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ROBERTSON RESEARCH INTERNATIONAL LIMITED

OILFIELDS REPORT NO. 2168

THE BIOSTRATIGRAPHY OF THE INTERVAL
1620' - 9500' FROM THE MOBIL NORWAY 33/12-4
NORWEGIAN NORTH SEA WELL

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Project No. IIA/756/1218

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SUMMARY

The oldest rocks penetrated in this well consist of red, green and yellow-brown shales and sandstones of Triassic age. These sediments were laid down in an arid continental and/or a marginal marine environment.

The succeeding Lower Jurassic (late Sinemurian - Carixian and Domerian) shales and silty shales were deposited in a nearshore shallow marine environment. No evidence for the Rhaetian, Hettangian and early Sinemurian has been found at the base of the Jurassic. In addition sediments of Toarcian age appear to be absent at the top of the Lower Jurassic. It is probable that the stratigraphic breaks at the top and bottom of the Lower Jurassic interval are not purely due to erosion, but may involve faulting.

The sands of the Middle Jurassic (Bajocian - early Bathonian and Bathonian) rest on the Lower Jurassic and are considered to have been laid down in a nearshore shallow marine environment influenced by some deltaic run off. A major unconformity follows the Middle Jurassic with Volgian sediments resting directly upon the Bathonian. The Callovian, Oxfordian and Kimmeridgian are all apparently absent. The dark grey shales of the Volgian were deposited in a restricted inner sublittoral environment.

A further stratigraphic hiatus marks the Upper Jurassic - Lower Cretaceous boundary with the Barremian resting directly on the Volgian. The Barremian and Aptian - early Albian units consist of red and white chalk laid down in an inner sublittoral environment. Upper Cretaceous sediments of

Coniacian - Maastrichtian age lie unconformably upon the Lower Cretaceous, the Cenomanian and Turonian stages being absent. The interval assigned to the Upper Cretaceous consists of a reasonably uniform sequence of shales laid down in an outer sublittoral - bathyal environment.

The absence of the Danian suggests that the Tertiary lies unconformably upon the Cretaceous. The Tertiary sediments range in age from Palaeocene to Pliocene and were initially (Palaeocene to early Oligocene) laid down in a deep water, outer sublittoral - bathyal, environment. The clays and shales of the Palaeocene, Palaeocene - Lower Eocene and Eocene intervals persist throughout the Oligocene, although at the top of the Oligocene glauconitic shales and clays are prominent. This change is a reflection of the environment which in later Oligocene to Middle Miocene times shallows to outer sublittoral depths. Further shallowing took place in the Upper Miocene - Pliocene with the shales and clays being deposited in a general sublittoral environment.

II

INTRODUCTION

This report summarises the results of the micropalaeontological, palynological and stratigraphical analyses which have been carried out on material received from the interval 1620' - 9500' from the 33/12-4 Norwegian North Sea Well under Project No. IIA/756/1218.

Under this project a total of 511 ditch cuttings, 21 core samples and 14 sidewall cores was analysed utilising standard micropalaeontological techniques. In addition 9 composited ditch cuttings, 20 core and 25 sidewall core samples covering the interval 8630' - 9500' were treated palynologically.

A summary of the determinations obtained by these analyses has already been communicated by telex and telephone and forms the framework of factual information on which this report is based. A summary of the sequence penetrated in this well can be seen in Table 1.

The terminology adopted for the environmental conclusions follows that of Hedgpeth (1957) from which Table 2 of this report is taken.

The Jurassic biostratigraphic units used in this report are those proposed in our recent study - "The Jurassic of Northwest Europe-Offshore". Their stratigraphical significance is summarized in Table 3.

The prepared samples and recorded information are now filed and curated in the confidential records section of these laboratories.

We wish to acknowledge the continued co-operation and assistance received from the various members of Mobil Exploration Norway Inc. with whom we have been associated during the course of this work.

