIC CARBON (% of Rock)
408-013	3677.5-680m	A 70% Shale, platy, brittle, slightly pyritic, silty in parts, non calcareous, medium dark grey	N4	0.35
		B 25% Mudstone, platy, brittle, rarely pyritic, slightly calcareous, light grey	N7	0.12
		C 5% Mudstone, blocky, soft, carbonaceous, slightly calcareous, greyish black to brownish black	N2-5YR2/1	2.92
		Minor lost circulation material - metal, minor free pyrite		
408-014	3692.5-695m	A 50% Shale, platy to blocky, brittle pyritic and silty in parts, slightly calcareous, light brownish grey to medium light grey	5YR6/1-N6	0.31,0.31
		B 35% Siltstone, blocky, soft, carbonaceous, slightly to non calcareous, greyish black to brownish black	N2-5YR2/1	3.58
		C 15% Mudstone, as 408-013B	N7	0.33
		Minor lost circulation material - metal		
408-015	3707.5-710m	A 90% Shale, platy, brittle, silty in parts, occasionally pyritic, non calcareous, medium light to light grey	N6-N7	0.31
		B 10% Siltstone, as 408-014B	N2-5YR2/1	3.00
		Minor mudstone, coal		
		Lost circulation material - metal		
408-016	3722.5-725m	A 65% Mudstone, blocky, silty, slightly calcareous, light brownish grey to light grey	5YR6/1-N7	0.36,0.36
		B 30% Coal, finely ground, soft to hard, dull to vitreous, lustre, greyish black to black	N2-N1	19.98
		C 5% Siltstone, as 408-014B	N2-5YR2/1	3.00
		Minor lost circulation material - metal		
408-017	3737.5-740m	A 85% Shale, blocky to platy, soft to hard, silty in parts, slightly calcareous, light brownish grey to light grey	5YR6/1-N7	0.30

TABLE 2
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION		GSA Colour Code	TOTAL ORGANIC CARBON (% of Rock)
408-017	3737.5-750m	B 10%	Siltstone, blocky, soft, carbonaceous, slightly to non calcareous, greyish black to brownish black	N2-5YR2/1	2.10
		C 5%	Coal, finely ground, greyish black to black	N2-N1	
			Minor other mudstone, shale		
			Lost circulation material - metal		
408-018	3752.5-755m	A 75%	Shale, platy, brittle, silty, non calcareous, brownish black to greyish black	5YR2/1-N2	2.11,2.10
		B 25%	Mudstone, blocky to platy, soft to hard, calcareous, light brownish grey to light grey	5YR6/1-N7	0.32
			Minor lime-mudstone, coal, free pyrite		
			Lost circulation material - metal		
408-019	3767.5-770m	A 70%	Shale, blocky to platy, soft to hard, silty in parts, slightly calcareous, light brownish grey to light grey	5YR6/1-N7	0.30
		B 20%	Shale, as 408-018A	5YR2/1-N2	2.50
		C 10%	Lost circulation material - metal, cement		
			Minor coal, mudstone, free pyrite		
408-020	3782.5-785m	A 65%	Shale, as 408-019A, minor cavings	5YR6/1-N7	0.26
		B 25%	Shale, as 408-018A, minor cavings	5YR2/1-N2	1.92
		C 10%	Lost circulation material - metal, cement		
			Minor other mudstone, shale		
408-021	3797.5-800m	A 55%	Shale, as 408-019A	5YR6/1-N7	0.31,0.31
		B 40%	Shale, as 408-018A	5YR2/1-N2	2.00
		C 5%	Lost circulation material - metal		
			Minor other shale, mudstone		
408-022	3812.5-815m	A 65%	Shale, platy, brittle, silty, non calcareous, iron stained in parts, dark grey	N3	1.95
		B 30%	Mudstone, blocky to platy, occasionally fissile, calcareous, silty in parts, iron stained, light grey to light brownish grey	N7-5YR6/1	0.32
		C 5%	Minor limestone, lime-mudstone, other shale, lost circulation material - metal		

TABLE 2
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION		GSA Colour Code	TOTAL ORGANIC CARBON (% of Rock)
408-023	3827.5-830m	A 60%	Shale, platy, brittle, silty, non calcareous, iron stained in parts, dark grey, moderate cavings	N3	2.16
		B 40%	Mudstone, blocky to platy, occasionally fissile, calcareous, silty in parts, iron stained, moderate cavings, light grey to light brownish grey	N7-5YR6/1	0.30,0.29
			Minor other shale, mudstone		
			Lost circulation material - metal		
408-024	3842.5-845m	A 80%	Shale, platy, brittle, silty, non calcareous, iron stained in parts, vitreous lustre to surface in parts, dark grey to greyish black	N3-N2	1.60
		B 15%	Mudstone, as 408-023B, moderate cavings	N7-5YR6/1	0.30
		C 5%	Lost circulation material - metal		
408-025	3857.5-860m	A 95%	Shale, as 408-024A, significant cavings	N3-N2	1.78
		B 5%	Mudstone, as 408-023B, mostly caved	N7-5YR6/1	
			Minor lost circulation material - metal		
408-026	3872.5-875m	A 85%	Shale, platy, brittle, occasionally fissile, silty in parts, non calcareous, dark grey	N3	1.86
		B 10%	Mudstone, blocky, soft, calcareous, light to very light grey	N7-N8	0.29,0.28
		C 5%	Mudstone, as 408-023B	N7-5YR6/1	0.24
408-027	3887.5-890m	A 75%	Shale, as 408-026A	N3	1.64
		B 20%	Mudstone, blocky to platy, soft, calcareous, light brownish grey to light grey	5YR6/1-N7	0.28
		C 5%	Mudstone, as 408-026B	N7-N8	0.22
408-028	3902.5-905m	A 98%	Shale, as 408-026A, moderate cavings	N3	1.60,1.60
			Minor mudstone, lost circulation material - metal		
408-029	3917.5-920m	A 98%	Shale, as 408-026A, minor cavings	N3	2.27
			Minor mudstone, lost circulation material - metal		

TABLE 2
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION	GSA Colour Code	TOTAL ORGANIC CARBON (% of Rock)
408-030	3932.5-935m	A 98% Shale, platy, brittle, occasionally fissile, silty in parts, non calcareous, dark grey Minor mudstone	N3	2.46
408-031	3947.5-950m	A 95% Shale, as 408-030A	N3	2.58
		B 5% Mudstone, blocky, soft, calcareous, light to very light grey	N7-N8	0.42
408-032	3962.5-965m	A 98% Shale, as 408-030A Minor mudstone	N3	2.44
408-033	3977.5-980m	A 90% Shale, as 408-030A, minor cavings	N3	2.62,2.62
		B 10% Mudstone, finely ground, soft, calcareous, light to very light grey Minor lost circulation material - metal		
408-034	3992.5-995m	A 98% Shale, as 408-030A, minor cavings Minor mudstone Lost circulation material - metal	N3	2.57
408-035	4007.5-010m	A 98% Shale, as 408-030A, minor cavings, minor bitumen Minor mudstone, lost circulation material - metal	N3	3.06
408-036	4022.5-025m	A 98% Shale, as 408-030A, moderate cavings, minor bitumen Minor mudstone, lost circulation material - metal	N3	2.58
408-037	4037.5-040m	A 98% Shale, as 408-030A, moderate cavings, minor bitumen Minor mudstone	N3	2.32
408-038	4052.5-055m	A 90% Shale, as 408-030A, moderate cavings, minor bitumen	N3	2.26,2.26
		B 5% Mudstone, blocky, soft to hard, calcareous, light brownish grey to light grey	5YR6/1-N7	0.31
		C 5% Lost circulation material - metal, paint		

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)
408-039	4067.5-070m	A 95% Shale, platy to blocky, non calcareous, occasionally sandy horizons, silty in parts, bituminous, dark grey	N3	2.83
		B 5% Mudstone, blocky, soft to hard, calcareous, light brownish grey to light grey Minor lost circulation material - metal	5YR6/1-N7	0.39
408-040	4082.5-085m	A 98% Shale, as 408-039A B 2% Mudstone, lost circulation material - metal	N3	2.34
408-041	4097.5-100m	A 98% Shale, as 408-039A, minor cavings Minor mudstone, lost circulation material - metal	N3	2.78,2.78
408-042	4112.5-115m	A 98% Shale, as 408-039A, minor cavings Minor mudstone, lost circulation material - metal	N3	2.34
408-043	4127.5-130m	A 98% Shale, as 408-039A, minor cavings, oil stain Minor mudstone, lost circulation material - metal	N3	2.40
408-044	4142.5-145m	A 98% Shale, as 408-039A, minor cavings, oil stain Minor mudstone, lost circulation material - metal	N3	2.80
408-045	4157.5-160m	A 98% Shale, as 408-039A, moderate cavings, oil stain Minor mudstone, lost circulation material - metal, sandstone	N3	2.42
408-046	4172.5-175m	A 75% Shale, as 408-039A, minor cavings,	N3	2.38,2.38
		B 15% Sandstone, consolidated, calcareous cement, subrounded, fine grained, no fluorescence, very light grey	N8	
		C 10% Shale, blocky, soft to hard, silty, non calcareous, deep orange-yellow fluorescence (blue cut) dark yellowish brown to moderate brown Minor lost circulation material - metal	10YR4/2-5YR3/4	19.24

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)
408-047	4187.5-190m	A	98%	Shale, platy, brittle, hard, silty in parts, non calcareous, patchy orange fluorescence, dark grey to brownish grey	N3-5YR4/1	3.40
				Minor sandstone		
408-048	4202.5-205m	A	95%	Shale, as 408-047A	N3-5YR4/1	2.54
		B	5%	Mudstone, blocky, soft, calcareous, light brownish grey	5YR6/1	1.24
				Minor sandstone, lost circulation material - metal, paint		
408-049	4217.5-220m	A	98%	Shale, as 408-047A	N3-5YR4/1	2.52
				Minor mudstone, sandstone, lost circulation material - metal		
408-050	4232.5-235m	A	98%	Shale, as 408-047A	N3-5YR4/1	2.59,2.59
				Minor sandstone, mudstone, lost circulation material - metal		
408-051	4247.5-250m	A	90%	Shale, platy, brittle, hard, occasionally silty, non calcareous, oil stained, dark grey to greyish black	N3-N2	2.95
		B	5%	Mudstone, as 408-048B	5YR6/1	0.54
		C	5%	Lost circulation material - metal, fibre		
				Minor sandstone		
408-052	4262.5-265m	A	95%	Shale, as 408-051A, oil stain	N3-N2	2.78
		B	5%	Mudstone, as 408-048B	5YR6/1	0.49
				Minor sandstone		
				Lost circulation material - metal		
408-053	4277.5-280m	A	98%	Shale, as 408-051A, minor caving	N3-N2	2.79,2.80
				Minor mudstone		
				Lost circulation material - metal, fibre		
408-054	4292.5-295m	A	95%	Shale, platy, brittle, silty in parts, non calcareous, oil stain, dark grey to dusky brown	N3-5YR2/2	2.51
		B	5%	Mudstone, as 408-048B	5YR6/1	0.33
				Minor lost circulation material - metal		
408-055	4307.5-310m	A	90%	Shale, blocky to platy, finely ground, non calcareous, minor cavings, dark grey to dusky brown	N3-5YR2/2	2.53
		B	5%	Mudstone, blocky, soft to hard, calcareous, light grey to light brownish grey	N7-5YR6/1	0.30

TABLE 2
ORGANIC CARBON RESULTS AND GROSS LITHOLOGIC DESCRIPTIONS

GEOCHEM SAMPLE NUMBER	DEPTH	GROSS LITHOLOGIC DESCRIPTION	GSA Colour Code	TOTAL ORGANIC CARBON (% of Rock)
408-055	4307.5-310m	C 5% Lost circulation material - metal, fibre, paint		
408-056	4322.5-325m	A 90% Shale, blocky to platy, finely ground, non calcareous, moderate cavings, slight oil stain, dark grey to dusky brown	N3-5YR2/2	2.70,2.70
		B 10% Mudstone, blocky, soft to hard, calcareous, light grey to light brownish grey	N7-5YR6/1	0.29
		Minor lost circuation material - metal, fibre		
408-057	4337.5-340m	A 90% Shale, as 408-056A, moderate cavings, slight oil stain	N3-5YR2/2	2.45
		B 10% Mudstone, as 408-056B	N7-5YR6/1	0.30
		Minor lost circulation material - metal, fibre		
408-058	4352.5-355m	A 98% Shale, platy, brittle, hard, non calcareous, occasionally silty, with rare interbedded mudstone, minor cavings, oil stain, dark grey to dusky yellowish brown	N3-10YR2/2	2.27
		Minor mudstone		
		Lost circulation material - metal		
408-059	4365-367m	A 80% Shale, platy, brittle, hard, non calcareous, dark grey	N3	2.58,2.60
		B 10% Shale, as 408-058A, minor cavings	N3-10YR2/2	2.62
		C 5% Mudstone, as 408-056B	N7-5YR6/1	0.38
		D 5% Lost circulation material - metal, fibre		

