Wessex Archaeology

BritNed Interconnector
Isle of Grain

Final Report
Stage 4 Analysis

Ref: 64495.01

July 2009

BRITNED INTERCONNECTOR
ISLE OF GRAIN

FINAL REPORT
STAGE 4 ANALYSIS

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The sample analyses were carried out by Nigel Cameron, Michael Grant, Jack Russell and Chris Stevens. Scanning Electron Micrography was undertaken by John Whittaker and Giles Miller.

This report was written by Jack Russell and figures were produced by Kitty Brandon.

John Gribble managed the project and edited the report for Wessex Archaeology and Stuart Leather provided quality assurance.

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1. INTRODUCTION

1.1. PROJECT BACKGROUND

1.1.1. Wessex Archaeology (WA) was commissioned by Metoc plc., on behalf of BritNed Developments Limited (the Client), to undertake Stage 4 analysis of sediment samples from an undisturbed core section of borehole BH120. This borehole formed part of a programme of geotechnical investigations on the site of the proposed BritNed Interconnector, located at the eastern extremity of the Isle of Grain, Kent (**Figure 1**).

1.1.2. WA's work has formed part of a staged process of archaeological mitigation proposals outlined in a Written Scheme of Investigation (Wessex Archaeology 2006a) including:

- A Watching Brief and Archaeological Assessment during geotechnical investigations (WA 2006b);
- Stage 2 Archaeological Assessment and Recording of geotechnical samples (WA 2007); and
- Stage 3 Sample Assessment of subsamples (WA 2008).

1.2. GEOARCHAEOLOGICAL BACKGROUND AND INTERPRETATION

1.2.1. The topography of the Isle of Grain is generally low-lying, with a maximum height of approximately 10m above sea level. The bedrock geology of the area is London Clay. In places this is overlain by Pleistocene sediments including river gravels (IGS 1977). These gravels may be part of the Thames Medway Pleistocene river system.

1.2.2. The London Clay and Pleistocene sediments are in turn overlain by alluvial deposits of clay, silt, sand and gravel with peat deposits. Borehole data examined by Metoc plc. prior to the commencement of the geotechnical investigations suggested that the depth of alluvium varied across the site, from *c.* 2.5 to 28 metres below Ordnance Datum (m below OD) (Wessex Archaeology 2006).

1.2.3. North Kent is an area rich in archaeological remains from the Palaeolithic to Industrial periods (Williams 2007). In particular, the north Kent marshes, from which this site is reclaimed, are at present little understood. Findspots of Neolithic and Bronze Age date are common in the Medway region of the north Kent marshes, although no prehistoric settlement sites on former marshland or within the intertidal zone have as yet been recorded in this area (Fulford *et al.* 1997).

1.2.4. The Stage 2 recording included an assessment of geotechnical data which provided a system of sedimentary units related to depth below ground level (Wessex Archaeology 2007). Levels reduced to Ordnance Datum and a more detailed geotechnical log for BH120 have since been received (Fugro 2006). Based on this a reinterpretation of the sedimentary units, with depths reduced to Ordnance Datum, is given in the table below and shown in **Figure 2**.

Sedimentary Unit	Description	Interpretation	m below OD
Unit 1	Brick and concrete	Made ground	3.18 to 2.38
Unit 2	Sandy clay and gravel	Holocene alluvium and Made ground	2.38 to 1.18
Unit 3	Sandy silty clay	Holocene alluvium	1.18 to -26.77
Unit 4	Gravelly clay	Possibly Tertiary bedrock	-26.77 to -28.87

1.3. SUMMARY OF ARCHAEOLOGICAL ASSESSMENTS

Desk-based Assessment

1.3.1. A desk-based assessment, combined with a limited archaeological walkover survey assessed the archaeological potential of the Site, the likely impact of the Scheme upon it and identified appropriate mitigation. An archaeological watching brief of ground works associated with the scheme was recommended (WA 2004).

Watching Brief and Stage 1 Assessment

1.3.2. A program of geotechnical investigations was undertaken on the Site by Parsons Brinckerhoff (PB) on behalf of the Client from 6 November to 1 December 2006. These investigations comprised test pits, cable percussion boreholes and cone penetrometer tests. WA undertook an archaeological watching brief during these investigations from 7 November to 1 December 2006.

1.3.3. The archaeological watching brief included a Stage 1 assessment of the core logs generated by the geotechnical contractors. This assessment established the likely presence of horizons of archaeological interest and broadly characterised them, as a basis for deciding what Stage 2 archaeological recording was required (Wessex Archaeology 2006).

1.3.4. This process identified sediments of interest (Wessex Archaeology 2006) and one U4 (undisturbed four inch diameter) core sample, retrieved at a depth of 24.85 - 25.24m below OD from borehole BH120, recommended for Stage 2 geoarchaeological recording (Wessex Archaeology 2007).

Stage 2 Archaeological Assessment and Recording

1.3.5. The 0.46m section of borehole BH120 was recorded and assessed at WA. The core was split longitudinally and the basic sedimentary characteristics of one half were recorded, including depositional structure, texture, colour and stoniness (cf. Hodgson 1976). A depth below ground level was assigned to each sediment horizon.

1.3.6. The geoarchaeological description of the core section is as follows:

Depth in metres below OD	Description
24.85 to 25.02mbOD	5Y2.5/1 Black clayey silt. Compact. Charcoal pieces <10mm diameter at 24.91 to 24.92m below OD and 24.96m below OD. Occasional charcoal flecks and rare organic material including plant stems from 24.89 to 25.01m below OD. Occasional microlaminae. Moderate molluscs (gastropods and bivalves) including *Theodoxus fluvialis*, *Bithynia* sp. and *Hydrobia ventrosa*. Diffuse boundary.
25.02 to 25.25mbOD	5Y2.5/1 Black clayey silt. Frequent organic material in including plant roots from 25.06 to 25.22m below OD and frequent molluscs from 25.14 to 25.22m below OD. Flecks of charcoal from 25.04 to 25.08m below OD.

1.3.7. Some of the pieces of charcoal, as large as 10mm in diameter, were recovered at depths of 24.91 - 24.92m, 25.22m and 24.96m below OD and were identified as oak (*Quercus* sp.). The charcoal is a possible indication of anthropogenic burning (*i.e.* forest clearance or the use of wood for fuel in hearths).

1.3.8. The occurrence of roots and plant remains from 25.06 - 25.22m below OD is an indication of emergent vegetation subsequent to and possibly during the deposition of the black clayey silt. No oxidisation or horizons altered or changed by soil formation processes were noted, indicating that the sediment was continually waterlogged.

Stage 3 Sample Assessment

1.3.9. Samples for palaeoenvironmental assessment (radiocarbon dating (^{14}C), pollen, diatoms, foraminifera, ostracods, plant macrofossils and molluscs) were taken from the core sample for laboratory analysis to establish the value of the palaeoenvironmental material surviving within the core. Based on the results of the Stage 3 assessment recommendations were made for any further Stage 4 work (Wessex Archaeology 2008). The samples were very productive with environmental remains present and often well-preserved. The results of the Stage 3 assessment can be summarised as follows:

- ^{14}C dating returned a result for an acorn cup *Quercus* (Oak) from 24.95m m below OD of 8,018±45 years Before Present (BP) (NZA-29846). This date falls within the late Mesolithic archaeological period.
- Pollen retrieved from samples included *Quercus* (oak) and *Corylus* (hazel), with *Ulmus* (elm) and *Poaceae* (grasses) forming a significant component.
- Waterlogged and charred plant remains including wood, acorns, nuts, seeds, buds and leaf fragments of woodland species *Quercus* (oak), *Corylus* (hazel) and *Viburnum opulus* (guelder rose). Remains of wetland species, including *Potomageton natans/perfoliatus* (pondweed), *Phragmites australis* (common reed)

and *Ruppia maritima* (tasselweed), a known brackish water species were recovered.

- Brackish water and marine-loving diatoms, including *Nitzschia levidensis* (syn. *Tryblionella levidensis*), *Nitzschia navicularis, Nitzschia punctata, Campylodiscus echeneis, Paralia sulcata* and *Cocconeis scutellum,* were recovered.

- Marine, brackish and freshwater molluscs were recovered, namely *Cerastoderma* spp. (cockle), *Hydrobia* spp. *Theodoxus fluviatilis* and operculae of *Bithynia* spp.

- A low abundance of shallow marine and brackish water tolerant foraminifera was recovered, dominated by species of the genus *Ammonia* (*A. limnetes*, *A. aberdoveyensis* and *A. tepida*).

- Ostracods were highly abundant within the samples and were dominated by adults and instars of the brackish water loving species *Cyprideis torosa.*

1.3.10. On the basis of these sample assessments it was recommended that Stage 4 work was undertaken upon diatoms, ostracods, pollen and plant remains. A further five samples were chosen to be processed for microfaunal remains, in particular ostracods, with particular regard to increasing the available sample size, identifying suitable specimens for SEM photography and retrieving identifiable plant macrofossils.

2. METHOD (STAGE 4 ANALYSIS)

Pollen

2.1.1. The four previously assessed pollen samples were subjected to full analysis. Minimum counts of 400 Total Land Pollen (TLP – excluding Aquatics, Pteridophytes and Bryophytes) were made for each level and calculated as a percentage of the pollen sum (Aquatics, Pteridophytes and Bryophytes calculated as percentage TLP + Group Sum). Identification was made using a Nikon Eclipse E400 microscope at x400 magnification (The full specialist report can be found in **Appendix 1**).

