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A palynological investigation of tills from the North Sea Basin

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A palynological investigation of tills from the North Sea Basin

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Foreword

This report comprises a palynological study of eight samples of Quaternary tills from eight BGS boreholes in the North Sea.

Contents

Summary

The palynofloras and kerogen from the eight samples proved relatively similar, however some differences in diversity and productivity were noted. All the samples yielded moderately abundant and diverse palynomorph assemblages, but two samples (4 and 2) proved relatively sparse. The samples produced a wide age range of palynomorphs, and were not dominated by any one age-related group. All the samples yielded Carboniferous spores and Quaternary palynomorphs, and therefore the Carboniferous provides the most consistent allochthonous signal. The samples also sporadically yielded Silurian, Upper Triassic (Rhaetian), Lower Jurassic (Lower Toarcian), Middle-Upper Jurassic, Cretaceous and Palaeogene palynomorphs. Despite some minor differences, the relative proportions of the marker taxa proved relatively similar. It is noteworthy that Mesozoic reworking is most common in samples 8-5. Sample 3 proved the most rich in Palaeogene and Quaternary forms. The occurrence of Silurian,

Carboniferous, Upper Triassic (Rhaetian), Lower Jurassic (Lower Toarcian), Middle-Upper Jurassic, Cretaceous, Palaeogene and Quaternary palynomorphs would be consistent with a derivation from northern Britain, including the western margin of the North Sea. Assuming that they are from the same till sheet, the ice may have been generated in Scotland and flowed south. To entrain the Silurian palynomorphs, the ice would have been generated in the Scottish Highlands and been deflected east along the Firth of Forth, perhaps by the Southern Uplands fault scarp, before flowing southwards in the North Sea Basin. An alternative source of the Silurian acritarchs would be the Ringerike area, Oslo region, Norway. The Carboniferous miospores are assumed to have been derived from Scotland and/or possibly northeast England. The Upper Triassic, Lower Jurassic, Middle-Upper Jurassic and Cretaceous palynomorphs were probably derived from northern and eastern England. The Palaeogene and Quaternary forms are assumed to have been derived locally, from the North Sea Basin.

1 Introduction

Eight samples of Quaternary glaciogenic sediments from eight boreholes in the North Sea were studied for their palynomorph content. This study aimed to determine the provenance of these sediments via allochthonous palynomorphs (e.g. Lee et al., 2002). This work has been undertaken in order to better understand the glacial history of the western margin of the North Sea Basin.

2 Sample Details

The eight samples are listed below. The columns are, respectively, the (informal) sample number, the BGS micropalaeontological registration number (prefixed MPA), the borehole number, the BGS borehole number, the depth in metres, the latitude, the longitude and the degree square.

1	MPA 57291	BH 81/26	375	54.80	58.139	-0.17717	+58-01
2	MPA 57292	BH 81/29	210	12.00	56.26517	0.82283	+56+00
3	MPA 57293	BH 81/34	230	34.00	56.128	1.58683	+56+01
4	MPA 57294	BH 81/43	595	4.00	54.64867	0.24183	+54+00
5	MPA 57295	BH 81/46	597	18.00	54.99983	0.53783	+54+00
6	MPA 57296	BH 81/48	549	8.00	53.80167	1.02267	+53+01
7	MPA 57297	BH 81/52	1232	42.07	53.531	0.73817	+53+00
8	MPA 57298	BH 82/19	622	10.30	54.7915	0.56883	+54+00

3 Palynology

The palynofloras are described in this section. Full listings of palynomorphs, including semiquantitative data, are held on the respective BGS micropalaeontology/palynology data sheets, which have been archived. The material was prepared using the sodium hexametaphosphate method of Riding and Kyffin-Hughes (2004).

The palynofloras from the eight samples proved somewhat similar, and the distribution of stratigraphically significant forms is summarised in Table 1. The kerogen assemblages are similar throughout; amorphous organic material, palynomorphs and wood generally proving relatively abundant. However, the samples exhibited some differences in diversity and productivity. All samples except numbers 4 and 2 produced moderately abundant and diverse palynomorph assemblages; samples 4 and 2 were relatively sparse (Appendix 1).

The samples are not consistently dominated by any one age-related group. All the samples yielded Carboniferous spores and Quaternary palynomorphs. Hence the Carboniferous provides the most consistent allochthonous signal. The samples also all sporadically include Silurian, Upper Triassic (Rhaetian), Lower Jurassic (Lower Toarcian), Middle-Upper Jurassic, Cretaceous and Palaeogene palynomorphs (Table 1). Despite some differences, the relative proportions of the key marker taxa proved remarkably similar. The percentages given in Table 1 refer only to the key marker species; the remainder of the palynomorphs are non age-diagnostic forms. The key marker taxa are described below, and the entire palynoflora is listed in Appendix 1. Below, the age-specific palynomorphs are discussed in eight sections.

