CALDICOT CASTLE LAKE: DIATOM ANALYSIS

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INTRODUCTION

As part of an integrated programme of environmental archaeological research, diatom analysis was carried out on deposits from palaeochannels discovered during the Caldicot Castle Lake excavation. The primary aim of diatom analysis was to determine the salinity conditions under which the sediments accumulated. In addition, it was hoped that other information from the diatom assemblages, for example species lifeform and autecology, would assist in the interpretation of the general environments in which the sediments formed and the taphonomy of deposits.

Battarbee (1988) has reviewed the international literature and archaeological applications of diatom analysis. The technique has been used infrequently at archaeological sites in the UK (eg. Battarbee *et.al.* 1985). An exception is Juggins' (1992) detailed quantitative study of diatom ecology and palaeoecology in the Thames Estuary. The diatom-salinity transfer function developed was applied to sediments from archaeological sites in the City of London (Juggins 1992 Ch.9). Diatom analysis continues to be used routinely at wetland, alluvial and coastal excavations in Mainland Europe (eg. Jansma 1990, Straub 1990) and particularly in Scandinavia (eg. Gaillard *et.al.* 1988, Håkansson 1988).

Unpublished assessments and diatom analyses have, however, been carried out at several archaeological sites in Britain during recent years (Cameron unpubl. results). In the Severn Estuary work is in progress at associated sites on the Gwent Levels (Barlands Farm) and the approaches to the English side of the Second Severn Crossing. Close to the Caldicot Castle Lake site diatom analyses were carried out on a sequence from Caldicot Pill (Cameron 1993) lying in the present day intertidal zone. The successful use of diatom analysis at these sites suggests that the approach has great potential both on and off site for qualitative and quantitative reconstruction of water quality parameters such as salinity, pH and nutrient levels.

METHODS

Wet samples were received in glass sample tubes sealed in polythene bags. Diatom sample and slide preparation followed standard techniques (Battarbee 1986, Renberg 1990). Counting was carried out using a Leitz research microscope (phase contrast x1000-x1250). Identifications were made with the aid of a range of diatom floras and taxonomic publications held in the collection of the ECRC, UCL. The floras most commonly consulted were: Cleve-Euler (1951-1955), Hendey (1964), Hustedt (1930-1966), Werff & Huls (1957-1974). Where diatoms were present in sufficient concentrations a total of c.200-300 valves were counted per sample. This sum was considered adequate to determine dominant taxonomic composition. Data were entered into the DISCO diatom database at the ECRC, these data, slides and cleaned valve suspensions are available for examination at the ECRC. Data manipulation was carried out using the program TRAN (Juggins

1993) and the diagrams were plotted using TILIA and TILIAGRAPH (Grimm 1991).

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

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.

The principle source of data on species ecology used was the recent survey of Denys (1992).

All radiocarbon dates given are uncalibrated radiocarbon years unless otherwise stated.

RESULTS

The results are described with reference to the interim report of Nayling (1993) including the site phasing scheme and associated section drawings. The relationships between diatom stratigraphies and particular contexts has been derived by measurement from scale section drawings.

A total of 69 samples from 6 sequences were prepared for diatom analysis. Of these a total of 51 samples contained countable diatom assemblages. Only in the 11 samples prepared from 23309 and 23310 were diatoms more or less absent from the whole sequence. In 2 samples from the base of the master column and 5 samples from the base of the sequence 23004/23005 diatoms were not countable. These sections were associated with Phase I pre-channel deposits in the respective sequences. A total of 209 diatom taxa were identified from the Calidicot Castle Lake site.

Monolith 23195: Sample Area 22300

A sequence of 7 samples, at 8 cm intervals, from the 50 cm monolith 23195 was analysed for diatoms. A total of 101 diatom taxa were identified in the sequence. A summary diatom diagram (Figure 1) shows species that occurred at abundances of more than 2%, grouped according to salinity preferences. According to the site phasing presented by Nigel Nayling this monolith cuts across 4 contexts associated with Phase II - Phase IV of the site scheme (Table 1).

Table 1. Summary table of diatom sequence in Monolith 23195

Sample context and associated Phase	Approx. corresponding depth in 23195 (cm) & OD	Diatom assemblage	Environment
22391 Phase II	130 to 116/111 2.43-2.57/2.62	basal part: mixed assemblage, upper part predominantly marine, brackish phase 120 cm	mixing of fw to marine elements followed by clear marine phase
22392 Phase III	116-111 - 89/88 2.57/2.62-2.84/2.85	marine spp dominant 112 cm decline to 104 fw dominant	marine then freshwater
22379 Phase III	89/88- 83/81 2.84/2.85-2.90/2.92	freshwater	freshwater
22382 Phase IV	83/81 - 80 2.90/2.92-2.93	freshwater	freshwater

The basal part of the monolith 23195 has a fairly evenly mixed assemblage of freshwater to marine diatom species. It is unlikely that these groups of taxa would grow under similar salinity conditions (see Discussion). The freshwater element is a predominantly non-planktonic assemblage whilst the marine component is of planktonic or tychoplanktonic species. This mixture of different elements at the base of the sequence could be the result of one or a combination of processes. For example post-depositional bioturbation and physical mixing of sediments may have resulted in the time averaging of diatom assemblages. Another possibility is that the assemblage represents the incursion of marine species into a freshwater (or possibly slightly brackish) environment. Alternatively the intrusion of freshwater into a tidal environment may have introduced benthic freshwater species.

However in the upper part of this section of the monolith there is a transition where brackish species, notably *Navicula cincta* (13%), and then marine species such as *Paralia sulcata* (maximum 42%) and *Cymatosira belgica* (maximum 20%) become dominant. At the same time the abundances of freshwater taxa decrease. This part of the sequence, in the upper part of 22391 and associated with Phase II of the site scheme, represents salinity conditions such as those that might be found in the tidal estuary today.

In the uppermost part of 23195, above about 90 cm depth and corresponding with Phase III and Phase IV, the assemblages continue to represent a predominantly freshwater environment. There are shifts in the abundances of freshwater taxa in this part of the sequence such as an increase in *Fragilaria construens* var. *binodis* at 80 cm. *Melosira varians,* a brackish water species, is present at a maximum abundance of 3%. However, marine taxa are present in low numbers, probably as a result of reworking of older material by bioturbation or physical mixing.

Monolith 23010: Sample area 22022

The 50 cm monolith 23010 was analysed for diatoms at 8 cm intervals. A total of 107 diatom taxa were identified in the 7 samples counted; a summary diatom diagram (Figure 2) shows species occurring at abundances of more than 2%. According the Caldicot Castle Lake phasing scheme the column cuts 4 contexts associated with Phase II and Phase III of the site scheme (Table 2).

Table 2. Summary table of the diatom sequence in Monolith 23010

Phase & associated contexts	Depth in monolith (cm) and height above OD (m)	Diatom assemblage & environment
II: 22220; 22240; 22241	50-32/30 2.40-2.58/2.60	Marine with halophilous taxa at base
III: 22246; 22170; 22169; 22042; 22217; 22216	32/30-0 2.58/2.60-2.90	Freshwater with slight increase in marine/halophilous spp. in 22216

The 3 samples (48-32 cm) analysed from the base of the sequence are dominated by coastal marine species, such as *Paralia sulcata* (max 20%), *Cymatosira belgica* (max 23%), *Rhaphoneis* spp. and *Thalassiosira decipiens*. There is also a significant element of halophilous species, such as *Navicula cincta* which has a maximum abundance of 10% at the base of the sequence.

Marine taxa decline from 32-24 cm and oligohalobous taxa become dominant, in particular *Fragilaria* spp. and *Achnanthes minutissima*. Freshwater species continue to dominate the diatom assemblages until the uppermost sample where there are slight increases in the percentages of polyhalobous taxa such as *Paralia sulcata*, *Rhaphoneis minutissima* and *Cymatosira belgica*.

Monoliths 23004/23005: Sample area 22022

A sequence of 24 samples at 4 cm intervals was analysed for diatoms from the sample columns 23004 & 23005. A summary diagram showing species occurring at abundances greater than 2% is presented (Figure 3). Diatoms were countable in the uppermost 19 samples of the sequence, but were either absent or present only in very low concentrations in the 5 basal samples of 23005 (Table 3). These diatom-poor samples were contained within the context 22221 which is related to pre-channel deposits of Phase I in the site scheme. A total of 128 taxa were identified in the 19 countable samples.

Table 3. Diatom evidence from 5 basal samples of 23004/5

Depth (cm)	Diatom assemblage	Possible environment
92-93	1 part of *Nitzschia navicularis* & indeterminate fragments	1 identifiable fragment is brackish to marine estuarine taxon
88-89	1 *Paralia sulcata* fragment	a coastal marine planktonic sp.
84-85	diatoms absent	unknown
80-81	diatoms absent	unknown
76-77	Fragments of *Fragilaria construens* v. *binodis* & *Meridion circulare*	Freshwater species

The sparse marine diatoms from the basal section of 23004/5 are however consistent with the interpretation of Phase I deposits as related to intertidal Severn Estuary (Wentlooge) deposits (Allen 1987). The appearance of fragments of freshwater species at the top of this part of the sequence may relate to down-mixing of material from the freshwater-deposited sediments above.

The first sample containing countable diatoms is at 72 cm depth which corresponds approximately to the lower horizon of context 22166 which belongs to Phase III. Samples at 72 and 68 cm have freshwater diatom assemblages, dominated by *Fragilaria* sp. and *Achnanthes minutissima*. A single sample, at 64-65 cm, is dominated by marine species including *Paralia sulcata* (22%), *Podosira stelligera* (11%), *Rhaphoneis* spp. and *Cymatosira belgica* (8%). However, although there are minimum abundances of diatoms such as *Fragilaria construens* var. *venter* and *Achnanthes minutissima*, other oligohalobous taxa, like *Fragilaria construens* var. *binodis* (15%) and *Fragilaria pinnata* (18%), are present in significant abundances. This level must therefore be interpreted as a mixed assemblage containing disparate marine to freshwater elements. It is probable that the record of a marine episode or series of episodes has become mixed with underlying and overlying, predominantly freshwater deposits. This level corresponds to the transition from context 22166 to 22239.

