British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

A palynological investigation of diamictons and tills from northern Caithness, Scotland

Geology and Landscape Northern Britain Programme

Internal Report IR/07/009

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/07/009

A palynological investigation of diamictons and tills from northern Caithness, Scotland

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Key words

palynomorphs, Devonian to Quaternary, glacial sediments, provenance, biostratigraphy, Scotland.

Bibliographical reference

RIDING, JAMES B. 2007. A palynological investigation of diamictons and tills from northern Caithness, Scotland. *British Geological Survey Internal Report*, IR/07/009. 13pp.

Keyworth, Nottingham British Geological Survey 2007

Foreword

This report comprises a study of the palynology of seven samples of diamictons and tills from Caithness, Scotland

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Summary

The matrices and erratics gave similar palynological signatures. Palaeozoic spores are rare, especially in the matrix. The relatively sparse Middle Devonian spores were sourced locally. The provenance of the rare Carboniferous spores is unclear. It is possible that these spores were sourced from north of the Firth of Forth, from the Outer Moray Firth, and/or are from Jurassic strata (i.e. were reworked from the Carbioniferous during the Jurassic). Miospores of Jurassic aspect are abundant, especially in the matrix. The source of these miospores is likely to be from paralic Middle Jurassic units. The level of input from Upper Jurassic strata is negligible. Lower Cretaceous dinoflagellate cysts are present in significant numbers, again especially in the matrix. Markers are indicative of of Volgian to Ryazanian/earliest Valanginian input. The likely source is the Ryazanian 'hot/warm shale' facies of the Kimmeridge Clay Formation. The probable sources of this Mesozoic material is probably offshore, possibly the Inner Moray Firth. It is highly unlikely that the Quaternary pollen is *in-situ*. The relative abundance of Palaeozoic material in the erratics, and Mesozoic material in the matrix is interpreted as reflecting the hardness and softness respectively of these sediments.

1 Introduction

The palynology of seven samples of diamictons and tills from northern Caithness, Scotland was studied in order to determine the provenance/derivation of these glaciogenic sediments. The study was undertaken in order to help better understand the glacial history of the area, and to contribute to the geological mapping of this region. The samples are from northeast of Miller Place and Wester Clett.

2 Sample Details

The samples studied are listed in the table below, and further details follow.

No.	Register No.	Collection No.	1:50k	Grid Reference	Locality
1	MPA 55454	PY 1921	116W	ND 10210 69447	Scrabster Harbour
2	MPA 55455	PY 1922	115E	NC 92053 65303	Wester Clett
3	MPA 55456	PY 1923	115E	NC 92076 65281	Wester Clett
4	MPA 55457	PY 1924	115E	NC 92112 65263	Wester Clett
5	MPA 55458	PY 1925	115E	NC 92112 65263	Wester Clett
6	MPA 55459	PY 1926	115E	NC 92112 65263	Wester Clett
7	MPA 55460	PY 1927	115E	NC 92112 65263	Wester Clett

Further details:

Sample 1 is from a coastal cliff, ca. 100 m NE of Miller Place

Samples 2-7 inclusive are all from Wester Clett, eastern area.

2 Locality 2 (CA 3011)

3 Locality 3 (CA 3012)

4 Locality 5, unit B (CA 3013)

5 Locality 5, unit C (CA 3014)

6 Locality 5, 8 m above the top of Unit C (CA 3015)

7 Locality 5, ca. 15 m above the top of Unit C (CA 3015)

1 Grey-green, clay/silt rich shelly till.

2 Diamicton below lower gravel (= Omand's Gravel), lower stream section, east side of valley; brown, sandy clay-rich diamicton.

3 Diamicton above Omand's Gravel, lower stream section, west side of valley; unconsolidated brown, sandy, clay-rich diamicton.

4 Shelly till at Adrian's excavation, above sandy silt with convolutions, lower stream section, west side of valley; dark brown, sandy, clay-rich till with shell fragments.

5 Shelly till, with shell fragments above Adrian's excavation, lower stream section, west side; brown, sandy, clay-rich till with occasional shell fragments.

