LATE-GLACIAL, FINE-RESOLUTION POLLEN AND SEDIMENT ANALYSES OF LITTLE DYKE LAKE SEDIMENTS, CENTRAL NOVA SCOTIA

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ABSTRACT

A detailed analyses of Little Dyke Lake basal sediments revealed two environmental disturbances occurred during the late-glacial. These disturbances were correlated to the previously reported Killarney and Younger Dryas climatic oscillations of the Maritimes. The late-glacial pollen record at Little Dyke Lake generally resembles that from other forested late-glacial sites of the region, but it also includes evidence of early successional phases, similar to unforested sites of the Scotian peninsula. Organic accumulation commenced at about 11 500 yrs BP. Macrofossil and pollen evidence indicate that a forest-tundra including abundant juniper and spruce krummholz had developed 300-600 years after deglaciation. With the onset of the Killarney cooling, the forest-tundra would have persisted and shrub birch would have become more important. Changes in the vegetation composition were followed by an increased inwash of coarser, siltier sediment. With climate amelioration, a spruce woodland grew during the time when paleo-Indians occupied the nearby Debert site. The deposition of clayey and organic rich sediments are associated with the growth of a spruce woodland. Comparing the pollen and sediment record suggests that the spruce woodland would have persisted for some time during the Younger Dryas cooling and in turn, it would have dampened erosion intensity within the lake catchment. Plants found in the understory, especially herbs and grasses, and those most apt to grow under cooler, drier and disturbed conditions then became more important in the landscape. This shift in the vegetation cover is accompanied with the sudden replacement of dark clayey sediment by a reddish coarse silt. The reddish silt is characterized by a low abundance of *Pediastrum* cenobia and it is overlain by a thin sand unit in which pollen trends depict climate amelioration after the Younger Dryas. The termination of the Killarney cooling is likewise reflected by an increase abundance of coarse mineral sediment. However, high *Juniperus* pollen percentages accompany a shrub *Betula* maxima when maximum erosion of sands arrives to the lake basin. Changes in the character of the sediment appear to coincide with pollen changes resulting from climatic cooling.

RÉSUMÉ

Un profil pollinique (73 spectres) et un profil de texture (41 spectres), de la partie inférieure d'une carotte de sédiment du lac Little Dyke, Nouvelle-Écosse, ont été reconstitués. Cette étude voulait: a) produire un profil pollinique détaillé, b) comparer le signal pollinique au signal textural lors des perturbations climatiques abruptes du tardi-glaciaire, c) fournir aux archéologues une référence paléo-environnementale pour l'étude du site paléo-Indien Debert-Belmont, et enfin, d) fournir une date miminum pour la déglaciation au centre de la Nouvelle-Écosse.

L'analyse détaillée de cette séquence d'environ 1 mètre atteste de la présence de deux périodes froides lors du tardi-glaciaire. Celles-ci furent correlées avec les oscillations climatiques déjà connues dans les Maritimes du Canada: le Killarney et le Dryas Récent. En général, le profil pollinique du lac Little Dyke ressemble au profil classique du tardi-glaciaire des Maritimes. C'est-à-dire, le profil est alternativement marqué par l'abondance du *Picea* et du *Betula*. En ce qui a trait aux spectres dans la partie inférieure de la séquence, le profil établi ressemble aux profils appartenant aux sites situés plus au sud de la péninsule de la Nouvelle Écosse. L'accumulation organique a débuté vers 11 500 années BP. La découverte de macrofossiles et le pollen indique qu'une tundra-forestière comprenant de nombreux genévrier et des krummholz d'épinettes s'est developpée 300-600 années après la déglaciation. Bien que le bouleau nain devient important avec l'avènement du Killarney, la tundra-forestière n'est pas remplacée par une tundra-arbustive. La composition floristique de la végétation n'aurait pas grandement changée grâce à l'élasticité de la végétation existante et la variabilité topographique du site. Lorsque le bouleau nain domine la pluie pollinique, l'érosion du silt au bassin Little Dyke s'accroît. Avec l'amélioration climatique, une pessière ouverte se développe avant à peu près 10 700 années BP. Il est possible que les paléo-Indiens occupe le site lorsque la pessière ouverte poussent dans la région. On prétend que la pessière ouverte, zone contact entre la forêt plus fermée à l'ouest et la tundra arbustive à l'est, constitue un territoire d'exploitation idéal pour les paléo-Indiens. Lorsque le climat se refroidit de nouveau, les épinettes qui forment la pessière ne sont pas immédiatement affectées mais ont tout probablement continué à grandir. Conséquemment elles ont pour une certaine période de temps réduit le degré d'érosion au bassin Little Dyke. Les plantes les plus tolérantes aux conditions froides, sèches et perturbées du Dryas Récent arrivent à dominer le paysage. Ceci est refleté dans le diagramme pollinique par l'augmentation relative du pollen *Artemisia*, *Oxyria*, Caryophyllaceae, Poaceae, Ericaceae et Cyperaceae. Cet assemblage pollinique appartient à une unité de silt rougeâtre qui repose sous une mince unité de sable. A l'intérieur du sable le pollen reflète le réchauffement climatique qui met fin au Dryas Récent. Semblablement, la fin du Killarney est caractérisée par une érosion maximum au bassin. Par contre, le spectre pollinique à la fin du Killarney est dominé par le pollen de *Juniperus* et non par le pollen de *Betula* (<20µm), tel est le cas pour la fin du Dryas Récent. Il semble exister une relation entre le type de végétation et la texture du sédiment au lac Little Dyke mais cette relation demeurera ténue jusqu'à ce que des

études comparatives soient effectuées sur les sédiments d'autres sites tardi-glaciaires des Maritimes. On constate en effet qu'avec le refroidissement climatique, les changements dans la nature du sédiment coincident avec les changements polliniques au lac Little Dyke. Les études qui peuvent faire la différence entre les effets directs et indirects des changements climatiques sur l'hydrologie des sites boisés et des sites non-boisés, serviront à l'évaluation de la texture comme détecteur de changement climatique. De plus, le feu et la glacio-eustasie sont jugés comme deux facteurs importants à considérer dans l'évolution du paléo-paysage tardi-glaciaire des Maritimes, et donc, ils méritent plus d'attention pour mieux comprendre les séquences sédimentologiques et polliniques de cette région.

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INTRODUCTION

In this study, variations in the pollen and texture assemblages of Little Dyke Lake sediments were examined in order to better understand the environmental history of central Nova Scotia. Pollen, *Pediastrum*, texture and carbon analyses were conducted on the dated basal portion of cores raised from the deepest part of the lake.

The deglaciation history of the Maritimes includes numerous complex events, many of which have had a bearing on the late-glacial vegetation communities and peopling of the area. With respect to the deglaciation history of the area, a study of Little Dyke Lake sediments promised to yield a record of the late-glacial vegetation and consequently enlarge the network of sites in central Nova Scotia which possess a record during this time.

Previous efforts to find a record for this area had been prompted by the archaeological study of the Debert paleo-Indian site but these were unsuccessful. Recent archaeological findings near Debert, have in part instigated this study, but field work, observations, discussions and readings have supplied the fuel for the working hypotheses of this study. Pollen and sediment analyses were done on the basal sediments of Little Dyke Lake in order to understand how different proxies responded to abrupt climatic change. These analysis were done at a short vertical core intervals to determine if theses responses were rapid and synchronous? Are the pollen and sediment record associated? Although this was applied to only one site, it provides insight for the future research which focuses on identifying the influence climatic cooling events has had on the paleo-landscapes of the late-glacial.

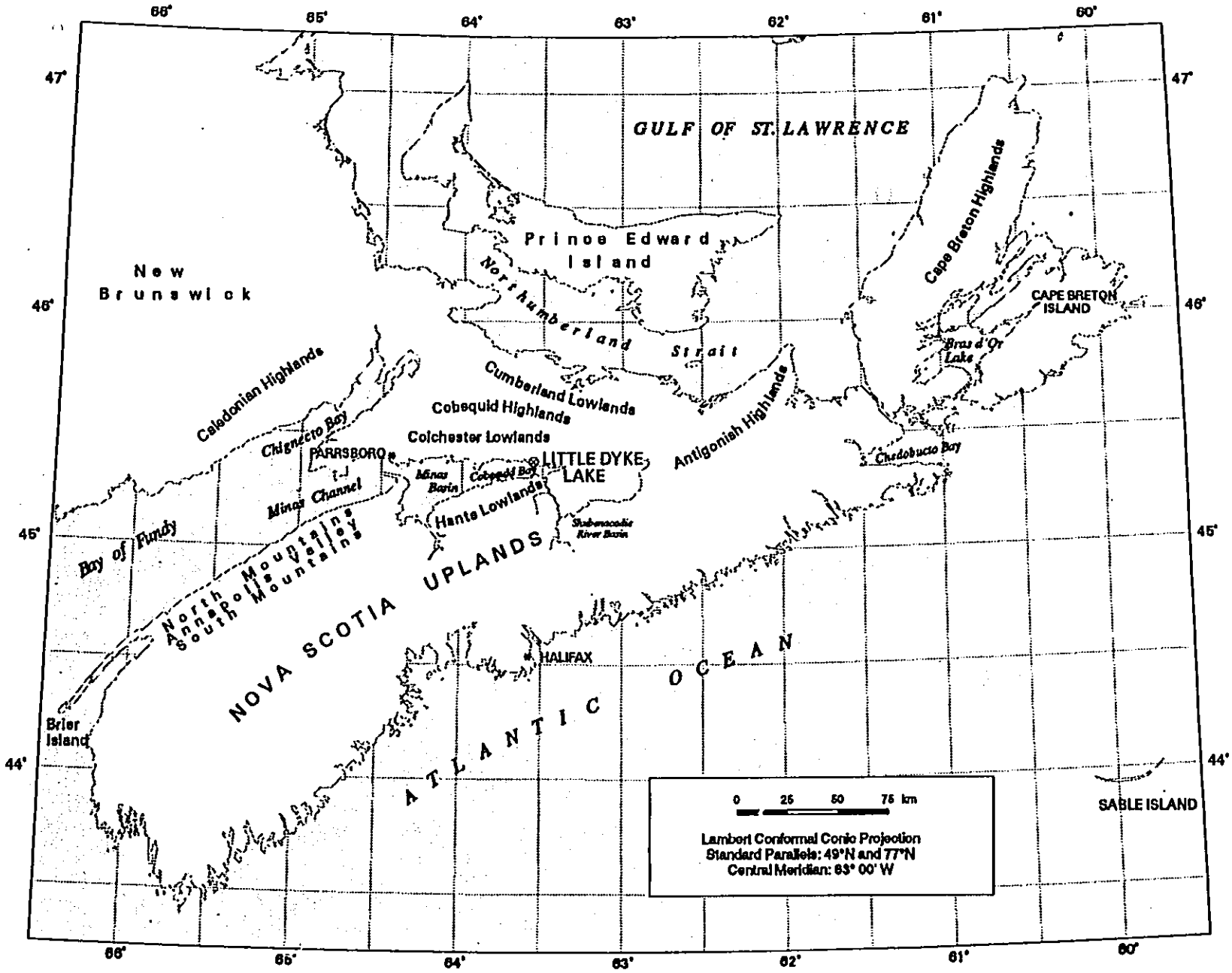

Figure A Physiography of Nova Scotia

CHAPTER 1 - LITERATURE REVIEW

In this section, the Younger Dryas is defined within the context of the European chrono- and bio-stratigraphy, because the literature itself demonstrates that this record had set the stage for the first palynological studies conducted in North America. This definition is followed with a glimpse of specific pollen and stratigraphic studies which played an important role in the recognition of the Younger Dryas in the Maritimes. The most popular arguments for and against a trans-Atlantic correlation are reviewed and then, hypothesis which help to explain the ever increasing distribution of the Younger Dryas are discussed. Through reading the first chapter, it becomes apparent that making sense of the "Younger Dryas" and all other climatic events necessitates more than knowing the regional setting but extends itself to a global perspective and more importantly, it requires an eye for the detection of temporal and spatial patterns at several scales.

1.1 Definition of the Younger Dryas

Various paleoclimatic records have indicated that North-west Europe experienced a period of cooling lasting approximately 1000 years at the end of the Lateglacial period. This short-term climatic oscillation is commonly known as the Younger Dryas. It followed the Bølling and the Allerød deglacial warming events (13 500/13 000 - 12 000 yrs. BP and 11 800 - 11 000 yrs. BP, respectively) in continental North-west Europe or the Windermere Interstadial in the British Isles (Coope 1977) (figure 1.1). In their proposed general climatostratigraphic scheme for NW Europe, Lowe and Gray (1979) defined the Younger Dryas stadial as:

> "The body of rock (sediment) strata formed between the thermal amelioration that took place between about 12,000 and 11,000 BP and the marked thermal improvement that took place between about 10,500 and 10,000 BP."

A study of varved lake sediments in Switzerland has revealed that the onset of the Younger Dryas cooling coincides with the deposition of the Laacher See Tephra (LST) at 11 000 yrs. BP while the Allerød/Younger Dryas biozone is constrained to a few centuries after the LST (Amman and Lotter 1989). Meanwhile, the abrupt termination (Dansgaard *et al.* 1989, Lemdahl 1991, Alley *et al.* 1993, Taylor *et al.* 1993) of the Younger Dryas at 10,000 yrs. BP marks the boundary between the Pleistocene and the Holocene (Mangerud *et al.* 1974, Mangerud *et al.* 1984, Mangerud 1987, Fairbridge 1983, 1992).

In general, pollen records of North-western Europe have recorded the Younger Dryas as a revertence from woodland vegetation to communities dominated by shrubs and herbs (Denmark: Krog 1954, Iversen 1954, France: Woillard 1979, Woillard and Mook 1982; Scotland: Birks and Mathewes

1978, British Isles: Watts 1979). These latter communities are often composed of colonizers that reappear from earlier deglacial time. For example, Iversen (1954) noted, after studying the Danish Late-glacial flora, that *Salix* sp., *Saxifraga oppositifolia*, *Oxyria digyna* and *Silene acaulis*, all appearing in the Older Dryas biozone (pollen assemblage zone I (PAZ I)), made "a come-back" during the Younger Dryas (PAZ III). A decrease in *Pinus* and *Betula* was accompanied by an increase in *Artemisia*. In addition to this vegetation reversal, Iversen (1954) noted that, with the exception of a few sites, the *Juniperus* curve reached its maximum during the Younger Dryas. A similar trend in the *Juniperus* curve is reported in Belgium and it appears to be related to latitude (see figure 5 in Vanhoorne and Verbruggen, 1969). With increasing latitude, the *Juniperus* curve does not attain a maximum but is instead interrupted due to the relatively colder conditions of the Younger Dryas.

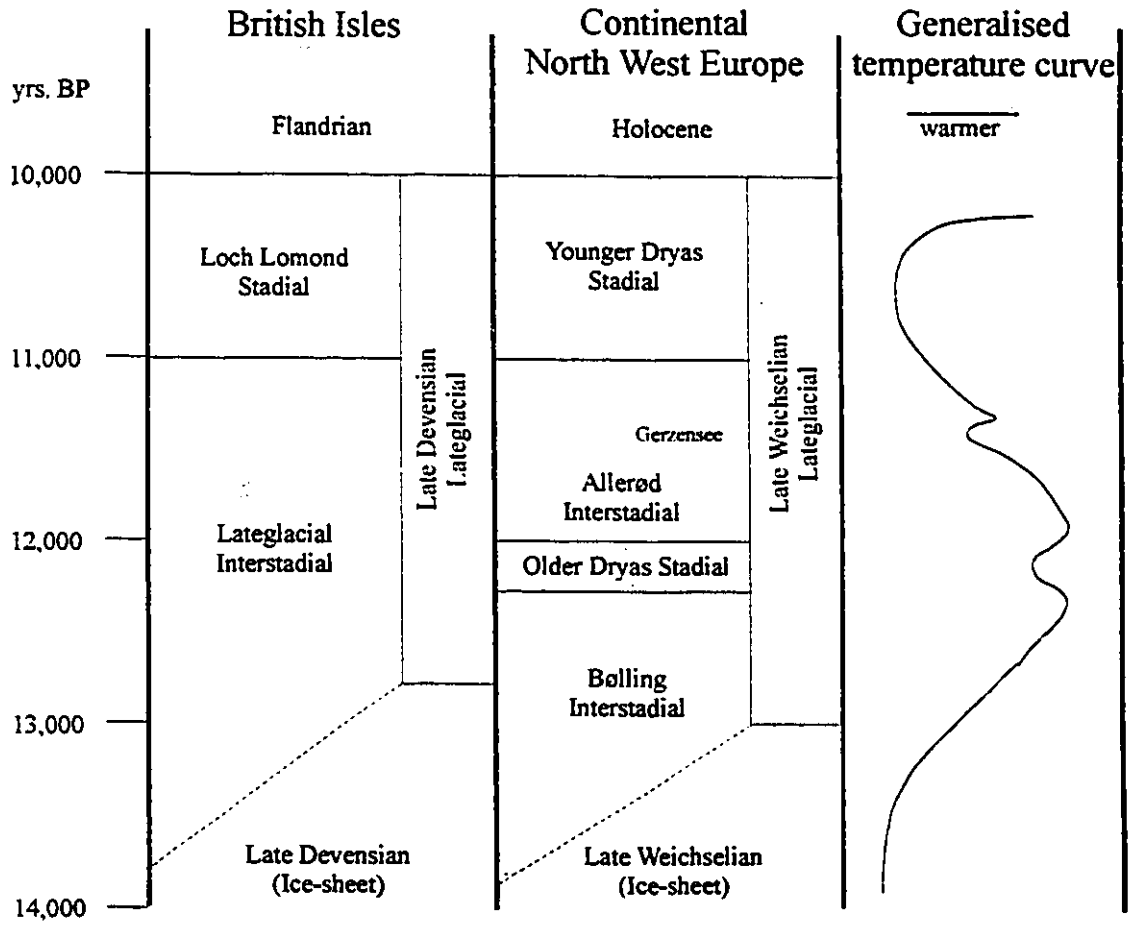

Figure 1.1 The chronostratigraphy of the Lateglacial in Britain and North West Europe (Lowe and Walker 1984, modified)

Biostratigraphically, the onset of the Younger Dryas is recognized by the increasing abundance of *Artemisia* in North-western Europe (Denmark: Iversen 1954; Belgium: Verbruggen 1979, Ireland: Watts 1977; Scotland: Walker 1975, Birks and Mathewes 1978; Switzerland: Amman and Lotter 1989). Amman and Lotter (1989) defined the beginning of the Younger Dryas biozone for the Swiss Plateau by increasing values of non-arboreal pollen (NAP) with *Artemisia* values reaching >2%. The vegetation which accompanied the increase in *Artemisia* comprised heliophilous herbs and shrubs (particularly *Juniperus*) (Lotter 1991). Conversely, the Younger Dryas/Preboreal biozone transition is defined by the decrease in the NAP with <2% *Artemisia* (Amman and Lotter 1989).

Regressive biotic changes that mark the Younger Dryas in North-west Europe are usually associated with increased inwash of minerogenic sediments into lakes and with periglacial processes (Birks 1986). Geomorphic and stratigraphic evidence of renewed glacial activity have served to indicate that the Younger Dryas cooling was of sufficient amplitude to initiate glacial advance/re-advance or hinder glacial retreat in high latitudes and altitudes. For example, the Loch Lomond advance in Scotland, thought to be equivalent to the Younger Dryas (Sisson 1979) has been defined by moraines, trim lines, melt water patterns and periglacial features (e.g.: ice wedge casts) (Lowe and Walker 1984). Probably the best-known evidence of Younger Dryas re-advance in northern Europe are the Fennoscandian moraines: Central Swedish Moraines (Sweden), Salpausselka Moraines (Finland) and Ra Moraine (Norway) (Aarseth and Mangerud 1974, Lowe and Walker 1984). The equilibrium line altitude of cirque glaciers in western Norway are reported to have descended at the time of the Younger Dryas (Mangerud 1987). Mangerud translated the equilibrium line depression to summer temperatures of 8-10°C lower than at present during the Younger Dryas. These paleotemperatures closely follow the mean annual temperatures estimated from fossil ice wedges. A 5-6°C temperature decrease of the summer temperature was estimated for the Allerød/Younger Dryas transition (Mangerud 1987). Quantitative estimates of Younger Dryas temperatures have been calculated from a variety of climate proxies from different areas of the world (table 4; Rind *et al.* 1986).

Sites from around the world hold evidence for a change in climate between about 11 000 and 10 000 yrs. BP: Greenland (Dansgaard *et al.* 1989), Canadian Arctic Islands (e.g. Koerner *et al.* 1988), Antarctica (Jouzel *et al.* 1987), Northeastern North America (Mott *et al.* 1986, Peteet *et al.* 1990a, 1990b, Mayle and Cwynar 1995), Northwest American Coast (Engstrom *et al.* 1990, Mathewes 1993, Patterson 1993, Peteet and Mann 1994), East central North America (Shane and Anderson 1993), South America (Markgraf 1988, 1991, 1993; Kuhry *et al.* 1993; Heusser and Streeter 1980, Ledru 1993, Heusser 1993), New Zealand (Denton and Hendy 1994), Switzerland (Ammann and Lotter 1989; Lotter 1990, 1991), Italy (Lowe 1992, Ponel and Lowe 1992), Germany (Walther 1990), France (Woillard *et al.* 1982, Pons *et al.* 1987, Laval *et al.* 1991), Poland (Rozanski *et al.* 1990), Russia (Delusin 1991), Great Basin USA (Haynes 1991, Benson *et al.* 1992), Haiti (Hodell *et al.* 1991). The strongest evidence for the Younger

Dryas climate change appears to be located in alpine and maritime environments around the world which in part explains why the Younger Dryas holds the contentious title of worldwide event (Global Younger Dryas? 1993).

1.2 Recognition of the Younger Dryas climatic oscillation in North America

In this section, an historical review on the discovery of a late-glacial oscillation in north-eastern North America will be presented. This review will include the identification of the "stratigraphic type sequence" that first served for correlating the late-glacial palynological events recorded in New England and in the Canadian Maritimes. It will explain why the concept of a late-glacial oscillation in North America was first questioned and later revived to eventually be recognized as the Younger Dryas.

1.2.1 Two Creeks Section

While studying abandoned shorelines in Wisconsin, Goldthwait (1907) discovered a buried forest bed at Two Creeks. Today, this "stratigraphic type section" is known as the Two Creeks Section and has been described as "one of the most famous localities in North American stratigraphy" (Flint 1971). Thwaites and Bertrand (1957) interpreted the Two Creeks Sequence all the while considering isostatic rebound, the dynamic of glaciers, the surrounding topography and the paleolake levels. The spruce forest, dated at 11 400 yrs. BP, explained Thwaites and Bertrand, was killed by the submerging glacial Lake Chicago. An ice re-advance of the Michigan lobe subsequently buried the varves deposited by Lake Chicago with a red clay till. This event was tentatively termed the "Valders" substage due to the lithostratigraphic similarity of the observed red clay deposit to the stratotype till of Valders, Wisconsin (Thwaites 1943).

1.2.2 Results from early pollen studies

Pollen sites recording a possible late-glacial climatic oscillation were discovered by Anderson (1954), Leopold (1955), Davis (1958) and Livingstone and Livingstone (1958). These authors reported, as Deevey (1951) had previously for northern Maine, an interruption in the general amelioration of climate after deglaciation in southern Michigan, southern Connecticut, central Massachusetts and northern Nova Scotia, respectively. In all of these instances, the authors associated the observed late-glacial oscillation with the Two Creeks Sequence and also suggested the Allerød oscillation of NW Europe as a possible analogue.

In north-eastern North America this late-glacial cooling caused the vegetation to revert to a park-tundra or tundra (Maine: Deevey 1951, Cape Breton Island: Livingstone and Livingstone 1958). To the south, there was an increase in spruce pollen at the same time (Michigan: Anderson 1954, Connecticut: Leopold 1955, 1958, Davis 1958). In the western Great Lakes region boreal forest gave way to an open spruce woodland with abundant *Artemisia* (West 1961; Wright *et al.* 1963). Palynologists explained the vegetation reversion as the result of climatic cooling and correlated their results with the glacial history of the region. The opening of the vegetation in more northern sites was easily explained by the direct effects of proximal ice (e.g. cooling and increased wind action) since the presence of late ice in the area at this time had been documented (Deevey, 1951; Livingstone and Livingstone, 1958; West, 1961). The spruce-dominated pollen assemblage associated with the Valders stadial in southern New England was however more difficult to explain.

Leopold (1955, 1958) speculated that the climatic deterioration, associated with ice re-advance, favoured the southward retreat of spruce in Connecticut. Davis (1958) attributed the change in the frequency of tree pollen for 3 lake sites in central Massachusetts to the Valders ice advance. The increase in abundance of spruce pollen (sub-zone A-4) would have resulted from cooler and more moist conditions from the previous cool-temperate, and perhaps dry climate that supported a mixed spruce and deciduous forest (sub-zone A-3). She wrote:

> The glacier border must have been far to the north; apparently the ice itself did not influence the climate of central Massachusetts. The landscape remained heavily forested; the climatic oscillation associated with the ice advance merely resulted in a change of percentage composition among the forest species. (Davis 1958, p.565)

Davis concluded from this interpretation that if a treeless corridor existed at the margin of retreating ice it was quickly colonized before the late-glacial cooling period.

1.2.3 Arguments against a late-glacial oscillation

When late Wisconsin ice lobe margin fluctuations were recognized not to be synchronous or equally influenced by regional climate (Wright 1971), correlations between pollen curves of north-eastern North America and ice margin fluctuations of the Great Lakes Region were also questioned. Pollen interpretations of north-eastern North America were also called into question with the age re-evaluation of the Two Creeks deposit (Broecker and Farrand 1963, Everson *et al.* 1976). Broecker and Farrand (1963) pointed out that a date only 450 years older would cause the Two Creeks deposit to correlate with the Bølling/Older Dryas transition (12 000 yrs. BP) rather than to the Allerød/Younger Dryas transition of Western Europe. Consequently, North American palynologists formulated alternate hypotheses to explain

the late-glacial climatic oscillation in north-eastern North America (Wright 1963, Davis and Deevey 1964, Davis 1965, 1967a and 1967b, Cushing 1967).

The most popular argument that challenged the existence of the late-glacial vegetation reversion was presented by Davis and Deevey (1964). By calculating the deposition rate of pollen grains (pollen/cm^2/year: also known as absolute pollen index (API) or pollen accumulation rate (PAR)) at Rogers Lake Connecticut, Davis and Deevey demonstrated that the pollen rain is not constant and therefore the relative maximum of one taxon does not indicate a maximum of producers (plants) in the vegetation community. Such calculations led Davis and Deevey to hypothesize that the increase in spruce pollen to the detriment of thermophilous taxa (in sub-zone A-4) was the product of dilution and not of cooling at Rogers Lake, in other words, a continuous increase in conifer pollen during a more or less stable contribution of thermophilous taxa to the pollen rain. These trends were interpreted (Davis and Deevey 1964, Davis 1965, p.393) as the arrival and the progressive increase in the number of both conifer and deciduous trees in the region (sub-zone A-4) of a suspected park-tundra (sub-zone A-3).

Davis (1967a) later compared ancient pollen accumulation rates with the modern pollen rain in regions of tundra, park-tundra, and forest. Correlation of pollen assemblage zones to present day pollen assemblages led Davis to present an alternative climatic interpretation to the tundra-forest interpretation fostered by the API results. Sub-zone A-4 was correlated to the boreal woodland of northern Québec. It would not have replaced a park tundra but possibly a prairie (sub-zone A-3). The favoured alternate prairie-forest transition hypothesis, Davis noted, offered direction to future research concerned with the confirmation of a late-glacial stade in North America. She reasoned that if the best modern analogue for the "spruce-hardwood zone" (sub-zone A-3 and lower), underlying the "spruce-fir / spruce-*Artemisia* zones" (sub-zone A-4) was to be found in southern Manitoba; an increase in the number of trees as indicated by the API for sub-zone A-4, reflected: 1) cooler climate and glacial advance or; 2) increase precipitation or; 3) decreased continentality. Davis concluded (1967a) that the "climate appears to have been cold and relatively continental, without a clearly recorded temperature oscillation correlative with the Allerød of northern Europe" (Davis 1967a, p.12). In addition to Davis's finding, the few and scattered sites recording a late-glacial climatic oscillation discredited the large scale climatic significance of the cool event (Livingstone and Estes 1967, Mercer 1969, Wright 1971, McDonald 1971). Livingstone (1967) wrote:

> I cannot help noticing that twenty-five years of looking for a correlative of the Allerød sequence in temperate North America have produced several false alarms but nothing that has stood the test of time. (Livingstone 1967 p.47)

1.2.4 The Younger Dryas cooling in the Canadian Maritimes

Mott (1975a, 1975b) reported the postglacial vegetation evolution of 6 sites in southwestern New Brunswick. Mott (1975a) noted the possibility of a late-glacial climatic deterioration but did not correlate it with the Younger Dryas. The pollen signature of this oscillation was a sudden decrease in the number of *Picea* pollen accompanied by an increase in the number of *Betula*, *Populus* and herb pollen. A late-glacial climatic oscillation correlative with the Allerød/Younger Dryas was reported in the Maritimes by Mott *et al.* (1984, 1985) and in Newfoundland by Anderson (1983) and Anderson and MacPherson (1984). However, a distinct climatic reversal from 11 000 to 10 000 yrs. BP remained uncertain. Most accounts of the spread of vegetation in north-eastern North America after deglaciation reported only a continuous change between 14 000 to 9 000 yrs. BP (Anderson 1984, Davis and Jacobson 1985).

Continued work in the Maritimes produced abundant evidence of a short and abrupt climatic deterioration during the late-glacial (Mott 1985). Mott presented 2 types of deposits which held evidence of a late-glacial oscillation: 1) sites with an organic unit overlain by minerogenic sediments (buried organic sites) and 2) lake sites. He explained the minerogenic sediments at 8 buried organic sites and 6 lake sites as the result of slope reactivation processes and solifluction during the climatic deterioration. Differences in the vegetation cover stemmed for the most part from a latitudinal gradient. The shrub tundra to the north-east had been quickly dominated by herbs while the arboreal community to the south-west had regressed to a shrub-tundra. *Picea* played a more important role earlier in SW New Brunswick and central Nova Scotia than in other parts of the Scotian peninsula and northern New Brunswick (Mott 1985). Mott suggested that the southern shift of the polar front (Ruddiman and McIntyre 1973) would have affected the vegetation of north-eastern North America as in Western Europe during the late-glacial. This link between the late-glacial history of Atlantic Canada to that of Europe was again proposed by Mott *et al.* (1986a) based on twenty sites: 14 buried organic sites and 6 lake sites. The large number of sites suggested regional and not local fluctuations of the vegetation.

A variety of analyses, based on the larvae of midges (chironomid) (Walker *et al.* 1991b, Wilson *et al.* 1993), plant and animal macrofossils (Mott *et al.* 1986b, Miller in Stea and Mott 1990), diatoms (Wilson *et al.* 1993, Rawlence 1992, Wolfe and Butler 1993), stratigraphy (e.g. Stea and Mott 1989) and loss-on-ignition (Mayle *et al.* 1993a, Levesque *et al.* 1993a) have better defined the Younger Dryas in the Canadian Maritimes. Similar analysis have also shown a pre-Younger Dryas oscillation of lesser magnitude occurred in north-eastern North America. Levesque *et al.* (1992, 1993a, 1993b, 1994) conducted high resolution loss-on-ignition, pollen and midge analyses on 6 lake sites which consistently showed a pre-Younger Dryas cooling. Levesque (1992, Levesque *et al.* 1993b) termed the pre-Younger Dryas oscillation the Killarney Oscillation and correlated it to the Gerzensee Oscillation of Europe, an intra-Allerød cold period reported to have occurred between about 11 500 and 11 300 yrs. BP (Eicher *et al.* 1981, Riezebos and Slotboom 1984).

The chronology of the Killarney Oscillation was defined, like the Younger Dryas of the Maritimes, with loss-on-ignition results (Levesque *et al.* 1993a) and AMS ^{14}C dates (Mayle *et al.* 1993a). The Killarney Os· 'ation was calculated to have lasted ~250 years, between 11 160 yrs. BP and 10 910 yrs. BP (Levesque *et al.* 1993a) while the Younger Dryas cooling was dated between 10 930 - 10 640 yrs. BP and 9 930 - 10 120 yrs. BP (Mayle *et al.* 1993a). A lake surface-water temperature curve derived from midge fossils using transfer functions show a decline of about 1 degree Celsius at the time of the Killarney event at Splan Pond (Basswood Road Lake) (Walker *et al.* 1991b). The lake surface-water temperature decrease, coinciding with the classical Younger Dryas period, was estimated to be about –6.5°C for Splan Pond and Killarney Lake (Walker *et al.* 1991b, Wilson *et al.* 1993)

A peak in *Alnus* spp. is proposed as an indicator of the Younger Dryas in eastern North America (Mayle *et al.* 1993b). Based on limited evidence, Mayle and his colleagues suspect *Alnus crispa* to be characteristic of Atlantic Canada and highland areas of New England and *Alnus rugosa*-type to possibly be characteristic of southern New England lowlands during this period. They propose that the *Alnus* pollen in Atlantic Canada represents either the expansion of the shrub population or that the pollen is extra-regional. The predominance of *Alnus rugosa*-type pollen in New England sites is attributed to the sites location in lowland areas. The source of *A. crispa* is suspected to be from Maine (Mayle *et al.* 1995).

Apart from pollen evidence, stratigraphical studies show evidence of late ice during about the time of the Younger Dryas. Stratigraphical studies indicate that late local ice may have persisted in Nova Scotia until about 10 500 yrs. BP or later (Grant 1977, 1989, Stea 1984, Stea *et al.* 1986, Stea 1988) and could have delayed sedimentation in several localities of the Maritimes. Stea *et al.* (1990, 1992) have presented a brief history of research on the glaciation of Nova Scotia. These authors note that the provenance, timing and extent of late ice in the Maritimes have been a topic of discussion since the turn of the century. At first, the concept of continental-based ice mass (Goldthwait 1924) had gained acceptance over the concept of local ice caps (Bailey 1898, Chalmers 1895). However, both these concepts were later unified to form the maximum and the minimum models of glaciation (Grant 1977, 1989). Both models generally purport that local glaciations was preceded by a continental glaciation. The major difference between the models would be the timing and extent of local ice re-expansion. The maximum model places late ice dispersal centers on the Scotian shelf and Newfoundland while the minimum model comprises of shifting ice dispersal centers on upland and broad lowland areas of Nova Scotia during the Late Wisconsin. Geochemical analysis, stratigraphic studies of till sequences and mapping have aided in determining a sequence of separate glacial advances which would support the minimum model of glaciation. Four major ice flow phases are identified to have affected the Scotian landscape (Stea 1984). The three first phases have been evaluated to be of Late Wisconsin age (Wang *et al.* 1986, Stea 1987).

The earliest and most extensive ice flow recorded in Nova Scotia possibly represents ice with a Laurentide or Appalachian source (Stea *et al.* 1992b). Glacial features indicate that the ice flowed eastward during Phase 1a, then south-eastward during Phase 1b (Stea *et al.* 1992b). Till associated with this eastward and south-eastward flow of ice are the Richmond Till(Cape Breton Island: Grant 1989), the McCarron Brook Till (Joggins: Stea *et al.* 1986), the Hartlen Till (near Halifax: Stea *et al.* 1986), the East Milford Till (central mainland) and the Red Head Till (southern Nova Scotia: Grant 1980).

Ice flow Phase 2 is characterized by a southward and south-westward ice flow from the "Escuminac Ice Centre". Young lake dates from Prince Edward Island (Mott personal communication 1992) and the radial pattern of ice flow features across the Island and New Brunswick (Grant 1989), together suggest that the Escuminac Ice Centre divide was located over Prince Edward Island or the Magdalen Shelf. Ice flow phase 2 would have extended to the Atlantic shelf edge of Nova Scotia (Stea 1987). An age range of 14 300 - 12 600 yrs. BP produced by shells uncovered from the bottomset beds of a glacio-marine delta at Spencers Island (Stea and Wightman 1987) was reported to be representative of the Escuminac Ice Centre retreat (Stea 1988). Tills formed during this phase are the Joggins and Eatonville Till (Cumberland Lowlands: Stea *et al.* 1986) and the Lawrencetown Till (Halifax area: Grant 1975).

The development of an ice divide in southern Nova Scotia (termed the Scotian Ice Divide) has helped explain the northward-trending striations found throughout the northern mainland of Nova Scotia and other northward dispersed glacial deposits. Granitic boulders found on the North Mountain cuesta and erratics found on the Carboniferous lowlands have been identified as belonging respectively to the Cobequid Highlands (Stea and Finck 1984) and the South Mountain Batholith (Hickox 1962). Northward flow has also been recorded over Cape Breton Island (Grant 1977, Stea and Finck 1984) and likely represents the northern offshore extension of the Scotian Ice Divide (Stea *et al.* 1992b).

Since glacial flow features of this ice flow phase event are limited to the eastern part of the Cobequids, it was assumed that the ice overrode Cobequid Bay and the head of the Minas Basin but did not do so at the mouth of the Minas Basin (Stea 1986). Ice calving at the mouth of the Minas Basin occurred due to the marine incursion at this time (Stea *et al.* 1986, Stea 1987). Based on pedological and stratigraphic studies, the Cobequids are believed not to have accommodated a late independent ice cap during this phase. It is possible that the eastern Cobequid Highlands received ice from the Carboniferous lowlands (Stea 1988, Stea and Mott 1989). The Hants Till (Atlantic Uplands: Stea 1982b) and the Beaver River Till (Yarmouth area: Grant 1980) were classified as Phase 3 till (Stea et al. 1992a). However, Grant (1989) related the Hants Till with the S and SE ice flow ascribed to Phase 2 and had qualified the Beaver River Till as one of the "young tills" of which Stea and Finck (1984) associate to Phase 4.

Stea (1988) proposed a west to east deglaciation of the Minas Lowlands to have occurred after the retreat of continental ice. A late, southwestward flowing ice lobe would have emanated from the Antigonish Highlands and possibly straddled the southern coast of the Cobequid Bay. This ice lobe characterizes the last of four major Late Wisconsin ice flow phases defined by geochemical and stratigraphical studies of till sequences (Stea 1984, Wang *et al.* 1986). Correlative tills associated to this ice flow phase (ice flow phase 4) are found in the Antigonish Highlands (Stea 1988), the eastern and western Cobequids (Stea and Finck 1984, Stea *et al.* 1986), and the Hants Lowlands (Stea and Finck 1984).

A final and younger stage of glaciation which included an ice/snow center over the Cobequids is possibly a remnant of the second stage of ice flow phase 4 (see figure 4: Stea *et al.* 1992b). However, the extent of ice advance or formation into the Colchester and Northumberland Lowlands remains however uncertain. Much of this uncertainty stems from the use of negative evidence to postulate the presence of late, local ice. The basal age for most sites in this region range between 11 000-10 000 yrs. BP suggesting that ice could have delayed organic sediment accumulation in the area (Stea and Mott 1989, Stea *et al.* 1992, Stea in press).

1.2.5 Evidence of the Younger Dryas from sites elsewhere in North America

Pollen evidence from southern New England has been re-evaluated by Peteet *et al.* (1990a). They interpret the spruce increase in pollen zone A-4 not to be an artifact of the percentage calculation but as a boreal forest expansion during the Younger Dryas time. Peteet *et al.* offered two arguments in support of this interpretation. First they noted that the pollen influx diagrams for several New England sites showed an increase in boreal taxa independent of the decrease in hardwoods. Second, they noted that the shift in the vegetation between 11 000 and 10 000 yrs. BP occurs over too large a latitudinal distance to be the product of a local phenomenon. Recently, Cwynar and Levesque (1995) have presented midge fossil evidence to support the hypothesis of late-glacial climatic cooling in Maine.

The North Pacific coast and east-central North America are two other regions that provide evidence of a climatic reversal correlative with the Younger Dryas chronozone. Some sites of the North Pacific show that a decrease in *Alnus* spp. curves occurs at the time of the Younger Dryas (Engstrom *et al.* 1990, Mathewes 1993). Meanwhile, a peak in mountain hemlock (*Tsuga mertensiana*) indicates cool and humid conditions prevailed during the time of the Younger Dryas on the British Columbia coast.

In east-central North America, Shane and Anderson (1993) have used pollen-climate transfer functions and response surfaces to quantify late-glacial climatic change observed earlier (Shane 1987, 1989). Despite the difficulty in finding modern day vegetation analogues, climatic trends for 12 sites show a vegetation reversal which is temporally equivalent to the European Younger Dryas. Shane and

Anderson note that, cooler conditions corresponding to the Younger Dryas are indicated by a recurrence in *Picea*, especially in the Till Plains. They have mapped the intensity gradient in the *Picea* recurrence (<or>50% *Picea* pollen) at 55 sites and have noted that the intensity of the Younger Dryas decreases to the SW. However, Shane and Anderson concluded, in view of the deglacial history of the Great Lakes Region, that the reversion in east-central North America may be the result of a regional meltwater event (Lake Agassiz) or the product of a global event which is possibly linked to the same regional meltwater event.

1.3 Hypotheses for the origin of the Younger Dryas

The network of sites which hold a clear signal of the Younger Dryas continually prompts researchers to formulate or modify hypotheses for the origin of the Younger Dryas. At first most sites appeared to be concentrated in and around the northern North Atlantic Ocean, especially the north-eastern North Atlantic, pointing to this region as the cause of the climatic cooling. Therefore, much research has focused on the role of the Atlantic Ocean in climatic forcing. Albeit the ever increasing evidence for a worldwide Younger Dryas, oceanic models still serve to explain this event. For all of the oceanic models, the spread of melt-products (melt-water and ice) into the Atlantic Ocean is important. In the following pages, some of the most popular oceanic models such as the thermohaline circulation model and CO_2 model, are discussed.

1.3.1 Earlier oceanic models

After exposing the sparse evidence for a worldwide Allerød oscillation, Mercer (1969) postulated that changes in the oceanic conditions could explain the "European Climatic Anomaly" (Allerød oscillation). He proposed that the Younger Dryas resulted from the cooling effect of the disintegration and melting of arctic ice shelves of the Barents Sea due to deglacial warming. Manley (1971) invoked an increase in zonal flow which would have ensured the meridional spread of cool, fresh "Arctic" waters as previously proposed by Mercer (1969).

Ruddiman and McIntyre (1973) briefly addressed the cause of a rapid south-eastward re-advance of the polar front when they studied deglacial warming of the North Atlantic Ocean. Analysis of deep-ocean sediment cores implied a re-advancement of the polar front to near its former glacial maximum position (50°N) during Younger Dryas time. They observed an abrupt up-core replacement of a diversified sub-polar fauna by a monospecific polar fauna (*Globigerina pachyderma* (sinistral)). This abrupt change in the faunal assemblage occurred just before a silicic shard layer, dated at 10 220 yrs BP (core V23-82) (Ruddiman and McIntyre 1973; p.119) and later re-evaluated at 9 800 yrs. BP (Duplessy *et*

al. 1981, Ruddiman and McIntyre 1981b, p.164). Mangerud *et al.* (1984) later recognized that this silicic shard layer was in part composed of the 10 600 year old Vedde ash. Ruddiman and McIntyre (1973) interpreted the polar faunal front re-advance as the direct result of a short-term atmospheric cooling. They also considered the influx of glacial melt-water from either "abrupt atmospheric warming or the sudden diversion of melt-water lake drainage" as plausible causes of the short-term North Atlantic polar water re-advance. Johnson and McClure (1976) identified an increase in continental melt-water influx into the Atlantic Ocean as a possible cause of polar water re-advance. They envisioned an eastward diversion of the discharge of proglacial lakes located to the south of the Laurentide Ice Sheet (LIS) from the Mississippi River toward the St. Lawrence River.

Later, Ruddiman and McIntyre (1981a) discounted the melt-water diversion hypothesis because oceanic productivity, primarily monitored by "variations in absolute foraminifera abundance", failed to indicate the expected decrease associated with continental melt-water inflow in the western Atlantic Ocean. Continental melt-water inflow would have increased surface water stratification by creating a thick surficial, low-salinity layer in the Atlantic Ocean. The density stratification would then have inhibited the nutrient upwelling needed to sustain planktonic life and would have also promoted the formation of sea-ice cover. Ruddiman and McIntyre observed, from a series of North Atlantic Ocean cores, a decrease in oceanic productivity in only two cores located to the S and SE of the subpolar North Atlantic Ocean. Although limited, this evidence supported Mercer's hypothesis on the outflow of large arctic ice-shelves (Mercer 1981).

1.3.2 The thermohaline conveyor belt model

The diversion hypothesis later served Broecker *et al.* (1985) for the development of one of the most significant models to explain regional changes in climate such as the Younger Dryas, the thermohaline conveyor belt model. They hypothesized that the eastward diversion of the Laurentide ice sheet melt-water would have occasioned changes in climate due to the resulting disruption of the deep-water production process of the North Atlantic Ocean. A simple outline of the thermohaline model is as follows. With increasing summer insolation, the excess heat released in high-latitudes would contribute to the increased continental melt-water discharge around the Atlantic. The increased freshwater flux would then disrupt the density stratification of the North Atlantic. Since the concentrations of salt in the northern North Atlantic govern the deep-water production process, a cessation or decrease in the North Atlantic deep water (NADW) production could result from the huge melt-water influx. Moreover, since the NADW production process contributes 5×10^{21} calories of heat per year into the atmosphere over the North Atlantic, its reduction would have cooled the maritime region of north-western Europe. In their study, Broecker *et al.* (1985) speculated that a turning "on" and "off", or a change in the rate of deep-

water production would correspond to different climatic modes of operation of the ocean-atmosphere system. A "weak" mode of operation would correspond to glacial times when salt enrichment of the northern North Atlantic Ocean and the heat flux to high-latitude atmosphere would be less. Conversely, a "strong" mode of operation of the deep-water production would correspond to interglacial times when salt enrichment and heat flux toward northern latitudes would be greater.

Fairbanks (1989) challenged the thermohaline conveyer belt model when he presented evidence demonstrating that the melt-water discharge into Gulf of Mexico by way of the Mississippi would have substantially decreased and not increased at the time of the Younger Dryas. This decrease would not necessarily be due to the eastern melt-water diversion. Fairbanks had derived a sea level curve from a ^{14}C dated *Acropora palmata* reef on the south coast of Barbados. From this curve, Fairbanks characterized early Younger Dryas cool event as a time of "minimal in melt-water-discharge, particularly between 11 000 - 10 500 yrs. BP, and is distinguished as an event primarily by its temporal position between two episodes of lower surface salinity" associated with melt-water pulses (mwp-1A at 12 000 and mwp-1B 10 390 - 9 360 yrs. BP). The last half of the Younger Dryas was associated with the youngest melt-water pulse IB (mwp-IB) (10 390 - 9 360 yrs BP, centered at 9 500 yrs BP and calibrated at 10 445 yrs BP) (Fairbanks 1989).