At 60cm marine species decline in importance and freshwater taxa become dominant again. Above this level marine taxa are present at abundances of less than 2%. Therefore in the contexts above this level the diatom assemblages indicate the dominance of freshwater conditions with a small but significant halophilous element. Notably the diatom assemblages between 58 cm and 38/35 cm depth corresponding to the context 22165, which contains the boat strake, are of predominantly freshwater species. The beginning of contexts associated with Phase IV at approximately 38 cm is accompanied by the establishment of continuous curves for the oligohalobous taxa *Fragilaria brevistriata*, *Fragilaria lapponica* and *Fragilaria construens* (see Discussion of this *Fragilaria* group).

Monoliths 23188, 23189: Sample area 22300

A total of 10 samples were analysed from the composite sampling column formed by the 2 monoliths: 23188 and 23189. 130 taxa were identified; a summary diatom diagram (Figure 4) shows taxa occurring at abundances of more than 2%. The base of the sequence, cutting contexts 22349 and 22309, belongs to Phase I according to the site scheme. The diatom assemblages in this part of the sequence c. 70-50 cm, represented by 3 samples 68-44cm, are consistent with this interpretation. The assemblages of the lower 2 samples consist entirely of marine and mesohalobous (brackish) taxa typical of the intertidal Severn Estuary. The dominance of *Diploneis bombus* in the basal sample is noteworthy. This is a benthic and often epipsammic (inhabiting the surface of sand grains) brackish/marine species and its abundance suggests that the species was growing *in situ* or that it was deposited with transported sand. *Diploneis bombus* is also a robust heavily silicified species and may have been preferentially preserved.

Between approximately 50-35 cm, cutting contexts 22351 and 22325, and associated with phase VI of the site scheme, the abundances of marine species decrease and oligohalobous taxa such as *Fragilaria pinnata*, *Achnanthes conspicua* and *Amphora pediculus* become dominant.

Freshwater species *generally* dominate the assemblages to the top of the monolith in the contexts associated with Phase VII of the site scheme. However, there are large variations in the salinity indicated by the assemblages. For example the dominance of *Navicula gregaria* (19%), a mesohalobous species, indicates that estuarine conditions were associated with the depositional environment of context 22321.

Monoliths 23309 & 23310: Sample area 22280

Diatom analysis was attempted on 11 samples from the sequence of samples taken from monoliths 23309 and 23310. These samples lay at 8 cm intervals between 0 cm and 80 cm in the composite monolith. The top of the sequence (0cm) lay at about +4.18 m OD, the base of the sequence was therefore at +3.38 m OD. As a result of the absence, or very low concentrations, of diatoms throughout the monolith, detailed diatom analysis was not possible. A summary table of the results of scanning the samples is presented below (Table 4).

Table 4. Results of scanning diatom slides prepared from columns 23309 and 23310

Sample depth (cm) & context	Top height + (m) OD	Diatom assemblage
0-1 22279	4.18	absent
8-9 22279	4.10	absent
16-17 22279	4.02	absent
24-25 22279	3.94	absent
32-33 22279	3.86	absent
40-41 22279	3.78	absent
48-49 22283	3.70	absent
56-57 22283	3.62	1 Podosira stelligera fragment (marine)
64-65 22284=22419	3.54	sparse fragments, indeterminate probably marine taxa
72-73 22284=22419	3.46	sparse fragments indeterminate probably marine taxa
80-81 22284=22419	3.38	sparse fragments indeterminate probably marine taxa

Comparing the results of diatom analysis with the section drawing from Area 22280: diatoms are absent from context 22279; a single fragment of *Podosira stelligera*, a tychoplanktonic marine diatom, was found in the lower level analysed from 22283; and low concentrations of diatom fragments (probably of marine taxa) were found in the 3 samples from 22284. All 3 contexts are associated with Phase I of the site scheme. The low concentrations of diatom valves and marine origin of those identified is consistent with the archaeological interpretation of this material as pre-channel (Wentlooge) deposits.

Master Column

Ten samples from the Master Column were analysed for diatoms. The sequence ranged from +2.40 m OD to +3.84 m OD. However, the 2 basal samples, at +2.40 and +2.48 m OD, from context 9033, were found to contain very low concentrations of diatom fragments, diatom counting was not therefore possible. A diatom diagram showing species occurring at abundances of greater than 2% is presented in Figure 5. The results of diatom analysis relative to the archaeological stratigraphy are tabulated below (Table 5).

Table 5. Master Column, summary of diatom assemblages vs. sample height and archaeological context.

Sample height +m OD	Context and Phase	Diatom assemblage & environment
2.40	9033, I	low concentration
2.48	9033, I	low concentration
2.64	22168, V	freshwater
2.88	22168, V	freshwater
2.96	9032, VI or VII	freshwater
3.12	9031, VI or VII	freshwater
3.28	9031, VI or VII	freshwater with increase in halophilous spp.
3.36	9031, VI or VII	freshwater with increased halophilous element
3.60	9034, VII	mixed marine to freshwater assemblage
3.84	9001, VIII	predominantly marine

The very low concentrations of diatom fragments in 9033 is consistent with the results of analysis of Phase I contexts elsewhere across the site (23189, 23005, 23310). The overlying Phase V deposits are dominated by freshwater species such as *Fragilaria pinnata* and *Achnanthes minutissima*.

Diatom assemblages from Phases VI/VII continue to be dominated by freshwater taxa up to a height of +3.12 m OD. In these levels the abundances of some oligohalobous (indifferent) taxa such as *Fragilaria construens* var. *venter*, *Achananthes minutissima* and *Achnanthes lanceolata* increase whilst the abundance of *Fragilaria pinnata* declines.

In the uppermost levels associated with Phase VI/VII, at +3.28 and +3.36 m OD the percentages of halophilous taxa increase, but the assemblages are composed predominantly of freshwater diatoms.

At +3.60 m OD the diatom assemblage is a mixed one, with significant marine, mesohalobous, halophilous and oligohalobous (indifferent) components. The top of the sequence at +3.84 m OD is dominated by marine taxa such as *Paralia sulcata* and *Cymatosira belgica*.

DISCUSSION

The diatom assemblages of the 6 sequences, relative to the site phasing scheme, are presented in Table 6. The approximate heights of these assemblages above Ordnance Datum are presented in Table 7. Further summary diatom diagrams showing the halobian classification of all taxa identified in each sequence relative to site phasing and heights above OD are shown in Figures 6-10.

Table 6. Diatom assemblages of the 6 sequences related to the site phasing scheme

Phase	Master	23188/9	23195	23010	23004/5	23310/9
VIII	inc. marine					
VII	fresh to brack. to mar.	fresh/ brack.				
VI	fresh	fresh				
V	fresh					
IV			fresh		fresh	
III			fresh	fresh	fresh, marine episode	
II			marine, mixed at base	marine		
I	?marine	marine			?marine	marine

Table 7. Approximate heights of the assemblages above OD.

Phase	Master	23188/9	23195	23010	23004/5	23310/9
VIII	3.73-3.84					
VII	3.12-3.73	3.18-3.53				
VI	2.91-3.12	3.04-3.18				
V	2.62-2.91					
IV			2.90-2.93		3.03-3.41	
III			2.60-2.90	2.58-2.90	2.69-3.03	
II			2.45-2.60	2.42-2.58		
I	2.40-2.62	2.85-3.04			2.48-2.69	3.38-4.18

It can be seen from Table 6 that there is good correspondence of diatom assemblages during the respective phases. Clearly the absolute heights of the facies depend on the location of the sequences across the site (Table 7). However, where channel features are close, for example in the case of 23195 and 23010 the Phases can be correlated quite well eg. diatom assemblages and heights in Phase II and Phase III and this is supported by palynological evidence (Astrid Caseldine pers.comm.). The diatom sequence is discussed below with reference to the site Phasing scheme of Nayling (1993).

Phase I

Sediments belonging to Phase I are included in 4 sequences: the Master column, 23188/9, 23004/5 and 23310/9. Diatom assemblages are either marine or marine-brackish or they are poorly preserved/absent. The sediment has been described by Nayling (1993: 3) as "a pre-channel sequence of horizontally bedded blue grey clays reminiscent of the Wentlooge formation (Allen 1987, 1990, 1992; Allen & Rae 1987) observed in the intertidal zone of the Severn Estuary". Phase I diatom assemblages are reasonably well preserved only in 23188/9 and are composed of c. 60-70% polyhalobous taxa (Figures 4 & 9) with a significant component (10-15%) of mesohalobous (brackish water) species.

It is possible that the poor survival of diatoms in Phase I deposits of the Master column and 23004/5 equate with the organic horizons described by Nayling (1993: 3) at c. 2.5-2.7 m OD. The level of these deposits is at approximately the same height. The sequence 23309/10 lies at the edge of the modern lake and the pre-channel deposits, which contain occasional valves of marine diatom species, survive to above +4.0m OD.

Radiocarbon determinations from Phase I deposits in sample area 22255, and correlated with the basal contexts in the other sequences, indicate Neolithic dates of 4360±80BP (CAR-1322) and 4670±80BP (CAR-1323). However, no archaeological material was recovered in this sequence

Phase II

Phase II deposits occurred in the lower parts of 23195 and 23010. The diatom assemblages in both cases are predominantly polyhalobous (60-70%) with 10-20% mesohalobous or halophilous taxa. Only in the basal sample of 23195 and upper level of Phase II sediments in 23010 are there mixed assemblages with high proportions of both marine and freshwater taxa. These probably represent, particularly in the case of 23010 where sediments dominated by oligohalobous taxa overlie, transitional, time averaged assemblages.