6 Calcareous diamicton above shelly till; unconsolidated, brown, sandy, clay-rich diamicton.

7 Calcareous diamicton above shelly till; dark brown, sandy, clay-rich diamicton.

3 Palynology

In this section of the report, the palynofloras are fully described in two subsections, followed by a concluding overview. Full listings of palynomorphs, including quantitative and semiquantiative data, are held on the respective BGS micropalaeontology/palynology data sheets, which have been archived. The diamicton/till matrix was prepared using the sodium hexametaphosphate method of Riding and Kyffin-Hughes (2004; 2006) and Riding et al. (2006). By contrast, the more resistant large erratic clasts were prepared using the traditional acid digestion methods. The reason for this dual preparation was that the sodium hexametaphosphate method effectively prepared the relatively unconsolidated matrix, but did not break down the significantly more indurated erratic clasts. This represents the first differential study of the palynology of the till matrix and the erratic clasts.

3.1 THE PALYNOLOGY OF THE MATRIX

The matrices of these samples all proved organically productive, with abundant kerogen and palynomorph associations. The most prominent elements were wood fragments, plant tissues and Jurassic, Cretaceous, Quaternary, and non age-diagnostic palynomorphs. The organic residues were relatively similar, except sample 2 which yielded a relatively sparse palynoflora that is dominated by Quaternary miospores. Therefore samples 7-3 and 1 are deemed to be from the same genetic sedimentary unit, and to have the same provenance, due to the similarity of their palynofacies.

The palynological data from the matrices are given in Table 1. Palaeozoic spores are sporadic and rare. The few Devonian spores in samples 7, 6, 3, and 1 are poorly-preserved and questionable. Identification to generic level was impossible. However their general similarity to the unequivocal Devonian spores in the erratic clasts (subsection 3.2) indicates that they are Devonian in age. A single specimen of the Carboniferous spore *Densosporites* was observed from sample 3 (Table 1). The most abundant palynomorph type in samples 7-3 and 1 are miospores of Mesozoic age (Table 1). These include *Araucariacites* spp., *Callialasporites* spp., *Cerebropollenites macroverrucosus, Classopollis classoides, Coronatispora valdensis, Ischysporites vareigatus,* and *Perinopollenites elatoides*. This association is of definite Middle Jurassic affinities. The presence of *Callialasporites* spp. indicates the incorporation of strata of Middle Jurassic to Lower Cretaceous (Riding et al., 1991). The absence of abundant Upper Jurassic dinoflagellate cysts and characteristic Lower Cretaceous spores (e.g. *Cicatricosisporites*) indicates that that this assemblage was derived from paralic facies of Mid Jurassic age, for example the Brora Coal Formation. As mentioned earlier, Jurassic dinoflagellate cysts are extremely rare (Table 1). These are confined to single specimens of *Ambonosphaera*? *staffinensis* and *Systematophora areolata* in sample 6. *Ambonosphaera*? *staffinensis* is confined to the mid Oxfordian to Volgian, but does occur sporadically up to the Berremian (Heilmann-Clausen, 1997; Poulsen and Riding, 1992). *Systematophora areolata* is common in the Oxfordian to Volgian (Late Jurassic) interval, especially in the Kimmeridgian (Riding and Thomas, 1988). This indicates that the level of input from the Late Jurassic was virtually negligible. There is, likewise, very little input of Lower Cretaceous spores. Rare specimens of the distinctive Lower Cretaceous spore genus *Cicatricosisporites* are present in samples 7, 6, 4, and 1 (Table 1). By contrast, Lower Cretaceous dinoflagellate cysts are consistent and relatively abundant (Table 1). These are dominated by *Canningia* spp., undifferentiated chorate cysts, *Cyclonephelium* spp., and thick-walled *Cribroperidinium* spp. Other forms, recorded in far lower numbers, include *Batioladinium* cf. *pomum* (sample 1), *Dingodinium* sp., *Gochteodinia villosa* subsp. *villosa* (sample 4), *Hystrichodinium pulchrum*, ?*Pterodinium* sp. (sample 1), *Scrinodinium pharo* (sample 1), *Senoniasphaera jurassica* (samples ?6, 4), and *Sirmiodinium grossii* (sample 5). The occurrences of *Batioladinium* cf. *pomum*, *Gochteodinia villosa* subsp. *villosa*, *Senoniasphaera jurassica*, and *Scrinodinium pharo* are indicative of input of material of Volgian (latest Jurassic) to Ryazanian/earliest Valanginian (Early Cretaceous) age to samples 4 and 1. Of these, *Batioladinium pomum* has the most restricted age, i.e. uppermost Volgian/Ryazanian (Heilmann-Clausen, 1997). The presence of prasinophytes (e.g. *Pterospermella* spp.), and dinoflagellate cysts such as *Canningia* spp., thick-walled *Cribroperidinium* spp., *Dingodinium* sp., and *Senoniasphaera jurassica* strongly suggests that the majority of the Early Cretaceous material is of Ryazanian age. However, it should be borne in mind that some of this may be derived from the Volgian-Ryazanian transition. Therefore, this is most likely to be from the uppermost part of the Kimmeridge Clay Formation. The common nature of prasinophyte alga such as *Pterospermella* spp. and *Tasmanites* spp. indicates a correlation with the 'hot shale' facies that is late Volgian to early Ryazanian in age (Rawson and Riley, 1982; Ineson et al., 2003). There is no evidence of any input from strata of Late Cretaceous to Neogene age. Pollen of Quaternary aspect is, however, consistently present in significant numbers (Table 1). These associations are dominated by *Corylus* (hazel) and *Pinus* (pine). Some palynomorphs which were observed in significant proportions have long geological ranges and were assigned to the 'non-age diagnostic' category (Table 1). These include acritarchs, *Botryococcus*, foraminiferal test linings, prasinophytes, and pre-Quaternary bisaccate pollen.

