PRELIMINARY

GEOCHEMICAL EVALUATION OF THE STATOIL 30/3-1 WELL NORWEGIAN NORTH SEA

SUMMARY

Eight (8) zones are recognised between 200 metres and 3718 metres.

Zone A (200-830± metres) lacks effective source rocks.

Mudstones (interbedded with sands) in Zone B (830-1310± metres), and shales above 1640± metres within Zone C, are good potential oil source rocks. They are immature on-structure and would require burial to below 4000± metres to realise this potential.

The shales and mudstones within Zones D^1 to F vary somewhat in richness but, in general, are poor immature source rocks. They have a limited potential for gas and associated liquids and only the minor shales at 2797-2857± metres are potentially good oil source rocks.

Fair (at 3457-3517± metres) and good (at 3607-3637± metres), but marginally mature oil prone shales are present in Zone G, (3457-3718± metres). The interval otherwise has a limited potential for gas and oil.

Traces of wet gas at 1940-2030± metres and shows of a light crude oil at 2150-2300± metres (with further shows between 2030± metres and 2677± metres) were detected. Intermittant shows of medium gravity crude oil are present between 2692± metres and 3718± metres with the best show occurring at 3472-3577± metres. These mature oils were not sourced by sediments within the analysed well section but possibly by off-structure equivalents of the mudstones and shales in Zones B and C.

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INTRODUCTION

This report presents a preliminary geochemical evaluation of the section between 200 metres and 3718 metres in the Statoil 30/3-1 well drilled in the Norwegian sector of the North Sea.

The study was designed to evaluate the hydrocarbon source potential of the section in terms of richness, maturity and hydrocarbon type. In addition, the analyses were selected to detect and characterise migrated hydrocarbons.

The study was authorised by Mr. S.G. Larsen, Statoil, Stavanger.

A. ANALYTICAL

A total of one hundred and sixty (160) canned ditch cuttings samples were received from 200-3718 metres. They were generally composited over intervals of thirty metres above 2450± metres and over 15 metres below 2467± metres, with additional samples at 2450-2467± metres and 3712-3718± metres. The samples were assigned the Geochem job number 360 and numbered sequentially.

The samples were screened using the light hydrocarbon and organic carbon analyses and samples for further analysis were selected on the basis of the screen results.

B. GENERAL INFORMATION

Three (3) copies of this report have been forwarded to Mr. S.G. Larsen, Statoil, Norway.

All of the results and conclusions related to this study are regarded as highly confidential and are proprietary to Statoil.

RESULTS AND DISCUSSION

Each of the parameters relevant to the evaluation of the section between 200 metres and 3718 metres will be considered in turn and then combined to form the "Conclusions".

No well logs were available for this study.

A. GEOCHEMICAL ZONATION

This zonation is based upon the light hydrocarbon data. A total of eight (8) zones are recognised.

Zone A (200-830± metres) consists of unconsolidated sands, shell debris and igneous intrusives with minor chalky limestones at 260-380± metres. Significant amounts of dark grey shale are present in the sample from 200-230± metres whilst those from 680-710± metres and 770-800± metres contain minor black and brownish grey shale.

No fluorescence was detected.

The C_1-C_4 hydrocarbons vary erratically between 421 ppm and 15235 ppm, but average 5000 ppm, in this interval. The gases are very dry (less than 3% C_{2+} hydrocarbons and the C_5-C_7 fraction non existant.

Zone B (830-1310± metres) is sandy with interbedded greenish grey-yellowish grey mudstones, coals and intrusives above 980± metres. Greenish grey (sandy) mudstones are abundant and igneous material significant in the underlying sediments. Significant sands are also present below 1160± metres whilst the lowermost sample contains appreciable amounts of brownish grey shale.

The sands were non fluorescent.

The Zone B sediments contain between 1458 ppm and 15837 ppm dry gas which decreases irregularly in abundance with depth. No gasoline range hydrocarbons were detected.

