

168
99

To the Graduate Council:

I am submitting herewith a thesis written by Peter A. Larabee entitled "Late-Quaternary Vegetational and Geomorphic History of the Allegheny Plateau at Big Run Bog, Tucker County, West Virginia." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

Paul A. Delcourt
Paul A. Delcourt, Major Professor

We have read this thesis
and recommend its acceptance:

Richard W. Gonsuk
Thomas Z. Broadhead
Rayl R. Delcourt

Accepted for the Council:

Lewminkel
Vice Provost
and Dean of The Graduate School

LATE-QUATERNARY VEGETATIONAL AND GEOMORPHIC HISTORY
OF THE ALLEGHENY PLATEAU AT BIG RUN BOG,
TUCKER COUNTY, WEST VIRGINIA

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Peter A. Larabee
June 1986

ACKNOWLEDGEMENTS

I would like to thank a number of people who participated or aided in the retrieval of the sediment cores. Dr. Joseph Yavitt, Dr. James McGraw, and Dr. Gerald Lang were sources of crucial information about the bog during field work. I thank Drs. Paul and Hazel Delcourt and Mr. Don Rosowitz for assistance during coring.

I would like to express my gratitude to Dr. Gerald Lang, West Virginia University, for providing access to relevant modern research completed on Big Run Bog, without which, this study would have been measureably more difficult.

This study was made possible thanks to financial assistance from the Discretionary Fund, Department of Geological Sciences, University of Tennessee, Knoxville and from the Ecology Program from the National Science Foundation, Grant Numbers BSR-83-00345 and BSR-84-15652.

Mr. E. Newman Smith Jr. and Mr. Don Rosowitz were important sources for both technical advice and assistance, as well as springboard for informal discussion concerning this study.

I would like to express my gratitude to the members of my committee Dr. Paul Delcourt, Dr. Hazel Delcourt, Dr. Thomas Broadhead, and Dr. Richard Arnseth for their advice, helpful suggestions, and constructive criticisms.

My final thanks are to my wife Elizabeth, for her faith, encouragement, and love.

ABSTRACT

Paleoecological analysis of a 2.3 m sediment core from Big Run Bog, Tucker County, West Virginia (39° 07'N, 79° 35'W), provides an integrated and continuous record of vegetation change for the Allegheny Plateau of the central Appalachians for the past 17,000 yr from the full-glacial conditions of the Wisconsin through the Holocene. Big Run Bog (980 m elevation) is high-elevation wetland within the Allegheny Mountain section of the Appalachian Plateaus physiographic province.

From 17,040 yr B.P. to 13,860 yr B.P. the plant communities surrounding the site were a mosaic of alpine tundra dominated by sedges (Cyperaceae) and grasses (Gramineae) with total pollen accumulation rates averaging $1158 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$. By 13,860 yr B.P., late-glacial climatic warming as well as an increase in effective available moisture allowed the migration of spruce (Picea) and fir (Abies) onto the plateau, and favored the concurrent increase in colluvial activity within the watershed of Big Run Bog. From 13,860 yr B.P. to 11,760 yr B.P., continuing episodes of colluvial activity and the instability of the montane landscape may have inhibited initial colonization and the eventual closing of the boreal forest, despite favorable climatic conditions. The period from 11,760 yr B.P. to 10,825 yr B.P. was a period of landscape stabilization, a changeover from colluvial to fluvial processes, and a fundamental change in clay mineralogy.

The boreal forest in the uplands surrounding Big Run Bog was displaced by a mixed conifer-northern hardwood forest by 10,500 yr

B.P., with oak (Quercus), birch (Betula), and hemlock (Tsuga) comprising the upland dominants. Through the period from 8190 yr B.P. to 115 yr B.P., upland forests were dominated by of oak, birch, and chestnut (Castanea). Spruce persisted around the bog margin and in selected ravine and ridgetop habitats. Extensive logging between 1880 and 1920 AD is documented in the plant-fossil record by an increase in disturbance-related taxa such as ragweed (Ambrosia type) and grasses and the decline in local populations of spruce, chestnut, and hemlock.

TABLE OF CONTENTS

SECTION	PAGE
I. INTRODUCTION	1
II. ENVIRONMENTAL SETTING	6
Site Description	6
III. METHODS	14
Field Sampling and Techniques	14
Laboratory Techniques	15
Statistical Techniques	21
IV. RESULTS	23
Lithostratigraphy	23
Chronology	24
Clay Mineralogy	24
Pollen Accumulation Rates	28
Biostratigraphy	31
V. PALEOECOLOGICAL INTERPRETATION	58
VI. DISCUSSION AND CONCLUSIONS	65
LIST OF REFERENCES	75
APPENDICES	82
A. EXTRACTION TECHNIQUES	83
B. LOSS-ON-IGNITION DATA	86
C. PALYNOMORPH CONCENTRATIONS AND TOTAL POLLEN ACCUMULATION RATES PAR	90
D. PALYNOMORPH TABULATION	92
E. POLLEN ACCUMULATION RATES FOR SELECTED TAXA	105
F. PLANT MACROFOSSIL TABULATION	109
G. VEGETATION RECONSTRUCTION DATA	112
VITA	115

LIST OF FIGURES

FIGURE	PAGE
1. Location map for relevant late-Quaternary sites in eastern United States	2
2. Location map for Big Run Bog, West Virginia with topographic map of Big Run watershed, bog plant communities, and coring location	7
3. Block diagram of Big Run Bog	10
4. Radiocarbon age and accumulation rate	26
5. Loss-on-ignition and clay mineralogy	29
6. Percentage diagram for trees and shrubs	32
7. Percentage diagram for upland herbs, ferns, fern allies, and aquatic plants	34
8. Measurements of internal-cap diameters for Diploxylon <u>Pinus</u> pollen for selected stratigraphic levels	36
9. Measurements of grain diameters of <u>Betula</u> pollen grains for selected stratigraphic levels	38
10. Palynomorph accumulation rates diagram for selected taxa	40
11. Plant macrofossil diagram	42
12. Reconstructed forest composition based upon taxon calibration for major tree species	44
13. X-ray diffractograms for 118 cm and 140 cm depth	70

I. INTRODUCTION

The extent to which changes in geomorphic processes influenced vegetation development during times of major climatic changes, such as the transition from Pleistocene to Holocene, can be investigated using paleoecologic techniques, particularly in montane regions such as the Appalachian Mountains of eastern North America (Watts, 1979; Spear, 1981; Shafer, 1984; Delcourt and Delcourt, 1986). Geomorphological features of sorted, patterned ground, indicative of Pleistocene periglacial conditions, have been documented for the central Appalachians (Clark, 1968; Péwé, 1983). Full-glacial and late-glacial tundra has been reconstructed from radiocarbon-dated fossil pollen sequences at several sites (Fig. 1) located along the axis of the Appalachian Mountains (Maxwell and Davis, 1972; Watts, 1979; Spear, 1981). Full-glacial tundra existed at least as far south as Cranberry Glades, West Virginia (38° 12'N, 80° 17'W, elevation 1029 m)(Watts, 1979).

At Buckle's Bog (39° 34'N, 79° 16'W, elevation 814 m), western Maryland, pollen assemblages dominated by sedges and herbs and with low pollen accumulation rates (PAR values between 1000 and 2000 grains·cm⁻²·yr⁻¹) persisted from 19,000 yr B.P. until 12,700 yr B.P. (Maxwell and Davis, 1972). From these paleoecological data, it may be inferred that although climatic conditions in the late-glacial interval may have been favorable for establishment of trees, disturbance-related colluvial processes favored the persistence of open

Figure 1. Location map for relevant late-Quaternary sites in eastern United States. The dashed lines illustrates the maximum Wisconsin glacial margin. Captions are identified as follows; JP= Jackson Pond, KY (Wilkins, 1985), SA= Saltville Valley, VA (Delcourt and Delcourt, 1986), INT= Interior, VA (Watts, 1979), CrG= Cranberry Glades, WV (Watts, 1979), CC= Clark's Cave, VA (Guilday et al., 1977), BuB= Buckle's Bog, MD (Maxwell and Davis, 1972), L= Longswamp, PA (Watts, 1979), LC= Lake of the Clouds, NH (Spear, 1981).

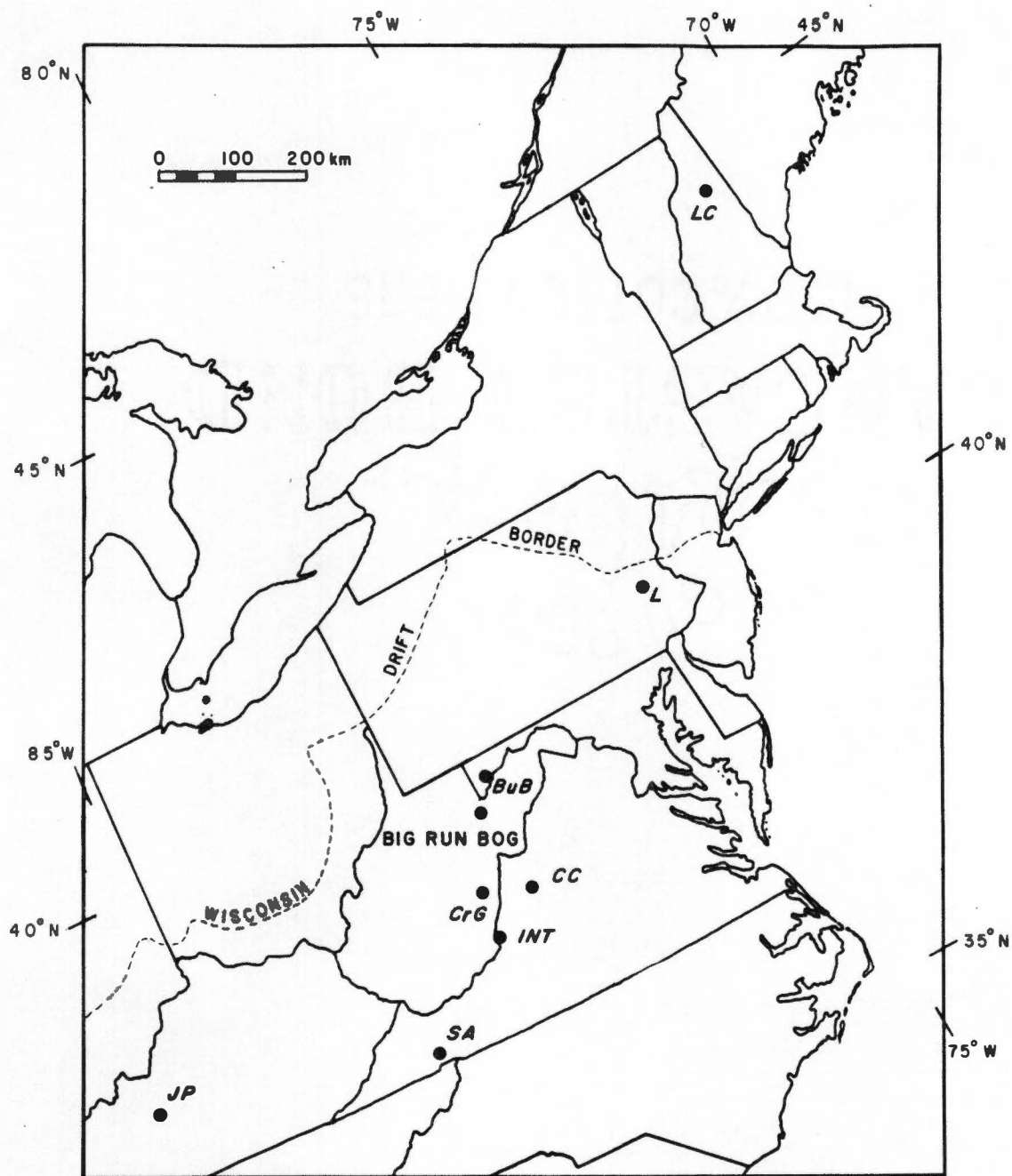


Figure 1.

herbaceous-dominated tundra or shrub-tundra vegetation. Organic lenses incorporated within block fields in Canaan Valley, West Virginia, and Interior, Virginia, however, contain pollen assemblages dominated by spruce (Picea), pine (Pinus), and fir (Abies), with low percentages of herbs (Watts, 1979). A plausible alternative hypothesis is that with climatic amelioration, mountain slopes and ridges may have remained unstable from intense colluvial process, even after the establishment of forest vegetation in the late-glacial interval.

Detailed reconstruction of the sequence of interrelated geomorphic and vegetational events through the full-glacial, late-glacial, and early-Holocene intervals requires analysis of a site containing a continuous accumulation of organic-rich sediments spanning the late Quaternary. This study examines the responses of vegetational and geomorphic processes in the Allegheny Mountains of the central Appalachians to late-Pleistocene and Holocene climatic change, based upon the paleoecologic record from Big Run Bog, a high elevation (980 m) wetland in Tucker County, West Virginia (Fig. 1). A 2.3 m core of sediment from Big Run Bog dates from the full-glacial interval at about 17,000 yr B.P. to the present. Fossil-pollen and plant-macrofossil assemblages provide complementary records of local changes in the wetland as well as the more regional mosaic of upland vegetation on the watershed. Analysis of changes in lithology, accumulation rates of both palynomorphs and inorganic mineral sediment, and clay mineral composition across the Pleistocene/Holocene transition provides a means of examining the degree of synchronicity between geomorphic and vegetational events at this site. Comparison of the timing of changes

in vegetation at Big Run Bog with the records from Buckle's Bog (Maxwell and Davis, 1972) and Cranberry Glades (Watts, 1979) should yield additional insight into the role of the Allegheny Mountains as a conduit for (Davis, 1976, 1981), or a barrier to (Watts, 1979), the migrations of arboreal species during the late-glacial and Holocene intervals (Fig. 1).

II. ENVIRONMENTAL SETTING

Site Description

Big Run Bog (39° 07'N, 79° 35'W, Mozark Mountain 7.5' U.S.G.S. Topographic Quadrangle, W. VA.) is located in Tucker County, West Virginia, along the Big Run headwaters of the Blackwater River at a mean elevation of 980 m above sea level. The wetland occupies 15 ha within a 291 ha forested watershed in the Monongahela National Forest (Fig. 2). Situated in a topographic depression along the crest of Backbone Mountain, the wetland occurs in a frost pocket, concentrating cold-air drainage (Hough, 1945).

The bog lies within the Allegheny Mountain section within the Appalachian Plateaus physiographic province (Fenneman, 1938). With local relief of approximately 500 m, the prominent steep-sided ridges and valleys of the Allegheny Mountain section trend NE-SW and are underlain by sedimentary rocks structurally deformed by broad anticlinal and synclinal folds. Ridge crests are typically above 900 m in elevation, and reach a maximum elevation of 1482 m at Spruce Knob, the highest point in West Virginia, approximately 47 kilometers south of Big Run Bog (Diehl and Behling, 1982). Thus, the Allegheny Mountain section represents a major orographic barrier between the Ohio River valley to the west and the adjacent Valley and Ridge physiographic province of the central Appalachian Highlands. The Allegheny Front, a thrust-fault escarpment approximately 26 kilometers east of Big Run

Figure 2. Location map for Big Run Bog, West Virginia with topographic map of Big Run watershed, bog plant communities, and coring location. The detailed map of the wetland (adapted from Wieder, 1985) delineates the areas occupied by the four major plant communities. The plant communities designations are; PC= Polytrichum-Carex canescens, PS= Polytrichum-shrub, SE= Sphagnum-Eriophorum virginicum, SS= Sphagnum shrub.

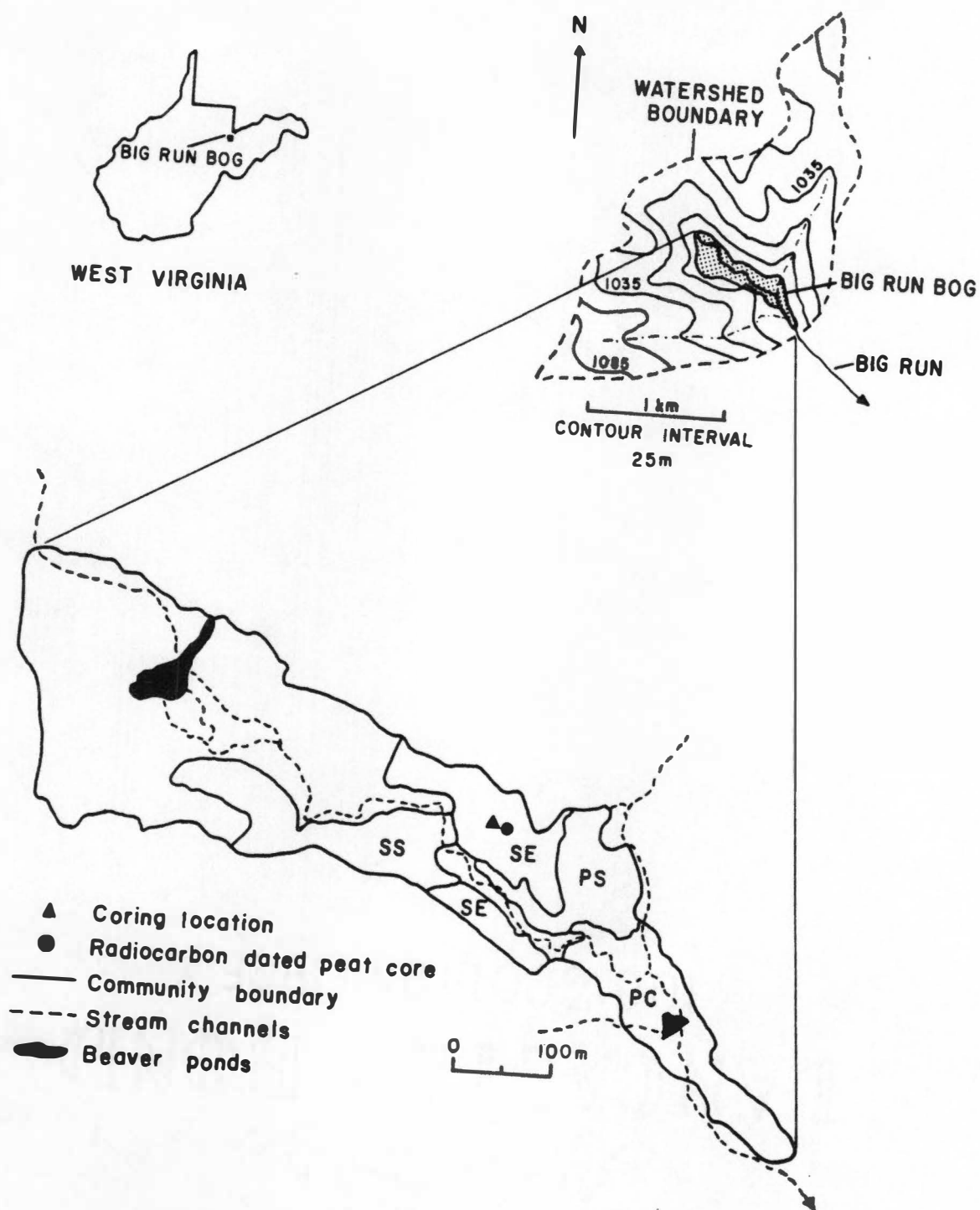


Figure 2.

Bog, represents the abrupt eastern boundary of the Allegheny Mountain section.

The Big Run watershed is underlain by the Upper Connoquenessing sandstone and the Homewood sandstone of the Pottsville Group and the Allegheny Formation (Pennsylvanian age) (Diehl and Behling, 1982) (Fig. 3). The Upper Connoquenessing is a massive, hard, white to grayish brown sandstone 37 to 46 m thick with interspersed dark sandy shales containing, in some places, either iron ore or thin coals often with fire clays. The Homewood sandstone is a massive yellowish white conglomeratic sandstone 23 to 47 m in thickness.

These gently southeasterly dipping units represent the resistant strata that cap the highland. Less than a kilometer downstream from Big Run Bog, the stream gradient of Big Run increases abruptly where it flows over the fluvial knickpoint created by the resistant ledge of the Upper Connoquenessing sandstone. The resistance of the highland strata to headward erosion by the stream has provided the stable, nearly flat-lying crest of Backbone Mountain suitable for the perching of water and the formation of the wetland (Diehl and Behling, 1982).

The moss-covered surface of the bog slopes gently (1-2%) from upstream to downstream as well as from the sides towards the stream, thus Big Run Bog receives inputs of water from the surrounding upland areas of the watershed. Thus physiographically, Big Run Bog is a minerotrophic fen, despite being chemically more similar to an ombrotrophic bog (Wieder, 1985). Upland soils formed on the nearby upper slopes and ridges include Typic Dystrochrepts and Entic Normorthods (moist soils with a cambic horizon and less than 30% base

Figure 3. Block Diagram of Big Run Bog
(Taken from Diehl et al., 1982)

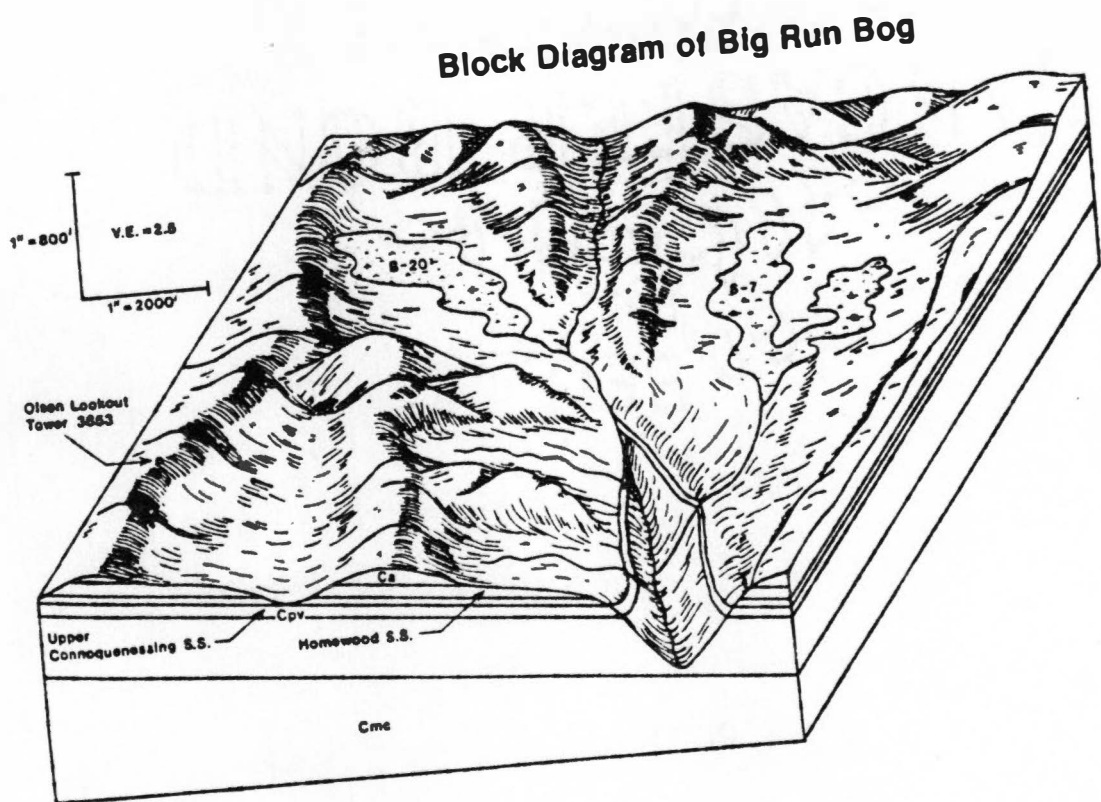


Figure 3.

metal saturation with the parent material sandy, loamy, and rich in quartz) and the lower slopes are Aquic Fragiudults or Typic Fragiaqualfs (young, moist soils with an argillic horizon, strongly weathered, and with base metal saturations of 35%) (Losche and Beverage, 1967).

