NANTWICH PALAEOENVIRONMENTAL ASSESSMENT

Diatom Analysis

By

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&

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October 2008

Contents

Acknowledgements

Thanks are extended to Dr Steve Ellis for discussion of the Nantwich sedimentary history,to Ian Panter for discussions relating to hydrology and burial environments and to Tim Malim for general discussion and maps showing borehole locations.

Summary

This report is an assessment of the diatom flora recovered from sampling in and around the town of Nantwich, and is undertaken on behalf of SLR Consulting Ltd.

The key aim of this study is the identification and assessment of diatom presence, state of preservation and indications on environment or water quality data. The samples were recovered from cores taken during an assessment of waterlogged preservation undertaken by PRS on behalf of SLR Consulting Ltd (Carrott *et al*. 2008). As such, the samples lack data relating to their specific archaeological context, and with the exception of the samples from borehole P, these samples are effectively ‘spot’ samples.

Although only one sample was recovered from the western side of the floodplain, the data reported here indicates that considerable differences occur between the west and the east sides of the River Weaver floodplain. This is commensurate with the results obtained from previous geochemical and palaeoenvironmental studies. In the areas to the east of the River Weaver, both within and above the floodplain area, it appears that the specific hydrological context (Upper River Terrace deposits away from the floodplain), and anthropogenic impacts (this area is more heavily developed), are producing compromised burial environments in relation diatom preservation. In the single location studied from the west of the floodplain, preservation appears to be good.

The strong freshwater component in these assemblages is likely to be associated with the river Weaver itself; many of the oligo-halophobous species are typical of river environments, and their presence suggests either normal environmental conditions associated with river function, or freshwater inputs from stream run-off and other sources such as precipitation etc. Whilst some of the species identified are tolerant of brackish conditions, the analysis undertaken in the current study cannot provide any indication of salinity and/or the spatial extent of brackish environments, as the samples studied were pre-selected, and not targeted from a sampling strategy designed to specifically identify these characteristics of the burial environment.

In addition, where a brackish environmental tolerance is suggested for the diatom species identified, this does not mean that brackish conditions prevailed, as these species are also influenced by substrate. *Pinnularia borealis* and *Cypatopleura solea*, for example, are diatoms associated with damp soil and it is possible that these species are derived from the surrounding substrate. Any attempts at inferring past salinity values for the samples analysed would be extremely limited due to the poor condition of the samples, the weak statistical representation of species in the dataset, and the lack of specific context in relation to brine springs and saltworkings. This latter observation reflects the fact that the precise location of brine springs and salt working areas were not targeted in the sampling strategy and, as such

Figures

Tables

1 Introduction

1.1 The current analysis is undertaken by the Wetland Archaeology & Environments Research Centre at the University of Hull, on behalf of SLR Consulting Ltd.

1.2 In the current study, fifteen samples recovered from boreholes excavated throughout Nantwich, are assessed. The assessment is aimed at the identification and assessment of diatom presence, state of preservation and indications on environment or water quality data. In addition, the data is compared against existing geochemical and palaeoenvironmental data from Nantwich in order to determine how the diatom assemblages investigated can inform studies of *in situ* preservation status.

1.3 In general, the analysis of diatoms may be useful in an archaeological context in order to assess past environmental conditions and produce a clearer picture of the immediate environment, thus providing information that may help to identify the preservation status of archaeological remains (Mannion, 1987). Fifteen sediment samples, taken from two predetermined preservation zones within Nantwich by PRS on behalf of SLR Consulting Ltd (i.e. Zone 1; the River Weaver floodplain and Zone 2; east of the river and above the floodplain), were processed and analysed with the aim of investigating whether the characteristics of the diatom assemblage can in fact provide useful information on the depositional environment, and to see if any differences in preservation can be detected both within and between sample points.

2 Methods

2.1 The samples were prepared following standard techniques (Battarbee 1986). Organic matter was oxidised in a 30% hydrogen peroxide (H_2O_2) solution, by placing samples in beakers on a hotplate at a temperature of 90ºC for approximately 2 hours. A few drops of concentrated hydrochloric acid (HCl) were added to each sample following oxidation in order to remove carbonates. The samples were then transferred to test tubes and washed with distilled water in a Centaur 2 centrifuge at a speed of 1200rpm for five minutes, to allow the clay particles to form in suspension while the diatoms and other silt-sized particles formed a pellet at the base of the test tubes. The water was decanted after each wash, leaving the pellet intact, and individually numbered plastic pipettes were used to re-mix each sample and avoid cross contamination. This process was repeated until all clays had been removed (i.e., when the supernatant ceased to be cloudy). Samples were then topped up with distilled water to 10ml.

