

**ROBERTSON RESEARCH INTERNATIONAL LIMITED**

**OILFIELDS REPORT NO. 2262**

**NORSK HYDRO 30/7-3 WELL:  
BIOSTRATIGRAPHY OF THE INTERVAL**

**1820 m - 4040 m**

**by**

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**PROJECT NO. IIA/767/1348**

**FEBRUARY, 1977**

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### ENCLOSURES

1. Biostratigraphical Charts Nos. 1-5 (7 sheets).
2. Summary Log.

SUMMARY

1. The section analysed commences at 1820m in beds of probable Lower Eocene age.
2. A Lower Tertiary section is present from 1820m to 2520m consisting essentially of non-calcareous grey shales. A large part of this interval is of Palaeocene age although the uppermost beds are considered to be of Palaeocene-Lower Eocene age, whilst micro-faunal evidence is also present to support the existence of a thin interval of Danian sediments at the base.
3. A distinct lithological and microfaunal change at 2570m indicates that the Tertiary/Upper Cretaceous boundary lies between 2520m and 2570m. Analysis suggests that a marked stratigraphical hiatus is present at this boundary.
4. The topmost Upper Cretaceous beds include chalk and limestone horizons, but from 2800m downwards shales predominate, with subordinate dolomites present at various levels. A fairly continuous Upper Cretaceous stratigraphic succession is indicated ranging from the youngest beds which are of Maastrichtian age down to Cenomanian at 3850m.
5. The foraminiferal content of the basal 230m of the section is poorly diagnostic but the presence of very occasional ostracodes and limited palynofloral evidence indicates the existence of a short Lower Cretaceous section ranging down from Albian at 3870m to include possible Aptian sediments.
6. The very base of the section may possibly be as old as late Barremian.

## 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 1820m - 4040m from the Norsk Hydro 30/7-3 Norwegian North Sea Well under Project No. IIA/767/1348.

Under this project a total of 54 ditch cuttings samples was analysed utilising standard micropalaeontological techniques. In addition 14 of these samples, covering the interval 3750m - 4040m, were treated palynologically.

The provision for this study of only 54 samples to represent more than 2000m of section inevitably results in unusually wide sample gaps. We feel that it is necessary, therefore, to emphasise the distribution of samples analysed :

- i) over the Tertiary part of this section our results are based upon an average spacing of 1 sample per 50 metres.
- ii) over the topmost Senonian, 3 samples represent 230 metres of drilled section.
- iii) over the later Campanian to Santonian, samples are again at 50 metre intervals.
- iv) no samples were provided over the lower part of the Santonian and upper part of the Coniacian (i.e. between 3300m and 3450m).
- v) over the Coniacian, Turonian and Cenomanian, a 50 metre interval was resumed.
- vi) over the basal Cenomanian and Lower Cretaceous (i.e. the basal 240m of the section) samples, with one exception, are at either 10m or 20m intervals.

This distribution has, in several instances, precluded a more exact definition of system or stage boundaries. In such instances where a boundary clearly falls within the 40m interval between two samples we have preferred to represent that boundary by an oblique line - thus implying a certain latitude to its precise position (see enclosures).

Our lithological examination of these samples leads us to suppose that individual bags represent spot samples taken at approximately 50 metre intervals, rather than composited samples each covering approximately 50 metres of section. Beneath 3800m many samples are badly contaminated with drilling cement; whilst between 3940m and 4000m the finer details of what appears to be a continuing shale lithology are obscured as a result of diamond bit drilling.

It is also emphasised that this report is based solely on ditch

cuttings samples. No cored samples or other information pertinent to this section were available for study. A limited part of the section has already been reported upon following a short period of well-site activity. That earlier information is fully corroborated by this more detailed and more extensive study.

A summary of the determinations obtained by these analyses has already been communicated by telex and verbal discussion and forms the framework of factual information on which this report is based. A complete summary of the sequence penetrated in this section can be seen in Table 1 (see p. 4):

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

The Robertson Research personnel who have contributed to this report are as follows:

- John Seymour - (Project Co-ordinator) Foraminiferal analyses and lithologies.
- Cyril Haskins - Tertiary and Lower Cretaceous ostracodes
- Chris Denison - Lower Cretaceous palynology.

We wish to acknowledge the continued co-operation and assistance received from the various members of Norsk Hydro A/S, with whom we have been associated during the course of this work.

## III

SUCCESSIONTABLE 1

<u>System/Subsystem</u>	<u>Stage</u>	<u>Interval</u>
Lower Eocene - Palaeocene	-	1820m - 2120m
Palaeocene	-	2170m - 2520m
Lower Palaeocene	Danian	c.2550m - c.2570m
	{ Maastrichtian	2570m
	{ early Maastrichtian - late Campanian	2670m - 2850m
Upper Cretaceous	{ early Campanian	2900m - 3100m
	{ Santonian	3150m - 3300m
	{ Coniacian	3450m - 3550m
	{ Turonian	3600m - 3700m
	{ Cenomanian	3750m - 3850m
	{ Albian	3870m - 3940m
Lower Cretaceous	{ early Albian - ?Aptian	3960m - 4030m
	{ ?late Barremian	4040m

N.B. This analysis is based solely on ditch cuttings samples, at the intervals indicated on the accompanying biostratigraphical charts. No well logs or core samples were available for this study.

## IV

TERTIARYINTERVAL 1820m - 2120m; LOWER EOCENE - PALAEOCENE

Sediments within this interval are identified as being no younger than Lower Eocene in age, although they could include beds at least as old as Palaeocene. This age determination rests upon the following criteria:

- the general aspect of a dominantly agglutinated foraminiferal assemblage.
- the inclusion within this assemblage of Spiroplectamina spectabilis and Globigerina patagonica.
- the presence, beneath 2120m, of sediments of undoubted Palaeocene age.

LITHOLOGY

Throughout this interval samples are composed almost entirely of relatively uniform, light grey coloured, non-calcareous shales. These shales are occasionally a darker mid-grey colour and may contain extremely fine, well disseminated mica and carbonaceous matter. At 2120m minor amounts of strongly calcareous, chocolate-brown shale are also present.

Accessory lithologies present in these samples include fawnish-grey, slightly calcareous, very fine grained siltstone or silty shale, together with traces of limestone and dolomite, all of which are persistent throughout. A small amount of greyish to greenish-grey, fine to medium grained sandstone, having a lightly calcareous cement, is present in the basal samples.

MICROPALAEONTOLOGY

A moderate assemblage comprised largely of agglutinated foraminifera is present in all samples. Cyclamina placenta and Bathysiphon eocenicus appear significantly in the higher samples; whilst lower in the interval Cyclamina challinori and Cystamina spp. are more conspicuous.

A few calcareous benthonic and planktonic elements appear in the basal sample.

Among the other fossils recorded from these samples are radiolaria (present abundantly throughout) and pyritised siliceous diatoms Coscinodiscus spp.; Coscinodiscus sp. 2 being present at 1920m, whilst Coscinodiscus sp. 1 appears for the first time at 2120m.

## ENVIRONMENT

The presence of a microfauna dominated by agglutinated foraminifera and abundant radiolaria is considered to indicate deposition in an outer shelf to bathyal environment. The occurrence of other types of foraminifera in the basal sample suggests a somewhat shallower environment (i.e. probably outer shelf margin with some open marine influence).

## INTERVAL 2170m - 2520m: PALAEOCENE

Palaeocene age is recognised at 2170m based on the following points:

- the occurrence of tuffaceous shales.
- the first appearance of the planktonic foraminifer Globigerina cf. triloculinoides.
- the persistent occurrence of the diatom Coscinodiscus sp. 1.

## LITHOLOGY

In the sample at 2170m non-calcareous, light to mid grey shales are again the predominant lithology. A considerable part of this sample, however, consists of finely silty and distinctly tuffaceous shale. A minor proportion of shale is chocolate-brown in colour and calcareous. Subsequent samples at 2200m and 2270m continue to include these same features, but over the remainder of the interval non-calcareous, light grey or variegated shales form the dominant lithology.

Minor amounts of dolomite, limestone and coarse grained, off-white to greyish sandstone are noted at various horizons; together with rare pyrite and granules of free quartz.

## MICROPALAEONTOLOGY

The coincidental occurrence of distinctly tuffaceous shale at 2170m and the first occurrence of Globigerina cf. triloculinoides provides satisfactory evidence that beds of unquestionable Palaeocene age have been penetrated at that depth.