Radiocarbon Dating

2.1.2. The ^{14}C date obtained during Stage 3 was recalibrated using the IntCal04 calibration curve (Reimer *et al.* 2004) within the calibration program OxCal v. 4.0.5 (Bronk Ramsey 1995; 2001) (The full specialist report can be found in **Appendix 1**).

Waterlogged and Charred Plant Remains

2.1.3. Waterlogged plant material was retrieved from the microfaunal (ostracod) sample at 25.21m below OD. The material was identified and tabulated with the two other larger assessed samples from Stage 3 taken from 24.88 - 24.95 and 25.12 - 25.19m below OD The material was visually inspected under a x10 to x40 stereo-binocular microscope and identifications of taxa were conducted using the taxonomy of Stace (1997) (The full specialist report can be found in **Appendix 2**).

Diatoms

2.1.4. The four assessed diatom samples (Wessex Archaeology 2008) all produced diatoms in generally high numbers with good preservation. Analysis included full counts. Diatom preparation, counting and analysis followed standard techniques (Battarbee *et al.* 2001) (The full specialist report can be found in **Appendix 3**).

Microfauna: Foraminifera and Ostracods

2.1.5. Five additional samples were processed predominantly for ostracod analysis at 24.89, 24.97, 25.05, 25.13 and 25.21m below OD, in addition to the six samples already assessed from 24.85, 24.93, 25.01, 25.09, 25.17, 25.25m below OD. Sediment of *c.*10cm^3 was wet sieved through a 63µm sieve. The sediment was dried and sieved through 500µm, 250µm, 125µm sieves. Microfossils were picked out under 10-60x magnification and transmitted and incident light using a Vickers microscope. Where possible a minimum of one hundred specimens per sample were picked out and kept in card slides. Identification and environmental interpretation of ostracods and foraminifera follows Athersuch *et al.* (1989), Meisch (2000) and Murray (1979 and 1991).

2.1.6. Microfaunal specimens suitable for Scanning Electron Microscopy were selected and stored in water soluble glue and card slides for transportation to the Palaeontology Department, Natural History Museum London. The specimens were there mounted, coated in gold and photographed digitally in a Scanning Electron Micrograph, see **Plates 1** to **4** (The full specialist report can be found in **Appendix 4**).

3. RESULTS (STAGE 4 ANALYSIS)

3.1.1. This section summarises the results of the sample analyses. The full reports of the individual analyses, containing detailed methodologies and discussions of results can be found in **Appendices 1** to **4**.

Pollen

3.1.2. The four assessed samples were analysed for their pollen content (**Appendix 1, Figure 3**). This included counts of a minimum of 400 pollen grains. The pollen assemblages bore out the results of Stage 3 and were dominated by the woodland species *Quercus* (oak) and *Corylus* (hazel), with *Ulmus* (elm) and Poaceae (grasses) forming a significant component.

3.1.3. The pollen spectra were indicative of a fairly open overstory canopy with Poaceae up to 20% and hazel (*Corylus avellana*) being dominant. *Sparganium emersum*-type (Bur-reeds) and *Thelypeteris palustris* (marsh fern), along with low numbers of Cyperaceae (sedge) and the later appearance of *Alnus glutinosa* (alder), together are indicative of areas of slow-moving water and/or marsh within the area in the past.

Radiocarbon Dating

3.1.4. As shown in the table below and in **Appendix 1**, the radiocarbon date 8,018±45BP (using calibration program OxCal v. 4.0.5) gave a 2σ calibrated range of 9,030 - 8,720cal.BP.

Depth (mbGL)	Depth (mbOD)	Sample Material	Lab Code	Radiocarbon Date (BP)	$\delta^{13}C$ (‰)	Calibrated date (2σ range; cal. BP)

Depth (mbGL)	Depth (mbOD)	Sample Material	Lab Code	Radiocarbon Date (BP)	$\delta^{13}C$ (‰)	Calibrated date (2σ range; cal. BP)
28.13	24.95	*Quercus* sp. acorn cup	NZA-29748	8018±45	-25.9	9030 - 8720

Waterlogged Plant Remains

3.1.5. The samples at 24.88 - 24.95 and 25.12 - 25.19m below OD and at 25.21m below OD produced both waterlogged and charred plant remains (see **Figure 2**). The charred plant remains consisted of *Quercus* (oak) wood. Waterlogged remains of woodland species, including *Quercus* (oak), *Corylus* (hazel) and *Viburnum opulus* (guelder rose) were represented by acorns, nuts, seeds, buds and leaf fragments. *Musci* (moss) was recovered from the lower samples at 25.12 - 25.19m below OD.

3.1.6. Wetland species recovered from the samples varied in type and abundance. Within the lower samples at 25.12 - 25.19m and 25.21m below OD *Zanichella palustris* (horned pondweed) and *Chara* (stonewort) were recovered but were not seen in the upper sample. The upper sample from 25.12 - 25.19m below OD contained *Carex* (sedge) and *Atriplex* cf. *littoralis* (grass-leaved orache). All samples contained *Potomageton natans/perfoliatus* (pondweed) and *Phragmites australis* (common reed). *Ruppia maritima* (tasselweed), a known brackish water species was recorded in the upper two samples (at 24.88 - 24.95 and 25.12 - 25.19 m below OD) (**Appendix 2**).

3.1.7. The sample at 25.21m below OD included oak (*Quercus* sp.) buds and pondweed (*Potomageton /Zanichella*) seed. Although smaller in size the sample contained similar elements to the lower assessed sample from 25.12 - 25.19m below OD.

Diatoms

3.1.8. The results of diatom percentage counting are presented in **Figure 4**, which shows the composition of diatom species and **Figure 5** which shows a summary of diatom halobian (salinity preference) groups. The halobian groups are defined and summarised in **Appendix 3**.

3.1.9. All four samples contained mixtures of freshwater, brackish and marine diatoms. The dominant brackish water taxa included *Nitzschia levidensis* (syn. *Tryblionella levidensis*), *Nitzschia navicularis, Nitzschia punctata* and *Campylodiscus echeneis.* Marine diatoms including *Paralia sulcata* and *Cocconeis scutellum* are common or abundant, especially within the basal sample at 25.24m below OD. An abundance of freshwater epiphytic diatoms at 25.10m below OD indicates a potential phase of slightly less saline conditions (see **Figure 5**, **Appendix 4**).

Microfauna: Foraminifera and Ostracods

3.1.10. The results of the microfaunal remains within the samples is summarised in **Appendix 4**. Abundance of ostracods was very high and the preservation was in general very good. Foraminifera were present in fewer numbers and noted to be of generally small size.

3.1.11. All of the samples were dominated by adults and instars of the brackish water ostracod *Cyprideis torosa.* Both the noded and smooth form (**Plates 1** and **2** respectively were present. The noded form typically made up around 10 to 20% of the assemblages and was most relatively abundant (40% of the assemblage) in the sample at 25.21m below OD. This is a possible indication of less saline conditions (see **Appendix 4**). Other brackish water tolerant species were recovered including *Elofsonia baltica*, *Loxoxconcha elliptica* and *Cytherura gibba* (**Plate 3**). Samples at the base of the sequence contained some "freshwater" tolerant species. The sample at 25.21m below OD contained a notable number of the ostracod *Darwinula stevensoni*. At the top of the sequence shallow marine tolerant taxa were present from 24.85 to 24.05m below OD including the ostracods *Hemicythere villosa* and *Cytheropteron* sp., and the foraminifera *Elphidium cuvilleri* and *Planorbulina mediterranensis*. This apparent increase in salinity up profile is shown on **Figure 2**.

3.1.12. Brackish and tidal marsh tolerant foraminifera were recovered, including species of the genus *Ammonia* and *Ammonia aberdoveyensis* (**Plate 4**). The foraminifera were noted to be generally small in size which may be an indication of an unsuitable environment for full development.

4. DISCUSSION

4.1.1. **Figure 2** shows the relative position of the sediments and the assessed and analysed samples. The pollen sequence described above and in **Appendix 1** is indicative of a *Quercus* (oak) and *Corylus* (hazel) woodland, with the pollen spectra unchanged throughout the sequence. This is the expected pollen spectrum for the radiocarbon date of 8,018±45BP (NZA-29846) (9,030–8,720cal.BP) which corresponds to the late Mesolithic archaeological period. The pollen sequences were also noted to be similar in nature and in date to those recovered from Cockleshell Hard, Isle of Grain (Devoy 1979), the Tillingham Marsh (Waller and Kirby 2002) and Langley Point near Eastbourne (Jennings and Smyth 1987). Dense woodland is unlikely to have been extensive as this would have inhibited flowering of the understorey herbs and shrubs.

4.1.2. The plant macrofossils recovered also confirm the presence of oak and hazel with significant amounts of oak charcoal suggesting the possibility of anthropogenic burning in the area. The possibility that the charcoal is the result of natural processes such as lightning strikes is also noted. The reasons for using fire as a tool for environmental management during the Mesolithic is summarised by Mellars (1976) and includes the improvement of the environment for hunting, human movement and for increasing plant food yields. More recent research has suggested that the controlled burning of young oak trees produces a more vigorous growth and thus a higher yield of acorns – a potentially important food resource (Mason 2000).

4.1.3. The *Cyprideis torosa* dominated ostracod fauna is indicative of low energy, brackish (*c.* 5-16‰ salinity) creeks with a muddy substrate. A slight increase in salinity is noted up profile. The molluscan content of the two assessed samples also confirms the results of the microfaunal analysis of increased salinity up profile. The on-site vegetation is also shown to have an increasing marine influence up profile with the appearance of plants such as tasselweed. This increase is shown in **Figure 2**. The diatom flora is generally in agreement, although the increase in freshwater tolerant diatoms at 25.10m below OD is anomolous. Comparison with sea level curves for southeast England and the North Sea (Devoy 1979, Long 1992, 1995 and Jelgersma 1979) would indicate that intertidal sediments at these depths are expected.