2.2 Sample residues of two different concentrations were dried overnight on 40mm round cover slips then mounted onto microscope slides using Naphrax®, which has a suitable refractive index. Slides were heated on a hotplate in the fume cupboard at a temperature of 90˚C for ten minutes, to evaporate the toluene from the Naphrax®, and then cooled before counting.

2.3 Taxonomic identification was made using a Leica DMLS under oil immersion at a magnification of x 1000 and identification was determined to species level using Germain (1981) and Krammer and Lange-Bertalot (1986, 1988, 1991a, b). Approximately 200-300 valves were counted per slide so as to provide a statistically reliable estimate of species composition; the number counted was dependant on the frequency of diatom frustules in each sample. To indicate their relative abundance, the species counts for each sample were converted to a percentage of the whole sample count and species present at under 4% were disqualified.

2.4 The preservation of diatom frustules was noted and diversity was categorised based on the number of species present in each sample; 1 to 10 = low; 11 to 14 = low-medium; 15 to 19 = medium; 20 and over = medium-high. For borehole P the diatom data were displayed using TILIA (Grimm, 1991) and TG View (Grimm, 2004) to highlight changes in species composition through the profile. For the discussion, the environmental affinities of individual species were taken from Germain (1981) and Juggins (2008).

3 Results

3.1 *Zone 1; The River Weaver Floodplain*

BH C (C3/P (190-195cm) – south-west river bank)

Diatom preservation in sample C3/P was excellent, with a total of 25 taxa present at >4%. Table 3.1 gives the results of diatom analysis and indicates that the diatom assemblage was composed of large benthic forms typical of shallow, freshwater environments and associated with epiphytic and epilithic habitats. The diversity and frequency of diatom frustules was medium to high and dominated by *N. cryptotenella* at 14.6% and a range of *Nitszchia* and *Achnanthese* spp. (16.2% and 11.4% respectively). *Surirella ovalis* (3.5%) and *Diatoma vulgare* (4.9%) were also present.

3.2 *Zone 2; East of the River Weaver and above the river floodplain*

All samples in this zone demonstrated a high degree of frustules breakage and a high mineral content that was difficult to remove using conventional diatom preparation techniques (Table 3.1).

BH P (P4/P - 250cm; P5/P - 217cm; P6/P - 191-200cm; P7/P - 173-191; P8/P - 168cm; P9/P -150-163cm; P10/P - 131-150cm)

Diatom preservation in these samples was poor, particularly in P4/P and P5/P, taken from the deepest part of the borehole. At these locations the breakage was so extreme that diatoms could not be counted. The results of diatom analysis for the remaining samples (P6/P to P10/P), expressed as percentage counts for taxa present at <4%, are given in Table 3.1 and Figure 3.1. Sample P6/P displayed the lowest diversity with only 8 identifiable species, whilst all other samples exhibited low to medium diversity. All samples contained high frequencies of *N. cryptotenella*, *Nitszchia* spp., and *Melosira varians* with samples P6/P and P10/P dominated by *N. cryptotenella* (32.9 and 30.2% respectively), sample P8/P by *N. umbonata* (43.0%), sample P9/P by *Pinnularia* spp. (22.3%) and sample P7/P by *M. varians* (29.7%). A profile of the main taxa found in these samples is given in Figure 1 to highlight changes in species abundance and composition between 195cm and 140cm.

BH F (F4/P (125-150cm)

Although sample F4/P exhibited a high degree of breakage again, there was an overall improvement in diatom preservation compared to BH P with 15 species present, thus exhibiting medium diversity (Table 1). *Melosira varians* dominated at

25.2% followed by *N. hungarica* at17.0%. The total relative abundance of *Nitszchi*a spp. was high at 21.4% and *Achnanthese* spp. were also high at 17.6%. *Cympatopleura solea* and *Navicula cohnii* were also present in this sample at 2.5% and 1.9% respectively.

