

Arcellaceans in Nova Scotia:
selected biostratigraphic studies

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ABSTRACT

Surficial sediment samples and cores from both Albro and Penhorn Lakes were examined to determine the biostratigraphy of the lakes, based on arcellaceans. Considerable morphological variation of species is noted and illustrates the taxonomic problems of previous authors. Microfaunal assemblages change over time in both total numbers and species diversity. An inverse relationship through time seems to exist between Centropyxis spp. and species of the genus Diffflugia. Results of the arcellacean analysis compared with carbon-14 and pollen data indicate an almost complete post-glacial record in these lakes. The results indicate that arcellaceans are a valuable tool in paleolimnological studies.

INTRODUCTION

Testate rhizopods, which include the protozoan superfamily Arcellacea, have been placed into an artificial group known as "thecamoebians" (Loeblich and Tappan, 1964). They are amoeboid protozoa consisting of a cytoplasmic body enclosed in a test, or shell, with an aperture from which fingerlike projections of cytoplasm, the pseudopods, are extruded. Most species are thought to be cosmopolitan and are present in a wide range of moist and freshwater habitats (Medioli and Scott, 1983).

Since the first description of Diffflugia in 1816 (LeClerc), hundreds of species of Arcellacea have been described, creating a number of taxonomic difficulties. These problems have arisen over the criteria used to classify thecamoebians, an asexual group, to the species level. A taxonomic review of Arcellacea in Eastern Canada has been completed by Medioli and Scott (1983) and has alleviated many of the problems present in the earlier literature.

Apparently most thecamoebians have no paleontological importance because only a few species of the superfamily Arcellacea are commonly found fossilized. The arcellaceans have agglutinated tests, which makes them resistant to dissolution or organic breakdown, and are primarily benthic, reflecting conditions at the sediment-water interface.

Many freshwater fossils, such as ostracods and molluscs, tend to dissolve after burial in low pH sediments. Microfossils with organic shields which are preserved, such as pollen, spores and diatoms, generally do not reflect the benthic environment, whereas arcellaceans are representative of bottom conditions and may be used as a tool for

biostratigraphic analysis of freshwater sediments.

This project was initially an attempt to correlate observed arcellacean assemblages and the pH conditions of the water. The two lakes selected for the study were Albro and Penhorn lakes, the former slightly acidic and the latter slightly alkaline. Although there are differences in the assemblages observed, it became obvious that the sample size was too small (ie. the number of lakes sampled) to make conclusions on the effects of pH since other chemical and physical parameters were also affecting the lakes. However, the faunal assemblages of these lakes were studied to give information on benthic conditions of the lakes throughout their history thus contributing to the current study of post-glacial history of Atlantic Canada.

STRATIGRAPHIC RANGE

Arcellaceans are commonly found in Holocene lacustrine sediments although there are reports of their presence in older deposits. Vasicek and Ruzicka (1957) report the presence of Arcellaceans in the Carboniferous although Medioli and Scott (1983) have some reservations about these records. Although the stratigraphic range of arcellaceans may be short, they have become important tools in paleolimnological studies (eg. Scott and Medioli, 1983) due to their cosmopolitan distribution and their resistance to dissolution in low pH conditions.

PREVIOUS WORK

From 1816 to the 1930's the taxonomy and biology of Arcellaceans had

been extensively studied. A review of the literature reveals that the taxonomy of this group is chaotic, due to the earlier author's problems in delimiting species. The taxonomic review by Medioli and Scott (1983) has alleviated many of the problems for the arcellaceans, although problems still exist for some species.

Few quantitative distributional studies have been done on fossil material in lakes from North America (Scott and Medioli, 1983) although there has been a shift toward ecological studies using arcellaceans as paleolimnological indicators. Some of these studies include Scott and Medioli (1983), Patterson (1983), Patterson et al. (1985), Kerr (1984) and McCarthy (1984). Honig (1984) used arcellaceans as an indicator of the transition from marine to freshwater conditions from a sea-level study in New Brunswick.

BIOLOGY

The biology of thecamoebians has been extensively studied by previous authors; Deflandre (1953) studied arcellacean biology in some detail. The organism consists of a cytoplasmic amoeboid body enclosed in a test and extrusions of the cytoplasm outside of the test, the pseudopods, are used for locomotion. Thecamoebian reproduction seems to take place almost exclusively by binary fission (Ogden and Hedley, 1980). Small thecamoebians feed mainly on bacteria, fungi and algae (Ogden and Hedley, 1980) while the larger, agglutinated forms tend to prey on other protozoans (Medioli and Scott, in press). Medioli et al., (in prep.), also indicate a large group of arcellaceans appear to be parasitic on filamentous algae.

Test composition and structure is quite variable in thecamoebians. Test composition may be organic or agglutinated and in some cases a combination of the two. The test of thecamoebians may be secreted by the organism; secreted components are termed idiosomes, and the test is referred to as being autogenous. Agglutinated tests are composed of foreign particles, referred to as xenosomes, imbedded in autogenous cement. These are referred to as xenogenous tests.

Line drawings (plate 1), are included to show in greater detail than observed in the SEM photographs (plate 2), the structure and composition of some specimens.

CHAROPHYTES

During the study of Arcellaceans, I have observed the remains of numerous organisms. Of these, only the remains of Characeae are of any paleontological importance and I shall review them briefly. Charophytes belong to the Characeae, a family of upright green plants common in ponds, rivers and lakes throughout the world (Wood, 1967). The plant is represented in fossil material by the presence of oospores (fertilized female cells) which are 500 to 900 microns long, depending on the species. The oospores are referred to as charophytes in this paper. They may be round to oblong while a distinct spiral pattern is visible on the oospore. Classification of charophytes to the species level was not attempted in this paper; only their presence or absence was noted in the samples observed.

The family Characeae has been subdivided into two groups, the Chareae containing the genus Chara and the Nitelleae to which the genus

Nitella belong (Hutchinson, 1975). Species of Nitella are predominantly found in acidic waters (pH 5.5 to around 7.1) while the Chara are common in alkaline waters (pH > 7.0, Hutchinson, 1975). There is some overlap between the two groups in neutral water. The distinction between the two groups was not recorded in this paper since the necessary literature was not available until after the stratigraphy was determined.

REASON FOR STUDY

The purpose of this study was to determine the biostratigraphy, based on arcellaceans, of Albro and Penhorn Lakes, as well as the paleoecology. The arcellacean assemblages give information on benthic conditions of the lake throughout its history. Pollen analysis of Penhorn Lake relates terrestrial conditions to the evolution of the lake. Carbon-14 dates give absolute age of the events.

GEOLOGICAL AND GEOGRAPHICAL SETTING

Albro Lake is located at 44° 41'N, 63° 35'W between 60 and 65 meters above sea level; Penhorn Lake is located at 44° 40'N, 63° 33'W between 50 and 55 meters above sea level (fig. 1). Both lakes are located in Halifax county in the Cambro-Ordovician Meguma Group; Albro Lake in the Goldenville Formation while Penhorn Lake is in the Halifax Formation. These lake basins were probably formed as the Pleistocene glaciers advanced across the area during the last glacial period.

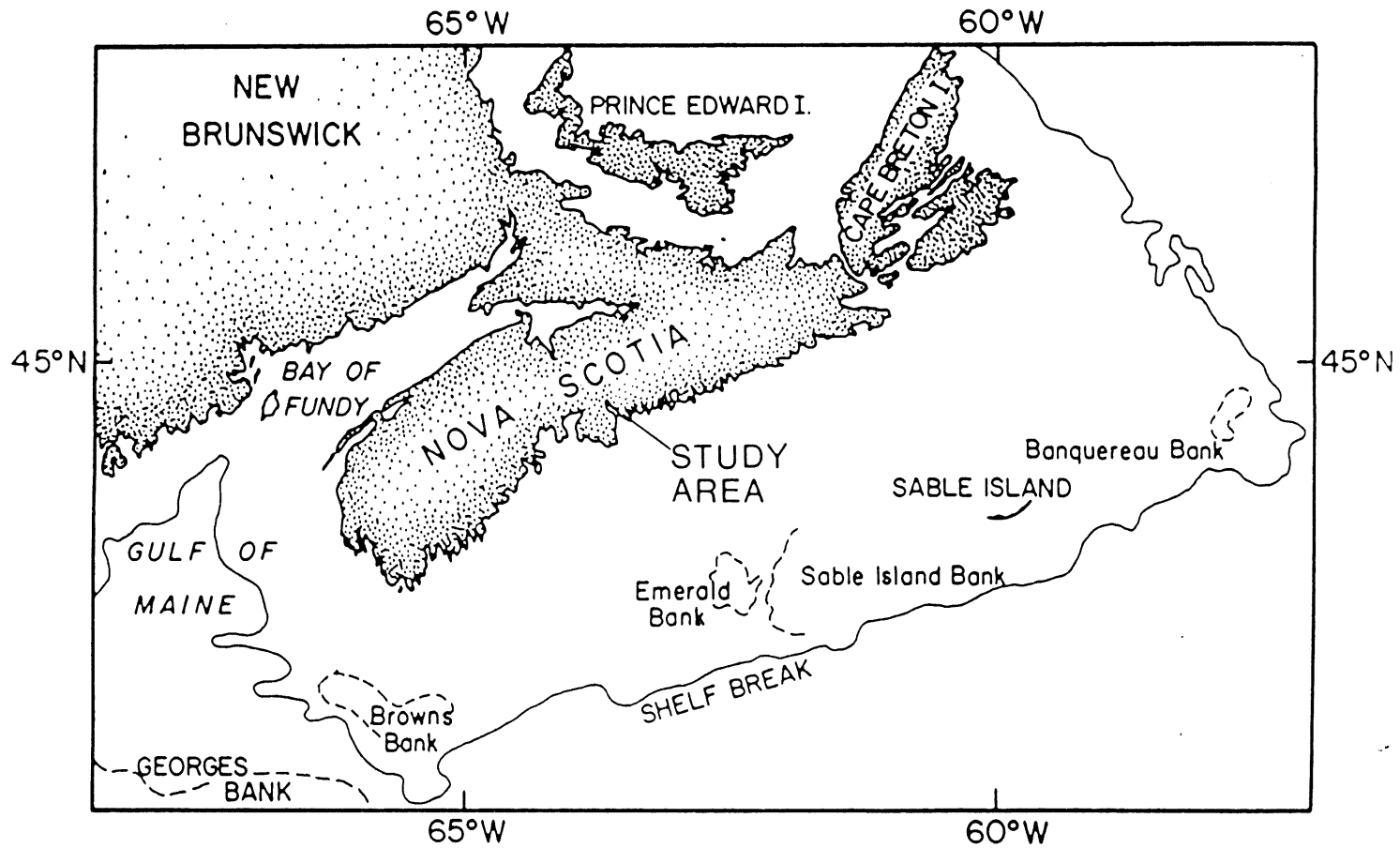


Figure 1. Map of Maritimes showing location of the study area.

METHODS OF COLLECTION AND PREPARATION

Surface samples were collected in June, 1983 from Penhorn Lake and in June and September, 1983 from Albro Lake. These samples were collected by the author and A. Khanna. Cores from both lakes were collected in August, 1984 by the author, T. Duffett, D. Smith and T. LaPierre.