4.1.4. Overall the samples indicate a surrounding environment of a primeval Mesolithic forest within the Medway Valley, with suggestions of its human inhabitants possibly selecting oak for fuel in hearths or managing the environment directly by the use of fire. This forest is then inundated by sea level rise with brackish intertidal creeks and emergent vegetation developing around the Site and an increasing influence from the sea. Some of the plants and animals noted within the samples are well-known and potential Mesolithic food resources (hazel, oak, cockles and reeds) and a woodland environment in proximity to the intertidal zone in southern Britain would have provided abundant resources for a human population.

4.1.5. Mesolithic archaeological material is common in Kent, although it is known mainly from isolated findspots with few living sites having been found or excavated. A significant early Mesolithic site consists of flint assemblages is known near the village of Lower Halstow on the southern bank of the Medway, *c.*10km southwest of the Site. The village has since given it's name to the Lower Halstow "culture", which is confined geographically to the southeast of England, is thought to be the chronological equivalent of the Danish Ertebølle culture and is characterised by the presence of true 'Thames picks' (Jacobi 1982). The Halstow type-assemblages were recovered from beneath marsh clays and peats indicating the potential of similar archaeological material to survive in the area of the Site.

4.1.6. Archaeological material becomes more frequent in Kent after *c.*8,000BP and it is argued that this may either be due to a real increase in human population size or the loss of lower-lying land (and thus the coastal sites) due to sea level rise which resulted in the aggregation of a previously more dispersed population (Williams 2007). It is also at this time that a uniquely British lithic industry, characterised by geometric microliths, appears in the archaeological record, as is apparent at the largest concentration of Mesolithic flint tools in Kent further up the Medway Valley and *c.*30km southwest of the Site at Addington (Williams 2007).

4.1.7. This lithic industry appears at about the same time as Britain became separated from mainland Europe by rising sea levels for the last time, the evidence of which is preserved within the sediments assessed and analysed as part of this study.

5. RECOMMENDATIONS

5.1.1. These analytical results should be worked up for publication in a relevant journal. This publication should take into account the results of the assessments, analyses and research referred to and presented in this report.

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APPENDIX 1: POLLEN ANALYSIS AND RADIOCARBON DATING

Michael James Grant
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Introduction

As part of archaeological mitigation in advance of construction works – an interconnecting cable at a power station. Sediments were investigated from a 'U4' sample from BH120. Pollen analysis (counts of 400 Total Land Pollen (TLP)) was carried out on four samples.

Methodology

Four samples were analysed from stratified sediment core samples at the base of a 28.5m borehole. The sediments from which pollen was analysed are described in **Table 1**.

Samples were processed using standard procedure (Moore *et al.* 1991). 1cm^3 of sediment was sampled. A *Lycopodium* spike was added to allow the calculation of pollen concentration. All samples received the following treatment: 20mls of 10% KOH at 80°C for 30 minutes; 20mls of 60% HF (80°C for 2 hours); 15 mls of acetolysis mix (80°C for 3 minutes); stained in 0.2% aqueous solution of safranin and mounted on glass microscope slides in silicone oil following dehydration with tert-butyl alcohol.

Minimum counts of 400 Total Land Pollen (TLP – excluding Aquatics, Pteridophytes and Bryophytes) were made for each level and calculated as a percentage of the pollen sum (Aquatics, Pteridophytes and Bryophytes calculated as percentage TLP + Group Sum). Identification was made using a Nikon Eclipse E400 microscope at x400 magnification. Pollen nomenclature is based on Bennett (1994; Bennett *et al.* 1994) and ordered according to Stace (1997). The pollen diagram was drawn using Tilia v 2.0.2 (Grimm, 1991).

Radiocarbon dating was undertaken by Rafter Radiocarbon Laboratory, GNS Science, New Zealand. The date was calibrated using the IntCal04 calibration curve (Reimer *et al.* 2004) within the calibration program OxCal v. 4.0.5 (Bronk Ramsey 1995; 2001).

Results

The pollen analysis results are shown in **Figure 3**, with pollen zones described in **Table 2**. The pollen assemblage is consistent with that generally associated with a sequence from the date indicated by the radiocarbon dating (NZA 29748, 8018±45; 9030 – 8720 cal. BP).

Interpretation

The pollen assemblage is dominated by *Quercus* (oak), *Corylus avellana* (hazel), *Ulmus* (elm) and Poaceae (grasses). The limited number of herb taxa identified implies a predominantly wooded environment. However, with Poaceae up to 20% and *C. avellana* being dominant, dense woodland is unlikely to have been extensive as this would have inhibited flowering of the understorey herbs and shrubs. *Viburnum opulus* (guelder-rose) and *Betula* (birch) are also recorded, indicative of local woodland. The *Pinus sylvestris* (pine) values are between 4-7%, suggesting that *P. sylvestris* is probably not present in the local vegetation, as its pollen is easily distributed over long distance, and has air sacks to enable easy transportation within flowing water (Bennett 1984).

The presence of *Sparganium emersum*-type (Bur-reeds) and *Thelypeteris palustris* (marsh fern), along with low amounts of Cyperaceae (sedge) and the later appearance of *Alnus glutinosa* (alder), indicate that there are areas of slow-moving water and / or marsh within the area, albeit if *A. glutinosa* is some distance from the sample site. The high Poaceae values may also be associated partly with wetland grasses. The presence of *Gentianella campestre*-type (field gentian) may be associated with scrub, grassland or even coastal dunes (it is not possible to distinguish *G. campestre*, normally associated with scrub, from other species such as *G. uliginosa* (dune gentian) which would be found upon coastal dunes). The low presence of Chenopodiaceae (probably including goosefoots and oraches) may be associated with local brackish water conditions, as a probable seed of *Atriplex littoralis* (grass-leaved orache) was found at the top of the sequence. There is no indication in the pollen record of any human interference, with only an isolated occurrence of *Plantago lanceolata* (ribwort plantain) at the base of the record.

Discussion

The radiocarbon date obtained in this study is in close agreement with that obtained by Devoy (1979) from Cockleshell Hard (NGR 588840 174400). In that study, the radiocarbon date came from the base of an organic deposit, directly overlying the basal gravels (Q-1286; 8,510±110; 26.42 m bOD; 9,890 – 9,140 cal. BP). The Devoy (1979) date has a deeper OD height, and is also related to the base of an organic deposit, compared to the date obtained during the current study from the top of an organic deposit. The results confirm that deep organic deposits were deposited *c.*9,500-8,800 cal. BP (weighted means of both radiocarbon dates). The pollen assemblages from both studies are also the same.

The pollen assemblages from the BritNed Interconnector borehole BH120 and Cockleshell Hard show a strong similarity to the deep pollen sequences from the Tillingham Valley, Romney Marsh (Waller and Kirby 2002). Here organic sediment accumulated during the early Holocene within a deep (25m below OD) channel incision that was created during the late Pleistocene. The sequence was similarly dominated by *C. avellana* dating from *c.*9,700 – 9,200 cal. BP prior to deposition of marine / brackish clastic sediments. This study, in addition to dated profiles from Langley Point, near Eastbourne (Jennings and Smyth 1987) is important as it adds important information to understanding early sea-level rise in southeast England.

Conclusion

Pollen analysis indicates a wooded environment dominated by *C. avellana*, *Quercus*, *Ulmus* and Poaceae, but with a fairly open overstorey canopy. The presence of slow-moving water or marsh communities are also evident, with possible taxa associated with local brackish conditions also identified.

Acknowledgements

Stratigraphic interpretations were provided by Jack Russell. Pollen samples were prepared by Karen Wicks, AFESS, University of Reading.

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Depth below ground level	Depth OD	Description
28.03 to 28.20mbGL	24.85 to 25.02mbOD	5Y2.5/1 Black clayey silt. Compact. Charcoal pieces <10mm diameter at 24.91 to 24.92mbOD and 24.96mbOD. Occasional charcoal flecks and rare organic material including plant stems from 24.89 to 25.01mbgl. Occasional microlaminae. Moderate molluscs (gastropods and bivalves) including *Theodoxus fluviatilis*, *Bithynia* sp. and *Hydrobia ventrosa*. Diffuse boundary
28.20 to 28.43mbGL	25.02 to 25.25mbOD	5Y2.5/1 Black clayey silt. Frequent organic material in including plant roots from 25.06 to 25.22mbOD and frequent molluscs from 25.14 to 25.22mbOD. Flecks of charcoal from 25.04 to 25.08mbOD.

Table 1: Sediment Description of basal sediments associated with pollen samples from Borehole 120.

