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Client Company	<u>STATOIL</u>
Title	<u>WELL 34/10-6</u> (1,550m-2,362m T.D.) NORWEGIAN OFFSHORE <u>PALAEONTOLOGICAL/STRATIGRAPHICAL FINAL REPORT.</u>
Project No.	699
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Date	March, 1980.

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1. INTRODUCTION.

This report presents the results of the stratigraphical and palaeontological study of samples from Well 34/10-6, drilled by Statoil in the North Sea (Norwegian offshore) during 1979 and 1980.

The information presented is based on the analysis of ditch samples collected at 10m intervals between 1,550m and 1,600m and 3m intervals between 1,600m and 2,362m T.D. Twenty nine sidewall cores were analysed between 1,815m and 2,345m.

A total of 40 samples (20 sidewall cores and 20 ditch samples) has been examined for palynology from the interval 1,992m-2,362m.

Interval tops are taken from sample depths, although petrophysical logs were provided by Statoil. A stratigraphical/palaeontological log (Scale 1:500) is presented with this report.



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2. CONCLUSIONS.

1. The highest sample studied (1,550m) is an Early Eocene green claystone deposited in a marine, outer sublittoral to bathyal environment.
2. The association of diatoms and tuffaceous claystones (1,570m-1,636m) characterises the North Sea "Ash Marker" which has been dated as Early Eocene to Paleocene. These sediments were deposited in a marine, outer sublittoral to bathyal environment with associated volcanic activity.
3. The Paleocene claystones, sandy claystones and sands (1,636m-1,762m) were probably deposited in a restricted marine, outer sublittoral to bathyal, environment.
4. The absence of Middle and Early Paleocene markers indicates that rocks of this age are missing; the Paleocene rests unconformably on the Late Cretaceous.
5. The Late Cretaceous section (1,762m-1,990m) comprises a monotonous sequence of claystones and occasional limestones, of Maastrichtian to possible Campanian age. Deposition was in a marine, outer sublittoral to bathyal environment; ratios of planktic to agglutinating foraminiferids indicate increasing influence from open sea circulation in the upper part.
6. No fossils of Late Cretaceous (Santonian-Cenomanian) and Early Cretaceous (Albian-Barremian) are present in the well. The highest part of the Late Cretaceous section (Maastrichtian-Campanian) rests with marked unconformity on the Early Cretaceous (Hauterivian).
7. The Early Cretaceous section (1,990m-1,996m) is represented by a thin sequence of marls and limestones of Hauterivian to possible Valanginian age, which were deposited in a marine sublittoral environment.



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8. The Kimmerian unconformity (1,996m) between the Early Cretaceous (Hauterivian-?Valanginian) and the underlying Late Jurassic (Kimmeridgian) marks a major phase of tectonic instability.
9. The Late Jurassic section (1,996m-Ca.1,999m) is represented by thin black organic claystones of the Kimmeridge Clay Formation which has been dated as Kimmeridgian. Deposition was in a marine, sublittoral restricted environment.
10. Palynological evidence indicates the presence of an unconformity between the Late Jurassic (Kimmeridgian) and the Middle Jurassic (Bathonian) at Ca. 1,999m.
11. The Heather Formation (Ca.1,999m-2,077m) comprises limestones, claystones and siltstones and has been dated in this well as Middle Jurassic (Bathonian). Deposition was in a marine, probably sublittoral environment, where abundant land derived organic material was being deposited.
12. The Brent Formation (2,077m-Ca.2,275m) is dominantly a sand/sandstone sequence with some interbedded claystones and coals, especially between 2,107m and 2,125m. Palynological dating indicates that it ranges from Bathonian to Bajocian.

There are two dinoflagellate markers which have been recorded in previous wells in the area which may be used in correlation, top *Nannoceratopsis gracilis* at 2,132m and the upper limit of the consistent occurrence of *N. gracilis* at 2,269m. Deposition of the sequence was probably in a shallow marine to deltaic environment; palynological evidence only indicates slight marine influence at the top of the interval, above 2,132m, and increasing marine influence at the base of the Brent Formation between Ca.2,269m and Ca.2,275m.



