Amoco Production Company

Research Department

WELL 6407/1-2 OFFSHORE NORWAY: PALYNOSTRATIGRAPHY, KEROGEN-PALYNOFACIES AND ORGANIC MATURATION ANALYSES

By

Dan N. Beju

Report No.: M84-G-3

Date: February 2, 1984

AMOCO PRODUCTION COMPANY
Tulsa, Oklahoma
January 30, 1984

84030ART0200

TO: Chief Geologist, Amoco Canada
Managers of Geology, Chicago
Regional Geologists
Regional Consulting Geologists
Regional Paleontologists

SUBJECT: Transmittal of Geological Research Division Report M84-G-3 Entitled "Well 6407/1-2 Offshore Norway: Palynostratigraphy, Kerogen-Palynofacies and Organic Maturation Analyses"

The attached report presents the biostratigraphy, kerogen analyses and organic maturation from this well from the Norwegian Basin of the North Sea. The age of the section ranges from Miocene to Late Triassic. The data base developed from this study will be of interest to exploration paleontologists, and the documentation of this section contributes to an in-house data base from the far northern latitudes. The results of this study have application for the North Sea, the North Atlantic and for northern North American exploration. Several sedimentary rock packages can be interpreted from the time control established from this study, which includes details of unconformities as well as kerogen-palynofacies zones.

Eric R. Michaelis

EJK:lmw/sl
Attachment

cc: C. Campbell, Stavanger, Norway (3 copies)
Regional Exploration Libraries
Exploration Systems Manager, TDC

Amoco Production Company

Research Department

WELL 6407/1-2 OFFSHORE NORWAY: PALYNOSTRATIGRAPHY, KEROGEN-PALYNOFACIES AND ORGANIC MATURATION ANALYSES

By

Dan N. Beju

Report No.: M84-G-3

Date: February 2, 1984

TABLE OF CONTENTS

SUMMARY

At the request of Amoco Norway, the offshore well 6407/1-2 was analyzed in careful detail from top to bottom as a normal consulting service. Because this well provides such a rich database for palynomorphs from a boreal environment and because so much new taxonomy was required in order to complete the analysis, it was decided to document this new data in Research Center report format rather than a normal technical service letter. A summary of the stratigraphy is as follows.

STRATIGRAPHIC SUMMARY

1. Tertiary

Undiagnostic	ca. 1000-1630m
Miocene	ca. 1640-1760m
Hiatus	ca. 1760m
Oligocene	ca. 1770-1919m
Eocene	ca. 1910-2190m
Paleocene	ca. 2190-2320m
Hiatus	ca. 2320m

2. Cretaceous

Senonian (Campanian to early Maastrichtian)	ca. 2320-2460m
Late Cretaceous, probably Senonian	ca. 2460-3100m
Hiatus	ca. 3100m
Cenomanian	ca. 3100-3450m

Albian (late?)	ca. 3450-3520
Hiatus	ca. 3520m

3. Jurassic

Late Portlandian to Berriasian	ca. 3520-3530m
Kimmeridgian	ca. 3530-3560m (or 3580m)
Oxfordian	ca. 3560 (or 3580m)-3661m
Middle Jurassic, probably Bathonian	ca. 3661.5-3740m
Bajocian to Toarcian	ca. 3750-4100m
Pliensbachian to Sinemurian	ca. 4140-4370m
Hettangian	ca. 4370-4540m

4. Triassic

Rhaetian	ca. 4540-4560m (T.D.)

Kerogen-Palynofacies. Five kerogen-palynofacies zones have been recognized within the Jurassic section, of which two are considered significant for hydrocarbon exploration: ca. 3530-3560m (Late Jurassic) with abundant, oil-prone amorphous kerogen; ca. 4200-4560m (Early Jurassic) with abundant, gas-prone coaly organic matter.

Degree of Organic Maturation. The Jurassic section is in the peak oil generation to early gas generation window.

INTRODUCTION

The offshore Norway 6407/1-2 well provides a rich and diverse palynoflora from a boreal environment. This assemblage of fossils is somewhat unique to Amoco's database and the Research Center report format is deemed the appropriate method of documenting this information. Sixteen time stratigraphic subdivisions have been interpreted from the approximately 330 palynomorph taxa that were recognized in this well. All data are summarized in the stratigraphic range chart (in pocket, sorted on "top"). These data were derived from 144 composited cuttings samples, 38 sidewall cores and 9 conventional core samples covering the interval 1000m to 4,560m (Appendix 1).

DISCUSSION OF PALYNOSTRATIGRAPHY

The stratigraphic interpretation and subdivisions from this well are discussed in descending order as follows:

TERTIARY

Undiagnostic ca. 1000-1630m

Twelve cuttings samples were found to be either undiagnostic or barren of palynomorphs.

Miocene, ca. 1640-1760m

Three cuttings samples yielded abundant dinocysts in a fair state of preservation. The assemblage is, however, rather vaguely defined. Some mixture by reworking is suspected. More significant dinocysts are:

Lingulodinium sp.

Lingulodinium siculum/macherophorum

Eocladopyxis sp.?

Homotryblium sp. A, B., cf. 3

Hemicystodinium sp.

Hemicystodinium congregatum

Tuberculodinium vancampoae

Hystrichokolpoma-1 (rigaudae)

Lejeuniacysta sp.

Rottnestia cf. 1 (borussica)

Spiniferites mirabilis

Spiniferites membranaceus

This assemblage supports a post-Oligocene, general Miocene age assignment.

