Quaternary Environmental Changes Inferred From Pollen Analysis of Ponds, Green Mountains, Vermont

A Proposal Presented

by

Lin Li

to

The Faculty of the Graduate College

of

The University of Vermont

In Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Geology

April 21, 1995

Abstract

Great changes have taken place in the Green Mountains of Vermont since the Wisconsin continental glacial ice sheet left. The Champlain Valley has undergone changes as Lake Vermont, and the Champlain Sea which was later replaced by Lake Champlain. Meanwhile, vegetation migrated northward following the retreating ice. Little pollen work has been done in Vermont. The only study with systematic radiocarbon dating was done by L.L. McDowell in 1971. The purpose of my research is to use pollen analysis to explain the distribution pattern and first arrival time of different tree species in the Green Mountains, Vermont, enrich the local pollen research data, and attempt to figure out whether the Younger Dryas climatic oscillation occurred in North America.

Pollen analysis is an effective way to interpret paleovegetation distribution and therefore infer changes in paleoclimate. Due to the extremely resistant characteristic of the pollen grain wall, pollen grain can be well preserved in lake, pond, bog, and peat sediments. The unique morphological characteristics of pollen grains make it easy to identify to species-level. By coring at the deepest portion of lakes or ponds, one can retrieve a complete pollen archive.

I have collected three cores from Sterling Pond, and two cores from Ritterbush Pond. Before the cores were taken, I made detailed bathymetric maps to identify depocenters. In the lab, the cores have been subsampled at five to ten centimeters interval. Pollen has been extracted from forty two of fifty seven samples at Dr. Ray Spear's lab. Six AMS radiocarbon dates of sediments and macrofossils have come back from the Lawrence Livermore National Laboratory. The sediment from the deepest part of Sterling Pond yielded an age of 12,760+/-70 years BP. High resolution loss-on-ignition and macrofossil identification will be done in the coming lab work. Because Ritterpush Pond are almost 1,000 feet lower and further north than Sterling Pond, it may help us understand the altitudinal and latitudinal migration pattern of vegetation.

Introduction

The most recent of the Pleistocene episodes of continental glaciation is called the Wisconsin, at least for North America east of the Rocky Mountains (Wright, 1983). After a long buildup during the Early and Middle Wisconsin, with some fluctuations in its extent, the Laurentide ice sheet reached its maximum extent in the late Wisconsin--before 20,000 ^{14}C years ago in the case of parts of its southeastern margin but as late as 14,000 ^{14}C yr BP for ice lobes west of the Mississippi River, at a time when more easterly lobes were already in retreat (Wright, 1983).

Soon after 14,000 ^{14}C yr BP, the Laurentide ice front was in full retreat throughout its southern perimeter (Cronin, 1976). By about 11,000 ^{14}Cyears ago, the Gulf of St. Lawrence had opened, leaving a residual ice mass in northern New England, and the postglacial Great Lakes had already had a complex history of different outlets and lake levels (Cronin, 1977). By 10,000 ^{14}Cyears ago, the ice front had withdrawn north of the Great Lakes, and other preglacial lakes had formed in Manitoba and northwestern Ontario, also with a complex history related to ice-margin fluctuations (Cronin, 1977).

The Wisconsin ice sheet eliminated the forest cover of Canada and the northern part of the United States. What was the progress of revegetation of the deglaciated terrain during the retreat, especially at times when the ice margin temporarily readvanced? What have been the subsequent shifts in vegetation through postglacial time? What vegetational changes result from climatic change? These have been the central questions for recent pollen investigations in North America.

In New England, especially the Champlain Valley, great environmental changes have taken place since deglaciation. As the glacial margin retreated northward, the melting water filled in Lake Vermont. Leveling of the elevated shore features on both sides of the Champlain Valley clearly shows two stages of glacial Lake Vermont (Chapman, 1937). As soon as the ice passed north of the St. Lawrence Valley, marine water invaded landward through the Valley, which ended the long period of stability of Lake Vermont stage, forming Champlain Sea in the

Champlain Valley. The Champlain Sea occupied Champlain Valley from about 12,500 to 10,000 ^{14}C yr BP. Figure 1 shows the maximum extent of the Champlain Sea in the North Champlain Valley (Cronin, 1977). Following an initial maximum limit of inundation, isostatic crustal rebound caused the sea's gradual regression, which is documented by the parallel alignment of tilted shorelines at successively lower elevations along a north-south profile (Cronin, 1977). When the invading marine water source was finally cut off by continued tilting, the present day Lake Champlain formed. As the continental glacier melted, the mountains deglaciated first. Numerous glacial lakes of various sizes were left on the mountain slopes. Vegetation followed the retreating ice and occupied the barren land.

Pollen analysis is concerned with the study of fossil assemblages of pollen grains and spores that have been isolated from sediments deposited in the recent past or as far back as the Paleozoic era. Due to the unique morphology of pollen from each species and the extremely resistant characteristic of the pollen grain wall, it is possible to concentrate pollen grains from sediment using various chemical treatments. Certain exceptional types of pollen are completely destroyed soon after entering the lake by bacteria or fungi (Havinga, 1967) or benthic organisms(Davis, 1969).

The changes in frequencies of pollen types within the stratigraphic column are assumed to reflect changes in proportions of species or genera in the surrounding vegetation. These changes are often interpreted as the result of climatic changes, one of the major factors affecting species composition of vegetation. Pollen analysis is not perfect. For example, different tree species have different pollen production and dispersal rates, sediment focusing, sediment resuspension are all the problems that need to be considered. In general, pollen analysis remains a powerful tool by which to interpret paleoclimate, especially with the modern AMS dating technique which makes the accurate dating of small samples possible.

LITERATURE RESEARCH / PREVIOUS WORK

I. Regional previous research

The landscape of northern New England and adjacent area of Canada changed greatly between

14,000 and 9,000 ^{14}C yr BP; deglaciation occurred, sea levels and shorelines shifted, and a vegetational transition from tundra to closed forest took place (R.B. Davis, et al., 1985). A continuum of tundra-woodland-forest passed northeastward and northward without major hesitation or reversal (R.B. Davis, et al., 1985). The early Holocene is characterized by sharp environmental changes including changing vegetation assemblage, floodplain aggradation, and the subsequent incision of rivers (Wright, 1983). The Middle Holocene was the warmest and driest period of postglacial time, based on the northward and upward advancement of deciduous trees, strong soil development, and floodplain stability (Wright, 1983). The Late Holocene was cooler and moister than Middle Holocene and vegetation was most like what we have today (R.B. Davis, et al., 1985).

Most New England pollen research has concluded that ice left Vermont about 14,000 ^{14}C yr BP, and that the landscape was characterized by the prevalence of tundra vegetation between 14,000 and 12,000 ^{14}C yr BP (Davis, M. B., 1986). Spruce pollen begin to increase about 11,700 ^{14}C yr BP (Spear, et al., 1994). An increased rate of progression of forest from 11,000 to 10,000 ^{14}C yr BP suggests a more rapid warming than in the prior 2000-3000 ^{14}C yr BP (R.B. Davis, et al.,1985). The work Margaret B. Davis (1968) did in Rogers Lake, Connecticut shows that an increase in the rate of tree pollen deposition occurred at 12,000 ^{14}C yr BP, when boreal woodland become established. She also pointed out that pollen deposition rates continued to increase until a sudden sharp rise for white pine, hemlock, poplar, oak, and maple pollen at 9,000 ^{14}C yr BP marked the establishment modern forests.

The results of Ray Spear's research (1994) in New Hampshire are that at low elevations the sequence of vegetation change was: 13,700-11,500 ^{14}C yr BP, tundra which is characterized by a high percentage of nonarboreal pollen and silt content, and a lack of macrofossils; 11,500-9,000 ^{14}C yr BP, transitional mixed-conifer woodland of first spruce and then fir, larch, poplar, and paper birch; 9,000-7,000 ^{14}C yr BP, forests dominated by pine and oak; 7,000 ^{14}C yr BP, mixed hardwood forests. In Mirror Lake, spruce pollen begin to increase at 11,500 ^{14}C yr BP, peaked at 10,800 ^{14}C yr BP, dropped gradually by 10,000 ^{14}C yr BP, and later increased beginning at 2,000 ^{14}C yr BP. Fir pollen percentages at Mirror Lake peaked around 10,000 ^{14}C yr BP and dropped by 9,000 ^{14}C yr BP. The vertical expansion of both white pine and hemlock during the 6,000 to 4,000 ^{14}C yr BP suggest greater warmth. During this period, most research sites in New England show that hemlock increased between within 4,000 to 7,000 ^{14}C yr BP reaching its peak around 4,850 ^{14}C yr BP, which is the minimum stage of pine. The pollen profile for beech shows the same altitudinal trends as hemlock. The peak of birch come after the decline of hemlock. The reappearance of spruce occurred at 3,000 ^{14}C yr BP, following the increase of beech, and reach its peak between 1,500 and 1,250 ^{14}C yr BP. Fir pollen percentage reached a small peak at 3,000 ^{14}C yr BP. The pollen percentage changes of spruce, beech and fir represent a cooler and moister climate which extended to the present (McDowell, L. L., 1971).

