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DIATOMS AS INDICATORS OF COASTAL PROCESSES AND SEDIMENTARY ENVIRONMENTS IN THE CANADIAN ARCTIC

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Keywords: Diatoms, coastal environments, paleoenvironmental reconstruction, Beaufort Sea

Abstract: Surface sediment diatom assemblages from 74 stations along the southeastern Beaufort Sea coasts were analysed to provide modern analogues for future stratigraphic studies. The modern environments sampled are believed to represent the full range of sedimentary facies that may have been preserved in Holocene stratigraphic records of the Beaufort Shelf. Samples were collected from coastal freshwater environments, backbarrier environments, the shoreface, the inner shelf, and the Mackenzie Delta front area. A total of 225 diatom taxa representing 60 genera were identified. The results of this study suggest that diatoms represent excellent indicators of environmental parameters such as the proximity of ponds and other freshwater bodies to the sea, the degree of communication of lagoonal environments with the open sea, the magnitude of tidal currents, the importance of storm-induced overwash processes; the salinity fluctuations induced by the Mackenzie River plume and other freshwater inputs from the land, the proximity of the polar pack ice and duration of the landfast ice, and the water depth.

LES DIATOMÉES EN TANT QU'INDICATRICES DE PROCESSUS CÔTIERS ET D'ENVIRONNEMENTS SÉDIMENTAIRES DANS L'ARCTIQUE CANADIEN

Mots clés: *Diatomées, environnements côtiers, reconstitution paléoenvironnementale, mer de Beaufort.*

Résumé : *Les assemblages diatomifères des sédiments de surface des côtes de la mer de Beaufort furent analysés afin de produire un cadre de référence pour l'identification des environnements sédimentaires préservés dans les séquences stratigraphiques de la plate-forme continentale. Les 74 échantillons prélevés proviennent d'un large éventail d'environnements, tels que des étangs côtiers, des lagunes, l'avant-côte, la plate-forme continentale et le front deltaïque du fleuve Mackenzie. Près de 225 taxa de diatomées furent identifiés, répartis en 60 genres. Les résultats de cette étude suggèrent que les diatomées constituent d'excellents indicateurs pour la reconstitution de paramètres paléoenvironnementaux tels que la distance séparant les étangs côtiers de la mer, le degré de communication entre les lagunes et la mer, la force des courants de marée, l'intensité des débordements de tempête, les fluctuations de salinité provoquées par le panache de turbidité du fleuve Mackenzie et par d'autres apports d'eau continentale, la proximité de la banquise polaire et la durée des gels saisonniers en milieu côtier, et la profondeur de l'eau.*

INTRODUCTION

Diatoms are unicellular algae composed of siliceous valves which are usually well preserved in the stratigraphic record since the Cretaceous. They are ideal paleoenvironmental proxies since they are single-celled organisms that respond rapidly to environmental changes and are very abundant in most marine, coastal and lacustrine environments. Diatoms can be used as indicators of environmental parameters such as water chemistry, paleosalinity, paleodepth, paleo-temperature, paleocurrents and paleonutrient concentrations. Most diatom taxa found in Quaternary sediments are extant and thus sound paleoecological interpretations are based upon similarities between populations found in modern habitats and recovered microfossil assemblages. Paleoenvironmental interpretations of downcore diatom data that have been based on previous studies of the surface sediment assemblages of modern environments have proven to be particularly valuable for example in the Bering Sea (Starratt, 1993), Baltic Sea (Witkowski, 1994), Thames estuary (Juggins, 1992), Pacific Northwest (Shennan *et al.*, 1996), northwest England (Shennan *et al.*, 1995; Zong, 1997) and in numerous paleolimnological studies (e.g., reviewed in Charles & Smol, 1994; and Moser *et al.*, 1996). In coastal areas, the characterization of modern diatom assemblages may yield reliable criteria to identify ancient analogues of sedimentary environments and provide a valid basis for the elucidation of paleo-oceanographic conditions and changes in sea level. The Beaufort Sea coasts represent an area of particular interest to studies of coastal paleoenvironments and sea-level variations as they lie within an area especially sensitive to both short- and long-term environmental changes. In the short-term, rates of coastal retreat in excess of 2 m yr^{-1} are common (Héquette & Ruz, 1991), while over a longer time-scale the area has undergone a persistent rise in sea level since the Late Pleistocene (Hill *et al.*, 1985). The purpose of this project is to provide a firmer basis for the use of diatoms as indicators of coastal paleoenvironments in the Beaufort Sea. To this end the diatom assemblages preserved in the surface sediments of a variety of coastal sub-environments, from salt marshes to the inner shelf, were analysed to define the present biofacies of these sedimentary basins and provide modern analogues for future stratigraphic studies.

