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A palynological study of the glacigenic sediments of the Aberdeen/Buchan area

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A palynological study of the glacigenic sediments of the Aberdeen/Buchan area

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Foreword

This report is the results of a palynological investigation of some glacigenic sediments in the Aberdeen/Buchan area, north-east Scotland.

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Summary

The thirteen samples produced variably productive organic residues and palynofloras. Typically, the samples include relatively low numbers of Carboniferous spores, abundant Mid-Late Jurassic miospores, moderate to low levels of Late Jurassic, principally Kimmeridgian, dinoflagellate cysts, extremely low levels of Early Cretaceous palynomorphs, variable levels of Cretaceous/Palaeogene-Neogene dinoflagellate cysts and some Quaternary pollen and spores. The bulk of the Carboniferous spores are most likely to have been derived from Westphalian strata. The vast majority of Jurassic dinoflagellate cysts are indicative of the Kimmeridge Clay Formation and typically each productive sample contains both early and late Kimmeridgian marker species. The Carboniferous, Jurassic and Cretaceous palynomorphs are probably derived from the Moray Firth Basin. Sample 4 from the Bellscamphie Railway Cutting Excavations yielded a highly unusual palynoflora, which is dominated by spores of Lower Carboniferous (Tournaisian-Viséan) aspect. Sample 10 from Camp Fauld, south-west of Peterhead, included definite Westphalian spore taxa. Sample 9 from Bearnie, Buchan produced low numbers of Callovian/Oxfordian dinoflagellate cysts. The presence of late Hauterivian-early Barremian markers in sample 8 at the Moss of Cruden excavations, south-west of Peterhead was not confirmed. Sample 7 from the Teuchan Clay Pit, north-east of Hatton produced an assemblage wholly comprising Quaternary pollen and spores. No derived Carboniferous, Jurassic, Cretaceous or Palaeogene/Neogene palynomorphs were observed. The dominance of spore taxa with minor herbaceous pollen indicates a damp, upland region with a moorland/heathland vegetation; this is probably the local pollen component.

1 Introduction

Following an initial study of the palynology of tills from eastern Aberdeenshire, Scotland (Riding and Stephenson, 2001), a further 13 samples were submitted for study in order to determine provenance and to differentiate the tills. The palynological content of tills and other glaciogenic sediments helps to determine provenance and individual units may have distinctive organic signatures (Lee *et al*., 2002; Riding *et al*., in press). The majority of the samples are from black-dark grey, clayey tills from the coastal areas of eastern Buchan and Aberdeen. The stratigraphy of the tills in this region and associated ice movement directions are currently being investigated. For example, successions similar to the Pitlurg Till are present throughout Buchan, possibly in a variety of stratigraphical positions. These tills possibly were derived from all directions. However, reconnaissance palynology appears to indicate that some of these localities yield Kimmeridgian-dominated palynofloras, but detailed quantitative work is lacking. One question to be addressed is if the palynomorphs are from the Moray Firth to the north-west and/or from more northerly sources (Hall and Jarvis, 1995). The northerly sources would include Cretaceous and Palaeogene strata.

2 Sample Details

2.1 NUMBER AND LOCATION OF SAMPLES

1	MPA 51007	Nigg Bay, Aberdeen, cleaned section 3 (NJ 9661 0439)	0.4 m above base
2	MPA 51008	Nigg Bay, Aberdeen, cleaned section 6 (NJ 9652 0448)	1.0 m below top of till
3	MPA 51009	Cross-Stone Gravel Pit, main sump section (NJ 9525 2825)	

4	MPA 51010	Bellscamphie Railway Cutting, Pit 2 (NK 0185 3370)	7.5 m below ground
5	MPA 51011	Bellscamphie Railway Cutting , Pit 3 (c. NK 0185 3370)	6.2 m below ground
6	MPA 51012	Invernettie Diversion Excavations, Peterhead (c. NK 1215 4495)	
7	MPA 51013	Teuchan Clay Pit, Buchan (NK 08387 38957)	
8	MPA 51014	Moss of Cruden excavations, Buchan, Pit No, 31 at base of pit	c. 5.5 m below ground
9	MPA 51015	Bearnie, Buchan, Pit 1 (NJ 9668 3402)	2.07 m depth
10	MPA 51089	Oldmill Quarry, Buchan, no. OM1 (NK 024 439)	c. 1.0 m from base
11	MPA 51090	Oldmill Quarry, Buchan, no. OM2 (NK 024 439)	middle of unit
12	MPA 51091	Oldmill Quarry, Buchan, no. OM3 (NK 024 439)	c. 1.75 m below ground

2.2 LITHOSTRATIGRAPHICAL UNIT, TYPE, DATE OF COLLECTION AND COLOUR OF SAMPLES

1	Nigg Till Member	<2 mm air dry	05.02.02	light brown
2	Nigg Till Member	<2 mm air dry	05.02.02	light brown
3	Lowest Greyish Brown Till	<2 mm air dry	05.09.00	light brown/grey
4	Bellscamphie Till Formation	<2 mm air dry		light brown
5	Pitlurg Till Formation	<2 mm air dry		light-mid grey
6	Hatton Till Formation	<2 mm air dry	15.08.80	dark grey clay
7	Hatton Till Formation	<2 mm air dry	31.05.02	dark grey/black clay
8	Light grey Greensand	bulk sample		
9	Bearnie Till (?= Pitlurg Till)	<2 mm air dry	26.10.92	dark brown clay
10	Whitehills Glacigenic Fm.	bulk sample	01.08.02	grey silt/clay diamicton
11	Whitehills Glacigenic Fm.	bulk sample	01.08.02	dark grey silt/clay diamicton
12	?Whitehills Glacigenic Fm.	bulk sample	01.08.02	brown silt/clay/sand diamicton

3 Palynology

The palynofloras recovered are described in this section. Full listings of the palynomorphs recovered, including quantitative data, are held on the respective BGS micropalaeontology/palynology data sheets, which have been archived. Table 1 illustrates the numbers and percentages of specimens per microscope slide in age-related groups.

