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LATE-QUATERNARY PALEOECOLOGIC, GEOMORPHIC, AND PALEOCLIMATIC HISTORY OF FLAT LAUREL GAP, BLUE RIDGE MOUNTAINS, NORTH CAROLINA

A Thesis

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David Scott Shafer

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ABSTRACT

Flat Laurel Gap, Haywood County, North Carolina, is a high-elevation (1,500 m) heath bald and bog. Colluvial and fluvial deposits, together with the sequence of fossil pollen spectra and plant macrofossils, provide a late-Quaternary record of landscape evolution for the Southern Appalachian Mountains.

Colluvial fans and periglacial block deposits (i.e., block-streams, blockfields, and talus) were mapped in the bog and its watershed in the vicinity of Mt. Pisgah. Thermoluminescence (TL) analysis at Flat Laurel Gap provides the first absolute-age determinations available for periglacial deposits in the Southern Appalachian Mountains. A TL date of 10,100±950 yr BP was obtained for sediments of a colluvial fan situated at the head of the bog. The colluvial fans represent late-Quaternary solifluction lobes, possibly related to episodic release of water and saturation of regolith that would accompany the collapse of discontinuous permafrost within the watershed during late-glacial and early-Holocene climatic amelioration. The TL date of 11,900±1,500 yr BP for a fluvial terrace in Flat Laurel Bog records the initial incision of late-glacial and early-Holocene dissection of the solifluction lobes and the formation of the modern alluvial-glade environment. A TL date of 7,400±1,000 yr BP for sediments within a blockstream entering the bog indicates reworking of Pleistocene periglacial material during a cool episode of the Holocene. A pegmatite dike exhumed during early-Holocene dissection

of the colluvial valley fill anchors the local base level for alluvial ponding and for Holocene deposition of organic sediments in the bog.

Three geomorphic surfaces are mapped within Flat Laurel Gap. Each surface is occupied by characteristic heath-bald plant communities: (1) topographically high colluvial fans with high-heath communities (Rhododendron and Kalmia shrubs more than 3 m in height); (2) dissected colluvial and alluvial terraces with low-heath communities (Kalmia and Vaccinium shrubs up to 3 m in height); and (3) active floodplain and stream channels with glade and wet-meadow communities (Sphagnum and Cyperaceae). A 3,340-year pollen record from an open alluvial glade indicates that heath shrubs have been the dominant extralocal vegetation at Flat Laurel Gap Bog for the late-Holocene interval, and documents the antiquity of some heath bald communities in the Southern Appalachians. The paleoecologic record also records the persistence of relict, boreal plant species at high-elevations of the Southern Blue Ridge through the late-Holocene interval. Abies fraseri, previously thought to have been extirpated from the Flat Laurel Gap/Mt. Pisgah area during the mid-Holocene Hypsithermal grew at Flat Laurel Gap in the late-Holocene until it was eliminated at the site during logging of the upland forests in the late nineteenth century (circa AD 1880).

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INTRODUCTION

The Southern Appalachian Mountains of the Blue Ridge Physiographic Province have been a center of debate concerning the extent of biotic, climatic, and geomorphic changes during glacial and post-glacial times (Deevey, 1949; Braun, 1950; Maxwell and Davis, 1972; Raymond, 1977; H. Delcourt, 1980). Recent investigations in the Central Appalachians and in areas at lower elevations surrounding the Southern Appalachians have provided a regional context for late-Quaternary paleoecological reconstructions (Watts, 1979, 1980; Delcourt and Delcourt, 1979, 1981). Speculations concerning full-glacial conditions in the Southern Appalachian Mountains, as extrapolated from studies of full-glacial conditions situated within perepheral areas of the Southeastern United States, hypothesize widespread boreal forests situated at low to mid-elevations (e.g., below 1,500 m) and severe periglacial conditions with alpine tundra occurring on peaks above 1,500 m (Watts, 1979; Delcourt and Delcourt, 1979, 1981; Whitehead, 1981). The modern ranges of many circumboreal species of plants extend south at high elevations in the Appalachians to the Southern Blue Ridge Province (Ramseur, 1960). The present distributions of these plant species may reflect remnants of once extensive boreal forests fragmented in areal distribution during the last 12,500 years of Holocene climatic warming (Delcourt and Delcourt, 1979). Geomorphological features of sorted, patterned ground, diagnostic of past periglacial environments, have been documented in the Central Appalachians (Clark, 1968) and Southern

Appalachians (King, 1964; Torbett, 1984; Clark, 1984). Blockfields and blockstreams, representing large block accumulations on upland slopes from 790 to 1,830 m elevation, and colluvial fans, from elevations of 610 to 1,600 m, have been mapped in the Southern Appalachians (Michalek, 1968); these relict geomorphic features have been attributed to periglacial conditions during the last glaciation (King, 1964; Michalek, 1968; Torbett, 1984). However, these interpretations concerning past periglacial regimes remain speculative as no absolute-age dates are available from these presumed Pleistocene deposits.

Previous syntheses of the late-Quaternary history of the Appalachian Highlands have examined either the geomorphology (Hack, 1960; Pewe, 1983) or the paleoecology of the region (Watts, 1979; Davis, et al., 1980). In this study, I have attempted to examine the interrelated response of geomorphic and vegetational processes to late-Quaternary climate change and to historic anthropogenic disturbances, based upon the paleoecologic, geomorphic, and paleoclimatic record at Flat Laurel Gap, Haywood County, North Carolina. This study area is situated at about 1,500 m along Pisgah Ridge in the southern section of the Blue Ridge Parkway. Flat Laurel Gap lies about 2.5 km south of Mt. Pisgah, one of a series of ten high-elevation areas in the Southern Appalachians (Ramseur, 1960). Flat Laurel Gap contains a small heath bald and bog whose sediments yield a plant-fossil record. The paleoecological sequence from Flat Laurel Gap offers important clues concerning the antiquity of heath balds, the extent of late-Holocene climatic fluctuations and their impact on the distribution of many rare and boreal plants, and the extent of historic anthropogenic

disturbance on the native vegetation of the Southern Appalachian Mountains.

The paleoecologic record is complemented by geomorphic analysis of a suite of landscape features in the area and the detailed mapping of periglacial, colluvial, and alluvial deposits within the watershed of Flat Laurel Gap Bog. Thermoluminescence (TL) analysis of these deposits provides the first absolute-age determinations available for periglacial deposits in the Southern Appalachians and for subsequent periods of landscape instability during the Holocene. Detailed mapping of the geomorphology and lithostratigraphy of the bog has helped to trace the development of high-elevation bog environments and the complex interaction of vegetation and geomorphic processes. In addition, quantitative studies of the relation of modern vegetation and pollen from local and extralocal plant communities (Jacobson and Bradshaw, 1981) were done at Flat Laurel Gap. In montane regions such as the Southern Appalachians with fairly high topographic relief and complex vegetation (Whittaker, 1956; Delcourt, et al., 1983; H. Delcourt, 1984), studies of the pollen-vegetation relationships are critical to interpreting the paleoecologic record from specific sites such as Flat Laurel Gap.

I. SITE INFORMATION

Flat Laurel Gap (Fig. 1) lies at an elevation between 1,475 and 1,500 m on the west side of Pisgah Ridge in Haywood County, North Carolina, at 35°24' N latitude and 82°45' W longitude (Cruso, NC, 7.5 minute series topographic quadrangle; Pittillo and Govus, 1978). Flat Laurel Gap lies within the Blue Ridge Parkway, National Park Service, U.S. Department of the Interior (parkway distance 658 km, 408.8 mi).

Flat Laurel Gap is a gently sloped, concave-profiled amphitheater-like area situated directly west of Pisgah Ridge (Fig. 2). The watershed of Flat Laurel Gap drains westward into Pisgah Creek. Flat Laurel Gap lies within the Blue Ridge Physiographic Province, an area characterized by high narrow ridges and steep, V-shaped valleys. The tightly folded gneisses, schists, and metasedimentary rocks underlying Flat Laurel Gap and the adjacent part of Pisgah Ridge constitute part of the Late-PreCambrian Great Smoky Group which unconformably lies upon Middle-PreCambrian layered gneisses and migmatites. These metamorphic rocks are locally cut by pegmatite dikes (Hadley and Wilson, 1971). Ridges range from 1,500 to 1,510 m in elevation immediately surrounding Flat Laurel Gap. Located 2.5 km north of Flat Laurel Gap, Mt. Pisgah rises to 1,744 m in elevation. Slopes within the area, including Mt. Pisgah, have an almost ubiquitous cover of colluvial material (Fig. 3). Talus occurs on some steep slopes (usually greater than 35°);

Figure 1. Location map of Flat Laurel Gap, Blue Ridge Parkway, Haywood County, North Carolina.

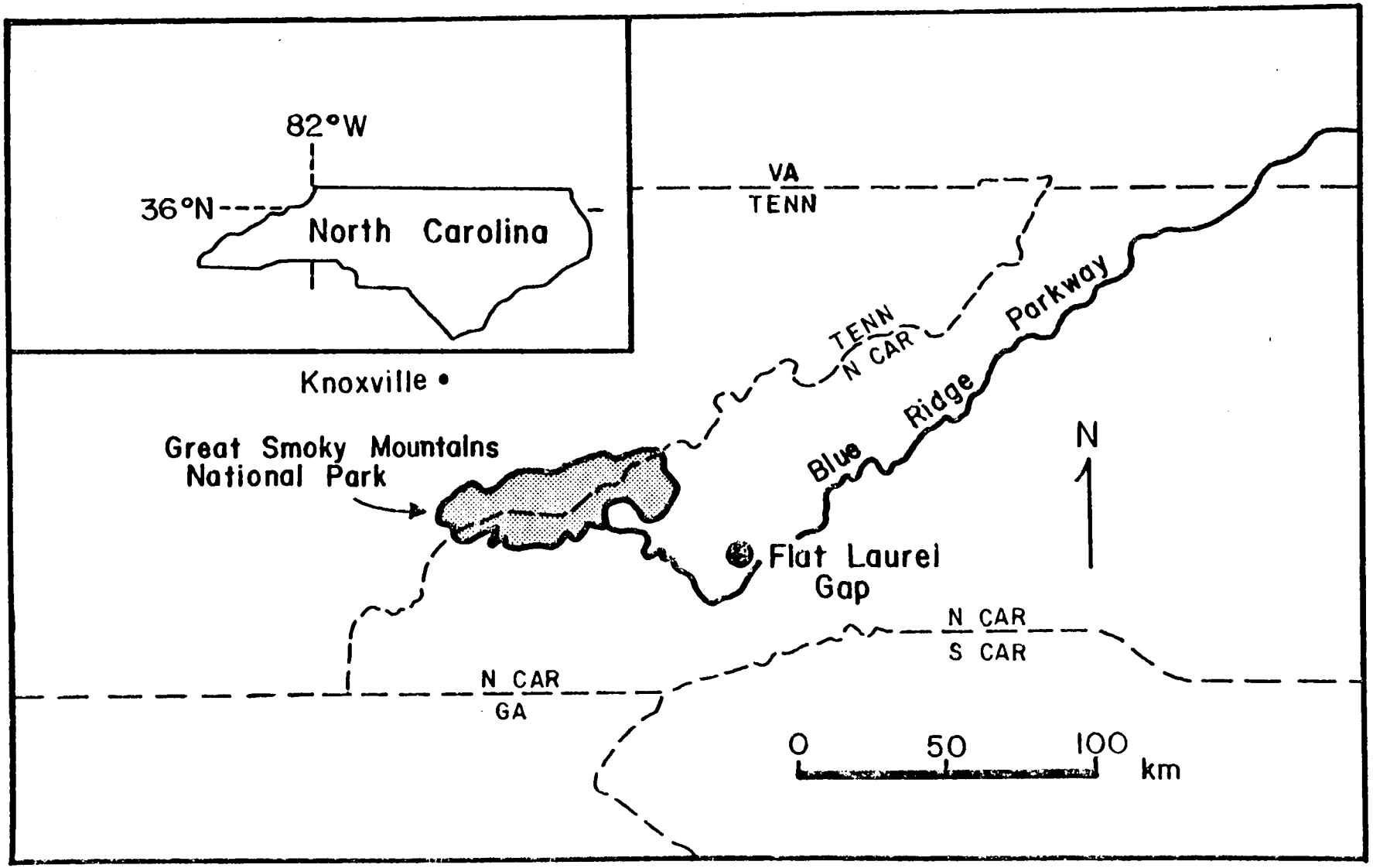

82°W
36°N
North Carolina
VA
TENN
TENN
N CAR
Knoxville
Great Smoky Mountains
National Park
Blue Ridge Parkway
N
Flat Laurel
Gap
N CAR
S CAR
N CAR
GA
0
50
100
km

Figure 1

Figure 2. Vicinity map of Flat Laurel Gap, including the summit of Mt. Pisgah and the northern segment of Pisgah Ridge.

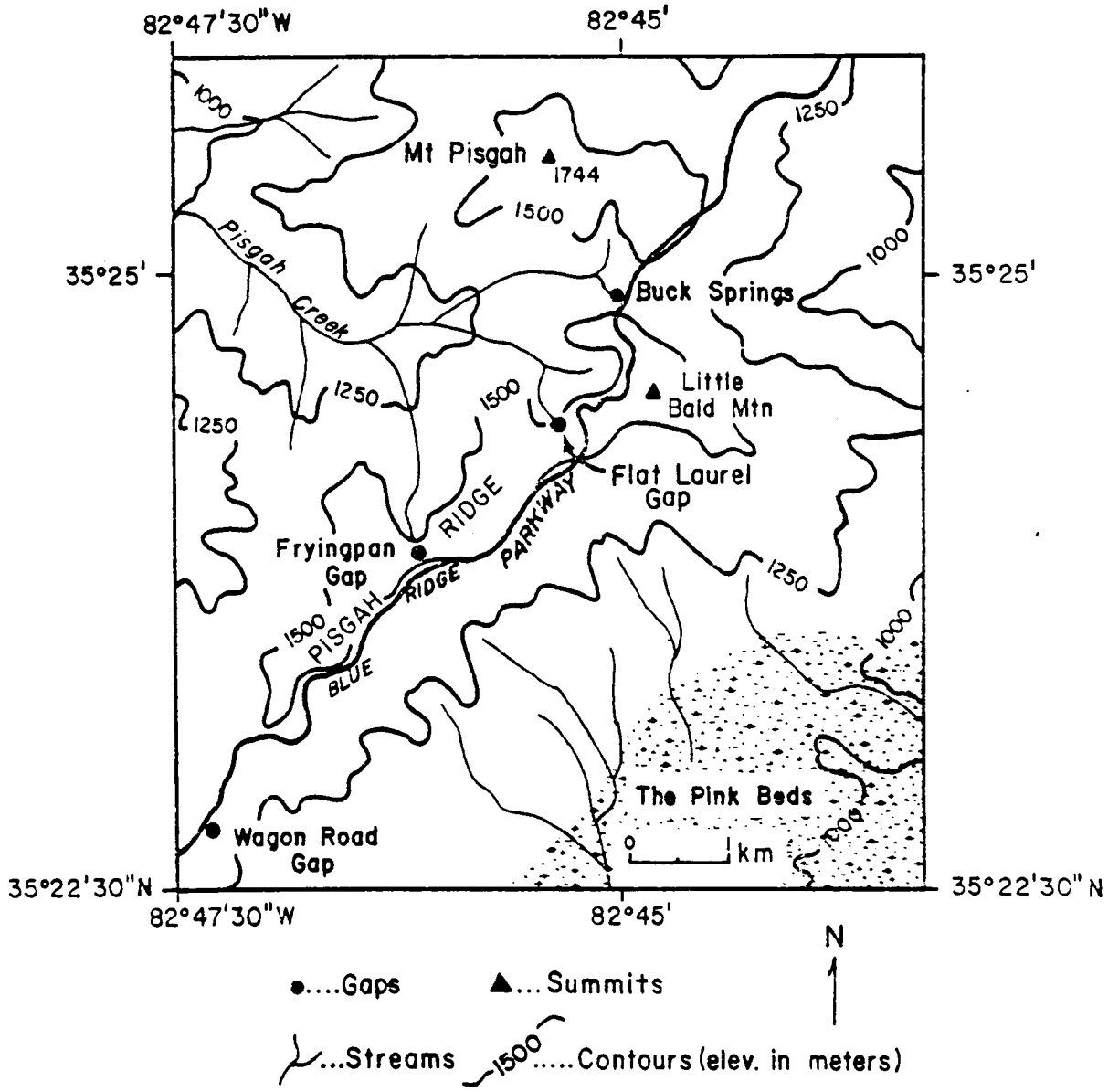

82°47'30"W
82°45'
35°25'
35°22'30"N
1000
1250
1500
Mt Pisgah
1744
Pisgah Creek
Buck Springs
Little Bald Mtn
Flat Laurel Gap
Fryingpan Gap
RIDGE
PARKWAY
PISGAH RIDGE
BLUE
The Pink Beds
Wagon Road Gap
0 km
N
●....Gaps
▲...Summits
...Streams
1500.....Contours (elev. in meters)

Figure 2

Figure 3. Colluvial and block deposits in the vicinity of Flat Laurel Gap from Big Bald Mountain to Little Bald Mountain.

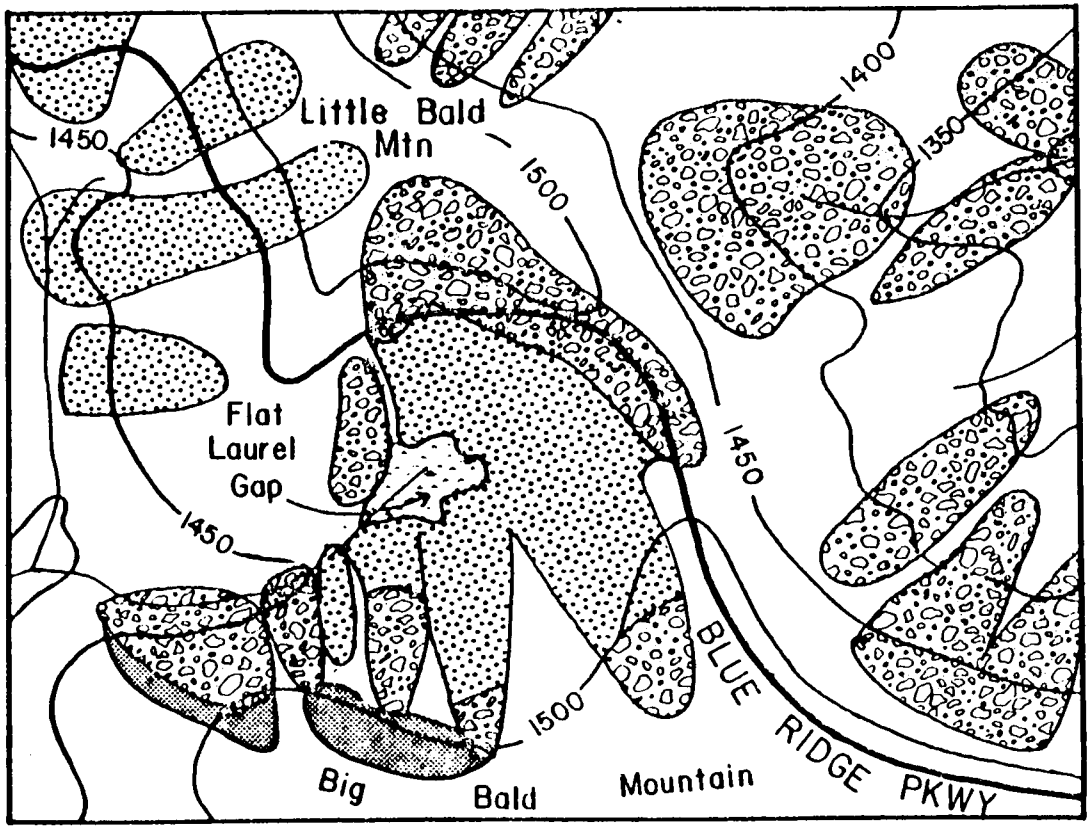

Little Bald Mtn
1450
1500
1400
1350
Flat Laurel Gap
1450
1450
1500
BLUE RIDGE PKWY
Big Bald Mountain
Talus
Colluvial fans
Blockstreams & Blockfields
Colluvial cover
Modern Floodplain
50 100 300 m
0 200
N
Contour Interval: 50m

Figure 3

blockstreams, blockfields, and colluvial fans occur on gentler slopes (usually less than 35^{o}) (Fig. 3).

The central part of Flat Laurel Gap is a bog and heath bald dominated by heath shrubs of the family Ericaceae and by grass wetlands or "glades" (Fig. 3). Locally within the bog, unvegetated areas of the modern floodplain are covered with an alluvial mantle of quartz pebbles, cobbles, and boulders. Three geomorphic surfaces exist within the bog: a topographically high, colluvial-fan surface; an intermediate level of low, dissected colluvial and fluvial terraces; and the modern floodplain and channels. Characteristic heath-bald communities exist on each of these surfaces.

The complex physiography and prevailing regional weather patterns make the Southern Appalachians an area of diverse local climates (Pittillo and Smathers, 1979). A mean annual temperature of $8.3^{o}C$ is estimated for Flat Laurel Gap based on a lapse rate of $0.6^{o}C$ per 100 m elevation change between Asheville and Mt. Mitchell, North Carolina (Pittillo and Smathers, 1979). Annual precipitation varies from 1,519 mm at Balsam Gap to 2,195 mm in the Richland Balsams, about 20 km south from Flat Laurel Gap. No distinct "wet" or "dry" season occurs on the Balsam/Pisgah Ridge although a relative decrease in precipitation occurs during the fall. During the winter, snow may accumulate to approximately 1,300 mm on the highest mountain peaks and persist into late April. The Pisgah Ridge/Balsam Mountains area has the highest annual precipitation levels in the eastern United States (Pittillo and Smathers, 1979).

Because of the great relief of the Southern Appalachians (over 1,500 m), there is a zonal distribution of forest-vegetation (Braun, 1950; Whittaker, 1956). Three vegetation zones are identified in the Flat Laurel Gap area (Ramseur, 1960). The Appalachian Oak Forest (formerly the Oak-Chestnut Forest) typically occurs between 400 and 1,370 m elevation. This zone had American Chestnut (Castanea dentata) as a co-dominant before nearly all mature chestnut trees were killed by passage of the introduced chestnut blight through the region between AD 1925 and AD 1935 (Anderson, 1974). Today, Castanea dentata has been replaced by species of oak (Quercus) and hickory (Carya) (McCormick and Platt, 1980). Tulip poplar (Liriodendron tulipifera) is an important constituent at lower elevations in the Appalachian Oak Forest but is replaced by Quercus at higher elevations. The Appalachian Oak Forest frequently has an understory of ericaceous shrubs (Braun, 1950). Hemlock is locally abundant in more mesic sites (Pittillo and Smathers, 1979). At mid-elevation sites (above 1,370 m), the Appalachian Oak Forest gives way to the Mixed Northern Hardwood Forest (Braun, 1950). Though oaks are abundant in this zone, especially on more xeric slopes (Pittillo and Smathers, 1979), beech (Fagus grandifolia), maples (Acer saccharum, A. spicatum, and A. pensylvanicum), and white pine (Pinus strobus) are important constituents. Viburnum is locally an important understory tree (Braun, 1950). Flat Laurel Gap is situated within the Mixed Northern Hardwood Forest but near the transition zone or ecotone with the Spruce-Fir Forest. Occurring generally at elevations above 1,500 m, the Spruce-Fir Forest is characterized by a canopy of red spruce (Picea rubens) and Fraser fir (Abies fraseri)

(Whittaker, 1956). The Spruce-Fir Forest ecosystem is similar to low-elevation boreal forests in Maine and Nova Scotia; however, in the Northeast the species of fir is balsam fir (Abies balsamea) instead of Abies fraseri (Shanks, 1954). Abies fraseri is restricted to the Southern Appalachian Mountains (Ramseur, 1960). Despite its relatively high elevation, Mt. Pisgah (1,744 m) conspiculously lacks a Spruce-Fir Forest. However, Spruce-Fir Forests occur in the Balsam Mountains 18 km south of Flat Laurel Gap (Ramseur, 1960). Heath balds and grass balds are common at high elevations (1,300-1,800 m) within both the Mixed Northern Hardwood Forest and the Spruce-Fir Forest (Whittaker, 1956; Ramseur, 1960).

In the immediate vicinity of Flat Laurel Gap red oak (Quercus rubra) and Picea rubens are the dominant canopy trees on the ridgetop (Big Bald Mountain) southwest of the bog (nomenclature of plants follows Radford, et al., 1968). Serviceberry (Amelanchier arborea), beaked hazelnut (Corylus cornuta), blackberry (Rubus canadensis), hawthorne (Crataegus flabellata), swamp azalea (Rhododendron viscosum), and smooth azalea (Rhododendron arborescens) are dominant understory trees and shrubs. Ridges northeast of the bog are dominated by northern red oak (Quercus rubra var. borealis). Other important species include disturbance-favored taxa such as yellow birth (Betula alleghaniensis), cherry birth (Betula lenta), and fire cherry (Prunus pensylvanica). Scattered Picea rubens also occur. Slopes are dominated by Quercus rubra and Betula alleghaniensis; stump sprouts of Castanea dentata are still common. A small remnant of primeval forest exists 1.5 km north of Flat Laurel Gap near Buck Springs (Fig. 2, p. 7).

Typical of the presettlement vegetation in the area, this remnant of late-successional forest is dominated by Picea rubens and eastern hemlock (Tsuga canadensis) with an understory of purple laurel (Rhododendron catawbiense) and great laurel (Rhododendron maximum). Vegetation descriptions were prepared with the assistance of Dr. Dan Pittillo, Western Carolina University.

Flat Laurel Gap has a heath flat containing shrub thickets (called "heath slicks") and grass wetlands. Representatives of the family Ericaceae, especially Rhododendron catawbiense, R. maximum, mountain laurel (Kalmia latifolia), and blueberry (Vaccinium constablaei) dominate the heath-bald vegetation of the bog. Other Ericaceae at the site include Rhododendron arborescens, R. viscosum, fetterbush (Leucothoe recurva), male-berry (Lyonia ligustrina), highbush blueverry (Vaccinium corymbosum), and lowbush blueberry (V. vacillans). Scattered among the heaths, especially in the head of the bog below Pisgah Ridge, are trees and shrubs including mountain ash (Sorbus americana), mountain holly (Ilex ambiqua var. montana), Amelanchier arborea, virburnum (Virburnum cassinoides), elderberry (Sambucus canadensis), red maple (Acer rubrum), tag alder (Alnus serrulata), and Rubus canadensis. Local stands of Picea rubens exist on higher, well-drained colluvial surfaces within the bog. The heath-shrub communities in the bog are broken by open-glade communities with grasses and sedges, along with Sphagnum species, turtlehead (Chelone species), dodder (Cuscuta pentagona), and cinnamon fern (Osmunda cinnamomea) (Pittillo and Govus, 1979; Horton and Totaling, 1981).

Human disturbance at Flat Laurel Gap began around AD 1875-1885 with the commencement of widescale logging of the upland forests in this part of the Southern Appalachians (Ashe and Ayres, 1911). However, at least part of Flat Laurel Gap was spared complete forest clearance; it became part of the George Washington Vanderbilt forest estate around AD 1888. The boundary of this forest reserve ran down the center of the main axis of Flap Laurel Gap. The summit of Mt. Pisgah became part of the estate in AD 1897. In AD 1914, the U.S. Forest Service purchased 80,000 acres around Mt. Pisgah to include in what is today the Pisgah National Forest. Construction of the original Pisgah Inn began in 1917; the modern facility at the head of Flat Laurel Gap was finished in 1967. Completion of the Blue Ridge Parkway Road was accomplished in the early 1960s as was construction of the campground which today surrounds the bog at Flat Laurel Gap.

II. METHODS

Comparison of Modern Vegetation and Pollen Rain

Comparisons were made between values of relative percent cover and percent pollen for some of the plant species forming the vegetation within Flat Laurel Gap. A total of eight 10 m x 10 m vegetation plots were sampled; one modern pollen sample was obtained from moss polsters situated in the geographic center of each vegetation plot. The eight vegetation plots, relocated for this study, represent plots initially sampled by Horton and Hotaling (1981) in a previous analysis of the vegetation of Flat Laurel Gap Bog. These plots are located at various distances perpendicular to a transect of 335.5^{o} along the main axis of the bog (see inset map, Fig. 4). Dr. Dan Pittillo identified vascular plants and cryptograms encountered on the transect. He verified and ammended, where necessary, the original analysis of the vegetation in each plot using the releve method of vegetation analysis (Mueller-Dombois and Ellenberg, 1974). For each plant species, a percent-cover value (i.e., area occupied by each plant species within the plot) was noted for each stratum. A total value for percent cover was obtained for each species by summing the percent-cover values for all vegetational strata for that species. A relative percent-cover value was calculated for each species using the following relationship:

Figure 4. Late-Quaternary deposits and their geomorphic surfaces within the watershed of Flat Laurel Gap, Haywood County, North Carolina. Colluvial block and alluvial deposits are mapped on the upland slopes around the bog as well as within the bog. Outcrops of the pegmatite dike are indicated with X's. Campground-road network is shown on inset map.