SETTING

The Beaufort Sea is the southernmost part of the Arctic Ocean. The southeastern Beaufort Sea is bordered by the Tuktoyaktuk Coastlands which are part of the Arctic Coastal Plain between the Mackenzie Delta and Amundsen Gulf (Rampton, 1988), and comprise the Tuktoyaktuk Peninsula and Richards Island (figure 1). The southwestern part of the Tuktoyaktuk Peninsula is primarily formed of ice-contact deposits, moraines or morainal veneer overlain by lacustrine sediments of Holocene age, while the northeastern part consists of glacial outwash sands which are in places covered by eolian or lacustrine sediments (Rampton, 1988). The Tuktoyaktuk Peninsula is believed to have been continuously ice-free for at least the past 13 ka (Ritchie, 1984; Vincent, 1989). Between 13 to 8 ka BP, climate was significantly warmer than at present, possibly as a result of an early Holocene Milankovitch insolation maximum (Ritchie *et al.*, 1983; Ritchie, 1984). Thermokarst occurred widely on the Tuktoyaktuk Coastlands (Rampton, 1988; Mackay, 1992), as the active layer deepened regionally and numerous retrogressive thaw slumps developed (Rampton, 1974). Rampton (1988) suggested that thermokarst basins formed where the deepening active layer intercepted massive icy beds. Ponds formed at such locations and developed into thermokarst lakes as the basins expanded, mainly by retrogressive thaw slumping. The paleoecological record from lake sites indicated that a gradual climatic cooling began ca 8 ka BP. The limit of the forests shifted southwards, reaching its present position at about 4.5 ka BP (Spear, 1983; Ritchie, 1984). The present-day climate of the southern Beaufort Sea coastlands is characterized by short cool summers and long harsh winters. The mean annual temperature at Tuktoyaktuk is -10 °C. Precipitation is low, with an annual mean of 142 mm, roughly half of which is accounted for by winter snowfall (Environment Canada, 1993). Cold climatic conditions during the Pleistocene have led to the formation of permafrost throughout the region. Permafrost is widespread beneath land areas, ranging from 200 to 500 m in thickness on the Tuktoyaktuk Peninsula, and over 700 m on Richards Island (Judge *et al.*, 1987). Much of the topography in the area can be attributed to the presence of subsurface ground-ice. Thermokarst lakes cover about 35 % of Richards Island and the Tuktoyaktuk Peninsula, and nearly 70 % of the northeastern part of the peninsula.

Forbes (1980) suggested that the relative sea level (RSL) of the Beaufort Sea has been rising over the last 15 ka. Hill *et al.* (1985) reported a number of additional ages and proposed a Late Quaternary sea-level curve for the Canadian Beaufort Sea. According to this curve, the RSL rose from -140 m at 27 ka BP to a relative highstand of -40 m at approximately 15 ka BP and was then lowered to a Late Wisconsinan lowstand of -70 m. During the Holocene, the RSL rose from -70 m to its present position. The rate of RSL rise during the Holocene was further investigated by Hill *et al.* (1993). During the Early Holocene, this rate was on the order of 4 to 5 mm yr^{-1}, and then increased to 7 to 14 mm yr^{-1} during the mid-Holocene. Over the last 3 ka, the rate of RSL rise slowed markedly. Recent radiocarbon dates on peats from modern coastal marshes on the Tuktoyaktuk Peninsula also suggest a slow rise in sea level during the last 1 ka (Hill *et al.*, 1990). Although not statistically significant, tide-gauge data from Tuktoyaktuk suggest that relative mean sea level is still rising at a rate of about 1 mm yr^{-1} (Forbes, 1980).

The coastal areas of the Tuktoyaktuk Peninsula are generally low lying with local relief less than 30 m. The coast consists mainly of bluffs developed in ice-bonded Quaternary sediments, and of barrier islands and spits enclosing, partially or completely, lagoons and embayments formed by the breaching of thermokarst lakes. Spits and barrier islands form approximately 30 % of the length of the coastline east of the Mackenzie Delta (Harper, 1990). Héquette & Ruz (1991) calculated that barrier islands migrate onshore at a mean rate of 3.1 m yr^{-1} while spits are retreating at an average rate of 1.7 m yr^{-1}. Causes of the widespread coastal retreat along the southeastern Beaufort Sea include: 1) wave-induced erosion; 2) thermal erosion (Harper, 1990); and 3) the ongoing relative sea-level rise (Hill *et al.*, 1993). The Canadian Beaufort Shelf extends offshore to 60-100 m water depth and is characterized by a very gentle gradient. The area is divided into three distinct physiographic regions: the narrow western shelf adjacent to the U.S. border, the Mackenzie Trough, and the broad eastern shelf. The fine surficial sediments (silts and clays) of the inner shelf are mainly derived from deposition of suspended sediments from the Mackenzie River.

The coastal ice regime is marked by four "seasons": open water, freeze-up, winter and break-up. Coastal ice forms and becomes intermittently stationary during the freeze-up season, usually from October to mid-December. The winter season, usually from mid-January through May, is characterized by stable coastal ice (fast ice). The break-up season from June to mid-July is associated with deterioration of the fast ice. This period is followed by the open water season, from mid-July to early October. During the open-water season, winds originate mainly from the east, southeast and northwest quadrants. Storm winds (>40 km h^{-1}) are usually from the northwest. The presence of sea ice during eight to nine months limits wave activity during most of the year and, even during the open-water season, wave generation is limited by the fetch-restricting pack ice. As a result, the Beaufort Sea is a moderate wave-energy environment and nearly 80 % of deep-water waves are less than 1 m in height (Harper & Penland, 1982). Tidal range is small, with typical ranges of 0.3 m for neap tides and 0.5 m for spring tides. Storm surges, however, are known to be significant. Surveys of log debris lines stranded on the tundra during these storm events indicate surge elevations up to 2.4 m above mean sea level in the Tuktoyaktuk area (Harper *et al.*, 1988).

The Tuktoyaktuk Coastlands are covered by low Arctic tundra vegetation. Upland sites are dominated by dwarf shrubs and lichens, whereas poorly drained peaty areas show ice-wedge polygon and frost hummock development with dominance by *Eriophorum vaginatum* and *Carex* stands (Corns, 1974). Sedge tussock flats occur around many lakes, on the bottom of drained lakes and along coastal lowlands (Mackay, 1963).