Surface samples were collected using a Ekman box sampler; at each station 10cc replicate samples were removed from the sampler and were then fixed in formalin. Only enough surface samples were counted to determine the general thecamoebian assemblages present at the surface. Cores were obtained using a Livingston square-rod sampler (Wright, 1967). See figure 2 for sample locations. A 1 cm slice (10 cc) was removed from the core at 10 cm intervals and in other areas of interest along the core.

The samples were wet sieved through a 0.5 mm screen (#35 mesh), to retain coarse sediment and organics, and a 0.063 mm screen (#230 mesh) to retain the arcellaceans. None of the samples were decanted as up to 95 per cent of the arcellaceans may be present in the decant (McCarthy, 1984). In the past this fraction has been systematically discarded (eg. Scott and Medioli, 1983). Following sieving, a mixture of formalin and rose Bengal (a stain used to detect living matter) was added to the surface samples and, after standing overnight, samples were rinsed and placed in denatured alcohol. Core samples were treated in a similar manner but no formalin or rose Bengal were added; after sieving the samples were simply placed in denatured ethanol.

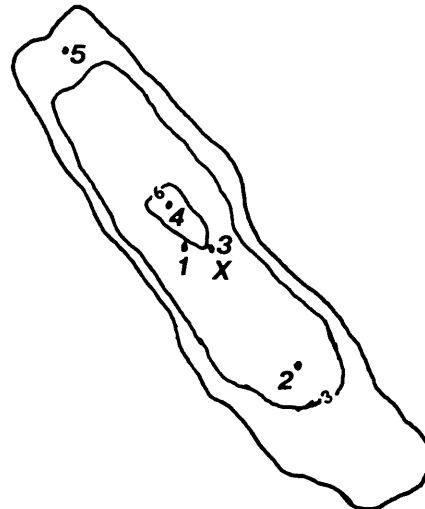
Samples were examined under a binocular microscope, usually at 32x, to determine the arcellacean species present. Representative specimens of

ALBRO LAKE



SCALE
100m

PENHORN LAKE



SCALE
100m

Figure 2. Bathymetric maps of Albro and Penhorn Lakes. Numbers indicate location of surface samples, x marks the sites from which cores were obtained. Black spots are islands.

each species observed were then photographed using a Cambridge 180 scanning electron microscope with Polaroid NP 55 film.

Selected samples from each core were sent to Geochron Laboratories, Cambridge, Massachusetts for carbon-14 dating.

Samples from the Penhorn Lake core were prepared for pollen analysis as outlined in Ogden (1959) by the author and J. Freeman, and the analysis was done by Dr. J. G. Ogden.

RESULTS

Surficial Sediment Samples

Living representatives from most of the arcellacean species were observed in many samples. Living populations were generally small in comparison to total populations, hence total populations were used to define the assemblages present. Total populations include both live and dead specimens that may have accumulated over a few years depending on sedimentation rates. Total populations have been shown (Scott and Medioli, 1980a) to be good indicators of long term, rather than seasonal bottom conditions.

Albro Lake: Fourteen arcellacean species, were identified in the surface material observed (Table 1). The assemblage is dominated by Diffflugia oblonga and Pontigulasia compressa although Centropyxis aculeata and Diffflugia corona also occurred in significant numbers. Total numbers of organisms are moderately large, up to 1516 individuals / 10 cc. Charophytes were present in small numbers in some samples.

Sample	1	2	3	4	5
Water depth (m)	3.0	2.6	10.9	3.6	2.4
Total number of species	14	13	14	13	11
Total number of individuals/10 cc	1211	1329	1156	1229	1516
<u>Centropyxis aculeata</u>	15	13	13	16	17
<u>C. constricta</u>	3	4	4	5	5
<u>Diffflugia bacillifera</u>	x	2	1	1	
<u>D. corona</u>	12	15	13	15	9
<u>D. oblonga</u>	19	23	26	22	24
<u>D. protaeiformis</u>	2	1	1	x	2
<u>D. tricuspis</u>	5	4	5	3	4
<u>D. urceolata</u>	3	3	1	5	4
<u>D. urens</u>	2	2	1	2	1
<u>Heleopera sphagni</u>	::	1	1	x	
<u>Lagenodifflugia vas</u>	6	3	4	4	6
<u>Lecquereusia spiralis</u>	5	4	4	3	6
<u>Nevela collaris</u>	x		x		
<u>Pontigulasia compressa</u>	25	24	24	21	20
Charophytes	6	2		1	3

Table 1. Percentage occurrences of arcellacean species from Albro Lake and listing of charophytes.

Penhorn Lake: Fourteen arcellacean species, the same as identified in Albro Lake, were also identified in the surface material from Penhorn Lake (Table 2). This assemblage is characterized by the dominance of Difflugia corona; however significant proportions of Difflugia oblonga and Centropyxis aculeata are present. Total numbers of organisms are very high, up to 6955 individuals / 10 cc. In most samples charophytes were present in small numbers.

Biostratigraphy of Albro and Penhorn Lakes

Albro Lake: Microfaunal assemblages contained in the Albro Lake core are summarized in figure 3 and table 3. The total number of individuals per sample is never large, ranging from 0 to 154 individuals /10 cc. Twelve arcellacean species were identified in this core but only two of these, Centropyxis aculeata and Difflugia urens, contributed substantially to the total numbers. A single specimen of Trochammina inflata, a foraminiferal species found typically in marshes (Scott and Medioli, 1980b), was found at 234-235 cm; this specimen was probably transported here by the wind or birds. Total numbers of charophytes fluctuate widely throughout the core. Basal clay, usually present on bedrock or glacial till, was observed at the base of the core, indicating that an almost complete history of Albro Lake since de-glaciation is recorded here.

The segment of the core from 273 cm to the bottom at 284 cm is almost barren; only one arcellacean per sample was present and no charophytes were observed. The largest populations of arcellaceans occur

Sample	1	2	3	4	5
Water depth (m)	6.0	3.6	6.0	8.8	1.8
Total number of species	14	13	14	13	11
Total number of individuals/10 cc	6761	6955	5240	4987	5786
<u>Centropyxis aculeata</u>	14	19	16	16	19
<u>C. constricta</u>	4	3	x	1	2
<u>Diffflugia bacillifera</u>	x	1	x	1	
<u>D. corona</u>	38	39	45	42	43
<u>D. oblonga</u>	17	20	19	20	18
<u>D. protaeiformis</u>	2	1	1	x	1
<u>D. tricuspis</u>	5	4	6	3	4
<u>D. urceolata</u>	3	2	1	5	4
<u>D. urens</u>	2	1	x	2	1
<u>Heleopera sphagni</u>	x	x	1	x	
<u>Lagenodifflugia vas</u>	3	1	2	4	2
<u>Lecquereusia spiralis</u>	5	4	4	3	3
<u>Nebela collaris</u>	x		x		
<u>Pontigulasia compressa</u>	4	4	4	1	2
Charophytes	2	1			

Table 2. Percentage occurrences of arcellacean species from Penhorn Lake and listing of charophytes.

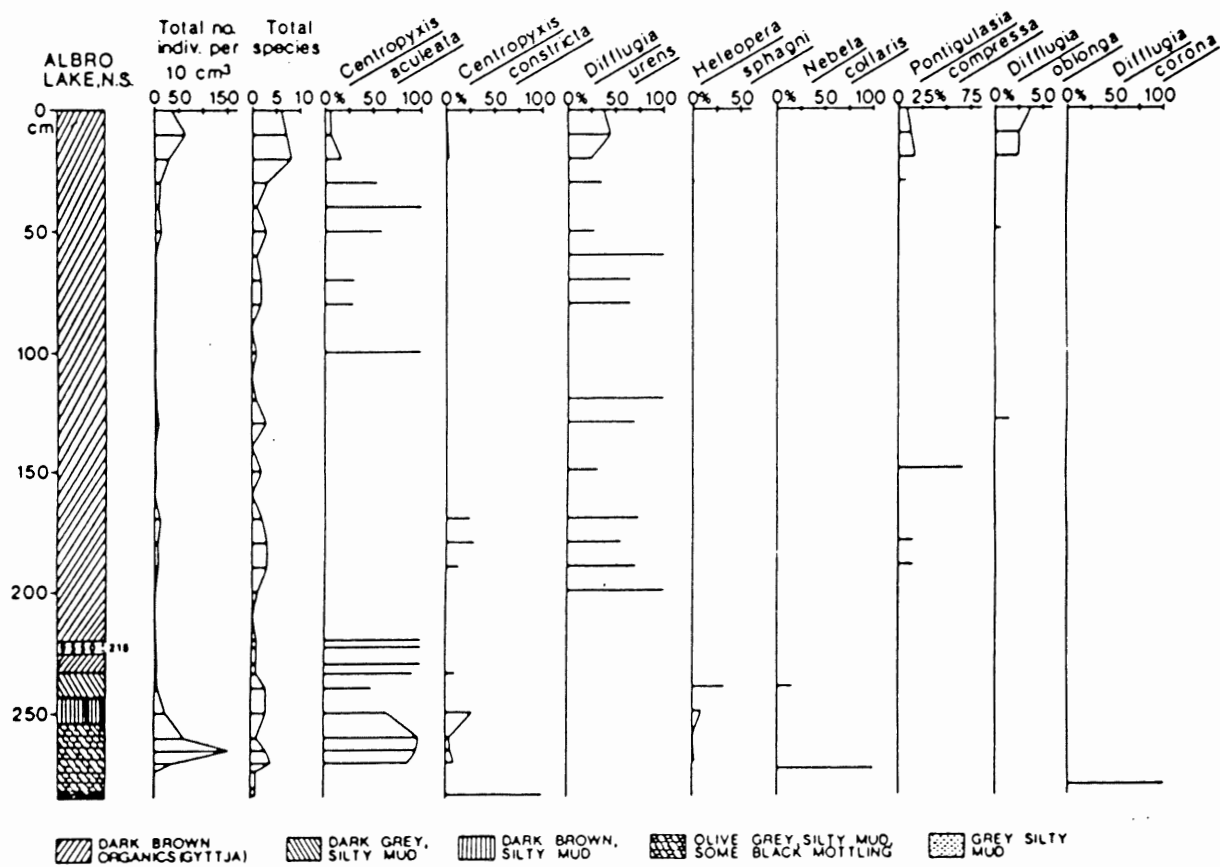


Figure 3. Lithology and biostratigraphy of Albro Lake core. Horizontal lines represent number and percentage values at corresponding levels and vertical lines are subjective averaging.