Zone C (1310-1910± metres) is largely composed of medium grey-light grey shales, with sandy interbeds at 1550-1670± metres. The samples also contained significant amounts of caved greyish-yellow green mudstone.

Fluorescence was not observed in the sands.

The trend of decreasing light hydrocarbon abundances established in Zone B continues in this interval. Values drop from 1652 ppm at 1370± metres to 287 ppm at 1610± metres and, apart from a kick of 720-3079ppm at 1720-1790± metres do not exceed 500 ppm below this depth. (Samples 049 and 050 appear to have lost most of their light hydrocarbons prior to analysis). Gas wetness increases from dry (less than 10% C_{2+} hydrocarbons) to marginally wet (maximally 42%) in the lowermost 50± metres.

Zone D^1 lies between 1910± metres and 2300± metres. Light grey shales and (sandy) mudstones, with pale brown interbeds, overlie at 2180± metres an interval of bluish grey shaly mudstones. It is possible that the light bluish grey mudstones which dominate the samples between 2180± metres and 2300± metres are caved and that the less abundant pale brown shales are indigenous and possibly underrepresented in the samples.

No fluorescence was detected.

The light hydrocarbons are comparatively abundant and wet in this interval. Thus, the C_1-C_4 fraction increases from 722 ppm at 1910-1940± metres to a maximum of 9452 ppm at 2210-2240± metres whilst the gasoline fraction rises from 833 ppm to 9472 ppm over the same interval. Gas wetness, with one exception (50.1% at 2060± metres), lies between 62.8% and 78.1%. Isobutane to normal butane ratios vary between 0.26 and 0.62 but are generally less than 0.40.

Zone D^2 (2300-2887± metres) apparently (caved material is frequently present in the samples) consists of bluish grey mudstones which pass, below 2420± metres, to an interval of light grey-greenish grey shales, with minor limestones at 2497-2542± metres. Medium-light grey shales, which extend from 2542± metres down to 2797± metres, contain minor coals at 2752-2797± metres and, below 2752± metres, limestones. The underlying sediments mainly consist of greenish grey shales although pale yellowish brown shales are present at 2797-2812± metres and 2842-2857± metres, minor limestones at 2752-2842± metres, and sandstones at 2857-2872± metres.

The limestones at 2527-2542± metres and 2812-2842± metres, siltstones at 2707-2722± metres and sands at 2857-2872± metres yielded a milky blue cut.

Hydrocarbon gases abundances vary irregularly between 674 ppm and 6968 ppm, but generally exceed 2000 ppm, within this interval. They are wet to very wet (62.9-94.3% C_{2+} hydrocarbons) although the C_5-C_7 hydrocarbons at 336-5432 ppm are, on average less abundant than those in Zone D[1]. Isobutane to normal butane ratios deviate only slightly from a mean value of 0.4.

Zone E (2887-3037± metres) greenish grey shales (largely caved) and medium-light grey mudstones overlie at 2947± metres a sequence of grey shales.

No fluorescence was observed.

Abundances of light hydrocarbons are lower than those in Zone D[2]. The gases are less than 1000 ppm (443-675 ppm) above 2962± metres but improve, to 844-1999 ppm, below this depth. Gas wetness varies erratically between 49.9% and 83.9% although the butane ratios decrease slightly with depth from 0.42 to 0.29. Gasoline range hydrocarbons, however, increase in abundance from 263 ppm at 2887± metres to 1410 ppm at 3037± metres.

Zone F (3037-3457± metres). Samples from this zone were often small and frequently contained lost circulation material. The interval is dominated by medium-light grey (generally silty) shales although minor to significant darker grey shales are also present at 3172-3292± metres. Medium-dark grey shales are abundant below 3382± metres.

No fluorescence was detected.

Zone F with 1000-16189 ppm C_1-C_4 and 1184-11420 ppm C_5-C_7 hydrocarbons is richer and the gases wetter (68-90% C_{2+} hydrocarbons) than most of the shallower zones. The isobutane to normal butane ratios, however, are virtually unchanged at 0.30-0.49.