Hiatus, ca. 1760m

A marked change of the microflora and its state of preservation suggests a break in sedimentation.

Oligocene, ca. 1770-1910m

The sidewall core at 1855m and three composited cuttings samples produced abundant dinocyst assemblages. The following significant taxa make their first downhole appearance within this interval:

Cordosphaeridium-8 (cantharellum)

Chiropteridium-1 (dispersum/lobospinosum)

Palaeocystodinium-2 (golzowense)

Deflandrea-25 (phosphoritica) - top at ±1800m

Homotryblium-sp. C

Distatodinium ellipticum

In addition, the S.W.C. at 1855m contains Wetzeliella-cf. 6 (=W. symmetrica/Gochtodinium simplex group).

The common occurrence of these species supports a middle to early Oligocene age. This distinct assemblage compares favorably and is broadly correlatable with well dated Oligocene assemblages described from Germany (Eisenack, 1954; Gocht, 1955, 1960, 1969); Benedek (1972); Morgenroth (1966); Norwegian Basin (Manum, 1976), offshore eastern Canada (Williams and Bujak, 1977; Williams and Brideaux, 1975).

Eocene, ca. 1910m-2190m

Diverse and exceptionally well preserved dinoflagellates recovered from 10 cuttings samples strongly suggest that a virtually continuous late-middle-early Eocene sequence was penetrated.

The top of this interval is marked by:

Rhombodinium-1 (draco)

Heteraulacacysta porosa

Thalassiphora-1 (pelagica)

Thalassiphora-4 (delicata)

Caligodinium-2 (amiculum)

Hystrichokolpoma-cf. 3 (cinctum/eisenacki)

Phthanoperidinium tritonium

Distatodinium craterum

Cordosphaeridium-1

Achomosphaera alcicornu

Spiniferites (pseudofurcatus/tertiarius)

Oligosphaeridium-1 (A. diktyoplokus)

Additional tops of typical Eocene taxa were recorded at 2010m, 2030m, 2050m and include:

Wetzeliella-3 (articulata)

Eatonicysta-1 (ursulae)

Kisselovia sp. (for K. clathrata)

Thalassiphora dynamica

Unimegasphaeropsis-1 (D. colligerum)

Hystrichosphaera-27 (S. cornutus)

Svalbardella-4 (cf. cooksoniae)

Lanternosphaeridium-1 (lanosum)

Other tops occur between ca. 2075-2150m and include numerous specimens of:

Wetzeliella-9 (K. coleothrypta)

Dracodinium-1 (D. pachyderma)

Dracodinium sp. (for D. solidum/varielongitudum)

Cordosphaeridium-2 (C. inodes)

Cordosphaeridium-7 (C. funiculatum)

Glaphyrocysta sp.

In general terms, this Eocene dinocyst succession compares closely and shows similar evolutionary trends to the well documented Eocene sequences of England (Williams and Downie, 1966; Eaton, 1976; Bujak, 1980); Germany (Gocht, 1969; Morgenroth, 1966); Belgium (De Coninck, 1975); Paris Basin (Chateauneuf and Graus-Cavagnetto, 1978, etc.).

Most of these dinoflagellates provide excellent markers for surface to subsurface and/or local correlations.

Late Paleocene (to earliest Eocene?) ca. 2190m-2250m

The sidewall cores at 2919m, 2232m, and several cuttings samples contain another highly distinctive dinocyst assemblage including tops of:

Deflandrea-28 (D. oebisfeldensis)

Ceratiopsis-1,2 (C. speciosa group)

Apectodinium-1 (A. augustum)

Wetzeliella-4 (A. homomorphum)

Recent data indicate that this group of species define a distinct biozone over large areas of the North Sea Basin (Harland, 1979; Knox and Harland, 1979; Clausen, 1982; Costa and Downie, 1976, 1979).

Paleocene (undifferentiated, possibly middle), ca. 2250m-2320m

The sidewall core at 2269m and three composited cuttings samples produced common dinoflagellates including the additional tops of:

Eisenackia-3 (crassitabulata)

Palaeoperidinium-1 (pyrophorum/basilium)

Palaeocystodinium-3 (cf. benjamini)

Fibrocysta-3 (axiale)

The sidewall cores at 2290m and 2330.5m are barren of diagnostic palynomorphs.

Hiatus ca. 2320m

The presence of a major hiatus is indicated by a marked change in the palynologic content. No clear evidence in support of Danian and latest Senonian ages was recovered.

CRETACEOUS

The existence of a Late Cretaceous boreal province characterized by geographically restricted microfloras is well documented at present (Srivastava, 1978; Herngreen and Chlonova, 1982; Lentin and Williams, 1980). Consequently, the composition and stratigraphic distribution of both marine and terrestrial assemblages present at Haltenbanken are strongly influenced by paleogeographic factors. The Haltenbanken microfloras tend to compare more closely with previously documented assemblages from the northern latitudes and to a lesser extent with those known from the middle and southern latitudes. Within the boreal realm, the palynomorph assemblages are well documented in the Maastrichtian to Santonian and Cenomanian to Albian intervals in northern North America, but precisely age dated Coniacian to Turonian assemblages are still not fully documented. Thus, the total stratigraphic ranges of some taxa, especially their oldest occurrences, are not precisely known. At the same time, published information regarding Western Siberia and Central Asia is only generally useful due to limited time-stratigraphic control.

