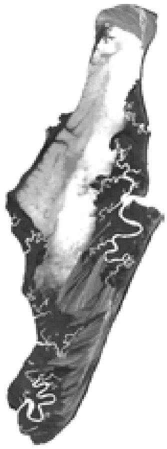

CHAPTER 2

EVOLUTION OF LATE PLEISTOCENE-HOLOCENE CLIMATES AND ENVIRONMENTS OF ST. CATHERINES ISLAND AND THE GEORGIA BIGHT

Fredrick J. Rich, Anthony Vega, and Frank J. Vento[1]

The most ancient floras of the Pleistocene of the American Southeast date back more than 50,000 years. This limit is probably not due to the proscribed distribution of the deposits, but clearly is controlled by our ability to date them using radiocarbon techniques. Beyond about 40,000 yr B.P., things are simply radiocarbon "dead," so one has difficulty defining actual ages before that time.

This situation notwithstanding, and regardless of the actual ages of the most ancient accumulations of plant debris, it remains true that the flora the first Native Americans encountered shaped their relationship with the land. Understanding the potential for resource exploitation that lay before them provides us with some insight into the types of economies that developed. This is true of both plant and animal resources, of course, but in this chapter we will examine the history of the flora of the general area of central and coastal Georgia and northern Florida—those areas that most likely held significant influence over the lives of the ancient occupants of St. Catherines Island.

Numerous investigators, most of whom have been palynologists, have worked on a variety of deposits from the Southeast (hereby designated as Georgia, Florida, Alabama, South Carolina, and North Carolina). While much of that work is briefly described here, it is advisable for the reader to refer to Russell et al. (2009) who provide an integrated interpretation of the late Pleistocene fauna, flora, and landscapes of a much more extensive region, but one that still lies within the geographical concept of "Southeast." Russell et al. provide the most comprehensive paleoecological interpretations to date, though the work does penetrate the details of direct evidence from archaeological sites. A brief recounting of the data cited by Russell et al. (2009) appears here, with several key additions based on archaeological site investigations.

We have ordered this chapter in chronological fashion, beginning with discussions of the oldest-dated deposits, and proceeding to the time of first European contact. The chronology of events consists of contributions from a number of authors, as mentioned above, and we have endeavored to order information from oldest to youngest, using radiocarbon chronologies as a guide.

THE MOST ANCIENT DEPOSITS

Grimm et al. (2001) note that "With the exception of Florida, sites with good Holocene records are few in the southeastern United States …" While this is also true of late Pleistocene sites, we do have access to some very informative locales that provide a variety of data that are pertinent to the current study. As mentioned above, the most ancient deposits fall outside the range of radiocarbon dating, but they provide us with background as to what the southeastern flora looked like over some part of the last 100,000 years. Watts (1969) conducted the classic study of strata from Mud Lake, Marion County, Florida; these analyses were destined to set the tempo for most subsequent efforts. Mud Lake sediments consist almost entirely of gyttja, a pasty, amorphous, highly organic-rich sediment of many possible origins. Watts' sample profile represented more than 13 m of lake sediment, and the samples proved to be very productive. Two situations operated against Watts being able to fill out a complete Quaternary history from Mud Lake: sediments were radiocarbon dead at only about 5 m depth, the date at that horizon being >35,000 yr B.P. and a hiatus of great duration occurred just above the >35,000 yr horizon. Atop the >35,000 year old gyttja was a layer of silt approximately 2.5 m thick, and the sediment immediately above the silt dated to 8160 yr B.P. (9080 cal B.P.). The significance of the hiatus is, of course, that it indicates a substantial drawdown of lake level during that period of time, which corresponds to the Last Glacial Maximum (LGM). These conditions notwithstanding, Watts divided the sample sequence into six major zones: (1) a *Pinus-Carya* (pine-hickory/pecan) zone at the bottom; (2) a *Carya-Liquidambar* (hickory-pecan/sweetgum) zone; (3) a *Pinus* zone; and (4) a *Quercus-Myrica* (oak-wax myrtle) zone (all below the >35,000 year B.P. horizon); (5) a *Quercus* zone; and, finally, at the top, (6) a *Pinus-Taxodium* (pine-cypress) zone. These taxa are all important contributors to the current flora of the southeastern U.S., and even the less common taxa that Watts encountered are familiar. Unusual components of the pollen flora include some *Picea* (spruce) in the lowest horizon. Aside from the spruce pollen, most of the taxa would be familiar to someone working in the region today, and Watts notes in his conclusions that ancient Mud Lake was characterized by a diverse aquatic flora that differed from one horizon to the next primarily as a result of varying water levels. Thus, hydrologic control was more important as a cause of variation than wholesale changes in the composition of floral communities.

Another of the longest and most well-known chronologies from the Southeast comes from Lake Tulane, Florida. Grimm et al. (1993) conducted palynological investigations on samples than span nearly all of the last 50,000 years. One of the more significant findings was that floras characterized either by *Pinus* or *Quercus*/*Ambrosia* (oak-ragweed) species oscillated; the *Pinus*-dominated landscape was replaced by the *Quercus*/*Ambrosia* landscape (grassland), then the situation reversed. This switch from pine forest to oak savanna/grassland suggests two things: (1) the plant communities were in place, providing a diverse background of plant species that could occupy later landscapes, and (2) the climate waxed and waned from moist (pine) to dry (oak) as time went by. We know that climate fluctuations occurred, but this oscillation of plant communities provides us with evidence of the terrestrial biotic response to the situation. What Grimm and colleagues learned at Lake Tulane reflects the situation that Watts encountered at Mud Lake—species remained more or less constant in the regional flora, but local changes in edaphic conditions (i.e., soil) and hydrology caused them to appear and disappear locally.