Depth (m BGL)	Depth (m bOD)	Sample Material	Lab Code	Radiocarbon Date (BP)	$\delta^{13}C$ (‰)	Calibrated date (2σ range; cal. BP)
28.13	24.95	*Quercus sp.* acorn cup	NZA-29748	8018±45	-25.9	9030 - 8720

Table 2: Radiocarbon Date from Borehole 120, Britned Interconnector

Zone	Depth (mBGL / mOD)	Description
Brit-2	28.03 to 28.20 *-24.85 to -25.02*	Dominated by *Corylus avellana*-type (42-50%), *Quercus* (17-18%) %), *Ulmus* (6-7%) and Poaceae (14-18%). Lower amounts of *Pinus sylvestris* (6-7%) and *Betula* (1-2%) are also present, with *Alnus glutinosa* (up to 1%) and *Salix* (1%) present in low amounts. *Sorbus*-type, *Hedera helix* and *Viburnum opulus* are present as isolated occurrences. Cyperaceae (up to 1% TLP + Cyperaceae) and Chenopodiaceae (up to 1%) are present throughout the zone, with isolated occurrences of *Urtica dioica*, Rosaceae undif., *Plantago media*, *P. lanceolata* and *Solidago virgaurea*-type. *Sparganium emersum*-type is present (1-2% TLP + aquatics). *Polypodium* (0.5% TLP + Pteridophytes) and Pteropsida (monolete) indet. (up to 2% TLP + Pteridophytes) are present throughout the zone, with isolated occurrences of *Pteridium aquilinum* and *Thelypteris palustris*. Pollen concentrations show little variation, increasing from 141576 to 145603 grains cm^{-3}.
Brit-1	28.20 to 28.43 *-25.02 to -25.25*	Dominated by *Corylus avellana*-type (35%), *Quercus* (28-33%) %), *Ulmus* (8-10%) and Poaceae (15%). Lower amounts of *Pinus sylvestris* (4-5%) and *Betula* (1%) are also present, with *Salix* (up to 2%) and *Hedera helix* (0.5%) present in low amounts. Cyperaceae (up to 1% TLP + Cyperaceae), Chenopodiaceae (up to 1%) and *Filipendula* (up to 2%) are present throughout the zone, with isolated occurrences of *Ranunculus acris*-type, Rosaceae undif., Apiaceae undif., *Gentianella campestris*-type, *Plantago lanceolata*, *Solidago virgaurea*-type and *Artemisia*-type. *Sparganium emersum*-type decreases (8-3% TLP + aquatics). *Pteridium aquilinum* (0.5% TLP + Pteridophytes) and Pteropsida (monolete) indet. (1% TLP + Pteridophytes) are present throughout the zone, with an isolated occurrence of *Thelypteris palustris*. Pollen concentrations show little variation, increasing from 231547 to 254276 grains cm^{-3}.

Table 3: Pollen Zone Descriptions for Borehole 120, Britned Interconnector

APPENDIX 2: WATERLOGGED PLANT REMAINS

Chris Stevens

Introduction

Three samples were taken from borehole BH120 at 24.88 to 24.95, 25.12 to 25.19 and 25.21m below OD. The samples were processed for the recovery of environmental material, including charred and waterlogged plant remains and molluscs.

A radiocarbon determination on a waterlogged fragment of an acorn cup (*Quercus* sp.) from 24.95 m below OD, yielded a date of 7080-6770 cal. BC (NZA-29846, 8018±45 BP), indicating that the material is late Mesolithic in date.

Methods

Three sub-samples were taken from the core. The samples from 24.88 to 24.95, 25.12 to 25.19 were around 500ml in volume and the sample at 25.21m below OD was 10ml in volume. The samples were wet-sieved through a 250μm mesh. They were visually inspected under a x10 to x40 stereo-binocular microscope to determine if waterlogged material occurred. Where waterlogged material was present, preliminary identifications of dominant taxa, were conducted and are presented below. Taxonomy follows that of Stace (1997).

Results

The samples produced waterlogged and charred plant remains. In terms of charred plant remains fragments of charcoal, probably mainly oak were quite common in the sample from 24.88-24.95mbOD, but relatively infrequent in the sample from 25.12 to 25.19m below OD. No such remains were recovered from 25.21m below OD.

The samples contained a mixture of woodland species and aquatics, with occasional wetland and saltmarsh species.

Woodland was represented mainly by remains of oak, particularly in the upper sample from 24.88-24.95m below OD. The remains consisted of acorns and probable bud and leaf fragments. A single nut of hazel (*Corylus avellana*) was also recovered, along with seeds of guelder-rose (*Viburnum opulus*).

Relating to wetlands were seeds of tasselweed (*Rorippa maritima*), broad-leaved/perfoliate pondweed (*Potamogeton natans/perfoliatus* type), and stems of common reed (*Phragmites australis*). A single seed of possible divided sedge (*Carex* cf. *divisa*) was found in the uppermost sample, while quite a high number of seeds of horned pondweed were recovered from the sample from 25.12 to 25.19m below OD, along with several gametes of stonewort (*Chara* sp.) and a single seed of water-crowfoot (*Ranunculus* subg. Batrachium). Seeds of horned pondweed (*Zannichellia palustris*) were present in the two lowest samples.

The only other identified seeds were a possible seed of grass-leaved orache (*Atriplex littoralis*) from the uppermost sample, a single seed of Polygonaceae, most probably water-pepper type (*Persicaria* sp.) and an unidentified grass seed resembling *Poa palustris* type.

There were also several seeds of two unidentified species. The first were small (*c.* 1mm) elongated seeds with a elongated reticulate cell pattern. The seeds were concave on one side and convex on the other. They tapered to a rounded tip at one end while the other was blunt. The longest edges of the seed were noted to be very obtuse almost square in profile, almost like a capsule fragment, but had clearly not been broken.

The second were possible seeds of bog myrtle (*Myrica gale*) from 25.12 to 25.19m below OD although positive identification could not be confirmed.

The results of the identification of waterlogged plant macroscopic remains from Borehole BH120 is presented in the table below:

	Depth metres below OD	**24.88-24.95m**	**25.12-25.19m**	**25.21m**
Latin Name	**Common Name**			
Chara sp. gametes	stonewort	-	5+	-
Musci	moss	-	+++	+
Ranunculus subg. Batrachium	water-crowfoot	-	1	-
Corylus avellana (nut)	hazelnut	1 whole	-	-
Quercus sp. (acorn)	oak acorn	2	-	-
Quercus sp. (buds)	oak possible buds	cf.5	3f	cf.1
Quercus sp. (leaf fragments)	oak possible leaves	cf.++	cf.+	
Quercus sp. (charcoal)	oak charcoal	++	1-2	-
Atriplex cf. *littoralis*	grass-leaved orache	2	-	-
Persicaria/*Polygonum* sp.	water-pepper/knotweed	-	1	-
Ruppia maritima	tasselweed	2	2	-
Viburnum opulus (seed/fruit)	guilder-rose	1	cf.1	-
Potamogeton natans/ *perfoliatus*	pondweed	cf.1	cf.1	cf.2
Zannichellia palustris	horned pondweed	-	16	2
Carex cf. divisa	divided sedge	1	-	-
Poaceae indet. *c.*1-2mm	grass seed	-	1	-
Phragmites australis (culm node)	common reed	cf.1	cf.1	cf.2
Indeterminate seeds 1mm – reticulate cells		-	5+	-
Indeterminate seeds 1mm – Myrica?		-	3	-
Other				-
Insect remains		+ (1 ant head)	+	-

Discussion

The presence of acorns and probable leaves and bud scales of oak, along with the hazelnut compare well with the dominance of these two species in the pollen record and show them to have been present in the immediate vicinity of the deposit. Guelder rose (*Viburnum opulus*) is often found in woodland on calcareous soils.

The seeds of wetland species are predominately those of floating or submerged aquatics. Of these tasselweed (*Ruppia maritima*) is only found in brackish waters and so the most prominent indicator of marine inundation and sea-level rise. However, horned pondweed (*Zannichellia palustris*) and the probable represented species of pondweed (*Potamogeton natans/perfoliatus*) while found in freshwater can also be found in brackish waters. The absence of *Zannichellia* from the upper levels may be significant in that it may indicate that salinity levels had risen to a point that this species was no longer able to tolerate. Of the other species present in the sample, some are slightly more indicative of the brief establishment of probable small localised areas with open conditions. These include stems of probable common reed (*Phragmites australis*), a seed of possible divided sedge (*Carex divisa*) which is common in grassy places near the sea, a probable seed of grass-leaved orache (*Atriplex littoralis*) and an unidentified fragment of *Polygonum*/*Persicaria* seed.

While small in size, the assemblage is unusual in its mix of estuarine or maritime and woodland elements. The sequence is in this respect highly suggestive of a submerged forest horizon comprising oak and hazel.

The absence of alder is of some interest given the radiocarbon dating for this species at other sites in southern England shortly prior to this date: for example Testwood in Hampshire (UB4258, 7881±36 BP; UB-4486, 7770±70 BP). This may be reflective of a general absence of alder from this part of Southern England at this date, or possibly just a localised absence.

The charcoal may come from natural forest fires, however, given the increasing wetness of the area and that the charcoal showed little indication of fluvial reworking, it may relate to human activity in the local vicinity. It might be noted that charred stumps of oak recovered from the Severn Estuary, dated to around *c.* 5700 cal. BC, have been associated to hunter-gather activity (Bell 2006).

While remains of oak were less frequent in the lower, earlier sample, it must be assumed that oak woodland was dominant in the local vicinity of the core at this time, as seen also in the pollen report. The increase of waterlogged and charred plant remains in this part of the core probably relate more to increased rates of sedimentation and possibly even to the destruction of this woodland through marine inundation.

Potential

The sample from borehole BH120 has the potential to provide information regarding the nature of the local environment during the deposition of the deposits. There is also some potential to examine changes within this environment during sea-level rise and inundation.

The remains and potential to study waterlogged submerged forests often only exists for sites of generally more recent Neolithic or Bronze Age date, for example, a submerged forest of Neolithic date is known from Erith near Dartford (Paddenberg and Hession 2007).

Often such remains are also confined to more accessable sites where isostatic rebound has resulted in some up-lifting of the coast, as in parts of Wales and North England. The recovery of such material from such depth then provides a unique opportunity to study the composition of primeval Mesolithic forest in southern England.

Recommendations

There is little further work to be carried out, although the presence of oak leaves and identification of some of the remaining taxa may be possible with reference material.

