Diatom analysis and aquatic environmental reconstruction using transfer functions for total phosphorus and pH

Site code: ONE94

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No. 1 Poultry (ONE94): diatom analysis and aquatic environmental reconstruction using transfer functions for total phosphorus and pH

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Introduction

A total of seventy-one sediment sub-samples, taken from a range of water-lain contexts at the No.1 Poultry site were assessed for diatoms (unpublished diatom assessment). Of the material that was screened, thirteen samples were found to have an adequate quality of diatom preservation to allow diatom counting to be carried out.

The purpose of applying diatom analysis was to reconstruct past water quality; specifically to make quantitative reconstructions of total phosphorus and pH. Further, it was hoped that qualitative analysis of diatom habitats and salinity would assist in environmental reconstruction for the site. At present, quantitative reconstruction of aquatic environmental variables, using transfer functions, has rarely been carried out in an on-site archaeological context. It is therefore hoped that these results will provide a pilot study for the application of these methods in environmental archaeology.

Methods

Diatom preparation and analysis followed standard techniques. Slides were counted using a Leitz research microscope at a magnification of x1250 or x1000 under phase contrast or differential interference contrast illumination. Given the relatively low diversity a total of approximately 125 diatom valves was considered an adequate counting sum for each sample.

Where necessary diatom identifications were confirmed using diatom floras and taxonomic publications held in the collection of the Environmental Change Research Centre (ECRC), UCL. The floras most commonly consulted were: Cleve-Euler (1951-1955), Hendey (1964), Hustedt (1930-1966), Werff & Huls (1957-1974). The principle source of data for species ecology used was Denys (1992).

Site, sample and diatom information were entered into the AMPHORA diatom database at the ECRC, where these data, slides and cleaned valve suspensions are available for examination. Diagrams were plotted using TILIA and TILIAGRAPH (Grimm 1991).

Diatom species' salinity preferences were classified using the halobian groups of Hustedt (1953, 1957: 199) summarised below:

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.

Diatom halobian groups are indicated above the percentage diatom diagrams and the halobian group composition is summarised at the right-hand side of each diatom diagram.

Diatom species have also been classified into lifeform groups using the scheme of Denys (1992). Planktonic diatoms complete their whole lifecycle in open water. Tychoplanktonic diatoms occur in the plankton but they are derived mainly from other (non-planktonic) habitats. Epontic forms are those species which live firmly attached to any kind of substratum (macrophytes, rocks, sand grains). Benthic diatoms are also non-planktonic species, however they are not strongly attached to any surface and the benthic group includes diatoms inhabiting surface mud (epipelic taxa).

Diatom-Total Phosphorus (TP) reconstructions were carried out using a European-wide diatom-TP training set (Bennion *et al.* 1996). The program TRAN was used to harmonise diatom taxa in the TWE98 data with those diatoms in the diatom-TP training set. The program CALI was used to model the diatom-TP data; modelled species data was $\log_{10}$ transformed and an inverse regression was used. Simple weighted averaging was used to reconstruct total aquatic phosphorus.

Diatom-based pH reconstructions were carried out using the modern diatom/water chemistry data-set derived from the Surface Waters Acidification Project (SWAP) (Stevenson *et al.* 1991). Classical regression was used for the diatom-pH model and weighted averaging was used to make the pH reconstructions.

Results

A total of 103 diatom taxa were identified from the thirteen samples on which percentage counts were carried out. Diatoms from epontic and benthic habitats are dominant whilst planktonic diatoms form a relatively small component of the total assemblage (Figure 1).

Classification of the diatoms into halobian groups (Figure 2) shows that freshwater (oligohalobous indifferent) taxa are dominant. However, in diatom samples 02, 03, 05, 08 and 11 (see Table 1 for site sample codes) there is a significant component of brackish water diatoms and in particular the benthic species *Navicula cincta*. Estuarine and marine planktonic diatoms are absent. Diatoms from these habitats would have been found had there been direct contact with the River Thames.

Table 1. Samples from ONE94 analysed for diatoms. LU checked JH

diatom sample	context	sub-group	group	l/use	period	sample	depth (cm)	diatom archive no.
02	18081	120326	480	OA75	10	995	20	21676
03	18087	120212	463	OA45	7	995	30	21677
05	18359	120210	462	OA43	6	1020	81	21678
07	18362	120209	493	OA43	6	1020	168	21679
08	18364	120208	493	OA43	6	1020	116	21680
11	18066	120325	836	OA75	10	980	?	21681
27	12965	10009	100	OA1	1	890	44	21682
56	12805	1023	212	OA18	2	898	24	21683
57	12805	1023	212	OA18	2	898	40	21684
60	12658	10035	222	OA19	2	900	28	21685
67	18304	120107	200	OA15	4	1036	16	21686
68	18304	120107	200	OA15	4	1036	22	21687
69	18309	12002	100	OA1	1	1036	30	21688

As a result of the dominance of freshwater diatoms, many of which are present in existing diatom-water chemistry training sets for total aquatic phosphorus and pH, it was thought appropriate to apply a transfer function to make both diatom-TP reconstructions and diatom-based pH reconstructions. Using a transfer function a quantitative estimate of the nutrient content of the water and its acidity can be made. Quantitative reconstruction of water quality where the diatom assemblages are diverse facilitates comparison between samples and allows specific estimates of water quality to be made.