Depth in core (cm)	0-	10-	20-	30-	40-	50-	60-	70-	80-	90-	100-	110-	120-	130-	140-	150-	160-	170-
Total number of species	1	11	21	31	41	51	61	71	81	91	101	111	121	131	141	151	161	171
Total number of individuals/10 cc	35	64	29	11	9	14	1	3	3	0	1	0	2	7	0	3	0	12
<u>Centropyxis aculeata</u>	6	6	17	55	100	64		33	33		100							
<u>C. constricta</u>		2	3															25
<u>Diffflugia corona</u>																		
<u>D. oblonga</u>	37	25	24			7								14				
<u>D. urceolata</u>	3	5																
<u>D. urceolata f. elongata</u>			3															
<u>D. urens</u>	37	44	24	36		29	100	67	67				100	71		33		75
<u>Heleopera sphagni</u>			3															
<u>Lagenodifflugia vas</u>	9	6	7											14				
<u>Mebela collaris</u>																		
<u>Pontigulasia compressa</u>	9	13	17	9													67	
<u>Trochammina inflata</u>																		
Charophytes	12	57	107	19	20	20	74	74	50	11	7	39	2	1		2	3	1

Depth in core (cm)	180-	190-	200-	210-	220-	223-	230-	234-	240-	250-	259.5-	265-	270-	273-	280-	283-
Total number of species	3	3	1	0	1	1	1	3	3	3	2	3	4	1	1	1
Total number of individuals/10 cc	7	7	1	0	1	2	5	24	6	22	60	154	37	1	1	1
<u>Centropyxis aculeata</u>					100	100	100	88	50	64	97	94	86			
<u>C. constricta</u>	25	29	14					8		27	3	5	8			100
<u>Diffflugia corona</u>																
<u>D. oblonga</u>																
<u>D. urceolata</u>																
<u>D. urceolata f. elongata</u>																3
<u>D. urens</u>	57	71	100													
<u>Heleopera sphagni</u>									33	9		1	3			
<u>Lagenodifflugia vas</u>																
<u>Mebela collaris</u>																100
<u>Pontigulasia compressa</u>		14	14													
<u>Trochammina inflata</u>								4								
Charophytes	36	28	189	120	55	289		24			3	7	83			

Table 3. Percentage occurrences of arcellacean species and foraminiferid *Trochammina inflata* down core in Albro Lake core and listing of charophytes.

in the interval from 270 to 250 cm although species diversity is low. Centropyxis aculeata is the dominant species in this assemblage. At the bottom of this interval charophytes were present in large numbers although they were absent at the top. From 240 to 30 cm arcellaceans are present in low numbers, some samples are barren, and species diversity is low. Centropyxis aculeata and D. urens are the dominant species in this assemblage. Total numbers of charophytes per sample fluctuate widely in this interval. In the top 20 cm of the core, the total number of arcellaceans increases, and the species diversity is higher. Diffflugia oblonga and D. urens are the dominant species in this assemblage. The number of charophytes decreases rapidly towards the top of the core. The top of the core does not match the surface assemblage indicating that the upper few centimeters were missed in coring.

A radiocarbon date of 9550 +/- 215 years B. P. (Lab no. GX-10695) was obtained from 221-225 cm.

Penhorn Lake: Microfaunal assemblages contained in the Penhorn Lake core are summarized in figure 4 and table 4. The total number of individuals per sample is quite variable, ranging from 1 to 1916 individuals /10 cc. Fifteen arcellacean species were identified in this core, although many of these had only a minor contribution to the total number of individuals. Charophytes were present in about two thirds of the samples; although the numbers were generally low, large numbers were present in some samples.

From the bottom of the core to the 393 cm level, assemblage A, reasonably large numbers of arcellaceans were present and six to twelve arcellacean species were identified. Centropyxis aculeata and Centropyxis

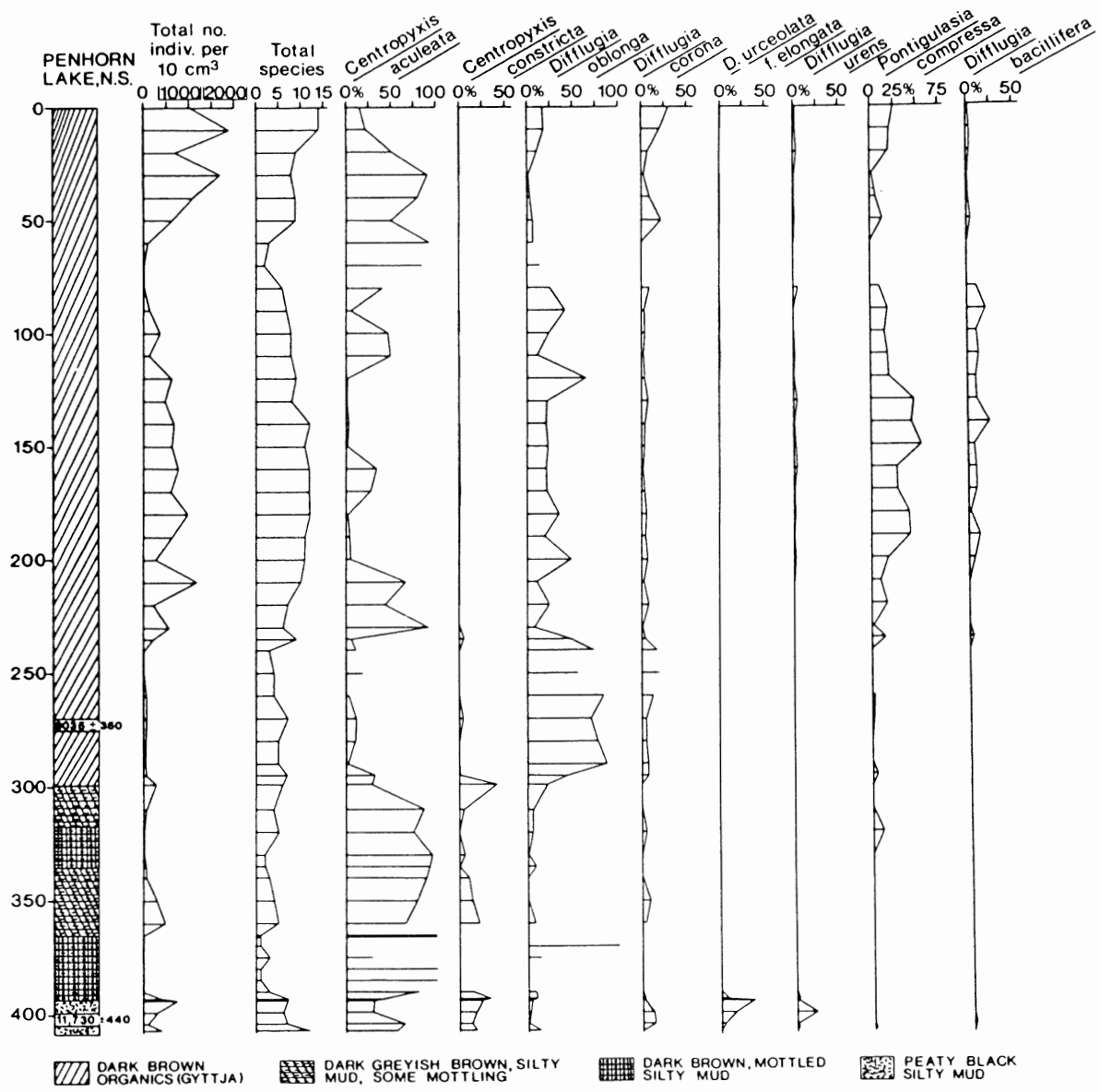


Figure 4. Lithology and biostratigraphy of Penhorn Lake core. Horizontal lines represent number and percentage values at corresponding levels and vertical lines are subjective averaging.

Depth in core (cm)	0-	10-	20-	30-	40-	50-	60-	70-	80-	90-	100-	110-	120-	130-	140-	150-	160-	170-	180-	190-	200-	210-	220-	230-	235-	240-
Total number of species	14	14	9	8	9	51	61	71	81	91	101	111	121	131	141	151	161	171	181	191	201	211	221	231	236	241
Total number of individuals/10 cc	1022	1916	738	1712	1116	648	106	7	20	147	367	129	623	469	679	625	769	602	966	609	280	1188	224	552	205	29
<i>Centropyxis aeneata</i>	15	22	51	91	79	50	92	86	40	10	46	50	2	2	3	2	33	27	2	4	5	67	42	90	6	10
<i>C. nonstrigata</i>	1	x	x	x							x		x		x		x									
<i>Puffinus bacillifera</i>	2	3	3	1	2	4			10	20	10	12	9	10	23	7	9	2	x	x	x	x	x	x		5
<i>D. sarsana</i>	30	22	8	3	9	21			10	3	4	2	3	7	4	4	2	4	6	5	7	6	x		4	4
<i>D. shibana</i>	17	18	10	1	3	6	7	14	25	41	23	12	63	22	21	24	21	22	34	18	48	10	23	6	47	72
<i>D. prolifera</i>	x	1	1												1	x	x	1	3	7	x	x				x
<i>D. trichaneta</i>	3	4	3	1	1	2				6	2	3	2	4	4		3	2	5	9	5	11	8	4	1	13
<i>D. macrocystis f. elongata</i>	x	x			x	x				1		1														
<i>D. macrocystis</i>	2	2	3	x	x	2	1		5		x	1		x	3	x	2	3	x	1		1	x			
<i>Halosira sarsana</i>	x	x																								
<i>Lagenodiffugia van</i>	1	3	x		x	x							x	2	2	1	x	x	x	2	1	1	4	x		2
<i>Lagenosira spiralis</i>	x	1													x	x										
<i>Halosira sarsana</i>	x																									
<i>Pontisulania sarsana</i>	26	22	21	3	6	14			10	19	16	19	21	49	41	56	29	30	42	43	19	10	17	1	15	
Charophytes	11	13	8	3	2	2		2	2					1									1			4

Depth in core (cm)	250-	260-	270-	280-	290-	295-	299-	310-	320-	330-	335-	340-	350-	360-	365-	366-	370-	375-	380-	385-	390-	393-	394-	399-	404-	407	
Total number of species	251	261	271	281	291	296	300	311	321	331	336	341	351	361	366	367	371	376	381	386	391	394	395	400	405	408	
Total number of individuals/10 cc	11	65	87	58	59	75	261	56	19	19	53	67	299	472	1	1	1	7	1	1	3	7	7	6	7	12	
<i>Centropyxis aeneata</i>	18	3	11	10	2	32	27	86	74	95	92	88	78	65	100	100		29	100	100	79	41	30	28	64	406	
<i>C. nonstrigata</i>			3			1	40	5		5		10	13	21							13	33	23	18	13	18	
<i>Puffinus bacillifera</i>	18	12	5	5	7	7							9	4													
<i>D. sarsana</i>	55	83	69	76	86	43	21	5	5		8			8			100	14				4	3	12	13	2	
<i>D. shibana</i>																											
<i>D. prolifera</i>			2																								
<i>D. trichaneta</i>				5	3	7	4		5													8	9	3	2	14	
<i>D. macrocystis f. elongata</i>	9		7	5	3	7	4		5																		
<i>D. macrocystis</i>																											
<i>Halosira sarsana</i>				3	2	5	3	4				1	x	3					57				3	1	22	1	1
<i>Lagenodiffugia van</i>																											
<i>Lagenosira spiralis</i>																											
<i>Halosira sarsana</i>							5		11																		
<i>Pontisulania sarsana</i>		2	2																								
Charophytes	9	77	13	1	5	21	3	69	72	2	5	10	8	181	2			18	3			13	74	32	8	41	32

Table 4. Penhorn Lake arcellacean distribution expressed as percentages of total count and listing of charophytes, x=less than 1%.

