Appendix III

BIOSTRATIGRAPHY OF WELL 31/2-6 (NORSKE SHELL)

by

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Enclosures

1. Microfaunal distribution chart (780-1481 m) - scale 1 : 1000
2. Palynological distribution chart (1481-1754 m) - scale 1 : 500

1. INTRODUCTION

On request of Norske Shell, SIPM (EP/12.1) carried out a biostratigraphic study of the sedimentary section penetrated by well 31/2-6.

The major objective of this study was an evaluation of the Jurassic sequence, down to a total depth of 1760 m. For the Tertiary and Cretaceous, the main interest was in establishing the major time-stratigraphic boundaries.

The biostratigraphic results led to the following time-stratigraphic interpretation:

(780 m, drd) - 820 m, drd	: Oligocene
870 m, drd - 1191 m, lgd	: Eocene
1200 m, drd - 1463.5 m, lgd	: Paleocene
1464 m, drd - 1479 m, drd	: Cretaceous
1464 m, drd - 1473 m, drd	: Early Maastrichtian
1476 m, drd - 1479 m, drd	: Hauterivian - Albian
1481 m, lgd	: Portlandian - Berriasian
1482 m, lgd - 1488.8 m, lgd	: Portlandian
1495 m, lgd - 1514.6 m, drd	: Kimmeridgian
1529.06 m, drd-1542 m, drd	: Late Oxfordian
1555.8 m, drd-1557.95 m, drd	: (?Early) Oxfordian
1578.90 m, drd-1591.75 m, drd	: Early Oxfordian
1594.4 m, drd	: Callovian - Oxfordian
1601.65 m, drd - 1754 m, lgd	: Callovian

2. MICROFAUNA

2.1 General

In order to establish the broad time-stratigraphic frame of the Lower Tertiary-Cretaceous section in well 31/2-6, 27 sidewall cores (858-1481 m, lgd), and 14 ditch cutting samples (780-1479 m, drd) have been analyzed on their microfaunal content. The investigations started at 780 m, drd, a level situated closely above the prognosed Oligocene-Eocene boundary.

As the micropalaeontological studies concentrated on checking of presence/absence of marker types only, the data as presented on the faunal distribution chart (encl.1) do not give a full account of the assemblages encountered, as only key types and more common species have been recorded.

Although microfaunal studies were concentrated on sidewall samples, the depth levels of which are log adjusted (lgd = log depth), some ditch cuttings from critical intervals had to be checked on their faunal content as well. Depth figures for the latter samples are based on driller's depths (drd).

2.2 Oligocene (highest sample examined at 780 m, drd - 820 m, drd)

This age interpretation is based on the co-occurrence in three cutting samples (780, 810, 820 m, drd) of

Turrilina alsatica ANDREAE
Rotaliatina bulimoides (REUSS)
Nodosaria longiscata d'ORBIGNY
Cibicides dutemplei (d'ORBIGNY) var. *praecinctus* (KARRER)

which occur in assocation with:

Alabamina wolterstorffi (FRANKE)
Bulimina marginata d'ORBIGNY
Cibicides cookei CUSHMAN var. *limbatosuturalis* V. VOORTHUIJSEN
Cibicides lobatulus (WALKER & JACOB) var. *grossa* TEN DAM & REINHOLD
Elphidiella hannai (CUSHMAN & GRANT)
Elphidium selseyense (HERON ALLEN & EARLAND)
Melonis affine (REUSS)
Pullenia bulloides d'ORBIGNY
diatoms
radiolaria
sponge spicules
echinoderm remains

Depositional environment: the microfaunal content of the three samples studied suggests an outer neritic to possibly bathyal environment of deposition.

