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ROBERTSON RESEARCH COMPANY LIMITED

OILFIELDS REPORT NO. 358

A STUDY OF SELECTED SECTIONS FROM PALAEOCENE SEQUENCES IN THE NORWEGIAN NORTH SEA WELLS 7/12-1X, 1/3-1, 2/3-1, 2/11-1 AND THE DANSK NORDSØ I-1X WELL

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THE MICROPALAEONTOLOGY AND STRATIGRAPHY OF THE PHILLIPS NORWAY 17/12-1X NORTH SEA WELL

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Enclosures

Micropalaeontological Analysis Charts Nos. 1-14.

Biostratigraphic Chart showing the distribution of the diagnostic Foraminifera and Ostracoda in the Phillips Norway 17/12-1X North Sea Well. (2 sheets).

I

INTRODUCTION

This report summarises the results of micropalaeontological, palynological and stratigraphical analyses which have been completed on material covering the interval from 1500' to 14100' in the Phillips (Norway) 17/12-1X North Sea Well under Project No. RRI/IIA/723/3½ (RRI/IIA/242).

Under this project a total of 888 ditch cuttings samples were analysed using standard micropalaeontological techniques. Additionally, 105 individual or composite samples from the Jurassic, Triassic and Permian sections of the well, were treated palynologically. The methods used in treating the samples and of assessing ages are similar to those described in earlier Oilfields Reports.

This well represents the first exploration hole to be drilled in Block 17/12 in the Norwegian concession area of the North Sea. It lies approximately 175 km due west of the southernmost tip of Norway and is situated close to the edge of the continental shelf on the western side of the Norwegian Trench.

Summaries of the determinations obtained by these analyses have already been communicated in a series of telex communications outlining the framework of factual information on which this present report is based. A complete summary of the stratigraphic sequence penetrated by this well is provided overleaf in Table 1.

The terminology adopted for the enviromental conclusions follows that of Hedgpeth, 1957; from which report Table 2 is taken.

All 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 various members of the Phillips Petroleum Company with whom we have been associated in the course of this work.

17/12-1x

SUCCESSION

TABLE 1

INTERVAL	THICKNESS	STAGE	SYSTEM/SUBSYSTEM
1500' - 2040'	+ 540'	-	Oligocene
2060' - 2260'	± 200'	Bartonian-Lutetian	Upper - Middle Eocene
2280' - 2420'	± 140'	Ypresian	Lower Eocene
2440' - 2520'	± 80'	-	?Palaeocene
2540' - 2580'	± 40'	Danian	Lower Palaeocene
2600' - 3440'	± 840'	Maestrichtian	Upper Cretaceous
3460' - 3680'	± 220'	Campanian	
3700' - 3820'	± 120'	Santonian	
3840' - 3980'	± 140'	Coniacian	
4000' - 4380'	± 380'	?Albian	?Lower Cretaceous
4405' - 5200'	± 795'	Albian	Lower Cretaceous
5225'	-	?Albian - Aptian & Barremian	
5250' - 5375'	± 125'	Lower Barremian - Hauterivian	
5400' - 5850'	± 450'	Hauterivian	
5875' - 5925'	± 50'	Hauterivian-Valanginian	
5950' - 6175'	± 225'	Valanginian	
6200' - 6225'	± 25'	Berriasian	
6250' - 6325'	± 75'	Kimmerdgian	Upper Jurassic
6350' - 6625'	± 275'	Lower Kimmeringian	