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APPENDIX 3: DIATOM ANALYSIS

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Introduction

Four samples for diatom analysis were taken from Borehole BH120 at the Britned Interconnector site, Isle of Grain, Kent. The diatom evaluation of these samples was reported in May 2008 (Cameron 2008). The quality and diversity of the four diatom assemblages that were assessed indicated that there was very good potential for percentage diatom counting. Full percentage counts have been made and diatom analysis is reported here.

Methods

Diatom preparation, counting and analysis followed standard techniques (Battarbee *et al.* 2001). Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendey (1964), Werff & Huls (1957-1974), Hartley *et al.* (1996) and Krammer & Lange-Bertalot (1986-1991). Diatom species' salinity preferences are discussed using the classification data in Denys (1992), Vos & de Wolf (1988, 1993) and the halobian groups of Hustedt (1953, 1957: 199), these salinity groups are summarised as follows:

1. Polyhalobian: >30 g l^{-1}

2. Mesohalobian: 0.2-30 g l^{-1}

3. Oligohalobian - Halophilous: optimum in slightly brackish water

4. Oligohalobian - Indifferent: optimum in freshwater but tolerant of slightly brackish water

5. Halophobous: exclusively freshwater

6. Unknown: taxa of unknown salinity preference.

Results & Discussion

The results of diatom percentage counting are presented in **Figure 4** and **Figure 5**. **Figure 4** shows the composition of diatom species and **Figure 5** shows a summary of diatom halobian groups.

The basal sample from BH120 at 25.24m below OD is dominated by the benthic brackish water diatom *Nitzschia navicularis* that represents almost 40% of the total flora. Overall mesohalobous diatoms comprise 55% of the assemblage at 25.24m below OD and other taxa in this group include *Nitzschia compressa, Nitzschia granulata* and

Campylodiscus echeneis. These benthic diatoms are associated with the epipelic, mud-surface habitat in tidal, brackish water environments. The freshwater oligohalobous indifferent and less saline halophilous to oligohalobous indifferent and mesohalobous to halophilous groups comprise about 10% of the assemblage. The most common of the freshwater taxa are shallow water epiphytes such as *Cocconeis placentula* and *Epithemia* spp. Open water, planktonic freshwater diatoms, such as *Cyclotella kuetzingiana* var. *planetophora* are rare. At 25.24m below OD polyhalobous to mesohalobous and polyhalobous diatoms together form over 20% of the assemblage. Most common are planktonic marine diatoms such as *Paralia sulcata, Cymatosira belgica* and *Podosira stelligera*. The most common marine-brackish taxa are non-planktonic, shallow water types including *Cocconeis scutellum, Diploneis smithii* and *Synedra gaillonii*. *Actinoptychus undulatus* is a planktonic or semi-planktonic marine-brackish species. Therefore, the diatom assemblage in the basal sample represents a tidal environment, dominated by brackish water diatoms found in mud surface habitats in relatively shallow water. Marine species are represented by a smaller component of allochthonous plankton, whilst freshwater diatoms form a relatively small component of the assemblage.

At 25.10m below OD the diatom assemblage is dominated by oligohalobous indifferent (freshwater) species which comprise over 40% of the total assemblage. The most common of these is the epiphyte *Cocconeis placentula* and other taxa include *Epithemia adnata* (also an epiphyte), *Amphora pediculus* and benthic diatoms such as *Gyrosigma acuminatum* and *Nitzschia tripunctata*. The epiphytic halophile *Rhoicosphaenia curvata* is present. At 25.10m below OD mesohalobes decrease to about 12% of the assemblage, the common mesohalobous species are benthic taxa such as *Nitzschia levidensis, Nitzschia navicularis, Nitzschia compressa* and *Campylodiscus echeneis*. *Achnanthes delicatula*, commonly an epiphyte, is also present.

The most common marine-brackish taxa are non-planktonic, shallow water diatoms such as *Cocconeis scutellum* and *Synedra gaillonii*. Again polyhalobous diatoms include planktonic species such as *Paralia sulcata* and *Cymatosira belgica*, but the most abundant marine diatom is the attached species *Cocconeis pelta* which comprises almost 8% of the diatom assemblage. The polyhalobous and polyhalobous to mesohalobous groups represent in total about 20% of the total diatoms at 25.10m below OD. The diatom assemblage at 25.10 m below OD seems to show a decrease in salinity with the establishment and dominance of oligohalobous indifferent, non-planktonic taxa such as *Cocconeis placentula*. The input of polyhalobous and mesohalobous diatoms reflects significant allochthonous input from tidal waters but may partly result from sediment mixing.

At 24.98 m below OD mesohalobous diatoms increase to 38% of the total assemblage whilst oligohalobous indifferent diatoms decline to 20% and polyhalobous and polyhalobous to mesohalobous diatoms together comprise about 20% of the total. Common mesohalobous diatoms are again non-planktonic epiphytic and benthic taxa such as *Achnanthes delicatula, Campylodiscus echeneis, Navicula gregaria, Nitzschia acuminata, Nitzschia compressa, Nitzschia navicularis, Rhopalodia gibberula*, *Syndra pulchella* and *Syndera tabulata*. However, the assemblage also includes open water plankton that originates from shallow water habitats such as *Melosira moniliformis*. Cocconeis placentula remains the most common freshwater diatom. Other oligohalobous indifferent taxa include *Epithemia adnata, Navicula tripunctata* and *Rhopalodia gibba*. Allochthonous marine and marine brackish diatoms include *Paralia sulcata, Cymatosira* *belgica, Podosira stelligera*, *Cocconeis pelta* and *Cocconeis scutellum*. The increase in abundance of non-planktonic mesohalobous diatoms and decline of oligohalobous indifferent diatoms suggests an increase in salinity and tidal influence.

At 24.86m below OD similar percentages of polyhalobous and polyhalobous to mesohalobous (18%), mesohalobous (decline to 30%) and oligohalobous indifferent (21%) taxa are maintained compared with the underlying sample. However, the percentages of intermediate halophilous salinity groups are increased compared with other samples (combined halophiles comprise about 22% of the total). Halophilous taxa include *Nitzschia levidensis, Rhoicosphaenia curvata* and the aerophile *Navicula mutica*. The mesohalobous planktonic diatom *Melosira moniliformis* is also common as is the freshwater epiphyte *Cocconeis placentula*. There are similar inputs of allochthonous marine diatoms to those found in the other samples. Again the assemblage represents brackish water with significant tidal influence.

Conclusions

- Mixtures of freshwater, brackish and marine diatoms are present in all four samples.
- The presence of significant numbers of attached and benthic mesohalobous diatoms and polyhalobous diatoms shows that tidal conditions were prevalent throughout.
- Percentage diatom counting of the basal sample (25.24 m below OD) confirms the evidence for more saline conditions here, with minimum numbers of oligohalobous indifferent taxa.
- The abundance of freshwater epiphytic diatoms at 25.10m below OD indicates a phase of less saline conditions.
- In the top two samples at 24.98 m below OD and 24.86m below OD there is a return to more saline conditions with a recovery in the percentage of mesohalobous (both benthic and planktonic) diatoms. In the top sample the intermediate halophile halobian groups also form a significant component of the saline flora.
- As well as diatom species environmental tolerances, sediment mixing, time averaging processes and allochthonous inputs will have influenced the composition of the mixtures of diatoms occurring in these estuarine assemblages. However, the diatom assemblages seem to reflect significant changes in salinity. The allochthonous input of polyhalobous diatoms does reflect tidal input whilst, for example, the contribution of freshwater aerophilous diatoms (e.g. *Ellerbeckia arenaria*) to the assemblages is small.

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APPENDIX 4: MICROFAUNAL ANALYSIS: FORAMINIFERA AND OSTRACODA

Jack Russell

Introduction

Eleven sediment subsamples from an unidisturbed "U4" core sample retrieved from a borehole (BH120) taken during construction work on the Isle of Grain, Kent have been assessed and analysed for the presence and environmental significance of their microfaunal contents, predominantly ostracods and foraminifera. Six subsamples had already assessed for their microfaunal contents at: 24.85, 24.93, 25.01, 25.09, 25.17, 25.25m below OD (Wessex Archaeology 2008). On the basis of this assessment further samples were recommended in particular for ostracod analysis and interval subsamples were taken at: 24.89, 24.97, 25.05, 25.13 and 25.21m below OD. The retrieved sediments are organic alluvial silts and clays. Ostracods and foraminifera occurred in all of the eleven samples. The ostracods were particularly well-preserved and highly abundant. Specimens were sent to the Natural History Museum, London for Scanning Electron microscopy, the results of which can be seen in **Plates 1** to **4**

Other plant and animal remains were also recovered from the samples. The plant remains have been identified and integrated with the results of the waterlogged plant assemblages recovered during Stage 3 (Wessex Archaeology 2008), see **Appendix 2**.

Method

Sediment was wet sieved through a 63µm sieve. The sediment was dried and then sieved through 500µm, 250µm, 125µm sieves. Microfossils were picked out under 10-60x magnification and transmitted and incident light using a Vickers microscope. Where possible a minimum of one hundred specimens per sample were picked out and kept in card slides. Identification and environmental interpretation of ostracods follows Athersuch *et al.* (1989) and Meisch (2000). Identification and environmental interpretation of foraminifera follows Murray (1979 and 1991).

Results

Abundance of microfaunal remains within the samples is summarised in **Table 1**. Abundance of ostracods was very high and the preservation was in general very good. Foraminifera were present in fewer numbers and noted to be of generally small size.