III

SUCCESSION

2586 133
 7500
 7500
 62500

TABLE 1

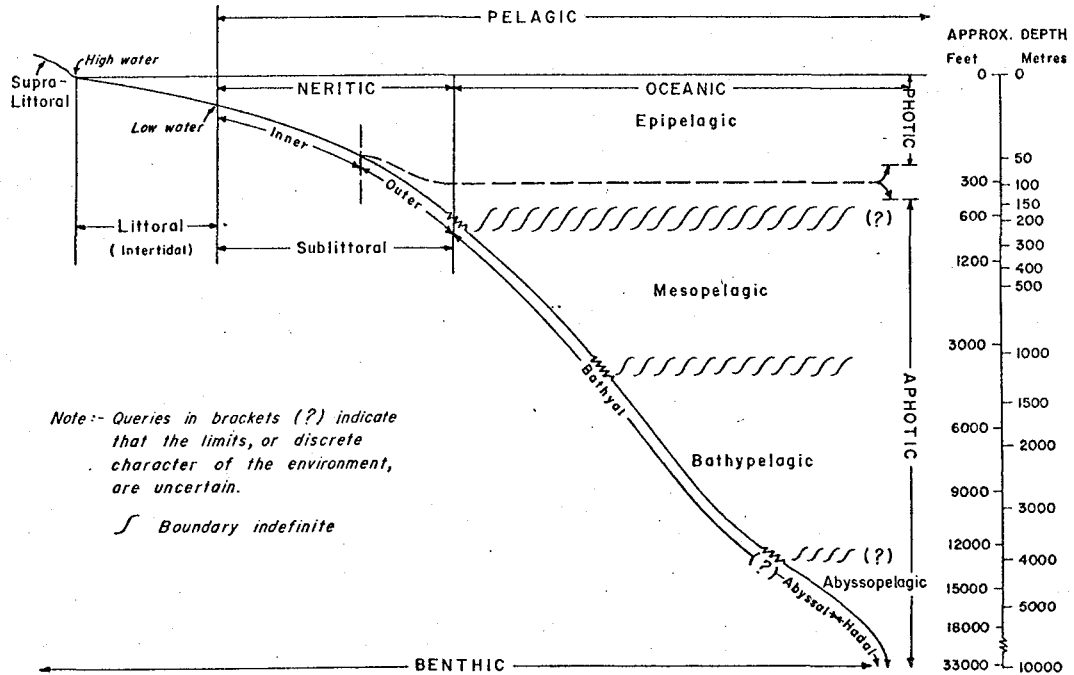
<u>Interval</u>	<u>Thickness</u>	<u>Stage</u>	<u>System/Subsystem</u>
1620' - 1740'	+ 120'	-	Upper Miocene
1760' - 2500'	+ 740'	-	Middle Miocene
2520' - 3040'	+ 520'	-	Middle - Lower Miocene
3070' - 4450'	+ 1380'	-	Oligocene
4480' - 4570'	+ 90'	-	Eocene
4600' - 5540'	+ 940'	-	Lower Eocene - Palaeocene
5560' - 6280'	+ 720'	-	Palaeocene
6300' - 6940'	+ 640'	Maastrichtian)	Upper Cretaceous
6960' - 7180'	+ 220'	late Campanian)	
7200' - 8220'	+ 1020'	early Campanian)	
8240' - 8400'	+ 160'	Santonian)	
8420' - 8620'	+ 200'	Coniacian)	
8630' - 8670'	+ 40'	early Albian-Aptian)	
8672' - 8750'	+ 78'	Barremian)	
8766' - 8770'	+ 4'	Volgian (n - o)	Upper Jurassic
8776' - 8821'	+ 45'	Bathonian (t - ?v))	Middle Jurassic
8848' - 8864'	+ 16'	early Bathonian - Bajocian (v))	

<u>Interval</u>	<u>Thickness</u>	<u>Stage</u>	<u>System/Subsystem</u>
8874' - 8889'	+ 15'	Domerian (x2)	Lower Jurassic
8896' - 9040'	+ 144'	Carixian - late Sinemurian (y)	
9060' - 9500'	+ 440'	-	Triassic

(Based on cuttings, sidewall core and core samples. Logs were not available although core logs were).

TABLE 2

CLASSIFICATION OF MARINE ENVIRONMENTS



The classification of marine environments used in this report is presented in diagrammatic form above. Pelagic (water) and Benthic (bottom) environments are recognised.

PELAGIC

- Neritic
- Oceanic
 - Epipelagic
 - Mesopelagic
 - Bathypelagic
 - Abyssopelagic

BENTHIC

- Supralittoral
- Littoral (Intertidal)
- Sublittoral
 - Inner
 - Outer
- Bathyal
- Abyssal
- Hadal

The classification is after Hedgpeth (1957) and results from several years discussion by a Committee of the Division of Earth Sciences, National Research Council, National Academy of Sciences, Washington D. C.

SUBSYSTEMS	STAGES		SUB-STAGE DIVISIONS AS USED IN THIS REPORT			
	Traditional English usage	AS USED IN THIS REPORT	INFORMAL SUB-STAGE AGES	BIOSTRAT. UNITS		
LOWER CRETACEOUS	BERRIASIAN					
UPPER JURASSIC	PORTLANDIAN		<i>late</i>	n		
	KIMMERIDGIAN	M. - U.	VOLGIAN	<i>mid</i>	o 1	
				<i>early</i>	2	
	KIMMERIDGIAN	LOWER	KIMMERIDGIAN	<i>late</i>	p 1	
				<i>early</i>	2	
	OXFORDIAN		<i>late</i>	q	1	
			<i>mid</i>		2	
			<i>early</i>	r		
	MIDDLE JURASSIC	CALLOVIAN		<i>late</i>	s	1
				<i>mid</i>		2
<i>early</i>				t	a	
BATHONIAN		<i>late</i>	1 b			
		<i>mid</i>	2 a b			
BAJOCIAN		<i>early</i>	v	1		
		<i>late</i>		2		
LOWER JURASSIC	TOARCIAN		<i>late</i>	w		
			<i>early</i>		x	1
	PLIENSACHIAN	U.	DOMERIAN		y	2
		L.	CARIXIAN			
	SINEMURIAN		<i>late</i>	z		
			<i>early</i>		1	
	HETTANGIAN				a	
				2		
UPPER TRIASSIC	RHAETIAN				b	

TABLE 3

THE BIOSTRATIGRAPHIC UNITS OF THE JURASSIC AS ESTABLISHED
BY ROBERTSON RESEARCH INTERNATIONAL LIMITED

DATE: OCT. 1975

IV

TERTIARY

INTERVAL 1620' - 1740'; Upper Miocene

General Lithology

The samples within this interval are contaminated with cement, but traces of greenish-light grey, non-calcareous shale and clay and minor poorly sorted sand grains are present.

Micropalaeontology and Stratigraphy

The occurrence within this interval of Cassidulina laevigata pliocarinata, Cibicides scaldisiensis and Elphidiella hannai, are all indicative of a Pliocene age. The additional presence, however, of Cibicides cf. pseudoungerianus suggests, that Upper Miocene sediments have also been encountered and therefore, an Upper Miocene age is assigned to this interval.

