DIATOM ANALYSIS OF RIVER THAMES FORESHORE DEPOSITS EXPOSED DURING THE EXCAVATION OF A ROMAN WATERFRONT SITE AT PUDDING LANE, LONDON

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ABSTRACT

Eighty-seven diatom taxa including marine, brackish, and freshwater forms were identified from foreshore sediments accumulated against pre-AD 100 quay structures exposed during the excavation of an early Roman waterfront site in the City of London. The spectra indicate that the Roman port was probably established close to the tidal head of the river.

INTRODUCTION

Archaeological excavation of a waterfront site near Pudding Lane in the City of London has revealed a series of early Roman quays that have River Thames foreshore deposits accumulated against them. The main foreshore accumulation (foreshore 1) occurs in front of an AD 70 quay an is sealed by dump deposits of about AD 100. Earlier quays with associated foreshore accumulation can also be observed, the earliest one, represented only by pile lines in the natural bank of the Thames, may be pre- or early Roman. Diatom analysis of these foreshore deposits has been carried out in attempt to determine the salinity conditions of the river in the city of London at the time when the early Roman port was being constructed.

SITE

The site (Fig. 1) excavated by staff at the Department of Urban Archaeology from the Museum of London, is bounded on the south by Lower Thames Street and on the east by Pudding Lane, and it is adjacent to the probable line of the Roman London Bridge. Behind the first century quay and above the earlier quays excavations have exposed Roman warehouses fronting on to the river and the basement and bathhouse of a merchant's home. A transverse section through the site (Fig 2) shows the relationships of the quays and the foreshore deposits accumulated against them.

STRATIGRAPHY AND SEDIMENTS

Four monoliths were taken by Vanessa Straker along the line of transect in Fig. 1. The positions of these samples are shown in Figure 2, and the stratigraphy of each section is described below.

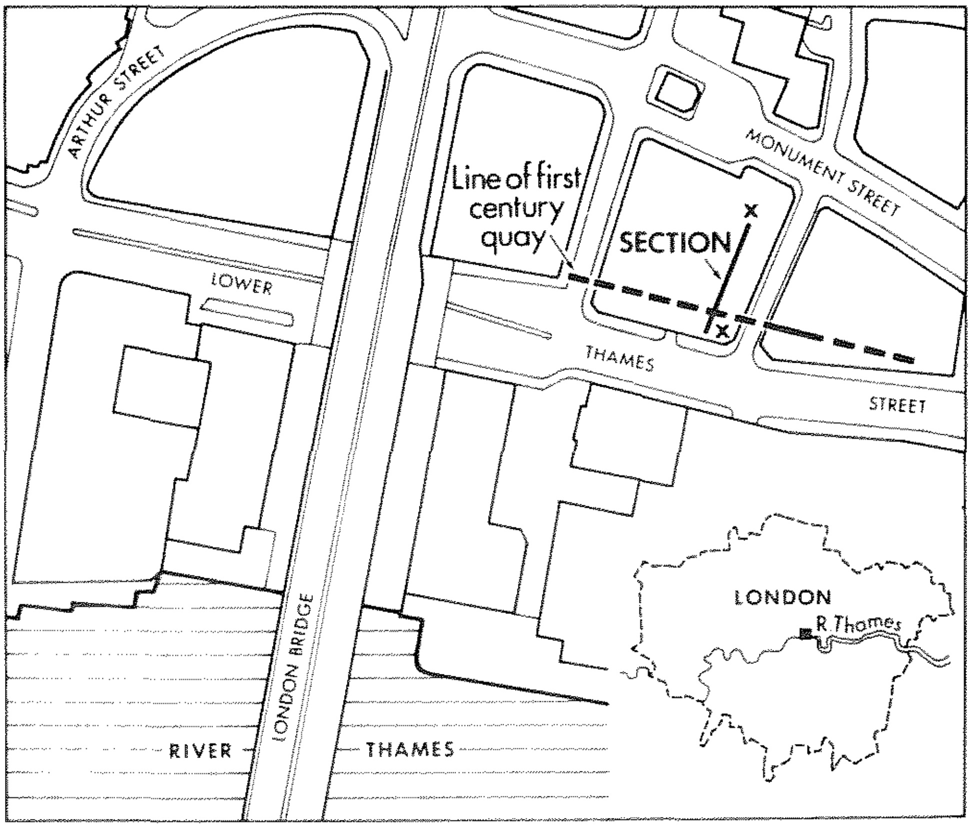

Fig. 1 Location of excavation site showing approximate line of the AD 70 quay and the line of transect.