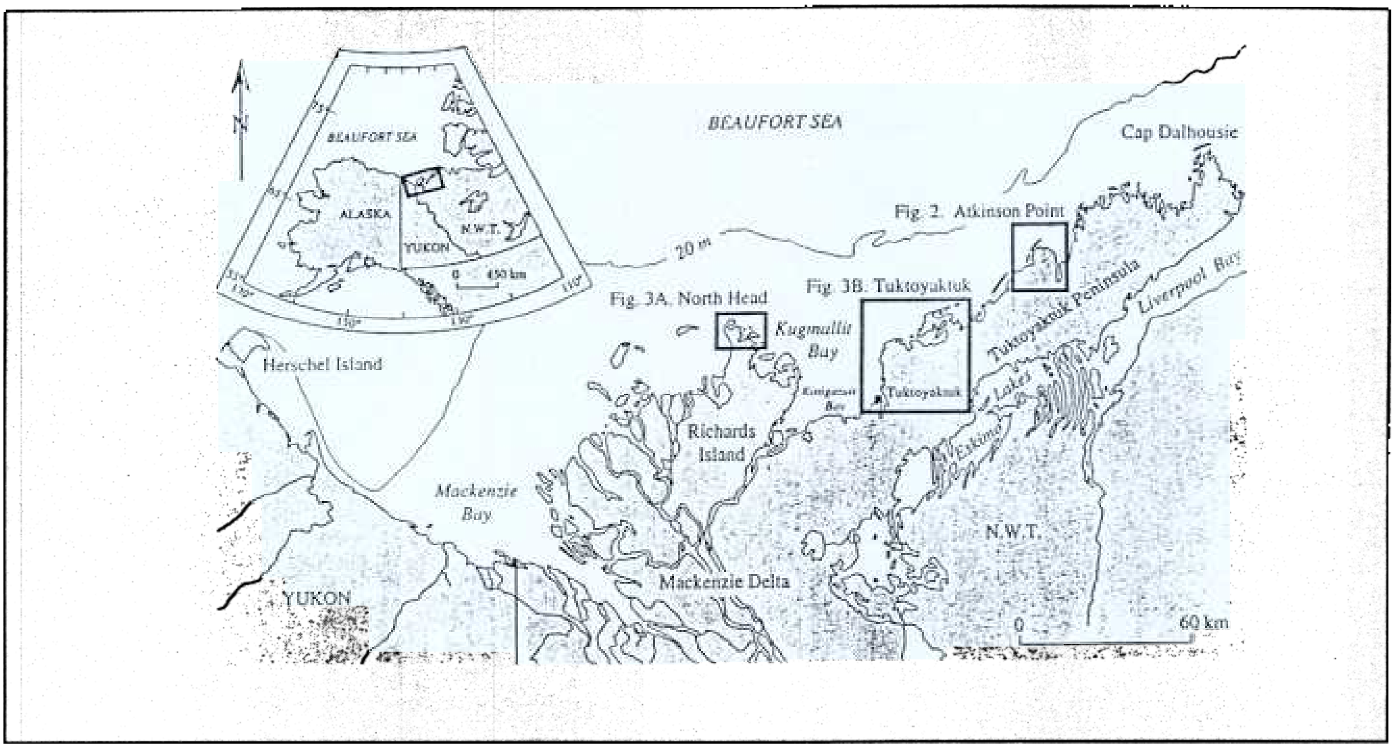

Figure 1:The southeastern Beaufort Sea.
Figure 1 : Le sud-est de la mer de Beaufort

METHODS

Sampling

Surface sediment samples were collected at 74 stations along the southeastern Beaufort Sea (figures 2 and 3). The stations were selected to encompass an environmental spectrum as broad as possible. The modern environments sampled in this study are thought to represent the full range of sedimentary facies preserved in the Holocene stratigraphic records of the Beaufort Shelf. Samples were collected from coastal freshwater environments, back-barrier environments, the shoreface, the inner shelf, and the Mackenzie Delta front area. Sampling was assisted by using a 200 kHz depth recorder (Raytheon Fathometer®). Surface grabs or top core sediments were collected. A Livingston coring system was utilized in the cases where sediments were unbonded and when they were anticipated to be very soft and highly organic (e.g. in breached lake basins). A portable vibracoring system was used in locations where sediments were unbonded and firmer than could be penetrated by the Livingston system. Ice bonded material was collected using a CRREL auger system with a Stihl power head mounted on a Winke Unipress drill stand. The upper 2 to 5 cm of sediment in cores or surface grabs was used. These surface sediments likely contain a time-averaged assemblage composed of diatoms deposited during a number of discrete events. The distributional patterns derived from these samples do not represent the ecological preferences of each species but may reflect all the processes that have led to the formation of the assemblages, including the ecological requirement of each species of the biocenosis, and the processes that have led to the final composition of the thanatocenosis. Seasonal variability in the composition of the biocenosis and discrete events responsible for the reworking of the assemblage may therefore be averaged out, but the time period represented by the sample will be unknown.

