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L'isolement de deux bassins lacustres et la régression marine dans la région de Kuujjuaq, reconstitués à l'aide de l'analyse des diatomées

Postglazialer Meeresrückzug und damit einhergehende Abtrennung zweier küstennaher Becken von marinem Einfluß Im Gebiet Kuujjuaqs, nordliches Québec: Eine Diatomeenanalyse

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Résumé de l'article

Le contenu diatomifère de carottes provenant du fond de deux lacs situés près de Kuujjuaq à 50 km au sud du rivage de la baie d'Ungava, a été examiné en vue de retracer les phases d'isolement de ces lacs de la mer postglaciaire d'Iberville. La succession stratigraphique des zones de diatomées démontre clairement les changements paléoenvironnementaux provoqués par le relèvement isostatique postglaciaire et la régression marine; on reconnaît en effet dans les séquences diatomologiques une phase d'occupation marine, une phase d'isolement de la mer et une phase lacustre subséquente. L'analyse des diatomées s'est révélée un outil utile pour identifier la phase et les modalités d'isolement des bassins devenus lacustres et pour retracer les changements de paléosalinités associés. En tenant compte des dates au 14C sur les unités d'isolement, de l'altitude du seuil de ces lacs et de la forme des courbes d'émersion des régions adjacentes, une courbe d'émersion préliminaire de la région de Kuujjuaq a pu être construite. Cette courbe montre qu'après la déglaciation, datée à 7000 BP, l'emersion fut rapide et continue à un taux moyen de l'ordre de 5,7-5,8 m/siècle jusqu'à environ 4800-4300 BP. Par après, l'emersion fut plus lente, à un taux d'environ 0,9 m/siècle. Cette étude s'ajoute à d'autres pour mettre en évidence le grand potentiel de l'analyse des diatomées pour la reconstruction précise de courbes de variation du niveau marin et de relèvement isostatique des régions englaciées.

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ISOLATION OF LACUSTRINE BASINS AND MARINE REGRESSION IN THE KUUJJUAQ AREA, NORTHERN QUÉBEC, AS INFERRED FROM DIATOM ANALYSIS

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ABSTRACT The Holocene sediment records of two lakes, located 50 km south of the Ungava Bay coast near Kuujjuaq have been examined using diatom analysis in order to trace basin isolation from marine influence. The succession of diatom zones clearly documents paleoenvironmental changes induced by glacio-isostatic uplift and regression of postglacial D'Iberville Sea through consecutive periods of marine occupation, isolation from the sea and subsequent lacustrine conditions. Diatom analysis proved to be an effective tool in identifying the position of the isolation contact in the sediment columns and in defining the related changes in paleosalinity and isolation dynamics. Based on the ^{14}C-dated isolation contacts and the threshold elevations of both lakes, a tentative emergence curve has been reconstructed which is in agreement with curves from adjacent areas. This allowed, for the first time, to infer trends in glacio-isostatic rebound and duration of marine submergence for an area from which paleogeographical data are almost entirely lacking. The curve shows that, following deglaciation about 7000 years ago, the Kuujjuaq area experienced continuous and rapid emergence in the order of 5.7-5.8 m/century until 4800-4300 years BP. Thereafter, emergence slowed to a rate of approximately 0.9 m/century. This study provides further evidence for the usefulness of diatom analysis in reconstructing sea-level changes and land uplift of formerly glaciated regions.

RÉSUMÉ *L'isolement de deux bassins lacustres et la régression marine dans la région de Kuujjuaq, reconstitués à l'aide de l'analyse des diatomées.* Le contenu diatomifère de carottes provenant du fond de deux lacs situés près de Kuujjuaq à 50 km au sud du rivage de la baie d'Ungava, a été examiné en vue de retracer les phases d'isolement de ces lacs de la mer postglaciaire d'Iberville. La succession stratigraphique des zones de diatomées démontre clairement les changements paléoenvironnementaux provoqués par le relèvement isostatique postglaciaire et la régression marine; on reconnaît en effet dans les séquences diatomologiques une phase d'occupation marine, une phase d'isolement de la mer et une phase lacustre subséquente. L'analyse des diatomées s'est révélée un outil utile pour identifier la phase et les modalités d'isolement des bassins devenus lacustres et pour retracer les changements de paléosalinités associés. En tenant compte des dates au ^{14}C sur les unités d'isolement, de l'altitude du seuil de ces lacs et de la forme des courbes d'émersion des régions adjacentes, une courbe d'émersion préliminaire de la région de Kuujjuaq a pu être construite. Cette courbe montre qu'après la déglaciation, datée à 7000 BP, l'émersion fut rapide et continue à un taux moyen de l'ordre de 5,7-5,8 m/siècle jusqu'à environ 4800-4300 BP. Par après, l'émersion fut plus lente, à un taux d'environ 0,9 m/siècle. Cette étude s'ajoute à d'autres pour mettre en évidence le grand potentiel de l'analyse des diatomées pour la reconstruction précise de courbes de variation du niveau marin et de relèvement isostatique des régions englaciées.

ZUSAMMENFASSUNG *Postglazialer Meeresrückzug und damit einhergehende Abtrennung zweier küstennaher Becken von marinem Einfluß im Gebiet Kuujjuaqs, nördliches Québec: Eine Diatomeenanalyse.* Um die Abtrennung (Isolation) zweier küstennaher Seen von marinem Einfluß rekonstruieren zu können, wurden deren holozäne Sedimente auf ihren Gehalt an fossilen Diatomeen untersucht. Die beiden Seen befinden sich etwa 50 km südlich der Ungava Bay in der Nähe Kuujjuaqs. Die Abfolge der Diatomeenassoziationen dokumentiert eindeutig durch isostatische Landhebung bewirkte paläogeographische Veränderungen, wie z.B. das Zurückweichen des postglazialen d'Iberville Meeres mit aufeinander folgenden Phasen mariner Überschwemmung, Isolation vom Meer und Übergang zu Süßwasserbedingungen. Die Diatomeenanalyse erlaubte die Festlegung der exakten Lage des Isolationshorizontes, der Sedimente marinen Ursprungs von Süßwassersedimenten trennt. Darüber hinaus erlaubte sie die Rekonstruktion der im Verlaufe der Heraushebung erfolgten Isolationsprozesse und Salzgehaltsschwankungen. Durch radiometrische Altersbestimmung (^{14}C) der Isolationshorizonte und Ermittlung der Höhenlage der randlichen Strandterrasse beider Seen konnte eine Landhebungskurve erstellt werden, die generell mit denen benachbarter Regionen im Gebiet der Ungava Bay übereinstimmt. Anhand dieser Landhebungskurve kann festgehalten werden, daß das Gebiet um Kuujjuaq in der Zeitspanne von letztem Eisrückzug vor etwa 7000 Jahren bis 4800-4300 BP kontinuierliche und schnelle Heraushebung in der Größenordnung von 5,7-5,8 m/Jahrhundert erfuhr. Danach hat sich die Heraushebungsgeschwindigkeit bis auf etwa 0,9 m/Jahrhundert verlangsamt.

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** Guy Lortie passed away August 2, 1988. His death was the result of a tragic accident within the context of a scientific expedition in northern Québec.

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INTRODUCTION

The late-glacial and postglacial history of extensive parts of the territory south of Ungava Bay still remains unstudied. According to Lauriol and Gray (1987), this area became deglaciated only after 7000 BP. Southwest of the bay, the ice masses lingered until about 6500 BP. Recent data reveal that deglaciation within the coastal areas was followed by immediate inundation from the postglacial D'Iberville Sea about 7400 to 7200 BP (Allard *et al.*, 1989). The D'Iberville Sea occupied the bay and the surrounding inland areas (Fig. 1), including major river valleys, such as that of the Koksoak River (Gray and Lauriol, 1985; Dyke and Prest, 1987; Lauriol and Gray, 1987).

In the Kuujjuaq (Fort Chimo) area, the deglaciation pattern, its chronology, and the resulting sea-level changes are still poorly known. The only available information has been obtained mainly by air photo interpretation and identification of glacio-marine deltas and washed till zones (Lauriol, 1982). Near the mouth of Koksoak River, the marine limit of D'Iberville Sea reaches elevations of 150-155 m above sea-level (asl) (Lauriol, 1982). Gangloff *et al.* (1976) believe it to be situated at 183 m asl near Kuujjuaq. The two lakes investigated in this study, Hendry Lake and Tasirlaq-sud Lake, are located 50 km south of Ungava Bay and are at elevations below this Holocene marine limit (Figs. 1 and 2).

Comprehensive studies on postglacial diatom histories have not previously been carried out in northern Québec and our knowledge of the diatom flora is limited to qualitative analysis of only a few samples from southeastern Ungava Bay (Lortie *in* Mathieu, 1984). The existing and more extensive palynological studies are restricted to the Ungava peninsula west of the bay (Richard, 1981) and to the Québec-Labrador peninsula in the east (*e.g.* McAndrews and Samson, 1977; Short and Nichols, 1977; Short, 1978; Lamb, 1980, 1985; Stravers, 1981). A major investigation of lake sediments and mires is that of Richard (1981), which describes the different stages of postglacial vegetation history southwest of the Ungava Bay. However, the region in question belongs to those many areas in northern Québec from which modern pollen and diatom analyses are still lacking.

Diatoms (class Bacillariophyceae) represent a valuable source of biological proxy data for paleoenvironmental reconstructions. They have proven to be especially useful in defining shore displacement and sea-level fluctuations in coastal localities since they are very sensitive to changes in salinity, tidal currents, water depth, trophic conditions and pH (*e.g.* Alhonen, 1971; Florin, 1977; Stabell, 1980, 1985; Kjemperud, 1981, 1986; Lie *et al.*, 1983; Haggart, 1986; Björck and Digerfeldt, 1986; Vos and de Wolf, 1988). Radiometric dating of marine to lacustrine transitions, preserved in cores from coastal basins, has been frequently used for establishing chronologies of relative sea-level change and isostatic uplift (*e.g.* Kaland *et al.*, 1984; Björck and Digerfeldt, 1986; Retelle *et al.*, 1989).

In the present study, diatom analysis has been used in order to add new paleoecological and paleogeographical data by tracing and dating the isostatic isolation of two emerged coastal lakes from marine influence; thus, special emphasis is placed in this paper on variations in diatom assemblage composition in connection with the marine to lacustrine transition. A more detailed analysis of floristic changes, spanning the entire lacustrine sequences of both lakes, is provided by Pienitz (1989).

PHYSIOGRAPHIC SETTING OF THE TWO LAKES

Hendry Lake (58°07′N, 68°14′W) and Tasirlaq-sud Lake (unofficial name; 58°14′N, 68°27′W) are located on opposite sides of the Koksoak River, near Kuujjuaq, at altitudes of 40 and 45 m, respectively (Fig. 2). Local bedrock consists mainly of granite-gneisses belonging to the Churchill Geological Pro-

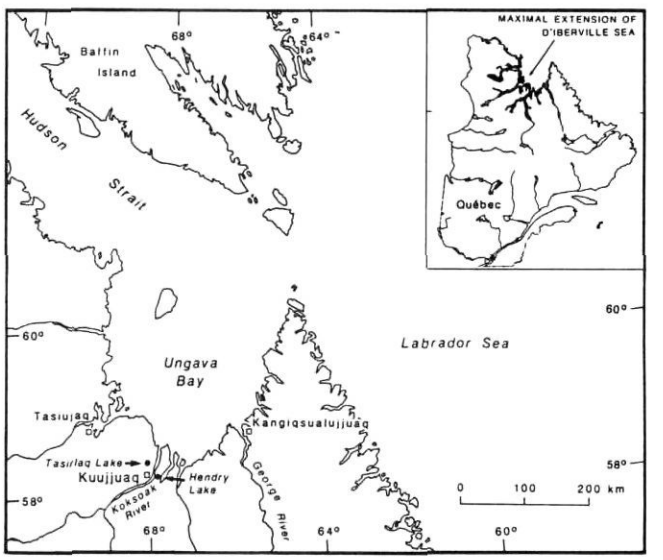

FIGURE 1. Location of lakes Hendry and Tasirlaq-sud.

Localisation des lacs Hendry et Tasirlaq-sud.

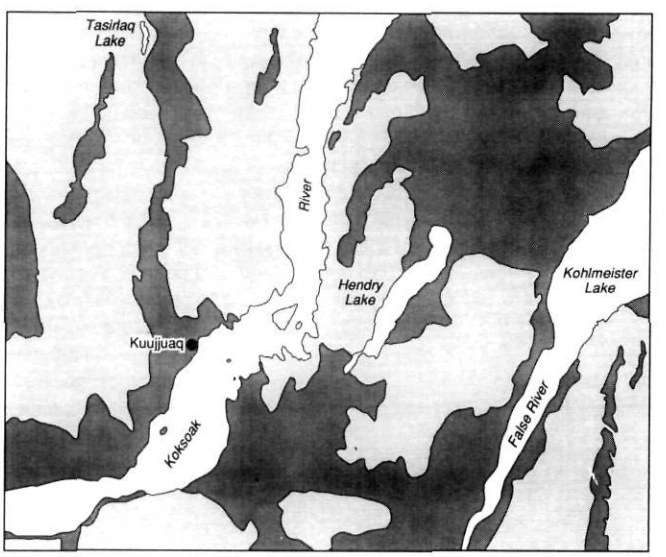

FIGURE 2. General distribution of Quaternary deposits (dark) and bedrock outcrops (light) in the study area. Simplified from Delisle *et al.*, 1986.

Distribution générale des dépôts quaternaires (foncé) et des affleurements rocheux (pâle) dans la région étudiée. Simplifiée de Delisle et al., *1986.*

vince of the Canadian Shield. Both lakes lie within the George Plateau physiographic region (Bostock, 1970), where sparsely vegetated upland plateaus with thin soils are dissected by structural depressions and valleys.

Surveys of glacial flow patterns along the Ungava Bay coast have revealed a converging flow of the Late Quaternary Laurentide Ice Sheet masses towards the Ungava Bay depression (Gangloff *et al.*, 1976; Lauriol, 1982). Intersecting glacial striae in the vicinity of Kuujjuaq suggest that a dominant northerly, Late Wisconsinan ice movement was superimposed on an earlier northeasterly flow into Ungava Bay (Gray and Lauriol, 1985).

The widespread and discontinuous mantle of surface deposits covering the bedrock is mainly of glacial origin and can be attributed to the last Wisconsin Glaciation. Subsequent incursion by the D'Iberville Sea (Delisle *et al.*, 1986) has intensively reworked and modified the distribution of these surficial deposits. The most extensive sediment accumulations occur within the more vegetated lowlands (Fig. 2).