Little pollen research has been done in Vermont, especially northern Vermont, compared with other states in New England. The pollen zonation used initially in Connecticut has been extended to other areas with few stratigraphic and absolute age measurements. Very few radiocarbon dates are available for correlation. Figure 2 is the site map showing the location of the 62 pollen cores taken in northeastern North America; Table 1 lists the references to Fig. 2. Among them, only one core was taken in Vermont. Figure 3 shows the location of sites with pollen data for 6 ka (black dots), 12 ka (open square mark), and 18 ka (open circle mark) in eastern North America. Again, few Vermont data are shown on this map. There are only three Vermont pollen study sites that are cited by other researchers, as shown in a table in R. B. Davis' 1985 paper (Fig. 4). Among them, one is unpublished. An equivalence in age, based largely on the similarity of pollen interpretations to climatic changes recorded elsewhere, has been associated with the pollen zonation at most locations, when in reality the time-stratigraphic sequence may not be the same. The chronologic record in sediments, vegetation, and climate in northern New England is incomplete. L. L. McDowell et al.'s work in Bugbee Bog (1971) is the only systematic attempt to combine pollen analysis of whole core sediment with detailed radiocarbon dating in Vermont. Their results are in general accord with other published findings for New England. Table 2 shows the pollen description and zone ages of Bugbee Bog.

II. Discussion of the Constraints of Pollen Analysis Method

A. Pollen production and dispersal rate.

It has long been recognized that the efficiency of pollen production and dispersal in different species of plants varies widely. A reasonable interpretation of a pollen spectrum can be made only if the relative pollen dissemination efficiency of each species is known. The complexity of past vegetation assemblage cannot be deduced accurately from fossil pollen spectra before the relation between the present pollen rain and the present vegetation is better understood. Attempts to estimate pollen production and dispersal distance have been made in Europe and Japan, but largely neglected in North America (M.B.Davis, et al. 1960). Pollen dissemination characteristics of most forest trees of New England are poorly known. M. B. Davis et al. (1960) compared the present vegetation of the Memphremagog quadrangle in northern Vermont with pollen spectra in samples collected from the bottom mud of ponds in that area. Their results, in regions of widely divergent vegetation, indicate that in forested regions, the majority of the pollen is contributed by trees within a few miles of the sampling station. Oak, pine, birch, and alder are over-represented pollen types while maple, arbor, vitae, fir, poplar, larch, and basswood are underrepresented pollen types. Changes of pollen frequency in the sediments of the lake may represent changes in the vegetation of an area ranging in size from 75-7500 sq. miles. Faegri and Iversen (1950) also believed that the natural limit of pollen transport is 50-100 km (30-60 miles) and that the great majority of pollen falls to the ground long before it has traveled that distance. Figure 5 shows the research result of R.G. West concerning the components of the atmospheric pollen rain and deposition. Janssen (1986) took pollen samples along nine transects across local vegetation belts bordering bogs or ponds in overall deciduous and coniferous-deciduous forest region. Three types of pollen rain are distinguished: local, extralocal, and regional. Local pollen is derived from plants that grow at or very close to the sample point; extralocal pollen is derived largely from trees that grow on the slopes and upland adjacent to the sample site, but not extensively over large areas; regional pollen is derived from plants commonly far beyond the immediate basin slope. When the extralocal and the local types are excluded from the sum of upland pollen types, the regional pollen rain differs little from site to site (Janssen, 1986). Ray Spear et al.'s (1994) work in the White Mountains, New Hampshire, focused on the vertical dispersal of pollen grains. They chose six study sites at different elevations along the White Mountains, and no obvious difference in pollen components was observed (Fig. 6); however, difference did exist in macrofossils.

One way of overcoming the above mentioned problems of pollen analysis is to compare contemporary distribution of pollen with the modern vegetation using various mathematic methods. Different workers using different methods have achieved different results. R.B. Davis et al. (1975) have mapped and summarized 478 pollen counts from surface samples at 406 locations in eastern North America. Their research documents the relationship between the distributions of pollen and vegetation on a continental scale. Overpeck et al. (1985) used "dissimilarity coefficients" to compare the modern and fossil pollen samples. They found that modern samples are so similar to fossil samples that almost three late Quaternary pollen diagrams could be "reconstructed" by substituting modern samples for fossil samples. Webb (1974) extracted pollen from the top 2 cm of short cores taken from 64 lakes in lower Michigan, and compared it to vegetation data from the Forest Inventory record. By using "principle component analysis" to compare, Webb showed that the pollen data reflected the patterns in the vegetation.

B. The selection of site for pollen analysis.

For the selection of sites for pollen analysis, the size, the elevation, the hydrological conditions, such as the inflow and outlet of the basin should be considered. Bradshaw et al. (1985) analyzed the scatter diagram and "regression analysis" of paired pollen and tree-inventory data. They concluded that small basins collect their pollen from smaller areas of surrounding vegetation than do large basins. The relationship between contemporary pollen and vegetation data is influenced by the size of the pollen collecting site and the size of the area surveyed for trees around each site. Jacobson (1981) suggested that according to the different study purposes, different size should be selected. For instance, small lakes might be suitable in studying extralocal vegetation research, peat deposits are useful in studying regional paleovegetation history, and small hollows are useful for reconstructing local vegetation.

C. Lag time for vegetation to climate changes.

Lag time for vegetation to react to climatic change is also a consideration for pollen researchers. Webb (1986) models the ratio of lag time for vegetation response to climate against the time scale of the climate change. His conclusion is that the rate of vegetation change is greater after a large climatic change than after a small climatic change, because the spread of time in climate change is large enough for the vegetation response to always "catch up." Prentice (1986) suggests that on large spatial and temporal scales, vegetation is in dynamic equilibrium with climate-- that is, forest range extensions follow climate patterns. As long as climate changes are much slower than vegetation response, the system can be said to be in equilibrium.

D. Sediment focusing, sediment resuspension, and preferential deposition.

a. Sediment focusing.

Sediment focusing refers to the phenomena which results in greater net accumulation of sediment in deeper parts of the basin. Regarding this problem, some researchers believe that focusing is only a minor factor for macrofossils and that differential input can be avoided by coring near the center of the lake. Other researchers, such as M. B. Davis et al. (1982), think that sediment as a whole may be resuspended and moved from shallow to deep parts of the basin by water currents. They observed that there were a parallel declines in accumulation rates of both pollen and inorganic sediments suggesting that the observed decline is due to the process of sediment focusing rather than to a change in decomposition rates or organic input. To a certain degree, sediment focusing makes interpreting the pollen assemblages on the basis of deposition rate less reliable.

b. Sediment resuspension.

The redeposition and resuspension mechanism was studied by many researchers. Redeposition of sediment and pollen has been reported from experiments with sediment traps in Frains Lake, in Michigan (Davis, 1968). This process was caused by the inflow of water from river or spring into the lake, redistributing sediment within the lake basin and thus affecting the final distribution of pollen grains in sediment, so it has obvious importance for the interpretation of fossil pollen. M.B. Davis (1973) used sediment traps set at various depths in various parts of lakes. Her results showed that resuspension occurs without sorting of differential movement of individual pollen grains. The pollen content of redeposited sediment serves as a tracer, showing that sediment is moved from the littoral zone to the deeper basin of the lake. In the littoral zone annual stirring may involved the uppermost 6-12 mm of sediment; even the deeper part of the basin, the uppermost millimeter at least is stirred by this process every year. Bonny (1978) used sediment traps which were put inside and outside of two experimental tubes with 45m in diameter and 12m in depth. Annual pollen catches in traps submerged inside the tubes were equivalent to only 15% of the catches outside, indicating that a high proportion of all pollen supplied to mid-lake must be streamborne (Bonny, 1978).

c. Preferential deposition.

Preferential deposition distorts the original ratios in which pollen enters the lake from the air, causing variations in the pollen percentages in sediment from different part of the lake (Davis, et al., 1973). Pollen grains with rapid rates of sinking fall downward through the water and are deposited evenly onto the sediment through out the lake (Davis, et al., 1973). Those with slower sinking speeds in water, due to small size or density, are kept in suspension and are deposited preferentially as littoral sediment.

C. Environmental factors influence pollen distribution.

The effect of environmental factors, such as local soil type, fire, pathogens, wind, independent changes of temperature, seasonality, and precipitation on pollen distribution were discussed by Spear et al. (1994). The equilibria of plant distribution with climate was also discussed by Spear et al. (1994). Migration lag can affect pollen assemblages. Different tree species entered New England at different times and spread northward at different rates (R. B. Davis et al., 1985). Several other authors (Wright, 1964; Wright and Watts, 1969; Davis, 1965, 1967; Cushing, 1965) acknowledge that nonclimatic factors also influence past vegetation patterns. Swain (1973) noticed that fire has always been an important ecological factor in the forest history of northeastern Minnesota. "Pollen analysis shows no change or only short-term changes in the percentages of major pollen types following charcoal peaks." (Swain, 1973). Davis (1981) explained the prehistoric decline of hemlock 4800 ^{14}C yr BP by the outbreak of a pathogen. Allison et al. (1986) compared the rapidity of the hemlock pollen decline with the decline of chestnut pollen recorded in the laminated sediments of Pout Pond in Belmont County, New Hampshire. They concluded that the decline was due to pathogen attack. Webb (1986) studied the potential role of passenger pigeons and other vertebrates in the rapid Holocene Migration of nut trees and found that heavy seeded tree population ranges could change rapidly in response to climate change or other disturbances with the aid of pigeon dispersal. Johnson et al. (1989) has studied the role of blue jays in the postglacial dispersal of oak trees in eastern North America. This paper links data from blue jay caching behavior to the high rate of range extension and suggests that blue jays may be an important biological vector for rapid postglacial range extension of fagaceous trees.

