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INTEGRATED PALYNOFACIES AN
SEDIMENTOLOGICAL CORE STUD
WELL 30/2–1

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Title

INTEGRATED PALYNOFACIES AND SEDIMENTOLOGICAL CORE STUDY, WELL 30/2–1

Project No.

1127b

Stratigraphers

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1. INTRODUCTION

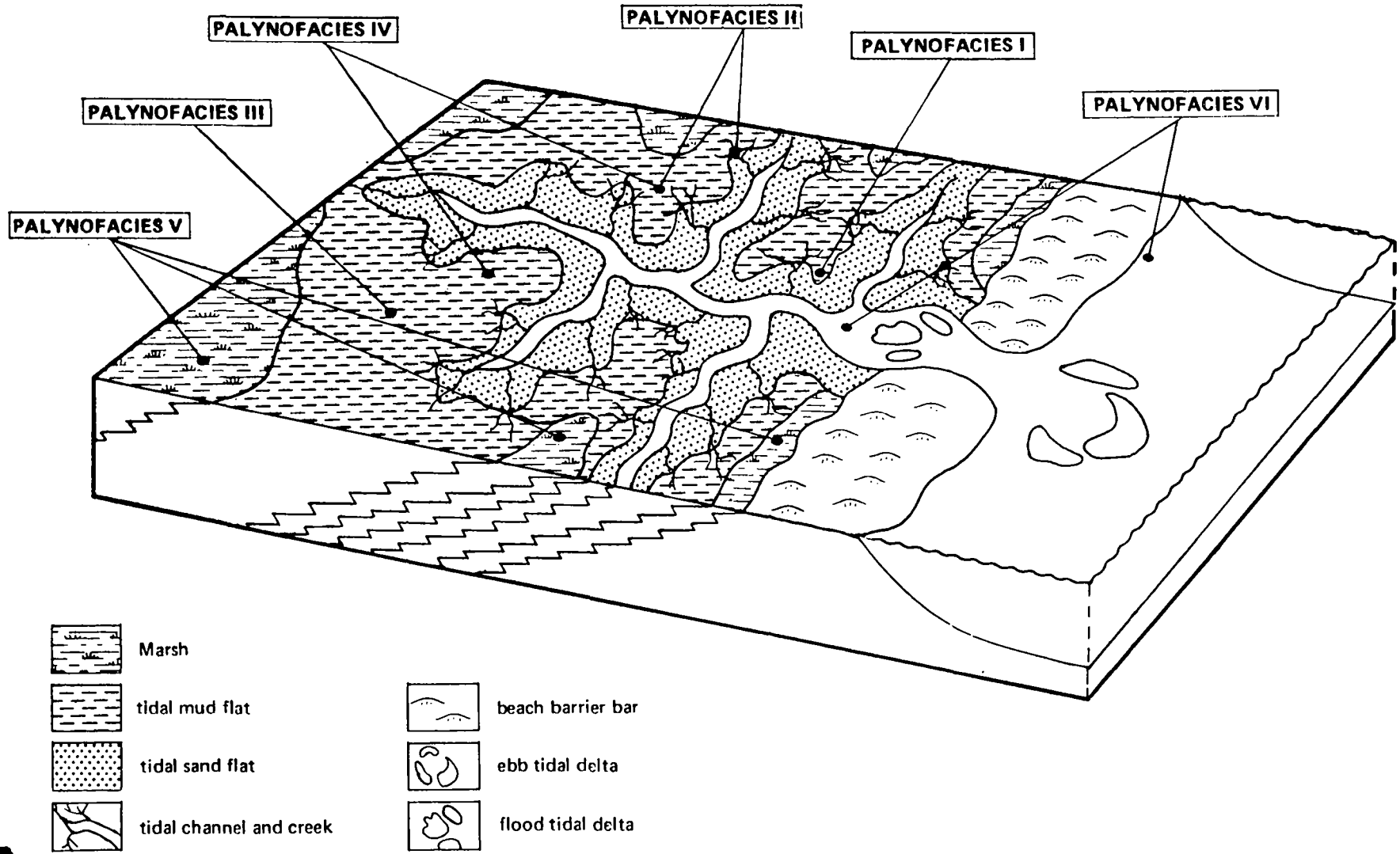
1.1 This report presents the results of an integrated palynofacies and sedimentological core study undertaken on Cores 3-11 from Well 30/2-1, drilled by Statoil in the North Sea.

1.2 Basic core analysis was undertaken by macroscopic examination of the slabbed core, supplemented by the examination of the core using a stereoscopic microscope; a 1:100 scale core log is presented (Enclosure 1).