Tasirlaq-sud Lake is a small (0,35 km^2) elongated basin located about 15 km northwest of Kuujjuaq. It lies within a narrow structural depression extending in a south-north direction towards Ungava Bay. To the east and the west, it is surrounded by the higher terrain of bordering uplands, with mean elevations ranging between 75 and 155 m asl. A prominent sill consisting of a 400 m long beach ridge at 45 m asl surrounds the northern and eastern margins of this lake; this ridge has served as an isolation threshold. Hendry Lake, with a surface area of 7.35 km^2, is situated 10 km east of Kuujjuaq on a plateau that separates the two important estuaries of the Koksoak and False rivers (at this site also called Lac Kohlmeister). While the southern half of the lake is contained within rocky hills, the northern end has very low shores on flat, boggy land that slopes very gently towards the actual estuary of False River. The most important morphometric features of both lakes are summarized in Table I.

In the Ungava Bay area, the very large tidal range (12.9 m maximum amplitude at the mouth of Koksoak River; Canada, 1990) is responsible for the presence of wide intertidal zones over rock platforms and mudflats (Lauriol and Gray, 1980). Air photo interpretation revealed that intertidal flats formerly extended within the surroundings of both lakes (Pienitz, 1989).

The present-day subarctic climate of the region is characterized by long winters, short summers, and by a mean annual temperature of –5.2°C. The mean annual precipitation is 476 mm of which about 40% falls in the form of snow. The frost-free season lasts about 60 days. Both lakes are ice-covered for a very long period; freeze-up and break-up generally occur in early November and late June respectively (Québec, 1984).

Phytogeographically, the Kuujjuaq region lies within the shrub subzone of the forest-tundra zone (Payette, 1983). This transitional zone extends between the forest-tundra and the tundra, and is dominated by a shrubby vegetation composed principally of dwarf birch (*Betula glandulosa*) and green alder (*Alnus crispa*), with isolated stands of coniferous trees (*Picea mariana, Larix laricina*).

MATERIAL AND METHODS

Sampling was carried out in May 1987 through 1.5 m of ice, using a modified Livingstone piston corer (internal diameter = 5 cm) and a casing of plastic drainpipe. Sediment cores were taken from the deepest part through 7 m and 4 m of water in lakes Hendry and Tasirlaq-sud, respectively. Consecutive core sections were recovered by repeated drives through the same cased hole.

The cores taken from Tasirlaq-sud Lake provided an undisturbed sedimentary sequence measuring 3.85 m in total length, including sediments deposited during basin isolation from the sea and the following period of lacustrine sedimentation. In the 1.25 m long core recovered from Hendry Lake, which presents a longer marine but considerably shorter lacustrine sequence, radiocarbon dates seem to reveal the absence of sediments spanning the period from 1440 BP until present. Since loss of sediment can be excluded, other factors such as contamination with "old" carbon, very low sedimentation rates, or both most likely account for this lack of recent record. Similar anomalies have been observed in lakes with extremely low sedimentation rates during the late Holocene (e.g. Short and Nichols, 1977; Diaz *et al.*, 1989; Retelle *et al.*, 1989), which caused surface sediments to be of considerable age rather than strictly modern. The considerable difference in core length, however, is most likely due to

TABLE I

Summary of morphometric and topographic data for lakes Hendry and Tasirlaq-sud.

Hendry Lake:	
Depth (m)	7
Surface area (km^2)	7.35
Total length of shoreline (km)	20.75
Maximum length (km)	5.56
Maximum width (km)	1.34
Drainage basin area (km^2)	45.8
Ratio lake surface area: drainage basin area	0.16
Elevation above sea-level (m)	40 ±
Elevation of surrounding relief (m)	75-105
Distance from Ungava Bay (km)	43
Aerial photograph series	A 11425/129-132 A 11444/88-91 A 12087/115-121
Tasirlaq-sud Lake:	
Depth (m)	4
Surface area (km^2)	0.35
Total length of shoreline (km)	4.2
Maximum length (km)	1.77
Maximum width (km)	0.30
Drainage basin area (km^2)	9.7
Ratio lake surface area: drainage basin area	0.036
Elevation above sea-level (m)	45 ±
Elevation of surrounding relief (m)	75-155
Distance from Ungava Bay (km)	38
Aerial photograph series	A 11444/139-141

the significantly different sedimentary processes prevailing in the two basins.

The cores were extruded in the Laboratoire de paléoécologie at Université Laval, surface cleaned, subsampled and then wrapped in plastic and aluminum foil for storage in a dark room at 4°C.

The seven radiocarbon dates obtained are listed in Table II. They are reported as uncorrected radiocarbon years before present (BP). The outer part of the 5 cm long core sections selected for radiocarbon dating was removed in order to eliminate possible contamination by smearing during coring or extrusion. Standard acid and basic sample pretreatments were followed by benzene syntheses which were given four times the normal counting time in order to minimize statistical errors.

The radiocarbon dates from the isolation contacts only yield minimum ages since the samples were taken from the lacustrine side of the contact. This was done in order to avoid potential errors caused by the "reservoir age effect" of sea waters (Mangerud and Gulliksen, 1975; Hillaire-Marcel, 1979; Kaland *et al.*, 1984). Also, one must keep in mind that the samples cover a distinct time interval. The magnitude of this latter error depends on the sedimentation rates, as well as on the thickness of the samples used for dating.

Particle-size analysis of the inorganic fraction of the sediments was carried out in order to help detect changes in the sedimentary environment. The samples were described using the textural classification system outlined in the glossary of earth science terms (Agriculture Canada, 1976).

Loss-on-ignition, commonly used as a measure of the organic matter content of a sediment, was determined by drying the samples for 24 hours at 65°C and subsequent combustion at 550°C for 2 hours.

Samples for diatom analysis (1 cm^3) were taken from the cores at intervals of 5 or 10 cm. All samples were first treated with hydrogen peroxide (30%H_2O_2), in order to bleach and destroy the organic matter, and then repeatedly rinsed to neutrality. Microsphere markers were added to the solution in order to facilitate quantitative assessment of diatom abundance according to the method of Battarbee and Kneen (1982). A 0.5 ml aliquot was transferred to a 22×22 mm cover slip and allowed to dry overnight. Permanent mounts were then prepared using Naphrax, a medium with a high refractory index (dn = 1.73).

For each sample 500 to 1000 valves were counted and identified on a Zeiss II Photomicroscope under oil immersion at 500X and 1250X magnifications. In the lowermost section of the Hendry Lake core, however, the very poor preservation of diatoms did not allow for quantitative analysis of the sample material. Analysis was complemented by observations on a JEOL-25IIS scanning electron microscope. Identifications were made with reference to the works of Bérard-Therriault *et al. (1986, 1987), Cardinal et al.* (1984, 1988), Cleve-Euler (1951-1955), Foged (1971, 1981), Germain (1981), Hendey (1964), Hustedt (1930-1966), Krammer and Lange-Bertalot (1986, 1988), Lortie (1983), Mölder and Tynni (1967-1973), Patrick and Reimer (1966, 1975), Patrick and Freese (1961), Poulin *et al.* (1984, 1987) and Tynni (1975, 1976, 1978, 1980).

The results of diatom analysis have been synthesized in the form of percentage diagrams (Figs. 3 and 4). Within these diagrams, the biostratigraphic zones are defined by the dominant species (>10%), and diatoms are classified according to the Halobian system defined by Kolbe (1927), which subsequently has been modified by Hustedt in 1957 (Table III).

RESULTS

Sediment stratigraphy/Core description

Both lakes contain a sequence of marine sediments overlain by lacustrine sediments (Figs. 3 and 4). The two units are separated by a more or less distinctive isolation contact that marks the isostatic emergence of the basins from the postglacial D'Iberville Sea (Pienitz and Lortie, 1988).

HENDRY LAKE

The sediment sequence consists of three main units (Fig. 3). From base to top these are:

TABLE II

List of radiocarbon dates obtained from lake sediments

Sample number	Depth (cm)	Material	^{14}C age	Lab number
HEN-III/I	0-10	gyttja	1440 ± 130	BETA-27207
HEN-III/II	45-50	gyttja	3180 ± 130	BETA-25715
HEN-III/III	70-75	gyttja	3850 ± 120	BETA-25727
HEN-III/IV	75-80	gyttja*	4300 ± 140	BETA-25713
TAS-I	180-185	gyttja	2720 ± 80	BETA-26568
TAS-II	240-245	gyttja	4080 ± 80	BETA-26569
TAS-III	366-371	gyttja*	4850 ± 120	BETA-26570

* situated at the transition with the basal inorganic sediments

TABLE III

Classification of diatoms according to their salinity tolerance (Hustedt 1957)

1. Polyhalobous taxa: marine taxa with an optimum range of 30‰ and more
2. Mesohalobous taxa:
   a) euryhaline mesohalobous taxa with their optimum and tolerance limit within the range of 30-0.2‰
   b) α-mesohalobous taxa of the «lower» brackish water, minimum salinity about 10‰
   c) ß-mesohalobous taxa of the «upper» brackish water, salinity about 10-0.2‰
3. Oligohalobous taxa:
   a) halophilous taxa that can live in both brackish and freshwater; optimum in slightly brackish water
   b) indifferent taxa that can live in both brackish and freshwater; optimum in freshwater
4. Halophobous taxa: exclusively freshwater taxa

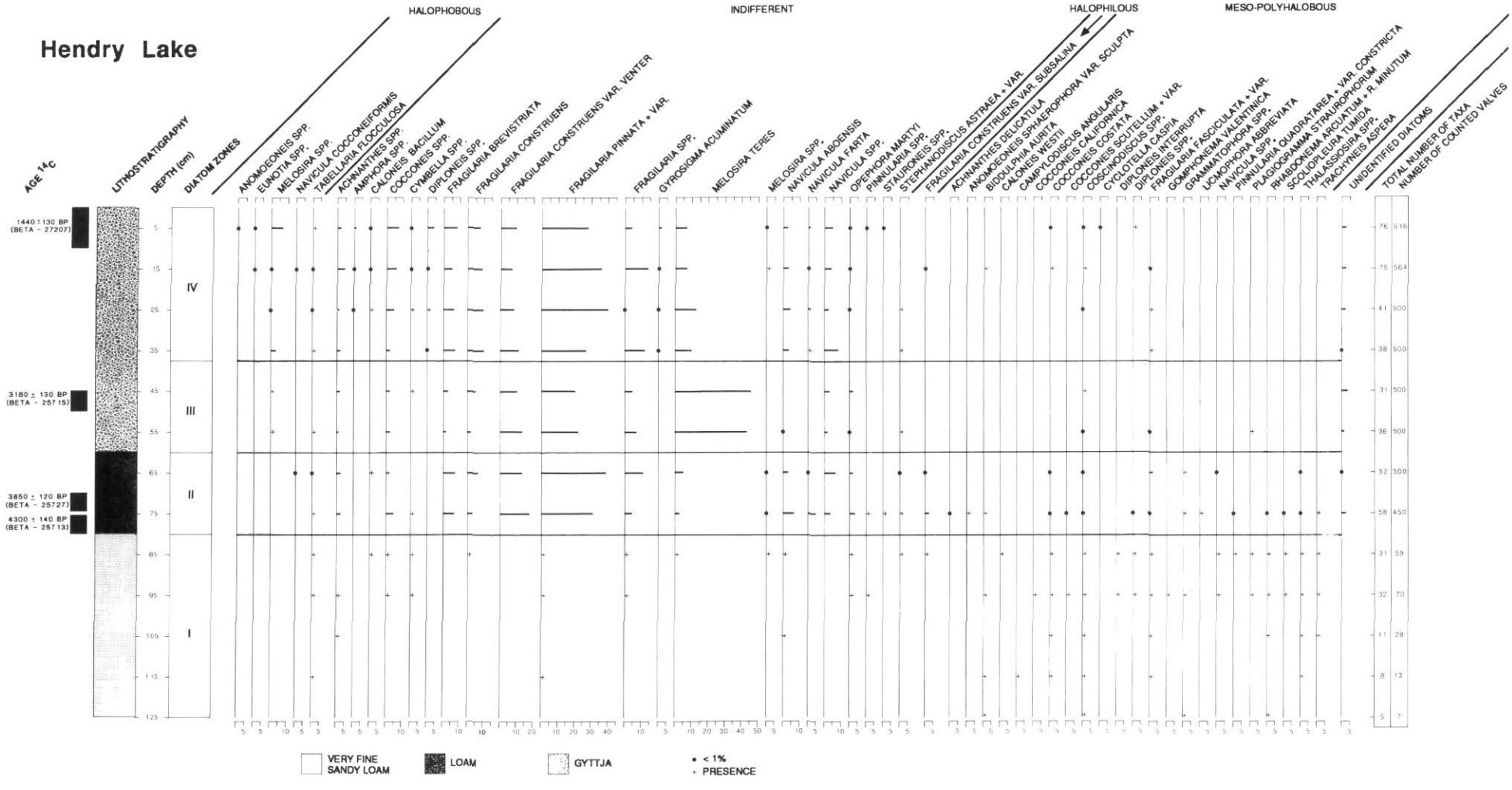

FIGURE 3. Percentage diatom diagram from Hendry Lake.

Diagramme d'abondance relative des diatomées du lac Hendry.