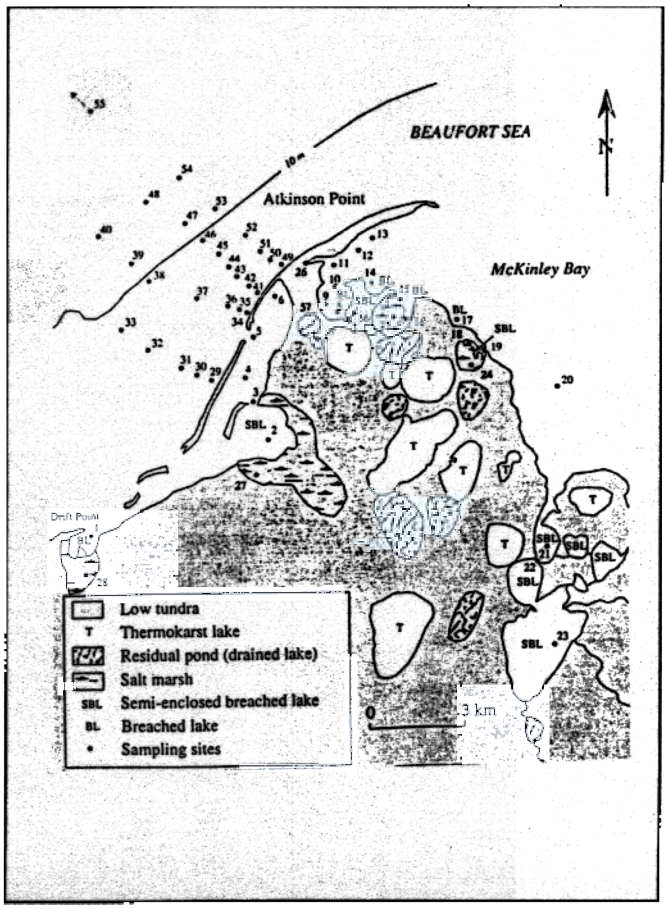

Figure 2: The Atkinson Point area and location of sampling sites.
Figure 2 : Localisation des sites d'échantillonnage dans le secteur de la pointe Atkinson.

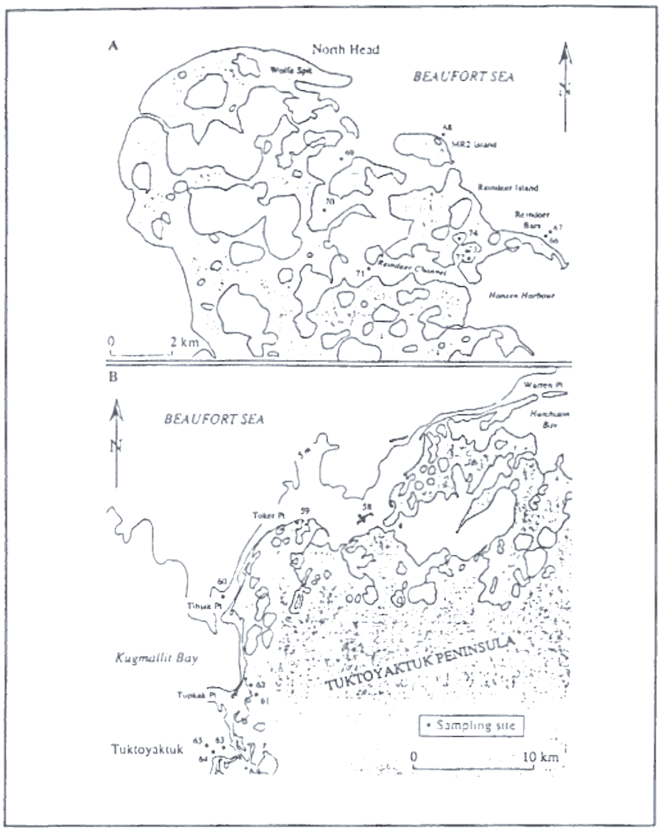

Figure 3: The North Head (A) and Tuktoyaktuk (B) areas and location of sampling sites.

Figure 3 : Localisation des sites d'échantillonnage dans les secteurs de North Head (A) et de Tuktoyaktuk (B)..

Cleaning and counting

In the Paleoecology laboratory at Laval University, a homogenized sediment subsample (ca. 1 cm^3) from each of the surface samples was digested in hot acid (30 % H_2O_2). The siliceous material was then repeatedly washed and decanted in order to remove acids. Coarse sand was removed by decanting. For samples with high proportions of clay-sized material, heavy-liquid separation with sodium polytungstate was used to concentrate diatom valves. An aliquot of the resulting slurry was evaporated onto coverslips, which were subsequently mounted onto glass slides with Naphrax®. Diatoms were identified and enumerated along transects using a Leica DMRB microscope under phase contrast illumination at a magnification of 1000x. When possible, 200-300 valves were counted per sample. Several slides had sometimes to be analysed to reach as high a number of diatom valves as possible, particularly in samples from shoreface environments. Broken valves consisting of more than half of the valve were counted as one valve. Diatom identifications were made to the lowest taxonomic level possible. The Shannon-Wiener diversity index (H') of the assemblages was calculated from the relative abundance data ($H' = -\Sigma\, p_i \log_e p_i$, where p_i is the proportion of species i in the assemblage). The ecology (salinity preferences and life-forms), distribution and taxonomy of the Beaufort Sea coastal diatoms is presented in Campeau *et al.* (1998).

