Research Papers

No. 24

PALAEOECOLOGICAL EVALUATION OF THE RECENT ACIDIFICATION OF WELSH LAKES

8. Eiddew Bach, Gwynedd

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Summary

i) Core studies of diatoms, pollen, chemistry, carbonaceous particles and magnetics together with a land use study have been conducted at Eiddew Bach, Gwynedd. An upland oligotrophic lake situated on the west side of the Rhinog plateau.

ii) The ^{210}Pb inventory is very low and there is evidence that sediment from the last two decades or so is missing from the top of the core. The top 2 - 3 cm represent sediment accumulated between the 1950's and 1960's.

iii) The diatom based pH reconstructions suggest that the pH of Eiddew Bach was 6.7 - 6.9 throughout the basal 10 cm of analysed sediment. From 8 cm a number of acidophilous taxa and undesignated *Navicula* species appear and increase in abundance, including *Navicula heimansii*, *N. meidocris*, *N. indifferens*, *N. tenuicephala* and *Navicula madumensis*. From 2 cm the most marked change occurs indicating incipient acidification as the planktonic *Cyclotella kutzinghiana* and the alkaliphilous *Fragilaria construens* var *venter* decline and acidophilous taxa like *Navicula hassica* increase.

iv) The core chemistry record demonstrates that trace metal contamination by lead and zinc of the lake sediments began at 7.5 cm.

v) The contamination of the sediments by carbonaceous particles commences at 9 cm. The concentration of these particles increase rapidly from 3 cm. A similar trend is shown by the magnetic data.

vi) The recent portion of the pollen diagram indicates that little change has occurred in the catchment vegetation over the last 150 years. The pollen diagram also reveals a major hiatus in the core at 20 cm below which sediments dating to approximately the elm decline 'ca. 5000 B.P.' occur.

vii) No appreciable land use change has occurred within the catchment. While sheep numbers have increased in the area in recent years the documentary evidence is not precise enough to assess whether the catchment has experienced a significant increase in grazing pressure. No liming has taken place within the catchment and burning has not been a significant management practice.

viii) Since recent sediment is missing from the top of the core it is not possible to present a complete picture of changing pH through time. However, a substantial acidification of the lake has occurred over the last 50 years or so. High concentrations of carbonaceous particles in lakes have only occurred since the 1930's. On this basis the uppermost 2 cm of the core clearly postdates 1930 and contains a diatom assemblage indicative of pH values > 6.0. Since the present pH is about 4.5 a pH decline of approximately 1.5 units must have occurred over the last few decades. Since no significant catchment changes have taken place during this period we must conclude as for other sites in the areas, that the acidification has been caused by acid deposition.

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A. Full diatom diagrams for the Eiddew Bach 2 core
B. Full pollen diagrams for the Eiddew Bach 2 core

Explanation of Abbreviations

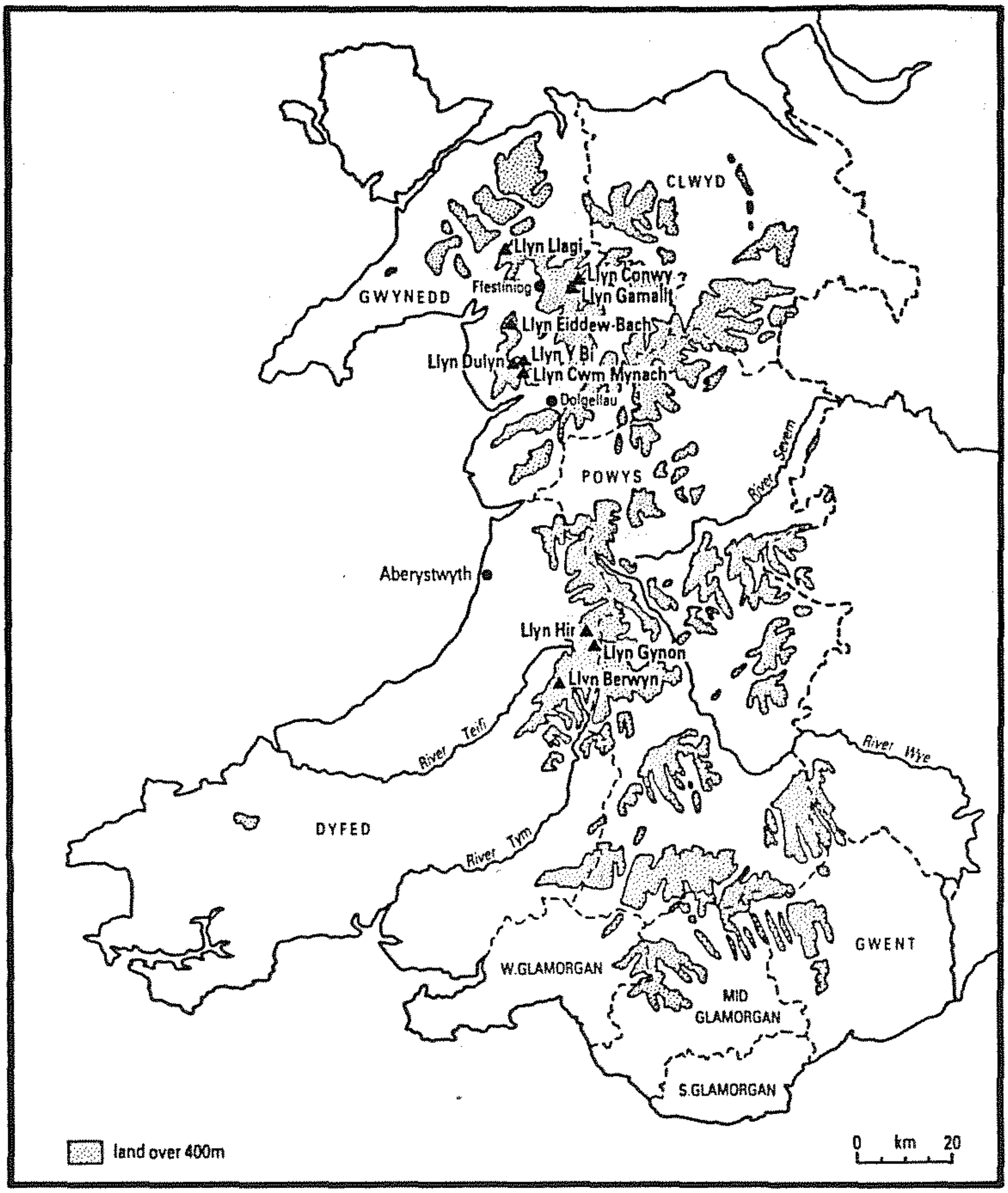
ADAS Agricultural and Development Advisory Service.
MAFF Ministry of Agriculture, Fisheries and Food.
NCC Nature Conservancy Council.
NLW National Library of Wales.
PAH Polyaromatic Hydrocarbons.
PRO Public Record Office.
WWA Welsh Water Authority.
SSSI Site of Special Scientific Interest.
UCNW University College North Wales.

1.0 Introduction

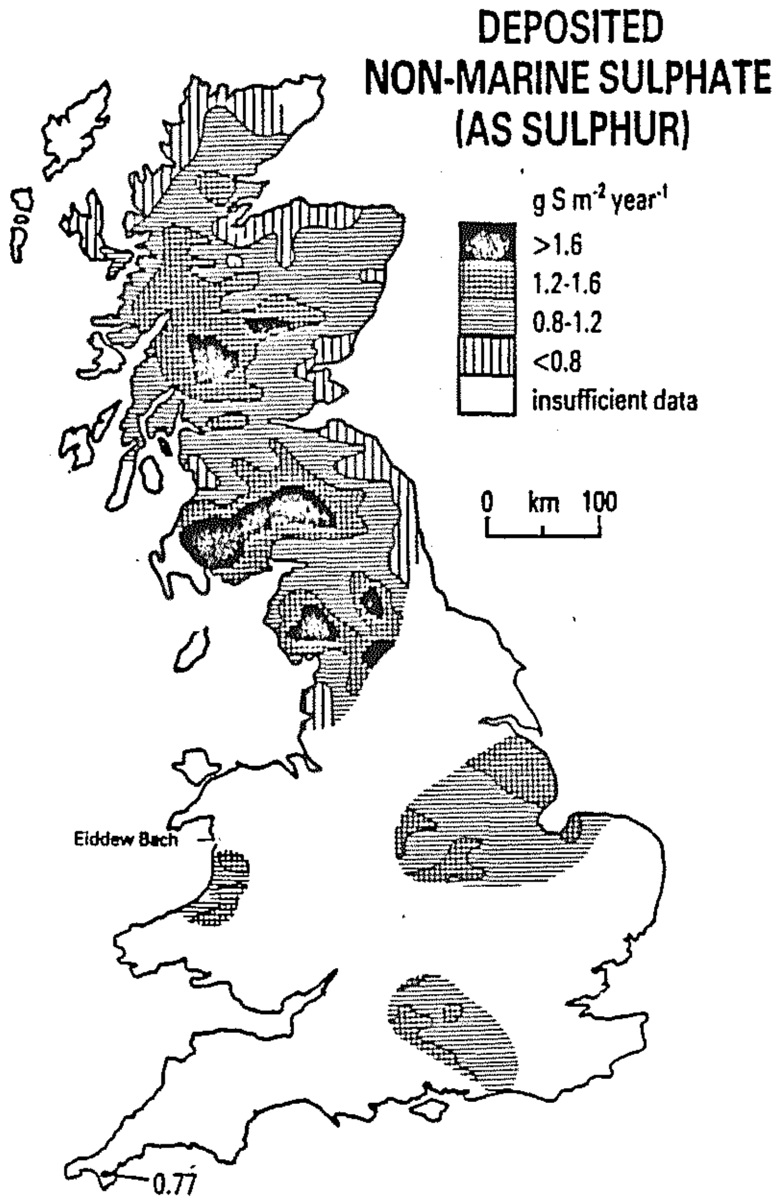
Surface water acidification is recognised as one of the most important environmental problems in Europe and North America, yet despite the pioneering work of Gorham on precipitation chemistry in Cumbria (Gorham 1958) the extent of acidification in the UK is still not known. In earlier papers (Flower and Battarbee 1983, Battarbee et al. 1985, Jones et al. 1986, Flower et al. 1987) we established that lakes on granitic rocks in Galloway, South West Scotland, were strongly acidified and that the most likely cause of the acidification was acid deposition. We have now extended our enquiry to acid lakes in Wales and other parts of Scotland to test the general hypothesis that clearwater lakes with pH values less than 5.5, occurring within areas of high acid deposition, are acidified due to an increase in acid deposition over recent decades.

Eiddew Bach located on the west side of the Rhinog plateau, Gwynedd, was the fifth site (Fig. 1) to be chosen in Wales. While there are no site records of acid deposition, records from nearby Aberystwyth reveal that the mean pH of precipitation is ca. 4.5 and the annual wet sulphate loading is 1.2 - 1.6 g m^{-2} yr^{-1} (Figs. 2 & 3). The catchment is largely undisturbed, comprising upland moorland and rough grazing for sheep. Sediment cores were obtained in August 1985.

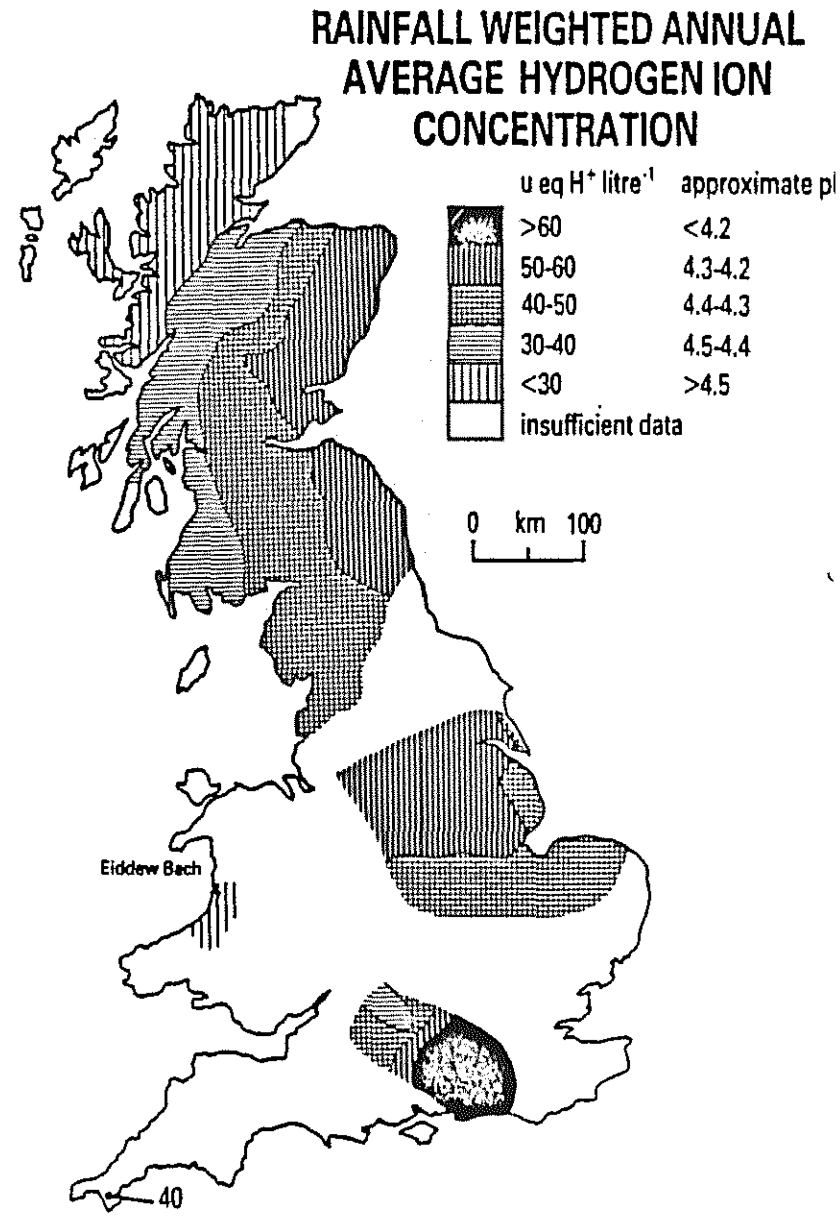
Our approach involves the use of diatom analysis to reconstruct past pH values; ^{210}Pb analysis to establish a lake sediment chronology; geochemical, magnetic and "soot" analysis to trace the history of atmospheric contamination; and pollen analysis and land-use history studies to evaluate the influence of catchment changes on the past ecology of the lake.



1. Eiddew Bach location map



3. Average annual deposition of non-marine sulphate for the U.K. (Redrawn from Barrett et al 1983)



2. Average annual rainfall weighted hydrogen ion concentration deposition for the U.K. (Redrawn from Barrett et al 1983)

2.0 Site details

2.1 Lake

The lake lies at an altitude of 380 m in an area which receives a rainfall of 2000 mm yr^{-1}. It is an narrow body of water (surface area 13,771 km^2), which drains a small catchment of 109,396 m^2. The detailed bathymetry (Fig. 4) reveals that it is composed of two, 8 m deep, sub-basins surrounded by an extensive shallow shelf. The drainage network is poorly formed and no distinct inflows exist. Most of the water movement is by groundwater and surface flow especially in 2 or 3 areas of very wet flushes dominated by *Eriophorum vaginatum**.

Table 1 Lake characteristics

Area	13771	m^2
Volume	37990	m^3
Maximum depth	8.7	m
Mean depth	2.76	m

2.1.1 Water chemistry

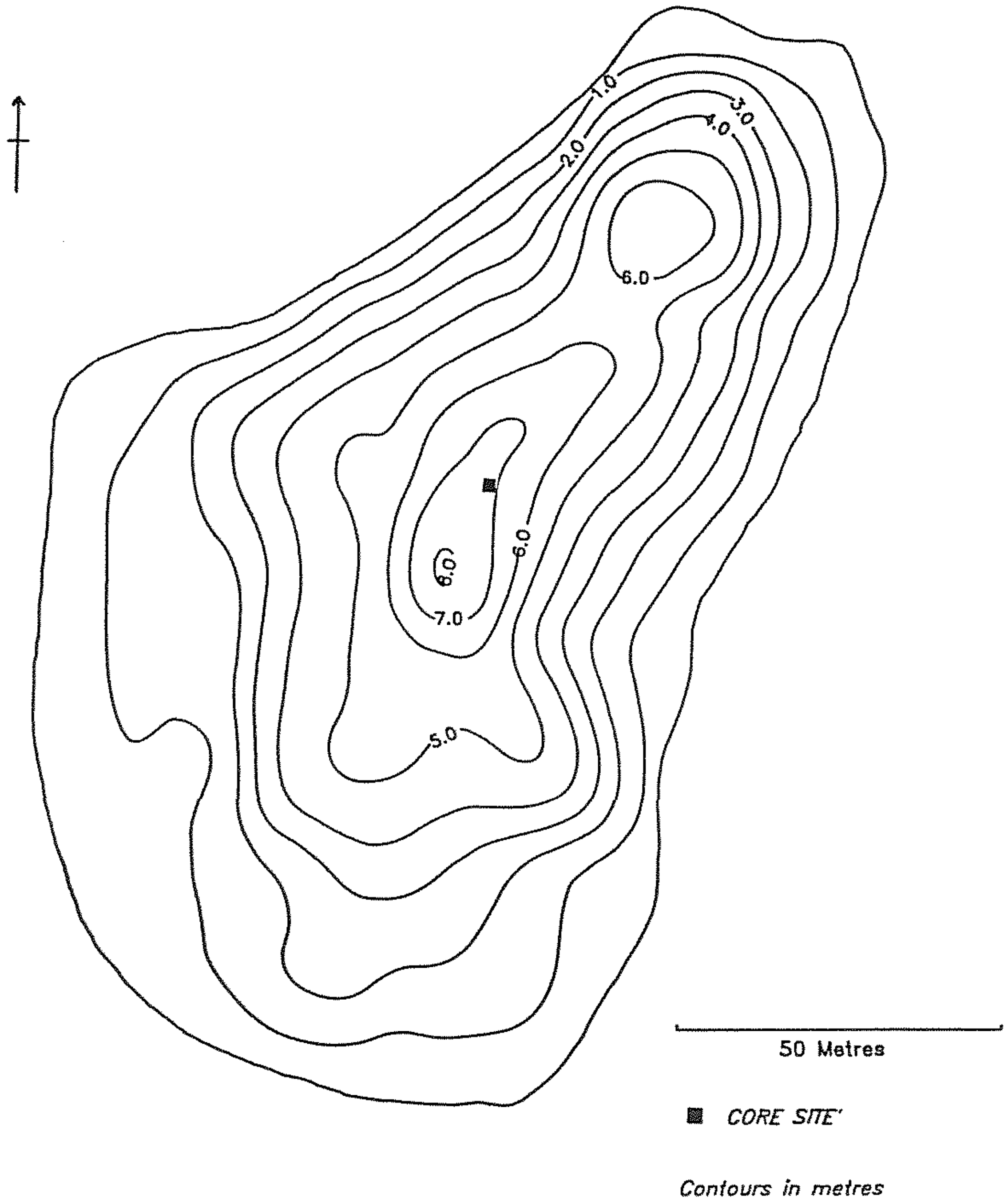
Quarterly records of water chemistry (Table 2) from January 1984 until March 1985 reveal that mean pH has been 4.82 with associated low levels of calcium (Table 2). High aluminium levels of 0.11 mg l^{-1} were recorded on 23/4/86.

2.1.2 Lake vegetation

Littoral plants in Eiddew Bach were mapped from the shore on the 30th May and seven sublittoral Ekman grab samples were taken on the 21st August 1985 (Fig. 5).

Rushes, *Juncus effusus* in particular, dominate the peaty margins of the western shore. Here the peat is undercut, forming a 0.5m underwater cliff. By contrast the eastern shore comprises large boulders, largely devoid of plantlife. Filamentous algae were abundant during the August visit but apart from extensive stands of *Lobelia dortmanna* on the western side, aquatic macrophytes are scarce (Fig. 5, Table 3). *Sphagnum* moss which is abundant in the surrounding mire systems occasionally encroaches into the water.

*Nomenclature follows Tutin et al. 1964-1980.



4. Bathymetry and coring locations for Eiddew Bach

Table 2 Water chemistry for Llyn Eiddew Bach

Date	pH	Total Oxidised Nitrogen $mg\ l^{-1}$	Total Alkalinity $mg\ l^{-1}$	Chloride $mg\ l^{-1}$	Dissolved Silicate $mg\ l^{-1}$	Dissolved Sulphate $mg\ l^{-1}$	Dissolved Sodium $mg\ l^{-1}$
11/06/84	4.3	0.18	1.0	14.0	0.300	6.0	6.3
11/12/84	5.0	0.20	1.0	9.0	0.428	5.0	4.6
06/02/85	4.6	0.10	2.1	6.4	0.100	4.62	-
06/02/85	4.8	0.10	2.0	8.6	0.100	4.35	-
14/03/85	5.4	0.30	-	7.0	---	--	-
23/04/86	4.9	0.12	1.4	8.0	0.230	--	3.9
27/11/86	4.7	0.20	0.6	6.0	0.200	3.55	3.5

Date	Dissolved Potassium	Dissolved Calcium	Dissolved Magnesium	Dissolved Zinc $mg\ l^{-1}$	Dissolved Copper	Dissolved Lead	Dissolved Manganese	Dissolved Iron
11/06/84	1.0	1.60	0.89	0.052	0.005	0.01	0.14	0.02
11/12/84	1.0	1.04	0.68	0.028	0.005	--	0.17	0.02
06/02/85	-	--	--	0.170	---	--	--	--
06/02/85	-	--	--	0.140	---	--	--	--
14/03/85	-	--	--	---	---	--	--	--
23/04/86	0.4	0.50	0.64	0.023	---	--	0.12	0.04
27/11/86	0.18	0.78	0.57	0.014	---	--	0.11	0.01

Date	Conductivity us	Labile Aluminium $mg\ l^{-1}$	Dissolved Organic Carbon $mg\ l^{-1}$ C
23/04/86	42	0.11	
27/11/86	40	0.09	1.2

Table 3: The fringing and aquatic vegetation of Eiddew Bach, August 1985
(A= abundant; lf= locally frequent; r=rare)

i) Marsh fringes (west side)
Juncus acutifloris (lf); J. articulatus (lf); J. effusus (A); Menyanthes trifoliata (r); Sphagnum spp (A).

ii) Littoral zone
Liverworts including Jungermannia spp (r); filamentous algae (lf); Sphagnum (r); Littorella uniflora (r); Lobelia dortmanna (lf); Juncus bulbosus var. fluitans (r).

iii) Sublittoral Ekman grab samples (site; depth; substrate; plants)
1. 2.5m; mud; Lobelia (A), Isoetes lacustris (r).
2. 1.5m; rock; -----
3. 2.0m; rock; -----
4. 1.5m; mud ; Lobelia (r), Isoetes (A).
5. 2.5m; mud ; Isoetes (A).
6. 1.5m; rock; -----
7. 1.0m; rock; -----

2.1.3 Fishing history

Little is known of the contemporary fishery status of Llyn Eiddew Bach (R. Hemsworth pers. comm.). It is small lake and rarely fished.

Cliffe (1860) described the trout in Llyn Eiddew Bach as being much larger (0.5 lbs upwards) than those in the adjacent Llyn Eiddew Mawr. However, owing to its limited extent the lake was not considered much of a fishery.

Ward (1931) reported that the fishing in Llyn Eiddew Bach belonged to Lord Harlech but that it was free. The trout were of 'fine quality'.

2.2 Catchment

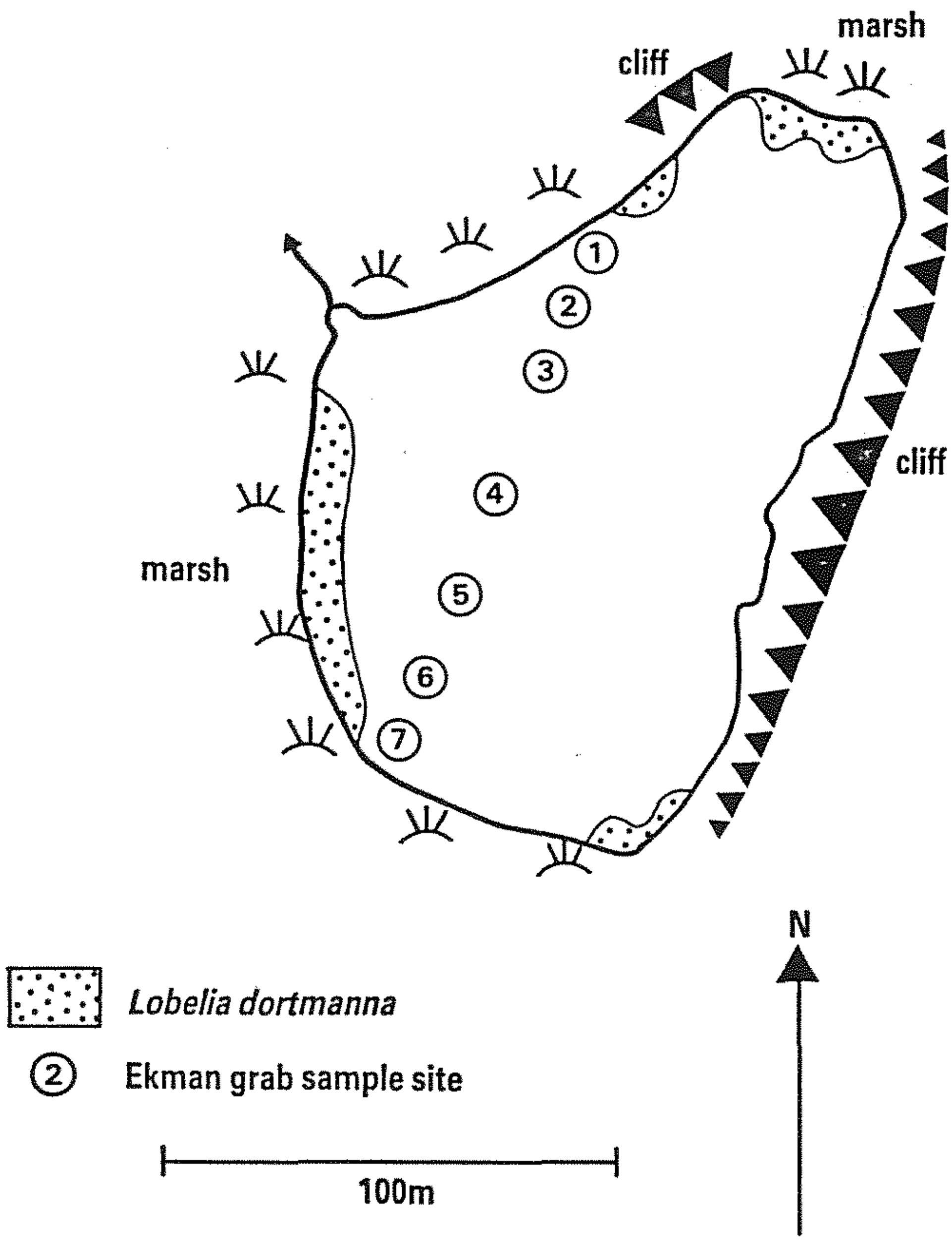
Eiddew Bach has a small catchment (123,167 m²) and relatively small catchment:lake ratio (7.9).