Phase II sediments are associated with the earliest channel identified on the site. They occur at approximately the same levels, around 2.4-2.6 m OD. This channel is straight sided cutting to c. 1.7 m OD (Nayling 1993), 3 radiocarbon determinations of archaeological material from the base and sides of the all give dates around 3500 BP uncalibrated radiocarbon years. The remains of flatfish (possibly flounder) and interim results of ostracod analysis (E.Robinson cited in Nayling 1993) suggest that the channel was estuarine. Diatom analysis is consistent with this conclusion. There are high percentages of marine tychoplanktonic taxa such as *Paralia sulcata* and *Cymatosira belgica* along with significant abundances of benthic halophilous taxa such as *Navicula cincta* in the sections of both sequences cutting Phase II sediments. It is probable that the benthic species were deposited close to their lifetime habitats and that, as is likely in such a large channel, diatoms of the foreshore and open water were readily introduced by incoming tides (see Discussion of present day Severn Estuary species).

Phase III

Phase III sediments occurred in 3 sequences: 23195, 23010 and 23004/5; at levels between approximately +2.6-3.0 m OD. These consist of a complex of channel bases which truncate the large Phase II channel. All Phase III sediments are dominated by oligohalobous (indifferent) taxa which are interpreted as indicating freshwater conditions (see Discussion of 'oligohalobous (indifferent)' diatom ecology). In the basal levels of 23010 and 23195 there are significant percentages of marine taxa. This is probably the result of both the coarse interval at which diatom samples were analysed and partly the result of sediment mixing between facies. There is however a separate peak of marine taxa (> 50%) at the base of 23004/5 in the transition from context 22166 to 22239 which might be interpreted as the result of an episode, or episodes, of marine incursion or possibly a longer period of tidal conditions. The polyhalobous species are predominantly tychoplanktonic, and therefore readily transported, such as *Paralia sulcata*, *Cymatosira belgica* and *Pseudoposodosira (Melosira) westii*. However, the scale and duration of this marine episode is uncertain from diatom analysis alone. This 'marine' episode may be archaeologically significant since the context (22165) immediately overlying 22239 contains the boat strake.

Radiocarbon dates for these deposits cluster in the range 3150-3450 BP (Nayling 1993) and of particular archaeological importance was the recovery of a Ferriby-type boat strake (3439± 19 BP), thought to derive from repair, rather than abandonment of a complete boat. Diatom analysis would suggest that the environment of deposition was, with the exception of the marine phase in 23004/23005, usually beyond the influence of tides.

Phase IV

Phase IV deposits occurred in 2 sequences analysed for diatoms: 23004/5 and a short section at the top 23195. These are organic channel deposits, the channel truncates Phase III deposits and itself has low densities of artefacts, these possibly derived from the earlier channel fills (Nayling 1993). A single radiocarbon determination of material from the interface of Phase III and IV deposits from Trench 22555 gives a date of 3000±60 BP. This suggests that the deposits post-date Phase III (Nayling 1993).

Both the detailed diatom analysis of the 23004/23005 sequence and the short Phase IV sequence from 23195 have assemblages consistently dominated by oligohalobous (indifferent) diatom taxa. The concentrations of halophilous to polyhalobous species are low. It is possible that the low but significant background of marine taxa, generally <5%, derives from marine incursions. True halophobous taxa are absent and there are peaks in the abundances of halophilous to polyhalobous taxa. This background of estuarine taxa could equally be derived from time averaging processes. However, like the Phase III deposits diatom analysis shows that the environment was predominantly beyond the range of tides.

Phase V

Phase V sediments consist of relatively inorganic channel deposits, largely eroded by later channels (Nayling 1993). In the sequences analysed for diatoms they survive only in the Master column. The diatom assemblages (Figures 5 & 10) are composed of about 75% oligohalobous (indifferent) taxa, marine and brackish taxa constituting 10% or less of the assemblages. The depositional environment is therefore interpreted as generally being above the high water mark.

Phase VI

Phase VI sediments were well preserved comprising the fill of a wide (c. 6.5m) flat-bottomed channel with substantial basal spreads of stone, wood and associated artefactual material (Nayling 1993). Radiocarbon dates are in the approximate range 3000-2900 BP and a plank associated with Phase VI sediments was dendrochronologically dated to 998/997 BC. Sediments associated with Phase VI occur in 23188/9 and possibly in the Master column, however, the association of this part of the Master column with Phase VI or VII is not clear.

Diatom analysis of Phase VI deposits indicates a mainly freshwater oligohalobous assemblage with only a background of marine, and brackish taxa such as *Achnanthes delicatula*. This background of diatoms of different ecology is discussed for earlier Phases.

Notably there are peaks of the oligohalobous species *Amphora pediculus* and *Achnanthes* taxa such as *Achnanthes conspicua* and *Achnanthes lanceolata* var. *rostrata*. The former is a benthic or epontic (firmly attached to a substrate such as sand grains, rock surfaces, or macrophytes) species and the later are epontic. This suggests that the species are more likely to have been deposited *in situ* or else their habitats (eg. macrophytes, sand grains) were transported to the depositional environment. Again it is concluded that the channel was generally beyond the range of tides. The later evidence of species of mammal and bird remains (F. McCormick cited in Nayling 1993) would support this conclusion.

Phase VII

Phase VII deposits consist of late channel deposits associated with wooden structures, uncalibrated radiocarbon dates ranging from approximately the middle to late 3rd millennium BP. Diatom analysis relating to this Phase was carried out on the Master column and on 23188/9. In the Master column initially there is a high percentage of oligohalobous (indifferent) taxa and then an increasing proportion of marine, brackish and halophilous taxa towards the top of the column. In 23188/9 oligohalobous indifferent taxa are generally dominant but in context 22321 (28 cm) there are maxima of brackish and halophilous species, notably *Navicula gregaria*. Both Phase VII sections therefore suggest an increasing marine/brackish influence and therefore a return to a periodically tidal environment such as a saltmarsh, although tolerant oligohalobous freshwater taxa remain dominant.

Phase VIII

Diatom analysis of Phase VIII post-channel deposits was carried out only on the Master column. A single sample at the top of this sequence shows an increasing influence of estuarine diatoms compared with Phase VII. Over 40% of the assemblage is composed of polyhalobous taxa and there is a similar proportion of oligohalobous (indifferent) taxa. Whether the marine component of the Phase VIII deposits is derived from contemporary changes in the salinity regime or whether the marine component derives from post-depositional sediment mixing, as the assemblage of diatoms from different environments might suggest, is not clear. The diatom content of overlying material is not known. Alternatively, the increasing marine/brackish influence noted in Phase VI would support the idea that there was a real increase in estuarine diatoms immediately before this time.

Diatom Ecology

Fossil diatom assemblages are derived from a mixture of community sources as well as being subject to post-depositional modification. For example the Caldicot material contained planktonic or tychoplanktonic species, epipsammic species, epipelic and epilithic/epiphytic species. The representation of each of these communities by the fossil assemblages is difficult to estimate, but an example of work on the present day ecology of the mudflat diatom communities may provide a useful comparison.

Recent studies have been carried out on epipelic (mud dwelling) diatoms in the intertidal surface sediments of the Severn Estuary (Paterson & Underwood 1990a,b). Some of this work has been concerned with the important role that benthic diatoms have in sediment stabilization on intertidal estuarine mudflats, where they are often the dominant group of primary producers (Underwood & Paterson 1993). However, the research programme has also been concerned with diatom taxonomy (Underwood & Yallop in press) and the seasonal and spatial distribution of epipelic diatoms in the Severn Estuary (Paterson & Underwood 1990a, Underwood in press).

Sites were investigated on the Avon shore of the Severn Estuary, at Sand Bay, Portishead and Aust (Underwood in press b). It was shown that diatoms usually comprise more than 95% of algal cells in counts of live cells trapped using lens tissue. Of the 60 diatom taxa identified, 20 or less taxa occurred regularly and 12 species were dominant in the samples. Comparison of the true epipelic diatoms found commonly on the Severn mudflats by Underwood (in press) with the estuarine assemblages found at Caldicot Castle shows some disparity. Of the common diatoms that Underwood identified, only *Cymatosira belgica*, *Rhaphoneis minutissima* and *Navicula gregaria* were *commonly* found in the estuarine assemblages recovered from the Caldicot Castle site, although other of the species were occasionally recorded in the Caldicot sediments. Estuarine or neritic (coastal) species such as *Paralia sulcata* however are not epepelic so this is hardly surprising. This species has a loose association with benthic habitats (tychoplanktonic), but is primarily planktonic. Other authors eg. Denys 1992, Juggins 1992 have classified taxa such as *Cymatosira belgica* in this group. Diatom assemblages from the sequence taken in the present day intertidal estuary at Caldicot Pill are similar to the kinds of assemblage recovered from the Caldicot Castle (Cameron 1993). This is probably because the assemblages are most heavily influenced by plankton, and also that robust planktonic species occurring in large numbers the estuary are easily transported and survive abrasion. These may therefore be better represented compared with for example benthic intertidal species. Another observation on the Caldicot data is the relative rarity of a dominant component of brackish (mesohalobous/halophilous taxa) which might be expected to occur at least as transitional phases between marine and apparently freshwater conditions. Rarely were high numbers of benthic saltmarsh taxa found in the diatom assemblages, the reasons for this are unclear.

The salinity classification of some diatom taxa is problematic. In particular of the abundant *Fragilaria* species, generally classified in the literature as oligohalobous (indifferent) but which have been observed to have tolerance to high salinities (eg. Denys 1988, Håkansson 1988).