Vegetation of the bog surface is primarily composed of an extensive mat (85%) of Sphagnum and Polytrichum mosses. A total of 9 bryophyte and 58 vascular plant species has been reported for Big Run Bog (Wieder et al., 1981). Vascular plant species include many aquatic sedges and rushes, with a peripheral zone of upland trees and shrubs generally restricted in their distribution to the wetland margins (Wieder et al., 1981). Following the treatment of major plant communities described and mapped by Wieder et al. (1981), the sediment cores (designated by the triangle symbol in Fig. 2) were extracted from within the Sphagnum-Eriophorum virginicum community.

Upland vegetation is primarily a mixed hardwood forest, resulting from extensive lumbering around 1880-1920 AD. On the upland slopes of the Big Run watershed, early- to mid-successional forests are composed of tree birch (Betula allegheniensis and B. lenta), beech (Fagus grandifolia), oak (Quercus spp.), striped maple (Acer pennsylvanicum), and black cherry (Prunus serotina). Along the margin of the bog, forest stands include species of red spruce (Picea rubens), eastern hemlock (Tsuga canadensis), tree birch, and evergreen shrubs of rhododendron (Rhododendron). Pre-settlement vegetation was primarily red spruce-hemlock-pine forest at higher elevations (generally above 800 m), such as near Big Run Bog, and Appalachian oak-chestnut and mixed

mesophytic beech-maple-birch forests at mid-elevations (Braun, 1950; Clarkson, 1964).

Climatological data for the study area was obtained from the closest climatological station at a comparable altitude, Canaan Valley, West Virginia, located 15 km southeast of Big Run Bog at an elevation of 991 m above sea level. Mean annual precipitation is 133 cm, distributed evenly throughout the year. Mean annual temperature is 7.9° C, with an average frost-free period of 97 days. The typical mean winter temperature is -3.1° C in January and the mean summer temperature of 18.3° C occurs in July (NOAA 1946-1950, 1952-1981).

III. METHODS

Field Sampling and Techniques

Big Run Bog was cored from a triangular wooden platform on 20 April 1985. A Hiller peat corer was used to collect the uppermost peat. A 5-cm diameter, 1 meter long, square-rod piston corer (Wright, 1967) was used to obtain the lower portion of the sedimentary sequence containing more mineral-rich clay and silt. Previous studies conducted by Dr. Gerald Lang at West Virginia University provided crucial information for locating the coring site within the bog. Systematic transects had been made measuring peat deposits throughout the wetland, identifying the locations of greatest peat thickness. Three radiocarbon dates were obtained by Dr. Lang and Dr. James Behling from the site of greatest peat thickness (indicated by circle symbol on Fig. 2); these range from 13,084 $\pm$ 420 yr B.P. (165 to 170 cm depth) to 6680 $\pm$ 750 yr B.P. (80 to 84 cm depth), indicating that the deposits of the bog spanned back to at least the late-glacial interval. Three new cores were obtained within a one meter radius from a site within 10 m of the location sampled and radiocarbon dated by Lang and Behling (Fig. 2). Cores BRB 85A, BRB 85B, and BRB 85C represent the sedimentary sequence from the bog surface down to a depth of 229 centimeters where the coring terminated on a rock substrate. The cores were extruded at the field site, described according to texture and color (Munsell Color, 1975), wrapped in plastic wrap and aluminum foil, labeled, and

transported to the University of Tennessee, Knoxville for subsequent storage at 4° C and analysis.

Laboratory Techniques

Loss-on-Ignition Analysis

Thirty sediment samples were taken using a calibrated 1 cm³ brass sampler (Delcourt, 1979) for loss-on-ignition (LOI) analysis (Dean, 1974). Samples were obtained at approximately 5 cm intervals from the sediment depth interval between 82 cm and 227 cm. Residual water content was determined by weighing each LOI sample before and after drying it at 100° C for 24 hours. The amount of organic matter was calculated from the subsequent loss in bulk sediment weight after combustion at 550° C for 1 hour. Organic-carbon content was determined by multiplying the value for organic matter by a correction factor of 0.47 (Dean, 1974). The amount of carbonate matter present (and/or water-of-hydration in the crystal lattice of the clay minerals) was determined from the loss in grams of the sample after combustion at 1000° C for one hour.

Radiocarbon Dates

Eight determinations for radiocarbon age were analyzed from sediment samples at the Laboratory of Isotope Geochemistry, University of Arizona, Tuscon, Arizona. Radiocarbon samples were selected in order to date major lithologic changes, the base of the core, and the first evidence of Euro-American anthropogenic influence within the watershed. LOI data were used to calculate the volume of each sediment-core

segment necessary to generally provide a minimum of five grams of organic carbon for dating. These radiocarbon dates were corrected for isotope fractionation with a $\delta^{13}\text{C}$ measurements. Based upon successive pairs of radiocarbon dates, sediment accumulation rates for Big Run Bog were calculated for the depth intervals between the midpoint depths of the corresponding core segments.

Pollen Analysis

Based upon the chronology established by the radiocarbon dates, 37 1-cm³ sediment samples were collected for pollen analysis at depths representing approximately 500-year intervals. The palynologic samples were prepared utilizing standard extraction techniques (Faegri and Iversen, 1975)(See Appendix A for a detailed description of specific extraction techniques utilized for Big Run Bog). Eucalyptus-pollen tablets were added to each sediment sample as a standard to permit the determination of absolute concentration and accumulation rates of native pollen grains (Maher, 1977; Birks and Birks, 1980). Each tablet (Stockmarr batch 903722) contained an average of 16,180 +/- 1460 Eucalyptus pollen grains (Maher, 1977).

Pollen grains were identified and tabulated using a Leitz Laborlux 12 microscope with 10 X eyepieces and a 40 X NPL objective (numerical aperture 0.70). A 100 X NPL oil-immersion objective (numerical objective 1.32) was used for identification of unknown grains. Running tallies were kept on a denominator tally counter. All slides were prepared by placing a small drop of silicone oil (2000 centistokes viscosity) on the slide and mixing a small amount of the concentrated

palynomorph residue and covering with a 22 mm X 22 mm coverslip (No. 1 thickness). Fingernail polish was used to tack down the edges of the coverslip to keep it from moving while palynomorph grains were rolled for better view in their identification. Microscope slides were prepared from each residue and the palynomorphs were counted using evenly spaced, non-overlapping transects which covered at least half of the coverslip for each slide (Faegri and Iversen, 1975). This eliminates bias towards an "edge effect" caused by the tendency for grains of different sizes to be unevenly distributed laterally under the coverslip. Counting continued until a minimum of 300 arboreal pollen grains was tallied for each stratigraphic level.

Palynomorph identification was based on two sources: reference slides of modern pollen grains and spores curated in the Program for Quaternary Studies of the Southeastern United States, Departments of Geological Sciences and Botany, the University of Tennessee, Knoxville; and standard keys, texts, and published papers concerning specific palynomorph taxa (Berglund and Praglowski, 1961; Helmich, 1963; Erdtman, 1966; Kapp, 1969; McAndrews et al., 1973; Faegri and Iversen, 1975; Amman, 1977; Bassett et al., 1978; Lieux, 1980a, 1980b; Lieux and Godfrey, 1982). All Pinus, Abies, and Picea grains were tabulated as halves when at least an identifiable portion of the cap was attached to a single bladder. Pollen tetrads of Ericaceae and Typha were counted as single dispersal units. Grains of Picea rubens were distinguished from Picea mariana/glauca type based upon morphological characteristics described by Birks and Peglar (1980). All three parameters of distal sculpturing, variation in cap-exine thickness, and bladder reticulum

had to be clearly observed on a Picea grain before its assignment to one species group or the other. Measurements of the internal diameter of pine-pollen caps and morphological differences in the marginal frill were used to differentiate between groups of northern and southern species of Diploxylon Pinus (Whitehead, 1964; Amman, 1977). Pinus grains were counted from each of several stratigraphic levels at approximately 1000-year intervals when Pinus was greater or equal to 12% of the Arboreal Pollen (AP) Sum (using the pine-pollen threshold for tree presence in Delcourt et al., 1984). Size measurements were also made on Betula grains in an effort to distinguish between dwarf shrub birches (primarily Betula glandulosa, B. pumila, or B. nana, Fernald, 1950) and tree birches (represented in eastern North America by B. lenta, B. populifera, B. papyrifera, and B. allegheniensis). Although considerable overlap exists in the diameter of pollen grains between the two groups (Ives, 1977), pollen grains of dwarf birches are predominantly less than 20 μ m in diameter, and the grains of tree birches generally exceed this size limit.

Percentages of arboreal (tree) pollen were tabulated based on the Arboreal Pollen (AP) Sum. Percentages for non-arboreal pollen (NAP), comprised of shrubs, lianas, upland herbs, ferns, horsetails, clubmosses, and unknown types were calculated based on the Total Upland Pollen and Spore Sum (AP and NAP). The palynomorph percentages for aquatic taxa were based on the Total Upland Pollen, Spore, and Aquatic sum. Indeterminable grain percentages were based on the Total Native Palynomorph Sum.

Plant Macrofossil Analysis

Eleven samples of plant macrofossils were analyzed at approximately 1000-yr intervals, with the samples centered on stratigraphic levels associated with pollen spectra. All macrofossil samples consisted of 60 cm³ of core (3 cm vertical section of whole core or 6 cm for split-core segments) which were sieved through USA Standard sieves with meshes of 212 μ m, 150 μ m, and 90 μ m. All seeds and fruits, conifer needles, bryophytes, other recognizable plant debris, and insect fragments were picked out and preserved in a solution consisting of 35% water, 50% glycerin, and 15% formaldehyde. Macrofossil identification was based on two sources: the Plant-Macrofossil Reference Collection curated at the Program for Quaternary Studies of the Southeastern United States; and standard keys, texts, and published papers concerned with specific taxa (literature cited in Delcourt et al., 1979). Particularly useful references included Martin and Barkley (1961), Berggren (1969), Schopmeyer (1974), Montgomery (1977), and unpublished keys developed by P.A. Delcourt and H.R. Delcourt.

Clay Mineral Analysis

Clay minerals were examined from eight stratigraphic levels, providing resolution across the three distinct lithologic boundaries. The clay minerals were obtained from the less than 90 μ m fraction while samples were wet sieved with distilled water for plant-macrofossil extraction.

The clay samples were placed in 1000 ml beakers and allowed to settle for 48 hours. Excess water was then pipetted off and the samples were placed in 500 ml beakers. The resulting sediment was treated for the removal of organic matter with the addition of 150 ml of 30% H_2O_2 and allowed to react for 24 hours until the reaction was complete. The samples were then centrifuged at 5000 RPM for 6-9 minutes, the supernatant decanted, rinsed several times in excess distilled water, and centrifuged after each rinse to remove any excess peroxide. The samples were placed in 1000 ml beakers and distilled water was added as needed to obtain a sufficient settling height of 10 cm, in accordance with clay particle behavior under Stoke's Law for size fractionation (Krumbein and Sloss, 1963). The samples were agitated and after 30 minutes, the top 5 cm of liquid were pipetted off to retain the $< 5 \mu\text{m}$ fraction of sedimentary particles. Distilled water was added again to the pipetted 5 cm, the slurry allowed to settle for 3 hours, and the top 5 cm pipetted off to fractionate the $< 2 \mu\text{m}$ fraction. The samples were concentrated by centrifugation and the supernatant decanted. Elutriated slides were made with the addition of 10 ml of distilled water to each sample, sedimented to frosted glass slides, and then subjected to X-ray diffraction analysis on a Norelco X-ray diffractometer. Each sample was X-rayed untreated, after glycolation for 24 hours at 70°C , and after heating to 550°C . Clay minerals present were identified utilizing Carroll (1970).

Statistical Techniques

Pollen accumulation rates were calculated using the following equation, $I = (n/a) * b * c * d$, where I equals palynomorph accumulation rate (PAR; grains·cm⁻²·yr⁻¹), n equals the total number of native palynomorph grains tallied from a stratigraphic level, a equals the number of Eucalyptus grains tallied at the level, b equals the concentration of Eucalyptus grains per tablet based on a mean of 16,180 grains/tablet (Maher, 1977), c equals the number of tablets added to the 1 cm³ of sediment, and d equals the net sediment accumulation rate in cm/yr.

The CONSLINK (constrained single-link cluster analysis) program of Birks (1979) was used to zone the pollen sequence from Big Run Bog. CONSLINK calculates the dissimilarity coefficient between stratigraphically adjacent pairs of pollen samples. CONSLINK is based on the Manhattan metric dissimilarity coefficient, stated as $d(j,k) = \sum_i |P_{ij} - P_{ik}|$, which is the summation of the absolute differences over all taxa; where "d" is the unweighted dissimilarity between two adjacent levels j and k, P_{ij} is the pollen percentage of taxon i in pollen spectrum j, and P_{ik} is the pollen percentage of taxon i in pollen spectrum k (Prentice, 1982).

Delcourt et al. (1984) developed taxon calibrations for nineteen major tree taxa utilizing approximately 1700 pairs of Continuous Forest Inventories and modern pollen samples distributed throughout eastern North America. Calibrations were developed using geometric-mean linear regressions for paired samples of percent AP in modern pollen spectra

versus growing-stock volume percent in forests. The resulting calibrations represent quantitative adjustment values for underrepresentation or overrepresentation of taxa as a function of pollen dispersability and productivity. These calibrations were utilized for recalculating pollen percentages of 17 fossil arboreal taxa found at Big Run Bog into quantitative estimates of past forest composition (Delcourt and Delcourt, 1985).

IV. RESULTS

Lithostratigraphy

The lithology shows an overall trend towards decreasing organic content and increasing mean particle size of mineral grains with depth. The detailed lithologic description of Big Run Bog is shown in Table 1.

Table 1. Lithology of Big Run Bog, WV

Depth in cm below bog surface	Sediment Description
0 - 24	Water saturated fibrous peat (10YR 2/2)
24 - 80	Fibrous clayey peat (10YR 2/2)
80 - 112	Slightly silty organic clay (10YR 2/1)
112 - 193	Fibrous organic clay (10YR 2/2)
193 - 200	Slightly silty organic clay (10YR 2/1)
200 - 229	Slightly silty clay (10YR 3/1) grading to clayey silt (10YR 3/1) at the base
229	Rock substrate

The results of loss-on-ignition analysis are recorded in Appendix B. Residual water content averaged 23.36% from 82 to 197 cm depth, and then increased to an average of 54.47% from 197 to 227 cm depth. Organic content of the oven-dried sediment averaged 17.43%, with maximum and minimum values of 25.21% and 13.44%, respectively. The

apparent value of "carbonate minerals" Calculated for the oven-dried sediment averaged 0.78% with a maximum value of 1.91%, within the range of loss attributable to the water-of-hydration in clayey sediment established by Dean (1974).

Chronology

Seven of eight radiocarbon dates (analyzed for this study and listed in Table 2) have been used to determine the chronology and rates for net sediment accumulation for Big Run Bog. The radiocarbon date obtained on the sample from 82 to 88 cm depth (A-4265) is considered anomalous; that sample was taken from the top of a sediment-core segment and was probably contaminated by younger material falling into the coring hole from the sidewall. Although not used in the calculation of accumulation rates, additional dates (collected within 10 m distance of this study by Lang and Behling) are consistent with the chronologic series of dates and are included in Table 2 and Fig. 4.

The rate of net sediment accumulation was highest (0.158 cm/yr) between 210 yr B.P. and 1985 A.D. and, in general, illustrates a linear decrease with time (Fig. 4). The base of the active Sphagnum vegetation was at 19 cm depth (Lang, personal communication). The lowest rate of sediment accumulation (0.006 cm/yr) occurs during the late-glacial, between 16,380 yr B.P. to 13,990 yr B.P. (Table 2).

Clay Mineralogy

X-ray diffraction analysis was completed on bulk samples and on size fractionations of less than 2 μm and 2-5 μm for eight stratigraphic levels. Other than increased intensities for quartz peaks

Table 2. Radiocarbon Chronology and Sediment Accumulation Rates for Big Run Bog, W.VA.

Radiocarbon Age (yr B.P. $\pm$ 1SD)	Sample Depth (cm below sed. surface)	Midpoint Depth (cm)	Time elapsed between dates (yr)	Sediment Interval (cm)	Accumulation Rate (cm/yr)	Accumulation Time (yr/cm)
1985 A.D.	0.0	0.0				
			245	38.8	0.158	6.3
210 $\pm$ 200 (A-4261)	37.5-40.0	38.8	4470	30.0	0.007	149.0
4680 $\pm$ 110 (A-4260)	67.5-70.0	68.8	6080	43.8	0.007	139.0
10,760 $\pm$ 160 (A-4264)	109.0-116.0	112.5	1840	41.5	0.023	44.3
12,600 $\pm$ 170 (A-4263)	151.0-157.0	154.0	1390	43.0	0.031	32.3
13,990 $\pm$ 220 (A-4259)	194.0-200.0	197.0	2390	14.5	0.006	164.8
16,380 $\pm$ 290 (A-4262)	208.0-215.0	211.5	530	14.0	0.026	37.9
16,910 $\pm$ 340 (A-4258)	222.0-229.0	225.5				
1770 $\pm$ 70 (A-4265)	82.0-88.0	85.0	(Rejected date)			
6680 $\pm$ 750	80.0-84.0	82.0	(Previous dates from peat core from Big Run Bog, see discussion in text)			
9160 $\pm$ 290	95.0-105.0	100.0				
13,084 $\pm$ 420	165.0-170.0	167.5				

Figure 4. Radiocarbon age and accumulation rate. Dates designated with triangles are from previous radiocarbon dated peat samples within 10 m of the coring site and are not included in the accumulation rate calculations. One anomalous date is not plotted: 1770 $\pm$ 70 from 82.0 to 88.0 cm depth.

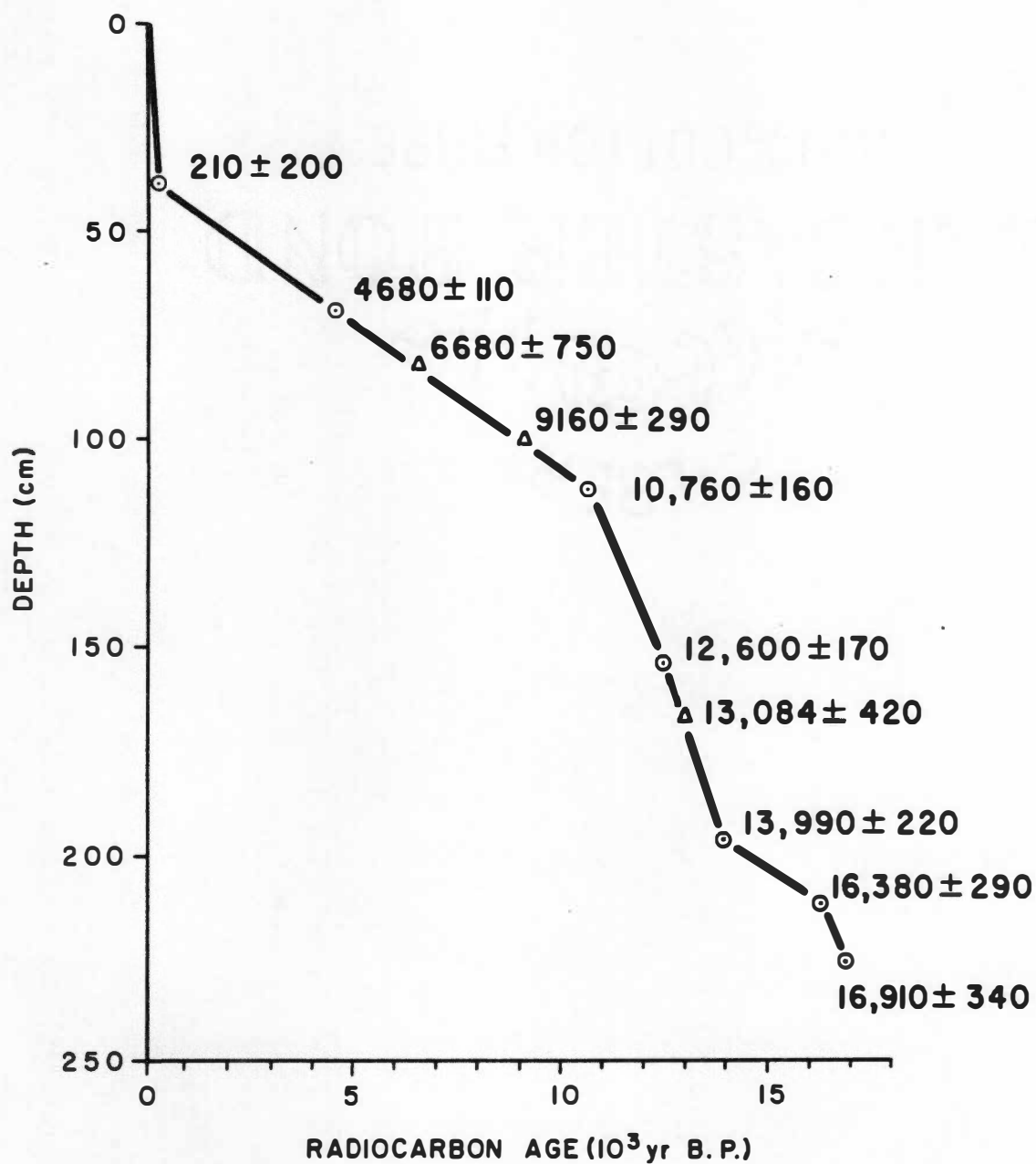


Figure 4.

in the larger size fractions, no apparent dissimilarities or changes occur between the $<2\ \mu\text{m}$ and $2\text{--}5\ \mu\text{m}$ fractions for each stratigraphic level.

