

REPORT TITLE/ TITTEL

BIOSTRATIGRAPHY OF WELL 6610/7-2

CLIENT/ OPPDRAGSGIVER

Statoil - Den norske stats oljeselskap a.s.

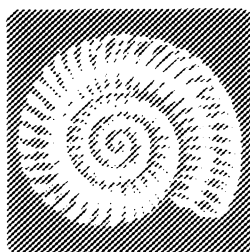
RESPONSIBLE SCIENTIST/ PROSJEKTANSVARLIG

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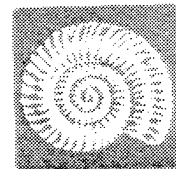
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SUMMARY/ SAMMENDRAG

A Pleistocene-Pliocene age is most likely for the coarse grained sediments down to 990 m in this well, although good Eocene dinocyst assemblages are found at 712 m and 806 m. The grey claystone from 990 m has a Late Paleocene aspect. Late Cretaceous sediments occur from 1255-1476 m followed by a thin Albian-(Late Barremian) unit between 1480 m and 1485 m. Sinemurian is penetrated at 1521.5 m (probably already from the top of sandstone at about 1490 m). An undivided Hettangian-Rhaetian coaly interval extends down to 1785 m. The Rhaetian-Norian interval contains marine palynomorphs toward the base (between 2146.5 m and 2159 m). A tentatively dated Norian unit below is followed by a thick Karnian from 2392.5, an undivided Karnian-Ladinian at 2637 m and Ladinian at 3135 m.

New evidence of marine deposition is present in the Ladinian. The well bottoms in Anisian to Spathian rocks at 4215 m and cored at 4180.77-4193 m

KEY WORDS/ STIKKORD

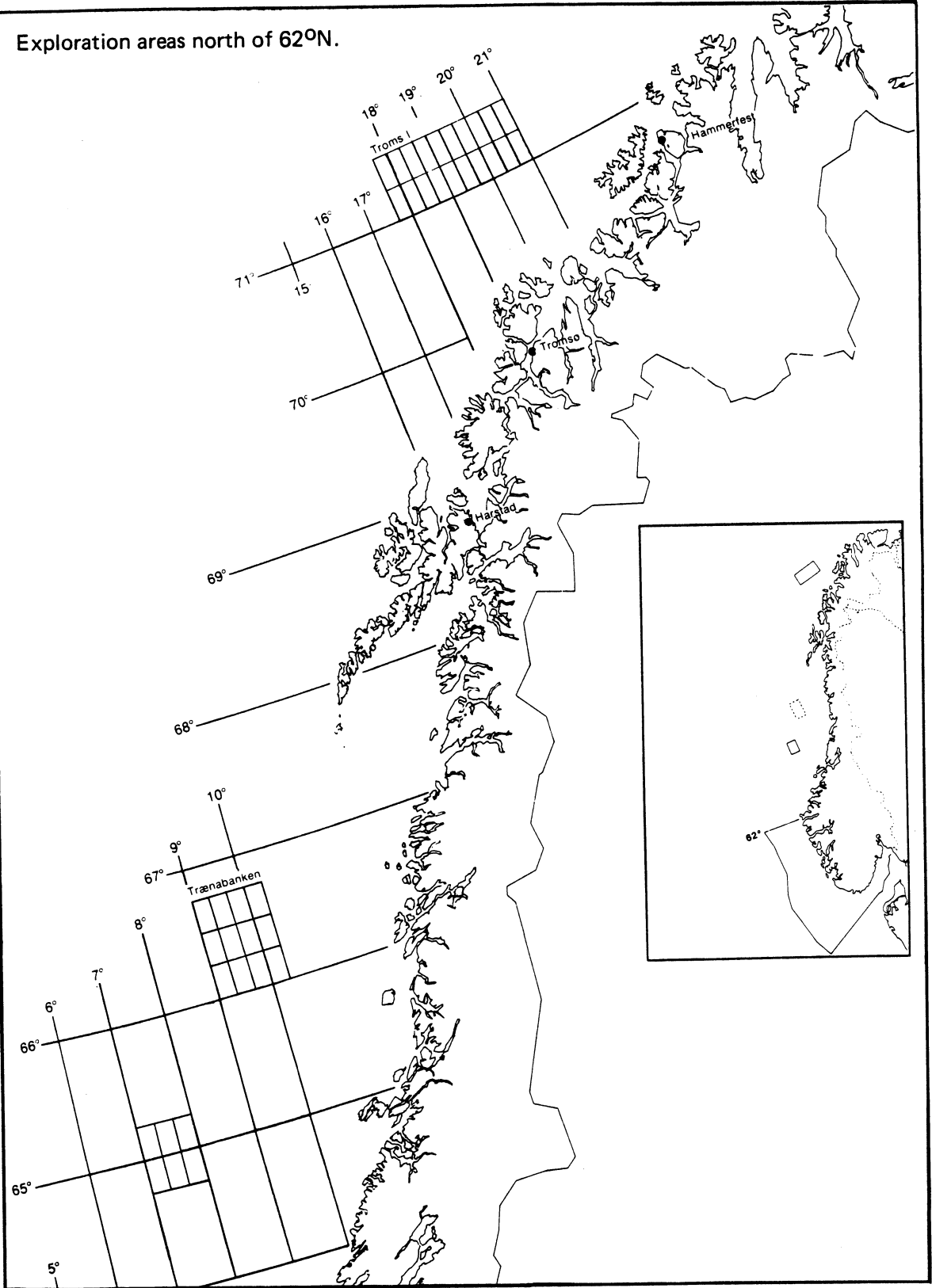
6610/7-2 Trænabanken

Biostr., Pleistocene-Triassic

Lithology, environment

Micropaleontology

Exploration areas north of 62°N.



