EASTERN HEMLOCK FOUND IN MACON COUNTY, ALABAMA

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Abstract—Alabama is currently the southern limit of the range of eastern hemlock [*Tsuga canadensis* (L.) Carriere]. In 2012, several well preserved stumps were excavated from a farm located in Notasulga, Alabama (32 ° 33" 6' N; 85° 40" 22' W). Even though they were buried in a saturated soil for approximately 1,500 years, the stumps were remarkably well preserved. The low-density wood from one stump was identified as hemlock (*Tsuga* spp.) due to presence of piceoid, cross-field pitting. We assume the excavated stump was eastern hemlock. Uncorrected carbon dating of one sample was 1580 radiocarbon years (± 25 years) before 1950. This equates to ca. 418 to 541 AD. The diameter of the largest stump excavated was approximately 50 cm. The age of a 26-cm stump was approximately 74 years. The location of this site is about 1 degree further south in latitude than the southernmost stand in Jefferson County (approximately 175 km southeast). To date, the Macon County location is likely the most southern documented Coastal Plain site where a hemlock stump has been excavated.

INTRODUCTION

Climate affects the migration of glaciers and forests. When the climate cools, North American tree species tend to migrate to warmer environments in the South (note: individual trees do not migrate). In contrast, when the climate warms and glaciers retreat, some species will migrate north and in some regions, they grow into higher latitudes (Bonnicksen 2000). Fossil findings from the Late Eocene period indicate that hemlock ancestors were growing in western Alabama over 34 million years ago (Leopold and Pakiser 1964; Frederiksen 1980). About 10,000 years ago, hemlock was growing near Birmingham, Alabama (Delcourt and others 1983).

When the environment becomes unfavorable for survival of eastern hemlock [*Tsuga canadensis* (L.) Carriere], disjunct populations can form. Disjunct populations in the 21st century occur in Michigan, Ohio, Indiana, Kentucky, Tennessee, Alabama and several Atlantic coast states (Hart 2008). Currently, the most southern extant population is in Jefferson County, Alabama. A disjunct population may have existed further south in Macon County, Alabama around 500 A.D.

MATERIALS AND METHODS

A small farm pond at Sandy Creek Stables in Notasulga, Alabama was expanded using soil moving equipment. During the expansion, several buried logs and stumps were uncovered. Some of the logs were southern pines (*Pinus* spp.) while others were not readily identifiable as to genus. The size of excavated stumps ranged in diameter from 50 cm (fig. 1) to 26 cm to less than 11 cm. The soil covering the stumps appeared to originate from ancient beach sand from the Tuscaloosa Group [perhaps from the Cretaceous, Cenomanian-Turonian Stage (Cahoon 1972)].

The wood was identified microscopically as *Tsuga* due to several factors including the presence of piceoid, cross-field pitting and no distinction between sapwood and heartwood (Kukachka 1960). The low-density wood had no particular odor, there was an abrupt to semi-abrupt transition from earlywood to latewood and the ray tracheids were narrow. The wood was not identified to species, but it was assumed to be *Tsuga canadensis.* One excavated stump had a diameter of 26 cm and an age of perhaps 74 years.

A sample from the largest stump was sent to the University of Georgia (Center for Applied Isotope Studies) for radiocarbon dating (Ramsey 2008). The results (UGAMS# 12498) indicated an uncorrected ^{14}C age of 1580 years B.P. (± 25) [note: B.P. = before 1950]. The corrected result indicates a date of 480 A.D. (± 62 yr). In theory, there is a 95 percent chance that the tree was alive from 418 A.D. to 541 A.D. Additional information about the radiocarbon age vs. calendar date is provided in figure 2.

A cross-section of a 26-cm diameter stump was sent to the University of Tennessee at Knoxville. The surface

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Citation for proceedings: Schweitzer, Callie J.; Clatterbuck, Wayne K.; Oswalt, Christopher M., eds. 2016. Proceedings of the 18th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–212. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 614 p.

Figure 1—Excavation of an eastern hemlock stump in Macon County, AL.

