Quantitative foraminiferal and palynomorph biostratigraphy of the Paleogene in the southwestern Barents Sea

JENÖ NAGY[1], MICHAEL A. KAMINSKI[2], FELIX M. GRADSTEIN[3], & KARI JOHNSON[4]

1. Department of Geology, University of Oslo, P.O. Box 1047 Blindern, N-0316 Oslo, Norway [jeno.nagy@geol.uio.no].
2. Department of Earth Sciences, University College London, Gower Street, London, WCIE 6BT, UK. *and* KLFR, 3 Boyne Avenue, Hendon, NW4 2JL, UK.
3. Paleontological Museum, University of Oslo, Sars gate 1, Tøyen, 0562 Oslo, Norway.
4. Rælingen Kommune, Bjørnholthagen 6, Box 100, 2025 Fjerdingby, Norway.

ABSTRACT

The stratigraphic distribution of both foraminifera and dinoflagellate cysts is recorded from the Paleocene to Eocene Torsk Formation in 12 petroleum exploration wells drilled in the southwestern Barents Sea. The foraminiferal assemblages are wholly agglutinated, and are referred to outer shelf to middle bathyal environments. A quantitative analysis of biostratigraphic events, mainly last occurrences (first downhole occurrences), is performed by means of the Ranking and Scaling (RASC) program. This procedure combined with conventional stratigraphic treatment has enabled us to establish the most likely order of microfossil events, and to propose a new quantitative zonal scheme for the southwestern Barents Sea.

In the studied wells the following six zones and subzones are distinguished (in ascending order): BSP 1, Ps*mmosphaera fusca – Hyperammina rugosa,* late early to early late Paleocene; BSP 2, *Spiroplectammina spectabilis* early late Paleocene; BSP 3A, *Reticulophragmium pauperum,* middle late Paleocene; BSP 3B, *Haplophragmoides* aff. *eggeri,* latest Paleocene; BSP 4, *Spiroplectammina navarroana,* earliest Eocene; BSP 5, *Reticulophragmium amplectens,* early to middle Eocene. Owing to the occurrence of cosmopolitan deep-water agglutinated foraminifera, the new zonal scheme compares well with previous zonations developed for the Paleogene of the mid-Norwegian shelf, the North Sea and Labrador Shelf.

INTRODUCTION

The present study is part of our long term project dealing with the Paleogene microfossil based stratigraphy and paleoceanography of the southwestern Barents Sea, comprising the Tromsø, Hammerfest, Nordkapp and Bjørnøya basins (Fig. 1). The research is focused on the examination of benthic foraminiferal, dinoflagellate cyst and diatom assemblages from borehole sections, to provide a firm basis for understanding the composition, systematic affinities, and distribution patterns of the Paleogene Boreal micro faunas and floras. The information gained from quantitative analysis of this material can provide much-needed constraints on the chronostratigraphy and facies assessments of the Cenozoic sedimentary successions, as well as on the subsidence history of the depositional areas.

We have previously recorded the stratigraphy and paleoecology of foraminiferal, dinocyst and diatom assemblages in a reference section for the western Barents Sea, based on data from a single well 7119/9-1 (Nagy *et al.* 1997). The paleobathymetric implications of Paleogene agglutinated foraminiferal assemblages has been discussed by Nagy *et al.* (2000), by combining the deeper water assemblages of the south-western Barents Sea well 7119/7-1 with shallow water faunas from onshore sections sampled in the Central Basin of Spitsbergen.

The primary goal of the present study is the construction of a regional biostratigraphic zonal scheme integrating foraminiferal and dinocyst distributions in the southwestern part of the Barents Sea. The zonation is aimed to be readily applicable over wide areas with changing paleoenvironmental conditions. To achieve this goal the mathematical sequencing method RASC (Ranking and Scaling) was used for establishing the most likely order of microfossil events, and for calculating and outlining the basic zonal succession. To strengthen regional applicability, emphasis is placed on foraminiferal and dinocyst events that are relatively widespread and readily recognised.

Background to the study

For exploration of petroleum resources in the south-western Barents Sea, offshore drilling commenced in 1980 and was concentrated to the Hammerfest and Tromsø basins. During the last two decades 54 wells have been drilled, with the main activity prior to 1990. Drilling targets were primarily Lower and Middle Jurassic sandstones, though minor hydrocarbon accumulations were found also in Permian, Upper Triassic and Lower Cretaceous strata. Because of the rather modest results and high operating costs, drilling activity has now sharply declined. The lithostratigraphical framework and nomenclature of the sedimentary formations in the area is mainly based upon petroleum exploratory borehole data (Fig. 2).

THE BARENTS SEA PALEOGENE SUCCESSION

Geological setting

In: Bubík, M. & Kaminski, M.A. (eds), 2004. Proceedings of the Sixth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication*, **8**, 359-379.

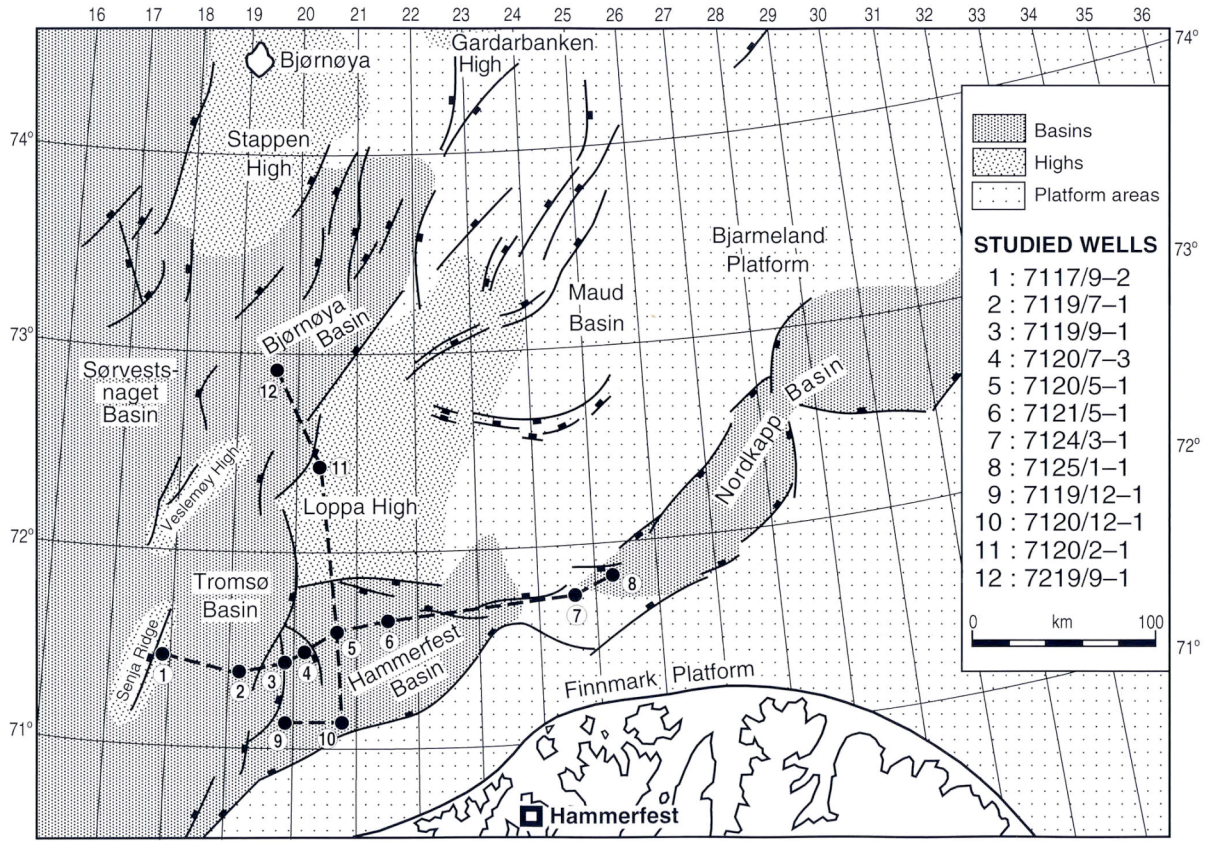


Figure 1. Geological map of the southwestern Barents Sea showing location of 12 exploration wells used to construct a Paleogene interval zonation based on foraminifera combined with dinoflagellate cysts.

Cenozoic sediments in the Barents Sea are restricted to the southwestern basinal areas and to the western and northern passive continental margins bounding the shelf. In the southwest, thick Paleocene to Eocene sediment packages are preserved in the Tromsø, Hammerfest and Bjørnøya basins, while in the Nordkapp Basin and on the Loppa High (Fig. 1) only strongly reduced Paleogene thicknesses are present. On the western and northern shelf margins, the Cenozoic is more complete, and includes extensive Plio-Pleistocene fan deposits. The Central Basin of Spitsbergen contains a thick sedimentary succession of Paleocene to Eocene age, deposited in marine shelf to fluvio-deltaic environments.

During much of its Mesozoic and Cenozoic history, the Barents Sea served as part of a marine passageway connecting the North Sea and North Atlantic to the Arctic Ocean. This marine connection was affected by Late Cretaceous to Paleogene plate tectonic movements which caused old seaways to close and new communications to develop. Of prime importance is the separation of the Greenland plate from the Barents Shelf and the consequent opening of the North Atlantic Ocean that established a deep water connection between the Atlantic and Arctic oceans. Accordingly, the complex tectonic and paleoceanographic history of the Barents Shelf has played an important role in the development of the Cenozoic climate and the evolution of Arctic biota.

The subsurface geology and tectonic history of the Barent Sea region have been discussed in several recent studies (e.g. Nøttvedt *et al.* 1992, Faleide *et al.* 1993, Reemst & Cloetingh 1994, Dowdeswell, 1988). However, these studies did not benefit from having access to detailed microfossil-based biostratigraphical information. Despite the fact that 54 exploratory wells were drilled during the last two decades by the petroleum industry, the Paleogene biostratigraphy of the southwestern Barents Sea was not studied in a regional manner.

Stratigraphic framework

Paleogene sediments of the southwestern Barents Sea comprise a single major lithostratigraphic unit, the Torsk Formation, which is the only formation currently included in the Sotbakken Group (Fig. 2). These units were formally defined by Worsley *et al.* (1988) in their outline of the Mesozoic and Cenozoic lithostratigraphy of the Barents Sea. The Torsk Formation is the lateral equivalent of the van Mijenfjord Group in Spitsbergen, but represents a more distal, deep marine environment as demonstrated by Nagy *et al.* (2000).

The Torsk Formation is a rather monotonous succession of claystones, with some clays in the upper part of the thicker sections. These fine-grained deposits are grey and greenish grey in colour and show a relatively homogeneous composition with calcium carbonate content around 1% and organic carbon content around 0.1%. The claystones contain volcanic

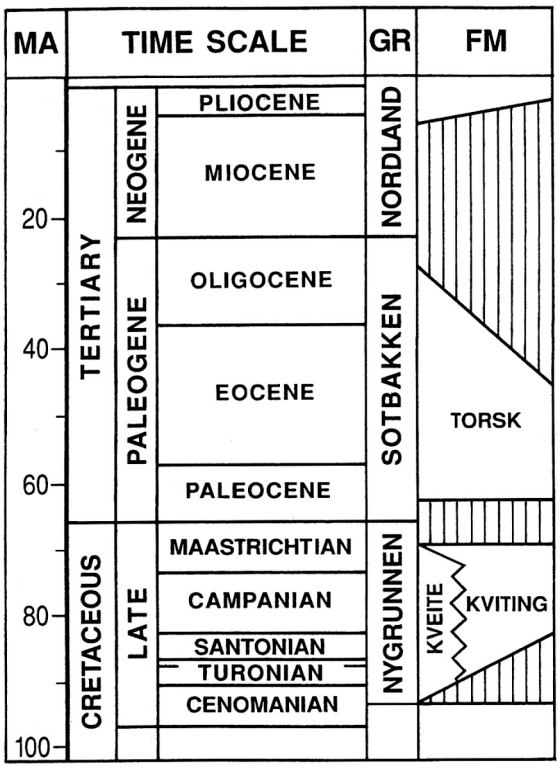


Figure 2. Lithostratigraphical scheme of the Upper Cretaceous through Tertiary succession of the southwestern Barents Sea.

tuff and numerous thin stringers of limestone or dolomite. Increased sand content is noted in the lower part of the formation in well 7119/7-1.

The Torsk Formation is separated from the underlying Upper Cretaceous Nygrunnen Group by a regional unconformity. The associated hiatus in basinal areas encompasses the latest Cretaceous and the earliest Paleocene, and can be traced on seismic lines throughout the southwestern Barents Sea (Rønnevik, 1981, Worsley *et al.* 1988). The base of the Torsk lies transgressively upon Mesozoic strata, which in the study area range in age from Triassic to Maastrichtian. The formation varies in thickness from 135m near the southern end of the Nordkapp Basin to 1040 m in the central parts of the Hammerfest Basin. There is a marked thickening to more than 2 km, toward the undrilled deepest part of the Tromsø Basin.

The top of the Torsk Formation was originally cut by an erosional unconformity originating from tectonic movements associated with mid-Oligocene rifting between Greenland and Spitsbergen. The seismic reflector marking this unconformity can be traced seaward to a position between marine magnetic anomaly 13 and 5 in the northern Norwegian Sea. The upper part of the Torsk Formation has been further truncated by Plio-Pleistocene glacial erosion, especially in the eastern part of the region. The unconformity is overlain by mainly Plio-Pleistocene glaciomarine deposits of the Nordland Group. On the western margin of the Barents Shelf the Nordland Group is more complete and includes Oligocene and probably Miocene strata.