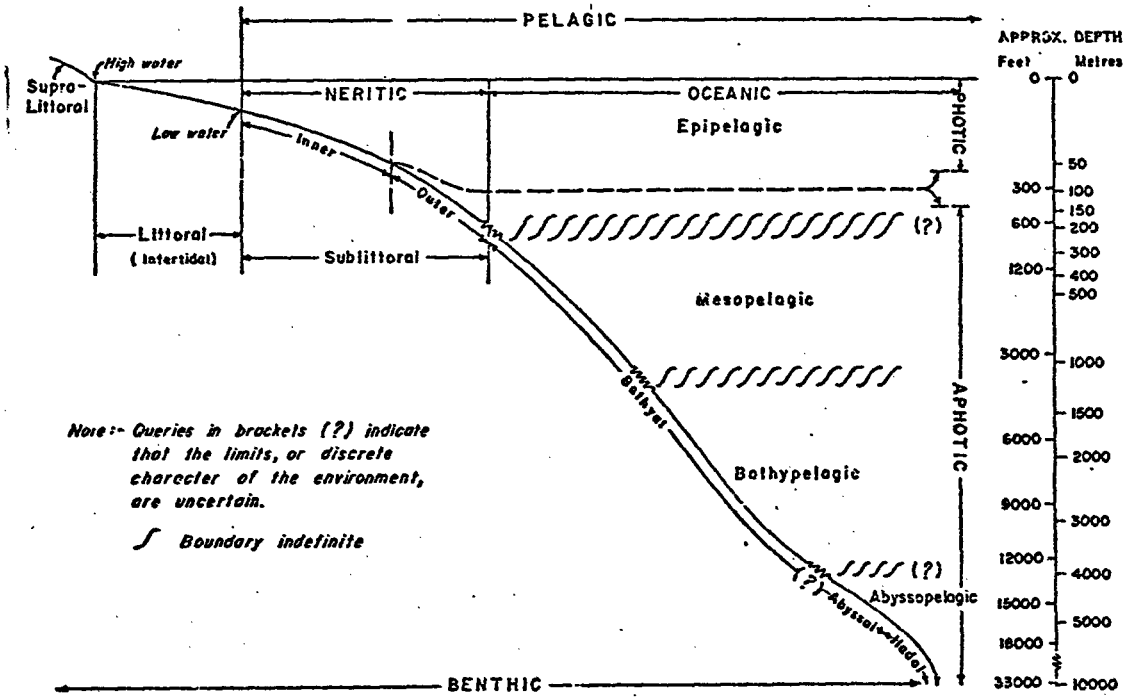
- TABLE 1

Continued

INTERVAL	THICKNESS	STAGE	SYSTEM/SUBSYSTEM
6650' - 7520'	± 870'	-	Upper Jurassic
7525' - 8040'	± 515'	-	?Middle Jurassic
8050' -13610'	± 5560'	-	Triassic
13640 -14100'	+ 460'	Zechstein	Upper Permian

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	BENTHIC
Neritic	Supralittoral
Oceanic	Littoral (Intertidal)
Epipelagic	Sublittoral
Mesopelagic	Inner
Bathypelagic	Outer
Abyssopelagic	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.

III

TERTIARY

INTERVAL 1500 - 2040'; Oligocene

General Lithology

This interval consists mainly of grey, glauconitic clays. Glauconite is particularly common between 1900' and 1940' and some of it at least, appears to have been formed by the replacement of faecal pellets in the clay. Several beds of grey or brownish grey, cryptocrystalline limestone are found interbedded with the clay. The limestone contains traces of glauconite, pyrite and mica, and in places silty material and iron oxides are also present.

Micropalaeontology and Stratigraphical Conclusions

Miocene forms such as Asterigerina staeschei and Uvigerina tenuipustulata were found as contaminants at the top of the well. An Oligocene age, however, is indicated for this upper section, based on the appearance of the following species Asterigerina gürichi, Globigerina ampliapertura and Gyroidina girardana. At 1840' Rotaliatina bulimoides and Alabamina perlata occur and these would indicate that the section below this depth at least, is of Middle - Lower Oligocene age.

Environmental Conclusions

A sublittoral environment is possibly indicated by the very varied calcareous benthonic microfauna, while the occurrence of various species of planktonic foraminifera indicates that open marine conditions existed at times.

INTERVAL 2060' - 2260'; Bartonian - Lutetian, Upper - Middle Eocene

General Lithology

In this section grey, pyritic clay, containing abundant green and yellowish green glauconite, predominates.

Micropalaeontology and Stratigraphical Conclusions

The top of the Eocene was taken at the first occurrence of Lenticulina decorata. Other characteristic forms present include Globigerapsis index, Truncorotaloides pseudodubia, Pseudohastigerina wilcoxensis, Uvigerina farinosa and Cibicides proprius. All the forms present within this interval range through the Upper and Middle Eocene and this age has been assigned to the section.

Environmental Conclusions

In this interval calcareous benthonic foraminifera such as Lenticulina spp., Polymorphinids and Gyroidina spp. become common, together with various planktonic foraminifera. According to Pokorny, Lenticulina (Robulus) spp. occur characteristically above 600m. while Gyroidina soldanii has been recorded in the Western Atlantic from 23 fathoms to 2369 fathoms and in the Bay of Biscay from 230m - 4200m with a maximum abundance at 1975m.

An outer sublittoral environment is therefore suggested for these sediments.

INTERVAL 2280' - 2420'; Ypresian, Lower Eocene

General Lithology

The upper part of this interval is composed of glauconitic clays similar to those found in the overlying section. Subordinate amounts of brownish grey, micaceous shale and hard, brownish grey chert occur at and below 2340'. The basal sample at 2420' contains some hard, pyritic, cryptocrystalline, grey limestone and abundant fragments of light grey, dark grey and brownish grey chert. Some of the chert has been tinged

pink or green by the iron compounds in it and it also contains finely disseminated pyrite and carbonaceous material.

Micropalaeontology and Stratigraphical Conclusions

Large radiolaria, which are taken to mark the top of the Lower Eocene in this region of the North Sea, dominate the samples around 2280'. Agglutinating forms such as Haplophragmoides spp., Cyclammina sp. and Bathysiphon eocenicus also become common at this level.

