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The application of microfaunas in the palaeoenvironmental interpretation of the Quaternary succession at Afton Lodge

Internal Report IR/05/040

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INTERNAL REPORT IR/05/040

The application of microfaunas in the palaeoenvironmental interpretation of the Quaternary succession at Afton Lodge

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Summary

Twenty one samples from Afton Lodge were examined for calcareous microfossils (Foraminifera and Ostracoda). The near absence of planktonic forms suggests that there was no or only poor access to open oceanic environments, however, cold, fully marine conditions prevailed during sediment accumulation and at times the influence of very shallow and estuarine conditions were observed. Water depth was shallow, although minor variations may be suggested.

1 Introduction

The Afton Lodge section exposed approximately 4 m of blue-grey clays and silts of Quaternary age, with occasional pebbles (?drop-stones) towards the base of the succession. Most samples contained fragments of bivalves and some contained gastropods and echinoid spines. 'Coal' chips were present in several samples, particularly towards the base and towards the top of the succession and trilete spores of presumed Carboniferous age were also occasionally observed. The site was discussed in BGS IR/03/134 when the results of 21 samples were presented. This report modifies to that report with the addition of eighteen further samples. In total, thirty nine samples (MPA 52016-52036 and 53622-53639 selected from MTD1941-1995), between the elevations 76.92 and 73.07 m OD, were collected for micropalaeontological analysis. Foraminifera were found throughout the succession (although planktonic species were exceptionally rare), but ostracods were generally rare. The micropalaeontological data are presented in Figures 1 and 2.

2 Sample details and faunal list

The registration numbers, elevations of the sample analysed and brief notes regarding the other organic remains seen are shown in Fig. 1. The vertical distribution of the calcareous microfaunas (foraminifera and ostracods) are shown in Figure 2.

3 Foraminiferal distribution

In overall terms, the faunas from the Afton Lodge Succession is characterised by common specimens of *Quinqueloculina seminulum*, with *Elphidium bartletti, Elphidium excavatum clavatum* and *Ammonia batavus*. However, there are variations in the faunas that allow informal 'assemblage zones' to be recognised.

3.1 ASSEMBLAGE ZONE 'A'

Assemblage Zone 'A' was identified between the elevations 73.19 and 73.67 m. The silty muds here contain small pebbles, notably in the samples from 73.46-73.43 and 73.19-73.07 m that may be drop stones. Only bivalve fragments were observed, presumably the result of high energy conditions, and the presence of 'coal' chips and trilete spores indicate reworking. The

assemblage is characterised by the presence of *Quinqueloculina seminulum, Elphidium bartletti* and rare, but consistently present, *Elphidium excavatum clavatum*. *Haynesina orbiculare* is also present and whereas *Ammonia batavus* occurs in the lower part of the zone, *Pyrgo williamsoni* appears in the upper part (Figure 2).

The presence of the two miliolids, *Q. seminulum* and *P williamsoni*, indicate that salinities were at or approaching fully marine. Pseudopodial activity is lost when salinity falls below 30‰ and death follows soon after. Recent distribution suggests that both species thrive in shelf conditions. Both occur where water depths exceed about 10 or 15 m, but *P. williamsoni* is found living down to depths of about 200 m and *Q. seminulum* tends to show a preference for the shallower parts of the shelf, especially in the turbulent zone (presumably where oxygenation is higher) and off the Atlantic Seaboard of America, it is extremely rare below 70m water depth. An important parameter for the reproduction of *Q. seminulum* is water temperature, which must be at minimum of about 15°C during the Spring/Summer when reproduction takes place.

Elphidium bartletti, Elphidium excavatum clavatum and *Haynesina orbiculare* are all species that show a preference for colder waters.

Elphidium bartletti usually shows a preference for shallow waters, although it has been recorded as deep as 200 m (although whether it is found living at these depths is not clear). Its modern distribution includes the coasts of Alaska, Labrador and Greenland, the Bering Sea, off Ochotsk in the Chukchi Sea and in the North western Pacific. Off Europe, it is not found living because the North Atlantic Drift brings warm waters to high latitudes, but it does occur off Iceland and Spitzburgen. Although not present living, its fossil record includes Britain, Germany, Denmark, Norway and Poland.

