

HOLOCENE ENVIRONMENTAL HISTORY OF PANTHERTOWN VALLEY IN THE
BLUE RIDGE MOUNTAINS OF NORTH CAROLINA

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in partial fulfillment of the requirements for
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ABSTRACT

HOLOCENE ENVIRONMENTAL HISTORY OF PANTHERTOWN VALLEY IN THE BLUE RIDGE MOUNTAINS OF NORTH CAROLINA

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Panthertown is a high-elevation valley in the Nantahala National Forest, and is one of few sites in western North Carolina with natural wetlands. Radiocarbon dating of multiple cores at a Panthertown valley wetland shows continuous deposition through the Holocene. This is one of the oldest continuous records in the Southern Appalachians; as such, this wetland is uniquely suited to provide information on vegetation dynamics and climatic regimes of the Holocene in the region. Using standard palynological techniques, pollen was extracted from sediment core samples and identified to genus or family at 400x; the resulting pollen percentages were used to describe the environmental history of Panthertown valley. Presence of *Alnus*, *Salix*, Asteraceae, and ferns throughout indicate a consistent open, moist wetland site. The early to mid-Holocene (~8,700-7,000 yr BP) forest appears to have been dominated by *Castanea* and *Quercus*, with minor contributions by *Betula*, *Carya*, *Acer*, and *Pinus*. The mid-Holocene (~7,000-3,500 yr BP) is characterized by decreases in *Castanea* and *Pinus*, with increases in *Quercus* and Poaceae, and, to a lesser extent, ferns, Asteraceae, and *Betula*; these increases coincide

with increases in $\delta^{13}\text{C}$ and organic C/N at the site. Increased $\delta^{13}\text{C}$ values are likely the result of contribution of organic matter derived from C_4 plants to the sediment pool. Greater variability in C/N values during that period indicate increased fluctuations in deposition of terrestrial organic matter. The late Holocene (~3,500 yr BP –present) assemblage shows a more diverse forest, with significant contributions from *Castanea*, *Quercus*, *Betula*, *Pinus*, and *Tsuga*. Taken together, these data support the idea of a warm, possibly dry, mid-Holocene “Hypsithermal” (~6,500-3,500 yr BP), and indicate the presence of temperate deciduous forests dominated by oak in the Blue Ridge Mountains from the early Holocene to the present.

INTRODUCTION

Wetlands and lakes can provide useful information about the geologic, climatic, and ecological history of a region. Layers of sediment accumulate in anoxic conditions, which promotes anaerobiosis and slows or prevents the decomposition of organic matter. These stratified sediments may hold plant, animal, and mineral matter that can contribute to our understanding of the history of the surrounding landscape. Plant material such as pollen, spores, phytoliths and macrofossils can be extracted from the sediments and identified to reveal the plant communities present through time (von Post 1916). The plant communities represented in the record can then be used to reconstruct the paleoenvironment, based on our current understanding of modern vegetation patterns and their associated environmental factors (e.g. Davidson 1983, Delcourt 1979, Goman and Leigh 2004, Shafer 1986, Viau et al. 2006, Watts 1980).

In the southern Appalachian region, there is a dearth of sediment records with which to describe the extent and duration of the climatic events of the Holocene (~11,700 yr BP to the present) for the region (Driese et al. 2008). This is mainly because the topography is not conducive to the natural development of wetlands or lakes, but also partly due to conversion of bottomlands to agriculture. Panthertown Valley in Jackson County, North Carolina, is one of few sites in the southern Appalachian Mountains with high-elevation wetlands (Pittillo 1994). One of these wetlands contains a sediment record that dates back approximately 8,000 years before present (yr BP; Table 2).

Because there is limited information available on the climate of the southern Appalachian region during the Holocene, it is not known how long, or to what degree,

cold temperatures persisted following the last glacial period. If cooler temperatures persisted through the early Holocene at Panthertown, boreal taxa typically found in northern regions may be present in the sediment record. Alternately, if the climate warmed considerably by 8,000 yr BP, the record could indicate the presence of temperate deciduous forest taxa similar to those found at Panthertown today (e.g. Delcourt 1979, LaMoreaux 2009, Watts 1980).

My research provides an analysis of the vegetation history of the Panthertown Valley, which will increase our understanding of Holocene environmental conditions in the Blue Ridge Mountains. Additionally, this study provides data on the successional dynamics of the bog itself, addressing a need specified by Weakley and Schafale (1994), who stated that there are no existing studies of the vegetation dynamics and successional patterns of Blue Ridge Mountain wetlands. Specific objectives of my research are to 1) study the pollen record of the Holocene from a Panthertown valley core in order to narrow the gaps in the ecological history of the region, and to identify and discuss short termed vegetation changes; 2) reconstruct the paleoenvironment and climatic changes qualitatively from the plant taxa present in the pollen record; and 3) provide a record of the history of the Panthertown wetland.

SITE DESCRIPTION

Panthertown Valley is an unusual high-elevation valley located in the Nantahala National Forest of North Carolina (Figure 1; Smith 1992). It lies in the southeastern part of Jackson County, approximately 8 km northeast of the town of Cashiers, within the Blue Ridge Mountains physiographic province of the Appalachian Mountains. The valley occupies approximately 2,550 ha and is distinctive amongst other high elevation valleys in the region because of its broad, sandy valley floor with slowly meandering streams surrounded by dramatic rock outcroppings (Smith 1992). Some of these granitic domes rise up hundreds of feet from the valley floor (Pittillo 1994).

Elevations in Panthertown Valley range from 1,036 m at the valley floor to 1,456 m at the top of Toxaway Mountain (Smith 1992). The mean winter (December – February) temperature at the nearest weather station (COOP:314788, Lake Toxaway, NC, elevation 939 m) is 2.8°C and the mean summer (June – August) temperature is 20°C (climate data from 1996 to 2012, NCDC). Mean annual precipitation at Lake Toxaway is 233 cm (climate data from 1961 to 2011 excluding 1995 and 1996, NCDC).

The varied terrain surrounding the valley supports many forest community types (Table 1; Pittillo and Smith 1994). Additionally, the valley and its surrounding rock outcrops and ridges have many ecologically unique areas, some of which have a high abundance of rare species (Smith 1992). Rock outcrop communities on the mountains surrounding the valley have populations of the rare plant species *Carex biltmoreana* (W), *Rhododendron vaseyi* (SR), *Trichophorum cespitosum* (*Scirpus cespitosus*, SR), *Packera millefolium* (*Senecio millefolium*, T, FSC), and *Chelone cuthbertii* (SC, FSC; SR-

significantly rare, SC- special concern, W- watch list; NC Natural Heritage Program 2012; T- threatened, E- Endangered, FSC- Federal Species of Concern). Spray cliff communities host the rare liverwort, moss, lichen and plant species *Plagiochila caduciloba* (SR), *Drepanolejeunea appalachiana* (SC), *Gymnoderma lineare* (E), *Carex biltmoreana* (W), and *Rhabdoweisia crenulata* (SR). The swamp forest – bog complex on the valley floor is a rare type of wetland community with *Sphagnum*-sedge mats, and Southern Appalachian bogs (as defined by Schafale and Weakley 1990 and Schafale 2012) are also present (discussed in detail further on).



Figure 1. Location of Panthertown Valley (orange star) in Jackson County, North Carolina (state map by Rudersdorf 2010).

Table 1. Forest communities found at Panthertown and their associated key species (from Schafale 2012 except where noted).

Forest type	Key species
Northern Hardwoods Forest	<i>Quercus rubra</i> , <i>Acer rubrum</i> , <i>Amelanchier laevis</i> , <i>Betula lenta</i> , <i>Magnolia acuminata</i> , <i>Magnolia fraseri</i> . (Pittillo and Smith 1994)
Acidic Cove Forest	<i>Liriodendron tulipifera</i> , <i>Betula lenta</i> , <i>Tsuga canadensis</i> , <i>Acer rubrum</i> , <i>Betula alleghaniensis</i> , <i>Rhododendron maximum</i> , <i>Leucothoe fontanesiana</i>
Rich Cove Forest	<i>Aesculus flava</i> , <i>Fraxinus americana</i> , <i>Tilia americana</i> var. <i>heterophylla</i> , <i>Magnolia acuminata</i> , <i>Liriodendron tulipifera</i> , <i>Acer rubrum</i> , <i>Tsuga canadensis</i> , <i>Betula alleghaniensis</i>
Montane White Oak Forest	<i>Quercus alba</i> , <i>Kalmia latifolia</i>
Montane Oak-Hickory	<i>Pinus strobus</i> , <i>Quercus alba</i> , <i>Carya alba</i>
Pine-Oak/Heath	<i>Pinus pungens</i> , <i>Pinus rigida</i> , <i>Quercus Montana</i> , <i>Kalmia latifolia</i> , <i>Vaccinium pallidum</i>
Swamp Forest Bog Complex	<i>Tsuga Canadensis</i> , <i>Acer rubrum</i> , <i>Liriodendron tulipifera</i> , <i>Nyssa sylvatica</i> , <i>Rhododendron maximum</i> , <i>Sphagnum</i>

A distinguishing feature of Panthertown Valley is its extensive complex of wetlands. The wetlands occupy approximately 12 ha of the valley floor, making it one of the largest wetland sites in the mountains of North Carolina (Smith 1992). There are three distinguishable wetland sites in the valley: Greenland Creek bog and Boardcamp Ridge bog, two small wetlands on the north side of the mouth of Greenland Creek, and the Panthertown Creek bog adjacent to Panthertown Creek near the middle of the valley (Smith 1992). Frolictown Creek and Panthertown Creek drain the watershed to the southwest of the valley and feed the Panthertown Creek bog (Figure 2). Total watershed area above the Panthertown Creek bog is 715 ha, and the elevation range within the watershed is 1115 to 1381 m.