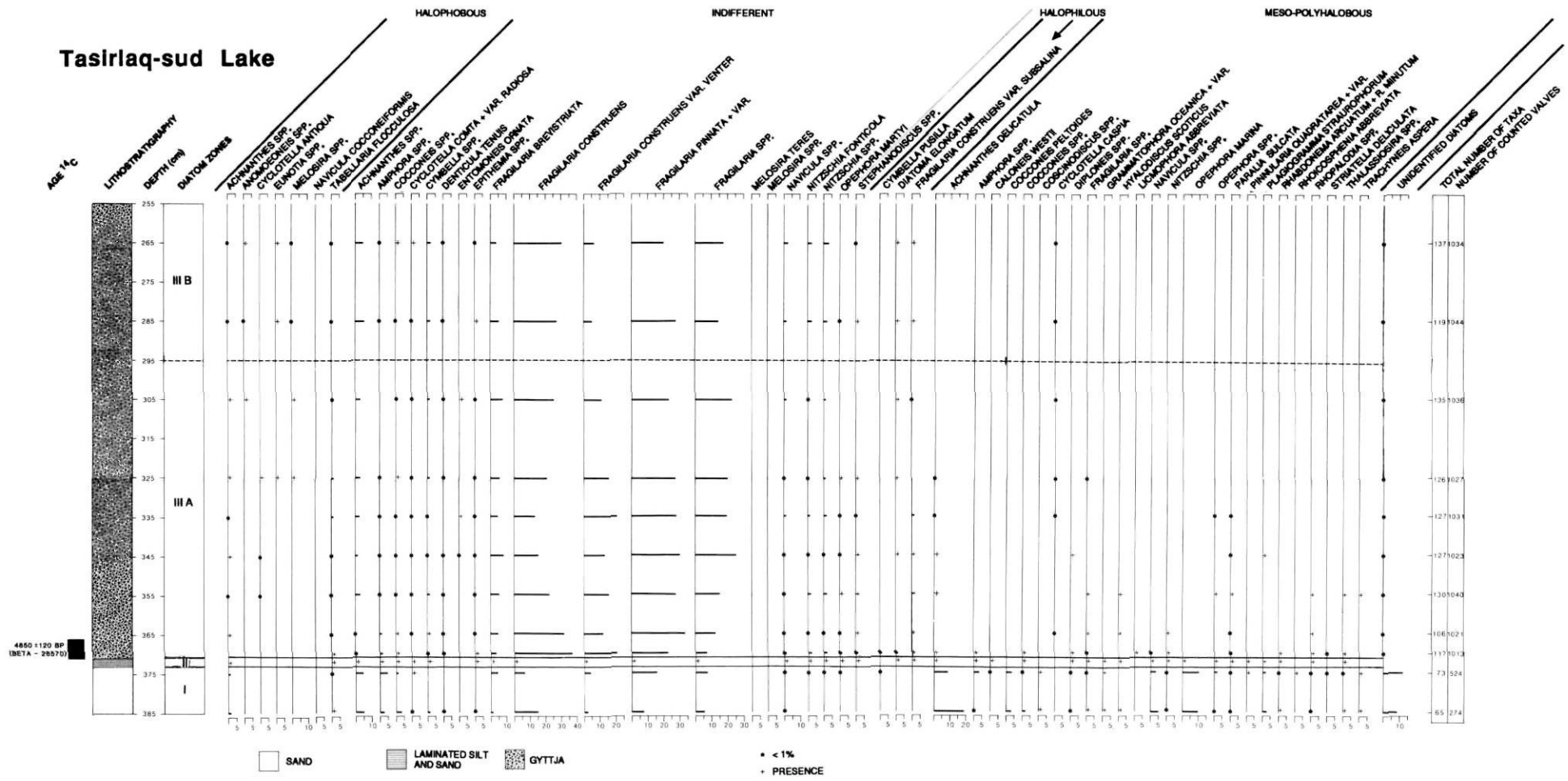

FIGURE 4. Percentage diatom diagram from Tasirlaq-sud Lake (lower section).

Diagramme d'abondance relative des diatomées du lac Tasirlaq-sud (partie inférieure).

1) Very fine sandy loam (125-80 cm)

The basal core section in Hendry Lake consists of massive and featureless blue-grey sandy loam which, by its compaction, limited the penetration of the corer. The average grain size distribution within this unit lies between 8 to 17% clay, 18 to 32% silt, and 56 to 74% sand. Loss-on-ignition (LOI) is generally low (1.5-3.5%), with upwards slightly increasing values (Fig. 5). A few mollusc shell fragments were found in this marine unit which was deposited prior to 4300 BP.

2) Loam (80-60 cm)

The sediments within this transitional zone display decreasing grain-size. Sand content (>63 μm) decreases to about 32%. The gradual change from coarser- to finer-grained sediments throughout this zone is paralleled by increases in LOI (3.5-11%) and water content (39-72%) as well as a change in colour to olive-grey (Fig. 5). Both lower and upper boundaries of this unit are smooth. As revealed by the microfossil assemblages (see below), it represents the transition from marine to lacustrine conditions.

3) Fine detritus gyttja (60-0 cm)

This facies consists mainly of olive-grey to olive gyttja representing entirely lacustrine conditions towards the top of the core. In its lower part, the most prominent sedimentary features include several dark laminae that are rich in well-preserved plant macrofossils (moss fragments, conifer leaves). Occurring at irregular intervals between the 60 and 25 cm levels, they represent short-lived perturbations brought about by disturbances in the lake's watershed. The uppermost 25 cm are composed of more homogeneous detrital gyttja. LOI exhibits the highest values (about 20%) between the 50 and 40 cm levels, after which a gradual decrease can be observed. Water content shows more constant values ranging between 72 to 82% (Fig. 5).

TASIRLAQ-SUD LAKE

Three lithostratigraphical units also characterize the lowermost section of this core (Fig. 4):

1) Medium sand (385-373 cm)

Penetration of the Livingstone corer was limited by this lowermost coarse-grained facies. The very low values obtained for both LOI (1.2%) and water content (9-13%) show that it is almost purely inorganic (Fig. 5). The total sand content amounts to approximately 98%. This massive and homogeneous fraction is mainly composed of medium (59%) and coarse sand (20%). This unit had been deposited prior to 4850 BP and probably represents a nearshore sedimentary environment dominated by high-energy, dynamic processes. The boundary with the overlying unit is very sharp.

2) Laminated silt and sand (373-371 cm)

This 2 cm long section consists of fine microlaminae thereby reflecting deposition in a low-energy sedimentary environment, characterized by very stable conditions. Sediments were examined under binocular and SEM microscopes, revealing a total of about 95 discrete laminations

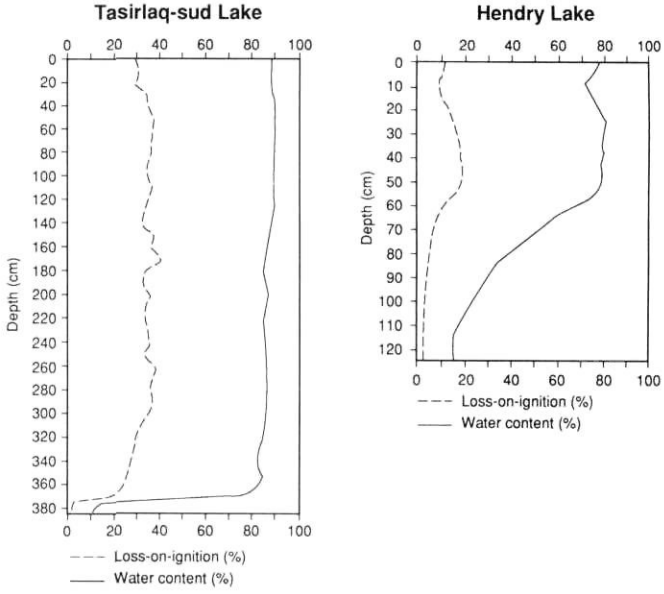

FIGURE 5. Percentage water and organic matter content in the cores from lakes Hendry and Tasirlaq-sud.

Teneurs en eau et en matière organique dans les carottes des lacs Hendry et Tasirlaq-sud.

averaging 0.2 to 0.3 mm in thickness. The majority of them appear in the form of light/dark couplets resembling varves. It is however not apparent that each couplet represents an annual deposit, as there is no evidence for this apart from their relatively uniform size. Although the laminae can be distinguished clearly by changes in colour and tone, there are only minor differences in texture, showing only a continuous upward fining and decreasing thickness of single laminations. This transitional facies probably represents meromictic conditions as the threshold of the basin prevented the outflow of marine water (Pienitz, 1989).

3) Fine detritus gyttja (371-0 cm)

This lacustrine sediment unit consists of a homogeneous olive-grey to olive gyttja. Both LOI and water content initially show sharp rises between the 371 and 370 cm levels. Thereafter, LOI values demonstrate a more gradual decrease in minerogenic matter and a corresponding, progressive increase in organic matter content from 18 to 38% (Fig. 5). Consequently, the detritus gyttja is relatively compact and gelatinous in its lower part, and becomes increasingly loose and watery towards the surface.

Diatom analysis

All diatom taxa presented in the taxonomic list (see Appendix) are accompanied by autecological information, indicated in conformity with the number code system used by de Wolf (1982). Some modifications were made in accordance with Stabell (1985). For each lake, these data have been used to prepare supplementary diagrams illustrating the ecological preferences of the algae with regard to salinity, pH, and life-form/habitat (Figs. 6 and 7).

Salinity tolerance of the various diatom taxa, as recorded in the Appendix, is based on the redefined halinity determina-

tions proposed by Simonsen (1962), with additional information from Edsbagge (1968), Foged (1981), Germain (1981), Hendey (1964), Hustedt (1930-1966), Pankow (1976), Patrick and Reimer (1966, 1975), and Van der Werff and Huls (1957-1974).

Specification on life-form/habitat and substrate affinity has been obtained mainly from Brockmann (1950), Edsbagge (1968), Hendey (1964), Pankow (1976), Van der Werff and Huls (1957-1974), and Vos and de Wolf (1988).

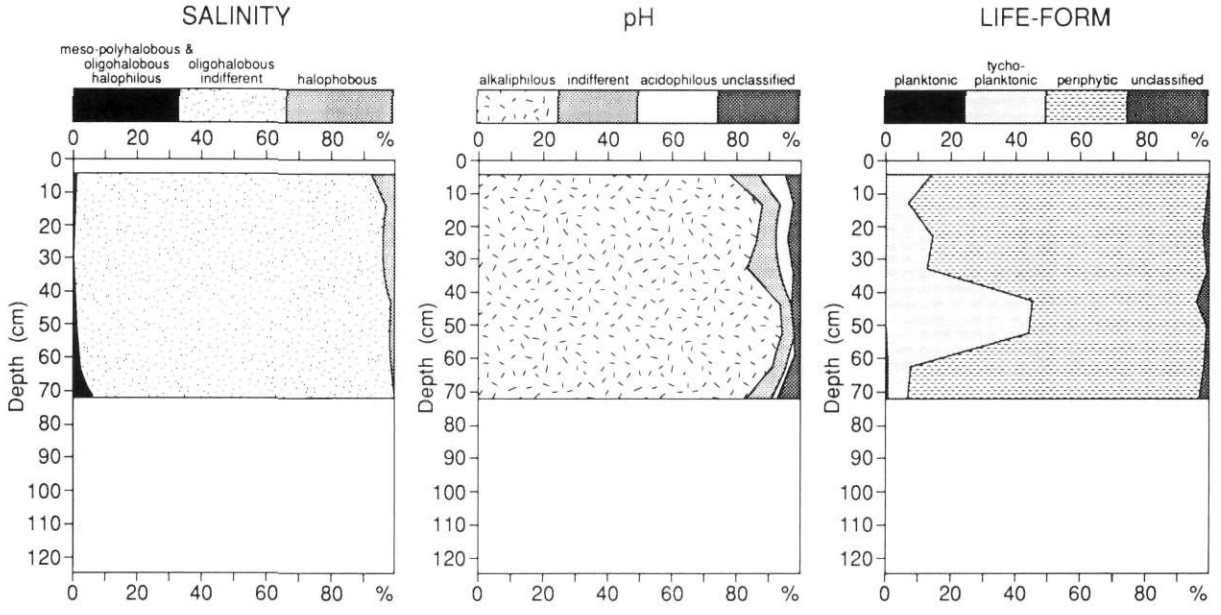

FIGURE 6. Diatom stratigraphy of Hendry Lake in ecological groups.

Stratigraphie des diatomées du lac Hendry selon leurs affinités écologiques.

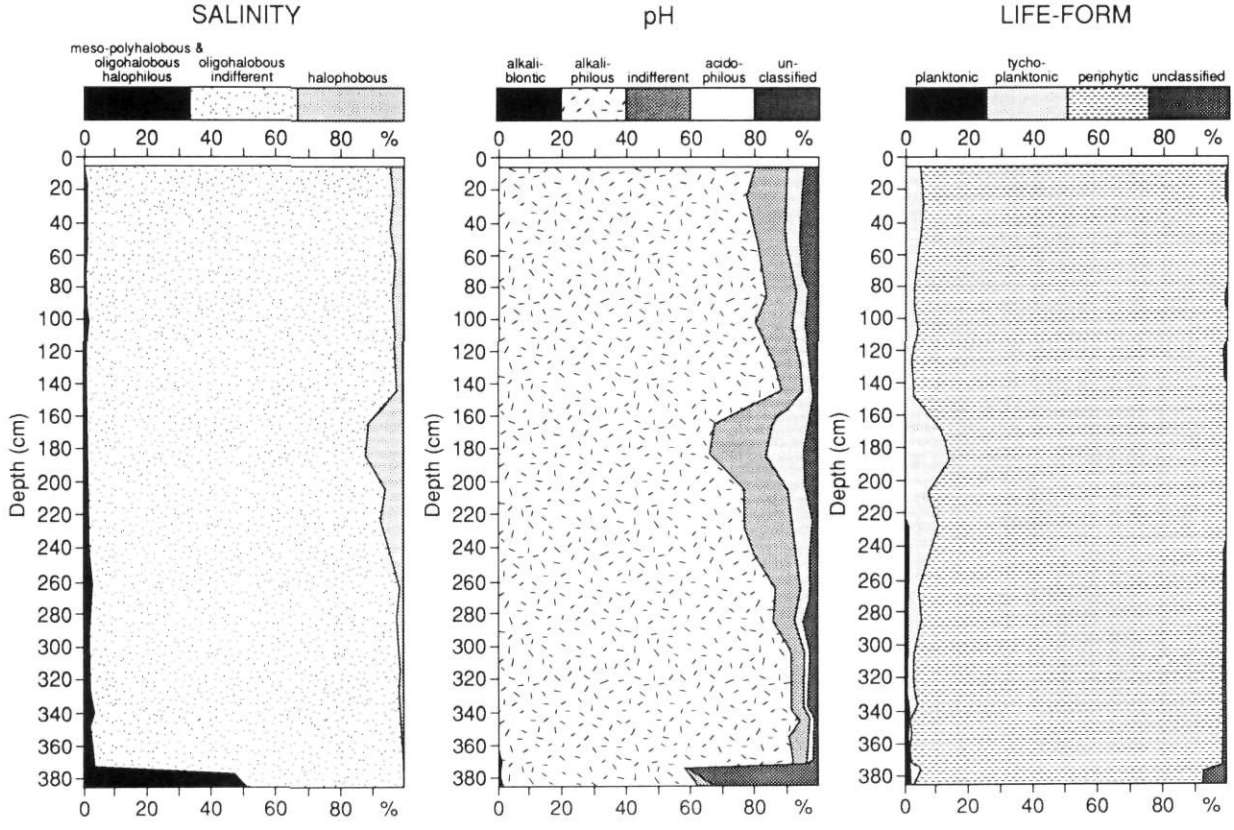

FIGURE 7. Diatom stratigraphy of Tasirlaq-sud Lake in ecological groups.

Stratigraphie des diatomées du lac Tasirlaq-sud selon leurs affinités écologiques.