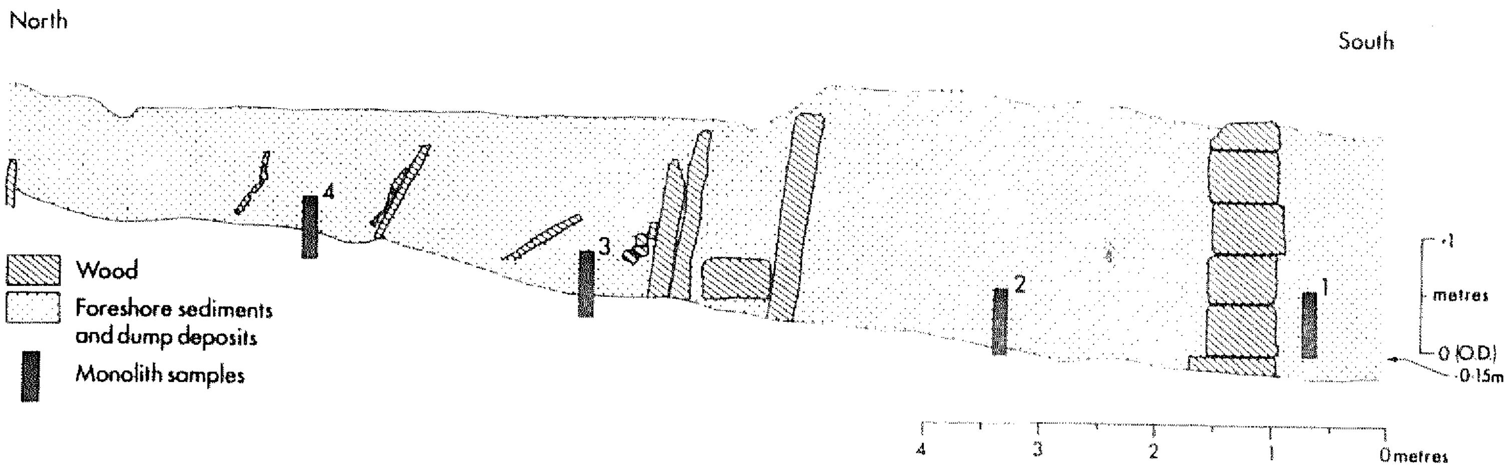

Fig. 2 N-S cross section of excavation site showing position of timber structures and location of sample monoliths.

Monolith 1 (Foreshore 1, AD 70-100, 0.41 to -0.15 m O.D.

0-10 cm: brown silty clay and pebbles above a layer of mortar and plaster.

10-14 cm: wood fragments and fine silt.

14-56 cm: foreshore accumulation.

Monolith 2 (Foreshore 2, AD ?50-70, O.D.)

0.22 cm: dump deposits with a muddy inclusion 8.5-10.5 cm.

22-25 cm: transition zone.

25-48 cm: foreshore accumulation.

48-50 cm: clay.

Monolith 3 (Foreshore ?2, AD ?50-70, O.D.)

0-14 cm: dump deposits.

14-25 cm: foreshore accumulation.

25-49 cm: clay.

Monolith 4 (Foreshore ?2, AD ?50-?70, O.D.)

0-31 cm: dump deposit consisting almost entirely of wood.

31-44 cm: foreshore accumulation.

44-50 cm: clay.

No samples were taken from 0-17 cm, 18-20 cm and 23-31 cm as solid wood occurred at these points.