2.3 Eocene (870 m,drd - 1191 m,lgd)

Although the two SWS (879 m, lgd and 887 m, lgd) shot in the uppermost part of this interval were barren of foraminifera and contained only radiolaria, diatoms and some fish remains, the top of the Eocene was defined in this well on a conspicuous change in faunal preservation and composition, as in cutting sample 870 m, drd, the foraminiferal assemblages consist of whitish coloured specimens.
Similar preservation changes were also observed in the neighbouring 31/2 wells, coinciding with the top occurrence of Eocene markers.
This extrapolation is further supported by log evidence which suggests the Oligocene/Eocene boundary to be located at 867 m, lgd.
Consequently, no additional detailed micropalaeontological investigations in the upper part of this interval were carried out (especially as no SWS were available between 887 and 1063.5 m, lgd).

The sidewall samples from 1063.5 m, lgd, to 1103.7 m, lgd, contain a relatively rich and well diversified arenaceous assemblage with, amongst others:

Ammodiscus sp.
Cyclammina amplectens GRZYBOWSKI
Haplophragmoides kirki WICKENDEN
Haplophragmoides sp.
Haplophragmoides glabra CUSHMAN & WATERS
Bathysiphon sp.
Glomospira charoides (JONES & PARKER)
Recurvoides obsoletum (GOES)
radiolaria
diatoms
fish remains

together with: *Spiroplectammina spectabilis* (GRZYBOWSKI)
Dorothia asiphonia (ANDREAE)
Textularia plummerae LALICKER

indicative for an Early Eocene age.

At 1101.7 m, lgd, and 1103.7 m, lgd, a few calcareous benthonic and planktonic foraminifera co-occur with the above-mentioned fauna.
Similar mixed arenaceous/calcareous assemblages have been encountered in wells

31/2-1 at 1170-1180 m, drd
31/2-2 at 1100-1130 m, drd
31/2-3 at 1130-1150 m, drd
31/2-4 at 1190 m, drd
31/2-5 at 1329 m, lgd, and 1340 m, drd.

The samples in the lower part of the Eocene section (1162.5, lgd - 1191 m, lgd) are characterized by rich occurrences of pyritized diatoms, such as

Coscinodiscus sp. 1 BETTENSTAEDT
Coscinodiscus sp. 2 BETTENSTAEDT
Triceratium sp. 1 BETTENSTAEDT

together with poorly preserved arenaceous foraminifera.
Depositional environment: deeper marine, outer neritic to bathyal.

2.4 Paleocene (1200 m, drd - 1463.5 m, lgd)

The four ditch cuttings examined from the uppermost interval (1200 m, drd - 1218 m, drd) contain a poor arenaceous fauna made up of components as observed in the Eocene interval. As the sections underlying deposits with rich diatoms are usually barren of foraminifera, the above fauna is considered as contamination by caving. If this assumption is correct, a Late Paleocene age can be attributed to interval 1200-1218 m, drd, in line with previous investigations of Paleocene sections in North Sea wells.

The interval 1224 m, drd, - 1351 m, lgd, yielded rich and diversified arenaceous faunas, similar to those observed in the Eocene section. However, they co-occur with the following Paleocene markers:

Bulimina denticulata CUSHMAN & PARKER
Saccammina rhumbleri (FRANKE)
Rzehakina epigona minima CUSHMAN & RENZ
Trochammina ruthven-murrayi CUSHMAN & RENZ

and some reworked Cretaceous species.

From 1307 m, lgd, downwards very coarse-grained *Bathysiphon* specimens were found. This phenomenon has also been observed in wells

31/2-1 below 1332.1 m, lgd
31/2-2 " 1284.3 m, lgd
31/2-3 " 1314 m, lgd
31/2-4 " 1317,2 m, lgd
31/2-5 " 1486 m, lgd.

In the underlying sequence (1363.5 m, lgd - 1446,3 m, lgd) the foraminiferal assemblages consist of species as above in association with the following calcareous benthonic Paleocene markers:

Bulimina denticulata CUSHMAN & PARKER
Rotalia parvula TEN DAM
Bulimina trigonalis TEN DAM

The co-occurring Cretaceous species are considered to be reworked:

Arenobulimina sp.
Gümbelina sp.
Chilogümbelina sp.
Globigerinelloides sp.
Marssonella oxycona (REUSS)
Heterohelix planata (CUSHMAN)
Spiroplectoides flexuosa (REUSS)
Textularia agglutissima HOFKER
Bulimina ventricosa BROTZEN.