Environmental Conclusions

The appearance of more agglutinating foraminifera, especially Cyclammina sp., indicate a bathyal environment of deposition. Tests of Cyclammina spp. have been found in the Bay of Biscay between 560m - 4175m with a maximum abundance at 1800m.

INTERVAL 2440' - 2520'; ?Palaeocene

General Lithology

This interval is composed predominantly of very hard, light and dark grey chert containing pyrite and carbonaceous material. The chert is interbedded with subordinate amounts of grey and brownish grey shale. Brown, buff and grey, highly carbonaceous tuffaceous shales, including some medium brown shale with a characteristic white mottling, are found between 2480' and the base of the unit.

Micropalaeontology and Stratigraphical Conclusions

This interval is assigned tentatively to the Palaeocene on the appearance of Coscinodiscus sp. 1 at 2440' and the presence of tuffs and tuffaceous shales.

Environmental Conclusions

The dominance of chert pebbles within this interval and the impoverished nature of the microfaunas suggests an inner sublittoral,

or even a possible littoral environment, of deposition.

INTERVAL 2540' - 2580'; Danian, Lower Palaeocene

General Lithology

This interval consists of hard, white, chalky limestone containing buff coloured flints and abundant fragments of bryozoa.

Micropalaeontology and Stratigraphical Conclusions

Anomalinoides velascoensis, Gavelinella cf. danica and Globigerina pseudobulloides are found within this interval, and their presence together with the appearance of hard, white, chalky limestone is indicative of the Danian, which occurs here as a thin, chalky develoment.

Environmental Conclusions

The occurrence of planktonic foraminifera together with chalk deposits indicate an open marine environment. Benthonic foraminifera are in greater abundance than planktonic foraminifera, and with the appearance of lamellibranchs and bryozoa, an inner sublittoral environment may also be inferred.

IV

CRETACEOUS

INTERVAL 2600' - 3440'; Maestrichtian, Upper Cretaceous

General Lithology

Moderately hard, white chalk predominates in this section. Buff coloured flints are very common, especially in the upper part of the interval.

Micropalaeontology and Stratigraphical Conclusions

Faunal elements indicative of a Cretaceous age are first encountered in the sample at 2600'. Samples beneath this depth contain a typical Upper Senonian assemblage and the presence of such foraminifera as Bolivinoides draco cf. draco, Bolivinita exigua, Bolivina incrassata gigantea and Spirillina subornata indicate that the uppermost beds are of Maestrichtian age.

Over the upper part of this interval the fauna consists almost entirely of calcareous benthonic species, with a small proportion of agglutinating forms and a marked paucity of planktonic species. Caved Tertiary material persists throughout and in some instances represents a significant portion of the samples.

Other species occurring in samples from the upper part of this interval, and which are typical components of an Upper Senonian fauna, are Stensiöina pommerana, Praebulimina carsevae, Bolivinoides decorata laevigata and Bolivina incrassata incrassata.

From 3400' to the base of this interval, somewhat richer faunas were encountered, in which Rugoglobigerina rugosa rugosa and Rugoglobigerina rugosa aff. rotundata become increasingly significant, and in which occasional Globotruncana arca were noted. These, together with such benthonic species as Reussella szajnochae, Stensiöina

labyrinthica and Stensiöina aff. exsculpta are typical Campanian - Lower Maestrichtian components.

In the general absence of forms indicative of the upper zones of the Maestrichtian, it is presumed that the younger Maestrichtian beds are absent. A specimen of Pseudotextularia elegans elegans was noted in the sample at 3000' but its preservation leads us to presume that it is a reworked specimen which was caved from the Teritary.

Environmental Conclusions

The virtual absence of planktonic foraminifera together with an abundance of bryozoan, crinoid and other fragmental extraneous material which is seen in samples over the upper 600' of this interval, must be taken to infer an inner sublittoral environment. At the commencement of Maestrichtian times, however, slightly more open marine conditions may have prevailed, though without necessarily implying any increased depth. This would account for the greater number of planktonic foraminifera found in samples between 3200' and 3440'.

INTERVAL 3460' - 3680'; Campanian, Upper Cretaceous

General Lithology

This interval consists of moderately hard, white chalk containing some buff coloured flints. The samples below 3600' are contaminated with cement.

Micropalaeontology and Stratigraphical Conclusions

Very little change is to be noted in the faunas from this interval, which for the most part are comprised of species already recorded in the overlying beds. Benthonic species still form the major part of this fauna, although planktonic species (mainly Rugoglobigerina are present.

Certain benthonic forms such as Stensiöina pommerana, Stensiöina aff. exsculpta and Globorotalites cf. micheliniana are often present in considerable numbers.