Rich, Elzea, and Newsom (2000) discovered a much more limited window on the late Pleistocene when they began work on an ancient beaver dam complex near Deepstep, Georgia. Excavation of overburden at the Boatright Mine, a kaolin operation, revealed abundant fine-grained sediments and a dense accumulation of short lengths of wood. A radiocarbon date of >47,479 ^{14}C yr B.P. indicates the age of the deposit, much of which was conifer wood, including *Taxodium*. Palynological analyses revealed a curious assortment of plants, including *Liquidambar*, *Pinus*, *Quercus*, *Taxodium*, *Gordonia* (loblolly bay or other Theaceae), and *Picea*. Such a mixed flora (mixed in the sense of "warm" and "cool" climate taxa) prompted the view of a mixed flora that was the result of plant migrations during the Pleistocene; northern taxa such as spruce moved south and southern taxa such as loblolly and bay remained in place.

Pirkle et al. (2007) and Rich (2007) provide descriptions and illustrations of a sequence of tree stump-bearing units at Reids Bluff, on the Florida side of the St. Marys River near St. Marys, Georgia. A series of stump-bearing (*Taxodium*) horizons and paleosols, as well as a prominent oyster- and clamshell-bearing unit have a range of dates. The lowest *Taxodium* horizon was dated at >38,130 yr B.P. *Mercenaria* shells were dated at 36,030 ± 610 yr B.P. and 36,270 ± 1,670 yr B.P. A bed of sand 3.1 m above river level bore wood that produced a date of 25,830 ± 373 yr B.P. Reids Bluff thus spans a considerable range of time, and records at least two shoreline regressions (the tree- and wood-bearing horizons) and a transgression (the shell layer). Pollen from a variety of contexts, including paleosols and infillings of shells, reveals a diverse, but familiar coastal flora for the time represented. *Pinus*, *Quercus*, and *Taxodium* are common, as is the family Chenopodiaceae (aka, cheno-ams or Chenopodiaceae/Amaranthaceae). In a summary statement, Rich (2007) writes that most of the plants "indicate communities of freshwater wetland trees, shrubs, and herbs, or maritime forest, which could be found anywhere along the current east coast of the United States south of Chesapeake Bay." One exception was the presence of hemlock, *Tsuga*. Hemlock does not currently grow on the coastal plain, though its pollen was found in both Reids Bluff paleosols, and in sediment from a ghost shrimp burrow and a blue-gray clay from nearby Bells Bluff. Rich concluded that this situation, which is also known from a sample suite described by Cronin et al. (1981) further up the East Coast, leaves one with the impression that, while these late Pleistocene floras reflect a temperate climate, it must have been cooler than what we see today to support the hemlock.

Work by LaMoreaux, Brook, and Knox (2009) provides important new information on the changing Pleistocene and Holocene paleoenvironment and associated paleoclimate along the Georgia coastal plain. Their studies were based on a core of sediment recovered from the valley bottom zone of Sandy Run Creek (upper coastal plain of Georgia, south of Macon). The sediments in the bottom zone suggest a braided stream pattern, with low water table and a cool, dry climate for the period 30,000 to 25,000 yr B.P. The vegetation consisted principally of open grassland species, with stands of pine and spruce. The results of this study are supported by pollen and ostracod studies completed on lacustrine sediments underlying modern Tampa Bay (Willard et al., 2007). The latter authors note that, during the LGM the climate in central Florida was much drier and cooler than at present; this is consistent with other studies, as cited herein. The lacustrine sediments were rich in pollen of the Chenopodiaceae and *Carya*, though there was rare *Pinus*.

With regard to climate, the Wisconsin glacial phase of the Pleistocene Epoch peaked at approximately 18,000 B.P. (21,240 cal B.P.), when permanent ice covered most of North America north of the Ohio River and extended across the pole to cover much of Europe and Asia. The ice advance left extensive proxy evidence of its existence across the continents including the final formation phase of the Great Lakes, Martha's Vineyard, Long Island, upstate New York's Finger Lakes, fiords in Maine, and the Yosemite Valley of California. Present-day circulation features generally include light mean winds from the southwest on through central to eastern North America. Glacial maximum winds were primarily from the northwest and approximately 50%–80% above present levels of average wind speed (Crowley and North, 1991). Therefore, most of North America was within the cold, dry, circumpolar vortex leading to a boreal climatic regime for eastern North America.

During this glacial maximum, sea levels fell as much as 170 m (550 ft) below current levels as vast stores of water were locked in the continental ice sheets. The eastern coast of North America extended much farther than today as a result. Further, many barrier islands currently located off the Eastern Seaboard were connected to the continent during this period. As the Holocene Epoch ensued, rapid ablation of the ice sheet occurred causing rapid sea level rise, a decrease in stream gradients, and the subsequent drowning of numerous rivers, like the Chesapeake, Delaware, and St. Lawrence.

During the last glacial maximum (18,000 B.P. [21,240 cal B.P.]), the average jet stream position migrated to approximately the Gulf Coast region, about 30°N. By comparison, the average jet position today is approximately centered over the conterminous United States. During this period, much of eastern North America was overlain by cold and dry polar air. The jet stream marked the stormy transition zone between cold, dry conditions and the warmer, wetter conditions of lower latitudes. For much of southeastern North America, jet stream amplification characteristics would have been relatively unimportant as the region lay primarily within persistent cool, dry conditions. Proxy evidence indicates, for example, that central Florida was approximately 3°–4°C cooler than present, and as such, the region was significantly drier than present (Willard et al., 2007).