Throughout the interval a limited suite of agglutinated foraminifera make up the bulk of individual sample assemblages. Haplophragmoides spp., Bathysiphon spp. and Cyclammina spp. represent the dominant genera and are accompanied by more occasional Glomospira charoides, Ammodiscus incertus and Spiroplectammina spectabilis. Samples from within the lower part of the interval also include Pelosina spp., Trochammina spp. and Reophax spp. At certain horizons a tendency to grey staining of specimens was noted. At 2520m a single specimen of Acarinina pentacamerata, a planktonic foraminifera, was recorded.



The sample at 2380m conspicuously includes common Upper Cretaceous foraminifera; by virtue of the fact that samples underlying this depth have assemblages comprised solely of Tertiary forms, this is judged to be re-worked material. Consequently a more limited suite of calcareous benthonic foraminifera, also present in this sample, could also represent reworking of earlier Palaeocene forms.

Other fossils conspicuous in samples from this interval include persistently abundant radiolaria, frequent occurrences of Coscinodiscus sp. 1 and C. sp. 2, and a single instance at 2420m of the diatom Triceratium sp. 1. This assemblage is typical of Palaeocene age.

#### ENVIRONMENT

In view of the similarity of both the lithologies and the foraminiferal assemblages persisting over this section to 2520m, the depositional environment for much of this interval would again appear to be of outer shelf to marginally bathyal character. The slightly shallower conditions inferred at the base of the preceding interval may well have been initiated late in Palaeocene times, when there are indications of active volcanicity at not too great a distance from this locality.

A somewhat deeper and more restricted environment existed for some considerable time prior to this episode; while at the beginning of the Palaeocene the presence of rare planktonic foraminifera is again taken to indicate slightly shallower waters with only tenuous connections to the open seas.

#### INTERVAL c.2550m - c.2570m; DANIAN, LOWER PALAEOCENE

The presence within the sample from 2570m of certain microfaunal elements suggests the likelihood of Danian sediments overlying the Upper Cretaceous-Tertiary boundary.

#### LITHOLOGY

By virtue of the fact that microfaunal elements of suspected Danian age are green-stained, it would appear likely that any Danian sediments are restricted to beds of shale.

#### MICROPALAEONTOLOGY

In addition to a new microfaunal assemblage representing Upper Cretaceous age and the inevitable presence of numerous agglutinated foraminifera representing Palaeocene age, the sample at 2570m also contains a small suite of planktonic foraminifera suggestive of Danian age. This includes several specimens of Globigerina spp., a number of Globigerina cf. triloculinoides, and at least two unquestionable specimens of Globigerina triloculinoides - many of these specimens are noticeably green stained.

The presence of these latter specimens points to the occurrence within this section of sediments of Lower Palaeocene, Danian age. It appears likely therefore that a thin intercalation of Danian sediments forms the base of the Tertiary succession and rests, with fairly certain unconformity, upon the youngest Upper Cretaceous sediments.

#### ENVIRONMENT

A depositional environment similar to that postulated for the Palaeocene sediments at 2520m probably prevailed at this location during Lower Palaeocene times.

v

CRETACEOUSSAMPLE 2570m; MAASTRICHTIAN, UPPER CRETACEOUS

The existence at 2570m of beds of Upper Cretaceous, Maastrichtian age is indicated by:

- a distinct change of microfauna.
- the presence of Globotruncana contusa.
- changes in lithology.

LITHOLOGY

Creamy, off-white, hard chalky limestone and softer chalk form the dominant lithology of this sample. The chalk contains scattered fine inclusions of pyrite, quartz, calcite and other rarer impurities.

Shales form the bulk of the remainder of the sample; these are slightly deeper grey coloured, sometimes becoming finely silty and generally similar in appearance to those noted in the overlying Tertiary beds. It is considered significant, however, that these shales now vary from non-calcareous to lightly calcareous.

Minor amounts of brown to buff dolomite, and rare fragments of chocolate-brown shale and nodular pyrite are also recorded.

MICROPALAEONTOLOGY

A rich assemblage of agglutinated foraminifera is present. This could represent Tertiary caving, or in situ Tertiary material present within the compass of this sample, or an in situ component of the Upper Cretaceous assemblage occurring in this section. As described above, certain Lower Palaeocene elements also appear within this sample.

The presence of Upper Cretaceous beds at this level is clearly indicated by a rich and varied suite composed principally of calcareous benthonic and planktonic foraminifera. The planktonic faction includes abundant Rugoglobigerina rugosa rugosa and common Globigerinelloides asper. Rugoglobigerina rugosa rotundata, Praeglobotruncana citae, various Heterohelix spp. and rare Globotruncana spp. complete this association.

The occurrence of three specimens of Globotruncana contusa indicates a Maastrichtian age and suggests the presence of relatively younger Maastrichtian beds. In addition the calcareous benthonic faction includes both Discopulvinulina binkhorsti and Bolivina hiltermanni which tends to confirm the younger Maastrichtian aspect.

In the absence of any indications of the Pseudotextularia faunule it appears probable that very youngest Maastrichtian beds are absent from this section. A distinct stratigraphical hiatus is thus inferred to exist at the Upper Cretaceous/Tertiary boundary.

### ENVIRONMENT

The rich assemblage of planktonic foraminifera indicates that at the close of Cretaceous times strong connections to the open seas and oceans prevailed. The associated presence of a reasonably well-developed calcareous benthonic suite, coupled with the presence of chalk and chalky limestone suggests, at the same time, a moderately deep environment having calm, clear waters. This combination of factors is taken to indicate an outer shelf environment of deposition.

INTERVAL 2670m - 2850m; EARLY MAASTRICHTIAN - LATE CAMPANIAN, UPPER CRETACEOUS

Widely spaced samples with accompanying changes of microfauna suggest the presence of older Maastrichtian or even late Campanian aged sediments. The following are regarded as significant points:

- a planktonic foraminiferal suite dominated by Rugoglobigerina spp., Globigerinella spp. and Heterohelix spp.
- the appearance of Reussella szajnochae subsp.

### LITHOLOGY

The sample at 2670m contains roughly equal amounts of shale and limestone. The shale in this instance is mid-grey, finely micaceous and lightly to moderately calcareous; occasionally becoming finely silty. The limestone is creamy-fawn coloured, varying from softish to moderately hard. A brittle greenish-grey shale, dolomite and rare fragments of coarse-grained sandstone are also present. Traces of cement and nodular pyrite are noted.

Over the remainder of the interval samples are composed predominantly of calcareous grey shales ranging from light to mid grey in colour. Subordinate amounts of glauconitic limestone are present at 2800m, and creamy-fawn to buff limestone at 2850m. Rarer free pyrite; sucrosic, grey-fawn dolomite; and greyish-white sandstone appear in the lower sample.

### MICROPALAEONTOLOGY

A rich assemblage of planktonic foraminifera dominates these samples and is accompanied by a subordinate suite of agglutinated foraminifera. The planktonic suite includes abundant Rugoglobigerina rugosa subsp., Globigerinelloides asper and Heterohelix spp. Rare Praeglobotruncana

citae, Biglobigerinella multispina and Globotruncana arca are also present, and this suite also includes Heterohelix globulosa, H. glabrans and H. pulchra.

Of greater significance is the appearance of the diagnostic calcareous benthonic forms Reussella szajnochae cf. elongata and R. szajnochae szajnochae. Their presence confirms the age of these sediments as being no younger than early Maastrichtian. At the same time the first appearance of Globorotalites umbilicata at 2850m might well be indicative of Campanian age towards the base of this interval.

#### ENVIRONMENT

The persistence of subordinate limestones and a strong suite of planktonic foraminifera suggest generally similar conditions to those prevailing at the end of Cretaceous time. An outer shelf environment maintaining strong open marine connections thus appears to have existed at least from late Campanian times and to have prevailed until the end of Cretaceous deposition.

#### INTERVAL 2900m - 3100m; EARLY CAMPANIAN, UPPER CRETACEOUS

The presence of beds of older Campanian age is considered to be indicated by the first appearance, at 2900m, of the agglutinated foraminifera Clavulinoides disjuncta.

#### LITHOLOGY

Fairly uniform, light to mid grey shales represent the dominant lithology of the five samples examined from within this interval. These shales vary from non- or lightly calcareous to moderately calcareous, and at 3050m include occasional fragments of greenish-grey and chocolate-brown coloured shales.