SAMPLES AND LABORATORY PROCESSING

The study is based on sediment samples from the Paleogene interval of 12 exploratory wells (Table 1). The samples are ditch cuttings in all the wells except number 7125/1-1, from which side wall core samples were available. The sample spacing is usually 10 m. All 12 wells were analysed for foraminifera while 11 wells were also analysed for palynomorphs. Well 7120/7-3 was omitted from the palynological analysis. The sample material was provided to the project by the following organisations: the Norwegian Petroleum Directorate, samples from wells 7117/9-2, 7119/9-1, 7120/7-3, 7121/5-1, 7124/3-1, 7119/12-1, 7120/12-1, 7120/2-1, 7219/9-1; Norsk Hydro A/S and the Norwegian Petroleum Directorate, samples from well 7119/7-1; Statoil, samples from well 7120/5-1; Saga Petroleum A/S, samples from well 7125/1-1.

For the foraminiferal analyses a total of 722 samples were used. In the laboratory the samples were dried, weighed, boiled in sodium carbonate solution, and washed over a sieve set of 63μm, 125μm and 500μm mesh. Benthic foraminifera were handpicked from the >125μm fraction, and mounted on cardboard slides. Palynological analyses were carried out on a total of 604 samples, which were treated in accordance with standard laboratory techniques.

MAIN FEATURES OF MICROFOSSIL ASSEMBLAGES

The Torsk Formation contains relatively rich foraminiferal and dinocyst assemblages of late early Paleocene to middle Eocene age. The stratigraphic position of numerous foraminiferal and dinocyst last occurrences are consistent in the 12 analysed wells suggesting that these events may serve as an adequate basis for stratigraphic correlation across the southwestern Barents Sea.

The Paleocene foraminiferal assemblages, occurring in the lower and middle parts of the Torsk Formation in the 12 analysed wells, are characterised by intermediate species diversities and common occurrence of tubular forms (referred to *Rhizammina, Bathysiphon* and *Hyperammina).* Dominant species include: *Spiroplectammina spectabilis, Haplophragmoides walteri, Recurvoides* sp. 1, *Ammosphaeroidina pseudopauciloculata,* and *Saccammina grzybowskii.* The assemblages reveal close affinities to deep water "flysch type" faunas well known from the Carpathians, North Sea and North Atlantic margins. The Barents Sea Paleocene assemblages are interpreted as reflecting upper to middle bathyal conditions (Nagy *et al.* 2000).
The upper part of the Torsk Formation contains Eocene foraminiferal assemblages in six of the wells In these assemblages the species diversities are reduced and tubular forms (referred to *Rhizammina)* occur only locally in significant amounts. Dominant species include: *Budashevaella multicamerata, Recurvoides* aff. *turbinatus, Ammosphaeroidina pseudopauciloculata* and *Reticulophragmium amplectens.* The diversity and composition of the assemblages suggest an outer neritic to upper bathyal environment (Nagy *et al.* 2000). The neritic faunal components display some affinities to contemporary prodelta shelf faunas recorded from Spitsbergen (Nagy *et al.* 2000).

Taxonomy

In the analysed samples over 100 foraminiferal and diatom species and more than 80 palynomorph taxa

Table 1. List of the studied Barents Sea wells with water depth, sampled interval and number of samples studied.

Operator	Well no.	Water depth	Interval studied	No. of samples
1. Norsk Hydro	7117/9-2	271 m	1095-1405 m	32
2. Norsk Hydro	7119/7-1	238 m	450- 1350 m	78
3. Elf Aquitaine	7119/9-1	201 m	510 - 1450 m	126
4. Statoil	7120/7-3	258 m	332 -1380 m	118
5. Statoil	7120/5-1	318 m	410 - 1208 m	99
6. Statoil	7121/5-1	336 m	440 - 1013 m	38
7. Saga	7124/3-1	273 m	400 - 570 m	18
8. Saga	7125/1-1	228m	403 - 580 m	16
9. Statoil	7119/12-1	200 m	403 - 625 m	43
10. Norsk Hydro	7120/12-1	167 m	440 - 750 m	32
11. Norsk Hydro	7120/2-1	387 m	480 - 635 m	17
12. Norsk Hydro	7219/9-1	333m	720 - 1490 m	78

have been recognized. The foraminiferal taxonomy used largely follows the works of King (1989), Charnock & Jones (1990), Kaminski & Geroch (1993), Gradstein *et al.* (1994), Gradstein & Kaminski (1997) and Kaminski, Gradstein *et al.* (in prep.). The main index taxa from offshore mid-Norway and the western Barents Sea area have been illustrated by Gradstein *et al.* (1994) and Nagy *et al.* (1997, 2000). The dinocyst taxonomy corresponds generally to that of Bujak & Mudge (1994) and Mudge & Bujak (1994, 1996).

STRATIGRAPHICAL METHODS

The stratigraphical integration of the agglutinated foraminiferal faunas with the dinocyst assemblages in the Torsk Formation is of particular importance because of the absence of calcareous planktonic microfossils. In these strata the dinocysts provide the best independent means of correlation with the standard plankton zonal schemes, and thus provide important chronostratigraphic constraint. As mentioned previously, the samples from all but one well are ditch cuttings. The effects of downhole caving appear to be minor, and abrupt faunal changes are observed at certain levels.

The fossil record utilised in the stratigraphic analysis consists of the last (first downhole) occurrence (LO) of foraminiferal and dinocyst taxa, as well as the last common occurrence (LCO) of selected species of these two groups. In addition the LO of a single diatom species is also included. The main database of the study consists of the total stratigraphic distribution of foraminifera and palynomorphs within the sampled intervals of the 12 wells.

The main stratigraphic method employed in the study is RASC (Gradstein *et al.* 1985, Agterberg & Gradstein, 1999) which calculates the most likely succession of events by comparing the stratigraphic order of all pairs of events in all wells. In the resulting optimum succession each event position is the average of all individual positions occurring in the well (Fig. 4). The optimum succession is scaled by calculation of the frequency of cross-overs of the relative position of each pair of events from well to well. An increase in the number of cross-overs results in decreased interfossil distance within the vertical succession. The distance calculations are displayed in dendrogram format where the density of clusters expresses nearness of events along a stratigraphic scale. Distinctive bundles of events are usually interpreted as stratigraphical zones, while large interfossil distances between successive bundles are regarded as zonal boundaries expressing breaks of varying magnitude in the fossil record.

STRATIGRAPHICAL ZONATION

The RASC analysis of biostratigraphic events supplemented with conventional stratigraphic treatment enabled us to define six zonal units within the Paleocene to Middle Eocene succession of the southwestern Barents Sea (Figure 3). The chronostratigraphy and faunal content of the zones are the main topics of this chapter. In the 12 wells studied, the record of microfossil events include the occurrence of 80 agglutinated foraminiferal species, 36 dinocyst species, and 3 siliceous microfossil events. Altogether, there are 126 dictionary entries for a total of 633 events, mostly last occurrences (listed in the Appendix). The majority of the events occur in a few wells only; 52 events were observed in 6 or more wells.

The RASC interval zonation presented in this paper was run with the threshold values kc = 6, mc1 = x and mc2 = x where kc is the minimum number of wells in which each event must occur in order to be ranked, mc1 is the number of wells in which each pair of events in the ranked optimum sequence must occur, mc2 is the minimum number of wells in which each pair of events in the scaled optimum sequence occur. The RASC interval zonation contains 52 microfossil events that occur in at least 6 of the 12 wells (Figs. 3 & 4). In addition it includes 4 "unique" events that occur in 5 or fewer wells. The unique events are listed below in descending stratigraphic order:

Deflandrea oebisfeldensis
Aschemonella grandis
Sphaerammina gerochi
Alisocysta margarita LCO

The unique events supplement the stratigraphic zonation and correlation of the well sections, and assist with the integration of the dinocyst and foraminiferal records. Summary range charts for the most important agglutinated foraminifera and palynomorphs are given in Figures 5 and 6, respectively. The scaled optimum sequence enables us to define the following zones:

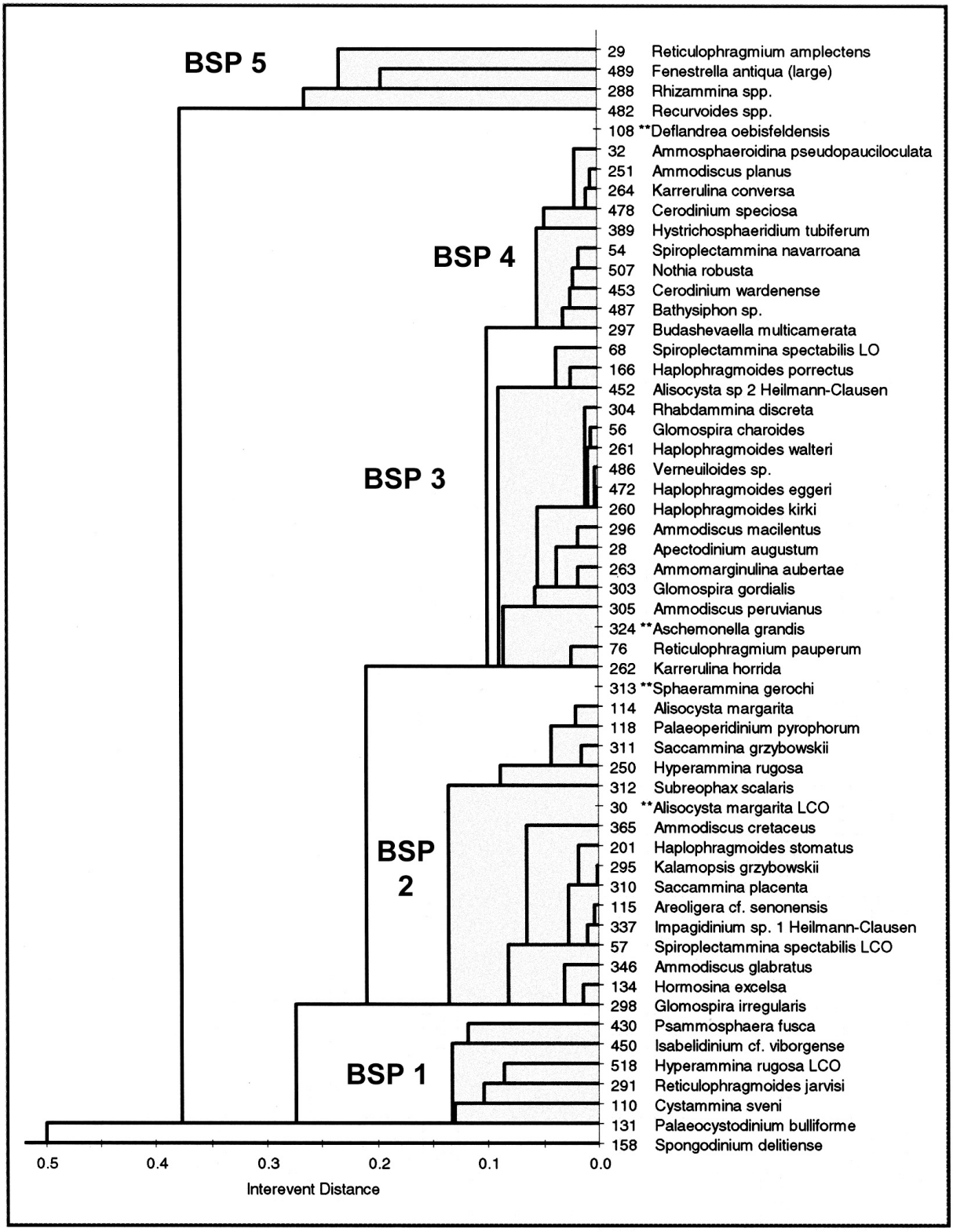


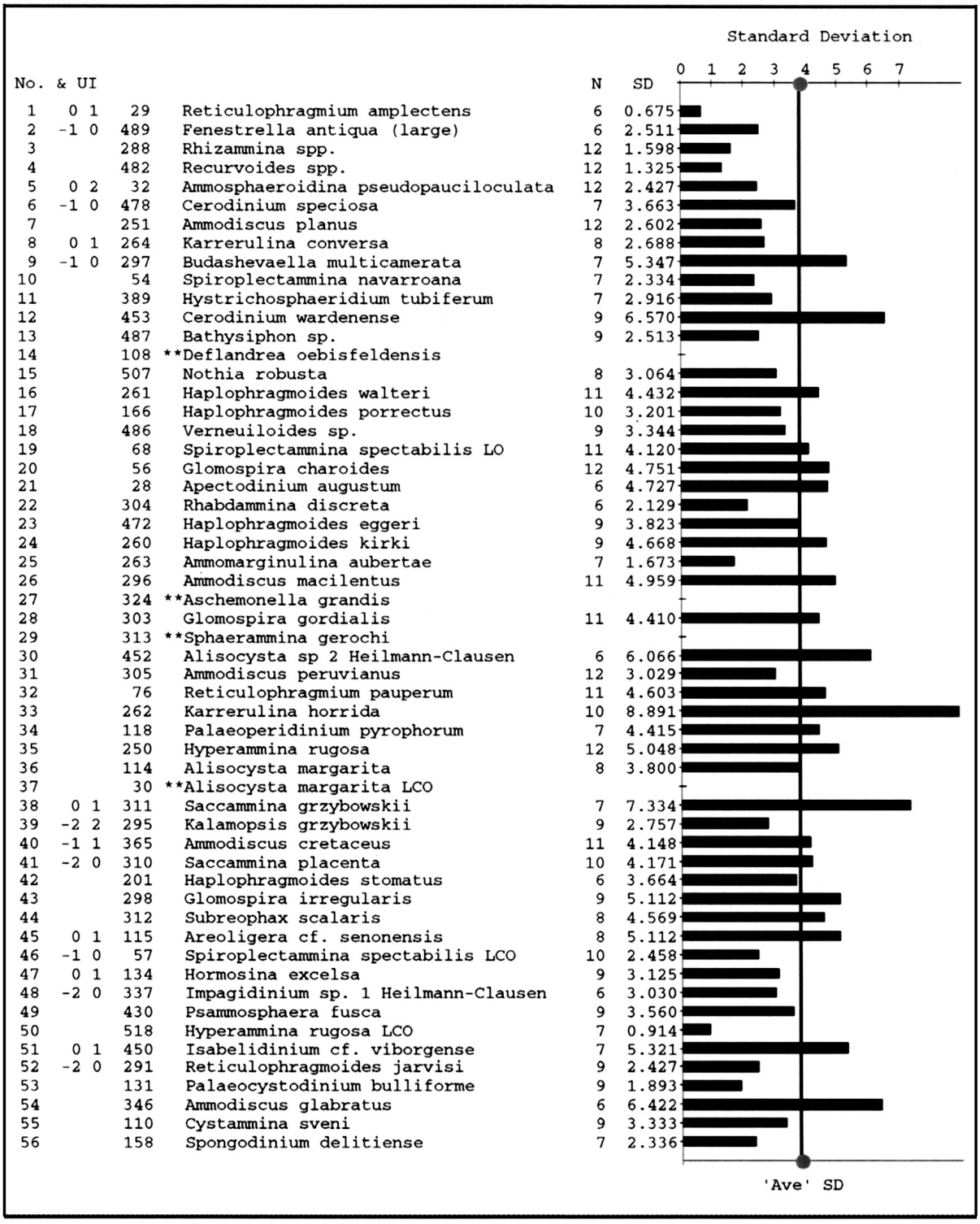
Figure 3. Scaled optimum succession of 56 microfossil events in the Paleogene Torsk Formation of the southwestern Barents Sea. Most events are last occurrences (LO, not marked except *S. spectabilis*) while some are last common occurrences (LCO) of foraminifera and dinocysts. The dendrogram displays inter–event distances. ** = Unique events. Distinct clusters of events are interpreted as stratigraphical zones, and labelled by the zone acronyms.