Broecker *et al.* (1990) later modified the thermohaline circulation model. The "on" and "off" states of thermohaline conveyer belt, they explained, would be driven primarily by natural salt oscillations and not the release of excess heat in high latitudes. When a maximum differential in salinity is reached throughout the world oceans, with a maximum salinity in the Atlantic, the conveyor belt is turned "on" until an equilibrium in the oceans salinity budget is again achieved. An equilibrium is achieved with an increase in the transport of heat and salt toward the northern latitudes accompanied by an increase in the export of salt to the rest of the oceans. This natural salt-oscillator hypothesis could account for oscillations recurring about every 2 000 years between 20 000 and 60 000 years ago and not only the Younger Dryas event (Jones 1991). However, this hypothesis still requires the input of continental melt-water into the Atlantic for the decrease in salinity of the ocean surficial water layer.

1.3.3 The CO_2 model

The CO_2 model found supporting evidence in Fairbank's (1989) findings. Proponents of the CO_2 model (e.g.: Broecker and Takahashi 1984, Jansen and Erlenkeuser 1985, Jansen and Veum 1990) argued that with a decrease of melt-water into the oceans during Younger Dryas, the NADW production increased. Deglacial melt-waters in northern latitudes would have reduced the temperature and salinity of surficial waters and in turn the vertical exchange of the ocean (Kudrass *et al.* 1991). Exchange of CO_2 between the ocean and atmosphere would consequently have been reduced, thus leaving the atmosphere

with CO_2 levels lower and comparable to glacial times. The expansion of vegetation onto the ice-free areas is viewed as contributing further to lower atmospheric CO_2 levels. Then, when the melt-water input was reduced, during early Younger Dryas time, deep-water production would have intensified along with a rise in oceanic productivity. The enhanced decrease in atmospheric CO_2 due to this oceanic productivity would have caused Younger Dryas cooling.

1.3.4 Recent research

Although hypotheses that have considered the ocean as an integral and/or primary component of the earth's climatic system have gained ascendancy, they are currently being tested and modified in view of our knowledge of the sensitivity of the oceanic and terrestrial records of climatic change. For example, paleoenvironmental proxies in ice cores from Greenland have indicated that significant temperature changes (7°C) have occurred in less than a decade at about 11 000 yrs. BP (e.g. electrical conductivity for dust content (Taylor *et al.* 1993) and ice thickness (Alley *et al.* 1993)). Relating orbital parameters (insolation, seasonality) to nonlinear response (e.g.: meltwater pulses (Hughes 1992, Fairbanks 1993)) and other climate forcing factors (e.g.: bedrock geology (Rind 1994, Denton 1994)) may eventually show if the Younger Dryas is a by-product of continuous warming or not.

CHAPTER 2 PURPOSE OF THE STUDY

2.1 A fine-resolution pollen record

Abundant pollen studies in the Maritimes and Newfoundland confirmed the Younger Dryas in north-eastern North America (Mott *et al.* 1986a). Many of these pollen profiles are of a coarse resolution and very few spectra span the inferred cool period that caused a vegetation reversion between approximately about 10 800 and 10 000 yrs. BP. In order to better refine age estimates for the Younger Dryas event, fine-resolution pollen analyses were recently conducted on sites in the Maritimes (Levesque 1992, Mayle *et al.* 1993a). Fine-resolution pollen analysis performed on LDL basal sediments will aid in outlining the effects of late-glacial climatic cool events on the regional and local vegetation of central Nova Scotia.

2.2 Sediment analyses compared to pollen analysis

Reddish minerogenic lake sediments are commonly associated with the pollen-inferred cooler climates of the late-glacial in the Maritimes (i.e. Younger Dryas: Mott *et al.* 1986a; Killarney: Levesque *et al.* 1993a). The presence of these mineral lake units is associated with thinning vegetation cover, increased erosion, frozen-ground phenomenon (e.g. solifluction and mass wasting), lake productivity and climatological factors (Mott *et al.* 1986a; Levesque *et al.* 1992), however, no studies have focused on the origin of these mineral lake units.

The coloration of the coarse reddish mineral sediment which make up distinct layers of the late-glacial lake stratigraphy of the Maritimes is attributed to the possible reworking of local red tills as a result of cooling (personal communication: Mott and Stea 1991). Ferruginous sediments most likely would have developed in an ærobic environment of the lake catchment. The coarser grain size layer suggests that the mechanism of deposition changed or that the force of the transporting agent had increased or changes in the supply source occured. Consequently, the possibility that reworked pollen was introduced into the lake basin would increase and in turn, possibly bias the pollen record. Therefore, the importance in distinguishing the origin of the sediments becomes invaluable to the interpretation of late-glacial Maritimes pollen sequences.

In this study, texture data, which is presumed to be correlated with erosion intensity, is combined with pollen data to aid in distinguishing pollen supply. Results from texture analysis in turn expose trends

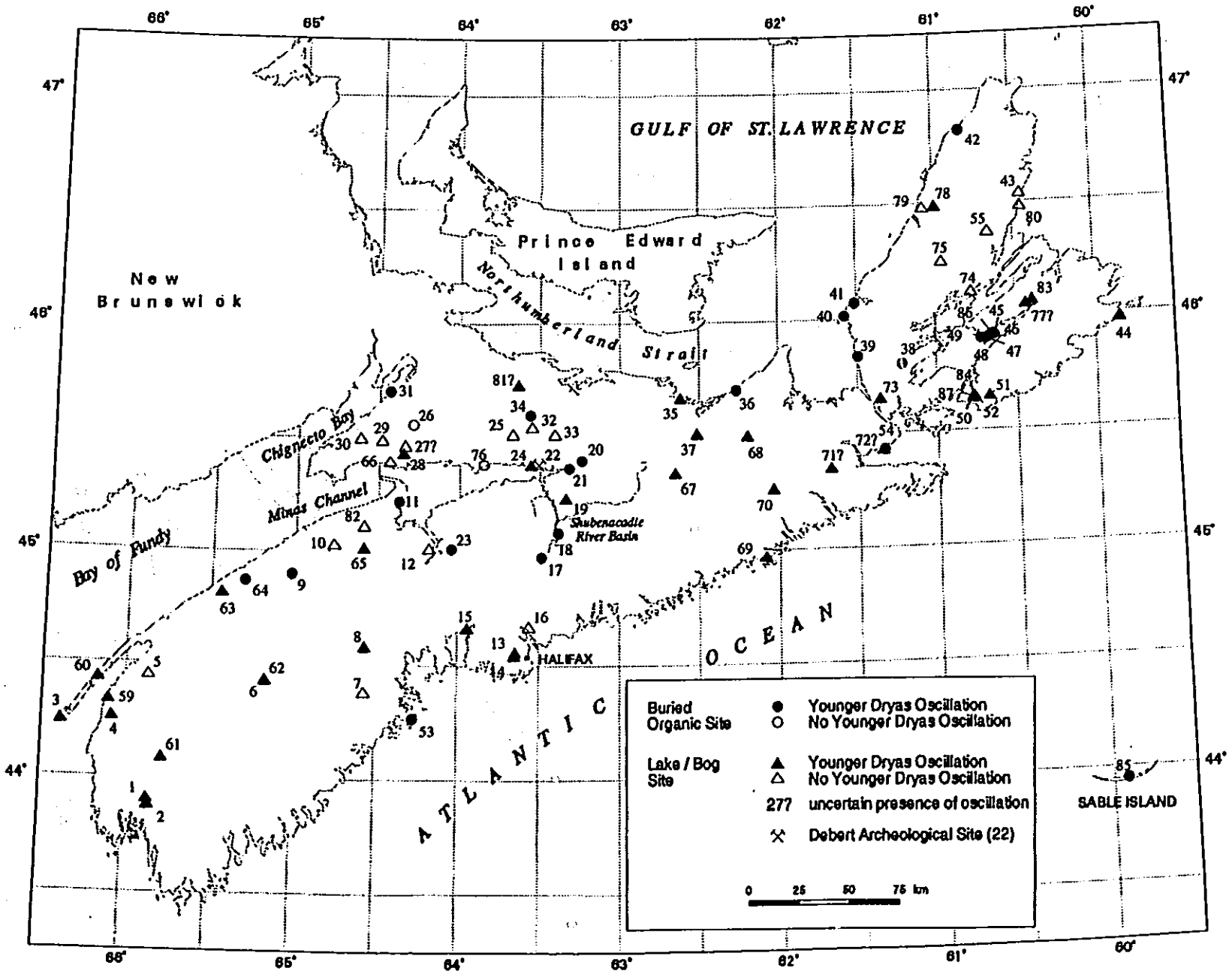

Figure 2.2 Studied sites in Nova Scotia - presence or absence of evidence for theYounger Dryas Oscillation.

Table 2.1 List of studied sites in Nova Scotia - presence or absence of evidence for the Younger Dryas Oscillation.

classification of the sites (*)

1 = buried organic site, oscillation absent
2 = buried organic site, oscillation present
3 = lake site, oscillation absent
4 = lake site, oscillation present

P = pollen evidence (and lithological evidence)
S = "exceptional" mineral unit
? = uncertain presence of oscillation

#	coordinates		*	site name	references
1	-65.8569	43.9083	4P	Thin-ice Pond	Levesque *et al.*, 1992
2	-65.8500	43.8833	4P	Curry Pond	Green, 1986; Levesque unpublished
3	-66.3838	44.2458	4P	Brier Island Bog	Wilson *et al.*, 1993
4	-66.0792	44.2639	4P	Lac à Magie	Levesque *et al.*, 1992; Mayle *et al.*, 1993a, b
5	-65.8666	44.4500	3P	Everitt Lake	Green, 1986
6	-65.1666	44.4333	3P	Minard Lake	Railton, 1973
7	-64.5666	44.3833	3P	Oak Hill Lake	Livingstone, 1968; Railton, 1973
8	-64.5667	44.5848	4P	Canoran Lake	Railton, 1972; Mott, 1985; McNeely and Jorgensen, 1993
9	-65.0182	44.9005	2P	Nictaux Falls	Mott, 1985; Mott and Stea, 1993
10	-64.7666	45.0333	3P	Caribou Bog	Auer, 1930; Ogden, 1960; Livingstone and Estes, 1967; Livingstone, 1968; Green, 1986
11	-64.3733	45.2217	2P	Blomidon	Mott and Stea, 1993
12	-64.1833	45.0166	3P	Shaws Bog	Hadden, 1975; Stea and Mott, 1989
13	-63.6428	44.5633	4P	Silver Lake	Livingstone and Estes, 1967; Livingstone, 1968; Green, 1986
14	-63.6436	44.5472	4P	Bluff Lake	Livingstone and Estes, 1967; Livingstone, 1968
15	-63.9389	44.6681	4P	Little Lake	Levesque *et al.*, 1992; Mayle *et al.*, 1993a, b
16	-63.5592	44.6750	3P	Penhorn Lake	Ogden, 1987; Stea and Mott, 1989
17	-63.4862	44.9778	2P	Lantz	Stea and Hemsworth, 1979; Mott, 1985; Mott *et al.*, 1986a; Mott and Stea, 1993
18	-63.3840	45.0843	2P	Shubenacadie	Stea and Mott, 1989; Mott and Stea, 1993
19	-63.3392	45.2367	4P	Brookfield	Mott, 1985; Mott *et al.*, 1986a
20	-63.2392	45.4015	2P	Brookside	Mott, 1985; Mott *et al.*, 1986b; Mott and Stea, 1993
21	-63.3188	45.3675	2P	Truro	Stea and Mott, 1989; Mott and Stea, 1993
22	-63.5083	45.3958	?	Debert	MacDonald, 1968; Stuckenrath *et al.*, 1966
23	-69.0444	45.0139	2P	Miller Creek	Stea *et al.*, 1992; Mott personal communication, 1994
24	-63.5558	45.3847	4P	Little Dyke Lake	this report
25	-63.6717	45.5188	3S	Sutherland Lake	Mott unpublished
26	-64.2917	45.5583	1P	West Brook	Mott in Stea *et al.*, 1986
27	-64.3400	45.4678	3S?	Gilbert Lake	Stea *et al.*, 1986; McNeely and Jorgensen, 1992
28	-64.3500	45.4361	4P	Leak Lake	Mott in Wightman, 1980; Mott 1985; Stea *et al.*, 1986; Levesque *et al.*, 1992
29	-64.4833	45.4917	3S	Welton Lake	Mott unpublished; McNeely and McQuaig, 1991
30	-64.6167	45.5000	3P	Sand River Bog	Mott in Stea *et al.*, 1986; Mott *et al.*, 1986a
31	-64.4353	45.7025	2P	Joggins-Lower Cove	Mott, 1985; Mott in Stea *et al.*, 1986; Mott and Stea, 1994

32	-63.5500	45.5500	3P	Folly Bog	Livingstone and Estes, 1967; Livingstone, 1968; Amman *et al.*, unpublished
33	-63.4083	45.5167	3P	Frog Lake	Livingstone, 1968; Amman *et al.*, unpublished
34	-63.5622	45.6008	2S	Wentworth	Stea *et al.*, 1992; Mott and Stea, 1993; McNeely and Jorgensen, 1993
35	-62.6222	45.6708	4P	Chance Harbour L.	Jetté and Mott, 1989
36	-62.2678	45.7003	2P	Lismore	Stea and Mott, 1989; Mott and Stea, 1993
37	-62.5181	45.5139	4P	Stillman Pond	Levesque *et al.*, 1992
38	-61.2167	45.8000	2P	River Denys-Big Brook	Mott, 1985; Mott and Stea, 1993
39	-61.4944	45.8367	2P	Campbell	Mott, 1985; Mott and Stea, 1993
40	-61.5750	46.0167	2S	Port Hood Island	Hickox, 1962; Terasmae, 1974; Lowdon and Blake, 1976; Mott, 1985; Mott *et al.*, 1986a; Mott and Stea, 1993
41	-61.5092	46.0733	2S	Hogs Back	Mott and Stea, 1993
42	-60.8236	46.8228	2S	Pleasant Bay	Mott *et al.*, 1986a; Mott and Stea, 1993
43	-60.4472	46.5403	3P	Wreck Cove Lake	Livingstone and Estes, 1967; Livingstone, 1968
44	-59.8458	45.9750	4P	Main-à-Dieu Pond	Levesque *et al.*, 1992
45	-60.6333	45.9166	2S	Eskasoni	Mott *et al.*, 1986a; Mott and Stea, 1993
46	-60.6700	45.9075	2P	Amaguadees	Mott *et al.*, 1986a; Mott and Stea, 1993
47	-60.6867	45.9025	2P	Benacadie (1)	Mott *et al.*, 1986a; Mott and Stea, 1993
48	-60.6847	45.9025	2P	Benacadie (4)	Mott *et al.*, 1986a; Mott and Stea, 1993
49	-60.7178	45.9033	2P	Benacadie Point	MacNeill, 1969; Lowdon and Blake, 1976; Mott, 1985
50	-60.7750	45.6444	3P	Salmon River Lake	Livingstone, 1968; Green, 1986
51	-60.6750	45.6514	4P	Chase Pond	Levesque *et al.*, 1992; Mayle *et al.*, 1993a, b
52	-60.7675	45.6512	4P	Gillis Lake	Livingstone and Livingstone, 1958; Deevey *et al.*, 1959; Livingstone and Estes, 1967; Livingstone, 1968; Mott, 1985; Mott *et al.*, 1986a
53	-64.2667	44.2667	2P	Hirtles Beach	Mott and Stea, 1993
54	-61.3383	45.4300	2P	Collins Pond	Stea and Mott, 1989; Mott and Stea, 1993
55	-60.6592	46.3743	3S	Timber Lake	Mott unpublished
56	-63.6669	44.5806		Lower Mud Pond*	Mayle and Levesque unpublished
57	-65.8444	43.0002		Mid Curry Pond*	Mayle and Levesque unpublished
58	-61.4944	45.4458		Simpson's Pond*	Mayle and Levesque unpublished
59	-66.1025	44.3375	4S	Church Point Lake	Mott unpublished
60	-66.1692	44.4347	4S	Sandy Cove Lake	Mott unpublished, McNeely and Jorgensen, 1993
61	-65.7760	44.0873	4S	Bower Lake	Mott unpublished
62	-65.1691	44.4347	4S	Pat Kempton Lake	Mott unpublished
63	-65.4407	44.8190	4S	Youngs Lake	Mott unpublished
64	-65.3005	44.8700	2P	Bridgetown	Mott unpublished
65	-64.5838	45.0167	4S	Tupper Lake	Mott unpublished
66	-64.4333	45.4000	3P	Diligent R. Lake	Wightman, 1980
67	-62.6563	45.3417	4S	Piper Lake	Mott unpublished
68	-62.2000	45.5015	4S	Indian Lake	Mott unpublished; McNeely unpublished
69	-62.0878	44.9717	4P	Pye Lake	Mott unpublished
70	-62.0400	45.2672	4S	Cumminger Lake	Mott unpublished
71	-61.6760	45.3537	4P?	Noname Lake	Mott unpublished
72	-61.3445	45.4335	4P?	Manasette Lake	Mott unpublished; McNeely and Jorgensen, 1993

73	-61.3575	45.6513	4S	Hector Lake	Mott unpublished
74	-60.7722	46.1125	3S	Baddeck Bog	Mott unpublished
75	-60.9533	46.2500	3S	Third O'Law Lake	Mott unpublished
76	-63.8508	45.3850	1S	Upper Economy	Mott in Stea *et al.*, 1986; McNeely and McQuaig, 1991
77	-61.4299	46.0528	4P?	McDougal Lake	Livingstone 1968
78	-60.9908	46.4910	4S	Pembroke Lake	Mott unpublished
79	-61.0667	46.4873	3S	Cormier Lake	Mott unpublished
80	-60.4467	46.4833	3S	MacInnis Lake	Mott unpublished; McNeely and Jorgensen, 1992
81	-63.6360	45.7333	4S?	Wigmore Lake	Mott unpublished
82	-64.5945	45.1135	3S?	Silver Lake	Mott unpublished
83	-60.3917	46.0666	4P	Upper Gillies Lake	Livingstone, 1968
84	-59.9166	43.9500	2P	Sable Island	Terasmae and Mott, 1971
85	-60.6458	45.9203	2S	Castle Bay	personal communication to Mott by Ochietti

(i.e. structures and bedding) which may help to explain mechanism operating in the lake catchment or basin. This study attempts to clarify the following questions: Do pollen variations at LDL indirectly or directly reflect climatic cooling? In other words, do variations in the pollen record reflect changes of the matrix in which they are embedded or climatic cooling? Are the variations in texture assemblages a response to effects of climatic cooling on the vegetation cover or the end-product of climatic cooling on the hydrological regime at LDL? A comparative approach of the texture and pollen record at LDL should expose these proxies sensitivity and response to environmental change. It should also expose if vegetation communities are associated with a particular texture assemblage of lake sediments.

2.3 A minimum date for deglaciation for central Nova Scotia

The study of LDL sediments is relevant to the deglaciation history of central Nova Scotia due to its geographic and stratigraphic location. It is a closed-basin lake located near the head of Cobequid Bay, an area for which evidence of late ice presence and movement has been reported. Little Dyke Lake has developed in glacio-fluvial sediments of the "Five Island Formation" (Stea *et al.* 1986 map sheet). This formation includes a series of deltas that form a discontinuous terraced plain of glacio-marine and -fluvial deposits bordering the north coast of the Minas Basin, between Advocate Harbour and Truro (Swift and Borns 1967; Wightman 1980; Stea *et al.* 1986). Marine shells found at the bottom of one of these deltas at Spencers Island, Chignecto Peninsula, have been dated at 14 300 - 12 000 yrs. BP (Stea and Wightman 1987). Therefore, the stratigraphic location of LDL suggest that it might hold a late-glacial sequence.

However, stratigraphical studies also indicate that late local ice may have persisted in Nova Scotia until about 10 500 yrs. BP or later (Grant 1977, 1989, Stea 1984, Stea *et al.* 1986, Stea 1988) and could have delayed sedimentation in several localities of the Maritimes. Out of more than a dozen sites which have been studied in central Nova Scotia, only a couple of site have provided a continuous late-glacial record (see figure 2.1: Leak Lake site 28 & Chance Harbour Lake site 36) and two other lake sites (site 27 & 81: figure 2.1) possibly hold such a record, indicating that ice did not persist at these localities. Occupation of the Debert site (MacDonald 1968) indicates the immediate lowland area was partly ice free at the time of the Younger Dryas. In contrast, the genetic classification of buried organic sites to the east (site 20 & 21: figure 2.1) and north (site 34: figure 2.1) of LDL shows that ice was again active in the region at the time of the Younger Dryas (Stea and Mott 1989). The regional deglaciation history of central Nova Scotia suggests that sediments at LDL would have begun to accumulated sometime after 12 000 yrs. BP, but evidence for the persistence or re-activation of ice in the region also suggests that a late-glacial record may be absent or truncated. The fact that LDL is located to the east of the 0 isobase (figure 2.1 in Stea 1988) indicates that if sediment accumulation began during the late-glacial, it would not have been

delayed or interrupted by marine transgression, thus LDL is a good candidate site for the study of the deglaciation history of central Nova Scotia.

2.4 A paleoenvironmental reference for the Debert-Belmont paleo-Indian site

The study of LDL basal sediments not only provides insight into the climatic history of central Nova Scotia but also into the historical geography of north-eastern North America. Results from this study will complement archaeological investigations conducted at the Debert-Belmont paleo-Indian site (MacDonald 1968, Davis 1991, 1992). MacDonald (1968) described the paleo-Indian occupation at the Debert site as a brief (at least 100 years) but intense occupation(s) at about 10 600 yrs. BP by one or many closely related microbands. He suspected that the Debert people may have evacuated the site due to unfavourable conditions. Cooperative efforts to determine the vegetational history of the Debert area (Livingstone in MacDonald 1968; Livingstone and Estes 1967; Livingstone 1968; Amman *et al.* unpublished manuscript) had not, however, produced a late-glacial profile that could support MacDonald's hypothesis.

LDL is the nearest lake to provide a late-glacial profile for the area. The study of LDL lake sediments would therefore provide a paleoenvironmental reference to the archaeologists who try to better understand the behaviour and adaptation (e.g. settlement and subsistence patterns) of the paleo-Indian vis-à-vis their changing physical environment. This study contributes to the inter-disciplinary program instigated by the discovery of two new localities which held paleo-Indian evidence, near the Debert site. These new sites are referred to as Belmont I and II and lithics from these sites resemble closely those uncovered from the Debert site (Davis 1992).

CHAPTER 3 SITE DESCRIPTION AND REGIONAL CONTEXT

Little Dyke Lake (54°23'08"N, 63°33'35"W) is located about 50 metres off the northern coast of Cobequid Bay and 9 km SW of Debert, Colchester County (figure 3.1) The lake's long axes (NNW-SSW) is 625 m and in the southern sector of the lake the maximum width is 350 m. The lake basin is comprised of two depressions and covers about 7.6km^2. The maximum depth of 4 m occurs in the major depression located in the south central section of the lake. A second basin with a depth of 2.5 m is present in the northern sector of the lake. (figure 3.1)

3.1 Geomorphology, soils and landuse

Little Dyke Lake is contained within a kettle of the Folly River delta, south of the eastern Cobequids. On air photos of the Folly River delta (A5925-77 and -78 (1938); A11787-124 and -125 (1947)), river terrace levels are discernible. A pair of terraces exists along the Folly River while only one terrace is seen along the Debert River. Stea *et al.* (1986) have reported a series of four terraces for the Parrsboro delta, Chignecto Peninsula and some of these may be related to base level lowering (Stea *et al.* 1987). Fewer terraces on the Folly River delta may be taken to indicate that the evolution of the Folly River is younger than the Parrsboro River and consequently agrees with the proposed west to east deglaciation reported for the area by Stea (1988).

Topographic maps do not show any streams flowing in or out of Little Dyke Lake. Air photos show stands of black spruce and tamarack near the NNW tip of the lake. It is probable that the imperfectly drained soils (Webb *et al.* 1991) may be channeling a slow inflow of water to the lake. In general, soils that surround Little Dyke Lake are comprised of Humo-Ferric Podzols that belong to the Hebert Association (He) (Webb *et al.* 1991). The soils that have developed to the east of the lake have been classified as imperfectly drained Gleyed Humo-Ferric Podzols (He3) and have been described to "commonly occur in depressional to level areas that are underlain by slowly permeable material, which reduces internal drainage and creates perched water tables during wetter periods" (Webb *et al.* 1991). In air photos, faint paleo-current channels are detected over these soils. Similarly, Stea *et al.* (1986) have reported that infrared imagery reveal relict braided stream patterns on the surface of deltas, such as the Parrsboro delta, which lie in the Minas Lowlands, Chignecto Peninsula.

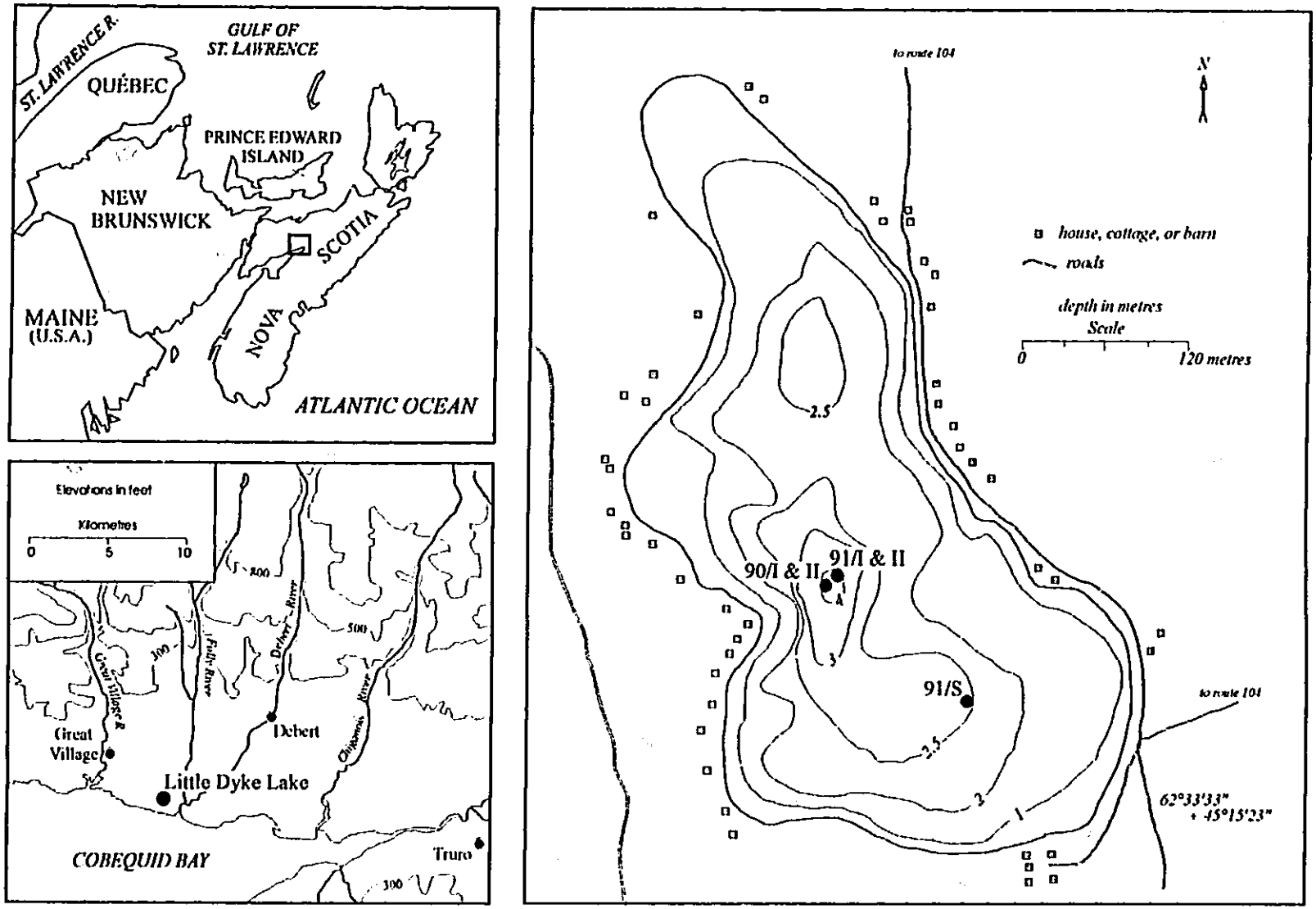

Figure 3.1 Location and bathymetry of Little Dyke Lake, Nova Scotia. Location of sediment sequences 90/I&II, 91/I&II, 91/S.

A band of imperfectly drained Gleyed Regosols (Ac3) of the Acadia Association (Webb *et al.* 1991) are found in a depression which separates the imperfectly drained terrain (He3) and the well-drained Orthic Humo-Ferric Podzol (He1) soil units to the east of the lake (Webb *et al.* 1991). Acadia soils are described as having developed on fine loamy, dyked, marine sediments (Webb *et al.* 1991). Stea and Finck (1984) have mapped the depression which holds the Acadia soil as a salt marsh, however, examination of the vegetation in this depression did not reveal the presence of halophytes. Today, it would seem that intertidal waters do not penetrate much further than the shallow channel to the south of the road. Although the bottom of the depression did not retain any water at the time of this investigation, the dominance of (*Alnus)* indicates that water level within the depression does fluctuate throughout the year.

Little Dyke Lake area has several residences concentrated around the lake, and a few farm houses are located farther south and north-east of the lake. All but 1/4 of the land around the lake is dedicated to agriculture, hence this region's classification as "cleared land" (Nova Scotia Resource Atlas 1986). Corn fields are interrupted by a few side road gravel pits. Evidence of irrigation on the air photos includes a rectilinear system of ditches that are linked to the southern end of Little Dyke Lake. Dykes are present to the SW of the confluence of the Debert and the Folly River. The construction of dykes to constrain the lateral movement of the rivers have permitted the agricultural exploitation of the nutrient enriched intertidal mudflats on the south-west sector of the delta.

3.2 Climate and vegetation

Growing degree days (GDD above 5°C) are amongst the highest of the province (Dzikowski 1983). The average frost free period is 110 to 120 days (Dzikowski 1983, Nova Scotia Development Atlas 1973). A southward flowing branch of the Labrador current prevents the Gulf Stream from reaching Nova Scotia's Atlantic coast (Nova Scotia Development Atlas 1973). Consequently, the water in the Bay of Fundy are the coldest of Nova Scotia and have a moderating influence on the precipitation and temperature. The Colchester Lowlands possess an average total annual precipitation of 1000-1200 mm.

Little Dyke Lake is found in the Central Lowlands Forest Section of the Acadian Forest Region (Rowe 1972). Well drained sites are composed of conifers : white, red and black spruce (*Picea glauca, P. rubens, and P. mariana*), balsam fir (*Abies balsamea*), eastern hemlock (*Tsuga canadensis*) and eastern white pine (*Pinus strobus*). Associate species include: white birch (*Betula papyrifera*), red maple (*Acer rubrum*), sugar maple (*Acer saccharum*), yellow birch (*Betula lutea*) and beech (*Fagus grandifolia*).

The vegetation bordering LDL is comprised of alder (*Alnus*), large-tooth *poplar (Populus grandidentata*), balsam poplar (*Populus balsamifera*), spruce (*Picea*), red maple (*Acer rubrum*), jack pine (*Pinus banksiana*), birch (*Betula*), mountain ash (*Sorbus*), juneberry (*Amelanchier sanguinea*) and cherry (*Prunus*); rose bushes (Rosaceae) and sweetfern (*Myrica gale*); ferns (Polypodiaceae) , grasses (Poaceae)

and sedges (Cyperaceae). The shallow sectors (=>1m depth), to the north and east of the lake held aquatics plants. Stands of large pine trees were observed over the well drained soils to the NE of the lake while swampy terrain to the NW of the lake was dominated by spruce.

CHAPTER 4 -METHODS AND TECHNIQUES

4.1 Field technique

Little Dyke Lake (LDL) was cored in 1990 and 1991. The bathymetry of LDL was recorded with a commercial echo sounder and coring was carried out in the deepest part of the lake. Two flat-bottom aluminium boats, bolted side by side with steel rods and anchored over the coring site, provided a stable platform for coring (Mott 1966). PVC casing served to direct the corer. A surface grab sample was collected with the aid of an Ekman dredge. A Brown corer (Brown 1956) equipped with a 4.4 cm (ID) transparent tube was used to sample the mud-water interface. Subsequent sequences were recovered with a modified Livingstone piston sampler (Livingstone 1955, Deevey 1965) of 8 cm diameter. Duplicate sequences were taken from adjacent holes.

Cores were extruded in the field. The upper soft sediment below the mud/water interface in the Brown corer was carefully extruded in 5 or 10 cm increments and placed in plastic bags. Once described, the remaining firm sediment cores were sectioned into 50 cm increments and wrapped in plastic wrap and aluminium foil. Upon return from the field, sediment was stored in a cold room at 4°C. Table 4.1 shows a log of all analyses performed on LDL sediment sequences.

4.2 Radiography

X-radiography was done on a close to shore sequence of LDL sediments (91-MS-01/S) to know the precise location of macrofossils which could be used for dating. It was also done on the basal sediment in order to characterize the upper and lower boundary of the most prominent minerogenic layer and to expose the existence of internal structure and boundaries of this layer.

X-radiography has proven valuable in sedimentology because of its non-destructive quality and its effectiveness at revealing density variations which are not always visible to the un-aided eye (Hamblin 1962, 1971). During the visual examination of a sediment core, it is possible to discern variations in particle size, shape, composition and colour. However, the internal arrangement of the particles or density of the particle may only be exposed on radiographic photos. Dense material readily absorb radiation and consequently appear lighter on the photo while less dense material inversely appear darker on the photo.

sediment sequences / type of analysis	90/I	90/II	91/I	91/II	91/S
gross stratigraphy	X	X	X	X	X
x-ray			X minerogenic layer 575.0-625.0cm		X entire sequence
carbon & carbonate		X 5 cm increments 667.0-762.0cm		X 1-2cm increments 596.5-690.5cm	
macrofossils				X 1-3cm increments 606.5-595.5cm	
radiocarbon dates	X	X	X	X	
pollen	X 5 cm increments 685.0- 710.0cm			X 1-2 cm increments 596-696cm	
texture				X 1- 5 cm increments 609-686cm	
chironomidae			X 2-10cm increments 577.0-660.0cm Dr. I. Walker		

Table 4.1 Type of analysis performed on Little Dyke Lake sediments.

The basal sediments were x-rayed with an industrial Hewlett-Packard X-Ray System, Faxitron series, model 43805N. Variations in density were recorded on Dupont Cronex film. The target-film distance and the type of film were set and the milliamperage remained about the same. The voltage and exposure time varied with the type of material. The voltage was generally raised with the visible increase in the proportion of mineral sediment to ensure absorption of the x-ray. Since an increase in voltage usually results in low contrast, instead, the exposure time was increased to allow penetration of the x-ray (Hamblin 1971).

A total core depth of 100 centimeters of a 1991 sediment sequence was prepared for pollen and sediment analyses. This core depth was described and then cut into 1cm thick slices. One quarter of its total diameter (1/4 of each slice) was archived and kept in the cool room. Subsamples for pollen analysis were extracted from the centre of each 1 cm thick slice to avoid contamination due to smearing along side the core. All slices were freeze-dried before picking for macrofossils and sediment analyses.

4.3 Radiocarbon dating: conventional and accelerator mass spectrometry

Macrofossils were recovered from the sediment for accelerator mass spectrometry (AMS) dating, but if identifiable they also provide environmental data and confirm the local presence of the taxa. After all 1cm slices were subsampled for pollen analysis, they were individually freezed dried (-20°C to -40°C). Weight loss due to sublimation of water was calculated as a percent from the total weight of the slice. Water loss thus included the constitutional water portion of clays. Most of the slices, especially those straddling lithological boundaries were picked for datable macrofossils under a binocular microscope (maximum magnification 100X). The duplicate cores were wet sieved (0.177mm) to concentrate plant macrofossils.

Conventional Carbon-14 dating was performed on bulk sediment at the Radiocarbon Laboratory, Geological Survey of Canada, Ottawa. Small-sized terrestrial samples, such as twigs, were identified. The attached sediment and bark were loosened in a ultrasonic bath and removed. The samples were rinsed and then dried slowly at 60-70°C before being sent to the Isotrace Laboratory, Toronto or Beta Analytic Inc., Miami for AMS dating.

4.4 Sediment analysis

4.4.1 Colour of the sediment

Colour of the wet sediment were determined by comparison with a Munsell Colour Chart. In the following text, Munsell "colour names" are italicized.

4.4.2 Carbon and carbonate determination

Carbon and carbonate content of the sediment are informative on the past local environment since they reflect primary productivity or indicate erosion (Mackereth 1966). Preliminary Carbon and carbonate determination were done at every 5 to 10 cm interval before returning in the field in 1991. The results of these analysis served to calculate the amount of sediment (a minimum of 2g of Carbon) required for conventional Carbon-14 dating.

An equivalent of >= 1 g wet sediment was taken from 79 slices of freeze dried sediment of the 91/II core depth. These were then submitted to the Sedimentology Laboratory, Geological Survey of Canada, Ottawa for Carbon and carbonate determination. A LECO^R CR-12 System, model 781-600 coupled to a measurement unit model 781-700 (accuracy $^+$/- 1 percent of the Carbon content) was used to determine the Carbon content of the sediments (LECO CORPORATION 1984). One half of each sample was digested with hydrochloric acid (for the removal of inorganic carbon) and then combusted at 2000°F (1093°C) for the determination of organic Carbon. The other halves were combusted without any chemical pre-treatment at 2500°F (1371°C) for the determination of total Carbon. The Carbon dioxide (CO_2) evolved during the oxidation of Carbon for both halves was measured by an infrared detector (% Carbon on the sample weight). The non-carbonate Carbon was obtained by subtracting the organic Carbon from the total Carbon (Foscolos and Barefoot 1970). The $CaCO_3$ equivalence is a function of the percent of non-carbonate Carbon in the sample. It is computed with the following formula:

$CaCO_3$ = [(total Carbon - carbonate Carbon) = non-carbonate Carbon] X 12 / 100
where 12 is the atomic mass of Carbon and 100 is the atomic mass of $CaCO_3$.

4.4.3 Particle size analysis

Five to 25 g of fine sediments are required to run the particle size analysis (Galehouse 1971). Adjacent 1 cm sections were joined when a minimum of 5 g (of freeze-dried sediment) could not be provided by one section alone. A total of thirty seven samples were prepared, each weighing about 10 g (before oxydizing the organic material).

Oxidation of organic matter and release of organically sorbed cations was achieved by rehydrating the freeze-dried samples with hydrogen peroxide (6% to 30%). Elimination of insolubles, carbonates, biogenetic silica or iron (Galehouse 1971, Rivière 1977, Lewis and McConchie 1994) was not performed. The samples were dispersed with sodium hexametaphosphate [1% w/v of 1000 ml] and wet sieved through nested 1, 2, 3 and 4 phi sieves. Fractions retained on these sieves were dried and weighed separately. Fractions bigger than 4 phi (< 62.5µm) was used for subsequent particle size analysis.

The "discontinuous subtraction method" (Gullentops 1993) was used for particle size analysis. It consists of a modification of the pipette method (Krumbein and Pettjohn 1938; Lambe 1951; Inman 1952; Folk 1966, 1974). In contrast to the pipette method, the discontinuous subtraction method withdraws samples from a perforated spout near the base of the cylinder rather than from the top. A slice of liquid is withdrawn through the spout. The combination of a perforated spout and the use of hydrostatic pressure minimizes the turbulence incurred while the spout is opened for sampling. Theoretical considerations of the pipette method (Galehouse 1971) are equally applicable to the discontinuous substraction method. Stoke's law, which express the rates of settling of spherical particles in a fluid (Baste and Jackson 1984), is used to convert a particle's settling velocity to particle diameter and the time needed for particles of a selected size to reach the spout.

Samples corresponding to 6 classes: 4-5, 5-6, 6-7, 7-8, 8-9, >9 phi were withdrawn from the settling tubes. Terms used for grain-size classes (e.g. fine sand, medium silt) are those which correspond to the classical Wentworth scale. The weight of each class is expressed in gram percent weight of the dehydrated, organic free slice(s). The percentage size data is statistically treated using CONISS (Grimm 1987) in the same matter as the pollen data (see below) to facilitate the comparison of both data sets. The established zones are referred to as texture assemblage zones (TAZ).

4.5 Pollen analysis

Since the pollen record of the Younger Dryas in the Maritimes is always associated with a distinct minerogenic layer, six subsamples of $1cm^3$ were taken at 5cm increments across the prominent minerogenic layer of the 1990 basal sequence. These subsamples served for preliminary pollen analysis and were treated in the same matter as those taken from the 1991 sediments.

One hundred $1cm^3$ subsamples were taken from the 1991 basal sequence and to be used for pollen analysis. Subsamples, extracted from the centre of each 1 cm thick section were subjected to the following treatment: 10% hydrochloric acid, 10% potassium hydroxide, 50% hydrofluoric acid, 38% hydrochloric acid, and acetolysis (Fægri and Iversen 1975). Samples rich in clays were sieved through a 10µm size mesh after acetolysis (Cwynar 1979). Tertiary butyl alcohol served to dehydrate the residue before mixing in silicon oil (2 000 cs) (Andersen 1960).

Identifications were made with the help of Erdtman (1954), Moore and Webb (1978, 1991), Fægri and Iversen (1964), Erdtman *et al.* (1968), McAndrews *et al.* (1973), Van Geel (1976) and Bassett *et al.* (1978) and the reference collection of the Paleoecology Laboratory of the Geological Survey of Canada, Ottawa. Photos of microfossils were taken with the aid of a Leitz diaplan photonic microscope

(ocular periplan 10X and objectives 40X, 100X (immersion), equipped with a Leitz periplan photographic tube (10X and 12.5X) and a magazine coupled with a Multiphotomat.

Computation of the pollen concentrations was made possible by the addition of a measured volume of exotic pollen mixture before any chemical treatment (Benninghoff 1962). The concentration of exotic pollen (*Eucalyptus globulus*) in the mixture was pre-determined with a hæmacytometer. The addition of *Eucalyptus* also permitted the identification of any destruction of pollen incurred by the treatment versus that of in situ deterioration (poor preservation) or recruitment to the core site. A count of three fragments of coniferous pollen was judged to be equivalent to one grain. *Pinus strobus* was differentiated from *Pinus banksiana*-type by size and the occurrence of nodula on the nexine of the corpus (Amman 1977). Measurements of the birch pollen size were recorded to differentiate the occurrence of shrub birch (<20μm) from tree birch (=<20μm) (eg: Davis 1958, Ives 1977, Edwards *et al.* 1985, Anderson and Lewis 1992, Mott and Stea 1993). Deteriorated grains were classified in one of 4 categories: corrosion, mechanical, degradation and obscured (Berglund and Ralska-Jasiewiczowa 1986). Deteriorated grains and unidentifiable grains are lumped together under the heading of unidentified grains on the diagram. The pollen sum for each spectrum included terrestrial taxa and sedges (Cyperaceae). A minimum of 100/200 count ratio of *Eucalyptus*/pollen grains for the 1990 residues was achieved. A 100/300 count ratio of *Eucalyptus*/pollen grains was set for the 1991 residues of Little Dyke Lake. A pollen sum less than 600 grains (Moore *et al.* 1991) was judged to be sufficient in view of the small intersample distance (1-2 cm). Excluding 690.5 and 641.5 cm spectra, the average pollen grain count was 358 grains with a minimum value of 299 and a maximum value of 446 grains.

A percentage pollen diagram was drawn to represent changes in the pollen of Little Dyke Lake basin over time. The abundance of pollen from aquatic plants and spores were likewise plotted together on a separate diagram. Pollen influx rates (grains/cm^2/year) (Davis and Deevey 1964) were not calculated because i) the stratigraphic column is made of different sediment types which suggest variable sediment deposition rates and, ii) chronological control was insufficient and its reliability questionable.

In order to facilitate the interpretation of the pollen sequence, pollen zones were delineated using a stratigraphically constrained cluster analysis method of incremental sum of squares (CONISS)(Grimm 1987). Orloci's chord distance (Orloci 1967, 1978) was used to measure the statistical distance between samples. Sub-zones (peak zones) were conveniently identified on the basis of pollen content alone (Moore *et al.* 1991). Pollen zone and sub-zones are referred to as pollen assemblage zone (PAZ) throughout this study.

The green algal genus *Pediastrum* is well preserved in lake sediments and withstands chemical treatments used to make pollen preparations. Analysis of this colonial chloroccales was therefore conducted on the same slides as those used for pollen analysis. The shape of the marginal cells (number

of prongs), the presence/absence and size of the meatus and the ornamentation of the membrane are the three fundamental taxonomic characteristics that permit the identification of the cenobia to the species level (Bourrelly 1990). The nomenclature used follows that established by Louise Venne from the Université de Québec à Montréal. Cenobia that could not be identified because of damage or crumpling were classified respectively as *Pediastrum* sp. unidentified or *P. Boryanum* sp. undifferentiated. The abundance of *Pediastrum* is expressed as a relative abundance of total *Pediastrum* counted per spectrum and plotted against the sediment depth. The *Pediastrum* concentration (count/cm^3 sediment) was calculated and plotted alongside the *Pediastrum* percentage diagram.

Finally, a correlation diagram of the PAZ and TAZ was constructed in order to discuss the similarities and dissimilarities of both paleoenvironmental variables through time. Results are then compared to other sites of central Nova Scotia.

CHAPTER 5 - RESULTS

In 1990, a 793.0 cm complete sequence of lake sediments, 90-MS-03/I, was extracted from the lake (figure 3.1). Its basal duplicate, 90-MS-03/II, measured a total of 225.5 cm and reached a maximum depth of 745.5 cm. During the 1991 field season, sequences 91-MS-01/I and its duplicate, 91-MS-01/II, were collected. These reached maximum depths of 692.0 cm and 723.0 cm respectively. A third and complete stratigraphic sequence (91-MS-01/S) was raised from the shallow basin in the northern section of LDL. Its total length was 620.0 cm. In the following text sequence 90-MS-03/I, 90-MS-03/II, 91-MS-01/I, 91-MS-01/II and 91-MS-01/S will be referred to as 90/I, 90/II, 91/I, 91/II and 91/S, respectively.

5.1 Gross stratigraphy (sequence 91/II)

In general , the basal portion of the 91/II sequence shows contrasting colour and textural changes (figure 5.1). The stratigraphic column is characterized by the recurrence of 2 distinct minerogenic layers that resemble, in colour and coarser grain size, the lowermost sediments of the sequence. These layers are intercalated by organic rich sediments.

The bottom 47.5 cm (723-666.5 cm) of this sequence is characterized by a faint banding of sand and silt (figure 5.2). Three quarters of this bottom section is a *dark reddish grey* (5YR 4/2) sediment which becomes darker up-core (*dark greyish brown* (10YR 4/2). The next 13 cm (666.5 - 653.5 cm) are a *very dark grey* (5Y 3/1) silt with some yellow detrital fragments. Upon cutting the core into 1 cm thick slices, the upper portion of the *very dark grey* silt revealed lighter coloured inclusions (*dark brown* 10YR 3/3) composed of sand. A convoluted contact was observed between the sand inclusions and the *very dark grey* silty matrix. The *very dark grey* silt unit is overlain by 7 cm of medium sand with a faint pinkish cast (*very dark greyish brown* 10YR 3/2). The upper boundary of this sand unit, as seen on figure 5.1; is gradual like its lower boundary. The next 7 cm (between 639.6-646.5cm) are *very dark grey* (10YR 3/1) laminated gyttja (<1 mm laminations). This dark grey gyttja contrasts with the overlying 8cm of *weak red* clayey-silt (2.5YR 4/2). The boundary between the gyttja and the clayey-silt (~639.5) is irregular and flammate. Sand inclusions near the upper portion of the *weak red* clayey silt unit resemble the overlying 2 cm layer of *dark reddish brown* sand (5YR 3/2). The next 9cm of dark sandy-silt (10YR 3/3 to 10YR 3/1), between 618.5 and 627.5cm, result from the resumption of organic sedimentation, interrupted by the *weak red* clayey-silt. An abrupt and regular contact exists between the dark sandy-silt and the overlying algal gyttja (10YR2/2 to 10YR2/1) (at 618.5cm).