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INTRODUCTION

The biostratigraphy of Statoil's well 6610/7-2 is based mainly on analysis of cuttings samples but with supporting evidence from relatively numerous sidewall cores. However the fossil recovery in the sidewall cores was often poor. Two chips were available from a core at the bottom of the well, and yielded the final evidence for the dating of the basal layers.

Mud additive on paraffin basis in parts of the Triassic sequence caused several problems during washing of the cuttings samples. Only samples needed for palynology were washed. The lithological information is therefore somewhat sparse in this part of the well.

Microfaunal analyses were carried out by Verdenius in the Pleistocene and Tertiary and by Løfaldli in the Cretaceous. Verdenius also examined some Cretaceous sidewall cores with respect to nannofossils, but with negative result. Aarhus carried out the palynology in the Cretaceous. He also examined a few sidewall cores above to support the poor faunal recovery. Vigran did the palynological analyses in the older strata.

330 -370 m PLEISTOCENE

Lithology

The washed sample contains sand and gravel. The grain size ranges from very fine sand to gravel. Unconsolidated clay represents a major lithology in the unwashed material. A few shell fragments are observed.

Micropaleontology

A fairly rich assemblage of calcareous benthonic foraminifera and some planktonic foraminifera is met in this interval. The presence of several species of Islandiella in the absence of restricted Pliocene species were the reasons for attributing a Pleistocene age to this interval. Some reworking of underlying Pliocene deposits were concluded from the observation of Cibicides pseudoungeranus and Bulimina marginata.

Environment

The fully marine microfauna and the abundant mollusc debris are evidence of a marine, shallow neritic environment.

400 - 980 m PLIOCENE?

Lithology

There is no lithologic indication of break in sedimentation between this unit and the interval above. The material consists of sand and gravel. In addition unconsolidated clay was present in the unwashed samples. Towards the lower boundary small amounts of brownish grey, greenish grey and grey claystone occurs. Shell fragments are present throughout and seem to increase downwards.

Micropaleontology

A marked faunal change distinguishes this unit from the Pleistocene deposits above. Cibicides grossa, Elphidium groenlandicum and

Sigmoilopsis schlumbergeri all have their highest occurrence at 400 m on which evidence we assume that the latest Pliocene is condensed or lacking. The foraminiferal association from 400 m to 710 m compares closely to zones MSB 14-15 (King 1983). A common feature in a comparison of the 460 - 960 m interval in 6610/7-1 to the 400 - 980 m interval in 6610/7-2 is the occurrence of Elphidiella hannai and Elphidium oregonense in the deeper part of the Pliocene unit, and the abundant mollusc debris down to the lower boundary. The samples are very poor, but there is no clear reason to select an undeterminate interval as has been done in 6610/7-1.

Microflora

A few sidewall cores were prepared for palynology. Eocene assemblages with Diphyes colligerum, Phtanoperidinium geminatum, Dracodinium varielongitudum (712 m) and several other age distinctive species occur in the 712 and 806 m SWC's. Less age significant floras are found in the 938 and 988 m SWC's. The Valanginian and older dinocysts Tubotuberella apatela and Scriniodinium pharo are at 888 and 938 m respectively.

The oxidized sandy material in the intervals 700 - 770 and 970 - 990 m and the conglomeratic character of the 712 and 806 m sidewall cores support the evidence of reworking.

Environment

The abundance of mollusc and echinoid? debris and the poor foraminiferal associations are considered evidence of a shallow marine, high-energy environment. The conglomeratic sidewall cores from 712 and 806 m and the oxidized sandy intervals support this.

1002 - 1248 m PALEOCENE

Lithology

Light brownish grey, silty claystone dominates from 1002 m to about 1040 m.

At 1040 m there is also a dark grey to dark brownish grey claystone and a certain amount of volcanic material. From 1030 m to 1070 m the amount of volcanic material is lower and the dominant claystones are dark brownish grey, dark grey to light greenish, light brownish grey and grey. From 1080 m to 1130 m the amount of volcanic material increases and is followed by a very light coloured claystone, greyish white to brownish white. Around 1120 m glauconite is present.

Between 1170 m and 1180 m significant amounts of medium to very coarse sand is present. From 1180 m to the base of the interval a green to greenish grey claystone is present in addition to the claystones mentioned above. Small amounts of sand occur in the lower part of the interval. Chalk is present below 1180 m and glauconite is observed in the lowermost few metres.

Micropaleontology

With the exception of a few possible diatom fragments and one specimen of Coscinodiscus sp. 1 at 1100 m, the samples down to 1100 m proved to be barren.

Abundant occurrence of Coscinodiscus sp. 1 is considered evidence of a Paleocene age. Down to 1200 m no other fossils are met and this interval fits best to Zone MSB 2. The radiolarian Caenosphaera sp. present from 1212 m downward characterizes zones MSP 1-2. The deepest samples contain a rich agglutinated foraminiferal assemblage known from Paleocene as well as Late Cretaceous sediments.