BSP 1: Psammosphaera fusca – Hyperammina rugosa Zone

Type section: Well 7119/9-1, interval 1410-1450 m.

Age: late early to early late Paleocene.

Taxa: The following foraminiferal species have their average last occurrences in this interval zone: *Psammosphaera fusca, Reticulophragmium jarvisi* and *Cystammina sveni*. The last common occurrence of *Hyperammina rugosa* is typical for the zone. Amongst



No.	& UI			N	SD
1	0 1	29	Reticulophragmium amplectens	6	0.675
2	-1 0	489	Fenestrella antiqua (large)	6	2.511
3		288	Rhizammina spp.	12	1.598
4		482	Recurvoides spp.	12	1.325
5	0 2	32	Ammosphaeroidina pseudopauciloculata	12	2.427
6	-1 0	478	Cerodinium speciosa	7	3.663
7		251	Ammodiscus planus	12	2.602
8	0 1	264	Karrerulina conversa	8	2.688
9	-1 0	297	Budashevaella multicamerata	7	5.347
10		54	Spiroplectammina navarroana	7	2.334
11		389	Hystrichosphaeridium tubiferum	7	2.916
12		453	Cerodinium wardenense	9	6.570
13		487	Bathysiphon sp.	9	2.513
14		108	**Deflandrea oebisfeldensis		
15		507	Nothia robusta	8	3.064
16		261	Haplophragmoides walteri	11	4.432
17		166	Haplophragmoides porrectus	10	3.201
18		486	Verneuiloides sp.	9	3.344
19		68	Spiroplectammina spectabilis LO	11	4.120
20		56	Glomospira charoides	12	4.751
21		28	Apectodinium augustum	6	4.727
22		304	Rhabdammina discreta	6	2.129
23		472	Haplophragmoides eggeri	9	3.823
24		260	Haplophragmoides kirki	9	4.668
25		263	Ammomarginulina aubertae	7	1.673
26		296	Ammodiscus macilentus	11	4.959
27		324	**Aschemonella grandis		
28		303	Glomospira gordialis	11	4.410
29		313	**Sphaerammina gerochi		
30		452	Alisocysta sp 2 Heilmann-Clausen	6	6.066
31		305	Ammodiscus peruvianus	12	3.029
32		76	Reticulophragmium pauperum	11	4.603
33		262	Karrerulina horrida	10	8.891
34		118	Palaeoperidinium pyrophorum	7	4.415
35		250	Hyperammina rugosa	12	5.048
36		114	Alisocysta margarita	8	3.800
37		30	**Alisocysta margarita LCO		
38	0 1	311	Saccammina grzybowskii	7	7.334
39	-2 2	295	Kalamopsis grzybowskii	9	2.757
40	-1 1	365	Ammodiscus cretaceus	11	4.148
41	-2 0	310	Saccammina placenta	10	4.171
42		201	Haplophragmoides stomatus	6	3.664
43		298	Glomospira irregularis	9	5.112
44		312	Subreophax scalaris	8	4.569
45	0 1	115	Areoligera cf. senonensis	8	5.112
46	-1 0	57	Spiroplectammina spectabilis LCO	10	2.458
47	0 1	134	Hormosina excelsa	9	3.125
48	-2 0	337	Impagidinium sp. 1 Heilmann-Clausen	6	3.030
49		430	Psammosphaera fusca	9	3.560
50		518	Hyperammina rugosa LCO	7	0.914
51	0 1	450	Isabelidinium cf. viborgense	7	5.321
52	-2 0	291	Reticulophragmoides jarvisi	9	2.427
53		131	Palaeocystodinium bulliforme	9	1.893
54		346	Ammodiscus glabratus	6	6.422
55		110	Cystammina sveni	9	3.333
56		158	Spongodinium delitiense	7	2.336

Figure 4. Optimum succession of 56 microfossil events of the Paleogene Torsk Formation, with mean and standard deviation. For each event the number of wells (N) is given where they are observed. Most events are last occurrences (LO, not marked except S. spectabilis), while some are last common occurrences (LCO), of foraminifers and dinocysts. ** = Unique event.

the dinocysts *Paleocystodinium bulliforme* and *Isabelidinium* cf. *viborgense* have their average last occurrences in this zone, although outliers of the latter species are found much higher in the succession. *Palaeoperidinium pyrophorum* displays its last common occurrence in the interval.

Discussion: The benthic foraminiferal assemblages at the base of the Torsk Formation display the highest diversity and abundance found within the formation. An example is the lower ca. 40m of the Paleocene in well 7119/9-1, comprising this zone (Nagy *et al.* 1997). The assemblages are dominated by species that agglu-

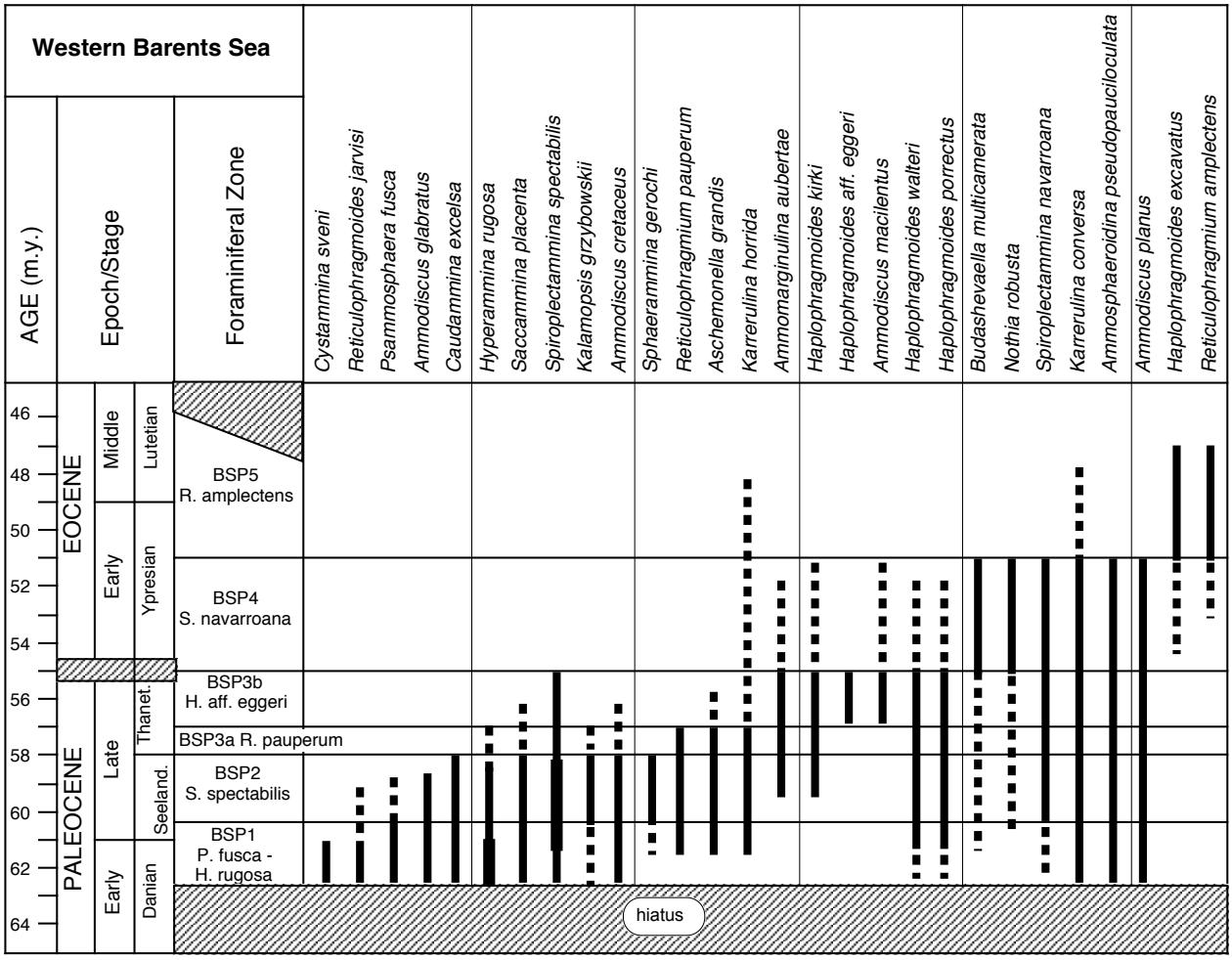


Figure 5. Stratigraphical range chart of selected foraminiferal species in the Paleogene Torsk Formation of the southwestern Barents Sea. The average stratigraphic range is in solid, while outliers and local extensions upward and downward in wells are dashed.

tinate coarse material for the construction of their test, such as *Hyperammina rugosa*, *Psammosphaera fusca* and an unnamed species of *Recurvoides*. *Psammosphaera fusca* reveals highest abundance near the base of the Torsk Formation. Other common forms in this interval include *Recurvoides* spp., *Rhabdammina* spp., *Karrerulina* sp., and *Ammosphaeroidina pseudopauciloculata*. Three distinctive species are restricted to this zone: *Cystammina sveni*, *Caudammina ovula* and *Rzehakina epigona*.

As mentioned previously, the Torsk Formation rests unconformably on Upper Cretaceous deposits belonging to the Kviting or Kveite formations of the Nygrunnen Group. The sediments occurring immediately below the unconformity contain highly diverse and entirely agglutinated assemblages. A Campanian to Maastrichtian age is indicated for these deposits by *Caudammina gigantea* and *Spongodinium delitiense*.

BSP 2: Spiroplectammina spectabilis LCO Zone

Type section: Well 7119/9-1, interval 1180-1400 m.

Age: early late Paleocene.

Taxa: Foraminiferal species having their average last occurrence in this interval zone are as follows: *Saccammina grzybowskii, Hyperammina rugosa, Subreophax scalaris, Ammodiscus cretaceus, Haplophragmoides stomatus, Kalamopsis grzybowskii, Saccammina placenta, Ammodiscus glabratus*, *Caudammina excelsa* and *Glomospira irregularis*. The nominate species *Spiroplectammina spectabilis* consistently displays its maxiumum abundance within this zone, and its LCO is normally observed here too. The zone is further characterised by the last occurrence of the dinocysts *Alysocysta margarita, Paleoperidinium pyrophorum, Areoligera* cf. *senonensis* and *Impagidinium* sp. 1 (of Heilmann-Clausen), and by the LCO of *Alisocysta margarita*

Discussion: A distinct maximum in the abundance of *Spiroplectammina spectabilis* is observed in the type section of this zone in the well 7119/9-1 from 1180 to 1400 m. The LCO of *S. spectabilis* also appears within the upper Paleocene in the North Sea and offshore mid-Norway, where it is observed near the base of Zone NSR2B of Gradstein & Bäckström (1996). In the Barents Sea, this event occurs on average just below the LO of *Impagidinium* sp. 1 (of Heilmann-Clausen).

An unusual feature of this zone is the large proportion of juvenile forms of *S. spectabilis,* consisting only of the planispiral coil. Other common taxa include *Rhizammina* spp., *Ammosphaeroidina pseudopauciloculata*, *Haplophragmoides walteri* and *Reticulophragmium pauperum*. In the lower part of the zone, single occurrences of *Rzehakina minima* were observed.