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

GEOCHEM SAMPLE NUMBER	-012	-014	-018	-022	-026
DEPTH	3662.5-665m	3692.5-695m	3752.5-755m	3812.5-815m	3872.5-875m
NORMALISED COMPOSITION					
isobutane	3.70	1.43	1.44	1.69	1.41
n - butane (nB)	8.75	5.22	7.59	10.18	8.18
isopentane	8.23	6.35	6.82	8.56	6.37
n - pentane (nP)	8.27	6.94	7.73	10.33	6.84
2,2 - dimethylB	0.11	0.07	0.05	0.08	0.02
cyclopentane (CP)	2.07	1.48	2.00	2.17	2.18
2,3 - dimethylB	0.34	0.36	0.37	0.31	0.72
2 - methylP	4.29	4.67	4.16	5.06	3.96
3 - methylP	3.11	3.51	3.35	3.73	3.28
n - hexane (nH)	7.45	6.66	6.15	6.29	6.03
methylCP (MCP)	9.38	10.68	12.73	9.87	10.00
2,2 - dimethylP	0.05	0.49	0.49	0.67	0.68
benzene	2.51	3.82	5.31	4.17	5.18
2,4 - dimethylP	0.11	0.04	0.05	0.10	0.12
2,2,3 - trimethylB	0.71	0.36	0.18	0.36	0.33
cyclohexane (CH)	4.38	4.45	3.30	3.40	4.09
3,3 - dimethylP	0.01	0.01	-	0.01	0.01
1,1 - dimethylCP	0.05	0.04	0.02	0.06	0.05
2 - methylH	4.16	4.37	3.05	3.07	3.80
2,3 - dimethylP	2.72	2.73	2.57	2.06	2.63
1,c,3 - dimethylCP	-	-	-	-	-
3 - methylH	2.69	2.58	2.48	2.00	2.51
1,t,3 - dimethylCP	-	-	-	-	-
1,t,2 - dimethylCP	6.60	7.91	6.76	5.27	6.14
3 - ethylP	-	0.02	-	-	-
n - heptane	6.56	8.95	5.70	5.60	7.03
1,c,2 - dimethylCP	0.62	0.74	0.76	1.09	1.33
methylCH (MCH)	12.60	14.52	15.48	12.68	15.37
toluene	0.50	1.59	1.44	1.22	1.75
ABUNDANCE (ppm)	2046	3700	6727	5667	17935
MCP/benzene	3.73	2.79	2.40	2.37	1.93
MCP/MCH	0.74	0.73	0.82	0.78	0.65
nC_5/nC_7	1.26	0.77	1.36	1.84	0.97
nap/p	1.15	1.43	1.51	1.06	1.39
%n - PARAFFINS	31.02	27.77	27.17	32.41	28.08
% ISOPARAFFINS	30.25	27.00	25.02	27.66	25.83
% NAPHTHENES	35.72	39.82	41.05	34.54	39.16
% AROMATICS	3.01	5.41	6.76	5.39	6.93

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

GEOCHEM SAMPLE NUMBER	-029	-031	-035	-039	-043
DEPTH	3917.5-920m	3947.5-950m	4007.5-010m	4067.5-070m	4127.5-130m
NORMALISED COMPOSITION					
isobutane	1.55	2.29	1.22	2.16	2.41
n - butane (nB)	8.00	4.52	6.88	10.58	11.13
isopentane	10.46	6.68	6.80	10.28	10.23
n - pentane (nP)	11.06	7.16	8.08	11.94	11.10
2,2 - dimethylB	0.06	0.03	0.04	0.04	0.08
cyclopentane (CP)	2.82	1.93	1.91	2.73	1.67
2,3 - dimethylB	0.60	0.50	0.33	0.32	0.42
2 - methylP	5.58	4.93	4.03	4.56	4.83
3 - methylP	4.22	3.92	3.52	3.75	3.70
n - hexane (nH)	6.25	6.93	5.79	6.21	6.55
methylCP (MCP)	11.84	10.24	11.87	10.07	10.73
2,2 - dimethylP	0.64	0.67	0.49	0.57	0.58
benzene	5.68	5.15	5.65	4.30	4.28
2,4 - dimethylP	0.17	0.11	0.08	0.13	0.14
2,2,3 - trimethylB	0.37	0.48	0.26	0.71	0.31
cyclohexane (CH)	2.66	3.92	3.31	2.84	2.60
3,3 - dimethylP	0.01	0.03	0.01	0.02	-
1,1 - dimethylCP	0.04	0.15	0.08	0.11	0.04
2 - methylH	2.26	3.87	3.01	2.65	2.32
2,3 - dimethylP	2.17	2.58	2.41	2.17	1.89
1,c,3 - dimethylCP	-	-	-	-	-
3 - methylH	1.94	2.87	2.34	2.44	1.85
1,t,3 - dimethylCP	-	-	-	-	-
1,t,2 - dimethylCP	4.80	6.62	5.98	4.98	4.53
3 - ethylP	0.10	0.37	-	-	0.11
n - heptane	3.90	6.43	5.64	4.18	4.14
1,c,2 - dimethylCP	0.68	0.98	1.17	0.46	0.57
methylCH (MCH)	11.41	15.41	17.58	11.23	13.01
toluene	0.71	1.22	1.70	0.59	0.77
ABUNDANCE (ppm)	17096	6772	3223	6273	6403
MCP/benzene	2.09	1.99	2.10	2.34	2.51
MCP/MCH	1.04	0.66	0.67	0.90	0.82
nC_5/nC_7	2.83	1.11	1.43	2.86	2.68
nap/p	1.17	1.56	1.59	0.98	1.01
%n - PARAFFINS	29.21	25.04	26.40	32.91	32.91
% ISOPARAFFINS	30.15	29.34	24.35	29.78	28.89
% NAPHTHENES	34.24	39.25	41.90	32.42	33.15
% AROMATICS	6.40	6.37	7.36	4.89	5.05

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

GEOCHEM SAMPLE NUMBER	-048	-051	-054
DEPTH	4202.5-205m	4247.5-250m	4292.5-295m
NORMALISED COMPOSITION			
isobutane	1.56	1.32	1.53
n - butane (nB)	7.15	6.93	7.21
isopentane	8.37	6.44	8.16
n - pentane (nP)	10.08	8.15	9.33
2,2 - dimethylB	0.06	0.09	0.03
cyclopentane (CP)	1.47	1.25	1.60
2,3 - dimethylB	0.46	0.43	0.45
2 - methylP	6.19	5.37	5.23
3 - methylP	4.29	3.95	4.00
n - hexane (nH)	8.34	8.28	7.37
methylCP (MCP)	9.65	9.03	11.20
2,2 - dimethylP	0.53	0.76	0.57
benzene	4.59	4.51	5.47
2,4 - dimethylP	0.07	0.05	0.09
2,2,3 - trimethylB	0.29	0.48	0.15
cyclohexane (CH)	3.92	4.67	3.48
3,3 - dimethylP	0.01	0.01	-
1,1 - dimethylCP	0.04	0.09	0.04
2 - methylH	3.34	4.24	2.95
2,3 - dimethylP	2.22	2.39	2.32
1,c,3 - dimethylCP	-	-	-
3 - methylH	2.10	2.26	2.25
1,t,3 - dimethylCP	-	-	-
1,t,2 - dimethylCP	5.24	5.69	5.54
3 - ethylP	0.05	0.02	-
n - heptane	5.74	7.93	5.03
1,c,2 - dimethylCP	1.13	1.02	0.94
methylCH (MCH)	12.32	13.26	14.18
toluene	0.78	1.44	0.86
ABUNDANCE (ppm)	24657	5756	8636
MCP/benzene	2.10	2.00	2.05
MCP/MCH	0.78	0.68	0.79
nC_5/nC_7	1.76	1.03	1.85
nap/p	1.08	1.12	1.28
%n - PARAFFINS	31.31	31.28	28.95
% ISOPARAFFINS	29.54	27.76	27.74
% NAPHTHENES	33.77	35.01	36.98
% AROMATICS	5.37	5.95	6.34

TABLE 4

VISUAL KEROGEN DATA

GEOCHEM SAMPLE NUMBER	DEPTH	ORGANIC MATTER DESCRIPTION TYPES	REMARKS	PARTICLE SIZE	PRESERV-ATION	THERMAL MATURATION INDEX
408-005A	3557.5-560m	W;H;Al-C	reworking	F-M	F	2-/2- to 2
408-007C	3587.5-590m	W;-;(H)		F-C	G	2-(?)
408-008A	3602.5-605m	W;-;(H-Al-Am)		F-VC	G	2-(?)
408-012A	3662.5-665m	W;-;Al-H-C	lean. Some material at 2-	F	P-F	2- to 2 max
408-014B	3692.5-695m	H*-Am+;W;Al-C	*generally passing to Am. +Includes incompletely developed material.	F-VC	F	2-/2- to 2
408-016A	3722.5-725m	W;H-Al;Am-C	some H at 2-	F-M	F	2-/2- to 2
408-018A	3752.5-755m	H;Am-W-Al;C	sapropelisation	F-C	F	2-/2- to 2
408-022A	3812.5-815m	W-H;Am-Al-C;-	sapropelisation. H at 2-	F-C	F	2- to 2 max
408-026A	3872.5-875m	W-H;Am*;Al-C	some H at 2-. Frequent foram linings. *Includes H passing to Am	F-VC	F	2- to 2
408-029A	3917.5-920m	W;H-Al-Am;C	sapropelisation, H and Al passing to Am. Material at 2-	F-C	P	2- to 2
408-032A	3962.5-965m	W;H-Al;Am-C	fresh wood apparent, H at 2. Foram linings. Sapropelisation	F-M	P	2- to 2
408-035A	4007.5-010m	H-W-Am-Al;-;C	H and Al passing to Am.	F-VC	P-F	2- to 2
408-039A	4067.5-070m	W-H;Al;Am-C	some H at 2-. Foram linings	F-C	F	2- to 2
408-043A	4127.5-130m	W-H;-;Am-C-Al	H passing frequently to Am	F-M	F	2- to 2
408-046C	4172.5-175m	H*;Am-W;Al-C	*includes material passing to Am	F-C	P-F	2- to 2
408-047A	4187.5-190m	H*;Am-W-Al;C	foram linings. *Passing to Am. Widespread sapropelisation	F-VC	P	2- to 2
408-051A	4247.5-250m	W-H;Am;Al-C	sapropelisation	F-C	P	2- to 2

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

TABLE 4

VISUAL KEROGEN DATA

GEOCHEM SAMPLE NUMBER	DEPTH	ORGANIC MATTER DESCRIPTION				THERMAL MATURATION INDEX
		TYPES	REMARKS	PARTICLE SIZE	PRESERV-ATION	
408-054A	4292.5-295m	W;H*-Am;Al-C	*includes H passing to Am	F-C	F	2- to 2
408-059A	4365-367m	W;H-Am*;Al-C	some material at 2. *Includes H and Al passing to Am	F-C	P-F	2- to 2