METHODS

The foreshore sediments were sub-sampled at consecutive 1 cm intervals. Sub-samples for diatom analysis were prepared at 4 cm intervals by heating the sediments with 30% H2O2, and then washing, centrifuging, and mounting slides with Mikrops 163 (cf. Battarbee 1979). A preliminary examination of the slides showed diatoms to be absent, or present in only very low concentrations, in some of the samples, especially in material from Monoliths 3 and 4. However, diatoms were relatively abundant at a number of levels in Monolith 1, the sequence of primary interest, and levels 14, 18, 22, 26, 30, 42, 46, 50 and 54 were examined in detail. Two levels from Monolith 2, 26 and 38, also contained high enough numbers for counts to be made.

RESULTS AND DISCUSSION

Monolith (Foreshore) 1

No diatoms were found in levels 30-42 and diatoms were so sparse in levels 22, 26, 30 and 42 that only 50 valves were counted in each of these samples. Levels 14, 18 and 54 had the greatest diatom concentrations. Diatoms were generally well preserved and it is likely that the low diatom concentration (or diatom absence) at some levels was the result of dilution by rapid sediment accumulation rather than the result of differential preservation. The assemblages at each level varied from 22 taxa at a count of 50 to 44 taxa at a count of 200. Combining the data 87 taxa in a count of 1000 individuals were encountered (Table 1).

Figure 3 shows the relative contributions of the most common taxa both stratigraphically and as a composite spectrum. The dominant taxon at all levels was the brackish water species Cyclotella striata. This is a very common planktonic diatom in European river estuaries (Hustedt 1957). In the R. Thames it occurs in abundance at the Saxon age Swan Lane site (Battarbee unpubl.), in River Fleet deposits of medieval age (Boyd 1981), and in the contemporary Thames, and it is clearly able to grow well in environments of fluctuating salinity. In the Pudding Lane material it is often exceptionally well preserved (see Plate 1) with intact frustules frequently occurring. This, together with its numerical