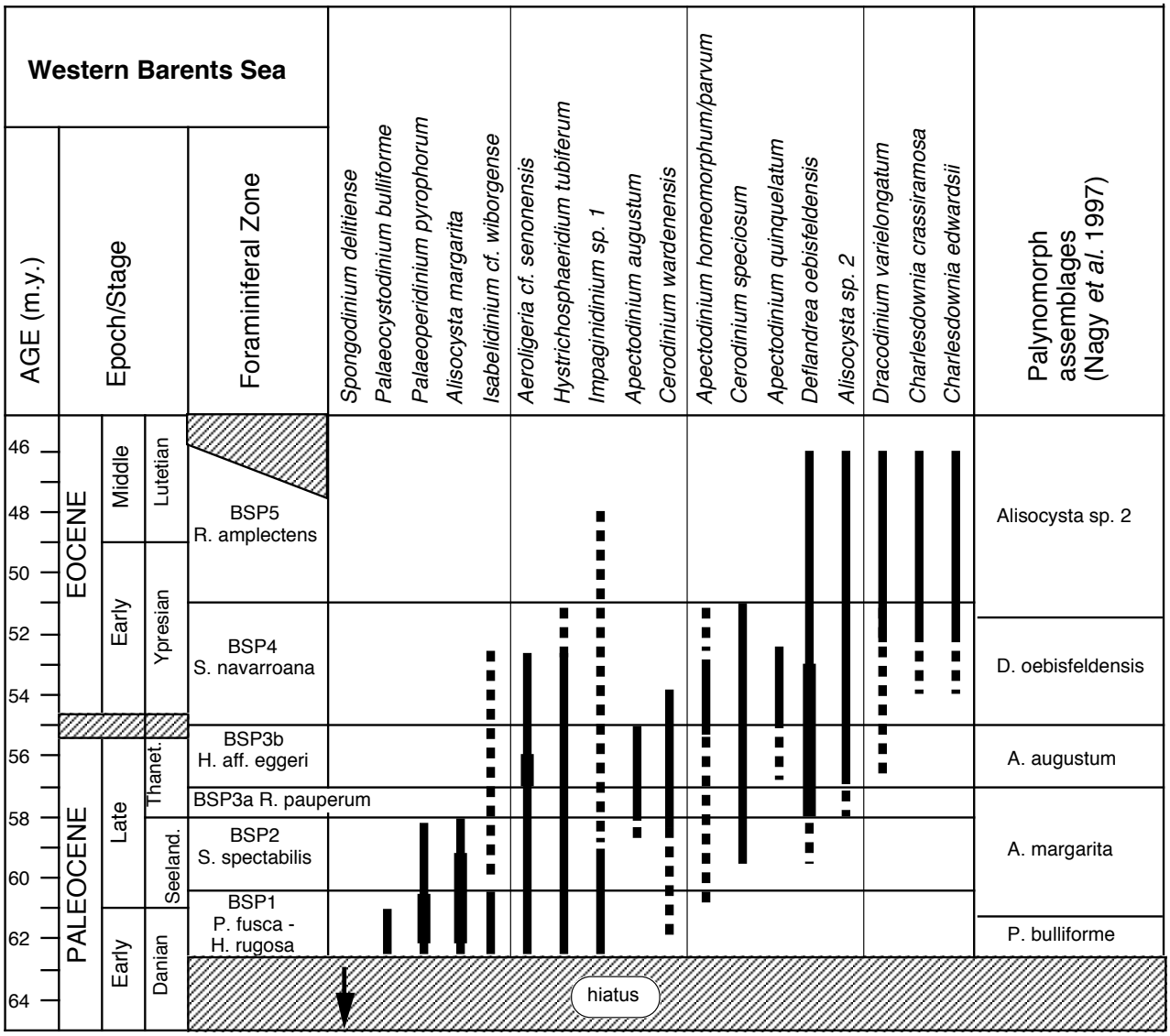


Figure 6. Stratigraphical range chart of selected dinocyst species in the Paleogene Torsk Formation of the southwestern Barents Sea. The average stratigraphic range is in solid, while outliers and local extensions upward and downward in wells are dashed.

Our *S. spectabilis* LCO Zone is roughly equivalent to the *Ammoanita ruthvenmurrayi* Zone in the North Sea and on the mid-Norwegian shelf defined by Gradstein *et al.* (1992) and Gradstein & Bäckström (1996), respectively. In the Barents Sea wells analysed in the present study, *A. ruthvenmurrayi* is rare or even absent. We therefore selected the *Spiroplectammina spectabilis* LCO, which occurs regionally in the southwestern Barents Sea, to be the nominate event of this zone.

BSP 3A: Reticulophragmium pauperum Subzone

Type section: Well 7119/9-1, interval 1080-1160 m.

Age: middle late Paleocene.

Taxa: This interval zone contains the average last occurrence of the following species: *Reticulophragmium pauperum, Karrerulina horrida* and *Aschemonella grandis.* Local outliers of the latter two species occur, however at higher stratigraphic levels.

Discussion: This zone is characterised by the consistent common occurrence of *Reticulophragmium pauperum,* an index taxon for the upper Paleocene of the North Sea and the mid-Norwegian shelf. In the later area, this is the nominate species of the upper Paleocene Zone NSR 2B of Gradstein & Bäckström (1996). In our RASC solution in the Barents Sea, the *R. pauperum* Zone is well separated from the underlying cluster of Paleocene species and actually forms a subcluster at the base of the overlying *Haplophragmoides* aff. *eggeri* Zone (Fig. 3). Other important species of the type section include *Haplophragmoides walteri* and tubular forms belonging mainly to *Rhizammina. Spiroplectammina spectabilis* is present in low numbers throughout this interval.

BSP 3B: Haplophragmoides aff. eggeri Subzone

Type section: Well 7119/9-1, interval 890-1070 m.

Age: latest Paleocene.

Taxa: The following foraminiferal species have their last average occurrence in this interval zone: *Spiroplectammina spectabilis, Haplophragmoides porrectus, Rhabdammina discreta, Glomospira charoides, Haplo-*

phragmoides walteri, Verneuilinoides sp., Haplophragmoides eggeri, H. kirki, Ammodiscus macilentus, Ammomarginulina aubertae, Glomospira gordialis and *Ammodiscus peruvianus.* Amongst the dinocysts, *Alisocysta* sp. 2 (of Heilmann-Clausen) and *Apectodinium augustum* have their last occurrence within this zone.

Discussion: The diversity of benthic foraminifra is generally low in this zone, and in addition the abundance is markedly reduced near the top of the unit. The assemblages are dominated by tubular forms and by specimens of *Haplophragmoides* tentatively designated as *H.* aff. *eggeri*. The LO of this species was observed at 910 m in well 7119/9-1. The foraminifera are not age-diagnostic, but the occurrence of the dinocyst *Apectodinium augustum* suggests that the zone encompasses the Paleocene/Eocene boundary interval. However, this event still lacks direct calibration to the carbon isotope excursion which defines the P/E boundary in carbonate-bearing sequences.

BSP 4: Spiroplectammina navarroana Zone

Type section: Well 7119/9-1, interval 710-890 m.

Age: earliest Eocene.

Taxa: The following foraminiferal taxa have their average last occurrence in this interval zone: *Ammodiscus planus, Ammosphaeroidina pseudopauciloculata, Spiroplectammina navarroana, Nothia robusta, Karrerulina conversa, Bathysiphon* sp. and *Budashevaella multicamerata*. The dinocysts *Deflandrea oebisfeldensis, Cerodinium speciosum, Hystrichosphaeridium tubiferum,* and *Cerodinium wardenense* have their last occurrences within the zone.

Discussion: The whole interval is characterised by a taxonomic turnover, and the LOs of many taxa are observed near 710 m in well 7119/9-1, including *Spiroplectammina navarroana, Ammosphaeroidina pseudopauciloculata, Haplophragmoides kirki* and *Ammodiscus macilentus*. The planktonic species *Subbotina patagonica* has not been observed in our western Barents Sea wells, therefore the agglutinated species *Spiroplectammina navarroana* was chosen as the nominate taxon for this zone. In the central North Sea, the LO of *S. navarroana* is an important event within the Early Eocene *Subbotina patagonica* Zone of Gradstein *et al.* (1994). While on the Mid-Norwegian Shelf, the same event is recognised within the middle part of Zone NSR 5A of Gradstein & Bäckström (1996). Mudge & Bujak (1996) correlated the LO of *S. navarroana* with the top of the Ypresian.

In well 7119/9-1 we observed a diminutive form of *Ammomarginulina aubertae*; a species first described from the North Sea and Labrador Shelf by Gradstein & Kaminski (1989). The distribution of this species is apparently diachronous in offshore Norway, as it characterises the late Middle Eocene Zone NSR 6 of Gradstein & Bäckström (1996) on the mid-Norwegian shelf and in the northern North Sea. It is rare in our Lower Eocene samples from the Barents Sea.

We did not observe any planktonic or calcareous benthic foraminifera in the lower Eocene in any of the wells in the south-western Barents Sea. Calcareous assemblages characterising the *Subbotina patagonica* Zone of Gradstein *et al.* (1994) have been observed as far north as the mid-Norwegian shelf (Gradstein & Bäckström 1996) and the outer Vøring Plateau (Hulsbos *et al.*, 1989). Either the northern limit of the Early Eocene planktonic foraminifera must have existed south of the Barents Sea area, or the deep waters of the southwestern Barents Sea were too corrosive to allow the preservation of calcareous microfossils.

BSP 5: Reticulophragmium amplectens Zone

Type section: Well 7119/9-1, interval 510-710 m.

Age: late early to early middle Eocene.

Taxa: The following foraminiferal taxa have their average last occurrence in this interval zone: *Rhizammina* spp., *Reticulophragmium amplectens,* and *Recurvoides* spp. The zone also contains common *Karrerulina* spp., *Haplophragmoides excavatus,* and *Budashevaella multicamerata.* A characteristic event is the LO of the diatom species *Fenestrella antiqua.*

Discussion: Because of the truncated nature of the top of the Torsk Formation, this zone was only found in five wells located in the axial trend of the Tromsø and Hammerfest Basins, and in a single well in the westernmost Nordkapp Basin. In the uppermost part of the Torsk in these wells, both the abundance and diversity of foraminifera are low, and the LO of *R. amplectens* is observed near the eroded upper contact of the formation. Therefore, these last stratigraphic occurrences are most probably not correlative to the true local extinction of the species.

At 710 m in well 7119/9-1 there is a sharp downhole increase in foraminiferal abundance, associated with a peak in the frequency of *R. amplectens.* The population of *R. amplectens* contains both the small compact variant referred to as *Reticulophragmium intermedium* (Mjatliuk) and the larger form with a marked umbilical depression and more rounded periphery. The smaller and more primitive form is characteristic of the Early Eocene while the larger variant is typical of the Late Eocene (Kaminski, Gradstein *et al.* in prep.). In the North Sea and on the mid-Norwegian shelf *R. intermedium* is the nominate form of the late Early Eocene to early Middle Eocene Zone NSR 5A, while *R. amplectens* is the nominate taxon of the late Middle Eocene Zone NSR 6 of Gradstein & Bäckström (1996). In the deep Labrador Sea *R. amplectens* ranges from the Early Eocene (P7) to the Eocene/Oligocene boundary (Kaminski *et al.*, 1989).

Pyritised diatoms are relatively common in the Barents Sea Paleogene. The youngest diatom event is the LO of *Fenestrella antiqua,* which is an important stratigraphic marker of Zone BSP 5. Rich occurrences of the species are recorded from the Sele and Balder formations of the North Sea and the Fur Formation of Denmark. The stratigraphy and morphology of *F. antiqua* in the North Sea Paleogene have been recently discussed by Bidgood *et al.*, (1999), who distinguished four morphotypes interpreted as stages in the life cycle of the species. Three of these stages (initial cell, normal vegetative cell and resting spores) are observed in zone BSP 5. The stratigraphic range of the species is Late Paleocene to Early Eocene, with the top (LO) depressed to earliest Eocene in the North Sea as is apparent from Bidgood *et al.*, (1999).

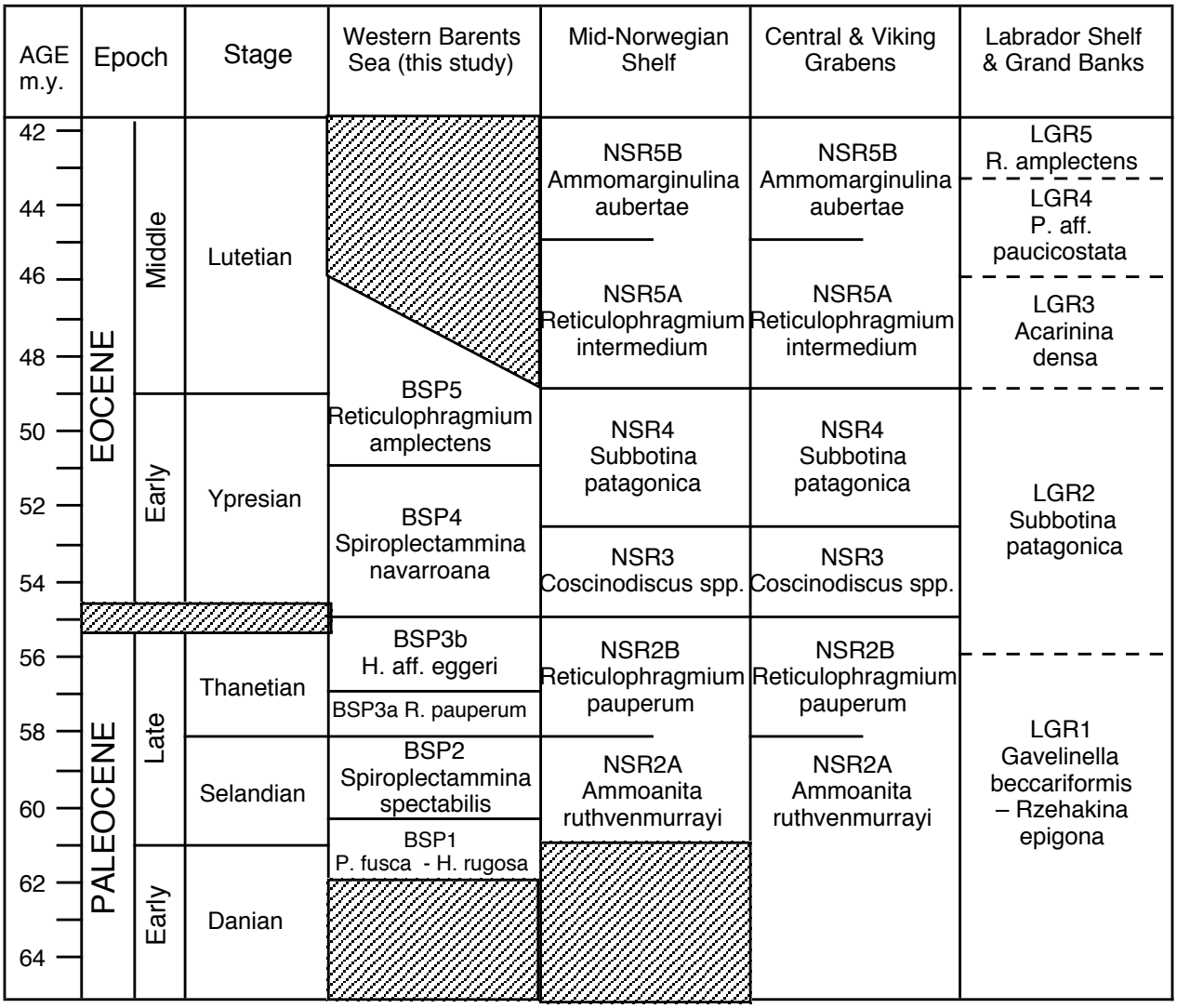


Figure 7. Stratigraphic correlation of the Paleogene foraminiferal zonation of the southwestern Barents Sea with the foraminiferal stratigraphy of the mid-Norwegian shelf, the Northern North Sea and the Labrador Shelf - Grand Banks region.