Denys (1988) observed the present day responses of a group of *Fragilaria* species in coastal habitats of the Belgian Plain. The group of species studied included *Fragilaria pinnata*, *Fragilaria brevistriata*, *Fragilaria construens* var. *venter* and *Fragilaria construens* var. *subsalina*. *Fragilaria pinnata* was found to be best developed under pronounced brackish conditions although the species is well known from freshwater. On the other hand *Fragilaria brevistriata*, *Fragilaria construens* var. *venter* and *Fragilaria construens* var. *subsalina* were most common in weakly brackish conditions although both can be abundant in freshwater. His general conclusion was that *Fragilaria* species were most abundant in slightly brackish salt-marsh sediments especially in areas with a strong freshwater influence. *Fragilaria* blooms develop mainly in marshy environments with little tidal influence. It seems that environmental instability stimulates the mass development of this group of *Fragilaria* species, an observation also made by diatomists working on late-glacial freshwater sediments and Baltic isolation lakes (see references cited in Denys 1988).

Peaks of Fragilaria species were observed by Denys to coincide with increased concentrations of other diatoms these were not, however, measured in the Caldicot sediments). It was hypothesised that in situations high on salt marshes nutrients might be available to tolerant colonising/weed species from the salt water sediments. Alternatively as a higher tidal level is reached accretion rates decrease and as a result the diatom component may become greater compared to other sediment components. In general though the largest blooms of *Fragilaria* spp. occurred where there was a considerable supply of freshwater from drainage. Clearly these species are tolerant to short term fluctuations in water chemistry and are well represented because of high cell division rates, competitive advantages (weedy spp.) and perhaps ease of transport.

Some authors eg. Håkansson have for specific reasons removed *Fragilaria* spp. from the diatom sum. However, it can be argued, as here, that these taxa are informative, weed species indicative of a changing environment. Since a true estuarine environment would be dominated by marine plankton and/or estuarine mudflat species and the dominant freshwater nature of the environment is supported by the occurrence of other freshwater taxa.

Problems of taphonomy

In addition to diatom ecology, consideration of the taphonomy of diatom assemblages is central to their interpretation. The question of diatom taphonomy and the interpretation of diatom assemblages in coastal and estuarine sediments has been addressed in the recent publications of Juggins (1992), Sherrod Rollins & Kennedy (1989), Vos & de Wolf (1988) and the references cited in these publications. At Caldicot the interpretation of the diatom assemblages will be assisted by the integrated results of archaeological analyses and other biostratigraphical investigations, particularly those of ostracod and pollen analyses. In addition detailed sedimentological analyses should help in the wider interpretation and incorporation of the diatom evidence. For example in elucidating the disparate origin of some contexts, and episodes of erosion which are apparent.

The Caldicot site is in many ways a problematic taphonomic environment for diatom analysis. The conditions of diatom taphonomy in tidal and supratidal channels of varying size, and effect of anthropogenic disturbance are unknown. For example the drainage and mass-movement of sediments in the tidal creeks of the Severn Estuary Levels has been discussed by Allen (1985). However, the general salinity conditions are clear from diatom analysis of palaeochannel sediments from Caldicot Castle Lake. Where parallel sequences were examined the results have been shown to be repeatable across the site. However, significant features such as the origin of the background of marine taxa in a freshwater environment are open to interpretation. *Paralia sulcata* which is often the dominant species of these "background" species has several possible origins. It is possible that the background concentration of this species represents transport of contemporary diatoms by extreme spring tides into a predominantly freshwater or freshwater-brackish environments. The highest cell concentrations of this planktonic species, in the autumn would be likely to coincide with the time of the highest tides and stormiest conditions. It has been suggested by more than one author (eg. Kjemperud 1981) that *Paralia sulcata* may be transported by in spray during stormy conditions although experimental evidence for this is not presented. Another likely source is from reworked estuarine sediments from the sides of channels or resuspended sediment from mudflats.

Comparison with 2 other Severn Estuary diatom analyses

Diatom analyses have been carried out at 2 other sites in the vicinity of Caldicot, at Caldicot Pill (Cameron 1993) and Goldcliff (Esho 1989). Although radiocarbon dates are not yet available for the core Oscar 3 at Caldicot Pill, on the basis of other evidence, Scaife (1993) has suggested that the freshwater muds identified from the Oscar 3 may date to the period c.5-

6000BP, in mid-Holocene (Atlantic) times, corresponding with the later Mesolithic period (see discussion in Scaife 1993). However, Phase I deposits from the palaeochannels at Caldicot Castle Lake date from this period (dates given above are uncalibrated) and indicate a marine environment, in a position further away from the present day estuary than the intertidal core Oscar 3. Although, radiocarbon dating is required to confirm the age of the Oscar 3 sequence, the existence of localised freshwater conditions at this time is not necessarily inconsistent with the Phase I deposits and may be the result of a barrier bar causing the formation of a lagoon (see Scaife 1993).

A single diatom sample was examined by Esho (1989), from an intertidal sequence at Goldcliff site 1 at a depth of 1350mm. The sample was taken from a blue "buttery" clay with a basal level of approximately +0.25 m OD. The diatom species list presented was without abundances but is interpreted as representing "estuarine conditions with a considerable freshwater influence". The species list indicates a mixture of diatoms from freshwater, brackish and marine environments. Conventional radiocarbon dates place this sample between 5530±90 and 5360±80 BP in Smith *et.al.*'s zone GC1-2 (Calibrated ages for this occasional incursion began at about 6470 BP and the period of marine influence lasted until about 6130 BP). It is suggested by Smith *et.al.* (1989) that the (laminated) clay was laid down in a small creek surrounded by alder carr. From the laminated nature of the clay in the vicinity of the diatom sample it is also suggested that the incursion of the sea was sporadic or only occurred at the highest tides.

CONCLUSIONS

Diatom analysis of 6 sediment sequences, together covering Phases I-VIII of the Caldicot Castle Lake site stratigraphy, show good agreement between diatom assemblages, implied salinities and estuarine/marine influence. Initial comparisons with other biostratigraphies and archaeology suggest a consistent picture of environmental change.

Phase I deposits associated with Neolithic time (uncalibrated dates of c. 4500 BP) have marine (Severn estuary) diatom assemblages which are probably related to the Wentlooge formation. Phase II sediments of c. 3500 BP are also of predominantly marine estuarine species. Phases III to VI with dates ranging from c. 2500 BP to c. 1500 BP are dominated by freshwater diatoms with a single marine episode recorded in 23004/5 during phase III. The contexts containing this feature immediately underlie the context containing the boat strake. During these predominantly freshwater phases there remains a background of marine species whose origin is uncertain. Most importantly for the archaeological interpretation this observation might imply at least occasional inundation by spring tides. The oligohalobous taxa, in particular a group of *Fragilaria* species dominating many of the assemblages are tolerant, "weed" species characteristic of changing environmental conditions. However, other hypotheses are put forward for the occurrence of ecologically very different diatom groups in the same assemblages. In Phase VII saltwater tolerant freshwater taxa are associated with true brackish species and in the Master column marine species increase towards the top of the Phase VII section. In Phase VIII sediments, recorded only from the Master column there are further increases in marine taxa, but there are also high percentages of oligohalobous species resulting in a mixed assemblage.

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APPENDICES

I diatom species list & codes
II diatom counts for each column

[NB The codes and species included in the appendices are uncorrected. For example several synonyms, and formerly unidentified ("ZZZ...") species altered in the diatom and summary diagrams remain uncorrected in these raw species lists].