Samples investigated from the lowermost part (1454 m, lgd - 1463.5 m, lgd) yielded the following markers which are restricted to the earlier Paleocene:

Bulimina (Pyramidina) curvisuturata BROTZEN
Siphonina eklundi (BROTZEN)
Zeauvigerina aegyptiaca SAID & KENAWY
Globorotalia compressa (PLUMMER)

together with the following forms which have their stratigraphic top in earlier Paleocene (but range into the Cretaceous), e.g.:

Eouvigerina americana CUSHMAN
Allomorphina allomorphinoides (REUSS)
Textularia laevis ROEMER
Parrella (Osangularia) lens BROTZEN
Gavelinella pertusa (MARSSON)
Cibicides excavata BROTZEN
Cibicides ekblomi BROTZEN
Anomalinoides nobilis BROTZEN
Gavelinella lorneiana (d'ORBIGNY)

and forms which range throughout the Paleocene, like:

Bulimina trigonalis TEN DAM
Allomorphina halli JENNINGS
Chilogümbelina crinata (GLAESSNER)
Pullenia quaternaria (REUSS)
Anomalinoides danica (BROTZEN)
Rotalia parvula TEN DAM
Rzehakina epigona minima CUSHMAN & RENZ
Saccammina rhumbleri FRANKE

Depositional environment: deeper marine, outer neritic to bathyal.

2.5 Cretaceous (1464 m, drd, - 1479 m, drd)

For technical reasons (casing depth) no SWS were taken over this interval, and six cutting samples only were available for investigation. The four higher samples (1464 m, drd - 1473 m, drd) yielded (apart from Tertiary caving), the following fauna, indicating a general Late Cretaceous to Paleocene age:

Parrella (Osangularia) lens BROTZEN
Pullenia quaternaria (REUSS)
Anomalinoides danica (BROTZEN)
Gyroidina nitida (REUSS)
Arenobulimina puschi (REUSS)
Guttulina problema (d'ORBIGNY)

with as Late Campanian-Early Maastrichtian markers:

Bulimina triangularis CUSHMAN & PARKER
Eponides beisseli SCHIJFSMA
Stensioina pommerana BROTZEN
Globorotalites multiseptus (BROTZEN)
Gyroidina globosa (HAGENOW)
Rugoglobigerina rugosa (PLUMMER)

The presence of some older (Turonian-Santonian) species is interpreted as reworking:

Pseudovalvulineria vombensis BROTZEN
Globotruncana marginata (REUSS)
Globotruncana linneiana (d'ORBIGNY)

Depositional environment: deeper marine, bathyal to outer neritic.

The deeper two cutting samples (1476 m, drd, and 1479 m, drd) yielded an assemblage, consisting of ostracods, crinoids and the following foraminifera:

Marssonella oxycona (REUSS)
Buliminella obtusa (d'ORBIGNY)
Ammobaculites parvispira TEN DAM
Falsogaudryinella alta (MAGNIEZ-JANNIN)
Haplophragmoides nonioninoides (REUSS)
Saracenaria crassicosta EICHENBERG
Falsogaudryinella moesiana (NEAGU)

indicative for an Albian age, whereas the simultaneous presence of

Falsogaudryinella tealbyensis (BARTENSTEIN)
Vidalina carpathica NEAGU & POPESCU
Marssonella hechti (DIENI & MASSARI)
Marssonella hauteriviana MOULLADE
Patellina subcretacea CUSHMAN & ALEXANDER
Trocholina sp.

points to a concurrence of Hauterivian/Barremian elements.
This co-occurrence of Hauterivian/Barremian and Albian indicators suggest a general Early Cretaceous age interpretation for interval 1476-1479 m, drd. A comparable sequence was found in well 31/2-1A, intervals 1395.8 m, lgd - 1402 m, lgd, and 1406 m, lgd - ?1416 m, lgd, respectively.

Depositional environment: possibly shallow marine, inner neritic.