REGIONAL CORRELATIONS

The stratigraphical succession of the Paleogene Barents Sea zones compares well with the zonations constructed for other circum North Atlantic areas (Figure 7): the Mid-Norwegian Shelf by Gradstein & Bäckström (1996); the Viking Graben of the North Sea by Gradstein *et al.* (1988, 1992, 1994) and Mudge & Bujak (1994, 1996); the Labrador Margin and Northern Grand Banks by Gradstein *et al.* (1994). Many of the stratigraphically important cosmopolitan deep-water foraminifera of the Barents Sea reveal last occurrences in a similar stratigraphic order to that observed in the North Sea and on the North Atlantic margins, such as: *Caudammina gigantea, Cystammina svenni*, *Caudammina excelsa, Spiroplectammina spectabilis, Reticulophragmium pauperum, Reticulophragmoides jarvisi, Spiroplectammina navarroana* and *Reticulophragmium amplectens.* Additionally, the occurrence of the diatom species *Fenestrella antiqua* provides a correlation with the North Sea "Coscinodiscus Zone" of Gradstein *et al.* (1988).

The analysed sections are arranged in two transects (Figure 1), to provide an overview of the chronostratigraphy and thickness variation of the Torsk Formation expressed by the lateral development of the RASC zonation (Figure 8). The first transect comprises eight wells, and extends along a W-E line from the Senja Ridge (on the western border of the Tromsø Basin) to the western extension of the Nordkapp Basin. The second transect consists of four wells, and extends along a S-N line from the southern margin of the Hammerfest Basin over the Loppa High into the Bjørnøya Basin. The two transects intersect at the 7120/5-1 well site. The 12 biostratigraphical events depicted in Figure 8 display a remarkable degree of consistency between individual wells, with nearly no cross-over.

In well 7117/9-2, located on the Senja Ridge, the Torsk Formation is 285m thick, measured between its unconformable lower and upper contacts with the Campanian and Plio-Pleistocene, respectively. In spite of its small thickness, the Torsk of the well contains all of the faunal zones that are recognised in the much thicker basinal sediment packages (Figure 8).

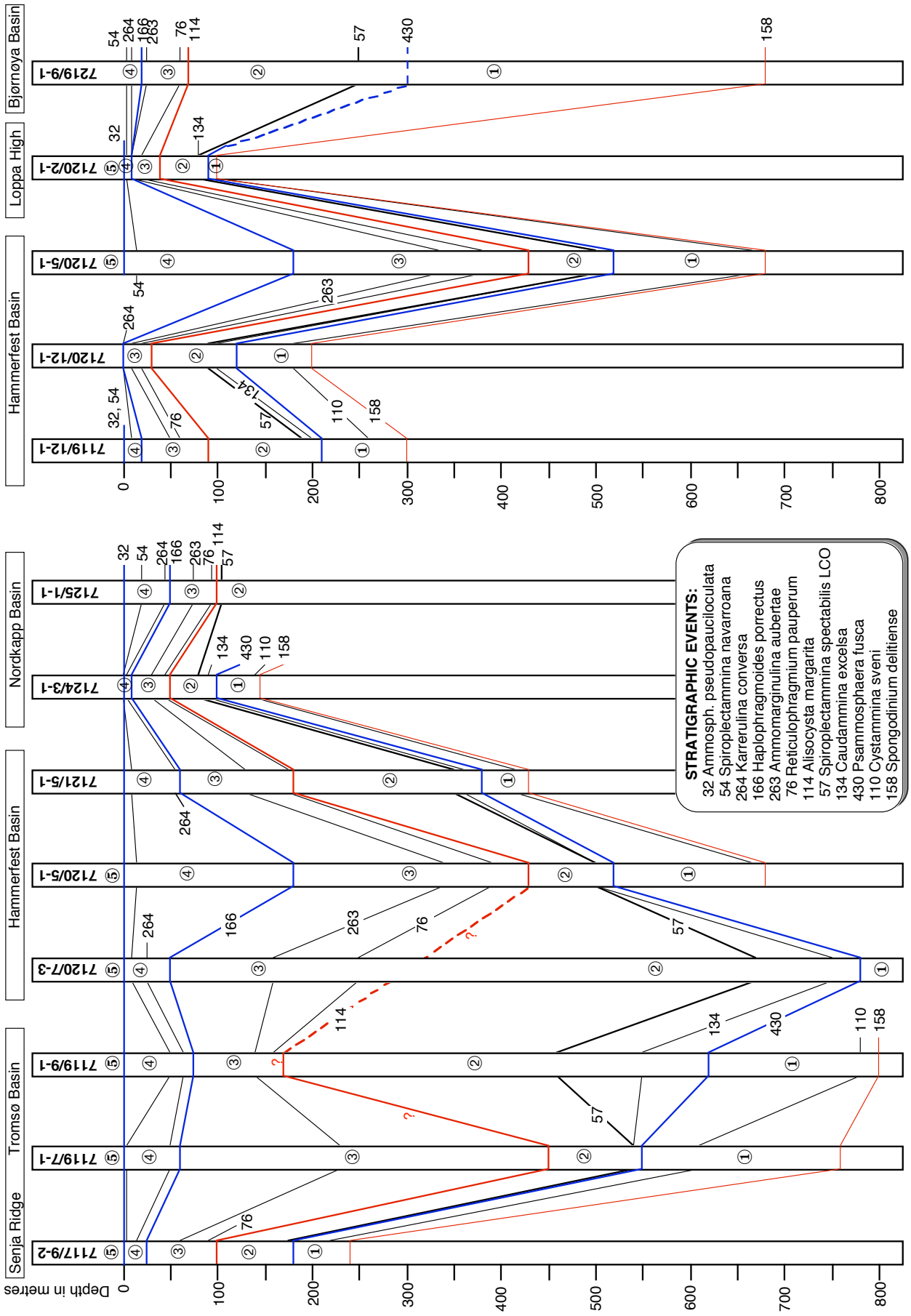


Figure 8. Stratigraphic correlation within the Paleogene Torsk Formation showing distribution of 12 microfossil events taken from the optimum succession (Figs 3,4). The wells are arranged in two transects: from Senja Ridge to Nordkapp Basin, and from Hammerfest Basin to Bjørnøya Basin (for location see Fig. 1). The zones BSP1 to BSP5 recognised in this study are numbered successively in each well column.

This indicates that the Senja Ridge well does not contain large hiatuses, in spite of the relatively small Paleogene thicknesses at this site. If hiatuses are present they are not more extensive than the stratigraphic resolution of the faunal zones.

Wells 7119/7-1, 7119/9-1, 7120/7-3 and 7120/5-1, are located in the deep axial part of the Tromsø and Hammerfest basins, where the Torsk Formation attains large thicknesses varying from 819m to 1040m. The formation here includes all five zones ranging in age from Early Paleocene (BSP 1) to Middle Eocene (BSP 5). In Well 7121/5-1, which is the easternmost site studied in the Hammerfest Basin, the thickness of the Torsk is reduced to 567m, and the Eocene BSP 5 Zone is absent from the top of the formation.

Wells 7124/3-1 and 7125/1-1 are located in the westernmost part of the Nordkapp Basin, and in both of these the Paleogene Torsk Formation shows strongly reduced thicknesses, to 170 m and 177 m, respectively. In spite of this decrease, well 7124/3-1 contains the zones BSP 1 to BSP 4, while BSP 5 is entirely removed by Plio-Pleistocene erosion. Well 7125/1-1 comprises zone BSP 2 to BSP 4, while BSP 1 and BSP 5 are missing from the base and top of the Torsk, respectively.

Close to the southeastern border of the Hammerfest Basin the Paleocene thicknesses are markedly reduced (Figure 8). In well 7119/12-1, the Torsk Formation is 330m thick and contains the Early Paleocene to Early Eocene zones BSP 1 to BSP 4. The other site in this area, Well 7120/12-1, contains a 260m thick Torsk Formation including the Paleocene zones BSP 1 to BSP 3. From the top of the formation, zone BSP5 is lacking in well 7119/12-1, while zones BSP4 and BSP5 are absent from Well 7120/12-1. The reduced zonal thicknesses are attributed to the basin-marginal position of the two wells, while the absence of the uppermost one or two zones are explained by Plio-Pleistocene truncation.

On the Loppa High, in well 7120/12-1, the Torsk Formation attains only 135m but includes the zones BSP1 to BSP4 of Early Paleocene to Early Eocene age. The strong thickness reduction suggests condensed deposition, or the presence of hiatuses with duration shorter than the time resolution of the zonal scheme. The position of the well on a platform area is in accordance with features suggesting erosion and sediment starvation.

In the Bjørnøya Basin the thickness of the Paleogene have markedly increased as it is apparent from Well 7219/9-1 where the Torsk Formation is 760 m thick. Zones BSP1 to BSP4 are present at this site, while BSP5 is apparently removed in the Plio-Pleistocene.

CONCLUSIONS

The Paleogene Torsk Formation, studied in 12 wells in the southwestern Barents Sea, contains relatively rich foraminiferal and palynomorph assemblages that are suitable for quantitative stratigraphic and biofacies analyses. The foraminiferal assemblages consist exclusively of agglutinating taxa showing deeper water, outer neritic to middle bathyal aspects. Both the foraminiferal and dinocyst successions reveal strong affinities to Paleogene assemblages recorded from bathyal facies of the mid-Norwegian Shelf, the North Sea and the Labrador Margin, facilitating stratigraphical correlation. The Eocene foraminiferal assemblages of the Torsk, however, display closer similarities also to neritic (prodelta shelf) faunas recorded from Spitsbergen.

The stratigraphical analysis combines foraminiferal (benthic) and palynomorph (planktonic) distribution data, mainly last occurrences. A single diatom species is also included. The analysis was performed by means of the RASC method combined with conventional stratigraphy, and resulted in a zonal scheme that includes the following. 1) Late early to late Paleocene zones: BSP 1, *Psammosphaera fusca – Hyperammina rugosa;* BSP 2, *Spiroplectammina spectabilis;* BSP 3A, *Reticulophragmium pauperum; BSP 3B*, *Haplophragmoides* aff. *eggeri.* 2) Early to middle Eocene zones: BSP 4, *Spiroplectammina navarroana;* BSP 5, *Reticulophragmium amplectens.*

On elevated structures and in basin marginal settings, the Paleogene Torsk Formation reveals strongly reduced thicknesses, usually coupled with the absence of one or both of the Eocene zones. Such reduced thicknesses are observed on the Senja Ridge, Loppa High, southeastern margin of the Hammerfest Basin and in the westernmost part of the Nordkapp Basin. The absence of the Eocene zones is attributed to truncation of the Torsk Formation by Plio-Pleistocene erosion. The thickness reduction of zones recognised in the formation is explained by condensation or hiatuses smaller in extent than the biostratigraphical resolution of the microfossil event succession.

In deeper basinal areas, such as the axial part of the Tromsø, Hammerfest and Bjørnøya basins, the thickness of the Torsk Formation is strongly increased, and attains a maximum of 1040 m. The three Paleocene zones are well developed here, and usually both of the Eocene zones are present, suggesting reduced effects of the Plio-Pleistocene erosional truncation.

ACKNOWLEDGEMENTS

This study is based on sample material obtained from the following organisations: Norsk Hydro A/S (Oslo), Norwegian Petroleum Directorate (Stavanger), Saga Petroleum A/S (Oslo), Statoil (Stavanger). The project was funded by the Statoil-VISTA Programe. Grateful thanks are due to Mufak Naoroz and Ingvild Hudøy for laboratory processing of the samples. We are grateful to Bob Jones (BP) for reviewing the manuscript. This is contribution nr. 69 of the Deep-Water Agglutinated Foraminiferal Project.

REFERENCES

Agterberg, F.P. & Gradstein F.M. 1999. The RASC method for ranking and scaling of biostratigraphic events. *Earth-Science Reviews,* **46,** 1-25.

Bidgood, M.D., Mitlehner, G.D., Jones, G.D. & Jutson, D.J. 1999. Towards a stable and agreed nomenclature for North Sea Tertiary diatom floras – the `*Coscinodiscus*` problem. *In:* Jones, R.V., & Simmons, M.D. (eds), Biostratigraphy in Production and Development Geology. *Geological Society, London, Special Publications,* **152,** 139-153.

Bujak, J.P. & Mudge, D.C. 1994. A high-resolution North Sea Eocene dinocyst zonation. *Journal of the Geological Society of London,* **151,** 449-462.

Charnock, M.A. & Jones, R.W. 1990. Agglutinated foraminifera from the Palaeogene of the North Sea. *In:* Hemleben,

C., Kaminski, M.A., Kuhnt, W. & Scott, D.B. (eds), *Paleoecology, biostratigraphy, paleoceanography and taxonomy of agglutinated foraminifera.* Kluver Academic Publishers, Amsterdam, 139-244.

Dowdeswell, L.M. 1988. Cenozoic evolution of the western margin of the Barents Shelf. *In:* Harland, W.B. & Dowdeswell, E.K. (eds), *Geological evolution of the Barents Shelf Region.* Graham & Trotman, London, 157-170.

Faleide, J.I., Vågnes, E. & Gudlaugsson, S.T. 1993. Late Mesozoic – Cenozoic evolution of the southwestern Barents Sea. *In:* Parker, J.R. (ed.), *Petroleum Geology of northwest Europe: Proceedings of the 4th Conference.* Geological Society, London, 933-950.

Gradstein, F.M. & Bäckström, S. 1996. Cainozoic biostratigraphy and palaeobathymetry, northern North Sea and Haltenbanken. *Norsk Geologisk Tidskrift,* **76,** 3-32.