3.1 SILURIAN

Samples 8, 4, and 3 each yielded single specimens of acritarchs of Silurian aspect. *Diexallophasis denticulata* is present in samples 8 and 4. This taxon ranges from the latest Ordovician to the Devonian, but is most characteristic of the Silurian. Sample 3 produced *Veryhachium* sp.; again the overall morphology is typical of the Silurian. These acritarchs are relatively light in colour. This means that they cannot have been derived from the cleaved slates of the Southern Uplands. The thermal alteration index of these rocks from the Southern Uplands is high, and all palynomorphs are dark brown to black in colour. The only possible British source would be the outcrops of Silurian strata in the Midland Valley of Scotland, south of the Firth of Forth, which have not been significantly metamorphosed. The ice was probably generated in Scotland and flowed south. To pick up the Silurian palynomorphs, the ice would have been generated in the Scottish Highlands and been pushed eastwards along the Firth of Forth, possibly by the Southern Uplands fault scarp, before flowing southwards into the North Sea Basin. The acritarchs appear to be similar to the floras described from the Early Silurian strata of the Ringerike area, Oslo region, Norway by Smelror (1987), and may have been derived from this area. A source from the North Sea basin is not tenable due to the high depths to the Palaeozoic strata. The Silurian acritarchs were identified by Dr S. G. Molyneux.

3.2 CARBONIFEROUS

Carboniferous spores are present throughout in relatively low proportions, generally approximately 1% of the overall palynoflora (Table 1). Carboniferous spores are especially prominent (2-3%) in sample 1. *Densosporites* spp. and *Lycospora pusilla* are the most prominent taxa; this is typically of derived Carboniferous palynomorphs (Riding et al., 2003). Also present in low numbers were *Radiizonates* spp., *Tripartites trilinguis, Tripartites vetustus* and *Tripartites* spp. *Radiizonates* spp. are characteristic of the Westphalian (Smith and Butterworth, 1967). However *Tripartites* spp. are indicative of input from the Late Viséan and Namurian (Smith and Butterworth, 1967). Therefore the Carboniferous input is from a wide interval within the Carboniferous, and is most likely to represent the incorporation of Namurian and Westphalian material. Because Palaeozoic strata are deeply buried in the North Sea basin, a local provenance is untenable. The most likely source of these miospores are the Midland Valley of Scotland and/or possibly northeast England.

3.3 UPPER TRIASSIC (RHAETIAN)

Upper Triassic miospores were also recorded in extremely low proportions between samples 8 and 5 (Table 1). These include *Krauselisporites reissingeri, Ovalipollis ovalis, Riccisporites tuberculatus, Triancoraesporites ancorae* and *Zebrasporites interscriptus*. These forms are typical of the Rhaetian Stage (e.g. Orbell, 1973; Dunay, 1978; Morbey and Dunay, 1978). Some of these have older range bases (e.g. *Ovalipollis ovalis*), or younger range tops (e.g. *Krauselisporites reissingeri* and *Riccisporites tuberculatus*) than the Rhaetian. However, this association is most indicative of the Late Triassic. Furthermore, a single, badly-preserved specimen of striate (taeniate) pollen was encountered in sample 1. These forms are typical of the Permian-Triassic interval. These miospores were probably derived from northern England; there are no obvious candidate sources in Scotland.

3.4 EARLY JURASSIC - LOWER TOARCIAN

Marine microplankton taxa which are highly characteristic of the Lower Toarcian were observed in extremely low numbers from samples 6, 7 and 8 (Table 1). These comprise *Halosphaeropsis liassica,* ?*Nannoceratopsis deflandrei* subsp *senex* and ?*Nannoceratopsis spp.* (Appendix 1). This association is typical of the early Toarcian oceanic anoxic event, which spanned the *Dactylioceras tenuicostatum* and *Harpoceras falciferum* biozones (Bucefalo Palliani et al., 2002; Bucefalo Palliani and Riding, 2003). Further evidence for this is the abundant levels of amorphous organic material in sample 6. These palynomorphs were probably sourced from northern England; a Scottish provenance seems unlikely. It may be significant that the Upper Triassic and Lower Toarcian reworking is confined to samples 8-5 (Table 1). No unequivocal representatives from these intervals were recorded in samples 4-1 (Table 1).