The notion that this is a cold water fauna also comes from the modern distribution *of E. excavatum clavatum*. This form is particularly characteristic of Arctic and High Boreal regions, including Northern Russia, Alaska, northern Canada, Iceland, Norway and is apparently relict in the Baltic Sea where temperatures do not generally exceed about 7 to 10°C. It does not extend as far south as the UK (where other subspecies of *E. excavatum* are found including *E. e. lidoense* and *E. e. selseyense*). The species is tolerant of a variety of salinities between 15‰ and fully marine (35‰) and can therefore be found in river estuaries and coastal areas. It is almost invariably found living where water depths are less than about 20-30 m. *Haynesina orbiculare* has a similar distribution to *E. e. clavatum* where there is good oxygenation of the water.

The presence of *Ammonia batavus* is surprising amongst the essentially cold water fauna outlined above. *Ammonia batavus* is an infaunal herbivore that is tolerant of a variety of salinities and is found in low marsh, estuarine, lagoon and shallow marine environments. It

shows a preference for water depths of less than 10 m, but has been found living down to depths of about 50 m. In Pleistocene deposits it is often considered to be a species of "southern aspect", a warm water indicator that may extend into the boreal waters, but not the Arctic. FUNNELL (1989) states that *Ammonia batavus* it is characteristic of interglacial stages in the North Sea Basin. It tends to favour water temperatures such as around the coast of Britain and from the Netherlands north to Oslo Fjord and South to the Gironde, but its northern limit is in the northern North Sea. It will tolerate temperatures down to 0°C for short periods, but requires water temperatures of about 15°C for reproduction.

Despite the apparent inconsistency in environmental requirements, *Ammonia batavus* is known to occur with common representatives of the cold water species. It is found living together with *Elphidium excavatum clavatum*, in the Skagerrak (Hansen, 1965; Van Weering & Qvale, 1983) and the Rappahannock Estuary, Virginia (ELLISON & NICHOLS, 1970) and WEISS (1974) recorded a *clavatum-batavus* association in the Late Pleistocene of the Hudson River, where it was indicative of estuarine, intertidal and coastal environments with low salinities. In the present situation, the salinity could not have been reduced greatly due to the presence of miliolids. The presence of *Ammonia batavus* in the Afton Lodge succession indicates, therefore, that water temperatures in assemblage zone A were not extreme, for here Arctic to Boreal and Temperate to Boreal species are able to co-exist.

3.2 ASSEMBLAGE ZONE 'B'

Assemblage Zone 'B' extends from elevations 73.86 to 74.26 m (Figure 2). The lowest sample within this assemblage zone contains small pebbles, but the remainder is a silty mud. Foraminiferal diversity (3-4 species) is reduced compared to the underlying assemblage zone (generally 6 or 7 species) and comprises common *Quinqueloculina seminulum*, and rare *Elphidium bartletti* and *Elphidium excavatum clavatum* (i.e. the species that are more or less consistently present throughout the succession). Interestingly, *Ammonia batavus* disappears from the record, suggesting a cooling of water temperatures below its tolerance levels; the species was probably close to its northern limit of endurance in assemblage zone 'A'.

3.3 ASSEMBLAGE ZONE 'C'

Assemblage Zone 'C' extends from elevation 74.53 to 74.90 m. Foraminifera are common throughout this assemblage zone, and found with fragmentary and entire bivalve shells, gastropods and occasional echinoid spine, 'coal' chips and trilete spores (presumably derived from the Carboniferous). The foraminiferal assemblage is characterised by common *Quinqueloculina seminulum* and *Ammonia batavus* and abundant *Elphidium excavatum clavatum*

(Figure 2). In addition *Miliolinella subrotunda, Buccella frigida, Cassidulina reniforme* together with a number of other, more patchily distributed and rare foraminifera were recorded. Amongst these are very rare planktonic taxa at 74.85-74.78 and 74.96-74.90 m, which are in a poor state of preservation and cannot be identified with certainty. Diversity is at its highest in this part of the succession with a jump from 3 to 4 species in assemblage zone 'B' to between 10 and 12 in assemblage zone 'C'.