A summary of the results from TP and pH reconstruction is presented below. After harmonisation of the diatom taxonomy of the fossil data with that of the TP training set, the fossil data was reduced from 103 to 99 taxa; 60 of these taxa are present in the calibration set. For the pH training set, all 103 taxa in the fossil data were used, however, of these only 45 were present in the calibration data (Table 2).

Table 2. The percentages of diatom assemblages present in TP and pH calibration sets and their reconstructed TP and pH values.

Diatom Sample	percentage of assemblage in TP calibration set	Reconstructed TP (ug l^{-1})	percentage of assemblage in pH calibration set	Weight.Av. reconstructed pH (pH units)
02	71	66	28	6.59
03	82	22	48	6.27
05	82	66	23	6.87
07	57	41	37	6.41
08	56	49	18	6.61
11	82	148	53	7.05
27	60	22	36	5.79
56	59	37	50	6.08
57	56	32	63	5.59
60	49	33	47	5.67
67	82	69	69	6.36
68	74	102	65	6.47
69	75	102	63	6.47

Discussion & Conclusions

1 Diatom habitats

All the samples analysed are dominated by non-planktonic, epontic or benthic, diatoms. No truly planktonic species, which complete their entire lifecycle in open water, are present. This is consistent with shallow-water habitats available for diatom colonisation, and also indicates that flooding, which often introduces allochthonous (freshwater, brackish or marine) plankton was not a significant factor. The classification of Fragilaria construens var. venter as a semi-planktonic species is contentious. This species is most commonly found attached to submerged surfaces in shallow water habitats. Its abundance in diatom samples 67,68 and 69, where maximum percentages exceed 20%, most probably reflects the growth of a non-planktonic autochthonous diatom population.

2 Salinity

In the majority of samples the diatom assemblage is dominated by oligohalobous indifferent diatoms with total abundances of 60 to 80%. However, samples 02, 03, 05, 08 and 11 have approximately 20-50% halophilous species, principally *Navicula cincta*, but also the mesohalobous-halophilous species *Navicula veneta* (maximum abundance of over 10% in sample 02) and *Cyclotella meneghiniana*. Consistent with the presence of these brackish water species halophilous-freshwater taxa, such as *Navicula accomoda* and *Rhoicosphaenia curvata*, are present in a number of the same samples. It should be noted that some halophilous taxa, for example *Navicula mutica*, are also aerophilous. Although the elevated salinity of the environment is supported by the presence of a halophious diatom community such semi-terrestrial diatoms may also reflect the ephemeral nature of the aquatic habitat or the inwash of diatoms from surrounding soils. For example, relatively high percentages of Navicula atomus, another aerophilous taxon, were recorded in 02, 03, and 05, and the species was present in samples 07 and 11.

3 Reconstruction of total aquatic phosphorus

Inferring the values of past aquatic phosphorus concentrations, or other chemical or environmental variables, from fossil diatom remains preserved in water-lain sediments involves two stages (eg. Cameron et al. 1999). First the relationship between diatom abundances and contemporary phosphorus (or other variables) are modelled using a modern training or calibration set of surface sediment diatom samples and associated water chemistry. These relationships are used to derive a transfer function. The second stage is to use the transfer function to infer past phosphorus concentrations from the fossil diatom assemblages. In this case the most comprehensive existing diatom training set, derived from a wide geographical range of shallow, lowland water bodies (Bennion et al. 1996), has been used to reconstruct the past nutrient status of the water bodies on the site.

The percentages of diatoms in the fossil assemblage present in the TP training set varied from 82% to 49% (Table 2). Generally, the coverage of fossil diatom assemblages by the training set was good or adequate and the reconstructions can be regarded, from this point of view, as reliable.

Generally TP values were found to be relatively low, ranging in 10 of the samples from 22-69 ug l^{-1}. These values represent fairly low levels of nutrients, and are comparable with the concentrations found in 'pristine' lowland waters, not impacted by anthropogenic phosphorus. However, for samples 11, 68 and 69 there is some evidence for 'cultural eutrophication' as TP levels are elevated to 102-148 ug l^{-1}. Certainly these values would be considered above background values (OECD 1982), but they remain relatively low TP levels when compared with late Medieval to Modern concentrations which, in can be of the order of several hundred ug $^{l-1}$ to approximately 1000 ug l^{-1} where there have been large inputs of organic waste.