Figure 1

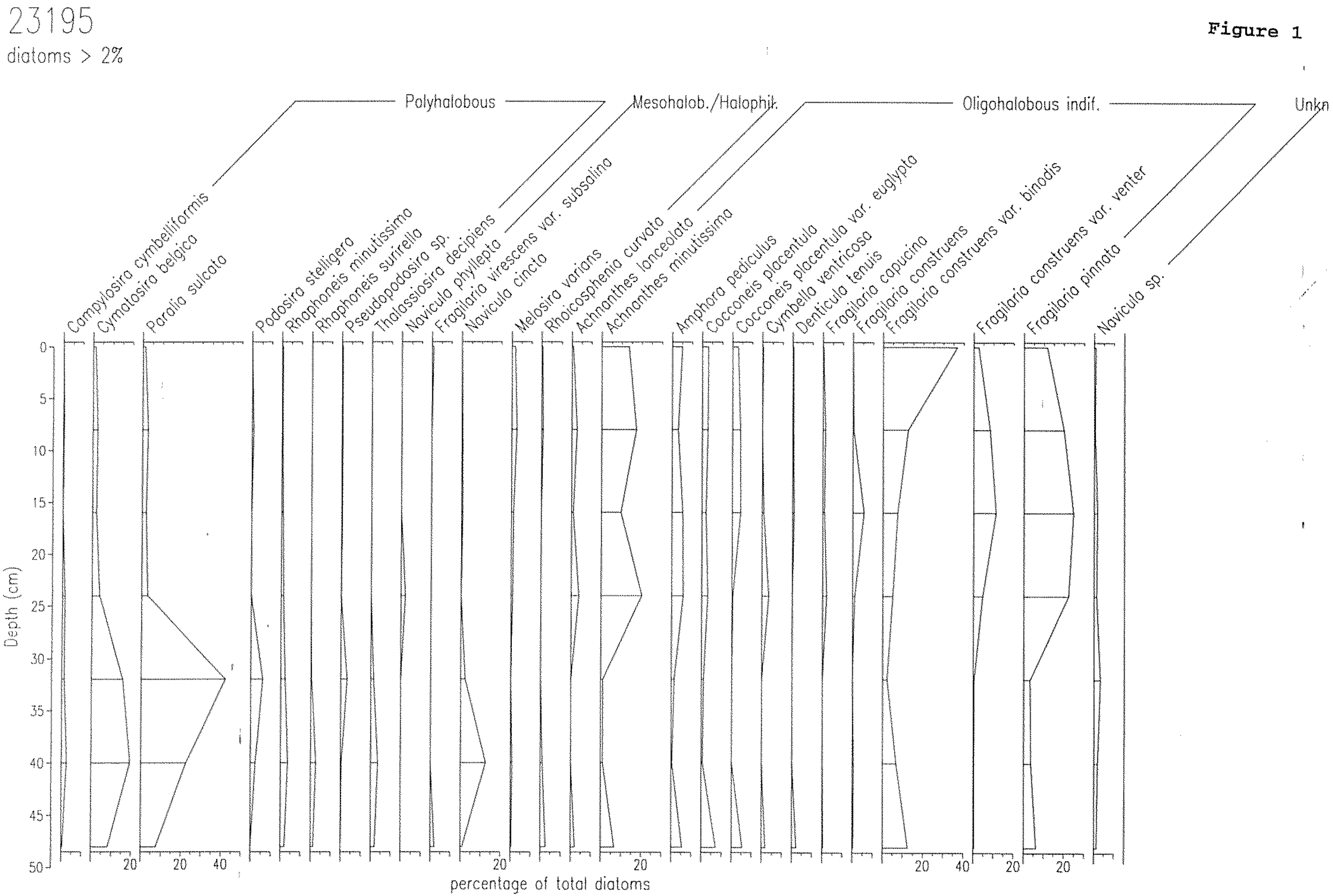
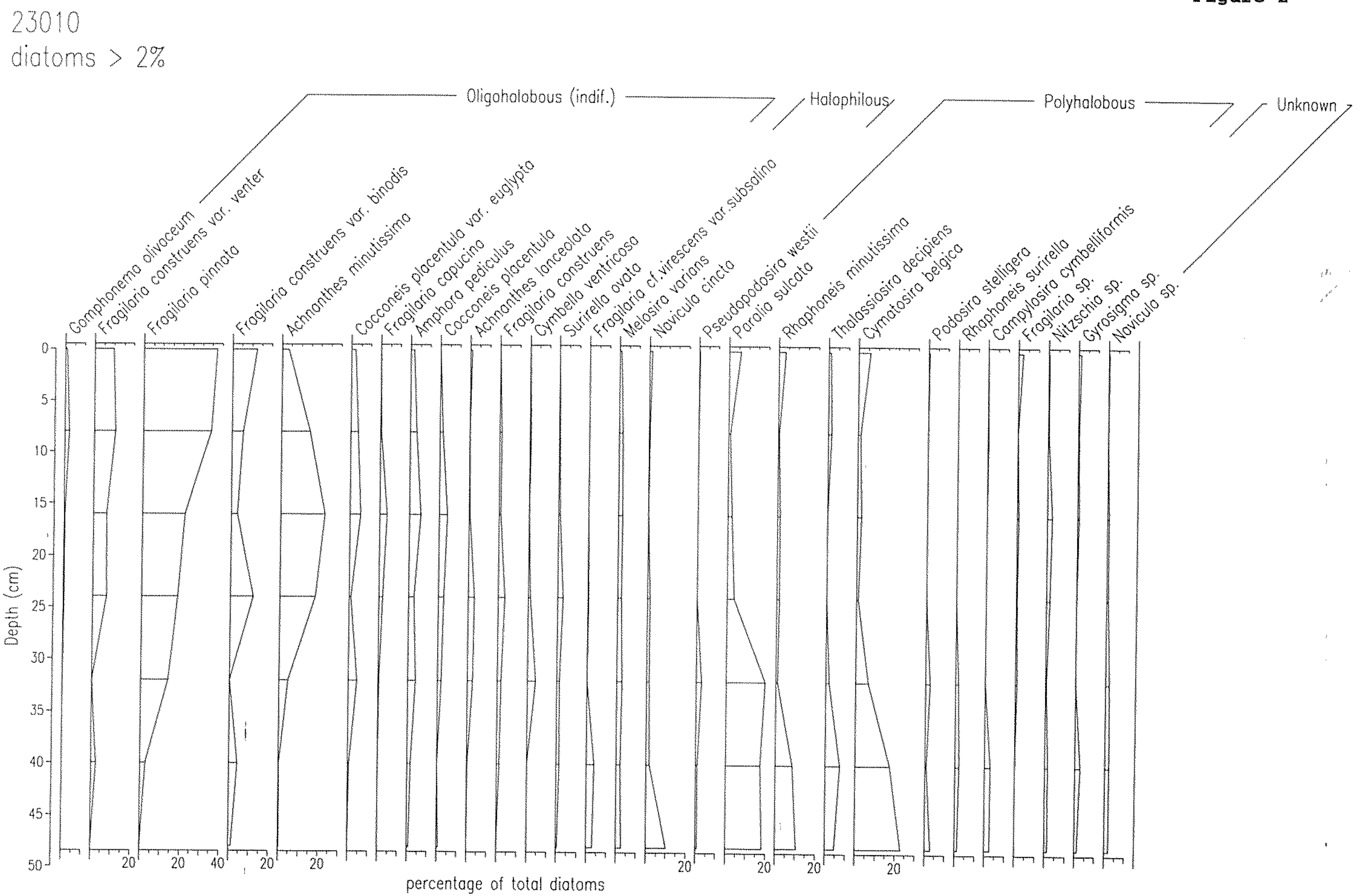

23195
diatoms > 2%
Polyhalobous
Mesohalob./Halophil.
Oligohalobous indif.
Unkn
Campylosira cymbelliformis
Cymatosira belgica
Paralia sulcata
Podosira stelligera
Rhaphoneis minutissima
Rhaphoneis surirella
Pseudopodosira sp.
Thalassiosira decipiens
Navicula phyllepta
Fragilaria virescens var. subsalina
Navicula cincta
Melosira varians
Rhoicosphenia curvata
Achnanthes lanceolata
Achnanthes minutissima
Amphora pediculus
Cocconeis placentula
Cocconeis placentula var. euglypta
Cymbella ventricosa
Denticula tenuis
Fragilaria capucina
Fragilaria construens
Fragilaria construens var. binodis
Fragilaria construens var. venter
Fragilaria pinnata
Navicula sp.
Depth (cm)
percentage of total diatoms

Figure 2



23010
diatoms > 2%
Oligohalobous (indif.)
Halophilous
Polyhalobous
Unknown
Gomphonema olivaceum
Fragilaria construens var. venter
Fragilaria pinnata
Fragilaria construens var. binodis
Achnanthes minutissima
Cocconeis placentula var. euglypta
Fragilaria capucina
Amphora pediculus
Cocconeis placentula
Achnanthes lanceolata
Fragilaria construens
Cymbella ventricosa
Surirella ovata
Fragilaria cf.virescens var.subsalina
Melosira varians
Navicula cincta
Pseudopodosira westii
Paralia sulcata
Rhaphoneis minutissima
Thalassiosira decipiens
Cymatosira belgica
Podosira stelligera
Rhaphoneis surirella
Campylosira cymbelliformis
Fragilaria sp.
Nitzschia sp.
Gyrosigma sp.
Navicula sp.
Depth (cm)
0
5
10
15
20
25
30
35
40
45
50
20
40
percentage of total diatoms