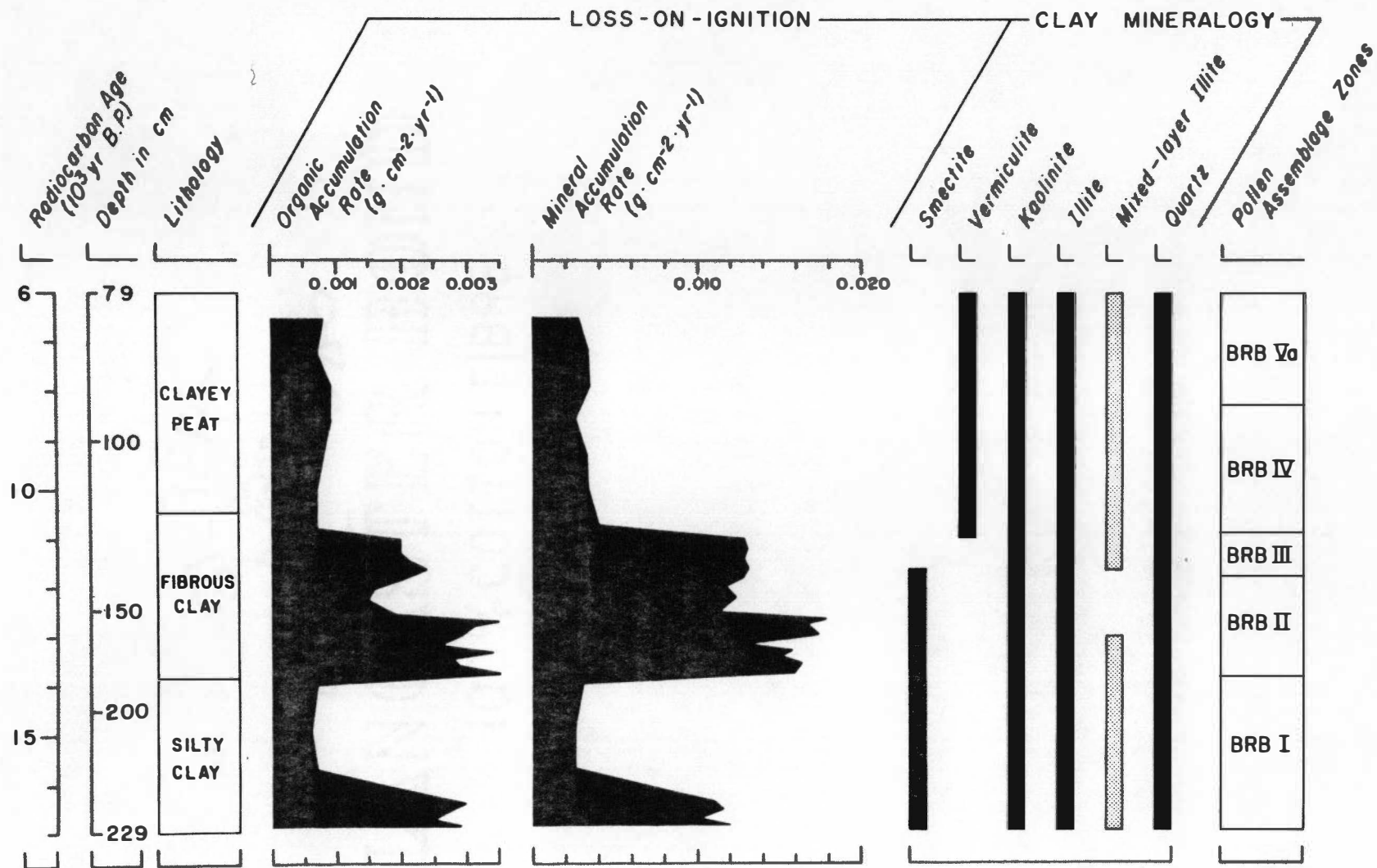
Quartz, illite, and kaolinite were ubiquitous in all eight samples (Fig. 5). A major transition in the clay mineral assemblage occurs between 119 cm and 139 cm, or between approximately 11,000 and 12,000 yr B.P., where vermiculite occurs, apparently at the expense of smectites found lower in the section. Mixed-layer illite was poorly developed at some stratigraphic levels; its presence or absence followed no discernible pattern.

Pollen Accumulation Rates

Pollen accumulation rate (PAR) was the greatest at 150 yr B.P. where total accumulation reached $33,032\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$. Pollen accumulation rates were lowest at 16,000 yr B.P., where accumulation reached a minimum of $310\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$. From the base of the core at 17,040 yr B.P. to 16,000 yr B.P., accumulation values decreased from $2992\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ to the minimum of $310\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$, then increased to $643\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ by 14,000 yr B.P., yielding an average of $1158\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ for the full-glacial. At 13,860 yr B.P., pollen accumulation rates increased markedly to $4517\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ and maintained an average of $3670\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ until 11,760 yr B.P. From 11,760 yr B.P. to 10,500 yr B.P. pollen accumulation rates averaged $4491\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$. From 10,500 to 8500 yr B.P., accumulation values remained consistently high, averaging $6702\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ with a maximum of $11,988\ \text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ at 9500 yr B.P. The period from 8500 to 150 yr

Figure 5. Loss-on-ignition and clay mineralogy. Stippling indicates trace presence for mixed-layer illite.

Figure 5.



B.P. was marked by lower pollen accumulation values averaging 5988 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ for the mid- and late-Holocene intervals.

Examination of mineral accumulation rates (Fig. 5) with palynomorph accumulation rates reveals two aspects. First, the initial rise in palynomorph accumulation at 13,750 yr B.P. is accompanied by an increase in mineral accumulation from an average of $0.0076 \text{ gm}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ (from 15,000 yr B.P. to 14,000 yr B.P) to an average of $0.0160 \text{ gm}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ (from 13,800 yr B.P. to 12,800 yr B.P.). The second aspect is that of the increase in palynomorph accumulation at approximately 11,000 yr B.P. coincides with the concurrent decrease in mineral sediment accumulation (Fig. 5).

Biostratigraphy

Six informal biostratigraphic zones have been delineated based upon changes in the upland pollen spectra. CONSLINK was utilized in distinguishing the zones and subzones based on palynomorphs reaching percentages of 5% or more at any stratigraphic level. The boundaries between biostratigraphic zones were based on a dissimilarity coefficient of 0.70 or greater. The zones are numbered in stratigraphic order from bottom to top, from BRB I to BRB VI. BRB V was divided into two subzones, BRB Va and BRB Vb. Diagrams for pollen percentages, measurements for grain diameters for Pinus and Betula grains, pollen accumulation rates, plant macrofossils, and reconstructed forest composition are illustrated in Figures 6-12.

The intervals of zones BRB I, BRB II, BRB III, BRB IV, BRB Va, BRB Vb, and BRB VI are equivalent to, in order, full-glacial, late-glacial,

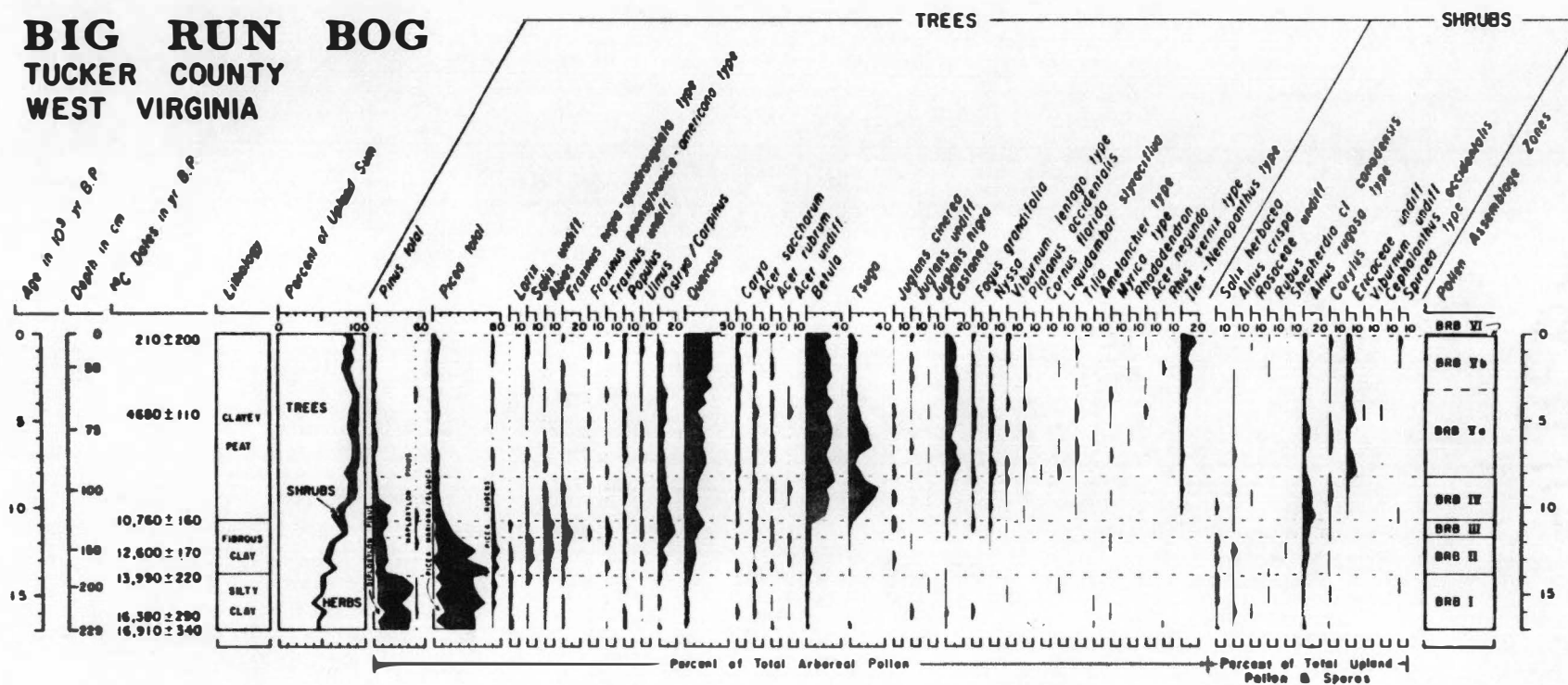
Figure 6. Percentage diagram for trees and shrubs.

BIG RUN BOG

TUCKER COUNTY

WEST VIRGINIA

Figure 6.



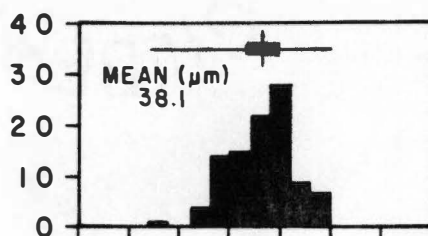
Analyst P.A. Lorahee, 1985-1986

Figure 7. Percentage diagram for upland herbs, ferns, fern allies, and aquatic plants.

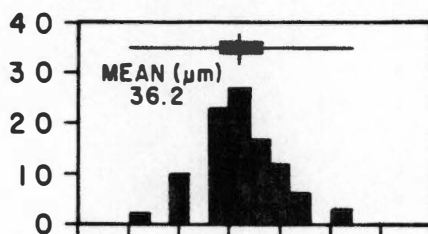


Figure 8. Measurements of internal-cap diameters for Diploxylon
Pinus pollen for selected stratigraphic levels.

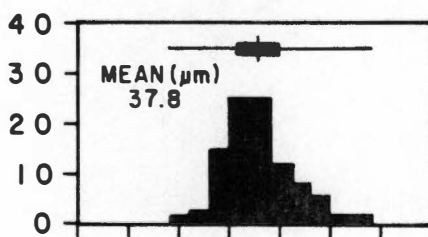
10,000 yr B.P.
(107 cm)



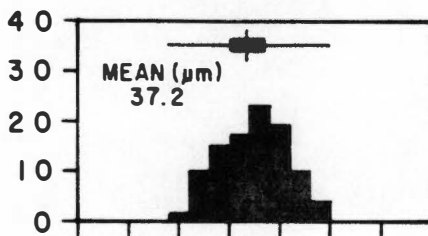
11,000 yr B.P.
(118 cm)



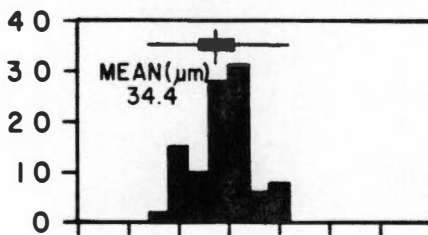
12,000 yr B.P.
(141 cm)



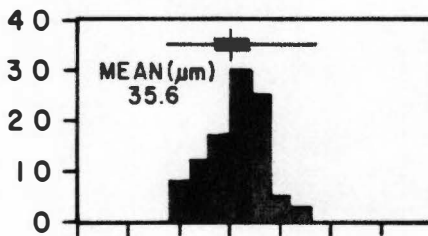
13,500 yr B.P.
(182 cm)



15,000 yr B.P.
(203 cm)



17,000 yr B.P.
(228 cm)



INTERNAL
CAP DIAMETER
(μm)

Figure 8.

Figure 9. Measurements of grain diameters of Betula pollen grains for selected stratigraphic levels.

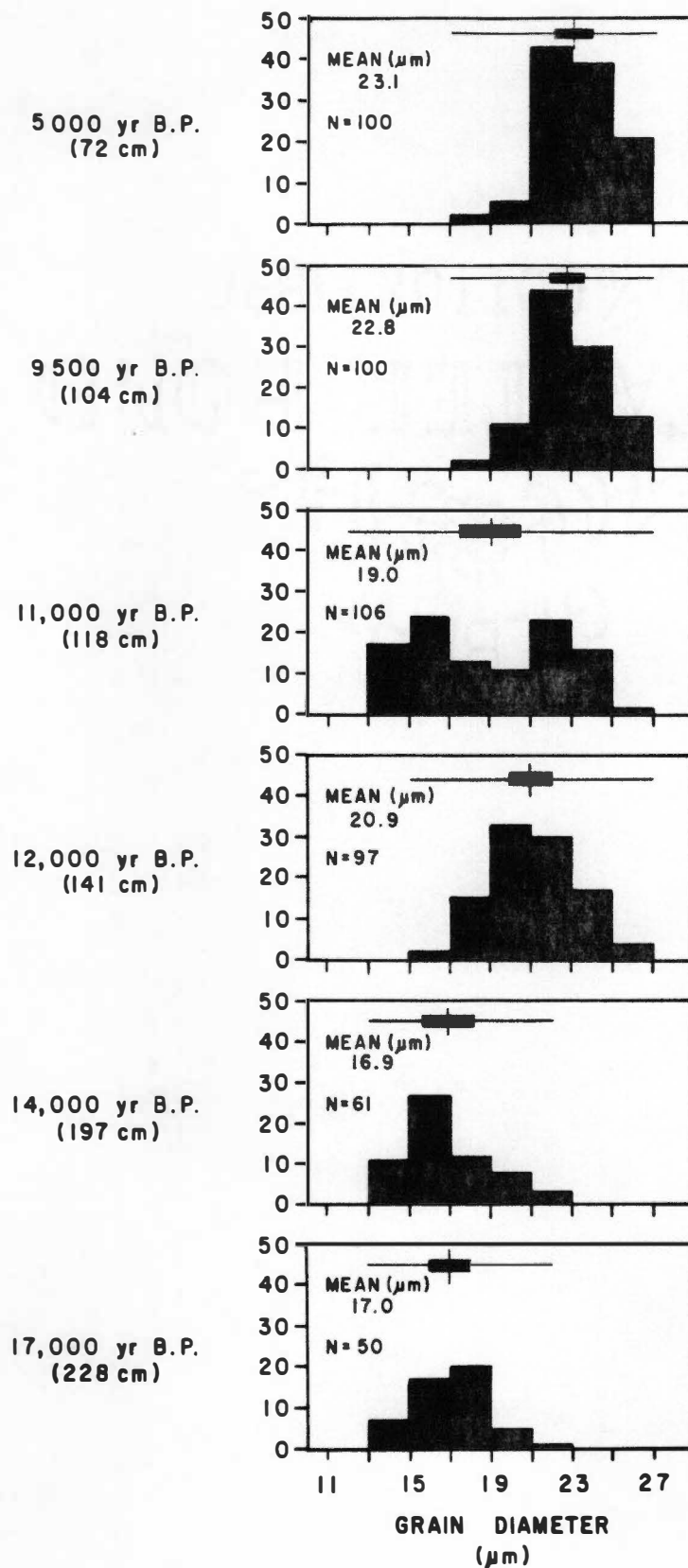


Figure 9.

Figure 10. Palynomorph accumulation rates diagram for selected taxa.

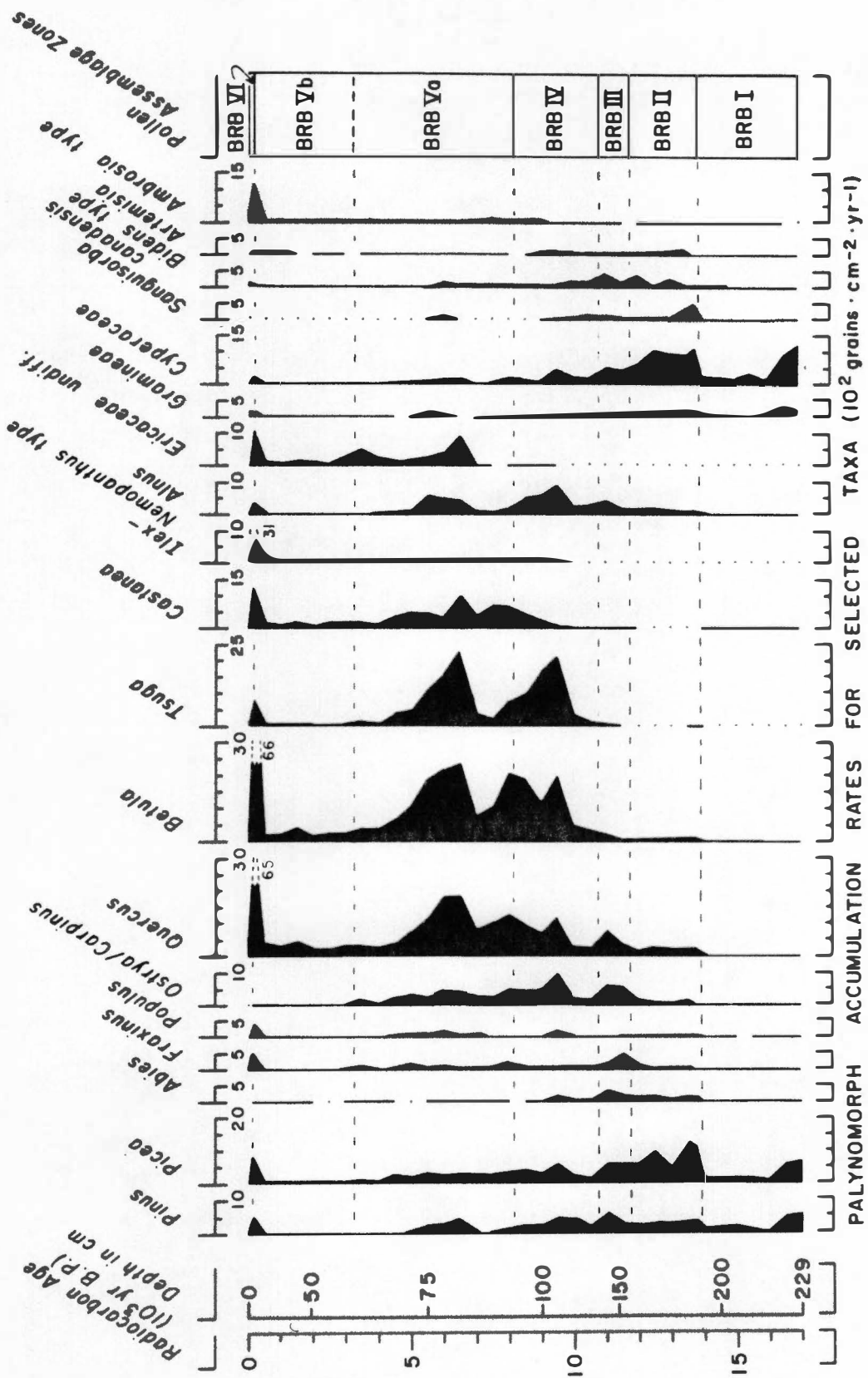
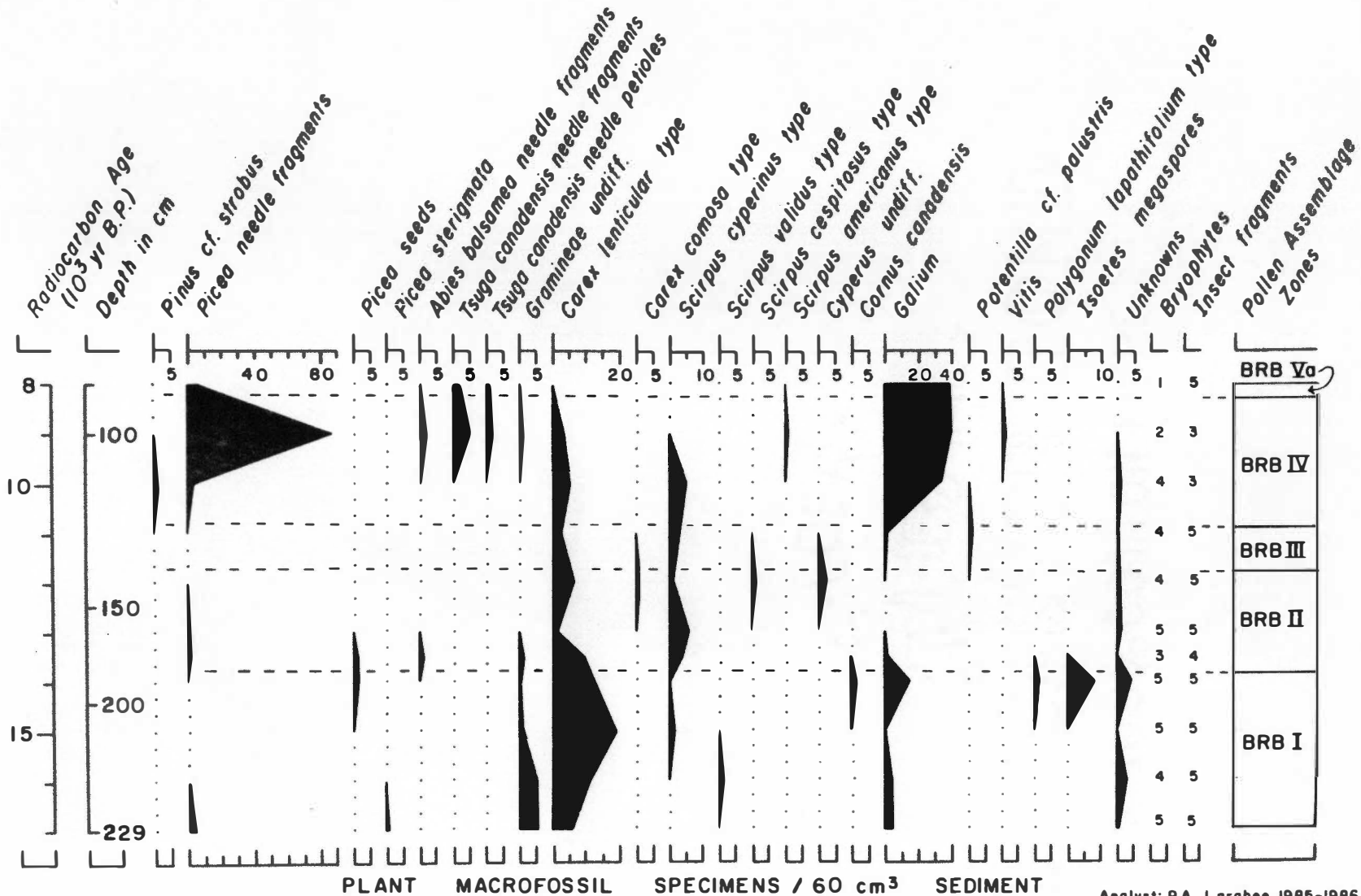


Figure 10.