All of the samples were dominated by adults and instars of the brackish water ostracod *Cyprideis torosa* (**Plates 1** and **2**). There were very high numbers of this ostracod in the samples and there are estimated to be several thousand in some of the samples. Over 50% of the identified ostracods were united carapaces. Given the excellent preservation and significance of relative abundance of noded surface morphology of *Cyprideis torosa* (see discussion below), attention was paid to the identification the nodose (**Plate 1**) or smooth (**Plate 2**) form (**Table 1**). It was noted that at the base of the sequence, from 25.05 to 25.25m below OD, the noded form was more abundant, typically forming between 10 and 20% of total numbers although at 25.21m below OD the noded form comprised 40% of the total numbers of *Cyprideis torosa.* At the top of the sequence the noded forms comprised less than 5% at 24.85, 24.89, 24.93, 24.97 and 25.01m below OD. The nodes were present up to a maximum of five sites, the full compliment of seven nodes only being known from the type material from Grays, Essex.

Loxoconcha elliptica was also noted in all of the samples, except at 25.21m below OD. The abundance of *Loxoconcha elliptica* was greatest at the top of the sequence between 24.85 and 25.01m below OD. Other ostracods commonly known from estuarine environments included *Cytherura gibba* (**Plate 3**) and *Elofsonia baltica*, both increasing in abundance towards the top of the sequence.

The ostracod fauna at 25.21m below OD contained a notable number of *Darwinula stevensoni*. Normally a freshwater indicator, this ostracod can tolerate small increases in salinity. It was present in small numbers in other samples, however it was most abundant at 25.21m below OD and the fauna contained both adult and juvenile female forms. It is interesting to note that *Bithynia* operculae were also more frequent towards the base of the sequence (25.13, 25.21 and 25.25m below OD).

Some noteable shallow marine ostracods were identified at the top of the sequence (at 24.85 and 24.89m below OD) including, *Hemicythere villosa* and *Cytheropteron* sp.. A shallow marine indicative foraminifera *Planorbulina mediterraneansis* was also recovered at this level.

Foraminifera were present throughout the samples in small numbers. These were predominantly of the genus *Ammonia*. Many were small and of those identified to species level, *A. limnetes*, *A. tepida* and *A. aberdoveyensis* (**Plate 4**) were numerically dominant. These species and *Jadammina macrescens* and *Trochammina inflata* (present in some of the upper samples at 24.83, 24.85, 24.89 and 25.01m below OD) are common in brackish tidal marshes, however their numbers, taphonomy and size all indicate that in these samples they are an allochthonous component.

A small but noteable number of shallow marine foraminifera were noted in the upper samples from 24.85 to 24.05m below OD including *Elphidium cuvilleri*, and *Planorbulina mediterranensis.* The taphonomy of these specimens was such that it is probable that they were transported.

Discussion

The abundance of ostracods within the samples was generally very high and preservation very good. The dominance and hyperabundance of the ostracod *Cyprideis torosa* throughout the sequence is an overwhelming indication of brackish tidal creeks with fluctuating salinity. One would expect large abundances of this taxa in a tidal creek with a muddy substrate and organic detritus..

The relatively high numbers of noded forms of *Cyprideis torosa* deserves some discussion. Although a euryhaline taxon, noded forms generally occur in lower salinities. Kilyeni (1972) suggests that the occurrence of nodes is a result of balanced genetic polymorphism (ie natural selection) and the fact that the nodes always occur at the same seven sites would seem to support this. However it is now more widely accepted that even though the node sites are genetically controlled, their development is a physiological response to external conditions and it appears that the nodes more frequently occur in low salinities 2-5‰ (Boomer 2002). At these salinities the noded forms would be expected to dominate the assmblage. Experiments have shown that nodes will develop on the smooth forms under laboratory conditions of reduced salinity although noded forms subjected to raised salinity in laboratory conditions retain their ornament (Meisch 2000). The nodes are developed on up to five of the seven sites in the specimens recovered from these samples, which is not unusual in Holocene faunas, the full compliment of ornamentation on seven sites only being recorded from the Pleistocene (MIS9) type material from Grays, Essex.

Mass development of *Cyprideis torosa* can occur on soft mud with organic detrital material within brackish water optimally between salinities of 2 and 16‰ (normal marine salinities are 30-35‰). Although *Cyprideis torosa* is a euryhaline taxon that can occur in freshwater to hypersaline conditions (60‰) (Meisch 2000).

At 25.21m below OD the noded forms of *Cyprideis* reach their greatest relative abundance. In this sample it is interesting to note a significant number of well preserved adults and juveniles of the taxon *Darwinula stevensoni*. This ostracod is normally associated with freshwater conditions although it can tolerate salinities of up to 16‰ (Meisch 2000). This sample also contained molluscan freshwater taxa including *Theodoxius fluviatalis* and the operculae of *Bithynia* sp.

Other "freshwater" ostracods recovered at the base of the sequence include *Candona candida* and *Cytherissa lacustris*. Only occasional single adult valves were noted and although normally associated with freshwater, both taxa can tolerate slight increases in salinity (Meisch 2000). It is considered that the basal two samples at 25.21 and 25.25m below OD have a slightly greater freshwater influence than the overlying samples. A slightly greater marine connection is noted in the upper samples with stray shallow marine/outer estuarine taxa.

Loxoconcha elliptica, present in all of the samples and represented by adult and juvenile forms is also indicative of predominantly brackish conditions. *Loxoconcha elliptica* becomes more abundant up profile which may indicate more open estuarine conditions. *Cytherura gibba* (**Plate 3**) present in the upper nine samples most is also indicative of brackish, estuarine conditions.

An increasing marine contact is seen up profile with stray valves of marine taxa including *Hemicythere villosa* and *Cytheropteron* sp..

Summary

- Mass development of the ostracod *Cyprideis torosa* has been recovered
- Low energy brackish (*c.* 5-16‰) creeks and a muddy substrate are indicated by the faunas recovered.
- A slight increase in salinity and marine contact is noted up profile.

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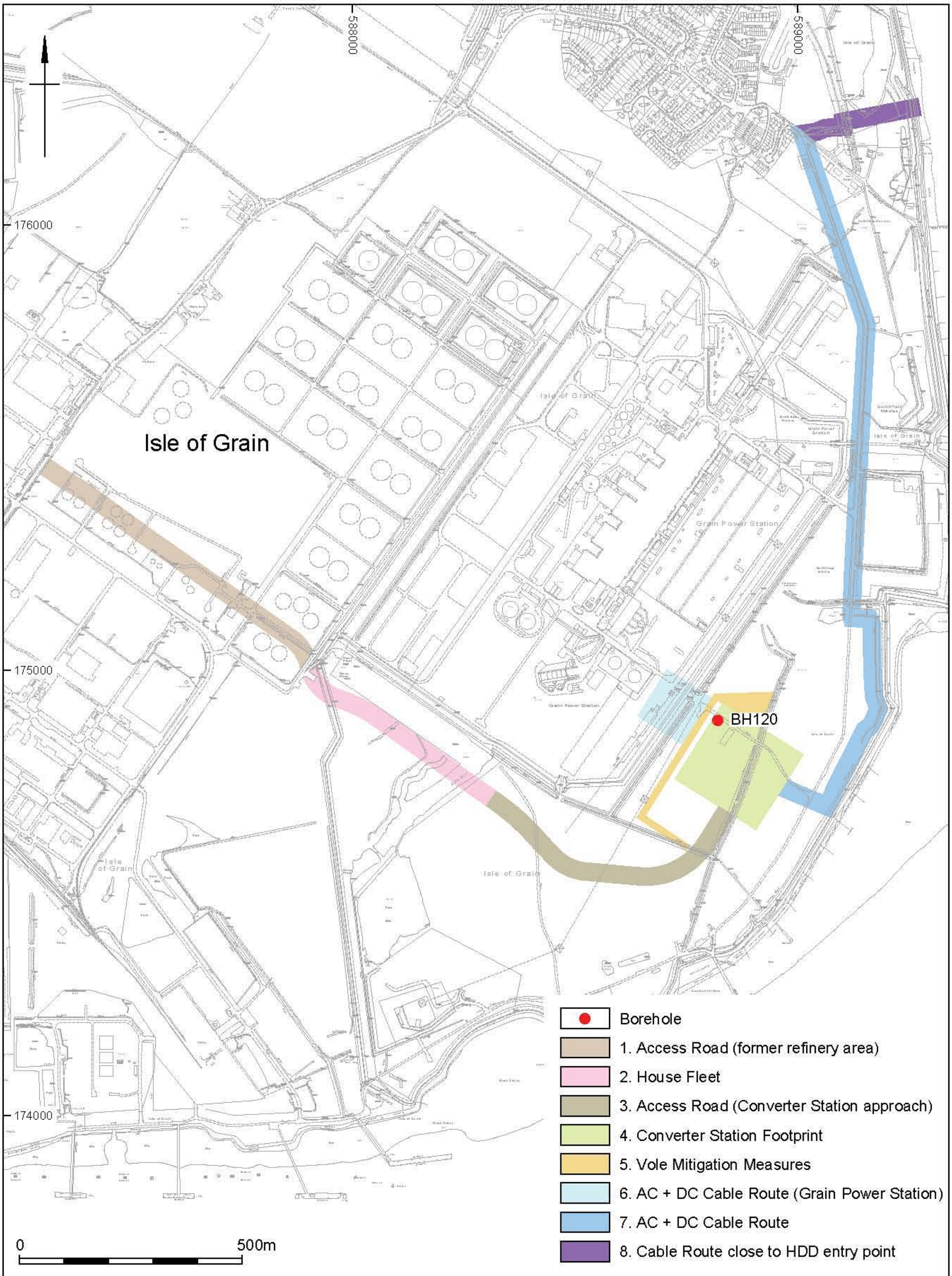
Ostracods / m below OD	**24.85**	**24.89**	**24.93**	**24.97**	**25.01**	**25.05**	**25.09**	**25.13**	**25.17**	**25.21**	**25.25**
Candona sp.									x	x	x
Candona candida		x									x
Cyprideis torosa smooth	xxxx	xxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxx	xxxx	xxx	xxxx
Cyprideis torosa noded	x	x	x	x	x	xx	x	x	x	xx	x
Cytheropteron sp.		x									
Cytherissa lacustris								x			
Cytherura gibba	x	xx	x	x	x		x	x	x		
Darwinula stevensoni ♀										xxx	x
Elofsonia baltica		xx		xx		x				x	
Fabaeformiscandona sp		x									
Hemicythere sp.			x				x		x		x
Hemicythere rubida				x							
Hemicythere villosa	xx										
Leptocythere castanea						x					
Leptocythere lacertosa		x						x			
Leptocythere ?macallona		x		x		x				x	
Loxoconcha elliptica	xx	xx	xx	xx	xx	x	x	x	x		x
Semicytherura cornutata			x								
Foraminfera											
Ammonia sp.		x		xx		x		x			
Ammonia aberdoveyensis	x			x	x	xx	x	xx	x	x	x
Ammonia batavus		x		xx		xx		xx		x	
Ammonia limnites	xx		x	xx	xx	xx	xx	xx	x	x	x
Ammonia tepida	x	x	x	x	x		xx		x		x
Elphidium cuvilleri			x	x							
Elphidium sp.	x	x		x		xx					
Jadammina macrescens	x		x								
Planorbulina mediterranensis	x										
Trochammina inflata	x	x	x			x					
Molluscs											
Bithynia operculae								x		x	x
Hydrobids				x			x				
Theodoxus fluviatilis	xx				xx					x	
Animal remains											
fish teeth								x			
Sponge spicules			x								
Plant remains											
Charcoal			x							x	
Diatoms			x								
Potomageton			x					x			
seed unid.		x		x							
Sphagnum			x								