The top of this interval is marked by the first appearance of Globotruncana marginata and Globorotalites cf. micheliniana in the sample 3440' - 3460'; the Campanian age being supported by the occurrence in the following sample of Globotruncana linneiana linneiana. Lower in this Campanian interval, true Globorotalites micheliniana appear together with specimens of Gavelinella clementina, and supporting this age determination.

Environmental Conclusions

The environment of deposition during Campanian times would have been generally similar to that indicated above - a sublittoral environment (possibly more outer sublittoral), with fairly open marine connections.

INTERVAL 3700' - 3820': Santonian, Upper Cretaceous

General Lithology

The samples in this interval are contaminated with cement and lost circulation material, but appear to consist of moderately hard, white chalk similar to that found in the overlying section.

Micropalaeontology and Stratigraphical Conclusions

Samples over this short interval display a noticeable increase in the numbers of Gavelinella costata and Stensiöina spp., coupled with a decrease in the number of planktonic foraminifera. The species of Stensiöina identified in these samples included S. exsculpta, S. exsculpta gracilis and S. praeexsculpta. These would suggest a Santonian age.

Environmental Conclusions

Similar general conditions of deposition are reflected to those already indicated above. The meagre number of planktonic specimens suggest that the open marine connections had only developed at the close of Santonian times.

INTERVAL 3840' - 3980'; Coniacian, Upper Cretaceous

General Lithology

The interval consists mainly of soft, creamy white chalk. Traces of glauconite are first seen in the chalk at 3900', and from 3940' to the base of the unit highly fossiliferous, glauconitic, white limestone is interbedded with the chalk.

Micropalaeontology and Stratigraphical Conclusions

A resurgance in the numbers of planktonic foraminifera occurring in samples below 3820' leads us to believe that the interval to 3980' represents the Coniacian. Rugoglobigerina rugosa rugosa, Globotruncana marginata and Globotruncana linneiana linneiana occur frequently in these residues. In addition, Globotruncana linneiana tricarinata and Globotruncana aff. imbricata are also recorded from samples towards the base of this section. Throughout this interval, samples contain a fairly prolific fauna of the benthonic species already encountered in the higher levels of the Senonian.

Environmental Conclusions

A sublittoral environment seems to have prevailed throughout Senonian time. From the planktonic content of the Coniacian samples it would appear that at the beginning of the Senonian, more open marine conditions were in existence.

1250 1335

INTERVAL 4000' - 4380'; ?Albian, ?Lower Cretaceous

General Lithology

The top of this interval is marked by the incoming of soft, grey clays. The clays are glauconitic and contain traces of fine-grained, subangular sand and silt. Subordinate amounts of pyrite are also present. Between 4150' and the base of the section, stringers of light brown, sucrosic sphaerosiderite are common.

Micropalaeontology and Stratigraphical Conclusions

This interval contains an extremely poor microfauna which is composed primarily of fragments of calcareous benthonic and agglutinating foraminifera. The most distinctive feature of this unit, by comparison with the preceding one, however, is the incoming of glauconitic grey clays.

Environmental Conclusions

The sparse microfauna does not allow any firm environmental conclusions to be made, although it is suggestive of a sublittoral environment. The clear seas of the Upper Cretaceous obviously do not occur in the ?Albian when the area was receiving considerable amounts of fine-grained terrigenous material.

1342 1585

INTERVAL 4405' - 5200'; Albian, Lower Cretaceous

General Lithology

Glauconitic, grey clays containing some sphaerosiderite predominate in the upper part of the interval. Below 4550' the clays are interbedded with limestone, dolomite and siderite. The limestone is light brown or grey, cryptocrystalline and frequently micaceous. The dolomite and siderite are dark grey or brown in colour and are often closely associated with each other. They are generally cryptocrystalline and contain black

specks of carbonaceous material.

Micropalaeontology and Stratigraphical Conclusions

At 4405' there is a distinct change in the microfauna with the appearance of agglutinating foraminifera, Haplophragmoides spp., in significant numbers, and of Epistomina chapmani. Subsequently, the assemblages consist primarily of agglutinating foraminifera with occasional incursions of calcareous benthonic forms. At the base of the section (5075' - 5175') the samples are particularly rich in agglutinating species. The calcareous benthonic element of the microfauna is dominated by species of Epistomina viz., E. cf. caracolla, E. chapmani, E. cretosa, E. spinulifera polypioides, E. spinulifera spinulifera and E. reticulata. The presence of the various species of Epistomina and Verneuilinoides subfiliformis indicates that this unit is of Albian age.

Environmental Conclusions

The moderate to rich microfaunas dominated by agglutinating foraminifera are suggestive of an inner sublittoral environment. This is supported by the absence of planktonic forms which indicates the lack of any open marine connections.

1592

INTERVAL 5225'; ?Albian - Aptian and Barremian, Lower Cretaceous

General Lithology

The single sample consists of clays containing stringers of limestone, dolomite and siderite similar to those found in the overlying interval. In addition a few small yellowish brown iron ooliths are present in the clay.