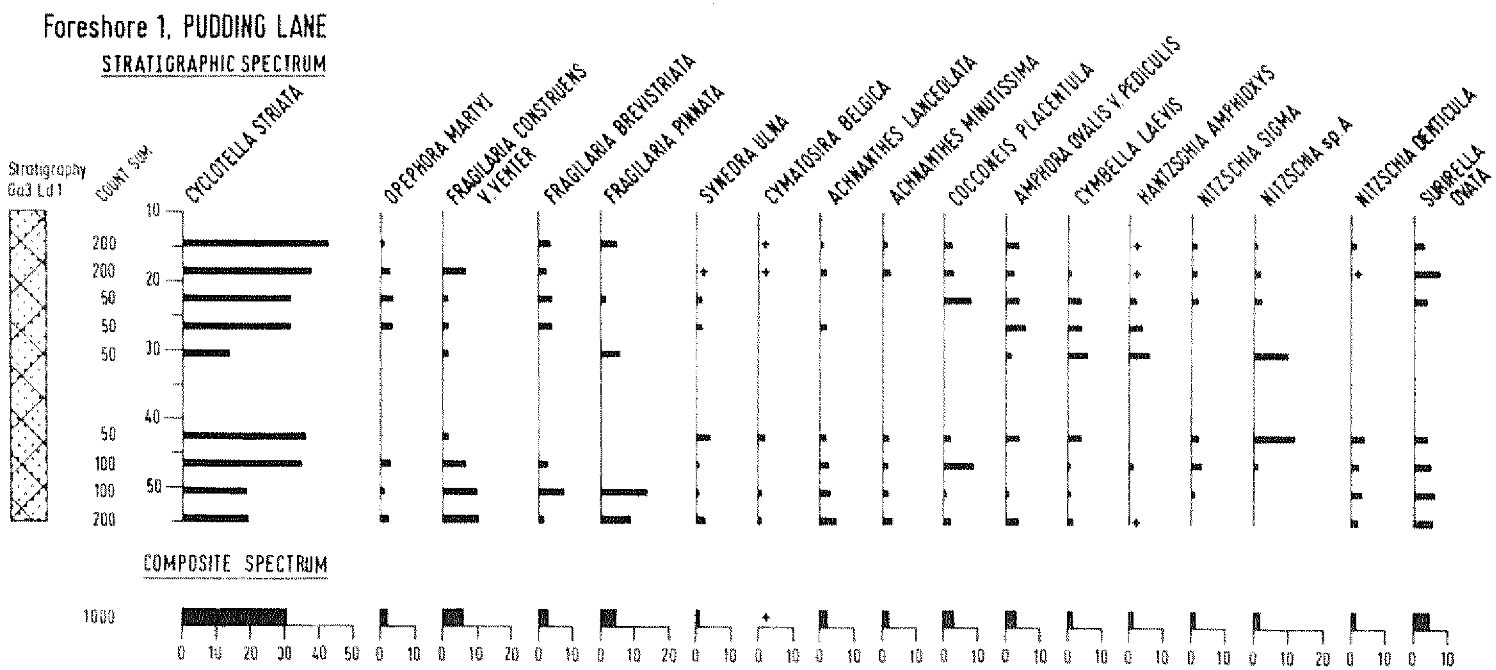

Fig. 3 Diatom diagram for Pudding Lane, Foreshore 1 monolith.

TAXON	FORESHORE 1											FORESHORE 2			
Sample	14	18	22	26	30	42	46	50	54	Σ	%	26	38	Σ	%
No. Counted	200	200	50	50	50	50	100	100	200	1000		200	100	300	
Achnanthes lanceolata Breb.	2	4	–	1	–	1	3	3	9	23	2.3	4	7	11	3.6
A. lanceolata v. rostrata Hust.	1	–	–	–	–	–	–	–	–	1	0.1	–	–	–	–
A. clevei Grun.	1	2	–	1	–	2	–	1	1	8	0.8	3	2	5	1.6
A. exigua Grun.	–	–	–	–	–	–	–	–	1	1	0.1	–	–	–	–
A. minutissima Kutz.	3	5	–	–	–	1	2	2	6	19	1.9	8	–	8	2.6
Amphora ovalis Kutz.	–	2	–	–	1	–	2	–	2	7	0.7	1	–	1	0.3
A. ovalis v. pediculus Kutz.	8	5	2	3	1	2	–	1	8	30	3.0	13	5	18	6.0
A. ovalis v. libyca (Ehr.) Cleve	1	–	–	–	–	–	–	–	–	1	0.1	–	–	–	–
Bacillaria paradoxa Gmelin	1	–	–	–	–	–	–	–	–	1	0.1	–	–	–	–
Cymatopleura solea (Breb.) W. Smith	–	–	–	–	–	–	–	–	–	–	–	1	–	1	0.3
Cymbella ventricosa Kutz.	2	1	–	–	–	–	1	1	4	9	0.9	2	1	3	1.0
C. turgida (Greg.) Cleve	–	2	–	–	–	–	–	–	–	2	0.2	–	–	–	–
C. sinuata Gregory	–	–	–	–	–	–	–	–	–	–	–	–	1	1	0.3
C. microcephala Grun.	–	–	–	–	–	–	–	2	–	2	0.2	2	3	5	1.6
C. laevis Naegeli	–	2	2	2	3	2	1	1	2	15	1.5	7	–	7	2.3
C. helvetica Kutz.	–	–	–	–	–	–	1	–	–	1	0.1	–	–	–	–
Cymbella sp.	–	–	–	–	1	1	–	–	–	2	0.2	–	–	–	–
Cocconeis placentula (Ehr.) Cleve	5	6	4	–	–	1	9	1	4	30	3.0	9	6	15	5.0
C. placentula v. lineata (Ehr.) Cleve	–	–	–	–	–	–	–	–	1	1	0.1	2	–	2	0.6
C. pediculus Ehr.	–	–	–	–	–	–	–	–	1	1	0.1	–	–	–	–
C. diminuta Pant.	2	3	–	–	2	–	–	2	–	9	0.9	6	–	6	2.0
C. scutellum Ehr.	–	–	–	–	1	–	–	–	–	1	0.1	–	–	–	–
C. disculus Schum.	–	1	1	2	–	1	1	–	3	9	0.9	2	3	5	1.6
Coscinodiscus nitidus Gregory	–	1	–	–	–	–	–	–	–	1	0.1	–	–	–	–
C. cf. velatus A.S.	–	–	–	–	–	–	–	–	1	1	0.1	3	–	3	1.0
Cymatosira belgica Grun.	1	1	–	–	–	1	–	1	2	6	0.6	1	–	1	0.3
Cyclotella meneghiniana Kutz.	–	2	–	–	–	–	–	–	–	2	0.2	–	–	–	–
C. striata (Kutz.) Grun.	86	76	16	16	7	18	35	19	39	312	31.2	30	20	50	18.6
Diploneis puella (Schum.) Cleve	1	–	–	–	–	–	–	–	–	1	0.1	–	–	–	–
Diatoma vulgare Bory	1	1	–	–	1	–	–	–	3	6	0.6	–	–	–	–
D. elongatum v. tenuis (Agardh) Kutz.	–	–	–	–	–	–	–	1	–	1	0.1	–	1	1	0.3
Fragilaria pinnata Ehr.	13	–	1	–	3	–	–	14	18	49	4.9	18	8	26	8.6
F. construens (Ehr.) Grun.	4	–	–	1	–	–	–	2	6	13	1.3	–	–	–	–
F. construens v. venter (Ehr.) Grun.	–	14	1	1	1	1	7	10	21	56	5.6	15	9	24	8.0
F. brevistriata Grun.	7	5	2	2	–	–	3	8	2	29	2.9	23	5	28	9.3
F. vaucheriae Boye Pet.	–	1	2	–	–	–	–	1	–	4	0.4	–	1	1	0.3