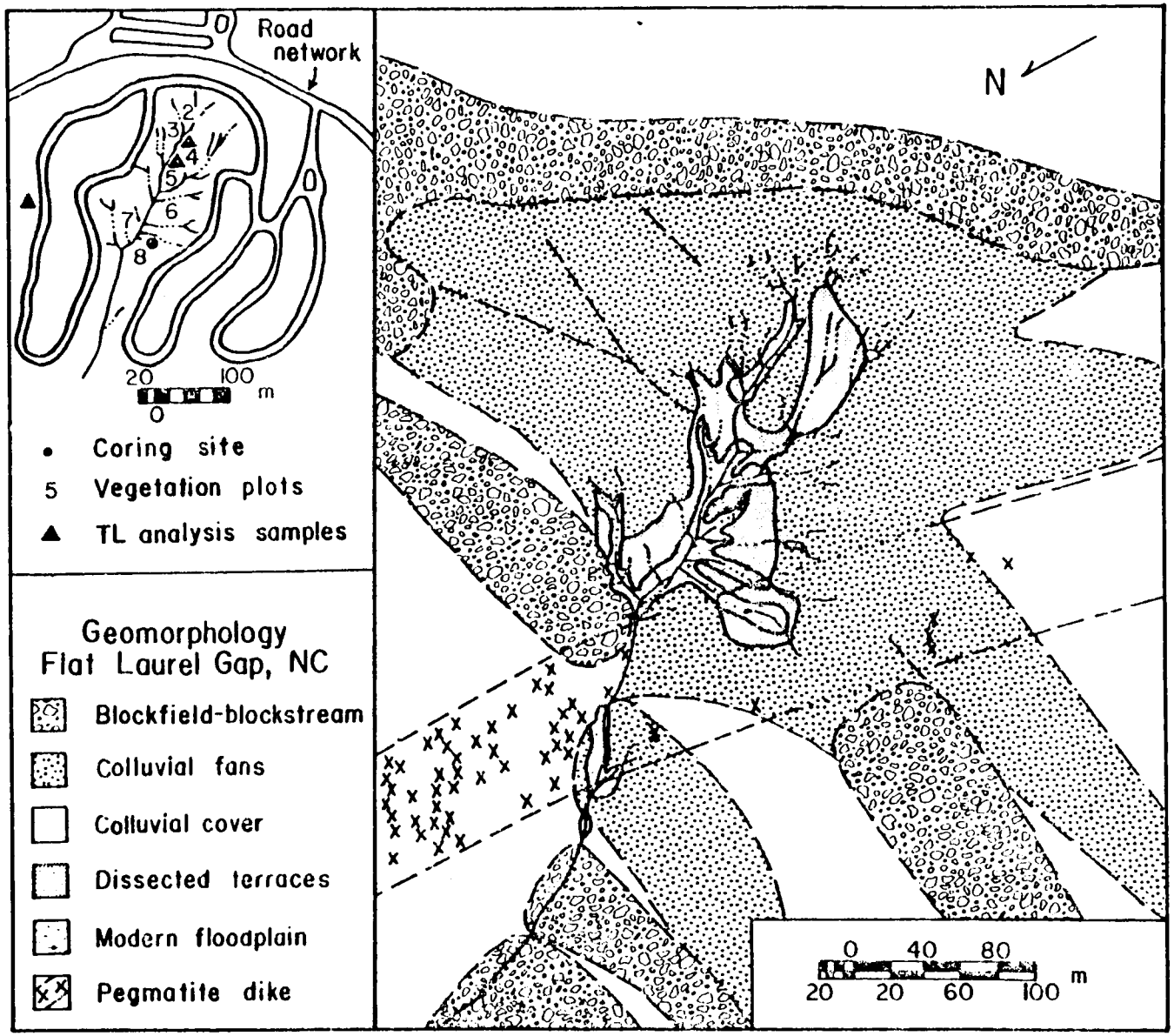

Road network
1
2
3
4
5
6
7
8
20
100
m
0
Coring site
5 Vegetation plots
TL analysis samples
Geomorphology
Flat Laurel Gap, NC
Blockfield-blockstream
Colluvial fans
Colluvial cover
Dissected terraces
Modern floodplain
Pegmatite dike
N
0
40
80
20
20
60
100
m

Figure 4

$$\text{Relative Percent Cover of Species A in Plot X} = \frac{\text{Percent Cover of Species A}}{\text{Percent Cover of all species in all strata in Plot X}} \times 100$$

Relative percent-cover values and percent-pollen values were then plotted as a function of distance along the topographic profile. The same pollen sums were used for both the modern pollen samples and for the paleoecologic pollen record. Where pollen morphological types are produced by several biological taxa (e.g., the two genera of Amelanchier and Sorbus that produce the Amelanchier/Sorbus pollen type), the relative percent-cover values for all component species were polled for direct comparison with the pollen percentages.

Paleoecology Field and Laboratory Techniques

Flat Laurel Gap Bog was cored in July of 1983 by a field crew consisting of myself, Paul Delcourt, Hazel Delcourt, and J. Dan Pittillo (Western Carolina University). A sediment core was obtained to a depth of 162 cm below the sediment surface. A 20 cm x 20 cm x 17 cm sediment monolith was collected to permit detailed analysis of the upper 17 cm of sediment consisting of humified sphagnum peat. A 5 cm-diameter square-rod piston corer (Wright, 1967) was used to collect the remainder of the core. The sediment between 30 and 70 cm in depth was water-saturated and unconsolidated; it could not be recovered in the core and was consequently recovered by hand at 5 cm intervals. Sets of sediment core were collected in the field to collect duplicate material. These sediments were extruded, lithologically described, wrapped in plastic wrap and aluminum foil,

labeled at the site, and then transported to the University of Tennessee where they were stored at $4^{o}C$ in a cold room. Samples of 1 cm^3 sediment volume were collected for loss-on-ignition analysis at 5 cm intervals throughout the sedimentary sequence. One set of volumetric samples was heated at $100^{o}C$ and then at $550^{o}C$ to determine the amount of water and organic matter present in the sediment. The procedure for loss-on-ignition analysis (LOI) follows that of Dean (1974).

The sediment core was subsampled using a calibrated 1 cm^3 brass sampler (H. Delcourt, 1979) at 2.5 cm intervals for the core section from 0 to 15 cm and at 5 cm intervals for the core section from 20 to 100 cm. Pollen samples were prepared using standard extraction techniques (Faegri and Iversen, 1975; H. Delcourt, 1979). No native pollen grains were recovered below 100 cm in the core. Eucalyptus tablets were added to each palynological sample processed to permit calculation of pollen influx rates (Maher, 1977).

Pollen grains were identified and tabulated using a Leitz Dialux-20 microscope with 12.5X eyepieces and 40X NPL objective (numerical aperature 0.70). A 100X NPL oil-immersion objective (numerican aperature 1.32) was used to identify unknown grains. The pollen grains were counted in evenly spaced transects until a minimum count of 300 arboreal pollen grains was reached and one-half or an entire coverslip of the microscope slide was traversed. Palynomorph grains were identified using two sources: reference slides of modern palynomorphs in the Program for Quaternary Studies of the Southeastern United States (Delcourt and Delcourt, 1982); and standard keys, texts,

and papers concerned with specific taxa (Helmich, 1963; Erdtman, 1966; Kapp, 1969; Richard 1970a, 1970b, and 1970c; McAndrews, et al., 1973; Basset, et al., 1978; Lieux, 1980a, 1980b; and Lieux and Godfrey, 1982). A key (Appendix 17) was develcped for the family Ericaceae based upon pollen reference slides and a compilation of descriptions of palynomorphs (Ikuse, 1956; Hyde and Adams, 1958; Janssen, 1967; Kapp, 1969; Heusser, 1971; Huang, 1972; McAndrews, et al., 1973; Nilsson, et al., 1977; Basset, et al., 1978; Adams and Morton, 1979; Comptois and LaRouche, 1981; Lieux and Godfrey, 1982). Broken halves of Abies, Picea, Pinus, and Osmunda grains were tallied separately, and tetrads of Ericaceae were counted as single dispersal units of pollen.

From a paried core to the one used for pollen and loss-on-ignition analysis, 50 cm^3 samples centered at 5 cm intervals for the core were collected from 0 to 100 cm and then wet-sieved for plant-macrofossil analysis. The plant macrofossils were extracted from the sediment residue and preserved using standard techniques (Wasylikowa, 1979). Extraction and identification of the macrofossils was done with a Bouch and Lomb binocular microscope at a magnification of 15X. Macrofossils were identified using standard keys, texts, and papers dealing with specific taxa (Durrel, 1916; Martin and Barkley, 1961; Berggren, 1969; Schopmeyer, 1974; Montgomery, 1977; Godfrey and Wooten, 1979; and Berggren, 1981). Reference material of modern and fossil seeds, leaves, fruits, and other vegetation material available in the Plant-Macrofossil Reference Collection in the Program for Quaternary Studies of the Southeastern United States were also used to identify plant material. For samples collected from 30 to 70 cm depth, the volume

of the samples was sometimes less than 50 cm^3. Consequently, macrofossil counts for such levels were adjusted by extrapolating values to a standardized 50 cm^3 volume to facilitate comparison of the data.

Palynologic Statistical Techniques

Percentages of tree (arboreal) pollen were calculated based on the Arboreal Pollen (AP) sum, consisting of a minimum of at least 300 arboreal grains. Percentages of shrubs, lianas, herbs, mosses, ferns and unknown grains were calculated based on the sum of total pollen grains and spores of upland plants (Upland Pollen and Spore Sum), the total grains in these categories of nonarboreal (NAP) and the AP sum. All pollen types of Ericaceae (except Monotropa) were classified as shrubs. The percentages of aquatic plants were calculated based on the Upland Pollen and Spore Sum plus the sum of pollen grains and spores of obligate-aquatic plants. The percentage of indeterminable grains (i.e., grains that could not be identified because of poor preservation or because they were obscured on the slide) was based on the total number of all palynomorph grains counted.

Influx rates for pollen and spore grains were calculated using the following equation (Davis, et, al., 1973; H. Delcourt, 1979).

$$I = \frac{n}{c}(a)(b)(d)$$

where I equals the palynomorph influx rate ($grains \cdot cm^{-2} \cdot yr^{-1}$), n is the number of pollen and spore grains tallied at a stratigraphic level, a is the number of Eucalyptus grains per tablet, b is the number of Eucalyptus tablets added per cm^3 of sediment, c equals the number of

Eucalyptus grains tallied at that stratigraphic level, and d is the sedimentation rate (cm/yr).

Constrained single-link cluster analysis (CONSLINK) in the computer program ZONATION was used to objectively establish informal pollen-assemblage zones from the fossil-pollen sequence (Birks, 1979). Only pollen grains and spores of non-aquatic plants representing 1% or more of the Upland Pollen and Spore Sum were used in the cluster analysis.

Geomorphology Field and Laboratory Techniques

The areal extent of modern floodplain, colluvial cover, colluvial fans, blockstreams and blockfields, and talus deposits was mapped from a combination of field inspection and analysis of black and white stereographic-photos (photographs 184-NE, 1966, TVA, scale: 1 cm to 240 m) and a color aerial photo (BRP-NC, 30-9, 1979, scale: 1 cm to 60 m) in the vicinity of Flat Laurel Gap (Fig. 3). More detailed mapping was conducted within the immediate watershed of the bog. For reconnaissance mapping, the lateral traces of the deposits were plotted on the USGS 7.5 minute topographic map of the area (Cruso, NC, 1941, photo-revised 1979); for detailed mapping, the late-Quaternary deposits were delineated on large-scale topographic maps (scale: 1 cm to 24 m, 1.52 m contour level) of Flat Laurel Gap supplied by R. G. Bruce at the Blue Ridge Parkway (National Park Service) office in Asheville, North Carolina, as well as on the black and white stereographic-photos.

Criteria for distinguishing different Quaternary deposits follow definitions by Washburn (1973), Michalek (1968), and Embelton and

King (1975). Talus is accumulations of rock debris at or near the angle of repose (30^{o} to 40^{o}) on a slope at the base of a ledge or cliff. Blocks are frequently chaotically piled atop one another. Typically, talus has a longer horizontal dimension. Blockfields and blockstreams are unconsolidated deposits of irregular, contiguous boulders with a finer-grained matrix. They occur on slopes varying from near 0^{o} to as high as 35^{o}. Blockfields and blockstreams are distinguished from one another in that the latter are relatively narrow and elongated downslope, whereas the former have a longer dimension parallel to slope. On steeper slopes blockstreams and blockfields may be transitional with talus and frequently display imbrication of the blocks. Blockstreams, blockfields, and talus all have greater than 50% surface boulder cover (Michalek, 1968).

Colluvial fans are cone- or fan-shaped deposits composed of a non-sorted mixture of boulders, cobbles, sand, and finer components; frequently there is a concentration of boulders on their surfaces. Colluvial fans bear some resemblance to alluvial fans of arid regions; however, colluvial fans typically do not have a conspicuous hollow or major drainage behind them (Michalek, 1968). Colluvial fans have less than 50% surface boulder cover (Michalek, 1968). The fans usually have a broad convex profile, similar to blockstreams, which grades gradually into the adjacent slopes. In addition to the concentrated colluvial and boulder deposits around Flat Laurel Gap, there is a nearly ubiquitous cover, less than 3 m thick, of colluvial material over other areas. This colluvial cover also has less than 50% surface boulder cover, but lacks the geomorphic profile of colluvial fans.

The modern floodplain is a low-lying, relatively flat area adjacent to the channels in Flat Laurel Gap; it is subject to periodic flooding such as during spring runoff. A boulder lag has developed on the modern floodplain locally in Flat Laurel Gap; the cover of boulders is less than 50% of the alluvial surface.

A topographic profile of Flat Laurel Gap Bog was constructed following the same transect along the 335.5^{o} bearing used by Horton and Hotaling (1981) and resurveyed during this study for the analysis of the vegetation plots in the bog. Slope measurements were taken using a Suunto inclinometer between survey stations 5 m apart along the transect. Where there were major topographic irregularities between stations, slope measurements were taken over shorter distances. In addition, at each 5 m station, a soil probe was used for qualitative characterization of the sediment lithology underlying each geomorphic surface.

Cross-valley topographic profiles of Flat Laurel Gap were constructed by using the 1.52 m (5 ft) contour-interval site-planning maps supplied by the National Park Service. The topographic profiles were extended to the ridgecrest with coarser resolution using the 7.5 minute USGS topographic map of the area (Cruso, 1941, photorevised 1979, 12.2 m (40 ft) contour interval). A pegmatite dike, passing through the central part of the bog, was mapped by determining the locations of individual outcrops of vein quartz on the detailed site-planning maps. The dike trends approximately N10W50E and varies between 75 and 85 m in width.

III. RESULTS

Modern Relationships of Pollen and Vegetation

Comparisons between relative percent cover and percent-pollen values at Flat Laurel Gap indicate good correspondence in the pattern of the pollen and vegetation curves for many taxa (Fig. 5 and 6). "Local vegetation" represents that growing within 20 m of the coring site while "extralocal vegetation" represents that growing from 20 to 200 m from the site (Jacobson and Bradshaw, 1981). Such comparisons between vegetation and pollen helps to determine the extent of pollen dispersal between the different vegetation communities at Flat Laurel Gap (H. Delcourt, 1984). In addition, different geomorphic surfaces in the bog can be characterized by certain vegetation assemblages, based on results from the eight vegetation plots. Taxa of Ericaceae for which pollen/vegetation curves were constructed include Rhododendron, Kalmia latifolia, Vaccinium constablaei, Leucothoe recurva, and Lyonia ligustrina-lucida type, as well as total Ericaceae. Other important ferns, mosses, herbs, shrubs, and trees analyzed include Osmunda, Sphagnum, Cyperaceae, Poaceae, Viburnum, Sambucus, Ilex, and Amelanchier/Sorbus.

Note that while the results of the eight vegetation plots were graphed as a function of distance along the topographic profile of the bog, the plots were centered 2 to 12 m perpendicular to the transect

Figure 5. Modern vegetation and pollen comparisons for heath shrubs and herbs in the local and extralocal vegetation in Flat Laurel Gap Bog. C% refers to relative percent-cover values while P% is the percent pollen based on the Upland Pollen and Spore Sum. Relative percent-cover values and pollen percentages from each vegetation plot are plotted as a function of distance along the topographic transect of the bog (see base of diagram).

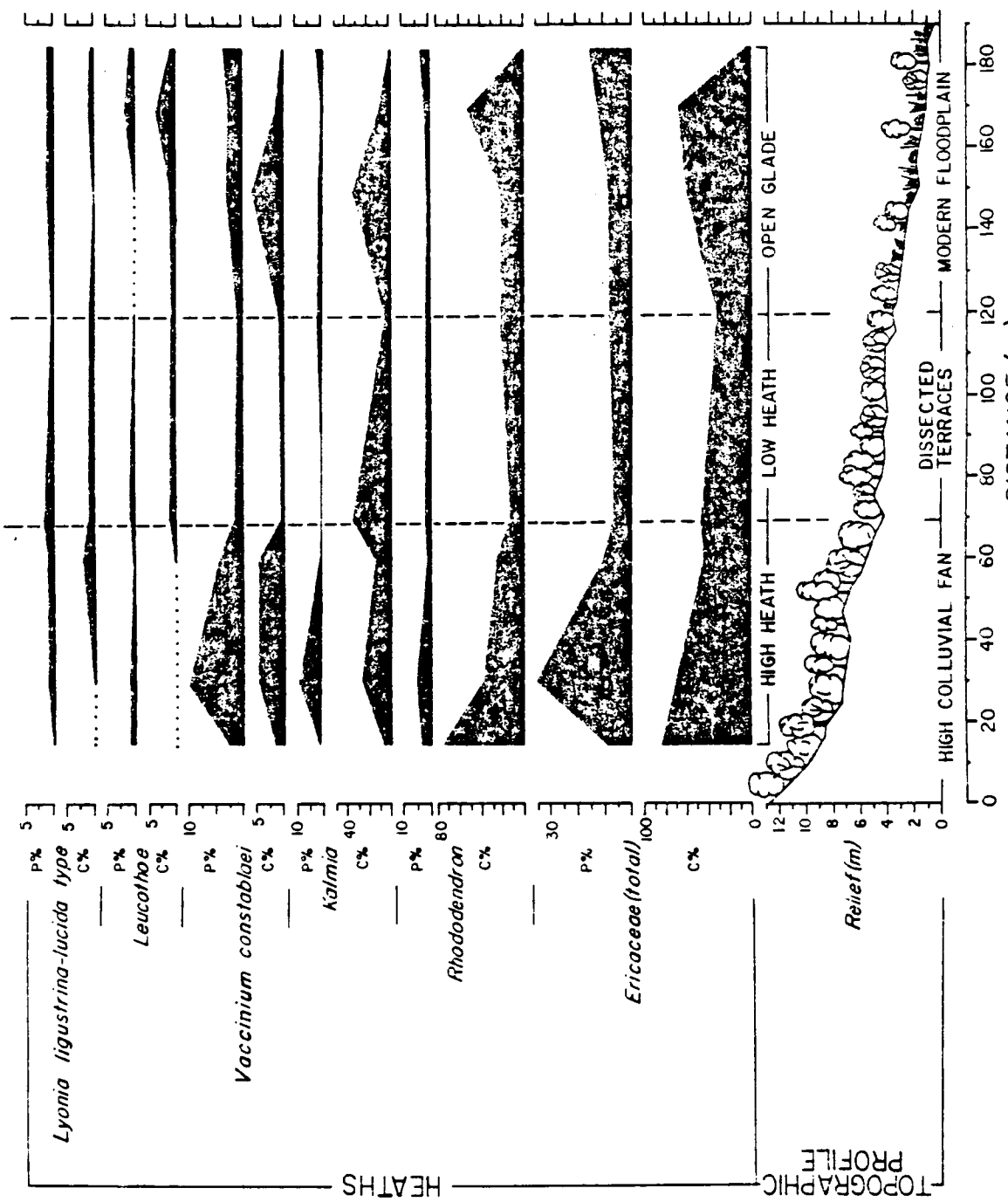

HEATHS
TOPOGRAPHIC PROFILE
Lyonia ligustrina-lucida type
Leucothoe
Vaccinium constablaei
Kalmia
Rhododendron
Ericaceae (total)
Relief (m)
P%
C%
HIGH HEATH
LOW HEATH
OPEN GLADE
HIGH COLLUVIAL FAN
DISSECTED TERRACES
MODERN FLOODPLAIN
DISTANCE (m)

Figure 5

Figure 6. Modern vegetation and pollen comparisons for some components, excluding heaths, of the local and extralocal vegetation at Flat Laurel Gap Bog. C% refers to relative percent-cover values while P% is the percent pollen based on the Upland Pollen and Spore Sum. Relative percent-cover values and modern pollen percentages from each vegetation plot are plotted as a function of distance along the topographic transect of the bog. Pollen percentages are calculated from the same sums as used for the fossil pollen spectra.

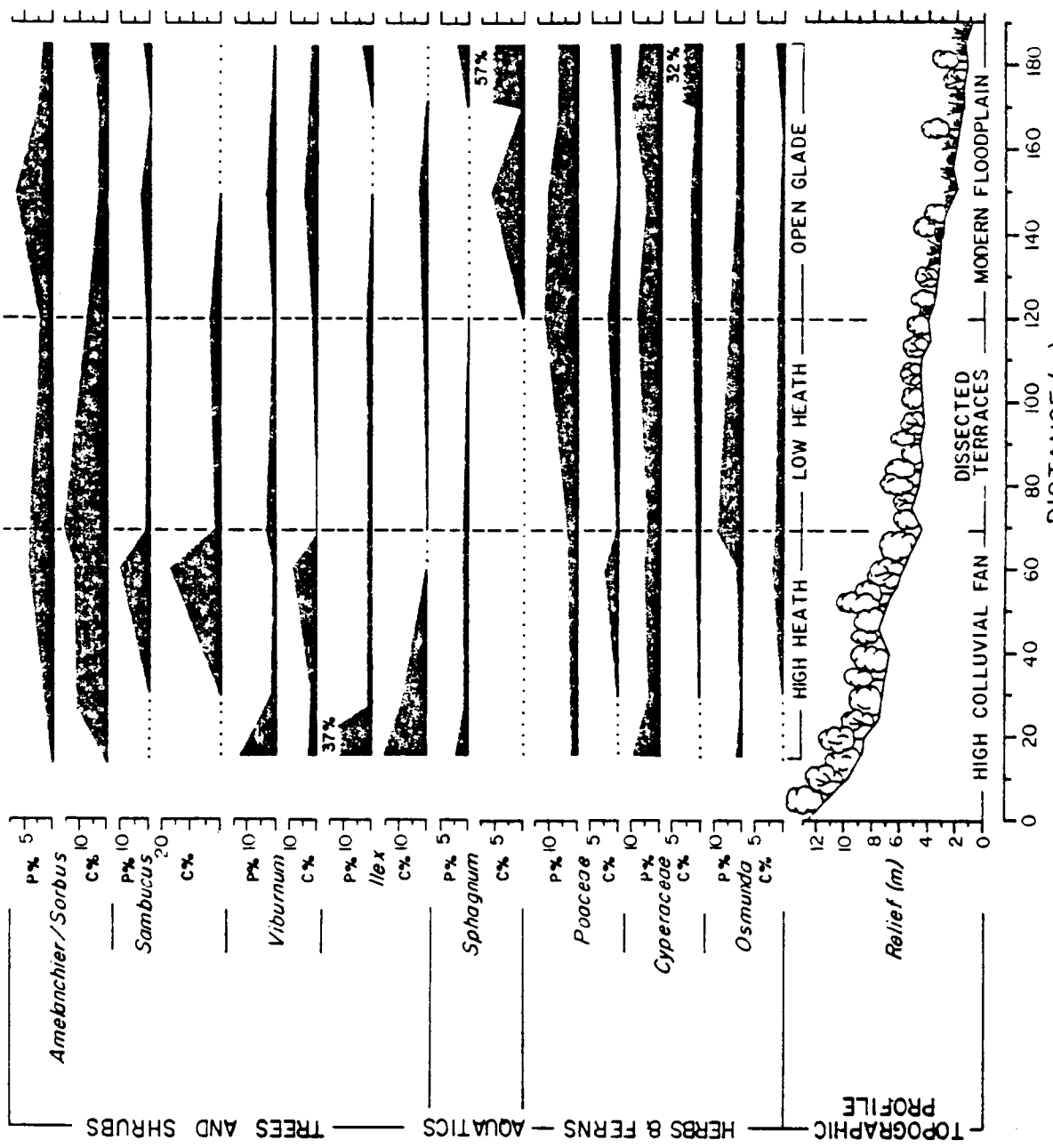

TREES AND SHRUBS
AQUATICS
HERBS & FERNS
TOPOGRAPHIC PROFILE
Amelanchier/Sorbus
Sambucus
Viburnum
Ilex
Sphagnum
Poaceae
Cyperaceae
Osmunda
Relief (m)
P%
C%
37%
57%
32%
HIGH HEATH
LOW HEATH
OPEN GLADE
HIGH COLLUVIAL FAN
DISSECTED TERRACES
MODERN FLOODPLAIN
DISTANCE (m)

Figure 6

along offsets for random sample design. Consequently, species lists prepared for each plot and pollen assemblages obtained from moss polsters in part reflect vegetation not typical of the vegetation at the corresponding position along the transect. For example, though the offset point for plot 5 is on the high colluvial fan surface, the vegetation plot is partly on the dissected terrace surface and consequently partly reflects the vegetation of that surface.

In the local and extralocal vegetation, Ericaceae are consistantly underrepresented in the modern pollen rain. Underrepresented taxa are those whose contribution to the pollen rain is proportionally less than their abundance in the vegetation (Delcourt, et al., 1984). For example, total Ericaceae in four plots exceeds 50% of the relative percent-cover values in the vegetation; however, the greatest percentage for Ericaceae pollen was 35% of the Upland Pollen and Spore Sum. However, several Ericaceae show good matches in the pattern of their percent-cover and percent-pollen curves including Vaccinium constablaei, Rhododendron, and to a lesser degree, Kalmia latifolia. Rhododendron is probably the least represented Ericaceae in the local and extralocal pollen rain at Flat Laurel Gap. In contrast to the Ericaceae, Sambucus and Viburnum exhibit a close correspondence between pollen and vegetation curves. Ilex, Osmunda, and Poaceae appear overrepresented in the pollen rains with respect to local and extralocal vegetation. Overrepresented taxa are those whose pollen contribution is disporportionately large compared with their abundance in the vegetation (Delcourt, et al., 1984).

Characteristic heath-bald plant communities occupy the three geomorphic surfaces within the bog at Flat Laurel Gap: (1) high-heath communities of Rhododendron and Kalmia shrubs more than 3 m high on topographically high colluvial fans; (2) low-heath communities of Kalmia and Vaccinium less than 3 m high on dissected colluvial and alluvial terraces; and (3) alluvial glade and wet-meadow communities of Sphagnum and Cyperaceae on active floodplain and stream channels. Other taxa are also good indicators. Poaceae is most prevalent on the modern floodplain. Osmunda is most abundant on the dissected colluvial and fluvial terraces and along narrow channels dissecting these geomorphic surfaces. Amelanchier and Sorbus occupy both the high-colluvial fan and dissected colluvial and fluvial terraces but are absent from the modern floodplain.

Paleoecologic Results

Core Lithology

A description of the sediment in the pollen and plant-macrofossil cores (Table 1) was prepared from field observations based on sediments collected within a 1 m radius: the surface monolith (FLG-83-P), and parallel core sections (FLG-83-A, FLG-83-B, FLG-83-C, FLG-83-D, FLG-83-E), and hand samples (FLG-83-F). The top 17 cm of sediment consists of humified sphagnum peat, while the sediment between 17 and 109 cm consists of micaceous, medium-grained to coarse-grained sand. The sediment from 89 to 103 cm is oxidized with subvertical color moddling, with poor preservation of pollen and plant macrofossils. Virtually no fossil material was recovered from the highly oxidized

TABLE 1

CORE LITHOLOGY

Depth in cm Below Sediment Surface	Sediment Description
0 - 17	Sphagnum peat (10YR2/2), humified toward base.
17 - 32	Fibrous peaty, micaceous, silty medium- to coarse-grained sand (10YR2/2) with granules and pebbles of quartz and gneiss.
45 - 50	Organic, micaceous, medium-grained sand (10YR2/2) with dispersed granules.
50 - 76	Organic, micaceous coarse-grained sand (10YR2/2) with pebbles to cobbles of quartz and gneiss.
76 - 83	Organic, micaceous, medium- to coarse-grained sand (10YR2/2) with abundant dispersed plant macrofossils.
83 - 89	Organic, micaceous, medium-grained sand (10YR3/2) with granules of quartz.
89 - 103	Micaceous, silty medium-grained sand (2.5YR6/4) with irregular subvertical mottling (2.5Y5/2).
103 - 109	Inorganic, micaceous, silty fine-grained sand (2.5Y6/4).
109 - 121	Inorganic, micaceous, very fine sandy silt (2.5Y6/6).
121 - 136	Inorganic, micaceous, fine sandy silt (2.5Y6/6).
136 - 157	Inorganic, micaceous, find sandy silt (2.5Y5/6).
157 - 162	Inorganic, micaceous, silty medium-grained sand (2.5Y5/6) with weathered gneiss cobbles.

sediments below 103 cm. From 103 to 162 cm depth, sediment is micaceous, fine-sandy silt or silty fine- to medium-grained sand. The sand and silt components are largely quartzose with minor feldspar.