Palynology

The first downhole record at 1002 m of an assemblage with Deflandrea oebisfeldensis, Caryapollenites and taxodiaceous pollen probably is associated with the income of claystone at 990 m, and we draw the Paleocene - Eocene boundary above this sample. D. oebisfeldensis has an acme in the 1010 - 20 and 1031.5 m samples. This acme may be correlated with the interval 1120 - 30 to 1150 - 60 m in 6610/7-1.

Abundant pollen are present down to at least 1129 m. Its presence below this level in cuttings samples probably is due to caving, since the 1206 m SWC is barren with respect to such pollen.

Palaeoperidinium pyrophorum, Alisocysta rugolirata and Ceratiopsis striata occur consistently from 1206 m and point to an Early Paleocene age from this depth.

The presence of Diconodinium arcticum (Campanian) is recorded at 1047 m and occurs probably as due to reworking. Cribroperidinium fimbriatum and Hystrichosphaeridium difficile (Cenomanian) is found at 1206 m and Gochteodinia villosa (Late Volgian - Ryazanian) at 1218 - 1221 m. Thus the reworked taxa may point to successively younger sources for the Paleocene beds through time, but reworked specimens are not common.

Environment

The absence of fossils from bottom-dwelling organisms above 1100 m may be caused by circumstances that prevent life such as extreme acidity, absence of oxygen or absence of nutrients. Bisaccate, taxodiaceous and angiosperm pollen are even quantitatively significant organic constituents down to at least 1129 m (possibly caved below) and point to heavily forested borderlands during Late Paleocene. Some cuticles and woody material were also derived from this forest to the sediment.

The income of amorphous matter of possible marine origin from 1100 m to the base of the interval may point to a relative reduction in the input of terrestrial debris to the basin.

Deposition may have taken place in an isolated deep basinal area with normal marine surface water and stagnant bottom conditions at times.

1255 - 1443 m EARLY MAASTRICHTIAN - CAMPANIAN

Lithology

The interval is claystone dominated, but sand, glauconite and chalk is present throughout.

Entering the interval the most significant change is the disappearance of dark grey and dark brownish grey claystones. At 1300 m, also green coloured claystones disappear and below this grey claystones dominate. Chalk is present throughout the interval. Siderite occurs in considerable amounts below 1325 m. Glauconite is present down to 1420 m and pyrite is found in the very lowermost part of the interval.

Micropaleontology

A rich fauna of mainly arenaceous and calcareous foraminifera is present in this interval. The arenaceous element includes species of Ammodiscus, Haplophragmoides, Saccamina, Trochamminoides, Reophax, Rhabdammina, Kalamopsis and Spiropletamina. The calcareous benthonic group consists mainly of nodosariids, polymorphiniids and species of Gaelinella, Gyroidinoides, Praebulimina, Allomorphina, Anomalinoidea and Globorotalites. The planktonic foraminifera are made up of Globigerinelloides, Hedbergella, Rugoglobigerina and Heterohelix. The occurrence of Bolivina incrassata, Pseudotextularia elegans and Reussella szajnochae from 1413-16 m suggests a deposition in Campanian - Maastrichtian times.

Radiolaria, diatoms and Inoceramus prisms are quite common throughout the sequence. Fish teeth, ostracoda, sponge spicules, bryozoa and gastropods were also recorded.

Palynology

Trithyrodinium suspectum, Turbiosphaera sp., Spongodinium delitiense, Senoniasphaera sp. and Cicatricosisporites sp. are recorded in the 1255 m SWC which is evidence for a Late Campanian or possibly Maastrichtian age. Additional Late Cretaceous forms are present in the 1270 m SWC where Ceratiopsis diebelii is common. A correlation line may possibly be drawn to 1405 m in 6610/7-1. Dapsilidinium sp. is recorded in high numbers from 1332 to 1362 m (1460 m in 6610/7-1). This may suggest that rates of deposition were in the same order of magnitude in the Late Cretaceous in wells of the 6610/7 area. Cenomanian or younger (probably Campanian) assemblages are present in cuttings and sidewall cores down to 1476 m.

Trithyrodinium suspectum and Palaeoperidinium pyrophorum are present in most samples, Isabelidinium bakerii towards the base of the interval. The ranges of Florentinia spp. (F. ferox at 1435, F. laciniata at 1460 m) are subject to discussion and may not range into the Campanian.

Paleocene caving occurs throughout this unit.

Environment

The microfauna points to a deposition in an open marine, neritic environment. Relatively diverse dinocyst assemblages in residues dominated by dark structured woody material support this. Terrestrially derived pollen and spores are preserved in some samples.

1455 - 1476 m LATE CRETACEOUS, POSSIBLY CENOMANIAN IN LOWER PART

Lithology

The interval is dominated by grey, micromicaceous claystone.

Micropaleontology

A quite rich fauna of mainly arenaceous foraminifera including Textularia foeda and abundant Inoceramus prisms are met in this sequence. The arenaceous element includes mainly the same taxa as found in the unit above. The calcareous benthonic group mainly consists of nodosariids. Diatoms, radiolaria and sponge spicules are also recorded. In the absence of good faunal index fossils the boundaries of this unit are based exclusively on palynological evidence.