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	
408-005A	3557.5-560m	CUTTING	0.44	0.62	0.73	13	17	6	4th pop. 0.86(8)
408-007C	3587.5-590m	CUTTING	0.35	-	-	59	-	-	
408-014B	3692.5-695m	CUTTING	0.32	0.41	0.32	11	5	7	4th pop. 0.60(7); 5th pop. 0.74(4) y-or to lt.or. fluor.
408-018A	3752.5-755m	CUTTING	0.35	0.46	0.63	3	3	2	4th pop. 0.92(5)
408-022A	3812.5-815m	CUTTING	0.31	0.50	0.58	18	4	2	4th pop. 0.68(8); 5th pop. 0.76(9); 6th pop. 0.93(5)
408-026A	3872.5-875m	CUTTING	0.31	0.46	0.61	5	1	4	4th pop. 0.74(3);y-or and lt.or. 5th pop. 0.94(3) fluor.
408-029A	3917.5-920m	CUTTING	0.29	0.51	0.73	10	1	8	4th pop. 0.86(1); 5th pop. 1.04(11)
408-035A	4007.5-010m	CUTTING	0.32	0.55	0.75	16	5	8	4th pop. 0.90(6);y-or and lt.or. 5th pop. 1.28(4) fluor.
408-039A	4067.5-070m	CUTTING	0.35	0.52	0.61	5	1	4	4th pop. 0.78(5);lt.-mid.or. 5th pop. 1.02(10) fluor.
408-043C	4127.5-130m	CUTTING	0.31	0.49	0.58	9	1	13	4th pop. 0.69(7);lt.-mid.or. 5th pop. 0.97(22) fluor.
408-046C	4172.5-175m	CUTTING	0.32	0.45	0.64	5	1	5	4th pop. 0.87(23); y-or and lt. 5th pop. 1.13(5) or. fluor.
408-051A	4247.5-250m	CUTTING	0.31	0.52	0.72	11	8	19	4th pop. 0.85(16); y-or. to mid. 5th pop. 1.02(9) or. fluor.
408-054A	4292.5-295m	CUTTING	0.34	0.50	0.68	15	1	7	4th pop. 0.82(6); mid or. fluor. 5th pop. 1.14(1)

TABLE 5A

VITRINITE REFLECTANCE - RAW DATA

GEOCHEM SAMPLE NUMBER	DEPTH	READINGS
408-005A	3557.5-560m	0.73, 0.93, 0.61, 0.64, 0.75, 0.59, 0.81, 0.63, 0.83, 0.82, 0.85, 0.84, 0.81, 0.60, 0.88, 0.60, 0.42, 0.59, 0.62, 0.73, 0.56, 0.67, 0.70, 0.63, 0.66, 0.51, 0.61, 0.62, 0.60, 0.67, 0.64, 0.75, 0.74, 0.90, 0.57, 0.69, 0.40, 0.37, 0.38, 0.44, 0.81, 0.49, 0.45, 0.47, 0.52, 0.44, 0.43, 0.43.
408-007C	3587.5-590m	0.33, 0.31, 0.35, 0.38, 0.36, 0.44, 0.34, 0.40, 0.36, 0.34, 0.30, 0.35, 0.31, 0.36, 0.39, 0.33, 0.33, 0.33, 0.33, 0.34, 0.38, 0.36, 0.38, 0.29, 0.41, 0.39, 0.31, 0.32, 0.30, 0.38, 0.34, 0.36, 0.32, 0.28, 0.37, 0.41, 0.34, 0.39, 0.33, 0.32, 0.41, 0.31, 0.36, 0.39, 0.33, 0.36, 0.35, 0.32, 0.34, 0.33, 0.34, 0.28, 0.35, 0.41, 0.40, 0.34, 0.34, 0.33, 0.35.
408-014B	3692.5-695m	0.29, 0.29, 0.32, 0.35, 0.30, 0.46, 0.43, 0.77, 0.32, 0.41, 0.49, 0.27, 0.59, 0.55, 0.53, 0.35, 0.53, 0.59, 0.60, 0.41, 0.40, 0.40, 0.34, 0.63, 0.84, 0.29, 0.61, 0.62, 0.36, 0.66, 0.69, 0.56, 0.51, 0.55.
408-018A	3752.5-755m	0.36, 0.32, 0.81, 0.46, 0.44, 0.66, 0.49, 0.80, 0.81, 0.97, 0.59, 1.20, 0.36.
408-022A	3812.5-815m	0.30, 0.74, 0.78, 0.69, 0.68, 0.78, 0.75, 0.30, 0.31, 0.32, 0.28, 0.28, 0.31, 0.33, 0.94, 0.85, 0.83, 0.64, 0.58, 0.75, 0.76, 0.39, 0.76, 1.11, 0.67, 0.30, 0.31, 0.32, 0.35, 0.70, 0.68, 0.67, 0.45, 0.34, 0.69, 0.73, 0.77, 0.92, 0.30, 0.30, 0.54, 0.48, 0.52, 0.59, 0.30, 0.30.
408-026A	3872.5-875m	0.30, 0.25, 1.01, 0.77, 0.72, 0.59, 0.34, 0.33, 0.46, 0.90, 0.92, 0.31, 0.54, 0.66, 0.75, 0.63.
408-029A	3917.5-920m	1.00, 0.74, 0.69, 0.86, 0.27, 1.07, 1.12, 0.27, 0.29, 0.35, 0.95, 1.08, 0.98, 0.78, 0.99, 0.25, 0.70, 0.65, 0.51, 0.26, 0.76, 0.27, 0.29, 0.34, 0.81, 0.74, 1.00, 1.14, 1.16, 0.96, 0.28.
408-035A	4007.5-010m	0.28, 0.28, 0.27, 0.28, 0.33, 0.36, 0.32, 0.28, 0.27, 1.24, 1.38, 1.16, 0.76, 0.93, 0.30, 0.53, 0.31, 0.54, 0.89, 1.33, 0.50, 0.64, 0.71, 0.85, 0.33, 0.34, 0.76, 0.96, 0.59, 0.75, 0.74, 0.76, 0.88, 0.89, 0.40, 0.76, 0.42, 0.39, 0.75.

TABLE 5A

VITRINITE REFLECTANCE - RAW DATA

GEOCHEM SAMPLE NUMBER	DEPTH	READINGS
408-039A	4067.5-070m	0.35, 0.33, 0.34, 0.88, 1.26, 0.80, 0.62, 1.16, 0.94, 0.99, 0.79, 0.75, 0.62, 0.52, 1.09, 0.91, 0.32, 0.60, 0.77, 0.78, 0.40, 0.60, 1.02, 1.04, 0.90.
408-043A	4127.5-130m	0.75, 0.61, 0.59, 0.93, 0.94, 0.92, 0.88, 0.61, 0.92, 1.12, 0.97, 1.19, 0.60, 0.94, 0.89, 0.84, 0.94, 1.03, 0.31, 0.53, 0.57, 0.98, 0.38, 0.38, 0.33, 0.60, 0.68, 1.05, 1.03, 0.96, 0.57, 0.57, 0.69, 0.49, 0.55, 0.91, 0.97, 0.94, 0.26, 0.26, 0.52, 0.36, 0.65, 0.69, 0.70, 0.66, 0.94, 1.06, 0.28, 0.25, 0.61, 0.57.
408-046C	4172.5-175m	0.97, 0.90, 0.82, 0.80, 0.95, 1.08, 1.16, 1.16, 0.85, 0.83, 0.88, 0.88, 0.77, 0.88, 0.78, 1.22, 0.83, 0.62, 0.64, 0.86, 0.36, 0.61, 0.90, 0.90, 0.88, 0.28, 0.45, 0.69, 0.88, 0.92, 0.86, 0.66, 0.29, 0.32, 0.34, 1.01, 0.77, 0.86, 0.85
408-051A	4247.5-250m	0.91, 0.85, 0.86, 0.77, 0.84, 0.31, 0.29, 0.25, 0.29, 0.30, 0.32, 0.69, 0.94, 1.03, 0.32, 0.37, 1.25, 0.83, 0.32, 0.76, 0.71, 0.77, 0.93, 0.83, 0.87, 0.96, 0.73, 0.83, 1.01, 0.56, 0.54, 0.69, 0.62, 0.66, 0.75, 0.84, 0.70, 0.91, 0.80, 0.31, 0.98, 1.13, 0.74, 0.72, 0.90, 0.83, 0.89, 0.69, 0.49, 0.96, 0.54, 0.55, 0.75, 0.80, 0.69, 0.77, 0.85, 0.49, 0.74, 0.46, 0.65, 0.30, 0.49.
408-054A	4292.5-295m	0.69, 0.67, 0.83, 0.88, 0.73, 0.82, 0.81, 0.41, 1.14, 0.69, 0.66, 0.35, 0.76, 0.81, 0.35, 0.38, 0.31, 0.50, 0.36, 0.71, 0.36, 0.37, 0.30, 0.32, 0.32, 0.27, 0.34, 0.36, 0.68, 0.34.

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				
				Preciptd. Asphaltenes	nC_5 soluble	Paraffin – Naphthenes	Aromatics	Eluted NSO's	Non-eluted NSO's	Sulphur
408-008A	3602.5-60	2.0300	0.01752	0.00926	0.00826	0.00136	0.00236	0.00416	0.00038	0.00000
408-009	3617.5-62	42.7600	0.01503	0.00722	0.00781	0.00230	0.00230	0.00321	0.00000	0.00000
408-012A	3662.5-66	32.8500	0.01200	0.00273	0.00927	0.00313	0.00238	0.00368	0.00008	0.00000
408-014B	3692.5-69	12.3500	0.03071	0.00448	0.02623	0.00936	0.01022	0.00599	0.00066	0.00000
408-018A	3752.5-75	15.0200	0.03642	0.00533	0.03109	0.01354	0.01166	0.00590	0.00000	0.00000
408-022A	3812.5-81	17.8600	0.02836	0.00347	0.02489	0.00944	0.01436	0.00064	0.00044	0.00000
408-026A	3872.5-87	11.0800	0.02076	0.00675	0.01401	0.00520	0.00473	0.00373	0.00035	0.00000
408-029A	3917.5-92	28.6100	0.08738	0.04433	0.04305	0.03823	0.00336	0.00146	0.00000	0.00000
408-032A	3962.5-96	48.8800	0.09884	0.01669	0.08215	0.03491	0.03209	0.01514	0.00000	0.00000
408-035A	4007.5-01	56.5300	0.07900	0.02330	0.05570	0.01791	0.02471	0.01308	0.00000	0.00000
408-039A	4067.5-07	11.0800	0.04012	0.00898	0.03114	0.01305	0.01137	0.00671	0.00000	0.00000
408-043A	4127.5-13	40.4200	0.08526	0.01466	0.07060	0.03025	0.02918	0.01117	0.00000	0.00000
408-047A	4187.5-19	16.2600	0.05435	0.00823	0.04612	0.02290	0.01689	0.00632	0.00000	0.00000
408-051A	4247.5-25	27.0700	0.05292	0.00795	0.04497	0.02062	0.01795	0.00640	0.00000	0.00000
408-054A	4292.5-29	65.1000	0.11138	0.01550	0.09588	0.04522	0.03557	0.01509	0.00000	0.00000

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
408-008A	3602.5-60	8631	670	1163	1833	4562	2049	187	0	6798
408-009	3617.5-62	351	54	54	108	169	75	0	0	244
408-012A	3662.5-66	365	95	72	168	83	112	2	0	198
408-014B	3692.5-69	2487	758	828	1585	363	485	53	0	901
408-018A	3752.5-75	2425	901	776	1677	355	393	0	0	748
408-022A	3812.5-81	1588	529	804	1333	194	36	25	0	255
408-026A	3872.5-87	1874	469	427	896	609	337	32	0	977
408-029A	3917.5-92	3054	1336	117	1454	1549	51	0	0	1601
408-032A	3962.5-96	2022	714	657	1371	341	310	0	0	651
408-035A	4007.5-01	1397	317	437	754	412	231	0	0	644
408-039A	4067.5-07	3621	1178	1027	2205	810	606	0	0	1416
408-043A	4127.5-13	2109	748	722	1470	363	276	0	0	639
408-047A	4187.5-19	3343	1409	1039	2448	506	389	0	0	895
408-051A	4247.5-25	1955	762	663	1425	294	236	0	0	530
408-054A	4292.5-29	1711	695	546	1241	238	232	0	0	470

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	Preciptd. Asphaltenes	Eluted NSO's	Non eluted NSO's	Sulphur	ASPH / NSO	
408-008A	3602.5-60	7.76	13.47	0.58	52.85	23.74	2.17	0.00	2.04	0.27
408-009	3617.5-62	15.30	15.30	1.00	48.04	21.36	0.00	0.00	2.25	0.44
408-012A	3662.5-66	26.08	19.83	1.32	22.75	30.67	0.67	0.00	0.73	0.85
408-014B	3692.5-69	30.48	33.28	0.92	14.59	19.51	2.15	0.00	0.67	1.76
408-018A	3752.5-75	37.17	32.01	1.16	14.63	16.19	0.00	0.00	0.90	2.24
408-022A	3812.5-81	33.29	50.65	0.66	12.24	2.27	1.56	0.00	3.19	5.22
408-026A	3872.5-87	25.05	22.78	1.10	32.51	17.97	1.69	0.00	1.65	0.92
408-029A	3917.5-92	43.75	3.85	11.37	50.73	1.68	0.00	0.00	30.27	0.91
408-032A	3962.5-96	35.32	32.47	1.09	16.89	15.32	0.00	0.00	1.10	2.11
408-035A	4007.5-01	22.67	31.28	0.72	29.49	16.56	0.00	0.00	1.78	1.17
408-039A	4067.5-07	32.54	28.35	1.15	22.38	16.73	0.00	0.00	1.34	1.56
408-043A	4127.5-13	35.48	34.22	1.04	17.19	13.10	0.00	0.00	1.31	2.30
408-047A	4187.5-19	42.14	31.08	1.36	15.14	11.63	0.00	0.00	1.30	2.74
408-051A	4247.5-25	38.96	33.92	1.15	15.02	12.09	0.00	0.00	1.24	2.69
408-054A	4292.5-29	40.60	31.94	1.27	13.92	13.55	0.00	0.00	1.03	2.64