The environmental requirements of *Miliolinella subrotunda* is unclear because some authors 'lump' several species together under the name *M. subrotunda* and others split it to a considerable degree. This is the reason why some authors state that it is a shallow water species of high latitudes with a modern distribution in the Arctic and Subarctic, while others state that it is restricted to the temperate waters off Europe. *Buccella frigida* is a geographically widespread shelf species that has been recorded from Arctic, Boreal and Cool Temperate marine waters, but is at its southern limit in the English Channel. It occurs living in all water depths down to about 200m, although it is most commonly founds in depths of less than 50-60 m. *Cassidulina reniforme,* is a cold water species that lives on the shelf off Spitzbergen, Norway and in the Barents Sea and thus is considered to be an Arctic to High Boreal form. The presence of the species indicate that the cold, boreal, shallow marine water conditions continued at Afton Lodge and the closest modern analogue is probably the Skagerrak. Finally, *Elphidium albiumbilicatum* occurs in small numbers at the top of this assemblage zone. This species is particularly indicative of Late-Glacial and Boreal conditions and is found in shallow (<20 m), brackish waters to marine waters of, for example, Denmark, the North Sea, northern Germany and the Baltic.

Planktonic foraminifera are confined to just two samples in the Afton Lodge succession. The presence of planktonic taxa is the only evidence of a connection with more open oceanic water masses and may represent a more ameliorated phase and/or one of transgression such that the planktonic foraminifera are washed into the area. Their rarity may be due to post mortum, preservational factors, but it is more likely that these few specimens were washed into the area, but were not living here. The stepwise introduction of shelf benthonic taxa between 74.53 and 74.85 m (Figure 2) may reflect the opening up of this area to the influence of open shelf areas.

3.4 ASSEMBLAGE ZONE 'D'

Assemblage Zone 'D' is one of slightly decreased diversity from the peak of zone 'C' culminating in the nadir in zone 'E'. *Elphidium excavatum clavatum* and *Quinqueloculina seminulum* dominate the fauna and although reduced in proportion, *Ammonia batavus* is still present, together with *E. bartletti* and *Cassidulina reniforme* (Figure 2). This appears to represent a

cooling of conditions and perhaps a shallowing again; planktonic taxa are not present, the shelf species that were introduced in zone 'C' disappear from the record and rare *Elphidium williamsoni* appears at the top of the assemblage zone (its only record in the whole succession). The last named species was regarded as restricted to the "Lusitanian" to "Boreal" waters by HAYNES (1973) and is found on low intertidal marsh, estuaries and mud flat environments, down to depths of 15-20 m, off Long Island to Nova Scotia and Prince Edward Island, Canada (Atlantic Seaboard of USA/Canada), Baltic, North Sea and around the coast of Britain. It seems to show a preference for very shallow water (often occurring in waters of less than 1 to 3 m). It can tolerate wide temperature ranges (-1 to 32°C), although its optimum water temperature range seems to be about 10-15°C, certainly in Spring and Summer when reproduction and the main period of growth takes place. Its presence here, at the top of assemblage zone 'D', may suggest very shallow waters and if sediment did not accumulate in an estuarine, lagoonal or intertidal area, these conditions must have been in the vicinity.

3.5 ASSEMBLAGE ZONE 'E'

The decline in diversity from the peak in assemblage zone 'C', through zone 'D' continues into 'E' where the simple diversity reaches 3 to 6 species (Figure 2). All species are rare and the only species consistently present are *Quinqueloculina seminulum*, *Elphidium bartletti and E. excavatum clavatum*. Miliolids such as *Q. seminulum* and *Pyrgo williamsoni* imply that salinities were fully marine, and the colder water forms predominate. *Ammonia batavus* is almost absent, only a single specimen being present at the top of the assemblage zone. The highest sample also yielded very rare *Elphidium gerthi*, a benthonic foraminifera distributed in brackish to fully marine waters of Temperate to Boreal regions. It shows a preference for shallow water and has been recorded, for example, on tidal flats of the Netherlands and in less than 10m in the Baltic and Taiwan, although it always forms a minor element in the association. It is best known from the Holocene to Recent, but its fossil record is not fully understood.

3.6 ASSEMBLAGE ZONE 'F'

This assemblage zone is recognised in only a single sample from an elevation of 76.20-76.05 m (Figure 2). It shows a sudden, if short lived, increase in diversity to that characteristic of assemblage zone 'C'. *Quinqueloculina seminulum* and *Ammonia batavus* are common and the cold indicators are much reduced. Shallow, nearshore, fully marine waters are indicated and temperature presently associated with Boreal waters, such as off northern Europe, are suggested. Bivalve fragments and 'coal' chips were present indicating continued reworking, a feature of the majority of samples from this succession.