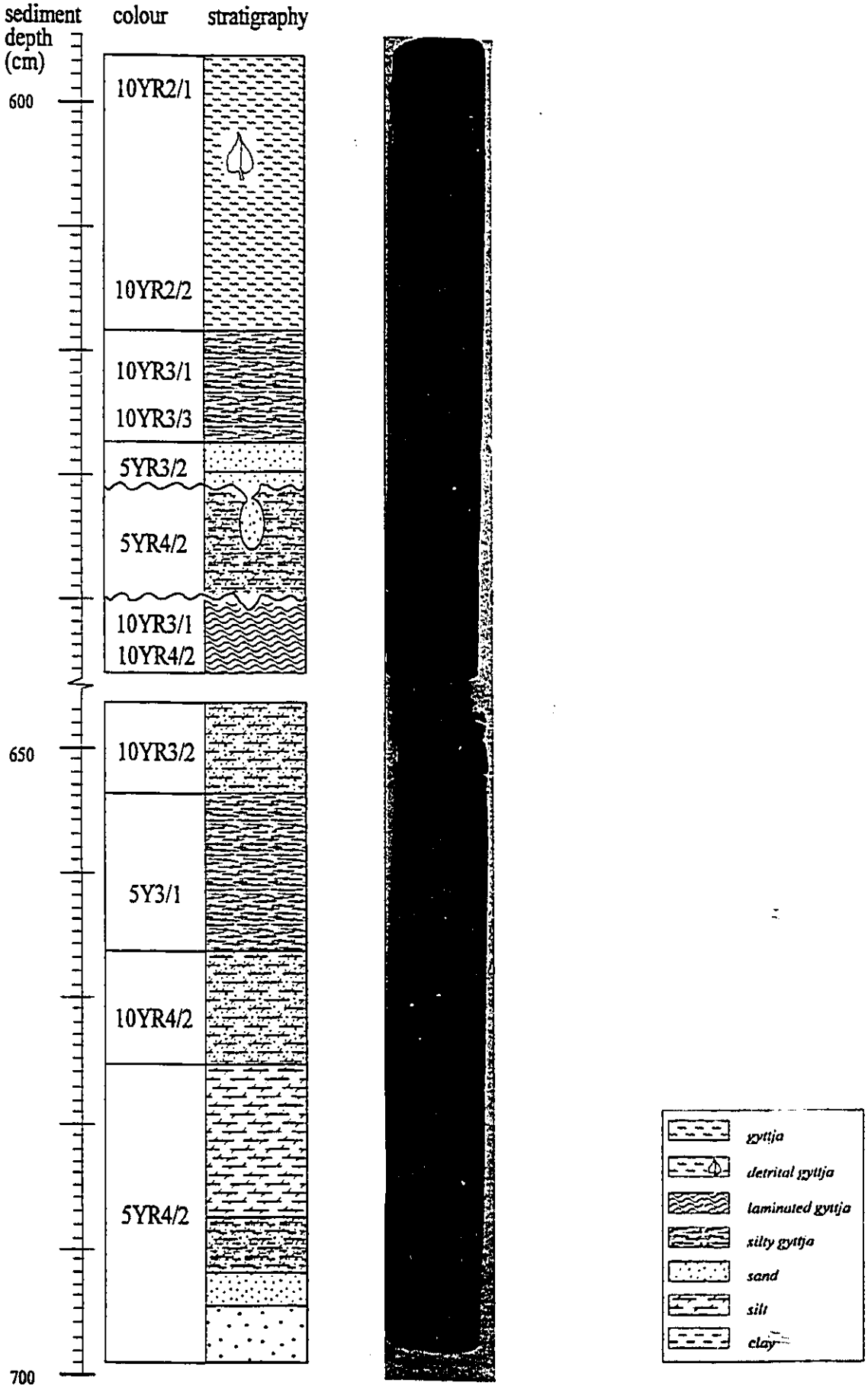

Figure 5.1 Picture of basal sediment sequence (91/II) with gross stratigraphy.

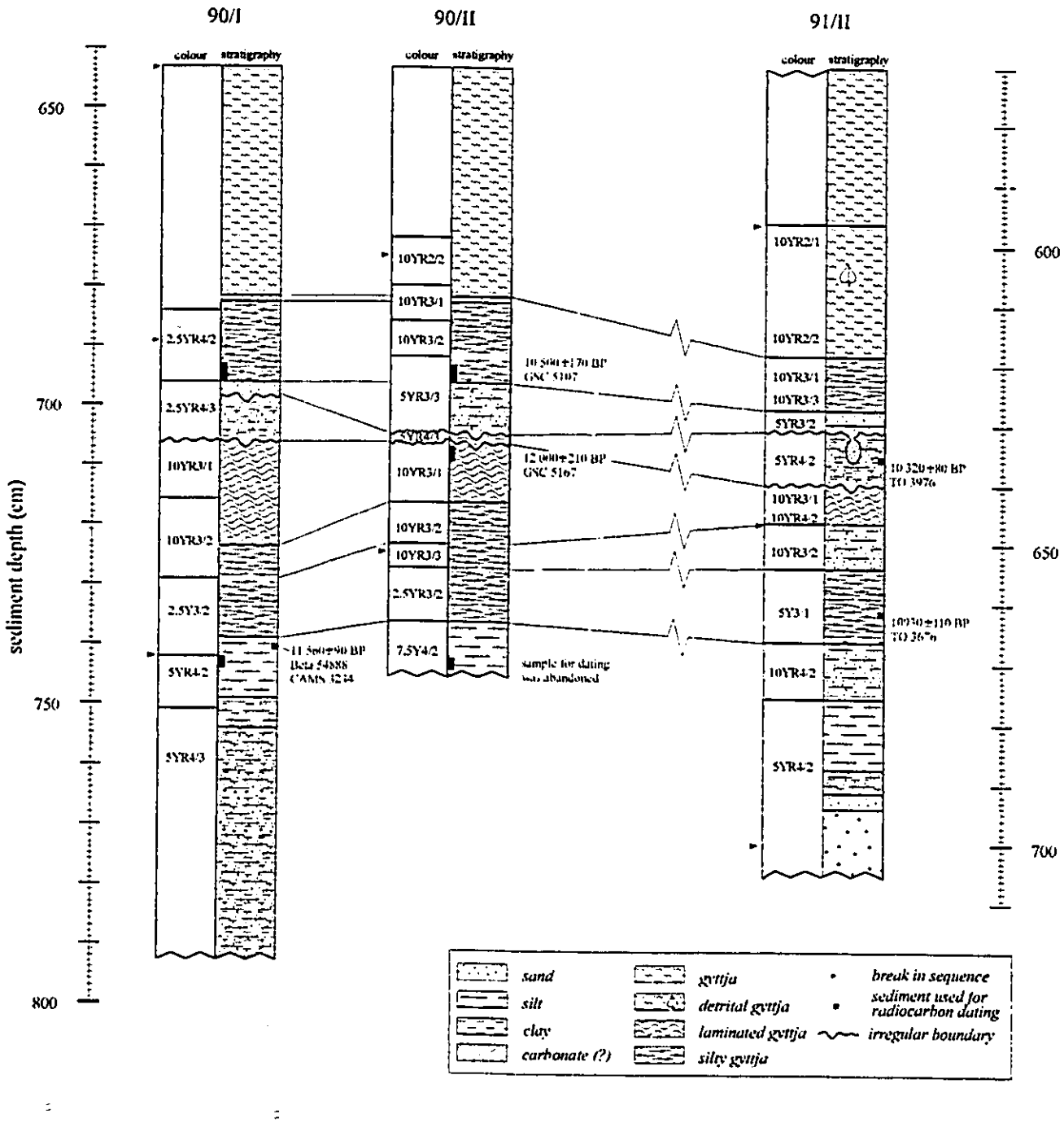

Figure 5.2
Gross stratigraphy, Munsell colour and C-14 dates from Little Dyke Lake basal sequences: 90/I, 90/II, 91/II.

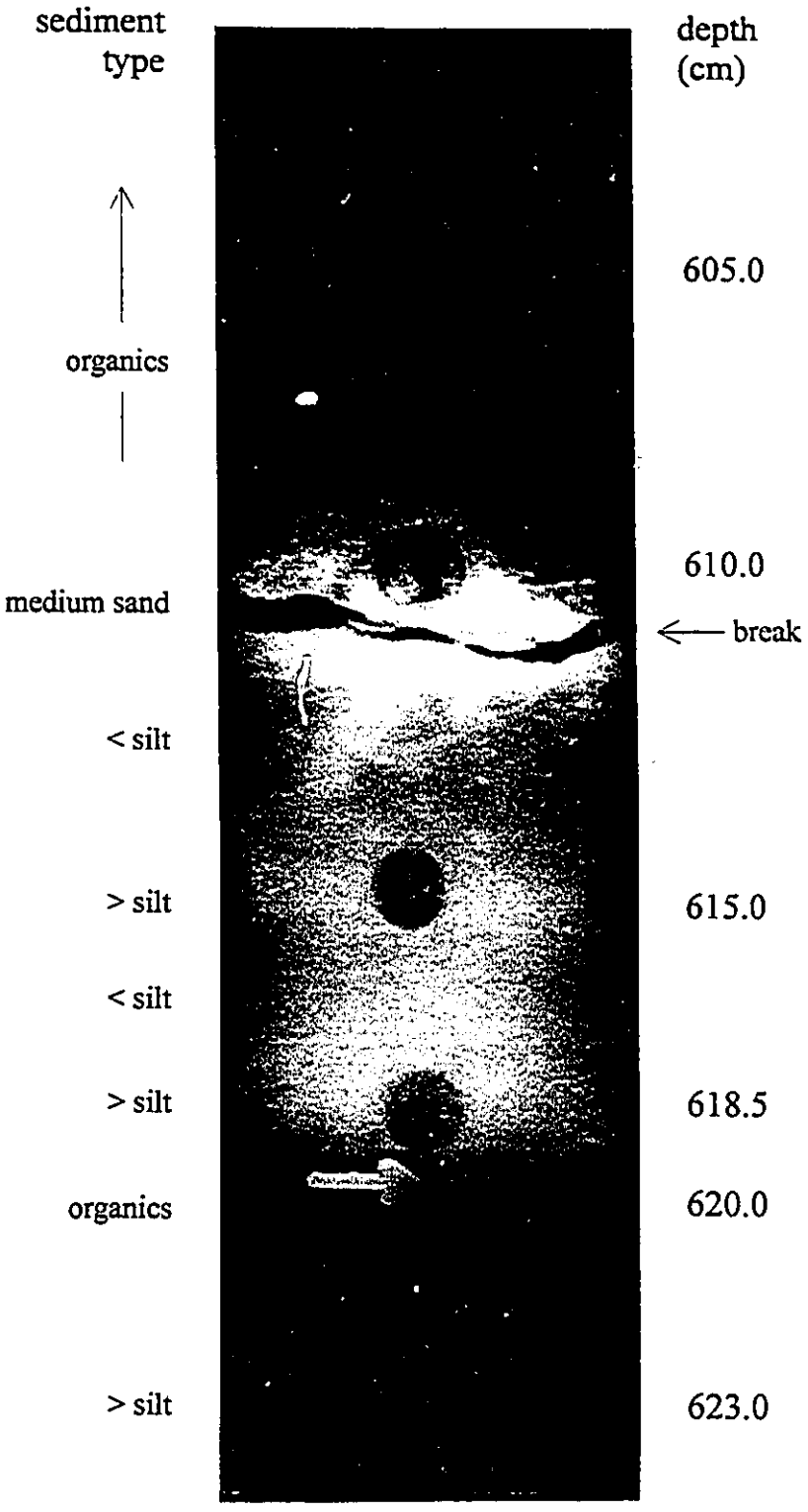

Figure 5.3 Photo of x-ray sequence 91/I

5.2 Radiography

Figure 5.3 is a positive print of the x-ray radiograph image of a section of 91/I. Since the stratigraphy of the basal portion of sequence 91/I is comparable to that of 91/II, references to the stratigraphic units identified above for 91/II with the x-ray results of 91/I are made below.

X-ray results exhibit a distinct *weak red* clayey-silt unit and the thin *dark reddish brown* sand unit as a thick white band in contrast to the darker adjacent organic-rich units of basal sequence 91/I (figure 5.3). The lighter shade of the combined clayey silt and sand units (minerogenic layer) on the photo is explained by the greater absorption of the x-rays by denser materials. Close examination of the thick white band also reveals details on the internal composition of this minerogenic layer. The light blotches that straddle the black fissure at the top of the mineral layer on the photo represents sand inclusions at a break in the core. Below the fissure two slightly darker bands, about 2 - 3 cm in thickness (between ~611.5 - 614.5 cm and 615.5 - 617.5 cm) occur. These bands result from the lower proportion of more absorbent material. In contrast, brighter bands are distinguishable at 615.0 and 618.5 cm. These result from the presence of a denser material, probably a higher proportion of finer, organic poor sediments. Since these minor variations were not detected while describing the core stratigraphy, confirmation which size fraction of the mineral sediments are displayed as brighter bands on the x-ray image will depend on the resolution of texture analysis.

The photo (figure 5.3) also shows that the lower contact of the bright mineral unit is abrupt. The flammate character of this contact is not apparent on the photo probably because of the thickness of the core (8 cm). X-ray radiography of thick samples results in the superposition of structural details (Hamblin 1971). The upper contact of the clayey silt unit, found above the prominent bright sand layer, grades into the overlying dark sandy-silt. The x-ray displays the gradual character of this boundary.

5.3 Radiocarbon dating

Macrofossils picked from the basal sediment sequence 90/II appear in Annex 5. Seven samples were radiocarbon dated to provide chronological control. The Geological Survey of Canada Radiocarbon Laboratory processed three bulk sediment samples for conventional C-14 dating. Four other samples were submitted to different laboratories for AMS dates (table 5.1).

	C-14 date	material	laboratory	sediment sequence	sediment depth (cm)	depth (cm) correlated to 91-MS-01 II
1	10 500±170 yrs. BP.	gyttja	GSC-5107	90-MS-03 I 90-MS-03 II	692.0-696.0	625.0-627.5
2	12 000±210 yrs. BP.	gyttja	GSC-5167	90-MS-03 I	706.5-709.0	640.0-641.5
3	abandoned not enough sediment	gyttja and sandy silt	GSC-	91-MS-03 I 91-MS-03 II	740.0-742.0	
4	11 560 ± 90 yrs. BP.	twig *Salix (?)*	Beta 54888 CAMS-3234	90-MS-03 I	741.0	670.0
5	10 320 ± 80 yrs. BP.	twig *Salix (?)*	TO-3976	91-MS-01 II	635.0-636.0	635.0-636.0
6	sample ampoule exploded during combustion	wood fragment	TO-3575	91-MS-01 II	634.0-635.0	
7	10 930±110 yrs. BP.	wood fragment	TO-3576	91-MS-01 II	661.0-662.0	661.0-662.0

Table 5.1 Carbon-14 dates from basal sediment sequences of Little Dyke Lake, N.S.

One sample was taken from the silty gyttja unit that overlies the prominent *weak red* clayey-silt unit of both 1990 sequences (692-696 cm). The purpose of this sample was to determine at what time resumption of organic deposition in the lake occurred, after its interruption by the *weak red* clayey-silt unit. The date obtained was 10 500 +/- 170 yrs. BP.

The second conventional C-14 date was obtained from gyttja and sandy-silt of the 1990 cores (740-742 cm). This sample dates the beginning of organic deposition at the site after deglaciation. This date was intended to provide a minimum date for deglaciation but the sample did not produce enough gas and was abandoned.

The third sample came from the gyttja unit which underlies the *weak red* clayey-silt unit from the 90/I (706.5-709 cm). It would give an approximate age of the sudden interruption of organic accumulation. The age of the sample turned out to be 12 000 +/- 210 yrs. BP.

A small twig (*Salix* sp. (?)) from the dark silty clay of the same interval depth as the unsuccessful C-14 date was later submitted for AMS dating. This twig came from the sandy portion of basal 90/I sequence (741 cm). The result was expected to provide an approximate age for organic accumulation at the site. It gave a date of 11 560 +/- 90 yrs. BP (Beta-54888; CAMS-3234).

Two AMS dates were obtained from the 91/II sequence. The younger date of the two, 10 320 +/- 80 yrs. BP (TO-3976), came from a small *Salix* sp. (?) twig found in the middle of the *weak red* clayey-silt unit, at exactly 635-636 cm. This sample was to replace a lost sample from a similar depth interval (91/II; 634-635 cm; TO-3575). The older AMS date of the 91/II sequence came from an unidentified wood fragment found imbedded in the basal silty sediments of the 91/II sequence (661-662 cm). It was to provide a minimum date for deglaciation. An age of 10 930 +/- 110 yrs. BP (TO-3576) was obtained. Although the younger date is placed within the prominent minerogenic layer of 91/II and not above it, as was the case for 90/I, sedimentation rates for both sequences are comparable. However, a constant rate of sedimentation for this depth is unlikely because different types of sediments suggest variable rates of accumulation. for the same reason as noted above.

5.4 Sediment analyses

5.4.1 Carbon and carbonate determination (sequence 91/II)

The profiles of total Carbon and non-carbonate Carbon (organic Carbon) are similar (figure 5.4). The two profiles are bimodal in the lower portion of the diagram. Both peaks (at 658.0 and 641.5 cm) occur in the very dark grey sediments. Up core, both profiles crash to values lower those obtained for the lowermost basal samples. This event coincides with the flammate contact between the very dark grey laminated gyttja and the weak-red clayey-silt. Values remain low within the reddish clayey silt unit and the overlying thin layer of sand, and then, they gradually reach their maximum values with the resumption of organic sedimentation (above 617.0 cm).

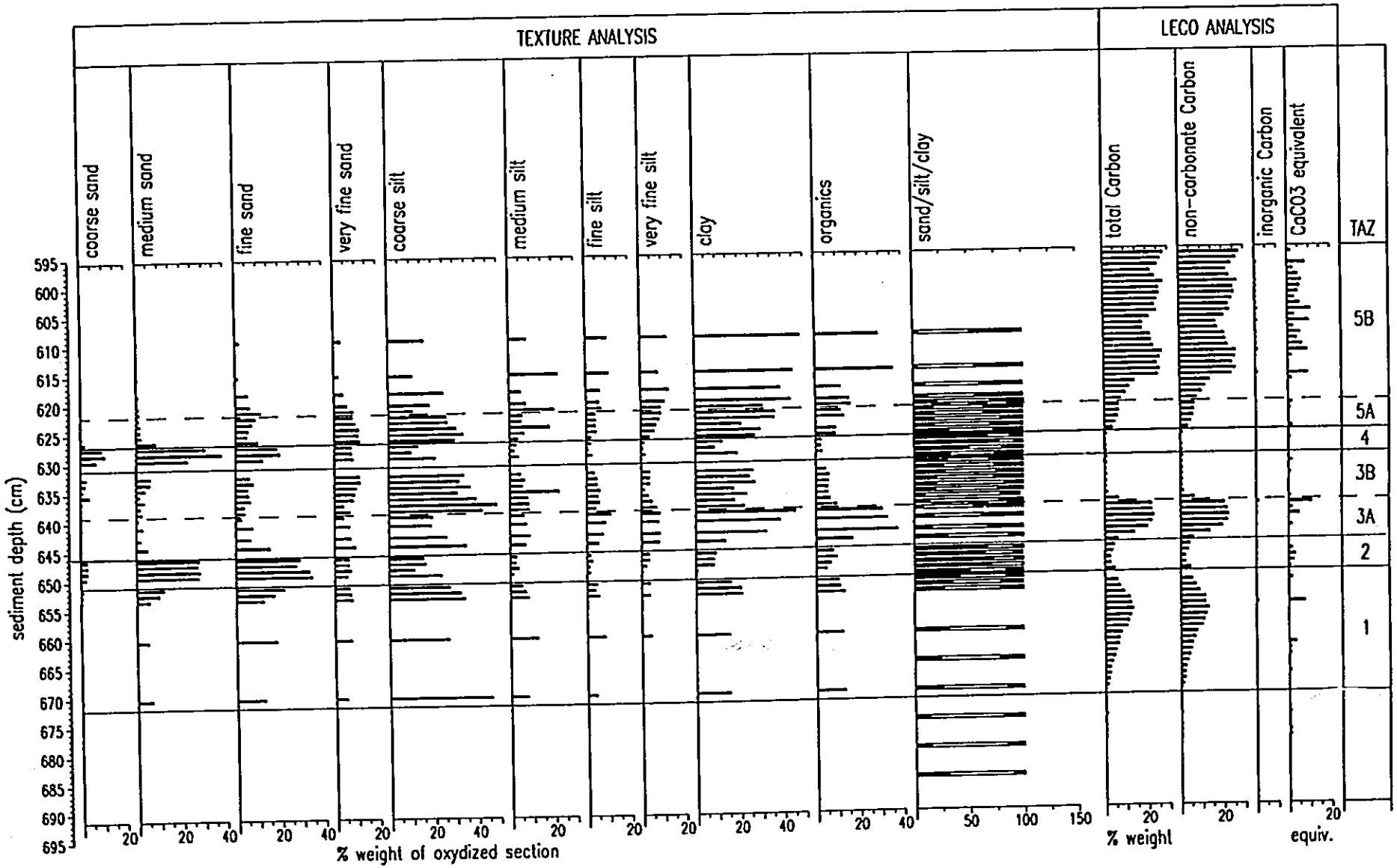

Figure 5.4 Texture percentage curves and carbon and carbonate curves.

The abundance of $CaCO_3$ (equivalent) remains relatively low for the analysed portion of the sediment sequence. Two distinct samples exhibit exceptionally high values (at 639.5 and 657.0cm) which coincide with the total Carbon peaks. This possibly results from an increase in erosion or a decline in lake productivity. It was noticed that the sediment at both these levels, there was an abundance of coarse organic remains and fine sand or clusters of sand (see macrofossil findings figure 5.5 and Annex 5). Disturbances in the landscape could be responsible for the erosion of organic litter which accumulated in the lake catchment. The abundance of $CaCO_3$ (equivalent) increases, much like the total Carbon, with the resumption of organic sedimentation. The inorganic carbon percent remain below 5% and its highest values, although not apparent, correspond with increases in the abundance of $CaCO_3$. Two small distinct increases in inorganic Carbon, occurring in the weak red slayey-silt (at 632.0 and 6334.0cm exactly), could correspond to the two unexplained brighter layers exposed on the x-ray. Bryophytes remains characterize the mineral layer. Associated with these remains is an increased presence of fungal sclerotia. Fungal sclerotia are today found on the surface or in soils (Lemdhal 1988) and these hollow spheres are easily dispersed by floatation or soil erosion (Pirosynski 1990). These have also been associated with alder communities (Pirozynski 1990).

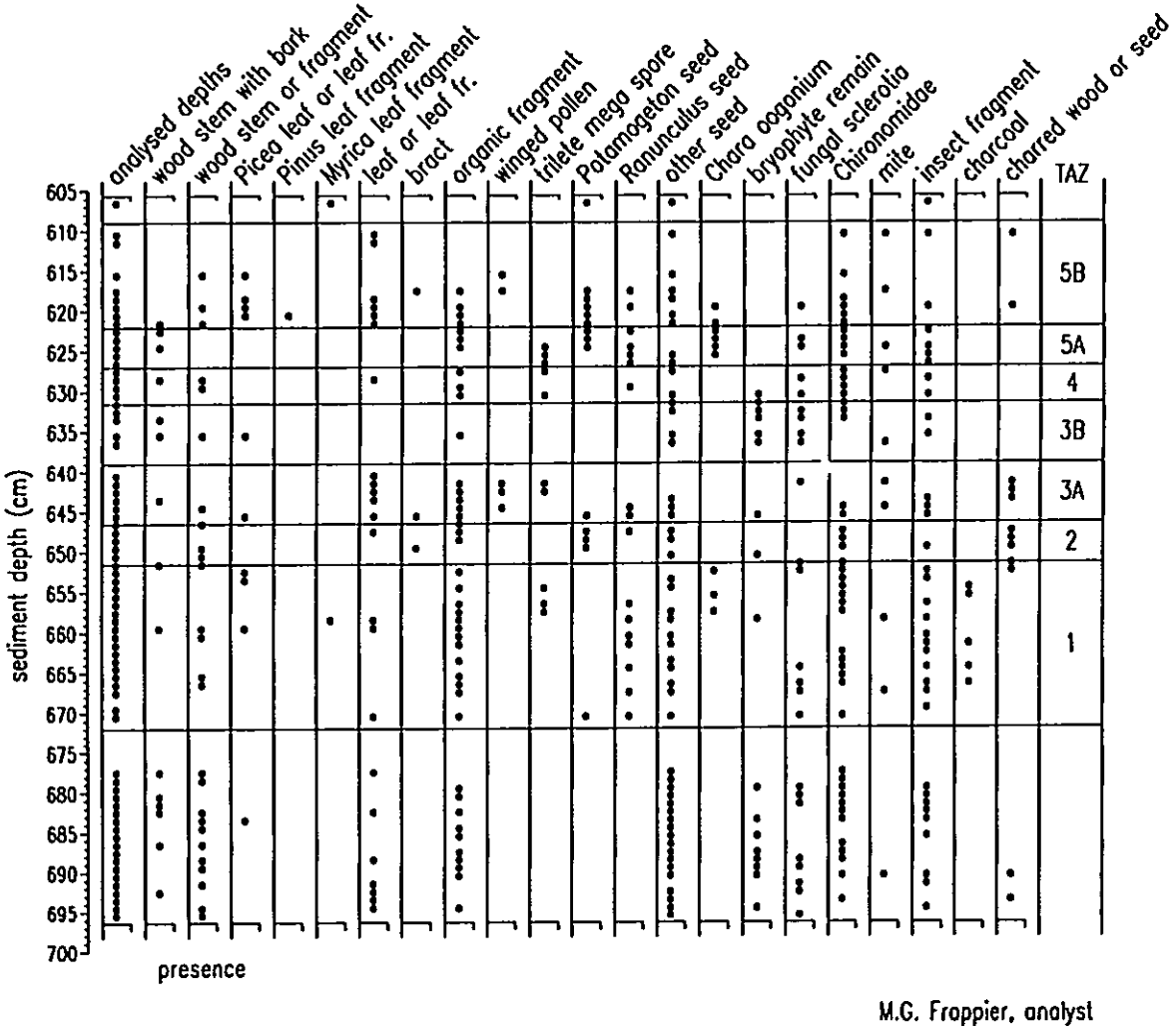

Figure 5.5 Macrofossil presence diagram.

5.4.2 Particle size distribution (sequence 91/II)

A total of 40 samples were processed for particle size distribution. Six samples, taken below the lower minerogenic layer, between 654 and 660 cm, were lost during oxidization of organics. No analyses were performed in the upper, more organic portion of the pollen analysed sequence. The increased organic content of these upper sediments, and the selected method for particle size analysis demanded bulk samples and consequently reduced the resolution. All percentages noted below for different size fractions are based on the total oxidized weight of analysed slice(s). The actual weights, corresponding percentages and log-normal cumulative and frequency distribution graphs are presented in the Annex 3.

The texture percentage diagram (figure 5.4) show the following recurring up-core sequence of dominant size fractions. Coarse silts are replaced by sands and then, the sand is in turn replaced by silt/clay. The flammate boundary between the dark laminated gyttja and the weak red clayey-silt unit marks where this up-core sequence reoccurs.

The texture percentage diagram is divided into 7 analytical zones (3 zones and 4 sub-zones) by cluster analysis (figure 5.6). Only spectra for which all 10 size fractions were measured were used for the zonation. Spectra which did not meet this criterion were 615.5, 621.5, 630.5, 631.5, 650.5, 665.5, 675.5, 680.5, and 685.5cm because they possessed negative values for certain size fractions. These values may be explained in view of sampling errors. Also, since these 9 samples are characterized by the predominance of finer or coarser sediment, the homogeneity of the suspension being samples possibly did not concord with theoretical assumptions of the selected method.

The seven texture analytical zones obtained from cluster analysis of 33 spectra are:

zone 1-	672.0 - 651.0 cm	5 spectra	coarse silt to clay/sand
zone 2-	651.0 - 646.0 cm	4 spectra	sand
sub-zone 3A-	646.0 - 639.0 cm	4 spectra	coarse silt to clay
sub-zone 3B-	639.0 - 631.0 cm	7 spectra	coarse silt to clay/sand
zone 4-	631.0 - 627.0 cm	3 spectra	sand
sub-zone 5A-	627.0 - 622.0 cm	5 spectra	coarse silt to clay
sub-zone 5B-	622.0 - 609.0 cm	5 spectra	clays

In general the textural zones correspond more or less to the gross stratigraphy, their boundaries differ by a few centimeters at the most (figure 5.6). Spectra with abundant sand (~>50%) were agglomerated to form TAZ 2 and TAZ 4. A minor, but distinct component of the composite sand curve in both these zones is coarse sand (figure 5.6). Zone 4 is composed of about three times more coarse sand (14%) than zone 2 (4%), therefore the diagrams. The log curve diagram for this zone is typically constrained between 10 and 100 % cumulative percent while the histograms are very positively skewed.

Both TAZ 2 and TAZ 4 correspond to stratigraphic units which are Carbon poor (figure 5.4). TAZ 2, represented by 4 spectra, corresponds to the *very dark greyish brown* medium sand unit (653.5-646.5) which is bound by gradual contacts. TAZ 4, represented by 3 spectra, corresponds to the narrow unit of *dark reddish brown* sand which is bound by an upper regular but abrupt boundary and a lower irregular boundary. The lower boundary of TAZ 4 extends into the underlying silt unit and follows the outer-edge of related sand clusters. This convoluted boundary likely results from differential sinking (load structures) but can also be the end-product of currents (frictional drag by sand) (Tucker 1982, Conybeare and Crook 1968).

In spite of the differences in boundary features for TAZ 2 and 4, changes in texture assemblages across these boundaries are similar. Variations in the abundance of sand fractions (especially medium sand) mark the lower and upper boundary of TAZ 2 and 4. The lower boundary of TAZ 2 and 4 corresponds with an increase in the abundance of fine, medium and coarse sand (fractions >125μm), while the abundance of (very fine sand), silts and clay (fractions <125μm) relatively decrease. The upper boundary of TAZ 2 and 4 corresponds with the sudden replacement of medium sand by coarse silt.

Although texture results are not available for the entire lower portion of the sediment sequence, combined results from TAZ 1 and TAZ 2 show a coarsening upward sequence. The upper boundary of TAZ 2 is, like TAZ 4, marked by the sudden replacement of high proportions of sand by coarse silt and clay. However, this sudden shift in texture contrasts with the gradual character of the boundary observed in the gross stratigraphy and the Carbon curves. Judging from the comparatively lower proportion of coarse sand, erosion intensity at this time was not as high as during TAZ 3B and 4 time. The lower boundary of the *very dark greyish brown* medium sand unit, associated with that of TAZ 2, is gradual, while the underlying dark silt, associated with upper 9 cm of TAZ 1, is noted for its presence of lighter sand inclusions. These features are not apparent in the texture results. Instead, a up-core continuum of texture populations has masked the effects of possible loading or bioturbation on the vertical organization of the sediment across TAZ 1/TAZ 2 boundary. This masking effect can also have occured in upper TAZ 3B. Sand clusters, that sank into the *weak red* clayey-silt unit associated to TAZ 3B are visually distinguishable. In the texture diagram, a gradual increase of sands coincides with these features. Observations made on the character of stratigraphic boundaries should therefore be considered in the final interpretation of the environmental history of LDL.

In TAZ 3A and 5A, particle size decreases up-core; the proportion of coarse silt decreases with an increase in clay. The clay fraction dominates the texture assemblages in both upper TAZ 3A and 5A reaching percentage values near =>30%. Excluding the bulk portion of clays, the histograms shows that the sediment becomes more or less well distributed amongst the different particles size fractions. Charred wood fragments were recovered from the sediment of TAZ 3A but not TAZ 5A. Texture trends above

both TAZ 5A and 3B diverge wherein that the proportion of clays, increase in TAZ 5B and, decrease with the significant increase of coarse silt in TAZ 3B.

TAZ 3B corresponds with the *weak-red* clayey silt unit identified in the gross stratigraphy. Its lower flammate boundary likely results from loading of silts onto the *very dark grey* laminated gyttja. The abrupt, concomitant changes in texture assemblage and carbon total at this boundary level suggests that a depositional hiatus exists. The convoluted upper boundary of TAZ 3B marks the drastic increase in sands which compose TAZ 4. In lower TAZ 3B, coarse silt attains a maximum abundance of about 50% (637.5 cm) and up-core it decreases with a gradual increase of sands The coarsening-upward sequence of the combined TAZ 3B and 4 could have resulted from a variety of different types of processes acting in the catchment area and in the lake basin. Since the reverse grading which characterizes TAZ 3 and 4 combined is bound by abrupt contacts, it suggests the occurrence of a singular event related to changes in the hydrological regime of the lake catchment or the result of slope instability. Whatever the provenance of the coarser mineral sediment (slope processes, streamborne or airborne?) the mechanism(s) responsible for their transportation to the core site ceased operating abruptly or their supply was rapidly exhausted.

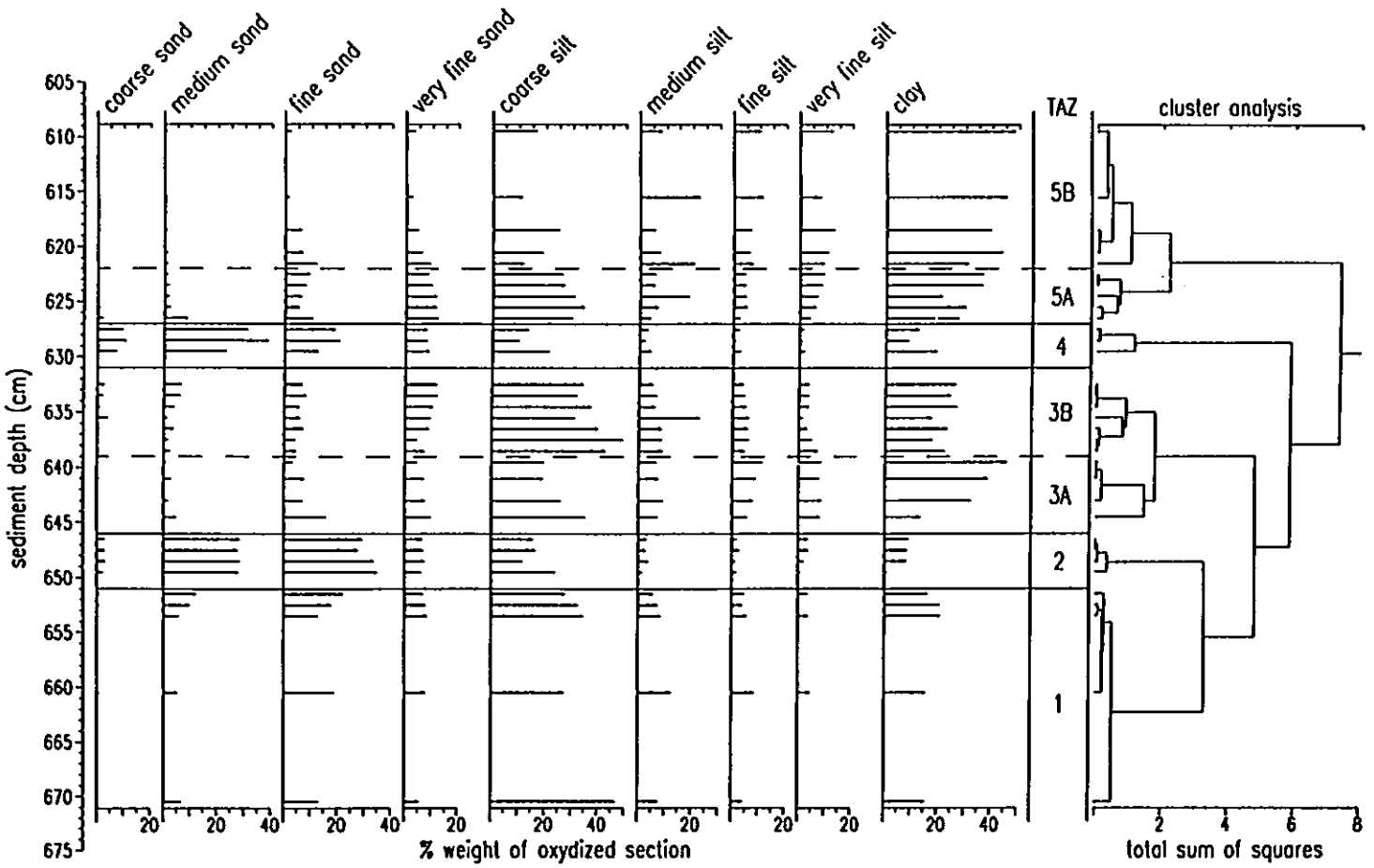

Figure 5.6 Texture percentage diagram with zonation.

5.5 Pollen diagram (sequence 91/II)

A total of 73 spectra are represented on the pollen percentage diagram (figure 5.7). This diagram is divided into 5 pollen zones by cluster analysis. To facilitate the description of zone 2, it was further divided into four sub-zones based on the variability in abundance and associated pollen types (Moore *et al.* 1991). The local pollen analytical zones are:

zone 1-	691.5 - 663.0 cm	11 spectra	Herbs and sedges
sub-zone 2A-	663.0 - 655.0 cm	6 spectra	Cupressaceae /*Betula*
sub-zone 2B-	655.0 - 645.0 cm	9 spectra	*Betula* / Cupressaceae
sub-zone 2C-	645.0 - 639.0 cm	5 spectra	*Picea*
sub-zone 2D-	639.0 - 628.0 cm	11 spectra	*Alnus*, *Betula*
zone 3	628.0 - 620.0 cm	8 spectra	Poaceae, *Betula*
zone 4	620.0 - 602.0 cm	17 spectra	*Picea*, *Myrica*
zone 5	602.0 - 596.5 cm	6 spectra	*Picea*, Cupressaceae

A description of the 5 pollen zones and 4 pollen sub-zones follows. Pollen and *Pediastrum* results will be correlated to the sediment results in the discussion. All percentages noted below are based on the pollen sum of terrestrial taxa (which includes Cyperaceae). A table with actual counts including non-terrestrial taxa is found in Annex 4.

POLLEN ZONE 1: **691.5 - 663.0 cm** Herbs and sedges

Relatively high values of *Artemisia* pollen (15%) occur between 675.5 and 669.5 cm but these abruptly decrease to values as low as 2% in the upper portion of the zone. Cyperaceae reaches the first of its two maxima (23.4%; 668.5 cm) just below the sudden appearance of *Isoetes* (9.4%; 666.5 cm). Cupressaceae pollen rises and attains 23% abundance. The *Betula* curve equally rises but then remains constant and below 26%. Inversely, the coniferous taxa (*Picea*, *Pinus*) decline and remain constant below 13%. *Salix*, *Shepherdia canadensis* pollen and Pteridophyta spores show a decline from their maxima (13, 10% and 3% respectively). *Myrica* and Poaceae pollen are present. *Salix* (?) twigs were picked from the freeze-dried sediments of this zone.

POLLEN ZONE 2:

sub-zone 2A **663.0 - 655.0 cm** Cupressaceae / *Betula*

Sub-zone 2A possess the highest values of Cupressaceae pollen (~23%). The Cupressaceae maximum is followed by one of *Myrica* (14%). Coincident with the *Myrica* pollen maximum is the recovery of leaf fragments (658.5 cm) identified as *Myrica gale*. *Picea* steadily

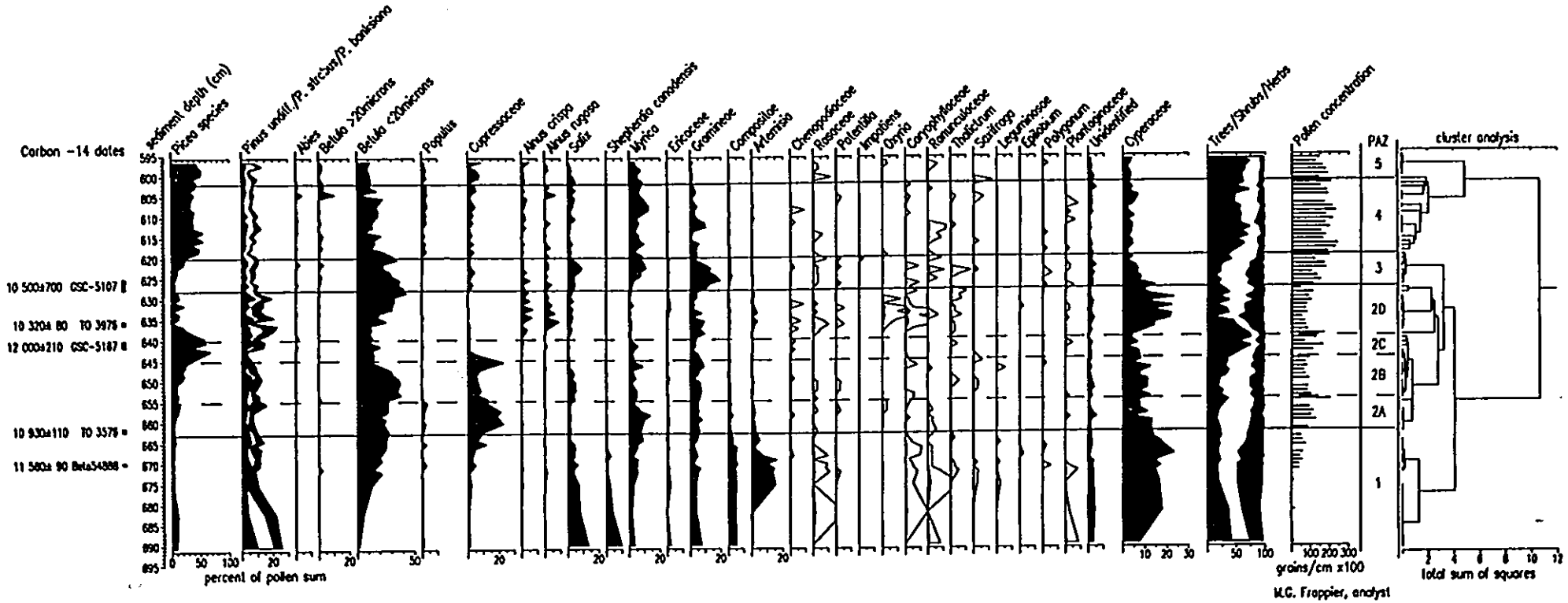

Figure 5.7 Pollen percentage diagram for terrestrial taxa with zonations.

increases from 6 to 15% while Cupressaceae decreases. A fragment of a conifer cone and spruce needle fragments (659.5 cm) were recovered attesting to presence of this tree in the landscape when Cupressaceae pollen percentage decreased. A general increase in the abundance of macrofossils was noticed while picking the freeze-dried sediment of this zone. *Betula* pollen percentages are maintained between 20 and 30%. Minor components of this sub-zone are *Populus* and *Potamogeton* pollen.

sub-zone 2B **655.0 - 645.5 cm** *Betula* / Cupressaceae

Betula pollen that are < 20µm in diameter dominate sub-zone 2B and percentage values reach a maximum value of 38%. One poorly preserved *Betula glandulosa* seed (identified by J.V. Matthews Jr. from the Geological Survey of Canada, 1994) was found near the top of this sub-zone (646-647 cm). The *Betula* pollen percentage maximum coincides with relatively constant percentages of *Picea* of about 10%. When *Betula* percentages values decrease, *Picea* pollen percentage values increase as do Cupressaceae pollen percentages. The latter taxa had decreased near 10% before reaching a second maximum of 23% in upper sub-zone 2C (645.5 cm). Small peaks of *Salix* pollen percentages (5%;652.5 cm) and Polypodiaceae spores (4%;652.5 cm) occur. Cyperaceae varies from 5 and 13%. An *Isoetes* maxima (10%;648.5 cm) marks the middle of this sub-zone (figure 5.8A).

sub-zone 2C **645.5 - 639.0 cm** *Picea*

A rapid decline in Cupressaceae, to percentages near 1%, distinguishes sub-zone 2C from the underlying sub-zone 2B. All shrub curves decline with the important increase of *Picea* pollen percentages. *Picea* comprises most of the arboreal component of the pollen rain and reaches a maximum of 68% (642.5 cm). A slight increase in the pollen concentration occurs.

Fossil R (figure 5.9A) curve displays a peak in the middle of PAZ 2C whereas the *Fossil A* (figure 5.9B) undifferentiated peak marks the PAZ 2C/2D boundary (figure 5.8B). *Fossil A* undifferentiated curve displays two sequential peaks reaching ~275%(641.0cm) and ~475%(639.5cm) of the pollen sum at this level. This fossil was observed during the pollen count. It is spherical and it's approximate diameter is 15µm. A *laesura*, appearing often in the shape of an inversed S, is a distinct feature of this fossil (figure 5.9B: B & C). *Fossil A* undifferentiated was classified according to sculpture: 1) "psilate" (figure 5.9B: A & G), 2) "echinate"(figure 5.9B: H & M). Fossils 234 and 128(A & B), described and figured by Van Geel *et al.* (1989) resemble *Fossil A* "psilate" and *Fossil A* "echinate", respectively. Marine dinoflagellates (?) appear in a few spectra of this sub-zone (640.5, 637.5, 628.5cm) but their identification needs to be confirmed.