3.5 MIDDLE AND UPPER JURASSIC

Palynomorphs characteristic of the Middle and Upper Jurassic are also consistently present, albeit in relatively low numbers (Table 1). These are dominated by miospores and include *Calamospora mesozoica, Callialasporites* spp., *Cerebropollenites macroverrucosus, Chasmatosporites* spp., *Classopollis classoides, Classopollis meyeriana, Cyathidites* spp., *Perinopollenites elatoides* and *Retitriletes* spp. (Table 1; Appendix 1). This association is characteristically Middle and Upper Jurassic. Jurassic dinoflagellate cysts are also present in minor proportions; these are most prominent in samples 6 and 8 (Appendix 1). They comprise *Chytroeisphaeridia chytroeides, Oligosphaeridium patulum, Pareodinia* sp., *Perisseiasphaeridium pannosum, Prolixosphaeridium* spp. The age-diagnostic Jurassic dinoflagellate cysts are *Oligosphaeridium patulum* and *Perisseiasphaeridium pannosum;* these are Kimmeridgian in age (Riding and Thomas, 1988). This is reliable evidence for the incorporation of the Kimmeridge Clay Formation into these sediments. Further evidence for the Kimmeridge Clay Formation is the abundant levels of amorphous organic material in sample 6. It seems most likely that these palynomorphs were derived from northern England; a Scottish provenance is more unlikely. The only potential sources of Jurassic palynomorphs from onshore Scotland are the Moray Firth area or the Inner Hebrides.

3.6 CRETACEOUS

Allochthonous Cretaceous dinoflagellate cysts were observed sporadically, and generally in low numbers. Sample 6 is relatively rich in typically Early Cretaceous dinoflagellate cysts. The other samples with Cretaceous palynomorphs are 3, 5 and 7, however these levels are minimal.

Sample 6 yielded *Batioladinium* sp., *Cassiculosphaeridia* spp., *Cribroperidinium*? *gigas*, *Cyclonephelium distinctum, Gochteodinia villosa*, *Gochteodinia virgula*, *Phoberocysta neocomica* and *Rotosphaeropsis thula* (Appendix 1). This association is indicative of the incorporation of latest Jurassic-earliest Cretaceous (Tithonian-Ryazanian) strata. In particular, *Cribroperidinium*? *gigas*, *Gochteodinia villosa*, *Gochteodinia virgula* and *Rotosphaeropsis thula* are especially characteristic of the Jurassic-Cretaceous boundary (Davey, 1979; 1982; Heilmann-Clausen, 1987; Costa and Davey, 1992; Riding and Thomas, 1992; Bailey, 1993). The oldest possible level in the Jurassic is the latest Tithonian Oppressus Zone (Davey, 1982). For example, *Gochteodinia virgula* is confined to the latest Jurassic-earliest Cretaceous interval (Oppressus-Runctoni zones) (Abbink et al., 2001). However, a spread of ages of earliest Cretaceous material was incorporated into sample 6 because the range of *Phoberocysta neocomica* is late Ryazanian to early Aptian (Heilmann-Clausen, 1987).

The Cretaceous reworking in sample 5 is represented by *Cribroperidinium* spp., which are not age-diagnostic. By contrast, samples 7 and 3 yielded rare cavate peridinioid forms characteristic of the Late Cretaceous. ?*Trithyrodinium* sp. was encountered in sample 3 and *Chatangiella* sp is present in sample 7. These sparse occurrences represent the incorporation of the Chalk Group.

The Cretaceous input may be local if these strata were exposed in the North Sea Basin. Onshore candidate sources would be northeast and eastern England.

3.7 PALAEOGENE/NEOGENE

Allochthonous Palaeogene dinoflagellate cysts were observed rarely and sporadically. These include *Cordosphaeridium gracile*, *Deflandrea oebisfeldensis, Glaphyrocysta ordinata, Homotryblium* spp., *Hystrichosphaeridium tubiferum, Thalassiphora pelagica* and *Wetzeliella* spp. These are most prominent and diverse in samples 5 and 3. Samples 8, 7 and 6 produced extremely sparse representatives. The presence of forms such as *Deflandrea oebisfeldensis, Glaphyrocysta* spp., *Homotryblium* spp., *Hystrichosphaeridium tubiferum* and *Wetzeliella* spp. in samples 5 and 3 is indicative of the Eocene. In particular, *Deflandrea oebisfeldensis* in sample 5 is indicative of the latest Thanetian to Ypresian interval (Powell, 1992; Stover et al., 1996). Therefore, significant levels of Eocene material was incorporated into samples 5 and 3. The input from the Palaeogene is interpreted as being local, from the North Sea Basin. There are no onshore candidate sources in eastern Britain.