TAXON	FORESHORE 1											FORESHORE 2			
Sample	14	18	22	26	30	42	46	50	54	Σ	%	26	38	Σ	%
No. Counted	200	200	50	50	50	50	100	100	200	1000		200	100	300	
F. capucina Desmaz.	–	–	–	–	–	–	–	–	1	1	0.1	–	2	2	0.6
F. capucina v. mesolepta (Rabh.) Grun.	3	1	–	–	–	–	–	–	–	4	0.4	–	–	–	–
F. lapponica Grun.	–	–	–	–	1	–	1	1	3	6	0.6	–	–	–	–
Fragilaria sp.	2	–	–	–	–	–	–	–	–	2	0.2	–	4	4	1.3
Gomphonema olivaceum (Lyngbye) Kutz.	–	1	–	–	–	1	7	–	4	13	1.3	5	1	6	2.0
G. angustatum (Kutz.) Rabenh.	2	1	–	–	–	–	–	2	–	5	0.5	–	–	–	–
G. abbreviatum (Agardh.) Kutz.	–	–	–	1	–	–	–	–	–	1	0.1	–	–	–	–
G. parvulum Kutz.	–	–	–	–	–	–	1	–	1	2	0.2	–	–	–	–
G. parvulum v. micropus (Kutz.) Cleve	1	–	–	–	–	–	–	–	–	1	0.1	–	–	–	–
G. intricatum Kutz.	–	–	–	1	1	–	–	–	–	2	0.2	1	–	1	0.3
G. lanceolatum Ehr.	–	–	–	–	–	–	–	–	–	–	–	–	1	1	0.3
Gomphonema sp.	4	11	2	2	–	–	1	2	4	26	2.6	2	2	4	1.3
Gyrosigma attenuatum (Kutz.) Rabenh.	–	–	–	–	–	–	–	1	1	2	0.2	1	–	1	0.3
G. spencerii v. nodifera Grun.	–	–	–	–	–	–	–	–	1	1	0.1	–	–	–	–
Hantzschia amphioxys (Ehr.) Grun.	1	1	1	2	3	–	1	–	1	10	1.0	–	–	–	–
Melosira sp.	–	–	–	–	–	1	–	–	–	1	0.1	–	2	2	0.6
Meridion circulare Agardh.	–	–	–	–	–	–	–	–	–	–	–	3	–	3	1.0
Navicula tuscula (Dhr.) Grun.	–	–	–	–	–	2	–	–	–	2	0.2	–	–	–	–
N. hungarica Grun.	–	–	–	1	–	–	–	–	–	1	0.1	–	–	–	–
N. hungarica v. capitata (Ehr.) Cleve	–	–	–	–	–	–	–	1	–	1	0.1	–	–	–	–
N. cryptocephala Kutz.	–	–	–	–	–	–	–	–	2	2	0.2	–	–	–	–
N. exigua (Greg.) O. Mull	–	–	–	–	–	–	–	–	–	–	–	1	2	3	1.0
N. pupula v. rectangul. (Greg.) Grun.	1	–	–	–	–	–	–	–	–	1	0.1	–	1	1	0.3
N. cincta (Ehr.) Kutz.	–	–	–	–	–	–	–	–	1	1	0.1	1	1	2	0.6
N. halophila (Grun.) Cleve	–	–	–	–	–	–	–	–	2	2	0.2	–	1	1	0.3
N. mutica Kutz.	–	1	–	–	–	–	–	1	2	4	0.4	1	1	2	0.6
N. viridula Kutz.	–	3	–	–	1	–	4	–	6	14	1.4	3	–	3	1.0
N. gracilis Ehr.	1	2	1	1	–	–	–	1	–	6	0.6	1	–	1	0.3
N. salinarum Grun.	1	1	1	–	–	1	1	–	1	6	0.6	1	–	1	0.3
Navicula sp.	12	–	3	–	3	–	1	–	4	23	2.3	–	–	–	–
Nitzschia denticula Grun.	3	1	–	–	–	2	2	3	2	13	1.3	3	2	5	1.6
N. sigma W. Smith	3	3	1	–	–	1	3	1	–	12	1.2	5	2	7	2.3
N. frustulum (Kutz.) Grun.	–	–	–	–	–	–	–	2	4	6	0.6	–	–	–	–
N. palea (Kutz.) W. Smith	–	–	–	2	–	1	–	–	–	3	0.3	–	–	–	–
N. tryblionella Hantzsch.	1	2	–	–	1	–	–	–	–	4	0.4	–	1	1	0.3