Table 4 Catchment characteristics

Total catchment area	123,167 m²
Area of land in catchment	109,396 m²
Area of lake	13,771 m²
Catchment/lake ratio	7.9
Maximum relief	20 m

2.2.1 Geology

Solid geology dominates the catchment and drift deposits are only found in the northeast of the site. Greywackes of the Rhinog formation of the Harlech grits predominate, while to the southwest fine grained grey siltstones of the Hafotty formation of the Harlech Grits are common. Igneous intrusions also exist and follow easterly running fault lines (Allen & Jackson 1985).



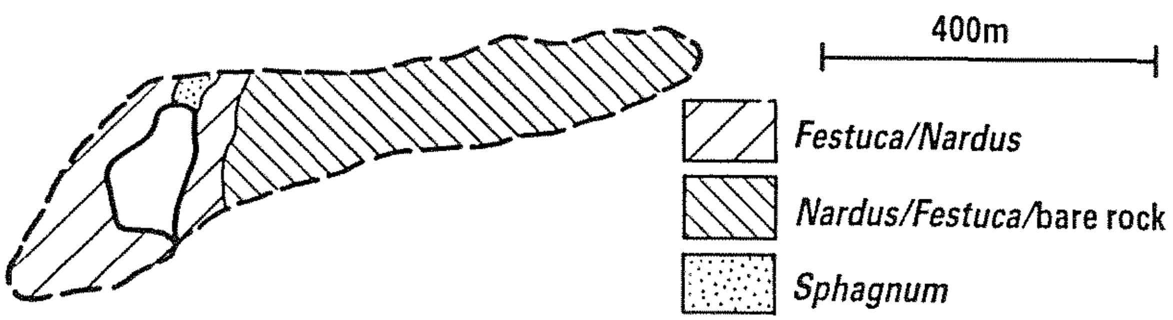
5. Lake vegetation for Eiddew Bach

2.2.2 Soils

Acid humic rankers belonging to the Revidge association (311a) dominate the catchment soils (Rudeforth *et al*. 1984).

2.2.4 Present Vegetation

Most of the catchment is characterised by *Nardus*/*Festuca* acid grassland with areas of bare rock to the east and *Festuca*/*Nardus* to the west. Small amounts of *Eriophorum*/*Sphagnum* occur around the incipient drainage channel to the north (Fig. 6).



6. The catchment vegetation of Eiddew Bach

3.0 Methods

3.1.1. Surveying

The lake was surveyed using the techniques described in Stevenson et al. (1987). Shore surveying stations were located on opposite shores at the narrowest section of the lake.

3.1.2. Collection of sediment cores and routine laboratory measurements of sediment characteristics

Cores were taken using a wide diameter piston corer operated from an inflatable boat. Sampling was carried out during August 1985.

Core Eiddew Bach 2, EIB 2, (131 cm) was extruded in the laboratory. The top 20 cm of sediment was sampled at 1/2 cm intervals and the remaining core sampled at 1 cm intervals. Subsamples were then taken for dry weight, loss on ignition (at 550°C) and wet density measurements.

Analyses for dating, magnetics, chemistry, soot, diatoms & pollen were all conducted according to the standard methods set out in Stevenson et al. (1987).

4.0 Results

4.1 Lake history

4.1.1. Sediment Description

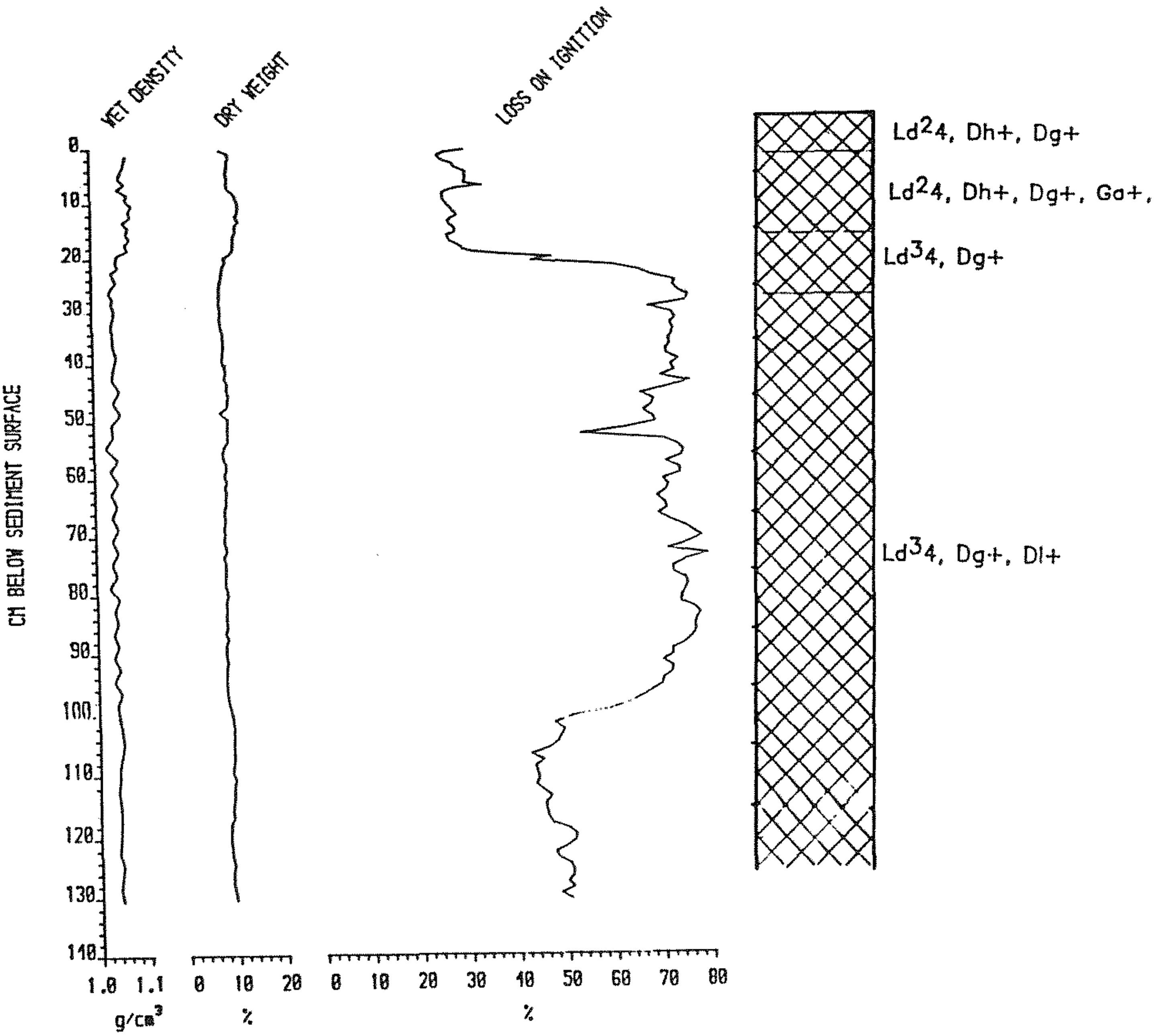
Fig. 7 shows the loss on ignition, wet density and dry weight profiles for the EIB 2 core. It can be immediately seen that the core can be divided into two main sections at 21 cm. From 131 cm to 21 cm the core consists of a highly organic (60%) mud with occasional tree bark and leaves ($Ld^3 4$, Dg+,Dl+). Throughout this section loss on ignition falls steadily while wet density and dry weight values vary little. Above 21 cm a rapid drop in the loss on ignition values is seen with increases recorded in both wet density and dry weight values. The sediment between 7 and 21 cm consists of a mid-brown organic mud with some coarse and fine detritus and fine sand ($Ld^2 4$, Dh+,Dg+,Ga+). Above 7 cm and associated with apparently stabilised low loss on ignition values (20%) the sediment consists of a very dark brown organic mud with occasional herbaceous plant fragments ($Ld^2 4$, Dh+,Dg+).

4.1.2. ^{210}Pb dating

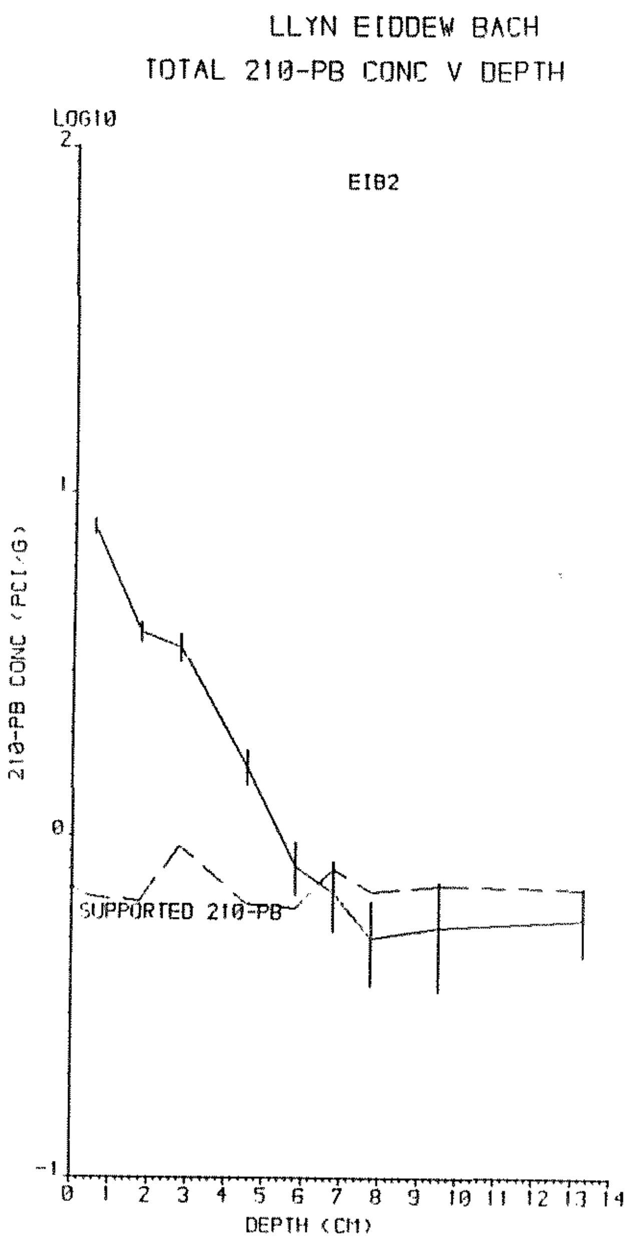
Sediments from Eiddew Bach 2 were analysed for ^{210}Pb, ^{226}Ra and ^{137}Cs by gamma spectrometry (Appleby et al. 1986). The ^{210}Pb and ^{226}Ra results are given in Table 5, and shown graphically in Figs. 8 & 9. The ^{137}Cs results are given in Table 6 and Fig. 10. Table 7 gives values of a range of other radioisotopes determined from the gamma spectra. The ^{210}Pb inventory of the core is 1.89 pCi cm^{-2}, and represents a mean ^{210}Pb flux of 0.06 pCi cm^{-2} yr^{-1}. The ^{210}Pb inventories for other nearby lakes indicate that this region may have a low atmospheric ^{210}Pb flux, due possibly to its coastal location. Nonetheless, the value for this core is so low as to cast doubt over the validity of the usual ^{210}Pb dating models. The relatively high ^{137}Cs concentration in the near surface sediments suggests that some post-1950's sediment is present. On the other hand the diatom data indicate a surface sediment hiatus and sediment loss may be the reason for the low inventory. There are no unusual changes in the ^{226}Ra or ^{40}K concentrations (Table 7) which might indicate changes in mineral type. Values of the other radioisotopes in this table are too low to give reliable information.

Fig. 11 shows the ^{210}Pb chronologies for core EIB2 given by the CRS and CIC ^{210}Pb dating models (Appleby and Oldfield 1978). Both models indicate a uniform sediment accumulation rate over the past 30 years of 0.0065 g cm^{-2} yr^{-1}. For older sediments the CRS model indicates a significantly reduced accumulation rate whereas the CIC model indicates only a slight reduction. Because of the uncertainties over the ^{210}Pb flux and the difficulty in this case of establishing the precise equilibrium depth it is probably safer to base the chronology on the CIC model although this is also probably in error if recent sediment has been lost. The CRS & CIC model chronologies are given in Table 8 & 9 respectively.

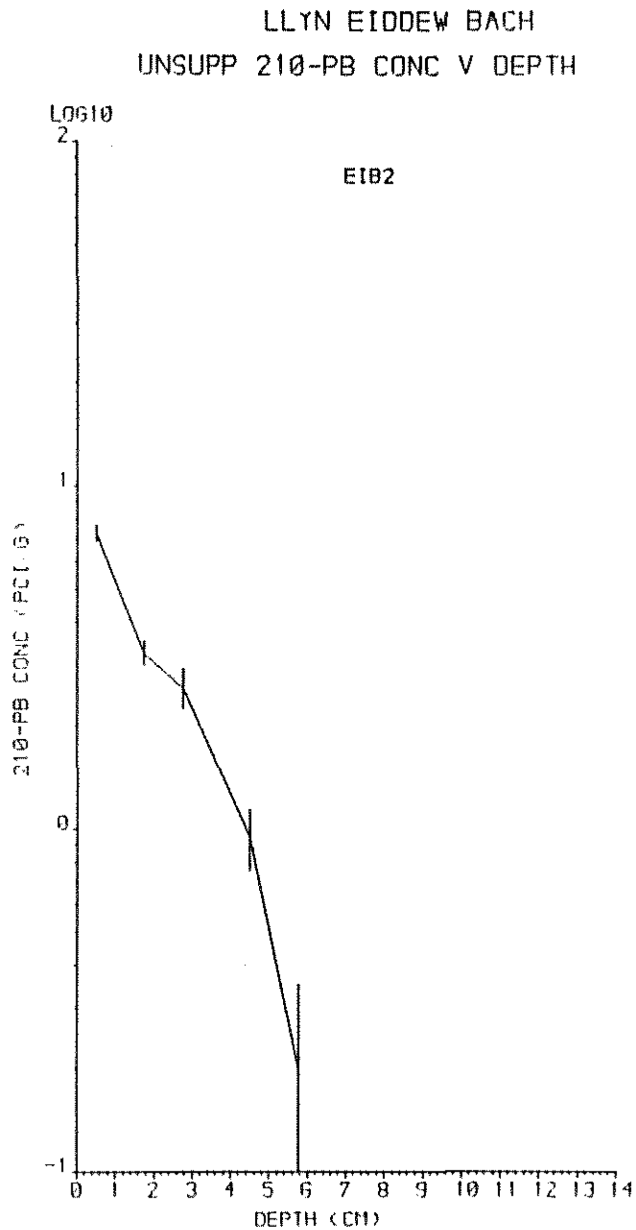
The ^{137}Cs data is of no chronological value for this core. The ^{137}Cs concentrations decline monotonically from a maximum value at the surface, and there are significant concentrations down to 13 cm, well below the ^{210}Pb equilibrium depth.



7. Profiles of variation in dry weight, wet density and loss - on - ignition for the Eiddew Bach 2 core



8. Total ^{210}Pb profile for the Eiddew Bach 2 core



9. Unsupported ^{210}Pb profile for the Eiddew Bach 2 core

Table 5. ^{210}Pb Data for Core Eiddew Bach 2.

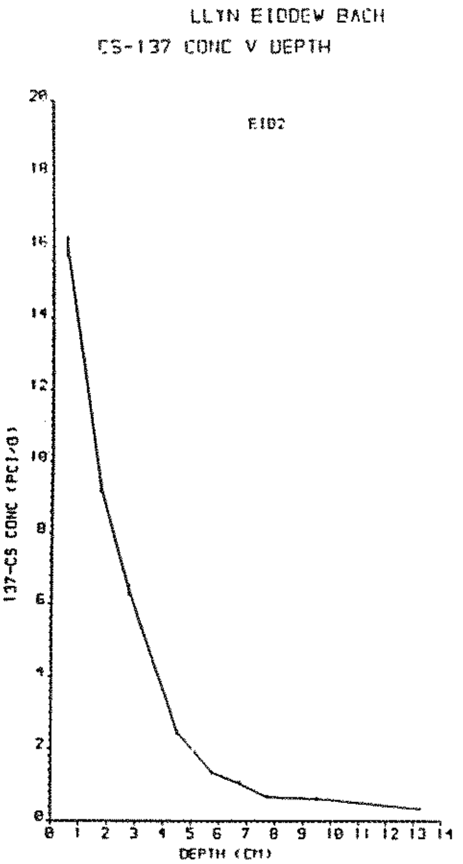
Depth	Dry Mass	^{210}Pb Concentration Total	Unsupported	Standard Errors Concent. Total	Uns.	^{226}Ra concentration	
cm	g cm^{-2}	pCi g^{-1}	pCi g^{-1}			pCi g^{-1}	+/-
0.50	0.0471	7.910	7.249	0.41	0.42	0.661	0.11
1.75	0.1801	3.900	3.256	0.26	0.27	0.644	0.08
2.75	0.2869	3.510	2.581	0.32	0.34	0.929	0.11
4.50	0.4701	1.580	0.947	0.18	0.19	0.633	0.06
5.75	0.6000	0.810	0.198	0.14	0.15	0.612	0.05
6.75	0.7046	0.680	-0.117	0.16	0.17	0.797	0.06
7.75	0.8116	0.500	-0.184	0.14	0.15	0.684	0.05
9.50	1.0251	0.540	-0.176	0.19	0.20	0.716	0.07
13.25	1.5002	0.570	-0.128	0.13	0.14	0.698	0.05

Table 6. ^{137}Cs data for Core Eiddew Bach 2

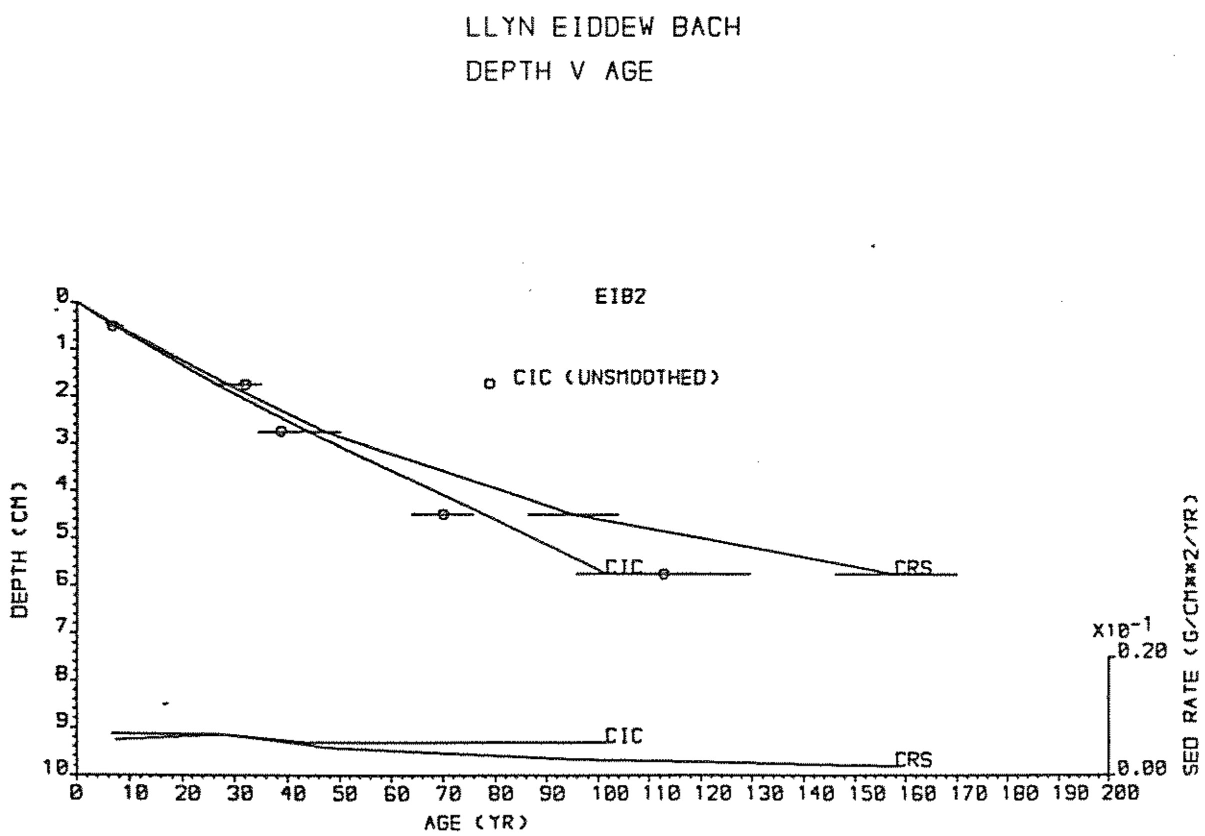
Depth	Dry Mass	^{137}Cs concentration		Cumulative ^{137}Cs		Fract
cm	g cm^{-2}	pCi g^{-1}	+/-	pCi cm^{-2}	+/-	
0.50	0.0471	15.98	0.28	0.75	0.04	0.158
1.75	0.1801	9.31	0.17	2.39	0.10	0.501
2.75	0.2869	6.41	0.17	3.22	0.11	0.675
4.50	0.4701	2.45	0.08	3.98	0.12	0.833
5.75	0.6000	1.32	0.05	4.22	0.12	0.882
6.75	0.7046	1.03	0.06	4.34	0.12	0.908
7.75	0.8116	0.66	0.04	4.43	0.12	0.926
9.50	1.0251	0.60	0.06	4.56	0.12	0.955
13.25	1.5002	0.34	0.04	4.78	0.12	1.000

Table 7. Other radioisotope data for Core Eiddew Bach 2.

Depth	^{226}Ra	^{238}U	^{230}U	^{228}Ac	^{228}Th	^{40}K
cm			pCi g^{-1}			
0.50	0.66	0.27	0.10	0.66	0.27	16.15
1.75	0.64	0.06	0.11	0.74	1.09	17.44
2.75	0.93	0.00	0.17	0.72	0.00	19.69
4.50	0.63	0.50	0.12	0.62	1.10	17.96
5.75	0.61	0.20	0.07	0.45	0.86	14.80
6.75	0.80	0.41	0.07	0.73	1.09	18.95
7.75	0.68	0.32	0.06	0.64	1.15	14.75
9.50	0.72	0.47	0.14	0.70	0.47	17.28
13.25	0.70	0.58	0.07	0.65	1.29	19.19



10. ^{137}Cs profile for the Eiddew Bach 2 core



11. CRS and CIC ^{210}Pb age/depth chronology for the Eiddew Bach 2 core

Table 8. CRS Model ^{210}Pb chronology *

Depth	Dry Mass	Cumul. Unsupp. ^{210}Pb	Chronology			Sedimentation Rate		
			Date	Age	Std. Error			Std. Error
cm	g cm^{-2}	pCi cm^{-2}	AD	Yr		g cm^{-2}	cm yr^{-1}	%
0.00	0.0000	1.89	1985	0				
0.50	0.0471	1.50	1977	8	2	0.0060	0.058	6.6
1.00	0.1003	1.15	1969	16	2	0.0063	0.060	8.2
1.50	0.1535	0.88	1961	24	2	0.0066	0.063	9.7
2.00	0.2068	0.67	1952	33	3	0.0063	0.059	10.6
2.50	0.2602	0.50	1942	43	3	0.0052	0.050	10.9
3.00	0.3131	0.35	1931	54	4	0.0044	0.042	13.3
3.50	0.3654	0.23	1917	68	6	0.0039	0.037	17.8
4.00	0.4178	0.15	1903	82	8	0.0033	0.032	22.4
4.50	0.4701	0.10	1890	95	9	0.0028	0.027	26.9
5.00	0.5221	0.04	1864	121	11	0.0023	0.022	30.0
5.50	0.5740	0.02	1839	146	12	0.0018	0.017	33.1

^{210}Pb Flux = 0.06 +/- 0.03 pCi cm^{-2}
90% Equilibrium Depth = 4.0 cm. or 0.40 g cm^{-2}
99% Equilibrium Depth = 5.7 cm. or 0.59 g cm^{-2}

Table 9. CIC Model ^{210}Pb chronology for Core Eiddew Bach 2. *

Depth	Dry Mass	Chronology			Sedimentation Rate	
		Date	Age	Std Error		
cm	g cm^{-2}	AD	Yr		g cm^{-2} yr^{-2}	cm yr^{-1}
0.00	0.0000	1985	0			
0.50	0.0471	1978	7	2	0.0069	0.067
1.00	0.1003	1970	15	3	0.0069	0.066
1.50	0.1535	1963	22	4	0.0069	0.065
2.00	0.2068	1955	30	4	0.0066	0.061
2.50	0.2602	1946	39	5	0.0059	0.057
3.00	0.3131	1937	48	5	0.0055	0.053
3.50	0.3654	1927	58	7	0.0055	0.053
4.00	0.4178	1918	67	9	0.0055	0.053
4.50	0.4701	1908	77	11	0.0055	0.053
5.00	0.5221	1899	86	13	0.0055	0.053
5.50	0.5740	1890	95	17	0.0055	0.053

90% Equilibrium Depth = 16.6 cm. or 2.75 g cm^{-2}
99% Equilibrium Depth = 31.3 cm. or 6.09 g cm^{-2}

* assumes no loss of surface sediment (see text).