Samples 1 to 9 inclusive were prepared using sodium hexametaphosphate as a dissagregant. This is an alternative to the traditional mineral acid preparation technique. The preparation method used for sample 10 is not known, but it was probably the acid digestion method. Samples 11 to 13 were prepared using the traditional acid digestion technique.

The samples proved generally high in palynological productivity (Table 1). Allochthonous Carboniferous, Jurassic and Quaternary elements proved common throughout and Cretaceous and Palaeogene forms are relatively rare. Non-age diagnostic palynomorphs were also abundant throughout. Carboniferous and Jurassic palynomorphs are frequently reworked into the Crag Group and the Tills of East Anglia (Riding *et al*., 1997, 2000; Lee *et al*., 2002). The Jurassic dinoflagellate cysts recorded in some of the samples in this study are characteristic of the Kimmeridge Clay Formation. This phenomenon is also observed in the Tills of north Norfolk and may be related to the organic-rich lithofacies. The tenacious nature of this unit would be less readily weathered than other, more susceptible, lithologies. However, outcrop patterns would also be a significant factor.

3.1 NIGG TILL MEMBER, NIGG BAY, ABERDEEN (SAMPLES 1 AND 2)

Two samples of the Nigg Till Member have been studied, in order to determine if this till unit contains any recognisable Palaeozoic/Mesozoic palynomorphs. These may have been derived from a presumed older unit described as 'black clay with arctic shells' from the Bridge of Dee, immediately west of Nigg Bay, but not seen since the 1930s. It is thought this 'black clay with arctic shells' may have been derived from the Jurassic sediments in the offshore Moray Firth. If so, this would be the southernmost occurrence of the Whitehills Glacigenic Formation (Merritt *et al*., 2000, table 1) and would represent the oldest till unit in this region. The Bridge of Dee black clay has been correlated with the Jurassic derived glacigenic sediments in Buchan, based on some 1940s matrix particle size data. This palynological study could help to confirm this correlation. It will also possibly further separate the Dee Valley strata from the palynologically distinctive Benholm Clay Formation in Kincardineshire.

The two samples of grey-brown till from the Nigg Till Member are from cleaned sections 3 and 6. It is thought that this unit, which is the oldest part of the Nigg section, is an inland-derived till. There is a possibility that this grey-brown till contains reworked fragments of the 'black clay with arctic shells', however clast analysis has not confirmed this.

The two samples produced variably productive palynofloras. Sample 1 yielded moderately abundant palynomorphs (507 specimens per slide), however sample 2 proved relatively sparse (199 specimens per slide) (Table 1); the preservation was fair to poor. The kerogen assemblages are dominated by black wood fragments, various other plant tissues and amorphous organic material; resistant mineral grains were also common. Despite the differing palynological yields, the palynofloras are similar, with material of Carboniferous, Jurassic, Cretaceous, Cretaceous/Palaeogene, and Quaternary age present.

Carboniferous spores are present in relatively small proportions (5.9% to 2.5% of the palynoflora) (Table 1). They are dominated by *Densosporites* spp. Other forms recorded include *Lycospora pusilla* and *Reticulatisporites* sp. *Densosporites* spp. and *Lycospora pusilla* are relatively long ranging, however *Reticulatisporites* is typical of the Westphalian (Clayton and Butterworth, 1984). The provenance of these Carboniferous spores is unknown.

The Jurassic palynomorph content of this till is considerable and is dominated by miospores. These terrestrially-derived forms represent 34.1% and 33.7% of the entire palynoflora respectively (Table 1). The taxa include *Callialasporites dampieri, Callialasporites microvelatus, Callialasporites* spp., *Cerebropollenites macroverrucosus, Chasmatosporites* spp., *Cibotiumspora juriensis, Classopollis classoides, Coronatispora valdensis, Ischyosporites variegatus, Perinopollenites elatoides* and *Retitriletes austroclavatidites.* Of these forms, *Cerebropollenites macroverrucosus, Classopollis classoides* and *Perinopollenites elatoides* are most common. This association indicates a significant input of Mid-Late Jurassic strata (Riding *et al*., 1991). The Moray Firth is probably the major source of these Jurassic miospores. Jurassic dinoflagellate cysts were recorded from both samples in low numbers (?1.0% and 0.5% respectively, Table 1). Sample 1 produced several questionable specimens of *Cribroperidinium globatum*, which is characteristic of the Kimmeridgian (Riding and Thomas, 1988). *Amphorula expirata* was recorded from sample 2. This species ranges from the late Kimmeridgian to the early Ryazanian (Riding and Thomas, 1992; Abbink *et al*., 2001). These occurrences thus indicate the incorporation of small levels of Late Jurassic strata. Again, the Moray Firth area is the obvious source for these.

The only indication of derived material from the Lower Cretaceous is in sample 1, where a single specimen of the characteristically Early Cretaceous spore genus *Cicatricosisporites* was recognised. The Moray Firth also seems to be the nearest potential source area. No Cretaceous or Palaeogene dinoflagellate cysts were found in this unit.

The two samples both yielded abundant Quaternary pollen and spores (46.6% and 51.7% respectively, Table 1). These forms include *Alnus, Laevigatosporites, Pinus, Polypodium* and

Stereisporites and were probably derived from the Quaternary strata of the North Sea, or locally on land.

Based on the palynomorph content, the samples are most likely having been derived from the 'black clay with arctic shells' reported by Bremner from the Bridge of Dee excavations in the 1930s. If this interpretation is correct, the 'black clay with artic shells' is likely to be the southernmost occurrence of the Whitehills Glacigenic Formation and derived from the Moray Firth.