1.3 Palynological analysis was undertaken on 23 samples to establish palynofacies and further supplement the sedimentological interpretation; a 1:100 scale palynofacies core log is presented (Enclosure 2).

DEPOSITIONAL MODEL
WELL 30/2–1

FIGURE 1



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2. OBJECTIVES

Determination of depositional environment is of utmost importance in understanding the geometry and distribution of reservoir sands. An understanding of paleoenvironments and in particular the geometry of sand bodies within the environment is important in basin evaluation; to improve exploration success and optimise recovery during the production stage.

Palynofacies analysis is a most useful aid particularly in the interpretation of the depositional environment of claystones which may be interbedded within a sandstone sequence and hence sampling within this study has been biased towards clay-rich facies. A precise knowledge of the depositional environment of claystones within a sequence provides an environmental framework for the more precise environmental interpretation of the interbedded sand bodies.

The integration of palynofacies and sedimentological analysis therefore provides a valuable tool in the identification of depositional environments especially within complex sequences such as the Middle Jurassic Brent Formation and enables a more accurate depositional model to be constructed.

The objectives of this integrated palynofacies and sedimentological study are to:

i) Produce a more accurate interpretation of the depositional environment of the sequence than could be produced by sedimentological analysis alone.

ii) Establish a series of standard palynofacies for the area; these could be used in subsequent core studies to enable more accurate correlation and prediction of paleoenvironments and in particular the geometry of the sands developed within these environments.

3. SUMMARY

The cored sequence has been interpreted to be of Middle Jurassic, earliest Bathonian to Bajocian in age, equivalent to the Ness, Etive and Rannoch Members of the Brent Formation and represents the deposits of coastal beach barrier bar and back-barrier tidal channel/creek, tidal flat and marsh deposits of a regressive mesotidal coast line (Figure 1).

Palynofacies analysis indicates that there is no major fresh water influence. The general paucity of marine microplankton and the general paucity and mixture of hinterland and locally derived miospores suggests that most of the sequence was deposited in a broad belt of tidal flats and channels/creeks some distance from either the marine and/or local parent floral source. The clastic supply does not appear to be derived directly from a hinterland fluvial source.

The cored sequence can be divided into three major genetic units as follows:-

3,696m-3,752.45m : This interval comprises interbedded coals, claystones, siltstones, sandstones and conglomerates deposited as a series of tidal flats and marsh dissected by migrating tidal channels and creeks. Palynofacies analysis enables the tidal flat claystones to be further divided with respect to their proximity to the marine source and local floral source.

Channel sands within the sequence contain no fresh to brackish water or marine indicators but are interpreted to be tidal due to their position within a framework of tidal flat claystone deposition.

3,752.45m-3,775m : This interval comprises an overall fining upwards sequence from conglomerates and sandstones into interbedded sandstones and silty claystones capped by a thick coal. This interval is interpreted to represent point bar deposits of a large-scale migrating tidal channel. The interbedded claystones and sandstones are interpreted to be point bar top or overbank tidal flat and marsh deposits. Palynofacies analysis of the claystones indicates deposition in a more proximal position relative to the marine source than the overlying interval and is compatible with an overall regressive model for the sequence.

The lack of palynomorphs within the channel sands reflects the high energy of the depositional environment, and the channel is interpreted to be tidal due to its setting within a framework of marine influenced tidal flat sedimentation.

3,775m-3,794.4m : This interval comprises sandstones overlying interbedded claystones and siltstones interpreted to have been deposited as a series of stacked beach barrier bars and back-barrier tidal flats. The lack of palynomorphs within the barrier beach sandstones reflects the high energy of the depositional environment.

4. CORE LOGS

4.1 A 1:100 scale core log and palynofacies core log of the sequence are presented (Enclosures 1 and 2). The core logs are self explanatory and the following parameters have been logged as a continuous graphic profile:-

Lithology
Grain size
Sorting
Degree of induration

Other parameters logged are:-

Bioturbation
Sedimentary structures and bed base type
Paleontological characteristics (fauna and flora observed macroscopically)
Accessory minerals
Main cements and other porosity/permeability affecting factors
Physical structures (fractures, slickensiding etc)

Palynological data logged on the palynofacies log includes:-
The following kerogen types:-
Inertinite/Vitrinite (Undifferentiated brown and black wood)
Vitrinite (brown wood)
Exinite/Cutinite (including spores and pollen)
Amorphous sapropel
Amorphous sapropel/degraded Inertinite/Vitrinite (Undifferentiated)

Kerogen sorting

Most frequently occurring spores (locally derived palynomorphs) and pollen (hinterland palynomorphs)
Microplankton
Species diversity

Interpretative data presented includes:-

Age
Facies, palynofacies and facies relationships
Trend (lithological and or environmental)
Environment

4.2 All depths quoted in this report are those recorded on the centre stick of the slabbed core and are in metres. However, Cores 9, 10 and 11 have been mislabelled and log depth from 3,751.9m is 40cm greater than the depth indicated on the core.