The results of loss-on-ignition analysis is recorded in Appendix 1. Organic matter ranges from 18.4 to 90.2% of the sediment calculated on the basis of dry weight in the samples from 0.0 to 20.0 cm; the average value for organic matter is 45.4%. For samples 25.0 to 60.0 cm, the percent of organic matter generally ranges from about 10.0 to 28.0%, except for an anomalously low value of 5.5% for the sample at 40.0 cm depth. From 60.0 to 103.0 cm in depth, the percent-organic matter typically drops to between 4 and 8% with a low value of 3.4% at 70.0 cm.

Core Chronology

The percent of organic matter was calculated, based on dry-sediment weight, from the number of grams of organic matter per cm^3 of sediment combusted after loss-on-ignition at 550^oC (Dean, 1974). The weight of organic carbon per cm^3 of sediment was calculated by dividing the weight of the organic matter by 2.13 (Dean, 1974). For each radiocarbon date, a core segment containing a minimum of 5.0 gm organic carbon was sent to the University of Arizona lab for radiocarbon analysis.

Radiocarbon dates of 960±60 yr BP at the midpoint of 25.0 cm (A-3633), 1520±60 yr BP at the midpoint of 80.0 cm (A-3634), and 7710±310 yr BP at the midpoint of 148.0 cm (A-3636) were used in part to calculate the sedimentation rate and chronology of the core (Table 2). In addition, a date of 48 yr BP (AD 1935) was assigned to

TABLE 2

CORE CHRONOLOGY AND SEDIMENTATION RATES

Radiocarbon Age (Years BP)	Sample Depth Interval (cm) (Lab # for Date)	Midpoint Depth (cm)	Time Elapsed Between Midpoint Depths (yr)	Sediment Interval (cm)	Deposition Rate (cm/yr)	Deposition Time (yr/cm)
	Sediment Surface 0.0	0.0				
			48	2.5	0.052	19.23
48 (AD 1935)*	2.5	2.5				
			55	5.0	0.091	10.99
103 (AD 1880)**	7.5	7.5				
			857	17.5	0.020	50.00
960±60	20.0-30.0 (A-3633)	25.0				
			560	55.0	0.098	10.20
1520±60	75.0-85.0 (A-3634)	80.0				
			210	20.0	0.098	10.20
1260±130***	91.0-108.0 (A-3635)	99.5				
3340 (estimated)	100.0	100.0	6190	68	0.011	90.90
7710±310	135.0-161.0	148.0				

*
** Based on passage of Chestnut blight.
*** Based on upland logging and declines in Castanea dentata.
Date rejected because of very low carbon content and possible contamination by modern fungal growth (Dr. Austin Long, personal communication).

2.5 cm in depth. This depth is marked by a sharp decline, less than 0.5% pollen values (based on the AP sum) of Castanea, reflecting passage of the chestnut blight through the Southern Appalachians resulting in the local extinction of Castanea dentata by AD 1935 (Anderson, 1974). Also, a date of 103 yr BP (AD 1880) was assigned to 7.5 cm depth where values of Castanea pollen began to decline prior to passage of the chestnut blight. This decline in Castanea dentata signals the beginning of widespread forest clearance in the Southern Appalachian Mountains, resulting in an initial die-off of Castanea dentata (Ashe, 1911). An additional radiocarbon date of 1260±130 yr BP centered at 99.5 cm (A-3635) provided an anomalously young date, probably due to very low carbon content and minor contamination from fungal growth in the sediment during storage (Dr. Austin Long, personal communication, Feb. 17, 1984).

The sedimentation rate from 7710 to 1520 yr BP was 0.011 cm/yr. Extrapolated to 100 cm, it provides an estimated date of 3340 yr BP for the oldest pollen spectrum. The sedimentation rate was relatively high from 1520 to 960 yr BP (0.098 cm of sediment/yr). From 960 to 103 yr BP the sedimentation rate slowed significantly (0.020 cm of sediment/yr). From 103 to 48 yr BP (AD 1880 to 1935) the sedimentation rate increased again to 0.091 cm of sediment/yr. From 48 yr BP to the present, the sedimentation rate slowed (0.052 cm of sediment/yr) but remained fairly high. The modern surface represents modern peat accumulation at the time the site was cored (AD 1983).

Pollen Assemblage Zones

The results of CONSLINK, based on percentages calculated from the Upland Pollen and Spore Sum, were used to delineate four pollen assemblage zones at Flat Laurel Gap. The four major zones (Figs. 7 and 8) are the Castanea-Ericaceae zone, occurring from 100.0 to 57.5 cm depth and from 3340 to 1280 yr BP; the Quercus-Ericaceae zone, occurring from 57.5 to 8.75 cm depth and from 1280 to about 103 yr BP (A.D. 1880); the Pinus-Sphagnum zone, occurring from 8.75 to 1.25 cm depth and from 103 to 25 yr BP (A.D. 1935); and the Picea-Cyperaceae zone from 1.25 to 0.0 cm depth and from 25 yr BP to the present (A.D. 1983), the year the site was cored for its palynologic record. Each of the zones is named for a dominant or characteristic upland contributer to the pollen rain during the zone, and secondly, a dominant local or extralocal taxon. The results of the pollen and spore analysis are summarized and are graphically depicted in Figs. 7 and 8. Tables A3, A4, and A5 of the Appendix contain percent values of pollen grains and spores for each stratigraphic level analyzed for its paleoecologic record. The following is a synopsis of the paleoecologic record of each zone.

Castanea-Ericaceae zone (100.0 to 57.5 cm depth, 3340 to 1280 yr BP):

This zone was characterized by moderately high percentages of Castanea (values ranging from 14.1 to 34.4% of the AP sum) and total Ericaceae (9.0 to 15.4%) based on the Upland Pollen and Spore Sum. Both the percentages of total Pinus (4.7 to 12.5%) and Quercus (16.7 to 25.0%) were high. Although the values of both taxa fluctuated, Quercus gradually increased as Castanea slightly decreased through the

Figure 7. Palynological diagram for trees, shrubs, and lianas at Flat Laurel Gap, Haywood County, North Carolina. Dashed lines demarcate pollen assemblage zones as illustrated on Figure 8. Palynological results are plotted as a function of depth below the bog surface.

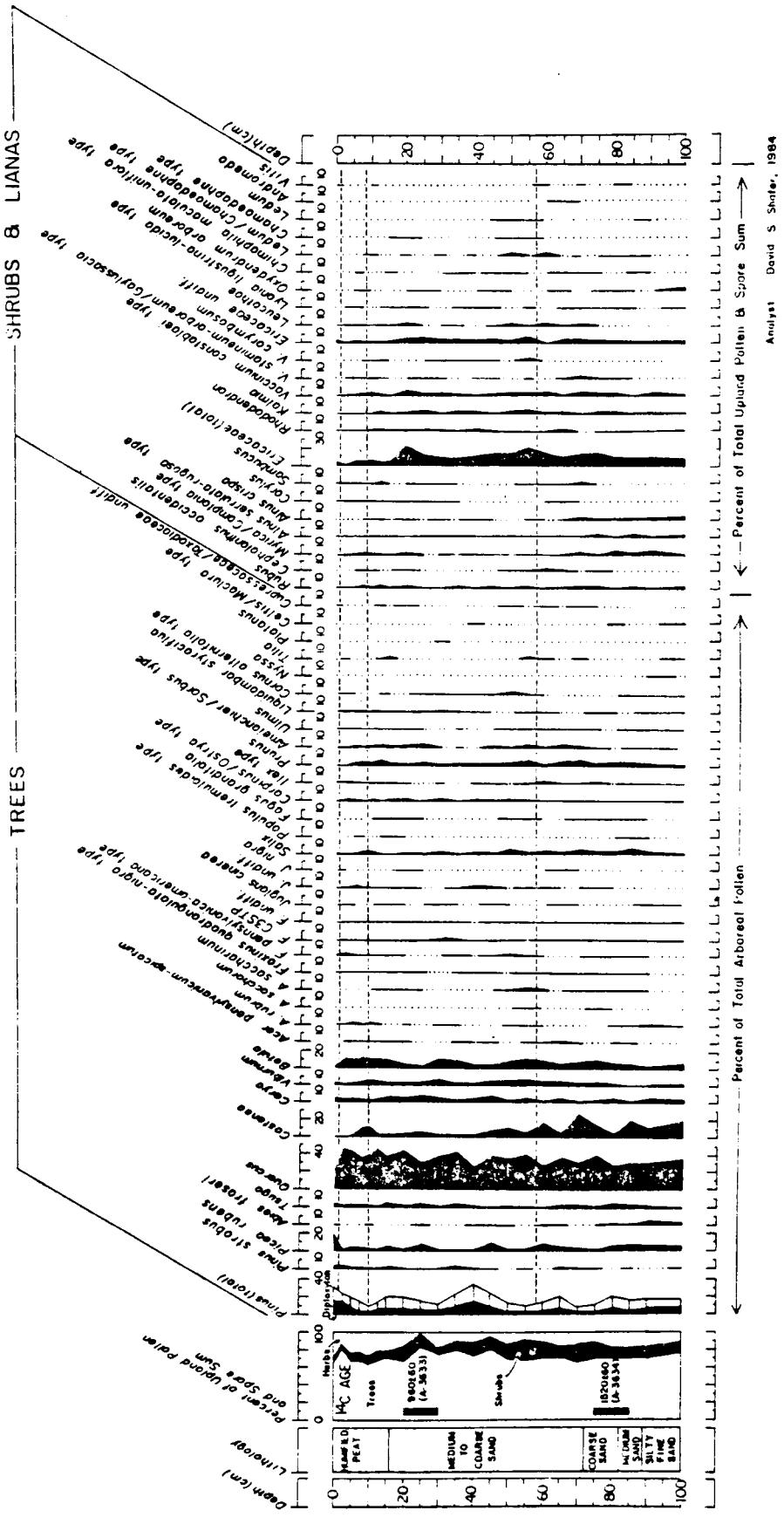

TREES
SHRUBS & LIANAS
Depth(cm)
Lithology
Percent of upland pollen and spore sum
Pinus (Diploxylon)
Pinus strobus
Picea rubens
Abies fraseri
Tsuga Canadensis
Betula
Carpinus caroliniana
Ostrya virginiana
Fagus grandifolia
Quercus rubra
Quercus velutina
Quercus alba
Quercus prinus
Quercus coccinea
Quercus palustris
Quercus (Erythrobalanus) undiff.
Quercus (Leucobalanus) undiff.
Castanea
Carya
Juglans cinerea
Juglans nigra
Salix
Populus tremuloides
Fagus grandifolia
Prunus/Ostrya type
Ilex type
Prunus
Ambrosia/Xanthium type
Ulmus
Liquidambar styraciflua
Cornus alternifolia type
Nyssa
Tilia
Platanus
Celtis/Maclura type
Quercaceae/Betulaceae undiff.
Rubus
Myrica/Comptonia occidentalis type
Alnus serrulata-rugosa type
Corylus
Comptonia
Ericaceae (total)
Rhododendron
Kalmia
Vaccinium constablei type
V. stamineum-arboreum/Coryllaceae type
Ericaceae
Leucothoe undulata
Osmanthus/Chionanthus
Chimaphila maculata-umbellata type
Ligustrina-lucida type
Leucothoe arborea
Cyrilla/Cliftonia
Leucothoe/Chamaedaphne type
Chamaedaphne type
Ilex
Vitis
Depth(cm)
Percent of Total Arboreal Pollen
Percent of Total Upland Pollen & Spore Sum
Analyst David S. Shafer, 1984
Herbs
Trees
Shrubs
HAC AGE
960±60 (A-3833)
1820±60 (A-3834)
HEAVY PEAT
MEDIUM TO COARSE SAND
COARSE SAND
MEDIUM SAND
SILTY FINE SAND

Figure 7

Figure 8. Palynological diagram for upland herbs and ferns and obligate aquatics at Flat Laurel Gap, Haywood County, North Carolina. Results of CONSLINK are shown and pollen assemblage zones are demarcated with dashed lines. Results are plotted as a function of depth below bog surface.

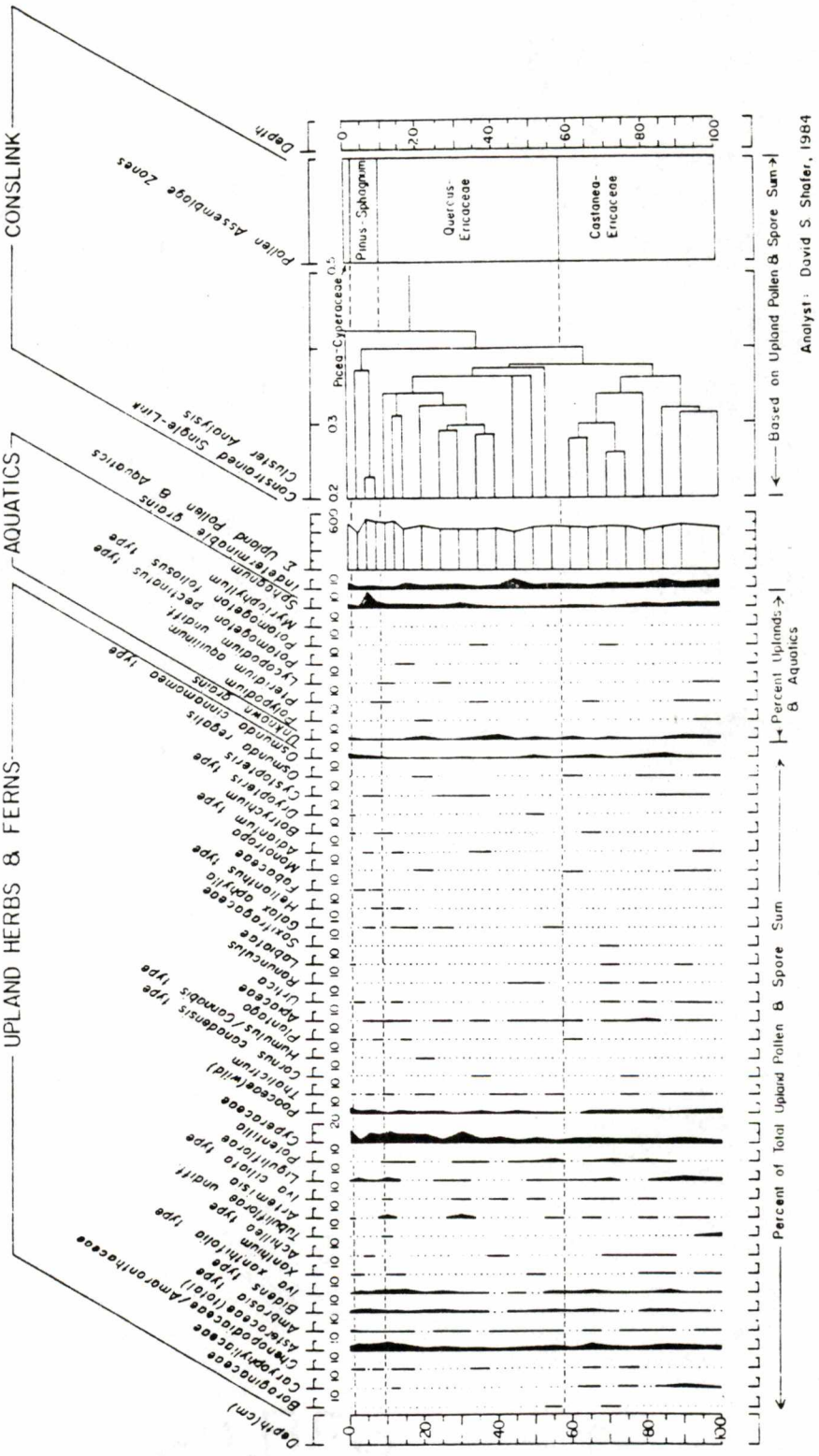

CONSLINK
UPLAND HERBS & FERNS
AQUATICS
Depth
Pollen Assemblage Zones
Constrained Single-Link Cluster Analysis
Picea-Cyperaceae
Pinus-Sphagnum
Quercus-Ericaceae
Castanea-Ericaceae
Percent of Total Upland Pollen & Spore Sum
Percent Uplands & Aquatics
Based on Upland Pollen & Spore Sum
Analyst: David S Shafer, 1984

Figure 8

zone. Other minor arboreal taxa (values less than 10.0% of the AP sum) included Picea rubens, Abies fraseri, Tsuga, Carya, Fagus, Viburnum, Salix, Ilex type, Prunus, and Amelanchier/Sorbus type. Values of Betula (2.2 to 6.2%) were moderately high and relatively consistant. The highest value of Abies fraseri in the organic core was recorded at 90 cm (2.5%), but its values declined to less than 1.0% through the remainder of the core. Ericaceae with relatively high values included Kalmia (0.4 to 2.0%) and Vaccinium constablaei type (0.8 to 1.7%). Other Ericaceae present included Rhododendron, Vaccinium stamineum-arboreum/Gaylussacia type, Leucothoe (up to 1.7%), Lyonia liquistrina-lucida type, Oxdendrum arboreum, Chimaphila maculata-uniflora type, Andromeda, Ledum, and Ledum/Chamaedaphne type. Other shrubs present in the zone and also reaching their greatest percent value in the paleoecologic record included Alnus crispa (0.0 to 1.3%), Alnus serrulata-rugosa type (0.2 to 3.5%), and Myrica/Comptonia type (0.2 to 3.5%). Rubus values (0.6 to 1.5%) were also fairly high.

Herbs and ferns with fairly high percentages in the zone included Cyperaceae (1.1 to 5.3%), Poaceae (0.0 to 4.9%) and Osmunda cinnamomea type (0.4 to 3.8%). Values of Osmunda cinnamomea type fluctuated inversely with those of Poaceae and Sphagnum. Sphagnum values declined fairly steadily through the zone (4.2 to 0.4% of the Total Pollen and Spore Sum plus aquatics) with the peak value in the zone at 100 cm depth. Other herbs and obligate aquatics present with values less than 2.0% in general included Tubiliflorae undiff., Liguliflorae, Thalictrum, Caryophyllaceae, Apiaceae, Urtica, and Pteridium aquilinum. Potentilla was recorded at most levels in the zone at less than 1.0%.

Percentages of total indeterminable grains were generally 3.2 to 10.5%, although somewhat higher toward the base of the zone. The average pollen influx during this period was the greatest of the four zones (11,074 grains·cm^{-2}·yr^{-1}). Pollen influx values (Table A2) increased gradually from 4070 grains·cm^{-2}·yr^{-1} at 100.0 cm to 9480 grains·cm^{-2}·yr^{-1} at 75.0 cm, followed by a sharp rise to 28,140 grains·cm^{-2}·yr^{-1} at 70.0 cm (1415 yr BP).

Quercus-Ericaceae zone (57.5 to 75 cm depth, 1280 to 103 yr BP (A.D. 1880):

This zone was marked by declines in Castanea, higher values of Quercus, and peak values of total Pinus and total Ericaceae. Castanea values ranged from 1.5 to 6.3%, Quercus from 19.3 to 29.8%, total Pinus from 6.1 to 22.4%, with a peak value at 40 cm for the core, and Ericaceae from 6.6 to 16.6%. Other arboreal taxa with fluctuating but increased values from the Castanea-Ericaceae zone were Carya (1.2 to 5.5%), Viburnum (0.7 to 4.0%), Carpinus/Ostrya type (0.2 to 2.0%), and Betula (2.6 to 7.6%). Betula peaks generally corresponded with lows in values of total Pinus. Other minor arboreal components (less than 7.0% of the AP sum) included Prunus, Amelanchier/Sorbus type, Salix, and Cornus alternifolia type. Liquidambar stymaciflua occurred consistently with trace values (less than 1.0%) throughout the zone. Ericaceae present at highest levels were Kalmia (0.0 to 3.7%) and Vaccinium constablaei type (0.7 to 5.6%). Andromeda and Ledum/Chamaedaphne type continued to be recorded. Other shrubs included Alnus serrulata-rugosa type (0.2 to 1.7%) and Alnus crispa (up to 0.4%), but both morphotypes at lower values than in the Castanea-Ericaceae

zone. Myrica/Comptonia type persisted at low percentages (less than 0.8%). Relatively abundant upland herbs and ferns as well as obligate-aquatics included Cyperaceae (1.8 to 12.67%), Poaceae (0.2 to 1.8%), Osmunda cinnamomea type (up to 1.8%), and Sphagnum (0.4 to 5.1%). Cyperaceae increased from the Castanea-Ericaceae zone while Osmunda cinnamomea type exhibited a slight decrease. However, both Cyperaceae and Osmunda cinnamomea type began to increase toward the end of the zone. In addition, Iva xanthifolia type (up to 4.3%) and Liguliflorae (up to 1.0%) increased noticeably toward the end of the zone, the former reaching a peak value at 15.0 cm. Other minor taxa of the Upland Pollen and Spore Sum (less than 2.0%) included Bidens type, Potentilla, Galax aphylla, and Thalictrum.

Levels of indeterminable grains were on the average lower than in the Castanea-Ericaceae zone (1.7 to 10.6%) though the peak value for the sediment core was reached at 45.0 cm. Influx of pollen and spores averaged 9488 grains$\cdot cm^{-2} \cdot yr^{-1}$ with a range from 20,376 to 2,251 grains$\cdot cm^{-2} \cdot yr^{-1}$. The influx in general decreased through the zone. However, the zone began with a significant rise in influx rates from 14,488 to 20,376 grains$\cdot cm^{-2} \cdot yr^{-1}$ from 60.0 to 55.0 cm (1313 to 1262 yr BP).

Pinus-Sphagnum zone (8.75 to 1.25 cm depth, 103 to 25 yr BP (A.D. 1880 to A.D. 1958):

The transition from the Quercus-Ericaceae to the Pinus-Sphagnum zone was characterized by a sharp rise in total Pinus values, a sharp fall in Castanea, high values of Betula, and increasing percentages of Sphagnum, and a major increase in the influx rate of pollen and spores. Total Pinus increased from 9.0% at 7.5 cm to 18.4% at 2.5 cm.

Meanwhile, Castanea, 14.8% at the beginning of the zone, fell to 0.0% at 2.5 cm. Sphagnum reached its highest value in the core at 5.0 cm (18.4%). Picea rubens reached one of its two lowest values, 1.0%, at 2.5 cm in this zone. Quercus had a low value in the zone at 7.5 cm (21.0%) and then rose to 37.0% at 2.5 cm. Betula (5.5 to 7.6%) remained consistently high through the zone. Total Ericaceae (5.4 to 6.4%), which began to decline in value late in the Quercus-Ericaceae zone, declined further in the Pinus-Sphagnum zone and reached its lowest value in the core at 2.5 cm. Vaccinium constablaei type (0.8 to 2.5%) and Kalmia (0.3 to 0.8%) declined noticeably throughout this zone. Two Ericaceae taxa, Ledum and Chamaedaphne type, both present in the Quercus-Ericaceae zone, were not found in the Pinus-Sphagnum zone. In addition, Alnus crispa was not recorded within this zone and Myrica/Comptonia type (0.0 to 0.7%) declined. Prunus (0.0 to 0.2%) and Amelanchier/Sorbus type (0.3 to 1.1%) also fell in percent value.

Cyperaceae (3.3 to 9.9%, Poaceae (2.1 to 3.0%), and Osmunda cinnamomea type (1.3 to 2.5%) were Upland herbs and ferns which continued to be recorded as high values. Osmunda cinnamomea type rose steadily through the zone as Kalmia and Vaccinium constablaei type declined. Other herbs with increased values in this zone included Bidens type (2.1 to 2.8%) and Iva xanthifolia type (1.7 to 2.8%). Potentilla was not recorded in the zone and Galax aphylla was less consistently present at levels in the core after the transition from the Quercus-Ericaceae to the Pinus-Sphagnum zone.

Percentages of total indeterminable grains were comparatively low throughout the zone (1.5 to 3.0%). Influx of pollen and spores

increased sharply across the transition zone between the Quercus-Ericaceae zone and the Pinus-Sphagnum zone from 3,453 grains·cm^{-2}·yr^{-1} at 10.0 cm (A.D. 1760) to 10,047 grains·cm^{-2}·yr^{-1} in the Pinus-Sphagnum zone.

Picea-Cyperaceae zone (1.25 to 0.0 cm depth, 25 yr BP to the Present (A.D. 1958 to A.D. 1983):

The transition from the Pinus-Sphagnum zone to the Picea-Cyperaceae zone was marked by a sharp increase in Picea rubens (1.0 to 11.8%), a steep decline in Quercus (37.0 to 14.2%), and a sharp rise in Cyperaceae (3.3 to 12.6%). The Cyperaceae rise was matched by a corresponding increase in the percentage of Poaceae (2.3 to 3.7%) across this transition. At 2.5 and 0.0 cm, Castanea reached minimum values (0.0 and 0.4%) in the paleoecologic record at Flat Laurel Gap. Arboreal taxa with fairly high percentages in the Picea-Cyperaceae zone were total Pinus (18.6%), Tsuga (2.6%), and Carya (3.2%). Betula declined across the transition from 7.6 to 2.4% and Amelanchier/Sorbus type (0.2%) had one of its three lowest values in the core at 0.0 cm.

Total Ericaceae (5.9%), particularly Vaccinium constablaei (0.4%) and Kalmia (0.6%), remained at low values. Osmunda cinnamomea type continued to increase (to 4.1%). Ambrosia type (1.4%) recorded its highest value at 0.0 cm. Galax aphylla was not recorded across the transition between the Pinus-Sphagnum and the Picea-Cyperaceae zones. Percentages of indeterminable grains rose in this zone to 6.6% and influx of pollen and spores was 1870 grains·cm^{-2}·yr^{-1}.

Plant Macrofossils Assemblages

Plant macrofossils were collected, identified, and counted from sediment samples centered at 5 cm intervals throughout the 1.0 m organic core. Plant macrofossil counts represent individual seeds and fruits unless otherwise noted. A minimum needle count for conifers was determined by summing the number of whole needles plus either the number of bases or tips, whichever figure was greater. Complete macrofossil data are provided in Appendix 9. Sphagnum was noted by abundance of its leaves: + represents only scattered leaves, ++ two to five leaves, and +++ greater than five leaves. Macrofossils are available for inspection at the Program for Quaternary Studies of the Southeastern United States, University of Tennessee, Knoxville, Tennessee. Insect parts were collected and counted as a measure of degree of preservation (Birks, 1979).

The results of plant macrofossil analysis are summarized by the same depth and time intervals as for the pollen assemblage zones (see Fig. 9).

Castanea-Ericaceae zone (100.0 to 57.5 cm depth, 3340 to 1280 yr BP):

This zone was characterized by moderately high macrofossil counts for Abies fraseri, Picea rubens, and Galium. At 80.0 cm a minimum of six Abies fraseri needles were counted. Galium counts ranged from 11 to 46. Counts of insect parts (1-10) were relatively low compared to the remainder of the zones. Other plant macrofossils present included Sorbus, Scirpus cespitosus type, S. cyperinus type, S. smithii

Figure 9. Plant macrofossil diagram for Flat Laurel Gap, Haywood County, North Carolina. Counts represent number of seeds or fruits per 50 cm^3 of sediment, unless otherwise noted. Counts of needles represent minimum needle counts. Note the change of scale for *Juncus* and *Galium*. Abundance of *Sphagnum* is noted by + = 0 to 2 leaves; ++ = 3 to 5 leaves; and +++ = greater than 5 leaves. *Picea* (other) refers to macrofossils other than needles (e.g., microsporophyll).