Over much of the interval samples contain only very minor amounts of other lithotypes. These include a little chalky limestone (at 2900m); some hard, crystalline, creamy-fawn limestone (at 2950m); and fawn to buff limestone (at 3010m and 3050m). The basal sample, however, comprises approximately 30% of fawn to brown coloured dolomite, with which is also associated discrete, orange-stained quartz granules and fragments. Rare pyrite is also recorded.

#### MICROPALAEONTOLOGY

A fairly varied foraminiferal microfauna is present in each of these samples. The assemblage is dominated by two distinct suites of foraminifera, a rich and varied agglutinated faction being dominant over a rich but less varied planktonic component.

The first occurrence of Clavulinoides disjuncta/Tritaxia dubia which is present in the topmost sample, is thought to be indicative of the

presence of older Campanian sediments. The only other form not previously encountered in overlying beds, is a single specimen, at 3010m, referred to Globotruncana aff. linneiana group.

Globigerinelloides asper, Heterohelix spp. and Rugoglobigerina rugosa subspp. are the more prolific species dominating the planktonic suite within this interval.

#### ENVIRONMENT

With little apparent change in either lithology or microfaunal association, there appears to be a continuity of deposition through from early to late Campanian times. A distinct increase in numbers of agglutinated foraminifera occurs at 2900m, however, and with this in mind a shift to a slightly deeper water environment may be indicated.

A return to an outer sublittoral/marginally bathyal environment of deposition is therefore postulated during earlier Campanian times.

#### INTERVAL 3150m - 3300m; SANTONIAN, UPPER CRETACEOUS

Based on the significance of certain faunal factors, 3150m is considered to be of Santonian age. The following points are noted:

- the appearance of a number of Globotruncana at 3150m, including G. arca, G. aff. linneiana group and G. cf. linneiana linneiana.
- a resurgence of agglutinated foraminifera referred to Clavulinoides disjuncta and/or Tritaxia dubia in that same sample.
- the first appearance of "Globotruncana sp. 1 and G. cf. marginata in the succeeding sample at 3203m
- a more consistent occurrence of radiolaria.

#### LITHOLOGY

Light grey to mid grey shales varying from non calcareous to moderately calcareous continue as the dominant lithology of the four samples within this interval. The shales tend to become a little siltier at 3300m.

Throughout this interval the shales are accompanied by subordinate amounts of buff to dark brown and fawn-grey dolomites. In addition, minor amounts of cream to buff limestone, pyrite and coarse quartz grains are also recorded.

### MICROPALAEONTOLOGY

A rich and varied assemblage of agglutinated foraminifera continues to be present in samples from this interval. These include a number of specimens referred to Clavulinoides disjuncta and Tritaxia dubia which may in fact be related forms.

Whilst the planktonic suite continues to be subordinate to the agglutinated faction, Globigerinelloides asper and Rugoglobigerina rugosa rugosa are common, and are supported by a slightly increased number of Globotruncana spp. at 3150m. "Globotruncana" sp. 1 first appears at 3203m and is again recorded from the following two samples.

Radiolaria which occur only sparsely in the Upper Cretaceous section appear more consistently within this interval.

### ENVIRONMENT

Bearing in mind the overall similarity of lithologies and micro-fauna a continuing outer sublittoral to bathyal environment is postulated for the deposition of sediments within this interval. A similar environment thus appears to have persisted at this location throughout Santonian and earlier Campanian times.

### INTERVAL 3450m - 3550m; CONIACIAN, UPPER CRETACEOUS

The first determination of Coniacian beds at 3450m is based on the following criteria:

- the first appearance, which is in abundance, of Globotruncana marginata.
- a distinct reduction in importance of agglutinated foraminifera.

### LITHOLOGY

Within this interval the lithology is even more predominantly shaly. The shales, which remain light to mid grey in colour, are perhaps slightly softer and occasionally become slightly silty; they are lightly to strongly calcareous.

Minor amounts of fawn to buff dolomite continue to be present at 3450m, whilst traces of free quartz are often present, and occasional fragments of cement were noted at 3550m.

### MICROPALAEONTOLOGY

The numbers of agglutinated foraminifera are reduced and planktonic

species represent the dominant faction. In the sample at 3450m the presence of abundant Globotruncana marginata accompanied by G. cf. linneiana tricarinata and more poorly preserved specimens referred to G. spp. clearly indicates that beds of Coniacian age have been penetrated. Although revealing markedly poorer preservation, succeeding samples are characterised by the presence of G. aff. marginata and a single specimen of G. cretacea.

It is emphasised that the sample 3450m represents the first indication of Coniacian age, but since there is a sample gap of 150m between this and the overlying sample of Santonian age the actual top of the Coniacian stage may be anywhere between 3450m and 3300m.

The sample at the base of this interval contains the first appearance of the calcareous benthonic species Conorbina supracretacea.

### ENVIRONMENT

Although the lithology continues unaltered, the reduction in agglutinated foraminifera and the increased dominance of planktonic foraminifera suggests a moderate reduction in water depth to a shelf sea environment. An outer sublittoral environment is therefore considered to have prevailed for the deposition of these sediments during Coniacian times.

### INTERVAL 3600m - 3700m; TURONIAN, UPPER CRETACEOUS

Turonian sediments are indicated at 3600m by the presence of a single foraminifer identified as Praeglobotruncana cf. stephani.

### LITHOLOGY

Shale continues as the dominant lithology throughout this interval and is generally similar to that already described above.

Minor amounts of creamy-fawn limestone and brown dolomite occur at 3700m - where a small amount of siderite is prominent in the washed residues.

### MICROPALAEONTOLOGY

The microfaunal assemblage present in these samples consists mainly of agglutinated and planktonic foraminifera. Initially, at 3600m, the planktonic element is dominant, but in succeeding samples this reduces and is compensated by a rise in the proportion of agglutinated specimens.

At the top of the interval Globotruncana marginata, Rugoglobigerina rugosa rugosa, Heterohelix spp. and Globigerinelloides asper appear commonly, but the first appearance along with these other forms of Praeglobotruncana cf. stephani and numerous Hedbergella "planispira"



indicates a faunal change and permits a determination of Turonian age. No further Praeglobotruncana are identified, but succeeding samples all include further specimens of H. "planispira".

Occasional radiolaria are also noted in these samples.

#### ENVIRONMENT

With no change in the shale lithology and only a marginal change in the microfaunal assemblage the environment during this period remains basically similar to that ascribed to the overlying Coniacian sediments. An outer sublittoral environment thus appears to have persisted at least from the beginning of Turonian time until the end of the Coniacian.

#### INTERVAL 3750m - 3850m; CENOMANIAN: UPPER CRETACEOUS

The identification of Cenomanian aged beds is based upon the following points:

- a marked faunal break first apparent at 3750m.
- the appearance of an unusual suite of agglutinated foraminifera in which species of Arenobulimina and Dorothia are particularly prominent.
- the occurrence at 3850m of the Cenomanian restricted dinocyst Pseudoceratium dettmanae.

#### LITHOLOGY

The initial sample at 3750m again consists mainly of grey shales which vary from non-calcareous to strongly calcareous and are often finely micaceous. More occasional fragments of creamy-buff limestone, dark brown siliceous limestone, and brown dolomite constitute approximately 10% of the sample.

Subsequently samples are badly contaminated with drilling cement, but light grey shales, a biscuit coloured dolomitic shale, and various fawn to brown limestones and dolomites are present at 3800m and 3810m.

From 3830m to 3850m, within the bottom part of this interval, firm, rather compacted, light grey shales are again predominant. At this depth the shales are moderately to strongly calcareous and exhibit a patchy, weak oil-staining. The sample at 3830m includes a minor amount of hard, fawn coloured dolomitic shale accompanied by a few fragments of creamy-white or grey limestone. The succeeding samples again contain a limited amount of cement contamination, but minor amounts of dolomitic shales and dolomite are also present.

#### MICROPALAEONTOLOGY

The topmost sample of this interval shows a marked change in the microfaunal assemblage in which agglutinated foraminifera again pre-

dominate and the planktonic suite is greatly reduced in importance. The general aspect of this microfauna is suggestive of the Cenomanian although diagnostic species are absent. Bathysiphon spp., Haplophragmoides spp. and Tritaxia dubia are common, and are accompanied by a supporting assemblage of Arenobulimina spp. and Dorothia spp. which includes Arenobulimina advena, A. conoidea, Dorothia concina, D. conulus and D. cf. pupa. Recurvoides cf. imperfectus and Trochammina cf. umiatisis are also identified. Rare Hedbergella spp. and badly preserved Globotruncana spp. also appear in this sample.