3.2 THE PALYNOLOGY OF THE ERRATIC CLASTS

The palynomorph and kerogen associations from the erratic clasts proved significantly different to those extracted from the matrix. Sample 2 was entirely dominated by mineral grains; the organic fraction proved extremely rare. All the other six samples are rich in light amorphous organic material, with lesser proportions of wood and plant tissue. Samples 7-3 and 1 are again interpreted as being from the same genetic sedimentary unit, and to have the same provenance, due to the similarity of their palynofacies. Palynomorphs proved rare throughout. The palynofloras were so sparse that counts were not made. A presence/absence grid is presented as Table 2. Devonian, Carboniferous, Jurassic, Lower Cretaceous, Quaternary, and non-age diagnostic palynomorphs were recovered, all in relatively low proportions.

Palaeozoic spores are present in all samples except number 2 (Table 2). The Devonian spores are somewhat variable in preservation. The better-preserved specimens were generally identifiable to generic level. *Hystrichosporites* is present in sample 4, and *Ancyrospora* in sample 6. These two genera are indicative of the Middle and Upper Devonian (e.g. McGregor and Playford, 1992). Rare specimens of the Carboniferous spores *Densosporites* and *Lycospora pusilla* were observed in samples 4, 3 and 1 (Table 1). Miospores of Jurassic aspect were found throughout (Table 2). These are similar to the associations found in the matrices (see subsection 3.1), and include *Callialasporites* spp., *Cerebropollenites macroverrucosus, Classopollis classoides, Perinopollenites elatoides* and *Vitreisporites pallidus*. This association is of distinct Middle Jurassic aspect, largely due to the presence of *Callialasporites* spp., and the rarity of characteristic Lower Cretaceous spores such as *Cicatricosisporites*. The absence/rarity of Upper Jurassic dinoflagellate cysts (Table 2) suggests that this assemblage was derived from paralic Middle Jurassic strata. A single, questionable specimen of *Systematophora areolata* was observed in sample 5. This species is present in the Oxfordian to Volgian (Riding and Thomas, 1988) and indicates that the level of Late Jurassic input was negligible. Lower Cretaceous spores were similarly rare; a single specimen of the Lower Cretaceous spore *Cicatricosisporites* is present in sample 4 (Table 2). Dinoflagellate cysts of Lower Cretaceous aspect are, however, consistently present, except in sample 2 (Table 2). These associations are comparable to those recorded form the matrices (subsection 3.1), and largely comprise *Canningia* spp., *Cyclonephelium* spp. thick-walled *Cribroperidinium* spp and *Oligosphaeridium* spp. A single specimen of *Batioladinium radiculatum* was recorded in sample 5. This taxon is indicative of the Jurassic-Cretaceous transition, ranging from the latest Volgian to the late Ryazanian (Davey, 1982; Costa and Davey, 1992). Volgian/Ryazanian markers were also recorded from the matrices (subsection 3.1). The presence of prasinophytes such as *Tasmanites* spp., and dinoflagellate cysts such as *Canningia* spp. and thick-walled *Cribroperidinium* spp. strongly support a Ryazanian age. This input is probably from the uppermost part of the Kimmeridge Clay Formation. The common presence of *Tasmanites* spp. indicates the late Volgian to early Ryazanian 'hot/warm shale' facies (e.g. Rawson and Riley, 1982). There is no evidence of any Late Cretaceous to Neogene input. Pollen of Quaternary aspect is, however, consistently present (Table 2); these associations are dominated by *Pinus*. Additionally, non-age diagnostic palynomorphs were observed throughout (Table 2).