<u>Reconstruction of pH</u>

A similar two step approach to the reconstruction of TP was used for the reconstruction of pH. In this case, the existing Surface Waters Acidification Programme (SWAP) diatom-water chemistry training set was used to infer past pH values from the fossil diatom assemblages (Stevenson *et al.* 1991). However, as this calibration set is biased towards upland lakes and low alkalinity waters it is less appropriate in this archaeological context than the TP training set. This is reflected in the lower numbers of diatom fossil taxa represented in the modern training set assemblage. An improved (dynamic) training set for European freshwaters is currently being assembled and may be more applicable for the reconstruction of pH in a lowland archaeological context (European Diatom Database Project). Despite these problems it was considered worthwhile using the existing diatom-pH calibration set to make comparisons between samples, whilst avoiding over-interpretation of relatively small variations in the reconstructed values.

There is some variation between samples in pH. The maximum reconstructed was 7.05 and the minimum 5.59. Unusually low or high pH values which might be associated with input of effluent from manufacturing processes were not present in these data. Indicator diatom taxa tolerant of extremes of acidity or alkalinity, for example large numbers of certain *Eunotia* spp., were not apparent from the individual species composition. Interpretation of smaller variations in pH are not warranted as a result of the low percentages of fossil diatoms which were also present in the pH calibration set.

Archaeological Contexts of the samples analysed for diatoms

Samples 995, 1020 (Terrace 4 OA43p6, OA45p7, OA75p10)

Samples 995 and 1020, represented by diatom samples 2,3,5,7 and 8, are from the continuous column at the 'apex' of the site in area 12. In the geoarchaeological assessment of sediment samples it was suggested that diatom analysis might indicate the effect of human occupation through time on the pollution of the water course.

Diatoms are only preserved well in the uppermost contexts of the sequence. As discussed for the TP and pH reconstructions, anthropogenic pollution which would affect these water quality parameters does not appear to have been significant. The qualitative reconstruction of salinity, however, indicates that, although there is apparently no direct contact with estuarine water there are elevated salinity levels and this is clearly reflected in the diatom assemblage composition. The diatom lifeforms represent shallow water habitats.

Samples 890, 898, 900 (OA1, OA18p2, OA19p2)

These samples record environments before the construction of the road. The context of the diatomaceous level from Sample 890 is unclear, but it represents a shallow, freshwater context of low nutrient content and low salinity with a below neutral pH value. The two levels from Sample 898 analysed for diatoms are from a Sample taken 0.5 m below 890 and it was hoped this Sample would provide useful information about water quality and flow. Again for Sample 898, TP and pH values do not indicate any anthropogenic impact. The diatom flora is non-planktonic and has a large proportion of robust species, which may be derived from soils, eg. *Pinnularia* sp. which will tolerate desiccation, but also diatoms such as *Achanthes lanceolata* and *Gomphonema angustatum* which are likely to have been epiphytic on macrophyte vegetation. It is probable that the diatom assemblages from Sample 898 are derived from a shallow, standing water environment rather than free-flowing conditions.

Sample 900 is a sequence taken below the level of the *Via Decumana* at the southern edge of the site. The diatom sample from context 12658 (12638?) is from a sandy organic silt. Similar to the diatom assemblages from Sample 898, this samples seems to represent a shallow, standing water habitat, with macrophyte growth and with some input of soil diatoms but with no clear evidence of flooding.

Sample 1036 (OA1, OA15p4)

The three diatom assemblages from Context 18304 (OA15p4) are distinct in having high percentages of *Fragilaria contruens* var. *venter* and to a lesser extent, other Fragilaria species such as *Fragilaria virescens*. These diatoms are often associated with ephemeral water bodies because they are early colonising species. However, the three diatom assemblages from Context

18304 also have some more stable non-planktonic elements such as *Gomphonema angustatum* and *Cymbella ventricosa*. Very low percentages of the flowing water species *Meridion circulare* are present at 16 cm and 30 cm respectively. Given the dominance of the group of *Fragilaria* taxa it is likely that there were frequent changes in water level followed by recolonisation with pioneer diatoms. Macrophyte growth is represented by the presence of *Gomphonema* spp. and other benthic diatom growth by diatoms such as *Cymbella ventricosa*, *Navicula elginensis* and *Amphora* spp.

The samples from 22 cm and 30 cm have significantly higher TP values than other samples from the site.

Sample 980 (OA75p10)

This sample was notable in having the highest reconstructed TP value. It is one of a group of bulk sediment samples and was noted as representing "?external activities". The reconstructed nutrient level, largely driven by the dominant taxon, *Nitzschia fonticola*, indicates that there was some anthropogenic impact on the water body concerned.

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