Zone G extends from 3457± metres down to 3718 metres. Light brownish grey (sandy) and medium dark grey (silty) shales overlie light grey shales and mudstones at 3517-3637± metres. Minor to significant dark grey shales occur at 3577-3637± metres. The shales are otherwise medium grey in colour.

Fluorescence was not detected.

Gas abundances vary erratically between 735 ppm and 51403 ppm but are generally higher than those in Zone F, particularly above 3740± metres where they

exceed 10,000 ppm. The gases are very wet (69.5-94.5% C_{2+} hydrocarbons) and the C_5-C_7 hydrocarbons correspondingly rich with values of (986) 1521-31700 ppm (notably above 3640± metres. Isobutane to normal butane ratios range narrowly between 0.39 and 0.49.

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 hydrocarbon source richness but also the nature (oil/gas) of the hydrocarbon product and the response of the organic matter to thermal maturation. Richness and oil proneness decrease in the order: amorphous-herbaceous-stem-woody. Wood has a primary but, not exclusive, potential for gas whereas coaly (inertinitic) debris has only a limited hydrocarbon potential.

Shales are sparse in Zone A (200-830± metres) and, although poor (0.09% organic carbon) at 200-230± metres, are rich 13.99% at 680-710± metres and fair (0.92% organic carbon) at 770-800± metres.

Within Zone B the minor coals at 860-920± metres are rich (26-37% organic carbon) whilst the mudstones, below 860± metres, are fair to good with values of 0.67-2.41% organic carbon. Both contain dominantly herbaceous and woody, with significant algal, and minor coaly and amorphous, organic matter. The same type of organic matter is present in the grey and brownish grey shales of Zone C. Above 1610± metres they have good (0.97-2.6%) organic carbon contents but the underlying medium dark grey shales are leaner (0.55-0.98%) and the medium grey-light grey shales (below 1700± metres) poor (0.1-0.32% organic carbon). The sparse organic matter in these latter shales mainly consists of a mixed woody-herbaceous and coaly assemblage. Only traces of partially developed amorphous kerogen are present.

Above 2030± metres, Zone D^1 is characterised by lean (0.21-0.43% organic carbon) grey shales which, organically, are similar to those in basal Zone C. They contain interbeds of pale brown shale and mudstone which have poor organic carbon contents (less than 0.52%). Woody and coaly (reworked) organic matter predominates in the lean, light grey shales (0.17-0.62% organic carbon) yellowish grey mudstones (less than 0.25% organic carbon) and pale brown shales (less than 0.11% organic carbon) between 2030± metres and 2180± metres. The same type of organic matter occurs, with minimal proportions of herbaceous and algal material, in the (caved?) light bluish grey shaly mudstones which extend from 2180± metres down to 2420± metres (in Zone D^2). These mudstones

also have poor (0.39-0.54%) organic carbon contents whilst the minor brown shales in this interval are even leaner with values of less than 0.11%. Below 2420± metres (in Zone D^2) the medium grey-greenish grey shales (caved?) have poor to fair contents of dominantly woody and coaly, with minor herbaceous and algal, organic matter. The woody material is largely reworked. Significant pale yellowish brown shales (between 2797± metres and 2857± metres) are richer than average (1.06-1.3% organic carbon) and contain an improved, dominantly amorphous, type of organic matter. Thin, but rich (38% organic carbon), coals are present at 2752-2797± metres.

Within Zone E the greenish grey (largely caved) shales, medium grey mudstones and, below 2977± metres medium dark grey shales are generally poor (less than 0.57% organic carbon, 0.73% at 2962-2972± metres) and their sparse organic matter consists largely of reworked woody and coaly debris. Only traces of algal, herbaceous and dark degraded amorphous kerogen are present.