4.1.3. Diatoms and pH reconstruction

Diatoms were analysed from the top 20 cm of the Eiddew Bach 2 core. The uppermost 6 cm encompasses the ^{210}Pb dated portion of the core. Fig. 12 shows the dominant diatom taxa in the core. Diagrams showing the stratigraphy of all taxa are included in Appendix A.

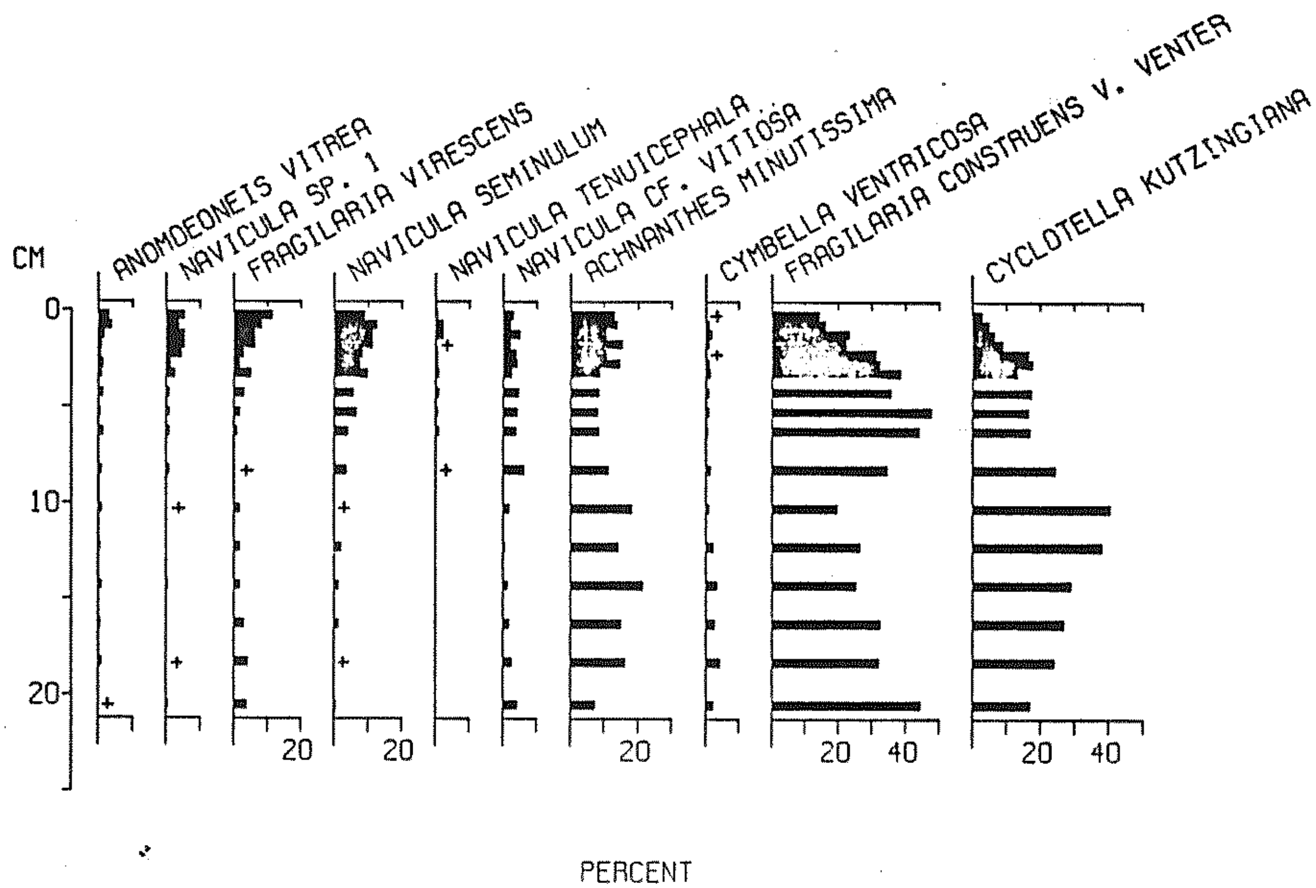
Only a small number of taxa are common (>2%) in the analysed sediments from Eiddew Bach. Except in the uppermost samples the flora is dominated by the planktonic Cyclotella kutzingiana (circumneutral) and the periphytic Fragilaria construens var. venter (alkaliphilous) and Achnanthes minutissima (circumneutral), with shifting proportions of Cyclotella kutzingiana and Achnanthes minutissima relative to Fragilaria construens var. venter. This flora is typical of oligotrophic clearwater lakes and is similar to the pre-acidification flora of Llyn Hir (Fritz et al. 1986), although percentages of Anomoeoneis vitrea, Fragilaria virescens and Melosira perglabra var. florineae are higher in the Llyn Hir sediments.

Above 8 cm a number of acidophilous and undesignated Navicula species appear and increase in abundance, including Navicula mediocris, N.madumensis, N. indifferens, N. heimansii and N. tenuicephala. The most marked changes occur in the uppermost 2 cm where Cyclotella kutzingiana and Fragilaria construens var. venter decline in relative abundance and Fragilaria virescens, Navicula sp. 1, Navicula seminulum, Navicula hassiaca and Anomoeoneis vitrea increase. The decline of the planktonic Cyclotella kutzingiana and the alkaliphilous Fragilaria construens var. venter suggests the incipient stages of acidification of Eiddew Bach (see Flower et al. 1985). This post-1950 onset of acidification at Eiddew Bach is considerably later than the correlative changes at Llyn Hir (Fritz et al. 1986), where the Cyclotella decline dates from the early 19th century.

pH reconstructions using index B-Scandinavia and index B-Galloway (Flower 1986) suggest a lakewater pH of 6.7 - 6.9 during the deposition of the basal 10 cm of analysed sediments. Between 10.0 and 2.5 cm pH values increase 0.3 units and subsequently fall, paralleling changes in the relative abundance of the alkaliphilous dominant Fragilaria construens var. venter. In the uppermost 2.5 cm pH values continue to decline 0.4 units below the pH of the basal sediments, paralleling the decline of Cyclotella kutzingiana and Fragilaria construens var. venter and the increase of several acidophilous Navicula spp. pH reconstructions using multiple regression of pH groups (Flower 1986) suggest fluctuating pH between 6.5 and 6.7, with no net change over the 20 cm sedimentary sequence.

All three pH reconstruction equations suggest a mean lakewater pH of 6.3 - 6.7 during deposition of the 0 - 0.5 cm sediment, whereas the present lake pH (Table 2) ranges from 4.3 - 5.4.

The diatom assemblage in the uppermost core sample is clearly atypical among pH 4.8 lakes, as indicated by the discrepancy between the reconstructed pH of that sample and present lakewater pH. The probable explanation for the poor fit of the pH reconstruction is that the core site is not presently accumulating sediment. This implies that the diatom assemblage at the top of the core is not a contemporary flora and hence should not reflect the current lakewater chemistry. Depositional hiatuses are clearly quite common



12. Diatom summary diagram for the Eiddew Bach 2core

in the highland lakes of Wales (Stevenson et al 1987ab, Kreiser et al 1986, Patrick & Stevenson 1987), including an earlier hiatus for Eiddew Bach at 20 cm (see section 4.1.7). Further evidence suggesting that the top most sediments are absent from the core comes from evidence of a Kajak core top which has a far more acid tolerant flora present.

The low ^{210}Pb inventory of Eiddew Bach is consistent with a contemporary hiatus in deposition, although the presence of ^{137}Cs suggests that occurs after 1954 (see section 4.1.2). and that the major period of lake acidification also occurred after this date. Data from both Llyn Gynon (Stevenson et al. 1987) and Llyn Llagi (Patrick et al. 1987) suggest that at these sites major acidification occurred quite late (post-1950).

Although we are presently unable to generate pH reconstructions for Eiddew Bach, we are still able to draw qualitative conclusions from the diatom data. The decline of *Cyclotella kutzingiana*, a common feature in many of the Scottish and Welsh lake stratigraphies, and the increased abundance of several acidophilous *Navicula* species are clearly indicative of incipient stages of lake acidification. The surface sample from a Kajak core obtained earlier in 1985 contained very low percentages of *Achnanthes minutissima* and the presence of the acidobiontic species *Tabellaria quadriseptata*.

4.1.4 Sediment chemistry

Major ions

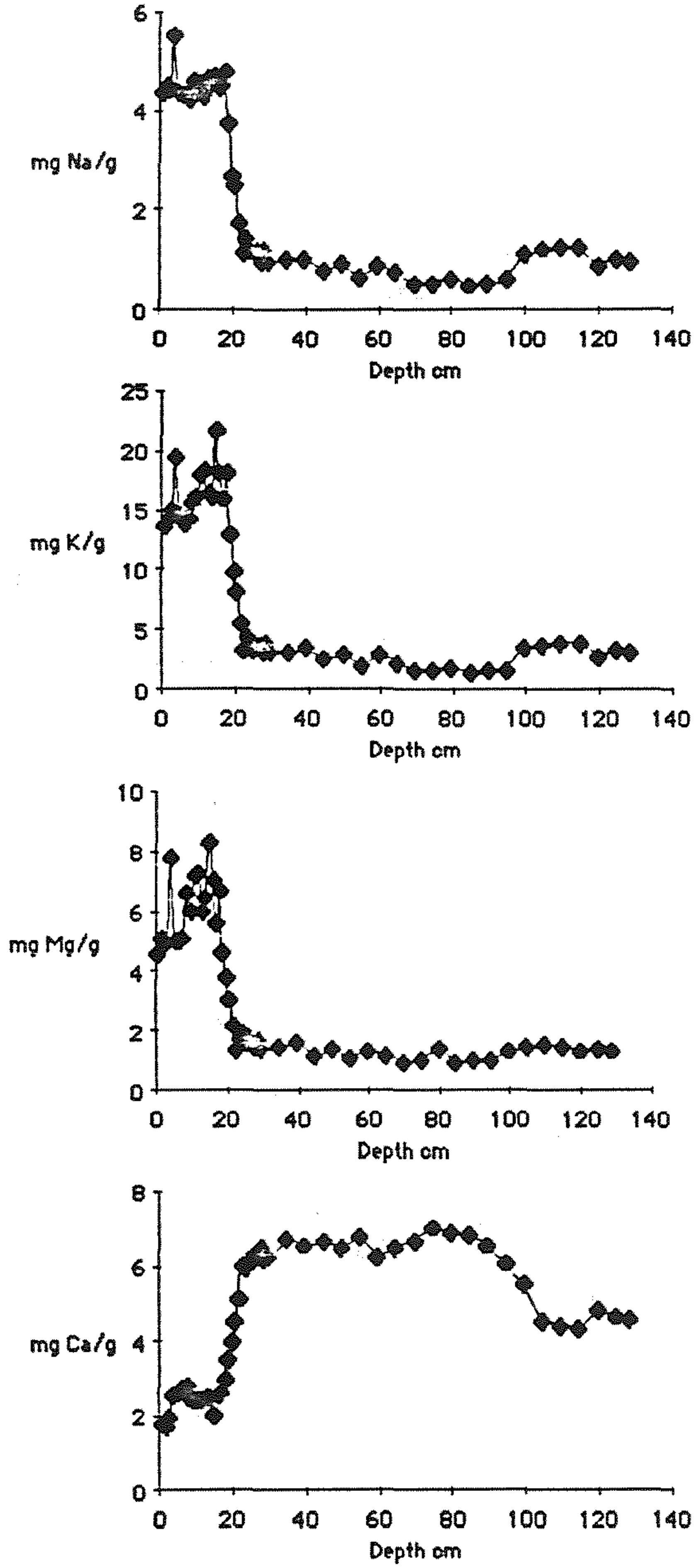
There are some major changes in the constitution of the Eiddew Bach core (Fig. 7). Above 20 cm the organic content falls from very high values around 70% to lower values around 25%. This change is accompanied by an increase in dry weight. Above 20 cm then coarser sediment with a much lower organic content was deposited. This 20 cm level when there was a change in the erosion regime from the catchment is before the dated part of the core (Table 9).

This change has a major effect on the major cation composition of the sediment (Fig. 13). The concentrations of sodium, potassium and magnesium all increase in the upper 20 cm of the sediment. A rise in concentrations would be expected because of the large decrease in organic content but the concentrations of these cations in the mineral component of the sediment also increase (Fig. 14). These changes in cation concentration in the upper 20 cm imply a change to higher erosion rates in the catchment (Engstrom & Wright 1984, Mackereth 1966).

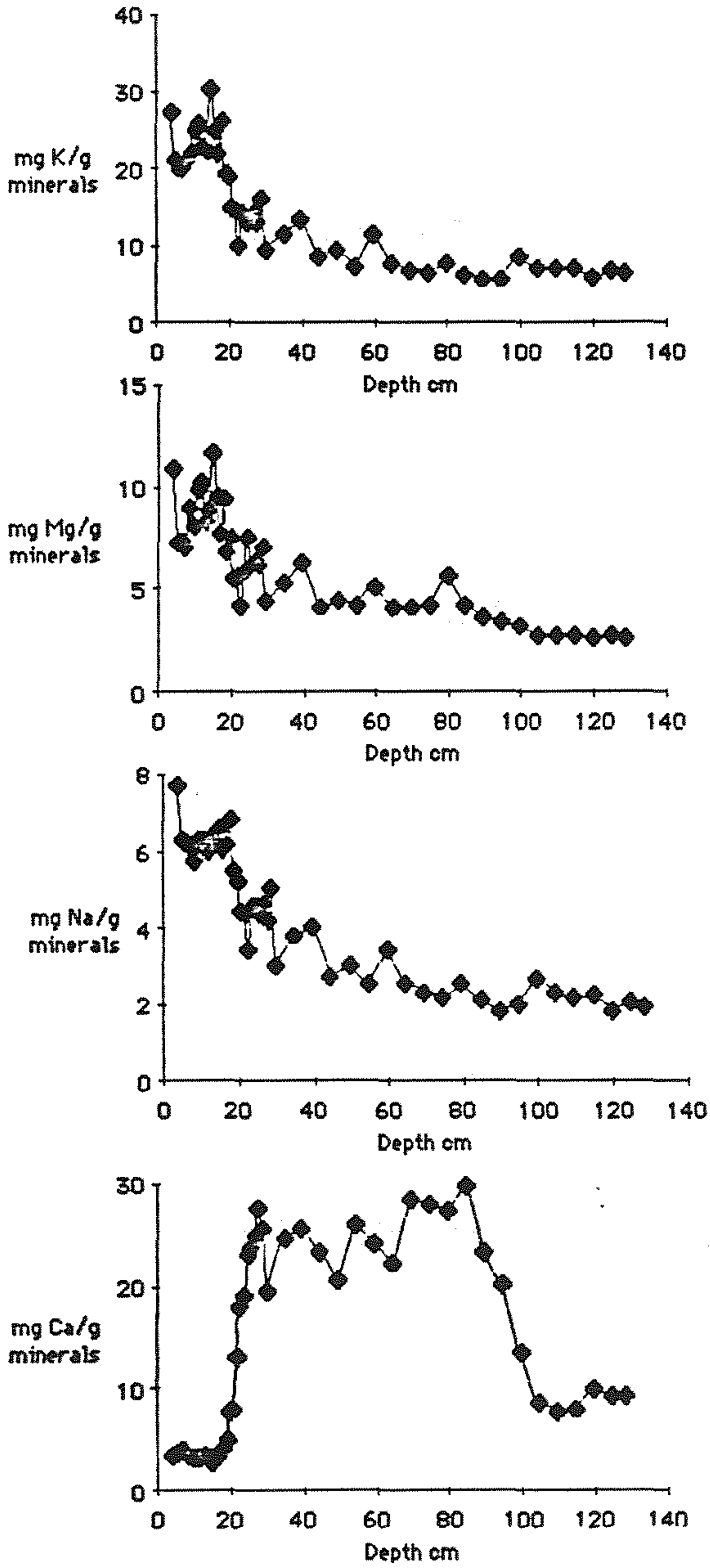
While the behaviour of sodium, potassium and magnesium is similar that of calcium is different. Its profile is similar to that of loss on ignition. This was also found in the other Welsh lakes in the study (Fritz et al 1986, Kreiser et al 1986, Stevenson et al 1987b, Fritz et al 1987).

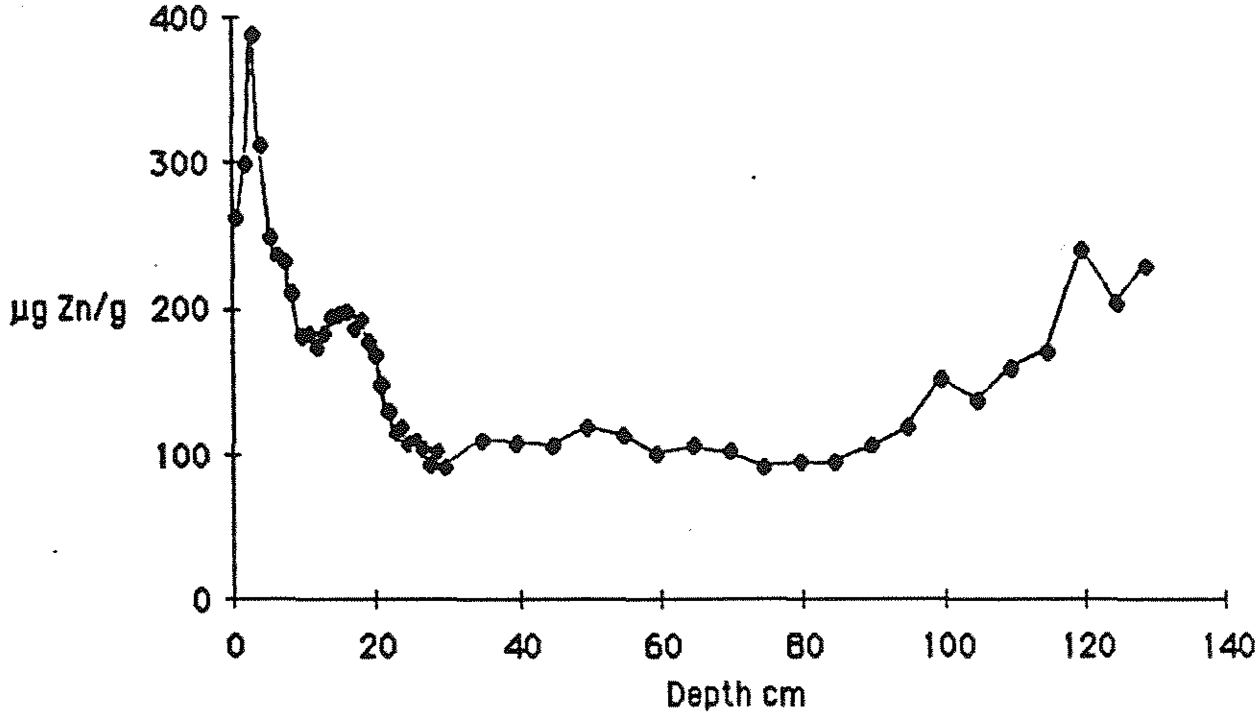
Trace metals

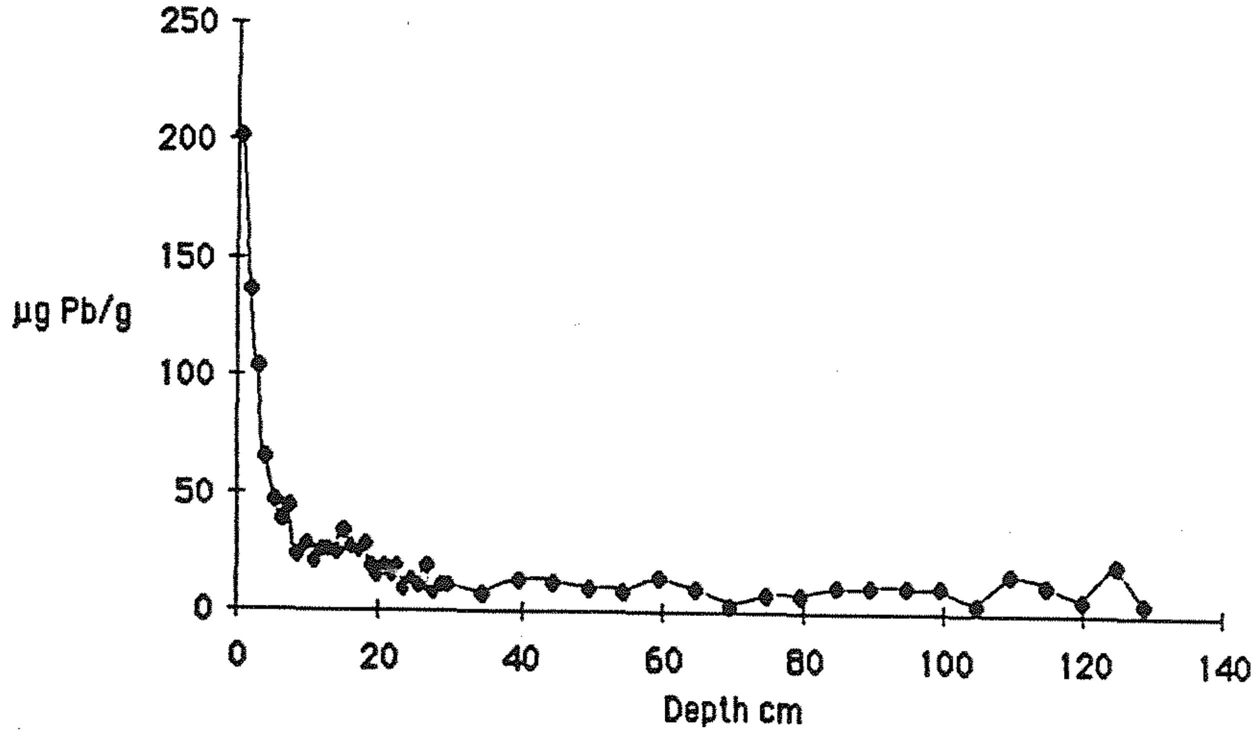
The change in sediment constitution above 20 cm which produces the rise in major cation concentration can be expected to produce an increase in trace metal concentrations. This must be taken into account in order to reveal contamination of the sediments by trace metals.