Through personal communication with Dr. Ray Spear (Feb. and Mar. 1995), I have learned that given all the "drawbacks" of pollen analysis, the most reasonable way to interpret paleoclimate from pollen records is to consider pollen percentage diagrams with deposition rate diagrams, pollen influx values, and macrofossil counting. My interpretations will be based on the integrated results of the above mentioned methods.

There is inconsiderable debate about whether or not a Younger Dryas cooling event also happened in North America during deglaciation 10,800-9,900 ^{14}C yr BP. I am interested in investigating the existence of such an oscillation in North America. Although the literature supporting the existence of Younger Dryas in North America is contradictory, I personally favor its existence. I believe the reasons why we haven't yet found evidence of such an event are the limitation of data and that the Younger Dryas influence in North America might be less strong than in Europe.

HYPOTHESIS:

Great environmental changes have taken place in Vermont since 14,000 ^{14}C yr BP. The continental glacier retreated northward and vegetation followed the ice, occupying the barren land. There are numerous glacial lakes and ponds in Vermont. By coring at the deepest part of two lakes or ponds, I will attempt to collect the thickest and the longest sediment record. With radiocarbon dating control and careful lab processes, the deposition rate of sediment and the introduction time of specific species can be obtained. Combined with loss-on-ignition and macrofossil identification, I will interpret vegetation changes and the consequent climate changes. By examining the core collected from the shallow part of the Sterling Pond which is adjacent to a steep hillslope, changes in hillslope erosion rates should be recorded. The purpose of my research is to determine when continental ice left the Green Mountain of Vermont, the ensuing change in vegetation assemblage as the climate warmed, and the existence of the Younger Dryas climate oscillation.

SIGNIFICANCE OF RESEARCH:

My research will:

1. Better constrain late glacial and Holocene chronology in northern Vermont with 15 new radiocarbon ages.

2. Improve our understanding of Holocene postglacial environmental changes in Green Mountains, Vermont.

3. Possibly provide information concerning the existing of Younger Dryas climatic oscillation in North America.

RESEARCH PLAN:

STEP ONE: SELECTING STUDY SITE.

Having examined many other ponds in Vermont and considered other constraints, such as the availability of transportation, Sterling Pond (Fig. 7) seemed to be an ideal site for winter access. It is situated on Sterling Peak and surrounding bed rock is primarily chlorite schist. Its elevation is 3050 feet. Figure 7 is the topographic map of Sterling Pond. Figure 8 is the air photo of the pond and surrounding area. The pond seems to have two inflows and one outlet. The surrounding soil type are StC (Stratton-Londonderry complex) and LoE (Londonderry-Stratton complex) (Soil Survey of Lamoille County, Vermont, Oct. 1981).

STEP TWO: MAKING BATHYMETRIC MAP OF THE STUDY SITE AND FINDING ITS DEPOCENTER.

Having augured nearly 400 holes through the ice, with the help of others, I made a detailed bathymetric map (Fig. 9). There are three deep points in the pond. The deepest point is 28 ft on the east part of the pond. Figure 10 is the profile across the deepest point of Sterling Pond. The second deepest is 18.6 ft which is on the south side of the pond. Since I have not been to the pond without snow on the ground, the features of the surrounding area are not clear to me.

STEP THREE: TAKING CORE IN THE FIELD.

With the gracious help of Tom Davis (Bently College), who designed the light-weighted Livingston piston coring equipment, I recovered one core from the deepest part of the pond (Site 1) and two cores from the second to the deepest part of the pond (Site 2 and Site 3 respectively) (see Fig. 9 for coring sites). In order to collect the cores, we relocated the deepest point that we have measured before. We augured through the ice, measured the water depth again, and started coring. All the extension rods were marked in order and the cores once taken out were kept vertical and unfrozen. Stoppers were put on both sides of the tube. When reaching the very bottom of the sediments which should strtigraphically be glacial till, we hammered the extension rod and pushed the tube until it could not be pushed further.

STEP FOUR: SUBSAMPLING OF CORES.

One core taken from the deepest point (site 1, see Fig. 9) in Sterling Pond has been extruded by pushing the stopper at the bottom of the tubes using a wood stick held against a stable surface. The lab length was 570 cm, 90-97% coverage to the extension rod length in the field. Table 3 is a description of this core. The core was cut into half and subsampled immediately after it was extruded in the lab. The average subsample interval was 10 cm, but for some depths, especially the depth that we suspected to contain Younger Dryas evidence, the subsample interval was 5 cm. Macrofossils which were big enough for AMS dating were picked out and kept separately. The sample volume is about 5 ml at each depth point. In total, 57 samples were collected from Site 1 of Sterling Pond. The rest of the core was enclosed in SARAN WRAP, well-marked, and kept horizontal in the cold room of Natural Resource Department of UVM. The last tube of Sterling Pond, Site 2 was also extruded and the length of the core was 580 cm. During this step, contamination was strictly prevented by carefully washed sampling equipment. With new volumetric subsampling equipment we have acquired recently, accurate quantitative subsample is now possible at UVM.

STEP FIVE: RADIOCARBON DATING.

Four samples from the Sterling Pond, Site 1 were sent to Livermore National Laboratory and dated by AMS date. The results are show in Table 4. The bottom most sample of Site 2 and the one in the middle of Site 1 were dated at Livermore National Laboratory; the results are shown in Table 5. Basal radiocarbon dates from these two cores are similar which means the deposition rate of these two study sites are also similar. I have funding for another 8 radiocarbon dates. I plan to use them to get better time control of these two cores, especially around Younger Dryas time.

STEP SIX: POLLEN SLIDE PREPARATION.

During the Spring Break, 1995, I took my samples from Site 1 to Dr. Ray Spear's lab at State University of New York at Geneseo. (See the attached two pages at the end of the proposal for lab procedure of extracting pollen). Before treating the samples, the slurrey is made. Slurrey contains the "marker" pollen which is eucalyptus pollen used for medical research. (See the attached two pages for detail procedure). By using the following function

$$\bar{x}\left(\frac{1000}{0.9}\right) \pm t\sqrt{\frac{\bar{x}}{n}}\left(\frac{1000}{0.9}\right)$$

($\bar{x}$ is the average number of eucalyptus pollen of 60 slides counted, "n" stands for the number of slide counted, "t" is the confidential number, 0.9 is the volume of slurrey under the cover slide with the unit of cubic centimeter)
the average number of eucalyptus pollen of 60 slides in one cubic centimeter was calculated, which is 59,794+/-2104 grains. By knowing the ratio of fossil pollen grains to eucalyptus pollen grains, input influx of fossil pollen grains can be calculated. Each sediment sample will go through HCL treatment, KOH treatment, HF treatment, acetolysis solution treatment, alcohol treatment, and TBA treatment. 42 of all 57 samples from Sterling Pond, Site 1 have been treated so far.

Intensive lab work will continue to be done this semester, summer break and early next semester, including sample treatment for pollen analysis, loss-on-ignition, and macrofossil identification, and pollen counting.

Along with all these steps, more literature research will be done and the draft writing of thesis progress report. This spring or summer, I am going to the Sterling Pond again to make modern vegetation investigation, sample surface pollen, survey the geological setting and examine the wetland to the east of Sterling Pond.

Time schedule

Aug. 20, 1994 --Dec. 8, 1994
Taking class, warming up my English, starting to do literature research. Finished the geomorphology term project concerning pollen analysis in Chickering Fen.

Dec. 8, 1994--Jan. 18, 1995
Read many papers along with Paul, started the bibliography collection, went to Sterling Pond four times, collected bathymetric data, finished the bathymetric map, collected the first core, subsampled core, got four radiocarbon dates back from Livermore.

Jan. 18--Mar. 19,1995

Prepared for the thesis proposal while still reading more papers and reread the papers I had read previously. Feb. 26, collected the second core from the second deepest part of Sterling Pond, collected two cores from Ritterbush Pond.

Mar. 19--27, 1995

Visit Dr. Ray Spear's lab at State University of New York at Geneseo. Learn pollen preparation and finished the making of slurry and the treatments of 42 of my samples taken from Sterling Pond, Site 1.

Mar. 27--April 21, 1995

Start making slides and counting the samples that were treated in Dr. Spear's lab. Prepared for the thesis proposal.