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
408-008A	3602.5-60	28.22	21.23	0.65	3.06
408-009	3617.5-62	0.93	30.61	1.16	3.78
408-012A	3662.5-66	0.52	45.92	3.23	7.02
408-014B	3692.5-69	3.70	63.76	4.28	6.72
408-018A	3752.5-75	2.89	69.17	5.80	8.39
408-022A	3812.5-81	2.34	83.93	5.70	6.79
408-026A	3872.5-87	2.36	47.83	3.80	7.94
408-029A	3917.5-92	2.24	47.59	6.49	13.63
408-032A	3962.5-96	2.12	67.79	6.47	9.54
408-035A	4007.5-01	3.75	53.95	2.01	3.73
408-039A	4067.5-07	2.53	60.89	8.71	14.31
408-043A	4127.5-13	2.36	69.70	6.23	8.94
408-047A	4187.5-19	2.58	73.23	9.49	12.96
408-051A	4247.5-25	2.19	72.88	6.51	8.93
408-054A	4292.5-29	2.10	72.54	5.91	8.15

TABLE 8

PYROLYSIS ANALYSIS

BEFORE EXTRACTION

SAMPLE NUMBER	DEPTH	ORGANIC CARBON	PPM BITUMEN*	PPM PYROLYSATE+	PYROLYSATE ORGANIC CARBON	BITUMEN PYROLYSATE	PEAK PYROL TEMP (oC)
408-005A	3557.5-60	0.27	64	309	0.114	0.208	500
408-007C	3587.5-90	22.16	1532	5479	0.025	0.280	490
408-008A	3602.5-05	21.49	2261	18085	0.084	0.125	510
408-009A	3617.5-20 1a	0.26	97	353	0.136	0.275	500
408-014B	3692.5-95	3.58	3888	21385	0.597	0.182	508
408-016A	3722.5-25	0.36	77	765	0.213	0.100	488
408-018A	3752.5-55	2.10	1021	13609	0.648	0.075	500
408-022A	3812.5-15	1.95	750	7221	0.370	0.104	500
408-026A	3872.5-75	1.86	1208	11782	0.633	0.102	510
408-029A	3917.5-20	2.27	1054	8957	0.395	0.118	499
408-035A	4007.5-10	3.06	1666	8165	0.267	0.204	500
408-039A	4067.5-70	2.83	1305	5555	0.196	0.235	500
408-043A	4127.5-30	2.40	1284	16936	0.706	0.076	512
408-046C	4172.5-75	19.24	7776	88873	0.462	0.087	512
408-051A	4247.5-50	2.95	2314	18515	0.628	0.125	500
408-054A	4292.5-95	2.51	910	8527	0.340	0.107	505
408-059A	4365-4367	2.60	2222	11109	0.427	0.200	513

not included

*50-340°C

+340-550°C

TABLE 8

PYROLYSIS ANALYSIS

AFTER EXTRACTION

SAMPLE NUMBER	DEPTH	ORGANIC CARBON	PPM BITUMEN*	PPM PYROLYSATE+	PYROLYSATE ORGANIC CARBON	BITUMEN PYROLYSATE	PEAK PYROL TEMP (oC)
408-014X	3692.5-95	3.70	28	22218	0.600	0.001	500
408-018X	3752.5-55	2.89	56	16664	0.577	0.003	500
408-035X	4007.5-10	3.75	56	17219	0.459	0.003	500
408-046X	4172.5-75	19.24	167	57767	0.300	0.003	513
408-051X	4247.5-50	2.19	28	11109	0.507	0.002	488
408-059X	4365-4367	2.10	101	9998	0.476	0.010	513

*50-340°C

+340-550°C

TABLE 9

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

GEOCHEM SAMPLE NUMBER	-008A	-009	-012A	-014B	-018A
DEPTH	3602.5-605m	3617.5-620m	3662.5-665m	3692.5-695m	3752.5-755m
SAMPLE TYPE					
nC_{15}	0.4	0.3	1.7	1.7	0.7
nC_{16}	0.5	0.6	4.7	5.9	3.5
nC_{17}	2.1	3.6	8.3	8.9	8.1
nC_{18}	3.7	6.8	12.5	10.4	7.8
nC_{19}	6.0	9.5	11.7	9.4	8.7
nC_{20}	11.1	10.2	11.8	8.7	9.0
nC_{21}	7.0	8.7	9.3	7.5	8.2
nC_{22}	7.7	8.8	8.6	6.9	8.0
nC_{23}	7.2	8.1	6.7	7.1	8.3
nC_{24}	5.8	6.1	5.4	6.4	7.3
nC_{25}	7.0	6.1	4.5	6.0	7.1
nC_{26}	4.6	4.1	3.2	6.5	4.8
nC_{27}	9.0	6.5	3.4	4.4	5.4
nC_{28}	4.0	3.2	2.0	2.8	2.9
nC_{29}	11.1	6.6	2.4	3.1	3.6
nC_{30}	6.7	3.0	1.5	1.6	2.7
nC_{31}	2.6	4.1	1.3	1.2	1.8
nC_{32}	2.8	1.8	0.6	0.7	1.1
nC_{33}	0.5	0.6	0.3	0.3	0.4
nC_{34}	0.2	0.7	0.1	0.2	0.4
nC_{35}	-	0.6	-	0.1	0.2
PARAFFIN	33.8	26.0	31.9	33.2	39.3
ISOPRENOID	1.1	1.7	4.1	6.6	5.4
NAPHTHENE	65.1	72.3	64.0	60.2	55.3
CPI INDEX A	1.20	1.16	1.03	1.00	1.13
CPI INDEX B	1.52	1.67	1.27	1.06	1.27
PRISTANE/PHYTANE	0.90	1.00	1.19	1.38	1.45
PRISTANE/nC_{17}	0.75	0.88	0.84	1.29	1.01

TABLE 9

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

GEOCHEM SAMPLE NUMBER	-022	-026	-029	-032A	-035
DEPTH	3812.5-815m	3872.5-875m	3917.5-920m	3962.5-965m	4007.5-010m
SAMPLE TYPE					
nC_{15}	2.2	0.1	3.3	7.0	4.9
nC_{16}	5.4	0.6	6.3	9.6	6.8
nC_{17}	8.4	4.0	9.5	10.8	10.7
nC_{18}	9.0	6.4	9.5	10.1	8.7
nC_{19}	9.4	8.9	9.5	8.8	9.1
nC_{20}	8.7	8.9	8.7	7.9	9.2
nC_{21}	8.2	9.3	8.0	7.2	7.4
nC_{22}	7.6	9.2	7.2	6.5	7.2
nC_{23}	7.7	9.6	7.4	6.6	7.1
nC_{24}	6.6	8.0	6.1	5.4	5.7
nC_{25}	6.5	7.9	6.0	5.5	5.9
nC_{26}	5.8	5.1	5.3	4.3	3.8
nC_{27}	4.6	6.2	4.2	3.6	4.4
nC_{28}	3.0	3.4	2.7	2.3	2.5
nC_{29}	2.6	4.1	2.8	2.2	2.9
nC_{30}	1.6	3.4	1.4	1.0	2.0
nC_{31}	1.2	2.4	1.0	0.9	1.4
nC_{32}	0.8	1.2	0.7	0.2	0.7
nC_{33}	0.3	0.5	0.3	0.2	0.3
nC_{34}	0.3	0.4	0.1	0.1	0.2
nC_{35}	0.1	0.2	0.1	-	0.1
PARAFFIN	42.2	37.5	43.9	41.6	22.2
ISOPRENOID	5.7	3.1	7.1	6.4	3.7
NAPHTHENE	52.1	59.4	49.0	52.0	74.0
CPI INDEX A	1.06	1.17	1.07	1.09	1.14
CPI INDEX B	1.11	1.30	1.15	1.24	1.33
PRISTANE/PHYTANE	1.28	0.82	1.33	1.56	1.67
PRISTANE/nC_{17}	0.90	0.91	0.97	0.86	0.98

TABLE 9

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

GEOCHEM SAMPLE NUMBER	-039A	-043	-047	-051A	-054A
DEPTH	4067.5-070m	4127.5-130m	4187.5-190m	4247.5-250m	4292.5-295m
SAMPLE TYPE					
nC_{15}	1.9	5.2	5.5	3.0	6.6
nC_{16}	5.6	8.6	7.8	6.7	8.7
nC_{17}	9.1	9.2	9.3	9.4	9.9
nC_{18}	10.0	8.6	9.0	9.3	8.7
nC_{19}	9.1	8.7	8.6	9.8	9.1
nC_{20}	8.3	8.0	8.2	8.5	7.9
nC_{21}	7.8	7.5	7.6	7.9	7.3
nC_{22}	7.2	7.0	7.0	7.3	6.7
nC_{23}	7.1	6.8	6.6	7.2	7.0
nC_{24}	6.4	5.9	5.7	6.1	5.6
nC_{25}	6.1	5.8	5.4	6.0	5.5
nC_{26}	4.3	4.2	5.1	4.5	4.8
nC_{27}	5.0	4.2	3.8	4.4	3.7
nC_{28}	2.8	2.9	2.7	2.9	2.5
nC_{29}	3.3	3.3	2.8	3.1	2.4
nC_{30}	2.5	1.5	1.6	1.3	1.2
nC_{31}	1.9	1.2	1.1	0.9	0.8
nC_{32}	1.0	0.8	1.0	0.9	0.7
nC_{33}	0.4	0.3	0.6	0.5	0.5
nC_{34}	0.1	0.1	0.4	0.3	0.3
nC_{35}	0.1	0.1	0.3	0.2	0.2
PARAFFIN	37.7	44.3	40.6	42.1	44.4
ISOPRENOID	5.7	7.4	5.8	6.3	6.0
NAPHTHENE	56.6	48.3	53.6	51.6	49.6
CPI INDEX A	1.13	1.09	1.03	1.09	1.07
CPI INDEX B	1.28	1.28	1.07	1.23	1.12
PRISTANE/PHYTANE	1.20	1.29	1.21	1.33	1.45
PRISTANE/nC_{17}	0.93	1.01	0.85	0.92	0.81

BRIEF DESCRIPTION OF THE ANALYSES PERFORMED BY GEOCHEM

"Screen Analyses" are described in sections A, C and D, "Sample Preparation" in section B, "Follow-up Analyses" in sections E through K and "Correlation Studies" in section L. 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 at least wet) for the C_4-C_7 analysis. The other analyses can be run on both canned and bagged 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 richness, maturity and the character of the hydrocarbons they can yield. Most importantly, it is extremely sensitive to the presence of migrated hydrocarbons and is an excellent method for their detection. As it provides the information on most of the critical parameters and is also economical, this analysis is excellent for screening samples to decide which of them merit further analysis.

During the time which elapses betwwen 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 E). The ppm 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.

Sample material remaining after analysis is retained for six months. Unless instructions are received to the contrary, Geochem Laboratories may then destroy the samples.

Our reports incorporate a gross lithological description of all the samples which have been analysed and litho percentage logs. 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, pyrolysis and C_{15+} analyses, the organic carbon content is used to evaluate the potential (not necessarily actual) hydrocarbon source richness of the sediment. This analysis is an integral part of a total evaluation and 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, standards 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) MINI-PYROLYSIS

An ideal screen analysis which provides a definitive measure of potential source richness upon those samples whose organic carbon contents suggest fair or good source potential. This is described in detail in section K.

E) 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 by capillary gas chromatography and their peak areas electronically integrated.

Normalised compositions, selected ratios and the ppm abundance of the total gasoline-range fraction are tabulated in the report and also presented graphically.

F) KEROGEN TYPE AND MATURATION

Kerogen is the insoluble organic matter in rocks. Visual examination of the kerogen gives a direct measure of thermal maturity and of the composition of the organic matter (organic facies) and indicates the source quality of the sediment - which is confirmed using the organic carbon, light hydrocarbon, pyrolysis and C_{15+} analyses.