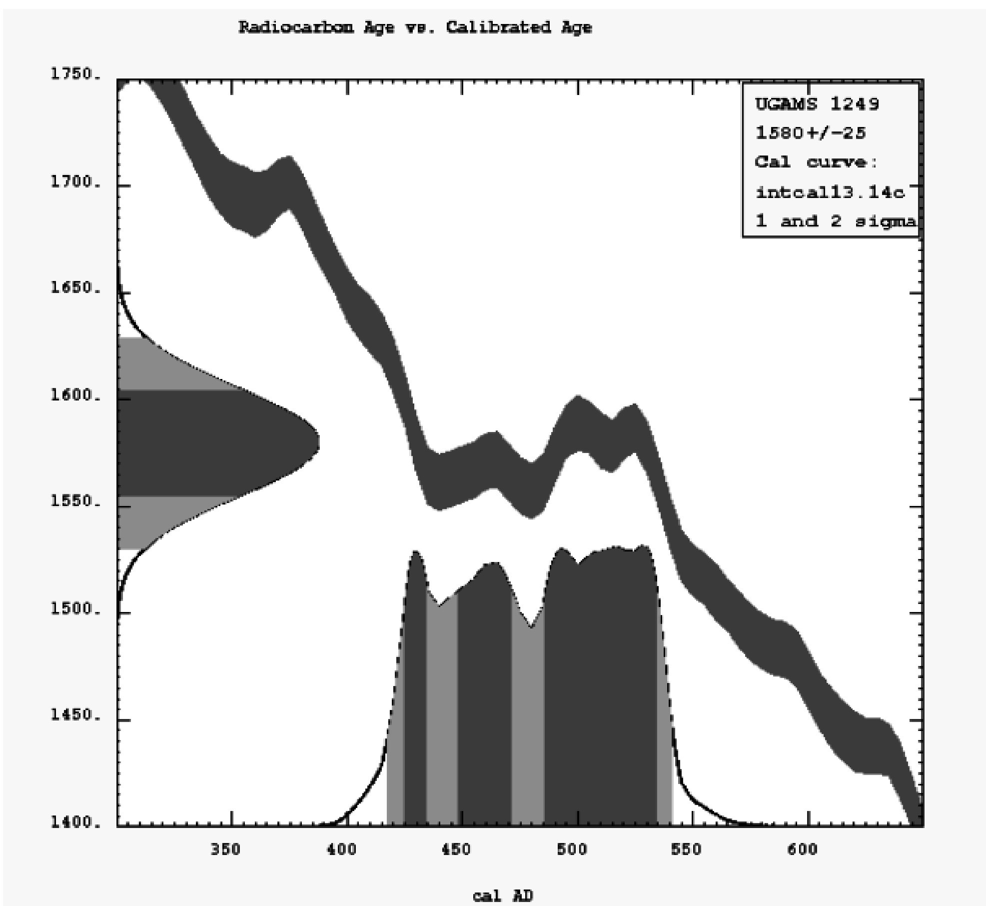

Figure 2—A calibration graph for converting radiocarbon date (Y-axis) to calendar date (X-axis).

was sanded (belt-sander) using a progression of grit sizes; beginning with ANSI 80-grit (177–210 μm) and ending with ANSI 400-grit (20.6–23.6 μm) (Orvis and Grissino-Mayer 2002). The surface was sanded until all cellular features of the rings were clearly visible under standard 7–10x magnification. Rings were annotated using the standard dot notation used in dendrochronology (Stokes and Smiley 1996). Ring widths were measured to 0.001 mm using a Velmex® moving stage micrometer interfaced with Measure J2X software (Speer 2010). These measurements were imported into ARSTAN® for Windows software to evaluate the growth trends. High resolution scans were obtained using an Epson® 10000 XL scanner.