3.7 ASSEMBLAGE ZONE 'G'

The highest samples, from an elevation between 76.38 and 76.83 m, show a return to low diversities of 4 to 9 species (Figure 2). Faunas are similar to assemblage zone 'F'. When taken as a whole most of the species are present in both assemblage zones 'F' and 'G'. However, individual samples have a much reduced diversity in zone 'G' compared to 'F'. It may be more appropriate to consider the two assemblage zones together and regard them as a single trend where diversity is high at the base, but reduces gradually up-section. Cold water forms are present although generally rare and patchily distributed through the assemblage zone.

Haynesina germanica (=*Protelphidium anglicum* of many authors) which is best known in Post-glacial to Recent, Lusitanian to Low-boreal conditions, is close to its northern limit of distribution around the modern coast of Britain according to MURRAY (1991). The species is particularly indicative of brackish intertidal marsh, estuarine and lagoonal environments, in which muds and silts accumulate, in which *Spartina*, for example, grow and in which plant detritus is present. A single specimen of *Elphidium albiumbilicatum* was also recorded. However, miliolids are also present indicating fully marine conditions. A phase of shallowing waters may be indicated in this unit. Bivalve fragments, echinoid spines, 'coal' chips, trilete spores and a single black charophyte were present suggesting reworking of presumed Carboniferous deposits.

4 Ostracod distribution

Ostracods are rare and patchily distributed throughout the Afton Lodge section and it is not possible to recognise assemblage zones as in the case of the foraminifera (Figure 2). *Elofsonella conicinna* is the most consistently present species, a typical shelf taxon that occurs from Spitzbergen to British waters (HAZEL, , 1970).

Heterocypris sorbyana, which has similar environmental requirement as *E. concinna* was present in the lowest sample examined and *Cytheroptern nodosum* and *Eucytheridea punctata* enter the record towards the top of Foraminiferal assemblage zone 'A', both of which are found from Norway and Baltic as far south as the British Isles (*S. punctillata* may be restricted to the north of Britain) where they inhabit all marine shelf environments.

Acanthocythereis dunelmensis appears for the first time within the samples assigned to Foraminifera assemblage zone 'B'. This is a boreal-low Arctic species which is found living in the shallow waters of Greenland, Norway and as far south as Scotland and north-eastern

England. *Rabilimis mirabilis*, which was found in the sample with the elevation 74.10-74.02 m, is the stratigraphically lowest cold Arctic species found in the Afton Lodge succession. This species is found living in waters off eastern Greenland, Spitzbergen, Novaya Zemlya, Franz Josef Land and Northern Norway. Its presence confirm the low temperatures at the time that this part of the succession accumulated.

Cluthia cluthae, which occurs at the elavation 74.71-74.65 m, in the middle of the succession yielding foraminifera of assemblage zone 'C', also shows a preference for cold waters, being distributed around the coast of Greenland, Franz Josef Land and in the Barents Sea. However, it is also found off Nova Scotia suggesting that it can tolerate Boreal waters and NEALE (1973) recorded it off Scotland, but in deeper waters only, presumably where temperatures were low. It was not included amongst the British fauna by ATHERSUCH et al. (1989).

A single specimen tentatively assigned to *Aurila convexa* was found associated with the zone 'E' foraminiferal assemblage. This species is a warmer water form compared to many ostracods present at Afton Lodge Its northern limit of endurance is around the coast of England where it lives in littoral and shallow sublittoral waters. Its occurrence in the Afton Lodge succession is therefore surprising as higher water temperatures would be implied than the present coastal waters of Scotland. It may be that this single specimen has been reworked.

Finally, *Rabilimis mirabilis* reappears at an elevation of 76.38-76.29 m, the basal elevation of foraminifera assemblage 'G'. This implies that the base of the zone was deposited in an Arctic milieu, even though more temperate conditions are indicated for the sample at 76.65-76.56 m and above. If this is correct, a very rapid amelioration in temperatures musty have occurred.

5 Comparative faunas from western Scotland

Two well dated sections at Lochgilphead and Ardyne contain a foraminifera fauna (WILKINSON in PEACOCK, et al., 1977, 1978; GRAHAM & WILKINSON, 1978).

At Lochgilphead, the 'Clyde Beds' were dominated by *Elphidium* and *Haynesina* with subordinate miliolids. In the lower part *Cibicides lobatulus* dominated, but in the middle of the succession it was joined by and *Elphidium excavatum clavatum* and *Haynesina orbiculare* and, in the upper part, *Elphidium williamsoni* and *Haynesina germanica* (=*anglica*) appeared. *Ammonia batavus* appeared for the first time at the very top of the succession. This was interpreted as equating with a warming trend between about 12,000 and 11,000 BP.