The assignment of diatoms to different pH categories was abstracted mainly from Dixit *et al.* (1988), Foged (1981), Hustedt (1930-1966), Meriläinen (1967), Patrick and Reimer (1966, 1975), and Van der Werff and Huls (1957-1974).

HENDRY LAKE

Diatom zone I (125-80 cm) (Table IV)

The lowermost diatom zone contains only very few diatom remains (less than 1×10^3 valves/mg dry weight) so that quantitative analysis was impossible. Differential diatom preservation is indicated since only fragments of the more silicified forms were found, whereas fragments of less silicified, fragile taxa are almost completely absent.

The bulk of these fragments belong to polyhalobous, meioeuryhaline benthic species (*e.g. Plagiogramma staurophorum, Rhabdonema arcuatum, R. minutum, Cocconeis costata, Odontella* (*Biddulphia*) *aurita*, and *Trachyneis aspera*) which, according to Simonsen (1962), have salinity preferences between 35 and 17‰. The predominance of these benthic forms and the rare occurrence of marine euplanktonic forms, such as *Coscinodiscus* sp. and *Thalassiosira* spp., is a clear indication of a shallow nearshore environment.

Meso- and pleioeuryhaline taxa with even higher salinity tolerances (*Pinnularia quadratarea; Diploneis smithii*) increase towards the upper part of the zone. The increasing number of mesohalobous euryhaline species like *Navicula digitoradiata* and *Scoliopleura tumida* (both α-mesohalobous), together with *Diploneis interrupta* and the more frequently occurring oligohalobous forms, indicate a transition to increasingly brackish water conditions. The strong euryhaline character of the dominant poly- and mesohalobous component suggests that large salinity fluctuations occurred.

The inwash of allochthonous material is indicated by a mixture of marine diatoms with fragments of aerophilic (*Pinnularia borealis* and *P. lata*) and freshwater forms (*e.g. Tabellaria flocculosa*).

Diatom zone II (80-60 cm) (Table IV)

This transitional zone is characterized by marked changes in diatom assemblage composition. The sharp rise in diatom valve concentrations to 5.3×10^6 valves/mg dry weight at the 65 cm level (Fig. 8) is paralleled by rapid increases in alkaliphilous freshwater taxa, especially the small benthic *Fragilaria* spp. (mainly *Fragilaria pinnata* and *Fragilaria construens* + *F. construens* var. *venter*). This assemblage is accompanied by rare marine forms.

The predominance of *Fragilaria* spp. (61-78%) and the general increase in alkaliphilous freshwater taxa (*e.g. Achnanthes calcar, Achnanthes clevei, Navicula jentzschii, Opephora martyi*) indicate strongly alkaline conditions prevailing at the time of sediment deposition. The large centric diatom *Melosira teres* appears for the first time at the 75 cm level with percentages of about 3 to 5% (Fig. 3).

According to Simonsen (1962), the littoral *Fragilaria* spp. are oligohalobous (indifferent) and mesoeuryhaline, which

TABLE IV

Summary of diatom assemblages from pre-isolation and isolation units of Hendry Lake

Diatom zone I (125-80 cm):

Substrate property: Very fine sandy loam

Dominant life-forms: littoral-marine benthic taxa; accompanied by some marine euplanktonic (neritic) forms

Salinity tolerance range: polyhalobous meio-, meso- and pleioeuryhaline; α-mesohalobous

Most important species: *Cocconeis californica, C. costata, C. scutellum* var. *parva, Coscinodiscus* spp., *Diploneis interrupta, D. smithii, Navicula digitoradiata, N. glacialis, Odontella aurita, Paralia sulcata, Pinnularia quadratarea, Plagiogramma staurophorum, Rhabdonema arcuatum, R. minutum, Rhaphoneis* sp., *Scoliopleura tumida, Thalassiosira* spp., *Trachyneis aspera*.

Diatom zone II (80-60 cm):

Substrate property: Loam

Dominant life-forms: freshwater benthic taxa; accompanied by some marine benthic + euplanktonic forms

Salinity tolerance range: oligohalobous mesoeuryhaline; β-mesohalobous; halophilous

Most important species: *Achnanthes calcar, A. clevei, A. delicatula, Anomoeoneis sphaerophora, A. sphaerophora* var. *sculpta, Ellerbeckia teres, Fragilaria brevistriata, F. construens, F. construens* var. *subsalina, F. construens* var. *venter, F. fasciculata, F. pinnata, Navicula jentzschii, N. peregrina, Opephora martyi*.

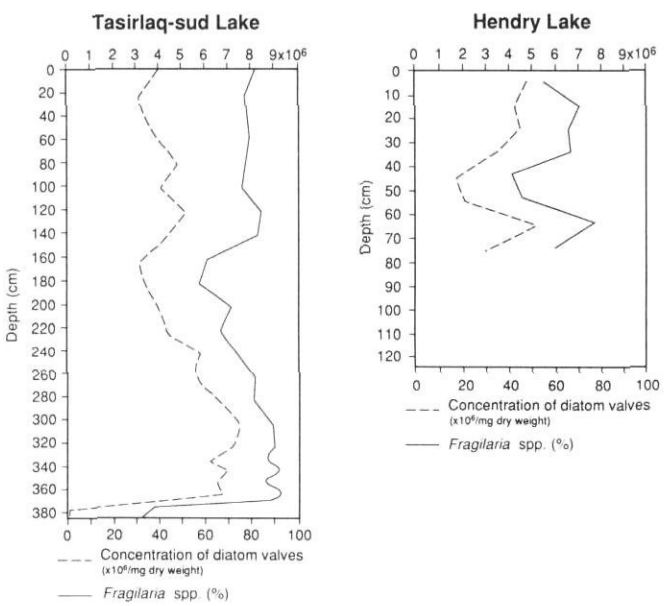

FIGURE 8. Concentration of diatom valves and percentage of *Fragilaria* spp. in lakes Hendry and Tasirlaq-sud.

Concentration totale des valves de diatomées et pourcentage de Fragilaria *spp. aux lacs Hendry et Tasirlaq-sud.*

means that they can tolerate salinities from 0 to about 10‰. The simultaneous presence of the halophilous *Fragilaria construens* var. *subsalina* (2.3%) and some mesohalobous forms, such as *Achnanthes delicatula, Anomoeoneis sphaerophora* var. *sculpta, Fragilaria fasciculata* and *Navicula per-*

egrina, reflects slightly brackish water conditions. However, the combined percentages of the halophilous and poly-/mesohalobous component show a continuous decrease from 7 to 2.8% between the 75 and 65 cm levels, confirming the tendency towards increasingly freshwater conditions (Fig. 6).

Diatom zone III (60-37.5 cm)

The most prominent feature of this diatom zone is the dominance of the large-celled *Melosira teres* Brun (recently transferred to *Ellerbeckia arenaria* var. *teres* (Brun) Crawford). Its relative abundance varies between 43 to 46% and it is accompanied by alkaliphilous freshwater forms (Fig. 3). This species is of special interest in terms of its paleoecologic and paleoclimatic significance because it defines a distinct biozone within this sequence. Its autecology has been discussed in detail in Lortie and Pienitz (1988) and Pienitz (1989).

The decrease in diatom valve concentration to 2.1-1.7 × 10^6 valves/mg dry weight is mainly due to the sharp decline in *Fragilaria* spp. to 46 and 42% at the 55 and 45 cm levels (Fig. 8). Oligohalobous (indifferent) taxa reach their maximum representation of about 96 to 98% whereas poly- and mesohalobous forms almost entirely disappear, thereby clearly indicating freshwater conditions.

Diatom zone IV (37.5-0 cm)

The diatom flora of this uppermost zone is again characterized by the dominance of species of the genus *Fragilaria* (mostly *Fragilaria pinnata* and *F. construens* + var. *venter*). They are accompanied by many other freshwater diatoms, indicating continuous lacustrine conditions until the present-day.

TASIRLAQ-SUD LAKE

Diatom zone I (385-373 cm) (Table V)

This diatom zone coincides with the deposition of the basal sand layer. It contains a mixture of brackish and freshwater forms with many marine-brackish species. The latter are typified by littoral benthic taxa having a wide salinity range (*e.g.* the euryhaline diatoms *Amphora crassa, Amphora proteus, Cocconeis peltoides, Paralia sulcata*, and *Plagiogramma staurophorum*). Such species are able to withstand large salinity fluctuations, like those occurring in marine littoral zones. Planktonic forms are almost completely absent, except for *Paralia sulcata*, which is a pleioeuryhaline marine planktonic form (Simonsen, 1962; Edsbagge, 1968), which sometimes also occurs in the benthic flora (Haggart, 1986).

The quantitatively most important taxon of the polyhalobous component is the littoral-benthic *Opephora marina*, with percentages of about 10% (Fig. 4). It is a pleioeuryhaline species common on most coasts (Simonsen, 1962) and has been proposed to be characteristic of the upper sublittoral zone (0.3-15 m water depth) on the Swedish west coast (Edsbagge, 1966).

The oligohalobous component makes up about 46 to 49% of the diatom flora (Fig. 7) and is dominated by small *Fragilaria* spp. (31-37%), whereas the meso- and polyhalobous taxa (40-45%) include the dominant brackish water form *Achnanthes delicatula* (>19% at the 385 cm level).

TABLE V

Summary of diatom assemblages from pre-isolation and isolation units of Tasirlaq-sud Lake

Diatom zone I (385-373 cm):
Substrate property: Medium sand
Dominant life-forms: littoral-marine benthic taxa (epipsammic and epipelic species); accompanied by some freshwater benthic forms
Salinity tolerance range: polyhalobous pleioeuryhaline; α + β-mesohalobous; oligohalobous mesoeuryhaline
Most important species: *Achnanthes delicatula, Amphora crassa, A. holsatica, A. interrupta, A. proteus, Caloneis westii, Cocconeis californica, C. costata, C. peltoides, Cymbella pusilla, Diploneis didyma, D. interrupta, D. smithii, Fragilaria construens, F. pinnata, Navicula cryptocephala, N. cryptolyra, N. digitoradiata, N. forcipata, N. glacialis, N. humerosa, N. litoricola, N. palpebralis, N. peregrina, N. pygmaea, N. tenera, N. subinflata, Opephora marina, O. olsenii, Paralia sulcata, Pinnularia quadratarea, Plagiogramma staurophorum, Rhopalodia musculus.*

Diatom zone II (373-371 cm):
Substrate property: Laminated silt and sand
Dominant life-forms: freshwater benthic (epiphytic) taxa; accompanied by some littoral-marine benthic forms
Salinity tolerance range: oligohalobous mesoeuryhaline; β-mesohalobous; halophilous
Most important species: *Anomoeoneis sphaerophora, A. sphaerophora* var. *sculpta, Cocconeis placentula, Diatoma elongatum, Diploneis splendida, Fragilaria brevistriata, F. construens, F. construens* var. *subsalina, F. construens* var. *venter, F. fasciculata, F. pinnata, F. pulchella, F. pulchella* var. *macrocephala, Hannaea arcus, Hyalodiscus scoticus, Mastogloia elliptica, M. elliptica* var. *dansei, Navicula crucicula, N. digitoradiata, N. gregaria, N. humerosa, N. peregrina, N. pygmaea, N. rhynchocephala, N. salinarum, Rhoicosphenia abbreviata, Rhopalodia musculus, Scoliopleura tumida, Stephanodiscus* sp.

The euryhaline *Achnanthes delicatula* (synonym = *A. hauckiana*) was found most commonly in slightly to moderately brackish water by Patrick and Reimer (1966), and only within areas influenced by freshwater on the Swedish west coast (Edsbagge, 1966). A mass occurrence of this taxon has been reported by Edsbagge (1968) in the west Norwegian supralittoral zone.

Habitat affinities manifested by the diatom assemblage show close correlation with the nature of the substratum (sand) as indicated by the preponderance of forms living attached to (epipsammon) or between sandgrains (epipelon). Such species are represented by the epipsammic *Achnanthes delicatula, Amphora crassa, A. holsatica, Cocconeis peltoides, Navicula cryptolyra, Opephora olsenii* and *Plagiogramma staurophorum*, as well as various epipelic diatoms like *Amphora proteus, Diploneis didyma, Navicula cryptocephala, N. digitoradiata, N. forcipata, N. humerosa, N. palpebralis, N. peregrina* + var. *kefvingensis* and *N. pygmaea*. The strong euryhaline character of this benthic community suggests deposition in a shallow brackish water environment.

Diatom concentrations are low due to the relatively poor preservation and high degree of frustule fragmentation, reflecting conditions of intensive mechanical reworking.

Diatom zone II (373-371 cm) (Table V)

Qualitative diatom analysis was carried out within this microlaminated zone using the tape peel technique developed by Simola (1977).

Pronounced peaks of diatoms occur rather irregularly throughout the short sequence within the light bands of individual couplets or "rhythmites". In the lower part, they are defined by large numbers of *Fragilaria fasciculata* and *Fragilaria pulchella* + var. *macrocephala*. Both are classified as strongly euryhaline brackish water species. They are accompanied by halophilous forms such as *Diatoma elongatum* and *Fragilaria construens* var. *subsalina*, and a great variety of mesohalobous species commonly occurring in slightly brackish water (*e.g.* the β-mesohalobous *Navicula pygmaea* and *Anomoeoneis sphaerophora* var. *sculpta, Navicula rhynchocephala, N. peregrina* + var. *kefvingensis, N. digitoradiata, N. gregaria, N. salinarum, Scoliopleura tumida*, and *Mastogloia elliptica* var. *dansei*).

In the uppermost part of the laminations, small *Fragilaria* spp. and *Stephanodiscus* spp. gain increasing importance. Freshwater species take over while meso- and polyhalobous taxa become increasingly rare.

The frequent occurrence of alkalibiontic forms, such as *Anomoeoneis sphaerophora* var. *sculpta, Mastogloia elliptica* var. *dansei, Navicula pygmaea, Rhopalodia gibberula* and *R. musculus*, as well as the strong alkaliphilous character of the flora, demonstrate conditions of high mineral input in a nutrient-rich environment.

Diatom zone IIIa (371-295 cm)

This initial phase of lacustrine sedimentation is characterized by a mass occurrence of benthic alkaliphils belonging to the *Fragilaria* spp. group (Figs. 4 and 8). *Fragilaria pinnata* and *F. construens* + var. *venter* are the dominant species in an assemblage almost exclusively composed of oligohalobous (indifferent) and alkaliphilous forms. The most important taxa, other than the mentioned *Fragilaria* spp., are *Amphora pediculus, Nitzschia fonticola* and small *Achnanthes* spp..