constricta were the dominant species in this segment of the core, although high percentages of Diffflugia urceolata forma elongata and Diffflugia urens were also present together with moderate numbers of charophytes. Directly above the 393 cm level, assemblage B is defined, and is a 28 cm unit which is almost barren. Assemblage C characterizes the next 25 cm, where initial high numbers decrease upcore. There is a decrease in species diversity although not as distinct as the change in total numbers. Centropyxis aculeata is the dominant species although high percentages of Centropyxis constricta were also observed. The next 25 cm is characterized by an assemblage very similar to assemblage B. Total numbers and diversity are low with the dominant member being Centropyxis aculeata. Assemblage C seems to be repeated over the next 20 cm. The microfaunal assemblage is similar to that present in assemblage C, although there was a higher percentage of Diffflugia oblonga observed at the top of the section. Assemblage D occurs over the next 35 cm, and is characterized by moderate numbers and diversity with Diffflugia oblonga being the dominant member. An inverse relationship seems to exist between Centropyxis aculeata and Diffflugia oblonga, and this relationship can also be observed in other sections of the core. The next 20 cm, assemblage E, is characterized by low numbers, although Diffflugia oblonga is the dominant species in this assemblage. The number of charophytes per sample also varies greatly throughout these assemblages. Assemblage F, over the next 160 cm is characterized by high diversity, being strongly co-dominated by Diffflugia oblonga, Pontigulasia compressa and Diffflugia bacillifera, all of which display an inverse relationship with Centropyxis aculeata, which is the dominant species at some intervals. This is the only interval in which Diffflugia bacillifera is present in

significant numbers. Together, these four species comprise 73 to 91 per cent of each sample. Charophytes are absent or in very low numbers throughout this interval. Assemblage G is recognized in the interval from 80 to 60 cm and is characterized by low populations and species diversity while Centropyxis aculeata is the dominant member. From 60 cm to the top of the core, assemblage H, populations and diversity are very high, with the greatest number of individuals observed in this material. Centropyxis aculeata dominates the assemblage to 20 cm, above which an inverse relationship exists with it and other co-dominant species such as Diffugia oblonga, Diffugia corona and Pontigulasia compressa. Charophytes are present in low numbers throughout this interval. The upper assemblage again does not match the surficial distribution indicating we have missed the upper few cm.

Radiocarbon dates of 9035 +/- 350 years B. P. (Lab no. GX-10693) were obtained from 270-273 cm and 11,730 +/- 440 years B. P. (Lab no. GX-10694) from 399-430 cm.

Results of the pollen analysis are summarized in tables 5,6,and 7. The density of pollen grains per sample varies throughout the core, with a dramatic decrease below 289 cm. Birch is the most common pollen type but there are varying quantities of pine, hemlock, spruce and oak as well. The appearance of beech occurs late in the Penhorn Lake record.

Below the 289 cm level of the core, the pollen spectrum reflects an area of open vegetation with few trees present in the vicinity of the deposit, and climatic conditions were probably similar to that of Baffin Island today (Ogden, pers. comm., 1985). The tree pollen was poorly preserved (Ogden, pers. comm., 1985) indicating the source was probably not local. Climatic conditions then improve and closed forests were

		RAW POLLEN DATA FOR 22 SAMPLES																								
ID	DEP	AB	LAR	PIC	PIN	TSU	ACR	BET	CRP	CRY	FAG	FRX	JUG	POP	QUE	TIL	ULM	ALN	COR	SAL	ERI	COM	CYP	GRS	SPH	
P-1	2	4.	3.	9.	10.	9.	0.	57.	8.	0.	7.	2.	0.	0.	6.	0.	0.	8.	7.	0.	2.	1.	1.	4.	54.	
P-1	9	4.	0.	16.	18.	10.	0.	38.	7.	0.	6.	0.	0.	1.	10.	0.	0.	6.	4.	1.	1.	0.	2.	1.	19.	
P-1	19	7.	0.	12.	22.	20.	2.	62.	3.	1.	11.	1.	0.	1.	16.	0.	0.	6.	8.	1.	0.	4.	2.	4.	104.	
P-1	39	4.	3.	8.	19.	24.	2.	70.	11.	0.	24.	1.	0.	0.	5.	0.	1.	8.	1.	1.	1.	1.	2.	3.	111.	
P-1	79	1.	5.	0.	26.	32.	2.	82.	12.	0.	6.	2.	0.	0.	17.	0.	0.	3.	2.	0.	2.	1.	1.	1.	74.	
P-1	99	1.	0.	2.	33.	15.	0.	67.	2.	0.	2.	0.	0.	0.	19.	0.	1.	3.	3.	0.	0.	2.	0.	4.	70.	
P-1	119	5.	4.	6.	41.	7.	1.	62.	9.	0.	0.	1.	0.	1.	18.	0.	0.	4.	0.	1.	0.	1.	2.	1.	87.	
P-1	149	0.	0.	3.	30.	37.	2.	53.	3.	0.	0.	2.	0.	0.	11.	0.	1.	3.	10.	0.	0.	0.	1.	3.	110.	
P-1	159	1.	2.	0.	38.	33.	0.	26.	8.	0.	0.	0.	0.	0.	7.	0.	0.	5.	1.	0.	0.	0.	2.	1.	92.	
P-1	179	0.	0.	5.	51.	18.	1.	17.	0.	0.	0.	0.	0.	0.	5.	0.	0.	4.	3.	1.	0.	0.	1.	0.	24.	
P-1	199	1.	6.	4.	51.	23.	3.	26.	6.	1.	0.	1.	0.	1.	13.	0.	1.	3.	5.	1.	1.	0.	1.	1.	39.	
P-1	239	1.	0.	4.	88.	13.	1.	28.	2.	0.	0.	1.	0.	0.	18.	0.	0.	2.	3.	0.	0.	0.	1.	0.	20.	
P-1	259	3.	6.	10.	59.	1.	1.	23.	6.	0.	0.	0.	0.	0.	6.	0.	2.	9.	3.	0.	1.	0.	2.	1.	42.	
P-1	279	6.	2.	20.	16.	0.	1.	68.	14.	0.	0.	0.	0.	1.	7.	0.	0.	4.	7.	1.	0.	1.	0.	0.	44.	
P-1	289	3.	1.	8.	13.	0.	1.	64.	14.	0.	0.	2.	1.	1.	7.	0.	1.	5.	1.	1.	0.	1.	2.	1.	41.	
P-1	309	0.	2.	4.	11.	0.	0.	9.	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.	2.	2.	1.	0.	6.	3.	41.	
P-1	329	0.	3.	10.	11.	0.	0.	15.	1.	0.	0.	0.	0.	1.	0.	0.	0.	0.	2.	1.	1.	0.	2.	1.	55.	
P-1	349	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	0.	37.	
P-1	369	0.	0.	1.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	0.	23.	
P-1	389	0.	0.	0.	2.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.	1.	1.	38.
P-1	398	0.	1.	1.	4.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	1.	2.	0.	0.	1.	49.	
P-1	406	0.	0.	3.	12.	0.	0.	10.	2.	0.	0.	0.	0.	0.	0.	0.	0.	3.	3.	0.	0.	1.	5.	5.	27.	

LEGEND

DEP- Depth in cm	POP- Poplar
AB- Fir	QUE- Oak
LAR- Larch	TIL- Basswood
PIC- Spruce	ULM- Elm
PIN- Pine	ALN- Alder
TSU- Hemlock	COR- Bayberry
ACR--Maple	SAL- Willow
BET- Birch	ERI- Heath Family
CRP- Hornbeam	COM- Composite Family
CYR- Hickory	CYP- Sedge
FAG- Beech	GRS- Grass
FRX- Ash	SPH- Microspheres
JUG- Walnut	

Table 5. Raw pollen data from Penhorn Lake core.

		PERCENTAGES FOR 22 POLLEN SAMPLES																							
ID	DEP	AB	LAR	PIC	PIN	TSU	ACR	BET	CRP	CRY	FAG	FRX	JUG	POP	QUE	TIL	ULM	ALN	COR	SAL	ERI	COM	CYP	GRS	SPH
P-1	2	2.9	2.2	6.5	7.2	6.5	0.0	41.3	5.8	0.0	5.1	1.4	0.0	0.0	4.3	0.0	0.0	5.8	5.1	0.0	1.4	.7	.7	2.9	
P-1	9	3.2	0.0	12.8	14.4	8.0	0.0	30.4	5.6	0.0	4.8	0.0	0.0	.8	8.0	0.0	0.0	4.8	3.2	.8	.8	0.0	1.6	.8	
P-1	19	3.8	0.0	6.6	12.0	10.9	1.1	33.9	1.6	.5	6.0	.5	0.0	.5	8.7	0.0	0.0	3.3	4.4	.5	0.0	2.2	1.1	2.2	
P-1	29	2.1	1.6	4.2	10.1	12.7	1.1	37.0	5.8	0.0	12.7	.5	0.0	0.0	2.6	0.0	.5	4.2	.5	.5	.5	.5	1.1	1.6	
P-1	79	.5	2.6	0.0	13.3	16.4	1.0	42.1	6.2	0.0	3.1	1.0	0.0	0.0	8.7	0.0	0.0	1.5	1.0	0.0	1.0	.5	.5	.5	
P-1	99	.6	0.0	1.3	21.4	9.7	0.0	43.5	1.3	0.0	1.3	0.0	0.0	0.0	12.3	0.0	.6	1.9	1.9	0.0	0.0	1.3	0.0	2.6	
P-1	119	3.0	2.4	3.7	25.0	4.3	.6	37.8	5.5	0.0	0.0	.6	0.0	.6	11.0	0.0	0.0	2.4	0.0	.6	0.0	.6	1.2	.6	
P-1	149	0.0	0.0	1.9	18.9	23.3	1.3	33.3	1.9	0.0	0.0	1.3	0.0	0.0	6.9	0.0	.6	1.9	6.3	0.0	0.0	0.0	.6	1.9	
P-1	159	.8	1.6	0.0	30.6	26.6	0.0	21.0	6.5	0.0	0.0	0.0	0.0	0.0	5.6	0.0	0.0	4.0	.8	0.0	0.0	0.0	1.6	.8	
P-1	179	0.0	0.0	4.7	48.1	17.0	.9	16.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0	3.8	2.8	.9	0.0	0.0	.9	0.0	
P-1	199	.7	4.0	2.7	34.2	15.4	2.0	17.4	4.0	.7	0.0	.7	0.0	.7	8.7	0.0	.7	2.0	3.4	.7	.7	0.0	.7	.7	
P-1	239	.6	0.0	2.5	54.3	8.0	.6	17.3	1.2	0.0	0.0	.6	0.0	0.0	11.1	0.0	0.0	1.2	1.9	0.0	0.0	0.0	.6	0.0	
P-1	259	2.3	4.5	7.5	44.4	.8	.8	17.3	4.5	0.0	0.0	0.0	0.0	0.0	4.5	0.0	1.5	6.8	2.3	0.0	.8	0.0	1.5	.8	
P-1	279	4.1	1.4	13.5	10.8	0.0	.7	45.9	9.5	0.0	0.0	0.0	0.0	.7	4.7	0.0	0.0	2.7	4.7	.7	0.0	.7	0.0	0.0	
P-1	289	2.4	.8	6.3	10.2	0.0	.8	50.4	11.0	0.0	0.0	1.6	.8	.8	5.5	0.0	.8	3.9	.8	.8	0.0	.8	1.6	.8	
P-1	309	0.0	4.9	9.8	26.8	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0	0.0	0.0	4.9	4.9	2.4	0.0	14.6	7.3	
P-1	329	0.0	6.3	20.8	22.9	0.0	0.0	31.3	2.1	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0	4.2	2.1	2.1	0.0	4.2	2.1	
P-1	349	0.0	0.0	0.0	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.3	0.0	
P-1	369	0.0	0.0	33.3	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	0.0	
P-1	389	0.0	0.0	0.0	28.6	0.0	0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.6	0.0	0.0	14.3	14.3	
P-1	398	0.0	8.3	8.3	33.3	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3	16.7	0.0	0.0	8.3	
P-1	406	0.0	0.0	6.8	27.3	0.0	0.0	22.7	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	6.8	0.0	0.0	2.3	11.4	11.4	

LEGEND

DEP- Depth in cm	POP- Poplar
AB- Fir	QUE- Oak
LAR- Larch	TIL- Basswood
PIC- Spruce	ULM- Elm
PIN- Pine	ALN- Alder
TSU- Hemlock	COR- Bayberry
ACR- Maple	SAL- Willow
BET- Birch	ERI- Heath Family
CRP- Hornbeam	COM- Composite Family
CYR- Hickory	CYP- Sedge
FAG- Beech	GRS- Grass
FRX- Ash	SPH- Microspheres
JUG- Walnut	

Table 6. Percentage pollen data from Penhorn Lake core.