Ordination techniques

Canonical correspondence analysis (CCA) was performed on surface samples data using the computer program CANOCO version 3.12 (ter Braak, 1987), with downweighting of rare taxa. CCA detects patterns of variation in species data that can be explained by the observed environmental variables (Jongman *et al.*, 1995). Diatom taxa that occurred in at least three of the 74 sampling sites with a relative abundance of ≥1% were included in the CCA. Of the 225 taxa identified in the surface sediments, 105 met the above criterion. In addition to the measured water depth at each station, the available environmental data consist of some sedimentological data, such as the percentage of sand (≥63 µm), mud (<63 µm) and organic matter, and the distance of the sampling stations from the Mackenzie Delta mouth. These variables had skewed distributions and were log-transformed ($\ln(x+1)$) prior to statistical analyses. In addition, the nine main sedimentary environments occurring in our set of sampling sites, including the freshwater environments (ponds, salt ponds and coastal peats), salt marshes, semi-enclosed breached lakes, tidal channels, breached lakes and lagoons, shoreface, inner shelf, delta front and delta front lagoons, were included as dummy (value 0 or 1) passive variables. Summary statistics for the variables used in the CCA are given in Table I. The environmental variables in the CCA biplot are represented by arrows, whereas species and sampling sites are marked by numbers. Variables with high positive correlations have small angles between their biplot arrows, while high negative correlations are usually depicted by arrows pointing in opposite directions (Jongman *et al.*, 1995). Variables with long arrows have high variance and their proximity to the axes summarizes the relative weight of each variable in determining each axis (ter Braak, 1987). The direction of each arrow indicates ascending values for each environmental variable. Each taxon's position in the ordination space is an approximation of its weighted-average optimum in relation to other taxa and each explanatory variable (Jongman *et al.*, 1995).

Table I: Summary statistics for the variables used in the canonical correspondence analysis.

Table I : ***Statistiques sommaires des variables utilisées dans l'analyse canonique des correspondances.***

Variable	Symbol	Minimum	Maximum	Median
Water depth (m)	DEPTH	0	14	
Sand (%)	SAND	0.5	99.9	
Mud (%)	MUD	0	98.2	
Organic matter (%)[2]	OM	0	98.2	
Distance to the Mackensie Delta (km)[3]	DIST	37.8	126	
Sedimentary environment (dummy (value 0 or1) passive variable		Symbol		Number of samples
Freshwater environments[4]		FRESH		3
Salt marshes		MARSH		8
Semi-enclosed breached lakes		SBL		6
Breached lakes and lagoons		BL		11
Tidal channels		TC		6
Shoreface		SHORE		21
Inner shelf		SHELF		
Delta front		DELTA		4
Delta front lagoons		DLAG		6

[1] **Mud: <63 µm**

[2] **As determined by loss on ignition**

[3] **Distance to the Mackenzie Delta mouth (southernmost part of Kittigazuit Bay (69° 20'00''N; 134° 00'00''W)**

[4] **Coastal peats and ponds**

RESULTS

A total of 225 diatom taxa representing 60 genera were identified in the 74 sediment samples. With respect to the salinity requirements, brackish-water forms were most abundant. The majority of the taxa had freshwater-brackish (42 %) or brackish water (34 %) affinities. Few had marine or marine-brackish (14 %) or freshwater affinities (9 %). In general, the relative abundance of freshwater-brackish species tended to increase towards the Mackenzie Delta front, while brackish and marine forms tended to increase towards the northeastern coasts of the Tuktoyaktuk Peninsula. Freshwater diatoms also reached greater abundances in some restricted areas along the peninsula, especially in lagoons influenced by freshwater inputs. The dominance of euryhaline taxa indicates important fluctuations in osmotic pressure due to the dispersion of the Mackenzie River plume along southeastern Beaufort Sea coasts. Benthic diatoms were predominant, with only 10.5 % of planktonic or tychoplanktonic forms. The dominance of benthic species reflects the preponderance of shallow water habitats in our sample set. Of the 225 taxa identified, 47 % were epipelic, 19 % epipelic or epiphytic, 8.5 % euplanktonic, 8.5 % epipsammic, 7 % epontic (sea ice diatoms), 7 % aerophilic and 2 % tychoplanktonic.

The CCA biplot (figure 4) presents a clear separation between shallow and deeper environments on the first axis, and between brackish-marine and freshwater-brackish environments on the second axis. Five main clusters can be easily distinguished (figure 4B) which regroup the sites located in deep muddy environments (upper left quadrant), the delta front (uppermost part of the ordination), shallow or subaerial environments with high organic matter contents (upper right quadrant), sandy backbarrier environments (lower right quadrant) and the shoreface (lower left quadrant). Axis 1 of the CCA ordination appears to represent a water depth gradient whereas axis 2 seems to represent a salinity and grain-size gradient. In general, as one moves from the top to the bottom of the biplots, the percentage of sand, the distance from the Mackenzie Delta and the salinity increase, whereas water depth increases from the right to the left. Diatom taxa that plot in the upper right quadrant (figure 4A) are mostly aerophilic forms that live in subaerial environments with high organic matter contents (salt marshes and ponds). Species plotting in the lower right quadrant are primarily epipsammic diatoms that prefer sandy shallow brackish environments such as lagoons and breached lakes. Species plotting on the lower left quadrant are epipelic, epipsammic and planktonic taxa present on the shoreface. Deeper sites are positioned in the upper left quadrant. Diatom taxa that plot in close proximity to these sites are mostly planktonic forms. Sites from the Mackenzie Delta front are plotted near the origin of the first axis as they have intermediate water depths. They contain species that are present both in shallow freshwater environments and in the inner shelf, but have few species in common with brackish backbarrier environments. Sites 60 and 65 (figure 4B), located in the Mackenzie Delta front, have diatom assemblages closely related to those of the southeastern inner shelf. Stations 66 to 68 are located in shoreface environments from the Mackenzie Delta front and contain diatom assemblages closely related to shoreface assemblages of the Tuktoyaktuk Peninsula (lower left quadrant). Samples 33, 37, 45 and 52 have been collected from the lower shoreface. Their diatom assemblages share similarities with stations both from the shoreface and the inner shelf.