3.2 LOWER GREY BROWN TILL, CROSS STONE QUARRY (SAMPLE 3)

Sample 3 is of a dark coloured clay containing ammonite fragments and fish scales. This unit was reported from railway cutting excavations in the 19th century, immediately to the west of the site which was sampled. This 'indigo till' south of Ellon is now inaccessible. The local stratigraphy suggests that this grey brown till is younger than the 'black clay' of section 3.1 and therefore it may contain reworked Mesozoic microfloras originally from the 'black clay'. The 'black clay' is equivalent to the Whitehills Glacigenic or Pitlurg Till formations (Merritt *et al.,* 2000).

The sample produced a sparse organic residue. The residue is dominated by resistant mineral grains. Black wood, plant tissue and palynomorphs are all relatively rare; 68 palynomorph grains are present per microscope slide (Table 1). The palynomorph preservation was poor.

Carboniferous spores are rare, comprising 7.4% of the palynoflora (Table 1). They are dominated by the long ranging genus *Densosporites*. The provenance of these spores is unknown.

Jurassic palynomorphs in this till are significant and dominated by miospores; these form 17.6% of the palynoflora (Table 1), and include include *Cerebropollenites macroverrucosus* and *Perinopollenites elatoides*. The species recovered are relatively long ranging. The only Jurassic dinoflagellate cyst observed was a single, questionable specimen of *Cribroperidinium globatum*, which is indicative of the Kimmeridgian. This suggests that at least some of the Jurassic reworking is from the Late Jurassic and the Morey Firth area is the probable source for these.

A single specimen of *Spiniferites* was encountered. This dinoflagellate cyst genus is long ranging from the Cretaceous to the Quaternary. Its source was probably from the Late Cretaceous to Palaeogene interval of the North Sea.

The sample yielded relatively common Quaternary pollen and spores (35.3%, Table 1). These forms include the moss pollen *Stereisporites* and were probably derived from the Quaternary strata of the North Sea or onshore. This low diversity association may be from mixed sources hence cannot give a definitive stratigraphical or palaeoclimatological breakdown.

The palynomorph content suggests with that this horizon was reworked from an occurrence of the 'Indigo till' (= the Whitehills Glacigenic Formation).

3.3 BELLSCAMPHIE RAILWAY CUTTING EXCAVATIONS (SAMPLES 4 AND 5)

Two samples from the Bellscamphie Railway cutting were studied. This locality is the type site for the Hatton, Pitlurg and Bellscamphie tills (Hall and Jarvis, 1995). Reconnaissance work indicates that the tills do contain palynomorphs. These two samples yielded profoundly differently palynomorph associations. Sample 4 is dominated by Early Carboniferous spores and the age diagnostic fraction of sample 5 largely comprises Jurassic forms.

3.3.1 Sample 4

Carboniferous spores dominate sample 4 and they comprise 69.6% of the assemblage. This is an unusual assemblage, because it is of Early Carboniferous aspect; the majority of the

Carboniferous spores in palynologically productive Till samples in the UK are rich in Westphalian spores (Lee *et al*., 2002). The following taxa are present: *Auroraspora macra*, *Convolutispora* spp., *Discernisporites micromanifestus*, ?*Lycospora pusilla*, *Murospora* cf. *aurita* and *Stenozonotriletes* spp. *Auroraspora macra* ranges from the latest Devonian to Viséan (LL to Pu biozones) (Higgs *et al*., 1988). The assemblage is similar to those associated with the Cementstone facies of the Midland Valley of Scotland which was deposited during the late Tournaisian to earliest Viséan. However it is unlikely that these spores had a southerly source and it is possible that they were sourced offshore.

Mesozoic material is extremely rare. Two typically Jurassic palynomorphs were recovered. These are the pollen grain *Perinopollenites elatoides* and the dinoflagellate cyst ?*Cribroperidinium globatum*. The latter species is typical of the Kimmeridgian Stage (Riding and Thomas, 1988) and these forms are assumed to have been derived from the Moray Firth area. No Cretaceous or Palaeogene dinoflagellate cysts were found in this sample. The sample yielded relatively common Quaternary pollen and spores (13.1%, Table 1). These forms are dominated by pine pollen (*Pinus*) and thus indicate the incorporation of upland pollen.

3.3.2 Sample 5

Sample 5 is overwhelmingly dominated by Jurassic palynomorphs which account for 44.9% of the entire palynoflora (Table 1). The kerogen association is dominated by wood fragments and amorphous organic material. Palynomorph preservation proved good/fair. Carboniferous spores are extremely rare, comprising 0.3% of the palynoflora (Table 1). Only representatives of the long ranging genus *Densosporites* are present; the provenance of these spores is unknown.