5. STRATIGRAPHY

The stratigraphic terminology utilised within this report follows that used within Paleoservices Ltd. Report No. 997.

The cored sequence is interpreted to be Middle Jurassic, earliest Bathonian to Bajocian in age and equivalent to the Brent Formation (Paleoservices Ltd. Report No. 997). The Ness Member (3,696m-3,760.9m) comprises interbedded coals, claystones, siltstones and conglomerates. The Etive Member (3,760.9m-3,775m) and Rannoch Members (3,775m-3,794.4m) comprise sandstones and minor conglomerate and claystones.

6. LITHOFACIES

6.1 Introduction

The cored sequence has been interpreted to represent coastal beach barrier bar and back-barrier deposits of a mesotidal coast line. Coastal beach barrier bar, tidal channel and creek, tidal flat and marsh environments have been identified (Figure 1).

The cored sequence can be divided into three major genetic units.

3,696m-3,752.45m (Ness Member)

This interval comprises interbedded coals, claystones, siltstones, sandstones and conglomerates interpreted to have been deposited as a series of back-barrier tidal flats and marsh dissected by migrating tidal channels and creeks.

3,752.45m-3,775m (Etive-Ness Member)

An overall fining upwards can be recognised within the interval 3,760.90m-3,775m from conglomerate through pebbly sandstone into sandstone, which is interpreted to represent lateral accretion point bar (?) deposits of a large migrating tidal channel. The overlying interval 3,752.45m-3,760.90m comprises an interbedded sandstone, silty sandstone and silty claystone sequence which is capped by a thick coal, and is interpreted to represent point bar top and/or overbank tidal flat and marsh deposits.

3,775m-3,794.40m (Rannoch Member)

This interval comprises a thick sandstone overlying an interbedded silty claystone/siltstone sequence. The sandstones are interpreted to represent a series of stacked coastal beach barrier/bar complexes and the underlying silty claystones to be back-barrier lagoonal/tidal flat deposits of an older coastal beach barrier bar.

6.2 Lithofacies

The cored sequence has been divided into 37 sedimentary units which comprise 9 sedimentary facies. The sequence is discussed with respect to these facies: See Enclosure 1 for distribution of these facies and sedimentary units and Figure 2 for the main characteristics of the palynofacies.

Facies A (Sedimentary Unit 34)

Main Characteristics:

Sandstone, reddish brown, moderately to well indurated, micaceous, well sorted, vfU-fL, common white 'matrix' clay, very minor visible porosity, planar bedded to low angle planar cross-stratified, red claystone flakes and darker clay-rich laminae, erosional basal contact with underlying facies B.

Environment:

Coastal beach barrier bar complex; an upper shoreface to lower foreshore environment is suggested by the low angle planar cross-stratification typical of a beach profile.

Palynofacies:

Palynofacies VI. Only one sample was analysed from this facies. The absence of palynomorphs within this facies reflects the high energy of the depositional environment, with fine grained palynomorphs and sediment being winnowed from the sandstone.

Factors Affecting Porosity and Permeability:

Porosity within this facies is low due to the abundance of "matrix" clay. The clay is unlikely to be detrital in such a high energy deposit and probably represents a later diagenetic precipitation.

Facies B (Sedimentary Units 34 and 36)

Main Characteristics:

Sandstone, reddish brown, moderately to well indurated, micaceous, well sorted, vfU-fL, common white 'matrix' clay and 'titer' darker red clay-rich laminae, low visible porosity, trough cross-stratified to planar bedded, coal and wood fragments up to 2cm across, rare siderite nodules, internal erosional surfaces common.

Environment:

Coastal beach barrier bar complex; lower to middle to upper shoreface. The presence of several internal erosional surfaces and a thin claystone bed (facies G?) suggests that this facies may be a stacked sequence.

Palynofacies:

No samples were analysed from this facies, but it is suggested that it would contain a similar palynofacies type to that found in Facies A.

Factors Affecting Porosity and Permeability:

As Facies A, the development of siderite nodules locally produces 'tite' zones.