Figure 3

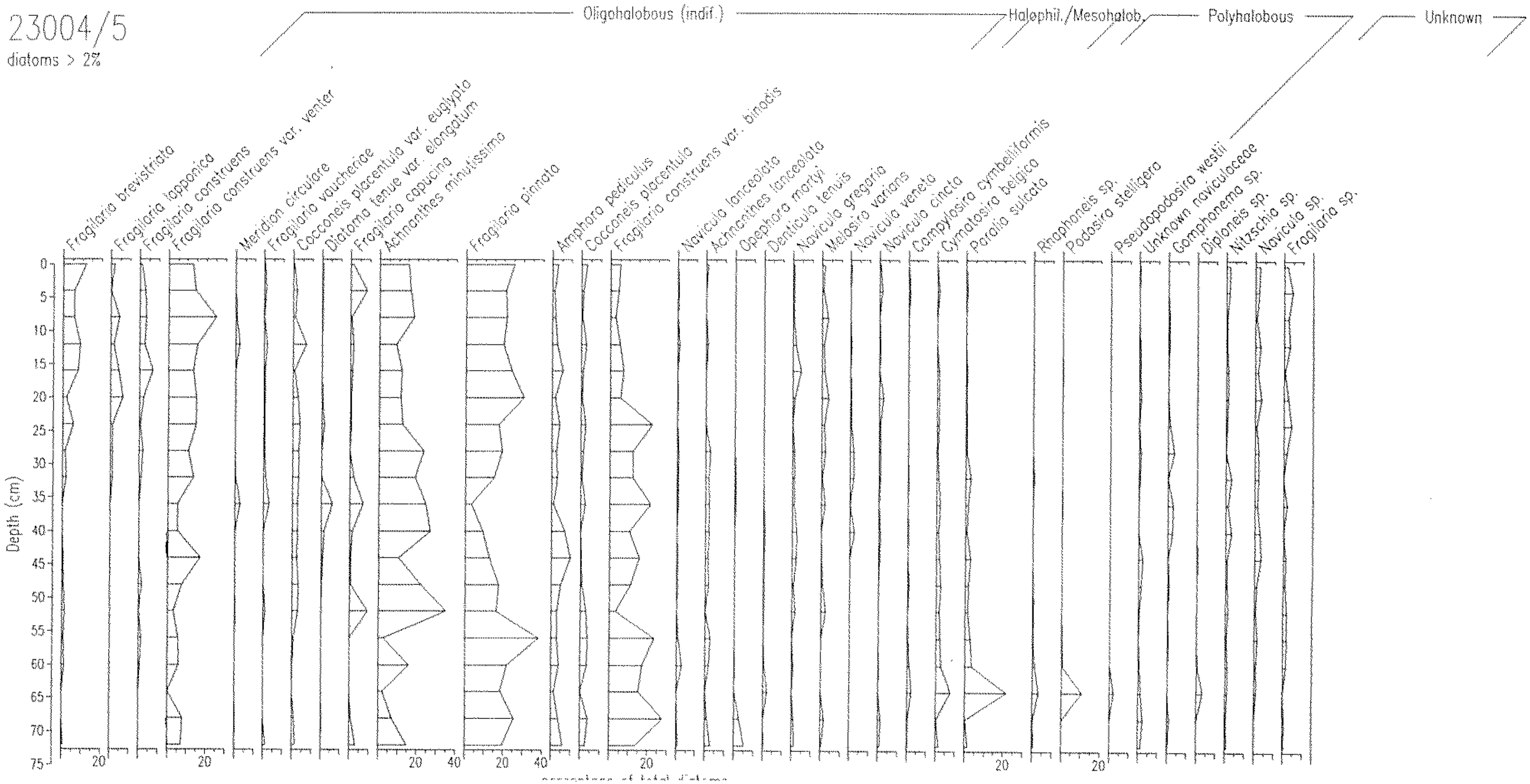

23004/5
diatoms > 2%
Oligohalobous (indif.)
Halophil./Mesohalob.
Polyhalobous
Unknown
Fragilaria brevistriata
Fragilaria lapponica
Fragilaria construens
Fragilaria construens var. venter
Meridion circulare
Fragilaria vaucheriae
Cocconeis placentula var. euglypta
Diatoma tenue var. elongatum
Fragilaria capucina
Achnanthes minutissima
Fragilaria pinnata
Amphora pediculus
Cocconeis placentula
Fragilaria construens var. binodis
Navicula lanceolata
Achnanthes lanceolata
Opephora martyi
Denticula tenuis
Navicula gregaria
Melosira varians
Navicula veneta
Navicula cincta
Campylosira cymbelliformis
Cymatosira belgica
Paralia sulcata
Rhaphoneis sp.
Podosira stelligera
Pseudopodosira westii
Unknown naviculaceae
Gomphonema sp.
Diploneis sp.
Nitzschia sp.
Navicula sp.
Fragilaria sp.
Depth (cm)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
20
40

Figure 4

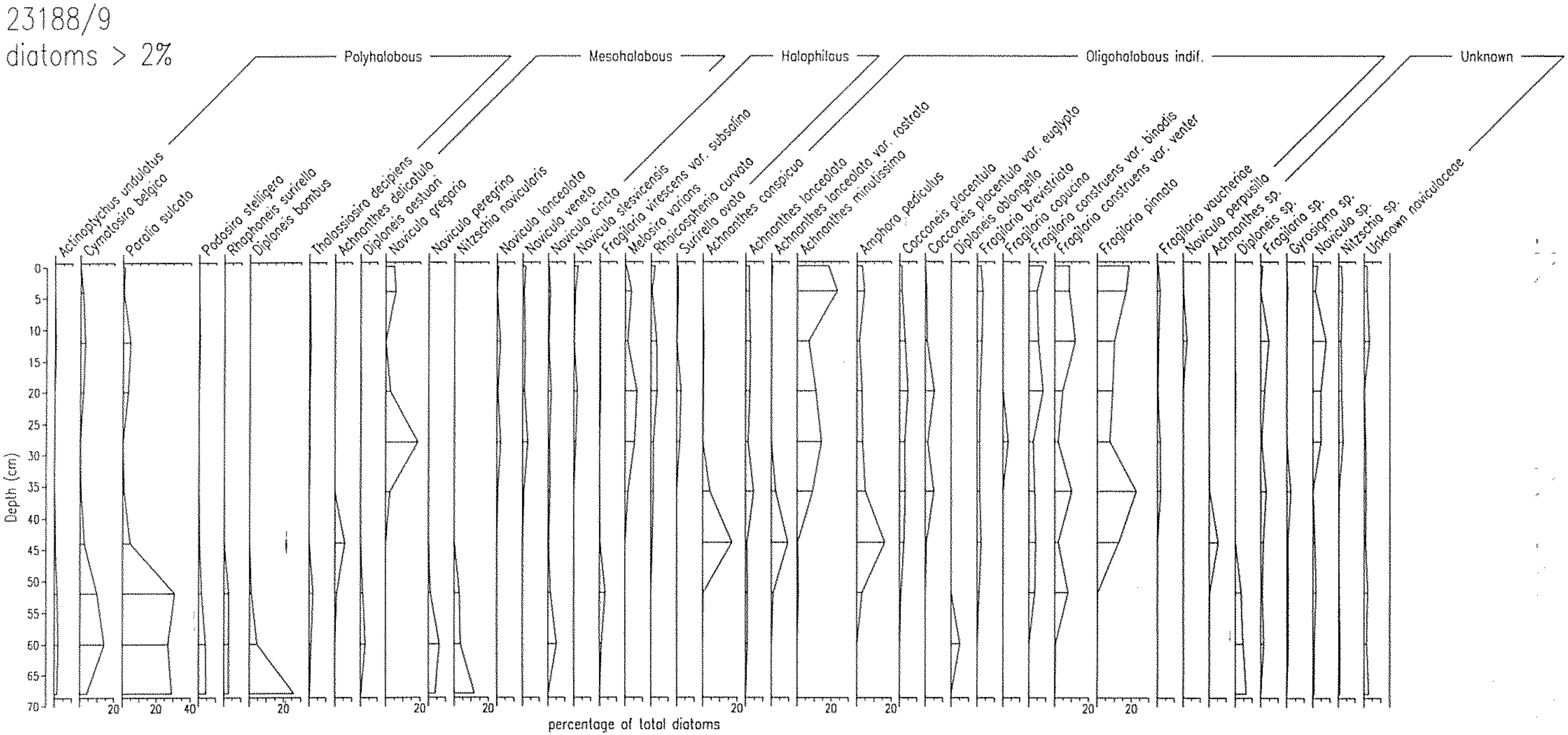

23188/9
diatoms > 2%
Polyhalobous
Mesohalobous
Halophilous
Oligohalobous indif.
Unknown
Actinoptychus undulatus
Cymatosira belgica
Paralia sulcata
Podosira stelligera
Rhaphoneis surirella
Diploneis bombus
Thalassiosira decipiens
Achnanthes delicatula
Diploneis aestuari
Navicula gregaria
Navicula peregrina
Nitzschia navicularis
Navicula lanceolata
Navicula veneta
Navicula cincta
Navicula slesvicensis
Fragilaria virescens var. subsalina
Melosira varians
Rhoicosphenia curvata
Surirella ovata
Achnanthes conspicua
Achnanthes lanceolata
Achnanthes lanceolata var. rostrata
Achnanthes minutissima
Amphora pediculus
Cocconeis placentula
Cocconeis placentula var. euglypta
Diploneis oblongella
Fragilaria brevistriata
Fragilaria capucina
Fragilaria construens var. binodis
Fragilaria construens var. venter
Fragilaria pinnata
Fragilaria vaucheriae
Navicula perpusilla
Achnanthes sp.
Diploneis sp.
Fragilaria sp.
Gyrosigma sp.
Navicula sp.
Nitzschia sp.
Unknown naviculaceae
Depth (cm)
percentage of total diatoms