The following interpretation reflects the present state-of-the-art. The upper and lower parts of the Cretaceous section can be age dated with a

reasonable degree of confidence. The median part is poorly defined by longer ranging taxa. Also, there are some apparently new species of uncertain chronostratigraphic value.

Senonian (Campanian to Early Maastrichtian) ca. 2320m-2460m

A highly distinctive assemblage formed by marine dinoflagellate and land-derived palynomorphs has been recovered from a sidewall core at 2454m and from ten composited cuttings samples.

Terrestrial palynomorphs include:

Orbiculapollis-1 (globosus)

Expressipollis-1 (operosus)

Translucentipollis-1 (plicatilis)

Aquilapollenites-3 (attenuatus)

Aquilapollenites-19

Aquilapollenites-27

Aquilapollenites-34

Anacolosidites sp.

This terrestrial microflora is formed almost exclusively by boreal taxa known from the "Aquilapollenites-Province" of Siberia, Central Asia, and western North America. This group of taxa is indicative of a middle-late Senonian age, whereas Orbiculapollis-1 is considered to be restricted to the late Campanian to Maastrichtian interval (Herngreen and Chlonova, 1981).

Concomitantly, Late Cretaceous dinocysts become increasingly abundant below 2350m and include:

Chatangiella sp.

Isabelidinium sp.

Odontochitina-1 (operculata) - top

Deflandrea- cf. 14 (C. niiga/vnigri)

Deflandrea-4 (C. victoriensis)

Deflandrea- cf. 15 (C. spectabilis/ditissima)

Deflandrea-6 (±I. cooksoniae)

Deflandrea-17 (I. glabrum)

Deflandrea- cf. 11 (C. cf. granulifera)

Alterbia-2 (recticornis)

Dinogymnium sp. (for D. sibiricum)

Diconodinium-3 (arcticum)

Trithyrodinium-2 (suspectum)

Similar assemblages have been reported from Campanian to Maastrichtian strata from northern North America (Felix and Burbridge, 1973; McIntyre, 1974, 1975; Doerenkamp, et al, 1976; Kidson, 1980) and Western Siberia (Vozzhennikova, 1967).

Late Cretaceous, probably Senonian ca. 2460m-3100m

The sidewall cores at 2540m, 2601.2m, 2687m, 2782m, 3070m and 30 composited cuttings samples yielded generally abundant assemblages dominated by microplankton. The group of peridinioid species encountered between

2320-2460m continues to commonly occur through this interval, but Aquilapollenites, Orbiculapollis and Expressipollis are no longer present.

New succession of tops include:

Deflandrea-33 (I. latum)

Deflandrea-35 (I. minor)

Deflandrea-32 (I. acuminatum)

Lejeunia-4 (P. cretacum)

Palaeohystrichophora-1 (infusorioides)

Exochosphaeridium-1 (C. striolata)

Odontochitina-3 (costata)

Consistent occurrence of these dinoflagellates supports a Late Cretaceous-Senonian age interpretation. But, in my opinion, there are no objective criteria for a more refined subdivision of this section.

Hiatus ca, 3100m.

Cenomanian (or younger?) ca. 3100m-3450m

The sidewall cores at 3167m, 3335m, 3404m, 3430m, and sixteen cuttings samples also contain common dinoflagellates. Representatives of the genera Chatangiella, Isabelidinium, and Alterbia continue to occur throughout this interval. These are common in the sidewall cores and, therefore, considered to be "in-situ." Their lowest appearance is documented in the sidewall core at 3430m.

In addition, new tops include:

Stephodinium-1 (coronatum)

Subtilisphaera-2 (perlucida)

Deflandrea- cf. 26 (I. magna)

Scriniodinium-6 (campanulum)

Spinidinium-4 (vestitum)

Chlamydophorella-2

Diphyes-6 (F. mantellii)

The concurrent ranges of these taxa suggest a Cenomanian age. Also, Deflandrea- cf. 26 (I. magna) has been reported from Cenomanian formations of Saskatchewan (Davey, 1968), whereas Stephodinium-1 (coronatum) and Scriniodinium-6 (campanulum) appear to have effective tops in the Cenomanian (Clarke and Verdier, 1967; Kidson, 1977). Reported younger occurrences are not precisely age dated. Amoco data based on measured, accurately dated sections indicate that Isabelidinium is not present in pre-Cenomanian strata (Kidson, 1977; Aurisano, 1982).

Albian (late?) ca. 3450-3520m

The sidewall cores at 3487.5m and 3500m contain another characteristic, in situ dinocyst assemblage, including:

Litosphaeridium-1 (siphoniphorum)

Litosphaeridium-2

Ascodinium sp.-4 (O. scabrosum)

Ovoidinium sp.

Pseudoceratium-3 (expolitum)

Pseudoceratium-4

Pseudoceratium-5 (dettmanni)

Apteodinium-2 (cf. maculatum)

Polysphaeridium-2 (laminaspinosum)

Spinidinium-4 (vestitum)

Scriniodinium-6 (campanula)

Florentinia sp.

Prolixosphaeridium-2 (parvispinum)

Most of these taxa are typical components of Albian or Albian-Cenomanian assemblages documented in numerous localities in Europe (Cookson and Hughes, 1964; Davey and Verdier, 1973, 1974), the North Sea (Amoco data), North Atlantic (Williams, 1975; Bujak and Wiliams, 1978), and North America (Brideaux, 1971; Brideaux and McIntyre, 1975; Singh, 1971). Litosphaeridium, Ascodinium-Ovoidinium and Spinidinium have not been recorded from pre-Albian strata (Amoco data). It is, therefore, considered that this interval is no older than Albian in age.