Comments:

Shoreface deposits are characteristically intensely bioturbated. However, the general lack of bioturbation within this facies may reflect high depositional energy.

Facies C (Sedimentary Units 4, 5, 11, 13, 16 17, 19, 21, 27 and 33)

Main Characteristics:

Sandstone, reddish brown, well indurated, micaceous, moderately to well sorted, vfU-vfL, locally vfU-mL, vfU-ucU, some units fine upwards into siltstone/ claystone. White "matrix" clay common within some beds, rare syntaxial quartz overgrowths, some visible porosity. Wood fragments and leaves common. Horizontal laminated to ripple laminated to trough cross-stratified, rare herringbone planar cross-stratification, basal contacts commonly sharp and erosional. Minor soft sediment folding and slumping, very rare stylolities, rare open fractures and micro-faults. Commonly forms part of fining upwards cycles with facies D, E, F, G, H and I.

Environment:

Tidal channel and creek sands. The presence of fining upwards cycles suggests channel deposition. Tidal influences are suggested by the rare herring-bone cross-stratification and the association with tidal flats. However, palynofacies does not suggest any marine influence (see below).

Palynofacies:

Palynofacies II. Only one sample has been analysed from this facies which contains a mixture of hinterland and locally derived miospores. The absence of marine indicators may suggest that the channel sands are fluviatile as opposed to tidal. However, no fresh to brackish water indicators occur within this palynofacies either.

The presence of marine indicators within the interbedded claystones and silty claystones interpreted to be tidal flat deposits indicates that there was some saline influence. The channels must have acted as the major conduits for introduction of sediment onto the tidal flats and this implies that the channels are tidally influenced to some degree.

Factors Affecting Porosity and Permeability:

This facies has the best overall poroperm characteristics within the sequence. Porosity has been locally reduced by clay authigenesis, development of syntaxial quartz overgrowths and rare calcite cement.

Facies D (Sedimentary Unit 33)

Main Characteristics:

Pebbly sandstone, reddish brown, micaceous, poorly sorted, mL-cL-pebble, clasts of quartzite/sandstone up to 7mm across, abundant white "matrix" clay, minor calcite cement, rare syntaxial quartz overgrowths, some visible porosity, massive to vague horizontal bedding, locally slumped?

Environment:

Tidal channel sands. This facies forms part of an overall (3,760.9m-3,775m) fining upwards sequence with facies C and E, interpreted to represent the deposits of a migrating large scale tidal channel.

Palynofacies:

Palynofacies V I, the limited assemblage of palynomorphs which contained only rare locally derived Cyathidites spp. within this facies probably reflects the high depositional energy with fine grained sediment and palynomorphs being winnowed from the sands.

Factors Affecting Porosity and Permeability:

Porosity and permeability is generally lower within this facies than in facies C due to the more abundant authigenic (?) clay, calcite cement and rare syntaxial quartz overgrowths.

Facies E (Sedimentary Units 11, 13, 16 and 33)

Main Characteristics:

Conglomerate, reddish brown, well indurated, micaceous, poorly sorted, vfU-pebble, clast supported, commonly forms the base of a fining upwards cycle, planar cross-stratified to trough cross-stratified to planar bedded, within some units the clasts are imbricated, clasts of quartztite/sandstone, claystone and wood fragments, rare to common clay matrix, rare syntaxial quartz overgrowths, some visible porosity. Pyrite common within some units.

Environment:

Tidal channel/creek lag deposit. This facies occurs associated with facies C and D as the base of fining upwards channel deposits.

Palynofacies:

Due to the coarse lithology it was considered unlikely that any palynomorphs would be recovered so no samples were analysed from this facies.

Factors Affecting Porosity and Permeability:

This facies has some visible porosity, however, the poorly sorted nature and locally abundant "matrix" clay has reduced porosity within some units.

Facies F (Sedimentary Units 3, 7, 8, 12,17, 25, 26 and 32)

Main Characteristics:

Silty sandstone to sandstone, reddish brown, moderately to well indurated, poorly to moderately sorted silt-vfU, locally well sorted vfL-vfU, some units contain abundant eroded clay flakes. Horizontal laminated to ripple laminated, locally intensely bioturbated with subvertical burrows generally less than 3cm long. Commonly occurs as beds up to 50cm thick interbedded with facies G.

Environment:

Tidal sand flat to mixed tidal sand/mud flat; low to middle intertidal flat. The presence of clay flakes is interpreted to represent erosion of tidal mud flat claystone.

Palynofacies:

No samples were analysed from this facies.