Micropalaeontology and Stratigraphical Conclusions

An abrupt change in the microfauna is apparent at this level. Although considerable numbers of agglutinating forms persist in this

sample, the general assemblage is dominated by calcareous benthonic and planktonic foraminifera.

The association of species however, is anomalous, for we have an influx of Hedbergella infracretacea (which normally occurs in Albian or Aptian sediments) in association with the first appearance of typical Barremian species - Gavelinella barremiana, Conorotalites intercedens and C. cf. bartensteni and the ostracodes Cytherella pyriformis and Pontocyprella rara. We would suggest, therefore, that although this sample is undoubtedly of Barremian age, we may here be dealing with a condensed sequence which represents both Albian - Aptian and Barremian sediments.

Environmental Conclusions

The influx of planktonic and calcareous benthonic species in this sample suggests that we are dealing with an outer sublittoral environment with good open marine connections.

1601 1639
INTERVAL 5250' - 5375'; Lower Barremian - Hauterivian, Lower Cretaceous

General Lithology

The interval consists mainly of soft grey, pyritic clays which contain subordinate amounts of dark brown and grey, cryptocrystalline siderite and dolomite.

Micropalaeontology and Stratigraphical Conclusions

The occurrence of Epistomina caracolla caracolla at 5250' and the subsequent appearance within this interval of Epistomina ornata and Lenticulina eichenbergi would strongly suggest that we are dealing with Hauterivian sediments, although these species do range into the Lower Barremian. The first appearance below the incoming of Epistomina caracolla caracolla of more typical Barremian species such as Planularia crepidularis, Lenticulina ouachensis ouachensis and L. ouachensis wisselmanni however, suggests the presence of Barremian rocks, but

we assume these forms have in all probability caved. The additional occurrence of Lower Barremian - Hauterivian forms such as Gavelinella ? sigmoicosta and Lenticulina schreiteri leads us to assign a Lower Barremian to Hauterivian determination to this unit.

Environmental Conclusions

An outer sublittoral environment is indicated for this interval by the large numbers of calcareous benthonic foraminifera which dominate the microfaunas.

1646 1784

INTERVAL 5400' - 5850'; Hauterivian, Lower Cretaceous

General Lithology

The upper part of this interval is composed of soft, grey, pyritic clays which contain traces of dark brown siderite. Fine to medium-grained, subangular sandstone is first seen at 5500' and below this depth the formation appears to consist of interbedded sandstones and clays. The sandstone contains fragments of carbonaceous material and is locally cemented with calcite. Some coarse, subrounded sand grains are present below 5650'.

Micropalaeontology and Stratigraphical Conclusions

The appearance of Hechtina antiqua, Citharina harpa and the more consistent occurrence of Epistomina ornata in this interval suggests that sediments of definite Hauterivian age have been encountered. The presence of the ostracodes Apatocythere simulans and Schuleridea rhomboidalis supports this determination.

Environmental Conclusions

The relatively rich microfauna dominated by calcareous benthonic foraminifera suggests an outer sublittoral environment for this interval.

1791 1806

INTERVAL 5875' - 5925'; Hauterivian - Valanginian, Lower Cretaceous

General Lithology

This section consists of interbedded clays and sandstones similar to those found in the overlying interval. Subordinate amounts of brown, cryptocrystalline dolomite are also present and traces of greenish grey, dolomitic shale are seen below 5885'.

Micropalaeontology and Stratigraphical Conclusions

The appearance in the essentially calcareous benthonic microfauna of the ostracodes Dolocytheridea aff. wolburgi and Schuleridea cf. thoerenensis tentatively suggests that Valanginian sediments have been penetrated. In the absence of any further evidence, however, we have assigned a ranging Hauterivian - Valanginian age, which is supported by the occurrence of Lenticulina nodosa.

Environmental Conclusions

A similar environment of deposition to that of the preceding interval is envisaged for this section.

1814 1883

INTERVAL 5950' - 6175'; Valanginian, Lower Cretaceous

General Lithology

Grey clay and soft, greenish grey shale predominate in this interval. Traces of sandstone, and some medium brown dolomite and light brown sphaerosiderite are found associated with the clay.

Micropalaeontology and Stratigraphical Conclusions

Initially the general microfauna is essentially similar to that of the overlying interval; but from 6100' until the base, a rich assemblage occurs, dominated by agglutinating foraminifera. The appearance of Ammovertella cellensis and the ostracodes Protocythere hannoverana and Schuleridea praethoerenensis in this unit indicates

that it is of Valanginian age.

Environmental Conclusions

The increase in the agglutinating element of the microfauna at the expense of the calcareous benthonic fraction suggests that the outer sublittoral environment of the preceding interval is more restricted here and may be more inner sublittoral.