Environment

A general sublittoral environment of deposition is postulated for this section, due to the association of shallow water forms, such as Elphidium spp. and Quinqueloculina spp., with deeper water forms such as Cassidulina spp.

INTERVAL 1760' - 2500'; Middle Miocene

General Lithology

Greenish - light grey, non-calcareous shales and clays occur throughout this interval. Subordinate amounts of fine to medium, subangular quartz sand, with occasional well rounded grains are also present, traces of pyrite and

bivalve shell fragments also occur.

Micropalaeontology and Stratigraphy

The samples examined from this interval are either very poorly fossiliferous or contain abundant cavings from younger sediments. The microfauna is dominated by benthonic foraminifera. A Middle Miocene age is indicated by the occurrence of "Cythere" latimarginata, Epistomina elegans, Sigmoilina celata and Spiroplectammina deperdita.

Environment

The predominance of deeper shelf benthonic species such as Bulimina spp., Epistomina elegans and Cassidulina laevigata in conjunction with a decrease in the number of shallow water species suggest an outer sublittoral environment for these sediments.

INTERVAL 2520' - 3040'; Middle - Lower Miocene

General Lithology

Clays and shales similar to those of the above interval are considered to be the dominant lithotypes. Small amounts of generally fine to medium, subangular sand grains, which are yellow and amber at 2860', are present throughout the interval. Between 2950' and 3040' light brown to tan, moderately hard, brittle, finely crystalline dolomite occurs in association with light grey to tan, dense, finely crystalline limestone. Rare scattered grains of pyrite, chamosite and fairly common bivalve shell fragments occur within the interval.

Micropalaeontology and Stratigraphy

This interval contains a moderate, but diverse microfauna which is dominated by calcareous benthonic foraminifera. A noticeable planktonic foraminiferal element also occurs within this interval.

A Middle - Lower Miocene age is suggested by the presence of Globigerina concinna, Globigerinoides trilobus, Sphaeroidina bulloides and Uvigerina hosi. The microfauna contains few diagnostic species and a more refined subdivision of this unit is not possible.

Environment

An outer sublittoral environment of deposition with strong open marine influence is suggested for this interval by the diverse foraminiferal assemblage which contains a number of planktonic species.

INTERVAL 3070' - 4450'; Oligocene

General Lithology

Shales and clays, which are similar to those in the interval above, are the dominant lithology within this interval. Loose, pale buff, fine to medium-grained, subrounded sand grains occur throughout the interval in fairly minor amounts, and light green to very dark green glauconite is present in moderate amounts between 3200' and 3400'. Light grey, buff, and tan, moderately hard, finely crystalline limestone and creamy white glauconitic sandstone occurs in fairly minor amounts. Minor white, light brown and red, locally silty, non-calcareous clay is also apparent and rare traces of pyrite occur scattered

throughout most of the interval.

Micropalaeontology and Stratigraphy

The sediments of this interval are either barren or very poorly fossiliferous. However, sponge spicules are common, particularly between 3380' - 3800' where they are the only microfaunal representatives.

An Oligocene age is assigned to this interval on the appearance of Siphonodosaria hirsuta at 3070'. This is substantiated by the occurrence of Pseudopolymorphina obscura at 3130' and Elphidium subnodosum at 3190'. Other characteristic Oligocene forms recorded include Sigmomorphina regularis and Sigmoilina schlumbergeri. Between 3920' - 4450' the poor microfaunas become almost completely dominated by agglutinating foraminifera.

Environment

An outer sublittoral environment of deposition is tentatively suggested for the upper part of the interval between 3070' - 3900'. Below this depth the appearance of deep water agglutinating foraminifera including Bathysiphon sp., Cyclammina placenta and Glomospira charoides indicates an outer sublittoral - bathyal environment of deposition.

INTERVAL 4480' - 4570'; Eocene

General Lithology

Light grey silty shale, and minor tan to light grey, friable, generally fine grained subangular sandstone, are present within this interval.

Micropalaeontology and Stratigraphy

An Eocene age is assigned to this short, very poorly fossiliferous interval on the appearance of Cyclammina challinori. The poor microfauna is composed entirely of agglutinating forms.

Environment

Although the microfaunal evidence is very sparse, the occurrence of Bathysiphon sp., Cyclammina challinori and Glomospira charoides suggests an outer sublittoral - bathyal environment of deposition.

INTERVAL 4600' - 5540'; Lower Eocene - Palaeocene

General Lithology

Soft light grey clay and light brown to tan sometimes silty, non-calcareous shales are the dominant lithology within this interval. Traces of free fine-grained sand and pyrite occur sporadically. Cement contaminates the samples between approximately 5420' and 5480'.

Micropalaeontology and Stratigraphy

The appearance of large flattened radiolaria at the top of this interval indicates that deposits of Lower Eocene - Palaeocene age have been penetrated. The microfauna is poor to moderate and dominated by agglutinating foraminifera. Near the base of the interval at 5400' the microfauna becomes more varied and includes different species of benthonic and planktonic foraminifera, including Globigerina eocaena, G. linaperta and Reussella abbreviata.

Environment

The common occurrence of deep water agglutinating foraminifera including Cyclammina challinori, Glomospira charoides and Ammodiscus incertus suggests an outer sublittoral - bathyal environment of deposition. The appearance of planktonic foraminifera at 5400' indicates that good open marine connections existed during at least part of the interval.