DISCUSSION

Tree Growth

The 26-cm diameter stump contained 74 measurable tree rings (table 1, fig. 3). During the first two decades (figs. 4A, 4B), ring boundaries did not have a distinct sharp edge in the spring (between latewood of the previous ring and earlywood of the current ring). A sharp edge is normally associated with conifers that grow in temperate regions. This suggests that when young, this tree did not cease diameter growth in the winter (although indistinct ring boundaries become more distinct with increasing age). We believe this type of growth pattern (indistinct ring boundaries grading into distinct ring boundaries) is a reflection of physiological

Table 1—Seventy four tree-ring widths for one eastern hemlock sample in 0.001 mm format (e.g. "5008" = "5.008 mm"). Each row represents a decade, i.e. first decade contain rings 1-9, second decade contain rings 10-19 etc

Ring number	0	1	2	3	4	5	6	7	8	9
1-9		5008	4519	3473	2164	2000	2176	4124	3175	1993
10-19	2340	3756	5895	5131	4829	3618	3177	2994	5245	4346
20-29	3687	2033	1807	1792	3180	3905	2894	2145	1945	3516
30-39	2409	2077	1860	2105	1557	1704	1381	1506	909	1438
40-49	1286	1355	1179	883	609	508	431	443	257	97
50-59	188	162	216	478	215	359	128	95	597	790
60-69	661	541	677	816	1015	772	472	188	167	228
70-74	144	137	143	138	141					

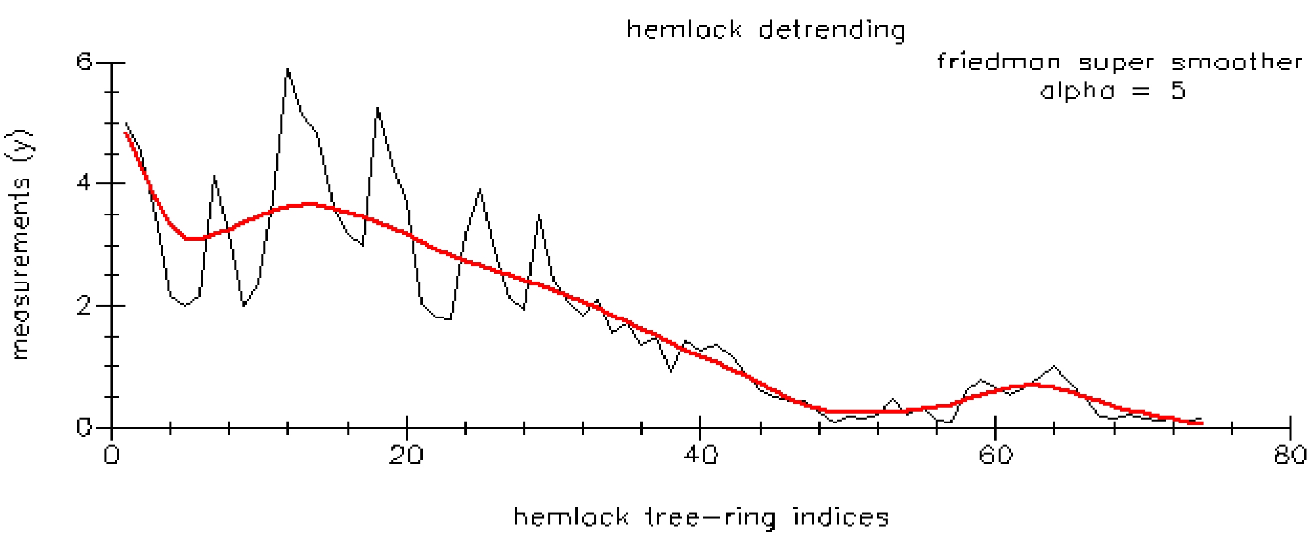

Figure 3—Measurements (in millimeters) of the 74 tree-ring widths for the eastern hemlock sample, showing the growth trend using a Friedman supersmoother variable span smoothing algorithm available in the detrending software ARSTAN.