3.3 OVERVIEW

Both the matrices and erratics gave a similar palynological signal. Palaeozoic spores are present in relatively low proportions. The occurrences of Devonian spores were expected, because the solid bedrock of this area is Middle Devonian. Clearly, these were probably sourced locally. The source of the (albeit rare) Carboniferous spores in not clear. The nearest onshore Carboniferous rocks are to the south, to the north of the Firth of Forth. However, rare reworked Carboniferous spores are present in the Jurassic strata of the Brora area (Riding, 2005). It is possible that the Carboniferous input came from offshore, e.g. the Outer Moray Firth, or from the reworked Jurassic strata. The most abundant palynomorph type in the matrix are miospores of Jurassic aspect. The source is likely to be Middle Jurassic units of paralic facies due to the relative lack of Jurassic dinoflagellate cysts. An example of this would be the Brora Coal Formation, or its offshore equivalents. The extreme rarity of Late Jurassic dinoflagellate cysts is indicative that the level of input from Upper Jurassic strata is negligible. Lower Cretaceous dinoflagellate cysts are consistently present in significant numbers. Key markers are indicative of input of material of Volgian (latest Jurassic) to Ryazanian/earliest Valanginian (Early Cretaceous) age. It seems likely that the primary source was Ryazanian in age. This is supported by occurrences of prasinophytes, indicating input of the uppermost part of the Kimmeridge Clay Formation, specifically, the 'hot/warm shale' facies. The probable sources of this Middle Jurassic and Ryazanian material is probably offshore. There may be sedimentological features that provide indications as to whether the ice direction was from the north, the south or the east. A southern derivation cannot be ruled out because the glacier may have been sourced from the Cairngorms. In this case the Mesozoic material would probably have been derived from the Inner Moray Firth. Because the tills/diamictons are glaciogenic sediments, it is highly unlikely that the Quaternary pollen were contemporaneous. Therefore, the glacier clearly incorporated significant levels of Quaternary sediment. This may be far-travelled or local, and this distinction is difficult to make on the basis of the rather low-diversity association observed. The source area for all this Devonian to Quaternary material may be easier to determine because of the lack of Late Cretaceous to Neogene input.

This study is the only one to separately study the matrix and the erratic clasts of till/diamicton. The results are interesting. It is clear that the erratics have higher proportions of Devonian spores than the matrix. The erratics therefore include significant levels of Devonian material. This is unsurprising as Devonian rocks are normally relatively well indurated, hence would be more likely to enter the glacier as clasts. A similar scenario is envisaged for the relatively low levels of Carboniferous input. The reverse is true of the Mesozoic input, which is in far greater proportions in the matrices than the erratics. Therefore the conclusion must be that the relative softness of the parent Mesozoic strata meant that these entered the glacier as finely dispersed debris (i.e. matrix), as opposed to relatively large erratics. The proportions of Quaternary pollen in the matrix and the erratics is relatively similar. It seems inconceivable that Quaternary sediments would be incorporated as competent erratics, so the Quaternary pollen in the preparations from the erratics is most likely to be matrix contaminating the surface of the erratics. The Mesozoic input into the erratic preparations also probably was derived similarly.