At Ardyne, *Elphidium* and *Haynesina* again dominated the fauna, with miliolids and small numbers of agglutinating taxa. *Elphidium excavatum clavatum* and *Cassidulina reniforme*

dominated the assemblage of Unit 1 (a little before 12000 BP). *E clavatum* and *H. orbiculare* were the dominant forms in Unit 2 about 11,500BP, but in the upper part of the unit an amelioration introduced *Ammonia batavus* and *Elphidium macellum* and temperate conditions were interpreted. Faunas of Unit 3 (dated to 11,159 BP) are less well known, but *A. batavus* was again present at times. Unit 4 showed a return to Arctic and Subarctic foraminifera and the upper part of this unit is dated to between approximately 10,200 to 10,400 BP. Unit 5 (of Flandrian age) contains a shallow water, more temperate fauna including *Ammonia batavus* and *Elphidium macellum*.

The foraminiferal association of the Afton Lodge succession differs from both the Lochgilphead and Ardyne sequences. The diversity is much reduced at Afton Lodge, perhaps suggesting more marginal conditions. The marine influence is greater here as indicated by the presence of frequent miliolids throughout, but like the other two sites, the influence of open oceanic conditions was not great as indicated by the lack of planktonic taxa. *Ammonia batavus* is present in the majority of samples at Afton Lodge (although *Elphidium macellum* was not present) suggesting higher water temperatures throughout compared to the other two sites. The appearance of *Ammonia batavus* was seen only at the very top of the Lochgilphead sequence (approximately 11,000 BP) and in units 2 and 3 (approximately 11,000 to 11,500 BP) and Unit 5 (Flandrian) of Ardyne.

6 Conclusions

Foraminifera and Ostracoda were recovered from a suit of samples through the Afton Lodge excavation.

1. *Quinqueloculina seminulum, Elphidium bartletti, Ammonia batavus, Elphidium excavatum clavatum* and *Haynesina orbiculare* were recovered throughout the succession. However, variations in foraminiferal distribution, together with the occurrence of other taxa, made it possible to identify seven informal assemblage zones (labeled 'A' to 'G' upsection). These zones are environmentally controlled, possibly by minor changes in temperature and water depth. The following environments (from the base upwards) are interpreted from the foraminiferal associations:

    'A': Cool, Boreal temperatures in shallow, marine conditions.

    'B': Cooling at the top of A continues into B and Arctic water ostracods also occur in very small numbers.

'C': Cool boreal water temperatures return. Weak links with open ocean conditions are indicated by the presence of planktonic taxa. The diversity is increased with the incursion of a number of shelf taxa.

'D': Boreal shallow water conditions with evidence of estuarine conditions towards the top of the zone.

'E': Colder temperatures in a shallow nearshore, marine environment.

'F': A brief phase of warmer (Boreal), fully marine conditions occur and a marked increase in diversity with the appearance of a number of shallow nearshore taxa.

'G': This zone begins with cold water species but an amelioration in water temperature takes place and several very shallow water taxa appear.

2. Ostracods are rare throughout and few conclusions can be drawn from them, although some are apparently restricted to arctic and high boreal conditions, the majority are environmentally more tolerant.
3. Reworking is a feature of the succession, with 'coal' and trilete spores of presumed Carboniferous age. Mollusc shells are almost invariably represented by small fragments and only in the sample from the elavation 74.71-74.65 m were entire bivalves observed.