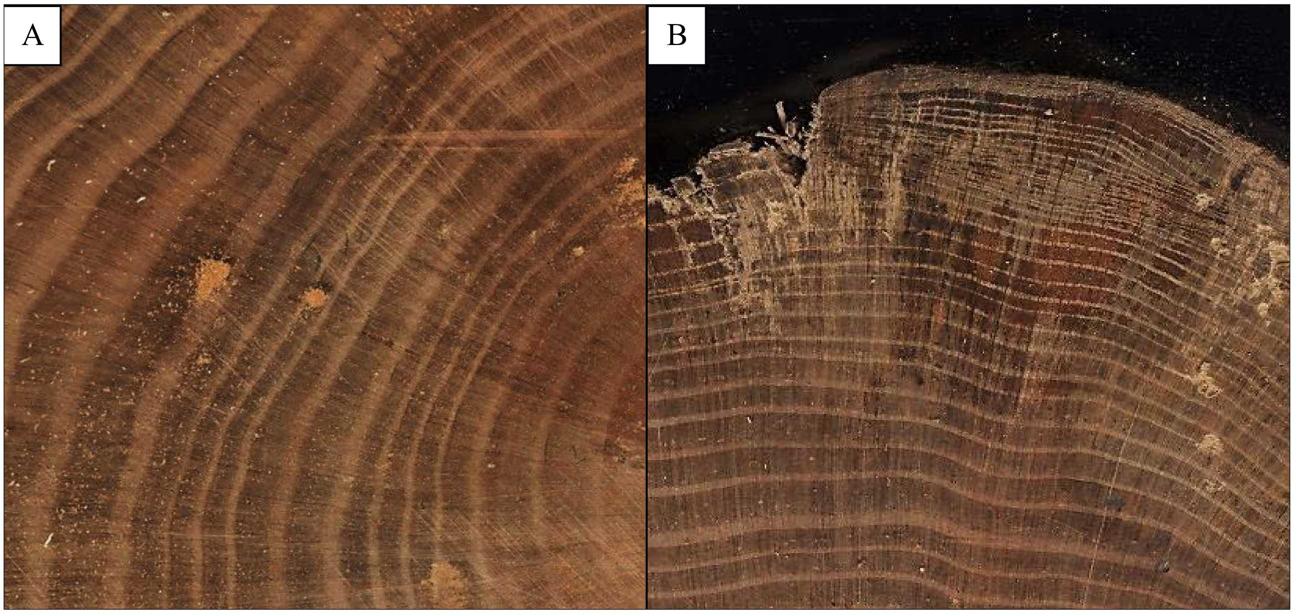

Figure 4—Rings formed in the earlier years of the eastern hemlock (A) did not have the distinct ring boundaries as rings that formed later in the tree's lifetime (B). Note also how the percentage of latewood increases from inner rings (A) to outer rings (B).

aging. When young, the tree was more vigorous and many conifers can produce photosynthates during the winter (Lundmark and others 1988; Hadley 2000) and can increase diameter. As the tree aged, the added biomass both vertically and laterally was more sensitive to seasonal changes, causing the tree to clearly shut down growth and form distinct boundaries.

Another notable feature was the large percentage of the ring dedicated to latewood. The earlywood (lighter colored) band is narrow in relation to the expansive latewood zone of the growth ring. Curiously, towards the outermost rings, the earlywood zone was demarcated by only a few cells in the radial file of cells before the thicker walled cells of the latewood formed (fig. 4A). A change in some aspect of environmental conditions is considered necessary for the initiation of latewood formation in conifers, and this can be both temperature (Begum and others 2012) or precipitation/drought related (Vaganov and others 2006). In eastern conifers, thicker-walled latewood cells can form when soil moisture that was recharged over the dormant period months becomes depleted during the early months of the growth season (Whitmore and Zahner 1966). The formation of latewood often occurs in mid-summer (i.e. July) for various eastern conifers, such as *Abies balsamea* in Canada (Deslauriers and others 2003) and *Pinus elliottii* in southern Florida (Harley and others 2012). For *Tsuga*, the percentage of latewood generally increases with increasing age, especially in the rings towards the outside of the tree bole (Edlin 1965). This pattern was clearly visible in our sample (fig. 5).