The grey shales within Zone F show little real variation in richness. Thus, the lighter grey shales average 0.34-0.63% organic carbon (0.18-0.31% at 3337-3382± metres) and the darker grey shales 0.50-0.71% although minor shales at 3187-3202± metres and 3217-3232± metres achieve values of 2.13% and 1.01% respectively. The organic matter closely resembles that in Zone E.

Light grey-greyish brown shales at the top of Zone G (above 3517± metres) have fair (0.59-0.64%) organic carbon contents whilst the interbeds of darker grey shale are somewhat richer with values of (0.61-0.78%). Woody and amorphous organic matter is dominant, and algal and coaly material significant, in the former shales whereas the latter contain almost exclusively amorphous kerogen, and only traces of algal, woody, coaly and herbaceous debris. The underlying medium grey and light grey shales generally have poor to fair (0.40-0.77%) contents of largely woody and coaly (mainly reworked) organic matter, although traces of algal herbaceous and amorphous material are also present. A slight improvement is noted in a minor dark grey shale at 3607-3637± metres which is not only richer than average (2.93-3.06% organic carbon) but contains a better (mixed woody, herbaceous and algal, including partially sapropelised material), type of organic matter. Dark grey shales containing 0.9-1.07% of dominantly woody and coaly organic matter occur below 3697± metres.

The environment at the seawater sediment interface was weakly reducing when the sediments above 2030± metres were deposited. Earlier sediments were generally laid down under oxidising conditions although brief interludes of a more reducing nature existed when the sediments at 2797-2857± metres and 3457-3517± metres were deposited.

C. LEVEL OF THERMAL MATURATION

Thermal maturity of the sediments has been assessed by the spore colouration and vitrinite reflectance methods.

Maturation indices, based upon spore colouration, range from 1+ to 2- at 830± metres to 2- at 2850± metres (possibly by 2690± metres) but only exceed this level in the basal 100± metres where they maximise at 2-/2- to 2.

The sediments above 2690± metres (possibly down to 2850± metres) are totally immature and, since their dominantly woody and coaly organic matter is immature, so are most of the sediments below this depth. Possible exceptions are the amorphous rich shales at 2797-2857± metres and 3457-3517± metres. However, on-structure these shales could only generate insignificantly minor volumes of liquids from the marginally mature amorphous-herbaceous fraction of their organic matter.

Mean vitrinite reflectance values range from 0.38% Ro up to a maximum of 1.37% although individual particles from 0.26% Ro up to 1.90% were measured. If mean reflectance values of less than approximately 0.35% , (due to bitumen) are ignored the remaining points, when plotted against depth, fall into two groups. The first group consists of data points between 0.55% Ro and 1.37% Ro (generally greater than 0.7%) which are randomly scattered throughout the section. This lack of trend against depth and the wide range of Ro values within a given vitrinite population clearly indicates that these measurements are based upon reworked material. The second group of mean Ro values defines a trend which passes through 0.38% Ro at 1000± metres and 0.49% at 3700± metres. This trend improves slightly if measurements on suspected bitumen and low reflectivity reworked material are excluded (e.g. at 2060-2090± metres, 2482-2497± metres and at 3397-3412± metres). The lowermost sample has a vitrinite population (four particles) with a mean Ro value of 0.44%. This value falls below the preferred trend (the other populations are either due to bitumen or to reworked organic matter) and because its appearance is atypical (possibly microscopic particles of coal dust) has not been considered.

The levels of thermal maturation from spore colouration and vitrinite reflectance measurements are in good agreement above 1900± metres. The correlation between the two methods is still reasonably good down to total depth although, due to the sparsity of good quality vitrinite (woody organic matter is largely reworked), maturation indices based upon spore colour are preferred below 1900± metres.

The maturation oil window is not penetrated in the analysed well section but is predicted (from available maturation data) to lie below 4000± metres.