The sidewall core at 3519m is barren of palynomorphs.

Hiatus-vicinity of 3520m.

No palynologic evidence in support of a pre-Albian age was recovered by Tulsa from this well. It appears that Aptian, Barremian, Hauterivian, and Valanginian strata are missing or may be partially represented by a very thin, barren interval.

JURASSIC

Portlandian to Berriasian ca. 3528.5

This interpretation is based on one diagnostic sample. The sidewall core at 3528.5m yielded another characteristic assemblage of common dinocysts. As most of the Early Cretaceous is missing, the palynomorph assemblage shows a considerable qualitative change. Virtually no taxa range from this level into the overlying middle-Late Cretaceous section.

Age diagnostic taxa include:

Imbatodinium-1 (villosum)

Egmontodinium-3 (torynum)

Egmontodinium-2 (expiratum)

Occisucysta sp.

Occisucysta-cf. 1 (evitti)

Sirmiodinium-1 (grossi)

Heliodinium- cf. 1

Gonyaulacysta sp.

"Surculosphaeridium" sp.

This group of dinocysts has repeatedly been recorded from the Late Jurassic/Early Cretaceous transition in the North Sea Basin (Thusu, 1978; Davey, 1979). Amoco data based on outcrop materials from England also support this interpretation.

Kimmeridgian? ca. 3530m-3560m (or 3580m?)

The sidewall cores at 3534.5m, 3546m, and three cuttings samples contain abundant terrestrial and marine palynomorphs, but the state of preservation is poor, precluding precise identifications. However, specimens attributable to the following dinocyst taxa are probably restricted to this interval.

Senoniasphaera-4 (jurassica)

Dinopterygium-4 (dimorphum)

Gonyaulacysta-25 (nuciformis)

Gonyaulacysta-24? (cf. longicornis)

Pareodinia sp.

Scriniodinium-2 (apatelum)

Although limited, this assemblage compares favorably with that of the Kimmeridgian of England (published and Amoco data - Beju, 1982) and Andoya and Spitsbergen (Thusu, 1978). This group of dinoflagellate taxa is associated with numerous degraded terrestrial palynomorphs, unicellular algae and acritarchs (e.g., Tasmanites, Leiosphaeridia, Pterospermopsis). The resulting palynofacies is characteristic and similar to that of the Kimmeridge Clay Formation. Furthermore, negative evidence, i.e., absence of terrestrial microfloras known to commonly occur around the Jurassic/Cretaceous transition strongly suggests a pre-Portlandian age for this level. At the same time, the entire assemblage has a distinctive post-Oxfordian aspect. Species of Oxfordian affinities become gradually

predominant only below 3580m. Also, the stratigraphic position of this unit, which is located between the well dated Portlandian and Oxfordian sections, indirectly supports a tentative Kimmeridgian age assignment. Hence, it is considered that the 3530m to 3560m or 3580m interval may represent a condensed Kimmeridgian section.

Oxfordian (to early Kimmeridgian?) ca. 3560m (or 3580m)-3661m

Another highly distinctive dinocyst assemblage has been recovered from a conventional core sample at 3661m and four composited cuttings samples. The top of this interval is marked by:

Scriniodinium-3 (crystallinum)

Nannoceratopsis-1 (pellucida)

Tubotuberella-3 (eisenacki)

Hystrichogonyaulax-2 (cladophora)

Adnatosphaeridium-4 (aemulum)

Gonyaulacysta-9 (jurassica)

Acanthaulax senta/venusta

In addition, samples at 3600m, 3620m, 3640m and 3661m contain:

Wanaea-1 (fimbriata)

Scriniodinium-11 (galeritum)

Stephanelytron-1 (redcliffense)

Leptodinium-9 (mirabile)

Ctenidodinium-2 (ornatum)

Chytroeisphaeridia cerastes

This group of dinoflagellate taxa is indicative of an Oxfordian age. Their stratigraphic ranges have been amply documented (published and Amoco data - Beju, 1982). Gonyaulacysta-9, Adnatosphaeridium-4, Nannoceratopsis-1 and Scriniodinium-3 become extinct in the vicinity of the Oxfordian/Kimmeridgian boundary, whereas Wanaea-1 and Stephanelytron-1 appear to be restricted to the early Oxfordian.

Middle Jurassic, probably Bathonian ca. 3661.5m-3740m

Eight conventional core samples and several cuttings samples yielded poor terrestrial microfloras including:

Callialasporites sp.

Callialasporites-5

Osmundacidites-3

Klukisporites-3

Contignisporites-1

Densoisporites-1

Cyathidites-1

Perinopollenites-2

Most of these taxa have rather long stratigraphic ranges in the Jurassic. However, the general aspect of the assemblage and its stratigraphic position in this section support a Middle Jurassic age interpretation.

Bajocian to Toarcian ca. 3750m-4100m

This interval is characterized by the consistent occurrence of Nannoceratopsis-2 (gracilis), which is known to be restricted to this age span. A few specimens attributable to Evansia-1 and Parvocysta sp. have been recorded in the vicinity of 4000m. These two taxa have been reported from independently dated Toarcian strata cropping out in Spitsbergen (Bjaerke, 1980) and are also present in a coeval subsurface section at Troms (Beju, 1981).