FLORAS OF THE FULL GLACIAL

Russell et al. (2009) present a table of chronologies that reflects significant events of the Pleistocene, dating back to 2.7 mybp. The event that is of greatest significance to the current discussion is the LGM, reported to extend from 23,000 yr B.P. to 19,000 yr B.P. (22,490 cal B.P.). During that time the Wisconsinan ice sheet had advanced southward toward the current positions of the Ohio and Missouri rivers. This had to have been a time of maximal climatic cooling, and maximal drawdown of sea level. In the chronology we borrow from Fairbanks (1989), sea level was at about –121 m in the Barbados. A map of the East Coast, with a shoreline drawn at the –120 m isobath illustrates a very wide coastal plain during the LGM (Russell et al., 2009). St. Catherines Island, and all the other barrier islands on the East Coast were far inland and must have been incorporated as parts of the coastal plain. Few fossil plant samples have been analyzed that represent this period of time, though the upper levels of Reids Bluff and the flora they preserve come close. Three samples recovered from 5–10 cm below the seafloor at Gray's Reef National Marine Sanctuary, 28 km east of St. Catherines Island, provide a glimpse of the flora that existed there when the area of the reef (now under about 18 m of seawater) was exposed to the atmosphere. Familiar southeastern taxa include *Pinus*, *Quercus*, *Carya* (probably pecan), and *Liquidambar* and there is quite a diversity of herbaceous plants, including grasses, sedges, ferns, and *Sphagnum*; a complete list appears in Russell et al. (2009). Three taxa that were present at Gray's Reef that one would not expect to see now are *Alnus* (alder), *Tsuga*, and *Picea*. Although the percentages were small, there was as much as 2.3% *Alnus* (minimum 300 total grain count) and 2.1% *Picea*. This is clear evidence of floral mixing, though it is equally clear that the dominant flora was the current flora of the southeastern coastal plain.

Jackson et al. (1997) undertook a comprehensive analysis of mapped plant macrofossils and pollen from eastern North America, and gathered data from 269 sites extending from eastern Canada to the Gulf Coast. Fewer than 10 sites come from the area of interest in this chapter, but some of the data are quite significant. For the LGM, Jackson et al. note that their plant macrofossil data confirm the southward migration of boreal and cool-temperate taxa, especially species of spruce and northern species of pine (*P. resinosa* and *P. banksiana*); spruce, they note, was particularly widespread along the Gulf Coast.

Cofer and Manker (1983), in an investigation of the strata associated with a kaolinite deposit in Andersonville (Georgia), noted that a peat deposit was exposed in the south wall of the Wilburn Mine. A 1.8 m sandy/clayey peat was overlain by 0.8 m of sand, which was in turn covered by 1.5 m of sandy peat. The upper peat was covered by the thin (<1 m) soil horizon of the floodplain of Sweetwater Creek. A sample recovered from 10 cm above the bottom of the lower peat layer contained spruce seed cones, which were subsequently dated at 21,300 ± 400 yr B.P. (26,000–24,610 cal B.P.) Wood fragments (unidentified) from the upper portion of the same stratum provided a date of 15,840 ± 300 yr B.P. (19,570–18,610 cal B.P.). A sample (unidentified) from the basal portion of the upper organic horizon yielded a date of 10, 570 ± 250 yr B.P. (12,980–11,610 cal B.P.) Thus, the Andersonville site provides us with some information that represents events in southwestern Georgia between, about 10,570 yr B.P. (12,580 cal B.P.) and 21,300 yr B.P. (25,780 cal B.P.). The critical piece of information is, of course, that the cone was identified as spruce, *Picea*. This corroborates reports cited above that document the presence of spruce on the Georgia coastal plains, both Atlantic and Gulf, during the LGM.

If we assume that the flora of the Southeast remained fairly stable during the LGM, and for the first few thousand years following glacial retreat, it would appear that the greatest environmental variable to affect the Georgia coastal plain was the presence or absence of the ocean itself. Alley et al. (2005) revisit the paleoglaciology of the Northern Hemisphere, and describe the meltwater pulses of the late Pleistocene that had such a significant effect on oceanic thermohaline circulation. The older of the two pulses has been dated at 19,000 yr B.P. (22,490 cal B.P.), with the younger one occurring at about 14,500 yr B.P. (17,420 cal B.P.) According to Alley et al. (2005), each meltwater pulse "… added the equivalent of 1.5 to 3 Greenland Ice Sheets to the oceans over a period of one to five centuries." Such additions to the world oceans might well have had an influence on conditions along the Georgia coast. Following the second meltwater pulse, a period of ice mass stabilization, the Younger Dryas cold interval ensued and lasted until about 11,500 yr B.P. (13,340 cal B.P.; Alley, 2000).

The interval between the LGM and the Younger Dryas (YD) is rather a *terra incognito*. Some data do exist, however, that help to flesh out that distant time. LaMoreaux, Brook, and Knox (2009) report a warmer and wetter climate for Georgia and Florida between 17,000 and 16,000 yr B.P. (20,130–19,180 cal B.P.) They note a change from an earlier braided channel system to that of a meandering system, with incision of the earlier valley fill deposits. Willard et al. (2007) inferred a warming of climate in central Florida at this time, with increases in *Pinus* reaching near modern levels of abundance. This occurred during the warmer and more moist climate of the Bolling/Allerod interval of 14,700 to 12,900 yr B.P. (17,770–15,250 cal B.P.) Additionally, Willard et al. (2007) were able to identify centennial-scale cold and dry events with the Bolling/Allerod sequence that corresponds to the Older Dryas (13,900 to 13,800 yr B.P.) and IntraAllerod intervals (12,900 to 12,700 yr B.P.), specifically.