POLLEN TOTALS FOR 22SAMPLES								
IDENT	DEPTH	SUMAP	SUMSAP	SUMNAP	TOTPOL	PCTAP	PCTSAP	PCTNAP
P-1	2	115.	17.	6.	138.	83.3	12.3	4.3
P-1	9	110.	12.	3.	125.	88.0	9.6	2.4
P-1	19	158.	15.	10.	183.	86.3	8.2	5.5
P-1	39	172.	11.	6.	189.	91.0	5.8	3.2
P-1	79	185.	7.	3.	195.	94.9	3.6	1.5
P-1	99	142.	6.	6.	154.	92.2	3.9	3.9
P-1	119	155.	5.	4.	164.	94.5	3.0	2.4
P-1	149	142.	13.	4.	159.	89.3	8.2	2.5
P-1	159	115.	6.	3.	124.	92.7	4.8	2.4
P-1	179	97.	8.	1.	106.	91.5	7.5	.9
P-1	199	137.	10.	2.	149.	91.9	6.7	1.3
P-1	239	156.	5.	1.	162.	96.3	3.1	.6
P-1	259	117.	13.	3.	133.	88.0	9.8	2.3
P-1	279	135.	12.	1.	148.	91.2	8.1	.7
P-1	289	116.	7.	4.	127.	91.3	5.5	3.1
P-1	309	27.	5.	9.	41.	65.9	12.2	22.0
P-1	329	41.	4.	3.	48.	85.4	8.3	6.3
P-1	349	1.	0.	5.	6.	16.7	0.0	83.3
P-1	369	2.	0.	1.	3.	66.7	0.0	33.3
P-1	389	3.	2.	2.	7.	42.9	28.6	28.6
P-1	398	7.	4.	1.	12.	58.3	33.3	8.3
P-1	406	27.	6.	11.	44.	61.4	13.6	25.0

LEGEND

DEPTH- cm
SUMAP- Sum Aboreal (Tree) Pollen= AP
SUMSAP- Sum sub-Aboreal (Shrub) Pollen= SAP
SUMNAP- Sum non-Aboreal (Herb) Pollen= NAP
TOTPOL- Sum AP+SAP+NAP (Terrestrial pollen only)
PCTAP- Percent AP
PCTSAP- Percent SAP
PCTNAP- Percent NAP

Table 7. Summary of pollen data from Penhorn Lake core.

developing around 9800 years ago (329 cm level) which is indicated by the higher percentage of tree pollen. The appearance of fir pollen, which has a very large pollen grain and cannot be transported far by wind, confirms that the forest vegetation was established in the vicinity of the site.

DISCUSSION

Albro Lake: A radiocarbon date of 9550 +/- 215 years B. P. at the 221-225 level gives an average sedimentation rate of 0.23 mm /yr since that time. If the sedimentation rate had been constant since the formation of the lake (which is unlikely), the 59 cm of sediment below this interval would represent another 2500 years. These approximate values suggest that the lake was formed in the late Pleistocene and most of the post-glacial history of the area is recorded in the core.

Arcellaceans were present in low numbers throughout most of the core; usually numbers present were too small to be statistically significant. The bottom 10 cm of the core is almost barren while directly above this section Centropyxis spp. are relatively abundant over a 20 cm interval. The total population then sharply declines until the 20 cm level in the core. This indicates that the conditions were initially favorable for the colonization of arcellaceans, although the sudden drop in population size means that there must have been some change in environmental conditions that was unfavorable for the continued growth of the arcellacean population.

Although the total number of arcellaceans is small in the interval from 240 to 30 cm, Centropyxis aculeata and Diffflugia urens are the dominant species, and show an inverse relationship throughout this

section of the core. From 20 cm to the top of the core, populations and species diversity increase indicating conditions were again favorable to establish a stable arcellacean population. The moderately high numbers of arcellaceans found in the surface samples show that arcellaceans are suited to the present environmental conditions of Albro Lake.

It is interesting to note that the inverse relationship between Centropyxis aculeata and Diffflugia urens is observed in the top 20 cm of the core, although Pontigulasia compressa and Diffflugia oblonga are also dominant members of this assemblage. Diffflugia oblonga and Pontigulasia compressa dominate the surface samples although there are also high percentages of Centropyxis aculeata and Diffflugia corona; Diffflugia urens is present in low numbers in the surface samples. The differences in the assemblage types from the top of the core and the surface samples indicate that the uppermost part of the core containing the transition zone is missing. It also indicates some kind of significant environmental change in the recent past. The presence of Diffflugia urens just below the surface, but not in the surface, is similar to patterns observed in other N. S. lakes (Patterson, et al., 1985).

Charophytes were present in most sections of the core, which indicate aquatic conditions were favorable for the growth of the plants (eg. water pH > 5.5) since soon after the lake formed.

The pollen record, although not determined, should be very similar to Penhorn Lake at corresponding absolute time intervals since the two lakes are close to each other.

Penhorn Lake: The sediment core from Penhorn Lake differs from the Albro Lake core in a number of ways. Total numbers and species diversity

are considerably higher in the Penhorn core, while numbers present in the Penhorn Lake surface samples are greater by an order of magnitude than observed in Albro Lake surface samples. The morphological variation of species observed in the Penhorn core was greater than that observed in the Albro Lake core; this may have been due to the greater number of specimens present in the Penhorn Lake samples.

The sediment column in Penhorn Lake is also much longer than in Albro Lake; four meters of sediment represent 11,730 +/- 440 years B. P. and there is at least another meter of sediment that could not be obtained during the coring procedure due to problems encountered. The radiocarbon dates reveal that the sedimentation rates have not been constant. The approximate rate for the past 9000 years is 0.30 mm/yr while the 2700 years prior to that had an approximate rate of 0.50 mm/yr.

Eight broad types of assemblages are observed in this core, stable over various time periods, and the transition between the assemblage types occurs over a relatively short time period.

The assemblage present in the lower 18 cm of the core is characterized by reasonably high numbers and species diversity. Species diversity is very high in the basal core sample, although the next appearance of many of these species is much higher up in the core. The morphotypes of most species in this assemblage were much smaller than observed throughout the remainder of the core; consistently small test size may be an expression of environmental conditions at that time. Two possible situations may account for the small test size. Conditions may have been unfavorable for thecamoebians, food being scarce, resulting in the organism having little cytoplasm. When the organism divides the new individuals would be smaller than the parent, and the expression of this

would be an organism with a small test. This has been shown in clonal lineages by Hegner (1919 and 1920). The other possibility is that conditions were extremely favorable for thecamoebians and the organisms divide so often they never get very large. This has been demonstrated with foraminifera (Bradshaw, 1961).

The sediment types correspond well to the repeated B and C assemblages. Dark brown, mottled silty mud was the sediment type assemblage B was observed in, while the similar microfaunal assemblage further upcore was also observed in this sediment type. Assemblage C was observed in another sediment type, but where the microfaunal assemblage was repeated, the corresponding sediment type was observed. This indicates cyclic events where depositional and environmental conditions return to what they had been previously, after a period of varying conditions.

The abundance of assemblages present over short intervals, in the section of the core from 240 to 408 cm, representing a relatively short time period (about 2000 years), indicates environmental conditions may not have been stable over this period and microfossil assemblages reflect this. The pollen profile indicates a warming trend during this time which may be affecting the composition of assemblages although other factors such as food supply and sedimentation rates probably also affect them. Charophytes were present throughout this section of the core so conditions must have been favorable for the growth of aquatic plants.

Population size is relatively constant over the interval assemblage F is observed in, and implies a period of stable conditions. This was the only interval in which Diffflugia bacillifera is present in significant numbers and although this species was not reported by Scott and Medioli

(1983) or Patterson et al. (1985), it has been observed in Newfoundland lakes (Kerr, 1984). Very few charophytes were observed over this interval which suggests that, although conditions were favorable for the establishment of a stable arcellacean population, this period was not favorable for the growth of aquatic plants.

From 60 cm to the top of the core, populations and diversity are very high, with the greatest number of individuals observed in this material. Centropyxis aculeata is the dominant species at some intervals, declining rapidly towards the top of the core, and an inverse relationship is observed with other co-dominant species such as Diffflugia oblonga, Diffflugia corona and Pontigulasia compressa. Charophytes were observed in low numbers which indicates conditions were again favorable for the growth of aquatic plants, although probably not as favorable as in the segment of the core below 240 cm.

It is interesting to note that there are two distinct clones of Diffflugia corona in the upper 60 cm of the core and in the surface material, the smaller (pl. 2, fig. 7) being the major contributor to the population. There is no other record of Diffflugia corona being the dominant member in observed modern assemblages from other areas, so there must be some unique environmental or chemical conditions present in Penhorn Lake today favorable for the dominance of Diffflugia corona.

Pollen analysis is done on lake cores since the pollen profiles reflect vegetational and climatic changes since deglaciation. Low abundances of pollen are indicative of glacial conditions while an abundance of tree pollen indicates warmer periods.

Mott (1975), analyzed sediment cores from two small lakes in southwestern New Brunswick and defined a zone where hemlock pollen

increased until about 5120 years ago and then abruptly declined in abundance. A sharp increase in beech pollen was also observed as hemlock decreased until about 3000 years ago when there was again an increase in hemlock. This period is known as the post-glacial "warm-dry maximum" (Ogden, 1971). This bimodal hemlock-beech-hemlock distribution was not observed in the Penhorn Lake core although a bimodal hemlock-oak-hemlock distribution was observed at approximately the corresponding time interval. Beech pollen was not present in the Penhorn Lake core until after the re-establishment of hemlock, so the establishment of beech in this part of Nova Scotia must have occurred later than in New Brunswick.

Livingston (1968), analyzed a core from Bluff Lake, N. S., about 35 km from Penhorn Lake, and the hemlock-oak-hemlock bimodal distribution, as well as the late arrival of beech were also observed in this core.