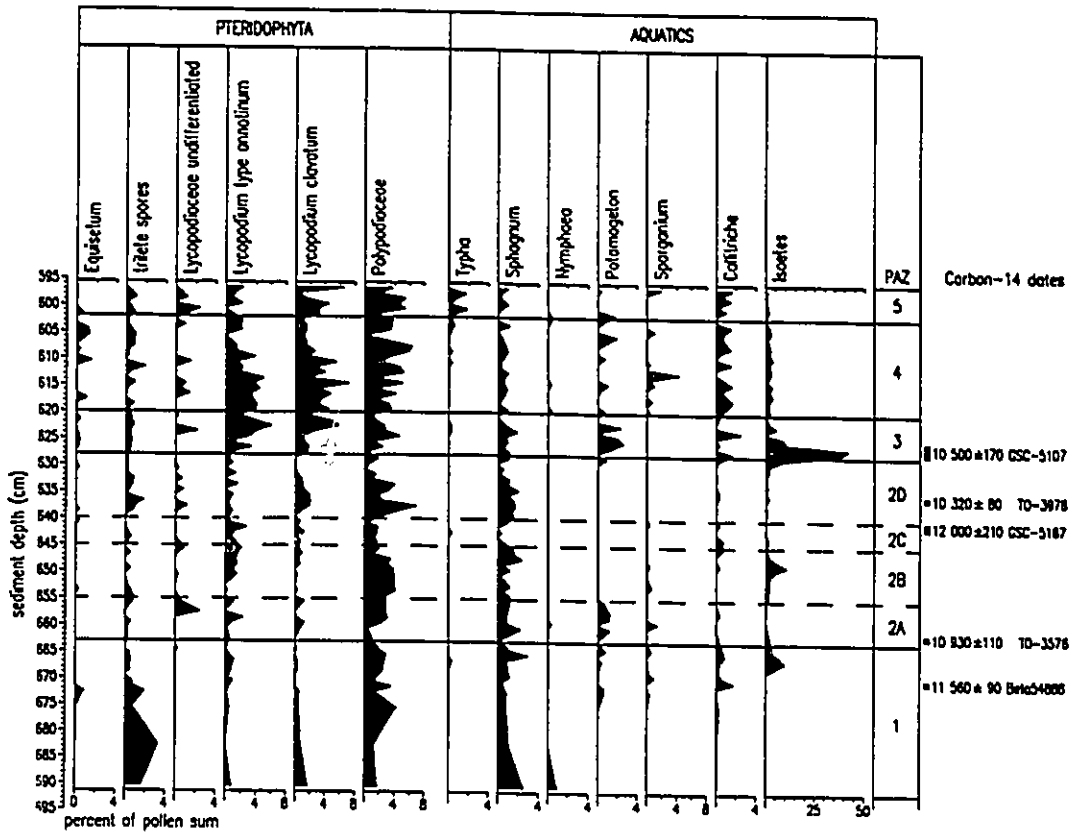

Figure 5.8A Pteridophyta and aquatic percentage diagram with pollen zones.

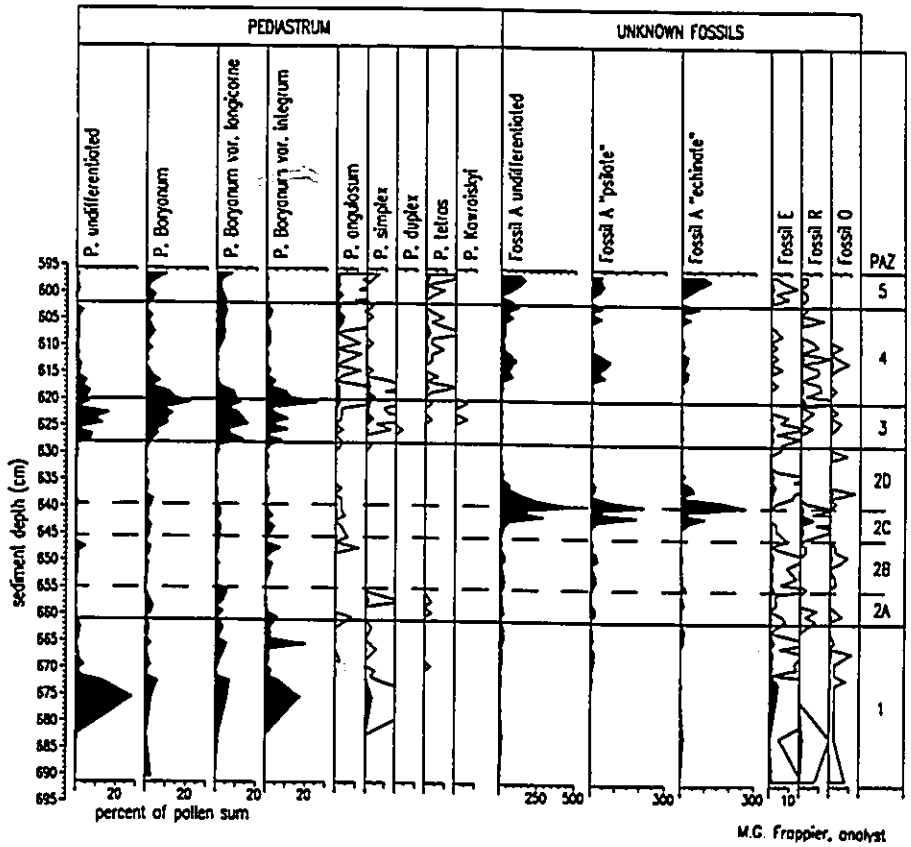

Figure 5.8B *Pediastrum* and unknown fossil percentage diagram with pollen zones

Figure 5.9A

Fossil R: 91/II, 600-601cm, specimen 1

A. 400X. Equatorial view. Aperture circumscribed by an involute ridge. High focus.

B. 400X. Equatorial view, longitudinal saccate ridges on either side of aperture. Scabrate sculpture between saccate ridges and aperture. Low focus.

C. 400X. Underside of specimen 1. Thin pointed, low longitudinal ridge located between two saccate longitudinal ridges.

Fossil R: 91/II, 600-601cm, specimen 2

D. 400X. Polar view ("col"), junction of two pairs of longitudinal ridges with minor ridge appearing as "knobs". Lack of sculpture around polar "knobs".

E. 400X. Thin pointed, low, longitudinal ridge. Becomes saccate near pole and appears to merge with saccate ridge.

F. 400X. Thin pointed, low, longitudinal ridge. Lack of sculpture on either side of ridge.

G. 400X. Saccate longitudinal ridge. Sacs are not aligned. High focus.

H. 400X. Polar view (col), junction of two pairs of saccate, longitudinal ridges. Lower central section ornate with intermediate "knobs" forming no ridge. Lack of sculpture around central "knobs".

I. 1000X. same as H

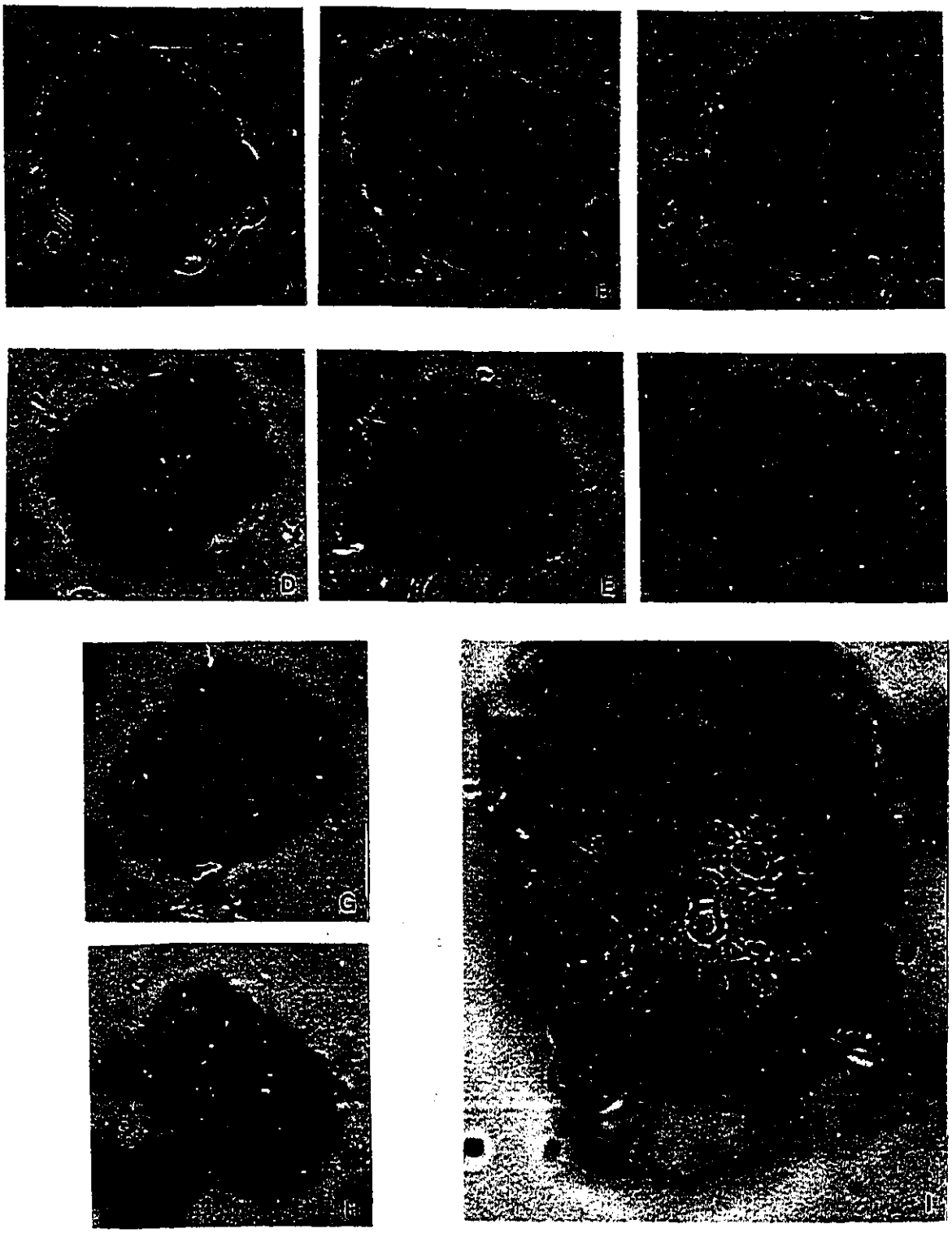

Figure 5.9A Fossil R: 91/II, 600-601cm.

Figure 5.9B
Fossil A (psilate type): 91/II, 599-600cm.
A. 1000X. Top of laesura.
B. 1000X. Inversed S shaped laesura.
C. 400X. Inversed, S shaped laesura.
D. 400X. Figure 8 shape of laesura when pressed under cover slip.
E. 400X. Rigid Fossil A in comparison to Juniperus pollen grain.
F. 400X. Inversed S shaped laesura. Psilate sculpture. High focus.
G. 400X. Thick membrane. Low focus.

Fossil A (echinate type): 91/II, 599-600.
H. 1000X. Thick base spines, regular pattern of distribution. High focus.
I. 1000X. Thick membrane. Length of spines. Low focus.
J. 400X. same as H.
K. 400X. same as I.
L. 400X. Spines evenly distributed. Laesura or broken. High focus.
M. 400X. Thick membrane. Length of spines. Low focus.

Fossil E: 91/II, 635-636cm.
N. 400X. Radial pattern exposed by the arrangement of spines. Membrane thickness.
O. 1000X. Fine spines gives inner membrane a serrated appearance.
P. 400X. Equatorial view. Heteropolar. Fine spines organized in rows.
Q. 1000X. same as P. Spines are longer at base.
R. 400X. Aperture at one pole circumscribed by gemmate. High focus.
S. 400X. Thick membrane. Length of spines. Low focus.

Fossil B: 91/II, 599-600cm.
T. 400X. Reticulate sculpture. Fissure.
U. 400X. Serrated silhouette.
V. 400X. Reticulate and folded. High focus.
W. 400X. Reticulate and folded. Low focus.

Fossil T: 91/II, 599-600cm.
X. 400X. Central brochus(hexagon) and floret formed by six brochi
Y. 400X. Surrounding membrane (perine?). Low focus.
Z. 1000X. same as X.

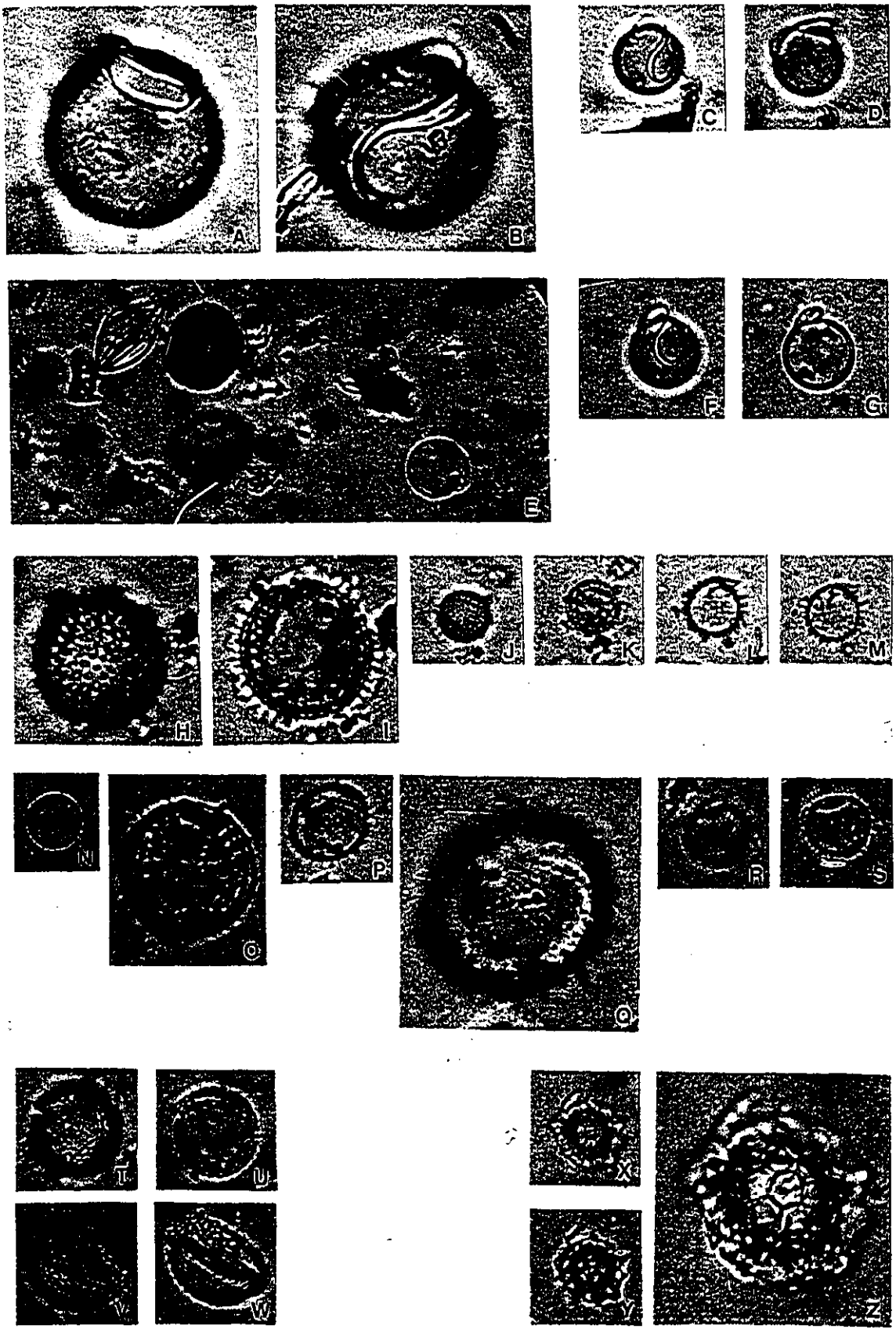

Figure 5.9B Fossil A (psilate & echinate), Fossil E, B & T: 91/II.

Figure 5.9C Fossil O: 91/II, 600-601cm.

A. 400X. Annulus circumscribed irregularly by gemmate.

B. 400X. Equatorial view. Heteropolar. Annulus at one pole and "skirt" (membrane) at other.

C. 400X. Variation in sculpture. Scabrate to spinulose.

D. 400X. Quasi-rows of spines.

E. 400X. Termination of quasi-rows of spine with "skirt" (membrane). Irregular and underside-discontinuous reticulum with clavate.

Figure 5.9C Fossil O: 91/II, 600-601cm.

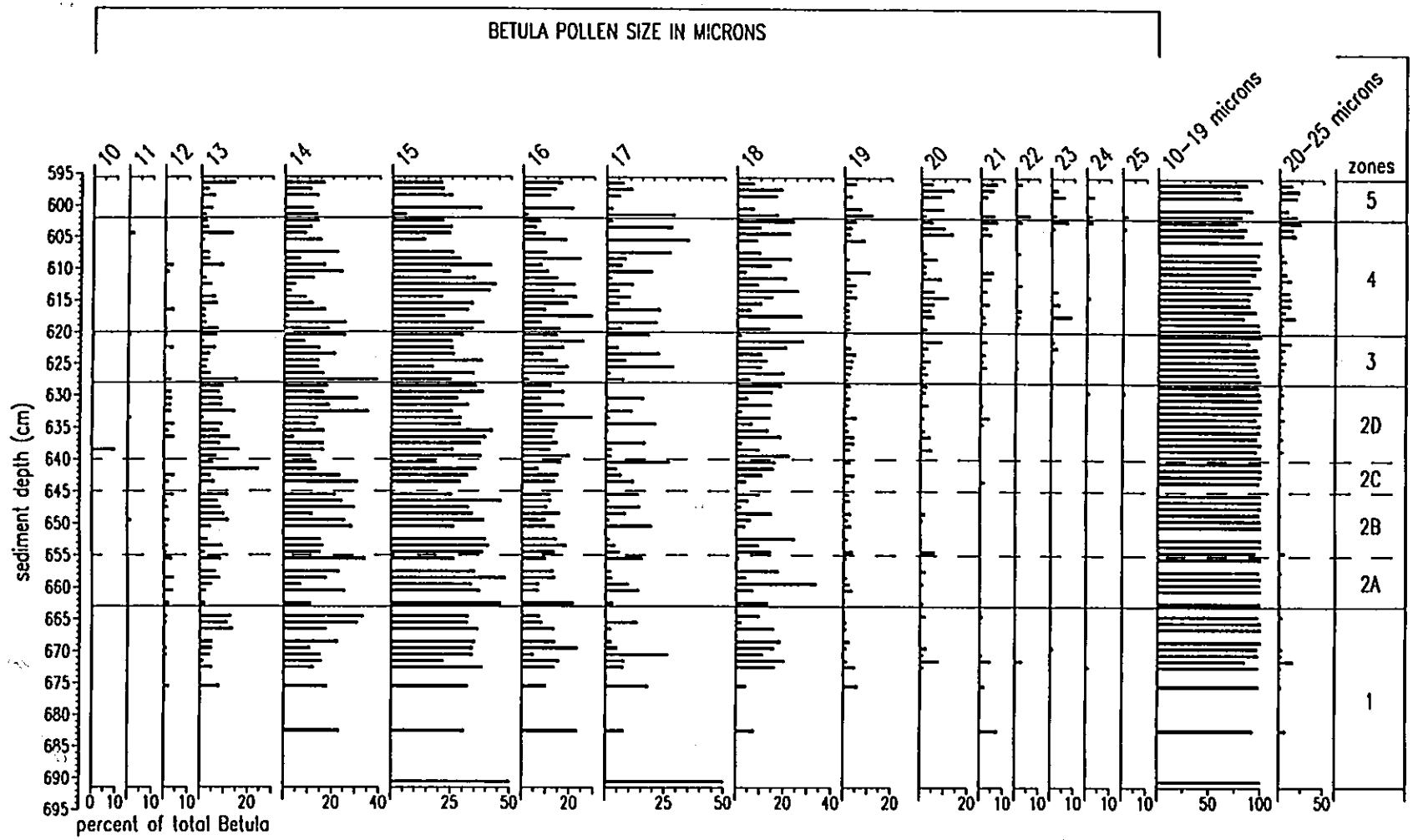

Figure 5.10 *Betula* size percentage diagram on total *Betula*.

sub-zone 2D **638.5 - 628.0 cm** *Alnus, Betula*

Betula, Salix and Cyperaceae pollen, which had reached low percentages in sub-zone 2C, increase with a decrease of *Picea* pollen percentage. *Picea* percentages reach a low of 3% at 635.5 cm. Parallel to the decrease in *Picea* pollen are maxima in *Pinus* pollen (23%;636.5 cm) and Polypodiaceae spores (7%; 637.5 cm). Almost coincident with these taxa are maxima of Cyperaceae pollen (23%) and *Alnus* spp. maximum (12%; 635.5 cm). The *Alnus* spp. pollen maximum, occurring at 635.5 cm, is comprised of as much as 80% *Alnus rugosa* type pollen. However, neither *Alnus crispa* nor *Alnus rugosa* dominates sub-zone 2D. The peak in *Alnus* spp. pollen coincides with minor maxima in Poaceae(10%), *Artemisia* (4%), *Lycopodium clavatum* type (2%;636.5 cm) and Pteridophyta (mostly *Botrychium*)(2%; 636.5 cm). Above the *Alnus* spp. pollen percentage maximum, the appearance of Oxyria/Rumex (~2%; 632.5 cm) accompanies maxima of Ericaceae (3%; 633.5) and Caryophyllaceae (3%; 633.5 cm).

POLLEN ZONE 3 **628.0 - 620.0 cm** Poaceae, *Betula*

The PAZ 2D/3 boundary coincides with the *Betula* pollen percentage maximum (43%;627.5 cm). While *Betula* spp. pollen percentages decline in PAZ 3, the occurrence of *Betula* pollen, >20μm in diameter, becomes prevalent (figure 5.10) and *Picea* pollen percentages increase. A Poaceae pollen percentage maximum (19%;625.5 cm) corresponds with a small increase in Tubuliflorae, and the increase of both taxa precedes the *Salix* pollen percentage maximum (9%;622.5 cm). Both *Alnus crispa* and *Alnus rugosa* type pollen percentages decrease from their maximum values occurring in PAZ 2D. *Quercus* and Cupressaceae pollen percentages do not surpass 1%. *Myrica* pollen percentages increase while *Artemisia* and Cyperaceae pollen percentages decrease. *Pteridophyta* and Ericaceae pollen percentages remain constantly low throughout while those of Lycopodiaceae generally increase in the upper portion of this zone. The re-appearance of *Potamogeton* (3%;628.5 cm) since sub-zone 2A corresponds to the sudden and prominent percentage peak of *Isoetes* (38%; 627.5 cm). Pollen concentrations in this zone have slightly risen to reach near constant values (10^4 to 10^5 grains/cm^3).

POLLEN ZONE 4 **602.0 - 620 cm** *Picea, Myrica*

This PAZ is marked by the highest pollen concentrations. *Picea* percentages are twice as high than in PAZ 3. In the lower portion of this zone, the Picea percentage curve reaches a minor maximum of 59% (at 613.5 cm). *Myrica* percentages are relatively high and vary between 4 and 13%. *Pinus* spp. pollen percentages have decreased, especially *Pinus banksiana*-type. *Betula* pollen percentages remain constant while a slight increase in Cupressaceae, *Salix* and Cyperaceae occurs. *Populus, Fraxinus, Abies* and *Typha* pollen are prevalent. In the upper portion of this zone, minor peaks of *Myrica* (10%;616.5 cm

and 13%;607.5 cm) and of *Artemisia* (below 1.5%) coincide with a slight decrease of *Picea* pollen percentages and *Fossil A* undifferentiated percentages from their minor maxima peaks.

POLLEN ZONE 5 **596.5 - 602.0 cm** *Picea*, Cupressaceae

Picea pollen percentages rise while *Betula* pollen percentages are constant. Cupressaceae pollen percentages increase to almost 8% while shrub *Salix* and *Myrica* begin to decline. Poaceae has decreased and *Typha* becomes important. Cyperaceae and *Lycopodium annotinum* type are constant, but *L. clavatum* increases. *Fossil A* percentages have risen and are comparable to those of mid PAZ 4. *Isoetes* percentages continue to decrease since lower PAZ 3. In general, shrub pollen percentages decrease while the tree pollen percentages increase. The pollen concentrations return to values similar to those exhibited in PAZ 3.

5.5.1 *Pediastrum*

Eight taxa of *Pediastrum* occur in the basal sediments of LDL (figure 5.11). The coenobium of *P. Boryanum*, *P. Boryanum* var. longicorne *and P. integrum* dominate the basal profile of LDL sediments. *Pediastrum* maxima in PAZ 1, 2B and 3 are composed of a higher number of different *Pediastrum* taxa. *P. simplex* and *P. tetras* make an early appearance in PAZ 1 but decrease at mid PAZ 2A. These later re-appear in PAZ 3. Also in PAZ 3, *P. duplex* and *P. Kawraiskyi* are present. The highest values of *P. Boryanum* occur in the upper portion of PAZ 3, along with a peak of *P. simplex*. The prominent re-occurrence of *P. tetras* in PAZ 4 follows that of *P. simplex* in pollen zone 3. *P. angulosum* attains its highest abundance in PAZ 4. The latter also characterizes the *Pediastrum* assemblages of the pollen sub-zone 2C.

5.6 Correlation diagram

In general, comparison of the pollen and texture results show that corresponding TAZ and PAZ zones vary in thickness and in turn, zone boundaries typically differ by a few centimeters (figure 5.12). The local PAZ 1, 2A and lower portion of 2B (herbs and sedges to *Juniperus* and increasing *Betula*) are associated with TAZ 1 (coarse silt to clay/sand). The remaining PAZ 2B (*Betula*) corresponds with TAZ 2 (sand). PAZ 2C (*Picea*) closely matches the core distance of TAZ 3A (coarse silt to clay). PAZ 2D (*Alnus* and increasing *Betula*) corresponds to TAZ 3B and 4 (coarse silt to clay/sand). PAZ 3 (Poaceae and decreasing *Betula*) covers slightly more vertical core distance than TAZ 5A (coarse silt). And, PAZ 4 (*Picea* and *Myrica*) corresponds to TAZ 5B (silt/clay).

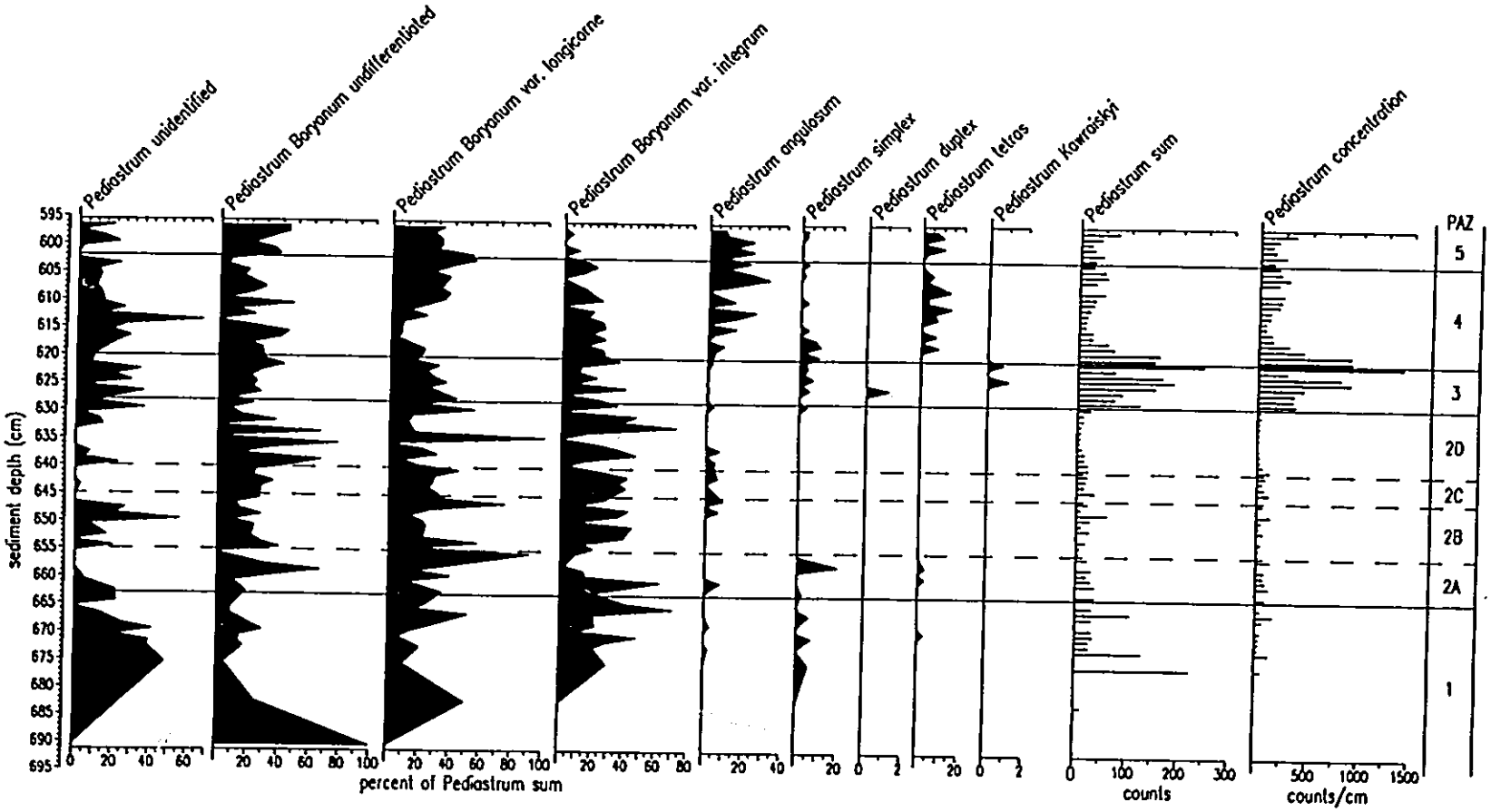

Figure 5.11 Pediastrum percentage diagram

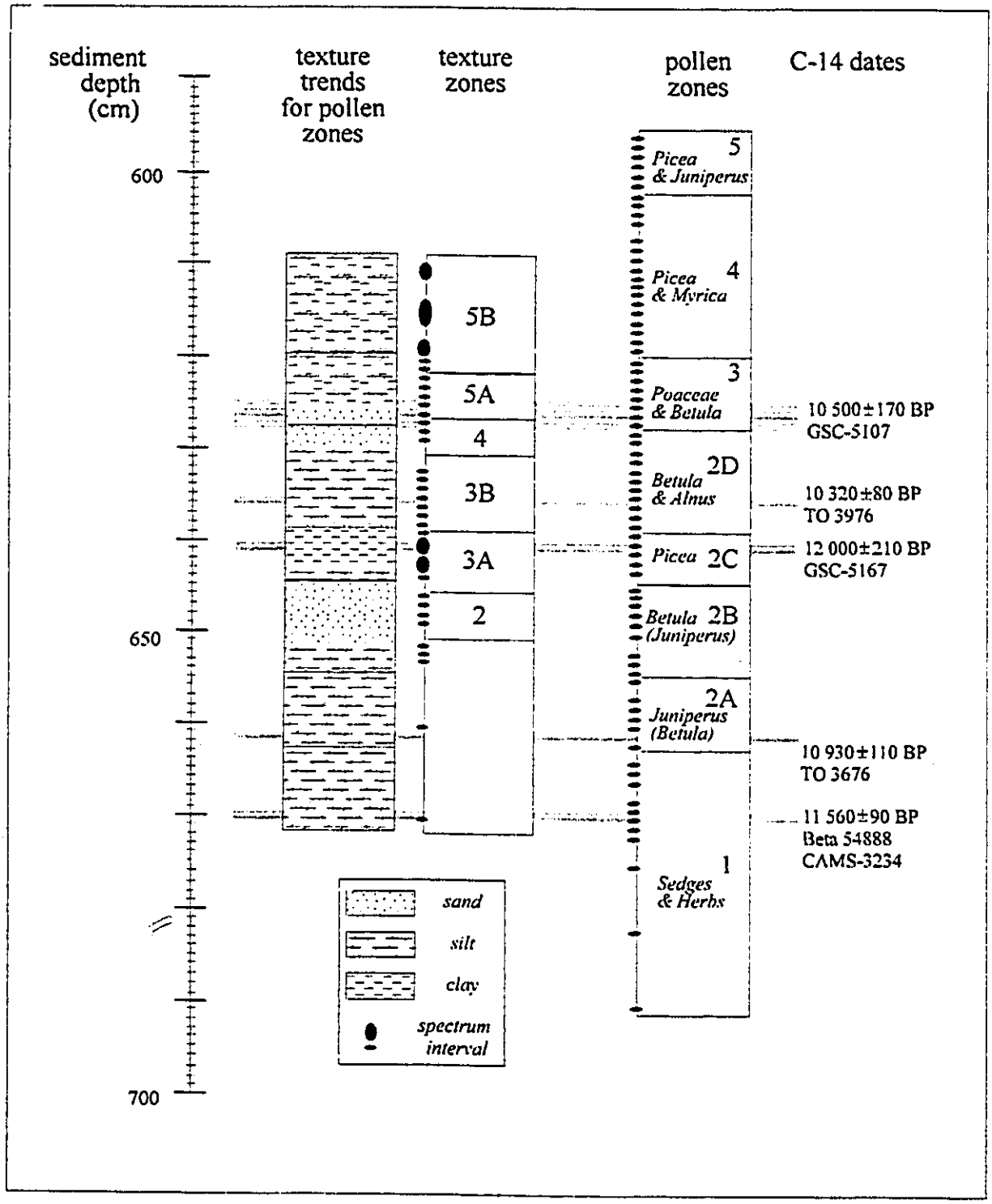

Figure 5.12 Dated correlation diagram: texture and pollen zones of basal sequence 91/II, Little Dyke Lake, Nova Scotia.

CHAPTER 6 - INTERPRETATION OF LOCAL POLLEN ASSEMBLAGES

At the base of PAZ 1 (figure 5.7), peaks of *Salix* and *Shepherdia canadensis* pollen percentages which are accompanied by an abundance of herb pollen suggest that after deglaciation, a shrub tundra with willow (*Salix*) and soapberry (*Shepherdia canadensis*) occupied the site. Other shrub components of the pollen rain such as *Betula* (birch), *Juniperus* (juniper) and *Myrica* (sweet gale) become more important in the upper portion of PAZ 1, most likely as a result of climatic improvement. Carbon-14 dating would place the initial shift in the dominance of the shrub community to *Juniperus* at about 11 600 yrs. BP. The abundance of Pteridophytes, Cyperaceae, Rosaceae, Poaceae, *Artemisia* and Ericaceae pollen, and the later appearance of ruderal herb pollen such as *Thalictrum*, *Polygonum* and Chenopodiaceae indicate that the landscape remained open along with the shift in the shrub composition of the vegetation. The discovery of a few grains of *Epilobium* and of *Typha* and the appearance of more-or-less thermophilous aquatics such as *Callitriche*, *Sparganium* and *Potamogeton* in the upper portion of the zone support the hypothesis of climatic warming.

In the lower portion of PAZ 1, *Picea* pollen percentages are low and they decrease up-core. *Picea* pollen is suspected to have been transported from long distances, and its decrease is attributed to an increased production of a more abundant and diverse local vegetation after deglaciation. This is also probably the case for *Pinus* pollen and thermophilous taxa such as *Ostrya/Carpinus*, *Fraxinus*, *Juglans* and *Quercus*. Relative frequencies of modern day *Pinus* pollen have been reported to reach values just above 20% when pine trees were not present in the immediate area (Terasmae and Mott 1965). The low pollen concentrations in the lower portion of this zone supports the explanation of long distance transport.

A sudden small peak in *Isoetes* spores (figure 5.8A) occurs with the development of juniper shrub tundra in upper portion of PAZ 1. *Isoetes* may have arrived in the lake at this time or conditions suddenly became favorable to its growth. *Isoetes* is described as an aquatic pteridophyte that prefers stony and sandy substrates poor in basic silts (Sculthorpe 1967). Ogden (1959) reported that a sharp peak in *Isoetes* may be related to increased slopewash and the development of acidic soil conditions near the margins of the lake. Krog (1954) reported that *Isoetes* indicates oligotrophic waters. Further studies which measure the size of *Isoetes* spores may be helpful in identifying the species type and, consequently, would yield more certain information on the state of the lake (Cody and Britton 1989).

Just below the *Isoetes* peak, *Pediastrum angulosum* occurs at LDL (figure 5.8B). Nielsen and Sorensen (1992) presumed this green algae was thermophilous and indicative of oligotrophic conditions. Crisman (1978) found *P. angulosum* to be dominant in lakes of the coniferous region of Minnesota and interpreted it as an indicators of acidic waters. Almost coincident with the appearance of *P. angulosum* in this PAZ is the occurrence of *Pediastrum tetras*. Nielson and Sorensen (1992) inferred from the maximum development of *P. tetras* in the middle of the Pre-Allerød (transition zone b to zone c) from a

former lake in the south-eastern part of Jutland, Denmark that conditions were primarily oligotrophic at this time. They were unable to associate the presence of *P. tetras* with cold water temperatures (unlike previous studies) because of the contradictory presence of thermophilous aquatics (e.g. *Typha*). Likewise, pollen of thermophilous aquatics, as is noted above, were detected in the second half of PAZ 1 at LDL. Throughout the same part of PAZ 1, *P. simplex* is also important. This chlorrocale has been associated with warming and eutrophic lake conditions (Goulden 1970). *P. simplex* does not occur at the same levels as *P. anguiosum* and *P. tetras* and its numbers progressively decline throughout the upper portion of zone 1. *P. Boryanum* is the most abundant in PAZ 1 but because this chloroccale is well represented at all analysed depths, and its ecology is not well known (Nielsen and Sorensen 1992) no inferences based on its occurrence are drawn. *P. Boryanum* var. *integrum*, comprises at least 30% of the total *Pediastrum* in zone 1. *P. integrum* (*P. Boryanum* var. *integrum* viz. L. Venne) has been considered by Nielsen and Sorensen (1992) a benthic species associated with cold water temperatures.

The pollen results for zone 1 suggest vegetation with a low arctic character occupied the area at about 11 500 yrs. BP. The juniper population, accompanied by birch and *Myrica gale* succeeded the willow and soapberry shrub community as a result of warmer and probably drier conditions. Well drained tills of the area and open grounds may have been favorable to the growth of the opportunistic juniper. Poplar (*Populus*) pollen percentages do not surpass 5%, but since this tree is usually underrepresented in the pollen rain (Webb *et al.* 1991) it possibly occurred in upland sites of the region. It is proposed that the mineral sediment input was an important factor to the production of *Pediastrum* sp. The climate resembled that near present day northern tree-line.

In PAZ 2A there is an increase abundance of shrub pollen, particularly Cupressaceae and *Myrica* (presumed *Myrica gale* based on the recovery of a leaf fragments) and a decrease of herb pollen (i.e. *Artemisia* and Tubuliflorae). Cupressaceae pollen values are considered to represent Juniperus because of the associated pollen assemblage. The Cupressaceae peak is taken to represents the maximum development of a juniper scrub population. The discovery of spruce (*Picea*) macrofossils (male part of flower and leaf fragments) attest to the presence of spruce in the area even though *Picea* pollen percentages do not surpass 20%. The low representation of *Picea* in the pollen diagram could result from the fact that this tree was reproducing vegetatively or shift in wind direction occured. A wood fragment picked from sediment just below the depth from which the spruce fossils were discovered was dated at 10 930 +/- 110 yrs. BP (TO-3576). With respect to the obtained chronology, spruce would have taken =<600 years to migrate to the site after deglaciation. Spruce and sweet gale (*Myrica gale*), a shrub which today extends "north nearly to the limit of trees" (Porsild and Cody 1980), would have together existed in the landscape at the same time the juniper population expanded. Then, with the continued amelioration of climate, *Juniperus* pollen percentages decreased while tree pollen percentages (i.e. *Picea* and *Populus*) slightly increased. The ground flora component of the pollen rain is comprised of increasing spore

percentages of Pteridophyta and *Lycopodium* indicating that open conditions persisted over parts of the landscape.

Visual examination of the sediment revealed that the core depth interval related to PAZ 2A is generally composed of less sand and is more organic than underlying sediment related to PAZ 1. A slight increase in the pollen concentration and the first maximum of total and non-carbonate Carbon supports the hypothesis of continued warming which allowed spruce to arrive and grow in the area. Careful examination of the upper sediment portion of PAZ 2A revealed that the sediment is mottled between 652-660cm and lighter coloured sand inclusions occur at the upper PAZ 2A boundary. These latter characteristics of the sediments correspond with the decline of juniper and the increasing proportion of Pteridophyta and *Lycopodium* spores. The pollen trends are difficult to explain in view of the texture data, but their associations suggest that erosion intensity in the lake catchment increased at the same time the ground cover of a forest-tundra was better represented in the pollen diagram. The discovery of charcoal fragments in PAZ 2A suggest that changes in the landscape were associated with fire. This is possible because the discovery of wood fragments in the sediment indicate fuel was available to sustain a fire. Further studies on the charcoal content of the sediment are needed because coal deposits are present in the region (Stea *et al.* 1987). Also, in the upper portion of PAZ 2A, *Isoetes* percentages slightly increase while the *Potamogeton* pollen percentage curve declines. The most simple explanation for these aquatic pollen trends is that these plants would have been influenced by the increase inwash of soils which had developed under the shrub cover.

The interpretation given to PAZ 2A time is that of a open forest-tundra community wherein juniper was prominent and spruce trees were present. Judging from the low pollen percentages of *Picea*, the recovery of *Picea* macrofossils and the pollen assemblage, spruce was rare, or in the form of krummholz in the landscape and, therefore, was not an important constituent of the pollen rain. A reduction in the juniper pollen percentages and an increase in fern and fern allies spores is associated with an observed increase in the proportion of coarser lake sediments. Together the evidence points to a disturbance in the juniper scrub community. It is uncertain if the decline of *Juniperus* pollen percentages is related with the successional development of the forest-tundra under climatic warming or due to disturbances occurring in the lake catchment.

In PAZ 2B, *Betula* pollen curve reaches its first maximum and then *Picea* pollen percentage curve clearly begins to rise. Spruce needle fragments were recovered throughout this sub-zone supporting the proposal that spruce trees continued to exist in the immediate landscape at this time. Since the *Betula* pollen peak is predominantly composed of *Betula* pollen that is <20μm (figure 5.10) and, that one poorly preserved *Betula glandulosa* (dwarf birch) seed (identification by John Matthews 1994) (646-647 cm) was recovered, it is reasonable to believe that the first *Betula* peak, composed of *Betula* grains <20μm, reflects

the expansion of shrub birch at LDL. Although *Betula* grains >20μm are not important, it remains uncertain if tree birch is present or near the site. Palynologists (Livingstone and Livingstone 1958, Leopold 1956b, Ives 1977 and Comptois 1981, Edwards 1990) have cautioned the use of pollen size to separate birch species.

When shrub birch spread in the area, it was accompanied by willow (*Salix*), as it is found today in the low-arctic shrub tundra (Porsild and Cody 1980). As the pollen percentages for these two shrubs increase, the *Juniperus* pollen percentages decrease markedly. Changes in the shrub component of the pollen rain may be due to the persistence of cooler conditions because modern distribution maps of shrub birch and juniper show that the former more commonly occurs above tree line whereas the latter shrub more commonly occurs below tree line (Porsild and Cody 1980). More evidence which suggest that open, cool conditions persisted over the delta at this time is the slightly more important herb and fern component of the pollen rain. This includes the re-occurrence of *Thalictrum, Saxifraga, Polygonum* and Leguminosae, which were particular to upper PAZ 1, and the slight increase in Poaceae and Pteridophyta percentages. The increased abundance of *Lycopodium* spp, especially *Lycopodium annotinum*-type pollen in upper PAZ 2B (figure 5.8A) points to cool temperatures. Open conditions which would have been maintained due to the persistence of cooler climate would give juniper the competitive advantage over shrub birch when climate warmed again. This explains the second *Juniperus* pollen percentage peak which accompanies increasing *Picea* pollen percentages in upper PAZ 2B.

The increased *Betula* and *Salix* pollen percentages in PAZ 2B are associated with the gradual increase of fine and medium sand observed in the upper portion of TAZ 1 (figure 5.6). Their maxima and subsequent decrease corresponds with the maxima in almost all sand fractions (excluding very fine sand) observed in TAZ 2. The 4 texture spectra of TAZ 2 possess >50% sand, pointing to an even higher marked erosion intensity than upper TAZ 1. Inorganic Carbon and calcium carbonate (equiv.) content is more important and the *Isoetes* pollen percentage curve reaches its second maximum. Other notable pollen trends associated with the coarse sand sediments are the increase of *Picea* and *Lycopodium annotinum*- type pollen percentages. The significant decrease of *Juniperus* pollen percentages from its second peak (upper PAZ 2B) coincides with the significant decrease of sand curve (upper TAZ 2).

An alternate interpretation of the combined pollen (PAZ 2A) and texture trends (TAZ 1 and 2) is that a certain pioneering community was maintained as a result of conditions which could have favored the recurrence of fires. Readily burnable material would have been available on the Folly delta. The increase of *Juniperus* pollen percentages in PAZ 2A which represent the early expansion of juniper, coincide stratigraphically with the recovery of charcoal fragments found in upper TAZ 1 and TAZ 2 (figure 5.5). Conversely, the low *Juniperus* pollen percentages and *Betula* peak of PAZ 2B are associated with the presence of charred wood fragments or seeds. If the decrease of *Juniperus* pollen percentages are

taken to indicate more frequent disturbances occurring in the immediate landscape, then increasing *Picea* pollen percentages may be explained in view of two climatic scenarios. Either, the latter merely reflect an opening of the landscape or the increasing proximity of the spruce forest due to continued warming. The vegetation succession after deglaciation may well reflect the ecology of fires. That is, ruderal plants such as grasses and juniper and some spruce would have persisted in the area until fire recurrence intervals decreased. When the scrub cover did thin, the soil's susceptibility to erosion increased, hence the sudden arrival of coarse sand (TAZ 2) to the lake basin. Topographical maps of the area show very well the variable topography over the Folly delta which would have allowed shrub birch to coexist with juniper, willow, sedges and spruce. Shrub birch would have covered the entire landscape whereas willow and sedges would have grown around LDL and occupied, along with spruce, slopes and the bottom of depressions. The ecological impact of fires would have permitted the sheltered lowland vegetation and regional vegetation to be better represented in the pollen rain than the local upland juniper and poplar. The same proposal noted above for the cooling hypothesis serves to explain the second *Juniperus* pollen percentage peak observed in upper PAZ 2C. However, the lower frequency of fires combined with the amelioration of climate in an open landscape, would have in this scenario, permitted the juniper population to expand for a short while.

Another interpretation of the pollen data is considered in view of the texture data. Since TAZ 2 is characterized by an abrupt and significant decrease in the proportion of sands which coincides with a sudden decrease of *Juniperus* pollen percentages, this suggest that the sediment possibly influenced the pollen record. The hypothesis is weakened by the fact that the sudden decrease in the *Juniperus* pollen and sand percentages contrasts with the gradual character of the boundary seen in the gross stratigraphy, some pollen curves (e.g. *Picea*, *Betula*), the Carbon curves and on the x-ray. However, the contrast in the response of different pollen producers may be explained by the continuous input of regional (*Picea* & *Betula)* pollen, although locally, conditions were unfavourable to the growth of juniper.

In view of the combined sediment and pollen data it is proposed that an increase in erosion intensity, detected in upper PAZ 2A occurred along with changes in the dominant shrub component of the pollen rain. The juniper scrub community persisted despite the disturbances which occurred in the landscape. It is uncertain if these disturbances were related to a cooler or warmer climate. The sediment supply to the lake may have governed to a certain degree the local pollen assemblage of upper PAZ 2B. Other factors that may have also played a role in the rapid reduction of the *Juniperus* pollen could be the closing vegetation cover and the organic enrichment of soils.

High values of Picea pollen percentages (PAZ 2C) and the recovery of many needle fragments (TAZ 3A) suggest that spruce was more important around the lake. The expansion of spruce affected the pollen percentages of *Juniperus*, *Betula*, *Salix*, Cyperaceae, Poaceae and Polypodiaceae. *Picea* pollen percentages as high as ~70%, as is the case for LDL, have been recorded for surface samples of the

northern boreal forest of Québec and Labrador (Delcourt *et al.* 1984) and the lichen woodland of northern Québec (Gajewski 1991). This implies cooler conditions than today existed in the area, but conditions were warmer then when the scrub community prevailed (upper PAZ 2A). The *Picea* peak and the general decline in the herb and shrub component of the pollen rain is interpreted as the development of a spruce woodland as a result of warming.