April 21--June 12,1995

I will sample the field area (using 10m x 10m sample type) to determine the distribution of the present vegetation and collect surface sediment sample. I will visit Dr. Spear's lab again, finish treating the rest of my samples, and improve my pollen identification ability. I plan to spend three weeks there right at the beginning of summer break. I will continue counting pollen back at UVM, and start writing progress report.

June 12--24, 1995

I will take a summer class entitled Field Method for Ecologist. In this class, I will learn how to sample vegetation and identity modern vegetation.

June 20--Oct. 1995

Thesis progress report preparation, keep doing lab work, especially loss-on-ignition and macrofossil identification, and literature research. Learn how the use the software for pollen assemblage drawing.

Oct. 1995--March, 1996

Keep doing lab work and starting writing the draft thesis.

March, 1996--May, 1996

Finish writing thesis and oral defense of thesis.

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Lab Procedures for Pollen Extraction and slides making:

Step one: Quantitative subsample.
Take 0.5 cube centimeter sediment sample from certain depth, put it into the centrifuge tube. Add 1 ml of slurrey (see the section "procedure of making slurry" at the end for detail) and DI water to 10 ml, stir up, centrifuge, decant the supernatant.

Step two: HCL treatment--To get rid off calcium carbonate.
(1). Add 10ml 10% HCL to the pellet, stir up, until no bubble come out, centrifuge, decant the supernatant.
(2). Add DI water to the pillet to 10 ml, stir up, centrifuge, decant.
(3). Repeat (2).

Step three: KOH treatment--To get rid off humic acid.
(1). Add 8ml 10% KOH to the pellet, stir up, put into waterbath heating for 5 minutes. (stir while heating)
(2). Centrifuge, decant.
(3). Add DI water to the pillet till 10 ml, stir up, centrifuge, decant.
(4). Repeat (3).

Step four: HF treatment (need to be finished in the hood)--To get rid off silica.
(1). Add 10 ml 49% HF to the pillet, stir up, put into waterbath for 15 minutes. Stir again after first 5 minutes' waterbath.
(2). Cool down a little while, Centrifuge, decant the supernatant to plastic bottle for wasted HF.
(3). Add 10 ml DI water to the pillet, stir up, centrifuge, decant.
(4). (First glacial acetic acid wash.) Add 10 ml glacial acetic acid to the pillet, stir up, centrifuge, decant.
(5). (Second glacial acetic wash.) Repeat (4).

Step five: Acetolysis treatment--To get rid off the organic material inside the pollen grains.
(1). The acetolysis solution consists of 9 parts (by volume) of acetic anhydride and one part (by volume) of concentrated sulfuric acid. Measure 54 ml of acetic anhydride and 6 ml of concentrated sulfuric acid. Mix them.
(2). Add 10 ml of acetolysis solution to the pillet. Stir up as quickly as possible, put into waterbath for no longer than 2 minutes.
(3). Centrifuge, decant the supernatant to bottle for wasted acid.
(4). Add 5 ml of glacial acetic acid and then DI water to 10 ml, stir up, centrifuge, decant.
(5). Add DI water till 10 ml, stir up, centrifuge, decant.
(6). Repeat (5).

Step six: Ethanol alcohol treatment.
(1). Add 10 ml 100% Ethanol alcohol to the pillet, stir up, centrifuge, decant.
(2). Repeat (1).

Step seven: TBA (Tertiary Butyl Alcohol) treatment.
(1). Add 10 ml of TBA to the pillet, stir up, centrifuge, decant.
(2). Add 1 ml of TBA to the pillet, stir up and transfer to the vial. Add little more TBA to transfer pollens which stick to the side of the tube to the vial.

(3). Add few drops of silicone oil. Sit the vial in the hood for 12 hours.
(4). Centrifuge the vial, decant the supernatant which is mostly TBA.

Step eight: Making slides.
(1). Stir the "stuff" at the bottom of your vial as even as possible. Usually, clockwise 20 times and then counterclockwise 20 times.
(2). Put one drop of silicone oil on the slide, add a little recently well-mixed pollen, smear them as even as possible on the slide but within the range of the on-coming coverslip.
(3). Put on coverslip, try to avoid bubbles. Apply a little finger oil at the opposite directions of the coverslip to stabilized it.
(4) Label the slide with permanent marker.

The procedure of making slurry.

1. Put approximately 0.5 cubic centimeter eucalyptus pollen to a centrifuge tube, add a little DI water to it.

2. Step three. (see above)

3. Step five. (see above)

4. Add some glycerol to the pillet, stir up. Meanwhile, put 300 ml glycerol into a beaker.

5. Transfer the well stirred pillet to the beaker with 300 ml glycerol. Put a magnetic bar inside the beaker, and then turn on the magnetic stirrer. Stir the slurrey for one hour before using it.

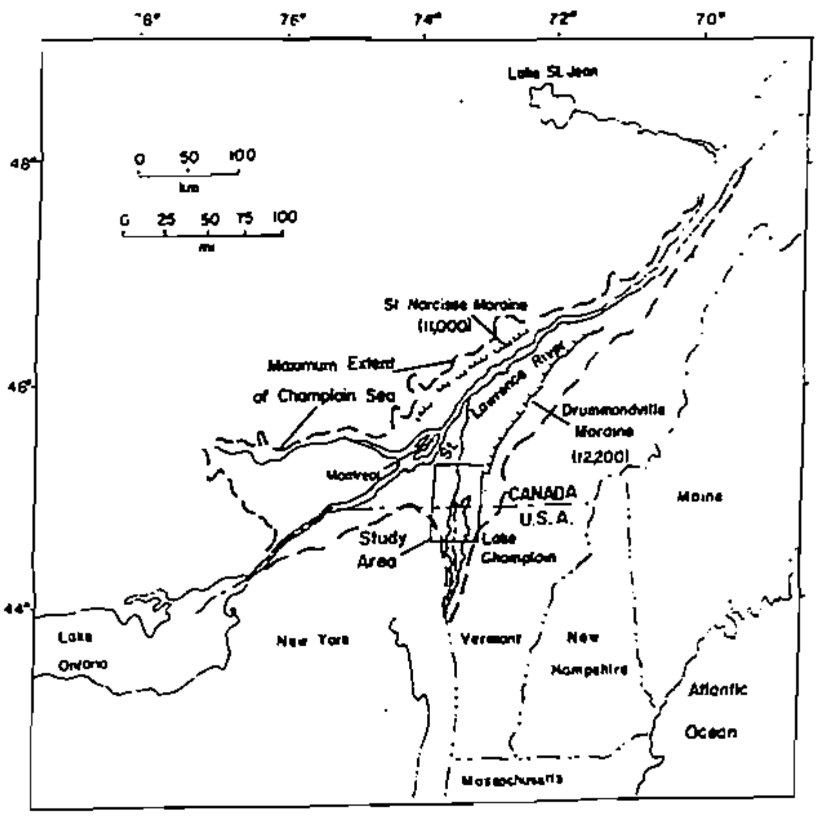


Fig. 1. Maximum extent of the Champlain Sea in the Northern Champlain Valley. (Cronin, T.M., 1977)

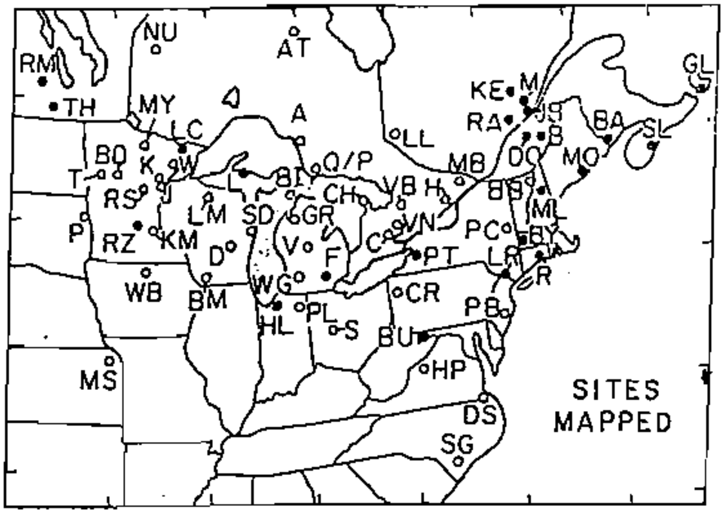


Fig. 2. Site map showing the location of the 62 pollen cores. Solid dots indicate sites where information on pollen concentration or influx data was available. (Bartlein and Webb, 1977)