2.6 Portlandian/Berriasian (SWS 1481 m, lgd)

In this sample a very rich, monospecific arenaceous fauna was encountered, consisting of *Haplophragmoides* sp. *B*, indicating a Portlandian/Berriasian age.

Depositional environment: restricted, shallow marine.

3. CALCAREOUS NANNOPLANKTON

3.1 General

The very reduced Cretaceous section, as well as the Paleocene immediately above this Cretaceous were dated with help of calcareous nannofossils. In total five sidewall cores and four samples of selected cuttings have been analysed.

3.2 Early Middle Paleocene (1454.0 m, lgd - 1463.5 m, lgd) Zone NP4c-5a

This age interpretation has been based on the presence of frequent *Neochiastozygus perfectus*, common *Prinsius martinii* and specimens intermediate between *P. martinii* and *P. bisulcus* as well as rare *P. bisulcus*. Representatives of the genera *Fasciculithus* and *Sphenolithus* have not been observed.

All four samples contain small quantities of (reworked) Late Cretaceous species.

3.3 Early Maastrichtian (1464 m, drd - 1476 m, drd), Zone NK 23-24

The presence of fragments of *Reinhardtites levis* points to an Early Maastrichtian age. No older nannofloral elements have been observed.

The investigations on three samples were carried out on selected chalky lithologies in these cuttings. In view of the contradictory age interpretations based on microfauna or nannoplankton on sample 1476 m, it can be assumed that the nannoplankton work was carried out on caved lithology.

3.4 Undiagnostic (1479 m, drd - 1481 m, lgd)

No autochthonous nannoplankton.

4. PALYNOMORPHS

4.1 General

Palynological investigations were carried out on interval 1481 m (lgd) - 1754 m (lgd). A total of 18 core samples and 18 sidewall cores were examined. These samples were prepared according SIPM's standard preparation method, as applied for the other 31/2-wells, viz. treatment with HCl and HF, followed by a heavy liquid separation (zinc bromide with S.G. of 2.2).
The resulting organic residue was further concentrated for palynomorphs by a light oxidation in cold HNO_3 and by sieving through a microsieve of 15 micrometer to concentrate sporomorphs, and of 30 micrometer in order to gain a concentration of dinocysts.

All samples, except one, contained palynomorphs, although some were very poor. Palynomorph occurrences have been recorded on a distribution chart (encl. 2).

Throughout the studied section, the sporomorph colour is estimated as "upper light" corresponding to a FCC of less than about 69.

4.2 Undiagnostic (1481 m, lgd)

The highest sample examined, a sidewall core at 1481 m, proved to be barren of palynomorphs. The residue consisted entirely of one type of organic matter of unknown affinity.

4.3 Portlandian (1482 m, lgd - 1488.8 m, lgd)

The 5 examined SWS contained rich and diversified dinoflagellate assemblages. A Portlandian age was inferred, based on the combined presence of

Pareodinia dasyforma (base in Portlandian)
Parvocavatus spinosus (idem)
Cannosphaeropsis apiculata (top in Portlandian)
Egmontodinium polyplacophorum (idem)
Hystrichogonyaulax sp. *1* (idem)

Also present are:

Egmontodinium expiratum
Gochteodinia virgula
Perisseiasphaeridium impolitum

These three species have recently been described from a borehole in Denmark (DAVEY, in press). Their occurrences were restricted to the Portlandian but their full range has yet to be established.

4.4 Kimmeridgian (1495 m, lgd - 1514.6 m, drd)

Two core samples and 4 SWS contained assemblages that were much poorer and less diversified than those of the overlying interval. The age interpretation is based on the presence of

Gonyaulacysta cladophora (top in Kimmeridgian)
G. jurassica (top in Kimmeridgian)

and the absence of Oxfordian types.

It is not excluded that only Early Kimmeridgian strata were sampled based on the consistent occurrences of the above two species.