The subsequent sample, at 3800m, is only poorly fossiliferous, but the sample at 3810m yielded a slightly better microfauna containing additional new elements. These include some specimens of ?Heterolepa cf. polyraphes and Lenticulina cf. muensteri; whilst Hedbergella spp. appear to be more numerous.

A second microfaunal break is evident between 3810m and 3830m and the assemblage in the lower part of the interval is dominantly planktonic in character. Hedbergella delrioensis appears abundantly at 3830m and this species together with poorer preserved Hedbergella spp. recurs commonly to the base of the interval in association with many of the agglutinated forms recorded higher in the Cenomanian. Gyroidinoides mauretanicus is present in the basal sample at 3850m.

#### PALYNOLOGY

At 3750m, in a dinocyst assemblage of otherwise general Cretaceous age, the occurrence of aff. ?Chatangiella scheii indicates a "middle" Cretaceous age, whilst Cleistosphaeridium polypes suggests that the Cenomanian has been penetrated.

Ovoidinium scabrosum/verrucosum, a dinocyst species having its acme in the Albian, was recorded by Davey (1970) as being rare in the Cenomanian of England and France. The occurrence of two specimens at 3830m and their absence at 3850m contrasts strongly with their abundance in the underlying Albian. Accordingly, these two samples are of probable early Cenomanian age. Confirmatory evidence of a Cenomanian age is provided by the occurrence at 3850m of Pseudoceratium dettmanae, a form which is essentially Cenomanian restricted.

#### ENVIRONMENT

An increase in the carbonate lithologies coinciding with the appearance of a microfauna in which Arenobulimina spp. and Dorothia spp. are prominent, is regarded as indicating a slight shallowing of the marine environment relative to the overlying Turonian beds. A more generalised shelf environment, ranging from deeper inner shelf to moderate outer shelf, is therefore postulated for the accumulation of these Cenomanian sediments.

The presence in the basal part of the interval of a strong planktonic assemblage suggests that connections to the open seas were

unrestricted during earlier Cenomanian times. The relatively common presence of dinocysts and rare occurrence of miospores suggests that open marine conditions with a distant shoreline prevailed until late in the Cenomanian.

#### INTERVAL 3870m - 3940m; ALBIAN, LOWER CRETACEOUS

Penetration of beds of Albian age at 3870m is indicated by the following criteria:

- the presence of a small suite of ostracodes of undoubted Albian age.
- a microfaunal break and resurgence of agglutinated foraminifera in which the Tritaxia gaultina group are prominent.
- the successive appearance within the interval of occasional specimens of Hedbergella cf. planispira, H. brittonensis and good H. planispira with planktonic foraminifera becoming dominant over the lower part of the interval.
- a distinct change in the palynoflora and the appearance of forms suggestive of Albian age.

#### LITHOLOGY

Cement or mudcake largely obscures the lithology at 3870m and 3880m, but, of the in situ lithologies, pale grey shales are again dominant and are accompanied by minor amounts of buff coloured dolomitic shale.

Beneath this, cement contamination is reduced and light to medium grey shales form the predominant lithology. These shales are strongly calcareous and again exhibit a light, patchy oil-staining. Minor amounts of dolomitic shales, limestones and dolomites are again present at 3890m and 3900m.

The basal sample, at 3940m, indicates diamond bit or turbo-drilling. From the material present the principal lithology would appear to be grey shale. Occasional fresh fragments of shale, limestone and cement probably represent caving.

#### MICROPALAEONTOLOGY

The occurrence of several specimens each of Cythereis bonnema and Schuleridea cf. jonesiana at 3870m is indicative of Albian age, neither of these species being recorded from beds younger than late Albian age.

At this level there is a resurgence of agglutinated foraminifera in which Haplophragmoides spp. appears abundantly and a suite of Tritaxia spp. is of significance. Tritaxia gaultina carinata and a number of broken specimens referred to T. gaultina group appear commonly at 3870m and 3890m; rarer occurrences of T. amorpha and T. pyramidata are also recorded.

Below 3870m planktonic foraminifera are predominant consisting essentially of small, poorly preserved Hedbergella spp. H. delrioensis occur commonly down to 3900m, together with rarer H. cf. planispira and H. brittonensis. True H. planispira are first recorded at the base of the interval.

#### PALYNOLOGY

There is a distinct change in the composition of palynofloras in the upper part of this interval (3870m to 3900m) compared with the overlying Cenomanian. Although miospores continue to be rare, dinoflagellate cyst abundances increase, notably the Spiniferites ramosus group. Odontochitina operculata and O. scabrosum/verrucosum, the abundance of the latter species complex suggesting an Albian age at this depth.

A mid - late Albian age is suggested by the appearance of Apteodinium grande in this section. It has a range extending from mid Albian to mid Cenomanian and as there are no specimens in the overlying Cenomanian interval, the occurrences in this upper part of the interval would indicate the presence of mid - late Albian deposits.

At 3940m only a very meagre palynoflora was recovered, containing non age-diagnostic elements.

#### ENVIRONMENT

The rich dinocyst assemblages from the upper part of this interval, allied with the paucity of miospores suggests that open marine environmental conditions similar to those of the overlying Cenomanian were already established in the late Albian. With the exception of the single sample at 3870m this is corroborated by the planktonic rich microfauna.

Slightly more restricted marine conditions are suggested by the meagre palynoflora in the lower part of this interval. Planktonic foraminifera, however, remain the dominant faction in an increasingly impoverished assemblage.

A general inner to outer shelf environment thus appears to have prevailed throughout late Lower Cretaceous and early Upper Cretaceous times.

INTERVAL 3960m - 4030m; EARLY ALBIAN - ?APTIAN, LOWER CRETACEOUS

The presence of older Lower Cretaceous beds below 3940m is

suggested by the following features:

- variations in the composition of palynofloral assemblages comparable with established regional patterns.
- a further distinct change in the composition of the microfaunal assemblage.

#### LITHOLOGY

Samples from 3960m to 4000m are all the product of diamond-bit drilling. Grey shale appears to represent the principal lithology. Occasional fragments of hard, brown-black dolomite are present at 3970m, and fawn-brown limestone at 3990m.

The sample at 4000m contains a little more fresh material in which the dominant grey shale appears to be non-calcareous. This shale contains well disseminated, very fine mica, and exhibits a little, patchy, weak oil-staining. A trace of light greenish-grey, slightly waxy shale together with a little associated pyrite were also noted in this sample.

At 4010m and in the succeeding samples the predominant shale becomes noticeably firm and splintery. This shale is mid to dark grey in colour and is non-calcareous. A little pyrite and ?chamosite are associated with the shale at 4020m; and at 4030m a few fragments of black, rather carbonaceous shale and black lignite were recorded.

#### MICROPALAEONTOLOGY

The sample at 3960m was barren and the succeeding sample only poorly fossiliferous. From 3990m and over the remainder of this interval a better microfauna was recorded. This assemblage is composed largely of agglutinated foraminifera in which non-diagnostic forms such as Haplophragmoides spp. and Bathysiphon spp. appear commonly. Rare Hedbergella planispira occur in samples in the upper part of the interval, and occasional specimens of Haplophragmium cf. inconstans gracile and Ammobaculites spp. are present in the lower part. There are no real indications of age to be deduced from this faunule although the predominantly agglutinating assemblage is suggestive of an early Albian - ?Aptian age.

#### PALYNOLOGY

Palynofloras from this interval do not contain species with ranges that could supply substantive evidence for the age suggested, and indicate only a general lower Cretaceous age. However, the variations in composition of assemblages, i.e. the generally high abundances of Oligosphaeridium/Hystrichosphaeridium spp., the high abundance of Odontochitina operculata at 3960m and Cribroperidinium edwardsi at 4000m, resemble some established regional patterns, and are considered to indicate the presence of early Albian - ?Aptian deposits.

### ENVIRONMENT

The lithology and microfauna suggest little change in the environment to that already described as prevailing in Albian times.

The dinocyst-rich palynofloras indicate open marine conditions, whilst a paucity of miospores indicates that deposition probably occurred at a considerable distance from a shoreline.

A general shelf environment of moderate water depth is thus envisaged for the accumulation of these sediments. Somewhat stagnant waters may be indicated for the sediments near to the base of this interval.

### SAMPLE 4040m; ?LATE BARREMIAN, LOWER CRETACEOUS

The presence at the base of this section of a thin interval of beds of possible Barremian age is postulated on palynological evidence, as follows:

- the presence of a single specimen of Broomea ?longicornuta.
- minor changes of palynofacies and a more distinct palynofloral change.