1890 1898

INTERVAL 6200' - 6225': Berriasian, Lower Cretaceous

General Lithology

This interval is composed of soft, grey pyritic clays which contain thin stringers of dark brown siderite and traces of fine-grained sand.

Micropalaeontology and Stratigraphical Conclusions

The upper of the two samples from this interval contains an influx of calcareous benthonic foraminifera, although agglutinating foraminifera still comprise a large part of the microfauna. The second sample is dominated by agglutinating forms with a corresponding reduction in calcareous benthonic species. The occurrence of the ostracodes Schuleridea juddi, Paracypris caerula, Orthonotacythere speetonensis and Mandelstamia sexti allows a Berriasian age to be assigned to these sediments.

Environmental Conclusions

The presence of both calcareous benthonic and agglutinating foraminifera in this interval suggests a sublittoral environment which is less restricted than either the preceding or succeeding intervals.

JURASSIC

1905.

INTERVAL 6250' - 6325'; Kimmeridgian, Upper Jurassic

General Lithology

The top of this interval is marked by a thin bed of creamy white cryptocrystalline, pyritic limestone. The remainder of the section consists of soft, grey clays containing traces of sandstone, siderite and pyrite.

Micropalaeontology and Stratigraphical Conclusions

The presence in an essentially agglutinating foraminiteral microfauna of Haplophragmoides sp. 2 and Mandelstamia aff. tumida is suggestive of a Kimmeridgian age for the first 50' of this section. There is a considerable increase in the numbers of agglutinating forms seen here when compared with the overlying interval.

At 6300' a further increase in agglutinating species is apparent, and the presence, as common species, of Trochammina spp. and the more common occurrence of Haplophragmoides sp. 2 leads us to assign a positive Kimmeridgian determination to these deposits.

Environmental Conclusions

A restricted sublittoral environment is indicated for this interval by the preponderance of agglutinating foraminifera in the microfauna.

INTERVAL 6350' - 6625'; Lower Kimmeridgian, Upper Jurassic

General Lithology

This interval consists entirely of soft, grey clay containing traces of pyrite and fine-grained sand.

INTERVAL 6350' - 6625'; Lower Kimmeridgian, Upper Jurassic

General Lithology

This interval consists entirely of soft, grey clay containing traces of pyrite and fine-grained sand.

Micropalaeontology and Stratigraphical Conclusions

The microfaunas of this interval are a continuation of those recorded in the Kimmeridgian unit. The presence of the ostracodes Galliaecytheridea elongata, Mandelstamia rectilinea and Galliaecytheridea oertlii are, however, more suggestive of Lower Kimmeridgian sediments.

Environmental Conclusions

The appearance of radiolaria, in assemblages dominated by agglutinating foraminifera (particularly below 6425'), suggests some deep open marine influence on the environment. We would suggest therefore that these rocks were deposited in a bathyal or outer sublittoral environment.

INTERVAL 6650' - 7520'; Upper Jurassic

General Lithology

The upper part of this unit is composed of grey, sandy, pyritic, clays similar to those found above. Thin intercalations of light grey, cryptocrystalline limestone occur below 6925' and at 7075' there is a bed of medium grey, silty dolomite. Traces of carbonaceous material are seen in the sample at 7100' and below this dark, grey and brown, silty shales containing abundant carbonaceous material are the predominant lithologies. These shales are dissected by calcite veins and contain thin beds of light grey limestone and yellowish brown, cryptocrystalline dolomite. Traces of fine-grained sand are present in the samples from 7475' to the base of the section.

Micropalaeontology and Stratigraphical Conclusions

The microfaunas of this interval are dominated by agglutinating foraminifera, in particular Haplophragmoides spp. and Ammobaculites spp. Ostracodes are virtually absent from these sediments: those forms present are not stratigraphically significant and merely indicate an undifferentiated Upper Jurassic age for the section.

Environmental Conclusions

The radiolaria and agglutinating foraminifera which predominate in these rocks suggest that deposition occurred in an outer sublittoral or bathyal environment.

INTERVAL 7525' - 8040'; ?Middle Jurassic

General Lithology

The uppermost sample at 7525' is composed mostly of dark grey, carbonaceous shale containing traces of sandstone. At 7530' there is a bed of yellowish brown, glauconitic, locally silty dolomite containing traces of mica, pyrite and iron oxides, and immediately below this at 7540' yellowish, fine-grained, subangular sandstone becomes predominant. The rest of the interval is composed of dark grey shales interbedded with white, fine-grained sandstone and minor amounts of coal. From 7980' to the base of the section the samples are composed almost entirely of fine to medium-grained sandstone. Some of the sand has been stained pale green or amber.