Decloitre (1953), suggested that Centropyxis spp. were tolerant to brackish conditions and this has been observed in cores by Patterson (1983), Honig (1984), and McCarthy (1984). Kerr (1984) relates Centropyxis aculeata to interglacial periods. There is no evidence from this study to indicate that the dominance of Centropyxis aculeata in many intervals of the core is related to brackish conditions. The observations do show that an inverse relationship exists between the genus Centropyxis and the genera Diffflugia and Pontigulasia. Centropyxis aculeata is observed almost exclusively in zones where total populations are very low, assumed to be times of adverse environmental conditions, therefore it seems to be a very hardy species and indicative of all harsh environments, not only brackish conditions. It also seems to be a poor competitor with most Diffflugia species and Pontigulasia compressa which is indicated by the inverse relationship with these species once their

population has been established.

In the 18 cm segment at the bottom of the core, Diffflugia spp. are present with Diffflugia urceolata f. elongata having the highest percentages. The inverse relationship with Centropyxis aculeata is also observed. The pollen analysis indicates conditions were cold at that interval and the higher percentage of this Diffflugia species may be indicative of cold, stable conditions although this is speculative due to the few samples available from this zone. This species is observed in both core and surface assemblages of New Brunswick lakes (Patterson, et. al., 1985) but has not been linked with an environmental factor except that it is not a cold water indicator in N. B.

Significant percentages of Diffflugia bacillifera were observed in the period determined from the pollen analysis to be the post-glacial warm-dry maximum, and high percentages of this species may be an indicator of warmer conditions. Kerr (1984), recognized higher percentages of this species at approximately the same time interval in a core from Newfoundland.

CONCLUSIONS

Arcellacean assemblages in lakes from the same general area may be quite variable. Climatic conditions at corresponding time intervals can be the same and the variation in the assemblages must be the result of other environmental or chemical factors specific to the lake. These could include food supply, sedimentation rates, pH or varying concentrations of other ions and minerals present in the water. The low populations observed in the Albro Lake core cannot be related to the paleoclimate

since high numbers of arcellaceans were observed in the Penhorn Lake core at the same time.

Assemblages within a lake change with time in species dominance and in total numbers. Centropyxis aculeata appears to be dominant in harsh environments, although it is a poor competitor with species of the genus Diffflugia and Pontigulasia compressa, which are successful in stable environmental conditions. Significant percentages of Diffflugia bacillifera in an assemblage may be an indicator of warmer paleoclimates. Therefore, arcellaceans may reflect environmental conditions and be useful tools in paleoecological analysis since deglaciation.

Presently, both Albro and Penhorn Lakes are favorable environments for the colonization of arcellaceans. The dominance of Diffflugia corona in surface material from Penhorn Lake may be an expression of alkaline conditions of the lake, or it may be related to some other chemical factor.

The pollen analysis revealed that the post-glacial warm-dry maximum is recorded in Nova Scotia by a bimodal hemlock-oak-hemlock distribution, and the migration of beech to Nova Scotia occurred later than in New Brunswick.

ABBREVIATED TAXONOMY

This paper is not taxonomic in nature. Descriptions of Diffflugia bacillifera and Nebela collaris are detailed since these species were not dealt with by Medioli and Scott (1983) in their major revisory study on arcellaceans from eastern Canada. That paper was the primary reference used for species identification. The original reference and the most recent have been listed for most species. Some synonyms have also been listed for those species for which taxonomic problems have been particularly severe.

Illustrations representing typical specimens observed are included. This iconography does not illustrate the total variability present in each taxon.

Centropyxis aculeata (Ehrenberg, 1832)

ab Ehrenberg, 1830

pl. 2, fig. 1.

Arcella aculeata EHRENBURG, 1832, (ab Ehrenberg, 1830, p. 60, nomen nudum), p. 91.

Centropyxis aculeata (Ehrenberg). STEIN, 1859, p. 43, MEDIOLI and SCOTT, 1983, p. 39, pl. 7, figs. 10-19.

Description: The test is yellow to brown in color, ovoid or circular, and depressed. The anterior slope is large with a small anterior angle, which Medioli and Scott (1983) report to be 15 to 40 degrees in material from Lake Erie. Medioli and Scott (1983) also reported a low height to

length ratio of 0.4 to 0.5 from material they examined. The aperture is usually subcentral, commonly slightly anterior, and invaginated. Spines, when present, are variable in number and are usually concentrated along the posterior margin. Although the test is largely organic, many of the specimens I observed were completely covered with minute silica grains giving the test a grey color. These specimens had no spines, were generally circular in dorsal view and had variable apertural shapes. Many specimens from the Penhorn Lake core showed intergradations with Centropyxis constricta.

Centropyxis constricta (Ehrenberg, 1843)

pl. 2, fig. 2

Arcella constricta EHRENBURG, 1843, p. 410, pl. 4, fig. 35; pl. 5, fig. 1.

Diffugia constricta (Ehrenberg). LEIDY, 1879, p. 120, pl. 18, figs. 8-55.

Centropyxis constricta (Ehrenberg). DEFLANDRE, 1929, p. 340, text-figs. 60-67. MEDIOLI and SCOTT, 1983, p. 41, pl. 7, figs. 1-9.

Description: The test is yellow to brown and may be chitinous but it is usually covered with minute silica grains. The test is much less depressed than in Centropyxis aculeata and usually elliptical in dorsal view. Medioli and Scott (1983) report a height to length ratio of 0.5 to 1.1. The aperture is invaginated to varying degrees, circular or oval and is in the antero-marginal position. One or more spines may be present at

the fundus although none were present on any chitinous tests observed here. Intergradations with C. aculeata were observed.

Diffflugia bacillifera Penard, 1890.

pl. 1, figs. 1-2; pl. 2, figs. 3-5

Diffflugia bacillifera PENARD, 1890, p. 146, pl. 4. figs. 61-66; 1893, p. 1079; 1899, p. 257; 1902, p. 230, figs. 1-4 (p. 231). (?) RHUMBLER, 1895, p. 76, pl. 4, fig. 20. CASH and HOPKINSON, 1909, p. 17, pl. 10, fig. 1. GROSPEITSCH, 1958, p. 44-45, Abb. 38, fig. C. OGDEN and HEDLEY, 1980, p. 124, pl. 51. KERR, 1984, p. 29, pl. 1, figs. 4-7.

Diffflugia pyriformis LEIDY (pars) 1879, p. 108, text fig. 22.

Diffflugia pyriformis var bacillifera LEVANDER 1895, p. 14.

Diffflugia septentrionalis var bacillifera AVERINTZEV 1906, p. 209.

Description: The test is largely xenogenous; the matrix usually fine grained and brown. Xenosomes are represented by more or less large clasts of quartz or other minerals and/or diatom frustules. The diatom frustules often obscure, because of their large size, the real shape of the test underneath. The test is elongate, ovoid on the fundus side tapering into a narrow, often cylindrical neck. In some specimens a lip at the end of the neck is visible. The shell may be slightly twisted. The aperture is small and subcircular.

Discussion: Medioli and Scott (1983) had tentively suggested that D. bacillifera could be a junior synonym of Diffflugia oblonga. Possibly part of the forms that they listed as junior synonyms of D. bacillifera are genuine junior synonyms of D. oblonga. The problem with this species is

represented by the large diatom frustules that obscure the shape of the test. Since the Medioli and Scott paper (1983), abundant new material has been dealt with and the decision has been reached that there is now sufficient evidence to suggest that some of the forms that Medioli and Scott (1983) listed under D. bacillifera probably do represent an independent taxon. Kerr (1984) considered D. bacillifera as a valid species. Some doubts still exist but I decided to keep this species separated from D. oblonga at least until new evidence becomes available.

The differentiation of D. bacillifera from D. oblonga is seldom an easy one. The overall shape of most pyriform D. oblonga specimens and the normal shape of most D. bacillifera (except for the deformation caused by the large diatom frustules) are almost identical. D. bacillifera, is often characterized by a well organized apertural lip which is commonly missing on D. oblonga in which, at best, the aperture is surrounded by a row of well oriented quartz grains. It is conceivable that when the diatom frustules are not present as xenosomes, the two species are systematically confused when the apertural lip, for some reason is missing from D. bacillifera.

Diffugia corona Wallich, 1864

pl. 1, figs. 3-4; pl. 2, figs. 6-7

Diffugia proteiformis (sic) (Ehrenberg) subspecies D. globularis (Dujarin) var. D. corona (Wallich). WALLICH, 1864, p. 244, pl. 15, figs. 4b, ?4a, ?4c; pl. 16, figs. 19, 20.

Diffugia corona Wallich. MEDIOLI and SCOTT, 1983, p. 22, pl. 1, figs. 6-14.

Description: The test is opaque, ovoid to spherical, quite variable in size and although composed of angular quartz grains has a smooth appearance. Two distinct morphotypes were observed in the samples studied. Both had a large, central, circular aperture and the larger morphotype had a variable number of spines and a crenulated apertural collar (pl. 2, fig. 6). The smaller morphotype had a smooth apertural collar that was thicker than the one present in the larger morphotype. No spines were observed on these tests (pl. 2, fig. 7).

Diffflugia oblonga Ehrenberg, 1832

pl. 2, fig. 8

Diffflugia oblonga EHRENBURG, 1832, p. 90. MEDIOLI and SCOTT, 1983, p. 25, pl. 2, figs. 1-17, 24-26.

Diffflugia pyriformis PERTY, 1849, p. 168.

Description: The test is brown, extremely variable in size and shape, typically oblong or pear-shaped, with a rounded fundus or may be expanded into one or more blunt spines. The test is composed of fine to coarse quartz grains. The neck is subcylindrical and tapers to a round or slightly oval aperture. Some of the specimens I observed exhibited a single blunt spine in the central fundal position while generally most were without spines.

Diffflugia protaeiformis Lamarck, 1816

pl. 2, fig. 9

Diffflugia protaeiformis LAMARCK, 1816, p. 95, figures in LeClerc, 1816, pl. 17, figs. 1-5. MEDIOLI and SCOTT, 1983, p. 17, figs. 15-20.

Diffflugia acuminata EHRENBERG, 1830, p. 95.

Description: The test is yellow to brown, shape is extremely variable, especially with regard to neck length, and is composed of various sized quartz grains and diatom frusules may also be present. The fundus is tapering and sometimes prolonged into one or more blunt spine processes. The transition from test to spine is a smoother curve than observed in D. oblonga. The aperture is large, almost circular and terminal. One spine was usually present at the periphery of the fundus on specimens from my samples.

Diffflugia tricuspis Carter, 1856

pl. 1, fig. 5; pl. 2, figs. 10-11

Diffflugia tricuspis CARTER, 1856, p. 221, pl. 7, fig. 80. MEDIOLI and SCOTT, 1983, p. 28, pl. 4, figs. 5-19.

Diffflugia lobostoma LEIDY, 1874a , p. 79.

Description: The test is opaque or grey, variable in shape, from subspherical to oval, with no neck. The aperture is small, deeply indented by three to six or more lobes. The test has a smooth appearance and is generally composed of fine quartz grains although diatom or other organic material may be incorporated into the test. Medioli and Scott(1983) suspect that in many cases the test is wholly autogenous

which could put this species outside of the genus Diffflugia as it is presently defined. Part of the definition for the genus Diffflugia is that the test be made out of hard organic matter and entirely covered with siliceous xenosomes of mineral and/or biological origin (Medioli and Scott, 1983). The specimen (pl. 2, fig. 11) appears to have an autogenous test so it may not actually be a test of D. tricuspis according to the above definition. This, and other similar specimens, were identified as D. tricuspis since the problem of proper classification has not yet been resolved.