A severe suppression of growth was noted from rings 48 to ca. ring 60 (fig. 4B). This suppressed and erratic growth occurred along at least half the circumference of the sample wherever these rings were present. Growth recovered after this period of suppressed growth returning to ring widths more characteristic of growth prior to the disturbance (fig. 4B). Many environmental factors can cause a tree to undergo suppressed growth. However, it is unlikely that a decade-long drought was the cause because the suppression was not uniformly distributed for each affected ring. It is more likely that a local (or stand-wide disturbance) slowed growth rate during this decade. Such disturbances could include (1) a treefall that damaged the hemlock crown, trunk, and/or root system (Hart and Grissino-Mayer 2009); (2) a lightning strike that damaged the crown and trunk but did not reach a lethal temperature (Palik and Pederson 1996); (3) a wildfire that caused damage to the crown, trunk, and/or root system (Rogers 1978); (4) insect herbivory from a number of known insect pests on eastern hemlock [e.g. *Diaspidide* scales (McClure and Fergione 1977) and *Lambdina fiscellaria* Guenée (Bhiry and Filion 1996)]; (5) damage to the crown (e.g. lean) caused by hurricane-force winds (Peterson 2000); or (6) damage to the crown caused by biomass loss from excessive branch loading during an ice storm (Lafon and Kutac 2003). Any one of these disturbances could have caused the suppression in growth rates. As

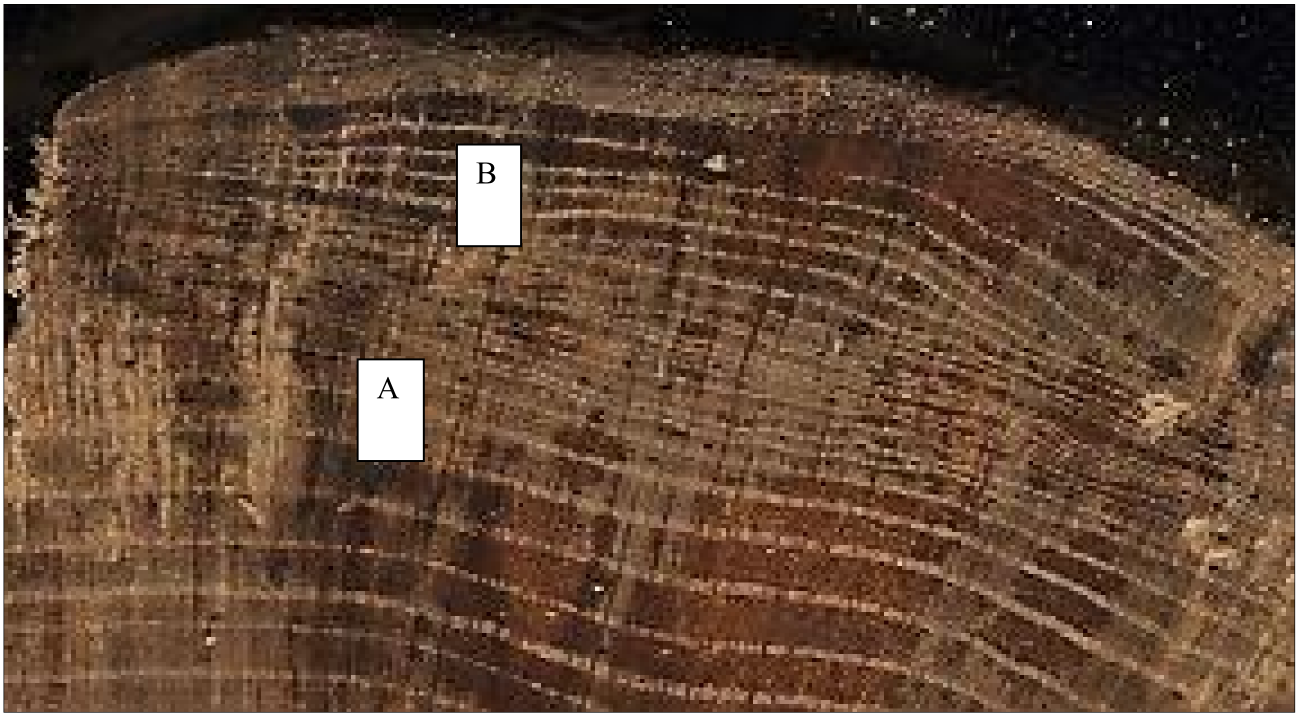

Figure 5—Close-up of the outermost rings that clearly show (A) the large percentage of latewood in each ring and (B) a change in growth rate to very narrow rings, suggesting a disturbance affected the tree's growth rate.

the tree recovered from this biomass loss or damage, diameter growth eventually recovered.