BH G (G3/P - 56-100cm)

Diatom preservation in sample G3/P was poor. This low to medium diversity assemblage, with 13 identifiable species, was dominated by *N. cryptotenella* (21.9%), followed by *N. hungarica* (16.6%). *C. solea* was present at 4.0% accompanied by a significantly high relative abundance of *M. varians* (13.9%) and *N. cohnii* (11.3%).

BH M (M1/P - 211cm, M2/P -142cm)

Diatom preservation in samples M1/P and M2/P was poor. Sample M1/P demonstrated low to medium diversity with 13 species present, whilst sample M2/P exhibited a low diversity assemblage containing only 10 species. Both samples were dominated by *N. cryptotenella* followed by *Pinnularia* spp. (17.5%) and *A. lanceolata* (13.5%) in sample M1/P and *Navicula cincta* (17.4%) and *N. palaea* (17.4%) in sample M2/P.

BH N (N8/P - 246-261cm, N17/P – 122-129cm)

Diatom preservation in samples N8/P and N17/P was poor with low to medium diversity assemblages containing 12 and 13 identifiable species respectively. Sample N8/P was dominated by *N. cryptotenella* at 53.7% followed by *Pinnularia* spp. at 20.6% and sample N17/P was dominated by *M. varians* at 44.5% presence. N17/P was the only sample where *Fragilaria pinnata* was clearly visible.

BH Q (Q3/P - 100-147)

Diatom preservation in this sample was also poor with a low to medium diversity assemblage of 12 species. Of these species *N. hungarica* dominated at 33.9%, followed by *M. varians* at 27%.

Environmental Tolerances of Diatom Species	Species Name	C3/P	P6/P	P7/P	P8/P	P9/P	P10/P	F4/P	G3/P	M1/P	M2/P	N8/P	N17/P	Q3/P
Mesohalobous (optimum brackish water)	***Nitszchia hungarica***		8.5	12.0	1.7	9.5	3.9	17.0	16.6	1.0	6.2	1.9	3.8	33.9
	***Surirella* ovalis**	3.5							1.3	1.5	1.2	1.9		0.5
Halophilous (optimum in slightly brackish water)	***Amphora ovalis***	1.1									1.2	2.8		4.8
	Cympatopleura solea							2.5	4.0					
	Melosira varians	0.3	16.6	29.7	12.0	9.1	29.9	25.2	13.9			2.8	44.5	27.0
	Navicula cincta		14.1	3.5	2.9	7.0	8.4			12.5	24.8			
	Navicula cohnii							1.9	11.3			1.4		4.2
	Navicula halophila	8.1						1.3	6.6	4.0	5.0			
	Nitszchia umbonata	4.3	16.6	20.8	43.0	7.9	11.2	2.5	3.3	8.5		5.6	5.5	
Oligohalobous (Freshwater with a tolerance of slightly brackish water)	***Achnanthese lanceolata***	3.8		4.2	2.3	9.1	1.7	9.4	2.0	13.5	5.0	1.4	5.9	2.1
	Achnanthese minutissima	5.4						6.3	2.6			1.4	4.2	
	Achnanthese saxonica	2.2	3.8	1.1				1.9	2.0					
	Caloneis bacillum	3.5			5.2	7.6	4.7			2.0			0.4	
	***Cocconeis* spp.**	2.7				1.8	0.6							1.1
	Cyclotella comta	0.8												
	Cymbella ventricosa	2.2												
	Diatoma vulgare	4.9												
	***Eunotia* spp.**						0.6						3.4	
	Fragilaria brevistraiata	0.5		1.1	1.7			1.3				1.9		
	Fragilaria construens	2.7												
	Fragilaria pinnata												1.3	
	Gomphonema angustatum	10.8				0.6		0.6		0.5			4.2	2.1
	Navicula capitata	1.6												
	Navicula radiosa	4.3					2.2	0.6	1.3		5.0	4.7	2.5	2.1
	Nitszchia palaea	9.7	0.9	3.9	5.7	3.0	1.7	1.9		3.5	17.4			
	***Pinnularia* spp.**	2.2	6.6	6.4	10.3	22.3	2.2	12.6	13.2	17.5		20.6	1.3	8.5
Halophobous (Freshwater)	***Fragilaria capucina***	1.1											5.1	
	Fragilaria virescens	5.9												
	Frustula rhomboides							0.6		1.5				1.6
	Navicula cryptocephala	3.2		2.5	5.2	0.6	2.8							
	Navicula cryptotenella	14.6	32.9	13.4	10.0	21.3	30.2	14.5	21.9	27.5	28.6	53.7	17.8	12.2
	Navicula sclevensis	0.8												
	Small Navicula			1.4						6.5	5.6			
	TOTAL %	100	100	100	100	100	100	100	100	100	100	100	100	100
	No. spp. present	25	8	12	11	12	13	15	13	13	10	12	13	12
	Diversity	Med-high	Low	Low-Med	Low-Med	Low-Med	Low-Med	Med	Low-Med	Low-Med	Low-Med	Low-Med	Low-Med	Low-Med
	Preservation of frustules	Excellent	Poor	Poor	Poor	Poor	Poor	Poor-Med	Poor	Poor	Poor	Poor	Poor	Poor