This "peak" or "bloom" represents the greatest relative abundance of *Fragilaria* spp. (87-95%), as well as the highest values in total diatom concentration (about 7.5×10^6 valves/mg dry weight at the 305 cm level: Fig. 8) during the postglacial period.

Diatom zone IIIb (295-0 cm)

Benthic alkaliphils remain the dominant component of diatom assemblages throughout the rest of the core. In general, diatom succession shows a continuous trend from the previous *Fragilaria*-dominated, "uniform" flora towards a much more diversified, heterogeneous freshwater flora. The floristic changes have been related by Pienitz (1989) to climatic and vegetational shifts.

DISCUSSION

BASAL PRE-ISOLATION UNITS

Hendry Lake

Detailed paleoenvironmental interpretation of changes within the basal inorganic sediments of Hendry Lake is rendered difficult due to certain limitations imposed by preservational and sedimentological factors. However, the extremely low concentrations and poor preservation of diatoms give evidence of disturbances, such as fragmentation, mixing and redeposition. These processes typically occur in unstable, high-energy, nearshore sedimentary environments controlled by tidal dynamics and the scouring action of sea ice. Strong fragmentation of diatom frustules has also been reported frequently in connection with repeated sediment reworking and long-distance transport in coastal environments (*e.g.* Beyens and Denys, 1982; Lortie *in* Vincent *et al.*, 1983; Vos and de Wolf, 1988).

Marked floristic heterogeneity is typical of coastal marine environments influenced by high glacial meltwater discharges (Kjemperud, 1981; Lichti-Federovich, 1983). The fossil microflora of the present zone is characterized by a mixed occurrence of polyhalobous and mesohalobous taxa with frequent freshwater forms (especially fragments of aerophilous forms). The dominant component, however, comprises polyhalobous euryhaline forms with the highest species representation in the meioeuryhaline (35 to 17‰) salinity range of Simonsen's halinity rating system. These criteria clearly reflect sediment deposition in a nearshore "mixing environment" subject to lowered salinities and extremely large salinity fluctuations, ranging from marine (>30‰) to estuarine conditions (*ca.*18‰). The degree of dilution was presumably controlled by large and seasonally varying volumes of meltwater from disintegrating inland ice masses and runoff from deglaciated supra-marine areas.

The geochemical study of stable isotopes ($^{18}O/^{16}O$ ratio) in fossil molluscs suggests similar paleohydrological conditions, with less saline surface waters in littoral zones of D'Iberville Sea and other postglacial seas in Québec (Hillaire-Marcel, 1979). The small quantity of shell fragments within this unit may be related to sediment disturbances caused by the abrasive work and mixing effect of grounding sea ice, which typically occurs in arctic and subarctic marine coastal zones (*e.g.* Ellis and Wilce, 1961; Hillaire-Marcel, 1979; Gilbert and Aitken, 1981; Aitken and Gilbert, 1986). Besides its erosive effects in macrotidal areas, annual melting and freezing of sea ice largely influences surface water salinities (Ellis and Wilce, 1961; Aitken and Gilbert, 1986).

Stress conditions created by high hydrological instability are expressed by the frequent occurrence of teratological diatoms (= morphological aberrants) in this unit, which is in accordance with observations made on phytoplankton samples from the southern Beaufort Sea (Lichti-Federovich, 1983).

Interpretative difficulties related to the distinction of autochthonous and allochthonous diatoms in "mixed assemblages", and frustule fragmentation in tidal environments have been

discussed in detail by Vos and de Wolf (1988). In order to reduce this uncertainty as much as possible, a preliminary analysis of other paleoecological indicators (foraminifera and ostracods) was jointly carried out at two selected levels (125-120 cm and 80-75 cm). Lists of foraminiferal and ostracod species, indicating the relative percentages of the most abundant taxa in each zone, are given in Table VI. According to the results supplied by Guilbault (1988, personal communication), they depict low diversity faunas characterized by euryhaline cold-water forms, such as *Elphidium excavatum, Haynesina (Nonion) orbiculare, Buccella frigida* and *Cassidulina reniforme*. Similar assemblages have been reported from nearshore (continental shelf) environments in both North America and Europe (reviewed *in* Guilbault, 1989).

While most of the identified diatom fragments belong to cosmopolitan forms, there are also some species of boreal-arctic affinity and circumpolar distribution indicating cold water conditions. These species include *Cocconeis scutellum* var. *stauroneiformis, Navicula glacialis, N. subinflata, Grammatophora arctica, Rhabdonema arcuatum, R. minutum, Diploneis reichardtii* var. *tschuktschorum, Thalassiosira lacustris* var. *hyperborea, Odontella aurita*, and *Diploneis bomboides* var. *media*. Both *Odontella aurita* and *Rhabdonema arcuatum* reach their maximum development at temperatures of about 1°C (Edsbagge, 1968).

The prevalence of littoral-neritic species and the rarity of euplanktonic forms suggest coastal proximity with depths ranging from shallow subtidal (<15 m) to intertidal conditions. Therefore, a rapidly changing paramarine environment in the form of a shallow embayment seems to have occupied the area (Fig. 9).

Tasirlaq-sud Lake

The basal minerogenic zone in the Tasirlaq-sud Lake core (385-373 cm) differs from that in Hendry Lake with respect to several sedimentary and biological features. The presence of the homogeneous, massive sand layer can be attributed to a sedimentary environment in the upper littoral zone. The distribution of surficial sediments (Fig. 2), as interpreted from aerial photographs, indicates that the basin was at the head of a narrow inlet when sea-level stood at its elevation. The well-sorted sands most likely represent sandflat deposits of a former intertidal zone. They are believed to be underlain by marine clays of the D'Iberville Sea (Pienitz, 1989).

Standstills during marine recession often involve accumulation of littoral sediments and formation of raised marine forms (*e.g.* beaches, boulder barricades). Shoreline processes are more effective at elevations where longer periods are available for geomorphic work (Lauriol and Gray, 1980). Along the Ungava Bay coast, such forms have been related to periods of stabilization in relative sea-level and can be found in abundance particularly below 60 m asl on the western coast (Hillaire-Marcel, 1979), and below 36 m asl on

TABLE VI

Foraminifera and ostracods in two selected samples from Hendry Lake

Sample HEN/125-120 cm	Sample HEN/80-75 cm
Foraminifers:	Foraminifers:
Buccella frigida	*Buccella frigida*
Cassidulina reniforme	*Elphidium excavatum*
Cibicides lobatulus	*Elphidium incertum*
Elphidium albiumbilicatum	*Miliolinella* sp.
Elphidium excavatum	*Nonion niveum*
Elphidium hallandense	*Nonion orbiculare*
Elphidium incertum	*Textularia torquata*
Nonion niveum	
Nonion orbiculare	Ostracods:
Trochammina ochracea	*Sarsicytheridea bradyi*
	Sarsicytheridea punctillata

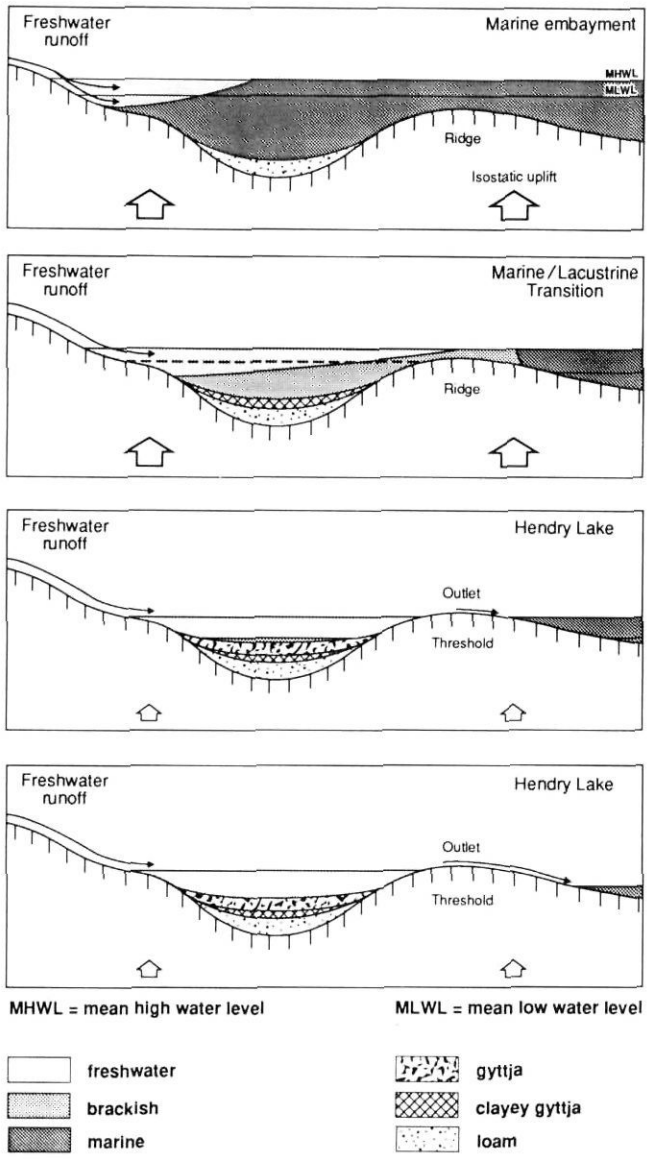

FIGURE 9. Series of schematic diagrams illustrating the developmental phases of Hendry Lake during isolation from D'Iberville Sea.

Succession de diagrammes schématiques illustrant les étapes d'évolution du lac Hendry durant son isolement de la Mer d'Iberville.

the eastern coast (Allard *et al.*, 1989). They reflect the decelerating postglacial emergence after 6000 BP.

The autochthonous character of the diatom thanatocoenosis is indicated by the strong "sand affinity" of its dominant epipsammic and epipelic components. This exactly reflects the textural nature of the substrate. Almost all of the polyhalobous and mesohalobous taxa encountered have extremely wide salinity tolerance ranges (pleioeuryhaline) and have been previously found closely associated with intertidal sandflats, sandy shoals and beaches (*e.g.* Brockmann, 1950; Vos and de Wolf, 1988).

Vos and de Wolf (1988) classified diatoms from Holocene coastal deposits of the Netherlands into ecological groups with respect to their salinity tolerances and life-form. Close floristic similarity exists especially between the fossil community of this zone and their *Achnanthes delicatula* and *Amphora proteus* ecological groups. These groups comprise epipsammic and epipelic diatoms that live in sandy sediments of the intertidal zone, or shallow marine basins, which are characterized by salinity ranges of 9 to 30‰.

ISOLATION UNITS

Hendry Lake

The next stage in the development of the lakes was their isolation from the sea (Fig. 9). In Hendry Lake, the exact position of the isolation contact cannot be determined on the basis of lithostratigraphical changes in the sediment column. This is due to a long-lasting, gradual isolation process which may be for the most part explained by the very large tidal range in the region. Considering a hypothetical rate of land uplift of about 5 m/century (see below) and a range of 13 m for large tides, it may have taken 250 to 300 years for the basin to gradually emerge from tidal influence. This tidewater influence would have diminished during the last 50 to 100 years, when the basin was less frequently invaded by large tides and storm surges.

Peculiarities in postglacial marine regression may also have played a role. Lauriol and Gray (1980) reported the presence of intertidal boulder barricades 40 m asl within the neighbouring Rivière aux Feuilles estuarine zone, near Tasiujaq. These barricades indicate "a pause in land emergence at the time of deposition". The above-mentioned intertidal flats formerly extended within the Hendry Lake basin and are located at exactly the same altitude. They may relate to these boulder barricades and suggest a corresponding temporary stabilization of relative sea-level.

Moreover, the local topography of the threshold region may have contributed to further protraction of the isolation process, the threshold level being very low and the basin being situated on the interfluve between two major estuaries (Fig. 2). Both the Koksoak and False River estuaries taper off at the latitude of Hendry Lake.

Floristic characteristics support the interpretation of a gradual isolation process; maintenance of slightly brackish conditions is indicated by the continuous representation of poly- and mesohalobous forms in assemblages dominated by freshwater diatoms (especially small *Fragilaria* spp.). Unstable depositional conditions and mechanical reworking of sediments are reflected in the strongly fragmented diatom frustules and broken sponge spicules.

In general, changes in diatom assemblage composition, total diatom concentration, LOI, and water content are more gradual than in the core from Tasirlaq-sud Lake.

Tasirlaq-sud Lake

The second stage of deposition is represented by the microlaminated zone that abruptly overlies the massive sand layer. The sharp nature of this contact reflects the rapid isolation of this basin.

As a number of studies show, formation and preservation of rhythmically laminated sediments in subarctic and arctic lakes depends on a multitude of interrelated hydrological, depositional and environmental factors (Gilbert *et al.*, 1985; Retelle, 1986; Lemmen *et al.*, 1988). The clastic laminations in question appear to be related primarily to seasonally varying influx of allochthonous material, derived from unconsolidated deposits in the lake's catchment. However, annual cycles in sediment deposition ("varved sediments") are not clearly recognizable on the basis of biostratigraphic patterns within the laminations. Variability of sediment inflow on a subseasonal scale may have further contributed to the structural complexity of the deposit. Thus, single laminae could represent discrete inflow events (climatic or geomorphic events), such as nival floods, storm surges, or other short-lived physical processes.

The presence of seawater trapped in the newly isolated basin is indicated by the important brackish water component of the corresponding fossil microflora. As a result, density stratification may have developed with denser, saline water in the hypolimnion underlying a fresh surface layer continuously replenished by runoff. Density stratification, and subsequent anoxic conditions at depth, appear to be features typical of certain lakes isolated from the sea (*e.g.* Kjemperud, 1981; Young and King, 1989). The combined effect of this situation with pronounced changes in sediment input, seems to have created favourable conditions for the preservation of sediment laminae.

The initial dominance of brackish epiphytes, such as *Cocconeis scutellum, Fragilaria fasciculata, F. pulchella, F. pulchella* var. *macrocephala, Diatoma elongatum, Rhoicosphenia curvata, Rhopalodia gibba, R. gibberula*, and *R. musculus*, gives evidence of conditions similar to those prevailing in non-tidal, lagoonal environments. Other species previously reported from brackish lagoons include *Hyalodiscus scoticus*. With increasing replenishment of the water column from runoff, brackish epiphytes were progressively replaced by freshwater epiphytes having broad salinity tolerances (*e.g. Cocconeis placentula, Epithemia sorex, E. turgida, E. zebra, Opephora martyi, Stephanodiscus* spp., and species of the genus *Fragilaria*, especially *F. construens* var. *subsalina*).

The shift in diatom assemblages from brackish to freshwater epiphytes, and the final takeover of *Fragilaria* spp.,

clearly reflects decreasing salinities and low-energy lagoonal conditions in a coastal isolation basin.