Figure 11. Plant macrofossil diagram. Bryophyte and insect fragment abundance is based on 1-5 scale, 5 being most abundant.

Figure 11.



Analyst: P.A. Larabee, 1985-1986

Figure 12. Reconstructed forest composition based upon taxon calibration for major tree species.

VEGETATION RECONSTRUCTION OF FOREST COMPOSITION

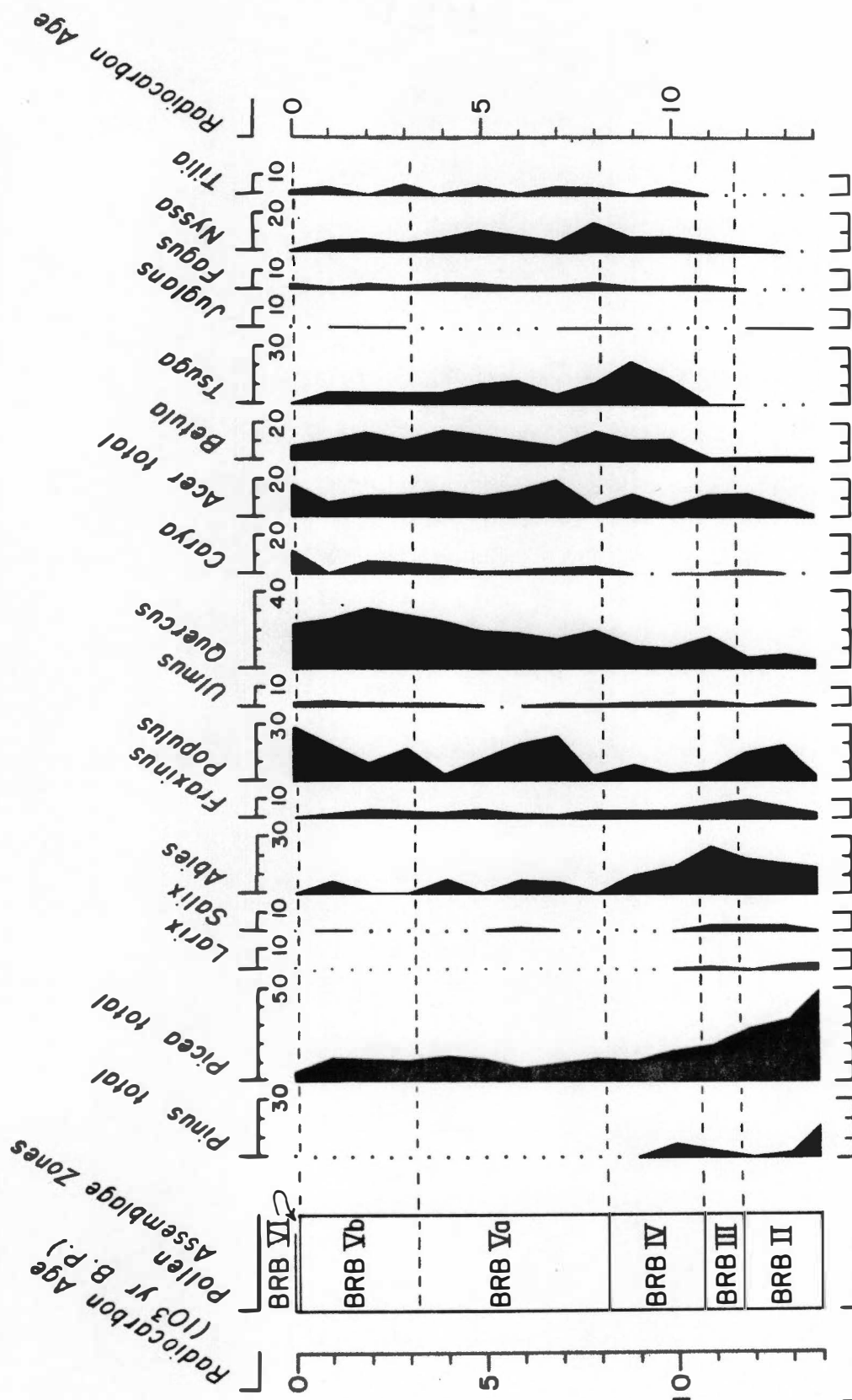


Figure 12.

glacial/postglacial transition, early- postglacial, mid-Holocene, and late-Holocene intervals.

BRB I: Picea-Cyperaceae zone (229 to 193 cm depth, 17,040 to 13,860 yr B.P.). BRB I is characterized by low arboreal pollen (AP) percentages, averaging only 48%, and thus, high NAP percentages typically dominate the total Upland Sum. Arboreal species were dominated by Picea and Pinus. Picea averaged 49% of the AP sum in this zone, reaching a maximum of 60% at 15,500 yr B.P., while Pinus averaged 40%, ranging from 30% to 47%. Picea mariana/glauca type maintained higher percentages than Picea rubens for the entire zone. Both Diploxylon and Haploxylon pine pollen grains were present, with internal cap diameter measurements for Diploxylon Pinus grains provided means of 35.6 μm and 34.4 μm from 17,000 and 15,000 yr B.P. respectively, indicating that either of the northern Diploxylon pines, red pine (Pinus resinosa) or jack pine (Pinus banksiana) was present (Whitehead, 1964) (Fig. 8). Minor arboreal taxa included Abies and Larix, both averaging less than 2% of the arboreal sum. Mean values for Betula grain diameters were 17.0 μm at 17,000 yr B.P. and 16.9 μm at 14,000 yr B.P., providing fossil evidence for past populations of dwarf or shrub Betula (Ives, 1977) (Fig. 9). The dominant shrubs were dwarf willow (Salix herbacea, 0 to 2%) and green alder (Alnus crispa, 0 to 1%) and A. rugosa type (0 to 1%).

Non-arboreal pollen was dominated by Cyperaceae and Gramineae. Cyperaceae maintained consistently high percentages, reaching a maximum of 45% at 15,500 yr B.P. and averaging 37% for the zone. Gramineae

percentages reached a maximum at 15,000 yr B.P. of 12% and averaged 8%. Minor NAP taxa that were present in values less than 2% include Stellaria, Silene, Polemonium, Polygonum viviparum-bistorta type, Sanguisorba canadensis, and Artemisia.

In this zone, total pollen accumulation rate averaged only 1158 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$, reaching a minimum of 310 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ at 16,000 yr B.P. Pollen accumulation rates include Picea (74 to 649 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Pinus (63 to 516 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Cyperaceae (101 to 1231 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$) and Gramineae (24 to 283 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$) (Fig. 10). Most of the individual accumulation rates decreased from 17,040 yr B.P. to 16,000 yr B.P.

Macrofossils recovered included two needle tips and a sterigma of Picea at 17,000 yr B.P., and one Picea seed at the top of the zone (14,000 yr B.P.). Lenticular Carex achenes and Galium which increased in abundance toward the top of the zone, while Gramineae undifferentiated decreased over the same interval. Also found were Scirpus cyperinus and validus types, Polygonum lapathifolium type, Isoetes megaspores at the top of the zone, and abundant bryophytes and insect fragments throughout (Fig. 11).

Reconstructions for past forest composition are not used in this zone as the average PAR for the zone did not exceed 2000 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$, criterion for the tundra/forest threshold used by Delcourt and Delcourt (1987).

BRB II: Picea-Sanguisorba zone (193 to 135 cm depth, 13,860 yr B.P. to 11,760 yr B.P.). Arboreal dominants were Picea and Pinus. Picea values decreased from 65.5% (13,750 yr B.P.) to 34.3% (12,000 yr B.P.),

with an average of 49%. Percentages of identified grains of Picea mariana/glauca and Picea rubens were generally equal. Total Pinus values decreased from BRB I to an average of 13%, with a maximum of 15.1% at 13,000 yr B.P. Diploxylon Pinus persisted through the zone at 3% and Haploxylon Pinus increased to 2% by 12,000 yr B.P. Diploxylon Pinus caps measured at the stratigraphic levels corresponding to 13,500 and 12,000 yr B.P. had mean values of 37.2 μm and 37.8 μm , respectively (Fig. 7). Averages for minor arboreal taxa present were Quercus (10%), Abies (6%), Ostrya/Carpinus (6%), Betula (4%), and Salix undifferentiated (3%). Populus, Larix, and Fraxinus nigra-quadrangulata type were present with values less than 3%. Measurements of Betula grain size at 12,000 yr B.P. had a mean diameter of 20.9 μm , within the mean values postulated by Ives (1977) for tree birch (Fig. 9). However, with the broad size range in grain diameters observed (15 to 27 μm), both shrub and arboreal Betula species may have been present. Shrubs present included Alnus crispa (about 1%), Alnus rugosa type (3%), and Salix herbacea which is continuous through the zone at less than 1%.

Nonarboreal pollen was dominated by Cyperaceae (average 24%). Several other nonarboreal types included Bidens type (1.1% to 11.2%), and Sanguisorba canadensis (1.9% to 10.2%). Gramineae values decreased to an average of less than 2%, while Artemisia dropped to 1%. Sphagnum percentages increased to 5.5%, and Potamogeton pectinatus and foliosus types are present, typically at values less than 2%.

BRB II is characterized by an increase in total pollen accumulation rates over BRB I, with values averaging $3670 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$. Pollen accumulation rates are highest at the base of the zone with an

accumulation rate of $4517 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$. AP values also increased to an average of 58%, and the shrub percentages increased to 4% of the upland sum. Conversely, a reduction in the NAP is evident with percentages decreasing to an average of 38%. Individual taxon pollen accumulation rates for select taxa include Picea (563 to $1712 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Pinus (216 to $304 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Betula (60 to $89 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Alnus (80 to $199 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Cyperaceae (517 to $1050 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Sanguisorba (16 to $452 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), and Bidens type (42 to $309 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$).

Picea PAR increase dramatically at the base of the zone, while Pinus PAR remain consistent throughout the zone. PAR values for Sanguisorba and Bidens type increase markedly in this zone (Fig. 10). Macrofossils recovered included the occurrence of Picea needle fragments, a Picea seed, and one Abies balsamea needle fragment at 13,500 yr B.P.

Lenticular Carex achenes decreased to an average of six per 60 cm^3 of sediment by 12,000 yr B.P. Taxa recovered over the zone interval included Galium, Carex comosa type, Scirpus cespitosus type, and Cyperus undifferentiated. Scirpus cyperinus type increased in abundance, whereas bryophytes and insect fragments remained abundant (Fig. 11).

Forest composition reconstructed from taxon calibrations indicate the development of a spruce-fir forest, with spruce representing approximately 32% and fir about 16% of the forest (Fig. 12). Pine and larch typically represented less than 2% of the reconstructed composition. Other canopy components included maple (6 to 12%), poplar (17 to 20%), ash (5 to 9%), and oak (6 to 8%).

BRB III: Ostrya/Carpinus-Fraxinus zone (135 to 114 cm depth, 11,760 yr B.P. to 10,825 yr B.P.). Arboreal taxa increased in dominance as total AP averaged 73% of the total Upland Sum. Characteristic of this zone are total Fraxinus (primarily Fraxinus nigra-quadrangulata type but including Fraxinus pennsylvanica-americana type), averaging 12% with a peak of 17.6% at 11,500 yr B.P., and Ostrya/Carpinus type, with a maximum of 19.4% at 11,500 yr B.P. and averaging 17%. Other arboreal components with their respective AP averages were Picea (20%), Quercus (18%), Pinus (13%), Abies (7%), and Betula (5%). Arboreal taxa present continuously at less than 2% included Larix, Ulmus, Carya, Acer spp., Tsuga, Juglans cinerea type, Castanea, Fagus grandifolia, and Nyssa. Both Picea mariana-glaucia and Picea rubens were equally represented. Diploxylon and Haploxylon Pinus are present. Betula grain size measurements at 11,000 yr B.P. provided an overall mean diameter of 19.0 μm with two primary modes, one at 16 μm and the other at 22 μm , representing local populations both shrub and tree species present (Fig. 9).

The nonarboreal component is dominated by Alnus (primarily Alnus rugosa type, 3.6 to 7.4%), Cyperaceae (9.3 to 10.9%), and Bidens type (4.5 to 7.0%). Minor nonarboreal taxa included Sanguisorba canadensis and Gramineae at values less than 2%. Sphagnum, increased in this zone from 2% to 6%. Total pollen accumulation rates averaged 4491 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ and reached a maximum of 5398 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ at 11,000 yr B.P. in this zone. Pollen accumulation rates for selected taxa are Picea (581 to 594 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Pinus (252 to 543 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Quercus (365 to 771 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Ostrya/Carpinus (505 to 523

$\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Fraxinus (181 to 458 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Abies (151 to 305 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Alnus (124 to 362 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Cyperaceae (380 to 457 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), and Bidens type (155 to 343 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$). These represent substantial PAR increases for Fraxinus, Ostrya/Carpinus, and Quercus from BRB II to BRB III (Fig. 10).

The macrofossils recovered from BRB III included achenes and seeds of lenticular Carex, Scirpus cyperinus type, Galium, Potentilla cf. palustris, abundant insect fragments, and common bryophytes (Fig. 11).

Forest reconstruction indicated a fir-spruce forest (24% and 19%, respectively), with smaller components of oak (17%), maple (12%), ash (6%), and poplar (6%). This reflects a late-glacial decline in spruce populations, replaced in part by fir populations (Fig. 12).

BRB IV: Betula-Tsuga zone (114 to 94 cm depth, 10,825 yr B.P. to 8190 yr B.P.). Arboreal percent of the Upland Sum averaged 75%, with shrubs becoming more prominent, averaging about 9%. Tsuga increased from 8.1% to a peak value of 30% at 9500 yr B.P. and averaging 20%. AP values rose for Betula (32% at 8500 yr B.P.), and Quercus (11.2 to 16.1%, averaging 14%). Measurements of Betula grain diameters were 22.8 μm at 9500 yr B.P., indicating a primary population of tree birch (Ives, 1977) (Fig. 9). Pinus was 14 to 19 % of the AP until 10,000 yr B.P., and then dropped to about 4% by 8190 yr B.P. Picea rubens declined through the zone from 11% to about 5%, while Ostrya/Carpinus declined from 13% to 7%. Abies and Fraxinus both decreased through this zone, from 4% and 3%, respectively, to 1% or less. Alternatively, AP values expanded for arboreal taxa of Castanea (to 6.8%), Fagus

grandifolia (to 3%), and Nyssa (to 2%). Other AP taxa present at low average values (2% or less) were Ilex-Nemopanthus type, Acer saccharum, Carya, Salix, and Populus. Shrub species were dominated by Alnus rugosa type (ranging from 6% to 13%), with undifferentiated Ericaceae and Corylus generally less than 2%.

Cyperaceae decreased from 6.6% to 1.5%. Substantial drops in percentages occurred for Bidens type (from 8 to 1%) and Sanguisorba canadensis (from 4 to less than 1%). Herbs present at 1% or less included Gramineae undifferentiated, Thalictrum, Artemisia, and Ambrosia type. Lycopodium annotinum and L. lucidulum were found consistently at 2% or less throughout this zone, while Pteridium aquilinum averaged about 1%. Sphagnum increase in this zone to an average of 12%, with a peak at 10,000 yr B.P. of 25.0%, and subsequent decline to 6.5% by 9000 yr B.P. Total PAR increased to an average of $6702 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$, reaching a maximum of $11,988 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ at 9500 yr B.P. within this zone. PAR values for individual taxa included Tsuga (110 to $2121 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Betula (300 to $1971 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Quercus (220 to $1123 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Ostrya/Carpinus (178 to $998 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Alnus (225 to $873 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), and Cyperaceae (100 to $349 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$) (Fig. 10).

Abundant recovery of coniferous macrofossils characterized BRB IV (Fig. 11). Picea needle fragments increased dramatically from 3 to 87 fragments between 10,000 yr B.P. and 9000 yr B.P., respectively. Populations of Pinus cf. strobus were locally present by 10,000 yr B.P. Abies balsamea needle fragments (2) and Tsuga canadensis needle fragments and petioles (7) were also recovered at 9000 yr B.P. Other

macrofossils included lenticular Carex achenes, an increase in the abundance of Galium (33 to 39 seeds), and the first occurrence for both Scirpus americanus type and Vitis. After 10,000 yr B.P., Scirpus cyperinus type was not found and bryophytes and insect fragments decrease in abundance.

The composition of forests reconstructed with taxon calibrations contains a species-rich mixed conifer-northern hardwood assemblage dominated by maple (6 to 12%), oak (about 11%), hemlock (up to 23%), birch (about 11%), spruce (11 to 16%), and fir (10 to 13%). From the reconstruction, populations of spruce, pine, fir, and ash decreased in the overall forest composition through this zone. Betula increased about five-fold over the previous zone, while Fagus is persistent at less than 2%. Minor populations of other taxa included Nyssa (8%), Populus (6%), and Ulmus (2%) (Fig. 12).

BRB V: Quercus-Castanea zone (94 to 24 cm depth, 8190 yr B.P. to 115 yr B.P.). This zone can be divided into two subzones, BRB Va: Ericaceae subzone (94 to 59 cm depth, 8190 yr B.P. to 3230 yr B.P.) and BRB Vb: Ilex subzone (59 to 24 cm depth, 3230 yr B.P. to 115 yr B.P.).

With AP values remaining high in subzone BRB Va, the dominant arboreal taxa were Quercus (12.8 to 24.0%), Betula (21.7 to 30.1%), Castanea (3.9 to 15.5%), and Tsuga (4.9 to 23.7%). Measurements on Betula grain diameters at 5000 yr B.P. had a mean of 21.3 μm , within the range of tree birch (Ives, 1977) (Fig. 9). Minor arboreal taxa include Nyssa (1.4 to 5.5%), Fagus (0.9 to 4.3%), Ostrya/Carpinus (3.7 to 9.0%), Picea (2.9 to 7.1%), Pinus (0.5 to 3.7%), Ilex-Nemopanthus

type increasing from 0.6% to 5.4% by 3500 yr B.P., and Acer (0.3 to 10.4%). Trace amounts of Populus, Ulmus, Platanus, Tilia, Liquidambar, and Viburnum lentago type were also found. Ericaceae is the dominant shrub for which the subzone is named and ranges in value from 10.3% of the Upland Sum at 8000 yr B.P., decreasing to 1.6% by 6000 yr B.P., and then increasing to about 5% at the top of the subzone. Other shrubs present included Alnus rugosa type peaking at 6.5% at 5500 yr B.P. and trace amounts of Corylus.

Herbs generally averaged less than 1% of the Upland Sum and included Gramineae undifferentiated, Cyperaceae, Bidens type, Artemisia, and Ambrosia type. Lycopodium lucidulum, Lycopodium annotinum, and Pteridium were present at low values (less than 2%). Aquatic species were dominated by Sphagnum, which averaged 3.4% with a range of 1.0% to 6.7% and included Nymphaea, Typha latifolia, and Potamogeton pectinatus type. In subzone BRB Va, total pollen accumulation rates varied from $1432 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$ to $11,395 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$, with an average of $6021 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$. Selected individual pollen accumulation rates were Quercus (285 to $1803 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$), Betula (352 to $2326 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$), Castanea (124 to $961 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$), Tsuga (79 to $2243 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$), and Ericaceae (49 to $893 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$). Individual accumulation rates generally peaked around 6000 yr B.P., descending to lower values by the top of the subzone (Fig. 10).