Except for non-age diagnostic palynomorphs, Jurassic pollen and spores are the largest component in this sample. Taxa represented include *Callialasporites dampieri, Callialasporites microvelatus, Callialasporites trilobatus, Callialasporites turbatus, Cerebropollenites macroverrucosus, Cibotiumspora juriensis, Classopollis classoides, Classopollis meyeriana, Coronatispora valdensis, Cyathidites* spp*.*, *Ischyosporites variegatus* and *Perinopollenites elatoides.* Of these forms, *Cerebropollenites macroverrucosus, Classopollis classoides, Cyathidites* spp*.,* and *Perinopollenites elatoides* are especially common. This miospore association indicates that the reworking is mostly no older than Mid Jurassic, largely due to the abundance and diversity of *Callialasporites* (Riding *et al*., 1991; Seidenkrantz *et al*., 1993, fig. 3). The Moray Firth is assumed to be the source of these Jurassic miospores. They are most likely to be derived from the Brora Coal Formation. If they were sourced from Callovian-Oxfordian formations, they would be accompanied by dinoflagellate cysts of this age. Although some dinoflagellate cysts which lie within this range are present, no intra Callovian-Oxfordian marker forms were encountered. The diverse Jurassic dinoflagellate cyst association (7.5% of the assemblage) is indicative of a Late Jurassic (Kimmeridgian) age. Forms recognised include ?*Aldorfia dictyota, Ambonosphaera*? *staffinensis*, *Cribroperidinium gigas/longicorne, Cribroperidinium globatum, Cribroperidinium* spp., *Endoscrinium galeritum, Endoscrinium luridum, Gochteodinia mutabilis, Leptodinium* sp., *Muderongia simplex, Pareodinia ceratophora, Pareodinia halosa, Senoniasphaera jurassica, Sirmiodinium grossii, Systematophora areolata* and *Systematophora* spp. There is some mixing of this assemblage. Certain species are indicative of the early Kimmeridgian; these include *Endoscrinium galeritum* and *Endoscrinium luridum.* Both these species are present in the Callovian and Oxfordian interval, however no Callovian or Oxfordian marker taxa are present. Forms such as *Gochteodinia mutabilis* and *Muderongia simplex* are confined to the late Kimmeridgian (Riding and Thomas, 1988). *Muderongia simplex* ranges into the overlying Portlandian (Riding *et al*., 2000). *Senoniasphaera jurassica* is also typical of the late Kimmeridgian (Riding and Thomas, 1988). Furthermore, the preponderance of amorphous organic material is typical of the Kimmeridge Clay Formation. The source of these Kimmeridgian forms is assumed to be the Moray Firth.

Sample 5 yielded a single specimen of the latest Jurassic-Early Cretaceous dinoflagellate *Gochteodinia villosa* (Table 1). This taxon ranges from the late Portlandian to the earliest Valanginian (Riding and Thomas, 1992; Costa and Davey, 1992). The presence of this species in isolation is surprising because Lower Cretaceous dinoflagellate cyst associations are typically diverse. The specimen is probably derived from the Moray Firth Basin.

Significant numbers (3.4%) of long ranging dinoflagellate cyst genera such as *Batiacasphaera*, *Circulodinium* and *Spiniferites* were found. These are not especially age diagnostic but they are thought to be derived from the Late Cretaceous to Palaeogene/Neogene interval.

Sample 5 yielded rare Quaternary pollen and spores (0.08%, Table 1). These forms include *Tilia* and this sparse flora cannot give a refined stratigraphical or palaeoclimatological breakdown.

3.4 INVERNETTIE ROAD WORKS EXCAVATIONS, PETERHEAD (SAMPLE 6)

This sample was taken from a large raft of dark grey/black calcareous, shelly clay diamiction within the Hatton Till Formation, exposed by road workings. Preliminary work has indicated a rich Mesozoic (?Late Jurassic-Early Cretaceous) flora. The purpose of analysing this sample is to determine whether this unit has an organic content similar to that of the type Pitlurg Till.

Sample 6 yielded an extremely abundant palynoflora (2768 grains per slide, Table 1). The kerogen assemblage is dominated by amorphous organic material and wood fragments. Carboniferous spores are extremely rare, comprising 0.3% of the palynoflora (Table 1). The long ranging genus *Densosporites* dominates this association and the provenance of these spores is unknown.

Jurassic pollen, spores and dinoflagellate cysts are the largest age-diagnostic component in this sample. Miospore taxa represented comprise *Callialasporites dampieri, Callialasporites microvelatus, Callialasporites trilobatus, Callialasporites turbatus, Callialasporites* spp., *Cerebropollenites macroverrucosus, Classopollis classoides, Classopollis meyeriana, Coronatispora valdensis, Cyathidites* spp., *Perinopollenites elatoides* and *Retitriletes austroclavatidites. Cerebropollenites macroverrucosus, Cyathidites* spp. and *Perinopollenites elatoides* are most common. This miospore association indicates that this fraction is mostly no older than Mid Jurassic, largely due to the abundance and diversity of *Callialasporites* (Seidenkrantz *et al*., 1993, fig. 3). The Moray Firth is assumed to be the source of these miospores, which are most likely to be derived from the Brora Coal Formation (see section 3.3).

The extremely diverse Jurassic dinoflagellate cyst association (17.3% of the assemblage) is indicative of a Late Jurassic (Kimmeridgian) age. *Chytroeisphaeridia chytroeides, Cribroperidinium gigas, Cribroperidinium longicorne, Cribroperidinium globatum, Endoscrinium luridum, Endoscrinium* sp., ?*Gochteodinia mutabilis, Hystrichosphaerina orbifera, Mendicodinium groenlandicum, Muderongia simplex, Pareodinia* spp., *Perisseiasphaeridium pannosum, Scriniodinium crystallinum, Senoniasphaera jurassica,* and *Systematophora daveyii* were recognised. Most of these forms are indicative of a Kimmeridgian age, which is consistent with the abundance of amorphous organic material. Like sample 5, there was incorporation of more than one Late Jurassic horizon into this unit. Some marker species such as *Endoscrinium luridum* and *Scriniodinium crystallinum* are indicative of the early Kimmeridgian. Both these species are also present in the Callovian and Oxfordian interval, however no other markers from this interval are present. Species such as *Cribroperidinium longicorne* and *Perisseiasphaeridium pannosum* are confined to the Kimmeridgian Stage (Riding and Thomas, 1988, fig. 6). Furthermore, the abundance of *Cribroperidinium globatum* (371 specimens per microscope slide) is additional evidence of a Kimmeridgian age. Forms such as *Gochteodinia mutabilis*, *Muderongia simplex* and common *Senoniasphaera jurassica* are present in the late Kimmeridgian (Riding and Thomas, 1988). Hence at least two Kimmeridgian levels have been incorporated. The source of these Kimmeridgian forms is assumed to be the Kimmeridge Clay Formation of the Moray Firth Basin.