D. SOURCE RICHNESS

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

Zones A to C generally have fair to good abundances of total light hydrocarbons. However, since source facies are sparse in Zone A and the cuttings gas analyses relatively poor, this "richness" is partially non indigenous. Similarly, in Zones D^1 and D^2 the light hydrocarbons are mainly contributed from the airspace (rather than the cuttings) which in view of their wet nature and the comparatively high abundance of C_5-C_7 hydrocarbons, suggests that they are largely non indigenous. A poor to fair rating, as suggested by the cuttings gas analyses, would appear to be more realistic. Zone E is rated as poor, possibly fair below 2960± metres. Zones F and G are, apparently, fair with good intervals at 3067-3112± metres, 3262-3277± metres, 3577-3607± metres and at 3637-3712± metres although the correlation between enhanced hydrocarbon abundances and gas wetness suggests that migrated species are also present.

Organic carbon values of (0.29%) 0.64 to 2.41% (average 1.3%) indicate a good source potential for Zone B, and for Zone C (0.62-2.60%) above 1640± metres. Below this depth, (in Zones C, D^1 and D^2) the sediments, with few exceptions, contain less than 0.63% (generally less than 0.5%) organic carbon. They are rated as poor source rocks although minor good shales (1.06-1.30% organic carbon) and thin coals are present between 2752± metres and 2857± metres. Apart from minor (good) shales at 3187-3217± metres Zones E and F are poor to fair source intervals. Potentially fair shales occur above 3517± metres in Zone G but the underlying sediments are generally poor source rocks with minor good shales at 3607-3637± metres and below 3697± metres.

Definitive assessments of source richness can be obtained from the C_{15+} hydrocarbon abundances. Between 124 ppm and 388 ppm C_{15+} hydrocarbons were extracted from selected mudstones and shales within Zones B and C. Although these values suggest fair and good source richness and the hydrocarbon to total extract ratios are relatively low, the paraffin-naphthene fraction chromatograms indicate that traces of contamination (possibly diesel) have augmented the indigenous hydrocarbons. The same is true of Zone D^1 above 2100± metres. Indigenous C_{15+} hydrocarbons are unlikely to exceed 150 ppm and an overall fair rating for Zones B-D^1 (above 2100± metres) would be more realistic. The sediments below 2100± metres in the analysed section yielded 211 to 6584 ppm C_{15+} hydrocarbons. However, the hydrocarbon to total extract ratios are high (50-94% generally in excess of 70%) for immature sediments and the richness must, therefore, be more indigenous. From the foregoing it is evident that the C_{15+} hydrocarbon data cannot be used for the evaluation of source richness.

Source richness, (at optimum maturation) may be determined by the pyrolysis technique. Pyrolysate yields measured by this method indicate good ratings for shales and mudstones represented by the analysed samples in Zones B and C. Zones D^1 to F are, apart from minor fair and good shales at 2030-2090± metres and 2797-2857± metres respectively, poor. Fair greyish brown and dark grey shales occur above 3517± metres and minor good shales at 3607-3630± metres in Zone G. Zone G is otherwise poor.

To summarise:

Source facies are sparse and possibly caved in Zone A.

The mudstones and shales in Zone B, and C above 1640± metres, are good potential source rocks for oil and gas.

Apart from minor fair shales at 2030-2120± metres, thin coals at 2752-2797± metres and minor good shales at 2797-2857± metres Zones C (below 1640± metres), D^1 and D^2 have a poor potential chiefly for gas.

Zones E and F are generally poor, with minor good shales at 3187-3202± metres and 3217-3232± metres.

Zone G contains fair (at 3457-3517± metres) and good (at 3607-3637± metres) shales which have a potential for oil and gas. The interval is otherwise rated as a poor source.

E. MIGRATED HYDROCARBONS

Potential reservoir facies are represented by sandstones between 800± metres and 980± metres and below 1160± metres in Zone B, by minor sands at 1220-1250± metres, 1310-1460± metres, 1580-1670± metres and at 1550-1580± metres in Zone C. Minor limestones occur at 2497-2542± metres, 2752-2842± metres, silts at 2707-2722± metres, at 2812-2842± metres and sandstones at 2857-2877± metres within Zone D^2. Reservoir facies, apart from a minor limestone at 3352-3367± metres, are (apparently) sparse in Zones E to G although it should be noted that the shales are occasionally silty or sandy in nature in Zones F and G. Unconsolidated sands are present throughout Zone A. They are, however, colourless and non fluorescent.