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

Kerogen is separated from the inorganic rock matrix by acid digestion and flotation methods which avoid oxidation of the organic matter. It is then mounted on a glass slide and examined at high and low magnifications with a Leitz microscope. Chemical methods measure the total kerogen population but, with this technique, individual particles can be selected for examination and spurious material identified. This is particularly valuable in reworked, contaminated and turbodrilled sediments.

The following data are generated: the types of organic matter present and their relative abundances, an estimate of the proportion of reworked material, preservation state, the thermal maturity of the non-reworked organic matter using the spore colouration technique. A ten point maturation scale is employed (1 through 10 but also including intermediate points (e.g. 1, 1+, 2 etc., see below)). A total of fourteen types of organic matter are sought based upon the primary categories of algal, amorphous, herbaceous, inertinite, wood and resin. This detail is essential for a proper understanding of hydrocarbon source potential as the different sub-groups within each category have different properties.

Maturation levels are identical to those reported by Geochem prior to 1980 and correlate as follows (old scale in brackets): 1(1), 2(1+), 3(2-), 4(2), 4+(2 to 2+), 5(2+), 6(3-), 7(3), 8(3+), 9(4), 10(5). The new scale has intermediate points e.g. 3, 3+, 4, 4+, 5 etc.

Upon completion of the study, the glass slides are sent to the client.

G) <u>VITRINITE REFLECTANCE</u>

Vitrinite reflectance is an alternative/confirmatory method for evaluating thermal maturation which is used in conjection with the visual kerogen analysis. The reflectivity of vitrinite macerals increases in response to thermal alteration and is used to define maturation levels and, by projection, to predict maturity at depth or the thicknesses of section removed by erosion.

Measurements are made upon kerogen separations in conjunction with polished whole rock samples. In general, this analysis is performed upon the same samples as the visual kerogen analysis, thus facilitating a direct comparison of the two sets of results.

If possible, forty to fifty measurements are taken per sample - unless the sediments are organically lean, vitrinite is sparse or only a single uniform population is present. The data are plotted in a histogram which distinguishes the indigenous vitrinite from possible reworked or caved material. Averages are calculated for each population. Comments upon exinite fluorescence and upon the character of the phytoclasts are noted on the histograms. The reports contain the tabulated data, histograms and the reflectivities plotted against depth.

The vitrinite and visual kerogen techniques provide mutually complementary information upon maturity, organic matter type and diagenesis.

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

Sections "A" and "E" 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 (i.e. the heavy end). The amount and composition of this extract indicates source richness and type, the level of thermal maturation and the possible presence of migrated hydrocarbons.

These results are integrated with those derived from the pyrolysis, visual kerogen, organic carbon and light hydrocarbon analyses.

The techniques involved in this analysis employ pure solvents and have been designed to give reproducible results. Hand picked samples are ground and then solvent extracted in a soxhlet apparatus, or by blending, with dichloromethane (the solvent system can be adapted to client's specifications). After asphaltene precipitation, the total extract is separated by column chromatography or high pressure liquid chromatography into the following fractions: paraffin-naphthene hydrocarbons, aromatic hydrocarbons, eluted NSO's (nitrogen-, sulphur-, and oxygen- containing non-hydrocarbons) and non-eluted NSO's. Note that the non-hydrocarbons are split into three fractions and not reported as a gross value. These fractions can be submitted for further analyses (carbon isotopes, gas chromatography, high mass spectroscopy) including correlation studies.

For convenience and thoroughness, the data are reported in three formats: the weights of the fractions, ppm abundances and normalised percentage compositions. The data are also presented diagramatically.

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

The gas chromatographic configurations of the heavy C_{15+} paraffin-naphthene hydrocarbons reflect source type, the degree of thermal maturation and the presence and character of migrated hydrocarbons or contamination.

Not only is this analysis an integral part of any source rock study but it also provides a fingerprint for correlation purposes and helps to define the geochemical/palynological environmental character of the source rocks from which crude oils were derived.

The paraffin-naphthene hydrocarbons obtained by column chromatography are separated by high resolution capillary chromatography. Excellent resolution of the individual normal paraffins, isoprenoids and significant individual isoparaffins and naphthenes is achieved. Runs are normally terminated at nC_{35}. A powerful in-house microprocessor system is being introduced to correct for the change in response factor with chain length.

The normal paraffin carbon preference indices (C.P.I.) indicate if odd (values in excess of 1) or even (values less than 1) normal paraffins are dominant. Strong odd preferences (± strong pristane peaks) are characteristic of immature land plant organic matter whilst even preferences (± strong phytane peaks) suggest a reducing environment of deposition. With increasing maturity, values approach 1.0 and oils are typically close to 1.0. The indices are calculated using the following formulae:

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

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

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; $C.P.I_A$ and $C.P.I_B$; pristane to phytane ratio; pristane to nC_{17} ratio.

K) PYROLYSIS

The process of thermal maturation can be simulated in the laboratory by pyrolysis, which involves heating the sample under specified conditions and measuring the oil-like material which is freed/generated from the rock. With this analysis, the potential richness of immature sediments can be determined and, by coupling the pyrolysis unit to a gas chromatograph, the liberated material can be characterised. These results are correlated with those obtained from the organic carbon, kerogen and C_{15+} analyses.

Small amounts of powdered sample are heated in helium to release the thermal bitumen (up to 340°C) and pyrolysate (340-550°C). The thermal bitumen correlates with the solvent extractable material (see above) whilst the pyrolysate fraction does not exist in a "free" state but is generated from the kerogen, thus simulating maturation in the subsurface. Abundances (weight ppm of rock) are measured with a flame ionisation detector against a standard. Thermal bitumen includes source indigenous, contaminant and migrated hydrocarbons but the pyrolysate abundance is a measure of ultimate source richness. The capillary gas chromatogram of the pyrolysate is used to evaluate the character of the parent organic matter and whether it is oil or gas prone. Peak temperature(s) of pyrolysate evolution is recorded and if necessary, methane yields are also measured. Carbon dioxide can be measured if requested but is normally ignored as the separation of the organic and inorganic species has been found to be artificial and unreliable.

Pyrolysate yields provide a definitive measure of potential source richness which avoids the ambiguities of the organic carbon data and the problem of contamination. This analysis is also used to evaluate the quality and character of the organic matter, whether it is oil or gas prone and the degree to which it has realised its ultimate hydrocarbon potential. Carbon dioxide yields are not used and Geochem does not employ the pyrolysis technique to evaluate maturation, preferring the more reliable kerogen and vitrinite reflectance analyses.

The data are tabulated and presented graphically. MINI-PYROLYSIS includes ppm thermal bitumen and ppm pyrolysate. PYROLYSIS-GC also provides the above together with the temperature of peak pyrolysate evolution and a capillary chromatogram of the pyrolysate. The Mini-Pyrolysis is recommended as a screening technique.

L) CORRELATION STUDY ANALYSES

Oil to oil and oil to parent source rock correlation studies require high resolution analytical techniques. This requirement is satisfied by some of the analyses discussed above but others have been selected specifically for correlation work. Many of these analyses also provide information upon the character of the environment of deposition of the parent source rocks.

- detailed C_4-C_7 hydrocarbon (gasoline range) analysis. See Section E. Although these hydrocarbons can be affected by migrational/alteration processes, they commonly provide a very useful correlation parameter.
- capillary gas chromatography of the C_{15+} paraffin-naphthenes. See section J. The branched$\pm$normal paraffin distributions are used to "fingerprint" the samples.
- capillary chromatograms of whole oils and of the C_{8+} fraction of source rocks.

- capillary gas chromatography of C_{15+} aromatic hydrocarbons. Separate chromatograms of the hydrocarbons and of the sulphur-bearing species are reproduced.
- high pressure liquid chromatograms.
- mass spectrometric carbon isotope analyses of crude oil and rock extract fractions and of kerogen separations. A powerful tool for comparing hydrocarbons and correlating hydrocarbons to organic matter. With this technique the problem of source rock contamination can be avoided. The data are recorded on x-y or Galimov plots.
- mass fragmentograms (mass chromatograms) of fragment ions characteristic of selected hydrocarbon groups such as the steranes and terpanes. The fragmentograms provide a convenient and simple means of presenting detailed mass spectrometric data and are used as a sophisticated fingerprinting technique. This provides the ultimate resolution for correlating hydrocarbons and facilitates the examination of hydrocarbon classes.
- vanedium and nickel contents.

Suites of (rather than single) analyses are employed in correlation studies, the actual selection depending upon the complexity of the problem. See also section N.

M) ANALYSES FOR SPECIAL CASES

M-1) ELEMENTAL KEROGEN ANALYSIS

This analysis evaluates source quality, whether the sediments are oil or gas prone, the character of the organic matter and its level of thermal maturation. It is the chemical equivalent of the visual kerogen analysis. The pyrolysis analysis is generally preferred to this technique, both methods providing similar information.

M-2) SULPHUR ANALYSIS

The abundance of sulphur in source rocks.

M-3) CARBONATE CONTENT

The mineral carbonate content of sediments is determined by acid treatment. These data are particularly useful when used in conjunction with organic carbon contents as a screening technique.

M-4) NORMAL PARAFFIN ANALYSIS

Following the removal of the branched paraffins and naphthenes from the total paraffin-naphthene fraction, a chromatogram of the normal paraffins is obtained. The resulting less complicated chromatogram facilitates the examination of normal paraffin distributions.

M-5) SOLID BITUMEN EVALUATION

Residual solid bitumen after crude oil is generated by three prime processes: the action of waters, gas deasphalting, thermal alteration. Thus it provides a means of determing the reservoir history of a crude and of evaluating whether adjacent traps will or will not be prospective for oil. In carbonate sections, where organic matter is sometimes sparse, this technique is also used to evaluate thermal maturation levels.

The analysis involves the determination of the solubility (in CS_2) of the solid bitumen and of the atomic hydrogen to carbon ratio of the insoluble fraction.

N) CRUDE OIL ANALYSIS

N-1) API GRAVITY

This can be performed upon large (hydrometer) and small (SG bottle, pycnometer) samples and even upon stains extracted from sediments (refractive index).

N-2) SULPHUR CONTENTS (ASTM E30-47).

N-3) POUR POINT (ASTM D97-66, IP15/67)

N-4) VISCOSITY (ASTM D445-72, IP71/75)

N-5) FRACTIONAL DISTILLATION

Graph of cumulative distillation yield against temperature. Five percent cuts taken for further analysis. Mass spectrometric studies of these fractions provide a detailed picture of the distribution of paraffins and of the various naphthene and aromatic groups within a crude, which is useful both for correlation and for refinery evaluation purposes.