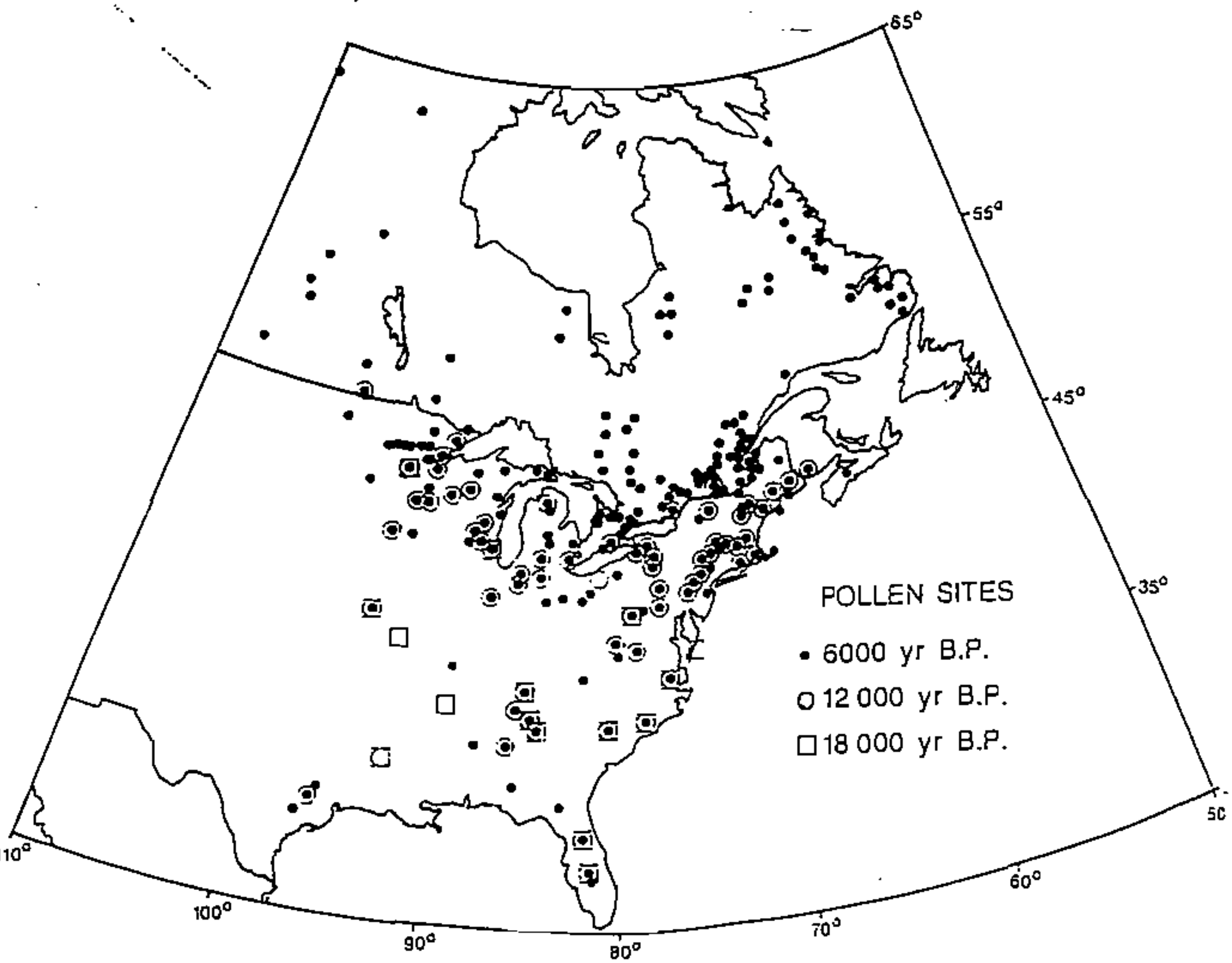


Fig. 3. Location of sites with pollen data for 6 ka (black dots). Open squares mark sites with data for 12 ka, and open circles mark sites with data 18 ka. (Jacobson et al. 1987)

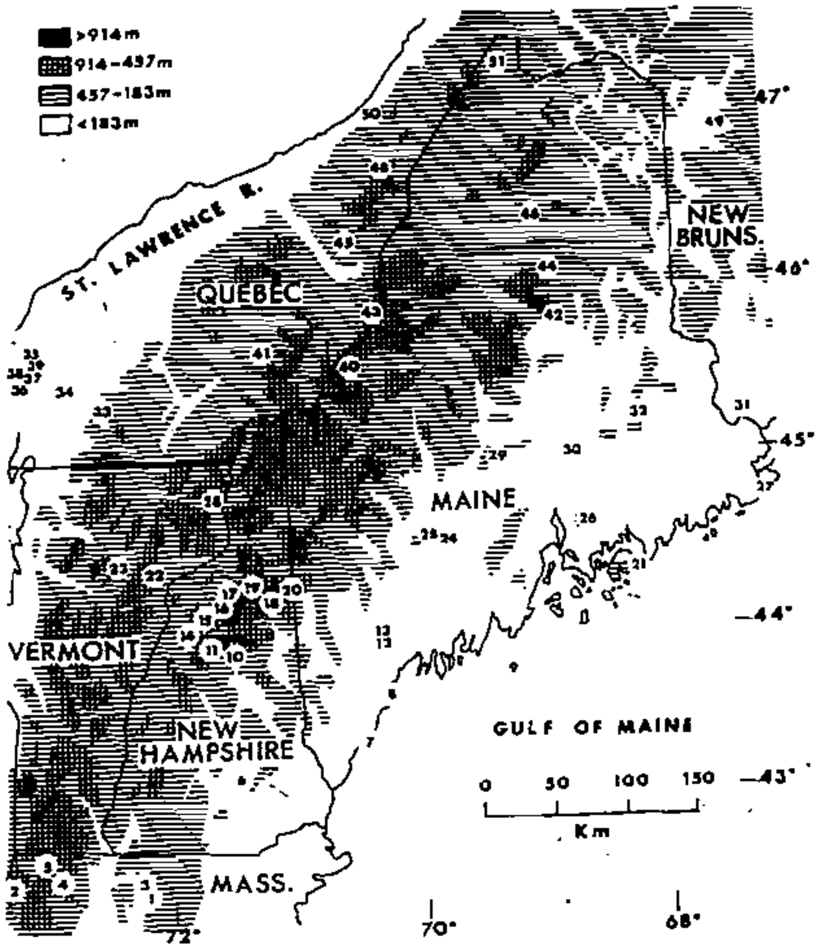


Fig. 4. Site of reference used in R.B. Davis (1985)'s paper about Late glacial and early Holocene landscapes in Northern New England and adjacent area of Canada.

Pollen zone	Pollen description	Zone Age (years B.P.)
C-3	Return of spruce and fir	0 ± 80 - 1600 ± 100
C-2	Hemlock minimum; pine, beech, oak, and birch maxima	1600 ± 100 - 4000 ± 120
C-1	Hemlock maximum; pine minimum	4000 ± 120 - 7250 ± 175
B	Pine maximum at about 8500 ± 180 years B.P.	7250 ± 175 - 9300 ± 200
A	Spruce and fir	9300 ± 200 - 10,500 ± 200

Tab. 2. Summary of the Bugbee Bog pollen zones and their chronology. (McDowell, L.L., et al. 1971)

Tab. 1. List of sites and reference to Fig. 2.

Code	Site	Reference
A	Alfies Lake, Ont.	Saarnisto, 1975
AT	Attawapiskat Lake, Ont.	Terasmae, 1968
B	St. Benjamin Lake, Que.	Richard, 1973c
BA	Basswood Rd. Lake, N.B.	Mott, 1975
BB	Bugbee Bog, Vt.	McDowell *et al.*, 1971
BD	Bog Pond D, Minn.	McAndrews, 1966
BI	Beaver Island, Mich. (Barney Lake)	Kapp *et al.*, 1969
BM	Blue Mounds Creek, Wis.	Davis, A., 1975
BU	Buckle's Bog, Md.	Maxwell and Davis, 1972
BY	Berry Pond, Mass.	Whitehead, 1976
C	Crieff Kettle Bog, Ont.	Terasmae, in Karrow, 1963
CH	Charles Lake, Ont.	Bailey, 1969
CR	Crystal Lake, Pa.	Walker and Hartman, 1960
D	Disterhaft Bog, Wis.	West, 1961; Baker, 1970
DO	Dosquet Bog, Que.	Richard, 1973c
DS	Dismal Swamp, Va.	Whitehead, 1965
F	Frains Lake, Mich.	Kerfoot, 1974
GL	Gillis Lake, N.S.	Livingstone, 1958
GR	Green Lake, Mich.	Lawrenz, 1975
H	Harrowsmith Bog, Ont.	Terasmae, 1968
HP	Hack Pond, Va.	Craig, 1969
HL	Hudson Lake, Ind.	Bailey, 1972
J	Jacobson Lake, Minn.	Wright and Watts, 1969
JB	Joncas Lake Bog, Que.	Richard, 1971
K	Kotiranta Lake, Minn.	Wright and Watts, 1969
KE	Kenogami Bog, Que.	Richard, 1973b
KM	Kirschner Marsh, Minn.	Wright *et al.*, 1963
L	Lost Lake, Minn.	Brubaker, 1975
LC	Lake of the Clouds, Minn.	Craig, 1972
LL	Lake Louise, Que.	Vincent, 1973
LM	Lake Mary, Wis.	Webb, 1974b
LR	Lake Rogerine Bog, N.Y.	Nicholas, 1968
M	Montagnais Bog, Que.	Richard, 1973b
MB	Mer Bleue Bog, Que.	Mott and Camfield, 1969
ML	Mirror Lake, N.H.	Likens and Davis, 1975
MO	Moulton Pond, Me.	Davis, R., *et al.*, 1975
MS	Muscotah Marsh, Kansas	Grüger, 1973
MY	Myrtle Lake, Minn.	Janssen, 1968
NU	Nungesser Lake, Ont.	Terasmae, 1967
P	Pickerel Lake, S.D.	Watts and Bright, 1968
PB	Pine Barrens Bog, N.J.	Florer, 1972
PC	Pine Log Camp Bog, N.Y.	Connally and Sirkin, 1971
PL	Pretty Lake, Ind.	Ogden, 1969
PT	Protection Bog, N.Y.	Miller, 1973
Q/P	Quadrangle Lake, Ont. (0–8000 YBP) Prince Lake, Ont. (8000–10.000 YBP)	Terasmae, 1967 Saarnisto, 1974
R	Rogers Lake, Ct.	Davis, M.B., 1969
RA	St. Raymond Bog, Que.	Richard, 1973a
RM	Riding Mountain, Man. (F Lake)	Ritchie, 1964 and 1969
RS	Rossburg Bog, Minn.	Wright and Watts, 1969
RZ	Rutz Lake, Minn.	Waddington, 1969
S	Silver Lake, Ohio	Ogden, 1966
SD	Seidel Lake, Wis.	West, 1961
SG	Singletary Lake, N.C.	Frey, 1951
SL	Silver Lake, N.S.	Livingstone, 1968
T	Terhell Pond, Minn.	McAndrews, 1966
TH	Tiger Hills, Man. (Glenboro Lake)	Ritchie and Lichti-Federovich, 1968
VN	van Nostrand Lake, Ont.	McAndrews, 1970
V	Vestaburg Bog, Mich.	Gilliam *et al.*, 1967
VB	Victoria Rd. Bog, Ont.	Terasmae, 1973
W	Weber Lake, Minn.	Fries, 1962
WB	Woden Bog, Iowa	Durkee, 1971
WG	Wintergreen Lake, Mich.	Bailey, 1973