Palynology

Trithyrodinium suspectum, Palaeoperidinium pyrophorum and representatives of the genera Chatangiella and Isabelidinium dominate and point to a general Late Cretaceous age for this interval.

Palaeohystrichophora infusoroides in the sidewall cores both at 1460 and 1470 m favours an age in the lower part of the Late Cretaceous.

This species occurs most regularly and commonly in the Cenomanian. Schizocystia laevigata, Florentinia laciniata and a questionable specimen of Stephodinium coronatum at 1470 m also point to an age in the earlier part of Late Cretaceous. Cribroperidinium fimbriatum, Surculosphaeridium longifurcatum and Florentinia mantellii at 1460 m are in accordance with this although they may range at least into the Turonian.

Environment

A deposition in an open marine, neritic environment is indicated from the microfauna. The palynological residues, dominated by dark woody material, abundant dinocysts, occasional pollen and spores support an open marine environment with good water circulation.

1480 - 1485 m ALBIAN - (LATE BARREMIAN)

Lithology

A grey, claystone containing sphaerosiderite and chalk dominates the cuttings material. The sidewall core 1480 m is redbrown. A few redbrown fragments also occur in the cutting samples. The 1485 m SWC is very silty.

Micropaleontology

The quite rich fauna mainly of arenaceous foraminifera in this unit includes the same taxa as recorded in the unit above. No good index fossils were found, and the boundaries are based entirely on palynological evidence.

Palynology

Cribroperidinium muderongense, Gardodinium trabeculosum and Odontochitina operculata in a palynoassemblage dominated by Oligosphaeridium complex in the 1485 m SWC point to a Middle Albian - Late Barremian age. Species that are restricted to pre Albian strata

were not recorded. The red claystone of the 1480 m SWC is barren with respect to palynomorphs. The upper boundary of the interval is suggested on lithological evidence.

Environment

As for the unit above an open marine, neritic environment is indicated from the microfauna. The dinocysts and the organic residue dominated by woody material point to an open marine environment with well ventilated bottom conditions. This assumption is strengthened by the presence of red claystone in the 1480 m SWC.

1485 - 1521.5 m INDETERMINATE

Lithology

This interval is dominated by a very fine to very coarse sandstone. Small amounts of grey claystone similar to the claystone above is present, but probably represents caved material.

Micropaleontology

The uppermost three samples contain a moderate to rich foraminiferal fauna, of which arenaceous foraminifera is the most common group. The lower portion of this unit are very poor in microfossils. All the microfossils found are thought to be caved from above, and no age determination is possible. The microfossil content also includes diatoms, radiolaria and Inoceramus prisms.

Palynology

Sparse residues in this interval include only longranging forms like Concentrisporites halleii, Cerebropollenites macroverrucosus, Perinopollenites elatoides, some bisaccates and occasional smooth trilete spores. There is not sufficient evidence for dating of this interval.

Environment of deposition

Shallow nonmarine to brackish.

1521.5 m EARLY SINEMURIAN

Lithology

This interval is represented by only one sample, the sidewall core at 1521.5 m.

It consists of a very fine to medium sandstone, rich in organic material (e.g. coal) and pyrite.

Palynology

The well preserved, but not restricted pollen include abundant Quadraeculina anellaeformis, Concentrisporites halleii, Chasmatosporites major, Araucariacites australis, Perinopollenites elatoides and large specimens of Alisporites. Trachysporites fuscus, Cerebropollenites macroverrucosus and C. thiergartii are rare members. Longranging, stratigraphically unimportant bisaccate pollen dominate the assemblage.

The high frequency and variation in this assemblage of Quadraeculina anellaeformis and the rare C. macroverrucosus and C. thiergartii in the North Sea are features connected with an Early Sinemurian age.

The presence of Late Rhaetian forms: Ovalipollis pseudoalatus, Kraeuselisporites reissingeri, Protodiploxypinus sp. and rare Taeniaepollenites sp. support an earliest Jurassic (Sinemurian to Hettangian) time of deposition.

Environment of deposition

Nonmarine, close to an area vegetated by gymnosperm trees and ferns.

1539 - 1629.3 m HETTANGIAN

Lithology

The entire interval is sandstone dominated. The sandstone is very fine to very coarse and also contains gravel size grains. Coal fragments are present throughout the interval. Small amounts of pyrite occur throughout. Dark claystone in minor amounts is present and may be a true lithology belonging to this interval.

Palynology

Assemblages from cuttings in this interval clearly are dominated by Chasmatosporites major and bisaccate pollen. Quadraeculina anellae formis occur in reduced numbers, but otherwise the assemblages resemble the Early Sinemurian sample above. Cerebropollenites thiergartii, however, was observed in one sample only (1575 - 78 m), and C. macroverrucosus was not recorded. Podocarpidites hallei was a striking element and common in the lowest sample.

These features together were taken to support a Hettangian age of deposition. Late Rhaetian forms which are known to extend into the Lower Jurassic (Ovalipollis pseudoalatus, Eucommiidites granulosus), have sporadic appearances in this interval. The lower limit was fixed above the highest appearance of common Limbosporites lundbladii and Riccisporites tuberculatus.

Environment of deposition

Nonmarine, shallow fairly high energy somewhat oxidative conditions. Some reworking of coals formed in the area.