Gradstein, F.M. & Kaminski, M.A. 1989. Taxonomy and biostratigraphy of new and emended species of Cenozoic deep-water agglutinated foraminifera from the Labrador and North Seas. *Micropaleontology,* **35,** 72-92.

Gradstein, F.M. & Kaminski, M.A. 1997. New species of Paleocene deep-water agglutinated foraminifera from the North Sea and Norwegian Sea. *Annales Societatis Geologorium Poloniae,* **67,** 217-229.

Gradstein, F.M., Agterberg, F.P., Brower, J.C. & Schwarzacher, W. 1985. *Quantitative Stratigraphy.* Unesco and Reidel Publications, 1-598.

Gradstein, F.M., Kaminski, M.A. & Berggren, W.A. 1988. Cenozoic foraminiferal biostratigraphy of the Central North Sea. *Abhandlungen der geologischen Bundesanstalt,* **41**, 97-108.

Gradstein, F.M., Kaminski, M.A., Berggren, W.A., Kristiansen, I.L. & D'Ioro, M.A. 1994. Cenozoic biostratigraphy of the North Sea and Labrador Shelf. *Micropaleontology*, **40** (Supplement), 1-152.

Gradstein, F.M., Kristiansen, I.L., Loemo, L. & Kaminski, M.A. 1992. Cenozoic foraminiferal and dinoflagellate biostratigraphy of the central North Sea. *Micropaleontology,* **38,** 101-137.

Hulsbos, R.E., Kroon, D., Jansen, H.S.M. & van Hinte, J.G. 1989. Lower Eocene benthic foraminifera and paleoenvironment of the outer Vøring Plateau, Norwegian Sea (DSDP Site 338). *Micropaleontology,* **35** (3), 256-273.

Kaminski, M.A., Gradstein, F.M. & Berggren, W.A. 1989. Paleogene benthic foraminifer biostratigraphy and paleoecology at Site 647, southern Labrador Sea. *Proceedings of the Ocean Drilling Program, Scientific Results,* **105**, 705-730.

Kaminski, M.A. & Geroch, S. 1993. A revision of foraminiferal species in the Grzybowski collection. *In:* Kaminski, M.A., Geroch, S., & Kaminski, D.G. (eds), The Origins of Applied Micropaleontology: The School of Jozef Grzybowski. *Grzybowski Foundation Special Publication,* **1,** 239-323.

Kaminski, M.A. & Gradstein, F.M. *et al.* (in prep). Paleogene cosmopolitan deep-water agglutinated foraminifera. *Grzybowski Foundation Special Publication.*

King, C. 1989. Cenozoic of the North Sea. *In*: Jenkins, D.G., & Murray, J.W. (eds), *A Stratigraphical Atlas of Fossil Foraminifera*, 2nd Edition. Ellis Horwood, Chichester, 418-489.

Mudge, D.C., & Bujak, J.P. 1994. Eocene stratigraphy of the North Sea Basin. *Marine and Petroleum Geology,* **11,** 166-181.

Mudge, D.C. & Bujak, J.P. 1996. An integrated stratigraphy for the Paleocene and Eocene of the North Sea. *In:* Knox, R.W.O´B., Corfield, R.M., & Dunay, R.E. (eds), *Correlation of the Early Paleogene in Northwest Europe.* Geological Society Special Publication, **101,** 91-113.

Nagy, J., Kaminski, M.A., Johnsen, K. & Mitlehner A.G. 1997. Foraminiferal, palynomorph, and diatom biostratigraphy and paleoenvironments of the Torsk Formation: A reference section for the Paleocene-Eocene transition in the western Barents Sea. *In:* Hass, H.C. & Kaminski, M.A. (eds), Contributions to the Micropaleontology and Paleoceanography of the Northern North Atlantic. *Grzybowski Foundation Special Publication,* **5,** 15-38.

Nagy, J., Kaminski, M.A., Kuhnt, W. & Bremer, M.A. 2000. Agglutinated foraminifera from neritic to bathyal facies in the Paleogene of Spitsbergen and the Barents Sea. *In:* Hart, M.B., Kaminski, M.A. & Smart, C.W. (eds), Proceedings of the Fifth International Workshop on Agglutinated Foraminifera. *Grzybowski Foundation Special Publication,* **7,** 333-361.

Nøttvedt, A., Cecchi, M., Gjellberg, J.G., Kristensen, S.E., Lønøy, A., Rasmussen, A., Rasmussen, E., Skott, P.H. & van Veen, P.M. 1992. Svalbard-Barents Sea correlation: a short review. *In:* Vorren, T.O., Bergsager, E., Dahl-Stamnes, Ø.A., Holter, E., Johansen, B., Lie, E. & Lund, T.B. (eds), Arctic Geology and Petroleum Potencial. *Norwegian Petroleum Society, Special Publication* **2,** 363-375.

Reemst, P. & Cloetingh, S. 1994. Tectonostratigraphic modelling of Cenozoic uplift and erosion in the southwestern Barents Sea. *Marine and Petroleum Geology,* **11,** 478-490.

Rønnevik, H.C. 1981. Geology of the Barents Sea. *In: Petroleum Geology of the Continental Shelf of North-West Europe,* 395-406.

Worsley, D., Johansen, R. & Kristensen, S.E. 1988. The Mesozoic and Cenozoic succession of Tromsøflaket. *In:* Dalland, A., Worsley, D., & Ofstad, K. (eds), A lithostratigraphic scheme for the Mesozoic and Cenozoic succession offshore mid-and northern Norway. *Norwegian Petroleum Directorate, Bulletin,* **4,** 42-61.

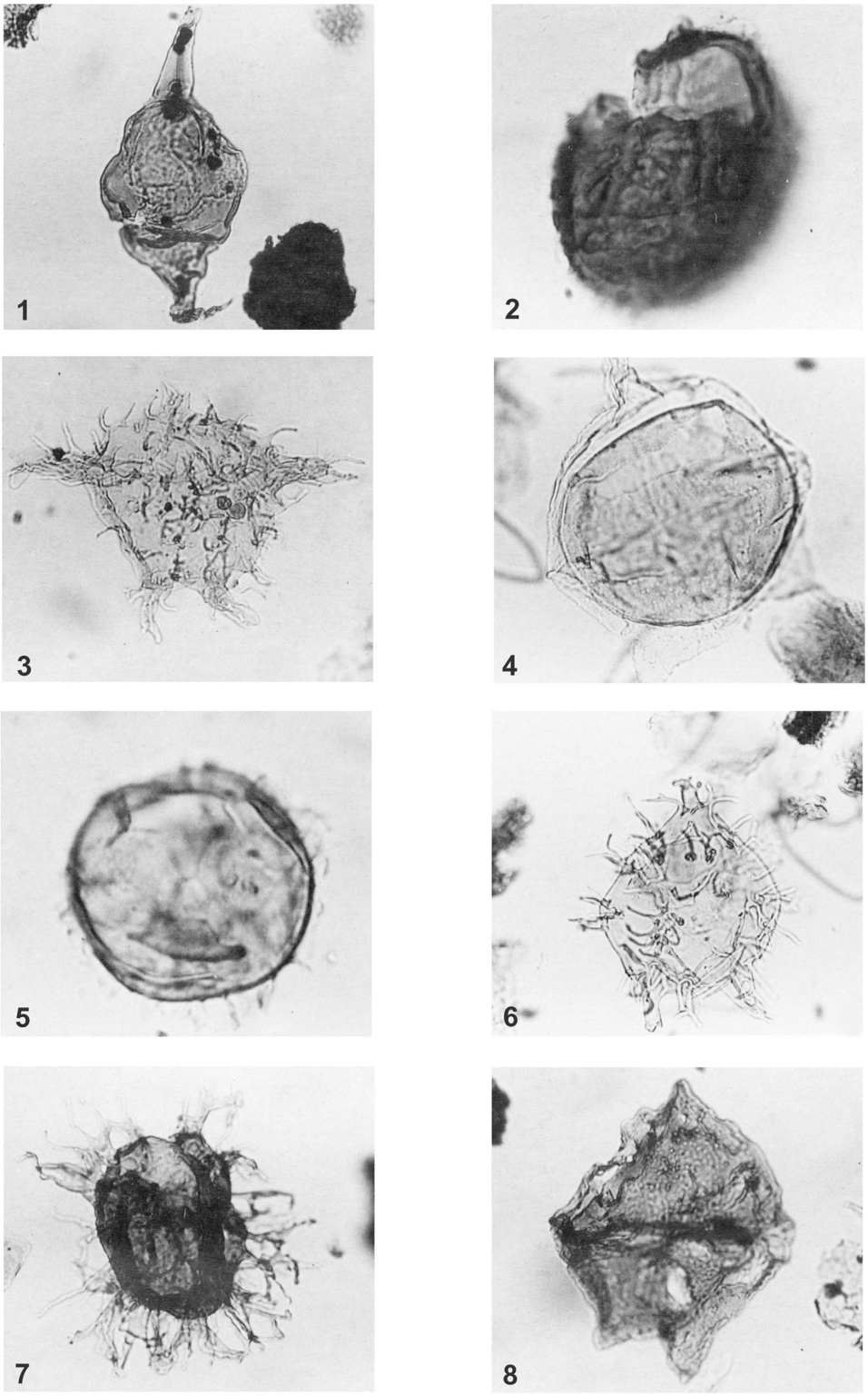


PLATE 1. 1. Selected palynomorph taxa from the Torsk Formation. All specimens from Well 7119/7-1. **1.** *Palaeocystodinium bulliforme* Ioannides, 1986, 1430m, x250; **2.** *Alistocysta marginata* (Harland) Harland, 1979, 1010m, x1000; **3**. *Apectodinium augustum* (Harland) Lentin & Williams, 1981, 1040m, x300; **4.** *Deflandrea oebisfeldensis* Alberti, 1959, 850m, x5000; **5.** *Alisocysta* sp 2. Heilmann-Clausen, 1985, 470m, x1000; **6.** *Apectodinium quinquelatum* (Williams, Downie-Costa & Downie, 1979), 730m, x500; **7.** *Areoligera* cf. *senonensis* Lejeune-Carpenter, 1938, 970m, x5000; **8.** *Palaeoperidinium pyrophorum* (Ehrenberg) Sarjeant, 1967, 950m, x500.

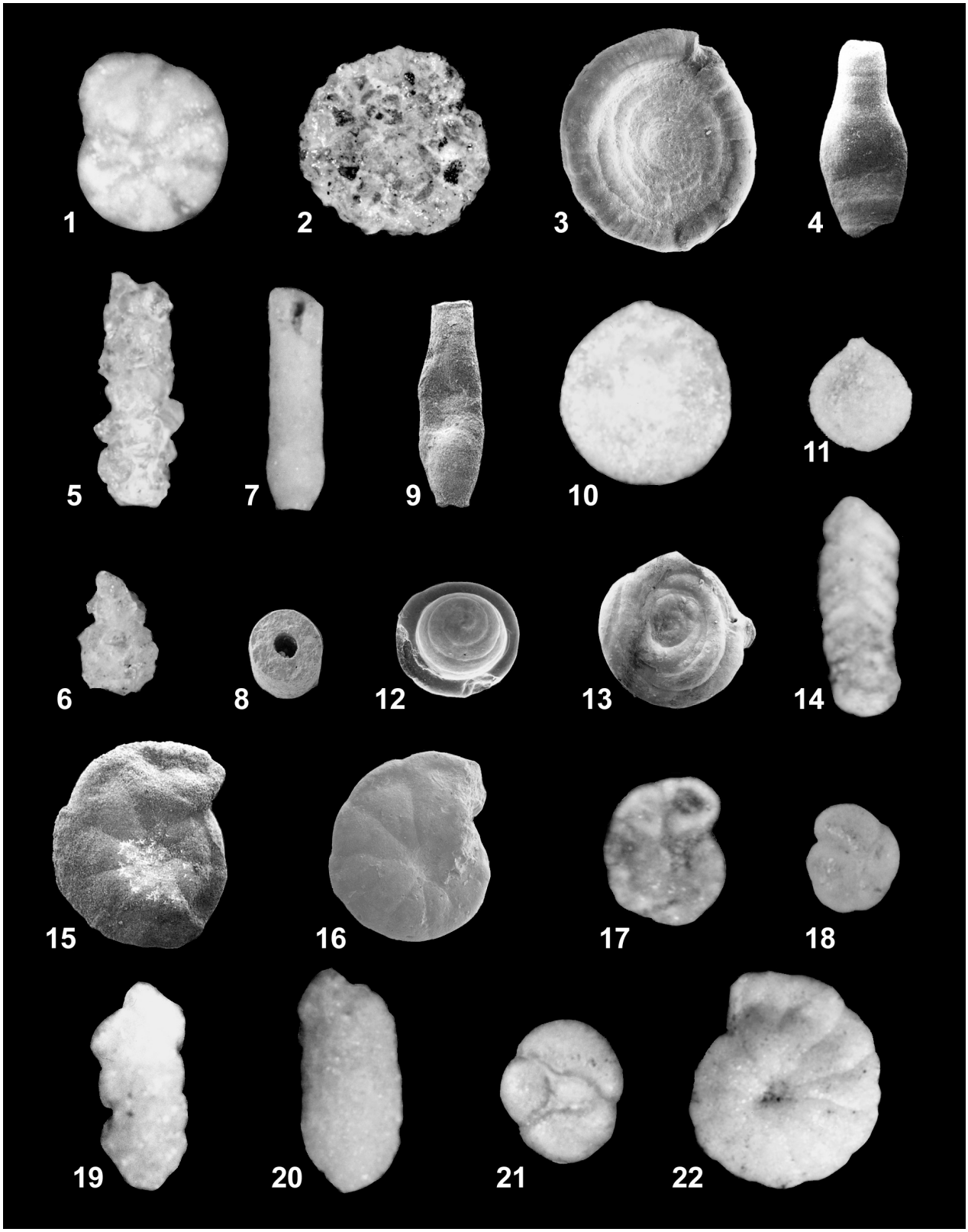


PLATE 1. 1. Selected foraminiferal taxa from the Torsk Formation. All specimens from Well 7119/7-1, except Figs. 4, 15, 16. **1.** *Reticulophragmoides jarvisi* (Thalmann, 1932), 1290m, x104; **2.** *Psammosphaera fusca* Schultze, 1875, 1110m, x38; **3.** *Ammodiscus glabratus* Cushman & Jarvis, 1928, 1270m, x45; **4.** *Caudammina excelsa* (Dylaznka, 1923), 7119/9-1, 1350m, x45; **5-6.** *Hyperammina rugosa* Verdenius & Van Hinte, 1983, 5. 1290m, x54, 6. 1200m, x54; **7-8.** *Bathysiphon* sp. 1 Nagy *et al*. 2000, 7. 1230m, x110. 8. 1200m, x70; **9.** *Kalamopsis grzybowskii* (Dylà˝anka, 1923), **10.** *Saccammina placenta* (Grzybowski, 1898), 1270m, x90; **11.** *Saccammina grzybowskii* (Schubert, 1902), 1250m, x85; **12.** *Repmanina charoides* (Jones & Parker, 1860), 1040m, x60. **13.** *Glomospira gordialis* (Jones & Parker, 1860), 1320m, x75. **14.** *Spiroplectammina spectabilis* (Grzybowski, 1898), 1060m, x110; **15.** *Reticulophragmium pauperum* (Chapman, 1904), 7119/9-1, 1380m, x50. **16.** *Haplophragmoides walteri* (Grzybowski, 1898), 7119/9-1, 590m, x90; **17.** *Haplophragmoides porrectus* Maslakova, 1955, 1260m, x100; **18.** *Haplophragmoides kirki* Wickenden, 1932, 1140m, x90. **19.** *Karrerulina conversa* (Grzybowski, 1901), 710m, x160. **20.** *Karrerulina horrida* (Mjatliuk, 1970), 750m, x140. **21.** *Ammosphaeroidina pseudopauciloculata* (Mjatliuk, 1966), 1290m, x90; **22.** *Reticulophragmium amplectens* (Grzybowski, 1898), 510m, x80.