Micropalaeontology and Stratigraphical Conclusions

The incoming of sands and coals at 7530' is accompanied by a marked reduction in the numbers of foraminifera recovered. No ostracodes occur in this section and it is possible that the foraminifera have all cavved. On the basis of this rather fragmentary evidence we have assigned a questionable Middle Jurassic age to the interval.

Environmental Conclusions

The presence of sand and coals in association with poor microfaunas suggests a nearshore or possibly lagoonal and deltaic deposits and environment for these sediments.

TRIASSIC

INTERVAL 8050' - 13610': Triassic

General Lithology

This interval can be divided into a number of lithological units. The first from 8050' to 10040' consists mainly of conglomeratic sandstone. The sandstone is composed of rock fragments, granules and small pebbles of quartz and fine to coarse-grained sand. Many of the quartz grains have been stained pink, green or amber and the majority are angular or subangular in shape. The sand is cemented with reddish brown or pale green marl or clay. Subordinate amounts of orange-red, reddish brown and pale green, locally silty shales and marls, and some soft, white, chalky limestone which grades into a creamy white, highly calcareous marl, are associated with the sandstones. Mica is a common constituent of both the shales and the sandstones, and the whole formation contains an unusual amount of accessory minerals.

Between 10050' and 10700' the formation remains predominantly arenaceous, but contains up to 30% of white, chalky limestone and marl. Limestone is virtually absent from the samples between 10710' and 11020' but at 11030' becomes a prominent constituent of the rocks again. White, chalky limestone remains common down to 11550', and in this section some rounded and subrounded sand grains are present.

The rocks between 11560' and 11790' consist mainly of sandstone, but from 11800' to 12470' soft, white, chalky limestone and light pink, slightly sandy, highly calcareous marl are the predominant lithologies.

Sandstones and conglomerates similar to those at the top of the interval are the principal lithotypes from 12480' to 13220'. The section between 12820' and 12990' contains a high proporation of white, chalky limestone.

The basal section from 13260' to 13610' is composed of fine to medium-grained sandstone interbedded with red, brown and pale green shales and marls. Light red marl is very common at 13280', and below 13480' buff and light pink, highly calcareous marls are abundant.

Palynology and Stratigraphical Conclusions

The lithologies encountered in this interval are unlike those normally encountered in the Triassic in the southern part of the North Sea. This makes correlation with the type section difficult. However, the predominance of coarse clastics in this interval and the presence of Zechstein sediments directly beneath it suggests that this interval is of Triassic age. The different character of the sediments in this well may be due to their having been derived from a different source area from those encountered to the south and west of the present well.

The only strongly arenaceous formation found in the Triassic elsewhere in the North Sea is the Middle Bunter, but the typical Middle Bunter sandstones are clean, rounded and moderately well-sorted whereas the sandstones in this well are angular and unsorted and contain many relatively unstable minerals. There is no definitive evidence in the ditch cutting samples that this interval belongs to the Bunter.

The middle part of the interval between 10050' and 12990' includes four sections rich in white, argillaceous limestone. These carbonates could have been deposited in the Muschelkalk sea, the margins of which probably lay fairly close to the location of this well. If the carbonate section does represent the Muschelkalk then the overlying sandstones would presumably belong to the Keuper and the sands beneath to the Bunter. The Muschelkalk is not normally so thick (nearly 3000') but the unusual aspect of the other Triassic sediments in this well indicates that conditions of deposition were rather different from those prevailing elsewhere.

Very few palynomorphs were recorded from this interval. The association of Cycadopites sp. NS1 and Duplicisporites cf. granulatus at 9490' strongly suggests that rocks of Neotriassic Carnian age (older Keuper) have been penetrated. This determination would be consistent with the theory that the white chalky limestones and marl at 10050' are representatives of the Muschelkalk. The indeterminate striate bisaccate recorded at 12000' and the single specimen of Striatoabietites sp. at 13460', together with the lithological evidence, provide further support for the Triassic age of this unit. Furthermore, the presence of a specimen with affinities to Aculeisporites variabilis at 13460' tentatively suggests that rocks of Palaeotriassic, Skythian age (Bunter) have been reached.

Environmental Conclusions

The coarse sands and conglomerates found in this interval were probably deposited by a large river which rapidly carried the eroded detritus down from the uplands and deposited it before many of the minerals in it could disintegrate or the more resistant grains become rounded or sorted. The white, chalky limestone could have been laid down on the margins of a large, partially enclosed sea where the rate of evaporation was not sufficiently high to precipitate the more soluble salts such as anhydrite and halite. It is probably therefore that these sediments were deposited in a restricted nearshore and arid environment.

VII

PERMIAN

INTERVAL 13640' - 14100', Zechstein, Upper Permian

General Lithology

The top of this interval is marked by the incoming of soft, greyish white anhydrite. The anhydrite has a sugary, fibrous or finely crystalline texture and is common throughout the interval. Soft, micaeous, locally silty buff and light greenish-grey, slightly dolomitic shales are interbedded with the anhydrite below 13660'. The subordinate amounts of reddish brown shale and sandstone present have probably caved from the overlying interval.