An increase in the proportion of organics versus mineral matter (TAZ 3A) associated with the development of the spruce woodland (PAZ 2C), indicates that erosion intensity in the lake catchment had diminished. The warmer climate may have favored lake productivity, yet the *Pediastrum* concentration curve displays no clear rise at this time. A small peak of *Pediastrum angulosum* does, however, characterize PAZ 2C and possibly reflects the warmer and more acidic conditions of the lake. The relative increase in organic carbon implies that humus had accumulated in parts of the lake catchment and the prevalent occurrence of leaves or leaf fragments in the sediment indicate that some of this humus was being washed into the lake. The production of aquatic plants appears to have been influenced by the increased accumulation of organic matter and warmer temperatures. The recovery of *Potamogeton* and *Ranunculus batrichium* grp. seeds at the TAZ 2/3A transition indicate that these plants were present at the lake margin before the increased inorganic content. Quillwort (*Isoetes*), which possesses an affinity for mineral sediments, produced less spores with the gradual increase in organic content, whereas the abundance *Callitriche* pollen percentages conversely increased.

The *very dark grey*, organic rich sediments in upper TAZ 3A contained coarser organic material, relatively more macrofossils and an increased proportion of inorganic carbon. These trends are interpreted to be the result of increased erosion into the lake catchment rather than increased lake productivity. The recovery of charred wood fragments or seeds at corresponding levels points to continued fire disturbance in the locality, yet a *Picea* pollen percentage peak and decline occur at these level. The peculiar peak(s) of *Fossil A* (figure 5.8B) which mark the PAZ 2C/2D boundary are associated with the decline of *Picea* pollen percentages. It is tempting to attribute the demise of the spruce woodland to the occurrence of fire. The bulk radiocarbon date obtained on the upper sediments of TAZ 3A gives an age of 12 000^{+}/-210 GSC-5167 for this event of litter erosion. However, the high carbonate content of this sediment (figure 5.4) puts into question the reliability of this date. Carbon-14 dates from the late-glacial sediments are notorious for contamination by old Carbon (Aravena 1990, Lowe and Walker 1984). The best-fit linear curve for dates obtained from LDL sediments (figure 6.2) would place this event at about 10 700 yrs. BP, meaning that after about 200 years the landscape became deforested.

In general, the vegetation of sub-zone 2C is characterized by the rapid development of an "open spruce woodland" as a result of a relatively warmer climate. Warmer, but still cool conditions would have favoured organic accumulation in and around LDL. With respect to the evidence exposed in PAZ 2C and corresponding TAZ 3A, local disturbances appear to accompany the spruce woodland with increased

erosion of organic soils. In the following PAZ 2D, the pollen assemblages indicate that cooler conditions prevailed causing a decrease of the spruce woodland.

In PAZ 2D, the increased *Salix* pollen and Polypodiaceae and Lycopodiaceae spores and the re-occurrence of ruderal herb pollen (*Artemisia*, *Thalictrum*, Plantaginaceae and Rosaceae) from the basal pollen zones are associated with the gradual decrease of *Picea* from its maximum pollen percentage. A maxima of *Alnus* sp. and Cyperaceae pollen percentages also mark this subzone. Alder (*Alnus*), willow (*Salix*), and sedges (*Cyperaceae*), which are together well represented in the pollen percentage diagram, are all adapted to seasonally waterlogged soils but also commonly occur in low-arctic. Also in PAZ 2D, taxa which are typical of today's northern Québec's "shrub sub-zone of the forest-tundra" pollen assemblage (Gajewski 1991) slightly increase, pointing to cooler conditions.

The pollen assemblages of PAZ 2D suggest that the spruce woodland was gradually replaced by a shrub tundra. With the decimation of the spruce population, ruderal plants which prevailed in the landscape became better represented in the pollen rain as did the extra-regional vegetation. Open and cooler conditions are indicated by the peak in the light requiring alder (*Alnus*), heaths (Ericaceae), grasses (Poaceae), herbs (*Artemisia*, *Oxyria*/*Rumex* and Caryophyllaceae) and sedges (Cyperaceae). The *Betula* pollen peak is principally composed of grains <20µm suggesting that shrub birch remained an important constituent of the vegetation. The percentage curve for *Pinus* spp. begins to rise at the expense of the *Picea* pollen in the upper portion of the organic rich TAZ 3A. The *Pinus* pollen percentage maximum (30%) would represent either long distance transport due to a less productive spruce community or a change in the direction of major winds. No *Pinus* macrofossils were discovered to confirm the presence of this tree in the immediate landscape. As *Picea* pollen percentages continued to decrease (PAZ 2D), erosion intensified. This is demonstrated by the prevalence of bryophyte remains found in association with the significant increase of silt characterizing TAZ 3B. The lower mid portion of this *weak red* clayey silt unit (TAZ 3B) also contains the highest abundance of *Alnus* pollen grains. Alder is usually recognized as an important successional shrub in deforested terrain (Davis and Webb 1975). However, judging from the relatively low percentages values of the *Alnus* maximum (15%), this shrub did not grow abundantly near LDL as did willow. Both *A. crispa* and *A. rugosa* type pollen are equally represented in the pollen diagram at this time. *A. rugosa* type is more common to the boreal forest whereas the dominance of *A crispa* pollen is reported to be characteristic of the forest-tundra transition (Anderson *et al.* 1991, Gajewski 1991). *A. rugosa* and *A. crispa* shrubs are known however to occupy the same terrain in the low-arctic (i.e. Mackenzie Delta: Porsild and Cody 1980). Alder possibly became better represented in the pollen rain because of open conditions (e.g. Ritchie 1977, Wang and Geurts 1989) or it arrived at the site. No macrofossils which could confirm the local presence of alder during the late-glacial were found. The decrease in *Populus* pollen percentages favors the hypothesis that cooler conditions were responsible for the vegetation revertance exposed by the pollen trends. However, because low *Populus*

pollen percentages are again associated with mineral sediments, as was the case for TAZ 2, there is a possibility the abundance of these grains is related to the preservation capability of the sediment (e.g. Mott 1978).

In brief, the humus which had accumulated under the open spruce cover (PAZ 2C) was in part eroded and redeposited into the lake basin at a time when conditions became unfavorable to the spruce woodland, possibly a cooling. Erosion intensified after the spruce woodland began to revert to a shrub-tundra. A shrub dominated community composed mainly of birch and possibly alder would have developed at this time. The *Betula* pollen percentage peak exhibited at the PAZ 2D/3 boundary coincides with a peak in sand (TAZ 4). The same pattern was observed lower in the core (PAZ 2B and TAZ 2). The vegetation reversion is bound by two chronologically inverted ^{14}C dates. The younger and stratigraphically lower date, was obtained from a *Salix* (?) twig taken from the *weak red* clayey-silt of TAZ 3B. It places the *Alnus* and *Pinus* peak at about 10 320 yrs. BP (TO-3576). The first standard deviation of this date overlaps the first standard deviation of the older and stratigraphically higher date of 10 500 */- 170 yrs. BP (GSC-5107). The inversion adds credence to the hypothesis that the 10 cm thick reddish mineral layer (TAZ 3B & 4) had rapidly accumulated to the bottom of LDL. Together, the abrupt boundary features of the combined TAZ 3B and 4, the nature of the sediment, the maintenance of low and constant values for total Carbon (figure 5.4), pollen concentration (figure 5.7) and *Pediastrum* total (figure 5.11) together favor the hypothesis of rapid accumulation. The gradual change in the proportion of different taxa was explained by possible long distance transport. Although results altogether suggests that the authocthonous sediment accumulated in the lake basin, along with a different, local pollen assemblage, the duration of this event remains uncertain. Since inversed dates may result from characteristics of carbone (ex: Amman and Lotter 1989), they are taken to indicate that the accumulation of the mineral matter occured sometime between about 10 500 and 10 300 yrs. BP.

The gradual recovery of the spruce forest cover is expressed by an increase in *Picea* pollen percentages in PAZ 3. The increase in the arboreal component of the pollen rain is attributable to the combined increase in *Picea* and thermophilous hardwoods (e.g. *Quercus, Tsuga, Fraxinus*). The latter are taken to indicate that postglacial warming had favoured a northern migration of the mixed-temperate forest. Poaceae, which predominates in the herb component of the pollen rain, is accompanied by a rise in *Myrica* and *Salix*. The latter two shrubs show an increase in pollen percentages which are comparable to those achieved in lower pollen analytical zones. The warmer conditions and the increasing tree cover would have favoured the local growth of sweet gale, willow and club mosses (*Lycopodium* spp.) over that of juniper, hence the low abundance of *Juniperus* pollen throughout the remainder of the profile. Although the *Betula* curve declines, the ratio of >20mm/<20mm of *Betula* has risen. This implies that tree birch was approaching the site, or most likely, that shrub birch contributed less to the pollen rain as a result of climatic amelioration. The increased proportion of organic sediments, as deduced from the

darker colour of the sediment and measured by the percent non-carbonate Carbon, is attributed to the stabilization of slopes by the increasing vegetation cover under warmer conditions. Accompanying the increased proportion in organics is the rapid replacement of all sand fractions by coarse silt and clays, thus pointing to decreased erosion intensity in the lake catchment. Progressively warmer lake conditions combined with the mineral substrate allowed quillwort (*Isoetes*) to prosper and aquatic plants to colonize the margins of lakes. *Pediastrum* sp. equally became more abundant at this time. More remarkable is the increased diversity of *Pediastrum* sp. from the upper portion of zone 1 (i.e. the occurrence *of P. duplex* and *P. Kawraiskyi*). The occurrence of *P. duplex* and *P. Kawraiskyi* have been associated with warmer conditions (Cronberg 1982; Alhonen and Ristiluoma 1973). Nutrients washed into the lake may have been important to the success of some *Pediastrum* spp. (e.g. *P. simplex* and *P. Boryanum* sp.) for these were also observed at the base of the profile where greater proportions of mineral sediment were accumulated during a cooler time.

In brief, the vegetation did not revert to an open spruce woodland like that exposed earlier in PAZ 2C. A vegetation community, more temperate in character is reflected in PAZ 3. The arrival of the tree birch in the region is suspected to concur with the slow regeneration of spruce trees. The warmer climate would have favored the expansion of the spruce cover, and, consequently, pollen percentage values of grasses (Poaceae) and shrub birch (*Betula*) relatively decreased. The gradual increase in the proportion of organics in the lake indicate that humus was again accumulating in the lake catchment. Increased temperatures and the organic silt likely played a role in the composition of the *Pediastrum* population.

In PAZ 4, the vegetation composition remained similar to PAZ 3, however, the significant increase in pollen concentrations suggest that the forest cover had become more continuous. Changes occurred in the general abundance of taxa. *Populus* percentages become important. This tree probably came to occupy, along with juniper and grasses, the open and well drained sites of the region early after deglaciation but had not since then been well represented in the pollen rain either as a result of poor preservation or dilution of the pollen by other taxa. Based on the recovery of one *Pinus* needle fragment at the base of PAZ 4, pine trees probably had migrated to the region by this time. An increase in the ratio of *Pinus strobus/Pinus. banksiana* is noticeable on the *Pinus* cumulative curve (figure 5.7). Both *P. strobus* (white pine) *and P. banksiana* (jack pine) are today part of the temperate boreal forest. However, *P. strobus* appears to be limited to the northern area of the Great Lakes and all of the Maritimes. *P. banksiana*, in addition to its more northern extension, appears to be more continental, growing throughout the entire Canadian boreal forest (Hosie 1980). The occurrence of *Abies* has increased. Although it remains low, it favors the hypothesis that warmer conditions and possibly more humid conditions prevailed because it is usually under-represented in the pollen rain. *Myrica* is the only other shrub that noticeably exhibits an increase in its percentage values. The recovery of *Myrica gale* leaf fragments at the

same level as the *Myrica* peak indicates that this shrub grew near the lake. The slight decline of total Carbon and the rise in $CaCO_3$ accompanied with the rise in shrub component of the pollen rain, suggests that disturbances may have occurred in the landscape. Inwash of nutrients would explain the corresponding slight increase in the concentration of *Pediastrum* coenobia in upper PAZ 4. Note, however, that *Pediastrum angulosum* and *P. tetras* are important constituents of the total *Pediastrum* assemblage during this period of climatic warming. Also, *Fossil A*, which had previously been associated with the inwash of soils (upper TAZ 3A) and the demise of the spruce woodland, makes an important come-back.

In PAZ 5, *Picea* percentage values have increased while *Myrica* and Poaceae percentage values generally decline. A more continuous forest cover probably inhibited the growth of grasses (Poaceae) and herbaceous plants, and their contribution to the pollen rain consequently diminished. The decrease in pollen concentrations to values similar to PAZ 3 is difficult to explain. It may be related to changes in the accumulation rate of the sediment. The rise in the frequency of *Typha* pollen and the low abundance of Cyperaceae point to warmer lake conditions. An abundance of aquatic plants such as *Potamogeon, Sparganium and Hippurus* (based on recovery of seeds) probably aided in the accumulation of organic matter in the lake bottom. This accumulation corresponds with the rapid decrease of *Isoetes* spores.

The upper portion of the pollen diagram (PAZ 4 & 5) represents an expansion of the tree cover which included pine and tree birch in addition to spruce. The contribution of the shrub component to the pollen rain generally tends to decrease at this time. Expansion of the boreal spruce forest as a result of increasingly warmer and possibly more humid conditions is associated with the accumulation of organic-rich sediments at LDL.

CHAPTER 7 - SYNTHESIS AND DISCUSSION: CORRELATION OF LITTLE DYKE LAKE DIAGRAM WITH THE REGIONAL PALYNOSTRATIGRAPHY

A low-arctic shrub community had already developed over the Folly delta by 11 500*/-90 yrs. BP. At first, the vegetation cover around LDL was dominated willow and heliophytic herbs (e.g. *Artemisia*). Buffalo-berry was also present. Open conditions persisted and juniper and birch were alternately important in the landscape. On the one hand the recovery of charred wood fragments and seeds from the sandy sediment favors the hypothesis that changes in the shrub cover and soil instability are related to the recurrence of local fires. On the other hand, changes in the shrub cover as a result of climatic cooling could just as well be responsible for an increase in erosion intensity and vegetation change. In any case, the prevailing shrub tundra eventually developed into a spruce woodland with the amelioration of climate. After no more than about 200 years, at ~10 700 yrs. BP, the spruce woodland became more open and soils which may have formed in the lake catchment were washed into LDL. These environmental changes are attributed to cooler conditions. The combination of climatic change and its effects on the local landscape would then have increased erosion intensity, hence the occurrence of the weak-red silty unit. Plants already in the area, which were most apt to grow (or most tolerant) during the time of increased erosion, became dominant. A shrub birch tundra developed and it likely included some alder. Consequently, erosion intensity increased. With the amelioration of climate, trees other than spruce and poplar had migrated nearer to LDL by about 10 000 yrs. BP to form a boreal forest, at which time organic accumulation became more important.

The pollen stratigraphy of LDL basal sediments resembles the classical pollen profile for late-glacial lake sites of Nova Scotia (Basswood Road Lake in southern New Brunswick: Mott 1975a, figure 16: Stea *et al.* 1992). This profile exhibits two distinct coniferous pollen percentage peaks which represent the development of a woodland followed by that of a forest. The bi-modal coniferous pollen curve (principally *Picea* grains) is interpreted as two warmer periods which are separated by a cool period. Mineral rich sediments mark the cool period. Relatively cooler temperatures would have caused the spruce woodland to revert to a shrub tundra before a spruce forest developed. This vegetation reversion is correlated to the classical Allerød Oscillation of Europe which occurred between about 11 000 and 10 000 yrs. BP and (Mott *et al.* 1986).

Comparison of LDL pollen sequence to late-glacial pollen sequences of the Maritimes shows that it shared traits with either unforested sites located to the east and southeast or forested sites located to the west. Sites closest to LDL which hold a late-glacial record are Leak Lake (Mott in Wightman 1980, Mott 1985; Mott in Stea et al. 1986, Levesque *et al.* 1993a) to the west, Chance Harbour Lake (Jetté and Mott 1989) to the north and Stillman Pond (Levesque *et al.* 1993a) to the east. Results from these three sites

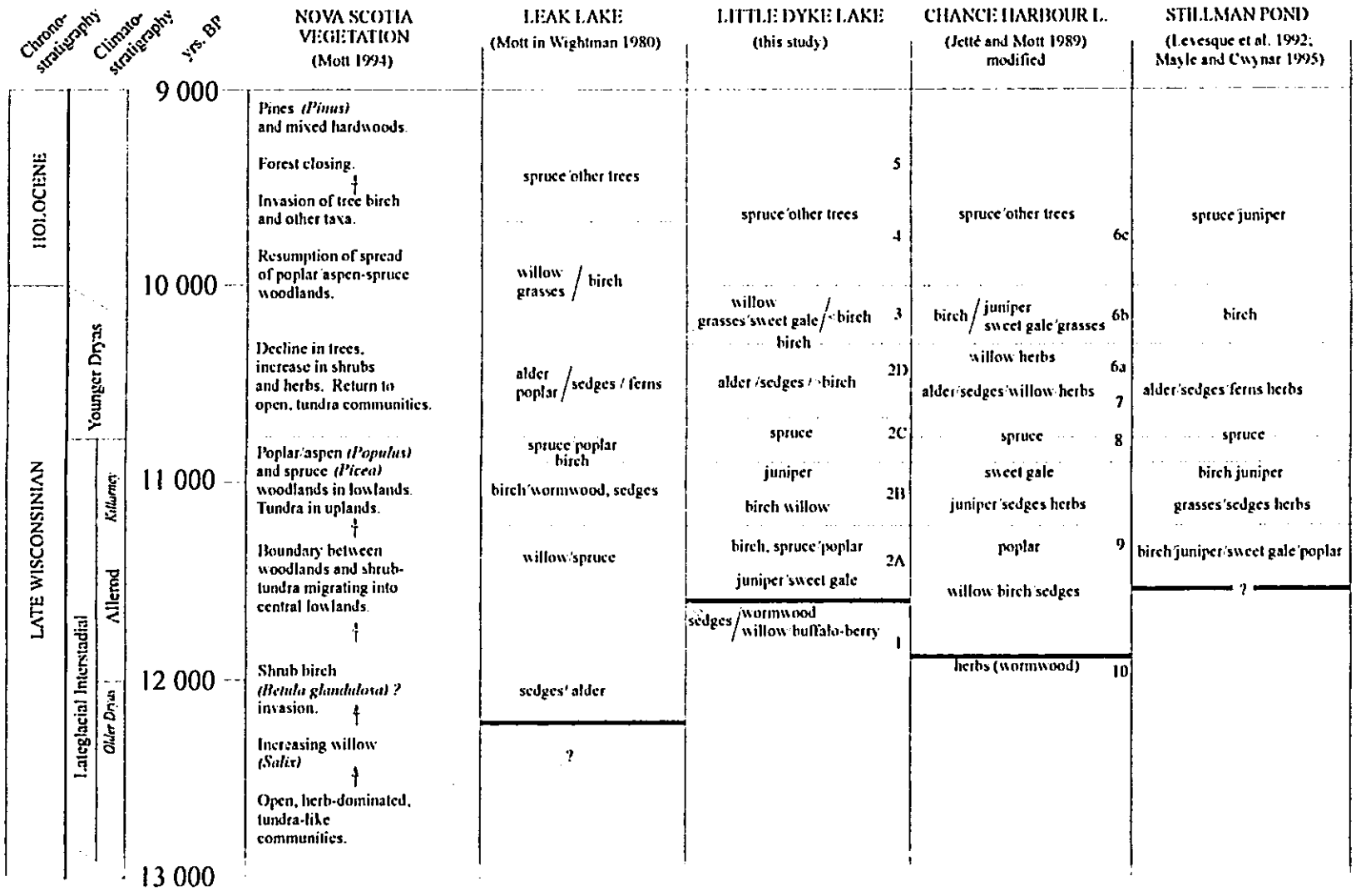

Figure 7.1 Comparison between the vegetation change template of the Maritimes' late-glacial palynostratigraphy of Little Dyke Lake and three other sites of north central Nova Scotia.

and those from this study appear in figure 7.1. in order to help develop a regional picture of the vegetation history of central Nova Scotia.

The typical pioneer phase exposed in several Nova Scotia pollen diagrams (e.g. Mott *et al.* 1986a, Mott 1994) occurs at LDL. At 11 500 yrs. BP, willow, *Artemisia* and sedges (PAZ 1) had already colonized the landscape. The basal date obtained at LDL (~11 500 yrs. BP) corresponds well with the other basal dates obtained for the area. Organic accumulation is believed to have started as early as 11 900 yrs. BP at Leak Lake (Stea and Mott 1990) and further west, at Basswood Lake, it is dated at 12 900 yrs. BP. (Mott 1975) but an AMS date gives an age of about a 1000 years younger, at 11 640 +/- 90 (Mayle et al. 1993a). The basal age for Stillman Pond (Levesque *et al.* 1993a, Mayle *et al.* 1993a) is estimated to be at least 11 500 yrs. BP.

At LDL, the pioneer community eventually included abundant juniper and possibly some poplar trees (PAZ 2A). Cupressaceae pollen percentages are amongst the highest of the Maritimes and these are comparable to those observed on the southern Scotian peninsula, at Lac à Magie (23%: Mayle and Cwynar 1990) and at Brier Island Bog (~20%)(Wilson *et al.* 1993). Cupressaceae pollen is also an important component of the pollen rain of sites of central Nova Scotia (e.g. Stillman Pond, Little Lake (Levesque *et al.* 1993b, Mayle and Cwynar 1995)), however its percentages remain near 10%. The recovery of *Juniperus communis* needles from the sediments of Lac à Magie and Little Lake were taken to indicate that this shrub is the source of Cupressaceae pollen at these two sites (Mayle and Cwynar 1995). At both these sites, the high *Juniperus* pollen is accompanied by low *Populus* pollen percentages (mid T2 pollen zone: Mayle and Cwynar 1995) just like at LDL. *Populus* pollen are significantly more important in the basal spectra of sites located in central and southwestern New Brunswick (Basswood Lake (>35%), Killarney Lake (>50%), Pine Ridge Pond (>30%), Mayflower Lake (~15%) (Levesque *et al.* 1993b, see lower pollen zone F3: Mayle and Cwynar 1995) and at Chance Harbour Lake, N.S. (>30%)(Jetté and Mott 1989).

At LDL, *Betula* pollen percentages increase at the expense of *Juniperus* pollen percentages (PAZ 2B). This change in the shrub component of the tundra is believed to be the result of either local disturbances (fire) or climatic cooling occurring sometime after ~10 900 yrs. BP. Pollen diagrams from sites of Nova Scotia and southwestern New Brunswick typically exhibit, with different amplitudes, a decline in Cupressaceae pollen percentage curve (Splan Pond, Mayflower Lake, Stillman Pond, Chance Harbour Lake, Chase Pond, Main-à-Dieu Pond, Lac à Magie and Little Lake). Meanwhile, more northern and continental sites (Chance Harbour Lake, Pine Ridge Pond, Killarney Lake and Joe Lake) show an increase of Cupressaceae pollen at this time. Unequivocal pollen changes (apart from those expressed by the Cupressaceae curve) at all these sites are attributed to a climatic cooling (Levesque *et al.* 1992). This cooling, termed the Killarney Oscillation would have occurred between 11 160 and 10 910 yrs. BP. (Mayle *et al.* 1993a) and is best indicated by the decline of percent loss-on-ignition curve (Levesque *et al.*

1993a). Since this cooling event coincides well with cooling events recorded throughout the North Atlantic seaboard, Levesque *et al.* (1993b) had correlated it with "the best-dated pre-Younger Dryas event from continental Europe": the Gerzensee Oscillation in Switzerland.

At LDL, the early expansion of the juniper population (PAZ 2A), represented by the Cupressaceae pollen percentage peak, is dated close to 10 930 +/- 110 yrs. BP. Although this date corresponds with the onset of Younger Dryas cooling (Mayle *et al.* 1993a), the major pollen trends (i.e. decreased, *Juniperus* and *Betula* pollen percentages and increase) resemble those which mark the Killarney cool event for different parts of the Maritimes. The vegetation response at LDL resembles most closely that recorded to the east, at Stillman Pond, with respect to an inflection of the Cupressaceae pollen percentage curve. However, the pollen record at LDL differs from Stillman Pond because it does not indicate that vegetation reverted to a herb tundra. Instead, LDL resembles sites located to the west (Pine Ridge Pond, Mayflower Lake and Killarney Lake) with respect to an increase of shrub birch percentages at this time. Results from this study, indicate that the pollen signal at LDL as a result of climatic cooling is not evident compared to other sites, perhaps because of its geographical location. The site's proximity to the shrub-tundra, to the west, could explain the increase of shrub birch pollen in PAZ 2B.

Correlating PAZ 2B with the Killarney cooling consequently gives a minimum estimate of 300 to 600 years for spruce to arrive and grow at LDL after deglaciation because spruce needle fragments were recovered at the transition of PAZ 2A and 2B. Other sites which hold macrofossil evidence for the presence of spruce in the landscape before the Killarney cooling are those found on the southern coast of New Brunswick (Mayflower Lake and Basswood (published as Splan Pond) and one site on eastern coast of the Scotian peninsula (Little Lake)(Mayle and Cwynar 1995). Spruce trees are reported to have been present at the Shubenacadie site before the Killarney Oscillation (by 11 400 yrs. BP) and at the Brookside site after the Killarney (by about 11 100 yrs. BP) (Stea and Mott 1990). Sites further south, Lantz, Lac à Magie and Brier Island Bog, would have held spruce trees later, by about 11 000 yrs. BP (Mott and Stea 1993, Wilson *et al.* 1993, Mayle and Cwynar 1995). The discontinuous west-east-south pattern of spruce migration revealed by the network of pollen sequences is explained in terms of environmental conditions suitable to the growth of spruce. Spruce would have migrated into the Scotian mainland from Maine, through southwestern New Brunswick and into Nova Scotia, via lowlands and valleys with some difficulty (Stea and Mott 1989), but once it arrived in the Shubenacadie River Basin, better environmental conditions would have favoured its expansion (Mott 1985, Mott 1990, 1992) compared to coastal lowlands.

Unlike most other sites which hold macrofossil evidence for the presence of spruce before the Killarney, LDL displays *Picea* pollen percentage below 20%. Sites which show *Picea* pollen percentages below 20% before the Killarney cooling are those located in central Nova Scotia (Stillman Pond and Lac à Magie) and more northerly sites (Joe Lake, Killarney Lake, Chase Pond and Main-à-Dieu). The discovery

of spruce needle fragments at LDL, associated with low *Picea* pollen percentages, therefore corroborates the hypothesis that spruce migrated with difficulty through lowlands areas.

Upper PAZ 2B at LDL is characterized by the second *Juniperus* pollen percentage peak which accompanies the expansion of spruce. This peak was interpreted as reflecting the gradual warming which would have given juniper the competitive ability over shrub birch until spruce trees became more important at this location. Stillman Pond and Lac à Magie both show a second *Juniperus* pollen percentages peak. Sites to the west, which held spruce trees before the Killarney cooling tend not to display a clear second peak in *Juniperus* but rather a parallel increase of *Myrica* and *Picea* pollen percentages as a result of warming. This is also the case at Little Lake located on the Atlantic coast (site 15: figure 2.2). Treeless sites of central New Brunswick and Cape Breton Island show an increase of *Betula* pollen with climate amelioration, while treeless sites to the south in Nova Scotia show an increase in *Myrica* percentages. In the later case, this occurs at the expense of *Juniperus* or herbs and sedges, respectively. In light of the available data, it is difficult to see the type of sediment which corresponds to this phase of climate amelioration at sites throughout the Maritimes. At LDL, coarse sand corresponds to the second *Juniperus* peak. This would suggests that the shrub cover, upon warming, was not effective at reducing erosion.

It is interesting that the Truro section, at the head of Cobequid Bay (site 21: figure 2.2), displays a pollen record resembling closely that of LDL. *Betula* pollen decreases with the arrival of sand and *Juniperus* (>20%) and *Salix* (~30%) pollen are important within the sandy diamicton at Truro (Stea and Mott 1989; Stea and Mott 1990, Stea *et al.* 1992). This diamicton is reported to have buried and eroded the underlying peat, dated at 11 400 yrs. BP. The abundance of spruce pollen (20%) in the peat matches well with the *Picea* pollen percentage record of sites of central Nova Scotia before the Killarney cooling. The overlying diamicton at Truro was distinguished from other diamictons of central Nova Scotia because it contains a higher proportion of coarser material, especially sand (between 2 and 6 phi) which is believed to have been derived from different sources (figure 42: Stea and Mott 1990). This diamict event was correlated with the onset of the Younger Dryas (Stea and Mott 1989, Stea and Mott 1990, Stea *et al.* 1992). The missing record for the spruce expansion, typically occuring before the Younger Dryas (Stea and Mott 1990), is suspected to have been eroded at Truro. This serve to explain the rather old date of 11 400 yrs. BP for the interruption of organic sedimentation as a result of the cooler conditions of the Younger Dryas. Since the study of LDL coincidentally shows an increase in sand (between 2 and 6 phi) at the termination of the Killarney indicates that sediment deposits of the area merit further investigation.

The pollen record at LDL shows very high *Picea* pollen percentages (~70% in PAZ 2C) above the abrupt decrease of the second *Juniperus* pollen peak. Since these are associated with an increase in organic content of the sediment and low pollen concentrations, they are taken to indicate that an open spruce woodland existed and not a closed forest. The difference between LDL and nearby sites (Leak

Lake, Splan Pond and Chance Harbour Lake) is that, at LDL, *Picea* percentages are the highest while pollen concentrations are amongst the lowest. The open spruce woodland which developed at Chance Harbour Lake after the Killarney cooling was compared to that of Splan Pond, dated 11 300 yrs. BP (Jetté and Mott 1989) and suspected to be closer in age to the closed spruce forest or woodland which existed on the southern coast of New Brunswick and in central Nova Scotia between about 10 900 and 10 770 yrs BP (Stea *et al.* 1992, Mayle *et al.* 1993a). The expansion of spruce populations of southwestern New Brunswick and central Nova Scotia would have been replaced by a forest-tundra of shrub tundra with the onset of climatic cooling. The study of a buried peat deposit in the Wentworth Valley (Stea and Mott in Stea *et al.* 1992), north of the Cobequid divide, shows that an open spruce woodland existed prior to 10 700 +/- 100 yrs. BP (GSC-4929). Lake sediments which buried the peat at this site are associated with clay deposits found along the north flank of the Cobequid Highlands suggesting that an extensive ice-dammed lake system existed due to the presence of ice in the Northumberland Lowlands at about the time of the Younger Dryas (Stea and Mott in Stea *et al.* 1992). At the Shubenacadie and Lantz sections, *Picea* percentages decrease rapidly from >40% and >50% due to abrupt environmental change at 10 800 +/- 100 yrs. BP (GSC-3981) and 10 900 +/- 90 yrs. BP (GSC-3771), respectively. Glacial outwash sands from glaciers to the east are believed to have buried the peat at the Shubenacadie section while rhythmic laminations which had formed in a paleo-lake covered the peat at Lantz (Stea and Mott in Stea *et al.* 1992). A drop-stone found in a nearby section of the original Lantz section (figure 7.2) supports this proposal. The demise of spruce populations is suspected to have occurred rapidly (e.g. 50 yrs. at Splan Pond, 110 yrs. at Lac à Magie) and lag response of other vegetation is judged to be negligible (~80 yrs.) in comparison to sedimentological changes (LOI)(Mayle and Cwynar 1995).

The interpretation for PAZ 2D at LDL does not contradict the vegetation record of the region (Mott *et al.* 1986a). A decrease of *Picea* pollen percentages at LDL (PAZ 2D) is found in sediment which contained coarser organic remains and high organic and inorganic carbon. Comparison of the particle size and pollen analysis revealed that the open spruce woodland responded to unfavorable conditions by reverting to a shrub birch tundra. This event is estimated to have occurred shortly after 10 700 yrs. BP. Also, the local landscape responded with an increase in erosion intensity, hence the occurrence of a weakred coarse silt unit (TAZ 3B) after the decrease of *Picea* pollen percentages. When the spruce woodland began to degenerate at LDL (PAZ 2D) the *Pinus* pollen percentages are noted to have increased along with *Alnus* and Cyperaceae. Inverted radiocarbon dates place this change at about 10 320 - 10 500 yrs BP. The increase of *Pinus* pollen percentages was explained by long distance transport by wind, whereas the increase of *Alnus* pollen percentages is suspected to indicate that this shrub was present on site. Shrub birch became most important (late PAZ 2D) when maximum erosion occurred (upper TAZ 3B & TAZ 4).

The pollen trends described above are typical signals of the Younger Dryas of the Maritimes (Mott *et al.* 1986b, Mayle and Cwynar 1995). Most diagnostic for this cool period is an *Alnus* pollen percentage peak (Mayle *et al.* 1993b). The *Alnus* peak at LDL is not primarily composed of *Alnus crispa* as at most sites of Atlantic Canada (Mayle *et al.* 1993b), but it is composed of about equal amounts of *Alnus crispa* and *Alnus rugosa* type pollen. Sites which display *A. rugosa* type pollen peaks at this time are found in New England, and this was explained by the sites' locality in lowland areas (Mayle *et al.* 1993b). No alder macrofossils were found from the sediment of 6 sites of the Maritimes. This led Mayle and Cwynar (1995) to conclude that the source of *A. crispa* pollen found in Maritime diagrams comes from populations in New England.

In view of the chronology obtained for LDL sediments, the *Pinus* peak at LDL correlates very well with the expansion of *Pinus* pollen in east-central North America centered at 10 300 yrs. BP (Shane and Anderson 1993). The *Pinus* pollen percentage peak of east-central North America is related to a drop in precipitation and relatively warmer conditions for the Allegheny Plateau and the Till Plains between about 10 500 and 10 000 yrs. BP. (Shane and Anderson 1993). This event would have followed a cooler period which is marked by the recurrence of spruce on the Till Plains and the decrease of spruce/increase of pine (esp. *Pinus banksiana*) on the Allegheny Plateau. Shane and Anderson suspect that environmental change, between 11 000 and 10 000 yrs. BP, resulted from the combined effects of the drainage of Lake Agassiz and the consequent spread of arctic air masses in summer.

In contrast, the usual *Pinus* pollen percentages maxima (5-30%) which accompanies the decrease of *Picea* pollen percentage in certain parts of the Maritimes is associated with cooler and wetter conditions of the Younger Dryas (Mott 1975, Mott 1994). The *Pinus* peak most likely reflects the northwestward migration of pine from the Appalachians to the Great Lakes area between 11 000 and 10 000 yrs. BP (Bernarbo and Webb III 1986). An opening of the landscape at about 10 800 yrs. BP, as a result of the Younger Dryas cooling, would have allowed more extra-regional pollen to arrive to Maritime

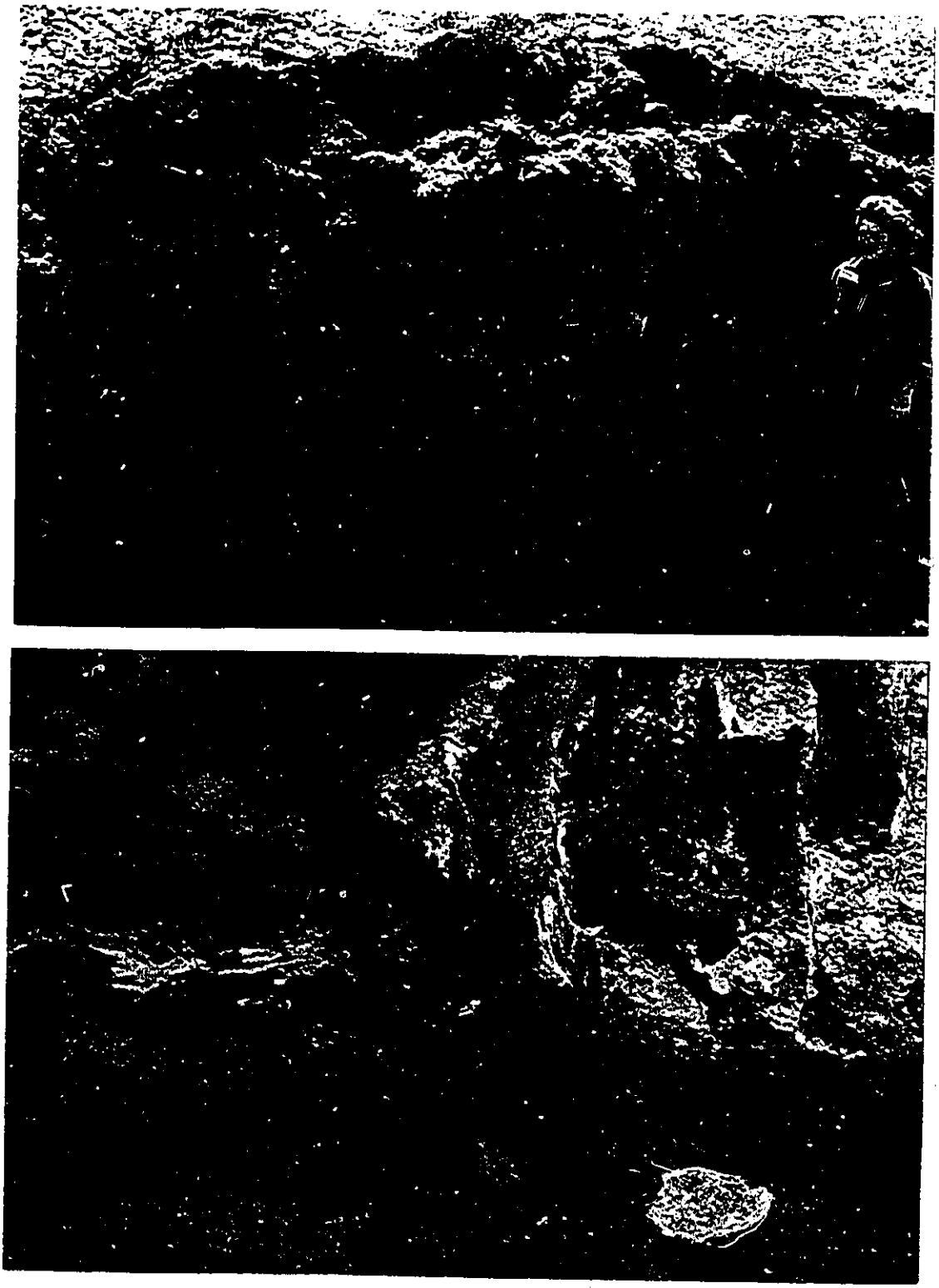

Figure 7.2 Drop-stone observed in section near the Lantz buried organic section.

sites. However, macrofossil evidence also indicates that white pine (*Pinus strobus*) had migrated to more northerly sites on the Atlantic coast by 10 000 yrs BP (northeastern New Jersey: Peteet *et al.* 1990a) and before this time (southwestern New Brunswick: Mayle and Cwynar 1995). In fact, *Pinus strobus* pollen percentages became more important with the increase *Pinus* pollen percentages at sites in southwestern New Brunswick and central and northern Nova Scotia (including LDL).

The mixture of an arctic/boreal pollen and macrofossil assemblage at 6 sites of the Maritimes during the Younger Dryas was explained by the increased seasonality of the time (Mayle and Cwynar 1995). It may also be explained by the amelioration of climate in the later phase of the Younger Dryas. This would imply that the spruce maxima in the Maritimes correspond with the transition from warm to cool or cooler conditions, such as is the case for the interpretation of New England (Peteet *et al.* 1990a) and east-central North America (Shane and Anderson 1993) late-glacial pollen diagrams. Both these regions show similar sequences to that of the Maritimes: The *Picea-Pinus* transition in these pollen diagrams is associated with the increased occurrence of *Alnus* pollen (minor increase in east-central N.A.). However, the major difference between the three regions may be attributed to interpretation and chronological control. In New England, the *Alnus* peak and subsequent recurrence of *Picea* (PAZ A4) is believed to have occurred between 11 000 and 10 000 yrs. BP. and, pine would have arrived near 10 000 yrs. BP (e.g. Peteet *et al.* 1993). In east-central North America, the recurrence of *Picea* (in the Till Plains (zone IIb, first phase)) or decrease of *Picea* (in Allegheny Plateau (transition between zones IIa/IIb)) is constrained to a time before or about 10 500 yrs. BP, whereas the *Pinus* maximum is centered at 10 300 yrs. BP for both these areas. In the Maritimes, the *Picea* decrease and the concurrent increase of *Pinus* and *Alnus* pollen percentages is usually attributed to more open and cooler conditions occurring between about 11 000 and 10 000 yrs. BP. (e.g. Mott *et al.* 1986b). Spruce populations may have expanded in certain parts of the Maritimes with regional cooling, such as is the case for east-central North America. However, for the Maritimes, the maximum of *Picea* pollen percentages which corresponds with the time of cooling could be explained by a short response lag of spruce populations (tolerance) to climatic cooling, because, based on cumulative studies (Stea and Mott 1989, Stea *et al.* 1992, Mayle and Cwynar 1995), the subsequent expansion of spruce populations in parts of the Maritimes would have occurred at a time (10 900 - 10 700 yrs. BP) which corresponds to the onset of Younger Dryas cooling (10 930 - 10 640 yrs. BP (Mayle *et al.* 1993a)). In view of this interpretation, questions on the effects that a persistent vegetation cover could have on the type of sedimentation are raised. If the mineral input into lakes is dependent of the demise of arboreal populations, then the sediment record (e.g. LOI, texture) is expected to show evidence of environmental change after or at the same time as the pollen record. In any case, changes in the character of the sediment would show, just like the pollen, a response lag to environmental change.

At LDL, the *weak red* mineral silt unit is associated with the subsequent decrease of *Picea* pollen percentages which suggest that the existing vegetation dampened erosion intensity. It was noted however

that other sediment characteristics accompany the initial decrease of *Picea* pollen percentages: coarser organic remains, and coincidentally, high organic and inorganic carbon occurred. Therefore either the sediment type affected the pollen record or both proxies coincidentally respond to climatic cooling. At first glance, the reverse grading and abrupt boundaries which characterize the *weak red* minerogenic layer (TAZ 3B & 4) suggest that an abrupt local disturbance (e.g. flow) would have influenced the pollen record at LDL. This is questionable by the fact that certain pollen curves displayed gradual changes across the abrupt stratigraphic boundary found between the *weak red* silty unit (TAZ 3A) and *dark grey* gyttja (TAZ 3B). However, pollen changes for regional and not local taxa are gradual. Nevertheless, the occurrence of an "exceptional" (Reading 1978) mineral unit, a good stratigraphic marker for the Younger Dryas in most late-glacial lake sites of Maritimes Canada, indicates that an external factor was responsible for regional vegetation change.

The deposition of a distinct mineral unit at LDL may be related to runoff over the delta's surface after the demise of the spruce population. With the lost and the poor regeneration of tree cover and cooler and drier conditions, the delta likely became prone to erosion and open to deflation (e.g. Ovenden 1988). Evidence indicating desiccation in the area are the sandy eolian deposits which underlie the structureless sand at the Debert archeological site (MacDonald 1968). However, since these deposits underlie the structureless sands which are rich in paleo-Indian artifacts, they would stratigraphically predate the paleo-Indian occupation, dated at 10 600 yrs. BP. The demise of the spruce woodland in the Maritimes occurred just before this time. However the occupation of the paleo-Indian at the time of the Younger Dryas is questionable (Bonninschen *et al.* 1991 unpublished, Davis 1992). This uncertainty is attributed to stratigraphic dating, wherein carbonized material used to calculate the average date site of occupation of 10 600 yrs BP were not stratigraphically representative. Questions are also raised on the pretreatment of the carbonized samples which were used for dating by MacDonald. Upon comparing results from the Debert site to those of the Vail site in Maine, Davis (1992) suggested that the time of occupation may have been older by about 500 years, that is nearer to 11 100 yrs. BP. Based on fossil evidence, MacDonald (1968) was able to associated the time of occupation with spruce populations, yet the type of vegetation cover (open or closed) remained uncertain. The quantity of charcoal found in "well defined hearths and pits" had led MacDonald to conclude "that firewood and kindling were readily available to the inhabitants of the site". Based on the lithic assemblage, MacDonald (1968) suspected that spruce parkland could support game animal such as caribou. Blood residue analysis on a single fluted point corroborates this hypothesis (Davis 1992). Pollen studies conducted on Folly bog (Livingstone and Estes 1967, Livingstone 1968) have only given a Holocene profile while those conducted on Frog Lake sediments revealed that the Debert people had likely been living in a tundra environment that supported some willows and conifers along rivers prior to Holocene warming (Amman, unpublished manuscript).

Findings at the Debert site may be combined with results of pollen studies conducted at LDL. A review of the stratigraphic descriptions presented by MacDonald (1968, p.17) and Byers (1975) clearly indicate that the artefactual material at the Debert site were found above frost features which developed in the underlying structured eolian deposits. This implies that the paleo-Indians occupied the site after a period of dry and cool conditions. Davis (1992) would place the time of occupation before the Younger Dryas cooling, at about 11 100 yrs. BP. and not 10 600 yrs. BP, as did MacDonald (1968).

This study shows that a forest with krummholz spruce would have occupied the Folly before the Younger Dryas. This forest tundra was correlated with the recently documented short Killarney cool period (11 160 - 10 910yrs. BP). Cool conditions before or during the Killarney could explain the frost features observed within the stratified eolian deposits. If the frost features observed in the structured sands at Debert did correspond with the Killarney cooling, then the overlying artefactual sand corresponds with the spruce woodland (PAZ 2C) which grew after the Killarney, between about 10 700 and 10 900 yrs. BP. The spruce woodland at LDL ecologically concurs with the biocultural environment of the paleo-Indians at Debert

It is interesting that the Killarney cool period in part corresponds with the "Clovis drought" (11 300 - 10 900 yrs. BP) for which evidence is abstracted from 18 paleo-Indian sites of the United States, especially the western United States (Haynes 1991). Could this period correspond to the stratified eolian deposits described at Debert? Also, the uppermost portion of a cross section of a gravel pit, nearby LDL, displayed V shaped features below the A horizon which suggest possible frost action over the delta in the past. Further investigations on the surficial sediments of the delta would be required to ascertain the origin and definite stratigraphic correlation of these features.

The tenuous correlation between the time of occupation and the spruce woodland, suggested above, does not differ much from the hypothesis that the paleo-Indians suddenly abandoned the Debert site due to unfavorable conditions as was previously proposed by MacDonald (1968). This study helps to constrain the time of occupation to a short period before and not necessarily during the Younger Dryas cooling. Consequently, the Debert-Belmont site would correspond more closely to the Bull Brook site in New England in terms of the time of occupation. Regional scale environmental change, such as that of Younger Dryas, could consequently have played a role in the subsistence patterns of the paleo-Indians and in turn led to the development of new technologies associated with the Archaic period (Bonnichsen *et al.* 1991, unpublished).