INTERVAL 5560' - 6280'; Palaeocene

General Lithology

Buff and brown and occasionally greenish-grey, non-calcareous shales and clays are the dominant lithologies within this interval; occasional limestone fragments and loose fine-grained, sub-angular, buff to white sand grains were seen. Minor buff and brown glauconite or chamosite occurs in the sample at 6000'. No volcanic rocks were recorded from this interval.

Micropalaeontology and Stratigraphy

The interval can be sub-divided into two units according to the microfaunas present.

The upper, poorly fossiliferous, unit, from 5560' down to 5800', contains the index fossils Globigerina triloculinoides, Coscinodiscus sp. 1 and Coscinodiscus sp. 2.

The lower unit, 5820' - 6280' is composed of a rich exclusively agglutinating foraminiferal assemblage which is green stained at the top and includes Spiroplectammina spectabilis, Cystammina sp. and Trochammina sp. A.

Common Coscinodiscus spp. appear at the top of this unit.

No evidence of Danian sediments has been found.

Environment

An outer sublittoral - bathyal environment is suggested for this interval due to the predominance of deep water agglutinating foraminifera.

CRETACEOUSINTERVAL 6300' - 6940'; Maastrichtian, Upper CretaceousGeneral Lithology

Light and medium grey, non-calcareous shales, light grey-brown shale and rare traces of reddish brown slightly micaceous, non-calcareous shale are the dominant lithology. Common dark green glauconite was seen in the upper samples within this interval, and traces of loose buff and medium-grained, moderately sorted, subrounded to occasionally subangular sand occur throughout the interval. At 6460' traces of light grey limestone were recorded, and at 6660' rare, soft, white chalk becomes evident. Minor light grey siltstone or silty shale is considered to be present below approximately 6840'.

Micropalaeontology and Stratigraphy

The microfaunas recovered from this interval are dominated by planktonic species, the most common forms being Globigerinelloides asper, Rugoglobigerina rugosa rugosa and Heterohelix pulchra. The presence of such diagnostic species as Globotruncana contusa, Pseudotextularia elegans elegans, P. elegans fructicosa, Bolivina incrassata incrassata, Bolivina incrassata gigantea and Abathomphalus mayaroensis indicates that the entire interval is of Maastrichtian age.

This interval can be subdivided into four sections:

The first 6300' - 6320' is characterised by Pseudotextularia elegans elegans, P. elegans fructicosa and Globotruncana contusa. These species

indicate that sediments of late Maastrichtian age are present in this well.

The second section 6340' - 6460' is characterised by the influx of Rugoglobigerina rugosa rugosa and Globigerinelloides asper.

The third section, 6480' - 6540' is characterised by a decrease in numbers and the more significant occurrence of agglutinating foraminifera.

The fourth and final section, 6560' - 6940', has proved difficult to define. It may be that the upper limit should be drawn lower in the Maastrichtian. This section is characterised by an increase in the numbers of Rugoglobigerina spp. and, when more positively developed, is used to identify the early Maastrichtian.

Environment

The occurrence of a planktonic rich assemblage, which also contains numbers of fine-grained, probably deep water, agglutinating foraminifera, suggests an outer sublittoral to bathyal environment.

INTERVAL 6960' - 7180'; late Campanian, Upper Cretaceous

General Lithology

Soft, calcareous, silty, sandy, light grey shales are considered to be the dominant lithology within this interval. Minor loose sand, pyrite and rare glauconite are also present. The samples below 7100' are contaminated by lost circulation material.

Micropalaeontology and Stratigraphy

The assemblages recovered from this interval are essentially similar to those of the Maastrichtian. With depth the numbers decrease, although the

agglutinating elements increases.

The appearance of Globotruncana sp. 1 in this interval signifies that late Campanian sediments have been penetrated.

Environment

An outer sublittoral to bathyal environment is indicated for these sediments by the microfauna which contains significant proportions of both planktonic and fine-grained agglutinating foraminifera.

INTERVAL 7200' - 8220'; early Campanian, Upper Cretaceous

General Lithology

Shales similar to the overlying interval predominate, although a prominent red shale horizon does mark the top of this interval. Persistent traces of hard brown to tan dolomite and fragments of softer, light grey limestone occur throughout the interval and probably represent thin interbeds. Minor, fairly friable, pale green, very fine-grained sand and siltstone also occur. Traces of pyrite persist throughout much of the interval.

Micropalaeontology and Stratigraphy

A pronounced change in the microfauna occurs at 7200' and 7220' with an influx of red-stained forms which contain a relatively high proportion of calcareous benthonic foraminifera.

This phenomenon has been noted elsewhere in this region at the top of the early Campanian and this age is confirmed by the occurrence of Tritaxia dubia and Conorbina supracretacea. The remainder of the interval is

impoverished and dominated by agglutinating foraminifera. Below 7840' the samples are exceedingly poor and, from 8110', are badly contaminated by lost circulation material.

Environment

The limited microfaunas of this interval suggest that a restricted outer sublittoral to bathyal environment prevailed during the deposition of these sediments. The uppermost interval (7200' - 7220'), however, with its varied assemblage, may represent a period when the environment was less hostile and probably more shallow in view of the increase in calcareous benthonic forms.

INTERVAL 8240' - 8400'; Santonian, Upper Cretaceous

General Lithology

Grey shale, silty shale and siltstone similar to the lithologies in the overlying interval are seen. The samples are, however, somewhat contaminated by lost circulation material.

Micropalaeontology and Stratigraphy

The samples from this interval are badly contaminated by lost circulation material and yield impoverished assemblages. The occasional presence of green stained radiolaria tentatively suggests that from 8240' this unit is of Santonian age. The basal samples of this interval contain appreciable numbers of radiolaria which gives further support to this determination.