Table 3.1: The results of diatom analysis expressed as percentage counts. The number of species present, diversity and the preservation condition of diatom frustules is also marked for each sample. Note: In terms of environment, epilithic species are attached to rock, epipelic is soil derived, epiphytic is attached to plants and periphytic is living around plants.

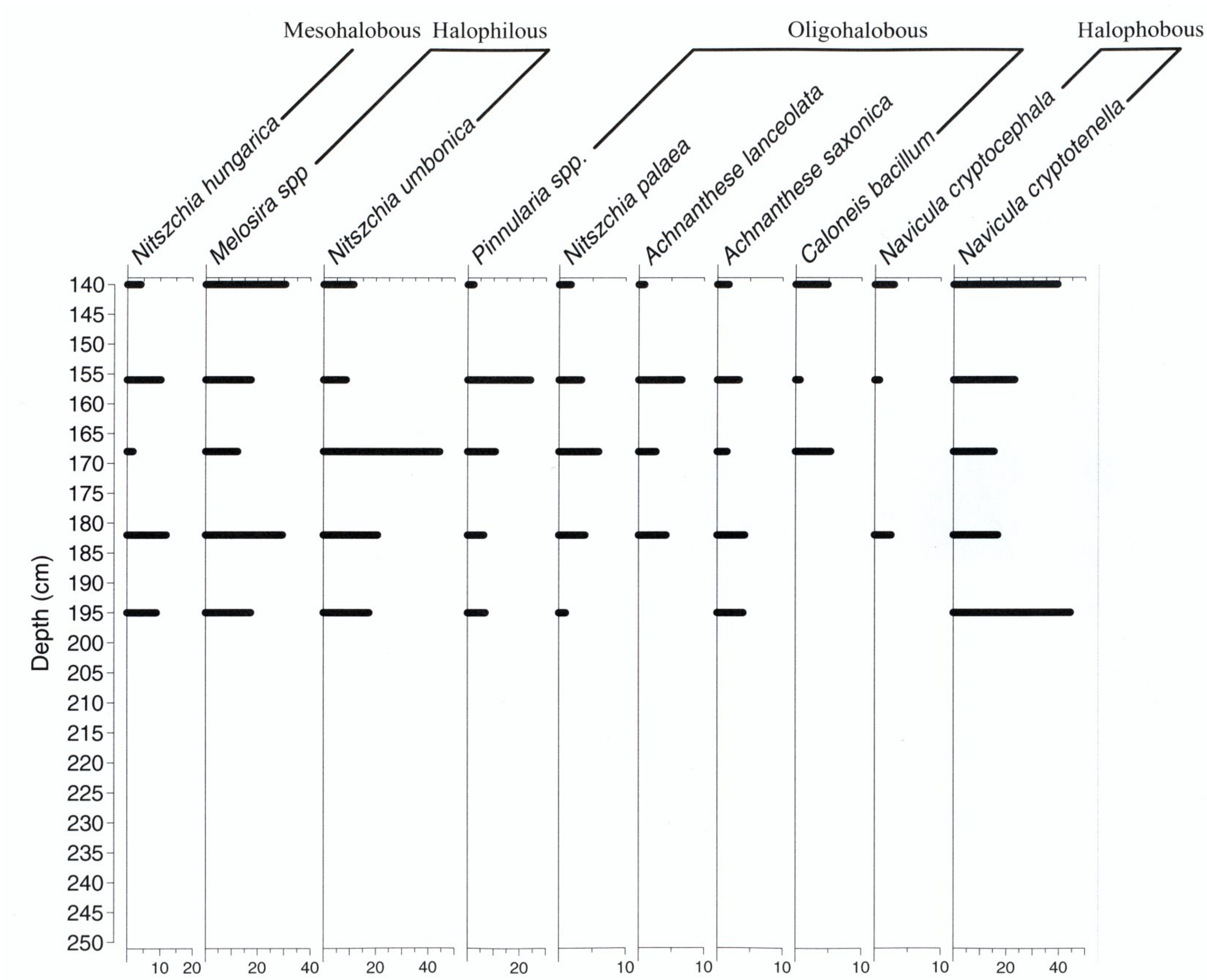

Figure 3.1: Analysis of samples from Borehole P – relative abundances and halobian preferences (see Table 3.1)

Finally, it should also be noted that, whilst there is a strong freshwater context in evidence in the samples, there are a broad range of non-planktonic species tolerant of slightly brackish conditions (Table 3.1, below). For instance, the presence of mesohalobian and oligohalobian species indicate the influence of dissolved salts on the diatom flora. The lack of marine influence (Nantwich is approx. 45km from the coast) suggests that samples with a high relative abundance of these latter species are directly influenced by the dissolved rock salts occurring in brine springs throughout the region (Penney and Shotter 1996). For example, sample Q3/P is dominated by *Nitzschia hungarica* (34%), samples P7/P and F4/P by *Melosira varians* and P8/P by *Nitzschia umbonata*. Although at low relative abundance, the presence of *Cympatopleura solea* and *Navicula cohnii* in samples F4/P and G3/P and *Surirella ovalis* in sample C3/P also indicates a salinity influence.

4 Discussion

4.1 Diatom analysis of samples taken from boreholes in the city of Nantwich has revealed two distinct categories of frustule preservation and sedimentary mineral content, corresponding to Zones 1 and 2 as determined by the preservation status of organic matter by PRS on behalf of SLR Consulting Ltd (Carrott *et al.* 2008). In terms of human impact and its effect on the sediment record, the results of this study have important implications for the *in situ* preservation of archaeological material.