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SAMPLE NUMBER (MPA)	COLLECTOR'S NUMBER (MTD)	SAMPLE ELEVATION (m)	NOTES
52016	1941	76.92-76.83	Bivalve fragments
53622	1942	76.83-76.74	Bivalve fragments, gastropod chips, echinoid spines, 'coal' chips, 'seed cases'
52017	1944	76.65-76.56	Bivalve fragments, echinoid spines, 'coal' chips, trilete spores
53623	1945	76.56-76.47	Bivalve fragments, gastropod chips, echinoid spines, 'coal' chips, trilete spores
52018	1947	76.38-76.29	Bivalve fragments, 'coal' chips, trilete spore, black charophyte
53624	1948	76.29-76.20	Bivalve fragments, 'coal' chips, trilete spores, ?fish debris
52019	1949	76.20-76.05	Bivalve fragments, 'coal' chips
53625	1951	75.99-79.93	Bivalve fragments rare, Bryozoan fragments, very rare, 'coal' chips, forams rare
52020	1952	75.93-75.88	Foraminifera rare. Bivalve fragments, trilete spores
53626	1954	75.83-75.78	Bivalve fragments rare, forams rare, 'coal' common
52021	1955	75.78-75.74	Foraminifera very rare
53627	1957	75.70-75.62	Barren of forams & ostracods, 'coal' and trilete spores
52022	1958	75.62-75.53	Foraminifera rare. Bivalve fragments
53628	1960	75.47-75.41	Bivalve fragments rare, 'coal' present
52023	1961	75.41-75.35	Bivalve fragments, echinoid spines
52024	1964	75.30-75.23	Bivalve fragments, echinoid spines
53629	1965	75.23-75.16	Bivalve fragments common, echinoid spines, 'coal' and trilete spores.
52025	1967	75.09-75.02	Bivalve fragments, echinoid spines, 'coal' chips, trilete spores
53630	1968	75.02-74.96	Bivalve fragments common, echinoid spines, 'coal'
52026	1969	74.96-74.90	Foraminifera common. Bivalve fragments, echinoid spines
52027	1971	74.85-74.78	Foraminifera common. Bivalves, gastropods, echinoid spines, 'coal' chips, trilete spores
53631	1972	74.78-74.71	Bivalve fragments frequent, 'coal' rare
52028	1973	74.71-74.65	Foraminifera common. Bivalves (entire and fragments)
53632	1974	74.65-74.59	Bivalve fragments frequent, gastropod fragments rare, 'coal' present
52029	1976	74.53-74.47	Foraminifera common. Bivalve fragments, 'coal' chips
53633	1977	74.47-74.41	Bivalve fragments rare, rare echinoid spines, 'coal' very rare, trilete spores very rare
52030	1979	74.35-74.26	Forams very rare. Bivalve fragments, 'coal' chips
53634	1980	74.26-74.19	Bivalve fragments rare, 'coal' rare
52031	1982	74.10-74.02	Forams very rare. Bivalve fragments, gastropods
53635	1983	74.02-73.94	Bivalves rare, echinoid spines very rare, 'coal' rare
52032	1985	73.86-73.78	Pebbles, bivalve fragments, 'coal' chips
52033	1987	73.75-73.67	Bivalve fragments, 'coal' chips
53636	1988	72.67-73.58	Bivalve fragents, 'coal'
52034	1989	73.58-73.52	Bivalve fragments
53637	1990	73.52-73.46	Bivalve fragments rare, ?fish debris (very rare), 'coal' present
52035	1991	73.46-73.43	Pebbles, bivalve fragments, 'coal' chips, trilete spores, fish debris
53638	1993	73.40-73.30	Bivalve fragnebts, ?fish debris and 'coal' all very rare.
52036	1995	73.19-73.07	Pebbles; bivalve fragments
53639	1996	73.07-72.95	