In the case of Tasirlaq-sud Lake, rapid isolation from the sea may have been provoked by fast construction of the beach ridge that presently contains it like a dam. Modern analogs of such gravel and boulder ridges isolating lake basins exist along the shores of the Ungava Bay.

POSTGLACIAL LAND EMERGENCE OF THE KUUJJUAQ REGION

The beginning of lacustrine conditions was dated at 4850 and 4300 years BP in lakes Tasirlaq-sud and Hendry, respectively. These dates therefore yield only minimum ages for the isolation from the sea. If marine transgression immediately accompanied deglaciation (Gangloff *et al.*, 1976; Hillaire-Marcel, 1979; Lauriol, 1982; Gray and Lauriol, 1985; Lauriol and Gray, 1987; Allard *et al.*, 1989), the studied lake basins would have been submerged for at least 2500 years. This is only a rough estimate, taking into account that the dated isolation contacts are located 40 to 45 m above present-day sea-level.

Because data associated with deglaciation and maximum marine transgression are almost entirely lacking, only general trends in postglacial land emergence can be traced here. The only data available relate to elevations of the maximum marine limit (MML), which have been determined by air photo interpretation.

According to Lauriol (1982), the 175 m MML isoline for the postglacial D'Iberville Sea passes through Kuujjuaq. Gangloff *et al.* (1976) indicate an elevation of 183 m asl for the same area. Thus, the mean value of about 180 m asl is considered here as its maximum position. Taking into account that the retreating ice masses were in contact with marine waters, and that the sea stood at its highest relative level at the moment of initial submergence (Hillaire-Marcel, 1979), the MML was presumably reached about 7000 years ago or shortly thereafter. This date represents the extrapolated age of deglaciation of the southern Ungava Bay coastal borderlands, near the mouth of Koksoak River (Lauriol, 1982). It was therefore selected as a reference point for the evaluation of subsequent absolute emergence. The time lag between deglaciation of this site and the Kuujjuaq area, some 50 km upstream, seems to have been insignificant. Rapid retreat of ice masses within the coastal area was favoured by direct calving of the ice front into the sea, as the Koksoak valley and adjacent lowlands open widely on Ungava Bay (Lauriol, 1982).

Based on these assumptions and the radiometric ages obtained from both isolation contacts, the respective emergence rates for the period prior to basin isolation were determined. The calculated rates are 6.3 cm yr^{-1} for the period 7000 to 4850 BP in Tasirlaq-sud Lake and 5.2 cm yr^{-1} for the period 7000 to 4300 BP in Hendry Lake. Hence, the postglacial marine level would have stood 125 to 115 m asl at 6000 BP and 75 to 55 m asl at 5000 BP. These values correspond approximately with the 120 to 80 m isobase-range of 6000 BP and the 75 to 50 m isobase-range of 5000 BP that can be inferred for the Kuujjuaq area from isobase maps illustrating postglacial rebound in northern Québec and Labrador (Lauriol, 1982).

Despite all uncertainties arising from the fact that these rates have been determined by approximation, they nevertheless provide a reasonable estimate of local uplift and permit correlation and comparison with other regions along the Ungava Bay coast. Postglacial emergence curves obtained from areas southwest and southeast of the bay show initial uplift rates of about the same magnitude (Fig. 10). In the Rivière Bérard Valley near Tasiujaq, 120 km west of Kuujjuaq, they reached about 5.6 cm yr^{-1} between 7000 and 5000 BP, according to the curve constructed by Lauriol (1982). In the George River area to the east, where the marine limit is only 100 m high, Allard *et al.* (1989) calculated a rate of 4.5 cm yr^{-1} for the period prior to 5800 BP (Fig. 10).

Based on the dated isolation contacts and known threshold elevations of both lakes, more reliable results can be obtained for the post-isolation period up until present-day. The calculations reveal identical emergence rates of 0.93 cm yr^{-1} for both sites. This reflects slightly faster land emergence in the Kuujjuaq region than in southeastern Ungava Bay, where Allard *et al.* (1989) reported a rate of 0.5 cm yr^{-1} for the period from 5800 BP until present-day. In general, the tentative emergence curve constructed for the Kuujjuaq area (Fig. 10) resembles those curves which present very rapid emergence after deglaciation, followed by a more or less strong inflexion and a subsequent slowing down in isostatic rebound. The rate

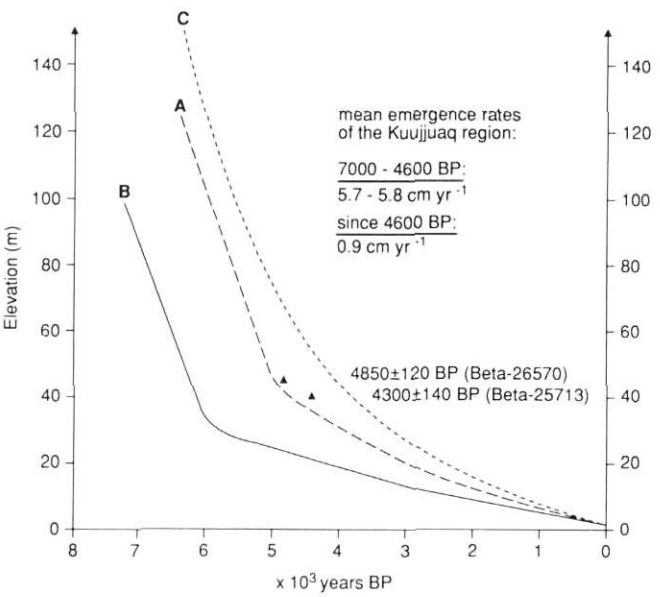

FIGURE 10. Probable land emergence curve in the Kuujjuaq area in comparison with those of adjacent regions along the Ungava Bay coast.

Courbe probable de l'émersion des terres à Kuujjuaq en comparaison avec celles de régions voisines, le long de la côte de la baie d'Ungava.

of change of these curves varies geographically due to proximity to the main load of the Laurentide Ice Sheet.

Differential glacioisostatic recovery occurs mainly in response to previous glacial loading (and related glacioisostatic depression) which explains regionally variable uplift rates (*e.g.* Hillaire-Marcel, 1979; Gray and Lauriol, 1985). Land emergence rates are the result of a complex interplay between glacial isostasy, glacial eustasy and geoidal eustasy, with changing magnitudes of each component through time (Kjemperud, 1986). The calculated rates suggest that the coastal lowlands in the vicinity of Kuujjuaq experienced rapid and progressive land emergence. Because initial rebound was extraordinarily rapid, approximately 76% of total land emergence had occurred by 4600 BP, by which time sea-level stood at the present 40 to 45 m contour. Emergence rates remained relatively high until the present-day (0.93 cm yr^{-1}), which may be the consequence of late ice withdrawal, delayed land uplift, and dominance of the isostatic component through time.

CONCLUSION

The main purpose of this study was to examine the record of Holocene paleoenvironmental changes preserved in the sediments of two coastal basins through an investigation of the diatom spectra. The succession of diatom zones documents changes induced by postglacial isostatic uplift of the Kuujjuaq region through consecutive periods of marine occupation, isolation from the sea and subsequent lacustrine conditions.

The passage from marine to lacustrine environments appears differently in the two lakes, due to differences in local topography and basin morphology: in Tasirlaq-sud Lake it is reflected in the abrupt change in depositional mechanisms, while the considerable extent of the transitional phase in Hendry Lake indicates a rather gradual and long-lasting isolation process. Reworking of sediments, caused by repeated marine incursions, may have prevented the formation of laminations similar to those preserved in Tasirlaq-sud Lake.

Diatom analysis turned out to be very effective in identifying the position of the isolation contact in the sediment columns and in defining the related changes in paleosalinity. Striking changes in diatom assemblage composition and sharp increases in small *Fragilaria* spp. have been found to be the most prominent features in connection with these marine/lacustrine boundaries.

Threshold height determination, and radiocarbon dating, facilitated a first estimate of regional trends in postglacial land emergence and an approximate reconstruction of uplift rates for an area from which paleogeographical data are almost entirely lacking. No marine transgression was recorded in the cores after 4850 and 4300 BP respectively, thereby suggesting progressive emergence of the coastal lowlands from the sea.

Additional "isolation"-dates from sites located at different altitudes are necessary in order to further define the relative sea-level history of the Kuujjuaq region and to build a more detailed land emergence curve. This approach could also be more widely used in regions that lack datable raised shorelines and to complement otherwise sparsely dated emergence curves.

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REFERENCES

Aitken, A. and Gilbert, R., 1986. The biota of intertidal flats at Pangnirtung Fiord, Baffin Island, Northwest Territories. Naturaliste canadien, 113: 191-200.

Alhonen, P., 1971. The stages of the Baltic Sea as indicated by the diatom stratigraphy. Acta Botanica Fennica, 92: 1-18.

Allard, M., Fournier, A., Gahé, E. and Seguin, M. K., 1989. Le Quaternaire de la côte sud-est de la baie d'Ungava, Québec nordique. Géographie physique et Quaternaire, 43 (3): 325-336.

Battarbee, R. W. and Kneen, M. J., 1982. The use of electronically counted microspheres in absolute diatom analysis. Limnology and Oceanography, 27 (1): 184-188.

Beyens, L. and Denys, L., 1982. Problems in diatom analysis of deposits: allochthonous valves and fragmentation. Geologie en Mijnbouw, 61: 159-162.

Björck, S. and Digerfeldt, G., 1986. Late Weichselian-Early Holocene shore displacement west of Mt. Billingen, within the Middle Swedish end-moraine zone. Boreas, 15: 1-18.

Brockmann, C., 1950. Die Watt-Diatomeen der Schleswig-Holsteinischen Westküste. Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft, 478: 1-26.

Canada, 1990. Canadian Tide and Current Tables. Vol. 4: Arctic and Hudson Bay. Fisheries and Oceans Canada, 47 p., ann. publ.

Cardinal, A., Poulin, M. and Bérard-Therriault, L., 1984. Les diatomées benthiques de substrats durs des eaux marines et saumâtres du Québec. 4. Naviculaceae. Naturaliste canadien, 111: 369-394.

——— 1986. Les diatomées benthiques de substrats durs des eaux marines et saumâtres du Québec. 5. Naviculaceae. Naturaliste canadien, 113: 167-190.

Cleve-Euler, A., 1951-1955. Die Diatomeen von Schweden und Finnland. Kungl. Svenska Vetenskapsakademiens Handlingar, Vol. I-V, Stockholm.

Delisle, C. E., Bouchard, M. A. and André, P., 1986. Les précipitations acides et leurs effets potentiels au nord du 55e parallèle du Québec. Collection Environnement et Géologie, vol. 2, 280 p.

de Wolf, H., 1982. Method of coding of ecological data from diatoms for computer utilization. Meded. Rijks Geologische Dienst, 36: 95-98.

Diaz, H. F., Andrews, J. T. and Short, S. K., 1989. Climate variations in northern North America (6000 BP to present) reconstructed form pollen and tree-ring data. Arctic and Alpine Research, 21 (1): 45-59.

Dixit, A. S., Dixit, S. S. and Evans, R. D., 1988. The relationship between sedimentary diatom assemblages and lakewater pH in 35 Québec lakes, Canada. Journal of Paleolimnology, 1 (1): 23-38.

Dyke, A. S. and Prest, V. K., 1987. Late Wisconsinan and Holocene history of the Laurentide Ice Sheet. Géographie physique et Quaternaire, 41 (2): 237-263.

Edsbagge, H., 1966. Grundlinien in der Verteilung von angehefteten Diatomeen an der schwedischen Westküste. Veröffentlichungen des Instituts für Meeresforschung Bremerhaven, Sonderband II.

——— 1968. Zur Ökologie der marinen angehefteten Diatomeen. Acta Universitatis Gothoburgensis VI, 153 p.

Ellis, D. V. and Wilce, R. T., 1961. Arctic and subarctic examples of intertidal zonation. Arctic, 14: 224-235.

Florin, M.-B., 1977. Late-Glacial and Pre-Boreal vegetation in southern central Sweden. II. Pollen and Diatom Diagrams. Striae 5, Uppsala, 59 p.

Foged, N., 1971. Diatoms found in a bottom sediment sample from a small deep lake on the northern slope, Alaska. Nova Hedwigia, 21 (2): 923-1035.

——— 1981. Diatoms in Alaska. Bibliotheca Phycologica, J. Cramer Verlag, Vaduz, 316 p.

Gangloff, P., Gray, J. T. and Hillaire-Marcel, C., 1976. Reconnaissance géomorphologique sur la côte ouest de la baie d'Ungava. Revue de Géographie de Montréal, 30: 339-348.

Germain, H., 1981. Flore des diatomées des eaux douces et saumâtres. Collection "Faunes et Flores actuelles", Boubée, Paris, 444 p.

Gilbert, R. and Aitken, A. E., 1981. The role of sea ice in biophysical processes on intertidal flats at Pangnirtung (Baffin Island), N.W.T.. National Research Council of Canada, Rimouski, ACROSES Publ. 3: 89-103.

Gilbert, R., Syvitski, J. P. M. and Taylor, R. B., 1985. Reconnaissance study of proglacial Stewart Lakes, Baffin Island, District of Franklin. *In* Current Research, part A. Geological Survey of Canada, Paper 85-1A: 505-510.

Gray, J. T. and Lauriol, B., 1985. Dynamics of the Late Wisconsin Ice Sheet in the Ungava Peninsula interpreted from geomorphological evidence. Arctic and Alpine Research, 17: 289-310.

Guilbault, J.-P., 1989. Foraminiferal distribution in the central and western parts of the Late Pleistocene Champlain Sea Basin, eastern Canada. Géographie physique et Quaternaire, 43 (1): 3-26.

Haggart, B. A., 1986. Relative sea-level change in the Beauly Firth, Scotland. Boreas, 15: 191-207.

Hendey, N. I., 1964. An introductory account of the smaller algae of British coastal waters. Part V: Bacillariophyceae (Diatoms). Ministry of Agriculture, Fisheries and Food, Fisheries Investigations, Series IV, London, 317 p.

Hillaire-Marcel, C., 1979. Les mers post-glaciaires du Québec: quelques aspects. Thèse de doctorat, Université Pierre et Marie Curie, Paris VI, 293 p.

Hustedt, F., 1930-1966. Die Kieselalgen Deutschlands, Österreichs und der Schweiz. *In* L. Rabenhorsts Kryptogamen-Flora von Deutschland, Österreich und der Schweiz. Akademische Verlagsgesellschaft, Vol. I-III, Leipzig.

Kaland, P. E., Krzywinski, K. and Stabell, B., 1984. Radiocarbon-dating of transitions between marine and lacustrine sediments and their relation to the development of lakes. Boreas, 13: 243-258.