TAXON	FORESHORE 1											FORESHORE 2			
Sample	14	18	22	26	30	42	46	50	54	Σ	%	26	38	Σ	%
No. Counted	200	200	50	50	50	50	100	100	200	1000		200	100	300	
N. trybl. v. debilis (Arnott) A. Mayer	–	–	–	–	–	1	2	–	–	3	0.3	1	–	1	0.3
N. amphibia Grun.	1	1	–	–	–	–	–	1	–	3	0.3	1	–	1	0.3
N. navicularis (Breb.) Grun.	–	–	–	1	–	–	–	2	–	3	0.3	–	–	–	–
Nitzschia sp. A	2	4	1	–	5	6	1	–	–	19	1.9	3	–	3	1.0
Nitzschia sp.	1	–	–	4	–	–	–	–	–	5	0.5	–	–	–	–
Opephora martyi Heribaud	–	2	7	2	2	–	3	1	4	21	2.1	2	–	2	0.6
O. pacifica (Grun.) Petit	–	–	–	–	–	–	–	–	1	1	0.1	–	–	–	–
Paralia sulcata (Ehr.) Cleve	–	–	–	–	–	–	–	1	–	1	0.1	1	–	1	0.3
Pinnularia borealis Ehr.	–	–	–	2	2	–	–	1	–	5	0.5	–	–	–	–
Pinnularia sp.	–	–	1	–	1	–	–	–	–	2	0.2	–	–	–	–
Raphoneis surirella (Ehr.) Grun.	–	–	–	–	–	–	–	–	1	1	0.1	–	–	–	–
R. amphiceros Ehr.	1	–	–	–	1	–	–	–	–	2	0.2	1	1	2	0.6
Rhoicosphenia curvata (Kutz.) Grun.	–	6	–	1	–	–	–	1	–	8	0.8	–	–	–	–
Surirella angustata Kutz.	–	–	–	–	–	–	–	–	3	3	0.3	–	–	–	–
S. ovata Kutz.	6	15	2	–	–	2	5	6	11	47	4.7	4	1	5	1.6
S. ovata v. crumena (Breb.) v. Heurck	–	–	–	–	–	–	–	1	–	1	0.1	3	2	5	1.6
S. peisonis Pant.	13	3	1	–	–	–	–	–	–	17	1.7	–	–	–	–
Synedra ulna (Nitz.) Ehr.	–	1	1	1	–	2	1	1	5	12	1.2	2	1	3	1.0
S. rumpens Kutz.	–	1	–	–	–	–	–	–	–	1	0.1	–	–	–	–
S. parasitica (W. Smith) Hust.	–	–	–	–	–	–	–	–	1	1	0.1	–	–	–	–
S. tabulata v. affinis (Kutz.) A.Cl.	–	–	–	–	4	–	–	–	–	4	0.4	–	–	–	–
Unknown	–	–	2	–	5	–	1	–	–	8	0.8	4	–	4	1.3