This study also points to three other aspects which merit further attention in the study of late-glacial sediments of the Maritimes. First, the retrieval of charred macrofossils at LDL suggest that fire played a role in the vegetation succession. Peteet *et al.* (1990a) have for the same reason questioned the pyric factor in the late-glacial vegetation record of Alpine Swamp, New Jersey. Macro-size charcoal

found in sediments of six lake sites from Maine indicate a significant increase in charcoal between 11 000 and 8 000 yrs. BP (Davis *et al.* 1986). Charcoal analysis done on a few sites in the Maritimes also show fire to have been important during the late-glacial. (Green 1986). Davis (1992) and Bonnichsen *et al.* (1991 unpublished) both have questioned the interpretation given to pits of the Debert archaeological site. They recognized that the abundant charcoal found in these pits could have resulted from tree-throw as a result of forest fires and are with difficulty distinguished from hearths. Obviously, more charcoal analysis are needed to evaluate the actual influence fire had on past environments of eastern North America.

The second point of interest is the abundance of Fossil A, identified as Sigmotype which marks the lower boundary of the weak red silt unit (TAZ 3B/3A). Bilodeau *et al.* (1989) report Sigmotype fossil (*Sigmopolis*) to occur in a marine transition environment. In view of this report, the study of dinoflagellates in the Maritimes could be interesting because marine dinoflagellates are suspected to occur in the *weak-red* silt unit at LDL. Could these fossils have be associated with sea level changes or blown in from raised marine features (Stea 1988) exposed along the northern coast of the Cobequid Bay?

The third point of interest raised during this study is the evolution of rivers during the late-glacial. Sea level change could have affected the evolution of rivers (e.g. sediment transfer, drainage density) of the Maritimes during the late-glacial. Stratigraphical evidence suggests that the rate of sea level rise varied during the late-glacial (Stea *et al.* 1987, Stea; personal communication 1992), but the lack of available data makes it difficult to try to link it with the environmental history of the region. Stea (1987) notes that after 12 000 yrs. BP, terraces which formed upon the Parsborro Delta possibly resulted from base level lowering. Stea and Mott (1989) report that sea level may have been at its lowest point at 11 000 yrs. BP (about 42 metres below present day sea level).

Mott (1994) describes conditions to have been colder and wetter between about 11 000 and 10 000 yrs. BP (Younger Dryas) and that during the later part of this millennium, "organic sedimentation in lakes resumed and peatlands began to form". Most sites located near the present day coast line show an percentage increase of *Salix*, Polypodiaceae, and Cyperaceae during the Younger Dryas which imply open, wet and cool conditions. The fact that alder characterizes the Younger Dryas cool period of the Maritimes recalls the description for the Atlantic Period (7450-4450 yrs. BP) of the British Isles. In that case, "the rapid expansion of *Alnus* (alder) and the extensive development of peats are clear signs of a wetter regime - an oceanic phase (Atlantic) replacing a continental one"(Pre-boreal) with climatic warming (Pears 1977). A similar alder phase characterizes the north eastern North American pollen disagrams at about the same time as the Atlantic Period (e.g. Nouveau Québec: Richard 1979, Hudson Bay area: Bilodeau *et al.* 1990). These notes on the pollen character of the Atlantic Period leads to the following question: Could the exchanges within the hydrosphere due to the retreat and melt of ice (e.g. melting of arctic ice shelves: Mercer 1969; melt water pulses: Fairbanks 1989, Lake Agassiz drainage: Lewis and Anderson

1992), have, apart from climatic cooling, significantly influenced the regional late-glacial environmental history of the Maritimes?

Since glacial features indicate that local ice was present or active in the Maritimes at the time of the Younger Dryas (Stea and Mott 1989), considerations of the consequent effects of climatic changes on the evolution of the glacio-hydrological regime are to be considered in the interpretation of late-glacial lake records. Response of a glacerized drainage basin to abrupt or continuous climatic change, either warming or cooling, is expected to be reflected in the lake sediment record for it is a component of the affected drainage basin. However, the influence that local ice or the supply of meltwater could have on the sediment supply and temperature of water bodies has never been a topic of investigation for the late-glacial of the Maritimes. Walker *et al.* (1991) do have reason to question the effects that meltwater supply could have on the air-water temperature balance of late-glacial lakes of the Maritimes when using temperature calibration sets derived from chironomid assemblage of non-glacial lakes.

Little Dyke Lake sediments show that like most late-glacial sites of the Maritimes, a mineral layer is associated with cooler Younger Dryas and Killarney periods. Comparison of the texture and pollen data at LDL show, however, that the lower silty portion of the mineral layers corresponds to the cool events whereas the upper sandy portion of both mineral layers (TAZ 2 and 4) correspond with climate amelioration. The pollen assemblages associated with the sandy sediment are thought to reflect a short time period wherein existing or migrating plants were responding to warmer conditions to eventually minimize erosion. Indeed, a sparse vegetation cover could favour erosion intensity in a drainage basin, but, the influence that warming would have on the capacity of rivers which fed lakes and bogs of the region may be more significant for the lake sediment record. Results from this study show that the character of the sediment (mottling, coarse organic remains or inorganic carbon) are probably good sensors of climatic change at LDL because changes in these proxies correspond with changes in the pollen assemblages. Meanwhile, texture trends taken to represent erosion intensity appear to be indirectly related to climatic change for shifts in the pollen assemblages precede the texture changes. Detailed texture analyses from several sites are required before conclusions are drawn on the inter-relationship between climate, sea level variations, the sedimentological end-products and vegetation change during the late-glacial.

Comparison with other profiles from the Maritimes indicates that after the Younger Dryas, the spruce population slowly recovered at LDL. During this time, grasses and willows became more abundant and then shrubs. The shrub tundra, dominated by shrub birch (second *Betula* peak at PAZ 2D/3), was gradually replaced by a forest community upon climatic warming. The lag response of the tree component of the vegetation would explain why erosion intensified further (TAZ 4) although climate warmed. The eventual expansion of the spruce cover and the arrival of other trees (e.g. tree birch) in the locality helped

to eventually stabilize slopes and reduce erosion. Organic accumulation resumed in the lake catchment and the basin (TAZ 5A), and the forest cover became closed (PAZ 4) at LDL.

Similarly to LDL, a *Betula* maximum occurs after the attenuation of the spruce cover for sites located in southwestern New Brunswick and central Nova Scotia (Splan Pond, Mayflower Lake, Leak Lake, Chance Harbour Lake, Stillman Pond, Little Lake). The *Betula* maximum at these sites coincides with an increase in *Picea* percentages and an increase in organic content of the sediment which are together interpretated as reflecting climate warming just before or about 10 000 yrs. BP. (Mott *et al.* 1986, Mayle and Cwynar 1995).

During PAZ 4 and 5 time, the forest cover at LDL became progressively more continuous. By this time, it included more temperate trees such as birch. These findings corroborate the vegetation change observed at sites located to the west of LDL, after 10 000 yrs. BP. (Mott 1994). Change to a more temperate vegetation are calculated to have been rapid, occurring over 50-100 yrs. (Mayle and Cwynar 1995). In contrast to southwestern and north central pollen diagrams of the Maritimes, LDL does not show a clear recurrence of *Betula* pollen but a slight increase in the ratio of Betula >=20µm/<20µm in upper PAZ 4 & PAZ 5. The increase in *Betula* percentages at other sites is thought to reflect the arrival of tree birch in the area (Jetté and Mott 1989). Correlating upper PAZ 4 at LDL with the recurrence of *Betula* percentages at Chance Harbour Lake (zone 6b) and southwestern New Brunswick (zone F6) does not help to explain the slight decline of the pollen concentration observed in PAZ 5 at LDL. Analysis higher up in the sequence are needed to show if this decline is significant. Since thermophilous, arboreal taxa which are usually under-represented (e.g. maple (*Acer*), fir (*Abies*)) contribute more regularly to the pollen rain at LDL in PAZ 5 it suggests that the temperate-hardwood forest was nearby. Macrofossil evidence attests to the presence of larch (*Larix*) and tree birch (*Betula papyrifera*) which were some of the first trees, besides spruce and pine, to leave a record of their presence in southwestern New Brunswick (Mayle and Cwynar 1995).

CONCLUSION

The study of Little Dyke Lake sediments provides evidence for the absence of active late ice over the Folly delta after deglaciation by providing a continuous late-glacial pollen sequence. The pollen sequence shows that the vegetation evolution was possibly influenced by two cool climatic events. High resolution pollen analysis of LDL sediments permit the correlation of this site with other sites of the region. During the early successional phase, the pollen record at LDL resembles other sites located on the Scotian peninsula. Abundant *Juniperus* pollen percentages characterize the pioneering communities of these sites. Otherwise, the pollen record more often resemble the pollen record of sites with trees located in south-western New Brunswick and central Nova Scotia. Comparing the pollen sequence of LDL with other sites of the Maritimes consequently help refine the picture of the spruce migration via lowlands and valleys. Relating the pollen sequence of LDL with different areas of the Maritimes reveals how the migration of spruce was climatically repressed and how the consequent openings of the landscape in forested sites played a role in the pollen record of central Nova Scotia. A good example is the not so well pollen-defined Killarney cooling at LDL. With the attenuation of the spruce populations in south-western New Brunswick the landscape was more open and shrub birch became more important in the pollen record of the area. LDL also showed a similar increase of *Betula* percentages at this time, but it also shared with east central sites, a decline of *Juniperus* pollen percentages. Sharing pollen traits with forested and unforested sites of the area, the pollen record at LDL can be read as a floristic change which occurred in the shrub cover. It can be compared to signals coming from different parts of today's forest-tundra.

This study also includes fine resolution pollen analysis in order to establish the role that the sediment supply played on the pollen input to LDL. The pollen results are compared to grain size analysis to help identify the sediment supply. Although the sediment supply could not be identified with certainty, this study did show that erosion intensity, depicted by an increased grain size, appears to be associated with the local vegetation's resilience to environmental change either in the form of climatic cooling or warming. Certain vegetation communities appear to be associated with certain types of sediments (figure 7.3). First, spruce forest communities (PAZ 2C and 4) were associated with normal grading of fine, organic rich sediments (TAZ 3A and 5B). Second, it was noticed that two spruce population recovery phases (upper PAZ 2B and lower PAZ 3) are associated with coarse sandy sediment (>125mm) (TAZ 2 and 4). These two recovery phases both represent climatic amelioration, but they differ on the basis of the dominant pollen taxon. In the first instance, the sandy sediment (TAZ 2) corresponds with the second *Juniperus* peak (upper PAZ 2B) at the end of the Killarney. In the second instance, the sandy sediment (TAZ 4) corresponds with abundant grass and the demise of the shrub birch population (lower PAZ 3) at the end of the Younger Dryas. Third, *Betula* pollen percentages reach a maximum or show an increase in the silty to sandy sediment which is associated with the cooler conditions of the

Killarney pollen percentages sequence	sediment type	Younger Dryas pollen percentages sequence
Picea peak PAZ 2C	gyttja TAZ 5 → ← silty organic TAZ 3A	*Picea* increase PAZ 4
Juniperus increase upper PAZ 2B	← sandy TAZ 2/TAZ 4 →	*Betula* decrease *Juniperus & Salix* increase PAZ 3
Betula peak lower PAZ 2B	← silty upperTAZ 1/TAZ 3B →	*Alnus* peak *Betula* increase *Picea* decrease PAZ 2D
Juniperus increase (*Picea* macrofossil)	coarse organic material (mottling) upper TAZ 1/upper TAZ 3A	*Picea* peak PAZ 2C

Figure 7.3 Recurring sequence in the pollen and sediment late-glacial record at Little Dyke Lake, Nova Scotia

Killarney and the Younger Dryas. Two different interpretations are offered to explain the two *Betula* maxima. The first peak reflects the effects of cooler conditions which changed the community composition and structure of the shrub tundra. Several factors may have intervened in the communities capability to respond to climatic cooling. The site's location, the topography, soils and the occurrence of fires, combined were important. The second *Betula* maximum is interpreted to be the result of combined effects of cooling and warming. That is, the open landscape which resulted from climatic cooling allowed a larger proportion of *Betula* pollen (especially <20mm) to arrive at LDL. With climate amelioration, the local spruce trees slowly recovered. Meanwhile, tree birch, which had not yet arrived but was nearer to the site, also contributed more to the pollen rain. Consequently, the total *Betula* pollen percentages increased until the shrub component of the vegetation became dominated by willow and sweet fern rather than shrub birch. Finally, results revealed that the onset of cooler conditions of the Killarney and the Younger Dryas are rapidly recorded in the character of the sediments at LDL. Coarse organic remains and mottled sediments (upper TAZ 1 and upper TAZ 3A) accompanied maxima of *Picea* and decreasing *Juniperus* pollen percentages (PAZ 2A and upper PAZ 2C respectively). The fact that changes in the pollen record and the character of the sediment coincide implies that both proxies were sensitive to climatic change. The efficacy of grain size analysis to depict climatic change needs, however, to be evaluated against further studies which could help discriminate the direct and indirect effects of climatic change on the hydrology of unforested and forested sites.

This study contributes to the Debert-Belmont paleo-Indian project in terms of providing a late-glacial vegetation record. Pollen results from LDL show that the late-glacial vegetation over the Folly delta was affected by climatic fluctuations which could help explain the behaviour of the paleo-Indian in eastern North America. Based on the pollen results of this study and examination of the chrono-stratigraphy of the Debert site it is proposed that the paleo-Indian occupied the site between the time of the Killarney and the Younger Dryas cooling events. The open spruce woodland would have been most appropriate for hunting and gathering activities. However, the task of deciphering paleo-Indian behaviour with respect to the changing biophysical environment is left to the informed archaeologist.

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ANNEX 1 ABBREVIATIONS

LDL.....Little Dyke Lake (Nova Scotia)

PAZ.....pollen assemblage zone

TAZ.....texture assemblage zone

~.....approximately

cs .....centistokes

%.....percent

°C .....degree Celsius

F.....Fahrenheit

cm .....centimeter

mm .....millimeter

µm .....micrometer

g .....gram

wv.....weight per volume

ml .....milliliters

km .....kilometers

yrs. BP .....years before present (1950)

ID .....inside diameter

AMS .....accelerator mass spectrometry

C-14 or C^{14} .....carbon 14

NADW.....North Atlantic Deep Water

BP.....before present (1950)

LST.....Laacher See Tephra

mwp.....melt-water pulse

GRIP .....Greenland Ice Core Project (European)

GIPS2.....Greenland Ice Project Group 2 (US)

ECM.....electrical conductivity measurements

Y.D.....Younger Dryas

PB.....Preboreal

$\delta^{13}C$.....isotope carbon 13

$\delta^{18}O$.....isotope oxygen 18

ANNEX 2 LIST OF VERNACULAR AND LATIN NAME OF PLANTS CITED

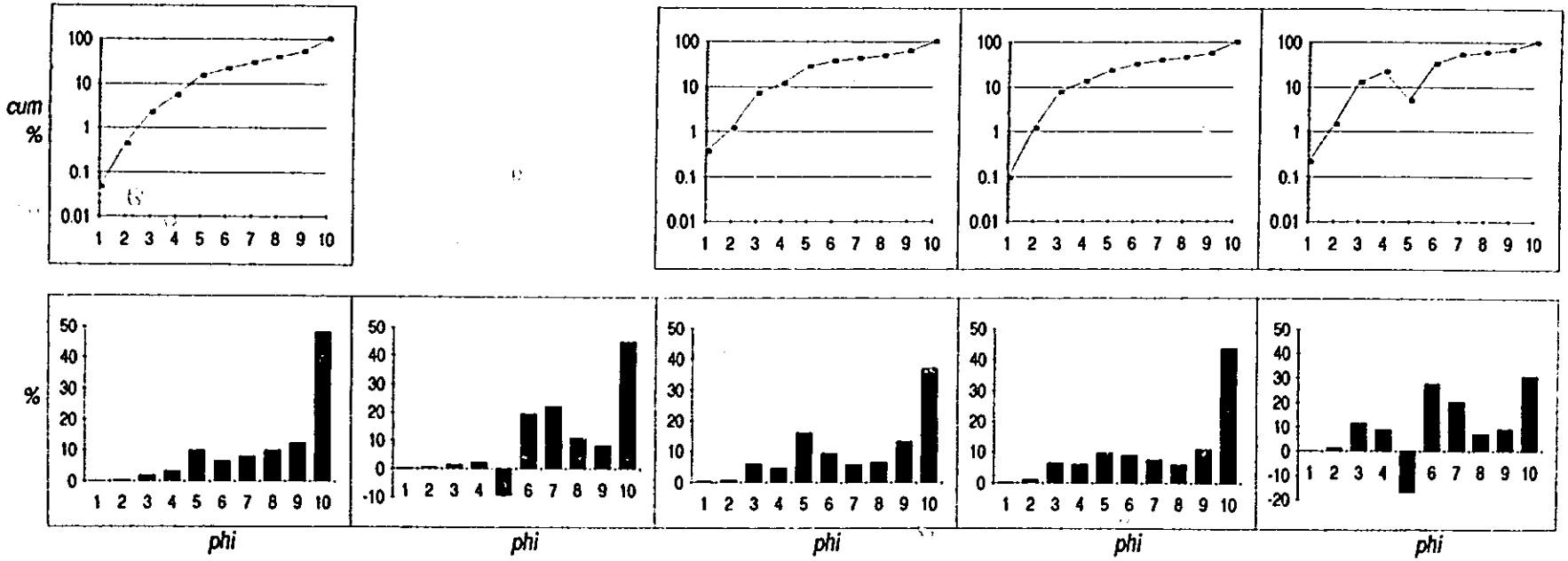
Picea	spruce
Pinus strobus	white pine
Pinus banksiana	jack pine
Abies	larch
Betula	birch
Betula glandulosa	shrub birch
Populus	poplar/aspen
Quercus	oak
Carya	hickory
Ulmus	elm
Tsuga	hemlock
Fraxinus	ash
Acer	maple
Tilia	basswood, linden
Ostrya/Carpinus	ironwood/hornbeam
Juglans	walnut
Cornus	dogwood
Amelanchier	service berry
Cupressaceae	juniper/eastern white cedar
Thuya	eastern white cedar
Juniperus	juniper
Alnus crispa	green alder
Alnus rugosa type	speckled alder
Salix	willow
Corylus	hazel-nut
Shepherdia canadensis	buffalo-berry
Myrica gale	sweet gale
Ericaceae	Heath Family
Poaceae	grasses
Compositae	Composite Family
Tubuliflorae	Composite
Ambrosia	ragweed
Artemisia	wormwood, sage, mugwort
Chenopodiaceae	Goosefoot Family
Rosaceae	Rose Family
Potentilla	cinquefoil
Impatiens	touch-me-knot
Oxyria/Rumex	mountain sorrel/dock
Caryophyllaceae	Pink Family
Ranunculaceae	Crowfoot Family
Thalictrum	meadow rue
Saxifraga	saxifrage
Leguminosa	legume
Onagraceae	Evening-primrose Family
Epilobium	willow-herb
Polygonum	smartweed
Plantaginacea	Plantain Family
Cyperaceae	Sedges Family
Equisetum	horsetail
Pteridophyta	ferns and fern allies
Lycopodiaceae	club mosses
Lycopodium clavatum	running pine
Lycopodium annotinum type	bristly club-moss
Polypodiaceae	Polypod Family
Typha	cattail
Sphagnum	sphagnum
Najas	naiad
Nymphaeae	Water lily Family
Potamogeton	pondweed
Sparganium	bur-reed
Callitriche	water starwort
Hippuris	mare's-tail
Isoetes	quillwort

ANNEX 3

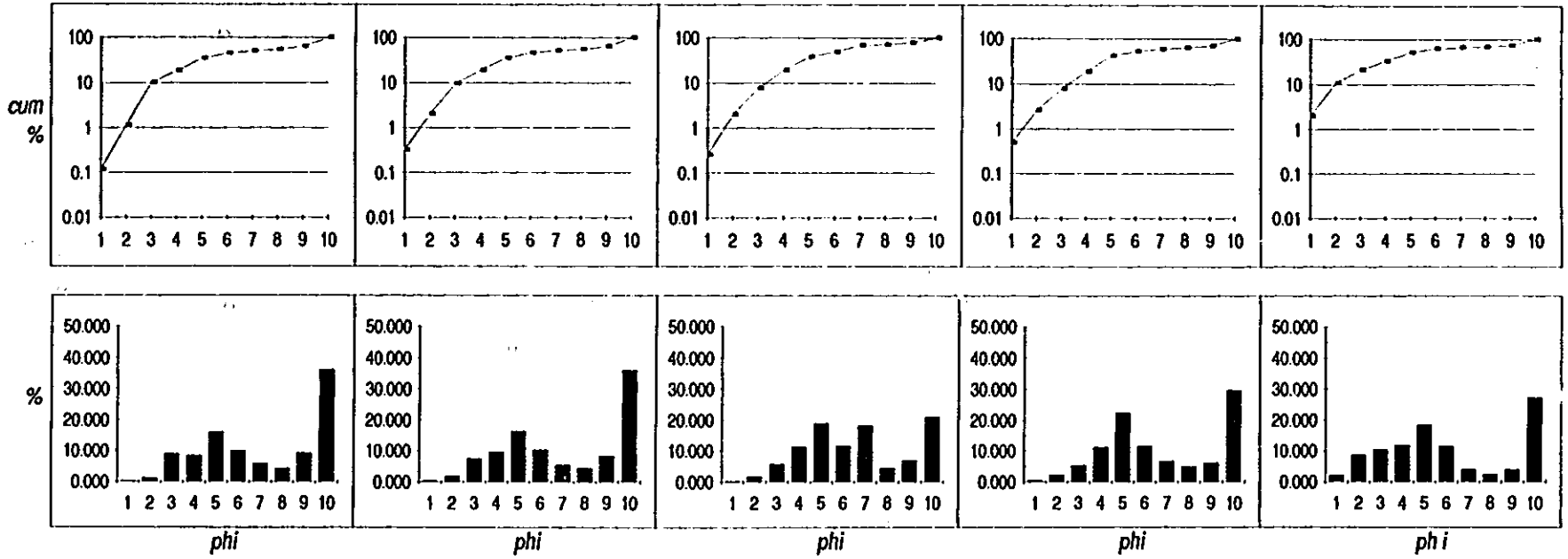
TEXTURE DATA AND STATISTICS

sediment depth (cm)	sample interval	sum of squares	cubed	quad	mean (weight)	mean (%)	median (weight)	median (%)	stdevp (weight)	stdevp (%)	variance (phi2)	variance in % (phi2)	var. coef. (stdevp/mean)	skewness (phi3)	Beta 1	kurtosis (phi4)	Beta 2	1 PHI weight (g)	2 PHI weight (g)	3 PHI weight (g)	4 PHI weight (g)	5 PHI weight (g)	6 PHI weight (g)	7 PHI weight (g)	8 PHI weight (g)	9 PHI weight (g)	10 PHI weight (g)	total weight (g)
610.5	609_612	7.580	14.644	38.631	0.651	10.00	0.470	7.22	0.871	13.37	0.758	178.630	1.337	1.464	4.925	3.863	6.724	0.003	0.025	0.121	0.205	0.640	0.420	0.520	0.640	0.800	3.140	6.514
615.5	614_617	7.652	7.327	20.914	0.595	10.00	0.303	5.08	0.875	14.70	0.765	216.059	1.470	0.733	1.198	2.091	3.572	0.007	0.033	0.076	0.125	-0.560	1.160	1.320	0.640	0.480	2.670	5.951
619.0	618_620	7.413	11.021	28.236	0.846	10.00	0.534	6.32	0.861	10.18	0.741	103.691	1.018	1.102	2.982	2.824	5.139	0.030	0.070	0.508	0.387	1.360	0.800	0.480	0.560	1.120	3.140	8.455
620.5	620_621	3.882	5.489	10.423	0.536	10.00	0.373	6.95	0.623	11.63	0.388	135.288	1.163	0.549	5.149	1.042	6.915	0.005	0.059	0.345	0.318	0.520	0.480	0.400	0.320	0.580	2.330	5.357
621.5	621_622	8.292	-1.756	18.283	0.685	10.00	0.616	8.99	0.911	13.29	0.829	176.618	1.329	-0.176	0.054	1.828	2.659	0.015	0.086	0.789	0.612	-1.160	1.900	1.400	0.480	0.620	2.110	6.852
622.5	622_623	5.521	7.128	16.009	0.759	10.00	0.658	8.66	0.743	9.78	0.552	95.730	0.978	0.713	3.020	1.601	5.253	0.009	0.079	0.678	0.638	1.220	0.760	0.440	0.320	0.700	2.750	7.594
623.5	623_624	7.291	10.997	28.002	0.879	10.00	0.700	7.96	0.854	9.71	0.729	94.297	0.971	1.100	3.120	2.800	5.268	0.029	0.153	0.659	0.842	1.440	0.900	0.480	0.380	0.740	3.170	8.793
624.5	624_625	4.914	0.792	3.093	0.997	10.00	0.908	9.10	0.701	7.03	0.491	49.400	0.703	0.079	0.053	0.309	1.281	0.025	0.173	0.570	1.136	1.880	1.160	1.820	0.440	0.680	2.090	9.974
625.5	625_626	6.380	5.862	12.129	0.907	10.00	0.570	6.29	0.799	8.81	0.638	77.589	0.881	0.586	1.323	1.213	2.980	0.044	0.194	0.472	1.008	2.040	1.040	0.600	0.440	0.540	2.690	9.068
626.5	626_627	4.722	3.201	6.732	0.909	10.00	0.863	9.49	0.687	7.56	0.472	57.204	0.756	0.320	0.973	0.673	3.019	0.182	0.791	0.934	1.069	1.680	1.040	0.360	0.200	0.360	2.470	9.086
627.5	627_628	7.096	7.871	19.619	0.974	10.00	0.828	8.50	0.842	8.65	0.710	74.834	0.865	0.787	1.734	1.962	3.896	0.934	3.033	1.826	0.775	0.680	0.420	0.300	0.220	0.140	1.210	9.738
628.5	628_629	11.623	20.444	63.349	0.976	10.00	0.708	7.25	1.078	11.04	1.162	121.987	1.104	2.044	2.662	6.335	4.690	1.064	3.764	1.988	0.775	0.640	0.340	0.200	0.060	0.080	0.850	9.761
629.5	629_630	4.460	1.701	3.974	0.969	10.00	0.765	7.90	0.668	6.89	0.446	47.527	0.689	0.170	0.326	0.397	1.998	0.680	2.225	1.202	0.850	1.520	0.520	0.400	0.260	0.180	1.850	9.687
630.5	630_631	5.843	0.402	10.128	0.953	10.00	0.941	9.88	0.764	8.02	0.584	64.349	0.802	0.040	0.008	1.013	2.967	0.384	1.118	0.775	0.962	1.480	1.580	-0.500	0.920	0.340	2.470	9.529
631.5	631_632	6.734	5.389	16.887	0.911	10.00	0.790	8.67	0.821	9.01	0.673	81.118	0.901	0.539	0.951	1.689	3.724	0.381	0.820	0.750	0.850	1.800	0.760	0.360	0.920	-0.360	2.830	9.111
632.5	632_633	5.663	4.758	8.607	0.954	10.00	0.615	6.44	0.753	7.89	0.566	62.271	0.789	0.476	1.247	0.861	2.684	0.249	0.615	0.614	1.108	2.200	1.040	0.480	0.360	0.360	2.510	9.536
633.5	633_634	4.809	3.580	5.949	0.941	10.00	0.689	7.32	0.693	7.37	0.481	54.353	0.737	0.358	1.152	0.595	2.573	0.214	0.590	0.757	1.135	2.160	0.840	0.620	0.440	0.340	2.310	9.406
634.5	634_635	6.279	5.164	9.843	0.942	10.00	0.542	5.75	0.792	8.41	0.628	70.730	0.841	0.516	1.077	0.984	2.497	0.096	0.379	0.523	0.974	2.240	1.260	0.560	0.480	0.360	2.550	9.422
635.5	635_636	8.184	6.266	14.615	1.056	10.00	0.643	6.09	0.905	8.56	0.818	73.332	0.856	0.627	0.716	1.461	2.182	0.425	0.155	0.626	1.008	2.820	0.480	2.380	0.660	0.160	1.850	10.564
636.5	636_637	6.112	5.007	9.734	0.944	10.00	0.716	7.58	0.782	8.28	0.611	68.558	0.828	0.501	1.098	0.973	2.606	0.075	0.339	0.651	0.827	2.560	1.180	0.780	0.520	0.300	2.210	9.442
637.5	637_638	6.652	4.961	10.626	0.934	10.00	0.627	6.72	0.816	8.74	0.665	76.306	0.874	0.496	0.836	1.063	2.401	0.023	0.173	0.377	0.694	2.660	1.920	0.800	0.560	0.460	1.670	9.337
638.5	638_639	5.579	3.479	6.586	0.903	10.00	0.651	7.21	0.747	8.27	0.558	68.451	0.827	0.348	0.697	0.659	2.116	0.044	0.228	0.385	0.661	2.360	1.480	0.800	0.400	0.640	2.030	9.028
639.5	639_640	1.461	1.245	1.442	0.306	10.00	0.220	7.19	0.382	12.49	0.146	156.043	1.249	0.124	4.967	0.144	6.753	0.008	0.028	0.088	0.136	0.360	0.240	0.200	0.340	0.260	1.400	3.060
641.0	640_642	3.694	5.055	9.404	0.611	10.00	0.464	7.59	0.608	9.95	0.369	99.043	0.995	0.506	5.070	0.940	6.892	0.028	0.171	0.467	0.441	0.600	0.580	0.460	0.540	0.460	2.360	6.107
643.0	642_644	2.327	1.835	2.758	0.578	10.00	0.470	8.14	0.482	8.35	0.233	69.761	0.835	0.184	2.672	0.276	5.092	0.019	0.110	0.394	0.433	0.820	0.680	0.520	0.440	0.500	1.860	5.776
644.5	644_645	1.918	0.136	0.498	0.765	10.00	0.678	8.86	0.438	5.73	0.192	32.788	0.573	0.014	0.026	0.050	1.354	0.026	0.376	1.201	0.736	1.120	1.560	0.540	0.420	0.620	1.050	7.649
646.5	646_647	6.344	6.309	11.539	0.820	10.00	0.494	6.02	0.796	9.71	0.634	94.347	0.971	0.631	1.559	1.154	2.867	0.234	2.316	2.392	0.548	0.840	0.440	0.260	0.140	0.280	0.750	8.200
647.5	647_648	6.446	6.445	11.870	0.856	10.00	0.543	6.34	0.803	9.38	0.645	88.052	0.938	0.644	1.551	1.187	2.857	0.260	2.360	2.441	0.585	0.920	0.500	0.220	0.220	0.320	0.730	8.556
648.5	648_649	10.032	13.986	32.314	0.930	10.00	0.540	5.80	1.002	10.77	1.003	115.912	1.077	1.399	1.938	3.231	3.211	0.289	2.654	3.111	0.699	0.520	0.560	0.360	0.120	0.200	0.790	9.303
649.5	649_650	12.688	15.698	41.806	0.953	10.00	0.393	4.12	1.126	11.82	1.269	139.731	1.182	1.570	1.207	4.181	2.597	0.226	2.661	3.311	0.581	0.560	1.720	0.140	0.180	0.060	0.090	9.529
650.5	650_651	5.494	2.296	7.047	0.893	10.00	0.680	7.61	0.741	8.30	0.549	68.842	0.830	0.230	-0.318	0.705	2.335	0.019	1.603	2.430	0.551	1.220	0.800	0.440	-0.120	0.560	1.430	8.933
651.5	651_652	3.215	0.667	1.678	0.894	10.00	0.848	9.48	0.567	6.34	0.321	40.213	0.634	0.067	0.134	0.168	1.624	0.083	1.082	1.970	0.616	1.400	1.080	0.500	0.420	0.340	1.450	8.941
652.5	652_653	4.154	0.455	2.467	0.889	10.00	0.789	8.87	0.645	7.25	0.415	52.548	0.725	0.045	0.029	0.247	1.430	0.044	0.902	1.560	0.675	1.800	1.080	0.640	0.340	0.000	1.850	8.891
653.5	653_654	3.529	1.350	2.425	0.867	10.00	0.718	8.29	0.594	6.86	0.353	46.999	0.686	0.135	0.415	0.243	1.948	0.028	0.499	1.092	0.716	1.960	1.020	0.720	0.480	0.320	1.830	8.665
660.5	660_661	2.276	-0.195	0.498	0.876	10.00	0.920	10.50	0.477	5.44	0.228	29.647	0.544	-0.020	0.032	0.050	0.963	0.018	0.450	1.631	0.672	1.120	1.260	1.100	0.740	0.400	1.370	8.761
665.5	665_666	4.061	1.326	3.086	0.801	10.00	0.696	8.69	0.637	7.96	0.406	63.323	0.796	0.133	0.263	0.309	1.871	0.039	0.343	0.844	0.672	1.920	1.260	0.720	0.440	-0.020	1.790	8.008
670.5	670_671	10.332	13.110	41.494	1.132	10.00	0.815	7.20	1.016	8.98	1.033	80.631	0.898	1.311	1.558	4.149	3.887	0.045	0.750	1.483	0.612	3.640	1.640	0.880	0.480	0.040	1.750	11.320
675.5	675_676	8.463	8.452	21.685	0.892	10.00	0.612	6.86	0.920	10.32	0.846	106.481	1.032	0.845	1.179	2.169	3.028	0.002	0.135	0.264	0.764	3.000	1.740	0.800	0.460	0.060	1.690	8.915
680.5	680_681	12.235	20.947	70.180	0.969	10.00	0.672	6.94	1.106	11.42	1.224	130.440	1.142	2.095	2.396	7.018	4.688	0.051	0.193	0.227	0.904	3.840	1.460	1.160	0.440	-0.100	1.510	9.685
685.5	685_686	9.744	16.149	49.323	0.932	10.00	0.650	6.97	0.987	10.59	0.974	112.078	1.059	1.615	2.819	4.932	5.195	0.149	0.544	0.755	1.336	3.560	1.340	0.520	0.340	-0.160	0.940	9.324

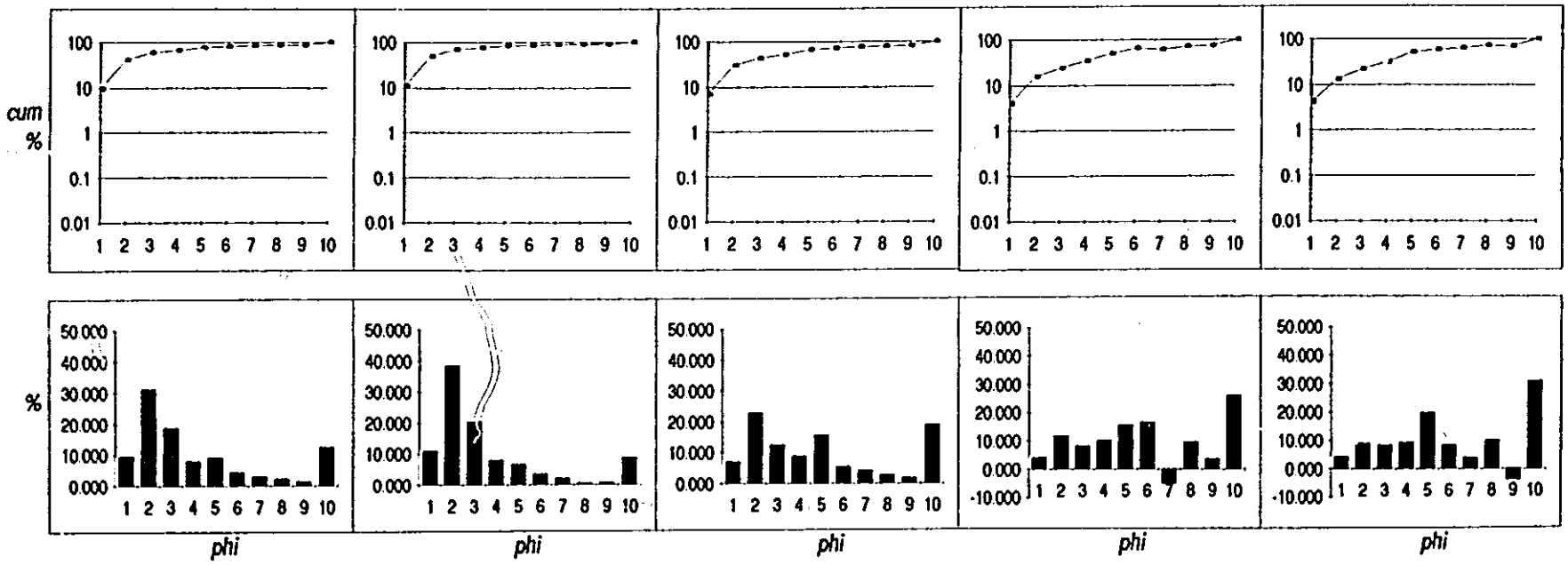
	609-612cm			614-617cm			618-620cm			620-621cm			621-622cm		
phi	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %
1.0	0.003	0.046	0.046	0.007	0.118	0.118	0.030	0.355	0.355	0.005	0.093	0.093	0.015	0.219	0.219
2.0	0.025	0.384	0.430	0.033	0.555	0.672	0.070	0.828	1.183	0.059	1.101	1.195	0.086	1.255	1.474
3.0	0.121	1.858	2.287	0.076	1.277	1.949	0.508	6.008	7.191	0.345	6.440	7.635	0.789	11.515	12.989
4.0	0.205	3.147	5.434	0.125	2.100	4.050	0.387	4.577	11.768	0.318	5.936	13.571	0.612	8.932	21.921
5.0	0.640	9.825	15.259	-0.560	-9.410	-5.360	1.360	16.085	27.853	0.520	9.707	23.278	-1.160	-16.929	4.991
6.0	0.420	6.448	21.707	1.160	19.493	14.132	0.800	9.462	37.315	0.480	8.960	32.238	1.900	27.729	32.720
7.0	0.520	7.983	29.690	1.320	22.181	36.313	0.480	5.677	42.992	0.400	7.467	39.705	1.400	20.432	53.152
8.0	0.640	9.825	39.515	0.640	10.754	47.068	0.560	6.623	49.616	0.320	5.973	45.679	0.480	7.005	60.158
9.0	0.800	12.281	51.796	0.480	8.066	55.134	1.120	13.247	62.862	0.580	10.827	56.506	0.620	9.048	69.206
12.0	3.140	48.204	100.000	2.670	44.866	100.000	3.140	37.138	100.000	2.330	43.494	100.000	2.110	30.794	100.000
SUM	6.514			5.951			8.455			5.357			6.852		



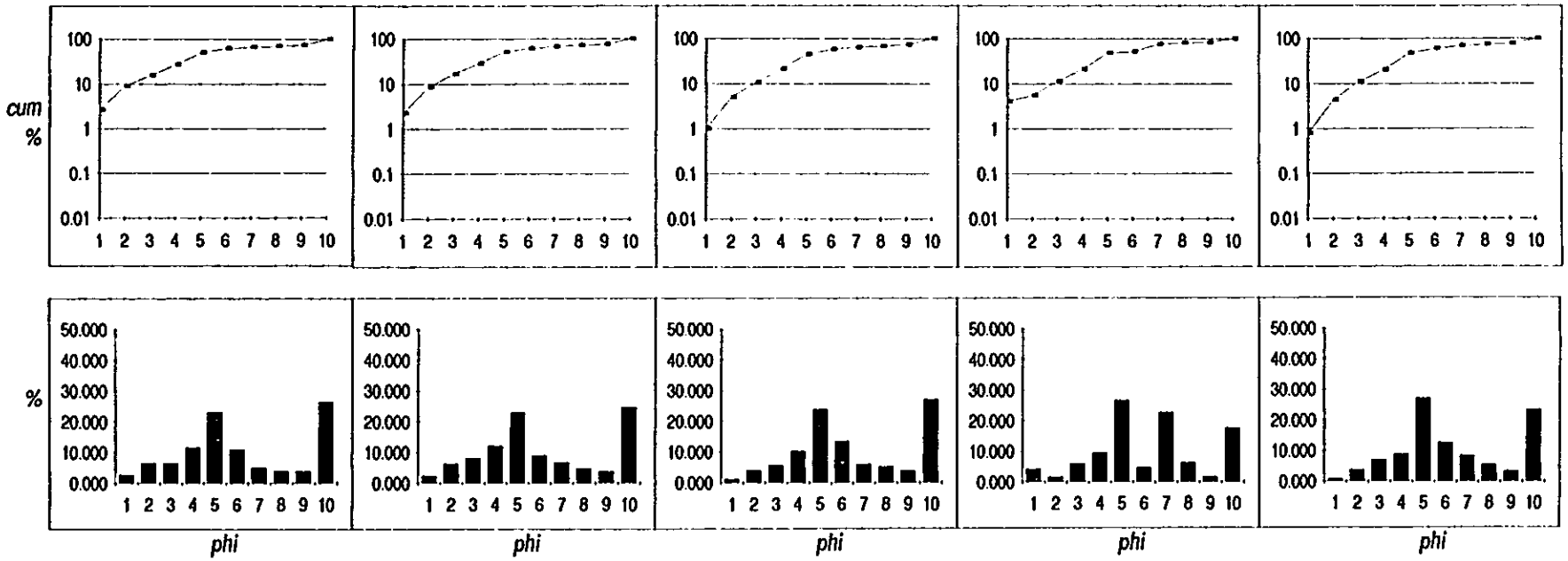
	622-623cm			623-624cm			624-625cm			625-626cm			626-627cm		
phi	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %
1.0	0.009	0.119	0.119	0.029	0.330	0.330	0.025	0.251	0.251	0.044	0.485	0.485	0.182	2.003	2.003
2.0	0.079	1.040	1.159	0.153	1.740	2.070	0.173	1.735	1.985	0.194	2.139	2.625	0.791	8.706	10.709
3.0	0.678	8.928	10.087	0.659	7.495	9.564	0.570	5.715	7.700	0.472	5.205	7.830	0.934	10.280	20.988
4.0	0.638	8.401	18.488	0.842	9.576	19.140	1.136	11.390	19.090	1.008	11.116	18.946	1.069	11.765	32.754
5.0	1.220	16.065	34.554	1.440	16.377	35.517	1.880	18.849	37.939	2.040	22.497	41.442	1.680	18.490	51.244
6.0	0.760	10.008	44.561	0.900	10.235	45.752	1.160	11.630	49.569	1.040	11.469	52.911	1.040	11.446	62.690
7.0	0.440	5.794	50.356	0.480	5.459	51.211	1.820	18.247	67.816	0.600	6.617	59.528	0.360	3.962	66.652
8.0	0.320	4.214	54.569	0.380	4.322	55.533	0.440	4.41[illegible]	72.228	0.440	4.852	64.380	0.200	2.201	68.853
9.0	0.700	9.218	63.787	0.740	8.416	63.949	0.680	6.818	79.046	0.540	5.955	70.335	0.360	3.962	72.815
12.0	2.750	36.213	100.000	3.170	36.051	100.000	2.090	20.954	100.000	2.690	29.665	100.000	2.470	27.185	100.000
SUM	7.594			8.793			9.974			9.068			9.086		



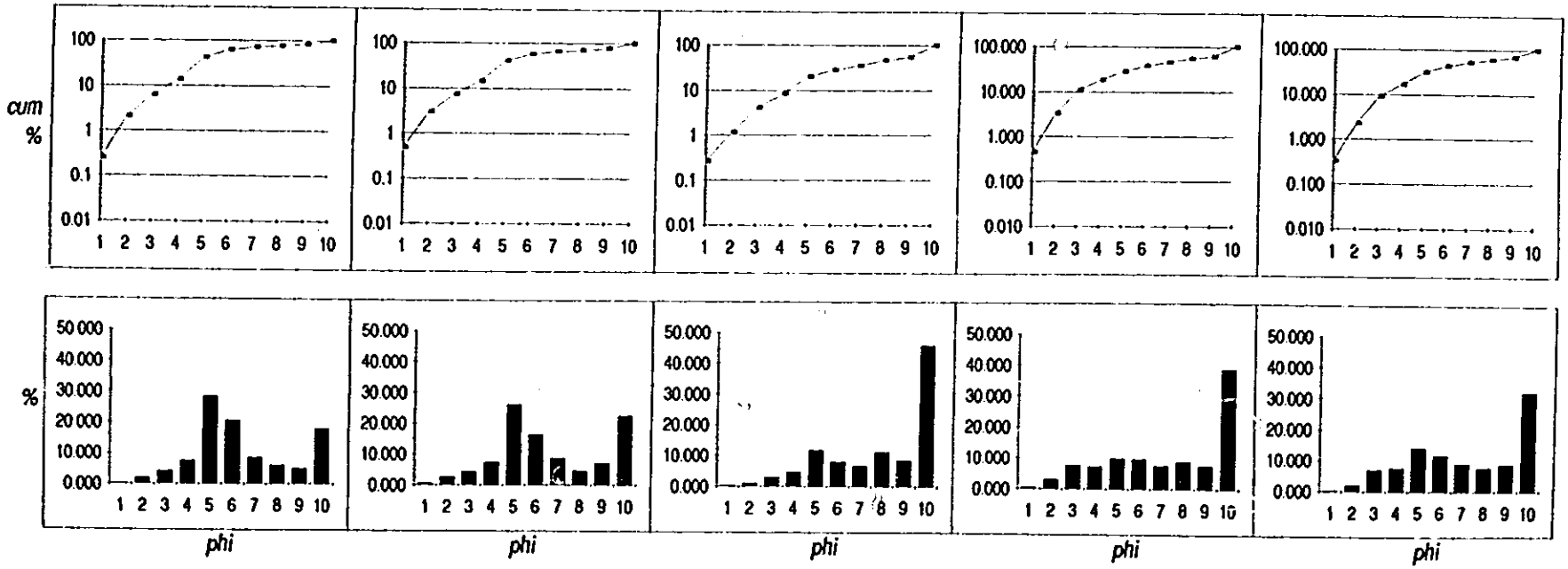
	627-628cm			628-629cm			629-630cm			630-631cm			631-632cm		
phi	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %
1.0	0.934	9.591	9.591	1.064	10.901	10.901	0.680	7.020	7.020	0.384	4.030	4.030	0.381	4.182	4.182
2.0	3.033	31.146	40.737	3.764	38.562	49.462	2.225	22.969	29.989	1.118	11.733	15.762	0.820	9.000	13.182
3.0	1.826	18.751	59.489	1.988	20.367	69.829	1.202	12.408	42.397	0.775	8.133	23.895	0.750	8.232	21.414
4.0	0.775	7.959	67.447	0.775	7.940	77.769	0.850	8.775	51.172	0.962	10.095	33.991	0.850	9.329	30.743
5.0	0.880	9.037	76.484	0.640	6.557	84.325	1.520	15.691	66.863	1.480	15.532	49.523	1.800	19.756	50.499
6.0	0.420	4.313	80.797	0.340	3.483	87.809	0.520	5.368	72.231	1.580	16.581	66.103	0.760	8.342	58.841
7.0	0.300	3.081	83.878	0.200	2.049	89.858	0.400	4.129	76.360	-0.500	-5.247	60.856	0.360	3.951	62.792
8.0	0.220	2.259	86.137	0.060	0.615	90.472	0.260	2.684	79.044	0.920	9.655	70.511	0.920	10.098	72.890
9.0	0.140	1.438	87.574	0.080	0.820	91.292	0.180	1.858	80.902	0.340	3.568	74.079	-0.360	-3.951	68.939
12.0	1.210	12.426	100.000	0.850	8.708	100.000	1.850	19.098	100.000	2.470	25.921	100.000	2.830	31.061	100.000
SUM	9.738			9.761			9.687			9.529			9.111		