A faint blue fluorescence was detected in sandstone at 860-890± metres whilst the limestones at 2527-2542± metres, silts at 2707-2722± metres and limestones, silts and sands at 2812-2872± metres yielded a milky blue cut.

The abundance and wetness of the light hydrocarbons are sensitive indicators of migrated species. Zones A to C (above 1460± metres) contain fair to good abundances of dry gas but no gasoline range hydrocarbons. Within Zones D^1 to G the light hydrocarbons are

generally of fair abundance, becoming fair to good below 3000± metres. Not only are the gases wet to very wet but the C_5-C_7 fraction is also of fair to good abundance. The richest intervals occur at 1940-2300± metres (peaking at 2210-2240± metres), 3050-3112± metres, 3457-3577± metres (peaking at 3472-3502± metres), 3607-3637± metres and 3712-3718± metres with a kick at 3262-3277± metres. These data suggest possible shows of crude oil/condensate within Zones D1 to G but only of dry gas in Zones A to C.

C_{15+} hydrocarbons totalling 124-388 ppm were extracted from the mudstones and shales within Zones B and C. Low C_{15+} hydrocarbon to total extract ratios (23-30%) and dry C_1-C_4 hydrocarbons do not indicate migrated crude oil within this interval. This conclusion is supported by the C_{15+} paraffin-naphthene fraction chromatograms which correspond to a mixture of immature indigenous and contaminant (possibly diesel oil) hydrocarbons.

Light hydrocarbons are fairly abundant and wet at 1940-2030± metres. This richness does not, however, extend to the C_{15+} fraction (357 ppm hydrocarbons including contamination from the mud system) neither does the hydrocarbon to total extract ratio (22.7%) suggest migrated crude oil. From the foregoing it is inferred that wet gas or condensate and not crude oil is present within the interval.

This interval of enhanced light hydrocarbon abundance and gas wetness, suggesting further possible shows, extends down to 2300± metres (notably below 2150± metres). The presence of migrated hydrocarbons is supported by the abundance of the C_{15+} hydrocarbons (1338-1512 ppm) and by the hydrocarbon to total extract ratios which, at 59.4% to 82.6%, are relatively high for immature sediments. Chromatograms of these heavy hydrocarbons suggest a light crude oil has penetrated the shales although the front end bias and base line "hump" indicate that traces of contamination (such as diesel oil) are also present. Minor shows of the same light crude occur at 2390-2450± metres, 2467-2512± metres and 2617-2677± metres. Traces of this oil may be present in the intervening sediments although the relevant light hydrocarbon data reflect contributions from the mud system rather than the cuttings.

Light hydrocarbon data point to further intermittant shows between 2692± metres and 3718± metres. Combining this information with the C_{15+} hydrocarbon abundances (960-6584 ppm in the richer samples) the best shows evidently occur at 2797-2872± metres, 3037-3127± metres, 3472-3577± metres and 3607-3637± metres. The C_{15+} hydrocarbon to total extract ratios generally exceed 70% (consistent with non indigenous hydrocarbons) but the paraffin-naphthene chromatograms reveal that, in addition to a medium gravity crude oil, traces of contaminant hydrocarbons from the mud system are also present. Nevertheless the richer intervals listed above (particularly 3472-3577± metres) represent good shows of a medium gravity crude oil. This oil is mature and believed to be derived

from a source rich in amorphous and herbaceous organic matter. It also shares some of the source related characteristics of the light oil described above. The possibility of a geochemically similar source for the two oils is supported by the detailed C_4-C_7 hydrocarbon analyses which show little real variation over the analysed section. Suitable source organic matter is found in the shales and mudstones of Zones B and C and, possibly in the minor shales at 2797-2857± metres or at 3457-3517± metres and 3607-3637± metres in Zone G. These sediments are, however, fair to good and not rich source rocks and more important, are immature or just marginally mature on-structure. More mature and probably thicker, or richer, equivalents of these shales are the postulated source of the shows. The presence of two physically dissimilar but (apparently) geochemically related oils may be attributed to variations in migrational pathway.