Diffflugia urceolata Carter, 1864

pl. 2, fig. 12

Diffflugia urceolata CARTER, 1864, p. 27, pl. 1, fig. 7. MEDIOLI and SCOTT, 1983, p. 31, pl. 3, figs. 1-23; pl. 2, figs. 1-4.

Description: The test is opaque, ovoid to spherical, large and composed of medium to fine sand grains and has a smooth appearance. The fundus is rounded with blunt proturbances in some specimens. A short neck terminates in a straight or recurved collar variable in size and shape. The aperture is quite large and circular.

Diffflugia urceolata forma elongata Penard, 1902

pl. 1, fig. 6; pl. 2, figs. 13-14

Diffflugia urceolata forma elongata PENARD, 1902, p. 270, text figs. 1-4. PATTERSON et al., p. 135, pl. 1, figs. 1-3.

Description: The test is opaque, spherical, very small and composed of coarse to fine sand grains. Under very high magnification the test has a rough appearance. The fundus is rounded and no blunt proturbances were observed, these may be masked by the coarse grainsize. A short neck terminates in a recurved, thick apertural collar variable in size and shape. The aperture is large and circular. This form is very similar to D. urceolata except for 1) the size of the test, 2) grainsize of material incorporated into the test, and 3) no proturbances were observed at the fundus of any D. urceolata f. elongata. Therefore, there seems to be little taxonomic significance in separating D. urceolata f. elongata from D. urceolata although I have done so in this paper.

Diffflugia urens Patterson, MacKinnon, Scott and Medioli, 1985.

pl. 1, fig. 7; pl. 2, fig. 15

Diffflugia urnula (Gruber, 1884). PATTERSON, 1983, p. 25, pl. 3, figs. 5-14.

Diffflugia urens PATTERSON et al., 1985, p. 135, pl. 3, figs. 5-14.

Description: The test is brown and composed of sand or silica fragments of various grainsizes. Diatom frustules and other biological material are also included in most specimens from my material. The shape is subspherical, with a narrow circular aperture, and an outward expanded flanged collar of variable width bordering the aperture. A diaphragm, partial or complete, may or may not cross the aperture. In many specimens I observed, such as the one illustrated here (pl. 2, fig. 15), the

aperture was partially or completely obscured.

Heleopera sphagni (Leidy, 1874b).

pl. 1, fig. 8; pl. 2, fig. 16

Diffflugia (Nebela) sphagni Leidy, 1874b, p. 157.

Heleopera sphagni (Leidy). CASH and HOPKINSON, 1909, p. 143, pl. 30, figs. 4-9. MEDIOLI and SCOTT, 1983, p. 37, pl. 6, figs. 15-18.

Description: The test is brown to pinkish brown in color, ovoid and laterally compressed with a narrow oval to slit-like aperture. The test is composed of fine grains near the aperture becoming coarser at the fundus with an overall smooth appearance in general. The test may be xenosomic or composed of scaly siliceous idiosomes (Deflandre, 1953).

Lagenodifflugia vas (Leidy, 1874b).

pl. 2, fig. 17

Diffflugia vas LEIDY, 1874b, p. 155 (binomen used for a variety of

Diffflugia pyriformis Perty, 1849), p. 99, pl. 12, figs. 2-9.

Pontigulasia vas (Leidy). SCHOUTEDEN, 1906, p. 338, footnote.

Lagenodifflugia vas (Leidy). MEDIOLI and SCOTT, 1983, p. 33, pl. 2, figs. 18-23, 27, 28.

Description: The test is brown and composed of sand grains and in some cases organic fragments may be incorporated into the test. The main part of the test is ovoid, and a constriction is present at the base of the

neck. The aperture is slightly oval and present at the extremity of the neck. In my samples the constriction is not always distinct and the specimens display an intergradatiion with D. oblonga as reported by Patterson (1983) and Kerr (1984).

Lecquereusia spiralis (Ehrenberg,1840).

pl. 2, figs. 18-20

Diffflugia spiralis EHRENBERG, 1840, p. 199.

Lecquereusia spiralis (Ehrenberg). PENARD, 1902, p. 326, text figs. 1-10.

Description: The test is practically colorless, ovoid with an asymmetrical neck and a constriction at the base of the neck where it meets the body. Medioli and Scott (1983) report that this constriction corresponds to an internal diaphragm and the neck is often asymmetrical because of the assymetrical position of the diaphragm. The internal diaphragm is shown in pl. 1, fig. 20, indicated by the arrow. The test is composed of various sizes of quartz grains and the siliceous idiosomes shaped like curved rods typical of Lecquereusia were not noted in any of my samples. Medioli and Scott (1983) suggest an intergradation between L. spiralis and Pontigulasia compressa and this was also observed in my material.

Nebela collaris (Ehrenberg,1848a).

pl. 1, fig.9; pl. 2, fig. 21

Diffflugia collaris EHRENBERG, 1848a, p. 218; (?) EHRENBERG, 1872, p. 143, pl. 2, fig. 27.

Diffflugia reticulata EHRENBERG, 1848a, p. 218; EHRENBERG, 1854, p. 331; (?) EHRENBERG, 1872, p. 143, pl. 2, Die terrestrischen Arcellinen sect., fig. 26.

Diffflugia cancellatta EHRENBERG, 1848b, p. 379; EHRENBERG, 1854, p. 331; EHRENBERG, 1872, p. 145, pl. 2, Die terrestrischen Arcellinen sect., fig. 3.

Diffflugia Carpio EHRENBERG, 1854, p. 331; EHRENBERG, 1872, p. 146, pl. 2, Die terrestrischen Arcellinen sect., figs. 27a,b.

Diffflugia carinata ARCHER, 1867, p. 178.

Diffflugia purpurescens EHRENBERG, 1872, p. 145, pl. 2, fig. 24.

Diffflugia binodis EHRENBERG, 1872, p. 145, pl. 2, figs. 22, 23.

Diffflugia (Nebela) equi-calceus LEIDY, 1874b, p.156; LEIDY, 1876, p. 118, figs. 12, 13; CASH and HOPKINSON, 1909, pl. 3, fig. 94.

Diffflugia (Nebela) numata LEIDY, 1874b, p. 157.

Nebela numata LEIDY, 1876, p. 116, figs. 1-5.

Nebela carinata (Archer), LEIDY, 1876, p. 118, figs. 10,11; LEIDY, 1879, p. 154, pl. 24, figs. 1-10; SCHOUTEDEN, 1906, p. 354-355, fig. 26

Nebela collaris (Ehrenberg), LEIDY 1879 (pars), p. 145, pl. 22, figs. 1-20; pl. 23, figs. 1-7; pl. 24, figs. 11, 12. CERTES, 1889, p. 11-13, pl. 2, figs. 2-5. PENARD, 1890, p. 157, pl. 6, figs. 21-24. PENARD, 1902, p. 347, figs. 1-7. SCHOUTEDEN, 1906, p. 354-356, fig. 27.

Nebela dentistomata PENARD, 1890,p. 162, pl. 6, figs. 98-100; pl. 7, figs. 1-5.

Nebela galeata PENARD, 1890, p. 161, pl. 6, figs. 78-84.

Nebela tubulosa PENARD, 1890, p. 159.

Nebela militaris PENARD, 1890, p. 164, pl. 7, figs. 16-22.

Description: The test is pale yellow; the outline is quite variable but essentially pyriform in broadside view and more or less elongated. It is always laterally compressed with the lateral border, usually, expanded into a keel that varies from broad and ill-defined to sharp edged. The test is pseudo-autogenous, often made of idiosomes of various shapes derived from other thecamoebians on which *Nebela* preys. Occasionally, but not often, it agglutinates xenosomes of mineral nature. Dimensions are quite variable, from 0.06 mm to 0.20 mm in length; 0.04 mm to 0.12 mm in breadth and from 0.008 mm to 0.06 mm in thickness although larger dimensions have been reported in the literature. The aperture varies from a simple elongated oval shape and sometimes convex downward. In narrow side view this often results in a notched appearance of the final part of the neck.

Discussion: This species is highly variable and different morphotypes have been separated in the literature under specific names. The shell is basically compressed pyriform, longer than broad but the relative proportions can vary exceedingly. The neck is attached to the main body either with convex lines or with nearly straight lines. Leidy (1879) had already noticed the extraordinary variety of xenosomes used by the organism to form the test. He had also noticed that the size of what he considered as idiosomes had no relationships with the size of the shell itself (ie. often the smaller test had the larger xenosomes). He also noticed that the elements composing the shell were of variable shapes and occasionally were substituted by quartz particles, diatom frustules and sponge spicules. Leidy (1879) elaborated on the origin of the supposed idiosomes but could not come up with an explanation. We know today that

these xenosomes are derived from idiosomes of other thecamoebians.

Nebela collaris was originally described by Ehrenberg (1848) under the name Diffflugia collaris. His Diffflugia reticulata, Diffflugia Carpio, Diffflugia cancellata, Diffflugia binodis and Diffflugia purpurescens are all synonyms of N. collaris. Probably Ehrenberg's Diffflugia annulata, Diffflugia laxa and Diffflugia cellulifera are also synonyms. In 1872, Ehrenberg rearranged most of the nominal species in a trinomial system in which they fell under the category Diffflugia reticella which is split into an edentate subgroup (allodictya) and a dentate one (odontodictya). The taxonomic value of these names vis a vis the binomial system is rather obscure. If they were taken as subgeneric groups then the entire taxonomy of thecamoebians would have to be rearranged. Nobody has used these names for the last century and a half and therefore I legitimately consider them as nomina oblita (International Code of Zoological Nomenclature, article, 23b; Stoll, 1964).

In 1874, Leidy created the new species Diffflugia numata which he put into the subgenus Nebela. In 1876, the subgenus Nebela was apparently elevated to the genus rank by the same author. In 1879, Leidy admitted that his Nebela numata was a junior synonym of Nebela collaris.

In my list of synonyms I have not even attempted to list all the cases in which the various binomena have been used by the various authors, nor have I listed all the nominal species that were obviously junior synonyms or that have been considered junior synonyms by other authors. I have limited the list of synonyms to the nominal species that have been used more frequently, or to those very old ones that are more likely to affect the name of the species. Under the name Nebela collaris (Ehrenberg, 1848a), Ogden and Hedley figure a form which is distinctly

wider than the form figured by Ehrenberg (1872) under the name Diffflugia Reticella collaris which, in Ehrenberg's opinion, was a synonym of his own (1848a) D. collaris. In the same paper the two authors differentiate, on what appears too be very questionable criteria, this species and Nebela carinata (Archer, 1867), Nebela dentistoma Penard 1890, Nebela galeata Penard 1890, Nebela militaris Penard 1890, and Nebela tubulosa Penard 1890. All these species appear to me to belong together under the name N. collaris.

The complete treatment of this species, which is one of the commonest in nature, and as such one of the most widely split in the literature, is a very major taxonomic problem that exceeds the limits of an honours thesis and cannot possibly be dealt with at this time.