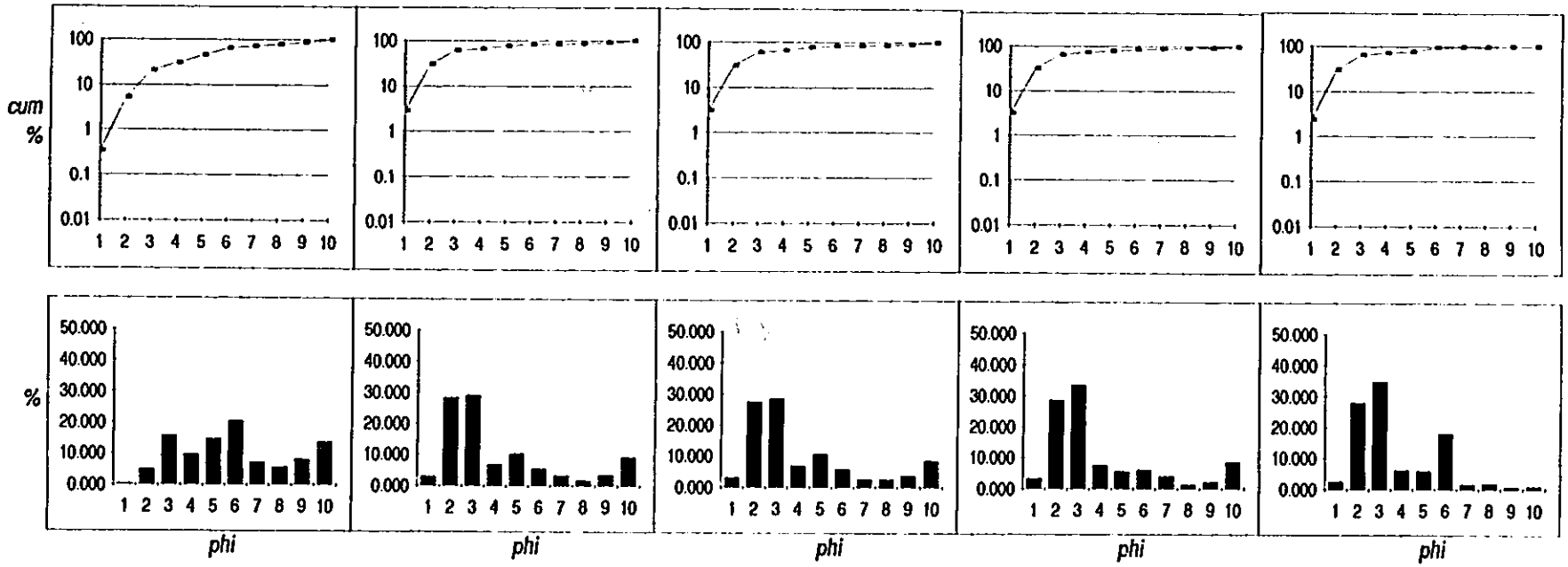
	632-633cm			633-634cm			634-635cm			635-636cm			636-637cm		
phi	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %
1.0	0.249	2.611	2.611	0.214	2.275	2.275	0.096	1.019	1.019	0.425	4.023	4.023	0.075	0.794	0.794
2.0	0.615	6.449	9.060	0.590	6.273	8.548	0.379	4.023	5.041	0.155	1.467	5.490	0.339	3.590	4.385
3.0	0.614	6.439	15.499	0.757	8.048	16.596	0.523	5.551	10.592	0.626	5.926	11.416	0.651	6.895	11.279
4.0	1.108	11.619	27.118	1.135	12.067	28.663	0.974	10.338	20.930	1.008	9.542	20.958	0.827	8.759	20.038
5.0	2.200	23.070	50.189	2.160	22.964	51.627	2.240	23.774	44.704	2.820	26.694	47.652	2.560	27.113	47.151
6.0	1.040	10.906	61.095	0.840	8.930	60.557	1.260	13.373	58.077	0.480	4.544	52.196	1.180	12.497	59.648
7.0	0.480	5.034	66.128	0.620	6.592	67.149	0.560	5.944	64.020	2.380	22.529	74.725	0.780	8.261	67.909
8.0	0.360	3.775	69.904	0.440	4.678	71.826	0.480	5.094	69.115	0.660	6.248	80.973	0.520	5.507	73.417
9.0	0.360	3.775	73.679	0.340	3.615	75.441	0.360	3.821	72.936	0.160	1.515	82.488	0.300	3.177	76.594
12.0	2.510	26.321	100.000	2.310	24.559	100.000	2.550	27.064	100.000	1.850	17.512	100.000	2.210	23.406	100.000
SUM	9.536			9.406			9.422			10.564			9.442		



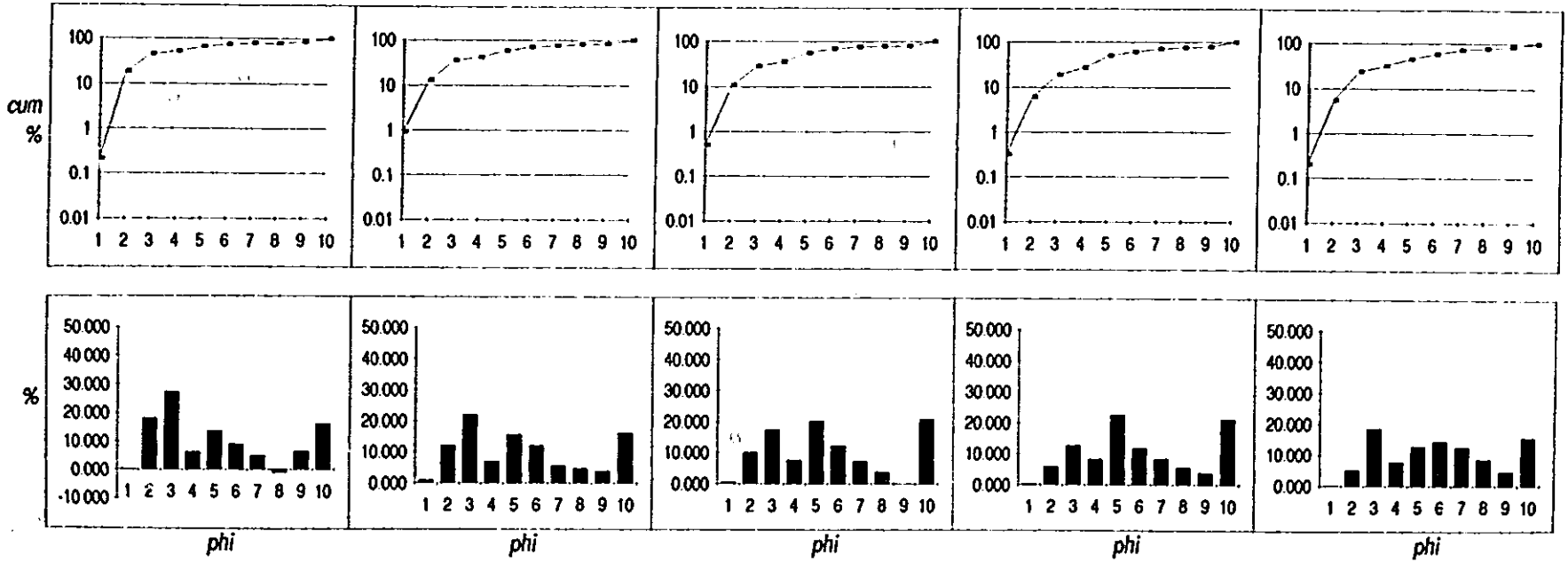
	637-638cm			638-639cm			639-640cm			640-642cm			642-644cm		
phi	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %
1.0	0.023	0.246	0.246	0.044	0.487	0.487	0.008	0.261	0.261	0.028	0.458	0.458	0.019	0.329	0.329
2.0	0.173	1.853	2.099	0.228	2.525	3.013	0.028	0.915	1.176	0.171	2.800	3.259	0.110	1.904	2.233
3.0	0.377	4.038	6.137	0.385	4.265	7.277	0.088	2.876	4.052	0.467	7.647	10.906	0.394	6.821	9.055
4.0	0.694	7.433	13.570	0.661	7.322	14.599	0.136	4.444	8.497	0.441	7.221	18.127	0.433	7.497	16.551
5.0	2.660	28.489	42.058	2.360	26.141	40.740	0.360	11.765	20.261	0.600	9.825	27.952	0.820	14.197	30.748
6.0	1.920	20.563	62.622	1.480	16.393	57.133	0.240	7.843	28.105	0.580	9.497	37.449	0.680	11.773	42.521
7.0	0.800	8.568	71.190	0.800	8.861	65.995	0.200	6.536	34.641	0.460	7.532	44.981	0.520	9.003	51.524
8.0	0.560	5.998	77.188	0.400	4.431	70.425	0.340	11.111	45.752	0.540	8.842	53.823	0.440	7.618	59.141
9.0	0.460	4.927	82.114	0.640	7.089	77.514	0.260	8.497	54.248	0.460	7.532	61.356	0.500	8.657	67.798
12.0	1.670	17.886	100.000	2.030	22.486	100.000	1.400	45.752	100.000	2.360	38.644	100.000	1.860	32.202	100.000
SUM	9.337			9.028			3.060			6.107			5.776		



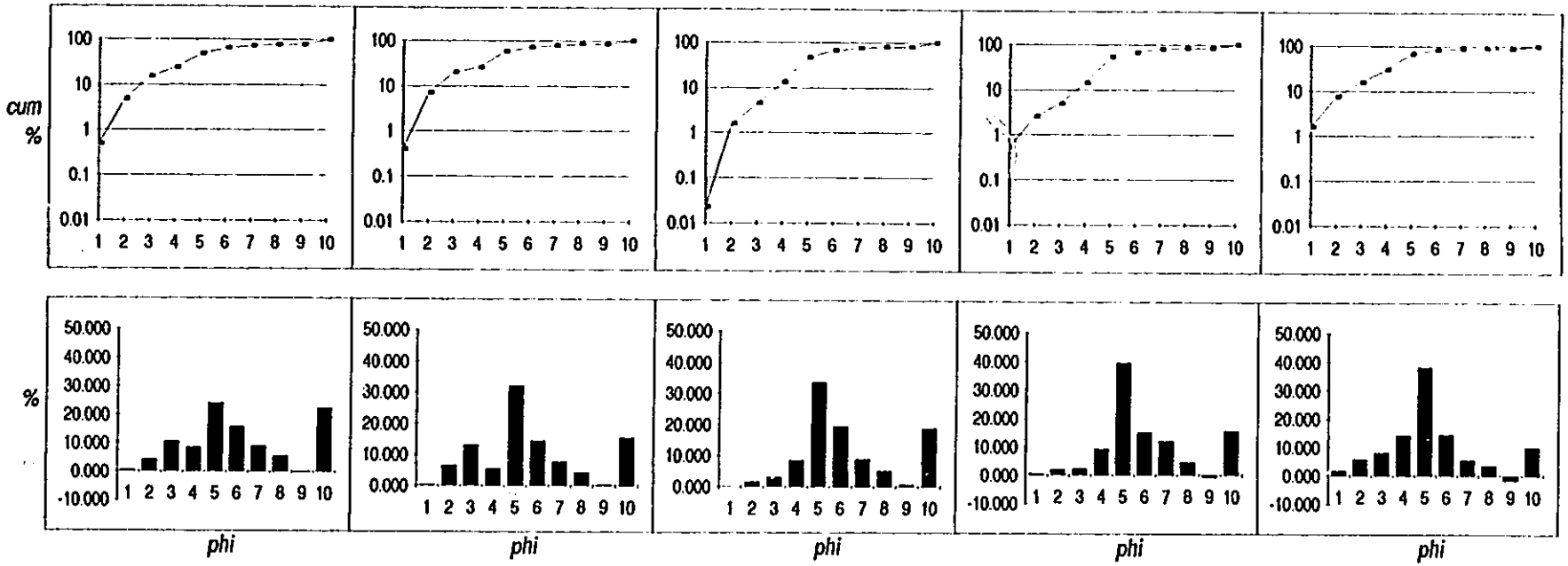
	644-645cm			646-647cm			647-648cm			648-649cm			649-650cm		
phi	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %
1.0	0.026	0.340	0.340	0.234	2.854	2.854	0.260	3.039	3.039	0.289	3.107	3.107	0.226	2.372	2.372
2.0	0.376	4.916	5.256	2.316	28.244	31.098	2.360	27.583	30.622	2.654	28.528	31.635	2.661	27.925	30.297
3.0	1.201	15.701	20.957	2.392	29.171	60.268	2.441	28.530	59.151	3.111	33.441	65.076	3.311	34.747	65.044
4.0	0.736	9.622	30.579	0.548	6.683	66.951	0.585	6.837	65.989	0.699	7.514	72.589	0.581	6.097	71.141
5.0	1.120	14.642	45.222	0.840	10.244	77.195	0.920	10.753	76.741	0.520	5.590	78.179	0.560	5.877	77.018
6.0	1.560	20.395	65.616	0.440	5.366	82.561	0.500	5.844	82.585	0.560	6.020	84.199	1.720	18.050	95.068
7.0	0.540	7.060	72.676	0.260	3.171	85.732	0.220	2.571	85.157	0.360	3.870	88.068	0.140	1.469	96.537
8.0	0.420	5.491	78.167	0.140	1.707	87.439	0.220	2.571	87.728	0.120	1.290	89.358	0.180	1.889	98.426
9.0	0.620	8.106	86.273	0.280	3.415	90.854	0.320	3.740	91.468	0.200	2.150	91.508	0.060	0.630	99.056
12.0	1.050	13.727	100.000	0.750	9.146	100.000	0.730	8.532	100.000	0.790	8.492	100.000	0.090	0.944	100.000
SUM	7.649			8.200			8.556			9.303			9.529		



	650-651cm			651-652cm			652-653cm			653-654cm			660-661cm		
phi	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %
1.0	0.019	0.213	0.213	0.083	0.928	0.928	0.044	0.495	0.495	0.028	0.323	0.323	0.018	0.205	0.205
2.0	1.603	17.945	18.157	1.082	12.102	13.030	0.902	10.145	10.640	0.499	5.759	6.082	0.450	5.136	5.342
3.0	2.430	27.203	45.360	1.970	22.033	35.063	1.560	17.546	28.186	1.092	12.602	18.684	1.631	18.617	23.958
4.0	0.551	6.168	51.528	0.616	6.890	41.953	0.675	7.592	35.778	0.716	8.263	26.947	0.672	7.670	31.629
5.0	1.220	13.657	65.185	1.400	15.658	57.611	1.800	20.245	56.023	1.960	22.620	49.567	1.120	12.784	44.413
6.0	0.800	8.956	74.141	1.080	12.079	69.690	1.080	12.147	68.170	1.020	11.771	61.339	1.260	14.382	58.795
7.0	0.440	4.926	79.066	0.500	5.592	75.282	0.640	7.198	75.368	0.720	8.309	69.648	1.100	12.556	71.350
8.0	-0.120	-1.343	77.723	0.420	4.697	79.980	0.340	3.824	79.192	0.480	5.540	75.188	0.740	8.447	79.797
9.0	0.560	6.269	83.992	0.340	3.803	83.783	0.000	0.000	79.192	0.320	3.693	78.881	0.400	4.566	84.363
12.0	1.430	16.008	100.000	1.450	16.217	100.000	1.850	20.808	100.000	1.830	21.119	100.000	1.370	15.637	100.000
SUM	8.933			8.941			8.891			8.665			8.761		



	665-666cm			670-671cm			675-676cm			680-681cm			685-686cm		
phi	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %	weight (g)	%	cumulative %
1.0	0.039	0.487	0.487	0.045	0.398	0.398	0.002	0.022	0.022	0.051	0.527	0.527	0.149	1.598	1.598
2.0	0.343	4.283	4.770	0.750	6.625	7.023	0.135	1.514	1.537	0.193	1.993	2.519	0.544	5.834	7.432
3.0	0.844	10.539	15.310	1.483	13.101	20.124	0.264	2.961	4.498	0.227	2.344	4.863	0.755	8.097	15.530
4.0	0.672	8.392	23.701	0.612	5.406	25.530	0.764	8.570	13.068	0.904	9.334	14.197	1.336	14.329	29.858
5.0	1.920	23.976	47.677	3.640	32.155	57.686	3.000	33.651	46.719	3.840	39.649	53.846	3.560	38.181	68.039
6.0	1.260	15.734	63.412	1.640	14.488	72.173	1.740	19.518	66.237	1.460	15.075	68.921	1.340	14.372	82.411
7.0	0.720	8.991	72.403	0.880	7.774	79.947	0.800	8.974	75.210	1.160	11.977	80.898	0.520	5.577	87.988
8.0	0.440	5.495	77.897	0.480	4.240	84.187	0.460	5.160	80.370	0.440	4.543	85.441	0.340	3.647	91.634
9.0	-0.020	-0.250	77.647	0.040	0.353	84.541	0.060	0.673	81.043	-0.100	-1.033	84.409	-0.160	-1.716	89.918
12.0	1.790	22.353	100.000	1.750	15.459	100.000	1.690	18.957	100.000	1.510	15.591	100.000	0.940	10.082	100.000
SUM	8.008			11.320			8.915			9.685			9.324		



ANNEX 4 POLLEN DATA

Sediment depth (cm)	Eucalyptus (# counted)	Volume of sediment (cm³)	Volume of spike (+l)	Concentration of spike /+l	Pollen sum	Pollen concentration (grains/cm³)	Picea	Pinus undifferentiated	Pinus strobus	Pinus banksiana	Abies	Betula >20 microns	Betula <20 microns	Populus	Quercus	Carya	Ulmus	Tsuga	Fraxinus	Acer	Tilia	Ostrya/Carpinus	Juglans	Cornus
596.5	148.0	1.0	0.5	132200.0	320.0	142918.9	140.0	7.0	14.0	5.0	2.0	6.0	37.0	5.0	8.0	0.0	1.0	1.0	3.0	0.0	0.0	6.0	0.0	0.0
597.5	160.0	1.0	0.5	132200.0	304.0	125590.0	142.0	10.0	24.0	7.0	1.0	8.0	29.0	5.0	10.0	0.0	1.0	1.0	3.0	3.0	0.0	5.0	1.0	0.0
598.5	124.0	1.0	0.5	132200.0	299.0	159386.3	157.0	5.0	8.0	1.0	2.0	7.0	29.0	8.0	4.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0
599.5	129.0	1.0	0.5	132200.0	341.0	174729.5	173.0	7.0	9.0	7.0	0.0	3.0	38.0	7.0	4.0	0.0	1.0	2.0	3.0	1.0	0.0	2.0	0.0	1.0
600.5	118.0	1.0	0.5	132200.0	339.0	189897.5	129.0	10.0	13.0	11.0	0.0	4.0	39.0	10.0	10.0	0.0	1.0	0.0	0.0	5.0	0.0	5.0	0.0	0.0
601.5	155.0	1.0	0.5	132200.0	331.0	141155.5	142.0	9.0	15.0	2.0	4.0	10.0	42.0	2.0	8.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
602.5	102.0	1.0	0.5	132200.0	313.0	202836.3	129.0	7.0	14.0	3.0	4.0	10.0	32.0	11.0	10.0	0.0	2.0	0.0	4.0	0.0	0.0	1.0	0.0	0.0
603.5	159.0	1.0	0.5	132200.0	354.0	147166.0	112.0	12.0	7.0	6.0	0.0	11.0	61.0	11.0	8.0	1.0	2.0	0.0	2.0	0.0	0.0	3.0	0.0	0.0
604.5	126.0	1.0	0.5	132200.0	345.0	180988.1	133.0	8.0	11.0	8.0	15.0	37.0	8.0	12.0	16.0	0.0	1.0	0.0	2.0	2.0	0.0	3.0	0.0	0.0
605.5	114.0	1.0	0.5	132200.0	322.0	186703.5	111.0	4.0	16.0	2.0	1.0	0.0	72.0	7.0	2.0	0.0	2.0	0.0	4.0	0.0	0.0	1.0	0.0	2.0
607.5	141.0	1.0	0.5	132200.0	367.0	172047.5	118.0	6.0	12.0	5.0	0.0	2.0	61.0	14.0	5.0	0.0	0.0	0.0	2.0	0.0	0.0	5.0	0.0	0.0
608.5	101.0	1.0	0.5	132200.0	320.0	209425.8	128.0	6.0	15.0	6.0	3.0	4.0	59.0	6.0	3.0	0.0	0.0	0.0	3.0	5.0	0.0	1.0	0.0	0.0
609.5	100.0	1.0	0.5	132200.0	345.5	228375.5	130.0	14.0	13.0	9.0	3.0	1.0	64.0	9.0	9.0	0.0	0.0	0.5	0.0	1.0	0.0	1.0	0.0	0.0
610.5	129.0	1.0	0.5	132200.0	349.0	178828.7	128.0	4.0	22.0	4.0	6.0	4.0	54.0	9.0	11.0	0.0	3.0	2.0	6.0	0.0	0.0	2.0	0.0	1.0
611.5	100.0	1.0	0.5	132200.0	320.0	211520.0	121.0	14.0	11.0	8.0	4.0	6.0	43.0	10.0	2.0	0.0	0.0	0.0	1.0	1.0	0.0	2.0	0.0	0.0
612.5	125.0	1.0	0.5	132200.0	330.0	174504.0	129.0	12.0	16.0	14.0	4.0	1.0	45.0	2.0	1.0	0.0	2.0	0.0	0.0	2.0	0.0	5.0	0.0	0.0
613.5	113.0	1.0	0.5	132200.0	342.0	200054.9	189.0	12.0	14.0	7.0	6.0	4.0	25.0	2.0	2.0	0.0	3.0	2.0	5.0	1.0	0.0	3.0	1.0	0.0
614.5	145.0	1.0	0.5	132200.0	336.0	153169.7	145.0	9.0	8.0	8.0	2.0	10.0	71.0	7.0	1.0	0.0	1.0	1.0	3.0	1.0	0.0	1.0	1.0	0.0
615.5	128.0	1.0	0.5	132200.0	342.0	176610.9	187.0	8.0	20.0	5.0	1.0	7.0	52.0	1.0	2.0	0.0	0.0	1.0	4.0	0.0	0.0	2.0	1.0	0.0
616.5	128.0	1.0	0.5	132200.0	316.0	163184.4	114.0	10.0	10.0	0.0	0.0	3.0	50.0	8.0	8.0	0.0	1.0	0.0	4.0	0.0	0.0	2.0	0.0	0.0
617.5	107.0	1.0	0.5	132200.0	387.0	239072.0	191.0	9.0	14.0	4.0	4.0	10.0	49.0	6.0	1.0	1.0	0.0	3.0	2.0	1.0	0.0	1.0	0.0	0.0
618.5	116.0	1.0	0.5	132200.0	398.0	226791.0	185.0	2.0	12.0	3.0	1.0	3.0	91.0	12.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
619.5	109.0	1.0	0.5	132200.0	307.0	186171.6	86.0	6.0	17.0	7.0	1.0	2.0	95.0	0.0	3.0	0.0	0.0	3.0	1.0	0.0	0.0	3.0	0.0	0.0
620.5	114.0	1.0	0.5	132200.0	339.0	196560.5	76.0	14.0	16.0	7.0	1.0	0.0	117.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
621.5	170.0	1.0	0.5	128800.0	313.0	118571.8	65.0	13.0	9.0	10.0	8.0	10.0	73.0	1.0	8.0	0.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
622.5	132.0	1.0	0.5	128800.0	347.0	169293.9	37.0	8.0	11.0	10.0	2.0	4.0	78.0	1.0	1.0	0.0	1.0	2.0	2.0	0.0	0.0	4.0	0.0	0.0
623.5	134.0	1.0	0.5	128800.0	373.0	179262.7	40.0	10.0	14.0	9.0	0.0	0.0	107.0	1.0	3.0	0.0	0.0	2.0	0.0	2.0	0.0	0.0	0.0	0.0
624.5	220.0	1.0	0.5	128800.0	346.0	101283.6	28.0	13.0	9.0	8.0	1.0	7.0	104.0	0.0	8.0	0.0	0.0	0.0	1.0	0.0	0.0	3.0	0.0	0.0
625.5	159.0	1.0	0.5	128800.0	319.0	129205.0	16.0	7.0	11.0	1.0	0.0	6.0	119.0	0.0	2.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
626.5	141.0	1.0	0.5	128800.0	333.0	152093.6	23.0	16.0	12.0	8.0	6.0	3.0	118.0	0.0	5.0	0.0	0.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0
627.5	215.0	1.0	0.5	128800.0	365.0	109330.2	24.0	8.0	21.0	5.0	0.0	1.0	147.0	1.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
628.5	549.0	1.0	0.5	128800.0	376.0	44106.4	45.0	20.0	15.0	11.0	1.0	5.0	161.0	0.0	1.0	0.0	0.0	3.0	1.0	0.0	0.0	4.0	0.0	0.0
629.5	206.0	1.0	0.5	128800.0	346.0	108167.0	52.0	32.0	17.0	19.0	1.0	2.0	113.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	5.0	1.0	0.0
630.5	303.0	1.0	0.5	132200.0	413.0	90096.7	26.0	16.0	24.0	18.0	0.0	0.0	134.0	0.0	0.0	0.0	1.0	2.0	0.0	0.0	0.0	1.0	1.0	0.0
631.5	217.0	1.0	0.5	132200.0	343.0	104480.6	76.0	19.0	4.0	26.0	0.0	4.0	108.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
632.5	301.0	1.0	0.5	132200.0	362.0	79495.7	15.0	10.0	16.0	18.0	0.0	0.0	110.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0
633.5	333.0	1.0	0.5	132200.0	382.0	75826.4	55.0	12.0	17.0	27.0	5.0	4.0	75.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0
634.5	329.0	1.0	0.5	128800.0	417.0	81625.5	55.0	34.0	18.0	36.0	0.0	1.0	75.0	5.0	1.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
635.5	557.0	1.0	0.5	132200.0	437.0	51859.4	14.0	11.0	4.0	12.0	1.0	2.0	111.0	0.0	4.0	1.0	0.0	0.0	2.0	0.0	0.0	4.0	0.0	0.0
636.5	359.0	1.0	0.5	128800.0	393.0	70499.2	78.0	21.0	28.0	41.0	2.0	2.0	46.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
637.5	325.0	1.0	0.5	128800.0	365.0	72326.2	99.0	20.0	33.0	24.0	0.0	0.0	48.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
638.5	268.0	1.0	0.5	128800.0	352.0	84585.1	145.0	24.0	13.0	22.0	1.0	2.0	40.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
639.5	129.0	1.0	0.5	136400.0	329.0	173936.4	189.0	17.0	7.0	11.0	7.0	0.0	45.0	0.0	2.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0
640.5	167.0	1.0	0.5	128800.0	327.0	126100.6	194.0	31.0	0.0	18.0	0.0	0.0	37.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
641.5	218.0	1.0	0.5	128800.0	224.0	66172.5	82.0	9.0	8.0	14.0	3.0	0.0	45.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0
642.5	136.0	1.0	0.5	128800.0	346.0	163841.2	234.0	4.0	5.0	5.0	1.0	0.0	47.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0
643.5	198.0	1.0	0.5	128800.0	336.0	109284.9	181.0	3.0	4.0	7.0	0.0	1.0	51.0	2.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0
645.5	261.0	1.0	0.5	136400.0	345.0	90149.4	89.0	10.0	0.0	18.0	0.0	0.0	51.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0
646.5	353.0	1.0	0.5	136400.0	364.0	70325.2	89.0	11.0	5.0	18.0	2.0	0.0	82.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
647.5	305.0	1.0	0.5	136400.0	348.0	77815.1	67.0	9.0	9.0	17.0	0.0	0.0	104.0	2.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
648.5	358.0	1.0	0.5	136400.0	333.0	63437.4	76.0	23.0	9.0	7.0	0.0	2.0	106.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0
649.5	319.0	1.0	0.5	128800.0	363.0	73282.8	65.0	19.0	4.0	24.0	2.0	1.0	132.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
650.5	248.0	1.0	0.5	128800.0	353.0	91666.1	36.0	12.0	1.0	29.0	0.0	0.0	133.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
652.5	271.0	1.0	0.5	128800.0	374.0	88878.8	37.0	17.0	6.0	8.0	1.0	0.0	131.0	0.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0
653.5	266.0	1.0	0.5	128800.0	340.0	82315.8	43.0	13.0	10.0	16.0	0.0	0.0	129.0	1.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	5.0	0.0	0.0
654.5	221.0	1.0	0.5	128800.0	352.0	102573.8	35.0	11.0	16.0	13.0	1.0	6.0	98.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
655.5	105.0	1.0	0.5	128800.0	336.0	206080.0	51.0	15.0	1.0	37.0	0.0	0.0	91.0	12.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0
657.5	253.0	1.0	0.5	136400.0	335.0	90304.4	37.0	12.0	6.0	6.0	0.0	2.0	89.0	5.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0
658.5	214.0	1.0	0.5	136400.0	355.0	113135.5	29.0	11.0	6.0	9.0	0.0	0.0	73.0	5.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0
659.5	223.0	1.0	0.5	136400.0	332.0	101535.4	21.0	8.0	8.0	9.0	0.0	1.0	82.0	3.0	4.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0
660.5	204.0	1.0	0.5	136400.0	372.0	124364.7	18.0	13.0	0.0	17.0	0.0	0.0	86.0	9.0	3.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0
662.5	276.0	1.0	0.5	136400.0	347.0	85744.2	19.0	18.0	9.0	9.0	1.0	1.0	97.0	4.0	6.0	0.0	0.0	0.0	3.0	0.0	0.0	7.0	0.0	0.0
664.5	496.0	1.0	0.5	136400.0	448.0	61325.0	27.0	22.0	11.0	17.0	0.0	3.0	90.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	2.0
665.5	438.0	1.0	0.5	136400.0	376.0	58546.1	22.0	17.0	2.0	17.0	0.0	0.0	97.0	13.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0
666.5	338.0	1.0	0.5	136400.0	360.0	72639.1	21.0	14.0	8.0	24.0	1.0	0.0	90.0	0.0	1.0	1.0	0.0	1.0	0.0	0.0	0.0	5.0	1.0	0.0
668.5	457.0	1.0	0.5	136400.0	401.0	59842.9	18.0	16.0	19.0	12.0	0.0	0.0	80.0	2.0	5.0	0.0	0.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0
669.5	575.0	1.0	0.5	136400.0	371.0	44003.8	15.0	20.0	10.0	15.0	1.0	3.0	79.0	3.0	1.0	0.0	2.0	0.0	3.0	0.0	0.0	5.0	0.0	0.0
670.5	520.0	1.0	0.5	136400.0	422.0	55348.9	22.0	27.0	1.0	22.0	0.0	2.0	77.0	13.0	6.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0
671.5	690.0	1.0	0.5	136400.0	367.0	36274.5	13.0	7.0	7.0	19.0	1.0	10.0	54.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0
672.5	223.0	1.0	0.2	115400.0	367.0	37983.7	19.0	13.0	0.0	21.0	0.0	2.0	79.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0
675.5	816.0	1.0	0.2	115400.0	382.0	10804.6	17.0	13.0	0.0	28.0	0.0	1.0	49.0	3.0	4.0	2.0	0.0	0.0	0.0	0.0	0.0	4.0	1.0	0.0
682.5	542.0	1.0	0.2	115400.0	388.0	16522.2	49.0	17.0	41.0	29.0	0.0	1.0	23.0	2.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0	3.0	0.0	0.0
690.5	322.0	1.0	0.2	115400.0	120.0	8601.2	12.0	12.0	13.0	6.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0

Sediment depth (cm)	Juniperus	Alnus crispa	Alnus rugosa	Salix	Corylus	Shepherdia canadensis	Myrica	Ericaceae	Poaceae	Tubuliflorae	Ambrosia	Artemisia	Chenopodiaceae	Rosaceae	Potentilla	Impatiens	Oxyria	Caryophyllaceae	Ranunculaceae	Thalictrum	Saxifraga	Leguminosa	Epilobium	Polygonum	Plantaginaceae
596.5	29.0	16.0	0.0	1.0	0.0	0.0	12.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
597.5	2.0	4.0	5.0	6.0	0.0	0.0	13.0	0.0	1.0	2.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0
598.5	16.0	3.0	6.0	7.0	0.0	0.0	23.0	0.0	3.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
599.5	26.0	6.0	0.0	7.0	2.0	0.0	18.0	0.0	4.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600.5	24.0	6.0	0.0	14.0	6.0	0.0	18.0	0.0	5.0	0.0	1.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
601.5	4.0	7.0	0.0	17.0	0.0	0.0	29.0	1.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0
602.5	15.0	1.0	10.0	8.0	0.0	0.0	24.0	0.0	7.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
603.5	19.0	7.0	1.0	18.0	0.0	0.0	22.0	0.0	11.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
604.5	6.0	0.0	24.0	7.0	0.0	0.0	22.0	1.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
605.5	5.0	11.0	1.0	14.0	0.0	3.0	29.0	0.0	2.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0	2.0	0.0	0.0	0.0	0.0
607.5	18.0	7.0	2.0	12.0	1.0	0.0	47.0	2.0	16.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
608.5	8.0	1.0	2.0	6.0	0.0	0.0	39.0	1.0	9.0	1.0	0.0	1.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
609.5	12.0	7.0	2.0	8.0	1.0	0.0	26.0	1.0	10.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
610.5	7.0	9.0	1.0	16.0	0.0	0.0	15.0	0.0	16.0	1.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
611.5	11.0	1.0	11.0	6.0	0.0	0.0	20.0	2.0	31.0	2.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
612.5	3.0	9.0	2.0	6.0	0.0	0.0	17.0	0.0	34.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	1.0	0.0	0.0	0.0	0.0	0.0
613.5	6.0	3.0	2.0	4.0	0.0	0.0	13.0	3.0	7.0	3.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
614.5	9.0	3.0	3.0	3.0	1.0	0.0	21.0	0.0	3.0	2.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0
615.5	3.0	1.0	0.0	5.0	0.0	0.0	23.0	0.0	2.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
616.5	12.0	6.0	5.0	10.0	0.0	0.0	30.0	1.0	18.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
617.5	2.0	0.0	13.0	5.0	0.0	0.0	22.0	1.0	16.0	3.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
618.5	17.0	6.0	0.0	10.0	0.0	0.0	15.0	0.0	17.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
619.5	5.0	0.0	9.0	5.0	0.0	0.0	26.0	1.0	15.0	3.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
620.5	5.0	4.0	2.0	13.0	3.0	0.0	27.0	4.0	11.0	4.0	0.0	0.0	0.0	3.0	1.0	1.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
621.5	3.0	3.0	8.0	21.0	0.0	0.0	31.0	1.0	27.0	4.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
622.5	9.0	3.0	9.0	32.0	0.0	0.0	37.0	3.0	45.0	4.0	1.0	1.0	1.0	1.0	1.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
623.5	16.0	11.0	1.0	27.0	0.0	0.0	27.0	5.0	46.0	4.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	4.0	5.0	1.0	0.0	0.0	1.0	1.0
624.5	9.0	1.0	6.0	14.0	0.0	0.0	25.0	3.0	57.0	7.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	2.0	0.0
625.5	3.0	16.0	1.0	14.0	0.0	0.0	10.0	3.0	62.0	3.0	1.0	3.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
626.5	10.0	3.0	14.0	16.0	1.0	0.0	7.0	2.0	41.0	2.0	0.0	3.0	0.0	1.0	1.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
627.5	8.0	7.0	5.0	16.0	0.0	0.0	6.0	2.0	38.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0
628.5	0.0	16.0	5.0	11.0	0.0	0.0	6.0	4.0	15.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0
629.5	0.0	5.0	10.0	8.0	5.0	0.0	2.0	3.0	17.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0
630.5	1.0	22.0	7.0	16.0	1.0	1.0	2.0	7.0	10.0	4.0	1.0	5.0	0.0	0.0	0.0	0.0	5.0	1.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0
631.5	0.0	1.0	16.0	3.0	0.0	0.0	10.0	7.0	10.0	0.0	0.0	4.0	3.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
632.5	3.0	26.0	9.0	13.0	1.0	0.0	2.0	9.0	8.0	3.0	1.0	9.0	0.0	0.0	2.0	0.0	7.0	2.0	0.0	1.0	0.0	0.0	1.0	0.0	1.0
633.5	3.0	3.0	25.0	10.0	0.0	0.0	5.0	4.0	30.0	4.0	1.0	15.0	0.0	1.0	0.0	0.0	4.0	13.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0
634.5	2.0	28.0	5.0	14.0	1.0	0.0	2.0	2.0	8.0	1.0	1.0	3.0	0.0	0.0	0.0	0.0	8.0	4.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0
635.5	1.0	10.0	40.0	13.0	0.0	1.0	8.0	1.0	42.0	3.0	3.0	17.0	3.0	3.0	1.0	0.0	4.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
636.5	6.0	0.0	21.0	6.0	0.0	0.0	7.0	1.0	32.0	3.0	1.0	7.0	0.0	4.0	2.0	0.0	2.0	8.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
637.5	6.0	13.0	4.0	10.0	0.0	0.0	6.0	2.0	24.0	4.0	0.0	5.0	2.0	2.0	0.0	0.0	1.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
638.5	3.0	7.0	2.0	7.0	0.0	0.0	3.0	0.0	34.0	2.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
639.5	5.0	0.0	0.0	2.0	0.0	0.0	4.0	1.0	15.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
640.5	4.0	4.0	0.0	1.0	0.0	0.0	7.0	1.0	11.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
641.5	3.0	1.0	3.0	2.0	0.0	0.0	13.0	0.0	8.0	2.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
642.5	3.0	0.0	0.0	2.0	0.0	0.0	12.0	1.0	5.0	2.0	0.0	4.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
643.5	18.0	2.0	0.0	2.0	0.0	0.0	7.0	1.0	17.0	2.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
645.5	80.0	0.0	0.0	5.0	1.0	0.0	14.0	2.0	29.0	4.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
646.5	53.0	0.0	2.0	3.0	0.0	0.0	33.0	2.0	34.0	2.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0
647.5	29.0	0.0	2.0	11.0	0.0	1.0	10.0	0.0	22.0	2.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	2.0	0.0	0.0	0.0
648.5	20.0	2.0	0.0	15.0	0.0	2.0	10.0	1.0	18.0	2.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
649.5	23.0	2.0	1.0	10.0	0.0	0.0	16.0	5.0	10.0	1.0	1.0	5.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
650.5	25.0	1.0	0.0	18.0	1.0	1.0	6.0	2.0	24.0	3.0	1.0	6.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	2.0	1.0	0.0	0.0	0.0	0.0
652.5	32.0	2.0	0.0	20.0	0.0	1.0	19.0	1.0	28.0	5.0	0.0	3.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
653.5	23.0	0.0	0.0	13.0	0.0	0.0	17.0	2.0	24.0	3.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
654.5	46.0	0.0	0.0	17.0	0.0	2.0	17.0	3.0	21.0	5.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
655.5	43.0	0.0	0.0	6.0	0.0	1.0	11.0	3.0	17.0	5.0	1.0	3.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
657.5	72.0	0.0	1.0	5.0	0.0	0.0	27.0	3.0	19.0	3.0	1.0	7.0	0.0	1.0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
658.5	67.0	0.0	2.0	8.0	0.0	1.0	49.0	1.0	17.0	9.0	1.0	8.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
659.5	63.0	0.0	0.0	7.0	0.0	2.0	35.0	5.0	26.0	5.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0
660.5	86.0	3.0	0.0	6.0	0.0	1.0	34.0	4.0	19.0	3.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
662.5	37.0	1.0	2.0	8.0	1.0	3.0	26.0	3.0	22.0	4.0	2.0	10.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
664.5	22.0	1.0	93.0	6.0	2.0	2.0	33.0	2.0	17.0	10.0	1.0	19.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
665.5	45.0	2.0	0.0	16.0	0.0	1.0	22.0	3.0	11.0	10.0	0.0	13.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
666.5	20.0	2.0	3.0	18.0	1.0	2.0	19.0	4.0	11.0	18.0	2.0	7.0	0.0	1.0	0.0	0.0	0.0	4.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0
668.5	12.0	0.0	0.0	19.0	0.0	12.0	12.0	4.0	20.0	17.0	2.0	32.0	1.0	4.0	0.0	0.0	0.0	4.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0
669.5	10.0	0.0	2.0	12.0	1.0	3.0	21.0	1.0	13.0	16.0	1.0	60.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
670.5	21.0	2.0	0.0	28.0	0.0	5.0	22.0	4.0	10.0	24.0	1.0	43.0	0.0	4.0	0.0	0.0	0.0	2.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0
671.5	12.0	3.0	3.0	16.0	3.0	4.0	19.0	5.0	26.0	14.0	1.0	54.0	0.0	3.0	0.0	0.0	0.0	2.0	1.0	1.0	0.0	0.0	0.0	2.0	1.0
672.5	3.0	1.0	6.0	14.0	0.0	3.0	21.0	4.0	20.0	17.0	2.0	50.0	0.0	4.0	1.0	0.0	0.0	3.0	3.0	2.0	1.0	0.0	0.0	0.0	3.0
675.5	10.0	2.0	1.0	28.0	1.0	11.0	12.0	9.0	16.0	20.0	0.0	60.0	0.0	0.0	0.0	0.0	0.0	2.0	8.0	0.0	1.0	1.0	0.0	0.0	0.0
682.5	4.0	0.0	0.0	32.0	1.0	18.0	9.0	0.0	17.0	16.0	4.0	2.0	0.0	8.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
690.5	1.0	0.0	0.0	16.0	1.0	12.0	4.0	3.0	9.0	5.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0