1629.3 - 1766 m HETTANGIAN TO RHAETIAN

Lithology

Down to about 1660 m coal dominates the lithology. The coal content decreases downwards and between 1660 m and 1680 m sandstone is the

dominant lithology. It is typically a very fine to very coarse sandstone occasionally with gravel grains. From 1680 m to 1690 m coal again is dominant.

Between 1690 m and 1740 m sandstone is dominant, but both coal and dark carbonaceous claystone is present in significant amounts.

From 1740 m to the lower boundary of the interval claystone is dominant. Grey to brownish grey claystone appears at 1740 m, and this lithology cooccurs with the carbonaceous claystone observed above. Sand is present but not in significant amounts and may represent caved material.

Palynology

Riccisporites tuberculatus and Limbosporites lundbladii, generally Late Triassic forms, are common at the top of this interval. Together with them we record abundant Chasmatosporites major, Cyathidites australis and other smooth trilete spores, and in lower numbers, Eucommiidites granulatus, Acanthotriletes varispinosus, Chasmatosporites spp. and Apiculatisporites ovalis. Rhaetipollis germanicus has its highest appearance at 1766 m, in an otherwise almost barren sample. Palaeocystis has a single appearance at 1654.5 m.

Downhole (1678 - 1766 m) the assemblages become very poor. Smooth thinwalled bodies and occasional acritarchs were observed in sidewall cores from this interval.

The described assemblage has earlier been recorded around the Triassic/Jurassic boundary in this area. It is separated from clearly Rhaetian - Norian layers by a poorly fossiliferous interval which cannot be dated from palynological evidence. In the North Sea this assemblage would have been evaluated as evidence for Triassic deposits.

Environment of deposition

The presence of acritarchs seem to support a shallow marine phase for this interval: fairly high energy conditions is the lower part,

develope into low energy swampy conditions, with coal formation in the upper part.

1785 - 2159 m RHAETIAN TO NORIAN

Lithology

The interval is characterized by a red claystone followed by a significant amount of sandstone.

The upper part is characterized by the gradual income of red lithologies, and disappearance of dark grey claystones.

Below 1845 m red claystone becomes dominant and remains so throughout the unit. The claystone is calcareous, and red marl is observed between 1990 m and 2000 m. The sandstone content varies between 10 and 50 percent and the sand is typically medium to very coarse.

Palynology

Limbosporites lundbladii and Riccisporites tuberculatus are abundant throughout the interval and allow a restriction to the Rhaetian or Norian. Other palynomorphs that continue from above are Chasmatosporites spp., Concentrisporites, Perinopollenites and Ovalipollis pseudoalatus. O. pseudoalatus is more frequent at 1929 m and below.

Downhole we note the income of Duplicisporites granulatus (1785 m) Aratrisporites spp., Protodiploxypinus spp., Conbaculatisporites hopenensis (1869 m), Anapiculatisporites spiniger (1890 m), Porcellispora longdonensis and Kraeuselisporites reissingeri (1953 m). This assemblage ranges within Norian to Rhaetian.

At 2146,5 m there are microforaminifera and at 2159 m common acritarchs including Micrhystridium setassinente, Micrhystridium spp., and Veryhachium sp. This assemblage is further characterized as the lowest level with consistent Granuloperculatipollis rudis and Rhaetipollis

germanicus which are distinguished and supposed to have their base in the Norian. Norian deposits in the Arctic are distinguished by and dated on the basis of (marine) dinoflagellate cysts (Fisher & Bujak 1975).

The palynomorphs have irregular appearances in cuttings throughout the interval and we cannot exclude caving within the interval. The preservation apparently is controlled by oxidative conditions that are reflected also by the content of dark coaly fragments. Sidewall cores generally are poor in organic material.

Environment of deposition

Shallow marine conditions at the base of this interval developed into more oxidative nonmarine environments with some production of coaly material in the upper part. The preservation is poor to good, partly influenced, also by the carbonate content of the lithology.

2159 - 2377 m INDETERMINATE TRIASSIC, ?NORIAN

Lithology

Oil has been added to the mud from this level and causes problems during washing of the samples. Only the samples needed for palynology have therefore been washed and the lithological interpretation is less accurate than above. The interval is dominated by sandstone and claystone. The uppermost 50 m are claystone dominated, with grey and reddish brown claystones. The claystones contain limestone laminae or chalk. Very fine to medium sandstone is present.

From 2220 m to the lower boundary of the interval sandstone seems to be the dominant lithology. The very coarse sandstone in the upper part gradually becomes finer grained downwards, and the silt content becomes significant in the lowermost samples. Small amounts of claystone is present, and a grey colour dominates the lowermost samples.

Palynology

The interval is virtually barren. It has been compared with the deposits above (2113.5 to 2159 m) on the basis of smooth thinwalled bodies and small quantities of grey amorphous material. The sidewall core from 2377 m yielded no organic residue.

Environment of deposition

Probably shallow marine deposits. The grey amorphous material was derived from lithologies rich in carbonate which also affected the preservation of palynomorphs.

2392.5 - 2637 m LATE KARNIAN

Lithology

Due to the low number of washed samples it is difficult to give a true estimate of the variation in the lithology. Claystone and sandstone are present in all samples, and there is variation between claystone dominated and sandstone dominated samples. In addition parts of the unit consist of marl and impure limestone.