4.2 In Zone 1, sample 3 from core C (C3/P), exhibited a low sedimentary mineral content which enabled clear assessment of species composition. Preservation of diatom frustules was of excellent quality, suggesting an undisturbed, post-depositional environment; even the more delicate species such as *Fragilaria capucina* and *Nitzschia palaea* were mostly intact. The diversity and frequency of diatoms was high (Table 3.1) with a dominance of *Navicula cryptotenella*, which is characteristic of British rivers and streams and was common in all of the samples from both Zones. There was a clear lack of planktonic taxa in this sample, and with the exception of *Cyclotella comta*, which was present at a low relative abundance of 0.8% and is more commonly found in shallow lakes or ponds with soils of high acidity, all taxa were benthic in nature and typical of fairly shallow, river habitats.

4.3 The character of the diatom assemblage was essentially freshwater, though some of the species present can also indicate brackish conditions (e.g. *Diatoma vulgare, Diploneis ovalis, Navicula halophila, Navicula sclevensis, Surirella ovalis*) suggesting either permanent, or the occasional influence of salinity, on the diatom flora (Table 3.1 above) (Cooper, 1999). The high proportion of periphytic and epiphytic forms (e.g, *Fragilaria*, *Cocconeis, Achnanthese, Navicula* spp.) also indicate a strong macrophyte influence on the diatom flora, which could suggest the presence of wetland areas where alluvial deposits are often prone to reducing conditions due to the anoxic nature of the sediments.

4.4 The presence of brackish water tolerant species in the samples from Nantwich is perhaps unsurprising given the fact that the Cheshire salt industry is based on the occurrence of thick Triassic rock salt beds which underlie a large part of the country (Penney and Shotter 1996:363). A salt production industry developed as early as the Iron Age in this region, in areas where the natural brine springs emerged at the surface under artesian pressure (*ibid*. 1996:363).