Palynology and Stratigraphical Conclusions

The abundance of anhydrite and dolomitic shales in the interval indicates that the Zechstein has been penetrated.

Rich microfloral assemblages were obtained from this interval and the association of Illinites tectus, Labiisporites granulatus, Lueckisporites virkkiae, aff. Perisaccus granulosus, Protohaploxypinus cf. chaloneri, P. cf. pennatulus, Taeniaesporites cf. albertae, T. hexagonalis, T. novimundi and Vittatina hiltonensis provides ample evidence for an Upper Permian age (Zechstein).

Environmental Conclusions

These rocks were probably deposited in a shallow, inland sea in a hot arid climate where the rate of evaporation was rapid.

VIII

CONSLUSIONS

The oldest deposits encountered in this well are of Upper Permian age. They comprise a series of evaporitic sediments which are inferred to have been deposited in an enclosed sea or lagoonal environment. Only the upper part of the Permian sequence were penetrated, and this is succeeded by a section of more than 5000' of sediments which are regarded as being of Triassic age. It is probable that the Triassic section is separated by discontinuity from the Permian beds beneath, although there is no direct evidence available as to the magnitude of this unconformity.

The Triassic interval is seen to consist of a basal section of some 600' which passes upwards from marls to shales, medium-grained sandstone, coarser sandstones and eventually to conglomerates. This deposition probably occurred in an inland sea under a strong continental regime. In the mid part of the Triassic succession some 2900' of similar sandstones interbedded with white limestones and sandy marls could represent marginal deposits in this shallow sea. At the top of the Triassic section a further 2000' of conglomeratic sandstones with occasional silty shale and calcareous marls, represents continuing deposition in a similar environment.

Sediments of Jurassic age are found in the interval 6250' - 8050'. The Lower Jurassic appears to be completely absent and the lower 500' of the Jurassic section is thought to be of Middle Jurassic age. A major unconformity therefore exists at the base of this section, implying a lengthy period of non-deposition, or, if sediments were deposited, a subsequent erosion which stripped away all traces of Lower Jurassic deposits. It is probably that additional unconformities of slightly less magnitude, may be interspersed through Middle and Upper Jurassic

times. The Jurassic section seen here, is comparatively thin, and palaeontological control is broad and generalized. In addition, whilst the sediments of the supposed Middle Jurassic section are typical nearshore, or coastal deposits, the overlying section of clays with thin intercalations of sands and limestones are regarded as indicating a gradual increase in depth to a sublittoral or even bathyal environment.

The Jurassic section is followed by Lower Cretaceous sediments foming an interval of 2200'. Good palaeontological control indicates that a fairly broad succession is present from early to late Lower Cretaceous times. Sediments of Beriasian age are seen only in a single sample which would indicate either a residual fauna, a condensed sequence or an extremely thin layer of sediments of this age. Valanginian and Hauterivian intervals have been determined, and Barremian elements are recognised in another thin interval. A break in succession then occurs in which it appears that the entire Aptian stage may be missing. However deposition re-occurred at some stage in the Albian and the top 1170' of the Lower Cretaceous is recognised as Albian or questionable Albian. Whilst the Lower Cretaceous sediments consist mainly of soft clays with occasional shales and interbedded sandstones, the environment reflected by the palaeontology is essentially sublittoral, alternating between inner and outer sublittoral suggestive of an intermittent shallowing and deepening of an outer area of shelf sea.

A moderately thin Upper Cretaceous section is found to contain Senonian sediments ranging through Coniacian to Maestrichtian times. The absence of a Cenomanian - Turonian interval implies a further major, non-depositional break during which time this area was either elevated to form a land area, or has subsequently been denuded of all sediments of that age. Throughout the Upper Cretaceous interval, the lithology consists of chalk with a little limestone at base, which is thought to have been deposited in a shelf sea; the intermittent appearance of planktonic foraminifera being

regarded as indicating more open connections in an otherwise partly enclosed, or similiarly restricted sea.

Despite the presumed absence of Upper Maestrichtian beds implying another depositional break, similar conditions are seen to extend up into the base of the Tertiary section, where 40' of Danian chalk was encountered. Above this 80' cherts and shales, tentatively ascribed to the Palaeocene, suggest a further shallowing of the seas.

At 2420' a change of fauna indicates that the overlying clays, which are of Lower Eocene age, were deposited in outer sublittoral or even bathyal seas and this suggests a further discontinuity in the sequence. The topmost 750' of section constitutes a predominantly clay lithology and by the nature of the faunas observed in these beds, it is believed that deposition through Middle Eocene to Oligocene times occurred in a sublittoral environment in which open marine connections were maintained.

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