Factors Affecting Porosity and Permeability:

This facies has virtually no visible porosity, porosity being reduced due to the poorly sorted nature of most of this facies. However, porosity would be higher in the better sorted sands.

Facies G (Sedimentary Units 3, 6, 12, 17, 18, 22, 24 26, 28,32, 35 and 37)

Main Characteristics:

Claystone to silty claystone, reddish brown grey, poorly to well indurated, horizontal laminated to wavy laminated to lenticular bedded with ripple laminated sand/silt lenses and interlamination of clay, silt and locally sand. Abundant bioturbation, subvertical dwelling and escape burrows up to 3cm in length, drifted wood and leaves common, locally rooted. Soft sediment deformation is common with ball and pillow structures and loaded basal contacts. This facies is often interbedded with facies F.

Environment:

Tidal mud flat, locally mixed tidal mud/sand flat; middle to high intertidal flat (marsh).

The presence of lenticular bedding within this facies indicates deposition under fluctuating energy conditions and suggests a tidal influence.

Palynofacies:

Palynofacies I, II, III and IV. The presence of marine microplankton within some units and the lack of fresh/brackish water indicators suggest that these are marine influenced and supports the interpretation of a tidal flat origin.

On the basis of the palynofacies it is possible to further refine the environmental interpretation on the basis of relative position to:

i) marine palynomorph source

ii) "local" marsh palynomorph source.

Factors Affecting Porosity and Permeability:

This unit has no visible porosity and is essentially 'tite', it will act as a permeability barrier to vertical flow.

Facies H (Sedimentary Units 2, 6, 10, 14, 15, 18, 23, 29 and 31)

Main Characteristics:

Claystone, locally silty claystone to sandy siltstone, medium grey to dark grey to reddish brown, moderately to well indurated, rooted, abundant wood fragments and leaves.

Environment:

Marsh - seat earth. This facies is usually developed beneath a coal and in some cases appears to have overprinted tidal sand/mud flat sediments and represents soils developed on the highest parts of the mud flats.

Palynofacies:

Palynofacies V. One sample was analysed from this facies and the paucity of the miospores probably reflects degradation of the palynomorphs by soil processes.

Factors Affecting Porosity and Permeability:

This unit is essentially 'tite' and will act as a permeability barrier to vertical flow.

Facies I (Sedimentary Units 1, 8, 15, 20 and 31)

Main Characteristics:

Coal, black, poorly indurated, humic (?).

Environment:

Marsh.

Palynofacies:

Due to the restriction on sampling no samples were analysed from the coals as their depositional environment was readily discernable. However, in future studies it may be useful to analyse coals to give an insight into the local floral assemblage.

Factors Affecting Porosity and Permeability:

This facies may locally act as a permeability barrier to vertical flow.

6.3 Reservoir Properties and Sand Development

The thickest development of sand within the cored sequence occurs within the interval 3,760.90m-3,780.13m interpreted to have been deposited as beach barrier bar and tidal channel sands. However, poroperm characteristics within the sands are poor due to the development of authigenic clay, rare syntaxial quartz overgrowths and minor calcite cement. The interbedded claystone beds and laminae within the sands will act locally as vertical permeability barriers.

Sandstones within the interval 3,696m-3,760.9m have the best overall porosity within the cored sequence and are interpreted to be mainly tidal channel and creek deposits. Sand body development by the migrating tidal channels and sands is thin but likely to be laterally persistent. The sandstones are separated by tidal flat and marsh claystones which will act as vertical permeability barriers and hence the relatively thin sandstones may not be well interconnected.

7. PALYNOFACIES

7.1 Introduction

During the detailed sedimentological logging of Cores 3-11 in Well 30/2-1, a total of twenty-three samples were collected for palynofacies analysis. These samples were prepared and analysed using a standard quantitative approach.

The organic content of the samples have been divided into five different kerogen types as follows:-

a) Inertinite/vitrinite which is undifferentiated brown and black wood.

b) Vitrinite which is brown wood.

c) Exinite/cutinite which includes the terrestrial spore and pollen grains and the marine micro-plankton.

d) Amorphous sapropel.

e) Undifferentiated amorphous sapropel and degraded inertinite/vitrinite.

The kerogen is graphically plotted on a Palynofacies Log (Enclosure 2).

Only the most frequently occurring terrestrially derived species of miospores are included on the Palynofacies Log.

The terrestrially derived palynomorphs can be divided into two types: spores, which are considered to be locally derived such as Cyathidites spp. and pollen which partially indicates a hinterland source e.g. bisaccate pollen.