Pliensbachian to Sinemurian ca. 4140-4370m

The sidewall cores at 4194m, 4295m, 4380m, and six composited cuttings samples yielded abundant land-derived palynomorphs associated with abundant plant and coal debris. The following taxa are generally frequent:

Chasmatosporites sp.

Chasmatosporites-1

Quadreculina anellaeformis

Leiotriletes mesozoicus

Deltoidospora sp.

Osmundacidites sp.

Baculatisporites sp.

Contignisporites problematicus

Cerebropollenites sp.

Hettangian ca. 4370m-4540m

A slight change of the land-derived microflora is discernible in the cuttings samples and especially sidewall cores at 4450m and 4534m. More prominent taxa include:

Trachysporites asper/fuscus

Conbaculatisporites sp. A

Calamospora mesozoica

Retusotriletes mesozoicus

Triancoraesporites-1

Annulispora-1

Polycingulatisporites-2

Heliosporites-1

Kyrtomisporis-1

Clavatipollenites sp. A

Most of these taxa are restricted or show an abundance maximum in the early Liassic (Nilsson, 1958; Pedersen and Lund, 1980).

TRIASSIC

Rhaetian (late?) ca. 4540m-4560m (T.D.)

Finally, the sidewall core at 4547m produced another highly distinctive assemblage, including:

Limbosporites-1

Ricciisporites-sp.

Ricciisporites-1

Rhaetogonyaulax-1

Ovalipollis-1

Striatoabietites sp.

Sulcatisporites-1

Striatopodocarpites-3

This assemblage is indicative of a Rhaetian age.

KEROGEN-PALYNOFACIES

Kerogen-palynofacies analyses have been limited to the Jurassic section (3530m-4540m), which appears to be more significant for exploration. Five principal kerogen-palynofacies zones have been recognized.

A. ca. 3530-3560m

The sidewall cores at 3534m and 3546m are diagnostic for this zone. Both samples contain similar types of kerogen consisting of abundant, compact, comparatively large and medium sized amorphous particles (up to 90%) with a bituminous, greasy aspect. These are subordinately associated with plant and coaly debris (ca. 10-15%), unicellular algae (Leiosphaeridia, Tasmanites, Pterospermopsis), land-derived palynomorphs and occasional dinoflagellates. Pyrite crystal marks are also present. All of these indicate a marginal marine, possibly restricted site of deposition with anoxic bottom conditions favoring the accumulation and preservation of a significant amount of organic matter.

Microscopic observations strongly suggest that the corresponding interval has an excellent hydrocarbon generation potential.

B. ca. 3560-3661m

Conventional core at 3661m and several cuttings samples contain a distinct type of kerogen formed by numerous dinoflagellates (up to 95% in the core sample) and small amounts of comparatively small plant and coaly debris (probably inertinite) with angular outlines and a lean, dry aspect. Terrestrial palynomorphs are present in low proportions (1-5%). The abundance of dinoflagellate cysts and small numbers of terrestrial palynomorphs together with small plant debris suggest an open to outer shelf marine site of deposition.

Microscopic observations suggest a low hydrocarbon generation potential for this interval.

C. ca. 3661.5-3750m

Most samples from this interval, which correspond to the Middle Jurassic sandstone unit, show a poor organic content formed by coal and plant debris.

D. ca. 3750-4220m

Mixed types of kerogen are generally predominant through most of this interval. Relatively small plant and coal fragments form the bulk of organic matter, whereas unstructured and powdery particles participate subordinately. Terrestrial palynomorphs are common and marine dinoflagellates occur occasionally. A marginal marine site of deposition with significant allochthonous influx is suggested.

E. ca. 4200-4560m

Structured kerogen is predominant within this interval. Most samples produced abundant plant and coal fragments, which are associated with various amounts of terrestrial palynomorphs. Also present are waxy-resinous and bituminous particles. Marine microfossils are virtually absent. In general terms, most of this section corresponds to a non-marine, intralittoral to sublittoral sequence deposited under cyclic conditions.

A fair to good hydrocarbon generation potential also is suggested for this Lower Jurassic interval.

DEGREE OF ORGANIC MATURATION

The degree of organic maturation shows a gradual increase with depth through all the sedimentary sequence penetrated, i.e., from carbonization scale 3 (immature) at ca. 2000m, to scale 4 at ca. 3400m, and scale 5 from ca. 4000m to T.D. Thus, the Upper Jurassic section is in the peak oil generation window, whereas the Lower Jurassic section is at an early gas generation to peak oil generation stage.

Dan N. Beju

DNB:sl

83343ART0060

SELECTED REFERENCES

Alberti, G.

1961: Zur Kenntnis mesozoischer und alttertiärer Dinoflagellaten und Hystrichosphaerideen von Nord- und Mitteldeutschland. Palaeontographica, Abt. A, v. 116, p. 1-58, pl. 1-12.

Aurisano, R. W.

1982: Aptian-Albian palynostratigraphy of the Isle of Wight, England. Amoco Production Co., Research Dept. Report F82-G-12.

Beju, D.

1980: Catalog of some Jurassic and Lower Cretaceous phytoplankton. Amoco Production Co., Research Dept. Report F80-G-20.