The Bolling Allerod Interstadial (BAI) marks a period of rapid warming and coincident Laurentide ice sheet ablation. The period began approximately 17,500 B.P. (20,700 cal B.P.) and lasted until approximately 14,700 B.P. (17,770 cal B.P.), the onset of the cooler Younger Dryas. The BAI marks a period in which average air temperatures increased to roughly modern levels as indicated by peak abundance of *Pinus* pollen in central Florida (Willard et al., 2007). Such warming indicates significant contraction of the circumpolar vortex and poleward jet stream displacement. This likely resulted in greater amplification of the jet, or meridional, conditions. Meridional conditions occur during periods of a stronger latitudinal thermal gradient. This in turn triggers higher changes in vorticity through the jet trajectory. The result is deeper amplification of the jet flow and stronger and longer lasting midlatitude cyclones. Therefore, such periods are coincident with increased precipitation. Proxy evidence agrees with such an assessment as vegetation changes indicate warmer and moister conditions through eastern North America during this period. The Younger Dryas represents a period of time for which we have very little palynological or paleobotanical evidence from the Southeast, though some records go back to that time, and are briefly reviewed here. In any analysis of palynological and/or paleobotanical data from that time, it is well to bear in mind the observation made by Jackson et al. (1997) that the "… transition period between 15 and 9 ka was characterized by pollen assemblages without modern analogs over much of eastern North America."

Grimm and Jacobson (1992) observed that, based on their analyses of 18 sites spread across the eastern half of the continent, in the subcontinental region of eastern North America there were a number of synchronous changes in ancient floras. Times of significant change occurred during the late glacial (~14,000 to 9000 yr B.P. (~16,670–10,200 cal B.P.), with peaks at about 13,700, 12,300, and 10,000 radiocarbon yr B.P. (16,350, 14,160, and 11,500 cal B.P.) and during the last 1000 years. We have tried to correlate those times with changes known from regional floras in the following synthesis.

At approximately 13,000 B.P. (16,200 cal B.P.), LaMoreaux, Brook, and Knox (2009) identified a horizon of organic sediment deposition along Sandy Creek Run. Low swales associated with more rapid vertical accumulation of sediments apparently developed in the valley floor of ancient Sandy Run Creek. The organic-rich deposits correlate with the age of the 4A paleosol from Yellow Banks Bluff, St. Catherines Island, and were dated at 13,600 yr B.P. (16,220 cal B.P.; Vento and Stahlman, chap. 4). During the subsequent Younger Dryas, the environment turned cool and moist, with open oak woodlands, trees of mesic forest type, and reduced amounts of pine (LaMoreaux, Brook, Knox, 2009) Similarly, the Younger Dryas stratigraphic record at Tampa Bay shows two distinct cool and dry phases, namely at 12,900–12,300 yr B.P. (15,250–14,160 cal B.P.) and 12,300–11,500 yr B.P. (14,160–13,340 cal B.P.) These dates correlate with the well-sorted eolian sands (2C), which cap the 13,600 yr B.P. Allerod subage paleosol and underlie the 10,790 yr B.P. (12,830 cal B.P.) paleosol exposed and dated along Yellow Banks Bluff. These eolian sands likely document less effective precipitation and drier climatic conditions that favored eolian deflation and subsequent burial of the Allerod subage paleosol.

Among other sites that provide us with some notion of the composition of the southeastern U.S. flora during the Younger Dryas is the remarkable archaeological site known at Windover. The Windover site, near Titusville, Brevard County, Florida, has been a wetland area, intermittently occupied by a pond, for nearly 11,000 years (nearly 13,000 cal B.P.). Doran (2002) presents exhaustive analyses of all the components of this site. An Early Archaic age is suggested for the horizon that contained abundant human remains (burials).

The oldest strata that were analyzed paleobotanically were sandy layers that predated the time of burial of the first humans. Holloway (in Doran, 2002) described a microflora dominated by pine, oak, and grasses and dated at 10,750 ± 190 yr B.P. (13,070–12,140 cal B.P.). The pine-oak savanna that Holloway describes is consistent with what is known of other sites in the region, including Lake Tulane.

Proxy evidence indicates that warming occurred between the peak of the Wisconsin glacial phase, 18,000 B.P. (21,250 cal B.P.), but abruptly ended at 13,000 B.P. (15,360 cal B.P.) when a cold phase ensued during the beginning of the Younger Dryas and lasted until 11,500 B.P. (13,340 cal B.P.) In Europe, this cold period is known as the Loch Lomond Stadial. The Younger Dryas (YD) is named after the dryas, a herbaceous tundra plant whose pollen grains in sediment and ice layers identified its chronological occurrence. The term "Younger" separates this more significant climatic episode from the Older Dryas, a less impressive stadial geological phase that occurred previously within the BAI (Yu and Eicher, 2001). The transition from the BAI to the YD was likely very abrupt, occurring over only a decade or so (Alley et al., 1993). Evidence suggests that temperatures were approximately 5°C cooler than current temperatures during this period.