From the top of the interval down to 2500 m a brownish grey to grey claystone dominates. Limestone laminae occur occasionally, and one sidewall core at 2468.5 m shows an argillaceous limestone.

From 2500 m to the base a very fine to medium sandstone dominates. Occasionally siltstone and grey claystone is present.

Palynology

The income of Triadispora spp., including T. verrucata at 2440 m, marks the top of this interval which is otherwise recognized on common to abundant Ovalipollis pseudoalatus, Camerosporites secatus and on persistent to common Granuloperculatipollis rudis.

The zone is below the Limbosporites/Riccisporites zone. The lower boundary was fixed by the lowest T. verrucata in a sidewall core.

Particularly Triadispora verrucata is important for the recognition of Late Karnian layers (Morbey 1977). In absence of Riccisporites it may suggest that deposition took place in an early part of the Late Karnian. As in the Rhaetian to Norian above the richest samples were derived from cuttings and some palynomorphs may have derived from caved lithologies.

Environment of deposition

Shifting nonmarine to marine deltaic environments. Oxidative conditions as well as influence of carbonate lithologies are reflected by colour and poor preservation of the palynomorphs.

2637 - 3135 m KARNIAN - LADINIAN

Lithology

The brownish grey fine to medium fine sandstone from the interval above continues to about 2675 m and contains small amounts of reddish brown claystone. Calcareous rocks including marl in this interval are followed by marl dominated layers that continue down to about 2850 m. The interval also includes light grey, brownish grey and redbrown claystones. Impure limestones are seen in sidewall cores. The lowermost cutting samples in the calcareous interval show very calcareous brownish grey, brown and grey claystones.

From 2920 m and down to the base of the interval a well cemented sandstone dominates, although claystone is recorded and dominates at 2975 m and 3070 m. The claystone is brown but grey fragments are present in the lowermost samples.

Palynology

Triadispora spp. and Ovalipollis pseudoalatus are dominant elements in the assemblages from cuttings samples below 2637 m. Sidewall cores are almost barren. The only new palynomorph identified Echinitosporites iliacoides at 2898-2901 m, indicates a possible Ladinian age from this level.

Environment of deposition

Nonmarine, strongly oxidative conditions are reflected by the organic matter dominated by black, partly structured woody fragments.

3135 (3252 m) - 3469 m LADINIAN

Lithology

The interval is claystone dominated, but dolomite, sand, evaporites and marl are also present. Due to solution some of the lithologies might be underrepresented.

The top of the interval is marked by a change in claystone colour from brown and grey to dark grey. In the uppermost samples are silty and are followed downwards by significant amounts of sand.

From 3250 m down to 3300 m the claystone is accompanied by a variable amount of dolomite. Below 3350 m the claystone colour becomes generally lighter, light grey being prominent. Observations in the cuttings suggest the presence of salt/evaporites, and one sidewall core at 3372.5 m probably contains evaporite. In the lowermost few metres of the Ladinian interval dark grey claystone reappears.

Palynology

This interval as the above-lying deposits is characterized by Ovalipollis pseudoalatus and common Triadispora spp. It is marked by the increase downhole of Tympanicysta (marine ?algae), Parillinites vanus

(3153 m), Podosporites amicus (3174 m), Striatoabieites aytugii (3174 m), Triadispora modesta (3222 m), Aratrisporites fimbriatus and small monosulcate pollen (Cycadopites spp.). All have their income between 3135 - 3252 m. The lowest Ovalipollis pseudoalatus in a sidewall core at 3469 m suggest an age no older than Ladinian.

Micrhystridium spp. and Veryhachium were observed throughout the interval.

Environment of deposition

Marine conditions prevailed. Probably fairly shallow and close to shore judged by the consistent acritarchs and fairly varied terrestrial input.

3469 - 3910 m LADINIAN TO ANISIAN

Lithology

The main lithologies in this interval are silty claystone, sandstone, limestone and coal.

Down to about 3505 m grey to dark grey silty claystone dominated. Limestone was recorded in the sample at 3500 m. At 3518 m the cuttings are dominated by limestone and marl. Below this down to 3555 m - very fine to medium sandstone dominates. This sandstone is well cemented and contains some dark grey claystone and coal. At 3575 m to 3577 m, grey, silty claystone is accompanied by limestone. Between 3600 m and 3630 m we find a mixture of claystone, sandstone, limestone and coal.

The samples from 3660 m to 3780 m are dominated by a coarse to very coarse sandstone, followed by reddish brown claystones. From 3830 m down to the lower boundary of the interval the lithology is dominated by reddish brown claystones grading to grey in the lowermost part, and accompanied by significant amounts of coarse to very coarse sandstones.

Palynology

The top of this interval was defined by the income of Kraeuselisporites sp., Lundbladispora sp., Nuskoisporites dulhuntui Lundbladispora obsoleta, Angustisulcites sp. and Micrhystridium spp. in a sidewall core which also yielded Ovalipollis pseudoalatus, Infernopollenits and Triadispora spp. Cuttings of this interval when productive yield dominantly Ovalipollis/Triadisporea/Striatoabilites aytugii, the assemblage of layers above.

Other sidewall cores in this interval were barren. A Ladinian to Anisian age is concluded, but with regular presence of reworked Early Triassic material.