Macrofossils recovered from 8000 yr B.P. were 2 needle fragments and a petiole of Tsuga canadensis, a significant decrease in needle fragments of Picea, and a persistence of Galium. Increased abundance of

insect fragments and a small number of bryophytes were encountered (Fig. 11).

The first decline in hemlock populations from about 8500 yr B.P. to 7000 yr B.P. is corroborated by a decrease in hemlock PAR (1645 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ at 9000 yr B.P. to 210 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ at 7500 yr B.P.). A second decline in hemlock populations was indicated by the drop in pollen percentages (from 20% to 10%) and PAR values (from 1146 to 79 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$) in the interval from 5500 yr B.P. to 4000 yr B.P.

The reconstruction of forest composition is dominated by deciduous taxa, although spruce and hemlock are persistent through the zone (Fig. 12). Dominants included increasing Quercus, Betula, Acer, and Populus. Minor forest components included Nyssa, Fagus, Tilia, Carya, and Fraxinus. Abies populations fluctuated between 0 and 7% and Tsuga having the same early decrease and subsequent recovery at the base of the zone that is mentioned previously.

BRB Vb is characterized by the highest single level total palynomorph accumulation rate of 33,032 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$ with an average of 5956 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$. AP values decreased from the previous subzone to about 78%, with the shrub component remaining about 8%. Dominant arboreal taxa were Quercus (24.3 to 31.2%), Betula (18.8 to 29.4%), and Castanea (5.3 to 12.2%). Ilex-Nemopanthus type, which increases sharply in this subzone to an average of 11% and ranged from 5.8% to 15.8%. Tsuga, Picea, and Ostrya/Carpinus persisted through the zone at approximately 5% each of the AP. Carya values fluctuated between 0.6 to 3.5%. The shrubs are dominated by Ericaceae (2.9 to 6.3%), while other persistent shrub taxa included Alnus rugosa type and Corylus.

The clubmoss Lycopodium lucidulum expanded in value from 5.0% to 8.6% of the Upland Sum. Sphagnum values oscillated between 2.6 to 13.7%; other aquatics included Potamogeton pectinatus and foliosus types, and Typha latifolia. Individual pollen accumulation rates include Quercus (201 to 6536 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Betula (189 to 6614 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), Castanea (55 to 1260 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$), and Ilex-Nemopanthus type (74 to 3150 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$) (Fig. 10).

The reconstructed forest reflect the northern hardwood assemblage dominated by Quercus, Populus, Betula, and Acer (Fig. 12). Coniferous taxa (Picea and Tsuga) decline in percentages to 12 and 6% respectively near the top of the subzone. Minor taxa included Tilia, Nyssa, Fraxinus, Juglans, Ulmus, and Salix.

BRB VI: Quercus-Ambrosia type zone (24 to 0 cm depth, 115 yr B.P. to A.D. 1985). This zone represents the historic interval of approximately the last 150 yr, characterized by a reduction in the total pollen accumulation (2428 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$) and an increase in the NAP percentage to 23%. Arboreal dominants were Quercus (40.6%) and Carya (9.6%). Historic declines occurred in Picea, Tsuga (from 3 to 1%), and Tilia. Castanea, Ilex-Nemopanthus type, Nyssa, and Ostrya/Carpinus dissappeared from the pollen record during this interval. Minor arboreal taxa included increases in Acer (4.9%) and Populus (3.7%). Shrubs of Alnus rugosa type, Ericaceae, and Cephalanthus were present at low percentages.

Nonarboreal pollen assemblage was dominated by Ambrosia type, which increased from 3.7% to 9.0% during the last 150 years. Gramineae

increased from 0.5% to 6.4%. Plantago type is reported for the first time at Big Run Bog during this interval. Pollen accumulation rates for selected individual taxa were Quercus ($709 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$), Betula ($439 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$), Ambrosia type ($211 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$), and Gramineae ($152 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$) (Fig. 9). Vegetative reconstruction from taxon calibration document an Appalachian oak forest (23.6), with sub-dominants of poplar (29.6%), hickory (10.4%) and birch (7.4%).

V. PALEOECOLOGICAL INTERPRETATION

Big Run Bog provides an integrated and continuous record of paleoecologic and geomorphic changes for the Allegheny Plateau of the central Appalachians dating from approximately 17,000 yr B.P., from the full-glacial conditions of the Wisconsin through the Holocene.

BRB I (17,040 yr B.P. to 13,860 yr B.P.). High NAP and low AP percentages combined with low pollen accumulation rates (averaging $1158 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$) provide evidence that the vegetation surrounding the Big Run Bog was probably alpine tundra dominated by sedges and grasses throughout this interval. The palynologic record contains herbaceous taxa considered diagnostic of tundra communities and open, poorly drained landscapes; these taxa include Stellaria, Silene, Polemonium, Saxifraga, and Polygonum viviparum-bistorta type. In addition, pollen values for dwarf shrub species of birch, willow, and green alder indicated that local populations grew within the vicinity, although they may have occurred in very limited populations, as no macrofossils were found. Unlike more continental tundras (Ritchie, 1984), values for both pollen percentages and pollen accumulation rates for Artemisia were low at Big Run Bog during this interval. The macrofossils of spruce (two needles and one sterigma) at 17,000 yr B.P. indicates that spruce populations grew within the region, but probably not within the immediate vicinity of the bog. Picea and Pinus pollen was probably derived from upslope transport from more favorable sites along the nearby steep slopes or valley bottoms at elevations as much as 500 m

lower than the bog. Arboreal taxa such as Abies and Larix probably existed at lower elevations in suitable habitats on protected mountain slopes and in the nearby valleys such as the nearby Cheat and Blackwater rivers.

BRB II (13,860 yr B.P. to 11,760 yr B.P.). This zone is marked by a rapid decrease in Pinus percentages, increased presence of arboreal and shrub taxa represented in the pollen record, and a fourfold increase in the total palynomorph accumulation to an average of $3670 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$. Macrofossils of both spruce and balsam fir (Abies balsamea) occurred consistently after 14,000 yr B.P. With late-glacial climatic amelioration, tree populations of spruce dispersed across the surrounding slopes and onto the plateau near Big Run Bog. Shrub spruce and fir (krummholz) probably grew on exposed ridges and rugged habitats.

In this zone, the major decrease in Pinus percentages is contrasted by consistent values for the pollen accumulation rate for pine from BRB I to BRB II, suggesting that pines did not grow within the vicinity of Big Run Bog, but probably grew within the Alleghenies as limited populations of northern Diploxylon Pinus. The previous high percentages for pine might have been reduced by the invasion of spruce and fir surrounding the bog; their tree structure would have effectively screened out long distance upslope transport of pine grains. The marked increases in PAR and pollen AP percentages for oak, birch, ash, hornbeam, and willow probably represent the invasion of limited populations of hardy deciduous taxa into the nearby, protected river bottoms and lower slopes.

Cyperaceae values remained consistently high through this interval, yet Gramineae values decreased to less than 2%, apparently from an increase in effective available moisture. Evidence for the increase in available moisture is also derived from the local establishment of Sanguisorba canadensis, characteristically found on boggy ground or wet meadows (Gleason and Conquist, 1963; Fernald, 1970). Both Sanguisorba and Bidens type are also indicative of disturbed ground. Additional evidence for wet sedge-meadow habitat is derived from macrofossil recovery of Scirpus cespitosus and cyperinus types (Fernald, 1970).

The relatively high NAP values may also indicate an open forest within the upland. Shrub alder, dwarf willow, and dwarf birch persisted in limited populations within or nearby the watershed during the late-glacial. Values reconstructed from taxon calibrations indicate that spruce and fir may have dominated the newly established boreal woodland with maples occupying mesic sites and aspen locally abundant in forest openings.

BRB III (11,760 yr B.P. to 10,825 yr B.P.). This zone, lasting approximately 1000 years, reflects a complex transition period along the Allegheny Plateau. Spruce, fir, and pine were able to partially or completely close the boreal forest canopy surrounding Big Run Bog as palynomorph accumulation rates reached nearly $5500 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$. This boreal forest was probably restricted to the cooler and moist midslopes, the high ridges, and plateau on which Big Run Bog is situated. Moist low lying areas on the plateau dominated by Cyperaceae

were gradually being reduced, yet exposed ridges and cryoturbated ground maintained by wind and topographic aspect probably continued to support disturbance-favored taxa such as Bidens and Sanguisorba. Also during this transitional interval, a Sphagnum mat became established across the bog surface, with Sphagnum values increasing to 5.5%.

As the boreal forest grew in the high elevation watershed, northern hardwoods probably increased in abundance on the mid and lower slopes and valley bottoms. With further climatic amelioration during the early-Holocene interval, ash, oak, and hornbeam displaced the boreal forest from the valley bottoms and lower slopes. Average pollen values for ash, oak, and hornbeam increased to 12%, 18%, and 19%, respectively. Vegetative reconstructions indicate that Abies and Picea represented prominent components of the boreal forest along with significant populations of maple, ash, and oak.

BRB IV (10,825 yr B.P. to 8190 yr B.P.). This zone is marked by the local collapse of the boreal forest and its replacement by a closed mixed conifer-northern hardwood forest. Total palynomorph accumulation reached a maximum of $11,988 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$ and averaged $6702 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$. By 9500 yr B.P., trees and shrubs contributed approximately 90% of the Upland Sum. Spruce percentages decreased from 19.4% to 3.5% AP. Pine percentages rose from 10,825 yr B.P. to about 10,000 yr B.P.; this increase probably represented the passage of Pinus strobus in the watershed. This interpretation is supported by the evidence of Haploxyton Pinus values increasing over the same interval and a needle fragment of Pinus cf. strobus was found in the plant

macrofossil sample dating 10,000 yr B.P. By 9500 yr B.P., pine values were greatly reduced and dropped below the threshold of 12% established for presence of pine by Delcourt et al., (1985).

Alnus rugosa type became the dominant shrub (5.9 to 12.6%) within the basin and probably existed around the edge of the bog in conjunction with geographically-limited, local spruce populations. This is consistent with the relatively large concentration of spruce macrofossils recovered at 9000 yr B.P. With the population reduction of the boreal trees, the uplands were successively colonized by tree birch, hemlock, and oak by 10,000 yr B.P. Hemlock reached a maximum of 30.5% AP by 9000 yr B.P.; macrofossils verify the local establishment of populations of eastern or Canadian hemlock (Tsuga canadensis).

Betula averaged nearly 25% of the arboreal sum. Betula size frequency measurements (mean diameter of 22.8 μ m at 9500 yr B.P.) indicate that tree birches were present in forests surrounding the site. Cyperaceae reduced to an average of 4%, while the predominant aquatic was Sphagnum (6.5 to 25.0%).

At about 8200 yr B.P. (the transition between the BRB IV and V zones), populations of both hornbeam and hemlock values decreased as tree birch populations expanded, possibly reflecting either a warming trend or a reduction in the available moisture. This would appear to coincide with the beginning of the Hypsithermal, a period of warmth. This zone records the slow population growth of chestnut in the area around Big Run Bog, contributing almost 7% of the arboreal pollen rain by 8200 yr B.P.

BRB V (8190 yr B.P. to 115 yr B.P.). The middle and late Holocene are recorded during this interval, representing a period of continuing minor adjustments in deciduous forest composition. Oak, birch, and chestnut became the dominant trees in the uplands. Minor upland trees included black gum, beech, elm, maple, spruce, poplar, and basswood. Sycamore probably existed along stream banks or the river bottoms of the Cheat and Blackwater rivers. Subzone Va (8190 yr B.P. to 3230 yr B.P.) was characterized by locally prominent shrub populations, dominated by Ericaceae and Alnus rugosa type. Ericales probably inhabited areas directly around the bog. Hemlock decreased initially within this subzone to 4.9% at 7500 yr B.P., possibly as available shade and or moisture was reduced within the basin during the middle Holocene. By 6500 yr B.P., climate apparently ameliorated as hemlock populations were prominent again. Between 5000 yr B.P. and 3300 yr B.P., hemlock populations were reduced to values of less than 10% of the arboreal sum, possibly from the infestation of hemlock by a forest pathogen (Davis, 1981b).

Subzone Vb (3230 yr B.P. to 115 yr B.P.) is characterized by upland forests composed primarily by oak, chestnut, and birch, and a distinctive increase in populations of holly (Ilex-Nemopanthus type) and the clubmoss Lycopodium lucidulum. Holly probably inhabited the wet areas surrounding the bog as a shrub or as a understory tree in the uplands. Hickory became a minor forest component (0.6 to 3.5%) through this subzone. Evergreen spruce and hemlock probably maintained limited populations at the edge of the bog, within the bog, or within favorable microenvironments along ridge tops or steep ravines. Total pollen

accumulation averaged $5955 \text{ gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$, with a maximum of 33,032 $\text{gr}\cdot\text{cm}^{-2}\cdot\text{yr}^{-1}$.

BRB VI (115 yr B.P. to 1985 A.D.). Changes in vegetation during this time interval reflect permanent settlement and forest clearance by Euro-American settlers during the first half of the twentieth century. NAP values increase to 23% of the Upland Sum. Major arboreal taxa, reflecting plant succession after deforestation, include increases in oak (40.6%) and hickory (9.6%). Minor arboreal species were maple and poplar. Nonarboreal taxa responded to forest clearance increases in grasses (Gramineae undifferentiated) and ragweed (Ambrosia type) to 6.4% and 9.0% respectively.

VI. DISCUSSION AND CONCLUSIONS

The paleoecologic record from Big Run Bog provides new insights concerning the landscape history along the Allegheny Front within the central Appalachians, from the full-glacial interval to the present. Several studies, including Buckle's Bog (Maxwell and Davis, 1972) and Cranberry Glades (Watts, 1979), have provided complementary insights into vegetational changes over portions of the last 17,000 years. Each of these sites has its own site-specific character in the form of topography, underlying bedrock, relief, vegetational composition and density, and other important variables, but the sites record broadly similar changes in vegetation that can be considered characteristic of the region.

The full- and late-glacial record from Big Run Bog documents a complex vegetational mosaic of herbaceous alpine tundra and shrub communities from 17,000 yr B.P. to 13,860 yr B.P. Topographic aspect and wind exposure are important in determining the distribution of tundra communities (Spear, 1981; Ritchie, 1984), probably features of the terrain that influenced the composition and structure of plant communities found at Big Run Bog during this interval. Continuous to discontinuous permafrost probably existed throughout the Allegheny Plateau as documented by sorted, patterned-ground ice polygons and stone stripes, and block streams found at comparable elevations and within 20 kilometers distance of Big Run Bog (Clark, 1968). A periglacial block stream, apparently incised during the Holocene,

borders the eastern edge of Big Run Bog, provides geomorphic evidence for local solifluction activity that probably occurred during the full- and late-glacial interval. In addition to the slopes close to the coring site, nearby high-exposure ridges, 50-125 m higher than the bog surface, probably provided excellent disturbed ground for the maintenance of tundra indicators such as Silene, Stellaria, and Polemonium. Low lying areas were probably filled with snow seasonally and provided moisture as well as protection from the cold and wind. Protected exposures and southern aspects might have provided limited habitats for the existence of shrub spruce.

Similar pollen records are also documented at both Buckle's and Cranberry Glades. The high percentages for spruce and pine (and low PAR) at Big Run Bog probably reflect upslope transport of the pollen from their tree populations growing along the valley slopes and river bottoms of the nearby Cheat and Blackwater rivers. A local relief of 370 m can be found within 3 kilometers of the bog and surrounding plateau. This type of accentuated topographic relief providing possible habitats for local populations of spruce and pine is not available at Buckle's Bog (elevation 814 m), and therefore might account for the lower values for spruce and pine within the Cyperaceae zone found at Buckle's Bog.

By 13,860 yr B.P., late-glacial climatic warming as well as increases in effective available moisture, favored the concurrent increase in colluvial activity within the watershed of Big Run Bog. First, total PAR increased nearly fourfold, reflecting the invasion of a spruce and fir into the watershed (Fig. 6). This PAR increase

coincides with increases in the accumulation rates for organic and mineral sediments into the basin (Fig. 5). The increased PAR may, in part, reflect a sedimentologic influence of pollen deposition in Big Run Bog, with contributions from both atmospheric transport of pollen grains as well as pollen reworked downslope by colluvial processes from upland soils. Second, the presence of pollen grains of Sanguisorba canadensis and Bidens type and seeds of Scirpus cespitosus and cyperinus types in substantial quantities, indicate wet-meadow and disturbed-ground conditions. Neither Buckle's Bog or Cranberry Glades record similar local wet meadow habitats during the late-glacial interval. The clay mineral assemblage of kaolinite, illite, mixed-layer illite, and smectite during this interval probably reflects the lack of soil development from seasonally frozen and cryoturbated ground within the Big Run watershed.

The period from 13,860 yr B.P. to 11,760 yr B.P. apparently was one of higher effective precipitation and an increase in the mean annual temperature (possibly to approximately 0° C). I suggest that during the late-glacial interval, the Allegheny Plateau was a significant orographic barrier that effectively screened out moisture from eastward moving airmasses. This interpretation is consistent with the late-Pleistocene precipitation shadow postulated by Guilday et al. (1977) from the Clark's Cave vertebrate bone deposit (Fig. 1). This is also consistent with the plant-fossil assemblage found at Longswamp, PA (Watts, 1979). Longswamp is located leeward of the central Appalachians (Fig. 1), and contains more Artemisia than does Big Run Bog, with sage populations more closely resembling the more xeric continental tundra

found today, for example, in the northwest Canadian arctic (Cwynar, 1982; Ritchie, 1984).

The relatively high percentages for deciduous taxa for this interval are also found in the corresponding age interval at Buckle's Bog. Maxwell and Davis (1972) postulate that changes in arboreal percentages reflected long-distance transport of pollen from a change in prevailing airmasses at 12,750 yr B.P. However, Jackson Pond, a late Quaternary site within the Interior Low Plateau region of Kentucky (Fig. 1), documents the invasion of populations of oak, ash, and hornbeam at approximately 11,500 yr B.P. (Wilkins, 1985), precluding a western source for the deciduous pollen. During the late-glacial interval within the central Appalachians of West Virginia and Maryland, I hypothesize that limited, cold-tolerant populations of temperate deciduous trees colonized the valley floor and lower slopes within a few kilometers distance of Big Run Bog. This interpretation is corroborated by palynological evidence, from at least 15,500 yr B.P., for deciduous arboreal populations within species-rich boreal forests of intermontane valleys, such as Saltville Valley, in the Valley and Ridge Province of southwestern Virginia (Delcourt and Delcourt, 1986).

The period from 11,760 yr B.P. to 10,825 yr B.P. represents a period of landscape stabilization and a changeover from colluvial to fluvial processes. Decreases in mineral and organic accumulation rates coincide with an increase in pollen accumulation rate during this interval (Figs. 5 and 7). This trend is consistent with either a stabilization of the landscape within the catchment basin or a fundamental change in the geomorphic processes acting upon the bog. An

important change in the clay minerals also occurred within this period. Within this stratigraphic interval, vermiculite became prominent within the clay mineral assemblage, apparently at the expense of the previously prominent smectites (Fig. 5). This fundamental change in clay mineralogy of the sediments can not be attributed to an in situ weathering profile, thus supporting the alternative hypothesis that a change in the clay mineral suite entering the basin reflects a change in the character of operative geomorphic processes within the watershed (Birkeland, 1974). The vermiculite might be 'soil chlorite' based on its non-expansion under glycolation and subsequent collapse upon heating (Fig. 13). If this is true, then the full- and late-glacial intervals probably represented periods of poor soil development, colluvially disturbed ground, and higher availability of base metal cations (Na, Ca, K) within the basin, allowing for the persistence of smectites. Subsequent late-glacial migration of evergreen coniferous and possibly deciduous taxa into the basin, along with increases in available moisture, might have provided both a stabilizing of the landscape and an increase in the production of humic acids from the soil leaf litter. With the relatively low pH values derived from the leaf matter and the high moisture content, Al^{3+} ions may have become mobilized and migrated into the smectite lattice, yielding 'soil chlorite' vermiculite. The lag time for such a change and the potential effects of the acidic and reducing depositional conditions is unknown. Therefore, the change from smectite to vermiculite could be attributed to changes in climatic conditions or vegetation composition.

Figure 13. X-ray diffractograms for 118 cm and 140 cm depth.

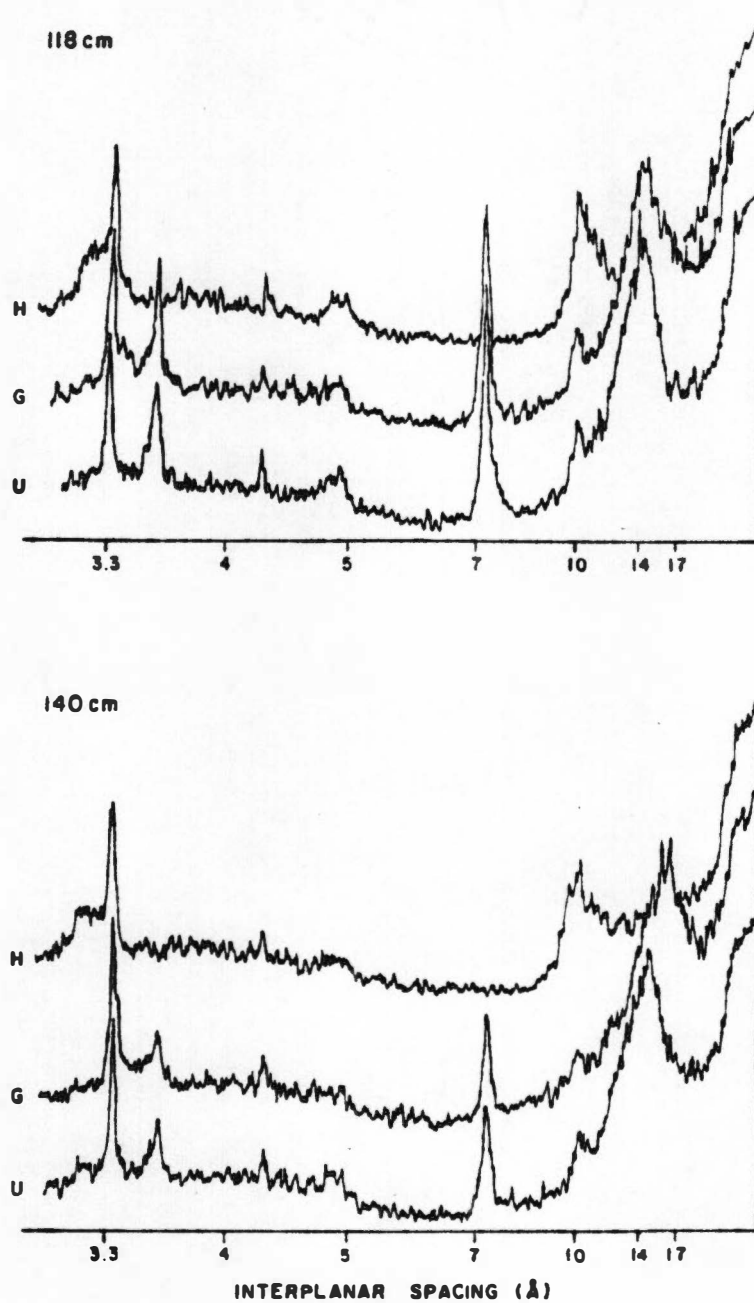


Figure 13.