During the YD, the circumpolar vortex expanded equatorward while strengthening significantly. This extended boreal conditions southward. This offset atmospheric and oceanic circulation regimes established during the previous BAI ablation period. While the cause of the YD is still debated, it is likely centered on atmospheric and oceanic circulation changes induced by cold meltwaters from the retreating Laurentide ice sheet. Before about 11,000 B.P. (12,920 cal B.P.), virtually all meltwaters were carried to the Gulf of Mexico via the Mississippi River (Marchitto and Wei, 1995). By 11,000 B.P. the ice sheet retreated to a position whereby the St. Lawrence River opened. This allowed the larger freshwater Lake Agassiz to drain significant quantities of cold meltwater into the northern Atlantic Ocean (Broecker, 2006). The resulting cold/low salinity lens in the North Atlantic significantly altered the ocean circulation. This hypothesis is supported by Bond (2005) who showed that significant Holocene climate shifts were accompanied by a 1°–2°C drop in North Atlantic sea surface temperature (SST). The lower SSTs triggered a positive feedback loop that altered the overlying atmospheric circulation leading to circumpolar vortex expansion and cooling for much of North America and Europe. This expansion brought cold, dry air over eastern North America and triggered significant ecotone changes from the previous warmer and wetter circulation regime. Proxy evidence through the southeastern United States indicates strong drying in a two- to three-step phase through the YD (Sissons, 1979; Willard et al., 2007). The YD ended as a new atmospheric/oceanic equilibrium was attained. Further ice sheet ablation eventually allowed contraction of the circumpolar vortex and expansion of the North Atlantic subtropical anticyclone. The poleward shift of these general circulation features caused net poleward migration of the polar jet stream and allowed for the advection of warmer, moisture air masses to higher latitudes over eastern North America. Evidence indicates that the YD ended as abruptly as it began (Dansgaard, White, and Johnsen, 1989). With the termination of the Younger Dryas, and following the renewal of climatic amelioration, it appears that local water levels, including that at Windover Pond, rose. This is manifest at Windover by the deposition of waterlily peats. Stout and Spackman (in Doran, 2002) identified *Nymphaea* peat that had accumulated between approximately 11,000 yr B.P. and 9500 yr B.P. (12,920 and 10,740 cal B.P.).[2] Not surprisingly, Holloway discovered abundant oak at the Windover site at 8990 ± 90 yr B.P. (10,300–9770 cal B.P.), with maximum development of freshwater taxa, including the Nymphaeaceae and *Sagittaria* (arrowhead, a common freshwater marsh plant). Within the time range of 9500–8000 yr B.P. (10,740–8890 cal B.P.), Stout and Spackman recorded a rising water table at Windover, with the deposition of very fine-grained/amorphous gyttja (similar to the Mud Lake sediment studies by Watts). It was within this interval that Holloway found an abundance of Chenopodiaceae pollen in the Windover strata; abundance gave way to dominance at 8430 ± 100 yr B.P. (9550–9140 cal B.P.). At this point it is important to say that, while the Chenopodiaceae and Amaranthaceae (now combined as a single family) are useful indicators of herbaceous communities, it is nearly impossible to distinguish the pollen of the freshwater/terrestrial species from those that dominate coastal salt marshes. One must rely on associated remains to derive detailed environmental interpretations. It is clear, however, that changing hydrology at Windover during this period of time lead to the establishment of marshlands in an area that had supported oak savanna and waterlily marshes. Stout and Spackman (in Doran, 2002) determined that the Windover site must have dried out considerably at about 7950 ± 100 yr B.P. (9080–8450 cal B.P.). Mixed hardwood swamp began to take over the site, and this was the type of ground cover that greeted the first inhabitants. Interments began as people buried the deceased within the swamp.

The period 9000–8000 B.P. (10,200–8540 cal B.P.) marked a continuation of cool-season zonal flow. However, higher warm-season potential evaporotranspiration rates led to prominent drying through the southeastern United States. Climatic conditions abruptly changed during the Atlantic (8000–4500 B.P.; 8890–5180 cal B.P.) climatic episode, as wetter conditions prevailed. Many relate this transition to increased meridional jet flow. However, the extremely long-term stability of the climate suggests that zonal conditions dominated but that the average position of the polar jet increased poleward. This placed the study region within warmer and moister air masses. Precipitation was predominantly light through the seasons and increases in vegetation helped offset infrequent large precipitation events relative to runoff.

THE EARLY TO LATE ARCHAIC

The Archaic spans roughly 4000–10,000 yr B.P. (4480–11,500 cal B.P.). Burials at Windover have a mean age of 7400 yr B.P. (8240 cal B.P. Doran, in Doran, 2002), so they fall nicely within that range, and are considered Early Archaic. Numerous additional archaeological sites of the southeastern United States fall within this range. While there are many more sites than we report on here, we have selected a few in the general area of Georgia and Florida (northern Florida, especially) that contain paleobotanical and palynological remains that reflect on the ancient environmental and habitat conditions that probably existed on or near St. Catherines Island. Among very recent reports is a compilation of data from the Mitchell River site, a complex of Middle and Late Archaic occupational horizons found at the easternmost end of Choctawhatchee Bay in the Florida panhandle (Saunders et al., 2009). The Mitchell and Choctawhatchee rivers have created a delta that was intermittently occupied between about 8000 and 3000 yr B.P. (8890–3210 cal B.P.). A multidisciplinary team identified artifacts, molluscs, pollen and spores, and siliceous microfossils in order to recover the greatest detail from the Mitchell River locality. Our interpretations of their data are necessarily brief, but we have tried to relate them to the developing matrix of site characteristics from other areas, such as Windover. The initial occupation of Mitchell River has been dated to cal 7200 yr B.P. The first occupants lived in an area dominated by sedge marsh. Returning to the Windover site, between 7000 and 6000 yr B.P. (7850–6840 cal B.P.); Stout and Spackman (in Doran, 2002) determined that subaerial exposure at Windover lead to the continuation of the mixed hardwood swamp. This might have been the result of a change in hydrology that resulted in the persistence of the arborescent species where open water or herbaceous plants had existed much earlier.