Environment

The impoverished microfaunas recovered from this section suggest a restricted probably outer sublittoral - bathyal environment, although the presence of radiolaria, particularly at the base, suggests some open marine influence.

INTERVAL 8420' - 8620'; Coniacian, Upper Cretaceous

General Lithology

Light grey shale is the dominant lithology within this interval, but below 8500' minor amounts of white chalk are present. Lost circulation material contaminates the samples below 8500' and the sample at 8600' consists almost entirely of cement. Light grey non-calcareous shale is also present in the sample at 8620'.

Micropalaeontology and Stratigraphy

Although the microfaunas recovered from this interval are relatively poor, there is a significant influx of species of Globotruncana. This feature and the presence of Globotruncana linneiana coronata indicate that Coniacian sediments are present.

Below 8560' the assemblages again become impoverished and at 8620' sphaerosiderite occurs in the residue.

Environment

The microfaunal association of this interval, (mainly composed of fine-grained agglutinating and planktonic foraminifera) suggests an outer sublittoral to bathyal environment which was receiving some open marine influence.

INTERVAL 8630' - 8670'; early Albian - Aptian, Lower Cretaceous

General Lithology

Red and buff chalk and white chalk, are considered to be the in situ lithologies. Dark grey shale, carbonaceous bone fragments and minor grey or clear, fine to medium angular sand, are considered to be reworked. Lost circulation material contaminates the samples from this interval.

Micropalaeontology and Stratigraphy

A marked change in the assemblages occurs at 8630' with an influx of radiolaria. This influx is not typical of the Lower Cretaceous in this region and may in fact represent a further change in the Upper Cretaceous microfauna. The occurrence of rare red stained species of Hedbergella delrioensis, however, suggests that Lower Cretaceous sediments have been penetrated and this is confirmed at 8650' by a rich, red-stained assemblage of early Albian - Aptian age. This determination is based on the presence of ? "Lingulogavelinella" gyroidinaeformis and the fact that agglutinating foraminifera form the major part of the microfauna. The possibility that a thin Albian section is also present cannot be entirely ruled out, although no positive evidence has been found.

Of note is the occurrence in this interval of black shale of typical Upper Jurassic aspect, and a single questionable specimen of the Jurassic radiolaria Lithostrobos sp. The presence of the black shale and radiolaria are attributed to reworking since below this undoubted Barremian sediments occur.

Environment

The sample at 8650' yielded a microfauna dominated by agglutinating foraminifera. The presence of these forms and the occasional calcareous benthonic foraminifera suggest an inner sublittoral environment.

INTERVAL 8672' - 8750'; Barremian, Lower Cretaceous

General Lithology

Firm red, pink and white chalk is present within both the ditch cuttings samples and sidewall cores from this interval. Minor white fairly firm limestone occurs in the ditch-cutting sample at 8750'.

Micropalaeontology and Stratigraphy

A pronounced change occurs in the sidewall core at 8672' with an influx of calcareous benthonic foraminifera, although agglutinating foraminifera still dominate the rich assemblage. The presence of species of Marssonella, Aulotortus (Spirillina) neocomiana, Trocholina infragranulata and the ostracodes Macrocypris parva and Cytherella cf. pyriformis indicate that these deposits are of Barremian age. The microfauna, which is red-stained, remains good to the base of the unit, although there is evidence at 8770' from caved white stained microfossils that the basal Barremian consists of a white limestone.

Environment

The association of large numbers of agglutinating and calcareous benthonic foraminifera with echinoderm debris suggests that deposition took place in an inner sublittoral environment.

VI

JURASSIC

INTERVAL 8766' - 8770'; Volgian, units n - o, Upper Jurassic

General Lithology

Although abundant caved material is present in the ditch cuttings samples, the sidewall cores consist of poorly fissile, dark grey, non-calcareous, slightly waxy, slightly micaceous shales.

Micropalaeontology, Palynology and Stratigraphy

No in situ microfauna has been recovered from this interval. The forms present consist almost entirely of caved Barremian forms, the remainder are long ranging forms or originate from younger levels.

The presence of abundant bituminous sapropel in sidewall core samples 8766' and 8770' suggests an Upper Jurassic age for this interval. The occurrence of sapropelic cavings in ditch-cuttings sample 8795' - 8840' associated with a single specimen of the presumably caved taxon Pterospermopsis aureolata would suggest that Volgian (units n - o) age restricted sediments have been penetrated.

Environment

The absence of terrestrially derived miospores and the presence of an impoverished microplankton assemblage and abundant bituminous sapropel would indicate an inner sublittoral, open marine, low energy and relatively shallow water environment with restricted water circulation and the development of anaerobic bottom conditions.

INTERVAL 8776' - 8821'; Bathonian, units t - ?v, Middle Jurassic

General Lithology

The lithology of this interval includes traces of hard grey limestone with calcite veins, medium to dark grey, silty, non-calcareous shale, minor green, soft, waxy, non-calcareous shale, and light brown fine to coarse sub-rounded sand, with some light grey friable siltstone. The ditch cuttings samples contain variable amounts of caved material.

Micropalaeontology, Palynology and Stratigraphy

None of the foraminifera or ostracodes recovered from this interval is considered to be in situ.

Palynological analysis of sidewall core and core samples over this interval suggest that a Middle Jurassic palynoflora of unit t aspect has been penetrated. The incoming of inertinite at 8776', its abundant association with vitrinite, the absence of bituminous sapropel, and the development of a typical 6 type palynoflora in samples at 8793' and 8796', characterise the Middle Jurassic and in particular the Bathonian.