The uplands immediately surrounding the bog were probably partially stabilized by 13,500 yr B.P. by the increasing density of the boreal forest, comprised of increasing populations of spruce and fir. By that time, the lower elevation midslopes were probably dominated by oak, ash, and hornbeam. Continuing episodes of colluvial activity and the instability of the montane landscape may have inhibited initial colonization and the eventual closing of the boreal forest, despite climatic conditions favorable for the colonization for arboreal taxa. The recovery of small numbers of plant macrofossils of boreal species, the colluvial association between organic and mineral accumulation rates, and the low palynomorph accumulation rates provide evidence that landscape instability inhibited effective colonization of tree populations between 14,000 yr B.P. and 11,800 yr B.P.

Maxwell and Davis (1972) suggested that the tundra community at Buckle's Bog was replaced by arboreal species in limited numbers at approximately 12,750 yr B.P. Correspondingly, Watts inferred an invasion of spruce and pine at Cranberry Glades dating 12,185 yr B.P. The record from Big Run Bog documents that limited populations of spruce invaded the tundra communities along the plateaus of the Allegheny Mountain section, as early as 13,860 yr B.P., and that both spruce (probably both red spruce and black/white spruce) and balsam fir occupied Backbone Mountain near Big Run Bog by 13,500 yr B.P.

By 10,500 yr B.P., the boreal forest in the uplands surrounding Big Run Bog was displaced by a mixed conifer-northern hardwood forest. Oak, birch, and hemlock became important upland dominants and shrubs, mostly alder, also invaded the watershed. Spruce and fir populations

were reduced to isolated favorable bog and ravine habitats. Spruce macrofossils become more abundant during this interval and probably represent local stands around the bog or within the bog. An initial maximum for chestnut ($71 \text{ gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$) occurred at 10,000 yr B.P., then decreased and reexpanded to a pollen accumulation rate of 233 $\text{gr} \cdot \text{cm}^{-2} \cdot \text{yr}^{-1}$ by 9000 yr B.P.; chestnut migrated into the area and consolidated its presence in the forest by 9000 yr B.P., approximately 1000 yr after its invasion into Cranberry Glades (Watts, 1979).

The record from Big Run Bog records the migration of Pinus strobus (white pine) through the area from 16,500 yr B.P. to 9000 yr B.P., but not at the population levels that are registered at Buckle's Bog (up to 30%) or at Cranberry Glades. These differences are attributed to site differences among the three basins.

The period from 8190 yr B.P. to 115 yr B.P. is a period with upland forests of oak, birch, and chestnut. Geographically-restricted populations of spruce persisted around the bog margin and in selected ravine and ridgetop habitats. Minor taxa included beech, black gum, maple, elm, and hickory. The early- and mid-Holocene intervals were marked by the broad decrease in hemlock values, apparently replaced by oak and chestnut. Correspondingly, Ericales become prominent during the early Holocene and may have existed at the fringes of the bog or as individual heath communities along selected ridges. Watts (1979) proposed that a comparable hemlock decline between 9000 yr B.P. and 6500 yr B.P. at Cranberry Glades, probably reflects the increase in warmth and aridity (Hypsithermal Period) during the early and middle Holocene. At Big Run Bog, hemlock values rise by about 6500 yr B.P., but do not

show the major decline in hemlock populations postulated to occur at 4800 yr B.P as a result of outbreaks of a possible pathogen (Davis, 1981b; Watts, 1979). During the late Holocene, starting around 3230 yr B.P., significant populations of holly (Ilex-Nemopanthus type) and the clubmoss Lycopodium lucidulum become important local components.

Extensive logging occurred within the watershed from about 1880 through 1920 A.D.; this event is documented in the palynological record by an increase in disturbance-related taxa such as grasses and ragweed. A dramatic increase in the sediment accumulation rate is probably related to the lumbering within the watershed. Logging effectively diminished populations of spruce, chestnut (chestnut blight probably eliminated what was not logged), and hemlock. Secondary forest succession was dominated by birch and poplar, and then by oak, hickory, and maple.

LIST OF REFERENCES

LIST OF REFERENCES

- Amman, B.R. (1977). A pollen morphological distinction between Pinus banksiana Lamb and Pinus resinosa Ait. Pollen et Spores 19, 521-529.
- Barry, Roger G. (1983). Climatic environment of the Great Plains, past and present. Transactions of the Nebraska Academy of Sciences, XI, 45-55.
- Bartlein, P.J. and Webb T., III (1982). Holocene climatic changes estimated from pollen data from the northern Midwest. In "Quaternary History of the Driftless Area", University of Wisconsin Geological and Natural History Survey, Field Trip Guidebook, No. 5, 67-82
- Bassett, I.J., Crompton, C.W., and Parmalee, J.A. (1978). An atlas of airborne pollen grains and common spores of Canada. Monograph No. 18 Research Branch, Canada Department of Agriculture, Quebec.
- Berggren, G. (1969). "Atlas of Seeds. Part II: Cyperaceae". Berlingska Boktryckeriet, Stockholm.
- Berglund, G.E. and Praglowski J. (1961). "An Introduction to a Scandinavian Flora". Almqvist and Wiskell, Stockholm.
- Birkeland, P.W. (1974). "Pedology, Weathering, and Geomorphological Research". Oxford University Press.
- Birks, H.J.B. and Birks, H.H. (1980). "Quaternary Palaeoecology". University Park Press, Baltimore, MD.
- Birks, H.J.B. and Peglar, S.M. (1980). Identification of Picea pollen of the late Quaternary age in eastern North America: a numerical approach. Canadian Journal of Botany, v. 46.
- Braun, E.L. (1950). "Deciduous Forests of Eastern North America". Hafner Press, New York.
- Bryson, R.A. (1966). Air masses, streamlines, and the boreal forest. Geographical Bulletin 8, 228-269.
- Bryson, R.A. and Wendland, W.M. (1967). Tentative climatic patterns for some late-glacial and postglacial episodes in Central North America, In "Life, Land, And Water, Proceedings of the 1966 Conference on Environmental Studies of the Glacial Lake Agassiz Region" (W.J. Mayer-Oakes, Ed.), pp. 271-298. University of Manitoba Press, Winnipeg.

- Cameron, C.C. (1970). Peat resources of the unglaciated uplands along the Allegheny structural front in West Virginia, Maryland, and Pennsylvania. U.S.G.S. Professional Paper 700-D, D153-D161.
- Carroll, D. (1970). Clay Minerals: A guide to their X-ray identification. Geological Society of America Special Paper 126.
- Clarkson, R.B. (1982). "Tumult on the Mountain: Lumbering in West Virginia 1770-1920" McClain Printing Company, Parsons, W.VA.
- Cwynar, L.C. (1982). A late-Quaternary vegetation history from Hanging Lake, Northern Yukon. Ecological Monographs, 52, 1-24.
- Davis, M.B. (1976). Pleistocene biogeography of temperate deciduous forests. Geoscience and Man 13, 13-26.
- Davis, M.B. (1981). Quaternary history and stability of forest communities. In "Forest Succession, Concepts and Applications" (West, D.C., H.H. Shugart, and D.B. Botkin, Eds.), pp. 132-153. Springer Verlag, New York.
- Davis, M.B. (1981b). Outbreaks of forest pathogens in Quaternary history. Proceedings of the Fourth International Palynological Conference, Lucknow, India (1976-1977) 3, 216-227.
- Dean, W.E. Jr. (1974). Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss-on-ignition: comparison with other models. Journal of Sed. Petrology 44, 242-248.
- Deevey, E.S. (1949). Biogeography of the Pleistocene. Geological Society of America Bulletin 60, 1315-1416.
- Delcourt, H.R. (1979). Late Quaternary vegetation history of the eastern Highland Rim and the adjacent Cumberland Plateau of Tennessee. Ecological Monographs 49, 255-280.
- Delcourt, H.R. and Delcourt, P.A. (1985). Comparison of Taxon Calibrations, Modern Analogue Techniques, and Forest-Stand Simulation Models for the Quantitative Reconstruction of Past Vegetation. Earth Surface Processes and Landforms, 10, 293-304.
- Delcourt, H.R. and Delcourt, P.A. (1986). Late-Quaternary vegetational changes in the central Atlantic states. In "The Quaternary of Virginia" (McDonald, J.N. and S.O. Bird, Eds.). Virginia Commonwealth Division of Mineral Resources (in press).
- Delcourt, P.A. and Delcourt, H.R. (1981). Vegetation Maps for Eastern North America: 40,000 years BP to the present. In "Geobotany II" (R. Romans, Ed.), pp. 123-166. Plenum Press, New York.

- Delcourt, P.A. and Delcourt, H.R. (1983). Late Quaternary vegetational dynamics and community stability reconsidered. Quaternary Research 19, 265-271.
- Delcourt, P.A. and Delcourt, H.R. (1987). "Long Term Dynamics of Temperate Forests, with particular reference to Late-Quaternary Forest History in Eastern North America". Ecological Studies Series, Springer-Verlag, N.Y., in press.
- Delcourt, P.A., Delcourt, H.R., Brister, R.C., and Lackey, L.E. (1980). Quaternary vegetation history of the Mississippi Embayment. Quaternary Research 13, 111-132.
- Delcourt, P.A., Delcourt, H.R., and Davidson, J. L. (1983). Mapping and calibration of modern pollen-vegetation relationships in the southeastern United States. Review of Paleobotany and Palynology 39, 1-45.
- Delcourt, P.A., Delcourt, H.R., and Webb, T., III (1984). Atlas of mapped distributions of dominance and modern pollen percentages for important tree taxa of eastern North American. American Assoc. of Stratigraphic Palynologists, Contribution No. 14.
- Delcourt, P.A., Davis, O.K., and Bright, R.C. (1979). Bibliography of Taxonomic Literature for the Identification of Fruits, Seeds, and Vegetative Plant Fragments. Oak Ridge National Laboratory, Oak Ridge, TN, TM-6818, 1-84.
- Diehl, J.W., and Behling, R.E. (1982). Geologic factors affecting the formation and presence of wetlands in the north central section of the Appalachian Plateaus Province of West Virginia. Symposium on Wetlands of the Unglaciaded Appalachian Region, pp. 3-9. West Virginia University, Morgantown.
- Douglas, L.A. (1977). Vermiculites. In "Minerals in Soil Environments" (Dinauer, R.C., Ed.). Soil Science Society of America, Madison, Wisconsin.
- Erdtman, G.M. (1966). "Pollen morphology and plant taxonomy: Angiosperms". Hafner Publishing Company, New York.
- Fægri, K. and Iversen, J. (1975). "Textbook of Pollen Analysis". McGraw-Hill, New York.
- Fenneman, N. (1938). "Physiography of Eastern United States". McGraw-Hill Inc., New York.
- Fernald, M.L. (1970). "Gray's Manual of Botany". D. Van Nostrand Company, Princeton, New Jersey.

- Gleason, H.A. and Conquist, A. (1963). "Manual for Vascular Plants of Northeastern United States and Adjacent Canada". D. Van Nostrand Company Inc., Princeton, New Jersey.
- Grim, R.E. (1968). "Clay Mineralogy", second edition. McGraw-Hill Inc., New York.
- Guilday, J.E., Parmalee, P.W., and Hamilton, H.W. (1977). The Clark's Cave bone deposit and the late Pleistocene paleoecology of the central Appalachian Mountains of Virginia. Bulletin of Carnegie Museum of Natural History 2, 1-87.
- Helmich, D.E. (1963). Pollen morphology in the maples. Papers of the Michigan Academy of Science, Arts and Letters 48, 153-164.
- Hough, A.F. (1945). Frost pocket and other microclimates in forests of the northern Allegheny Plateau. Ecology 26, 235-250.
- Ives, J.D. (1977). Pollen separation of three North American birches. Arctic and Alpine Research 9, 73-80.
- Kapp, R.O. (1969). "How to Know Pollen and Spores". William C. Brown, Dubuque, Iowa.
- King, J.E. (1981). Late Quaternary vegetational history of Illinois. Ecological Monographs 51, 43-62.
- Krumbein, W.C. and Sloss, L.L. (1963). "Stratigraphy and Sedimentation". W.H. Freeman and Company, San Francisco, CA.
- Lieux, M.H. (1980a). An atlas of pollen of trees, shrubs, and woody vines of Louisiana and other southeastern states, Part I. Ginkgoaceae to Lauraceae. Pollen et Spores 22 (1), 7-57.
- Lieux, M.H. (1980b). An atlas of pollen of trees, shrubs, and woody vines of Louisiana and other southeastern states, Part II. Plantanaceae to Betulaceae. Pollen et Spores 22 (2), 192-243.
- Lieux, M.H. and Godfrey, W.M. (1982). An atlas of pollen of trees, shrubs, and woody vines of Louisiana and other southeastern states, Part III. Polygonaceae to Ericaceae. Pollen et Spores 24 (1), 21-64.
- Losche, C.K. and Beverage, W.W. (1967). Soil survey of Tucker County and part of northern Randolph County, West Virginia. United States Department of Agriculture, Soil Conservation Service, United States Forest Service and West Virginia Agricultural Experiment Station.
- Maher, L.J. Jr. (1977). The confidence limit is a necessary statistic for relative and absolute pollen data. Proceedings of the Fourth International Palynological Conference. Lucknow, India, (1976-1977), 3, 1-20.

- Martin, A.C. and Barkley, W. (1961). "Seed Identification Manual". University of California Press.
- Maxwell, J.A. and Davis, M.B. (1972). Pollen evidence of Pleistocene and Holocene vegetation on the Allegheny Plateau, Maryland. Quaternary Research 17, 93-104.
- McAndrews, J.H., Berti, A.A., and Morris, G. (1973). "Key to the Quaternary Pollen and Spores of the Great Lakes Region". Royal Ontario Museum, Toronto, Canada.
- Montgomery, F.H. (1977). "Seeds and Fruits of Eastern Canada and Northeastern United States". University of Toronto Press, Toronto.
- Munsell Color. (1975). Munsell Soil Color Charts. MacBeth Division. Kollmorgen Corporation, Baltimore, Maryland.
- National Oceanic and Atmospheric Administration 1946-1950, 1952-1981. Climatological data. Annual Summaries. West Virginia. Environmental Data and Information Service, National Climatic Center, Asheville, North Carolina.
- Péwé, T.L. (1983). The periglacial environments in North America during Wisconsin time. In "Late-Quaternary Environments of the United States" (H.E. Wright, Ed.), pp. 157-190. University of Minnesota Press.
- Prentice, I.C. (1982). Multivariate methods. In "Palaeohydrological Changes in the Temperate Zone in the Last 15,000 Years", pp. 53-74. International Geological Correlation Programme Project 158b.
- Ritchie, J.C. (1984). "Past and Present Vegetation of the Far Northwest of Canada". University of Toronto Press, Toronto.
- Schopmeyer, C.S. (1974). Seeds of woody plants in the United States. U.S. Department of Agriculture. Agriculture Handbook 450.
- Schumm, S.A. (1965). Quaternary Paleohydrology, In "The Quaternary of the United States" (Wright, H.E. Jr. and D.G. Frey, Eds.), pp. 783-794. Princeton University Press, Princeton, New Jersey.
- Shafer, D.S. (1984). "Late Quaternary paleoecologic, geomorphic, and paleoclimatic history of Flat Laurel Gap, Blue Ridge Mountains, North Carolina". M.S. Thesis, University of Tennessee, Knoxville.
- Stuckey, R.L. (1981). Origin and development of the concept of the Prairie Peninsula. In "The Prairie Peninsula- in the shadow of Transeau: Proceedings of the Sixth North American Prairie Conference" (R.L. Stuckey and K.J. Reese, Eds.). Ohio Biological Survey, Biological Notes No. 15.

- Warshaw, C.M. and Roy, R. (1961). Classification and a scheme for the identification of layer silicates. Geological Society of America Bulletin 72, 1455-1492.
- Watts, W.A. (1970). The full-glacial vegetation of northwestern Georgia. Ecology 51, 17-33.
- Watts, W.A. (1979). Late Quaternary vegetation of central Appalachia and the New Jersey Coastal Plain. Ecological Monographs 49, 427-469.
- Whitehead, D.R. (1981). Late Pleistocene vegetational changes in northeastern North Carolina. Ecological Monographs 51, 451-471.
- Winter, T.C. and Wright, H.E., Jr. (1977). Paleohydrologic phenomena recorded by lake sediments. EOS Volume 58 (3), 188-196.
- Wright, H.E., Jr. 1968. History of the Prairie Peninsula. In "The Quaternary of Illinois" (R.E. Bergstrom, Ed.). University of Illinois, College of Agriculture, Special Publication No. 14.
- Wieder, R.K., McCormick, A.M. and Lang, G.E. (1981). Vegetational analysis of Big Run Bog, a non-glaciated Sphagnum bog in West Virginia. Castanea 46, 16-29.
- Wieder, R.K. (1985). Peat and Water Chemistry at Big Run Bog, a peatland in the Appalachian mountains of West Virginia, USA. Biogeochemistry 1, 277-302.
- Wieder, R.K., Bennett, C.A., and Lang, G.E. (1984). Flowering phenology at Big Run Bog, West Virginia. American Journal of Botany 71, 203-209.
- Wilkins, G.R. (1985). "Late-Quaternary Vegetational History at Jackson Pond, LaRue County, Kentucky". M.S. Thesis, University of Tennessee, Knoxville.
- Wright, H.E., Jr. (1976). The dynamic nature of Holocene vegetation, a problem in paleoclimatology, biogeography, and stratigraphic nomenclature. Quaternary Research 6, 581-596.

APPENDICES

APPENDIX A
EXTRACTION TECHNIQUES

CHEMICAL TREATMENT OF SAMPLES

1. Transfer sediment and exotic pollen to a 15-ml polypropylene centrifuge tube with 10 ml 10% hydrochloric acid (HCl), stir, heat several minutes in a boiling water bath until reaction with calcareous sediment and matrix of Eucalyptus tablets stops; add tertiary butyl alcohol (TBA) to wet particles that otherwise might float on the meniscus; centrifuge 2 minutes, decant supernatant into a bucket containing sodium bicarbonate to neutralize excess acid.

2. Add 10 ml 10% potassium hydroxide (KOH); stir, heat for 2 minutes in boiling water bath to disperse organics and break down humic substances.

3. If sandy or containing large bits of organic matter, sieve through a 250 um mesh screen. Wash clay particles through mesh with distilled water. Concentrate by centrifugation, adding TBA each time; decant.

4. Wash with 10 ml distilled water until supernatant is clear, stir, add TBA, centrifuge, decant after each wash. These washes remove humic substances and clay-size particles that, if not removed, would later interfere with dispersion.

5. Add 10 ml 10% HCl, stir, add TBA, centrifuge, and decant.

6. Add 5 ml concentrated hydrofluoric acid (HF), stir, heat in boiling water bath 20 minutes, stirring after 10 minutes; add 95% ethyl alcohol (ETOH) to reduce density, add TBA, centrifuge, decant; if still silty, repeat this step up to 4 times to remove silicate minerals.

7. Add 5 ml concentrated HCl, stir, heat in boiling water bath for 12 minutes, stirring after 6 minutes, add ETOH, centrifuge, decant; repeat if necessary. If this material threatens to boil over, squirt with ETOH in the centrifuge tube. This step removes the silicofluoride gel that may form from the HF reaction with silicate-rich sediments.

8. Rinse with 10 ml glacial acetic acid to further dehydrate, stir, add TBA, centrifuge, decant.

9. Acetolyze with 4.5 ml acetic anhydride + 0.5 ml concentrated sulfuric acid, added directly to each centrifuge tube and well-stirred; heat 1 minute, stirring after 30 seconds; add 5 ml glacial acetic acid, stir, centrifuge, decant.

10. Rinse with 10 ml glacial acetic acid to remove the acid-soluble products of acetylation, stir, add TBA, centrifuge, decant.

11. Rinse with 7 ml water + 3 ml 10% KOH to neutralize and disperse material, stir, add TBA, centrifuge, decant.

12. Add 10 ml water + 1 drop Safranin O stain, stir, add TBA, centrifuge, decant.

13. Wash with 10 ml TBA to dehydrate, stir, centrifuge, decant.

14. Transfer to labeled 1 dram vials with TBA, centrifuge, decant.

15. Add a few drops of silicone oil (2000 centistokes viscosity), stir, allow TBA to evaporate overnight in a dust-free place.