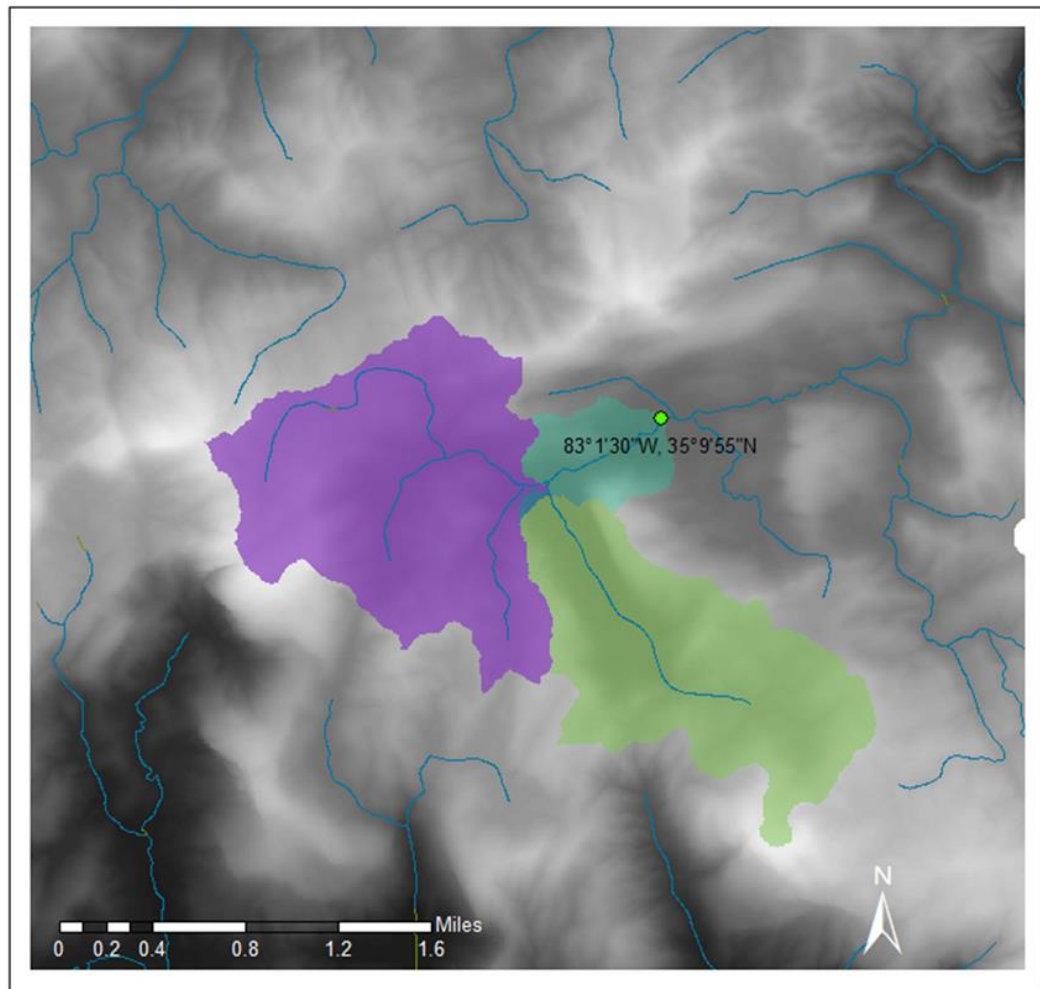


Figure 2. Watershed of the Panthertown Creek wetland. Frolictown Creek watershed shown in purple and Panthertown Creek watershed shown in light green. Entire watershed for the wetland (green dot) consists of teal, purple and light green areas.

The history of the wetlands is unclear. In 1994, Weakley and Schafale speculated, “the Panthertown bog (Jackson County) may have formed as a result of logging and catastrophic fire, followed by beaver activity in the flat valley bottom of Panthertown and Frolictown creeks” (p. 378). This hypothesis was supported in part by a lack of northern disjunct species in the wetland; although northern species at the southern limit of their ranges are found at the site, there are no recorded northern species that are

disjunct from their northern range, whereas northern disjunct species can be found at other wetland sites in the southern Blue Ridge mountains and have been interpreted as a sign of the antiquity of those sites (Weakley and Schafale 1994). Logging of the valley occurred in the 1920s and '30s and beaver activity has been noted in the area (Pittillo 1974, Pittillo and Smith 1994), but radiocarbon dates indicate that the wetland has existed in some form since the early Holocene (Table 2). It is possible, however, that the persistence of the bog is partly due to beaver activity (Pittillo and Smith 1994, Schafale and Weakley 1990), similar to Whiteoak Bottoms (Macon County, NC), a peatland recently described and dated to 14,000 yr BP, which is now maintained by groundwater and beaver activity (McDonald and Leigh 2011).

The Panthertown bogs have been listed as examples of the Southern Appalachian bog, southern subtype community, based on their vegetation assemblage and site characteristics (as defined by Schafale and Weakley in the Classification of the Natural Communities of North Carolina 1990), but Pittillo and Smith (1994) mentioned that they may be closer to the northern subtype based on the presence of button sedge (*Carex bullata*). In the more recent Guide to the Natural Communities of North Carolina (Schafale 2012), the wetlands would be classified as Southern Appalachian Bog, typical subtype, defined as open, acidic, permanently saturated wetlands occurring at mid-elevations with extensive *Sphagnum* and abundant northern disjunct species, although no northern disjunct species have been noted at the Panthertown wetlands. Despite the name, these wetlands are hydrologically and chemically similar to a poor fen because of inputs from groundwater sources (Tanner, pers. comm, Weakley and Schafale 1994).

The bogs of Panthertown valley are ecologically significant because of the rarity of wetlands in the region as well as the presence of rare species (Smith 1992, Warren II et al. 2004). Six state listed plant species are found within this bog: marsh bellflower (*Campanula aparinoides*, SR), Cuthbert's turtlehead (*Chelone cuthbertii*, SC), spinulose woodfern (*Dryopteris carthusiana*, W7), narrowleaf willowherb (*Epilobium leptophyllum*, W1), narrowleaf peatmoss (*Sphagnum angustifolium*, SR), and pretty peatmoss (*Sphagnum fallax*, SR; SR- significantly rare, SC- special concern, W- watch list; NC Natural Heritage Program 2012).

LITERATURE REVIEW

Climate History

The Quaternary Period is earth's most recent geologic period, spanning the last 2.58 million years (Gibbard et al 2010). Much of it is characterized by cool temperatures and cyclic glaciation during what is known as the Pleistocene Epoch, with the last glacial event extending from approximately 110,000 to 11,500 years before present (yr BP; Clayton et al. 2006, Mayewski 2004). This event saw multiple freeze-thaw cycles of the Laurentide ice sheet, which covered most of Canada, the Upper Midwest, and New England at its greatest extent in North America. As a result of the most recent global cooling and corresponding glacial growth approximately 26,000 to 19,000 yr BP (Clark et al. 2009), northern species of plants and animals migrated further south. The climate subsequently warmed, the glacier receded, and northern species often became restricted to high elevations in the Southern Appalachian Mountains because of their adaptations to cooler climates (Delcourt & Delcourt 1988).

The warming trend is known as the Holocene Epoch, the current inter-glacial, extending from approximately 11,700 yr BP to the present (Walker et al. 2009). The Holocene has been a period of relatively stable temperatures compared to the variability of the previous glacial period, and this climatic stability has allowed the development of modern civilization and the present distribution of plants and animals. There have been some notable fluctuations, however, including the Hypsithermal period (a warming trend in the eastern United States from 9,000 to 5,000 yr BP) and the Medieval Climate Anomaly (a warm period from 1,050 to 750 yr BP), which was followed by the Little Ice

Age (600 to 300 yr BP; Driese et al. 2008, Mann et al. 2009). Current research indicates that there have been many other climate fluctuations throughout the Holocene as well, some to the degree that they could have affected humans and ecosystems (Mayewski 2004, Wurster and Patterson 2001, Viau et al. 2006).

There are multiple lines of evidence supporting the hypothesized Hypsithermal in the continental United States, but it is not certain how wet it may have been. There is evidence in the western United States that the Hypsithermal was much more arid than the early or late Holocene. For example, in central Texas, conditions were drier from ~5,000 to 2,500 yr BP than before that time or at present (Toomey et al. 1993), and conditions were also warm and dry during that time in the Great Plains (Meltzer 1999). This arid period is also noted further east. In northern Michigan, a warm, dry climate prevailed from 8,000 to 5,300 cal. yr BP (Delcourt et al. 2002), and on the coastal plain along the Gulf of Mexico, records indicate that the climate was more arid prior to the late Holocene (Otvos and Price 2001). More locally, warmer and drier conditions are evident during the mid-Holocene from a site in southeastern West Virginia (Driese et al. 2005). Conversely, an increase in mixed mesophytic forest taxa during that time at Cliff Palace Pond in Kentucky suggests a warm-temperate climate with increased humidity (Delcourt et al. 1998).