It was within this window of time (6870 ± 50 yr B.P [7800–7610 cal B.P] to 5050 ± 50 yr B.P.[5910–5660 cal B.P]) that a pine savanna had developed in Coffee County, in central southern Georgia, at what has become known as the McClelland Sandpit Site (Zayac, Rich, and Newsom, 2001). McClelland is not an archaeological site, but it did preserve a beautiful forest of buried trees. Dozens of pine tree stumps and their enclosing sediments were exposed at McClelland as a result of removal of overlying sandbeds. Analysis of pollen and siliceous sediments from McClelland lead Zayac and her colleagues to the interpretation that the trees had grown in the floodplain of what must have been an anastomosed stream (many channels that tend to intertwine). Anastomosis occurs among streams, such as the Platte and Saskatchewan rivers, where sharply seasonal rainfall in a largely arid but vegetated region creates the anastomosed condition. Pollen data from McClelland led to the conclusion that the land cover in Coffee County consisted of prairie, similar to what one would find in the high plains of the western United States and Canada.

It's worth noting at this point that prairie is a truly unusual occurrence anywhere in the Southeast. As Gremillion (2004) points out, the deciduous forest of the southeastern United States changes, at its western edge, to grasslands. Within the area that she mapped as the "Southeast," grasslands exist only in isolated patches where demanding environmental conditions (dryness, windiness, and heat) prevent the growth of woody vegetation. There might be relicts of once more extensive grasslands, but they are invariably small.

It is significant that the McClelland site, and the period of maximum dryness at Windover, fall within what is known as the Holocene Climatic Optimum, or Hypsithermal. It has been shown that between about 4000 and 8000 yr B.P. (4480–8890 cal B.P.) the earth experienced a period of greater than average warmth. This is in remarkable contrast to the recently passed ice age, and the effects were widespread. Where one would have expected to find permanent streams bounded by cypress-tupelo forest (the current condition at McClelland), the environment was clearly substantially drier than it now is. Wetland species did not leave the general area of southern Georgia and Florida, they merely relocated to more propitious sites.

Another Archaic site, known as Harney Flats, in Hillsborough County, Florida, was investigated by Austin et al. (2004). One radiocarbon date from Harney Flats, obtained from a piece of wood, showed that native people lived there 6820 ± 40 yr B.P. (7720–7580 cal B.P.). This, then, is another site that was occupied during the Hypsithermal. Though palynological data were collected, the Harney Flats site proved to be rather monotonous. Rich (in Austin et al., 2004) found the strata to be dominated by the Chenopodiaceae. This now familiar association could show little more than that the site was probably coastal marshland or tidal flats. This is in contrast to the vegetation existing at the site now which, though heavily disturbed by 20th-century human activity, has a fairly high level of species diversity, including an array of woody plants. Extensive salt marsh in the area of Tampa would have been consistent with a generally warmer, perhaps dryer, condition.

Within the time of the middle Hypsithermal it has been shown that the basin of the Okefenokee Swamp, in southeasternmost Georgia, was still dry (Rich, 1979). The oldest dated peats from the swamp appeared 6640 ± 95 yr B.P. (7680–7330 cal B.P.; Spackman et al., 1976). Multiple basal samples from the Okefenokee have been dated over the years, but none of them dates back to the Younger Dryas. Additionally, Rich (1979), in a survey of the palynological composition of the deepest Okefenokee peats, determined that they seem to represent only irregularly distributed wetlands of limited size. Interestingly, they included *Typha* (cattail), a plant that is no longer native to the swamp. In his reconstruction of the basal peat-forming environments, Rich (1979, and in Russell et al., 2009) described a hilly landscape composed of grass-covered sand ridges with small streams that supported intermittent wetlands.

It was at the same time as the development of the most ancient Okefenokee peats that Saunders et al. (2009) determined that sea level rose at the Mitchell River site (6640–5950 yr B.P.; 7640–6790 cal B.P.). Oddly enough, this event seems to have prompted the first of three episodes of site abandonment. The hunter-gatherers are believed to have left the site as rising base level lead to the establishment of a *Taxodium-Nyssa* forest. This is believed to have displaced the important marine food sources that the Mitchell River people had come to rely upon. That situation notwithstanding, an apparent still-stand at Mitchell River between 5900 and 5300 yr B.P. (6710–6090 cal B.P.) led to reoccupation of the site, even though it remained cypress-tupelo forest. Coincident with these developments in Georgia and the Florida panhandle, Holloway (in Doran, 2002) determined that at the Windover site there was a dominance of grasses and composites (flowers such as the daisy, sunflowers, etc.). This, again, suggests an open pine or oak savanna type of environment.