Table 1. Abundance of taxa per sample in BH120.
Abundance:
x – 1-9 specimens
xx – 9-50 specimens
xxx – greater than 50 specimens
xxxx – greater than 100 specimens



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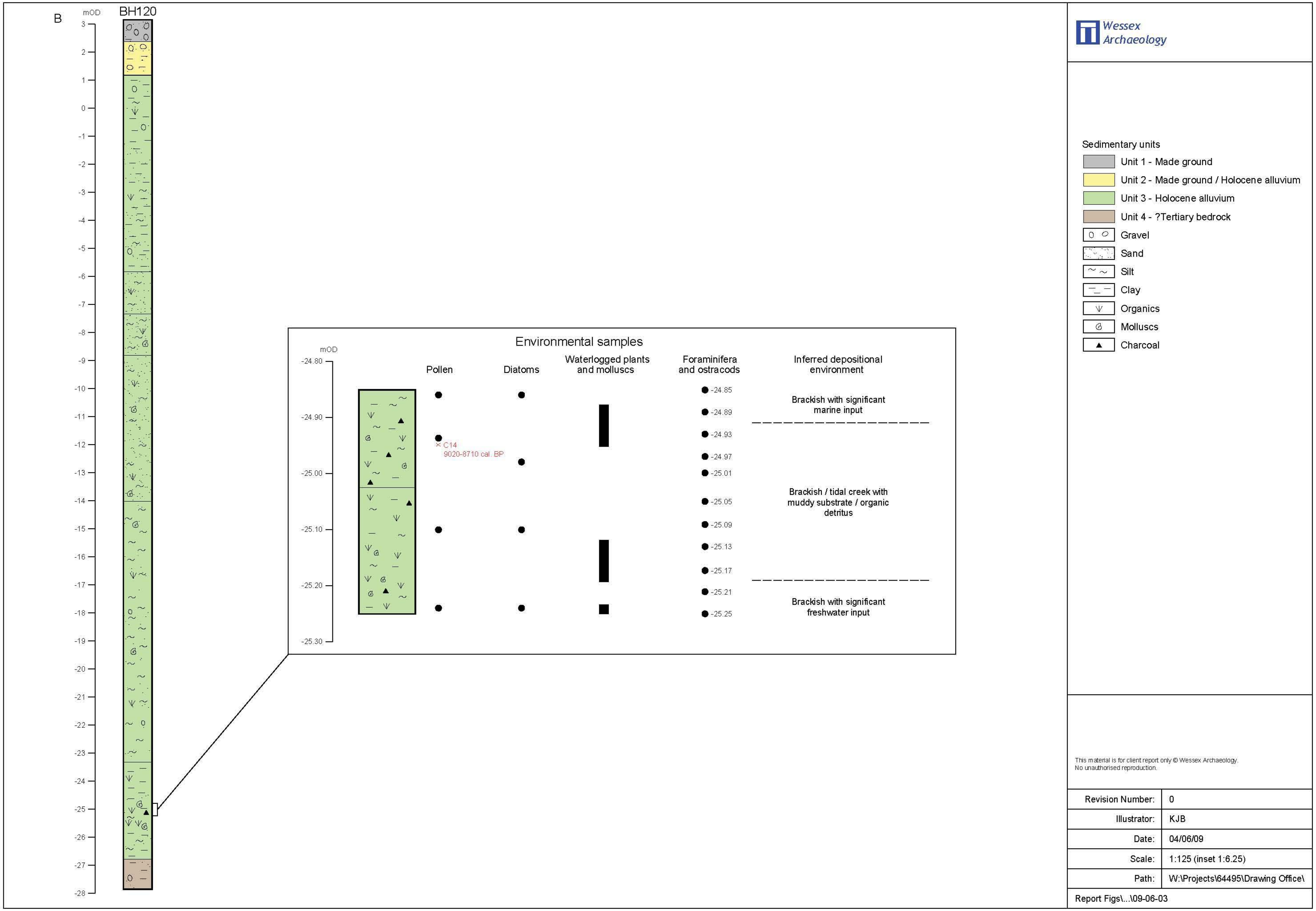
Site and borehole location

Figure 1



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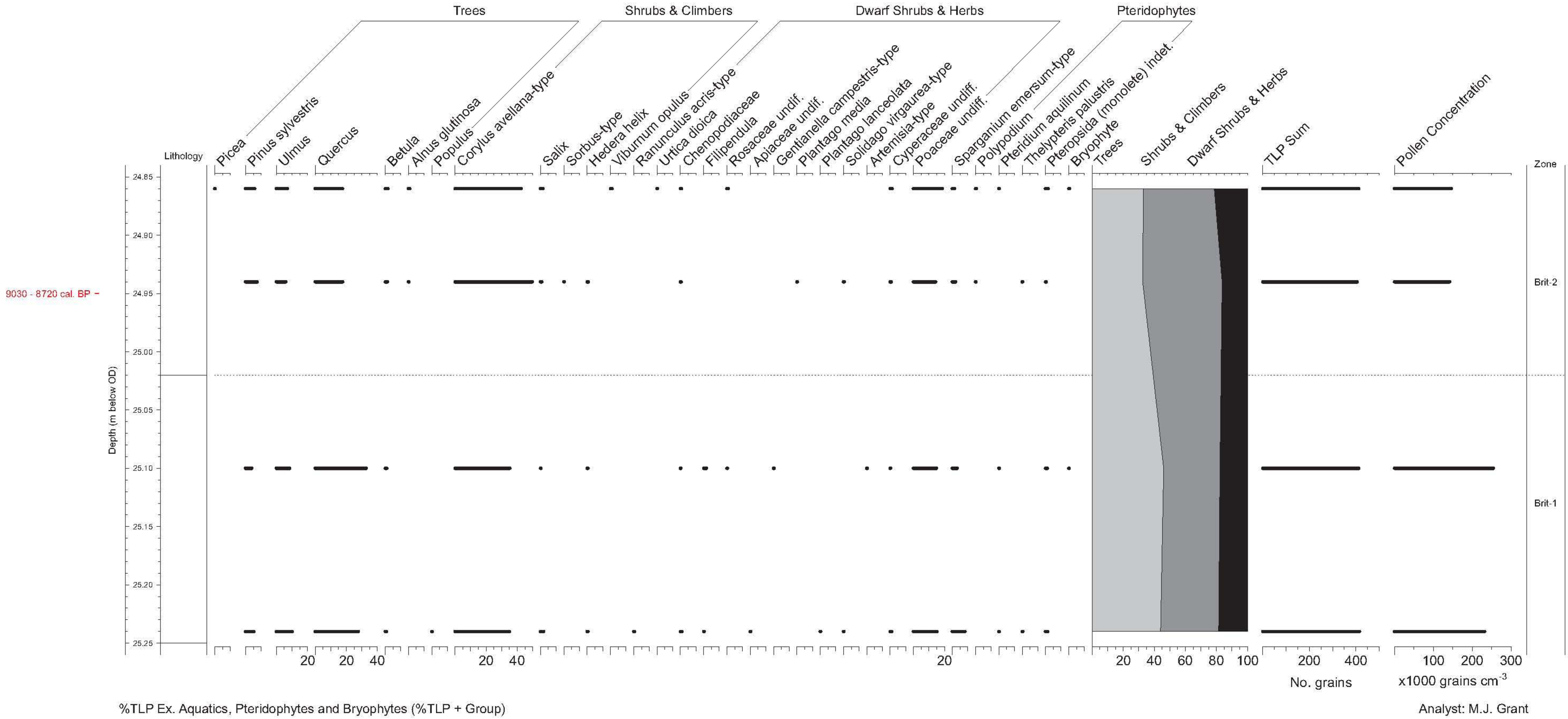
Sedimentary units and environmental samples