1981: Palynologic analyses and visual estimates of kerogen of core and cuttings samples from the Amoco-Norsk Hydro Troms 7120/12-1 - Well, northern North Sea, Norway. Amoco Production Co., Research Dept. Technical Service Report 9115 and 5727.

1982: Palynostratigraphy of the Middle-Upper Jurassic of southern England. Amoco Production Co., Research Dept. Report F82-G-19.

Benedek, P. N.

1972: Phytoplanktonten aus dem Mittel- und Oberoligozän von Tönisberg (Niederrheingebiet); Palaeontographica, Abt. B, v. 137, p. 1-71, pl. 1-16.

Bjaerke, T.

1980: Mesozoic palynology of Svalbard IV, Toarcian dinoflagellates from Spitsbergen; Palynology, v. 4, p. 57-77, pl. 1-5.

Bjaerke, T. and Manum, S. B.

1977: Mesozoic palynology of Svalbard-I. The Rhaetian of Hopen, with a preliminary report on the Rhaetian and Jurassic of Kong Karls Land. Norsk Polarinstitut Skr. 165, p. 1-48.

Brideaux, W. W.

1971: Palynology of the Lower Colorado Group, central Alberta, Canada, I. Introduction remarks. Geology and microplankton studies; Palaeontographica, Abt. B, v. 135, p. 53-114, pl. 21-30.

Brideaux, W. W. and McIntyre, D. J.

1975: Miospores and microplankton from Aptian-Albian rocks along Horton River, District of Mackenzie; Geological Survey of Canada, Bulletin 252, p. 1-85, pl. 1-14.

Bujak, J. P.

1980: Dinoflagellate cysts and acritarchs from the Eocene Barton Beds of southern England; in Bujak, J. P., Downie, C., Eaton, G. L., and Williams, G. L., Dinoflagellate cysts and acritarchs from the Eocene of southern England; The Palaeontological Association, Special Papers in Palaeontology, no. 24, p. 36-91.

Bujak, J. P. and Williams, G. L.

1978: Cretaceous palynostratigraphy of offshore southeastern Canada. Geol. Surv. Canada, Bull., 297, p. 1-19.

Caro, Y.

1973: Contribution á la connaissance des dinoflagellés du Paléocène-Eocène inférieur des Pyrenées espagnoles; Revista Española de Micropaleontologia, v. 5, p. 329-372, pl. 1-5.

Châteauneuf, J.-J. and Graus-Cavagnetto, C.

1978: Les zones de Wetzeliellaceae (Dinophyceae) du bassin de Paris; Bulletin du Bureau des Recherches Geologiques et Minières (deuxiéme série), Section IV; no. 2-1978, p. 59-93, pl. 1-5.

Clarke, R. F. A. and Verdier, J.-P.

1967: An investigation of microplankton assemblages from the Chalk of the Isle of Wight, England; Verhandelingen der K. Nederlandsche Academie van Wetenschappen, Afdeeling natuurkunde, Eerste Reeks, v. 24, p. 1-96, pl. 1-17.

Cookson, I. C. and Hughes, N. F.

1964: Microplankton from the Cambridge Greensand (mid-Cretaceous); Palaeontology, v. 7, p. 37-59, pl. 5-11.

Cookson, I. C. and Manum, S.

1964: On Deflandrea victoriensis n. sp., D. tripartita Cookson and Eisenack, and related species; Proceedings of the Royal Society of Victoria, v. 77, p. 521-524, pl. 76.

Costa, L. I. and Downie, C.

1976: The distribution of the dinoflagellate Wetzeliella in the Palaeogene of northwestern Europe; Palaeontology, v. 19, p. 591-614, pl. 92.

Davey, R. J.

1968: Non-calcareous microplankton from the Cenomanian of England, northern France and North America, Part I; Bulletin of the British Museum (Natural History) Geology, v. 17, p. 103-180, pl. 1-11.

Davey, R. J.

1979: The stratigraphic distribution of dinocysts in the Portlandian (Latest Jurassic) to Barremian (Early Cretaceous) of northwest Europe; AASP Contributions Ser., 5B, 49-81.

Davey R. J. and Verdier, J.-P.

1973: An investigation of microplankton assemblages from latest Albian (Vraconian) sediments; Revista Española Micropaleontologia, v. 5, p. 173-212, pl. 1-5.

1974: Dinoflagellate cysts from the Aptian type sections at Gargas and La Bédoule, France; Palaeontology, v. 17, p. 623-653, pl. 91-93.

De Coninck, J.

1975: Microfossiles á paroi organique de l'Yprésien du Bassin belge; Service Géologique de Belgique, Prof. Paper No. 12, p. 1-151, pl. 1-22.

Doerenkamp, A., Jardine, S. and Moreau, P.

1976: Cretaceous and Tertiary palynomorph assemblages from Banks Island and adjacent areas. Bull. Canad. Petrol. Geol., 24, 3, p. 372-417.

Eaton, G. L.

1976: Dinoflagellate cysts from the Bracklesham Beds (Eocene) of the Isle of Wight, Southern England; Bulletin of the British Museum (Natural History) Geology, v. 26, p. 227-332, pl. 1-21.

Eisenack, A.

1954: Mikrofossilien aus Phosphoriten des Samlandischen Unteroligozäns und über die Einheitlichkeit der Hystrichosphaerideen; Palaeontographica, Abt. A., v. 105, p. 49-95, pl. 7-12.

Felix, C. J. and Burbridge, P. P.

1973: A Maestrictian age microflora from Arctic Canada; Geoscience and Man, 7, p. 1-29.