From the coastal plain in the southeast there is conflicting evidence of both aridity and increased moisture during the Hypsithermal (Goman and Leigh 2004, Leigh 2008, LaMoreaux 2009, Zayac et al. 2001). In the sediment and fossil pollen record from a peat deposit on the coastal plain of Georgia, wetter conditions were recorded in the early to mid-Holocene (11,000 to 4,500 yr BP) followed by cooler, drier conditions

(LaMoreaux et al. 2009). Similarly, a peat deposit from the upper coastal plain of North Carolina showed an increase in moisture and a higher frequency of flooding from ~9,000 to 6,000 yr BP (Goman and Leigh 2004). In contrast, another study from coastal Georgia showed increases in prairie taxa up to ~4,000 yr BP, indicating increased aridity (Zayac et al. 2001).

In the ridge and valley province of southeastern Tennessee, a soil profile studied by Driese et al. (2008) suggests that the Hypsithermal was not simply a static warm period, but had multiple warming/drying episodes of ~300 years spanning the period ~6,500 to ~5,000 yr BP. In northeastern Tennessee, also in the ridge and valley province, carbonate samples from freshwater drum (*Aplodinotus grunniens*) sagittal otoliths were used to evaluate climate change from 5,500 yr BP to the present, and results suggest a gradual decrease in maximum summer temperatures from 5,500 to ~1,000 yr BP with variation on the scale of one or two hundred years (Wurster and Patterson 2001).

Brief climate anomalies of 100 to 300 years may or may not be reflected as a change in forest composition because of the time it takes for forest composition to shift in response to a change in climate (Wurster and Patterson 2001, Delcourt and Delcourt 1987). Duration and magnitude of changes in temperature, precipitation and other atmospheric influences determine the degree to which regional vegetation may change, and therefore the degree to which pollen records indicate the change (Webb 1986). Webb (1986) describes two types of vegetation response to climate shifts: Type A is an immediate response, "...in which range extensions and soil development are not necessary for the vegetation to reach its new composition;" type B is a "full" response, "...in which range extensions and soil development are key factors." A type A response is considered

to be on the scale of 100-300 years (Webb 1986, Delcourt and Delcourt 1987). The Southern Appalachian landscape is more likely to have had a type A response to any major climate shifts during the Holocene both because of the antiquity of the mountains and because the southern limits of glaciation throughout the Pleistocene were far north of the Southern Appalachians and therefore disturbance to the soil or seed bank would not have been minimal.

Vegetation History

The southern Appalachian spruce-fir forest is thought to be a legacy of the last glacial period (Delcourt and Delcourt 1988). At the greatest extent of the Laurentide ice sheet (~19,000 yr BP), a forest of spruce, pine and fir dominated at low elevations at least as far south as 34°N latitude, while at higher elevations, tundra species and conditions were dominant (Delcourt and Delcourt 1985). Following the retreat of the glacier, the low elevation spruce and fir forest migrated north and up in elevation as temperatures warmed, establishing the current spruce-fir forest at the highest elevations in the Southern Appalachian mountains by 6,000 yr BP (Delcourt 1985). During the late Holocene (after 4,000 yr BP), spruce and fir appear to have increased in range, indicating a shift to cooler temperatures (Delcourt 1985).

The presence of *Picea* (spruce) or *Abies* (fir) indicates moist to wet conditions, with high rainfall, low temperatures, dense cloud cover and an increase in soil water-holding capacity (Schafale and Weakley 1990). Other major species of the region, such as *Quercus* and *Pinus*, tolerate a wider range of environmental conditions and are found in cool or warm and mesic or xeric sites (Schafale and Weakley 1990). As such, they are not as diagnostic for reconstructing climate history as *Picea* or *Abies*. Further, although

individual species of *Quercus* and *Pinus* have particular environmental niches, identifying pollen to species is not within the scope of this thesis, given the constraints of time and expertise.

Picea rubens (red spruce) and *Abies fraseri* (Fraser fir) are the dominant species of the Southern Appalachian spruce-fir forest, typically found at elevations above approximately 1,350 m (Schafale and Weakley 1990, White et al. 1993). *Picea* can be present in pollen records when *Abies* is not because they have different elevation ranges. In the Southern Appalachians, *Picea* occurs as low as 1,100 m in elevation and becomes dominant at 1,700 m, while *Abies* does not occur until 1,700 m and becomes dominant at 1,850 m (White et al. 1993). This indicates that *Picea* can tolerate warmer and/or drier conditions than *Abies* due to greater rates of evapotranspiration at lower elevations, and therefore is useful as an indicator of the transition from deciduous hardwoods forest to spruce-fir forest (or the reverse).

Other examples of extant forest types in the southern Appalachians that are dependent on cool temperatures are northern hardwoods forest and high-elevation oak forest (Schafale and Weakley 1990). The northern hardwoods forest is a mix of mesophytic trees, dominated by *Fagus grandifolia* (American beech), *Betula alleghaniensis* (yellow birch), and *Aesculus flava* (yellow buckeye, Schafale and Weakley 1990). High elevation oak forests are typically dominated by either *Quercus rubra* (red oak) or *Quercus alba* (white oak).

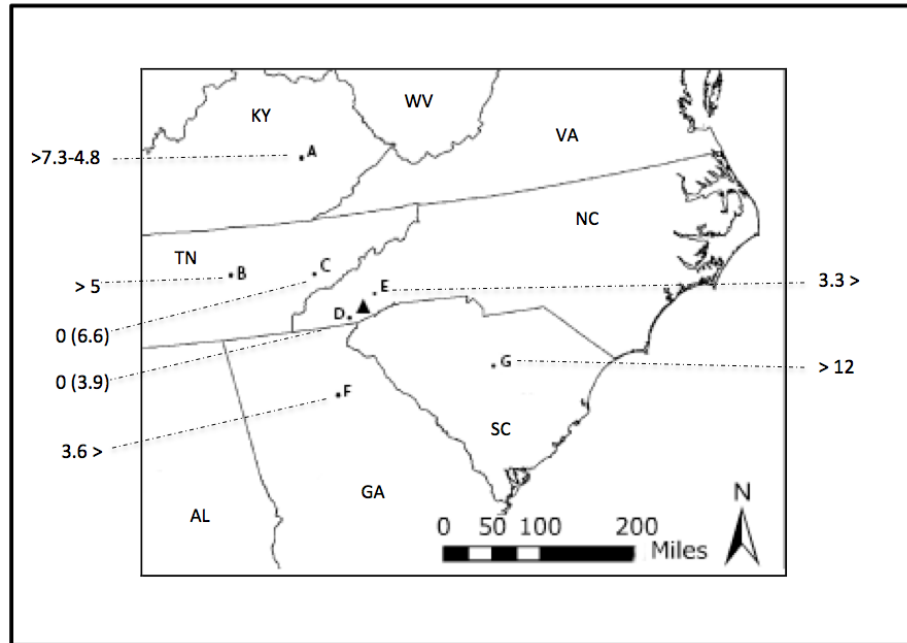


Figure 3. Location of Panthertown Valley in western North Carolina (denoted by triangle) and surrounding regional peatland sites with Holocene pollen records (A. Cliff Palace Pond, KY, B. Anderson Pond, TN, C. Lake in the Woods, TN, D. Horse Cove Bog, NC, E. Flat Laurel Gap, NC, F. Nodoroc site, GA, G. White Pond, SC). Numbers for each site show the appearance and duration of *Picea* pollen in thousands of years before present. For example, *Picea* pollen was present at site B before 5,000 yr BP, while at site C there was no trace of *Picea* in the record, which spans the last 6,600 years.

A high-elevation bog at Flat Laurel Gap, North Carolina (1,500 m elevation; Figure 3, Site E) contains a pollen record of the last 3,340 years that describes the history of surrounding heath balds (Shafer 1986). The record shows an oak-chestnut forest with low percentages of *Abies* and *Picea* pollen present throughout the history of the bog. Although the bog is situated in the northern hardwood forest near its ecotone with the spruce-fir forest, there is currently no *Abies* in the immediate vicinity. The persistence of *Abies* and *Picea* led Shafer (1986) to conclude “the Hypsithermal may have been a relatively minor event in the Southern Appalachians.”

At Horse Cove Bog, North Carolina (887 m elevation; Figure 3, Site D), which describes the last 3,900 years, *Quercus* and *Castanea* were the dominant canopy species throughout the record until the chestnut blight in the early 1900s significantly diminished the *Castanea* population (Delcourt and Delcourt 1997, Hepting 1974). *Abies* and *Picea* are not present in the record, indicating that temperatures had warmed and/or moisture had decreased by 3,900 yr BP.

Although the Nodoroc site in northeastern Georgia (Figure 3, Site F) lies in the Piedmont physiographic province at a much lower elevation (280 m) than Flat Laurel Gap or Horse Cove bog, there is evidence that *Picea* was present there until relatively recently (Jackson and Whitehead 1993). The Nodoroc site contains a record that describes 26,000 to 22,000 yr BP as well as the last 3,600 years (dates approximate and uncertain from 22,000 to the present, Jackson and Whitehead 1993). The arboreal pollen assemblage from 3,600 yr BP to the present shows dominance by *Pinus* and *Quercus* and is similar in assemblage to records from Alabama and north Georgia, although it differs in that *Picea* is occasionally present (Jackson and Whitehead 1993).