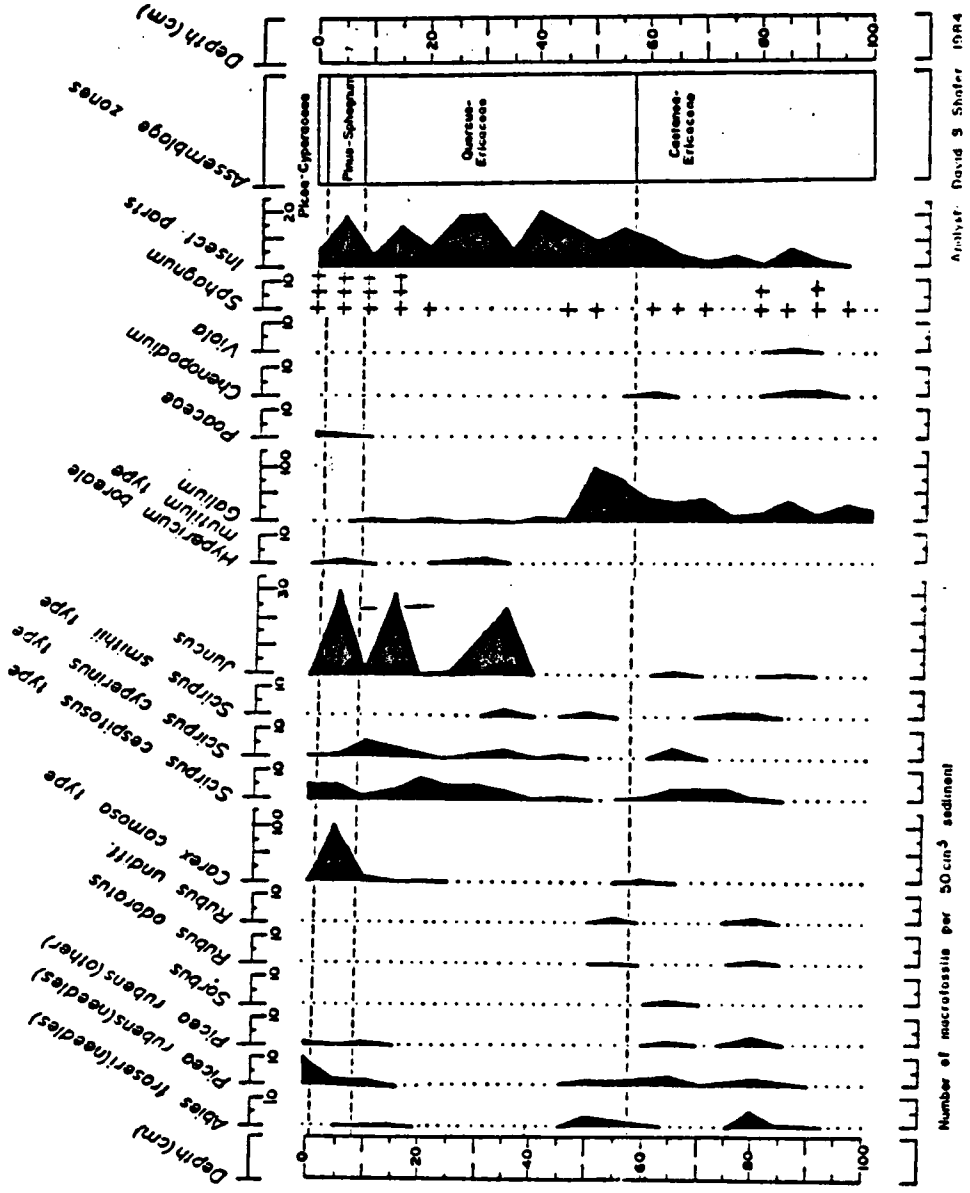

Depth (cm)
Assemblage zones
Pinus-Cyperaceae
Pinus-Sphagnum
Quercus-Ericaceae
Castanea-Ericaceae
Insect. poris
Sphagnum
Viola
Chenopodium
Poaceae
Galium
Myriophyllum type
Hypericum boreale
Juncus
Scirpus smithii type
Scirpus cyperinus type
Scirpus cespitosus type
Carex comosa type
Rubus undiff.
Rubus odoratus
Sorbus
Picea rubens (other)
Picea rubens (needles)
Abies fraseri (needles)
Depth (cm)
Number of macrofossils per 50 cm³ sediment
Analyst: David S. Shafer 1984

Figure 9

type, Juncus, Chenopodium, and Viola. Sphagnum was relatively abundant at the base of this zone.

Quercus-Ericaceae zone (57.5 to 8.75 cm depth, 1280 to 103 yr BP (A.D. 1880):

This zone was marked by sharp increases in counts of Scirpus types and fluctuating counts of Juncus. Juncus counts, for example, increased from 0 at 40.0 cm to 25 at 35.0 cm. Macrofossils of Abies fraseri and Picea rubens were absent from 45.0 to 20.0 cm depth interval. Sphagnum leaves were sparse while insect parts (10 to 21) were much higher than in the Castanea-Ericaceae zone.

Pinus-Sphagnum zone (8.75 to 1.25 cm depth, 103 to 25 yr BP (A.D. 1880 to A.D. 1958):

This zone was marked by high levels of Juncus and Carex camosa type and abundant Sphagnum leaves. Abies fraseri needles, present at the close of the Quercus-Ericaceae zone, were absent at 5.0 cm. Carex camosa type and Juncus numbered 101 and 31, respectively, at 5.0 cm.

Picea-Cyperaceae zone (1.25 to 0.0 cm depth, 25 yr BP to the Present (A.D. 1958 to A.D. 1983):

Increased abundance of Picea rubens macrofossils and the presence of Poaceae highlighted this zone. Picea rubens macrofossils included a minimum of 9 needles. In addition, Sphagnum leaves remained very abundant, continuing a trend from the Pinus-Sphagnum zone. Other macrofossil types identified included Carex camosa type and Scirpus cespitosus type.

Geomorphology

Chronology of Late-Quaternary Deposits

Thermoluminescence (TL) analysis yields late-Pleistocene to early-Holocene ages for three depositional units at Flat Laurel Gap. TL analysis at the site provides the first absolute-age determinations available for such deposits in the Central and Southern Appalachian Mountains. A TL date of 10,000±950 yr BP was obtained for the high colluvial fan; 11,900±1,500 yr BP for the dissected fluvial terrace in the bog; and 7,400±1,000 yr BP for the blockstream (Table 3).

Characterization of Late-Quaternary Deposits

Various block, colluvial, and alluvial deposits were mapped in the area surrounding Flat Laurel Gap from Little Bald Mountain to the crest of Big Bald Mountain southwest of the bog, and on the east side of Pisgah Ridge (Figs. 3 and 4, pp. 9, 17). Colluvial fans, blockstreams and blockfields, talus, fluvial terraces, and modern floodplain alluvium along with a ubiquitous colluvial cover were mapped in the area.

Talus is limited in the area to the northeast slope of Big Bald Mountain where it was generated by freeze-thaw processes from a 450 m long and 5 to 8 m high line of bedrock exposures just below the summit. Other deposits which appear similar to talus occur locally below the Blue Ridge Parkway Road on the east side of Pisgah Ridge below Big Bald Mountain, but represent rock debris generated during construction of the highway. Thus, they are not delineated on the map. Rock outcrops, generally sparse in the area, are limited to scattered localities along Big Bald Mountain, the south side of the ridge

TABLE 3

CHRONOLOGY OF LATE-QUATERNARY DEPOSITS

Lab Number	Sample Number	Sample Material	Sediment Description	Sample Depth Collected below Land Surface	TL Age (Yr BP)
Alpha 893	FLG-83-FT	Sediment of fluvial terrace in upper bog	Oxidized, clayey to silty fine to medium-grained sand (7.5YR6/8) with granules and pebbles of quartz and gneiss	25 cm	11,900±1,500
Alpha 894	FLG-83-CO	Sediment of high colluvial fan at head of bog	Micaceous, fine- to medium-grained sand with granules and pebbles of quartz and deeply weathered gneiss	70 cm	10,000±950
Alpha 895	FLG-83-BS	Sediment matrix of blockstream at edge of bog	Organic, silty fine-grained sand (10YR2/2)	90 cm	7,400±1,000

immediately to the northeast of the bog, the east side of Pisgah Ridge below Big Bald Mountain, and the east flank of Little Bald Mountain (Fig. 3, p. 9). The attitude of the bedrock in the area varies between N30W and N70E with dips 50 to 80W.

Blockstreams and blockfields either begin below low-angle bedrock outcrops or where talus deposits grade downslope. Individual blocks in these deposits tend to be oriented parallel to slope except on steeper slopes where blocks typically lie perpendicular to slope. Exceptions to this are the flanks and toes of deposits where the preferred fabric was transverse to slope. Locally, strips of blocks running parallel to the axis of the blockstream consist of blocks standing on end, similar to stonestripes (Embelton and King, 1975). Elsewhere, the tabular blocks, typically 20 to 60 cm in diameter with some blocks as large as 2 m, are stacked with the size of the blocks in general decreasing with depth. In a cross-section of the blockstream used for TL analysis (Fig. 4, p. 17), blocks at 0.5 m depth measure 15 to 40 cm diameter, and at 1.0 m depth only 8 to 12 cm. Several blockstreams and blockfields display imbrication of 0 to 10° in road-cuts and other exposures. Surface blocks are subrounded to rounded at the corners and usually have a pitted, weathered surface. The degree of weathering increases strongly with depth. At 1.0 m depth in the blockstream sampled for TL analysis, larger blocks (12 cm dia) can easily be broken with a rock hammer and smaller blocks (8 cm dia) can sometimes be broken by hand. The matrix becomes more clay-rich with depth, reflecting the weathering of muscovite and biotite mica in the clasts. Blockstreams in the area usually display an overall

convex profile. On the east slope of Pisgah Ridge, blockstreams were traced from 1,470 m to as low as 1,180 m in elevation. The individual boulders in the blockstreams and blockfields are typically quartz-rich; block deposits may be absent locally where the mica content of the rock was high. Length-width ratios of blockstreams averaged 2.21, that of blockfields 0.65.

Block deposits usually grade downslope into colluvial fans in the area. The fans, like the blockstreams, show a convex profile but have less than 50% boulder cover on the land surface. In addition, the individual blocks are more highly weathered and are frequently more mica-rich than the blocks exposed at the surface of the blockstreams and blockfields. Colluvial fans are more numerous on the west side of the Blue Ridge Parkway road, and blockstreams more numerous to the east. Although the colluvial fans probably vary greatly in thickness, well-logging records from the colluvial fan deposits at the head of Flat Laurel Gap bog indicate a thickness of about 8 m (Blue Ridge Parkway, National Park Service office records, Asheville, North Carolina). Average length-width ratio for colluvial fans mapped in the area is 2.87. In addition to the colluvial fans, there is a nearly ubiquitous cover of colluvial material mantling slopes where concentrated colluvial fans or block deposits are lacking. This colluvial cover is variable in thickness, but typically does not exceed 3 m in thickness.

Detailed mapping within the confines of Flat Laurel Gap (Fig. 4, p. 17). reveals a variety of geomorphic features and their diagnostic deposits in the vicinity or within the bog: blockstreams and blockfields, colluvial fans, dissected colluvial and fluvial terraces, and the

modern floodplain and channels. Colluvial fans and blockstreams are more common on the northeast and east slope of the gap on the flank of Big Bald Mountain, though the blockstream of greatest penetration into the bog was generated from the southwest-facing slope above the bog. Although blockstreams and colluvial fans occur on a variety of slope settings in Flat Laurel Gap and in the vicinity, they are most frequent on the interfluves between drainage channels or on the flanks of interfluves. A blockfield at the head of Flat Laurel Gap bog grades downslope into a series of colluvial fans which coalesced to form a fan complex at the head of the bog. Three blockstreams enter the bog vicinity or reach the channel draining the area below the bog. The same blockstream whose matrix was dated by TL analysis (7,400±1,000 yr BP) extends into the bog displacing the position of the main channel in the area of greatest lateral constriction of the modern floodplain (Fig. 4, p. 17). The two blockstreams downstream from the bog once extended across the creek; the stream now cascades in a narrow channel incised through the block deposits.

Detailed mapping and construction of the topographic profile, together with lithologic description of deposits reveals three geomorphic surfaces in the bog with diagnostic underlying sediments. The first, the high-colluvial fan, ranging from 1,480 to 1,495 m elevation, consists of a gently sloping surface formed by the coalescing of several colluvial fans and was dated by TL analysis at 10,000±950 yr BP. The high colluvial-fan surface, sloping between 20 and 34%, is periodically incised by ephemeral channels 1.0 to 1.5 m deep and 3.0 to 4.0 m in width. In contrast, the lower, distal part of the high

colluvial-fan surface slopes only 4 to 10%. The high colluvial-fan material consists of micaceous, silty fine-grained to medium-grained sand with pebbles and granules of deeply weathered, light reddish to yellow-brown gneiss. The second mapped surface in the bog is formed from a dissected colluvial terrace and one fluvial terrace, grouped together because of their similarity in relief, vegetation, and the extremely limited extent of the fluvial terrace (Fig. 4, p. 17). The fluvial terrace consists of oxidized, clayey to silty fine- to medium-grained sand (7.5YR6/8) with granules and pebbles of quartz and gneiss. The fluvial terrace was dated by TL analysis at 11,900±1,500 yr BP. The dissected colluvial terrace material consists of medium brown, micaceous, fine- to medium-grained sand with granules and pebbles of weathered gneiss, and quartz, overlain by 1 to 3 cm of humified clay. The dissected colluvial and fluvial terrace surface lies about 75 to 100 cm below the high colluvial-fan surface and 50 to 75 cm above the modern channels in the bog; the surface generally slopes between 2 and 10%, but locally is undulatory, between -2.0 and 6.5%.

The third surface in the bog is the modern floodplain and stream channels. The modern floodplain slopes between -4.0 to 6.0%, but with typical slopes of 0.5 to 2.0%. The modern channels are steeply banked, narrow, and typically incised 25.0 to 55.0 cm below the modern floodplain. Although the modern alluvial sediment is variable in mineralogic composition, it largely consists of micaceous, medium- to coarse-grained sand, medium brown in color, with granules and pebbles of quartz, quartzite, gneiss, and granules of garnet. The quartz particles include igneous, quartz, and metamorphosed quartz and quartzite. The

sparse gneiss clasts are rounded, to well-rounded and deeply weathered, the more abundant quartz clasts usually subangular. The modern floodplain near the margins of the colluvial deposits contains abundant vein-quartz clasts with boulders up to 35.0 cm in diameter within a matrix of coarse-grained sand with granules of quartz, quartzite, garnets, and rare gneiss material, together less than 10% of the sediment volume. The sediment of coarse gravel and boulders occasionally armors the modern floodplain of exposed massive vein-quartz material, angular to subangular, in a matrix of coarse-grained sand with garnets. These areas are relatively unvegetated and subject to periodic mild sheet wash. Modern, active frost-sorted stone circles, up to 40.0 cm in diameter, form in these channel-lag areas. The drainage pattern of the area consists of a dense network of ephemeral-stream channels and one main channel. The channel network is dendritic, but the main channel is strongly oriented parallel to the main axis of the bog, with only short ephemeral channels perpendicular to the main axis. Many of the ephemeral stream channels are separated by very narrow and low interfluves of the high colluvial-fan or dissected-terrace surfaces. A low ridge, mainly of high colluvial-fan material, runs down the center of the bog and separates the upper modern floodplain area into two main sections.

The topographic profile of the bog shows a concave profile grading to a resistant pegmatite dike intercepted 265 m west of the head of the bog (Fig. 4, p. 17). The dike varies between 75.0 and 85.0 m in width and projects approximately N10W across the bog. In the vicinity of the pegmatite dike, there is a significant narrowing in the areal

extent of the modern floodplain and a decrease in the density of ephemeral-stream channels. Although there are no pegmatite outcrops within the channels, the channels do contain local concentrations of coarse, angular pegmatitic vein quartz, including boulders up to 50.0 cm in longest dimension. Across the pegmatite dike, the channel is deeply incised, up to 90 cm below an abandoned subterrace channel. A widening of the modern channel marks the end of the pegmatite dike, although there is a concentration of coarse pegmatitic vein-quartz material in the channel for 20.0 m below the pegmatite dike. Downstream below the dike, the stream draining the bog drops steeply in a series of cascades as it enters a narrow valley to the west and leaves Flat Laurel Gap.

Cross-valley profiles of Flat Laurel Gap bog show steep, convex profiles toward the ridgetops and alternating and comparatively low-angle convex and concave profiles near the bog, but with an overall concave profile (Fig. 10). Similar profiles of upper stream valleys have been noted in the Shining Rock area (Haselton, 1973), 18 km south, and at Grandfather Mountain, North Carolina (Raymond, 1977), 180 km northeast of Flat Laurel Gap.

Figure 10. Cross-valley profiles for Flat Laurel Gap, Haywood County, North Carolina. Data points below the "X" were obtained from detailed National Park Service site planning maps (1.52 m counter interval) while points below the "X" were obtained from USGS topographic map of the area (Cruso, NC, 1941, photorevised 1979, counter interval 12.2 m). Trend of the profiles is N65.5°E. Profile A is approximately centered at station 110.0 m along the topographic profile; profile B is centered at 155.0 m.

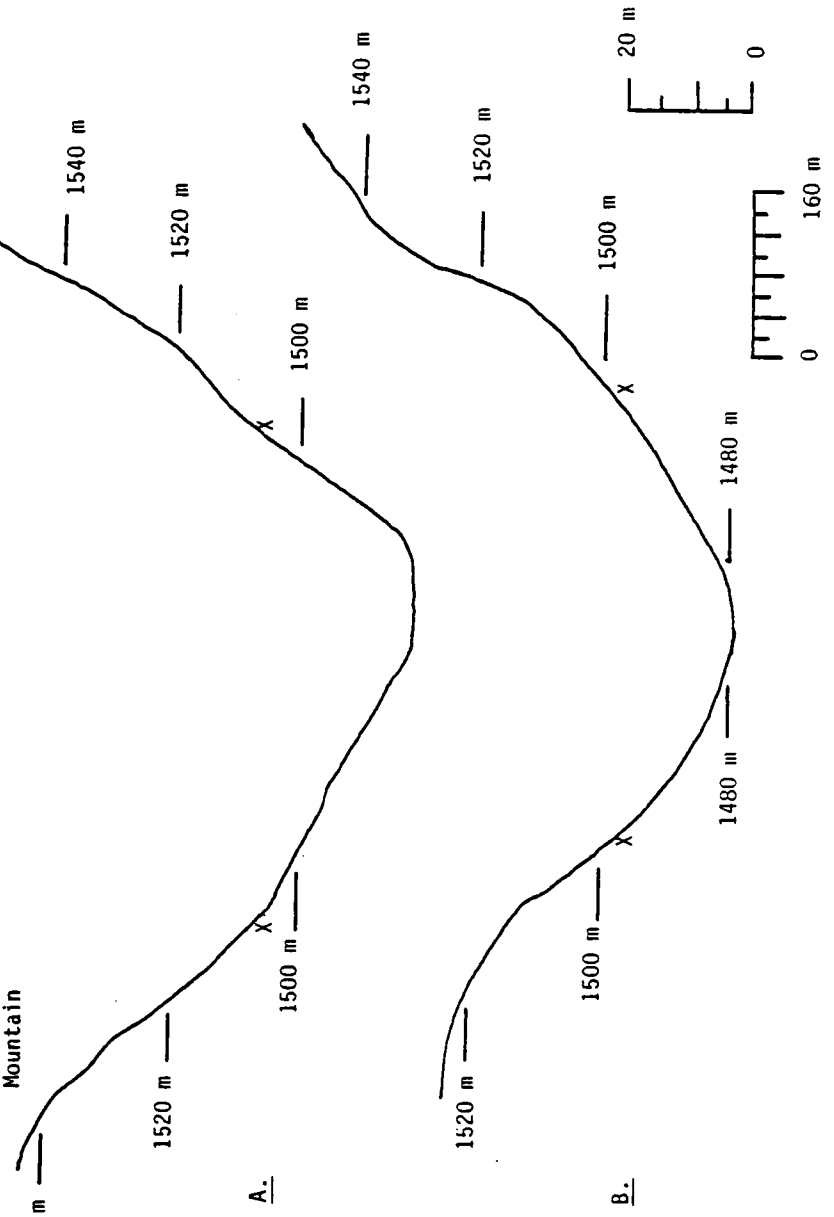

Big Bald Mountain
1560 m
1540 m
1520 m
1500 m
Little Bald Mountain
1540 m
1520 m
1500 m
A.
1540 m
1520 m
1500 m
1480 m
1520 m
1500 m
1480 m
B.
20 m
0
0
160 m

Figure 10

IV. INTERPRETATIONS

Paleoecology of Flat Laurel Gap

The sediment from Flat Laurel Gap provides a late-Holocene paleoecologic record spanning the last 3340 years. The pollen and plant-macrofossil sequences from the bog sediments record the changing vegetation in both the local bog environment and the upland slopes above the bog. Interpretation of the geomorphic history of the local basin is important to distinguish local and regional changes in vegetation.

The paleoecologic record from Flat Laurel Gap documents the antiquity of the local heath bald community, with Ericaceae consistently dominating the local and extralocal vegetation in the late-Holocene. However, a slow reduction in the extent of Ericaceae occurred in the late-Holocene due to progressive incision of the high colluvial fan and the dissected fluvial and colluvial terraces, the major substrates for heaths in the local and extralocal vegetation. This incisement was pronounced from approximately 500 to 200 yr BP during a cool, moist episode corresponding to the Little Ice Age in the Northern Hemisphere (Gribben and Lamb, 1978). During the last 100 years, historic anthropogenic impact on the upland forests around Flat Laurel Gap bog resulted in forest clearance and initiated an episode of erosion or renewed erosion of the slopes, and accelerated

fluvial incision within the bog. The following is a characterization of the paleoecologic interpretation from each of the four pollen assemblage zones (Figs. 7 and 8, pp. 38, 40).

Castanea-Ericaceae zone (3340 to 1280 yr BP)

This zone was characterized by both upland taxa and taxa in the bog which reflect a relative drying trend in the area. Castanea, Quercus, Pinus, and Carya, taxa which tolerate drier conditions, characterized the upland forest vegetation in the watershed surrounding the bog during this zone. Sphagnum, Cyperaceae, and Poaceae, taxa indicative of cooler and moister conditions, had relatively low palynomorth values. High pollen values of Picea rubens and Abies fraseri, and their relative abundance as plant macrofossils, indicate a cool episode during the late-Holocene in the southeastern United States (Watts, 1979). Picea rubens and Abies fraseri would have expanded their populations responding to cooler temperatures and higher precipitation levels during the growing season. Many areas in the northern hemisphere experienced a cooler climatic period which culminated between 2900 and 2300 yr BP (Gribbin and Lamb, 1978). In east Tennessee during this early late-Holocene episode, the Little Tennessee draining the Great Smoky Mountains about 65 km west of Flat Laurel Gap began to incise its channel, in part a response to higher precipitation levels (P. Delcourt, 1980).

Ericaceae were the dominant local and extra local vegetation during this time. The heaths along with Picea and Abies may have been protected by cold air drainage from mountain slopes surrounding the

bog. Comparatively high values of Kalmia and Vaccinium constablaei type indicate that little incision of the colluvial valley fill was occurring, resulting in a relatively stable landscape in the bog for the heaths.

Quercus-Ericaceae zone (1280 to 168 yr BP)

The early part of this zone was characterized by a continuation of the drying trend of the Castanea-Ericaceae zone, both within the bog and on the slopes above the bog. High pollen percentages of Quercus, Pinus, and Carya indicate the development of progressively more xeric conditions on the slopes and ridges. Declines in Castanea may have been caused by increasing density of oaks on the slopes, outcompeting the more shade-sensitive taxon, Castanea dentata (Fowells, 1965). A peak of Pinus at 40 cm (1100 yr BP) may have been due to a period of increased fire frequency which would have created openings in the upland forests favorable to the generation of Pinus seedlings. Fagus grandifolia, a fire-sensitive taxon, is not recorded during this time. Also during the early part of the Quercus-Ericaceae zone in the bog, Cyperaceae, Poaceae, and Sphagnum continued to decline, reflecting a drying trend in the bog. Lower levels of water in the open glade environment may have allowed Ericaceae such as Kalmia and Vaccinium sp. to begin invading parts of the modern floodplain. However, increased levels of Picea rubens pollen may indicate periods of greater effective moisture.

Beginning at about 20 cm (approximately 710 yr BP), there was a reversal in the trend and the area seems to have begun a cooler and

moister cycle. This was reflected in pollen increases in Picea rubens and Betula and higher percentages of Sphagnum, Cyperaceae, and Poaceae as the open-glade environment became more moist. Acer pensylvanicum and Acer spicatum, although low in pollen percentages, also increased during this time, reflecting more moisture and cooler temperatures. Pollen grains of Acer are invariably poorly represented in the pollen record and populations of maples may be quite abundant to be represented even by low levels of pollen (P. Delcourt, et. al., 1983). The initiation of this cooling trend probably caused a temporary expansion in the density of Ericaceae shrubs. However, greater precipitation also began a period of renewed incision of the high colluvial fan and the dissected colluvial and fluvial terraces. This reduction in the favorable substrate for Ericaceae was reflected in declines in pollen percentages of Kalmia and Vaccinium constablaei type. Renewed incision in the channels expanded the habitat for Osmunda cinnamomea type. Increased moisture and reduced fire frequency permitted Fagus grandifolia to reexpand its populations on mesic sites in the gap.

This period of cooler and moister conditions probably corresponds with the Little Ice Age, a cool period in the Northern Hemisphere which is particularly marked betwen about 630 and 130 yr BP (A.D. 1350 to A.D. 1850) (Gribben and Lamb, 1978). During this period of alluvial incision, the sedimentation rate declined at the coring site in Flat Laurel Gap. This may indicate the incision and lateral shifting of channels in the bog such that the coring site was receiving only limited stream-overbank deposits within the modern floodplain.

Increased pollen abundance of Picea rubens, Pinus strobus, Betula, Prunus, Fagus grandifolia, and Acer pensylvanicum-spicatum signals the lowering in elevation of an ecotone during the Little Ice Age. These taxa, typical of the Mixed Conifer-Northern Hardwood Forest (Braun, 1951), indicate that the ecotone with the lower elevation Appalachian Oak-Chestnut Forest was depressed during this time, another indication of cooler and moister conditions. Thus, during the late-Quercus-Ericaceae zone, the forests surrounding Flat Laurel Gap were part of the Mixed Conifer-Northern Hardwood Forest.

Pinus-Sphagnum zone (168 to 25 yr BP)

The logging of the upland forests around Flat Laurel Gap beginning about A.D. 1880 commenced the first episode of historic, anthropogenic landscape instability at Flat Laurel Gap. Clearance of the forests from logging and related fires caused a decrease in the abundance of Castanea dentata and an increase in Pinus on slopes above the bog (Ashe and Ayres, 1905; Ashe, 1911). Although Pinus experienced an initial decline because of logging, the land clearance and burning created dry, open slopes favorable for Pinus growth which then caused a sharp increase in pine populations in the area. However, populations of Castanea dentata declined due to its susceptibility to fire damage, the destruction of soil humus, and impoverishment of the upland soils which accompanied the land clearance (Ashe, 1911). Low values of Picea pollen at this time were probably due to the cutting of the mature spruce trees in the bog area. Land clearance resulted in an increase in the amount and rate of overland flow and erosion of upland slopes, which resulted in an increase in the sedimentation rate in the

bog, and greater pollen influx. The increase in the extent of the modern floodplain permitted an increase in open-glade species such as Carex camosa type and Sphagnum, as indicated from the plant macrofossil record. Greater overland flow also began an episode of incision in channels within the bog and accelerated erosion of the high colluvial fan surface and surfaces of the dissected colluvial and fluvial terraces. Reduction in the extent of these surfaces reduced the available habitat for Amelanchier/Sorbus type, Prunus, and for Ericaceae, resulting in declining abundance of Kalmia and Vaccinium constablaei type. Osmunda cinnamomea type, most abundant on the edge of the modern floodplain and along drainages (Fig. 6, p. 29), increased with accelerated erosion of the colluvial fill in Flat Laurel Gap. Betula alleghaniensis, a disturbance-favored taxon (Pitillo and Smathers, 1979) is probably the principal Betula species responsible for high levels of Betula pollen in this zone.

Logging in the area during the Pinus-Sphagnum zone coincides with major modifications of environments and the time of extirpation of Alnus crispa and Abies fraseri in the Pisgah area and locally from Flat Laurel Gap bog. Land disturbance also caused the elimination of Andromeda and Chamaedaphne, species of boreal heaths, from the bog and severe areal restriction in the distribution of Potentilla tridentata and Comptonia peregrina. This is documented in the pollen record by the termination in the curves for Alnus crispa, Chamaedaphne type, and Potentilla during this historic period.

Picea-Cyperaceae zone (25 to 0 yr BP)

Dating from A.D. 1958, this zone represents the period that is post-chestnut blight at Flat Laurel Gap. At the time of the transition from the Pinus-Sphagnum zone to the Picea-Cyperaceae zone, essentially all the mature Castanea dentata trees were killed by A.D. 1935 because of passage of the Chestnut blight through this part of the Southern Appalachians. Although no mature Castanea dentata remained in the area, stump sprouts were common, providing a pollen source for the low level of Castanea pollen recorded in the modern pollen sample.