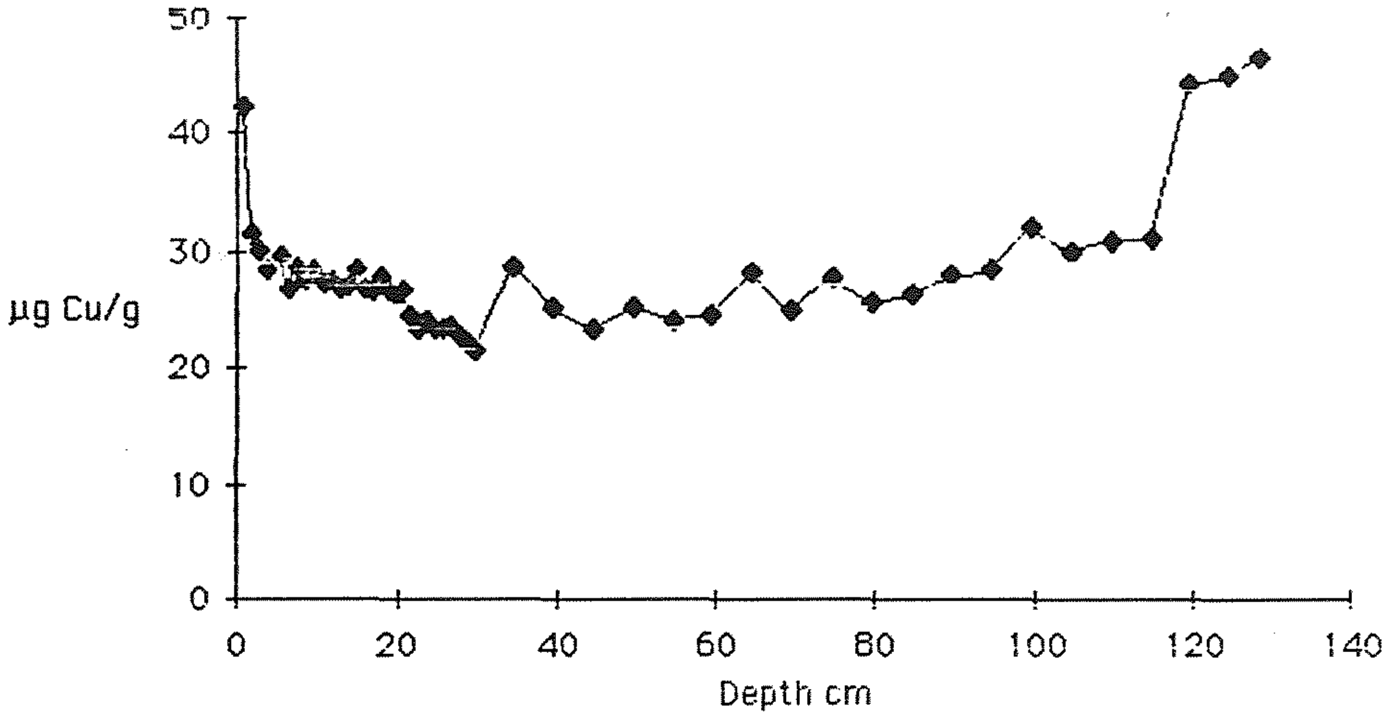
13. Variations in Na, K, Mg & Ca gdw^{-1} for the Eiddew Bach 2 core

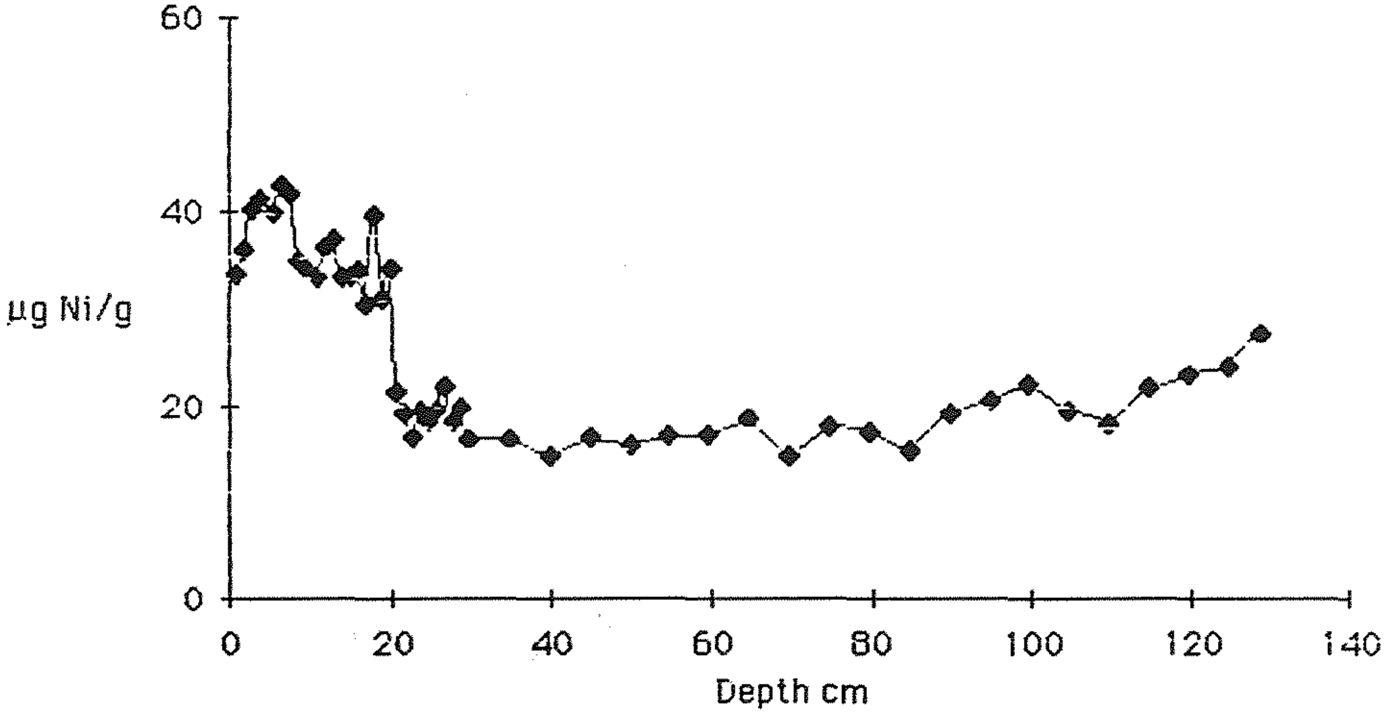

mg K/g minerals
Depth cm
mg Mg/g minerals
Depth cm
mg Na/g minerals
Depth cm
mg Ca/g minerals
Depth cm



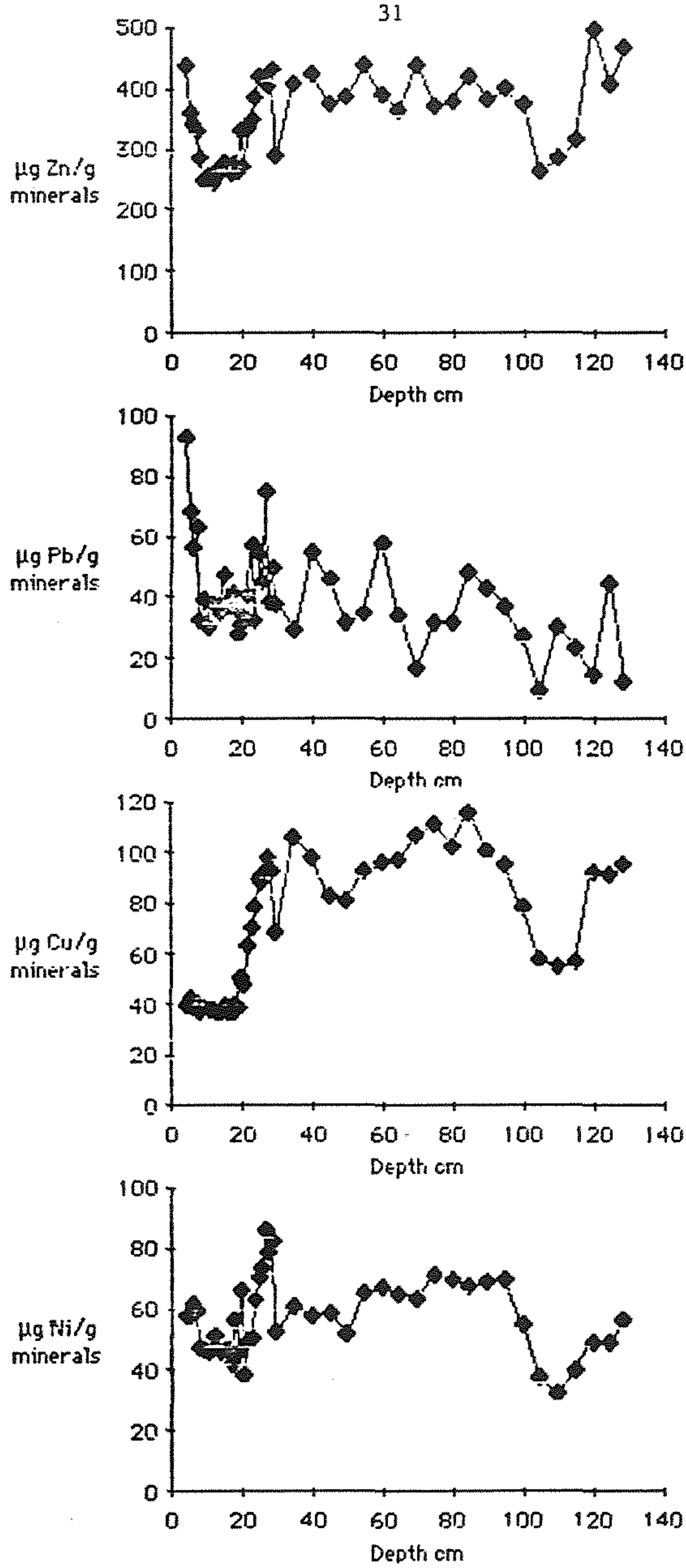


15. Variations in Pb & Zn gdw^{-1} for the Eiddew Bach 2 core

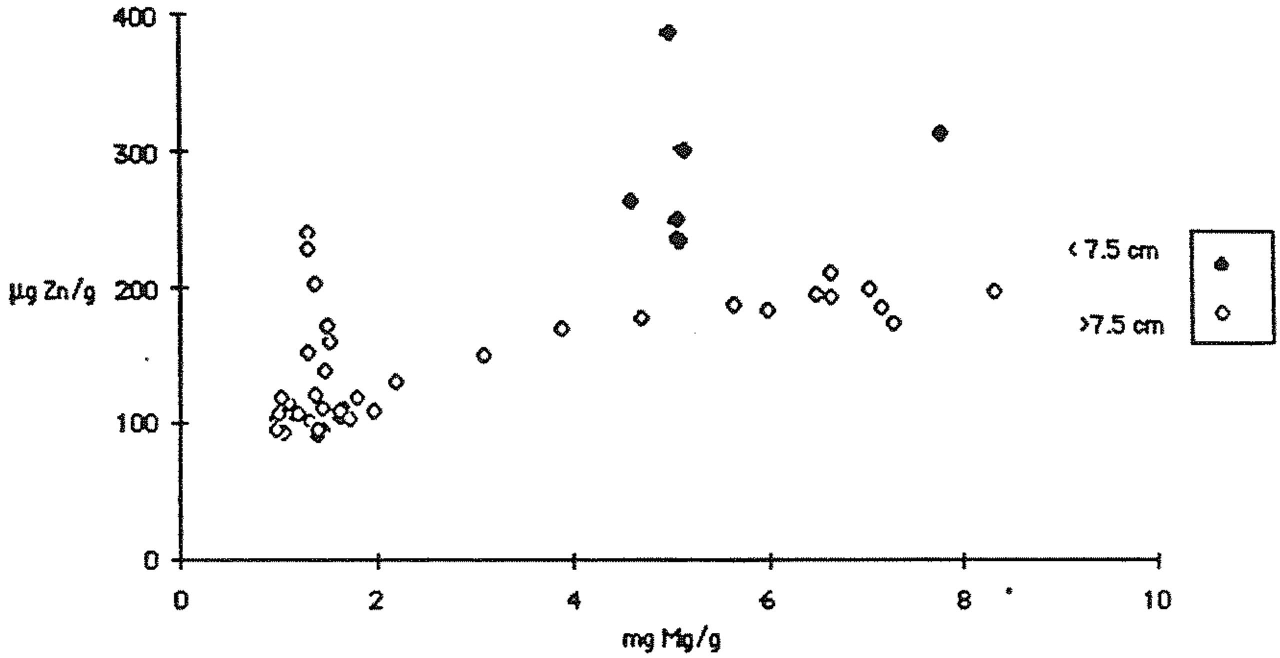


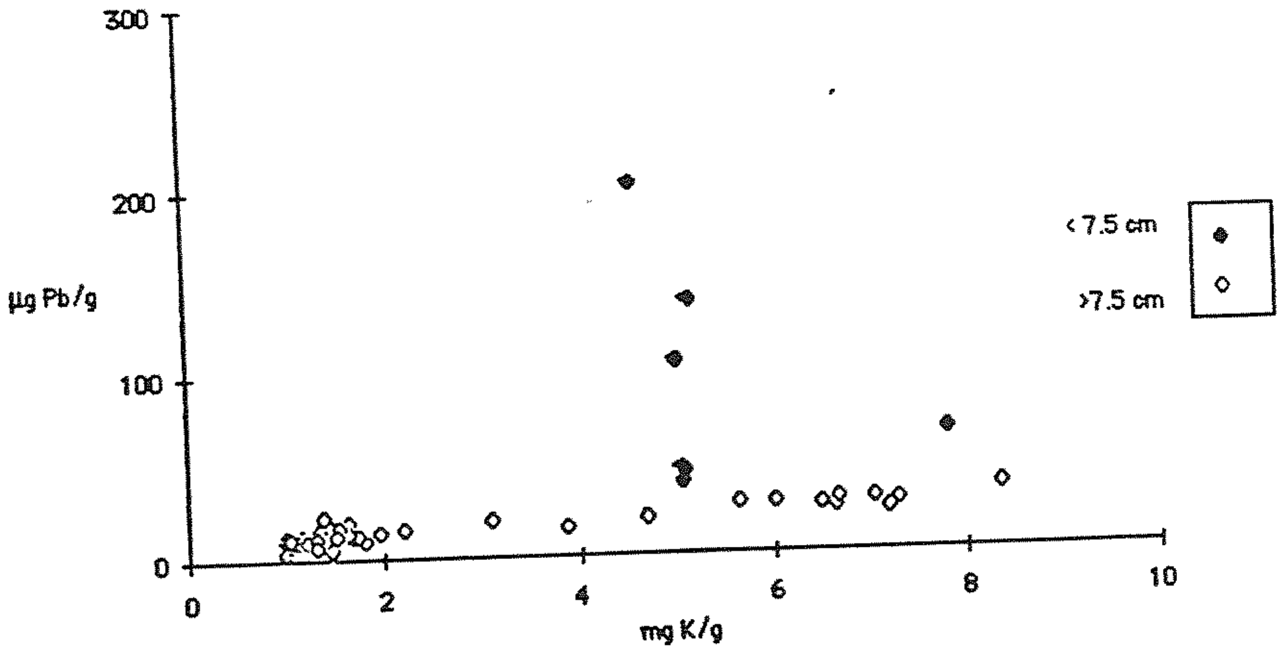


16. Variations in Ni & Cu gdw^{-1} for the Eiddew Bach 2 core



17. Variation of trace metal concentrations with depth for Eiddew Bach expressed as per gram minerals





18. Variations in Zn/Mg & Pb/K concentrations for the Eiddew Bach 2 core

Two points indicate that there is zinc and lead contamination in the upper 7.5 cm of sediment (Figs. 15 - 17). Comparing the zinc and lead profiles with magnesium for example shows that the zinc and lead concentrations increase above 20 cm like magnesium but that above 7.5 cm they increase greatly while the magnesium concentration remains roughly constant. There is an additional source of these trace metals which causes the concentrations to rise further.

Secondly, when the zinc and lead concentrations are plotted against either sodium, potassium or magnesium there is a good linear relationship below 7.5 cm but above this the trace metal concentrations are higher than expected on the basis of the cation concentrations. This is illustrated by two such plots (Fig. 18). The natural linear relationship is established before contamination starts and this is destroyed when there is an additional source of the trace metals.

There is contamination of the upper 7.5 cm of the sediment by zinc and lead while there is little if any contamination by copper and nickel. This depth is outside the dated part of the core but a rough date by extrapolation is 1850 A.D. (using 0.053 cm yr^{-1}, Table 9). This contamination as in the other Welsh lakes studied is from the atmosphere. Trace metal containing wastewaters in this remote lake is very unlikely.

The sedimentary fluxes of the trace metals are low. This has been found in all but one of the lakes in north-west Wales (Stevenson et al 1987a). The most likely reason for this is that the low dry mass accumulation rates mean that the trace metal sedimentation efficiency is low.

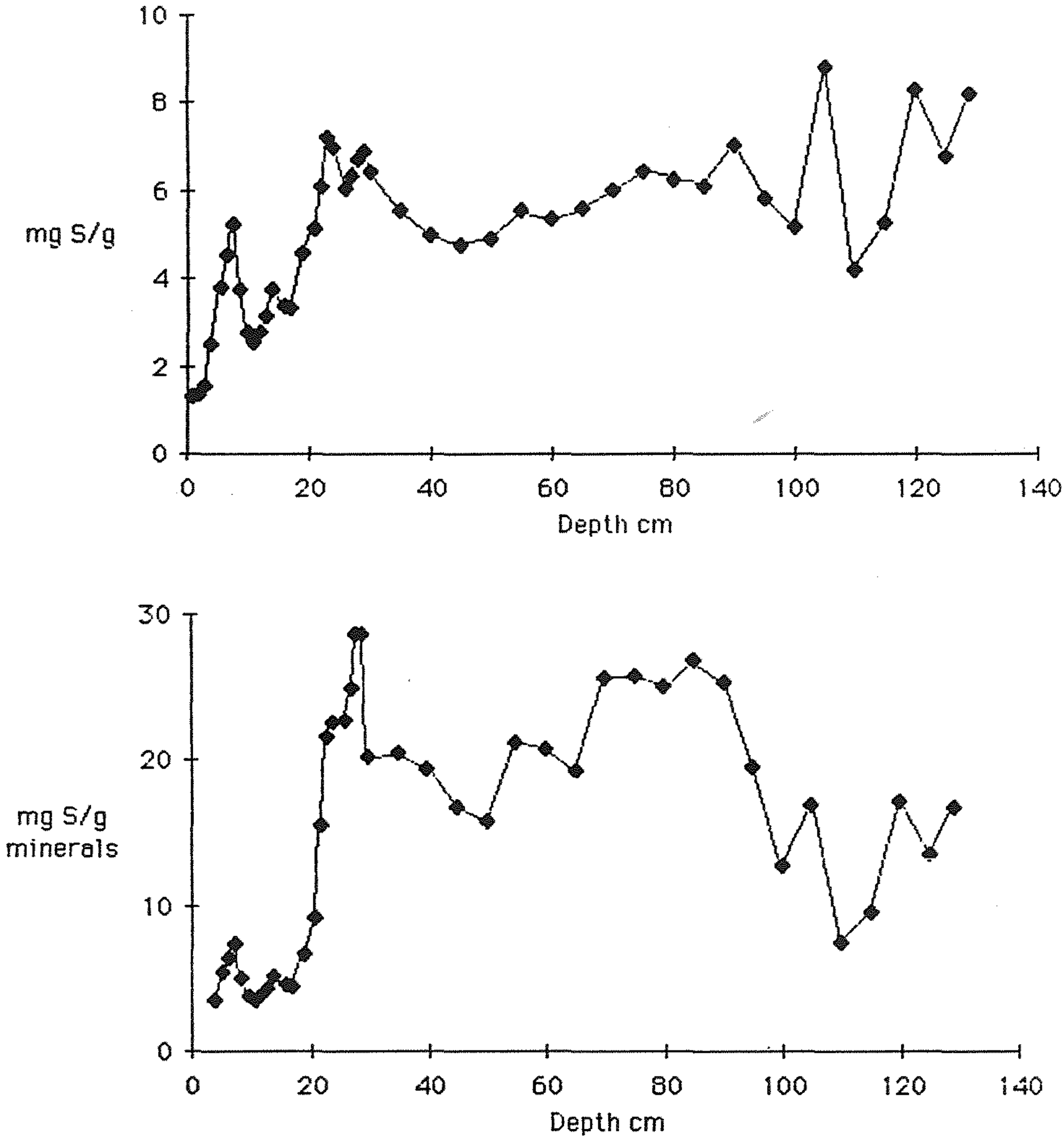
Sulphur

The sulphur profile is similar to that of the loss on ignition, especially above 100 cm (Fig. 19). There is no strong evidence that the sediments record an increase in the deposition rate of sulphur from the atmosphere. Above 7.5 cm where zinc and lead provide evidence for contamination from the atmosphere the sulphur concentration drops. A relationship between the sulphur and loss on ignition profiles was found in Llyn y Bi (Fritz et al 1987) and so in certain circumstances the size of the natural inputs of sulphur to the sediment and microbiological cycling within the lake can obscure any record of increased atmospheric loadings.

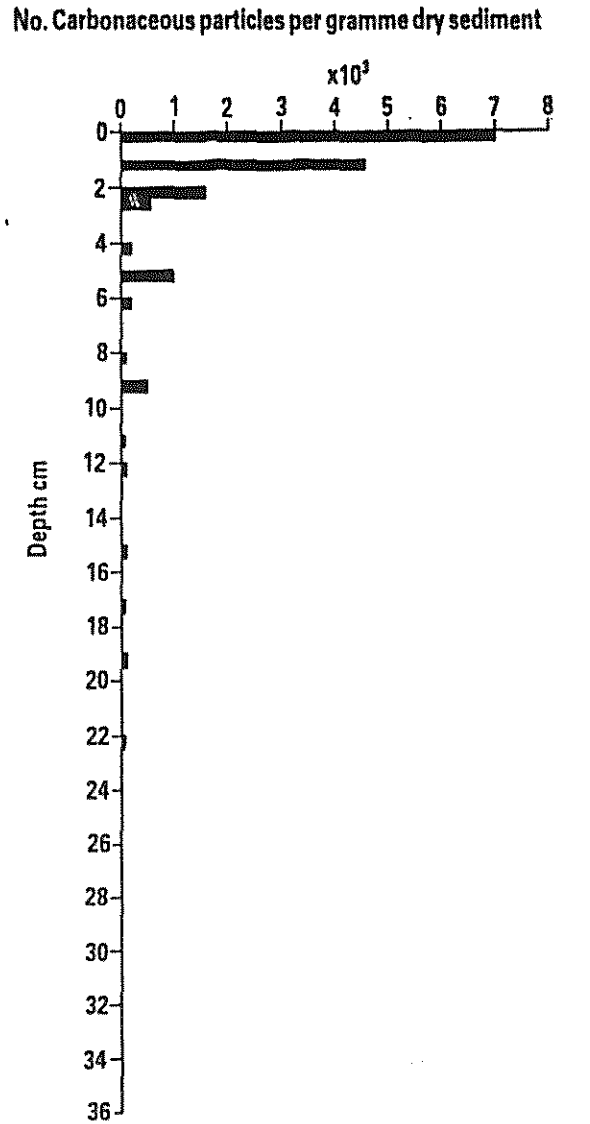
4.1.5. Carbonaceous particle

The carbonaceous particle pattern for Eiddew Bach, illustrating the number of particles per gram dry sediment is given in Fig. 20 & Table 10. It shows the presence of soot in small numbers at a depth of 22 cm onwards. Two small peaks in concentration are seen at 9 cm and 5 cm. The onset of a rapid rise in concentration occurs from 3 cm.

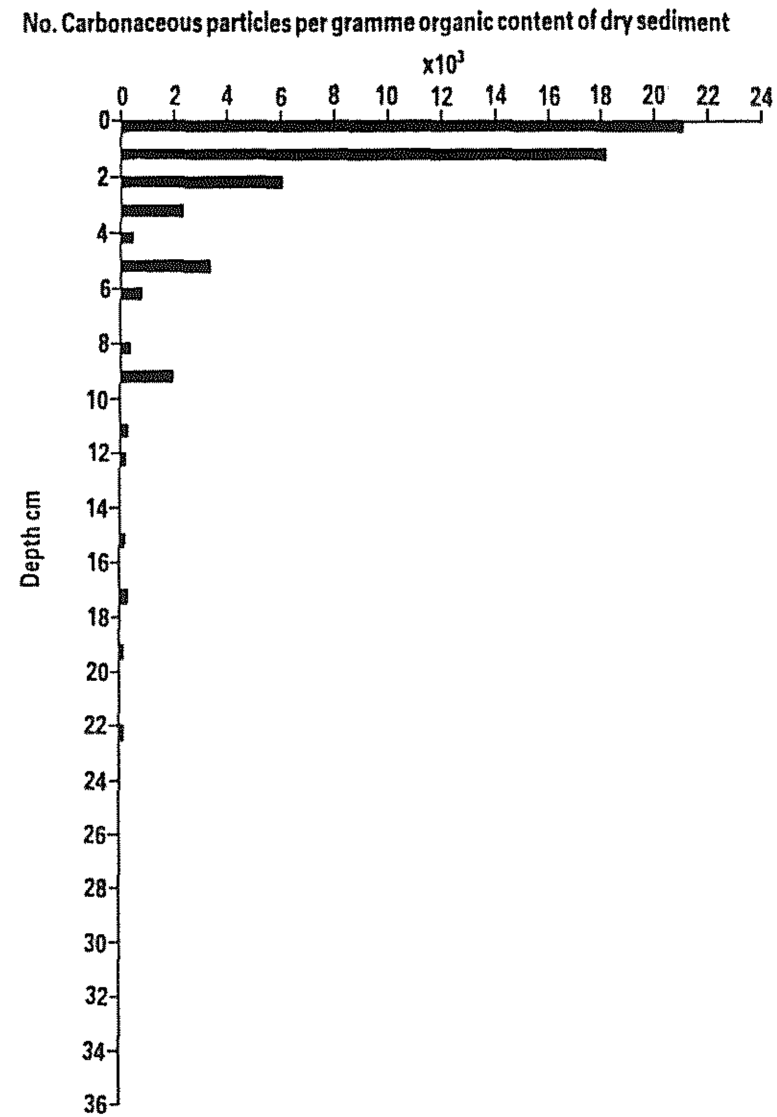
The pattern for the soot count in terms of the organic content of dry sediment is given in Fig. 21. Soot patterns in terms of the organic fraction of sediment (using LOI) may be considered to be more precise as the supply of organic material to the sediment tends to be more uniform over time than the input of mineral matter which can vary widely. Using LOI as a base has the effect of 'smoothing' the soot pattern, and this can be observed for Eiddew Bach. Otherwise, the pattern is very similar to that in



19. Variations in S for the Eiddew Bach 2 core



20. Carbonaceous particle record gdw⁻¹ for the Eiddew Bach 2 core



21. Carbonaceous particle record per gram mineral dry weight for the Eiddew Bach 2 core

Table 10: Carbonaceous particle analysis for Eiddew Bach 2

Depth (cm)	No. Carbonaceous Particles per g dry sed $\times 10^3$	No. Carbonaceous Particles per g organic content $\times 10^3$
0.0 - 0.5	7.04	23.1
1.0 - 1.5	4.59	18.2
2.0 - 2.5	1.61	6.1
2.5 - 3.0	0.60	2.1
4.0 - 4.5	0.17	0.5
5.0 - 5.5	1.04	3.4
6.0 - 6.5	0.22	0.7
7.0 - 7.5	0	0
8.0 - 8.5	0.10	0.4
9.0 - 9.5	0.51	1.9
10.0 - 10.5	0	0
11.0 - 11.5	0.08	0.3
12.0 - 12.5	0.07	0.2
13.0 - 13.5	0	0
14.0 - 14.5	0	0
15.0 - 15.5	0.06	0.2
16.0 - 16.5	0	0
17.0 - 17.5	0.09	0.3
18.0 - 18.5	0	0
19.0 - 19.5	0.07	0.2
20.0 - 21.0	0	0
21.0 - 22.0	0	0
22.0 - 23.0	0.05	0.1
24.0 - 25.0	0	0
26.0 - 27.0	0	0
28.0 - 29.0	0	0
30.0 - 31.0	0	0

Fig. 20.