### LITHOLOGY

Flaky and splintery, mid to dark grey shale continues as the dominant lithology. A little pyrite and a scattering of fragments of calcite and limestone are also present in this sample.

### MICROPALAEONTOLOGY

This sample contains a meagre, non-diagnostic assemblage of foraminifera composed entirely of agglutinated forms, and a non-diagnostic fragment of ostracode.

### PALYNOLOGY

The sample at 4040m exhibits changes in both palynofacies and palynoflora. The palynofacies change is rather minor, the inertinitic kerogen being finer grained than in preceding samples. Cyclonephelium distinctum become a relatively common element of the palynoflora; Oligosphaeridium/Hystrichosphaeridium spp. are relatively unimportant. Evidence for a Barremian age for this interval comes from the presence of a single specimen of Broomea ?longicornuta, a species which does not range into deposits younger than Barremian.

### ENVIRONMENT

From the evidence available there is no reason to suspect any

in environment and a general shelf sea environment thus appears to have prevailed at this locality from mid Lower Cretaceous to early Upper Cretaceous times. Open marine conditions at some distance from a shoreline are suggested by the palynological evidence.

## VI

PALAEOENVIRONMENTAL SUMMARY

The oldest sediments in this section, consisting of probable late Barremian deposits, are regarded as relatively shallow shelf sea sediments. They are thought to have accumulated in rather stagnant, open marine waters at some little distance from the shoreline. Later in the early Albian, - ?Aptian, more open marine conditions prevailed.

The entire Lower Cretaceous section from 3870m to 4040m comprises grey shales and suggests that a similar type of shelf environment prevailed through into Cenomanian times and ranged from deeper inner shelf to moderate outer shelf. Thin carbonates are associated with the shales over the upper part of this interval and their presence suggests intermittently clearer and calmer seas.

Steady deposition appears to have prevailed from the end of the Lower Cretaceous until late in Maastrichtian times. The lithology continues as a dominantly shale series with thin carbonate intercalations. This lithology and the accompanying microfauna suggest that Upper Cretaceous deposition commenced in a general shelf environment. Steady deepening resulted in the development of an outer shelf environment which persisted through Turonian and Coniacian times and eventually reached outer marginal shelf depths during the Santonian and Campanian.

Slight shallowing is indicated during the late Campanian and Maastrichtian by a greater proportion of limestone and chalk accompanied by a more varied calcareous benthonic foraminiferal assemblage.

A pronounced microfaunal break is evident at the top of the Cretaceous section, which, coupled with the relatively thin Maastrichtian development suggests a sharp stratigraphical hiatus.

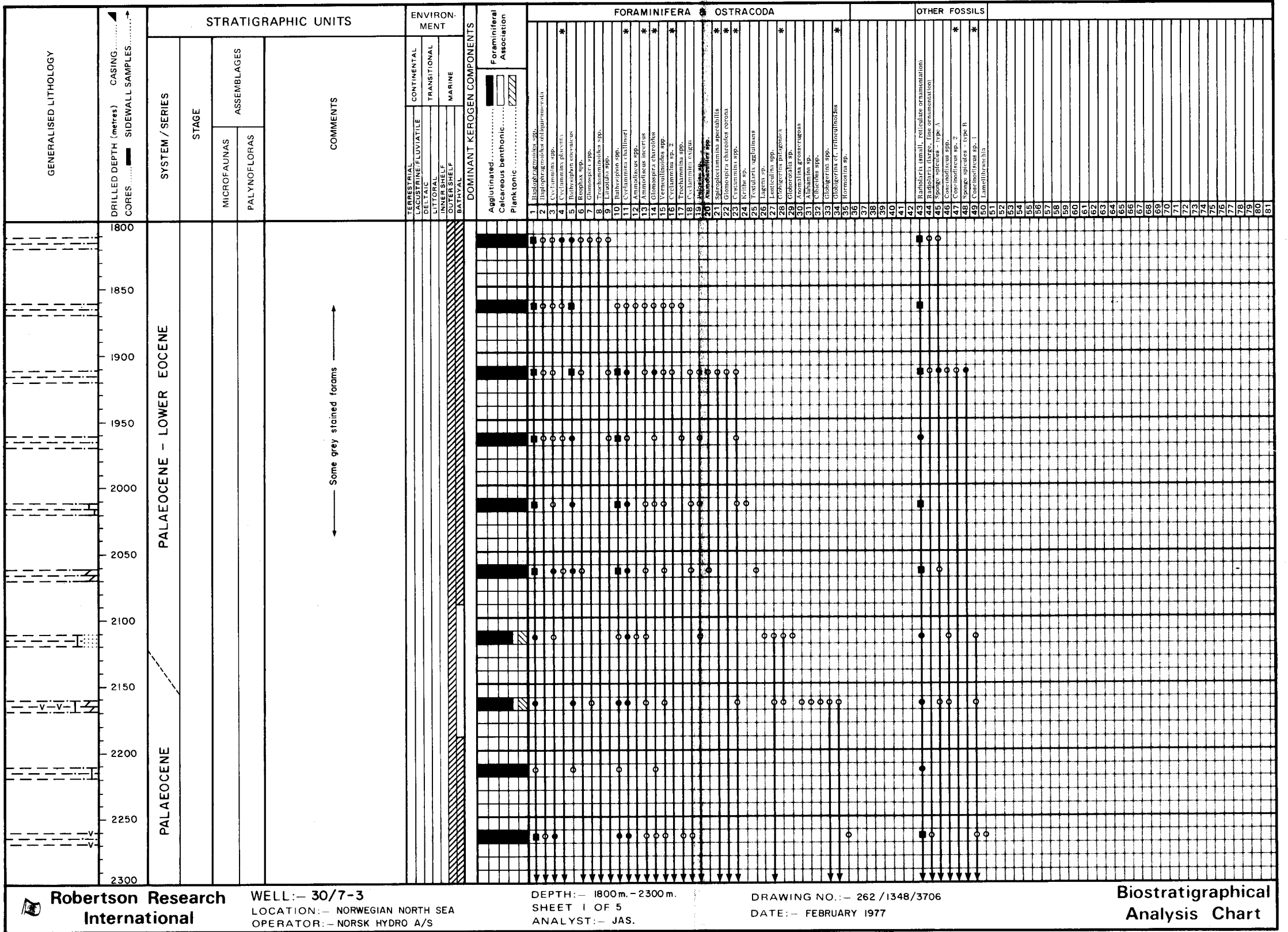
From 2520m to the top of the analysed section at 1800m beds are of older Tertiary age and again comprise a thick sequence of grey shales with associated minor developments of dolomite, dolomitic shale and rarer limestones. The Tertiary section is mostly of Palaeocene age, with the possibility of a condensed Danian sequence at the base, but probably reaching up into Lower Eocene above 2000m. A deep water environment of outer shelf to marginally bathyal character appears to have prevailed during the deposition of these sediments.