Anthropogenic disturbance of the bog and its watershed continued during this period due to construction of the Pisgah Inn, the Blue Ridge Parkway Road, and the campground around the bog. The sharp decrease in Quercus reflects clearance of many of the upland mature oaks when the campground road network and the lodge were completed. This period of land clearance continued to result in greater overland flow and landscape erosion. Consequently, there continued to be a reduction in the extent of the high colluvial surface and the dissected colluvial and fluvial terraces and a concomitant increase in the extent of the modern floodplain. Cyperaceae, Poaceae, and Sphagnum increased in abundance due to the greater available open-glade habitat. Plant macrofossil counts of Carex camosa type and Scirpus cespitosus type were high during this period, indicating more habitat on the modern floodplain.

During the last 25 years, high influx levels of Picea pollen and more Picea macrofossils only in part reflect increased Picea rubens on

the upland slopes around the bog. Within the bog, local pollen assemblages record the impact on the pollen rain from a line of Picea rubens trees growing on a high colluvial fan surface in the central part of the bog. The Picea rubens trees lie along the old fenceline of the Vanderbilt estate and were probably seedlings when the area outside the estate was cleared during logging of the area in the late-1880s. As the seedlings matured, they contributed locally derived Picea pollen; this is consistent with the occurrence of Picea microsporophyll in the surface sample and other Picea macrofossils. Slight increases in Carya pollen during this zone may reflect the replacement of Castanea dentata by Carya in the forest after passage of the chestnut blight (McCormick and Platt, 1980). The increase in Ambrosia type pollen indicates land settlement and clearance in the major lowland valleys below Pisgah Ridge. An increase in Ambrosia type pollen is typical at many sites as an indication of forest clearance and cultivation due to Euro-American settlement (Bassett and Terasmae, 1962).

Rare Plants and Local Extinctions at Flat Laurel Gap

The modern ranges of many circumboreal species extend south at high elevations along the crest of the Appalachian Mountains to the highlands of the Southeastern United States. These species include running clubmoss (Lycopodium clavatum), reed grass (Calamagrostis canadensis), Carex pensylvanica, bluebead-lily (Clintonia borealis), false lily of the valley (Maianthemum canadense), sweet fern (Comptonia peregrina), cinquefoil (Potentilla tridentata), and fireweed (Epilobium angustifolium) (Ramseur, 1960). Two of these species,

Potentilla tridentata and Comptonia peregrina, still occur today on Mt. Pisgah in close proximity to Flat Laurel Gap (White, et al., 1984). The paleoecologic record of Flat Laurel Gap bog documents the persistence of these boreal plant species at high elevations of the Southern Blue Ridge Province through the late-Holocene. Furthermore, several boreal plant species greatly restricted or totally absent from the Southern Appalachians today may not have been extirpated in the Pisgah Ridge area until early historic time.

During the full- and late-glacial intervals (23,000 to 16,500 yr BP, and 16,500 to 12,500 yr BP), alpine-tundra vegetation occurred at least as far south as Cranberry Glades ($80^{o}17'W$, $38^{o}12'N$) in West Virginia at 1,029 m in elevation (Watts, 1979). Geomorphic evidence from Flat Laurel Gap, including blockstreams and blockfields and colluvial fans dating from the late-Pleistocene/early-Holocene transition, documents that periglacial conditions with treeless vegetation probably occurred on mountain peaks above 1,500 m. A full-glacial boreal forest of jack pine, spruce, and fir is documented at 527 m from Saltville Valley, in the Valley and Ridge Province of southwestern Virginia (Delcourt and Delcourt, 1984). Circumboreal and northern species became established in the Southern Appalachians as vegetation retreated southward in response to climatic deterioration during the late-glacial (Delcourt and Delcourt, 1981). Thus, boreal species were widespread in the mid-latitudes of the Southeastern United States 18,000 yr BP (Delcourt and Delcourt, 1979). However, fragmentation of the boreal assemblage began about 12,500 yr BP, the regional Pleistocene/Holocene boundary (Delcourt and Delcourt, 1979),

and is documented by the changeover from periglacial, colluvial activity to an alluvial regime between 11,900 and 10,100 yr BP at Flat Laurel Gap. Certain boreal taxa, such as Larix, Populus balsamifera, and northern Diploxylon Pinus became extinct in the Southern Appalachians at the close of the Pleistocene (H. Delcourt, 1984b). Other boreal species became increasingly restricted, especially during the warm interval from 10,000 to 6,000 yr BP in the Central and Southern Appalachians (Watts, 1979). Circumboreals and other northern species have since been largely restricted to a series of ten areas in the Southern Appalachians, including Mt. Pisgah, with mountain peaks exceeding 1,680 m (5,500 ft) (Ramseur, 1960). Continued disturbance in the early-Holocene resulting from reactivation of blockstreams and other deposits at Flat Laurel Gap during catastrophic storms may have created disturbed habitat favorable to the survival of some boreal species (Williams and Guy, 1973; Mills, 1982).

Needles and pollen of Abies fraseri occurred in the plant fossil record at Flat Laurel Gap until the time of early Euro-American settlement. Fraser fir is today restricted to high-elevation areas in the Southern Appalachian Mountains, including the Balsam Mountains 18 km to the south of Mt. Pisgah, although it is conspicuously absent from the Pisgah area today (Ramseur, 1960; White, et al., 1984). Abies fraseri occurs with Picea rubens in the Southern Blue Ridge as part of the Spruce-Fir forest, generally above 1,500 m on high peaks. Warming during the mid-Holocene (Hypsithermal) Interval between 8,500 and 4,000 yr BP and the consequential retreat of spruce-fir forests to elevations above 1,750 m has been hypothesized as the probable cause

of extirpation of Abies fraseri from Mt. Pisgah and Whitetop Mountain in Virginia (Whittaker, 1956; White, et al., 1984). Mt. Pisgah, elevation 1,744 m, may have been below the critical elevation threshhold for maintenance of spruce and fir during the Hypsithermal.

During post-Hypsithermal cooling, spruce and fir would have advanced farther downslope except on Mt. Pisgah and Whitetop Mountain where no relict Spruce-Fir forest remained to colonize the peak (Billings and Mark, 1957; Ramseur, 1960; White, et al., 1984). However, the late-Holocene persistence of Abies fraseri at Flat Laurel Gap demands other scenarios. Hypsithermal warming may not have been sufficient to extirpate the Spruce-Fir forest on Mt. Pisgah. Alternately, a Spruce-Fir forest was reestablished in the area during the cooler episodes in the Holocene from populations in the Plott Balsam and Balsam Mountain to the south. Pollen of Abies occurs most abundantly within the forest stands in which the taxa is dominant, and generally is not transported far beyond the limits of its plant community (H. Delcourt, 1984). In addition, macrofossils of coniferous trees rarely are dispersed much more than 200 m from their source trees (Birks, 1980). Consequently, the needles and pollen of Abies clearly indicate that populations of fir grew locally at Flat Laurel Gap.

The late-Holocent palynologic record of Flat Laurel Gap illustrates the persistence of other boreal taxa including Alnus crispa, Chamaedaphne calyculata, bunchberry (Cornus canadensis), bog-rosmary (Andromeda floribunda), and Comptonia/Myrica. Comptonia peregrina occurs at Mt. Pisgah today; the other species have been extirpated

locally. Alnus crispa, the common boreal alder in central and eastern Canada, today occurs in the Southern Appalachians at 1,800 m elevation only on Roan Mountain in North Carolina (Radford, et al., 1968). Cornus canadensis is today found no farther south in the Appalachians than the mountains of West Virginia (Gleason and Cronquist, 1963). Chamaedaphne calyculata persisted until early historic times in poorly drained swamps and bogs in the mid-elevation Hendersonville basin of western North Carolina (Dr. J. Dan Pittillo, personal communication).

Relict boreal plants may have owed their continued persistence at Flat Laurel Gap to both the late-Holocene cooling trend in the Southern Appalachians (Barclay, 1957; Watts, 1979), as well as to the combination of periodic alluvial and colluvial disturbance and cold-air drainage into the bog, helping to maintain open glades and heath-shrub vegetation.

By A.D. 1900, the natural vegetation of the Southern Appalachian Mountains had been drastically altered by logging and related fires, grazing, and land clearance (Ashe and Ayres, 1905). Declines in Castanea pollen levels in the 1880s to the early 1900s A.D. prior to the Chestnut blight as well as declines in oak levels record the historic clearance of the upland forests (Ashe, 1911). At least a portion of Flat Laurel Gap was probably completely cleared of mature trees at the turn of this century; a line of spruce trees bordering an old barbed-wire fence running down the center of Flat Laurel Gap marks the property line of the Vanderbilt estate which once included Mt. Pisgah. South of the fence and outside of the estate, many fewer mature Picea rubens trees remain. Within the estate, the forest

received at least partial protection evidenced by the virgin Picea-Tsuga forest near Buck Springs (Fig. 2, p. 7). Thus, in or near Flat Laurel Gap in the early historic period, extirpation and further restriction in ranges of many boreal species occurred because of anthropogenic disturbance.

Significant questions concerning relict boreal plants remain in the Flat Laurel Gap area and the Southern Appalachian region in general. The existence of some reported plants such as twinflower (Linnaea borealis) still remain in question (White, 1981). In addition, Mt. Pisgah conspicuously lacks several boreal plants common to other high-elevation areas in the Southern Appalachians, including Clintonia borealis, Maianthemum canadense, Streptopus roseus, Ribes gladulosum, Circaea alpina, and Aster acuminatus (White, et al., 1984). In addition, the extent of anthropogenic impact on the natural vegetation is still not complete. Abies fraseri is now seriously threatened with extinction because of the balsam wooly aphid, an introduced pathogen (White, et al., 1984).

The Problem of the Balds

Flat Laurel Gap is an example of a Southern Appalachian heath bald. Heath balds and grass balds are both relatively open areas at high elevations in the Southern Appalachian Mountains in what is otherwise continuous forest cover. Heath balds are dominated by shrubs and herbs of the family Ericaceae, while the perhaps better-known grass balds are dominated by grass communities (Wells, 1936; Whittaker, 1956).

The origin and persistence of heath balds as prominent vegetation features in the Southern Appalachians is highly controversial and numerous theories have been proposed. However, the major issue remains unresolved (Stratton and White, 1982): How long have heath balds such as Flat Laurel Gap existed? The heath communities of the Southern Appalachians, similar to other heath communities of the world, tend to occur in cool, humid areas and form acidic soils of low nutrient content, with significant accumulations of raw humus. The heath balds of the Southern Appalachians occur most frequently on ridges and steep slopes below the ridgetops, commonly at elevations between 1,220 and 1,500 m. Annual precipitation at heath balds commonly exceeds 200 cm (Whittaker, 1963).

Mixed heath balds, such as Flat Laurel Gap, have a closed shrub stratum 1 to 3 m high dominated by Rhododendron catawbiense and Kalmia latifolia, with Vaccinium constablaei, Pyrus melanocarpa, and Viburnum cassinoides as associates. Rhododendron carolinianum, R. maximum, and Gaylussacia baccata are often present. Toward high elevation above 1,800 m, heath balds occur with single-shrub dominance. At such elevations, the heath balds are best developed on steep, south-facing slopes (Whittaker, 1963).

Flat Laurel Gap is dominated by Rhododendron catawbiense, R. maximum, Kalmia latifolia, and Vaccinium constablaei. Other Ericaceae present include Lyonia ligustrina, Rhododendron arborescens, R. viscosum, Vaccinium corymbosum, V. vacillans, and Leucothoe recurva (Pittillo and Govus, 1978). Heaths make up over 84% of the relative

percent cover of some of the vegetation plots at the head of Flat Laurel Gap (Appendix A8).

Various theories have been applied to the origin of heath balds. Cain (1930) believed heath balds were due to destruction of the forest canopy by fire, windfall, landslide, or their combination of natural disturbance factors. Once established on these disturbed sites, the heath shrubs in the understory inhibited regeneration of trees by an increase in heath cover and through soil acidification. Cain (1937) further suggested that exposure to wind may be another factor influencing the distribution of heath balds, noting that balds tend to be more often developed on the windward side of ridges where moisture-stress during the summer would be more severe.

Stratton and White (1982) studied the distribution and ecology of heath balds in Great Smoky Mountain National Park and found some correlation between the level of human disturbance and the frequency of heath balds. For example, although logging was practiced in every watershed in the park in the early 20th century, watersheds where less timber was removed tend to have fewer heath balds today. A similar pattern emerges with respect to fire history. Some ridges with extensive heath cover were burned, sometimes repeatedly, between A.D. 1900 and 1920. However, severe fires occurred on other ridges which today lack heath balds. Disturbance has been a central feature in the development of heath communities in other parts of the world. Pollen studies from heath communities in Europe show that there was forest cover prior to the heaths becoming dominant. This change from forest cover to heath shrubs dates to the time of widespread anthropogenic

forest clearance. Likewise, fire has been important to the formation of rock-heath communities in New England (Strang, 1970).

Gant (1978) examined the role of allelopathic interference in the maintenance of heath balds in the Southern Appalachians. Alelopathic interference represents reactions where plants deleteriously affect other plants by the introduction of phytotoxins. Gant studied heath balds in the Balsam Mountains 18 km south of Flat Laurel Gap and isolated nine phytotoxins from canopy drip, leaves, litter, roots, and soils. The phytotoxins were found to have varying degrees of adverse impact on three important genera of trees likely to replace heath bald communities: Abies, Betula, and Tsuga. Abies was found to be the most susceptible, Tsuga the least. Gant concluded that allelopathic intereference is an important factor in delaying the successional replacement of heath balds dominated by Rhododendron maximum. Balds dominated by Rhododendron catawbiense and Kalmia latifolia are probably very persistent vegetation features because of their highly effective allelopathic-interference properties. Allelopathic interference has likely been an important factor in the persistence of the heath community at Flat Laurel Gap; Rhododendron catawbiense, R. maximum, and Kalmia latifolia are all abundant Ericaceae on the high colluvial fan and dissected colluvial and fluvial terrace surfaces. These heaths have moderately high or very high allelopathic-interference properties (Gant, 1978). While both Picea rubens and Abies fraseri have persisted locally at Flat Laurel Gap throughout the late-Holocene, they have not replaced the shrub communities, although Picea rubens is locally established with a heath understory.

Abies fraseri may have been confined to better drained sites on the modern floodplain where heaths are less abundant until it was extirpated in the area by logging. Although heath balds at high elevations in the Southern Appalachians may succeed to spruce-fir or spruce forests (Ramseur, 1960), this succession apparently did not occur at Flat Laurel Gap.

In addressing the question of heath balds, the origin of grass balds cannot be ignored since at high elevations in the Southern Appalachian Mountains they frequently succeed to a heath bald community (Ramseur, 1960). Many grass balds received extensive human impact in historic times from grazing by cattle or sheep, fires, and land clearance; some of the best known grass balds of the Great Smoky Mountains National Park probably owe their entire existence to historic human impact (Lindsay, 1976). Wells (1936) suggested that the grass balds were the product of Indian burning and land clearance at high elevations to create open areas for campsites and "forest-edge" habitat for game animals. Alternately, Billings and Mark (1957) cited the importance of Holocene climatic warming for the distribution of spruce-fir forests in the Southern Appalachians and indirectly for the location of grassy balds. Billings and Mark suggested that during the mid-Holocene "Hypsithermal" that the spruce-fir forests retreated up the mountains to higher elevations but were locally extirpated except on some peaks such as Mt. Pisgah near Flat Laurel Gap which were not high enough in elevation to support a spruce-fir population. As the climate cooled after the Hypsithermal, the spruce-fir forest advanced downslope except at those locations where it had been

eliminated. At such locations, balds developed in its place just above the upper limit of the Mixed Northern Hardwood Forest. This theory was used to explain the existence of balds today on Mt. Pisgah (Billings and Mark, 1957). However, the persistence of Picea rubens and Abïes fraseri at Flat Laurel Gap in the late-Holocene paleoecological record demonstrates that other scenarios are necessary.

Although conclusions based on one bald cannot be indiscriminantly applied to all balds (Stratton and White, 1982), the paleoecologic and geomorphic record of Flat Laurel Gap suggests that its heath bald is the product of late-Quarternary biotic response to environmental change and not a product of historic human impact. The palynologic record of Flat Laurel Gap indicates that Ericaceae have been the dominant local and extralocal vegetation for at least the past 3,340 years of the late-Holocene. This is the first palynologic evidence to document with chronologic control the antiquity of heath balds in the Southern Appalachian Mountains. Likely, heaths have been present at the site since their migration into Southern Blue Ridge during the late-glacial (Watts, 1979). Andromeda glaucophylla and Chamaedaphne calyculata are both relict boreal heaths which were present at Flat Laurel Gap in the late Holocene but which are absent at the site today. Both species probably became established at Flat Laurel Gap during the full to late-glacial but persisted when boreal forests advanced north during postglacial climatic amelioration and relict populations of boreal plants in the Southern Appalachian Mountains became increasingly restricted to high peaks and areas of cold-air drainage, such as Flat Laurel Gap (Delcourt and Delcourt, 1981).

The establishment of the heath-bald community at Flat Laurel Gap may be related to the period of natural-landscape instability and disturbance at the Pleistocene-Holocene boundary when solifluction lobes created a colluvial fill in Flat Laurel Gap. Ericaceae shrubs probably became established on the colluvial surfaces because the colluvium would have been fairly well-drained, acidic and nutrient poor, conditions common to heath balds today (Whittaker, 1956). The overall area of heath cover at Flat Laurel Gap has probably slowly decreased through the Holocene as the colluvial valley fill has slowly been dissected and replaced by glade habitat. However, dissection has been limited by the tendency for a lag surface to develop which inhibits further erosion. The accumulation of acidic humus beneath the Ericaceae shrubs has further enhanced conditions for their survival. However, Ericaceae dominance has decreased at Flat Laurel Gap over the last century due to historic expansion of the glade environment. With logging of the upland slopes surrounding the bog and removal of Abies fraseri trees within the bog, runoff of water and sediment accelerated. This caused renewed incision of the colluvial valley fill, reducing the overall area of the high colluvial fan, dissected fluvial and colluvial terraces, and thus reducing the total area of Ericaceae habitat in the local and extralocal vegetation.

Geomorphology

The widespread existence of relict talus, blockstreams, and blockfields, and colluvial fans that date from the late-Pleistocene and early-Holocene is evidence of a former severe periglacial

environment characterized by intense freeze-thaw processes in and around Flat Laurel Gap during the full- and late-glacial. Blockfields, blockstreams, and colluvial fans at or near Flat Laurel Gap probably developed as a result of mass-wasting processes accompanying the collapse of discontinuous permafrost in the area during the late glacial and early Holocene. Severe periglacial conditions with alpine tundra and discontinuous permafrost have been hypothesized for high-elevation areas in the Southern Blue Ridge Province (Michalek, 1968; Watts, 1979; Delcourt and Delcourt, 1979, 1981; Whitehead, 1981). The block material was generated by freeze-thaw processes which fractured and spalled blocks off bedrock exposures on upland slopes above the bog. Although bedrock outcrops are relatively sparse in the area, they probably were more abundant during the late-glacial interval but were largely removed by frost action or are only obscured by soil, rubble, and blocks (Michalek, 1968).

Talus accumulated near the summit of Big Bald Mountain (Fig. 3, p. 9) because of intense frost-shattering of exposed outcrops. The material accumulated on slopes too steep for solifluction processes to occur. The talus may have developed on the north side of Big Bald Mountain because this slope received less insolation which could enhance freeze-thaw cycles. The major mechanism for movement of the blockstreams and blockfields and the colluvial fans was frost-action aided by solifluction acting within the active zone above the permanently frozen ground. Most of the blockstreams and blockfields have or had a matrix of fine-grained rock materials. The matrix would have aided downslope movement by absorbing moisture from the active zone of the permafrost,

reducing friction between the boulders, and promoting frost heaving. Solifluction involving the matrix would have helped carry the blocks along in the form of a viscous layer, carpeting the permafrost. The rough, irregular surface of the blockstreams and blockfields would have served as a catchment for snow. The snow would have been protected by the shadowing influence of the surrounding boulders. The moisture derived from the snow would have enhanced freeze-thaw and facilitated downslope movement of the blocks (Michalek, 1968). Downslope movement of blocks was strongly controlled by the permafrost which would have permitted only overland flow and throughflow in the active layer with little or no infiltration. This overland flow would favor intense sediment and block movement on nearly bare slopes which existed at higher elevations in the late-glacial (Starkel, 1983).

Solifluction rather than frost-heaving was the dominant mechanism of movement for formation of colluvial fans (Michalek, 1968; Washburn, 1973; Embelton and King, 1975). The fine components of the colluvial fans probably represent soil and colluvium that formerly blanketed the higher slopes (King, 1964). The TL date of 10,100±950 yr BP for the high colluvial fan in Flat Laurel Gap indicates that the colluvial fans were actively forming in the late Pleistocene and early Holocene. Development of the active zone on slopes with colluvium would create conditions of downslope flow of supersaturated, viscous, mobile sheets of soil and rock material. In some cases the colluvial fan lobes coalesced in hollows such as Flat Laurel Gap bog and created colluvial fan complexes. The lower reaches of some of the fans may have been emplaced more by alluvial processes when water filtered out of the

deposits or where the toes were partially reworked by fluvial processes operating on a limited scale in the area of the bog. In some cases, colluvial fans lie below blockstreams and blockfields; in these situations the colluvial fans may be composed of the finer material of the block deposits being worked farther downslope. Large blocks which litter the surface of some of the colluvial fans around Flat Laurel Gap were carried downslope by the viscous flow during active solifluction. Concentration of the blocks on the surface may have been due to freeze-thaw heaving of coarse material after or during movement of the deposit (Michalek, 1968). Colluvial fans may have formed in lieu of blockstreams or blockfields where the bedrock was locally higher in mica content which would have favored the development of matrix and inhibited block formation during freeze-thaw cycles.

Within the watershed of Flat Laurel Gap bog, colluvial fans and blockstreams are most abundant on the northeast slope above the bog. Although such deposits occur on slopes of many different aspects in the area, they are in general better developed on north-facing slopes perhaps because north-facing slopes receive lower solar input which could enhance freeze-thaw cycles. There is disagreement concerning which aspects are most conducive to solifluction and freeze-thaw processes (Michalek, 1968). During cold seasons, southerly exposures would receive greater insolation resulting in more freeze-thaw cycles, greater frost-action, and greater downslope movement of rock debris. However, north-facing slopes, because of lower insolation, would be subject to frost action for longer periods of time during a single year and during climatic episodes conducive to freeze-thaw processes

(Michalek, 1968; Washburn, 1973; Embelton and King, 1975). The attitude of the rock locally may have been a strong controlling factor for the distribution of colluvial and block deposits. Obsequent slopes would experience more infiltration of meltwater along bedding planes, favoring frost-shattering to generate blocks (Potter and Moss, 1968).

Upper-valley profiles similar to Flat Laurel Gap (amphitheater-like or cirque-like) have previously been noted elsewhere along Pisgah Ridge (Haselton, 1973; Raymond, 1977), and at Grandfather Mountain, North Carolina (Berkland and Raymond, 1977). Especially noted are U-shaped upper valley profiles, suggestive of possible former alpine glaciation (Raymond, 1977). Although cross-valley profiles and longitudinal profiles indicate a step-like aspect at Flat Laurel Gap, such features likely could have formed by solifluction and freeze-thaw processes operating through the late-glacial which created lobes of material which today overlap at various positions on the slopes. The cirque-like profile of the bog may have resulted entirely from the colluvial fan and solifluction activity which at high elevations tend to have imparted broad, sweeping profiles to the landscape (Michalek, 1968). Alternatively, the cirque-like form could have developed by nivation processes in the full- and late-glacial. Nivation freeze-thaw cycles would have been most effective on the margins of snowfields which probably lingered much later in the spring and summer at Flat Laurel Gap during the Pleistocene. Material generated by the nivation processes could then be worked downslope by solifluction (Embelton and King, 1975).

The TL date of 7,400±1,000 yr BP for the blockstream entering the bog environment from the northeast slope above Flat Laurel Gap indicates some reworking of the late-glacial and early-Holocene deposits during wetter and perhaps cooler episodes of the Holocene. The reactivated blockstream caused constriction in part of the open glade environment of the bog just upstream of the pegmatite dike (Fig. 4, p. 17). This and other blockstreams below the bog, which at one time crossed the creek draining Flat Laurel Gap, may have temporarily served as ponding mechanisms. Reworking or reactivation of the blockstream may have occurred during a high precipitation event (Kockel, et al., 1982). The blockstream was likely not created entirely because of a Holocene storm event. A blockfield with similar well-developed imbrication of boulders at the head of Flat Laurel Gap grades downslope into the colluvial fan material dated by TL analysis at 10,100±950 yr BP. Similar colluvial and block deposits as those mapped at Flat Laurel Gap have been ascribed to debris avalanching generated by high-intensity precipitation events (Hack and Goodlet, 1960). However, although storms may have caused reworking of some of the colluvial fans and blockstreams and movement of colluvium which makes up the general colluvial cover in the area, such deposits as at Flat Laurel Gap do not owe their initial formation to such events. To create conditions for debris slides to generate deposits similar to those at Flat Laurel Gap, runoff would need to be concentrated in drainageways to effectively move the large block material. However, the deposits at Flat Laurel Gap are situated at or just below the Pisgah Ridge. At such a setting, the drainage area is so small that even during an

intense storm, it is unlikely that the runoff could be sufficiently concentrated to move such large blocks. In addition, colluvial fans lack well-developed hollows or drainageways behind them where water could be collected. Instead, drainageways are better developed on the flanks of the fans which would permit only reworking of the material on the margins of the fans.

There is ample evidence for stability of the deposits in and around Flat Laurel Gap today. Colluvial fans are slowly being incised by the network of channels in the bog. In addition, fans are showing some indication of soil development, especially on their lower reaches, and the blocky appearance of the fans may have been accentuated by removal of fine-matrix around the blocks (Michalek, 1968). Many of the blocks on the fans and in the blockstreams and blockfields have discolored weathering rinds and pitted surfaces. The rounded edges on the blocks in the blockstreams and blockfields indicate that intensive freeze-thaw processes are no longer operating. Mature trees, especially Betula alleghaniensis, today grow up through the blockstreams. In this situation, blocks do not appear to be piled against trees nor are the trees bruised or scarred. There is thus no indication of downslope movement of the deposits today (Michalek, 1968).

A major result of late-Pleistocene and early-Holocene solifluction was the creation of a colluvial valley fill at Flat Laurel Gap. During the Holocene there had been a slow but largely progressive incision of the colluvial lobes except for minor episodes of reactivation of deposits. The TL date of 11,900±1,500 yr BP for the fluvial terrace in Flat Laurel Gap bog records the incision of the colluvial valley

fill and commencement of extensive alluvial deposition in the bog. Since the TL date for colluvial-fan emplacement (10,100±950 yr BP) and fluvial-terrace formation (11,900±1,500 yr BP) overlap in time, there was a period of time at the end of the Pleistocene when solifluction lobes overrode fluvial deposits. The pegmatite dike to which the topographic profile of Flat Laurel Gap grades was exhumed during early-Holocene dissection of the colluvial fill and subsequently began to anchor the local base level for alluvial ponding and Holocene deposition of organic sediment in the bog. The pegmatite dike probably had previously been buried by the colluvial valley fill. Only a 3,340-year organic sediment record was recovered at Flat Laurel Gap; lateral shifting of channels had probably eliminated earlier deposits or organic sediment of the bog during the Holocene. Filling behind and erosion of the pegmatite dike has now largely removed outcrops of the dike within the bog.

Three geomorphic surfaces were mapped with Flat Laurel Gap. The highest, the high colluvial fan surface, represents a feature created by the coalescing of colluvial fan lobes during the late Pleistocene and early Holocene and either may represent the original surface of the colluvial valley fill in Flat Laurel Gap or may represent a surface that has been lowered as a result of sheetwash. The high colluvial-fan material has been dissected progressively the network of channels in Flat Laurel Gap bog to create the dissected colluvial fan surface. Incision of the high colluvial-fan surface has been slowed by development of a coarse boulder lag surface. This has resulted in an intermediate surface, similar in relief to the fluvial terrace, which has

developed by partial erosion of the high colluvial fan. The third surface at Flat Laurel Gap bog, the modern floodplain, postdates the early Holocene reworking of the blockstream and indicates a mid-Holocene period of landscape stability and aggradation. Locally a lag surface of bouldery material has also developed on the modern floodplain, the blocks let-down by removal of the finer material during erosion of the dissected colluvial surface. The angular nature of the quartz, quartzite, and quartz-rich clasts in the modern alluvial material is evidence that (1) there has been relatively little re-working of the modern alluvium, and (2) the material was generated by frost shattering, a process which is occurring on a limited scale at the site today and resulting in the small frost-sorted stone circles.