Kjemperud, A., 1981. Diatom changes in sediments of basins possessing marine/lacustrine transitions in Frosta, Nord-Trøndelag, Norway. Boreas, 10: 27-38.

——— 1986. Late Weichselian and Holocene shoreline displacement in the Trondheimsfjord area, central Norway. Boreas, 15: 61-82.

Kolbe, R. W., 1927. Zur Ökologie, Morphologie und Systematik der Brackwasser-Diatomeen. Pflanzenforschung, Gustav Fischer Verlag, Jena, 7: 1-146.

Krammer, K. and Lange-Bertalot, H., 1986. Bacillariophyceae, Teil I: Naviculaceae. *In* H. Ettl, J. Gerloff, H. Heynig and D. Mollenhauer, eds., Süβwasserflora von Mitteleuropa. Band 2/1, Gustav Fischer Verlag, Stuttgart/New York, 876 p.

——— 1988. Bacillariophyceae, Teil II: Bacillariaceae, Epithemiaceae, Surirellaceae. *In* H. Ettl, J. Gerloff, H. Heynig and D. Mollenhauer, eds., Süβwasserflora von Mitteleuropa. Band 2/2, Gustav Fischer Verlag, Stuttgart/New York, 596 p.

Lamb, H. F., 1980. Late Quaternary vegetational history of southeastern Labrador. Arctic and Alpine Research, 12: 117-135.

——— 1985. Modern pollen spectra from Labrador and their use in reconstructing Holocene vegetational history. Journal of Ecology, 72: 37-59.

Lauriol, B., 1982. Géomorphologie quaternaire du sud de l'Ungava. Collection Paléo-Québec 15, 174 p.

Lauriol, B. and Gray, J. T., 1980. Processes responsible for the concentration of boulders in the intertidal zone of Leaf Basin, Ungava. *In* S. B. McCann, ed., The coastline of Canada. Geological Survey of Canada, Paper 80-10: 281-292.

——— 1987. The decay and disappearance of the Late Wisconsin ice sheet in the Ungava peninsula, northern Québec, Canada. Arctic and Alpine Research, 19 (2): 109-126.

Lemmen, D. S., Gilbert, R., Smol, J. P. and Hall, R. I., 1988. Holocene sedimentation in glacial Tasikutaaq Lake, Baffin Island. Canadian Journal of Earth Sciences, 25: 810-823.

Lichti-Federovich, S., 1983. Diatoms from the southern Beaufort Sea. Geological Survey of Canada, Paper 83-1B: 267-271.

Lie, S. E., Stabell, B. and Mangerud, J., 1983. Diatom stratigraphy related to Late Weichselian sea-level changes in Sunnmøre, western Norway. Norges geologiske Undersøkelse, 380: 203-219.

Lortie, G., 1983. Les diatomées de la mer de Goldthwait dans la région de Rivière-du-Loup, Québec. Géographie physique et Quaternaire, 37 (3): 279-296.

Lortie, G. and Pienitz, R., 1988. *Melosira teres* Brun (Bacillariophycée): Nouvelles données biogéographiques et systématiques. Annales de l'ACFAS, 56: 33.

Mangerud, J. and Gulliksen, S., 1975. Apparent radiocarbon ages of recent marine shells from Norway, Spitsbergen, and Arctic Canada. Quaternary Research, 5 (2): 263-275.

Mathieu, C., 1984. Morphogénèse holocène des dunes et des palses de la basse vallée du Koroc (Nouveau-Québec). M.Sc. thesis, Université de Montréal, 209 p.

McAndrews, J. H. and Samson, G., 1977. Analyse pollinique et implications archéologiques et géomorphologiques, Lac de la Hutte Sauvage (Mushuau Nipi), Nouveau-Québec. Géographie physique et Quaternaire, 31: 177-183.

Meriläinen, J., 1967. The diatom flora and the hydrogen-ion concentration of the water. Annales Botanici Fennici, 4: 51-58.

Mölder, K. and Tynni, R., 1967-1973. Über Finnlands rezente und subfossile Diatomeen. Part I-VII, Bulletin of the Geological Society of Finland, Helsinki.

Pankow, H., 1976. Algenflora der Ostsee. II. Plankton. Gustav Fischer Verlag, Stuttgart, 493 p.

Patrick, R. and Freese, L. R., 1961. Diatoms (Bacillariophyceae) from northern Alaska. *In* Proceedings of the Academy of Natural Sciences. Philadelphia, 112 (6): 129-301.

Patrick, R. and Reimer, C. W., 1966. The diatoms of the United States. Part I: Fragilariaceae, Eunotiaceae, Achnanthaceae, Naviculaceae. Academy of Natural Sciences, Philadelphia, 688 p.

——— 1975. The diatoms of the United States. Part II: Entomoneidaceae, Cymbellaceae, Gomphonemaceae, Epithemiaceae. Academy of Natural Sciences, Philadelphia, 213 p.

Payette, S., 1983. The forest tundra and the present tree-lines of the northern Québec-Labrador Peninsula. *In* P. Morisset and S. Payette, eds., Tree-line ecology: Proceedings of the northern Québec tree-line conference. Collection Nordicana, 47: 3-24.

Pienitz, R., 1989. Regression of D'Iberville sea and paleolimnology of two lakes from southern central Ungava Bay. M.A. thesis, Université Laval, Québec, 125 p.

Pienitz, R. and Lortie, G., 1988. Diatoms and post-glacial regression of D'Iberville Sea in the Kuujjuaq area, northern Québec (Canada). 10th International Symposium on Living and Fossil Diatoms, Joensuu (Huhmari, Finland), Abstracts, p. 101.

Poulin, M., Bérard-Therriault, L. and Cardinal, A., 1984. Les diatomées benthiques de substrats durs des eaux marines et saumâtres du Québec. 1. Cocconeioideae. Naturaliste canadien, 111: 45-61.

——— 1984. Les diatomées benthiques de substrats durs des eaux marines et saumâtres du Québec. 2. Tabellarioideae et Diatomoideae. Naturaliste canadien, 111: 275-295.

——— 1984. Les diatomées benthiques de substrats durs des eaux marines et saumâtres du Québec. 3. Fragilarioideae. Naturaliste canadien, 111: 349-367.

Québec, 1984. Le Nord du Québec: Profil régional. Ministère de l'aménagement et du développement régional, Québec.

Retelle, M. J., 1986. Stratigraphy and sedimentology of coastal lacustrine basins, northeastern Ellesmere Island, N.W.T. Géographie physique et Quaternaire, 40 (2): 117-128.

Retelle, M. J., Bradley, R. S. and Stuckenrath, R., 1989. Relative sea level chronology determined from raised marine sediments and coastal isolation basins, northeastern Ellesmere Island, arctic Canada. Arctic and Alpine Research, 21 (2): 113-125.

Richard, P. J. H., 1981. Paléophytogéographie postglaciaire en Ungava par l'analyse pollinique. Collection Paléo-Québec 13, 153 p.

Short, S. K. and Nichols, H., 1977. Holocene pollen diagrams from subarctic Labrador-Ungava: Vegetational history and climatic change. Arctic and Alpine Research, 9 (3): 265-290.

Simola, H., 1977. Diatom succession in the formation of annually laminated sediment in Lovojärvi, a small eutrophicated lake. Annales Botanici Fennici, 14: 143-148.

Simonsen, R., 1962. Untersuchungen zur Systematik und Ökologie der Bodendiatomeen der westlichen Ostsee. Internationale Revue der Gesamten Hydrobiologie, Systematische Beihefte 1, Akademie-Verlag, Berlin, 144 p.

Stabell, B., 1980. Holocene shorelevel displacement in Telemark, southern Norway. Norsk Geologisk Tidsskrift, 60: 71-81.

——— 1985. The development and succession of taxa within the diatom genus *Fragilaria* Lyngbye as a response to basin isolation from the sea. Boreas, 14: 273-286.

Stravers, L. K. S., 1981. Palynology and deglaciation history of the central Labrador-Ungava peninsula. MSc. thesis, University of Colorado, Boulder, 171 p.

Tynni, R., 1975. Über Finnlands rezente und subfossile Diatomeen. Part VIII, Geological Survey of Finland, Bulletin 274: 1-55.

——— 1976. Über Finnlands rezente und subfossile Diatomeen. Part IX, Geological Survey of Finland, Bulletin 284: 1-37.

——— 1978. Über Finnlands rezente und subfossile Diatomeen. Part X, Geological Survey of Finland, Bulletin 296: 1-55.

——— 1980. Über Finnlands rezente und subfossile Diatomeen. Part XI, Geological Survey of Finland, Bulletin 312: 1-93.

Van der Werff, A. and Huls, H., 1957-1974. Diatomëenflora van Nederland. Abcoude, Den Haag.

Vincent, J.-S., Occhietti, S., Rutter, N., Lortie, G., Guilbault, J.-P. and De Boutray, B., 1983. The late Tertiary-Quaternary stratigraphic record of the Duck Hawk Bluffs, Banks Island, Canadian Arctic Archipelago. Canadian Journal of Earth Sciences, 20: 1694-1712.

Vos, P. C. and de Wolf, H., 1988. Methodological aspects of paleoecological diatom research in coastal areas of the Netherlands. Geologie en Mijnbouw, 67: 31-40.

Young, R. B. and King, R. H., 1989. Sediment chemistry and diatom stratigraphy of two high arctic isolation lakes, Truelove Lowland, Devon Island, N.W.T., Canada. Journal of Paleolimnology, 2: 207-225.

APPENDIX

TAXONOMIC LIST AND AUTECOLOGY OF DIATOMS FROM LAKES HENDRY AND TASIRLAQ-SUD

S = Salinity (1 = polyhalobous; 2 = mesohalobous; 3 = oligohalobous halophilous; 4 = oligohalobous indifferent; 5 = halophobous)
P = pH (1 = alkalibiontic; 2 = alkaliphilous; 3 = pH-indifferent; 4 = acidophilous; 5 = acidobiontic)
H = Habitat/Life-form (1 = euplanktonic; 2 = tychoplanktonic; 3 = periphytic; 4 = aerophilic)

	S	P	H
ACHNANTHES Bory			
biasolettiana (Kützing) Grunow	4	–	3
brevipes var. *parvula* (Kützing) Cleve	2	2	3
calcar Cleve	4	2	3
clevei Grunow	4	2	3
conspicua A. Mayer	4	2	3
delicatula (Kützing) Grunow	2	2	3
depressa (Cleve) Hustedt	5	4	3
exigua Grunow	4	2	3
exigua var. *heterovalva* Krasske	4	2	3
flexella (Kützing) Brun	5	4	3
flexella var. *alpestris* Brun	5	4	3
gracillima Hustedt	4	3	1
holstii Cleve	4	3	3
lanceolata (Brébisson) Grunow	4	3	3
lanceolata var. *elliptica* Cleve	4	2	3
laterostrata Hustedt	4	3	3
levanderi Hustedt	4	3	3
linearis (W. Smith) Grunow	4	3	3
linearis var. *pusilla* Grunow	4	2	3
marginulata Grunow	5	4	3
microcephala (Kützing) Cleve	4	4	3
minutissima Kützing	4	3	3
œstrupii (Cleve-Euler) Hustedt	4	3	3
peragallii Brun & Héribaud	4	3	3
suchlandtii Hustedt	4	3	3
sp.1			
sp.2			
sp.3			
AMPHORA Ehrenberg			
acutiuscula Kützing	2	–	3
coffeaeformis (Agardh) Kützing	2	2	3
crassa Gregory	1	–	3
dusenii Brun	4	3	4
fogediana Krammer	4	3	3
holsatica Hustedt	2	2	3
inariensis Krammer	4	–	3
interrupta Heiden & Kolbe	–	–	–
libyca Ehrenberg	4	2	3
pediculus (Kützing) Grunow	4	2	3
proteus var. *oculata* (Gregory) Cleve	1	–	3
terroris Ehrenberg	–	–	3
thumensis (A. Mayer) Cleve-Euler	4	2	3
wisei (Salah) Simonsen	–	–	–
sp. 1			
ANOMOEONEIS Pfitzer			
brachysira (Brébisson) Grunow	5	4	3
brachysira var. *zellensis* (Grunow) Krammer	5	4	3
sphaerophora (Ehrenberg) Pfitzer	2	1	3
sphaerophora f. *sculpta* (Ehrenberg) Krammer	2	1	3
styriaca (Grunow) Hustedt	4	3	3
vitrea (Grunow) Ross	4	2	3
ASTERIONELLA Hassal			
ralfsii W. Smith	4	4	1
CALONEIS Cleve			
bacillum (Grunow) Cleve	4	2	3
obtusa (W. Smith) Cleve	4	2	3
silicula (Ehrenberg) Cleve	4	2	3
tenuis (Gregory) Krammer	5	3	3
undulata (Gregory) Krammer	4	3	3
westii (W. Smith) Hendey	2	2	3
CAMPYLODISCUS Ehrenberg			
angularis Gregory	1	–	3
noricus var. *hibernicus* (Ehrenberg) Grunow	4	2	3
COCCONEIS Ehrenberg			
californica Grunow	1	–	3
costata Gregory	1	–	3
diminuta Pantocsek	4	2	3
peltoides Hustedt	1	–	3
placentula Ehrenberg	4	2	3
placentula var. *euglypta* (Ehrenberg) Grunow	4	2	3
scutellum Ehrenberg	1	–	3
scutellum var. *parva* (Grunow) Cleve	1	–	3
scutellum var. *speciosa* (Gregory) Cleve-Euler	1	–	3
scutellum var. *stauroneiformis* W. Smith	1	–	3
COSCINODISCUS Ehrenberg			
sp.1			
CYCLOTELLA Kützing			
antiqua W. Smith	5	4	2
bodanica Eulenstein	4	3	–
caspia Grunow	2	–	1,2
comta (Ehrenberg) Kützing	4	3	1
comta var. *radiosa* Grunow	4	3	1
kuetzingiana Thwaites	4	3	2
ocellata Pantocsek	4	3	2
pseudostelligera Hustedt	4	3	1
stelligera (Cleve & Grunow) Van Heurck	4	3	2
CYMATOPLEURA W. Smith			
solea (Brébisson) W. Smith	4	2	3
CYMBELLA Agardh			
affinis Kützing	4	2	3
angustata (W. Smith) Cleve	4	3	3
aspera (Ehrenberg) H. Peragallo	4	2	3
behrei Foged	4	3	3
brehmii Hustedt	–	–	–
cesatii (Rabenhorst) Grunow	4	3	3
cistula (Ehrenberg) Kirchner	4	2	3
cuspidata Kützing	4	2	3
cymbiformis Agardh	4	2	3
delicatula Kützing	4	3,2	4
ehrenbergii Kützing	4	2	3
gaeumannii Meister	5	4	3
gracilis (Ehrenberg) Kützing	5	3	3
hustedtii Krasske	4	2	3
hybrida Grunow	4	3	3
incerta (Grunow) Cleve	5	4	3
lanceolata (Ehrenberg) Kirchner	4	2	3
leptoceros (Ehrenberg) Kützing	4	2	3
microcephala Grunow	4	3	3
minuta Hilse	4	3	3
muellerii Hustedt	4	3	3
muellerii f. *ventricosa* (Temp. & Perag.) Reimer	4	3	3
prostrata var. *auerswaldii* (Rabenhorst) Reimer	4	3	3
pusilla Grunow	3	3	3
sinuata Gregory	4	3	4
DENTICULA Kützing			
tenuis Kützing	4	1	3
tenuis var. *crassula* (Naegeli) Hustedt	4	1	3
DIATOMA De Candolle			
elongatum Lyngbye	3	3,2	2
DIPLONEIS Ehrenberg			
didyma (Ehrenberg) Ehrenberg	1	2	3
elliptica (Kützing) Cleve	4	2	3
entomon (Ehrenberg) Cleve	1	–	3
finnica (Ehrenberg) Cleve	4	3	3
interrupta (Kützing) Cleve	2	2	3
marginestriata Hustedt	4	2	4
oculata (Brébisson) Cleve	4	2	4,3
ovalis (Hilse) Cleve	4	2	3
puella (Schumann) Cleve	4	4	3
reichardtii var. *tschuktschorum* (Cleve) Heiden	1	–	3
smithii (Brébisson) Cleve	1	–	3
splendida (Gregory) Cleve	1	–	3
stroemii Hustedt	1	–	3