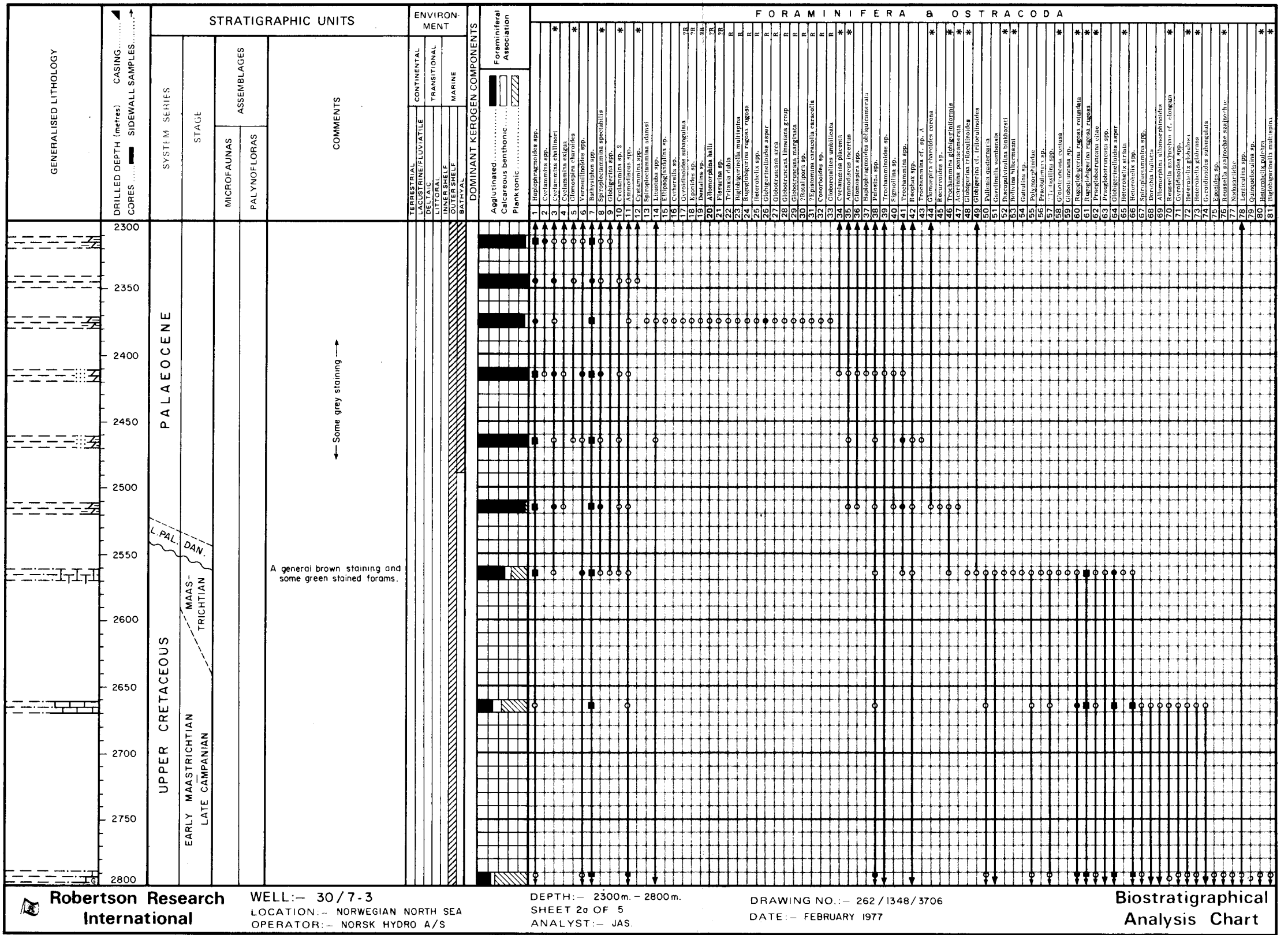


## VII

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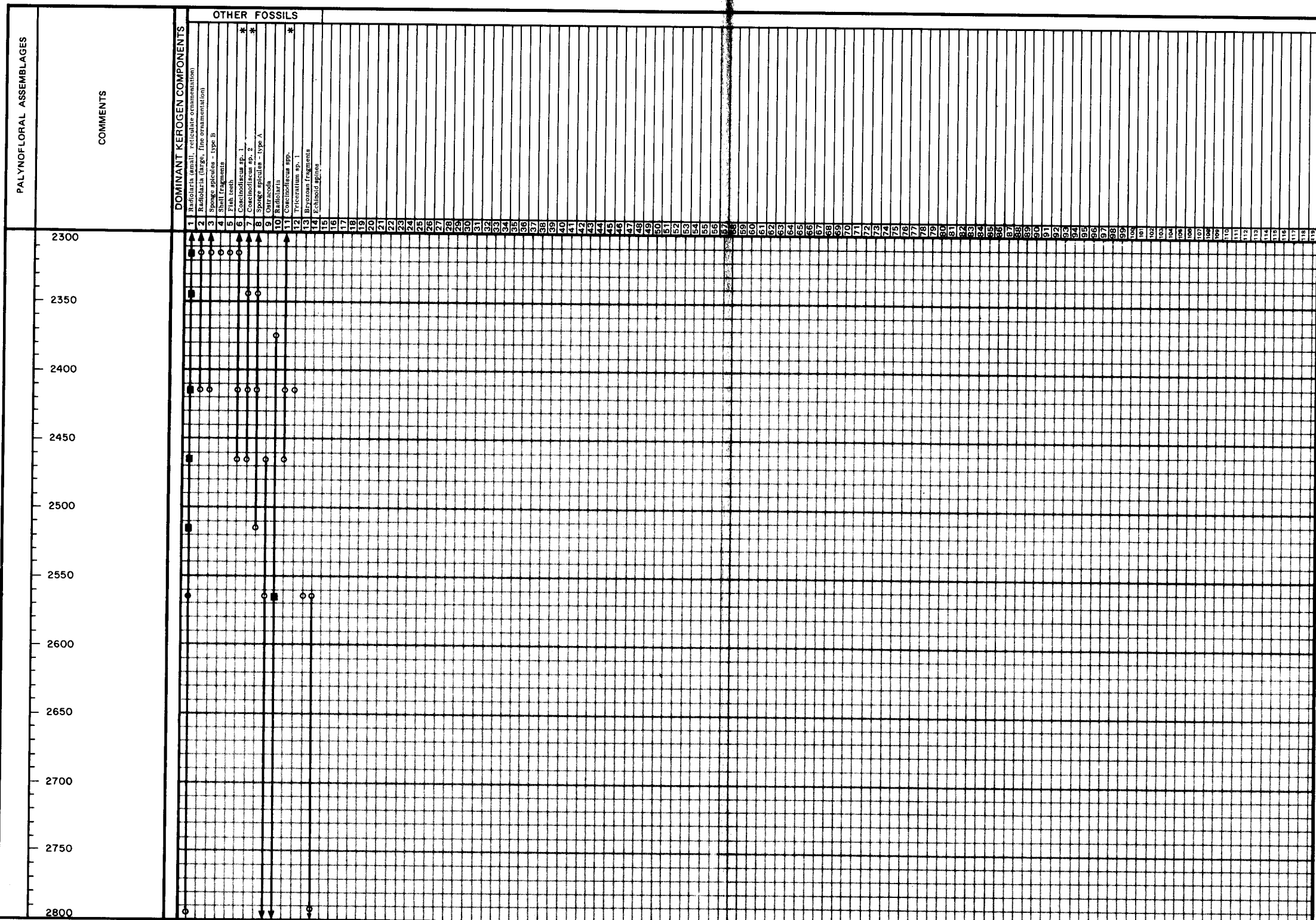
Robertson Research International

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 LOCATION: - NORWEGIAN NORTH SEA  
 OPERATOR: - NORSK HYDRO A/S

DEPTH: - 2300m. - 2800m.  
 SHEET 2 of 5  
 ANALYST: - JAS.