F. CONCLUSIONS

Eight zones are recognised between 200 metres and 3718 metres in the 30/3-1 well.

Zone A (200-830± metres) largely consists of sands, shell debris and igneous material, with only minimal quantities of shales and carbonates. The minor shales are rich (14% organic carbon) but possibly caved at 686-710± metres and fair at 770-800± metres. Zone A evidently lacks effective source rocks and therefore has a negligible hydrocarbon potential.

Zone B (830-1310± metres) is composed of sandstones and mudstones, with igneous intrusives and minor coals, above 980± metres. Mudstones are generally dominant in the underlying sediments although further sandstone interbeds are present below 1160± metres. The coals (at 860-920± metres) are rich (26-37% organic carbon) and the mudstones generally good with values of 0.67-2.41%. Both contain land plant derived dominantly herbaceous and woody, with significant algal, organic matter. The sediments are immature on-structure and therefore incapable of realising their potential for oil and gas. The Zone B mudstones are a good but immature source for oil and gas.

Zone C (1310-1910± metres) is dominated by light grey shales, with darker grey interbeds below 1610± metres. Minor sands and (caved) mudstones are also present. The shales above 1640± metres resemble the Zone B mudstones in richness (0.97-2.60% organic carbon) and organic matter type (dominantly herbaceous and woody, with significant algal, kerogen). Below this depth the medium grey shales are fair (0.55-0.98% organic carbon) and the light grey shales poor (0.1 to 0.32% carbon) although in both the organic matter consists of a mixed algal, woody, coaly and herbaceous assemblage. The Zone C shales, above 1640± metres, are good source rocks for oil and gas but on-structure they are

immature and therefore unable to generate hydrocarbons. The underlying shales are fair with poor interbeds.

Zone D^1 (1910-2300± metres). Light grey (silty) shales and mudstones pass below 2180± metres to an interval dominated by (caved?) light bluish grey shaly mudstones. Minor pale brown shales occur intermittantly throughout the interval. They may be underrepresented in the samples below 2180± metres where caving is a problem. Above 2030± metres the light grey shales are lean (0.21-0.43% organic carbon) and resemble (organically) those in basal Zone C whereas the pale brown shales contain sparse (less than 0.52% organic carbon), largely reworked, woody and inertinitic debris. The underlying shales are also poor (less than 0.62% often less than 0.5% organic carbon) and this leanness is not enhanced by the fact that their dominantly woody and coaly, organic matter is largely reworked. Zone D^1 is thus rated as a poor immature source with a limited hydrocarbon potential (chiefly for gas).

Zone D^2 (2300-2887± metres). Light bluish grey mudstones (caved?) overlie at 2420± metres a medium grey shale unit which extends down to 2797± metres. Below this depth the shales are mainly medium grey-greenish grey in colour although significant yellowish brown interbeds occur at 2797-2857± metres. Minor limestones are present at 2497-2542± metres, siltstones at 2707-2722± metres, coals and limestones at 2752-2842± metres and a thin sand at 2857-2872± metres. The grey shales have uniformly poor to fair (0.35-0.62%) organic carbon contents and, only in the yellowish brown shales and coals do the values improve to 1.06-1.3% and 38% respectively. Reworked woody and coaly organic matter is, again, dominant and this means that the more abundant grey shales have a poor rather than fair potential (for gas and associated liquids). However, the yellowish brown shales have good contents of marginally mature, mainly amorphous, organic matter. These shales are only just starting to generate hydrocarbons and would need to be thicker and more mature to be prospective oil source rocks. Zone D^2 is, apart from minor oil prone shales at 2797-2857± metres and thin coals, a poor immature source (for gas and associated liquids).