Interestingly, *Picea* and *Abies* pollen are absent throughout the fossil pollen record from Lake in the Woods (elevation 530 m), on the western side of the Great Smoky Mountain National Park in Tennessee, which spans the last 6,600 years (Davidson 1983; Figure 3, Site C). *Quercus*, *Liquidambar*, *Salix*, *Castanea* and *Pinus* were the major species present at Lake in the Woods from 6,600 yr BP to the present.

Other southeastern fossil pollen sites show *Picea* pollen persisting to different points in time during the Holocene. At Anderson Pond, Tennessee (Figure 3, Site B), *Picea* disappears at 5,000 yr BP (Delcourt 1979), although the Holocene dates at this site

are in question and therefore the pollen record is unreliable (Liu et al. 2013). At Cliff Palace Pond in Kentucky (Figure 3, Site A), it drops out of the record between 7,300 and 4,800 yr BP (Delcourt et al. 1998), and at White Pond, South Carolina (Figure 3, Site G), it disappears at 12,000 yr BP (Watts 1980). Thus, presence of *Picea* is highly variable among the sites surrounding Panthertown.

Human Influence

At sites near Panthertown, evidence of human influence on the environment began in the Late Archaic period (roughly 6,000 to 3,000 yr BP; Delcourt et al. 1986, Delcourt and Delcourt 1997). Horse Cove Bog near Highlands, North Carolina, is the nearest site with long term evidence of human impact. Charcoal and pollen records indicate that selective use of fire had an influence on the forest assemblage (Delcourt and Delcourt 1997). The Horse Cove Bog pollen profile revealed that "...during most of the last 4,000 years Native Americans played an important role in determining the composition of southern Appalachian vegetation through selective use of fire" (Delcourt & Delcourt 1997). The paleoecological record in the Little Tennessee River Valley in eastern Tennessee provides evidence of human impact over the last 10,000 yr BP, with a marked increase in impact at 4,000 yr BP with the introduction of agricultural crop species (Delcourt et al. 1986).

There may be evidence of anthropogenic disturbance at Panthertown, beginning in the late Archaic cultural period (5,000 to 3,000 yr BP). An overall increase in non-arboreal pollen along with an increase in "weedy" species from a wetland pollen record may indicate anthropogenic disturbance (Behre 1981). Taxa that would indicate the presence of humans include weedy herbaceous species such as *Ambrosia* (ragweed),

Chenopodium (goosefoot), *Portulaca* (purslane), *Poaceae* (grasses), *Cyperaceae* (sedges) or agricultural crop species such as *Zea mays* (maize) or *Cucurbita* species (squash) along with increased abundances of disturbance-favoring woody taxa such as *Pinus* and *Liriodendron tulipifera*.

METHODS

I extracted one soil core using a Dutch auger from the Panthertown Valley fen at approximately 35° 9' 59.824" N, 83° 1' 30.385" W in November, 2011. The core reached alluvial basal sediments at 173 cm depth. After extraction, the core was wrapped in plastic wrap to prevent contamination by modern pollen and placed in PVC tubes for transport to WCU. In the lab, I unwrapped the core and, using a clean knife, cut a layer approximately one cm deep off the length of the core to expose the uncontaminated interior. I took samples of approximately 2 cm³ at 5 cm intervals for a total of 32 samples. Two samples of approximately 4 cm³ were taken at depths of 77.5 cm and 147.5 cm, dried, and sent to Beta Analytic for radiocarbon dating. The remaining samples were dried at room temperature in open polyethylene centrifuge tubes under a fume hood and stored in the Geosciences Department.

Samples were processed according to standard techniques modified from Faegri and Iversen (1989; see Appendix A). Seventeen of the 32 samples were analyzed for pollen using a Bausch & Lomb compound microscope. Transects across each slide were spaced to account for the possibility of grains migrating by size toward the perimeter of the cover slip. Pollen was identified at 400x to the lowest taxonomic level possible, using modern pollen reference collections and published pollen guides and keys (Bassett et al. 1978, Hesse et al. 2009, Kapp et al. 2000, McAndrews et al. 1973, Moore et al. 1991). Reference pollen was provided by Dr. Sally Horn at the University of Tennessee, Knoxville, and Dr. Chad Lane at University of North Carolina, Wilmington; additional

reference pollen was produced at WCU for this research. For each sample, counting of grains and spores proceeded until 300 arboreal pollen grains were counted.

Calculating pollen influx rates can be helpful because the comparison of absolute pollen numbers between samples gives an indication of pollen concentrations resulting from differential deposition and deterioration of pollen (Hall 1981). Pollen influx rates were calculated using the following equation, with indeterminate and unknown grains included in the fossil pollen sum:

$$\frac{\text{sedimentation rate } (\frac{cm}{year}) * (\frac{\text{fossil pollen counted}}{\text{tracer spores counted}}) * \text{tracer spores added}}{\text{volume of sample}}$$

Samples from the Panthertown core were analyzed for carbon and nitrogen content and isotopes. These analyses were run on a Costech Elemental Analyzer coupled to a Thermo Delta V Plus Mass Spectrometer at the University of North Carolina Wilmington.

Data Analysis

Stratigraphic pollen diagrams were produced with the C2 program (version 1.7.4, Juggins 2013). An NMDS (Non-metric Multidimensional Scaling) ordination was used to evaluate the relationships in vegetation among samples using the Sorenson (Bray-Curtis) distance measure. From these relationships I delineated pollen assemblage zones. An Indicator Species Analysis (ISA) was used to show the influence of each taxon on the pollen assemblage zones. NMDS and ISA were performed using PC-ORD 5.0 (McCune and Mefford 1999).

RESULTS

Chronology

At 77.5 cm depth, the 2σ calibrated radiocarbon age of the core was 5312 - 5466 yr BP; at 147.5 cm depth, the calibrated age was 7983 - 8167 yr BP (Core 4, Table 2, Figure 4). These results corroborate those of three previously dated cores from the Panthertown wetland, all of which indicate continuous deposition throughout the last 8,000 yr BP (Table 2, Figure 4; Tanner, unpublished). From 8,067 to 5,405 cal yr BP (147.5 to 77.5 cm, median calibrated ages), the sedimentation rate was 0.026 cm/yr. From 5,405 cal yr BP to the present (77.5 to 0 cm), the sedimentation rate was 0.014 cm/yr. Sedimentation rates were calculated for Core 4 using the median calibrated ages and the depth; sedimentation rates were not calculated for Cores 1, 2 and 3.

Table 2. Radiocarbon dates for Panthertown cores 1-4. Ages were calibrated using OxCal v.4.2 (IntCal13).

Depth (cm)	Conventional Radiocarbon Age (yr BP)	$\delta^{13}\text{C}$	Calibrated 2σ range (cal. yr BP)	Calibrated 2σ range median (cal. yr BP)	Dated material	Laboratory number
Core 1						
152	7150 \pm 50	-25.3	8149 to 8144 8106 to 8095 8053 to 7916 7905 to 7854	7973	peat	β -242155
Core 2						
25	1740 \pm 40	-26.1	1777 to 1758 1739 to 1551	1651	charred material	β -250456
50	4030 \pm 40	-21.9	4784 to 4766 4615 to 4416	4497	organic sediment	β -250457
95.5	4950 \pm 70	-23.4	5892 to 5804 5796 to 5779 5773 to 5587	5693	organic sediment	β -250458
142.5	5850 \pm 50	-26.6	6784 to 6529 6519 to 6507	6666	wood	β -250459
158.5	4840 \pm 50	-26.7	5697 to 5694 5662 to 5467	5584	charred material	β -250460
158.5	3910 \pm 40	-26.3	4499 to 4187 4440 to 4232 4197 to 4183	4343	peat	β -251927
Core 3						
71	4550 \pm 40	-21.4	5434 to 5423 5320 to 5211 5196 to 5049	5165	organic sediment	β -295385
136.5	6870 \pm 40	-26.5	7790 to 7619	7701	peat	β -295386
Core 4						
77.5	4650 \pm 30	-23.2	5466 to 5345 5335 to 5312	5405	organic sediment	β -317062
147.5	7250 \pm 40	-26.5	8167 to 7983	8076	charred material	β -317063