Table 1 Diatoms found in Foreshore 1 and 2 sediments at Pudding Lane.

dominance, suggests that it is derived directly from the adjacent river. Other brackish forms include *Nitzschia sigma*, *Synedra tabulata* var. *affinis* and *Bacillaria paradoxa*.

There is a small number of marine taxa in the sediments such as *Cymatosira belgica*, *Raphoneis surirella*, *R. amphiceros* and *Cocconeis scutellum* but these are infrequent and either small forms or small fragments. The source of these marine diatoms is probably a rather distant one with the few forms that do occur probably having been carried up river on high or flood tides.

The majority of the taxa in the assemblages are freshwater forms, although many of the dominants e.g. *Fragilaria pinnata*, *Surirella ovata*, *Cocconeis placentula*, are often also found in weakly brackish environments. Consequently, they could have been growing close to the site of deposition. Other non-halophilous freshwater forms are likely to have been carried down the river from sites upstream above the tidal head. No freshwater plankton was observed.

The nine samples examined from foreshore 1 cover 40 cm of foreshore accumulation. Figure 4 shows variations in the salinity spectrum after grouping the individual taxa according to the halobian classification (Hustedt 1957). It can be seen that there are no clear stratigraphical trends in the data indicating, as would be expected over such a short period, no significant changes in the salinity of the river during the period of deposition. The variations that do occur are more likely to be related to statistical artifacts associated with the relatively large standard errors of small sample counts and to such factors as short term