During historic time there has been accelerated and increased runoff, erosion, and incision of the high colluvial and dissection colluvial and fluvial terrace surfaces. This period of landscape instability resulted first from logging and accompanying fires on the upland slopes above the bog, especially in the late-19th century; and in this century by construction of the Blue Ridge Parkway Road, the Pisgah Inn Lodge, and the campground. Consequences of this have been renewed incision on channels in the bog and an expansion of the modern floodplain and glade environment.

It is possible to estimate temperatures at Flat Laurel Gap for the late-Quaternary and particularly the period of periglacial activity by extrapolating climatic data determined for the Wisconsinan glacial period for lower elevations in the southeastern United States. Based on an environmental lapse rate of 6.5^{o}C/km of elevation change

Mayfield, 1981) and an annual temperature of 0.0°C for full-glacial conditions at Anderson Pond, Tennessee at 300 m (H. Delcourt, 1979), Flat Laurel Gap may have had an average annual temperature as low as -7.0°C at 18,000 yr BP, suitable for the support of continuous permafrost. In addition, paleotemperature reconstructions permit an estimation of the time of different geomorphic thresholds for the periglacial environment at Flat Laurel Gap. Based on a mean annual temperature threshold of -6.2°C (Billings and Money, 1968), Flat Laurel Gap likely experienced the shift from continuous permafrost with significant freeze-thaw generation of block material to discontinuous permafrost about 16,500 yr BP (Fig. 11). Continuous permafrost may have persisted longer within the bog where it would have possibly been supported by cold-air drainage and the insulating influence of surrounding ridges. Collapse of the remaining permafrost probably commenced about 12,500 yr BP when mean annual temperatures exceeded a second geomorphic threshold, that of 8.3°C (Billings and Money, 1968).

Figure 11. Environmental reconstructions for Flat Laurel Gap, Haywood County, North Carolina, 20,000 yr BP to the present. Temperature thresholds were established by Billings and Money (1968). Precipitation curve is that reconstructed for Anderson Pond, Tennessee (H. Delcourt, 1979).

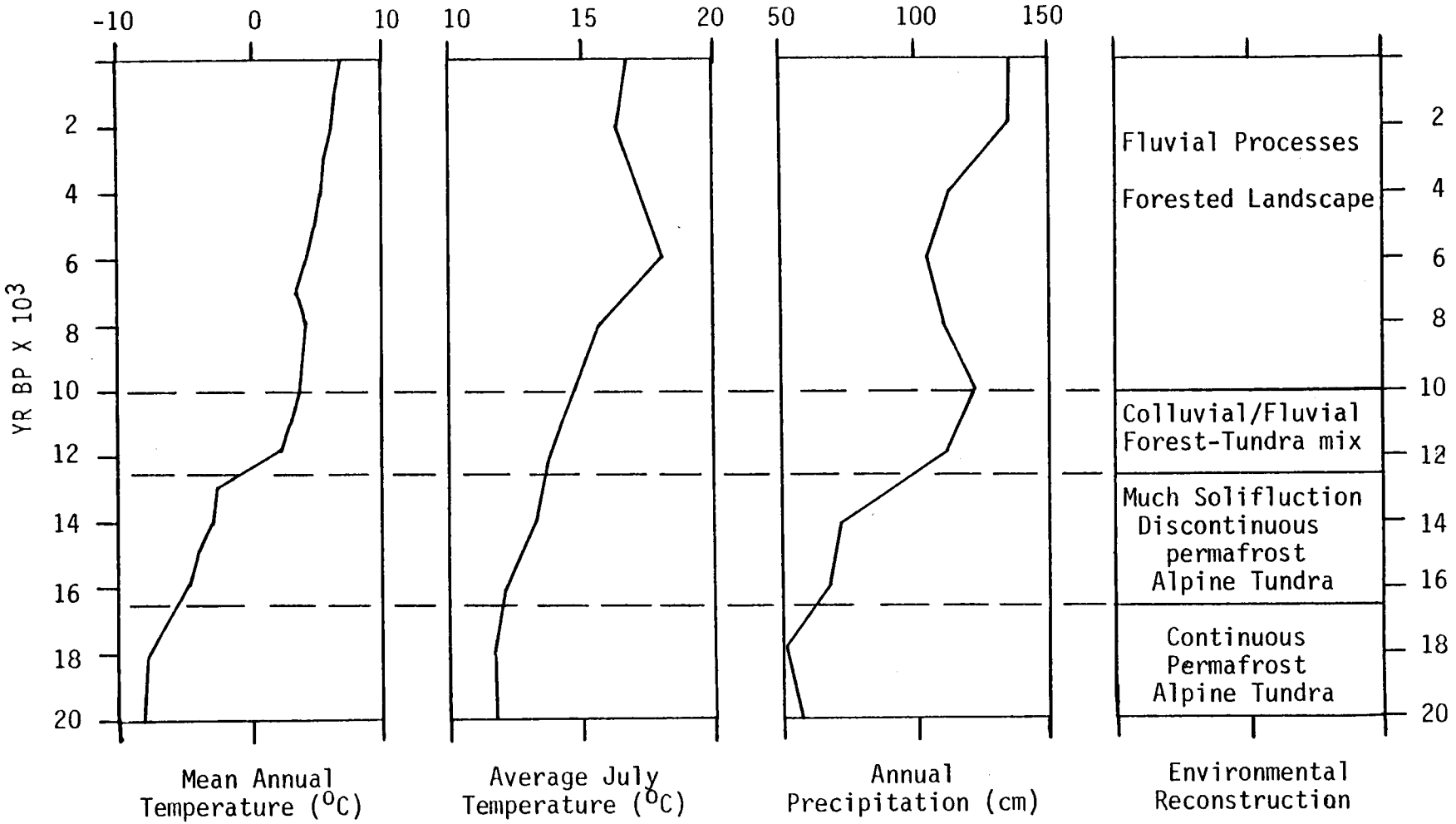

-10
0
10
10
15
20
50
100
150
YR BP X 10^3
2
4
6
8
10
12
14
16
18
20
Fluvial Processes
Forested Landscape
Colluvial/Fluvial
Forest-Tundra mix
Much Solifluction
Discontinuous
permafrost
Alpine Tundra
Continuous
Permafrost
Alpine Tundra
Mean Annual
Temperature (^oC)
Average July
Temperature (^oC)
Annual
Precipitation (cm)
Environmental
Reconstruction

Figure 11

V. SUMMARY AND CONCLUSIONS

The paleoecologic and geomorphic records at Flat Laurel Gap indicate that high elevation areas in the Southern Appalachian Mountains, such as the study site, have been dynamic areas with both physical and biotic responses to late-Quaternary climatic change and historic human disturbance. Paleoclimatic reconstructions in conjunction with the paleoecologic and geomorphic records allow environmental reconstructions for different episodes of the late-Quaternary at Flat Laurel Gap (Fig. 11).

The period of late-Wisconsinan glaciation prior to 16,500 yr BP probably saw the existence of a severe periglacial environment characterized by discontinuous permafrost and alpine tundra vegetation within Flat Laurel Gap bog and on Pisgah Ridge. The existence of relict populations of circumboreal plant species on Mt. Pisgah and other high peaks of the Southern Appalachians (Ramseur, 1960; Watts, 1979; White, et al., 1984) also suggest that the former periglacial environment was characterized by largely treeless tundra vegetation and low mean annual temperatures, probably below -6.2^{o}C (Billings and Money, 1968). This temperature threshold separates conditions of stability of continuous versus discontinuous permafrost. Climatic amelioration from full-glacial conditions probably began when this mean annual temperature was exceeded. During the period from 16,500

to 12,500 yr BP the study area was likely characterized by discontinuous permafrost with alpine tundra vegetation existing in an open patchwork of Spruce-Fir communities. This period also probably witnessed significant solifluction activity and consequental emplacement of blockstreams and blockfields.

The period of rapid climatic amelioration began about 12,500 yr BP and lasted until about 10,000 yr BP when Flat Laurel Gap probably had mean annual temperatures exceeding 8.3^{o}C, a critical upper temperature threshold for the persistence of discontinuous permafrost (Billings and Money, 1968) (Fig. 11). The 12,500 yr BP date coincides with the effective regional Pleistocene/Holocene climatic shift (Delcourt and Delcourt, 1981). During this period there was a mix of colluvial slope processes operating on the slopes and fluvial processes at work in the bog. The TL date of 11,900±1,500 yr BP for the dissected fluvial terrace records the initiation of incision of the colluvial valley fill in Flat Laurel Gap Bog. This late-Pleistocene period (12,500 to 10,000 yr BP) likely witnessed a dynamic mosaic of tundra and forest components with significant downslope reworking of freeze-thaw generated material on the slopes. Colluviation was fueled both by collapse of the permafrost as well as rising precipitation levels in the southeastern United States (H. Delcourt, 1979). Emplacement of colluvial fans was probably widespread at this time. Slope processes may have created openings in the forest to which spruce and fir, disturbance adapted taxa, were likely well adapted.

It may seem puzzling that TL analysis of the colluvial fan material at Flat Laurel Gap shows its emplacement occurred in the

late-glacial and not the full-glacial. The period from 12,500 to 10,000 yr BP was probably, though, the time of greatest landscape instability at Flat Laurel Gap. Rising annual temperatures and a sharp increase in annual precipitation (H. Delcourt, 1979) probably caused relatively rapid deterioration and collapse of the permafrost. The quick pulse of water in the active zone would have fueled solifluction activity, reworking block material on the slopes. The late-Pleistocene likely was a time when large amounts of rock debris were generated by freeze-thaw shattering because temperatures more often fluctuated around freezing temperatures. The number of freeze-thaw cycles rather than continually low temperatures, is the key to the generation of frost-shattered slope material (Davies, 1969).

The beginning of the Holocene saw the commencement of a period dominated by fluvial processes in a forested landscape and comparatively stable slopes. However, there were two likely cooler and moister periods at Flat Laurel Gap during the Holocene. These periods of landscape instability resulted in the reworking of some of the blockstreams and colluvial fan materials, and was likely related to changes in the position of major airmasses in eastern North America (Delcourt, 1984). Moisture from the Maritime Tropical airmass was concentrated in the southeastern United States from 8,000 to 6,000 yr BP, resulting in increased precipitation during the growing season and a greater frequency of severe storms. It was in such a setting that the blockstream dated by TL analysis at 7,400±1,000 yr BP at Flat Laurel Gap was reworked. Likewise, during the last 4,000 years of the late-Holocene, meridional flow was increased (P. Delcourt, 1984). This

resulted in a period of cool-temperate climate and abundant precipitation as the area was dominated in the winter by the Pacific airmass and in the summer by the Maritime Tropical airmass. Relatively higher levels of Abies and Picea at the base of the paleoecologic sequence from Flat Laurel Gap indicate expanded fir and spruce populations which developed in the area in response to cool, moist conditions during the growing season in the early late-Holocene.

The persistence of Abies fraseri at Flat Laurel Gap throughout most of the late-Holocene suggest that the impact of the mid-Holocene Hypsithermal may have been relatively minor in the Southern Appalachians. The Hypsithermal has been hypothesized as the cause of the extirpation of Spruce-Fir forests at Mt. Pisgah (Billings and Mark, 1957; White, et al., 1984). The Southern Appalachians may have been south of the influence of the Pacific airmass during the mid-Holocene. This airmass resulted in increased mid-continent warmth and aridity during the Hypsithermal (Wright, 1976). Instead, the Southern Appalachians may have remained more under the influence of the Maritime Tropical airmass which would have brought more summer moisture to the region (P. Delcourt, 1984).

While Flat Laurel Gap in the late-Quaternary has undergone considerable natural paleoecologic and geomorphic change in response to climatic change, the historic anthropogenic impact and the comparatively rapid rate at which human induced changes occurred, illustrate again the considerable potential we have to radically alter the natural environment. At Flat Laurel Gap this has included the extirpation of many rare and relict circumboreal and boreal plant

species, considerable changes in the composition of the upland forests above the bog, and changes in the areal extent of geomorphic surfaces in the bog.

Although complete reconstructions of the late-Quaternary at such high elevation sites as Flat Laurel Gap are unlikely because of the prevalent disturbance regimes which tend to destroy parts of the record, the record at Flat Laurel Gap yields some of the first absolute-age determinations available for periglacial deposits in the region, demonstrates the antiquity of some heath balds, and indicates the historic extirpation of many rare plants such as Alnus crispa and Abies fraseri. Flat Laurel Gap thus provides valuable insights for interpreting the late-Quaternary history of the Southern Appalachian Mountains.

LIST OF REFERENCES

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Adams, R. J., and Morton, J. K. (1979). An atlas of pollen of the trees and shrubs of eastern Canada and the adjacent United States. Part IV, No. 11. Department of Biology, University of Waterloo, Waterloo, Ontario.

Anderson, T. W. (1974). The chestnut pollen decline as a time line in sediments in Eastern North America. Canadian Journal of Earth Sciences 11, 678-685.

Ashe, W. W. (1911). Chestnut in Tennessee. Tennessee Geological Survey Series 10-B, pp 1-35.

Ayres, H. B., and Ashe, W. W. (1905). The Southern Appalachian forests. United States Geological Survey Professional Paper No. 37.

Barclay, F. H. (1957). The natural vegetation of Johnson County, Tennessee, past and present. PhD Thesis, University of Tennessee, Knoxville, 147p.

Bassett, I. J., and Terasmae, J. (1962). Ragweeds, Ambrosia species, in Canada and their history in postglacial times. Canadian Journal of Botany 40, 141-150.

Belling, A. J., and Heusser, C. J. (1974). Spore morphology of the Polypodiaceae of northeastern North America, I. Bulletin of the Torrey Botanical Club 101, 326-339.

Belling, A. J., and Heusser, C. J. (1975). Spore morphology of the Polypodiaceae of northeastern North America, II. Bulletin of the Torrey Botanical Club 102, 115-127.

Benedict, J. B. (1970). Downslope movement in a Colorado alpine region: Rates, processes, and climatic significance. Arctic and Alpine Research 2, 165-227.

Berggren, G. (1969). Atlas of seeds. Part II: Cyperaceae. Berlingska Boktryckeriet, Stockholm.

Berggren, G. (1981). Atlas of seeds. Part III: Salcaceae-Cruciferae. Berlingska Boktryckeriet, Stockholm.

Berkland, J. O., and Raymond, L. A. (1973). Pleistocene glaciation in the Blue Ridge Mountains, North Carolina. Science 181, 651-653.

Billings, W. D., and Mark, A. F. (1957). Factors involved in the persistence of montane treeless balds. Ecology 38, 140-142.

Billings, W. D., and Money, H. A. (1968). The ecology of arctic and alpine plants. Biological Reviews 43, 481-529.

Birks, N. J. B. (1979). Numerical methods for the zonation and correlation of geostratigraphical data. In "Palaeohydrological changes in the temperature zone in the last 15,000 years, International Geological Correlation Programme 158, Subproject B, Lake and Mire Environments, Project Guide, Vol. 1" (B. Berglund, Ed.), pp 99-123. Department of Quaternary Geology, Lund University, Lund, Sweden.

Braun, E. L. (1950) (reprinted 1974). Deciduous forests of eastern North America. Hafner Press, MacMillan, New York, New York.

Cain, S. A. (1930). Ecological studies of the heath balds of the Great Smoky Mountains. Butler University Botanical Studies 1, 177-208.

Cain, S. A. (1937). A preliminary guide to the Greenbriar-Brush Mountain Nature Trail in Great Smoky Mountains National Park. Unpublished, Great Smoky Mountains National Park Library, Gatlinburg, Tennessee.

Clark, G. M. (1968). Sorted patterned ground: New Appalachian localities south of the glacial border. Science 161, 355-356.

Clark, G. M. (1984). Debris slide/debris flow events in the high Appalachians south of the glacial border: Processes, site factors, and hillslope development in selected historical events. Geological Society of America Abstracts with Programs, Reno (submitted).

Comptois, P. and LaRouche, A. (1981). Morphologie pollinique des Ericales due Quebec. Naturaliste Canadae 108, 245-262.

Davies, J. L. (1969). Landforms of cold climates. Massachussetts Institute of Technology Press, Cambridge.

Davis, M. B., Brubaker, L. B. and Webb, T., III. (1973). Calibration of absolute pollen influx. In "Quaternary plant ecology" (H. J. B. Berks and R. G. West, Eds.), pp 9-25. Blackwell Scientific, Oxford, England.

Dean, W. E., Jr. (1974). Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss-on-ignition: Comparison with other methods. Journal of Sedimentary 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 adjacent Cumberland Plateau of Tennessee. Ecological Monographs 49, 255-280.

Delcourt, H. R. (1984). Holocene vegetational changes in the Southern Appalachian Mountains, U.S.A. In "Proceedings of the Annual Meeting of IGCP 158b" (J. L. de Beaulieu, Ed.), Marseilles.

Delcourt, H. R., Delcourt, P. A. and Webb, T., III. (1983). Dynamic plant ecology: The spectrum of vegetational change in space and time. Quaternary Science Reviews 1, 153-175.

Delcourt, P. A. (1980). Quaternary alluvial terraces of the Little Tennessee Valley, East Tennessee. In "The archaeological-geological investigations in the Tellico Reservoir" (J. Champman, Ed.), pp 110-121. University of Tennessee Department of Anthropology Report of Investigation No. 29, University of Tennessee Press, Knoxville.

Delcourt, P. A. (1984). The influence of late-Quaternary climatic and vegetational change on paleohydrology in unglaciated eastern North America. In "Proceedings of the Annual Meeting of IGCP 158b" (J. L. de Beaulieu, Ed.), Marseilles.

Delcourt, P. A., and Delcourt, H. R. (1979). Late-Pleistocene and Holocene distributional history of deciduous forests in the southeastern United States. Veroff Geobotanik Institute ETH, Stiftung Rubell, Zurich 68, 79-107.

Delcourt, P. A., and Delcourt, H. R. (1981). Vegetation maps for eastern North America: 40,000 yr BP to the present. In "Geobotany, an integrating experience" (R. Romano, Ed.). Proceedings of the 1980 Geobotany Conference, Plenum Pulbishing Company.

Durrell, L. W. (1916). Notes on some North American conifers based on leaf characteristics. Proceedings of the Iowa Academy of Science 23, 519-582.

Embelton, C., and King, C. A. M. (1975). Periglacial geomorphology. John Wiley and Sons, New York, 203p.

Erdman, G. M. (1966). Pollen morphology and plant taxonomy: Angiosperms. Hafner Publishing Company, New York.

Faegri, K., and Iversen, J. (1975). Textbook of pollen analysis, third revised edition. Hafner Publishing Company, New York.

Fowells, H. A. (1965). Silvics of forest trees of the United States. United States Department of Agriculture, Agriculture Handbook No. 271, Washington, D. C., 762p.

Gant, R. E. (1978). The rate of allelopathic interference in the maintenance of southern Appalachian heath balds. PhD dissertation, University of Tennessee, Knoxville, 123p.

Gleason, H. A., and Cronquist, A. (1963). Manual of vascular plants of the northeastern United States and adjacent Canada. D. Van Nostrand Company, Princeton, New Jersey.

Godfrey, R. K., and Wooten, J. W. (1979). Aquatic and wetland plants of the Southeastern United States, Monocotyledons. University of Georgia Press, Athens, 712p.

Gribbin, J., and Lamb, H. H. (1978). Climatic change in historic time. In "Climate change" (J. Gribbin, Ed.). Cambridge University Press, Cambridge, 280p.

Hack, J. T., and Goodlett, J. C. (1960). Geomorphology and forest ecology of a mountain region in the central Appalachians. United States Geological Survey Professional Paper 347, 66p.

Hadley, J. B., and Nelson, A. E. (1971). Geologic map of the Knoxville quadrangle, North Carolina, Tennessee, and South Carolina. United States Geological Survey Miscellaneous Geologic Investigations Map I-654, Scale 1:250,000.

Haselton, G. M. (1973). Possible relict glacial features in the Black Balsam Knob and Richland Balsam area, North Carolina. Southeastern Geology 15, 119-125.

Helmich, D. E. (1963). Pollen morphology in the maples. Papers of the Michigan Academy of Science, Arts and Letters 48, 151-164.

Heusser, C. J. (1971). Pollen and spores of Chile. University of Arizona Press, Tucson, 167p.

Horton, J. H., and Hotaling, L. G. (1981). Floristics of selected heath communities along the Southern Section of the Blue Ridge Parkway. United States Department of the Interior, National Park Service, NPS-SER Research Resources Management Report No. 45, 36p.

Huang, T-C. (1972). Pollen flora of Taiwan. National Taiwan University Botany Department Press, Taipei, 297p.

Hyde, H. A., and Adams, K. F. (1958). An atlas of airborne pollen grains. MacMillan and Company, Ltd., St. Martin's Press, New York, 112p.

Ikuse, M. (1956). Pollen grains of Japan. Herokawa Publishing Company, Tokyo, 304p.

Jacobson, G. L., and Bradshaw, R. H. W. (1981). The selection of sites for paleovegetational studies. Quaternary Research 16, 80-96.

Janssen, C. R. (1967). A postglacial pollen diagram from a small typha swamp in northwestern Minnesota, interpreted from pollen indicators and surface samples. Ecological Monographs 37, 145-172.

Kapp, R. O. (1969). How to know pollen and spores. William C. Brown Company Publishers, Dubuque.

King, P. B. (1964). Geology of the Central Great Smoky Mountains, Tennessee. United States Geological Survey Professional Paper 349-C, pp 130-142.

Kocker, R. C., Johnson, R. A., and Valastu, S. (1982). Repeated episodes of Holocene debris avalanching in Central Virginia. In "Geological Society of America Annual Meeting Abstracts with Programs, Northeastern and Southeastern Sections". Washington D. C.

Lieux, M. H. (1980a). An atlas of pollen of trees, shrubs, and woody vines of Louisiana and other southeastern states, Part II. Ginkgoaceae to Lauraceae. Pollen et Spores 22, 17-57.

Lieux, M. H. (1980b). An atlas of pollen of trees, shrubs, and woody vines of Louisiana and other southeastern states, Part III. Plantanaceae to Betulaceae. Pollen et Spores 22, 191-243.

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. Museum Nacional D'Histoire Naturelle 24, 21-64.

Lindsay, M. (1976). History of the grassy balds in Great Smoky Mountains National Park. Unites States National Park Service, Great Smoky Mountains National Park Management Report 4, Gatlinburg.

Martin, A. C., and Barkley, W. D. (1961). Seed identification manual. University of California Press, Berkeley, 221p.

Maxwell, J. A., and Davis, M. B. (1972). Pollen evidence of Pleistocene and Holocene vegetation on the Allegheny Plateau, Maryland. Quaternary Research 2, 506-530.

Mayfield, M. W. (1981). The question of glaciation of the Southern Appalachians: A new approach. Preliminary manuscript, unpublished.

McAndrews, J. H., Berti, A. A., and Norris, G. (1973). Key to the Quaternary pollen and spores of the Great Lakes Region. Royal Ontario Museum of Life Sciences, Miscellaneous Publication, University of Toronto Press, Toronto, Ontario.

McCormick, J. F., and Platt, R. B. (1980). Recovery of an Appalachian forest following the chestnut blight or, Catherine Keever--you were right! American Midland Naturalist 104, 264-273.

Michalek, D. D. (1968). Fanlike features and related periglacial phenomena of the Southern Blue Ridge. PhD dissertation, University of North Carolina, Chapel Hill, 198p.

Mills, H. H. (1982). Surficial geology and geomorphology of the Mountain Lake area, Giles County, Virginia, including sedimentological studies of colluvium and boulder streams. United States Geological Survey Professional Paper (submitted).

Montgomery, F. H. (1977). Seeds and fruits of plants of eastern Canada and northeastern United States. University of Toronto Press, Toronto, Ontario, 232p.

Muetter-Dombois, D., and Ellenberg, H. (1974). Aims and methods of vegetation ecology. John Wiley and Sons, New York, 547p.

Nilsson, S., Praglowski, J., and Nilsson, R. (1977). Atlas of airborne pollen grains and spores in northern Europe. Natur och Kultur Stockholm, 159p.

National Oceanic and Atmospheric Administration. (1974). Climates of the States, Volume 1: Eastern United States. United States Department of Commerce, New York.

Pewe, T. L. (1983). The periglacial environment in North America during Wisconsinan time. In "Late-Quaternary environments of the United States, Volume I, The late-Pleistocene" (S. C. Porter, Ed.,), pp 157-189. University of Minnesota Press, Minneapolis.

Pittillo, J. D., and Gorvus, T. E. (1978). Important plant habitats of the Blue Ridge Parkway from the Great Smoky Mountains National Park to Roanoke, Virginia. A report to the National Park Service.

Pittillo, J. D., and Smathers, G. A. (1979). Phytogeography of the Balsam Mountains and Pisgah Ridge, Southern Appalachian Mountains. Veroff Geobotanik Institute ETH, Stiftung Rubell, Zurich 68, 206-245.

Potter, N., Jr., and Moss, J. H. (1968). Origin of the Blue Rocks blockfield and adjacent deposits, Berks County, Pennsylvania. Geological Society of America Bulletin 79, 255-262.

Radford, A. E., Ahles, H. E., and Bell, C. R. (1968). Manual of vascular flora of the Carolinas. The University of North Carolina Press, Chapel Hill.

Ramseur, G. S. (1960). The vascular flora of high mountain communities of the Southern Appalachians. Journal of the Elisha Mitchell Scientific Society 76, 82-112.

Raymond, R. A. (1977). Glacial, periglacial, and pseudoglacial features in the Grandfather Mountain area, North Carolina. Southeastern Geology 18, 213-229.

Richard, P. (1970a). Atlas pollinique des arbres et de quelques arbustes indigenes du Quebec, I. Introduction generale, II. Gymnospermes. Le Naturaliste Canadien 97,

Richard P. (1970b). Atlas pollinique des arbres et de quelques arbustes indigenes du Quebec, III. Angiospermes (Salicacees, Myricacees, Juglandacees, Corylacees, Fagacees, Ulmacees). Le Naturaliste Canadien 97, 97-161.

Richard, P. (1970c). Atlas pollinique des arbres et de quelques arbustes indigenes du Quebec, III. Angiospermes (Rosacees, Anacardiacees, Aceracees, Rhamnacees, Tiliacees, Cornacees, Oleacees, Caprifoliacees). Le Naturaliste Canadien 97, 241-306.

Schopmeyer, C. S. (1974). Seeds of the woody plants in the United States. United States Department of Agriculture, Forest Service, Washington, D. C., 883p.

Shanks, R. E. (1954). Climates of the Great Smoky Mountains. Ecology 35, 354-361.

Starkel, L. (1983). The reflection of hydrologic changes in the fluvial environment of the temperate zone during the last 15,000 years. In "Background palaeohydrology, A perspective" (K. J. Gregory, Ed.), pp 213-235. John Wiley and Sons, Ltd., Chichester.

Strang, R. M. (1970). Ecology of the rock heathlands of western Nova Scotia. Proceedings of the Tall Timbers Fire Ecology Conference 10, 287-293.

Stratton, D. A., and White, P. S. (1982). Heath balds of the Great Smoky Mountains: Flora, distribution, and ecology. National Park Service, Southeast Regional Office Research Resource Management Report Series.

Torbett, C. A. (1984). Sorted patterned ground: New locality in the Appalachian Great Smoky Mountains, North Carolina, Tennessee. (abstract). Proceedings of the Meeting on Scientific Research in the National Parks of the Uplands Section of the Southeastern Region, Gatlinburg.

Washburn, A. L. (1973). Periglacial processes and environments. Edward Arnold, London, 320p.

Wasylikova, K. (1979). Plant macrofossils. In "Palaeohydrological changes in the temperate zone in the last 15,000 years, International Geological Co-relation Programme 158, Subproject B, Lake and Mire Environments, Project Guide, Vol. 2, Guideline for Specific Methods" (B. Berglund, Ed.). Department of Quaternary Geology, Lund University, Lund, Sweden.

Watts, W. A. (1979). Late-Quaternary vegetation of central Appalachia and the New Jersey coastal plain. Ecological Monographs 49, 427-469.

Watts, W. A. (1980). The Late-Quaternary vegetation history of the Southeastern United States. Annual Review of Ecology and Systematics 11, 387-409.

White, P. S. (1981). Looking for Linnaea. The Tennessee Conservationist 47, 14-16.

White, P. S., Miller, R. I., and Ramseur, G. S. (1984). The species-area relationship of the Southern Appalachian high peaks: Vascular plant richness and rare plant distributions. Castanea 49, in press.

Whitehead, D. R. (1981). Late Pleistocene vegetational changes in northeastern North Carolina. Ecological Monographs 51, 451-471.

Whittaker, R. H. (1956). Vegetation of the Great Smoky Mountains. Ecological Monographs 26, 1-69.

Whittaker, R. H. (1963). Net production of heath balds and forest heaths in the Great Smoky Mountains. Ecology 44, 176-182.

Williams, G. P., and Guy, H. P. (1973). Erosional and depositional aspects of Hurrican Camille in Virginia, 1969. United States Geological Survey Professional Paper 804, 80 p.