From the CCA biplot, it appears that surface sediment diatoms exhibit distinct distributional patterns which may be related to sedimentary environments. In coastal ponds, diatom assemblages were mostly dominated by epipelic and epiphytic freshwater diatoms, such as *Eunotia praerupta* and *Caloneis tenuis*. Coastal peat assemblages were dominated primarily by freshwater-brackish aerophilic and epiphytic diatoms, such as *Diatoma* cf. *vulgaris*, whereas salt marsh assemblages consisted mainly of brackish aerophilic and epipelic taxa, such as *Diploneis interrupta*. As a consequence of the highly variable environmental conditions and the predominance of sandy material, breached lake and lagoon assemblages were dominated by euryhaline epipsammic diatoms with broad ecological tolerances. The epipsammon consists of small appressed species or species with very short stalks, which occupy depressions in the surface of sand grains. Such epipsammic taxa occur generally in intertidal environments with pronounced currents and sediment displacement (de Jonge, 1985). Along the Tuktoyaktuk Peninsula, *Achnanthes delicatula* ssp. *hauckiana* was the dominant epipsammic diatom of backbarrier environments. The other epipsammic taxa of considerable abundance were *Achnanthes lemmermannii, Opephora olsenii, O. cf. parva, O. marina, Fragilaria cassubica, F. schulzii, and Navicula perminuta.* Despite the dominance of epipsammic taxa, diatom assemblages varied according to an exposure gradient to coastal processes, from semi-enclosed breached lakes to tidal channels. Although dominated by epipsammic species, semi-enclosed breached lake assemblages contained more epipelic and epiphytic taxa than lagoons. Lagoonal assemblages were characterized by an increase in epipsammic diatoms and a decrease in species diversity. These tendencies were amplified in tidal channels which were almost entirely dominated by epipsammic taxa and had the lowest species diversity index (2.5) of all the environments investigated.

Both backbarrier and shoreface environments consisted mainly of sandy sediments. However, backbarrier sediments, although subjected to strong tidal currents, are little reworked by waves, whereas shoreface sediments are strongly reworked by breaking and shoaling waves. This results in a shift in diatom assemblage composition. Backbarrier environments were dominated by epipsammic species, while upper shoreface assemblages were dominated by motile epipelic taxa which are able to reposition themselves in the top layer of sediments on unstable wave-exposed sandy beaches. Lower shoreface assemblages contained mostly planktonic species that had settled out of the water column during fairweather conditions, as well as some epipelic and epipsammic diatoms. Inner shelf assemblages were primarily dominated by euplanktonic and tychoplanktonic forms that were able to settle owing to the low energy environment of the shelf.

Lower shoreface and inner shelf assemblages also contained a number of planktonic and tychoplanktonic forms with freshwater-brackish affinities. The occurrence of these species in inner shelf sediments reflects the freshwater influence of the Mackenzie River plume along the Tuktoyaktuk Peninsula. For example, *Aulacoseira* *islandica*, the most common species of inner shelf assemblages, was also the dominant species of Mackenzie Delta front sediments.

Delta front assemblages contained strongly silicified planktonic species, such as *Aulacoseira islandica* and the resting spores of *Chaetoceros* spp., and epipelic species. Due to the proximity of the Mackenzie River, delta front lagoons differ from the lagoons of the Tuktoyaktuk Peninsula through their lower surface water salinities and finer sediments. Consequently, diatom assemblages contained less epipsammic species, more freshwater-brackish taxa, and more epipelic species adapted to muddy surfaces than lagoonal assemblages of the Tuktoyaktuk Peninsula. The most common diatoms present were *Diploneis smithii*, *Nitzschia sigma*, and *Tryblionella acuminata*. Finally, although never abundant, sea ice (epontic) diatoms were a common component of the Beaufort Sea coastal assemblages.