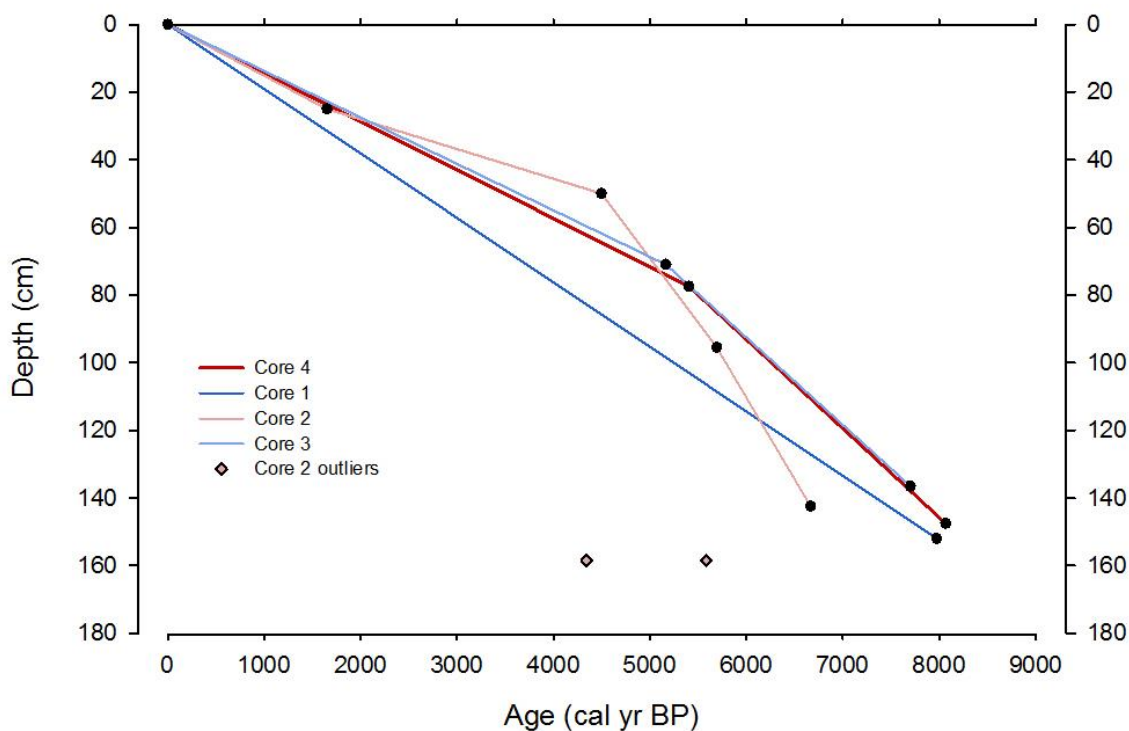


Figure 4. Age-depth model for Panthertown Valley, North Carolina.

Core Description

The following core description is from a core pulled within a meter of the site of Core 4 and is used here to illustrate the stratigraphic characteristics of the Panthertown bog sediments (Table 3). The core was almost all highly decomposed organic-rich sediment, with a loose layer of peat and roots near the surface and gravelly alluvium at the bottom. In Core 4, alluvium was reached at 170 cm.

Table 3. Panthertown bog sediment description. Depths correspond to those in Core 4 within 5 cm.

Depth in cm below sediment surface	Sediment description	Munsell color
0 - 19	High water content. Peat with roots and identifiable fibers.	10 YR 2/2
19 - 63.5	Organic-rich muck with infrequent identifiable fibers.	10 YR 2/1
63.5 - 75.5	Higher mineral content. Mucky mineral. Silty clay loam.	10 YR 2/1
75.5 – 145	Silty clay loam. Mucky mineral. More micaceous with depth. Mineral rich throughout.	Gley 1 2.5/5G
145 - 160	Loam. Micaceous mucky mineral.	Gley 1 2.5/5G
160 - 169	Alluvium with high water content.	

Palynology

Pollen grains were mostly identified to the genus or family level. Identifications to the species level were rare because species within a family can be nearly identical, making their identification problematic. The rates of pollen influx throughout the sequence ranged from 1,508 to 41,797 pollen grains/cm⁻²/yr⁻¹ (Appendix B). Thirty pollen taxa were positively identified (Figure 3). Only two taxa, *Quercus* and *Alnus*, were present throughout all core samples.

Arboreal pollen constituted over 50% of the total counts of pollen and spore taxa in all samples but one (see Appendix C for pollen counts). From 165 to 125 cm (~8,744 to ~7,217 cal. yr BP), herb and shrub pollen accounted for approximately 20 to 30% of the total identified pollen while arboreal pollen accounted for the rest. At 115 cm (~6,836

cal. yr BP), herbs increased, making up just over 50% of the total pollen. At that depth, there was also a sharp increase in both the total unidentified grains (393; this category includes both unknown and unidentifiable grains) and the *Lycopodium* tracer spores (287), indicating extensive degradation of the sediment. At 105 cm (~6,454 cal. yr BP), very few *Lycopodium* spores were counted (7), and the total unidentified grains also dropped (96), which indicates excellent preservation of pollen in the sediment at that depth. From 105 to 65 cm (~6,454 to ~4,523 cal. yr BP), herb and shrub pollen accounted for 30 to 40% of the total pollen sum. At 55 cm (~3,818 cal. yr BP) there was an increase in herb and shrub pollen, bringing the percentage to about 45%, with a slight increase in total unidentified grains but no change in the number of *Lycopodium* grains counted, indicating good preservation of pollen in the sediment. The increase in herbaceous pollen is due to increases of both Poaceae and Asteraceae pollen. From 45 to 5 cm (~3,112 to ~291 cal. yr BP), herb and shrub pollen comprised about 25% of the total identified pollen. Pollen degradation during that period appears moderate, as both unidentified grains and *Lycopodium* grains counts were moderate.

NMDS (non-metric multidimensional scaling) ordination revealed three clusters of samples, which were used to delineate stratigraphic pollen zones (Figures 5,6,7). In the ordination graph, the samples are plotted so that distances between them in the graph reflect the differences between them in taxonomic richness and abundance.

Organic carbon, C/N, and $\delta^{13}\text{C}$ values all show increases between ~7,000 to ~3,500 cal. yr BP (Figure 7). The organic carbon content ranges from 0.07 to 33.7%, C/N ratio values range from 17.1 to 34.3, and $\delta^{13}\text{C}$ values range from -27.8 to -22.8‰.

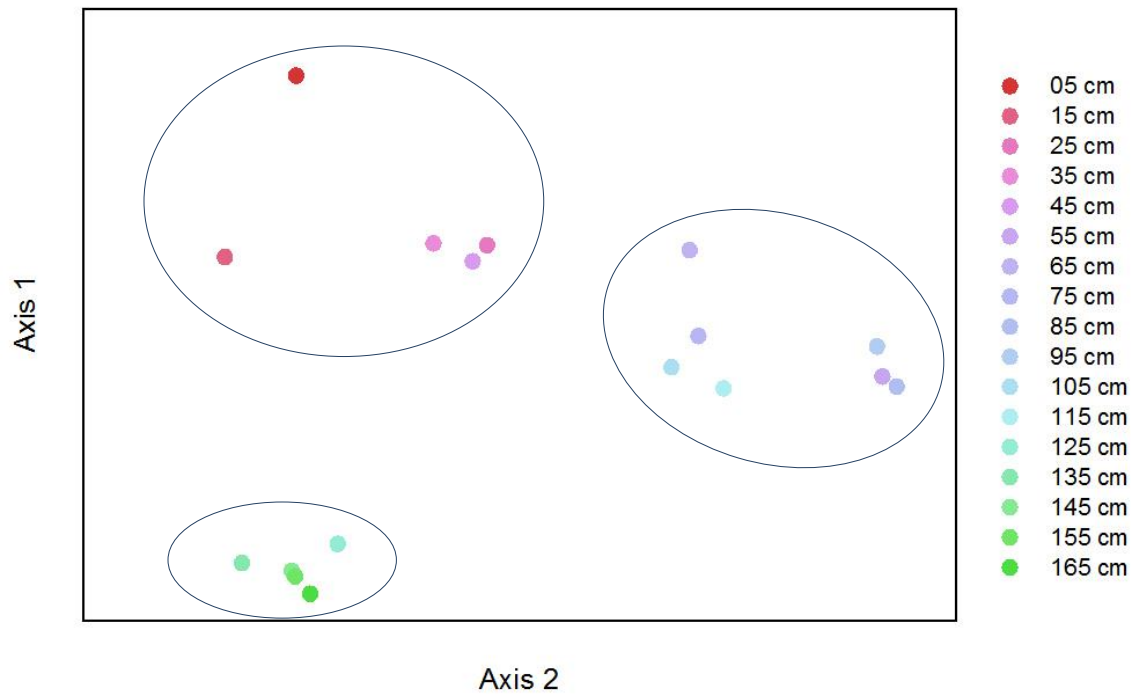


Figure 5. NMDS ordination plot illustrating the differences in vegetation assemblages between samples. Three groups of data points (05-45 cm, 55-115 cm, and 125-165 cm) were delineated to assist in interpretation of pollen results.