Figure 5

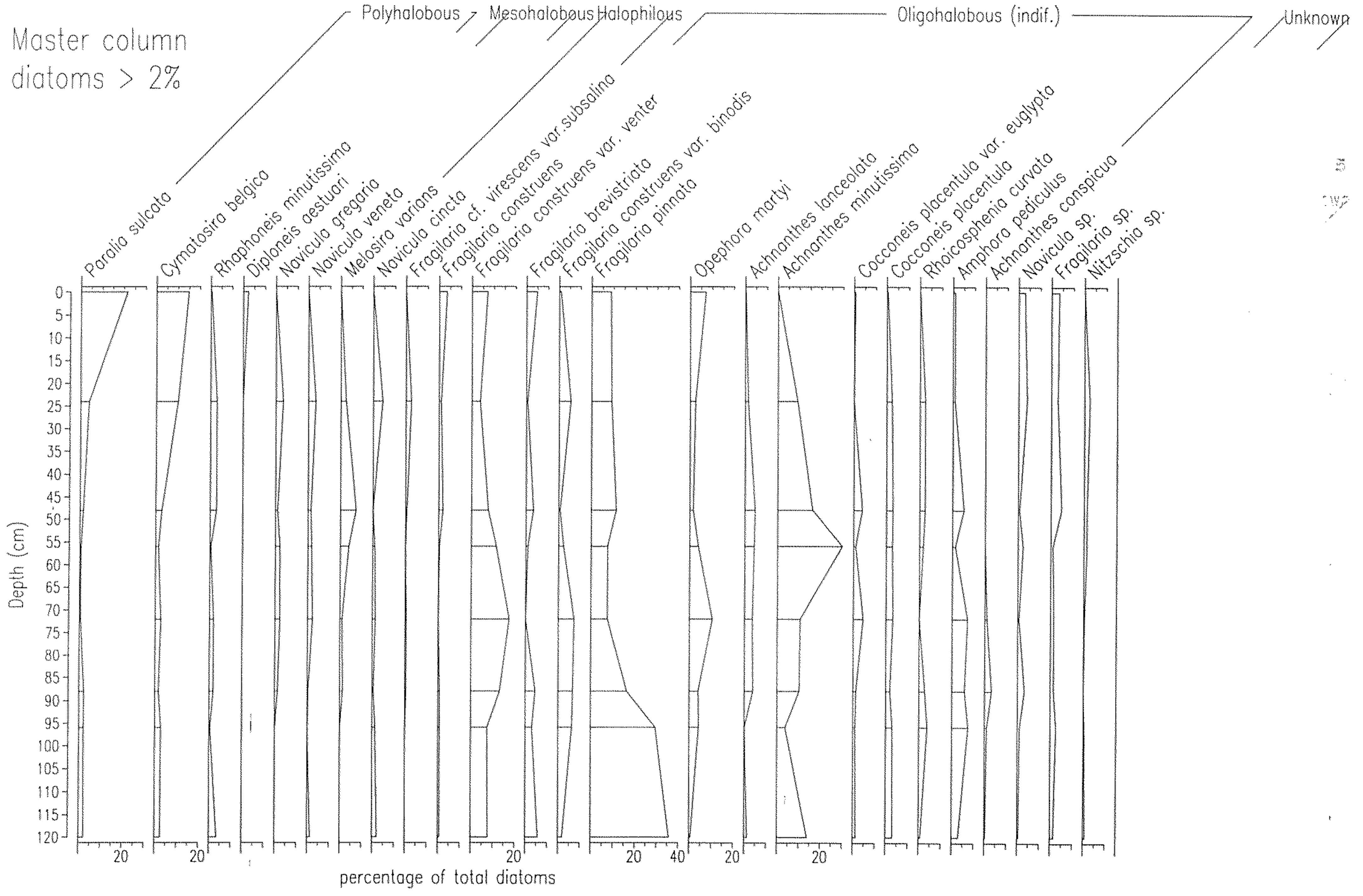
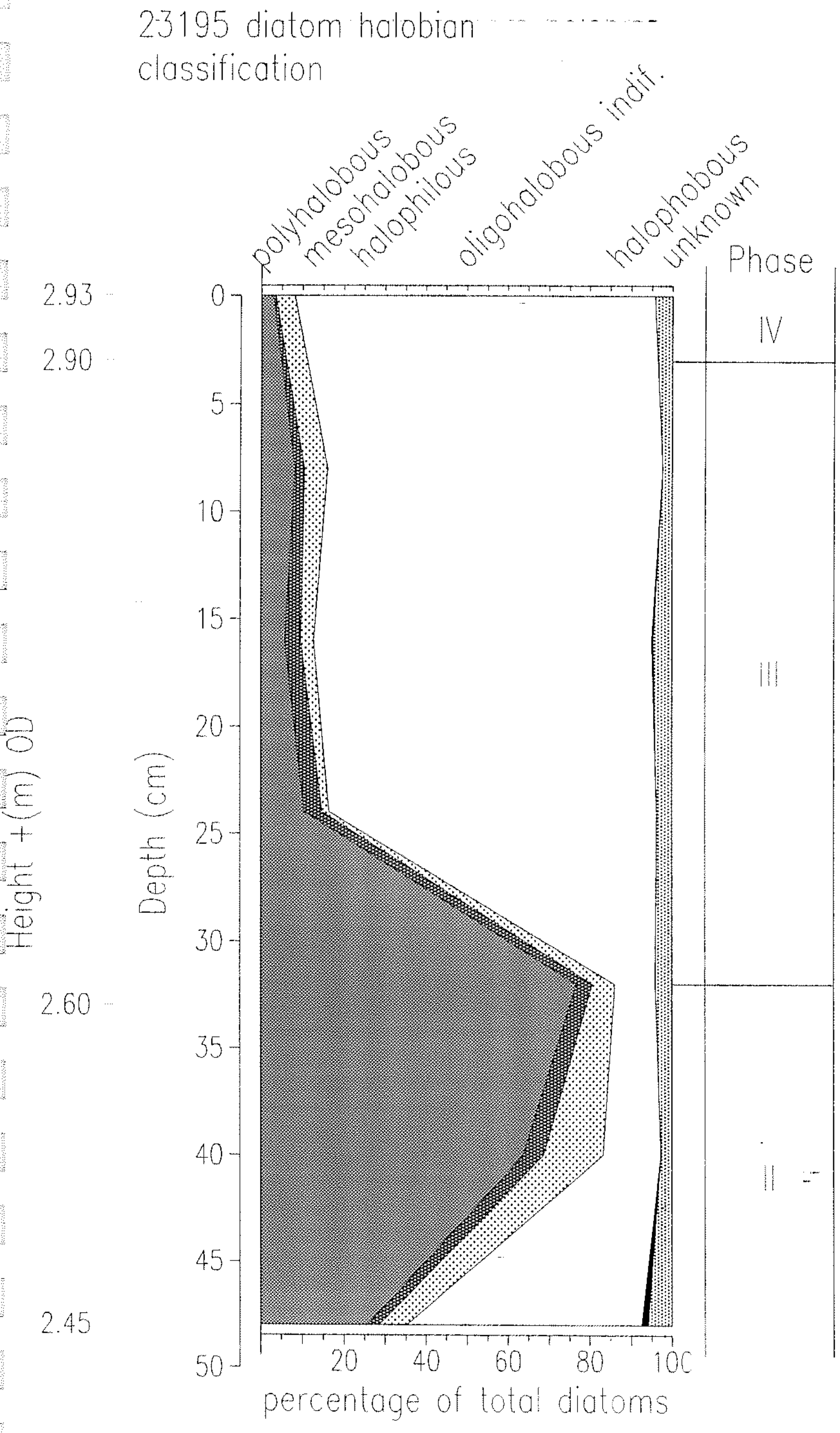

Master column
diatoms > 2%
Polyhalobous
Mesohalobous
Halophilous
Oligohalobous (indif.)
Unknown
Paralia sulcata
Cymatosira belgica
Rhaphoneis minutissima
Diploneis aestuari
Navicula gregaria
Navicula veneta
Melosira varians
Navicula cincta
Fragilaria cf. virescens var.subsalina
Fragilaria construens
Fragilaria construens var. venter
Fragilaria brevistriata
Fragilaria construens var. binodis
Fragilaria pinnata
Opephora martyi
Achnanthes lanceolata
Achnanthes minutissima
Cocconeis placentula var. euglypta
Cocconeis placentula
Rhoicosphenia curvata
Amphora pediculus
Achnanthes conspicua
Navicula sp.
Fragilaria sp.
Nitzschia sp.
Depth (cm)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
20
20
20
20
40
20
20
percentage of total diatoms

Figure 6



23195 diatom halobian
classification
polyhalobous
mesohalobous
halophilous
oligohalobous indif.
halophobous
unknown
Phase
IV
III
II
2.93
2.90
2.60
2.45
Height +(m) OD
Depth (cm)
0
5
10
15
20
25
30
35
40
45
50
20
40
60
80
100
percentage of total diatoms

Figure 7

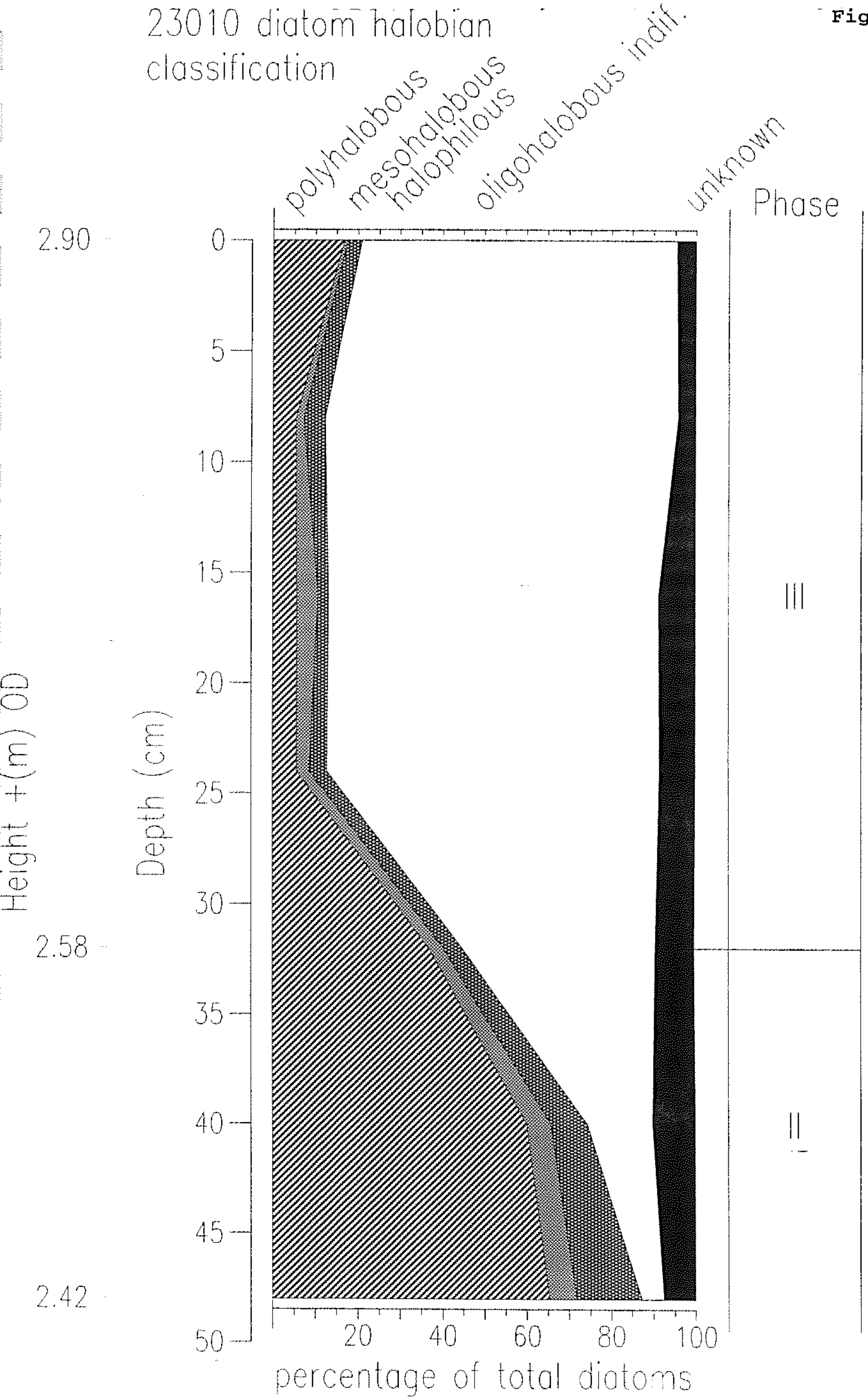

23010 diatom halobian classification
polyhalobous
mesohalobous
halophilous
oligohalobous indif.
unknown
Phase
2.90
2.58
2.42
Height +(m) OD
Depth (cm)
0
5
10
15
20
25
30
35
40
45
50
III
II
20
40
60
80
100
percentage of total diatoms