4.1.6. Magnetic Measurements

Sediments from Eiddew Bach core 2 were packed into previously screened styrene pots and subjected to the following sequence of magnetic measurements:-

1. Anhysteritic Remanent Magnetization (ARM) using a Molspin AF Demagnetizer set with a peak AF field of 100mT and a DC bias of 0.04mT.

2. 'Saturation' Isothermal Remanent Magnetization (SIRM) using a Molspin Pulse Magnetizer with a maximum DC field of 850mT.

3. Isothermal Remanence (IRM) measured at each step in a sequence of reverse field DC demagnetization at -20mT, -40mT, -100mT and -300mT for samples from 0 - 30 cm.

All remanences were measured on a Minispin Slow-speed spinner Fluxgate Magnetometer. Susceptibilities were not measured as the combination of small sample size and relatively weak magnetization made the samples unsuitable.

Fig. 22 plots the magnetic measurements for this core. The right hand graph shows reverse field ratios (IRM_{-n}/SIRM) plotted against a horizontal scale of percentage reverse-saturation. Thus 50 represents the point during DC demagnetization at which IRM is zero and 100 represents the point at which IRM/SIRM is -1.

The noisy SIRM/ARM quotient, especially below 20 cm, reflects ARM measurements close to the instrumental noise limit. SIRM values are also very low below this depth and reverse field ratio measurements were discontinued below 30 cm. The increase in ARM and SIRM around 20 cm dates from several centuries before present and would appear to reflect a change in sediment regime maintained from that time onwards but unrelated to atmospheric deposition or industrial processes. The increases in SIRM, ARM and SIRM/ARM above 3.5 cm parallel those found in late 19th and 20th century peats.

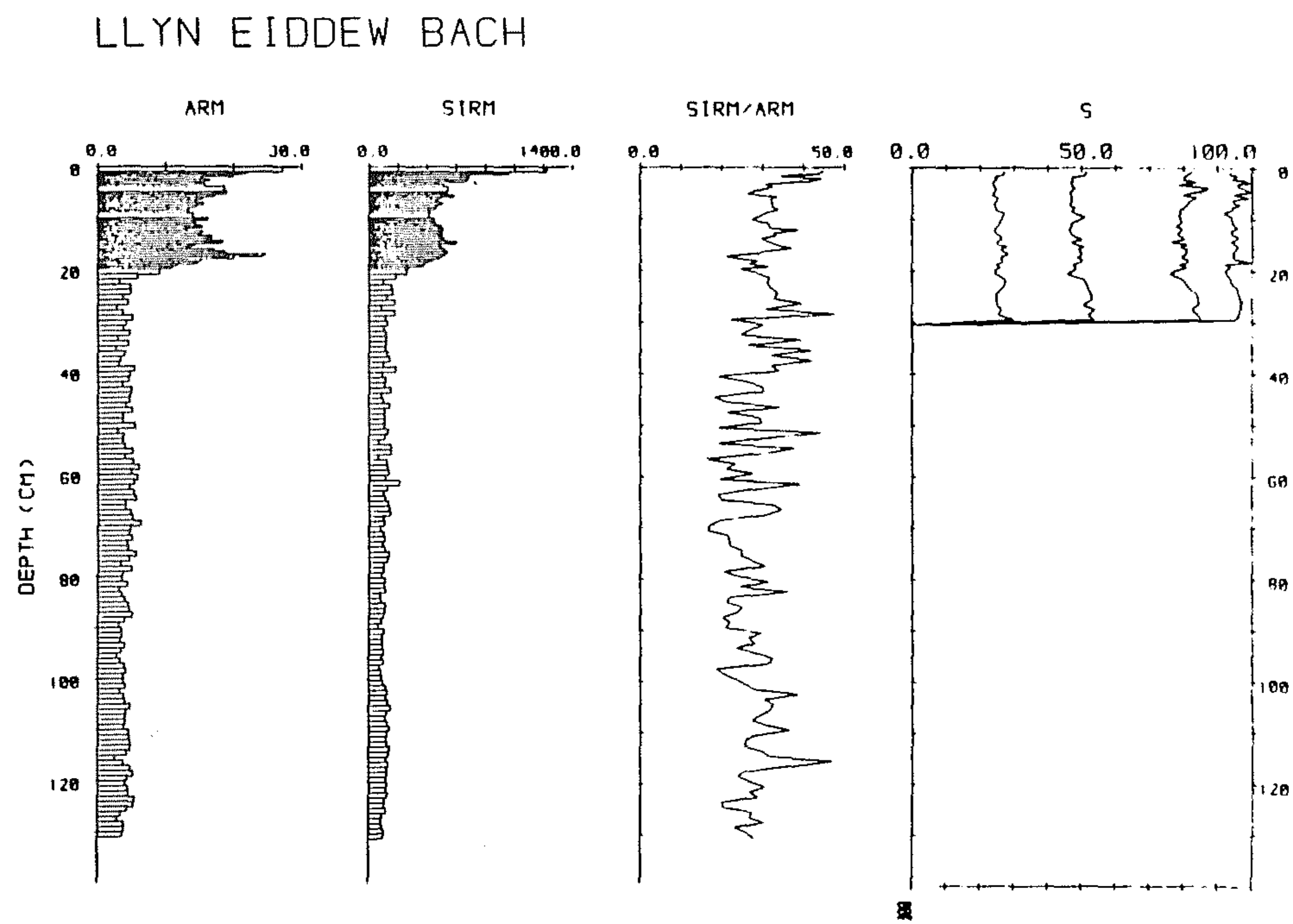
4.1.7. Pollen

Figs. 23 & 24 present summary pollen diagrams of the Eiddew Bach core. Appendix B contains the full pollen diagram.

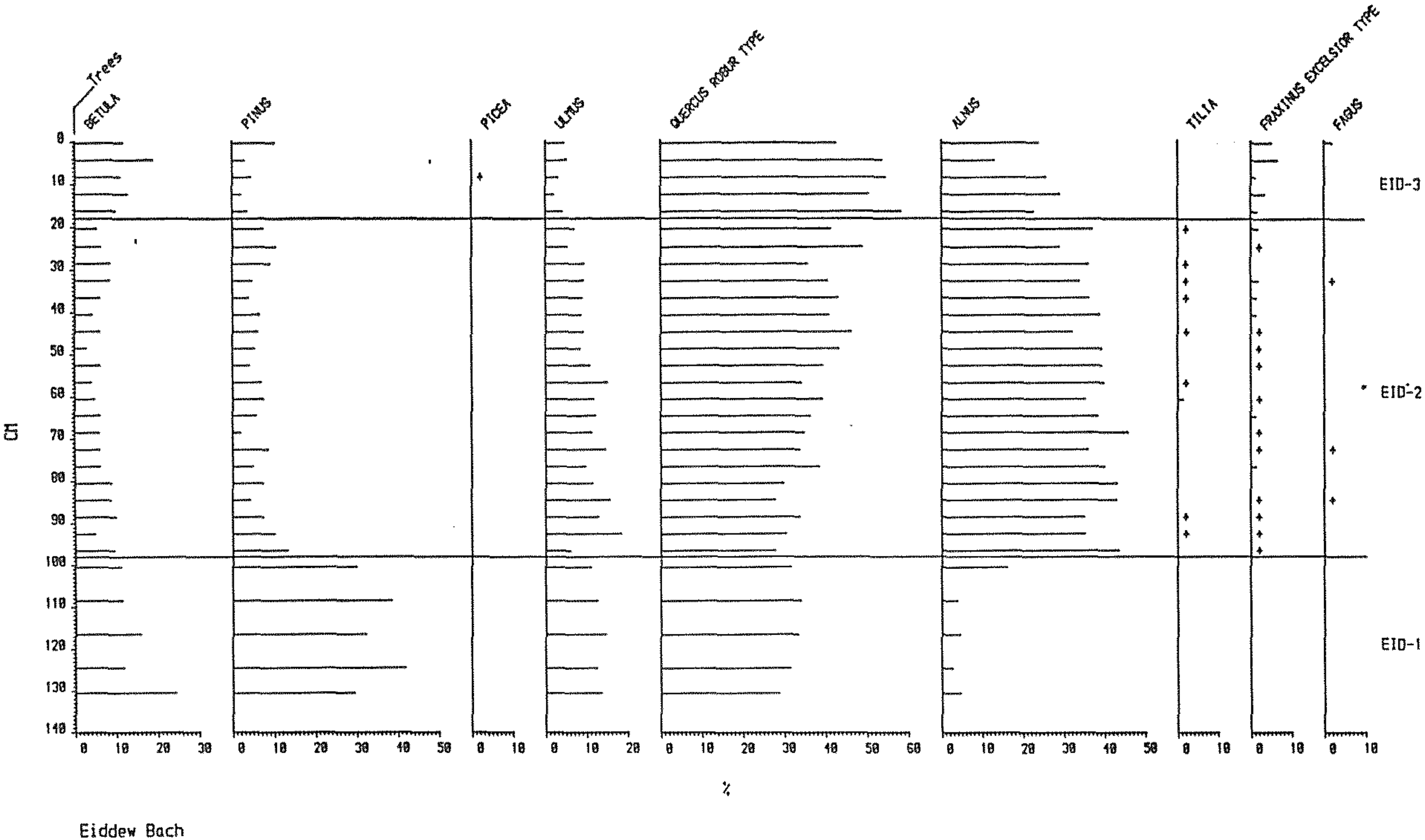
The diagrams have been zoned according to the zonation program of Birks & Gordon (1985).

EID-1 Pinus / Ulmus / Quercus PAZ (131 - 98 cm)

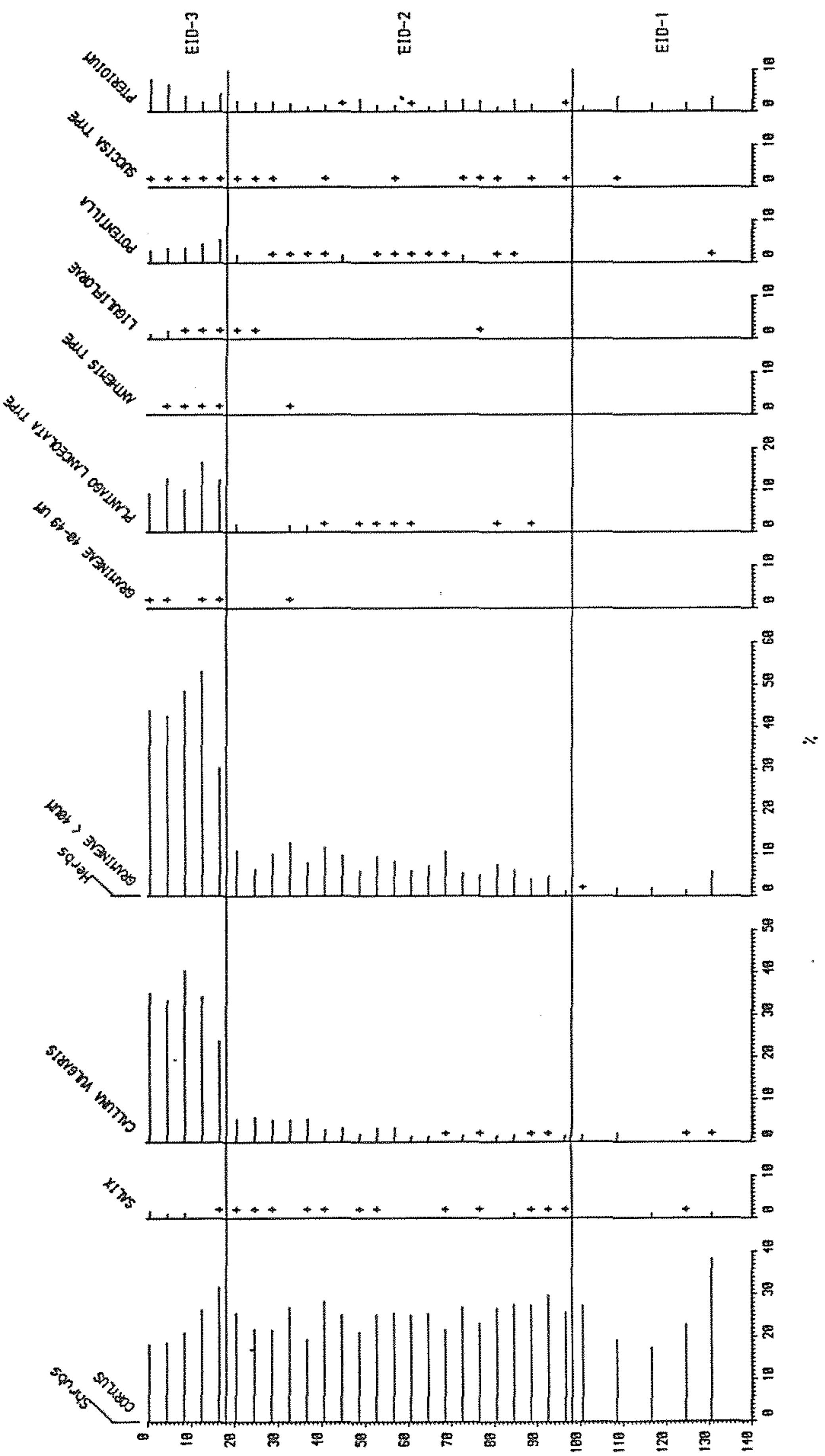
The high but declining values of Betula and high values of Quercus, Ulmus and Pinus clearly indicate that the zone represents an early postglacial wooded landscape around Eiddew Bach. Since values of Alnus are low the suggested timespan is between 8500 and 7500 B.P. The end of the zone probably dates to ca. 7500 B.P. as suggested by the increase in Alnus values marking the beginning of a pronounced alder rise (Smith 1984).



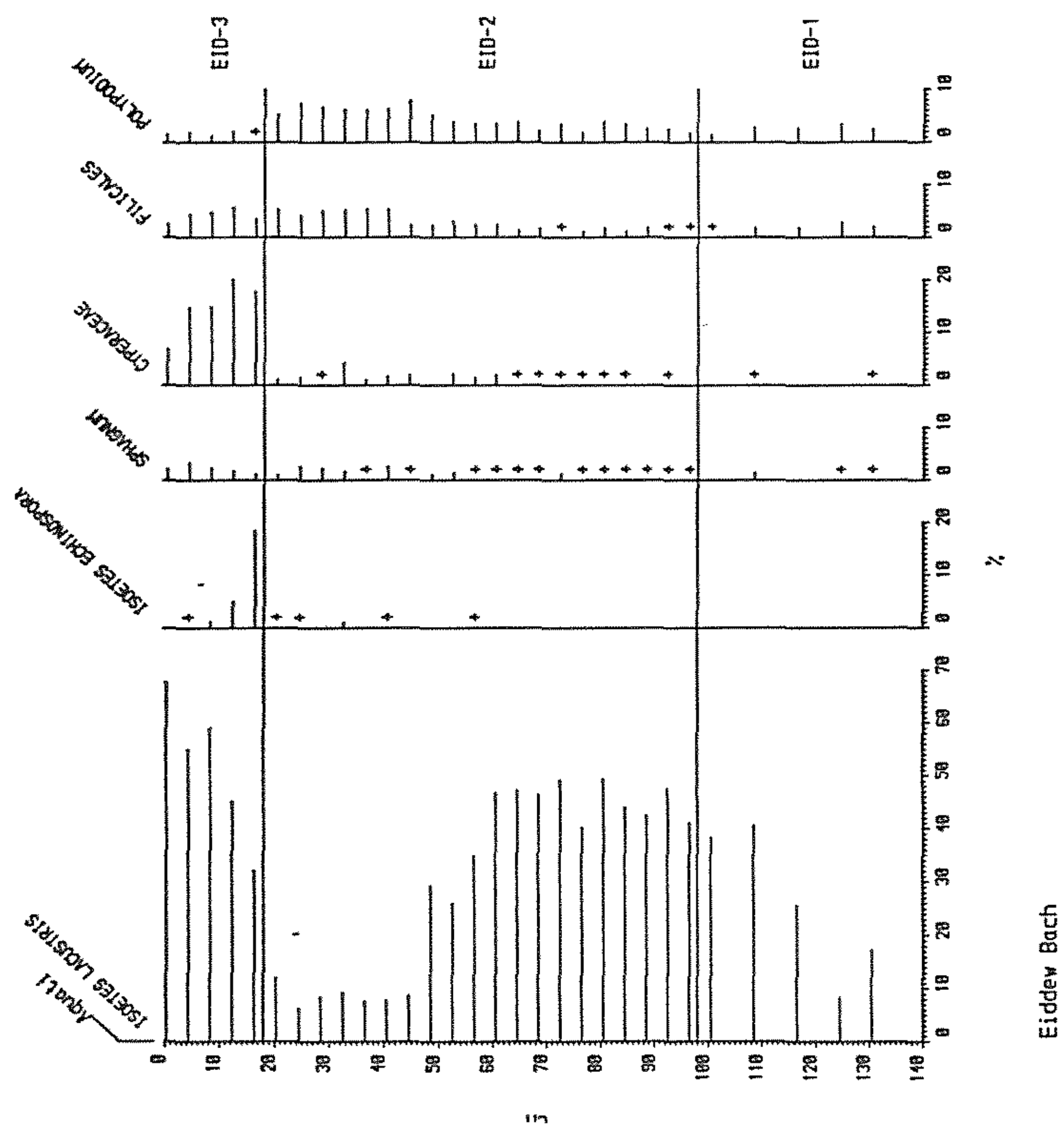
22. ARM, SIRM and SIRM/ARM versus depth, 0-130 cm. Reverse field ratios (see text) are plotted for the top 30 cm only

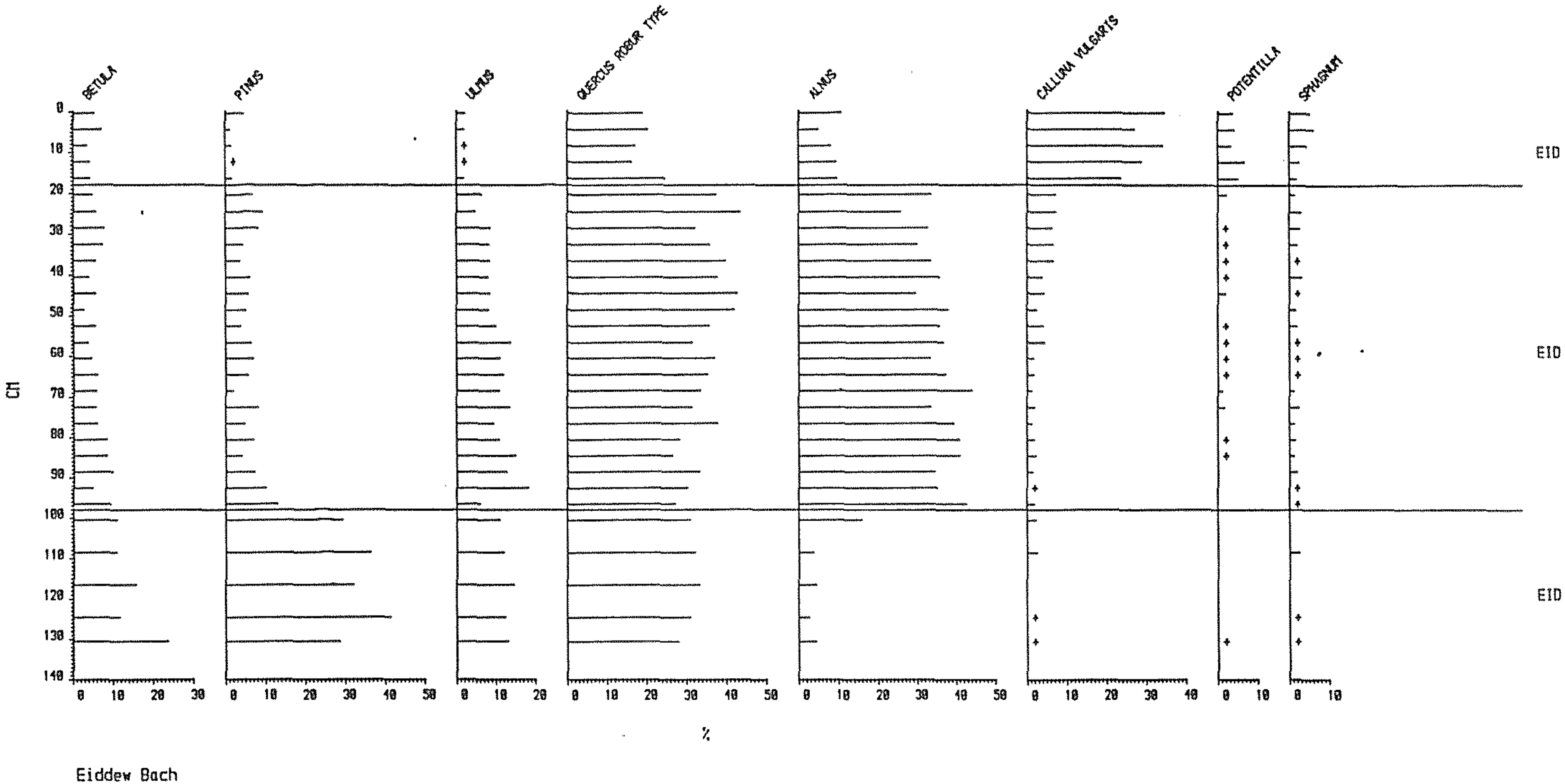


23. Summary pollen diagram for the Eiddew Bach 2 core. Trees expressed as a percentage of the arboreal pollen. All other groupings as a percentage of the arboreal pollen + the respective grouping


Shrubs
CORYLUS
SALIX
CALLUNA VULGARIS
Herbs
GRAMINEAE < 40µm
GRAMINEAE 40-49 µm
PLANTAGO LANCEOLATA TYPE
ANTHEMIS TYPE
LIGULIFLORAE
POTENTILLA
SUCCISA TYPE
PTERIDIUM
EID-3
EID-2
EID-1
%

Eiddew Bach


Aquatics
ISOETES LACUSTRIS
ISOETES ECHINOSPORA
SPHAGNUM
CYPERACEAE
FILICALES
POLYPODIUM
EID-3
EID-2
EID-1
%
cm
Eiddew Bach



24. Summary pollen diagram for the Eiddew Bach 2 core. All taxa expressed as a percentage of the arboreal pollen + peatland indicators sum

EID-2 Quercus / Alnus PAZ (98 - 20 cm)

The high values of Quercus and Alnus pollen throughout this zone clearly indicate the establishment of an extensive oak and alder forest within the catchment. Small open patches in the generally acid soils are dominated by Calluna and Gramineae. The zone covers a period from approximately the time of the alder rise (7500 B.P.) to the elm decline (5500 B.P.). The end of the zone is clearly marked by a 5000 - 5200 year long hiatus before sedimentation recommences in the early 1800's.

Throughout the zone a progressive but small increase in the amount of open acid moorland habitat within the oak and alder forest is indicated as values of Calluna, Gramineae and Sphagnum all rise mid-way through the zone. At the same time indicators of general regional forest disturbance such as Fraxinus and Plantago also increase.

A marked erosion phase is also associated with this disturbance phase and is marked by a collapse in the pollen values of Isoetes (cf Fritz et al 1987, Stevenson et al. 1987) and peaks in the loss on ignition curve.

EID-3 Gramineae PAZ (20 cm - 0 cm)

The recommencement of sedimentation within the core appears to have occurred in the early eighteenth century. The catchment is now dominated by pollen indicators of open moorland (Calluna and Gramineae). Agricultural indicators suggest intensive agricultural activity with the extremely high values of Plantago and Rumex.

4.2 Land use and Management (1)

4.2.1 Land use

At over 350 m on acidic soils the Llyn Eiddew Bach catchment consists of unimproved moorland utilised for rough grazing. In terms of its vegetational composition (see Section 2.1.3) it contains species representative of 'grassy heath' (eg. King 1977, Ball et al. 1982).

In terms of the ADAS (2) land capability classification the catchment comprises land of categories H3 - 'improvements generally severely limited but of moderate or high grazing value' and H4 - 'generally not improvable and of low grazing value' (MAFF 1980).

The altitude, soil acidity, wetness of the land immediately to the north of the lake and the rocky terrain to the east (the greater proportion of the catchment - Fig. 6) determine that the catchment is inherently unimprovable. There is no evidence from documentary sources (see below), from air photographs, or on the ground to suggest that the catchment has ever supported a land use other than rough moorland grazing.

It is unreasonable to expect any attempt to have been made towards improving the acid moorland with lime. Merioneth is almost entirely devoid of limestone deposits and in the 19th century the high price of imported lime together with the cost of carriage over poor roads, ensured that it was rarely used in remoter areas (Davies 1813). Contemporary farmers (A. Griffiths, G. Lloyd pers. comms.) and authorities (D. Jarrett pers. comm.) confirm that agricultural lime has not been applied to the catchment in living memory.

Documentary evidence (3)

The tithe map and schedule of Llanddecwyn (4) describe the catchment as 'mountain land' but the state of cultivation as 'pasture'. The notation 'pasture' does not necessarily indicate improved grazing land (cf. Morgan 1959, Kain and Prince 1985).

The unimproved nature of the catchment was suggested by Murray (1885) who described the 'wild scenery' around the Eiddew lakes.

The first and subsequent editions of the six inch ordnance survey map of the area (5) show the catchment to consist of 'rough or heathy pasture', with the wet area at the north of the lake described as 'marsh'

The First Land Utilisation Survey six inch manuscript map of 1937 (6) classifies the lake catchment in the 'moorland/rough grazing' category. The Second Land Utilisation Survey six inch manuscript map of 1970 (7) indicates a vegetation cover and distribution very similar to the present situation.