APPENDIX B
LOSS-ON-IGNITION DATA

Loss-on-Ignition Data

Depth (cm)	Sediment Sample	Water	Organic Matter	Carbonate Minerals	Noncarbonate Minerals
82	.7101	.2085	.1174	.0003	.3842
87	.7331	.1790	.0983	.0009	.4558
92	.8460	.2485	.1236	.0016	.4739
97	.7100	.2225	.1229	.0017	.3646
102	.8932	.3200	.1223	.0032	.4509
107	.8797	.3080	.1068	.0035	.4649
112	.8170	.1489	.1077	.0014	.5604
117	.8288	.1658	.0891	.0022	.5739
122	.7867	.1214	.0898	.0009	.5755
127	.7926	.1299	.0942	.0010	.5685
132	.8187	.1303	.1056	.0009	.5828
137	.7878	.1317	.0890	.0016	.5671
142	.7396	.1381	.0810	.0044	.5205
147	.7459	.1139	.0865	.0034	.5455
152	.8519	.2647	.0849	.0076	.5023
157	.8399	.1479	.1144	.0034	.5776
162	.7700	.1308	.1002	.0036	.5390
167	.8051	.1518	.0932	.0042	.5601
172	.6485	.1429	.0841	.0040	.4215
177	.8197	.2015	.1088	.0053	.5094
182	.7547	.1748	.0918	.0045	.4881
187	.8245	.2019	.0951	.0053	.5275
192	.9014	.2754	.1143	.0084	.5117
197	.8843	.2589	.1233	.0072	.5021
202	1.1112	.5921	.1058	.0075	.4133
207	1.1625	.6221	.1087	.0093	.4317
212	1.1972	.6579	.1120	.0094	.4273
217	1.1580	.6102	.1031	.0080	.4447
222	1.1291	.6377	.0940	.0094	.3974
227	1.2970	.7248	.1091	.0101	.4631
Maximum	1.2970	.7248	.1236	.0101	.5828
Minimum	.6485	.1139	.0810	.0003	.3646

Note: Weight in grams per cubic cm of sediment volume

Loss-on-Ignition Data

Depth (cm)	Percent water	Percent organic matter	Percent carbonate minerals	Percent noncarbonate minerals
82	29.36%	16.53%	.04%	54.11%
87	24.42%	13.41%	.12%	62.17%
92	29.37%	14.61%	.19%	56.02%
97	31.34%	17.31%	.24%	51.35%
102	35.83%	13.69%	.36%	50.48%
107	35.01%	12.14%	.40%	52.85%
112	18.23%	13.18%	.17%	68.59%
117	20.00%	10.75%	.27%	69.24%
122	15.43%	11.41%	.11%	73.15%
127	16.39%	11.88%	.13%	71.73%
132	15.92%	12.90%	.11%	71.19%
137	16.72%	11.30%	.20%	71.99%
142	18.67%	10.95%	.59%	70.38%
147	15.27%	11.60%	.46%	73.13%
152	31.07%	9.97%	.89%	58.96%
157	17.61%	13.62%	.40%	68.77%
162	16.99%	13.01%	.47%	70.00%
167	18.85%	11.58%	.52%	69.57%
172	22.04%	12.97%	.62%	65.00%
177	24.58%	13.27%	.65%	62.14%
182	23.16%	12.16%	.60%	64.67%
187	24.49%	11.53%	.64%	63.98%
192	30.55%	12.68%	.93%	56.77%
197	29.28%	13.94%	.81%	56.78%
202	53.28%	9.52%	.67%	37.19%
207	53.51%	9.35%	.80%	37.14%
212	54.95%	9.36%	.79%	35.69%
217	52.69%	8.90%	.69%	38.40%
222	56.48%	8.33%	.83%	35.20%
227	55.88%	8.41%	.78%	35.71%
Maximum	56.48%	17.31%	.93%	73.15%
Minimum	15.27%	8.33%	.04%	35.20%

Note: Percent of wet sediment weight

Loss-on-Ignition Data

Depth (cm)	Percent organic matter	Percent carbonate minerals	Percent noncarbonate minerals
82	23.41%	.06%	76.54%
87	17.74%	.16%	82.10%
92	20.69%	.27%	79.05%
97	25.21%	.35%	74.44%
102	21.34%	.56%	78.11%
107	18.68%	.61%	80.71%
112	16.12%	.21%	83.67%
117	13.44%	.33%	86.23%
122	13.50%	.14%	86.37%
127	14.21%	.15%	85.63%
132	15.34%	.13%	84.53%
137	13.57%	.24%	86.19%
142	13.47%	.73%	85.80%
147	13.69%	.54%	85.78%
152	14.46%	1.29%	84.25%
157	16.53%	.49%	82.98%
162	15.68%	.56%	83.76%
167	14.27%	.64%	85.09%
172	16.63%	.79%	82.58%
177	17.60%	.86%	81.54%
182	15.83%	.78%	83.39%
187	15.27%	.85%	83.87%
192	18.26%	1.34%	80.40%
197	19.72%	1.15%	79.13%
202	20.38%	1.44%	78.17%
207	20.11%	1.72%	78.16%
212	20.77%	1.74%	77.49%
217	18.82%	1.46%	79.72%
222	19.13%	1.91%	78.96%
227	19.07%	1.77%	79.17%
Maximum	25.21%	1.91%	86.37%
Minimum	13.44%	.06%	74.44%

Note: Percent of dry sediment weight

APPENDIX C

PALYNOMORPH CONCENTRATIONS AND TOTAL PALYNOMORPH ACCUMULATION RATES PAR

Palynomorph concentrations and total Palynomorph Accumulation Rates PAR

Depth (cm)	Native/ Exotic Grain	Exotic Grain/ Tablet	Number of Tablets	Concentration	Total PAR
0	.32	16,180	3	15,353	2428
31	6.45	16,180	2	208,846	33032
39	7.35	16,180	2	237,742	1596
44	6.61	16,180	2	213,936	1436
47	5.99	16,180	3	290,929	1953
51	3.18	16,180	3	154,364	1036
54	3.77	16,180	3	182,913	1228
58	4.31	16,180	3	209,172	1404
61	5.99	16,180	3	290,855	1952
64	4.40	16,180	3	213,409	1432
69	16.21	16,180	2	524,605	3775
71	21.98	16,180	2	711,111	5117
75	23.47	16,180	3	1,139,342	8198
79	28.20	16,180	3	1,368,828	9850
82	32.62	16,180	3	1,583,618	11395
85	17.74	16,180	2	574,038	4131
89	15.17	16,180	3	736,190	5297
92	25.94	16,180	3	1,259,343	9062
96	22.89	16,180	3	1,111,311	7997
100	20.43	16,180	3	991,603	7135
104	34.32	16,180	3	1,665,962	11988
107	11.31	16,180	3	549,160	3952
110	10.47	16,180	2	338,897	2439
120	4.93	16,180	3	239,323	5398
130	4.91	16,180	2	158,874	3583
140	4.01	16,180	2	129,676	2925
155	3.32	16,180	2	107,412	3323
166	3.30	16,180	2	106,637	3299
180	2.85	16,180	3	138,541	4286
190	4.51	16,180	2	146,011	4517
198	3.28	16,180	2	106,004	643
200	3.30	16,180	2	106,773	648
203	2.98	16,180	2	96,546	586
206	2.81	16,180	2	90,822	551
210	1.58	16,180	2	51,039	310
215	2.78	16,180	2	89,989	2377
228	3.50	16,180	2	113,260	2992

APPENDIX D
PALYNOMORPH TABULATION

Depth														
0.0	31.0	39.0	44.0	47.0	51.0	54.0	58.0	61.0	64.5	69.0	71.0	75.0		
79.0	82.0	85.0	89.0	92.5	96.0	100.0	103.5	107.0	110.0	120.0	130.0	140.0		
155.0	166.5	180.0	190.0	197.5	200.0	203.0	206.0	210.0	215.0	228.0				
MAX			MIN				AVG							
ABIES														
0.0	0.0	.1	.2	.1	0.0	0.0	0.0	.2	.2	0.0	0.0	0.0		
.5	.6	.3	.5	0.0	0.0	1.2	1.7	2.1	3.6	8.9	5.8	6.7		
9.0	5.0	4.3	5.1	2.4	1.9	.3	1.3	1.0	.2	.5				
9.0			0.0			1.7								
ACER UNDIFFERENTIATED														
0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	4.0	0.0	0.0		
0.0	0.0	0.0	0.0	0.0	0.0	1.5	.3	0.0	0.0	0.0	0.0	.6		
.3	.6	.3	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0				
4.0			0.0			.2								
ACER NEGUNDO														
0.0	0.0	.3	0.0	0.0	0.0	0.0	.3	0.0	0.0	1.2	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	0.0	0.0		
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
1.2			0.0			.0								
ACER RUBRUM														
4.0	.7	.3	.3	.9	1.0	.6	0.0	1.3	1.3	.9	.6	.3		
1.5	1.5	2.3	1.4	0.0	1.2	.6	.9	0.0	0.0	.3	.6	.6		
0.0	0.0	1.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	.7				
4.0			0.0			.7								
ACER SACCHARUM														
.9	1.0	.9	.6	.3	0.0	1.0	1.0	.3	.3	5.2	.6	.6		
.9	.9	2.3	1.6	.3	1.9	.9	.9	.3	2.5	1.4	1.8	1.3		
.3	0.0	1.0	0.0	0.0	.3	.3	0.0	.7	0.0	0.0				
5.2			0.0			.9								
AMELANCHIER TYPE														
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		
.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	.3				
.3			0.0			.0								
BETULA														
25.0	27.9	18.8	21.5	27.4	26.2	29.4	22.2	23.0	29.7	22.3	26.0	29.3		
27.9	24.6	21.7	25.4	30.1	31.6	21.8	24.6	23.0	22.0	5.3	3.6	3.8		
3.3	5.5	3.0	3.6	3.3	.8	.3	.3	.3	.6	.3				
31.6			.3			16.6								
CARPINUS/OSTRYA TYPE														
0.0	0.0	1.8	5.2	3.2	3.6	1.3	3.2	9.0	6.6	7.0	7.8	4.1		
5.7	3.7	6.4	5.7	6.9	6.8	8.6	12.5	7.7	13.0	15.2	19.4	10.2		
2.6	9.3	4.3	1.6	1.7	.3	.3	.7	0.0	.3	2.0				
19.4			0.0			5.3								

CARYA													
9.6	2.3	3.0	.6	2.6	3.3	2.9	3.5	1.6	2.5	1.8	1.2	.9	
.9	.9	2.0	1.9	2.6	0.0	.6	.3	0.0	.6	.8	.3	1.3	
.3	.3	.7	0.0	0.0	0.0	0.0	0.0	.7	0.0	0.0			
9.6			0.0			1.4							
CASTANEA													
0.0	5.3	8.0	9.8	10.1	7.6	12.2	11.6	11.5	10.4	10.7	11.4	7.8	
3.9	10.1	10.4	15.6	9.2	6.8	4.3	.6	3.5	.9	.3	.9	0.0	
0.0	0.0	0.0	0.0	.3	0.0	.3	0.0	.7	.3	.3			
15.6			0.0			5.0							
CORNUS FLORIDA													
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
.3			0.0			.0							
FAGUS													
1.9	1.3	.3	0.0	.9	1.3	1.0	.3	1.0	1.3	4.3	3.0	3.4	
1.2	.9	1.4	1.4	2.0	2.8	.3	.9	.3	.9	.6	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0			
4.3			0.0			.9							
FRAXINUS UNDIFFERENTIATED													
0.0	0.0	0.0	.6	0.0	0.0	0.0	0.0	1.0	0.0	0.0	.9	0.0	
.3	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	1.7	6.0	2.9	
0.0	0.0	1.6	.3	0.0	0.0	0.0	0.0	0.0	0.0	.3			
6.0			0.0			.6							
FRAXINUS QUADRANGULATA-NIGRA TYPE													
0.0	2.0	0.0	0.0	0.0	2.0	.6	1.3	2.2	.9	.6	1.2	.6	
.9	.6	1.2	1.1	1.4	.9	1.5	0.0	.9	3.4	3.6	10.7	6.7	
1.6	4.2	.3	0.0	1.1	0.0	.3	.7	1.0	1.0	.3			
10.7			0.0			1.5							
FRAXINUS PENNSYLVANICA-AMERICANA TYPE													
0.0	0.0	0.0	.6	0.0	0.0	.3	0.0	0.0	.3	.3	.6	0.0	
0.0	0.0	.3	.3	.3	.6	0.0	0.0	.3	0.0	0.0	.9	0.0	
0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
.9			0.0			.1							
ILEX-NEMOPANTHUS TYPE													
0.0	13.3	15.9	8.6	5.8	11.3	9.0	10.0	5.4	3.5	2.1	2.4	.6	
.6	.9	2.6	1.4	1.4	0.0	2.5	0.0	.6	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			
15.9			0.0			2.6							
JUGLANS CINEREA TYPE													
0.0	.3	0.0	.3	.3	.3	0.0	.3	0.0	0.0	.6	.3	.6	
0.0	.3	0.0	0.0	.6	0.0	0.0	.6	0.0	0.0	.6	0.0	0.0	
0.0	1.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
1.0			0.0			.2							

JUGLANS UNDIFFERENTIATED

.6	.7	0.0	0.0	1.2	.3	1.0	.3	.3	.3	.3	0.0	0.0
.3	.6	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	.3	.3
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	.3	0.0		
1.2			0.0			.2						

JUGLANS NIGRA TYPE

0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	.3	0.0	0.0
0.0	0.0	.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	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0		
.3			0.0			.0						

LARIX

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.8	0.0	0.0
.7	1.6	0.0	1.0	1.7	1.1	1.3	1.3	0.0	2.6	2.3		
2.6			0.0			.4						

LIQUIDAMBAR

0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	.3	0.0	0.0	.6	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	.3	0.0	0.0	0.0	0.0	0.0		
.6			0.0			.0						

MYRICA TYPE

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	0.0	.3	.3	0.0
0.0	0.0	.3	0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	.3
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0		
.6			0.0			.1						

NYSSA

0.0	1.3	.9	.3	2.0	.3	1.0	.3	2.6	1.6	1.5	4.8	3.1
2.7	1.8	1.4	5.5	5.5	2.2	1.5	.6	1.8	.3	.6	.3	.3
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
5.5			0.0			1.2						

PICEA TOTAL

2.3	3.3	6.5	6.2	5.3	3.5	5.3	4.3	6.4	6.0	6.9	4.6	4.4
2.9	2.9	7.1	6.0	4.8	5.7	4.8	7.3	9.2	1.0	16.9	22.8	34.3
49.5	34.9	63.1	65.5	45.3	46.2	51.4	60.4	45.7	47.9	48.4		
65.5			1.0			20.2						

PICEA MARIANA-GLAUCA TYPE

0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
.3	0.0	.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	2.1	4.6
7.1	1.3	7.4	9.2	3.6	10.5	2.6	9.1	13.8	2.9	15.9		
15.9			0.0			2.6						

PICEA RUBENS

0.0	0.0	.7	.9	.3	0.0	0.0	.6	1.0	0.0	1.5	.3	.3
0.0	0.0	1.4	.8	0.0	0.0	.6	0.0	.6	1.2	1.9	3.0	2.6
7.2	1.9	5.6	.7	1.1	4.5	0.0	2.3	.3	.6	.3		
7.2			0.0			1.1						

PINUS TOTAL

3.4	2.2	1.0	1.7	1.3	2.0	1.3	2.7	1.3	2.2	1.5	.6	3.3
3.6	3.7	1.9	.5	1.6	3.5	4.8	5.1	19.4	14.3	15.8	9.7	12.9
14.5	15.1	11.2	12.3	34.5	46.1	42.3	29.9	42.8	42.3	38.5		
46.1			.5			12.2						

PINUS DIPLOXYLON

.9	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3
.3	0.0	.6	0.0	0.0	.3	.6	0.0	.3	2.5	.3	1.2	2.2
2.6	2.9	4.0	3.3	4.5	5.0	4.9	5.2	13.8	5.8	8.3		
13.8			0.0			1.9						

PINUS HAPLOXYLON

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6	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	1.6	1.4	.9	1.6
0.0	0.0	0.0	0.0	0.0	.3	0.0	.3	1.3	0.0	0.0		
1.6			0.0			.2						

PLATANUS

1.2	0.0	0.0	.9	.6	0.0	1.3	0.0	.3	.6	0.0	0.0	.9
.3	.6	0.0	.5	.3	0.0	.3	0.0	0.0	.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	0.0		
1.3			0.0			.2						

POPULUS

3.7	2.0	1.5	1.5	1.4	.7	1.3	1.3	1.9	.3	1.8	.9	1.2
1.8	.6	2.6	.3	0.0	.9	.6	1.6	.3	.9	.6	1.2	1.9
1.3	1.9	1.0	1.3	0.0	1.1	0.0	0.0	.7	1.6	2.0		
3.7			0.0			1.2						

QUERCUS

40.6	27.5	31.2	28.9	28.6	29.5	24.3	29.6	20.2	24.0	12.8	19.7	17.8
22.5	19.0	22.8	23.5	19.1	15.4	13.2	14.0	11.2	16.1	22.4	14.0	9.6
12.2	11.3	7.6	8.2	5.3	1.9	1.6	3.6	3.0	2.6	.7		
40.6			.7			16.6						

RHODODENDRON

0.0	1.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
.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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
1.0			0.0			.0						

RHUS VERNIX TYPE

0.0	0.0	0.0	0.0	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	0.0	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	.1		
.5			0.0			.0						

SALIX

.6	.3	1.2	1.2	0.0	.3	1.0	1.0	.6	0.0	.6	.3	0.0
0.0	0.0	2.3	0.0	.3	.3	.3	0.0	.6	.6	1.4	.3	5.8
3.6	6.8	.3	.7	4.2	0.0	0.0	0.0	.3	.3	0.0		
6.8			0.0			1.0						

TILIA													
.3	0.0	.3	.6	.3	0.0	0.0	.6	.3	0.0	1.5	.6	.3	
0.0	1.2	.9	.3	.3	.3	0.0	.3	.3	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
1.5			0.0			.2							
TSUGA													
1.2	3.3	6.8	7.1	5.2	5.3	4.5	5.1	8.0	6.6	10.7	12.3	18.4	
19.5	23.7	9.0	4.9	11.3	16.0	30.5	26.5	17.4	8.1	.6	0.0	.3	
0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3			
30.5			0.0			7.1							
ULMUS													
1.6	1.3	.6	2.2	.3	.7	.3	1.0	.3	.3	0.0	0.0	1.6	
1.5	.3	.6	.3	.3	.9	1.2	.3	1.2	.6	1.7	1.5	.3	
.3	2.3	0.0	0.0	.3	0.0	0.0	.3	0.0	0.0	0.0			
2.3			0.0			.7							
VIBURNUM LENTAGO TYPE													
2.8	2.7	.6	.9	2.3	0.0	.3	0.0	.3	.9	0.0	0.0	.6	
0.0	0.0	0.0	1.9	0.0	2.2	.3	.3	0.0	0.0	.3	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0			
2.8			0.0			.5							
TOTAL ARBOREAL POLLEN GRAINS													
322.5	301.5	336.0	325.0	346.5	301.5	312.5	311.0	312.5	316.5	327.5	334.5	320.5	
333.0	325.5	346.0	366.0	346.0	324.0	325.0	320.5	338.5	322.0	361.0	335.5	313.0	
304.0	311.0	303.5	304.5	359.5	377.5	303.5	306.5	304.0	311.0	302.5			
377.5			301.5			324.6							

ALNUS CRISPA													
0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	.3	0.0	.3	
.3	0.0	.5	.2	.4	0.0	.5	0.0	.2	0.0	.2	0.0	0.0	
1.5	.2	.4	.2	0.0	.3	0.0	.3	.9	.1	.1			
1.5			0.0			.2							
ALNUS RUGOSA													
1.4	1.1	.7	.2	1.6	1.5	1.3	1.6	0.0	1.1	1.0	2.0	6.5	
4.6	3.5	.5	.9	1.8	5.9	7.8	8.7	7.5	12.6	7.2	3.6	3.8	
4.6	3.9	1.5	2.0	1.2	.6	.8	1.1	.2	1.0	.6			
12.6			0.0			2.9							
CEPHALANTHUS													
.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.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	0.0	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	
.3			0.0			.0							
CORYLUS													
0.0	0.0	1.4	1.4	0.0	.2	.3	0.0	.3	0.0	0.0	.2	.5	
.8	.8	0.0	0.0	0.0	.3	.5	1.0	0.0	.2	.8	.2	0.0	
0.0	.3	0.0	.2	0.0	0.0	.2	0.0	0.0	0.0	.1			
1.4			0.0			.3							
ERICACEAE UNDIFFERENTIATED													
1.1	3.7	4.1	5.4	6.3	3.0	4.8	2.9	4.8	3.5	6.9	9.3	3.0	
1.8	1.6	6.0	7.1	10.3	.5	0.0	.2	.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	0.0	0.0	0.0			
10.3			0.0			2.3							
ROSACEAE UNDIFFERENTIATED													
.2	0.0	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	0.0	0.0	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	.1	0.0	0.0			
.2			0.0			.0							
RUBUS													
0.0	.3	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	.2	0.0	0.0	.2	0.0	0.0	0.0	0.0			
.3			0.0			.0							
SALIX HERBACEA													
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	0.0	0.0	0.0	1.5	
0.0	1.2	0.0	.4	2.2	.7	.5	.6	0.0	.4	.7			
2.2			0.0			.2							
SHEPHERDIA CF. CANADENSIS													
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0			
.2			0.0			.0							

SPIRAEA TYPE													
0.0	0.0	.5	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	0.0	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	0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0		
.5			0.0			.0							
VIBURNUM UNDIFFERENTIATED													
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.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	0.0	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		
.3			0.0			.0							
ACHILLEA TYPE													
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	.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	0.0	0.0	0.0	0.0	0.0	0.0		
.3			0.0			.0							
AMBROSIA TYPE													
9.0	3.7	2.6	4.0	1.1	2.5	2.3	1.0	1.7	.8	1.5	1.2	.5	
.8	.3	1.0	1.1	.2	.5	.8	.5	.6	1.0	.4	0.0	0.0	
.2	.3	.2	.2	.3	1.0	.5	.4	.2	.1	.1			
9.0			0.0			1.2							
ARTEMISIA													
.2	.3	1.2	.5	0.0	0.0	.3	0.0	0.0	.3	0.0	.7	0.0	
.5	.3	0.0	.2	0.0	0.0	1.0	.7	.8	1.0	.2	.7	.6	
.4	.2	1.7	.2	1.4	1.0	1.0	.8	1.4	.6	.1			
1.7			0.0			.5							
BIDENS TYPE													
1.8	0.0	.2	.2	.7	.7	1.0	.3	0.0	.3	.3	.5	.3	
.8	.3	.8	.5	.9	.8	.8	.7	3.7	7.8	7.0	4.5	11.2	
1.3	7.5	1.1	1.3	.8	1.0	.6	1.1	.5	.9	1.3			
11.2			0.0			1.7							
CHENOPODIACEAE/AMARANTHACEAE													
.2	0.0	.2	.5	0.0	.2	0.0	.3	0.0	0.0	.3	0.0	.3	
.5	.3	.2	0.0	0.0	0.0	0.0	0.0	.2	.2	0.0	.2	.2	
0.0	.3	0.0	.2	0.0	.1	0.0	0.0	.2	0.0	0.0			
.5			0.0			.1							
CORNUS CANADENSIS TYPE													
.7	0.0	0.0	.7	0.0	0.0	0.0	0.0	0.0	0.0	.5	0.0	0.0	
0.0	.5	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	.2	0.0	
0.0	.2	.2	0.0	1.4	.1	.6	.5	.5	.1	0.0			
1.4			0.0			.2							
CRUCIFERAE													
0.0	0.0	.5	0.0	0.0	0.0	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	0.0	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			
.5			0.0			.0							