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13. Due to heavy caving the top Dunlin Formation is only tentatively picked at Ca.2,275m. Typical Dunlin lithologies and fossils appear at 2,284m and indicate that the claystones, siltstones and limestones penetrated range in age from Middle-Early Jurassic, Early Bajocian (=Aalenian) to Toarcian.



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3. STRATIGRAPHICAL SUMMARY.

<u>Interval</u>	<u>Age.</u>	<u>Thickness.</u>
1,550- 1,570m	Early Eocene	20m
1,570- 1,636m	Early Eocene-Paleocene	66m
1,636- 1,762m	Paleocene	126m
----- ? ----- ?	----- UNCONFORMITY ----- ? ----- ?	
1,762- 1,792m	Late Cretaceous, Late Maastrichtian	30m
1,792- 1,990m	Late Cretaceous, Maastrichtian-Campanian	198m
----- UNCONFORMITY -----		
1,990- 1,996m	Early Cretaceous, Hauterivian-?Valanginian	6m
----- UNCONFORMITY -----		
1,996-Ca.1,999m	Late Jurassic, Kimmeridgian	3m
----- UNCONFORMITY -----		
Ca.1,999- 2,077m	Middle Jurassic, Bathonian (Heather Formation)	78m
2,077- 2,132m	Middle Jurassic, Bathonian (Brent Formation pars.)	55m
2,132- 2,269m	Middle Jurassic, earliest Bathonian-Bajocian (Brent Formation pars.)	137m
2,269-Ca.2,275m	Middle Jurassic, Early Bajocian (=Aalenian) (Brent Formation pars.)	6m
Ca.2,275- 2,284m	Middle Jurassic, Early Bajocian (=Aalenian) (?Dunlin Formation pars.)	9m
2,284- T.D.	Middle-Early Jurassic, Early Bajocian (=Aalenian)-Toarcian (Dunlin Formation)	78m



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4. STRATIGRAPHY.

This discussion supplements the information presented on the stratigraphic log (Enclosure 1). The lithology and biota are described and the age and depositional environment interpreted.

4.1 1,550m-1,570m EARLY EOCENE.

Lithology:

Claystone, green and occasionally light brown.
Cement below 1,560m.

Biostratigraphy:

The fauna is dominated by agglutinating foraminiferids, including Rhabdammina, Plectina, Bolivinopsis, Cyclamina and Bathysiphon. The presence of the planktic foraminiferid Globigerina gr. triloculinoides marks a regional event of Early Eocene age.

Environment:

Marine, outer sublittoral to bathyal.

4.2 1,570m-1,636m EARLY EOCENE-LATE PALEOCENE.

Lithology:

Claystone, green and grey, occasionally tuffaceous and below 1,612m sandy.

Biostratigraphy:

The diatoms Coscinodiscus sp. 1 and C. sp.2 appear at the top and continue through this interval; their association with tuffaceous claystones corresponds to the North Sea "Ash Marker" which is of Early Eocene - Late Paleocene age.

Environment:

Marine, outer sublittoral to bathyal with contemporaneous volcanic activity.



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4.3 1,636m-1,762m PALEOCENE.

Lithology:

1,636m-1,726m Claystone, green, with occasional sandy claystone; sand, fine grained, angular and at 1,672m limestone, brown.

1,726m-1,762m Dominantly sand, fine-medium grained, subangular, with sandy claystone and claystone, green.

Biostratigraphy:

The top of this interval is taken at the highest occurrence of a diverse fauna of agglutinating foraminiferids, with Cystamina, Glomospira and Cyclamina, together with the characteristic Paleocene taxon Bolivinopsis spectabilis. This fauna is regionally typical of the Late-?Middle Paleocene. Middle and Early Paleocene markers are absent, suggesting that rocks of these ages are missing.