The marine derived microplankton shown on the Palynofacies Log comprises the dinoflagellate cysts Nannoceratopsis gracilis and N. triceras, together with acanthomorphic acritarchs. The fresh to brackish water indicator Botryococcus sp. was not recorded in any of the assemblages from this study although it may constitute a common componentof Brent assemblages elsewhere (see Parry 1981).

In general the samples contained low yields of palynomorphs with moderate to poor species diversity. The marine influence where it is recorded is only slight with very rare microplankton present. The samples in general contain a mixture of fine to coarse grained organic material which is poorly to moderately sorted. The fine grained organic particles suggest low energy environments. Slight differences in environments may be indicated by the degree of sorting within this general low energy regime.

Using the criteria of kerogen types and sorting, species diversity, relative proportions of spore/pollen types and presence or absence of marine indicators, six palynofacies assemblages are recognised. The main characteristics of these palynofacies types is shown in Figure 2. However, because of the low palynomorph yield and the general similarities between most of the samples, these palynofacies assemblages are tentative but may be corroborated in future work.

The sample at 3,696.6m was not included in this study when after preparation it was found to be contaminated with Cretaceous palynomorphs.

7.2 Palynofacies Types

In this section the palynofacies types recognised are defined, their distribution is described and any significant environmental indicators are noted.

Palynofacies Type I

Main Characteristics:

This palynofacies type contains the following association of moderately sorted kerogen. Abundant inertinite/vitrinite, very common to abundant vitrinite, rare to common exinite/cutinite and occasional traces of amorphous sapropel.

Species diversity is moderate to good, with the terrestrial taxa, bisaccate pollen and Cyathidites spp. generally the dominant palynomorphs. Rare marine microplankton also occur.

Variations:

The sample at 3,715.3m contains a similar assemblage to those in this palynofacies type but differs in the percentage of the kerogen types with very common inertinite/vitrinite and common vitrinite.

Distribution:

This palynofacies type is recognised in the following samples:-

3,699.35m, 3,746.6m, 3,751.45m, 3,755.55m, 3,760.83m and 3,765.45m.

Significant Environmental Indicators:

The presence of rare specimens of Nannoceratopsis gracilis triceras and acritarchs throughout the palynofacies, indicates a slight saline influence. There is a stronger marine influence in the sample at 3,751.45m. The locally derived trilete fern spores such as Cyathidites spp. and Lycopodium-sporites spp. are generally more common that the hinterland miospores, e.g. bisaccate pollen, in the samples down to 3,751.45m, probably indicating a higher proportion of locally derived marsh palynomorphs in the sediments. The remaining samples between 3,755.55m and 3,765.45m show a slightly decreased local input with a greater percentage of transported hinterland taxa. This suggests that the samples in this palynofacies at and below 3,775.55m are slightly more distant from the local palynomorph source than those above. However, the general sparcity of all palynomorphs suggests a distal environment from the parent floras.

The moderate sorting of the kerogen types is also consistent with a distal environment from the marsh source, where there is possibly more tidal activity.

Associated Sedimentary Facies:

This palynofacies is associated with sedimentary facies G, commonly interbedded with F and H facies.

Palynofacies Type II

Main Characteristics:

Palynofacies type II is very similar to Palynofacies Type I, but is distinguished by the absence of any microplankton. This palynofacies contains moderately sorted kerogen types, with abundant inertinite/vitrinite, very common to abundant vitrinite and rare to common exinite/cutinite.

Species diversity is moderate with a mixture of hinterland and locally derived fern spores. There is a slightly higher percentage of fern spores to hinterland taxa. Of hinterland components, bisaccate pollen dominate while Cyathidites spp., Baculatisporites/Osmundacidites spp. and Lycopodium-sporites spp. are the main locally derived elements. No microplankton is recorded.

Distribution:

Palynofacies Type II is present in the following samples:-

3,724.4m, 3,725.6m and 3,786.75m.

Significant Environmental Indicators:

As in Palynofacies Type I, the general sparcity of all palynomorphs suggests a depositional environment at some distance from the parent floras.

There is a slightly higher amount of locally derived miospores to hinterland types probably indicating a higher input of palynomorphs from the local floras than those washed in from more distal environments and possibly suggesting more local sourcing than palynofacies Type I. The moderate sorting of the kerogen types suggests wave or current activity and the absence of any marine indicators may just reflect the overall very slight marine influence on the palynomorph assemblages in this area and not a total absence of marine conditions. The absence of Botryococcus sp. suggests that there is no fresh to brackish water feeding the sediments.

Associated Sedimentary Facies:

This palynofacies type is associated with the following sedimentary facies: C, G and H.