3.8 QUATERNARY

Both marine and terrestrial palynomorphs characteristic of the Quaternary were observed throughout. The most productive samples were numbers 3 and 1 (Table 1). Typically Quaternary dinoflagellate cysts include *Achomosphaera andalousiensis*, *Bitectatodinium tepikiense*, *Lingulodinium machaerophorum*, *Operculodinium centrocarpum*, *Selenopemphix quanta* and *Spiniferites* spp. (Table 1; Appendix 1). This association is characteristic of the Quaternary (Harland, 1992). Pollen and spores which are reminiscent of the Quaternary are also encountered including *Alnus,* Caryophyllaceae, *Dryopteris*, Gramineae, *Pinus*, *Polygonium vulgare* and *Stereisporites.* The presence of the freshwater alga *Pediastrum* spp. is consistent with the reworking of Quaternary/Neogene deposits. These palynomorphs are interpreted as being derived from the Quaternary sediments which blanket the North Sea.

3.9 NON AGE-DIAGNOSTIC PALYNOMORPHS

Several palynomorph types were observed throughout in significant proportions which are not age-diagnostic. These include acanthomorph acritarchs of Mesozoic/Cenozoic aspect, *Botryococcus braunii* and foraminiferal test linings.

4 Conclusions

The palynofloras and kerogen from the eight samples proved relatively similar, however some differences in diversity and productivity were noted. All the samples yielded moderately abundant and diverse palynomorph assemblages, but two samples (4 and 2) proved relatively sparse. The samples produced a wide age range of palynomorphs, and were not dominated by any one age-related group. All the samples yielded Carboniferous spores and Quaternary palynomorphs, and therefore the Carboniferous provides the most consistent allochthonous signal. The samples also sporadically yielded Silurian, Upper Triassic (Rhaetian), Lower Jurassic (Lower Toarcian), Middle-Upper Jurassic, Cretaceous and Palaeogene palynomorphs. Despite some minor differences, the relative proportions of the marker taxa proved relatively similar. It is noteworthy that Mesozoic reworking is most common in samples 8-5. Sample 3 proved the most rich in Palaeogene and Quaternary forms. The occurrence of Silurian, Carboniferous, Upper Triassic (Rhaetian), Lower Jurassic (Lower Toarcian), Middle-Upper Jurassic, Cretaceous, Palaeogene and Quaternary palynomorphs would be consistent with a derivation from northern Britain, including the western margin of the North Sea. Assuming that they are from the same till sheet, the ice may have been generated in Scotland and flowed south. To entrain the Silurian palynomorphs, the ice would have been generated in the Scottish Highlands and been deflected east along the Firth of Forth, perhaps by the Southern Uplands fault scarp, before flowing southwards in the North Sea Basin. An alternative source of the Silurian acritarchs would be the Ringerike area, Oslo region, Norway. The Carboniferous miospores are assumed to have been derived from Scotland and/or possibly northeast England. The Upper Triassic, Lower Jurassic, Middle-Upper Jurassic and Cretaceous palynomorphs were probably derived from northern and eastern England. The Palaeogene and Quaternary forms are assumed to have been derived locally, from the North Sea Basin.

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No.	**B/H**	**Depth (m)**	**Silurian**	**Carb.**	**U.Triassic**	**L. Jurassic**	**M. and U Jurassic**	**Cret.**	**Palaeogene**	**Quaternary**
					Rhaetian	**L. Toarcian**				
1	81/26	54.80	…	2-3%	?<1%	…	<1%	…	…	ca. 5%
2	81/29	12.00	…	1%	…	…	…	…	…	1%
3	81.34	34.00	<1%	1-2%	…	…	1-2%	<1%	1-2%	ca. 3-4%
4	81/43	4.00	<1%	1-2%	…	…	ca. 1%	…	…	ca. 1%
5	81/46A	18.00	…	1-2%	<1%	…	ca. 1%	?<1%	2-3%	ca. 2%
6	81/48	8.00	…	ca. 1-2%	<1%	ca. 1%	ca. 1-2%	ca. 2%	?<1%	<1%
7	81/52A	42.07	…	<1%	<1%	ca. 1%	<1%	<1%	ca. 1%	?ca. 1-2%
8	82/19	10.30	<1%	ca. 1-2%	<1%	<1%	? ca. 1%	…	<1%	<1%

Table 1. The percentages of age-diagnostic palynomorphs in age-related groups for each sample. Non-age diagnostic palynomorphs are not depicted here. Three dots (...) indicates that the respective palynomorph group is not represented.