Environment:

Marine, outer sublittoral to bathyal, possibly restricted.

4.4 1,762m-1,990m LATE CRETACEOUS (Maastrichtian-Campanian).

Lithostratigraphy:

Shetland Group.

1,762m-1,813m Claystone, grey and green (the latter may be caved); between 1,771m and 1,777m thin beds of white chalky limestone; occasional pyrite and glauconite.

1,813m-Ca.1,921m Sample quality poor, dominantly cement and drilling mud additives. In place lithologies are dominantly claystone, grey, occasionally silty, with rare beds of white chalky limestone and brown limestone.



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Ca. 1,921m-1,990m Sample quality poor. In place lithology is probably claystone, grey, occasionally silty and rarely sideritic; beds of brown limestone especially between 1,925m and 1,954m.

Biostratigraphy:

1,762m-1,792m Late Maastrichtian.

The foraminiferid fauna is abundant and diverse, comprising the Late Maastrichtian association of *Pseudotextularia elegans*, *Globotruncana contusa*, *Racemiguembelina fructicosa*, *Rugoglobigerina rugosa*, *Globigerinelloides messinae*, *Globotruncanella havanensis* and *Abathomphalus mayaroensis*.

1,792m-1,990m Maastrichtian-Campanian.

The highest occurrence of *Reussella szajnochae* (1,792m) is a consistent regional marker shown elsewhere to lie within the lower part of the Late Maastrichtian.

This interval is characterised by a downhole increase of long ranging agglutinating foraminiferids and a decrease of planktic taxa.

The planktic taxa *Globotruncanella havanensis* and *Rugoglobigerina rugosa* persist to the bottom of the interval; if in place they suggest that the interval does not range in age below Late Campanian. The presence of *Abathomphalus intermedius* in a sidewall core at 1,890m indicates an age at this depth of Late-"mid" Maastrichtian.

Environment:

Marine, outer sublittoral to upper bathyal. The dominance of planktic foraminiferids in the upper part indicates the influence of oceanic water masses. The increased ratio of agglutinating taxa to planktic taxa in the lower part indicates more restricted conditions.



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4.5 1,990m-1,996m EARLY CRETACEOUS (Hauterivian-?Valanginian).

Lithostratigraphy:

Cromer Knoll Group.

Marl and chalky limestone, white and very light brown.

Biostratigraphy:

Microfauna:

The sidewall core at 1,992m and ditch cuttings contain a diverse benthic foraminiferid fauna of probable Hauterivian age which includes *Marssonella kummi*, *Patellina subcretacea*, *Trocholina infragranulata*, and *Uvigerinammina moesiana*, together with smooth ostracods and echinoderm debris.

Microflora:

A very restricted assemblage, without age diagnostic taxa, was obtained from the sidewall core at 1,992m.

Environment:

Marine, sublittoral.

4.6 1,996m-Ca.1,999m LATE JURASSIC (Kimmeridgian).

Lithostratigraphy:

Kimmeridge Clay Formation:

Sidewall core at 1,996m - claystone, dark grey-black, organic, non-calcareous, pyritic.

The ditch cutting residue contained no in-place lithologies.



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Biostratigraphy:

Microflora:

The sidewall core at 1,996m contains a rich microflora which includes the dinoflagellates *Gonyaulacysta cladophora* (common), *G. jurassica*, *Pareodinia ceratophora* and *Sirmiodinium grossii* together with common spores and pollen. The presence of *G. jurassica* suggests the sample is not younger than Late Kimmeridgian, while *G. cladophora*, although long-ranging, is usually common in the Early Kimmeridgian. No taxa typical of the earliest Kimmeridgian to Late Oxfordian have been recorded.

Microfauna:

The sidewall core at 1,996m and the ditch cuttings contain the radiolarian *Dictyomitra* sp. which regionally characterises rocks of Portlandian and Kimmeridgian age.