APPENDIX - DATA LIST OUTPUT

The list contains 633 microfossil events, which is the total registered in the 12 wells studied. The majority of events are last occurrences, unless marked otherwise (e.g., LCO).

Norsk Hydro 7117/9-2

Rotary table height: 24 m
Water depth: 271 m

Depth(m)	Event (fossil) name
1081	Reticulophragmium amplectens
	Fenestrella antiqua (large)
1095	Recurvoides spp.
	Verneuilinoides sp.
	Azolla spp.
	Impagidinium aculeatum
	Haplophragmoides walteri
	Karrerulina conversa
	Rhizammina spp.
	Spiroplectammina spectabilis LO
1105	Achomosphaera ramulifera
	Ammodiscus macilentus
	Budashevaella multicamerata
1115	Paleocystodinium golzowensis
	Cerodinium speciosum
	Caryapollenites simplex
	Deflandrea oebisfeldensis
	Apectodinium augustum
	Apectodinium spp.
	Apectodinium hyperacanthum
	Spiroplectammina navarroana
1125	Apectodinium homomorphum
1145	Reticulophragmium pauperum
	Hyperammina rugosa
	Glomospira gordialis
1155	Palaeoperidinium pyrophorum
1175	Hystrichosphaeridium tubiferum
1185	Glomospira charoides
1205	Isabelidinium cf. viborgense
	Rhabdammina discreta
	Ammodiscus planus
1225	Impagidinium sp. 1 Heilmann-Clausen
1235	Alisocysta sp. 2 Heilmann-Clausen
	Ammosphaeroidina pseudopauciloculata
1245	Alisocysta margarita
	Ammodiscus peruvianus
1255	Glomospira irregularis
	Subreophax scalaris
1265	Areoligera cf. senonensis
1275	Ammodiscus glabratus
1285	Ammodiscus cretaceus
1315	Spiroplectammina spectabilis LCO
	Cerodinium wardenense
1325	Haplophragmoides kirki
1335	Cerodinium cf. striatum
1345	Hyperammina rugosa LCO
	Saccammina grzybowskii
1355	Psammosphaera fusca
1365	Caudammina excelsa
1385	Psammosphaera fusca LCO
	Reticulophragmoides jarvisi
	Karrerulina horrida
	Saccammina placenta
	Cystammina sveni
1405	Aquilapollenites spinulosus
	Spongodinium delitiense

Norsk Hydro 7119/7-1

Rotary table height: 23 m
Water depth: 238 m

Depth(m)	Event (fossil) name
436	Reticulophragmium amplectens
450	Systematophora placacantha
	Deflandrea oebisfeldensis
	Dracodinium varielongitudum
	Cerodinium wardenense
	Azolla bloom
	Taxodiaceaepollenites spp.
	Hystrichosphaeridium tubiferum
	Charlesdowniea edwardsii
460	Apectodinium spp.
	Glomospira charoides
466	Fenestrella antiqua (large)
470	Recurvoides spp.
480	Haplophragmoides excavatus
	Cribrostomoides subglobosus
490	Glomospira gordialis
	Ammodiscus planus
	Budashevaella multicamerata
	Recurvoides contortus
	Ammosphaeroidina pseudopauciloculata
	Verneuilinoides sp.
500	Rhizammina spp.
	Cenosphaera spp. LCO
510	Karrerulina conversa
530	Apectodinium homomorphum
540	Aschemonella grandis
550	Haplophragmoides kirki
	Haplophragmoides eggeri
560	Cerodinium dartmoorium
	Ammodiscus glabratus
	Haplophragmoides walteri
	Bathysiphon sp.
580	Ammomarginulina aubertae
	Psammosphaera trinitatensis
	Sphaerammina gerochi
590	Haplophragmoides porrectus
610	Apectodinium augustum
	Alisocysta sp. 2 Heilmann-Clausen
	Glaphyrocysta ordinata LCO
740	Cerodinium speciosa
940	Reticulophragmium spp.
950	Spiroplectammina spectabilis LO
	Hyperammina rugosa
960	Cystammina sveni
	Rhabdammina spp.
	Ammodiscus peruvianus
	Spiroplectammina spectabilis LCO

970 Reticulophragmium pauperum
Caudammina excelsa
Ammodiscus cretaceus
Kalamopsis grzybowskii
Recurvoides sp. 1 (coarse)
980 Alisocysta margarita
Paratrochamminoides mitratus
Haplophragmoides stomatus
990 Impagidinium sp. 1 Heilmann-Clausen
Paratrochamminoides olszewskii
1000 Alisocysta margarita LCO
Recurvoidella lamella
Saccammina placenta
1020 Haplophragmoides walteri-jarvisi
Saccammina grzybowskii
Recurvoides gerochi
Cribrostomoides trinitatensis
1030 Ammodiscus macilentus
1040 Glomospira irregularis
Haplophragmoides sp. 3
1050 Karrerulina horrida
1070 Areoligera cf. senonensis
1090 Jaculella sp.
1110 Psammosphaera fusca
1200 Pseudobolivina lagenaria
1240 Isabelidinium cf. viborgense
1290 Psammosphaera fusca LCO
Rhabdammina cylindrica
Reticulophragmoides jarvisi
1300 Palaeocystodinium bulliforme
Cenosphaera sp. (disc or flat)
1307 Palaeocystodinium bulliforme LCO
1330 Alisocysta reticulata
Haplophragmoides horridus
1340 Spongodinium delitiense
1350 Cerodinium diebeli
Senoniasphaera inornata
Rzehakina epigona
Trochamminoides subcoronatus

Elf Aquitaine 7119/9-1
Rotary table height: 24 m
Water depth: 201 m
Depth(m) Event (fossil) name
405 Deflandrea oebisfeldensis
Alisocysta sp. 2 Heilmann-Clausen
486 Fenestrella antiqua (large)
510 Karrerulina horrida
520 Rhizammina spp.
526 Reticulophragmium amplectens
550 Haplophragmoides excavatus
Ammodiscus planus
Haplophragmoides porrectus
Karrerulina conversa
590 Budashevaella multicamerata
610 Haplophragmoides eggeri
Recurvoidella lamella
700 Ammodiscus macilentus
Haplophragmoides horridus
710 Haplophragmoides kirki
Spiroplectammina navarroana
Ammosphaeroidina pseudopauciloculata
Recurvoides spp.
720 Hystrichosphaeridium tubiferum
Deflandrea oebisfeldensis LCO
Apectodinium spp.
Rhabdammina spp.
Verneuilinoides sp.
730 Psammosphaera trinitatensis
Bathysiphon sp.
740 Spiroplectammina spectabilis LO
760 Nothia robusta
780 Areoligera cf. senonensis
790 Ammodiscus peruvianus
Ammomarginulina aubertae
800 Glomospira charoides
810 Kalamopsis grzybowskii
Saccammina placenta
Haplophragmoides stomatus
Sphaerammina gerochi
820 Glomospira gordialis
Haplophragmoides walteri
830 Saccammina grzybowskii
845 Cerodinium wardenense
890 Apectodinium augustum
930 Evolutinella rotulata
970 Alisocysta margarita
1020 Palaeoperidinium pyrophorum
1070 Spiroplectammina spectabilis LCO
Ammodiscus cretaceus
1080 Reticulophragmium pauperum
Hyperammina rugosa
1100 Reticulophragmium sp. (robust)
1130 Aschemonella grandis
Bathysiphon microraphidus
1180 Caudammina excelsa
1230 Ammomarginulina foliaceus
1270 Psammosphaera fusca
1310 Paratrochamminoides spp.
1340 Reticulophragmoides jarvisi
1350 Hyperammina rugosa LCO
Rzehakina minima
1370 Palaeoperidinium pyrophorum LCO
1380 Haplophragmoides walteri-jarvisi
1420 Palaeocystodinium bulliforme
1430 Psammosphaera fusca LCO
1440 Isabelidinium cf. viborgense
Rzehakina epigona
1450 Spongodinium delitiense
Jaculella sp.
Glomospira irregularis
Spiroplectinella aff.dentata
1460 Caudammina ovulum
Hormosina velascoensis
Ammodiscus glabratus
Cystammina sveni
Pseudobolivina lagenaria
Spirosigmoilinella sp. 1 (Ch.& J.)

Statoil 7120/7-3
Rotary table height: 24 m
Water depth: 258 m

Depth(m)	Event (fossil) name
332	Nothia robusta
350	Haplophragmoides horridus
356	Fenestrella antiqua (large)
	Reticulophragmium amplectens
360	Rhizammina spp.
	Spiroplectammina spectabilis LO
370	Recurvoides spp.
	Budashevaella multicamerata
	Ammosphaeroidina pseudopauciloculata
	Haplophragmoides porrectus
	Cenosphaera spp. LCO
380	Reticulophragmium sp. (robust)
	Karrerulina conversa
390	Aschemonella grandis
	Recurvoides contortus
	Haplophragmoides kirki
	Karrerulina horrida
	Haplophragmoides excavatus
	Ammodiscus macilentus
	Spiroplectammina navarroana
400	Saccammina grzybowskii
410	Evolutinella rotulata
420	Rhabdammina discreta
430	Verneuilinoides sp.
	Ammomarginulina aubertae
460	Ammodiscus planus
530	Ammodiscus peruvianus
550	Ammodiscus cretaceus
620	Glomospira gordialis
	Bathysiphon sp.
	Trochamminoides subcoronatus
	Recurvoidella lamella
640	Glomospira charoides
	Paratrochamminoides spp.
650	Ammodiscus glabratus
660	Haplophragmoides walteri
690	Tuff
940	Hyperammina rugosa
	Haplophragmoides stomatus
	Haplophragmoides eggeri
	Saccammina placenta
	Reticulophragmium spp.
960	Reticulophragmium pauperum
1010	Caudammina excelsa
1040	Reticulophragmoides jarvisi
1050	Bathysiphon microraphidus
	Ammomarginulina foliacea
1150	Psammosphaera fusca
	Kalamopsis grzybowskii
1170	Spiroplectammina spectabilis LCO
1270	Haplophragmoides walteri-jarvisi
1300	Trochamminoides proteus
	Rzehakina minima
1310	Glomospira irregularis
	Psammosphaera fusca LCO
	Cystammina sveni
	Ammolagena clavata
1320	Hyperammina rugosa LCO
	Jacuella sp.
1330	Rhabdammina cylindrica
	Subreophax scalaris
1340	Spiroplectinella aff.dentata
	Trochammina ruthvenmurrayi

Statoil 7120/5-1
Rotary table height: 24 m
Water depth: 318 m

Depth(m)	Event (fossil) name
376	Fenestrella antiqua (large)
396	Karrerulina conversa
	Reticulophragmium amplectens
420	Rhizammina spp.
	Spiroplectammina navarroana
	Glomospira charoides
	Ammodiscus planus
440	Rhabdammina spp.
470	Karrerulina horrida
490	Saccammina grzybowskii
	Recurvoides spp.
510	Dracodinium varielongitudum
	Deflandrea oebisfeldensis LCO
	Hystrichosphaeridium tubiferum
	Apectodinium spp.
530	Ammosphaeroidina pseudopauciloculata
	Nothia robusta
	Psammosphaera irregularis
	Psammosphaera trinitatensis
550	Cerodinium wardenense
	Bathysiphon sp.
560	Ammomarginulina foliacea
	Evolutinella rotulata
640	Haplophragmoides excavatus
670	Apectodinium hyperacanthum
	Azolla spp.
710	Apectodinium homomorphum
	Apectodinium augustum
750	Caryapollenites simplex
780	Reticulophragmium pauperum
	Verneuilinoides sp.
790	Palaeoperidinium pyrophorum
	Hyperammina rugosa
	Reticulophragmium spp.
810	Haplophragmoides walteri
901	Alisocysta margarita
920	Haplophragmoides eggeri
	Rhabdammina discreta
	Spiroplectammina spectabilis LO
	Haplophragmoides horridus
	Ammomarginulina aubertae
930	Sphaerammina gerochi
940	Bathysiphon microraphidus
950	Haplophragmoides kirki
960	Jacuella sp.
	Psammosphaera fusca
980	Hormosina velascoensis
	Caudammina excelsa