Appendix 1 – listing of the palynomorph taxa recognised arranged in age-related groupings

1 Silurian acritarchs

Diexallophasis denticulata (samples 8, 4)

Veryhachium sp. (sample 3)

2 Carboniferous spores:

Carboniferous spores - undifferentiated

Densosporites spp.

Lycospora pusilla

Radiizonates sp. (samples 4 and 8)

Tripartites trilinguis (samples 3, 4 and 8)

Tripartites vetustus (sample 8)

Tripartites spp. (sample 5)

3 Upper Triassic palynomorphs:

Krauselisporites reissingeri (sample 7)

Ovalipollis ovalis (samples 5 and ?8)

Riccisporites tuberculatus (samples 6, 7, and 8)

Zebrasporites interscriptus (sample 7)

Triancoraesporites ancorae (sample 8)

4 Jurassic

4.1 Typically Lower Toarcian palynomorphs

Halosphaeropsis liassica (samples 6, 7 and 8)

?*Nannoceratopsis deflandrei* subsp. *senex* (sample 6

?*Nannoceratopsis* spp. (sample 7)

4.2 Middle and Upper Jurassic dinoflagellate cysts:

Chytroeisphaeridia chytroeides (sample 3)

Oligosphaeridium patulum (sample 6)

Pareodinia spp. (samples 5, 6 and 8)

Perisseiasphaeridium pannosum (samples 6 and ?8)

?*Prolixosphaeridium* spp. (sample 6)

?*Systematophora* sp. (sample 3)

4.3 Typically Middle and Upper Jurassic miospores:

Calamospora mesozoica

Callialasporites spp.

Cerebropollenites macroverrucosus

Chasmatosporites spp.

Cibotiumspora juriensis

Classopollis classoides

Classopollis meyeriana

Cyathidites spp.

Gleicheniidites senonicus

Perinopollenites elatoides

Retitriletes austroclavatidites

5 Cretaceous palynomorphs:

Batioladinium sp. (sample 6)

Cassiculosphaeridia spp. (sample 6)

Chatangiella sp. (sample 7)

Cribroperidinium gigas (sample 6)

Cribroperidinium spp. (samples 5, 6)

Cyclonephelium distinctum (samples 3 and 6)

Gochteodinia villosa (sample 6)

Gochteodinia virgula (sample 6)

Hystrichodinium spp. (sample 6)

Oligosphaeridium spp. (sample 6)

peridinioid cyst, cavate (sample 7)

Phoberocysta neocomica (sample 6)

Rotosphaeropsis thula (sample 6)

Senoniasphaera sp. (sample 6)

?*Trithyrodinium* sp. (sample 3)

6 Palaeogene dinoflagellate cysts:

Areoligera spp. (samples 3, 5, 8)

Chorate dinoflagellate cysts undifferentiated (samples 3, 5, ?6)

Cordosphaeridium gracile (samples 3, 5, 8)

Deflandrea oebisfeldensis (sample 5)

Deflandrea spp. (sample 5)

Glaphyrocysta ordinata (sample 5)

Glaphyrocysta spp. (sample 3)

Homotryblium spp. (samples 3, 5)

Hystrichosphaeridium tubiferum (samples 3, 7)

Palaeogene dinoflagellate cysts – undifferentiated (sample 3)

Thalassiphora pelagica (sample 5)

Wetzeliella spp. (samples 3, 5, 8)

7 Quaternary

7.1 Quaternary dinoflagellate cysts

Achomosphaera andalousiensis (samples 1, 3)

Bitectatodinium tepikiense (sample 3)

Lingulodinium machaerophorum (samples ?5, 3)

Operculodinium centrocarpum (samples 8, 3, 2, 1)

Operculodinium spp. (sample 5)

Selenopemphix quanta (sample 3)

Selenopemphix spp. (samples 2)

Spiniferites membranaceus (sample 3)

Spiniferites spp (samples ?7, 1).

7.2 Quaternary pollen and spores

Alnus (sample 1)

Anthemis type (sample 1)

Caryophyllaceae (sample 1)

Dryopteris type (samples 5, 4, 3, 2, 1)

Erica (sample 5)

Gramineae (sample 1)

Pinus (samples 5, 3, 2, 1)

Polygonium vulgare (sample 1)

quadraporate pollen (sample 1)

Stereisporites (samples 5, 3, 2, 1)

tricolpate pollen (sample 3)

triporate pollen (samples 5, 3, 1)

8 Non age-diagnostic miscellaneous microplankton:

Botryococcus braunii

Foraminiferal test linings

Micrhystridium spp.

Pediastrum spp.

Tasmanites spp.