The Crown common on which the catchment lies was grazed primarily by the Maesneuadd Estate until ca. 1950. However, papers in the Maesneuadd collection at UCNW Bangor provide no historical information on the land use or management of the Llyn Eiddew Bach area.

Non agricultural land use

Tracks to the south and west of the lake (8) provided access to mineral workings (primarily manganese mines) outside of the catchment to the east. However, there is no evidence from documentary sources or on the ground to suggest that any mineral was ever exploited or prospected for within the lake catchment.

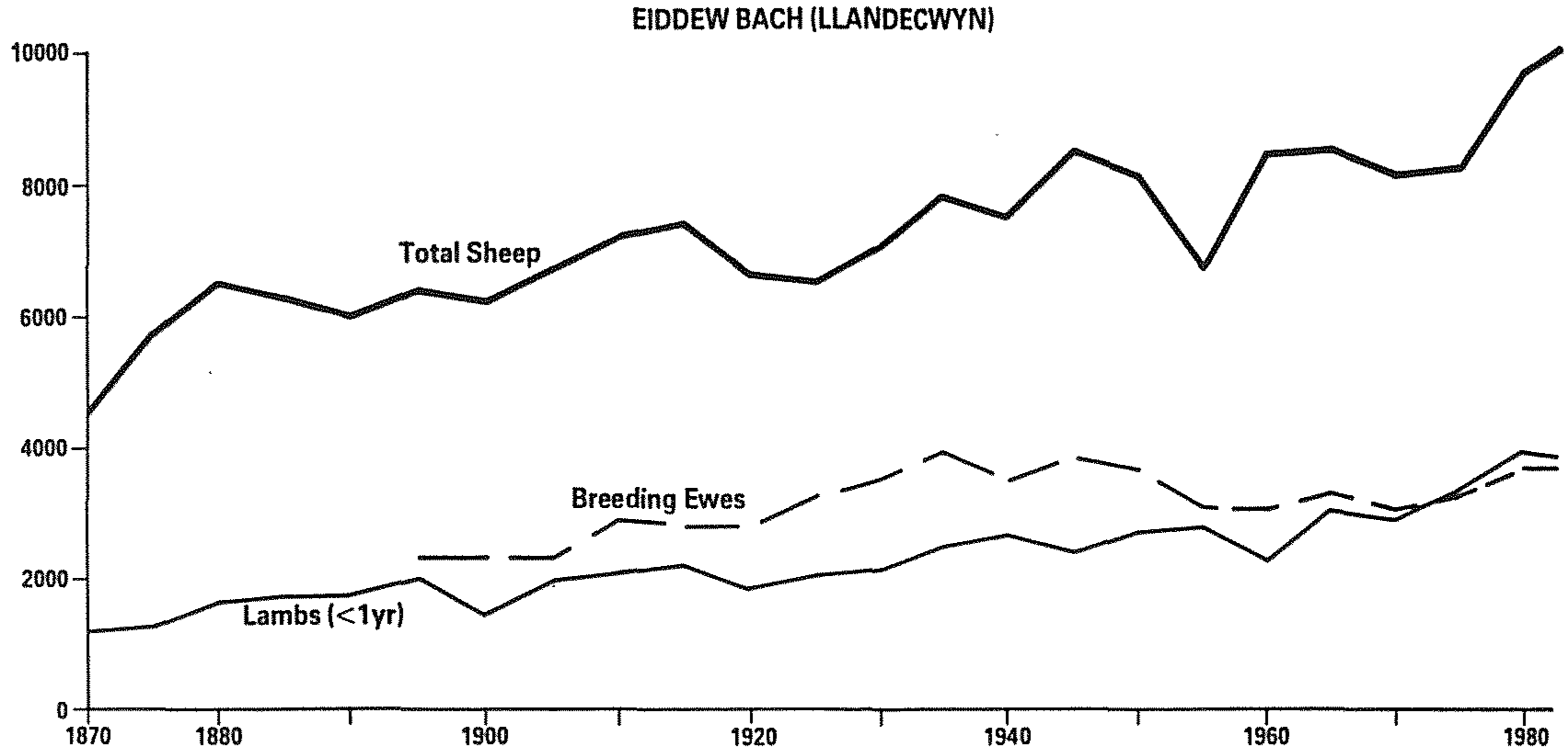
4.2.2 Land management

Pastoralism

Until the mid-19th century black cattle were an important component of the pastoral economy of north Wales (Roberts 1959, Emery 1965, Hughes et al. 1973). Goats also ranged the hills in significant numbers (Evans 1812, Roberts 1959, Emery 1965, Hughes et al.1973), as did young ponies which stayed on the hills year round (Davies 1813). However, the central issues of pastoral management in the catchment concern its utilisation for sheep grazing.

The only quantitative data relating to sheep numbers in the vicinity of Llyn Eiddew Bach are those of the annual parish agricultural returns of Llanddecwyn (9). These were analysed at quinquennial intervals and are presented in Fig. 25.

Although they represent the source of information most applicable to the Llyn Eiddew Bach catchment, the spatial resolution of these data do not



25.. Sheep numbers in Llanddedywn parish 1867-1983 permit catchment-specific assertions to be drawn and their interpretation is hindered by several other constraints. In particular they take only a limited account of changes in sheep type and no account of changes in grazing regime (Patrick 1987).

Sheep numbers have increased in the period 1867-1983. (Fig. 25). The increasing significance of ewes and lambs at the expense of wether sheep over the last century, is also suggested from Fig. 25.

However, within the Llyn Eiddew Bach catchment a broad decrease in sheep numbers has been recognised since ca. 1950 (A. Griffiths, D. Lloyd pers. comms.). An example is thus apparent whereby parish data prove misleading in the context of a small catchment such as Eiddew Bach (cf. Patrick 1987)

A change in grazing regime has been apparent through the late 19th and 20th centuries. The transition from hardy wethers to ewes and lambs, the declining viability and eventual abandonment of the higher farms and the greater availability of winter grazing on lower land, has resulted in fewer sheep over-wintering on the high hills and a shortening of the grazing season at these altitudes (Patrick 1987).

Until the 1970's sheep were washed in the lake prior to shearing (A. Griffiths, D. Lloyd pers. comms.). A now derelict sheep pen on the southern shore of the lake was the focus of that activity. Another derelict sheep pen at the western edge of the catchment provides further evidence of a higher intensity of sheep grazing in the past (10).

Contemporary farmers (A. Griffith, D. Lloyd pers. comm.) can recall no burning in the catchment since the 1950's, although the adjacent catchment of Llyn Eiddew Mawr is periodically burnt. Aerial photographs taken in 1946 (11) indicate strips and patches of burnt land surrounding, but not in the catchment of Llyn Eiddew Bach.

The catchment lies in the Snowdonia National Park but the Park Authority exert no direct control over contemporary management practices.

Subsidiary management practices

There is no evidence that this area was ever managed for game nor that game was actively pursued in the locality of the catchment.

5.0 Conclusions

i) Sediment accumulation rates over the last 100 years at the core site were low, the ^{210}Pb inventory is very low, and there is evidence that sediment from the last two decades or so is missing from the top of the core. This is indicated by the presence of a carbonaceous particle increase at about 2 cm, usually dated to 1930-1940 at other sites and high values of ^{137}Cs in the surface sediments. The top 2-3 cm therefore represent sediment accumulated between the 1930's and 1960's.

ii) The diatom based pH reconstructions suggest that the pH of Eiddew Bach was 6.7 - 6.9 throughout the basal 10 cm of analysed sediment. From 8 cm a number of acidophilous taxa and undesignated *Navicula* species appear and increase in abundance, including *Navicula heimansii*, *N. meidocris*, *N. indifferens*, *N. tenuicephala* and *Navicula madumensis*. From 2 cm the most marked change occurs indicating incipient acidification as the planktonic *Cyclotella kutzinghiana* and the alkaliphilous *Fragilaria construens* var *venter* decline and acidophilous taxa like *Navicula hassica* increase.

iii) The core chemistry record demonstrates that trace metal contamination by lead and zinc of the lake sediments began at 7.5 cm. There appears to be no contamination of the sediments by copper and nickel. The cation chemistry record identifies a major change in erosion rates from the catchment at 20 cm and correlates with the major changes in the pollen record.

iv) The contamination of the sediments by carbonaceous particles commences at 9 cm, earlier than the beginnings of lake acidification. The concentration of these particles increase rapidly from 3 cm and parallel the incipient acidification of the lakewater as suggested by diatom analysis. A similar trend is shown by the magnetic data.

v) The recent portion of the pollen diagram indicates that little change has occurred in the catchment vegetation over the last 150 years. The pollen diagram also reveals a major hiatus in the core at 21 cm below which sediments dating to approximately the elm decline 'ca. 5000 B.P.' occur. A period of catchment erosion is identified by an *Isoetes* decline from 50 cm to 20 cm and matches a period of increased cation concentrations in the lake sediments.

vi) No appreciable land use change has occurred within the catchment. While sheep numbers have increased in the area in recent years the documentary evidence is not precise enough to assess whether the catchment has experienced a significant increase in grazing pressure. No liming has taken place within the catchment and burning has not been a significant management practice.

vii) Since it appears that recent sediment is missing from the top of the core it is not possible to present a complete picture of changing pH through time. However, it is possible to demonstrate that a substantial acidification of the lake has occurred over the last 50 years or so. High concentrations of carbonaceous particles in lakes have only occurred since the 1930's. On this basis the uppermost 2 cm of the core clearly postdates 1930 and contains a diatom assemblage indicative of pH values > 6.0. Since the present pH is about 4.5 a pH decline of approximately 1.5 units must have occurred over the last few decades. Since no significant catchment changes have taken place during this period we must conclude as for other sites in the areas, that the acidification has been caused by acid deposition.

6.0 References

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7.0 Acknowledgments

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8.0 Notes

1. See Patrick (1987) for definitions of 'land use' and 'land management'.

2. ADAS - Agricultural Development Advisory Service (MAFF). Manuscript 1:25,000 maps accessed at ADAS Aberystwyth.

3. See Patrick (1987) with regards to sources (and their interpretation) used in documenting land use and land management change.

4. Tithe map and schedule for the parish of Llanddecwyn, 1841. PRO (Kew) IR30 52/16.

5. First edition surveyed 1887, published 1891.
   Second edition surveyed 1899, published 1901.
   Third edition ammended 1949, published 1953.

6. Held at the London School of Economics archive.

7. Held at King's College London Geography Department. Sheet no. 532.

8. The first cartographic record of these tracks is from the Ordnance Survey Surveyor's Drawings (British Map Library sheet no. 302, drawn 1819, published 1837-1840, 2 inches:1 mile).