Metrics of tree growth show a mean ring width of 1.76 mm for the 74 measured rings and a mean sensitivity of 0.31 mm (mean sensitivity is a measure of ring width variability) (Speer 2010). The International Tree-Ring Data Bank houses 51 site chronologies for eastern hemlock and the mean measurement for several hundred eastern hemlock trees in these data sets is 0.75 mm with an average mean sensitivity of 0.24 mm, which indicates this sample has rings that are wider than average for eastern hemlock. Ring widths are also more variable from year to year, suggesting sensitivity to year to year weather variations. The first-order autocorrelation for these 51 data sets is 0.81 while our sample has a comparable value of 0.89. In general, this eastern hemlock was likely growing in a southern environment that was conducive to enhanced sensitivity to climate fluctuations when compared to eastern hemlock trees growing in more northern latitudes today.

Species Migration

When the climate cooled during the last ice age, trees in parts of the North were crushed due to the advancement of glaciers. Eastern hemlock south of the glaciers survived and the cooler climate allowed regeneration to occur further south. However, the extent of hemlock in the eastern United States during that time is not clear. From 19,000 to 17,000 radiocarbon years B.P., there was no hemlock pollen found at various sites in the eastern United States (Delcourt and Delcourt 1987). This does not mean that eastern hemlock did not exist, it just means that sampling intensity for these dates was low. Based on ice cores from Greenland (Dansgaard and others 1969), temperatures during glacial times were likely cool enough to allow hemlock to survive and grow. Pollen samples suggest that *Fagus* spp. were dominant in Alabama about 12,000 years ago (Williams and others 2004, Delcourt and Delcourt 1987) and hemlock was growing near Birmingham perhaps 10,000 years ago (Delcourt and others 1983). Pollen recovered from one location in Pike County, Alabama (i.e. south of Macon County) suggests hemlock did not occur that far south (Delcourt 1980).

The discovery of buried hemlock stumps in Macon County raises several questions. First, when did hemlock first arrive in Macon County, Alabama? We do not know. Fossils from the Late Eocene period indicate that hemlock ancestors were growing in western Alabama over 34 million years ago (Frederiksen 1980). About 36,000 years B.P., fossil hemlock spores were produced near the Atlantic Ocean along the border between Florida and Georgia (Pirkle and others 2013). Soil cores near Birmingham, Alabama indicate hemlock pollen was produced near Birmingham, Alabama about 11,000 radiocarbon years B.P. (Delcourt and others 1983). One might assume that hemlock arrived in Macon County after that time. However, surveys in Macon County found no hemlock pollen in Macon County (from either 250 or 5,300 radiocarbon years B.P.) (Markewich and Christopher 1982). This does not mean that hemlock did not exist in Macon County, it just means that no hemlock pollen was recovered from the sampled strata.

Why did hemlock become extinct in Macon County? We do not know. If a disjunct population of hemlock was alive in Macon County in 500 A.D., then something increased the mortality rate. One possibility is the agent responsible for the hemlock decline about 5,000 years ago (Delcourt and Delcourt 1987; Filion and Quinty 1993) finally reached this region. Another possibility is that natives increased the use of fire. If a wildfire (or human set fire) occurred during a drought, this might have killed young, fire-sensitive seedlings. It also may be that hemlock succumbed to higher summer temperatures during the Medieveal Warm Period (fig. 6). Alternatively, an extended drought may have contributed to the decline (Haas and McAndrews 2000). The climate of Macon County during the 20th Century was almost as moist as that in northern Alabama, but the average temperatures were higher (table 2). It is believed that climate does affect the growth of hemlock in Alabama (Hart and others 2010).

Low-severity fires can kill seedlings and sapling hemlocks. In some cases, 60 percent of mature trees died or were severely injured by a fire (Swan 1970). Although fires near streams will occasionally produce fire scars on hemlock (Lafon and others 2010), they are not typically found on hemlock. Since the roots were underground, no fire scars were noted on the outside of any of the excavated stumps.