Palynofacies Type III

Main Characteristics:

This palynofacies type contains poorly sorted kerogen types, with very common to abundant inertinite/vitrinite, common to abundant vitrinite, rare to common exinite/cutinite and occasional trace of amorphous sapropel.

Species diversity is moderate, with the fern spores Cyathidites spp. and the hinterland element bisaccate pollen the dominant taxa. No microplankton is present.

Variations:

The samples at 3,730.5m and 3,790.15m contain similar kerogen types but differ by having a poor species diversity. The sample at 3,750.5m contains a mixture of hinterland and locally derived miospores. In the sample at 3,790.15m rare microplankton were recorded which indicates a slight marine influence.

Distribution:

Palynofacies Type III is present in the following samples:-

3,734m, 3,739.5m, 3,743.55m and 3,793.7m.

Significant Environment Indicators:

Within the samples from palynofacies Type III there is a general decrease downhole in the proportion of locally derived fern spores compared to the hinterland taxa washed into the depositional environment, possibly suggesting the distance from

source increases downhole. The sample at 3,734m is dominated by the fern spores Cyathidites spp., Lycopodiumsporites spp., and Baculatisporites/Osmundacidites spp., with rare bisaccate pollen compared to the sample at 3,793.7m where there are only rare fern spores but common bisaccate pollen.

The poorly sorted assemblages are consistent with a low energy regime which may suggest an environment some distance from major tidal influences.

No marine or fresh to brackish water influences were recorded in this facies.

Associated Sedimentary Facies:

This palynofacies type is associated with the following sedimentary facies: G and G/H.

Palynofacies Type IV

Main Characteristics:

This palynofacies type contains moderately sorted kerogen types including abundant inertinite/vitrinite and abundant vitrinite with rare exinite/cutinite.

Species diversity is poor with Cyathidites spp. and bisaccate pollen the dominant taxa. No microplankton is recorded.

Variations:

The sample at 3,790.1m differs from the normal palynofacies type by containing lower percentages of kerogen types with very common inertinite/vitrinite and rare vitrinite. A very low species diversity is present. This difference may be caused by a slightly higher energy environment which has winnowed out a lot of the organic matter.

Distribution:

This palynofacies type is found in the two samples at 3,704.9m and 3,749.7m.

Significant Environmental Indicators:

The two assemblages show a mixture of both locally derived and hinterland miospores suggesting deposition some distance from source. The moderate sorting may indicate some current or wave activity, again suggesting deposition some distance from source.

No marine or fresh to brackish water indicators were recorded.

Associated Sedimentary Facies:

This palynofacies type is associated with the following sedimentary facies:G and G/H.

Palynofacies Type V

Main Characteristics:

The main components of this palynofacies type are poorly sorted kerogen types with abundant inertinite/vitrinite, very common vitrinite and rare exinite/cutinite.

Species diversity is poor with only the locally derived fern spore Cyathidites spp. present. No microplankton is recorded.

Distribution:

This palynofacies type is found in the sample at 3,706.65m.

Significant Environmental Indicators:

Numerous rootlets were recorded during the sedimentary logging which would suggest the presence of an in-situ flora.

The presence of very few specimens of Cyathidites spp. may reflect the action of soil processes which have broken down the palynomorphs.

No marine or fresh/brackish water influences were recorded.

Associated Sedimentary Facies:

This palynofacies is associated with sedimentary facies H.

Palynofacies Type VI

Main Characteristics:

This palynofacies contains ?poorly sorted kerogen types dominated by waxy amorphous sapropel with rare inertinite/vitrinite and rare exinite/cutinite.

Species diversity is very poor with only Cyathidites spp. present in the sample at 3,771.86m.

Distribution:

This palynofacies type is present in the samples at 3,771.86m and 3,776.22m.

Significant Environmental Indicators:

The waxy amorphous sapropel is probably a residual hydrocarbon artifact which was introduced after deposition and burial of the sediments.

The presence of only rare in-situ kerogen suggests that the depositional environment is high energy and most of the kerogen and palynomorphs have been winnowed out of the sediments.

No marine or fresh/brackish water influences are recorded in the two assemblages.

Associated Sedimentary Facies:

This palynofacies type is associated with the following sedimentary facies: A and D.

8. DISCUSSION

The cored sequence has been interpreted to represent coastal beach barrier bar and back-barrier tidal channel/creek, tidal flat and marsh deposits of a mesotidal coast line.

Palynological analysis was undertaken mainly on claystones and silty claystones and six palynofacies have been identified on the basis of kerogen types and sorting, species diversity, relative proportions of spore/pollen types and presence or absence of microplankton.