Figure 2



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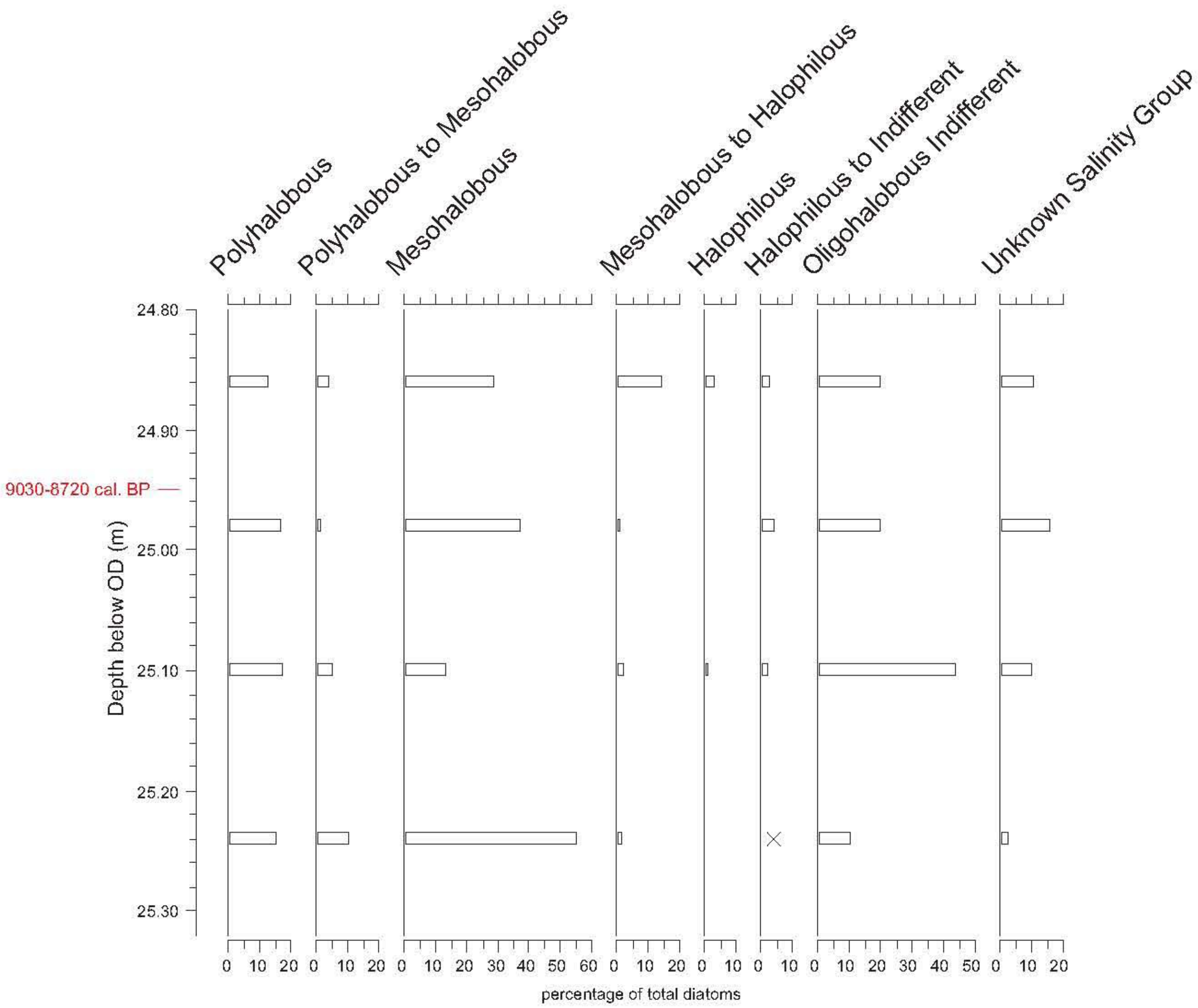
Pollen diagram from borehole 120

Diatom diagram

Figure 4



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Diatom diagram

Figure 5

Plate 1: *Cyprideis torosa* ♂ Right valve. Lateral view. Noded.

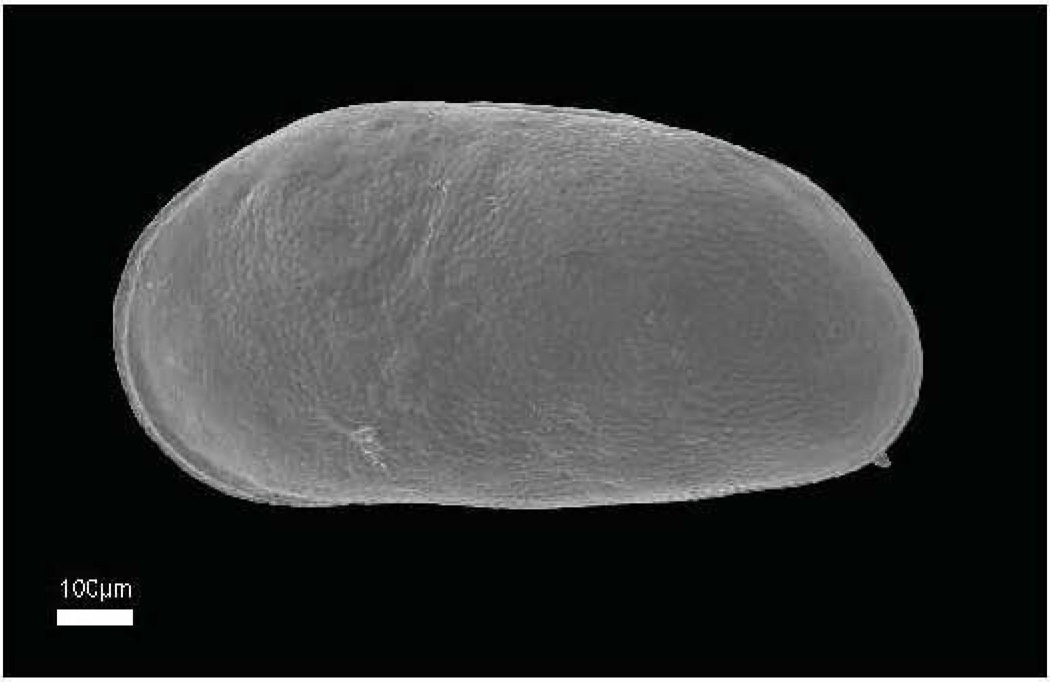

Plate 2: *Cyprideis torosa* ♂ Left valve. Lateral view. Smooth.

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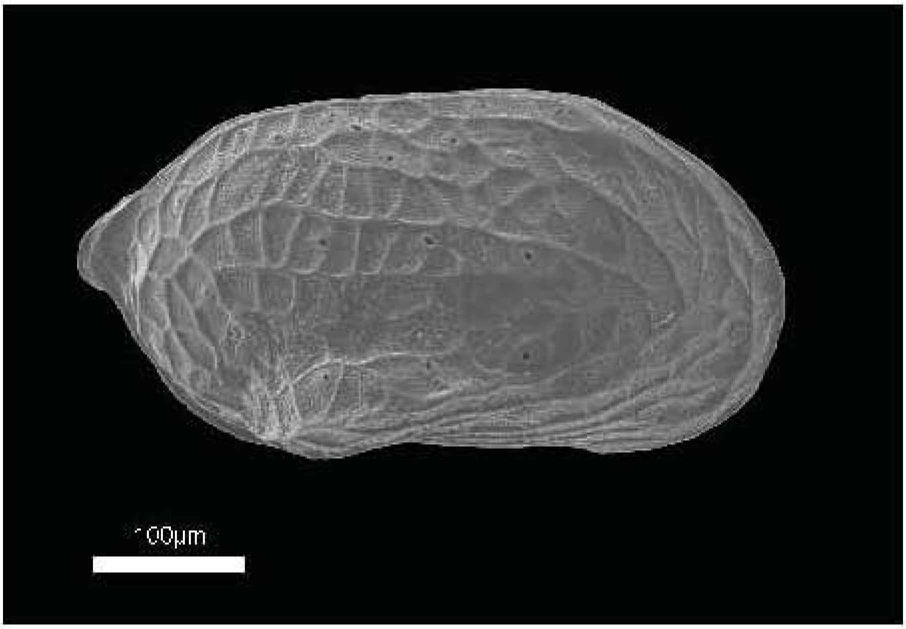

Plate 3: *Cytherura gibba.* ♀ Right valve. Lateral view.

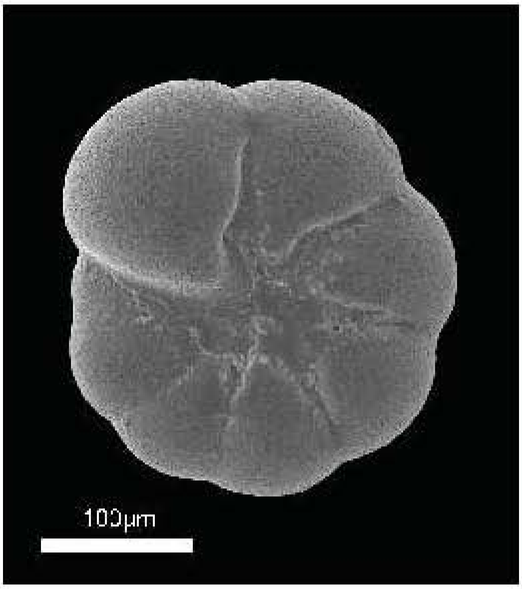

Plate 4: *Ammonia aberdoveyensis.* Umbilical view.

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