4.5 In Zone 2, when compared against sample C3/P from Zone 1, the diversity and frequency of diatom frustules in all of the samples was low (Table 3.1), with a high degree of frustules breakage. This situation can cause bias in the sub-fossil assemblage, and demonstrates a significant tendency towards the preservation of the more robust species (e.g. *Pinnularia* spp., *Melosira varians*). The differences in species composition between the samples could not be used to analyse differences in the immediate environment as there is a strong possibility that between-sample differences in breakage is occurring. Analysis of the full diatom assemblage was also inhibited by the extremely high mineral content, which is difficult to remove using standard techniques without further diluting the assemblage in the cleaning process, and probably introducing further bias.

Interestingly, and apparently in contrast to the geochemical data, the diatom samples from borehole N (N8/P & N17/P – Table 3.1), in the Weaver floodplain area, exhibit poor preservation and reduced species diversity in line with the general situation for all diatom samples from Zone 2. In addition, the palaeoenvironmental assessment of borehole N reports that preservation of waterlogged plant macrofossils was higher at this location than elsewhere in the study area, and that saturation occurred from *c*. 0.7m depth in the profile (Carrott *pers. comm*.). This suggests that the poor preservation occurring in samples N8 and N17 is not a reflection of the current *in situ* status of these samples, and may well reflect the conditions prevailing at the time of deposition of the diatom assemblage. However, the reported high sulphate/sulphide levels (depending on depth through the profile) may complicate this suggestion, as the diatoms may be more susceptible than the waterlogged plant macrofossil remains (Carrott *et al*. 2008:6 & 10) in relation to the specific geochemical composition of this depositional context.

4.6 Furthermore, the high mineral content of the samples in Zone 2 is likely to be implicated as a cause of frustules breakage; Flower (1993) states that dry, carbonate rich sediments, common in areas of human impact, are a major cause of diatom frustule fragmentation and that this can seriously bias the diatom record. When compared to the site map of borehole locations, it is clear that the high degree of breakage in samples from the east side of the River Weaver could be a direct reflection of human impact and the reworking of dry, mineral rich sediments.

4.7 The identifiable taxa in the samples from Zone 2 were all common components of freshwater assemblages, with species typical of river environments and particularly characteristic of epilithic (e.g. *Gomphonema* spp., *Nitszchia* spp.) and epipelic (e.g. *Pinnularia borealis, Cymatopleura solea, Surirella ovalis*) substrates. The species *Navicula cryptotenella,* is in evidence, and whilst these species have little value in the assessment of specific environmental conditions, they do, unfortunately, dominate in the majority of the samples studied (e.g. M1, M2, C3, G3 and N8). Of the five remaining samples two (F4 and N17) are dominated by *Melosira varians*. This species is often found in slow moving waters, and has been found to increase during periods of flooding (Biggs, 2006). Its presence in diatom flora is also common under brackish conditions often reflecting estuarine conditions or, as noted for Nantwich, saltworkings (Juggins, 1992).

4.8 On the whole the sample from borehole C (sample 3) from Zone 1, reflects excellent potential for the *in situ* preservation of organic remains, and further analysis of samples from the boreholes on the western side of the river floodplain is recommended in order to reconstruct any through-the-profile changes in the diatom assemblage character, and examine the causes of the changes identified.

A consideration of the reasons for the marked variability between the west and east sides of the River Weaver floodplain, in terms of diatom preservation status, suggests that hydrological conditions to the east of the river (wherein water levels occur up to *c*. 3m+ below the modern ground level [Panter *pers. comm*.]) alongside increased urban developmental impacts, are resulting in compromised conditions in the burial environments studied. In addition, the geochemical data indicates that reducing conditions occur in the alluvial floodplain sequences associated with borehole C, and that LOI values reflect relatively high organic content in this area (Panter *pers. comm*.).

4.9 The strong freshwater component in these assemblages is likely to be associated with the river Weaver; many of the oligo-halophobous species are typical of river environments and their presence suggests either normal environmental conditions associated with river function, or freshwater inputs from stream run-off and other sources such as precipitation etc. As noted above, some of the species are tolerant of brackish conditions, however, these species are also influenced by substrate. *Pinnularia borealis* and *Cypatopleura solea*, for example, are diatoms associated with damp soil and it is possible that these species are derived from the surrounding substrate. Any attempts at inferring past salinity values for the samples would be tentative due to the poor condition of the samples, the weak statistical representation of species in the dataset, and the lack of specific context in relation to brine springs and saltworkings.