FIGURE 1 $C_1 - C_7$ HYDROCARBONS WELL 2/9-2

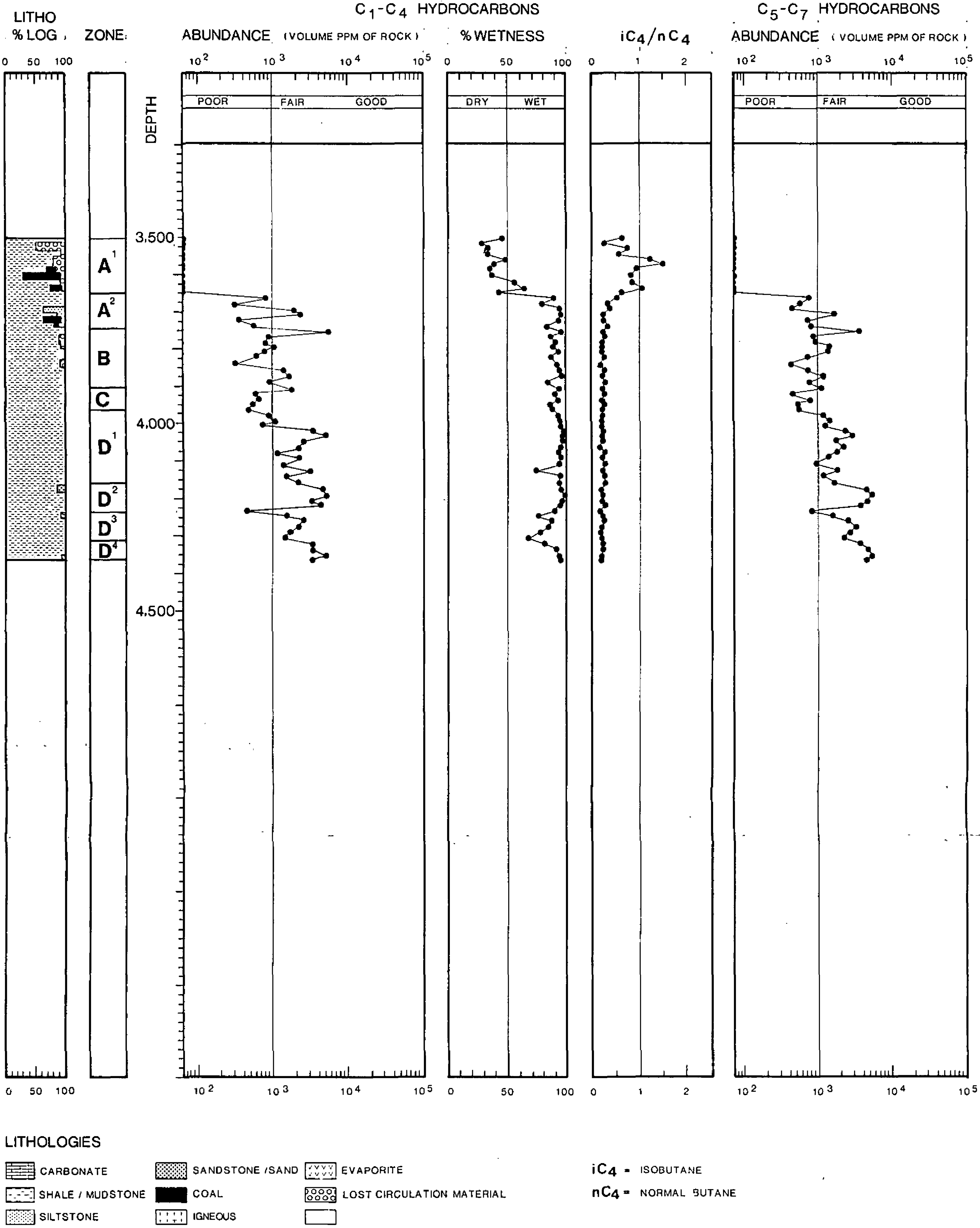
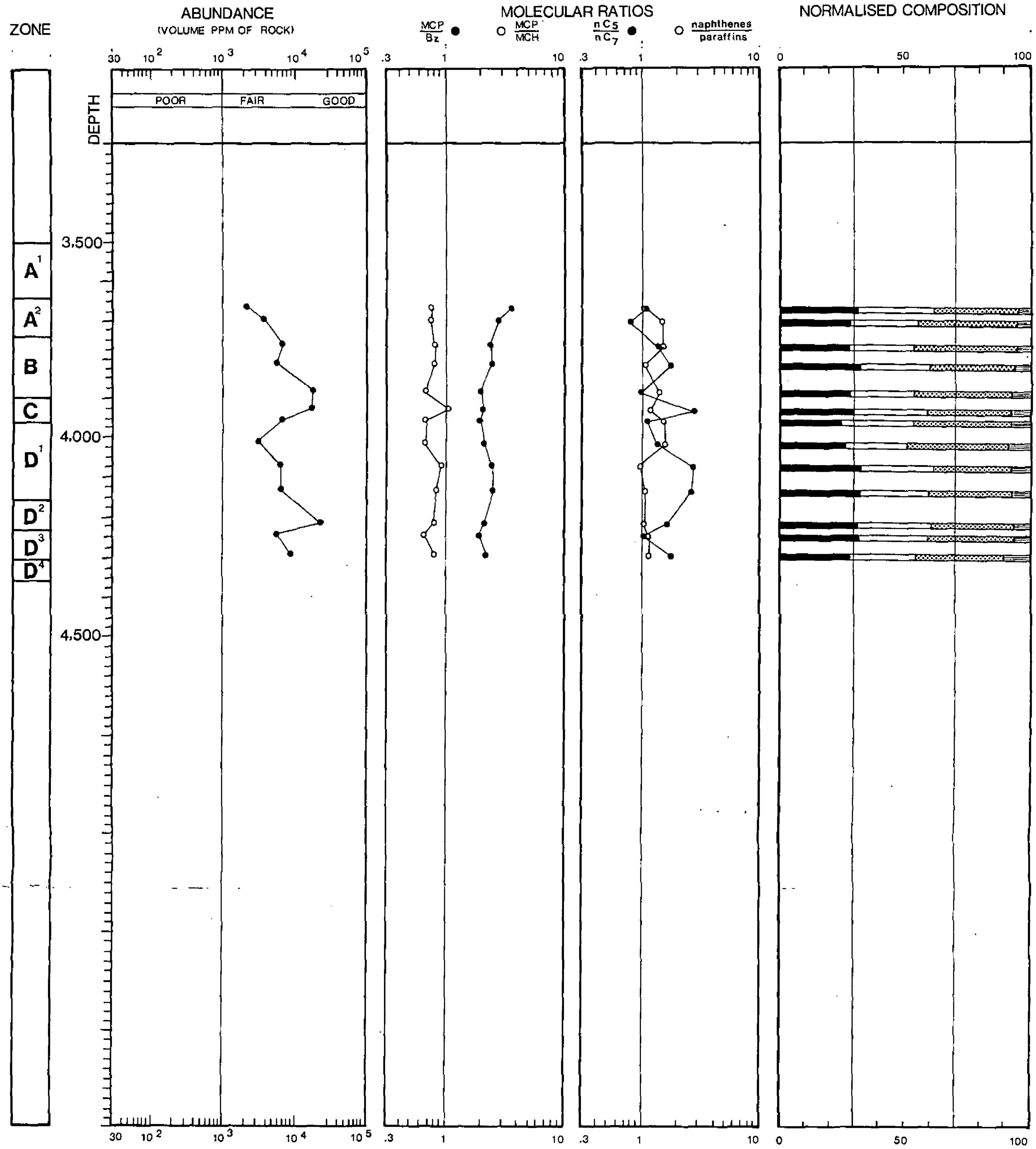


FIGURE 2

$C_4 - C_7$ HYDROCARBONS

WELL 2/9-2



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

MCP = METHYLCYCLOPENTANE
MCH = METHYLCYCLOHEXANE
Bz = BENZENE

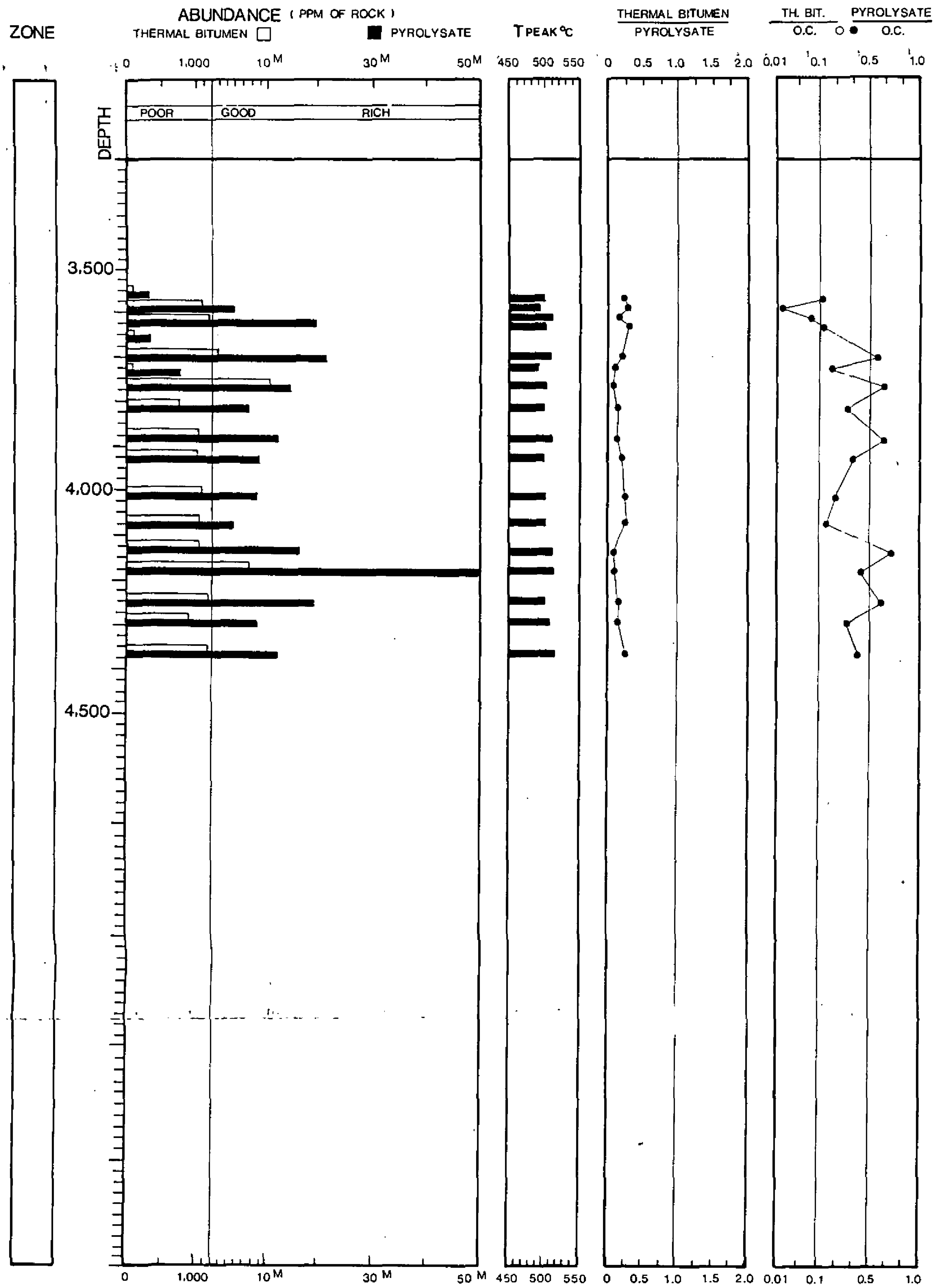
nC_5 = NORMAL PENTANE
nC_7 = NORMAL HEPTANE