CYPERACEAE													
1.4	.5	.5	.5	.9	.7	.3	1.0	0.0	.3	1.3	.5	1.0	
1.0	1.1	0.0	.7	2.0	1.5	1.5	3.5	6.3	6.6	9.3	10.9	18.7	
29.8	28.1	20.1	23.7	37.8	33.5	32.1	44.8	33.0	37.4	41.4			
44.8			0.0			11.7							
GALIUM													
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	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	.1	0.0	.3	0.0	0.0	0.0			
.3			0.0			.0							
GRAMINEAE													
6.4	.5	.5	1.2	.5	0.0	1.0	.3	.6	.8	0.0	0.0	1.5	
.5	0.0	0.0	.2	.7	1.0	1.3	1.0	.6	1.6	1.9	.9	.4	
2.2	1.4	1.3	4.0	3.9	6.9	12.1	8.7	7.8	12.0	7.3			
12.1			0.0			2.5							
IVA CILIATA TYPE													
0.0	0.0	0.0	0.0	.2	0.0	0.0	0.0	0.0	.8	0.0	0.0	0.0	
0.0	.5	0.0	.2	.2	0.0	0.0	.2	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0			
.8			0.0			.1							
IVA XANTHIFOLIA													
0.0	0.0	0.0	0.0	.7	.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	0.0	0.0	.2	0.0	0.0	0.0	0.0	
0.0	.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
.7			0.0			.1							
LABIATAE													
0.0	0.0	.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.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	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
.5			0.0			.0							
LEGUMINOSAE													
0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
.2			0.0			.0							
LIGULIFLORAE													
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	.2	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	0.0	0.0	0.0	0.0	0.0	0.0			
.4			0.0			.0							
PLANTAGO													
.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
.7			0.0			.0							

POLEMONIUM

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	.2	0.0	.1	.1	0.0	0.0	0.0	0.0	0.0	0.0	
.2			0.0			.0						

POLYGONUM AVICULARE TYPE

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
.2			0.0			.0						

POLYGONUM VIVIPARUM-BISTORTA TYPE

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	.2	0.0	0.0	0.0	0.0	0.0	0.0	.1		
.2			0.0			.0						

POTENTILLA TYPE

1.1	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0
.2	0.0	0.0	.5	.1	0.0	0.0	.1	0.0	.1	0.0		
1.1			0.0			.1						

PRUNELLA TYPE

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
.2			0.0			.0						

SANGUISORBA CANADENSIS

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
.3	0.0	0.0	0.0	0.0	0.0	0.0	.2	.6	4.1	1.0	.4	1.9
1.8	.5	7.9	10.2	.4	.1	.2	.3	.2	.1	0.0		
10.2			0.0			.8						

SAXIFRAGA

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0	0.0		
.1			0.0			.0						

SILENE

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	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	.2	0.0	0.0	0.0	.6		
.6			0.0			.0						

STELLARIA

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6		
.6			0.0			.0						

THALICTRUM

0.0	0.0	.2	0.0	.2	0.0	0.0	.3	0.0	0.0	.3	0.0	0.0
0.0	.3	.5	0.0	0.0	.3	0.0	.2	.8	0.0	.4	.2	.4
.4	.9	0.0	.5	.4	.1	1.0	.3	.9	.7	.9		
1.0			0.0			.3						

UMBELLIFERAE

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.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	0.0	.2	0.0	0.0
.4	.5	.4	0.0	.1	.4	.2	.1	.3	.3	.1		
.5			0.0			.1						

XANTHIUM

0.0	0.0	0.0	0.0	0.0	0.0	.5	0.0	0.0	0.0	.3	0.0	0.0
0.0	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	.2	0.0	.3	.2	0.0	0.0	0.0	0.0		
.5			0.0			.0						

DENNSTAEDTIA

0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	.5
0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	2.2	0.0	.2	.7	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
2.2			0.0			.1						

EQUISETUM

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	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	.3	.6	1.6	0.0	0.0	0.0		
1.6			0.0			.1						

LYCOPODIUM ANNOTINUM

0.0	.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.5	.8
1.0	.5	0.0	0.0	.2	1.5	.8	1.5	1.2	0.0	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		
1.5			0.0			.2						

LYCOPODIUM CLAVATUM

0.0	0.0	0.0	0.0	0.0	0.0	.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	0.0	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	0.0	0.0	0.0		
.3			0.0			.0						

LYCOPODIUM LUCIDULUM

.7	6.4	5.0	5.8	7.0	8.5	8.6	7.8	2.8	2.5	1.5	2.0	1.3
.3	.8	2.0	3.0	4.0	1.8	1.3	0.0	.4	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		
8.6			0.0			2.0						

LYCOPODIUM OBSCURUM

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	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	0.0	.1	0.0	0.0	0.0	0.0	0.0		
.4			0.0			.0						

LYCOPodium SELAGO TYPE

0.0	0.0	0.0	.5	.5	.2	.3	0.0	0.0	0.0	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	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
.5			0.0			.0							

LYCOPodium UNDIFFERENTIATED

.2	.3	1.4	1.9	0.0	2.0	.3	0.0	.3	.8	1.5	0.0	0.0	
0.0	.3	.5	.5	.4	0.0	.3	0.0	0.0	0.0	0.0	.4	0.0	
0.0	.2	0.0	.2	0.0	0.0	0.0	0.0	.2	0.0	0.0			
2.0			0.0			.3							

MONOLETE SPORES UNDIFFERENTIATED

0.0	.5	0.0	.5	.7	.7	0.0	0.0	.6	1.1	0.0	1.2	1.0	
1.3	1.9	.8	.7	.9	1.0	.3	1.7	1.4	1.9	.8	.9	.6	
0.0	.7	0.0	0.0	0.0	0.0	.8	.1	.7	.6	.7			
1.9			0.0			.7							

OSMUNDA CINNAMOMEA

0.0	.3	0.0	0.0	.2	0.0	0.0	.3	0.0	.3	0.0	0.0	.5	
0.0	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
.5			0.0			.0							

OSMUNDA REGALIS TYPE

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	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	0.0	0.0	0.0	0.0	0.0
.3			0.0			.0							

PTERIDIUM

.5	1.1	0.0	0.0	0.0	1.7	0.0	.3	1.1	0.0	0.0	.7	.8	
.5	.5	.2	0.0	.2	2.3	0.0	1.0	3.3	0.0	0.0	.4	.2	
0.0	.2	0.0	0.0	0.0	0.0	0.0	0.0	.3	0.0	0.0			
3.3			0.0			.4							

UNKNOWN

0.0	0.0	0.0	.5	0.0	0.0	0.0	.3	0.0	0.0	.5	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.2	0.0	0.0	.2	0.0	
.2	0.0	0.0	.2	0.0	0.0	0.0	.1	0.0	0.0	.1			
.5			0.0			.1							

TOTAL POLLEN AND SPORE UNIVERSE

435.5	373.5	416.0	428.0	442.5	401.5	395.5	383.0	356.5	365.5	392.5	409.5	395.5	
391.0	375.5	400.0	435.0	448.0	393.0	395.0	404.5	490.5	514.0	515.0	447.5	520.0	
541.0	587.0	467.5	548.5	722.5	725.5	623.5	794.5	576.0	690.0	671.5			
794.5			356.5			483.0							

NYMPHAEA													
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	.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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
.2			0.0			.0							
POLYGONUM HYDROPIPER TYPE													
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	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	.2	0.0	0.0	0.0	.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
.2			0.0			.0							
POTAMOGETON FOLIOSUS TYPE													
0.0	0.0	.2	.2	.7	0.0	0.0	0.0	.3	0.0	0.0	0.0	0.0	0.0
.2	0.0	0.0	0.0	.4	.2	.2	0.0	.3	1.6	2.3	0.0	.2	
.9	1.3	0.0	0.0	1.1	1.1	0.0	0.0	.2	0.0	0.0			
2.3			0.0			.3							
POTAMOGETON PECTINATUS TYPE													
0.0	.2	.4	.6	.7	.2	0.0	.2	.5	0.0	.2	0.0	1.0	
.2	.3	0.0	0.0	.2	.7	.9	.4	.3	.7	.2	0.0	1.6	
.7	1.8	.8	1.4	0.0	.1	.2	0.0	0.0	.6	.1			
1.8			0.0			.4							
SPHAGNUM													
2.7	9.9	6.7	8.7	2.6	5.8	13.7	6.8	3.7	2.9	2.7	4.4	4.1	
6.7	2.8	1.0	2.9	2.6	8.3	6.5	14.2	25.0	8.0	5.5	2.2	2.9	
.2	3.5	.4	0.0	.3	0.0	.2	.6	.2	.3	0.0			
25.0			0.0			4.6							
TYPHA LATIFOLIA													
0.0	0.0	.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	.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	0.0	
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	
1.2			0.0			.1							
INDETERMINABLE													
.2	1.0	.9	.6	1.5	1.2	1.1	1.4	1.1	1.6	2.8	2.0	1.4	
.5	1.0	.7	1.5	.9	.5	.2	1.5	1.2	.5	1.2	.9	.5	
0.0	1.3	1.0	.5	.7	.7	1.0	.7	.7	.3	.4			
2.8			0.0			1.0							
TOTAL POLLEN & SPORE + AQUATICS + INDETERMINABLE GRAINS													
448.5	419.5	455.0	476.0	467.5	432.5	463.5	418.0	377.5	382.5	421.5	439.5	422.5	
423.0	391.5	408.0	455.0	467.0	435.0	429.0	478.5	667.5	576.0	567.0	461.5	549.0	
551.0	636.0	479.5	559.5	730.5	732.5	632.5	805.5	582.0	698.0	675.5			
805.5			377.5			513.9				TOTAL	19014		
EUCALYPTUS GRAINS													
1418.0	65.0	62.0	72.0	78.0	136.0	123.0	97.0	63.0	87.0	26.0	20.0	18.0	
15.0	12.0	23.0	30.0	18.0	19.0	21.0	14.0	59.0	55.0	115.0	94.0	137.0	
166.0	193.0	168.0	124.0	223.0	222.0	212.0	287.0	369.0	251.0	193.0			
1418.0			12.0			142.8							

APPENDIX E

POLLEN ACCUMULATION RATES FOR SELECTED TAXA

Pollen Accumulation Rates

Age (yr B.P.)	Pinus	Picea	Larix	Salix	Abies	Fraxinus	Populus	Quercus	Betula	Tsuga
0	59	41	0	11	0	0	22	709	439	22
150	512	787	0	79	0	472	472	6536	6614	787
500	12	77	0	14	4	0	18	368	221	81
1000	17	60	0	12	2	12	15	284	211	69
1500	19	77	0	0	2	0	21	413	397	75
2000	14	25	0	2	0	14	5	213	189	38
2500	11	44	0	8	0	8	11	201	244	37
3000	29	45	0	10	0	13	13	309	232	54
3500	21	103	0	10	3	52	31	326	372	129
4000	26	71	0	0	2	15	4	285	352	79
4500	45	202	0	18	0	26	52	376	654	305
5000	23	181	0	12	0	105	35	769	1014	478
5500	204	272	0	0	0	39	78	1107	1825	1146
6000	280	221	0	0	35	93	140	1744	2164	1515
6500	349	277	0	0	58	58	58	1803	2326	2243
7000	66	248	0	81	10	50	91	800	759	314
7500	23	256	0	0	23	58	12	1000	1081	210
8000	107	320	0	19	0	155	0	1280	2015	757
8500	212	340	0	18	0	92	55	919	1873	956
9000	258	258	0	17	67	83	33	715	1181	1645
9500	412	586	0	0	137	0	125	1123	1971	2121
10,000	387	184	0	12	41	24	6	225	461	349
10,500	195	150	0	8	49	47	13	220	300	110
11,000	543	581	29	48	305	181	19	771	181	19
11,500	252	594	0	8	151	458	31	365	93	0
12,000	216	574	0	96	112	160	32	160	64	0
12,500	265	908	12	66	166	30	24	223	60	0
13,000	244	563	26	109	80	73	31	182	88	0
13,500	304	1712	0	9	116	54	27	206	80	0
13,750	303	1611	24	16	125	8	32	202	89	8
14,000	109	144	5	15	7	4	0	17	11	0
14,500	154	154	4	0	6	0	4	6	3	0
15,000	119	144	4	0	1	1	0	5	4	0
15,500	63	127	3	0	3	1	0	8	3	0
16,000	69	74	0	1	2	4	1	5	2	0
16,500	448	508	27	3	2	10	17	27	7	0
17,000	516	649	31	0	7	9	27	27	31	0
Maximum value	543	1712	31	109	305	472	472	6536	6614	2243

Pollen Accumulation Rates

Age (yr B.P.)	Castanea	Ilex type	Ostrya/Carpinus	Alnus	Ericaceae	Gramineae	Cyperaceae
0	0	0	0	32	27	152	32
150	1260	3150	0	315	1102	157	157
500	195	186	21	11	60	0	7
1000	97	84	51	3	69	15	6
1500	146	84	46	29	117	8	17
2000	55	81	26	14	29	0	7
2500	101	74	11	13	50	11	3
3000	121	104	34	23	37	3	13
3500	186	88	145	0	88	10	0
4000	124	41	79	15	49	11	4
4500	314	63	206	45	242	0	44
5000	443	93	303	93	443	0	23
5500	485	39	252	524	233	116	78
6000	303	47	443	443	163	47	93
6500	961	87	349	379	175	0	116
7000	364	91	223	40	243	0	0
7500	664	58	245	58	361	12	35
8000	621	97	466	194	893	58	175
8500	405	0	405	423	37	74	110
9000	233	133	466	549	0	83	100
9500	50	0	998	873	25	100	349
10,000	71	12	154	225	12	18	184
10,500	13	0	178	275	0	34	144
11,000	10	0	523	362	0	95	457
11,500	13	0	505	124	0	31	380
12,000	0	0	170	107	0	11	517
12,500	0	0	48	199	0	72	971
13,000	0	0	50	124	0	41	856
13,500	0	0	116	80	0	54	840
13,750	0	0	40	97	0	178	1050
14,000	1	0	5	8	0	25	240
14,500	0	0	1	5	0	44	215
15,000	1	0	1	5	0	69	184
15,500	0	0	1	7	0	47	244
16,000	1	0	0	3	0	24	101
16,500	3	0	3	27	0	283	879
17,000	4	0	27	22	0	217	1231
Maximum value	1260	3150	998	873	1102	878	1231

Age (yr B.P.)	Pollen Accumulation Rates			
	Sanguisorba	Bidens type	Artemisia	Ambrosia type
0	0	42	5	211
150	0	0	79	1102
500	0	4	18	39
1000	0	3	6	51
1500	0	13	0	21
2000	0	7	0	24
2500	0	11	3	24
3000	0	3	0	13
3500	0	0	0	31
4000	0	4	4	11
4500	0	9	0	52
5000	0	23	35	58
5500	0	19	0	39
6000	23	70	47	70
6500	0	29	29	29
7000	0	30	0	40
7500	0	23	12	58
8000	0	78	0	19
8500	0	55	0	37
9000	0	50	67	50
9500	25	75	50	0
10,000	18	107	24	18
10,500	89	169	21	21
11,000	48	343	10	19
11,500	16	155	23	0
12,000	53	309	16	0
12,500	60	42	12	6
13,000	16	228	5	10
13,500	331	45	72	9
13,750	452	57	8	8
14,000	3	5	9	2
14,500	1	6	6	6
15,000	1	4	6	3
15,500	1	6	4	2
16,000	1	2	4	1
16,500	3	20	7	14
17,000	0	40	4	4
Maximum value	452	343	79	1102

APPENDIX F
PLANT MACROFOSSIL TABULATION

Plant Macrofossil Tabulation *

Species	Radiocarbon Age (thousands of yr B.P)					
	17	16	15	14	13.5	13
Pinus cf. strobus						
Picea needle fragments	2				1	1
Picea seeds				1	1	
Picea sterigma	1					
Abies balsamea needle fragments					1	
Tsuga canadensis needle fragments						
Tsuga canadensis needle petioles						
Gramineae undifferentiated	5	5	1		1	
Carex lenticular type	6	11	19	12	9	2
Carex comosa type						
Scirpus cyperinus type			1		4	6
Scirpus validus type		1				
Scirpus cespitosus type						
Scirpus americanus type						
Cyperus undifferentiated						
Cornus canadensis				1		
Galium	4	3		14	1	
Potentilla cf. palustris						
Vitis						
Polygonum lapathifolium type				1		
Isoetes megaspores				8		
Bryophytes	5	4	5	5	3	5
Insect fragments	5	5	5	5	4	5
Unknowns	1	3		4		1

* Numbers of specimens per 60 cubic cm of sediment

Plant Macrofossil Tabulation *

Species	Radiocarbon Age (thousands of yr B.P)				
	12	11	10	9	8
Pinus cf. strobus			1		
Picea needle fragments			3	87	5
Picea seeds					
Picea sterigma					
Abies balsamea needle fragments				2	
Tsuga canadensis needle fragments				5	2
Tsuga canadensis needle petioles				2	1
Gramineae undifferentiated				1	
Carex lenticular type	6	5	5	3	
Carex comosa type	1				
Scirpus cyperinus type	3	3	5		
Scirpus validus type					
Scirpus cespitosus type	1				
Scirpus americanus type				1	
Cyperus undifferentiated	2				
Cornus canadensis					
Galium		1	33	39	39
Potentilla cf. palustris		1			
Vitis				1	
Polygonum lapathifolium type					
Isoetes megaspores					
Bryophytes	4	4	4	2	1
Insect fragments	5	5	3	3	5
Unknowns	1		1		

* Numbers of specimens per 60 cubic cm of sediment

APPENDIX G
VEGETATION RECONSTRUCTION DATA

=====

VEGETATION RECONSTRUCTION

=====

Age (yr B.P.)	Abies	Acer	Betula	Carya	Fagus	Fraxinus	Juglans	Larix	Nyssa
0	0.0	17.6	7.4	10.4	1.7	0.0	0.0	0.0	0.0
1000	6.4	8.1	9.6	0.0	0.0	2.2	0.0	0.0	5.0
2000	0.0	10.1	13.9	5.7	2.6	3.7	.1	0.0	5.9
3000	0.0	10.4	10.4	5.4	1.6	2.4	0.0	0.0	5.2
4000	7.3	12.9	15.3	3.8	2.5	2.6	0.0	0.0	7.7
5000	0.0	10.3	12.8	1.2	3.5	4.4	0.0	0.0	12.1
6000	6.4	13.5	11.3	.5	1.9	2.0	0.0	0.0	7.4
7000	5.0	18.8	7.3	1.9	1.7	1.8	0.0	0.0	4.9
8000	0.0	6.4	16.4	4.3	3.1	4.2	.4	0.0	14.5
9000	9.7	11.9	10.7	0.0	1.7	2.8	0.0	0.0	7.3
10,000	12.6	6.1	11.7	0.0	1.8	2.5	0.0	0.0	8.0
11,000	24.2	12.1	1.7	.3	1.5	6.1	0.0	.7	4.7
12,000	17.0	11.9	.9	.9	0.0	9.2	0.0	0.0	3.8
13,000	15.5	5.7	1.7	0.0	0.0	5.2	.4	2.2	0.0
Maximum value	24.2	18.8	16.4	10.4	3.5	9.2	.4	2.2	14.5

=====

VEGETATION RECONSTRUCTION

=====

Age (yr B.P.)	Picea	Pinus	Populus	Quercus	Salix	Tilia	Tsuga	Ulmus
0	5.0	0.0	29.6	23.6	0.0	1.9	1.4	1.6
1000	11.5	0.0	18.4	25.4	.1	4.2	5.8	3.2
2000	10.4	0.0	10.1	30.6	0.0	0.0	5.5	1.5
3000	10.0	0.0	16.6	27.1	0.0	4.4	4.8	1.7
4000	12.8	0.0	4.2	23.8	0.0	0.0	6.3	.8
5000	10.8	0.0	12.0	18.5	0.0	4.6	10.0	0.0
6000	7.4	0.0	19.8	17.5	0.0	0.0	12.3	0.0
7000	9.3	0.0	23.8	14.8	.7	4.1	5.3	.8
8000	12.1	0.0	4.4	19.7	0.0	3.5	10.2	.9
9000	11.0	0.0	8.0	12.0	0.0	0.0	22.7	2.1
10,000	16.4	7.0	4.2	10.4	0.0	3.3	14.0	2.1
11,000	19.1	2.6	6.3	16.7	.2	0.0	1.5	2.2
12,000	29.7	.3	17.4	5.8	2.5	0.0	0.0	.6
13,000	33.9	2.0	19.6	7.8	3.4	0.0	0.0	2.8
Maximum value	33.9	7	29.6	30.6	3.4	4.6	22.7	3.2

VITA

Peter Andrew Larabee was born in Schenectady, New York on March 12, 1960. He attended Severna Park High School and graduated in June 1978. The following September he entered Saint Lawrence University, and in May 1982 he received a Bachelor of Science degree with honors in Geology.

After a provisional course of study the following fall at University of Alaska, Fairbanks, he entered The Graduate School in Geological Sciences at the University of Tennessee, Knoxville in September 1983.

He was married to Elizabeth Morgan Hill in August 1982 and became a father in February 1986 with the birth of Shannon Morgan.