The presence of Nannoceratopsis pellucida at 8793' within a core sample would suggest that strata no older than late Bathonian (unit t1b) have been penetrated at this depth.

Environment

An abundance of water transported terrestrially derived miospores and wood detritus (inertinite-vitrinite) characterise a palynofacies rare in microplankton and highly buoyant water-borne/wind blown saccate pollen. This

would tend to suggest than an inshore, shallow, marginal marine environment of deposition prevailed (deltaic - littoral - ?inner sublittoral), where truly marine conditions, as reflected in the microplankton content, were only partially, if not rarely, developed; the considerable terrestrial run off being an indicator of an adjacent fluctuating delta front.

INTERVAL 8848' - 8864'; early Bathonian - Bajocian, unit v, Middle Jurassic

General Lithology

This interval was cored and consisted of very fine-grained, sub-rounded, calcareous, micaceous sandstone down to 8854'. Below this depth a thin bed of brown grey slightly micaceous limestone was evident, and the remainder of the interval was considered to consist of fine and very fine-grained sandstone with minor black shale horizons and laminae.

Micropalaeontology, Palynology and Stratigraphy

The incoming of Nannoceratopsis gracilis in a core sample at 8848' associated with fairly common Chytroeisphaeridia spp., Cerebropollenites mesozoicus, Tsugaepollenites group, and Klukisporites variegatus suggest that strata of unit v aspect have been penetrated.

The presence of a ?7 type palynoflora in core sample 8850' associated with the development of a more diversified microplankton assemblage containing fairly common polygonomorph acritarchs, Botryococcus spp., and poorly documented dinoflagellates of Liassic aspect (viz. Dapcodinium spp., Dinoflagellate indet.), suggest , in conjunction with the incoming of N. gracilis

at 8848', the existence of Middle - Lower Jurassic transitional palynofloras.

Environment

The presence of relatively common saccate pollen grains in association with more diversified microplankton assemblages typified the palynofacies of the productive core interval 8848' and 8850'. A shallow water marginal marine to open marine (littoral - inner sublittoral) environment of deposition is suggested for the argillaceous horizons. A certain degree of terrestrial (deltaic) influence is evident by the occurrence in the palynofacies of water transported microspores, wood detritus and the freshwater algae of

Botryococcus.

INTERVAL 8874' - 8889'; Domesian, unit x2, Lower Jurassic

General Lithology

The core from this interval consisted of dark grey, highly micaceous, friable, argillaceous siltstone or silty shale, with minor black waxy shale occurring between 8887' and 8889'.

Micropalaeontology, Palynology and Stratigraphy

The microfaunal assemblages recovered from this interval are extremely poor. The occurrence of the ostracode Hungarella etaulensis at 8877', however, indicates that sediments of Pliensbachian age are present.

The core samples analysed palynologically over this interval produced a palynoflora of similar aspect to that recorded in the lower part of subunit x2 in this region.

The absence of definitive Toarcian palynofloras in a somewhat unproductive palynofloral interval between 8850' and 8874' would suggest that this stage (unit w - subunit x1) is not represented in this well.

The Domerian (subunit x2) is characterised by a 7 type palynoflora containing common bisaccates, fairly common Chasmatosporites spp., Osmundacidites - Baculatisporites group and wood detritus (inertinite - vitrinite), the consistent occurrences of Nannoceratopsis gracilis, a few Spheripollenites - Sphaeromorph types, ?Mancodinium spp., and tasmanitids, and the incoming and consistent occurrences of Lycopodiacidites rugulatus (8874') and Cerebropollenites cf. thiergartii (8886') types.

Environment

The overall palynofacies suggests an intermixing of inshore marginal and more open marine, but still shallow water, environmental conditions (littoral - inner sublittoral). The terrestrially derived microspores, wood detritus and bisaccate pollen represent both water-borne and wind blown transportation into a marginal sea subjected to slight, but marked changes in sea level (? tidal).

INTERVAL 8896' - 9040'; Carixian - late Sinemurian, unit y, Lower Jurassic

General Lithology

The top part of this interval has been caved between 8896' and 8927' and consists mainly of dark grey shale and claystone, sometimes carbonaceous, non-calcareous, micaceous, with occasional pyrite nodules. Between 8910' and

8913' minor dark grey limestone is present. The samples in the lower part of this interval are very badly contaminated with lost circulation material and the in situ lithology has been inferred.

Micropalaeontology, Palynology and Stratigraphy

An influx of calcareous benthonic foraminifera occurs in the core samples at 8900'. The presence of common Lenticulina varians, Dentalina matutina, D. terquemi, Ichthyolaria sulcata, Geinitzinita tenera tenera and Marginulina prima prima and the ostracodes Healdia mouhersensis and Hungarella sp. B (APOSTOLESCU) indicates a Carixian to late Sinemurian age. The occurrence at 8940' of the ostracode Lophodentina cf. crepidula suggests that from this depth the sediments may be of late Sinemurian age only.

In this well, unit y is differentiated from the overlying subunit x2 on the incoming and consistent occurrences of abundant bisaccates, Osmundacidites - Baculatisporites types and Cerebropollenites cf. thiergartii. Chasmatosporites spp., form a less common constituent of the unit y palynofloras than in the overlying subunit x2.

Seemingly characteristic locally of unit y palynofloras are the incomings of Uvaesporites glomeratus (8896') and Stereisporites - Annulispora spp. (8926'), the consistent occurrence of Lycopodiacidites rugulatus and Botryococcus spp. the occasional occurrence of N. gracilis and Sverdrupiella - Heibergella type dinoflagellates, and the incoming of more obvious reworked Triassic taxa (viz. Striatoabieites sp., Camarozonosporites cf. rudis, Tigrisporites cf. halleinis).