It is interesting to note that much of the spodic soil (Bhs) package that underlies the surface A/Ap horizon and which caps the high Pleistocene core of St. Catherines Island likely dates to this period of Middle Archaic dryness. This statement is supported by a radiocarbon date on a now buried cumulic A horizon (6440 ± 40 yr B.P.; 7280–7430 cal B.P.), which is disconformably mantled by a 1.5 m (5 ft) thick uppermost soil generation (Ap-Bhs) that was emplaced during this period of late Middle Archaic dryness. The 6440 yr B.P. (7280–7430 cal B.P.) buried A horizon documents a return to more mesic conditions with subsequent drying and rapid sediment emplacement for the Ap-Bhs soil sequa. It appears that the stratigraphic occurrence of an eolian sand horizon (2C) that now buries a 10,790 yr B.P. (12,850–12,800 B.P.) paleosol and the thick spodic soil package (Ap-Bhs), which caps the 6440 yr B.P. (7280–7430 cal B.P.) paleosol, represent increased eolian deflation in response to soil water deficits and a drier climate during the Hypsithermal or the Climatic Optimum. This warm period, culminating between 8000 and 5000 B.P. (8890–5730 cal B.P.), saw average global temperatures 2°–5°C (4°F) higher than present. Hemispheric circulation changes triggered changes in the North Atlantic anticyclone and the Intertropical Convergence Zone (ITCZ) during this period. The former involved a poleward shift of approximately 10°–15° latitude, placing much of Europe under the drying conditions of high atmospheric pressure (Davis et al., 2003). This shift also allowed for the net poleward migration of the ITCZ, bringing warmer and wetter conditions to higher latitudes (Suzuki, 1975).

The subboreal, at 4500–3000 B.P. (5180–3210 cal B.P.), marks another abrupt transition to a drier climate regime. The dryness was likely induced by expansion of the Bermuda-Azores anticyclone, particularly during the warm season. Such occurrences, which induce widespread atmospheric stability, are common today during summer. By the Sub-Atlantic period (3000–2000 yr B.P.; 3210–1960 cal B.P.) the climate system made a transition to a more meridional situation similar to present. This engendered more frequent and greater magnitude midlatitude cyclone migrations through the study region, resulting in an overall increase in moisture.

THE ST. CATHERINES ISLAND SCENARIO

It is within this period of stable, but lower than modern sea level, and general terrestrial dryness that we see the next phase of development of terrestrial floras on St. Catherines Island. The island clearly must have been a part of the mainland during the LGM. The advance of the marine shoreline toward the island during the years between 18,000 yr B.P. (21,250 cal B.P.), and the separation of the island from the mainland is a span of time for which we have little information from the island itself. It is evident that the vegetation of the Southeast had sufficient diversity to allow conifer and hardwood forests, marshes, and savannas to inhabit what was to become St. Catherines Island. What can be said is that, according to sources cited by Thomas (2008: chap. 4; see also Thomas, chap. 1, this volume) sea level rose 2 m at the site of the island between 5300 and 4300 cal B.P. This local manifestation of higher sea level lead to the docking, or attachment of the now-eroded island of Guale to the northeast quarter of the main island at about 5000 cal B.P. This was about the same time that sawgrass marsh (*Cladium jamaicensis*) came to dominate the Windover site. Salt marsh habitat appeared around St. Catherines Island between 5000 and 4000 cal B.P. (Thomas, 2008; chap. 1, this volume) and, according to Saunders et al. (2009) there were a number of episodes of sea level rise and fall at the Mitchell River site (4900 to 4700 yr B.P.). This led to the second abandonment of Mitchell River, though the cypress-tupelo forest seems to have remained intact. Between cal 4840 and 3500 yr B.P. [5670–3790 cal B.P.], sea level rose at Mitchell River, leading to increasingly brackish conditions; this was accompanied by reoccupation of the site during the most brackish phase of site development.

As the brackish marshes and their resources were being exploited at Mitchell River, the oldest shorelines developed on the Georgia barrier islands (4500 to 3700 cal B.P., according to sources cited in Thomas, 2008: chap. 4). This was also the time when the first ceramics of the St. Simons style began to appear. This evidence suggests a seemingly anomalous 2 m drop in sea level at St. Catherines between 4300 and 3600 cal B.P., an event that does not appear to be duplicated at the other sites. This period of time does correlate with observations in the mid-Atlantic region for a period of warm and dry conditions associated with the subboreal climate phase. Vento et al. (2008) documented that many of the drainage lines in the mid-Atlantic region responded to these drier conditions by increased lateral channel migration and episodes of rapid vertical accretion, often associated with channel aggradation.

In a final series of events, the last few thousand years of coastal history comes together. By 4200 yr B.P. and coinciding with the end of the warm and dry subboreal climate interval, interisland marshes were established on the Georgia coast. This was the approximate time of first appearance of marine shells in the vicinity of Cracker Tom Hammock (4060 yr B.P.; 4540 cal B.P., as documented by Booth and Rich (1999). Thomas (2009) inferred that rising sea level at the island followed that time (cal 1600 B.C.). Interestingly, Spackman et al. (1976) identified 3500 yr B.P. (3790 cal B.P.) to be the likely minimal age for bay sediments in Florida Bay. Prior to this time sawgrass-waterlily peats were part of the basal sedimentary sequence, illustrating clear freshwater origins for the most ancient strata. By this time, peat accumulation was well underway in the Okefenokee Basin. Saunders et al. have written that, at the Mitchell River site, the time between 3400 and 1000 yr cal B.P. was characterized by the accumulation of tempestites. Associated with that time, brackish marsh vegetation gradually disappeared at Mitchell River, humans made only light use of the site, and it was finally abandoned for good about 800 yr cal B.P.

HOLOCENE PALEOFAUNA

Unlike the Holocene botanical record, there is a dearth of information regarding evidence for faunal change in the southeastern United States during the Holocene. This is due in part to early excavation methods which failed to collect microfaunal elements and to the occurrence of strongly acidic soils on the coastal plain and the effects of leaching upon postdepositional preservation.