4.5 Oxfordian (1529.06 m, drd - 1591.75 m, drd)

Nine core samples were investigated, allowing the following subdivision:

a) Late Oxfordian (1529.06 m, drd - 1542 m, drd)

The four investigated samples contained a rich palynoflora, including a well diversified dinocyst assemblage with, amongst others, *Adnatosphaeridium aemulum* (top in Oxfordian)
Endoscrinium galeritum (Callovian-Oxfordian)
Leptodinium mirabile
Nannoceratopsis pellucida (top in Oxfordian)
Scriniodinium crystallinum (top in Early Kimmeridgian, top regular occurrences in Late Oxfordian)
Stephanelytron redcliffense

Furthermore, the marker for the Early Oxfordian,
Occisucysta areolata, is absent.

b) (?Early) Oxfordian (1555.8 m, drd - 1557.95 m, drd)

One fragment only of *Occisucysta areolata* was found at 1555.8 m (drd). No other Early Oxfordian markers were present, either in this sample or at 1557.95 m (drd).

c) Early Oxfordian (1578.90 m, drd - 1591.75 m, drd)

All three core samples contained *Occisucysta areolata*, which is restricted to the Early Oxfordian. *Wanaea fimbriata*, another species restricted to this age interval, was present in two samples.

4.6 Callovian to Oxfordian (1594.4 m, drd)

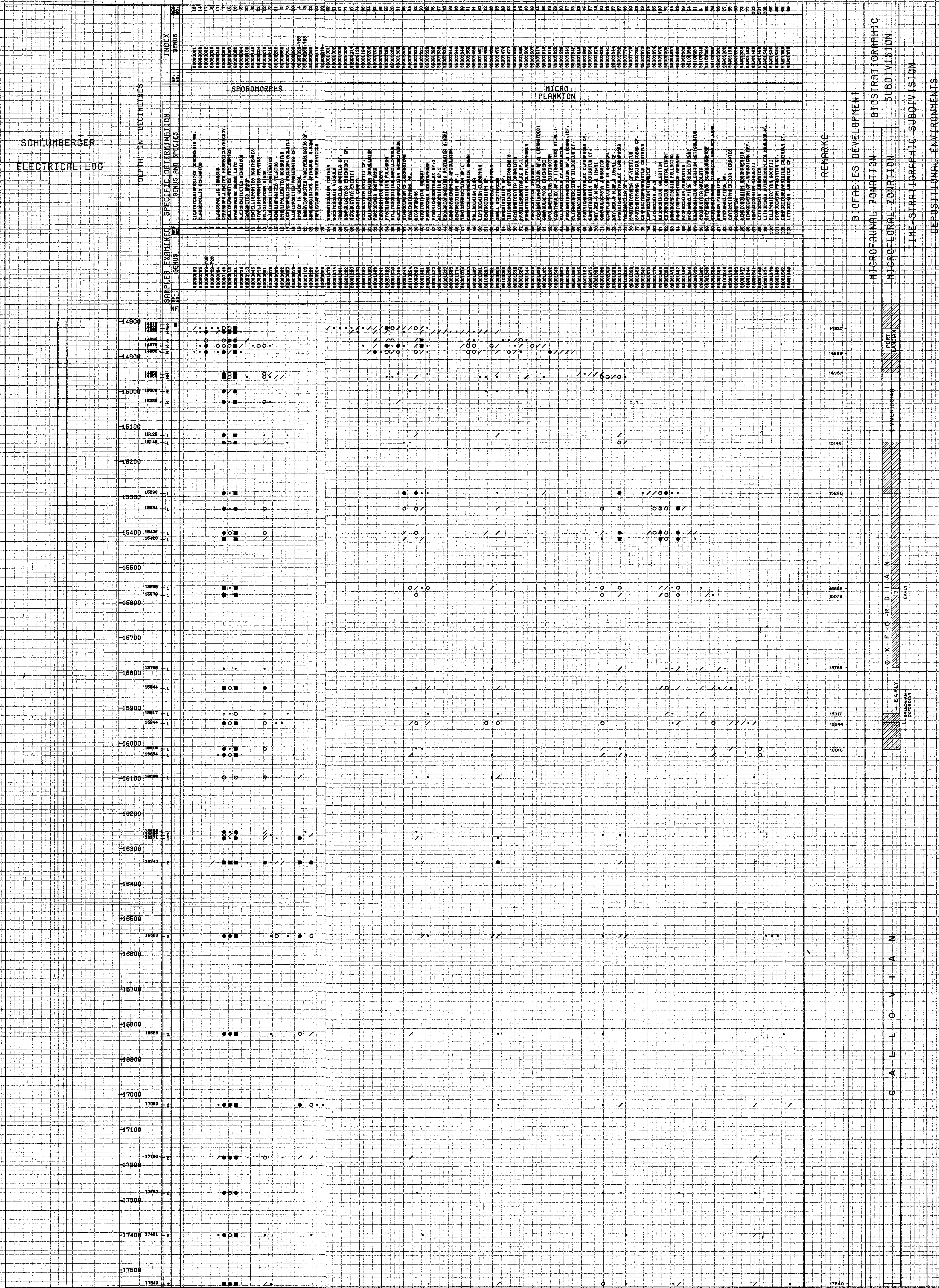
The core sample at 1594.4 m contained only types that occur in both the Oxfordian and the Callovian.