Wright, H. E., Jr. (1967). The use of surface samples in Quaternary pollen analysis. Review of Palaebotany and Palynology 2, 321-330.

Wright, H. E., Jr. (1976). The dynamic nature of Holocene vegetation, A problem on paleoclimatology, biogeography, and stratigraphic nomenclature. Quaternary Research 6, 581-596.

APPENDICES

APPENDIX 1

LOSS-ON-IGNITION DATA

(FLAT LAUREL GAP, NORTH CAROLINA)

Depth (cm)	Sample Weight (gm/cm^3)	Organic Matter (gm/cm^3)	Percent Organic Matter	Organic Carbon ($gm/100cm^3$)	Percent Organic Carbon
0	0.063	0.052	90.22	2.69	42.36
5	0.1329	0.0677	59.76	3.18	28.06
10	0.2915	0.0771	26.45	3.62	12.42
15	0.2906	0.0927	31.89	4.35	14.97
20	0.4896	0.0902	18.42	4.23	8.65
25	0.5213	0.0578	11.09	2.71	5.21
30	0.5310	0.0661	12.45	3.10	5.85
35	0.2354	0.0649	27.57	3.03	12.94
40	0.8632	0.0475	5.50	2.23	2.58
45	0.3121	0.0490	15.70	2.30	7.37
50	0.3500	0.0449	12.83	2.11	6.02
55	0.4213	0.0540	12.82	2.54	6.02
60	0.5258	0.0522	9.92	2.45	4.66
65	0.7167	0.0426	5.94	2.00	2.79
70	0.8173	0.0275	3.36	1.29	1.58
75	0.7363	0.0697	9.47	3.27	4.45
80	0.7997	0.0696	8.70	3.27	4.08
85	0.7515	0.0305	4.06	1.43	1.91
90	0.7408	0.0575	4.06	2.70	3.64
95	0.7260	0.0330	4.55	1.55	2.14

APPENDIX 1 (Continued)

Depth (cm)	Sample Weight (gm/cm^3)	Organic Matter (gm/cm^3)	Percent Organic Matter	Organic Carbon ($gm/100cm^3$)	Percent Organic Carbon)
100	0.6115	0.0300	4.91	1.41	2.31
110	0.6555	0.0294	4.49	1.38	2.11
120	0.4914	0.0362	7.37	1.70	3.46
130	0.8615	0.0505	5.86	2.37	2.75
140	0.5494	0.0311	5.66	1.46	2.66
150	0.4567	0.0406	8.89	1.91	4.17
160	0.3185	0.0452	14.19	2.12	6.66

APPENDIX 2

INFLUX OF POLLEN AND SPORES

(FLAT LAUREL GAP, NORTH CAROLINA)

Depth (cm)	Influx Rate (grains·cm^{-2}·yr^{-1})
0.0	1,870
2.5	2,958
5.0	5,412
7.5	10,047
10.0	3,453
12.5	5,210
15.0	4,620
20.0	3,253
25.0	2,251
30.0	4,353
35.0	9,982
40.0	17,525
45.0	19,533
50.0	13,809
55.0	20,376
60.0	14,489
65.0	10,424
70.0	28,140
75.0	9,480
80.0	7,312
85.0	4,040
90.0	10,634
100.0	4,070

APPENDIX 3

POLLEN PERCENTAGES, 0.0 TO 25.0 CM DEPTH

(FLAT LAUREL GAP, NORTH CAROLINA)

	Depth (cm)								
	0.0	2.5	5.0	7.5	10.0	12.5	15.0	20.0	25.0
TREES									
Abies fraseri	0.8	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.2
Acer negundo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4
Acer pensylvanicum-spicatum type	0.0	0.0	0.2	0.5	0.0	0.6	0.7	0.4	0.0
Acer rubrum	0.2	0.3	0.6	0.2	0.8	0.2	0.0	0.2	0.0
Acer saccharinum	0.0	0.0	0.0	0.0	0.4	0.0	0.5	0.4	0.0
Acer saccharum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Betula	2.4	7.6	5.5	7.2	6.1	6.3	6.5	2.6	4.2
Carya	3.2	2.7	2.9	1.4	1.2	2.8	4.5	3.0	4.4
Castanea	0.4	0.0	1.3	14.8	6.3	1.7	1.6	2.2	4.2
Celtis	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cornus alternifolia	0.0	0.3	0.4	0.2	0.0	0.2	0.0	0.0	0.2
Corylus	0.0	0.3	0.0	0.4	0.0	0.6	0.0	0.0	0.0
Cupressaceae/Taxodiaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Fagus grandifolia	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0
Fraxinus undiff.	0.6	0.0	0.6	0.2	0.4	0.0	0.2	0.2	0.2
Fraxinus nigra-quadrangulata type	1.0	1.0	0.4	0.4	0.0	0.6	0.5	0.0	0.0
Fraxinus pennsylvanica-americana type	0.0	1.0	0.4	0.4	0.0	0.6	0.5	0.0	0.0
Fraxinus C3STP	0.6	0.0	0.6	0.2	0.4	0.0	0.2	0.2	0.2
Ilex	0.0	1.0	0.0	0.0	0.4	0.4	1.1	0.4	0.0
Juglans undiff.	0.2	0.3	0.6	0.2	0.0	0.0	0.2	0.2	0.0

APPENDIX 3 (Continued)

	Depth (cm)								
	0.0	2.5	5.0	7.5	10.0	12.5	15.0	20.0	25.0
Juglans cinerea type	0.0	0.3	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Juglans nigra type	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Liguidambar	0.0	1.0	0.0	0.0	0.2	0.2	0.0	0.2	0.6
Liriodendron	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0
Myrica/Comptonia type	0.2	0.0	0.4	0.7	0.0	0.2	0.2	0.8	0.4
Nyssa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostrya/Carpinus type	0.2	0.8	0.6	0.5	1.2	0.2	0.7	1.7	0.6
Picea rubens	11.8	1.0	3.6	2.0	2.1	1.7	3.5	1.2	4.8
Pinus undiff.	6.1	3.3	5.5	6.5	4.0	4.6	7.9	7.3	5.5
Pinus diploxylon	10.3	11.3	5.5	1.3	1.7	4.2	4.4	3.8	3.6
Pinus haploxylon	2.3	3.8	1.5	1.2	0.6	0.8	1.7	0.2	0.8
Platanus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Populus	0.0	0.0	0.0	0.2	0.0	0.2	0.2	0.0	0.0
Quercus	14.2	37.0	28.3	21.0	24.5	28.8	25.5	24.9	21.1
Salix	0.8	0.5	0.0	1.8	1.9	0.4	0.7	0.9	0.2
Tilia	0.0	0.3	0.0	0.0	0.0	0.4	0.9	0.0	0.0
Tsuga	2.6	1.5	1.9	1.4	1.5	0.6	2.5	1.1	2.7
Ulmus	0.2	0.8	0.4	0.5	0.2	0.2	0.7	0.8	0.0
Rubus	0.0	0.5	0.4	1.4	0.4	1.9	1.1	0.8	0.6
Viburnum	2.2	1.3	1.9	1.4	3.3	2.6	0.7	0.9	1.5
Prunus	0.6	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0
Amelanchier/Sorbus type	0.2	0.3	0.4	1.1	1.2	1.5	0.2	0.4	1.9
SHRUBS AND LIANAS									
Alnus crispa	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.4	0.0
Alnus ruguosa	1.8	0.5	0.4	0.2	0.8	0.9	1.1	0.8	0.4
Corylus	0.0	0.3	0.0	0.4	0.2	0.0	0.0	0.5	0.0

APPENDIX 3 (Continued)

	Depth (cm)								
	0.0	2.5	5.0	7.5	10.0	12.5	15.0	20.0	25.0
Vitis	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sambucus	0.8	0.0	0.4	0.2	0.0	1.5	0.0	0.0	0.2
Ledum/Chamaedaphne type	0.0	0.0	0.0	0.0	0.8	0.4	0.0	0.8	0.0
Cephalanthus	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.2	0.0
Kalmia	0.6	0.3	0.8	0.5	0.8	1.5	0.0	1.3	1.9
Lyonia	0.0	0.0	0.6	0.4	0.0	0.7	0.2	0.2	1.2
Rhododendron	1.2	0.0	0.2	0.5	0.0	0.2	0.2	0.2	1.5
Leucothoe	0.2	0.3	0.0	0.2	0.4	0.0	0.5	1.3	0.4
Oxydendrum	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.6
Andromeda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chimaphila	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0	0.0
Ledum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chamaedaphne	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Vaccinium corymbasum	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Vaccinium stamineum-arboreum/ Gaylussacia type	0.0	0.8	0.0	0.2	0.0	0.7	0.0	0.0	0.2
Vaccinium constablaei type	0.4	0.8	1.1	2.5	3.1	1.7	0.7	5.6	2.1
HERBS AND FERNS									
Ambrosia type	1.4	0.3	0.8	0.9	0.8	0.4	0.7	0.0	0.2
Artemisia	0.2	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Caryophyllaceae	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Chenopodiaceae/Amaranthaceae	0.0	0.3	0.0	0.2	0.0	0.6	0.5	0.0	0.0
Brassicaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyperaceae	12.6	3.3	9.9	8.3	12.6	8.9	9.5	8.2	2.9
Poaceae	3.7	2.3	2.9	2.1	0.8	1.5	1.8	1.2	1.5
Fabaceae	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Apiaceae	0.0	0.5	0.0	0.2	0.0	0.0	0.0	0.0	0.0

APPENDIX 3 (Continued)

	Depth (cm)								
	0.0	2.5	5.0	7.5	10.0	12.5	15.0	20.0	25.0
Liguliflorae	0.0	1.0	0.4	0.4	1.0	0.6	0.0	0.0	0.2
Potentilla	0.0	0.0	0.0	0.0	0.4	0.2	0.2	0.0	0.0
Ranunculaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Saxifragaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thalictrum	0.2	0.0	0.2	0.0	0.2	0.0	0.0	0.4	0.0
Tubuliflorae undiff.	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Urtica	0.0	0.5	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Xanthium	0.6	0.3	0.0	0.0	0.3	0.4	0.0	0.0	0.0
Achillea type	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Adiantun type	0.0	0.0	0.2	0.0	0.0	0.4	0.0	0.0	0.0
Bidens type	1.2	2.8	3.1	2.1	1.2	1.7	0.9	1.5	1.3
Boraginaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Botrychium	0.4	0.0	0.0	0.5	0.6	0.0	0.0	0.0	0.0
Cornus canadensis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dryopteris	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
Helianthus	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.2
Humulus/Cannabis type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Iva ciliata type	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Iva xanthifolia type	1.0	2.3	1.7	2.8	3.4	3.7	4.3	0.0	1.2
Osmunda cinnamomea type	4.1	2.5	2.5	1.2	1.2	0.0	1.8	1.2	0.6
Osmunda regalis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Monotropa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Galax aphylla	0.0	0.0	0.6	0.0	0.0	0.4	0.5	0.0	0.6
Cystopteris	0.0	0.0	0.2	0.7	0.0	0.7	0.0	0.0	0.2
Lycopodium undiff.	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.2
Pteridium aquilinum	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0
Polypodium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0

APPENDIX 3 (Continued)

	Depth (cm)								
	0.0	2.5	5.0	7.5	10.0	12.5	15.0	20.0	25.0
UNKNOWNS	1.8	0.8	0.8	0.2	0.4	0.7	0.5	0.2	0.4
OBLIGATE AQUATICS									
Myriophyllum	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Potamogeton foliosus type	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Potamogeton pectinatus type	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Sphagnum	4.5	1.8	18.4	6.5	3.0	2.7	3.0	2.3	1.4
INDETERMINABLE GRAINS	6.6	1.5	2.6	3.0	1.7	2.6	6.6	3.7	5.0

APPENDIX 4

POLLEN PERCENTAGES, 30.0 TO 70.0 CM DEPTH

(FLAT LAUREL GAP, NORTH CAROLINA)

	Depth (cm)								
	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0
TREES									
Abies fraseri	0.0	0.0	0.2	0.3	0.2	0.0	0.4	0.2	0.6
Acer negundo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acer pensylvanicum-spicatum type	0.0	0.0	0.0	0.2	0.0	0.4	0.2	0.6	0.4
Acer rubrum	0.2	0.4	0.0	0.2	0.4	0.2	0.0	0.0	0.0
Acer saccharinum	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.2
Acer saccharum	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Betula	7.6	6.3	2.6	2.8	5.4	6.1	5.3	3.6	4.0
Carya	3.5	2.5	3.0	5.3	1.6	3.2	1.0	3.2	0.6
Castanea	1.5	1.5	1.8	0.7	6.2	3.0	9.5	3.4	14.1
Celtis	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Cornus alternifolia	0.2	0.6	0.4	0.0	0.4	0.3	0.0	0.0	0.0
Corylus	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Cupressaceae/Taxodiaceae	0.0	0.0	0.0	0.0	0.4	0.0	0.6	0.0	1.1
Fagus grandifolia	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.2
Fraxinus undiff.	1.1	0.2	0.0	0.2	0.4	0.5	0.8	0.2	0.2
Fraxinus nigra-quadrangulata type	0.0	0.8	1.8	0.2	0.0	0.4	0.0	0.8	1.3
Fraxinus pennsylvanica-americana type	0.0	0.2	0.0	0.2	0.6	0.0	0.2	0.0	0.0
Fraxinus C3STP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ilex	0.4	0.0	0.2	0.2	0.6	0.2	1.5	0.2	0.0
Juglans undiff.	0.0	0.4	0.2	0.2	0.0	0.4	0.2	0.0	0.0

APPENDIX 4 (Continued)

	Depth (cm)								
	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0
Juglans cinerea type	0.4	0.0	0.0	0.7	0.0	0.0	0.0	0.2	0.0
Juglans nigra type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Liquidambar	1.1	0.6	0.2	0.0	0.0	0.2	0.2	0.0	0.2
Myrica/Comptonia type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nyssa	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ostrya/Carpinus type	2.0	0.2	1.0	0.2	0.8	0.5	0.4	0.4	0.2
Picea rubens	1.6	1.5	5.6	6.3	1.2	1.8	4.8	2.6	2.0
Pinus undiff.	5.4	7.4	11.6	10.8	5.6	4.0	5.5	5.4	3.0
Pinus diploxylon	2.9	6.8	9.9	6.5	2.4	1.8	2.8	4.8	1.5
Pinus haploxylon	0.4	2.5	0.8	0.4	0.0	0.4	0.0	1.0	0.2
Platanus	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Populus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Quercus	27.8	29.8	19.2	27.3	22.2	22.8	16.6	24.1	17.1
Salix	2.0	0.4	0.8	0.4	2.8	0.7	2.1	1.0	2.4
Tilia	0.0	0.0	0.0	0.0	0.0	0.9	0.2	0.0	0.2
Tsuga	1.1	3.1	1.6	0.4	1.4	0.2	0.4	1.6	0.7
Ulmus	0.0	0.0	0.0	0.4	0.2	0.0	0.2	0.4	0.6
Rubus	0.2	0.8	0.6	0.8	0.4	0.9	0.6	1.0	1.5
Viburnum	1.7	4.0	1.8	1.5	3.2	2.8	4.2	3.4	2.9
Prunus	0.2	0.2	0.2	0.0	0.6	0.2	0.0	0.2	0.4
Amelanchier/Sorbus type	1.1	0.4	0.2	1.1	0.6	1.4	0.4	1.8	1.1
SHRUBS AND LIANAS									
Alnus crispa	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.6	0.0
Alnus rugosa	0.4	1.7	0.8	0.4	0.2	1.2	1.0	1.8	0.7
Corylus	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

APPENDIX 4 (Continued)

	Depth (cm)								
	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0
Vitis	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2
Sambucus	0.7	0.0	0.0	0.0	0.0	0.2	0.2	0.2	1.3
Ledum/Chamaedaphne type	0.4	0.0	0.2	0.0	1.4	0.0	1.7	0.0	0.4
Cephalanthus	0.0	0.0	0.0	0.0	0.0	0.2	1.0	0.6	0.0
Kalmia	0.7	1.0	2.4	0.0	2.4	3.7	1.0	2.0	1.7
Lyonia	0.0	0.4	0.2	0.7	0.0	0.9	0.2	0.8	0.4
Rhododendron	0.9	0.4	1.2	0.7	0.8	0.5	1.1	1.0	0.0
Leucothoe	0.0	0.6	0.8	0.7	1.4	0.5	1.1	0.6	1.7
Oxydendrum	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.4	0.0
Andromeda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Chimaphila	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.2	0.4
Ledum	0.0	0.0	0.0	0.0	0.4	0.0	0.8	0.0	0.0
Chamaedaphne	0.0	0.2	0.0	0.0	0.6	0.0	0.8	0.0	0.4
Vaccinium corymbosum	0.4	0.6	0.4	0.2	0.0	1.7	0.0	0.0	0.0
Vaccinium stamineum-arboreum/ Gaylussacia type	0.2	0.0	0.6	0.4	0.0	0.4	0.0	0.6	1.7
Vaccinium constablaei type	3.3	2.1	2.2	3.5	4.6	4.0	4.5	1.4	4.8
HERBS AND FERNS									
Ambrosia type	0.0	0.0	0.0	0.4	0.2	0.2	0.0	0.6	0.0
Artemisia	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.2	0.4
Caryophyllaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Chenopodiaceae/Amaranthaceae	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.0
Brassicaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyperaceae	10.6	4.0	4.9	1.8	5.4	1.8	4.5	4.6	3.7
Poaceae	1.3	0.8	0.2	0.9	0.8	0.5	1.7	1.0	2.2
Fabaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Apiaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX 4 (Continued)

	Depth (cm)								
	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0
Liguliflorae	0.2	0.0	0.0	0.0	0.2	0.2	0.4	0.6	0.2
Potentilla	0.4	0.2	0.0	0.2	0.4	0.5	0.4	0.6	0.2
Ranunculaceae	0.0	0.0	0.0	0.2	0.4	0.0	0.4	0.0	0.4
Saxifragaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Thalictrum	0.0	0.0	0.2	0.4	0.2	0.0	0.0	0.0	0.0
Tubuliflorae undiff.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urtica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Xanthium	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Achillea type	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2
Adiantum type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bidens type	0.7	0.6	0.0	0.2	1.0	1.4	0.4	1.2	0.4
Boraginaceae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Botrychium	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.4	0.0
Cornus canadensis	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Dryopteris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Helianthus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Humulus/Cannabis type	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iva ciliata type	0.2	0.0	0.2	0.0	0.4	0.0	0.0	0.2	0.2
Iva xanthifolia type	0.4	0.4	0.0	0.4	0.0	0.9	0.2	2.0	0.6
Osmunda cinnamomea type	1.3	0.4	0.8	0.2	1.8	0.4	1.0	2.0	0.4
Osmunda regalis	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Monotropa	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Galax aphylla	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0
Cystopteris	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lycopodium undiff.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pteridium aquilinum	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Polypodium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX 4 (Continued)

	Depth (cm)								
	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0
UNKNOWNS	1.1	1.5	3.6	0.7	1.2	0.9	1.9	0.8	2.0
OBLIGATE AQUATICS									
Myriophyllum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Potamogeton foliosus type	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Potamogeton pectinatus type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sphagnum	5.1	1.7	0.9	0.8	0.7	0.4	1.1	1.8	0.6
INDETERMINABLE GRAINS	5.1	1.8	4.0	10.3	3.4	5.0	3.5	3.2	6.0

APPENDIX 5

POLLEN PERCENTAGES, 75.0 TO 100.0 CM DEPTH

(FLAT LAUREL GAP, NORTH CAROLINA)

	Depth (cm)				
	75.0	80.0	85.0	90.0	100.0
TREES					
Abies fraseri	0.2	0.9	0.3	2.5	1.6
Acer negundo	0.0	0.2	0.0	0.0	0.0
Acer pensylvanicum-spicatum type	0.0	0.4	0.2	0.0	0.0
Acer rubrum	0.0	0.2	0.2	0.8	0.0
Acer saccharinum	0.2	0.6	0.2	0.0	0.0
Acer saccharum	0.2	0.0	0.0	0.0	0.0
Betula	6.2	4.2	3.6	2.2	3.8
Carya	2.4	3.2	0.8	3.8	2.4
Castanea	9.1	5.9	12.8	7.3	14.0
Celtis	0.0	0.0	0.5	0.0	0.0
Cornus alternifolia	0.0	0.0	0.2	0.2	0.4
Corylus	0.0	0.2	0.0	0.0	0.0
Cupressaceae/Taxodiaceae	0.0	0.0	0.0	0.0	0.0
Fagus grandifolia	0.2	0.2	0.2	0.0	0.0
Fraxinus undiff.	0.4	0.6	0.6	0.2	0.2
Fraxinus nigra-quadrangulata type	0.8	0.4	0.6	0.0	0.0
Fraxinus pennsylvanica-americana type	0.4	0.0	0.2	0.0	0.0
Fraxinus C3STP	0.4	0.4	0.4	0.2	0.2
Ilex	1.1	0.0	0.6	0.2	0.9
Juglans undiff.	0.2	0.0	0.0	0.0	0.0

APPENDIX 5 (Continued)

	Depth (cm)				
	75.0	80.0	85.0	90.0	100.0
Juglans cinerea type	0.0	0.0	0.0	0.2	0.0
Juglans nigra type	0.0	0.0	0.0	0.0	0.0
Liquidambar	0.2	0.0	0.0	0.2	0.0
Liriodendron	0.0	0.0	0.0	0.0	0.0
Myrica/Comptonia type	0.4	2.5	0.8	3.6	0.2
Nyssa	0.0	0.0	0.0	0.2	0.0
Ostrya/Carpinus type	0.0	0.6	0.6	0.0	0.2
Picea rubens	0.8	4.2	4.6	5.8	6.1
Pinus undiff.	5.1	7.7	8.3	6.1	4.1
Pinus diploxylon	1.8	4.8	2.3	4.9	4.9
Pinus haploxylon	0.2	0.0	0.3	0.0	0.2
Platanus	0.0	0.0	0.0	0.0	0.0
Populus	0.0	0.0	0.2	0.0	0.0
Quercus	25.0	16.9	19.5	19.9	23.8
Salix	1.8	2.1	4.2	1.4	3.1
Tilia	0.0	0.0	0.0	0.0	0.2
Tsuga	1.1	2.7	1.1	1.0	0.2
Ulmus	0.2	0.0	0.0	0.2	0.0
Rubus	1.4	1.1	1.5	0.8	1.3
Viburnum	1.0	2.7	0.4	0.2	0.9
Prunus	0.2	0.2	0.4	0.2	0.0
Amelanchier/Sorbus type	0.4	0.6	0.6	0.2	0.0
SHRUBS AND LIANAS					
Alnus crispa	1.0	1.3	0.4	0.8	0.9
Alnus rugosa	3.0	0.6	2.5	0.2	1.6
Corylus	0.0	0.2	0.0	0.0	0.0

APPENDIX 5 (Continued)

	Depth (cm)				
	75.0	80.0	85.0	90.0	100.0
Vitis	0.0	0.0	0.0	0.0	0.0
Sambucus	0.0	0.0	0.0	0.0	0.0
Ledum/Chamaedaphne type	0.0	0.6	0.2	0.4	0.0
Cephalanthus	0.4	0.0	0.0	0.0	0.0
Kalmia	1.8	1.3	0.6	1.4	0.4
Lyonia	0.6	0.0	0.6	0.0	0.2
Rhododendron	0.6	0.2	0.0	0.4	0.7
Leucothoe	0.6	0.0	0.0	0.0	0.0
Oxydendrum	0.2	0.2	0.0	0.0	1.8
Andromeda	0.0	0.0	0.0	0.0	0.0
Chimaphila	0.2	0.0	0.6	0.4	0.0
Ledum	0.0	0.0	0.0	0.2	0.0
Chamaedaphne	0.0	0.0	0.0	0.0	0.0
Vaccinium corymbosum	0.0	0.0	0.0	0.0	0.0
Vaccinium stamineum-arboreum/ Gaylussaccia type	0.8	0.4	0.6	0.0	0.0
Vaccinium constablaei type	3.2	3.8	0.8	3.4	1.1
HERBS AND FERNS					
Ambrosia type	0.2	0.4	0.0	0.0	0.7
Artemisia	0.4	0.2	0.0	0.0	0.0
Caryophyllaceae	0.2	0.0	0.4	0.0	0.0
Chenopodiaceae/Amaranthaceae	0.4	0.0	0.0	0.0	0.0
Brassicaceae	0.0	0.0	0.0	0.0	0.0
Cyperaceae	3.8	3.6	4.0	5.3	1.1
Poaceae	0.0	4.0	1.9	2.4	4.9
Fabaceae	0.0	0.0	0.0	0.2	0.0
Apiaceae	0.0	0.0	0.0	0.0	0.0

APPENDIX 5 (Continued)

	Depth (cm)				
	75.0	80.0	85.0	90.0	100.0
Liguliflorae	0.0	0.0	1.1	1.0	0.0
Potentilla	0.0	0.2	0.6	0.2	0.0
Ranunculaceae	0.0	0.2	0.0	0.0	0.0
Saxifragaceae	0.0	0.0	0.0	0.0	0.0
Thalictrum	0.2	0.0	0.2	0.0	1.1
Tubuliflorae undiff.	0.0	0.0	0.0	0.0	1.1
Urtica	0.0	0.4	0.0	0.6	0.0
Xanthium	0.0	0.2	0.2	0.0	0.2
Achillea type	0.2	0.2	0.2	0.4	0.0
Adiantum type	0.0	0.0	0.0	0.0	0.4
Bidens type	0.4	1.3	1.5	0.8	0.0
Boraginaceae	0.0	0.0	0.0	0.0	0.0
Botrychium	0.0	0.0	0.0	0.0	0.0
Cornus canadensis	0.2	0.0	0.0	0.0	0.0
Dryopteris	0.0	0.0	0.0	0.0	0.0
Helianthus	0.0	0.0	0.2	0.0	0.0
Humulus/Cannabis type	0.0	0.0	0.0	0.0	0.0
Iva ciliata type	0.0	0.2	0.0	0.0	0.0
Iva xanthifolia type	0.4	0.6	1.3	0.6	0.2
Osmunda cinnamomea type	1.0	3.0	3.8	1.4	0.4
Osmunda regalis	0.0	0.2	0.2	0.0	0.2
Monotropa	0.0	0.0	0.0	0.2	0.0
Galax aphylla	0.0	0.0	0.0	0.0	0.0
Cystopteris	0.0	0.0	0.4	0.2	0.0
Lycopodium undiff.	0.0	0.0	0.0	0.0	0.2
Pteridium aquilinum	0.9	0.2	0.0	0.6	0.0
Polypodium	0.0	0.0	0.0	0.0	0.4

APPENDIX 5 (Continued)

	Depth (cm)				
	75.0	80.0	85.0	90.0	100.0
UNKNOWNS	0.8	1.0	1.3	3.0	1.8
OBLIGATE AQUATICS					
Myriophyllum	0.0	0.0	0.0	0.0	0.0
Potamogeton foliosus type	0.0	0.0	0.0	0.0	0.0
Potamogeton pectinatus type	0.0	0.0	0.0	0.0	0.0
Sphagnum	2.6	4.0	2.9	4.0	4.2
INDETERMINABLE GRAINS	5.5	5.4	10.5	6.3	9.5

APPENDIX 6

MODERN POLLEN PERCENTAGES FOR VEGETATION PLOTS

(FLAT LAUREL GAP, NORTH CAROLINA)

	Vegetation Plots							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TREES								
Abies	0.0	0.0	0.0	0.3	0.3	0.0	0.3	0.0
Acer undiff.	0.0	0.6	0.0	0.6	0.3	0.0	0.6	0.3
Acer negundo	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acer rubrum	0.3	0.3	0.0	0.3	0.7	1.3	1.9	1.2
Acer pensylvanicum-spicatum	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Acer saccharum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acer saccharinum	0.0	1.3	0.7	0.3	0.0	1.0	0.0	0.0
Betula	6.1	10.6	15.8	13.9	12.8	11.5	14.2	8.6
Carpinus/Ostrya type	0.0	1.3	0.7	1.3	0.7	0.7	0.6	0.3
Carya	1.3	5.8	2.6	5.7	2.6	1.0	6.0	3.7
Castanea	0.6	0.0	0.0	0.3	0.3	1.0	0.3	2.8
Celtis/Maclura type	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cornus alternifolia type	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cupressaceae/Taxodiaceae type	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Fagus grandifolia	0.0	0.0	0.0	0.3	0.3	0.0	0.0	0.0
Fraxinus undiff.	0.5	0.2	0.6	0.2	0.2	0.0	0.0	0.2
Fraxinus quadrangulata-nigra type	1.6	1.0	3.0	1.0	0.3	1.6	0.0	0.6
Fraxinus pennsylvanica-americana type	0.3	0.0	0.3	0.0	0.3	0.0	0.0	0.9
Fraxinus C3STP	0.5	0.2	0.6	0.2	0.2	0.3	0.0	0.2
Ilex	37.3	0.6	0.0	1.0	0.7	0.0	0.0	1.2
Juglans cinerea type	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX 6 (Continued)