The incoming of Stereisporites - Annulispora and Sverdrupiella - Heibergella types associated with Lycopodiacidites and Chasmatosporites types

is suggestive of the penetration of the late Sinemurian at 8926'.

The presence of relatively common Deltoidospora spp. and Cerebropollenites cf. thiergartii types associated with a 7 type palynoflora in ditch cuttings sample 8980' - 9040' is locally suggestive of a correlation to basal unit y.

Environment

The occurrence of a relatively rich microfauna dominated by calcareous benthonic foraminifera and the presence of echinoderm debris suggest that deposition took place in a sublittoral environment.

A gradual transgressive phase is suggested by the palynofacies as developing from early to late unit y.

The initial palynofacies of unit y is characterised by a predominance of terrestrial water-borne microspores over wind and water carried saccate pollen taxa associated with a relatively high wood detritus content, some reworking, and a lack of microplankton. This would tend to suggest a nearshore shallow marine (littoral - ?inner sublittoral) environment of deposition affected by high terrestrial run off.

Through unit y, the palynofacies shows a gradual decrease and increase in wood detritus and saccate pollen content respectively associated with an increase in the diversification of miospore and microplankton content. The resultant palynofacies suggests a shallow water (inner sublittoral) open marine environment of deposition with some freshwater source of influence as is indicated by the occurrence of small quantities of wood detritus and the freshwater algae of Botryococcus sp.

VII

TRIASSIC

INTERVAL 9060' - 9500'; Triassic

General Lithology

The lithology of this interval was examined in ditch cuttings samples, sidewall cores and cores numbered 5, 6 and 7. Red, red-brown, purple, light greenish grey, dark to medium grey, yellow-brown, mottled, earthy, sometimes fissile, micaceous, and calcareous shales occur throughout the whole interval. Light grey, dense, fairly hard, roughly rounded limestone nodules occur in the ditch cuttings samples and in the cores occur within shale horizons. Rare traces of carbonaceous material were seen in some cores. Fine, medium and coarse, poorly sorted, angular, pink, white and light grey sand, and soft to friable sandstone, occasionally grading to siltstone, with a white, usually soft, weakly calcareous or kaolinitic matrix, occurs as interbeds. Rare, finely disseminated pyrite was seen in some of the sandstones.

Palynology and Stratigraphy

No diagnostic palynomorphs have been recovered from these sediments. The lithotypes present, however, suggest a Triassic age.

Environment

The predominantly red colouration of the shales and sand grains may indicate that continental conditions prevailed at the time of deposition. Deposition may have taken place under fluvial conditions on land, in an enclosed lake, or in areas marginal to the land mass. The presence of grey and green shales

interbedded with red beds is an indication of changes in the prevailing climatic regime, the grey horizons representing wetter or moister climatic conditions than the red shales, which tend to imply aridity. The green shales reflect transitional conditions from red to grey.

The existence of the above mentioned environmental conditions is supported by the organic content of the sediments. The sole presence of comminuted wood detritus (inertinite) - associated presumably with the lignitic horizons - does indicate large scale oxidation and degradation of palynomorphs within an alternating/fluctuating wet to dry continental environment. The inertinite represents a relict, highly oxidised palynosediment.

VIII

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APPENDIX 1

Sidewall Core Descriptions

<u>Depth</u>	<u>Run</u>	<u>No.</u>	<u>Description</u>
8655'	1	1	<u>SHALE</u> . Soft, very dark grey fissile, non-calcareous, with a trace of lignite.
8660'	1	3	<u>SHALE</u> . Soft, very dark grey, fissile, non-calcareous, slightly micaceous.
8672'	1	5	<u>CHALK</u> . Soft to firm, brick red, highly calcareous.
8691'	1	7	<u>CHALK</u> . As at 8672'.
8714'	1	9	<u>CHALK</u> . As at 8672'.
8766'	2	1	<u>SHALE</u> . Soft, very dark grey, fissile, non-calcareous, slightly waxy, slightly micaceous.
8770'	1	12	<u>SHALE</u> . Firm, very dark grey, poorly developed fissility, non-calcareous.
8776'	1	14	<u>SHALE</u> . Firm to soft, dark grey, non-calcareous micromicaceous, silty.
8796'	1	16	<u>SILTSTONE</u> . Firm to soft, light grey, non-calcareous, argillaceous, very micaceous.
8806'	1	18	<u>SANDSTONE</u> . Soft, friable, light buff, non-calcareous, fine and very fine, angular.
8821'	1	20	<u>SANDSTONE</u> . Soft, friable, light buff, weakly calcareous, fine and very fine, angular, argillaceous, with parting of lignite.
8864'	2	3	<u>SANDSTONE</u> . Firm, friable, light buff, fine, very fine, angular, very micaceous, weakly calcareous.
9056'	1	21	<u>SANDSTONE</u> . Firm, friable, white, coarse to fine, poorly sorted, angular, ?Kaolinitic, non-calcareous.