Early Cretaceous elements were found in extremely low proportions (Table 1). A single specimen of the typically Early Cretaceous spore genus *Cicatricosisporites* was recovered. As in sample 5, this horizon produced the latest Jurassic-Early Cretaceous dinoflagellate *Gochteodinia villosa*. This taxon ranges from the late Portlandian to the earliest Valanginian (section 3.2.2). The Moray Firth seems to be the nearest potential source area for these forms.

Relatively small proportions (2.6%) of long ranging dinoflagellate cyst genera such as *Circulodinium, Hystrichosphaeridium, Oligosphaeridium* and *Spiniferites* were found. These are not age diagnostic but they are thought to be derived from the Late Cretaceous to Palaeogene/Neogene interval.

Sample 6 yielded extremely rare Quaternary pollen/spores (0.1%, Table 1); this sparse flora does not give a refined stratigraphical or palaeoclimatological breakdown.

3.5 TEUCHAN CLAY PIT ('NEW PIT') NORTH-EAST OF HATTON (SAMPLE 7)

No definite *in situ* Pitlurg Till has been observed in these new excavations near Hatton. Nearby boreholes suggest it is present beneath *c*. 5 m of the Hatton Till Formation. However, rafts and lenses of black/dark grey clay diamicton were observed on 31st May 2002 by E. R. Connell. This sample was taken from the most extensive raft/lens of this facies.

Sample 7 produced a moderately abundant organic residue and palynoflora; 2287 palynomorphs were counted per microscope slide. Preservation proved good to fair. Black wood and other plant tissues were common; silicious remains are also present. The palynoflora entirely comprises Quaternary pollen and spores, no derived Carboniferous to Palaeogene/Neogene palynomorphs were observed. Forms identified include *Bryonia/Gentianella*, Compositae, Ericales, *Laevigatosporites*, *Pinus*, *Polypodium* and *Sphagnum*. *Laevigatosporites, Polypodium* and the spores of *Sphagnum* moss (*Stereisporites*) are most common. This spectrum, together with the accessory forms, is indicative of a wet, upland moorland/heathland vegetation. Tree pollen, except for minor levels of *Pinus*, is absent. This pine pollen may have been transported via wind.

3.6 MOSS OF CRUDEN EXCAVATIONS, SOUTH-WEST OF PETERHEAD (SAMPLE 8)

A sample of 'Greensand' from *c*. 5.5 m at Pit 31 at the Moss of Cruden Excavations was studied. This locality was described by Hall and Jarvis (1994). Preliminary palynological work on this horizon has indicated a well preserved microflora of late Hauterivian-early Barremian age. However the original slide preparations have apparently been lost. A possible belemnite (or a circular, elongate dissolution feature) and a superbly preserved small echinoid is also present in this sample of white/cream/light grey sandstone.

This sample proved extremely sparse organically, in fact it is virtually palynologically barren. The residue is dominated by resistant mineral grains and fragments of black wood. Poorly preserved palynomorphs are extremely rare (11 per slide; Table 1). Two possible Jurassic pollen grains, ?*Callialasporites* sp. and ?*Perinopollenites elatoides*, and 5 miospores of Quaternary aspect were observed. The remainder of the palynomorphs are not age diagnostic. Due to this sparse palynoflora, the incorporation of late Hauterivian-early Barremian markers was not confirmed.

3.7 BEARNIE, BUCHAN (SAMPLE 9)

A single sample from the Bearnie Till Member was studied (Merritt *et al*., 2000, table 1). This material was thought to have been derived from basic igneous rocks west and north of Ellon. However, a preliminary palynological study has indicated a rich Mesozoic assemblage.

Therefore the Bearnie Till may be a representative of the Pitlurg Till. Sample 9 produced an abundant and diverse palynoflora, which is well preserved; the sample yielded 2897 specimens per slide (Table 1). The kerogen assemblages are rich in amorphogen and black wood; other plant tissues are less common. Carboniferous, Jurassic, Cretaceous, Cretaceous/Palaeogene, and Quaternary palynomorphs are represented.

Carboniferous spores proved rare, comprising 1.5% of the palynoflora (Table 1). The long ranging forms *Densosporites* and *Lycospora pusilla* were recognised; the provenance of these spores is not known.

Jurassic palynomorphs are overwhelmingly the largest age-diagnostic component in this sample, totalling 39.2% (Table 1). Miospores comprise the majority of this and make up 35.1% of the entire palynoflora. The Jurassic miospore taxa recognised include *Callialasporites dampieri, Callialasporites microvelatus, Callialasporites trilobatus, Callialasporites turbatus, Cerebropollenites macroverrucosus, Cibotiumspora juriensis, Classopollis classoides, Contignisporites* sp., *Coronatispora valdensis, Cyathidites* spp., *Ischyosporites variegates* and *Perinopollenites elatoides. Cerebropollenites macroverrucosus, Classopollis classoides, Cyathidites* spp. and *Perinopollenites elatoides* are the most common elements. This miospore assemblage indicates that this spectrum is mostly no older than Mid Jurassic, largely due to the significant occurrence of the genus *Callialasporites*. The Moray Firth Basin is assumed to be the principal source of these miospores, which are possibly derived from the paralic Brora Coal Formation. However, Callovian-Oxfordian taxa are present in low proportions, thus some input of miospores from this interval is entirely possible. They may also be derived from the Kimmeridgian, which appears to be the principal source of the Jurassic input into this sample.