	Vegetation Plots							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Juglans undiff.	0.0	0.3	0.0	0.0	0.0	0.0	0.3	0.3
Juglans nigra type	0.0	1.3	0.0	0.0	0.0	0.3	0.0	0.0
Liquidambar	0.0	0.3	0.0	0.0	0.7	0.7	0.3	0.6
Myrica type	0.0	0.0	0.0	0.3	0.7	0.0	0.3	0.0
Nyssa	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Picea rubens	2.7	5.9	1.3	1.6	2.3	3.4	4.5	3.2
Pinus undiff.	4.3	13.3	9.7	9.9	8.8	11.6	13.6	13.4
Pinus diploxylon	2.3	11.4	8.9	10.3	16.8	9.2	12.5	10.2
Pinus haploxylon	2.3	7.0	5.6	4.7	8.0	4.9	2.8	4.2
Prunus	0.3	0.6	0.7	0.3	0.0	0.0	0.0	0.3
Quercus	21.9	30.4	35.3	39.1	34.4	38.0	36.3	34.3
Rubus	7.1	1.0	0.3	1.6	0.7	0.7	0.3	1.9
Amelanchier/Surbus type	0.0	0.6	2.0	1.9	1.3	3.6	1.0	0.6
Salix	1.9	1.3	8.3	0.3	0.7	0.7	0.0	0.9
Tilia	0.0	0.0	0.0	0.6	0.3	0.0	0.3	0.6
Tsuga	1.0	3.2	2.6	1.6	2.0	2.0	2.2	1.9
Ulmus	0.3	0.0	0.0	0.3	0.3	1.0	0.3	0.3
Viburnum	6.8	1.0	0.7	1.9	2.6	5.6	1.3	1.9
SHRUBS AND LIANAS								
Alnus rugosa type	0.3	1.4	1.4	1.1	0.4	0.2	1.4	0.2
Cephalanthus	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0
Corylus	0.0	0.7	0.2	0.7	0.2	0.0	0.0	0.5
Sambucus	0.0	0.0	5.2	0.2	0.0	2.2	0.0	0.2
Rhododendron	3.0	4.1	0.2	0.9	1.5	0.7	1.4	3.5
Kalmia	1.7	9.0	1.8	0.7	0.9	0.5	0.3	1.4
Vaccinium constablaei type	2.2	10.9	4.3	1.6	0.4	2.9	1.4	3.2

APPENDIX 6 (Continued)

	Vegetation Plots							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Vaccinium stamineum-arboreum/ Gaylussacia type	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.2
Vaccinium corymbosum	0.0	2.8	0.2	0.0	0.0	0.0	0.5	0.0
Ericaceae undiff.	1.0	7.7	2.5	2.4	1.1	2.7	2.6	4.0
Leucothoe	0.5	0.0	0.0	0.2	0.0	0.0	1.2	0.5
Lyonia liguistrina-lucida type	0.0	1.3	0.5	0.9	0.9	0.7	0.3	0.7
Oxydendrum arboreum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chimaphila maculata-uniflora type	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Ledum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vitis	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HERBS								
Caryophyllaceae	0.3	0.0	0.0	0.2	0.4	1.5	0.2	0.5
Chenopodiaceae/Amaranthaceae type	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
Ambrosia type	1.7	0.9	1.8	3.3	0.4	1.5	2.9	0.7
Artemisia	0.5	0.0	0.2	1.1	0.7	0.2	0.2	0.0
Bidens type	0.5	0.0	2.9	0.7	10.7	1.0	0.2	1.2
Iva xanthifolia	4.2	1.8	2.7	2.0	0.9	1.2	2.2	2.1
Iva ciliata	0.7	0.0	0.0	0.4	0.4	0.2	0.7	0.2
Xanthium	0.5	0.2	0.7	1.1	0.2	0.0	1.0	0.0
Achillea	0.3	0.2	0.5	0.9	0.0	0.0	0.0	0.0
Liguliflorae	0.3	0.0	0.2	0.0	0.7	1.0	0.0	0.0
Cyperaceae	4.4	1.6	2.7	1.8	3.9	1.9	5.0	3.9
Poaceae	0.3	1.1	0.5	1.6	6.1	5.3	0.7	1.6
Humulus	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Thalictrum	0.5	0.0	0.2	0.4	0.0	0.2	0.0	0.0
Umbelliferae	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Helianthus	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0

APPENDIX 6 (Continued)

	Vegetation Plots							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ranunculaceae	0.5	0.2	0.5	0.0	0.0	0.0	0.2	0.0
Galax aphylla	0.0	0.0	0.0	0.0	0.0	0.0	017	0.0
Urtica	0.0	0.0	0.2	0.0	0.0	0.5	0.0	0.0
Lobelia	0.0	0.0	0.0	0.0	0.4	0.5	0.5	0.0
Fabaceae	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
Plantago	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
FERNS								
Osmunda cinnamomea type	0.3	0.0	0.0	4.7	0.2	0.0	0.7	0.9
Cystopteris	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0
Pteridium	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2
CLUBMOSSES								
Lycopodium undiff.	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL UNKNOWNS	0.0	0.2	1.8	2.4	0.7	0.7	0.0	0.7
OBLIGATE AQUATICS								
Sphagnum	1.0	0.4	0.0	0.2	0.0	0.2	0.0	1.0
Polygonum hydropiper type	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
TOTAL INDETERMINATES	4.5	2.6	4.7	4.8	3.4	5.0	9.9	4.2

APPENDIX 7

RELATIVE PERCENT COVER VALUES FOR VEGETATION PLOTS

(FLAT LAUREL GAP, NORTH CAROLINA)

	Vegetation Plots							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TREES								
Ilex ambiqua var. montana	12.4	8.8	0.0	0.0	0.5	2.3	0.0	0.0
Amelanchier arborea var. laevis	0.0	10.6	8.5	12.8	5.4	0.0	3.5	0.0
Sorbus melanocarpa	0.0	0.0	0.0	0.0	0.5	1.1	0.0	0.0
Sorbus arbutifolia	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.3
Amelanchier/Sorbus type	0.0	10.6	8.5	12.8	5.9	2.2	3.5	1.3
Viburnum cassinoides	3.3	0.9	4.3	0.0	1.0	4.5	3.5	0.6
Acer rubrum	0.0	0.0	0.0	0.0	0.0	3.4	0.2	0.0
SHRUBS								
Kalmia latifolia	4.1	26.5	12.8	34.5	1.5	35.2	10.6	0.6
Rhododendron catawbiense	45.5	26.5	17.1	12.3	12.3	12.5	28.4	0.6
Rhododendron maximum	28.9	8.8	8.5	0.0	0.5	5.7	0.7	0.0
Rhododendron viscosum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Rhododendron (total)	74.4	35.3	25.6	12.3	12.8	18.2	29.1	1.0
Vaccinium constablaei	1.7	4.4	4.3	0.0	0.5	5.7	0.7	0.0
Vaccinium vacillens	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Vaccinium constablaei type	1.7	4.4	4.3	0.0	0.5	5.7	0.7	1.3
Lyonia ligustrina	0.0	0.0	1.7	0.5	0.5	0.0	0.0	0.0
Leucothoe recurva	0.0	0.0	0.0	0.5	0.5	1.1	3.5	0.6
Ericaceae (total)	80.2	66.2	44.4	47.8	15.8	60.2	73.0	9.9
Alnus serrulata	0.0	0.0	0.0	0.0	0.0	5.7	0.0	0.6
Sambucus canadensis	0.0	0.0	17.1	0.0	3.4	0.0	0.0	0.0

APPENDIX 7 (Continued)

	Vegetation Plots							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
HERBS								
Galax aphylla	4.1	13.3	0.0	36.9	12.3	5.7	3.5	0.0
Chelone sp.	0.0	0.0	21.4	0.5	7.4	1.1	0.0	0.0
Cuscuta pentagona	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0
Aster puniceus	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0
Eupatorium rugosum	0.0	0.0	0.9	0.0	0.5	0.0	0.0	0.0
Solidago patula	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.6
Carex sp.	0.0	0.0	0.0	0.0	1.0	0.0	0.0	31.8
Juncus subcaudatus	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0
Eriophorum virginicus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Cyperaceae (total)	0.0	0.0	0.0	0.0	1.0	1.1	0.0	32.2
Lobelia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Agrostis alba	0.0	0.0	0.9	0.0	1.0	1.1	0.0	0.6
Danthonia sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Poaceae undiff.	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.4
Holcus lanatus	0.0	0.0	0.9	0.0	0.5	0.0	0.0	0.0
Poaceae (total)	0.0	0.0	1.8	0.0	2.0	1.1	0.0	1.4
Mitchella repens	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Trillium undulatum	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Hypericum puncatum	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
Houstonia serpyuifolia	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0
Drosera rotundifolia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4

APPENDIX 7 (Continued)

	Vegetation Plots							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FERNS								
Osmunda cinnamomea	0.0	0.0	0.9	0.5	0.5	1.1	0.0	0.0
OBLIGATE AQUATICS								
Sphagnum sp.	0.0	0.0	0.0	0.0	0.0	5.7	0.0	57.3

APPENDIX 8

PLANT MACROFOSSIL DATA

(FLAT LAUREL GAP, NORTH CAROLINA)

	Depth Intervals (cm)							
	0.0 to 1.0	4.5 to 5.5	9.5 to 10.5	14.5 to 15.5	17.5 to 22.5	22.5 to 27.5	27.5 to 32.5	32.5 to 37.5
TREES								
Abies fraseri (needles)								
tips	0	0	0	1	0	0	0	0
bases	0	0	0	0	0	0	0	0
fragments	0	0	1	0	0	0	0	0
whole	0	0	0	0	0	0	0	0
Picea rubens (needles)								
tips	4	0	0	0	0	0	0	0
bases	1	0	0	0	0	0	0	0
fragments	1	0	0	0	0	0	0	0
whole	5	2	2	0	0	0	0	0
Picea rubens								
microsporophyll	1	0	0	0	0	0	0	0
twigs (two or more sterigmata)	0	0	0	0	0	0	0	0
sterigmata	0	0	1	0	0	0	0	0
seed wings	0	0	0	0	0	0	0	0
Sorbus	0	0	0	0	0	0	0	0

APPENDIX 8 (Continued)

	Depth Intervals (cm)							
	0.0 to 1.0	4.5 to 5.5	9.5 to 10.5	14.5 to 15.5	17.5 to 22.5	22.5 to 27.5	27.5 to 32.5	32.5 to 37.5
SHRUBS								
Rubus Odoratus	0	0	0	0	0	0	0	0
Rubus undiff	0	0	0	0	0	0	0	0
HERBS								
Carex camosa type	1	101	4	0	2	1	0	0
Scirpus cespitosus type	5	5	1	4	7	5	5	3
Scirpus cyperinus type	0	1	5	4	1	0	1	3
Scirpus smithii type	0	0	0	0	0	0	0	3
Juncus	0	31	2	30	0	1	0	25
Hypericum boreale-mutilum type	0	2	0	0	0	1	2	0
Galium	0	0	4	0	5	0	4	0
Poaceae	2	1	0	0	0	0	0	0
Chenopodium	0	0	0	0	0	0	0	0
Viola	0	0	0	0	0	0	0	0
OBLIGATE AQUATICS								
Sphagnum	+++	+++	+++	+++	+			
INSECT PARTS	6	19	4	16	7	20	20	7

APPENDIX 8 (Continued)

	Depth Intervals (cm)							
	37.5 to 42.0	42.5 to 47.5	47.5 to 52.5	52.5 to 57.5	57.5 to 62.5	62.5 to 67.5	67.5 to 72.5	72.5 to 77.5
TREES								
Abies fraseri (needles								
tips	0	0	4	3	1	0	0	0
bases	0	0	0	0	0	0	0	0
fragments	0	0	0	0	0	0	0	0
whole	0	0	0	0	0	0	0	0
Picea rubens (needles)								
tips	0	0	0	0	0	1	0	0
bases	0	0	0	0	0	0	0	0
fragments	0	0	0	2	3	4	0	2
whole	0	0	4	0	0	0	0	0
Picea rubens								
microsporophyll	0	0	0	0	0	0	0	0
twigs (two or more sterigmata	0	0	0	0	0	0	0	0
sterigmata	0	0	0	0	0	0	0	0
seed wing	0	0	0	0	0	1	0	0
Sorbus	0	0	0	0	0	1	0	0
SHRUBS								
Rubus odoratus	0	0	0	1	0	1	0	0
Rubus undiff.	0	0	0	0	0	0	2	0

APPENDIX 8 (Continued)

	Depth Intervals (cm)							
	37.5 to 42.0	42.5 to 47.5	47.5 to 52.5	52.5 to 57.5	57.5 to 62.5	62.5 to 67.5	67.5 to 72.5	72.5 to 77.5
HERBS								
Carex camosa type	0	0	0	0	1	0	0	0
Scirpus cespitosus type	1	1	0	0	1	4	0	4
Scirpus cyperinus type	0	1	0	0	0	4	0	0
Scirpus smithii type	0	0	2	0	0	0	0	1
Juncus	0	0	0	0	0	1	0	0
Hypericum boreale-mutilum type	0	0	0	0	0	0	0	0
Galium	8	4	104	80	44	40	46	8
Poaceae	0	0	0	0	0	0	0	0
Chenopodium	0	0	0	0	1	0	0	0
Viola	0	0	0	0	0	0	0	0
OBLIGATE AQUATICS								
Sphagnum	0	0	0	0	0	0	0	0
INSECT PARTS	21	15	10	14	10	4	2	4

APPENDIX 8 (Continued)

	Depth Intervals (cm)				
	77.5 to 82.5	82.5 to 87.5	87.5 to 92.5	92.5 to 97.5	97.5 to 102.5
TREES					
Abies fraseri (needles)					
tips	6	1	0	0	0
bases	3	0	0	0	0
fragments	4	2	0	0	0
whole	0	0	0	0	0
Picea rubens (needles)					
tips	1	0	0	0	0
bases	1	1	0	0	0
fragments	0	0	0	0	0
whole	2	0	0	0	0
Picea rubens					
microsporophyll	0	0	0	0	0
twigs (two or more sterigmata)	2	0	0	0	0
sterigmata	1	0	0	0	0
seed wing	0	0	0	0	0
Sorbus	0	0	0	0	0
SHRUBS					
Rubus odoratus	0	0	0	0	0
Rubus undiff.	1	1	0	0	0

APPENDIX 8 (Continued)

	Depth Intervals (cm)				
	77.5 to 82.5	82.5 to 87.5	87.5 to 92.5	92.5 to 97.5	97.5 to 102.5
HERBS					
Carex camosa type	0	0	0	0	0
Scirpus cespitosus type	1	0	0	0	0
Scirpus cyperinus type	0	0	0	0	0
Scirpus smithii type	1	0	0	0	0
Juncus	0	1	0	0	0
Hypericum boreale-mutilum type	0	0	0	0	0
Galium	19	42	11	35	23
Poaceae	0	0	0	0	0
Chenopodium	0	2	2	0	0
Viola	0	1	0	0	0
OBLIGATE AQUATICS					
Sphagnum	++	+	++	+	
INSECT PARTS	1	6	3	1	0

APPENDIX 9

TOPOGRAPHIC TRANSECT

(FLAT LAUREL GAP, NORTH CAROLINA)

Station (m)	Distance to Next Station	Elevation Change (m)	Slope (Percent)	Slope (Degrees)
0	5	1.20	-24.0	-13.5
5	5	1.70	-34.0	-18.8
10	5	1.20	-23.5	-13.2
15	5	0.20	-4.5	-2.6
20	5	1.10	-22.5	-12.7
25	5	0.20	-4.5	-2.6
30	5	0.20	-4.5	-2.6
35	5	0.40	-7.5	-4.3
40	5	0.80	+16.0	+9.1
45	5	0.50	-10.5	-0.9
50	5	0.50	-10.5	-6.0
55	5	0.30	-6.5	-3.7
60	5	1.10	-21.0	-11.9
65	5	0.50	-9.5	-5.4
70	5	1.00	+19.5	+11.0
75	5	0160	-12.0	-6.3
80	5	0.10	-1.0	-0.6
85	5	0.00	0.0	0.0
90	5	0.10	-2.5	-1.4
95	5	0.00	0.0	0.0
100	5	0.10	+2.5	+1.4
105	5	0.50	-10.0	-5.7
110	5	0.30	-5.5	-3.0
115	5	0.10	+1.0	+0.6
120	5	0.40	-7.5	-4.3
125	5	0.10	-1.5	=0.9
130	5	0.10	-2.0	-1.2
135	5	0.30	-6.5	-3.7
140	5	0.20	-4.5	-2.6
145	5	0.70	-14.0	-8.0
150	5	0.10	+2.0	+1.2
155	5	0.10	-1.0	-0.6
160	5	0.20	-4.0	-2.3
165	5	0.40	-8.5	-4.9
170	5	0.10	-1.0	-0.6
175	5	0.20	-4.0	-2.3
180	5	0.03	-0.5	-0.3
185	5	0.30	-0.6	-3.4

APPENDIX 9 (Continued)

Station (m)	Distance to Next Station	Elevation Change (m)	Slope (Percent)	Slope (Degrees)
190	5	0.03	+0.5	+0.3
195	5	0.03	-0.5	-0.3
200	5	0.10	-1.5	-0.9
205	5	0.10	-1.5	-0.9
210	5	0.10	-2.0	-1.2
215	5	0.10	-1.5	-0.9
220	5	0.10	-2.5	-1.4
225	5	0.03	-0.5	-0.3
230	5	0.23	-4.5	-2.6
235	5	0.03	+0.5	+0.3
240	5	0.30	-5.0	-3.9
245	5	0.10	+2.0	1.2
250	5	0.13	2.5	1.5
255	5	0.20	-3.0	-1.7
260	5	0.10	-1.0	-0.6
265	5	0.04	-0.7	-0.4
270	5	0.03	-0.5	-0.3
275	5	0.03	-0.5	-0.3
280	5		End of Transect	

Notes: Bearing 335.5^{o} from stations 0 to 260
Bearing 340.0^{o} from stations 260 to 280

Transect begins on west side of Blue Ridge Parkway Highway across from entrance road to Pisgah Inn Restaurant.

APPENDIX 10

KEY TO SOME ERICACEAE POLLEN TYPES OF THE SOUTHERN APPALACHIAN MOUNTAINS

Ericaceae pollen grains are tricolpate or tricolporate and are dispersed in tetrahedral tetrads produced during meiosis within the anther (Kapp, 1969).

1a. Tetrad diameter > 50 μm, exine thick (2.5 μm) 2
1b. Tetrad diameter < 50 μm, exine thinner (1.75 μm) 3

2a. Tetrad diameter 51-56 μm; finely nanno-rugulate to nanno-verrucate . . . . . *Rhododendron canescens*
2b. Tetrad diameter 55-56 μm; transverse furrows slender, exine psilate . . . . . *Rhododendron maximum*
2c. Tetrad diameter 50-70 μm; characteristics other than above . . . . . *Rhododendron* undiff.

3a. Tetrad diameter < 20 μm, exine finely reticulate . . *Monotropa*
3b. Tetrad diameter > 20 μm 4

4a. Tetrad circular or nearly so 5
4b. Tetrad subtriangular, triangular, or globular 6

5a. Tetrad circular, diameter 32-35 μm . . . *Oxydendrum arboreum*
5b. Tetrad more-or-less circular, diameter 44-60 μm, exine verrucate . . . . . *Arctostaphylos*

6a. Pollen grains forming tetrad only joined together for a small portion of their surface with a gap present in the middle; tetrad strongly lobed, furrows indistinct . *Chimaphila*
6b. Pollen grains forming tetrad joined together along most of their surface; gap in tetrad lacking 7

7a. Ektexine with distinct columellae 8
7b. Ektexine lacking distinct columellae 9

8a. Exine psilate but coarsely dotted or granular in appearance due to thick columellae; transverse furrows distinct . . . . . *Lyonia mariana*
8b. Surface slightly verrucate, grains tricolpate or tricolporate; pores indistinct or slightly elongate into short transverse furrows . . . . . *Pyrola rotundifolia*

9a. Exine psilate and intectate 10
9b. Exine rugulate (sometimes with psilate furrow margins), reticulate, scabrate, granular, verrucate, or psilate. If psilate, then exine is tectate 11

APPENDIX 10 (Continued)

10a. Furrows short, polar index ≈ 0.55, tetrad diameter about 36 μm . . . . . Epigea ripens
10b. Furrows longer, polar index ≅ 0.30, transverse furrows sometimes obscure. Tetrad occasionally somewhat spherical . . . . . Vaccinium corymbosum

11a. Exine regulate or nanno-rugulate; costae colpi present. . . 12
11b. Exine otherwise; costae colpi sometimes present 13

12a. Colpi rims ragged and thickened, furrows short and nearly closed . . . . . Kalmia latifolia
12b. Colpi rims smooth 14

13a. Grains globular or only slightly subtriangular 15
13b. Grains triangular to subtriangular 16

*14a. Colpi with broadly thickened rims with psilate or weakly nanno-rugulate margins. Tetrad diameter 32-36 μm . . . . . Lyonia ligustrina-lucida type
*14b. Sculpturing extends nearly to edge of colpi; tetrad diameter 30-35 μm . . . . . Andromeda floribunda

* If extent of sculpturing on furrow margins difficult to discern, then grain can be classified as . . . . . Lyonia/Andromeda type

15a. Exine reticulate, finely reticulate, or scabrate with annulate aperatures, perhaps protruding. Costae colpi sometimes present; colpi < 14 μm in length . Gaultheria hispidula
15b. Colpi > 14 μm; exine scabrate to faintly reticulate . . . . . Gaultheria procumbens

16a. Exine psilate; tetrad diameter 35-45 μm . . . . . Vaccinium stamineum-arboreum/Gaylusaccia type
16b. Exine finely reticulate, scabrate, or granular 17

17a. Tetrad smooth to finely granular at the poles and margos but coarsely wrinkled to granular between . . . . . Leucothoe
17b. Exine finely reticulate 18

18a. Colpi longer than 3 μm and with distinct costae 19
18b. Colpi lacking costae 20

**19a. Inner walls of tetrad thicker than outer walls . . . . . Ledum
**19b. Inner walls of tetrad thinner than outer walls . . . . . Chamaedaphne calyculata

** Not always possible to distinguish between Ledum and Chamaedaphne calyculata. Grain can be classified as Ledum/Chamaedaphne type.

APPENDIX 10 (Continued)

20. Tetrad diameter 30-45 μm; exine reticulate to finely reticulate . . . . . *Vaccinium constablaei* type[++]

[++] Includes *Pieris* and *Menziesia*.

APPENDIX 11

RADIOCARBON ANALYSIS

(FLAT LAUREL GAP, NORTH CAROLINA)

Lab Number A#	Depth Interval (cm)	$l \cdot CO_2/g \cdot sed$	^{14}C date yr BP	^{13}C POB (0/00)
3633	20-30	0.065	960±60	-27.7
3634	75-85	0.033	1,520±60	-27.7
3635	91-108	0.005	1,260±130	-26.5
3636	135-161	---	7,710±310	-21.4

APPENDIX 12

BLOCKSTREAM FABRIC DATA

(FLAT LAUREL GAP, NORTH CAROLINA)

Distance	Maximum Diameter of Block (m)	Long Axis Orientation	Strike and Dip of Tabular Face
0.0-1.9	3.1	N83W	N20W24S
1.9-4.7			
4.7-4.9	0.7	N78W	N80W37W
4.9-5.9			
5.9-6.0	0.3	N40E	N87E75E
6.0-6.7			
6.7-7.9	0.3	N63E	N70W41E
7.9-8.0	0.3	N69@	N50W38E
8.0-8.5			
8.5-8.8	0.7	N22E	N30E77E
8.8-9.1			
9.1-9.6	1.0	N85E	N10E8W
9.6-9.8			
9.8-10.1	0.3	N12E	N70E36E
10.1-10.2			
10.2-10.3	0.1	N83W	N6 W55W
10.3-10.6			
10.6-11.2	1.6	N78E	N78E54E
11.2-11.3			
11.3-11.4	0.5	N78E	N78E545
11.4-11.5			
11.5-11.6	0.3	N78E	N78E64E
11.6-11.9			
11.9-12.0	0.1	N52E	N52E68E
12.0-15.1			
15.1-15.3	0.2	N63W	N63WO
15.3-15.4			
15.4-16.1	0.8	N81E	N81EO
16.1-16.2			
16.2-16.3	0.3	N74E	N74E28E
16.3-16.4			
16.4-16.55	0.1	N10E	N10E74E
16.55-16.65	0.2	N20E	N20E43E
16.65-16.9			
16.9-17.2	0.8	N13E	N4E60W
17.2-17.3			
17.3-17.5	0.4	N40E	N87E58S
17.5-18.1	0.8	N85E	N40W32E
18.1-19.15			

APPENDIX 12 (Continued)

BLOCKSTREAM FABRIC DATA

(FLAT LAUREL GAP, NORTH CAROLINA)

Distance	Maximum Diameter of Block (m)	Long Axis Orientation	Strike and Dip of Tabular Face
19.15-19.35	0.6	N83E	N58E28W
19.35-19.45	0.1	N35E	N35E0
19.45-19.50			
19.5-20.5	0.4	N55E	N65E54E
20.5-20.75	0.25	N68E	N68E0
20.75-30.0	0.2	N29W	N55E28W
30.0-31.2			
31.2-31.5	0.3	N13E	N15E80W
31.5-32.0			
32.0-32.1	0.6	N57E	N25E13W
32.1-32.6			
32.6-32.85	0.5	N67E	N52E28E
32.85-33.05	0.2	N57W	N37E24E
33.05-33.35	0.3	N55W	N70W7S
33.35-33.8	0.7	N30W	N47W33S
33.8-34.2			
34.2-34.5	2.3	N52W	---
34.5-37.0			
37.0-37.1	0.25	N55E	N37W8S
37.1-37.2	0.20	N65E	N54E35N
37.2-37.3			
37.3-37.5	0.20	N23W	N22W73E
37.5-37.7			
37.7-37.8	0.20	N48W	N66W12S
37.8-38.05			
38.05-38.15	0.20	N59W	N90E19W
38.15-38.35			
38.35-38.6	---	---	N62W25N
38.6-39.4			
39.4-39.5	0.2	N38E	N48E58E
39.5-41.5			
41.5-41.55	0.2	N38E	N38E80E
4155-41.75			
41.75-41.80	0.1	N67E	N67E78W
41.80-42.20			
42.2-42.9	0.8	N30E	N17E29E

APPENDIX 12 (Continued)

Notes: Location of blockstream - Deposit within Flat Laurel Gap sampled for TL analysis.

Location of transect - Approximately perpendicular to long axis of blockstream at N12E; about 20 m above upper campground road near site 90. Measurements begin from north end of deposit.

Where maximum block diameter, long axis orientation, and strike and dip are lacking, no block was present on surface.

APPENDIX 13

TOPOGRAPHIC PROFILE OF BLOCKSTREAM

(FLAT LAUREL GAP, NORTH CAROLINA)

Station	Slope (degrees)	Distance (m)
1	23.0	7.9
2	21.0	6.1
3	16.0	5.0
4	14.0	8.4
5	12.0	5.6
6	10.5	14.5
7	9.5	15.6
8	3.0	6.7
9	end of transect at road	

Note: Location - Blockstream at Flat Laurel Gap used for TL analysis profile begins at top of bedrock outcrop which is probable source of boulders.

Trend - N75E

APPENDIX 14

LATE-QUATERNARY PALEOTEMPERATURE RECONSTRUCTIONS

(FLAT LAUREL GAP, NORTH CAROLINA)

Years BP	Mean Annual Temperature °C	Average July Temperature °C
0	6.7	16.7
1,000	6.2	16.5
2,000	5.7	16.2
3,000	5.5	16.7
4,000	5.2	17.2
4,000	4.7	17.5
6,000	4.2	17.7
7,000	3.7	16.7
8,000	4.2	15.7
9,000	4.0	15.2
10,000	3.7	14.7
11,000	3.0	14.2
12,000	2.2	13.7
13,000	-2.5	13.5
14,000	-2.8	13.2
15,000	-3.8	12.7
16,000	-4.8	12.2
17,000	-6.3	12.0
18,000	-7.8	11.7
19,000	-8.2	11.7
20,000	-8.5	11.7

Note: Lapse rate = 6.5°C/km
Temperatures based on environmental reconstruction for Anderson Pond, Tennessee (300 m) (H. Delcourt, 1979)

VITA

David Scott Shafer was born in Portland, Oregon, on April 30, 1959. After graduation from John Marshall High School in Portland in 1977, he entered Oregon State University and completed a Bachelor of Science degree with Honors in 1982. After working four months as a naturalist at Lehman Caves National Monument in Nevada, David entered the graduate program in the Department of Geological Sciences at the University of Tennessee, Knoxville, Tennessee. He completed his Master of Science degree in August 1984.