<u>Depth</u>	<u>Run</u>	<u>No.</u>	<u>Description</u>
9073'	1	23	<u>SHALE</u> . Firm to soft, mottled pale green and red brown, very sandy, silty and micaceous non-calcareous.
9085'	1	25	<u>SANDY SHALE</u> . Soft, light grey, kaolinitic, waxy, non-calcareous, poorly sorted, angular, fine to coarse sand grains.
9126'	1	26	<u>SHALE</u> . Firm to soft, medium grey, waxy, very micaceous, non-calcareous.
9194'	1	28	<u>??SHALE</u> . Firm to soft earthy mottled medium grey, red, buff. (May not be in situ).
9208'	1	29	<u>SHALE</u> . Firm, earthy, yellowish brown, mottled, non-calcareous, waxy.
9268'	2	8	<u>SANDSTONE</u> . Firm, friable, white to very light grey, coarse to fine grained, angular, slightly micaceous, ?kaolinitic, non-calcareous.
9274'	2	10	<u>SANDSTONE</u> . As at 9268'.
9277'	2	12	<u>SHALE</u> . Firm, medium grey, waxy, ?kaolinitic, non-calcareous.
9282'	2	14	<u>SHALE</u> . Firm, earthy, mottled brown, yellowish, reddish brown, waxy, non-calcareous.
9302'	2	16	<u>SHALE</u> . Firm, earthy, occasionally waxy, mottled yellowish brown, grey, silty.
9312'	2	18	<u>SHALE</u> . Firm, earthy, reddish brown, weakly calcareous, trace of angular sand and silt.
9344'	2	20	<u>SANDSTONE</u> . Fairly hard, white, mainly medium grained, angular, calcareous, ?kaolinitic.
9348'	2	22	<u>SANDSTONE</u> . Soft, friable, white, coarse to fine-grained, angular, ?kaolinitic, non-calcareous.
9365'	2	24	<u>SHALE</u> . Fairly firm, red-brown, silty, with very fine and fine sand, weakly calcareous.

<u>Depth</u>	<u>Run</u>	<u>No.</u>	<u>Description</u>
9375'	2	26	<u>SHALE.</u> Soft, red brown, slightly micaceous, moderately calcareous.
9395'	2	28	<u>SANDSTONE.</u> Soft, light greenish grey, fine to medium-grained, angular, micaceous, ?kaolinitic, calcareous.
9410'	2	30	<u>SANDSTONE.</u> Firm, friable, light grey, fine to medium, angular, micaceous, moderately calcareous, pyritic.

APPENDIX II

Core Descriptions

CORE 1

- 8790' - 8792' SANDSTONE. Friable, buff to light brown, fine to coarse, sub-rounded, medium to well sorted, slightly pyritic, with shaly laminae and bands.
- 8792' - 8802' SHALE/CLAY. Dark grey to brown, waxy micaceous, carbonaceous with minor brown, medium to fine-grained, subrounded sand stringers.

CORE 2

- 8837' - 8844' SHALE/CLAY. Dark grey, waxy, occasionally micaceous, slightly pyritic.
- 8844' - 8846' SANDSTONE. Brown, coarse to very coarse, conglomeratic, sub-rounded, poorly sorted.
- 8846' - 8850' SANDSTONE. Buff, fine-grained, silty subrounded well sorted, bioturbated with shaly partings.
- 8850' - 8854' SANDSTONE. Buff, fine-grained, silty, laminated, micaceous.
- 8854' - 8855.5' CALCAREOUS SILTSTONE. Light-medium grey, hard, micaceous.
- 8855.5' - 8859' SANDSTONE. Brown, friable, with ripple bedded shaly laminae and occasional coaly bands.

CORE 3

- 8874' - 8888' SILTSTONE. Light to medium grey, intensely laminated with occasional buff rounded concretions and shaly partings; slightly bioturbated and with minor fault and slump structures.

8888' - 8893' SHALE/CLAYSTONE. Grey-brown, waxy, micaceous.

8893' - 8894' DOLOMITE Grey-brown, dense, argillaceous.

8894' - 8900' SHALE/CLAYSTONE. Grey to dark grey, micaceous, slightly waxy, occasional small shell fragments, with ?ironstone oolites in 1½" band.

CORE 4

8901' - 8905.5' SILTSTONE. Light grey, calcareous, intensely laminated mottled, micaceous with pyrite nodules.

8905.5'- 8910' SHALE. Dark grey, laminated, waxy, micaceous, carbonaceous with white siltstone flasers, traces of pyrite.

8910' - 8928' SHALE. As above, often intensely laminated with siltstone and pyrite and local glauconite at 8914.5'. Shell fragments, carbonaceous fragments and buff clay concretions also present.

CORE 5

9071'- 9072.5' SANDSTONE Coarse to very coarse, sub-angular, kaolinitic.

9072.5'- 9074' SANDSTONE Fine to medium, light grey, kaolinitic.

9074' - 9075' SANDSTONE Fine-grained, light grey, laminated.

9075' - 9077' CLAYSTONE Green-grey, variegated red brown, chloritic.

9077' - 9080' SANDSTONE Light green-grey, fine to medium, micaceous, friable, kaolinitic with clay partings.

9080' - 9083' CLAYSTONE Variegated red brown and green, trace carbonaceous.

CORE 6

9106' - 9107' SHALE Soft medium grey with carbonaceous partings, micaceous.

9107' - 9108' SANDSTONE. Medium grey, fine to coarse, kaolinitic.

9108' - 9110.7' SANDSTONE. Green-grey, soft, fine to coarse.

9110.7' - 9111' SANDSTONE. Grey, light grey, sandy, streaked and mottled.

CORE 7

9146' - 9147' SHALE/MUDSTONE. Dark green, sandy, silty, carbonaceous.

9147' - 9149.7' SAND. Light grey, poorly sorted, with waxy
SHALE silty, brown, fairly hard.

9149.7' - 9152' CLAYSTONE Green and red brown, very soft, slightly sandy.