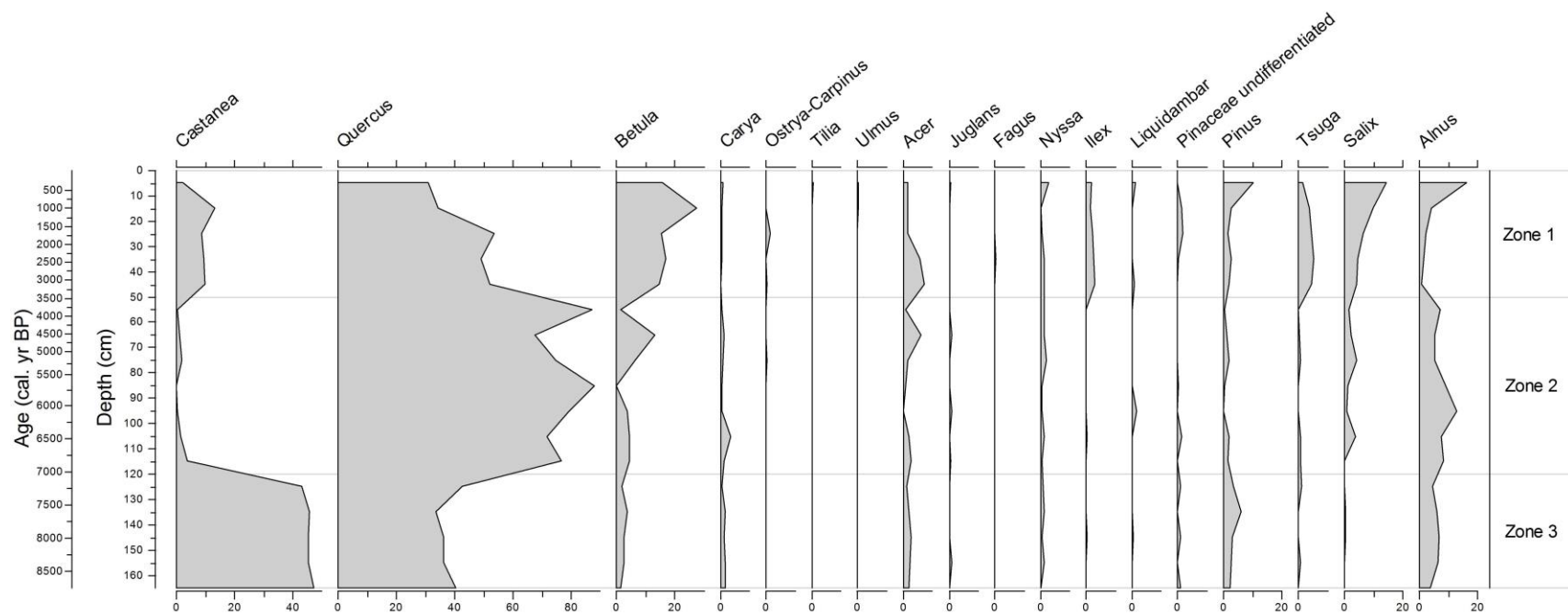


Figure 6. Arboreal pollen abundances as percentages of total arboreal pollen.

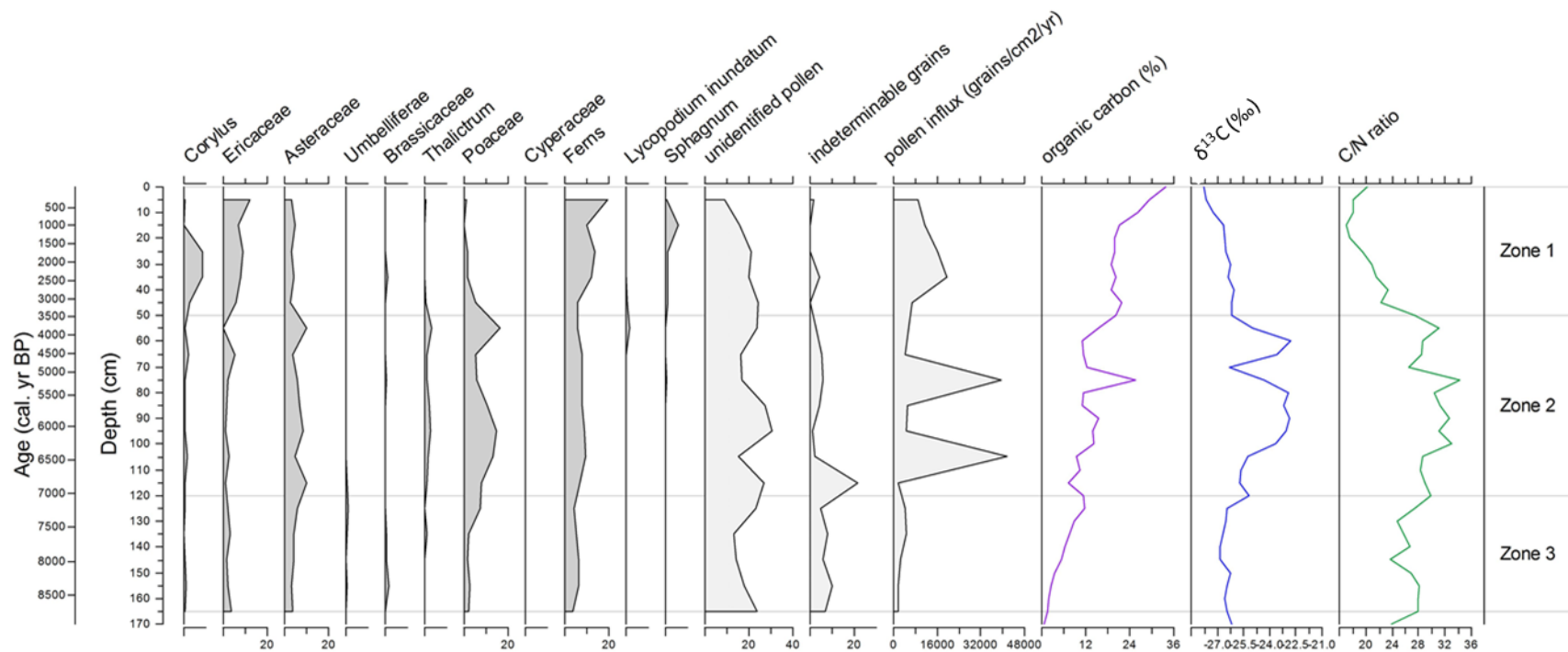


Figure 7. Non-arboreal pollen abundances, pollen influx rates, percent total organic carbon, carbon to nitrogen ratios, and organic carbon isotope composition ($\delta^{13}\text{C}$). Non-arboreal pollen abundances as percentages of total identified pollen and spores, not including *Lycopodium clavatum* marker spores. Unidentified pollen and indeterminable grains are percentages of total pollen and spores. Pollen influx rates are as grains/cm²/year. Total organic carbon and carbon to nitrogen ratios were determined from elemental analysis of organic material in bulk sediment samples. Organic carbon isotope composition is relative to the Vienna Pee Dee Belemnite standard.

Pollen percentages for arboreal taxa were calculated from the arboreal pollen sum, while pollen percentages for shrub and herbaceous taxa were calculated from the total identified pollen sum (arboreal, shrub and herbaceous pollen) to illustrate the changes in community composition over time. An indicator species analysis (ISA) based on the zones delineated by NMDS showed how much each taxon in a zone contributed to the zone designation (Table 4).

Table 4. Taxa identified by ISA as significantly contributing to the zone designations 1, 2 and 3 as indicated by the ordination.

Zone	Taxon	p-value
1	<i>Sphagnum</i>	0.0002
	<i>Salix</i>	0.0004
	<i>Ilex</i>	0.0006
	Ericaceae	0.0008
	<i>Betula</i>	0.001
	<i>Tsuga</i>	0.0012
2	<i>Quercus</i>	0.0002
	<i>Thalictrum</i>	0.0002
	Poaceae	0.0004
	Ferns	0.0056
	Asteraceae	0.0064
3	<i>Castanea</i>	0.001

Pollen Zone 3: 120 cm to 165 cm, 7,027- 8,744 cal yr BP

The zone 3 pollen assemblage is co-dominated by *Castanea* (45.3%) and *Quercus* (37.9%), with moderate contributions from *Alnus* (5.5%), *Pinus* (3.5%), *Betula* (2.5%), *Acer* (2.1%), *Carya* (1.3%). *Nyssa*, *Tsuga*, *Juglans*, and *Salix* are all present but each

comprises less than 1% of the arboreal pollen sum. The herb and shrub assemblage shows moderate inputs from Ericaceae (2.5%), ferns (5.2%), Poaceae (3.1%), and Asteraceae (4.1%). ISA showed that *Castanea* was the determining factor in the zone designation ($p < 0.01$).

Pollen Zone 2: 50 cm to 120 cm, 3,465- 7,027 cal yr BP

Zone 2 shows a shift to a pollen assemblage dominated by *Quercus* (78.0%), with much less influence from *Castanea* (1.3%). Arboreal taxa present in moderate to low amounts are *Alnus* (8.0%), *Betula* (4.8%), *Acer* (2.0%), *Salix* (1.9%), *Carya* (1.1%), *Pinus* (1.0%), and *Nyssa* (1.0%). *Tsuga*, *Liquidambar*, *Juglans*, *Ostrya/Carpinus* (counted in one category because their pollen is morphologically indistinguishable), and *Ilex* each comprise less than 1% of the arboreal pollen sum. The herb and shrub pollen assemblage accounted for over 30% of the total pollen sum. The major contributions were from the following taxa: Poaceae (10.6%), ferns (7.8%), and Asteraceae (7.0%), Ericaceae (2.1%), and *Thalictrum* (1.8%). ISA determined that *Quercus*, *Thalictrum*, Poaceae, Asteraceae, and Ferns all strongly influenced this zone designation (for each taxa, $p < 0.01$).

Pollen Zone 1: 0 cm to 50 cm, 0 - 3,465 cal yr BP

Quercus is the dominant pollen species in Zone 1 (44.0%), but many other taxa contributed in moderate amounts to the arboreal pollen sum, such as *Betula* (18.0%), *Castanea* (8.7%), *Salix* (7.8%), *Alnus* (5.0%), *Tsuga* (3.8%), *Pinus* (3.8%), *Acer* (3.6%), *Ilex* (2.2%), and *Nyssa* (1.0%). The following taxa were present in this zone but each was less than 1% of the arboreal pollen sum: *Ostrya/Carpinus*, *Carya*, *Liquidambar*, *Ulmus*, *Tilia*, *Juglans*, and *Fagus*. Herb and shrub taxa account for more than 30% of the

total pollen sum. Moderate contributions were found from ferns (12.4%), Ericaceae (8.4%), *Corylus* (4.0%), Asteraceae (3.6%), *Sphagnum* (1.9%) and Poaceae (1.9%). ISA determined that *Sphagnum*, Ericaceae, *Salix*, *Ilex*, *Betula*, and *Tsuga* strongly influenced this zone designation ($p < 0.01$ for all taxa).