Environment of deposition

Shallow marine conditions judged by the acritarchs present. The cuttings samples suggest variably oxidative environment and reworking. Caved or/and reworked material may be present, and the interpretations have low to medium confidence.

3924 - 4215m (TD) ANISIAN TO SPATHIAN

Lithology

The entire interval is sandstone dominated. The small amounts of claystone present throughout probably represents horizons in the sandstone. The sidewall core samples show mainly claystone.

The claystone is typically dark reddish brown and dark grey. Reddish brown claystone dominates except in the lower part of the interval. In the lowermost part of the well the core shows a greenish grey sandstone with mica rich laminae.

Palynology

The core samples close to the base of the hole interval 4180.77 m - 4180.83 m and 4192.94 m - 4193 m yielded Triadispora spp,

Nevesisporites limulatus, Infernopollenites claustratus,
Angustisulcites sp. Aratrisporites fimbriatus Lunatisporites acutus,
Klausipollenites schaubergii, dark opaque spores and rare Vittatina sp.
This assemblage is suggested to be of Anisian to Spathian age (compare
Visscher & Brugman 1980 and Fisher 1979).

Sidewall cores of the interval 3924-4215 m are barren. The evidence
from cuttings samples, as in the Ladinian to Anisian interval above, is
mainly of the Ovalipollis/Triadispora/Striatoabiites aytugii
assemblage which could also be caved in from layers above.

Income downwards in the cuttings of Jugasporites delasaucei (3924 m),
Triadispora aurea and Lueckisporites virkkiae (3951 m), Florinites sp.
(4050 m), Heliosaccus dimorphus (4083 m) and Vittatina sp. (4095 m)
were on this background originally taken to represent evidence for
Permian deposits. A Permian dating must be dismissed on the basis of
Triassic evidence from the cores at the bottom of the hole.

Environment of deposition

Probably nonmarine fairly oxidation conditions with some reworking
possibly in a deltaic type of environment.

APPENDIX

S I D E W A L L C O R E S

- 712 Claystone, greenish grey to grey, silty sandy and micaceous
- 806 Sandstone, grey, with clay matrix, very fine to coarse, unsorted
- 888 Sandstone, grey, with abundant clay matrix, unsorted, pyritic
- 938 Claystone, grey, with silt and sand grains.
- 986 Claystone, grey with abundant gravel, sand and silt
- 1002 Claystone, light grey, silty, blocky
- 1031,5 Claystone, light grey, blocky, silty, laminated and subfissile.
- 1047 Tuffaceous claystone, rich in clay matrix, pyritic
- 1070 Claystone, grey to brownish grey, with tuff lenses and laminae
- 1129 Claystone, dark grey to dark brownish grey, silty, micaceous
- 1206 Sandstone, very fine to medium, rich in clay matrix, very micaceous
- 1255 Claystone, grey to brownish grey with sand grains and mica
- 1270 Claystone, grey, micaceous and sandy
- 1305 Claystone, grey to brownish grey, laminated and waxy

- 1344 Claystone, grey, micaceous
- 1400 Claystone, grey, micaceous
- 1435 Claystone, grey, micromicaceous, slightly pyritic
- 1460 Claystone, grey to brownish grey, silty and sandy,
micaceous
- 1476 Claystone, brownish grey, sandy and silty,
micaceous
- 1480 Claystone, reddish brown, calcareous, micaceous
- 1485 Siltstone, grey, clayey, micaceous
- 1521,5 Sandstone, very fine to medium, rich in organic
material (coal) and pyrite, subangular to
subrounded grains.
- 1629 Claystone, dark grey, micaceous, carbonaceous,
sandy, with coal laminae
- 1635,3 Coal, black to brownish black, pyritic
- 1654,5 Claystone, dark brownish grey, micaceous, with
thin coal laminae, slightly calcareous
- 1678,0 Claystone, light brownish grey to brownish grey,
waxy, calcareous, micromicaceous.
- 1705,0 Claystone, brownish white, calcareous,
disintegrates in dilute HCl, micaceous, subfissile
- 1723,5 Claystone, brownish grey, waxy, micromicaceous,
blocky calcareous
- 1751,0 Claystone, light brownish grey, waxy, subfissile,
slightly pyritic, disintegrates in dilute HCl

- 1766,0 Sandstone, white to reddish brown, well cemented, calcite cement, medium grained, angular to subangular, micaceous.
- 1805,0 Sandstone, light grey, very fine to fine, abundant clay matrix, micaceous, slightly calcareous
- 1842,0 Sandstone, white to reddish brown, very fine to fine, angular to subangular, abundant matrix, micaceous
- 1910,0 Siltstone, light grey to light reddish grey, occasionally sandy and micaceous
- 1953,0 Claystone, reddish brown, micaceous, calcareous, locally with light grey spots, occasionally silty and sandy, calcareous
- 1995,0 Chalk, white alternating with reddish brown calcareous claystone
- 2078,0 Claystone, light reddish brown, blocky, slightly micromicaceous, noncalcareous, disintegrates easily in dilute HCl.
- 2113,5 Claystone, grey, brownish grey, reddish brown, sandy, silty, micaceous, calcareous
- 2146,5 Claystone, light grey, grading to very fine sandstone, slightly laminated, micaceous, noncalcareous
- 2159 Sandstone, light grey to reddish brown, micaceous, calcareous
- 2167 Sandstone, light grey, very fine to medium, firm, moderately sorted, well cemented, mainly calcite cement, micaceous