NORMAL PARAFFINS
ISOPARAFFINS
NAPHTHENES
AROMATICS

FIGURE 3

PYROLYSIS

WELL 2/9-2



M = 10 3

O.C. = ORGANIC CARBON

FIGURE 4 **RICHNESS** WELL 2/9-2

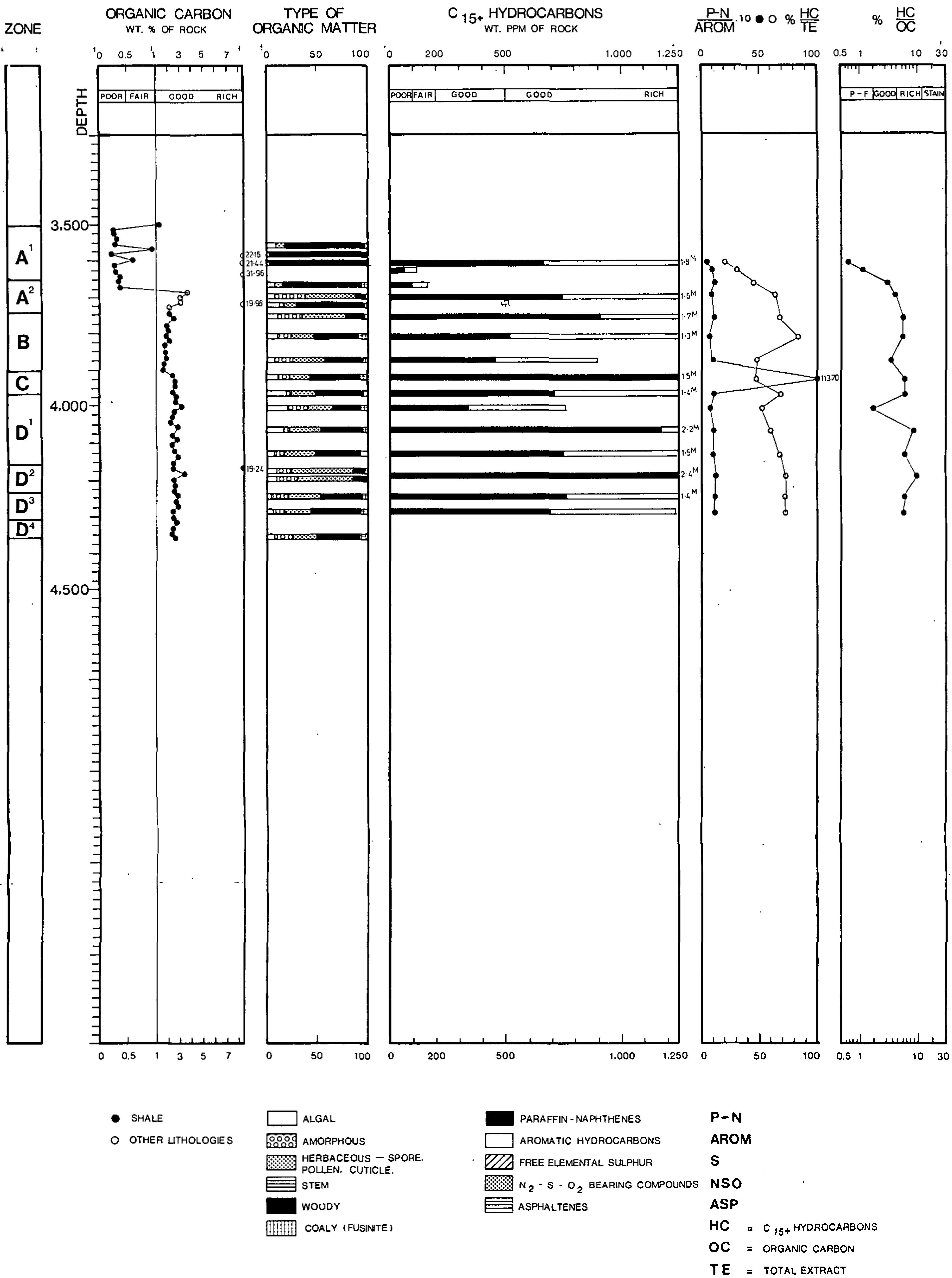
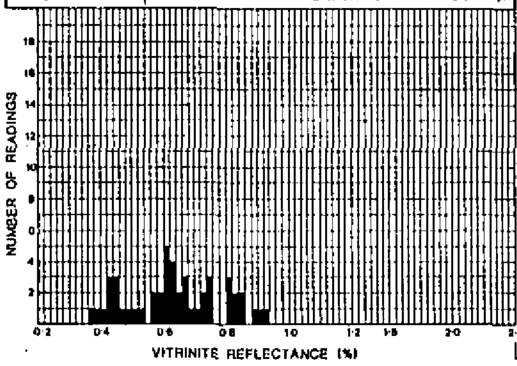


FIGURE 5a

VITRINITE HISTOGRAMS

WELL 2/9-2

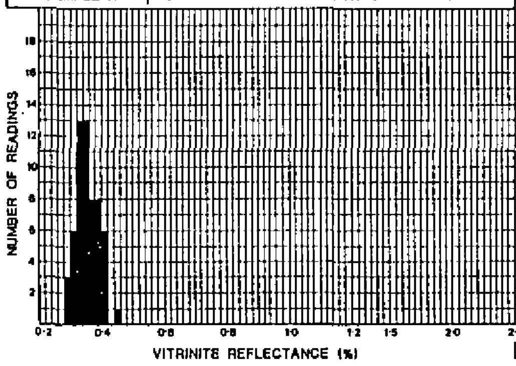
SAMPLE Nº 408-005A DEPTH 3557.5-3560m



APPEARANCE IN U.V.
NO CONVINCING ORGANIC FLUORESCENCE.

REMARKS
LOW TO MODERATE PERCENTAGE OF ORGANIC MATERIAL; CHIEFLY VITRINITE PARTICLES OF VERY VARIABLE REFLECTANCE. OCCASIONAL BITUMEN AND LOOSE (COAL?) PARTICLES ALSO EVIDENT. LITTLE INERTINITE.

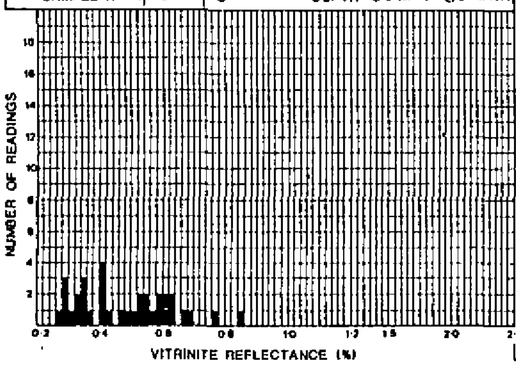
SAMPLE Nº 408-007C DEPTH 3587.5-3590m.



APPEARANCE IN U.V.
POSSIBLE DULL YELLOW SPORE FRAGMENTS

REMARKS
TYPICAL COAL. VITRINITE DOMINANT. SUBORDINATE INERTINITE

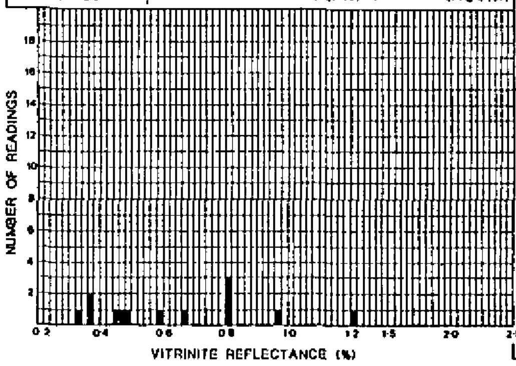
SAMPLE Nº 408-014B DEPTH 3692.5-3695m.



APPEARANCE IN U.V.
ALGAE, YELLOW-ORANGE TO LIGHT ORANGE SPORES

REMARKS
EXINITE DOMINANT. SMALL VITRINITE PARTICLES OF VARIABLE REFLECTANCE AND INERTINITE ALSO PRESENT.

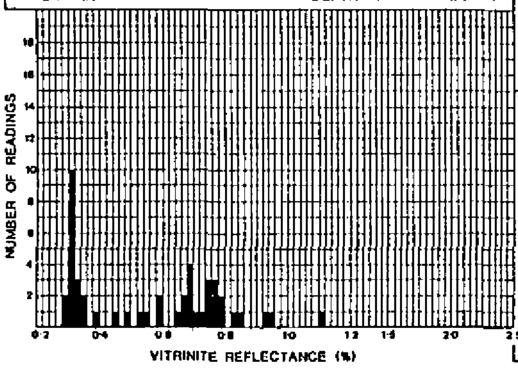
SAMPLE Nº 408-018A DEPTH 3752.5-3755m.



APPEARANCE IN U.V.
ALGAE, POSSIBLE LIGHT ORANGE SPORES

REMARKS
EXINITE DOMINANT. A FEW SMALL PARTICLES OF VITRINITE AND INERTINITE ALSO PRESENT.

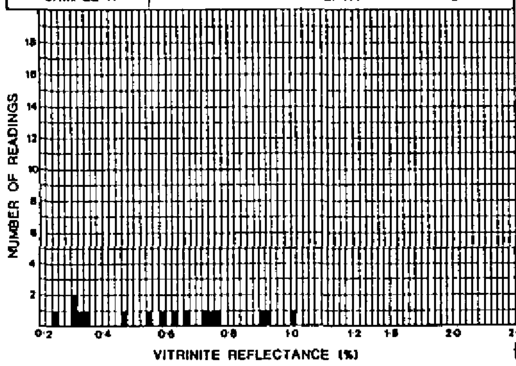
SAMPLE Nº 408-022A DEPTH 3812.5-3815m.



APPEARANCE IN U.V.
POSSIBLE YELLOW-ORANGE SPORES, ALGAE, DULL BITUMEN

REMARKS
MIXTURE OF EXINITE, FREQUENT PARTICLES OF VITRINITE OF VERY VARIABLE REFLECTANCE, AND INERTINITE.

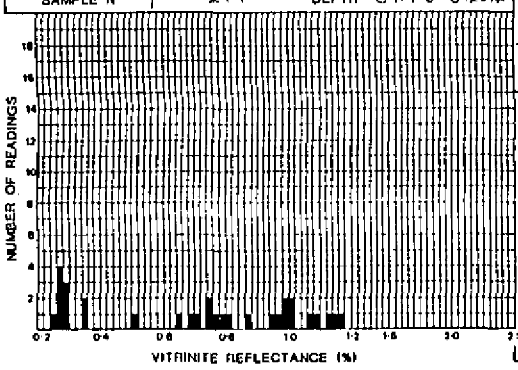
SAMPLE Nº 408-026A DEPTH 3872.5-3875m



APPEARANCE IN U.V.
ALGAE, YELLOW-ORANGE AND LIGHT ORANGE SPORES, A FEW MID TO DEEP ORANGE

REMARKS
MIXTURE OF SMALL VITRINITE PARTICLES AND EXINITE CHIEFLY. OCCASIONAL INERTINITE.

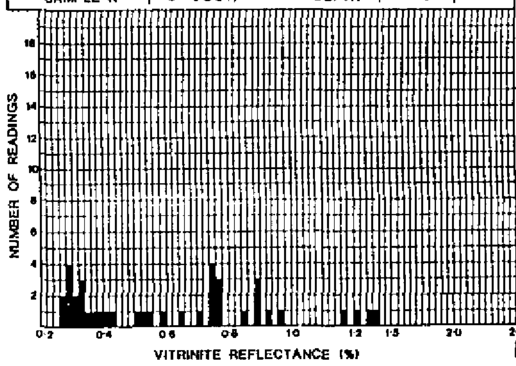
SAMPLE Nº 408-029A DEPTH 3917.5-3920m.



APPEARANCE IN U.V.
ALGAE, DULL BITUMEN, POSSIBLE DULL YELLOW-ORANGE SPORES.

REMARKS
AS 408-026A

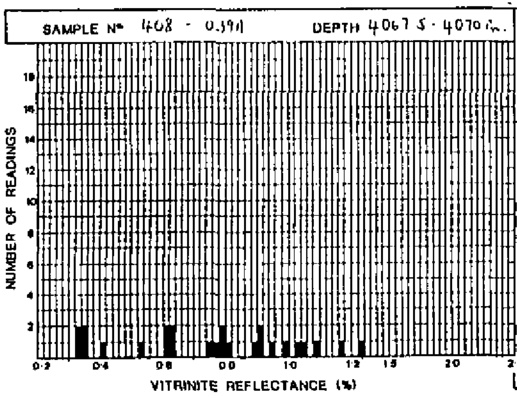
SAMPLE Nº 408-035A DEPTH 4007.5-4010m.



APPEARANCE IN U.V.
YELLOW-ORANGE AND LIGHT ORANGE SPORES

REMARKS
CHIEFLY EXINITE, PLUS PARTICLES OF LOW REFLECTANCE (~ 0.3%) OF UNCERTAIN AFFINITY OCCASIONAL TINY VITRINITE PARTICLES (MAINLY REWORKED) AND INERTINITE.

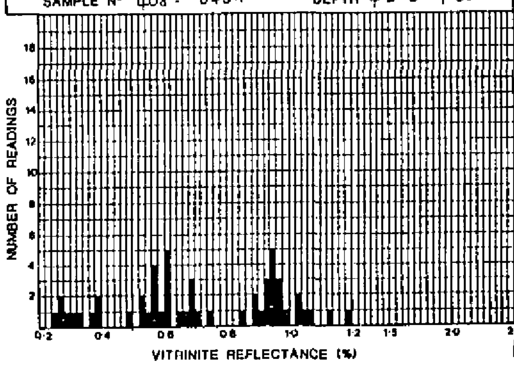
SAMPLE Nº 408-039A DEPTH 4067.5-4070m.



APPEARANCE IN U.V.
MID TO DEEP ORANGE BITUMEN LIGHT TO MID ORANGE SPORES

REMARKS
FREQUENT SMALL VITRINITE PARTICLES OF VARIABLE REFLECTANCE (MAINLY REWORKED), PLUS INERTINITE. EXINITE LOCALLY WELL DEVELOPED.

SAMPLE Nº 408-043A DEPTH 4127.5-4130m.



APPEARANCE IN U.V.
ALGAE, VARIABLE BITUMEN FLUORESCENCE, LIGHT TO MID-ORANGE SPORES

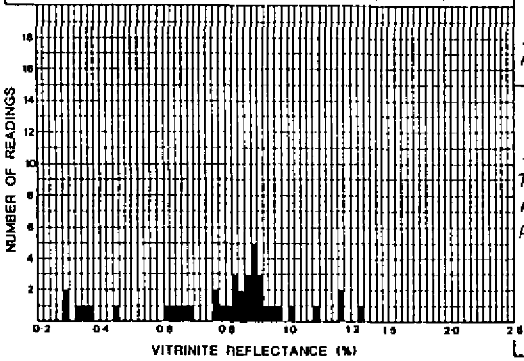
REMARKS
MIXTURE OF EXINITE AND VITRINITE PARTICLES OF VARIABLE REFLECTANCE CHIEFLY. OCCASIONAL INERTINITE.