Zone E (2887-3037± metres) is composed of medium grey mudstones (the greenish grey shales are believed to be caved) and, below 2947± metres, interbedded light grey and medium dark grey shales. Organic carbon contents range from 0.41% up to 0.73% (generally less than 0.5%) and the sparse, dominantly woody and coaly, organic matter is largely reworked and immature. The interval has a poor potential for gas (and oil).

Zone F lies between 3037± metres and 3457± metres. It consists mainly of medium grey-light grey shales, with darker grey shales at 3172-3292± metres and below 3382± metres. Lost circulation material was commonly found in the samples from the interval

3037-3212± metres. Apart from minor medium dark grey shales at 3187-3202± metres and 3217-3232± metres, containing 2.13% and 1.01% organic carbon, the shales are generally poor to fair with values of 0.34-0.71%. At 3337-3382± metres the lighter grey shales are somewhat leaner (0.18-0.31% organic carbon). Organically the shales resemble those in Zone E containing mainly reworked woody and coaly organic matter together with significant proportions of fresh algal and minor herbaceous kerogen. Since the immature woody-coaly organic matter is dominant it dictates the effective maturity of the sediments. This type of organic matter has a limited hydrocarbon potential (for gas and associated liquids) so that the shales should be more realistically rated as poor rather than poor to fair.

Hydrocarbon generation from the algal and herbaceous kerogen will be limited, by its sparsity and marginal maturity to insignificantly minor values of liquids. Zone F is, thus, effectively immature and has a strictly limited potential for gas and oil.

Zone G (3457-3718± metres) is largely composed of shales. They are generally light grey-brownish grey (with darker grey interbeds) but become darker in colour with increasing depth. Light grey mudstones are present at 3517-3637± metres. Organic carbon contents are generally fair (0.59-0.78%) in the shales above 3517± metres and in the underlying medium grey shales (0.40-0.77%) but improve significantly (2.93-3.06%) in the minor dark grey shales at 3607-3637± metres. The latter shales contain a mixed woody-herbaceous and algal (partially sapropelised) organic assemblage whereas those above 3517± metres have fair contents of amorphous and woody, or dominantly amorphous, kerogen, and minor algal, coaly and herbaceous organic matter. Largely reworked, woody and coaly, organic matter is otherwise dominant and herbaceous, algal and amorphous kerogen minor. The amorphous rich shales above 3517± metres are fair oil source rocks whilst the minor dark grey shales at 3607-3637± metres are good. The remaining shales are, due to the limited hydrocarbon potential of their organic matter, poor. Fair marginally mature shales occur above 3517± metres in Zone G. They are sufficiently mature on-structure to start generating minor volumes of liquids. Apart from minor good shales at 3607-3637± metres the underlying shales are poor source rocks.

The oil window corresponding to peak hydrocarbon generation is not penetrated in the analysed well section. By extrapolating the available maturation data it is predicted to lie below 4000± metres.

Traces of wet gas or condensate were detected at 1940-2030± metres.

A light crude oil has diffused into the shales and mudstones (occasionally silty or sandy) at 2030-2300± metres. The best shows are between 2150± metres and 2300± metres although further minor shows of the same oil are present at 2390-2450± metres,

2467-2512± metres and 2617-2677± metres.

Shows of a slightly heavier, medium gravity, oil were observed between 2692± metres and 3718± metres. The interval 3472-3577± metres is undoubtedly the richest and further shows occur at 2797-2872± metres, 3037-3127± metres and 3607-3632± metres.

Both types of oil are mature and believed to be derived from the same type of organic matter. Oil prone organic matter is present in the shales and mudstones within Zones B and C although they are immature on-structure. More mature, and preferably richer or thicker, equivalents of these sediments could act as a source for these migrated hydrocarbons.