Figure 8

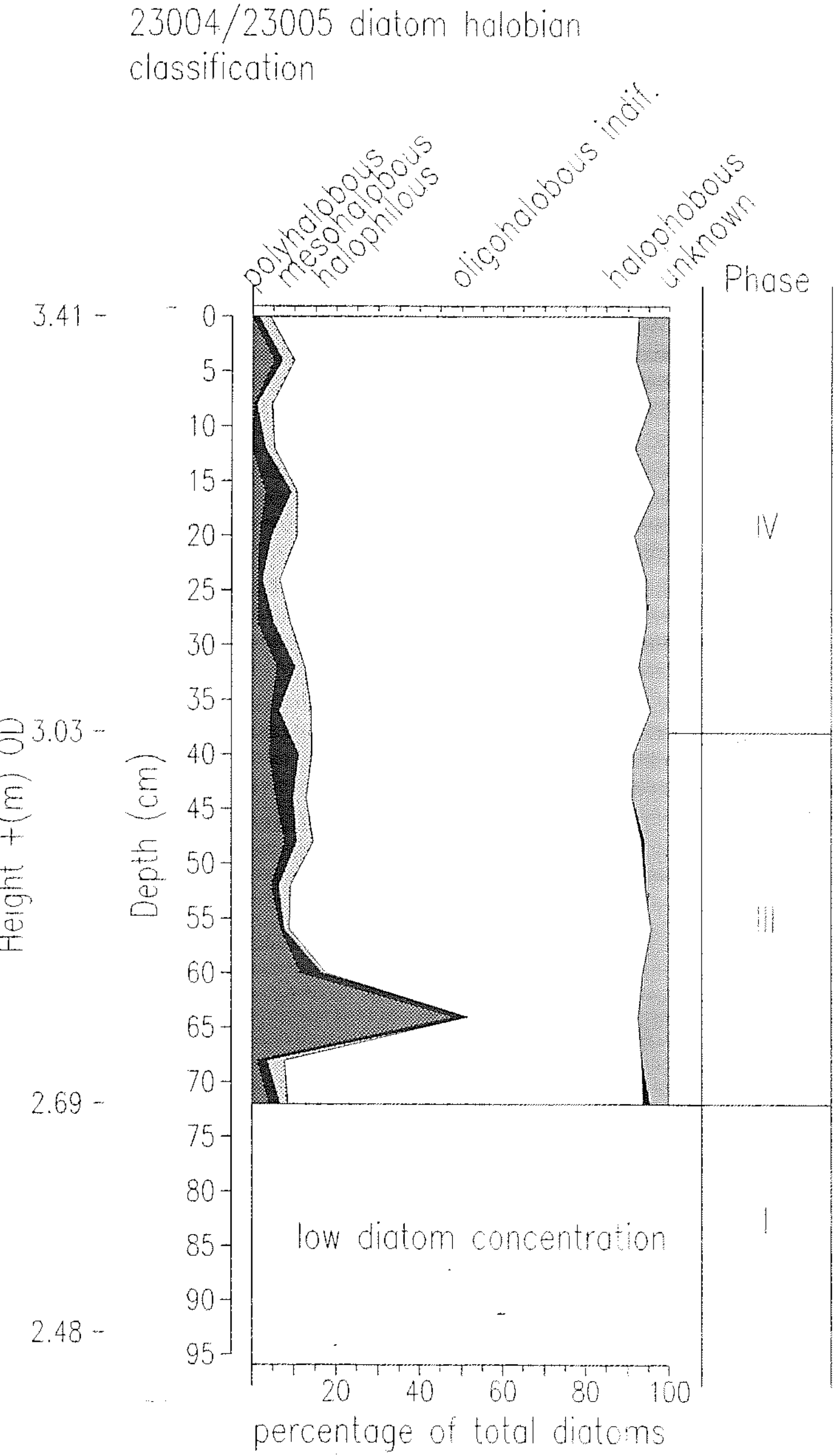

23004/23005 diatom halobian classification
polyhalobous
mesohalobous
halophilous
oligohalobous indif.
halophobous
unknown
Phase
IV
III
I
Height +(m) OD
3.41
3.03
2.69
2.48
Depth (cm)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
low diatom concentration
20
40
60
80
100
percentage of total diatoms

Figure 9

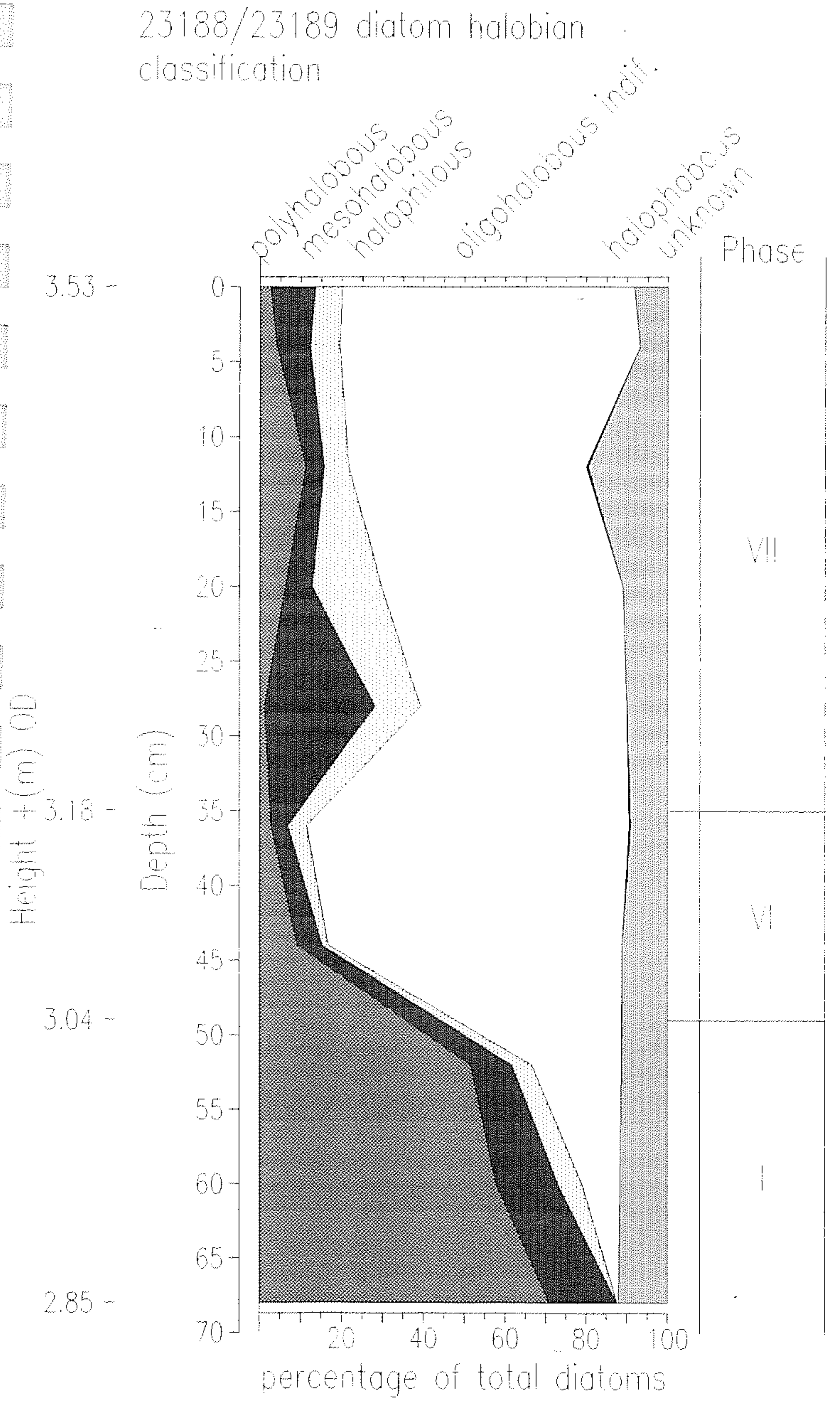

23188/23189 diatom halobian classification
polyhalobous
mesohalobous
halophilous
oligohalobous indif.
halophobous
unknown
Phase
VII
VI
I
3.53
3.18
3.04
2.85
Height +(m) OD
Depth (cm)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
20
40
60
80
100
percentage of total diatoms

Figure 10

Master column diatom halobian classification
polyhalobous
mesohalobous
halophilous
oligohalobous indif.
unknown
Phase
VIII
VII
VI/VII
V
I
low diatom concentration
Height + (m) OD
Depth (cm)
3.84
3.73
3.12
2.91
2.62
2.40
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
125
130
135
140
145
20
40
60
80
100
percentage of total diatoms