Environment:

Marine, sublittoral, restricted, anaerobic bottom conditions.

4.7 Ca.1,999m-2,077m MIDDLE JURASSIC (Bathonian).

Lithostratigraphy:

Heather Formation.

Ca.1,999m-2,077m. Poor heavily caved samples. Claystone, grey, siltstone and rare very fine sandstone, pyritic; with glauconite especially in the upper part and lignitic debris especially below 2,047m; interbedded with limestone, brown.



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Biostratigraphy:

Microflora:

Assemblages are generally rich and diverse through this interval, with abundant pollen and spores and common dinoflagellates. The latter include *Chytroei-sphaeridia chytroeides*, *C. "granulata"*, *Pareodinia evittii* (at 1,999m and below), *Tenua asymmetra* (at 2,050m and below) and *Tenua verrucosa* (generally common or abundant). The spore/pollen assemblages are dominated by long-ranging bisaccate pollen, *Cerebropollenites mesozoicus*, *Cyathidites* spp. and *Perinopollenites elatoides*. Less common but significant taxa include *Quadraeculina anellaeformis* (from 1,999m). The presence together of *Q. anellaeformis* and the dinoflagellates *P. evittii* and *Tenua verrucosa* indicates a Bathonian age for this interval.

Microfauna:

Agglutinating foraminiferids, including *Haplophragmoides* sp. and *Verneuilinoides* sp., are present but are all long-ranging taxa. Their preservation is typical of forms found in the Heather Formation elsewhere in this region.

Environment:

Marine, sublittoral. The presence of abundant land-derived woody debris and spores and pollen indicates a near-shore environment.

4.8 2,077m-Ca.2,275m MIDDLE JURASSIC (Bathonian-Early Bajocian).

Lithostratigraphy:

Brent Formation.

2,077m-2,107m Sand/sandstone, fine-medium and fine grained, angular, with lignitic debris and mica; occasional claystone, dark grey, non-calcareous. Poor, heavily caved, samples.



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2,107m-2,125m Sand/sandstone as above, interbedded with coal and claystone, brown and dark grey with lignitic debris.

2,125m-2,164m Sand/sandstone, fine-medium and occasionally fine-coarse, angular to subangular, with fine lignitic debris, mica and pyrite; occasional beds of claystone, grey, often lignitic.

2,164m-2,266m Sand/sandstone, fine and fine-medium grained, mica common in the lower part; below 2,236m occasional sandstone, fine, calcareous. Sample quality extremely poor, dominantly drilling mud additives.

2,266m-2,275m Sand, fine-coarse grained, angular to subrounded, pyritic, matrix of grey-green claystone and brown dolomite below 2,269m. A sidewall core at 2,269m is a laminated sandstone, finegrained, angular, micaceous and claystone, dark grey, lignitic. The coarse sand of this interval represents the Broom Member.

Biostratigraphy:

2,077m-2,132m Bathonian.

Microflora:

Spore and pollen assemblages are similar to those in the overlying interval with bisaccate pollen, *Cerebropollenites mesozoicus* and *Perinopollenites elatoides*. *Classopollis torosus* and *Quadraeculina anellaeformis* are common at 2,086m and *Chasmatosporites major/apertus* occurs at 2,077m and below. Dinoflagellates are extremely rare; *Pareodinia ceratophora* occurs in the sidewall core at 2,077m and *Chytroeisphaeridia "granulata"* at 2,086m. The fresh to brackish-water colonial alga *Botryococcus* is present at 2,106m and 2,116m. This association suggests a Bathonian age for this interval.



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Microfauna:

No in-place microfauna:

2,132m-2,269m earliest Bathonian-Bajocian.

Microflora:

Apart from the sidewall core at 2,132m the other four sidewall cores through this interval contain rare palynomorphs without age-restricted taxa. Assemblages from ditch samples are generally poor and are contaminated by Cretaceous and Bathonian caving. The long-ranging spores and pollen recorded above continue to dominate the assemblages.