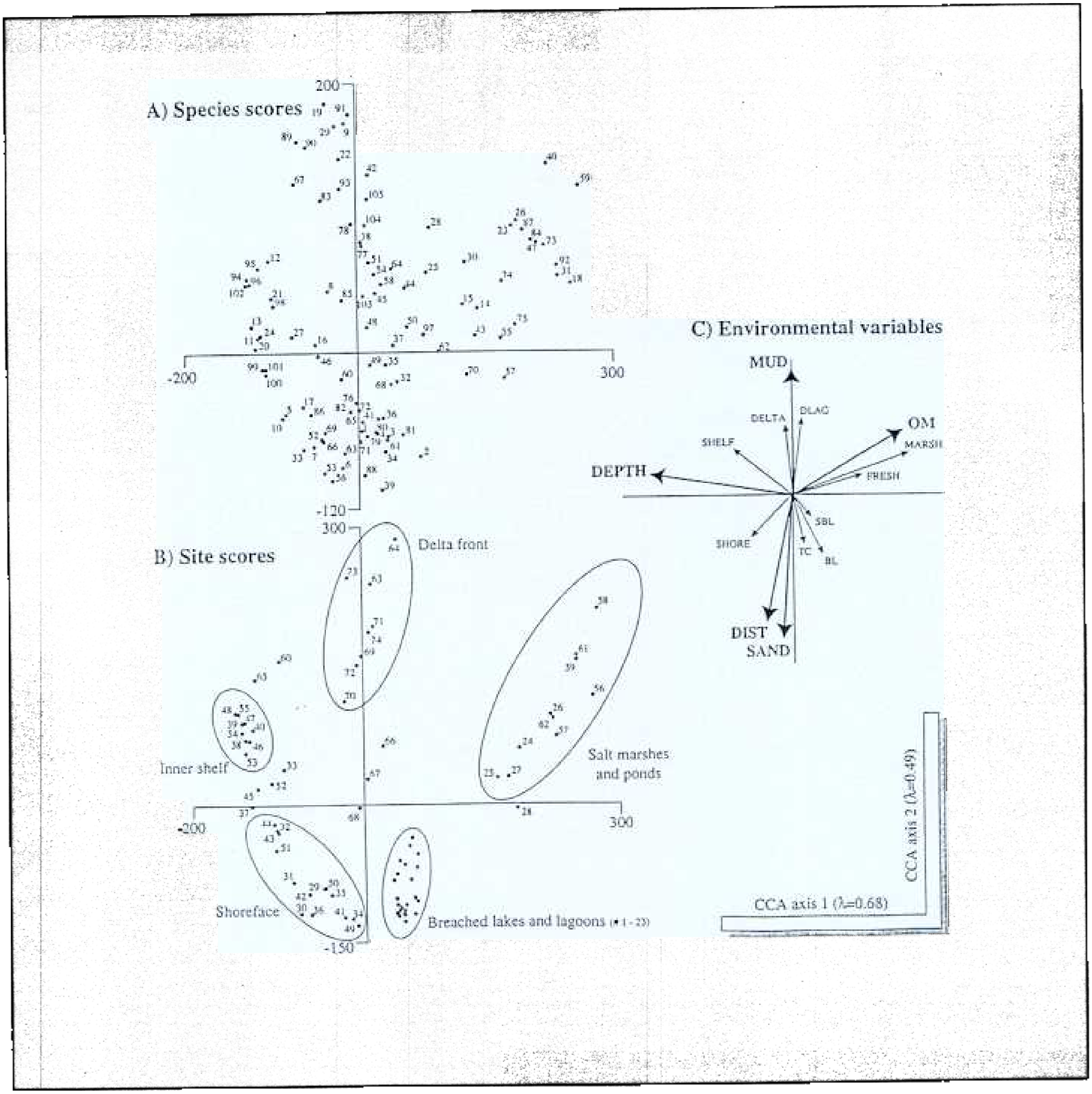

Figure 4: Canonical correspondence analysis (CCA) for the 105 most common diatom taxa (A) and the 74 sampling sites (B). A list of the full diatom names with corresponding numbers used in the CCA is given in Table II. The sampling sites are illustrated in figures 2 and 3. Abbreviations as follows: ACTIVE VARIABLES; DEPTH: Water depth (m); SAND: Sand (%);MUD: Mud (%); OM: Organic matter (%); DIST: Distance to the Mackenzie Delta (km); SEDIMENTARY ENVIRONMENTS (dummy passive variables); FRESH: Freshwater environments; MARSH: Salt marshes; SBL: Semi-enclosed breached lakes; BL: Breached lakes and lagoons; TC: Tidal channels; SHORE: Shoreface; SHELF: Inner shelf; DELTA: Delta front; DLAG: Delta front lagoons.

Figure 4 : Analyse canonique des correspondances (ACC) pour les 105 taxa de diatomées les plus abondants (A) et les 74 sites d'échantillonnage (B). La liste complète des diatomées présentes dans l'ACC est donnée dans le Tableau II. La localisation des sites d'échantillonnage est présentée sur les figures 2 et 3.

Table II: Maximum relative abundances (Max.) of the 105 most abundant diatom taxa, their number of occurrences (Num. Occ.) and the numbers used in the CCA (figure 4).

Table II : Abondances relatives maximales (Max.) des 105 taxa de diatomées les plus abondants, leurs occurences (Num. Occ.) et les numéros utilisés dans l'ACC (figure 4).