The Jurassic dinoflagellate cyst association (4.1% of the assemblage) is largely indicative of the Late Jurassic. This relatively diverse association includes *Cribroperidinium gigas, Cribroperidinium longicorne, Cribroperidinium globatum, Crussolia deflandrei, Gochteodinia mutabilis, Gonyaulacysta jurassica* subsp. *adecta, Gonyaulacysta jurassica* subsp. *jurassica, Mendicodinium groenlandicum, Pareodinia* spp., *Senoniasphaera jurassica, Systematophora areolata, Systematophora daveyii* and *Systematophora* spp. *Cribroperidinium globatum* and *Systematophora* spp. are the most common elements. The majority of these forms are indicative of a Kimmeridgian age, which is consistent with the abundance of amorphous organic material (Riding and Thomas, 1988). The entire Kimmeridgian Stage appears to be represented and there appears to have been some mixing. *Cribroperidinium longicorne* is confined to this stage, having its range top within the *P. hudlestoni* standard (ammonite) zone (Riding and Thomas, 1988, fig. 6). *Cribroperidinium globatum* and *Systematophora daveyii* are also typical of the entire Kimmeridgian Stage. *Gonyaulacysta jurassica* subsp. *jurassica* has its range top at the Lower-Upper Kimmeridgian boundary (Riding and Thomas, 1988), but may also have been incorporated from Oxfordian strata (see below). *Senoniasphaera jurassica* is present in significant numbers and, like *Cribroperidinium gigas* and *Gochteodinia mutabilis* which are also present, is most typical of the Upper Kimmeridgian (Riding and Thomas, 1988, fig. 3). The source of these Kimmeridgian dinoflagellate cysts is probably the Kimmeridge Clay Formation of the Moray Firth Basin.

There is also evidence of the incorporation of more than one Late Jurassic horizon into this unit. Sample 9 also provides evidence of minor amounts of Callovian-Oxfordian reworking. A single specimen of *Gonyaulacysta jurassica* subsp. *adecta* was recovered. This form is most typical of the Callovian Stage, but ranges into the Oxfordian (Riding and Thomas, 1992). Also a single representative of *Crussolia deflandrei* strongly suggests the early Oxfordian (Riding and Thomas, 1997). The occurrences of *Gonyaulacysta jurassica* subsp. *jurassica* and *Mendicodinium groenlandicum* are also consistent with the incorporation of Oxfordian strata. This could be derived from the Heather Formation from the offshore Moray Firth Basin and/or its onshore equivalents.

Two specimens of the typically Early Cretaceous spore *Cicatricosisporites* were recovered. This is the only evidence for the Cretaceous, and the Moray Firth is postulated as a source area.

Small proportions (1.4%) of long ranging dinoflagellate cyst genera such as *Oligosphaeridium* and *Spiniferites* were found. These are not particularly age diagnostic but they are thought to be derived from the Late Cretaceous to Palaeogene/Neogene interval.

This sample 6 produced rare Quaternary pollen/spores (0.8%, Table 1) and this sparse flora does not permit a stratigraphical or palaeoclimatological breakdown.

Sample 9 produced an association which has a similar palynological signature to that of sample 5, which is unequivocally from the Pitlurg Till, indicating a probable correlation.

3.8 CAMP FAULD, SOUTH-WEST OF PETERHEAD (SAMPLE 10)

Two palynological slides from Pit A at *c*. 4.0m depth from the Camp Fauld Till (Merritt *et al*., 2000, table 1,) at Camp Fauld near Peterhead were submitted for analysis. The sample of dark grey, silty diamicton was presumably prepared in the normal way using mineral acids and the residue has been oxidised. The sampled horizon is a dark grey silty diamicton and is thought to have been derived from Mesozoic mudstones in the Moray Firth. This is the only known site where a till with a matrix probably derived from Mesozoic rocks occurs in an apparently unequivocal pre-Oxygen Isotope Stage (OIS) 5 position (i.e. within the last interglacial) (Whittington *et al*., 1993). The slides are, unfortunately badly damaged and this factor makes them rather difficult to study. Nevertheless, they yielded a moderately abundant palynoflora (597 specimens per slide), which is reasonably well preserved. Wood fragments and plant tissue are also present; amorphogen is virtually absent.

Carboniferous spores are present in low proportions (1.5%, Table 1). The association includes *Densosporites* spp., *Endosporites zonalis* and *Radiisporites aligerens*. *Endosporites zonalis* and *Radiisporites aligerens* are confined to the Westphalian (Clayton *et al*., 1977; Clayton and Butterworth, 1984), indicating a Westphalian source for these spores. The provenance of these spores is unknown.

Jurassic miospores are the largest age-diagnostic component in sample 10. Taxa recognised include *Callialasporites dampieri, Callialasporites trilobatus, Callialasporites turbatus,* ?*Callialasporites* sp., *Cerebropollenites macroverrucosus, Chasmatosporites* sp., *Classopollis classoides, Cyathidites* spp., *Dictyophyllidites* sp. and *Perinopollenites elatoides. Cerebropollenites macroverrucosus, Classopollis classoides* and *Perinopollenites elatoides* are the most common elements. This miospore association indicates that this fraction is mostly no older than Mid Jurassic, largely due to the significant occurrence of *Callialasporites*. The Moray Firth is assumed to be the source of these miospores, which are possibly derived from the paralic Brora Coal Formation (see section 3.3). If they were sourced from the Callovian-Oxfordian formations, they would be accompanied by marker dinoflagellate cysts of this age (Riding and Thomas, 1992). Jurassic dinoflagellate cysts are extremely sparse. Questionable single specimens of *Cribroperidinium longicorne* (Kimmeridgian) and *Nannoceratopsis deflandrei* subsp. *deflandrei* (Toarcian-Aalenian) are present. However, 14 specimens of the typically Kimmeridgian dinoflagellate cyst *Cribroperidinium globatum* were counted. The source of this Kimmeridgian material is assumed to be the Kimmeridge Clay Formation of the Moray Firth Basin.