DRAWING NO.: - 262 / 1348 / 3706  
 DATE: - FEBRUARY 1977

Biostratigraphical Analysis Chart



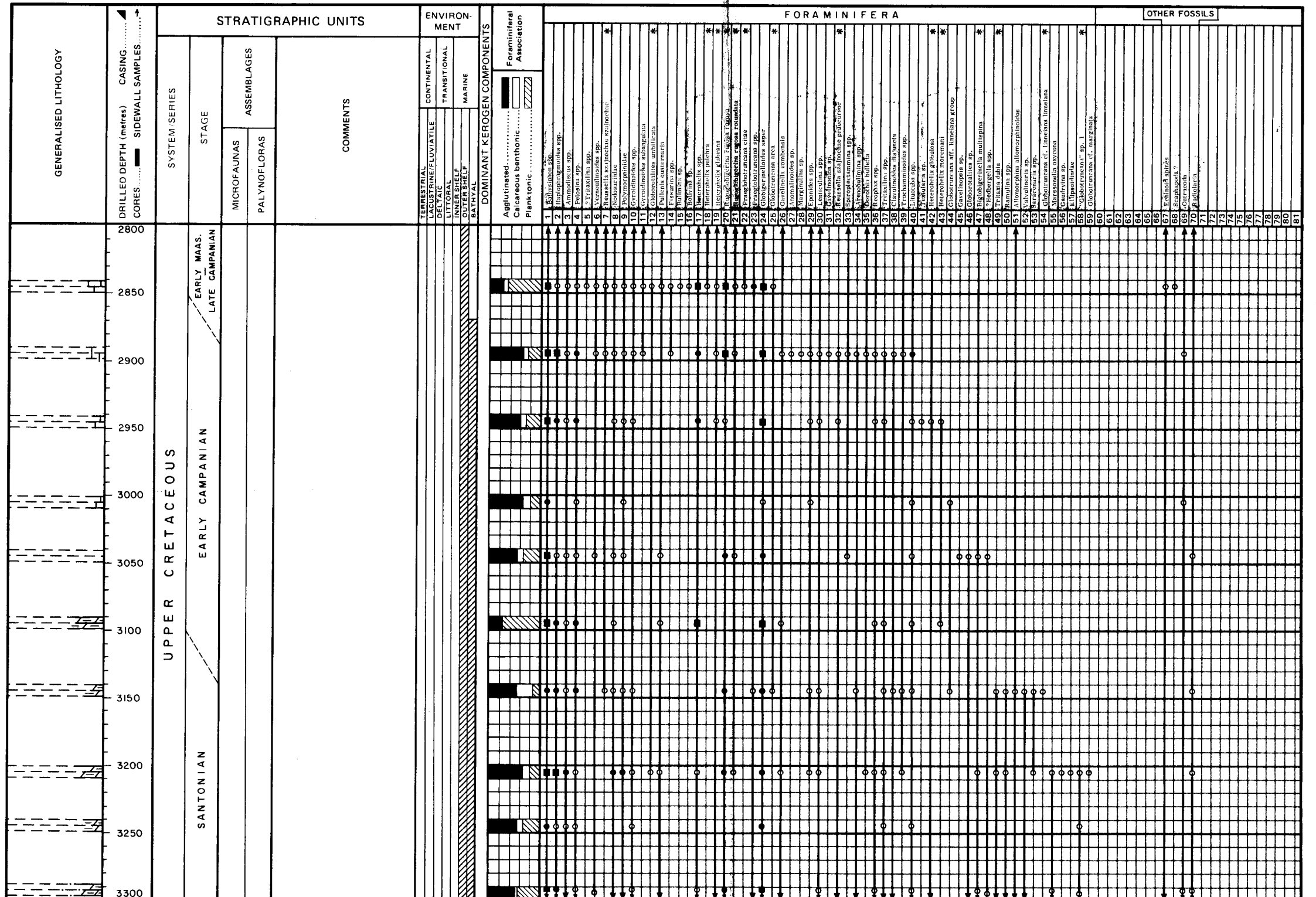
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 OPERATOR: - NORSK HYDRO A/S

DEPTH: - 2300m. - 2800m.  
 SHEET 2b OF 5  
 ANALYST: - JAS.

DRAWING NO.: - 262/1348/3706  
 DATE: - FEBRUARY 1977

**Biostratigraphical Analysis Chart**



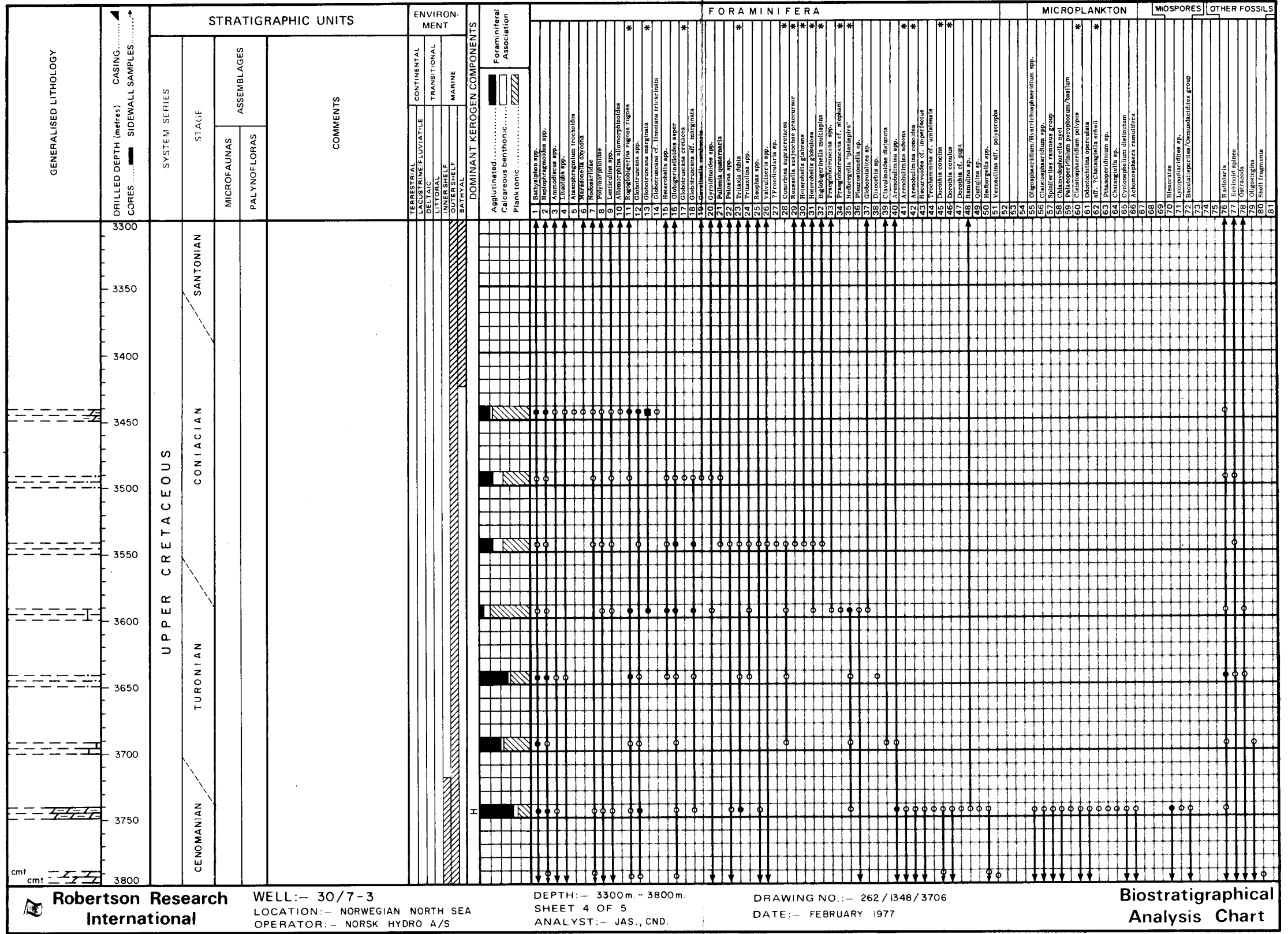
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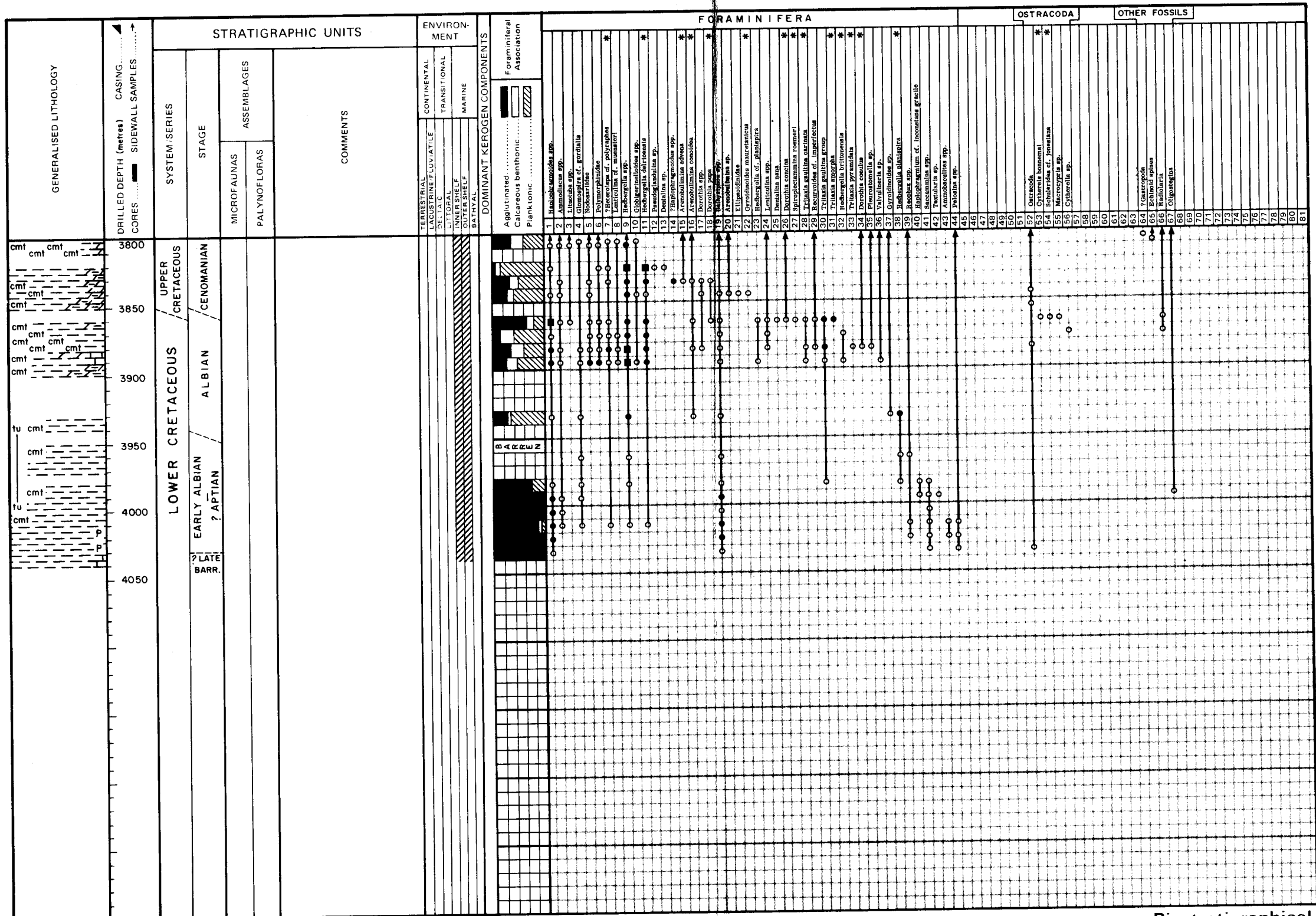
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 ANALYST:- JAS.