N°	Taxon	Max. (%)	Num. Occ.
1	*Achnanthes deliculata* (Kützing) Grunow ssp. *delicatula*	25.3	57
	Achnanthes delicatula fo.2	4.1	3
	Achnanthes delicatula ssp. hauckiana (Grunow) Lange-Bertalot *in* Lange-Bertalot	45.5	43
	Achnanthes lemmermanii Hudstedt	23.1	42
	Achnanthes taeniata Grunow *in* Cleve & Grunow	11.4	16
6	*Amphora acutiuscula* Kützing	2.9	14
7	*Amphora coffeaeformis* (Agardh) Kützing	12.3	30
8	*Amphora copulata* (Kützing) Schoeman & Archibald	20	47
9	*Amphora pediculus* (Kützing) Grunow in Schmidt *et al.*	2.5	7
10	*Amphora* sp. (aff. *ocellata sensu* Peragallo & Peragallo)	5	9
11	*Aulacoseira alpigena* (Grunow) Krammer	2.2	14
12	*Aulacoseira islandica* (Müller) Simonsen	54.9	32
13	*Aulacoseira* cf. *italica* var. *tenuissima* (Grunow) Simonsen	3.6	15
	Berkeleva rutilans (Trentepohl) Grunow	15.7	18
	Caloneis bacillum (Grunow) Cleve	11.7	20
	Caloneis crassa (Gregory) Ross in Hartley	4.6	34
	Caloneis schumanniana (Grunow) Cleve	33.1	36
	Caloneis tenuis (Gregory) Krammer	25.3	3
	Caloneis westii (Smith) Hendey	2	6
	Chaetoceros diadema (Ehrenberg) Gran	4.1	15
	Chaetoceros sp. 1	19.4	33
	[illegible]	1	12
	Cosmioneis pusilla (Smith) Mann & Stickle	4.4	11
24	*Craspedopleura kryophila* (Cleve) Poulin	1.4	7
25	*Denticula kuetzingii* Grunow	4	10
26	*Diploneis interrupta* (Kützing) Cleve	74.1	28
27	*Diploneis litoralis* (Donkin) Cleve	1.2	15
28	*Diploneis ovalis* (Hilse) Cleve	5.3	14
29	*Diploneis smithii* var. *dilatata* (Peragallo) Terry	52.6	26
	Diploneis stroemii Hustedt	1.6	7
	Eunotia praerupta Ehrenberg	23.3	5
32	*Fallacia pygmaea* (Kützing) Stickle & Mann	7.9	20
33	*Fallacia solutepunctata* (Hustedt) Mann	23.1	19
	Fragillaria cassubica Witkowski & Lange-Bertalot	22.5	34
35	*Fragilariopsis cylindrus* (Grunow) Krieger	3.3	7
36	*Fragilariforma virescens* var. *exigua* (Grunow) Poulin	39.2	17
	Fragilaria pinnata f. 1	6.5	11
	[illegible]	3.2	7
	[illegible]	1.7	5
	[illegible]	9.3	8
	[illegible]	9.8	38
42	*Mastogloia elliptica* (Agarth) Cleve	6	5
43	*Mastogloia exigua* Lewis	1.6	5
44	*Navicula abscondita* Hustedt	4.4	4
	Navicula bipustulata Mann	34.6	39
	Navicula cancellata Donkin	11.4	28
	Navicula cincta (Ehrenberg) Ralfs in Pritchard	14.7	12
	Navicula cruciculoides Brockmann	3.9	19
	Navicula sp. 2	4.5	21
	Navicula cryptonella Lange-Bertalot	2.4	6
	Navicula digitoradiata (Gregory) Ralfs in Pritchard	12.6	46
	Navicula directa var. *javanica* Cleve	6.7	15
	Navicula finmarchica (Cleve & Grunow) Cleve	2.3	9
	Navicula flanatica Grunow	15.8	34
	Navicula gragaria Donkin	18.8	18
	Navicula jamalinensis Cleve in Cleve & Grunow	8.8	14
57	*Navicula* sp. [aff. *margalithii* Lange-Bertalot]	38	9
58	*Navicula meniscus* Schumann	23.1	12
59	*Navicula* cf. *microdigitoradiata* Lange-Bertalot	20.4	4
	[illegible]	23.7	33
	[illegible]	17	25
	[illegible]	10	36
	[illegible]	5.1	5
	[illegible]	2.5	10
	[illegible]	7.3	25
	[illegible]	25.4	45
	[illegible]	2.4	12
	[illegible]	3.7	8
	[illegible]	7.1	12

Table II (continued)

N°	Taxon	Max. (%)	Num. Occ
70	*Navicula* sp. (aff. *subadnata* Hustedt)	4.9	12
	Navicula subinflata Grunow in Cleve	2.6	24
	Navicula transitans Cleve	5.8	45
	Neidium ampliatum (Ehrenberg) Krammer	5.4	4
	Nitzschia bilobata Smith	1.6	10
	Nitzschia clausii Hantzsch	8.1	12
	Nitzschia dissipata (Kützing) Grunow	2.2	9
	Nitzschia sigma (Kützing) Smith	17.3	49
78	*Opephora gemmata* (Grunow) Hustedt	2.6	6
79	*Opephora marina* (Gregory) Petit	8.9	19
80	*Opephora olsenii* Moller	16.2	35
81	*Opephora* cf. *parva* (van Heurck) Krasske	12.7	26
82	*Petroneis humerosa* (Brébisson) Stickle & Mann	1.6	18
83	*Petroneis marina* (Ralfs) Mann	15	24
		11.2	9
		9.1	23
		2.5	20
		5.8	4
		33.7	22
		4.5	14
		6	15
		2	7
		10.8	5
		13.1	35
		4.3	13
		15.2	22
		1.5	8
97	*Tabularia fasciculata* (Agardh) Williams & Round	3.4	28
98	*Thalassiosira baltica* (Grunow) Ostenfeld	17.8	31
99	*Thalassiosira hyperborea* var. *septentrionalis* (Grunow) Hasle 1989		32
100	*Thalassiosira hyperborea* (Grunow) Hasle	8.6	19
101	Cf. *Thalassiosira* sp. 1	9.3	19
102	*Thalassionema nitzschioides* (Grunow) Grunow ex Hustedt	11.9	14
103	*Tryblionella apicula* Gregoryi	2.8	10
104	*Tryblionella acuminata* Smith	15	27
105	*Tryblionella levidensis* Smith	4.5	19

CONCLUSION

The analysis of the relationships between modern diatom assemblages and sedimentary environments has enabled the definition of "analogues" of modern facies that may occur in sedimentary sequences of the Beaufort Sea. Comparison of microfossil assemblages with modern populations could yield valuable information on the paleoenvironment. For example, high abundances of aerophilic freshwater species and a variable amount of brackish water taxa could reflect the close proximity of ponds and other freshwater bodies to the sea. The relative abundance of epipsammic taxa could serve as an indication of the degree of communication of lagoonal environments with the open sea and of the magnitude of tidal currents. High occurrences of shoreface diatoms in backbarrier environments could point to intense storm-induced overwash processes. High frequencies of freshwater planktonic and ichtyoplanktonic species on the inner shelf could reflect the extent of the Mackenzie River plume, whereas high frequencies of such species in backbarrier environments could be indicative of localized freshwater inputs from the land. Unusual high abundances of sea ice diatoms in the coastal zone could point to a closer proximity of the polar pack ice or to changes in the duration of the landfast ice. Finally, the ratio between benthic and planktonic species along the shoreface profile could be used to infer the water depth.

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