Without additional investigations, we may never know why these stumps in this sandy soil were buried. We

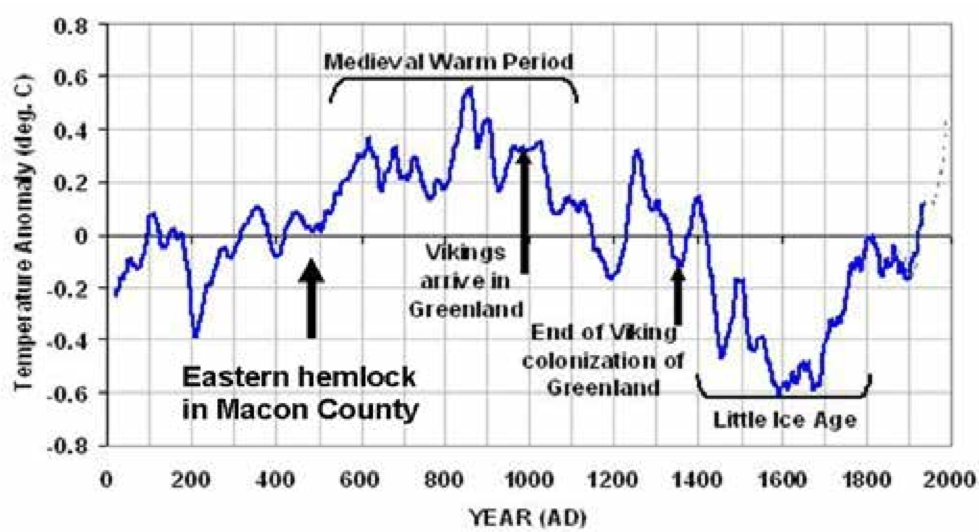

Figure 6—A global temperature reconstruction based on non-tree ring proxies (Loehle and McCulloch 2008). Data for this graph is online at www.econ.ohio-state.edu/jhm/agw/loehle/ Hemlock was growing in Macon County, Alabama prior to the Medieval Warm period.

Table 2—Average climatic conditions (1901-2000) for three NOAA climate divisions in the Southeastern United States. In the past, hemlock was present in Climate Division #9 in Georgia (Pirkle and others 2013) and in Climate Division #6 in Alabama (which includes Macon County)

State	NOAA Climate Division	Maximum July temperature (°C)	Average Maximum July temperature (°C)	Average Annual Temperature (°C)	Average Annual Precipitation (mm)	July Palmer Drought Severity Index	Hemlock present in the 21th Century
Alabama	Appalachian Mountain (#2)	36.0	32.1	15.7	1404	-0.14	Yes
Alabama	Prairie (#6)	36.5	33.1	17.8	1347	-0.22	No
Georgia	Southeast (#9)	35.9	33.2	19.1	1249	-0.04	No

know that horizontal logs in creeks can be buried due to sedimentation (Cahoon 1972). There have been documented cases where standing trees have been buried when earthquakes cause "sand blows." These sand "volcanoes" are formed when liquefaction of water-saturated sands results in rapid sand accumulation at the surface (Tuttle 2010; 2011). Roots of the hemlock stumps were growing in white sandy soil (originating from an ancient beach over 90 million years ago). When water-saturated, this soil would be a prime candidate for a sand blow. Although the upper portions of the trees were removed during the excavations, the remaining stumps appeared to be vertical with no lean. Obviously, the hemlock trees were either (A) growing on top of the ancient beach sand and then sank when the sand became "liquefied" or (2) were growing on a more recent soil type and then the trees were buried in sand from a "sand blow." Further investigations at this site by geologists might solve this puzzle.

CONCLUSION

Paleo-dominance range maps for hemlock for 500 years A.D. are based on pollen samples. These range maps do not include Macon County, Alabama (Delcourt and Delcourt 1987; p. 278). For that date, it was assumed that the southern limit for Tsuga was approximately 34 ° N. However, a buried stump from Macon County suggests that hemlock was growing at 32 ° N at that time. Updated paleo-dominance maps for hemlock for 500 years A.D. should reflect this knowledge. More intensive pollen sampling would likely support this finding.

ACKNOWLEDGMENTS

We acknowledge Dr. Graeme Lockaby for providing funds for the radiocarbon analysis and to Grant Bond for helping with the extraction of the large stump.

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