No Cretaceous to Quaternary marker species were recovered. Low proportions (1.3%) of long ranging dinoflagellate cysts such as *Batiacasphaera* and *Circulodinium* were encountered; these are not age diagnostic. They are thought to have been derived from Cretaceous to Palaeogene/Neogene strata. The sample yielded rare Quaternary pollen and spores (2.0%); this sparse flora cannot provide a refined stratigraphical/palaeoclimatological breakdown.

3.9 OLDMILL QUARRY, BUCHAN (SAMPLES 11 TO 13)

Three till samples were submitted from this locality which was described by Merritt and Connell (2000). Samples 11 and 12 come from diamictons associated with glacigenic rafts within the Whitehills Glacigenic Formation. They are both samples of dark grey/black massive silt/clay diamicton. This colour and lithology suggests a derivation from the Mesozoic mudstone units in the Moray Firth. Sample 13 is a brown, massive silt/clay/sand diamicton which overlies samples 11 and 12. This uppermost brown unit closely resembles the underlying grey/black till and is thought to be an exposed weathered profile of the Whitehills Glacigenic Formation. This brown deposit is apparently different to the Hythie Till Formation. This unit is thin (max. 2.0 m) and laterally discontinuous; it was originally seen in the first exposures at Oldmill Quarry. The Hythie Till Formation 'plastered' onto the west facing slope of the valley in which this pit was dug by the easterly advancing East Grampians ice (Merritt and Connell, 2000, fig. 31).

3.9.1 Samples 11 and 12

Samples 11 and 12, from the unweathered lithofacies of the Whitehills Glacigenic Formation produced abundant, diversity, well preserved palynomorph associations. The samples yielded 2300 and 2219 specimens per microscope slide respectively (Table 1). The kerogen assemblages are rich in amorphogen, black wood and other plant tissues. Both palynofloras are remarkably both in terms of species and relative proportions; material of Carboniferous, Jurassic, Cretaceous, Cretaceous/Palaeogene, and Quaternary age are represented.

Carboniferous spores proved extremely rare, comprising 0.05% of the palynoflora (Table 1). The only recognisiable form is ?*Densosporites* in sample 11 and the provenance of these spores is unknown.

Jurassic palynomorphs are by far the largest age-diagnostic component in samples 11 and 12. The miospore taxa recognised include *Callialasporites dampieri, Callialasporites microvelatus, Callialasporites trilobatus, Callialasporites turbatus, Callialasporites segmentatus, Cerebropollenites macroverrucosus, Classopollis classoides, Contignisporites* sp., *Coronatispora valdensis, Cyathidites* spp., *Ischyosporites variegatus, Perinopollenites elatoides, Retitriletes austroclavatidites, Sestrosporites pseudoalveloatus* and *Vitresporites pallidus. Callialasporites* spp., *Cerebropollenites macroverrucosus, Classopollis classoides, Cyathidites* spp. and *Perinopollenites elatoides* are most common. This miospore association indicates that this fraction is mostly no older than Mid Jurassic, largely due to the significant occurrence of *Callialasporites* (Seidenkrantz *et al*., 1993, fig. 3). The Moray Firth is assumed to be the source of these miospores, which are possibly derived from the paralic Brora Coal Formation (see section 3.3). If they were sourced from Callovian-Oxfordian formations, these miospores would be accompanied by marker dinoflagellate cysts of this age (Riding and Thomas, 1992). Although some dinoflagellate cysts which lie within this range are present, no specific intra Callovian-Oxfordian marker forms were encountered. The diverse Jurassic dinoflagellate cyst associations (10.9% and 6.6% of the assemblages respectively) are indicative of a Kimmeridgian age. Forms recognised include *Acanthaulax venusta, Aldorfia dictyota* subsp. *papillata, Cribroperidinium longicorne, Cribroperidinium globatum, Cribroperidinium* spp., *Ctenidodinium* sp., *Endoscrinium galeritum, Endoscrinium luridum, Glossodinium dimorphum, Gonyaulacysta jurassica* subsp. *jurassica, Hystrichosphaerina orbifera, Leptodinium arcuatum, Leptodinium subtile*, *Leptodinium* spp., *Muderongia simplex, Oligosphaeridium patulum, Pareodinia ceratophora*, *Pareodinia halosa, Pareodinia* spp., *Perisseiasphaeridium pannosum, Rhynchodiniopsis cladophora, Scriniodinium crystallinum, Senoniasphaera jurassica, Sirmiodinium grossii, Systematophora areolata* and *Systematophora daveyii*. *Cribroperidinium globatum, Glossodinium dimorphum, Pareodinia* spp. and *Senoniasphaera jurassica* are most common. This association is indicative of the Kimmeridgian Stage at its type locality and elsewhere in Europe (Riding and Thomas, 1988). The entire Kimmeridgian Stage is represented and there has been some mixing. *Cribroperidinium longicorne, Oligosphaeridium patulum* and

Perisseiasphaeridium pannosum are confined to this stage (Riding and Thomas, 1988, fig. 6). Certain species are present which have known range tops in the early Kimmeridgian; these are *Aldorfia dictyota* subsp. *papillata, Endoscrinium galeritum, Endoscrinium luridum, Gonyaulacysta jurassica* subsp. *jurassica, Rhynchodiniopsis cladophora* and *Scriniodinium crystallinum.* The latter species has a last appearance datum in the earliest Kimmeridgian *Pictonia baylei* standard (ammonite) zone (Riding and Thomas, 1992). These early Kimmeridgian species are present in the Callovian/Oxfordian, yet no specific Callovian and/or Oxfordian markers are present. *Muderongia simplex* has a range of late Kimmeridgian to mid Portlandian (Riding *et al*., 2000) and *Senoniasphaera jurassica* is most typical of the late Kimmeridgian (Riding and Thomas, 1988, fig. 3). The abundance of amorphous organic material is typical of the Kimmeridge Clay Formation. The source of these Kimmeridgian forms is assumed to be the Kimmeridge Clay Formation of the Moray Firth Basin. There is a minor indication of derived material from the Lower Cretaceous in sample 11. At this level, a single specimen of the typically Early Cretaceous spore genus *Cicatricosisporites* is present. Additionally, a single specimen of the long ranging Cretaceous (Barremian-Maastrichtian) dinoflagellate cyst *Odontochitina operculata* was found in sample 12. The Moray Firth also is the most likely source area for both these specimens.