4.10 Finally, it should be noted that the rationale for the selection of samples for the analysis undertaken in this report is influenced by pre-determined conditions in the burial environment. This has resulted in a biased dataset, against Zone 1, where more favourable *in situ* conditions are suggested by the analyses undertaken to date. In addition, and compounding this bias, it should also be noted that the analysis of random 'spot' samples does not enable a full assessment of either the diatom assemblage or the environmental conditions relating to deposition over time (i.e. through-the-profile), and as such the analysis of these samples only provides a 'snap shot' in time, as opposed to the more informative aspects of environmental change over time, which can influence the diatom record.

Similarly, no insights into the main depositional processes responsible for the composition of the diatom assemblages are forthcoming from this approach. Essentially, this problem is only partly solved by the assessment of borehole P, and as is demonstrated by the stratigraphy and state of preservation in evidence from this borehole (Figure 3.1), there may be changes in species abundance throughout a sequence, as a result of differential depositional environments and specific *in situ* conditions such as geochemical status, that are missed by spot sampling. Identifying these changes using through-the-profile studies may help to better explain changes in the immediate environment.

5 Conclusions & Recommendations

5.1 The diatom analysis presented above has provided an extremely useful technique for identifying the preservation status of sediments from a series of boreholes in Nantwich. The results obtained correspond with the two preservation Zones predetermined by the analysis of organic matter by SLR Consulting Ltd.

5.2 Based on the diatom record, Zone 1 demonstrates excellent preservation status and suggests that there is a good potential in this zone for environmental reconstruction, in order to assess environmental change and the potential influencing factors impacting on the diatom record (e.g. salinity, wetland vegetation). Although a full evaluation of the character of the diatom assemblage in Zone 2 was not possible, due to the high breakage factor in this zone, this information in itself provides important evidence of the preservation status of the sediments and the possibility of reworking due to human impact. However, it should be noted that the specific environmental conditions during initial deposition could be an influencing factor in relation to the generally poor preservation in evidence at these locations.

5.3 In conclusion, the analysis of diatoms from the depositional contexts at Nantwich has provided an effective indicator of sedimentary preservation status. In addition, the differences in preservation states between Zones 1 (west side of River Weaver floodplain) and 2 (east side of floodplain and urbanised area) would appear to suggest that important information pertaining to the effect of human impact on the burial environment, and consequently any *in-situ* remains, may be forthcoming from these analyses, i.e. preservation is better away from the settlement areas, and elevation and development in Zone 2 appears to be resulting in compromised burial environments.

5.4 Recommendations

- If the analysis of samples from Zone 2 is considered important, the application of other methods of preparation (e.g. flotation) could be applied in order to isolate the mineral faction. However, it should be noted that the high degree of breakage indicates that the removal of the mineral component (which utilises harsh chemicals) may not assist in the diagnosis of the character of the diatom assemblage to any significant degree.

- The nature of this study, i.e. pre-selected samples aimed at assessing *in situ* preservation status inhibits the application of a salinity transfer function as full, targeted through-the-profile analysis of areas with known brine springs and/or saltworkings were not being assessed. In addition, borehole survey and limited pre-assessment in order to identify areas with good preservation conditions would enable a more useful study to be carried out. As such, alongside further investigation of borehole C from Zone 1 (or other boreholes from within the western areas of the River Weaver floodplain), the analysis of full sequences from known areas of brine springs and/or salt workings, with a proven abundant/good representation and preservation of diatom species, would be required in the future should the incorporation of a salinity transfer function be of interest. Such a targeted approach, to both sampling and analysis, would be of great value in helping to identify changes in the diatom assemblage, tolerances and external influences on the diatom flora. The through-the-profile analysis of borehole P (Figure 3.1) highlights the greater validity of such approaches.

- Furthermore, comparison of the diatom and plant fossil records from the river floodplain in Zone 1 would help to identify the presence of varying wetland contexts, thereby providing an indication of the potential for reducing conditions and the preservation of organic material. Similarly, the identification of the specific contexts of deposition associated with the samples studied from the eastern side of the Weaver floodplain would assist in the identification of the specific factors responsible for the compromised preservation status in evidence in the samples from Zone 2.

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