	Ammodiscus macilentus
990	Aschemonella grandis
1000	Glomospira gordialis
	Spiroplectammina spectabilis LCO
1010	Budashevaella multicamerata
	Saccammina placenta
	Ammodiscus cretaceus
1020	Ammodiscus peruvianus
1040	Dorothia retusa
1050	Kalamopsis grzybowskii
1169	Ammodiscus glabratus
	Trochamminoides proteus
1178	Hyperammina rugosa LCO
	Rzehakina minima
	Trochamminoides subcoronatus
	Haplophragmoides stomatus
1187	Pseudobolivina lagenaria
	Cystammina sveni
1196	Glomospira irregularis
	Rhabdammina cylindrica
	Caudammina gigantea
1209	Isabelidinium cf. viborgense
	Areoligera cf. senonensis
1220	Spongodinium delitiense

Statoil 7121/5-1

Rotary table height: 23 m

Water depth: 336 m

Depth(m)	Event (fossil) name
450	Cerodinium speciosum
560	Rhizammina spp.
	Ammodiscus planus
	Recurvoides spp.
	Ammosphaeroidina pseudopauciloculata
570	Bathysiphon sp.
	Spiroplectammina navarroana
	Glomospira charoides
600	Glomospira gordialis
610	Haplophragmoides walteri
620	Nothia robusta
	Rhabdammina discreta
	Ammodiscus peruvianus
	Sphaerammina gerochi
	Saccammina placenta
	Haplophragmoides porrectus
640	Reticulophragmium pauperum
670	Subreophax scalaris
740	Hyperammina rugosa
750	Haplophragmoides eggeri
790	Spiroplectammina spectabilis LO
	Psammosphaera irregularis
800	Cerodinium dartmoorium
890	Alisocysta margarita LCO
900	Ammodiscus macilentus
910	Caudammina excelsa
920	Ammodiscus cretaceus
962	Reticulophragmoides jarvisi
968	Spiroplectammina spectabilis LCO
	Kalamopsis grzybowskii
	Paratrochamminoides spp.
992	Hyperammina rugosa LCO
	Haplophragmoides stomatus
	Karrerulina horrida
998	Palaeocystodinium bulliforme
1010	Spongodinium delitiense

Saga 7124/3-1

Rotary table height: 24 m

Water depth: 273 m

Depth(m)	Event (fossil) name
400	Cerodinium wardenense
	Rhizammina spp.
	Ammodiscus planus
	Rhabdammina discreta
	Spiroplectammina spectabilis LO
410	Azolla spp.
	Haplophragmoides walteri
	Haplophragmoides eggeri
	Subreophax scalaris
	Ammodiscus macilentus
	Recurvoides spp.
420	Haplophragmoides porrectus
430	Ammodiscus peruvianus
	Reticulophragmium pauperum
440	Alisocysta margarita LCO
450	Karrerulina horrida
480	Spiroplectammina spectabilis LCO
	Kalamopsis grzybowskii
	Ammosphaeroidina pseudopauciloculata
490	Palaeoperidinium pyrophorum
	Hyperammina rugosa
	Glomospira charoides
530	Glomospira gordialis
550	Verneuilinoides sp.
560	Palaeocystodinium bulliforme

Saga 7125/1-1

Rotary table height: 24 m

Water depth: 228 m

Depth(m)	Event (fossil) name
379	Reticulophragmium amplectens
403	Rhizammina spp.
415	Cerodinium wardenense
435	Cerodinium speciosum
	Ammodiscus cretaceus
	Ammosphaeroidina pseudopauciloculata
	Recurvoides spp.
445	Ammodiscus planus
	Ammodiscus peruvianus
	Fenestrella antiqua (large)
455	Cerodinium dartmoorium
465	Alisocysta sp. 2 Heilmann-Clausen
	Bathysiphon sp.
	Budashevaella multicamerata
475	Rhabdammina spp.
	Nothia robusta
487	Alisocysta margarita
	Karrerulina conversa
500	Verneuilinoides sp.
530	Areoligera cf. senonensis

545 Palaeocystodinium bulliforme
Impagidinium sp. 1 Heilmann-Clausen
550 Palaeoperidinium pyrophorum LCO
560 Glomospira gordialis
Glomospira charoides
Haplophragmoides porrectus
566 Hyperammina rugosa
Karrerulina horrida
568 Spiniferites "magnifica"
595 Spongodinium delitiense

Statoil 7119/12-1
Rotary table height: 24 m
Water depth: 200 m

Depth(m)	Event (fossil) name
450	Glomospira charoides
470	Rhizammina spp.
	Recurvoides spp.
480	Deflandrea oebisfeldensis
	Spiroplectammina spectabilis LO
	Spiroplectammina navarroana
	Ammosphaeroidina pseudopauciloculata
	Nothia robusta
	Ammodiscus planus
	Glomospira gordialis
	Ammodiscus macilentus
	Haplophragmoides kirki
	Haplophragmoides porrectus
	Karrerulina horrida
490	Cerodinium speciosum
	Paleocystodinium golzowensis
	Karrerulina conversa
500	Ammomarginulina aubertae
	Psammosphaera trinitatensis
510	Hystrichosphaeridium tubiferum
	Apectodinium hyperacanthum
	Alisocysta sp 2 Heilmann-Clausen
520	Palaeoperidinium pyrophorum
530	Ammodiscus peruvianus
	Glomospira irregularis
550	Cerodinium wardenense
605	Apectodinium augustum
620	Hyperammina rugosa
	Reticulophragmium pauperum
	Reticulophragmium intermedium
630	Palaeoperidinium pyrophorum LCO
	Spiroplectammina spectabilis LCO
	Caudammina excelsa
640	Isabelidinium cf. viborgense
	Haplophragmoides walteri
650	Kalamopsis grzybowskii
670	Alisocysta margarita
680	Saccammina placenta
	Psammosphaera sp. 1
690	Subreophax scalaris
700	Alisocysta margarita LCO
	Saccammina grzybowskii
	Paratrochamminoides olszewskii
	Psammosphaera fusca
720	Reticulophragmoides jarvisi
750	Ammodiscus cretaceus
760	Rzehakina epigona
780	Spongodinium delitiense
	Palaeocystodinium bulliforme
800	Labrospira pacifica
	Bathysiphon microraphidus
	Cystammina sveni
820	Caudammina ovula
	Caudammina gigantea

Norsk Hydro 7120/12-1
Rotary table height: 24 m
Water depth: 167 m

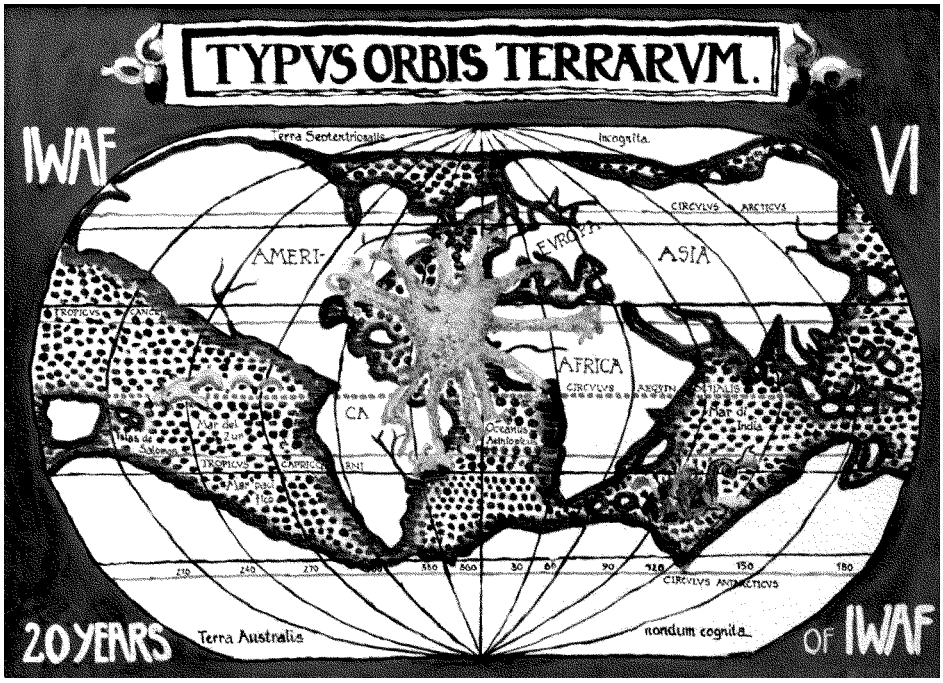
Depth(m)	Event (fossil) name
460	Apectodinium hyperacanthum
	Apectodinium spp.
	Deflandrea oebisfeldensis
470	Rhizammina spp.
	Reticulophragmium pauperum
480	Apectodinium augustum
	Bathysiphon sp.
500	Alisocysta sp. 2 Heilmann-Clausen
	Cerodinium speciosum
	Ammodiscus macilentus
	Ammosphaeroidina pseudopauciloculata
	Recurvoides spp.
	Haplophragmoides walteri
	Haplophragmoides eggeri
	Spiroplectammina spectabilis LO
	Ammodiscus peruvianus
	Rhabdammina discreta
	Hyperammina rugosa
510	Ammodiscus cretaceus
	Ammodiscus planus
	Glomospira irregularis
	Haplophragmoides kirki
520	Saccammina placenta
	Glomospira charoides
	Haplophragmoides stomatus
	Spiroplectammina spectabilis LCO
530	Alisocysta margarita
	Haplophragmoides porrectus
550	Paratrochamminoides olszewskii
560	Alisocysta margarita LCO
580	Areoligera cf. senonensis
	Caudammina excelsa
	Subreophax scalaris
590	Psammosphaera fusca
660	Impagidinium sp. 1 Heilmann-Clausen
	Palaeoperidinium pyrophorum
680	Hyperammina rugosa LCO
	Reticulophragmoides jarvisi
690	Isabelidinium cf. viborgense
	Paleocystodinium golzowensis
	Palaeocystodinium bulliforme
710	Palaeoperidinium pyrophorum LCO
	Trochamminoides subcoronatus
720	Cystammina sveni
	Ammodiscus glabratus

Norsk Hydro 7120/2-1
Rotary table height: 23 m
Water depth: 387 m

Depth(m)	Event (fossil) name
480	Cerodinium wardenense
	Cerodinium speciosa
	Hystrichosphaeridium tubiferum
495	Rhizammina spp.
	Spiroplectammina spectabilis LO
515	Ammosphaeroidina pseudopauciloculata
	Subreophax scalaris
525	Haplophragmoides walteri
	Haplophragmoides kirki
	Haplophragmoides porrectus
	Recurvoides spp.
535	Bathysiphon sp.
	Ammodiscus planus
	Ammomarginulina aubertae
545	Areoligera cf. senonensis
	Nothia robusta
	Ammodiscus macilentus
	Glomospira gordialis
	Haplophragmoides eggeri
	Ammodiscus peruvianus
555	Impagidinium sp. 1 Heilmann-Clausen
	Reticulophragmium pauperum
	Saccammina placenta
	Kalamopsis grzybowskii
	Hyperammina rugosa
	Ammodiscus cretaceus
	Glomospira charoides
	Verneuilinoides sp.
565	Glomospira irregularis
575	Spiroplectammina spectabilis LCO
585	Paratrochamminoides spp.
	Cystammina sveni
	Pseudobolivina lagenaria
595	Hyperammina rugosa LCO
	Palaeocystodinium bulliforme
605	Palaeoperidinium pyrophorum LCO
	Caudammina excelsa
	Psammosphaera fusca
	Reticulophragmoides jarvisi
730	Cerodinium dartmoorium
	Alisocysta margarita
	Nothia robusta
	Ammodiscus planus
	Ammodiscus peruvianus
	Reticulophragmium pauperum
	Ammosphaeroidina pseudopauciloculata
740	Rhizammina spp.
	Reticulophragmium sp. (robust)
	Haplophragmoides walteri
	Haplophragmoides eggeri
750	Hystrichosphaeridium tubiferum
	Haplophragmoides porrectus
	Glomospira gordialis
760	Rhabdammina spp.
	Haplophragmoides kirki
	Budashevaella multicamerata
	Verneuilinoides sp.
770	Aschemonella grandis
	Karrerulina conversa
	Glomospira charoides
	Cribrostomoides subglobosus
	Ammomarginulina aubertae
	Pseudobolivina lagenaria
780	Karrerulina horrida
	Ammodiscus macilentus
	Spiroplectammina navarroana
790	Cerodinium cf. striatum
	Haplophragmoides horridus
	Saccammina grzybowskii
800	Palaeoperidinium pyrophorum
	Spiroplectammina spectabilis LO
	Glomospira irregularis
810	Spiniferites "magnifica"
820	Psammosphaera fusca
830	Kalamopsis grzybowskii
860	Subreophax scalaris
	Sphaerammina gerochi
950	Saccammina placenta
1090	Ammodiscus cretaceus
1210	Areoligera cf. senonensis
1390	Impagidinium sp. 1 Heilmann-Clausen
1430	Paratrochamminoides spp.
	Reticulophragmoides jarvisi
	Bathysiphon microraphidus
1450	Cystammina sveni
1460	Isabelidinium cf. viborgense
1470	Palaeocystodinium bulliforme
	Palaeocystodinium bulliforme LCO
	Hyperammina rugosa

Norsk Hydro 7219/9-1
Rotary table height: 23 m
Water depth: 333 m

Depth(m)	Event (fossil) name
720	Cerodinium wardenense
	Recurvoides spp.
	Bathysiphon sp.


TYPVS ORBIS TERRARVM.
IWAF
VI
Terra Sententrionalis
Incognita.
CIRCVLVS ARCTICVS
AMERI-
EVROPA
ASIA
TROPICVS CANCRI
AFRICA
CIRCVLVS
Mar del Zur
Islas de Salomon
TROPICVS
CAPRICORNI
Oceanus Pacificus
India
270
300
330
360
30
60
90
120
150
180
CIRCVLVS ANTARCTICVS
20 YEARS
Terra Australis
nondum cognita
OF IWAF