DISCUSSION

The Panthertown Valley bog provides a continuous record of sedimentation from ~8,935 cal. yr BP to the present. Relatively homogeneous organic-rich sediment and sedimentation rates indicate the persistence of the wetland and a geologically stable landscape in the valley throughout its history. As natural hydrologic variation has been shown to have a greater influence on sediment yield than large climate events or forest succession in small mountain streams (Royall 2000), greater sedimentation rates in the older part of the core (0.026 cm/yr until 5,405 cal. yr BP) compared to the younger part (0.014 cm/yr after 5,405 cal. yr BP) may mean there was a shift from higher precipitation rates to lower precipitation rates. On the other hand, the shift toward decreased deposition may be a function of the infilling of the wetland site over time.

A shift toward more positive values of the Carbon/Nitrogen (C/N) ratio and $\delta^{13}\text{C}$ between ~7,000 to ~3,500 cal. yr BP support decreased precipitation during the mid-Holocene at Panthertown. The C/N ratio measures relative abundances of organic matter from algae and terrestrial plants, and therefore is used to assist in determining the extent of moisture/precipitation (Meyers and Teranes 2001, Meyers 1997). Vascular land plants have C/N ratios of 20 or more, while algae typically have C/N values between 4 and 10; this is due to the abundance of cellulose in terrestrial plants but not in algae, as well as the abundance of protein in algae but not in terrestrial plants (Meyers and Teranes 2001, Meyers 1997). In the Panthertown core, high, but variable, C/N values (mostly above 25) are evident from the oldest sediment until ~3,500 cal. yr BP. In general, this indicates higher influxes of organic material from vascular land plants during that time. The

greatest variability is seen during the mid-Holocene, ~7,000 to ~3,500 cal. yr BP, indicating increased fluctuations in moisture during that period, possibly on the scale of a few hundred years. There is then a steady decline in the C/N ratio until ~1,000 yr BP, indicating an increasingly wet period, after which there is a slight increase leading up to the present.

$\delta^{13}\text{C}$ values reflect the proportion of C_3 to C_4 plants in the landscape. C_3 plants include most trees, shrubs, and herbaceous plants, as well as cool-season grasses, while C_4 plants are mostly monocots (warm-season grasses and some sedges) and some dicots (Ehleringer et al. 1997). The proportion of C_3 to C_4 plants present at a particular site is determined by climatic or environmental factors; for example, to a certain degree, increased aridity, temperature, or salinity, as well as decreased atmospheric CO_2 are known to increase the presence of C_4 plants in the landscape (Clark et al. 2002, Ehleringer et al. 1997, Nelson et al. 2004). Increases in C_4 monocots are associated primarily with increased temperature, while increases in C_4 dicots are primarily associated with increased aridity (Ehleringer et al. 1997). Overall, increases in C_4 plant abundance causes $\delta^{13}\text{C}$ values to become more positive, because C_3 plants have a mean $\delta^{13}\text{C}$ value of -27‰, while C_4 plants have a mean $\delta^{13}\text{C}$ value of -13‰ (Ehleringer et al. 1997, O'Leary 1988). The $\delta^{13}\text{C}$ values for Panthertown ranged from -27.8 to -22.8‰, and were likely due to organic inputs from the surrounding deciduous forest. An overall increase mid-Holocene suggests a shift toward greater inputs of organic matter from C_4 plants during that time. Two large increases in $\delta^{13}\text{C}$ values during the mid-Holocene correspond with similar increases in the pollen influx of Poaceae, which is expected if the

Poaceae increase is dominated by C₄ plants. This result provides support for a warm and/or dry mid-Holocene Hypsithermal in the Blue Ridge Mountains.

As total organic carbon is a measure of the abundance of organic matter in sediments (Meyers and Teranes 2001), a gradual increase in total organic carbon from 0.07% at a depth of 170 cm to 33.7% at a depth of 0 cm indicates the gradual decay of organic matter in the wetland over time. Increased variability in the percentage of organic carbon during the mid-Holocene indicates greater variability in either sedimentation of organic matter, e.g. because of increased production of biomass, or in the rate of decomposition of that matter as a result of changes in climatic factors (Meyers 1997).

The size of the basin surrounding a site determines the contributions of pollen from different sources to the basin (e.g. directly from the plant, local wind effects from the surrounding vegetation, flowing water from the watershed, or wind influx from a larger regional area; Jacobson and Bradshaw 1981): the larger the area, the greater the ratio of regional and upland pollen to local pollen (Jacobson and Bradshaw 1981). Regional pollen is defined as derived from plants at several hundred meters or greater distance from the basin; extra-local pollen is defined as 20 to several hundred meters from the basin, and local pollen is defined as within 20 m of the basin (Jacobson and Bradshaw 1981). Because of the large area of the basin surrounding the Panthertown wetland (715 ha), the pollen profile is likely composed of regional taxa, with local and extralocal influences making up less than 15% of the total pollen counts.

The presence of *Alnus* pollen throughout the core indicates that the wetland was present in the valley for the last ~9000 yr BP. *Alnus serrulata* is a large shrub/small tree

that prefers wet or moist sites and is listed as a facultative to obligate wetland species (Lichvar 2013); it is currently found at Panthertown valley and throughout North Carolina (Smith 1992, Weakley 2012). It is the only species of alder commonly found today in the region, but it is possible that other alders were present in the past. For example, *Alnus viridis*, a typically northern species of alder, is now found at a few sites in western North Carolina and northeastern Tennessee above 1600 m, in mesic to xeric situations (Weakley 2012). Although the presence of alder in the core is likely due to *Alnus serrulata* in and around the wetland, it is possible that *Alnus viridis* was present at Panthertown at some point.

Picea (spruce) and *Abies* (fir) were not found in the pollen record, which suggests that either the boreal forest had moved from the area around Panthertown Valley to higher elevations before ~9,000 yr BP, or it was never present in the Panthertown area. Pollen throughout the core indicates the presence of hardwood mesic to somewhat drier forests surrounding Panthertown Valley through most of the Holocene, as described below.

Pollen Zone 3: 8,744-7,027 cal yr BP

The zone 3 pollen diagram is co-dominated by *Quercus* and *Castanea* pollen with minimal inputs from *Alnus*, *Pinus*, *Betula*, *Acer*, *Carya*, *Nyssa*, *Tsuga*, *Juglans*, and *Salix*. The understory has moderate inputs from ferns, Asteraceae, Poaceae, and Ericaceae. This suggests a chestnut-oak dominated forest with low diversity. Chestnut most often grows on well-drained, subxeric to mesic soils and is historically known as an upland ridgetop dominant although it can tolerate a wide range of soils (Paillet 2002). Oak has a similar range of moisture tolerance, and is primarily associated with xeric to mesic sites

in the Southern Appalachian mountains (Weakley 2012). The fern presence is likely due to the wetland area and moist seeps surrounding the valley. Poaceae and Asteraceae both have hydrophytic, mesophytic and xerophytic species, making them less diagnostic of a particular moisture regime than other taxa, but both families tend to prefer an open habitat. The presence of these taxa is most likely from the forest edge at the valley floor or around the wetland, or possibly also from rock outcrop communities such as those surrounding Panthertown today. Overall, the vegetation assemblage indicates a moderately dry situation from 8,744 to 7,027 cal yr BP.

At the end of this period there was a rapid decrease in the presence of chestnut, which remained a minor influence in the canopy for ~3,500 years. No evidence exists of corresponding rapid declines in chestnut at other mid-Holocene dated sites. There are many possible explanations for the decline of chestnut at the Panthertown site, such as climate change, a pathogen or insect blight, or a combination of the two, and ascribing this decline to a particular cause is beyond the scope of this thesis.

Pollen Zone 2: 7,027- 3,487 cal yr BP

In zone two, decreases in pine and chestnut, along with increases in maple, birch, ferns, willow and alder, suggest a wetter climate, although the increase in bottomland taxa could be due to increased openness in and around the valley, possibly as a result of increased warmth and/or aridity. The decrease in pine pollen supports the idea of a wetter climate because extant pines in the mountains typically prefer xeric sites, although some will tolerate moist sites (*Pinus rigida*, *P. pungens*, *P. strobus*, *P. virginiana* and *P. echinata*; Weakley 2012). Additionally, the two common species of willow now found at Panthertown and throughout North Carolina are both obligate wetland species (*Salix*

nigra and *S. sericea*; Lichvar 2013, Smith 1992, Weakley 2012). *Salix humilis*, an uncommon species in North Carolina, is also present in the valley today and is a facultative species, able to grow in both moist sites and dry upland areas (Lichvar 2013, Weakley 2012). The birch, maple, and hickory pollen present in zone two may all be floodplain species, as all three genera are typically bottomland, riverbank or moist cove plants (Weakley 2012).