Figure 1. Sample details and palaeontological notes

SAMPLE NUMBER (MPA)	COLLECTOR'S NUMBER (MTD)	SAMPLE ELEVATION (m)	ASSEMBLAGE ZONES	FORAMINIFERA: BENTHONIC: *Quinqueloculina seminulum*	*Ammonia batavus*	*Elphidium excavatum clavatum*	*Haynesina orbiculare*	*Elphidium bartletti*	*Miliolinella subrotunda*	*Quinqueloculina pygmaea*	*Cibicides lobatulus*	*Lagena clavata*	*Pyrgo williamsoni*	*Elphidium subarcticum*	*Buccella fridgida*	*Elphidium williamsoni*	*Haynesina germanica*	*Cassidulina reniforme*	*Trifarina angulosa*	*Bolivina pseudopunctata*	*Virgulina loeblichi*	*Elphidiella arctica*	*Oolina williamsoni*	*Lagena sp.*	*Nonion auricula*	*Elphidium albiumbilicatum*	*Lagina substriata*	*Bolivina pseudplicata*	*Oolina caudigera*	*Elphidium subarctica*	*Lagena semilineata*	*Elphidium macellum*	*Elphidium gerthi*	*Elphidium incertum*	*Elphidium asklundi*	*Oolina melo*	*Nonionella* sp cf *turgida*	*Ammobaculites* sp	PLANKTONIC: *Globigerina* sp (frag)	*Globigerina* sp cf *G. falconensis*	SIMPLE DIVERSITY	OSTRACODA: *Elofsonella concinna*	*Eucytheridea punctata*	*Eucytheridea bradyi*	*Heterocyprideis sorbyana*	*Cytheropteron nodosum*	*Acanthocythereis dunelmensis*	*Rabilimus mirabilis*	*Cluthia cluthae*	*Loxoconcha guttata*	*Cythere lutea*	*Cytheropteron latissimum*	*Cytheropteron sp* (fragment)	*Robertsonites tuberculatus*	*Aurila* cf. *convexa*	SIMPLE DIVERSITY
52016	1941	76.92-76.83		▮	▮	●			●																										●					4																		0
53622	1942	76.83-76.74		▮	▮	▮	●				●				●	●										●								●		●			10			●			●											3
52017	1944	76.65-76.56	G	▮	▮	●	●		●								●	●								●								●					9																	0
53623	1945	76.56-76.47		▮	▮	●	●		●		●															●								●					9				●				●								3
52018	1947	76.38-76.29		●		●	●	●	●	●																													6					●				●							2
53624	1948	76.29-76.20		●		●	●																											●					4																	0
52019	1949	76.20-76.05	F	▮	▮	●		●	●				●					●									●							●	●	●			11	●	●															2
53625	1951	75.99-79.93		▮	●													●																					3								●								1
52020	1952	75.93-75.88		●	●	●		●					●					●															●					6										●	●					3
53626	1954	75.83-75.78		●	●	●		●					●					●																				6												●		●		2
52021	1955	75.78-75.74	E	●		●		●																														3	●															1
53627	1957	75.70-75.62		BARREN																																		0																0
52022	1958	75.62-75.53		●		●		●	●				●																									5												●		●		2
53628	1960	75.47-75.41		▮	●	●												●														●						5	●	●				●			●	●						5
52023	1961	75.41-75.35		▮	●	▮	●	●		●				●				●																●					9																	0
52024	1964	75.30-75.23	D	▮	●	●		●			●							●																					6		●							●							2
53629	1965	75.23-75.16		●	●	●																																3										●						1
52025	1967	75.09-75.02		▮	●	▮	●	●	●									●															●					8											●					1
53630	1968	75.02-74.96		●	●	▮			●									●																					6	●	●							●	●						5
52026	1969	74.96-74.90		●	▮	▮	●	●	●			●		●												●											●		10																	0
52027	1971	74.85-74.78		▮	●	★			●		●			●				●								●	●		●	●									12	●	●															2
53631	1972	74.78-74.71	C	●	▮	★					●				●	●		●								●	●		●	●									12	●																2
52028	1973	74.71-74.65		●	▮	★		●	●		●			●				●																					11	●																3
53632	1974	74.65-74.59		●	●	▮												●																					4		●															1
52029	1976	74.53-74.47		▮	▮	▮	●	●	●		●							●	●	●																			10	●																1
53633	1977	74.47-74.41		●	●	●											●																						4	●																1
52030	1979	74.35-74.26		▮	●	●																																	3																	0
53634	1980	74.26-74.19		▮	●	●		●	●							●																							6	●	●					●									3
52031	1982	74.10-74.02	B	●		●		●																															3	●							●								2
53635	1983	74.02-73.94		●																																			1	●																1
52032	1985	73.86-73.78		▮		●		●							●																								4		●					●									2
52033	1987	73.75-73.67		●		●	●	▮			●																												5	●																1
53636	1988	72.67-73.58		●	●	●	●																																4							●									1
52034	1989	73.58-73.52		●	●	●	●	●			●	●																											7		●		●													2
53637	1990	73.52-73.46	A		●	●		●																															3																	0
52035	1991	73.46-73.43		▮	●	●		▮		●	●																												6	●																1
53638	1993	73.40-73.30		●	●																																		2	●																1
52036	1995	73.19-73.07		▮	●	●	●	●	●	●																													7	●			●													2
53639	1996	73.07-72.95		●	●	●	●	●																															4	●	●	●														3

● < 10 specimens
▮ 10 -50 specimens
★ > 50 specimens

Figure 2. Range chart showing the vertical distribution of foraminifera and ostracods through the Afton Lodge succession.