Palynofacies analysis indicates that there was no major fresh to brackish water influence and supports the sedimentological interpretation that the clastic supply was tide dominated. The general paucity of marine microplankton suggests that most of the sequence was deposited in a broad belt of tidal flats/creeks where marine influence on palynomorph assemblages was weak. However, the general sparsity and mixture of hinterland and locally derived palynomorphs suggests a depositional environment some distance from the parent floras.

Palynofacies analysis may suggest that there is an overall decrease in marine influence towards the top of the sequence. Palynofacies I becomes the dominant palynofacies within the claystones of the interval 3,752.45m-3,775m and an assemblage which is similar to palynofacies III contains rare marine indicators within the claystone of the interval 3,775m-3,794.4m. This supports an overall regressive model for the sequence.

The general sparsity of palynomorphs and similarly of palynofacies types in this study is in marked contrast to that found in the more typical deltaic Brent sequences (see Parry 1981). Parry was able to recognise palynofacies types from the fluvial regime through to the delta front. The absence of Parry's palynofacies types in Well 30/2-1 highlights the difference in depositional environments between a tidal flat mesotidal coast line and a deltaic influenced coast line.

The cored sequence is discussed with regard to the three genetic units outlined in section 5.1.

3,696m-3,752.45m

This interval comprises relatively thin tidal creek/channel sandstones, separated by tidal flat and marsh sandstones, siltstones, claystones and coals.

Palynofacies analysis was undertaken mainly on claystones and silty claystones from sedimentary facies G, interpreted to be tidal flat deposits. Palynofacies I, II, III and IV have been identified from this facies. On the basis of the palynofacies, it is possible to further refine the environmental interpretation, on the basis of the position relative to:

i) the marine palynomorph source.

ii) the 'local' marsh palynomorph source.

Palynofacies I contains rare marine indicators and is interpreted as reflecting tidal flats deposited in a more proximal position relative to the marine source than palynofacies II, III and IV. Palynofacies III has a greater abundance of locally derived palynomorphs than palynofacies II and IV which might reflect tidal flats deposited in a more proximal position relative to the local marsh source, and hence may be closer to the more extensive inland marsh development.

One seat earth claystone from this interval was analysed and is classified as palynofacies V. The paucity of miospores is interpreted to reflect degradation of palynomorphs by soil processes.

Sedimentary structures within the channel and creek sands rarely provide evidence for tidal influence. Palynological analysis of one sandstone sample was undertaken and this was classified as palynofacies II, which lacks marine indicators. However, the channel/creek sandstones occur within a framework of tidal flat deposits that contain marine indicators. The channels must have acted as the conduits for transport of the marine organisms deposited upon the tidal flats and hence must have been tidally influenced. The absence of marine microplankton within the sandstones is more likely to reflect the high energy of the environment.

3,752.45m-3,775m

This interval comprises an overall fining upwards interpreted to be a channel point bar sequence. Point bars can occur in both meandering river and tidal channels.

The channel sands have been classified as palynofacies VI, which contains no brackish to fresh water or marine indicators. However, the claystones within the interbedded sandstone/ silty claystone point bar top/overbank deposits and a thin claystone within the channel sandstones all yield kerogen assemblages typical of palynofacies I, which contains marine indicators, which supports the sedimentological interpretation that they are tidal flats. It is therefore feasible that the channel sandstones are tidal in origin and the lack of marine microplankton and palynomorphs in general reflects the high energy of the channel environment, with the fine grained palynomorphs only being deposited within low energy environments.

The predominance of palynofacies I within the tidal flat sediments suggests that deposition occurred in a more proximal position relative to the marine source than the overlying unit and is compatible with an overall regressive model for the sequence. However, proximity need not necessarily be to the sea but to a major tidal channel/inlet.

3,775m-3,794.4m

This interval comprises coastal beach barrier bar sandstones overlying back-barrier tidal flat claystones and siltstones.

The beach/barrier sandstones have been classified as palynofacies VI and the lack of palynomorphs is thought to reflect the high energy of the depositional environment.

Palynofacies III and IV occur within the claystones and siltstones. An assemblage similar to palynofacies III within this interval contains rare marine microplankton unlike palynofacies III in the overlying intervals, possibly reflecting deposition in a more proximal position relative to the marine source, but the marine influence is very weak.

9. REFERENCES

PARRY, C.C., 1981. Integration of palynological and sedimentological methods in facies analysis of the Brent Formation. In Petroleum Geology of the continental shelf of North-West Europe, pp.205-215.