4.7 Callovian (1601.65 m, drd - 1754 m, lgd)

Six core samples and 8 SWS were examined. In general, palynomorph occurrences were relatively poor, hampering age interpretations. The highest sample contained *Lithodinia jurassica*, a Middle-Late Callovian marker. The deepest sample yielded *Adnatosphaeridium aemulum* and *Sentusidinium rioultii*, both not older than Callovian, in combination with common *Gonyaulacysta jurassica*, which has its base regular occurrences in the Callovian.

A subdivision of this Callovian interval is more difficult to achieve in view of scarcity to absence of useful markers. *Systematophora "divarica"*, present at 1601.65 m (drd) and 1603.40 m (drd), suggests a Late Callovian age as it normally is much more common in the Late Callovian (and Early Oxfordian) than in the Middle Callovian.

Sentusidinium rioultii occurs regularly between 1634 m (lgd) and 1754 m (lgd) and, in combination with the absence of Late Bathonian to Early Callovian markers, could indicate a Middle Callovian age. This interpretation is supported by the presence at 1655 m (lgd) of one specimen of *Lithodinia "suturocomplexa"* restricted to the Middle Callovian.



STANDARD LEGEND

NF	NO FAUNA/FLORA	S SINGLE	1 CORE SAMPLE
•	1 SPECIMEN	R RARE	2 SIDEWALL SAMPLE
/	2 -5 SPECIMENS	C COMMON	3 DITCH CUTTING
○	6 -20 "	F FREQUENT	4 SURFACE SAMPLE
●	21-100 "	A ABUNDANT	5 SEABOTTOM SAMPLE
■	> 100 "		
▪	QUALITATIVE DETERMINATION		

SAMPLES EXAMINED:

SHELL INTERNATIONALE PETROLEUM MIJ.