FIGURE 5b

VITRINITE HISTOGRAMS

WELL 2/9-2

SAMPLE No. 408 - 046C DEPTH 4172.5 - 4175 m.



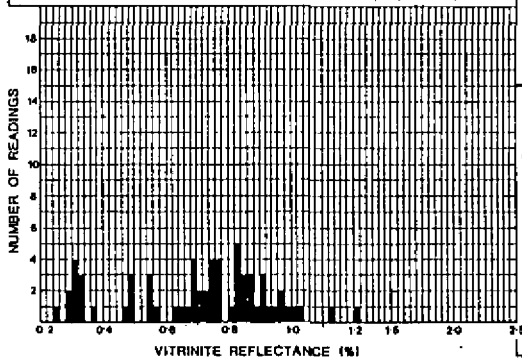
APPEARANCE IN U. V.

ALGAE, DULL DEEP ORANGE-RED BITUMEN, YELLOW-ORANGE AND LIGHT ORANGE SPORES

REMARKS

ALMOST EXCLUSIVELY EXINITE. SMALL VITRINITE PARTICLES OF VARIABLE R_o AND INERTINITE ALSO APPARENT.

SAMPLE No. 408 - 051A DEPTH 4247.5 - 4250 m.



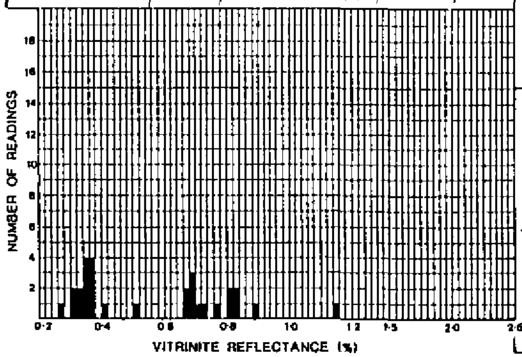
APPEARANCE IN U. V.

YELLOW-ORANGE TO MID-ORANGE SPORES, ALGAE.

REMARKS

FREQUENT EXINITE AND VITRINITE PARTICLES OF VARIABLE REFLECTANCE. OCCASIONAL INERTINITE.

SAMPLE No. 408-054A DEPTH 4292.5 - 4295 m.



APPEARANCE IN U. V.

MID-ORANGE SPORES, A FEW YELLOW-ORANGE.

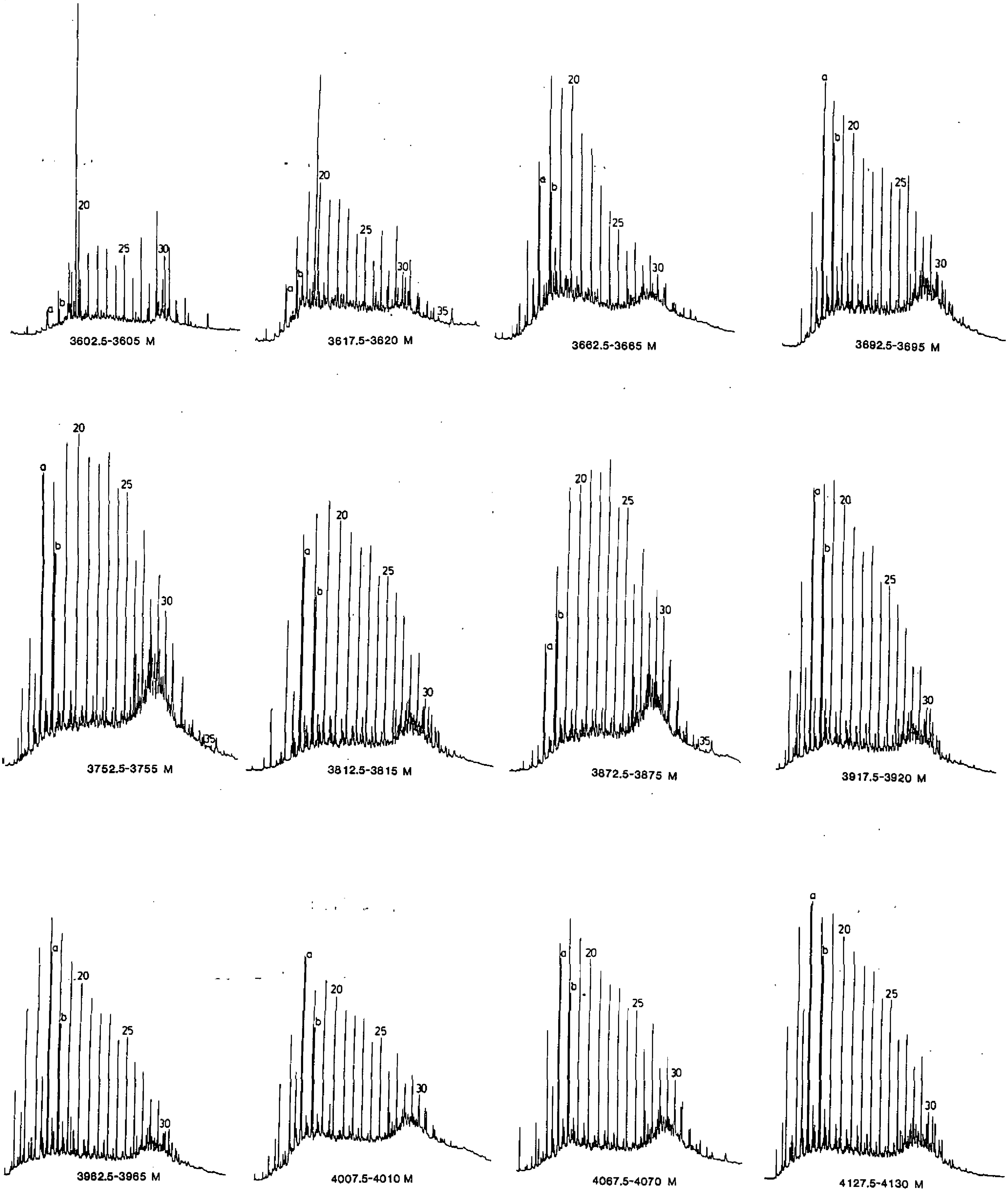
REMARKS

PARTICLES OF REWORKED MATERIAL AND INERTINITE. FREQUENT BITUMEN. VITRINITE VERY VARIABLE IN R_o.

FIGURE 6a

C_{15+} PARAFFIN - NAPHTHENES

WELL 2/9-2



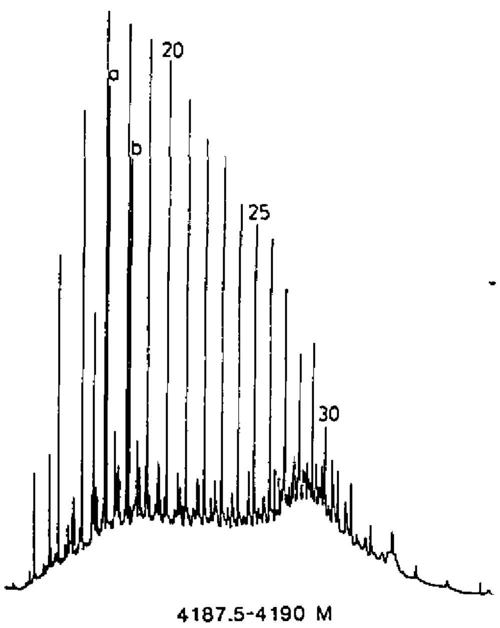
a = PRISTANE
b = PHYTANE

CARBON NUMBERS OF NORMAL PARAFFINS INDICATED ($20 = nC_{20}$)

FIGURE 6b

C_{15+} PARAFFIN - NAPHTHENES

WELL 2/9-2



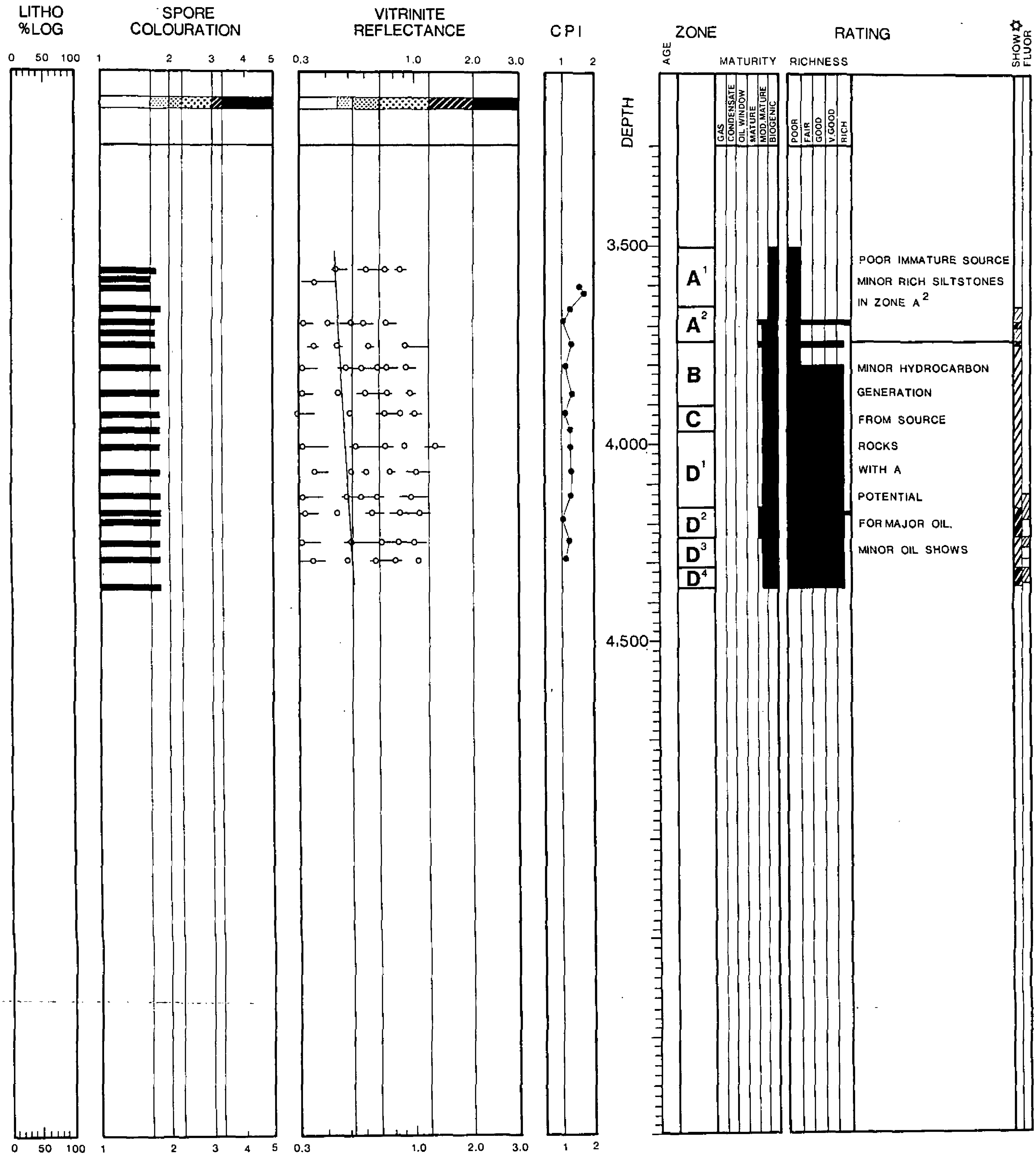
a = PRISTANE
b = PHYTANE

CARBON NUMBERS OF NORMAL PARAFFINS INDICATED (20 = nC_{20})

FIGURE 7

INTERPRETATION

WELL 2/9-2



LITHOLOGIES

- CARBONATE
- SHALE/MUDSTONE
- SILTSTONE
- EVAPORITE
- LOST CIRCULATION MATERIAL
- SAND
- COAL
- IGNEOUS

× RECALCULATED VALUE
● CORE
▬ PREFERRED TREND

CPI CARBON PREFERENCE INDEX

SPORE COLOURATION

2-	2	2 to 2+	3	3+	
IMMATURE	MARG.MATURE	MATURE	OIL WINDOW	COND.	EOMETA

REFLECTIVITY 0.53 0.7 1.2 2.0

✡ GEOCHEMICAL