Low proportions (0.7% and 1.1%) of long ranging dinoflagellate cysts such as *Circulodinium, Cleistosphaeridium* and *Spiniferites* were encountered. These are not age diagnostic but are thought to be derived from the Cretaceous to Palaeogene/Neogene interval.

Both samples yielded rare Quaternary pollen and spores (0.6% and 0.5%); this sparse flora cannot provide a refined stratigraphical/palaeoclimatological breakdown.

3.9.2 Sample 13

Sample 13 produced an extremely sparse, poorly preserved palynoflora and kerogen residue. The organic residue comprised rare wood fragments, finely comminuted debris and palynomorphs. Only 24 palynomorph grains were counted on one microscope slide (Table 1). Three possible Jurassic palynomorphs were found; these are a single specimen of ?*Callialasporites turbatus* and two specimens of ?*Classopollis* spp. These are not especially biostratigraphically significant and were probably derived from the Moray Firth. The remainder of the association are non age diagnostic palynomorphs such as bisaccate pollen and prasinophytes. The sparse, poorly preserved nature of this sample is entirely consistent with the uppermost brown till having being exposed and weathered. The organic material has been largely oxidised during this weathering episode.

4 Summary/Conclusions

The thirteen samples produced variably productive organic residues and palynofloras. Typically, the samples include relatively low numbers of Carboniferous spores, abundant Mid-Late Jurassic miospores, moderate to low levels of Late Jurassic, principally Kimmeridgian, dinoflagellate cysts, extremely low levels of Early Cretaceous palynomorphs, variable levels of Cretaceous/Palaeogene-Neogene dinoflagellate cysts and some Quaternary pollen and spores. The bulk of the Carboniferous spores are most likely to have been derived from Westphalian strata. The vast majority of Jurassic dinoflagellate cysts are indicative of the Kimmeridge Clay Formation and typically each productive sample contains both early and late Kimmeridgian marker species. The Carboniferous, Jurassic and Cretaceous palynomorphs are probably derived from the Moray Firth Basin. Sample 4 from the Bellscamphie Railway Cutting Excavations yielded a highly unusual palynoflora, which is dominated by spores of Lower Carboniferous (Tournaisian-Viséan) aspect. Sample 10 from Camp Fauld, south-west of Peterhead, included definite Westphalian spore taxa. Sample 9 from Bearnie, Buchan produced low numbers of

Callovian/Oxfordian dinoflagellate cysts. The presence of late Hauterivian-early Barremian markers in sample 8 at the Moss of Cruden excavations, south-west of Peterhead was not confirmed. Sample 7 from the Teuchan Clay Pit, north-east of Hatton produced an assemblage wholly comprising Quaternary pollen and spores. No derived Carboniferous, Jurassic, Cretaceous or Palaeogene/Neogene palynomorphs were observed. The dominance of spore taxa with minor herbaceous pollen indicates a damp, upland region with a moorland/heathland vegetation; this is probably the local pollen component.

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No.	Grains /slide	Carb. spores	Jur. miospores	Jur. d. cysts	L. Cret. spores	Cret. d. cysts	Cret./P.gene d. cysts	Quat. miospores	Non age-diagnostics
1	507	30 (5.9%)	173 (34.1%)	?5 (?1.0%)	1 (0.2%)	…	…	235 (46.4%)	63 (12.4%)
2	199	5 (2.5%)	67 (33.7%)	1 (0.5%)	…	…	…	103 (51.7%)	23 (11.6%)
3	68	5 (7.4%)	12 (17.6%)	?1 (?1.5%)	…		1 (1.5%)	24 (35.3%)	25 (36.7%)
4	260	?181 (?69.6%)	1 (0.4%)	?1 (?0.4%)	…	…	…	34 (13.1%)	43 (16.5%)
5	3578	11 (0.3%)	1339 (37.4%)	270 (7.5%)	…	1 (0.02%)	123 (3.4%)	3 (0.08%)	1831 (51.3%)
6	2768	9 (0.3%)	747 (27.0%)	478 (17.3%)	3 (0.1%)	3 (0.1%)	71 (2.6%)	3 (0.1%)	1454 (52.5%)
7	2287	…	…	…	…	…	…	2287 (100%)	…
8	11	…	?2 (?18.2%)	…	…	…	…	5 (45.4%)	4 (36.4%)
9	2897	42 (1.5%)	1017 (35.1%)	120 (4.1%)	2 (0.1%)	…	41 (1.4%)	24 (0.8%)	1651 (57.0%)
10	597	9 (1.5%)	306 (51.3%)	16 (2.7%)	…	…	8 (1.3%)	12 (2.0%)	246 (41.2%)
11	2300	?1 (?0.05%)	1088 (47.3%)	251 (10.9%)	1 (0.05%)	…	17 (0.7%)	14 (0.6%)	928 (40.4%)
12	2219	1 (0.05%)	924 (41.6%)	146 (6.6%)	…	1 (0.05%)	25 (1.1%)	12 (0.5%)	1110 (50.1%)
13	24	…	?3 (?12.5%)	…	…	…	…	…	21 (87.5%)

Table 1.

The overall numbers of palynomorphs per microscope slide and the numbers and percentages of palynomorphs of Carboniferous to Quaternary age in the thirteen samples of this study. Three dots (...) indicates that the respective palynomorph group is not represented.