The top of this interval is taken at the first downhole occurrence of the dinoflagellate *Nannoceratopsis gracilis* (sidewall core 2,132m) which is a useful marker in this area, indicating an age not younger than earliest Bathonian.

Microfauna:

No in-place microfauna.

2,269m-2,275m Early Bajocian (=Aalenian).

Microflora:

The top of this interval is taken at the upper limit of the consistent occurrence of *Nannoceratopsis gracilis* (sidewall core at 2,269m) which characterises the Early Bajocian (=Aalenian) in this area. The super-abundance (acme) of *N. gracilis* which usually occurs at the base of the Brent Unit has not been recorded in this well, probably as a result of the sampling interval.

Microfauna:

No in-place microfauna.



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Environment:

Shallow marine-'deltaic'.

In the upper part of this interval, between 2,077m and 2,132m, the abundance of land-derived plant debris and pollen/spores associated with very rare dinoflagellate cysts suggests deposition in a near-shore environment, possibly deltaic in part, with only limited marine influence. At 2,132m the incoming down-hole of rare *Nannoceratopsis gracilis* is a palynoevent which commonly occurs in the Ness Member in this area and may mark a period of widespread marine influence.

There is no positive palynological evidence of marine influence within the sands between 2,132m and Ca.2,269m but an increase in marine influence is indicated at the base of the Brent Formation (c.2,269m in this well) by the presence of acritarchs and common *Nannoceratopsis gracilis*.

- 4.9 Ca.2,275m-2,362m T.D. MIDDLE-EARLY JURASSIC (Early Bajocian (=Aalenian) - Toarcian).

Lithostratigraphy:

?Dunlin Formation.

2,275m-2,284m Sample quality extremely poor; possibly claystone, often silty, grey.

Dunlin Formation.

2,284m-2,305m Sample quality poor. Claystone, grey often silty, with occasional pyrite, siderite, glauconite and very fine lignitic debris.

2,305m-2,362m Claystone and siltstone as above, together with beds of brown dolomite/limestone.



Biostratigraphy:

Microflora:

Spore/pollen assemblages are similar to those recorded above, with slight increases in *Classopollis torosus* and *Spheripollenites* sp. Several dinoflagellate taxa make their first downhole appearance in the sidewall core at 2,287m, and continue down to 2,345m. These include *Comparodinium* aff. *punctatum*, Plankton Type 2 (of Schulz and Mai 1966), Dinoflagellate Type 4 (internal species) and from 2,300m, Dinoflagellate Type C (internal species), *Fromea elongata* and *Mancodinium semitabulatum*. *Nannoceratopsis gracilis* is abundant at 2,275m and common below. This dinoflagellate association (between 2,287 and 2,345m) is characteristic of the Early Bajocian (=Aalenian) - Late Toarcian in this area.

Dinoflagellate Type 3 *Thusu* makes its first downhole appearance in the sidewall core at 2,345m. Elsewhere in this area this top is closely associated with the incoming of the ostracod *Kinkinella intrepida*, a marker horizon within the Early Toarcian.

Microfauna:

In previous reports the top Dunlin Formation has been taken at the first downhole association of claystones with agglutinating foraminiferids, below the Brent Formation. In this well poor samples make this boundary less certain and it is only tentatively taken at 2,275m. Below 2,284m age diagnostic foraminiferids and ostracods appear which indicate an Early Bajocian-Toarcian age, including *Camptocythere parvula*, *Camptocythere* aff. *toarciana*, *Nodosaria regularis*, *Haplophragmoides kinga-kensis* and *Lenticulina clathrata*. The distinctive *Kinkinella intrepida* level of the Early Toarcian, found in previous wells in this area, does not appear to have been penetrated.

Environment:

Marine, sublittoral, probably inner.