Baker Bluff Cave in eastern Tennessee (Guilday et al., 1978) preserves 19 species of mammals in Archaic through late Woodland deposits, with only the Thirteen-lined Ground Squirrel absent from the area today—strongly indicating no major changes during the Holocene. Russell Cave and the Stanfield-Worley Bluff rockshelters in northern Alabama similarly show a continuity of the mammalian faunas throughout the Holocene. Aside from the extinct passenger pigeon, long-nosed peccary, and porcupine, all the mammalian faunal remains from Early Archaic through late Woodland horizons at Russell Cave can be found in the area today (Semken, 1983). At Stanfield Worley Rockshelter, the sparse faunal remains recovered from the entire stratigraphic sequence clearly document similar frequencies of white-tailed deer and gray squirrel for the Holocene deposits and provide little information regarding changes in Holocene climate. Semken (1983) notes that the faunal lists from these sites do not contain any mammalian species smaller than a chipmunk. This occurrence may limit the recognition of subtle climatic changes that have been identified by pollen studies conducted by Delcourt (1980) for the southeastern deciduous forests. At Salts Cave, Kentucky (Duffield, 1974), detailed excavations revealed a clear relationship between the occurrence of microfaunal remains, increase in grassland species, and associated warm and drier climatic conditions between 2940 and 2560 yr B.P. (3080 and 2670 cal B.P.). Climate was stabilized after 2500 yr B.P. (2610 cal B.P.) with the initiation of the warm and moist sub-Atlantic climate phase and forest conditions that persisted after that date (Semken, 1983).

The Devils Den fauna of Florida has been dated to 8000 to 7000 yr B.P. (8890–7850 cal B.P.; Martin and Webb, 1974). The faunal list contains eight extinct taxa regarded as early Holocene in age. The extinct taxa reflect a xeric parkland-savanna similar to that present in the region today. Martin and Webb (1974) note that the forest in the vicinity of the site was more mesic than now because wood rats, flying squirrels, and gray squirrels occur in the early Holocene deposits (Semken, 1983). Three other species found among the Devils Den taxa, the muskrat, the meadow vole, and the gray myotis all now occur well to the north of this locality, suggesting cooler summers during the period of deposition (Semken, 1983). The Devils Den fauna suggests that the early Holocene climatic conditions in Florida were cooler and moister than today. Avery Island, Louisiana, has yielded a complex and diverse assemblage of both Recent and extinct mammals with dates as recent as 8390 yr B.P. (9450 cal B.P.) for extinct taxa (Gagliano, 1967; Semken, 1983). The stratigraphic sequence records a change from early through middle Holocene prairie grassland with parklike stands of hardwoods around water holes to a seashore environment beginning at around 5000 yr B.P. (5730 cal B.P.). By 3650 yr B.P. (3960 cal B.P.) sea levels had reached near modern levels with the establishment of coastal swamps. One of the most interesting sites is Little Salt Spring, in southwestern Florida, a freshwater collapse doline. During dry intervals of the Holocene, sediments there preserved a record for climate change since 12,030 yr B.P. (13,890 cal B.P.). The most interesting remains recovered, from a Paleo-Indian horizon, were those of a giant tortoise, which had a pointed wooden stake driven into its carapace. As noted by Semken (1983), faunal modifications resulting from climate change will likely be most apparent on the xeric Florida peninsula where the water table dropped 8 m between 8500 and 5500 yr B.P. (9510–6300 cal B.P.) and where local environments (swamps, sinkholes) are more likely to preserve the faunal remains that are often (aside from shell middens) missing as a result of the strongly acidic soils and intensive chemical weathering on the coastal plain. In sum, while there are radiocarbon dates associated with extinct taxa, none of the extinct mammals has been recovered from any defined archaic sites in Florida or Georgia.

LITTLE ICE AGE (LIA)

Between A.D. 1450 and A.D. 1850, a cold and dry period occurred through the Northern Hemisphere. This period is known as the Little Ice Age (LIA). Because the LIA coincides with the onset of formal climatic instrumentation, records are available from at least some locations. Three major global climatic cooling periods, each separated by slight warming phases, have been identified using these records.

It is generally recognized that reductions in solar radiation and increases in volcanic activity contributed to the onset of the LIA. Further, ocean current changes and oscillations may have also contributed to a shift in the generalized atmospheric flow conditions over the Northern Hemisphere and possibly globally. Generally, cooling on the order of 1°–2°C was likely (Vento et al., 2008) but in some cases, there was more substantial cooling, perhaps as much as 3°–8°C.

The LIA coincides with the Maunder Minimum, a period of very low solar activity, especially sunspots. The Sporer Minimum, a period of slightly higher solar activity than the Maunder Minimum, coincides well with cooling during this time. Further exacerbating the overall reduction in insolation was the 1815 eruption of Tambora. The following year came to be known as the year without a summer due to temperature reductions related to the stratospheric ash cloud which resulted from the massive Tambora eruption. Other major volcanic eruptions contributed to cooling during this period.

Some evidence suggests that an alteration to the deep thermohaline oceanic circulation occurred during this period. The slowing of circulation is likely related to the LCO, which decreased the amount of cold, salty water sinking to bottom waters. The result caused an alteration of the deep ocean conveyor that transports huge volumes of energy through the world's ocean and ultimately influences climatic conditions.

THE PRESENT

Between the late 1800s and 1945, warming ensued. There was a short period of cooling between 1945 and 1980, and abrupt and dramatic warming has occurred since; the 10 warmest years present in the instrumental record occurred since 1990. Global sea levels have increased by 15 cm (6 in) over the past century, coincident with this overall warm period. It is believed that greater climatic extremes have developed over the last 100 years than at any other time over the past 500 million years.

NOTES

1. Order of authorship determined alphabetically.