ENTOMONEIS Ehrenberg			
ornata (Bailey) Reimer	4	–	–
EPITHEMIA Brébisson			
reicheltii Fricke	–	–	–
smithii Carruthers	–	2	–
sorex Kützing	4	2	3
turgida (Ehrenberg) Kützing	4	2,1	–
adnata (Kützing) Brébisson	4	2	3
adnata var. *saxonica* (Kützing) Patrick	4	2	3
EUNOTIA Ehrenberg			
diodon Ehrenberg	5	4	–
exigua (Brébisson) Rabenhorst	5	5	3,4
flexuosa (Brébisson) Kützing	4	4	3,4
monodon Ehrenberg	5	4	–
monodon var. *major* (W. Smith) Hustedt	5	4	–
pectinalis (Kützing) Rabenhorst	5	4	3,2
praerupta Ehrenberg	5	4	3,4
praerupta var. *bidens* (W. Smith) Grunow	5	4	3,4
praerupta var. *inflata* Grunow	5	4	3,4
rhomboidea Hustedt	5	4	3,4
FRAGILARIA Lyngbye			
brevistriata Grunow	4	2	3
construens (Ehrenberg) Grunow	4	2	3
construens var. *binodis* (Ehrenberg) Grunow	4	2	3
construens var. *subsalina* Hustedt	3	2	3
construens var. *venter* (Ehrenberg) Grunow	4	2	3
fasciculata (Agardh) Lange-Bertalot	2	2	3
intermedia Grunow	4	2	3
lapponica Grunow	4	3	3
leptostauron (Ehrenberg) Hustedt	4	2	3
pinnata Ehrenberg	4	2	3
pinnata var. *intercedens* (Grunow) Hustedt	4	2	3
pinnata var. *lancettula* (Schumann) Hustedt	4	2	3
pulchella (Ralfs) Lange-Bertalot	2	–	3
pulchella var. *macrocephala* Grunow	2	–	3
vaucheriae (Kützing) Petersen	4	3	–
virescens Ralfs	5	3	3
virescens var. *oblongella* *f. clavata* Grunow	2	–	3
sp. 1			
FRUSTULIA Rabenhorst			
rhomboides var. *saxonica* (Rabenhorst) De Toni	5	4	3,4
GOMPHONEMA Ehrenberg			
acuminatum Ehrenberg	4	2	3
acuminatum var. *coronatum* (Ehrenberg) W. Smith	4	2,3	3
affine Kützing	4	3	3
angustatum (Kützing) Rabenhorst	4	3	3
gracile Ehrenberg	4	2	3
parvulum (Kützing) Kützing	4	3	3
rhombicum Fricke	–	–	–
subtile Ehrenberg	4	3	3
subtile var. *sagitta* (Schumann) Cleve	4	3	3
truncatum Ehrenberg	4	2	3
valentinica Nikolajev	1	–	3
GRAMMATOPHORA Ehrenberg			
arctica Cleve	1	–	–
oceanica Ehrenberg	1	–	2
oceanica var. *macilenta* (W. Smith) Grunow	1	–	2
GYROSIGMA Hassall			
acuminatum (Kützing) Rabenhorst	4	2	3
HANNAEA Patrick			
arcus (Ehrenberg) Patrick	4	3	1
HANTZSCHIA Grunow			
amphioxys (Ehrenberg) Grunow	4	3	4
HYALODISCUS Ehrenbeg			
scoticus (Kützing) Grunow	2	–	3
LICMOPHORA Agardh			
abbreviata Agardh	1	–	3
MASTOGLOIA Thwaites			
elliptica (Agardh) Cleve	2	2	3
elliptica var. *dansei* (Thwaites) Cleve	2	1	3
exigua Lewis	2	1	3
smithii var. *lacustris* Grunow	2	2	–
MELOSIRA Agardh			
ambigua (Grunow) Müller	4	2	1
distans (Ehrenberg) Kützing	5	4	2
distans var. *humilis* Cleve-Euler	5	4	2
italica (Ehrenberg) Ralfs	4	2	2
italica var. *valida* Grunow	4	2	2
lirata (Ehrenberg) Kützing	5	4	2
perglabra Østrup	5	4	2
perglabra var. *floriniae* Camburn	5	4	2
teres Brun	4	3,2	2
MERIDION Agardh			
circulare (Greville) Agardh	4	2	2
NAVICULA Bory			
abiskoensis Hustedt	4	3	3
aboensis (Cleve) Hustedt	4	–	3
aurora Sovereign	4	–	3
bacillum Ehrenberg	4	2	3
bryophila Petersen	4	3	4
capitata var. *hungarica* (Grunow) Ross	4	2	3
capitata var. *lueneburgensis* (Grunow) Patrick	4	2	3
cocconeiformis Gregory	5	3	3
concentrica Carter	4	–	3
crucicula (W. Smith) Donkin	2	2	3
crucicula var. *cruciculoides* (Brockm.) Lange-Bertalot	2	–	3
cryptocephala Kützing	4	2	3
cryptolyra Brockmann	2	–	3
cryptotenella Lange-Bertalot	4	3	3
cuspidata (Kützing) Kützing	4	2	3
digitoradiata (Gregory) Ralfs	2	2	3
diluviana Krasske	4	2	3
elginensis (Gregory) Ralfs	4	2	3
explanata Rustedt	4	3	3
farta Hustedt	4	3	3
forcipata Greville	1	–	3
fossalis Krasske	4	–	3,4
fossalis var. *obsidialis* (Hustedt) Lange-Bertalot	4	–	3,4
fracta Hustedt	–	–	3
gastrum (Ehrenberg) Kützing	4	3	3
glacialis (Cleve) Grunow	1	–	3
granulata Bailey	1	–	3
gregaria Donkin	2	2	3
halophila (Grunow) Cleve	2	2	3
harderii Hustedt	–	–	3
humerosa Brébisson	1	–	3
hustedtii Krasske	4	3	3,4
jaagii Meister	4	–	3
jaernefeltii Hustedt	4	3	3
jentzschii Grunow	4	2	3
lacuna Patrick & Freese	4	3	3
laevissima Kützing	4	–	3
levanderii Hustedt	5	4,5	3
litoricola Hustedt	1	–	3
mediocris Krasske	5	3	3
menisculus Schumann	4	2	3
minima Grunow	4	3	3
minuscula Grunow	4	2	4
minuscula var. *muralis* (Grunow) Lange-Bertalot	4	–	3
modica Hustedt	4	2	3
mutica Kützing	4	3	3
oblonga (Kützing) Kützing	4	2	3
palpebralis Brébisson	1	–	3
peregrina (Ehrenberg) Kützing	2	2	3
peregrina var. *kefvingensis* (Ehrenberg) Cleve	2	2	3
peregrina var. *polaris* (Lagerstedt) Cleve	2	2	3
porifera Hustedt	4	–	3
pseudoscutiformis Hustedt	4	3	3
pseudosilicula Hustedt	4	3	3
pseudoventralis Hustedt	4	–	3
pupula Kützing	4	3	3
pupula var. *rectangularis* (Gregory) Grunow	4	3	3

pupula f. *rostrata* (Hustedt) Hustedt	4	3	3
pygmaea Kützing	2	1	3
radiosa Kützing	4	3	3
reinhardtii (Grunow) Grunow	4	1	3
rhynchocephala Kützing	4	2	3
salinarum Grunow	2	2	3
schmassmannii Hustedt	–	–	3
scutelloides W. Smith	4	2	3
seminuloides Hustedt	4	3	3
seminulum Grunow	4	3	3
slesvicensis Grunow	4	–	3
soehrensis var. *hassiaca* (Krasske) Lange-Bertalot	5	4	4
subinflata Grunow	2	–	3
tenera Hustedt	1	–	3
trivialis Lange-Bertalot	4	–	3
tuscula (Ehrenberg) Grunow	4	1	3
vitabunda Hustedt	4	2	3
vulpina Kützing	4	2	3
sp.1			
sp.2			
sp.3			
NEIDIUM Pfitzer			
affine (Ehrenberg) Pfitzer	4	3	3
bisulcatum (Lagerstedt) Cleve	4	2	3
hitchcockii (Ehrenberg) Cleve	4	4	3
iridis (Ehrenberg) Cleve	4	4	3
iridis var. *ampliatum* (Ehrenberg) Cleve	4	4	3
temperei Reimer	–	–	–
NITZSCHIA Hassall			
acuminata (W. Smith) Grunow	1	–	3
angustata var. *acuta* Grunow	4	2	3
denticula Grunow	4	2	3,2
fonticola Grunow	4	2	2
frustulum (Kützing) Grunow	3	2	3
hollerupensis Foged	4	3	–
sigma (Kützing) W. Smith	2	2	3
sigmoidea (Nitzsch) W. Smith	4	2	3
sinuata (Thwaites) Grunow	4	2	–
valdestriata Aleem & Hustedt	3	2	4
sp.1			
sp.2			
sp.3			
ODONTELLA Agardh			
aurita (Lyngbye) Agardh	1	–	2
OPEPHORA Petit			
marina (Gregory) Petit	1	–	3
martyi Héribaud	4	2	3
olsenii Möller	2	–	3
PARALIA Heiberg			
sulcata (Ehrenberg) Cleve	1	2	2
PERONIA Brébisson & Arnott			
heribaudii Brun & M. Peragallo	4,5	4	3
PINNULARIA Ehrenberg			
acrosphaeria var. *turgidula* Grunow	4	3	3
balfouriana Grunow	4	4	3
borealis Ehrenberg	4	3	4
divergens W. Smith	5	3	3
episcopalis Cleve	4	3	3
gibba Ehrenberg	4	3	3
gibba var. *mesogongyla* (Ehrenberg) Hustedt	5	3	3
biceps Gregory	4	4	3
legumen (Ehrenberg) Ehrenberg	5	3	3
maior (Kützing) Rabenhorst	5	4	3
microstauron (Ehrenberg) Cleve	4	4	3
nodosa (Ehrenberg) W. Smith	4	3	3
quadratarea (A. Schmidt) Cleve	1	–	3
quadratarea var. *constricta* (Østrup) Heiden	1	–	3
subrostrata (A. Cleve) Cleve-Euler	5	4	3
viridis (Nitzsch) Ehrenberg	4	3	3
sp.1			
sp.2			
PLAGIOGRAMMA Greville			
staurophorum (Gregory) Heiberg	1	–	3
RHABDONEMA Kützing			
arcuatum (Agardh) Kützing	1	–	3
minutum Kützing	1	–	3
RHAPHONEIS Ehrenberg			
cf. *nitida* (Gregory) Grunow	–	–	–
RHOICOSPHENIA Grunow			
abbreviata (Agardh) Lange-Bertalot	3	2	3
RHOPALODIA O. Müller			
gibba (Ehrenberg) O. Müller	4	1	3
gibberula (Ehrenberg) O. Müller	4,3	–	3
musculus (Kützing) O. Müller	2	–	3
parallela (Grunow) O. Müller	2	1	3
SCOLIOPLEURA Grunow			
tumida (Brébisson) Rabenhorst	2	–	3
STAURONEIS Ehrenberg			
acuta W. Smith	4	2	3
anceps Ehrenberg	4	3	3
anceps f. *gracilis* Rabenhorst	4	3	3
anceps var. *siberica* Grunow	4	3	3
barrowiana Patrick & Freese	4	3	–
pachycephala var. *alaskana* Foged	4	–	–
phoenicenteron (Nitzsch) Ehrenberg	4	3	3
smithii Grunow	4	2	3
wislouchii Poretzky & Anisimova	–	–	–
STEPHANODISCUS Ehrenberg			
rotula (Kützing) Hendey	4	2	1
medius Håkansson	4	2	1
minutulus (Kützing) Cleve & Möller	4	2	1
STRIATELLA Agardh			
delicatula (Kützing) Grunow	1	–	2
SURIRELLA Turpin			
amphioxys W. Smith	3	3	–
elegans Ehrenberg	4	2	2
linearis W. Smith	4	3	3
linearis var. *constricta* Grunow	4	3	3
ovalis Brébisson	2	2	2
SYNEDRA Ehrenberg			
parasitica (W. Smith) Hustedt	4	2	3
ulna (Nitzsch) Ehrenberg	4	2	2
TABELLARIA Ehrenberg			
fenestrata (Lyngbye) Kützing	4	4	2
flocculosa (Roth) Kützing	5	4	2
quadriseptata Knudson	5	4	–
TETRACYCLUS Ralfs			
emarginatus (Ehrenberg) W. Smith	4	4	–
THALASSIOSIRA Cleve			
cf. *decipiens* (Grunow) Jørgensen	1	–	1
lacustris var. *hyperborea* Grunow	2	2	1
sp.1			
TRACHYNEIS Cleve			
aspera (Ehrenberg) Cleve	1	–	2
TRIGONIUM Cleve			
arcticum f. *balaena* (Brightwell) Cleve	1	–	3