4 Summary

The matrices and erratics gave similar palynological signatures. Palaeozoic spores are rare, especially in the matrix. The relatively sparse Middle Devonian spores were sourced locally. The provenance of the rare Carboniferous spores is unclear. It is possible that these spores were sourced from north of the Firth of Forth, from the Outer Moray Firth, and/or are from Jurassic strata (i.e. were reworked from the Carbioniferous during the Jurassic). Miospores of Jurassic aspect are abundant, especially in the matrix. The source of these miospores is likely to be from paralic Middle Jurassic units. The level of input from Upper Jurassic strata is negligible. Lower Cretaceous dinoflagellate cysts are present in significant numbers, again especially in the matrix. Markers are indicative of of Volgian to Ryazanian/earliest Valanginian input. The likely source is the Ryazanian ‘hot/warm shale’ facies of the Kimmeridge Clay Formation. The probable sources of this Mesozoic material is probably offshore, possibly the Inner Moray Firth. It is highly unlikely that the Quaternary pollen is *in-situ*. The relative abundance of Palaeozoic material in the erratics, and Mesozoic material in the matrix is interpreted as reflecting the hardness and softness respectively of these sediments.

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No.	Grains	Dev.	Carb.	Jur.	Jur.	L. Cret.	L. Cret.	Quat.	Non-age
	per slide	spores	spores	mios.	d. cysts	spores	d. cysts	mios.	diagnostic
1	725	?2 (0.3%)	…	340 (46.9%)	…	3 (0.4%)	78 (10.8%)	24 (3.3%)	278 (38.3%)
2	590	…	…	…	…	…	…	553 (93.7%)	37 (6.3%)
3	971	?2 (0.2%)	1 (0.1%)	330 (34.0%)	…	…	81 (8.3%)	293 (30.2%)	264 (27.2%)
4	695	…	…	228 (32.8%)	…	1 (0.1%)	132 (19.0%)	26 (3.8%)	308 (44.3%)
5	1096	…	…	458 (41.8%)	…	…	148 (13.5%)	34 (3.1%)	456 (41.6%)
6	703	?6 (0.9%)	…	269 (38.3%)	1 (0.1%)	3 (0.4%)	100 (14.2%)	136 (19.4%)	188 (26.7%)
7	489	?1 (?0.2)	…	179 (36.6%)	1 (0.2%)	1 (0.2%)	56 (11.5%)	49 (10.0%)	202 (41.3%)

Table 1. The numbers and percentages (in parentheses) of Devonian, Carboniferous, Jurassic, Lower Cretaceous, Quaternary, and non-age diagnostic palynomorphs in the matrices of the samples studied from northern Caithness. Three dots (…) indicates the absence of the respective age/group of palynomorphs.

No.	Dev.	Carb.	Jur.	Jur.	L. Cret.	L. Cret.	Quat.	Non-age
	spores	spores	mios.	d. cysts	spores	d. cysts	mios.	diagnostic
1	X	X	X	…	…	X	X	X
2	…	…	X	…	…	…	X	…
3	X	X	X	…	…	X	X	X
4	X	X	X	…	X	X	X	X
5	X	…	X	?X	…	X	…	X
6	X	…	X	…	…	X	X	X
7	X	…	X	…	…	X	….	X

Table 2. A presence/absence grid of Devonian, Carboniferous, Jurassic, Lower Cretaceous, Quaternary, and non-age diagnostic palynomorphs from the erratic clasts in the samples studied from northern Caithness. A capital x (X) indicates presence, and three dots (…) indicates the absence of the respective age/group of palynomorphs.