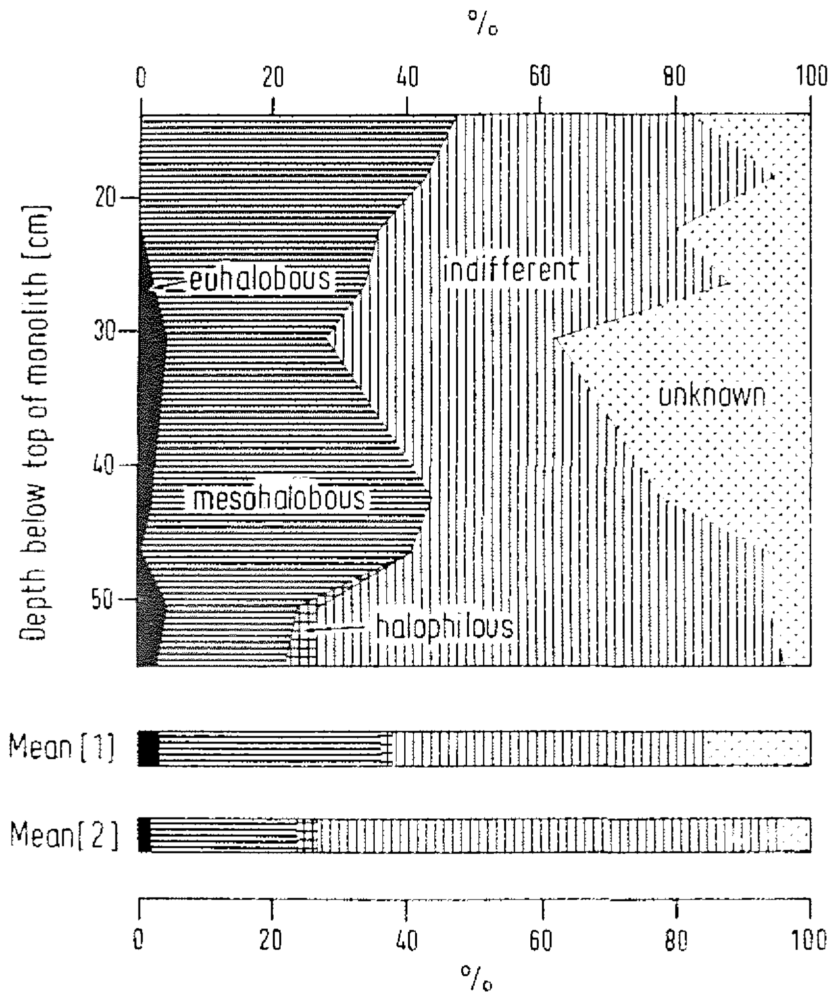

Fig. 4 Salinity spectra for Pudding Lane diatoms.

variations in flooding and river discharge. Because of this it is probably valid and environmentally more representative to regard the data as a single assemblage. Figure 4, therefore, also shows mean values for each salinity group.

Monoliths 2, 3 and 4

The samples examined from Monolith 2 material showed assemblages not significantly different from Monolith 1 either in relation to the pattern of dominance or range of flora (cf. Table 1). Only three additional taxa (represented by 7 individuals) were found in Monolith 2 material. As in Monolith 1 the results were combined to form a single assemblage and Figure 4 shows the salinity spectrum.

The diatoms found in Monolith 3 and 4 deposits were insufficient to make percentage counts but their general similarity with Monolith 1 and 2 diatoms was clear, Cyclotella striata being the dominant.

CONCLUSION

Whilst the spectra are dominated by freshwater taxa it is evident from the importance and condition of the planktonic and brackish-water species Cyclotella striata that the river adjacent to the site was estuarine during the period the deposits were accumulating. It is difficult to estimate likely salinities with accuracy although the spectrum is somewhat less saline than that from the Saxon-age Swan Lane site (Battarbee unpubl.) where 11% of the assemblage was euhalobous. The much smaller percentage (2%) of these marine forms at Pudding Lane may indicate that the tidal head of the river was closer to the City of London in Roman times than in Saxon times.

Such an increase in salinity would accord well with the hypothesis of progressive saline intrusion following the late-Flandrian subsidence of the London basin (cf. Willcox 1975, Devoy 1979). On the other hand only 2 sites representing 2 time periods have been examined. Samples from the younger sediments now being exposed at the Billingsgate site and other samples from a range of ages within the City area are needed to fully assess the relationship between the diatom salinity spectrum and changes in water level, and the position of the tidal head.

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PLATE I

C. striata from River Thames. (a) external view of whole valve with colliculate central area (x 3,000); (b) idem, larger specimen (x 1,500); (c) external margin with the openings of the fultoportulae situated at the ends of the hyaline ridges (x 8,250); (d) internal view of whole valve, central fultoportulae in concave half (x 2,175); (e) detail of internal margin showing partial occlusion of alveoli and approximately 1:3 fultoportula:costa ratio (x 5,850); (f) detail of internal margin showing position and form of rimoportula (x 5,700).

PLATE I