Fisher, M. J. and Riley L. A.

1980: The stratigraphic distribution of dinoflagellate cysts at the boreal Jurassic-Cretaceous boundary; Fourth International Palynology Conference, Lucknow (1976-77) Proceedings, 2, p. 313-329, pl. 1-4.

Gocht, H.

1969: Formengemeinschaften Alttertiären Microplanktons aus Bohrproben des Erdölfeldes Meckelfeld bei Hamburg; Palaeontographica, Abt. B, v. 126, p. 1-100, pl. 1-11.

Herngreen, G. F. W. and Chlonova, A. F.

1982: Cretaceous microfloral provinces; Pollen et Spores, 23, p. 441-555

Harland, R.

1979c: The Wetzeliella (Apectodinium) homomorphum plexus from the Palaeogene/earliest Eocene of northwest Europe; Fourth International Palynology Conference, Lucknow (1976-1977), Proceedings, 2, p. 59-70, pl. 1-2.

Kidson, E. J.

1977: The dinoflagellate biostratigraphy of the Isle of Wight and Folkstone sections, England; Amoco Production Company, Research Dept. Report F77-G-6.

1980: Palynomorphy biostratigraphy of the Late Cretaceous Red Bird Section, Niobrara County, Wyoming; Amoco Production Company, Research Dept. Report M80-G-2.

Kjellström, G.

1973: Maastrichtian microplankton from the Höllviken Borehole No. 1 in Scania, southern Sweden; Sveriges geologiska undersökning, Afhandlingar och uppsatser, v. 67, p. 1-59.

Knox, R. W. and Harland, R.

1979: Stratigraphic relationship of the early Palaeogene ash-series of N.W. Europe; Jour. Geol. Soc. London, 136, 4, p. 463-470.

Lentin, J. K. and Williams, G. L.

1980: Dinoflagellate provincilaism with emphasis on Campanian peridiniaceans; American Association of Stratigraphic Palynologists, Contributions Series, No. 7, p. 1-47, pl. 1.

Lund, J. J.

1977: Rhaetic to Lower Liassic palynology of the onshore south-eastern North Sea Basin; Geol. Survey Denmark, Ser. II, 109, 128 pp.

Manum, S.

1963: Some new species of Deflandrea and their probable affinity with Peridinium

Norsk Polarinstitutt, Arbok 1962, p. 55-67, pl. 1-3.

1976: Dinocysts in Tertiary Norwegian-Greenland Sea sediments (Deep Sea Drilling Project Leg 38), with observations on palynomorphs and palynodebris in relation to environment; Initial Reports D.S.D.P., v. 38, p. 897-919.

Manum, S. and Cookson, I. C.

1964: Cretaceous microplankton in a sample from Graham Island, Arctic Canada, collected during the second "Fram"-Expedition (1898-1902). With notes on microplankton from the Hassel Formation, Ellef Ringnes Island; Schrifter utgitt av Det Norske Videnskaps-Adademi i Oslo, I. Mat-Naturv. Klass, Ny Series 17, p. 1-35, pl. 1-7.

McIntyre, D. J.

1974: Palynology of an Upper Cretaceous section, Horton River District of MacKenzie, N.W.T.; Geol. Surv. Canada, Paper 74-14, p. 1-57.

1975: Morphologic changes in Deflandrea from a Campanian section, District of Mackenzie, N.W.T., Canada; Geoscience and Man, v. 11, p. 61-76, pl. 1-4.

Miller, F. X.

1983: Exploration applications of the graphic correlation - composite standard methodology; Amoco Production Company, Research Dept. Report F83-G-4.

Morgenroth, P.

1966a: Mikrofossilien und Konkretionen des nordwesteuropäischen Untereozäns; Palaeontographica, Abt. B, v. 119, p. 1-53, pl. 1-11.

1966b: Neue in organischer Substanz erhaltene Mikrofossilien des Oligozäns; Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, v. 127, p. 1-12, pl. 1-2.

Nilsson, T.

1958: Über das Vorkommen eines mesozoischen Sapropelgesteins in Schonen; Lunds Universitets Arsskrift, N. F., Avd. 2, 54, pp. 1-112, 8 pls.

Pedersen, K. R., Lund, J. J.

1980: Palynology of the plant-bearing Rhaetian to Hettangian Kap Stewart Formation, Scoresby Sund, East Greenland; Rev. Palaebotany and Palynology, 31, p. 1-69.

Rawson, P. F. and Riley, L. A.

1982: Latest Jurassic-Early Cretaceous Events and the "Late Cimmerian Unconformity" in North Sea Area; AAPG Bulletin, 66, 12, p. 2628-2648.

Singh, C.

1971: Lower Cretaceous microfloras of the Peace River area, northwestern Alberta; Research Council of Alberta, Bulletin 28, p. 301-542, pl. 39-80.

Srivastava, S. K.

1978: Cretaceous spores pollen floras: a global evaluation; Biol. Mem., 3, 1, 130 pp.

Stanley, E. A.

1965: Upper Cretaceous and Paleocene plant microfossils and Paleocene dinoflagellates and hystrichosphaerids from northwestern South Dakota; Bulletin of American Paleontology, v. 49, p. 179-384, pl. 19-49.

Stover, L. E.

1977: Oligocene and Early Miocene dinoflagellates from Atlantic Corehole 5/5B, Blake Plateau; American Association of Stratigraphic Palynologists, Contributions Series, No. 5A, p. 66-89, pl. 1-3.