9. PRO (Kew) Class MAF 68.

10. The first cartographic record of this structure is from the first edition Ordnance Survey 6 inch map (see note 5).

11. Air Photograph Office, Welsh Office, Cardiff. 1:10,000.
    340: 3268, 3269. May 2nd 1946.

LLYN EIDDEW-BACH SPECIES LIST

AC002A	ACHNANTHES LINEARIS	W. SMITH
AC002C	ACHNANTHES LINEARIS V PUSILLA	GRUN.
AC003A	ACHNANTHES MICROCEPHALA	KUTZ.
AC006B	ACHNANTHES CLEVEI V ROSTRATA	HUST.
AC013A	ACHNANTHES MINUTISSIMA	KUTZ.
AC014A	ACHNANTHES AUSTRIACA	HUST.
AC017A	ACHNANTHES KRYOPHILA	BOYE PETERSON
AC022A	ACHNANTHES MARGINULATA	GRUN.
AC030A	ACHNANTHES UMARA	CARTER
AC042A	ACHNANTHES DETHA	
AC9999	ACHNANTHES SP	
AM001B	AMPHORA OVALIS V PEDICULUS	KUTZ.
AN004A	ANOMOEONEIS VITREA	(GRUN.) ROSS
CA002A	CALONEIS BACILLUM	(GRUN.) MERESCHKOWSKY
CM001A	CYMBELLA VENTRICOSA	KUTZ.
CM004A	CYMBELLA MICROCEPHALA	GRUN.
CM007A	CYMBELLA CYMBIFORMIS	(AGARDH/ KUTZ.) V. HEURCK
CM010A	CYMBELLA PERPUSILLA	A. CLEVE
CM017A	CYMBELLA HEBRIDICA	(GREGORY) GRUN.
CM018A	CYMBELLA GRACILIS	(RABH.) CLEVE
CM020A	CYMBELLA GAEUMANNI	MEISTER
CM022A	CYMBELLA AFFINIS	KUTZ.
CM031B	CYMBELLA MINUTA V PSEUDOGRACILIS	(CHOLNOKY) REIMER
CM9992	CYMBELLA SP 1	PIRLA
CM9999	CYMBELLA SP.	
CO001C	COCCONEIS PLACENTULA V LINEATA	(EHR.) CLEVE
CO006A	COCCONEIS DIMINUTA	PANT.
CY004A	CYCLOTELLA STELLIGERA	CLEVE ET GRUN.
CY006A	CYCLOTELLA KUTZINGIANA	THWAITES
DE001B	DENTICULA TENUIS V CRASSULA	(NAEGELI) HUST.
DP012A	DIPLONEIS MARGINESTRIATA	HUST.
EU001A	EUNOTIA VENERIS	(KUTZ.) O. MULLER
EU002A	EUNOTIA PECTINALIS	(KUTZ.) RABH.
EU002B	EUNOTIA PECTINALIS V MINOR	(KUTZ.) RABH.
EU005A	EUNOTIA ALPINA	(NAEGELI) HUST.
EU006A	EUNOTIA LUNARIS	(EHR.) GRUN.
EU011A	EUNOTIA RHOMBOIDEA	HUST.
EU012A	EUNOTIA ROBUSTA	RALFS
EU025A	EUNOTIA FALLAX	CLEVE
EU9983	EUNOTIA SP 1	L.HIR (SF)
EU9989	EUNOTIA SP 7	L.HIR (SF)
EU9991	EUNOTIA SP 3	L.HIR (SF)
EU9999	EUNOTIA SP	
FR001A	FRAGILARIA PINNATA	EHR.
FR002A	FRAGILARIA CONSTRUENS	(EHR.) GRUN.
FR002C	FRAGIALRIA CONSTRUENS V VENTER	(EHR.) GRUN.
FR005A	FRAGILARIA VIRESCENS	RALFS
FR006A	FRAGILARIA BREVISTRIATA	GRUN.
FR007A	FRAGILARIA VAUCHERIAE	(KUTZ.) BOYE PETERSON
FR9995	FRAGILARIA CF PINNATA V LANCETTULA	L.HIR (SF)
FR9999	FRAGILARIA SP	
FU002A	FRUSTULIA RHOMBOIDES	(EHR.) DE TONI
FU002B	FRUSTULIA RHOMBOIDES V SAXONICA	(RABH.) DE TONI
GO003A	GOMPHONEMA ANGUSTATUM	(KUTZ.) RABH.
GO004A	GOMPHONEMA GRACILE	EHR.
GO006A	GOMPHONEMA ACUMINATUM	EHR.
GO013A	GOMPHONEMA PARVULUM	KUTZ.
GO014B	GOMPHONEMA INTRICATUM V PUMILA	GRUN.
GO9999	GOMPHONEMA SP	
ME004A	MELOSIRA LIRATA	(EHR.) KUTZ.
ME004C	MELOSIRA LIRATA V LACUSTRIS	GRUN.
ME005A	MELOSIRA DISTANS	(EHR.) KUTZ.
ME010A	MELOSIRA PERGLABRA	OSTRUP
ME010B	MELOSIRA PERGLABRA V FLORINIAE	CAMBURN
ME014A	MELOSIRA NYGAARDII	CAMBURN
ME9999	MELOSIRA SP	
NA002A	NAVICULA JARNEFELTII	HUST.
NA003A	NAVICULA RADIOSA	KUTZ.
NA003B	NAVICULA RADIOSA V TENELLA	(BREB.) GRUN.
NA005A	NAVICULA SEMINULUM	GRUN.
NA006A	NAVICULA MEDIOCRIS	KRASSKE
NA007A	NAVICULA CRYPTOCEPHALA	KUTZ.
NA009A	NAVICULA LANCEOLATA	(AGARDH) KUTZ.
NA013A	NAVICULA PSEUDOSCUTIFORMIS	HUST.
NA014A	NAVICULA PUPULA	KUTZ.
NA015A	NAVICULA HASSIACA	KRASSKE
NA016A	NAVICULA INDIFFERENS	HUST.
NA032A	NAVICULA COCCONEIFORMIS	GREGORY
NA033A	NAVICULA SUBTILISSIMA	CLEVE
NA037A	NAVICULA ANGUSTA	GRUN.
NA038A	NAVICULA ARVENSIS	HUST.
NA041A	NAVICULA HEIMANSII	VAN DAM & KOOY.
NA042A	NAVICULA MINIMA	GRUN.
NA043A	NAVICULA SUBATOMOIDES	HUST.
NA045A	NAVICULA BRYOPHILA	PETERSEN
NA082A	NAVICULA MURALIS	GRUN.
NA084A	NAVICULA ATOMUS	(KUTZ.) GRUN.
NA099A	NAVICULA BREMENSIS	HUST.
NA123A	NAVICULA MODICA	HUST.
NA129A	NAVICULA SEMINULOIDES	HUST.
NA135A	NAVICULA TENUICEPHALA	HUST.
NA140A	NAVICULA MADUMENSIS	JORGENSEN
NA141A	NAVICULA DISJUNCTA	HUST.
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NA9945	NAVICULA CF STRENZKEI	EIDDAW BACH (SF)
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NA9955	NAVICULA CF VITIOSA	L.HIR (SF)
NA9957	NAVICULA CF SCHASSMANNII	L.HIR (SF)
NA9960	NAVICULA SP 8	L.HIR (SF)
NA9961	NAVICULA SP 4	L.HIR (SF)
NA9962	NAVICULA SP 2	L.HIR (SF)
NA9963	NAVICULA SP 1	L.HIR (SF)
NA9965	NAVICULA PELLICULOSA/PERMITIS	L.HIR (SF)
NA9999	NAVICULA SP	
NE003B	NEIDIUM AFFINE V LONGICEPS	(GREGORY) CLEVE
NE004A	NEIDIUM BISULCATUM	(LAGERSTEDT) CLEVE
NE9999	NEIDIUM SP	
NI005A	NITZSCHIA PERMINUTA	GRUN.
NI014A	NITZSCHIA AMPHIBIA	GRUN.
NI9989	NITZSCHIA CF FONTICOLA	L.HIR (SF)
NI9999	NITZSCHIA SP	
OP001A	OPEPHORA MARTYI	HERIBAUD
PI007C	PINNULARIA VIRIDIS V FALLAX	CLEVE
PI015A	PINNULARIA ABAUJENSIS	(PANT.) ROSS
PI018A	PINNULARIA BICEPS	GREGORY
PI021A	PINNULARIA HILSEANA	(JANISCH) MULL.
PI031A	PINNULARIA ACROSPHAERIA	BREB.
PI033B	PINNULARIA BRAUNII V AMPHICEPHALA	(A. MAYER) [illegible]
PI9992	PINNULARIA CF TERMITINA	L.HIR (SF)
PI9999	PINNULARIA SP	
SA001B	STAURONEIS ANCEPS F GRACILIS	(EHR.) CLEVE
SA004A	STAURONEIS ALPINA	HUST.
SA006A	STAURONEIS PHOENICENTERON	(NITZSCH) EHR
ST004A	SYNEDRA PARASITICA	W. SMITH
TA001A	TABELLARIA FLOCCULOSA	(ROTH) KUTZ.
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UN9996	PERIPHYTON	
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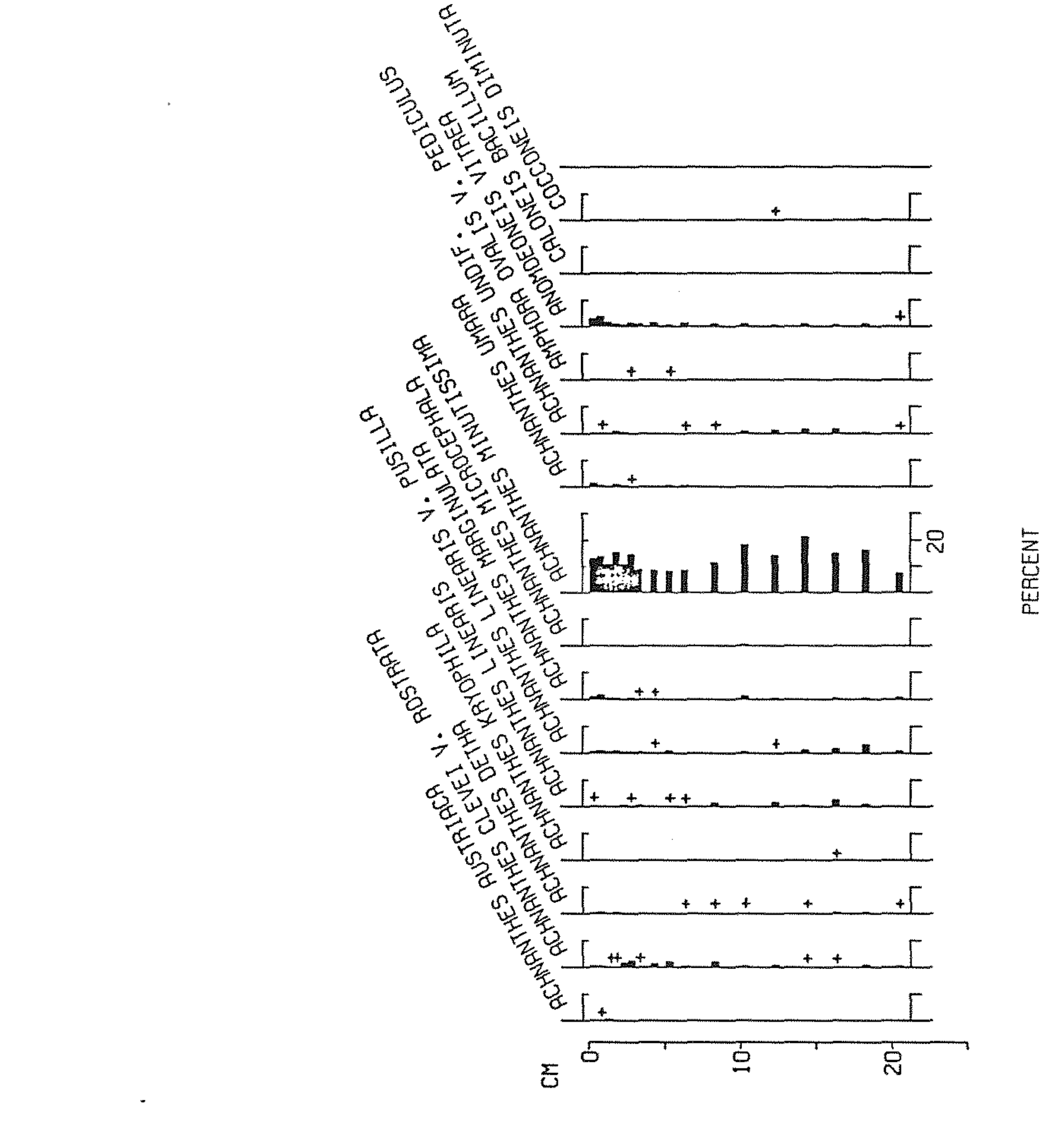
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ACHNANTHES MINUTISSIMA
ACHNANTHES UMARA
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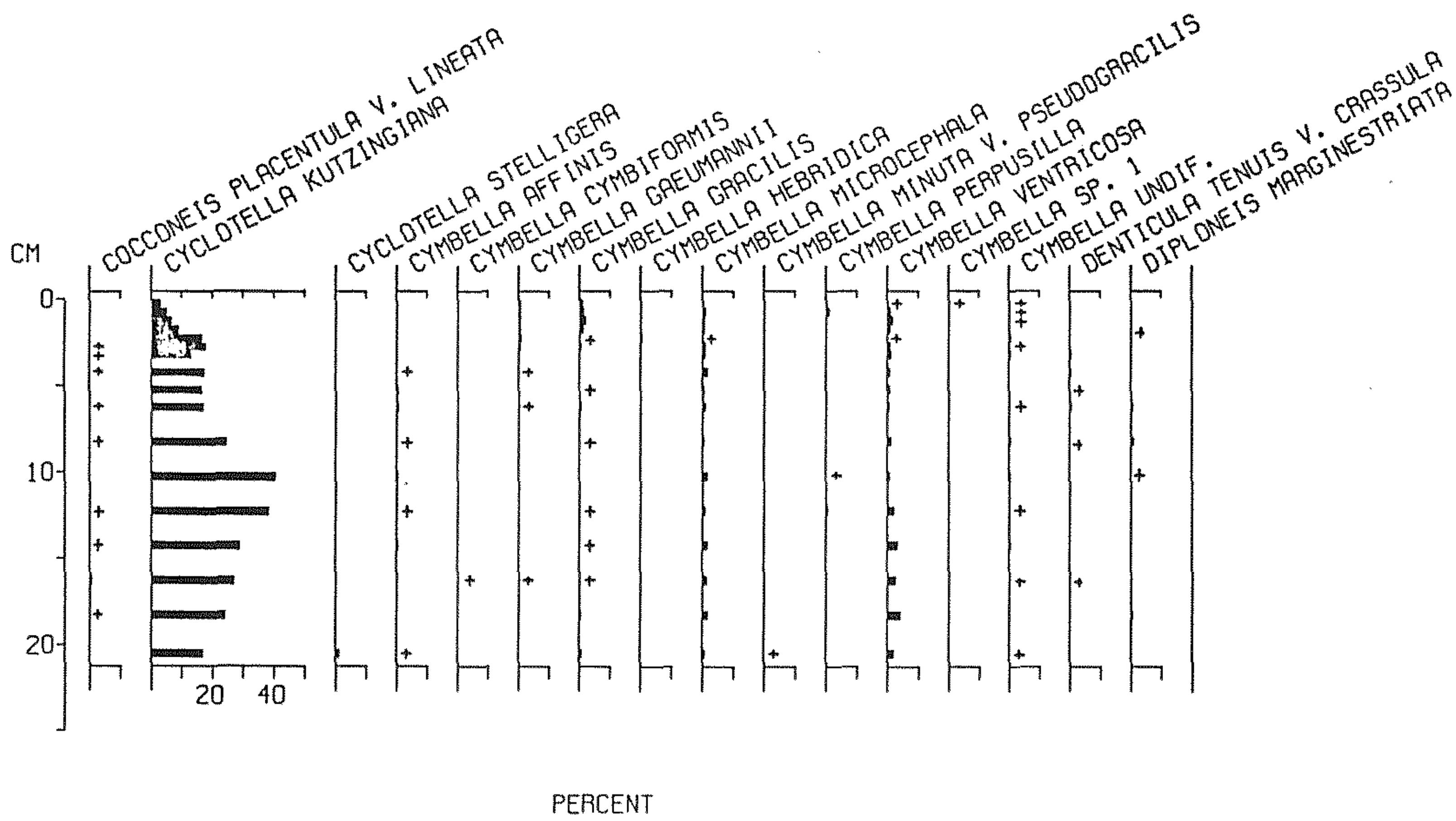
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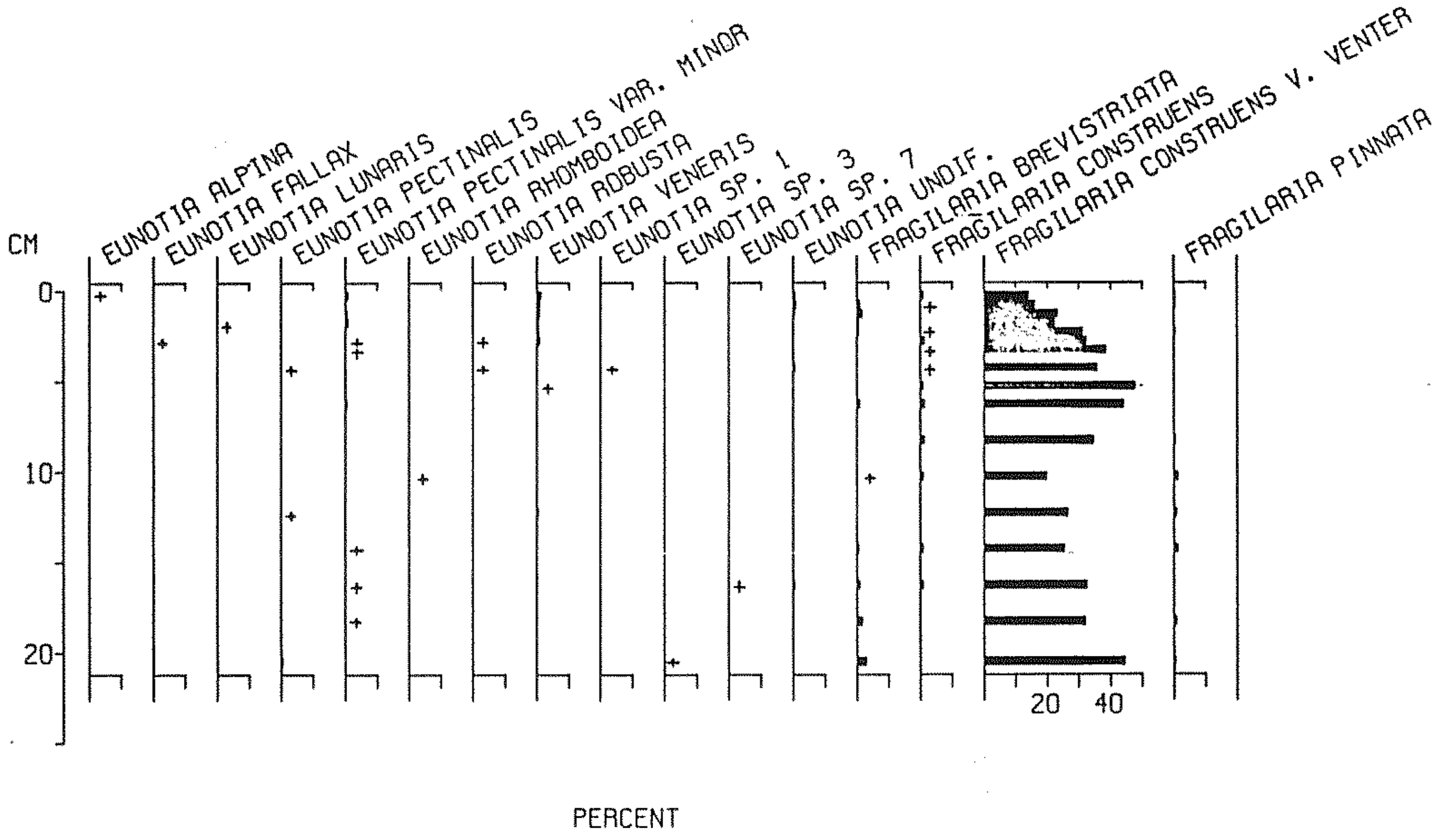
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EUNOTIA RHOMBOIDEA
EUNOTIA ROBUSTA
EUNOTIA VENERIS
EUNOTIA SP. 1
EUNOTIA SP. 3
EUNOTIA SP. 7
EUNOTIA UNDIF.
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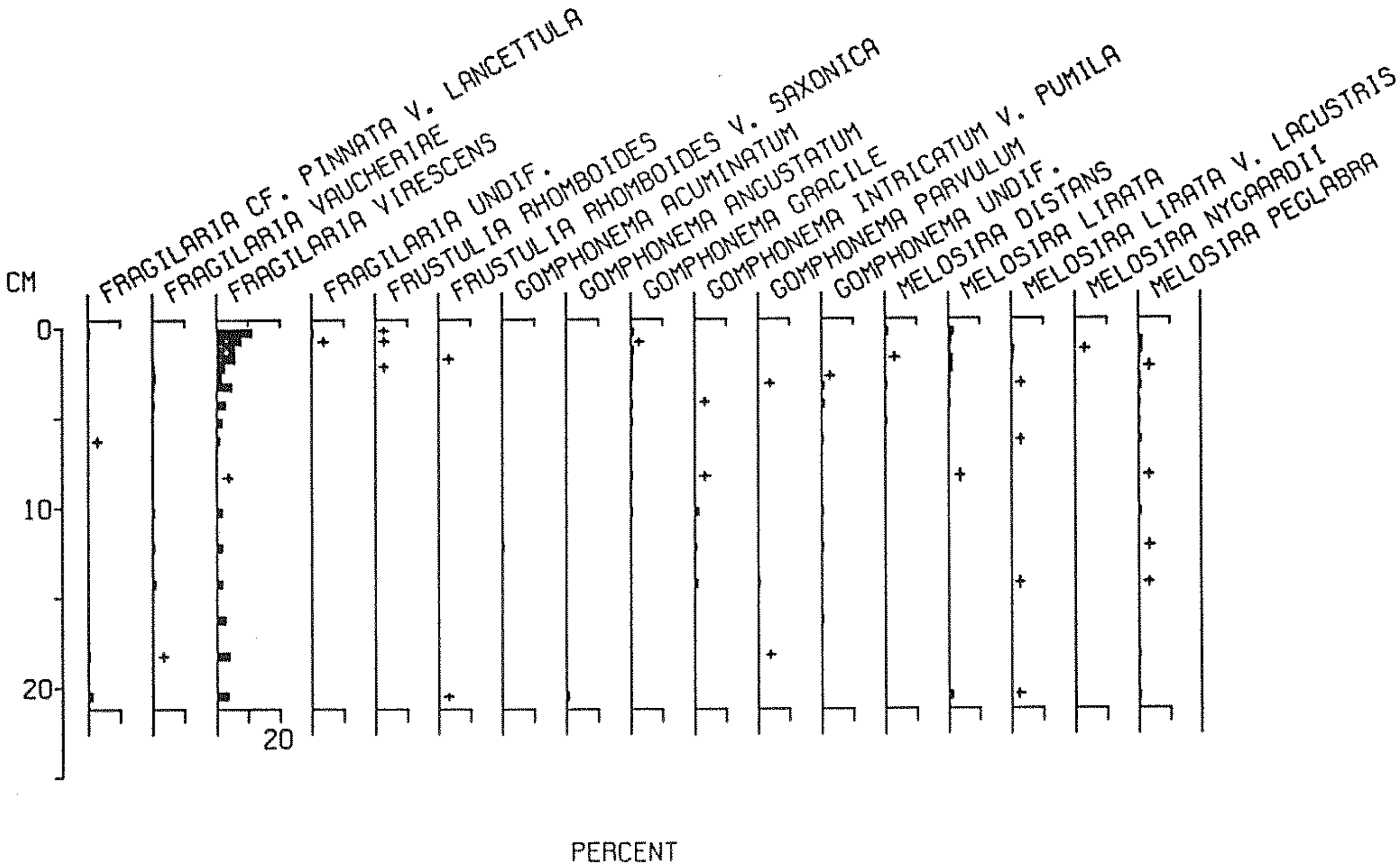
PERCENT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FRUSTULIA RHOMBOIDES V. SAXONICA
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GOMPHONEMA PARVULUM
GOMPHONEMA UNDIF.
MELOSIRA DISTANS
MELOSIRA LIRATA
MELOSIRA LIRATA V. LACUSTRIS
MELOSIRA NYGAARDII
MELOSIRA PEGLABRA
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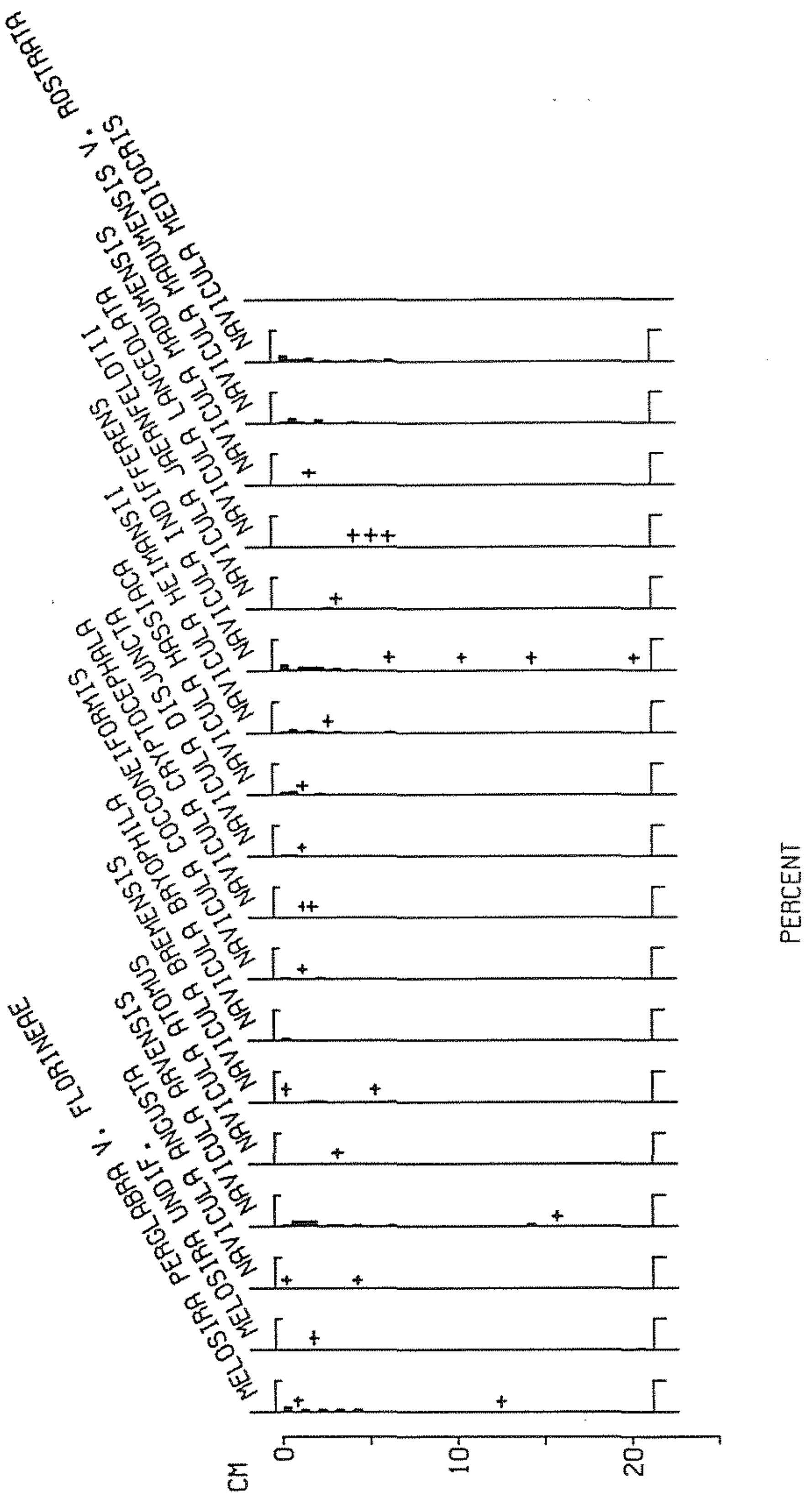
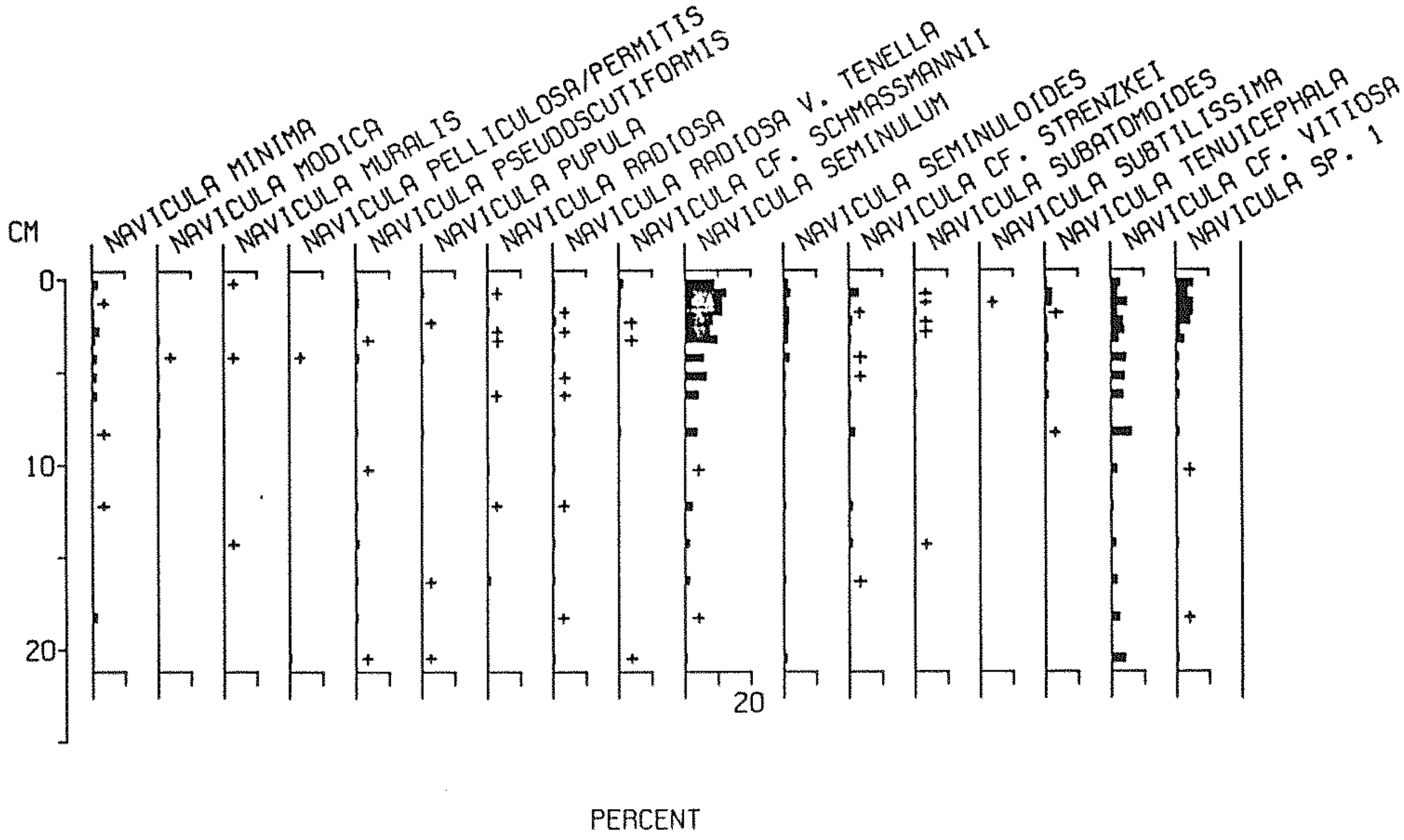
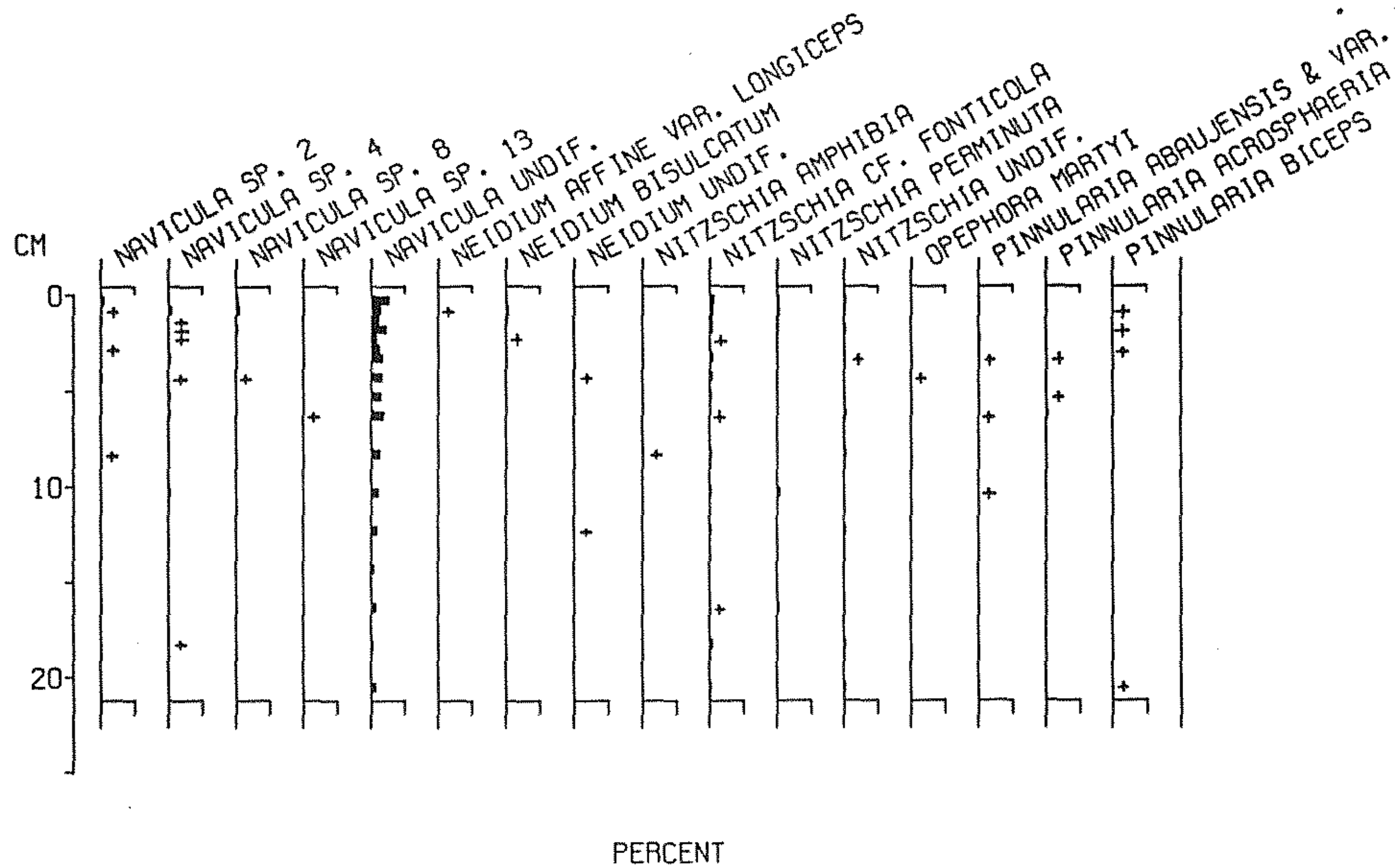
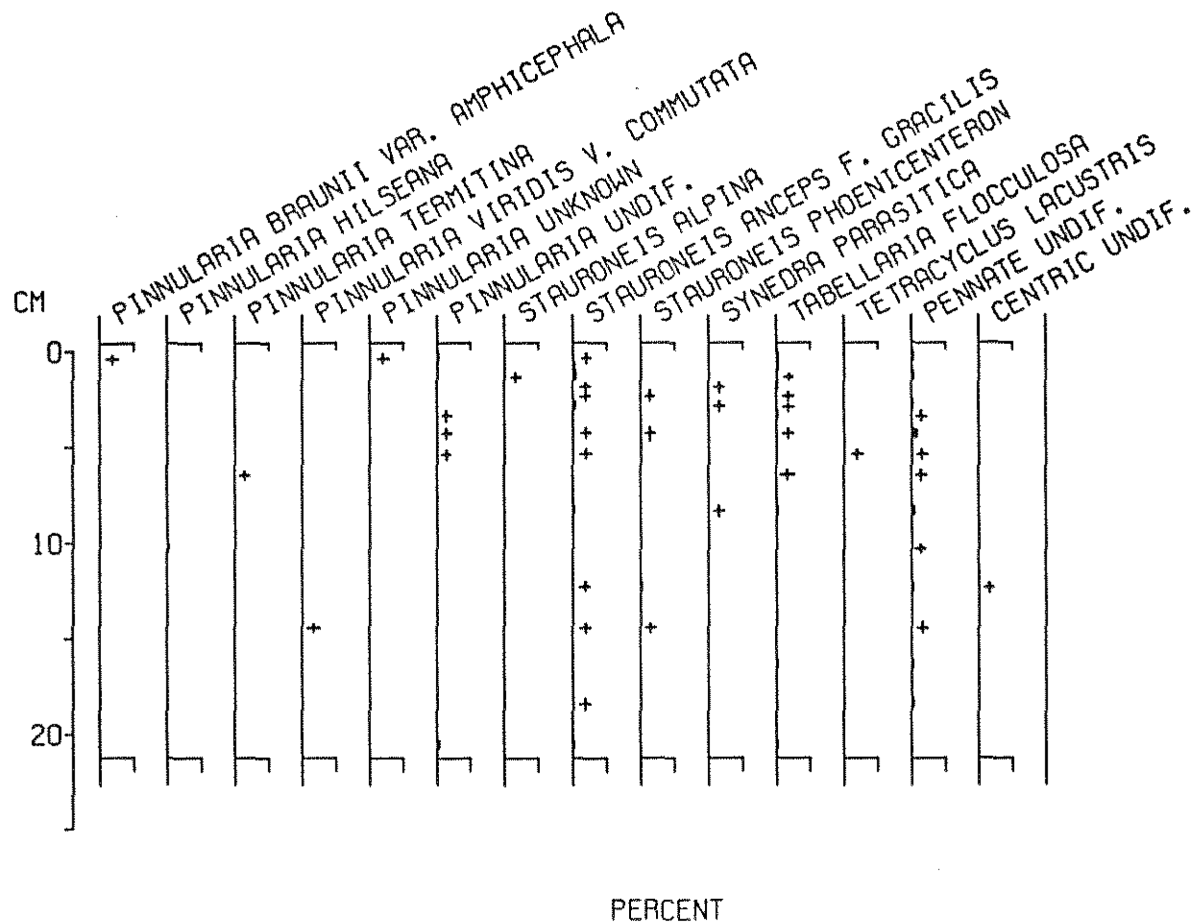
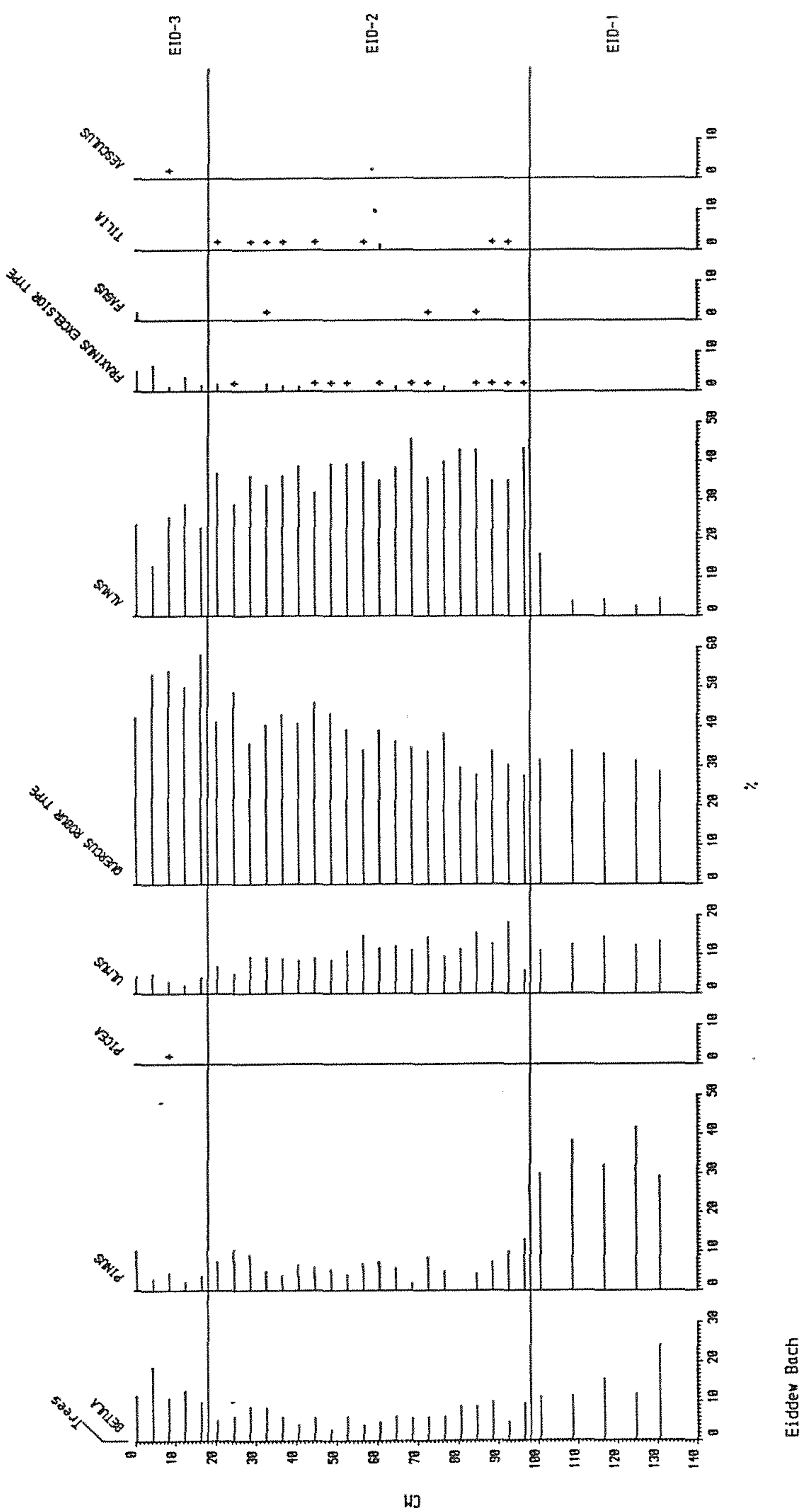
10
20
20
PERCENT