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NORWAY OFFSHORE

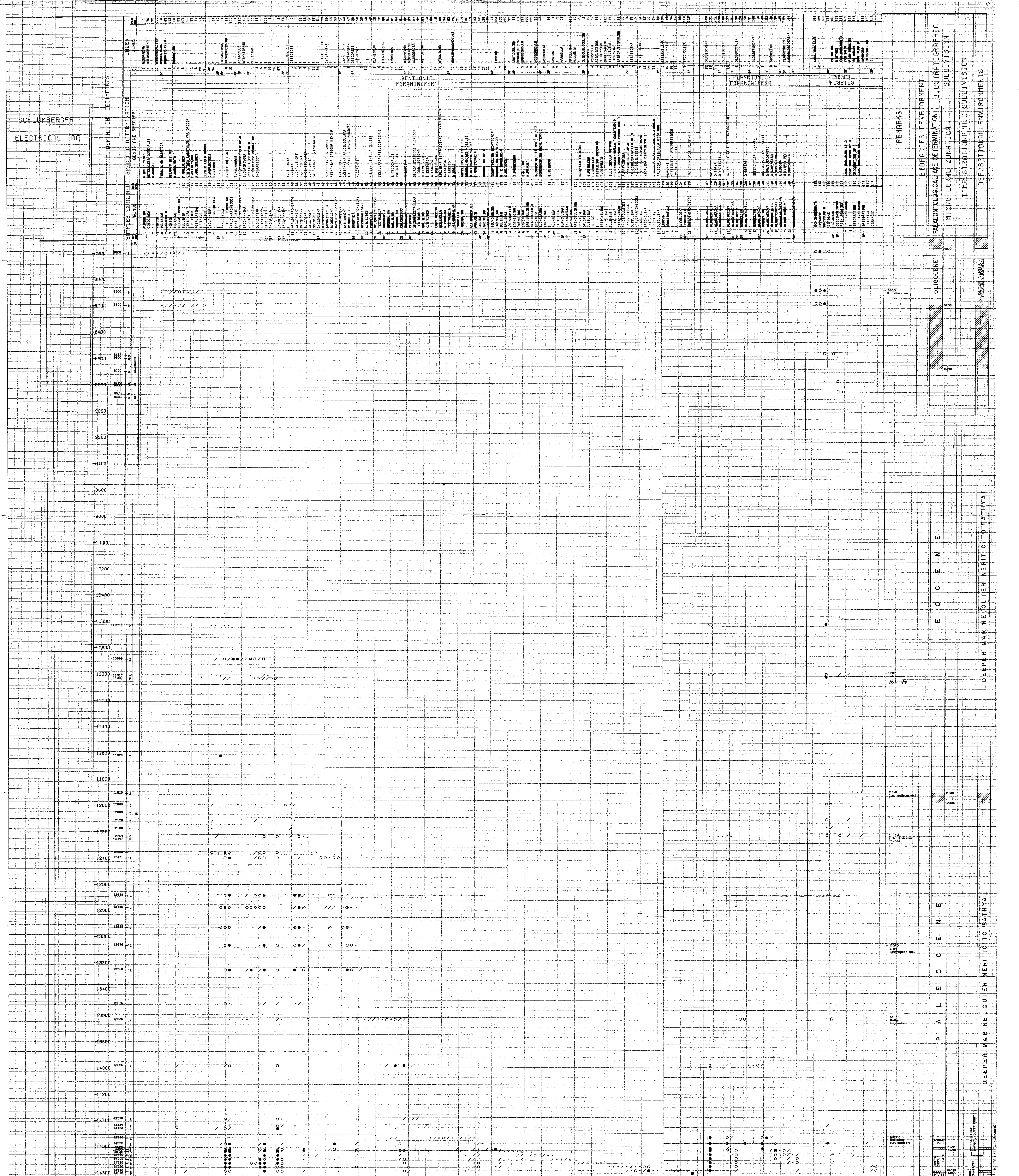
PALYNOLOGICAL DISTRIBUTION CHART

WELL : 31/2-6

SCALE 1:500

AUTHOR: J.P. van Niel | ENCL. 2 | DATE: Dec. 1981

Well résumé 31/2-6, appendix III | DRAW NO: 66249/2



STANDARD LEGEND

NF	NO FAUNA/FLORA	S	SINGLE
•	1 SPECIMEN	R	RARE
/	2 -5 SPECIMENS	C	COMMON
O	6 -20 "	F	FREQUENT
●	21-100 "	A	ABUNDANT
■	> 100 "		
*	QUALITATIVE DETERMINATION		

SAMPLES EXAMINED:

1 CORE SAMPLE
2 SIDEWALL SAMPLE
3 DITCH CUTTING
4 SURFACE SAMPLE
5 SEABOTTOM SAMPLE

SHELL INTERNATIONALE PETROLEUM MIJ.
THE HAGUE — EXPLORATION & PRODUCTION

NORWAY OFFSHORE
MICROFAUNAL DISTRIBUTION CHART
WELL : 31/2-6
SCALE 1 : 1000

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