- 2202,5 Claystone, brown to reddish brown with light greenish spots green reduced, firm to hard, calcareous blocky, nonlaminated
- 2223 Argillaceous limestone, brownish grey, firm to hard, blocky, micaceous, disintegrates readily in dilute HCl
- 2355 Claystone, grey, micaceous with sand lenses and laminae, subfissile slightly calcareous, easily disintegrates in dilute HCl
- 2377,5 Claystone, dark reddish brown with local olive grey and grey areas, randomly fractured with striations on fracture planes. The rock is waxy, subfissile and calcareous. Disintegrates in dilute HCl
- 2392,5 Claystone, grey to dark grey, laminated with a 5 mm coal seam, and sand/silt laminae. The claystone is organic rich, and contains pyrite, calcareous
- 2440 Claystone, dark grey, laminated, with limestone (?dolostone) laminae, and lenses. Occasionally silty and micaceous
- 2468,5 Argillaceous limestone, grey, blocky, disintegrates in dilute HCl. No lamination observed. Contaminated by diesel?
- 2541,5 Silty claystone, grey to dark grey laminated, with thin sandstone, laminae, pyritic micaceous, subfissile
- 2589,5 Siltstone, brownish grey argillaceous, sideritic micaceous, occasionally sandy

- 2637 Claystone, grey to dark grey, greenish grey with white siltstone, laminae, slightly calcareous, water escape structures observed
- 2707 Claystone, laminated with white siltstone laminae, the claystone is reddish brown in some laminae and dark grey in others. Micromicaceous, calcareous
- 2738 Limestone, brownish grey to dark grey, micaceous, occasionally sandy.
- 2836 Limestone, dark grey, brittle, micaceous, sandy
- 2883,5 Limestone, dark grey to dark brownish grey, subfissile, micaceous, clayey
- 2961,5 Claystone, brown, micaceous, nonlaminated, but with a few lenses of white limestone
- 3034 Siltstone, brown, clayey, micaceous, with some dark brown caly laminae, cross-bedding observed, very calcareous
- 3062 Claystone, calcareous, brown, micromicaceous, nonlaminated
- 3135 Claystone, grey to black with white to grey sandstone laminae, micromicaceous, blocky, slightly calcareous
- 3196 Claystone, silty, with siltstone, limestone and sandstone, laminae, the claystone is very calcareous. The lamination is thin and well defined.
- 3232,5 Sandstone, coarse to very coarse, subangular to subrounded grains. Well cemented with calcite

cement. Clay clasts also observed. The sorting is moderate and feldspar grains are observed.

- 3274,5 Claystone, dark grey to black, brittle to hard, blocky calcareous (?sideritic), carbonaceous.
- 3290 Dolostone, grey, laminated, with white laminae, blocky, occasionally silty
- 3372,5 Evaporite, probably anhydrite, laminated, with dark grey laminae. The lamination is often contorted.
- 3469 Claystone, dark grey, blocky hard, slightly calcareous, laminated with carbonate laminae, probably carbonaceous
- 3502 Mudstone, silty and sandy, very calcareous pyritic, micaceous
- 3530 Sandstone, well cemented, calcite cement, white, with coal laminae. In connection with the coal laminae one can observe pyrite and a grey metallic mineral probably graphite or molybdenite. The sandstone grain size is fine to medium
- 3577 Limestone, argillaceous grey, moderately hard, blocky
- 3642,5 Sandstone, very fine to medium, clayey, brown to reddish brown, micaceous goethite coated sand grains observed
- 3710 Sandstone, very fine, occasionally silty, calcite cemented, micaceous, grey to brown. The sample is contaminated by reddish brown mud.

- 3750,5 Siltstone, brown, sandy with very fine to medium sand grains, micaceous, with abundant calcite
- 3804,5 Claystone, grey, very calcareous, soft, laminated, subfissile, contains thin coal laminae
- 3852,5 Mudstone, brown to reddish brown, very calcareous, sandy, micaceous
- 3910 Mudstone, brown to reddish brown, silty and sandy, very calcareous, micaceous, hard.
- 3960 Mudstone, brown to reddish brown, very calcareous, in part very dark grey, carbonaceous, micaceous
- 4000,5 Mudstone, reddish brown, nonlaminated, blocky very calcareous, micaceous
- 4007 Mudstone, brown to reddish brown, very calcareous, sandy and silty, micaceous, blocky
- 4055 Mudstone, reddish brown to brown, nonlaminated, blocky, very calcareous, with greenish grey reduction spots, micaceous
- 4110 Mudstone, greyish red to reddish brown, nonlaminated, silty, sandy, micaceous, very calcareous
- 4147 Mudstone, reddish brown, nonlaminated, very micaceous, very calcareous, blocky to subfissile

C O R E S

- 4180,77-.83 Sandstone, grading to siltstone, very fine well cemented. Rich in clay and silt matrix, hard,

thin laminae with abundant mica

4192,94-
4193,0

Sandstone, very fine grading to siltstone, with
clay and silt matrix, well cemented, hard, thin
laminae with abundant mica