DRAWING NO.:- 262/1348/3706  
 DATE:- FEBRUARY 1977

**Biostratigraphical Analysis Chart**







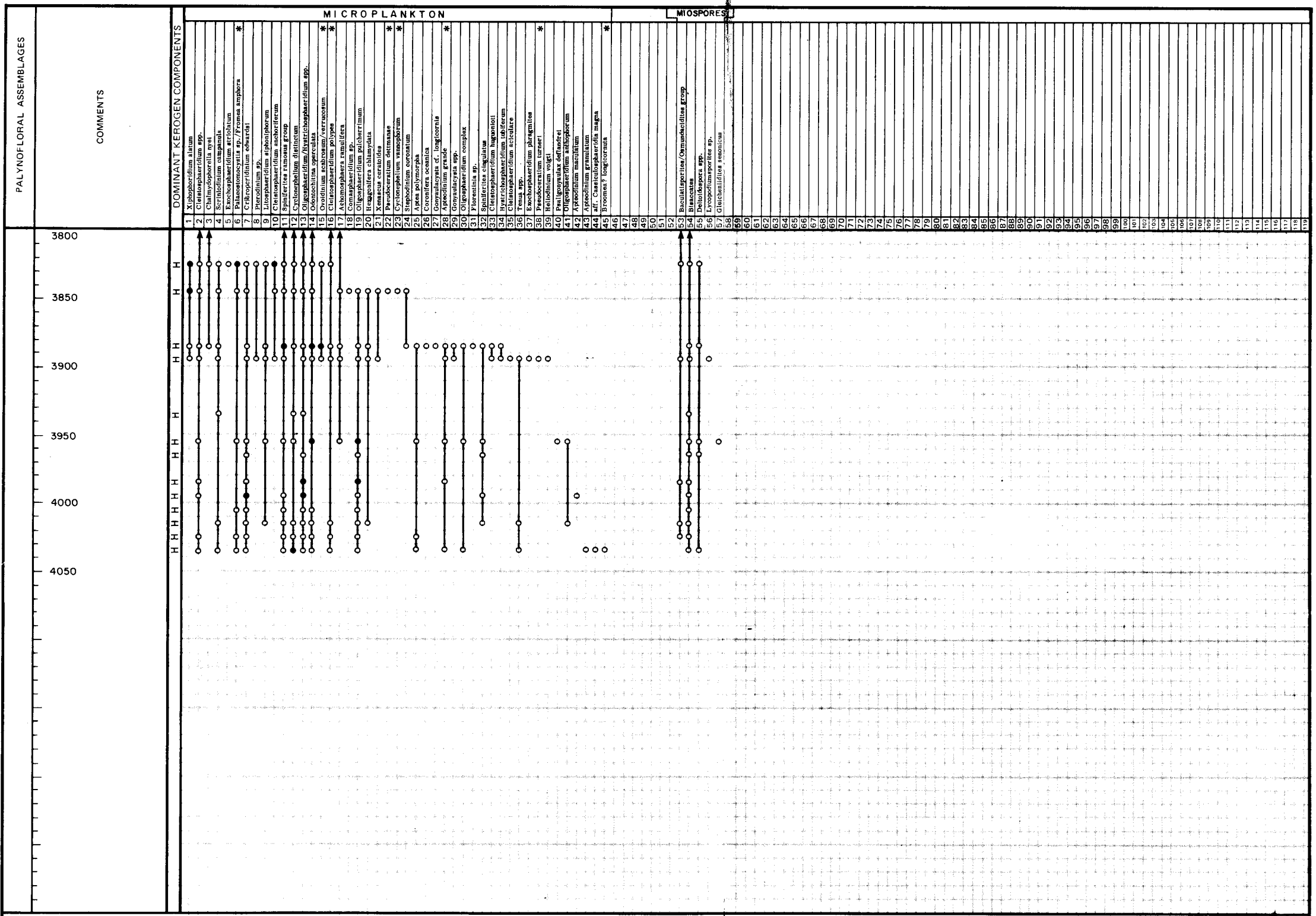
Robertson Research International

WELL: - 30/7-3  
 LOCATION: - NORWEGIAN NORTH SEA  
 OPERATOR: - NORSK HYDRO A/S

DEPTH: - 3800m. - 4040m.  
 SHEET 5a OF 5  
 ANALYST: - JAS., CWH., CND.

DRAWING NO.: - 262/1384/3706  
 DATE: - FEBRUARY 1977

Biostratigraphical Analysis Chart



Robertson Research  
International

WELL:-- 30/7-3  
LOCATION:-- NORWEGIAN NORTH SEA  
OPERATOR:-- NORSK HYDRO A/S

DEPTH:-- 3800m. - 4040m.  
SHEET 5b OF 5  
ANALYST:-- CND.

DRAWING NO. :-- 262 / 1348 / 3706  
DATE:-- FEBRUARY 1977

Biostratigraphical  
Analysis Chart



# LEGEND FOR STRATIGRAPHIC CHARTS

## LITHOLOGY COLUMNS

Clay / Shale / Mudstone		Chalk	
Carbonaceous shale		Anhydrite	
Silty / sandy shale; mudstone		Salt	
Silt / siltstone		Coal / lignite	
Sand / sandstone	{ very fine to medium	Lavas	
	{ coarse sand to granules	Undifferentiated volcanics	
	{ conglomerate	Quartzite	
Dolomitic sandstone		Basement (undifferentiated)	
Argillaceous sandstone		Calcareous sedimentary rocks	
Carbonaceous sandstone		Anhydritic sedimentary rocks	
Limestone		Mudflakes	
Silty / sandy limestone		Ooliths	
Argillaceous limestone		Scattered pebbles	
Dolomite		Concretions	
Silty / sandy dolomite		Sample gap	

## LITHOLOGICAL AND DRILLING ABBREVIATIONS

Red sedimentary rocks	red
Silica	Si
Pyrite	P
Ironstone	Fe
Glauconite	G
Kaolinite	K
Siderite	S
Shell fragments	F
Cement	cmt
Lost circulation material	lcm
Turbo drilling or diamond drilling	tu

*(Samples unsuitable for good stratigraphic analysis)*

## PALAEONTOLOGICAL SYMBOLS

Present	o
Common	•
Abundant	■
Diagnostic forms	*
Caved forms	C
Reworked forms	R
Sapropelic kerogen	S
Humic kerogen	H

**ROBERTSON RESEARCH  
INTERNATIONAL LIMITED**

# SUMMARY LOG : 30/7-3

AREA : NORWEGIAN NORTH SEA      SPUD DATE :

COMPANY : NORSK HYDRO A/S      COMPLETION DATE :

INTERVAL STUDIED : 1820m-4040m      T. D. ? 4040m

Dr. No. 262/1348/3706

SCALE 1 : 5000

Date : Feb.1977

■ Cored Interval

▲ Casing Shoe

*The lithological symbols are a generalisation of those shown on  
Biostratigraphical Analysis Charts*