Thusu, B. (Ed.)

1978: Distribution of biostratigraphically diagnostic dinoflagellate cysts and miospores from Northwest European Continental Shelf and adjacent areas; Continental Shelf Inst., Publ. 100, p. 1-109.

Tralau, H.

1968: Botanical investigations into the fossil flora of Eriksdal in Fyledalen, Scania. II. The Middle Jurassic microflora; Sveriges Geol. Undersokning, 62, 4, 185 p.

Vozzhennikova, T. F.

1967: Iskopaemye peridinei yurskikh, melovykh i paleogenovykh otlozheniy SSSR; Adak. Nauk SSSR, Sib. Otd., Inst. Geol. Geofiz., Tr., 347 p., 121 pl. (Fossil peridinians of the Jurassic, Cretaceous and Paleogene deposits of the U.S.S.R.)

Wall, D.

1967: Fossil microplankton in deep-sea cores from the Caribbean Sea; Palaeontology, v. 10, p. 95-123, pl. 14-16.

Williams, G. L.

1975: Dinoflagellate and spore stratigraphy of the Mesozoic-Cenozoic, offshore Eastern Canada; Geol. Surv. Canada, Paper 74-30, v. 2, p. 107-161.

Williams, G. L. and Brideaux, W. W.

1975: Palynologic analyses of Upper Mesozoic and Cenozoic Rocks of the Grand Banks, Atlantic Continental Margin; Geol. Surv. Canada, Bull., 236, p. 1-163.

Williams, G. L. and Bujak, J. P.

1977: Cenozoic palynostratigraphy of offshore eastern Canada in W. C. Elsik, ed., Contrib. Stratigr. Palynol., v. 1, Cenozoic Palynology, AASP, Contrib. Ser. 5A, p. 14-47.

DNB:sl
83343ART0060

APPENDIX 1

Locality 12,515 - Statoil 6407/1-2, Haltenbanken, Offshore Norway

List of Samples Analyzed

1. Core Chips

3661m
3661.5m
3665.90-3665.95
3675.40-3675.45
3683.56-3683.61
3686.18-3686.22
3969.74-3696.78
3699.35-3699.40
3719.05-3719.10

2. Sidewall Cores

1855m
2191.50m
2232m
2269m
2290.20m
2330.50m
2454.10m
2540m
2601.20m
2687m
2782.10m
3070m
3167m
3335m
3404m
3430.50m
3487m
3500.60m
3519m
3528m
3534.50m
3546.00m
3982m
4194m
4295m
4380m
4450m
4534m
4547m

3. Composited Cuttings Samples

1000-1030m
1080-1100m
1130-1160m
1200-1230m
1260-1290m
1320-1340m
1360-1380m
1400-1430m
1450-1480m
1500-1520m
1530-1560m
1570-1600m
1610-1630m
1640-1670m
1680-1700m
1720-1740m
1770-1790m
1810-1830m
1850-1870m
1890-1910m
1930-1950m
1970-1990m
2010-2020m
2030-2040m
2050-2070m
2080-2100m
2110-2130m
2140-2150m
2160-2170m
2180-2200m
2202-2210m
221.5-2220m
222.5-2230m
2235-2242.5m
2260-2270m
2272.5-2282.5m

2290-2300m
2305-2315m
2320-2330m
2335-2345m
2350-2357.5m
2360-2367.5m
2370-2380m
2382.5-2390m
2400-2410m
2415-2422.5m
2425m
2430m
2437.2447.5m
2460-2470m
2480-2490m
2500-2510m
2520-2530m
2540-2550m
2560-2570m
2580-2590m
2600-2610m
2620-2630m (2 spl.)
2642.5-2655m (2 spl.)
2670-2680m
2692.5-2705m
2715-2727.5m
2745-2755m
2770-2782.5m
2795-2812.5m
2825-2837.5m
2850-2860m
2870-2880m
2887.5-2897.5m
2900-2907.5m
2910-2920m
2930-2940m
2950-2960m
2970-2980m
2990-3000m
3010-3020m
3030-3040m
3050-3062.5m
3080-3090m
3100-3110m
3120-3130m
3140-3150m
3160-3170m
3180-3190m
3200-3210m
3220-3230m
3240-3250m
3260-3270m
3280-3290m
3300-3310m
3320-3330m
3340-3350m
3360-3370m
3380-3390m
3400-3410m
3420-3430m
3440-3450m
3460-3470m
3480-3490m
3500-3510m
3520-3530m
3540-3550m
3560-3570m
3580-3590m
3600-3610m
3620-3630m
3640-3650m
3660-3670m
3680-3687.5m
3700-3712.5m
3725-3735m
3747.5-3762.5m
3777.5-3787.5m
3800-3810m
3822.5-3832.5m
3835-3845m
3855-3865m
3875-3882.5m
3890-3897.5m
3910-3925m
3940-2952.5m
3967.5-3980m
3992.5-4002.5m
4032.5-4045m
4070-4082.5m
4092-4105m
4132.5-4137.5m
4152.5-4170m
4190-4205m
4235-4255m
4280-4300m
4325-4340m

4355-4375m
4390-4400m
4412.5-4422.5m
4432.5-444.5m
4460-4472.5m

4485-4502.5m
4515-4525m
4532.5-4542.5m
4550-4560m

DNB:sl
83343ART0060