Pontigulasia compressa (Carter, 1864).

pl. 2, fig. 22

Diffflugia compressa CARTER, 1864, p. 22, pl. 1, figs. 5, 6.

Pontigulasia compressa (Carter). AVERINTSEV, 1906, p. 169. MEDIOLI and SCOTT, 1983, p. 35, pl. 6, figs. 5-14.

Description: The test is brown, usually large, laterally compressed with a well defined neck of variable length joining the body in a v-shaped wedge. The junction between the neck and the test is marked by a visible constriction which Medioli and Scott (1983) report to be the location of a doubly perforated internal diaphragm. The aperture, located at the end of the tapering neck, is rounded or elliptical in cross section. The test is composed of fine grained silica particles. Intergradation between this

species and Lecquereusia spiralis was observed in some specimens as reported by Medioli and Scott (1983) and McCarthy (1984).

PLATE 1

Drawings courtesy of F. S. Medioli

Note: bar scales present below each drawing

Figures 1,2 Diffflugia bacillifera Penard, 1890

1. side view of fine grained specimen with xenosomes of diatoms: note apertural lip
2. side view of specimen with coarse xenosomes although fine xenosomes at the aperture

Figures 3,4 Diffflugia corona Wallich, 1864

3. side view of specimen with spines and crenulated apertural collar
4. side view of specimen with a smooth, thick apertural collar

Figure 5 Diffflugia tricuspis Carter, 1856

5. side view of specimen with poorly developed lobes at the aperture

Figure 6 Diffflugia urceolata f. elongata Penard, 1902

6. side view of specimen with coarse xenosomes and a short neck

Figure 7 Diffflugia urens Patterson et al., 1985

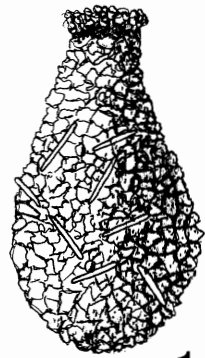
7. side view of specimen with xenosomes of various sizes and composition

Figure 8 Heleopera sphagni (Leidy, 1874)

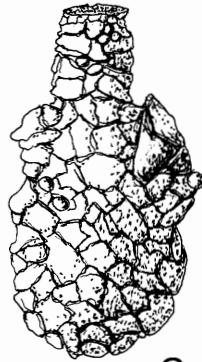
8. side view of specimen; note grainsize increase at fundus

Figure 9 Nebela collaris (Ehrenberg, 1848a)

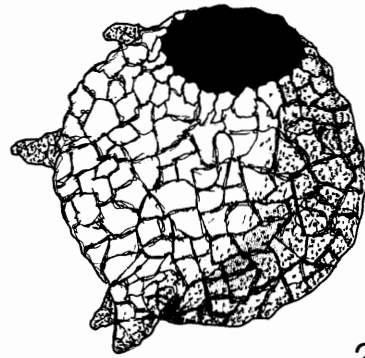
9. side view of pseudo-autogenous test; note keel on lateral border



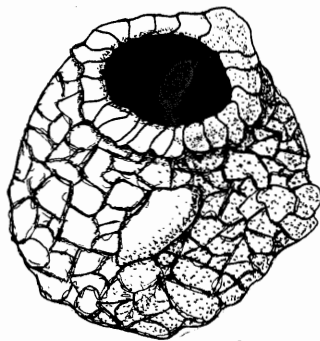
30µm 1



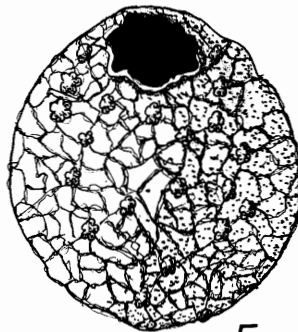
100µm 2



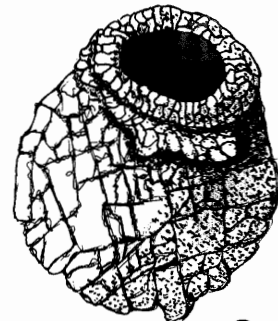
100µm 3



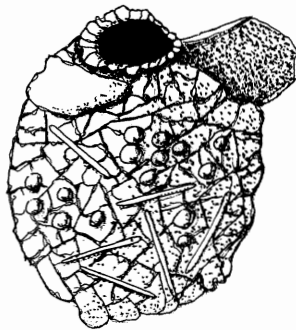
20µm 4



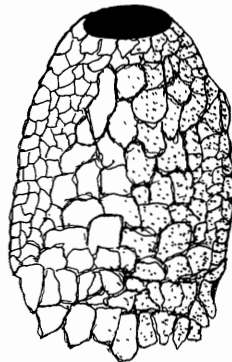
30µm 5



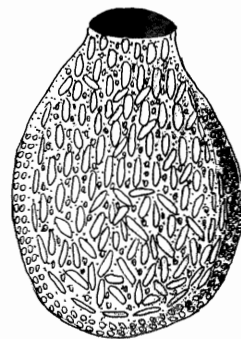
30µm 6



100µm 7



100µm 8



100µm 9

PLATE 2

Note: bar scales present below each photograph

Figure 1 Centropyxis aculeata (Ehrenberg, 1830)

1. ventral view of specimen without spines

Figure 2 Centropyxis constricta (Ehrenberg, 1843)

2. side view of specimen with two spines

Figures 3-5 Diffflugia bacillifera Penard, 1890

3. side view of large specimen with variable
xenosome composition

4. side view of specimen with coarse xenosomes
although finer at the aperture

5. side view of fine grained specimen with a
well developed apertural lip

Figures 6,7 Diffflugia corona Wallich, 1864

6. side view of specimen with spines and
and crenulated apertural collar

7. side view of specimen with coarse xenosomes
and a smooth, thick apertural collar

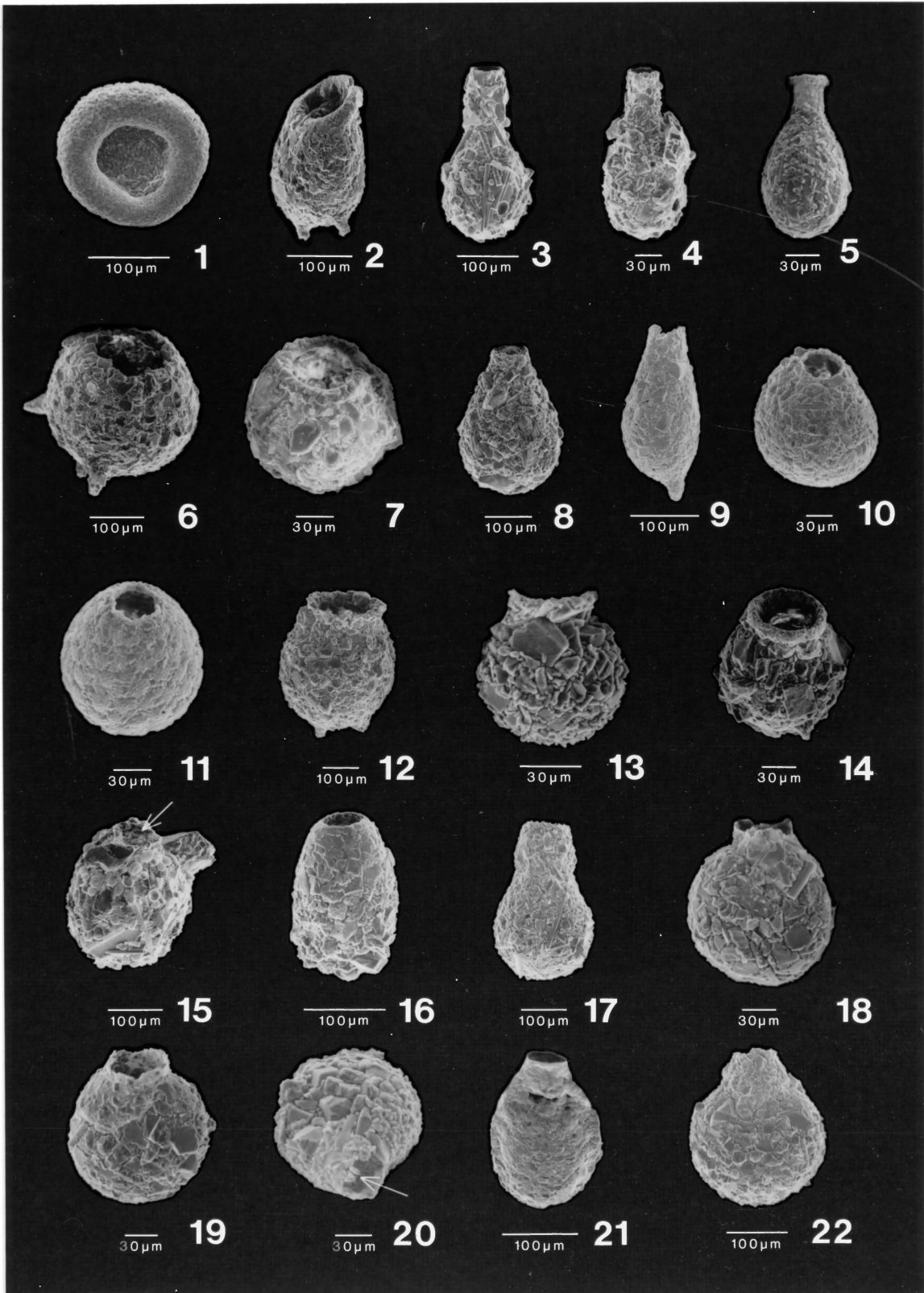
Figure 8 Diffflugia oblonga Ehrenberg, 1832

8. side view of typical specimen

- Figure 9 Diffflugia protaeiformis Lamarck, 1816
9. side view of specimen with a broken aperture:
fundus tapers to a blunt spine
- Figures 10,11 Diffflugia tricuspis Carter, 1856
10. side view of xenogenous specimen with
poorly developed apertural lobes
11. side view of autogenous specimen with
well developed apertural lobes
- Figure 12 Diffflugia urceolata Carter, 1864
12. side view of specimen with a recurved apertural
collar and blunt proturbances at the fundus
- Figures 13,14 Diffflugia urceolata f. elongata Penard, 1902
13. side view of specimen with xenosomes of various
sizes and a recurved apertural collar
14. side view of typical specimen
- Figure 15 Diffflugia urens Patterson et al., 1985
15. side view of specimen with xenosomes of various
sizes and composition: arrow indicates location
of aperture which is completely obscured by a
diaphragm at the opening
- Figure 16 Heleopera sphagni (Leidy, 1874)
16. side view of laterally compressed specimen:

note grainsize increase at fundus

- Figure 17 Lagenodifflugia vas (Leidy, 1874)
17. side view of specimen with a slight constriction
at the base of the neck
- Figures 18-20 Lecquereusia spiralis (Ehrenberg, 1840)
18. side view of typical specimen
19. side view of typical specimen
20. apertural view of specimen with coarse xenosomes:
arrow indicates the location of an internal
diaphragm
- Figure 21 Nebela collaris (Ehrenberg, 1848a)
21. side view of specimen that collapsed slightly
at the base of the neck: note keel on lateral
border
- Figure 22 Pontigulasia compressa (Carter, 1864)
22. side view of typical specimen with
v-constriction at base of the neck



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