The increases in oak, asters and grasses in zone two may indicate an expansion of warm or dry conditions. These three taxa tolerate a wide range of moisture conditions and have many extant species in the mountains, making it difficult to pinpoint a moisture regime based on their presence or absence; however, all have a greater abundance of species in warmer climates, and their expansion during this time may be due to warmer temperatures. As noted earlier, asters may also indicate an open situation at the forest edge or around the wetland. Moderate presence of pine, chestnut, and blackgum (*Nyssa*) along with dominance by oak suggests well-drained slopes and ridges, which agrees with the steep slopes surrounding the valley.

Pollen Zone 1: 3,487- 0 cal yr BP

The most recent forest is much more diverse than previous vegetation. Presence of basswood and beech, and the overall diversification of the forest, suggest a shift toward cooler temperatures and increased precipitation. High percentages of ferns and willow as well as increases in alder and *Sphagnum* indicate the valley floor was consistently wet. The extant hemlock, maple and holly species in the mountains are all facultative wetland species, making them less diagnostic of a particular climate regime than other taxa (Lichvar 2013, Weakley 2012). The pine, chestnut and blackgum

(*Nyssa*), along with the dominance by oak, are probably from the drier upland slopes and ridges.

Disturbance

Approximately 15 km from Panthertown Valley at Horse Cove Bog, increases in the abundance of chestnut and oak during the late Archaic and Woodland cultural periods indicate higher rates of sprouting due to frequent fire (Delcourt and Delcourt 1997). An overall increase in vegetation richness between 3,000 and 4,000 yr BP led the authors to “infer that this regime of wildfire use was an intermediate-scale disturbance regime that promoted a heterogeneous mosaic of different vegetation types” (Delcourt and Delcourt 1997).

Similarly, the intermediate disturbance hypothesis might also explain the diversification of taxa in the late Holocene at Panthertown. Increases in birch and maple in zone 1 may indicate increased wind disturbance at Panthertown, as both taxa favor open disturbed sites (Frelich 2002). The Panthertown core was not analyzed for charcoal and the pollen assemblage is at too coarse a resolution to allow inferences about possible agricultural disturbance. Key taxa that indicate crop cultivation are in the Asteraceae and Poaceae, and I was not able to differentiate genera within those families.

CONCLUSION

Panthertown Valley during the Holocene appears to have been surrounded by a temperate mixed mesophytic forest, and data presented suggest the continuous presence of the wetland in the valley throughout this period. Corresponding increases in Poaceae pollen and $\delta^{13}\text{C}$ values, increased deposition of terrestrial organic matter evidenced by the C/N values, and the pollen record from ~7,000 and ~3,500 yr BP all support a warm and possibly drier Hypsithermal in the Southern Appalachian mountains. From ~3,500 yr BP to the present, diversification of the forest and an increase in northern hardwoods taxa, along with lower C/N values, indicates increased moisture and cooling in the late Holocene.

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APPENDIX A

Pollen Processing Methods

Samples were ground with a mortar and pestle, and 0.5 cm³ of material was placed in a clean 15 ml centrifuge tube and weighed. One tablet of exotic pollen marker grains (*Lycopodium clavatum*, batch #177745, $x = 18584 \pm 829$) was added to samples in order to determine pollen concentrations. A three minute treatment of 10% hydrochloric acid in a warm bath was used to remove the carbonates and break up the *Lycopodium* tablets, followed by two washes with hot distilled water. Potassium hydroxide (5%) was added to the sample and placed in a boiling water bath for 10 minutes to dissolve the humic acids. Four washes with hot distilled water followed, and then the sample was sieved through a 125 μm screen to remove particles larger than pollen. A 20 minute treatment of 49-52% hydrofluoric acid in boiling water dissolved silicates in the sample. Following that, hot Alconox solution was added to the sample and let sit for 5 minutes to deflocculate the material. The sample was washed three times with hot distilled water, then dehydrated with glacial acetic acid in preparation for acetolysis. An acetolysis solution of sulfuric acid and acetic acid was mixed and added to the sample for the purpose of removing cellulose and other polysaccharides, and the sample was placed in a boiling bath for 5 minutes. Glacial acetic acid was then added to the sample to quench the reaction, followed by one hot water wash. The sample was then treated with 5% KOH for 5 minutes in a boiling bath and then washed with hot water three times. One drop of Safranin stain was added to the sample and vortexed to mix, with up to three drops of stain added depending on the amount of residual organic matter present. The

sample was washed once with water and then again with TBA (tert-butyl alcohol) to dehydrate it. TBA was added again, mixed and decanted, and the pollen residue was transferred to the appropriately labeled glass vial. Silicone oil was added and the vial was placed under a fume hood to allow the remaining TBA to evaporate.

All treatments and washes throughout the process were centrifuged for 2 minutes at 400 RPM and decanted into appropriate waste containers.

Modified from Faegri and Iverson (1989).

APPENDIX B

Total identified grain count, number of *Lycopodium* spores, weight, pollen concentration (grains/g), and pollen influx rates (grains/cm²/yr) by sample depth.

Depth (cm)	Weight (g)	<i>Lycopodium</i> marker spores	Total pollen and spore count	Concentration (grains/g)	Rate of Influx (grains/cm ² /yr)
5	0.18	32.00	407.00	1,313,140.28	9,060
15	0.28	23.00	395.00	1,139,857.14	11,331
25	0.26	20.00	429.00	1,533,180.00	16,228
35	0.25	17.00	431.00	1,884,636.24	19,499
45	0.29	42.00	410.00	625,569.79	6,700
55	0.29	64.00	535.00	535,691.81	5,496
65	0.24	67.00	443.00	511,984.58	4,065
75	0.26	7.00	434.00	4,431,569.23	39,437
85	0.30	66.00	478.00	448,644.04	5,103
95	0.26	77.00	465.00	431,646.35	4,769
105	0.28	7.00	496.00	4,702,889.80	41,797
115	0.29	287.00	624.00	139,329.76	1,508
125	0.26	63.00	426.00	483,320.15	4,441
135	0.23	52.00	399.00	619,984.62	4,653
145	0.35	95.00	361.00	201,769.14	2,440
155	0.56	174.00	384.00	73,237.44	1,553
165	0.57	147.00	369.00	81,841.46	1,809

APPENDIX C

Arboreal pollen counts by sample depth for all identified arboreal taxa.

Depth (cm)	5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165
Castanea	7	40	26	28	29	1	3	6	0	1	5	11	129	137	136	136	142
Quercus	93	103	160	147	157	262	203	225	264	238	215	230	128	101	109	109	121
Betula	47	82	46	51	44	4	39	19	0	11	13	14	6	11	8	8	5
Carya	2	1	1	1	0	1	3	2	1	1	10	4	1	5	3	5	5
Ostrya/Carpinus	0	0	4	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Tilia	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulmus	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acer	5	5	5	17	22	2	19	5	2	0	6	8	4	6	8	7	6
Juglans	1	0	0	0	0	0	2	0	0	2	0	1	0	0	0	2	0
Fagus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Nyssa	8	0	1	3	3	3	4	6	1	1	4	1	2	3	1	4	0
Ilex	5	4	7	8	9	0	0	0	0	0	1	0	0	0	1	0	0
Liquidambar	3	0	0	0	2	0	0	0	0	5	0	0	0	0	1	0	0
Pinaceae																	
undifferentiated	0	4	6	1	0	0	0	0	1	0	4	0	3	0	3	0	3
Pinus	31	8	4	8	6	1	3	6	1	0	6	4	10	18	9	8	7
Tsuga	4	11	13	16	13	0	1	2	0	0	2	2	3	0	0	2	0
Salix	43	29	19	14	12	4	7	12	3	2	11	0	0	1	1	0	0
Alnus	49	12	7	5	2	22	16	16	27	39	23	25	14	18	20	19	11

APPENDIX C, CONTINUED

Non-arboreal pollen counts, total unidentifiable, and unknown counts by sample depth

Depth (cm)	5	15	25	35	45	55	65	75	85	95	105	115	125	135	145	155	165
Corylus	3	0	41	39	10	3	9	3	3	2	8	3	2	0	1	4	2
Sphagnum	3	23	5	5	4	0	0	2	1	0	0	0	0	0	0	0	0
total fern spores	18	24	14	18	34	79	74	64	80	37	85	233	65	59	35	42	35
Lycopodium inundatum	1	0	0	0	2	8	0	1	1	0	1	0	0	0	0	0	0
Poaceae	5	0	7	7	22	80	21	23	46	69	59	34	27	7	5	10	7
Ericaceae	59	29	44	37	23	1	21	9	7	5	13	5	7	12	5	8	13
Asteraceae	15	19	15	20	11	48	14	24	29	39	22	42	21	15	14	12	12
Umbelliferae	0	0	1	0	1	0	0	1	0	0	1	3	4	1	0	2	0
Thalictrum	2	0	1	1	3	16	4	5	10	13	6	4	0	3	0	0	0
Brassicaceae	0	0	1	4	0	0	0	2	1	0	1	0	0	2	1	6	0
Cyperaceae	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lycopodium marker	32	23	20	17	42	64	67	7	66	77	7	287	63	52	95	174	147
unidentifiable	50	77	127	125	128	156	84	86	173	209	83	218	122	59	61	90	118
unknown	10	0	0	26	0	19	26	31	28	9	13	175	26	36	26	52	34