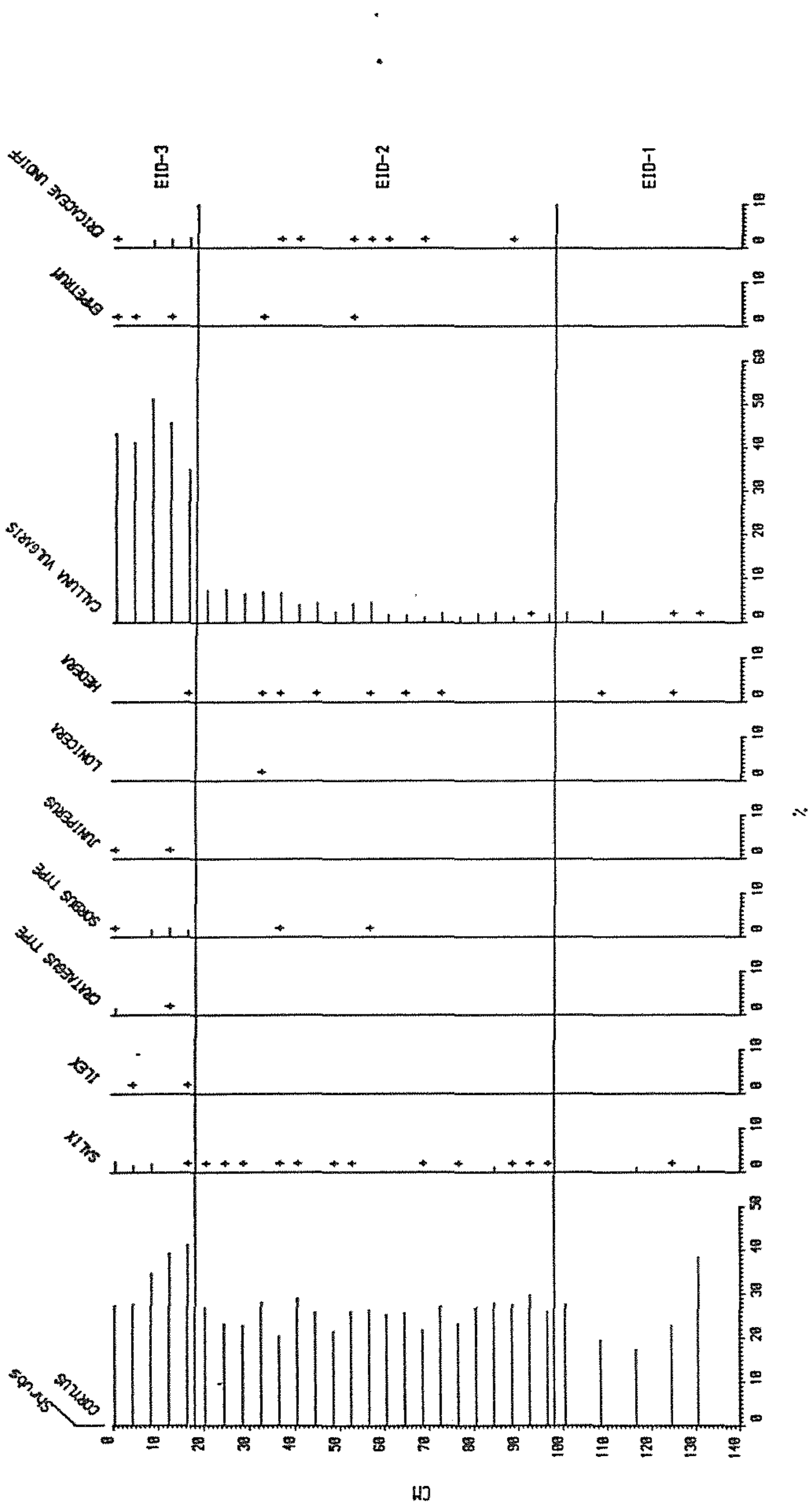

MELOSIRA PERGLABRA V. FLORINEAE
MELOSIRA UNDIF. ANGUSTA
NAVICULA ARVENSIS
NAVICULA ATOMUS
NAVICULA BREMENSIS
NAVICULA BRYOPHILLA
NAVICULA COCCONEIFORMIS
NAVICULA CRYPTOCEPHALA
NAVICULA DISJUNCTA
NAVICULA HASSIACA
NAVICULA HEIMANSII
NAVICULA INDIFFERENS
NAVICULA JAERNFELDTII
NAVICULA LANCEOLATA
NAVICULA MADUMENSIS
NAVICULA MADUMENSIS V. ROSTRATA
NAVICULA MEDIOCRIS
CM
0
10
20
PERCENT


NAVICULA MINIMA
NAVICULA MODICA
NAVICULA MURALIS
NAVICULA PELLICULOSA/PERMITIS
NAVICULA PSEUDOSCUTIFORMIS
NAVICULA PUPULA
NAVICULA RADIOSA
NAVICULA RADIOSA V. TENELLA
NAVICULA CF. SCHMASSMANNII
NAVICULA SEMINULUM
NAVICULA SEMINULOIDES
NAVICULA CF. STRENZKEI
NAVICULA SUBATOMOIDES
NAVICULA SUBTILISSIMA
NAVICULA TENUICEPHALA
NAVICULA CF. VITIOSA
NAVICULA SP. 1
CM
0
10
20
20
PERCENT

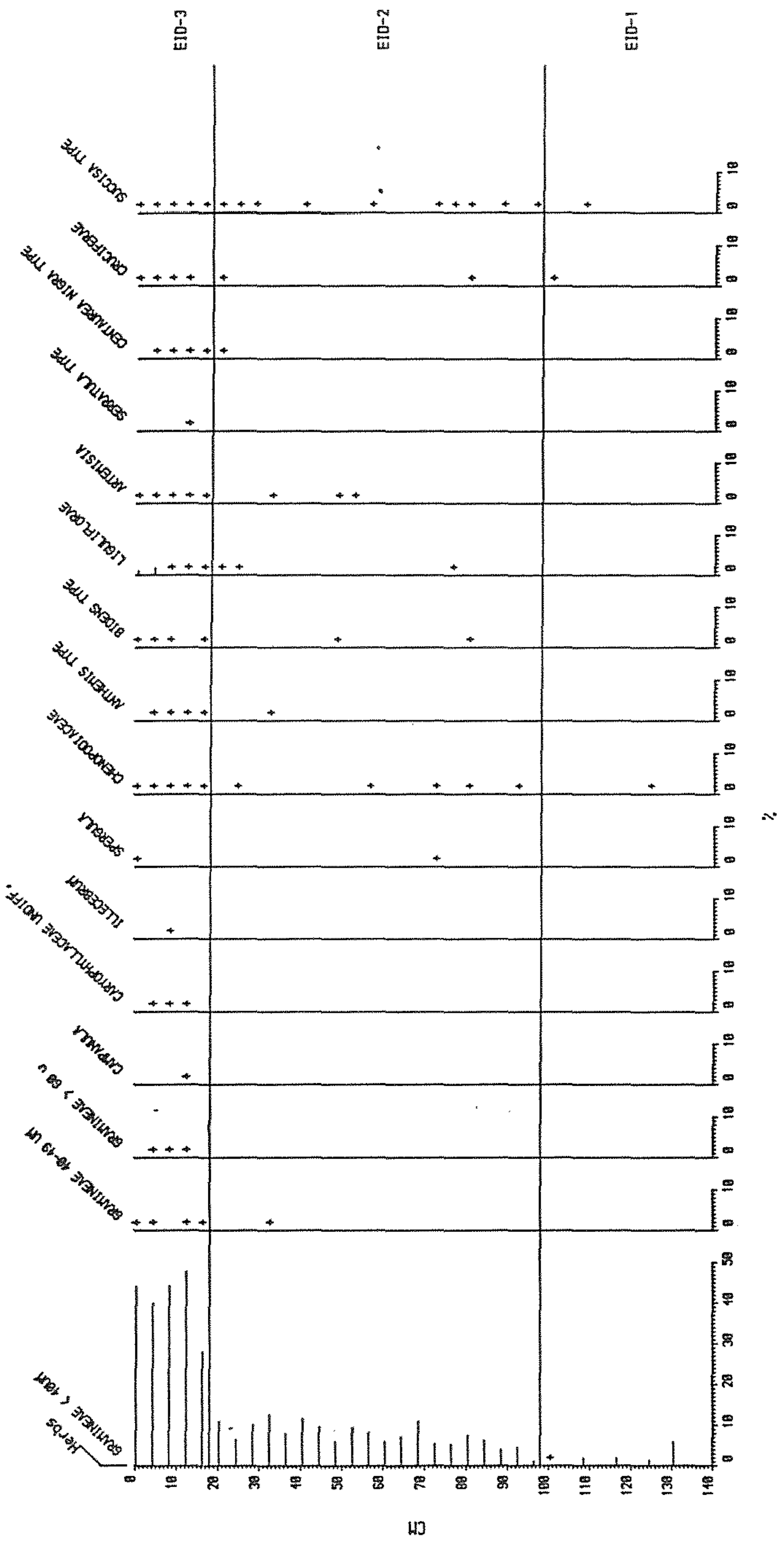

CM
0
10
20
NAVICULA SP. 2
NAVICULA SP. 4
NAVICULA SP. 8
NAVICULA SP. 13
NAVICULA UNDIF.
NEIDIUM AFFINE VAR. LONGICEPS
NEIDIUM BISULCATUM
NEIDIUM UNDIF.
NITZSCHIA AMPHIBIA
NITZSCHIA CF. FONTICOLA
NITZSCHIA PERMINUTA
NITZSCHIA UNDIF.
OPEPHORA MARTYI
PINNULARIA ABAUJENSIS & VAR.
PINNULARIA ACROSPHAERIA
PINNULARIA BICEPS
PERCENT


CM
0
10
20
PINNULARIA BRAUNII VAR. AMPHICEPHALA
PINNULARIA HILSEANA
PINNULARIA TERMITINA
PINNULARIA VIRIDIS V. COMMUTATA
PINNULARIA UNKNOWN
PINNULARIA UNDIF.
STAURONEIS ALPINA
STAURONEIS ANCEPS F. GRACILIS
STAURONEIS PHOENICENTERON
SYNEDRA PARASITICA
TABELLARIA FLOCCULOSA
TETRACYCLUS LACUSTRIS
PENNATE UNDIF.
CENTRIC UNDIF.
PERCENT

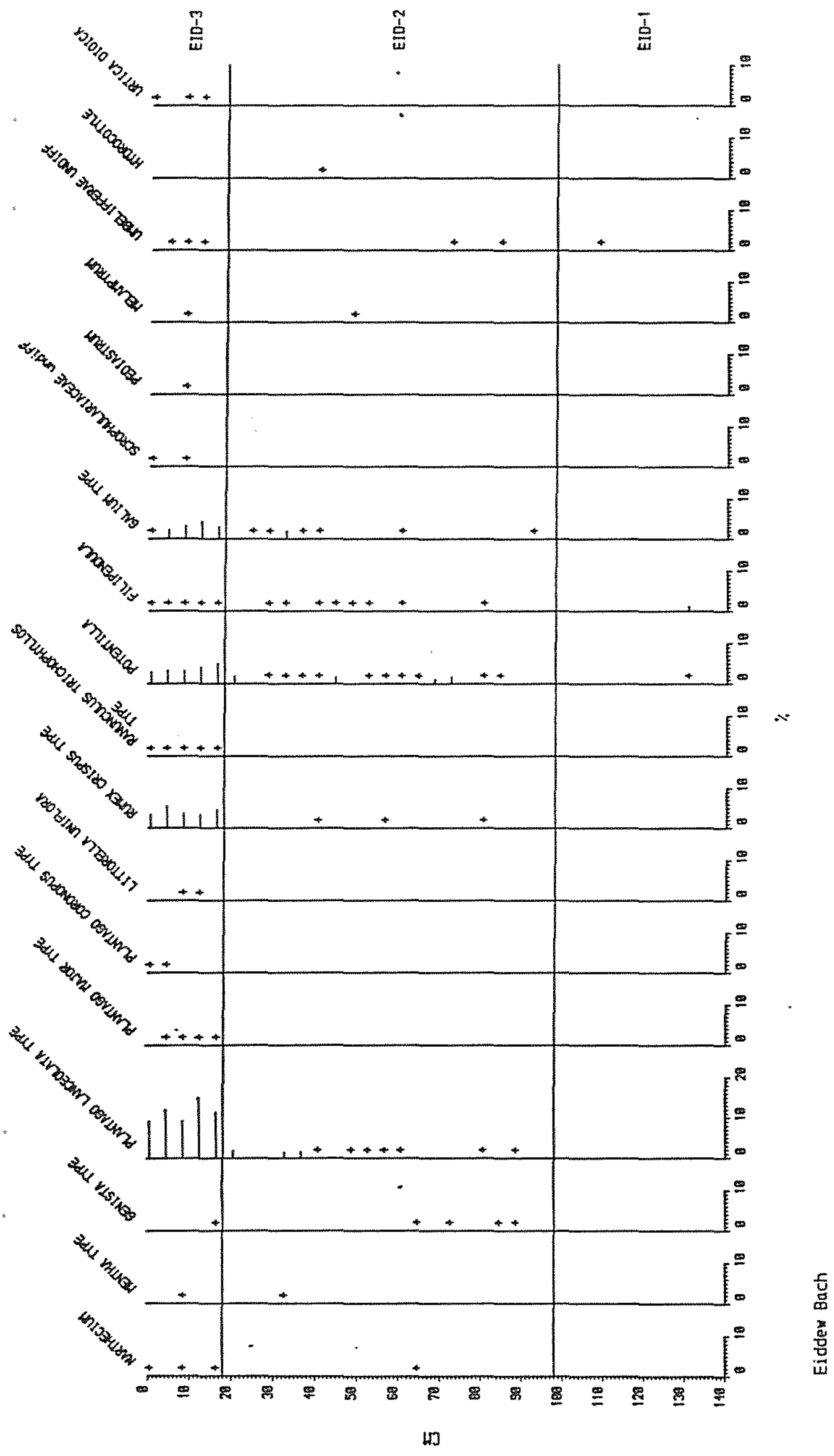

Trees
BETULA
PINUS
PICEA
ULMUS
QUERCUS ROBUR TYPE
ALNUS
FRAXINUS EXCELSIOR TYPE
FAGUS
TILIA
AESCULUS
EID-3
EID-2
EID-1
CM
%
Eiddew Bach

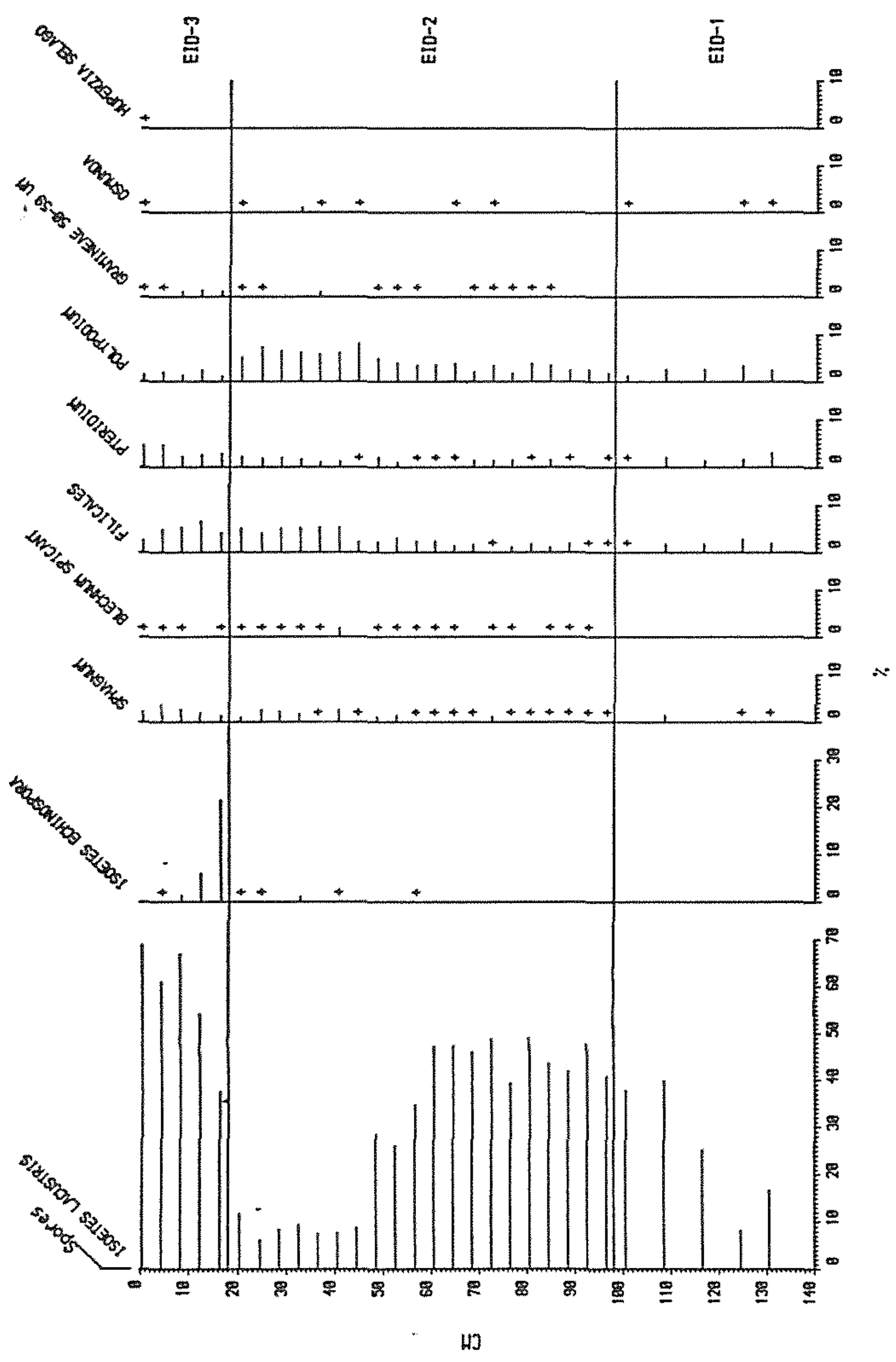

Shrubs
CORYLUS
SALIX
ILEX
CRATAEGUS TYPE
SORBUS TYPE
JUNIPERUS
LONICERA
HEDERA
CALLUNA VULGARIS
EMPETRUM
ERICACEAE UNDIFF
EID-3
EID-2
EID-1
CM
%

Eiddew Bach

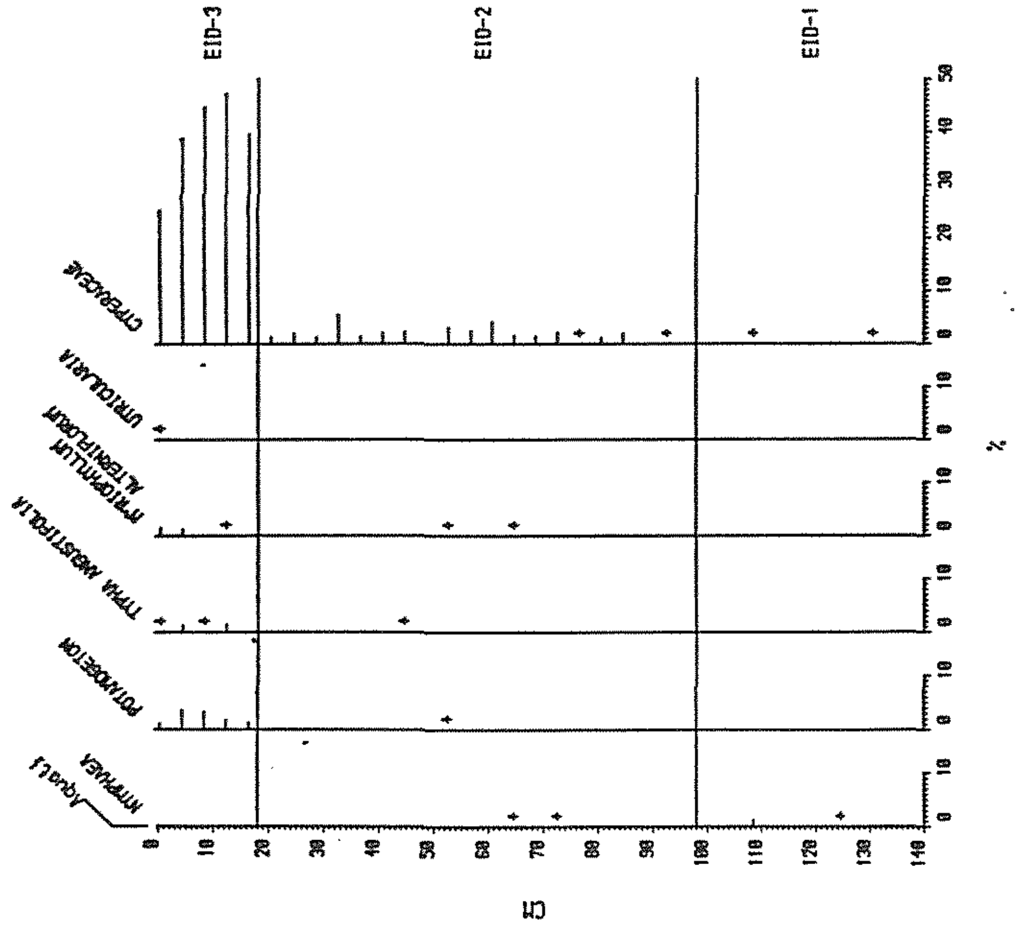

EID-3
EID-2
EID-1
SUCCISA TYPE
CRUCIFERAE
CENTAUREA NIGRA TYPE
SERRATULA TYPE
ARTEMISIA
LIGULIFLORAE
BIDENS TYPE
ANTHEMIS TYPE
CHENOPODIACEAE
SPERGULA
ILLECEBRUM
CARYOPHYLLACEAE UNDIFF.
CAMPANULA
GRAMINEAE > 60 u
GRAMINEAE 40-19 UM
Herbs
GRAMINEAE < 40UM
%
CM

Eiddew Bach


URTICA DIOICA
HYDROCOTYLE
UMBELLIFERAE UNDIFF
HELIANTHEMUM
PEDIASTRUM
SCROPHULARIACEAE undiff
GALIUM TYPE
FILIPENDULA
POTENTILLA
RANUNCULUS TRICHOPHYLLOS TYPE
RUMEX CRISPUS TYPE
LITTORELLA UNIFLORA
PLANTAGO CORONOPUS TYPE
PLANTAGO MAJOR TYPE
PLANTAGO LANCEOLATA TYPE
GENISTA TYPE
MENTHA TYPE
NARTHECIUM
EID-3
EID-2
EID-1
CM
%
Eiddew Bach


Spores
ISOETES LACUSTRIS
ISOETES ECHINOSPORA
SPHAGNUM
BLECHNUM SPICANT
FILICALES
PTERIDIUM
POLYPODIUM
GRAMINEAE 50-59 UM
OSMUNDA
HUPERZIA SELAGO
EID-1
EID-2
EID-3
CM
%

Eiddew Bach


EID-3
EID-2
EID-1
CYPERACEAE
UTRICULARIA
MYRIOPHYLLUM ALTERNIFLORUM
TYPHA ANGUSTIFOLIA
POTAMOGETON
NYMPHAEA
Aquatics
cm
%

Eiddew Bach

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