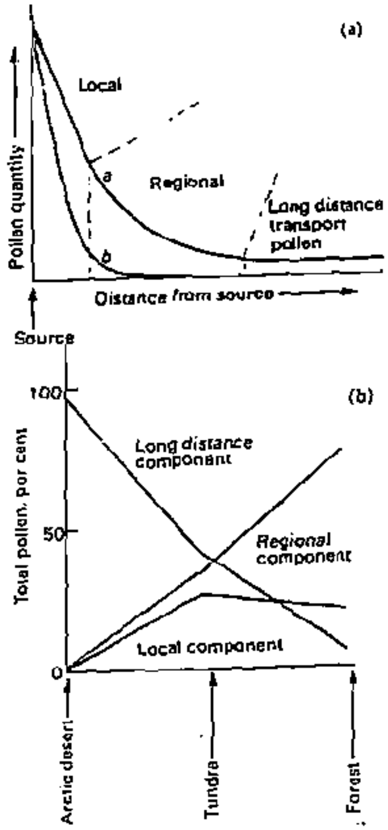


Fig. 5. Component of the atmospheric pollen and deposition. (a) Curves showing *quantities of pollen dispersed at increasing distance* from pollen source. (b) Components of atmospheric pollen deposition in relation to increasing regional pollen productivity. (West, R.G., 1971)

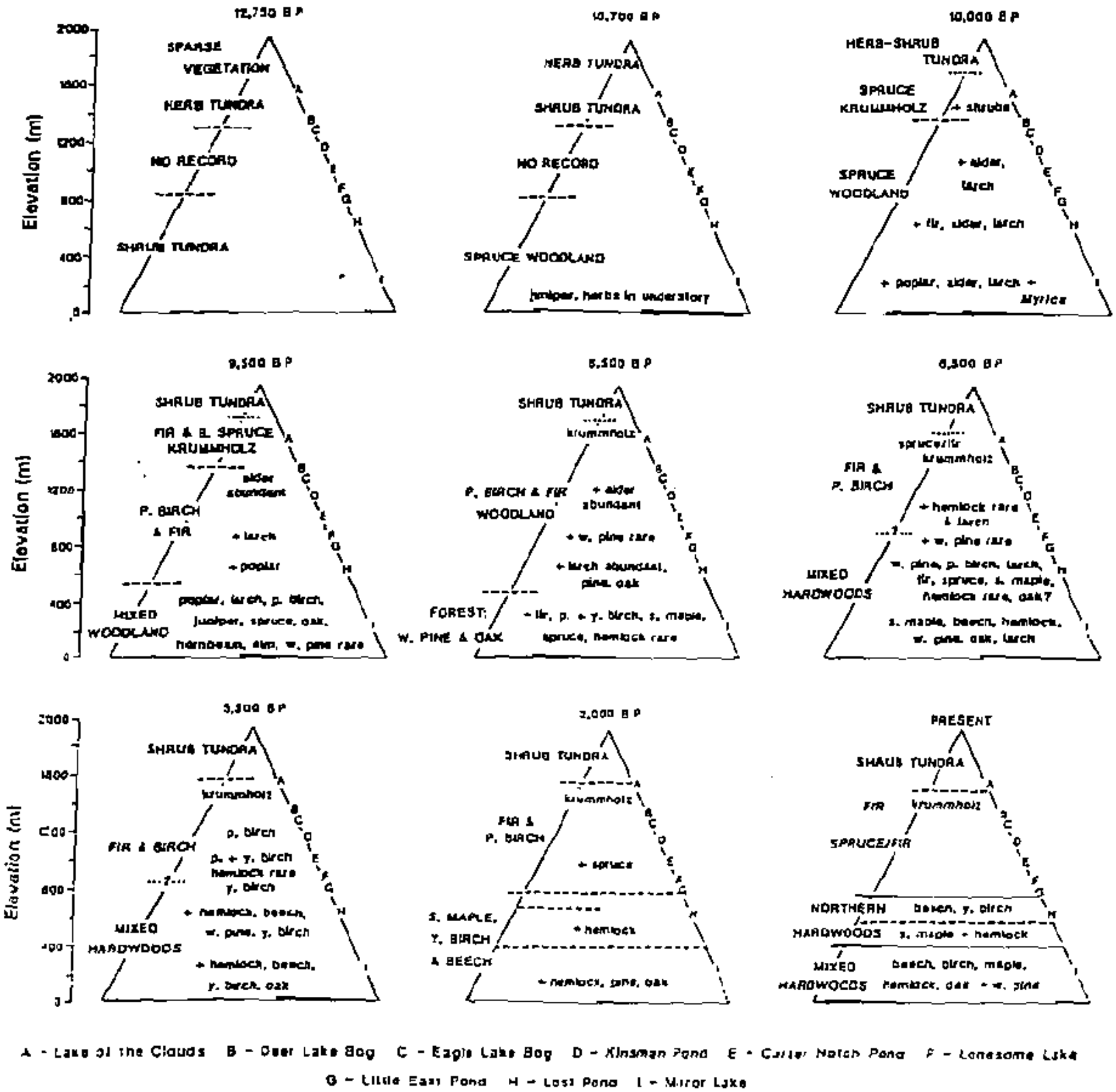


Fig. 6. Schematic summary of vegetation change through time and across elevation gradients in White Mountains region of New Hampshire. (Spear, R.M., 1994)

The combination of 120 and 300 lines of center 2		
point	distance	depth
1	0	5.3
2	20	6.4
3	40	13.5
4	60	18.2
5	80	22.3
6	100	26.7
7	120	27.2
8	140	28
9	160	26.5
10	180	24.8
11	200	23
12	220	21.3
13	240	19.9
14	260	18.9
15	280	16.2
16	300	12.2
17	320	6.8
18	340	5.7
19	360	5.3
20	380	4.6
21	400	3.8