Sediment depth (cm)	Cyperaceae	Unidentified	Reworked grains	Trees	Shrubs	Herbs	Equisetum	Pteridophyta (trilete spore)	Lycopodium undifferentiated	Lycopodium type annotinum	Lycopodium clavatum	Polypodiaceae (monolete spore)	Typha	Sphagnum	Nymphaea	Potamogeton	Sparganium	Callitriche	Isoetes
596.5	13.0	6.0	0.0	198.0	96.0	7.0	0.0	0.0	0.0	7.0	21.0	12.0	0.0	3.0	0.0	1.0	6.0	5.0	3.0
597.5	10.0	5.0	0.0	221.0	59.0	9.0	0.0	2.0	2.0	4.0	2.0	7.0	5.0	1.0	0.0	0.0	0.0	2.0	2.0
598.5	6.0	7.0	0.0	195.0	84.0	7.0	0.0	3.0	3.0	3.0	4.0	16.0	2.0	1.0	0.0	0.0	0.0	4.0	1.0
599.5	11.0	5.0	1.0	220.0	97.0	7.0	0.0	1.0	0.0	7.0	15.0	16.0	1.0	3.0	0.0	0.0	0.0	1.0	4.0
600.5	13.0	11.0	0.0	198.0	107.0	10.0	0.0	2.0	8.0	0.0	11.0	18.0	6.0	1.0	0.0	0.0	0.0	3.0	5.0
601.5	11.0	11.0	3.0	199.0	100.0	7.0	2.0	3.0	4.0	3.0	11.0	6.0	2.0	0.0	1.0	6.0	0.0	0.0	1.0
602.5	9.0	8.0	0.0	195.0	90.0	11.0	0.0	1.0	0.0	7.0	3.0	12.0	1.0	0.0	1.0	2.0	0.0	0.0	2.0
603.5	15.0	18.0	3.0	175.0	128.0	15.0	0.0	1.0	3.0	7.0	5.0	13.0	2.0	4.0	0.0	0.0	0.0	5.0	8.0
604.5	11.0	6.0	1.0	248.0	68.0	11.0	4.0	2.0	0.0	7.0	5.0	12.0	1.0	0.0	0.0	0.0	3.0	3.0	10.0
605.5	22.0	7.0	1.0	152.0	132.0	8.0	4.0	3.0	0.0	0.0	4.0	1.0	0.0	1.0	0.0	6.0	0.0	2.0	4.0
607.5	16.0	9.0	0.0	169.0	150.0	23.0	0.0	3.0	0.0	5.0	6.0	23.0	0.0	3.0	0.0	0.0	0.0	5.0	9.0
608.5	5.0	5.0	0.0	180.0	116.0	14.0	1.0	1.0	0.0	5.0	8.0	19.0	1.0	3.0	0.0	0.0	0.0	1.0	7.0
609.5	10.0	9.0	0.0	190.5	121.0	15.0	0.0	1.0	0.0	13.0	7.0	12.0	0.0	2.0	0.0	2.0	0.0	0.0	12.0
610.5	17.0	3.0	3.0	202.0	102.0	22.0	5.0	0.0	5.0	6.0	19.0	9.0	1.0	1.0	0.0	0.0	1.0	5.0	7.0
611.5	7.0	3.0	0.0	180.0	94.0	36.0	0.0	6.0	0.0	7.0	10.0	15.0	0.0	1.0	0.0	0.0	0.0	0.0	9.0
612.5	14.0	4.0	2.0	188.0	82.0	40.0	0.0	2.0	0.0	7.0	13.0	17.0	0.0	3.0	0.0	0.0	14.0	0.0	8.0
613.5	14.0	6.0	0.0	251.0	56.0	15.0	0.0	0.0	0.0	17.0	8.0	7.0	0.0	2.0	0.0	0.0	2.0	3.0	3.0
614.5	13.0	3.0	0.0	198.0	111.0	11.0	0.0	3.0	3.0	13.0	24.0	17.0	0.0	2.0	1.0	3.0	3.0	5.0	10.0
615.5	9.0	3.0	0.0	239.0	84.0	7.0	0.0	1.0	2.0	15.0	12.0	7.0	0.0	3.0	0.0	1.0	0.0	2.0	7.0
616.5	13.0	5.0	1.0	160.0	114.0	23.0	0.0	0.0	4.0	11.0	15.0	13.0	0.0	2.0	0.0	0.0	0.0	3.0	11.0
617.5	17.0	9.0	1.0	247.0	92.0	21.0	4.0	0.0	0.0	14.0	14.0	8.0	0.0	1.0	0.0	0.0	2.0	6.0	7.0
618.5	10.0	6.0	1.0	220.0	139.0	22.0	0.0	3.0	0.0	16.0	13.0	13.0	0.0	1.0	0.0	0.0	0.0	5.0	7.0
619.5	6.0	9.0	0.0	129.0	141.0	22.0	0.0	1.0	0.0	12.0	14.0	11.0	0.0	3.0	1.0	2.0	1.0	2.0	6.0
620.5	14.0	8.0	2.0	117.0	175.0	23.0	0.0	2.0	1.0	7.0	6.0	4.0	0.0	0.0	0.0	0.0	0.0	1.0	2.0
621.5	7.0	7.0	0.0	127.0	140.0	32.0	1.0	2.0	0.0	12.0	15.0	5.0	0.0	1.0	0.0	0.0	0.0	0.0	6.0
622.5	19.0	16.0	0.0	83.0	171.0	58.0	0.0	3.0	0.0	21.0	20.0	9.0	1.0	3.0	0.0	8.0	0.0	0.0	17.0
623.5	26.0	7.0	1.0	81.0	194.0	64.0	0.0	2.0	8.0	15.0	10.0	11.0	1.0	7.0	0.0	0.0	0.0	9.0	0.0
624.5	22.0	13.0	0.0	78.0	162.0	71.0	1.0	2.0	0.0	11.0	4.0	16.0	0.0	3.0	0.0	7.0	0.0	0.0	30.0
625.5	26.0	8.0	2.0	45.0	166.0	72.0	1.0	2.0	0.0	3.0	4.0	5.0	0.0	3.0	0.0	8.0	0.0	1.0	35.0
626.5	25.0	10.0	0.0	76.0	171.0	51.0	1.0	2.0	0.0	11.0	6.0	8.0	0.0	2.0	0.0	5.0	0.0	0.0	137.0
627.5	53.0	10.0	3.0	63.0	191.0	45.0	0.0	2.0	0.0	4.0	6.0	2.0	0.0	4.0	0.0	0.0	0.0	6.0	140.0
628.5	35.0	4.0	0.0	106.0	203.0	28.0	0.0	1.0	0.0	2.0	0.0	7.0	0.0	4.0	0.0	3.0	0.0	1.0	33.0
629.5	42.0	5.0	0.0	131.0	144.0	24.0	0.0	1.0	0.0	3.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0
630.5	96.0	8.0	0.0	89.0	191.0	29.0	1.0	1.0	1.0	1.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0	0.0	6.0
631.5	36.0	12.0	0.0	131.0	145.0	19.0	0.0	1.0	0.0	4.0	1.0	5.0	0.0	1.0	0.0	0.0	0.0	0.0	2.0
632.5	81.0	10.0	1.0	62.0	173.0	35.0	0.0	3.0	2.0	0.0	3.0	5.0	0.0	4.0	0.0	0.0	0.0	0.0	2.0
633.5	53.0	8.0	0.0	125.0	125.0	71.0	0.0	3.0	0.0	6.0	4.0	15.0	0.0	4.0	0.0	0.0	0.0	0.0	3.0
634.5	92.0	10.0	1.0	154.0	129.0	31.0	0.0	2.0	3.0	0.0	5.0	14.0	0.0	8.0	0.0	0.0	0.0	1.0	2.0
635.5	93.0	18.0	0.0	55.0	185.0	86.0	0.0	1.0	0.0	4.0	8.0	9.0	0.0	5.0	0.0	0.0	0.0	1.0	7.0
636.5	57.0	11.0	0.0	178.0	87.0	60.0	0.0	7.0	0.0	2.0	8.0	10.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0
637.5	52.0	5.0	0.0	178.0	89.0	41.0	0.0	4.0	4.0	2.0	7.0	25.0	0.0	6.0	0.0	0.0	0.0	0.0	2.0
638.5	33.0	8.0	0.0	210.0	62.0	39.0	1.0	3.0	1.0	3.0	3.0	15.0	0.0	5.0	0.0	0.0	0.0	0.0	2.0
639.5	15.0	3.0	0.0	236.0	57.0	18.0	0.0	0.0	0.0	2.0	0.0	8.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0
640.5	12.0	1.0	0.0	246.0	54.0	14.0	1.0	0.0	0.0	2.0	2.0	2.0	0.0	3.0	0.0	0.0	1.0	1.0	1.0
641.5	15.0	6.0	0.0	122.0	67.0	14.0	0.0	0.0	0.0	6.0	1.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
642.5	8.0	4.0	0.0	257.0	65.0	12.0	0.0	1.0	0.0	4.0	4.0	6.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0
643.5	24.0	6.0	0.0	203.0	81.0	22.0	0.0	2.0	0.0	3.0	2.0	5.0	0.0	0.0	0.0	0.0	0.0	2.0	4.0
645.5	28.0	7.0	0.0	119.0	153.0	38.0	0.0	0.0	3.0	7.0	2.0	7.0	0.0	5.0	0.0	0.0	0.0	2.0	3.0
646.5	17.0	3.0	0.0	127.0	175.0	42.0	0.0	2.0	1.0	6.0	3.0	5.0	0.0	6.0	0.0	0.0	0.0	0.0	7.0
647.5	44.0	8.0	0.0	109.0	157.0	30.0	0.0	0.0	0.0	5.0	2.0	12.0	0.0	8.0	0.0	0.0	0.0	0.0	18.0
648.5	28.0	4.0	0.0	123.0	156.0	22.0	0.0	0.0	0.0	5.0	2.0	11.0	0.0	2.0	0.0	0.0	1.0	1.0	34.0
649.5	27.0	7.0	0.0	121.0	189.0	19.0	0.0	2.0	0.0	4.0	0.0	14.0	0.0	4.0	0.0	0.0	0.0	0.0	17.0
650.5	40.0	9.0	0.0	78.0	187.0	39.0	0.0	0.0	1.0	5.0	1.0	14.0	0.0	1.0	0.0	0.0	0.0	0.0	7.0
652.5	41.0	15.0	0.0	73.0	206.0	39.0	0.0	1.0	0.0	0.0	0.0	15.0	0.0	4.0	0.0	0.0	2.0	0.0	7.0
653.5	26.0	6.0	0.0	91.0	184.0	33.0	1.0	2.0	0.0	1.0	1.0	14.0	0.0	2.0	0.0	0.0	0.0	0.0	4.0
654.5	44.0	10.0	0.0	84.0	183.0	31.0	0.0	3.0	1.0	0.0	0.0	10.0	0.0	4.0	0.0	0.0	0.0	0.0	4.0
655.5	25.0	3.0	2.0	123.0	155.0	28.0	0.0	3.0	2.0	4.0	4.0	10.0	0.0	4.0	0.0	2.0	0.0	0.0	1.0
657.5	27.0	5.0	0.0	72.0	197.0	34.0	0.0	0.0	8.0	0.0	0.0	10.0	0.0	3.0	0.0	4.0	0.0	1.0	1.0
658.5	40.0	11.0	0.0	67.0	201.0	36.0	0.0	0.0	0.0	8.0	1.0	11.0	0.0	3.0	0.0	4.0	0.0	0.0	0.0
659.5	18.0	18.0	2.0	57.0	200.0	37.0	0.0	2.0	0.0	3.0	4.0	8.0	0.0	3.0	1.0	0.0	4.0	0.0	1.0
660.5	49.0	7.0	2.0	63.0	220.0	31.0	0.0	1.0	0.0	1.0	3.0	2.0	0.0	8.0	0.0	4.0	0.0	0.0	3.0
662.5	45.0	6.0	0.0	77.0	178.0	41.0	0.0	1.0	0.0	2.0	0.0	4.0	0.0	1.0	0.0	0.0	0.0	1.0	8.0
664.5	50.0	9.0	2.0	85.0	251.0	49.0	0.0	0.0	1.0	1.0	1.0	9.0	0.0	5.0	0.0	3.0	2.0	3.0	17.0
665.5	65.0	10.0	2.0	76.0	186.0	37.0	0.0	2.0	0.0	2.0	0.0	11.0	0.0	11.0	0.0	0.0	0.0	3.0	25.0
666.5	67.0	10.0	2.0	77.0	159.0	45.0	0.0	2.0	0.0	4.0	1.0	10.0	1.0	3.0	0.0	1.0	0.0	1.0	34.0
668.5	94.0	6.0	5.0	75.0	139.0	82.0	0.0	2.0	0.0	3.0	1.0	10.0	0.0	4.0	0.0	0.0	1.0	1.0	0.0
669.5	68.0	4.0	0.0	78.0	129.0	92.0	0.0	0.0	0.0	2.0	0.0	7.0	0.0	4.0	0.0	0.0	3.0	2.0	0.0
670.5	61.0	16.0	3.0	95.0	159.0	88.0	0.0	3.0	0.0	4.0	0.0	6.0	0.0	2.0	0.0	0.0	0.0	7.0	0.0
671.5	63.0	11.0	0.0	69.0	119.0	105.0	0.0	3.0	0.0	2.0	0.0	13.0	0.0	2.0	0.0	2.0	0.0	0.0	1.0
672.5	54.0	13.0	0.0	63.0	131.0	106.0	3.0	7.0	0.0	1.0	2.0	6.0	0.0	3.0	0.0	2.0	1.0	0.0	0.0
675.5	64.0	14.0	0.0	73.0	123.0	108.0	0.0	3.0	0.0	2.0	2.0	16.0	0.0	3.0	0.0	0.0	0.0	1.0	0.0
682.5	70.0	18.0	14.0	145.0	87.0	54.0	0.0	13.0	0.0	0.0	3.0	5.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0
690.5	9.0	4.0	0.0	50.0	39.0	18.0	0.0	2.0	0.0	1.0	2.0	2.0	0.0	3.0	1.0	0.0	0.0	0.0	0.0

Sediment depth (cm)	Pediastrum unidentified	Pediastrum Boryanym undifferentiated	Pediastrum Boryanum var. longicorne	Pediastrum Boryanum var. integrum	Pediastrum angulosum	Pediastrum simplex	Pediastrum duplex	Pediastrum tetras	Pediastrum kawraskyi	Freshwater Dinoflagellate	Marine Dinoflagellate (?)	Peridinium	Fossil A total	Fossil A "psilate"	Fossil A "scabrate"	Fossil E	Fossil R	Fossil O
596.5	4.0	33.0	25.0	0.0	6.0	2.0	0.0	5.0	0.0	21.0	1.0	23.0	436.0	134.0	302.0	1.0	1.0	0.0
597.5	1.0	18.0	11.0	2.0	4.0	1.0	0.0	4.0	0.0	21.0	0.0	33.0	482.0	121.0	361.0	2.0	1.0	0.0
598.5	3.0	7.0	7.0	0.0	5.0	0.0	0.0	0.0	0.0	12.0	0.0	19.0	362.0	142.0	220.0	4.0	0.0	0.0
599.5	6.0	6.0	9.0	0.0	4.0	0.0	0.0	3.0	0.0	10.0	0.0	9.0	239.0	114.0	125.0	1.0	1.0	0.0
600.5	1.0	15.0	13.0	4.0	10.0	0.0	0.0	1.0	0.0	33.0	1.0	18.0	0.0	0.0	0.0	3.0	1.0	0.0
601.5	0.0	12.0	16.0	0.0	3.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	237.0	0.0	0.0	0.0	0.0	0.0
602.5	0.0	2.0	15.0	4.0	6.0	1.0	0.0	0.0	0.0	14.0	0.0	16.0	371.0	140.0	231.0	0.0	1.0	0.0
603.5	11.0	3.0	19.0	10.0	5.0	0.0	0.0	1.0	0.0	35.0	0.0	20.0	173.0	0.0	0.0	0.0	0.0	0.0
604.5	6.0	10.0	15.0	7.0	12.0	1.0	0.0	3.0	0.0	15.0	0.0	20.0	252.0	133.0	119.0	0.0	4.0	0.0
605.5	4.0	5.0	12.0	0.0	10.0	0.0	0.0	1.0	0.0	9.0	0.0	0.0	88.0	0.0	0.0	0.0	0.0	0.0
607.5	5.0	15.0	16.0	7.0	0.0	0.0	0.0	7.0	0.0	21.0	0.0	12.0	106.0	0.0	0.0	2.0	0.0	0.0
608.5	4.0	7.0	12.0	6.0	2.0	0.0	0.0	1.0	0.0	8.0	0.0	18.0	47.0	22.0	25.0	0.0	2.0	0.0
609.5	4.0	2.0	10.0	7.0	4.0	1.0	0.0	1.0	0.0	14.0	0.0	23.0	63.0	27.0	36.0	1.0	3.0	2.0
610.5	3.0	10.0	5.0	0.0	0.0	0.0	0.0	3.0	0.0	4.0	0.0	0.0	94.0	0.0	0.0	0.0	0.0	0.0
611.5	4.0	2.0	2.0	3.0	4.0	0.0	0.0	1.0	0.0	7.0	0.0	20.0	204.0	123.0	81.0	1.0	5.0	1.0
612.5	2.0	3.0	3.0	2.0	2.0	0.0	0.0	1.0	0.0	18.0	0.0	13.0	323.0	244.0	79.0	0.0	0.0	3.0
613.5	8.0	0.0	1.0	3.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	14.0	232.0	194.0	38.0	2.0	3.0	1.0
614.5	7.0	6.0	2.0	7.0	4.0	1.0	0.0	0.0	0.0	8.0	0.0	30.0	193.0	101.0	92.0	0.0	3.0	0.0
615.5	5.0	12.0	2.0	5.0	1.0	0.0	0.0	2.0	0.0	3.0	0.0	23.0	255.0	173.0	82.0	0.0	0.0	0.0
616.5	15.0	21.0	3.0	14.0	0.0	4.0	0.0	0.0	0.0	7.0	0.0	16.0	22.0	0.0	0.0	1.0	3.0	0.0
617.5	15.0	15.0	10.0	11.0	6.0	7.0	0.0	6.0	0.0	24.0	0.0	17.0	65.0	36.0	29.0	0.0	4.0	1.0
618.5	26.0	45.0	35.0	40.0	7.0	4.0	0.0	1.0	0.0	7.0	0.0	22.0	5.0	0.0	0.0	0.0	1.0	0.0
619.5	17.0	43.0	31.0	39.0	5.0	14.0	0.0	0.0	0.0	8.0	0.0	15.0	18.0	16.0	2.0	0.0	7.0	0.0
620.5	22.0	76.0	42.0	88.0	7.0	7.0	0.0	1.0	2.0	1.0	0.0	0.0	7.0	0.0	0.0	0.0	0.0	0.0
621.5	6.0	31.0	23.0	9.0	1.0	3.0	0.0	0.0	0.0	2.0	0.0	7.0	16.0	8.0	8.0	0.0	2.0	1.0
622.5	56.0	45.0	39.0	18.0	1.0	4.0	0.0	0.0	0.0	5.0	0.0	0.0	24.0	19.0	5.0	3.0	1.0	0.0
623.5	38.0	40.0	52.0	40.0	1.0	12.0	0.0	1.0	2.0	9.0	0.0	4.0	8.0	0.0	0.0	2.0	0.0	2.0
624.5	44.0	37.0	54.0	13.0	0.0	2.0	0.0	0.0	0.0	8.0	0.0	13.0	43.0	24.0	19.0	6.0	2.0	1.0
625.5	5.0	19.0	22.0	34.0	1.0	4.0	1.0	0.0	0.0	2.0	0.0	45.0	18.0	0.0	0.0	1.0	0.0	0.0
626.5	26.0	20.0	25.0	2.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0	12.0	30.0	11.0	19.0	5.0	0.0	0.0
627.5	26.0	13.0	52.0	29.0	1.0	0.0	0.0	0.0	0.0	39.0	0.0	6.0	19.0	0.0	0.0	2.0	0.0	0.0
628.5	3.0	6.0	6.0	9.0	1.0	1.0	0.0	0.0	0.0	42.0	1.0	3.0	25.0	11.0	14.0	2.0	0.0	0.0
629.5	4.0	1.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	55.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	3.0
630.5	3.0	2.0	2.0	6.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	34.0	0.0	0.0	0.0	0.0	0.0
631.5	1.0	3.0	1.0	3.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	13.0	43.0	24.0	19.0	0.0	0.0	0.0
632.5	1.0	0.0	1.0	5.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	4.0	23.0	0.0	0.0	1.0	0.0	0.0
633.5	0.0	4.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.0	26.0	49.0	7.0	0.0	0.0
634.5	0.0	0.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.0	0.0	0.0	5.0	0.0	0.0
635.5	0.0	7.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	2.0	246.0	70.0	176.0	12.0	0.0	0.0
636.5	0.0	5.0	3.0	5.0	1.0	0.0	0.0	0.0	0.0	7.0	0.0	8.0	255.0	58.0	197.0	5.0	0.0	5.0
637.5	1.0	2.0	4.0	6.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	1.0	547.0	0.0	0.0	4.0	0.0	0.0
638.5	1.0	14.0	2.0	3.0	1.0	0.0	0.0	0.0	0.0	15.0	0.0	16.0	862.0	248.0	614.0	1.0	1.0	1.0
639.5	5.0	11.0	4.0	1.0	1.0	0.0	0.0	0.0	0.0	8.0	0.0	18.0	1568.0	700.0	868.0	0.0	6.0	0.0
640.5	0.0	5.0	9.0	5.0	1.0	0.0	0.0	0.0	0.0	19.0	1.0	0.0	468.0	0.0	0.0	0.0	2.0	0.0
641.5	0.0	4.0	5.0	7.0	1.0	0.0	0.0	0.0	0.0	8.0	0.0	55.0	628.0	413.0	215.0	0.0	15.0	0.0
642.5	0.0	5.0	4.0	5.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	39.0	193.0	84.0	109.0	1.0	3.0	0.0
643.5	1.0	10.0	9.0	14.0	1.0	0.0	0.0	0.0	0.0	16.0	0.0	28.0	79.0	0.0	0.0	1.0	6.0	0.0
645.5	0.0	6.0	8.0	6.0	2.0	0.0	0.0	0.0	0.0	4.0	0.0	102.0	5.0	0.0	0.0	3.0	0.0	0.0
646.5	0.0	1.0	6.0	1.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	11.0	34.0	30.0	4.0	0.0	1.0	1.0
647.5	16.0	9.0	6.0	25.0	4.0	0.0	0.0	0.0	0.0	6.0	0.0	15.0	9.0	0.0	0.0	3.0	1.0	1.0
648.5	6.0	8.0	4.0	10.0	0.0	0.0	0.0	0.0	0.0	13.0	0.0	16.0	84.0	71.0	13.0	6.0	0.0	3.0
649.5	5.0	1.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	20.0	112.0	96.0	16.0	5.0	0.0	2.0
650.5	2.0	6.0	6.0	11.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	19.0	0.0	0.0	3.0	0.0	0.0
652.5	3.0	4.0	4.0	7.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	17.0	94.0	74.0	20.0	5.0	0.0	1.0
653.5	0.0	2.0	4.0	1.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0	20.0	93.0	70.0	23.0	2.0	0.0	1.0
654.5	1.0	2.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	24.0	89.0	28.0	61.0	7.0	1.0	0.0
655.5	0.0	0.0	20.0	2.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	33.0	16.0	0.0	0.0	1.0	0.0	0.0
657.5	0.0	9.0	13.0	1.0	0.0	6.0	0.0	1.0	0.0	7.0	0.0	27.0	48.0	3.0	45.0	1.0	0.0	0.0
658.5	0.0	14.0	4.0	3.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	21.0	63.0	59.0	4.0	0.0	3.0	1.0
659.5	1.0	11.0	12.0	5.0	0.0	0.0	0.0	1.0	0.0	7.0	0.0	37.0	71.0	60.0	11.0	2.0	1.0	2.0
660.5	2.0	4.0	5.0	23.0	3.0	0.0	0.0	0.0	0.0	2.0	0.0	25.0	15.0	0.0	0.0	3.0	3.0	0.0
662.5	8.0	7.0	13.0	8.0	0.0	1.0	0.0	0.0	0.0	14.0	0.0	29.0	80.0	26.0	54.0	0.0	0.0	0.0
664.5	7.0	4.0	8.0	13.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	16.0	101.0	42.0	59.0	10.0	0.0	1.0
665.5	0.0	10.0	21.0	76.0	0.0	1.0	0.0	0.0	0.0	10.0	0.0	24.0	33.0	0.0	0.0	2.0	0.0	0.0
666.5	4.0	3.0	17.0	7.0	0.0	2.0	0.0	0.0	0.0	10.0	0.0	21.0	55.0	49.0	6.0	6.0	0.0	4.0
668.5	8.0	7.0	9.0	7.0	1.0	0.0	0.0	0.0	0.0	5.0	0.0	10.0	58.0	53.0	5.0	5.0	0.0	1.0
669.5	14.0	10.0	5.0	4.0	0.0	0.0	0.0	1.0	0.0	3.0	0.0	7.0	38.0	30.0	8.0	5.0	0.0	1.0
670.5	6.0	4.0	2.0	13.0	0.0	2.0	0.0	0.0	0.0	11.0	0.0	15.0	11.0	0.0	0.0	0.0	0.0	1.0
671.5	11.0	4.0	4.0	8.0	0.0	1.0	0.0	0.0	0.0	10.0	0.0	15.0	41.0	35.0	6.0	12.0	0.0	3.0
672.5	50.0	22.0	27.0	27.0	0.0	3.0	0.0	0.0	0.0	6.0	0.0	37.0	23.0	11.0	12.0	17.0	0.0	1.0
675.5	108.0	12.0	23.0	66.0	0.0	14.0	0.0	0.0	0.0	10.0	0.0	23.0	2.0	0.0	0.0	14.0	0.0	1.0
682.5	3.0	3.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	43.0	0.0	62.0	51.0	1.0	50.0	2.0	6.0	1.0
690.5	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	9.0	5.0	4.0	1.0	2.0	1.0	1.0

ANNEX 5 MACROFOSSILS LABORATORY NOTES

Macrofossils picked or observed from freezed dried sediments of Little Dyke Lake basal sequence 91/II, Transcript of laboratory notes

606-607 cm
leaf: fr. peculiar dentation at leaf apex, covered with resin sacs, yellow, octolobate sacs, (micron size),
distribution pattern on leaf not apparent, width of apex is ~1/2 cm (identified as *Myrica gale*)
seed: like # 3 but yellow
seed: *Potamogeton*
insect: fr. (2) of prothorax, large, black

*610-611 cm
slide 1:
leaf: fr. pattern yellow on sediment
seed: (#3), elongate, brown-russet, sculp. longitudinal grid, same as 620-621 picture
seed: same as #3 but yellow
org. fr. stem and other charred
disc same has picture of 617-618 cm
insect: fr. unknown
Chironomidae

slide 2:
leaf: fr. several, one has central nerve and branching of 2nd nerves
Chironomidae + white filament attached

*610-611 cm
note: stored in 2 slides
sediment: organic
leaf: tip with mite
seed: subtriangular base of black seed
seed: *Hipurus*? same as 615-616 cm
wood: charred fr. of wood ?
black fr. of twig or insect
pollen winged (might be difficult to see)
insect: wing (tip broke off)
mites
Chironomidae

*611-612 cm
leaf: print to be checked resembles *Betula* (?)

*615-616 cm
leaf: *Picea* needle fr., base, cross section
leaf: *Picea* needle fr.
seed: (#3), elongate, brown-russet, sculp. longitudinal, same as 620-621 picture
seed: same as #3 but yellow
wood: stems without bark
insect: fr. inner lobe of maxilla (?) 2 fr. that are fused and one of them has a series of small "hairs" along the edge
insect: fr. unknown

*615-616 cm
leaf: small fr. with circular, shiny disk, yellow near perimeter
leaf: *Pinus* needle fr.
leaf: *Picea* needle fr.
seed: yellow, ~2mm long, elliptical, hammered texture, collapsed
seed: (2.5), elliptical shape, similar to yellow one but brown, harder shell, texture is org. longitudinally, long axis is 3-4 mm long, possibly *Hpurus* (?)
two disks
pollen winged abundant
Chironomidae

*617-618 cm
seed: (#3) elongate, brown-russet, sculp. longitudinal same as 620-621 cm
seed: same as #3 but yellow
seed: *Potamogeton*
seed: *Ranunculus*
bract fr. *Betula* (?) like in picture of 645-646 cm
disk egg-like shape, small, brown with darker yoke center and thicker, rim is very narrow.
shell bulbous with one aperture, funnel shape at aperture, brown-russet, lustrous, dented.
pollen: winged abundant good for AMS
mite fr.

*618-619 cm
leaf: *Picea* needle fr., base and point, cross section, very small
leaf: fr. with resin
seed: *Potamogeton*
seed: (#3) several, elongate, brown-russet, sculpture longitudinally, same as 620-621 cm, is it *Najas* ?
seed: (#4) shell with porous inner with smaller black sphere
seed: black, spherical, broken, internal part exposed
ball white, opaque, hard 1/2 mm diameter
filaments rust and black colour
Chironomidae

*619-620 cm
charcoal wood
leaf: *Picea* fr. and base
leaf: fr. adhere to stem (could be principal nerve)
leaf: spruce but short cross shape trans.
leaf: fr. dark brown non id.
seed: *Potamogeton* (5)
seed: 1/2 fr. *Ranunculus* + (2)
seed: elongate, brownish-yellow, rectangular grill like sculpture (9)
nyas? seed #3 see pic of 620-621 cm
seed: 1/2 fr. brownish
seed: poorly preserved, flat, brown, fragile, fat tear shape
see: kidney shape, brown russet, darker at one end, yellow section, ~ 1mm long see pic 621-622 cm
wood stem fr. that flares out
several org, mostly leaf fr, broken due to desiccation
fungal sclerotia
insect fr.: wing, amber colour
Chironomidae

*620-621 cm
leaf: fr. with resin
leaf: *Picea* tip (wider at tip, cross shape in cross section)
leaf: fr. with partial margin and central nerve, leaf are very friable
leaf: fr. subtriangular, no central hole like other in 645-646cm spruce
leaf: fr. base of *Pinus* needle (?)
seed: *Potamogeton*
seed: long bottom stem, bulbous shape with point, broken in picking, fragile (*)
seed: shiny, date (fruit)-like, lustrous, spherical but flattened, dented sculpture (*)
seed: elongate, russet brown with yellow inside, sculpture longitudinal (*)

org. fr. with resin lobate resemble conifer seed
Chironomidae

*621-622 cm
sediment: well rounded opaque grain quartz
leaf: fr. similar to conifer needle, poorly preserved
leaf: fr. with resin nodules present sacs on underside, not lobate like *Myrica* but spherical
seed: *Potamogeton*
seed: kidney shape, small, convex
seed: black, tear shape
seed: brown with two prongs at bottom, Alnus, or *Betula*?
org. ball brown tomentose?
Chara
Chironomidae

*621-622 cm (revised)
leaf: fr. with resin sac not lobate but spherical
seed: *Potamogeton*
seed: black, flat, pinched (cut off), rigid shell, is it like picture B or A of 625-626 cm ?
seed: bean shape, brown-russet, small, darker at one end, yellow section with small point
seed: 2 poorly preserved
wood: fr. with bark, small, non id.

*622-623 cm
seed: *Potamogeton*
seed: *Ranunculus*
wood fr. branched with bark grey approx. 2mm L, 1.5mm W
org. fr. similar to seed, with prominent ridge, thick, rigid (see pic)
Chara
insect fr.: sternite
Chironomidae

*623-624 cm
charcoal (?), black/silver, vitreous flat fr.
seed: *Potamogeton*, some are non intact (turbulent?)
org. fr., nodule
Chara
fungal sclerotia
Chironomidae

*624-625cm
seed: *Ranunculus*
seed: *Potamogeton*
org. fr.: herb stem
wood stem broken into 3 fr. (2 fr. with bark, tapering, ~5mm L & ~.1mm W; 1 fr. ~6mm L, ~.75mm W)
Chara
megaspore broken
fungal sclerotia
insect fr.: pronotum
insect fr.: sphere with ball inside (eye ?)
mite
Chironomidae

*625-626 cm
seed: *Ranunculus*
seed: black, tear shape, in 2 fr., broken
seed: brown, bulbous with point (2)
Chara
spore: megaspore crushed
insect fr.: elytra
insect fr.: 2 spherical thickening on platelet
Chironomidae

*626-627 cm
seed: fr. *Ranunculus*
seed: 1/2 fr. yellow, kidney shaped, small
seed: brown, broken, ridge on each side, resemble black nut (2 fr.)
megaspore (trilete?) broken (2)
shell-like, lustrous, brown, elliptical shape
insect fr.: conical with several hairs and hollow
insect fr.: metasternum of Dystiscidae?)

*627-628 cm
seed: *Najas*
seed: 1/2 fr., black, flat, (resemble a watermelon seed)
seed: other half of "watermelon seed", with meat that is brown
org. fr. 1/4 funnel shape ?
megaspore trilete that is swollen open
mite (2)
Chironomidae (with white filament)

*628-629 cm
leaf: palmate nerve structure, 1mm²
wood fr.: hard, 1/4 stem, porous
wood fr. with grey bark
wood fr.: with buds, 8 mm L, stem is hollow and bud with concentric circles, infilled with calcite (?)
fr. black, lustrous, angular, conchoidal fracture (?)
fungal sclerotia
insect fr. black with 2 ridges (?)
insect fr.: gula ? spherical in shape with T shape as part of cut out at top
Chironomidae with white filament

*629-630 cm
sediment: clusters of medium size sand
seed: *Ranunculus*
wood: fr. grey without bark, 9mm long
shell-like, light brown, bivalve, white border
Chironomidae

*630-631 cm
seed: brown, elongate, tapered at both ends
stem wood or herb?, 8mm long
megaspore, trilete with insect fr.
fungal sclerotia
insect fr. or bryophyte, conical with seam attached to cylindrical short section, 2mm long
Chironomidae

*631-632 cm
sediment: clusters of medium size sand
seed: brown, elliptical, broken
bryophytes fr.
Chironomidae

*632-633 cm
clusters of medium size sand
seed: black, elongate, pointed to one side, (*Dryas*?)
seed: black, spherical, grooves and ridges like basketball
bryophytes fr.
fungal sclerotia
Chironomidae
insect fr. ? subtriangular, thick, black

*633-634 cm
wood fr. with bark
fungal sclerotia
bryophyte fr. gametophyte
insect (?) fr., black-burgundy, u shape

insect fr. pincher
Chironomidae

*635-636 cm
charcoal fr. (?), angular
wood: large twig fr. (2), with bark, glaucous and shiny dated at Isotrace c.10 320+/-80 TO-3976 *Salix* (?)
wood fr. "émoussé"
bark fr. (2) scroll shape, glaucous colour, shiny
shell like , ellipsoid, black
bryozoan
bryophyte: fr.
fungal sclerotia
insect: many fr.

*635-636 cm (continued)
sediment: mineral particle covered with sediment (powder), orange colour, spherical
seed: dark brown, elongate, pinched at one end, sculpture appears to longitudinal, possibly 3 sided or
collapsed due to desiccation, fragile, poorly preserved, 1.5mmL, <1mm W

*635-636 cm (continued)
leaf: *Picea* needle base
wood fr., light brown
bark: rolled like scripture
bark (?) brown underneath and goldish on top
fr. black vitreous angular, charcoal (?)
org. f. conical shape, brown-russet, about 1.5mm long, hollow, seam longitudinal
fr. conical shape, black, pointed, curved and longitudinal seam, smaller
spinoblast
fungal sclerotia
Chironomidae

*636-637 cm
seed: 1/2 fr., black
bryophyte: point of operculum
bryophyte: fr. of gametophyte
fungal sclerotia
mite

*640-641 cm
leaf: dark brown, too large to be bryophytes, several, too fragile and in pieces due to desiccation

*641-642 cm
sediment: clusters of sand
leaf fr. with bud
wood charred
pollen winged abundant
megaspore, sphagnum -like, collapsed
orange stain, 1.5mm long
balls brown hollow
fungal sclerotia
mite

*642-643 cm
leaf: fr. elongate (*Alnus*?)
wood partially charred
balls brown hollow
pollen winged abundant
spores collapsed

*643-644 cm
leaf: fr. of spruce (?)
leaf: fr. of stripped leaf
seed: yellow, prune like
wood stem: divided in 2 fr. with bark
wood charred
balls brow hollow
insect fr. spotted yellow and brown
insect fr. brown sphere, hollow

*644-645 cm
seed: *Ranunculus*
seed: black, crushed, dented
seed: 1/2 fr., black, flat, rigid, see pic p. 123 (2)
seed: half open, prune like and paler ridges (yellow) and rest is brown
seed: 1/2fr., yellow with sed. inside
stem, long black-brown
wood fr.
org. pellet, 4mm long, 1.5mm wide resemble a cluster of bryophyte leaves
shell, black lustrous
ball brown hollow
horn shape, conical, hollow black (lost in picking)
pollen winged abundant
insect fr. several
insect f. 3.5mm long and ~2mm wide, excluding fragment 1mm = Dystiscidae (Coleoptera) (* p.100)
insect fr. shape of bat but one side is flat, 1.5mm long
insect crushed, hairs, wing (?) detached from main body
insect fr.: leg (?) with hairs
insect crushed
mite
Chironomidae (Diptera)

*645-646 cm
leaf: fr.
leaf: *Picea* needle (?) short!
seed: *Ranunculus*
seed: *Potamogeton*
seed: 1/2, subtriangular, black
seed: subtriangular, black
white filament frag. (?)
bryophyte: gametophyte fr.
insect: sternite
Chironomidae (bodies filament)

slide 1:
leaf: subtriangular, needle like, two rows of stomata, rounded end, cross section at bottom
similar to fr. found in same sample (slide 2), 3/4 cm long. (*Pinus*?): identified by J. Matthews as *Picea*
leaf: fr., dark brown, non id.
seed: onion shape, brown, yellow tip and stem, sculp is dense chain like, longitudinal org.,
yellowish, yellow inner liner
seed: *Potamogeton* (2)
seed: *Ranunculus*
seed: black, pyramidal, angular, carex like picture for 670-671 cm
white filamentous gathered with roddish back 1mm square
insect: sternite (?) black lustrous, rectangular
Chironomidae

slide 2:
sediment: fr., black vitreous like quartz or coal
leaf: triangular fr. with central hollow tube resemble *Pinus* but very small size

bract: *Betula* (?) with two prongs, identified by J. Matthew as conifer cone male
bract: *Betula* (?)
seed: *Ranunculus*
seed: *Potamogeton*
seed: identified by J. Matthews as *Carex*
wood: piece of charred wood (?) or mineral
org. fr. black possibly part of a bract
org. clumps 4.5mm long and 1.5mm wide
Chironomidae

*646-647cm
sediment: sand, reddish clay patches
seed: *Carex* or *Rumex* identified by J. Matthews as dwarf birch
wood: twig fr. small
stem herb

*647-648 cm
charcoal wood or seed fr. (?)
leaf: fr.
leaf: fr. dark brown, nerve
seed: *Ranunculus*
seed: *Potamogeton*
seed: brown, flat, round and pointed with stem at bottom, no sculpture
stem: 3 long stems 6 to 8 mm long, brown-burgundy, sev. overlay of layers make up stem, end piece in relief
stem: yellow, u shape
org. fr. unidentified
Chironomidae

*648-649 cm
sediment: sand is abundant, part of the sediment was lost and not recoverable
charcoal (?), fr. black angular
charcoal wood
seed: *Potamogeton*
seed: fr., amber-russet, shell only, thin and fragile
org. fr. black grey several layers like lettuce
org. stem
Chironomidae

*649-650 cm (spring '93)
charcoal wood
seed: with two prongs, *Betula* or *Rumex*?
seed: *Potamogeton*
insect: partial elytra
insect: sternite
Chironomidae

*649-650 cm (sept 27/94)
charcoal (?): fr. small, black, vitreous, angular, conchoidal fracture
seed: *Potamogeton*
wood: fr. (2) 1/2 cm long
wood: stem with bud, 1 cm long
Chironomidae

*650-651 cm
charcoal (?):fr. black, vitreous, angular
seed: (?) fr., same has 648-649 cm, amber-russet, shell only, thin, fragile
wood: fr. small non id.
fungal sclerotia
bryophyte (?): stem branched, 2 cm long, black
bryophyte (?): 1 cm long, black, small light brown tufts that resemble leaves
bryophyte: several stems - gametophytes

*651-652 cm
note: wood good for dating
wood: branch and knot from stem with bark (got broken sin slide into two small pieces)
wood: fr. porous center with rays, full length of radius, compressed
wood: fr. with bark, compressed, 1/2 moon shape in cross section
fr. black, angular, charred wood
fungal sclerotia
Chironomidae

*652-653 cm
note: out on the shelf open for several months
slide 1:
seed: charred
fungal sclerotia, not spherical, subangular broken, maybe charcoal
Chironomidae

slide 2: leaf: spruce needle fr.
stem with no bark, possibly an herb
Chara
frons, black, two holes, large
Chironomidae

*653-654 cm
leaf: base of spruce needle
seed: fragmented, yellow-brown, bulbous sculpture, black inner liner with similar sculpture
insect: fr. of elytra, brown/yellow
insect: elytra fr.
Chironomidae

*654-655 cm
sediment: small clusters of fine sand
sediment: grey stains (silver microspheres)
charcoal
seed: black, subtriangular
seed: black, round, cracked
balls brown, hollow
spore: yellow
Chironomidae

*655-656 cm
sediment: grey stains (silver microspheres)
charcoal
seed: black (2)
seed: yellow broken
seed: fr., shell-like with longitudinal ridge (2)
plate perforated
Chironomidae
Chara

*656-657 cm
charcoal
seed: *Ranunculus* batrichium grp.
shell-like brown with small wood fr.
twig hollow with two megaspores
insect: small with wings
insect: sternites
insect fr.
Chironomidae

*657-658 cm
sand fine abundant
seed: with brown liner
seed: shell-like, elliptical black
spore (?) tricolpate and oblong shape

shell-like conical shape
Chironomidae
Chara

*658-659 cm
sediment: grey stains (silver microspheres)
leaf: -main nerve
leaf: fr. with resin sacs *Myrica* (?)
seed (?) shell-like stripped black
seed: *Ranunculus* batrichium grp.
seed: black small
seed: *Carex* (black triangular, 3 sides)
seed tear or bulb shaped or insect fr.
stem branched (2 parts)
stem of an herb or conifer leaf fr. (3 rays of one side and flat on the other) (2 parts)
shell-like yellow and brown
organic fr. yellow and dark brown
powder -orange aggregate (ball)
clusters of yellow particles - kidney shaped
bryophytes leaves
insect: thorax coleopteran (?)
insect: shell-like, staphylindae (?)
insect: mite
insect: fr. (junction of 2 leg fr. possibly femur and tibia)

*659-660 cm
leaf conifer (2 fr.)
leaf conifer (2 fr. thicker than first ones)
leaf fr. dark brown
leaf bud (?) on stem, stem is 1.1cm long and 1mm wide, peculiar pattern on bark
stem fragmented wood
stem (3 tubes stuck together, giving flat appearance to stem, divide when wetted)
stem wood 7mm long, 1mm wide, transverse cut has celery appearance
stem like preceding one but smaller (2 fr.)
org. fr. greenish brow with small yellow hair like at one end (peristome of moss?)
spore: megaspore *Tsuga* like

*660-661 cm
charcoal
seed prune like sculpture, brown with yellowish ribs, 1/2mm long, bean shaped
seed: *Ranunculus* 1/2 fr.
seed: 1/4 fr., black
seed: orange brown, somewhat conical
seed: brown with black liner, bulbous sculpture on brown, dents on black liner
stem wood (2 fr. cross section is u shaped) and thin coat resembling a "bark"
insect: fr., abundant...

*661-662 cm
sediment: poor in abundance of fossils relative to 660-661cm
sediment: abundant sand
seed: subtriangular not well preserved
seed: brown, prune like, fragile will divide in two
seed: *Ranunculus* (?)
org. fr. bulbous (2 bulbs) dated 10 930 +/- 100 TO-3576
insect fr. : legs; shell-like black stripped; several hell-like
charcoal

*662-663 cm
Chironomidae
insect fr: several shell like

*663-664 cm
seed: 1/2, yellow with brown enveloppe, deteriorated, no texture - smooth
seed: brown-yellow, flat, pointed with leaf like structure
shell-like black stripped
Chironomidae

*664-665 cm
sediment: grey stains (silver microspheres)
charcoal
seed: *Ranunculus* (?)
seed: 1/2 fr., flat fragile, spherical with trilete mark
seed: black, subtriangular or mineral grain (?)
seed: 3/4 fr., spherical, sculpture not apparent
fungal sclerotia
insect fr.
Chironomidae

*665-666 cm
wood: 2 fr. were together
black fragments
Chironomidae

*666-667 cm
charcoal
seed: black
stem wood with bud (2)
wood: separated from 2 preceding samples
fungal sclerotia
insect fr.: brown black; perforated plate, etc..
Chironomidae

*667-668 cm
sediment: very fine sediment, fine powder
sediment: grey stain (silver microspheres)
charcoal (?)
seed: *Ranunculus* fr. (?)
seed: 1/2 fr., brown, subovate, flattened, fragile
seed: black, flat, subspherical, pointed at one end, 2mm W, 1.5mmL, not well preserved, fragile, broken
seed: 2X1/2, yellow, subspherical to kidney shape, not sculpture, thick, brown inside and stripped, it is open
seed: 1/2 brown with black inner liner, bulbous sculpture on brown and dented on black
seed: black, elongate, tricolpate, pointed, not well preserved
seed: black, elongate, 2 flat sides and 1 rounded side similar to orange piece
stem with whorls of small hair
stem branched and charred
seed or insect: black, lustrous, 2 pieces, yellow inside, thin section, not deep (2)
org. fr. black, square shape
balls brown hollow
fungal sclerotia
bryophyte: gametophyte without leaves (?)
insect: fr. black
coleoptera
mite

*669-670 cm
shell-like backside of Dyticidae (?)

*670-671 cm
sediment: quartz grains are rounded and angular

sediment: black viterous particles, subangular, size of Chironomidae capsule (4)
charcoal fr (?)
leaf: middle nerve
seed: *Ranunculus*
seed: *Potamogeton*
seed: *Carex* (2)
seed: black, flattened, ellipsoid, poorly preserved at apex
seed: elongate, brown
fragment, black, tapering into cone like shape, ~1.5mm long, rupture lengthwise
fungal sclerotia
Chironomidae

*677-678 cm
seed: grey, fractured
leaf: fr. plumose shape
wood stem branched and with seed
wood stem with bark, dark center and porous layer around center, 2 layers seen in cross section
wood stem
Chironomidae

*678-679 cm
sediment: grey stain (silver microspheres)
charcoal (?) shiny triangular possible insect fr.
seed: subtriangular, poorly preserved
seed: with beige, rigid shell
seed: brown yellow
wood stem (2 fr.) cross section view reveals porous rings
Chironomidae

*679-680 cm
sediment: clumps of fine sand
shell like small brown
seed: grey, big
seed: 1/2 fr., yellow, sculpture ...
org. fr. peculiar shape, bulb with crown, dark sphere under bulb
fungal sclerotia
bryophyte fr. gametophyte
insect fr. possibly sternites
Chironomidae

*680-681 cm
sediment: clumps of fine sand
seed: black, broken
seed: black, tear shape, bulb section torn, 2.3mm long, or weevil fr.
wood fr. (3): flattened with thick bark, porous wood with pattern of rays
org. fr.: black clump with concavity
shell like, small brown
fungal sclerotia
insect fr. (2)
Chironomidae

*681-682 cm
seed: brown-black, bean shape, 2 fr. bulbous sculpture
seed: fr.
seed: *Ranunculus* (?)
seed: elongate brown with longitudinal depressions
seed: 1/2 fr. black, rigid, subtriangular
wood stem with bark (2)
fungal sclerotia
insect fr.: leg fr. with hairs
Chironomidae

*682-683 cm
leaf coniferous (spruce or Ables?)
seed: black, stripped long.
wood fr.
wood fr. with bud detached, rigid bark, cross section view reveals subtriangular shape with 2 bulbous corners
org. (?) fr.: tubular shape with distinct junction, yellow-brown (4), (Chironomidae?)
insect fr.: 2 elytra
Chironomidae

*683-684 cm
leaf fr.: spruce, very small
seed: black
seed: black, elongate with longitudinal depressions like in 681-682 cm (2)
wood fr. (2) bud and stem
wood chunk
wood fr. with porous centre yellow
wood fr. with buds similar to 684-685 cm
bryophyte: gametophyte fr.
Chironomidae
insect fr.: perforated plate, black

*684-685 cm
seed: 1/2 fr., black or wood charcoal
wood fr. eroded or seed (several)???
wood stem, broken into 5 fr.
wood stem, broken into 2 fr.
shell-like, brown rigid

*685-686 cm
seed: brown-black, spherical
shell-like, black, elliptical
bryophyte: gametophyte fr.
insect fr. with mane of short hairs, 1.5mm long, (inner lobe of maxilla?)
insect fr.
insect fr.: gula ?
insect fr.: 2 fr. that are detached elytra ?

*686-687 cm
seed: 1/2 fr., flattened, with longitudinal depressions
seed: 1/2 fr., brown, hollow
seed: yellow, kidney shape, broken in centre, black inside
wood stem, thick in middle, cross sect. reveal 3 centre with several layer, bark as perforated appearance, charred?
wood stem: broken into 8 fr., cross section: dark central band and encasing band, porous in between bands, dark centre with irregular border
plate with central spherical thickening, brown
shell-like, black, elliptical, lustrous
Chironomidae

687-688 cm
seed: black, elliptical
seed: black, bean shape
seed: 2 halves separated, brown, flat
shell-like, brown, elliptical
tuff of "hair"
bryophyte: gametophyte fr.
insect fr. (?) conical struc. (2)
Chironomidae

688-689 cm
note: fossils are partially replaced by mineral particles (white powder inside)
leaf: large yellow-brown fr.

seed: 1/2 fr. well desiccated, black, subspherical with one point
seed: black
wood stem divided into 5 fr. part of wood stem in 689-690 cm
wood stem divided into 3 fr. much larger than above, and well rounded
org. egg shell shape 1/2 fr.
shell-like brown yellow, shiny, like in sample 689-690 cm
fungal sclerotia
bryophyte: gametophyte fr.
Chironomidae

689-690 cm
seed: 1/2 fr.
seed: covered with sediment
seed: black, spherical, fungal sclerotia (?)
wood stem divided into 2 fr.
wood fr. u shaped
fr. like in 692-693 cm black and yellow (3)
shell-like brown yellow, shiny same has in 688-689 cm sample
fungal sclerotia
bryophyte: gametophyte fr.

690-691 cm
seed: 1/2 fr., capsule shape
seed: 2/3 fr. broken
wood fr. charred
org. fr. similar shape has operculum on moss or weevil fr.
org. fr. 2 tubes in the shape of crescent joined at one end to form a stem
bryophyte: leaf
bryophyte: capsule
bryophyte: gametophyte fr.
insect fr. pointed
insect fr. peculiar pattern black spot on yellow, 2.5mm long
mite
Chironomidae

691-692 cm
leaf fr. 7mm long
leaf fr. with central nerve and parallel lines same has in 692-693 cm or insect fr.
org. fr. stem shape, divided in 3 fr., cross section reveals spherical shape with porous center & outside layer with rays
org. fr. 2 tubes in the shape of crescent joined at one end to form a stem like in 690-691 cm
fungal sclerotia
insect fr., elytra fr. with longitudinal stripes
insect fr. black, 1/2 spherical

692-693 cm
charcoal wood?, lustrous, angular, black
leaf fragments
leaf fr. with central nerve with parallel lines
leaf, conical shape, hollow, broken
seed: black with 1/2 envelope, poorly preserved
seed: 1/2 black, hollow, capsule like
bark, tube
org. fr. point possibly top of operculum?
fungal sclerotia

693-694 cm
charcoal wood
leaf fr. of conifer
seed: 1/2 fr., black, capsule like
seed: small elliptical
tuft of "hair" black
Chironomidae

694-695 cm
leaf: entire with stem *Dryas*?
seed: black, poorly preserved
wood fr.
insect fr. (2)
org. fr. tube shape with light coloured sand inside
shell like, seed or insect fr.
bryophyte: gametophyte fr. is long

695-696 cm
sediment: fine to coarse sand
seed: fr. or leaf ?
seed: fr. charred, elongate
seed: 1/2 fr., black, 2 folds, poorly preserved
wood fr.
org. fossil (?)
shell-like, white, artificial/ctm?
fungal sclerotia
insect: fr. black lustrous, pitted0