5. REFERENCES.

- SCHULZ, E. & MAI D.H. 1966. Erläuterungen zur Tabelle der stratigraphischen Verbreitung des Phytoplanktons im Lias und Dogger.
Abh. zentr. geol. Inst. 8, 35-46.





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DATE: 31st March, 1980.

TO: Stat Oil,
Lagardosveien 78,
P.O. Box 300.
N-4001 Stavanger,
NORWAY.

For the attention of D.I. Milton.

Please acknowledge, by signing and returning one copy
of this letter, receipt of ~~...seven~~..... copies of the
Final Report on Well ...~~34/10-6~~.....
The top copy of the seven enclosed is the original.

PALEOSERVICES LIMITED.

Received by

Date

WELL 34/10-6
1550 m. - 2362 m.
NORWEGIAN OFFSHORE
STRATIGRAPHIC LOG

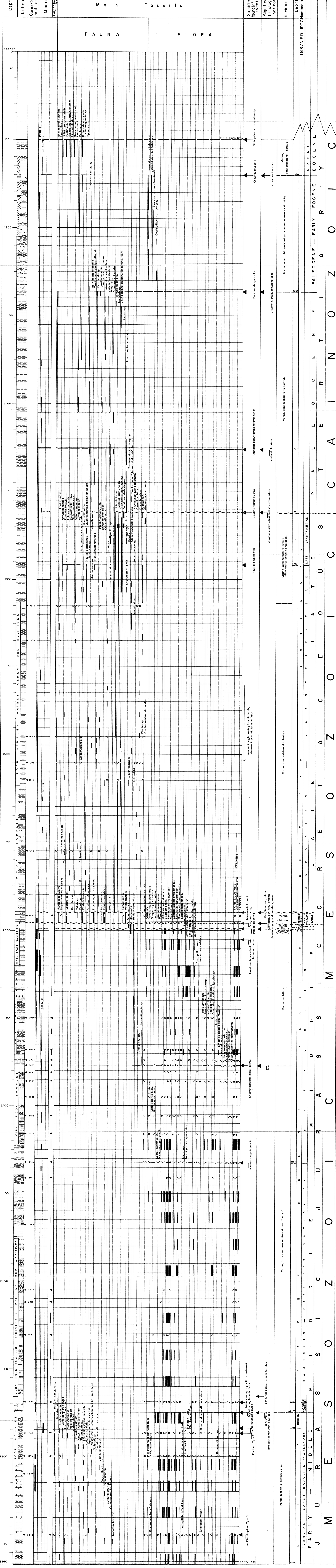
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LEGEND

- CLAY/CLAYSTONE, SHALE, MARL-CALCAREOUS SHALE, SILTSTONE/SILT, SAND, MEGAFOSSILS, CHERT, PYRITE, SANDSTONE, CONGLOMERATE, VOLCANICS-LAVAS/TUFFS, UNDIFFERENTIATED BASEMENT, NO SAMPLES, GLAUCONITE, SIDERITE, LIGNITE/COAL, LIMESTONE, CHALK, DOLOMITE, CEMENT, ANHYDRITE/GYPSUM, FOSSILS AND ACCESSORY MINERALS, FOSSILS IN SIDEWALL CORFS, PALYNOLOGICAL ANALYSES



Depth (metres) scale from 2360 to 1550. Lithology descriptions: SAND, SANDSTONE, CLAY, etc. Fossil lists: FAUNA (Ammonites, Belemnites, etc.), FLORA (Dinoflagellates, etc.). Geological time scale: CRETACEOUS, PALEOCENE, EARLY EOCENE, EARLY EOCENE, PALEOCENE, EARLY EOCENE, EARLY EOCENE, OLI-GOCENE, MIocene, Pliocene.

Very poor samples, dominantly drilling mud additives. Poor samples, mainly cement and additives. Poor samples, mainly cement and additives. Poor samples, mainly cement and additives.

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