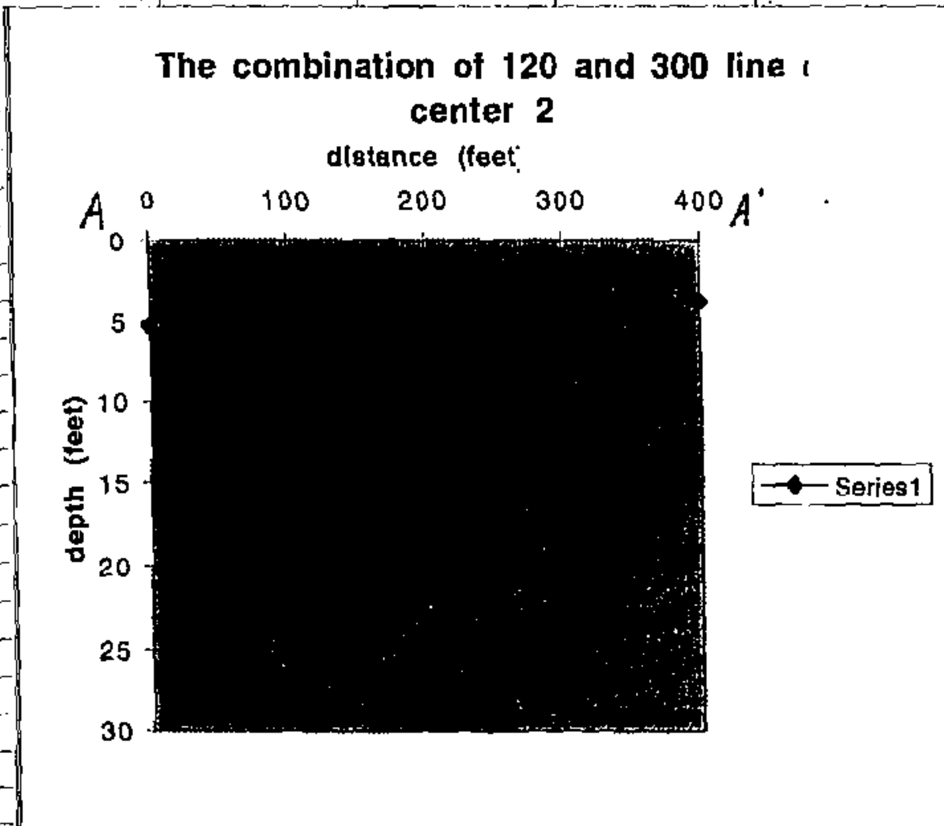
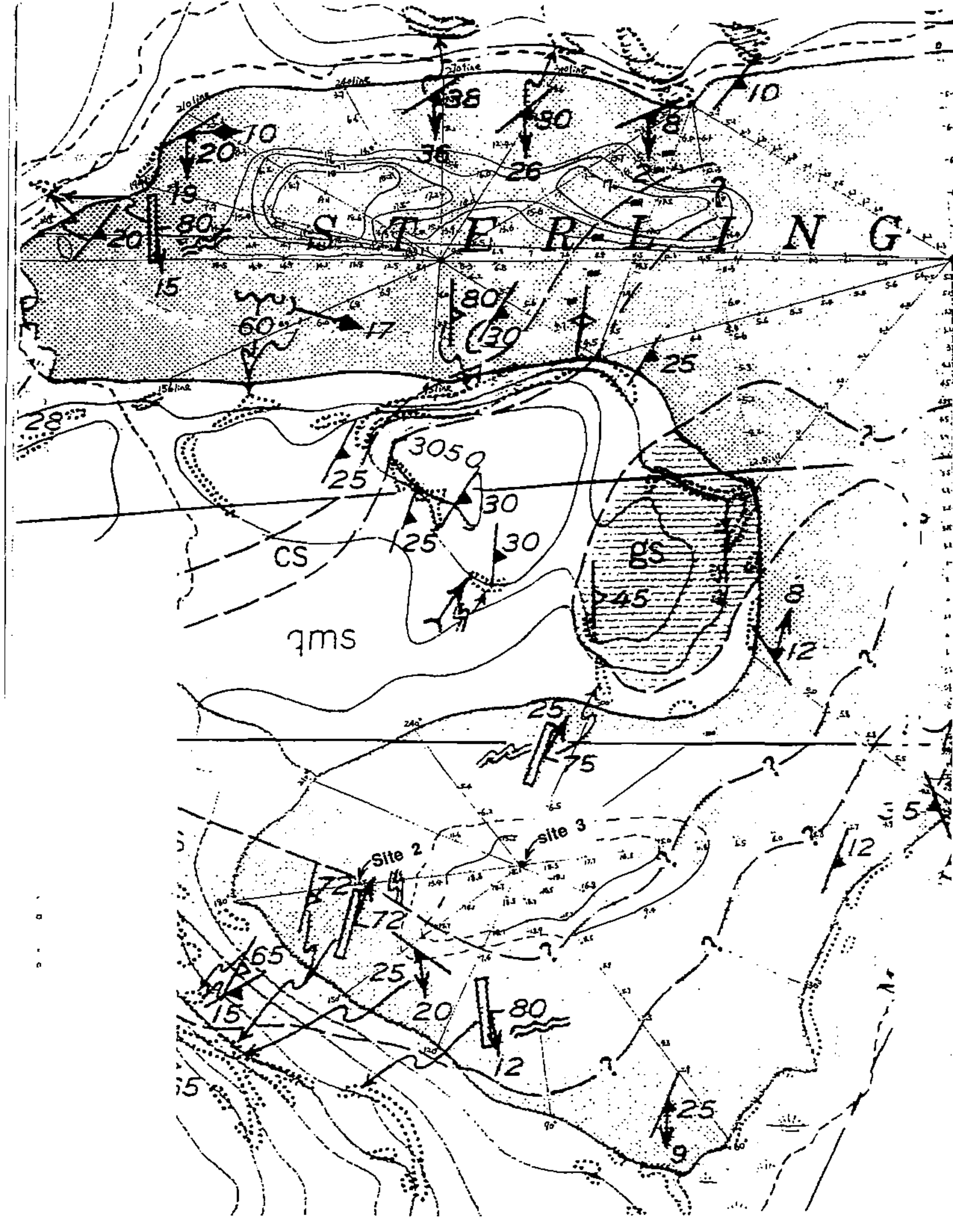


Fig. 10. Profile across the deepest point of Sterling Pond.
(A–A')

Lin Li	core 1	Sterling Pond	ST 1				
		extension length					
		depth from surface	depth from surface	thrust length	lab length	ercent recovery	
		top of thrust	bottom of thrust	in field	of core		
		cm	cm	cm	cm		
Core tube 1	thrust 1	0	96.5	96.5		0.0	
Core tube 2	thrust 2	96.5	193	96.5	94	97.4	
Core tube 3	thrust 3	193	297	104	104	100.0	
Core tube 4	thrust 4	297	393	96.25	94	97.7	
	thrust 5	393	497	103.75	101	97.3	
	thrust 6	497	582	94	85	90.4	

Tab. 3. Summary of the coverage of lab length of Sterling Pond, Site 1.



STERLING
cs
qms
gs
Site 2
site 3

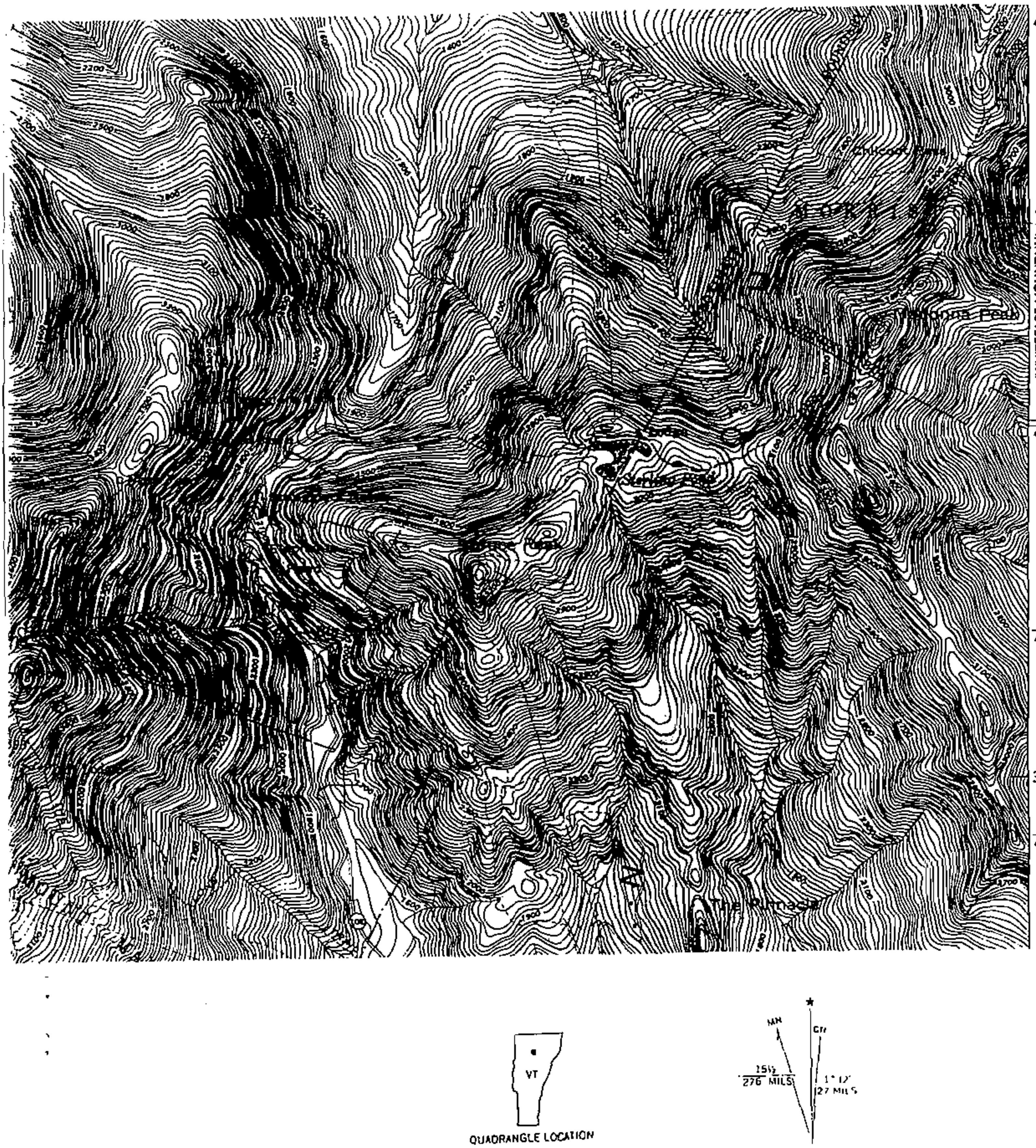


Fig. 7. USGS topographic Map of Sterling Pond. (1948, contour interval 20 feet)
scale 1: 24, 000

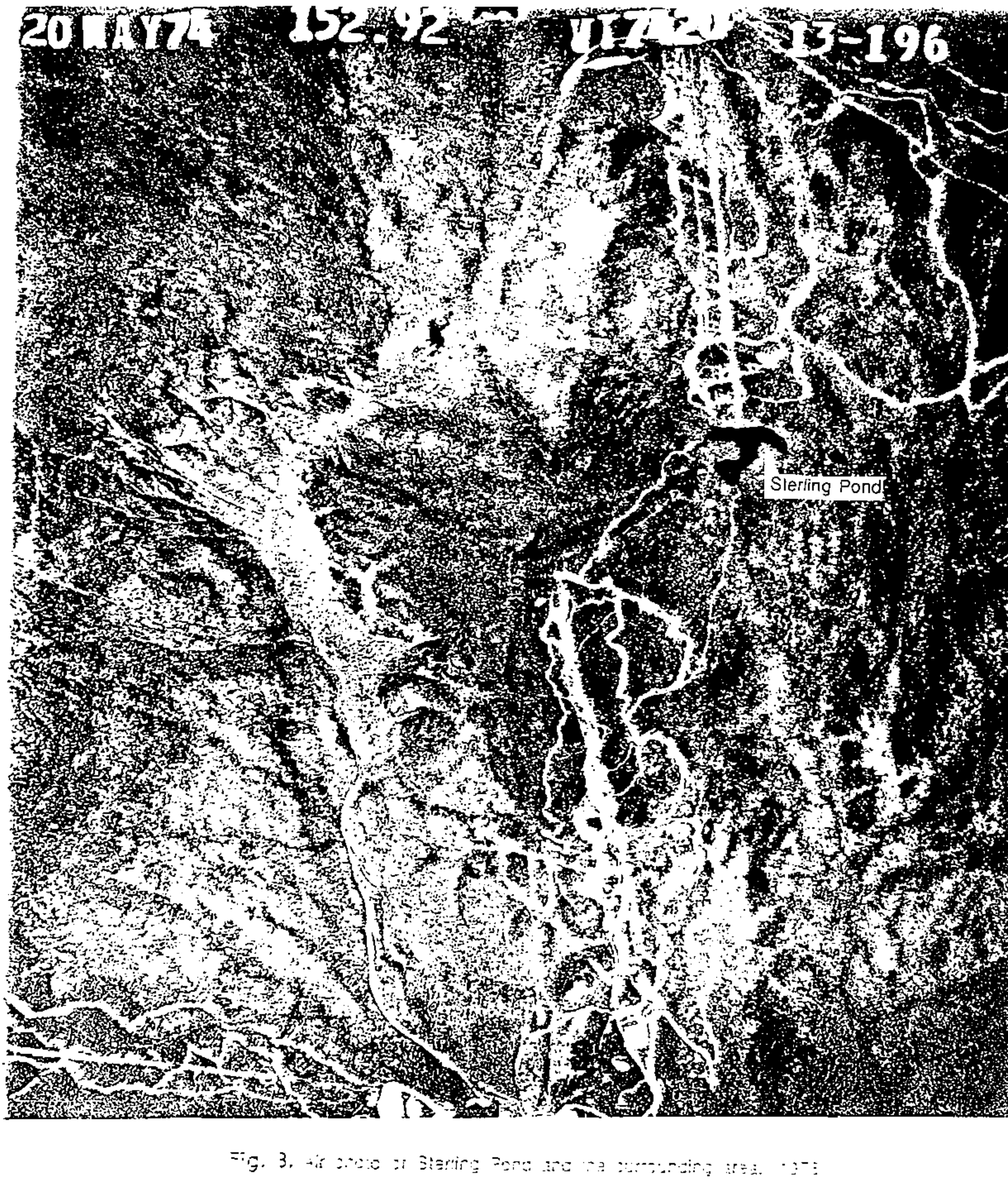


Fig. 3. Air photo of Sterling Pond and the surrounding area, 19[illegible]

Scale 1:20 000

Tab. 4. AMS Date of 4 samples from Sterling Pond, Site 1.

CENTER FOR ACCELERATOR MASS SPECTROMETRY
Lawrence Livermore National Laboratory

^{14}C results | Bierman | January 24, 1995

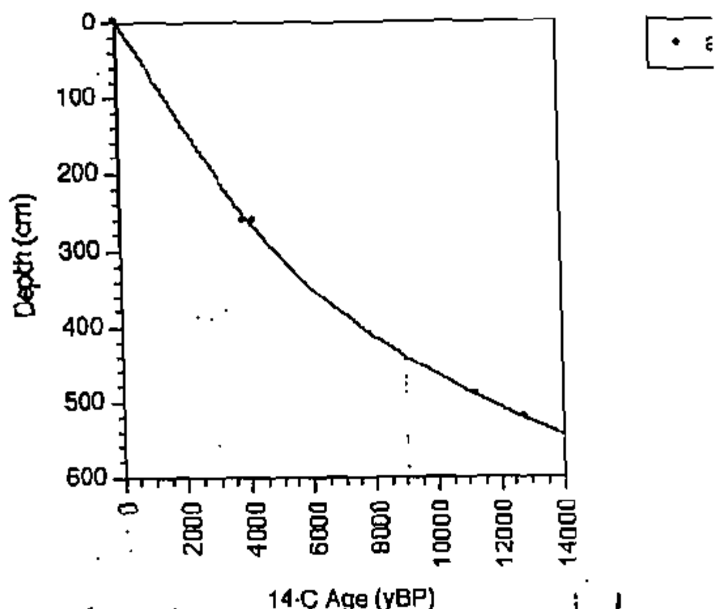
CAMS #	Sample Name	Other ID	$\delta^{13}C$	fraction Modern	±	$D^{14}C$	±	^{14}C age	±
17893	St-1-260 gyttja		-25	0.5940	0.0035	-406.0	3.5	4180	50
17894	St-1-490 gyttja		-25	0.2487	0.0017	-751.3	1.7	11180	60
17895	St-1 521-523 gyttja		-25	0.2042	0.0018	-795.8	1.8	12760	70
17896	St-1-260 twig		-25	0.6151	0.0043	-384.9	4.3	3900	60

1) Delta ^{13}C values are the assumed values according to Stuiver and Polach (Radiocarbon, v. 19, p.355, 1977) when given without decimal places. Values measured for the material itself are given with a single decimal place.

2) The quoted age is in radiocarbon years using the Libby half life of 5568 years and following the conventions of Stuiver and Polach (ibid.).

3) Radiocarbon concentration is given as fraction Modern, $D^{14}C$, and conventional radiocarbon age.

4) Sample preparation backgrounds have been subtracted, based on measurements of samples of ^{14}C-free coal. Backgrounds were scaled relative to sample size.



f(x) = 7.086602E-5*x^3 + -2.083773E-2*x^2 + 1.601188E+1*x + 5.155709E-15
R3^2 = 9.692610E-1,R2^2 = 9.958007E-1,R1^2 = 9.659527E-1,R0^2 = 1.000000E+0

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Lawrence Livermore National Laboratory

^{14}C results — Bierman — March 14, 1995

CAMS #	Sample Name	Other ID	$\delta^{13}C$	fraction Modern	±	$D^{14}C$	±	^{14}C age	±
18923	ST1-420		-25	0.3428	0.0023	-657.2	2.3	8600	60
18924	ST2-522-523		-25	0.2669	0.0023	-733.1	2.3	10610	70

1) Delta ^{13}C values are the assumed values according to Stuiver and Polach (Radiocarbon, v. 19, p.355, 1977) when given without decimal places. Values measured for the material itself are given with a single decimal place.

2) The quoted age is in radiocarbon years using the Libby half life of 5568 years and following the conventions of Stuiver and Polach (ibid.).

3) Radiocarbon concentration is given as fraction Modern, $D^{14}C$, and conventional radiocarbon age.

4) Sample preparation backgrounds have been subtracted, based on measurements of samples of ^{14}C-free coal. Backgrounds were scaled relative to sample size.

5) There was no carbon in sample ST2-565-566.

Tab. 5. AMS Date of 1 bottom sample from Sterling Pond, Site 2 and 1 sample from the middle depth of Site 1. (Done by Livermore National Laboratory)